rec'd by LEPO April 13, 2016

Report

Water Resources Evaluation
Water Use in Closed Basins

Prepared for

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March 2016

Executive Summary

2016 WATER RESOURCES EVALUATION
WATER USE IN CLOSED BASINS

Introduction

This 2016 water resources evaluation study updates and supersedes previous versions dated 2007, 2008 and 2012. The general objective of the study is to apply scientific methodology in the form of water budget evaluations of water supply and water use in four high growth areas in closed basins (Ravalli, Missoula, Lewis and Clark, and Gallatin). The specific objective includes the utilization of the basin water budgets to assess the relationship of population growth on water supply resources over relatively recent times and then project impacts into the future.

The development of these water studies started at the time period (mid 2000s) when Montana was experiencing a drought period and unprecedented growth at the same time. As a result, opponents to growth claimed the lower river flows of the period resulted from the recent growth and then sought to limit new water use by new laws and regulations. A key Montana Supreme Court Decision (Trout Unlimited v. DNRC 2006) significantly restricted new groundwater appropriations in closed basins. Since that time, there has been an ongoing effort to restrict the use of relatively small domestic wells on properties not serviced by municipal supplies.

At the time, it seemed that basic science was not understood and applied in developing new water policy, thus the impetus for the development of the water budget based water resource evaluations preceding this report. This effort seems to be successful to some extent as the 2009 Legislature directed (SB303) to prepare and issue a Montana State Water Plan to provide a continuing comprehensive inventory of the water resources of the state.

The ensuing Montana State Water Plan 2015 (DNRC, 2015) considers larger study areas (four major water basins covering the state) and utilizes some different water use assumptions and calculations, but still reports similar results about the overall water supply and consumptive uses.

As related to the objectives of this study, the Montana Water Plan reports the following percentages of consumptive uses in Montana and the four major drainage basins:

	Percent of Total Consumptive Use		
	Domestic	**Municipal**	**Irrigation**
Montana	0.4%	2.0%	67.3%
Upper Missouri	0.4%	3.2%	95.3%
Clark Fork and Kootenai	1.0%	4.0%	92.0%
Lower Missouri	0.1%	0.3%	42.0%
Yellowstone (Montana Portion)	0.4%	2.6%	83.3%

This water budget approach is applied to relatively large-scale hydrologic study areas. It is not intended to address site specific issues, but to provide water supply and use data and projections of future use in high growth basins to support water policy decision makers to make determinations regarding long-term water availability.

Water Budget

A water budget is the numerical accounting of the inputs and outputs of water over a set volume such as a hydrologic basin. In the simplest form, the water budget for the State of Montana includes the following statistics:

Total Precipitation (average)	145,800,000 acre-feet
River Flow Into Montana	15,333,000 acre-feet
River Flow Out of Montana	43,800,000 acre-feet
Consumed Water Used	2,662,000 acre-feet
Agriculture	2,494,000 acre-feet
Public Water Supplies	56,000 acre-feet
Self-supplied Domestic Wells	25,700 acre-feet

Of the average total quantity of water leaving the state per year; about 6 percent is used. 0.19 percent is used for domestic use and only 0.06 percent is used by exempt wells.

The 2016 report provides water budget evaluations of the four geographic areas of interest listed above. Key findings and observations are listed below.

Comparison, Consumptive Uses versus River Flows
(acre-feet per year)

	Bitterroot	Lewis & Clark	Missoula	Gallatin
River Flow	1,597	2,334	3,866	827
Agriculture Irrigation with Surface Water	96	43.3	22	112.1
Agriculture Irrigation with Groundwater	4.85	9.7	4.9	3.88
Public Water Supplies	1.68	3.3	11.27	3.62
Lawn and Garden Individual Wells	8.2	9.3	8.8	6.45
Domestic Individual Wells	0.093	0.1	0.062	0.053
Total Use by Individual Wells	8.29	9.40	8.86	6.50
Percent Individual Well Use to River Flow	0.52%	0.40%	0.23%	0.79%

Evaluation Observations and Findings

Some key observations include the following:

- Streamflows are mainly dependent upon mountain snowpack conditions. The trends of streamflows in the Bitterroot, Clark Fork, Missouri, and Gallatin Rivers echo the trends of snowpack conditions over time (see Figures ES-2 and ES-3).
- By far, the greatest human-induced water uses are agricultural irrigation and reservoir evaporation (primarily in the Upper Missouri River Basin).
- Public water supply and individual well demands are comparatively small from a water budget perspective. See Figures ES-4 through ES-4. There is no evidence of cumulative impacts to streamflows on a watershed scale. Although localized affects may occur in a few instances, any net cumulative effect at the watershed scale, if it exists, is simply too small to be discerned.
- There is no evidence that the overall consumptive water use has increased with the growth of subdivisions and their accompanying use of groundwater. The primary reason for this is that many of these subdivisions have been placed in areas where agricultural irrigation activity has historically occurred.
- It is concluded via water budgeting assessments that there is no measurable evidence of so-called "cumulative impacts" of exempt wells[1], public water supply wells, or even agricultural irrigation wells on streamflows at the watershed scale for any of the watersheds evaluated. In effect, any net cumulative effect is simply too small to be discerned or prevent continued utilization of existing water uses.
- Projections were made on future water demands on groundwater. Based upon these projections, the impacts of groundwater development by 2030 will not be measurable or observable in the streams that were evaluated.
- The nature of land use changes are a factor in the overall water budgeting evaluation. The water use by new development is offset when the development occurs on previously irrigated farm lands as is typical of high growth valleys in Montana.
- Groundwater level changes are mainly due to natural factors in areas that were

[1] "Exempt" or "individual" wells as used throughout this report refer to wells that are 35 gpm or less and 10 AF per year outside of stream depletion zones or within stream depletion zones, 20 gpm or less and under 2 AF per year. *See*, Mont. Code Ann. § 85-2-306(3)(a). These wells are "exempt" only to the extent that they are exempt from the full-blown permitting process required of larger wells. The small wells are still subject to enforcement under the priority system and are still issued water rights. It should also be noted that within controlled groundwater areas, the parameters for exempt wells can be set by rule and can vary widely.

evaluated in this study. Groundwater levels and aquifer storage have remained relatively constant from year-to-year for the watersheds examined. One exception to this is the localized area known as the Helena North Hills in Lewis and Clark County. This is likely due to the fact that domestic wells in the North Hills have been completed in a bedrock aquifer that has limited water bearing capacity. The North Hills area is a good example of an area where existing statutory and regulatory management tools such as controlled groundwater areas would be appropriate to manage a localized water supply/availability issue.

The plots shown in Figures ES-4 through ES-6 demonstrate that the primary reasons why detectable impacts to streamflows from groundwater development are not observed. Groundwater development generally represents an inconsequential component of the overall water budget.

Recommendations

Based upon the current studies, NE&W recommendations are as follows:

- Recognize that the water budget in Montana is overwhelmingly dominated by climatic factors and agricultural surface water use. In effect, any changes in groundwater use that transpire in the 10 to 20 years will not substantively change this water budget.
- Regular delineation of water use, including irrigated areas, would assist in understanding potential trends or lack thereof on the overall water budget. Information could then be coupled with the water budgeting process to provide information at the state and local levels to assist decision makers, water users, and their representatives.
- Since there is an abundance of water compared to uses, especially during spring runoff, storage is a proven effect water management approach to satisfy all users at times when water supply is stressed (late summer and drought periods).

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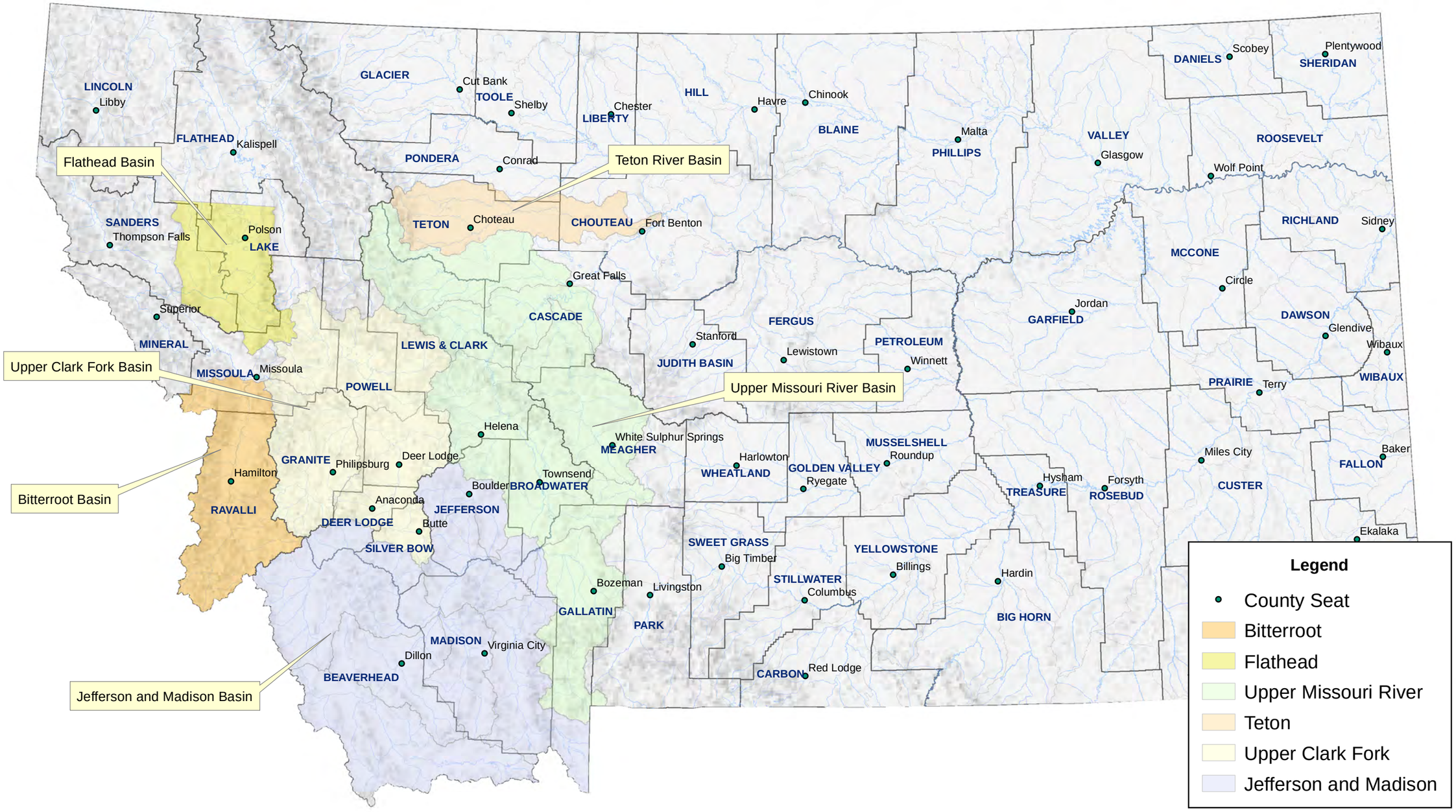

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File: ES-1

40 Miles

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Figure ES-1
Closed Basins in Montana
Water Resources Evaluation

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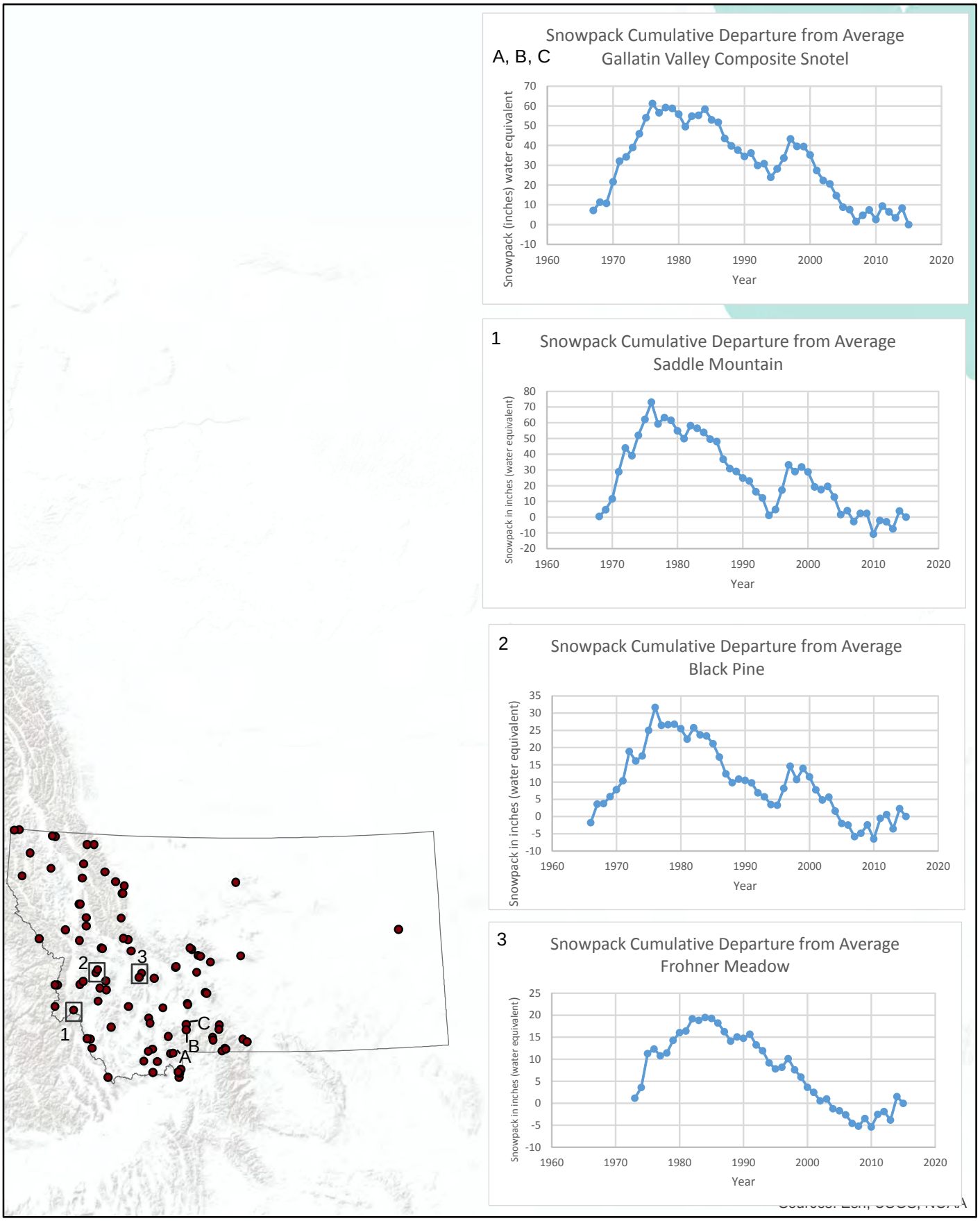

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Date: 1/11/2016
File: Figure ES-2

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Figure ES-2
A Comparison of Snowpack Cumulative Departure from Average in Other Basins Compared to SNOTEL Stations Gallatin Drainage

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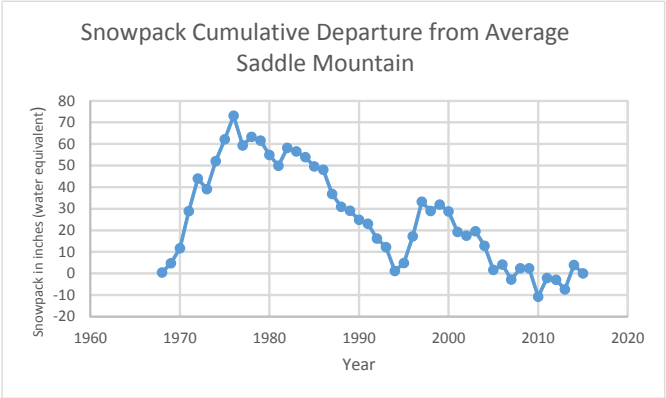

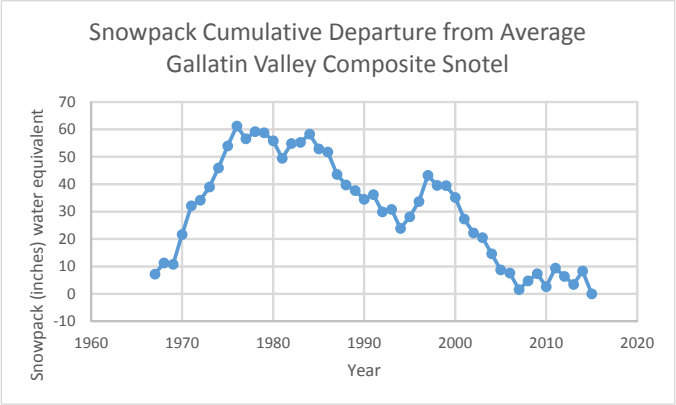

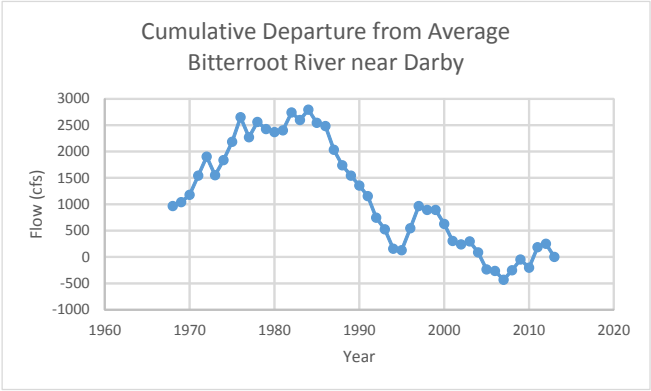

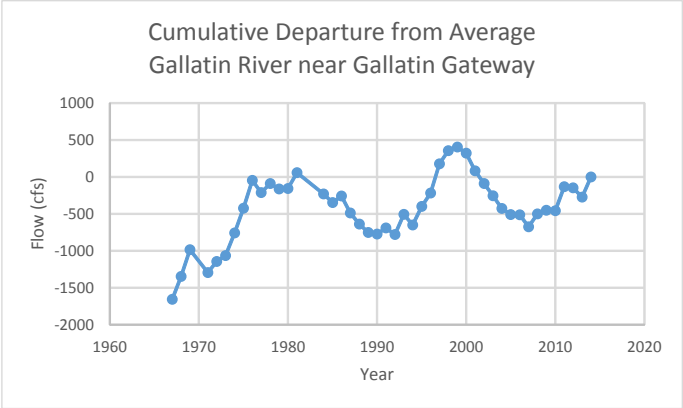

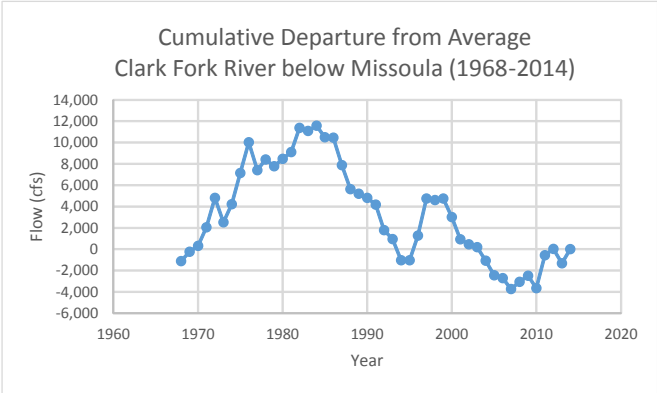

Notes:
Streamflow cumulative departure plots tend to mirror snowpack conditions at the SNOTEL stations, which demonstrates that climate dominates in the streams that were evaluated.
This figure also demonstrates that the observations that were made apply from mountain watershed to mountain watershed.

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Date: 1/11/2016
File: Figure ES-3

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Figure ES-3
Surface Water Flows Compared to Snowpack

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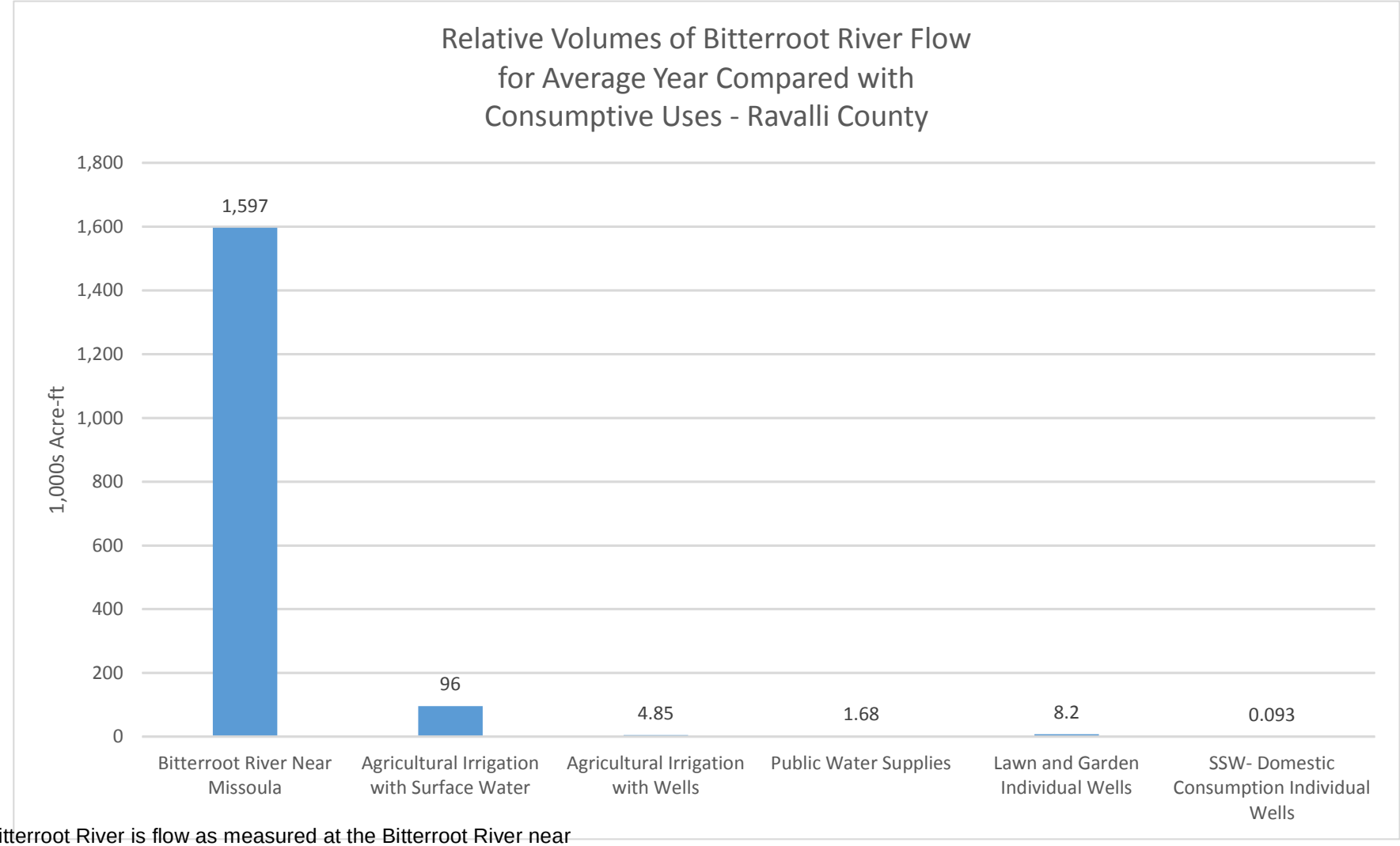

Bitterroot River is flow as measured at the Bitterroot River near Missoula USGS gaging station. Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells.

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Figure ES-4
Surface Water Flows at Bitterroot River Compared to Ravalli County Consumptive Uses

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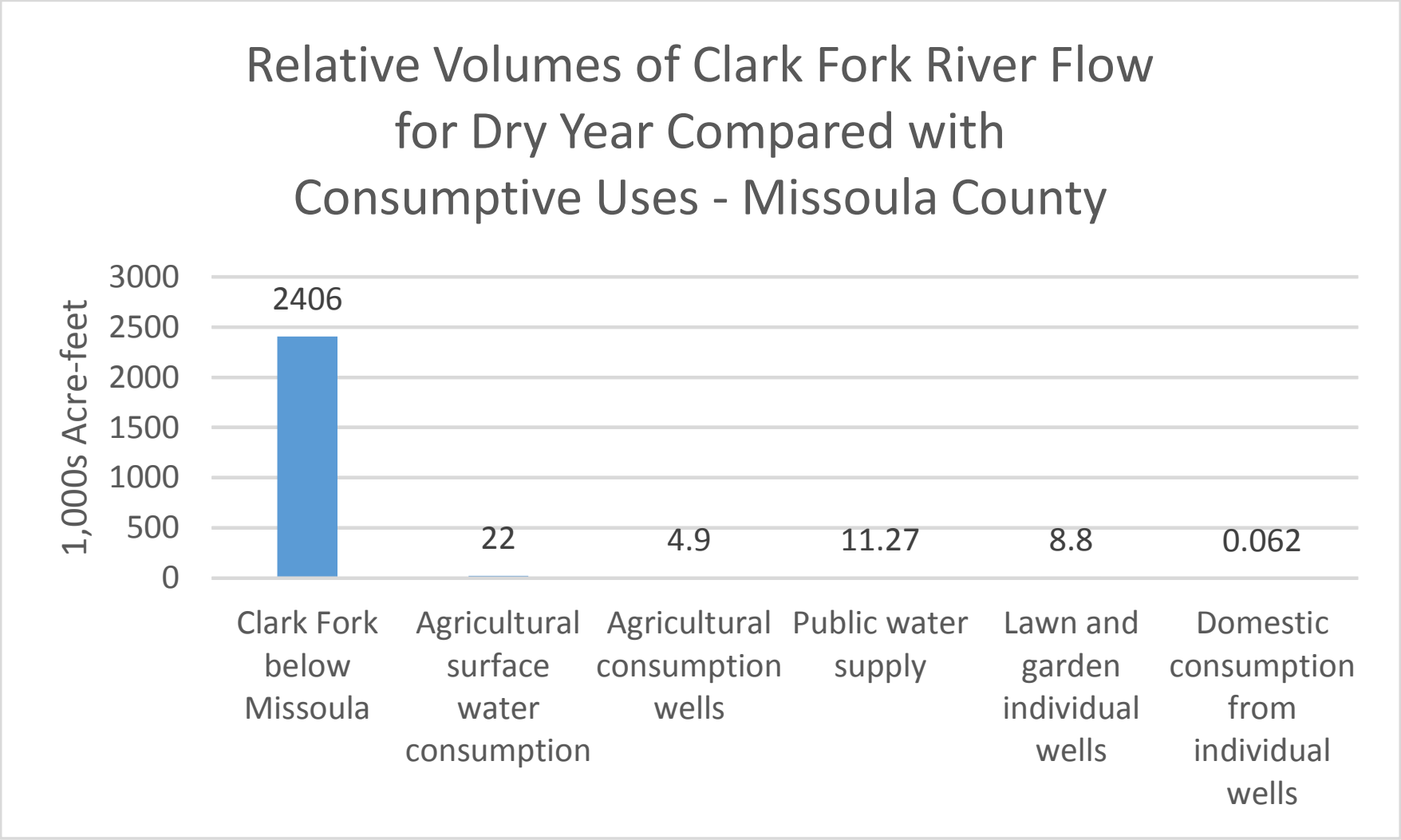

Notes:
1) Clark Fork River flows for 2001 used.
Consumptive use is based in part upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered in these plots.
Individual wells include exempt wells.

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Date: 1/12/2016
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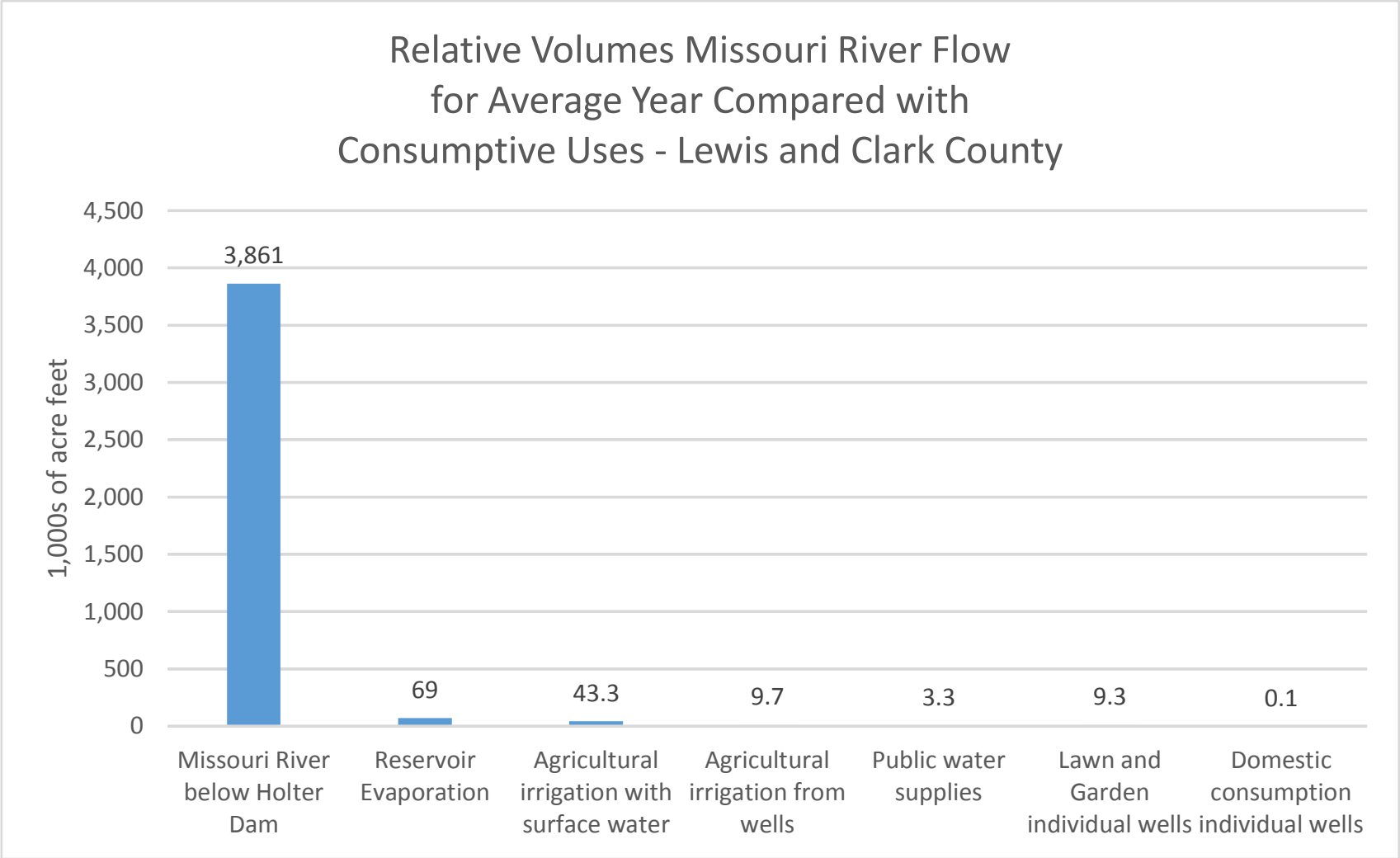

Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Note that significant portions of the consuptive use occur in Lewis and Clark County outside the Upper Missouri Watershed.

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Date: 12/22/2015
File: Figure 4-18

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Draft Report
2016 WATER RESOURCES EVALUATION
WATER USE IN CLOSED BASINS

1.0 INTRODUCTION

1.1 Overview

Growth, climate, a Montana Supreme Court decision, District Court decisions, and new laws and regulations have caused focus on the issues of groundwater appropriations in closed basins and exempt wells. Closed basins (See Figure 1-1) and associated counties and rivers include:

Closed Basin	Counties	Rivers
Upper Missouri	Gallatin	Gallatin
	Broadwater	Missouri
	Meagher	Smith
	Lewis and Clark	Dearborn
	Cascade	Sun
Madison / Jefferson	Madison	Madison
	Jefferson	Jefferson
	Beaverhead	Beaverhead
		Big Hole
		Boulder
		Ruby
Upper Clark Fork	Deer Lodge	Clark Fork
	Granite	Blackfoot
	Powell	Flint / Rock Creeks
	Missoula	
Bitterroot	Ravalli	Bitterroot
Teton	Teton	Teton

Population growth in Montana, especially in high growth counties, has been unprecedented over the recent past. Key population data (US Census) include:

	1990	2000	Percent Change per year 1990 to 2000	2010	Percent Change per year 2000 to 2010
Montana	799,065	902,165	1.29%	989,415	0.97%
Ravalli County	25,010	36,070	4.42%	40,212	1.15%
Missoula County	78,687	95,802	2.18%	109,299	1.41%
Lewis and Clark County	47,495	55,716	1.73%	63,395	1.38%
Gallatin County	50,463	67,831	3.44%	89,513	3.20%

The Montana Department of Commerce (MDC 2016) predicts that the population in Montana will increase by 278,521 (28%) from 2010 to 2060. Of that increase, 139,933 (50%) is predicted to occur in the high growth counties associated with closed basins listed above.

	2010	2020	2030	2040	2050	2060	Increase 2010 to 2060	Percent Change 2010 to 2060
Montana	989,415	1,094,712	1,156,494	1,162,854	1,192,262	1,267,936	278,521	28%
Ravalli County	40,212	42,450	44,691	45,371	45,277	46,826	6,614	16%
Missoula County	109,299	123,553	134,085	140,339	151,878	167,735	58,436	53%
Lewis and Clark County	63,395	70,208	74,495	75,965	78,016	82,402	19,007	30%
Gallatin County	89,513	105,568	116,627	122,432	133,016	145,389	55,876	62%

This increasing population will use additional water when compared to current. Over the same time period, there have been concerns related to climate change and its potential effects on Montana's water resources. Statewide drought conditions generally prevailed from 2000 to 2009. At the same time, Montana experienced significant growth. Some have mistakenly attributed the drought-related streamflow reductions to development for population growth and its attendant groundwater demands. In 2006,

the Montana Supreme Court decision "Trout Unlimited v. DNRC 2006," negated the methodology used by Montana Department of Natural Resources and Conservation (DNRC) regarding "direct and immediate" considerations in the appropriation process for groundwater in closed basins, effectively eliminating new groundwater appropriations in closed basins. That has led, in turn, to legislation passed by the 2007 Legislature, House Bill 831. Since that time, there has been significant attention to the issue of exempt wells, cumulating in a 2014 Montana First Judicial District Court decision (a.k.a, Clark Fork Coalition, *et al.* v. DNRC) striking down the combined appropriations rule regarding exempt wells. In turn, DNRC developed new combined appropriation guidance (last updated 9/18/15) restricting the use of exempt wells. The 2013 Montana legislature passed SB 346 establishing stream depletion zones and reducing exempt flow rates and volumes within those zones.

In order to provide an assessment of groundwater availability and groundwater development impacts on streamflows, Nicklin Earth & Water, Inc. (NE&W) conducted a watershed evaluation of the Gallatin Valley using basic water budgeting methodology. This culminated in the report: "Gallatin Valley Water Resources Evaluation, A Test of the Rationale of Montana Department of Natural Resources & Conservation Proposed Legislation to Amend Montana Water Law" (NE&W, 2007). NE&W was then retained in 2008 to evaluate the water use in three additional high growth areas including: Ravalli County (Bitterroot Watershed), Missoula County, and Lewis and Clark County. Since then, additional data was evaluated and reported in 2011. This 2016 update presents an updated evaluation based on available more recent data. This latest update will hereafter be referred to as the 2016 study. The information set forth in this 2016 study supersedes the 2007, 2008, and 2011 reports.

In 2015, Montana DNRC issued the Montana State Water Plan (DNRC 2015) as directed by the 2009 Legislature (SB303) to provide a comprehensive inventory of the water resources of the state. It is noteworthy that this water plan incorporated, to some extent, the approach of this and previous versions of this report. The State Water Plan is comprised of individual plans for the four main water basins encompassing the state, whereas this report studies four smaller high growth basins. Additionally, the state water plan uses some different approaches to estimate and project future water use when compared to this study. As related to the objectives of this study, the Montana Water Plan reports the following percentages of consumptive uses in Montana and the four major drainages:

	Percent of Total Consumptive Use		
	Domestic	**Municipal**	**Irrigation**
Montana	0.4%	2.0%	67.3%
Upper Missouri	0.4%	3.2%	95.3%
Clark Fork and Kootenai	1.0%	4.0%	92.0%
Lower Missouri	0.1%	0.3%	42.0%
Yellowstone (Montana Portion)	0.4%	2.6%	83.3%

As recommended in this and previous water studies, the first step towards sound and rational water policy should include consideration of water budgets that quantify water supply and use in the area(s) of interest.

1.2 Objectives

The objectives of this report are to:

- Present the results of the data analysis performed for the four study areas (Ravalli, Missoula and Lewis and Clark Counties and the Gallatin Valley);
- Project the relative increase in consumptive use in association with individual well water supply growth; and
- Develop recommendations for assisting water policy decision makers in establishing practical water policy that is both protective of the rights of existing appropriators and considers overall water budgeting factors in the process.

1.3 Report Organization

In order to assist the reader, this report is organized as follows:

- Section 2 - Approach
- Section 3 - Water Resources and Water Budget Summary of Ravalli County (Bitterroot Valley)

- Section 4 - Water Resources and Water Budget Summary of Missoula County
- Section 5 - Water Resources and Water Budget Summary of Lewis and Clark County
- Section 6 - Water Resources and Water Budget Summary of Gallatin Valley
- Section 7 - Summary and Recommendations

It is also noted that the figures relevant to each section above are placed at the end of each of these respective sections.

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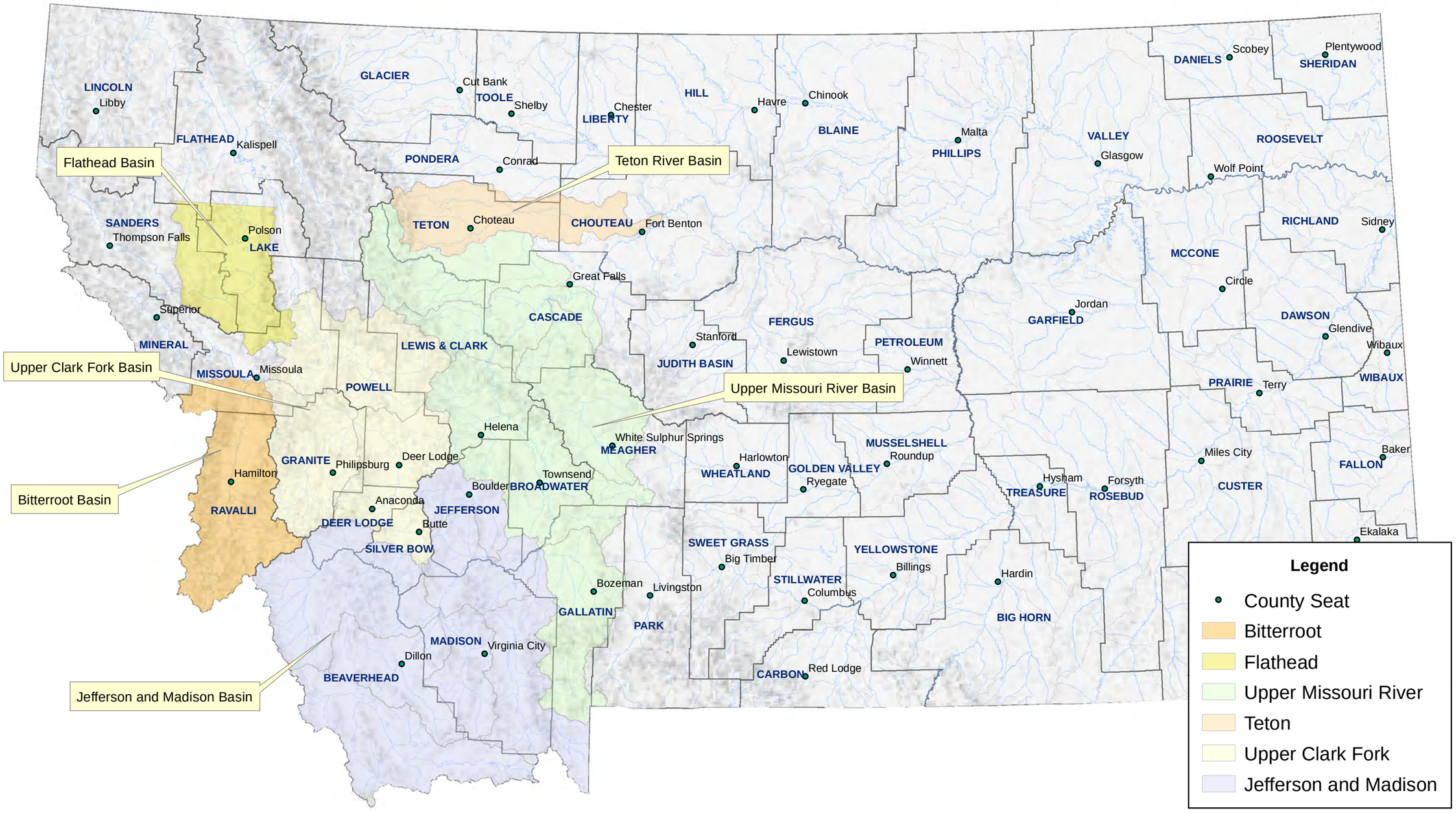

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40 Miles

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Figure 1-1
Closed Basins in Montana
Water Resources Evaluation

2.0 APPROACH

A scientific approach should be used to assess hydrologic conditions on a local, watershed, or even regional scale in order to understand how a system behaves. This is appropriate before posing solutions to a perceived problem that may or may not exist. Otherwise, the proposed solution may either be inappropriate, unnecessary, or it may create a new set of problems (i.e., unintended consequences).

One method of employing the scientific approach is to establish a hypothesis and then test that hypothesis via thorough evaluation of relevant observations. If the hypothesis is demonstrated to be true via the scientific analysis, the hypothesis is accepted; otherwise it is rejected. The scientific method allows individuals with different belief perspectives to approach a given issue (e.g., a perceived problem), to apply data evaluation, and then to ultimately draw the "correct conclusion." For example, the following are alternate hypotheses offering differing viewpoints addressing the potential significance of exempt wells on the overall water budget:

Hypothesis 1: Exempt wells are causing an overall increase in consumptive use that causes observable changes in groundwater levels and streamflows.

Hypothesis 2: Exempt wells are not causing an overall increase in consumptive use of water, as changes in groundwater levels and streamflows are not being observed.

Another factor that needs to be considered in testing the aforementioned hypotheses is the overall water budget. For example, if a subdivision is placed on land that had been historically irrigated, then it is likely that this same land will see less consumptive use from irrigation. On the other hand, if land that had not been irrigated is subdivided, then that land would see increased consumptive use. The key is to complete a water budget analysis, or, in other words, include both the addition and subtraction before concluding that there will “cumulative” effects that lead to reduced or increased streamflow.

Regardless of which hypothesis the analyst chooses to start with or the initial bias of the scientist who is undertaking the analysis, a serious and proper evaluation of all the relevant data will allow the analyst to draw the correct conclusion. For example, in order for Hypothesis 1 to be accepted, it must be demonstrated through data evaluation that there is clear, compelling, and statistically significant evidence that exempt wells

are causing changes in both groundwater levels and streamflows. If this can be demonstrated, then Hypothesis 1 is accepted. Otherwise, Hypothesis 1 is rejected.

For Hypothesis 2 to be accepted, the data would have to demonstrate a compelling case that there are no "cumulative impacts." If the data exhibit evidence that demonstrates that there are "cumulative impacts," then Hypothesis 2 would be rejected. Ultimately, each analyst, regardless of their initial point of view, would have ended up drawing the same conclusion based upon data as the acceptance of Hypothesis 1 is the same as rejection of Hypothesis 2 and vice versa.

A second important method consists of the evaluation of data for causal relationships. For example, consider the relationship of streamflows to precipitation. In either method, care must be taken to account for as many factors as possible before drawing a conclusion. For example, it is well known that during the mid-2000s, streamflows were below average in the primary drainages that are evaluated in this report (e.g., Bitterroot, Clark Fork, Missouri, and Gallatin Rivers). Most scientists attribute such declines to the drought (e.g., reduced snowpack) that had been observed. If drought is responsible for groundwater level declines and streamflow changes, then it is inappropriate to attribute that response to another factor. The effects of drought are easily demonstrated by developing cumulative departure-from-average plots comparing streamflows to snowpack.

This water budget approach is applied to relatively large-scale hydrologic study areas. It is not intended to address site specific issues, but to provide a framework of understanding of water supply and use in high growth basins for consideration in water policy decision making.

2.1 Methodology

In its initial study of the Gallatin Valley, NE&W defined the hydrology of the area on the basis of the available hydrologic database. The Gallatin Valley is well known to have one of the higher individual well densities in the state of Montana. Similarly, Ravalli, Missoula, and Lewis Clark Counties also have large numbers of individual wells. All these areas are also seeing relatively high rates of population growth. A substantial fraction of this growth depends on water obtained using individual wells.

There are several factors affecting surface water and groundwater conditions that are

compiled and assessed in this report. These factors can be evaluated with the following sources of information:

- Precipitation and snowpack data as summarized respectively at the Western Regional Climate Center ("WRCC") and the U.S. Department of Agriculture Natural Resources Conservation Service ("NRCS");
- Streamflow data from the U.S. Geological Survey ("USGS");
- Groundwater wells and groundwater level data assembled by the Montana Bureau of Mines and Geology ("MBMG");
- DNRC water rights data;
- Land use information including, but not necessarily limited to, the following:
    - Evaluation of aerial photographs
    - Subdivision mapping
    - USDA Census of Agriculture

A substantial portion of the above geospatial information, including mapping, was obtained from the Natural Resource Information System of the Montana State Library ("NRIS").

All these data sources contributed to the water resources evaluations that are provided in this report.

2.2 Hydrologic Cycle

Groundwater and surface water are components of a complex dynamic system that is known as the hydrologic cycle. These and other components of this cycle are shown in Figure 2-1. Precipitation ultimately seeps into the ground, flows overland and in streams, evaporates, or is transpired to the atmosphere from plants.

2.3 Water Budget

A water budget is the numerical accounting of the inputs and outputs of water over a set volume (control volume). In other terms, it may be considered to be a quantification of all or a portion of the hydrologic cycle. The water budget equation is simple, universal,

and adaptable because it relies on few assumptions about the fundamentals of water movement and storage. A basic water budget for a watershed can be expressed as follows (from Healy, et al, 2007):

$$P + Qin = ET + \blacktriangle S + Qout$$

where

P	is precipitation
Qin	is water flow into the watershed
ET	is evapotranspiration (the sum of evaporation from soils surface water bodies, and plants)
▲S	is change in water storage
Qout	is water flow out of the watershed

The water budget can be applied to various scales, for example it can be state-wide, or it can be at a local scale, such as a specific watershed. Inputs and outputs can be estimated when specific data are not available.

2.3.1 USGS Reports

The USGS uses water budget methodology for water resources evaluations. This was a basic component of analyses performed for the study areas that were evaluated. The following are two more recent USGS reports that are highly relevant to this work and that demonstrate the importance of water budget methodology:

- "Estimated Water Use in Montana in 2000, In cooperation with the Montana Department of Natural Resources and Conservation," USGS Scientific Investigations Report 2004-5223, 2004 (USGS: Cannon and Johnson, 2004).
- "Water Budgets: Foundations for Effective Water-Resources and Environmental Management" USGS Circular 1308, 2007 (USGS: Healy, et al, 2007).

In particular, the latter report states the following:

> *"Water budgets provide a means for evaluating availability and sustainability of a water supply. A water budget simply states that the rate*

> *of change in water stored in an area, such as a watershed, is balanced by the rate at which water flows into and out of the area. An understanding of water budgets and underlying hydrologic processes provides a foundation for effective water resource and environmental planning and management. Observed changes in water budgets of an area over time can be used to assess the effects of climate variability and human activities on water resources."* [emphasis added].

Again, the water budget method is standard procedure in water resource assessment. The types of evaluations set forth by the USGS are paramount to developing orderly and meaningful water management strategies in Montana.

2.3.2 Montana Bureau of Mines and Geology Reports and Studies

The MBMG also employs the water balance (budget) approach. The report, "Hydrogeology of the North Hills, Helena, Montana" (Madison, MBMG, 2006) uses the water budgeting approach. Furthermore, careful evaluation of these studies reveals results and conclusions akin to those that were reported in the Gallatin Valley study (NE&W, 2007) as well as for the study areas described in the present report.

MBMG continues the groundwater investigation program per the direction of the legislature. Current, completed, and scheduled investigations are listed on the MBMG website http://www.mbmg.mtech.edu/gwip/gwip.asp .

2.4 Consumptive Use

The focus of this report is on human induced consumptive uses that may affect the water budget and streamflows at various scales. Consumptive use is a use of water that transforms water from its liquid state to vapor state. Consumptive use reduces the available supply of surface water and groundwater to others. The primary types of consumptive use include:

- Agricultural (irrigation and livestock)
- Industrial
- Commercial

- Domestic

By far, the dominant consumptive use in Montana is by agricultural irrigation.

Typically, not all surface water that is diverted from a stream or groundwater that is withdrawn from an aquifer is consumed or "lost" to the atmosphere. Rather, a substantial portion of that water reenters streams or underlying aquifers as unconsumed water returns. Examples include treated wastewater, irrigation infiltration, ditch losses, and ditch return flows. This returned water is then available for use by others.

There are additional losses of water influenced by human actions that are not necessarily beneficial uses, but are significant in terms of the overall water budget. These important losses include surface water evaporation and natural vegetation evapotranspiration (ET) (i.e., by phreatophytes).

As an example, reservoir evaporation is a major source of non-beneficial consumptive use in Montana. All natural vegetation consumes water. Even "natural" vegetation may be influenced dramatically by human intervention. For instance, many wetland areas have evolved over time in association with artificially elevated groundwater levels that resulted from long-term agricultural irrigation practices. This is particularly evident in the Bitterroot and Gallatin Valleys. These elevated groundwater levels are caused by recharge from irrigation ditch leakage and seepage from irrigated land surfaces. These elevated groundwater levels are responsible, in some part, for the presence of springs and seeps in lower elevation portions of the valleys. This, in turn, has encouraged increased growth of phreatophytes such as cottonwood and willow trees, etc. at these springs and seeps and along irrigation ditches. The net effect is to cause a substantial increase in evapotranspiration when compared to natural conditions before irrigation development. Such increases are known to cause significant and measurable reductions in streamflows in some cases.

A water budget approach can be used to quantify the implications of consumptive use and other hydrologic factors. For instance, at the statewide scale, one component of the water budget is the quantity of surface water leaving Montana each year. Annual runoff from Montana rivers averages about 43,800,000 acre-feet (ac-ft) per year[1]

[1] About 35 percent of this water originates in Wyoming and Canada.

(Cannon and Johnson). A relatively small fraction of water in Montana is consumptively used when compared to runoff.

Cannon and Johnson reported that the total consumptive use in Montana in year 2000 was about 2,662,000 ac-ft[2]. Hence, only about 6 percent of Montana's runoff was consumptively used that year. Using information set forth in Cannon and Johnson, the statewide runoff can be compared to the following (see Figure 2-2):

Agriculture consumptive use	2,494,000 ac-ft
Public water supplies	56,000 ac-ft
Individual or self-supplied domestic wells (a.k.a., exempt wells)	25,700 ac-ft

The relative amount of consumptive use compared to runoff in terms of percentages is:

Agriculture	5.7 percent
Public water supplies	0.13 percent
Individual or self-supplied domestic wells (a.k.a., exempt wells)	0.06 percent

These statistics provide a reasonable perspective of the relative significance of consumptive use from exempt wells and public water supplies in the state of Montana compared to streamflows.

2.4.1 Comparison to Other States

A common theme often used to justify additional strict controls on groundwater development in Montana includes statements akin to "look at what has happened in other states." However, caution is warranted when comparing the water supply and use in other states to that of Montana. If all the conditions were the same from state to state, there would be little need or purpose for conducting the scientific investigations and watershed studies that are routinely performed by professional and governmental entities such as the USGS and the MBMG. Factors relative to water resource quantities, conditions, demands, and other issues are not the same from state to state.

[2] Note that the level of significant figures from the Cannon and Johnson Report was reduced in this report.

Yet, it is not that unusual to hear that because of the water resource issues that exist in Arizona or Colorado, that there must be a pending water crisis in Montana.

In summary, there are obvious differences in geologic, hydrogeologic, climatological and surface water factors from state to state in the United States. There are also differing water policy and water demand histories that may or may not be applicable to Montana. Again, although examining another state's water policies does have merits and benefits, care should be used to be sure that those comparisons are appropriate and that the laws and rules that are ultimately developed make sense for Montana based upon the conditions and circumstances existing in the state.

As an example, compare the situation of Colorado to that of Montana. There are substantial differences as seen below (Hutson, et al, 2004):

	Montana	**Colorado**	**Percent Difference**
Population (2000 Census)	902,195	4,301,261	377%
Land Area (square miles)	145,552	103,718	-29%
Annual Precipitation (million gallons/day)	105,685	83,951	-21%
Total Withdrawals (million gallons/day)	9,300	14,200	53%
Percent Withdrawals to Annual Precipitation	9%	17%	
Total Withdrawals Surface Water (million gallons/day)	8,100	10,300	27%
Total Withdrawals Groundwater (million gallons/day)	**188**	**2,320**	**1,134%**
Total Withdrawals Irrigation (million gallons/day)	7,950	11,400	43%
Total Withdrawals Public Supply (million gallons/day)	149	899	503%
Total Withdrawals Domestic (million gallons/day)	18.6	66.8	259%
Public and Domestic Withdrawals per capita (gallons/day)	186	225	21%

It is noteworthy that Colorado has significantly higher population and higher total withdrawals and relies on groundwater to a much greater extent than does Montana. Colorado uses about 11.3 times the amount and rate of groundwater as Montana. In a broader sense, groundwater in Montana is largely an untapped resource in comparison to groundwater in Colorado.

Even as demands on groundwater grow in proportion to the population growth, the groundwater demand in Montana for public water supply and individual wells will remain

only a very small fraction of Colorado's groundwater use. Again, caution is warranted in applying water policies from other states to Montana without first considering if water supply and demands are comparable.

2.4.2 Agriculture

Beneficial uses of water by agriculture include irrigation and stock water use. Agriculture is by far the largest user of water in Montana. According to the USGS, irrigation consumptive use for 2000 was 93.6 percent of the total water consumption in Montana. Stock water accounted for 1.7 percent of total water consumption. The total agricultural use is over 95 percent of Montana's total consumptive use.

Components of irrigation consumptive use include crop evapotranspiration, uncontrolled evaporation (e.g., spray loss), and conveyance losses (e.g., evaporation and natural ET). Almost all, at about 99 percent, of the irrigation related consumptive use, is from surface water diversions. The percentage of consumption from groundwater sources is very small (1 percent) in comparison.

2.4.3 Industrial

Industrial use includes water from both public water supplies and by individual wells. Based upon information from Cannon and Johnson (2004), the amount of groundwater withdrawals for industry is about 36,000 ac-ft year. Most of this withdrawal is located in Missoula and Flathead Counties.

2.4.4 Domestic

Domestic use includes water from both public water supplies and individual wells. This is the water normally used inside the dwelling and does not include irrigation water for lawns and gardens, and other landscaping. The majority of the water used in a dwelling is returned to either surface water or groundwater as treated wastewater.

Consumptive use is typically estimated by multiplying a consumptive use factor by a per capita water demand value. Typically, water supply demands in Montana are developed on the basis of a 100 gallon per day (gpd) per capita assumption. Consumptive use factors have been reported to range from 2 to 15 percent of the total water demand (e.g. total withdrawal). The most reliable studies indicate domestic

consumption ranges from 2 to 5 percent. The most detailed and comprehensive study known to NE&W is an internal memorandum entitled "Domestic Consumptive Use - Summary" (Kimsey and Flood, 1987). Using information in that study, domestic or household consumptive use was determined to be less than 2 percent.

Some entities in Montana have recently reported additional consumptive uses associated with septic tank drain fields (up to 15 percent) in Montana. However, a careful evaluation reveals that the basis of this 15 percent number is likely not well understood by those entities. The source of this information is from studies in Colorado whereby the drain fields lie beneath land that is not irrigated. However, in most instances in Montana, drain fields lie below irrigated lawns. When a septic tank drain field lies beneath an irrigated lawn, the lawn consumption remains unchanged by the presence of a septic tank drain field (personal communications with Stenzel, 2008). In effect, counting the consumption of turf from lawn irrigation and then counting consumption again for that portion of the lawn lying above a drain field is a form of double counting.

In summary, for Montana's situation, it is deemed that use of the 2 percent consumption per household total withdrawal factor is applicable for water budgeting purposes. Assuming 100 gpd per capita and a population of 902,000 (per 2000 census) and applying the 2 percent household consumptive use rate, the total annual consumption for all domestic purposes, including both exempt and non-exempt wells and surface water use is about 2,000 ac-ft per year for the entire State of Montana. This equates to about 0.02 percent of the entire consumption of water by agriculture in the State of Montana. This household consumption also equates to about 0.005 percent of the flow (43,800,000 ac-ft) leaving Montana each year.

2.4.5 Domestic Irrigation

Domestic irrigation consumptive use is the evapotranspiration and evaporative conveyance losses resulting from the irrigation of vegetation, including lawns, gardens, trees, flowers, and other landscaping. Such irrigation may be from either public water supplies or individual domestic wells.

Domestic irrigation consumptive use is typically estimated by multiplying the irrigated area by the net irrigation requirement (ET minus effective precipitation). The total combined domestic consumptive use (public water deliveries and individual wells) for

lawn and garden irrigation and household consumption is about 45,000 ac-ft per year for Montana. This compares to 11,630,000 ac-ft per year used by agriculture which is about 250 times the annual volume of water used for lawn and garden irrigation and household use. Also, lake and reservoir evaporation of 1,000,000 ac-ft per year is about 22 times the total domestic lawn and garden irrigation consumptive use in the entire State of Montana. As another measure, the amount of all the lawn and garden irrigation and household consumption in Montana equates to about 0.1 percent of the water leaving Montana each year.

2.4.6 Commercial

Commercial enterprises (i.e., retail, offices, motels, etc.) receive water from both public water supplies and individual wells. About 28,000 ac-ft of water was delivered by public water supply services for commercial purposes in Montana in 2000. This water is likely used for a combination of purposes. The actual consumptive use involved is, therefore, difficult to estimate. However, based upon information presented in Cannon and Johnson (2004), it is probably reasonable to assume that about 40 percent of this 28,000 ac-ft is consumptively used. Accepting this rate, the amount of water consumptively used by commercial entities is about 0.03 percent of the water leaving Montana each year.

2.4.7 Non Beneficial Use Water Consumption

2.4.7.1 Surface Water Evaporation

A significant amount of water is lost each year via evaporation from surface water in Montana. Cannon and Johnson (2004) estimate a loss of about 891 million gallons per day (nearly 1,000,000 ac-ft per year) from the 60 largest reservoirs and regulated lakes in 2000. As a point of comparison, this reservoir and regulated lake evaporative loss grossly exceeds the total consumptive use of 170,000 ac-ft per year associated with groundwater withdrawals in Montana. In other words, the reservoir and regulated lake loss is about six times the consumption from all groundwater withdrawals in Montana each year. In comparison, this evaporation loss equates to about 2.3 percent of the streamflow leaving the state of Montana each year.

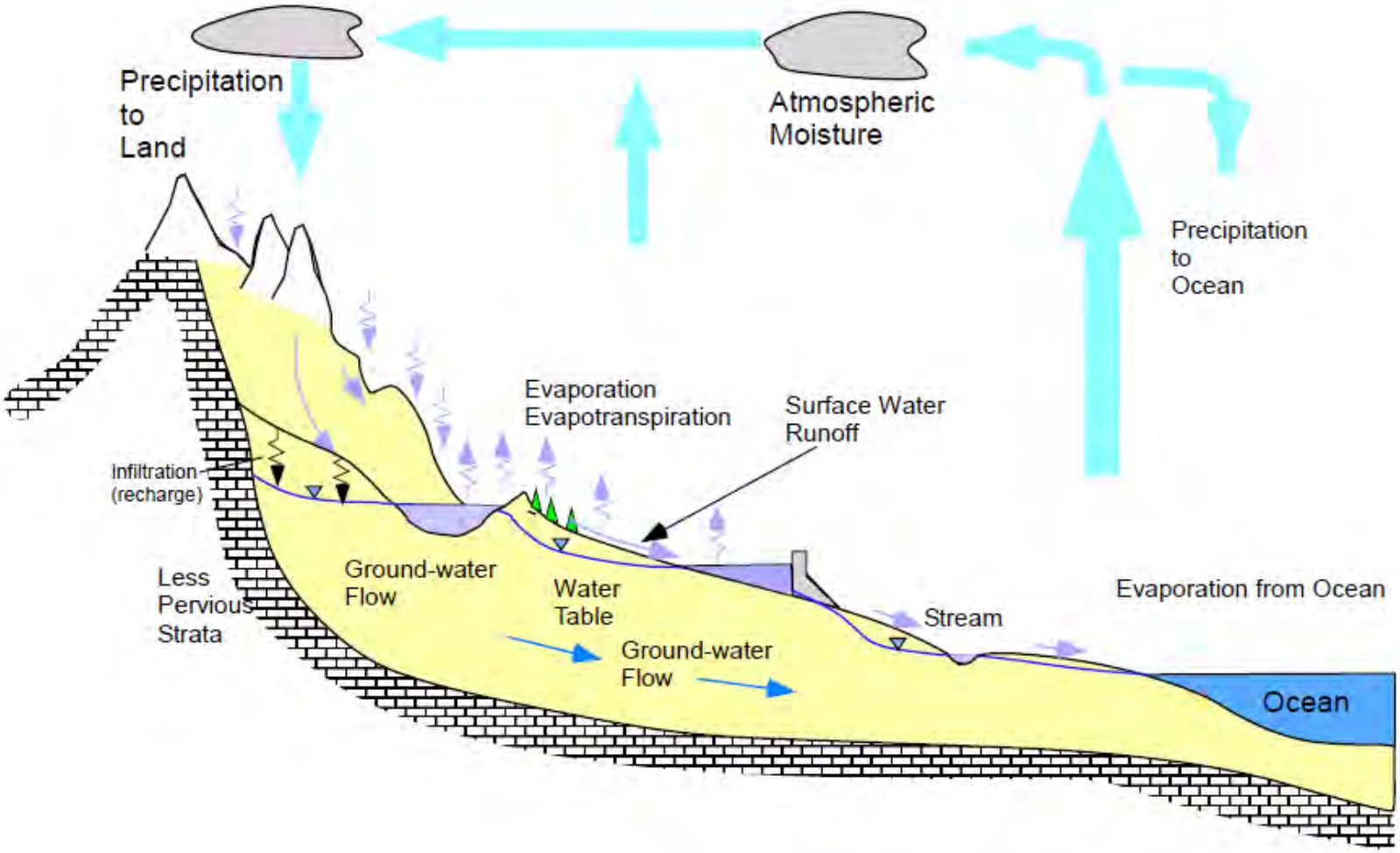
2.4.7.2 Natural Vegetation Evapotranspiration

All natural vegetation consumes (transpires) water. The consumption by native vegetation that is not irrigated or sub-irrigated is limited to what is termed effective precipitation (personal communications with Dr. Gerald Westesen, 2007). Where vegetation is located adjacent to surface water, or where groundwater is shallow, much larger rates of water may be consumed by phreatophytes such as cottonwoods and willows. As an example of their significance, Hackett, et al (1960) reports an estimated 15,000 acres of cottonwoods and willows in the Gallatin Valley in 1953 that consume from 30,000 (lower estimate based on ET) to 90,000 ac-ft (higher estimate based on specific yield) per year. If the higher end of this range is applicable, the evapotranspiration by these phreatophytes alone is as significant as that of all irrigated crop consumptive use in the Gallatin Valley.

Considering that transpiration is limited to the growing season, and assuming that the growing season is 174 days in the Gallatin Valley[3] , the phreatophyte consumption equates to an approximate Gallatin River streamflow equivalent of about 90 to 260 cubic feet per second. Given that phreatophytes are ubiquitous near irrigation ditches and other areas associated with high groundwater levels, their significance is likely substantial as well in Ravalli, Missoula, and Lewis and Clark Counties.

[3] It is assumed that phreatophytes will not survive cold temperatures below 24.5^{o} F (for purposes of the evaluation set forth in this report, the phreatophyte growing season is conservatively defined by NE&W as 174 days using data from WRCC). The actual growing season ranges significantly from year to year.

rec'd by LEPO April 13, 2016



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Notes:

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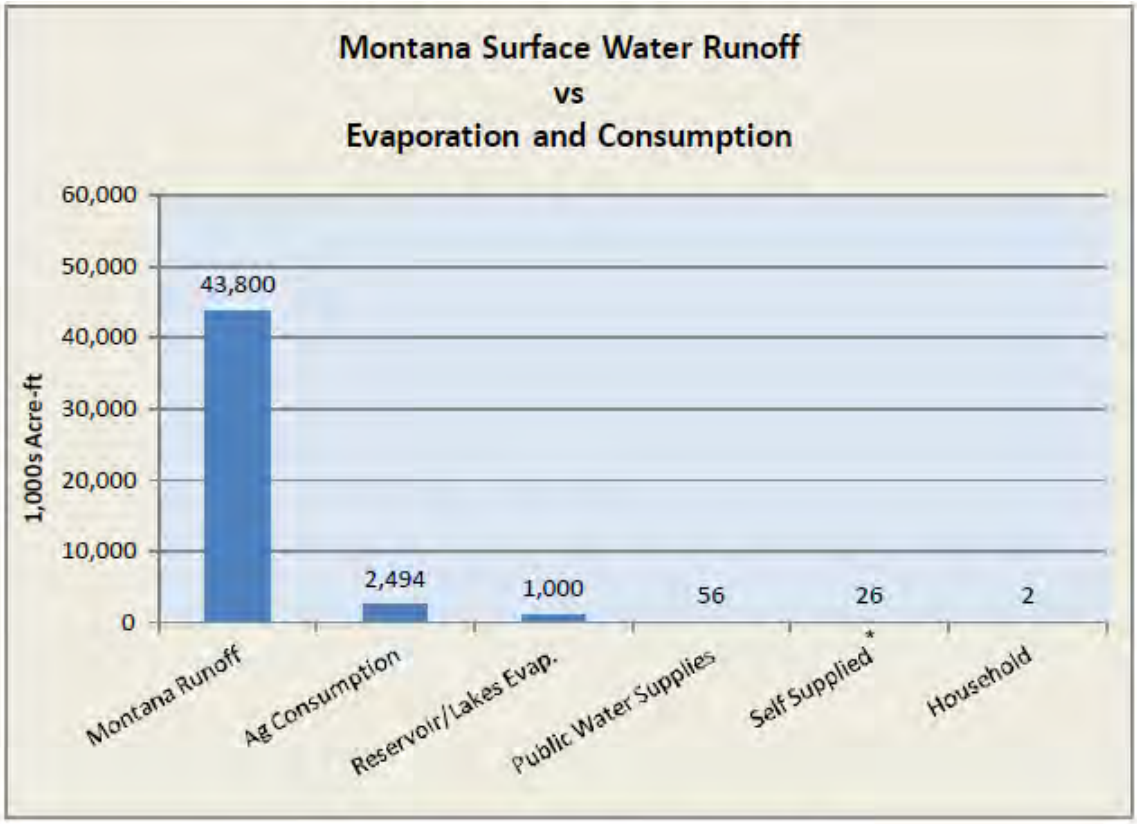
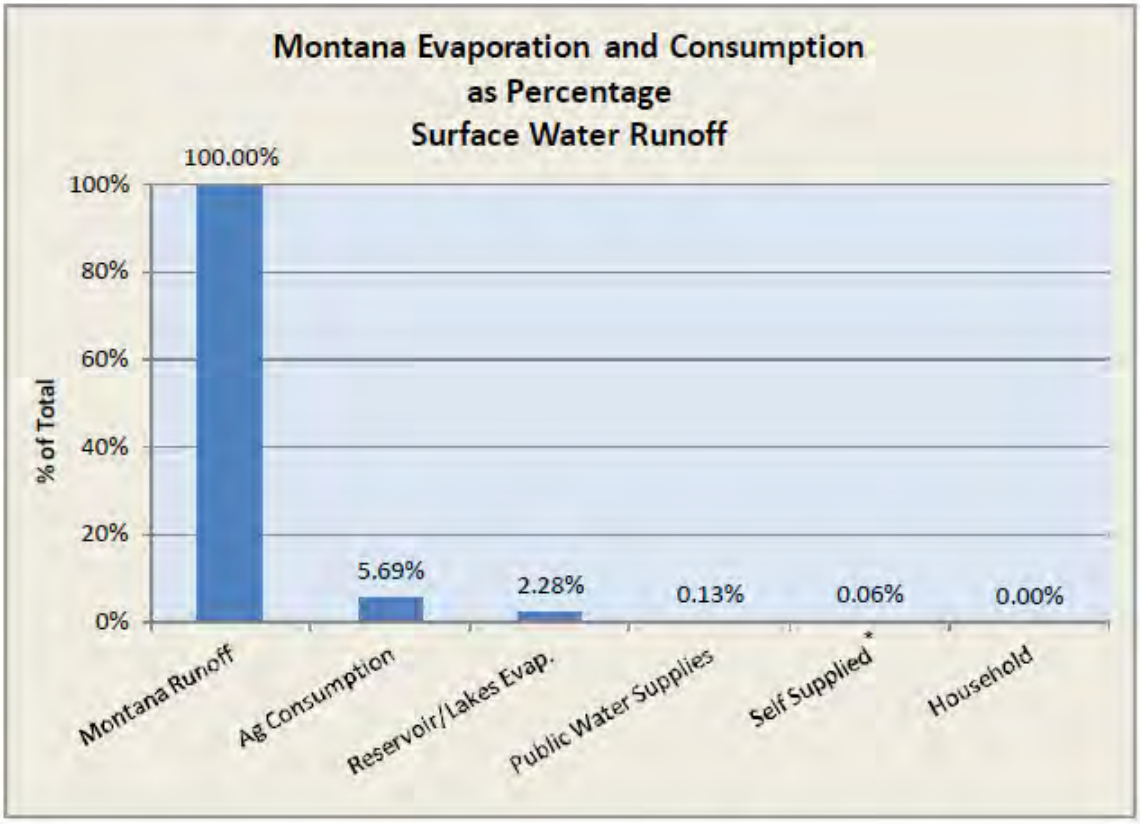
Figure 2-1
Global Hydrologic Cycle





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Date: 12/16/2015
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Notes:
Both public water supplies and self supplied domestic wells include lawn and garden irrigation. Note that some of the information from categories may overlap. In effect, the projections are for comparison purposes. Information is adapted from Cannon and Johnson, 2004.

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Figure 2.2
State-wide Surface Water Flows
VS Evaporation and Consumption

3.0 RAVALLI COUNTY - BITTERROOT WATERSHED

3.1 Physical Setting and Overview

Ravalli County generally encompasses the Bitterroot River watershed in western Montana (see Figure 3-1). The Bitterroot Watershed has been designated as a closed basin. This basin is bounded on the east by the Sapphire Mountain Range and on the west by the Bitterroot Mountain Range. Land elevations range from 3,200 to over 10,000 feet above sea level. About 70 percent of Ravalli County is federally owned and managed including the Bitterroot and Lolo National Forests and the Selway Bitterroot Wilderness. Ravalli County has seen relatively rapid growth in population and subdivisions. Most of the growth in this county has occurred within the valley portion of the watershed (refer to Figure 3-2).

All of Ravalli County is drained by the Bitterroot River and its tributaries. The total area of the Bitterroot Watershed is approximately 2,860 square miles, with Ravalli County occupying about 2,400 square miles.

3.1.1 Project Specific Information Sources

A variety of information sources were used in the evaluation of the Bitterroot River watershed and Ravalli County including the following:

- MBMG GWIC Database; and Geologic Mapping
- DNRC water rights permit database
- USDA NRCS Snow Course and SNOTEL data
- WRCC data
- USDA Census of Agriculture data

Much of the above information, especially mapping resources, was obtained from the Montana NRIS database.

3.1.2 Land Use

The predominant land use in the Bitterroot Valley is agricultural. According to data from the USDA Census of Agriculture, about 61,574 acres of crop land and pasture were irrigated in 2012. More recently, major economic activity in the valley has included significant growth in building construction. Based upon USDA census data, there has been a reduction in irrigated agricultural cropland acreage in the valley since the 1980s. This decline is likely related to irrigated cropland and pastureland being replaced with subdivisions in concert with population growth.

3.1.3 Climate

Lower portions of the Bitterroot River Valley are semiarid. Average annual precipitation ranges from 12 to 14 inches in the lower portions of the valley. Precipitation amounts increase substantially to about 18 inches near the mountain flanks at the edge of the valley. Much more substantial annual precipitation occurs extending up into the mountain ranges that bound the valley. Figure 3-3 shows mean annual precipitation up to about 80 inches in mountainous portions of the Bitterroot Watershed.

Temperatures vary substantially with the minimum average daily temperature in the valley being 16.7^{o} F in January and the average maximum daily temperature in the valley being 84.8^{o} F in the summer months of July and August (at Hamilton Station 243885). The minimum and maximum temperatures ever recorded at this weather station have been -39° F (February, 1934) and 105° F (July 1895) respectively.

3.1.4 Geology

The Bitterroot Valley between is bounded on the west by the Bitterroot Mountains and on the east by the Sapphire Mountains. Figure 3-4 presents a geologic map of the Hamilton vicinity that shows the main geologic units of the Bitterroot Watershed. The Bitterroot Mountains are formed mostly of Cretaceous intrusive rocks and associated masses of metamorphosed Precambrian rocks. The Bitterroot and Sapphire Mountains are formed mostly of Precambrian sedimentary rocks and contain lesser amounts of Cretaceous intrusive rocks and associated metamorphic rocks. Early Tertiary volcanic rocks are observed locally at the edge of the mountains and the valley. There is also Tertiary sedimentary rock located on lower flanks of the mountains.

3.1.5 Aquifers

From a groundwater flow perspective, the rock in the Bitterroot and Sapphire Mountains generally yield either low or only modest amounts of groundwater. This flow and/or water yields generally come from small fractures in the rock. Such flows are generally sufficient only for stock, domestic, and lawn irrigation purposes.

The most significant hydrogeologic features from a water supply perspective are the Quaternary deposits within the Bitterroot Valley. These deposits tend to be very coarse grained interbedded sand and gravel and can produce large rates of groundwater flow. Progressing outwardly from the edge of the valley to the Bitterroot River, the deposits include the following: colluvial deposits, fan deposits, floodplain deposits, which include the lower level terrace deposits and channel deposits.

The colluvial and fan deposits tend to be finer grained than the deposits located in the flood plain. The alluvium beneath the flood plain and deposits beneath the lower level terraces is more coarse-grained than the other deposits. Generally, the most permeable portion of the alluvial deposits is about 40 feet thick. It is likely that the alluvial deposits and colluvial/fan deposits inter-finger to a degree nearer the eastern edge of the valley. In addition, even within the flood plain boundaries, there is likely a mixture or inter-fingering of highly permeable material and low permeability fractions.

The coarser-grained alluvial deposits tend to thin nearer the edges of the valley. As a result, it is intuitive that the relative transmissivity of the floodplain deposits are highest at the center of the valley and that transmissivity gradually decreases progressing easterly to the edge of valley.

Tertiary deposits also underlie the Quaternary deposits in lower portions of the valley. These Tertiary deposits are considered to possess relatively lower permeability than the Quaternary deposits (see Figure 3-4). However, these Tertiary deposits are known to contain coarse-grained fluvial deposits that can produce substantial quantities of groundwater if tapped. The Tertiary deposits are up to 2,000 feet thick in portions of the Bitterroot Valley.

3.1.6 Surface Water

The Bitterroot River is the primary stream that drains the Bitterroot Watershed. It flows

for about 75 miles (121 km) south-to-north through the Bitterroot Valley extending from the confluence of its West and East Forks near Conner to the Clark Fork near Missoula. Figure 3-5a shows the main stream drainage network, as well as the current and historic flow gaging stations in this watershed.

3.2 Hydrologic Data Summary and Evaluations

3.2.1 Precipitation

Precipitation in the Bitterroot Valley is measured by both weather and by snowpack (SNOTEL) stations. Each of these is discussed below.

3.2.2 SNOTEL Data Collection Network

The NRCS installs, operates and maintains an extensive, automated system designed to collect snowpack and related climatic data in the Western United States and Alaska. This system, called SNOTEL (for Snowpack Telemetry), operates over 660 remote sites in mountain snowpack zones. In the mid-1930's, Congress mandated NRCS (then the Soil Conservation Service) to measure snowpack in the mountains of the West and forecast water supply.

Snow water equivalent is the measure that defines the depth of water that would be produced by a given snowpack. It is measured at a SNOTEL station by a pressure sensor which quantifies the weight of snowpack that lies on a snow pillow. Figure 3-5b shows the local SNOTEL stations as well as other climate stations relative to the Bitterroot River watershed. The four stations that were selected for the analyses presented in this report are Saddle Mountain (1968 through 2015), Nez Perce Camp (1977 through 2015), Skalkaho Summit (1977 through 2015), and Twelve Mile Creek (1968 through 2015). These SNOTEL stations were selected because they have sufficiently long periods of records to allow evaluations for this study.

Again, the NRCS collects SNOTEL data for forecasting streamflows. In fact, it is well known that the amount of mountain snowpack (as water equivalent) in each given water year (from October 1 through September 30) dominates the rate that streamflow enters and then exits the Bitterroot Watershed. This evaluation focused on each of the above SNOTEL stations as they possessed a sufficiently long period of record that could be

compared to the stream discharge data collected for the Bitterroot River.

Another SNOTEL station, Twin Lakes, is also present within the Bitterroot River drainage. However, the duration of record at this station was considered to be too short for evaluation purposes and therefore was not incorporated into the evaluation.

A summary of the results from the snowpack analysis is given below.

3.2.2.1 Saddle Mountain

Figure 3-6a provides a summary of the Saddle Mountain snow water equivalent over time. The upper plot presents the maximum annual water equivalent of the snowpack in inches over the period of record. The water equivalent has ranged from about 13 inches (1977) to more than 40 inches (1971, 1972, 1974, 1996 and 1997) over the period of record.

The lower plot in Figure 3-6a provides a cumulative departure-from-average snowpack for the period of data collection. Positive (upward) slopes in this plot define long-term periods of above average snowpack whereas negative (downward) slopes express long-term periods of below average snowpack. For example, a period of greater than average snowpack was observed from about 1968 to 1977. On the other hand, beginning in about 1999 or 2000, the snowpack was below average to 2005 and has been about normal since that time.

3.2.2.2 Nez Perce Camp

Figure 3-6b provides a summary of the Nez Perce Camp snowpack water equivalent over time. This SNOTEL station has the longest period of observation record of any of the SNOTEL Stations evaluated. The snowpack has ranged from about 7 inches (2005) to nearly 25 inches (1972) over the period of record.

The behavior of the CDFA plot (lower plot) in Figure 3-6b is similar to what was observed at the Saddle Mountain SNOTEL station for the period of time up to about 1998. However, since then, the Nez Perce snowpack was about normal whereas the Saddle Mountain was less than normal to about 2010. Since 2010 snowpack has been normal to above normal.

3.2.2.3 Twelve Mile Creek

Figure 3-6c provides a summary of the Twelve Mile Creek snowpack water equivalent over time. The snowpack has ranged from less than 10 inches to over 30 inches over the period of record.

The behavior of the CDFA plot (lower plot) in Figure 3-6c is, again, similar to what was observed at the Saddle Mountain SNOTEL station for the period of time from 1968 to present.

3.2.2.4 Skalkaho Summit

Figure 3-6d provides a summary of the Skalkaho Summit snowpack water equivalent over time. The snowpack has ranged from less than 12 inches (1977) to over 42 inches (1977) over the period of record.

The shape of the CDFA plot (lower plot) in Figure 3-6d is, again, similar to what was observed at the Saddle Mountain SNOTEL station for the period of time from 1977 to present.

3.2.3 Valley Precipitation

Long-term valley precipitation data have been collected at the following climate stations: Darby (Station 242221), Hamilton (Station 243885), and Stevensville (247894).

Figures 3-7a through 3-7c tabulate both the annual precipitation in inches and the cumulative departure-from-average (mean) for these respective stations. The plots demonstrate that temporal precipitation patterns vary in the valley from station to station. For instance, the Hamilton Station shows a CDFA plot of a substantially different form when compared to the Darby and Stevensville weather stations. It is important to recognize the spatial variability of precipitation within a study area as it may lead to misunderstandings about the impacts of climate and development on river flows. For example, river flows may be higher than normal during localized periods of low precipitation or vice versa. Again, the key factor impacting river flows is mountain snowpack.

3.2.4 Streamflow Data Evaluation Summary

Stream discharge rates and volume are primarily dependent upon each water year's snowpack. Long-term streamflow data have been collected at two stream gaging stations on the Bitterroot River as follows (shown in Figure 3-5a):

- USGS 12344000 (Bitterroot River near Darby). The drainage area above this station is 1,049 square miles, which represents about 37 percent of the total area of the Bitterroot Watershed.
- USGS 12342500 (West Fork of Bitterroot River near Conner). The drainage area above this station is 317 square miles, which represents about 11 percent of the total area of the Bitterroot Watershed.

Most of the remaining gaging stations along the Bitterroot and its tributaries have relatively shorter periods of record and are not as helpful in evaluating long-term streamflow trends. One of these gaging stations retained for evaluation is USGS 12352500 (Bitterroot River near Missoula). This gaging station is located near the mouth of the Bitterroot River at its confluence with the Clark Fork River. Hence, it represents about 100 % of the Bitterroot Watershed having a total area of 2,814 square miles. This gaging station has a flow measurement record extending from 1990 to present, which is a period of time wherein substantial population growth has occurred in the Bitterroot Watershed.

Figure 3-8a provides mean monthly and annual flow hydrographs for the Bitterroot River near Darby. The lower plot in Figure 3-8a is a cumulative departure-from-average streamflow plot for this gaging station extending from 1938 to present. An upward trend in the cumulative departure plot (lower plot) indicates a long term period of above average flow whereas downward trends indicate long term periods of below average flow. Relatively horizontal portions of a given plot demonstrate time periods when the flow is nearer the average flow. The following are general observations that can be made from these plots:

- The cumulative departure-from-average plots for both stations demonstrate that a relatively long-term trend for above average flows began in the mid-1940s and extended to about 1975.
- Flows from about 1975 to 1985 tended to be nearer average.

- Flows from 1985 to 2008 tended to be below average.
- Since 2008 flows have tended to be above average.

Figure 3-8b provides mean monthly and annual flow hydrographs for the Bitterroot River near Missoula gaging station. Data have been collected continuously at this gaging station since 1990.

3.2.5 Comparison of Streamflow to Precipitation

Again, streamflow in the Bitterroot Watershed is highly dependent upon precipitation for a given water year. The dominating factor for streamflows tends to be the magnitude of each water year's snowpack (snow water equivalent). Figure 3-9a provides a comparison of the snowpack as measured at Nez Perce Camp to Bitterroot River flow at Darby. Figure 3-9b provides another comparison of snowpack at Saddle Mountain versus the Bitterroot River near Darby. Figure 3-10 provides regression evaluations of Bitterroot River flow near Darby and at Missoula versus composited mountain snowpack. Figures 3-11 compares cumulative departure-from-average plots of valley precipitation, snowpack, and streamflow.

The plots shown in the above figures demonstrate that streamflow tends to mirror snowpack. Figure 3-11 demonstrates that streamflow is poorly correlated to valley precipitation.

Figure 3-12 and 3-13 present regression plots of the relationships between streamflows, valley precipitation and mountain snowpack. Again, Figure 3-12 demonstrates that the correlation between streamflow and valley precipitation is poor. Figure 3-13 shows three plots. The upper plot indicates that there has been a slight upward trend in flow since 1990 at the Bitterroot River near Missoula. The middle plot demonstrates that the correlation between streamflow and valley precipitation is poor. The lower plot shows that streamflow correlates much better to snowpack than to valley precipitation. This is logical since most of the precipitation, from a volumetric perspective, falls in the mountainous portions of the Bitterroot Watershed.

In summary, this analysis demonstrates what is already well known. The amount of snowpack is the dominating factor determining the magnitude of streamflow in the Bitterroot River.

3.2.6 Groundwater Level Summary

According to the MBMG's GWIC database there are presently about 19,209 total wells in Ravalli County (see Figure 3-14). These include water supply wells, monitoring wells, industrial wells, etc. Thirty-nine of these wells are observation wells that provide water level data. Most data collection began in the early 1990s from the MBMG's state-wide data collection network. Thirty-three of these wells have a period of record of at least ten or more years (see Figure 3-15 and Plate 3-1). Most of the wells reflect the impacts of climate (wet vs drought) and show seasonal variations (see Plate 3-1). Groundwater levels tend to increase during the late spring and early summer when recharge from precipitation and from surface-water irrigation activity is the highest. Most of the wells in Ravalli County have not shown any significant/ persistent long-term trends over time. It appears that some wells that had tended to show slight declines by 2008 are now either recovering or showing stable water levels. This tendency indicates that the limited downward trends observed in 2008 were mainly associated with drought. In other words, during periods of time of below average precipitation, water levels tend to decline (e.g., GWIC well 50808, 168180). During periods of above average precipitation, groundwater levels will tend to increase. In general, when the wells are collectively evaluated as a whole, groundwater levels have remained stable in Ravalli County over time.

3.2.7 Groundwater Storage

Groundwater storage in the Bitterroot Valley is an important component of the water budget for the Bitterroot Watershed. The MBMG has estimated the volume of storage in the shallow basin fill in this valley to be about 628 billion gallons (1.93 million ac-ft). This storage estimate was developed assuming 40 feet of saturated strata in the valley portions of the watershed. This estimate does not consider the Tertiary deposits, which would add significant additional aquifer storage in the Bitterroot Watershed. Hence, the above storage volume should be considered highly conservative.

Since groundwater levels have generally remained stable from year to year in the valley, the overall groundwater storage has also remained relatively constant from year to year as well. In order for storage to change there would need to be either an overall decline in groundwater levels (reduced storage) or an overall increase in groundwater levels (increased storage). It is also noted that groundwater flux (inflow and outflow) will

remain essentially the same from year to year when groundwater levels remain relatively constant. In general, groundwater flux entering and exiting the control volume is relatively small in comparison to surface water inflow and outflow. Hence, groundwater storage's potential contribution is considered inconsequential for water budgeting purposes.

3.3 Groundwater Use

3.3.1 Public Water Supply

Public water supply is water supplied by publicly or privately owned utilities for public distribution (Cannon and Johnson, 2004). Any water system that provides potable drinking water to at least 25 people for at least 60 days of the calendar year, or has at least 15 service connections is considered by law to be a public water supply. *See,* Mont. Code Ann. § 75-6-102(14). Water from public water supply systems is distributed to multiple users for domestic, commercial, industrial, and public uses. It should be noted that exempt wells are used as a source for public water supply system as long as they meet the criteria defined above.

According to Cannon and Johnson, in 2000, about 6,280 people were served by public water supply systems using groundwater in Ravalli County. This includes public water supply systems supplied by both exempt and larger wells. According to the MBMG (GWIC), as of 2015, there are currently about 263 public water supply wells in Ravalli County. These entities include subdivisions, commercial entities, and municipalities.

According to Cannon and Johnson, two million gallons per day (mgd) were delivered for public water supplies using groundwater in Ravalli County in 2000. This equates to 2,240 ac-ft per year. Using data from Cannon and Johnson it is estimated that about 40 percent of this delivered water is consumed. Therefore, the net consumption is estimated to be about 896 ac-ft per year. On a basin-wide basis (which includes portions of Missoula County), 3.74 mgd were delivered to public water supplies in 2000. This equates to 4,190 ac-ft per year. Using the 40 percent consumption assumption, the net consumption from groundwater for public water systems in the Bitterroot Watershed is 1,680 ac-ft per year.

3.3.2 Domestic Consumption from Individual Wells

Domestic use is water used within the dwelling for domestic purposes (does not include irrigation). The withdrawal (e.g., total demand) from individual wells is estimated based on the number of domestic wells, 2.5 persons per dwelling (well), and the demand of 100 gpd per capita. This volumetric criterion is based upon the Montana Department of Environmental Quality (DEQ) standards for designing public water supply systems. The total consumptive use associated with this withdrawal is based on the consumption rate of 2 percent of the total withdrawal. The 2 percent criterion is based upon Kimsey and Flood (1987). According to the MBMG GWIC database, there are 18,564 domestic wells in the Bitterroot Watershed. Assuming the methodology described above yields a total domestic consumption from individual wells in the Bitterroot Watershed of about 104 ac-ft per year. The amount of domestic consumptive use attributable to individual wells in Ravalli County is 92 ac-ft/year.

3.3.3 Lawn and Garden - Individual Wells

The estimate of water consumption attributed to domestic lawn and garden irrigation sourced by individual wells depends primarily on the area of land that is irrigated. Obviously, some property owners, especially with smaller lots, will irrigate relatively smaller areas. Similarly, some property owners will irrigate larger areas. Estimates of typical irrigated areas range from 1/8 to 3/4 acres per well. This study uses an average irrigated area of 1/2 acre per domestic well as a conservative approach to estimate the quantity of consumed water from individual wells used for lawn and garden irrigation.

This study considers three estimates of domestic irrigation consumptive use:

1. Assuming that each individual well (GWIC) irrigates 1/2 acre of lawn and garden results in about 9,282 irrigated acres with the net consumption of 15,036 ac-ft in the Bitterroot Watershed.

2. The DNRC projects that 5,797 exempt wells were present in the Bitterroot Closed Basin in 2006. If it is assumed that each of these exempt wells irrigates about 1/2 acres of land, then the net irrigated acreage from exempt wells is 2,900 acres of land resulting in a net consumptive use of 4,700 ac-ft for the Bitterroot Watershed.

3. It is noteworthy that the estimate of total withdrawals in the year 2000 from individual wells in the Bitterroot River basin developed by Cannon and Johnson is 3,400 ac-ft. Generally, the total groundwater withdrawal significantly exceeds consumptive use. The Cannon and Johnson study was reportedly coordinated with the DNRC. The amount of withdrawals reported by Cannon and Johnson would yield much smaller consumption rates than that estimated using the 1/2 irrigated acre per well assumption. For instance, the number of wells in the Bitterroot Watershed increased from 2000 to 2010 by about 27 percent. Prorating Cannon and Johnson estimates from year 2000 to 2010 would yield about 4,320 ac-ft of total withdrawals individual wells.

Hence, net consumption by irrigation from individual wells from the three approaches listed above ranges from 4,320 to 15,036 ac-ft/year. This study uses the average of that range for the following water budget analyses.

Suffice it to say that there is significant uncertainty as to the actual consumptive use from irrigation of lawns and gardens from individual wells in the Bitterroot Watershed and Ravalli County.

3.3.4 Agricultural Irrigation

The most dominant use of water in the Bitterroot Watershed is agricultural irrigation. Historically, most of the agricultural irrigation has been from surface water sources. Groundwater use for irrigation of agricultural crops is very limited in this valley.

3.3.4.1 Agricultural Irrigated Acreage

USDA Census of Agriculture data (http://www.agcensus.usda.gov/) provides information about the extent of irrigated land in Ravalli County. As of the 2012 census, there were 182,373 acres of land in irrigated farms and 61,574 acres were irrigated in that year.

NE&W also evaluated the irrigated land census data from 1982 to 2012 (five year census cycle) to assess if there was an overall decline in irrigated acreage.

Year	Acres
1982	76,401
1987	**77,247**
1992	65,717
1997	76,873
2002	75,505
2007	72,235
2012	61,574

The maximum acreage is indicated in **bold** and the minimum underlined.

Based upon this analysis it appears that irrigated acreage in the valley has decreased by about 15,000 acres from 1987 to 2012 (see Figure 3-16).

3.3.4.2 Irrigation Well Consumptive Use

Using the Blaney-Criddle method and assuming that there are currently 61,574 acres of irrigated land, the total net consumptive use for all surface water and groundwater irrigation for Ravalli County is estimated to be about 101,731 ac-ft. Cannon and Johnson (2004) reported the consumptive use volume from agricultural irrigation for Ravalli County to be about 96,000 ac-ft for 2000.

3.4 Water Budget Summary

This water budget summary includes water budgets for average and dry (drought) years. It also discusses factors that can affect the water budget including the significance of long-term drought, housing development, and agricultural irrigation. Finally, this summary presents the implications of future projected population growth in Ravalli County and the accompanying groundwater development on the water budget and streamflows.

Figure 3-17 provides a water budget of the annual volume of water entering and exiting the Bitterroot Watershed for an average water year. The basis of this figure is developed from the information set forth previously. Figure 3-18 provides another valley

water budget example under conditions representative of a drought year using 2001 SNOTEL records, precipitation, and streamflow data. Groundwater storage is assumed to be constant from year to year in each of these situations. Again, in order for storage to change there would need to be either an overall decline in groundwater levels (reduced storage) or an overall increase in groundwater levels (increased storage). Given that groundwater levels have been relatively stable, the assumption that groundwater storage is constant is deemed appropriate.

Referring to Figure 3-17, the amount of water entering the Bitterroot Watershed as precipitation for an average year is 4,963,000 ac-ft. The amount of water leaving the valley each year may be subdivided as follows:

- Surface-water flow: 1,597,000 ac-ft (water leaving the watershed at Missoula)
- Evaporation and transpiration (including consumptive use): 3,366,000 ac-ft
- Groundwater outflow (The groundwater flow is very small compared to the main water budgeting factors)

Nearly all the evaporative loss in the valley is from evapotranspiration by vegetation, which includes both irrigated and non-irrigated land as well as forested land, etc. Based upon information and calculations performed above, the evaporation and transpiration for the entire Bitterroot River Watershed can be subdivided as follows:

- Agricultural irrigation (all sources): 106,840 ac-ft

  This volume is adapted from the Bitterroot River Watershed using Cannon and Johnson (2004). The proportion attributable to Ravalli County is 100,700 ac-ft (all sources).

- Public water supply (1,680 ac-ft)

  - Surface water (327 ac-ft)
  - Groundwater (1,348 ac-ft)

These volumes are quantified using groundwater withdrawal information provided for the Bitterroot River Watershed by Cannon and Johnson and represent year 2000 evaluations. Actual values of consumptive use have likely increased in association with public water supplies that serve increased population growth.

- Lawn and garden irrigation from individual wells (9,678 ac-ft) [“midway” value] with the proportion attributable to Ravalli County being 8,404 ac-ft.
- Domestic consumption from individual wells being 104 ac-ft with the proportion attributable to Ravalli County being 93 ac-ft.
- All other evaporation and evapotranspiration (3,248,000 ac-ft). This is mainly watershed wide evapotranspiration associated with natural factors. It also includes the effective precipitation for irrigated areas which can be considered “nature’s contribution” to irrigated land evapotranspiration. In effect, about 96.4 percent of the watershed “losses” are associated with natural factors.

Again, Figure 3-18 provides the same information, but considers a drought year applying 2001 data. All consumptive uses were assumed to be the same as for a normal year for presentation purposes. In reality, there will be some difference, but this difference is difficult to quantify and is also inconsequential in the overall scheme of things.

Figures 3-19 through 3-21 compare the consumptive uses from above to provide a graphical representation of the relative significance of the various consumptive uses on the overall water budget. Figure 3-19 presents comparisons of consumptive uses to inflows from streamflow and precipitation into the valley for a normal year. Figure 3-20 provides comparisons of consumptive uses to inflows from streamflow and precipitation into the valley for a dry year. Figure 3-21 provides a comparison in terms of the shallow aquifer storage of the Bitterroot Valley. Again, these figures demonstrate that the relative amount of consumption from all groundwater uses is very small compared to both streamflows and to the amount of aquifer storage present.

Based upon the above assessment, it is obvious that the impact of groundwater development on the overall water budget and streamflow in the Bitterroot River watershed is very small.

3.5 Water Use Projections

The relative significance of future growth in the Bitterroot Watershed can be evaluated by projecting future demands and comparing those demands to the overall water budget

developed previously. There is significant uncertainty related to projecting future water use based on projected population growth. NE&W deems that the best approach for projecting future demand in Ravalli County and in Montana is to use a combination of historical population data and census-based growth projections.

The population of Ravalli County increased by 4,142 from 2000 to 2010. Based on 2.5 persons per dwelling, this results in an increase of about 1,657 new dwellings. Based on historical ratios, about 1,263 of these new dwellings will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 1/2 acre, this equates to a consumptive use increase of 1,025 ac-ft as of 2010.

The Montana Department of Commerce reports population projections provided by eREMI (a product of Regional Economic Models, Inc). The latest available projections are dated April 2013. These projections show the population of Ravalli County increasing from 40,212 per the 2010 census to 44,691 in 2030. It is assumed that about 2.5 persons per dwelling results in 1,792 new dwellings over that same time period. Based on historical ratios, about 1,378 of these new dwellings will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of about 1,117 ac-ft due to additional individual wells by year 2030. This equates to about 0.2 percent of the flow leaving the Bitterroot Watershed near Missoula each year during a normal flow year.

From a public water supply perspective, it is assumed that such consumption will increase similarly in proportion to population growth. Thus, the net increase in consumption for public water supplies sourced by groundwater is estimated at 234 ac-ft from 2000 to 2010 and projected to be an additional 304 ac-ft per year by 2030 for Ravalli County.

Again, it should also be noted that there is likely to be a corresponding decrease in agriculturally irrigated acreage as much of the development can be expected in the valley floor. The USDA Census of Agriculture irrigated acreage irrigation data can be used to illustrate this. The ten year average of irrigated acreage in Ravalli County was quantified for two different periods of time with the following results:

- 1982 through 1992 (73,122 acres)
- 2002 through 2012 (69,771 acres)

This represents a 3,350 acre decline in irrigated crop land in Ravalli County. Applying the 17 % assumption to estimate pasture land yields a decline 816 acres. Using the Blaney-Criddle approach, this represents a decrease in consumption of about 5,863 ac-ft. Therefore, most of the projected increase in consumption from population growth in Ravalli County will likely be offset by decreased consumption from agricultural irrigation.

The above illustration demonstrates the importance of completing both the addition and subtraction in the water budgeting process.

3.6 Projected Increase in Consumptive Use Versus Seasonal Streamflow

The relative significance of projected increases in consumptive use from individual wells can be compared to gaged streamflow. The projected increased consumption for Ravalli County from 2010 to 2030 is 1,116.5 ac-ft. Note that wells are distributed over a relatively broad area of the Bitterroot Watershed. Hence, it is deemed reasonable to assume that the relative depletion associated with this projected growth can be defined using a steady-state approximation in 2030. This equates to about 1.5 cfs of depletion in the Bitterroot River.

On a year-to-year basis, the relative change by year would be about 56 ac-ft.

Figures 3-22a and 3-22b compare the relative significance of the projected depletions on streamflows as measured at the Bitterroot River near Missoula. A 5 percent flow measurement accuracy criterion is shown on each figure to assess if it is possible that a depletion of 1.5 cfs (by year 2030) would be detectable in the gaging data. If the 5 percent flow measurement criterion were to fall below the projected depletion of 1.5 cfs, then the projected change would be considered potentially detectable. Otherwise, the projected change is considered not detectable.

Given that the 1.5 cfs depletion falls beneath the 5 percent flow measurement criterion, it is concluded that the relative significance of the individual well growth would not be detectable in the flows as measured at the Bitterroot River near Missoula.

As another perspective, it is useful to define the projected net increase in consumption (and depletion) from individual wells on a year to year basis. The year to year change is about 0.075 cfs (or about 34 gpm). This is approximately the same as the flow in about

6 garden hoses. Such a rate of change in flow is obviously not detectable in the flow of Bitterroot River.

Finally, it should be noted that the projected depletion does not account for increases in streamflow associated with potential land use change transitions from irrigated agriculture to residential subdivisions. The trend has been for much of the new development to occur on previously irrigated farmland. As development uses less water compared to agricultural irrigation, the result is a net increase in water availability. As such, the new development generally does not impact the ability of existing surface water appropriators to fully utilize their water rights.

BITTERROOT
Watershed

Slope Classes from NED

0 5 10 15

Mapscale 1: 550000 Scale in miles:

MONTANA Natural Resource Information System

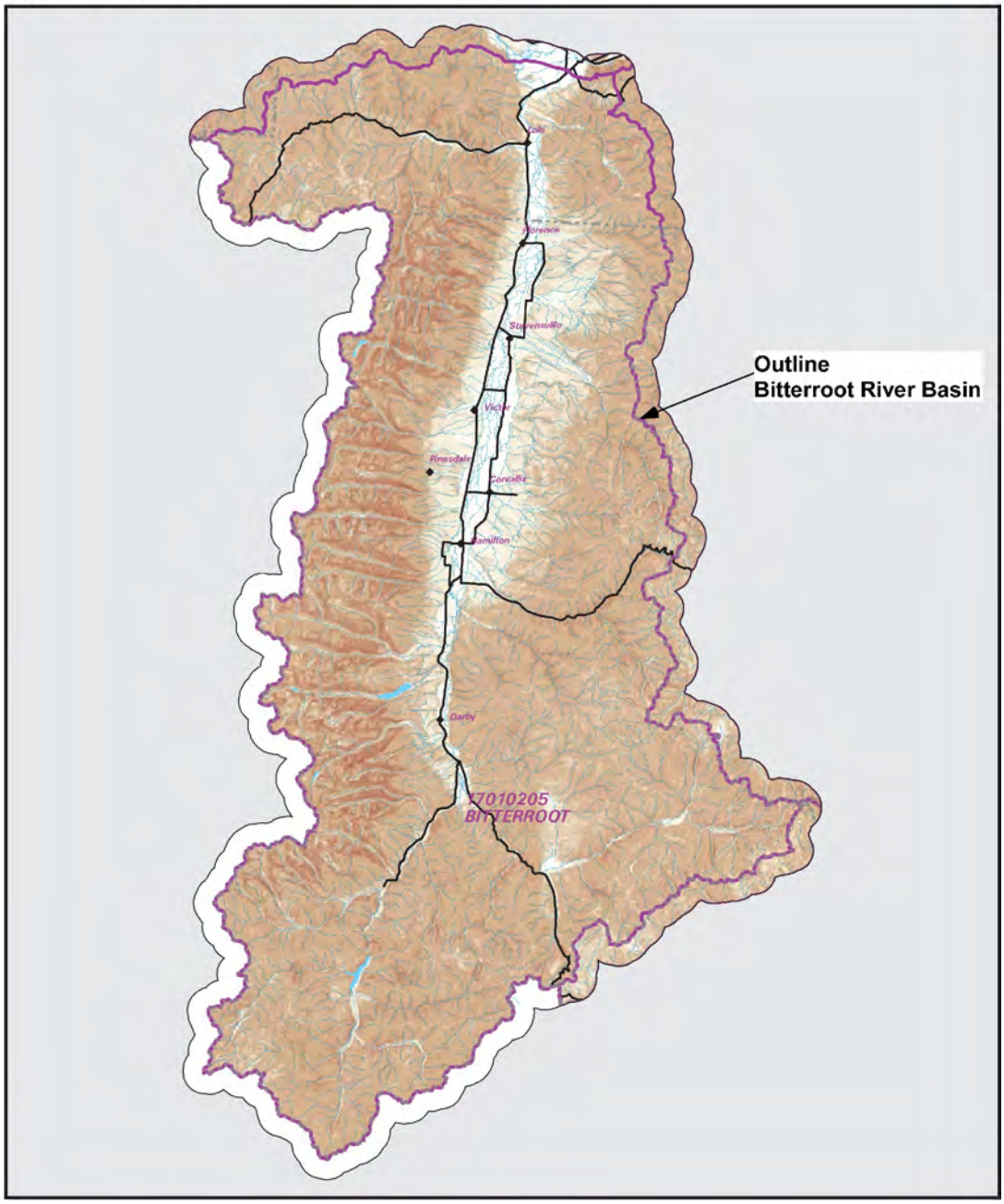
Date created: December 04, 2003

Map Request: 04MSL0001 - 17010205 - SLOPE

County Border
Highway
Fourth Code Watersheds
0 < X < = 4
4 < X < = 10
10 < X < = 30
30 < X < = 45
45 < X < = 60
60 < X = 90
Flat, 0

SOURCE:
US Geological Survey National Elevation Dataset (NED) files.
NED has been developed by merging the highest resolution elevation data available for the United States into a seamless dataset.
The slopes displayed are derived from the NED solely to illustrate one application of the dataset. This slope data is intended to display slope patterns, rather than a particular point of slope.

This map is to be used as a primary reference source and is not intended for use in site - specific planning. This is public information and may be interpreted by organizations, agencies, units of government, or others, based on needs; however,they are responsible for the appropriate application. Federal, State, or local regulatory bodies are not to reassign to the Natural Resource Information System any authority for the decisions they make.



NICKLIN EARTH & WATER, INC.

Date: 12/24/2015
File: Figure 3-1

Montana Association of REALTORS®

Figure 3-1
Bitterroot Watershed
Resource Information System Report

rec'd by LEPO April 13, 2016

NICKLIN EARTH & WATER, INC.

Date: 12/11/2015
File: 3-2

4 Miles

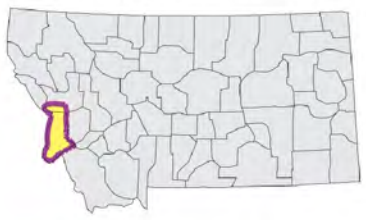
Montana Association of REALTORS®

Figure 3-2
Streams in Bitterroot Watershed
Water Resources Evaluation

rec'd by LEPO April 13, 2016

BITTERROOT Watershed

PRISM Precipitation



0 5 10 15

Mapscale 1: 550000 Scale in miles:

MONTANA Natural Resource Information System
Montana State Library — 1515 East 6th Avenue
Helena, Montana — (406) 444-3357

Date created: November 06, 2003

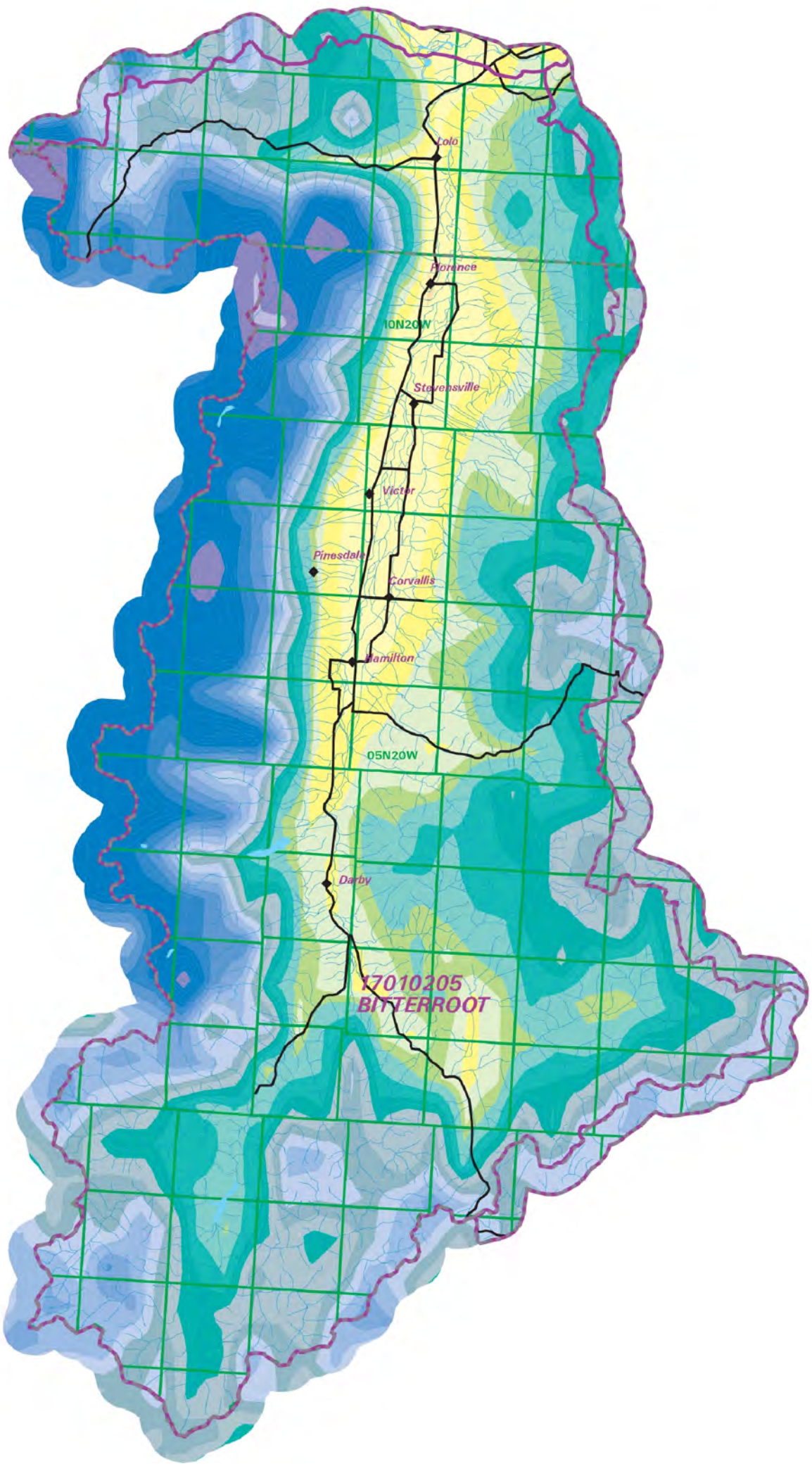
Map Request: 04MSL0001 - 17010205 - PRECIP

- County Border
- Highway
- Public Land Survey System Townships
- Fourth Code Watersheds

10-12
12-14
14-16
16-18
18-20
20-24
24-28
28-32
32-36
36-40
40-44
44-48
48-52
52-56
56-60
60-70
70-80
80-90

SOURCE: Spatial Climate Analysis Service at OSU.
These data were produced using the PRISM modeling system of the Spatial Climate Analysis Service at Oregon State University. The project was directed and sponsored by the NRCS National Water and Climate Center in Portland, Oregon. PRISM stands Parameter-elevation Regressions on Independent Slopes Model.

This map is to be used as a primary reference source and is not intended for use in site - specific planning. This is public information and may be interpreted by organizations, agencies, units of government, or others, based on needs; however,they are responsible for the appropriate application. Federal, State, or local regulatory bodies are not to reassign to the Natural Resource Information System any authority for the decisions they make.



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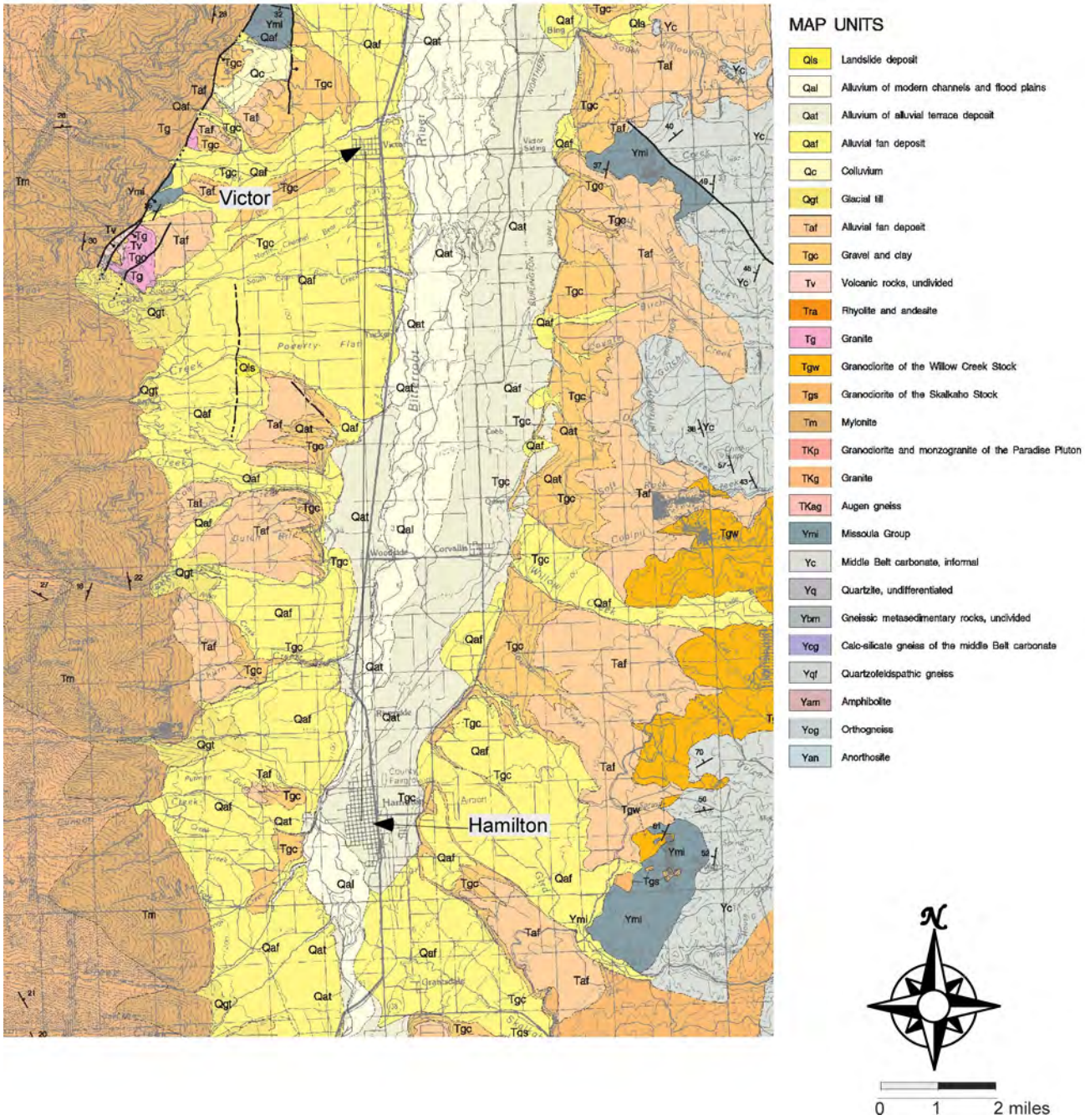
Date: 12/16/2015
File: Figure 3-3

Montana Association of REALTORS®

Figure 3-3
Bitterroot River Basin Precipitation
Montana NRIS Report

rec'd by LEPO April 13, 2016



From GEOLOGIC MAP OF THE HAMILTON 30' x 60' QUADRANGLE, WESTERN MONTANA
Compiled and mapped by Jeffrey D. Lonn and Richard Berg
Montana Bureau of Mines and Geology
Open File Report MBMG 340 (revised: 8/03)

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Date: 12/16/2015
File: Figure 3-4

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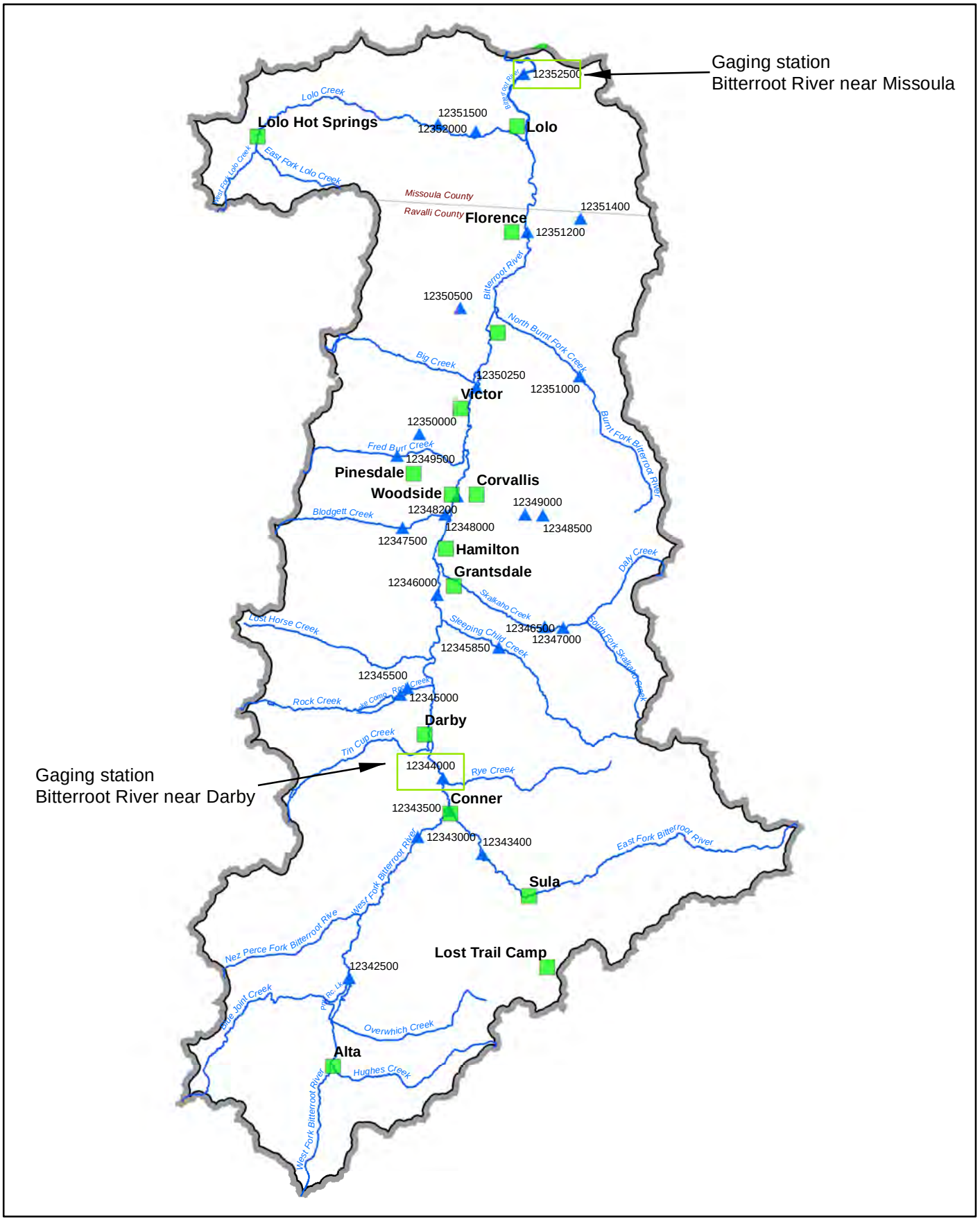
Figure 3-4
Bitterroot Valley Geologic Map
Hamilton Vicinity

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/17/2015
File: Figure 3-5a

4 Miles

Legend

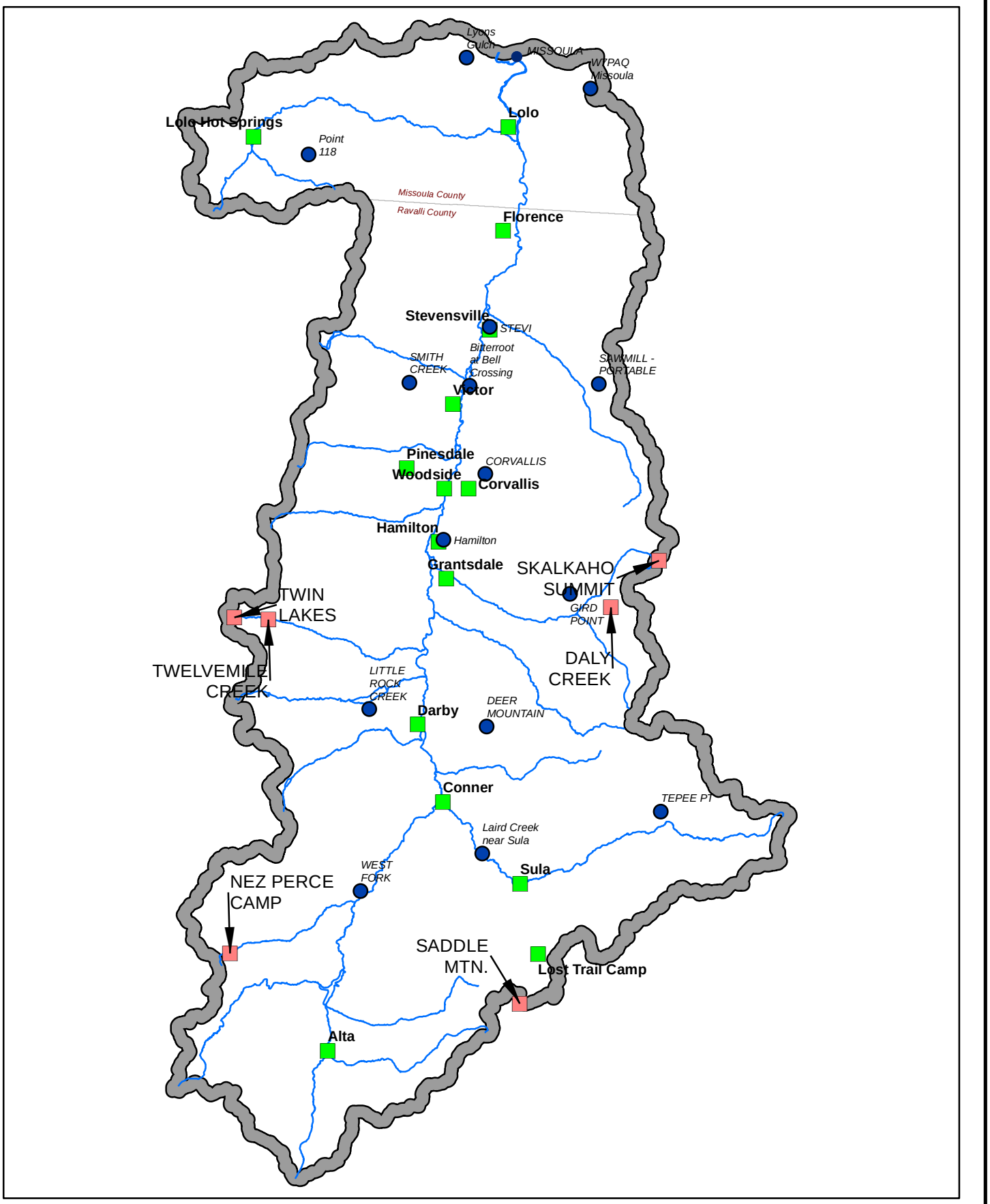
Towns

USGS stream gaging station

Montana Association of REALTORS®

Figure 3-5a
Streamflow Gaging Stations
Bitterroot Watershed

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/18/2015
File: Figure 3-5b

4 Miles

Legend

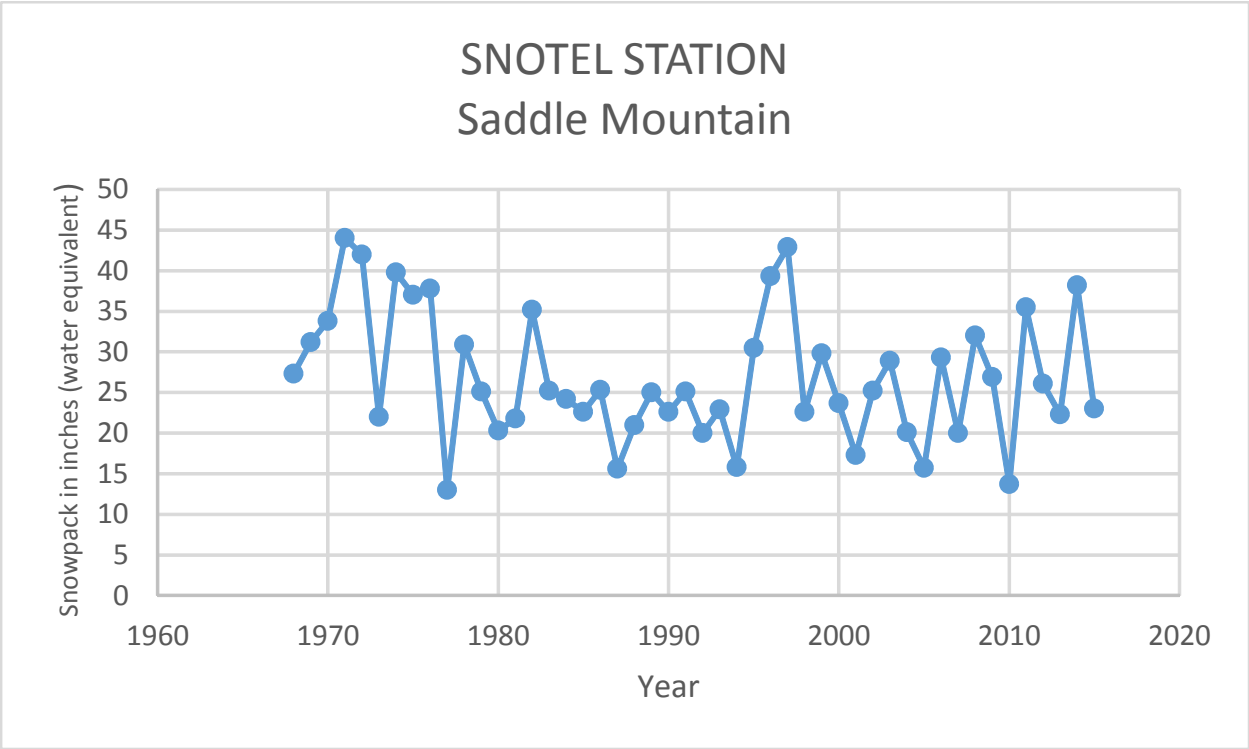
Snotel selection

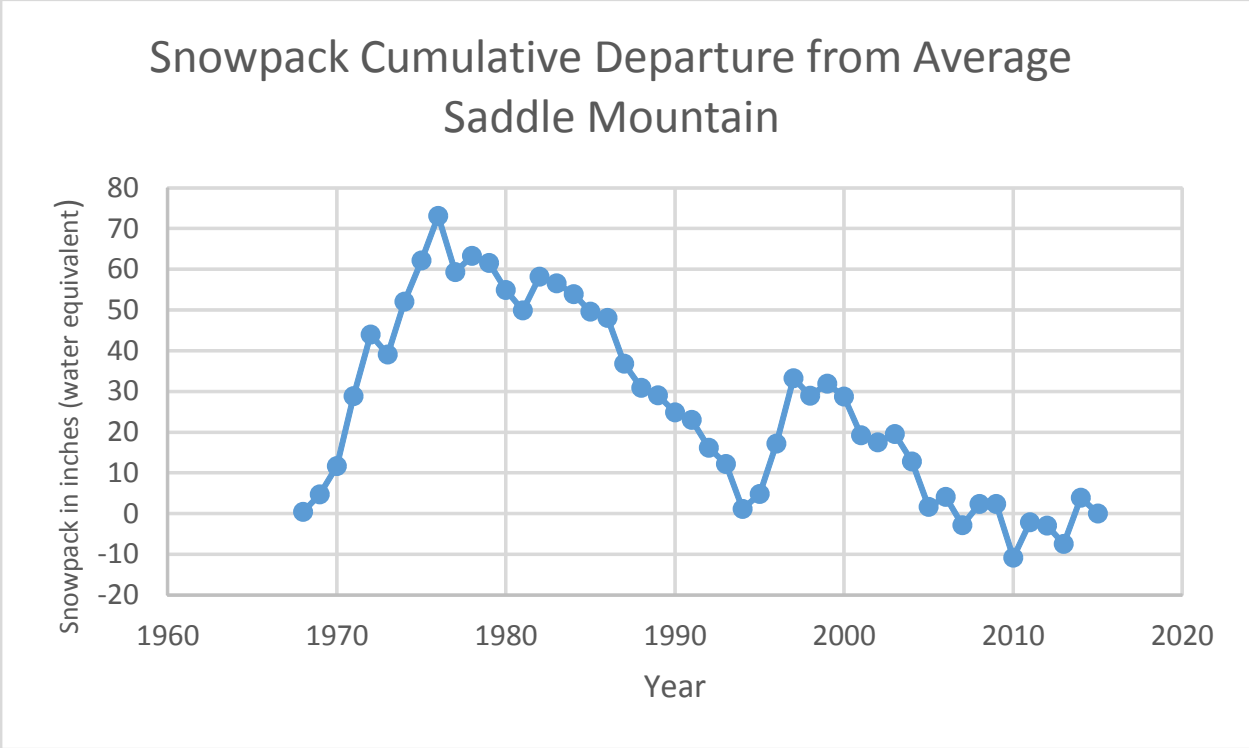
Climate Station

Montana Association of REALTORS®

Figure 3-5b
Climate Stations
Bitterroot Watershed

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/11/2015
File: Figure 3-6a

Notes:
Data source: National Water and Climate Center
SNOTEL Snow Water Equivalent Data Tables for Montana
Note: For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends implay periods of below average snowpack.

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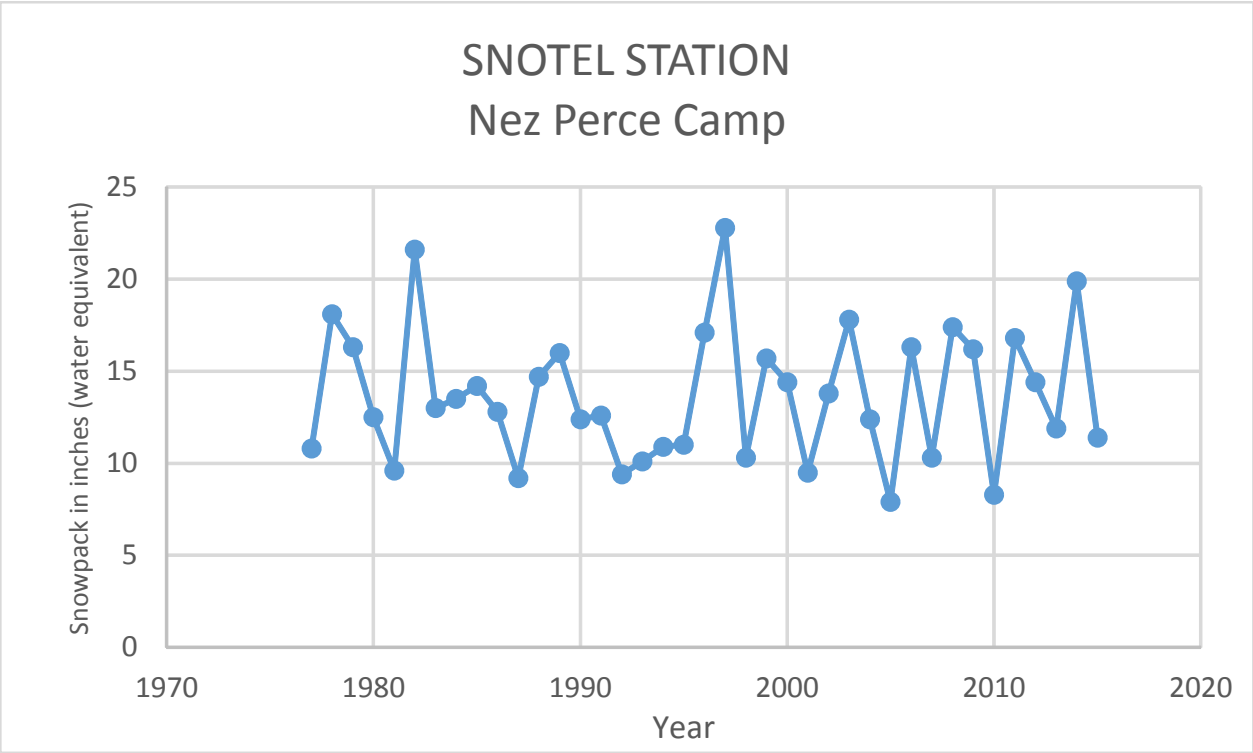
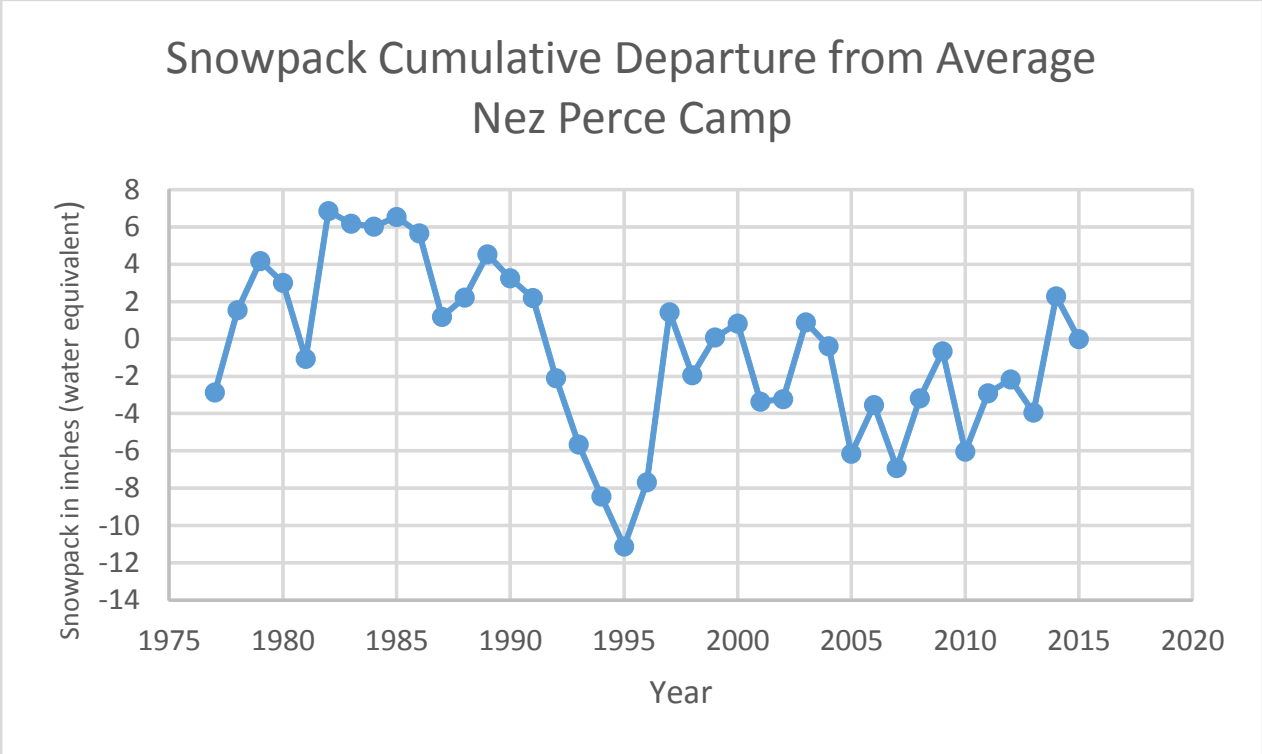
Figure 3-6a
SNOTEL Data Summary
Saddle Mountain

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/11/2015
File: Figure 3-6b

Notes:
Data source: National Water and Climate Center
SNOTEL Snow Water Equivalent Data Tables for Montana
Note: For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends implay periods of below average snowpack.

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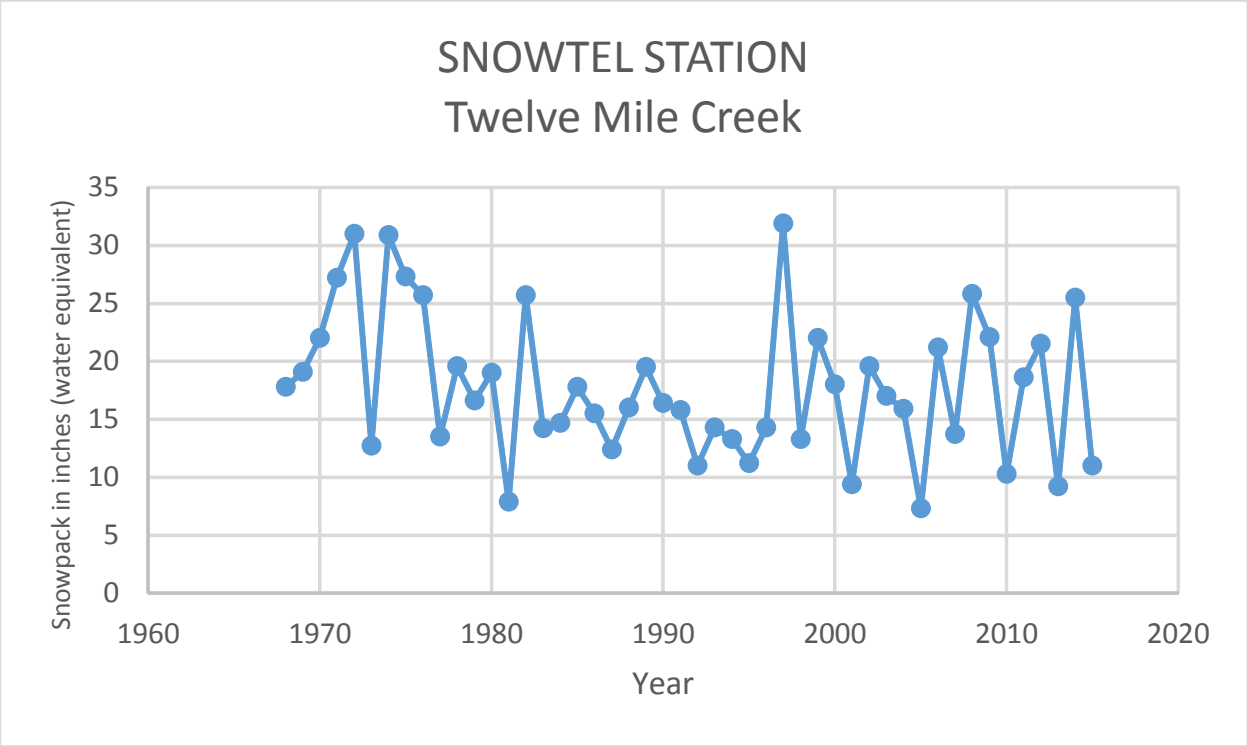
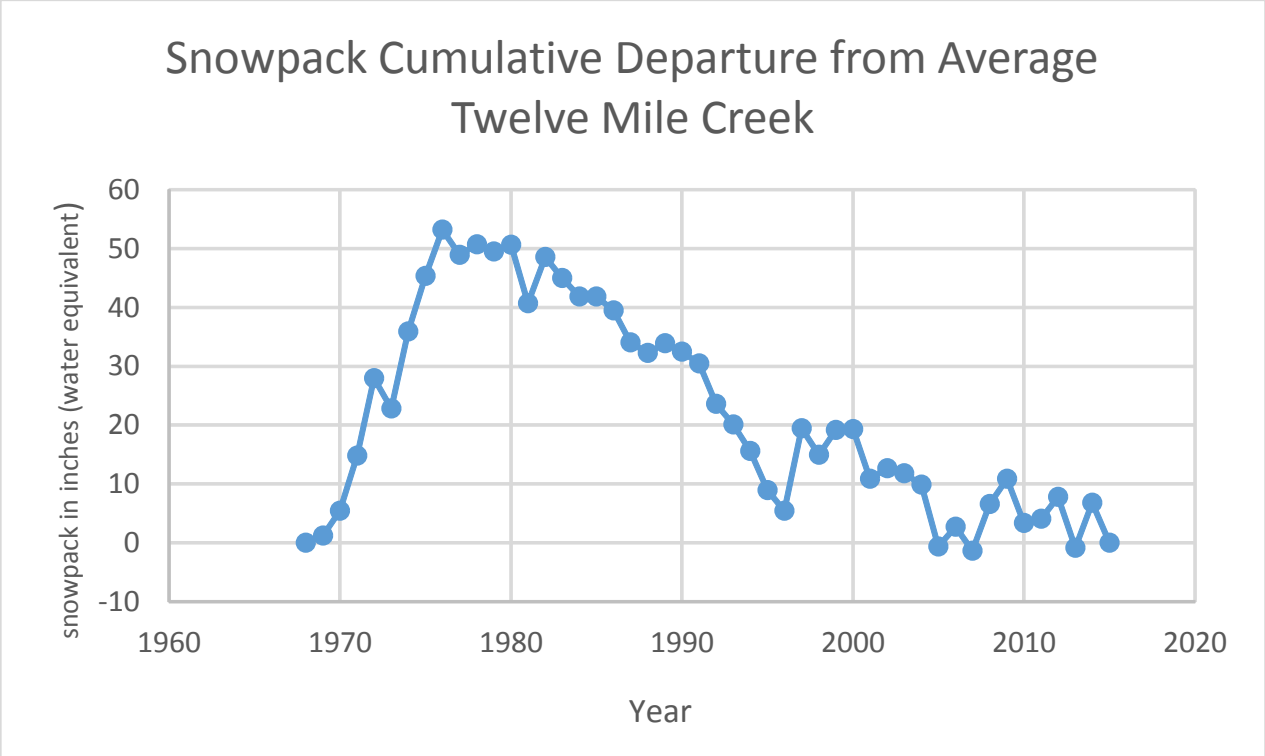
Figure 3-6b
SNOTEL Data Summary
Nez Perce Camp

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/11/2015
File: Figure 3-6c

Notes:
Data source: National Water and Climate Center
SNOTEL Snow Water Equivalent Data Tables for Montana
Note: For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends implay periods of below average snowpack.

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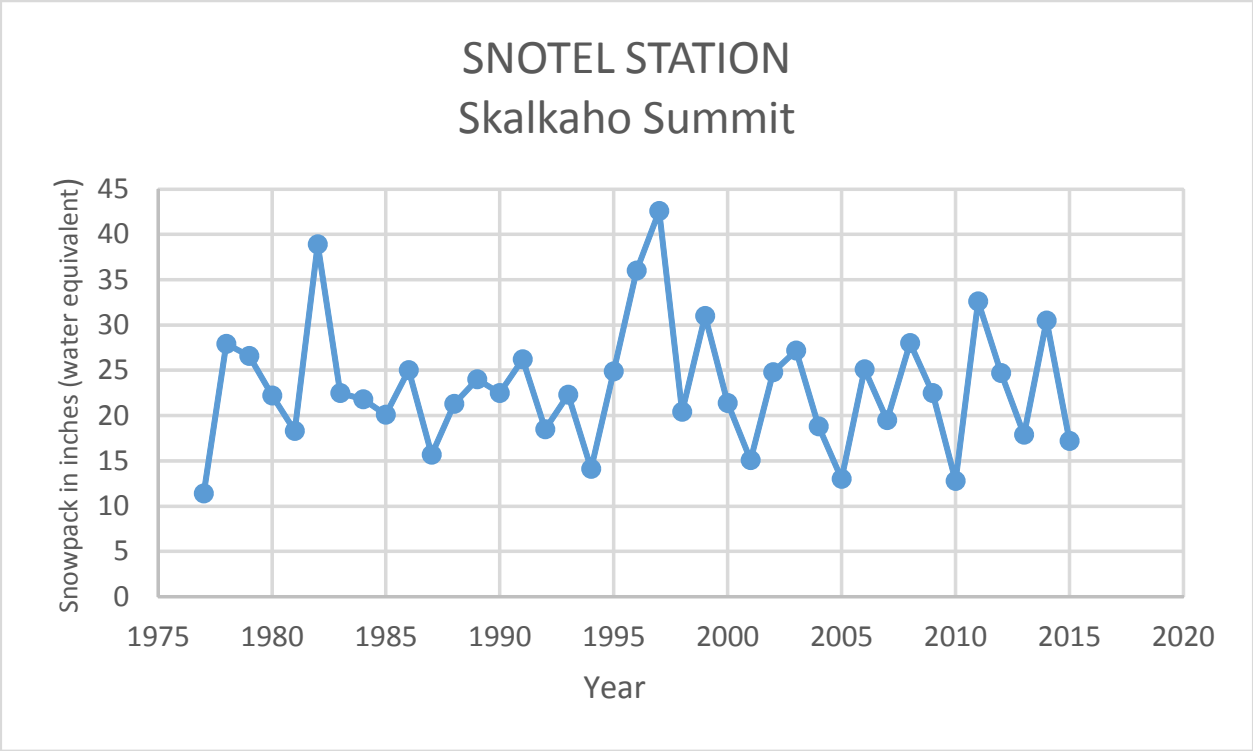
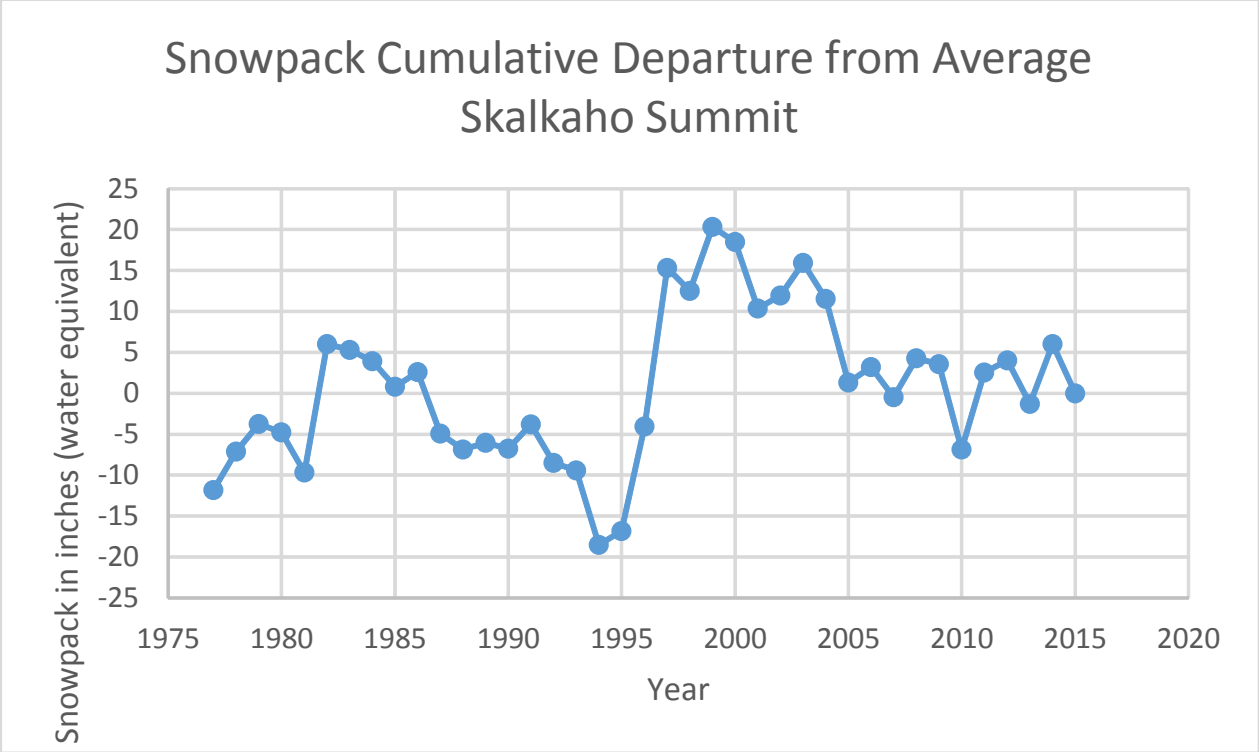
Figure 3-6c
SNOTEL Data Summary
Twelve Mile Creek

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 3-6d

Notes:
Data source: National Water and Climate Center
SNOTEL Snow Water Equivalent Data Tables for Montana
Note: For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends implay periods of below average snowpack.

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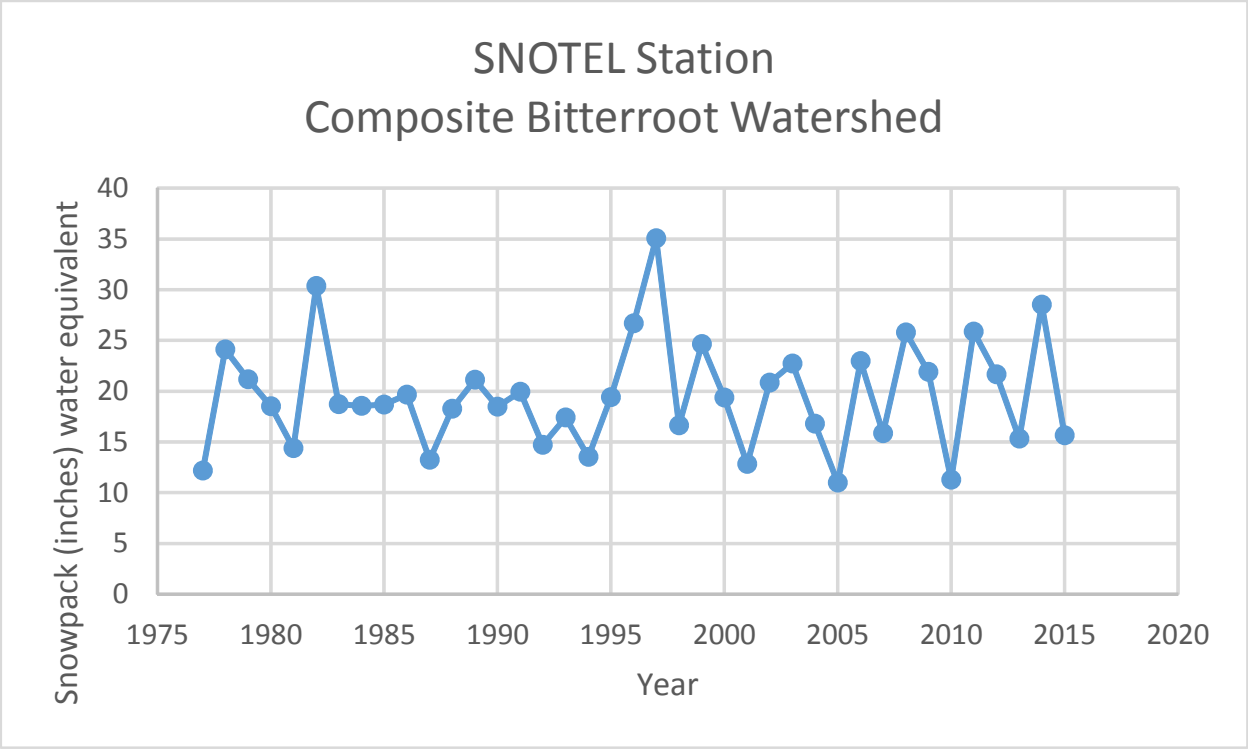
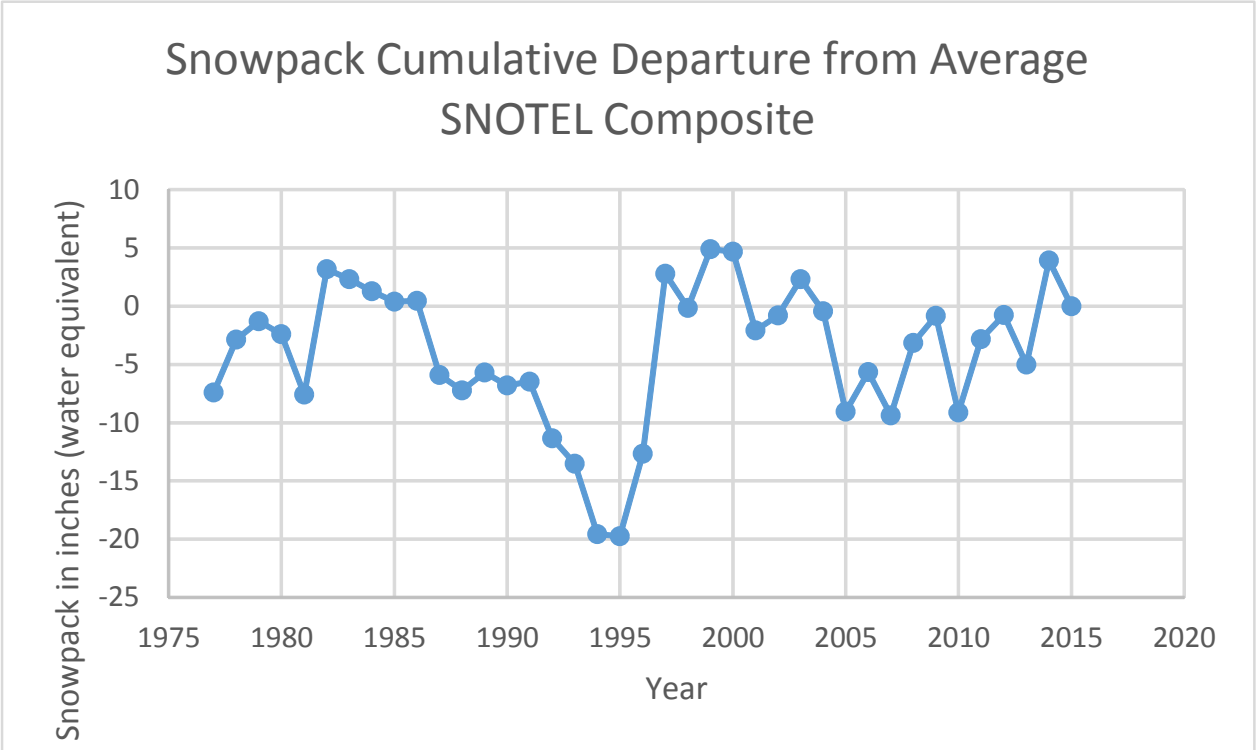
Figure 3-6d
SNOTEL Data Summary
Skalkaho Summit

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 3-6e

Notes:
Data source: National Water and Climate Center
SNOTEL Snow Water Equivalent Data Tables for Montana
Note: For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends implay periods of below average snowpack.

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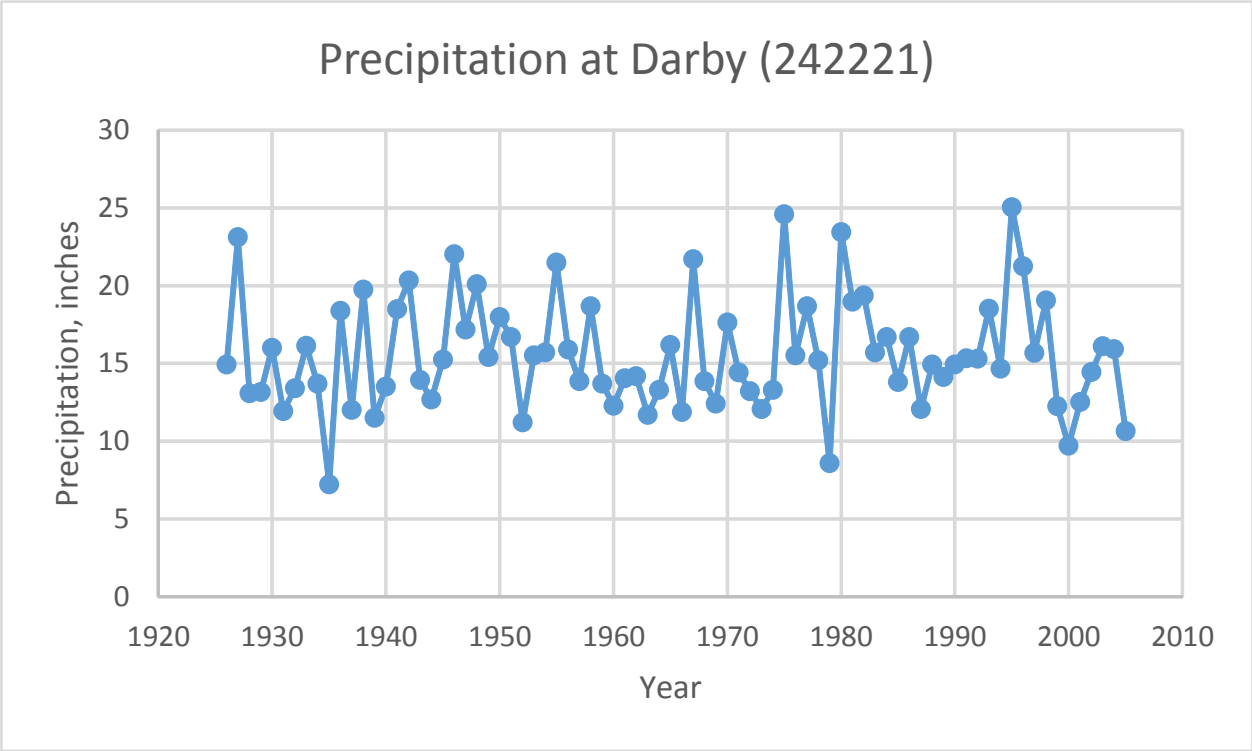
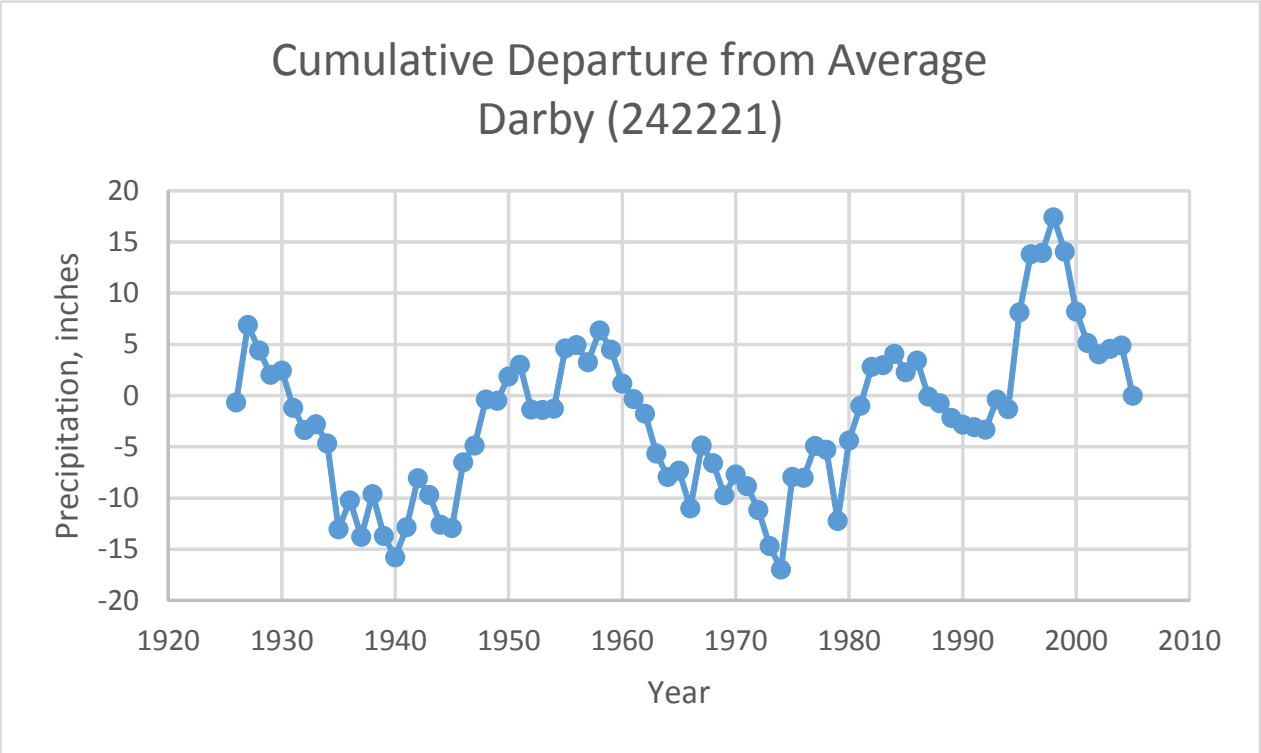
Figure 3-6e
SNOTEL Data Summary
Composite SNOTEL Stations

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/11/2015
File: Figure 3-7a

Notes:
Precipitation data from WRCC.
Data after 2004 were intermittent and are not included in graphs.

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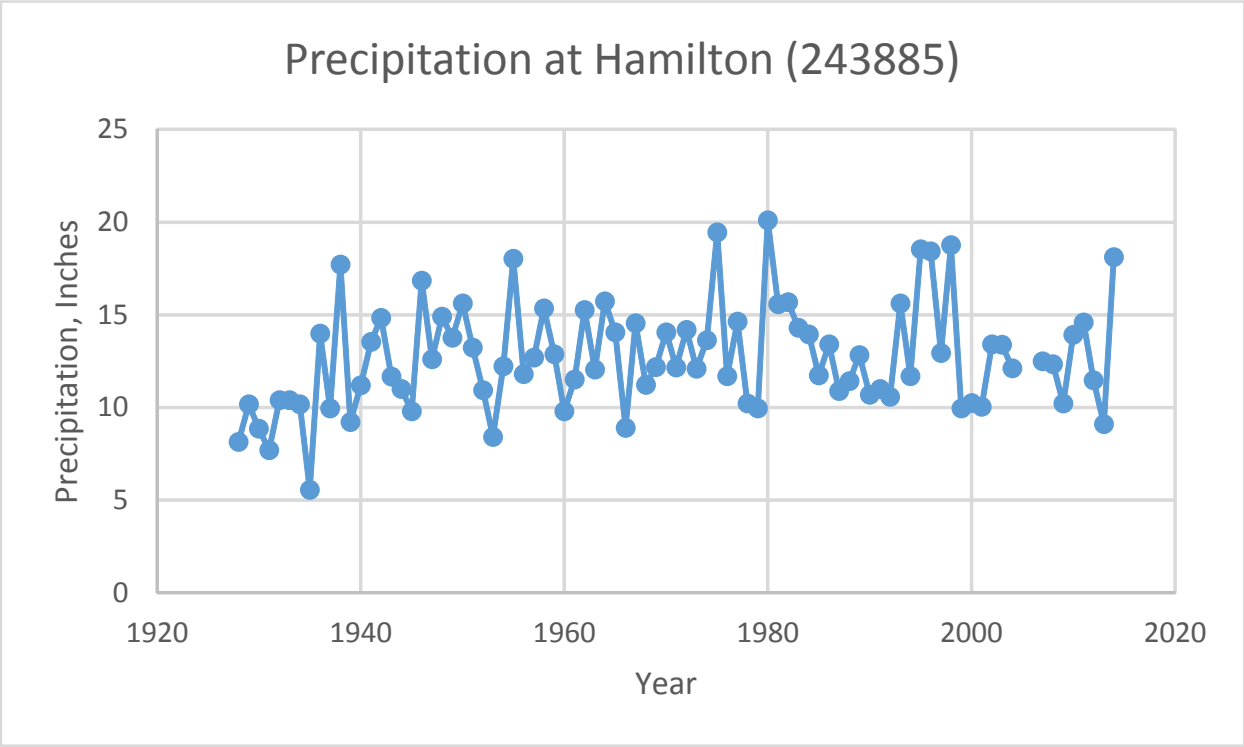
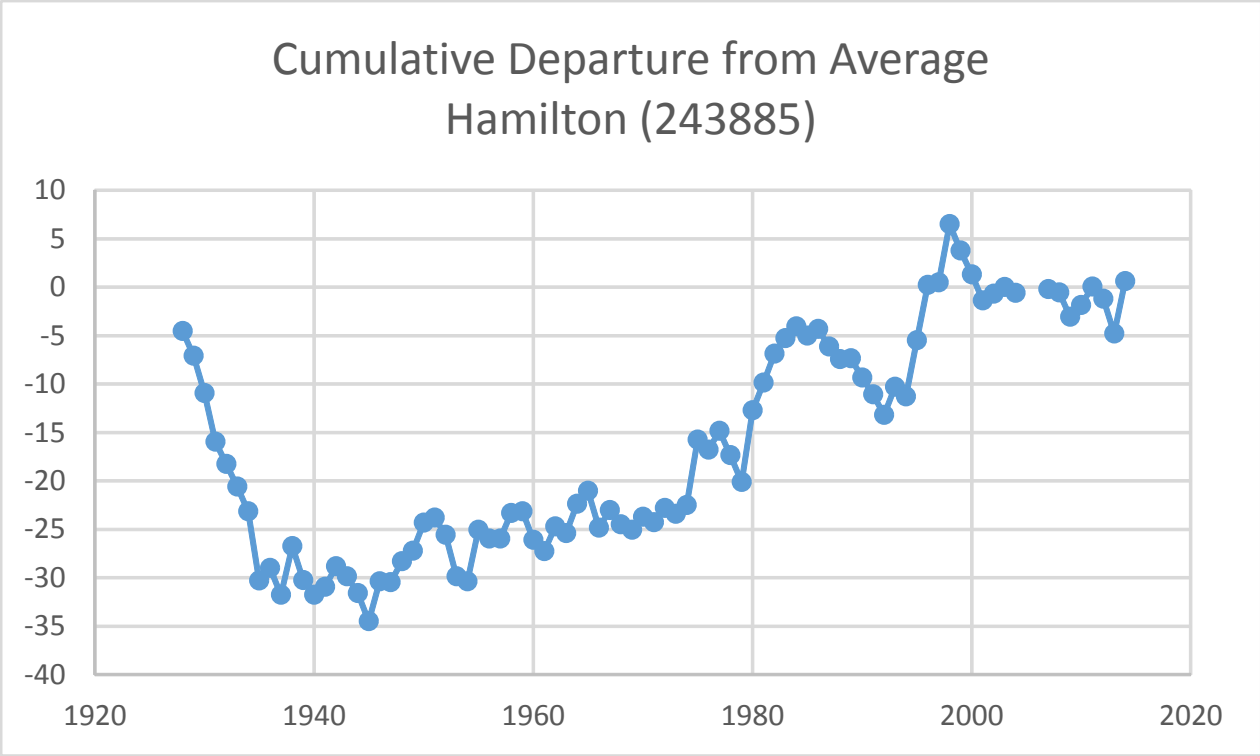
Figure 3-7a
Precipitation at Darby
Bitterroot Valley

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 3-7b

Notes:
Precipitation data from WRCC.
Before 1928 on intermittent data are available.
These data were not included. Precip data for
2005 and 2006 were missing and are not included.

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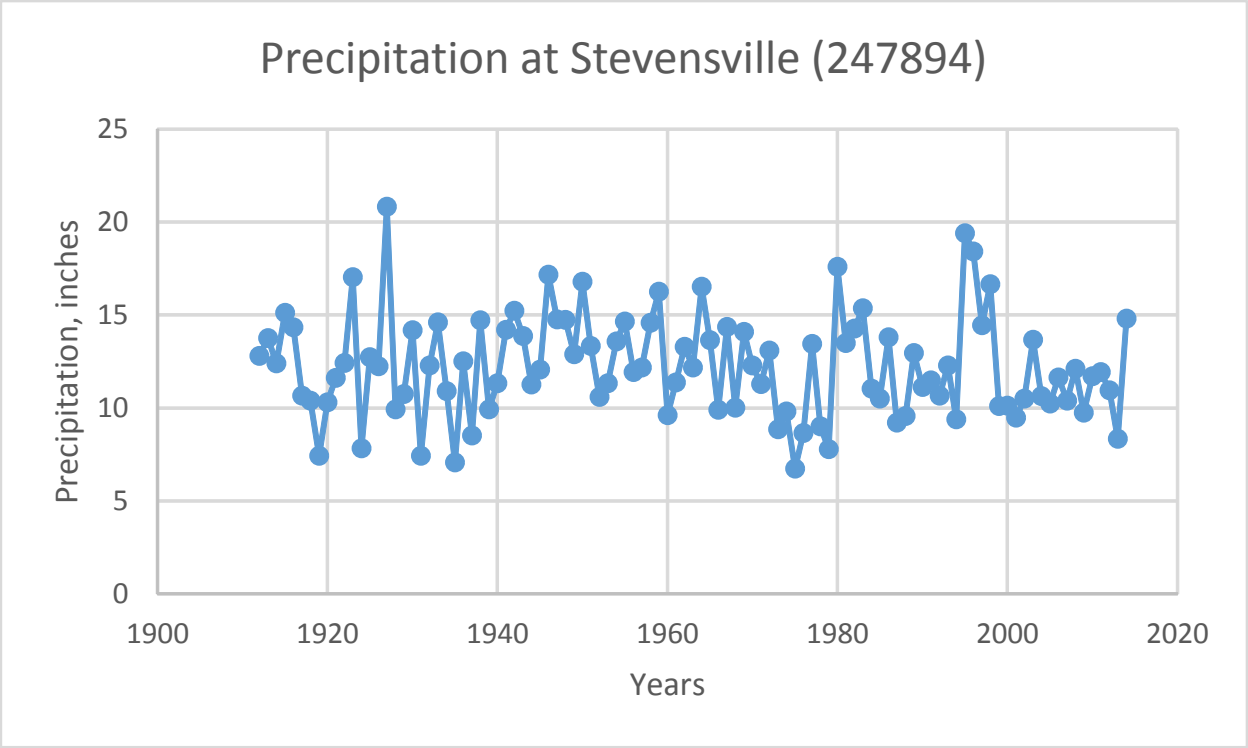
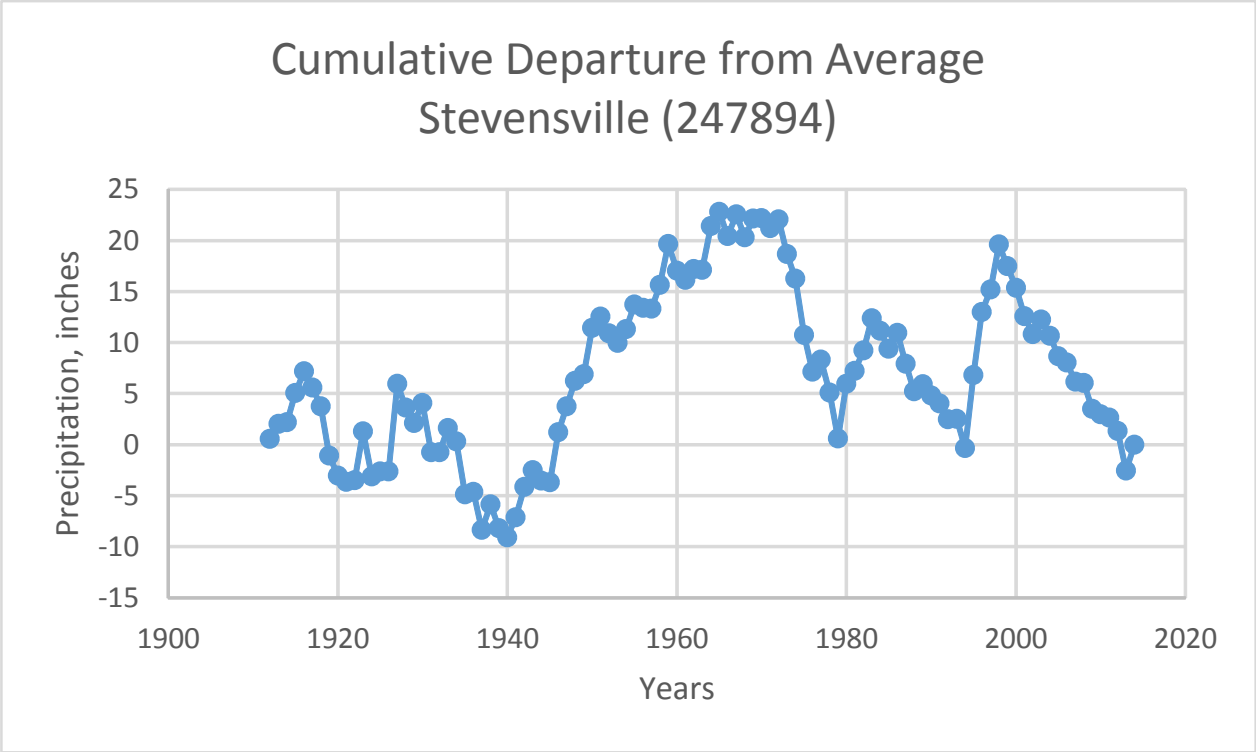
Figure 3-7b
Precipitation at Hamilton
Bitterroot Valley

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 3-7c

Notes:
Precipitation data from WRCC.

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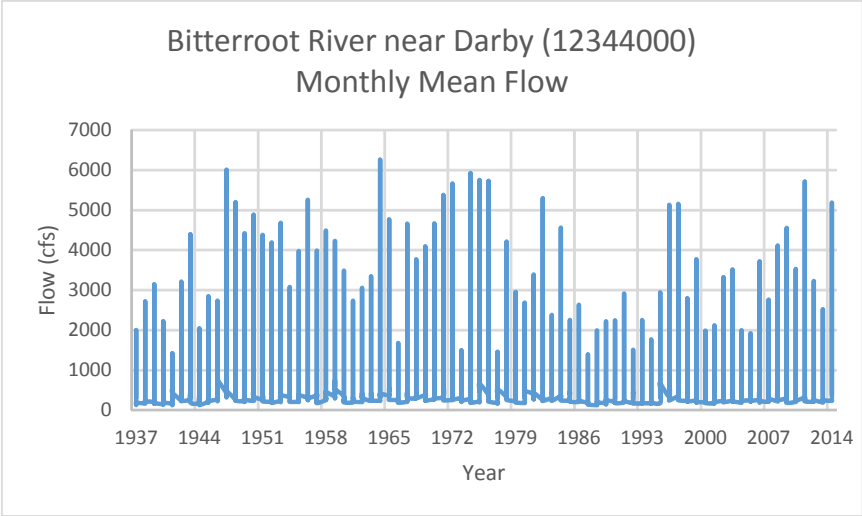
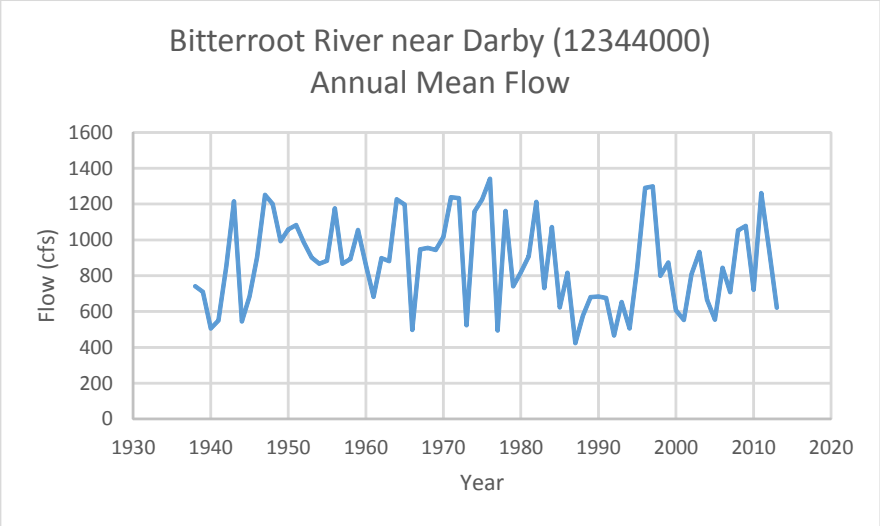
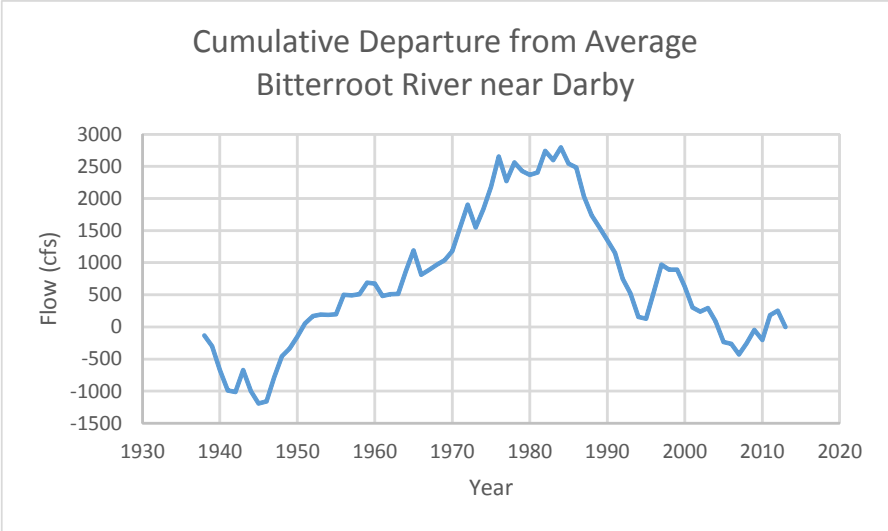
Figure 3-7c
Precipitation at Stevensville
Bitterroot Valley

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

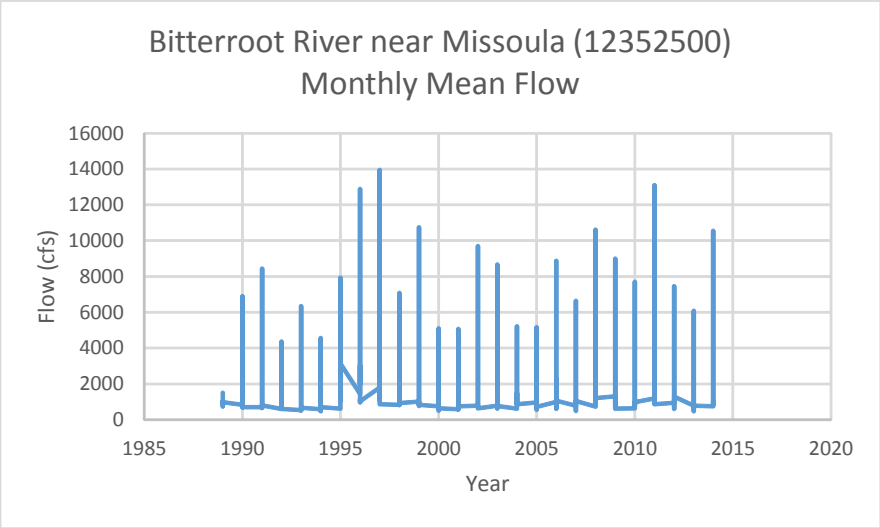
Date: 12/14/2015
File: Figure 3-8a

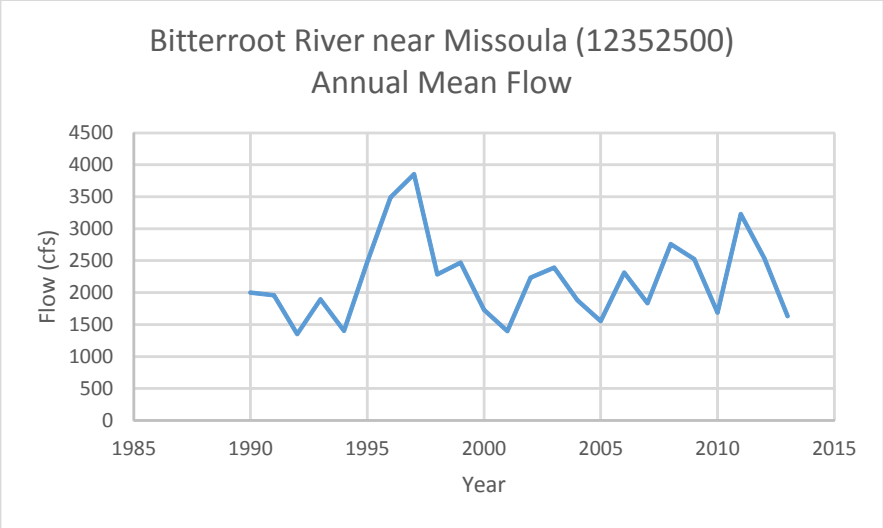
Notes:
Data from USGS

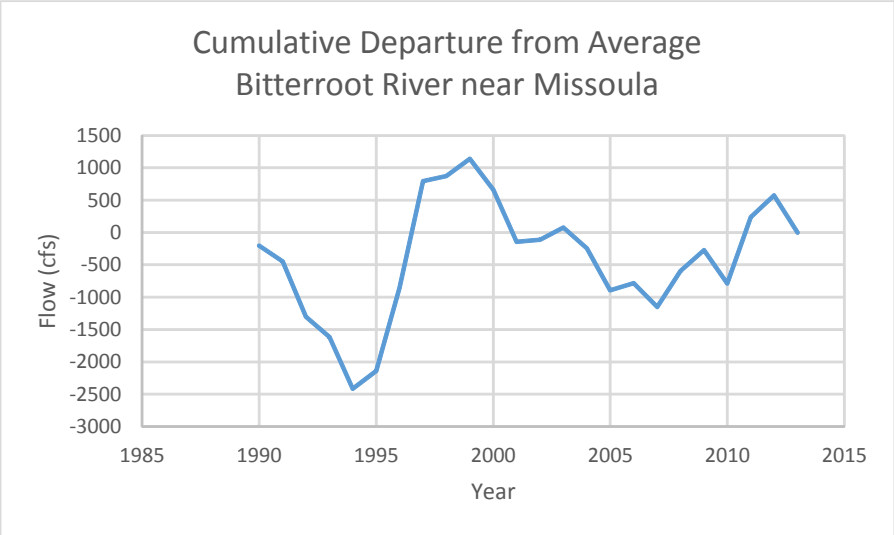
Montana Association of REALTORS®

Figure 3-8a
Stream Discharge
Bitterroot River near Darby

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 3-8b

Notes:
Data from USGS

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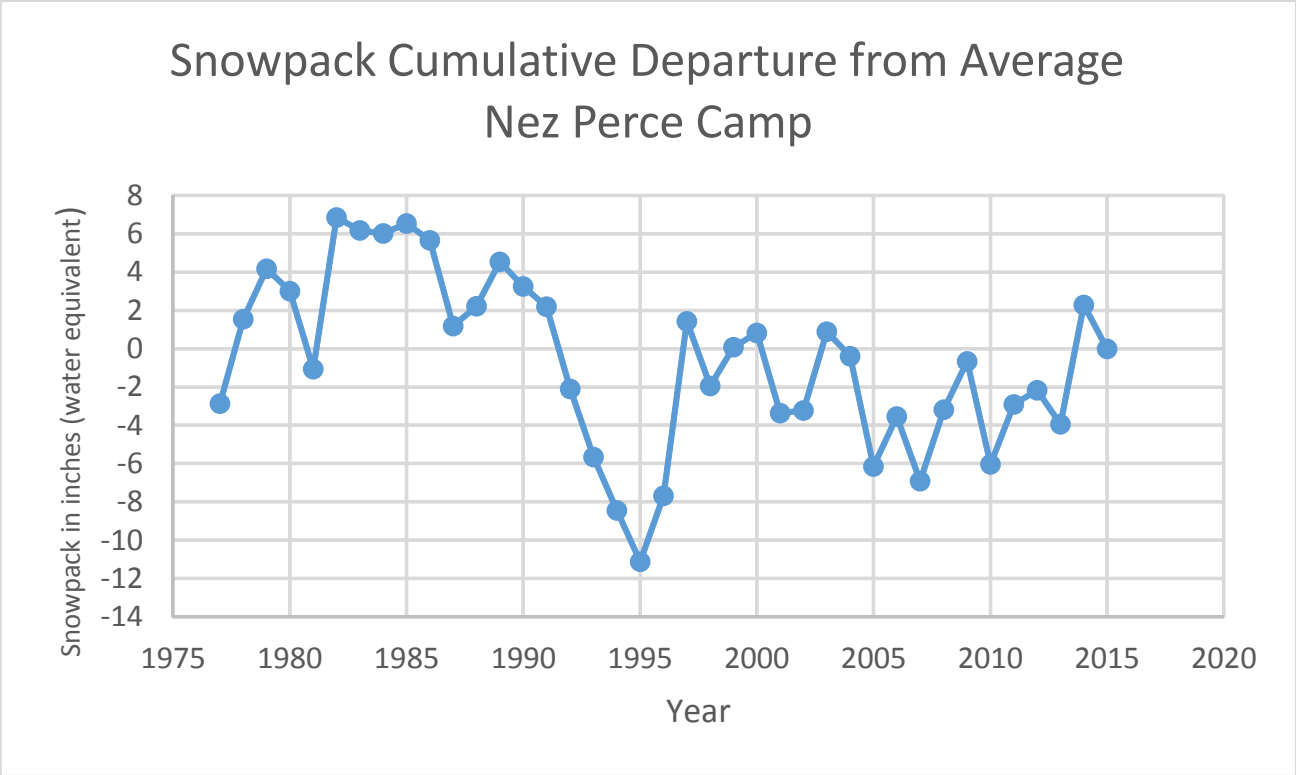
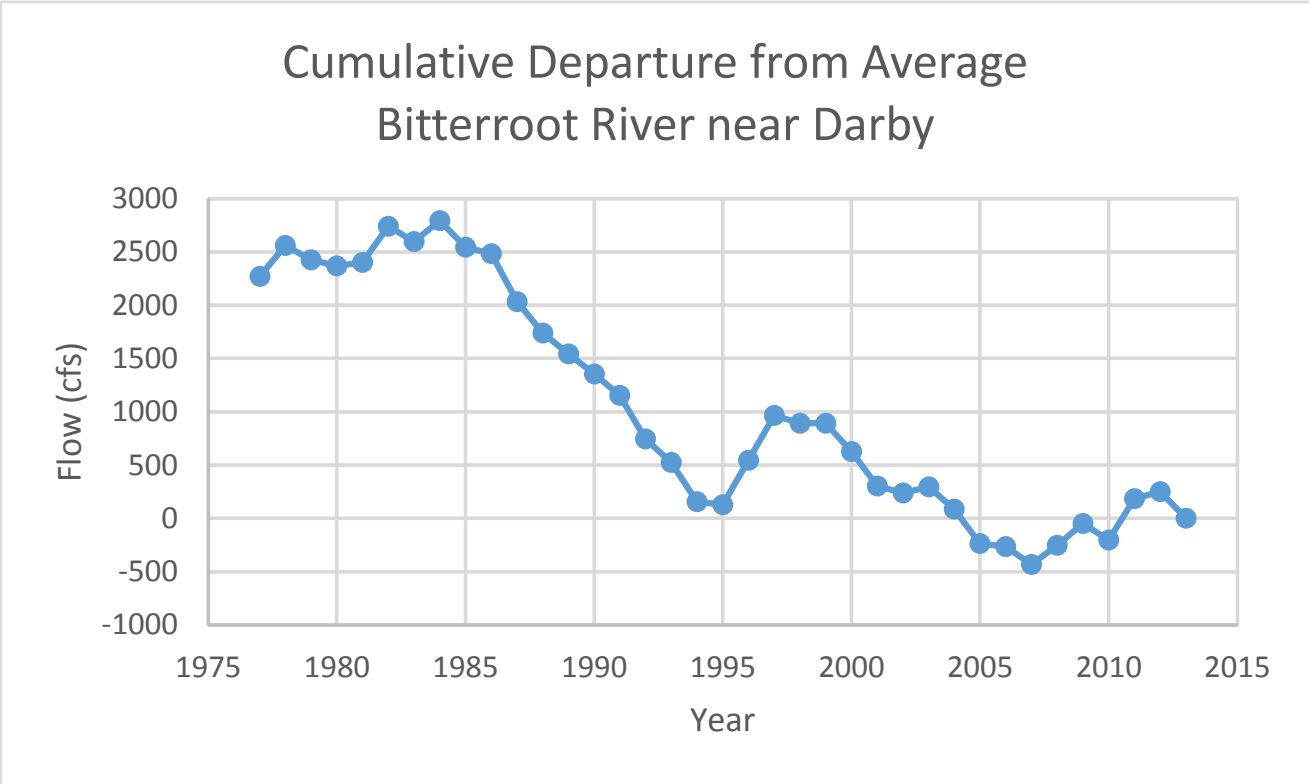
Figure 3-8b
Stream Discharge
Bitterroot River near Missoula

rec'd by LEPO April 13, 2016





Notes:

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Date: 12/14/2015
File: Figure 3-9a

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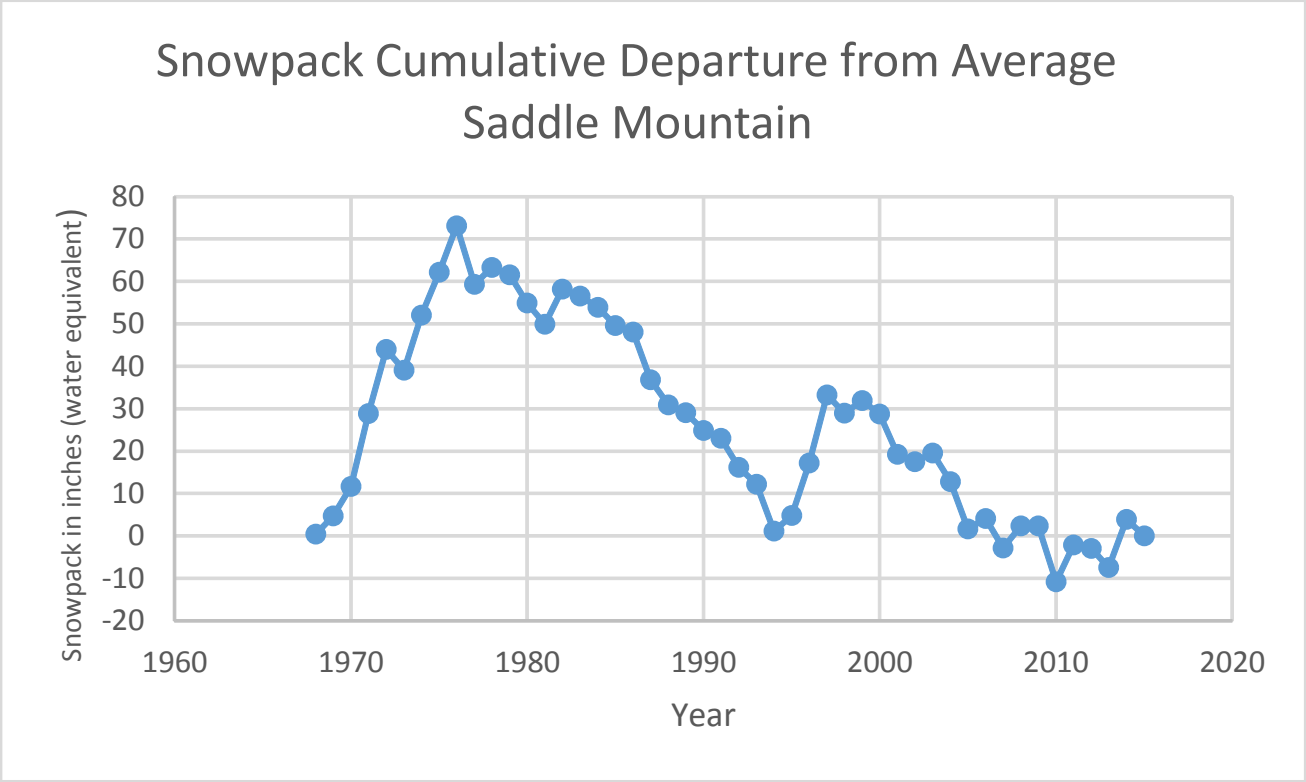
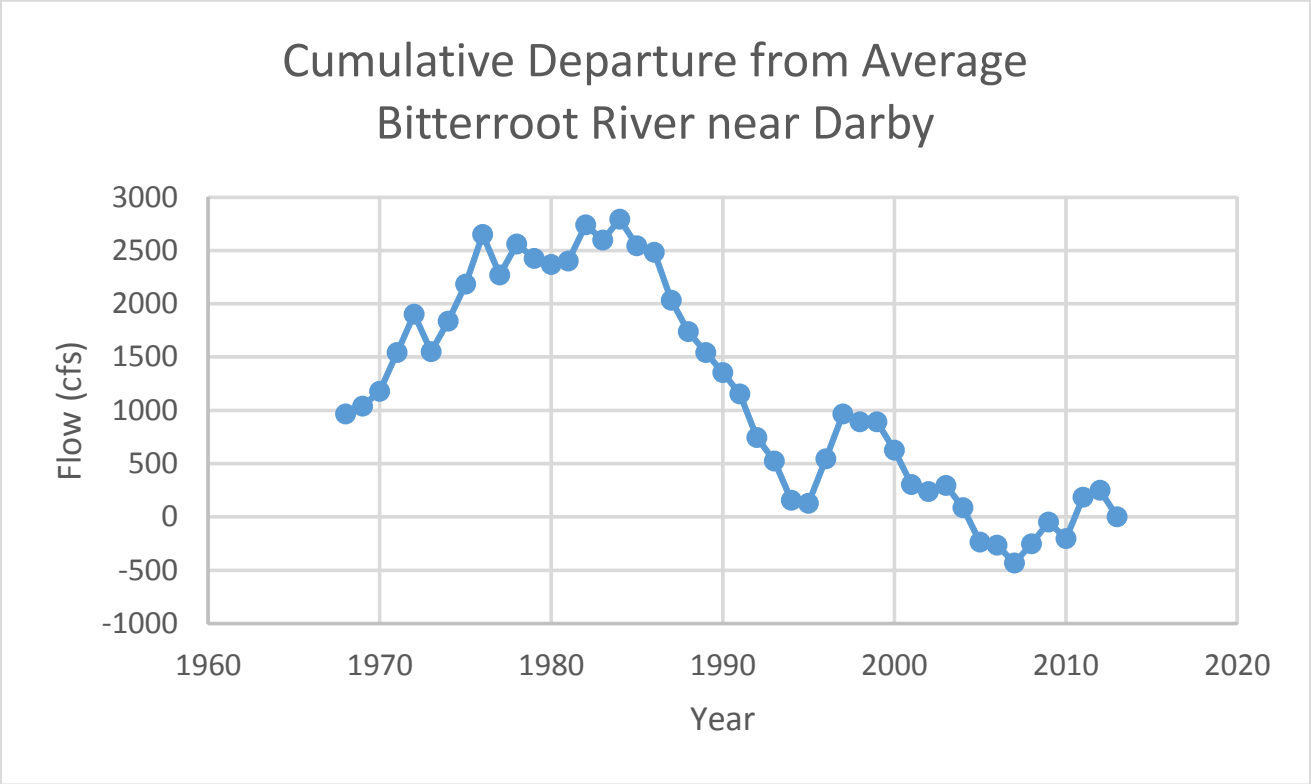
Figure 3-9a
Comparison of Streamflow to Snowpack at Nez Perce
Cumulative Departure from Average

rec'd by LEPO April 13, 2016





Notes:

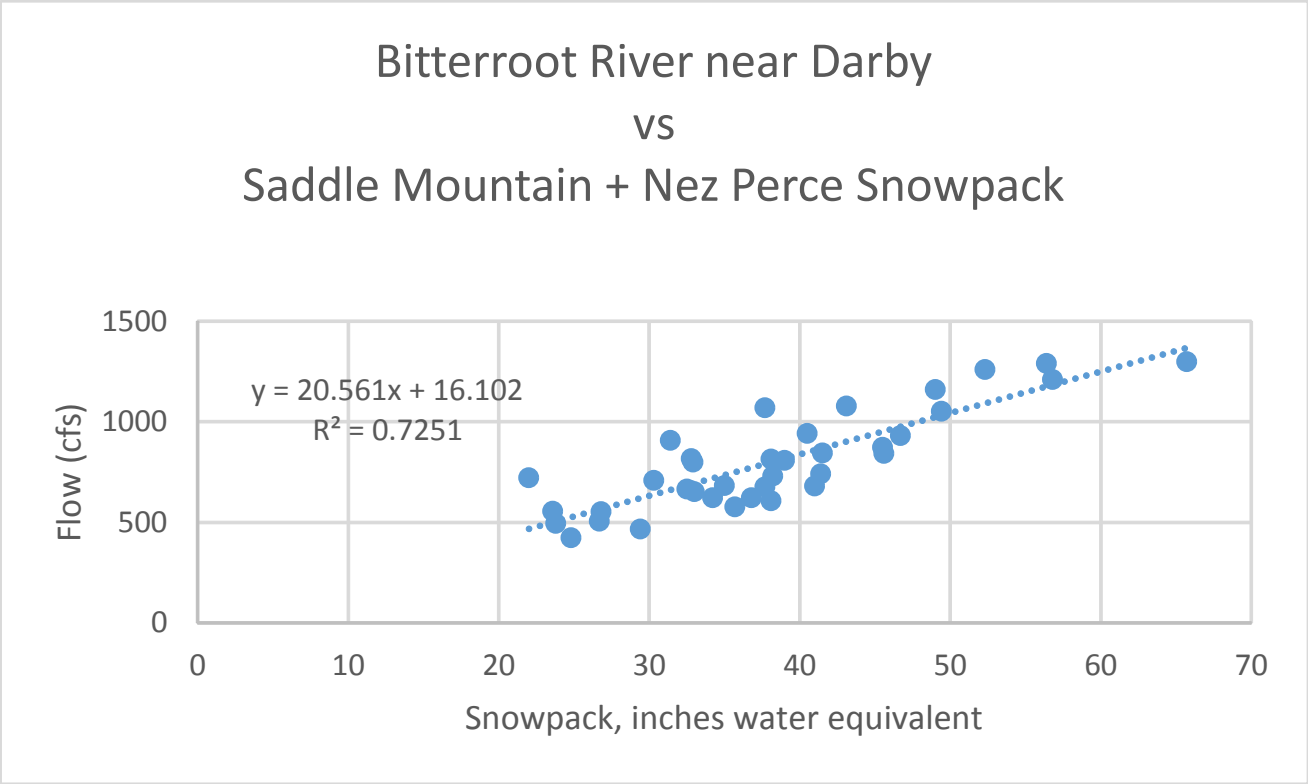
NICKLIN EARTH & WATER, INC.

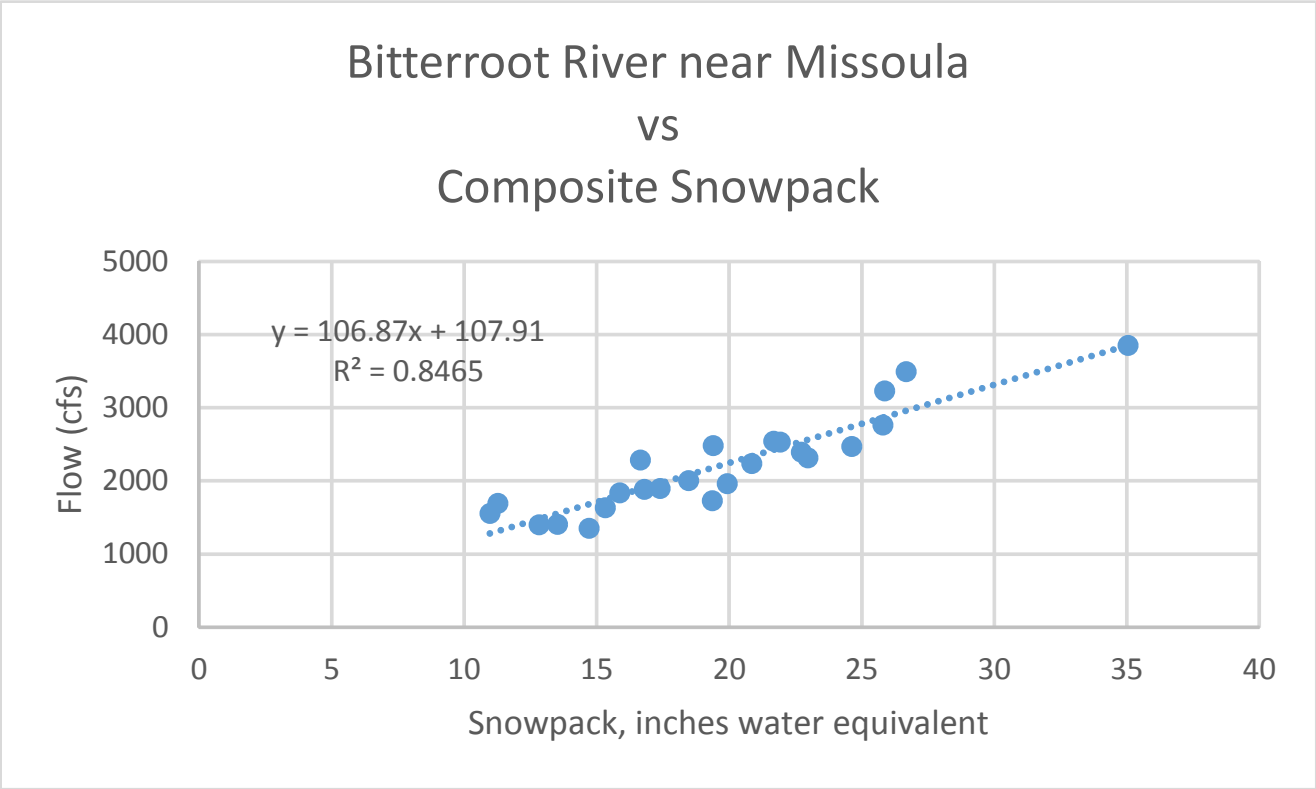
Date: 12/14/2015
File: Figure 3-9b

Montana Association of REALTORS®

Figure 3-9b
Comparison of Streamflow to Snowpack at Saddle Mountain Cumulative Departure from Average

rec'd by LEPO April 13, 2016





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Date: 12/14/2015
File: Figure 3-10

Notes:
Saddle Mountain and Nez Perce Camp snowpack are composited.

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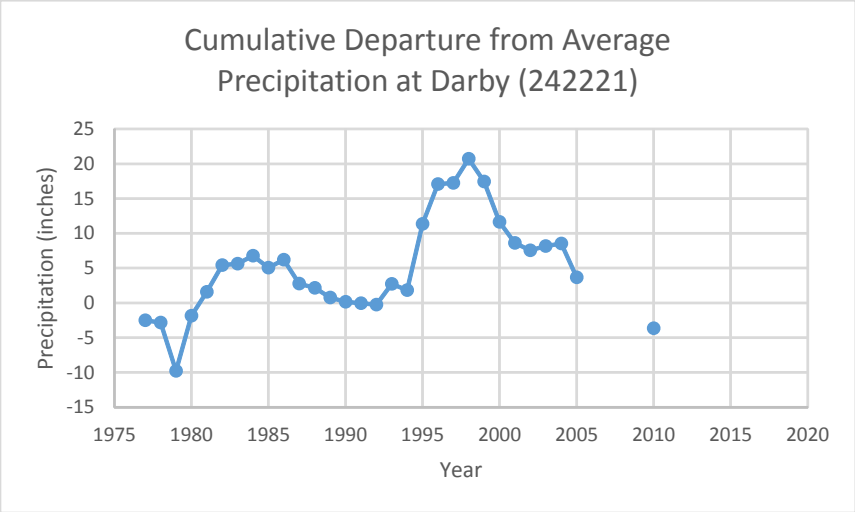
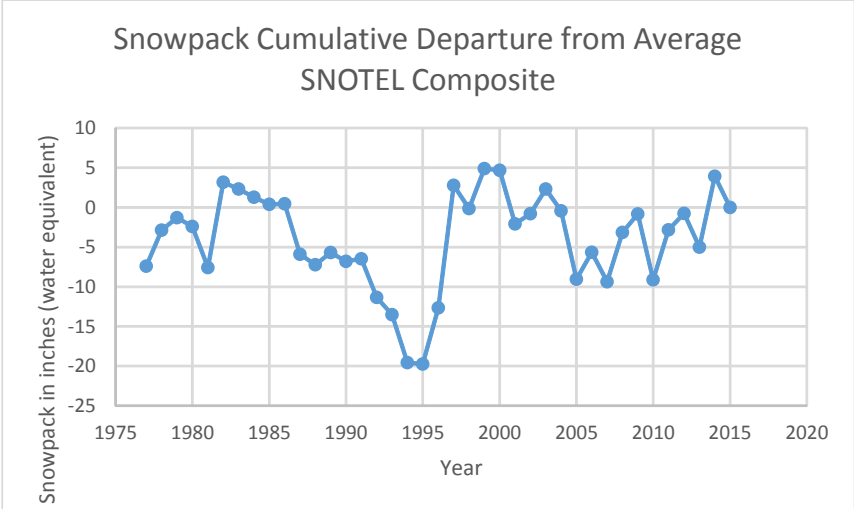
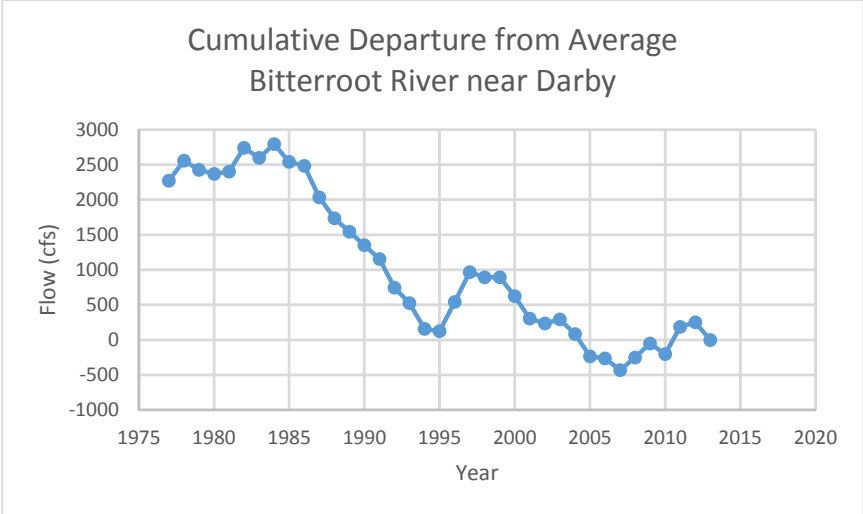
Figure 3-10
Bitterroot River Annual Mean Flow vs. Snowpack

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 1/11/2016
File: Figure 3-11

Notes:
Flow in the Bitterroot River correlates well to snowpack and poorly to valley precipitation as measured at Darby.

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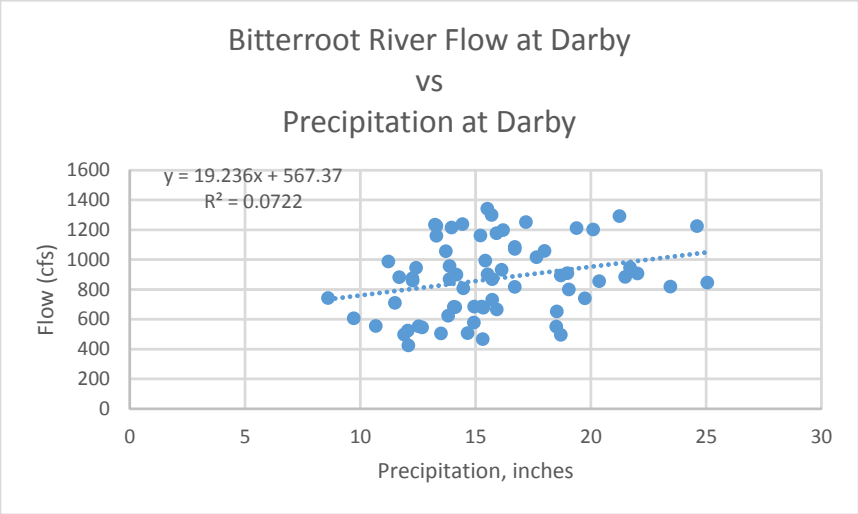
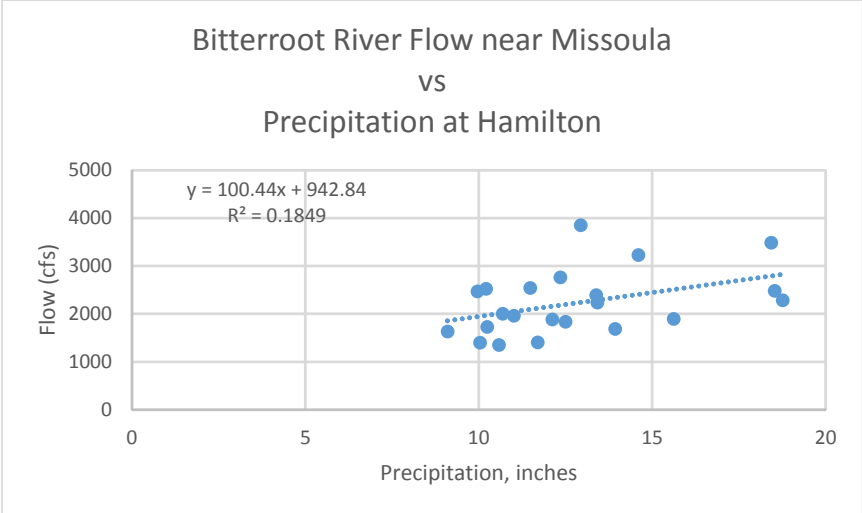
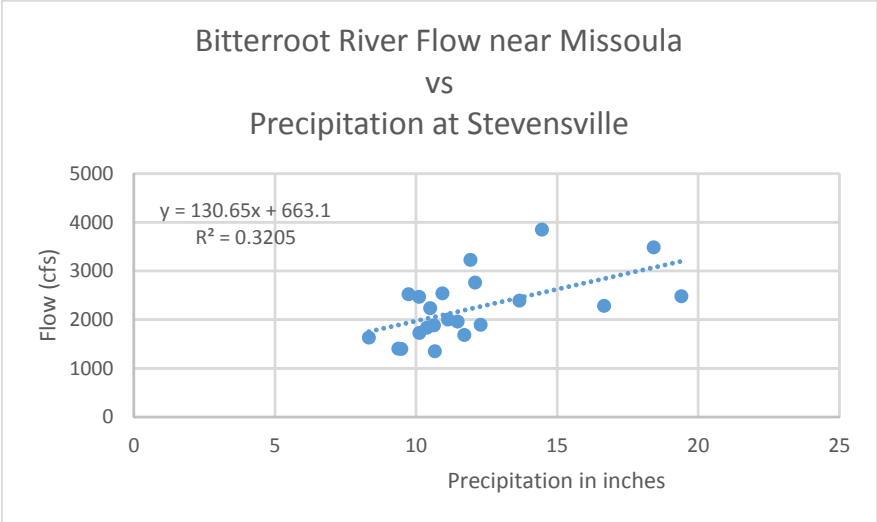
Figure 3-11
Cumulative Departure from Average Comparisons

rec'd by LEPO April 13, 2016







Notes:

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Date: 12/14/2015
File: Figure 3-12

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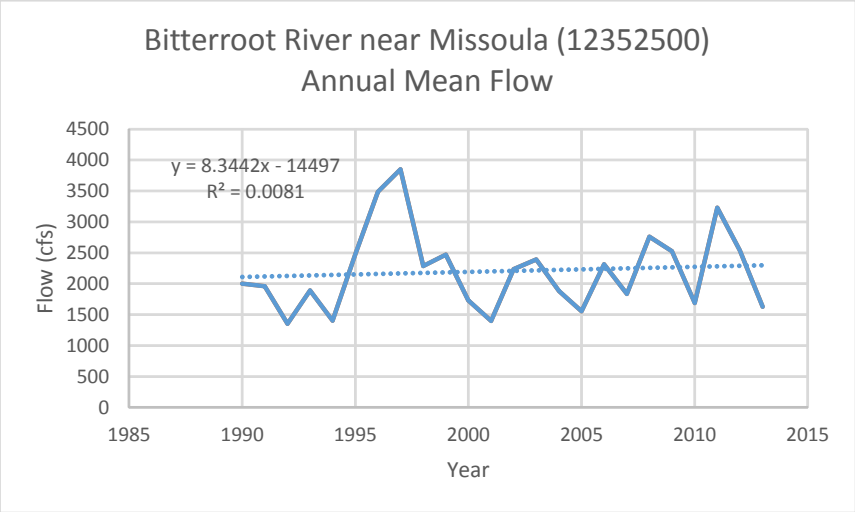
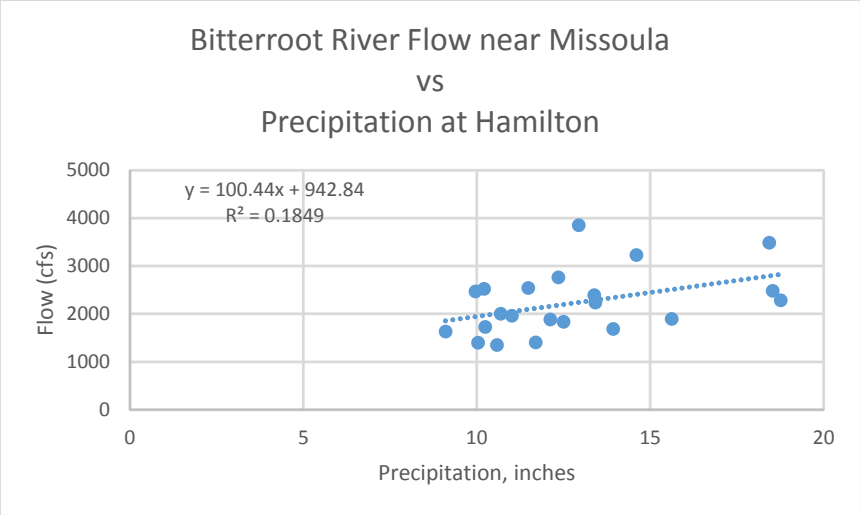
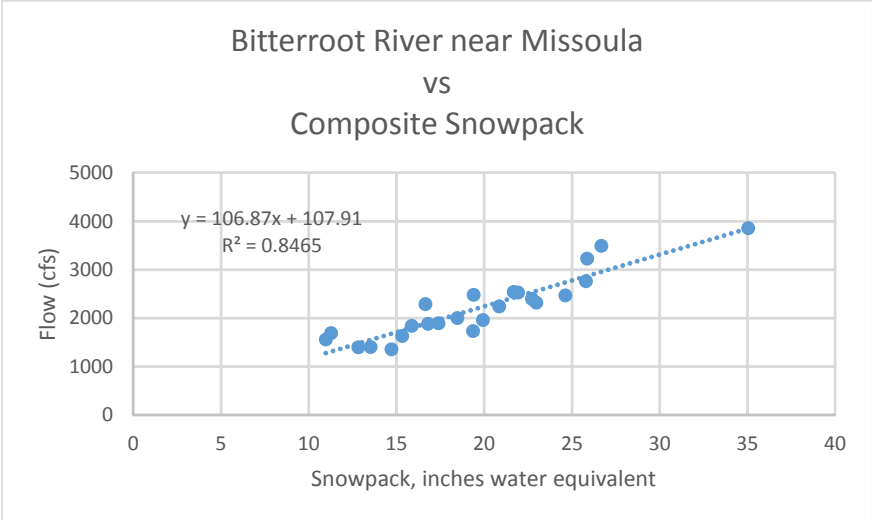
Figure 3-12
Bitterroot River Annual Mean Flow vs Precipitation

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 3-13

Notes: Stream discharges of the Bitterroot River watershed exiting the valley near Missoula show no visible trends since 1990. The annual streamflows over this time period are poorly correlated to valley precip and well correlated to mountain snowpack.

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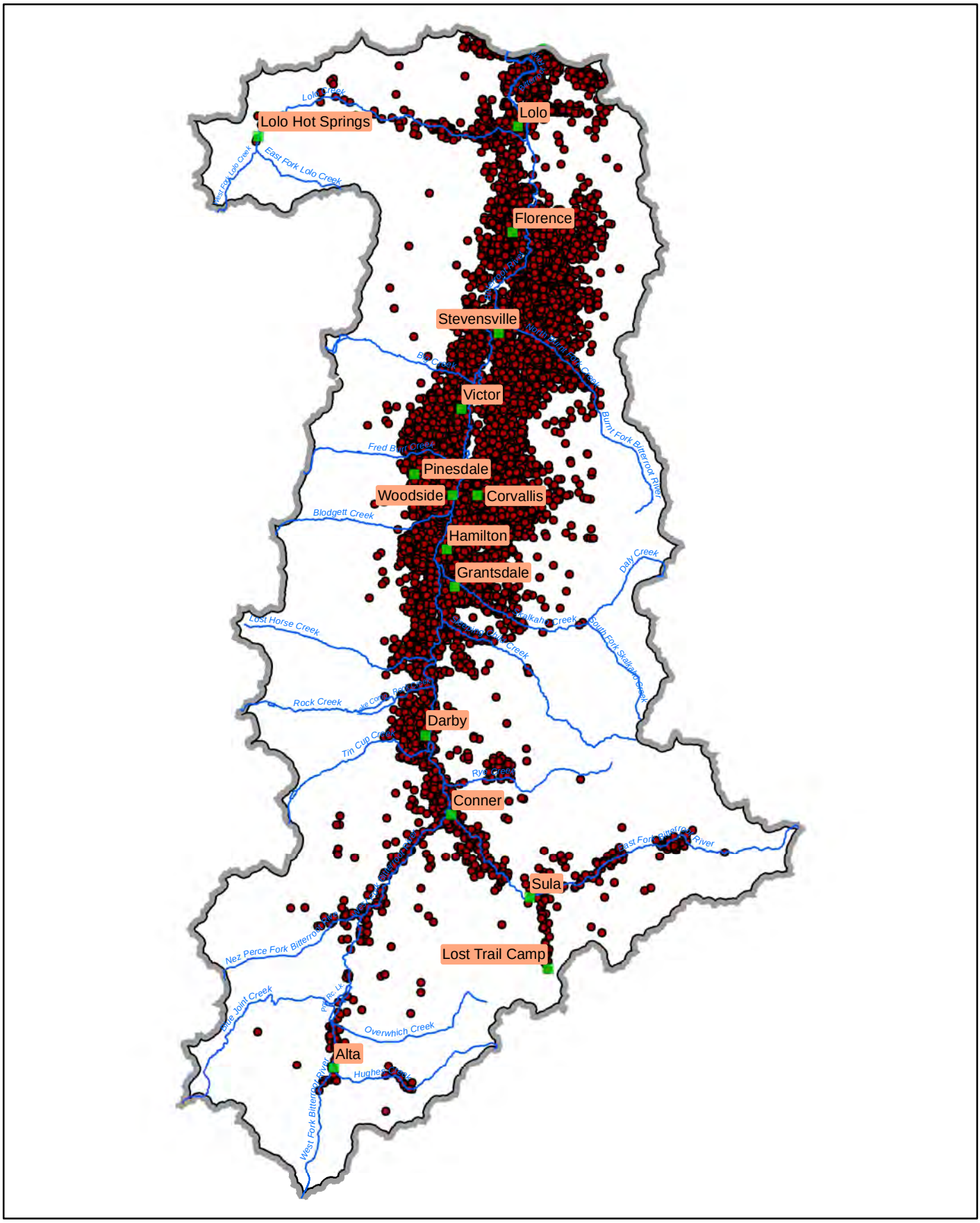
Figure 3-13
Regressive Assessment
Streamflow vs. Time
Precipitation and Snowpack

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/17/2015
File: Figure 3-14

4 Miles

Legend

- Towns
- DOMESTIC

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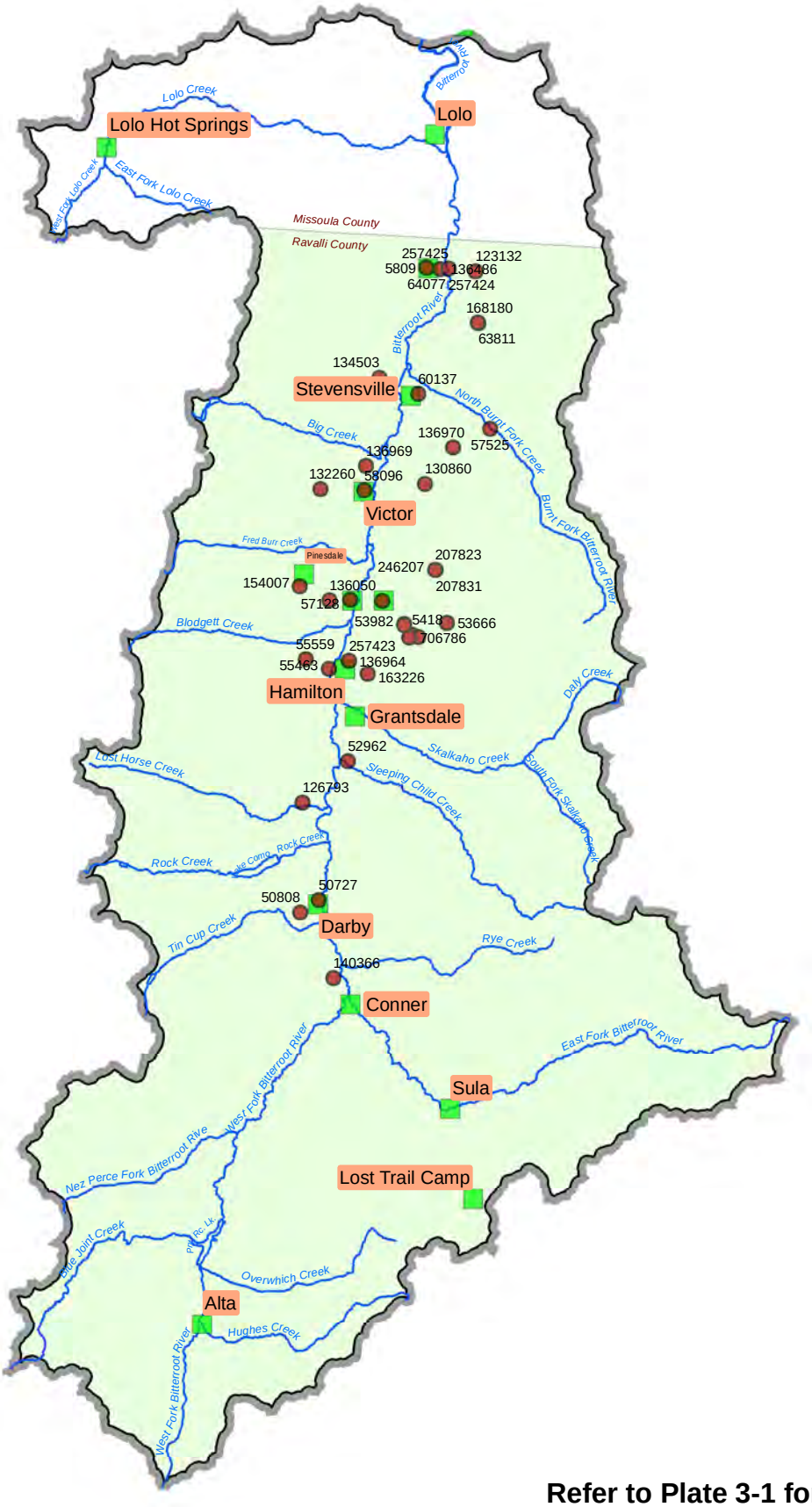
Figure 3-14
Ravalli County and Bitterroot River Watershed Wells

rec'd by LEPO April 13, 2016



Refer to Plate 3-1 for Hydrographs

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Date: 12/17/2015
File: Figure 3-15

4 Miles

Legend

- Observation Well
- Towns

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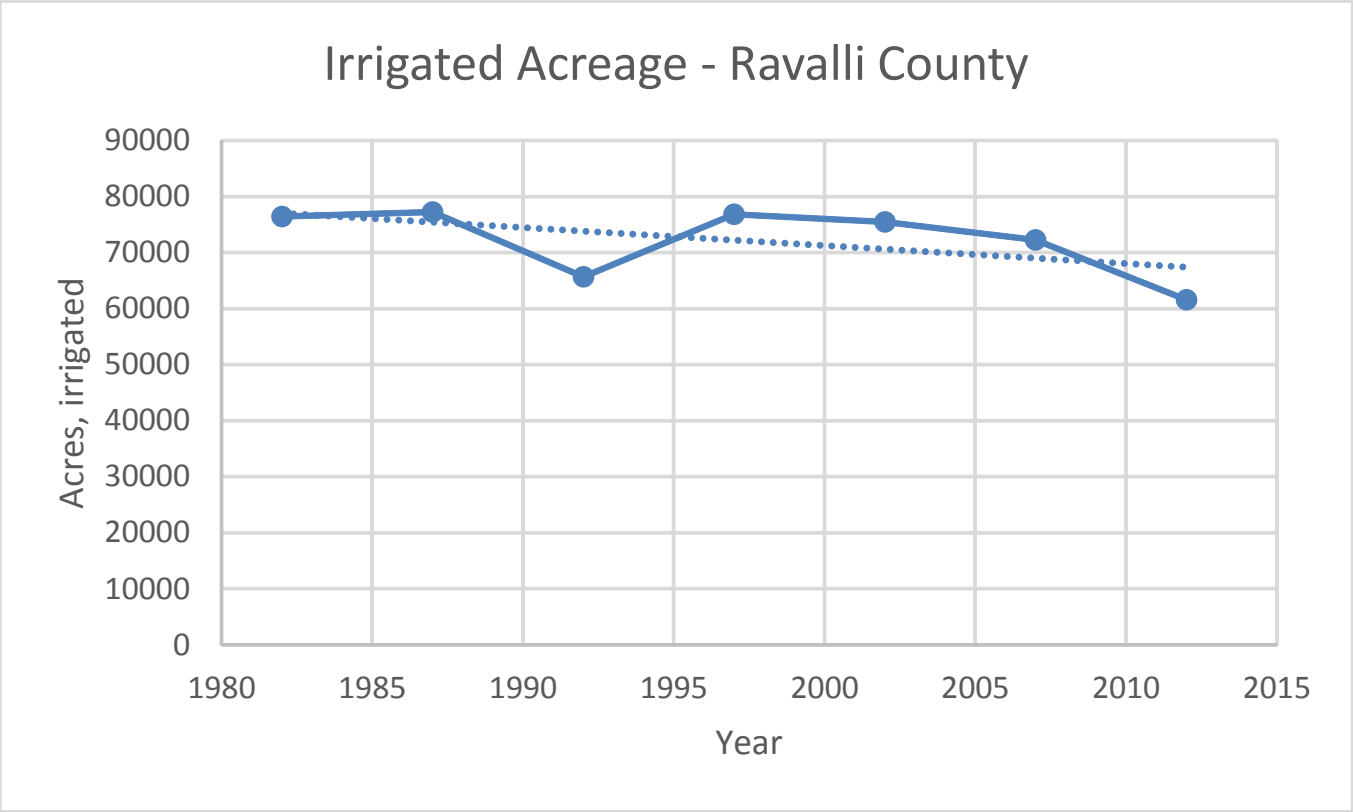
Figure 3-15
Ravalli County Observation Wells
Montana Bureau of Mines and Geology

rec'd by LEPO April 13, 2016



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Date: 1/11/2016
File: Figure 3-16

Notes:
Irrigated acreage obtained from
USDA Census of Agriculture (2015).

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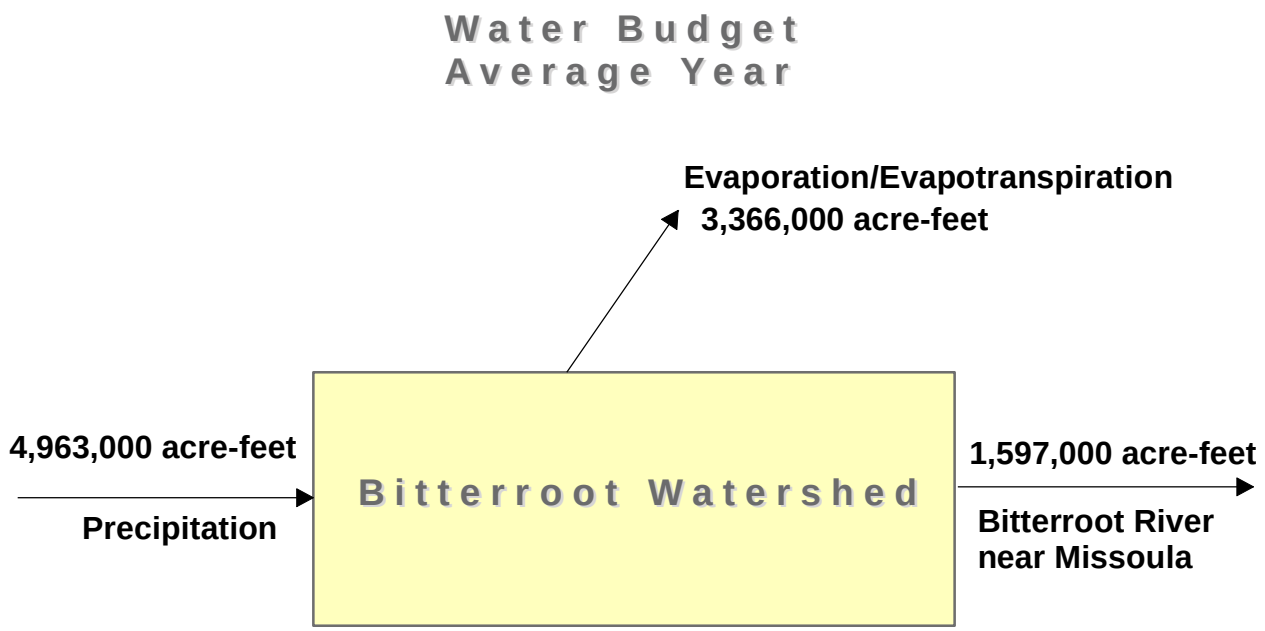
Figure 3-16
Trend in Reported Irrigated Acreage
Ravalli County

rec'd by LEPO April 13, 2016



Average precipitation for the watershed is esitmated using PRISM data from NRIS.
Average flow at Bitterroot River near Missoula from USGS (period of record is 1990-2013)
Note that the above water balance assumes that aquifer storage remians constant.
Furthermore, carry-over moisture is not considered in the water budget calculations.

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Date: 12/16/2015
File: Figure 3-17

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Figure 3-17
Water Budget Average Year
Bitterroot Watershed

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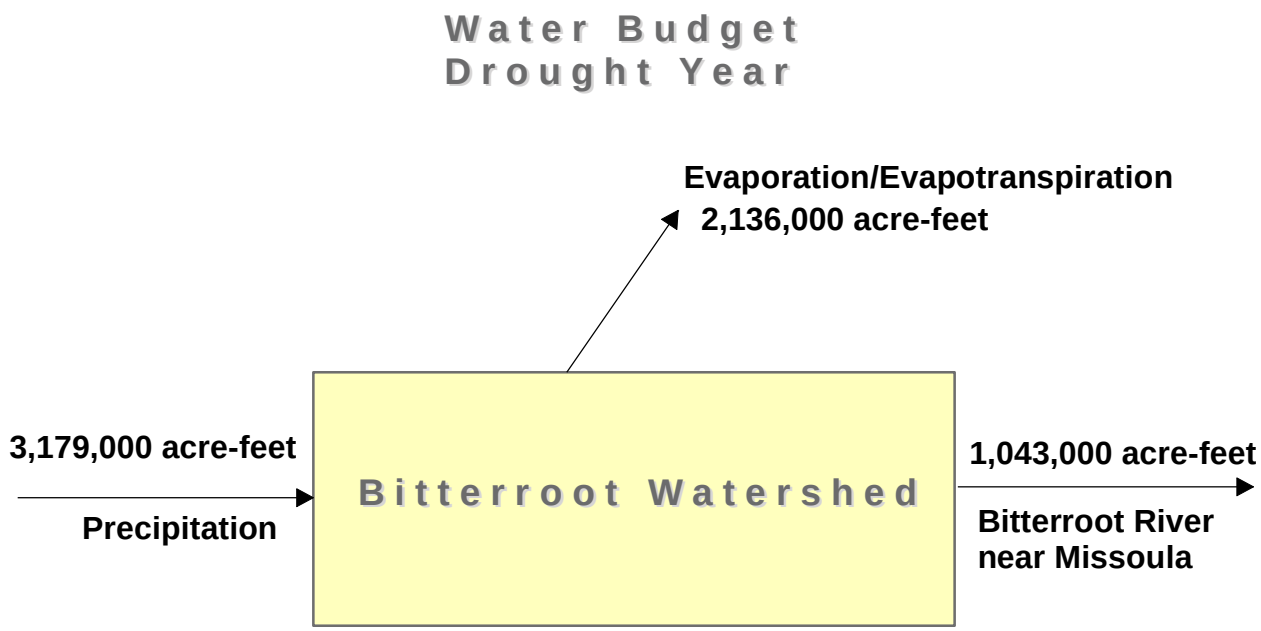

Average precipitation for the watershed is esitmated using PRISM data from NRIS.
Average flow at Bitterroot River near Missoula from USGS during 2001 water year.
Note that the above water balance assumes that aquifer storage remians constant.
This may not be the case during a drought year.

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Date: 12/16/2015
File: Figure 3-18

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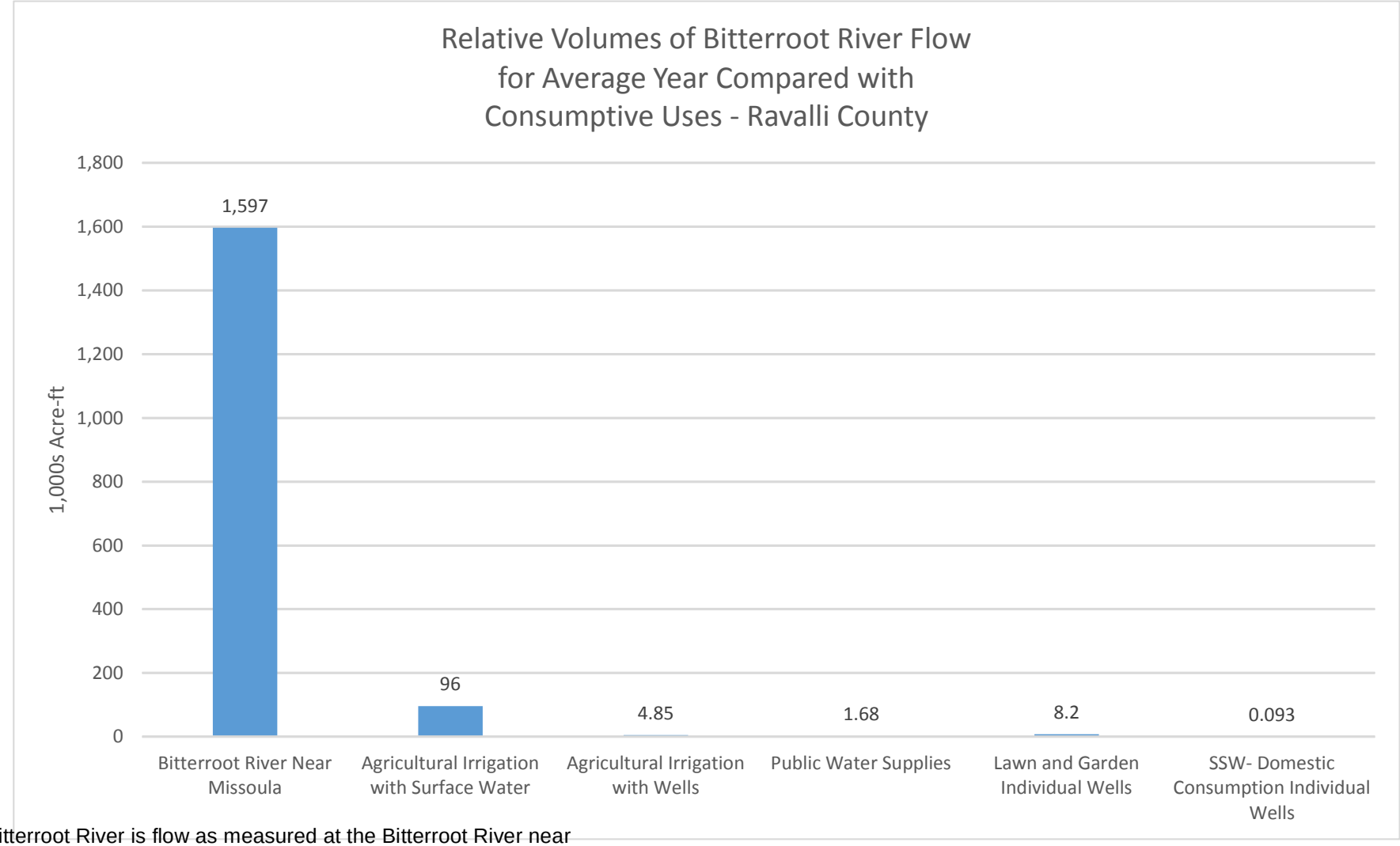
Figure 3-18
Water Budget Drought Year
Bitterroot Watershed

rec'd by LEPO April 13, 2016



Bitterroot River is flow as measured at the Bitterroot River near Missoula USGS gaging station. Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells.

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Date: 12/21/2015
File: Figure 3-19

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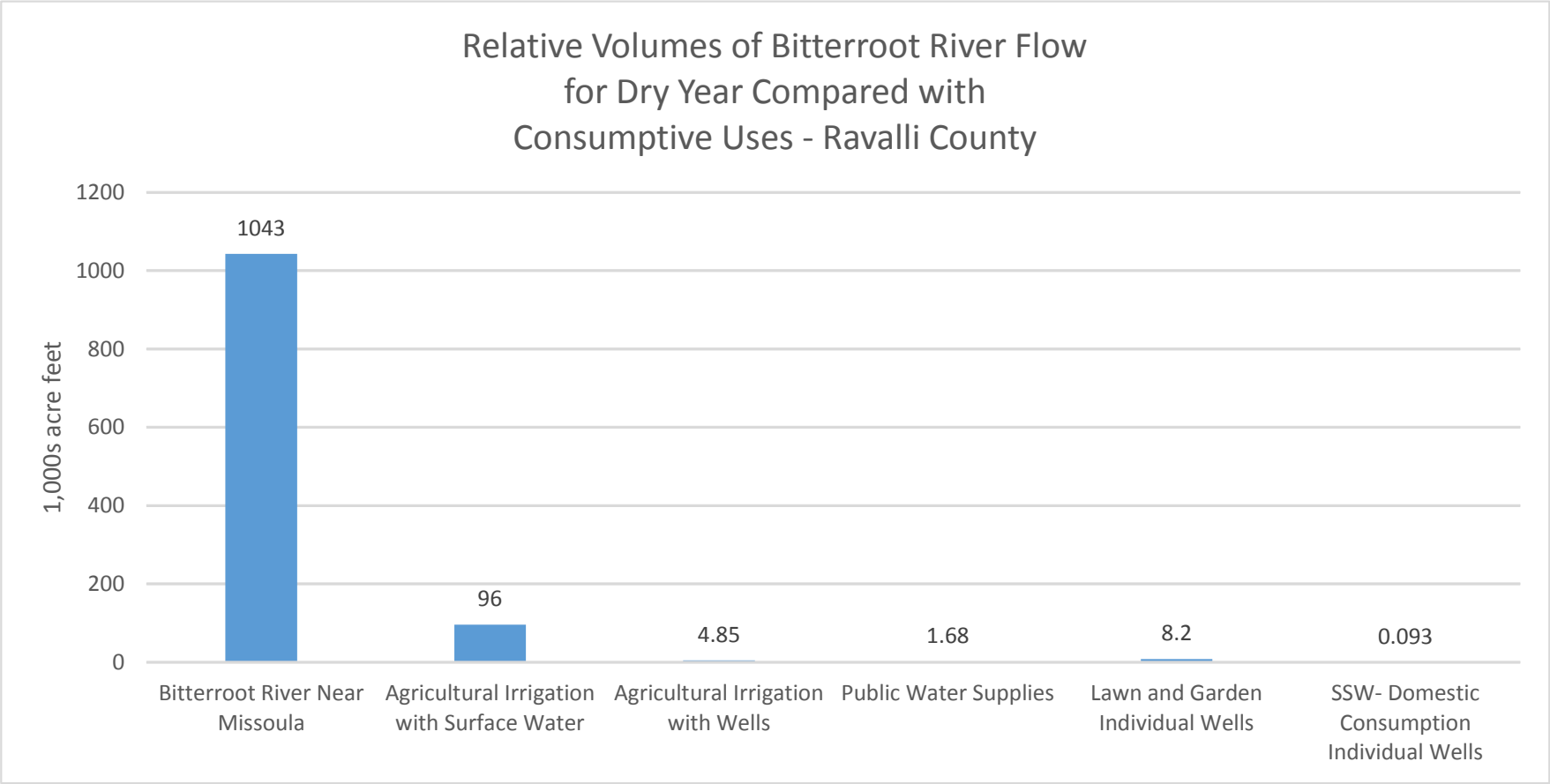
Figure 3-19
Surface Water Flows at Bitterroot River Compared to Ravalli County Consumptive Uses

rec'd by LEPO April 13, 2016



Bitterroot River is flow as measured at the Bitterroot River near Missoula USGS gaging station uses 2001 flows. Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells.

NICKLIN EARTH & WATER, INC.

Date: 12/21/2015
File: Figure 3-20

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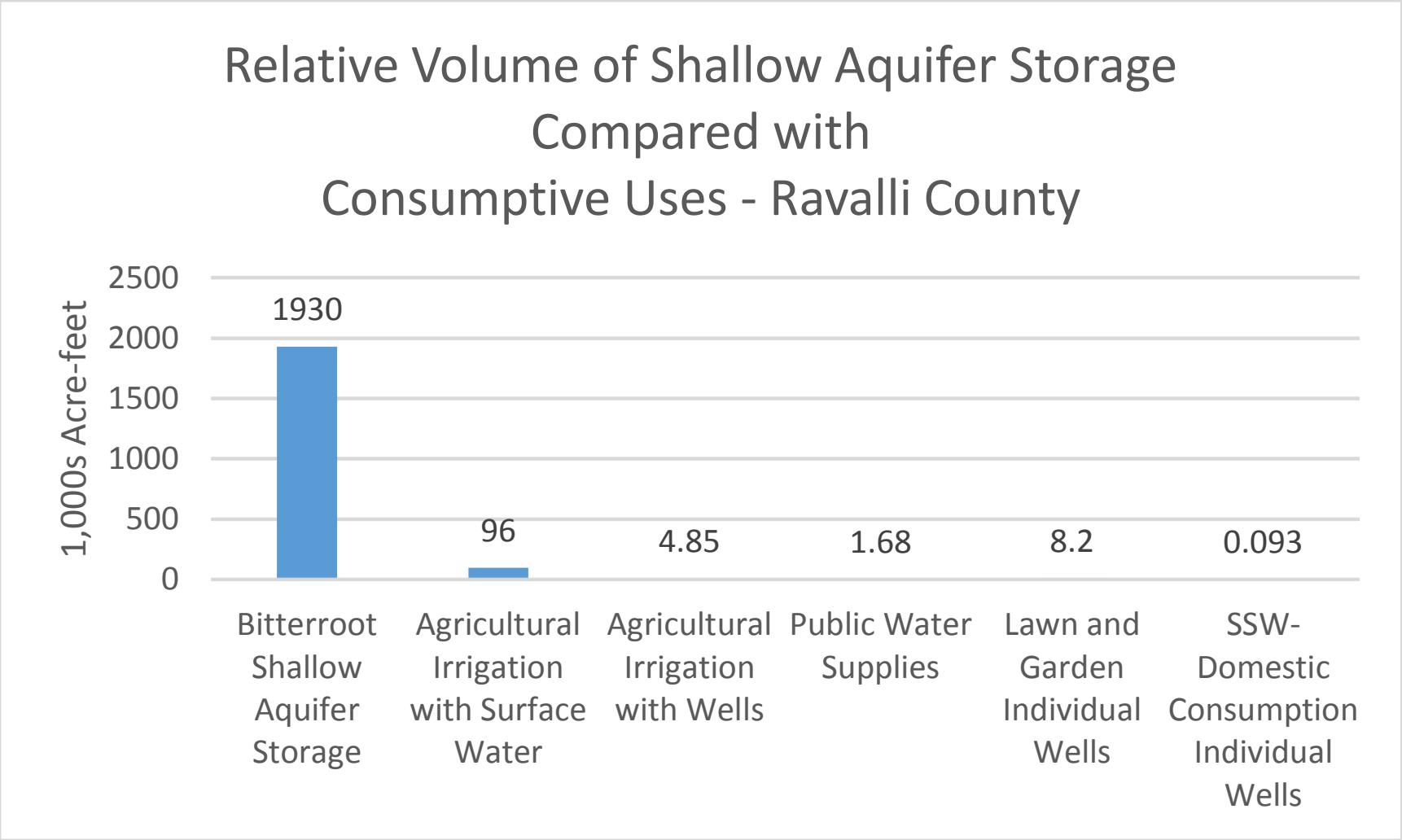
Figure 3-20
Surface Water Flows at Bitterroot River Compared to Ravalli County Consumptive Uses

rec'd by LEPO April 13, 2016



Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Storage estimate is adapted from MBMG presentation at the Water Policy Interim Committee meeting at Choteau.

NICKLIN EARTH & WATER, INC.

Date: 12/21/2015
File: Figure 3-21

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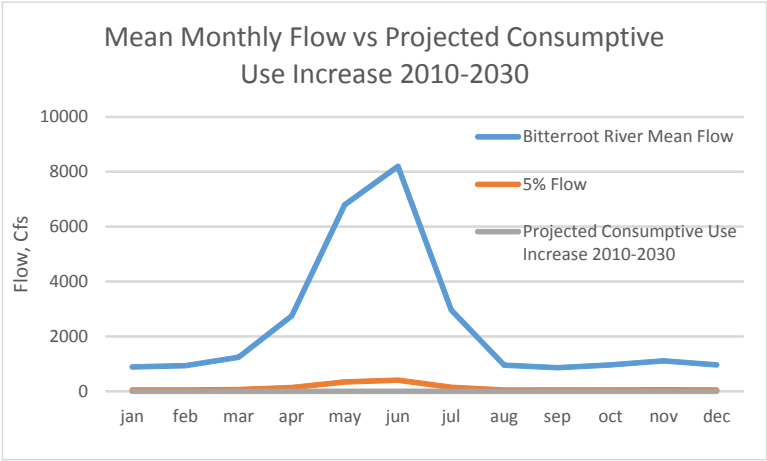
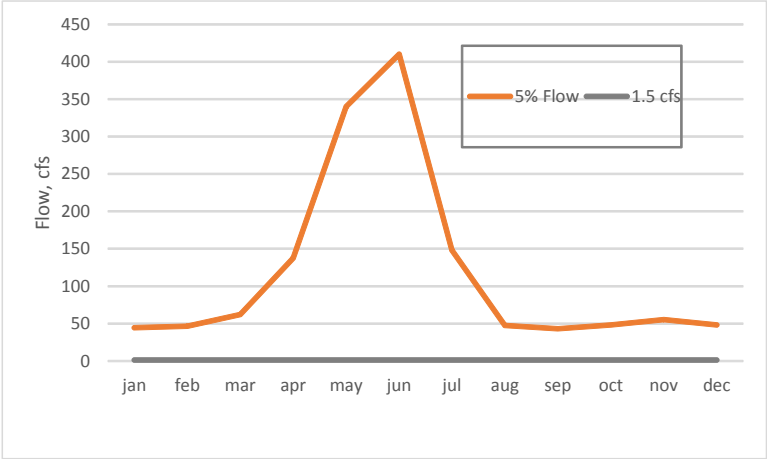
Figure 3-21
Storage Volume of Shallow Aquifer Compared to Ravalli County Consumptive Uses

rec'd by LEPO April 13, 2016





The blue line plot in the upper graph shows the average monthly flows for the period of record for the Bitterroot River as it is measured near Missoula. The middle line plot shows 5% of the same flows. In effect, this represents an approximate magnitude of the uncertainty of stream flow measurements at gaging stations. The lower line of 1.5 cfs represents the total projected increase in consumptive use from 2010 to 2030 for Ravalli County. In effect a flow of 1.5 cfs is far too small to be reliability discerned at this gaging station at flows near the mean monthly flow.

NICKLIN EARTH & WATER, INC.

Date: 1/8/2016
File: Figure 3-22a

7.5 Miles

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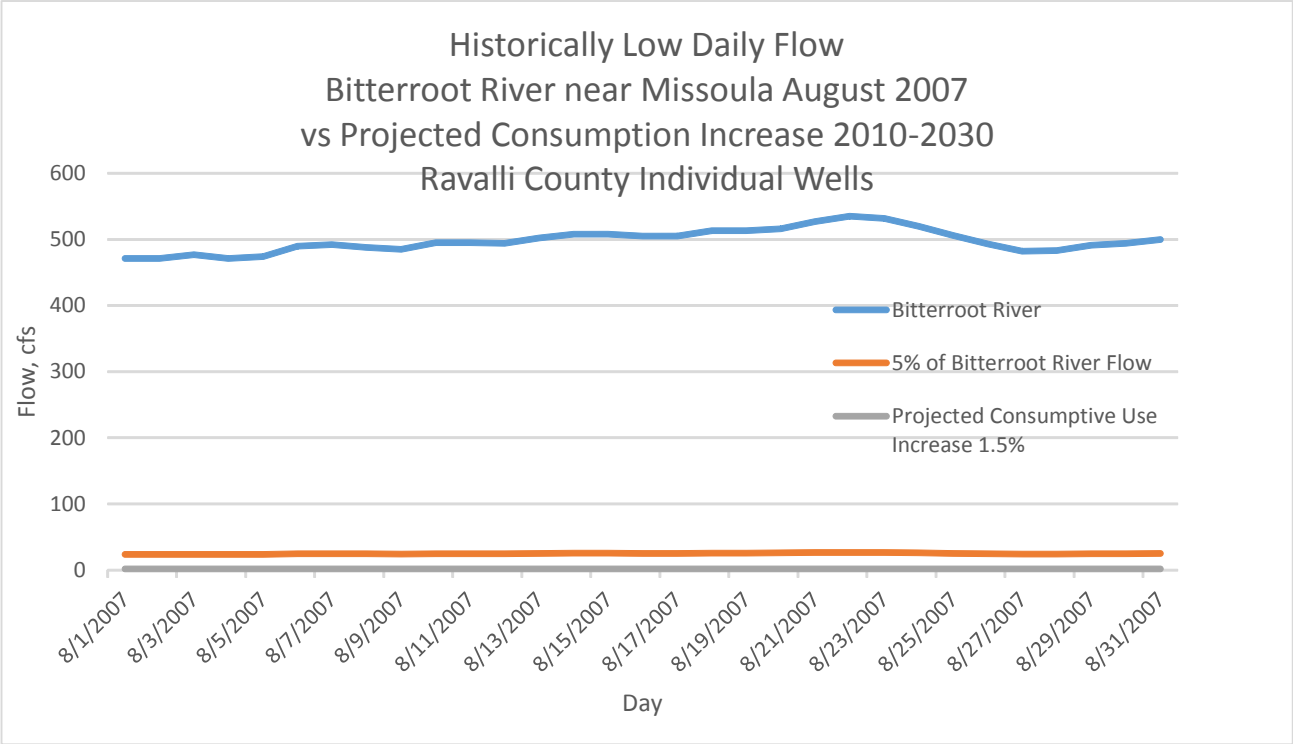
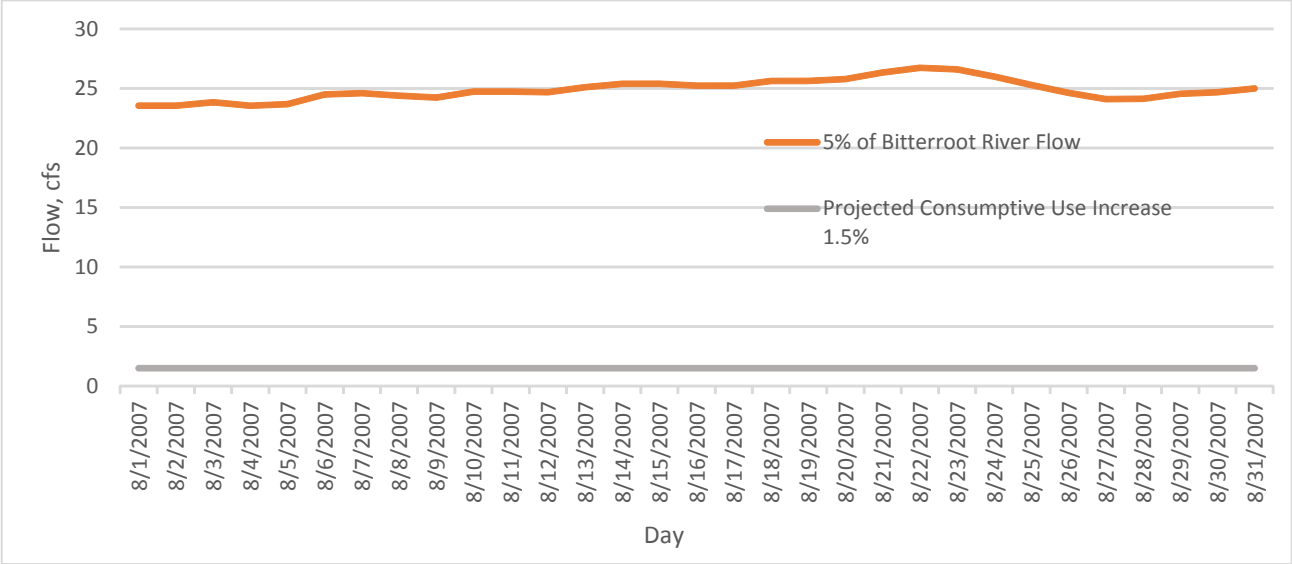
Figure 3-22a
Mean Monthly Flow of Bitterroot River Compared to Projected Individual Well Consumptive Use Increase - Ravalli County





Note that the above figure represents the minimum daily flow month of record for August which occurred in August 2007. Note that there may be some seasonal variation in streamflow depletions from individual well pumping. However, this seasonal variation in depletion will be very subdued owing to the fact that the average distance of individual wells from the Bitterroot River is between 1.5 and 2 miles. Even if seasonal variability is accounted for any net monthly depletion would remain in the noise level (below 5% of streamflow) in the Bitterroot River as measured near Missoula. In essence, any depletions could not be reliably discerned in the streamflow measurements. Finally, the above graph does not account for any reduction in surface water use associated with conversion of irrigate dland to subdivision. If effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects."

NICKLIN EARTH & WATER, INC.

Date: 1/8/2016
File: Figure 3-22b

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Figure 3-22b
August 2007 Bitterroot River Flows Compared to Projected Individual Well Consumptive Use Increase - Ravalli Co

4.0 LEWIS AND CLARK COUNTY - UPPER MISSOURI RIVER BASIN

4.1 Physical Setting and Overview

Lewis and Clark County is located in West-Central Montana (see Figure 4-1). The continental divide subdivides the county into two drainage basins, the Columbia to the west and the Missouri to the east. The Upper Missouri is designated as a closed basin. About half of Lewis and Clark County's area of 3,477 square miles is mountainous, primarily national forest. Most of the population resides in Helena and the Helena Valley. The City of Helena is located on the mountain edges and in the valley proper. The Missouri River flows through the valley towards the north and is characterized by Canyon Ferry, Hauser and Holter Dams and Reservoirs (see Figure 4-2).

4.1.1 Project Specific Information Sources

A variety of information sources was used in the evaluation of Lewis and Clark County high growth area and the Upper Missouri Watershed including the following: MBMG GWIC Database and Geologic Mapping, DNRC water rights permit database, USDA NRCS SNOTEL, WRCC data, and USDA Census of Agriculture data.

Much of the geospatial information used in this evaluation, especially mapping resources, was obtained from the Montana NRIS database.

4.1.2 Land Use

About half of Lewis and Clark County is mountainous and federally owned (national forest). The majority of the population and economic activities occur in the Helena Valley. Key economic factors include agriculture, government (Montana Capital), and recreation with growing building construction and service industries.

With population growth, municipal and rural subdivisions are being constructed on previously irrigated agricultural lands.

4.1.3 Climate

The Helena Valley is semiarid with average annual precipitation that ranges from 10 to 14 inches. The periphery of the Upper Missouri Watershed shows mean annual

precipitation as high as 52 inches in mountainous areas (refer to Figure 4-3).

The mean precipitation for this period of record at Helena (Station 244055) is 11.87 inches (see Figure 4-4).

Temperatures vary substantially with the minimum average daily temperature in the valley being 11.4 ^{o}F in January and the average maximum daily temperature in the valley being 83.0 ^{o}F in July. The minimum and maximum temperatures ever recorded at the Helena weather station have been -42 ^{o}F (December 31, 1893 and February 2, 1996) and 105 ^{o}F (July 12, 2002 and August 24, 1969) respectively.

4.1.4 Geology

The USGS has completed two studies which are helpful in understanding the geology of the Helena area and they are the following:

- Hydrology of the Helena Area Bedrock, West-Central Montana, 1993-1998 (Thamke and Reynolds, Water-Resources Investigation Report 00-4212, October 2000).
- Hydrogeology of the Helena Valley-Fill Aquifer System, West-Central Montana (Briar and Madison, Water-Resources Investigation Report 92-4023, April, 1992).

According to Thamke and Reynolds (2000), the primary bedrock units relevant in the study area are deposits ranging from Middle Proterozoic to Tertiary in age and include sedimentary rock sequences, igneous intrusive rock units, and volcanic rock sequences (see Figure 4-5). There are two principal faults in the Helena area that are important as well. They include the Helena Valley Fault Zone that crosses the north and northeast margin of the area and the Bald Butte Fault Zone that crosses the central part of the area. These faults are components of a major fracture system known as the Lewis and Clark Fault Zone. These faults are significant features from a hydrologic perspective.

4.1.5 Aquifers

The primary sources of groundwater of interest include the following:

- Bedrock (includes joints, fractures, and other forms of secondary porosity);

- Valley fill is composed primarily of Quaternary alluvial (about 100 feet thick) and Tertiary deposits (up to 6,000 feet thick).

The water found in the bedrock flows primarily through joints and fractures that are present in the consolidated deposits. The most productive water-bearing deposits tend to be the Quaternary alluvial deposits, which is the upper-most portion of the valley fill. These deposits are coarse-grained which is important in two aspects. First, they receive substantial amounts of recharge from streams that enter the valley and readily receive recharge associated with leakage from irrigation canals/ditches and from irrigation applications. Secondly, they are capable of producing substantial rates and quantities of groundwater.

According to Briar and Madison (1992), the nature of the Tertiary deposits underlying the Quaternary portion of the valley fill is not well known, principally because of the abundance of water found in the shallower Quaternary. Hence, there is no need to drill deeper. Nonetheless, these Tertiary deposits likely contain substantial quantities of groundwater because they contain stratified lenses of coarse-grained deposits as part of a complex matrix of cobble, gravel, sand, silt, and clay. In effect, they are currently an untapped resource in the Helena Valley.

Wells installed in bedrock (valley periphery) may not be as reliable as the valley fill wells. Their ability to produce water is highly dependent upon the nature and distribution of fractures that are found where wells are drilled. The zones recharging the area's bedrock aquifers are typically not as extensive as those found for valley aquifers. Hence, they tend to show much greater response to drought and to well pumping when compared to the valley fill wells.

4.1.6 Surface Water

Most of the population in Lewis and Clark County from a water budgeting aspect resides in the Upper Missouri Watershed (see Figure 4-3). Hence, this evaluation focuses on the relative significance of groundwater development in the Helena area. The primary stream in the vicinity of Helena is the Missouri River. Other streams that flow into and through the valley include Silver Creek, Seven Mile Creek, Ten Mile Creek and Prickly Pear Creek (see Figure 4-6). Prickly Pear Creek has an extensive gaging record near Rimini. The other streams have relatively short gaging records.

4.2 Hydrologic Data Summary and Evaluations

Precipitation in the Upper Missouri Watershed is measured by climate stations including snowpack (SNOTEL) stations. Each of these is discussed below.

4.2.1 SNOTEL and Snow Course Data Collection Network

There are two SNOTEL/Snow Course data stations within the Upper Missouri Watershed and they include Frohner Mountain (1973 through 2015) and Tizer Basin (1989 through 2015). Figure 4-7 presents the SNOTEL/Snow Course locations in the Upper Missouri Watershed and in areas that are up-gradient (south) of this watershed. This same figure plots historic snowpack and also cumulative departure-from-average plots for most locations. Generally, only those locations with a period of record exceeding 30 years were included in this evaluation.

A careful evaluation of Figure 4-7 demonstrates that the snowpack as measured at each location shows similar cumulative departure-from-average plots from station to station. This suggests that each area of southwestern and west central Montana has responded very similarly to long-term climate conditions. Generally, snowpack tended to be above average from about 1965 to about 1975. Then, snowpack tended to be nearer average from about 1975 to 1985. This in turn was followed by a period of below average snowpack until about 1995. From 1995 to 1998 snowpack was above average. The snowpack from about 1999 to about 2007 tended to be below average. Since 2007, snowpack has been about average.

4.2.2 Valley Precipitation

Valley precipitation as measured at two climate stations (Helena WSO and Townsend) was evaluated in this hydrologic study (refer to Figure 4-4). Figures 4-8a and 4-8b present annual precipitation and the cumulative departure-from-average plots of these data. It is noted that these cumulative departure-from-average plots do not correlate very well to the snowpack cumulative departure-from-average plots presented in Figure 4-7. This suggests that climatic conditions that occur in the valley are independent of climatic conditions of the mountainous areas.

4.2.3 Streamflow Data Evaluation Summary

Long-term streamflow data have been collected at two stream gaging stations on the Missouri River:

- USGS 06054500 (Missouri River at Toston; the drainage area above this station is 14,669 square miles and includes several watersheds well above the Upper Missouri Watershed, including those contributing flow to the Jefferson, Madison, and Gallatin Rivers),
- USGS 06066500 (Missouri River below Holter Dam near Wolf Creek, the drainage area above this station is 17,149 square miles). The net additional area is 2,480 square miles when compared to the Missouri River at Toston.

The remaining gaging stations in the vicinity of the Helena Valley have relatively shorter periods of record and are not helpful in evaluating long-term streamflow trends.

Figure 4-9a provides mean monthly and annual flow hydrographs for the Missouri River at Toston. The lower plot in Figure 4-9a is a cumulative departure from mean streamflow plot for this gaging station extending from 1942 to present. Generally, an upward trend in the cumulative departure-from-average plot (lower plot) indicates a long-term period of above average flow whereas downward trends indicate long term periods of below average flow. Relatively horizontal portions of a given plot demonstrate time periods when the flow is nearer the average flow.

Figure 4-9b provides mean monthly and annual flow hydrographs for the Missouri River below Holter Dam near Wolf Creek. The lower plot in Figure 4-9b is a cumulative departure from mean streamflow plots for this gaging station extending from 1946 to present.

The following are general observations that can be made from comparing the hydrographs for inflow to the Upper Missouri at Toston and outflows below the Holter Dam:

- The cumulative departure-from-average plots for both stations demonstrate that a relatively long-term trend for above average flows began in the mid-1960s and extended to about 1985.
- Flows from 1985 until the mid-1990s were below average.

- Flows from the mid-1990s to the late 1990s were above average.
- Flows from the late 1990s to 2007 tended to be below average.
- Since 2007, flows have been near average.

4.2.4 Comparison of Streamflow to Precipitation

Again, streamflows in the Upper Missouri Watershed and those basins contributing flow to this watershed are highly dependent upon precipitation for a given water year. The dominant factor for streamflows tends to be the magnitude of each year's snowpack (snow water equivalent). Figure 4-10 provides a comparison of the snowpack as measured at the Clover Meadow station with the Missouri River at Toston and below Holter Dam near Wolf Creek. These graphs show that streamflows emulate snowpack conditions.

Figures 4-11a and 4-11b provide regression evaluations comparing the Missouri River flow to snowpack at these same stations. Again, these graphs show that the Missouri River flows are dependent upon the snowpack conditions up-gradient.

Figure 4-12 compares valley cumulative departure-from-average plots for snowpack, Helena valley precipitation, and streamflow. These plots provide another demonstration that snowpack dominates the nature of flow in the Missouri River. There are three reasons for this observation. First, most of the streamflow that enters the Missouri River is attributable to snowmelt runoff from up-gradient sources. Secondly, a high percentage of precipitation that falls in semiarid valley areas, including the Helena Valley, leaves as ET. Finally, the Helena Valley area is proportionately very small compared to the area of the Missouri River Watershed.

Again, the amount of snowpack governs the magnitude of streamflow in the Missouri River. In effect, the near average snowpack of recent years (since 2007) explains the reason that flows in the Missouri River have been near average since 2007.

4.2.5 Groundwater Level Summary

According to the MBMG's GWIC database, there are presently about 13,899 wells in the Helena area (see Figure 4-13). These include water supply wells, monitoring wells, etc. Forty-six of these wells are observation wells that provide water level data over time

(see Figure 4-14 and Plate 4-1). Most of the wells show seasonal variations and are responsive to changes in climate (wet vs drought). Groundwater levels tend to increase during the late spring and early summer when recharge from precipitation, surface water flows and surface-water irrigation activity is the highest. Eight wells showed declines in water levels. The wells showing declines are limited to the North Hills portion of the Helena area. Otherwise, there have been no long-term persistent declines in groundwater levels in other portions of the valley. Some wells are showing recovery and/or increases in groundwater levels (e.g., GWIC wells 62006 and 58923) since drought conditions subsided beginning in 2008.

According to Thamke (2000), the types of water level observations that occur in the bedrock aquifers are normal behavior in aquifer systems as variable as those found in the Helena Valley area. The MBMG concluded the following with respect to observation wells in the North Hills area (Madison, 2006):

> *"Although the decline in some wells is near the most developed part of the North Hills, the decline has also been measured in wells where development is minimal. The decline, therefore, is probably related more to climatic anomalies and to a lesser extent over drafting by well withdrawals."*

The observation wells in the North Hills area have not shown signs of recovery as other wells in the Helena area have. Hence, the North Hills area appears to be one example where withdrawal rates may be exceeding effective recharge rates. A likely factor here is that most bedrock aquifers tend to have much less storage capacity than do coarse-grained alluvial aquifers. This is because groundwater is generally isolated to bedrock fractures. Hence, there is much less groundwater readily available to be pumped at the local level, as is the case in the North Hills area. The North Hills area is a good example of an area where existing statutory and regulatory management tools such as controlled groundwater areas would be appropriate to manage a localized water supply/availability issue.[4]

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[4] A temporary controlled groundwater area for the North Hills was in place until April 2010, when the designation was allowed to expire. Rationale for the designation included that the North Hills was one of the priority areas for additional study. It was anticipated that DNRC would re-visit the North Hills after

4.3 Groundwater Use

4.3.1 Public Water Supply

Public water supply is water supplied by public or privately owned utilities for public distribution (Cannon and Johnson, 2004). Any water system that provides water to at least 25 people for at least 60 days of the calendar year or has at least 15 service connections is considered by law to be a public supply. *See,* Mont. Code Ann. § 75-6-102(14). Water from public water supply (PWS) systems is distributed to multiple users for domestic, commercial, industrial, and public uses. It should be noted that exempt wells may be used as a public water system source as long as they meet the criteria defined above.

According to Cannon and Johnson, about 9,200 people in 2000 were served by public water supply systems using groundwater from both exempt and larger wells in Lewis and Clark County. The City of Helena uses surface water as its source of water. According to the MBMG (GWIC), as of 2015, there are currently about 335 public water supply wells in Lewis and Clark County. These serve entities such as subdivisions, commercial/businesses, municipalities, etc.

According to Cannon and Johnson, 9.2 million gallons per day were delivered for public water supplies in Lewis and Clark County in 2000. This equates to 8,132 ac-ft per year. It is assumed that about 40 percent of this delivered water is consumed. Therefore, the net consumption is estimated to be about 3,252 ac-ft per year.

4.3.2 Typical Domestic Consumption - Individual Wells

Domestic use is water used within the dwelling for domestic purposes (does not include irrigation). The withdrawal (e.g., total demand) from individual wells is estimated based on the number of domestic wells, 2.5 persons per dwelling (well), and the demand of 100 gpd per capita. This volumetric criterion is based upon the Montana Department of Environmental Quality (DEQ) standards for designing public water supply systems. The total consumptive use associated with this withdrawal is based on the consumption

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such additional study was completed. The projected timeline for completion of the MBMG study of the North Hills was Fall 2011. Further DNRC analysis of the North Hills is still pending.

rate of 2 percent of the total withdrawal. The 2 percent criterion is based upon Kimsey and Flood (1987). The domestic consumption from individual wells (11,420 per GWIC) in the Upper Missouri River Watershed of Lewis and Clark and Jefferson Counties is estimated at 64 ac-ft per year.

4.3.3 Lawn and Garden - Individual Wells

The estimate of water consumption attributed to domestic lawn and garden irrigation sourced by individual wells depends primarily on the area of land that is irrigated. Obviously, some property owners, especially with smaller lots, will irrigate relatively smaller areas. Similarly, some property owners will irrigate larger areas. Estimates of typical irrigated areas range from 1/8 to 3/4 acres per well. This study uses an average irrigated area of 1/2 acre per domestic well as a conservative approach to estimate the quantity of consumed water from individual wells used for lawn and garden irrigation. There are 11,420 domestic individual wells identified in the GWIC database for the Helena area (Lewis and Clark and Jefferson Counties). The lawn and garden consumptive use associated with these wells is estimated at 9,364 ac-ft based on the methodology described above.

4.3.4 Agricultural Irrigation

As in many other areas of Montana, the most dominant use of water in Lewis and Clark County is for agricultural irrigation. Historically, most (95 percent) of the irrigation water is from surface water sources. Groundwater use for irrigation of agricultural crops is very limited (5 percent) in this county.

USDA Census of Agriculture data (http://www.agcensus.usda.gov/) provides information about the extent of irrigated land in Lewis and Clark County. As of the 2012 census, there were 629,627 acres of land in irrigated farms and 47,504 acres were irrigated in that year.

NE&W also evaluated the irrigated land census data from 1982 to 2012 (five year census cycle) to assess if there was an overall decline in irrigated acreage.

Year	Acres
1982	39,639

1987	39,974
1992	39,798
1997	40,032
2002	43,392
2007	**50,257**
2012	47,504

The maximum acreage is indicated in **bold** and the minimum underlined.

Based upon this analysis, it appears that the amount of irrigated acreage in the valley has increased over the time period evaluated. However, the acres of land in irrigated farms decreased by 21% from 1982 to 2012. This may indicate irrigation of more acres on fewer irrigated farms (see Figure 3-16).

Cannon and Johnson projected that the total consumption from agricultural irrigation is 53,090 ac-ft in Lewis and Clark County in 2000. About 9,700 ac-ft of this is estimated by NE&W to be associated with irrigation wells.

4.4 Water Budget Summary

This water budget summary includes water budgets for an average and a dry (drought) year. It also discusses factors that can affect the water budget including the significance of long-term drought, housing development, and agricultural irrigation. Finally, it presents implications of future projected population growth in the Helena area and the accompanying groundwater development on the water budget and streamflows. Figure 4-16 provides a water budget of the annual volume of water entering the Upper Missouri River watershed for an average water year. The basis of this figure is developed from the information set forth previously. Figure 4-17 provides a water budget under conditions representative of a drought year using 2004 snowpack data, precipitation, and streamflow data. Groundwater storage is assumed to be constant from year to year in each of these situations. Also, groundwater entering and exiting the valley watershed boundaries is not included. Again, in order for storage to change there would need to be either an overall decline in groundwater levels (reduced storage) or an overall increase in groundwater levels (increased storage). It is noted that there is a decline in groundwater levels at a very localized level in the Helena North Hills. However, on a basin scale groundwater levels have been relatively stable. Hence, the

assumption that groundwater storage is constant is deemed appropriate.

Referring to Figure 4-16, the amount of water entering the watershed as precipitation for an average year is 3,022,000 ac-ft. The amount entering as streamflow is 3,403,000 ac-ft. The amount leaving the valley as surface water flow is 3,861,000ac-ft. Hence, the amount of flow leaving as evaporation and consumption is about 2,564,000 ac-ft.

One component of the water budget includes reservoir losses, which are estimated to be about 69,000 ac-ft annually.

Nearly all the remaining “loss” in the valley is from evapotranspiration by vegetation (includes both irrigated and non-irrigated land, forested land, etc.). Based upon information and calculations performed heretofore, the evaporation and transpiration for the entire Upper Missouri Watershed attributable to groundwater demand in the Helena area are as follows:

- Public water supply wells 3,252 ac-ft
- Individual well lawn and garden irrigation 9,364 ac-ft
- Individual well domestic consumption 64 ac-ft

Again, Figure 4-17 provides the same information but considers a drought year applying 2004 data. All consumptive uses were assumed to be the same as for a normal year for presentation purposes. In reality, there will be some difference but this difference is difficult to quantify and it is also considered inconsequential in the overall scheme of things.

Figures 4-18 and 4-19 compare the consumptive uses from above to provide a graphical representation of the relative significance of the various consumptive uses on the overall water budget. Figure 4-18 presents comparisons of consumptive uses to streamflow for a normal year. Figure 4-19 provides comparisons of consumptive uses to streamflow for a dry year.

Based upon the above assessment, it is obvious that the impact of groundwater development on the overall water budget and streamflow in the Upper Missouri River watershed is very small.

4.5 Water Use Projections

The relative significance of future growth in Lewis and Clark County can be evaluated by projecting future demands and comparing those demands to the overall water budget developed previously. There is significant uncertainty related to projecting future water use based on projected population growth. NE&W deems that the best approach for projecting future demand in Lewis and Clark County and in Montana is to use a combination of historical population data and Census-based growth projections.

The population of Lewis and Clark County increased by 7,679 from 2000 to 2010. Based on 2.5 persons per dwelling, this results in an increase of about 3,072 new dwellings. Based on historical ratios, about 1,051 will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of 862 ac-ft as of 2010.

The Montana Department of Commerce reports population projections provided by eREMI (Regional Economic Models, Inc). The latest available projections are dated April 2013. These projections show the population of Lewis and Clark County increasing from 63,395 per the 2010 census to 74,495 in 2030. It is assumed that about 2.5 persons per dwelling results in 4,440 new dwellings over that same time period. Based on historical ratios, about 1,531of these new dwellings will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of about 1,255 ac-ft due to additional individual wells by year 2030.

As another perspective, it is useful to define the projected increase in consumption (and depletion) from individual wells on a year to year basis. The year to year change is about 0.145 cfs (or about 69 gpm). This is approximately the same as the flow in 10 garden hoses. Such a rate of change in flow is obviously not detectable in the flow of Missouri River.

From a public water supply perspective, it is assumed that such consumption will increase similarly in proportion to population growth. Thus, the net increase in consumption for public water supplies sourced by groundwater from both exempt and larger wells is estimated at 416 ac-ft from 2000 to 2010 and projected to be an additional 1,230 ac-ft per year by 2030.

Again, it should also be noted that there is likely to be a corresponding decrease in agriculturally irrigated acreage in the Helena area as the land use changes to residential. In effect, some of the subdivision growth will likely occur in areas that are currently agriculturally irrigated acreage. From a water budgeting perspective, it would be necessary to consider this change in irrigated areas to determine actual "cumulative" impacts from groundwater use. It should also be noted with either a decrease or increase in irrigated land from subdivision development, any net change will simply be too small to be manifested at any detectable level in the Missouri River. The primary reason for this is that the flows of the Missouri River are about three to four orders of magnitude greater than any total projected change in consumptive use over the next 20 years. This is far below any gaging instrument accuracy for measuring Missouri River flows.

4.6 Projected Increase in Consumptive Use Versus Seasonal Streamflow

The relative significance of projected increases in consumptive use from individual wells can be compared to gaged streamflow. The projected increased consumption for Lewis and Clark County from 2010 to 2030 is 1,255 ac-ft. Note that wells are distributed over a relatively broad area of the Helena Valley area. Hence, it is deemed reasonable to assume that the relative depletion associated with this projected growth can be defined using a steady-state approximation in 2030. This equates to about 1.7 cfs of depletion in the Missouri River.

Figures 4-20a through 4-20b compare the relative significance of the projected depletions on streamflows as measured at the Missouri River below Holter Dam. A 5 percent flow measurement accuracy criterion is shown on each figure to assess if it is possible that a depletion of 1.7 cfs would be detectable in the gaging data. If the 5 percent flow measurement criterion were to fall below the projected depletion of 1.7 cfs, then the projected change would be considered potentially detectable. Otherwise, the projected change is considered not detectable.

Given that the 1.7 cfs depletion falls far beneath the 5 percent flow measurement criterion, it is concluded that the relative significance of the individual well growth would not be detectable in the flows as measured at the Missouri River below Holter Dam.

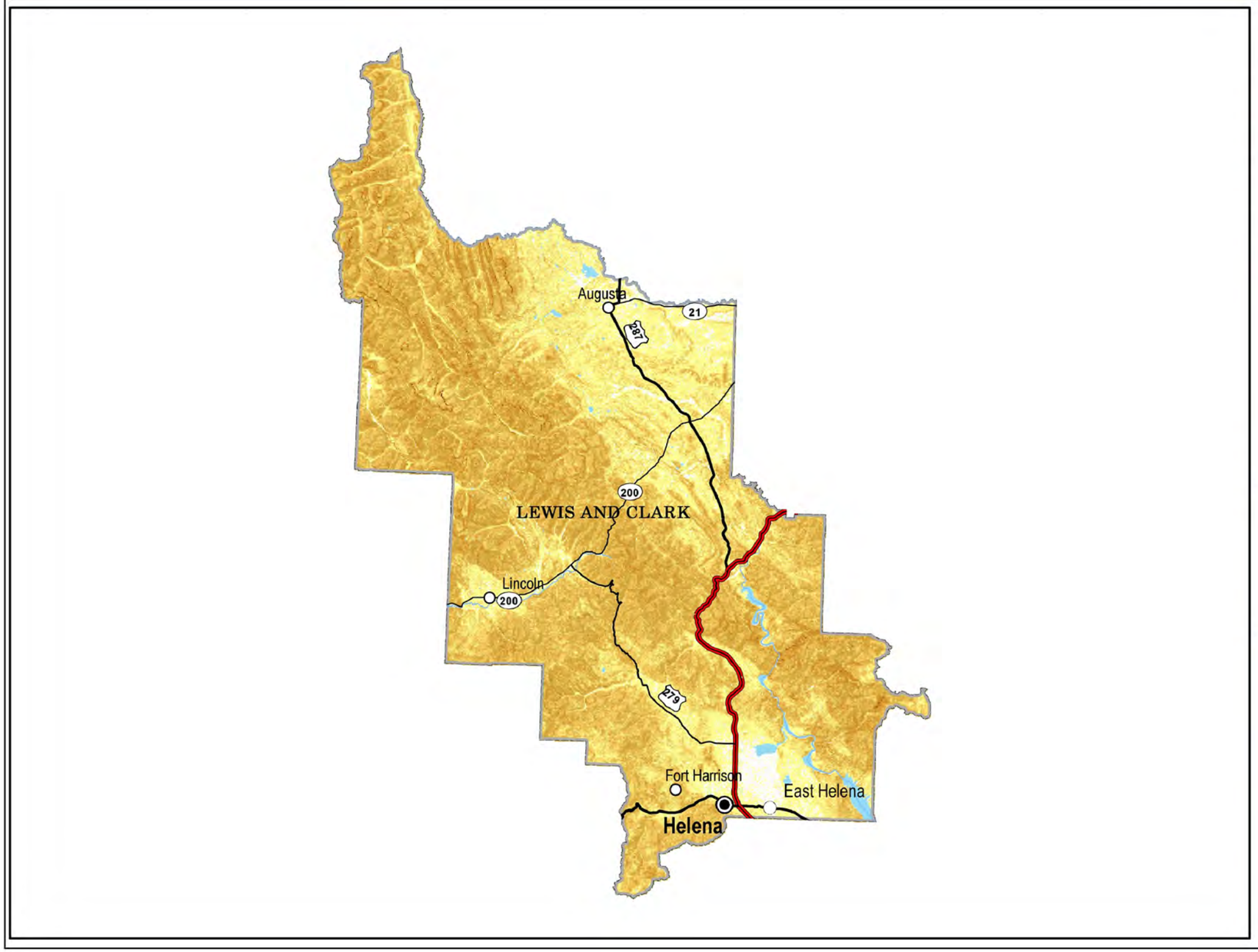
Again, the projected relative change on a year to year basis is about 0.09 cfs. It is obvious that any year to year change would not be detectable in the Missouri River.

Finally, it should be noted that the projected depletion does not account for increases in streamflow associated with potential land use change transitions from irrigated agriculture to residential subdivisions. The trend has been for much of the new development to occur on previously irrigated farmland. As development uses less water compared to agricultural irrigation, the result is a net increase in water availability. As such, the new development generally does not impact the ability of existing surface water appropriators to fully utilize their water rights.

rec'd by LEPO April 13, 2016

LEWIS AND CLARK

Slopes Derived from USGS NED



Population

- Under 50
- 51 - 1000
- 1001 - 2500
- 2501 - 10000
- Over 10,000
- Interstate
- U.S. Route
- Secondary
- Montana Ro
- Rivers
- Lake or Reservoir

Degree of Slope

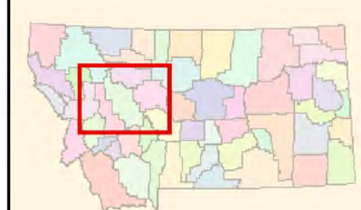
- 0 < X <= 4
- 4 < X <= 10
- 10 < X <= 30
- 30 < X <= 45
- 45 < X <= 60
- 60 < X <= 90
- Flat

The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best-quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US .

7.53.75 0 7.5 15 22.5

Miles

1:800,000



County-Maps-Slope.mxd

MONTANA Natural Resource Information System

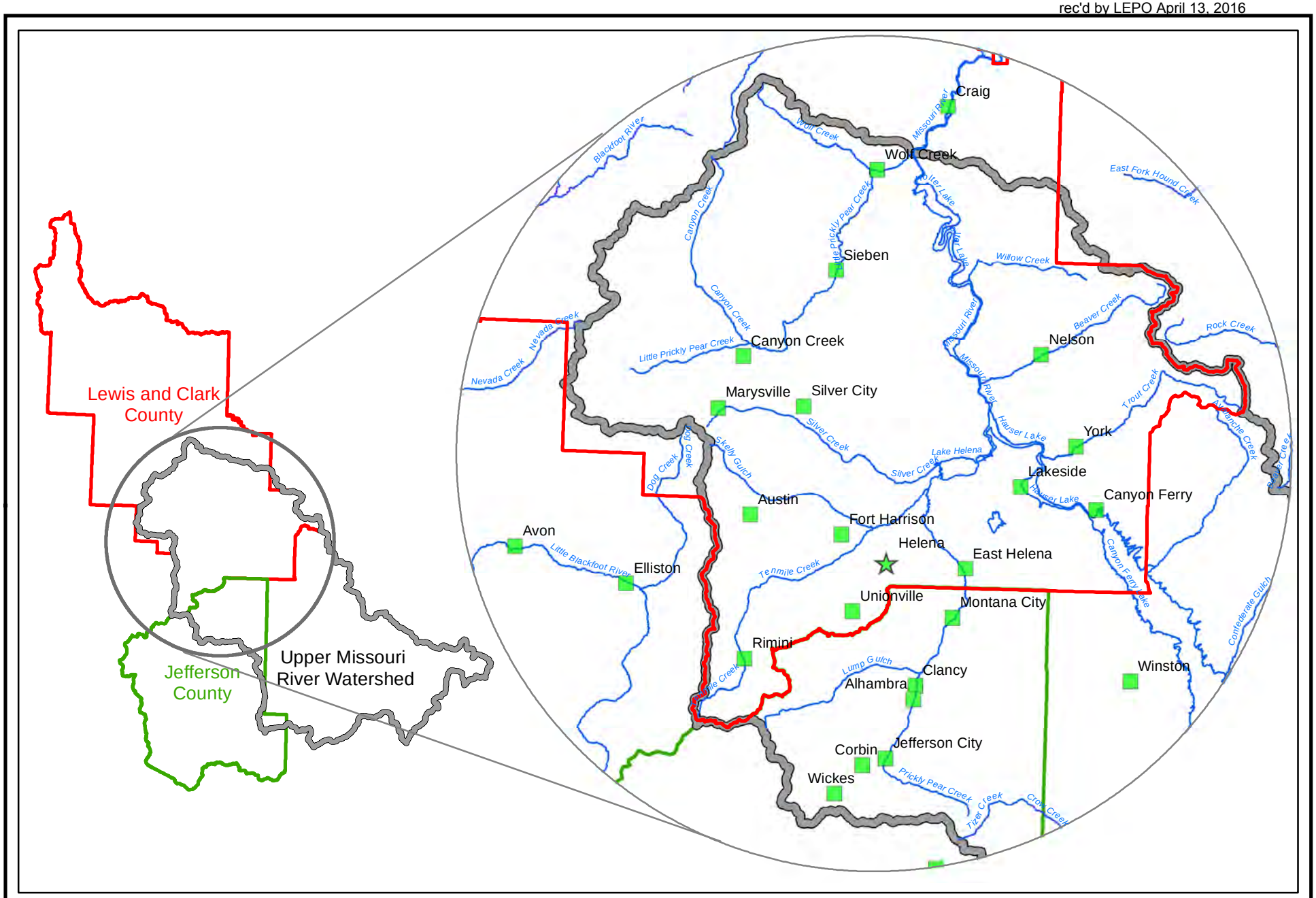
NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 4-1

Montana Association of REALTORS®

Figure 4-1
Lewis and Clark County
Montana NRIS Report

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

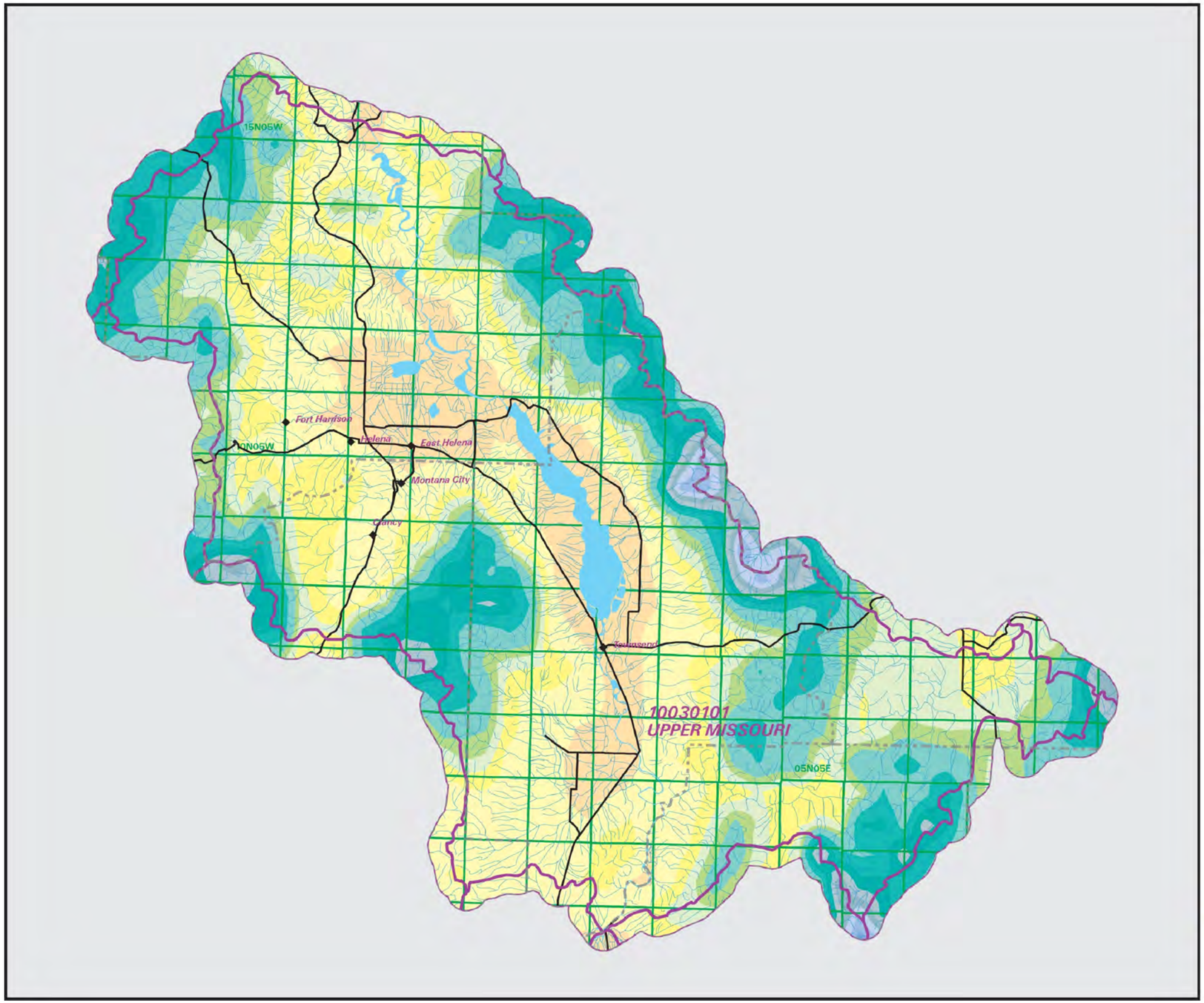
Date: 12/23/2015
File: Figure 4-2

Scale not indicated

Montana Association of REALTORS®

Figure 4-2
Watersheds and Streams
Helena and Vicinity

rec'd by LEPO April 13, 2016



UPPER MISSOURI Watershed

PRISM Precipitation

- County Border
- Highway
- Public Land Survey System Townships
- Fourth Code Watersheds

- 10-12
- 12-14
- 14-16
- 16-18
- 18-20
- 20-24
- 24-28
- 28-32
- 32-36
- 36-40
- 40-44
- 44-48
- 48-52

SOURCE: Spatial Climate Analysis Service at OSU. These data were produced using the PRISM modeling system of the Spatial Climate Analysis Service at Oregon State University. The project was directed and sponsored by the NRCS National Water and Climate Center in Portland, Oregon. PRISM stands Parameter-elevation Regressions on Independent Slopes Model.

This map is to be used as a primary reference source and is not intended for use in site - specific planning. This is public information and may be interpreted by organizations, agencies, units of government, or others, based on needs; however,they are responsible for the appropriate application. Federal, State, or local regulatory bodies are not to reassign to the Natural Resource Information System any authority for the decisions they make.

0 5 10 15

Mapscale 1: 600000, Scale in miles:

MONTANA Natural Resource Information System

Montana State Library -- 1515 East 6th Avenue
Helena, Montana -- (406) 444-5357

Date created: November 04, 2003

Map Request: 04MSL0001 - 10030101 - PRECIP

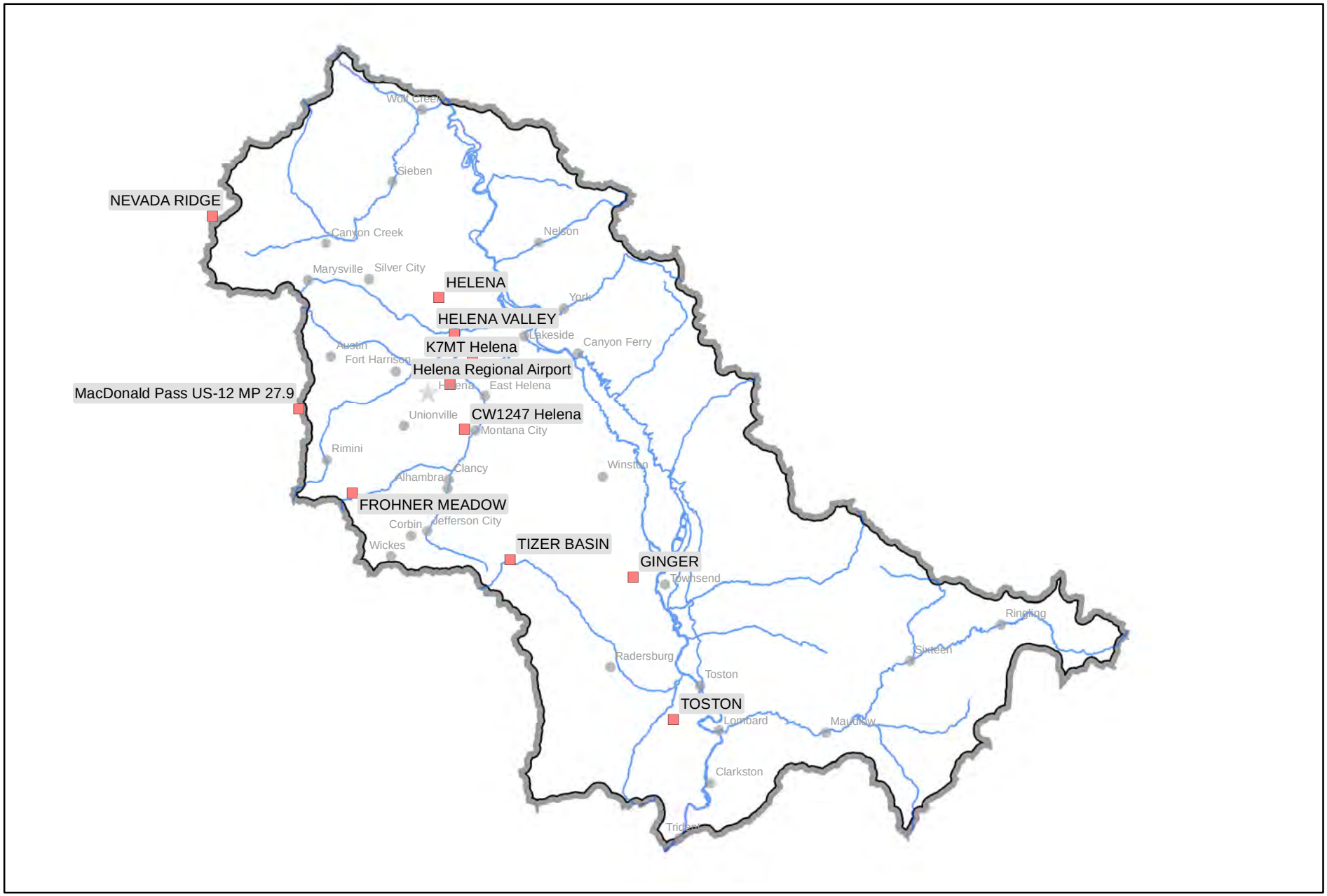
NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 4-3

Montana Association of REALTORS®

Figure 4-3
Upper Missouri Annual Report
Montana NRIS Report

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/23/2015
File: Figure 4-4

Scale not indicated

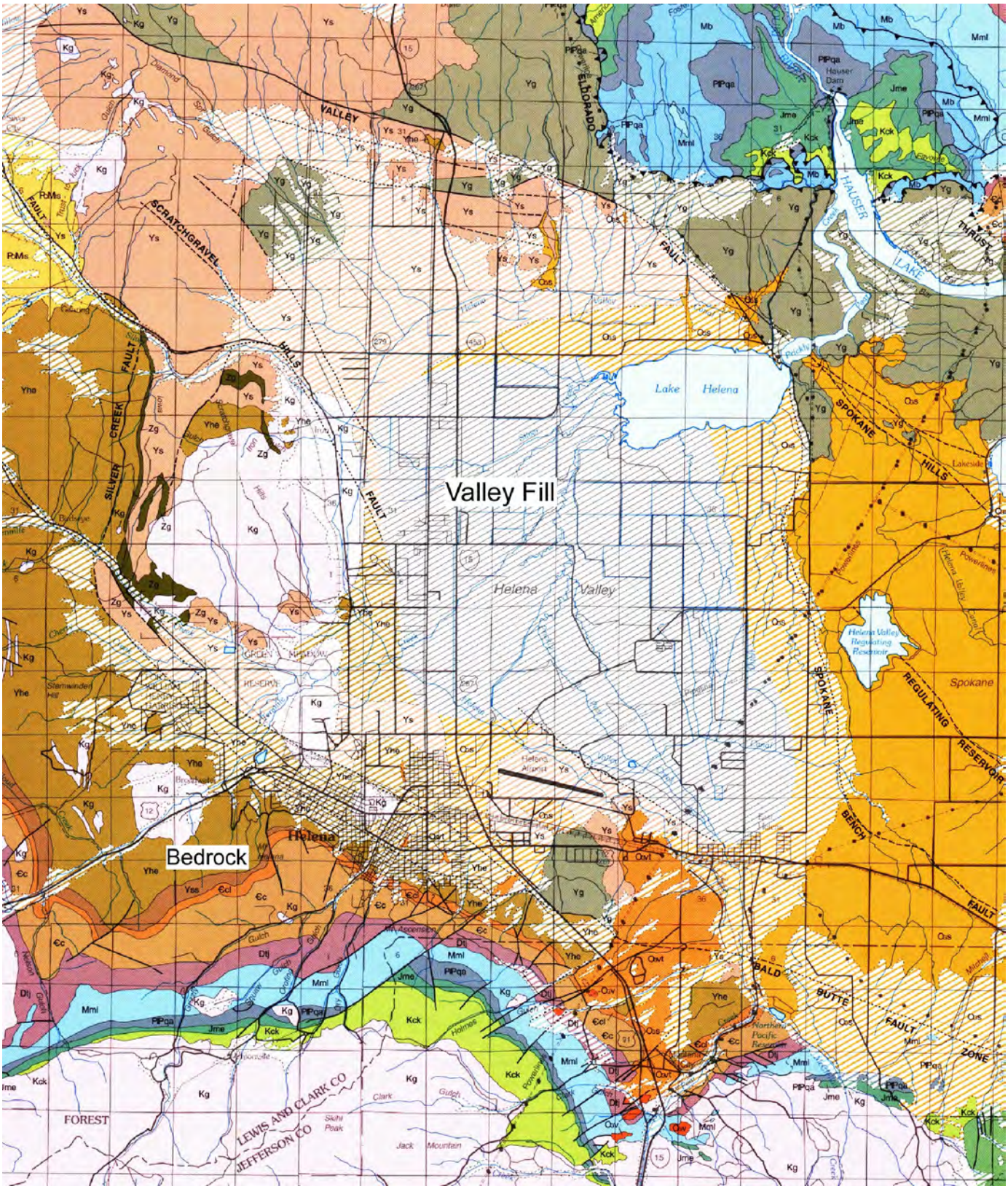
Legend

Climate Station

Montana Association of REALTORS®

Figure 4-4
Climate Stations
Upper Missouri River Basin

rec'd by LEPO April 13, 2016



Adapted from Generalized Bedrock Geologic Map of the Helena Area, West-Central Montana from Reynolds, 2000.

NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 4-5

Scale not indicated

Montana Association of REALTORS®

Figure 4-5
Geologic Mapping
Helena Vicinity

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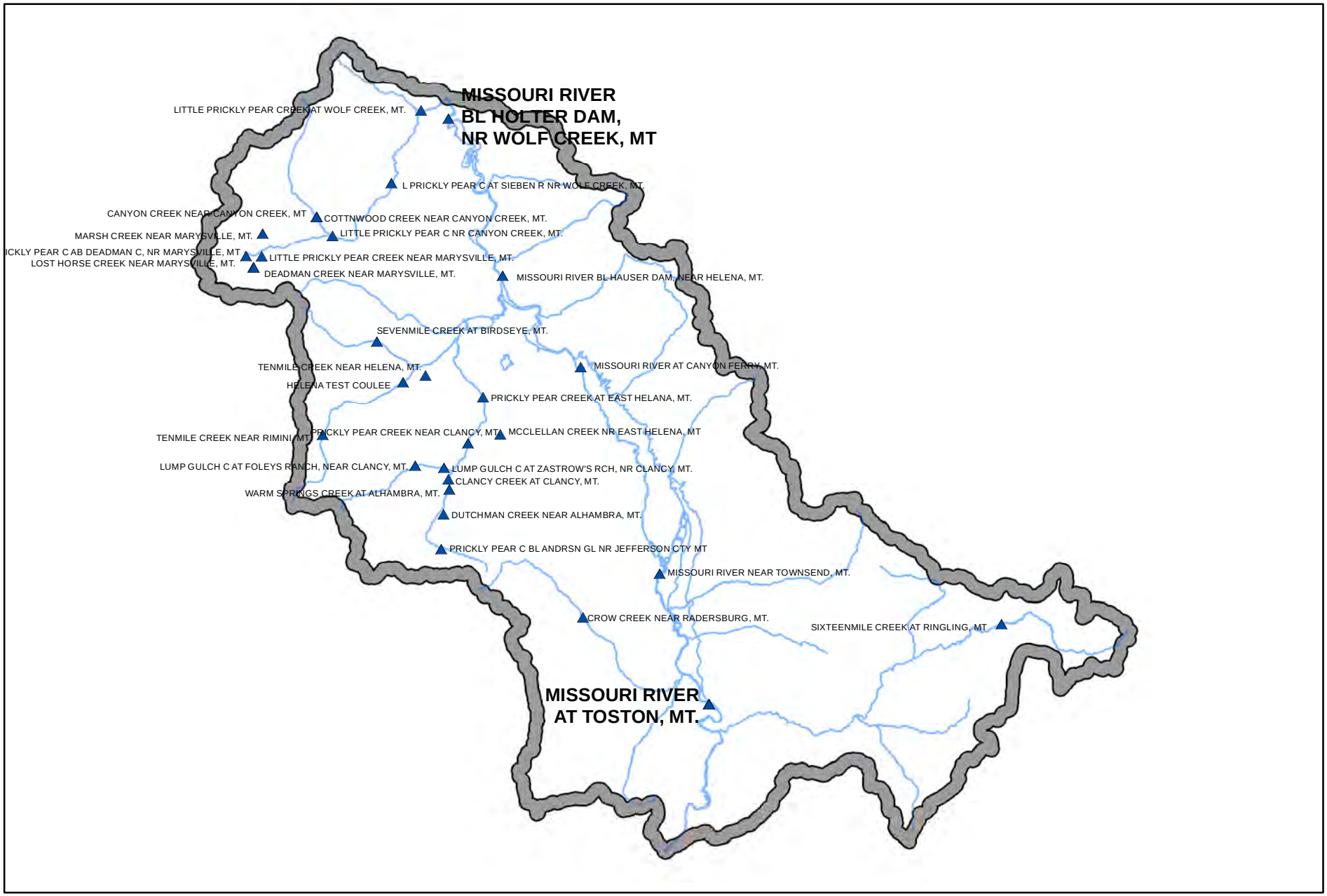


NICKLIN EARTH & WATER, INC.

Date: 12/23/2015
File: Figure 4-6

Scale not indicated

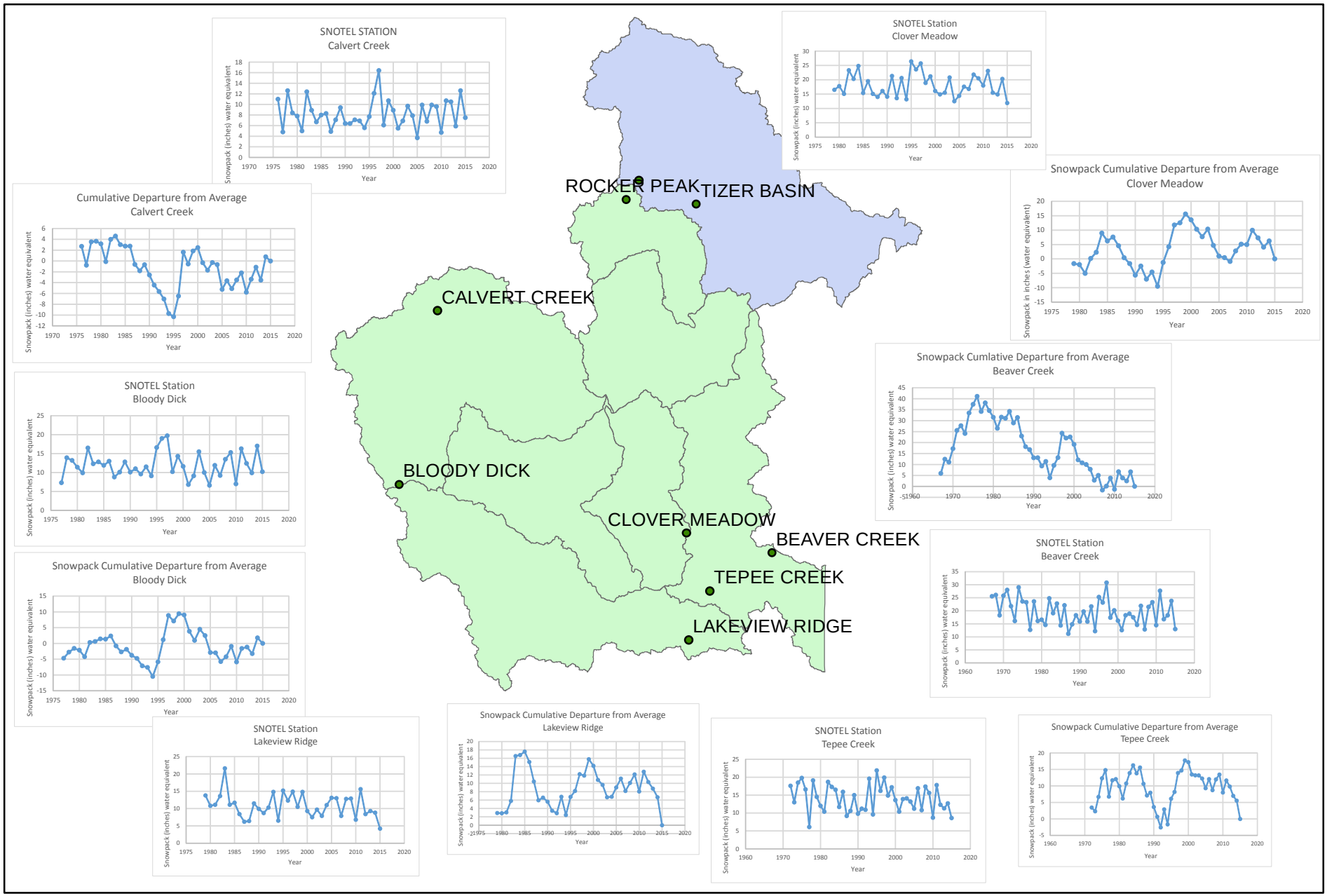
Legend

▲ USGS Gaging Station

Montana Association of REALTORS®

Figure 4-6
Streamflow Gagin Stations
Upper Missouri River Basin

rec'd by LEPO April 13, 2016



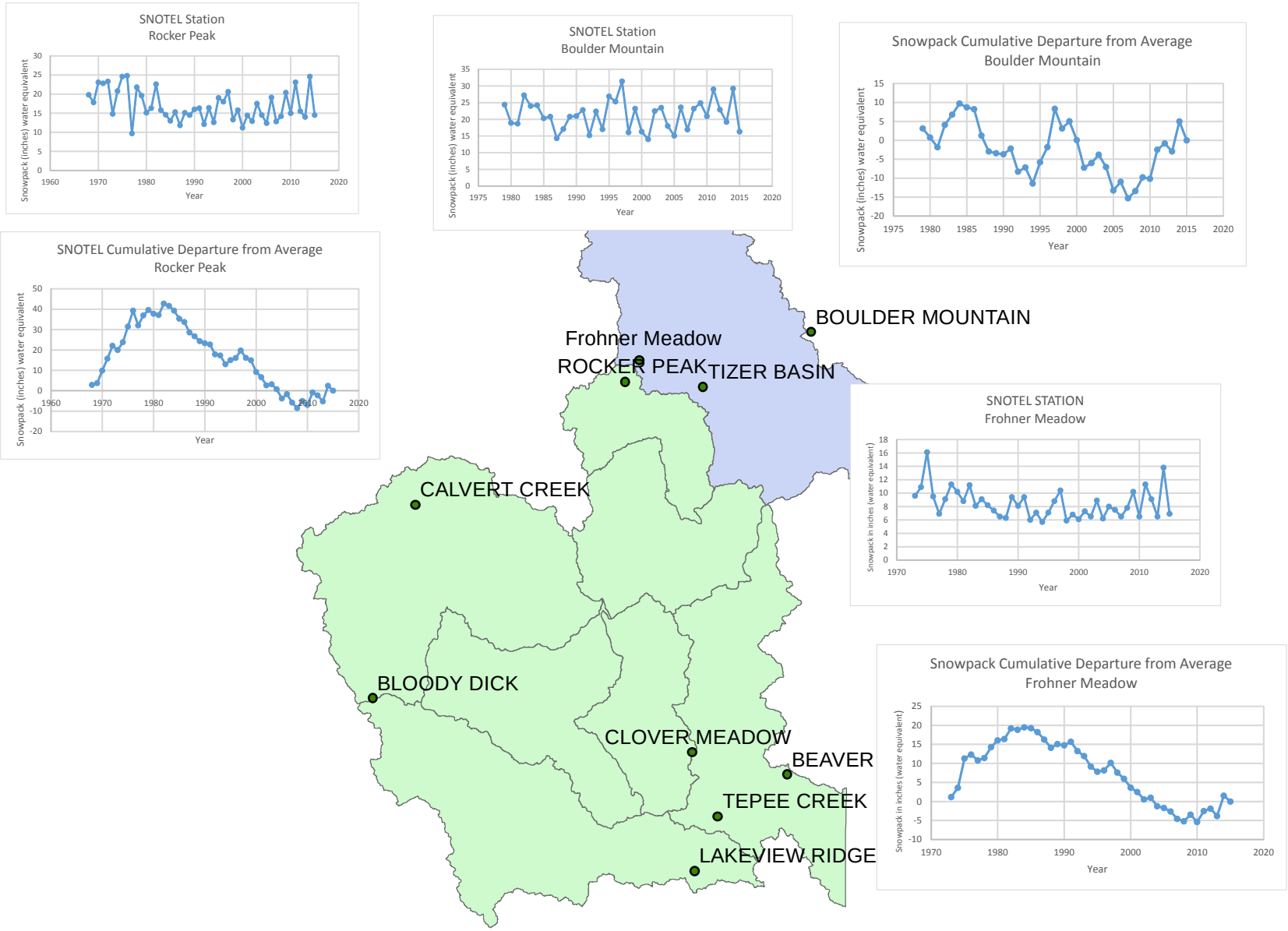
NICKLIN EARTH & WATER, INC.

Date: 12/18/2015
File: Figure 4-7(1)

Montana Association of REALTORS®

Figure 4-7(1)
Snotel Sites Which are Upgradient of Upper Missouri River Watershed

rec'd by LEPO April 13, 2016



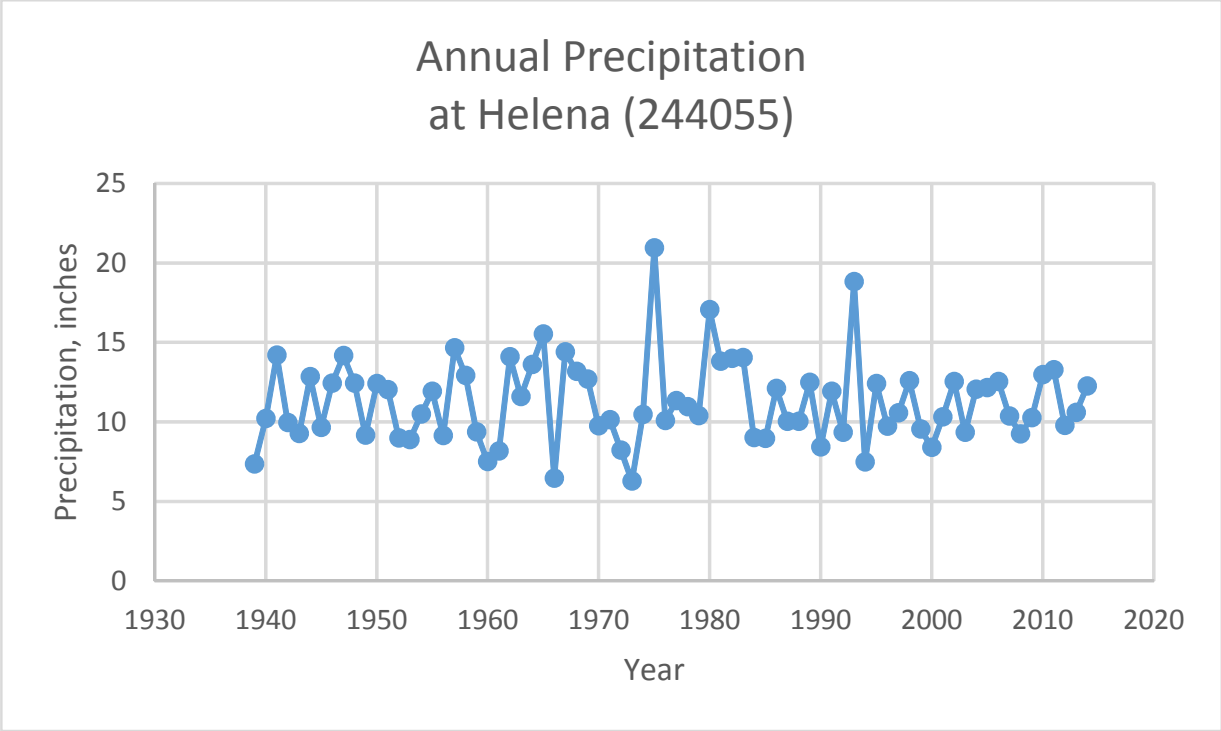
NICKLIN EARTH & WATER, INC.

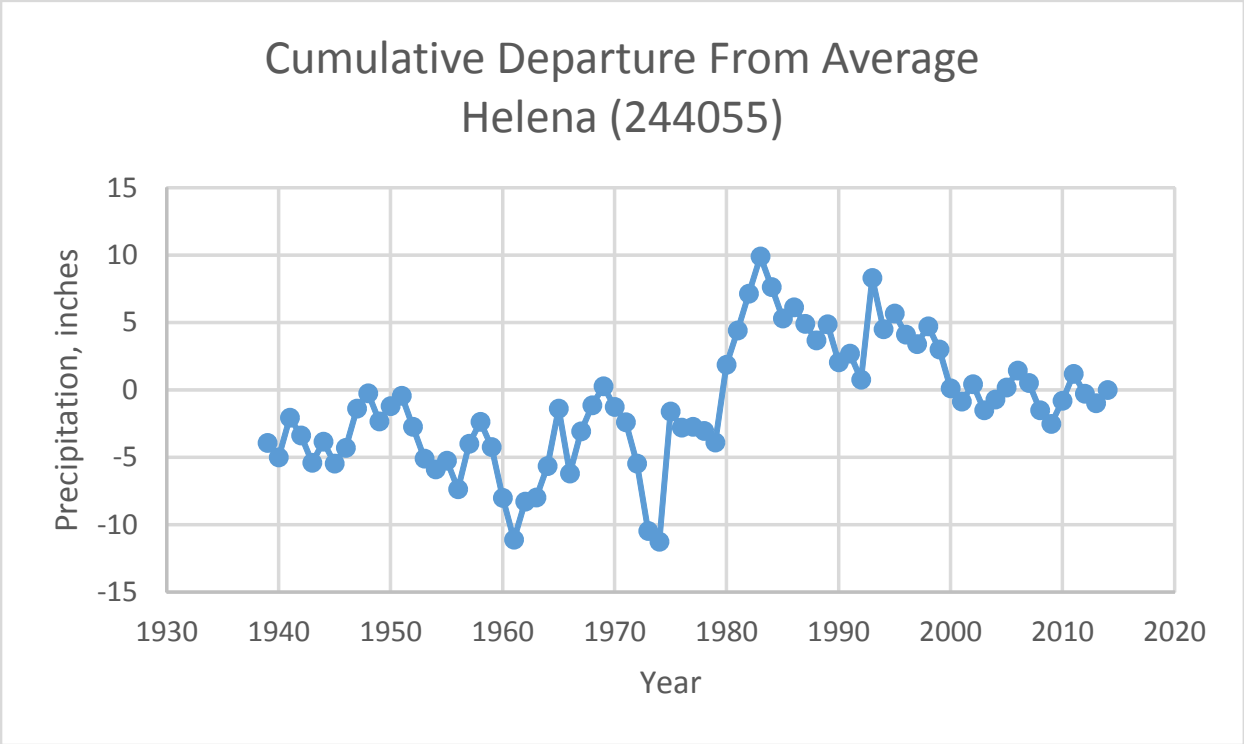
Date: 12/18/2015
File: Figure 4-7(2)

Montana Association of REALTORS®

Figure 4-7(2)
Snotel Sites Which are Upgradient of Upper Missouri River Watershed

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

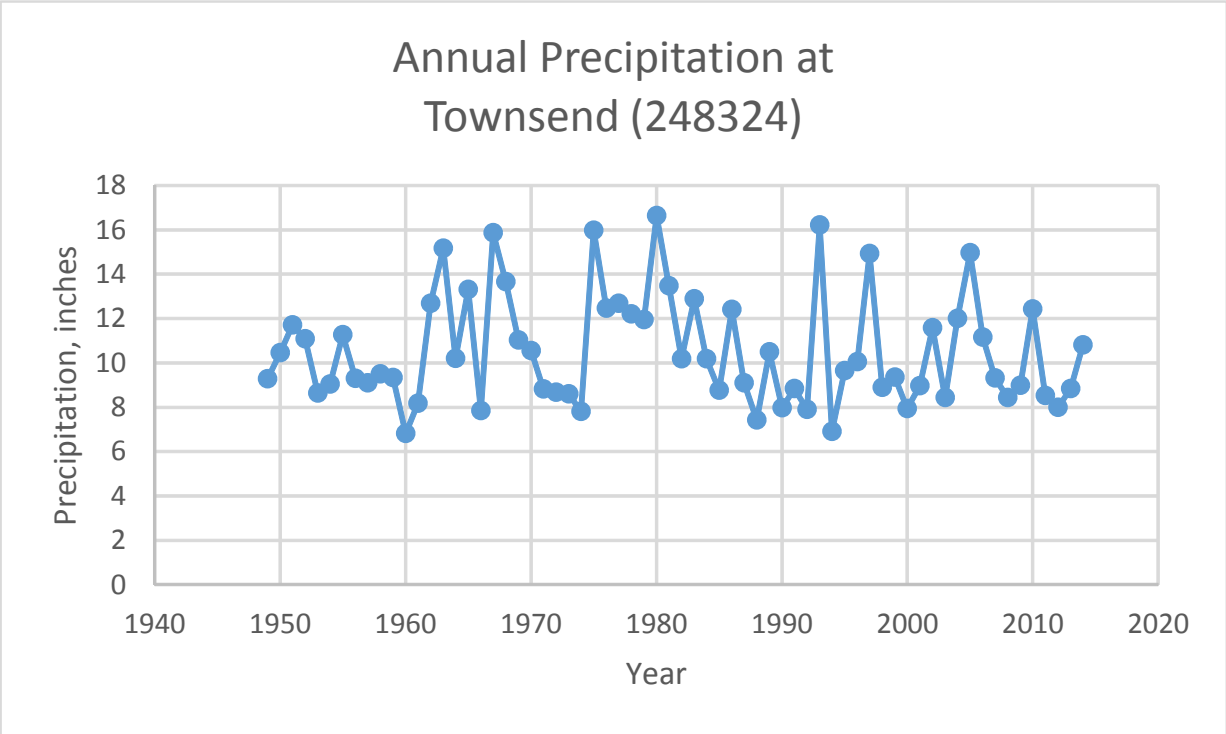
Date: 12/14/2015
File: Figure 4-8a

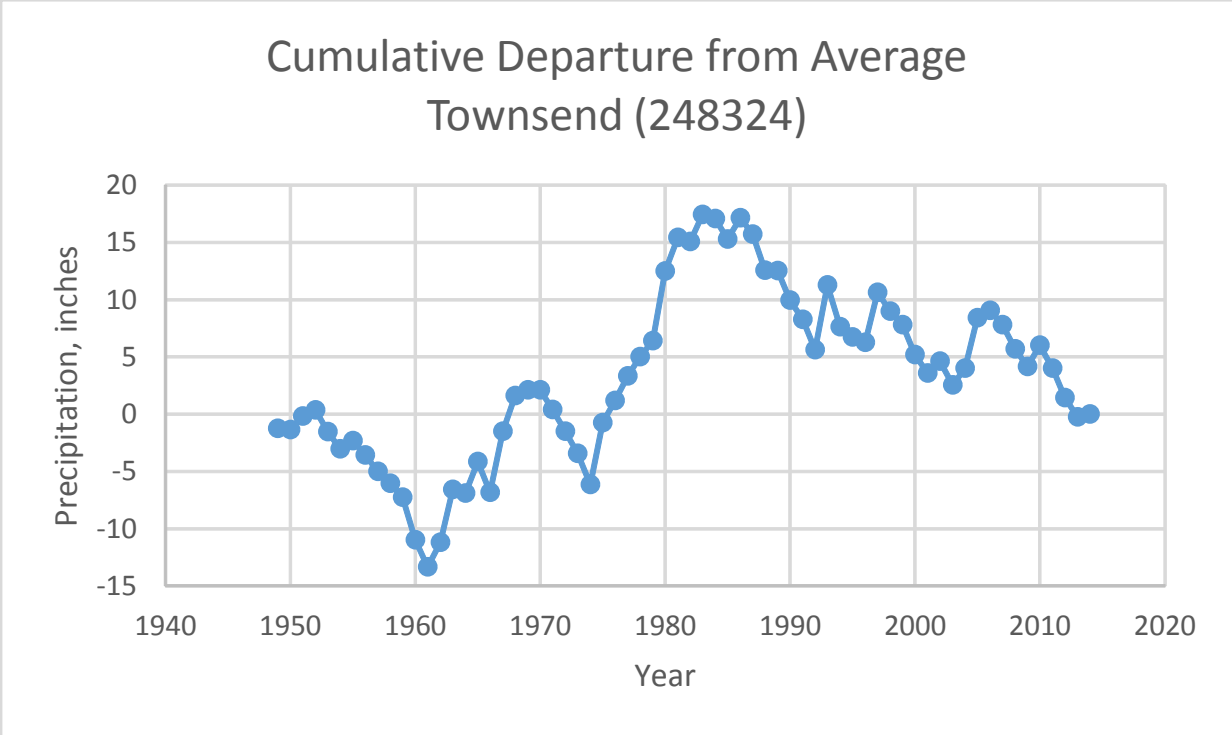
Notes:
Data source: Precipitation data from WRCC.

Montana Association of REALTORS®

Figure 4-8a
Precipitation at Helena

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 4-8b

Notes:
Data source: Precipitation data from WRCC.

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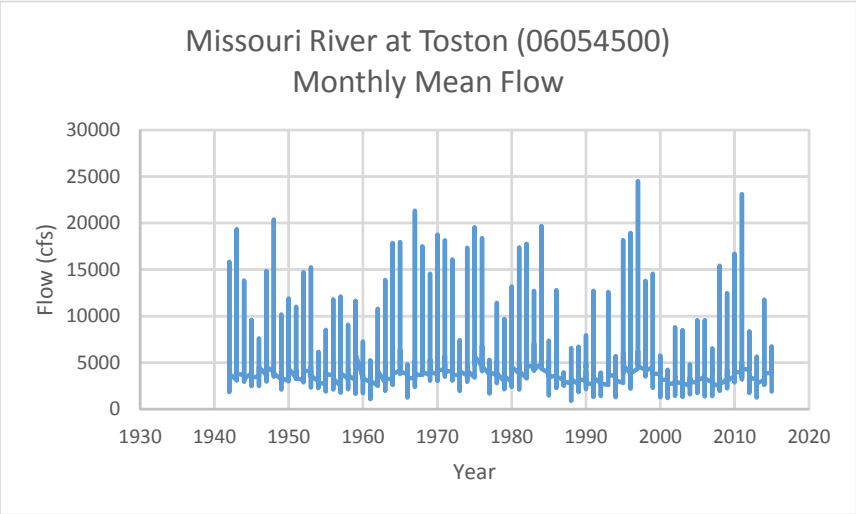
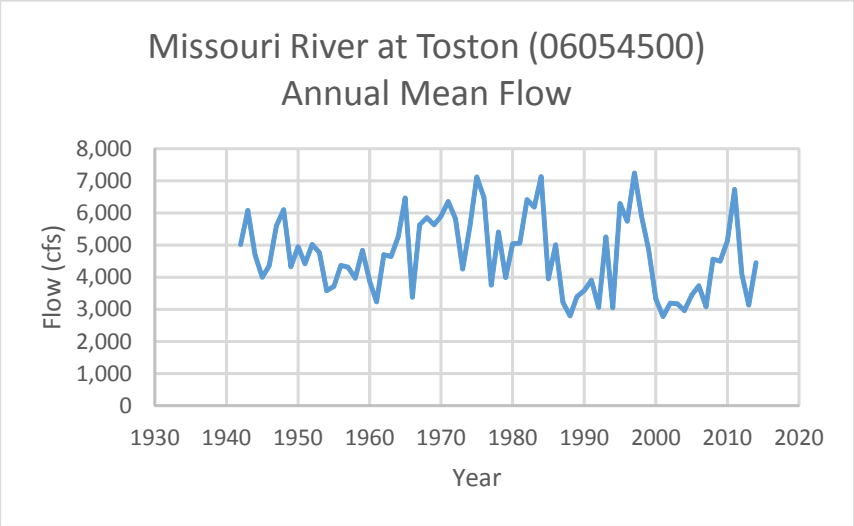
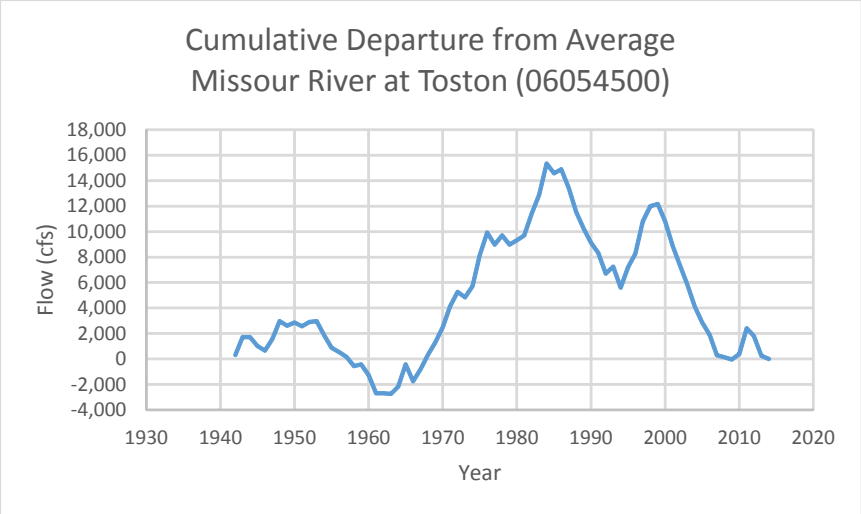
Figure 4-8b
Precipitation at Townsend

rec'd by LEPO April 13, 2016







Notes:

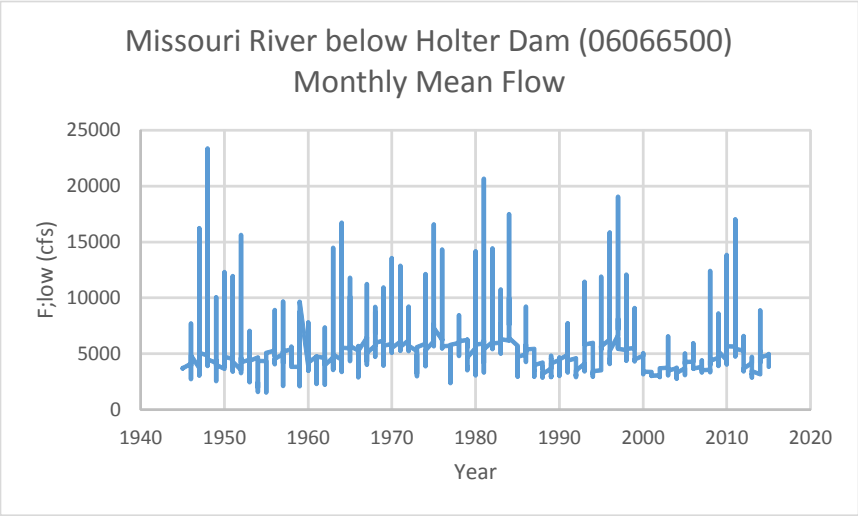
NICKLIN EARTH & WATER, INC.

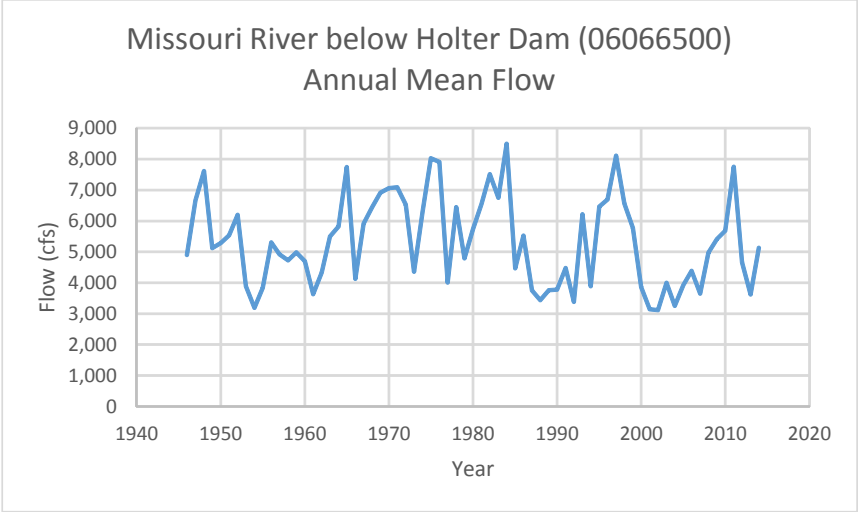
Date: 12/14/2015
File: Figure 4-9a

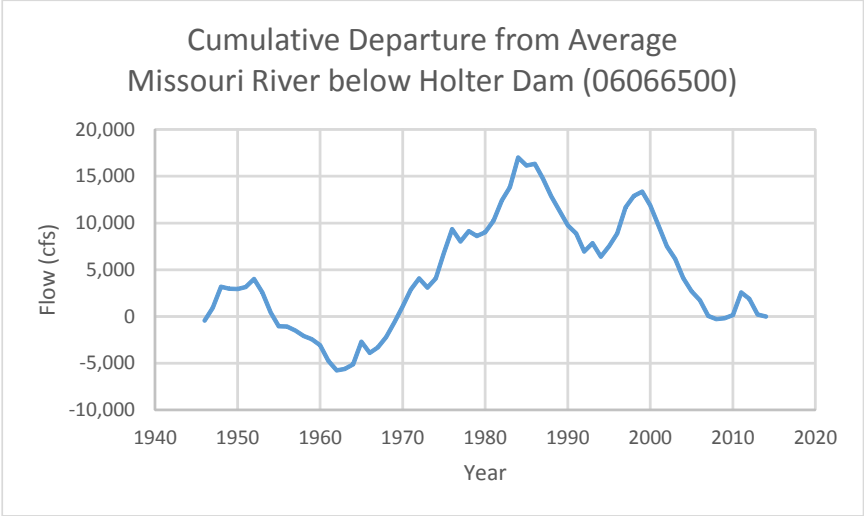
Montana Association of REALTORS®

Figure 4-9a
Stream Discharge
Missouri River at Toston

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

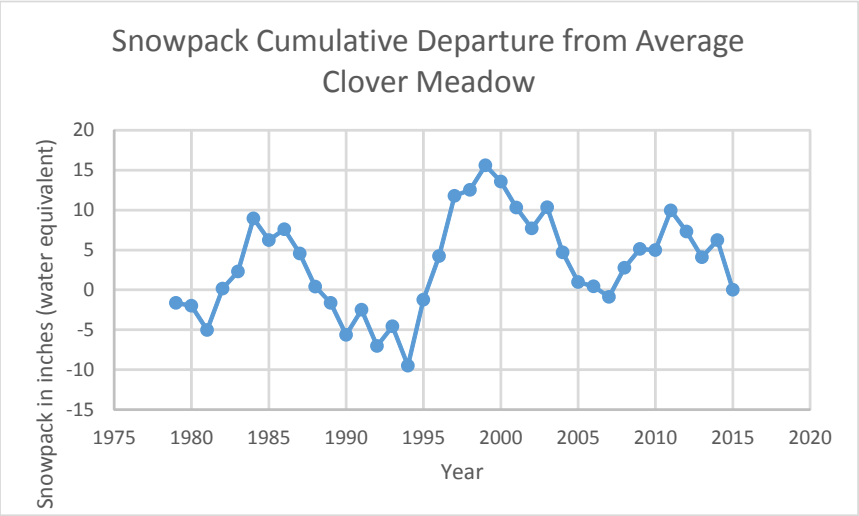
Date: 12/14/2015
File: Figure 4-9b

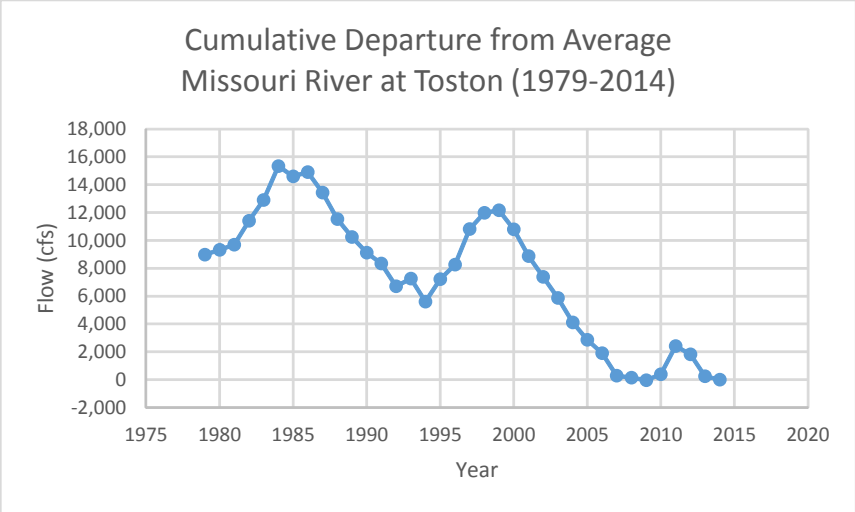
Notes:
Missouri River below Holter Dam near Wolf Creek

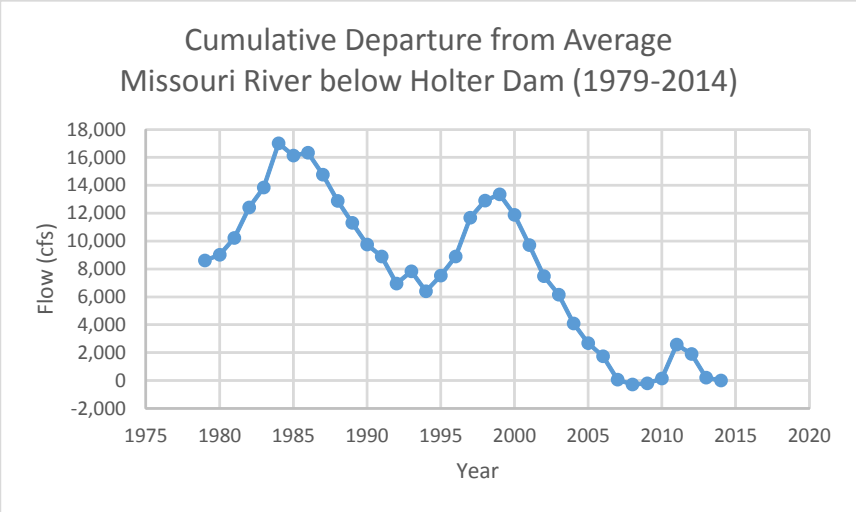
Montana Association of REALTORS®

Figure 4-9b
Stream Discharge
Missouri River below
Holter Dam near Wolf Creek

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

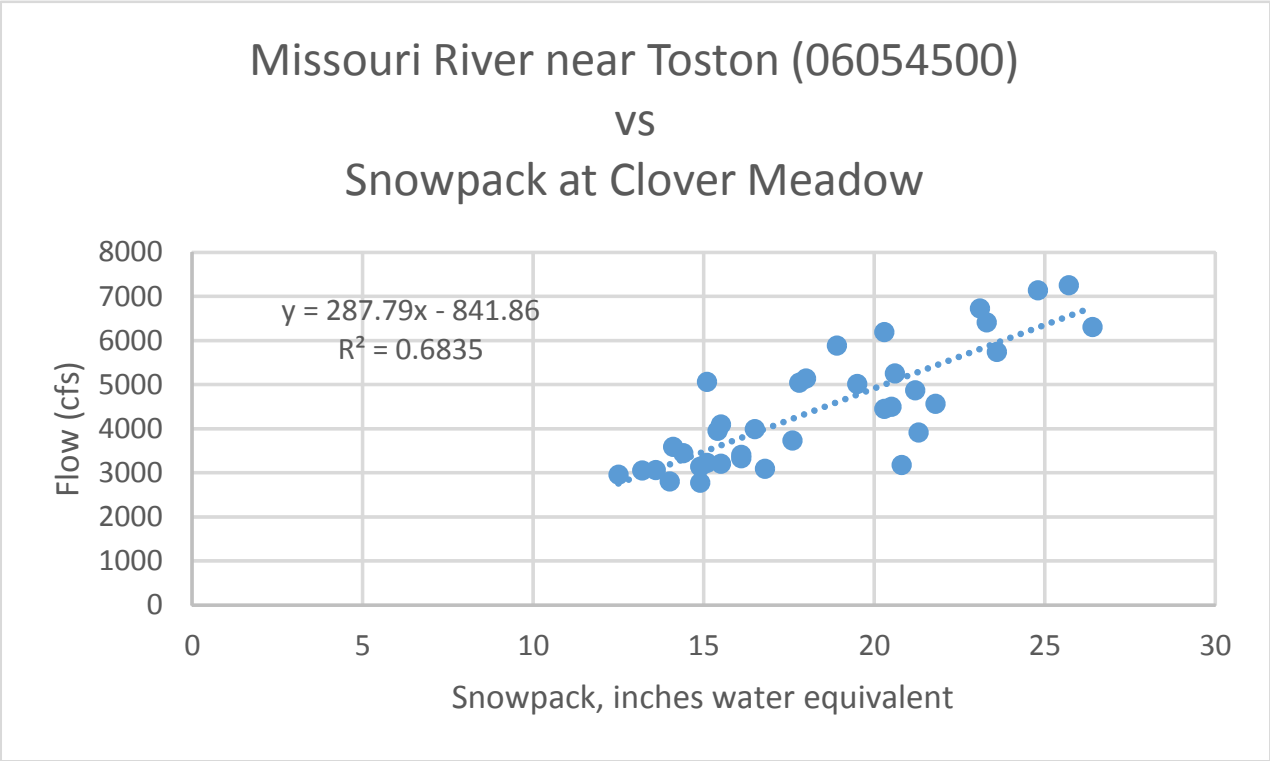
Date: 12/14/2015
File: Figure 4-10

Notes:
Clover Meadows SNOTEL station is located in an area that drains to both streamflow gaging stations. Other SNOTEL stations could have been selected and would have provided an equally representative comparison.

Montana Association of REALTORS®

Figure 4-10
Comparison of Flows
Cumulative Departure Plots
Snowpack vs. Streamflow

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

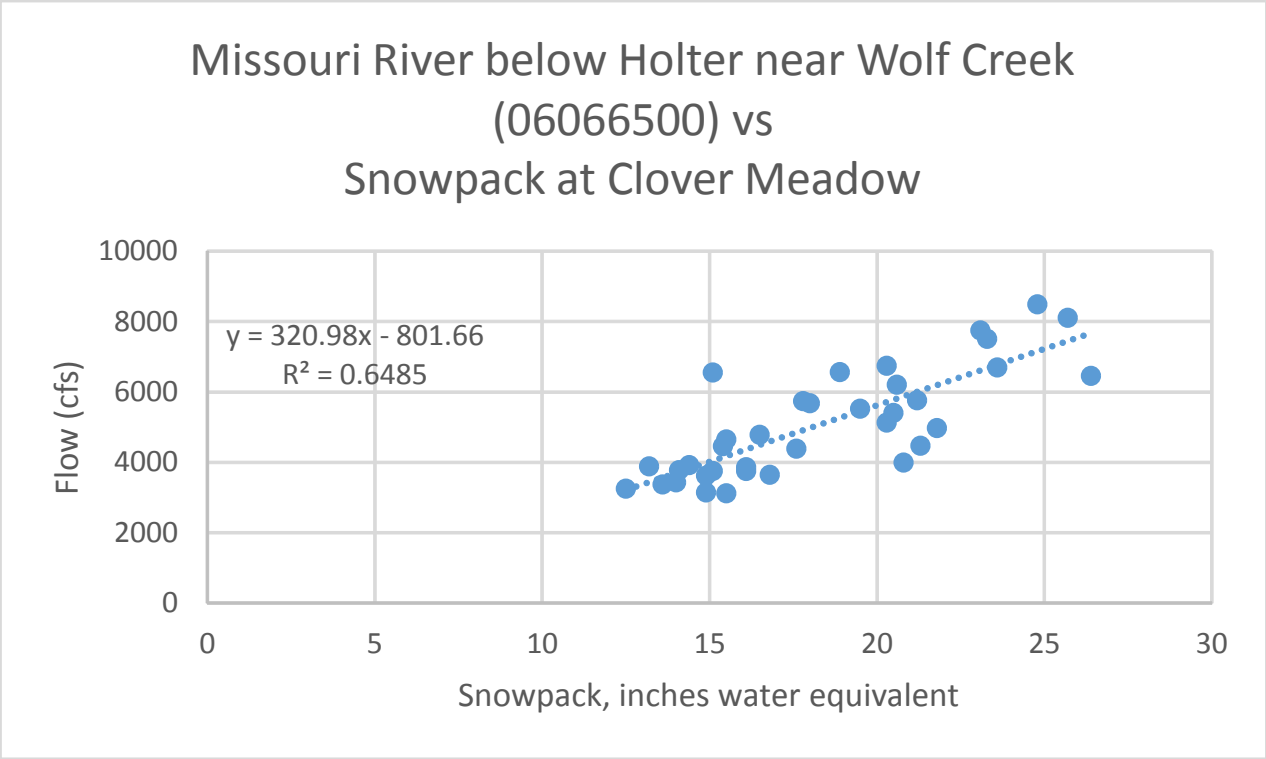
Date: 12/14/2015
File: Figure 4-11a

Notes:
Clover Meadows SNOTEL station is located in an area that contributes flow to the Missouri River. It is above the Toston gaging station. Other SNOTEL sites could have been selected and would have provided an equally representative comparison.

Montana Association of REALTORS®

Figure 4-11a
Missouri River near Toston
Annual Mean Flow VS.
Snowpack

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

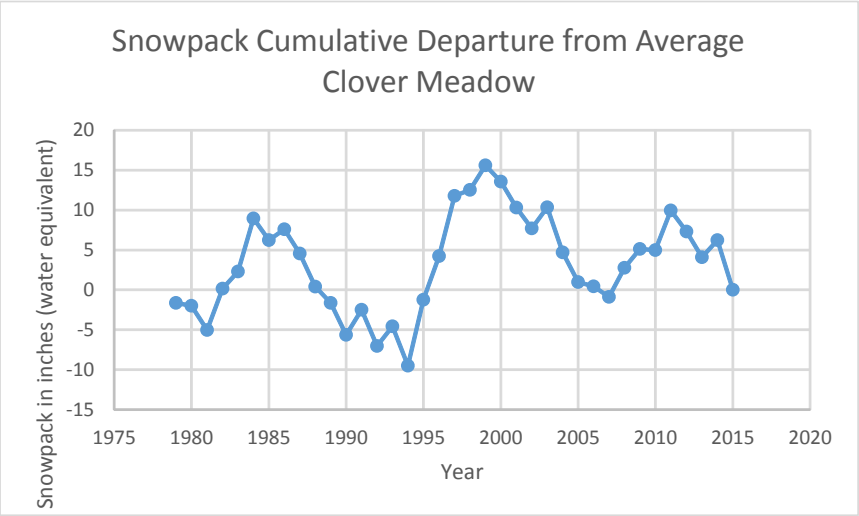
Date: 12/14/2015
File: Figure 4-11b

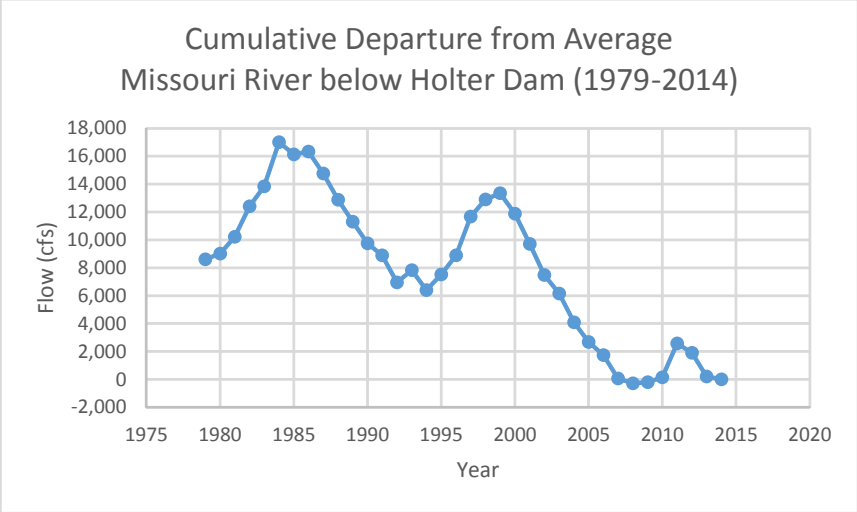
Notes:
Clover Meadows SNOTEL station is located in an area that contributes flow to the Missouri River. It is above the gaging station indicated. Other SNOTEL sites could have been selected and would have provided an equally representative comparison.

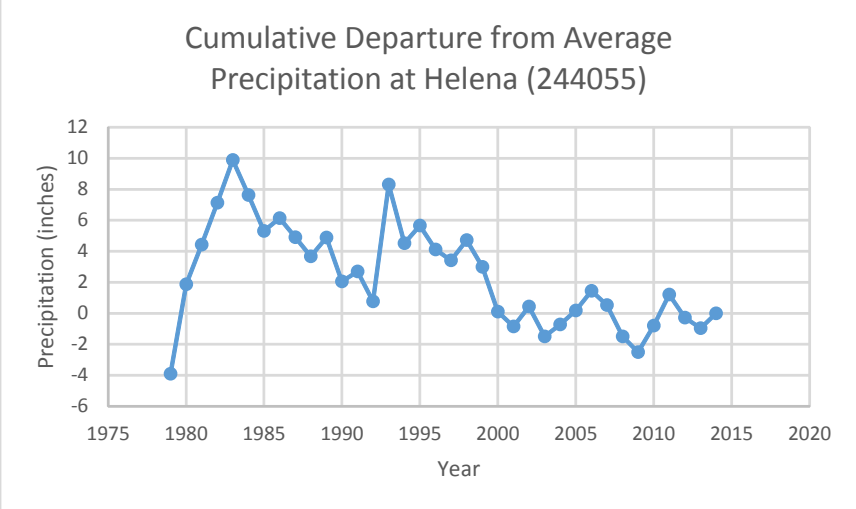
Montana Association of REALTORS®

Figure 4-11b
Missouri River below Holter Dam
Annual Mean Flow VS.
Snowpack

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

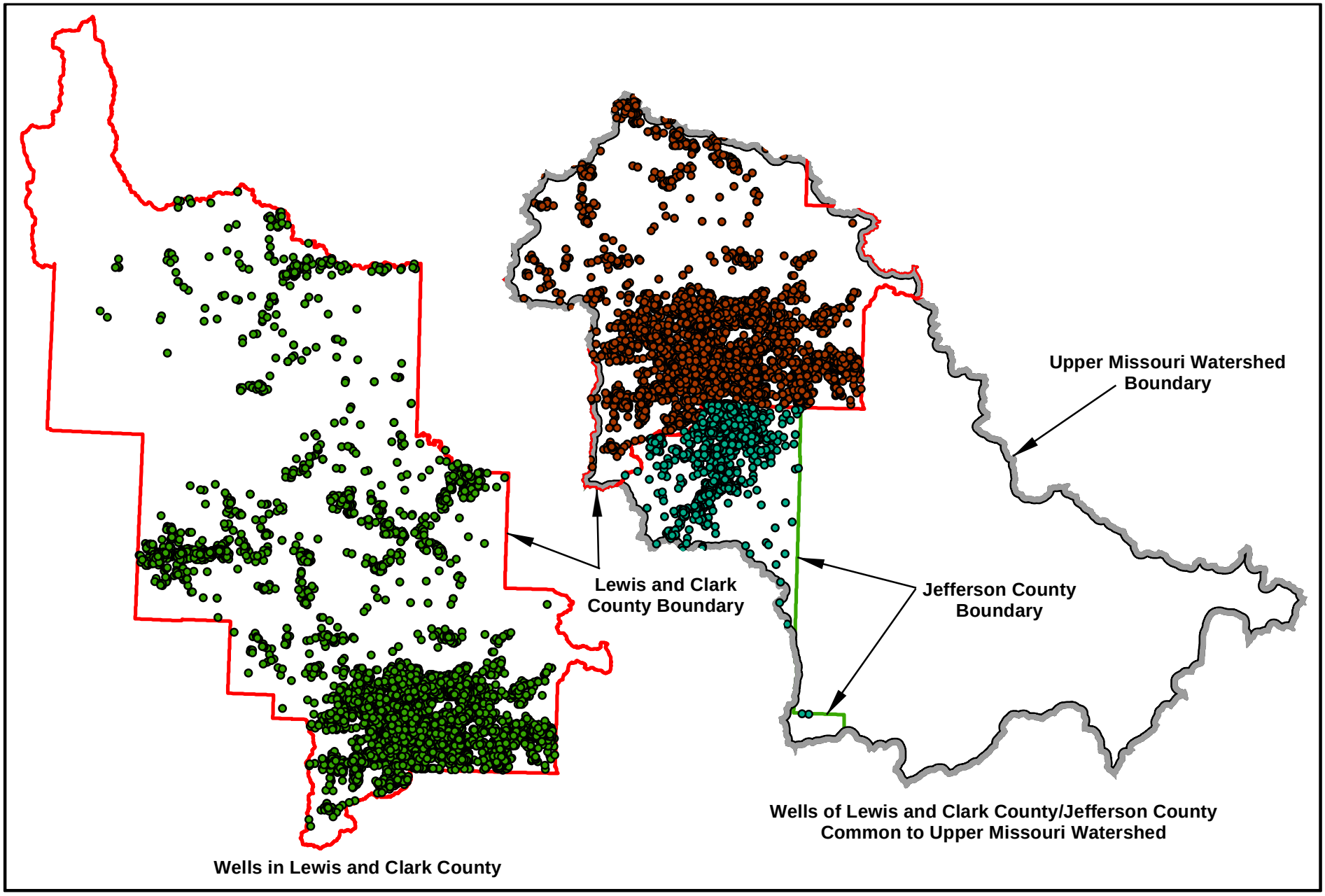
Date: 12/14/2015
File: Figure 4-12

Notes:
The above plots demonstrate that flows as measured in the Missouri River are much more dependent upon up-gradient snowpack conditions when compared to local precipitation at Helena.

Montana Association of REALTORS®

Figure 4-12
Comparison of Flows
Cumulative Departure Plots
Helena, SNOTEL and Streamflow

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/21/2015
File: Figure 4-13

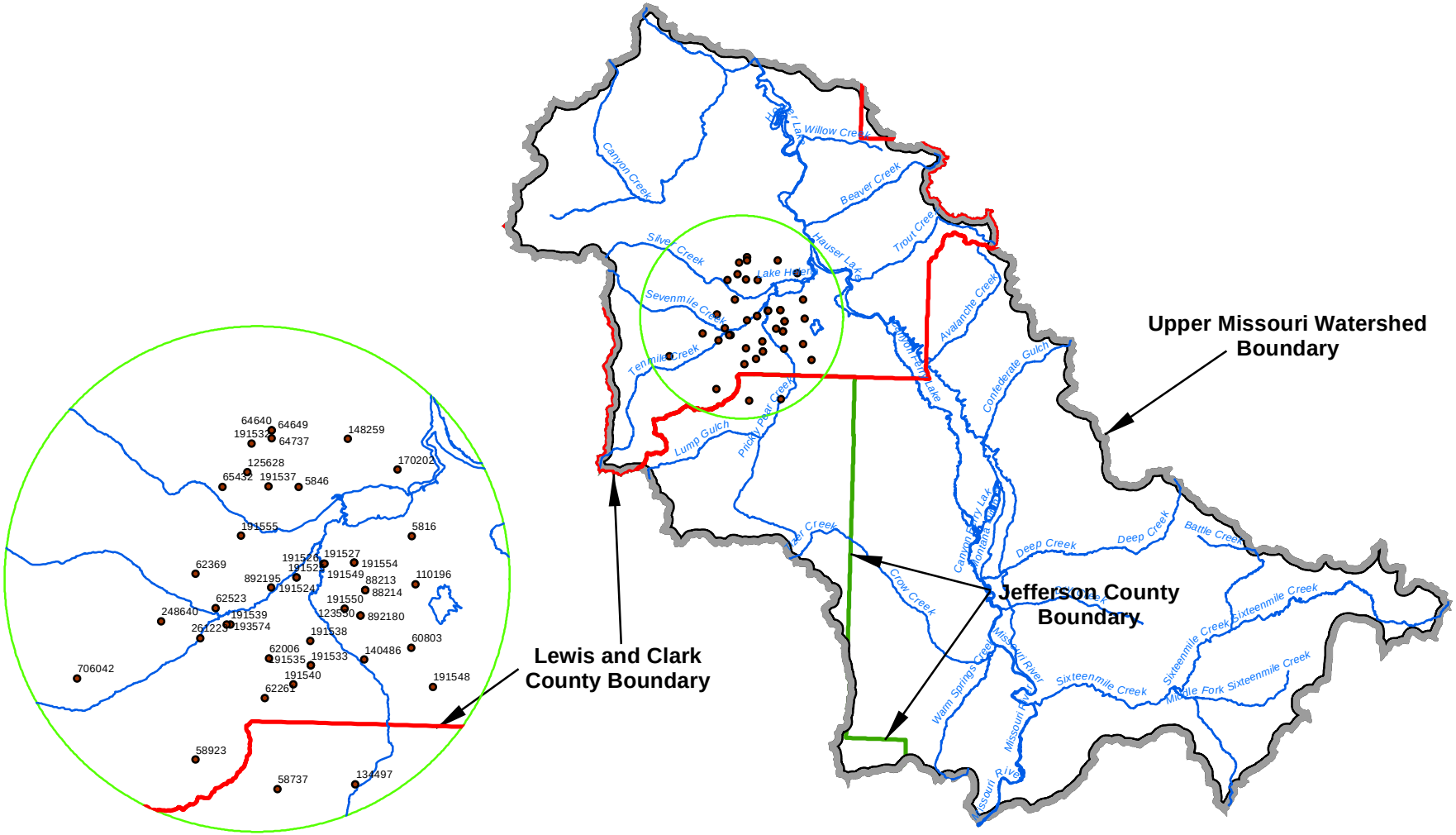
Scale not indicated

Notes:
1) Data source is MBMG GWIC

Montana Association of REALTORS®

Figure 4-13
Wells in Lewis and Clark County

rec'd by LEPO April 13, 2016



Notes:
1) Data source is MBMG GWIC. Only wells located in Upper Missouri Watershed are shown.

Refer to Plate 4-1 for Hydrographs

NICKLIN EARTH & WATER, INC.

Date: 12/23/2015
File: Figure 4-14

Scale not indicated

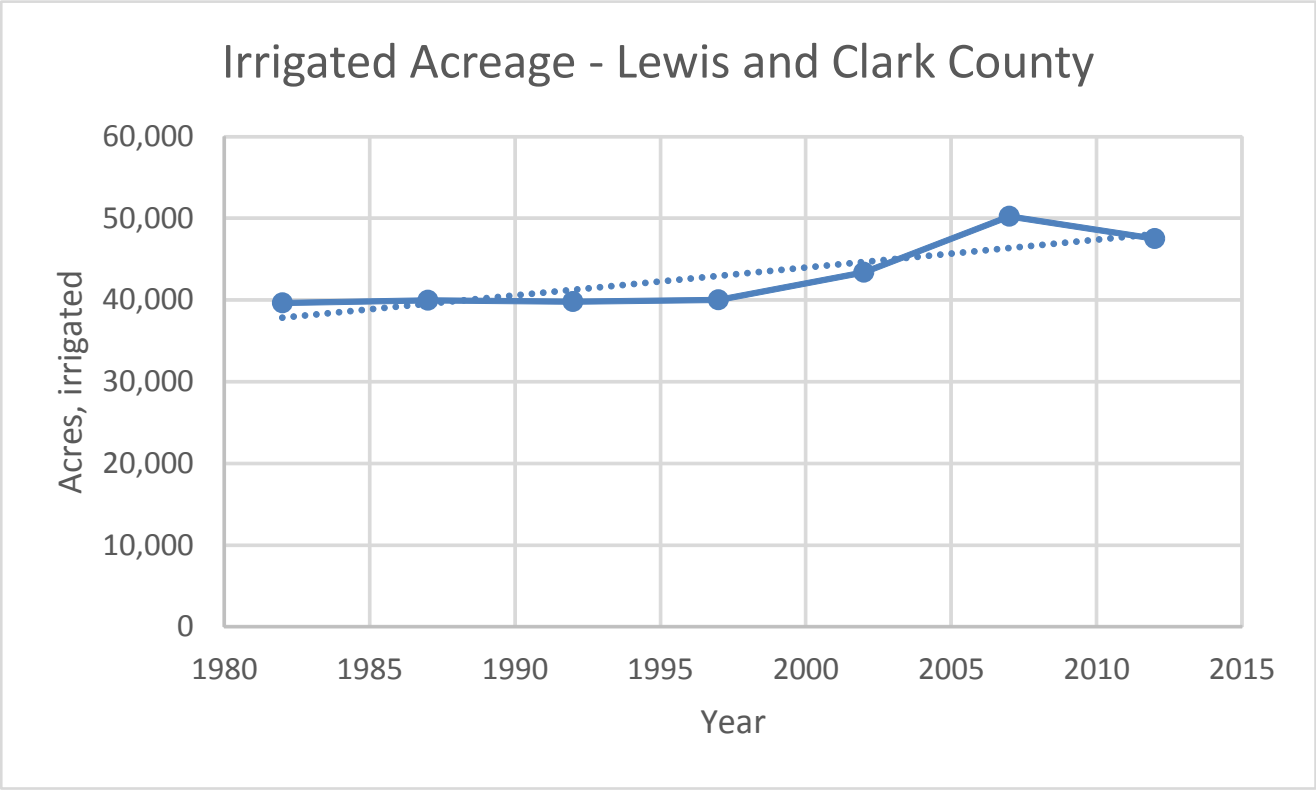
Legend

• Observation Well

Montana Association of REALTORS®

Figure 4-14
Observation Wells in Lewis and Clark County

rec'd by LEPO April 13, 2016



Notes:
Irrigated acreage obtained from USDA Census of Agriculture (2015).

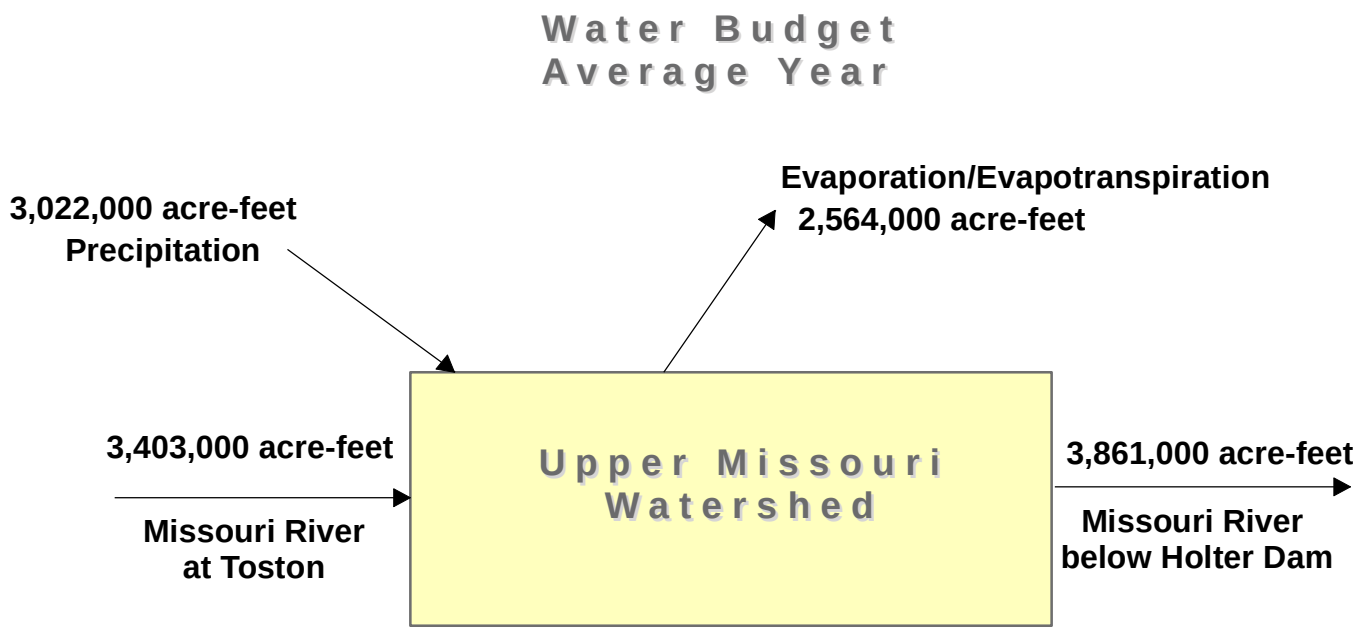
NICKLIN EARTH & WATER, INC.

Date: 1/11/2016
File: Figure 4-15

Montana Association of REALTORS®

Figure 4-15
Trend in Reported Irrigated Acreage
Lewis and Clark County

rec'd by LEPO April 13, 2016



Average precipitation for the watershed is esitmated using PRISM data from NRIS. Note that the above water balance assumes that aquifer storage remians constant. It does not consider the relative flow into and out of the model as ground water underflow which is considered to be very small when compared to the above primary water budget factors.

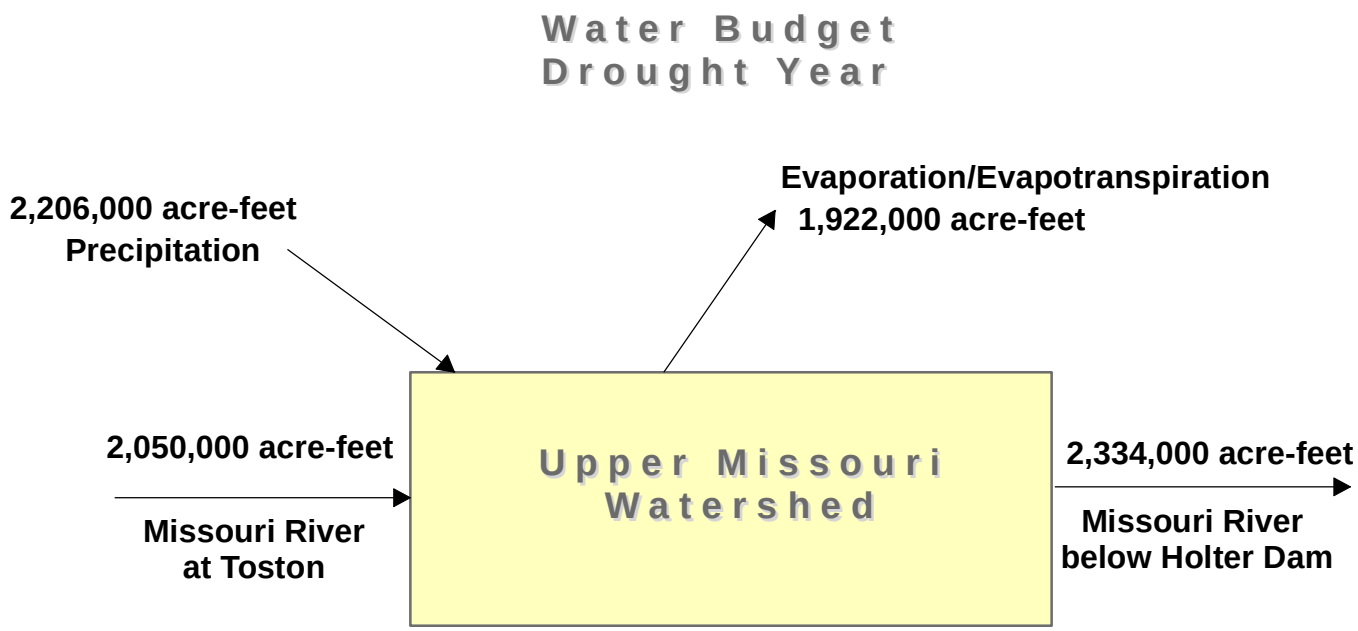
NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 4-16

Montana Association of REALTORS®

Figure 4-16
Water Budget Average Year
Upper Missouri River Watershed

rec'd by LEPO April 13, 2016



Average precipitation for the watershed is esitmated using PRISM data from NRIS. SNOTEL data and valley precipitation data used to estimate watershed precipitation for 2004. Flow as measured during 2004 water year. Note that the above water budget assumes that aquifer storage and reservoir storage remains constant. This may not be the case during a drought year.

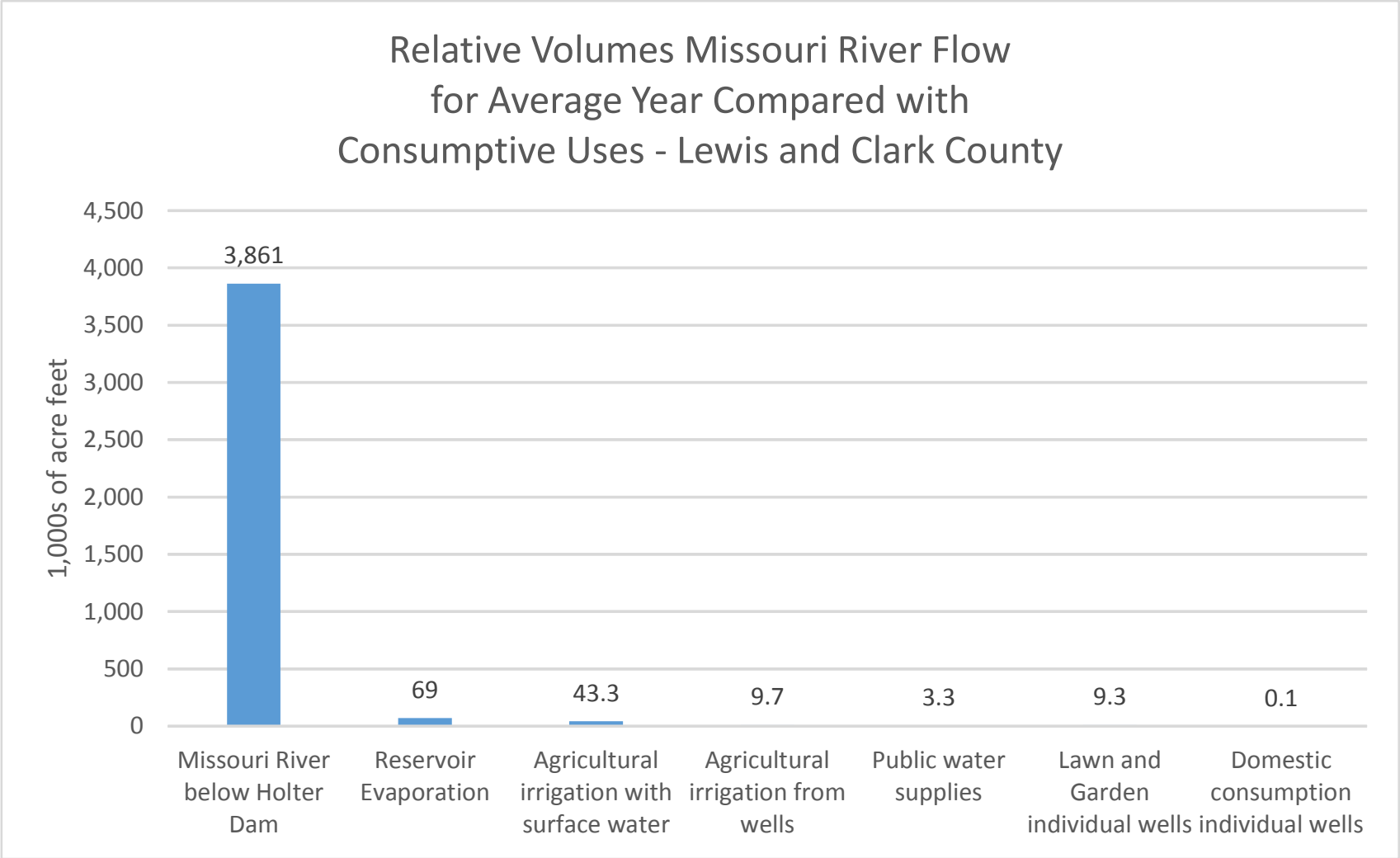
NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 4-17

Montana Association of REALTORS®

Figure 4-17
Water Budget Drought Year
Upper Missouri River Watershed

rec'd by LEPO April 13, 2016



Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Note that significant portions of the consuptive use occur in Lewis and Clark County outside the Upper Missouri Watershed.

NICKLIN EARTH & WATER, INC.

Date: 12/22/2015
File: Figure 4-18

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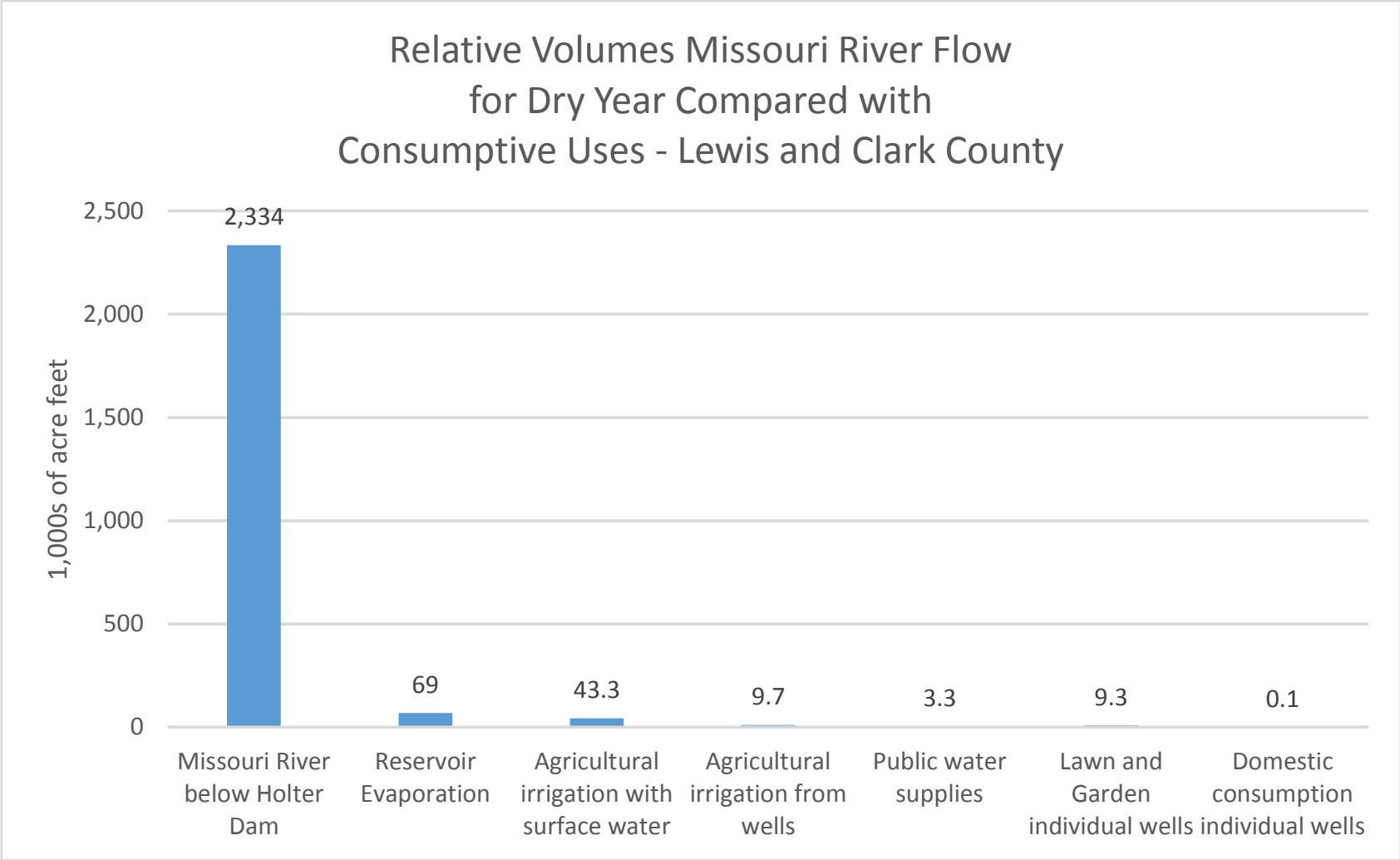
Figure 4-18
Surface Water Flows for Missouri River Average Year Compared to Lewis and Clark County Consumptive Uses

rec'd by LEPO April 13, 2016



Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Note that significant portions of the consuptive use occur in Lewis and Clark County outside the Upper Missouri Watershed.

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Date: 12/22/2015
File: Figure 4-19

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Figure 4-19
Surface Water Flows for Missouri River Drought Year Compared to Lewis and Clark County Consumptive Uses

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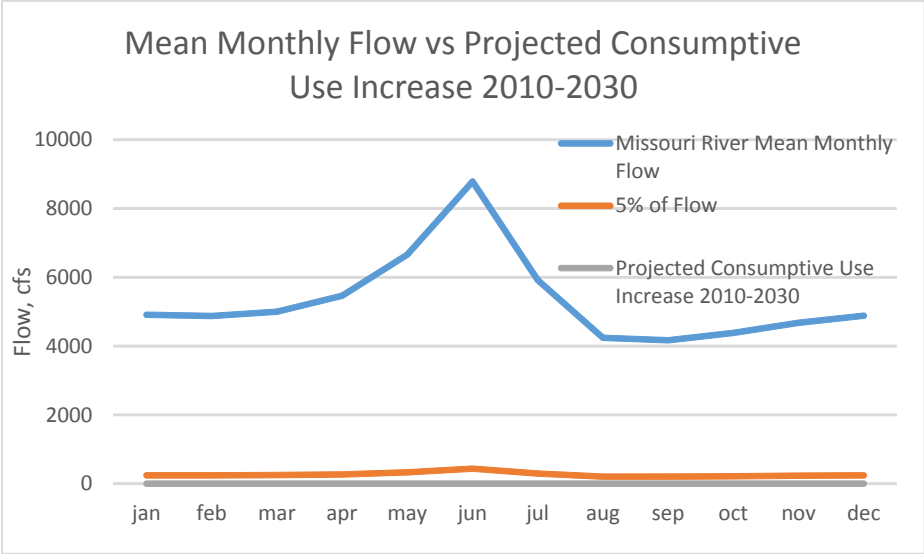
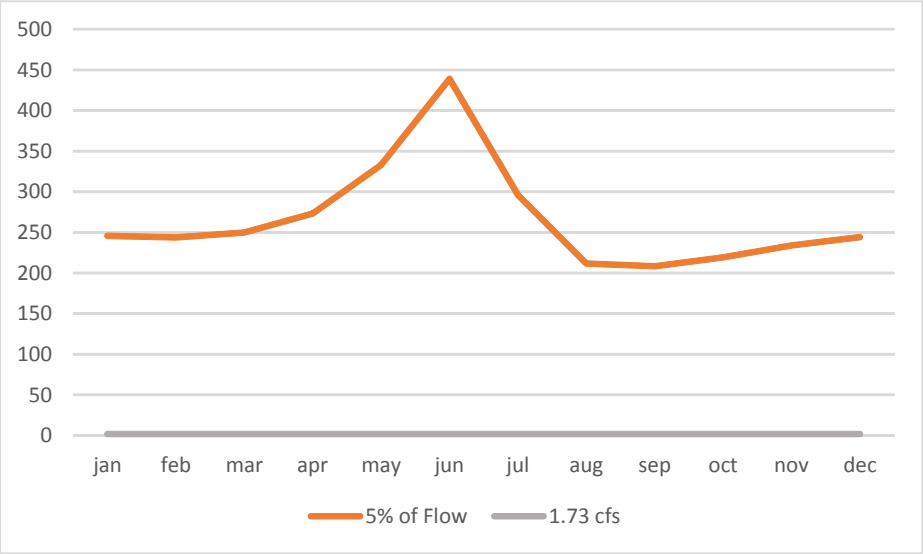


The blue line plot in the upper graph shows the average monthly flows for the periodof record for the Missouri River as it is measured below Holter Dam. The middle line plot shows 5% of the same flows. In effect, this represents an approximate magnitude of the uncertainty of stream flow measurements at gaging stations. The lower line 1.73 cfs represents the total projected increase in consuptive use from 2010-2030 Ravalli County. In effect, a flow of 1.73 cfs could not be reliably discerned at this gaging station. Note that the computed 1.73 cfs depletion does not take into consideration the potential accretions from reductions in stream-flow diversions from reducted irrigated acreage. The net depletion may be much less than 1.73 cfs once the net accretions are accounted for.



NICKLIN EARTH & WATER, INC.

Date: 1/8/2016
File: Figure 4-20a

10 Miles

Legend

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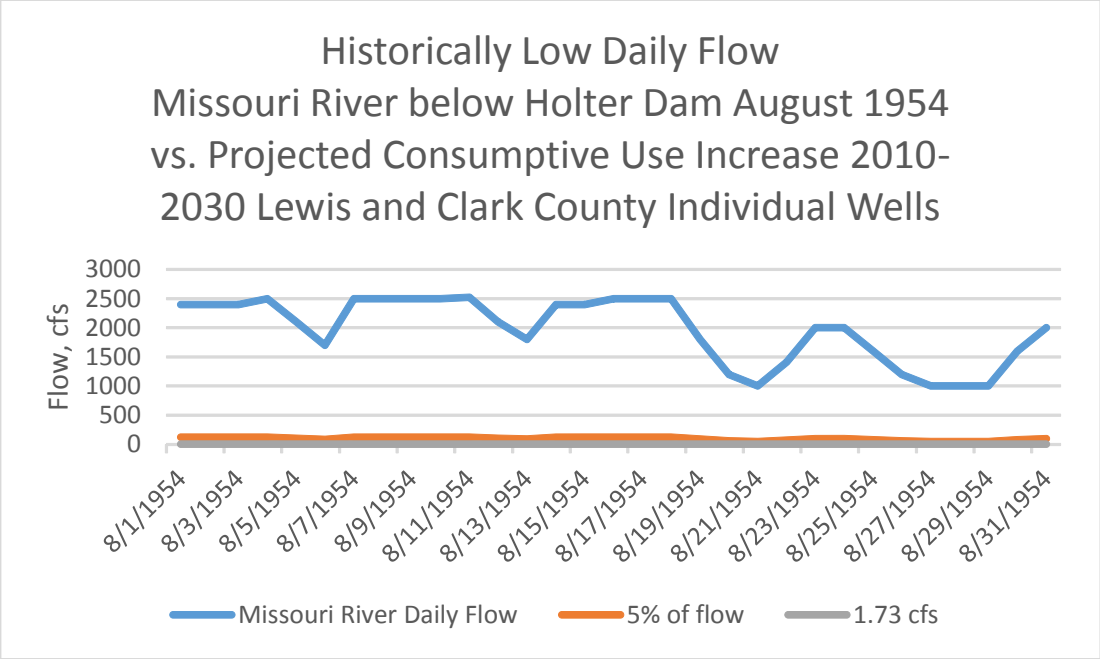
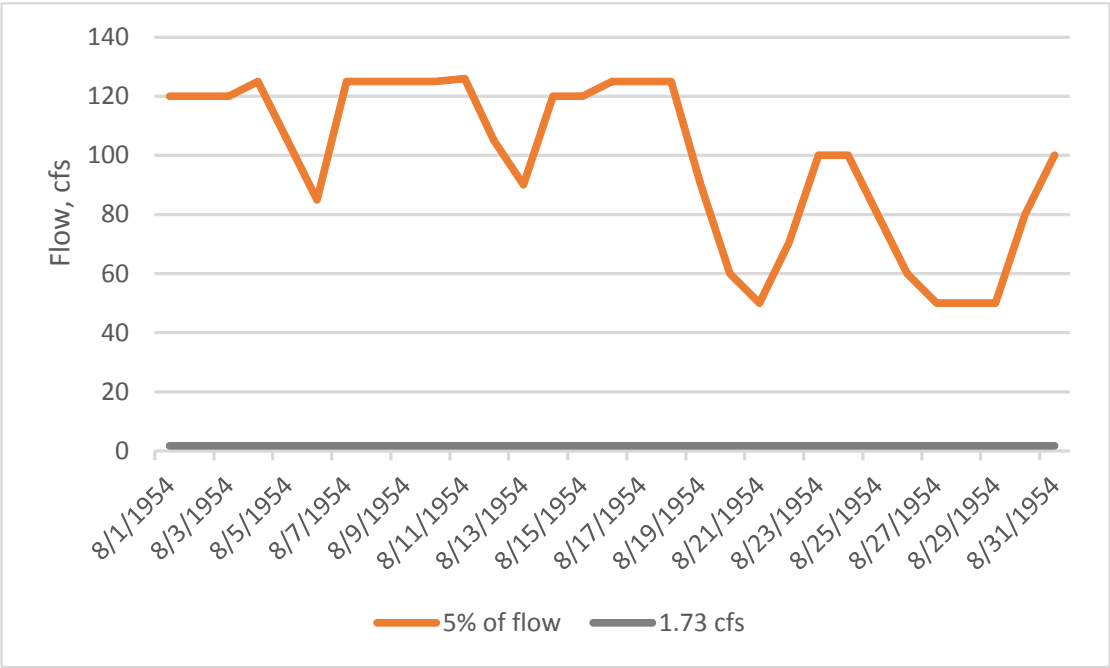
Figure 4-20a
Mean Monthly Flow of Missour River Compared to Lewis and Clark County Projected Individual Well Consumptive Use Increase

rec'd by LEPO April 13, 2016





Note that the above figure represents the minimum daily flow month of record for August which occurred in August 1954. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal variation in depletion will be very subdued owing to the fact that most wells in Lewis and Clark County are located at significant distances from streams. Even if seasonal variability is accounted for any projected increase in net monthly depletion would remain in the noise level (below 5% of streamflow) in the Missouri River as measured below Holter Dam. Finally, the above graph does not account for any reduction in surface water use asociated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects."

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Date: 1/8/2016
File: Figure 4-20b

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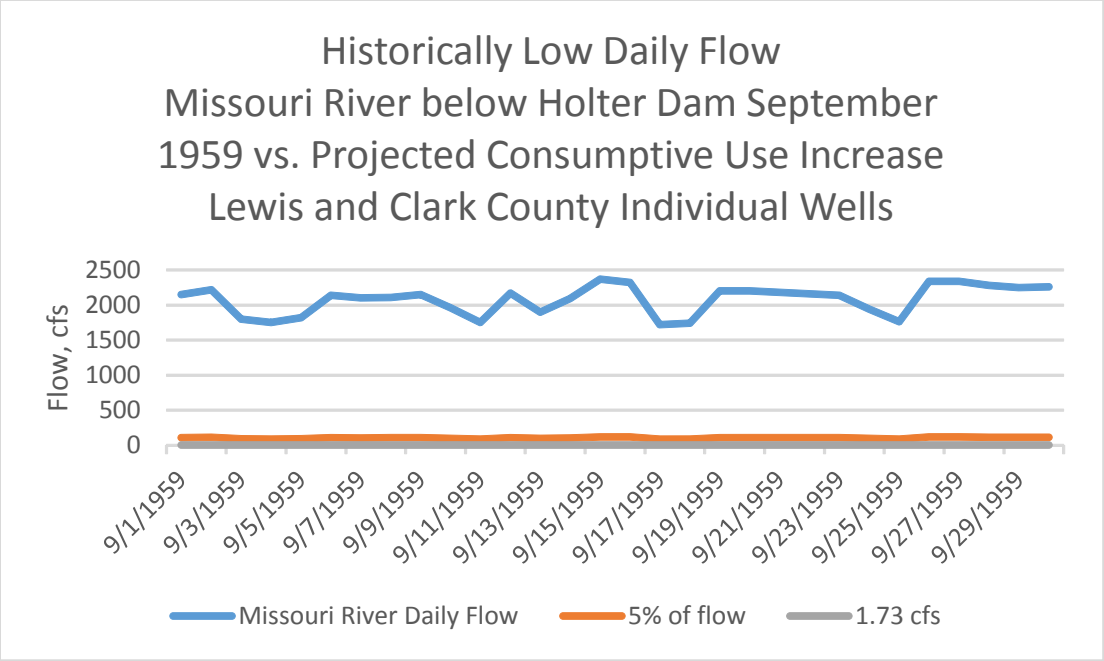
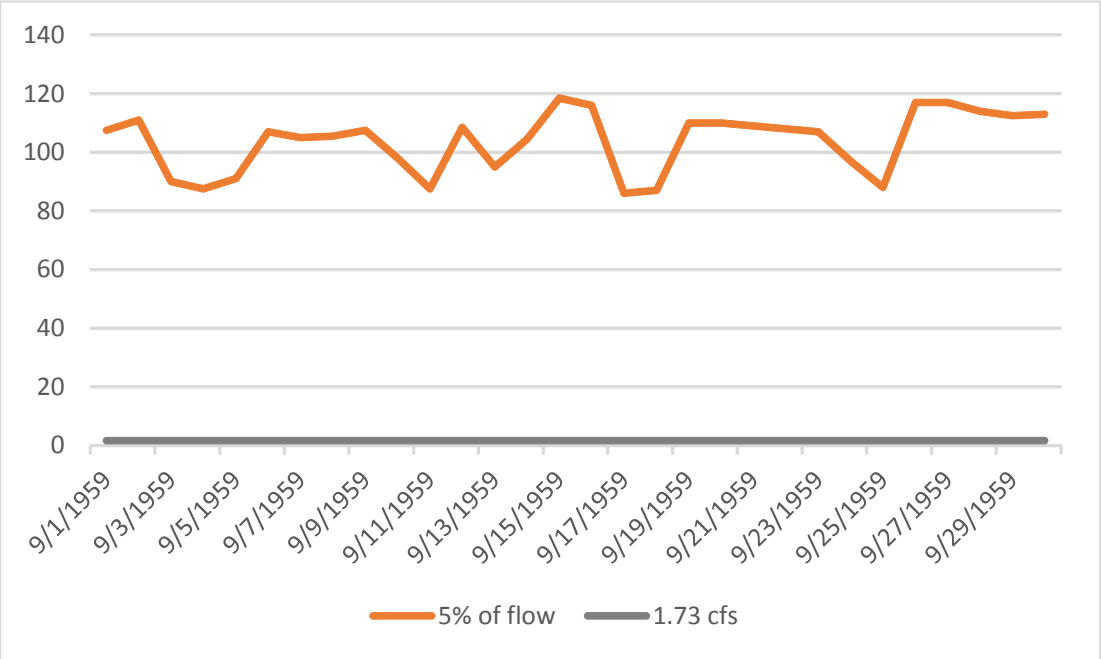
Figure 4-20b
August 1954 Missouri River Flows Compared to Projected Individual Well Consumptive Use Increase Lewis and Clark County





Note that the above figure represents the minimum daily flow month of record for September which occurred in September 1959. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal variation in depletion will be very subdued owing to the fact that most wells in Lewis and Clark County are located at significant distances from streams. Even if seasonal variability is accounted for any projected increase in net monthly depletion would remain in the noise level (below 5% of streamflow) in the Missouri River as measured below Holter Dam. Finally, the above graph does not account for any reduction in surface water use asociated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects."

NICKLIN EARTH & WATER, INC.

Date: 1/8/2016
File: Figure 4-20c

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Figure 4-20c
September 1959 Missouri River Flows Compared to Projected Individual Well Consumptive Use Increase Lewis and Clark County

5.0 MISSOULA COUNTY - UPPER AND MIDDLE CLARK FORK BASINS

5.1 Physical Setting and Overview

Missoula County covers about 2,600 square miles in the Clark Fork Basin in western Montana. Five large valleys and two major rivers wind through this mountainous region. The county consists of high mountains with sediment filled valleys. Most of the county drains to the Clark Fork River. About half of the county is publicly owned (federal and state lands).

Missoula County encompasses portions of three key basins (see Figure 5-1): Middle Clark Fork, Upper Clark Fork (contains Flint Rock Creek and Blackfoot River watersheds), and Bitterroot. There are portions of two other watersheds contained in Missoula County, the Swan River and South Flathead Watersheds. There are a relatively small number of individual wells in these two watersheds. The impacts from these wells would likely be inconsequential from a water budgeting perspective. Thus, these two watersheds are not considered in the evaluation that follows.

5.1.1 Project Specific Information Sources

Information sources used in the evaluation of Missoula County water supply and use include the following:

- MBMG GWIC Database and Geologic Mapping
- DNRC water rights permit database
- USDA NRCS SNOTEL/Snow Course, WRCC data
- USDA Census of Agriculture data

Much of the geospatial information used in this evaluation, especially mapping resources, was obtained from the Montana NRIS database.

5.1.2 Land Use

As noted previously, about half of Missoula County is publicly owned with the majority of

that being national forest. Most of the population and commerce is located in the valleys. Major economic activities include agriculture, forest products, the University of Montana and government. Building construction and service industries have expanded more recently.

5.1.3 Climate

The Missoula Valley is semiarid with average annual precipitation ranging from 12 to 16 inches (see Figure 5-2). The mean precipitation for the period of record at the Missoula weather station (Missoula Bell Field) is 13.61 inches (see Figure 5-3). Temperatures vary substantially with the minimum average daily temperature in the valley of 15 ^{o}F in January and the average maximum daily temperature in the valley of 84.3 ^{o}F in July. The minimum and maximum temperatures ever recorded at the Missoula weather station are -33 ^{o}F (January 9, 1953) and 105 ^{o}F (July 12, 1961 and August 4, 1961) respectively.

5.1.4 Geology

Geologic mapping has been completed by the MBMG that includes the Missoula Valley (Lewis, 1998). The main geologic units in the vicinity of the Missoula are the Quaternary alluvial deposits in the valley (see Figure 5-4). These deposits are bounded beneath and on the east by Tertiary gravel-clay fill and by Tertiary alluvial fan deposits. The geologic strata to the southwest of the valley include the Belt Supergroup. Those members of this supergroup nearest the valley are the Mount Shields members (undifferentiated).

5.1.5 Aquifers

The primary aquifer in the Missoula Valley is present in the Quaternary alluvial deposits. These deposits are very coarse grained and are about 70 feet thick in the valley where present. This aquifer possesses some of the highest transmissivities (water-bearing capacity) found in Montana and can yield copious amounts of water when tapped. Owing to the high water bearing capacity of the alluvium, there has been little need to drill into the underlying Tertiary for water supply purposes. The water-bearing capacity of the Tertiary is orders of magnitude lower than that of the overlying alluvium.

Hydraulic conductivities for the Quaternary aquifer range from about 830 to 18,000

ft/day. Given that this aquifer is about 70 feet thick in the Missoula Valley, transmissivity values range from about 58,000 square feet per day to well over several hundred thousand square feet per day.

5.1.6 Surface Water

The primary surface water running through Missoula County is the Clark Fork River. It is joined by the Bitterroot River at the west edge of the Missoula Valley. There are several other streams as shown on Figure 5-5. From an overall water budgeting perspective these other streams are relatively inconsequential as they possess very small flows compared to the Clark Fork and Bitterroot Rivers.

5.2 Hydrologic Data Summary and Evaluations

5.2.1 SNOTEL/Snow Course Data Collection Network

There are several SNOTEL/snow course data stations that measure the snowpack in portions of the watershed up-gradient of Missoula that affect the flows of the Clark Fork River and its tributaries. Some of these stations were also used in the assessment of the Bitterroot Watershed as discussed in Section 3.0 of this report. These stations record snowpack that contributes snowmelt and runoff to both the Clark Fork and Bitterroot Rivers which join near Missoula.

Figure 5-6 plots the snowpack data from those stations with a period of record that originated during 1978. These SNOTEL stations have sufficiently long periods of records to allow evaluations for this study. This same figure plots historic snowpack and also presents cumulative departure-from-average plots for most stations. Evaluation of this figure demonstrates that the snowpack as measured at each location shows similar cumulative departure-from-average plots from station to station. This suggests that each area of southwestern and west central Montana has responded very similarly to long-term climate conditions. Generally, snowpack tended to be above average from about 1965 to about 1977. Then, snowpack tended to about average until the mid-1980s. This was followed by a period of below average snowpack which extended to about 1995 to 1997, followed by a couple years of above normal levels. Generally, from 1999 to 2007 snowpack tended to be below average. More recently, snowpack has been near or above average.

5.2.2 Precipitation

Valley precipitation data are available for several climate stations in the Missoula area. The two stations utilized include Missoula 2 WNW and Missoula WSO. Precipitation data from these stations were composited and are summarized in Figure 5-7.

It is noted that these cumulative departure-from-average plots do not correlate very well to the snowpack cumulative departure-from-average plots presented in Figure 5-6.

5.2.3 Streamflow Data Evaluation Summary

Again, stream discharge rates and volume are primarily dependent upon each water year's snowpack.

Long-term streamflow data have been collected at two stream gaging stations along the Clark Fork River as follows (see Figure 5-5):

- USGS 12340500 Clark Fork above Missoula MT. The drainage area above this station is 5,999 square miles.
- USGS 12353000 Clark Fork below Missoula MT. The drainage area above this station is 9,003 square miles. This drainage includes the Bitterroot River drainage which is the subject of Section 3 of this report.

The remaining gaging stations in the immediate vicinity of Missoula have relatively shorter periods of record and are not as helpful in evaluating long-term streamflow trends. The USGS 12352500 Bitterroot River near Missoula MT gaging station (drainage area of 2,814 square miles) was evaluated in Section 3.0.

Figure 5-8a provides mean monthly and annual flow hydrographs for the Clark Fork River above Missoula. The lower plot in Figure 5-8a is a cumulative departure-from-average plot of streamflow for this gaging station extending from 1938 to present. An upward trend in the cumulative departure-from-average plot (lower plot) indicates a period of above average flow whereas downward trends indicate periods of below average flow. Relatively horizontal portions of a given plot demonstrate time periods when the flow is nearer the average. The following general observations indicated by these plots include:

- The cumulative departure-from-average plot demonstrates that a relatively long-term trend of above average flows began in the mid-1940s and extended to about 1985.
- Flows from 1985 to about 2004 tended to be below average.
- More recently flows have been nearer average to above average.

Figure 5-8b provides mean monthly and annual hydrographs and cumulative departure-from-average plots for the Clark Fork River below Missoula.

As in the case of other basins, streamflows in the Clark Fork Basin are highly dependent upon precipitation for a given water year. The dominant factor, again, for streamflows tends to be the magnitude of each year's snowpack (snow water equivalent). Figure 5-9 provides a comparison of the snowpack as measured at two SNOTEL/Snow Course stations with streamflows at the Clark Fork River above Missoula and the Clark Fork River below Missoula gaging stations. The Saddle Mountain station was discussed previously as it is within the Bitterroot River drainage. This station was included for this basin evaluation as the Bitterroot River joins the Clark Fork at Missoula. The Warm Springs station is located within the Upper Clark Fork drainage west of Warm Springs, Montana. Figure 5-9 shows that streamflows emulate snowpack conditions.

Figures 5-10a and 5-10b provide regression evaluations comparing the Clark Fork streamflow to snowpack at these same stations. Again, these graphs show that the Clark Fork River flows are dependent upon the up-gradient snowpack conditions.

Figure 5-11 compares cumulative departure-from-average plots for snowpack, Missoula Valley precipitation, and streamflow. These plots provide another demonstration that snowpack dominates the nature of streamflow in the Clark Fork River. There are two reasons for this observation. First, most of the water that enters the Clark Fork River is attributable to snowmelt runoff from up-gradient sources. Secondly, a high percentage of precipitation that falls in semiarid valley areas, including the Missoula Valley, leaves as evapotranspiration by vegetation.

Figure 5-12 provides plots comparing the streamflow as measured in the Clark Fork below Missoula with Missoula Valley precipitation and snowpack as measured at the Saddle Mountain SNOTEL/Snow Course station in the Bitterroot Valley. The statistical

correlation is much better using snowpack data when compared to valley precipitation. Again, this is primarily because the streamflows in the Clark Fork Basin as a whole are predominantly dependent upon snowpack conditions.

In summary, as is the case for all the watersheds examined in this study, the amount of snowpack dominates the magnitude of streamflow in the Clark Fork River. In effect, the relatively lower snowpack of recent years explains the reason that flows in the Clark Fork River were well below average until about 2004. More recently, flows have returned to average or above average rates.

5.2.4 Groundwater Level Summary

According to the MBMG's GWIC database, there are presently about 14,118 wells present in Missoula County (see Figure 5-13). This includes water supply wells and monitoring wells. Thirty four of these wells are observation wells, which provide water level data (see Figure 5-14 and Plate 5-1). The hydrographs show that most of the wells exhibit seasonal variations. Groundwater levels tend to increase during the late spring and early summer when recharge from precipitation, surface water flows, and surface-water irrigation activity is highest. Some wells had showed minor declines likely in response to drought conditions, but most have stabilized and even increased in water levels in more recent years. In effect, groundwater storage has remained relatively stable or constant.

5.3 Groundwater Use

5.3.1 Public Water Supply

Public water supply is water supplied by publicly or privately owned utilities for public distribution (Cannon and Johnson, 2004). Any water system that provides water to at least 25 people for at least 60 days of the calendar year or has at least 15 service connections is considered by law to be a public supply. *See*, Mont. Code Ann. § 75-6-102(14). Water from public water supply systems is distributed to multiple users for domestic, commercial, industrial, and public uses. It should be noted that even exempt wells may be used as a public water supply system source as long as they meet the criteria defined above.

According to Cannon and Johnson, about 69,130 people in 2000 were served by public water supply systems using groundwater in Missoula County. According to the MBMG (GWIC), as of 2015, there are about 607 public water supply wells in Missoula County. Groundwater is the sole source of water supply for the City of Missoula (Mountain Water).

According to Cannon and Johnson, 28,183 ac-ft were delivered for public water supplies in Missoula County in 2000. It is assumed that about 40 percent of this delivered water is consumed. Therefore, the net consumption associated with public water supplies is estimated to be about 11,273 ac-ft per year.

5.3.2 Typical Domestic Consumption - Individual Wells

Domestic use is water used within the dwelling for domestic purposes (does not include irrigation). The withdrawal (e.g., total demand) from individual wells is estimated based on the number of domestic wells, 2.5 persons per dwelling (well), and the demand of 100 gpd per capita. This volumetric criterion is based upon the Montana Department of Environmental Quality (DEQ) standards for designing public water supply systems. The total consumptive use associated with this withdrawal is based on the consumption rate of 2 percent of the total withdrawal. The 2 percent criterion is based upon Kimsey and Flood (1987). According to MBMG GWIC data, there are 11,200 domestic wells in Missoula County within the watersheds that drain to the Clark Fork River (a.k.a., Missoula Valley). Applying the above criteria, this would yield a net domestic consumption of 62 ac-ft per year in Missoula County.

5.3.3 Lawn and Garden - Individual Wells

The estimate of water consumption attributed to domestic lawn and garden irrigation sourced by individual wells depends primarily on the area of land that is irrigated. Obviously, some property owners, especially with smaller lots, will irrigate relatively smaller areas. Similarly, some property owners will irrigate larger areas. Estimates of typical irrigated areas range from 1/8 to 3/4 acres per well. This study uses an average irrigated area of 1/2 acre per domestic well as a conservative approach to estimate the quantity of consumed water from individual wells used for lawn and garden irrigation. Application of the above methodology and assumptions results in about 5,600 irrigated acres with net lawn and garden consumptive use of 8,848 ac-ft in the Missoula Valley.

This estimate is significantly higher when compared to the groundwater withdrawals for the entirety of Missoula County of 2,780 ac-ft presented in Cannon and Johnson (2004), a study which was coordinated with the DNRC. Hence, it is clear there is significant uncertainty regarding actual consumptive use from individual wells. Based upon the information provided by Cannon and Johnson, the analysis conducted in this report should be considered conservative.

5.3.4 Agricultural Irrigation

Another significant use of water in Missoula County is agricultural irrigation. Historically, most (94 percent) of the irrigation water is from surface water sources. Groundwater use for irrigation of agricultural crops is very limited (6 percent) in this county.

Much of the irrigation that occurred historically in Missoula County is confined to the Missoula Valley. USDA Census of Agriculture data (http://www.agcensus.usda.gov/) provides information about the quantity of irrigated land in Missoula County. As of the 2012 census there were 116,857 acres of land in irrigated farms and 16,798 acres were irrigated in that year.

NE&W also evaluated the irrigated land census data from 1982 to 2012 (five year census cycle) to determine if there was an overall decline in irrigated acreage.

Year	Acres
1982	19,746
1987	18,941
1992	22,161
1997	**22,291**
2002	19,088
2007	16,555
2012	16,798

The maximum acreage is indicated in **bold** and the minimum underlined.

Based upon this analysis, it appears that the amount of irrigated acreage in the county has decreased by about 5,000 acres from 1997 to 2012.

This irrigation activity has likely declined as a result of subdivision development. Hence,

the amount of consumption associated with irrigation has likely declined accordingly. Figure 5-15 provides evidence indicating the magnitude and nature of this change.

For water budgeting purposes, a consumptive use quantity of about 23,000 ac-ft per year is estimated using the Blaney-Criddle method for Missoula County. This estimate is based upon a running average of the last five years of irrigated acreage defined in USDA Census of Agriculture data for Missoula County. Since it is applied to the entire county, this estimate should be considered to be conservative.

A similar consumptive use quantity was defined by Cannon and Johnson (2004) who estimated 26,850 ac-ft of consumptive use for Missoula County in 2000. Based upon data in Cannon and Johnson, this can be subdivided into about 22,000 ac-ft being associated with surface water irrigation and the remainder, 4,850 ac-ft, being due to groundwater irrigation.

5.3.5 Industrial use

According to Cannon and Johnson (2004) approximately 21,000 ac-ft of groundwater is used for industrial purposes in Missoula County. The amount that is consumed is unknown.

5.4 Water Budget Summary

A watershed budgeting approach was not applied for Missoula County evaluation in the same manner it was performed for the other study areas. The reason for this is that Missoula County contains several different watersheds, and three of these drainages join together within the Missoula Valley. Hence, the focus of this analysis compares the water consumption rates to the streamflows measured at the Clark Fork River below Missoula gage. This gaging station shows the following annual flow volumes:

- 3,859,000 ac-ft normal year; and
- 2,406,000 ac-ft drought year (using 2001 flow data).

The water consumption rates defined earlier are the following:

- Domestic consumption from individual wells 62 ac-ft

- Lawn and garden from individual wells 8,848 ac-ft
- Agricultural irrigation (surface water) 22,000 ac-ft
- Agricultural irrigation (groundwater) 4,900 ac-ft
- Public Water Supply 11,273 ac-ft

It is clear that these uses represent a very small portion of the flows of the Clark Fork River. Based upon the above assessment, it is obvious that the impact of groundwater development in the Missoula Valley on the overall water budget and streamflows in the Clark Fork River is very small. Figures 5-16a and 5-16b provide comparative evaluations of these uses versus the Clark Fork River average and low year flow respectively.

5.5 Water Use Projections

The relative significance of future growth in Missoula County can be evaluated by projecting future demands and comparing those demands to Clark Fork River streamflows. Again, there is significant uncertainty related to projecting future water use based on projected population growth. This study utilizes a combination of historical population data and census-based growth projections to evaluate future water use demands.

The population of Missoula County increased by 13,497 from 2000 to 2010. Based on 2.5 persons per dwelling, this results in an increase of about 5,399 new dwellings. Based on historical ratios, about 1,452 new dwellings will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of 1,147 ac-ft as of 2010.

The Montana Department of Commerce reports population projections provided by eREMI (a product of Regional Economic Models, Inc.). The latest available projections are dated April 2013. These projections show the population of Missoula County increasing from 109,299 per the 2010 census to 134,085 in 2030. It is assumed that about 2.5 persons per dwelling results in 9,914 new dwellings over that same time period. Based on historical ratios, about 2,666 will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a

consumptive use increase of about 2,106 ac-ft due to additional individual wells by year 2030. It represents about 0.04 percent of the streamflow at the Clark Fork River below Missoula for a normal year scenario and 0.08 percent for a drought year scenario.

From a public water supply perspective, it is assumed that such consumption will increase similarly in proportion to population growth. Thus, the net increase in consumption for public water supplies sourced by groundwater is estimated at 3,078 ac-ft from 2000 to 2010 and projected to be an additional 7,057 ac-ft per year by 2030.

Again, it should also be noted that there has likely been a corresponding decrease in agriculturally irrigated acreage in the Missoula Valley (see Figures 5-15).

The USDA Census of Agriculture irrigated acreage irrigation data can be used to illustrate this. The ten year average of irrigated acreage was quantified for two different periods of time in Missoula County with the following results:

- 1982 through 1992 20,283 acres
- 2002 through 2012 17,480 acres

This represents a 2,802 acre decline in irrigated crop land in Ravalli County. Using the Blaney-Criddle approach, this represents a decrease in consumption of about 4,837 ac-ft. Therefore, most of the projected increase in consumption from population growth in Missoula County will likely be offset by decreased consumption from agricultural irrigation. It should be noted as well that either with a decrease or increase in irrigated land from subdivision development, any net change will simply be too small to be manifested at any detectable level in the Clark Fork River.

5.6 Projected Increase in Consumptive Use Versus Seasonal Streamflow

The relative significance of projected increases in consumptive use from individual wells can be compared to gaged streamflow. The projected increased consumption for Missoula County from 2010 to 2030 is 2,106 ac-ft. Note that wells are distributed over a relatively broad area of the Missoula Valley. Hence, it is reasonable to assume that the relative depletion associated with this projected growth can be defined using a steady-state approximation as of year 2030. This equates to about 2.9 cfs of depletion

in the Clark Fork River.

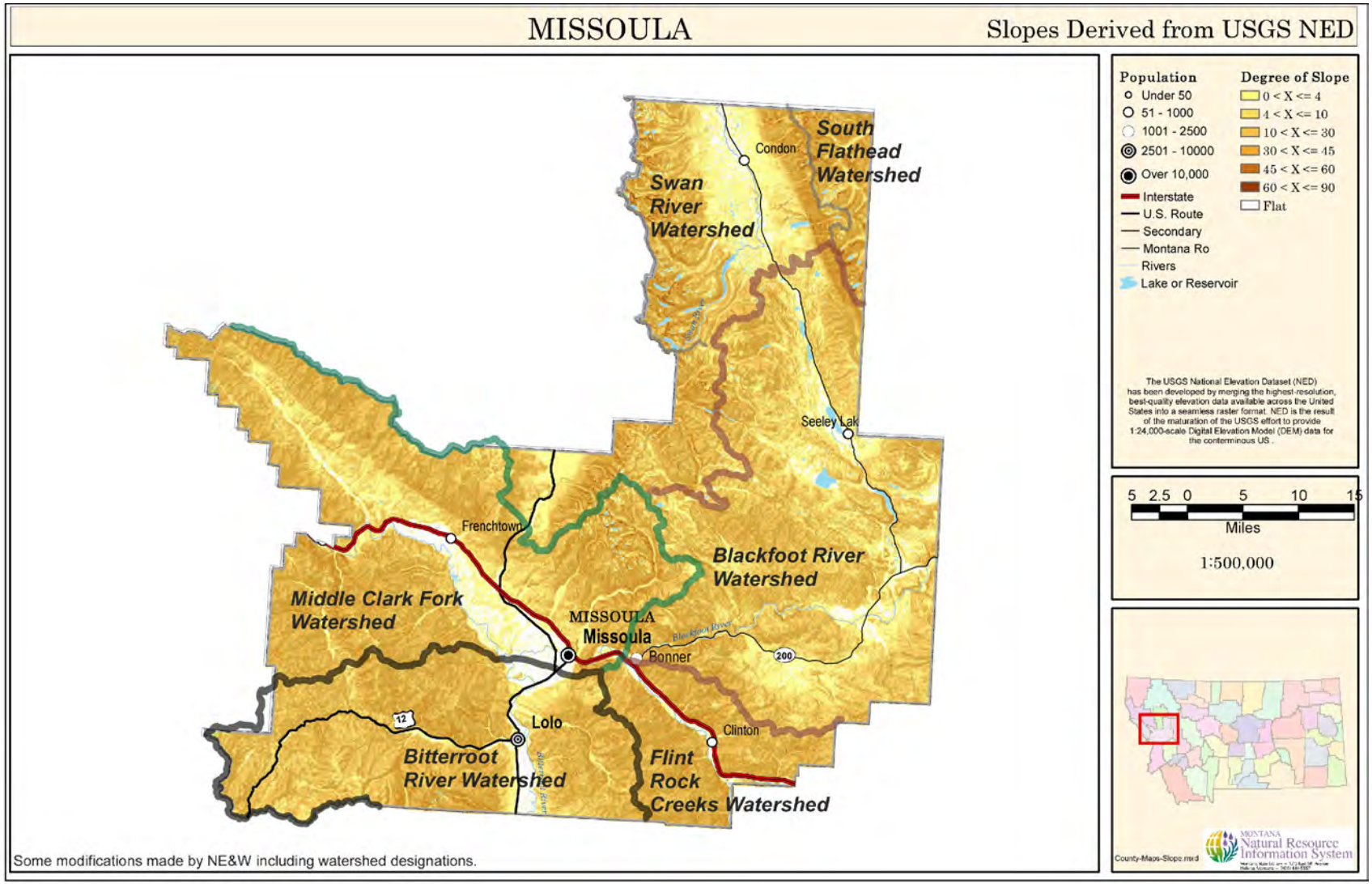
Figures 5-17a through 5-17c compare the relative significance of the projected depletions on streamflows as measured at the Clark Fork River below Missoula. A 5 percent flow measurement accuracy criterion is shown on each figure to assess if it is possible that a depletion of 2.9 cfs would be detectable in the gaging data. If the 5 percent flow measurement criterion were to fall below the projected depletion of 2.9 cfs, then the projected change would be considered potentially detectable. Otherwise, the projected change is considered not detectable.

Given that the 2.9 cfs depletion falls far beneath the 5 percent flow measurement criterion, it is concluded that the relative significance of the individual well growth would not be detectable in the flows as measured at the Clark Fork River below Missoula.

Again, the projected relative change on a year to year basis is about 0.145 cfs (about 65 gpm). It is obvious that any year to year change would not be detectable in the Clark Fork River.

Finally, it should be noted that the projected depletion does not account for increases in streamflow associated with potential land use change transitions from irrigated agriculture to residential subdivisions. The trend has been for much of the new development to occur on previously irrigated farmland. As development uses less water compared to agricultural irrigation, the result is a net increase in water availability. As such, the new development generally does not impact the ability of existing surface water appropriators to fully utilize their water rights.

rec'd by LEPO April 13, 2016



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Date: 1/11/2016
File: Figure 5-1

Notes:
1) Some modifications made by NE&W including watershed designations.

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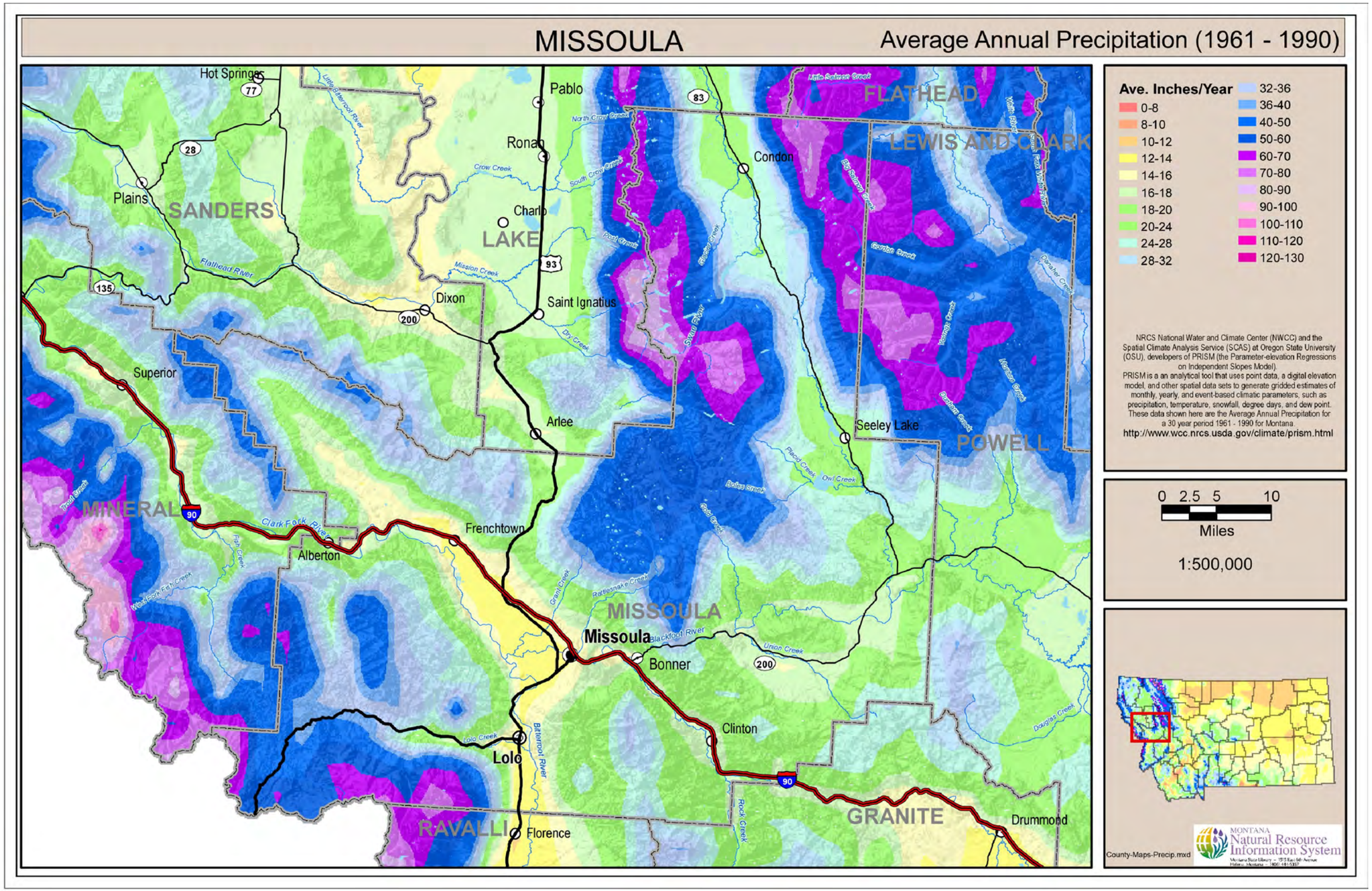
Figure 5-1
Missoula County
Montana Natural Resource Information System

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/16/2015
File: Figure 5-2

Notes:
1) Aerial Photograph: 2011 NAIP

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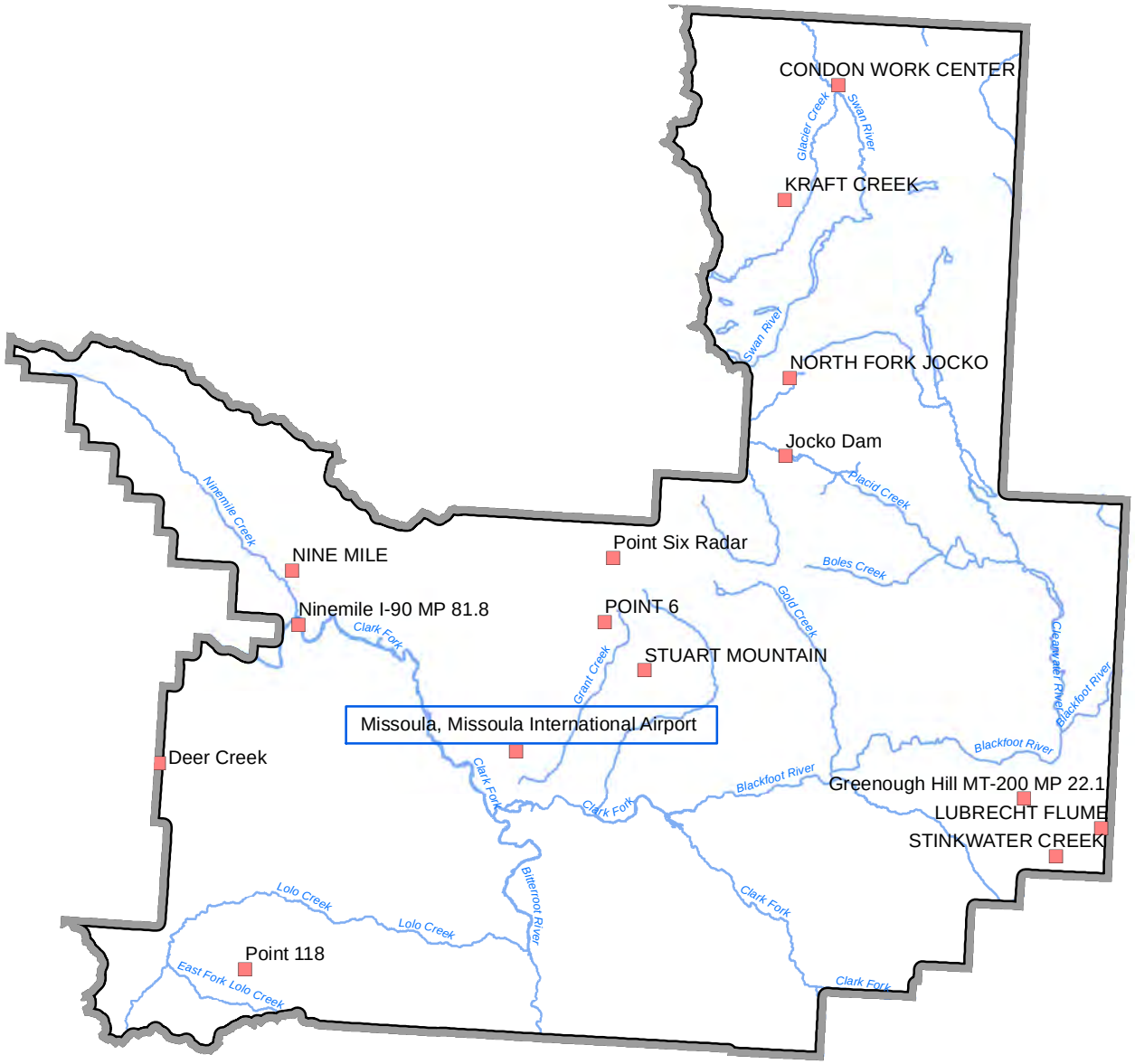
Figure 5-2
Missoula County Annual Precipitation Distribution
Montana NRIS Report

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/23/2015
File: Figure 5-3

Scale not indicated

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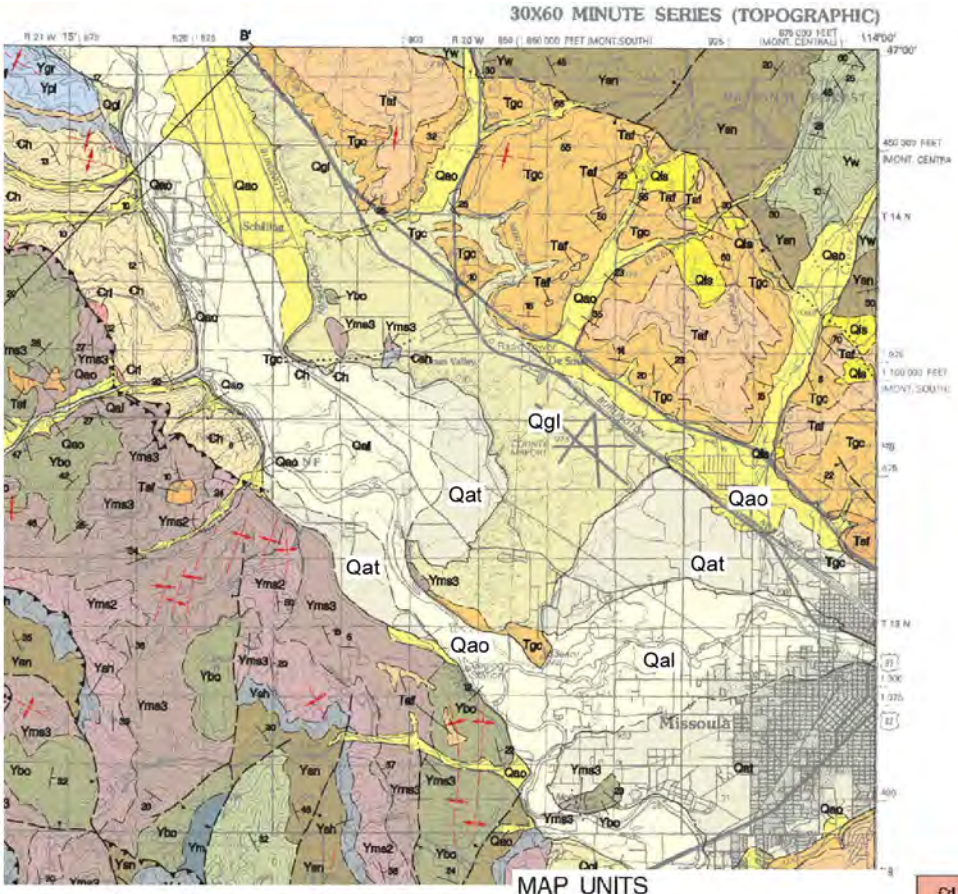
Figure 5-3
Weather Stations
Missoula County Vicinity



Note that the key hydrogeologic units in the Missoula Valley are from a ground-water supply perspective are the Qal, Qao, and Qat. These deposits are highly transmissive and yield copious amounts of water.

MAP UNITS

Qal	Alluvium of modern channels and floodplains
Qao	Alluvium, older, undivided
Qat	Alluvium of alluvial terrace deposit
Qls	Landslide deposit
Qgl	Glacial lake deposit
Qgt	Glacial till
Tsf	Sedimentary deposit, fluvial
Taf	Alluvial fan deposit
Tgc	Gravel and clay
Tr	Rhyolite or rhyolitic sediment
Trt	Rhyolite tuff
Td	Dacite
Tfv	Felsic volcanic rocks
Tg	Granite
Tmy	Mylonite
TKgd	Granodiorite
TKgb	Diorite and gabbro
Kgd	Granodiorite
Kto	Tonalite
Crl	Red Lion Formation
Crl	Red Lion Formation
Ch	Hasmark Dolomite
Csh	Silver Hill Formation
Cf	Flathead Formation
Yan	Anorthosite
Ypl	Pilcher Formation
Ygr	Garnet Range Formation
Ym	McNamara Formation
Ybo	Bonner Formation
Yms	Mount Shields Formation
Yms3	Mount Shields Formation, member 3, informal
Yms2	Mount Shields Formation , member 2, informal
Ysh	Shepard Formation
Ysn	Snowslip Formation
Yw	Wallace Formation
Ycg	Calc-silicate gneiss of the middle Belt carbonate
Ywm	Wallace Formation, middle member, informal
Ywl	Wallace Formation, lower member, informal
Yq	Quartzite, undifferentiated
Yqfg	Quartzofeldspathic gneiss of the Belt Supergroup
Ysgn	Schist and gneiss

Excerpted from GEOLOGIC MAP OF THE MONTANA PART OF THE MISSOULA WEST 30' X 60' QUADRANGLE
Compiled and Mapped by Reed S. Lewis
1998
Montana Bureau of Mines and Geology
Open File Report MBMG 373

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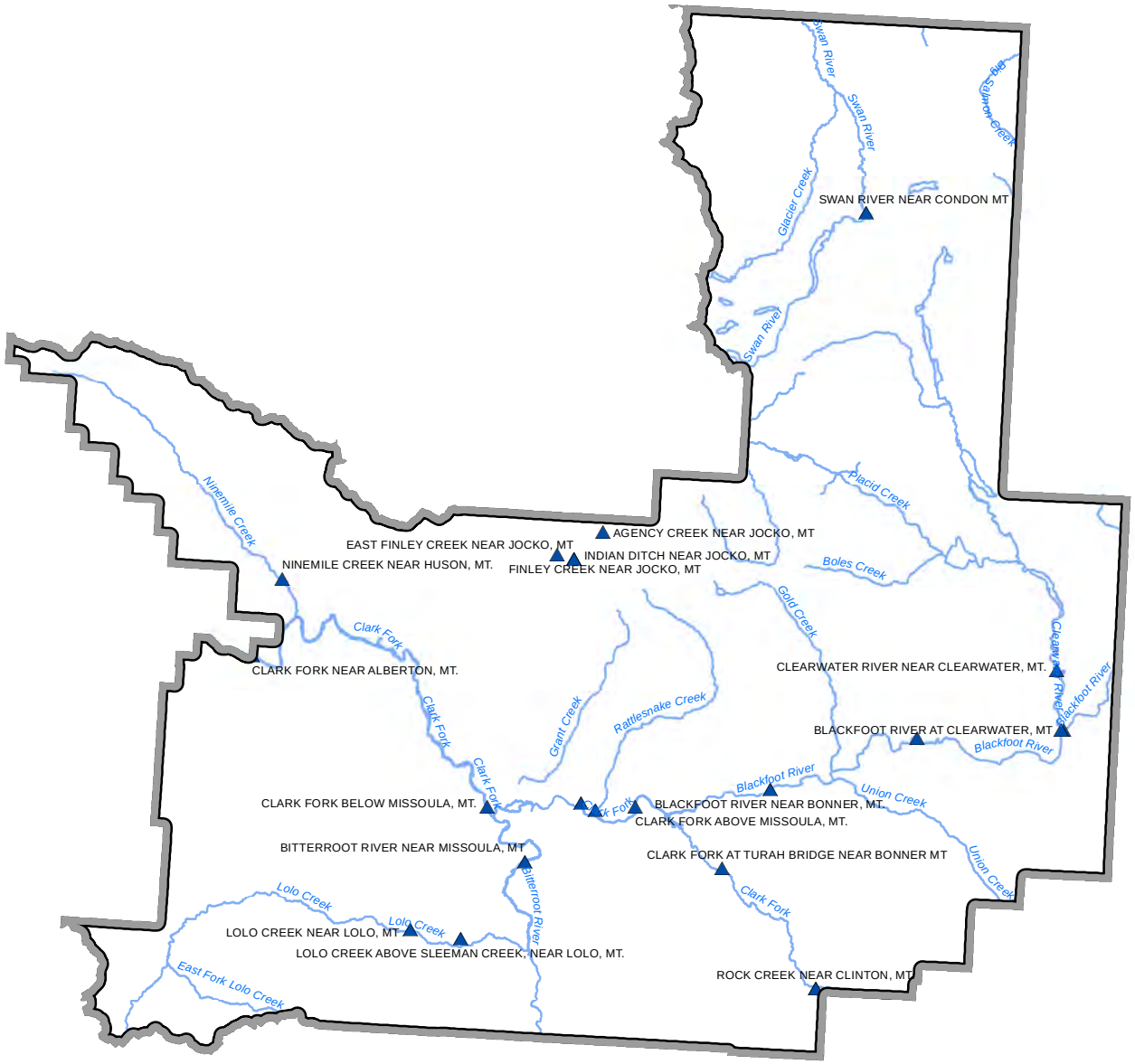
Figure 5-4
Geologic Units
Missoula Valley Area

rec'd by LEPO April 13, 2016



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Date: 12/23/2015
File: Figure 5-5

Scale not indicated

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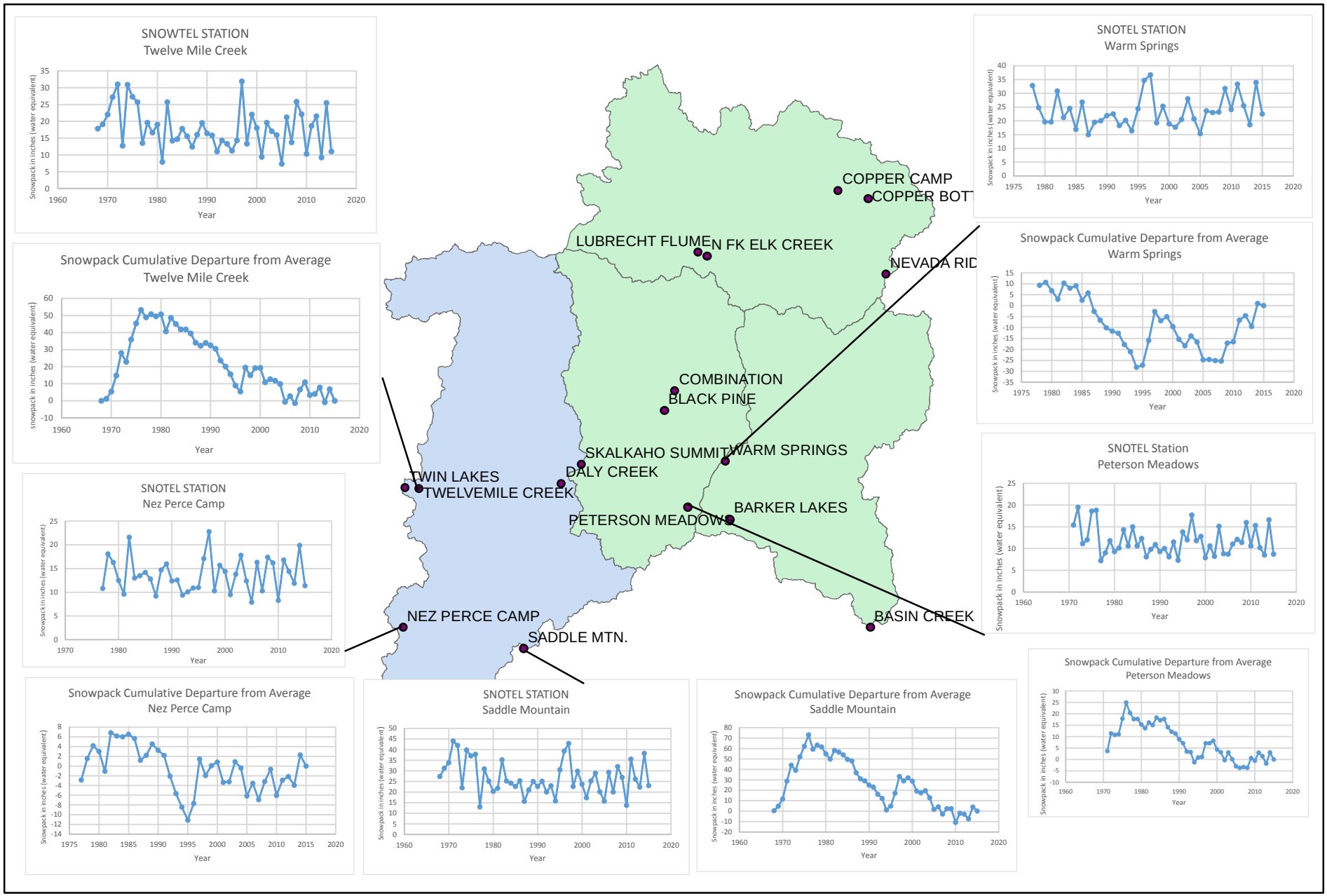
Figure 5-5
Streamflow Gaging Stations
Missoula County Vicinity

rec'd by LEPO April 13, 2016



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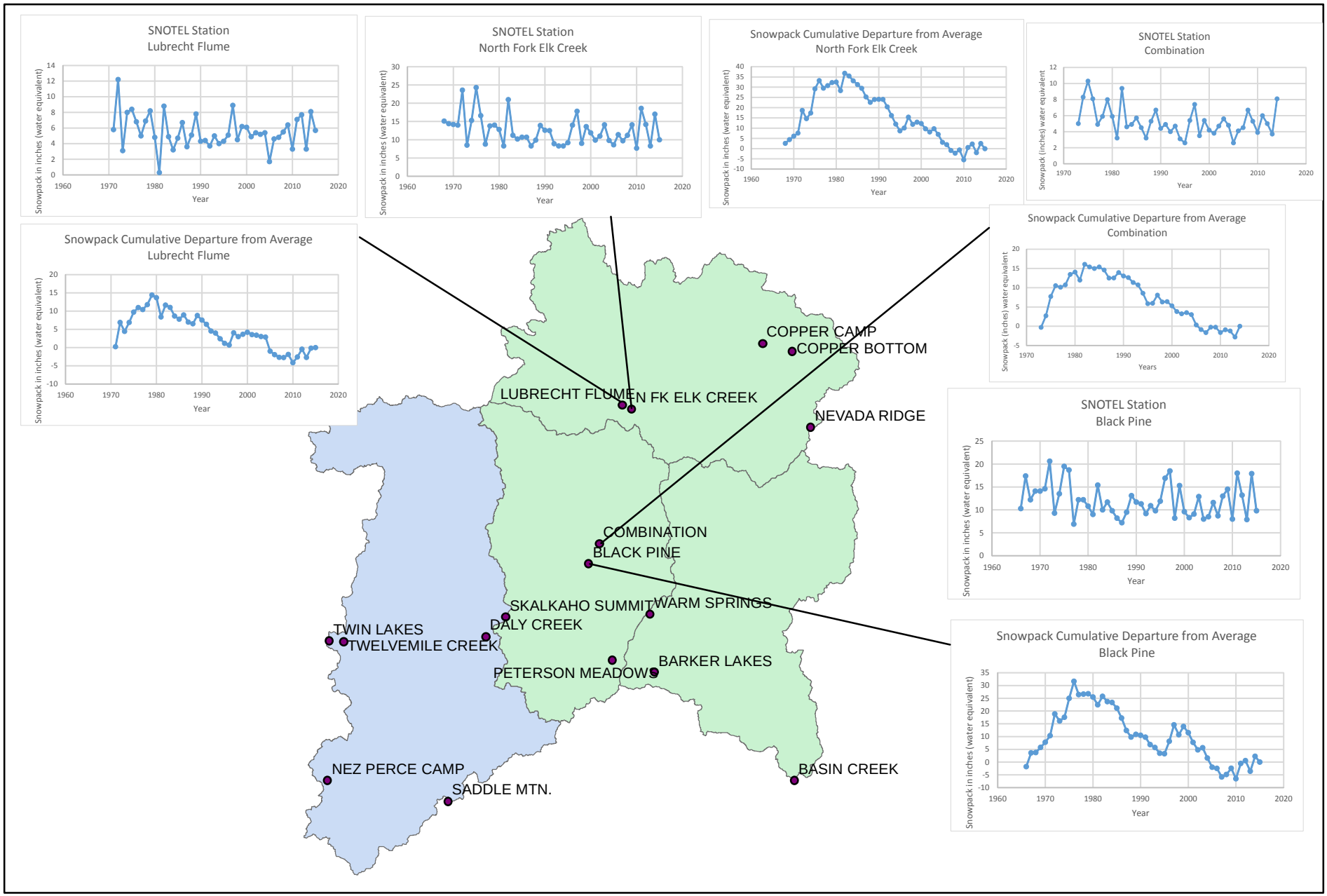
Date: 12/21/2015
File: Figure 5-6(1)

Montana Association of REALTORS®

Figure 5-6 (page 1)
SNOTEL Stations
Clark Fork Basin

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/21/2015
File: Figure 5-6(2)

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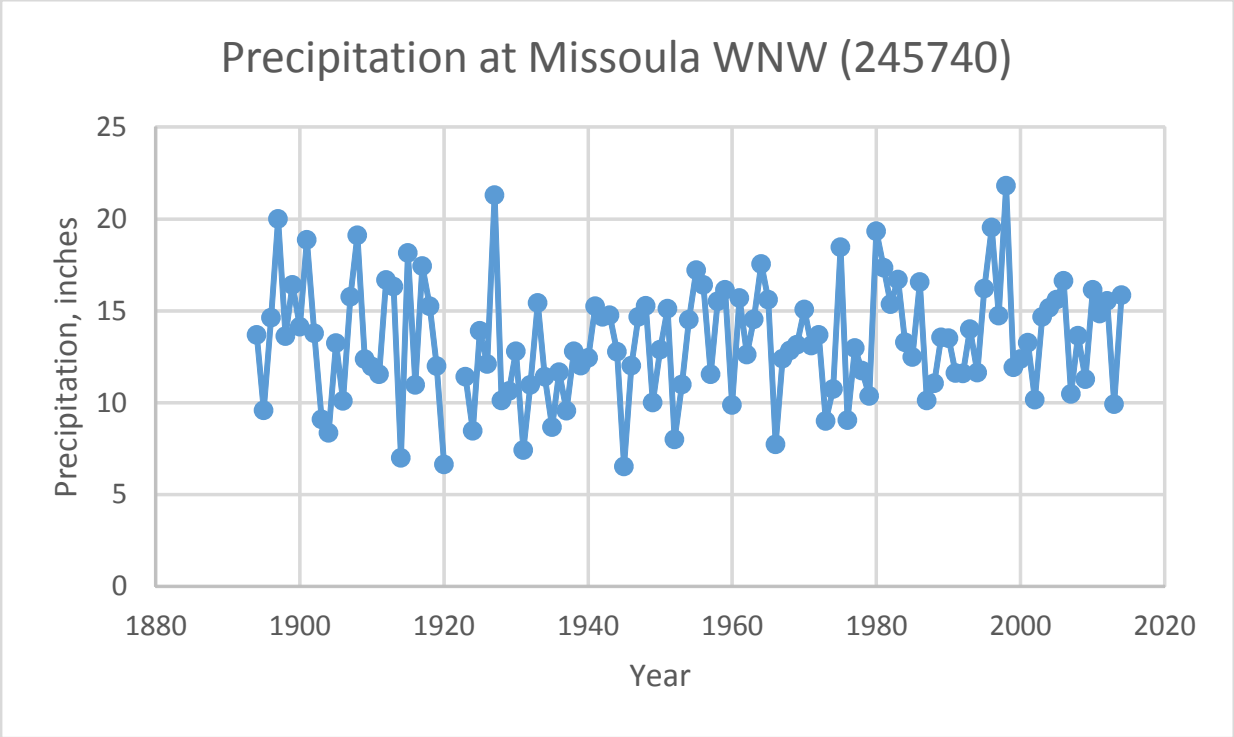
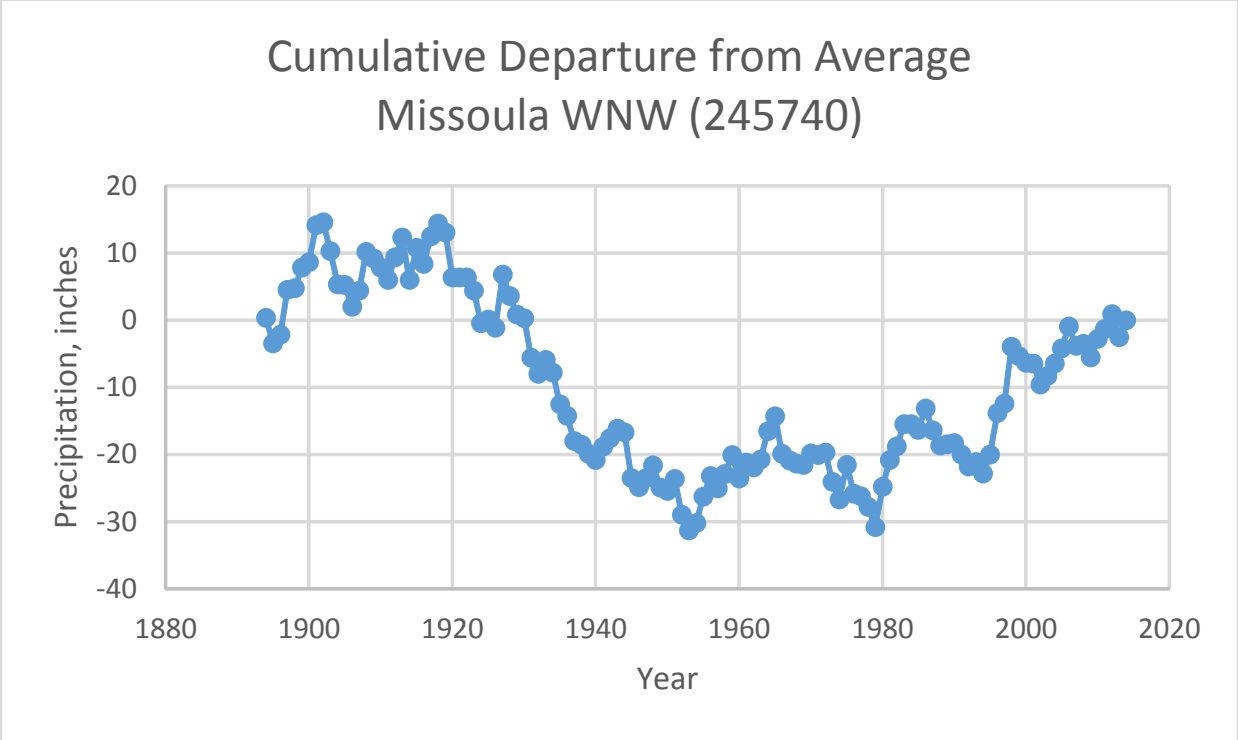
Figure 5-6 (page 2)
SNOTEL Stations
Clark Fork Basin

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 5-7

Notes:
Data source: Precipitation data from WRCC. Note that missing records were supplemented by measurements at Missoula WSO AP, MT.

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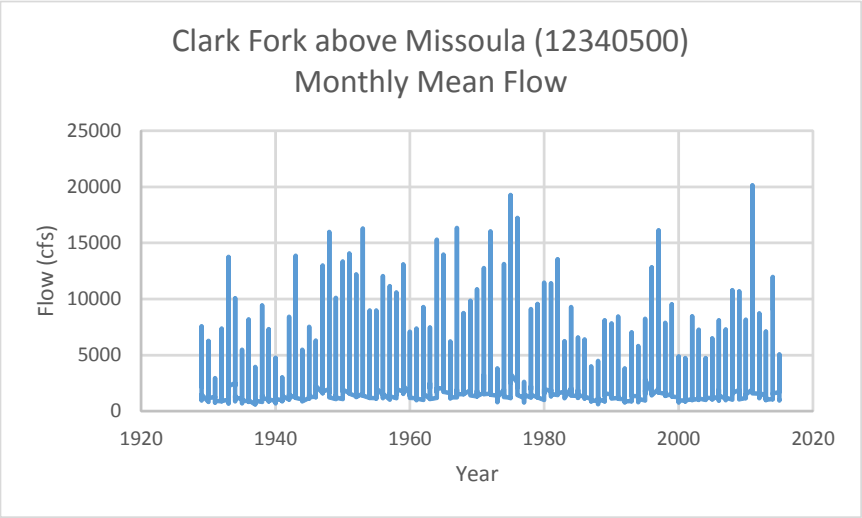
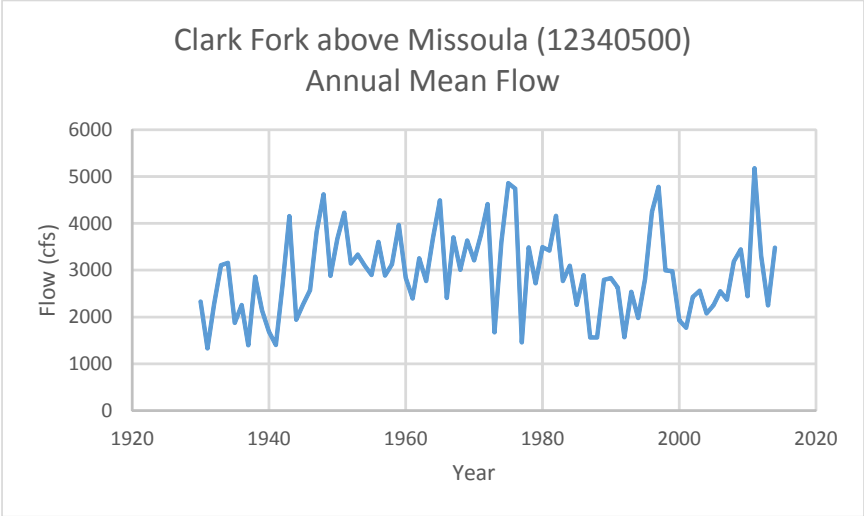
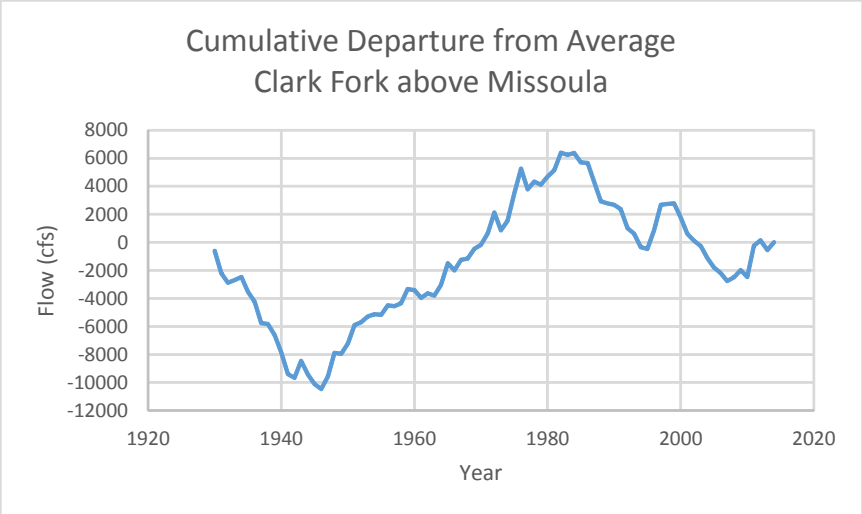
Figure 5-7
Precipitation at Missoula

rec'd by LEPO April 13, 2016







Notes:

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Date: 12/14/2015
File: Figure 5-8a

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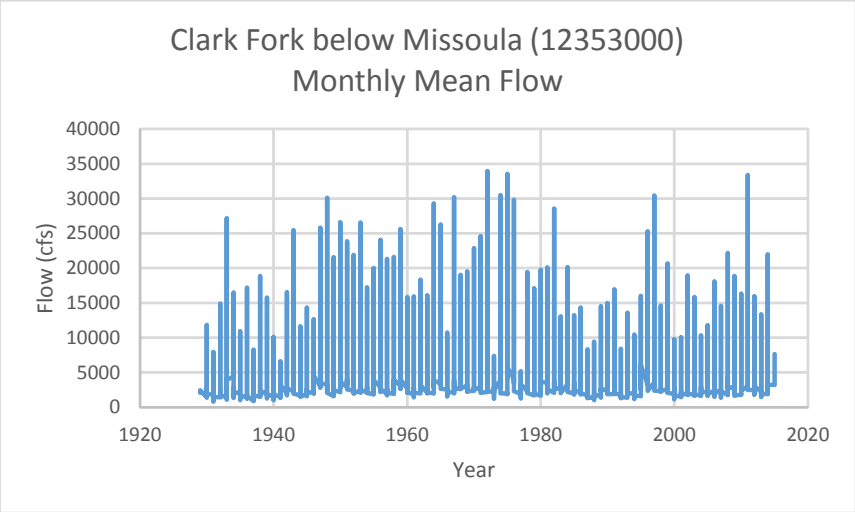
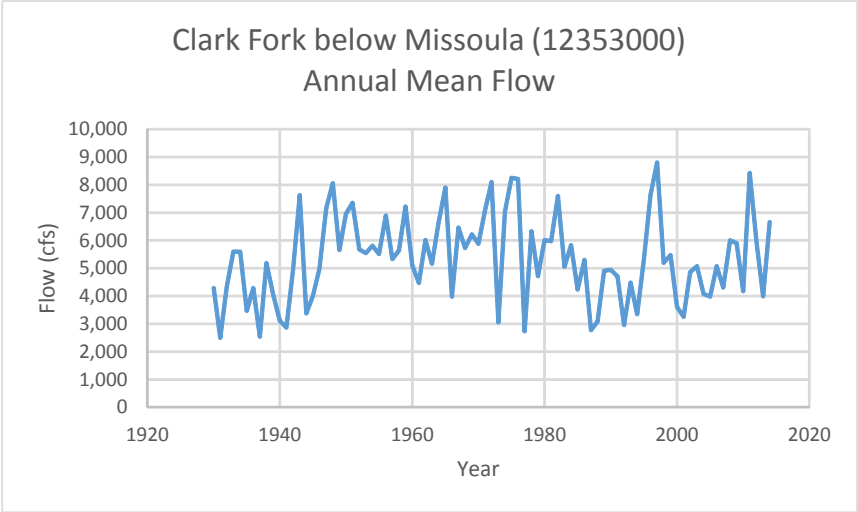
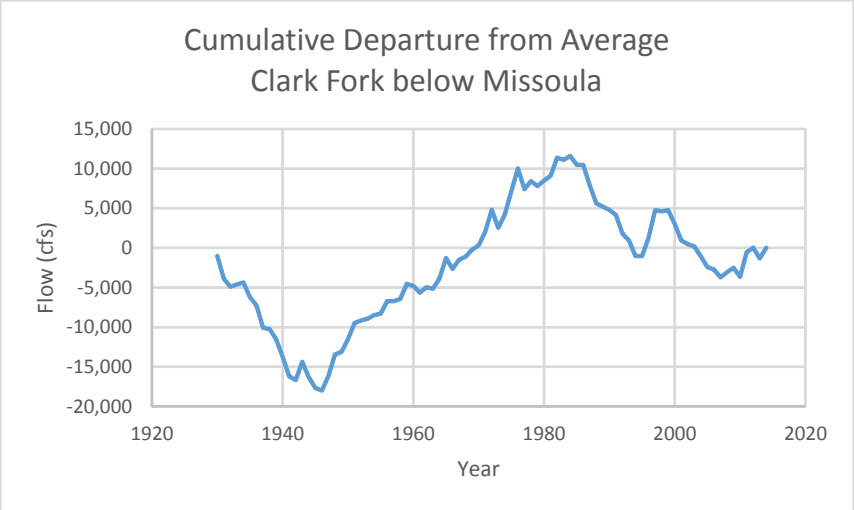
Figure 5-8a
Stream Discharge
Clark Fork River
Above Missoula

rec'd by LEPO April 13, 2016







Notes:

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Date: 12/14/2015
File: Figure 5-8b

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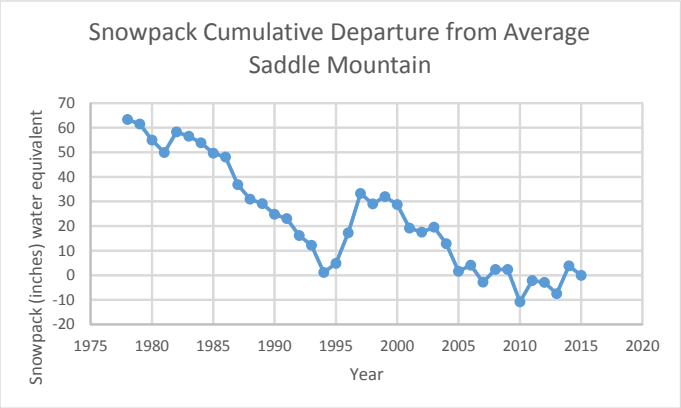
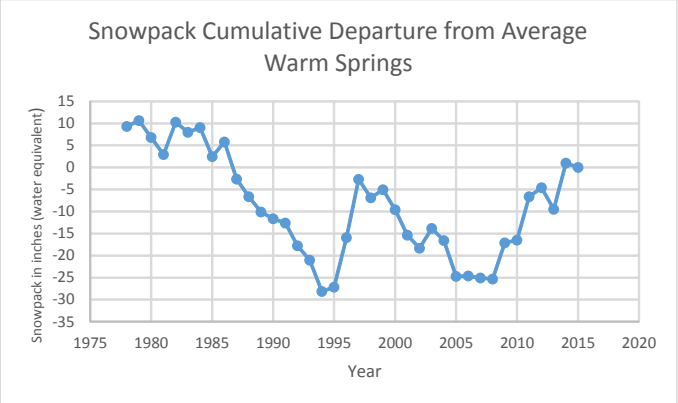
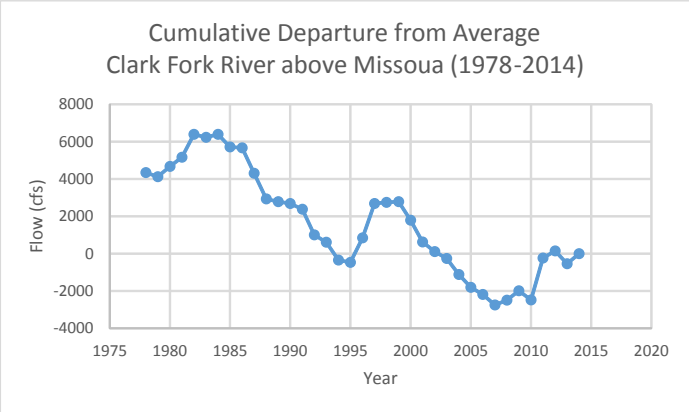
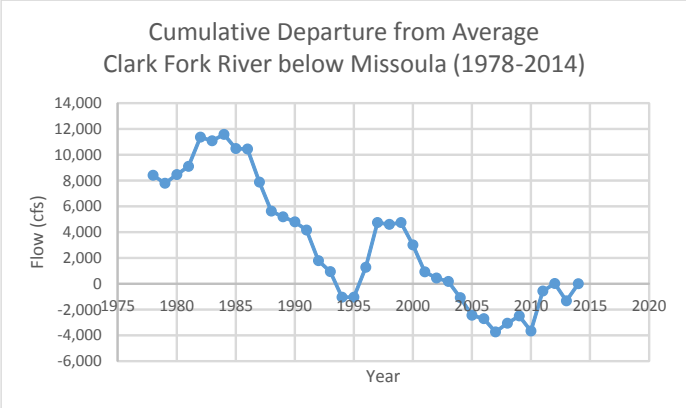
Figure 5-8b
Stream Discharge
Clark Fork River
Below Missoula

rec'd by LEPO April 13, 2016









Notes:

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Date: 12/14/2015
File: Figure 5-9

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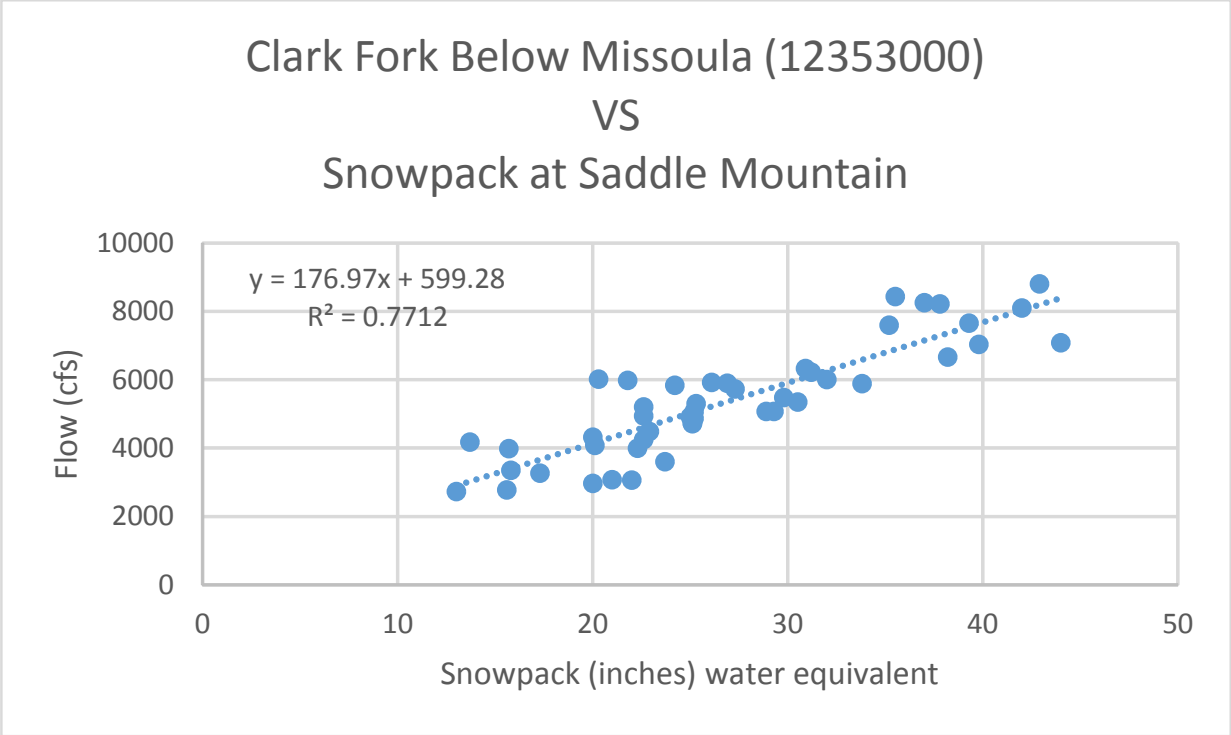
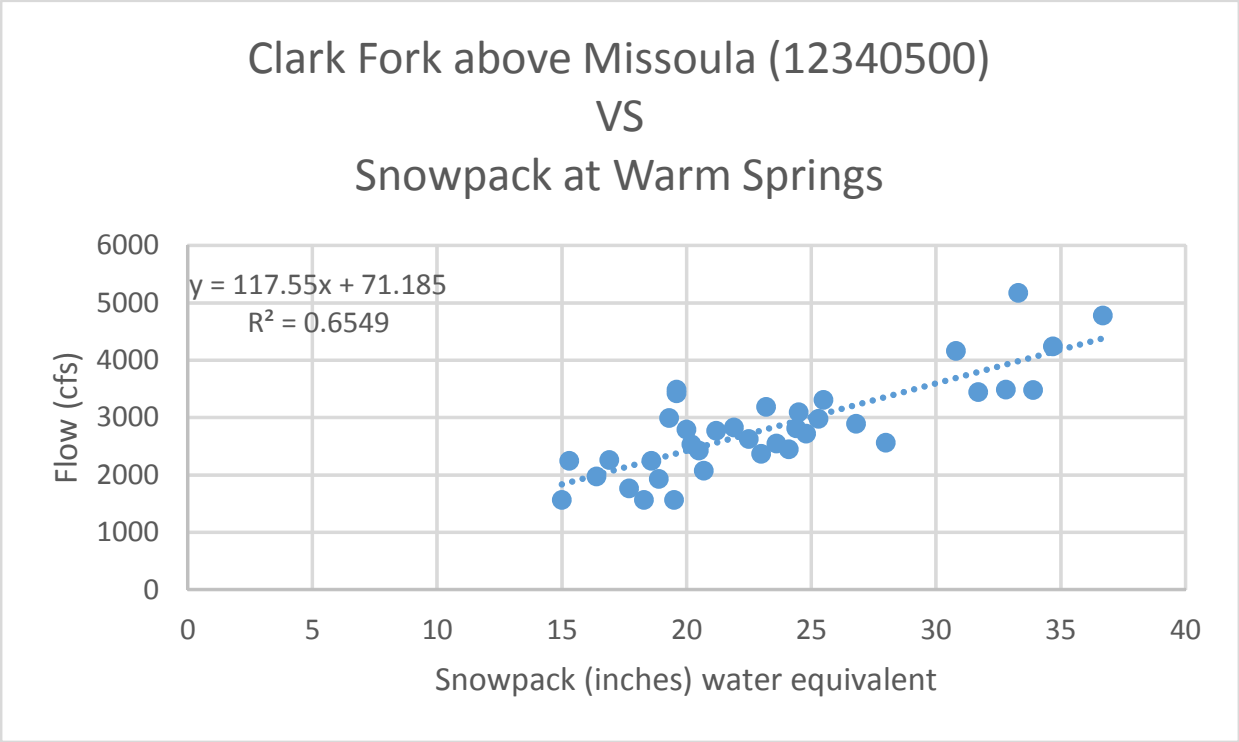
Figure 5-9
Comparison of Flows
Cumulative Departure Plots
Snowpack VS Streamflow

rec'd by LEPO April 13, 2016





Notes:

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Date: 12/14/2015
File: Figure 5-10

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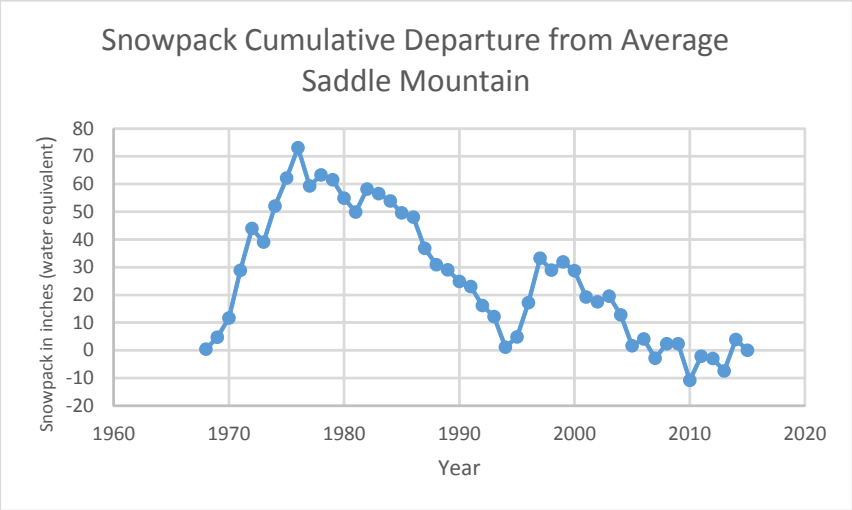
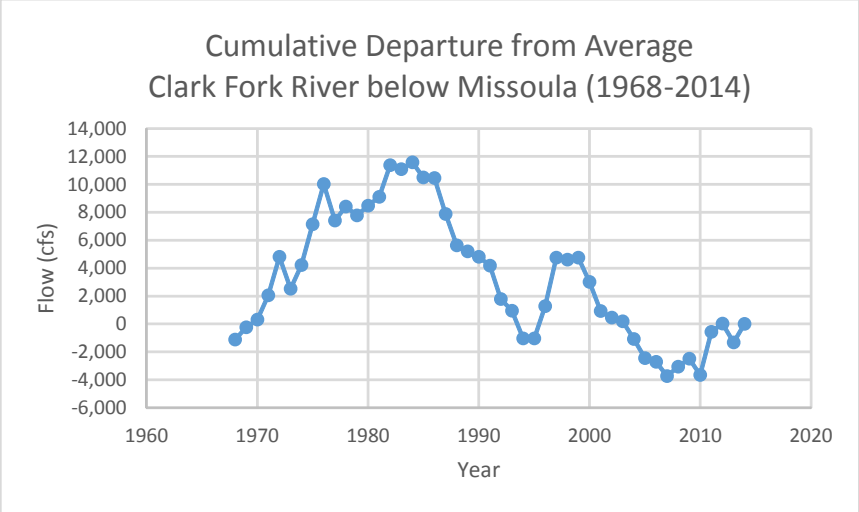
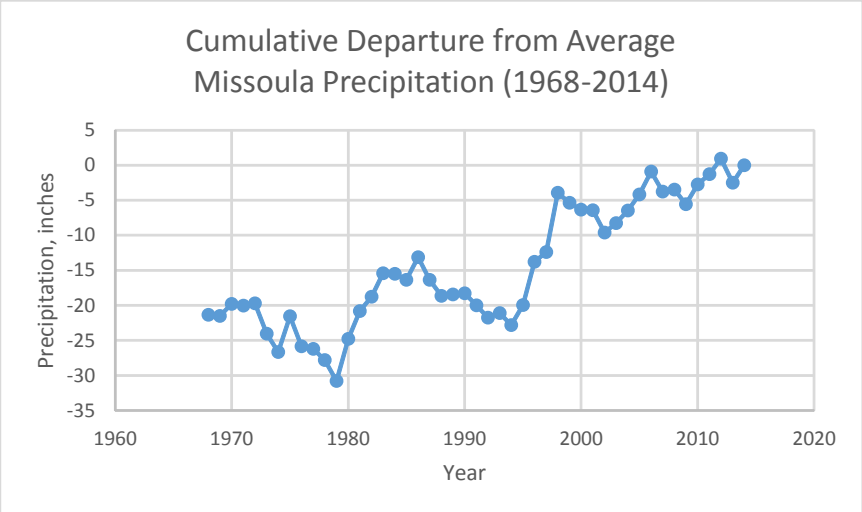
Figure 5-10
Clark Fork Above/Below Missoula Discharge VS Snowpack

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 5-11

Notes:
Note that streamflows tend to mirror snowpack. They do not correlate that well with valley precipitation.

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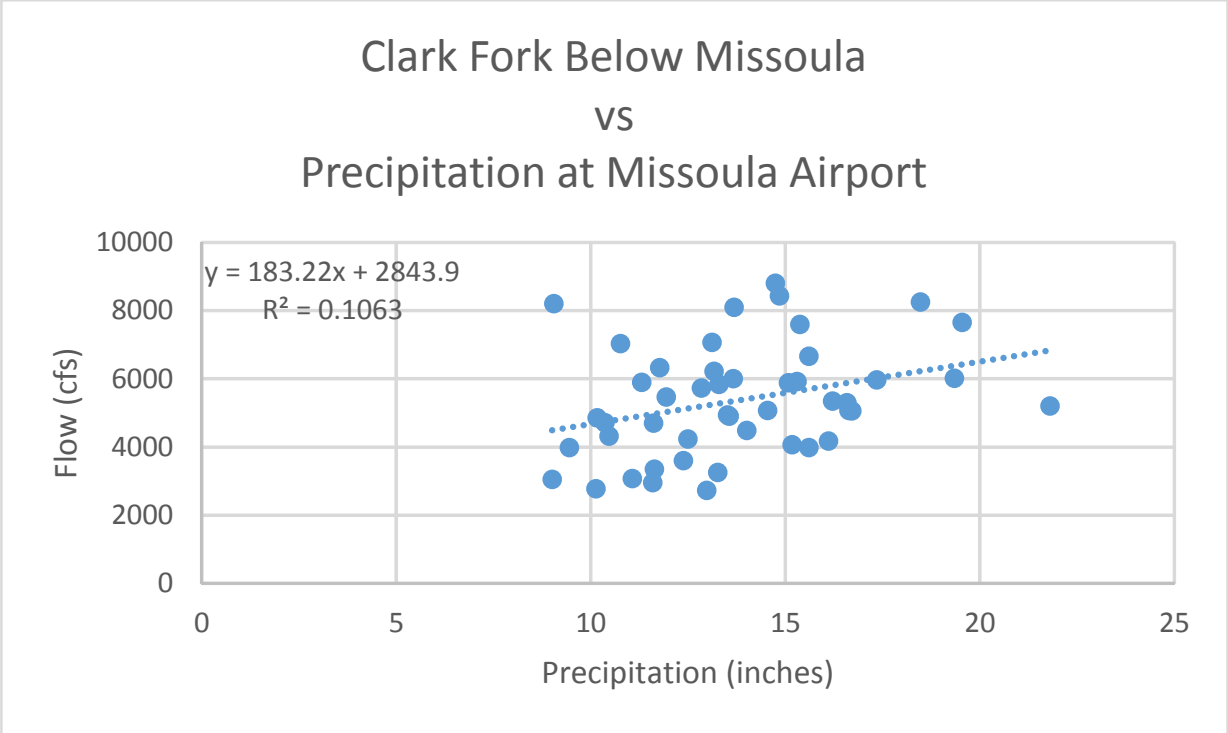
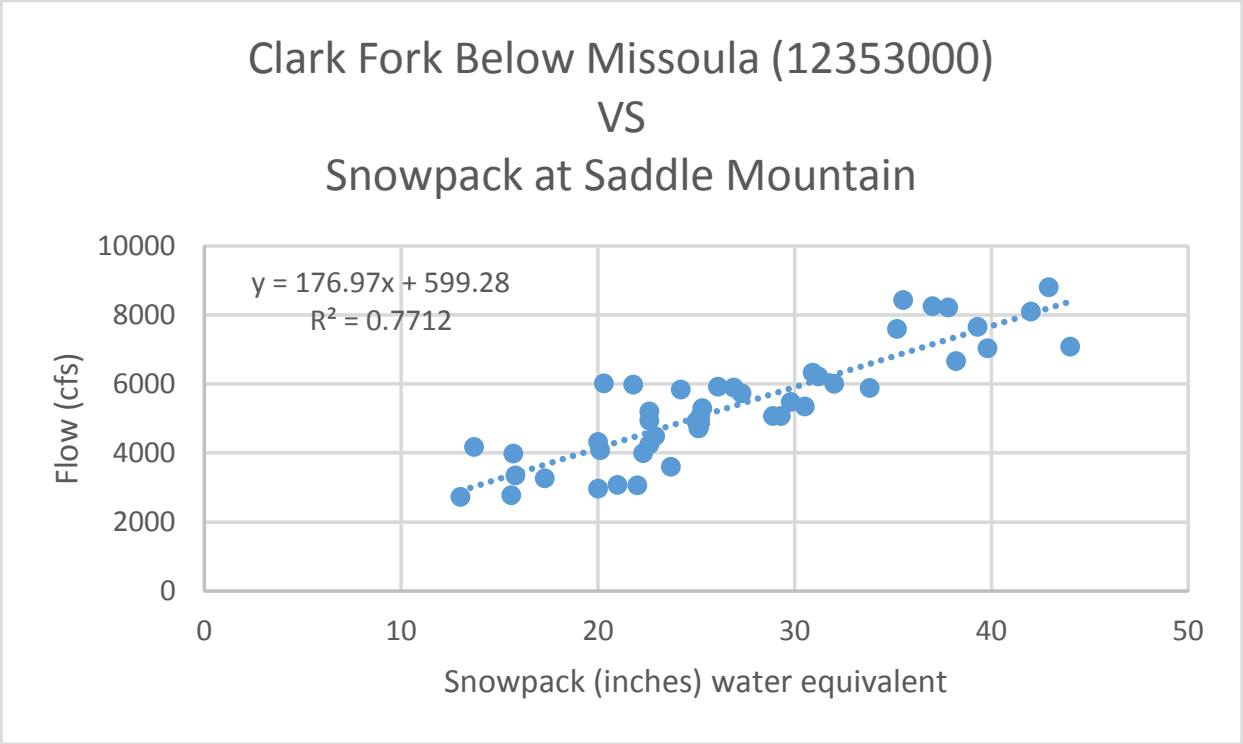
Figure 5-11
Comparison of Flows
Cumulative Departure Plots
Missoula, SNOTEL and Streamflow

rec'd by LEPO April 13, 2016





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Date: 12/14/2015
File: Figure 5-12

Notes:
Clark Fork River Flow is well correlated to snowpack but not to valley precipitation.

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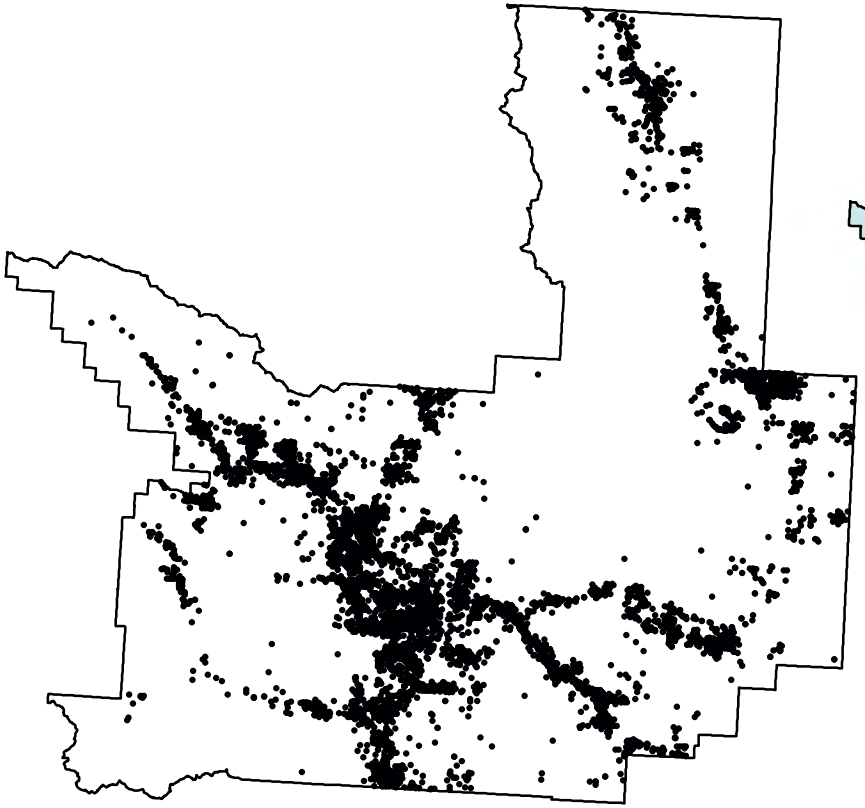
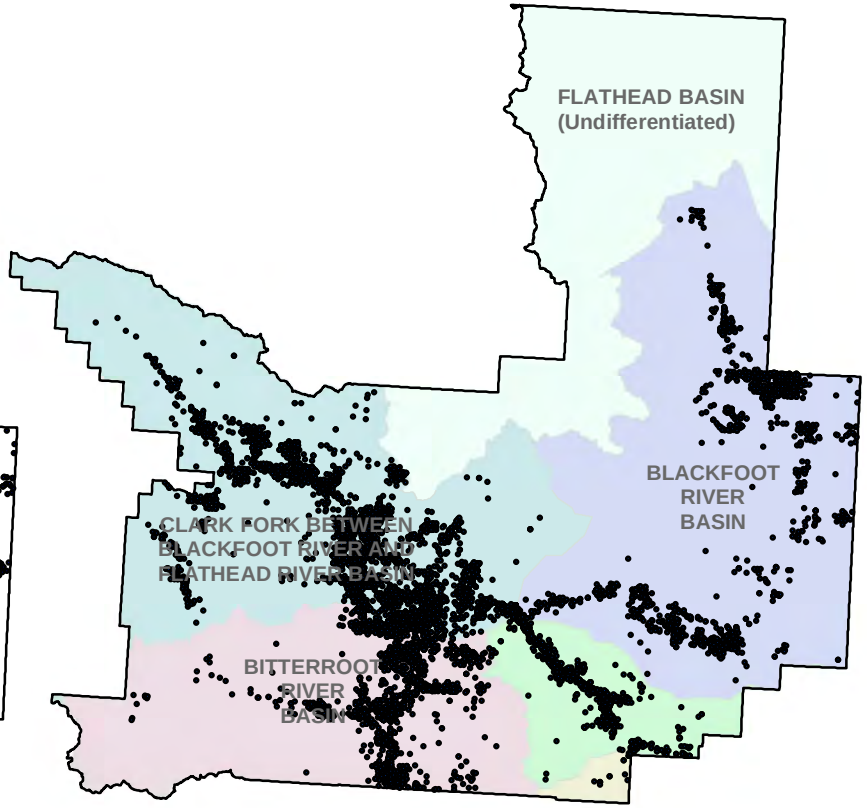
Figure 5-12
eamflow of Clark Fork below Missoula VS Precipitation and Snowpack

rec'd by LEPO April 13, 2016



Wells in Missoula County



Wells of Missoula County Common to Clark Fork Drainage

NICKLIN EARTH & WATER, INC.

Date: 12/21/2015
File: Figure 5-13

Scale not indicated

Notes:
1) Data source is MBMG GWIC

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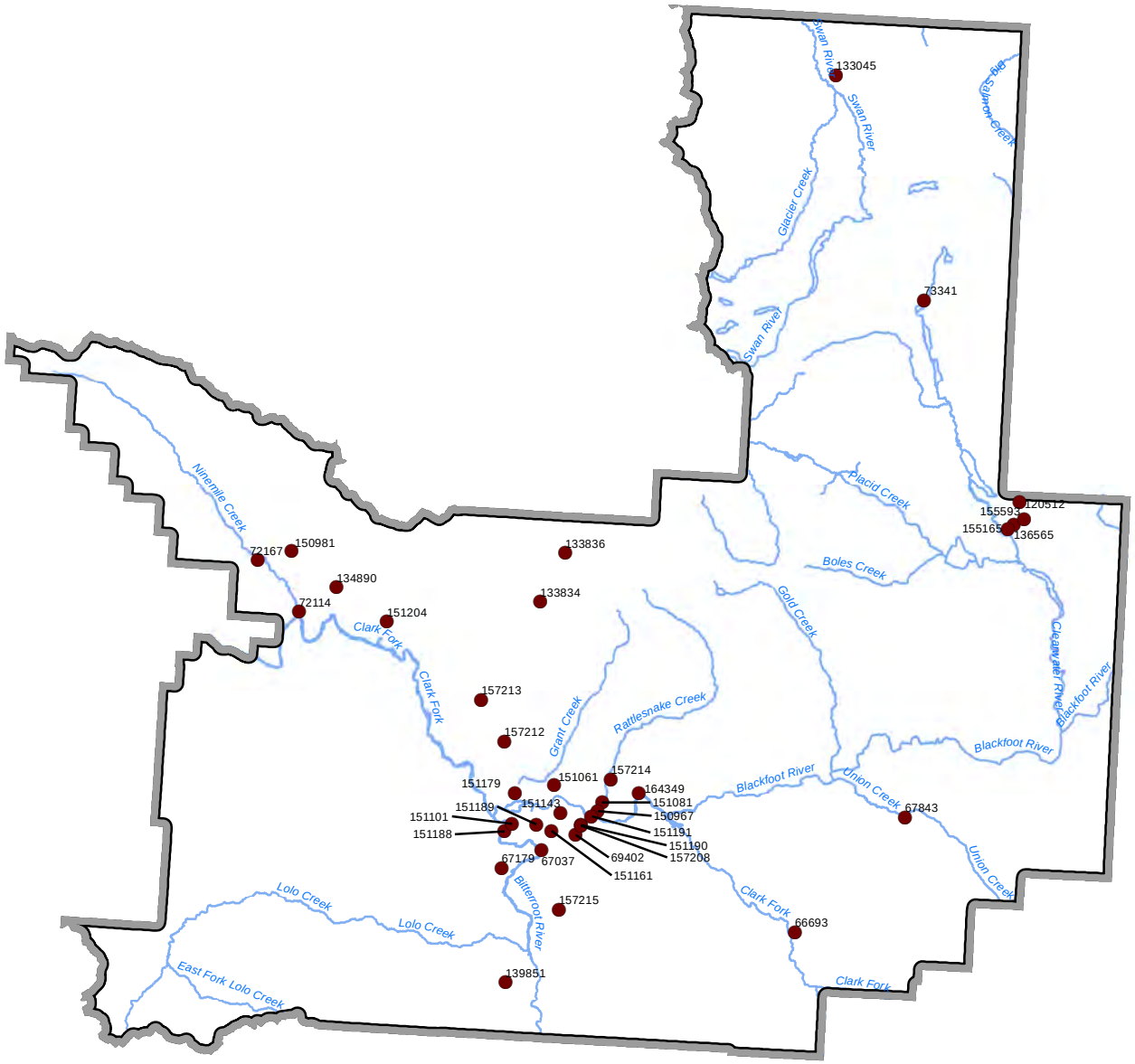
Figure 5-13
Wells in Lewis and Clark County

rec'd by LEPO April 13, 2016



NICKLIN EARTH & WATER, INC.

Date: 12/23/2015
File: Figure 5-14

Scale not indicated

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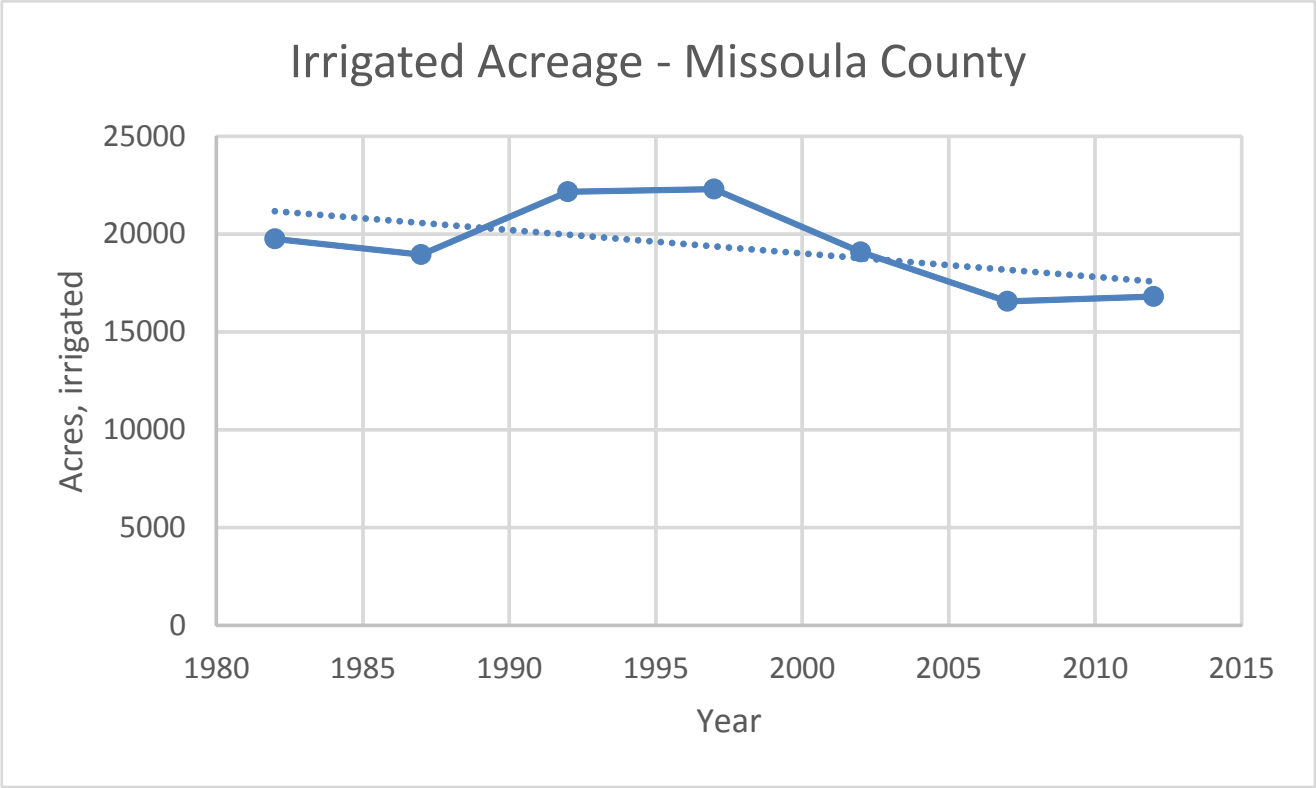
Figure 5-14
Observation Wells
Missoula County Vicinity

rec'd by LEPO April 13, 2016



Note that the water budgeting process needs to consider both the accretions and depletions associated with consumptive uses. For Missoula County, the transition from agricultural lands to subdivisions has led to a decline in irrigated corpland of about 10,000 acres. This reduction in irrigated land has likely led to a net overall decline in consumptive use in Missoula County.

NICKLIN EARTH & WATER, INC.

Date: 1/11/2016
File: Figure 5-15

Notes:
Irrigated acreage obtained from USDA Census of Agriculture (2015).

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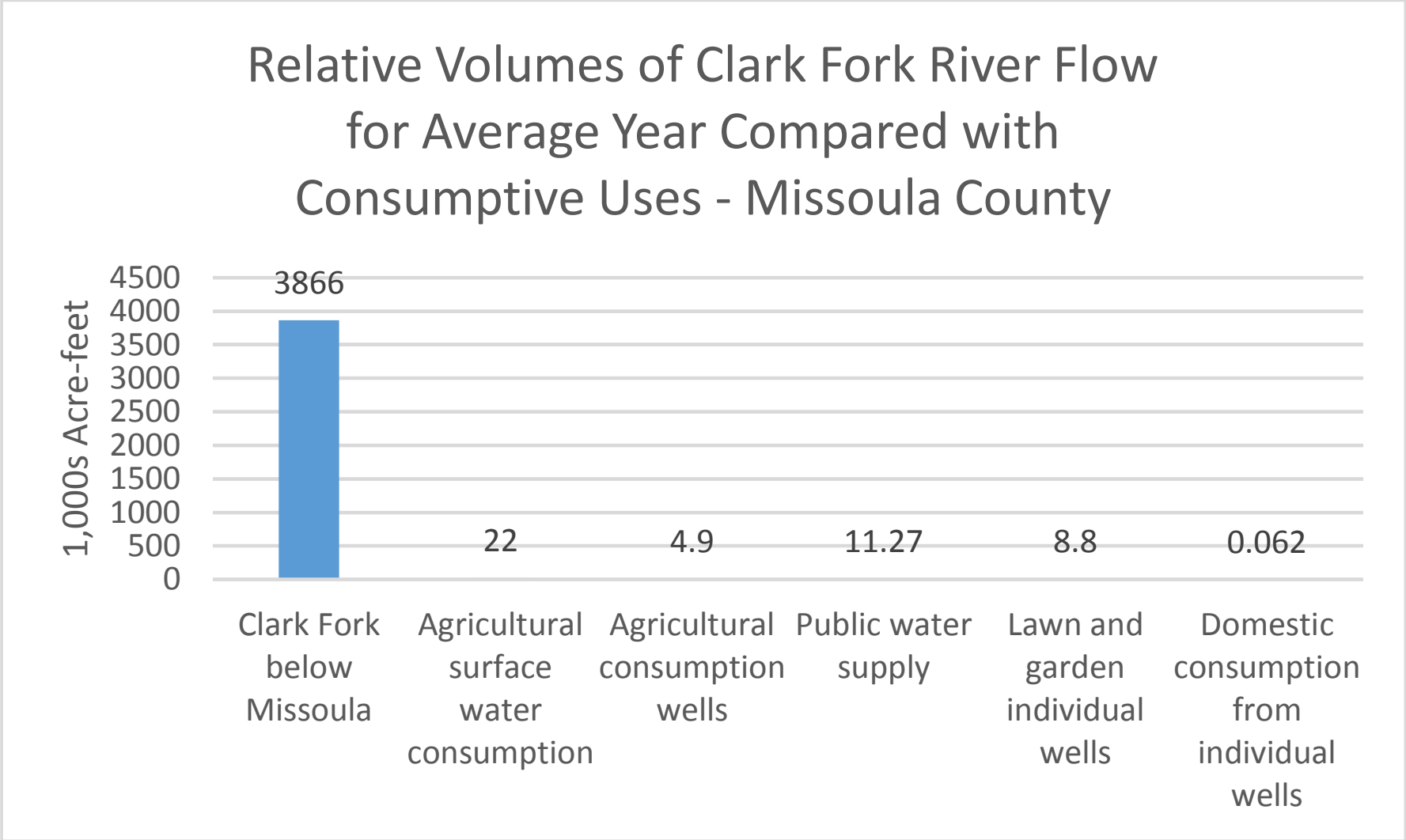
Figure 5-15
Trend in Reported Irrigated Acreage
Missoula County

rec'd by LEPO April 13, 2016



Notes:
1) Average Clark Fork River flows used.
Consumptive use is based in part upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered in these plots.
Individual wells include exempt wells.

NICKLIN EARTH & WATER, INC.

Date: 1/12/2016
File: Figure 5-16a

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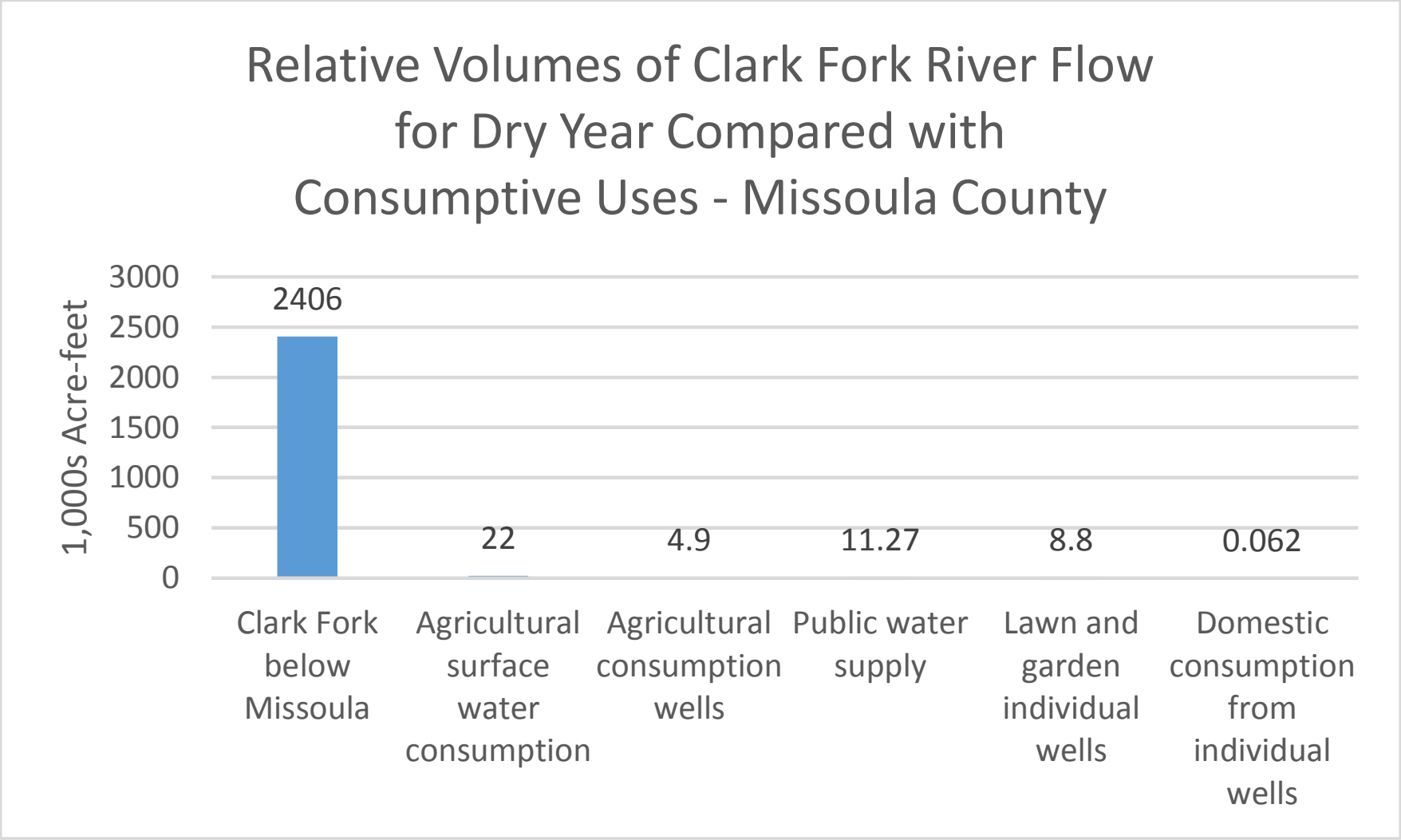
Figure 5-16a
Surface Water Flows at Clark Fork River Compared to Missoula County Consumptive Uses

rec'd by LEPO April 13, 2016



Notes:
1) Clark Fork River flows for 2001 used.
Consumptive use is based in part upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered in these plots.
Individual wells include exempt wells.

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Date: 1/12/2016
File: Figure 5-16b

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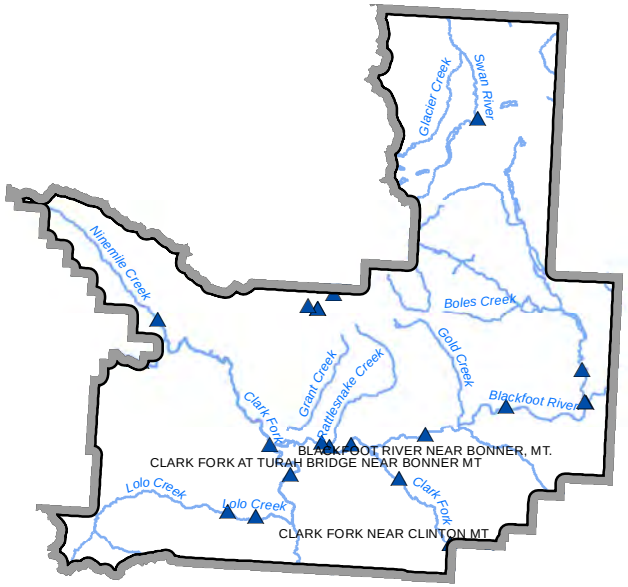
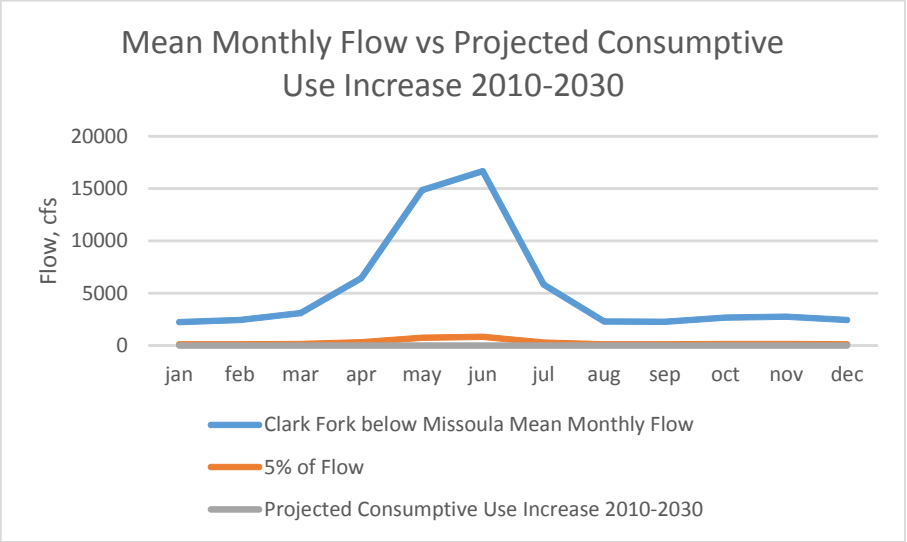
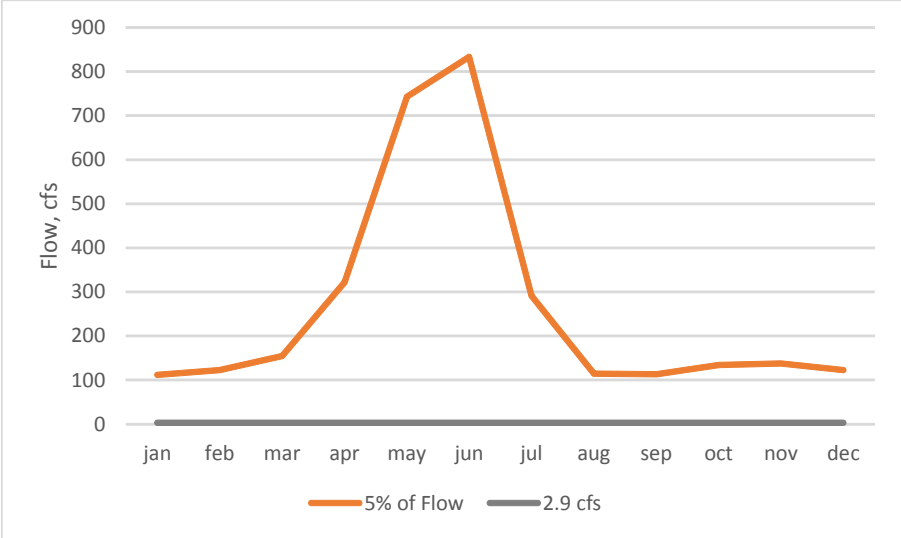
Figure 5-16b
Surface Water Flows at Clark Fork River Compared to Missoula County Consumptive Uses







The blue line plot in the upper graph shows the average monthly flows for the period of record for the Clark Fork River as it is measured below Missoula. The middle line plot shows 5% of the same flows. In effect, this represent an approximate magnitude of the uncertainty of stream flow measurements at gaging stations. The lower line of 2.9 cfs represents the projected increase in consumptive use from 2010 to 2030 for Missoula County. In effect, a flow of 2.9 cfs could not be reliably discerned at this gaging station. Note that the 2.9 cfs depletion does not take into consideration the potential accretions from reductions in stream-flow diversions from reduced irrigated acreage. The net depletion will likely be much less than 2.9 cfs once the net accretions are accounted for.

NICKLIN EARTH & WATER, INC.

Date: 1/12/2016
File: Figure 5-17a

Scale not indicated

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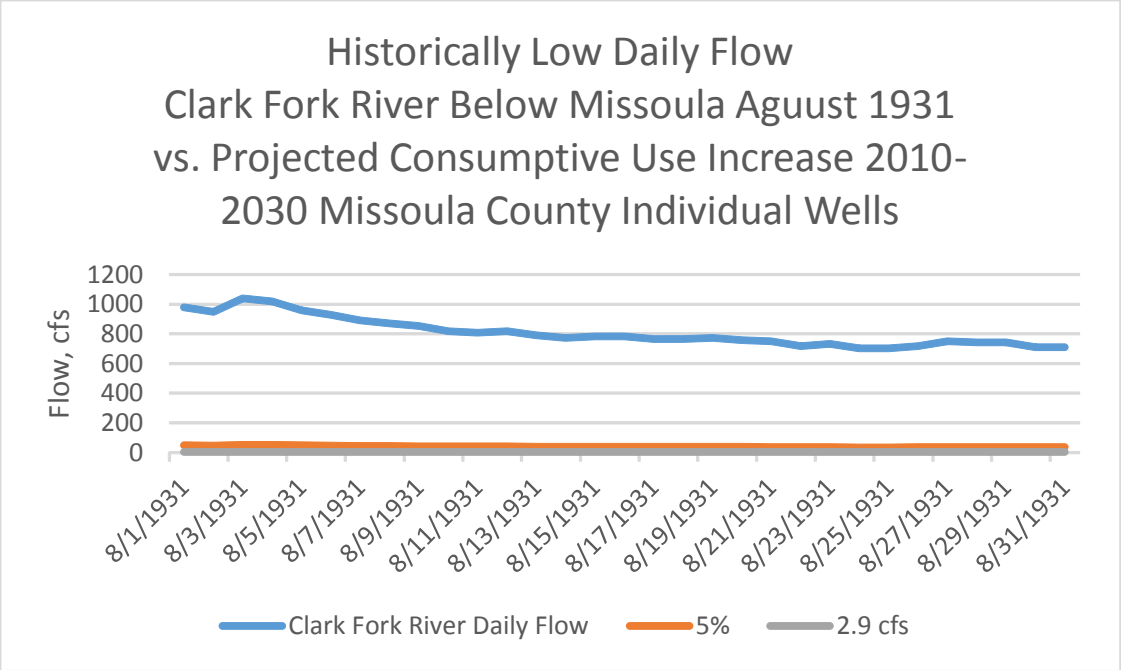
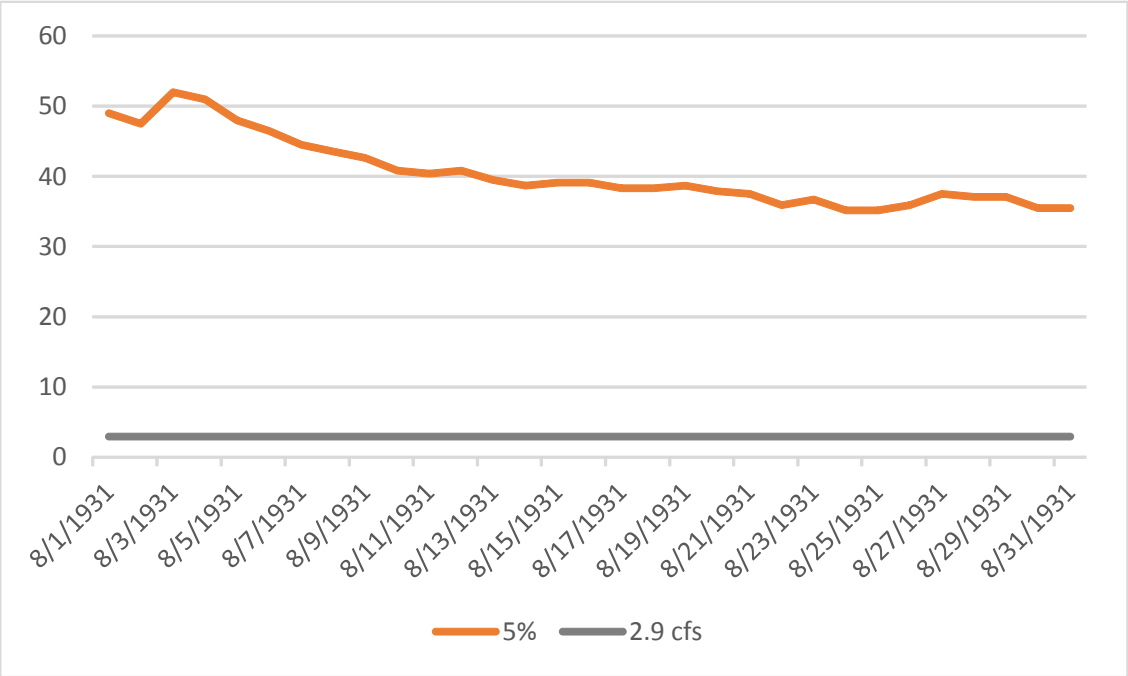
Figure 5-17a
Mean Monthly Flow Clark Fork River Compared to Projected Individual Well Consumptive Use Increase - Missoula County





Note that the above figure represents the minimum daily flow month of record for August which occurred in August 1931. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal variation indepletions will be very subdued owing to the fact that most wells in Missoula are located at significant distances from streams. Even if seasonal variability is accounted for any net monthly depletion would remain in the noise level (below 5% of streamflow) in the Clark Fork River as measured below Missoula. Finally the above graph does not account for any reduction in surface water use associated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects".

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Date: 1/12/2016
File: Figure 5-17b

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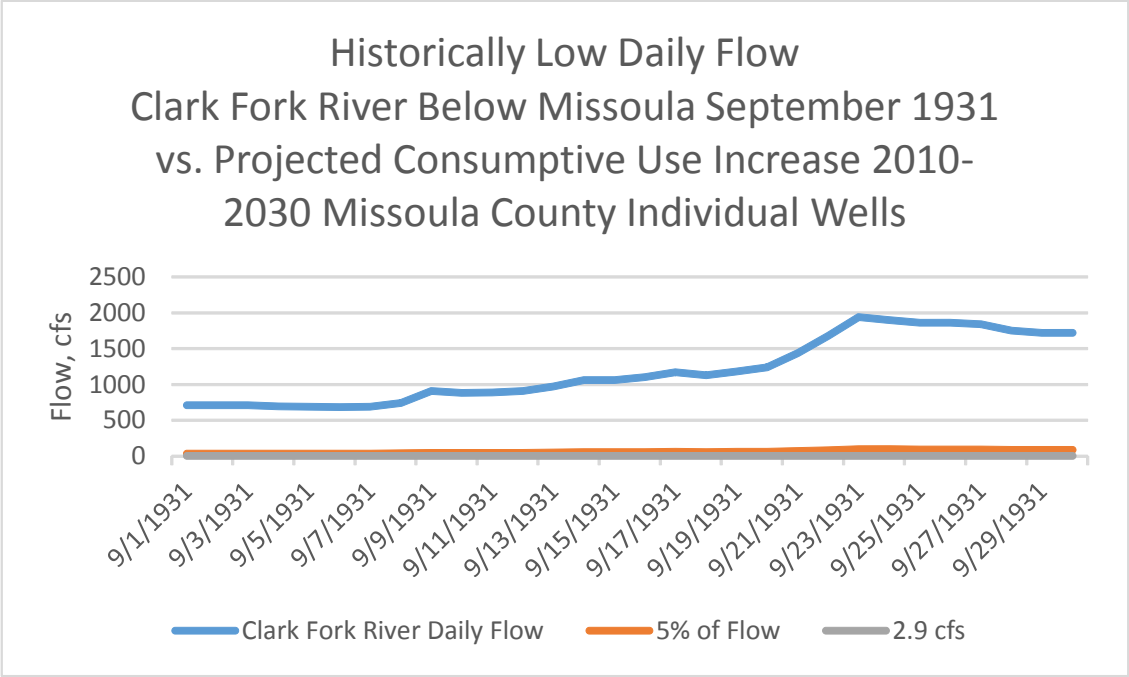
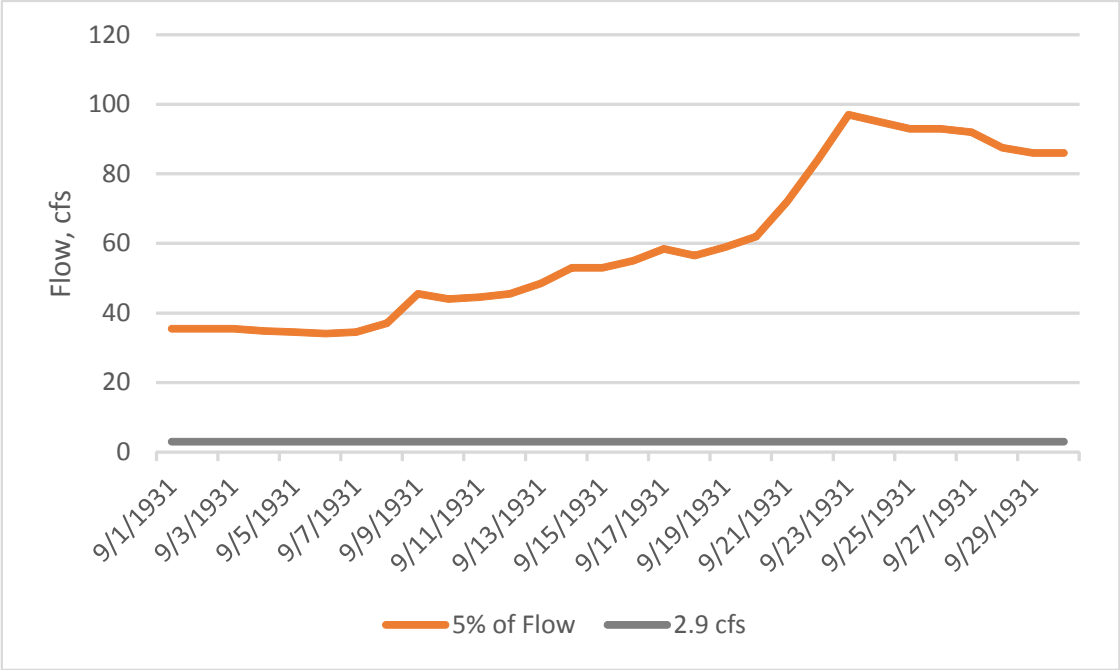
Figure 5-17b
August 1931 Flow Clark Fork River Compared to Projected Individual Well Consumptive Use Increase
Missoula County





Note that the above figure represents the minimum daily flow month of record for September which occurred in September 1931. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal variation indepletions will be very subdued owing to the fact that most wells in Missoula are located at significant distances from streams. Even if seasonal variability is accounted for any net monthly depletion would remain in the noise level (below 5% of streamflow) in the Clark Fork River as measured below Missoula. Finally the above graph does not account for any reduction in surface water use associated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects".

NICKLIN EARTH & WATER, INC.

Date: 1/12/2016
File: Figure 5-17c

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Figure 5-17c
September 1931 Flow Clark Fork River Compared to Projected Individual Well Consumptive Use Increase
Missoula County

6.0 GALLATIN VALLEY

6.1 Physical Setting and Overview

The Gallatin Valley is located in southwest Montana as shown on Figure 6-1.

The Gallatin Valley is an intermontane basin contained within the Gallatin River watershed of southwestern Montana. An excellent overview of the physical setting is set forth in Hackett, et al (1960). The approximate area of the valley is about 540 square miles. This valley is bounded on the east by the Bridger Mountain Range and on the south by the Gallatin Mountain Range.

6.1.1 Project Specific Information Sources

A variety of information sources were used in the evaluation of Gallatin County including the following:

- MBMG GWIC Database and Geologic Mapping
- DNRC water rights permit database
- USDA NRCS SNOTEL/Snow Course
- WRCC data
- USDA Census of Agriculture data, Census Bureau, and Canon and Johnson (2004)

Much of the geospatial information used in this evaluation, especially mapping resources, was obtained from the Montana NRIS database.

6.1.2 Land Use

The predominant land use in the Gallatin Valley is agricultural. Most of the crop land on the valley floor, the Bozeman fan, and the Manhattan terrace is irrigated, as are about one-third of the Camp Creek Hills. According to data compiled by Hackett, et al (1960) from the Montana State Engineer's office, 107,261 acres (about 168 squares miles) were irrigated in 1952. This represents about 31 percent of the land surface area of the

valley. More recently, major economic activity in the valley has become more diversified and includes agriculture, building construction, Montana State University, and evolving technological/ entrepreneurial companies. The service industry has expanded as well.

Based upon infrared mapping, it appears that the overall irrigated acreage in some portions of the valley has declined. This decline appears to be concentrated in areas at and near city and rural subdivisions. For instance, there are many abandoned irrigation ditches and laterals present in areas near and south of Bozeman. Much of the land in this area that had been formerly irrigated agricultural cropland and pasture is now occupied by both city and rural subdivisions. Similar observations are seen elsewhere in the valley.

6.1.3 Climate

Much of the Gallatin Valley is semiarid. The average annual precipitation valley wide is 16 inches. Average annual precipitation ranges from 12 inches in the lower northwestern portions of the valley to 26 inches nearer the mountain flanks (see Figure 6-2 for climate stations and Figure 6-3 for precipitation ranges).

Temperatures vary substantially with the minimum average daily temperature in the valley being 11.9 degrees Fahrenheit in January and the average maximum daily temperature in the valley being 81.3 degrees Fahrenheit in the summer month of July (at Montana State University, MSU). The minimum and maximum temperatures ever recorded have been -43 F (February 8, 1936) and 105 F (July 31, 1892) respectively (at MSU).

6.1.4 Geology

The Gallatin Valley is considered a high intermontane basin. A detailed and excellent summary of the geology is presented in Hackett, et al (1960). Figure 6-4 provides recent geologic mapping of the area by Vuke, et al (2002).

The geology bounding the valley is very complex. However, the surface geology within the valley itself is not as complex as surficial deposits tend to consist of valley floor alluvium, alluvial terrace, alluvial fans, or Tertiary strata. The alluvial deposits are the most recent geologic units in the valley. The Tertiary deposits are valley-fill geologic

material, which consists of moderately indurated to well-indurated tuffaceous sand and siltstone. The Tertiary deposits tend to be finer-grained materials when compared to the alluvial deposits.

6.1.5 Aquifers

The primary aquifers in the Gallatin Valley include the Tertiary Basin fill and the Quaternary alluvial aquifer system. Lower portions of the Quaternary alluvial deposits generally prove to be the most productive aquifers in Gallatin Valley. In particular, Quaternary alluvial strata near the Gallatin River and East Gallatin River yield copious amounts of water. Although the Tertiary deposits produce water as well, the magnitude of discharges tends to be lower and less predictable than what is derived from the shallower alluvial deposits. The primary reason for this is, again, related to the fact that the Tertiary deposits tend to be finer-grained. However, intervals of relatively coarser-grained strata exist within the Tertiary and can produce an abundant water supply. For instance, the most productive Tertiary wells tend to be in the Camp Creek Hills (Madison Plateau) area in western/northwestern portions of the valley. Wells producing between several hundred gallons per minute (gpm) to over 2,000 gpm from the Tertiary have been completed in this area.

6.1.6 Surface Water

The two largest streams in the valley are the Gallatin River and the East Gallatin River (see Figure 6-5). The Gallatin River is the dominant stream and originates to the south of the valley in Yellowstone National Park. There are numerous smaller streams and irrigation ditches and canals in the valley.

6.2 Hydrologic Data Summary and Evaluations

6.2.1 SNOTEL/Snow Course Data Collection Network

Snowpack data for a relatively long period of time are available at three SNOTEL/Snow Course stations for the Gallatin River Drainage. Figure 6-2 shows the local SNOTEL stations relative to the Gallatin Valley. The three used for the snowpack analysis presented in this report are the following:

- Carrot Basin (water years 1967 through 2015)
- Shower Falls (water years 1966 through 2015)
- Lick Creek (water years 1966 through 2015).[5]

These SNOTEL stations have sufficiently long periods of records to allow evaluations for this study. Other stations, including those at Sacajawea, Brackett Creek, and Lone Mountain, are within the Gallatin River drainage. However, the duration of record at these stations was considered to either be too short or the available record contained too many estimated values. Therefore, the latter stations were not used in the statistical assessments that are presented in this report.

A summary of the results from the snowpack analysis is given below.

6.2.1.1 Carrot Basin

Figure 6-6a provides a summary of the Carrot Basin snowpack water equivalent over time. The upper plot presents the maximum annual water equivalent of the snowpack in inches over the period of record. The snowpack water equivalent has ranged from less than 20 inches to more than 45 inches over the period of record.

The lower plot in Figure 6-6a provides a cumulative departure-from-average snowpack for the period of data collection. Positive (upward) slopes in this plot define long-term periods of above average snowpack whereas negative (downward) slopes express long-term periods of below average snowpack. For example, a period of greater than average snowpack was observed from 1967 to 1976. On the other hand, beginning in about 1999 or 2000, the snowpack was below average through about 2005. More recently, snowpack has been near average for this station.

6.2.1.2 Shower Falls

Figure 6-6b provides a summary of the Shower Falls snowpack water equivalent over time. The snowpack has ranged from less than 20 inches to more than 40 inches over

[5] The data for 2008 presented in this report are through the end of April, 2008.

the period of record.

The behavior of the cumulative departure-from-average plot (lower plot) in Figure 6-6b is similar to what was observed at the Carrot Basin station. A long-term declining trend for snowpack at the Shower Falls station commenced beginning about 1998. More recently, beginning in water year 2008, this station has been showing a snowpack that is above average.

6.2.1.3 Lick Creek

Figure 6-6c provides a summary of the Lick Creek station snowpack in terms of water equivalent over time. Again, the upper plot presents the maximum annual water equivalent of the snowpack in inches. The snowpack has ranged from less than 10 inches to nearly 30 inches over the period of record.

A long-term declining trend for snowpack at this station began about 1985 (lower plot of Figure 6-6c). More recently, since water year 2007, this station has been showing snowpack that is near to slightly below the long term average.

6.2.2 Precipitation

Direct precipitation has been measured at the following climate stations in the Gallatin Valley:

- Montana State University Experiment Station (1967 to 2014)
- Belgrade Airport (1941 to 2014)
- Montana State University (1907 to 2014)

Figures 6-7a through 6-7c tabulate both the annual precipitation depths in inches and the cumulative departure-from-average for these respective stations.

The plots demonstrate that precipitation patterns vary in the valley from station to station. For instance, both the Experiment Station and Belgrade Airport cumulative departure-from-average plots indicate relatively lower precipitation had occurred from about 1998 to current (see Figures 6a and 6-b respectively). Yet, this trend is not apparent in the cumulative departure-from-average plot at Montana State University that has generally shown above normal precipitation since 1965 and in that same time

period (Figure 6c).

6.2.3 Streamflow Data Evaluation Summary

Stream discharge rates and volume are primarily dependent upon each water year's snowpack. Slightly more than 70 percent of the surface-water flow entering Gallatin Valley enters via the Gallatin River at the mouth of Gallatin Canyon as measured at a gaging station near the Spanish Creek confluence (Hackett, et al, 1960).

Long-term streamflow data have been collected at two stream gaging stations for the Gallatin River as follows (see Figure 6-5):

- USGS 06043500 (Gallatin River near Gallatin Gateway). This station is located below (north of) the confluence with Spanish Creek. It is also situated up-gradient of valley irrigation ditches. The drainage area above this station is 825 square miles.
- USGS 06052500 (Gallatin River at Logan MT). The station is situated at a location at the northwest corner of the Gallatin Valley. Nearly all water ultimately exiting the valley leaves in the Gallatin River at this location owing to a geologic restriction in this area. The drainage area above this station is 1,795 square miles.

Again, just above 70 percent of the surface water entering the Gallatin Valley is via the Gallatin River as measured at the mouth of the Gallatin Canyon (see Hackett, et al, 1960). The remainder is from other streams entering the valley. Interpretations involving the other streams are given in Hackett et al, 1960.

Figures 6-8a and 6-8b provide hydrograph and cumulative departure-from-average streamflow plots for the Gallatin River gaging stations extending from 1930 to present. An upward trend in the cumulative departure plot (lower plot) indicates a period of above average flow whereas downward trends indicate periods of below average flow. Relatively horizontal portions of a given plot demonstrate time periods when the flow is nearer the average flow. The following are general observations that can be made from these plots:

- The cumulative departure plots for both stations demonstrate that the longest period of low flow (drought) was during water years extending from the early 1930s to 1941.
- A long-term period of above average streamflow at Gallatin Gateway and Logan began in the early 1960s and extended to the mid-1970s.
- A more recent long-term period of low streamflow (drought) began about water year 2000 extending to about 2007.
- Most recently flows have tended to be above average.

6.2.4 Comparison of Streamflow to Precipitation

Again, streamflow in the Gallatin River watershed is highly dependent upon the magnitude of each year's snowpack (snow water equivalent). Figures 6-9a and 6-9b present plots demonstrating the relationship between snowpack and streamflow on the basis of cumulative departure-from-average plots between SNOTEL/Snow Course data and Gallatin River flows and show almost mirror images of cumulative departure trends.

Figure 6-10 presents regression plots of the relationship between precipitation, snowpack, and streamflow observations as measured south of Gallatin Gateway and at Logan. Again, this figure demonstrates that streamflow entering and exiting the valley is better correlated to snowpack than it is to direct valley precipitation.

This analysis demonstrates what is already well known. The amount of snowpack dominates the magnitude of streamflow entering and exiting the Gallatin Valley. In effect, the relatively lower snowpack in the period 1997 to 2008 explains the reason that flows in the Gallatin River in the valley have been below average over the same period. Similarly, snowpack has improved since 2008, and Gallatin stream flows have increased.

Annual Gallatin River flows were compared to the annual precipitation data at all three locations located in the valley. The Gallatin River flows demonstrated virtually no direct correlation to valley precipitation.

6.2.5 Groundwater Level Summary

According to the MBMG's GWIC database, there are about 12,871 wells, including both exempt and larger wells, present in the Gallatin Valley (see Figure 6-11). This includes water supply wells and monitoring wells. Twenty-nine of these wells are observation wells, which provide water level data for a continuous period of record of at least ten years (see Figure 6-12 and Plate 6-4). Review of the hydrographs shows most of the wells exhibit seasonal variations. Groundwater levels tend to increase during the late spring and early summer when recharge from precipitation, surface water flows, and surface water irrigation activity is highest. Generally, few wells have shown any persistent/long-term declines A Recent Montana Bureau of Mines and Geology groundwater study (2012 and 2014) also reports that subdivisions have had a minimal effect on groundwater levels in the Four Corners area to date.

6.3 Groundwater Use

6.3.1 Public Water Supply

Public water supply (PWS) is water supplied by public or privately owned utilities for public distribution (Cannon and Johnson, 2004). Any water system that provides water to at least 25 people for at least 60 days of the calendar year or has at least 15 service connections is considered by law to be a public supply. *See,* Mont. Code Ann. § 75-6-102(14). Water from public water supply systems is distributed to multiple users for domestic, commercial, industrial, and public uses. It should be noted that even exempt wells may be used as a public water supply system source as long as they meet the criteria defined above.

According to Cannon and Johnson, about 16,640 people in 2000 were served by public water supply systems using groundwater from both exempt and larger wells in Gallatin County. According to the MBMG (GWIC), as of 2015, there are currently about 505 public water supply wells in Gallatin County. PWS serve subdivisions, commercial/businesses, towns, etc.

According to Cannon and Johnson, 9,051 ac-ft per year were delivered for public water supplies in Gallatin County in 2000. It is assumed that about 40 percent of this delivered water is consumed. Therefore, the net consumption associated with public

water supplies from groundwater (exempt and larger wells)is estimated to be about 3,620 ac-ft per year.

6.3.2 Typical Domestic Consumption - Individual Wells

Domestic use is water used within the dwelling for domestic purposes (does not include irrigation). The withdrawal (e.g., total demand) from individual wells is estimated based on the number of domestic wells, 2.5 persons per dwelling (well), and the demand of 100 gpd per capita. This volumetric criterion is based upon the Montana Department of Environmental Quality (DEQ) standards for designing public water supply systems. The total consumptive use associated with this withdrawal is based on the consumption rate of 2 percent of the total withdrawal. The 2 percent criterion is based upon Kimsey and Flood (1987). According to MBMG GWIC data, there are 9,419 individual wells in the Gallatin Valley. Applying the above criteria, this would yield a net consumption of 53 ac-ft per year from exempt wells.

Nearly all consumptive use in the valley is from evapotranspiration by vegetation (includes both irrigated and non-irrigated land). Consumption from domestic (household) use and water surface evaporation is inconsequential when compared to evapotranspiration. The majority of all domestic water is recycled as treated effluent. Again, according to a Colorado study, household consumptive use (from showers, drinking, etc.) is typically less than 2 percent of daily demand. Thus, a conservative estimate of the net average consumption per household is 5 gallons per day under full-time occupancy. For the resort area of Big Sky, where a high percentage of homes tend to be occupied only a fraction of the year, the net consumptive use for household use is more likely about 1 to 2 gallons per household per day.

6.3.3 Lawn and Garden - Individual Wells

Review of aerial mapping reveals a wide range in the size of irrigated domestic lawns in the Gallatin Valley. NE&W performed a qualitative evaluation of lawn sizes in the Gallatin Valley using GIS data including infrared aerial photography and subdivision mapping. Five rural subdivisions that utilize individual wells were targeted and assessed for a “typical” lawn size. Based on this evaluation, NE&W found that the most representative irrigated lawn size for the rural subdivisions in the valley examined ranges from about 0.4 to 0.5 acres. Some properties tend to irrigate greater acreages

while others tend to irrigate less.

Assuming that each individual well irrigates 1/2 acre of lawn and garden results in about 4,710 irrigated acres with net consumptive use in the Gallatin Valley of 6,452 ac-ft.

It should be noted that evapotranspiration for native vegetation occurred prior to irrigation activity. Hence, only the net increase in evapotranspiration associated with irrigation activity should be quantified in order to accurately portray the impact of irrigation on the water budget.

The irrigated acreage per lot in the Big Sky area is substantially less when compared to the Gallatin Valley. Also, because of the relatively higher precipitation at Big Sky, the overall net consumptive increase per acre in the Big Sky area is much smaller. In fact, in many cases, the net runoff from impermeable surfaces may actually either offset, or more than offset, the net consumption associated with lawn irrigation. Again, this points out the need to consider all components of the water budget before making predictions about consequences.

6.3.4 Agricultural Irrigation

Again, by far the dominant use of water in the Gallatin Valley watershed is agricultural irrigation. Historically, most of the irrigation water is from surface water sources. However, from the 1970s to the 1990s there was an increasing trend toward use of groundwater as a supply source. Some of this groundwater irrigation activity likely has evolved as follows to:

- Irrigate new land(s)
- Supplant surface water source(s)
- Serve as a supplemental source of irrigation water

USDA Census of Agriculture data (http://www.agcensus.usda.gov/) provides information about the quantity of irrigated land in Gallatin County. As of the 2012 census, there were 323,231 acres of land in irrigated farms and 79,100 acres were irrigated in that year.

NE&W also evaluated the irrigated land census data from 1982 to 2012 (five year

census cycle) to assess if there was an overall decline in irrigated acreage.

Year	Acres
1982	87,424
1987	99,806
1992	94,547
1997	90,671
2002	**101,823**
2007	81,651
2012	79,100

The maximum acreage is indicated in **bold** and the minimum underlined.

The census data show that irrigated acreage in the valley has decreased by about 22,000 acres from 2002 to 2012 (see Figure 6-13).

Cannon (2004) projected 115,960 ac-ft of consumption associated with agricultural irrigation in Gallatin County in 2000. Cannon also projected 97,540 ac-ft of consumption in the Gallatin watershed. Given that most of the agricultural development is in the Gallatin Valley, this latter consumption value should be reasonably representative of the consumption for the Gallatin Valley.

6.3.5 Industrial use

According to Cannon and Johnson (2004) approximately 101 ac-ft of groundwater is used for industrial purposes in Gallatin County. The relative amount that is consumed is unknown.

6.4 Water Budget Summary

This water budget summary includes the following components:

- Water budget for the average year
- Water budget for a dry (drought) year

- Discusses factors that can affect the water budget including the significance of long-term drought, housing development, agricultural development, etc.
- Presents implications of future projected population growth in the Gallatin Valley and the accompanying groundwater development on the water budget and streamflows in the valley

Figure 6-15 provides a water budget for the annual flows for the Gallatin Valley for an average water year. The basis of this figure is developed from the information set forth previously. It also adapts information presented in Hackett, et al (1960). Figure 6-16 provides another valley water budget example under conditions representative of a drought year using 2001 SNOTEL records, precipitation, and streamflow data. The groundwater storage is assumed to be constant from year to year in each of these situations. Again, in order for storage to change there would need to be either an overall decline in groundwater levels (reduced storage) or an overall increase in groundwater levels (increased storage). Given that groundwater levels have been relatively stable, the assumption that groundwater storage is constant is deemed appropriate.

Referring to Figure 6-15, the amount of water entering the Gallatin Valley for an average year may be subdivided as follows:

- Surface-water flow into the valley is 747,600 acre-ft;
- Direct precipitation is 465,000 acre-ft.

Hence, based upon the aforementioned assumptions, the total estimated inflow into the valley is 1,212,600 acre-ft per year.

The amount of water leaving the valley each year may be subdivided as follows:

- Surface-water flow: 827,300 acre-ft (water leaving the valley at Logan)
- Evaporation and transpiration: 385,300 acre-ft

These amounts do not include the water entering and exiting the valley at its boundaries as groundwater under-flow. The latter contributions are considered to be small in comparison to the above factors. The actual underflow exiting the valley is probably substantially smaller than that entering the valley.

Nearly all the evaporative loss in the valley is from evapotranspiration by vegetation (includes both irrigated and non-irrigated land). Based upon information and calculations performed heretofore, the evaporation and transpiration can be subdivided as follows:

- Agricultural irrigated crops (97,540 ac-ft) [Gallatin County]
  - Surface water (93,880 ac-ft)
  - Groundwater (3,660 ac-ft)
- Public water supply
  - Surface water (2,272 ac-ft)
  - Groundwater (1,349 ac-ft)
- Individual well lawn/garden irrigation (6,452 ac-ft)
- Individual well domestic consumption (53 ac-ft)
- Cottonwoods and willows (60,000 ac-ft)
- All other evaporation and evapotranspiration (318,800 ac-ft) [this is mainly evapotranspiration valley-wide (exclusive of irrigation consumptive use and phreatophytes), but it includes other factors such as free water surface evaporation, etc.].

Figure 6-16 provides the same information but considers a drought year using year 2001 data.

Figures 6-17 through 6-19 compare the consumptive uses from above to provide a graphical representation of the relative significance of the various consumptive uses on the overall water budget. Figure 6-17 presents comparisons of consumptive uses to inflows from streamflow and precipitation into the valley for a normal year. Figure 6-18 provides comparisons of consumptive uses to inflows from streamflow and precipitation into the valley drought year. Figures 6-19 gives consumptive uses compared to estimated aquifer storage in the Gallatin Valley.

Based upon the above assessment, it is obvious that the level of groundwater

development on the overall water budget when compared to streamflow of the Gallatin River is insignificant.

6.5 Water Use Projections

The relative significance of future growth in the Gallatin Valley can be evaluated by projecting future demands and comparing those demands to the overall water budget developed previously.

There is significant uncertainty related to projecting population growth in efforts to project future demands. This evaluation utilizes a combination of historical population growth and Montana Department of Commerce population growth projections to projecting future demand in Gallatin County and in Montana

The population of Gallatin County increased by 21,682 from 2000 to 2010. Based on 2.5 persons per dwelling, this results in an increase of about 8,673 new dwellings. Based on historical ratios, about 2,962 new dwellings utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of 2,039 ac-ft as of 2010.

The Montana Department of Commerce reports population projections provided by eREMI (a product of Regional Economic Models Inc.). The latest available projections are dated April 2013. These projections show the population of Gallatin County increasing from 89,513 per the 2010 census to 116,627 in 2030. It is assumed that about 2.5 persons per dwelling results in 10,846 new dwellings over that same time period. Based on historical ratios, about 3,704 new dwellings will utilize individual wells. If it is assumed that the average irrigated area per dwelling is 0.5 acres, this equates to a consumptive use increase of about 2,537 ac-ft due to additional individual wells by year 2030. This also equates to about 0.3 % of the flow leaving the valley at Logan each year during a normal flow year.

From a public water supply perspective, it is assumed that such consumption will increase similarly in proportion to population growth. Thus, the net increase in consumption for public water supplies sourced by groundwater (from both exempt and larger wells) is estimated at 1,464 ac-ft from 2000 to 2010 and projected to be an additional 3,205 ac-ft per year by 2030.

The USDA Census of Agriculture irrigated acreage irrigation data can be used to illustrate this. The ten year average of irrigated acreage in Gallatin County was quantified for two different periods of time with the following results:

- 1982 through 1992 93,926 acres
- 2002 through 2012 87,525 acres

This represents a 6,401 acre decline in irrigated crop land in Gallatin County. Using the Blaney-Criddle approach, this represents a decrease in consumption of about 11,050 ac-ft. Therefore, much of the projected increase in consumption from population growth in Gallatin County will likely be offset by decreased consumption from agricultural irrigation. It should be noted as well that either with a decrease or increase in irrigated land from subdivision development, any net change will simply be too small to be manifested at any detectable level in the Gallatin River. Hence, as a practical matter, the overall consumptive use in the valley will likely decrease with additional housing development in the future with growth. Therefore, actual flows leaving the Gallatin Valley will likely increase simply because less land in total will be irrigated.

6.6 Projected Increase in Consumptive Use Versus Seasonal Streamflow

The relative significance of projected increases in consumptive use from individual wells can be compared to gaged streamflow. The projected increased consumption from individual wells for Gallatin County from 2010 to 2030 is 2,537 ac-ft. Note that wells are distributed over relatively broad areas of the Gallatin Valley. Hence, it is deemed reasonable to assume that the relative depletion associated with this projected growth can be defined using a steady-state approximation in 2030. This equates to about 3.5 cfs of depletion in the Gallatin River at Logan.

Figures 6-20a through 6-20c compare the relative significance of the projected depletions on streamflows as measured at the Gallatin River at Logan. A 5 percent flow measurement accuracy criterion is shown on each figure to assess if it is possible that a depletion of 3.5 cfs would be detectable in the gaging data. If the 5 percent flow measurement criterion were to fall below the projected depletion of 3.5 cfs, then the projected change would be considered potentially detectable. Otherwise, the projected change is considered not detectable.

Given that the 3.5 cfs depletion falls far beneath the 5 percent flow measurement criterion, it is concluded that the relative significance of the individual well growth would not be detectable in the flows as measured at the Gallatin River at Logan.

Again, the projected relative change on a year to year basis is about 0.175 cfs (79 gpm). It is obvious that any year to year change would not be detectable in the Gallatin River. Finally, it should be noted that the projected depletion does not account for changes in streamflow associated with potential land use change transitions from irrigated agriculture to residential subdivisions. The trend has been for much of the new development to occur on previously irrigated farmland. As development uses less water compared to agricultural irrigation, the result is a net increase in water availability. As such, the new development generally does not impact the ability of existing surface water appropriators to fully utilize their water rights.

rec'd by LEPO April 13, 2016

GALLATIN Watershed

Slope Classes from NED

0 5 10 15

Mapscale 1: 488000 Scale in miles:

- County Border
- Highway
- Fourth Code Watersheds
- 0 < X < = 4
- 4 < X < = 10
- 10 < X < = 30
- 30 < X < = 45
- 45 < X < = 60
- 60 < X = 90
- Flat, 0

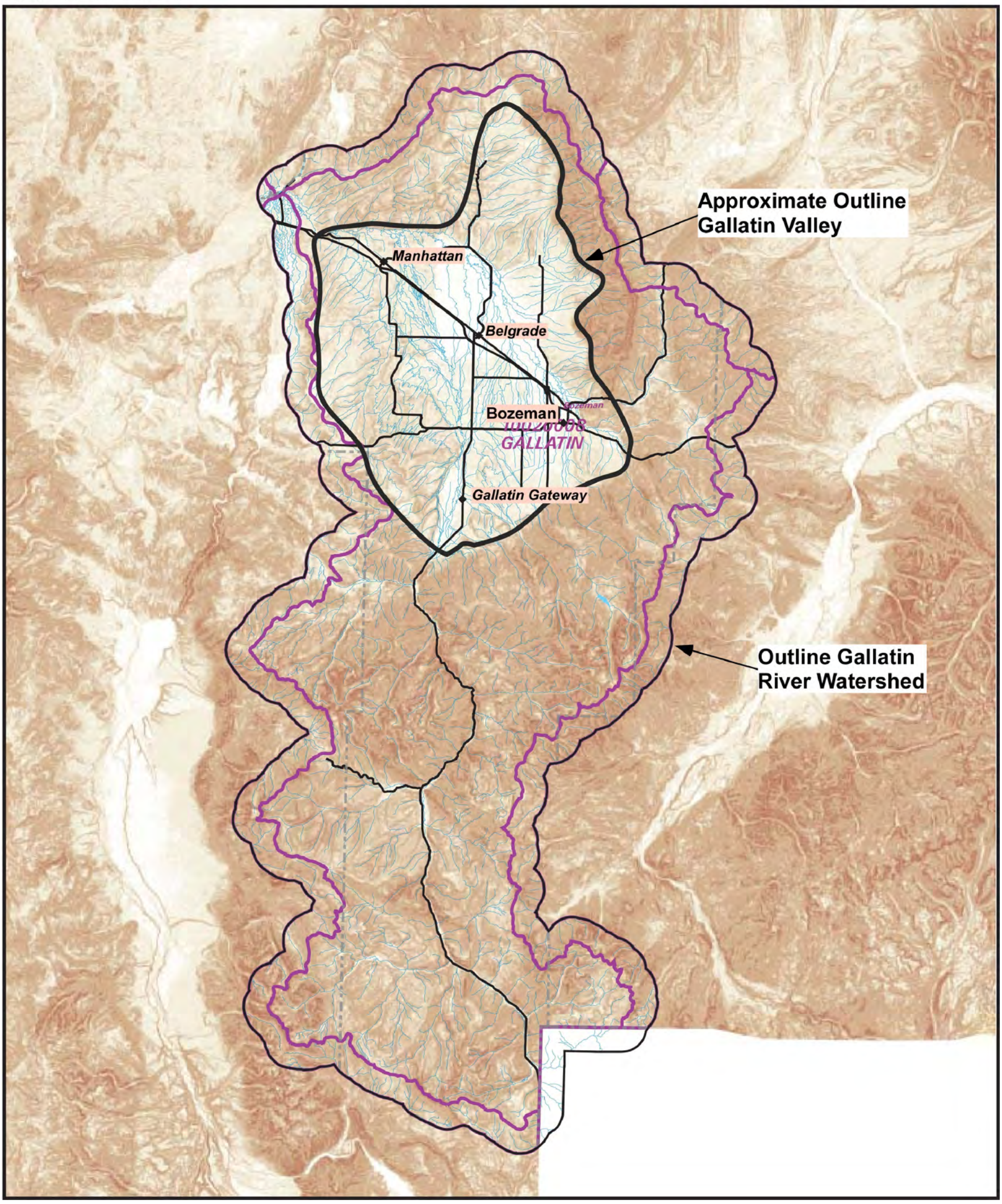
SOURCE:
US Geological Survey National Elevation Dataset (NED) files.
NED has been developed by merging the highest resolution elevation data available for the United States into a seamless dataset.
The slopes displayed are derived from the NED solely to illustrate one application of the dataset. This slope data is intended to display slope patterns, rather than a particular point of slope.

MONTANA Natural Resource Information System
Montana State Library – 1515 East 6th Avenue
Helena, Montana – (406) 444-5357

Date created: December 03, 2003

Map Request: 04MSL0001 - 10020008 - SLOPE

This map is to be used as a primary reference source and is not intended for use in site - specific planning. This is public information and may be interpreted by organizations, agencies, units of government, or others, based on needs; however,they are responsible for the appropriate application. Federal, State, or local regulatory bodies are not to reassign to the Natural Resource Information System any authority for the decisions they make.



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Date: 12/16/2015
File: Figure 6-1

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Figure 6-1
Gallatin River Watershed
Montana Natural Resource Information System Report

rec'd by LEPO April 13, 2016

Legend

- Snotel Station Used in Report Evaluations
- Snotel Station Not Used in Report Evaluation

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Date: 12/21/2015
File: Figure 6-2

3.5 Miles

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Figure 6-2
SNOTEL Stations
Gallatin Watershed

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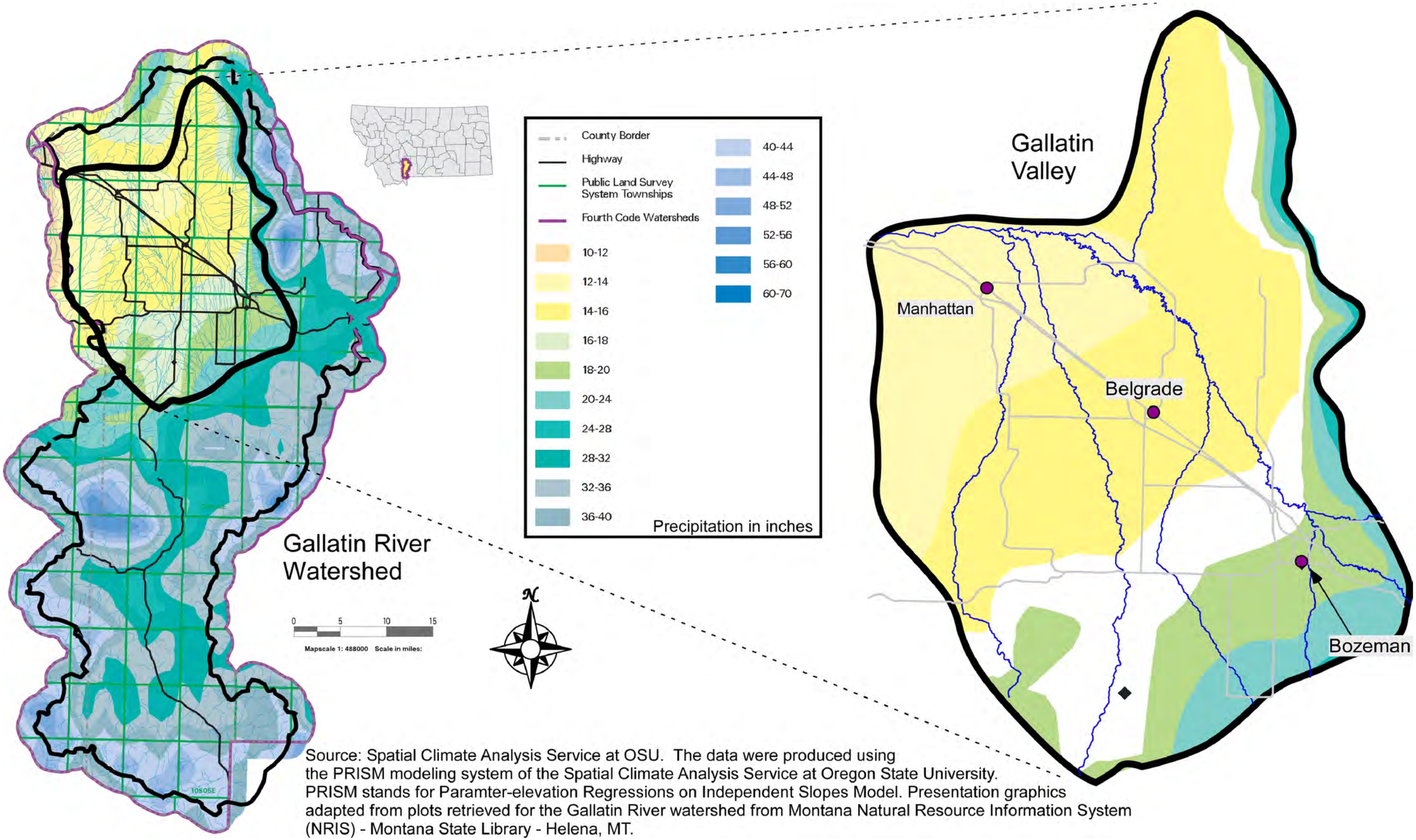

Source: Spatial Climate Analysis Service at OSU. The data were produced using the PRISM modeling system of the Spatial Climate Analysis Service at Oregon State University. PRISM stands for Paramter-elevation Regressions on Independent Slopes Model. Presentation graphics adapted from plots retrieved for the Gallatin River watershed from Montana Natural Resource Information System (NRIS) - Montana State Library - Helena, MT.

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Date: 12/16/2015
File: Figure 6-3

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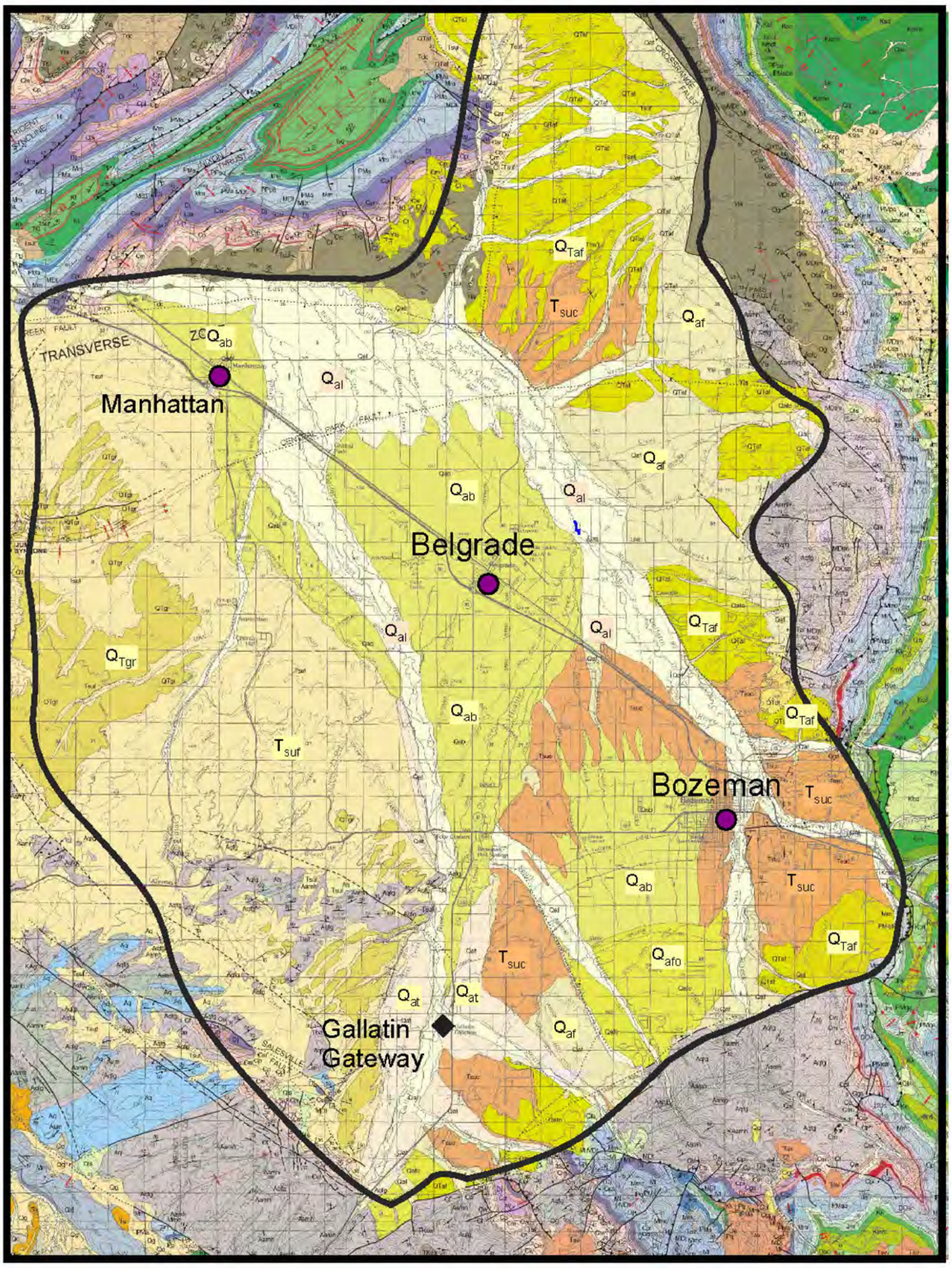
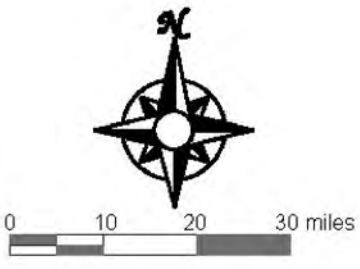
Figure 6-3
Annual Precipitation
Gallatin Watershed and Gallatin Valley

rec'd by LEPO April 13, 2016



Dominant Gallatin Valley Geologic Facies

Qal	Alluvium (Holocene)
Qat	Alluvial terrace deposit (Holocene and Pleistocene)
Qaf	Alluvial fan deposit (Holocene and Pleistocene)
Qgr	Gravel deposits, undivided (Holocene and/or Pleistocene)
Qab	Alluvial braid plain deposit (Holocene? and Pleistocene)
Qat	Alluvial terrace deposit (Pleistocene)
Qafo	Older alluvial fan deposit (Pleistocene)
Qg	Glacial deposits, undivided (Pleistocene)
QTgr	Gravel deposits (Pleistocene, and/or Pliocene)
Qtaf	Alluvial fan deposit (Pleistocene and/or Pliocene)
Tsuf	Dominantly fine-grained facies (Miocene)
Tsuc	Dominantly coarse-grained facies (Miocene and Pliocene?)



Adapted from PRELIMINARY GEOLOGIC MAP OF THE BOZEMAN 30' x 60' QUADRANGLE SOUTHWESTERN MONTANA Compiled and mapped by Susan M. Vuke, Jeffrey D. Lonn, Richard B. Berg, and Karl S. Kellogg; Montana Bureau of Mines and Geology Open File Report MBMG 469, 2002.
GEOLOGIC MAP OF THE LIVINGSTON 30' x 60' QUADRANGLE SOUTH-CENTRAL MONTANA by Richard B. Berg, David A. Lopez, and Jeffrey D. Lonn, Montana Bureau of Mines and Geology Open File Report MBMG 406, 2000.

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Figure 6-4
Dominant Geologic Units
Galatin Valley

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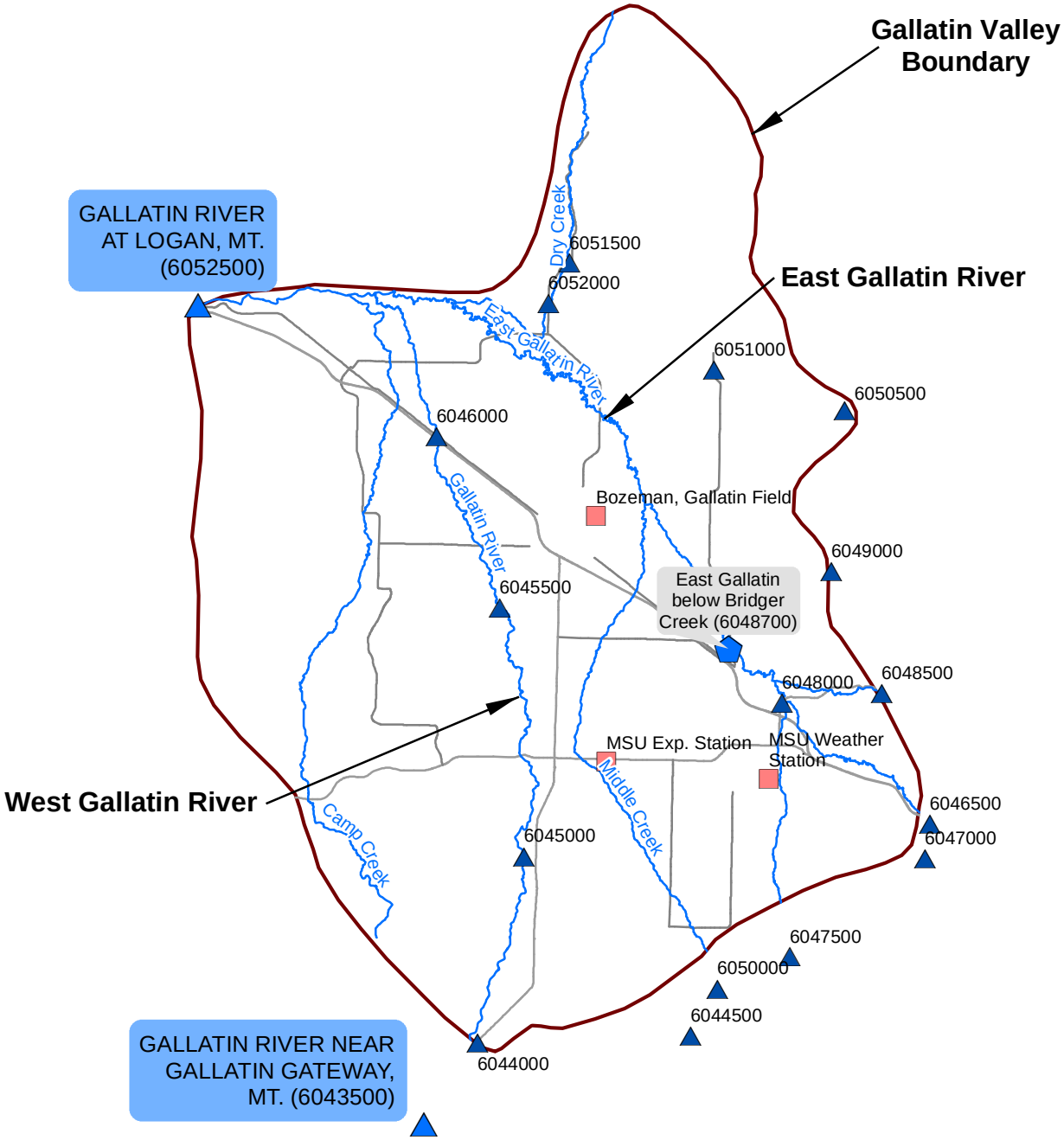

Legend

- Weather Station
- Active gaging stations with brief measurement record.
- Active gaging stations with extensive measurement
- Inactive gaging stations with brief measurement record (many were part of an 1950s investigation conducted by the U.S. Geological Survey (Hackett, et al, 1960)).

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Date: 12/23/2015
File: Figure 6-5

2 Miles

Notes:
1) Data source is MBMG GWIC and Montana State Library, NRIS

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Figure 6-12
Observation Wells
Gallatin Valley

Refer to Plate 6-1 for Hydrographs

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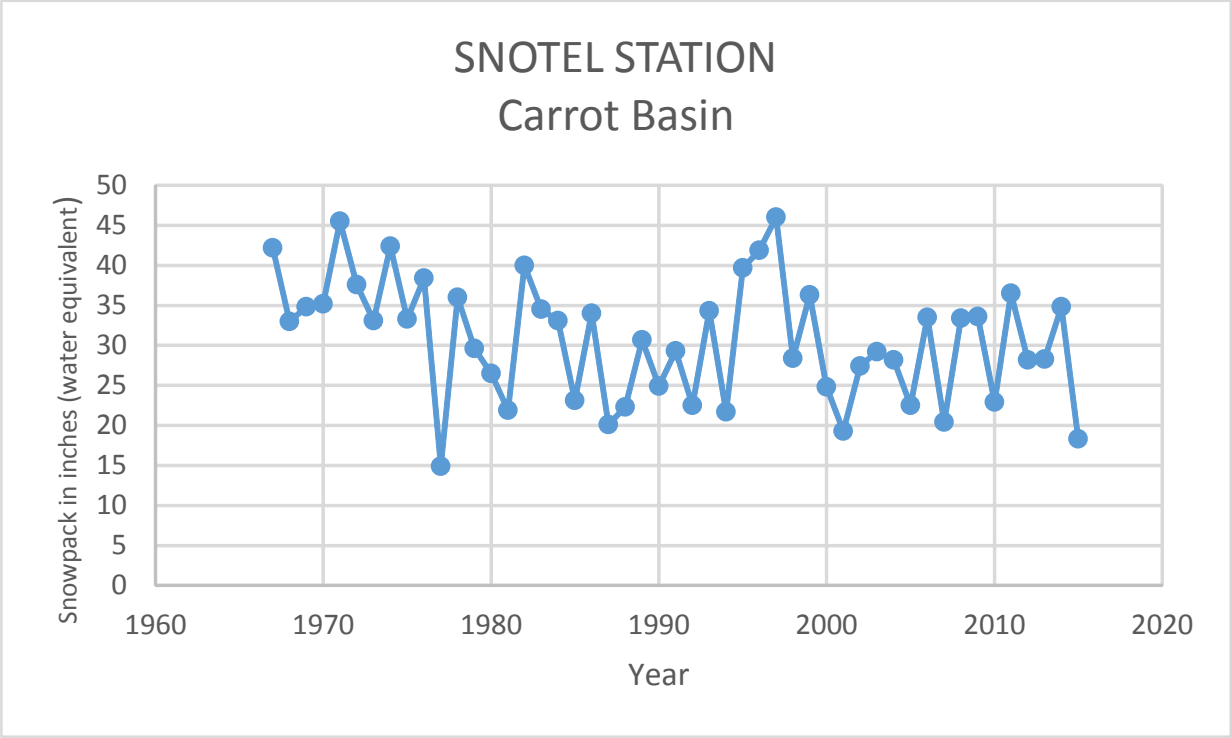

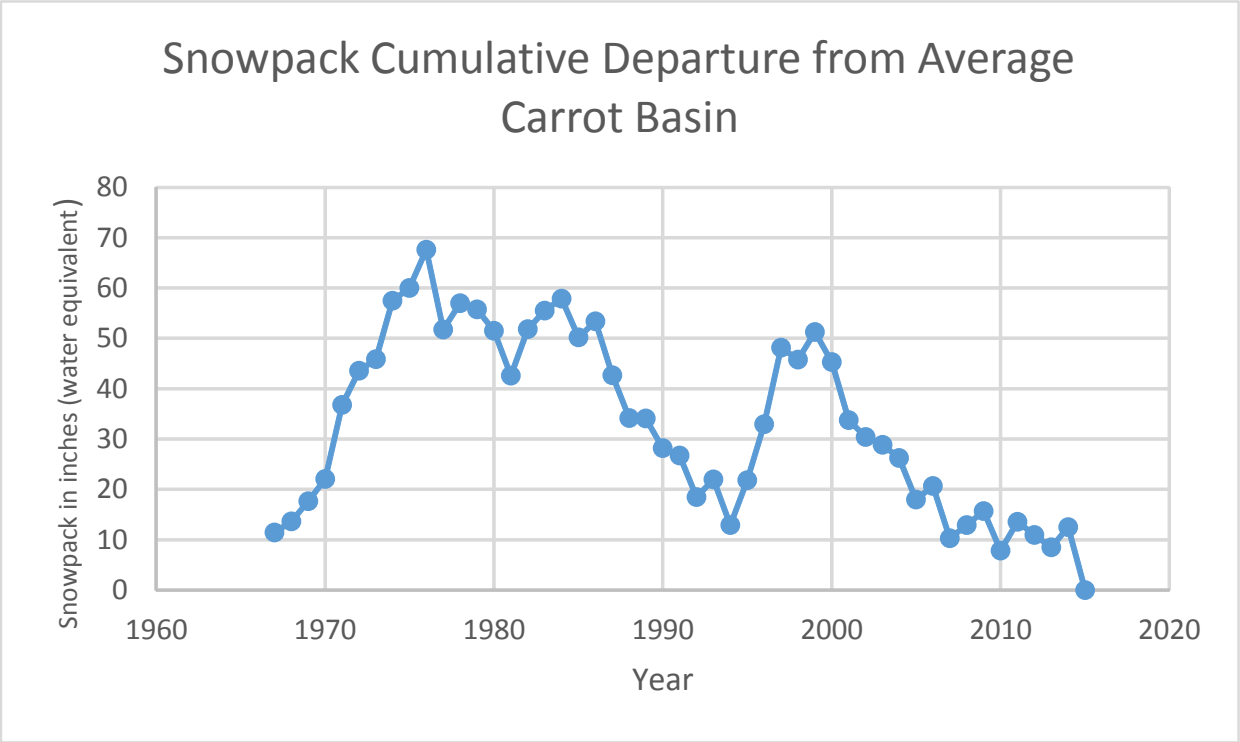

NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-6a

Notes:
Data Source: National Water and Climate Center
For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends imply periods of below average snowpack.

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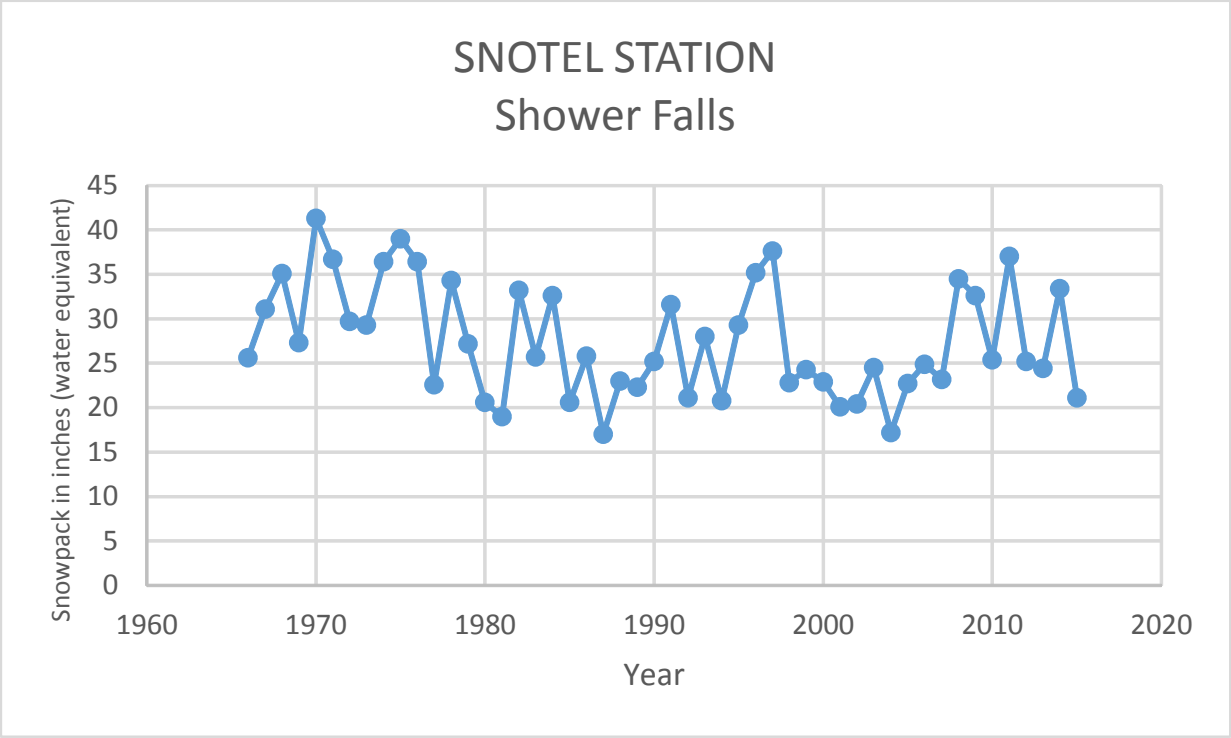
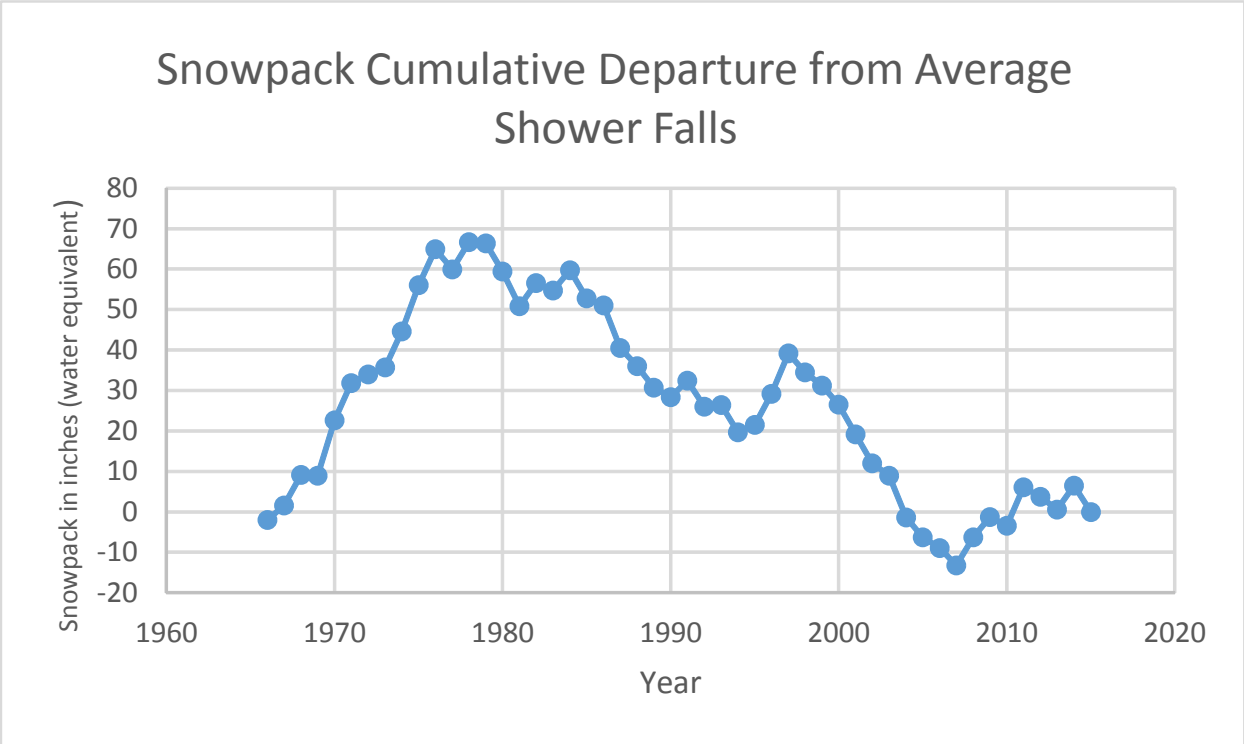
Figure 6-6a
SNOTEL Data Summary
Carrot Basin

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-6b

Notes:
Data Source: National Water and Climate Center
For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends imply periods of below average snowpack.

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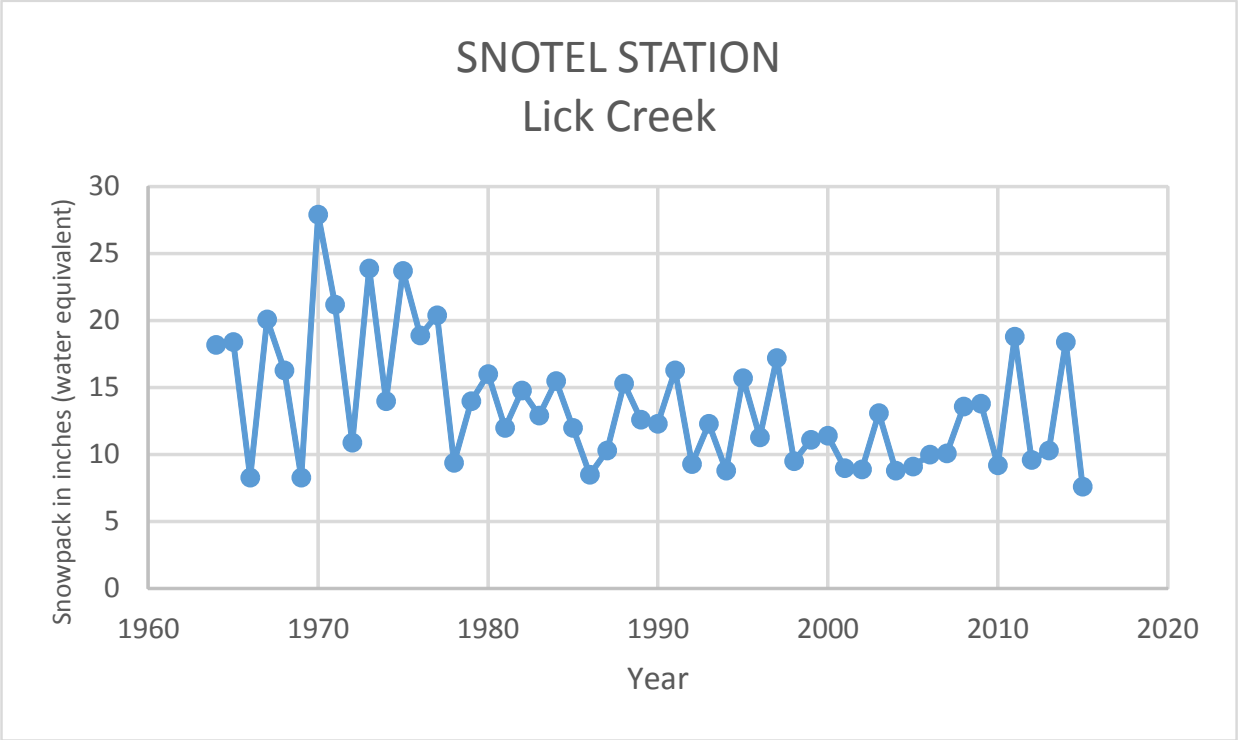
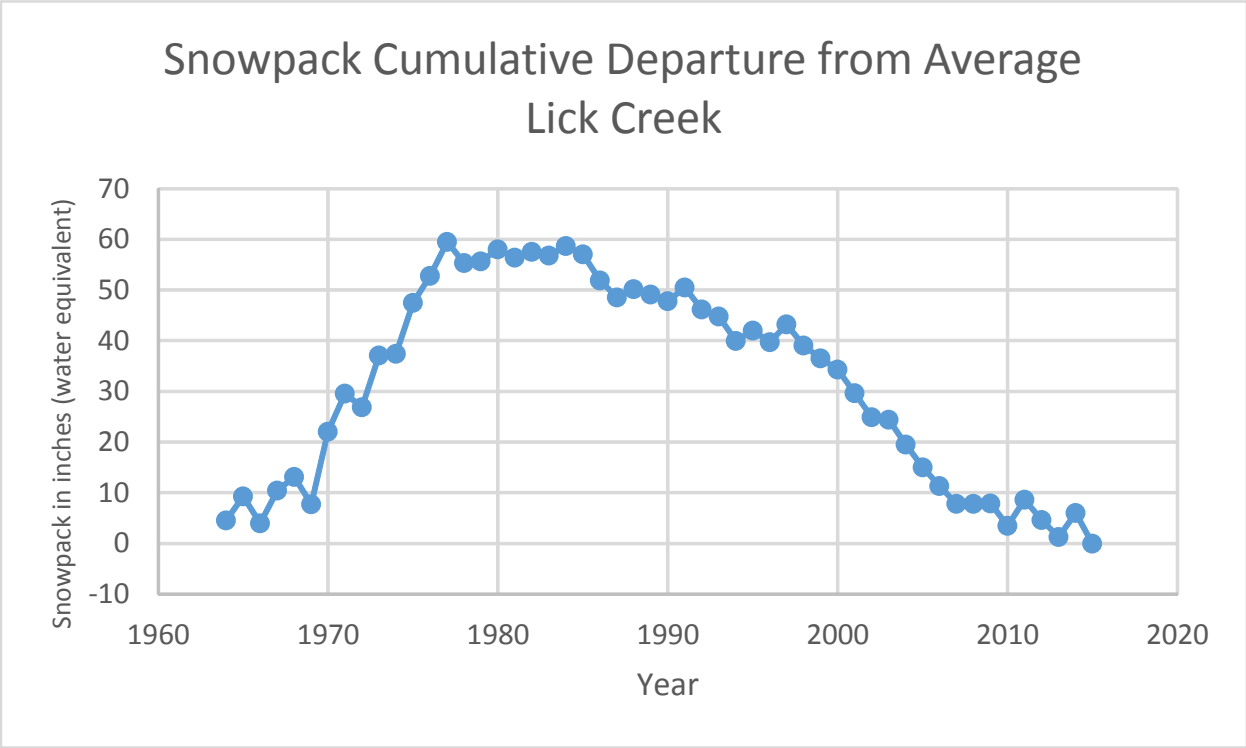
Figure 6-6b
SNOTEL Data Summary
Shower Falls

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-6c

Notes:
Data Source: National Water and Climate Center
For the cumulative departure from average plot, upward trends imply a period of above average snowpack whereas downward trends imply periods of below average snowpack.

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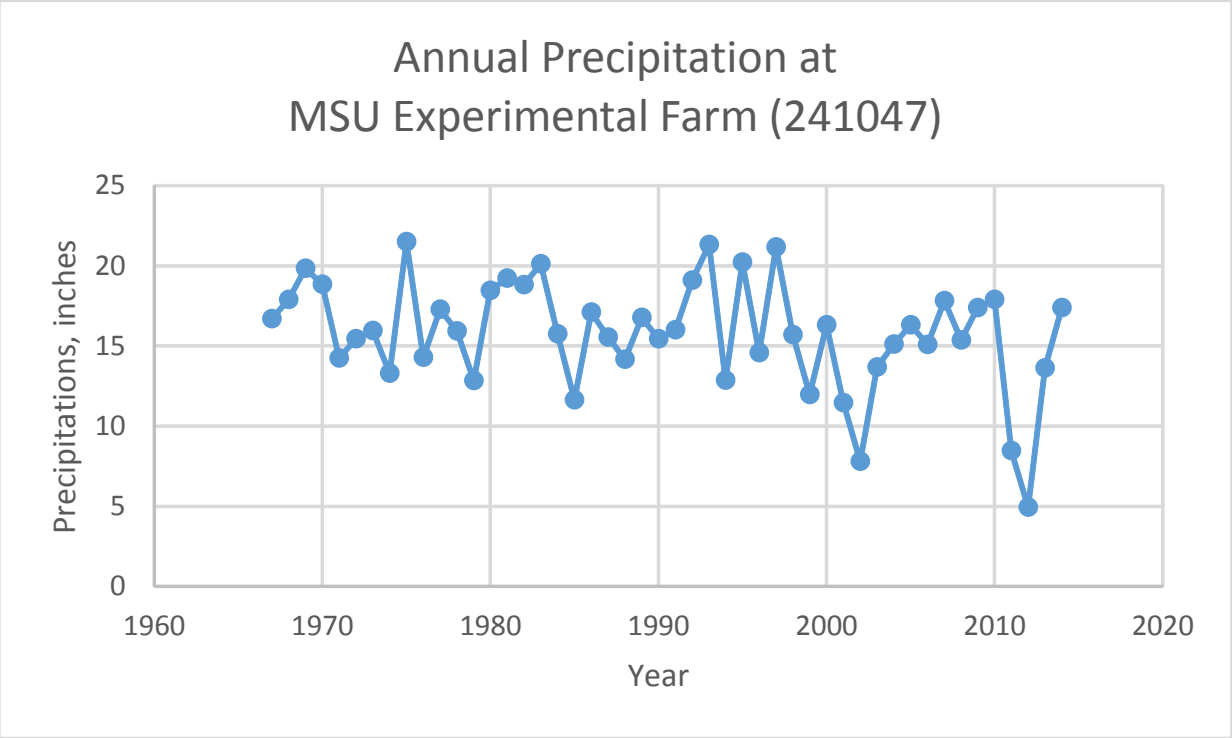
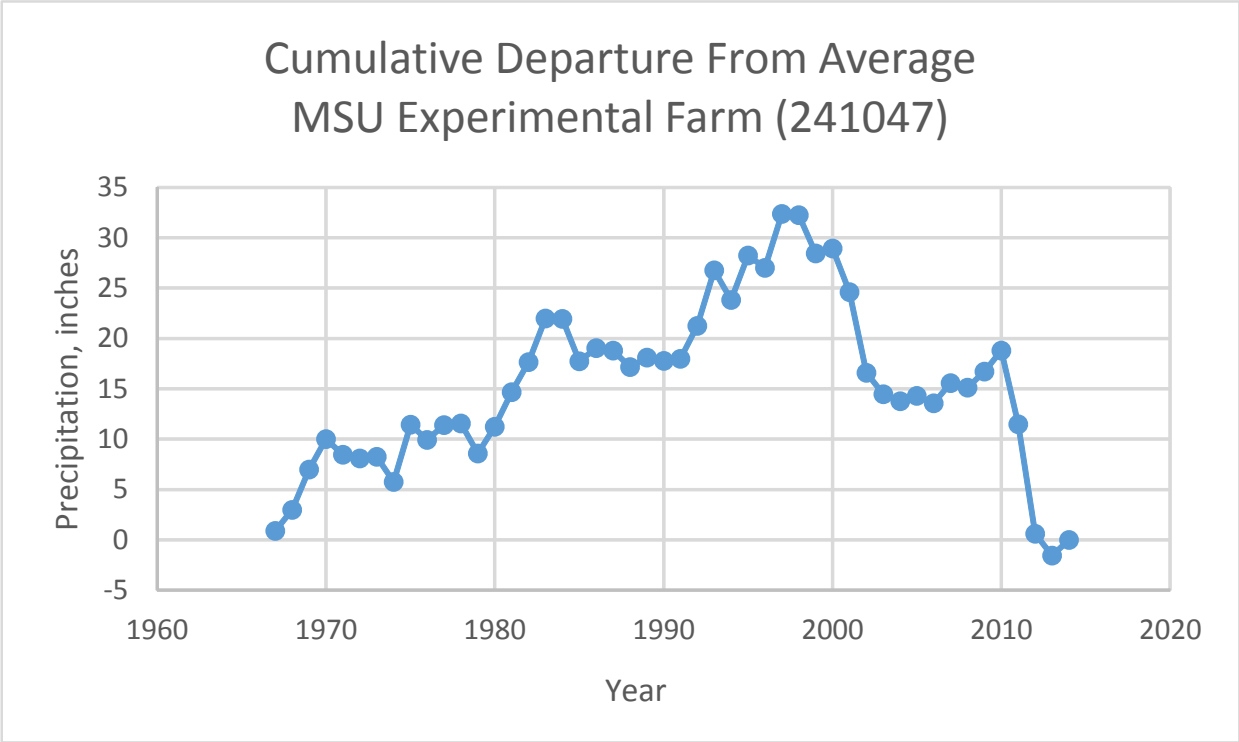
Figure 6-6c
SNOTEL Data Summary
Lick Creek

rec'd by LEPO April 13, 2016





Notes:

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Date: 12/14/2015
File: Figure 6-7a

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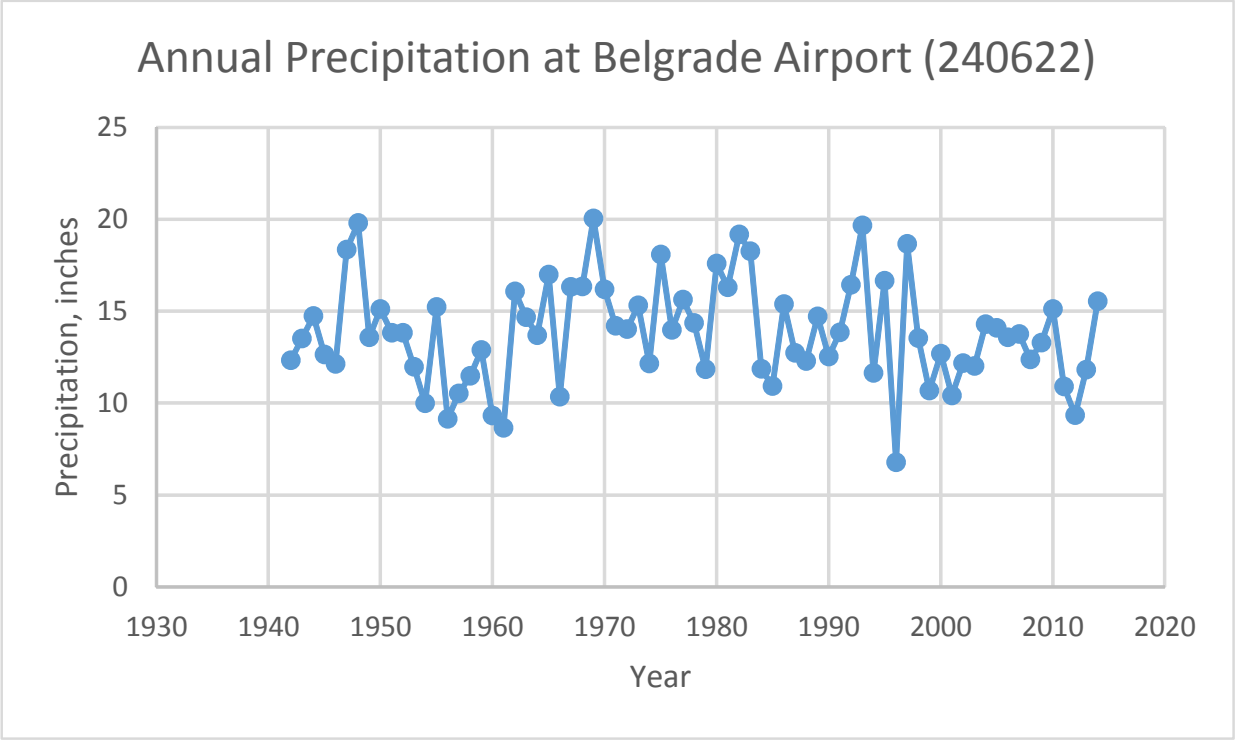
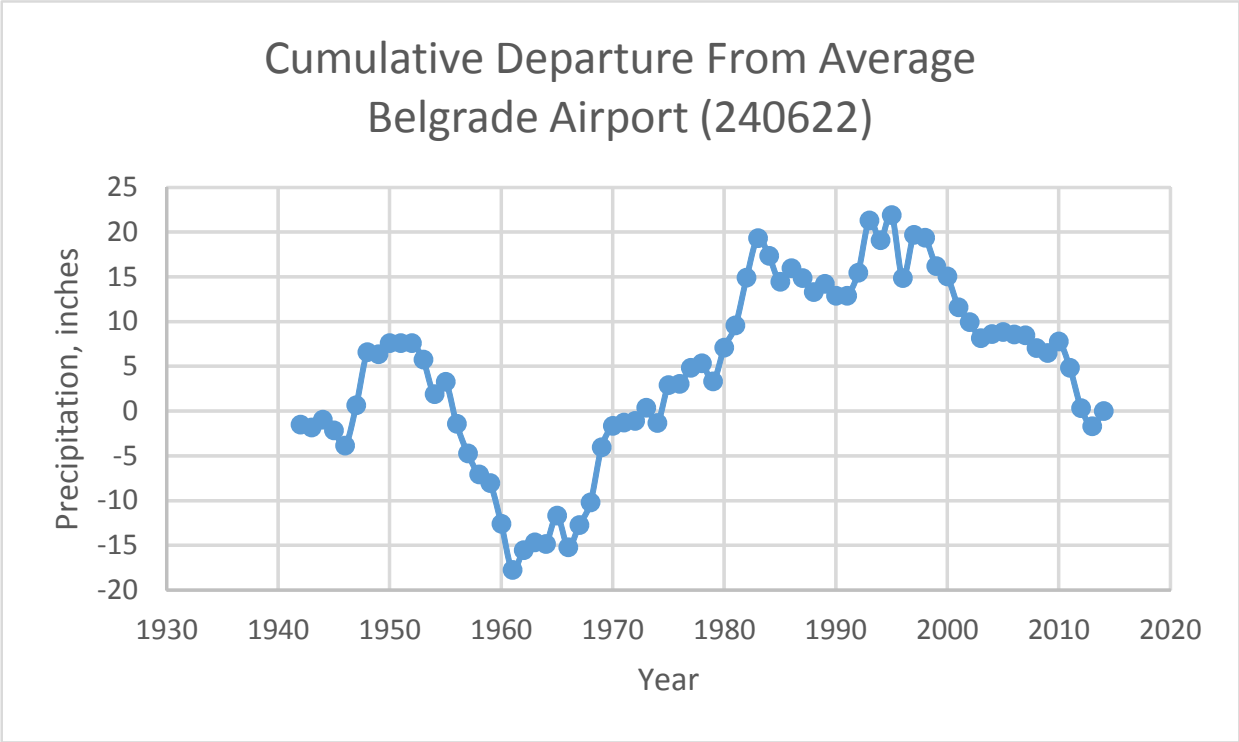
Figure 6-7a
Annual Precipitation and Cumulative Departure from Average
MSU Experiment Station

rec'd by LEPO April 13, 2016





Notes:

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Date: 12/14/2015
File: Figure 6-7b

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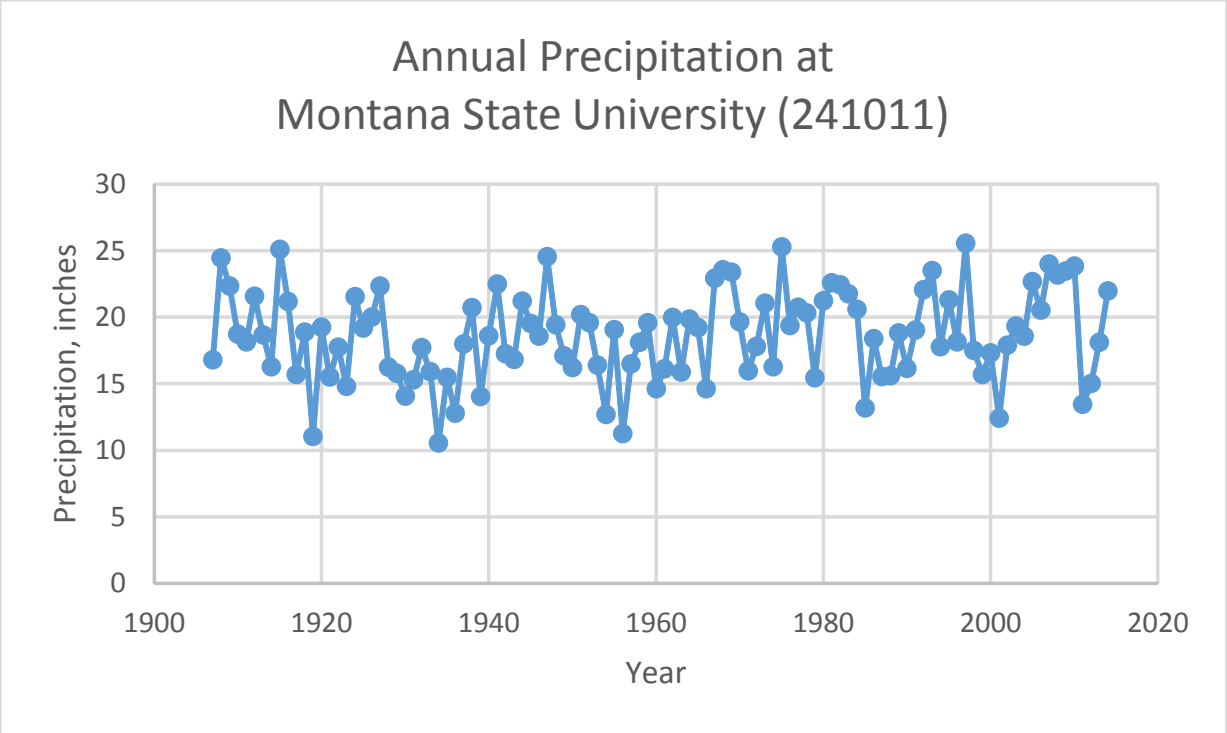
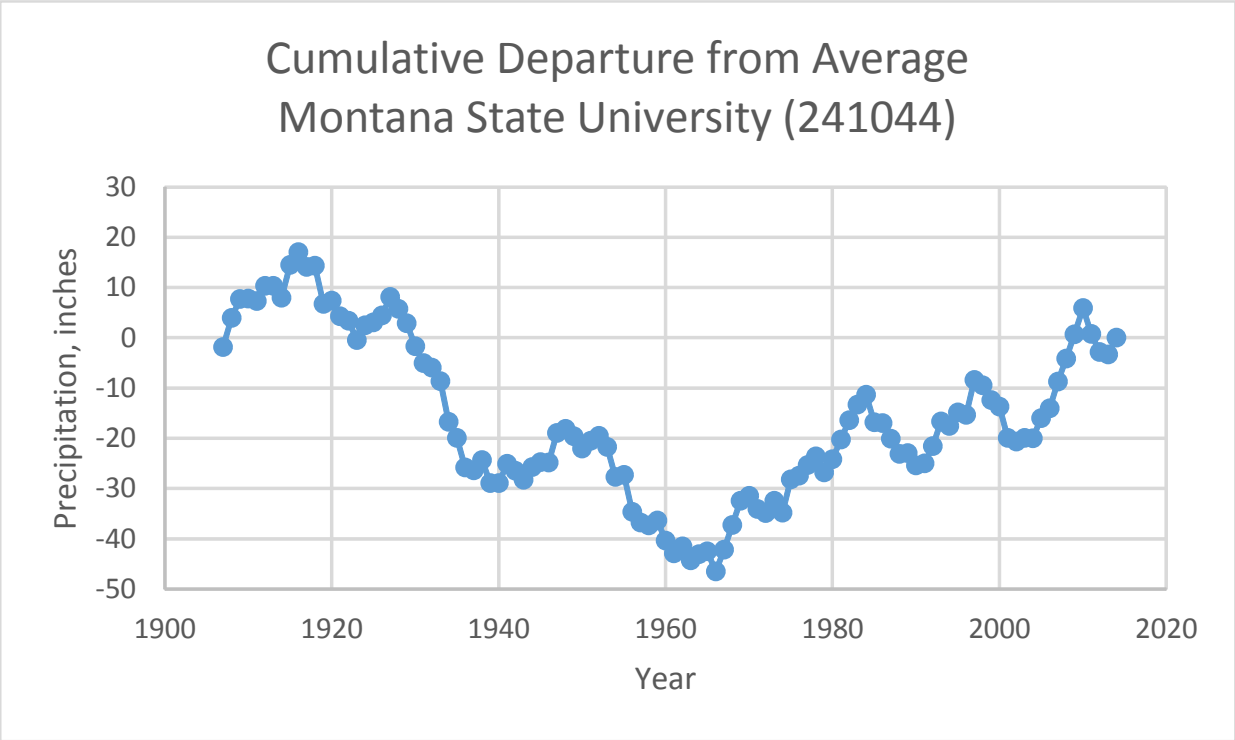
Figure 6-7b
Annual Precipitation and Cumulative Departure from Average Belgrade Airport

rec'd by LEPO April 13, 2016





NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-7c

Notes:
Data source: Western Regional Climate Center

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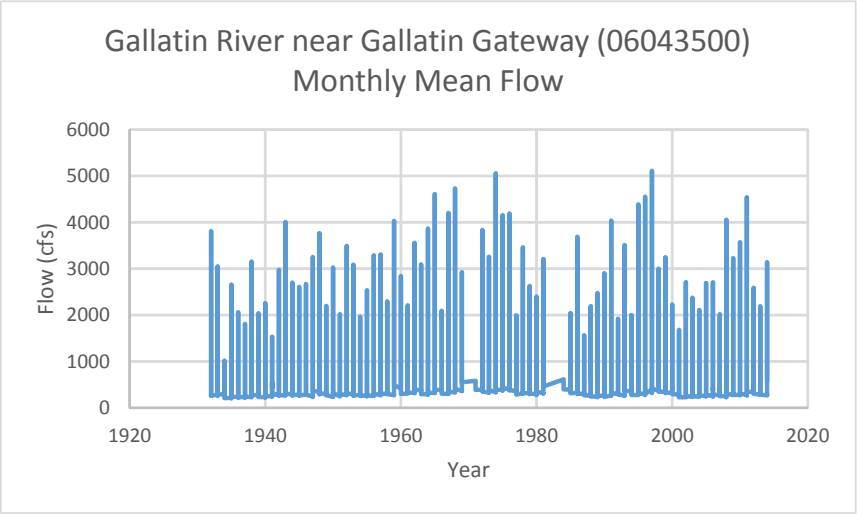
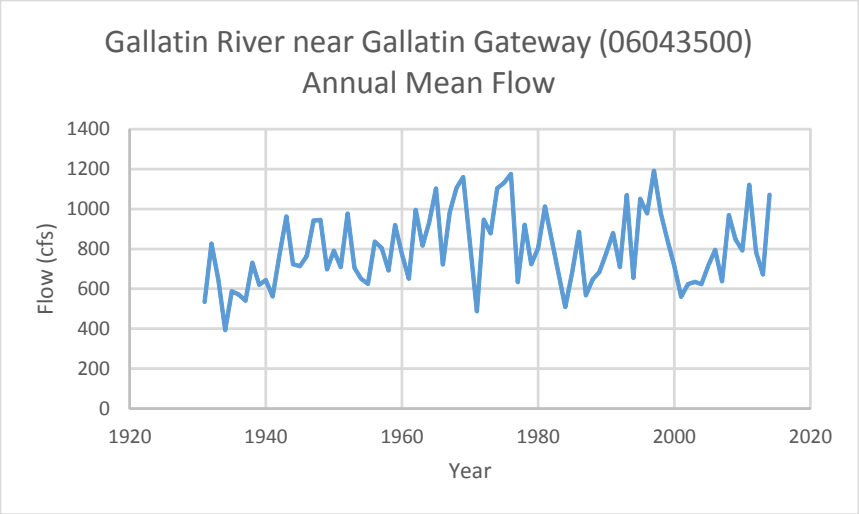
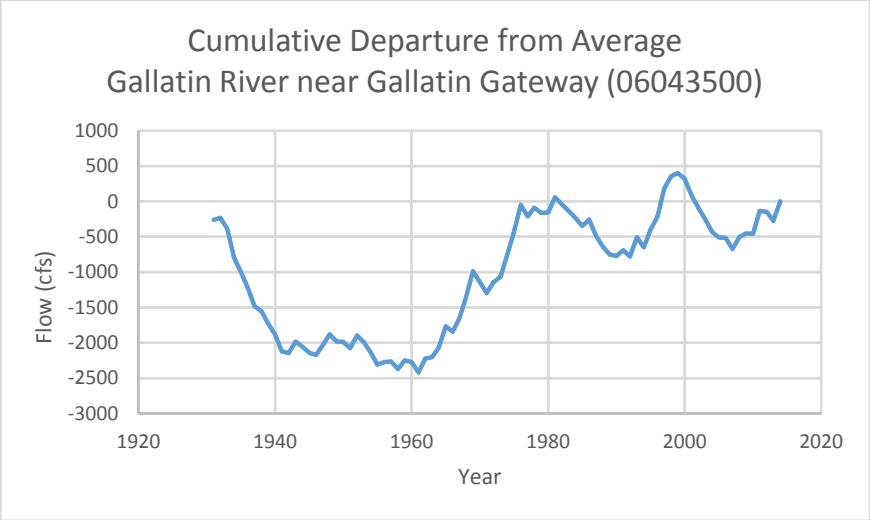
Figure 6-7c
Annual Precipitation and Cumulative Departure from Average
Montana State University

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-8a

Notes:
Data source: USGS

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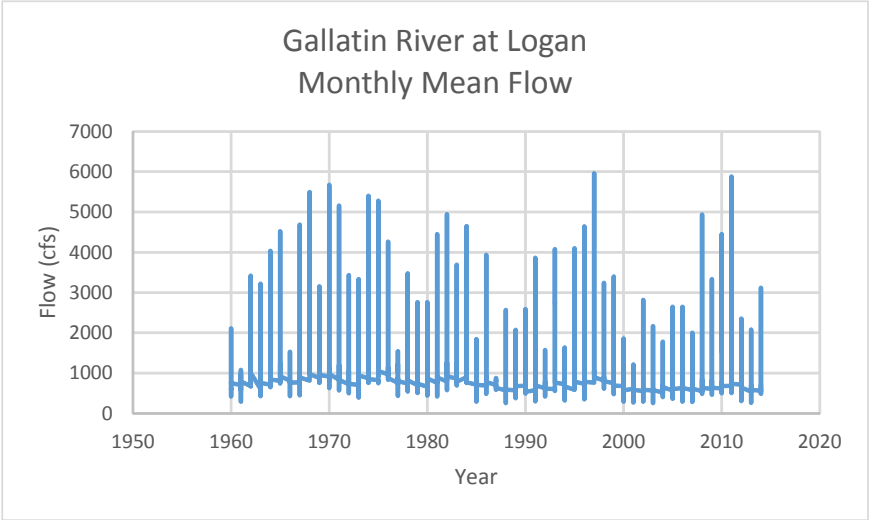
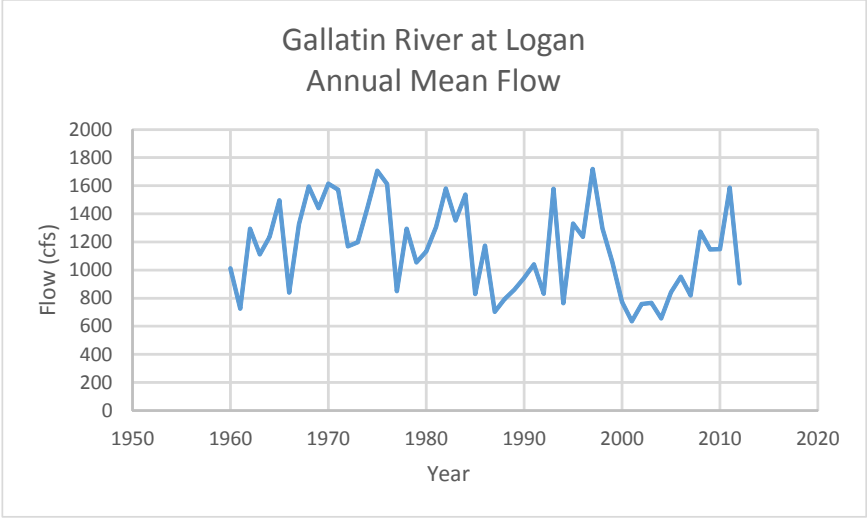
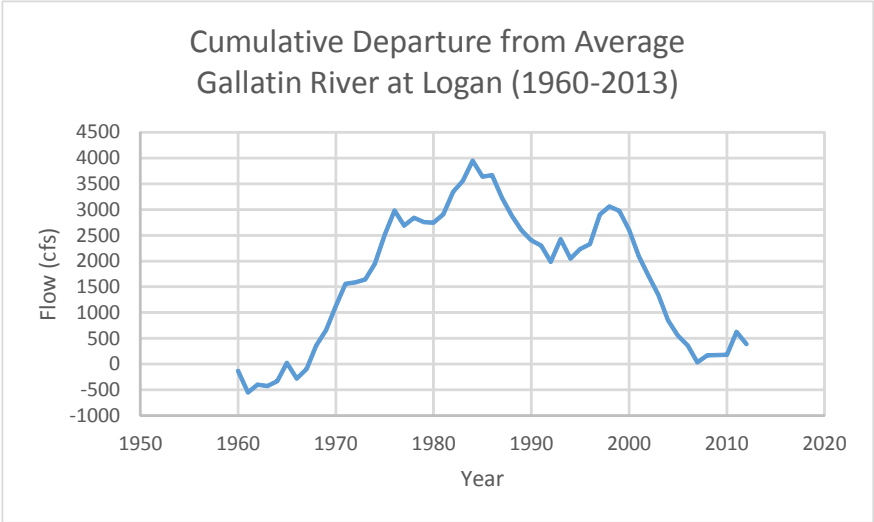
Figure 6-8a
Stream Discharge
Gallatin River Near
Gallatin Gateway

rec'd by LEPO April 13, 2016







NICKLIN EARTH & WATER, INC.

Date: 12/14/2015
File: Figure 6-8b

Notes:
Data source: USGS

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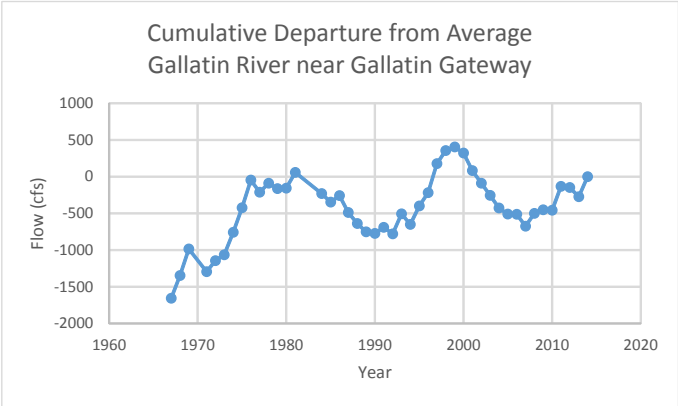
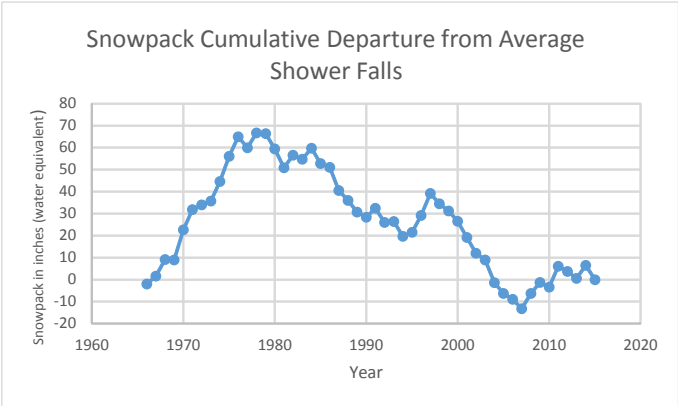
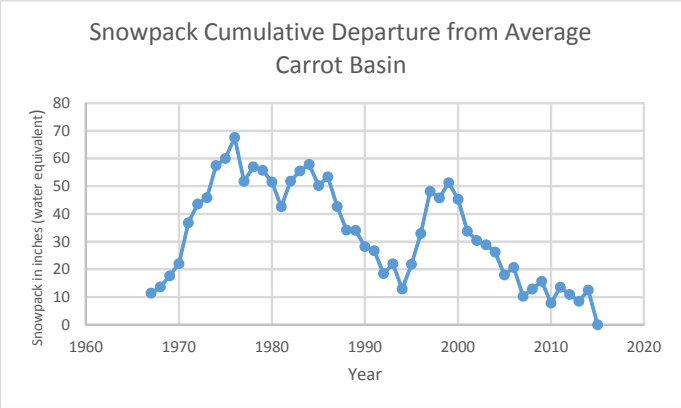
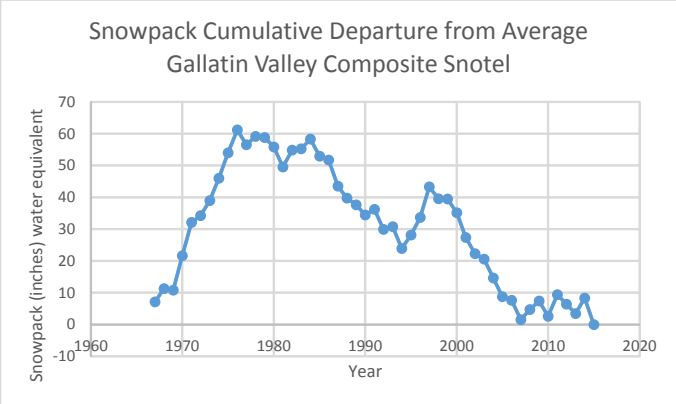
Figure 6-8a
Stream Discharge
Gallatin River at Logan

rec'd by LEPO April 13, 2016









Notes:

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Date: 12/15/2015
File: Figure 6-9a

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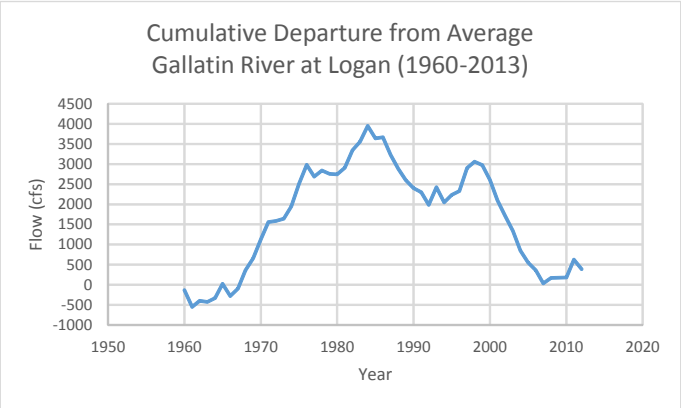
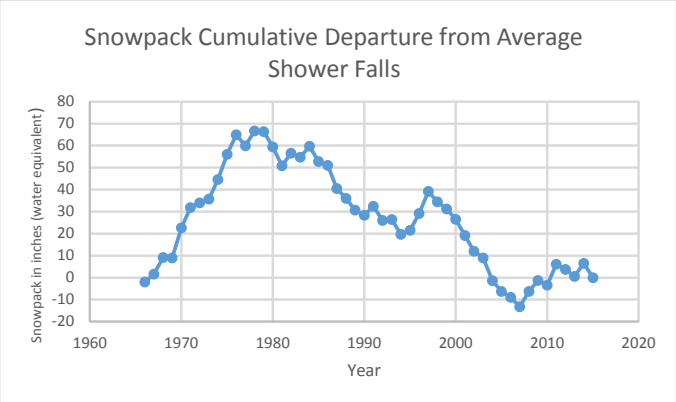
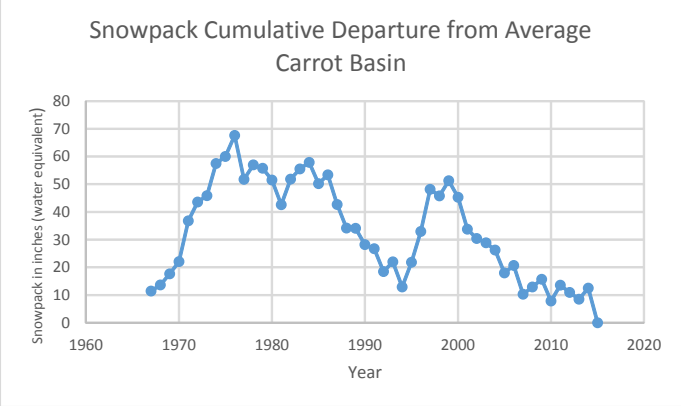
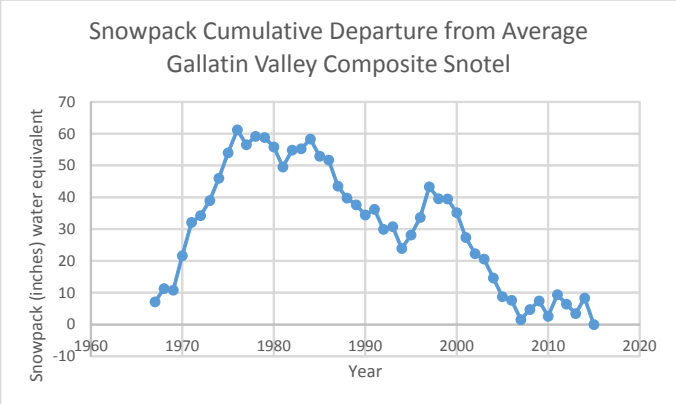
Figure 6-9a
Gallatin River near Gallatin Gateway
VS SNOTEL Stations

rec'd by LEPO April 13, 2016









Notes:

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Date: 12/15/2015
File: Figure 6-9b

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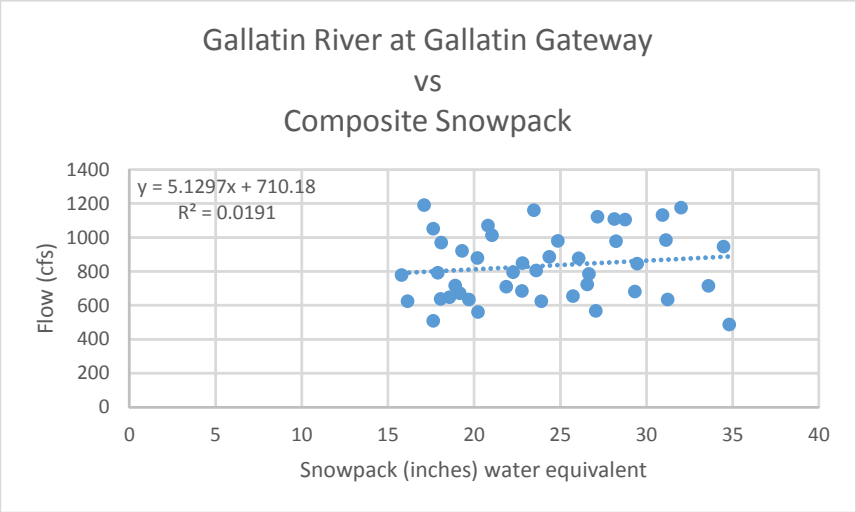
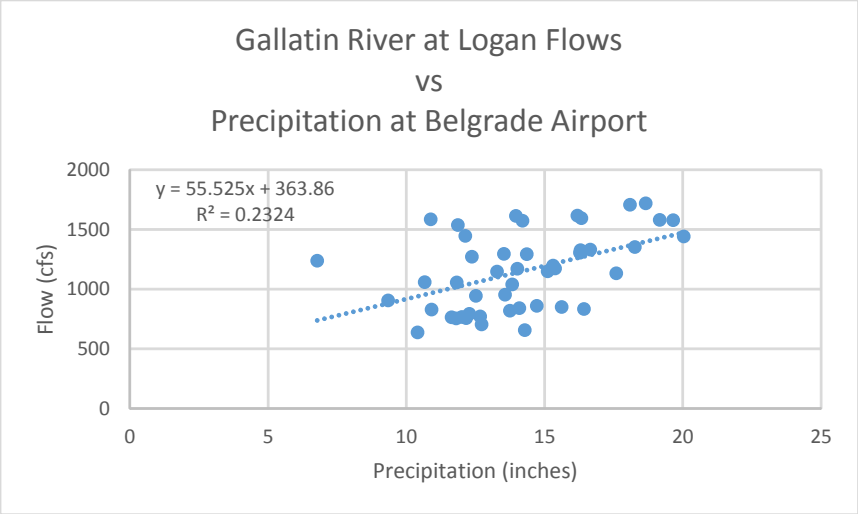
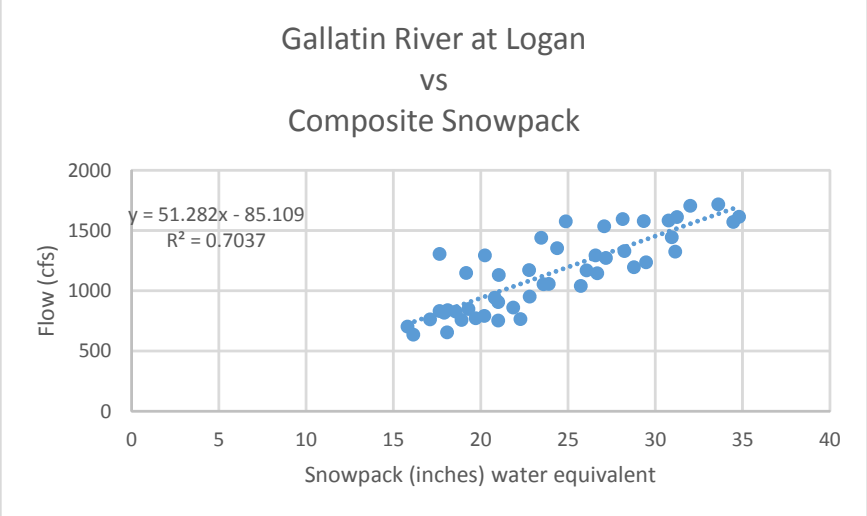
Figure 6-9b
Gallatin River at Logan
VS SNOTEL Stations

rec'd by LEPO April 13, 2016







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Date: 12/15/2015
File: Figure 6-10

Notes:
Data source: USGS

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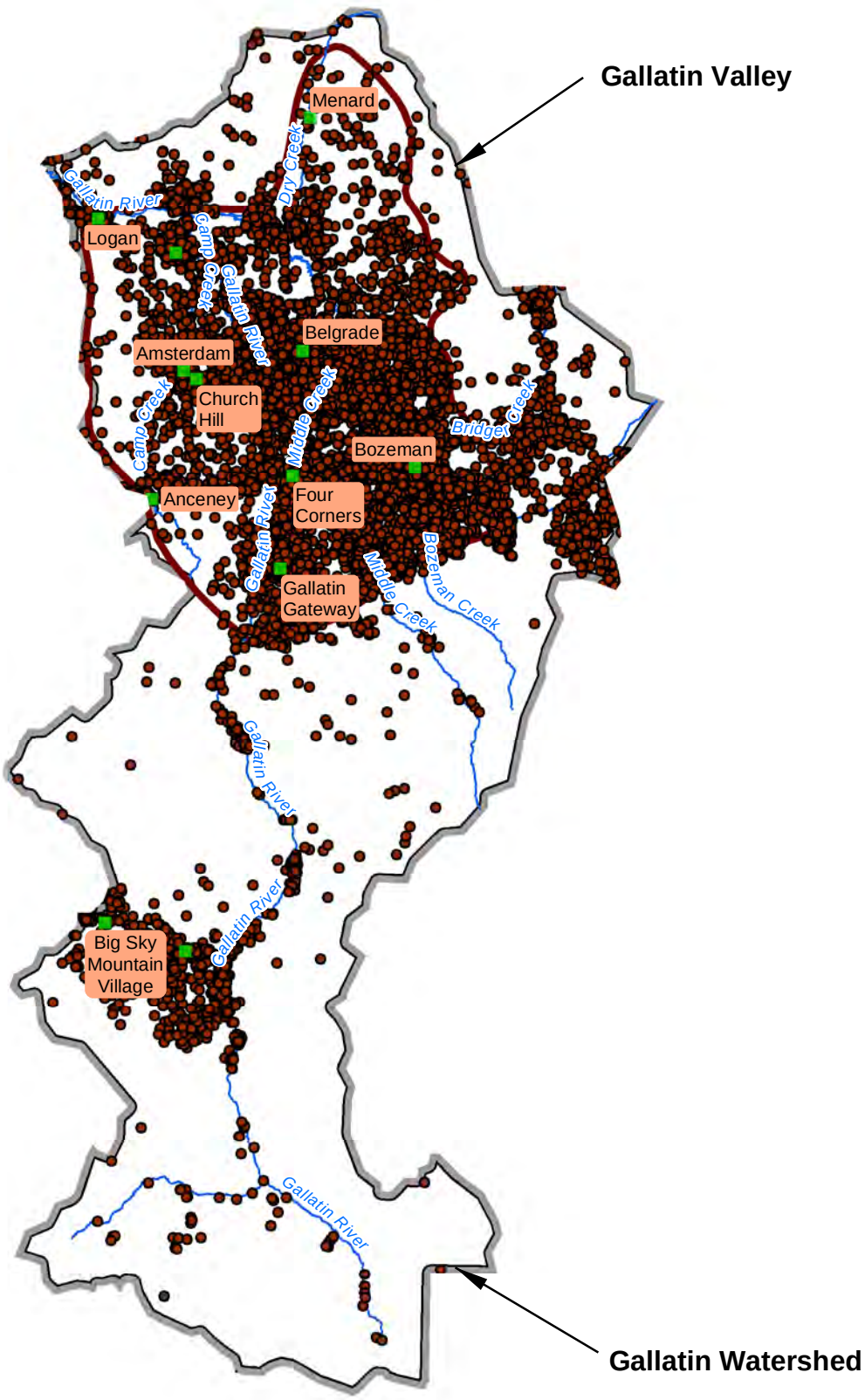
Figure 6-10
Comparison of Streamflow
VS Snowpack and Precipitation

rec'd by LEPO April 13, 2016



Notes:
1) Data source is MBMG GWIC and Montana State Library, NRIS

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Date: 12/23/2015
File: Figure 6-11

3.5 Miles

Legend

Towns

Well

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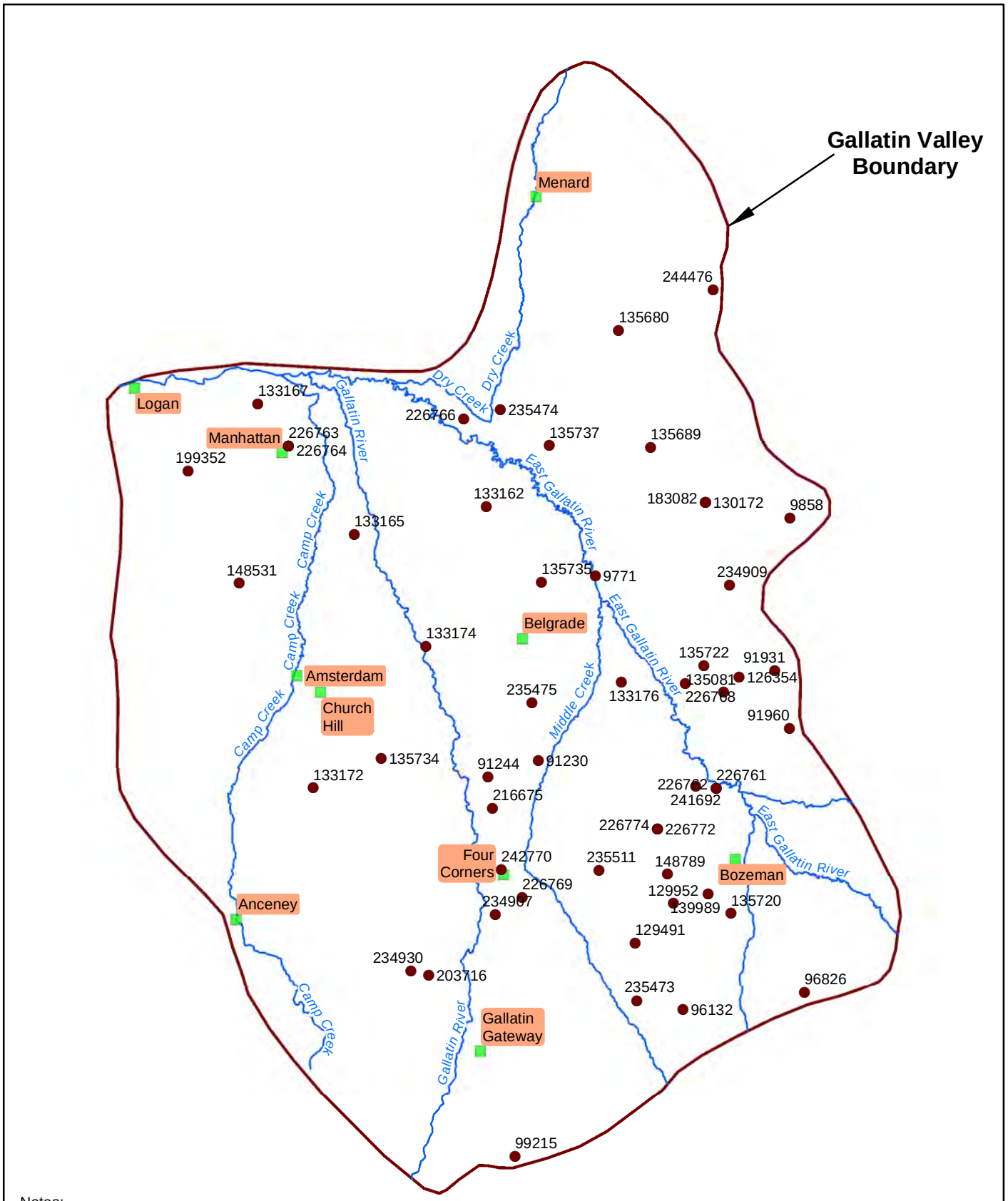
Figure 6-11
Wells in Gallatin Watershed

rec'd by LEPO April 13, 2016



Notes:
1) Data source is MBMG GWIC and Montana State Library, NRIS

Refer to Plate 6-1 for Hydrographs

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Date: 12/23/2015
File: Figure 6-12

1.5 Miles

Legend

- Towns
- Observation Well

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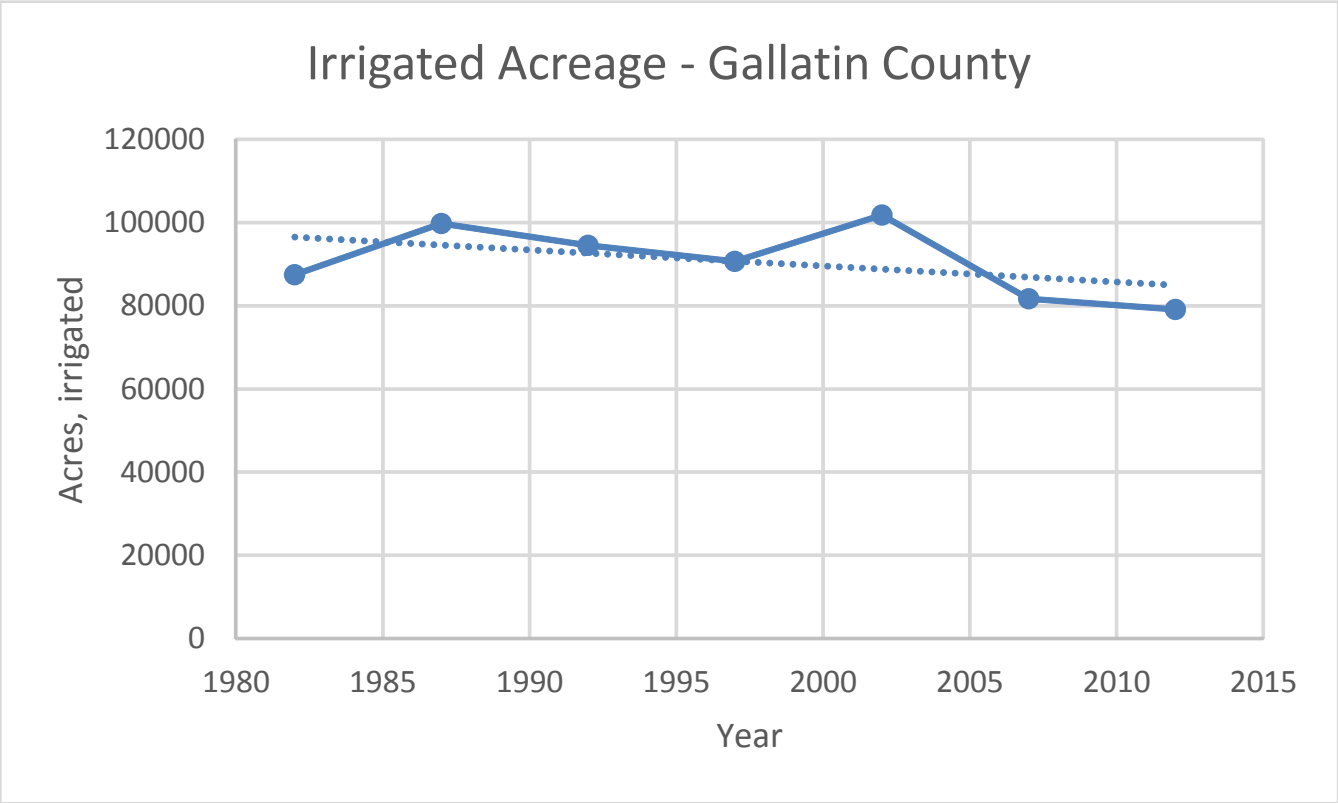
Figure 6-12
Observation Wells
Gallatin Valley

rec'd by LEPO April 13, 2016



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Date: 1/11/2016
File: Figure 6-13

Notes:
Irrigated acreage from USDA Census of Agriculture. Note that this summary includes irrigated lands in portions of Gallatin County outside the Gallatin Valley.

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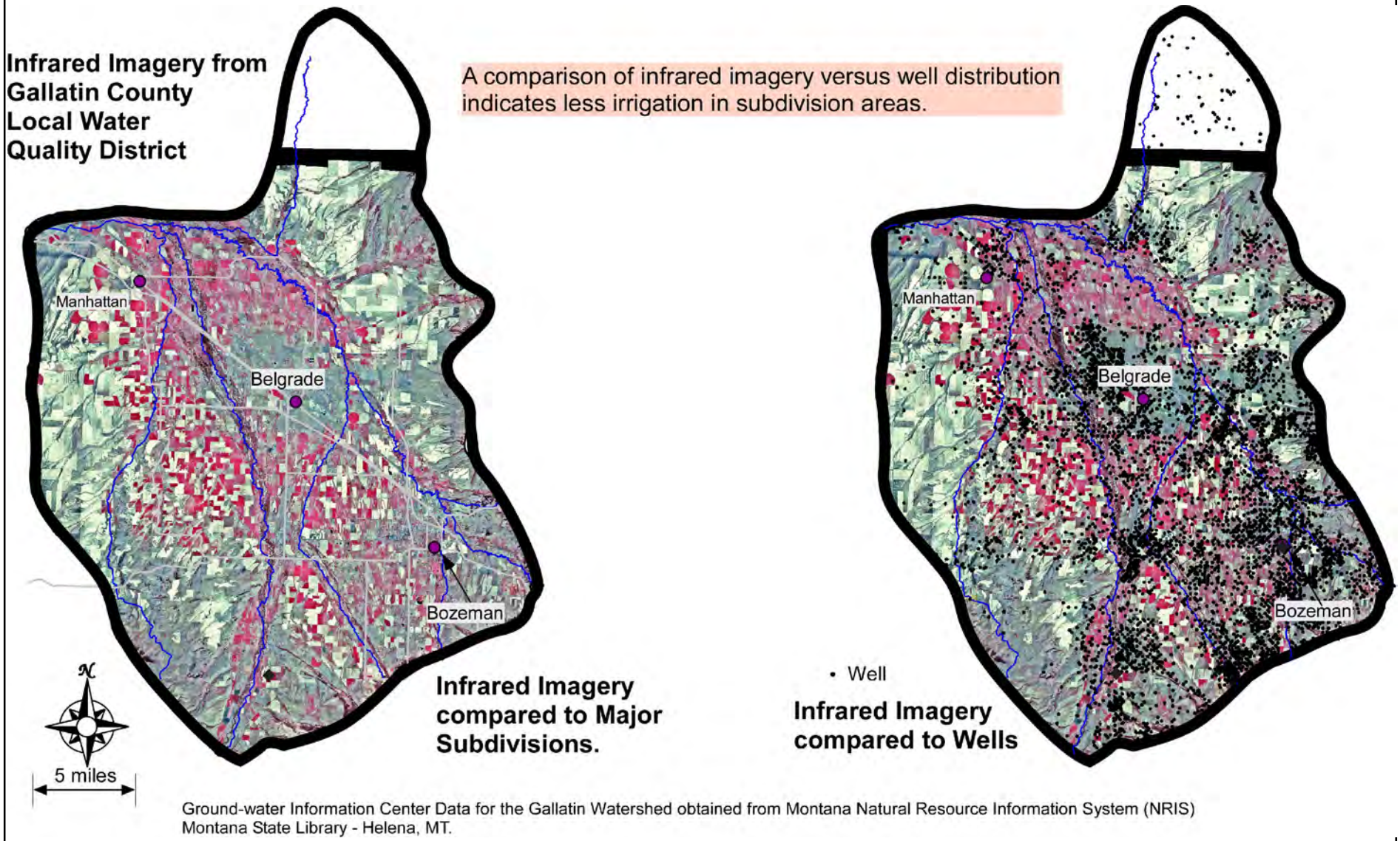
Figure 6-13
Irrigated Acreage
Gallatin County

rec'd by LEPO April 13, 2016



Ground-water Information Center Data for the Gallatin Watershed obtained from Montana Natural Resource Information System (NRIS) Montana State Library - Helena, MT.

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Date: 12/21/2015
File: Figure 6-14

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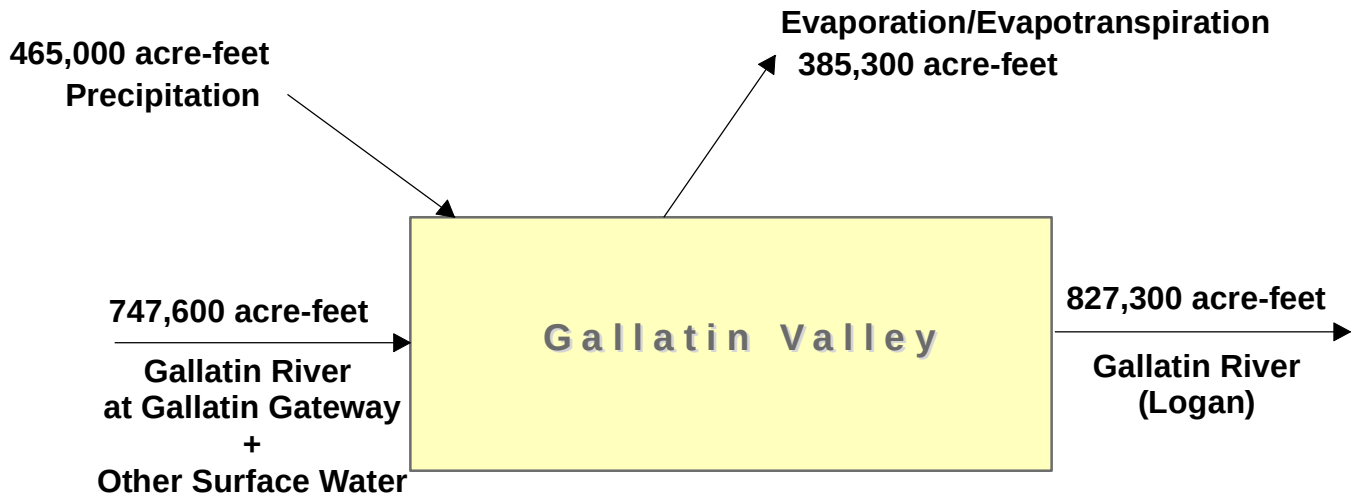
Figure 6-14
Infared Imagery Compared to Well Distribution for the Gallatin Valley

rec'd by LEPO April 13, 2016

Average Water Year
Valley Floor Mass Balance (Budget)
Historic Period of Record



USGS 06052500 Gallatin River at Logan MT (period of record through present)
USGS 06043500 Gallatin River near Gallatin Gateway MT (period of record through present).
Other surface water defined on the basis of 1952 and 1953 interpretations by Hackett, et al (1960)
Precipitation data based on PRISM interpretations.

This value computed on the basis of the difference between other inputs and outputs. Storage changes over the period of record are assumed to equate to zero. Furthermore, groundwater contributions and losses at valley periphery are assumed to be small. This evaporation/evapotranspiration includes that due to natural factors and that associated with irrigation activity.

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Date: 12/16/2015
File: Figure 6-15

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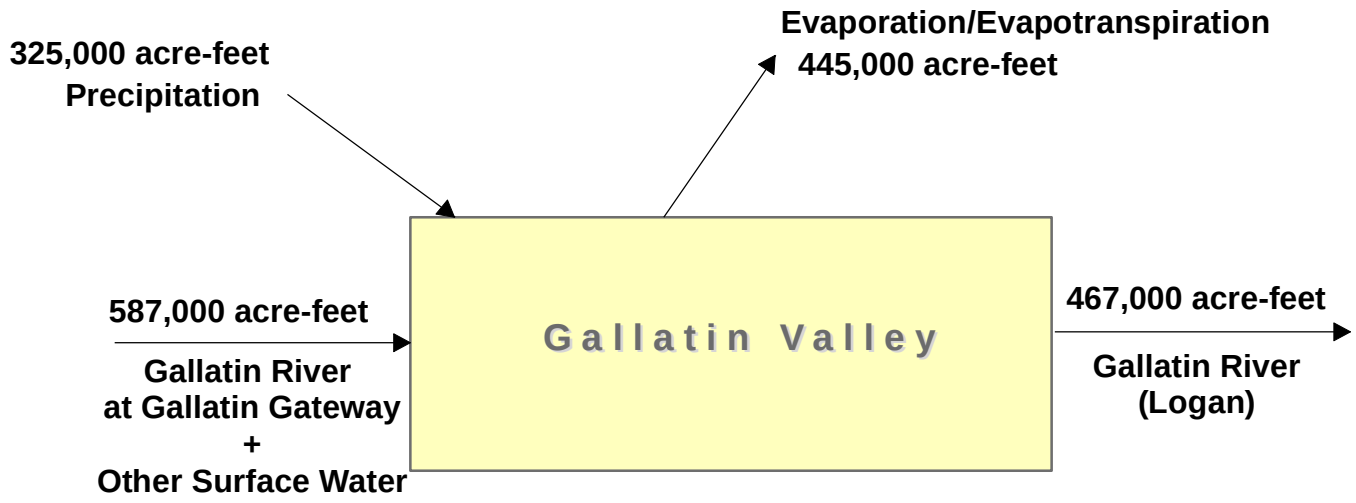
Figure 6-15
Water Budget Average Year
Gallatin Valley

rec'd by LEPO April 13, 2016

Average Water Year
Valley Floor Mass Balance (Budget)
Historic Period of Record



USGS 06052500 Gallatin River at Logan MT (period of record through present)
USGS 06043500 Gallatin River near Gallatin Gateway MT (period of record through present).
Other surface water defined on the basis of 1952 and 1953 interpretations by Hackett, et al (1960)
Precipitation data based on PRISM interpretations.

This value computed on the basis of the difference between other inputs and outputs. Storage changes over the period of record are assumed to equate to zero. Furthermore, groundwater contributions and losses at valley periphery are assumed to be small. This evaporation/evapotranspiration includes that due to natural factors and that associated with irrigation activity.

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Date: 12/16/2015
File: Figure 6-16

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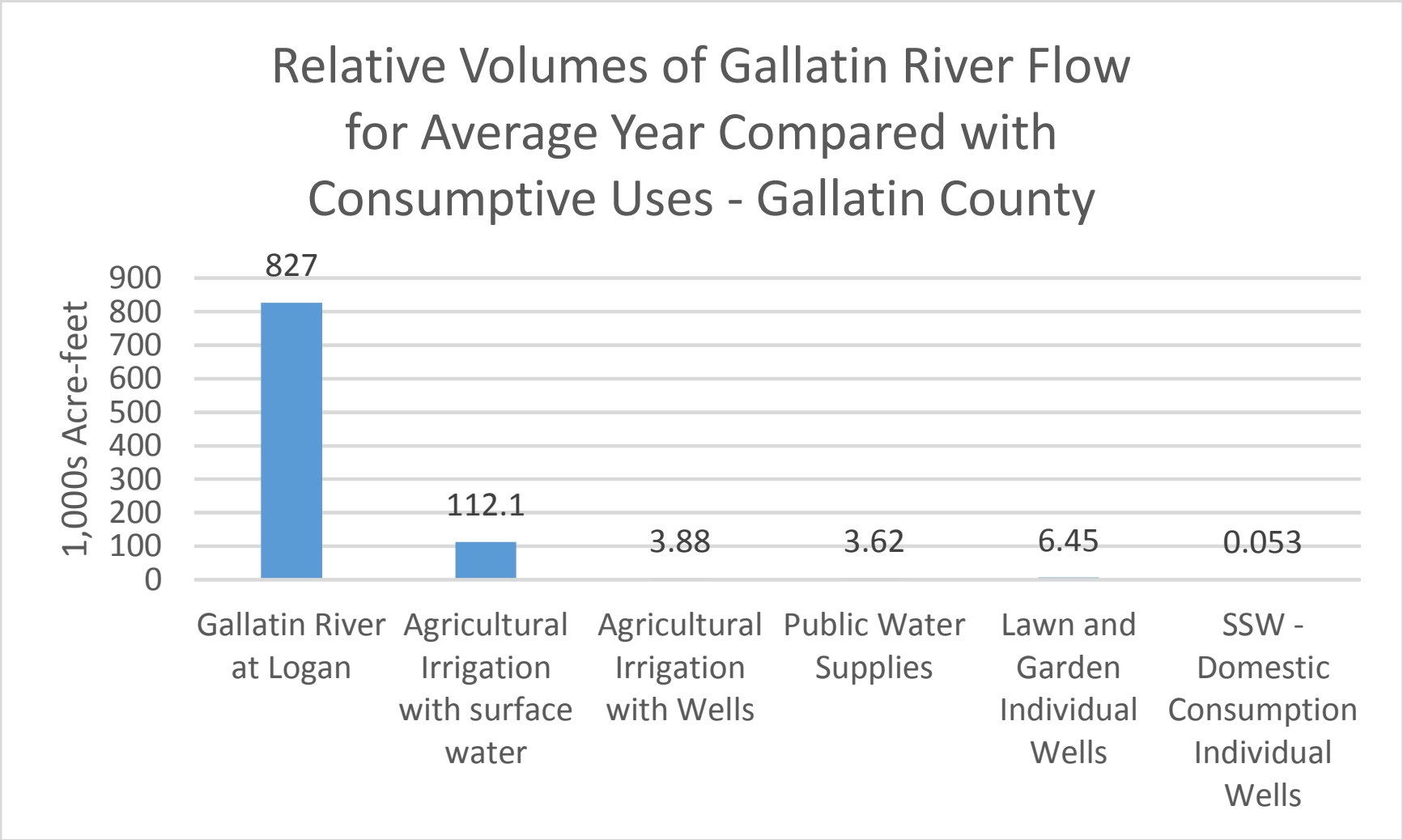
Figure 6-16
Water Budget Dry Year
Gallatin Valley

rec'd by LEPO April 13, 2016



Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Gallatin River is flow as measured at the Logan gaging station.

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Date: 12/22/2015
File: Figure 6-17

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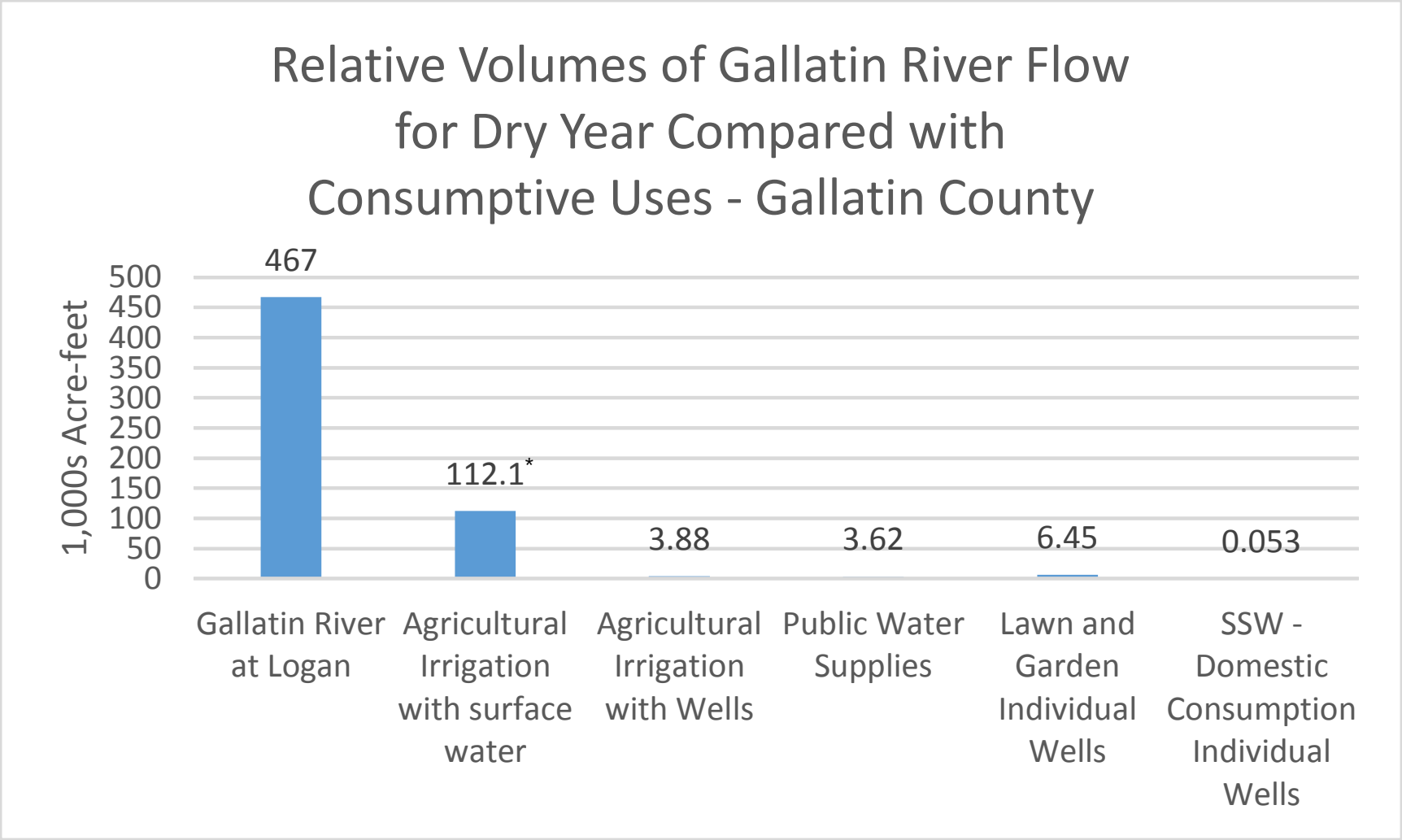
Figure 6-17
Surface Water Flows at Gallatin River Compared to Gallatin County Consumptive Uses

rec'd by LEPO April 13, 2016



Consumptive use is in part based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exempt wells is considered. Individual wells include exempt wells. Gallatin River is flow as measured at the Logan gaging station (uses 2001 flows).

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Date: 12/22/2015
File: Figure 6-18

*Actual consumptive uses are likely lower for a dry year owing to availability of surface water.

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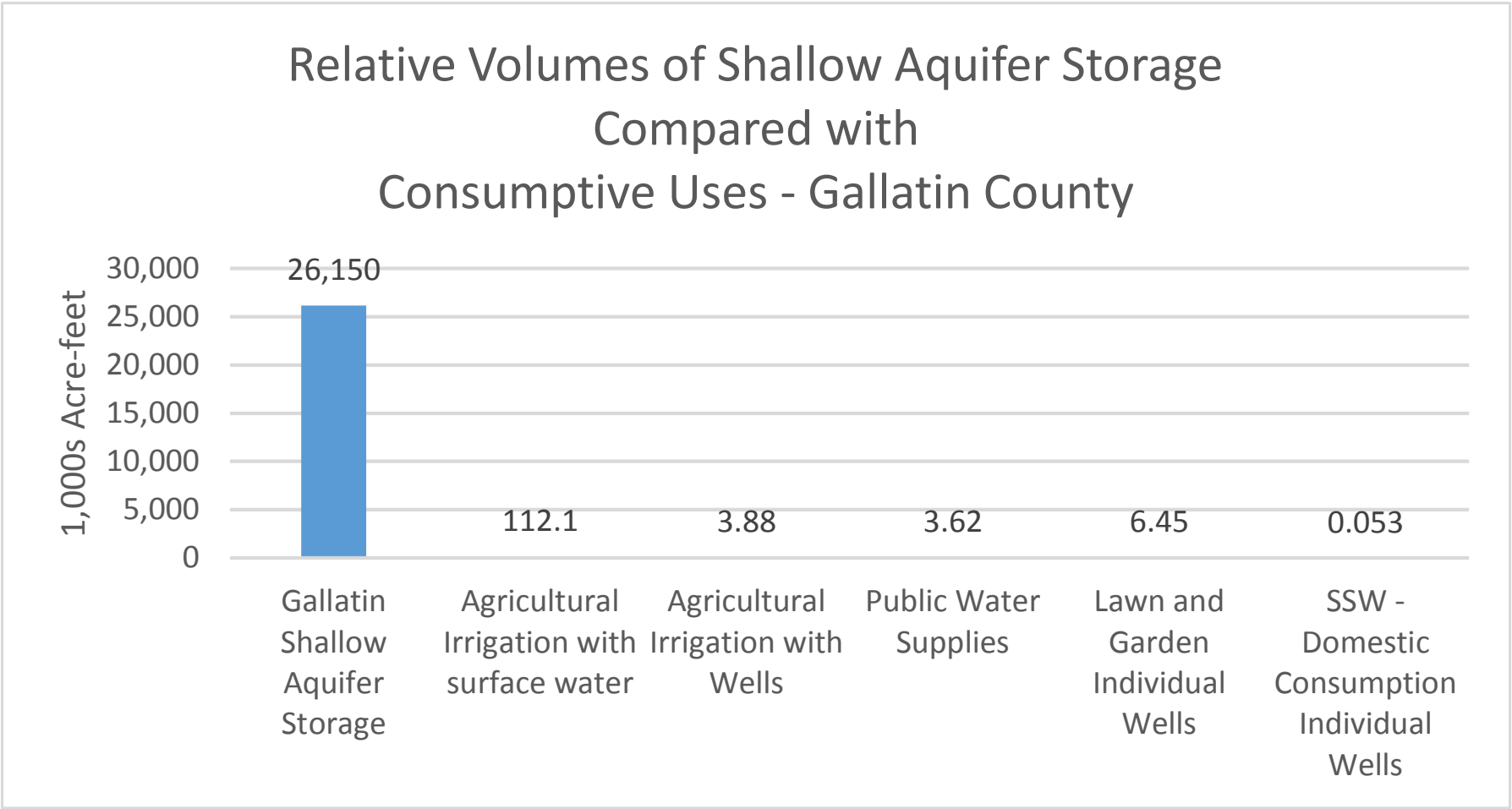
Figure 6-18
Surface Water Flows at Gallatin River Compared to Gallatin County Consumptive Uses - Dry Year

rec'd by LEPO April 13, 2016



Consumptive use is based upon information adapted from Cannon and Johnson (2004) and as modified by NE&W. Data from DNRC memorandum on consumptive use for exept wells is considered in these plots. Individual wells include exempt wells. Storage estimate is adapted from the MBMG presentation at the Water Policy Interim Committee meeting at Choteau.

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Date: 12/22/2015
File: Figure 6-19

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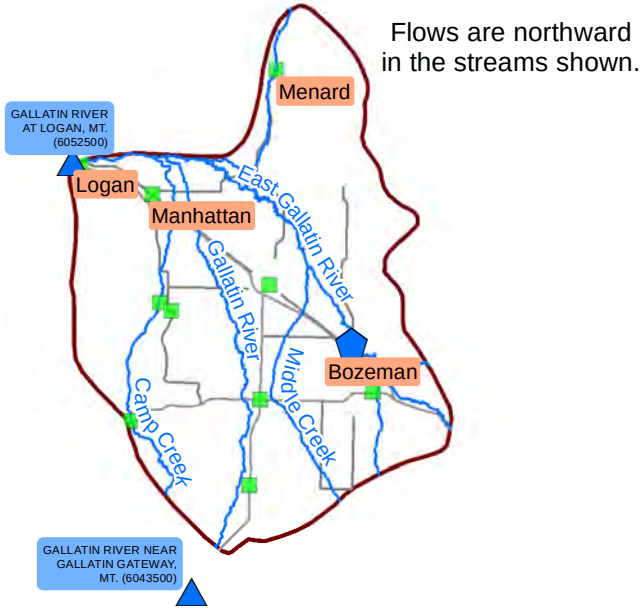
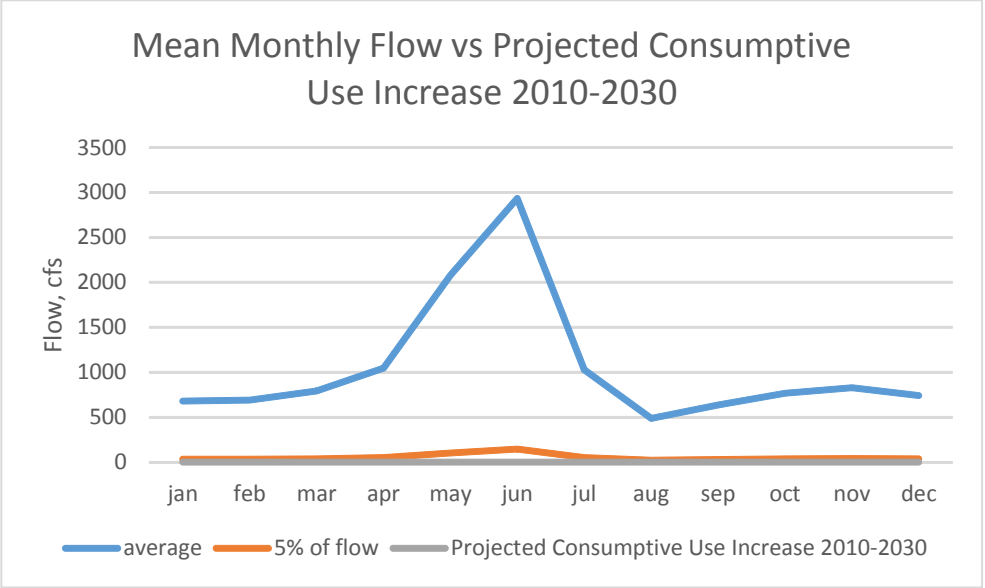
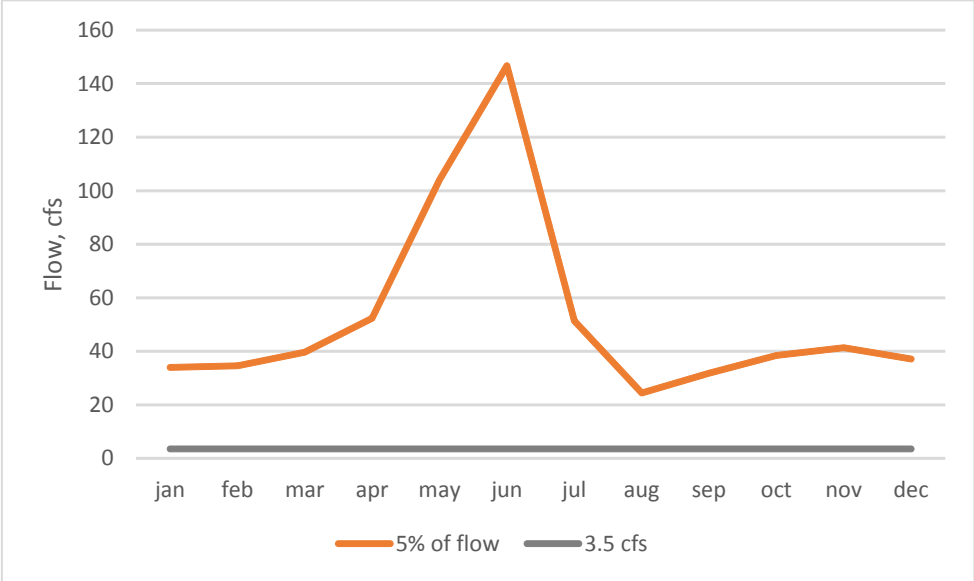
Figure 6-19
Storage Volume of Shallow Aquifer Compared to Gallatin County Consumptive Uses

rec'd by LEPO April 13, 2016





The blue line plot in the upper graph shows the average monthly flows for the period of record for the Gallatin River as it is measured near Logan. The middle line plot shows 5% of the same flows. In effect, this represents an approximate magnitude of the uncertainty of stream flow measurements at gaging stations. The lower line of 3.5 cfs represents the projected consumptive use increase from 2010 to 2030 for the Gallatin Valley. In effect, a flow of 3.5 cfs could not be reliably discerned at this gaging station. Note that the 3.5 cfs depletion does not take into consideration the potential accretions from reductions in streamflow diversions from reduced irrigation acreage. The net depletion will likely be much less than 3.5 cfs once the net accretions are accounted for.



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Date: 1/11/2016
File: Figure 6-20a

Scale not indicated

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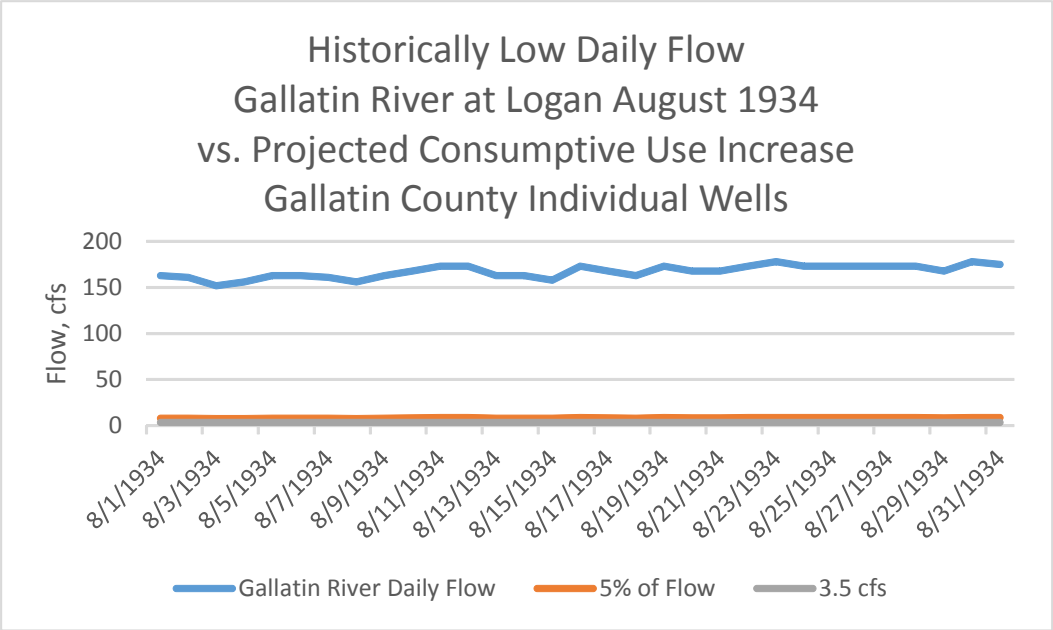
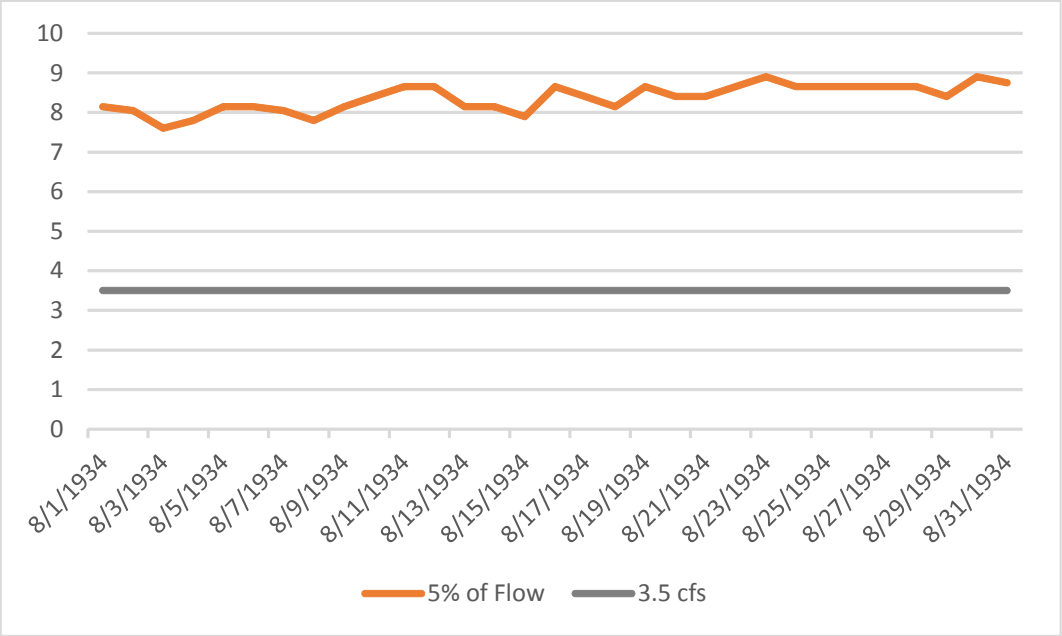
Figure 6-20a
Mean Monthly Flow of Gallatin River Compared to Projected Individual Well Consumptive Use Increase (2010-2030) - Gallatin Valley





Note that the above figure represents the minimum daily flow month of record for August which occurred in August 1934. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal varaition in depletion will be very subdued owing to the fact that most wells in the Gallatin County are located at significant distances from streams. Even if seasonal variability is accounted for any net monthly depletion would remain in the noise level (below 5% of streamflow) in the Gallatin River as measured near Logan. Finally, the above graph does not account for any reduction in surface water use associated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects."

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Date: 1/11/2016
File: Figure 6-20b

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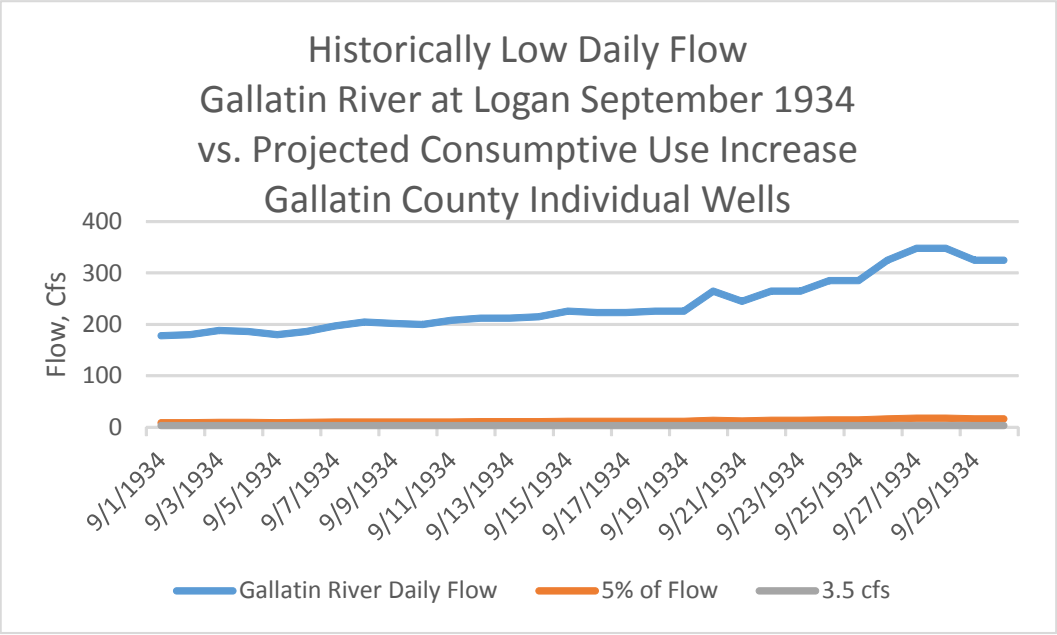
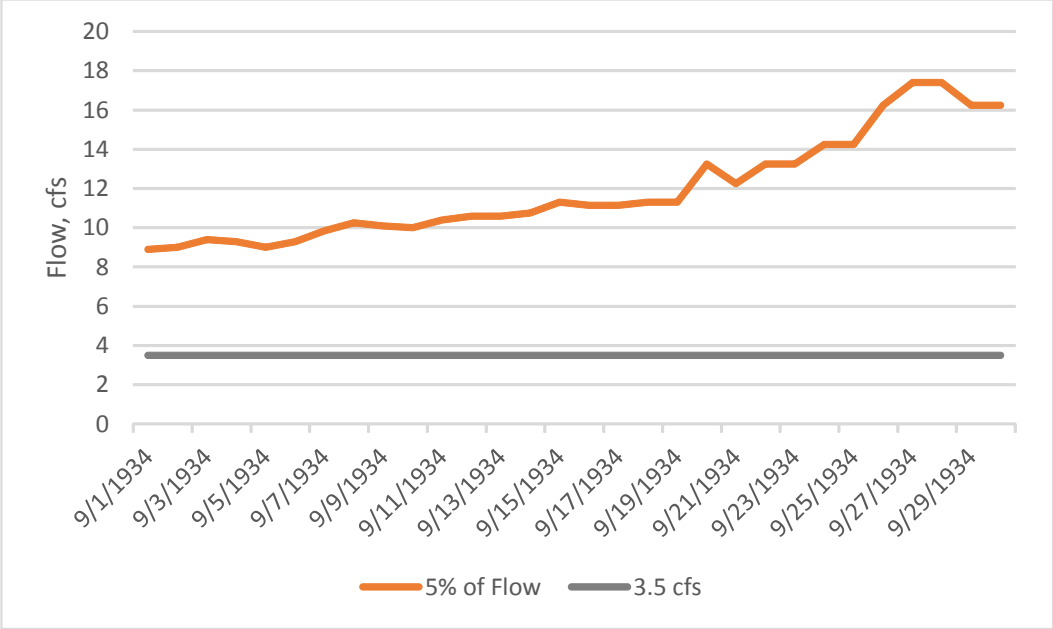
Figure 6-20b
August 1934 Gallatin River Flows Compared to Projected Individual Well Consumptive Use Increase (2010 to 2030)
Gallatin County





Note that the above figure represents the minimum daily flow month of record for September which occurred in September 1934. Note that there may be some minor seasonal variation in streamflow depletions from individual well pumping. However, this seasonal varaition in depletion will be very subdued owing to the fact that most wells in the Gallatin County are located at significant distances from streams. Even if seasonal variability is accounted for any net monthly depletion would remain in the noise level (below 5% of streamflow) in the Gallatin River as measured near Logan. Finally, the above graph does not account for any reduction in surface water use associated with conversion of irrigated land to subdivisions. In effect, all the addition and subtraction must be performed before drawing conclusions with respect to "cumulative effects."

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Figure 6-20c
September 1934 Gallatin River Flows Compared to Projected Individual Well Consumptive Use Increase (2010 to 2030)
Gallatin County

7.0 SUMMARY

Water budget evaluations of Lewis and Clark, Ravalli, and Missoula Counties and the Gallatin Valley were performed. Databases evaluated include climatic data (precipitation including SNOTEL and local climate data), stream flow (focus on long-term stream flow data collected for the relevant streams), and groundwater level data (Montana Bureau of Mines and Geology GWIC data).

Based upon that evaluation, the following were key findings:

- Stream flows depend principally upon each given year's mountain snow pack in the subbasins that were evaluated. Snow pack, as measured in terms of water equivalent, from about the late 1990s to about 2005 were been below average. This has led to lower than average stream flows during that time period.

- By far the most significant human-related influence on stream flow in the watersheds examined is surface water diversions for irrigation. Reservoir evaporation was a significant factor for Lewis and Clark County in the Upper Missouri River basin. Groundwater use from all wells, both exempt and larger wells, for all purposes is very small when compared to stream flow diversions.

- Groundwater levels and, hence, aquifer storage have remained relatively constant from year-to-year for all watersheds that were examined. One exception to this was identified in a localized area known as the Helena North Hills in Lewis and Clark County.

- There is no evidence that the overall consumptive water use at the watershed scale has increased with the growth of subdivisions and their accompanying use of groundwater. The primary reason for this is that many of these subdivisions have been placed in areas where agricultural irrigation activity has historically occurred, thus having a minimal or even positive impact on water consumption by replacing high-consumption agricultural irrigation with lower consumptive use for domestic purposes.

- It is concluded via water budgeting assessments that there is no measurable evidence of so-called “cumulative impacts” of exempt wells, public water supply wells, or even agricultural irrigation wells on stream flows in any of the watersheds evaluated. Although localized effects may occur in a few instances,

any net cumulative effect at the watershed scale, if it exists, is simply too small to be discerned or to impact existing surface water rights.

- Projections were made on future water demands on groundwater. Based upon these projections, the impacts of groundwater development by 2030 will not be measurable or observable in streams and, therefore, will be of little to no consequence to surface water users.

- Comparisons of projected increased demands from 2010 to 2030 were made to seasonal variations in stream flow, including during drought periods when stream flows were very low. It was determined that increased demands using individual well supplies would not be measurable or detectable at any of the locations examined even during periods of low flow.

Based upon the current studies, NE&W recommendations are as follows:

- Recognize that the water budget in Montana is overwhelmingly dominated by climatic factors and agricultural surface water use. In effect, any changes in groundwater use that transpire in the next five to 10 years will not substantively change this water budget.

- Regular delineation of water use, including irrigated areas, would assist in understanding potential trends or lack thereof on the overall water budget. Information could then be coupled with the water budgeting process to provide information at the state and local levels to assist decision makers, water users, and their representatives.

- Use the results from the basin or subwatershed evaluations to determine if there are conjunctive surface water/groundwater management measures that could be implemented. For instance, the possibility exists that groundwater pumping (*e.g.*, supplemental irrigation) could be coupled with leaving surface water in streams during critical low stream flow periods.

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rec'd by LEPO April 13, 2016

Plates

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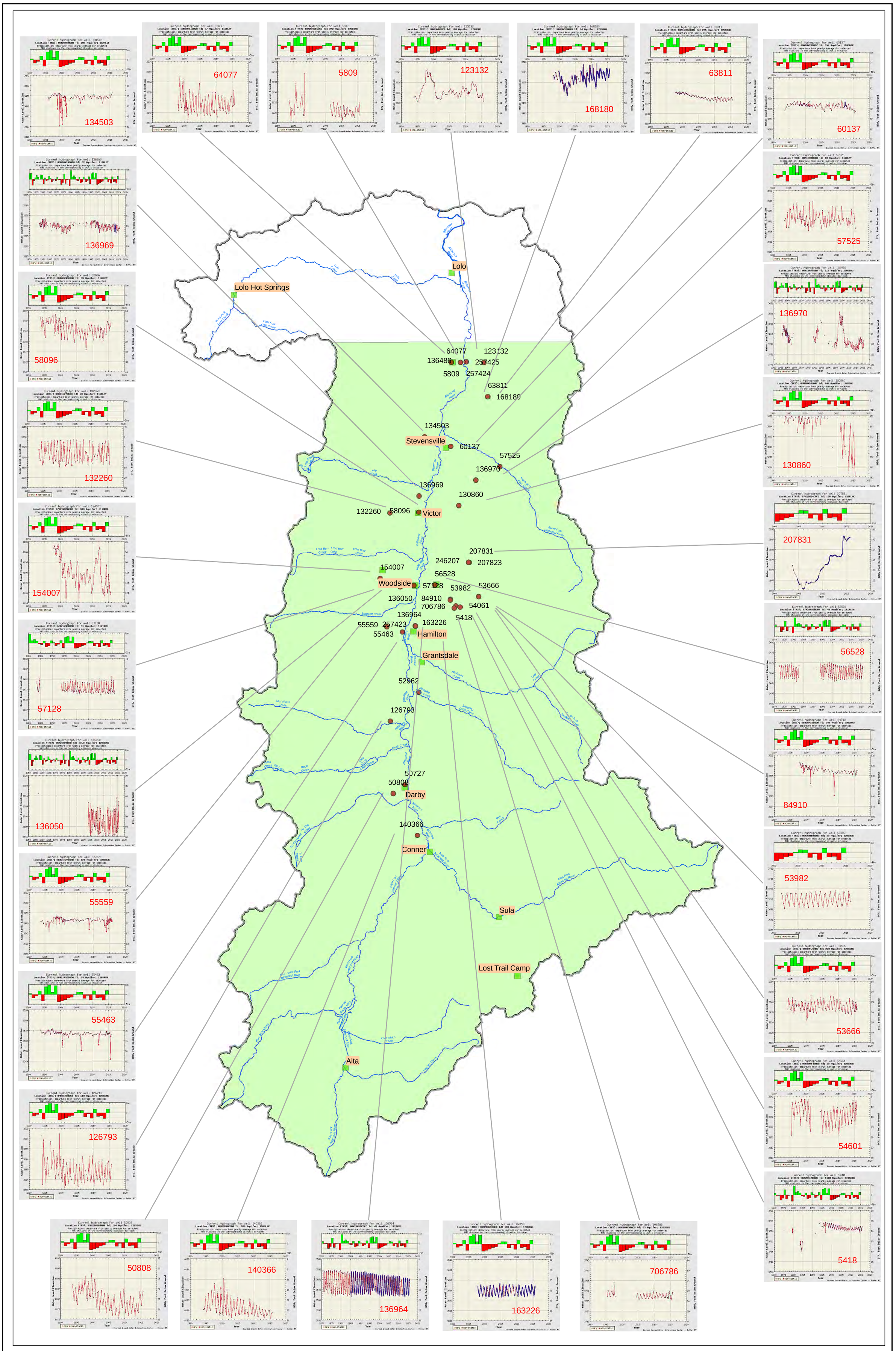

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Scale Not Indicated

Legend

- Observation Well
- Town

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Plate 3-1
Monitoring Well Hydrographs Ravalli County
Montana Bureau of Mines and Geology
Statewide Monitoring Wells

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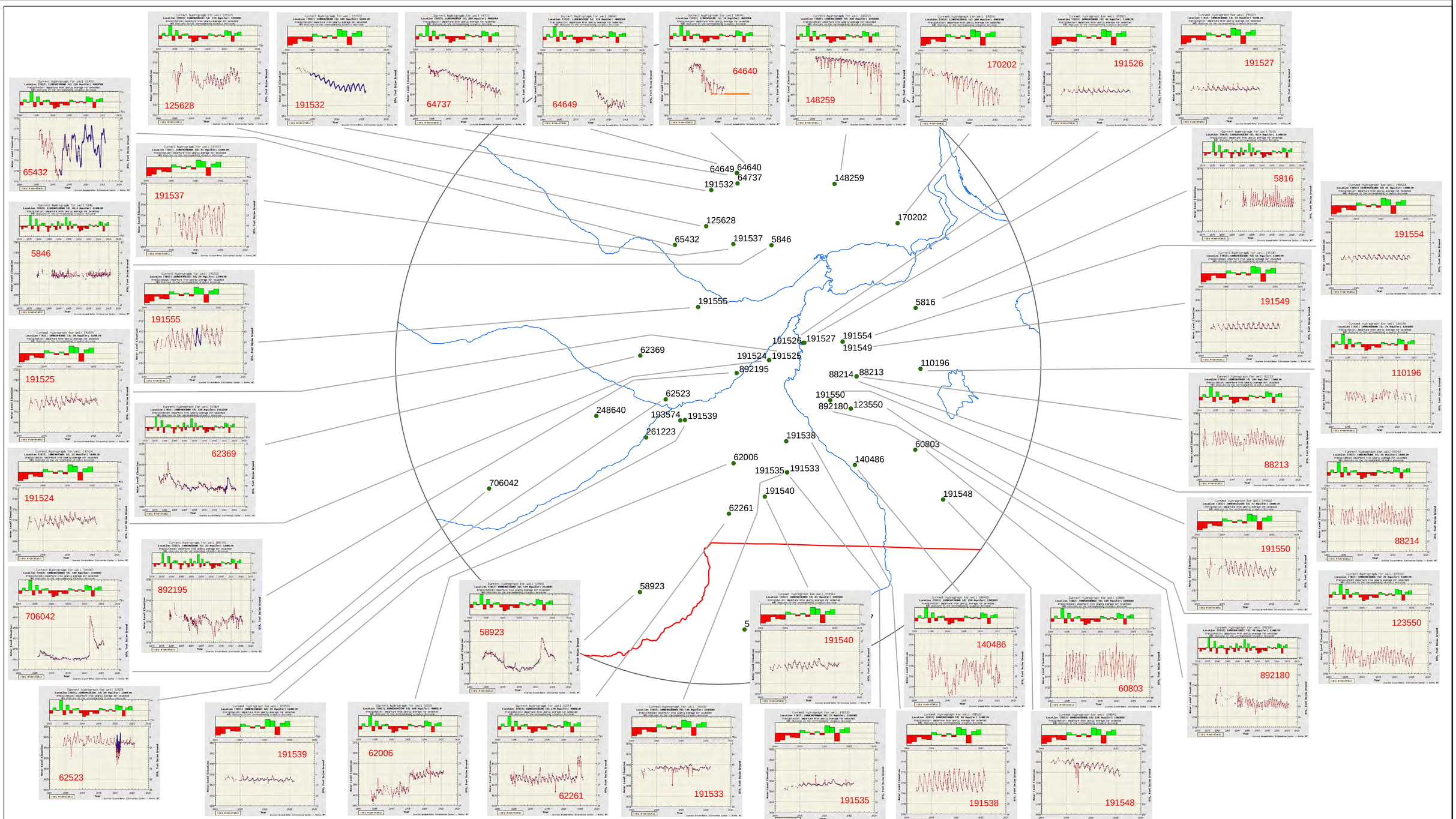

Monitoring well plots taken directly from http://mbmggwic.mtech.edu/. The upper graph on each plot represents precipitation departure from average. The lower plot presents both water level elevation and the depth to water. Time axis enhanced for visualization. Note that some wells have been monitored for less than 7 years. Hence, inferences regarding factors influencing water levels should be made with caution.

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Date: 1/11/2016
File: Plate 4-1

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Plate 4-1
Monitoring Well Hydrographs Lewis and Clark County
Montana Bureau of Mines and Geology Statewide Monitoring Wells

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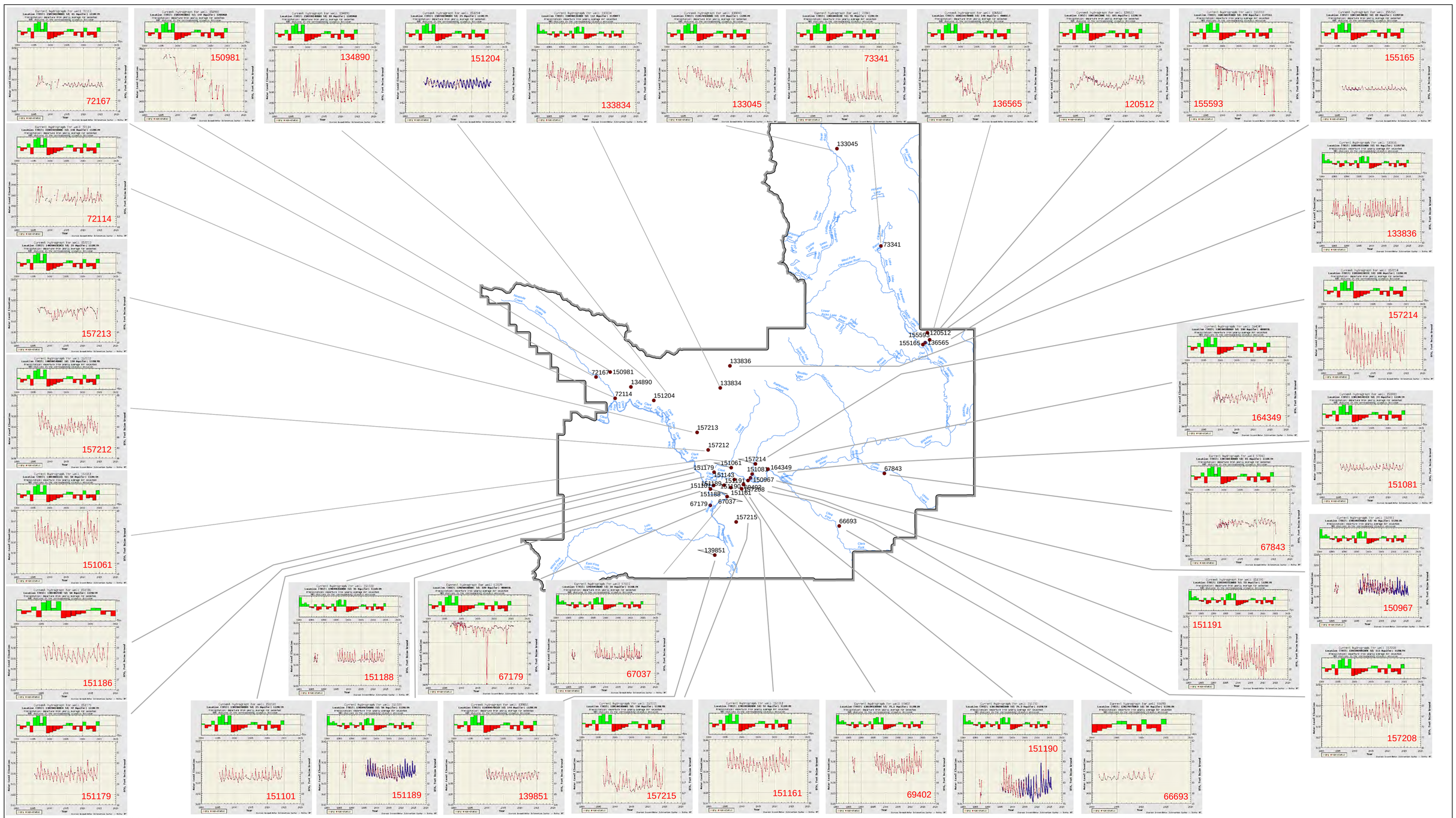

Monitoring well plots taken directly from http://mbmggwic.mtech.edu/. The upper graph on each plot represents precipitation departure from average. The lower plot presents both water level elevation and the depth to water. Time axis enhanced for visualization. Note that some wells have been monitored for less than 7 years. Hence, inferences regarding factors influencing water levels should be made with caution.

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Date: 1/11/2016
File: Plate 5-1

Scale not indicated

Legend

- MBMG Observation Well

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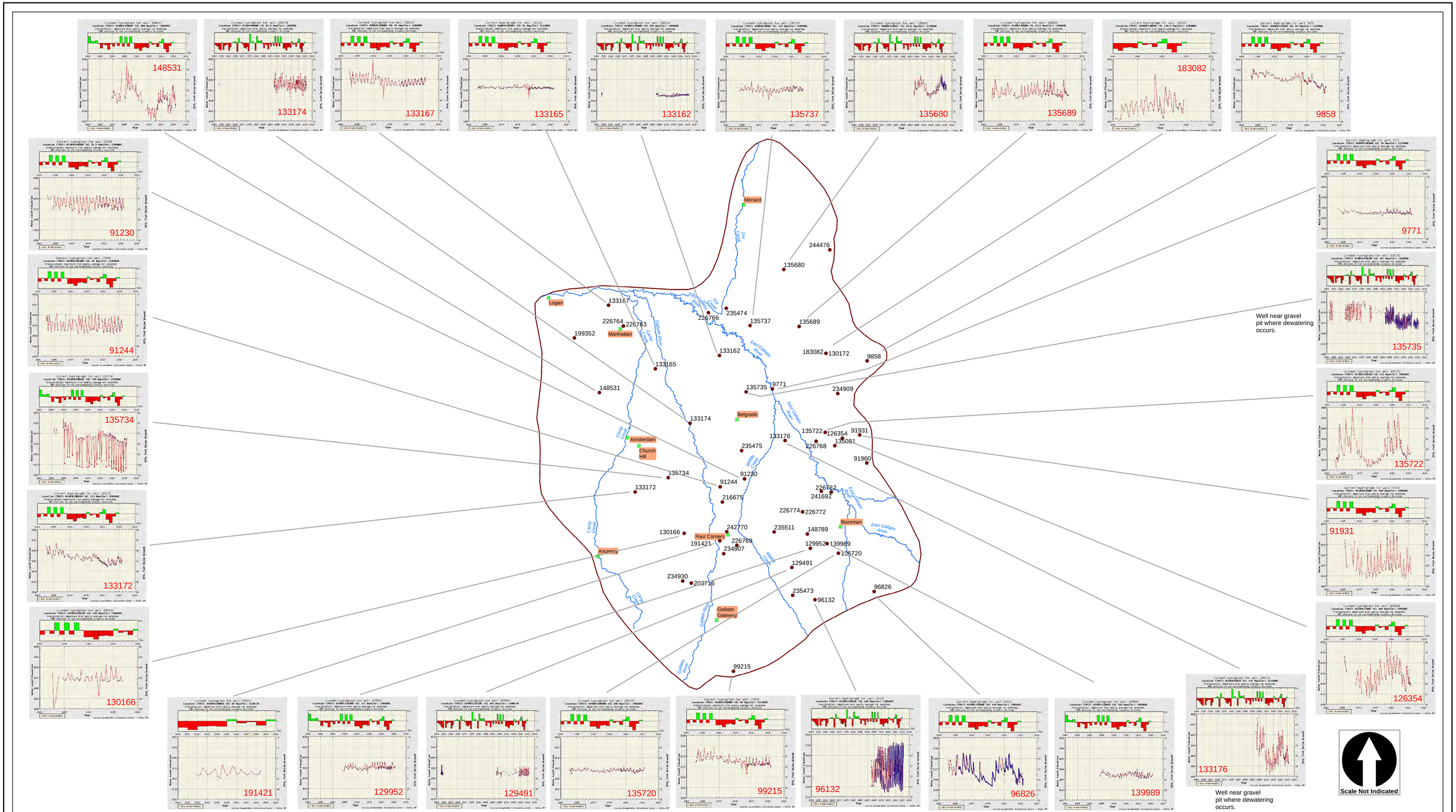
Plate 5-1
Monitoring Well Hydrographs Missoula County
Montana Bureau of Mines and Geology
Statewide Monitoring Wells

rec'd by LEPO April 13, 2016



Monitoring well plots taken directly from http://mbmggwic.mtech.edu/. The upper graph on each plot represents precipitation departure from average. The lower plot presents both water level elevation and the depth to water. Current wells with a minimum of 10 years of observations are shown.

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Date: 12/23/2015
File: Plate 6-1

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Plate 6-1
Monitoring Well Hydrographs Gallatin Valley
Montana Bureau of Mines and Geology
Statewide Monitoring Wells