Emerald Ridge Area Ground Water Resource Assessment

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Since development in 2004, yields from private wells for residents of the Emerald Ridge subdivision have diminished, resulting in numerous replacement wells. In response to the problems, the Lewis and Clark Water Quality Protection District (LCWQPD) began a monitoring program, collecting monthly water levels at selected wells in the subdivision in December 2012. As part of the monitoring program, a limited number of water quality samples were collected at this time to determine major ion water quality type, nutrient and trace metal concentrations. Data indicate that significant ground water depletion of the local aquifer has occurred in the area since 2004, and likely continues at this time. This report presents the available data on ground water hydrogeology in the Emerald Ridge area, and provides a discussion of the long-term sustainability of the water supply.

The Emerald Ridge subdivision is located along the northeastern margin of the Helena Valley (Figure 1). Ground water in the Helena area has historically been correlated with two major aquifer systems. The Helena Valley aquifer comprises coarse grained, unconsolidated valley fill sediments in the central portion of the valley, characterized by shallow ground water and high yields (Briar & Madison, 1992). The bedrock aquifers, the second aquifer system, comprises low permeability bedrock units present along the valley margins and is characterized by variable water levels and well yields within fracture flow systems (Thamke, 2000). The contact between the base of the Helena Valley aquifer and underlying older Tertiary basin deposits is poorly defined, resulting in inclusion of Tertiary strata within the general definition of the Helena Valley aquifer. Recent studies by the Lewis & Clark Water Quality Protection District (LCWQPD) have demonstrated that based on hydrologic properties and yield, ground water occurrence in Tertiary strata represents a third aquifer system for the area (Swierc, 2013).

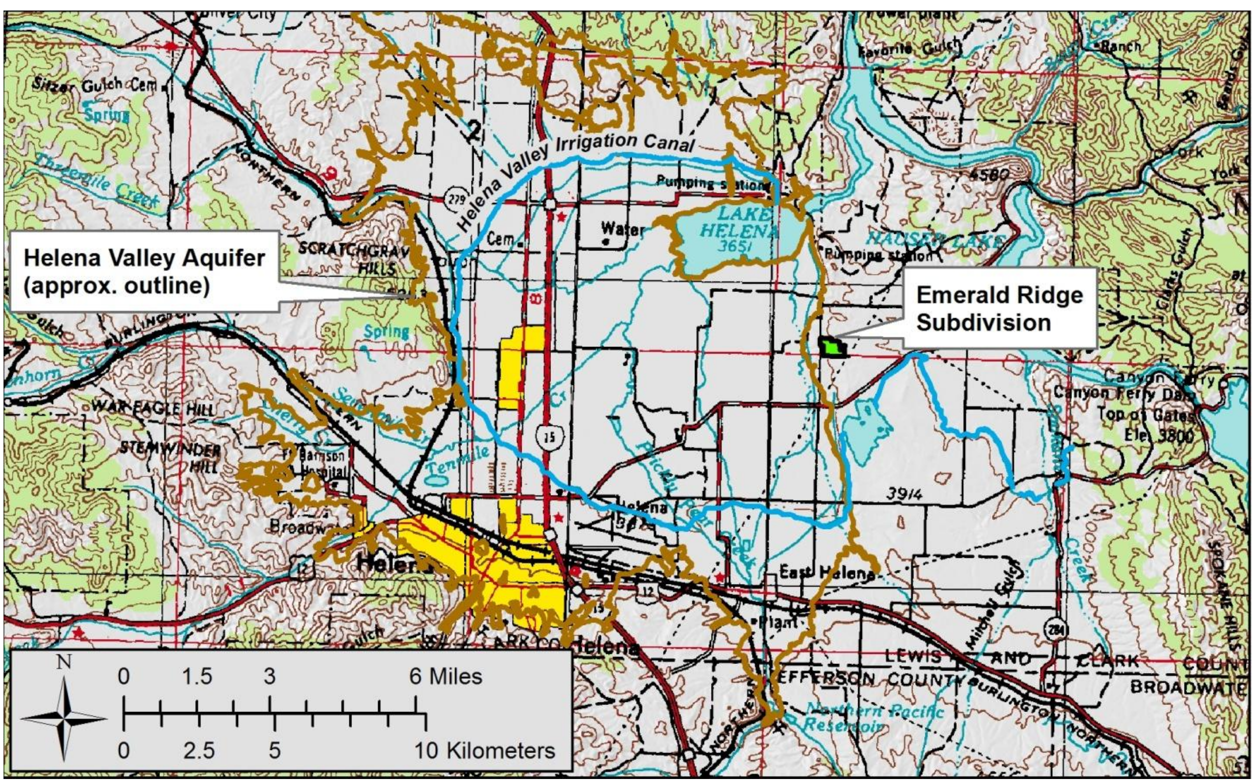


Figure 1 Emerald Ridge Subdivision and Helena Valley Location Map

Planning for the Emerald ridge subdivision began in 2003, with an aquifer assessment completed in early 2004 (Brooke, 2004). At the time, water levels at the site were less than 100 feet below ground surface with a flow gradient to the northwest. A ground water surface map from March 15, 2004 is included in Figure 2. The original development plans called for 67 residential lots in the subdivision, with potential future phases on adjacent lands. Individual wells were recommended to be installed to depths greater than 320 feet below ground surface, and the combined seasonal drawdown in the aquifer, from 67 wells, was estimated at 14 feet (Brooke, 2004). This conclusion assumed that the wells would always have more than 200 feet of available drawdown, and that annual aquifer recharge would occur.

Depletion of the aquifer resulted in homeowners installing deeper replacement wells on 28 lots in the subdivision, as of February 2014, with two homeowners installing third replacement wells. Several of the replacement well depths exceed 700 feet below ground surface. The depletion of the aquifer surface is depicted in Figure 2, which compares the water table surface prior to development in 2004 with the surface in December 2012. The estimated depletion ranges from approximately 100 feet in the southeastern corner of the subdivision, to 150 feet in the northwestern corner. At the time of preparation of this report, approximately seventeen lots were still undeveloped due to the depletion issue (Hiltunen, 2014).

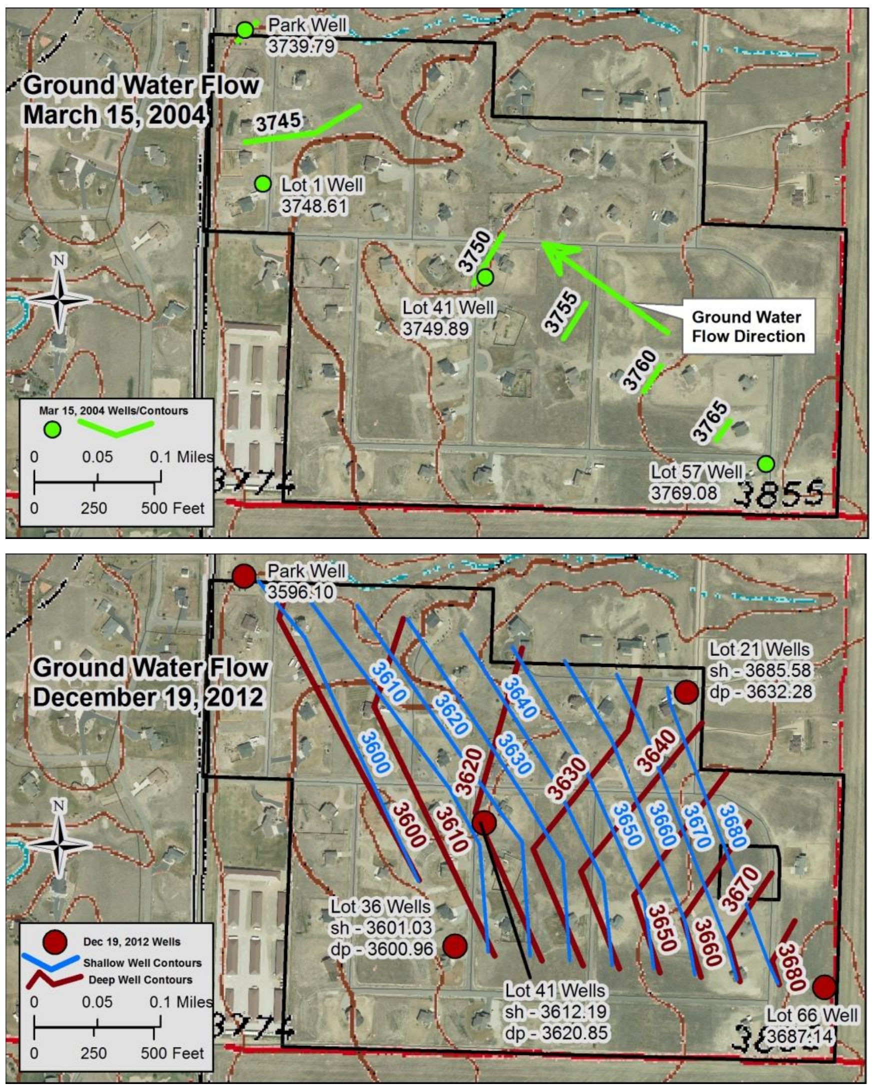
Figure 2 Emerald Ridge Ground Water Surface March 15, 2004 and December 19, 2012.

Basemap is 1:24,000 USGS topographic map over aerial photograph. Map contour interval is 20' with surface elevation at southeast and southwest corners of subdivision. Ground water surface elevations shown for wells.
Sh represents shallow wells;
Dp represents deep wells.

March 2004 ground water data plotted with a 5-foot contour interval.

December 2012 water table surface depicts both shallow and deep well data from Lot 36, Lot 41 and Lot 22; with singles wells at the other two locations. Data plotted with a 10-foot contour interval. Ground water flow direction is perpendicular to flow contours, with both surfaces indicating a generally western flow direction.

Dewatering of water surface visible, ranging from approximately 100 feet in southeast corner, and 150 feet in northwest corner.



Ground Water Table (Potentiometric) Surface

Water levels provide data to estimate the water table (potentiometric) surface and ground water flow direction across the Emerald Ridge subdivision. The water table surface for the Emerald Ridge subdivision area for March 15, 2004 and December 19, 2012 is presented in Figure 2. The water table surface shows a general northwesterly flow direction towards the Park well for the northern part of the subdivision, with a flow direction to the southwest for the southern part. A hydrograph comparing water levels at the site is presented in Figure 3. The hydrograph shows how water levels change over time, providing information regarding recharge to the local aquifer. The Lake Helena surface level is shown since this represents the elevation of the downgradient discharge point for local surface and ground water in the Helena Valley (Briar & Madison, 1992; Waren et al., 2012).

The water table surface on March 14, 2004, prior to development of the subdivision, was determined as part of the planning process for the area (Brooke, 2014). Available wells were used to determine the hydraulic gradient across the site as depicted Figure 2. Since the wells are essentially along a line rather than spatially distributed, the results show a gradient between the wells, but may not be representative of the specific flow direction at that time. However, the data is sufficient to indicate that flow is generally to the west or northwest, following topography towards the Helena Valley. The water levels are indicated on the hydrograph in Figure 3, for comparison with current water levels. At that time in 2004, water levels are above the Lake Helena water surface level, consistent with flow to the west towards the Helena Valley.

The LCWQPD water level monitoring program began in November 2012, with monthly water levels collected at several wells across the subdivision (Figure 3). The water level collection program initially comprised 8 wells at 5 locations shown in Figure 2. The wells at the 3 locations with two wells represent nested wells, drawing water from the original shallower wells installed for the subdivision, and from deeper replacement wells. The two single well locations represent the Park well, and the Lot 66 well located in an upgradient position. The water surface map for December 2012 depicted in Figure 2 indicates flow gradients using both deep and shallow data for locations with multiple wells. Monitoring at one of the dual well locations was discontinued in early 2013. The water surface map with shallow well data indicates a southwestern flow direction for shallow ground water, at a slightly higher gradient.

The water level data for the different locations depicted in the hydrograph in Figure 3 provides the following information about the local aquifer system:

- **Park Well** – the Park well has been utilized for irrigation of the park area at the northwest corner of the subdivision. The well represents the original well for the propert y, utilized as a pumping well for a pump test to determine the hydraulic properties of the local aquifer. The well is located in a downgradient position near the lowest elevation in the subdivision, and obtains water from approximately 300 to 360 feet below ground surface (ft bgs). The water level indicates depletion of approximately 140 feet over the last 10 years. Drawdown of approximately 40 feet occurred during summer 2013, with no visible recharge peak associated with the beginning of irrigation season. The water level began to recover in Fall 2013; however, the recovered water level appears to be approximately 10 feet lower than during the previous winter. With water levels below the Lake Helena and Helena Valley Aquifer levels, a hydraulic gradient must exist from the valley westward towards this well; however, significant recharge does not appear to be occurring to this location.

- **Lot 21 Wells** – The wells in the northeastern part of the subdivision are installed to depths of 220 feet and 483 feet bgs. At this location, the shallow well draws water from above the screened portion of the Park Well. The hydrograph pattern is different between the deep and shallow wells, indicating that the shallow well receives recharge and draws water from a part of the aquifer that is disconnected from the water bearing interval in the deep well. The difference is the deep well shows a seasonal drawdown with recovery similar to the Park Well. Since it is located on the hillside above the Park Well, the deep well is screened at a similar depth to the Park Well. Based on the summer drawdown and recovery, the deep well is interpreted to be within the same water bearing interval as the Park Well. However, recovery to the previous winter water level does not appear to have occurred.

- **Lot 36 Wells** – The wells on the eastern side of the southern area of the subdivision are installed to depths of 245 and 600 feet depth. While the base of the shallow well is near the top of the water table surface, both wells follow the same seasonal drawdown and recovery behavior as the Park and Lot 21 wells. This suggests that at this location, the upper and deeper parts of the aquifer system are hydraulically connected.

- **Lot 41 Wells** – These wells, located in the central part of the subdivision, are installed to depths of 280 and 696 feet depth. Only a limited number of measurements were taken at these wells, during winter 2012-2013. The hydrograph data show an upward vertical gradient from the deeper well to the shallower well, showing that the two water bearing intervals in the aquifer are separated by an less permeable layer which restricts ground water flow (an aquitard) at this location. Data over the summer irrigation season is not available for this location.

- **Lot 67 Well** – This well is installed to a depth of 356 feet bgs. The hydrograph does not show any significant drawdown during the summer, and follows the same general pattern as the shallow well in Lot 21. This pattern suggests that this well is located within the upper part of the aquifer system. While the water level appears stable, the water levels do not appear to reach the levels from the previous year. In addition, the water level in the well in Lot 57, across the street from this lot, was approximately one hundred feet higher in 2004.

The hydrograph data indicates that the shallower part of the aquifer system is not connected to the deeper part along the northeastern part of the subdivision, but is connected along the southwestern part. Since water levels do not appear to be recovering to similar levels as previous years, continued depletion of the aquifer continues.

The drawdown of the shallow aquifer is further evidenced by drawdown observed in a shallow monitoring well E-8 on the southwest corner of the Lewis & Clark County landfill, as shown in Figure 4. In this hydrograph of wells, the trend in water level elevations in other wells clearly differs from well E-8.

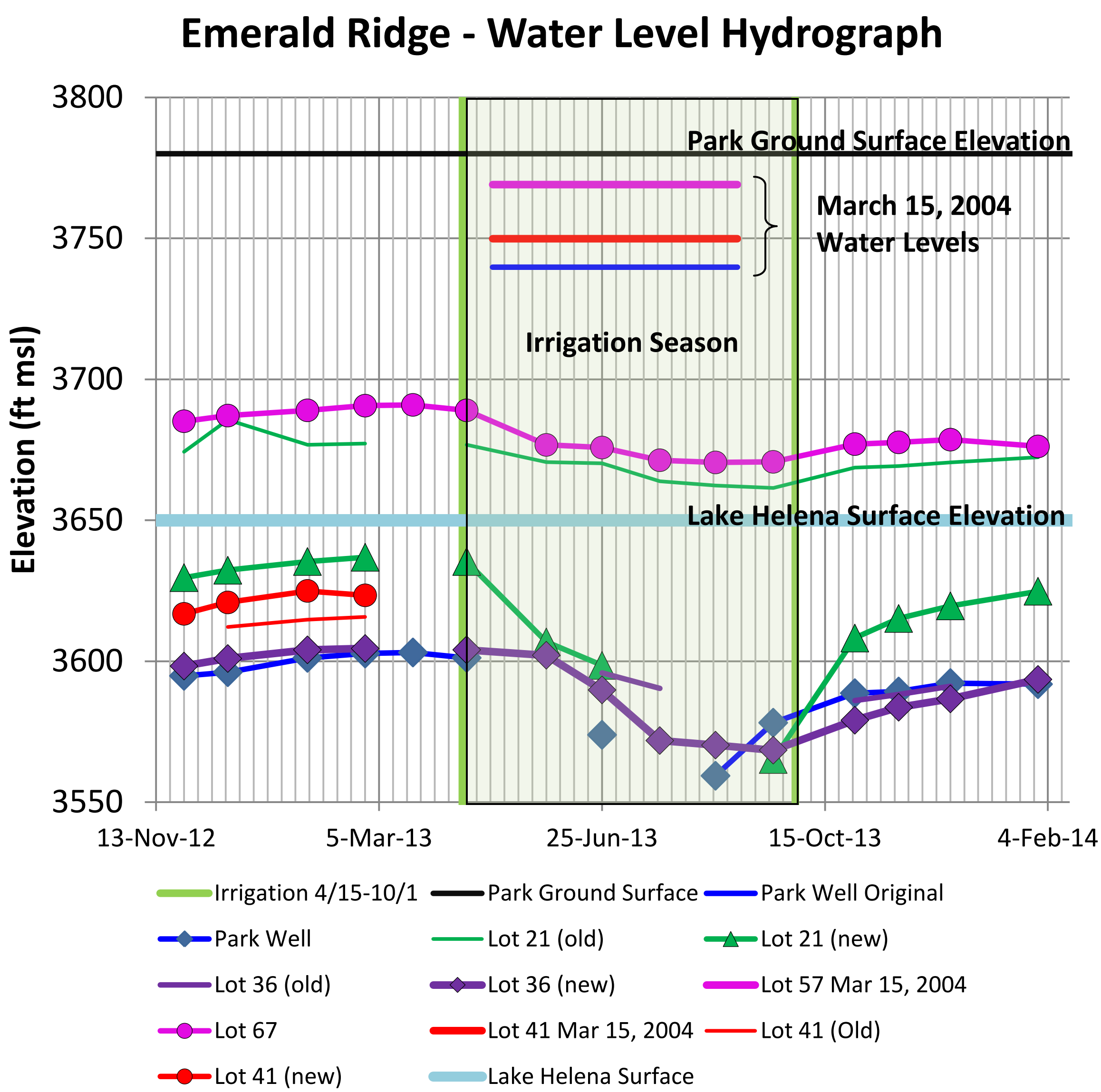


Figure 3 Hydrograph of Emerald Ridge Water Levels.

Water levels collected monthly by LCWQPD staff since November 2012. Primary aquifer recharge in the Helena area occurs during Irrigation season, from April 15 to October 1. Dewatering of the aquifer is visible with the change in elevation since 2004. The deep wells appear connected to the same aquifer system as the Park well, with similar drawdown patterns. Note no recharge visible from irrigation waters, and recovery levels in Winter 2014 are below levels from Winter 2013.

Note: For clarity in the text of this document,
"Old" wells are also referred to as "shallow" wells, and represent the "upper" part of the aquifer.
"New" wells are also referred to as "deep" wells, and represent the "lower" part of the aquifer.

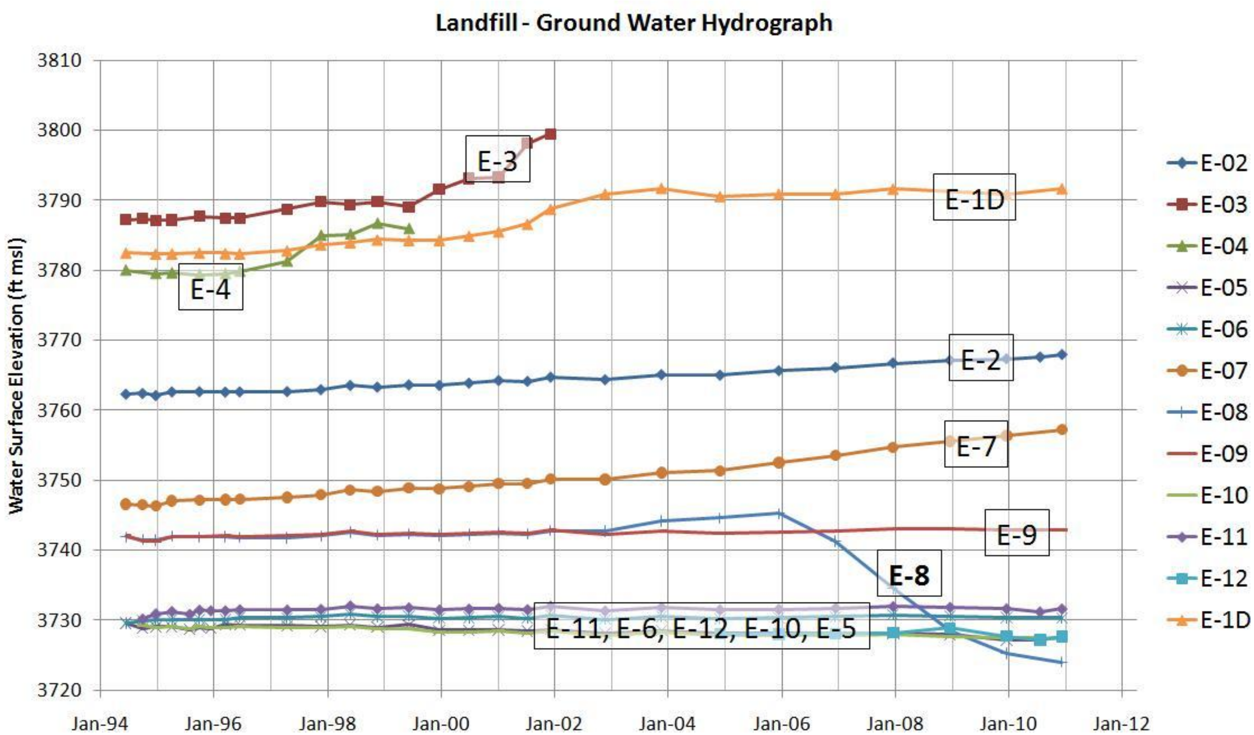


Figure 4 Hydrograph of Water Levels at Lewis & Clark County Landfill

Data obtained from monitoring report for the Landfill (Tetra-Tech, 2012)

Geologic Setting and Aquifer Properties

The Emerald Ridge area is located on the hills above the eastern margin of the Helena Valley (Figure 1). The geology around the the subdivision comprises the fine-grained sedimentary deposits of the characteristic of local Tertiary deposits. As an aquifer, the Tertiary deposits have limited yields, and water generally occurs within small, discontinuous lenses of coarser grained materials within the dominant clay-rich deposits. The clay deposits include volcanic ash layers with bentonite clays. These types of clays significantly expand when in contact with water, and are generally associated with aquitards that restrict ground water flow. The lack of water in the area is evidenced by the location of the Lewis & Clark County Landfill approximately ¼ mile northeast of the subdivision. This location was selected since potential impacts to ground water were considered unlikely due to the limited amount of ground water in the Tertiary deposits (MDHES, 1994).

The properties of the Tertiary deposits as an aquifer are in contrast with other aquifer systems in the area. In the lower elevation areas of the Helena Valley west of the site, the soils and underlying geologic deposits of the Helena Valley Aquifer comprise lenses of coarse grained sand and gravels interlayered with finer grained silt and clay-rich deposits, characterized by high yields from high permeability sedimentary deposits. The bedrock aquifers surrounding the southern, western and northern boundaries of the Helena Valley are dominated by fracture flow systems with variable yields which are difficult to predict. The fracture flow system develops from regional stresses to the rocks creating a fracture system. There is relatively little primary porosity in the dense bedrock units, so fractures represent the only conduits for water to flow. In addition, the bedrock lithologies are relatively consistent with little to no available fine-grained clays present which may retard flow within fractures. The bedrock aquifers generally show a strong response to recharge from local precipitation events.

Aquifer recharge is necessary for sustainable development of ground water resources. The Emerald Ridge subdivision is located on a local drainage divide between the Helena Valley and Hauser Lake. As a result, the primary source for local recharge is from direct infiltration of precipitation and snowmelt into the subsurface. Additional local recharge may occur from infiltration of irrigation waters to the east of the Emerald Ridge subdivision; however, the location of the irrigation canal east of the divide suggests that shallow ground water would follow topography to the east (Figure 5). When water levels are above the Helena Valley aquifer, local recharge represents the primary potential mechanism for recharge to the aquifer. As water levels drop below the level of Lake Helena and the Helena Valley Aquifer, a gradient between the valley into the Emerald Ridge area occurs, suggesting that flow directions may reverse with recharge. The recharge for Emerald Ridge contrasts with the recharge to the Helena Valley Aquifer, which receives abundant recharge from stream loss where streams enter the valley, stream loss from irrigation canals, from Mountain Block recharge in the subsurface, and direct infiltration of precipitation. Mountain block recharge represents ground water recharge to alluvial aquifers as flow in bedrock from mountain ranges which discharges into valley-fill alluvium in the subsurface.

The local geology defines the aquifer system and potential recharge paths for the Emerald Ridge area. North-south trending faults are present along the eastern margin of the Helena valley near the site (Figure 5). These faults reflect the geologic processes that formed the Helena Valley. While specific faults are identified near the Emerald Ridge area, the nature of the faults near the subdivision has been approximated. The faults appear to control local ground water flow, including recharge.

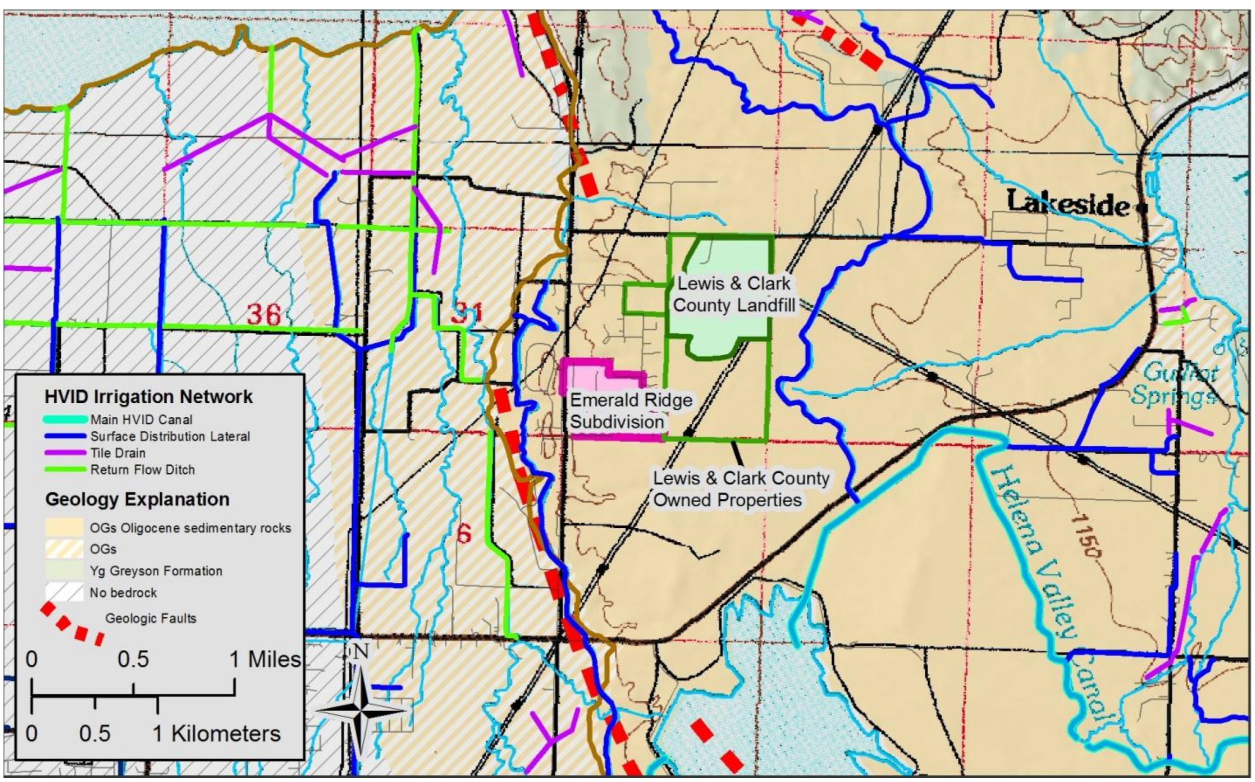


Figure 5 Emerald Ridge Area Geologic Map.
Geology adapted from Reynolds, in Thamke (2000). Basemap is 1:100,000 USGS topographic map..

Local Ground Water Quality

Water quality parameters include major ions, comprising the majority of dissolved solids in the water, and trace elements such as metals present at much smaller concentrations. Water types are classified based on the relative ratios between concentrations of the major ions. The different water types have different properties, such as hardness, that (may) require different types of treatment. Water samples were collected from three wells on September 18, 2012 and analyzed for major ion, nutrients and selected trace metals. The sampled wells included two wells at the Hiltunen Residence (Lot 36), with total depths of 245 and 600 feet, and the Park Irrigation Well, with a total depth of 400 feet. The data is listed in Table 1. The data results show relatively high concentrations of dissolved solids (TDS) associated with high sodium and sulfate concentrations. As shown in Figure 6, a stiff diagram of the data, the water is classified as a Sodium Sulfate water. For comparison, in the Helena area, locally recharged ground water (from direct infiltration of precipitation, stream loss or irrigation waters) is typically a Calcium-Magnesium Bicarbonate water (Swierc, 2013). For specific potential contaminants, nitrate was only detected in one sample, at the detection limit of 0.01 mg/L. Iron was detected in both the shallow and deep Hiltunen wells at 1.0 and 1.68 mg/L respectively, above the secondary drinking water standard of 0.3 mg/L. For trace metals, the only detection of concern is Arsenic in the shallow Hiltunen well, at 0.012 mg/L, slightly above the drinking water standard of 0.01 mg/L. In Tertiary aquifer sediments, Arsenic and Iron are common natural contaminants present in formation ground waters.

Table 1 – Summary of Water Quality Data for Ground Water Samples

Sample Location	MBMG-GWIC Identification Number	Total Depth (ft bgs)	Sample Date and Time	pH	Temp (°C)	Specific Conductivity (µs/cm)	Dissolved Oxygen (mg/L)
Hiltunen Deep Well	258900	600	9/18/12 11:30	7.79	16.8	742	0.27
Hiltunen Shallow Well	244157	245	9/18/12 11:55	8.14	14.7	752	0.56
Park - Irrigation Well	214268	400	9/18/12 12:20	8.05	15.7	989	4.55

Sample Location	Solids, Total Dissolved TDS @ 180 C, mg/L	Alkalinity, Total as CaCO3, mg/L	Bicarbonate as HCO3, mg/L	Carbonate as CO3, mg/L	Hardness as CaCO3, mg/L	Cl, mg/L	SO4, mg/L
Hiltunen Deep Well	537	180	220	<1	103	33	200
Hiltunen Shallow Well	617	170	200	<1	183	29	280
Park - Irrigation Well	809	150	180	<1	233	43	410

Sample Location	NO3+NO2 as N, mg/L	Phosphorus, Total as P, mg/L	Ca-D, mg/L	Mg-D, mg/L	K-D, mg/L	Na-D, mg/L
Hiltunen Deep Well	<0.01	0.004	39	2	7	139
Hiltunen Shallow Well	0.01	0.011	67	4	10	137
Park - Irrigation Well	<0.01	0.007	87	4	14	171

Sample Location	As-D, mg/L	Cd-D, mg/L	Cu-D, mg/L	Fe-D, mg/L	Pb-D, mg/L	Se-D, mg/L	U-D, mg/L	Zn-D, mg/L
Hiltunen Deep Well	< 0.003	<0.00008	0.001	1.00	<0.0005	<0.005	0.007	0.34
Hiltunen Shallow Well	**0.012**	<0.00008	0.011	1.68	0.0088	<0.005	0.008	0.03
Park - Irrigation Well	< 0.003	<0.00008	< 0.001	0.07	<0.0005	<0.005	0.007	0.03

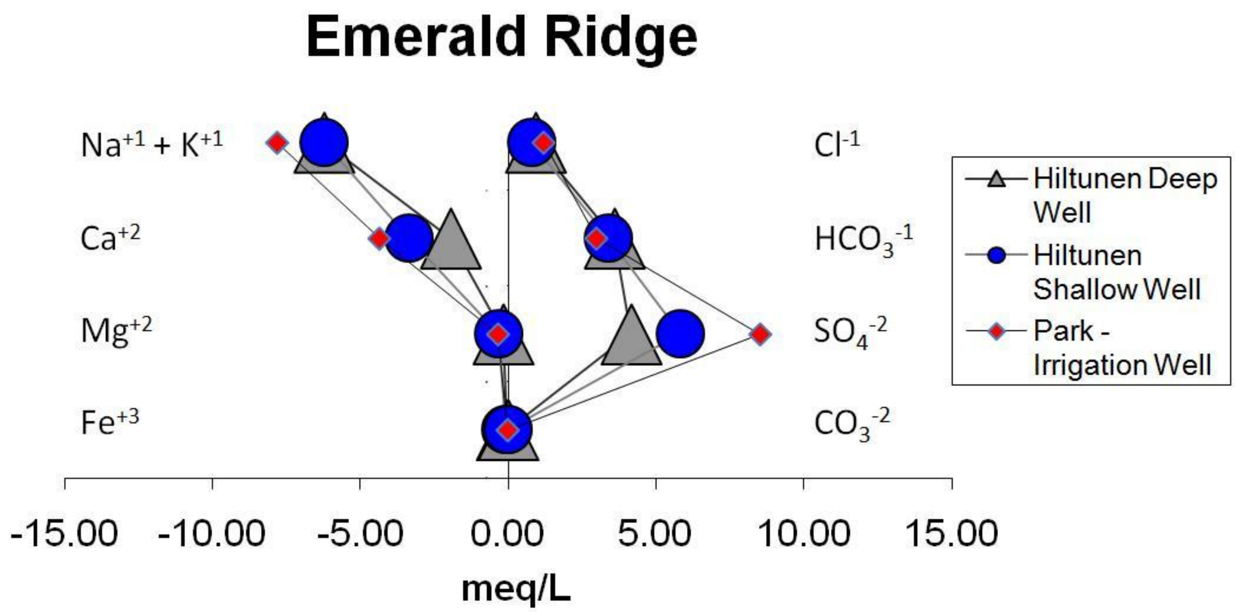


Figure 6 Stiff Diagram of Major Ions in Emerald Ridge Ground Water.
The stiff diagram shows relative proportions of major ions as milliequivalents reflecting the total ionic charge from each compound. The total size of the polygon reflects the concentration of Total Dissolved Solids in the sample.

Ground Water Temperature

The Tertiary aquifer water quality type for the Emerald Ridge subdivision aquifer indicates that direct recharge does not occur from local streams or irrigation waters. While local precipitation may infiltrate into subsurface within the subdivision, this is not considered likely to be a significant recharge source to the deeper aquifer due to the fine-grained nature of the soils and geologic units in the area. Ground water temperature provides additional information indicating that recharge to the local depleted aquifer occurs from depth, likely in the deepest part of the Helena Valley. This is consistent with the local regional conceptual model of ground water flow, where all ground water upwells towards Lake Helena as a discharge point for both surface and ground waters in the valley (Briar & Madison, 1992; Thamke, 2000).

Ground water temperatures typically are just above the mean normal annual temperature for an area. Near the surface, temperatures will fluctuate seasonally due to thermal heating from the surface, with this effect generally gone by about 75 feet below ground surface (Heath, 1983). Beneath this depth, ground water temperatures increase with depth at approximately 0.55°C/100 feet depth – with this trend referred to as the ***geothermal gradient***. Local studies in the Helena area have indicated that valley waters are typically heated above what would be expected by the normal geothermal gradient (Swierc, 2013). From background wells in bedrock wells north and west of the Helena Valley, the general background temperature at the surface is 8°C, with temperatures increasing with depth along the normal geothermal gradient. Ground water temperature data from around the Helena area is depicted in Figure 7, with data from the Emerald Ridge wells. The data shows numerous ground water temperatures above those expected by the normal geothermal gradient. The Emerald Ridge data shows a consistent thermal overprint, with temperatures increasing along the geothermal gradient as expected. This indicates a similar recharge source and connection for the upper and lower parts of the aquifer.

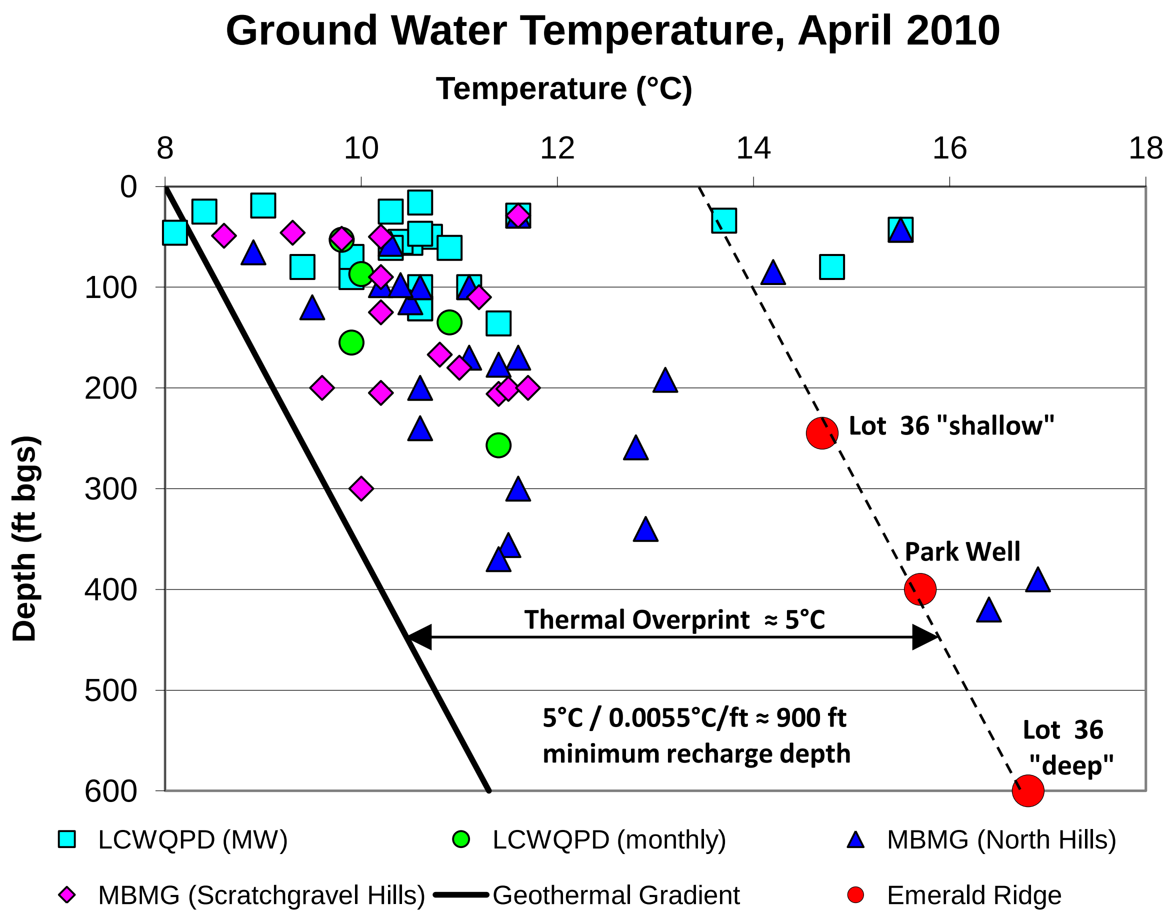


Figure 7 Emerald Ridge and Helena Valley Ground Water Temperature.
Data plotted from sampling events in April 2010. LCWQPD Samples were collected as part of the Helena Ground Water Project (Swierc, 2013). MBMG data were collected as part of the Ground Water Investigation Program projects implemented in the Helena area, including the North Hills (Waren et al., 2012) and Scratchgravel Hills (Bobst et al., 2013). Data for Emerald Ridge indicates similar recharge source for area based on consistent thermal overprint on what would be predicted at the normal geothermal gradient.

Discussion

Water level data indicates that depletion of the local aquifer at the Emerald subdivision has occurred since initial development of the area in 2004. With depletion of the water table surface by 100 to 150 feet over a ten year period, simple math indicates depletion rates ranging from 10 to 15 ft/year across the property. Without recharge to the aquifer, continued pumping at current levels will likely continue to further deplete the local aquifer system. With time, the risk to wells will increase with relative risk higher for shallower wells than deeper wells. In other words, shallow wells may require replacement sooner than deeper wells, but the deeper wells are still at risk.

While the lower part of the aquifer appears to have sufficient permeability and connectivity across the site for withdrawals, significant recharge to the system does not appear to be occurring demonstrated by the continuing depletion of the aquifer. The ground water quality type based on major dissolved ions, and ground water temperature, demonstrate that the water is not representative of ground water in the Helena Valley aquifer. Based on available data, the recharge mechanism is interpreted to occur from deep Helena Valley ground water present in Tertiary strata. Vertically upward ground water flow along the faults on the east side of the Helena Valley provide conduits for recharge. Unfortunately, the recharge rate to this aquifer is extremely slow due to the fine-grained nature of the Tertiary sediments. In addition, while an eastern gradient from the Helena Valley aquifer to the local aquifer at Emerald Ridge is present, recharge does not appear to be occurring from this source. As a result, continued withdrawal of ground water from this aquifer represents a non-sustainable source which is unlikely to continue to provide sufficient yields for even domestic wells for the long-term future.

Continuing Activities by LCWQPD

The LCWQPD will continue to collect data at the Emerald Ridge subdivision to characterize the ground water system. These activities include:

Water quality sampling from the Park Well – A sample for major ion chemistry will be collected to determine if local recharge is occurring. The most likely source would be from the Helena Valley Irrigation District canal located west of Emerald Ridge (see Figure 5). Increasing relative proportions of calcium/magnesium and bicarbonate to sodium/potassium and sulfate from water samples would indicate that recharge is occurring from the west. However, a number of residential well are present which may intercept this water, and also may contribute to the depletion of the aquifer at Emerald Ridge subdivision.

Water level transducer to be installed in the Park Well – Continuous measurement of water levels from the Park Well will help indicate if recharge is occurring coincident with the major recharge events for other aquifers in the area. These events represent high surface water flows during spring runoff, and the start of irrigation season.

Additional water levels from two to four locations for both shallow and deep wells. Continued monitoring of water levels on a monthly basis will provide data to determine ground water flow directions for the upper and lower parts of the aquifer, and provide data to determine aquifer depletion rates over time. Additional water level monitoring and sampling will be attempted at residential wells west of Emerald Ridge, and at the storage area located to the southwest.

Determination of the aquifer geology is critical to understanding the ground water system. Since well logs show different interpretation, the hydrogeologist from the LCWQPD would like to be present when additional deep wells are drilled to observe subsurface lithologies for the well long, and to collect samples of geologic materials encountered.

Recommendations

While studies may be performed to characterize the rate of recharge to the local aquifer, continued depletion can be expected based on current data. As the base water level lowers each year, the risk of well loss from ground water depletion will increase yearly, with higher risk to more shallow wells. With the current and potential future impacts to the system, the need for a replacement water system should be discussed so that the related issues can be addressed.

While there are different potential solutions, they all involve locating a new water source for residents. The biggest issue with this represents water rights for a new water source, since the Helena Valley and surrounding area represents a “closed” basin for new water right development. The best water sources, based on location, would be from the Helena Valley Aquifer and/or Lake Helena, or from Helena Valley Irrigation District waters.

The following are potential solutions.

- Cisterns could be installed at each house as well become unserviceable due to lowering water levels. This would require residents to obtain water from another source, usually a licensed public water supply system, which would be transported and pumped to individual tanks at houses.

- Development of a traditional Public Water Supply (PWS) for the subdivision, which would require a treatment and distribution system.

- Develop a managed aquifer recharge, or aquifer storage and recovery system, which would pump water into the aquifer for recharge. This option may allow for the continued use of existing wells; however, further characterization of the aquifer properties is necessary to determine the feasibility of such a program.

Regardless of the solution, obtaining an engineering assessment which compares installation and long term operation costs between potential solutions is recommended.

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