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Montana Bureau of Mines and Geology
A Department of Montana Tech of The University of Montana

Dissolved-Constituents Map of the Southern Part of the Flathead Lake Area, Lake, Sanders, and Missoula Counties, Montana

by

John I. LaFave

Note - this map was originally published at a scale of 1:100,000 but the page sizes have been modified to fit the size of the paper in your printer. A full sized 36” X 48” colored print of this map can be ordered from the Office of Publications and Sales of the Montana Bureau of Mines and Geology, 1300 West Park Street, Butte, MT 59701.
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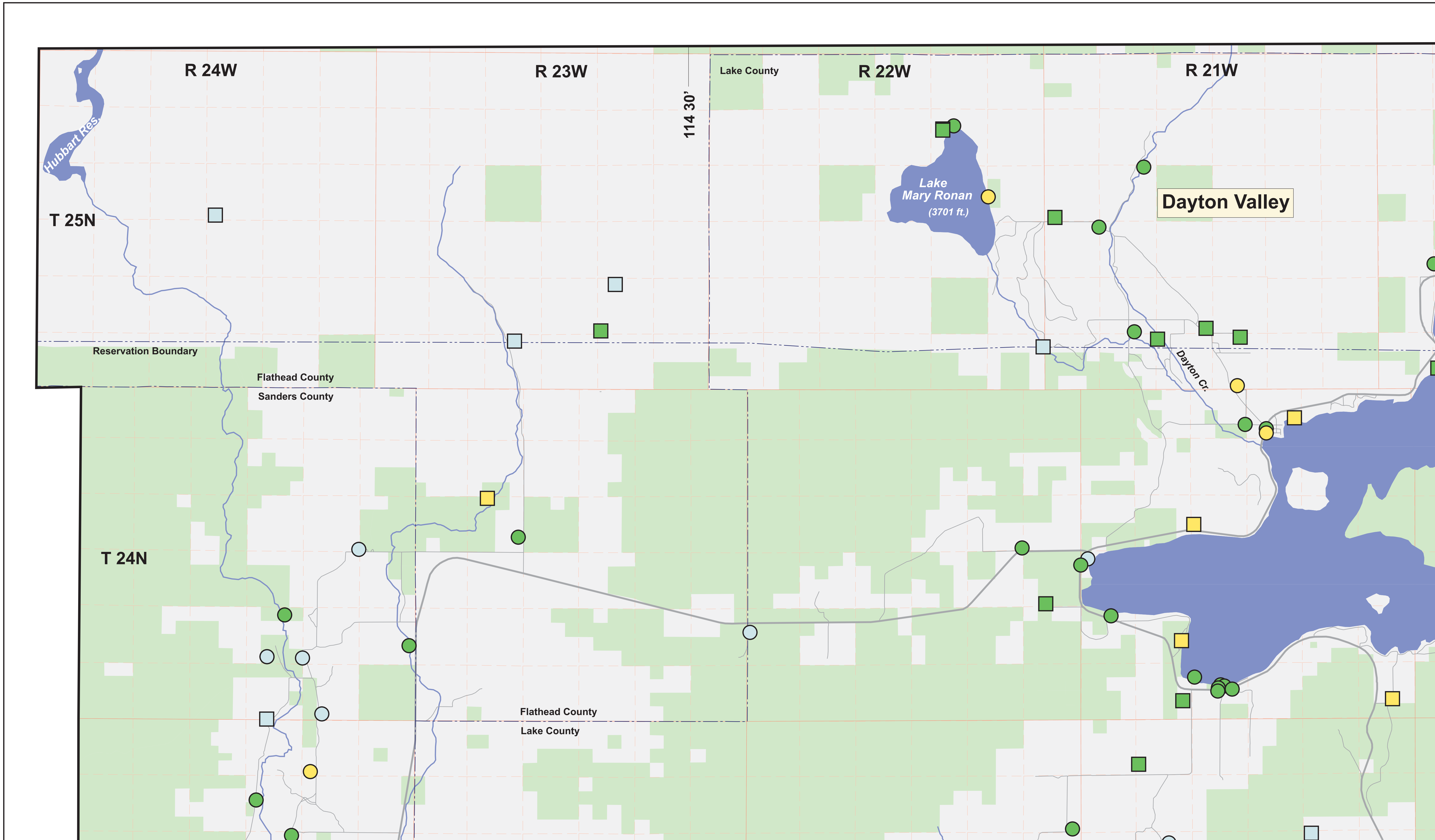
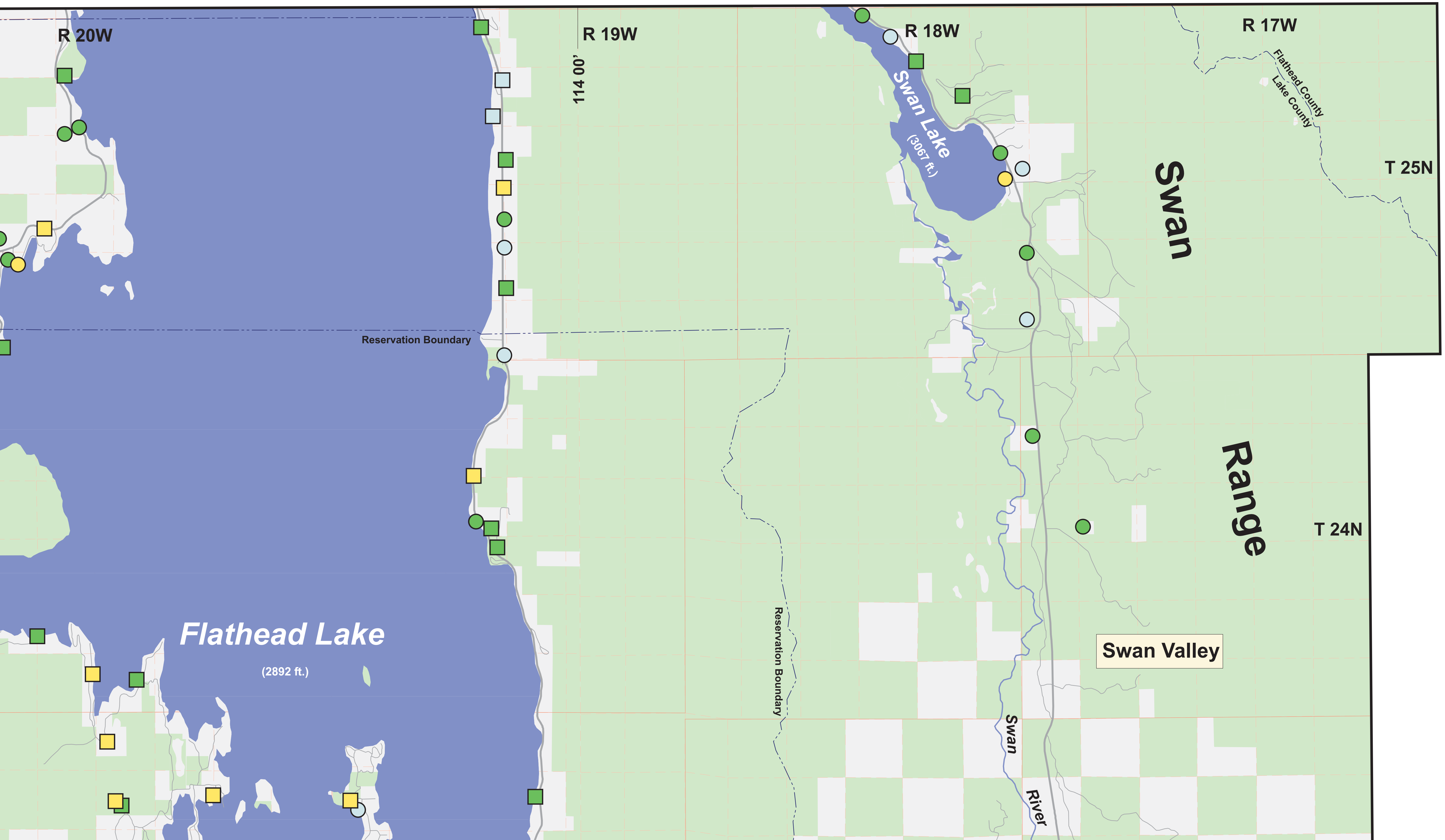
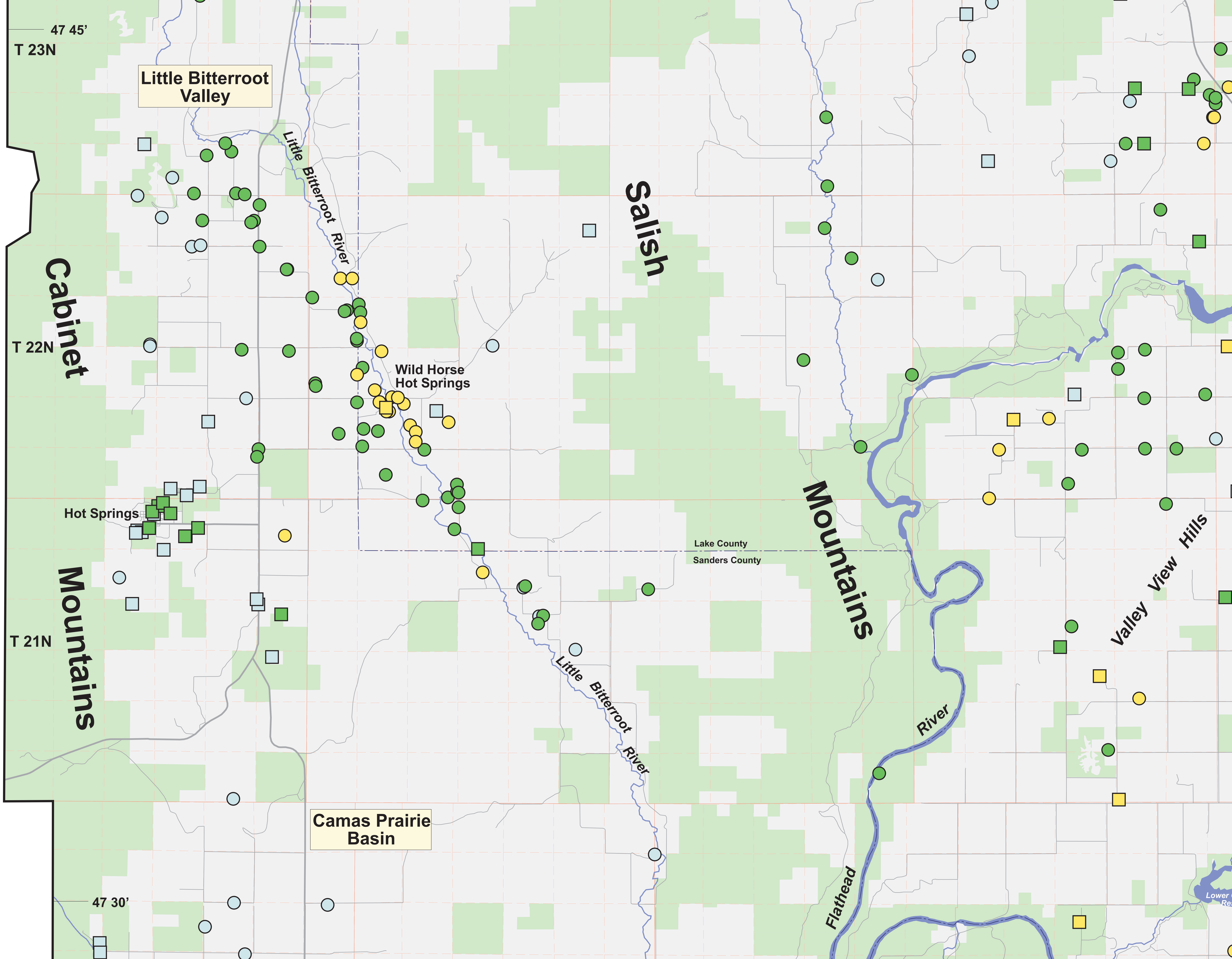
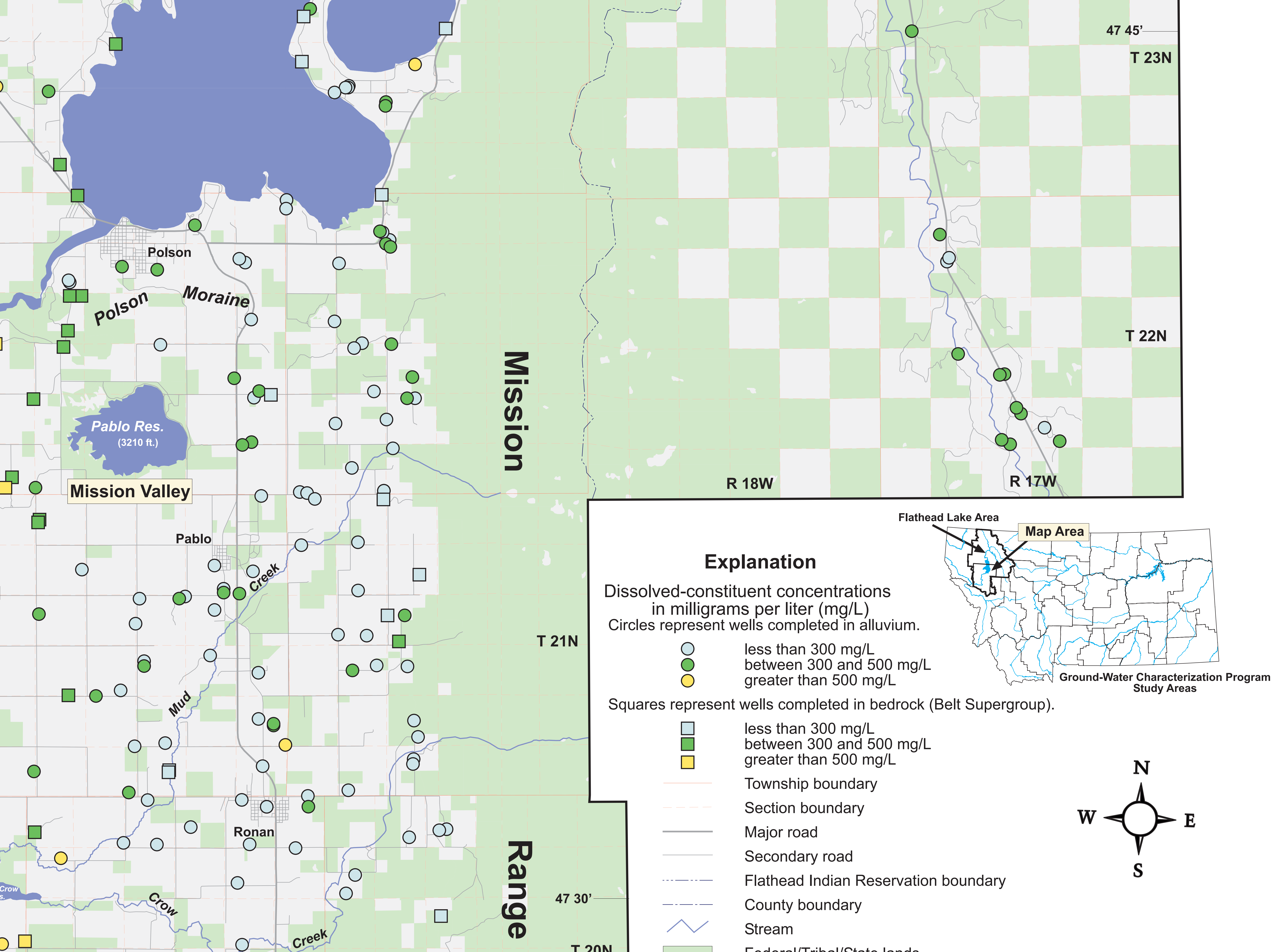
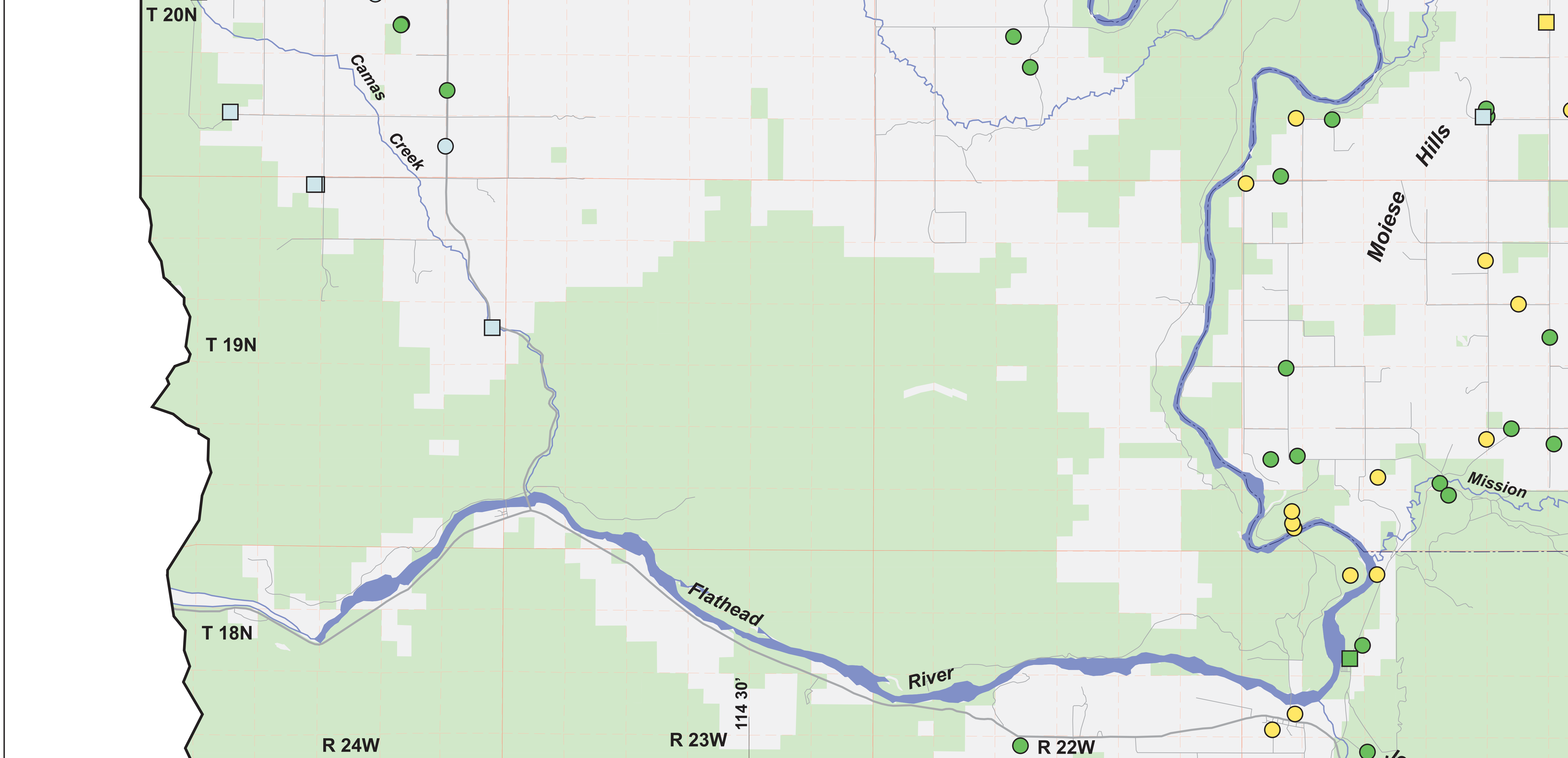



R 20W
R 19W
R 18W
R 17W
114 00'
Swan Lake
(3067 ft.)
Flathead County
Lake County
T 25N
Swan
Range
T 24N
Reservation Boundary
Reservation Boundary
Flathead Lake
(2892 ft.)
Swan Valley
Swan
River



47 45'
T 23N
Little Bitterroot Valley
Little Bitterroot River
Salish
Cabinet
T 22N
Wild Horse Hot Springs
Hot Springs
Mountains
Lake County
Sanders County
Mountains
Valley View Hills
T 21N
Mountains
River
Camas Prairie Basin
47 30'
Flathead


47 45'
T 23N
T 22N
T 21N
T 20N
47 30'
R 18W
R 17W
Polson
Polson Moraine
Pablo Res.
(3210 ft.)
Mission Valley
Pablo
Mud Creek
Ronan
Crow Creek
Mission Range
Flathead Lake Area
Map Area
Ground-Water Characterization Program Study Areas
Explanation
Dissolved-constituent concentrations in milligrams per liter (mg/L)
Circles represent wells completed in alluvium.
less than 300 mg/L
between 300 and 500 mg/L
greater than 500 mg/L
Squares represent wells completed in bedrock (Belt Supergroup).
less than 300 mg/L
between 300 and 500 mg/L
greater than 500 mg/L
Township boundary
Section boundary
Major road
Secondary road
Flathead Indian Reservation boundary
County boundary
Stream
Federal/Tribal/State lands
N
W
E
S



Dissolved-Constituents Map of the Southern Part of the Flathead Lake Area, Lake, Sanders, and Missoula Counties, Montana

by
John I. LaFave

Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Flathead Lake Area ground-water characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Flathead Lake Area the reader is referred to Part A (descriptive overview) and other Part B maps of the Montana Ground-Water Assessment Atlas No. 2.

INTRODUCTION
This map presents the distribution of dissolved constituents in the major basin-fill aquifers in the southern part of the Flathead Lake Ground-Water Characterization Study Area. The area is

primary openings through which water moves in the rocks are fractures or "cracks") to yield water to wells and is included as part of the basin-fill aquifers because it appears, based on the potentiometric surface(s), to be in hydraulic communication with the basin-fill deposits. It should be noted, that ground water in the Belt bedrock occupies and moves through fractures and voids within the rock, rather than through intergranular spaces as in the sand and gravel deposits. Because of the irregular distribution and orientation of the fractures, ground-water occurrence in the bedrock can be unpredictable, and yields from bedrock wells can vary widely between locations.

In most of the valleys, the potentiometric surface generally reflects the surface topography, and ground-water flow is away from the mountains along the valley margins toward the streams that drain the valleys (LaFave, 2002). The ground-water flow systems in the valleys are strongly controlled by topography and the distribution of permeable layers within the basin-fill deposits.

SAMPLE SITES AND WATER QUALITY DATA
Three sets of dissolved constituents data are presented on the map; laboratory

located in the Little Bitterroot valley, is greater than that of the other valleys, with a median of 398 mg/L. The median dissolved constituent concentration in the other valleys, with the exception of the Dayton valley, is less than 350 mg/L (figure 1).

GROUND-WATER QUALITY
Recent and historic chemical analyses of ground water from 242 wells were reviewed to assess background water quality in the mapped area. The results show that the ground-water quality is fairly uniform in the basin-fill aquifers (with the exception of the Lone Pine aquifer in the Little Bitterroot valley). The most common ions are calcium, magnesium and bicarbonate; there is little sodium, sulfate, or chloride (figure 2). Ground water from the Lone Pine aquifer is chemically distinct from the other valley-fill aquifers, with relatively higher concentrations of dissolved constituents (figure 1), sodium and bicarbonate, and lower concentrations of calcium and magnesium (figure 2). There is no discernable difference in chemical composition between ground water from wells completed in the alluvium and from wells completed in the Belt bedrock that surrounds the valley (figure 2).

Nuisance levels of iron and manganese are common throughout the mapped area. Iron and manganese are essential to plants and animals, but may cause unpleasant taste, odor, and staining of plumbing fixtures. The primary source of iron and manganese in ground water is dissolution of minerals in the bedrock. Iron concentrations in well water may also be elevated (increased) by corrosion of iron well casings and from bacterial activity in and around the well screen. The secondary level of 0.3 mg/L for iron was exceeded in 30 samples, and 42 samples had manganese concentrations above the secondary level of 0.05 mg/L.

The sodium adsorption ratio (SAR) describes the suitability of water for irrigation. SAR values below 10 are desirable for irrigation waters. The results from the 120 samples analyzed as part of this study suggest that water from the valley-fill aquifers is well suited for irrigation. Other than samples from the Little Bitterroot Valley, SAR values did not exceed 3, indicating that the potential sodium hazard is low. Only samples from the Lone Pine aquifer in the vicinity if Hot Springs and Wild Horse Hot Springs had SAR values greater than 10, suggesting that ground water impacted by geothermal systems may not be suitable for irrigation.

Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte, Montana.

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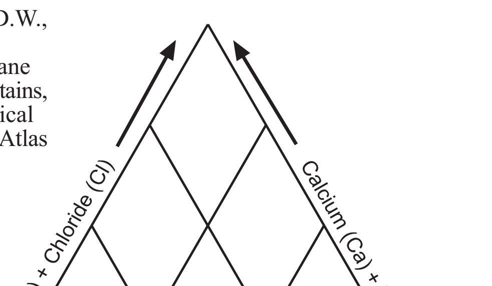

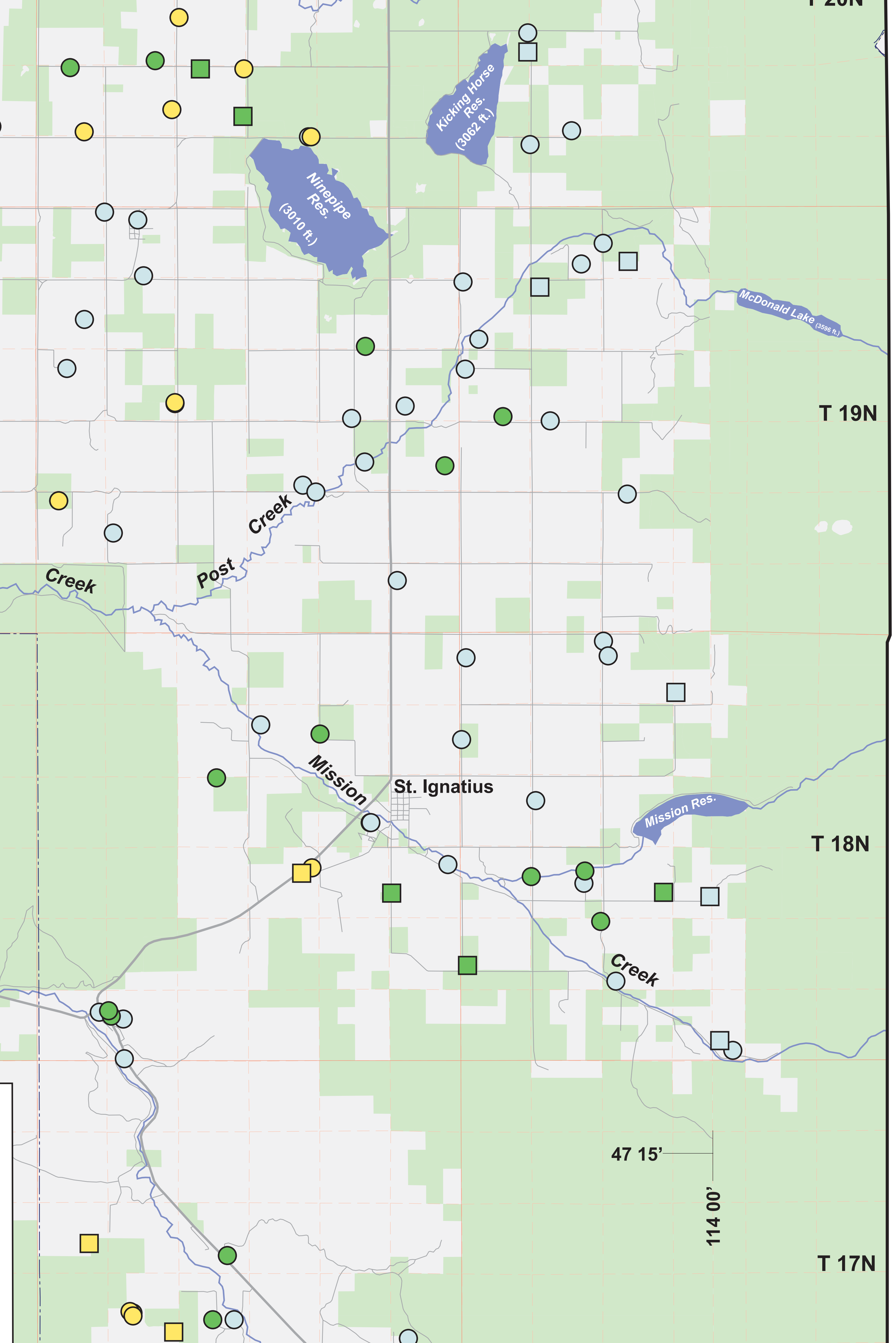

Federal/Tribal/State lands

Other lands

Scale 1:100,000
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2 0 2 4 6 Miles

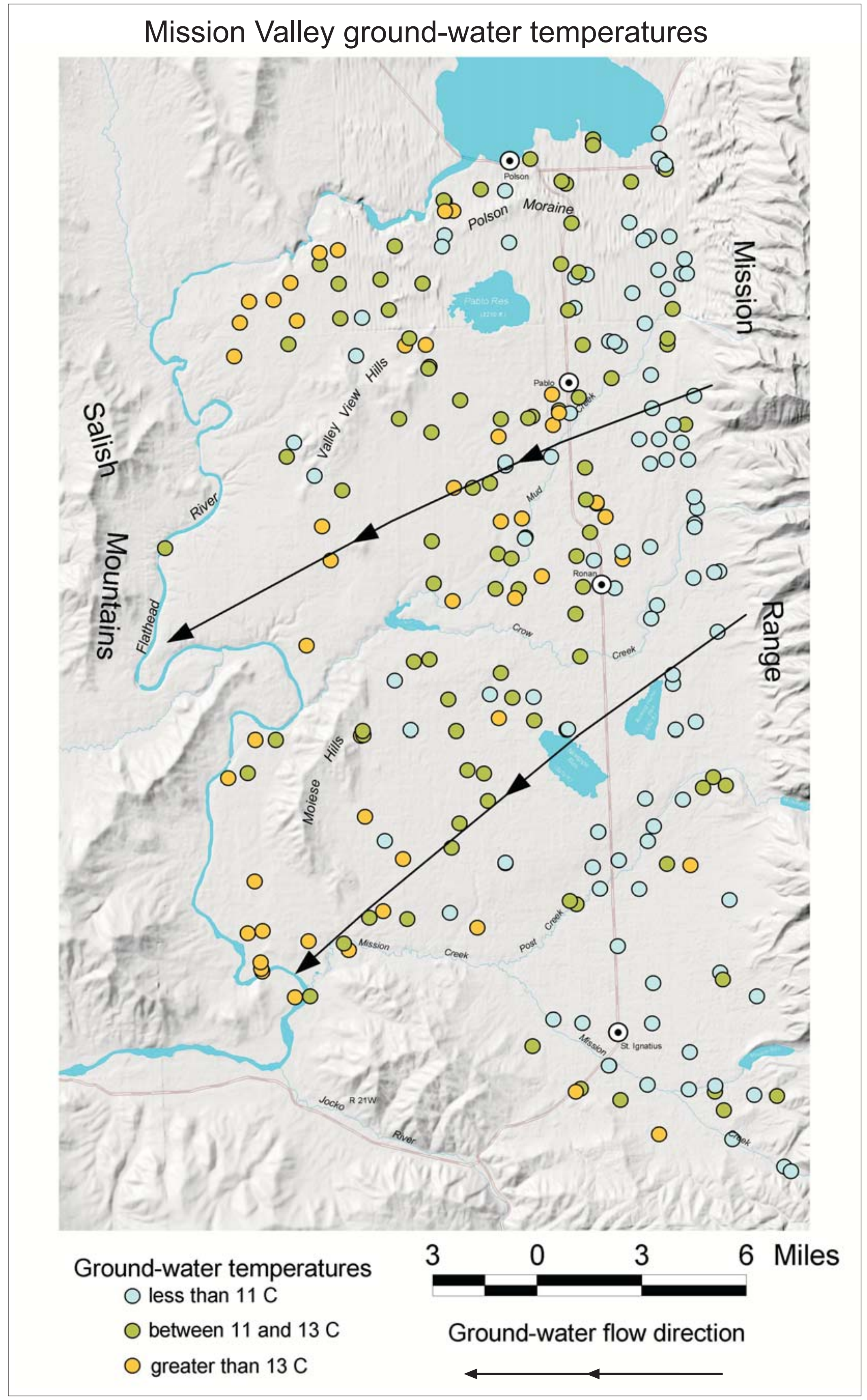
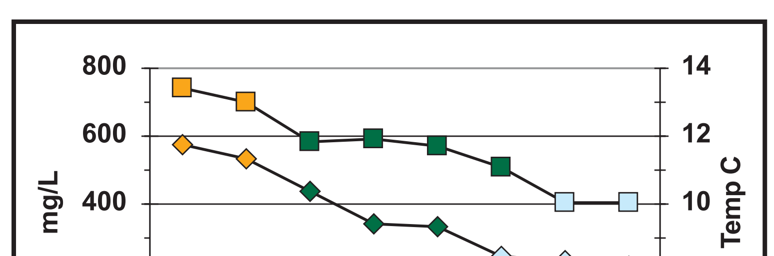
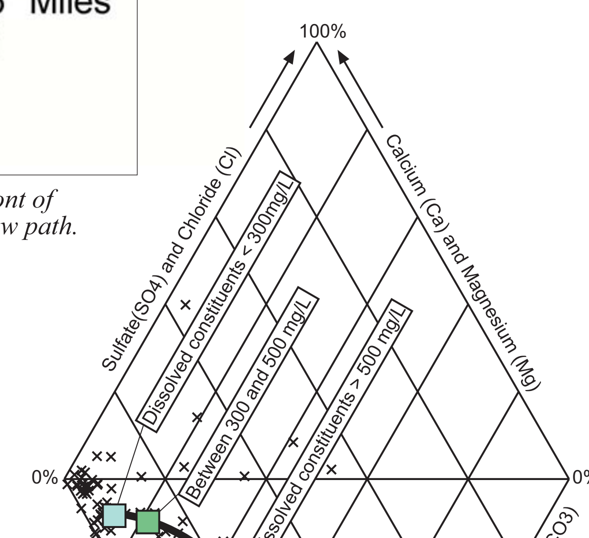


Figure 3. In the Mission Valley, ground-water temperatures are cool near the front of the Mission Range; temperatures generally increase down the ground-water flow path.





Characterization Study Area. The area is characterized by a series of north-northwest trending, structurally controlled intermontane basins that are bounded by mountains formed mostly of metamorphosed sedimentary rocks of the Proterozoic Belt Supergroup (bedrock). The basins are filled with consolidated to unconsolidated Tertiary and Quaternary sediment; most of the upper and surficial basin-fill deposits are of glacial or glacial-lake origin. Overviews of the area's geology are presented in Smith (2002a, 2002b), and Tuck and others (1996). The hydrogeology of various parts of the study area are presented in Kendy and Tresch (1996), Briar and others (1996), Slagle (1988), Makepeace (1994), Donovan (1985), Boettcher (1982), Thompson (1988) and Abdo (1997). The Flathead River and its tributaries drain the valleys in the mapped area. Ground water in the basin-fill sediment and the fractured bedrock along the valley margins is an important source of municipal, domestic, irrigation, and stockwater.

Aquifers are saturated geologic materials that yield sufficient water to supply wells and springs. Non-aquifer materials (also known as confining beds) also may be saturated, but have low permeability and do not produce usable amounts of water to wells or springs. Within the basin-fill deposits, permeable layers of sand and gravel form the aquifers and are composed of alluvium (silt, sand, and gravel most likely deposited by glacial meltwater streams). These permeable layers are typically covered and/or interfinger with glacial till (poorly sorted clayey gravel deposited directly by glaciers), and glacial-lake deposits (clay and silt deposited in glacial lakes); their depth, continuity, and character vary from valley to valley reflecting the variable depositional history of each valley. The basin-fill aquifers can be unconfined, semi-confined, or fully confined. Shallow alluvium along rivers and streams typically contains unconfined aquifers, whereas the deeper aquifers that are capped by till or glacial-lake deposits are typically semi- to fully confined. Although the permeable layers within the basin-fill deposits may not be contiguous over large areas, they generally have sufficient hydraulic continuity to be considered a single entity in terms of ground-water flow on a valley-wide scale (Slagle, 1988; LaFave, 2002). One notable exception is located in the Little Bitterroot valley where a 7 to 60 foot- thick layer of Pleistocene sand and gravel forms an aquifer that underlies most of the valley. The aquifer, known informally as the Lone Pine aquifer (Donovan, 1985), is confined by as much as 350 feet of silt and clay that separates it hydraulically from shallow alluvial aquifers along the Little Bitterroot River and the valley margins.

The Belt Supergroup bedrock which occurs around the fringes of the valleys generally has sufficient fracture permeability (the

are presented on the map: laboratory analyses obtained as part of this study and a recent study by Abdo (1997), laboratory analyses from earlier studies, and values estimated from field data. Water from 120 domestic, stock, public supply and monitor wells was analyzed for major ions and trace metals between May 1993 and November 1996. Field measurements of specific conductance, pH and water temperature also were obtained from each of the sampled wells. To ensure collection of a representative sample, each well was pumped prior to sample collection until the field parameters stabilized and at least three well-casing volumes were removed. Analyses were performed by the Montana Bureau of Mines and Geology's (MBMG) Analytical Laboratory. An additional 122 ground-water samples collected by the MBMG or the U.S. Geological Survey prior to 1993 were also used. The laboratory data were supplemented by dissolved-constituents concentrations estimated from field measurements of specific conductance at an additional 346 wells. The laboratory analyses and field measurements presented on this map are available from the Montana Ground-Water Information Center database.

DISSOLVED CONSTITUENTS

Water quality may be characterized by the type and concentrations of its dissolved constituents. The dissolved-constituents value is the sum of the major cations (Na, Ca, K, Mg, Mn, Fe) and anions (HCO_3, CO_3, SO_4, Cl, SiO_3, NO_3, F) expressed in milligrams per liter (mg/L). To highlight areal patterns of dissolved constituents within the aquifer the concentrations are presented in three categories. Values less than 300 mg/L are plotted in blue symbols; those between 300 and 500 mg/L are in green; and those greater than 500 mg/L are in orange.

Dissolved constituents in ground water are a result of the initial chemistry of the recharge water and subsequent interactions of that water with soils and aquifer materials. Their total concentration provides a general indicator of water quality; the lower the total, the better the water quality. Typically, water does not become too salty to drink until the concentration of dissolved constituents reaches about 2,000 mg/L. All of the ground water in the basin-fill aquifers in the mapped area was well below this threshold; in general, the water is of good quality for drinking and other uses. Based on the 588 ground-water measurements used in this study, dissolved-constituent concentrations averaged 357 mg/L. Ground water from wells completed in the bedrock (374 samples, average = 357 mg/L) was slightly higher in dissolved constituents than wells completed in the alluvium (146 samples, average = 345 mg/L); the difference however (less than 5 percent), is not significant. In general, the dissolved-constituent concentration of ground water from the Lone Pine aquifer (Abdo, 1997),

In the Mission Valley, temperature and chemistry of the ground-water evolve along flow path. Ground water generally flows from the Mission Mountains on the east to the Flathead River which bounds the valley on the west (LaFave, 2002). Measurements of ground-water temperature show a wedge of cooler water (less than 11 degrees C) along the flanks of the Mission front where water enters the ground-water flow system, whereas ground- water temperatures downgradient, near the discharge area along the Flathead River, are generally greater than 13 C (figure 3). The increase in ground-water temperature along flow path coincides with an increase in dissolved constituents. Near the Mission front concentrations are generally less than 300 mg/L; downgradient, near the Flathead River, concentrations are generally greater than 500 mg/L (figure 4). The chemical composition of the ground water changes as well. The cooler water with lower dissolved-constituent concentrations near the Mission front is a calcium-magnesium-bicarbonate type water; as the water becomes warmer and the dissolved constituents increase, the water becomes more enriched in sodium and bicarbonate (figure 5).

MAJOR IONS AND SUITABILITY FOR WATER USE

Table 1 summarizes the results of the 120 ground-water analyses performed for this study and from Abdo (1997). For reference, the U. S. Environmental Protection Agency's recommended maximum contaminant levels (MCL) and secondary maximum contaminant levels (SMCL) for public water supplies are also presented. Constituents for which maximum levels have been set may pose a health threat at elevated concentrations. Secondary levels are set for aesthetic reasons--elevated concentrations of these constituents may be a nuisance (bad taste or odor, or staining) but do not normally pose a health risk.

Ground water in the basin-fill aquifers is suitable for domestic and stock consumption as well as for irrigation. In the 120 samples, only fluoride (23 samples), arsenic (8 samples), and barium (3 samples) were detected above their respective health standards (table 1). All of the fluoride and barium and most of the arsenic (5 out of 8) exceedences occurred in the Little Bitterroot valley; most were from wells in the vicinity of the Wild Horse Hot Springs geothermal area (also referred to as the Camp Aqua geothermal area). Solute concentrations of geothermal water are commonly higher than those of nonthermal waters (Hem, 1992). Abdo (1997), Donovan (1985) and Kendy and Tresh (1996) all report higher concentrations of dissolved solids in the geothermal areas of the Little Bitterroot valley.

Nitrate (NO_3) is an essential nutrient for plant life, yet is potentially toxic to humans (especially infants) when present in drinking water at excessive concentrations. High levels of nitrate in well water typically indicate seepage from septic tanks, fertilizers, land application of animal wastes or other nonpoint sources. None of the sampled wells had nitrate concentrations above the health standard of 10 milligrams per liter-nitrogen (mg/L-N); the highest concentration detected was 5.1 mg/L-N. In general nitrate was not detected in the valley-fill aquifers at concentrations greater than 1.5 mg/L-N; only ten samples had nitrate concentrations between 1.5 and 5.1 mg/L-N suggesting little impact from surface sources of nitrate to the basin-fill aquifers in the mapped area.

MAP CONSTRUCTION

This map was constructed by plotting "low," "intermediate" and "high" concentrations of dissolved constituents of 242 ground-water samples. The laboratory data were supplemented by estimates of dissolved- constituent concentrations derived from specific-conductance measurements made at an additional 346 wells. The specific-conductance (SC) measurements were used to estimate dissolved constituents (DC) according to the equation: DC = A x SC (Hem, 1992). Based on a straight-line regression of data from the mapped area, a value of A = 0.92 was used in the above equation.

ACKNOWLEDGMENTS

Well owners who granted access and personnel from the Confederated Salish and Kootenai Tribes who assisted with the data collection are gratefully acknowledged. Reviews of this report by Tom Patton, and Wayne Van Voast improved its clarity.

SOURCES OF DATA

Geographic Features:

Population centers and roads are from 1:100,000-scale U.S. Geological Survey (USGS) Digital Line Graph files available from the Natural Resources Information System (NRIS) at the Montana State Library, Helena, Montana. Hydrography has been simplified from the 1:100,000 Digital Line Graph files. Township boundaries are from U.S. Forest Service. The land ownership base was modified from 1:100,000-scale land ownership data available from NRIS.

Point Data:

Well-location and water-quality samples were obtained by the Ground-Water Characterization Program and personnel from the Confederated Salish and Kootenai Tribes. Well locations are accurate to the 2.5-acre level (to within +/- about 300 feet). All water-quality data used on this map are available from the Ground-Water Information Center (internet: http://mbmggwic.mtech.edu) at the

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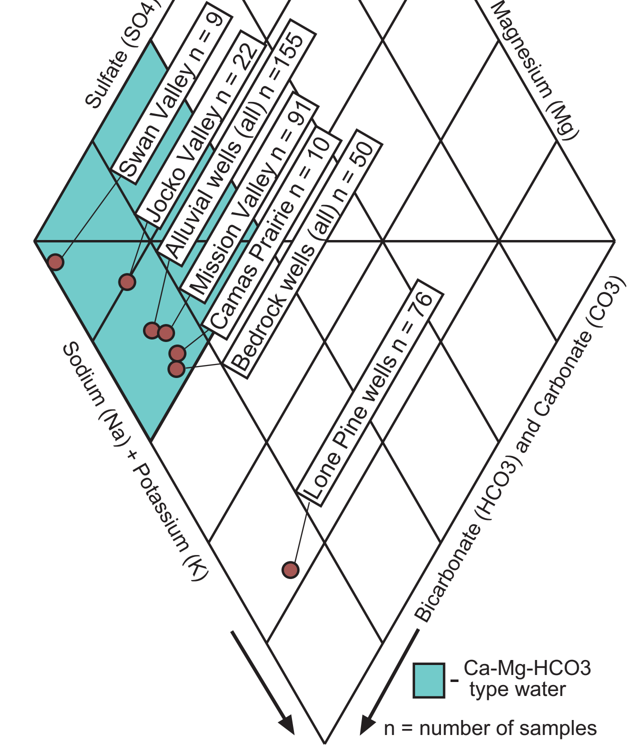


Figure 2. Ground water across the mapped area is predominately a calcium-magnesium-bicarbonate type, except for water from the Lone Pine aquifer which has a distinct sodium-bicarbonate signature.

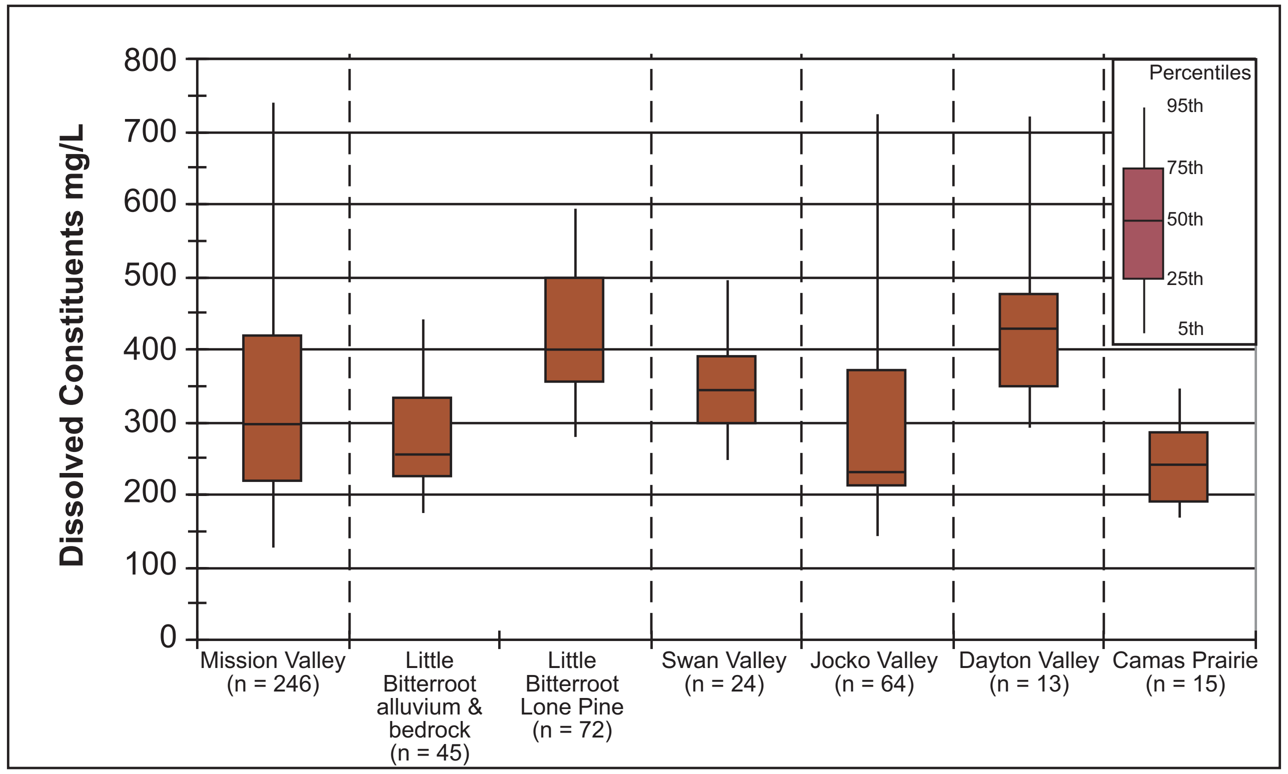
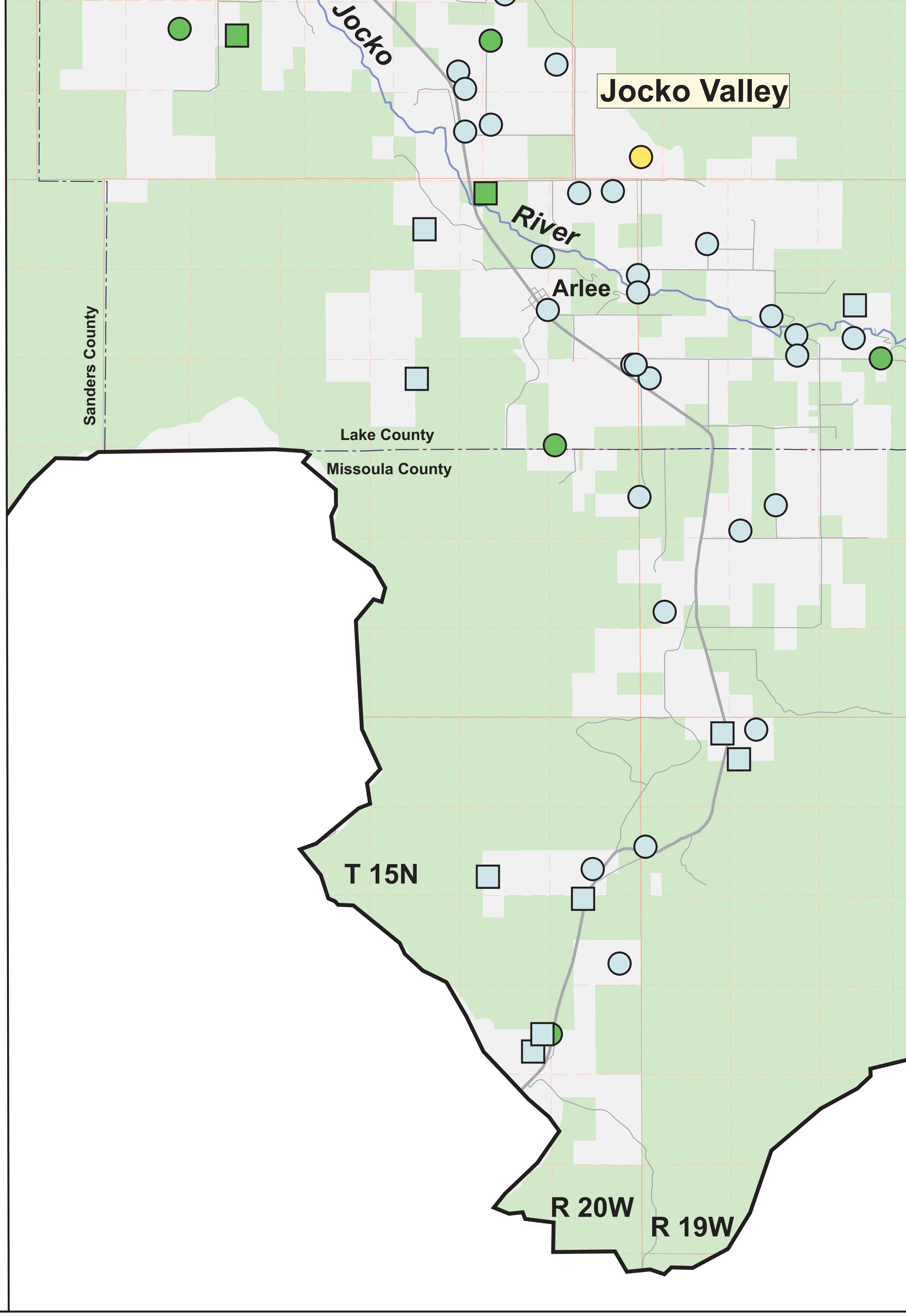


Figure 1. Dissolved constituents in ground water are generally less than 500 mg/L across the mapped area. However, median concentrations from the Dayton valley and the Lone Pine aquifer in the Little Bitterroot valley are higher than those in ground water from the other valleys.



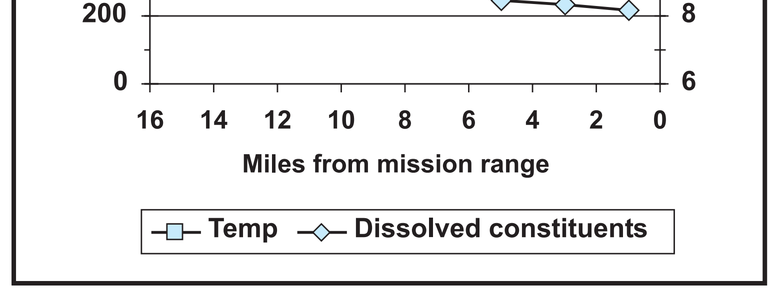


Figure 4. The average dissolved constituent concentration and temperature of ground water in the Mission Valley increases with distance away (downgradient) from the Mission Range. (Colors refer to general locations on figure 3.)

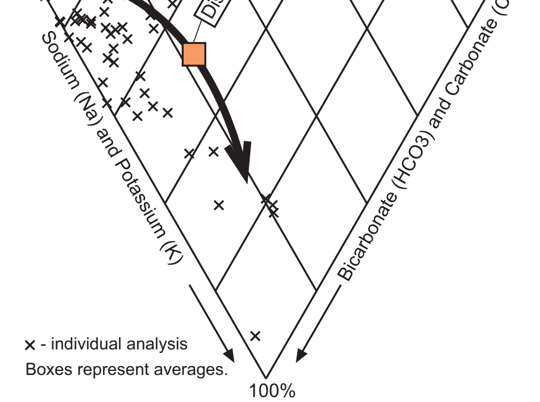


Figure 5. As the dissolved-constituent concentration increases, the ground-water chemistry evolves from a calcium-magnesium-bicarbonate type to more of a sodium-bicarbonate type water.

Table 1. Summary of water-quality data for 120 wells sampled during this study and in the Little Bitterroot Valley by Abdo (1997).

Common constituents	**Min**	**Mean**	**Median**	**Max**	**SMCL**	**MCL**	**Number exceeding**
Dissolved constituents-sum (mg/L)*	120	347	352	657	--	--	--
Total dissolved solids (mg/L)**	84	234	236	429	500	--	0
Sodium (mg/L)	0.7	40.5	21.8	156.0	250	--	0
Potassium (mg/L)	<0.1	1.6	1.4	6.5	--	--	--
Calcium (mg/L)	0.8	28.9	30.2	93.8	--	--	--
Magnesium (mg/L)	<0.1	11.2	9.8	42.9	--	--	--
Chloride (mg/L)	<0.5	6.6	2.6	93.8	250	--	0
Bicarbonate (mg/L)	69.8	222.1	224.8	448.5	--	--	--
Sulfate (mg/L)	<2.5	8.4	4.7	107.3	250	--	0
Nitrate (mg/L as N)	<0.25	0.5	<0.25	5.1	--	10	0
Fluoride (mg/L)	<1.0	1.5	<1.0	8.1	--	4	23
Iron (mg/L)	<0.003	0.4	0.02	5.6	0.3	--	30
Manganese (mg/L)	<0.002	0.2	0.01	4.3	0.05	--	42
Selected trace elements							
Arsenic (ug/L)	<1.0	10.5	1.1	169.0	--	50	8
Barium (ug/L)	<10.0	224.6	131.4	1675	--	1000	3
Chromium (ug/L)	<2.0	4.6	2.0	16.6	--	100	0
Selenium (ug/L)	<1.0	0.5	<1.0	6.4	--	100	0

Other parameters	**Min**	**Median**	**Max**	**SMCL**	**MCL**	**Number exceeding**
Sodium adsorption ratio (SAR)	0	0.8	27	--	--	--
Hardness as $CaCO_3$	56	207	401	--	--	--
pH	6.7	8.1	9.5	6.5 - 8.5	--	6

'--', No standard available or not applicable.
* Dissolved constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions (HCO_3, CO_3, SO_4, Cl, SiO_3, NO_3, F) in mg/L.
** Total dissolved solids reported as equivalent weight of evaporation residue.
MCL - U.S. EPA maximun contaminant level for public water supplies.
SMCL - Secondary contaminant level for public water supplies.