Summary Report on the Status of Helena Area Groundwater Resources
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Introduction

This report was prepared to present information on the current status of local groundwater resources in the Helena Valley and surrounding area in 2020. Data from Lewis & Clark Water Quality Protection District (LCWQPD) monitoring projects provides a basis for assessing the current conditions in local groundwater systems. Information on the local hydrologic system includes data and conclusions from studies completed by the United States Geological Survey (USGS) and the Montana Bureau of Mines and Geology (MBMG). This report focuses on water availability and does not address water quality issues. For more information, readers are referred to the references cited for the information presented.

Background

Residents of the Helena Valley and surrounding area obtain potable water primarily through either private wells or a public water supply (PWS). The cities of Helena and East Helena both maintain PWS for residents, and there are numerous additional PWS for subdivisions within the Helena Valley. These PWS all have water rights, managed by the Montana Department of Natural Resources & Conservation (DNRC). However, at this time the Upper Missouri River Basin, including the Helena Valley and surrounding area, are closed to issuing new water rights. As a result, new developments utilize “exempt” wells for potable water, where each residence has a private well and water use is limited. The wells are considered “exempt” as they do not require a formal water right with the assumption that water consumption from a private well will not impact any neighboring wells. For developed areas with smaller lot sizes, there is the potential that the use of exempt wells will result in depletion of the local groundwater resource, impacting well yields. The yield and sustainability of groundwater resources from any location reflects the geology of the aquifer, and the presence of streams and local precipitation providing groundwater recharge to the system. Since they are connected, the presence of both ground and surface and water should be treated as a single resource.

Several groundwater hydrology studies of the Helena area have been completed by the USGS and MBMG. The first published hydrology study was completed by the USGS in 1948 to determine the general properties of ground water flow and chemistry in the valley (Lorenz & Swenson, 1951). This study presented major ion chemistry data for water samples from 17 wells at locations across the Helena Valley, including two wells drilled into the Tertiary sediments beneath unconsolidated valley fill material. With increased growth in the area, the USGS completed additional studies in 1971 (Wilke & Coffin, 1973) and 1978-79 (Moreland et al., 1979; Moreland & Leonard, 1980) to examine the impacts of urban growth on water quality, with limited sampling for major ions and trace metals, and more extensive sampling for nitrates. These studies concluded that urban growth was impacting ground water quality in the area. The most detailed study of the Helena Valley Aquifer was performed in 1989-90, with a ground water numerical (computer) flow model completed for the aquifer coupled with ground water quality sampling and analysis to characterize water quality across the valley (Briar & Madison, 1992). The nature of the bedrock aquifers bounding the Helena Valley were investigated during the period 1993-98, with additional water quality sampling (Thamke, 2000). Focused ground water studies were performed on the impact of irrigation drainage to ground water quality in 1995 (Kendy et al., 1997; Tuck, 2000). MBMG completed studies on the hydrogeology of the North Hills area of the Helena Valley (Madison, 2006; Waren et al, 2012). Concurrent with the second North Hills study, MBMG completed a focused study on the hydrogeology and water quality of the Scratchgravel Hills area along the western margin of the Helena Valley (Bobst et al., 2013).

Overview of Local Hydrologic System

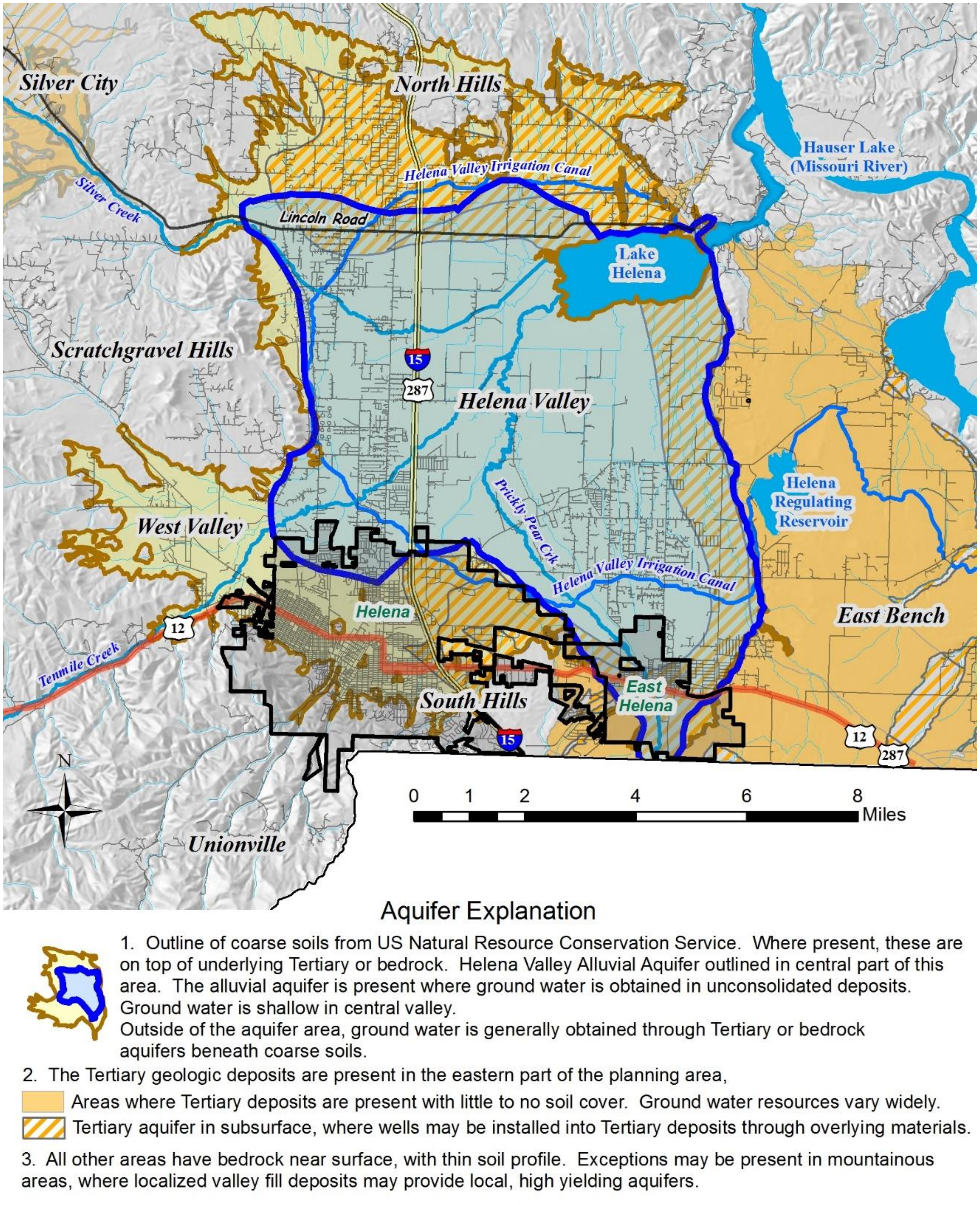
Helena is located within the Lake Helena Watershed, a tributary system to the northward flowing Missouri River east of the Helena Valley. A simplified description of the surface and groundwater combined hydrologic system for the watershed notes that all waters follow general topography and flow towards and into Lake Helena, connected to Hauser Lake on the Missouri River. Higher amounts of precipitation in upland areas surrounding the valley provide recharge to groundwater from infiltration of precipitation, and streams from surface runoff. Streamflow is maintained, and increases, from groundwater flowing into the base of streams as the elevation decreases with flow towards the valleys. As the streams cross from flowing over bedrock into valley alluvium, the gradient decreases and streams lose flow to groundwater recharge. Within the valley, groundwater flows towards the lowest elevation in the Helena Valley, Lake Helena, where it flows into the base of the lake. With the lake connected to groundwater, the elevation of the lake surface represents the lowest elevation for groundwater to occur in the Helena Valley, under normal conditions. The hydrologic system of the Helena Valley receives additional input from outside of the Lake Helena Watershed – obtained from Canyon Ferry Lake on the Missouri River, transported into the valley via the Helena Valley Irrigation system. The irrigation system provides additional groundwater recharge, which results in shallow groundwater within the central part of the Helena Valley. Groundwater properties are generally controlled by the geologic conditions of an area, and the proximity to groundwater recharge sources. Groundwater in areas outside of the main Helena Valley Irrigation Canal (HVIC) generally occurs under different geologic conditions, with less recharge. These areas are also more susceptible to reduced yields and water availability during periods of drought.

Geology of Helena Area Aquifers

The geologic conditions of any area determine how groundwater occurs. *Aquifers* are underground geologic formations that yield water in generally usable quantities. They may be sedimentary rocks with permeable pores, relatively impermeable rocks with interconnected fracture system, or unconsolidated deposits of sand, gravel and/or silts. Geologic units with low permeability, such as clay-rich deposits, that transit small amounts of water are referred to as *aquitards*. Impermeable units which do not yield measurable amounts of water are called *aquicludes*. Aquicludes or aquitards present over an aquifer create *confined aquifers,* where the water is under pressure and rises to a level over the top of the aquifer unit. *Unconfined aquifers* are generally present near the surface, with the surface present at atmospheric pressure.

Geologic maps of the Helena area show the many different types of geologic formations and deposits in the area. While there are numerous geologic rock formations in the area, they all generally have similar water bearing properties. The USGS Bedrock Aquifer Report, prepared by Thamke (2000), provides a good overview of the general hydrologic properties of each different geologic formation in the area. The Helena Valley is filled with alluvium deposited over the surface by local streams, with several hundred feet of alluvium in the central part of the valley. On the Spokane Bench east of the Helena Valley, and other areas, clay-rich deposits are present with lenses of more permeable sediments. From their studies, the USGS and MBMG identified three general aquifer types in the Helena area. These units were identified by LCWQPD staff in support of the 2015 regional growth planning effort. Figure 1 shows the general location of the different aquifer types in the area. The aquifer types can be described as follows:

- The Helena Valley (Alluvial) Aquifer comprises an unconfined aquifer within the unconsolidated alluvial sand, gravel, silt and clay deposits within the Helena Valley.
- Tertiary aquifers are present on the Spokane Bench east of the Helena Valley, and comprise semi-consolidated geologic deposits with thick clay-rich deposits present under coarser, sand and gravel rich deposits. The aquifers are generally unconfined when near the surface, with confined conditions in clay-rich deposits.
- Bedrock aquifers comprising the numerous older geologic units surrounding the northern, southern and western boundaries of the Helena Valley. Bedrock aquifers are also present beneath Tertiary aquifers. Shallow groundwater is unconfined, but confined conditions occur in deeper wells.



Aquifer Explanation

1. Outline of coarse soils from US Natural Resource Conservation Service. Where present, these are on top of underlying Tertiary or bedrock. Helena Valley Alluvial Aquifer outlined in central part of this area. The alluvial aquifer is present where ground water is obtained in unconsolidated deposits. Ground water is shallow in central valley.
Outside of the aquifer area, ground water is generally obtained through Tertiary or bedrock aquifers beneath coarse soils.

2. The Tertiary geologic deposits are present in the eastern part of the planning area,

🟧 Areas where Tertiary deposits are present with little to no soil cover. Ground water resources vary widely.

▨ Tertiary aquifer in subsurface, where wells may be installed into Tertiary deposits through overlying materials.

3. All other areas have bedrock near surface, with thin soil profile. Exceptions may be present in mountainous areas, where localized valley fill deposits may provide local, high yielding aquifers.

Note: The primary data sources for the map include Briar & Madison (1992), Thamke (2000), NRCS Soils, and local MBMG studies (2012, 2013).
Boundaries in the subsurface are estimated from listed sources, and reflect current estimates of locations.
Unit boundaries are valid at a valley-scale, and can't be used for site-specific assessments where site data is required.

Figure 1 – Map of 3 Aquifers in Helena Valley and Surrounding Area.
This map was developed and presented with the 2015 Growth Plan update for the Helena area.

Depletion in Local Aquifers

Groundwater depletion comprises the decline in water levels in an aquifer from pumping at rates that exceed recharge to the system. Management of groundwater resources for long-term sustainable use requires understanding the full hydrogeologic system, from recharge sources and areas to the downgradient discharge points where groundwater may flow into a surface water body. Wells pumping from the aquifer within the system change the dynamics of the local system. The impacts from well withdrawals of water are greater for aquifers with lower permeabilities and groundwater flow rates, since the slower flow rates within the system result in a slower recharge rate for the aquifer. The impacts, such as depletion, can result from pumping from fewer high yielding wells, or from larger numbers of wells providing smaller yields. Long-term groundwater level monitoring programs provide data to assess changing conditions within aquifers and provide a basis for developing and implementing aquifer management programs to limit the magnitude of any depletion occurring from excess pumping from an aquifer. Developing aquifer management programs to support sustainable yields are difficult without these types of long-term monitoring datasets providing baseline conditions. When these datasets are not available, as is common in many areas, the risk of depletion increases with greater long-term impacts present before yield problems are identified. When depletion occurs, consumer water conservation programs help preserve well yields, while engineered solutions such as Managed Aquifer Recharge (MAR) programs can provide artificial recharge to a depleted aquifer. These programs are also independent of the varying impacts of drought to different aquifer systems.

For more than a decade, LCWQPD has maintained a monthly long-term water level monitoring program at approximately 120 locations across the Helena Valley and surrounding area. The program was expanded during the MBMG studies of the North Hills and Scratchgravel Hills completed from 2009-2011 (Waren et al., 2012; Bobst et al., 2013). Over time, the water level monitoring program has been modified with new locations to address new areas with water concerns. In other cases, locations were removed as permission for well access from local landowners was rescinded. The period from 2010-2011 provides the most comprehensive groundwater level dataset for the area, with the most monitoring locations. A groundwater surface map for April 2011, before flooding occurred in the Helena Valley, shows the general groundwater flow directions at that time. A comparison of the 2011 map with a groundwater flow map from 1992 can be used to identify areas where groundwater depletion has occurred (Figure 2). Note that the map from 1992 was developed using a numerical model calibrated with onsite well water level data and is considered representative of the groundwater surface in the Helena Valley Aquifer at that time.

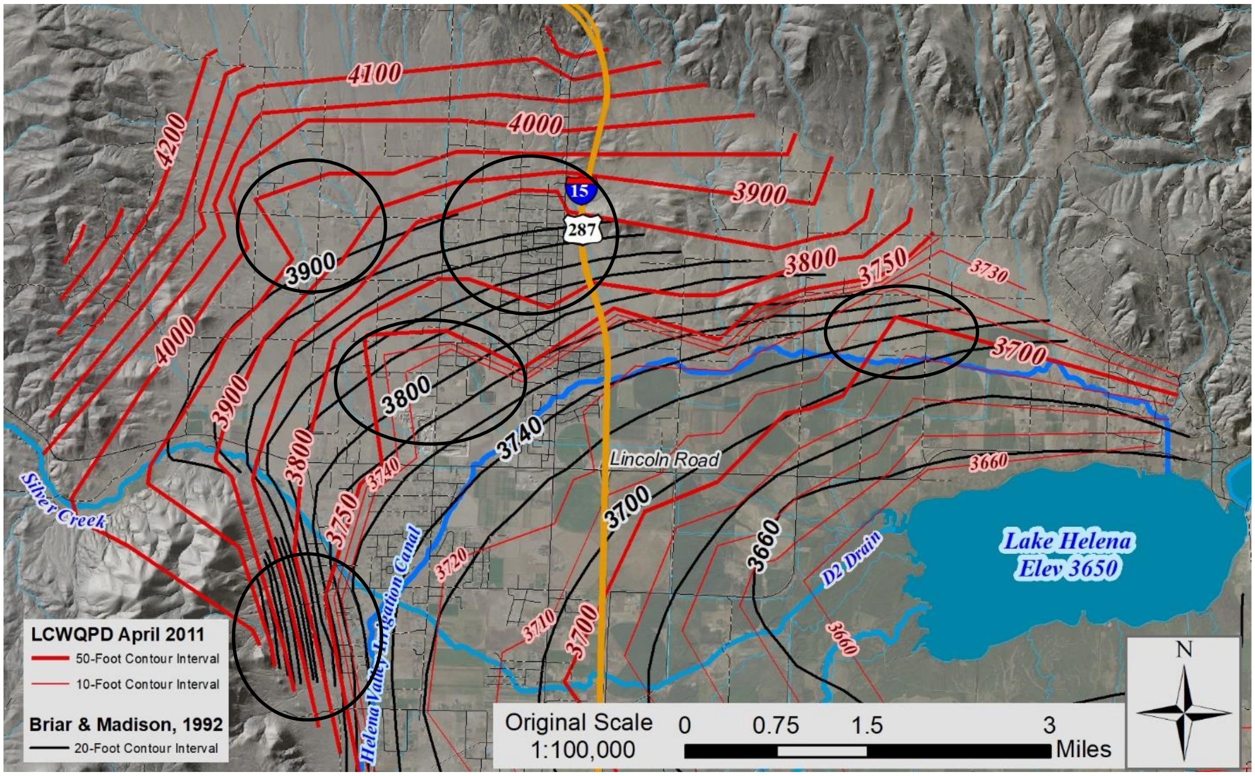


Figure 2 – Comparison of Groundwater Surfaces in North Hills, 1992 to 2011.

The circled areas represent locations where groundwater contours show changes over time, indicating that water levels have declined and depletion may have occurred. The black contours are from Briar & Madison (1992), with a regular 20-foot contour interval. The red contours are from LCWQPD Staff map prepared with data from April 2011, with bold lines at a 50-foot contour interval, and lighter lines in the Helena Valley at a 10-foot contour interval.

Examples of Changing Water Levels in the Helena Area

Regular monitoring of water levels in area wells provides crucial data to understanding the local hydrologic system, for example to identify when recharge occurs seasonally, or to assess long-term changes in the water surface elevation. Water levels in Helena area wells typically rise during the spring wet season, with recharge from direct infiltration of precipitation and stream loss during periods of high runoff. The irrigation season, from April 15 – October 1, results in additional recharge to the Helena Valley aquifer in the central portion of the valley. The seasonal low groundwater period is generally during the late fall and winter, when recharge is limited. *Hydrographs* are graphs that show how the depth to water, or elevation of the groundwaters surface changes over time. The normal or average hydrograph for a Helena area well shows rising water levels in the spring, and falling water levels in the winter, with a long-term sinusoidal pattern as previously described. Since water levels conditions change seasonally, the best way to assess the condition of the aquifer is to identify the seasonal high-water levels each year, over time, to determine whether long-term changes in water levels in an aquifer are occurring. For wells outside of the influence of irrigation water recharge, dry years associated with drought, and less precipitation, can naturally result in a lowering of the water table and subsequent recharge to wells. Conversely, during wet years with abundant precipitation, regional water levels may rise. Groundwater *depletion* occurs when pumping from wells results in lowering the water table surface and may occur generally independent of climate pattern.

Since 2009, LCWQPD monitors water level conditions at more than 120 wells each month (Figure 3), providing valuable data for assessing local groundwater conditions. While the network is generally considered useful for monitoring water levels conditions regionally, some areas have a higher density of monitoring locations to address specific local concerns. The network has been modified each year, with some changing permissions for access, and to obtain information for areas with only limited amounts of data. In some cases, water level datalogging sensors are installed in wells to collect high frequency data. The water level monitoring program was partially suspended during early 2020 as a result of the COVID-19 pandemic, with measurements collected from monitoring wells, but not private potable wells. The program has not been fully restored as of July 2020 at the time of preparation of this report. The water level data is available through the MBMG-GWIC website, and through a storymap portal through the LCWQPD website.

While conditions are continually changing each year with different winter/spring precipitation patterns, varying streamflows, and dry periods during summer, there are currently three areas of concern regarding the long-term sustainability of local groundwater resources. The locations are noted on Figure 3, comprising Emerald Ridge, the North Hills, and the Southeast Helena Valley. While each area has multiple monitoring locations, hydrographs for selected wells have been presented to highlight the issues at hand. The data was presented to the Montana water resource technical community at the Montana AWRA conference with an oral presentation in October 2017, with hydrologists from state and federal agencies present. The presentation was provided to the LCWQPD district board members in Fall 2017.

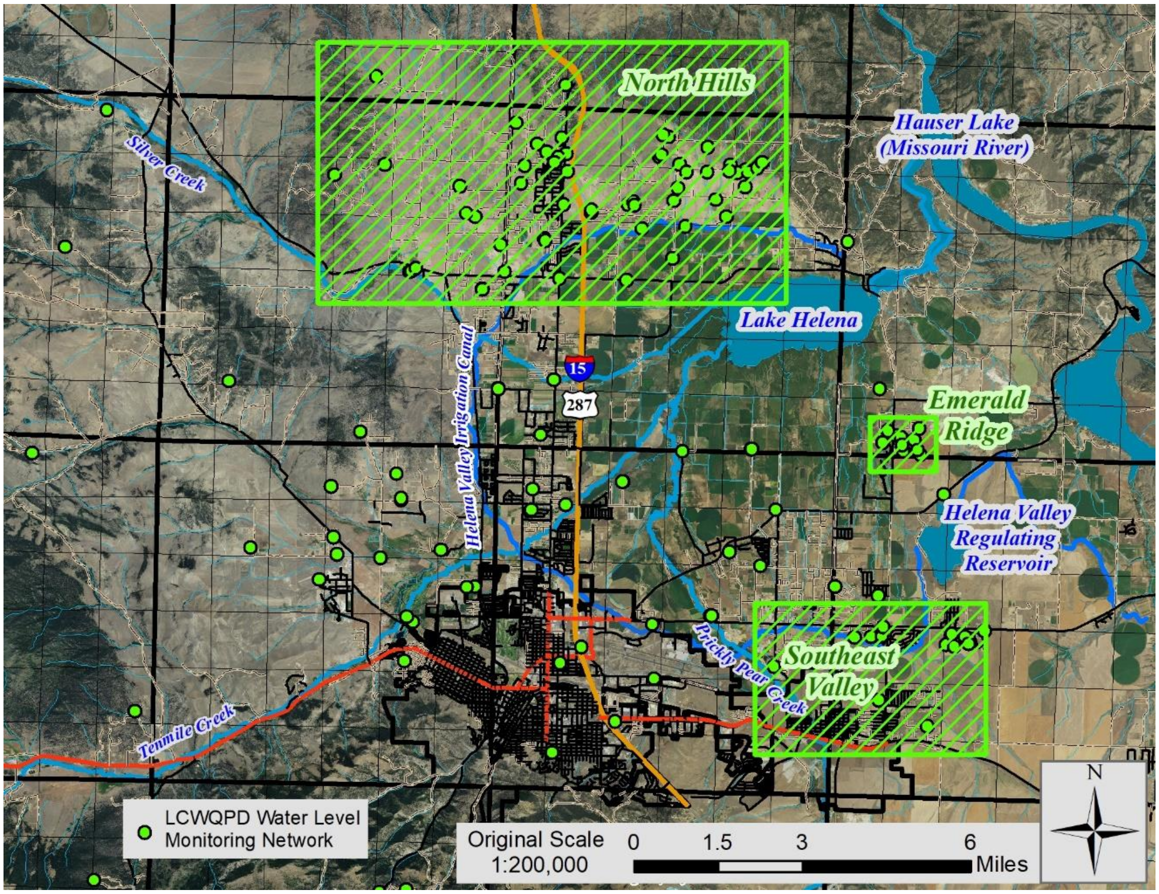


Figure 3 – LCWQPD Water Level Monitoring Network and Areas of Concern

Specific areas where groundwater impacts have occurred are identified

Emerald Ridge

The Emerald Ridge subdivision, located on the Spokane Bench adjacent to the northeast boundary of the Helena Valley, has experienced significant depletion since the initial development in 2004. The initial wells were installed to depths approximately 300 feet (plus/minus) below ground surface; however, deepening of wells and/or installation of replacement wells began several years after the initial development. LCWQPD staff began investigating the issue during Fall 2012, with implementation of a focused water level collection program. During this time, numerous replacement wells were present, and some homeowners had installed a third replacement well. The deeper wells are installed to depths often exceeding 700 feet below ground surface. The rate of depletion for this subdivision can be observed in a hydrograph presented in Figure 4, showing depletion of the water table surface approaching 200 feet for some wells. Recent mapping by MBMG staff have demonstrated that the local geology near the Emerald Ridge subdivision is the Tertiary Climbing Arrow Formation (Stickney & Vuke, 2017). This formation is characterized by thick (> 100 feet) sequences of clay-rich deposits with water occurring in small, discontinuous lenses of sand and silts, with some gravel. The conditions here demonstrate the sensitivity of development on this geologic unit, the Climbing Arrow Formation, to depletion, from pumping from exempt wells. The geology and magnitude of depletion are illustrated in a cross section in Figure 5.

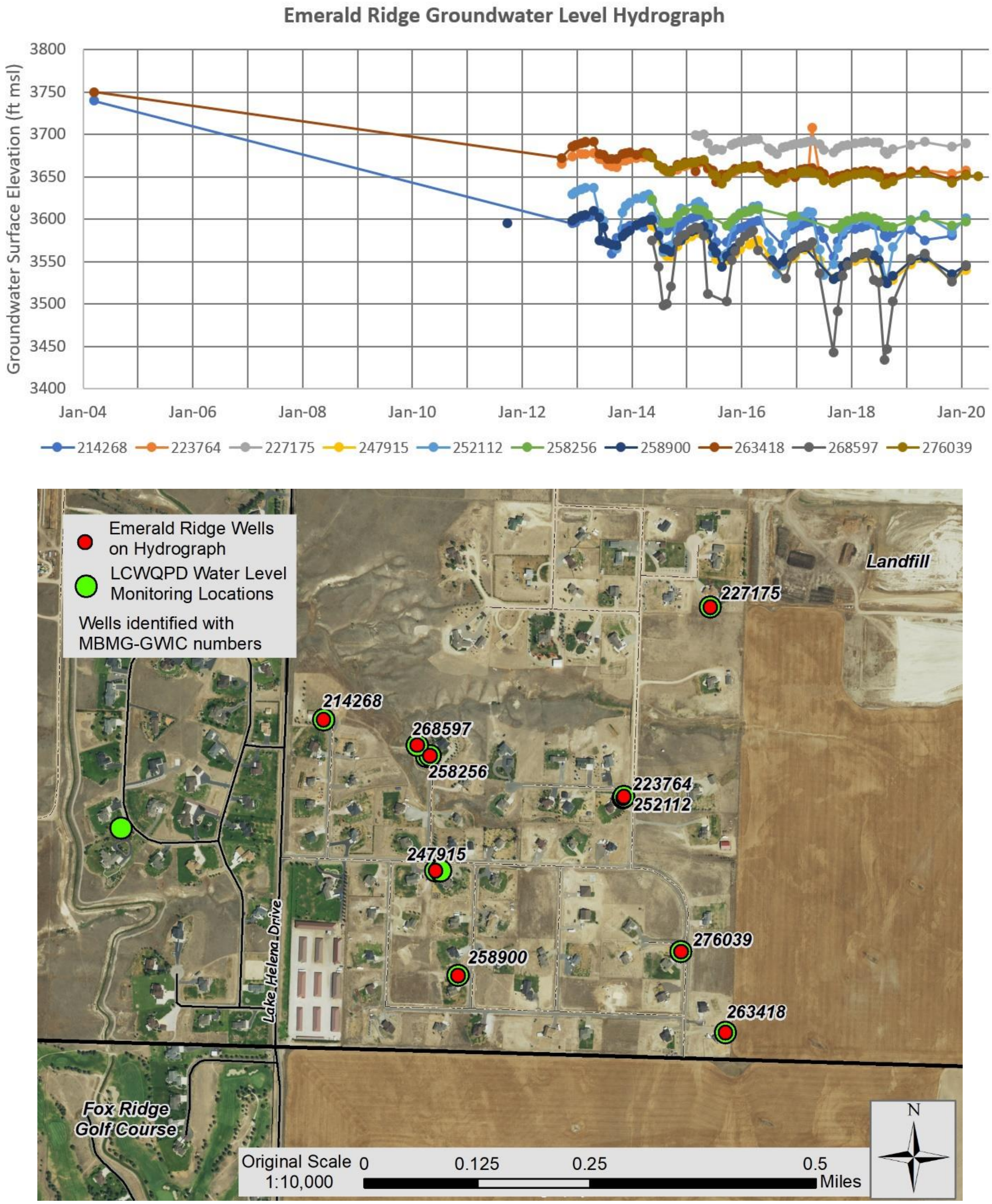


Figure 4 – Emerald Ridge Subdivision Hydrograph and Monitoring Locations
The location of wells on the hydrograph can be identified with MBMG-GWIC numbers on the map. The upper 4 wells, showing less depletion, are completed at shallower depths than the deeper wells; and the rate of depletion of the shallow aquifer slowed with more wells completed to greater depths. The different deeper and shallower aquifers are a single unit in the southern part of the subdivision.

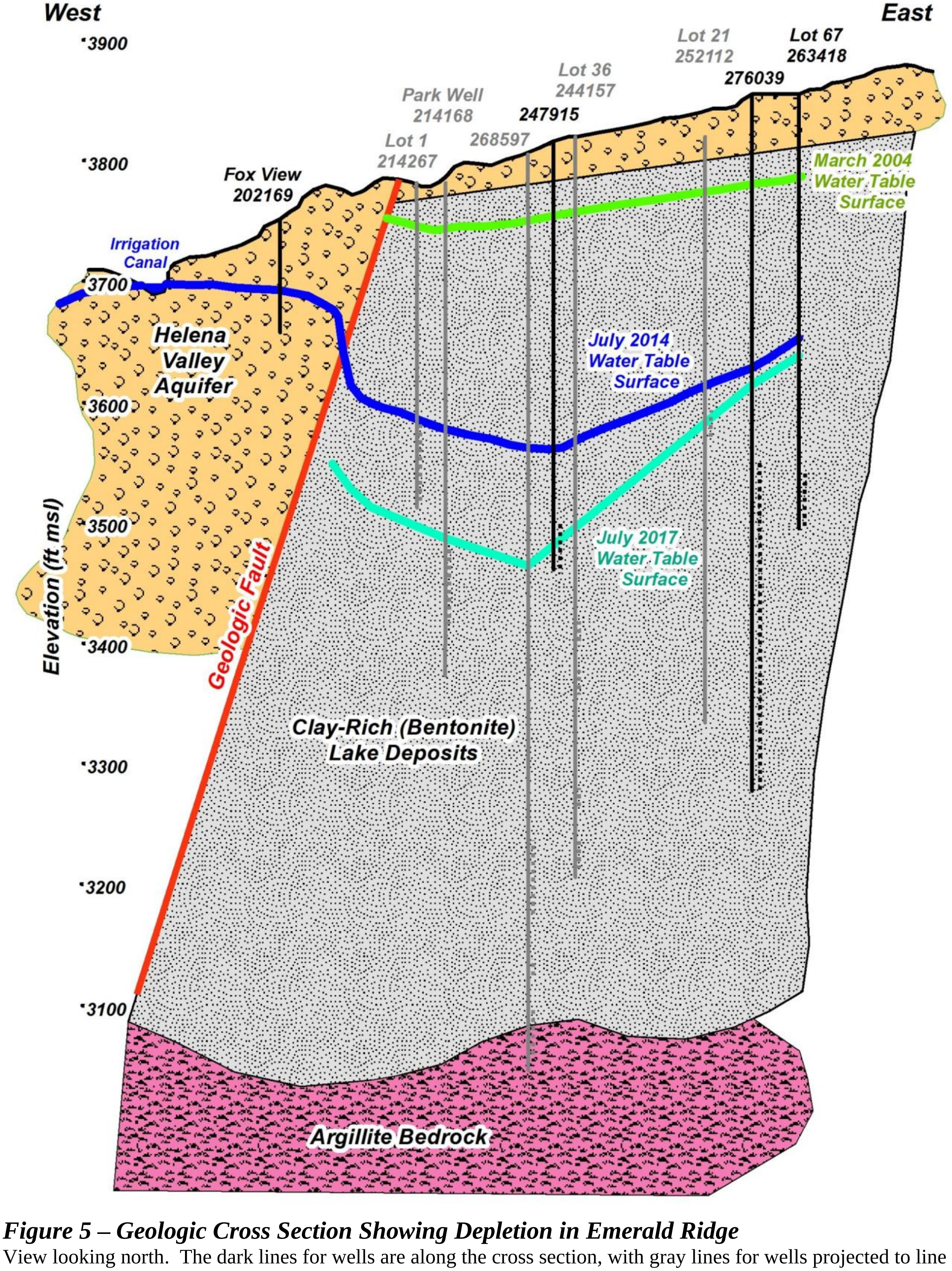


Figure 5 – Geologic Cross Section Showing Depletion in Emerald Ridge

View looking north. The dark lines for wells are along the cross section, with gray lines for wells projected to line of cross section. Wells are identified by MBMG-GWIC numbers. The decline in the top of the water table surface from 2004 to 2017 is shown

North Hills

There are multiple issues in the North Hills area, as evidenced by the two petitions for a Controlled Groundwater Area (CGWA) and subsequent MBMG studies to characterize conditions (Madison, 2006; Waren et al., 2012). These studies included water quality sampling, water level measurements, and developing a calibrated numerical groundwater flow model for the area. The model provides a tool to assess how increased pumping or changes in recharge can affect the local system (Waren et al., 2013). LCWQPD recently completed a focused investigation of conditions in the northern part of the East North Hills, with a report presenting the results currently in review at MBMG. The primary issue for the North Hills is depletion observed in Well 64755. The hydrograph in Figure 6 shows that water levels were stable during the MBMG study in 2010 – 2011 but have declined significantly since that time. Data for Well 207290, located east of this well, shows a similar trend. The suspected pumping source is PWS well for a subdivision, which was installed during early 2011. The hydrograph for that time period shows drawdown in the Well 64755 when they performed the pump test for the PWS well, demonstrating the connection between the two. Well 257065, located further east of Well 207290 shows a similar drawdown pattern (Figure 6). The high-volume pumping shows seasonal depletion to depth lower than 3600 feet, below the surface elevation of Lake Helena, which is the lowest level of the Helena Valley Aquifer where it discharges into the base of the lake (see Figure 2). The geometry of the cone of depression in this area is dictated by local geology, and has not been fully defined at this time; however, it is important to consider that the radius of influence from the pumping well extends to areas where private exempt wells are present, and will likely influence yields in those wells in the future. The hydrograph shows that the depletion rate was slower during 2019, suggesting that the large snowpack during Spring 2019 provided additional recharge to the local aquifer, helping to mitigate the effects of depletion during this time. The MBMG groundwater flow model presented two specific development scenarios, with the locations shown in Figure 6. The scenarios address well density and compare pumping from high yield wells versus numerous private wells. Graphics from the modeling report illustrating the different scenarios are presented in Appendix III. Note that one scenario, with 8 pumping wells, showed increased drawdown up to 120 feet or more with increased pumping rates. This modeled drawdown is similar to conditions observed near the location, with depletion noted for Well 64755.

Southeast Valley

East Helena and the Eastgate area have several developments with PWS wells, and other areas served by private residential wells. LCWQPD has only a limited amount of monitoring locations in this area. The location and a hydrograph from 2 wells in the area is shown in Figure 7. Drawdown observed in Well 153703 during summer months is attributed to pumping from a nearby set of PWS wells. The second well on the hydrograph, Well 238195, is located adjacent the Helena Valley Irrigation Canal north and downgradient from Well 153703. This hydrograph shows the increase in water levels during the summer from infiltration of irrigation waters, as water levels are seen rising all summer. During this same period, water levels are falling in Well 153703. This depletion is concerning since the low water levels for Well 153703 during late summer indicates an area of depletion, with a gradient forming such that water is flowing south from the canal area in the normally upgradient direction, during the summer months.

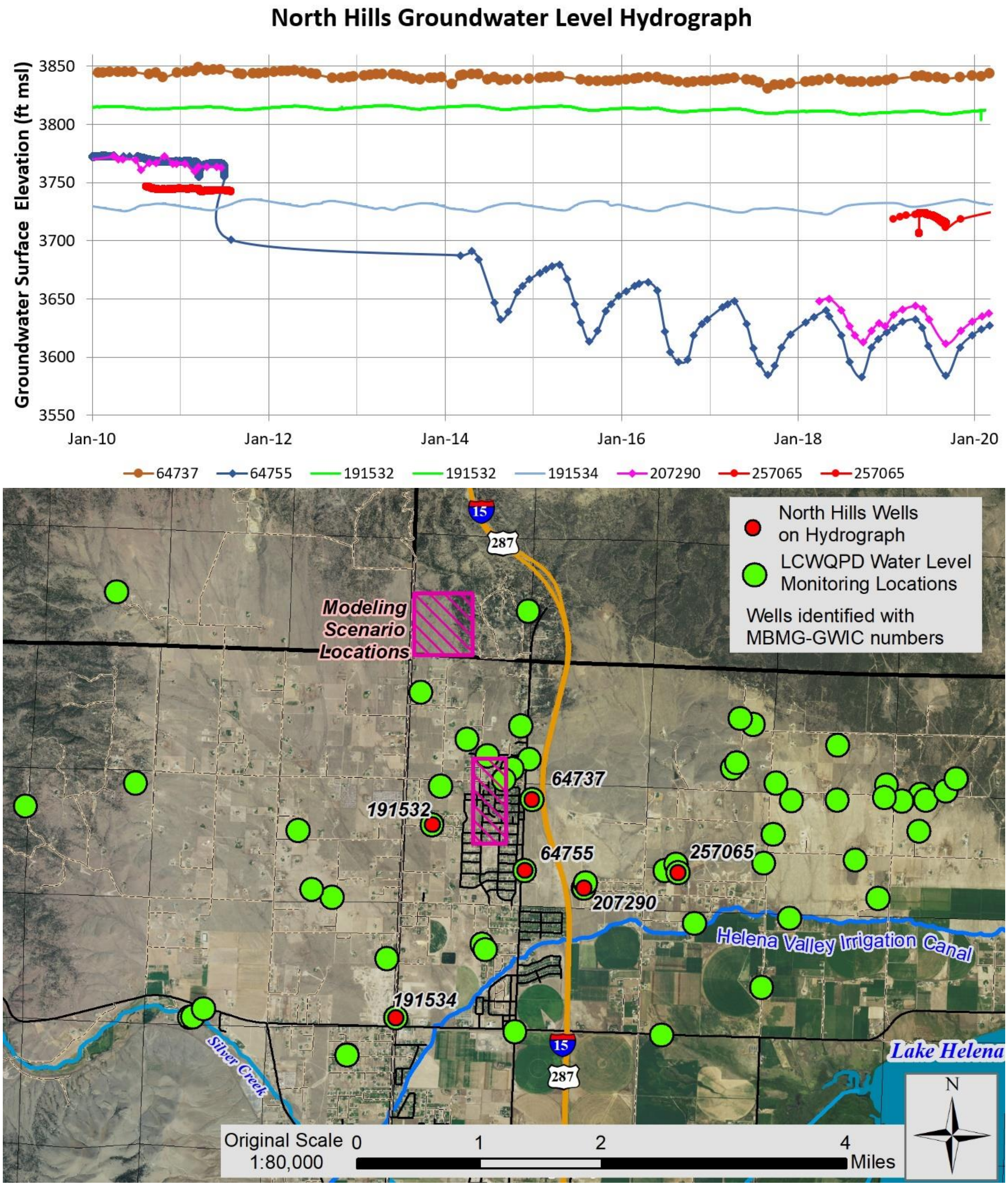


Figure 6 – North Hills Hydrograph and Monitoring Locations

The location of wells on the hydrograph can be identified with MBMG-GWIC numbers on the map. The central location of the pumping source near Well 64755 demonstrates the potential for impacts to nearby areas with private wells, as the radius of influence from the pumping source is at least a mile to the east. The hydrograph for well 191534 shows the general stability of water levels in the Helena Valley Aquifer. The area of the groundwater modeling scenarios presented from the MBMG North Hills Modeling Report (Waren et al., 2013) is shown, with more information in Appendix III.

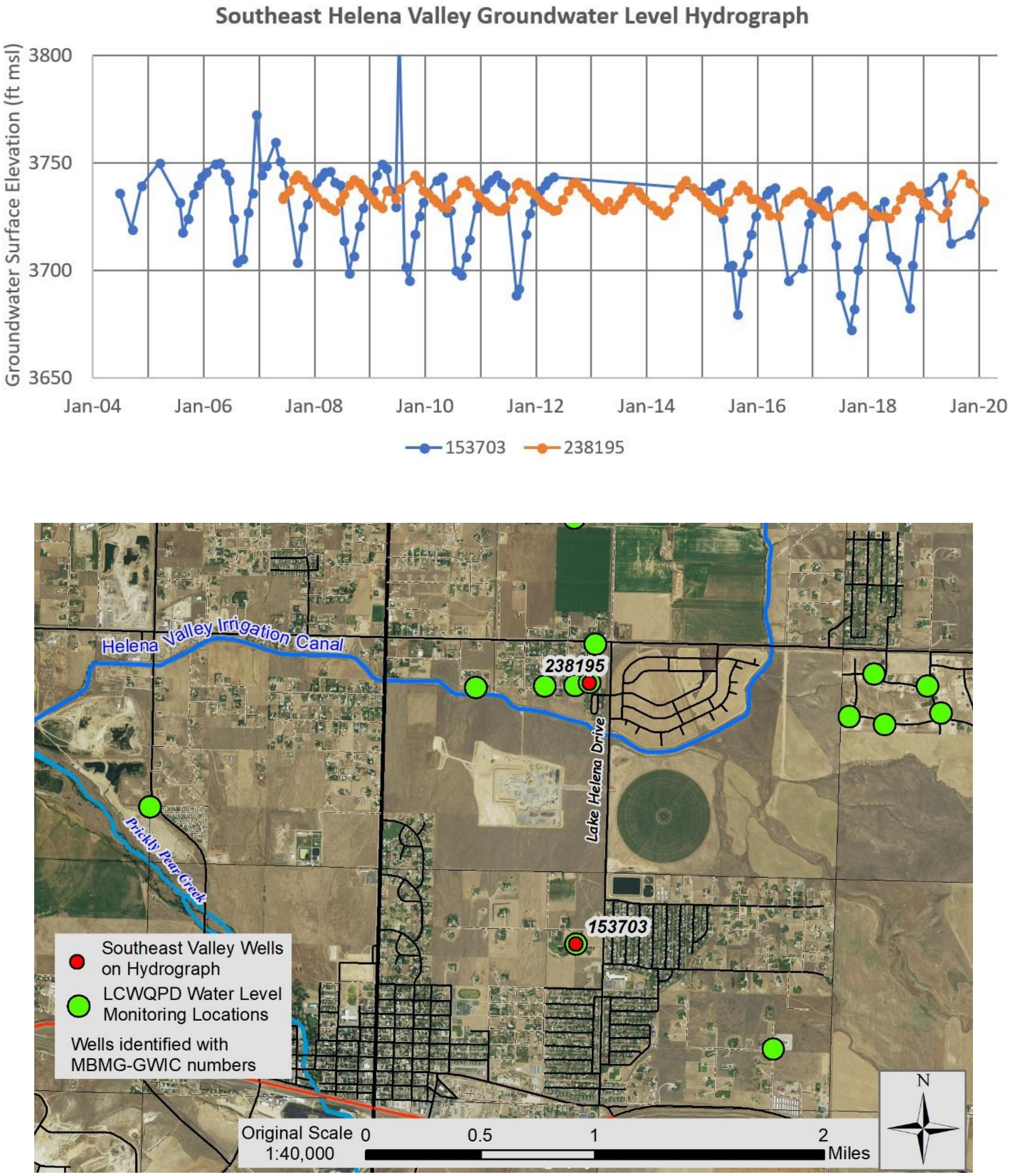


Figure 7 – Southeast Helena Valley Hydrograph and Monitoring Locations

The location of wells on the hydrograph can be identified with MBMG-GWIC numbers on the map. Pumping near Well 153703 during summer months creates a depletion area, where recharge from the Helena Valley Irrigation Canal to the south may occur as the drawdown changes the local gradient.

The Local Water Cycle and a Water Balance

The water cycle (a/k/a hydrologic cycle) reflects the different phases that water moves through, as it changes from different phases – evaporating into the atmosphere, condensing into clouds and moving in the atmosphere, precipitation to the surface, surface runoff, and infiltration and movement in the ground. From a local perspective, the precipitation into a watershed is generally the only source of water into the system, with discharge from the system as surface water runoff or groundwater baseflow. Surface runoff in the Lake Helena Watershed comprises the major streams and tributaries, including Prickly Pear Creek, Tenmile Creek and Silver Creek.

The Lake Helena Watershed defines the limits of the local hydrologic system, with the total amount of water present reflecting the total precipitation in the watershed. The Water Balance concept accounts for the movement of water through different phases into and out of the system, with the system defined as the Lake Helena Watershed boundaries. Since precipitation into the system is the primary source of new waters, this approach acknowledges that there is only a finite amount of water in the system added each year. The snowpack in the upland headwaters of the watershed provides recharge to stream flows during spring runoff, with a component infiltrating into the ground providing groundwater recharge. The groundwater in the upland areas flows back towards streams after the snowpack has melted, providing a source of water that maintains flows in streams during the summer and fall. As streams flow into the valley, they typically lose flow from the base as groundwater recharge to the Helena Valley Aquifer.

Infiltration of precipitation across the watershed provides for recharge of groundwater in many cases, representing the primary recharge mechanism for bedrock aquifers away from streams, and upland areas where the Tertiary aquifers are present. Estimates of annual precipitation for the North Hills and Scratchgravel Hills from the MBMG studies are presented in Appendix I. During the Fall and Winter months groundwater recharge from surficial sources to the Helena Valley Aquifer is limited, as streamflow and infiltration of precipitation are generally held as ice. During this period, recharge to the Helena Valley Aquifer occurs primarily from groundwater flow from the bedrock aquifers directly into the valley alluvium in the subsurface (Briar & Madison, 1992; see Appendix III).

Much of the area around the Helena Valley, where the bedrock and Tertiary aquifers are present, does not have any connection to surface water recharge sources except infiltration of precipitation. After a precipitation event, a portion evaporates back to the surface, with the rate of infiltration controlling whether there is surface runoff. Water will also evaporate from near-surface soils. Infiltration rates are generally slow in surficial soils, where soil water is available for plant growth. The use of water by plants, where root systems draw in water, which is then evaporated from leaves, is referred to as *transpiration*. Since both move water from the soils into the atmosphere, the combined processes are referred to as *evapotranspiration*. For the Helena area, the transpiration rates for the North Hills and Scratchgravel Hills from MBMG studies are presented in Appendix I.

The difference between precipitation and evapotranspiration for an area represents the amount of water that infiltrates as groundwater recharge. When the evapotranspiration rate exceeds the amount of precipitation, there is no recharge for the aquifer at that location. The MBMG study of the North Hills presents a map showing annual infiltration as groundwater recharge across their study area (Appendix I). This map shows recharge from irrigation waters, but immediately upgradient, in the Pediment area of the North Hills, there evapotranspiration rates exceed rainfall, so there is no recharge in this area. The northern part of the area, with more precipitation at higher elevations, provides the recharge to this system. This relationship demonstrates the limited amount of recharge that occurs from precipitation in other upland areas away from streams in the Helena area.

The Helena Valley receives additional water from outside of the watershed as the Helena Valley Irrigation system, with water obtained from the Missouri River and Canyon Ferry Dam. The main Helena Valley Irrigation Canal flows around the valley discharging into Lake Helena, adding water to Helena Valley Aquifer system. These irrigation waters generally do not provide recharge to upgradient areas directly, but the addition of water as stream loss from the base of the main canal raises the water table at these locations and helps maintain higher water levels upgradient from the canal. A simulation completed with the North Hills study groundwater model predicted a lowering of the water table up to 35 feet in the study area if the canal was removed from the system (see Appendix III). Smaller irrigation systems upgradient from the Helena Valley, such as the Sunny Vista Canal with water from Sevenmile Creek in the Scratchgravel Hills, provides additional recharge to the area near the specific canals.

Groundwater Flow Rates and Yields

Groundwater flow rates are determined by *Darcy's Law*, where the rate of groundwater flow is directly proportional to the gradient, or slope of the water table surface and the permeability or *Hydraulic Conductivity* (K) of an aquifer. Under normal conditions, groundwater flow generally follows topography, and a groundwater surface map depicts the configuration of the water table surface with contours similar to the elevation contours on a topographic map. The slope of the water table can be determined from the map as the change in water surface elevation over a distance. This is measured along the flow direction of the groundwater, which is perpendicular to the contours. A groundwater surface map of the Helena Valley and surrounding area, obtained from the MBMG GWIP study of the Scratchgravel Hills, is shown below in Figure 8. The map shows water flow directions towards the Helena Valley in bedrock areas outside of the valley, with a much shallower gradient within the valley where the Helena Valley Aquifer is present. This map does not extend onto the Spokane Bench area, and the southern part of the Helena Valley, reflecting the limited amount of data for these areas.

The occurrence of groundwater in aquifers requires constant replenishment, or recharge, in upgradient areas to replace water removed in downgradient areas. Direct infiltration of precipitation represents a primary recharge method across the area, noting that precipitation and snowpack is greater at higher elevations surrounding the Lake Helena Watershed and Helena Valley. Percolation of snowmelt from the mountain snowpack into the ground provides recharge to both the groundwater system, with surface runoff leaving as streamflow. As streams flow towards lower elevations, flows increase by groundwater flowing towards and discharging into the base of streams. When streams enter the valley, where the land surface flattens and the alluvial aquifer is present, streamflow decreases from percolation of stream water downward to

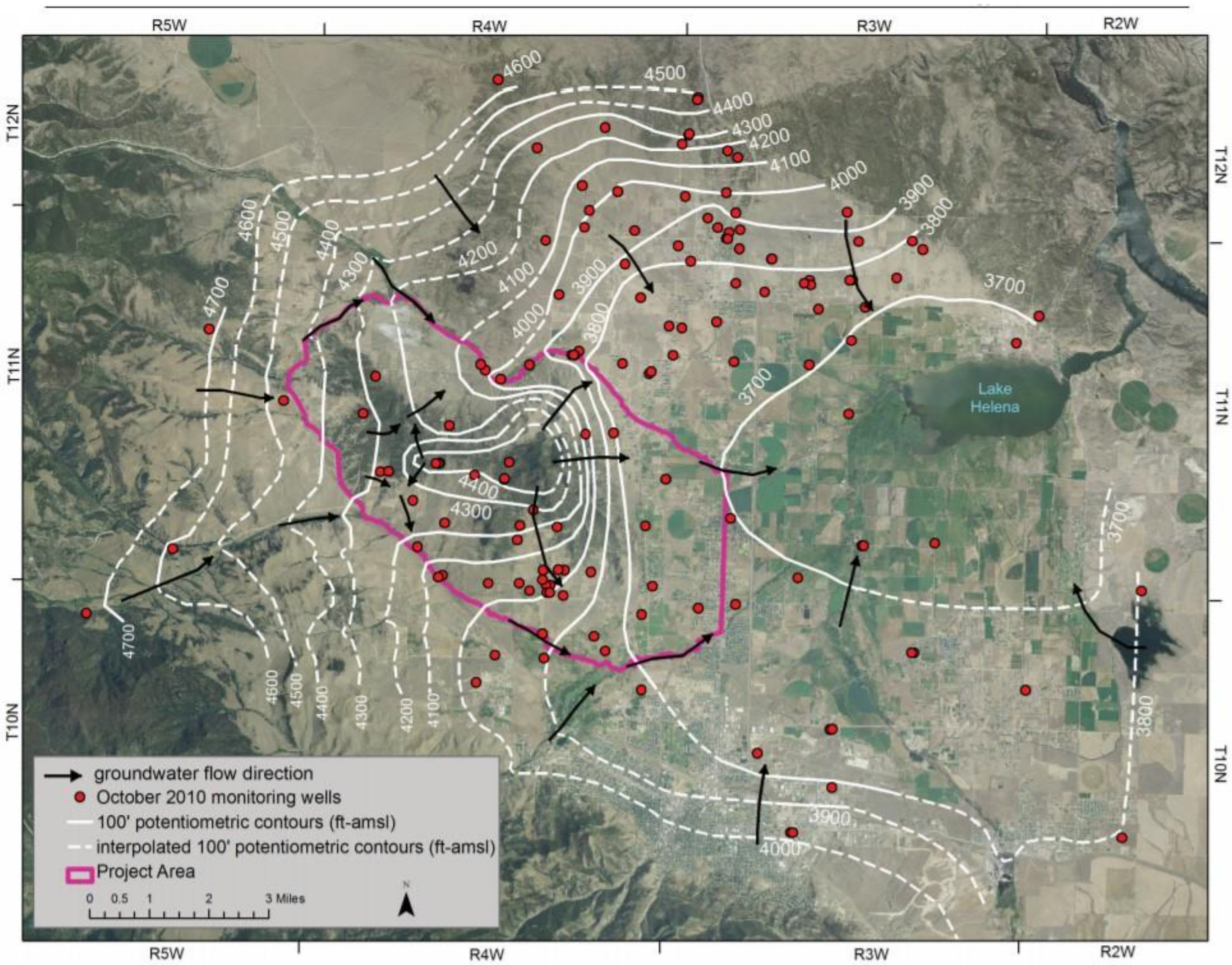


Figure 14. This potentiometric surface map of the area surrounding the Helena Valley is from October 2010 (based on water levels from the MBMG's North Hills study (Waren and others, 2012), Lewis and Clark County's monitoring, and this study). This map shows that groundwater flow is generally from the basin margins towards Lake Helena. The alluvial sediments along stream valleys act as drains for the less permeable bedrock. Local recharge and low-permeability bedrock within the Scratchgravel Hills study area uplands causes a 400 ft 'high' in the potentiometric surface.

Figure 8 – Groundwater Surface and Flow Map for Helena Area, from Bobst et al., 2013.

recharge the water table. In the Helena Valley, the discharge point for groundwater is into Lake Helena as pumping from wells removing water from the system.

The *Hydraulic Conductivity* (K) of different aquifer types reflects the size and amount of pore space in an aquifer, and controls how fast water can move through the geologic unit. The flow parameter generally reflects pore spaces within unconsolidated aquifers and some consolidated bedrock units. For granite and other bedrock with little porosity, flow generally occurs within fracture patterns as a substitute for grain porosity. In these cases, the reported K value reflects an average groundwater flow parameter for the generally impermeable unit over a larger area. Bedrock units, such as sandstones, with primary porosity typically also have fracture patterns which result in a higher overall permeability for the unit. The Helena area has numerous bedrock aquifers present in the different geologic units surrounding the Helena Valley.

Since the Hydraulic Conductivity (K) reflects the ability of an aquifer to transmit water, it can be used as a measure of the ability of an aquifer to provide sufficient yields for potable water use.

The K value for an aquifer is generally determined by an aquifer test, where the pumping rate is measured with respect to the rate of changes in the water level in the pumping well and nearby wells. When wells pump from an aquifer, the water level during pumping falls, referred to as *drawdown*, from the static water level downwards towards the pump. During pumping, well yields are sustained by groundwater flow within the aquifer towards the well. The *radius of influence* is the area near the well where water flows towards the well. The full area drawn down by the well can be considered an inverted cone around the top of the wellhead, with the radius of influence the distance to the location where no drawdown occurs. These concepts are illustrated in Figure 9. When pumping, the shape of the cone of depression reflects the aquifer K values. Pumping in an aquifer with a high K value has a smaller amount of drawdown, with a wider radius of influence; whereas in an aquifer with a lower K value, the drawdown is greater with a smaller radius of influence. During pumping, drawdown continues until the recharge rate to the aquifer equals the discharge rate and equilibrium is obtained. The higher the pumping rate, the longer it takes for equilibrium to occur. Another important consideration is that the drawdown from multiple pumping wells at a single location can be added together, increasing the total drawdown in an area

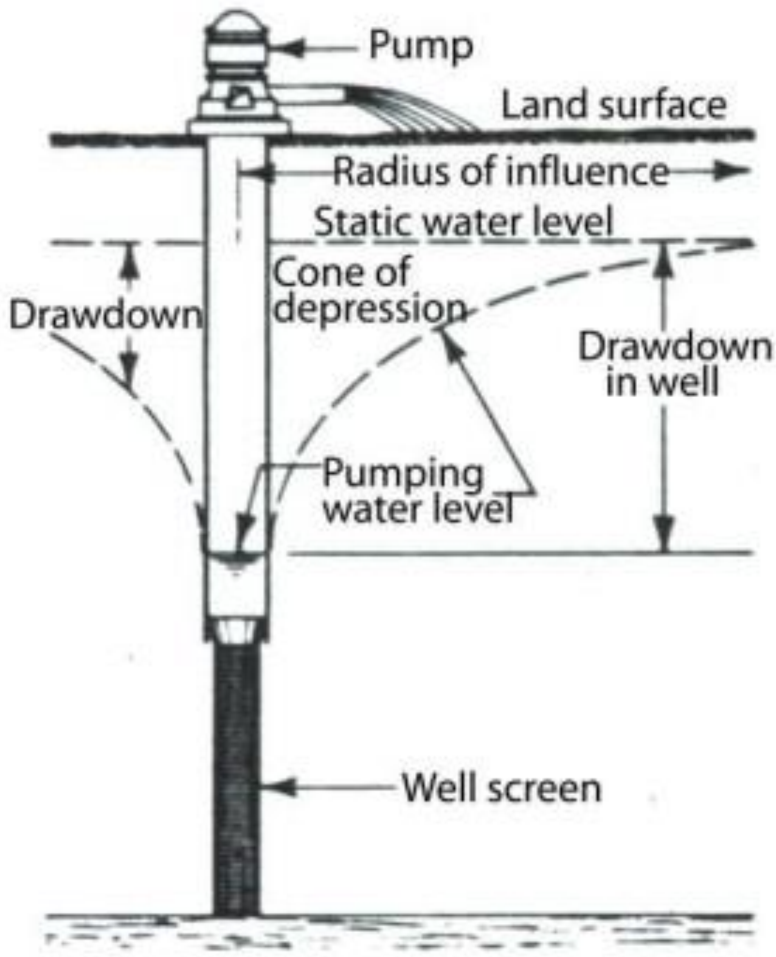


Figure 9 – Cross Section of Subsurface During Well Pumping

Hydrologic parameters for aquifers are generally determined and estimate using pump tests. Estimates of the K values for local aquifers from pump tests in the area were compiled by MBMG staff during completion of the North Hills and Scratchgravel Hills GWIP projects. A summary of the statistics of the K values for different geologic units is listed below in Table AQ2 from Waren et al., 2014. The MBMG studies used the geometric mean as more representative of averaged values of the K values, since it is derived from the three-dimensional physical properties of geologic aquifer materials. While the variability within different aquifers is noted, the order of magnitude difference between the K value for the Helena Valley Aquifer and the Tertiary Aquifers, and the bedrock aquifers is notable. The Argillite, Gabbro and Helena Formation bedrock aquifers have relatively low K values, reflecting the limited yield from these aquifers. These depletion observed in the North Hills occurs from these bedrock aquifers.

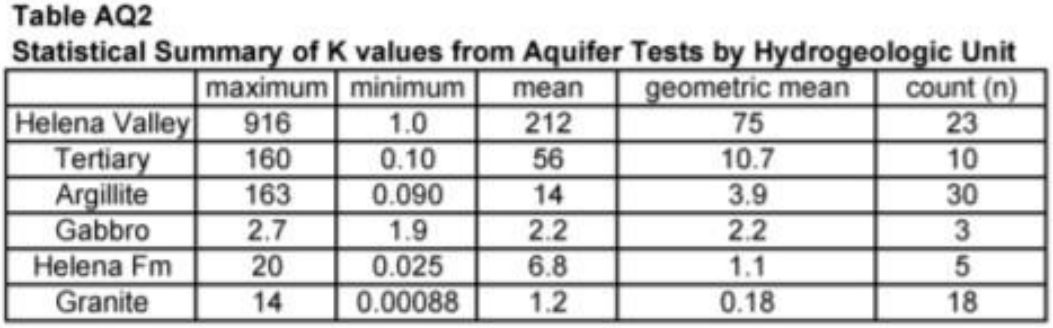


Table AQ2
Statistical Summary of K values from Aquifer Tests by Hydrogeologic Unit

	maximum	minimum	mean	geometric mean	count (n)
Helena Valley	916	1.0	212	75	23
Tertiary	160	0.10	56	10.7	10
Argillite	163	0.090	14	3.9	30
Gabbro	2.7	1.9	2.2	2.2	3
Helena Fm	20	0.025	6.8	1.1	5
Granite	14	0.00088	1.2	0.18	18

Table directly from MBMG studies (Waren et al., 2013; Butler et al., 2013)
Units in ft/day

The relative hydraulic conductivities determined for the groundwater modeling efforts for the North Hills and Scratchgravel Hills are presented in Figure 10 and Figure 11, respectively. These figures show the higher permeability in the lower elevations of the Helena Valley, where the Helena Valley Aquifer is present, and lower permeabilities for the bedrock and Tertiary aquifer areas outside of the valley. Bedrock areas outside across the Helena area are expected to have similar values for Hydraulic Conductivity in general. It is important to note that bedrock aquifers are dominated by fracture flow systems, and not porous media, and there is always the potential of finding wells with higher yields when drilling intersects larger fracture systems. Conversely, there is also the risk of drilling relatively deep wells without obtaining sufficient yields for potable use, resulting in “dry” wells.

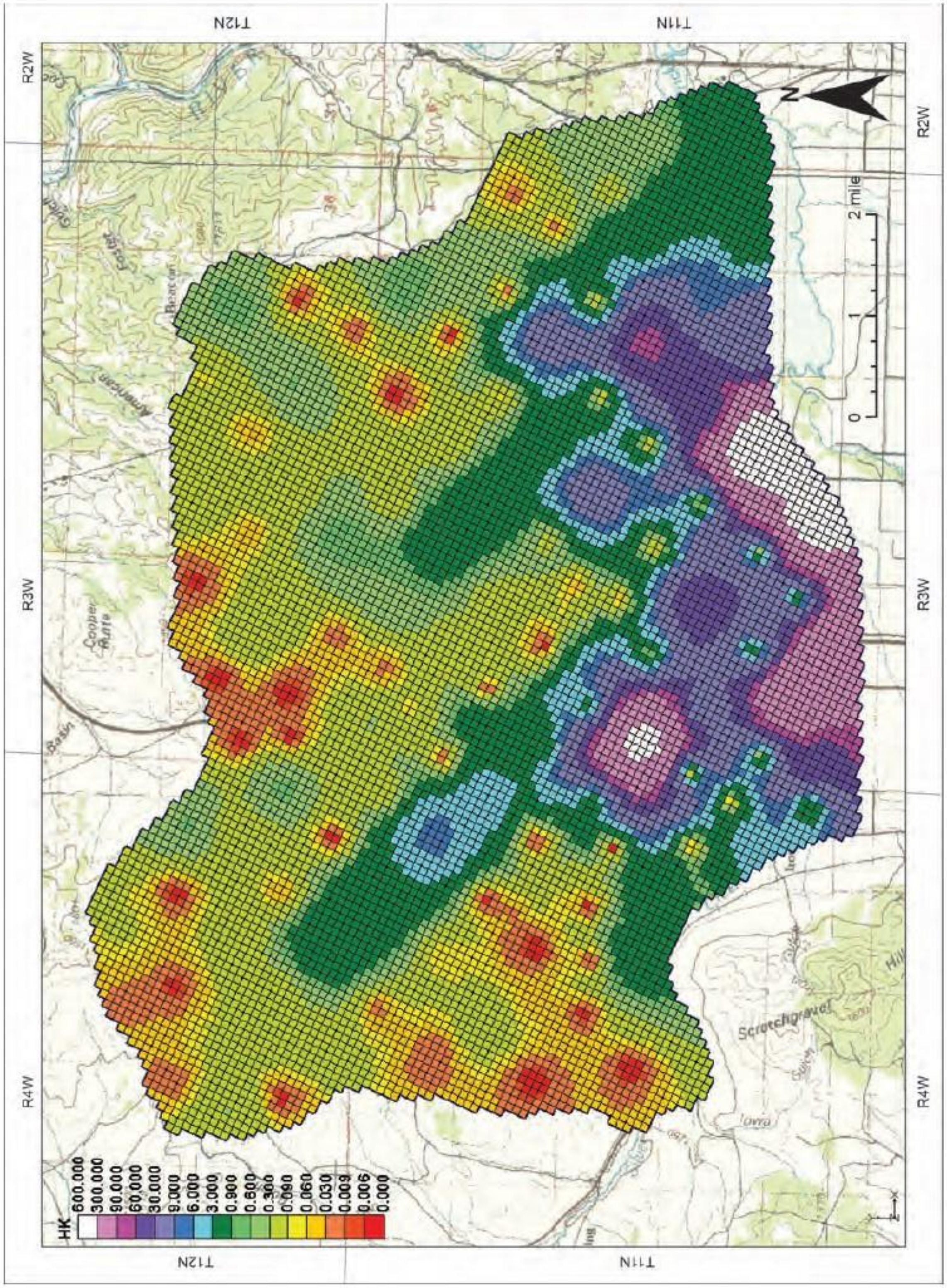


Figure 37. Hydraulic conductivity ranges for the North Hills Area model shown by colored zones labeled HK in the legend. Individual cells have independent values within the specified range. Values are in ft/day.

Figure 10 – Hydraulic Conductivity Values for North Hills Groundwater Model (from Waren et al., 2013). Units in ft/day

The hydraulic conductivity values show that the majority of the North Hills area has relatively low permeability reflecting bedrock aquifers. The higher values show the location of the Helena Valley Aquifer.

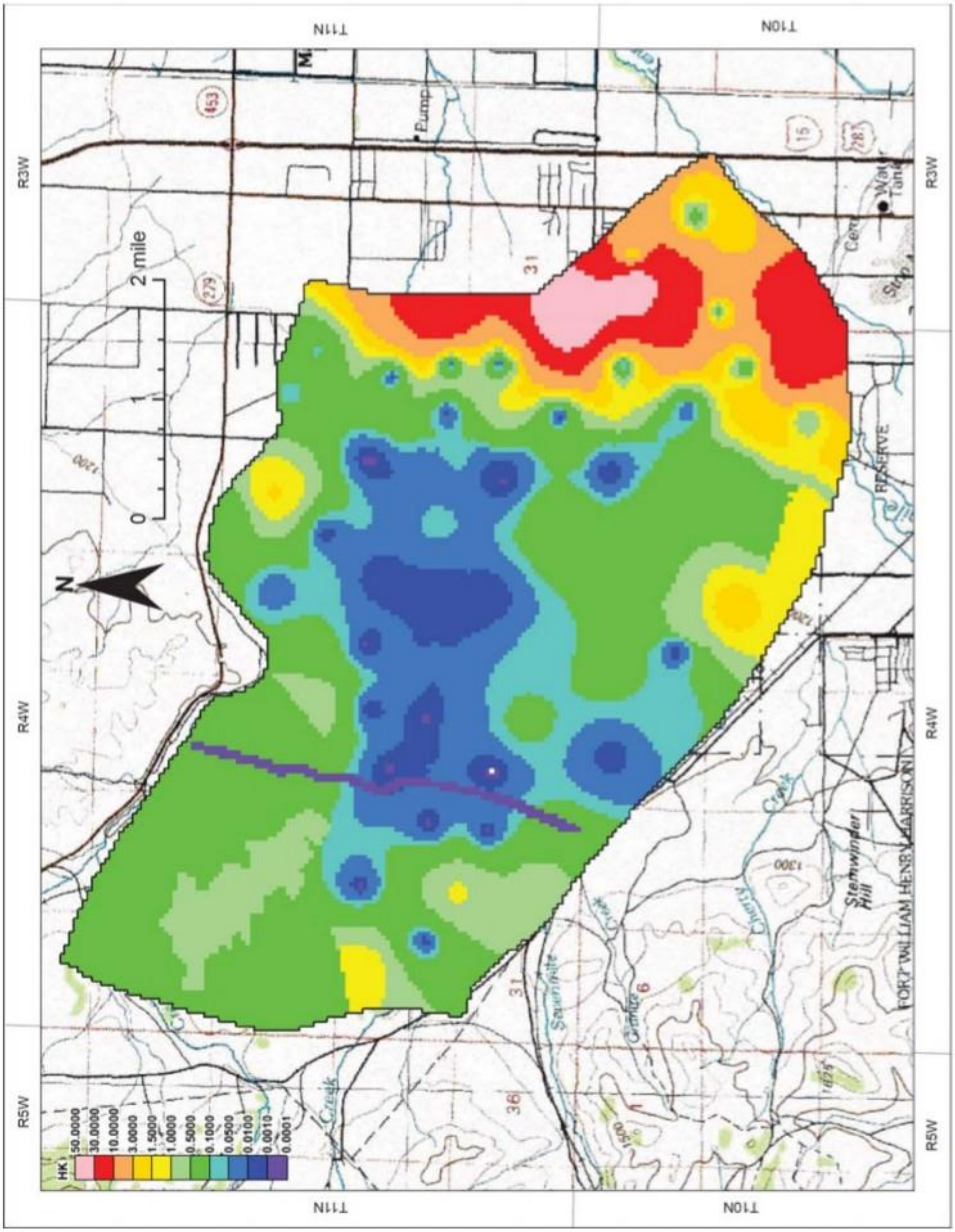


Figure 18. The modeled distribution of hydraulic conductivity is consistent with the conceptual model of the area. The bedrock in the core of the Scratchgravel Hills has the lowest permeability, with slightly higher values for bedrock near the edges of the study area. The Quaternary alluvium is the most permeable. Hydraulic conductivity is labeled as HK in the legend, and values are in ft/day. Individual cells have independent values within the specified range.

Figure 11 – Hydraulic Conductivity Values for Scratchgravel Hills Groundwater Model (from Butler et al., 2013). Units in ft/day

The hydraulic conductivity values show that the majority of the Scratchgravel Hills area has relatively low permeability reflecting bedrock aquifers. The higher values show the location of the Helena Valley Aquifer.

Discussion

Groundwater development in the Helena Area has generally occurred with limited problems; however, as the population increases, the need for additional sources of potable water increases. The Lake Helena Watershed is located in the Upper Missouri River Basin, which was closed to new water appropriations by the Montana legislature in 1993, with some exceptions. As a result, obtaining water right to construct a new PWS for development is difficult. Since this time, development within the area frequently utilize “exempt” wells for potable water sources. The concept of “exempt” wells assumes that single wells will have little or no impacts to yields from the aquifer, without considering the specific local hydrogeologic characteristics. While some developments have not seen impacts, others, such as the Emerald Ridge subdivision, resulted in depletion of sufficient magnitude to force homeowners to obtain water from greater depths.

The occurrence of depletion and installing a replacement well demonstrates the risk for installing a new well. The risk of depletion can be related to numerous factors, including factors related to both natural conditions, and well use, construction and use. Some of these that are relevant to Helena area wells can be summarized as follows:

Factors related to natural conditions

1. Risk ***increases*** with decreasing hydraulic conductivity
Since the hydraulic conductivity reflects groundwater flow and ultimately yield rates, a correlation may be made such that, in general terms, the risk of groundwater depletion for a well increases with decreasing groundwater flow rates within an aquifer. The lower flow rates reduce the rate at which recharge waters can flow to the wellbore. The hydraulic conductivity of different geologic formations varies, so that general correlations can be made. A general assessment of the geology of different aquifers in the Helena area with respect to hydraulic conductivity is presented in Table 1.

Table 1 – Comparison of Different Aquifers Reflecting Lithology and Permeability
Helena Area Aquifers Correlate to Chart by Hydraulic Conductivity Values

<table>
<tr><th rowspan="2">K (ft/day)</th><td>100,000</td><td>10,000</td><td>1,000</td><td>100</td><td>10</td><td>1</td><td>0.1</td><td>0.01</td><td>0.001</td><td>0.0001</td><td>0.00001</td><td>0.000001</td><td>0.0000001</td></tr>
<tr><td>10^5</td><td>10^4</td><td>10^3</td><td>10^2</td><td>10^1</td><td>10^0</td><td>10^{-1}</td><td>10^{-2}</td><td>10^{-3}</td><td>10^{-4}</td><td>10^{-5}</td><td>10^{-6}</td><td>10^{-7}</td></tr>
<tr><th>Relative Permeability</th><td colspan="4">Pervious</td><td colspan="4">Semi-Pervious</td><td colspan="5">Impervious</td></tr>
<tr><th>Aquifer Productivity</th><td colspan="5"><i>Good</i></td><td colspan="4"><i>Poor</i></td><td colspan="4"><i>None</i></td></tr>
<tr><th>Unconsolidated Deposits</th><td colspan="2">Well Sorted Gravel</td><td colspan="3">Well Sorted Sand or Sand & Gravel</td><td colspan="4">Very Fine Sand, Silt, Loess, Loam, Layered Silt/Clays</td><td colspan="4">Unweathered Clay</td></tr>
<tr><th>Consolidated Rocks</th><td colspan="4">Highly Fractured Rocks, Karstic Limestone</td><td colspan="3">Moderately Fractured Rocks</td><td colspan="2">Fresh Sandstone</td><td colspan="2">Fresh Limestone, Dolomite</td><td colspan="2">Fresh Granite</td></tr>
<tr><th><i>Helena Area Aquifers</i></th><td colspan="4"><i>Helena Valley Aquifer; Upper Part of Tertiary Aquifer</i></td><td colspan="3"><i>Bedrock Aquifers</i></td><td colspan="2"><i>Tertiary Climbing Arrow Aquifer</i></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

⇨ **Increasing risk of depletion**

Adapted and Modified from Bear (1972) for Helena Area Aquifers
Bear, J. (1972). *Dynamics of Fluids in Porous Media*. Dover Publications. ISBN 0-486-65675-6.

2. Risk ***increases*** during drought periods when recharge declines
The MBMG studies of the North Hills (Madison, 2006; Waren et al., 2012) demonstrate the susceptibility of groundwater availability in the northwest part of the Helena Valley to impacts from drought. Specifically, the falling water levels during the drought of 2000 – 2002 in the area where Silver Creek enters the valley were initially attributed to depletion from pumping. During this time, there were only minimal flows in Silver Creek, with all flow infiltrating into the valley alluvium near the point where it enters the Helena Valley. However, when flows in Silver Creek increased during wetter years after the drought, the water levels came back up to previous levels.

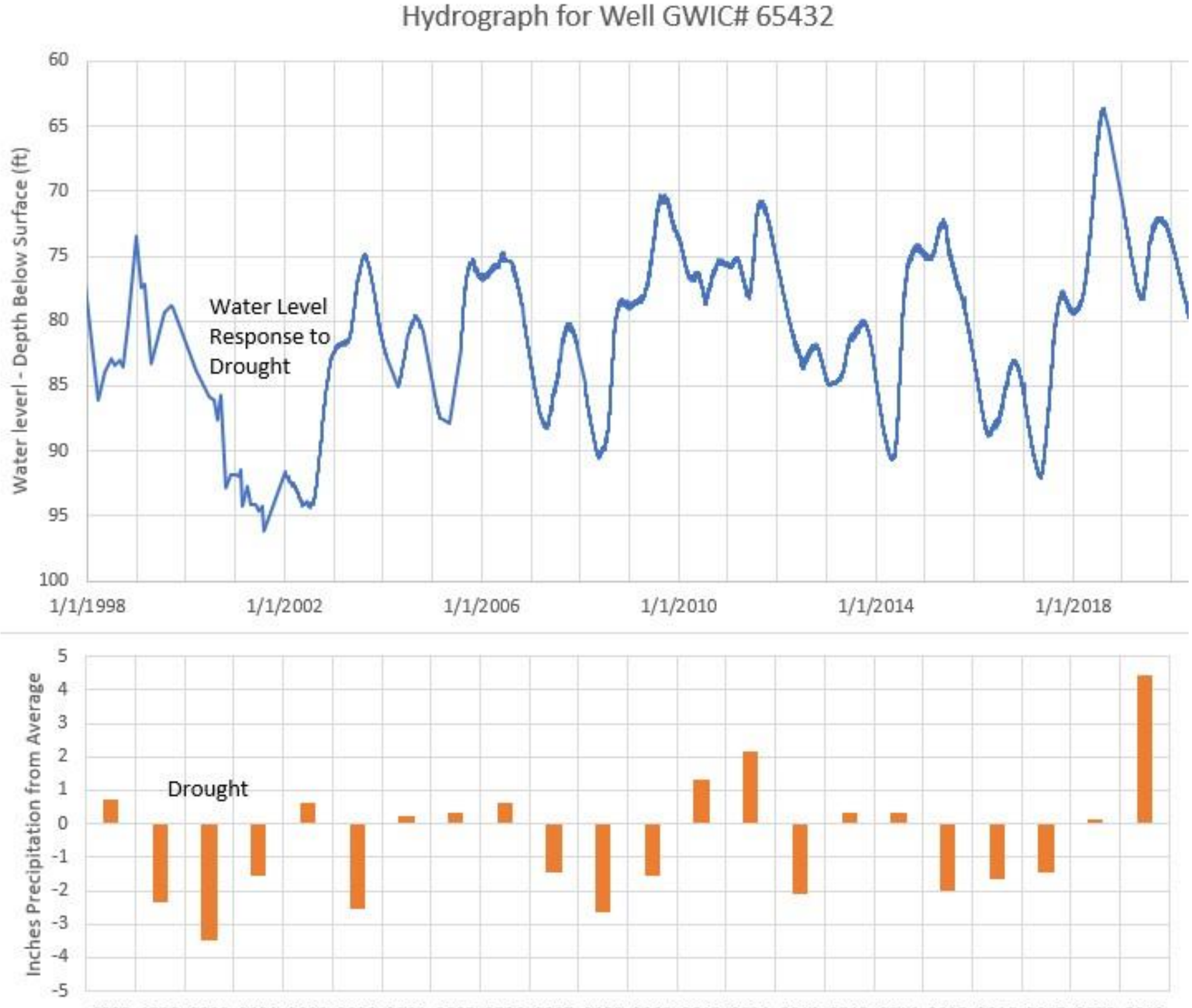


Figure 12 – Comparison of Annual Precipitation with Hydrograph for Well 65432
Hydrograph shows response of well to drought, with lowering of water table. Note annual precipitation doesn't differentiate between seasonal variations, so correlation is not always complete at snowpack drive spring runoff and flows in Silver Creek, which correlate to groundwater recharge.

3. Risk ***decreases*** with proximity to surface water recharge sources

For wells installed into alluvium in the Helena Valley, and in other drainages with perennial flows (flows that are present year-round), stream loss as recharge to the aquifer reduces the risk of declining groundwater levels. The stream recharge also reflects streamflow rates, with drought potentially impacting yields.

Stream loss from the base of irrigation canals provides the same effect; however, in areas where canals are present without alluvium, the stream loss may be reduced. The Helena Valley Irrigation system provides significant groundwater water recharge to the Helena Valley Aquifer. The modeling simulation for the North Hills area showed that ambient water levels would decline up to 35 feet should recharge from irrigation be removed, demonstrating the importance of the connection of irrigation system waters as recharge to location groundwater (Appendix III). This connection applies to many parts of the Helena Valley, including the Southeast Helena Valley where recharge from the main Helena Valley Irrigation Canal appears to be a component to maintain groundwater supplies for the area.

Factors related to well use, well construction and water usage

1. Risk ***increases*** with pumping/extraction rates and volumes

The greater the pumping rate from a well, the greater the radius of influence to local hydrologic system. High volume pumping from PWS wells appear to account for depletion in the North Hills and Southeast Helena Valley as presented in this report. Pumping at lower rates to achieve desired volumes will ultimately result in similar impacts to the area. These effects are additive with multiple wells, as the drawdown from pumping at two or more wells at a specific location reflect the combined drawdown from all of the pumping sources. The recent MBMG studies present groundwater model result simulations demonstrating the impact of high yield pumping to the local groundwater system (Appendix III). The results of these simulations show similar drawdown to that observed as occurring in the North Hills, as presented with this report.

2. Risk ***increases*** with consumptive use

While related to pumping rates and yields as described above, consumptive use is the amount of water pumped from a well that is removed from the local aquifer, without any recharge. Consumptive use increases dramatically during the summer months when household irrigation for lawns and gardens increases. Non-consumptive use would reflect water pumped from the aquifer, but then released back after household use. For example, the discharge from septic system drainfields is considered non-consumptive use, as it is released such that it can percolate back to the aquifer system. For confined aquifers, or areas with clay-rich deposits limiting percolation rates, the drainfield waters do not provide recharge to the deeper aquifer. An example of the estimated consumptive use for North Hills residents from the recent MBMG studies is presented in Appendix II (Waren et al., 2012; Bobst et al., 2013).

3. Risk ***decreases*** with increasing depth of well below water table surface
Wells that are installed deeper into an aquifer will provide more storage in the borehole for water yields from pumping. The lower the yield in the well, the greater the importance of borehole storage for maintaining pumping rates. The deeper wells also provide a buffer to the impacts of depletion or lowering water levels related to drought or changing precipitation patterns from climate change.

4. Risk ***increases*** with well density in an area or subdivision
As the number of wells in an area increases, the greater the stress on the aquifer with more withdrawals. The depletion at the Emerald Ridge subdivision from private potable wells provides an excellent example of the impacts of wells at a greater density than the local aquifer can support. This applies to developing subdivisions using "exempt" wells, especially in the bedrock aquifer areas outside the Helena Valley (see Figure 1), and in the Tertiary Climbing Arrow Formation areas on the Spokane Bench and other areas around Helena. The MBMG studies of the North Hills and Scratchgravel Hills provide several simulations demonstrating the impact of multiple wells at different densities. Information from the modeling studies with maps from groundwater simulations showing the effects of different well densities are presented in Appendix III. The modeling studies concluded that developing water from bedrock aquifers for high density subdivisions would likely result in noticeable declines in the groundwater surface elevation.

For existing homeowners, the loss of yields from private house wells represents a significant financial hardship, typically requiring replacement or deepening of a current well. As the population in the area increases, the demand between water sources for high yield PWS wells will compete with the demand for development with individual wells. For private landowners, the relevant issue is the risk that well yields from private potable wells will not be sustainable.

Drawdown from high yield PWS wells in the Southeast Helena Valley show that an area of depletion occurs during summer months, with a potential change in flow direction. The size and geometry of the depletion area is limited due to lack of water level monitoring locations. The area near the well where depletion is observed has multiple PWS systems and source wells. Currently, several PWS with available water rights are working to install additional PWS source wells in the Southeast Helena Valley area. Installation of these wells will further stress the local groundwater system in this area.

With changes in climate, and expanding service areas, PWS within the noted drawdown areas have instituted watering restrictions due to limited well yields during summer months. Proposals for deepening of current wells, or installation of new wells to greater depths to obtain additional yields, will likely create expanded cones of depression with a larger radius of influence in the areas – increasing the risk to nearby properties using private wells for potable water. In some cases, it is likely that existing depletion conditions have already impacted existing wells resulting in installation of replacement wells. Unfortunately, information on replacement wells is generally anecdotal, with little documentation of specific well problems. Regardless, the problem demonstrates the need to develop better water management options to help ensure the sustainability of local groundwater resources for the future.

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Recent Geologic Maps

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Appendix I

Precipitation and Groundwater Recharge

Recharge in a groundwater system is necessary to maintain water levels within the system as depletion occurs when pumping rates exceed recharge rates to an aquifer. In areas near streams or the irrigation canals, a component of recharge occurs from infiltration of water downward through the base of the streambed. Additional recharge may occur from infiltration of applied irrigation waters beneath the root zone of crops. For areas without stream recharge, infiltration of precipitation provides recharge. For areas with limited surface drainage, the amount of water which evaporates and is utilized by plants for growth, referred to as *evapotranspiration*, must be subtracted from the total amount of precipitation to determine the amount of recharge. When evapotranspiration exceeds the rainfall amount, there is no recharge from precipitation since the water is utilized by plants for growth.

The recent MBMG Ground Water Investigation Program (GWIP) studies of the North Hills (Waren et al., 2012) and Scratchgravel Hills (Bobst et al., 2013) developed estimates of recharge from precipitation for the study areas. Precipitation maps show the increasing amount of precipitation with elevation. Evapotranspiration maps were developed using remote sensing methods. These study areas have similar soils, precipitation and vegetation to the upland areas with bedrock aquifer surrounding the Helena Valley. Based on these similarities, this data is considered representative of conditions in upland areas with bedrock aquifers surrounding the Helena area.

The maps showing precipitation and evapotranspiration for the study areas are presented below. A map showing the recharge polygons, the amount of precipitation considered to recharge the aquifer, is included for the North Hills study area. The map shows that for this area, there is no direct recharge from precipitation in the central part, with recharge occurring in the northern part of the area. This map also shows the amount of recharge water estimated to occur from the irrigation canal to the southern part of the study area. A similar map was not presented with the Scratchgravel Hills study.

The discussion of aquifer recharge does not consider discharge from septic systems drainfields as recharge sources, since the water is obtained from the aquifer. After consumptive use is removed, the remaining water that percolates into the ground is accounted for with the discussion of water use in the Water Usage Per Household section of this report.

Annual Precipitation, Inches/Year, North Hills and Scratchgravel Hills

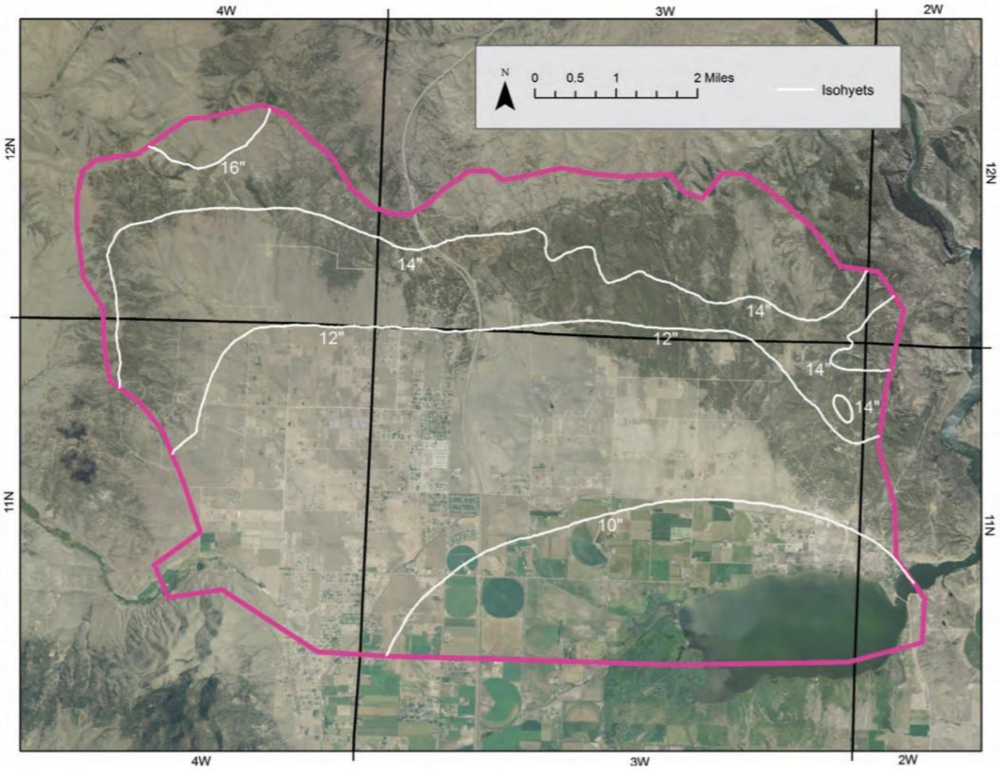


Figure 14. Average annual precipitation isohyets in the North Hills Study Area (1970–2000; P. Farnes, written commun., 2010) show that precipitation ranges from less than 10 in. in the Helena Valley to over 16 in. in the hills.

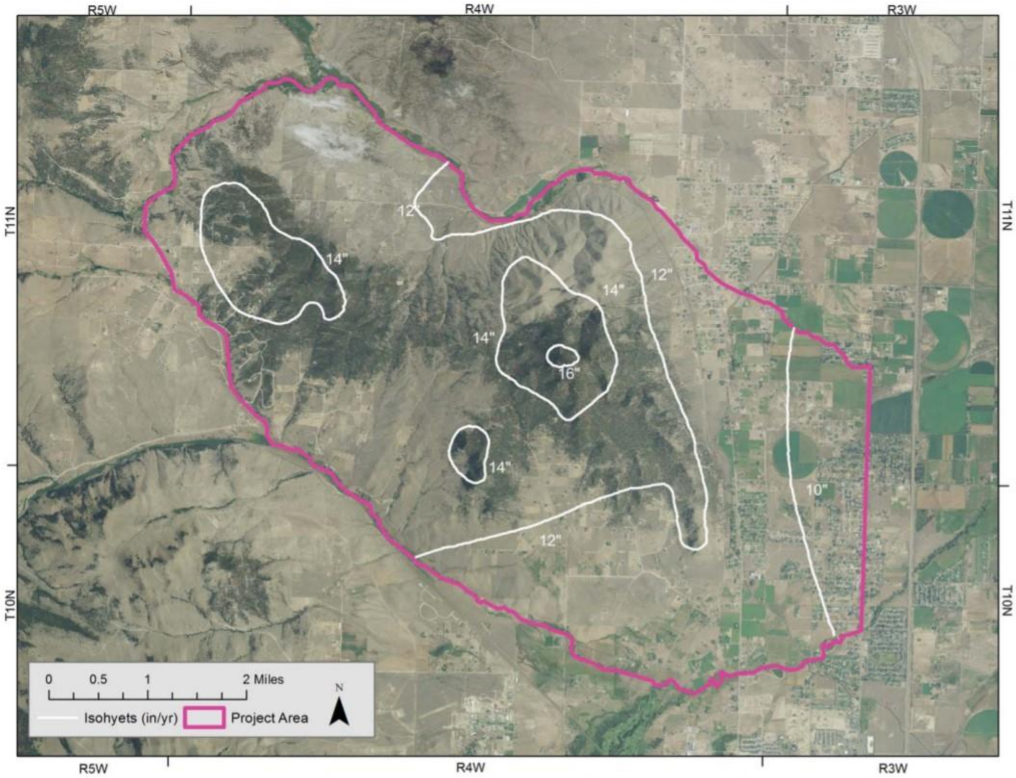


Figure 6A. Average annual precipitation isohytes in the Scratchgravel Hills study area (1970–2000; P. Farnes, written commun., 2010) show that precipitation ranges from less than 10 in. in the Helena Valley to over 16 in. in the hills. The highest precipitation rates occur at the highest elevations.

Maps show precipitation amounts increase with elevation.

Annual Evapotranspiration, Inches/Year

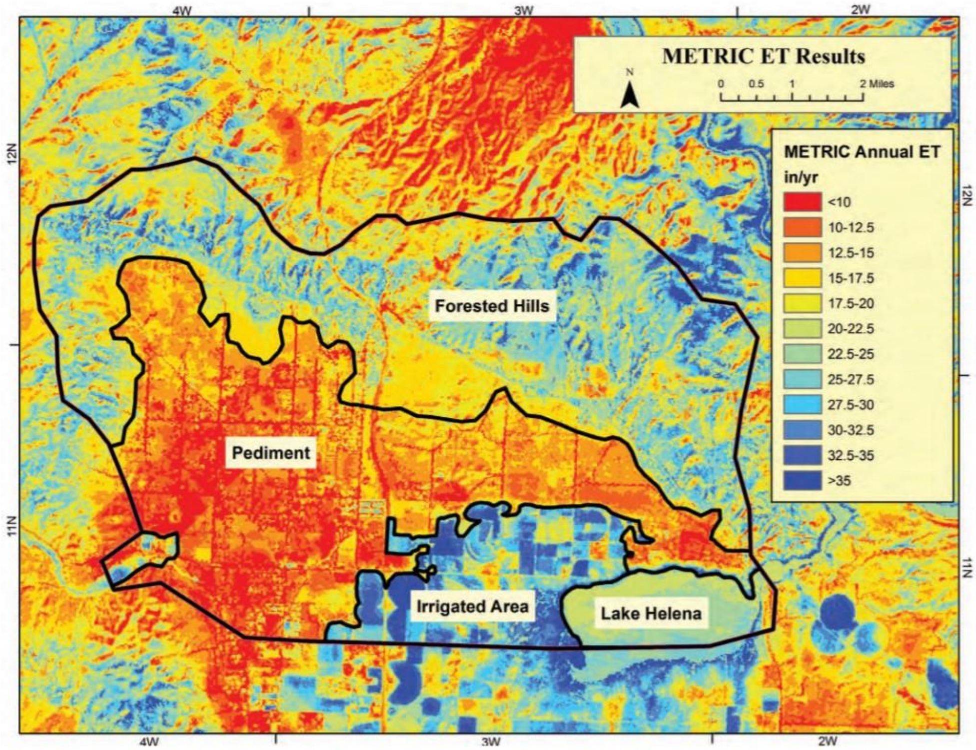


Figure 15. The METRIC ET analysis indicates that ET is approximately 28 in per year in the irrigated area, 13 in per year on the pediment, and 22 in per year in the forested area. Note that precipitation in the forested area averages 15 in per year (fig. 14). The method is considered useful for the pediment and irrigated area, but results for the forested hills are problematic.

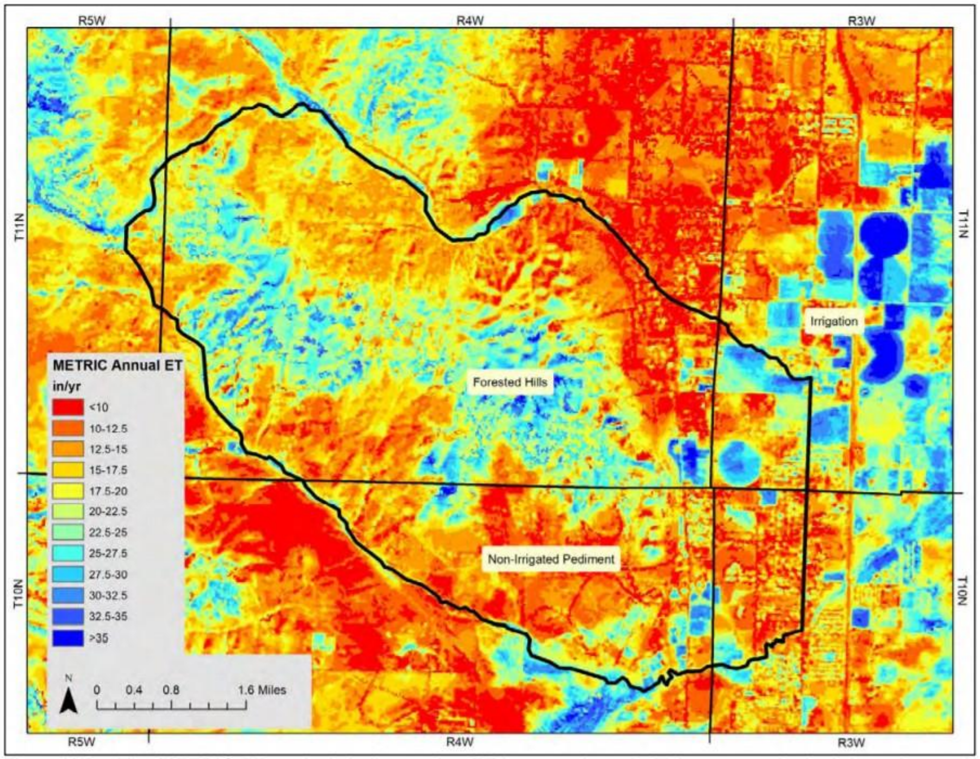


Figure WB5. The METRIC ET analysis indicates that ET is approximately 28 in per year in the irrigated area, 13 in per year on the pediment, and 22 in per year in the forested area. Note that precipitation in the forested area averages 15 in per year (fig. WB4).

Evapotranspiration accounts for evaporation and transpiration from plants

Estimated Aquifer Recharge, Inches/Year, North Hills

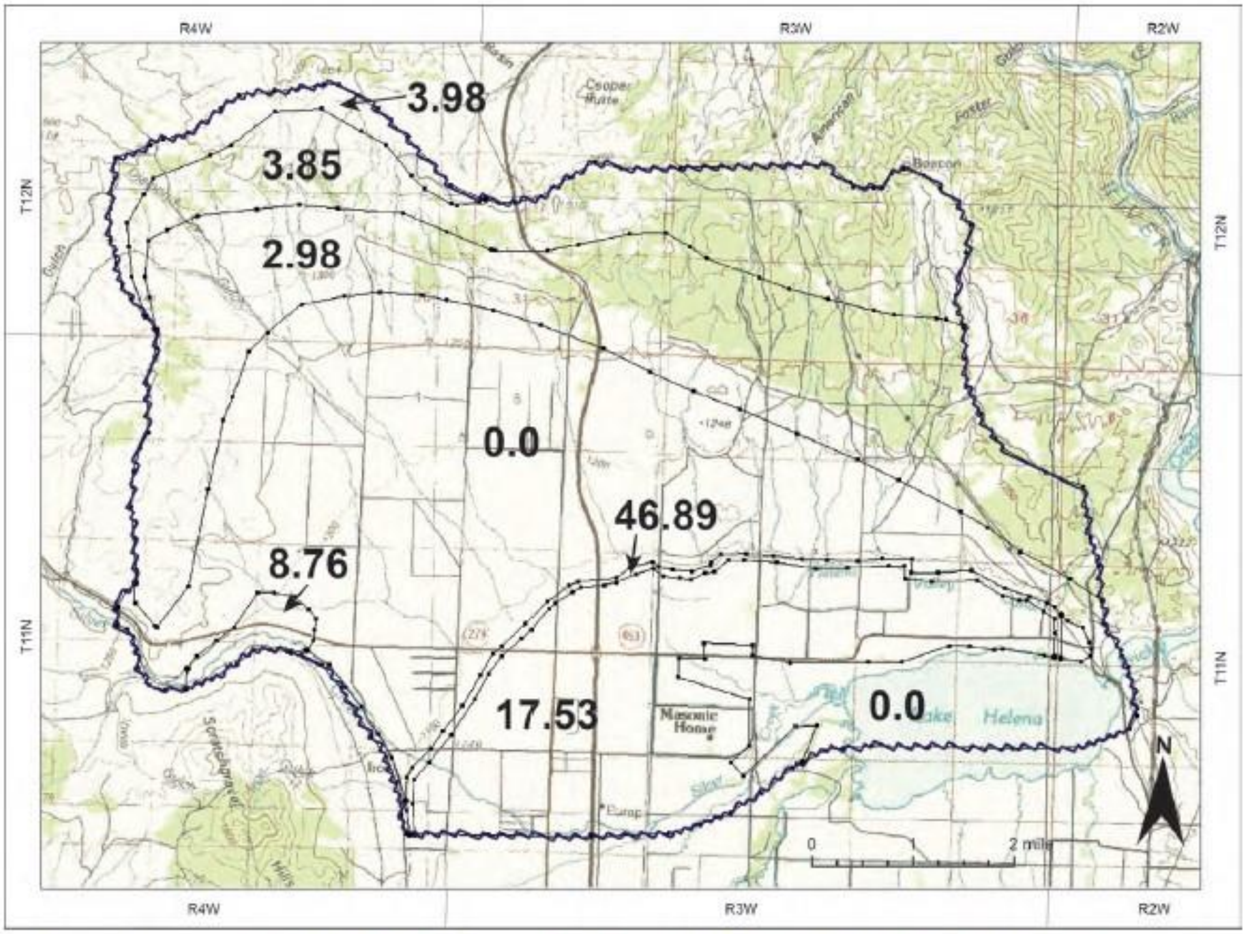


Figure 36. Recharge polygons used in the North Hills Area model steady-state calibration and recharge values applied (inches per year).

In upland areas, the estimated recharge represents the difference between precipitation and evapotranspiration. There is no recharge to the aquifer in the central part of the study area. In the southern part of the study area, the 46.89 inches/year reflects recharge from the main Helena Valley Irrigation Canal, with 17.53 inches/year in the irrigated central part of the valley. A similar figure was not developed for the Scratchgravel Hills Report. The figure demonstrates the limited amount of recharge to groundwater from precipitation in areas outside of the Helena Valley. The recharge in the forested areas at higher elevations around the Helena area are considered similar to the northern part of the North Hills, but with more precipitation at higher elevations.

Appendix II

Water Usage Per Household

The amount of water obtained and utilized by a residence with a private well for potable water, and a septic system and drainfield for wastewater treatment, includes both consumptive use and water that infiltrates back to the subsurface as return flows. Consumptive use increases significantly during summer months when irrigation for lawn and gardens occur on a regular basis. The EPA estimates household water usage at approximately 90 gallons per person per day, not accounting for summer withdrawals for irrigation use. Return flow estimates from septic system drainfields vary, and are difficult to quantify since the soil type, depth to the water table and discharge rates can vary significantly depending on location and local geology. Note that in some areas, thin soil profiles over bedrock limit the efficacy of the onsite wastewater treatment system.

The recent MBMG Ground Water Investigation Program (GWIP) studies of the North Hills (Waren et al., 2012) and Scratchgravel Hills (Bobst et al., 2013) included an assessment of water consumption from several subdivisions to estimate individual household use. The following table, presented in both referenced reports, shows the data sources used to estimate the amount of consumptive water use per house, used for the modeling program implemented for each project. These studies used an estimated 435 gallons/day per residence for withdrawals from pumping, with data used for this estimate listed in Table WB-2. The dataset for the Townview Subdivision in the North Hills present the most complete dataset for the assessment. The average amount of water supplied to each household annually, from 1991 to 2009 is depicted in Figure WB-7, developed from the total monthly withdrawals in Figure WB-8 and average monthly withdrawals in Figure WB-9. This data demonstrates an average amount of 603 gallons delivered to a residence per day over the year, with 168 gallons discharged back into the aquifer through the septic drainfield to arrive at the estimated consumptive use amount of 435 gallons per residence per day. This represents an averaged value, noting that higher pumping rates and use occur during summer months.

Table WB-2
Comparison of Calculated Consumptive Water Use per Home

Source	Delivered (gpd/residence)	Septic Return (gpd/residence)	Consumptive Use (gpd/residence)
EPA, 2008	400	NR	NR
DNRC, 1986	312	NR	NR
Madison, 2006	464	162	302
DNRC	629	152	477
Townview Subdivision	572	164	408
Combined Ranchview and Skyview Subdivisions	607	188	420
Northstar Subdivision	506	NA	506
Average	499	167	423
Average (Excluding EPA; DNRC, 1986; Madison; and Northstar)	603	168	435

NR = Not Reported
NA = Not Applicable

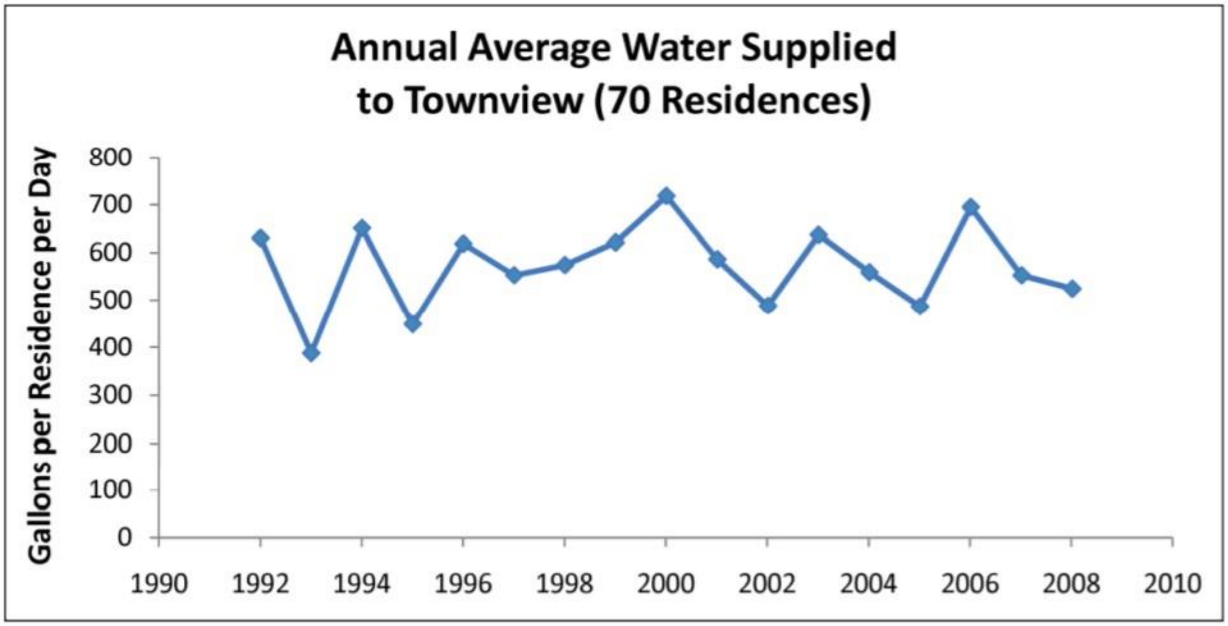


Figure WB-7. Average amount of water delivered to each home in the Townview Subdivision, by year.

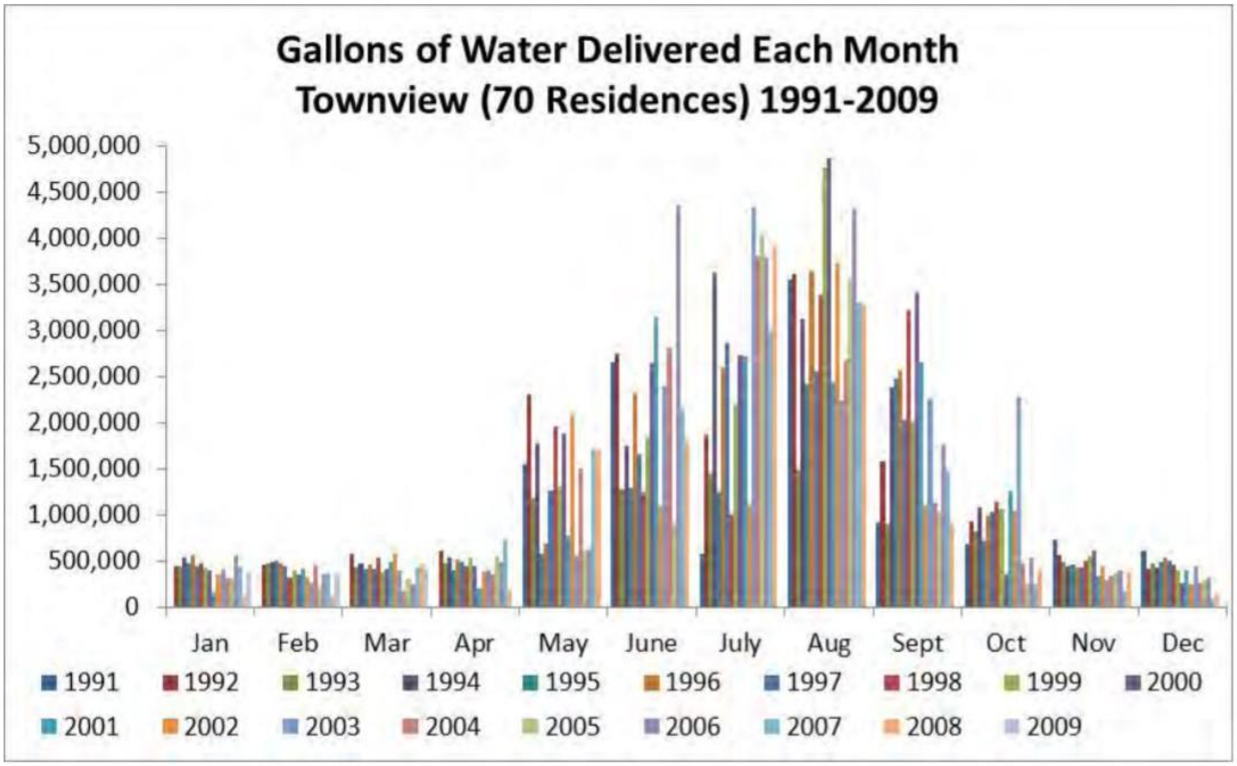


Figure WB-8. Water delivered to homes in the Townview Subdivision by month, 1991–2009.

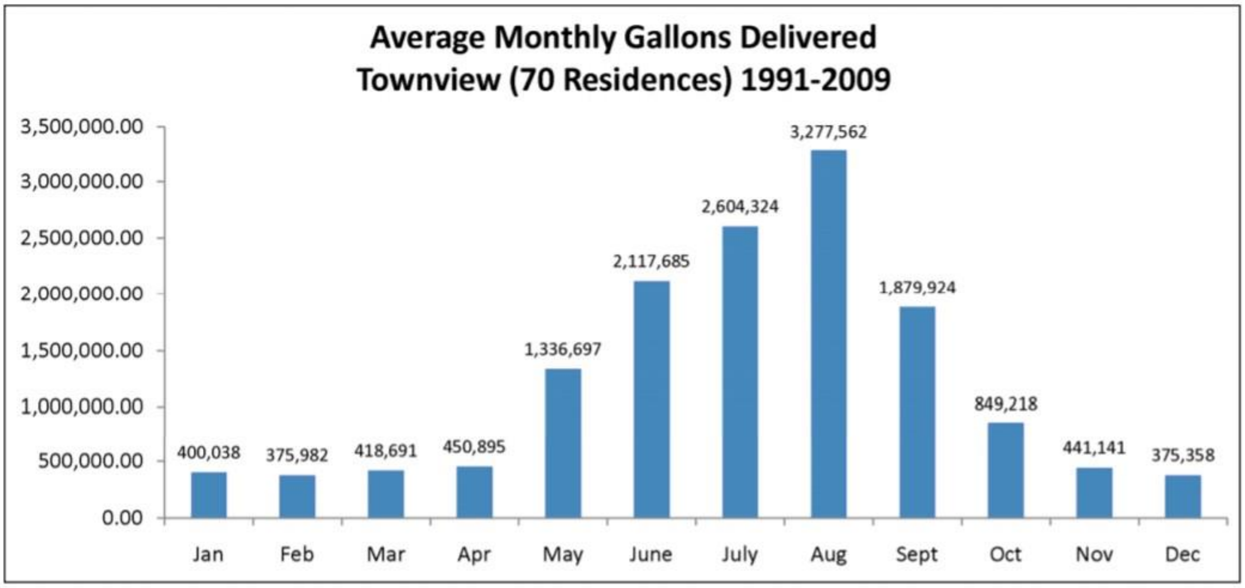


Figure WB-9. Average monthly water delivered to 70 homes in the Townview Subdivision.

Appendix III

Groundwater Modeling in the Helena Area

Groundwater models are used to simulate hydrologic systems, as a tool to provide an informed estimate of how changes to one part of the system may impact other parts. Site scale models are commonly developed and utilized for environmental sites for the design of groundwater remediation systems. Regional scale models are developed to simulate the impacts of development, or the connections between different aquifers. Models are developed from information on the geology of local aquifers, aquifer properties such as K determined from pump tests, local precipitation and streamflow data, and from water levels collected from wells in the study area. The final model is calibrated, with the help from the computer, to account for all of the available physical data used to develop the model. Proper calibration of the model to observed conditions results in a simulation that is representative of the natural system. An important component of any model is a water balance, that accounts for the disposition of all water within the system – including recharge into the system, how groundwater flows, the connection between surface and groundwater, and discharge of water from the system as either natural springs or streamflow and/or from pumping from wells. Researchers have completed several models to simulate groundwater conditions in the Helena area. While other models may have been completed for specific projects, the following represent the major published models with results that help characterize groundwater conditions in the area.

- Briar, D.W. and J.P. Madison, 1992. Hydrogeology of the Helena valley-fill aquifer system, west-central Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4023, 92 p.

The Briar and Madison model was developed as a tool to look at the water balance for the Helena Valley Aquifer system. The model developed data specific to the valley groundwater system. The water balance for the model determined that storage of water in the subsurface increased during summer months but was depleted during winter months – resulting in recharge to the valley aquifer directly from bedrock bounding the valley in the subsurface. This information from the report is presented in Figure B&M -1.

Ground-Water Recharge and Discharge

Recharge to and discharge from the Helena valley-fill aquifer system can be derived from the following equation:

LS_in + LC_in + IF_in + PN_in + BR_in = SD_out + LH_out + WL_out (1)

where:

LS_in = Recharge from infiltration of streamflow,
LC_in = Recharge from infiltration of water in irrigation canals,
IF_in = Recharge from infiltration of excess water applied to irrigated fields (applied irrigation water plus precipitation on irrigated fields minus evapotranspiration),
PN_in = Recharge from infiltration of precipitation on non-irrigated areas (precipitation minus evaporation during the non-growing season; precipitation minus evapotranspiration during the growing season),
BR_in = Recharge from inflow from bedrock,
SD_out = Discharge through leakage to streams and drains,
LH_out = Discharge through upward leakage to Lake Helena, and
WL_out = Discharge through withdrawals from wells.

Table 4.--*Estimated water budget for the valley-fill aquifer system*

	Acre-feet												
	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Annual (rounded)
<u>Recharge</u>													
LS_in	1,100	1,140	1,100	1,140	1,140	920	1,090	1,060	1,090	1,080	980	1,100	12,900
LC_in	270	1,410	1,370	1,410	1,410	1,140	46	0	0	0	0	0	7,060
IF_in	-480	8,970	9,070	10,600	3,180	-4,230	-76	0	0	0	0	0	27,000
PN_in	0	0	0	0	0	0	0	0	0	0	0	0	0
BR_in	3,270	3,380	3,270	3,380	3,380	3,270	3,380	3,270	3,380	3,380	3,050	3,380	39,800
Total (rounded)	4,160	14,900	14,800	16,500	9,110	1,110	4,440	4,330	4,470	4,460	4,030	4,480	86,800
<u>Discharge</u>													
SD_out	2,980	3,070	2,980	3,070	3,070	2,980	3,070	2,980	3,070	3,070	2,780	3,070	36,200
LH_out	4,110	4,250	4,110	4,250	4,250	4,110	4,250	4,110	4,250	4,250	3,840	4,250	50,000
WL_out	72	282	427	634	225	69	68	66	68	68	61	68	2,110
Total (rounded)	7,160	7,600	7,520	7,950	7,540	7,160	7,390	7,160	7,390	7,390	6,680	7,400	88,300

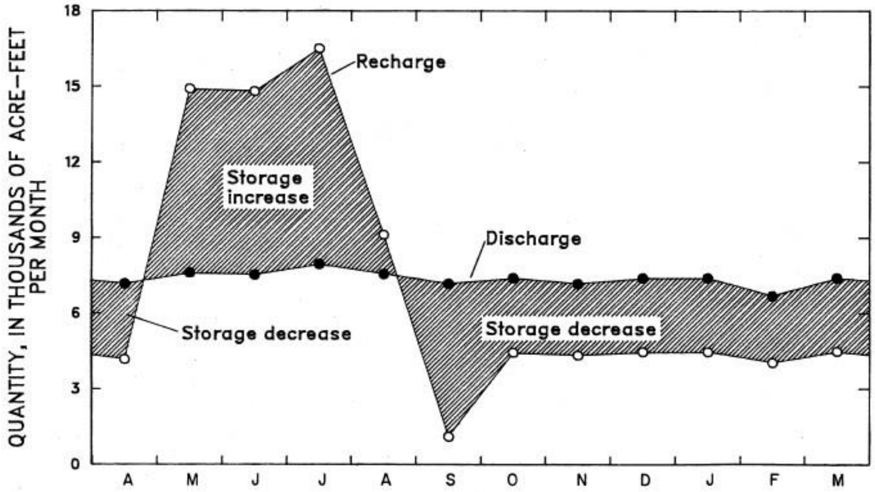


Figure B&M-1 – Water Balance from Briar & Madison Report
Data shows connection between Helena Valley Aquifer and surrounding bedrock aquifers.

- Waren, K., Bobst, A., Swierc, J., and Madison. J.D., 2012, Hydrogeologic Investigation of the North Hills Study Area, Lewis and Clark County, Montana, Interpretive Report: Montana Bureau of Mines and Geology Open-File Report 610, 99 p.
- Waren, K., Bobst, A., Swierc, J., and Madison. J.D., 2013, Hydrogeologic Investigation of the North Hills Study Area, Lewis and Clark County, Montana, Groundwater Modeling Report: Montana Bureau of Mines and Geology Open-File Report 628.

The North Hills study represents the initial study completed by the MBMG Ground Water Investigation Program (GWIP), funded by the Montana Legislature to address groundwater conditions in areas where development resulted in potential impacts to local water resources. In this case, the project was developed to assess water availability issues related to changes in climate AND from increasing amounts of pumping with development. The final project presents 3 documents, with the summary interpretive report listed above, a modeling report (Open-File Report 628) and a technical report presenting results of field investigations (Open-File Report 654).

The North Hills model was developed to assess groundwater availability, including the connection between Silver Creek and the Helena Valley Irrigation Canal to groundwater conditions in the study area. The area where Silver Creek enters the Helena Valley was determined to be susceptible to drought conditions and reduced flows in Silver Creek. These conditions were observed during the drought period of 2000 – 2003, when water levels in wells in the area fell creating local concerns over groundwater availability.

The modeling program included two specific scenarios related to drawdown from wells with one simulation including 10 pumping wells in the central part of the study area, along the developed area on North Montana west of interstate I-15, and north of Lincoln Road. The second simulation addresses a proposed development in the northern part of the area where a bedrock aquifer is present. The simulations reflect a constant amount of precipitation as the only recharge to the system, upgradient from Silver Creek, the Helena Valley Irrigation Canal, and the Helena Valley Aquifer in general. As a result, the system is sensitive to changes in precipitation patterns. Additional precipitation would reduce the drawdown levels, while drought would increase the drawdown in the aquifer. The simulations utilize the average value of 435 gallons consumptive use per household per day.

The North Hills study conclusions recognize that “sustained drawdown”, or depletion, was observed between 2005 and 2010 in the central part of the study area, the focus area for the first simulation. The simulations for the study are intended to address the impacts from increased pumping rates from additional wells to the system. An important conclusion from the assessment is that as drawdown/depletion levels increase, more wells in the area will be impacted such that replacement wells will be necessary.

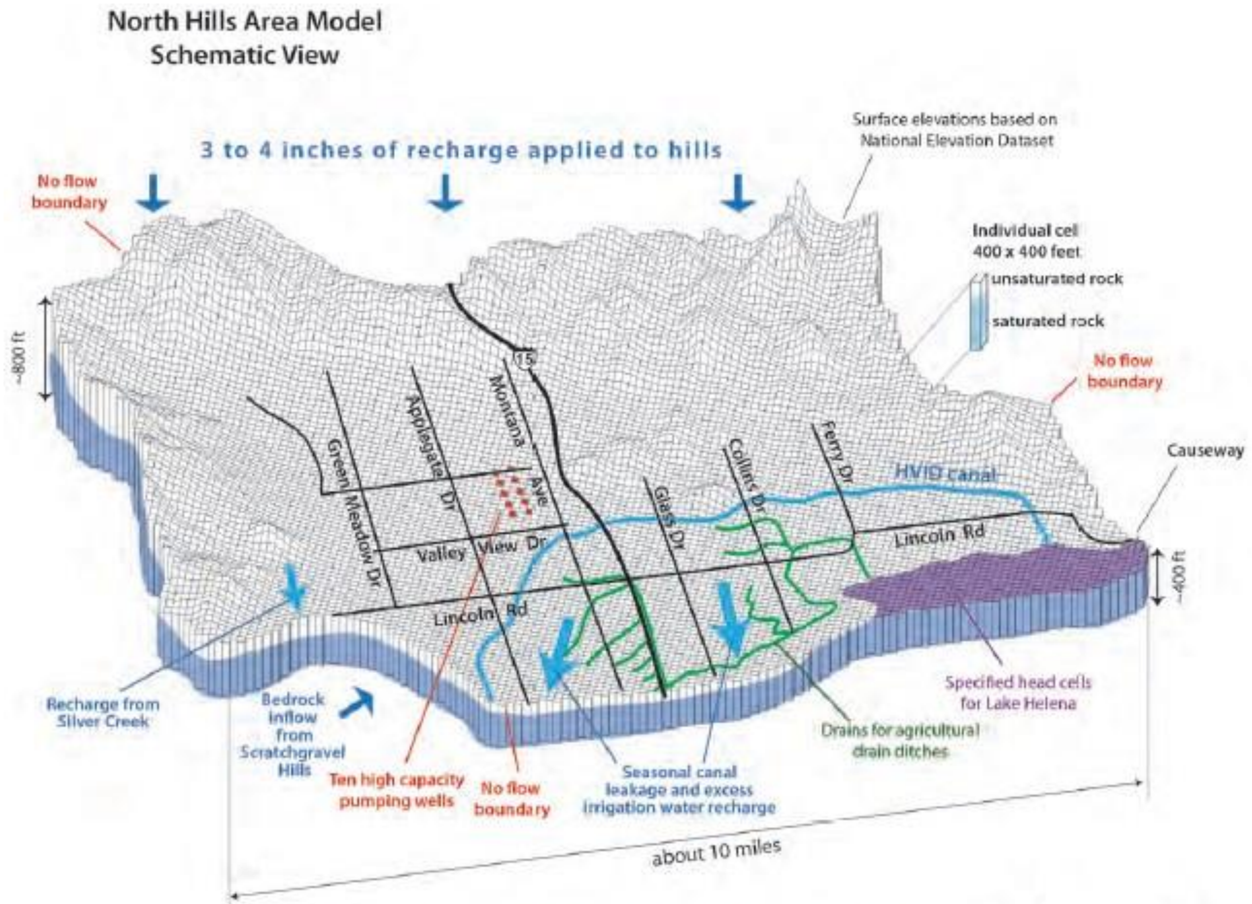


Figure 34. Schematic illustration of the North Hills Area model grid. Vertically exaggerated 5 x

This diagram presents the factors utilized to assemble the groundwater flow model as a simulation of the natural hydrogeologic system. The high capacity pumping wells in the central part of the study area are identified. These well locations were used to simulate additional growth and pumping from the aquifer.

Steady State Drawdown, with no simulated pumping

Steady state drawdown from existing pumping sources is depicted for 2006, with 10 well locations shown for simulations of additional pumping from the area.

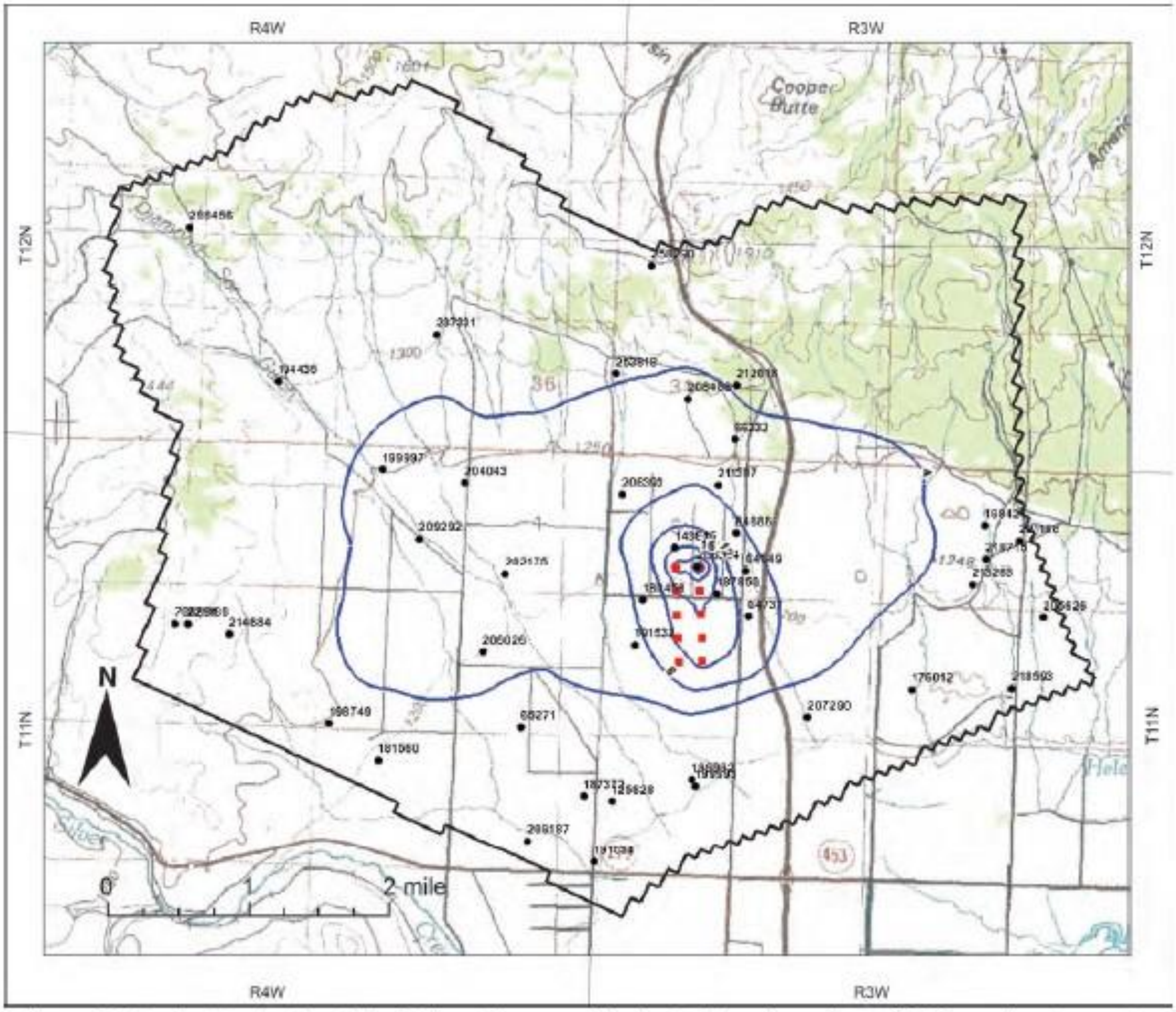


Figure 23. Steady-state drawdown in the Pediment Focus model calculated based on estimated 2006 pumping rates, contour interval, 4 ft. Red squares represent modeled wells.

Steady State Drawdown, with no simulated pumping

Steady state drawdown from existing pumping sources is depicted for 2010, with pumping increased from 2006 rates. The 10 well locations shown for simulations of additional pumping from the area.

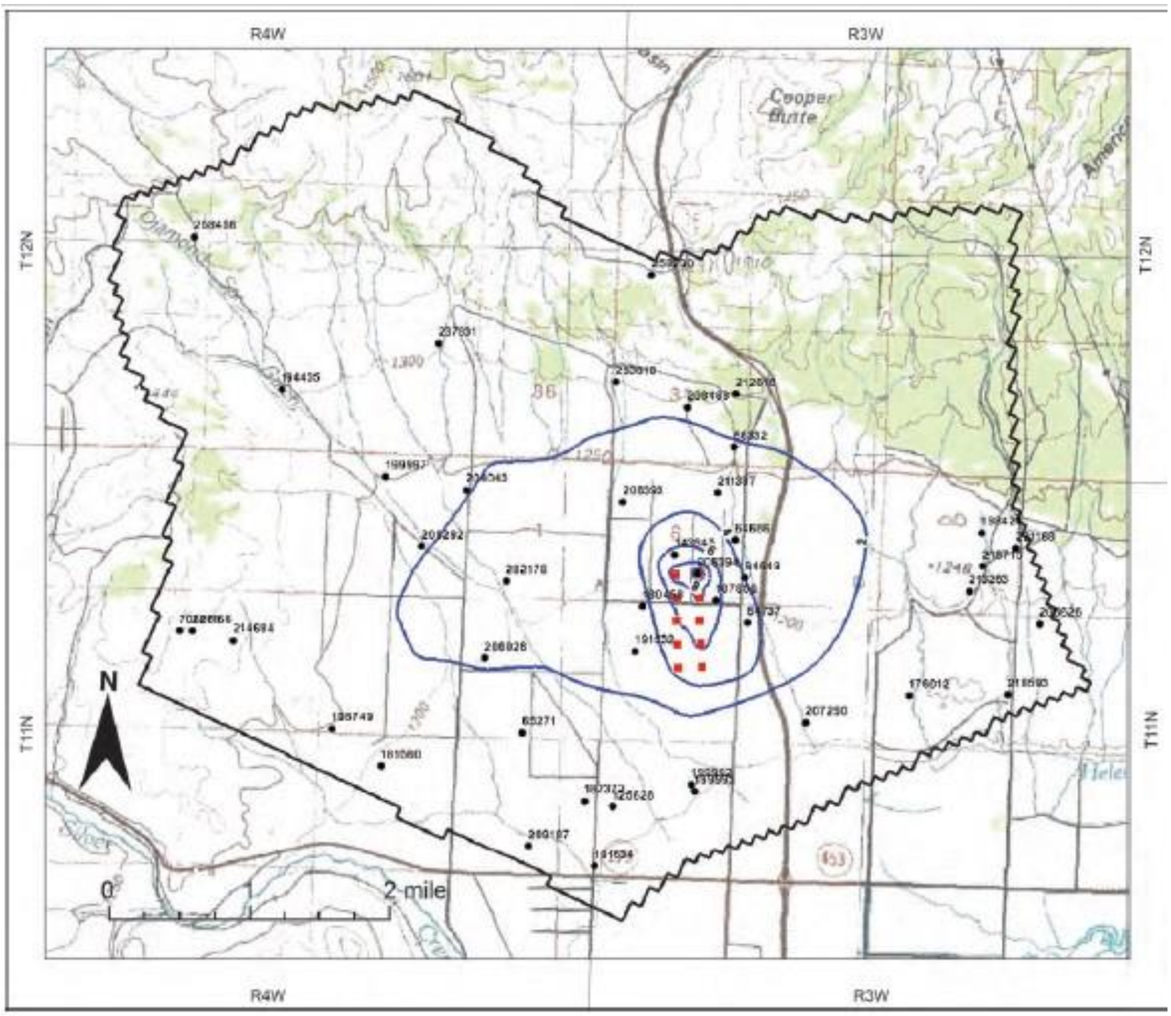


Figure 25. Additional steady-state drawdown calculated in the Pediment Focus model by comparing calculated steady-state drawdown from 2006 estimated pumping rates with calculated steady-state drawdown resulting from increased 2010 estimated pumping rates, contour interval 2 ft. Red squares represent modeled wells.

Simulated pumping from 10 High Capacity wells

Drawdown with pumping rate increased to 2014, with continued pumping until 2025.

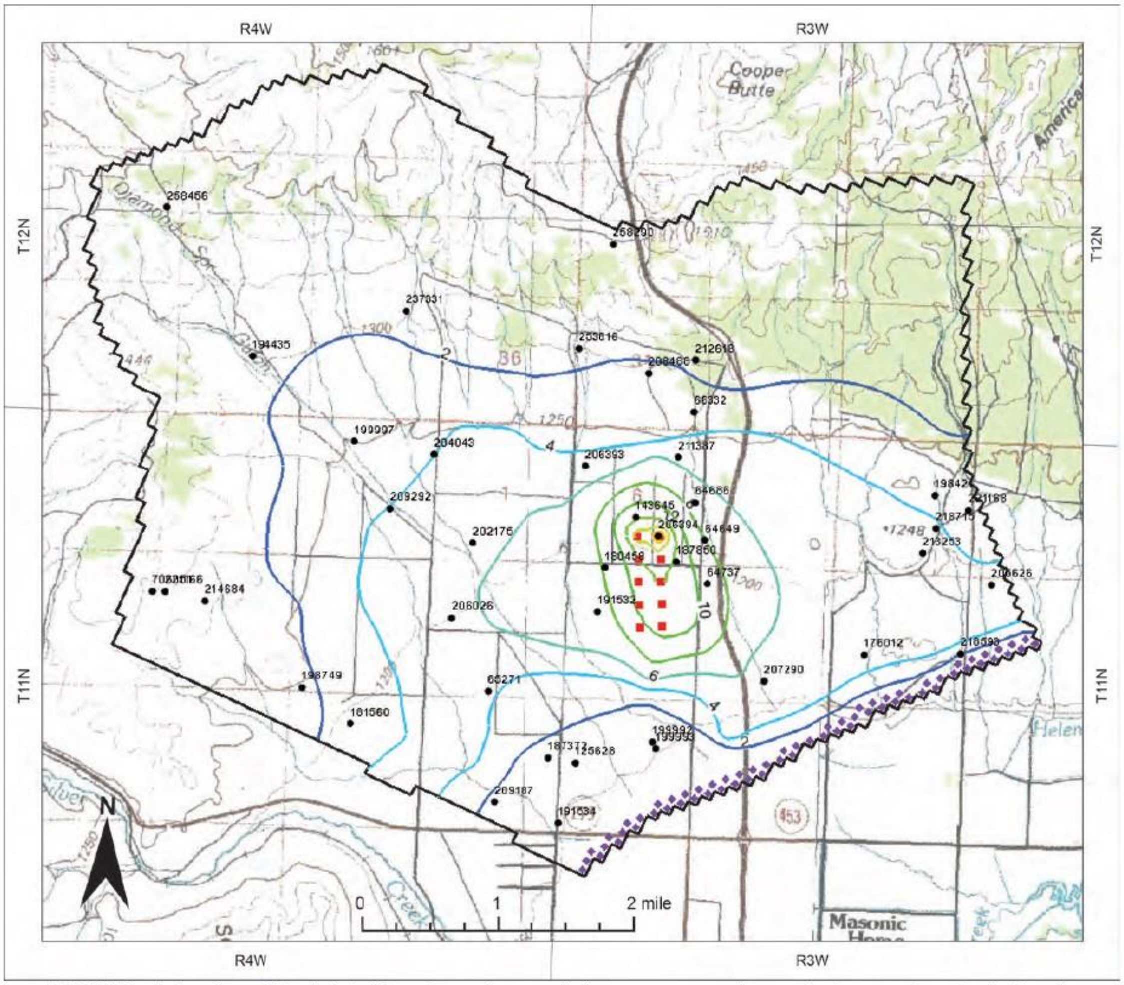


Figure 47. Additional drawdown (ft) calculated for a 5-year increase in the average annual groundwater pumping rates in Pumping Center A of the same amount as that estimated to have occurred from 2005 through 2009. An increase in the pumping rate from the Pumping Center of 7,500 ft³/d is applied at the end of model year 2014 and continued until the end of the modeled time period, the end of August 2025. This map shows calculated additional drawdown as of March 1, 2025.

Simulated pumping from 10 High Capacity wells

Drawdown with pumping rate increased to 4 times the 2009 pumping rates. The model predicts an additional 120 feet of drawdown in the area. This model result shows the predicted groundwater surface, and not the drawdown around the pumping wells.

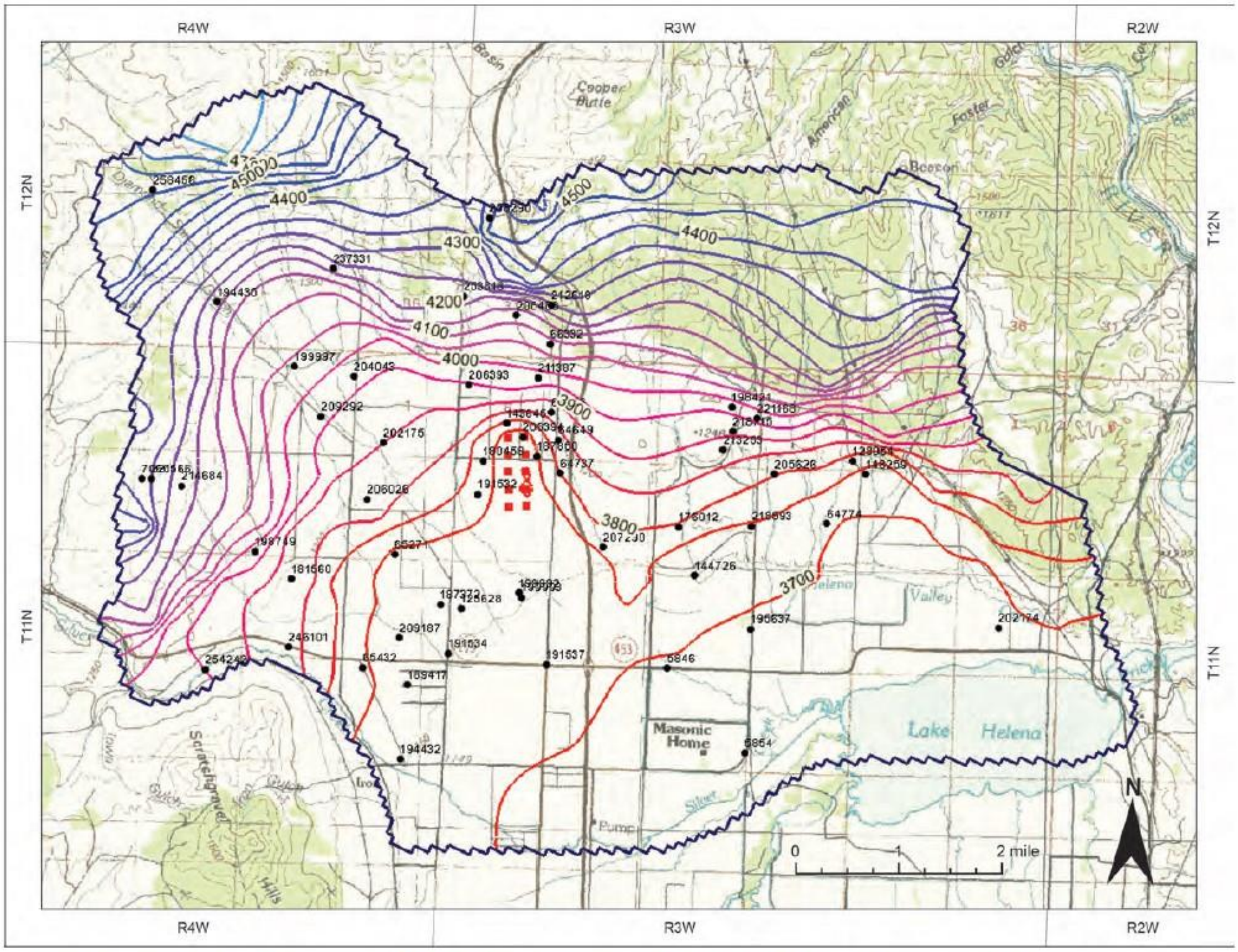


Figure 48. Potentiometric surface predicted by the North Hills Area model if the pumping rates at Pumping Center A were increased to four times the 2009 estimated pumping rates. The model suggests about 120 ft of additional drawdown would occur at the pumping center, drawing water down to about the elevation of groundwater beneath the HVID canal.

47 Homes, 3.5 acre lots, Individual Wells

The drawdown in this scenario is approximately 14 feet around the development. The contours show the depth of the drawdown, with distance, away from the wells in the central portion.

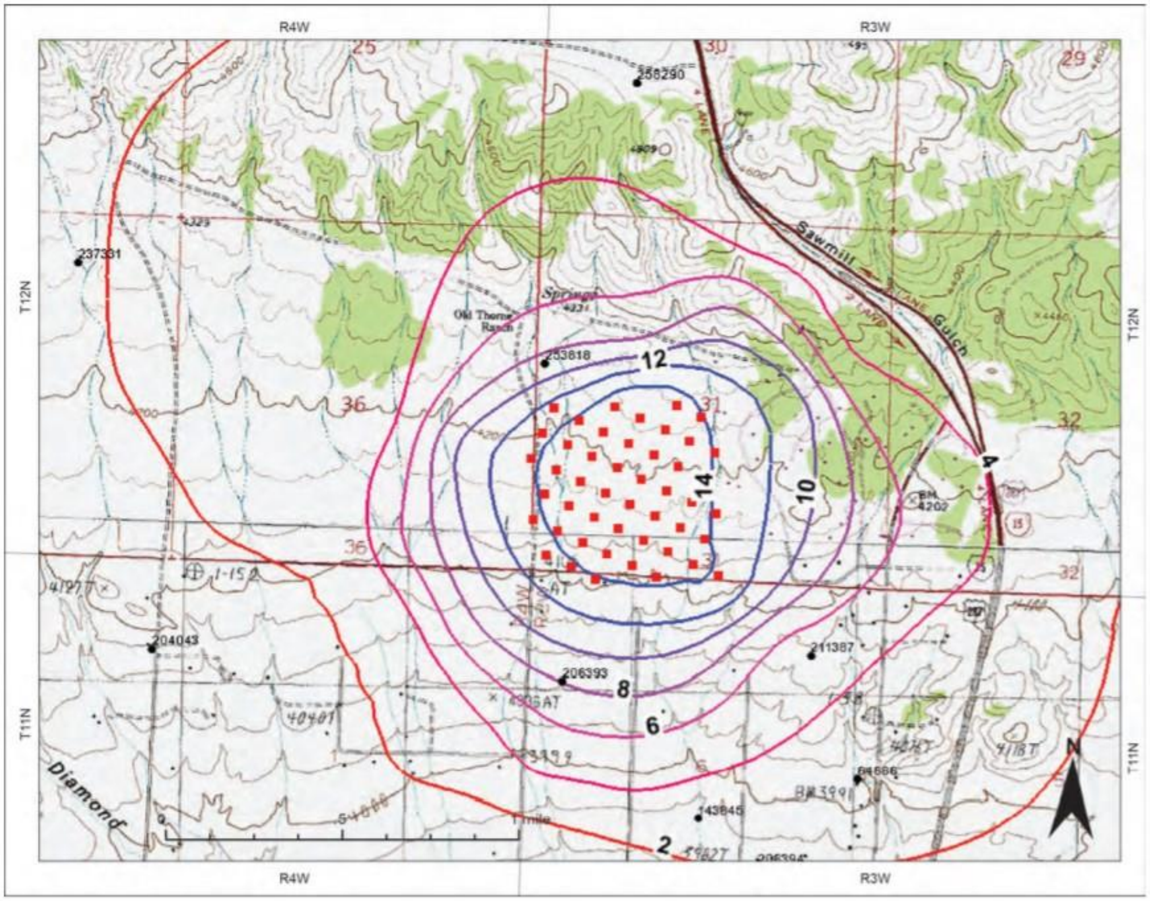


Figure 51. Steady-state drawdown (ft) calculated for 47 wells each pumping 435 gallon per day at the locations shown on the map. This represents the calculated long-term impact of the modeled stress of 47 households pumping an average of about 435 gallons per day (3.67 acre-ft/yr) per household. The red symbols are modeled well locations.

470 Homes, 0.35 acre lots, Individual Wells

The drawdown in this scenario is approximately 160 feet around the development. The contours show the depth of the drawdown, with distance, away from the wells in the central portion. With this type of drawdown, wells would need to be installed to much greater depth to account for the depletion.

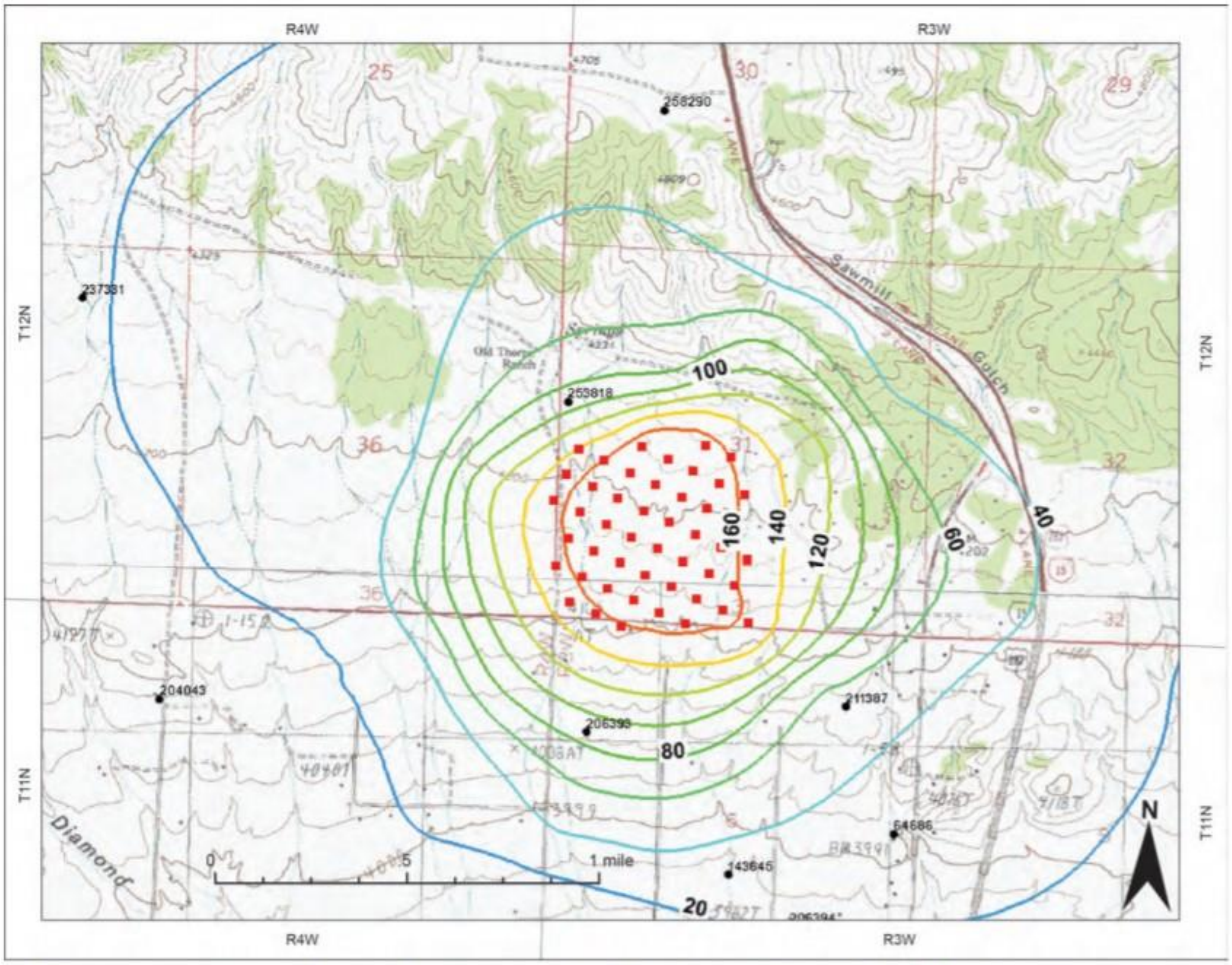


Figure 56. Calculated drawdown (ft) for ten times the amount of steady-state pumping shown in Figure 51.This shows the approximate impact resulting if lots were reduced to about 0.35 acres in size, and groundwater withdrawals for 470 homes averaging 435 gallons per day each for a total annual extraction of about 230 acre-ft per year for the hypothetical subdivision.
60

470 Homes, 0.35 acre lots, Single Public Water Supply Well

The drawdown in this scenario is more than 200 feet around the pumping well, and 160 feet around the margins of the development, similar to the drawdown from using individual wells. The contours show the depth of the drawdown, with distance, away from the wells in the central portion. The Public Water Supply well would need to be installed to significant depth to account for the drawdown and include sufficient depth into the saturated zone to maintain required yields.

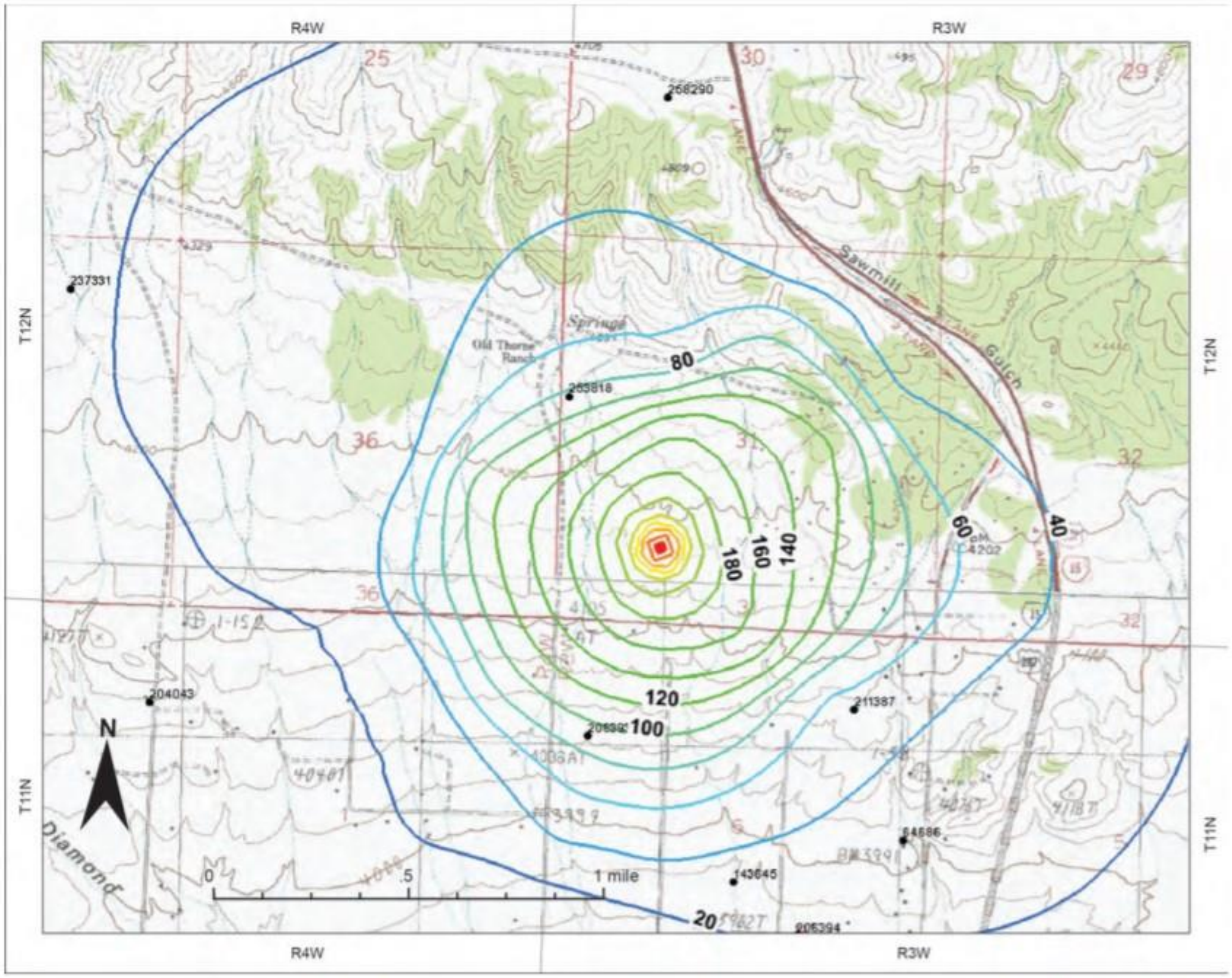


Figure 57. Calculated drawdown (ft) for a single public water-supply well for 470 homes instead of individual wells. Note that the 160-ft contour, and those outside of it, are not changed much from the locations calculated for individual wells. The main difference is the drastic drawdown within the vicinity of the subdivision.

Remove Helena Valley Irrigation Canal from System

The main Helena Valley Irrigation Canal provides significant recharge to the Helena Valley Aquifer. The simulation showing conditions without the canal being used indicate that water levels would fall up to 35 feet without recharge from irrigation waters.

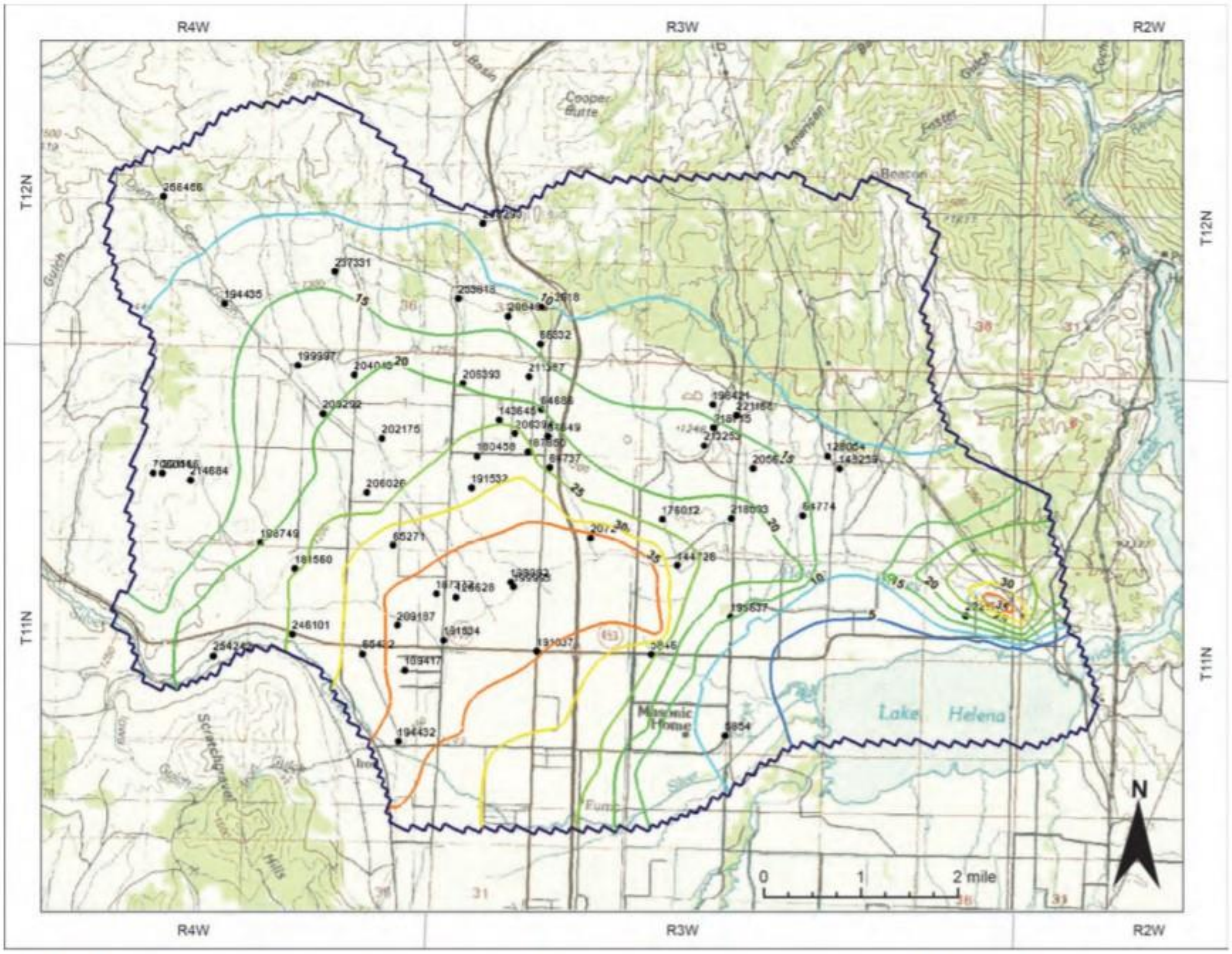


Figure 62. The model-estimated steady-state drawdown (relative to current conditions) that would occur if the HVID irrigation project were to be shut off entirely.

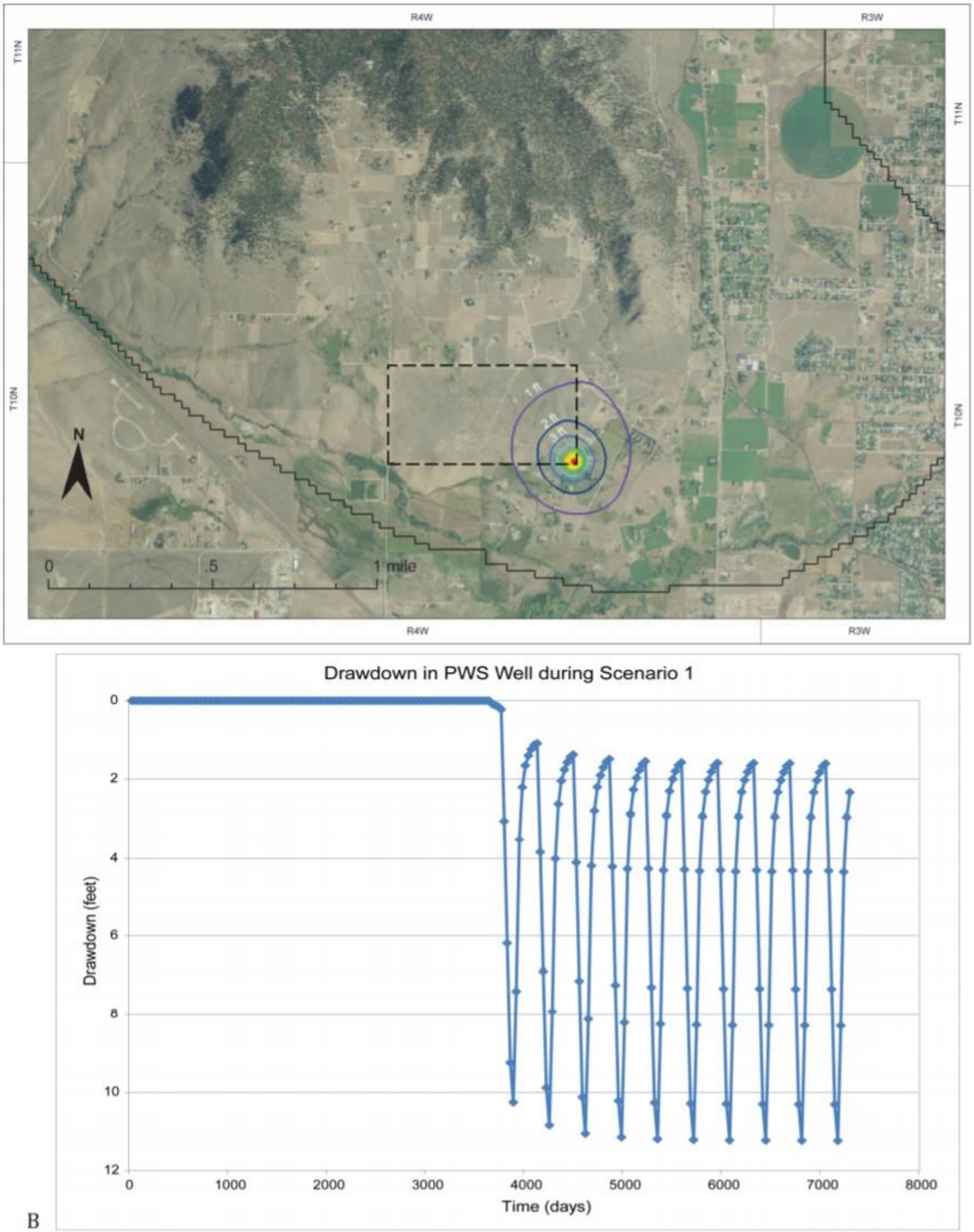
- Bobst, A.L., Waren, K.B., Butler, J.A., Swierc, J.E., and Madison, J.D., 2013, Hydrogeologic investigation of the Scratchgravel Hills study area, Lewis and Clark County, Montana, Interpretive Report: Montana Bureau of Mines and Geology Open-File Report 636, 63 p.
- Butler, J.A., Bobst, A.L. and Waren, K.B., 2013, Hydrogeologic investigation of the Scratchgravel Hills study area, Lewis and Clark County, Montana, Groundwater Modeling Report: Montana Bureau of Mines and Geology Open-File Report 643.

The Scratchgravel Hills study represents the second study completed by the MBMG Ground Water Investigation Program (GWIP) and was completed concurrent with the North Hills study. This project was developed to assess water availability issues related to a proposed development on a bedrock aquifer system. The final project presents 3 documents, with the summary interpretive report listed above, a modeling report (Open-File Report 643) and a technical report presenting results of field investigations (Open-File Report 646).

The Scratchgravel Hills model was developed to assess groundwater availability in the hills and surrounding area. The study area extends into the Helena Valley Aquifer area; however, simulations of water availability are focused on the area where high density development had been proposed.

The following simulation results presented for the project address a proposed development in the area where a bedrock aquifer is present. The simulations reflect a constant amount of precipitation as the primary recharge to the system, with some connection to water in the Tenmile Creek Floodplain. The simulations reflect development of 33 homes on 10 acre lots, and 267 homes on 1.2 acre lots – with both private wells and a public water supply well for each scenario. The simulations utilize the average value of 435 gallons consumptive use per household per day.

33 Homes, 10 acre lots, Single Public Water Supply Well



Drawdown in PWS Well during Scenario 1

Figure 24. Scenario 1 illustrates modeled drawdown from a public water supply well located in the SE¼SE¼NE¼ sec. 11, T. 10 N., R. 4 W., designed to provide water to 33 homes on 10-acre lots. This well is completed in the alluvium. The well's maximum radius of influence extends about 0.5 mile (A), its maximum drawdown is approximately 11 ft, and water levels stabilize during the 10-yr model run (B).

33 Homes, 10 acre lots, Individual Wells

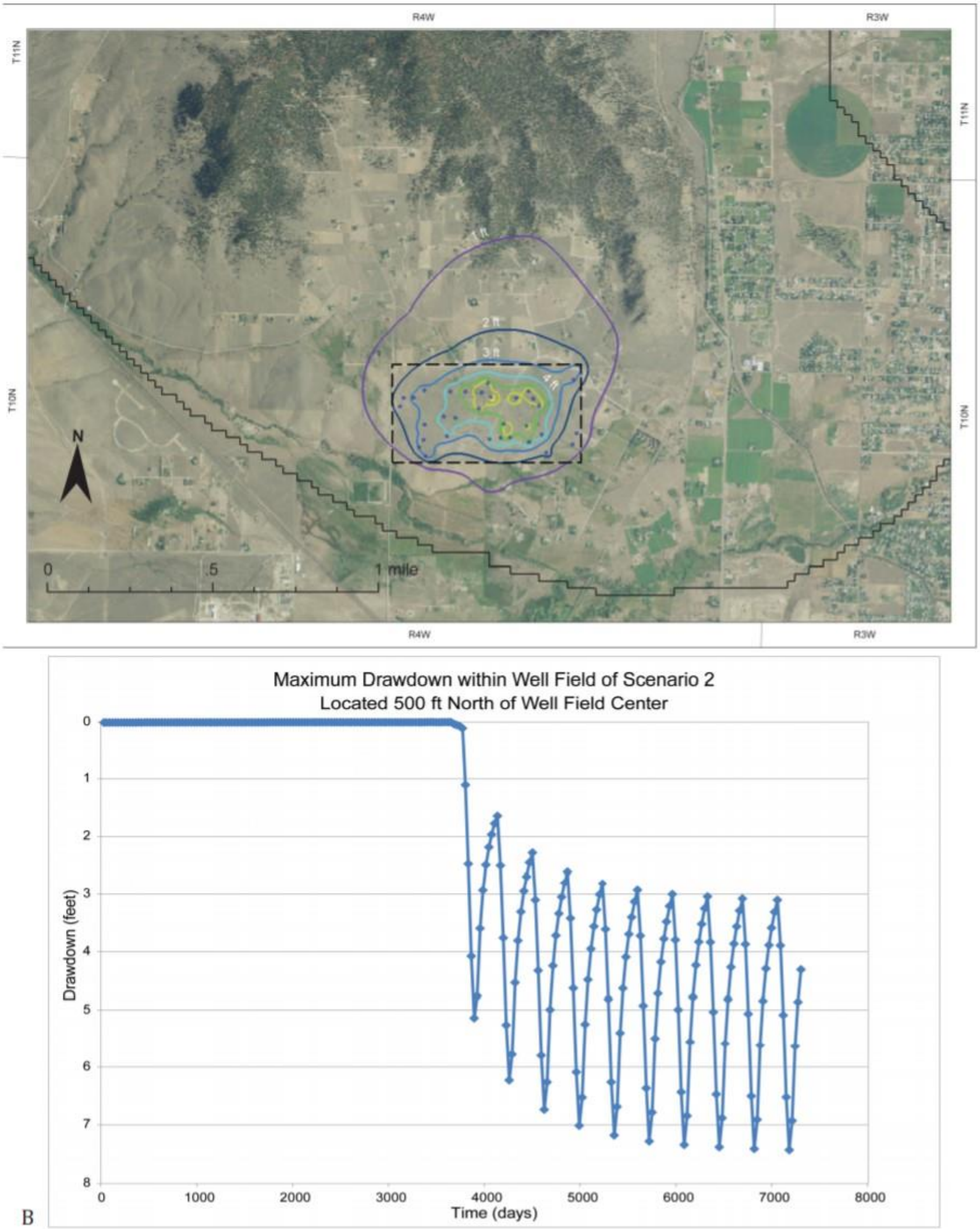


Figure 25. Scenario 2 illustrates modeled drawdown from individual wells used for 33 homes on 10-acre lots in the north half of sec. 11, T. 10 N., R. 4 W. Most of these wells are completed in the granite. The maximum radius of influence extends about 0.9 miles beyond the outermost well (A), maximum drawdown is approximately 7 ft, and water levels stabilize during the model run (B).

267 Homes, 1.2 acre lots, Single Public Water Supply Well

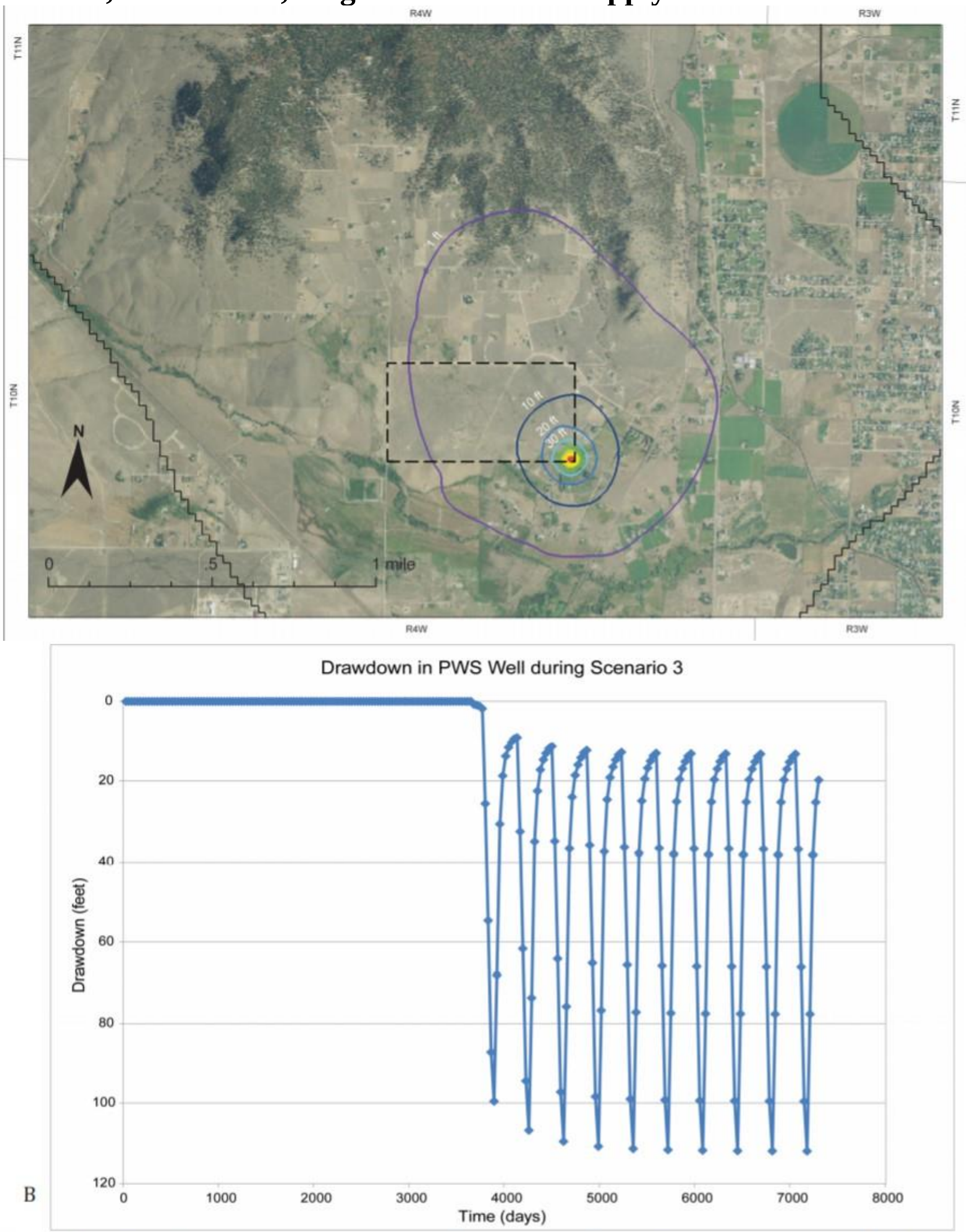
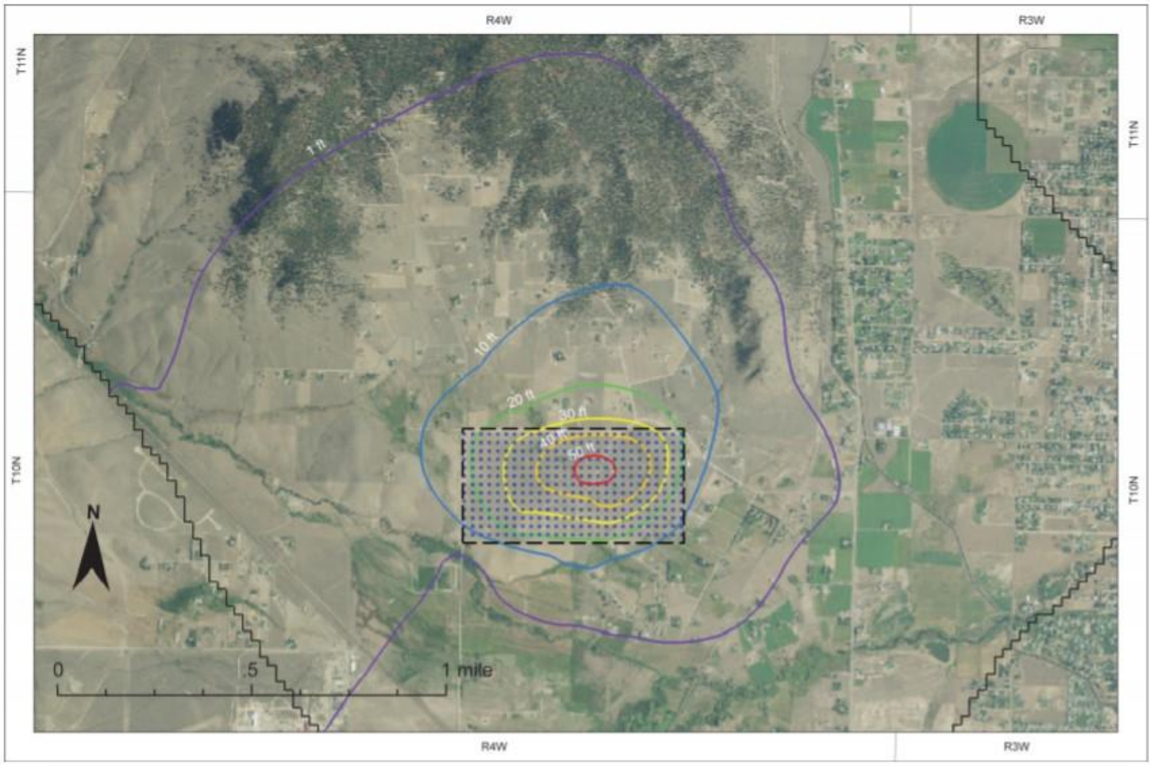
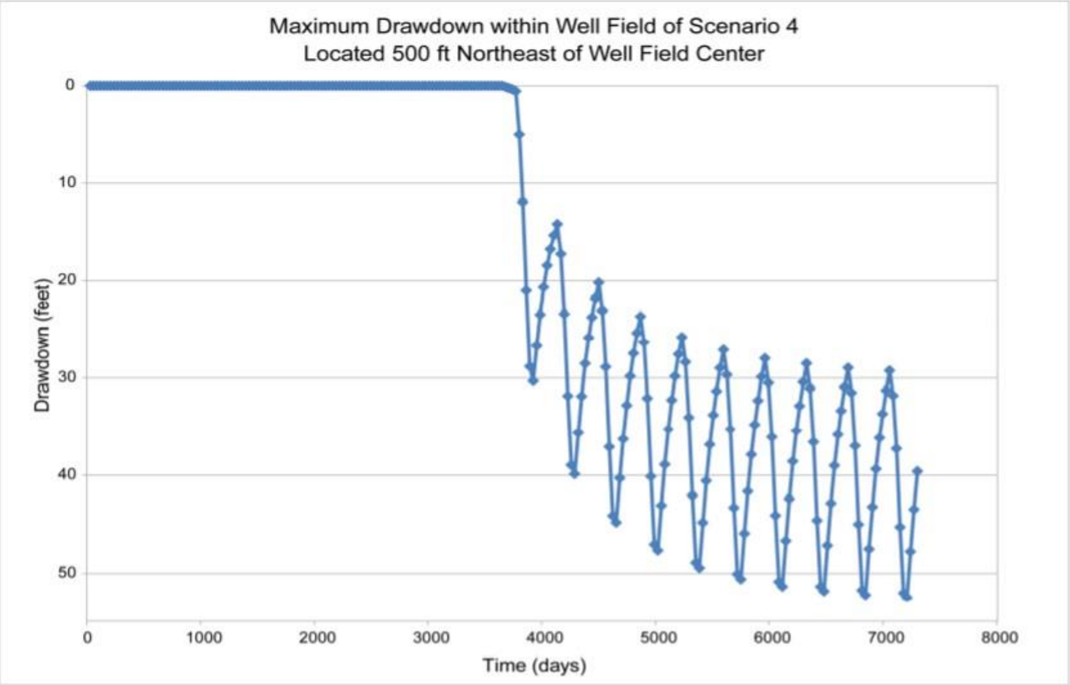


Figure 26. Scenario 3 illustrates modeled drawdown from a public water supply well located in the SE¼SE¼NE¼ sec. 11, T. 10 N., R. 4 W., designed to provide water to 267 homes on 1.2-acre lots. This well is completed in the alluvium. The well's maximum radius of influence extends about 1.3 miles (A), maximum drawdown is approximately 112 ft, and water levels stabilize during the model run (B).

267 Homes, 1.2 acre lots, Individual Wells





B

Figure 27. Scenario 4 illustrates modeled drawdown from individual wells used for 267 homes on 1.2-acre lots in the north half of sec. 11, T. 10 N., R. 4 W. Most of these wells are completed in the granite. The maximum radius of influence extends 2 miles beyond the outermost well (A), maximum drawdown is approximately 52 ft, and water levels do not fully stabilize during the model run (B). Well interference within the well field causes the maximum drawdown to occur in an area 500 ft northeast of the well field's center.