SUMMARY OF GROUND WATER RESOURCES
FLATHEAD INDIAN RESERVATION, MONTANA

CSKT Water Resources Program April, 2020

The enclosed summary, generally compiled from existing information, concerns ground water resources located on the Flathead Indian Reservation in northwest Montana. Across many parts of our blue planet there is a substantial focus on surface water and fewer resources and less emphasis is placed on ground water. This, despite our reliance on ground water as a primary drinking water supply source and our well-developed understanding of the role of ground water to support surface water systems, both from a quantity and quality perspective. This summary is not inclusive of our full understanding of Reservation ground water resources, but serves as an entry point for readers who wish to expand their understanding.

Hydrogeology – the field which studies and manages ground water – is multi-disciplinary, and relies on an understanding of geologic processes; the physics of flow through porous earth materials; and the components of a water budget, both in space and time, that drive ground water systems. Ground water quality evolves based on these physical processes, and in certain settings is modified by human inputs and contaminants.

Below we focus on a few themes: the geologic and hydrogeologic framework for Reservation ground water resources; ground water flow; general ground water budgets; ground water use as a potable water supply; and, we summarize information from the Tribes' ground water level monitoring network. Maps and figures are relied upon to examine these topics.

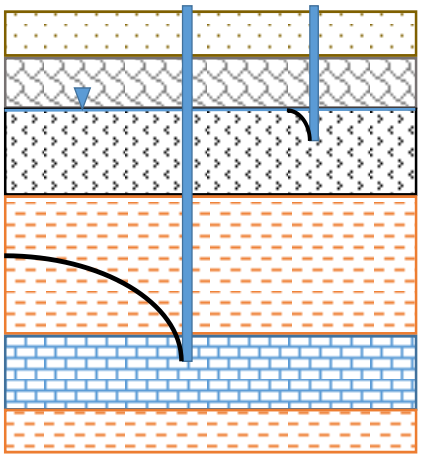
This summary draws from a number of existing regional and Reservation-specific reports. To promote use and readability of the content, we do not rigorously apply citations in the text, but instead include an index of citations. This is consistent with the perspective that the summary reflects a compilation of Water Resources Program knowledge.

Hydrogeologic Framework

With surface water resources, we often organize our understanding around watersheds of varying hierarchical scale. A hydrogeologic framework forms a parallel organizing structure for ground water systems. The framework will vary depending on the questions being addressed, the scale of the question, and the level of information available. Below, we define and map a framework which attempts to organize aquifers – saturated water-bearing earth materials capable of yielding water to a well; confining layers – saturated- to unsaturated earth material caps or barriers overlying and underlying aquifers in certain settings; and unsaturated soil and subsoil materials - into map units. These are often termed hydrostratigraphic units when map units occur over larger geographies; in our application we refer to them as hydrogeologic units.

We apply a repeating format to describe the framework for valley fill aquifers, including: a map of the unit boundaries; a map showing total well depth from wells found in the MBMG Ground Water Information database (GWIC); and we provide a short text discussion of map units.

Ground water definitions and simplified cross section through portions of the Mission Valley



Soil – top layer of earth surface where mineral particles interact with organic and biological processes (top 5+ feet)

Unsaturated zone – sub-soil mineral particles, pore spaces ranging from unsaturated to saturated condition. Thickness - shallow in wet areas up to several 100's of feet in arid areas

Water table – boundary between fully saturated and unsaturated pore space in an unconfined aquifer. Water table fluctuate as pore space fills or drains in response to recharge and discharge

Unconfined aquifer – saturated water bearing geologic material capable of transmitting substantial volumes of water; water table is the upper boundary of the aquifer. Thickness of unconfined aquifer and storage volume of water will change as water table fluctuates

Confining layer (aquitard) – low permeability layer, may transmit water but not in sufficient quantity to yield water to wells

Confined aquifer – aquifer separated by two confining layers. Water level - termed potentiometric surface -will generally rise above the top of the aquifer. Artesian flow occurs when the potentiometric surface is at or above land surface. Thickness of aquifer remains ~ constant, and water is removed from storage through compression of aquifer sediments and expansion of water. Confined aquifer has lower storage volume available per unit of drawdown than unconfined aquifer

Well and drawdown zone (cone of depression) – water withdrawal will lower the water table or potentiometric surface. Storage volume higher in unconfined aquifer – zone of drawdown more limited (10's to 100's of feet). Storage volume lower in confined aquifer – zone of drawdown larger (100's to 1,000's of feet or more)

Ground water wells are completed in a number of areas outside of mapped units; these are often but not exclusively wells completed in fractured bedrock.

Throughout, the reader should understand that boundaries between map units are transitional; there is a high level of heterogeneity within map units; and the information base is limited, thus requiring some level of interpretation. Further, ground water moves both horizontally and vertically between units and it is generally more appropriate to consider ground water flow at a valley scale.

Geologically, we conceptualize the Reservation as a series of north to northwest-aligned intermontane valleys bordered by fault-bounded mountain blocks. The mountain blocks form from the Belt Supergroup – an immensely thick assemblage of fine-textured and moderately metamorphosed sedimentary rock primarily deposited between 1,450 to 1,400 Ma (million years ago). Valleys contain a complexly interbedded accumulation of sediments, ranging from Tertiary-age (~30 Ma-5 Ma) semi-consolidated clays, sandstones, and conglomerates with coal and wood seams, to Quaternary-age (2.6 Ma-present) glacial, glaciofluvial, glaciolacustrine and alluvial sediments. The arrangement of valley floor sediments is complex due to the concurrent intersection between late Quaternary alpine glaciers, the Flathead Lobe of the Cordilleran ice sheet, and Glacial Lake Missoula filling and draining cycles. As a simplifying matter, we identify three groupings of hydrogeologic units that are applicable at both a Reservation and broader regional scale.

Belt Supergroup bedrock occurs in mountain and foothill areas, as elevated islands within valleys, and underlying shallow unconsolidated sediments on valley margins. At depth, the Belt Supergroup forms the basement floor underlying each valley. Belt rocks have enough fracture permeability to sustain ground water development, although well yields are often low and it can be difficult to predict where ground water will occur.

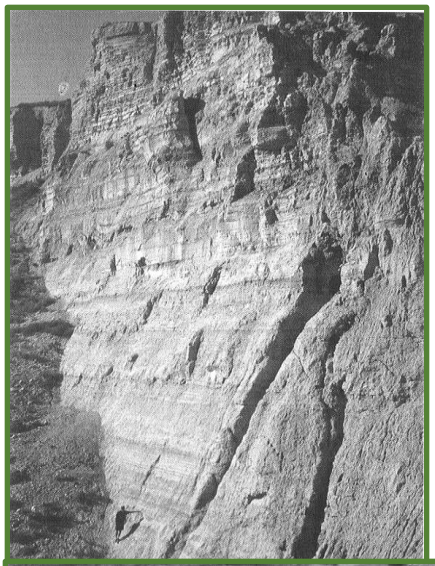
Tertiary-age sediments are a minor hydrogeologic unit on the Reservation encountered in deep valley wells, and surficially in valley margin areas not subjected to glaciation. The unit is referenced by geologic age as spanning the Oligocene through middle Pliocene and is thought to include the older Renova Formation – fine-grained consolidated to semi-consolidated sediment, the younger Six Mile Formation – coarse-grained sand and gravel conglomerates, and likely other undifferentiated deposits. Tertiary sediments may be described in well logs as varicolored, compacted clays – often lumped as ochre-colored or blue clays, interbedded with green and tan-colored sandstones and consolidated gravels. Minor coal or wood seams are common. Well yields are generally poor. When exposed at the surface, Tertiary sediments are often observed as ochre-colored clays.

Water bearing intervals often have reducing water chemistry due to distance from recharge areas - older ground water with greater time for rock-water interactions; and the mineral properties of Tertiary sediments.

Quaternary-Age sediments are exploited as the primary potable water supply and include Pleistocene-age (2.6 Ma-11,700 BP) glacial, glaciofluvial, glaciolacustrine and more recent Holocene sediments (11,700 BP-P) generally distributed along stream corridors. The most prolific aquifers on the Reservation are located in Pleistocene glacial outwash and glaciofluvial sediments (photos – glacial outwash in Jocko Valley).









Glacial Lake Missoula glaciolacustrine sediments are extensively distributed across the Reservation, and form a continuous section exceeding 300 feet in thickness along the Flathead River. Sediments include varved (laminated) silts and clays, thin sand and gravel partings, and diamict – poorly sorted, dense unconsolidated conglomerate comprised of gravel through boulder-size clasts embeddd in a silt and clay matrix.

Glaciolacustrine sediments form well-recognized confining layers and are also exploited as low water yielding aquifers. Certain areas, including the area around and west of Round Butte in the Mission Valley, have deep sections of glaciolacustrine sediment. (photos Glacial Lake Missoula sediments – Landslide Bend on Flathead River).

Jocko Valley Hydrogeologic Units (Hydrogeologic Unit Map and Total Well Depth Map)

Eight hydrogeologic units are identified in the Jocko Valley. As noted above, boundaries between units are transitional, and heterogeneity observed within units will depart from the generalized descriptions.

JV-BR: Jocko Valley Bedrock Unit: This unit is a fractured bedrock aquifer overlain by unconsolidated sediments. In the Evaro Area, depth to bedrock varies between 50 feet to 125 feet and total well depths are variable but increase to the west. Near surface sediments include clays and silts with interspersed sands and gravels. Wells exhibit confined to semi-confined behavior. Well yields are reported as low – test pumped between 5 gpm and 10 gpm with specific capacities generally less than 1 gpm/ft. In the northerly map unit near Valley Creek, there are a limited number of wells but fractured bedrock is overlain by glacial Lake Missoula silts and clays and reported well yields are low.

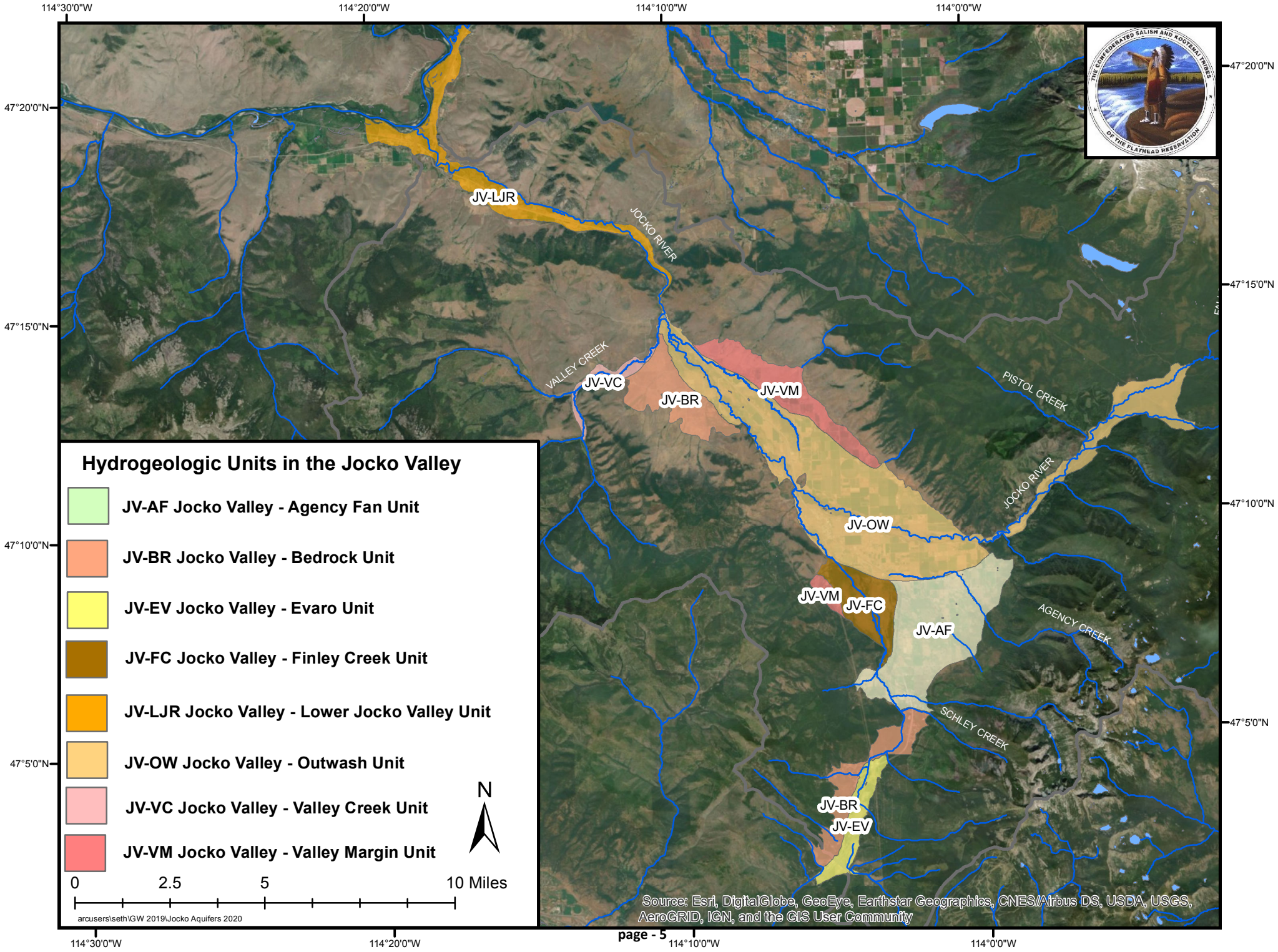
JV-EV: Jocko Valley Evaro Unit: This is a minor unit which parallels the course of Finley Creek. The aquifer is unconfined, comprised of moderately sorted gravels, and depth to water is reported between 30 feet and 60 feet. Well logs that penetrate to depth report grey and orange clays, suggestive of Tertiary sediments. Well yields are moderate and average specific capacities are around 3.5 gpm/ft. Tertiary sediments are exposed at the surface west of the Highway 93 near Evaro as ochre-colored clays.

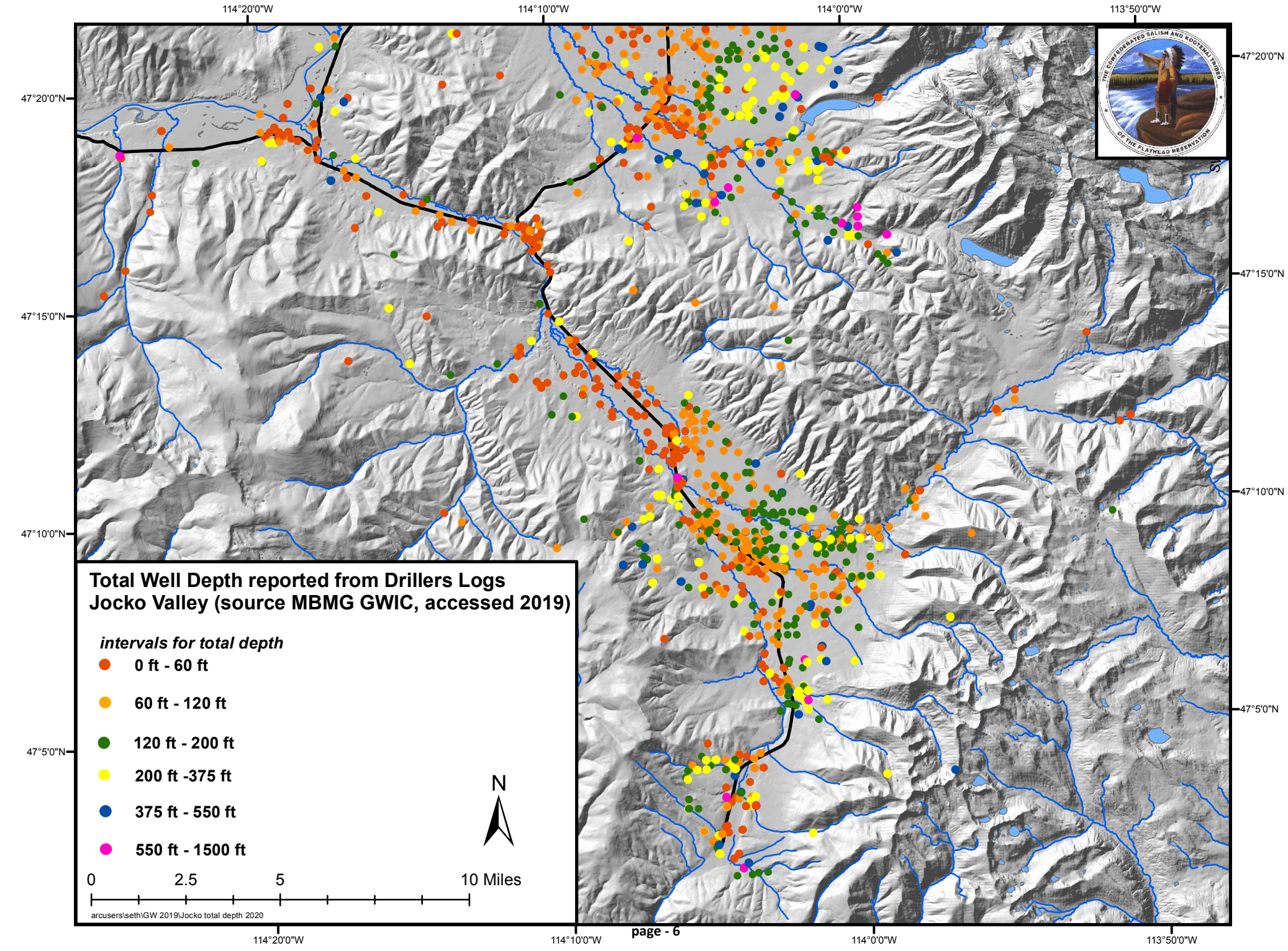
JV--AF: Jocko Valley Agency Fan Unit: This is a heterogenic unit comprised of a mix of glacial sediments, recent streamside sediments and Tertiary sediments at depth. The unit is mapped based on surface expression, which is described as a composite, depositional fan feature. Sediments are generally moderately to poorly-sorted gravels with a high percentage of silt and clay fines. Wells near the south margin penetrate to 500 feet and intercept Tertiary sediments. As a generalization, there appear to be two water-bearing intervals – one between 10 feet and 50 feet concentrated along stream corridors and one in excess of 150 feet. Well yields are generally modest with average specific capacity values around 0.8 gpm/ft.

Well specific capacity (S_c) is a measure of well performance and indirectly aquifer yield potential. Specific capacity is determined from drillers logs using the test pumping rate (Q in gpm) divided by the water level drawdown at the end the pumping period (drawdown in ft). Specific capacity is in units of gpm/ft. Specific capacity information is often reported because it is readily available from a well log. There are notable limitations, including that wells may not be test pumped at their full capacity. The reported values are solely intended as supporting descriptive information.

JV-FC: Jocko Valley Finley Creek Unit: This unit is defined by surface morphology, and was deposited as a distributary fan network by ancestral braids of Finley Creek. Sediments are comprised of moderately sorted gravels with interstitial sand and silt. Wells are generally less than 100 feet in depth, and do not penetrate the full aquifer thickness. To the north, depth to ground water decreases and a substantial ground-water recharge wetland system has developed. Well yields are moderate and specific capacity values average 2.5 gpm/ft.

JV-OW: Jocko Valley Outwash Unit: This is the primary aquifer unit in the Jocko Valley, and is heavily exploited as a source of domestic drinking water. Valley floor sediments include glacial outwash, reworked sands and gravels along the Jocko River, and Tertiary sediments at depth. The aquifer is unconfined, however in the vicinity of Arlee, a finer silt interval is reported at approximately 40 feet in depth and may create semi confined conditions. Total well depths and depth to ground water decrease relatively uniformly to the north, and the water table is at or near land surface in the north extent of the


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JV-LJR
JOCKO RIVER
VALLEY CREEK
JV-VC
JV-BR
JV-VM
PISTOL CREEK
JOCKO RIVER
JV-OW
JV-VM
JV-FC
JV-AF
AGENCY CREEK
SCHLEY CREEK
JV-BR
JV-EV
Hydrogeologic Units in the Jocko Valley
JV-AF Jocko Valley - Agency Fan Unit
JV-BR Jocko Valley - Bedrock Unit
JV-EV Jocko Valley - Evaro Unit
JV-FC Jocko Valley - Finley Creek Unit
JV-LJR Jocko Valley - Lower Jocko Valley Unit
JV-OW Jocko Valley - Outwash Unit
JV-VC Jocko Valley - Valley Creek Unit
JV-VM Jocko Valley - Valley Margin Unit
N
0
2.5
5
10 Miles
arcusers\seth\GW 2019\Jocko Aquifers 2020
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


114°20'0"W
114°10'0"W
114°0'0"W
113°50'0"W
47°20'0"N
47°15'0"N
47°10'0"N
47°5'0"N
Total Well Depth reported from Drillers Logs
Jocko Valley (source MBMG GWIC, accessed 2019)
intervals for total depth
0 ft - 60 ft
60 ft - 120 ft
120 ft - 200 ft
200 ft -375 ft
375 ft - 550 ft
550 ft - 1500 ft
N
0
2.5
5
10 Miles
arcusers\seth\GW 2019\Jocko total depth 2020

unit. Substantial volumes of ground water discharge to the Jocko River and valley floor wetlands, and ground water discharge forms Jocko Spring Creek. Well yields can be high and specific capacity values average around 20 gpm/ft.

JV-VM: Jocko Valley Margin Unit: This is a minor hydrogeologic unit formed in unconsolidated sediments on the valley fringe. Sediments include colluvium, glaciolacustrine diamict, and fine sand near the surface. Water bearing intervals are generally intercepted below 125 feet and well yields are moderate, with average specific capacity values around 1.8 gpm/ft.

JV-LJR: Jocko Valley Lower Jocko Valley Unit: This unit is comprised of a confined aquifer along the valley axis. The confined aquifer is comprised of well-sorted gravels with fine-textured sand through silt at the surface. Depth to the aquifer is shallow and the water table rises to between 5 and 15 feet below land surface. Artesian conditions occur in the northern portion of the unit. Well yield are moderate to high, with average specific capacity values around 15 gpm/ft.

Little Bitterroot Valley Hydrogeologic Units (Hydrogeologic Unit Map and Total Well Depth Map)

Three hydrogeologic units are identified in the Little Bitterroot Valley. We also include aquifers delineated in Camas Prairie and White Earth Creek in this section.

LB-SF: Little Bitterroot Sullivan Flats Unit: Three distinctive zones are identified – Sullivan Flats, Big Draw, and Elmo. Each zone shares a common geologic origin, having been formed by coarse-grained glacial outwash derived from the Elmo Arm of the Flathead Lobe of the Cordilleran ice sheet.

The most productive aquifer occurs in Sullivan Flats. This a fully confined sand and gravel aquifer occurring around 300 feet in depth. The aquifer is overlain by a thick sequence of glacial Lake Missoula silts and clays, and trending towards Big Draw, a sand and gravel interval at the surface. The aquifer is artesian and is capable of yields in the 300 gpm to 500 gpm range. The Sullivan Flats unit is likely an extension of the Lonepine aquifer, but is mapped as a separate unit to reflect the large discharge at Sullivan Springs and a potential geologic discontinuity near Niarada.

Glaciolacustrine sediments are generally absent in Big Draw and the Sullivan Flats portion of the aquifer grades to a deep thickness of glacial outwash sediment here. There are very few wells in Big Draw, but it appears there is very limited potential for ground water development. Unconsolidated sediments exceed 400 feet in depth and include sands and gravels with interbeds of fine textured sediment. Generally, this area should not be considered as a viable source for ground water development.

The moraine crest west of Elmo represents a ground water divide with ground water flowing east toward Flathead Lake or west towards Niarada, depending on topographic position. Aquifer sediments in the vicinity of Elmo occur below 100 feet and are generally well sorted gravels. Glaciolacustrine sediments cap the aquifer and create artesian conditions in some wells.

What's in a well log we look at well log information from a well recently drilled in the lower Crow Creek area (GWIC id 298563) https://mbmggwic.mtech.edu/sqlserver/v11/reports/SiteSummary.asp?gwicid=298563&agency=mbmg&session=1032211&reqby=P&. Well logs are maintained in GWIC and are accessible from the MBMG website. Below, we provide the reader insight into the methods applied to infer hydrogeologic units and aquifer hydraulic properties. We illustrate with one well log, but in practice try to use a weight-of-evidence approach, utilizing information from multiple logs.

Well completion details

Borehole dimensions

From	To	Diameter
0	724	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	672	6.6	0.25	540.0	WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
672	672	6.6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	35	BENTONITE	Y

Well is open bottom (no screened interval), it was cased to 672 feet, and advanced open hole to 724 feet. The well provides water level and hydraulic information at the base of the well – 672 feet. No screens or slots were placed in other intervals – either due to flowing sands or no water yield potential.

Lithology

From	To	Description
0	5	FILL DIRT
5	210	TAN CLAY AND GRAVELS
210	217	SATURATED TAN CLAY AND GRAVELS
217	320	COBBLES, GRAVELS AND LOTS OF SAND AND WATER
320	350	TAN CLAY AND GRAVELS
350	355	LOTS OF FINE GRAY SAND, VERY SMALL PEA GRAVELS AND WATER
355	410	GRAY CLAY
410	417	VERY SMALL PURPLE AND GREEN GRAVELS, LOTS OF SAND AND SILTS AND WATER
417	431	WHITE HARDPAN CLAY
431	502	PEACH COLORED TAN CLAY AND SOME GRAVELS
502	552	DARK GREEN HARDPAN CLAY
552	612	DARK BROWN HIGHLY COMPACTED HARDPAN CLAY
612	664	GREEN HIGHLY COMPACTED HARDPAN CLAY
664	674	FRACTURED GRAYISH PURPLE AND GREEN ROCK AND SOME WATER

0 – 217 ft: glaciolacustrine sediment – diamict	**confining layer**
217 – 320 ft: glaciofluvial sediment – cobble to sand, water	**aquifer sediments, likely low yield or unable to clear sand**
320 – 350 ft: glaciolacustrine – diamict (possibly start of Tertiary)	**confining layer**
350 – 612 ft: Tertiary sediments – various textures	**confining layer, no indication of water bearing intervals**
612 – 664 ft: Tertiary or weathered Belt bedrock	**confining layer**
664 – 724 ft: Fractured bedrock, water	**aquifer, water**

Well test data and well hydraulics

Total Depth: 724
Static Water Level: 123
Water Temperature:

Air Test *

5 gpm with drill stem set at 700 feet for 2 hours.
Time of recovery 3 hours.
Recovery water level 123 feet.
Pumping water level _ feet.

Static water level at 123 ft – confined aquifer response, consistent with lithology. Test pumped at very low rate – 5 gpm, aquifer has very low yield potential; this is corroborated by water level time of recovery – 3 hours. Specific yield cannot be determined, since pumping water level not reported. Although inferred, this suggests a deep drawdown, below range of driller's measurement equipment.

LB-LP: Little Bitterroot Lonepine Unit: Unit LB-LP, locally known as the Lonepine aquifer, is a laterally extensive glacial outwash aquifer comprised of well sorted gravels occurring between 250 feet and 300 feet below land surface. Wells that penetrate the aquifer suggest that the aquifer thickness varies between 20 feet and 50 feet. The overlying confining layer is glaciolacustrine silt and clay. The aquifer is fully confined, and artesian conditions occur south of Lonepine. The aquifer is capable of high yields, and some wells flow in excess of 800 gpm. Aquifer extent and well yield decrease down gradient towards the Flathead River.

Northwest, towards Mill Creek, the confining layer thins and transitions to alluvial terraces comprised of sands and gravels. This is thought to be a primary recharge area for the Lonepine Aquifer.

Geothermal conditions occur in the immediate vicinity of Camp Aqua, but rapidly attenuate away from the core area. The geothermal system here has high water temperatures and high well yield due to its connection with the Lonepine Aquifer. The geothermal system is tapped from a well finished at just under 1,000 feet, where bedrock is in proximity to overlying unconsolidated sediments.

LB-HS: Little Bitterroot Hot Springs Unit: This is a composite map unit which includes unconsolidated sediments along Hot Springs Creek and a fractured bedrock system on the valley margin, notably in the Camas townsite area. Generally, aquifer materials occur at depths exceeding 100 feet and are comprised of moderately sorted gravels. The aquifer exhibits a semi confined response and unsaturated zone materials are a mix of sands and gravels through silts and clays.

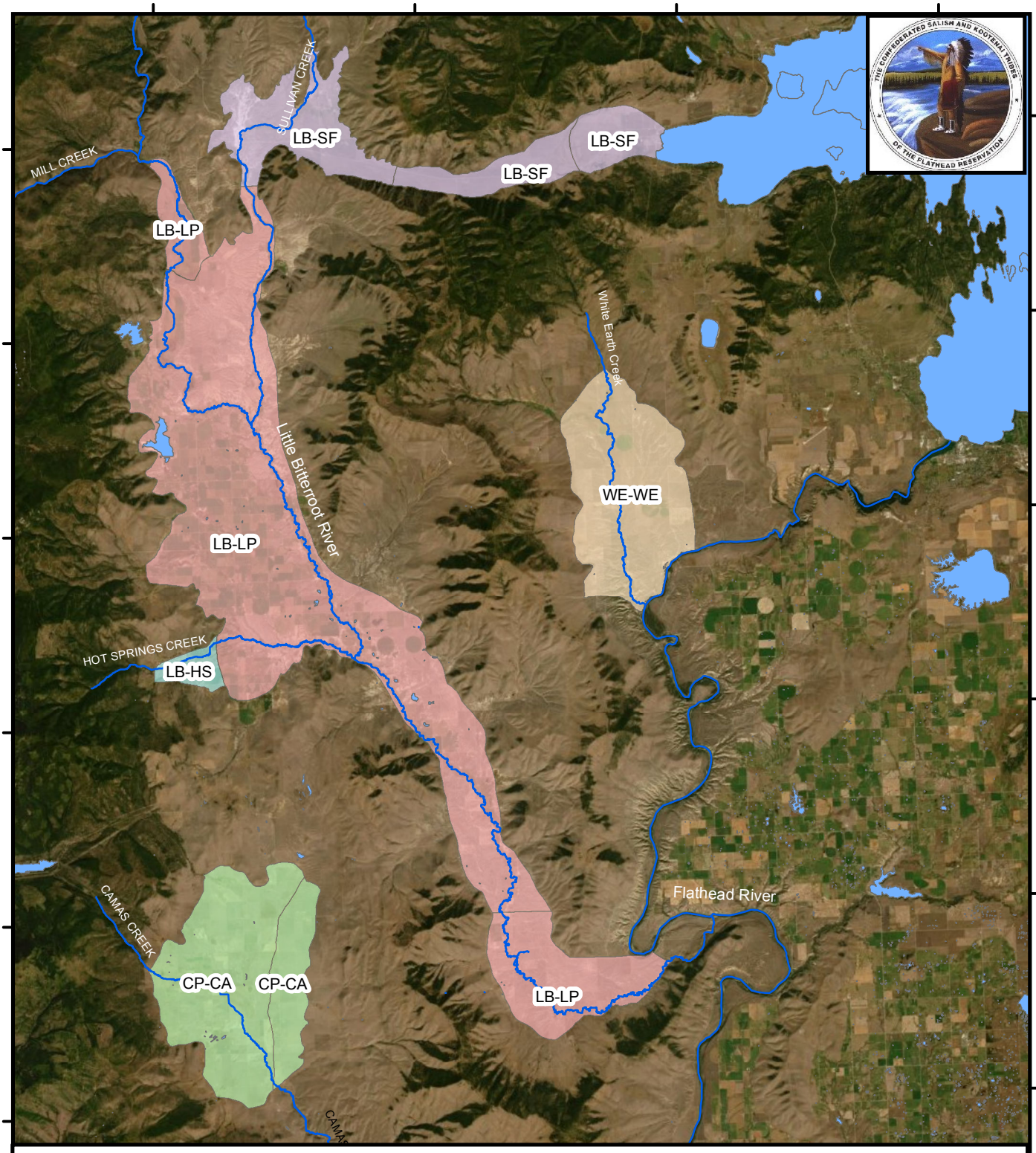
Where wells penetrate to fractured bedrock, geothermal conditions may occur. Geothermal temperatures are lower than in Camp Aqua and well yields are generally modest.

CP-CA: Camas Prairie Camas Prairie Unit: Camas Prairie has characteristics of a closed basin, with a narrow outlet where Camas Creek drains to the Flathead River. The valley was unglaciated in the late Quaternary and outwash sediments found in the Little Bitterroot Valley are not observed here. An unconfined aquifer occurs on the east margin of the valley and grades to a fully confined aquifer to the west. Depth to ground water trends from approximately 50 feet to over 100 feet from east to west. Aquifer yields are generally low and well which penetrate through the topmost aquifer to Tertiary sediments have very low yield potential.

Spring systems and perched ground water occur in the west part of the valley and initiate aspen seeps and small channel networks.

WE-WE: White Earth Creek Unit: This unit underlies a sparsely populated area and data are limited. In general, there is a continuous thickness of varved glaciolacustrine silt and clay with aquifer sediments comprised of gravel lenses interbedded in glaciolacustrine sediments. Aquifer materials generally occur at depths exceeding 100 feet. Artesian conditions are observed along the central axis of the valley.

White Earth Creek does not maintain perennial flow and groundwater recharge is limited to valley marginal areas.



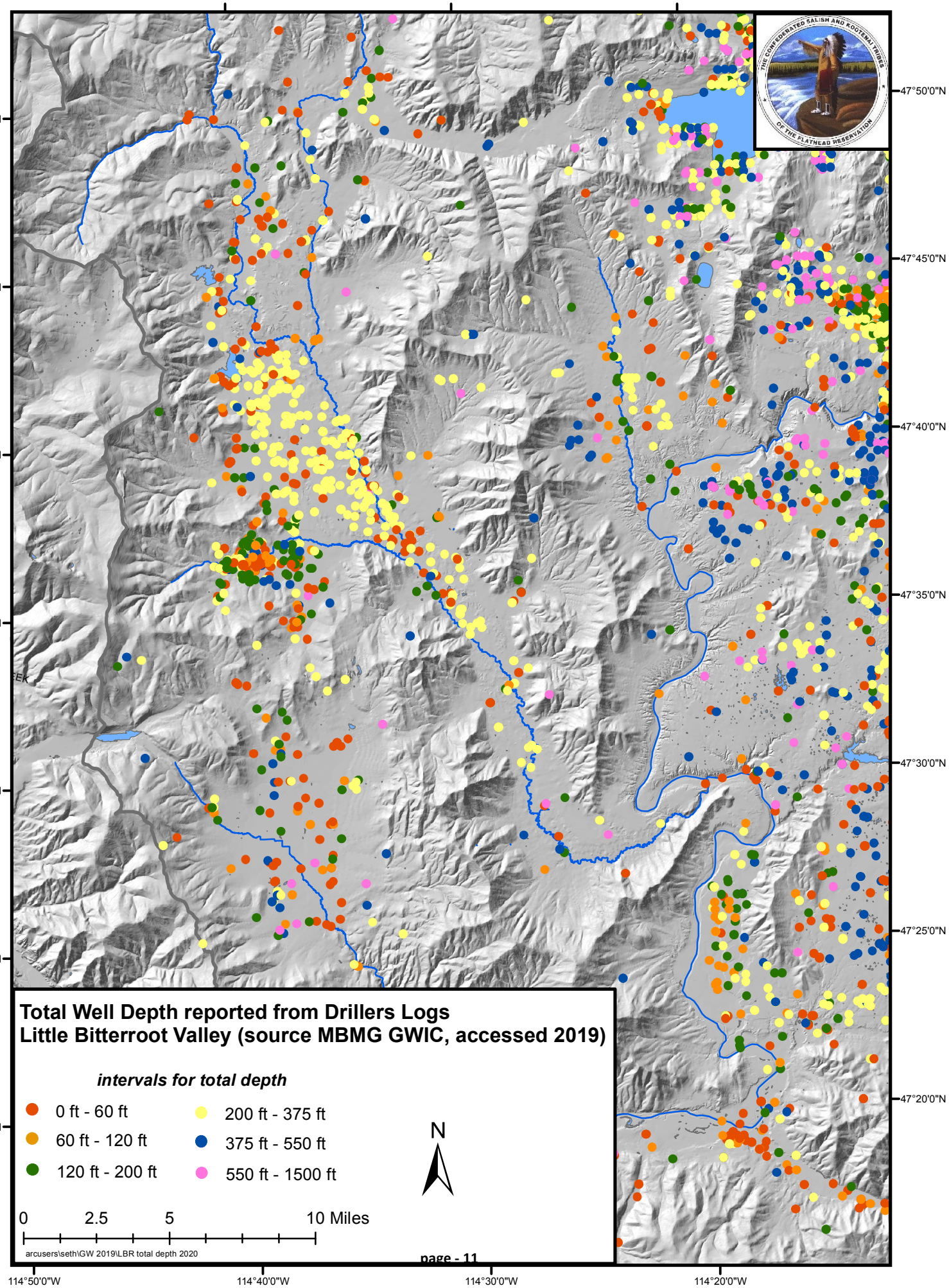
Hydrogeologic Units in the Little Bitterroot Valley

- Little Bitterroot - Lonepine Unit
- Little Bitterroot - Sullivan Flats Unit
- Little Bitterroot - Hot Springs Unit
- White Earth Creek - White Earth Unit
- Camas Prairie - Camas Unit

N

0 2.5 5 10 Miles

arcusers\seth\GW 2019\LBR Aquifers 2020


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114°30'0"W
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47°50'0"N
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47°35'0"N
47°30'0"N
47°25'0"N
47°20'0"N
THE CONFEDERATED SALISH AND KOOTENAI TRIBES
OF THE FLATHEAD RESERVATION
Total Well Depth reported from Drillers Logs
Little Bitterroot Valley (source MBMG GWIC, accessed 2019)
intervals for total depth
0 ft - 60 ft
60 ft - 120 ft
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200 ft - 375 ft
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arcusers\seth\GW 2019\LBR total depth 2020
114°50'0"W
114°40'0"W
114°30'0"W
114°20'0"W

Mission Valley Hydrogeologic Units (Hydrogeologic Unit Map and Total Well Depth Map)

We identify thirteen hydrogeologic units for the Mission Valley and include units bordering the south bay of Flathead Lake. The Quaternary geology in the Mission Valley is complex, and the discernment of individual map units may not reflect transitional and heterogeneous properties within and between units. The mapping units should be considered an organizing framework for further understanding of the ground water system.

Very few wells penetrate through unconsolidated sediments to the bedrock floor. Deep wells generally encounter Tertiary sediments, and geophysical and test well information suggest depth to Belt basement rocks may exceed 3,000 feet in the center of the valley. As a result, the map units reflect our understanding of the upper approximately 500 feet of the ground water system.

Total well depths and aquifer orientation relate to the source and axis of Quaternary depositional systems. With liberal use of imagination, these can be seen in the NRCS soil parent materials map, the total well depth map and the orientation of the hydrogeologic units. At its simplest, south of Post Creek the axis of orientation is east to west away from the Mission Front. North of Crow Creek, the axis of orientation is northeast to southwest, following the depositional train from Flathead Lake and the Polson moraine. Additionally:

- An east to west sloping depositional surface is evident between Mission and Post Creeks. Well depth and depth to ground water decrease relatively uniformly along this axis. The water table intersects land surface east of Highway 93, initiating a number of sub-parallel, perennial flow drainages.
- The Charlo Area – locally known as the Big Flat, is underlain by a deep aquifer system that is not in proximity to mountain front recharge sources. Ground water age is likely older, and reducing water chemistry conditions are widespread. Along the south margin of the unit, the depth to ground water decreases as the topographic slope decreases.
- North of Crow Creek, the axis for aquifer systems and alignment of total well depth changes to a northeast to southwest orientation. This occurs because Quaternary geology was dominated by ice-marginal contact and depositional processes along the southern extent of the Flathead Lobe of the Cordilleran ice sheet. Northeast to southwest-trending coarse pro-glacial sediment is evident from Turtle Lake to Lower Crow Reservoir. Sediment distributions, and the occurrence of the deep Mud Creek aquifer, strongly suggest that the Turtle Lake area was a pro-glacial discharge zone for the Flathead ice sheet at some time.
- The Moiese Valley was extensively modified by rapid draining of Glacial Lake Missoula. Mega-scale gravel bars (found in other areas along the Flathead River) occur at the surface and form an unconfined aquifer in the south part of the valley.
- Along the Mission Front, there are several alpine moraines which emerge onto the valley floor. Prominent moraines occur at Mission Creek, Ashley Creek, Post Creek and North Crow Creek. Well depths are generally quite deep, exceeding 400 feet, and well yields are moderate to low. Aquifer materials are generally very poorly sorted gravel through boulder materials embedded in a clay and silt matrix.
- Eolian (wind-blown) sands and silts are common in pro-glacial settings due to glacial erosion and occurrence of abundant sands and silts, and the development of strong wind gradients between ice and terrestrial surfaces. Eolian deposits developed in this manner, and in the north Mission Valley, record the alignment of outwash and glaciofluvial sediments exploited as sand and gravel sources

and productive aquifers. Several locations around Pablo have dune topography; these features are termed coppice dunes (stable vegetated dunes).

- We also note the occurrence of peat deposits on the soil parent materials map, often interfingered with eolian deposits. These appear to be Holocene in age, formed where a perched aquifer has developed on glaciolacustrine sediments. Anaerobic conditions persist and allow for preservation of organic matter. Peat deposits in the Pablo area are 3 to 5 feet thick and are often separated from glaciolacustrine sediments by a thin veneer of flowing sands.
- Finally, the west parts of the valley – Round Butte and Valley View were shielded from Flathead ice sheet depositional processes by bedrock islands and very large thicknesses of glaciolacustrine silt and clay are preserved. In the Round Butte area, these are generally considered non-aquifer materials.

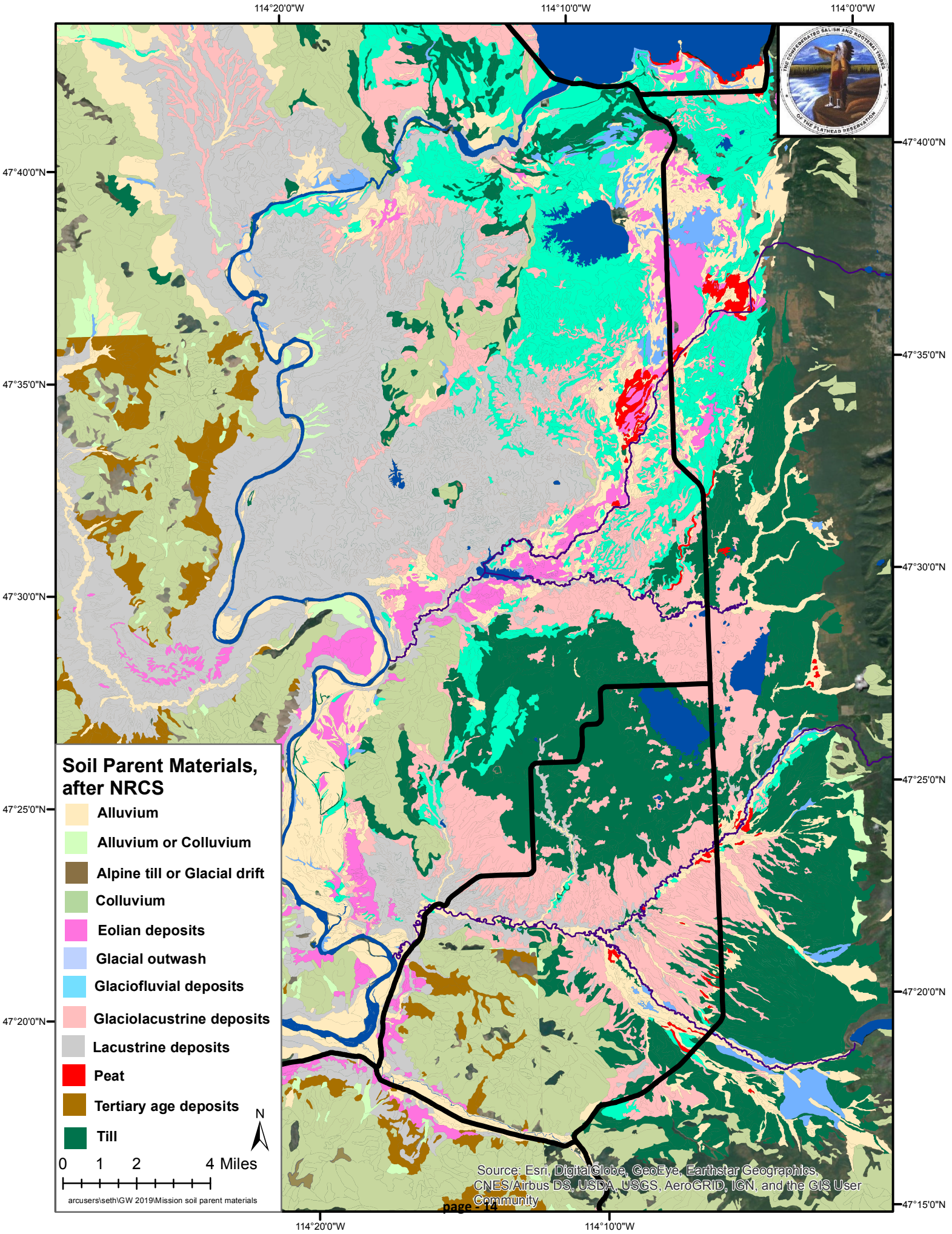
MV-VM: Mission Valley Valley Margin Unit: This is a highly variable unit located on the south margin of the Mission Valley. Aquifer materials are comprised of gravels with a silt to clay matrix. Some wells penetrate to Tertiary sediments, and in some cases, fractured bedrock. Depth to water bearing intervals generally exceeds 100 feet, with wells indicating semi- to confined conditions. Wells finished in fractured bedrock may exhibit artesian conditions. Most wells were test pumped below 10 gpm, and average specific capacities are around 2.6 gpm/ft.

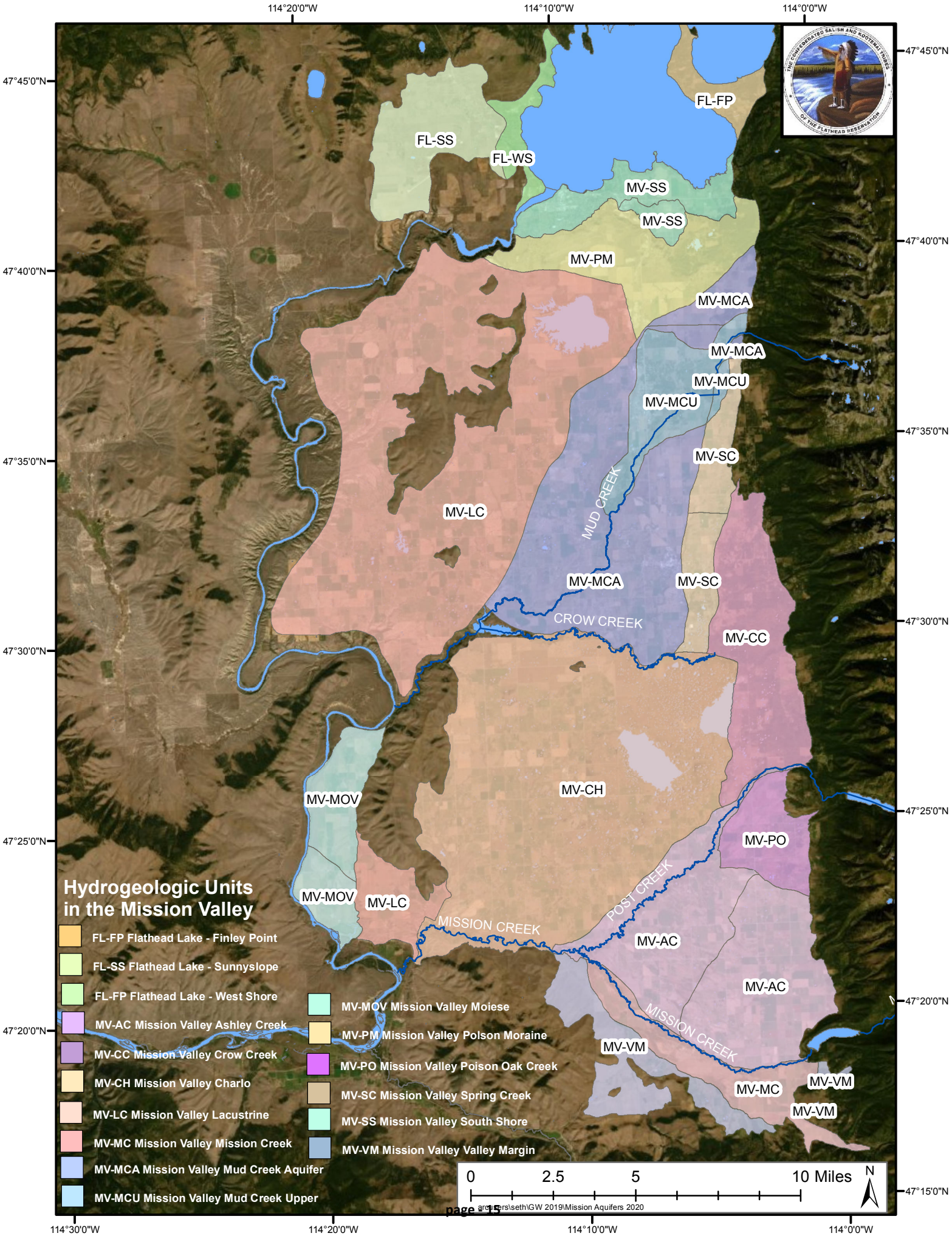
MV-MC: Mission Valley Mission Creek Unit: This unit follows the course of Mission Creek and includes reworked stream gravels in the near-surface. Aquifer materials include gravels with sand and clay intervals and water-bearing intervals occur between 50 feet to 100 feet below land surface and decrease in a down gradient direction. Sand and poorly sorted gravels are reported in the unsaturated zone, and these create semi-confined conditions throughout the unit. Although the unit borders Mission Creek, there is little indication of a highly prolific alluvial aquifer and specific capacity data average around 1.3 gpm/ft. Wells that penetrate through aquifer materials generally report very low yields.

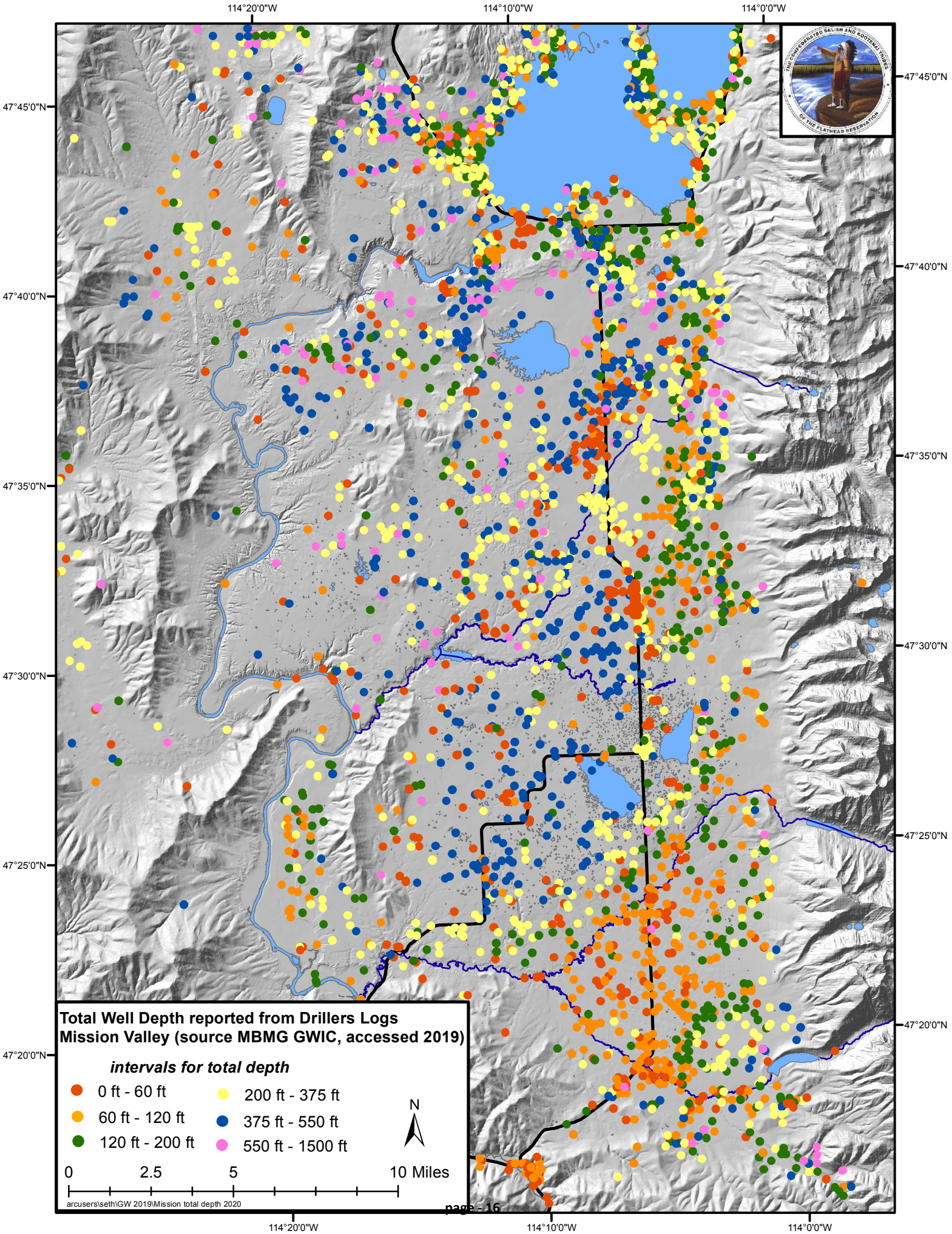
A glacial outwash fan emanates from St. Mary's Canyon and contains a deep section of moderately to well sorted gravels. This feature is combined with the MV-MC unit at the scale of this effort.

MV-AC: Mission Valley Ashley Creek Unit: This unit has fan-shaped topography and is recognized to have been partially deposited sub-aqueously into Glacial Lake Missoula. The unit shows a regular progression from the Mission Front to the west and this is evident in the total well depth figure. Aquifer materials trend from poorly sorted gravels with a high percentage of fines along the Mission Front to clean gravels along Post Creek. Concurrently, depth to ground water decreases and well yields increase to the west. Along the Mission Front, depth to ground water generally exceeds 200 feet, and along Post Creek is less than 50 feet. Adjacent to, and presumably underlying Post Creek, there are 30 feet to 50 feet of silt and clay overlying the aquifer. The aquifer trends from a semi confined condition along the Mission front to strong artesian conditions along Post Creek. Valley floor wetlands, springs, and ground-water gaining reaches occur along Post Creek and across the unit starting east of Highway 93. Specific capacity data average around 3.5 gpm/ft across the unit, but the aquifer is capable of high yields to the west.

MV-PO: Mission Valley Poison Oak Creek Unit: This unit does not contain a laterally continuous aquifer, however based on common surface morphology and a prevalence of ochre-colored clay in well logs, it appears the unit shares a common depositional history. Two water-bearing intervals are identified – a

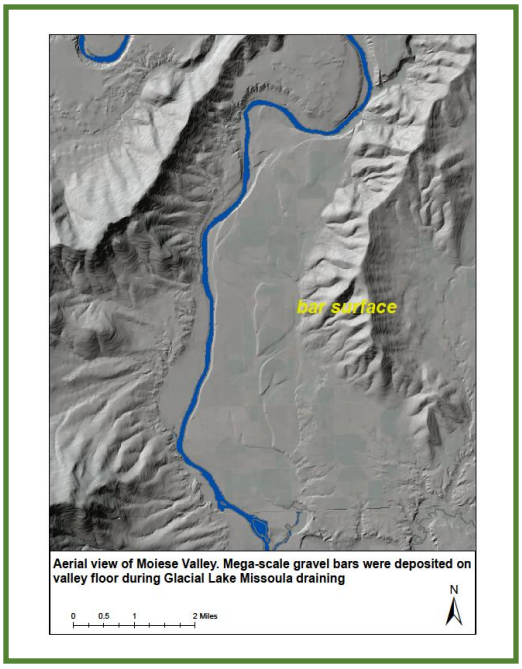

114°20'0"W
114°10'0"W
114°0'0"W
47°40'0"N
47°35'0"N
47°30'0"N
47°25'0"N
47°20'0"N
47°15'0"N
Soil Parent Materials, after NRCS
Alluvium
Alluvium or Colluvium
Alpine till or Glacial drift
Colluvium
Eolian deposits
Glacial outwash
Glaciofluvial deposits
Glaciolacustrine deposits
Lacustrine deposits
Peat
Tertiary age deposits
Till
N
0 1 2 4 Miles
arcusers\seth\GW 2019\Mission soil parent materials
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


114°20'0"W
114°10'0"W
114°0'0"W
47°45'0"N
47°40'0"N
47°35'0"N
47°30'0"N
47°25'0"N
47°20'0"N
47°15'0"N
114°30'0"W
FL-FP
FL-SS
FL-WS
MV-SS
MV-SS
MV-PM
MV-MCA
MV-MCA
MV-MCU
MV-MCU
MV-SC
MV-LC
MUD CREEK
MV-MCA
MV-SC
CROW CREEK
MV-CC
MV-CH
MV-MOV
MV-PO
MV-MOV
MV-LC
MISSION CREEK
POST CREEK
MV-AC
MV-AC
MISSION CREEK
MV-VM
MV-MC
MV-VM
MV-VM
Hydrogeologic Units in the Mission Valley
FL-FP Flathead Lake - Finley Point
FL-SS Flathead Lake - Sunnyslope
FL-FP Flathead Lake - West Shore
MV-AC Mission Valley Ashley Creek
MV-CC Mission Valley Crow Creek
MV-CH Mission Valley Charlo
MV-LC Mission Valley Lacustrine
MV-MC Mission Valley Mission Creek
MV-MCA Mission Valley Mud Creek Aquifer
MV-MCU Mission Valley Mud Creek Upper
MV-MOV Mission Valley Moiese
MV-PM Mission Valley Polson Moraine
MV-PO Mission Valley Poison Oak Creek
MV-SC Mission Valley Spring Creek
MV-SS Mission Valley South Shore
MV-VM Mission Valley Valley Margin
0
2.5
5
10 Miles
N
aquifers\seth\GW 2019\Mission Aquifers 2020


114°20'0"W
114°10'0"W
114°0'0"W
47°45'0"N
47°40'0"N
47°35'0"N
47°30'0"N
47°25'0"N
47°20'0"N
Total Well Depth reported from Drillers Logs
Mission Valley (source MBMG GWIC, accessed 2019)
intervals for total depth
0 ft - 60 ft
60 ft - 120 ft
120 ft - 200 ft
200 ft - 375 ft
375 ft - 550 ft
550 ft - 1500 ft
N
0
2.5
5
10 Miles
arcusers\seth\GW 2019\Mission total depth 2020

deeper interval in excess of 200 feet and a shallow interval at less than 50 feet. Wells in the deeper unit penetrate thick clay layers and withdraw water from thin, laterally discontinuous gravel lenses. Shallow wells are located along surface water bodies. Combined specific capacity data average around 1.0 gpm/ft. Due to the prevalence of surficial clays, there are several spring areas, surface wetlands and seep features.

MV-CH: Mission Valley Charlo Unit: This unit contains a laterally continuous gravel aquifer with thickness ranging between 10 feet and 25 feet between 350 feet and 450 feet below land surface. The aquifer is overlain by a thick sequence of silt and clay with interspersed gravels. Depth to aquifer materials decreases towards Kicking Horse Reservoir and to the south toward Post Creek; lower total well depths to the south are partly related to the topographic slope in the area. The primary aquifer is fully confined, with the potentiometric surface at approximately 50 feet below land surface. Numerous well logs report a thin interval of blue clay directly above the aquifer. Shallow perched ground water occurs along drainages and in depressional areas. Well yields are moderate and specific capacities average around 1.9 gpm/ft.



Aerial view of Moiese Valley. Mega-scale gravel bars were deposited on valley floor during Glacial Lake Missoula draining

MV-MOV: Mission Valley Moiese Valley Unit: Sediment properties change in a regular progression in a southerly direction. To the north, aquifer sediments are comprised of poorly sorted gravel lenses occurring at depths greater than 140 feet. Down gradient, aquifer sediments are comprised of clean gravels with interstitial sand and occur at around 90 feet. Unsaturated zone sediments include interbeds of clay and silt with sand and gravel, with silt and clay decreasing to the south. Well yields are moderate and specific capacity data average around 2.8 gpm/ft. Along the east margin of the unit, some wells are completed in fractured bedrock or low-yielding clay-rich gravels.

MV-CC: Mission Valley Crow Creek Unit: This unit is transitional to units MV-CH and MV-SC. Aquifer materials are poorly to moderately sorted gravels with similar materials in the unsaturated zone. Depth to water bearing intervals ranges between 100 feet and 150 feet and the system exhibits a semi confined response. Although the unit follows the Crow Creek drainages, there is little evidence for a high-yielding alluvial aquifer. Well yields are moderate and average specific capacity values are around 2.6 gpm/ft. Along the Mission Front, some wells are completed in alpine moraine sediments. These are deep wells, generally with low water-yielding potential. East of Kicking Horse Reservoir, there is a clusters of forested, closed depression wetlands. Their presence demonstrates that fine-textured sediments occur in the near-surface and create a perched aquifer condition.

MV-SC: Mission Valley Spring Creek Unit: This unit is distinguished from the more westerly, Mud Creek aquifer because depth to ground water is lower, there is northeast-trending topographic feature which aligns with the depth to ground water information, and the aquifer appears to be the source for Ronan Spring Creek discharges near the south extent of the unit. To the north, aquifer materials occur at

depths between 100 feet and 140 feet and include moderately sorted gravels with interstitial silts and clays. Unsaturated zone sediments contain a higher percentage of sandy and gravelly intervals. To the south, aquifer materials grade to well sorted gravels with interstitial sand at depths between 100 feet and 150 feet. Clays and silt content increases in the unsaturated zone, and the aquifer transitions to fully confined conditions and locally artesian conditions. Well yields are highest to the south, but across the unit specific capacity values average around 2.7 gpm/ft. Ronan Spring Creek initiates as a high volume spring discharge (~ 9,900 gpm), and is likely a discharge feature for the aquifer.

Several deep wells are observed near North Creek and to the north; these are not associated with a specific map unit, but are completed in alpine moraine sediments. Well yields are low, and in certain locations, water is not intercepted in deeper wells.

MV-MCA: Mission Valley Mud Creek Unit: This unit contains a glacial outwash aquifer at depths between 350 feet and 450 feet below land surface and is the most productive aquifer in the Mission Valley. The communities of Pablo, Ronan, and the Round Butte Water Company rely on this aquifer for community water supply. Few wells penetrate through the gravel aquifer; those that do indicate the aquifer thickness is between 20 feet and 40 feet in depth. There is also indication of productive gravel layers around 550 below land surface. Overlying sediments are complex and include thick clay and silt intervals, sand intervals, and interbedded or disbursed gravel layers. Along the main axis of the aquifer artesian conditions are observed and well yields may exceed 500 gpm. On the lateral margins of the aquifer artesian condition are not observed, but the water table rises to within 50 feet of land surface. To the northeast, the confining layer thins, sand content increases, and the aquifer transitions to unconfined conditions; this is the primary recharge area for the unit. In particular, Big Creek - a Mission Front stream with an annual runoff volume of approximately 5,500 acre-feet, completely infiltrates into the aquifer at the base of the Mission Range. Average specific capacity values across the aquifer are around 5.0 gpm/ft.

MC-MCU: Mission Valley Mud Creek Upper Unit: The upper Mud Creek aquifer is a shallow unconfined system, which is stacked on top of the confining layer for unit MV-MCA. This is evident in the bimodal distribution between shallow and deep total well depths in the total well depth figure. The aquifer is comprised of sands and gravels, with northeast to southwest aligned sand ridges (coppice dunes) across the unit. Depth to water decreases from 50 feet to 70 feet in up gradient areas, to less than 20 feet underlying Pablo, and is at land surface south of Pablo. There are several surface expressions of the aquifer, including large extents of forested and emergent wetlands, extensive peat deposits and spring channels. The aquifer also discharges to initiate Stinger Creek. Specific capacity data averaged across the unit are around 4.0 gpm/ft.

MV-PM: Mission Valley Polson Moraine Unit: This unit is located in the Polson moraine and an outwash sheet south of the moraine. The moraine aligns with and partially forms a ground water divide with ground water flow towards Flathead Lake north of the moraine and towards Pablo south of the moraine. The depositional record of the moraine is complex, but is characterized as a thick complex of laterally discontinuous sand, gravel and silt layers. Depth to water bearing intervals is variable, but is generally in excess of 400 feet, and may reach to 800 feet. Along the west margin of the unit wells are completed in fractured bedrock, which is intercepted at approximately 400 feet. Several dry wells have been drilled on the moraine, either because they did not intercept water or because they were unable to clear silty sand from the well. Specific capacity data average around 0.8 gpm/ft.

MV-SS: Mission Valley South Shore Unit: Unit MV-SS is closely interconnected to unit MV-PM. However, since depth to water is less, aquifer yields more reliable, and lateral continuity in aquifer properties more uniform, the unit is delineated separately. Water bearing intervals are comprised of clean gravels and sandy gravels, and depth to aquifer materials is around 200 feet. The unsaturated zone contains interbeds of silt and clay, sand and gravel and thick sand sections to the east. Towards Flathead Lake and underlying Polson, glaciolacustrine silts and clays are more in evidence and the degree of aquifer confinement increases. The aquifer is capable of high yields, and specific capacity data average around 2.8 gpm/ft.

MV-LC: Mission Valley Lacustrine Unit: This is a widespread unit occurring along the western portion of the valley. Wells are generally deep and draw water from thin sand and gravel interbeds stacked within glaciolacustrine sediments. Water bearing intervals are generally below 250 feet in depth. There are portions of this unit around Round Butte where water bearing intervals are lacking, and this area is served by the Round Butte Water Company.

FL-WS: Flathead Lake West Shore: Wells in this unit withdraw water from fractured bedrock at depths ranging from 150 feet to 225 feet. Unsaturated zone materials are glaciolacustrine silts and clays. Confined conditions occur and artesian conditions are noted in some wells. Well yields are generally moderate and specific capacity data average around 0.6 gpm/ft.

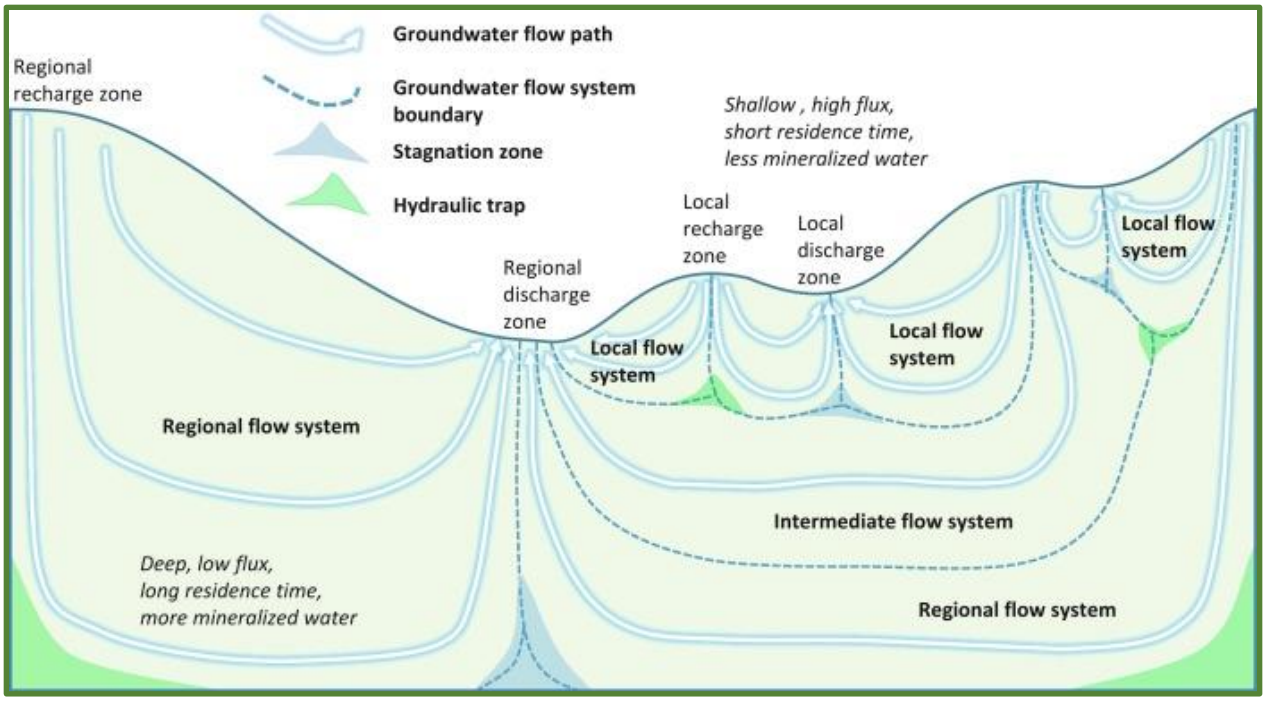
FL-SS: Flathead Lake Sunnyslope Unit: Aquifer properties, including depth to water bearing intervals and potential yield are variable across this unit. As a generalization, aquifer materials consist of laterally discontinuous gravel lenses. Wells on the margin of the unit penetrate to bedrock, and most wells in the Jette area are finished in fractured bedrock. Many deep wells are located in the unit, and depth to aquifer materials is usually greater than 150 feet, and in some areas over 300 feet. Along drainages depth to aquifer materials may be less than 50 feet. Unsaturated zone sediments are predominantly lacustrine silts and clays with some sand and gravel interbeds. The aquifer exhibits a confined to semi confined response and artesian conditions are observed on the east margin of the unit. In certain zones irrigation wells withdraw water at rates exceeding 500 gpm, although well interference related to high pumping rates has been documented.

Ground Water Flow Systems

Ground water flow systems are described generally and then by looking at valley-scale flow systems on the Reservation.

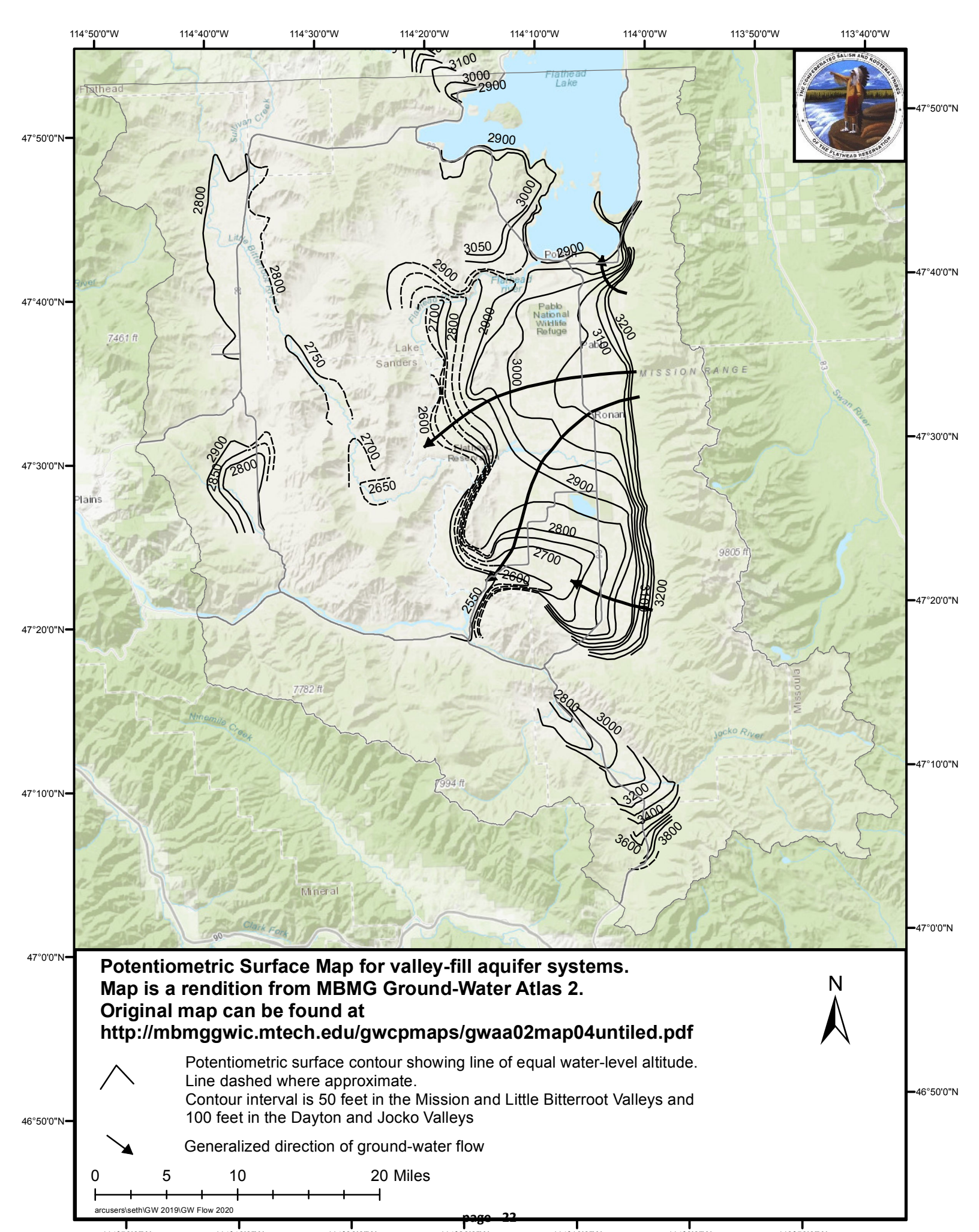
We describe ground water flow systems with water table (potentiometric surface) maps - essentially contour maps connecting points of equal ground-water surface elevation (equal potential). Water surface elevation is determined by measuring the depth to which water will rise in a well; this information can be combined with the elevation of a surface water feature, which we understand to represent a ground water discharge zone, and therefore the approximate elevation of the water table. Ground water flows down a potentiometric surface (from higher to lower elevation) following a path that is perpendicular to the contours. This visualization can leave the impression that ground water flow is two-dimensional and relatively simple. However, were we too tightly space a set of wells and complete the wells at different depths, we would likely observe a different water surface elevation in each well. This is a demonstration that there are vertical gradients to ground water flow – either upward or downward in direction. Flow paths are also modified by the occurrence of lower permeability layers in the subsurface (for example glaciolacustrine silts) and by seasonally variable recharge and discharge sources, for example groundwater mounds that may develop under leaky canals.

Toth (1963), and earlier work, developed the concept of nested flow systems and this is illustrated in the following graphic, adapted from his work. The graphic identifies regional, intermediate, and local flow systems and demonstrates the three dimensional nature of ground water flow. Below, we take this graphic and provide local examples to demonstrate its applicability.



- Due to the geologic setting, the driver for ground water flow is mountain front recharge and subsequent discharge into and toward the Flathead River; this is true in all valley settings. This would be considered the regional flow system at the scale of Reservation valleys, although these valleys are relatively small and the term regional becomes relative. A well-recognized example of a large regional flow system in Montana would be recharge in the Madison Limestone on the Rocky Mountain Front, and deep flow paths from west to east towards North Dakota, where the Madison Limestone persists at depth.
- All valleys on the Reservation have intermediate flow systems, and the discharge areas commonly support stream flows and larger wetland complexes. Intermediate flow systems are prevalent, in part due to the widespread occurrence of glaciolacustrine silts and clays along the Flathead River. These impede groundwater flow and initiate upward hydraulic gradients prior to discharge into the river.
- A well-developed intermediate flow system occurs in the south Mission Valley. Mountain front recharge discharges to sustain lower Ashley Creek, Poison Oak Creek, and Post Creek starting upstream of Highway 93. Also, small sub-parallel streams between Mission and Post Creeks (ex: Matt Creek) maintain perennial flow due to discharge from this intermediate flow system. This flow system would persist absent any modification to hydrology, such as development of the irrigation project and canal network, but the timing and volumes of ground water flow are altered by the modified hydrology.
- An intermediate flow system in the north Mission Valley can be described for the upper Mud Creek aquifer. Recharge occurs along the Mission Range, through streamflow infiltration, canal and onfarm infiltration, and valley precipitation in the northeast part of the system. Discharge occurs in the vicinity of, and down gradient of, Pablo and initiates large valley floor wetlands some of which organize into small streams (ex: Stinger Creek).
- A final example of an intermediate flow system would be the Sullivan Flats aquifer. This system discharges into a discrete spring (Sullivan Springs), which is the source of flow to Sullivan Creek.
- Local flow systems are very common across the Reservation, again in part due to the prevalence of glaciolacustrine silts and clays. Silts and clays are often overlain by a veneer of Holocene surficial sediment and perched, small-scale aquifers develop. Local flow systems develop along many ephemeral drainages, where canal seepage occurs, and in a number of wetland systems. Often, early domestic wells were completed in these shallow systems (< 50 feet in depth), and appear as outliers on the total well depth maps.
- An example of a local flow system would be the palustrine potholes which occur across the central Mission Valley. Water levels are supported by localized flow paths and water regimes for palustrine wetlands are recognized as one of the three types: flow-through systems where ground water flows into and out of a depressional pothole; flow systems which are local ground water discharge zones; and depressional potholes which are basically driven by precipitation and evapotranspiration – closed systems. Each end member can often be distinguished by topographic position and basic water chemistry, for example total dissolved solids.

We include a rendition of the MBMG potentiometric surface map for valley fill aquifers on the Reservation. The map is an aggregate of depth to ground water information, with emphasis on deeper wells, and is described in greater detail in MBMG Groundwater Atlas 2. The Water Resources Program



Potentiometric Surface Map for valley-fill aquifer systems.
Map is a rendition from MBMG Ground-Water Atlas 2.
Original map can be found at
http://mbmggwic.mtech.edu/gwcpmaps/gwaa02map04untiled.pdf

N

Potentiometric surface contour showing line of equal water-level altitude.
Line dashed where approximate.
Contour interval is 50 feet in the Mission and Little Bitterroot Valleys and 100 feet in the Dayton and Jocko Valleys

Generalized direction of ground-water flow

0 5 10 20 Miles

arcusers\seth\GW 2019\GW Flow 2020

has a number of additional, often more detailed potentiometric maps for specific valleys, but they generally mirror this widely accessible map.

Ground water flow in the Jocko Valley is from southeast to northwest, and the pattern of the contours demonstrates ground water flow converges toward the Jocko River. The Jocko River, Jocko Spring Creek, and other tributaries experience large ground water gains, and these support stream base flows. The Jocko Valley Outwash aquifer has high permeability and wide water table fluctuations, and the extent of gaining and losing reaches migrate up and down the river depending on seasonal recharge and the resultant water table elevation.

The south Mission Valley flow system, referenced above, also converges on Post Creek and explains the large ground water gains observed in this stream system. The north Mission Valley system flows east to west, with the hydraulic gradient indicating lower hydraulic conductivity to the west. The MBMG atlas map indicates flow under Mud and Crow Creeks, but more recent detailed potentiometric surface

Darcy Equation for Ground Water Flow

Surface water discharge is often calculated as the product of:

*Q = V * A, where*

Q = surface discharge in units of volume per unit of time (cubic feet per second),

V = velocity in units of length per unit of time (feet per second),

*A = cross sectional area in units of length * length (feet^2).*

This equation is termed the continuity equation for surface water flow. Continuity ($Q_{upstream} = Q_{downstream}$) is maintained along a stream reach without inflows or outflows through adjustments in V or A.

A similar equation is available for ground water flow – the Darcy Equation:

Q = K(dh/dl)*A, where*

Q = discharge through porous media (aquifer) in units of volume per unit of time (cubic feet per second),

K = coefficient termed hydraulic conductivity in units of length per unit of time (feet per second), higher K values indicate more permeable materials capable of transmitting greater volumes of ground water,

dh/dl = hydraulic gradient, where dh is the change in head or water table elevation, between two points dl. Hydraulic gradient is abbreviated as i, following common notation, and is in units of length per length (feet per feet),

*A = cross section of aquifer material in units of length * length (feet^2).*

This is a more complex equation, and our presentation is a simplification of the terms. However, we can use the Darcy Equation, in conjunction with the potentiometric surface map to inform on the relative permeability of aquifer materials. If we rearrange the equation and assume steady state conditions - no change in ground water discharge or cross sectional area:

$K \propto 1/i$, or

Hydraulic conductivity is proportional to one over the hydraulic gradient; so the steeper the hydraulic gradient (closer together potentiometric contours), the lower the hydraulic conductivity of the aquifer materials, all things equal.

When viewing the potentiometric surface map, we see relatively wide contour intervals in the Little Bitterroot Lonepine aquifer, the Jocko Valley Outwash aquifer, and the Mission Valley Mud Creek aquifer. These are glaciofluvial and outwash aquifers, generally with the highest permeability and hydraulic conductivity over the map extent. Conversely, we see tight contour intervals along the Mission Front and along the Flathead River. These are either glaciolacustrine sediments or silt and clay-rich sediments along the Mission Front.

mapping suggests that ground water may converge on Mud Creek and lower Crow Creek. It is likely there is a combination of an intermediate flow system interacting with surface streams and a deeper system that flows under the surface streams to the southwest.

Flow in the Little Bitterroot Lonepine aquifer follows the alignment of the valley, with a likely decrease in both hydraulic conductivity and aquifer cross-sectional area in down gradient areas.

Two additional points are highlighted relative to the flow system schematic and potentiometric map.

- A ground water divide occurs along the Polson Moraine, with ground water flow lines either to the north or south. While the moraine contains very high permeability sediments, dry wells are drilled here. The ground water divide may create null points, or stagnation zones, where there is limited ground water movement; the same phenomena is observed on the crest of the Elmo moraine. This inference would require additional work to verify and understand.
- We generally consider that ground water flows toward Flathead Lake – a discharge feature. This perspective is based on the elevation of water table contours relative to lake elevation, but has not been rigorously evaluated. The City of Polson drilled a well in fractured bedrock, west of the Flathead River, and generally away from mountain-front recharge sources. The well is high yielding (~ 800 gpm), and at least opens the question that Flathead Lake may serve as a recharge area for areas surrounding the lake.

Ground Water Budgets

A ground water budget is an structured approach to understand the sources of water into, and sources of water out of a ground water system. Water budgets are often the starting point for a water supply analysis – either surface or ground water, and initiate with a few commonalities.

- The system, or boundaries for the water budget are defined. For a surface water system, this may be a watershed or stream reach. For an irrigation evaluation, this may be an individual field, a canal service area, or a larger delivery system. With ground water, the system boundaries may be hard to define, but can telescope from valley scale, to aquifer scale, to project scale. Specific to ground water, we define boundary types for water budget and modeling analyses. Examples include: a no flow boundary, such as might exist at the interface between dense, unfractured bedrock and alluvial sediments (physical boundary); a flow through boundary, such as might occur in the Mission Valley where we have valley fill aquifers that are adjacent to each other (hydraulic boundary); or a head dependent boundary (also hydraulic boundary). This type could include a boundary along a lake water body or a river reach. In the case of a river reach, the head will vary in response to river discharge and river water depth.
- We also think of water budgets in terms of time, where: a steady state condition is a snap shot of a water budget over a vanishingly small time period; a transient condition is a time-varying water budget that changes in response to changes in inflow and outflow. With transient water budgets, we have to consider the time step for analysis. If we are trying to understand climatic influences on ground water systems, our time steps and time frame may be seasons to decades. If we are trying to understand ground water recharge during a river flood pulse, our time step and time frame may be days in a month.

- Finally, water budgets start with a simplified equation for the system of interest.

  $I = O +- \Delta S$,

  or inflows equal outflows plus or minus changes in storage. Changes in storage vanish when we think of a steady state budget, but are critical for a transient budget.

The concepts behind a water budget are simple to comprehend, but understanding and enumerating each component of a budget can be complex and highly uncertain. The Water Resources Program, working with various entities, has developed numerical ground water budgets for the larger valleys on the Reservation. For this summary, our objective is to identify the elements of a generalized ground water budget so readers can understand the issue, and not to parse out details.

Inflows, or recharge components for a ground water budget follow:

- **Mountain front recharge** – precipitation, including snowpack accumulation, in excess of evapotranspirative demand will reveal itself as streamflow or deep infiltration into soil and subsoil materials. Since most precipitation on the Reservation occurs in mountainous areas, mountain front recharge is a large element of ground water recharge.
- **Valley precipitation** – this is lower elevation precipitation which infiltrates through the soil profile and recharges ground water. This can occur when precipitation exceeds evapotranspirative demand, and also during winter months, when plant utilization of water is negligible. Recharge during winter periods is more likely if soil substrates are not frozen. Later when reviewing well hydrographs, we will illustrate how the deep winter snowpack in 1996 and subsequent warm rains led to a large and unusual winter recharge event.
- **Stream losses** - stream systems often lose water through their bed and banks and this water infiltrates to recharge ground water. This often occurs where streams emanate from a mountain canyon and flow onto a valley floor. In these settings, the stream is often perched, or elevated above the water table. The Jocko River, as it emanates from the Jocko Canyon, is a losing stream reach and an important source of recharge to the Jocko Outwash aquifer.
- **Canal seepage** – the construction of an extensive network of unlined canals in native geologic materials across the Reservation has introduced a development related source of ground water recharge. To illustrate, the photo shows seepage from the Pablo Feeder Canal into an area of glaciolacustrine silts and clays; this has resulted in a series of fingered wetlands and saturated soil profiles. This would be an example of a local flow system, which may or may not recharge a deeper aquifer. Conversely, seepage in canals overlying the Jocko Outwash aquifer would not be visible in a surface view, but canal water likely infiltrates down to the water table as an important source of recharge.



- **Onfarm irrigation** – Deep infiltration of applied irrigation water is recognized as a source of development-related ground water recharge. It is a difficult term to determine since it can vary by irrigation system and by individual operator practices. We try to prompt a reader's image of this process with the attached photograph, which shows the contrast between a flood application and a center-pivot sprinkler delivery system.



O**utflows, or discharge components for a ground water budget follow:**

- **Evaporation and evapotranspiration** – Outflow through evaporation is a ground water discharge process. An example would be a palustrine wetland maintained by ground water. Evapotranspiration adds in plant (phreatophyte) uptake where the source of water is soil moisture and shallow ground water. At a valley scale this is an important discharge process. The photo shows the discharge area for the upper Mud Creek aquifer, south of Pablo. Large multi-section wetlands have developed (mottled color) where plant transpiration is a ground water discharge pathway. Note that the linear features are ground-water drainage ditches constructed in an effort to dry lands for agricultural purposes.



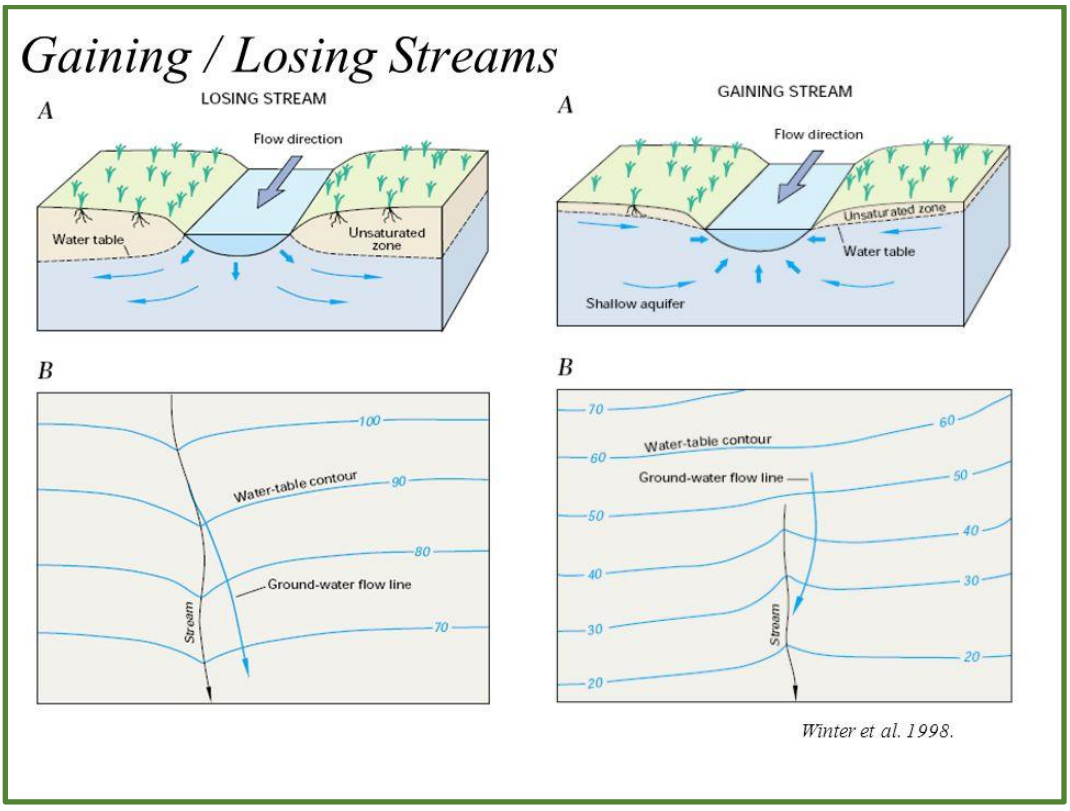
- **Stream gains** – ground water discharge to streams is well recognized and is examined with a set of case examples below.
- **Outflow to Flathead Lake and the Flathead River** – when we think in terms of the flow system discussion and the geologic setting for the Reservation, ground water that does not discharge to a surface feature or the atmosphere, eventually reaches the Flathead system. Interested readers can complete a surface water budget for the USGS gages – Flathead River at Polson and Flathead River at Perma, removing the tributary inflows. Our experience indicates a variable but large amount of unaccounted for flow, which we presume is ground water discharge.
- **Well withdrawals** – Wells withdraw water from all valley floor aquifers. Some water is returned through losses and some is consumed. It can be difficult to quantify the cumulative effect of well withdrawal from domestic wells. Larger capacity wells – municipal and irrigation wells, and also uncapped artesian wells, can reduce water table elevations. We identify some examples where this has occurred when reviewing specific well hydrographs.
- **Subsurface outflow** - this discharge mechanism occurs when there is saturated subsurface flow between hydrogeologic units. The process is sometimes termed Darcy flux, and can be calculated

using the Darcy Equation described above. On the Reservation, subsurface outflow will vary depending on the scale of the system being examined. For example, subsurface outflow for the Little Bitterroot Valley could be estimated for a cross section above the confluence with the Flathead River. Subsurface outflow from the Reservation would be estimated for a cross section downstream of Perma.

Changes in storage are determined by consistently measuring water table elevations over time. A change in water table elevation indicates an increase or reduction in the volume of water in storage in an aquifer. Seasonal changes related to recharge and discharge processes are generally observed. Longer term changes related to well withdrawal (ground water utilization) or climate change are also observed. Changes in storage are critical to understand for ground water management, and are only directly observable through a sustained monitoring program.

We close the discussion of ground water budgets by examining a critical process for integrated water management and floodplain ecological processes – surface and ground water interactions.

Stream systems may either gain water (increase flow volume) from ground water, lose water to ground water (reduce flow volume), or are disconnected from ground water. The first two examples are illustrated in two widely utilized graphics adapted from U.S. Geological Survey publications (Winters, 1998, 1999).



Gaining stream reaches occur where the water table elevation is at or higher than the streambed elevation. Losing stream reaches occur where the water table elevation is lower than the streambed

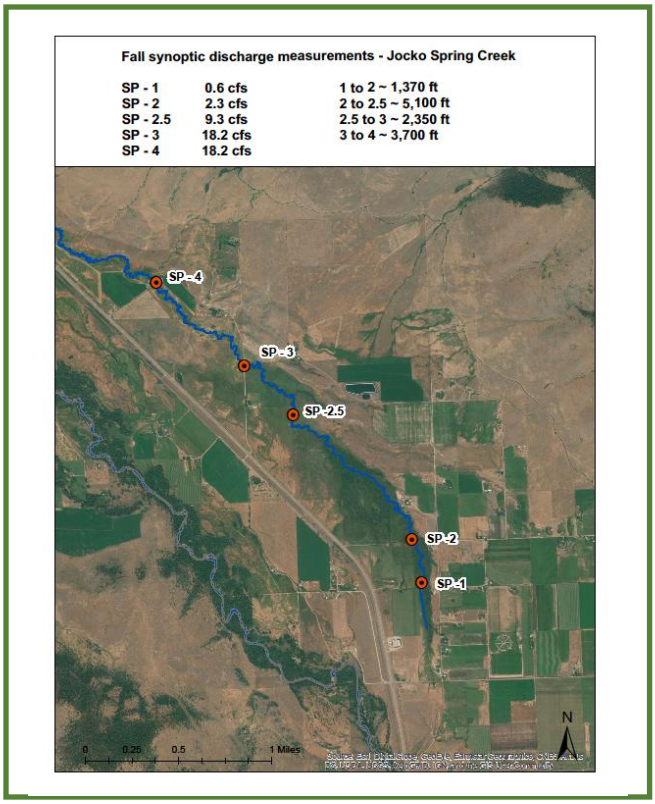
elevation. The magnitude of gaining and losing volumes is related to the permeability of the streambed sediments, and the difference in water table elevation between the stream and aquifer. A disconnected stream would be one where there is little or no interaction between a stream and the underlying sediments. This may occur where a channel flows over bedrock or glaciolacustrine silts and clays. Disconnection is a matter of degree, since there is always some volume of seepage into or away from a streambed.

Each of the major valleys on the Reservation has a spring-fed surface stream.

- **Sullivan Springs** in the upper Little Bitterroot Valley is a discrete spring discharge that occurs along the base of a bedrock hill near Niarada (tree patch in photo). The spring shares a geochemical signature with ground water in the Sullivan Flats aquifer, and is thought to be the primary discharge point for the aquifer. The spring maintains an approximately constant discharge of 2.2 cfs (990 gpm). Constant flow likely occurs because the aquifer is fully confined and maintains a potentiometric surface elevation greater than the spring elevation through the year.



- **Ronan Spring Creek** is similar to Sullivan Springs in that it is a discrete spring and the source of flow to Ronan Spring Creek. The spring is presumed to be the primary discharge point for the Spring Creek aquifer. This is inferred and would require additional investigation, such as geochemical tracing, to confirm. The spring source is a remarkable feature, with sand boils and other evidence of strong upward hydraulic gradients. The spring discharges between 18 and 22 cfs (up to 9,900 gpm) and maintains fairly constant flow through the year. The source aquifer(s) is confined and generally maintains a potentiometric surface elevation greater than the spring elevation through the year.
- **Jocko Spring Creek** behaves differently than Sullivan and Ronan Spring Creeks. Flow in the creek occurs as a result of discharge from the unconfined, Jocko Outwash aquifer. Water table elevations in the aquifer fluctuate over 10's of feet in a year, and the magnitude of discharge to Jocko Spring Creek depends on the water table elevation. The photo and discharge values show the upper portions of the creek, and a set of synoptic discharge measurements (measurements completed over short time period) completed in a fall

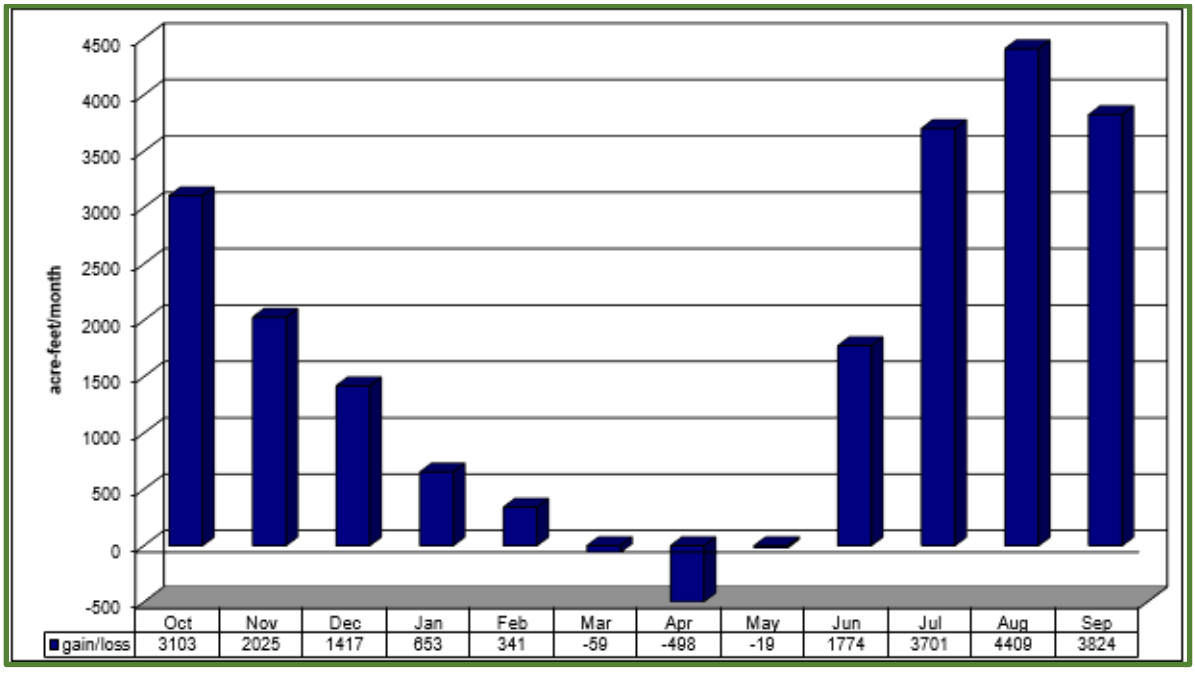


period. The magnitude of flow increased downstream, and stabilized at 18.2 cfs where the water table intersected land surface. This location will migrate up or downstream through the year as the water table fluctuates.

Two additional examples are provided, and similar to the examples above, illustrate how surface water recharge processes vary depending on aquifer properties.

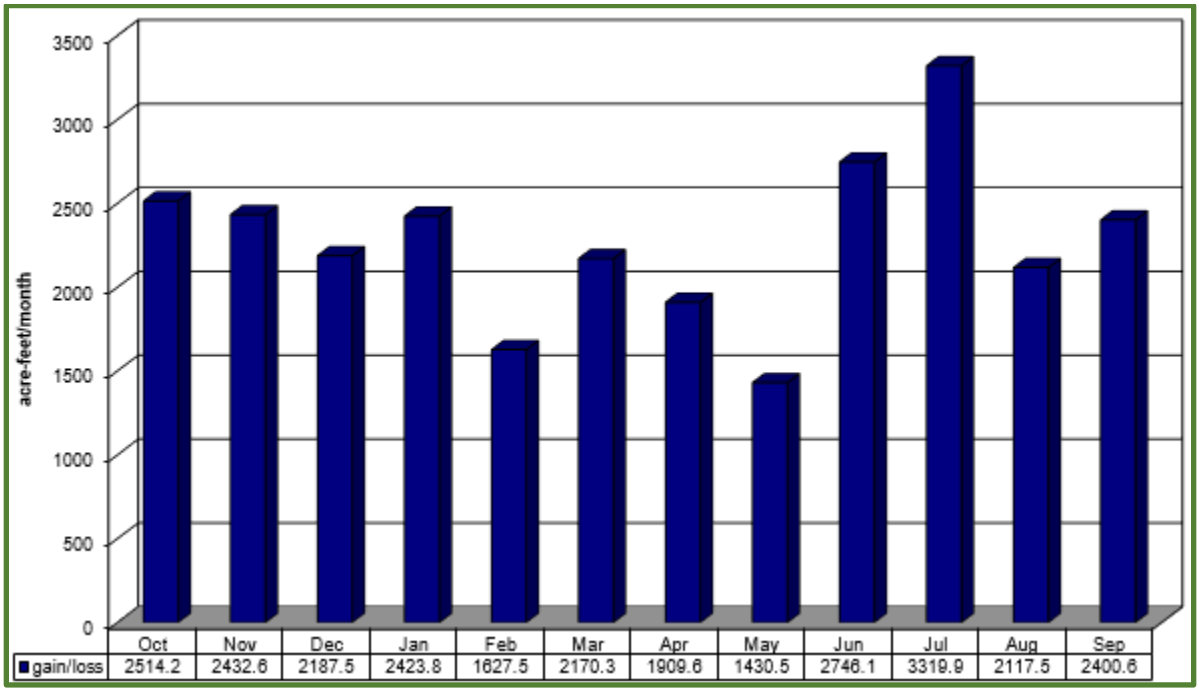
Example one is based on a surface water budget, utilizing daily flow information from our stream gage network, for two reaches of the Jocko River - one reach is from the Jocko River below Big Knife Creek to downstream of the confluence with Finley Creek below Highway 93, and one is from downstream of Finley Creek to the Jocko River downstream of Ravalli. The two hydrographs are developed by completing reach-scale surface water budgets - removing tributary inflows and identifying the remaining water as ground water gain or loss. The hydrographs report values in acre-feet per month and average results over a 10-year period.

The initial figure is for the Big Knife Creek to Finley Creek reach. Water tables elevations fluctuate up to 50 feet in the Jocko Outwash aquifer and the timing and magnitude of river gains and losses change in response to this. At a reach scale, the river loses ground water in the late winter period, corresponding to the low in water table elevation. The peak in gain to the river occurs in July, August and September, corresponding to the high in water table elevation. The net gain in ground water for the period of review was 20,700 acre-feet per year. This is substantial, and is a critical source of streamflow and a driver for ecological processes throughout the floodplain.



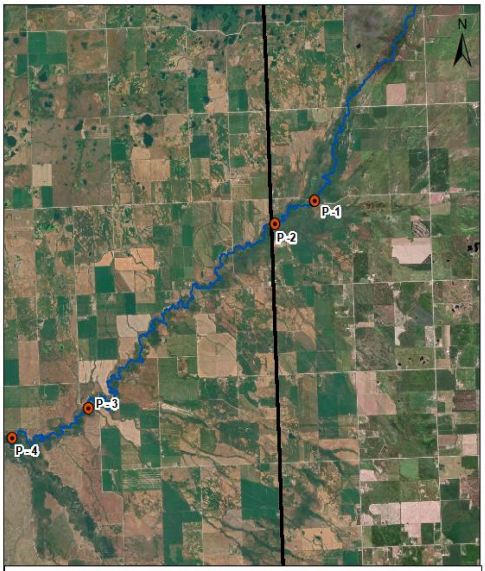
The second figure is for the Finley Creek to downstream of Ravalli reach. The water table in the lower Jocko Outwash aquifer approaches, or is at land surface, and exhibits much lower seasonal fluctuation.

The river reach gains ground water through the year, and the magnitude of gain exceeds 24,000 acre-feet per year. Again, this is a substantial volume and a critical source of streamflow and contributor to riverine ecology.



Our final example is for Post Creek, from the start of the F Canal at the stream crossing on McDonald Lake Road to its confluence with Mission Creek. This reach is recharged from the Ashley Creek aquifer, as discussed elsewhere. Four synoptic discharge measurement events are reported. The consistency in total gain over the five events is remarkable and suggests stability in the potentiometric surface and artesian flow conditions in the aquifer.

Date	Total gain over 6.3 miles
11/3/1999	68.3 cfs
11/13/1999	65.0 cfs
9/25/2008	74.3 cfs
10/8/2008	76.0 cfs
10/30/2008	66.2 cfs



Results of synoptic discharge measurements: Lower Post Creek

		11/3/1999	11/13/1999	9/25/2008	10/8/2008	10/30/2008	average of
total distance 33,200 ft				all in cfs			difference
P-1		13.2	18.8	26.5	32	45.8	
P-2	1-2: 11,600 ft	44.5	49.2	55.5	62.3	73.3	29.7
P-3	2-3: 15,000 ft	65.2	69.1	86.2	91.1	969	24.7
P-4	3-4: 6,600 ft	81.7	83.8	100.8	108	112	15.6

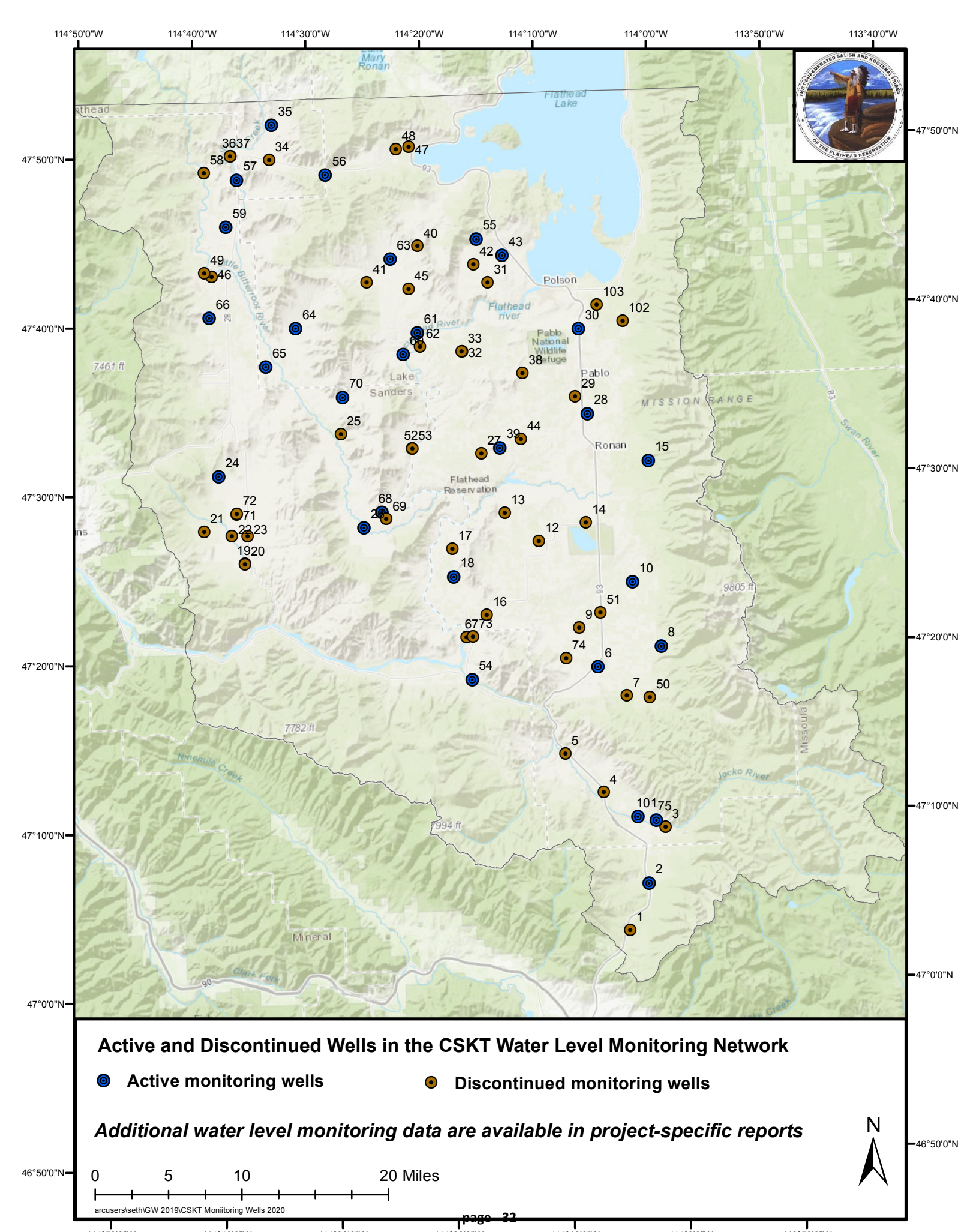
Water Level Monitoring Network and Well Hydrographs

The Water Resources Program ground-water level monitoring network dates from 1983, and at some locations contains over 35 years of record. Wells are measured four times per year in July, October, January and April. Some resolution in recharge/discharge dynamics is lost with the limited sampling schedule, but changes in storage and general recharge and discharge patterns are evident. There are also a number of project specific reports where more frequent monitoring data are available; data are generally available over shorter time periods, but at a higher resolution.

The attached map identifies currently active and discontinued wells. The well network has been reduced over the last several years, partly by design and partly as well owners discontinue access to a well. Water level data are available for various periods at the wells identified in the figure, and water level data not reported below can be requested from the Program.

We include a set of hydrographs for wells in the Jocko, Little Bitterroot and Mission Valleys. Water levels fluctuate in response to seasonal changes in water budget components, notably spring snowmelt, increases in stream flow, and canal seepage; pumping and use of ground water; and infrequent recharge events.

Infrequent recharge events are observed over the 1996-1997 and 2010-2011 periods. Examples include wells 56, 35, and 55. Recharge occurs as wetting fronts migrate below the plant rooting zone and through the unsaturated zone; in the case of well 56, the wetting front moved down over 200 feet. The long time period of observation suggests that water levels in wells such as 56 and 55 are quasi-stable, but the return to high water levels occurs on a decadal or greater time frame. Depending on the time view into the data, one could conclude the water levels and aquifer storage are declining. The concept of the time frame for long-term equilibrium should be explored further.

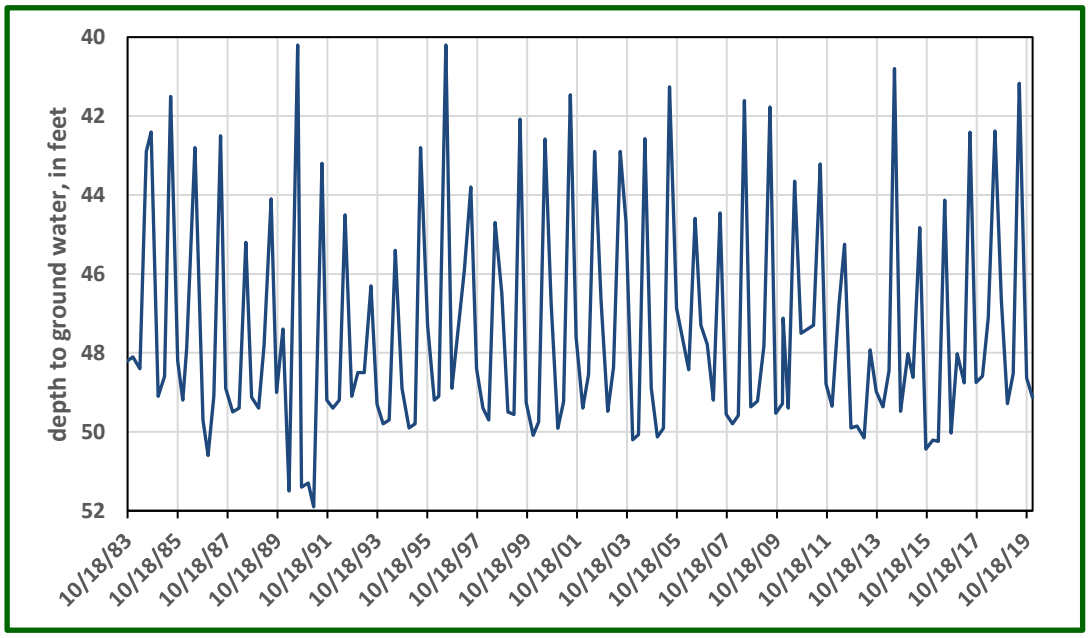


Active and Discontinued Wells in the CSKT Water Level Monitoring Network

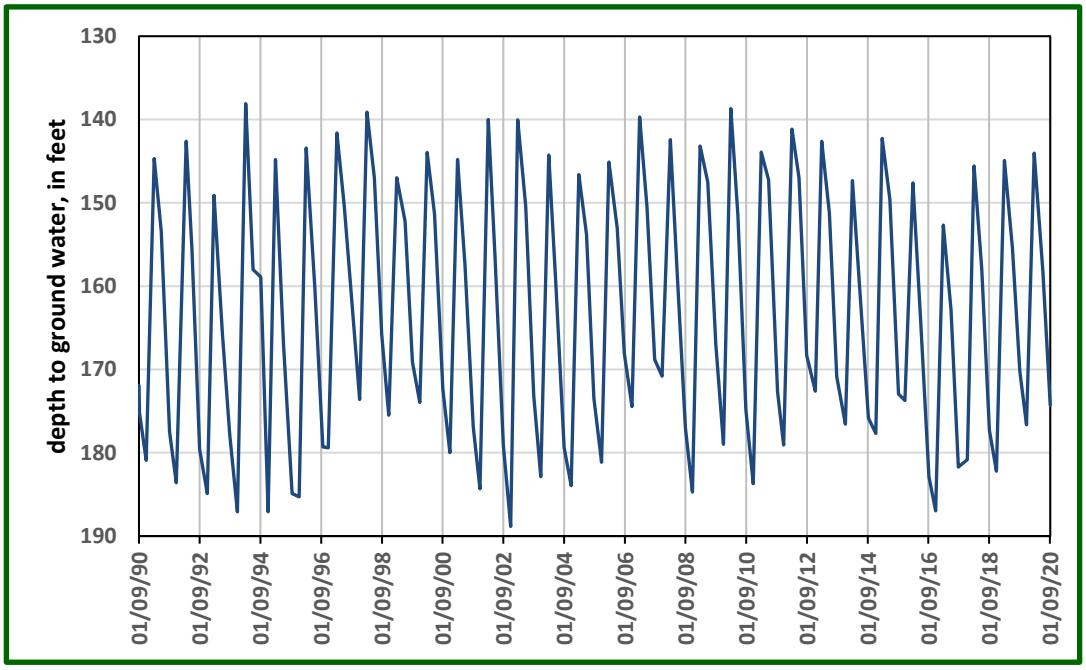
Active monitoring wells **Discontinued monitoring wells**

Additional water level monitoring data are available in project-specific reports

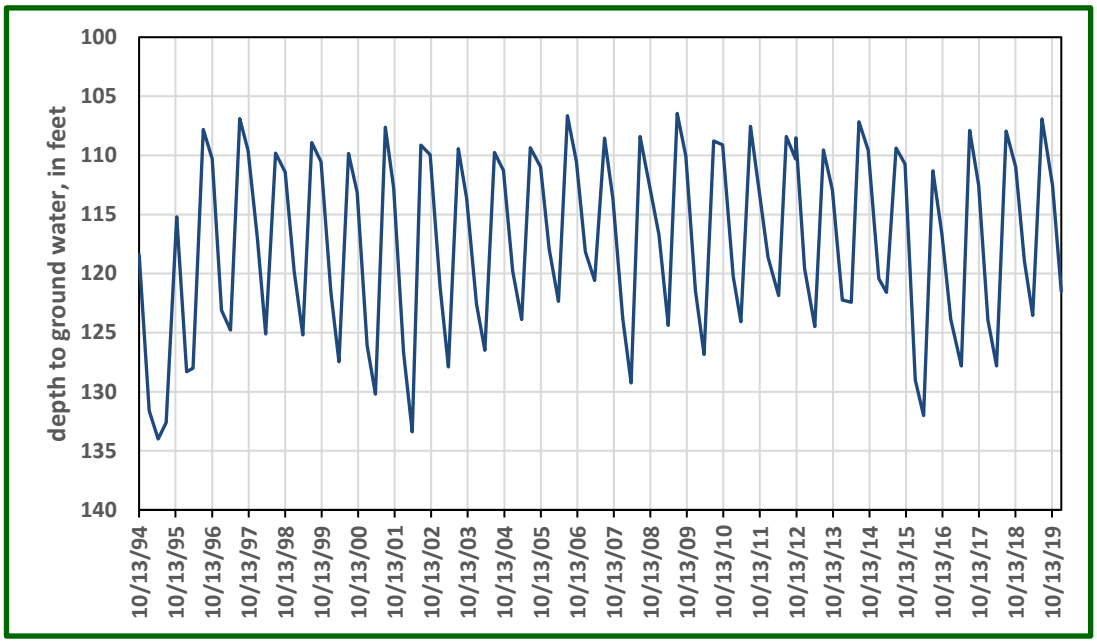
arcusers\seth\GW 2019\CSKT Monitoring Wells 2020



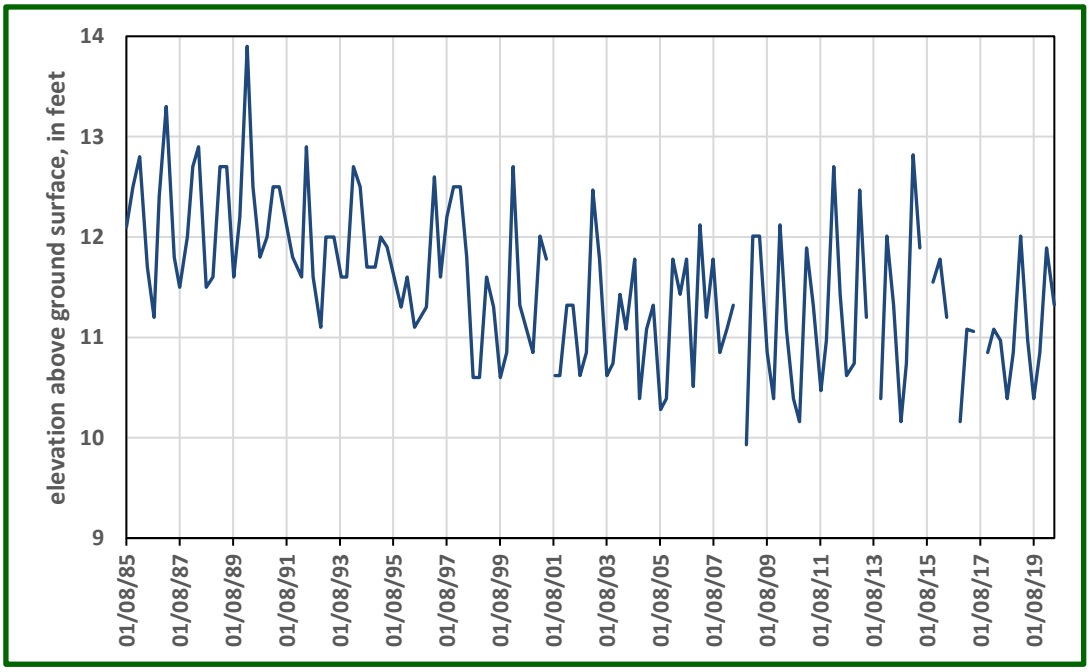
Well #2. JV-AF. T16NR19WDABD. Total depth 71 feet. No lithology.
Water level responds to canal seepage and snowmelt, seasonal high in July.
No long term change in storage observed



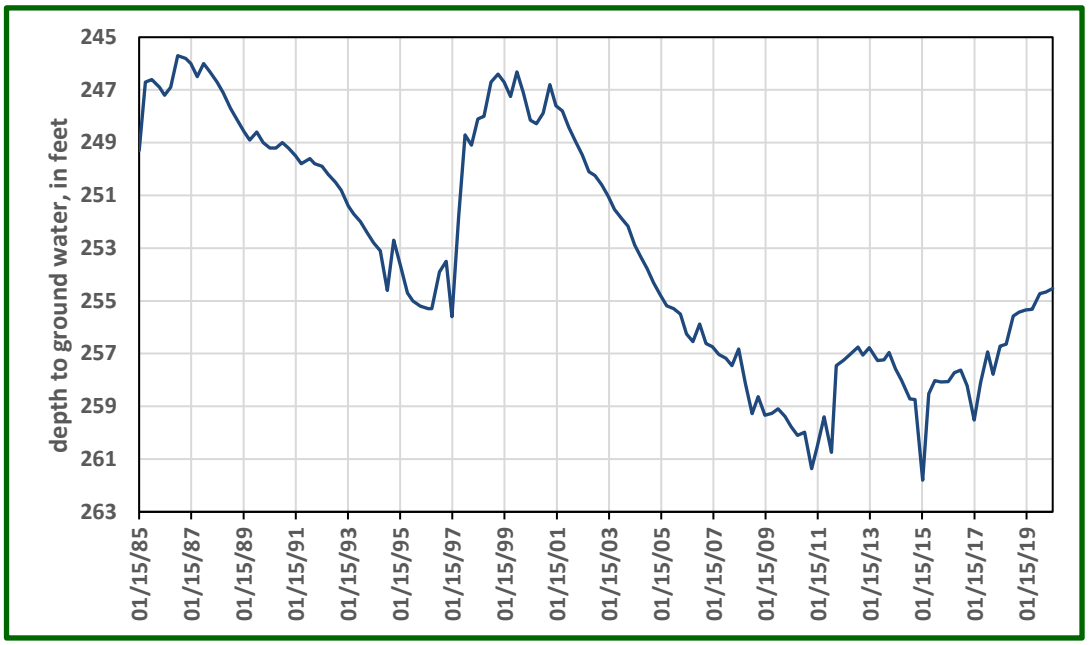
Well#75. JV-OW. T16R18S08ACBB. Total Depth 400 feet. Outwash to 320 feet
Tertiary to 400 feet. Water levels respond to seasonal river recharge and canal seepage.
Up to 50 feet of seasonal water level change. Large seasonal change in storage,
no long term change in storage observed.
Change in water level corresponds to migration of gaining and losing reach in Jocko River



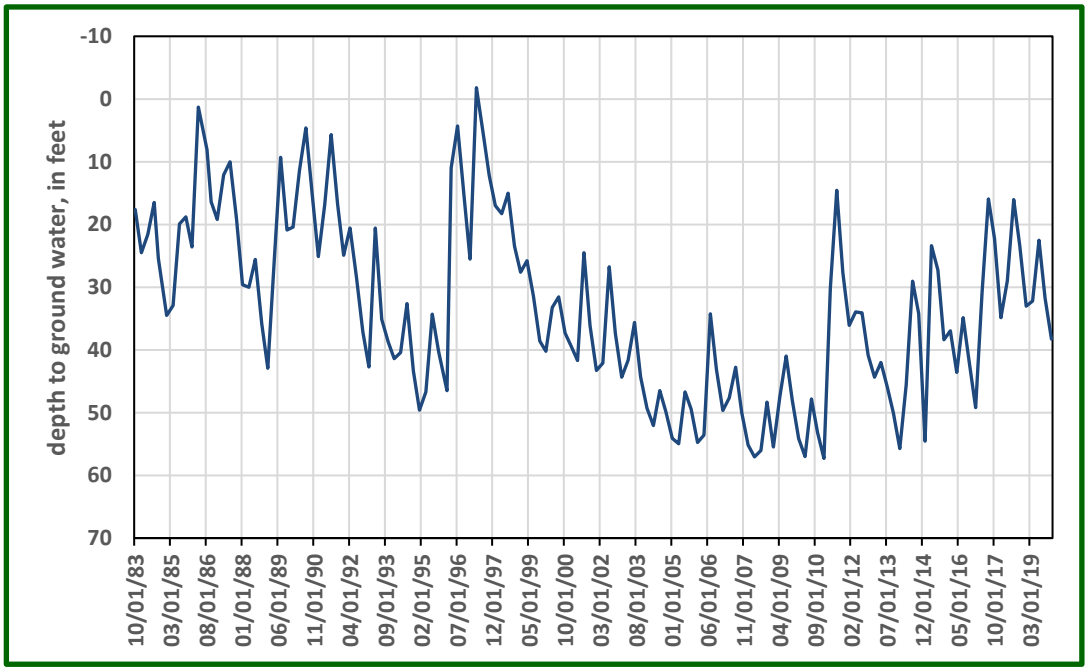
Well #101. JV-OW. T16R19S07BABB. Total depth 134 feet. No lithology - well completed in outwash. Water level responds to canal seepage and snowmelt, seasonal high in summer. No long term change in storage observed



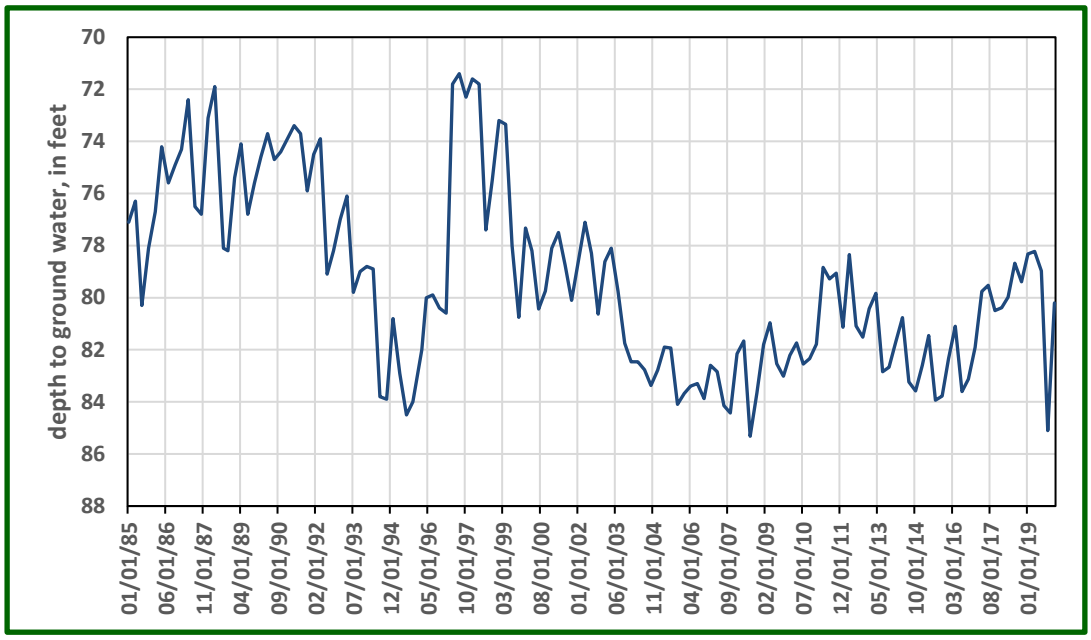
Well #54. JV-LJR. T18R21S21BCBB. Artesian flow. Silt and sand, some gravel to 40 feet 40-80 feet sand; 80-95 feet silty clay; 95-130 feet gravel; 130-138 feet Tertiary sandstone. Decline in artesian pressure, uncertain if related to decline in storage or well performance



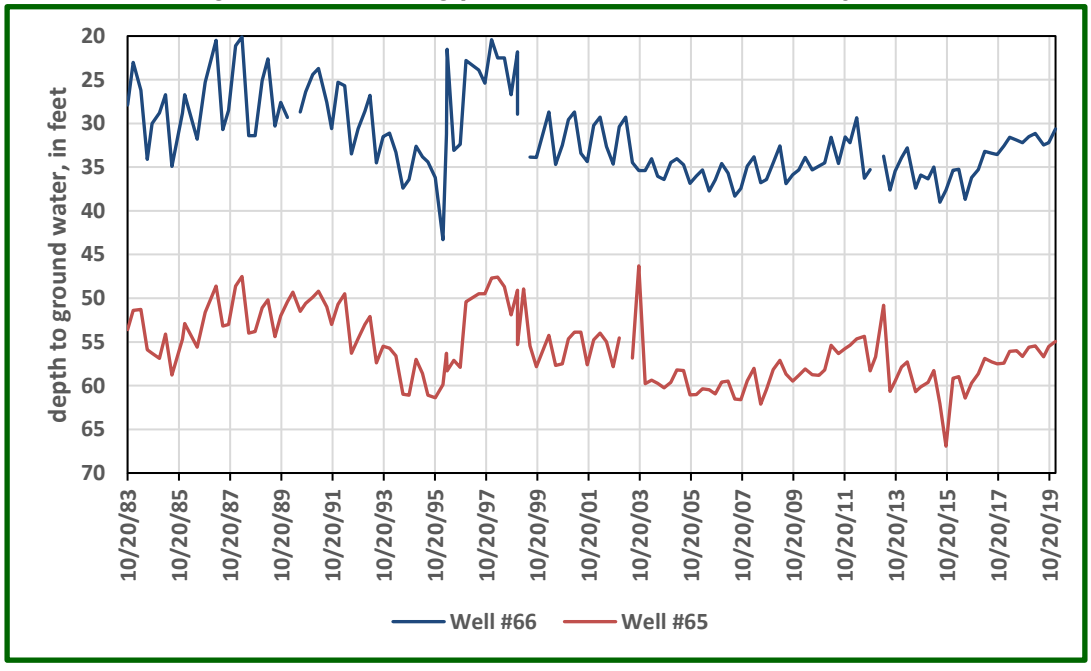
Well #56. LB-SF. T24R22S30CBBC. Total depth 480 feet. Top 448 feet glaciofluvial sediment.
Transition to Tertiary sediment at 448 feet.
Water levels do not show seasonal recharge - no sources.
Large recharge event starting winter 1996, followed by decadal decline in water level.



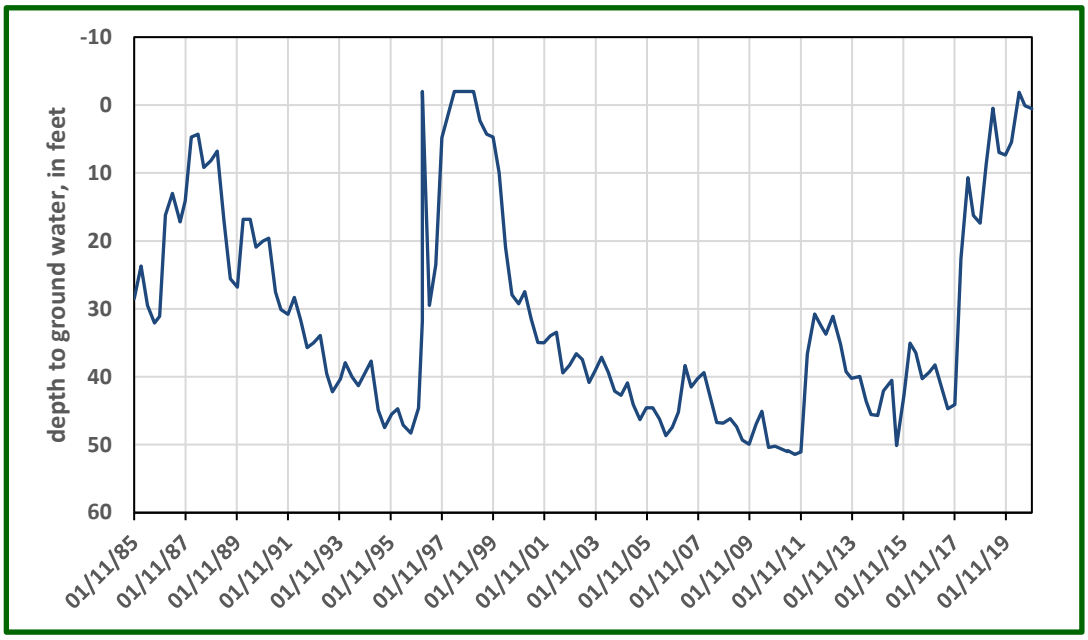
Well #35. LB-SF. T24R23S09BABB. Total depth 168 feet. No lithology. Neg. depth artesian.
Well located in alluvial floodplain of Cromwell Creek.
Water levels show seasonal recharge related to snowmelt.
Winter 1996 and 1997 recharge event.
Large changes in storage and moderate decline in storage over monitoring time period.



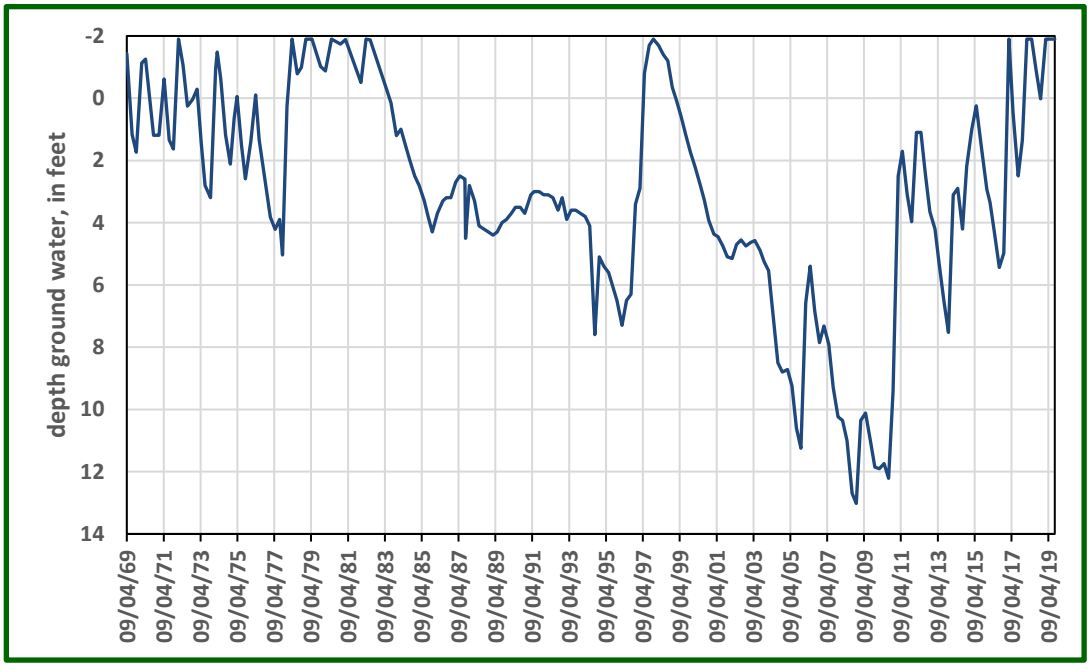
Well #57. LB-SF. T24R24S25DACC. Total depth 328 feet. Top 319 feet glaciolacustrine sediment. 319-326 feet glaciofluvial aquifer sediment. 326-328 feet bedrock.
Confined aquifer response. Water level seasonal peak in April. 1997 recharge event.
Water level seasonal peak in April
Decline in storage over monitoring period, but stable over last 16 years



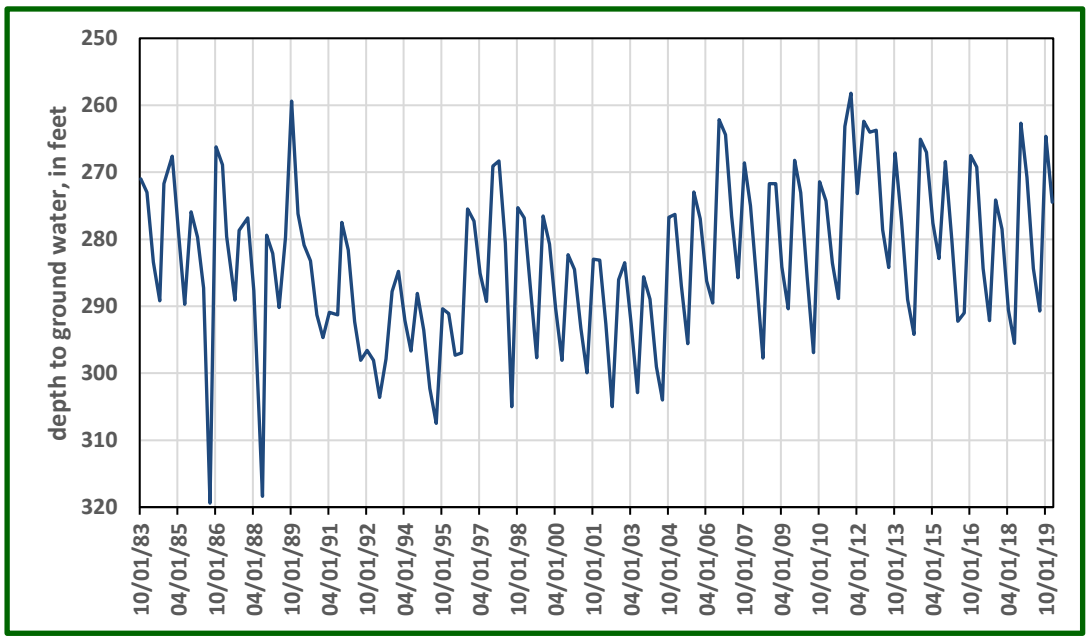
Well #66. LB-LP. T22R24S15ABAD. Total depth 300 feet. No lithology
Well #65. LB-LP. T22R23S32DBBB. Total depth 306 feet. No lithology
Wells completed in glaciofluvial sediment.
Confined aquifer response. Water levels show minor seasonality with high in April. Both wells responded to winter 1996, 1997 event. Long term decline in storage when compared to start of monitoring period.



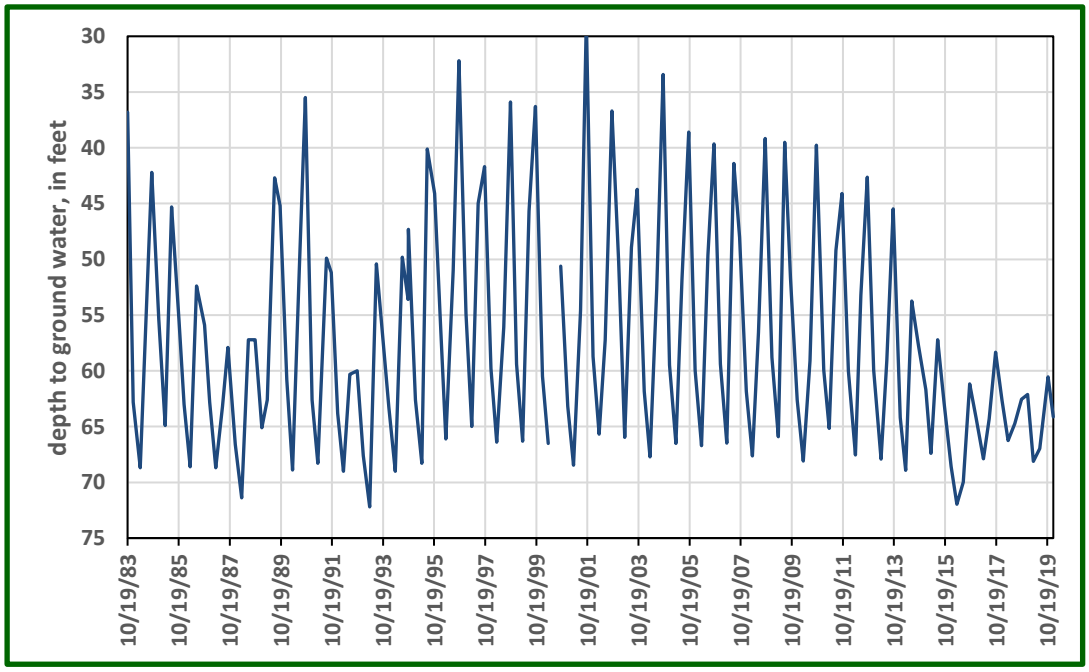
Well #70. unmapped, LB-LP fringe. T21R22S07DCAA. Total depth 186 feet. Neg. depth artesian 0-79 feet glaciolacustrine sediment. 79-105 feet sand and gravel alluvium.105-140 feet glaciolacustrine. 140-186 feet sand and gravel, water alluvium or glaciofluvial. 186-192 bedrock. Confined aquifer response. Minor seasonal recharge with peak in April. Susceptible to infrequent recharge events - 1996, 1997, 2010 and 2017-p



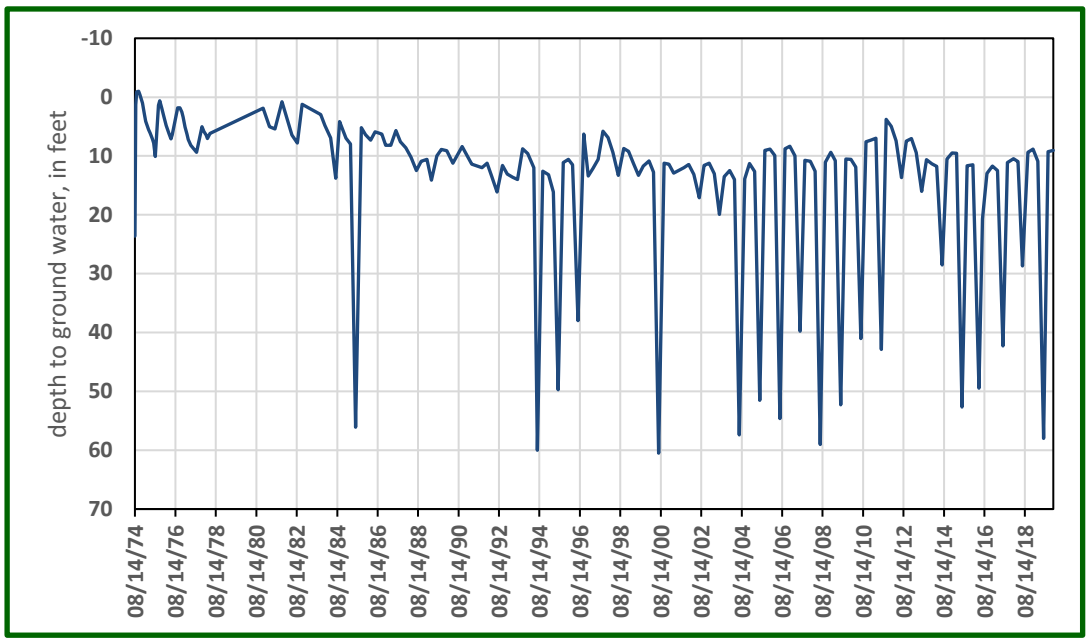
Well #26. LB-LP. T20R22S30DADD. Total depth 305 feet. 50-year dataset. No lithology. Well completed in glaciofluvial sediment. Water level seasonal high in October. Water levels respond to infrequent recharge events. Recovery in storage starting in 2010



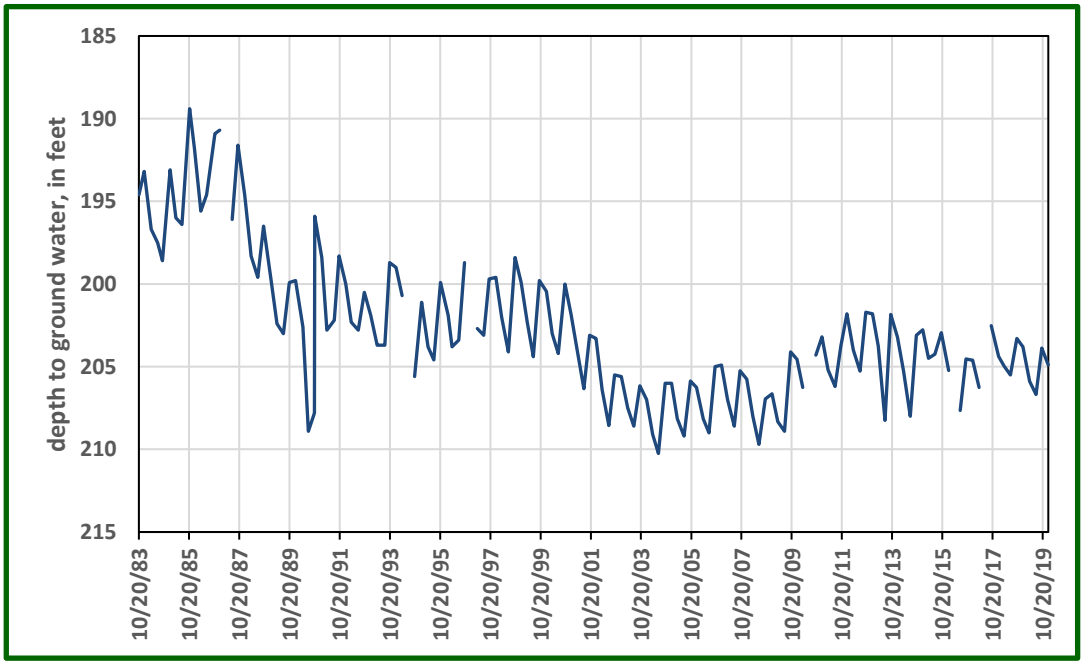
Well #8. MV-AC. T18R19S10BCCC. Total depth 305 feet. No lithology.
Well completed in glacial till, diamict.
Water levels seasonal high in October - lagged response.



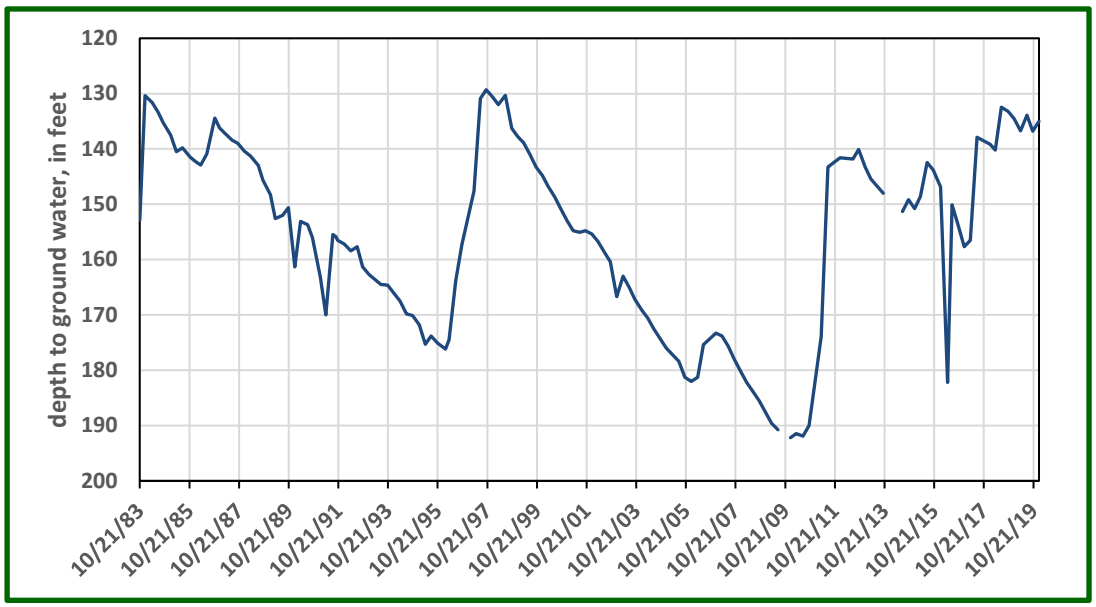
Well #18. MV-MO. T19R21S17BCBB. Total depth 75 feet. No lithology.
Water levels show wide seasonal fluctuation, responding primarily to canal seepage.
Water levels peak in October. Cause for change in seasonal amplitude post 2014 unknown



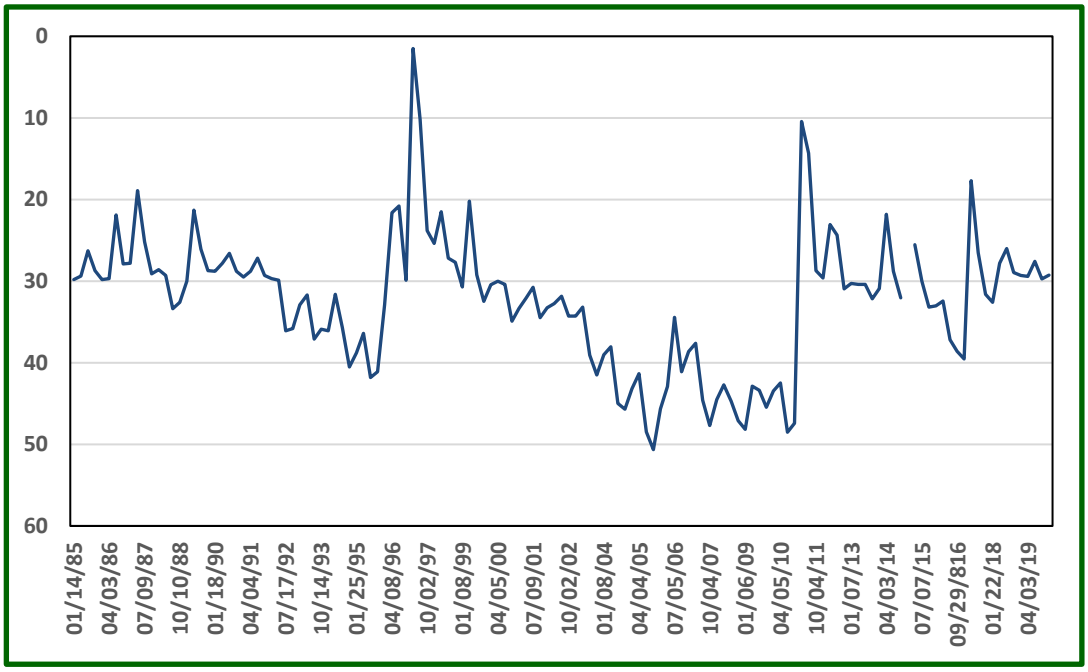
Well #28, MV-MCA. T21R20S24BDCD. Total depth 302 feet. Monitoring well adjacent to high capacity irrigation well. 0-44 feet sandy clay; 44-212 feet glaciolacustrine sediment. 212-269 feet gravels, silt, sand; 269-302 fine to coarse gravel and cobbles, water glaciofluvial. Water level declines rapidly during pumping cycles then stabilizes. Well hydrograph indicates some long term loss of storage



Well #30. MV-PM. T22R23S20DADA. Total depth 340 feet. Missing values depth to water > 300 feet. 0-107 feet gravel, cobbles glacial outwash. 107-245 clay, silt, sand; 245-336 feet clay and gravel glaciolacustrine sediment. 336-340 feet gravel glaciofluvial sediment. Well does not yield sufficient water for pumping. Recent well on parcel completed to 1,200 feet, yielding water in Tertiary sediments at 1,150 feet



Well #55. FL-SS. T23R21S23BCAA. Total depth 300 feet. 0-25 feet clay;
25 feet - 300 feet bedrock
Water levels do not show seasonal recharge pattern. Recharge related to infrequent deep wetting events - winter 1996. Large drawdowns occur during pumping. Missing record - pump on



Well #63. WE WE. T23R22S26BDCC. Total depth 200 feet. 0-17 feet sand fine gravel;
17-73 feet gravel in silt/clay matrix glaciolacustrine sediment.
73-200 feet Tertiary - siltstone, claystone.
Water levels have seasonal high in April. Recharge occurs during infrequent wetting events - winter 1996

Utilization of Ground Water Resources

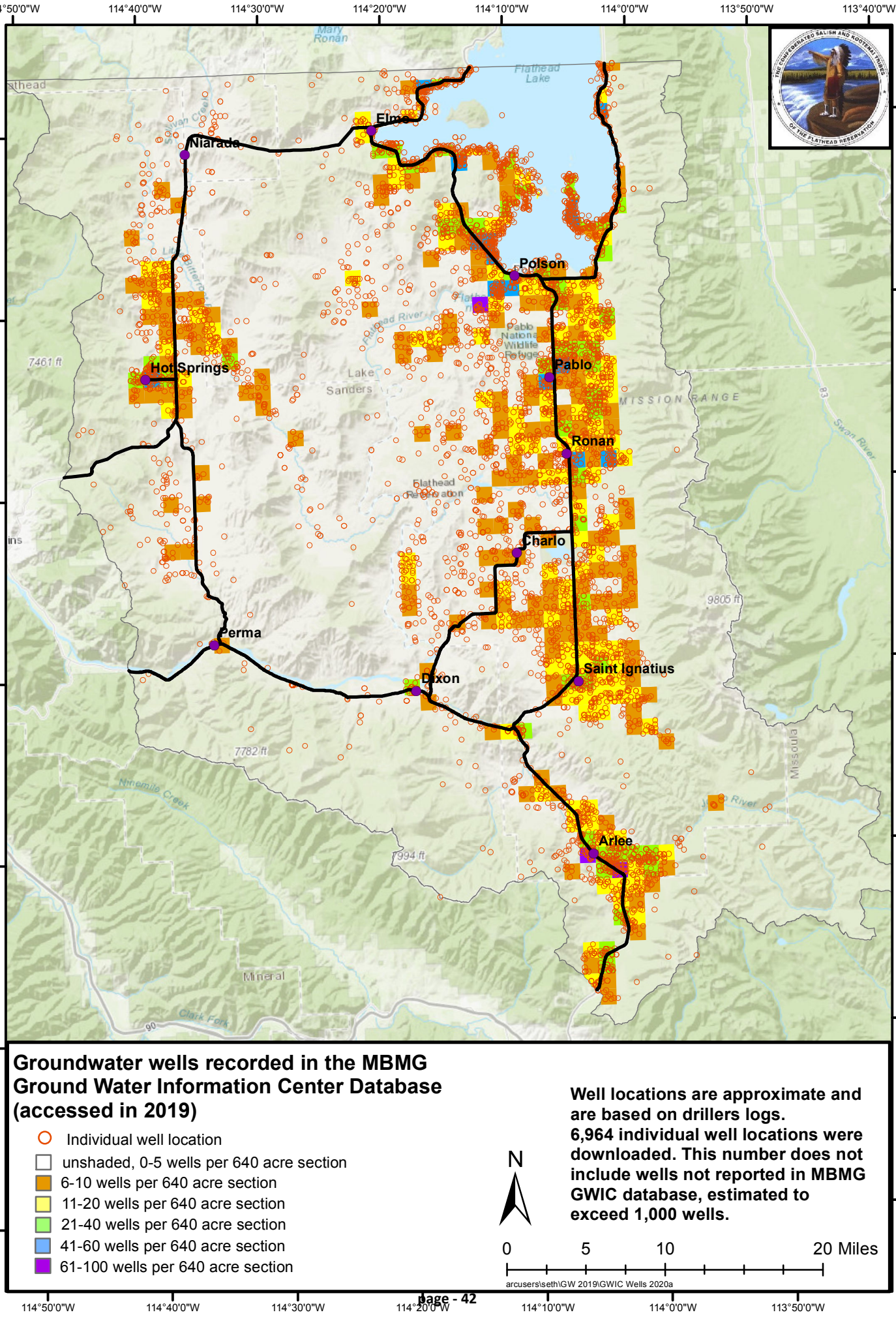
Ground water serves as the principal source of potable water on the Reservation, and we demonstrate the extent of use by summarizing information from publically available information resources. GWIC well logs were downloaded and placed in a spatial (map) framework. Wells are reported as individual point locations and by reporting well density – number of wells per section (640 acres). Our most recent download in 2019 identified 6,964 individual wells. The highest density of wells occurs along the Highway 93 and Flathead Lake corridors. Densities of up to 100 wells per section are reported around Arlee, Pablo, and Polson. We note that the GWIC database likely underestimates wells that have been drilled on the Reservation, including over 500 wells drilled by the Tribal Housing Program. The GWIC database includes wells utilized for domestic water supply and public water supply (PWS).

Public water supply wells are defined in the Safe Drinking Water Act (SDWA) as a "*system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such a system has at least fifteen service connections or regularly serves at least twenty-five individuals*." Montana DEQ identifies a public water supply system as "*a water system that has at least 15 service connections or that regularly serves at least 25 persons daily for any 60 or more days in a calendar year*." The definitions are important, as the map-base and table summary of public water systems comes from the SDWA SDWIS database, the Montana DEQ Source Water Protection Program database, and Tribal Housing Program community water supply records.

The attached map and data table identify public water supplies as Private/Public (P) or Tribal (T). Public/private systems are owned and/or operated by a private entity or by some form of organized community water supply entity. Tribal systems include Tribal community water supply systems and Tribal businesses. PWS systems are also defined as Community Water Systems (CWS), which include public municipal water supplies in incorporated and unincorporated communities; private water supplies serving subdivisions and developments, and Tribal systems serving Tribal communities and homesite clusters. Non-Transient Non-Community (NTNC) systems provide potable water to a minimum of 25 of the same group of people for at least six months of the year; an example would be a school water supply system. Finally, Transient Non-Community (TNC) systems do not regularly serve a minimum of the same 25 people for at least six months of the year; examples include restaurants and churches.

We have identified 137 active PWS systems drawing from three data sources (MDEQ Source Water program; USEPA SDWIS database; CSKT Housing records and/or CSKT/EPA source water protection plans).

PWS system	Public/Private	Tribal	Total
Community Water Systems	47	38	85
Non-Transient Non-Community Systems	8	1	9
Transient Non-Community Systems	41	2	43



Groundwater wells recorded in the MBMG Ground Water Information Center Database (accessed in 2019)

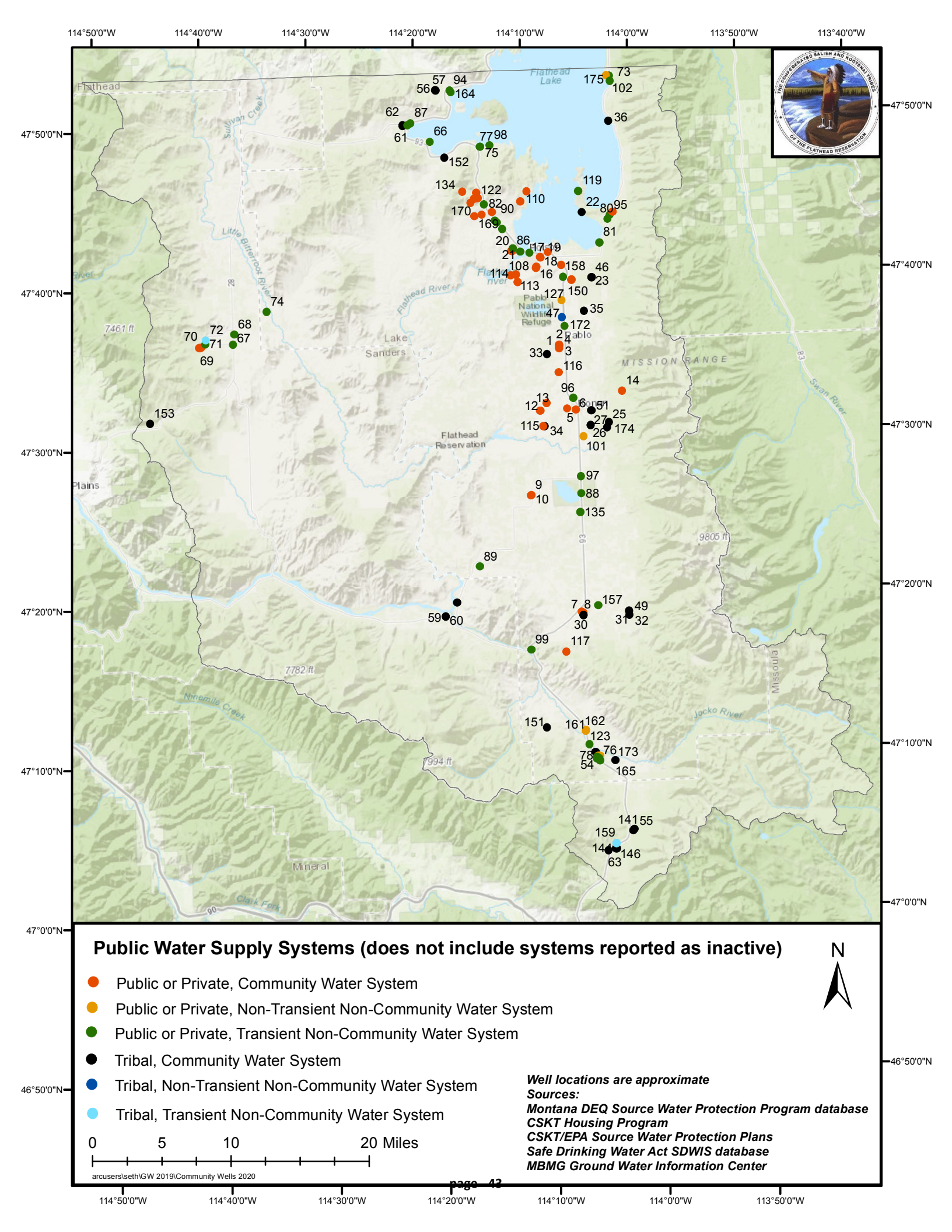
- Individual well location
- unshaded, 0-5 wells per 640 acre section
- 6-10 wells per 640 acre section
- 11-20 wells per 640 acre section
- 21-40 wells per 640 acre section
- 41-60 wells per 640 acre section
- 61-100 wells per 640 acre section

Well locations are approximate and are based on drillers logs. 6,964 individual well locations were downloaded. This number does not include wells not reported in MBMG GWIC database, estimated to exceed 1,000 wells.

N

0 5 10 20 Miles

arcusers\seth\GW 2019\GWIC Wells 2020a



Public Water Supply Systems (does not include systems reported as inactive)

N

- Public or Private, Community Water System
- Public or Private, Non-Transient Non-Community Water System
- Public or Private, Transient Non-Community Water System
- Tribal, Community Water System
- Tribal, Non-Transient Non-Community Water System
- Tribal, Transient Non-Community Water System

0 5 10 20 Miles

arcusers\seth\GW 2019\Community Wells 2020

Well locations are approximate
Sources:
Montana DEQ Source Water Protection Program database
CSKT Housing Program
CSKT/EPA Source Water Protection Plans
Safe Drinking Water Act SDWIS database
MBMG Ground Water Information Center

Map ID	System	System Type	Owner	Public Water Supply ID	Completion Date	Total Depth	Location	Poulation Served
1	Pablo	CWS	Private	MT0001917	12/01/79	408	T21NR20WS11ACBD	2350
2	Pablo	CWS	Private	MT0001917	08/01/73	390	T21NR20WS11ACC	2350
3	Pablo	CWS	Private	MT0001917	08/01/72	595	T21NR20WS11ACC	2350
4	Pablo	CWS	Private	MT0001917	11/01/89	454	T21NR20WS11ACBA	2350
5	Ronan	CWS	Private	MT0000318	11/01/73	490	T20NR20WS2BD	2230
6	Ronan	CWS	Private	MT0000318	09/01/61	345	T20NR20WS2AA	2230
7	St Ignatius	CWS	Private	MT0001740	07/01/83	51	T18NR20WS14DD	700
8	St Ignatius	CWS	Private	MT0001740	07/01/61	80	T18NR20WS14DD	700
9	Charlo	CWS	Private	MT00172	03/01/48	486	T19NR20WS5BAD	450
10	Charlo	CWS	Private	MT00172	09/01/74	473	T19NR20WS5BD	450
12	Round Butte	CWS	Private	MT0000320	02/01/95	508	T21NR20WS31BA	500
13	Round Butte	CWS	Private	MT0000320	06/01/46	355	T20NR20WS4BAA	500
14	Ronan	CWS	Private	MT0000318		0	T21NR19WS27CC	2230
15	Polson	CWS	Private	MT0000308	05/01/69	525	T22NR20WS2SCB	5280
16	Polson	CWS	Private	MT0000308	04/01/60	166	T22NR20WS10CCA	5280
17	Polson	CWS	Private	MT0000308	12/01/76	177	T22NR20WS10CCA	5280
18	Polson	CWS	Private	MT0000308	04/01/00	150	T22NR20WS10ABA	5280
19	Polson	CWS	Private	MT0000308	03/01/00	135	T22NR20WS10ABA	5280
20	Polson	CWS	Private	MT0000308	10/01/99	385	T22NR20WS5CAA	5280
21	Polson	CWS	Private	MT0000308	05/01/01	350	T22NR20WS5DBB	5280
22	Houle Villa	CWS	Tribal	3090026	10/01/94	385	T23NR19WS19DC	44
23	Turtle Lake	CWS	Tribal	3090032	11/01/69	30	T22NR19WS17CBA	225
24	Pache	CWS	Tribal	3090036	12/01/79	195	T20NR20WS1AA	250
25	Woodcock	CWS	Tribal	3090033	12/01/75	550	T20NR19WS8BB	140
26	Clarice Paul	CWS	Tribal	3090021	08/01/79	102	T20NR20WS12AD	55
27	Clarice Paul	CWS	Tribal	3090021	10/01/79	219	T20NR20WS12AD	55
28	St Ignatius	CWS	Tribal	3090031	07/01/79	103	T18NR20WS14DD	840
29	St Ignatius	CWS	Tribal	3090031	07/01/07	63	T18NR20WS14DD	840
30	St Ignatius	CWS	Tribal	3090031	10/01/08	70	T18NR20WS14DD	840
31	Mission Dam	CWS	Tribal	3090029	12/01/75	305	T18NR19WS16CC	129
32	Mission Dam	CWS	Tribal	3090029	06/01/01	464	T18NR19WS21BB	129
33	Carbine	CWS	Tribal			465	T21NR20WS15	
34	Sundowner	CWS	Tribal		11/19/03	503	T20NR20WS9	
35	Mountain Vista	CWS	Tribal		08/28/97	275	T22NR19WS31	
36	Blue Bay	CWS	Tribal	3090308	07/01/83	203	T24NR19WS21	
46	Turtle Lake	CWS	Tribal	3090032	06/03/05	77	T22NR19WS17CBA	225
47	SK Housing/Electronics	NTNC	Tribal	3090028	05/01/83	456	T22NR20WS35ADCA	163
49	Mission Dam	CWS	Tribal	3090029	09/29/08	503	T18NR19WS16CC	129
51	Pache	CWS	Tribal	3090036	09/17/82	200	T20NR20WS1AA	250
53	Arlee-Jocko	CWS	Tribal	3090027	12/01/79	107	T20NR16S2DC	140
54	Arlee-Jocko	CWS	Tribal	3090027	05/01/99	110	T20NR16S2DC	140
55	Schley	CWS	Tribal	3090030	02/01/81	473	T15NR19WS5CB	113
56	Dayton	CWS	Tribal	3090022	01/01/96	69	T24NR21WS4CA	30
57	Dayton	CWS	Tribal	3090022	03/16/99	58	T24NR21WS4CA	30
58	Dixon-Agency	CWS	Tribal	3090023	1983	175	T18R21S8DC	100
59	Dixon	CWS	Tribal	3090034	03/05/54	250	T18NR21WS18DA	216
60	Dixon	CWS	Tribal	3090034	05/04/74	160	T18NR21WS18DA	216
61	Elmo	CWS	Tribal	3090024		348	T24NR22WS24AA	210
62	Elmo	CWS	Tribal	3090024	05/12/03	348	T24NR22WS24AA	210
63	Evaro	CWS	Tribal	3090025	11/01/72	431	T15NR20WS13BA	50
66	Big Arm State Park	TNC	Private	MT0042403	06/01/88	298	T24NR21WS29AD	75
67	Cornerstone Convenience LLP	TNC	Private	MT0002841		0	T21NR24WS2DAA	500
68	Second Home Restaurant	TNC	Private	MT0003965	08/01/95	285	T22NR24WS36CC	51
69	Hot Springs Municipal	CWS	Private	MT0000251	10/01/39	241	T21NR24WS4DBCC	555
70	Hot Springs Municipal	CWS	Private	MT0000251	08/01/63	383	T21NR24WS4DBDC	555
71	Symes Hotel	TNC	Private	MT0003933	06/01/47	248	T21NR24WS4ADDD	54
72	CamasHotSprings	TNC	Tribal	MT0003920		0	T21NR24WS3BBB	15
73	Yellow Bay State Park	TNC	Private	MT0042409	03/01/88	444	T24NR19WS4AAAC	25

Map ID	System	System Type	Owner	Public Water Supply ID	Completion Date	Total Depth	Location	Poulation Served
74	Wild Horse Hot Springs	TNC	Private	MT0001096	04/01/13	240	T22NR23WS29ACBB	34
75	Timberlane Resort	TNC	Private	MT0003221	04/01/71	120	T24NR21WS25CDCA	25
76	Stockmans Bar	TNC	Private	MT0004427		86	T16NR20WS11AD	30
77	Timberlane Resort	TNC	Private	MT0003221		326	T24NR21WS25CDCA	25
78	Sanders/Ricks Kustom Kuts	TNC	Private	MT0004494		0	T16NR20WS11AD	65
80	Finley Point Grill	TNC	Private	MT0004235	07/01/89	124	T23NR19WS28ADDA	100
81	Paradise Cove	TNC	Private	MT0001016	09/01/88	420	T22NR19WS5AABD	254
82	Polson Four Square Church	TNC	Private	MT0004591	11/01/92	52	T23NR20WS30BDB	100
86	Polson KOA	TNC	Private	MT0003351	11/01/87	282	T22NR20WS5ACBB	43
87	North BigArm Bay LOA	TNC	Private	MT0004463		0	T24NR21WS19BA	25
88	Ninepipes Lodge LLC	TNC	Private	MT0001002	02/01/54	274	T19NR20WS1BBCB	50
89	NatlBisonRangeVisitorsCenter	TNC	Private	MT0003617	07/01/79	273	T19NR21WS34BADD	507
90	MissionValleyChurchofChrist	TNC	Private	MT0004444	11/01/02	167	T23NR20WS30BD	70
94	Idle Spur Saloon	TNC	Private	MT0001004	01/01/91	64	T24NR21WS3CACC	75
95	EastShoreSmokehouse	TNC	Private	MT0001015		0	T23NR19WS28AC	111
96	Diamond S RV Park	TNC	Private	MT0003428	07/01/81	320	T21NR20WS36BDAA	8
97	Connies Countryside Cafe	TNC	Private	MT0001003	05/01/73	310	T20NR20WS25CCCC	158
98	Camp Marshall	TNC	Private	MT0004230	05/01/80	375	T24NR20WS30DD	50
99	Bison Cafe	TNC	Private	MT0001023	08/01/79	50	T18NR20WS31ADAD	25
101	Jore Corporation	NTNC	Private	MT0004060	06/01/92	296	T20NR20WS13BABB	200
102	Flathead Lake Bio Station	NTNC	Private	MT0003724		15	T24NR19WS4AABD	48
103	Arlee Junior High School	NTNC	Private	MT0003416	03/01/86	160	T16NR20WS11AADC	110
104	Arlee High School	NTNC	Private	MT0000982		93	T16NR20WS11AAD	145
105	Arlee Elementary School	NTNC	Private	MT0003417		80	T16NR20WS11AAC	305
106	South Hills WUA	CWS	Private	MT0003104	07/01/75	380	T22NR20WS13DBDA	60
107	PonderillaHills	CWS	Private	MT0003103	02/01/70	410	T22NR20WS17DBDB	38
108	PonderillaHills	CWS	Private	MT0003103	02/01/74	900	T22NR20WS17DDBB	33
109	Pinewood Shores WUA	CWS	Private	MT0003224	07/01/77	275	T23NR20WS16ACAB	38
110	Pinewood Shores WUA	CWS	Private	MT0003224	07/01/77	166	T23NR20WS16ABCD	38
111	Paradise Pines Resort	CWS	Private	MT0001018	07/23/75	73	T23NR19WS21DD	86
112	Paradise Pines Resort	CWS	Private	MT0001018		0	T23NR19WS21DD	86
113	Overlook Subdivision	CWS	Private	MT0003792	11/01/92	400	T22NR20WS17ABAB	40
114	Overlook Subdivision	CWS	Private	MT0003792	11/01/92	360	T22NR20WS17ABAB	40
115	Mission Mountain View HOA	CWS	Private	MT0003157		426	T20NR20WS9BADD	65
116	Mission Meadows RV Court	CWS	Private	MT0000621	05/01/71	349	T21NR20WS23BDDA	225
117	Christian Childrens Ranch	CWS	Private	MT0003720		0	T18NR20WS34DB	120
118	Clearview Heights Water Assn	CWS	Private	MT0003233	10/22/04	405	T22NR20WS11DAAD	35
119	Finley Point State Park	TNC	Private	MT0042404	11/01/75	228	T23R19WS18BDAC	30
120	Flathead River RV Resort	TNC	Private	MT0004164		507	T22NR20WS4CB	48
122	Jette Store	TNC	Private	MT0004002		710	T23NR21WS24AB	100
123	Jocko Hollow Campground	TNC	Private	MT0000977	05/01/79	150	T16NR20WS2BC	29
124	Wilson Foods	TNC	Private	MT0000978		0	T16NR20WS11AC	850
125	The Biscuit	TNC	Private	MT0004429		0	T16NR20WS11AD	92
126	Arlee Senior Center	TNC	Private	MT0004428		0	T16NR20WS11AC	45
127	Lake County Transfer Station	NTNC	Private	MT0004515		0	T22NR20WS26AA	62
129	JetteMeadowsPhase2	CWS	Private	MT0003101	08/01/80	405	T23NR21WS14DCCD	200
131	JetteLakeWaterUsersAssociation	CWS	Private	MT0003102	04/01/74	285	T23NR21WS13BBCC	200
132	JetteLakeWaterUsersAssociation	CWS	Private	MT0003102	04/01/74	585	T23NR21WS13CBBD	200
133	JetteLakeWaterUsersAssociation	CWS	Private	MT0003102	09/01/74	640	T23NR21WS14DACA	200
134	JetteLakeWaterUsersAssociation	CWS	Private	MT0003102	03/01/74	450	T23NR21WS14BBBC	200
135	Mission ValleyMethodist Church	TNC	Private	MT0004558	03/01/06	280	T19NR20WS2DA	82
140	JetteMeadowsPhase1	CWS	Private	MT0003100	10/18/95	495	T23NR20WS19CB	140
141	Schley	CWS	Tribal	3090030	05/03/05	484	T15NR19WS5CB	113
142	Mission Mountain W & C Dist	CWS	Private	MT0003801	05/01/87	340	T21NR20S34BDD	148
143	Mission Mountain W & C Dist	CWS	Private	MT0003801	1991	484	T21NR20S34BDD	148
144	Corriacan Village	CWS	Tribal	3090038	02/08/00	74	T15NR20WS12DD	35
145	Corriacan Village	CWS	Tribal	3090038	10/05/98	78	T15NR20WS12DD	35
146	Corriacan Village	CWS	Tribal	3090038	10/06/98	96	T15NR20WS12DD	35

Map ID	System	System Type	Owner	Public Water Supply ID	Completion Date	Total Depth	Location	Poulation Served
147	Clearview Heights Water Assn	CWS	Private	MT0003233		0	T22NR20WS11DAAD	35
150	South Hills WUA	CWS	Private	MT0003104	11/14/97	423	T22NR20WS13DBDA	60
151	Valley Creek	CWS	Tribal		01/29/1998	516	T17NR20WS32	4
152	Big Arm	CWS	Tribal	3090309	08/16/1998	195	T24NR21WS33	13
153	Dog Lake	CWS	Tribal		12/06/2000	350	T21NR25WS35	
156	Christian Alliance Church	TNC	Private	MT0004534		0	T23NR20WS30DC	216
157	Mission General Store	TNC	Private	MT0004360		0	T18NR20WS13AD	76
158	Ivanhoe Water company	TNC	Private	MT0004390	1974	355	T22R20S13CBB	211
159	Grey Wolf Casino	TNC	Tribal	3090103	08/01/2001	120	T15NR19WS7BC	80
161	Ashley Martin MFG LLC	NTNC	Private	MT0003791		0	T17NR20WS20AC	79
162	Ashley Martin MFG LLC	NTNC	Private	MT0003791		0	T17NR20WS20AC	79
163	Blacktail Grocery	TNC	Private	MT0003897		0	T22NR20WS9	413
164	Dayton Harbor Cottages	TNC	Private	MT0004893		0	T24NR21WS4	28
165	Huckleberry Patch	TNC	Private	MT0004437		0	T16NR20WS11AAD	160
168	North Big Arm Bay LOA	TNC	Private	MT0004463		0	T24NR21WS19A	
169	Pleasant View Subdivision	CWS	Private	MT0004671		0	T23NR21WS23CDD	31
170	Pleasant View Subdivision	CWS	Private	MT0004671		0	T23NR21WS24BDC	31
172	Seven Acres	TNC	Private	MT0004494		0	T21NR20WS1BBB	24
173	Chief Martin Charlo	CWS	Tribal	3090305		0	T16NR19WS7CB	75
174	Timberlane	CWS	Tribal			0	T20NR19WS8CB	10
175	Many Springs Resport	TNC	Private	MT0003204		0	T24NR19WS4DD	27

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