Characterization of Groundwater in the Upper Grande Ronde Basin

NOTE: *It is important to note that this information is for planning purposes only; any interpretation is done at the discretion of the planning group. If the group would like to use this information beyond its initially intended use as an informational resource to inform planning, OWRD requests that the group contact OWRD staff. Also, OWRD requests that staff be able to review any products that this information is used in – including those related to place-based planning- in order to ensure accurate use of the data and analysis.*

Introduction and Purpose

This memo is intended to expand upon the background and data included in the Upper Grande Ronde (UGR) Place-Based Planning Step 2 and Step 3 reports regarding groundwater supply for current and future appropriation. The purpose of the memo is to introduce and document foundational groundwater concepts important to the Upper Grande Ronde basin and how those concepts, along with legal controls, impact current and future groundwater supply. For a broader exploration of groundwater, please review the USGS Publication, "Groundwater and Surface Water – A Single Resource" (Winter 1998).

This memo is organized by the following sections:

- Understanding groundwater supply for appropriation
- Understanding capture
- What we know about the UGR groundwater resources – physical and legal controls
- Summary of gaps in groundwater data and knowledge and future proposed work to improve groundwater data sets

Understanding Groundwater Supply for Appropriation- Background

This section describes foundational groundwater concepts for understanding groundwater supply and utilizes a simplified Groundwater supply, or the amount of water available for withdrawal, is ultimately a balance between the three major components of a groundwater system:

- Recharge - the groundwater coming into an aquifer system controlled by surficial and subsurface characteristics, precipitation variability in space and time, climate patterns, and groundwater flow from other aquifers. Think of this as a deposit to the groundwater budget "account". Note that annual recharge will vary with climate variability.

- Storage - the groundwater slowly moving through an aquifer system controlled by the characteristics of the aquifer such as its porosity and the degree of fracturing. This can be thought of as a "savings account" for groundwater. That said, storage and supply are not the same thing – supply is the water that can be appropriated and is a function of how storage responds to other factors.

- Discharge – the groundwater leaving an aquifer system, naturally through discharge to rivers and streams, springs, into other aquifers or pumped from wells. Think of this as a withdrawal from the groundwater budget "account".

The amount of groundwater available for withdrawal over a period of time depends on the management tradeoffs made between these three system components. Ultimately, the three components achieve a balance (known as dynamic equilibrium), and it is the understanding and management of this balance that is key to defining and achieving sustainable groundwater development (e.g., Theis, 1940).

To introduce conceptually how these components can work together, below is a description of a very simplified aquifer system as it responds to increased pumping over time. For this example, we are assuming that recharge remains constant over the example, and we are assuming the entire aquifer system is homogenous and therefor responds similarly across the aquifer systems. As a reminder, this is a simplified system and actual aquifer systems will have many complicating factors that shift the response of the system in time and space.

Stage 1 – Dynamic Equilibrium. In a system where there is no pumping, the components of recharge, storage, and discharge are in equilibrium over the long term, with fluctuations in the system occurring as climate patterns shift rates of recharge, or over geologic periods when the characteristics of aquifers change (Figure 1).

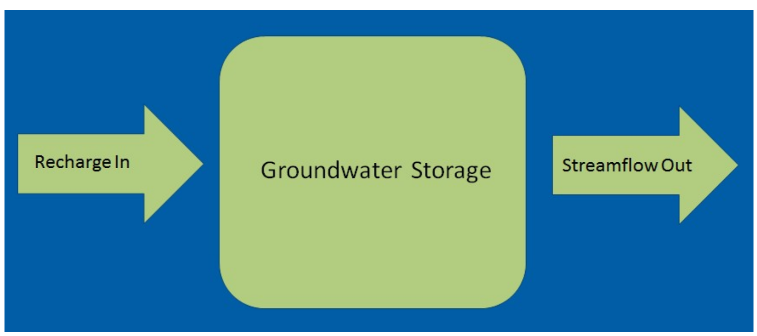

Figure 1. A groundwater system in equilibrium where, generally on average, recharge is equivalent to discharge, and storage doesn't increase or decrease.

Stage 2 - Increased discharge. In this hypothetical example, pumping has greatly increased, and so discharge overall has increased (Figure 2). The immediate impacts of increased discharge on the groundwater system may not be noticeable for some time depending on the characteristics of the aquifer and stream system, with initial development affecting groundwater storage to a larger degree than stream discharge (e.g., Barlow and Leake, 2012).

Figure 2. In this system, groundwater discharge has increased, but there is yet to be a measureable change in the groundwater storage or other aspects of discharge such as streamflow from groundwater.

Stage 3 – Decreased storage. If pumping continues to increase or continues at the same rate for a long time, eventually the groundwater storage in our hypothetical aquifer is decreased since recharge is not changing (Figure 3). If there are wells that are not deep enough to reach the lowering water table, they will no longer be able to withdraw water without being deepened.

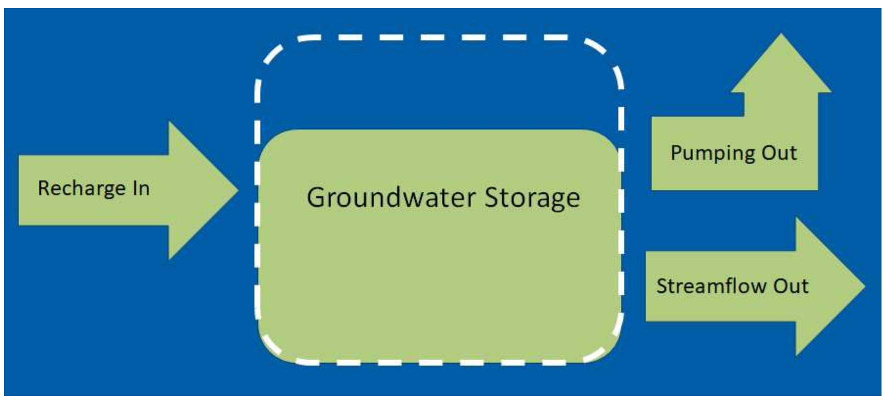

Figure 3. In this system, groundwater storage has now decreased given that discharge is now greater than recharge because discharge to pumping and streamflow is greater than recharge.

Stage 4 – Continued declines or new equilibrium. In this hypothetical example, the storage volume has dropped enough that natural discharge to streams has decreased, and therefore overall discharge has decreased (Figure 4). In this new equillibrium, recharge and discharge are once again equivalent, and groundwater storage ceases to decrease. If the rate of discharge continued to increase beyond the rate of recharge, groundwater storage would continue to decline until the rate of stream discharge decreased or stopped, otherwise known as capture (see below). If pumping continued to increase, storage would diminish to the point where the only groundwater available would be year-to-year recharge, what may be described as “living paycheck to paycheck.”

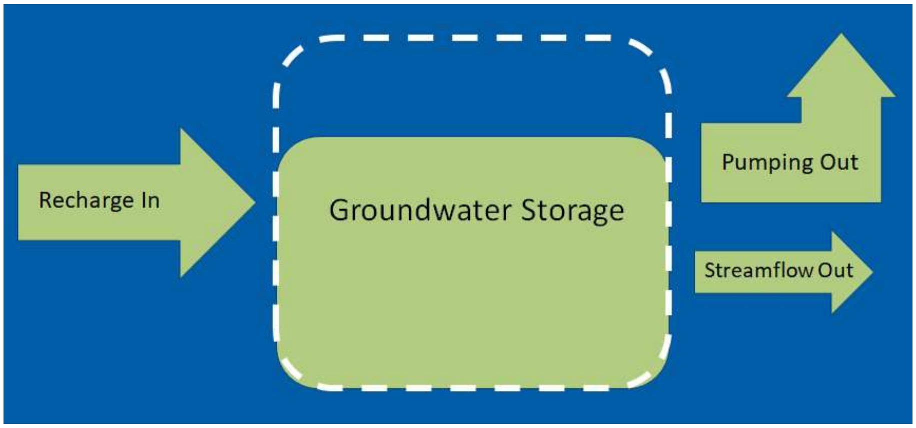

Figure 4. A new equilibrium is established when groundwater discharge decreases, in this example because discharge to rivers and streams has decreased significantly and discharge to pumping has decreased minimally.

Understanding Capture – interaction between groundwater discharge and pumping

Capture is a term used to describe any decreases in groundwater discharge and/or increases in groundwater recharge at interfaces with surface waters caused by pumping of groundwater (Barlow, 2018). Almost all pumping captures some groundwater discharge (Figure 5). Capture is important to understand because it may limit groundwater supplies in the future.

Within the simplified groundwater development process described above, capture occurred when pumping interfered with groundwater discharge to streamflow (Stage 4). Capture, and the concepts discussed here, highlight the complexity of managing groundwater.

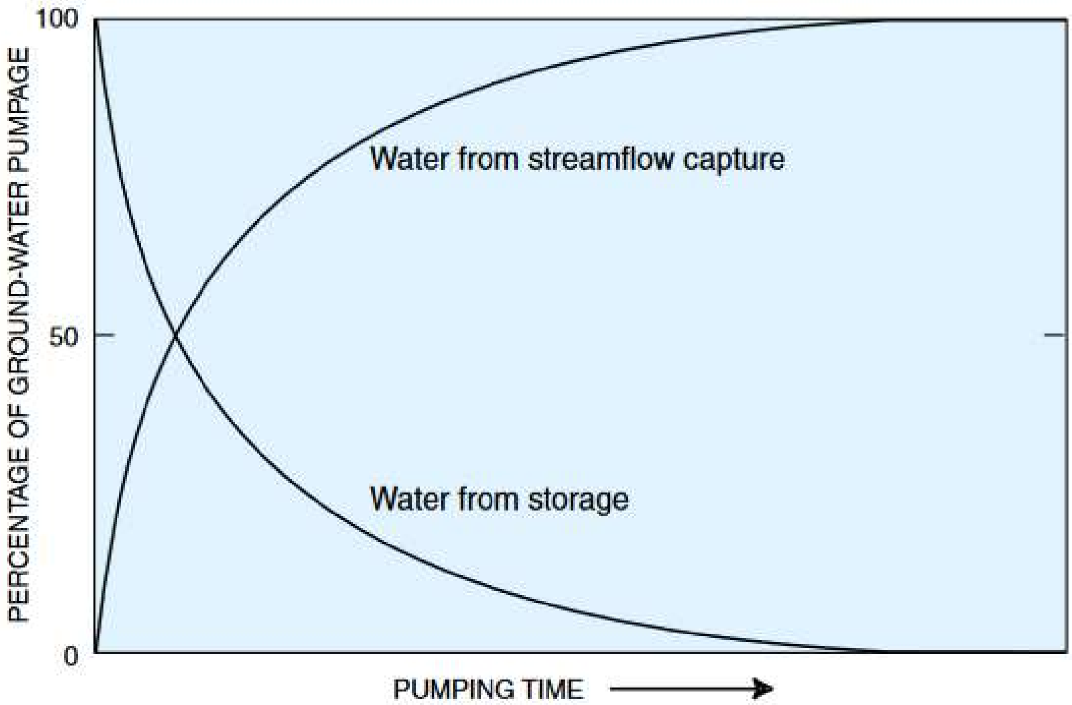

Figure 5. Copied from Alley, 1999. Graph relating the percent of pumped water coming from storage versus that being captured from streamflow over time in a theoretical, simple aquifer system.

Reviewing this same stage-wise process across the landscape can help demonstrate how capture occurs in terms of flow-paths (Figure 6). Under natural conditions (Figure 6, A), groundwater discharges to the stream. Once a well is drilled and water is being pumped from that well, the flow paths of the water change, and some of the groundwater that would have discharged to the stream naturally now is captured by the well (Figure 6, B). If pumping were to occur at a higher rate, the hydraulic gradient may be reversed, resulting in a losing reach of the stream where surface water is lost to the surrounding geologic materials. If this condition persists, it is possible that captured surface water from the stream would inevitably be discharged from the well (Figure 6, C).

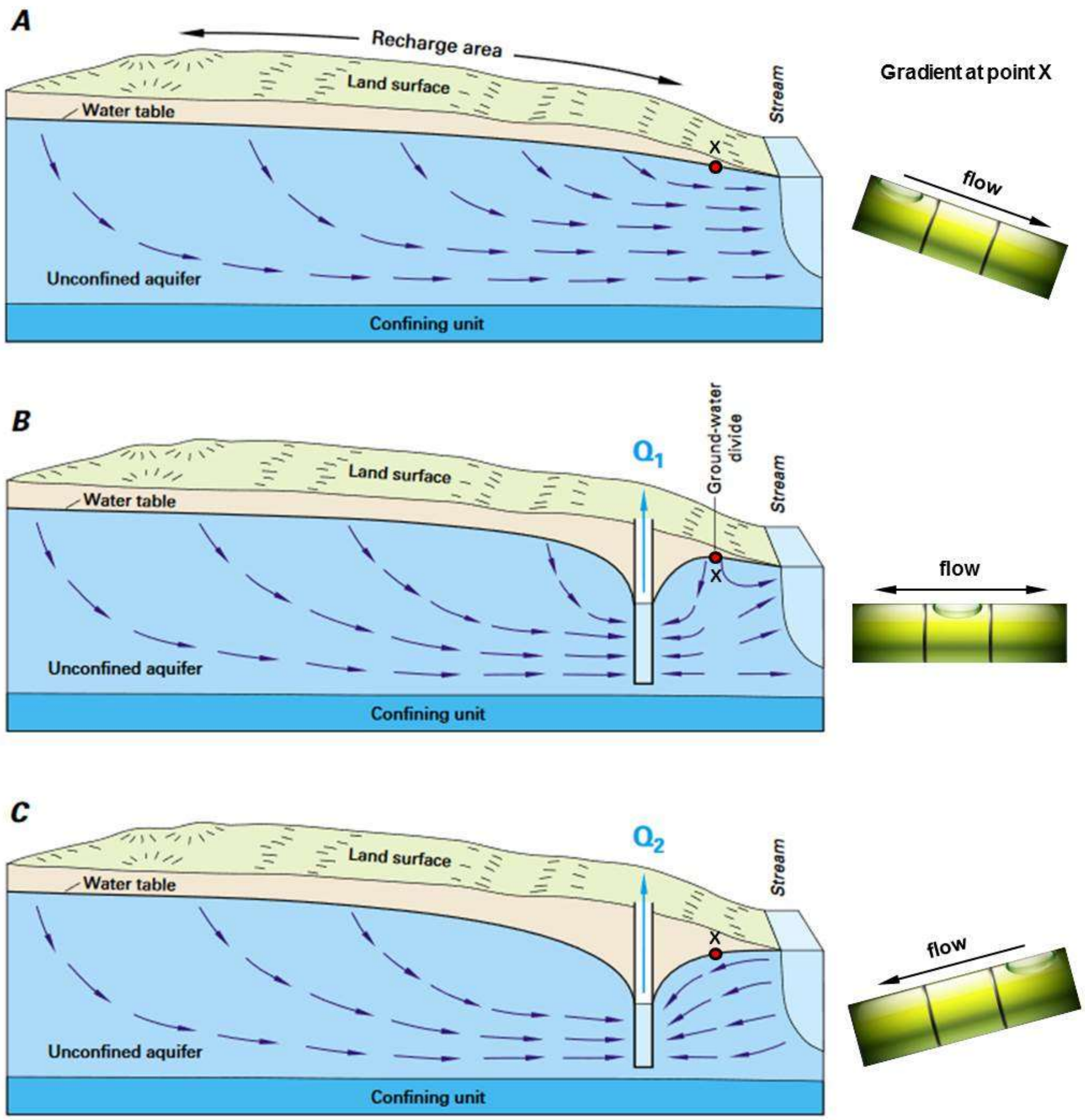

Figure 6. Adapted from Alley, 1999. Diagram showing the development of groundwater capture at two different pumping rates (Q1<Q2) and the impact of pumping rates on hydraulic gradient and ultimately, flow path direction.

In more complex aquifer systems, where there may be a mix of different aquifers and variation in the characteristics of those aquifers, flow paths can vary both in their length and the time it takes water to move along the pathway to a point of discharge (Figure 7).

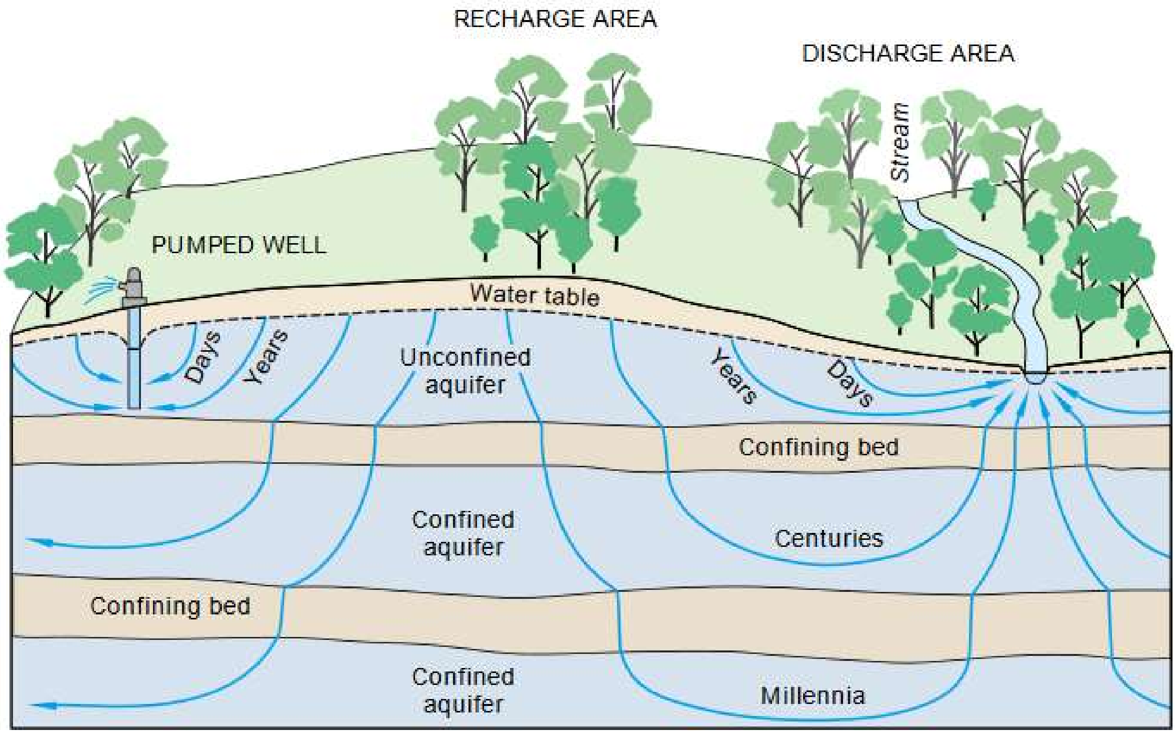

Figure 7. Copied from Winter, 1998. Diagram showing how groundwater flow paths, literally the path that water takes from a recharge area to discharge into a stream or by pumping from a well. These flow paths vary by length and the amount of time it takes to traverse the path.

Understanding Aquifer Systems of the Upper Grande Ronde (UGR) Basin

In the UGR basin, there are multiple aquifers, though generally they can be divided into two systems: the alluvial system and the Miocene volcanic system. These systems, though governed principally by the characteristics of each system (permeability, porosity, specific yield), are also impacted by interaction with the other aquifer systems, though these interactions have not been directly studied. It is important to note that these aquifer systems are distributed unevenly across the basin, with the alluvial systems found only in the valley bottoms. The alluvial basin-fill aquifer system was created primarily by the deposition of sediments from water that has flowed through the valley (Figures 8 and 9) and is composed of fragments of rock and soil from higher elevation drainages. Miocene volcanic rocks are exposed at the surface on the edges and outside of the low-lying river valleys, where subsided volcanic rocks have not been covered by sedimentary deposits. Within the valley, alluvium above the Miocene volcanics may be greater than 2,500 feet thick in many cases making it expensive or infeasible to drill wells targeting the volcanic aquifers. Below are described past and, where available, current information about both aquifer systems.

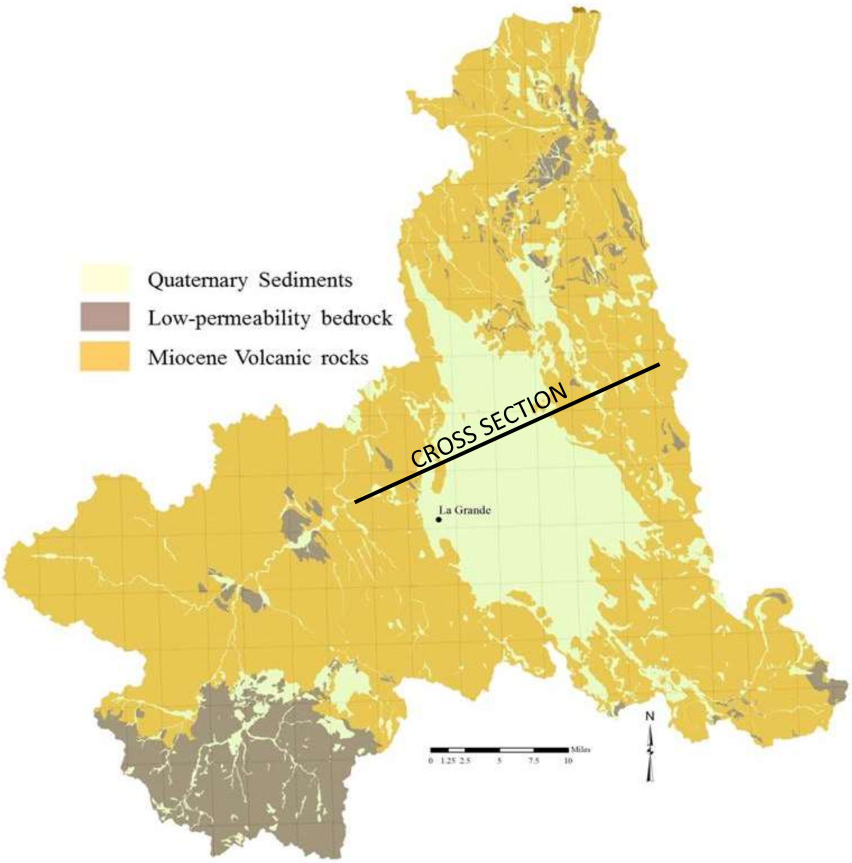

Figure 8. Geologic map of the UGR basin. The Quaternary sediments are the alluvial sediments referred to earlier in this memo, the Miocene Volcanic rocks are inclusive of the Columbia River Basalt Group (CRBG) and later erupted Powder River Volcanics (PRV). The low-permeability bedrock generally underlays these two other systems and typically does not yield adequate groundwater for economic use (Ferns et al., 2010).

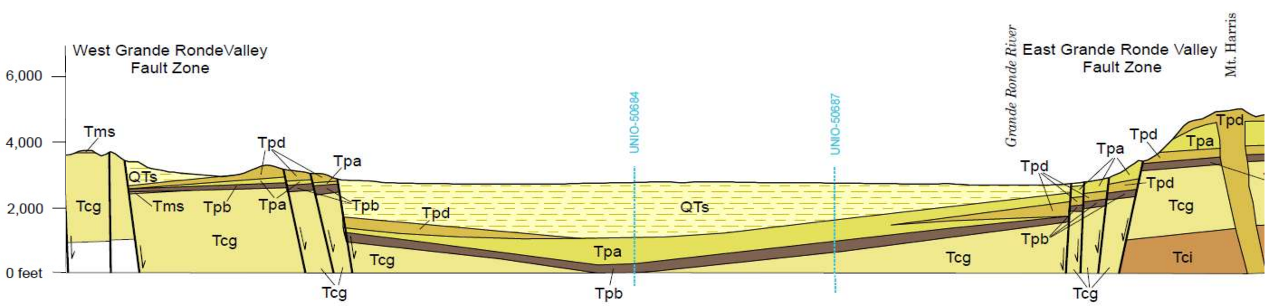

Figure 9. Geologic cross-section of the UGR basin (see Figure 6 for location). The valley formation is clearly visible here where the QTs (quaternary) sediments have collected (Ferns et al., 2010).

Alluvial groundwater system

The unconfined alluvial aquifer system is characterized by sediments ranging in size from clay to boulders that were deposited as the Grande Ronde Valley deepened during the last 8 million years (Ferns, 2010) and is over 2,500 feet deep in places. Generally, the alluvial aquifer of the Grande Ronde Valley yields moderate to low rates of groundwater to wells, has relatively high rates of recharge, has an efficient hydraulic connection to surface waters, and supports the largest share of groundwater use in the basin. Recharge in the alluvial system is dependent on precipitation, flood events, and deep infiltration from surface water irrigation in excess of crop evapotranspiration.

In 1966, Herbert Ham of the Bureau of Reclamation published a groundwater supply study of the Grande Ronde basin. Using available precipitation and pumping data at the time, Ham estimated recharge rates from precipitation within the La Grande-Union – Upper State Ditch area of between 24,000 and 41,000 acre-feet per year. Note that this estimate of recharge should not be used to define a “safe yield” – although recharge does affect the water budget, including groundwater storage, it is the characteristics of the historic aquifer flow system relative to rates of pumping that are most important for informing management decisions around the amount of groundwater development that can be sustained while limiting impact on groundwater quality and freshwater ecosystems (Bredehoeft, 2002).

The alluvial system is recharged predominantly by precipitation that falls onto the valley fill and infiltrates below the vegetative rooting zone. Water level hydrographs show that there is a direct relationship between increased precipitation and rising water tables in the aquifer, indicating recharge from precipitation happens relatively rapidly (Ham, 1966). Ham concluded that recharge of groundwater was also occurring during high flow events from seasonally varying streams, primarily in areas of alluvial fans and unconsolidated deposits near the base of steep mountain slopes bordering the valley floor. Some additional recharge, he asserted, is likely to come from deep infiltration of irrigation water that originated from surface water.

Ham estimated that the average, annual contribution of groundwater to the Grande Ronde river and its tributaries was 13,000 acre-feet, with the majority occurring between June and October, though this number is estimated and should be used with caution (Ham, 1966). Ham speculated that given what is known about the geologic structure of the basin that there is likely little inter-basin flow. An advanced groundwater study would be required to determine the magnitude and direction of exchanges of water between aquifers. At this time, OWRD cannot easily estimate the annual volume of groundwater consumed by water rights since there is little to no metered water use reported to the Department.

Miocene volcanic groundwater system

The alluvial groundwater system is underlain by an aquifer system hosted in extrusive volcanic rocks of the Powder River Volcanics (PRV) and Columbia River Basalt Group (CRBG), initially erupted between 17 and 10.4 million years ago (Ferns and others, 2010). Portions of these thick lava flows are quite porous, providing high to moderate yield to wells. Existing estimates of recharge to the volcanic groundwater system are poorly quantified; there are no known location-specific estimates of rates of recharge for the volcanic aquifers in the UGR area. The volcanic groundwater system generally displays relatively low rates of recharge, though portions of this system may be connected to surface waters or other recharge conduits.

The regional volcanic aquifer system is known to produce significant rates and volumes of groundwater to wells, though much of this volume is thought to be derived from groundwater storage. Storage of water in these layered volcanic sequences largely takes place in the interflow zones between layers of dense rock. The dense interiors of flows themselves do not store or transmit groundwater effectively, it is the zones in between flows or the brecciated (cracked) areas of the flows that provide storage (Burns et al., 2012). Most of the discharge from subsurface Miocene volcanics is likely from pumping, though little is known about the total volume of water pumped from this aquifer. There are no known estimates of input from and discharge to the Miocene volcanics from other aquifer units within the basin. Some wells within the area show water levels which infer there is a pressure gradient driving water from the CRBG to the overlying PRV and alluvium (where present), though this data is sparse and may represent only small areas.

Groundwater Level Trends within the Alluvial and Volcanic aquifer systems

Groundwater levels can provide insight into the stability of groundwater supplies within a region, as well as the stability of aquifer storage. Within the UGR, declines in both major aquifer systems have been observed. Water levels show an estimated long-term average decline of 0 to 0.5 feet per year of the alluvial system, depending on the well (Figure 10a and 10b). Limited monitoring of the volcanic aquifer shows long-term average declines of 0.5 to 2.5 feet per year, depending on the well (Figure 11a and 11b). It is important to note that only limited data is available for both of these assessments, and without a more comprehensive network of monitoring wells and consistent measurements made over time, it is difficult to determine the spatial extent and long-term trends of any declines.

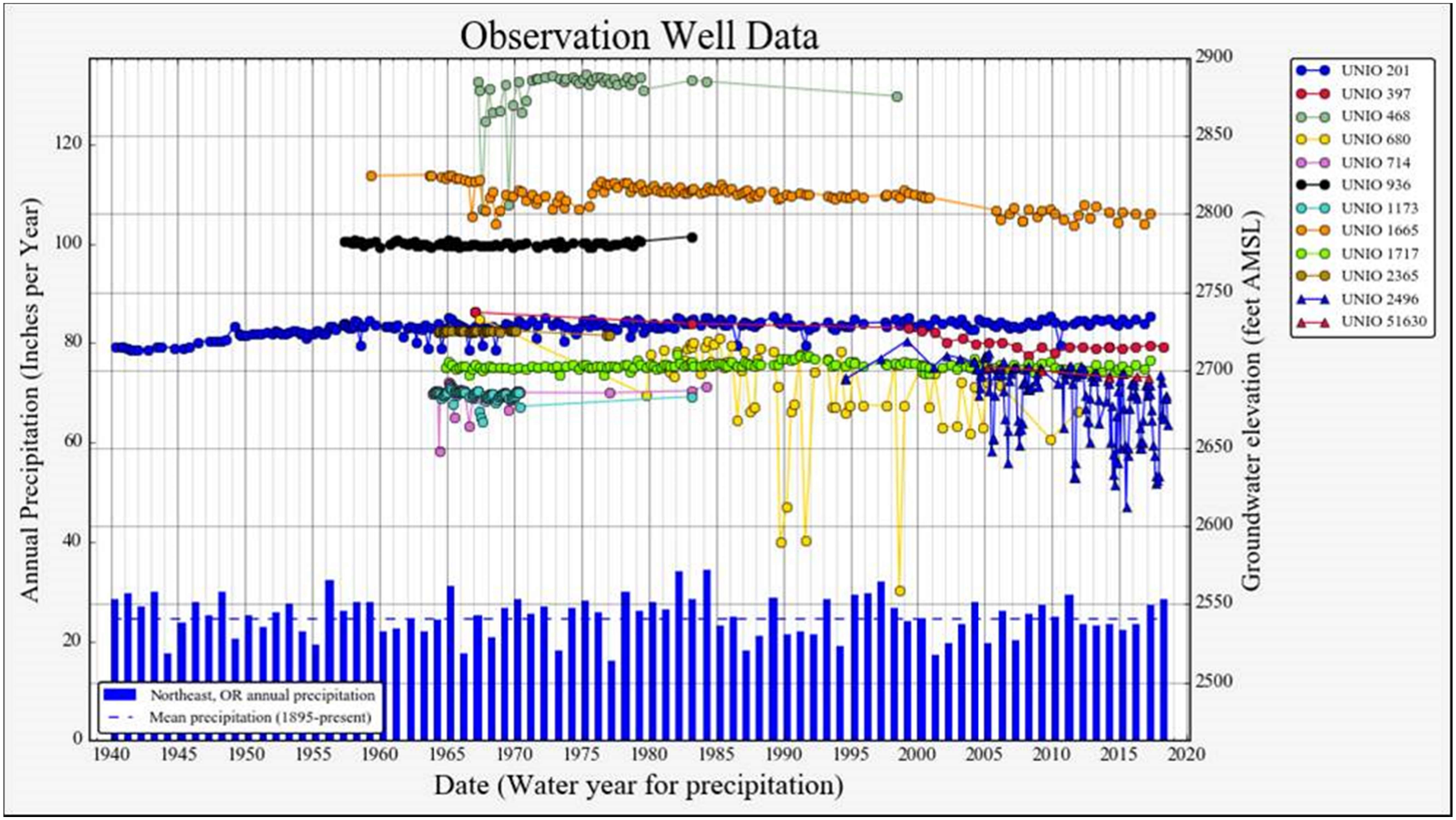

Figure 10a: Hydrographs for alluvial wells within the upper Grande Ronde Basin suggest that groundwater elevations are fairly stable. Groundwater elevations vary greatly depending on location and surface elevation of each observation well. Seasonal variations in water levels are much more pronounced in some alluvial wells (UNIO 680 and UNIO 2496) than others.

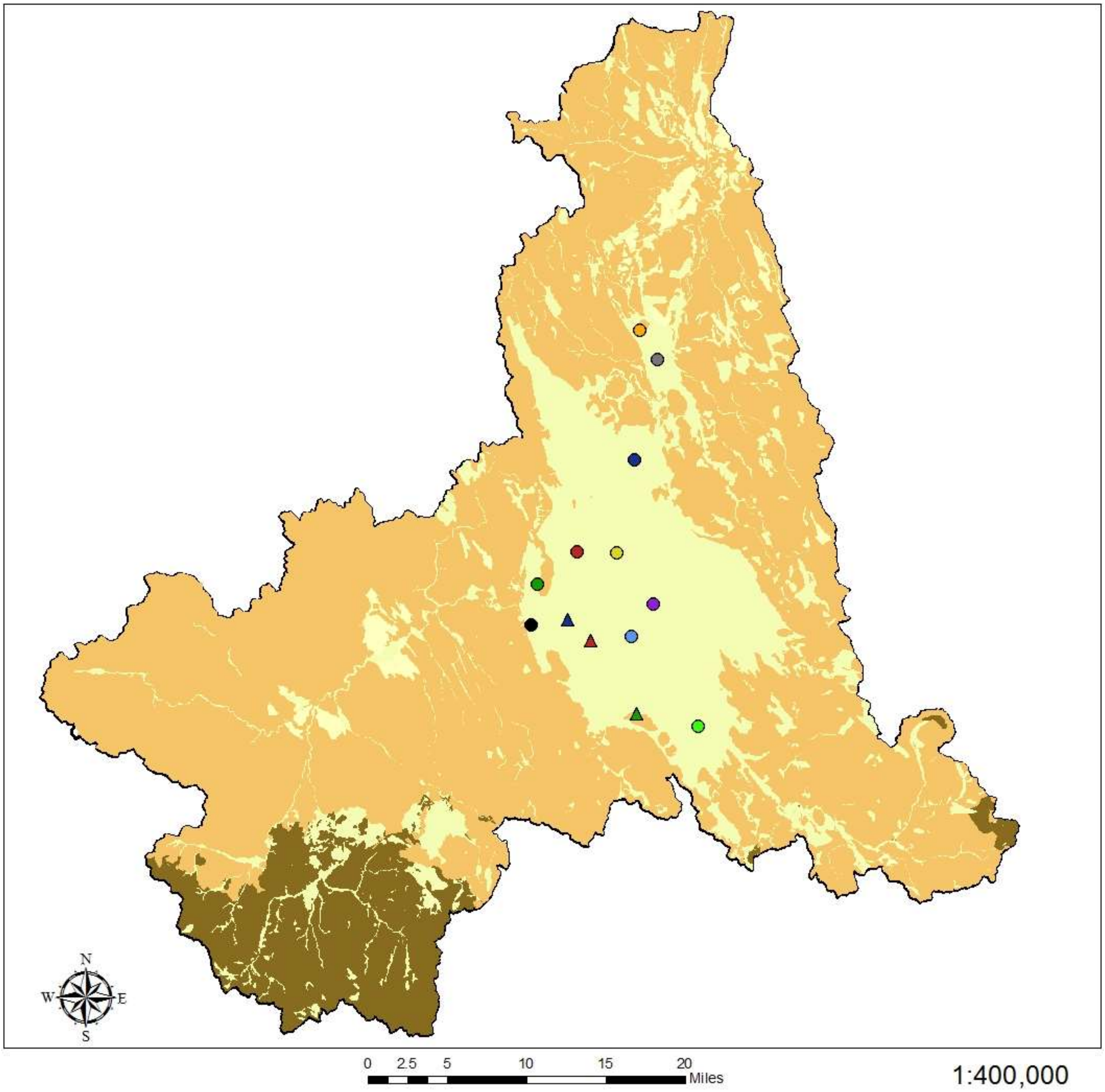

Figure 10 b. Accompanying map of the locations of alluvial wells with data displayed in figure 10 a. Note that all of the observations wells are located within the alluvial fill area (light yellow).

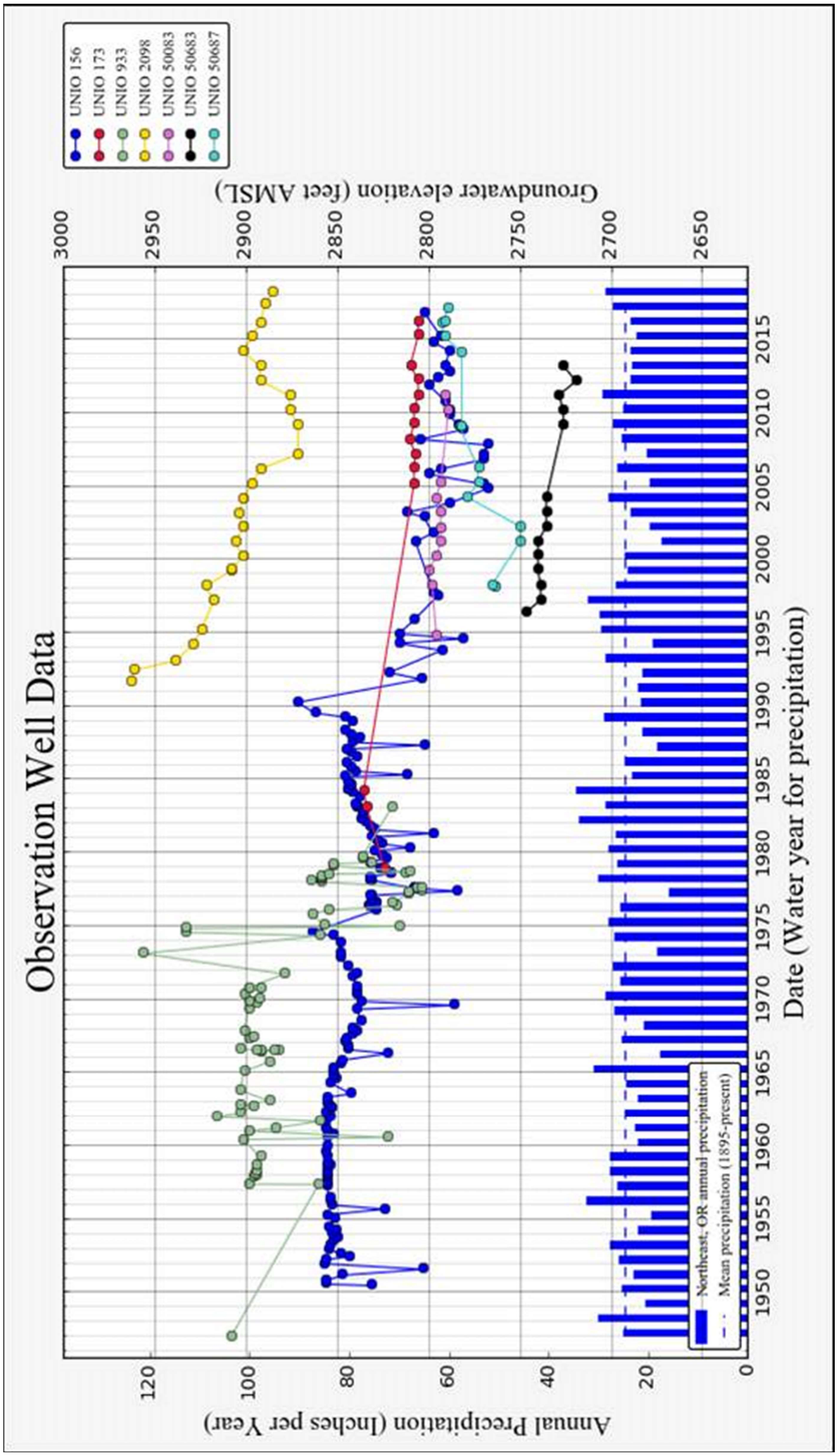

Figure 11a: Groundwater elevations within volcanic aquifers display relatively rapid changes in trend as compared to the alluvial groundwater system. The data suggest that there may be at least three distinct and separate aquifer systems represented here, based on groundwater elevation, with all three groups displaying some degree of decline.

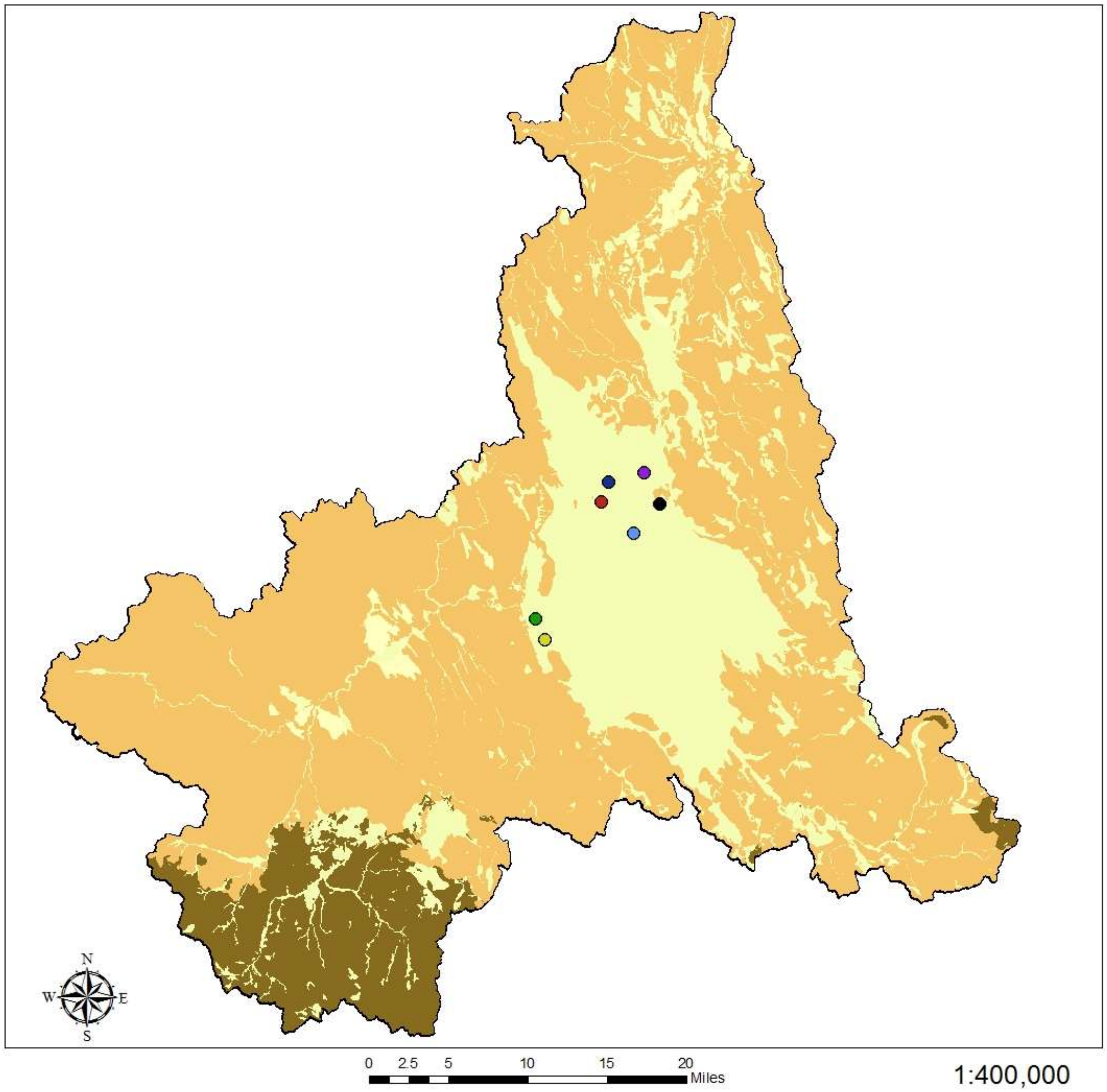

Figure 11b. Accompanying map of the locations of wells producing from Miocene volcanics with data displayed in figure 11a. Note that there are very few volcanic observation wells and that their locations are clustered.

Management of Groundwater Supply

Potential for development of additional groundwater resources

As noted in UGR's Step 2 report, OWRD has closed the alluvial system to new appropriation of groundwater within the basin to comply with State Scenic Waterway (SSW) rules which limit the granting of water rights from hydraulically connected groundwater to one percent of the mean daily flow of the SSW or 1 cfs (whoever is greater) once available surface water has been allocated (OAR 690-310-0260(9)). The intention of the rule is to consider the concept of capture in protecting instream flows such that new allocations of hydraulically connected groundwater do not measurably impact the protective SSW flows. Division 310 allows for mitigation of groundwater impacts, including impacts to SSWs, though there currently are no specific rules or laws governing groundwater mitigation for state scenic waterways outside of the Deschutes Basin. The UGR PBP group is welcome to pursue conversations with the Department regarding a new basin-wide mitigation program, though note that this would be a significant action and the Department would need time to prepare and coordinate with the PBP group. Any conversations about this solution would benefit from the establishment of an improved well monitoring network in order to collect more spatially and temporally complete data to be able to characterize the system and develop a better informed mitigation program.

The volcanic groundwater system is not closed to development, though as mentioned earlier, the cost of deep wells needed to develop this aquifer within the Grande Ronde Valley may prevent affordably accessing this resource. Additionally, there are many unknowns regarding the source, including large regional declines in volcanic aquifer water levels and unknown aquifer characteristics, which may discourage water users from investing in this source.

Summary of Key Findings

- Groundwater supplies are controlled by recharge, available storage, and discharge within the basin and groundwater interflow between the two major aquifer systems, as well as the underlying geologic structure of the basin
- Groundwater pumping, especially from the alluvial system, captures some natural groundwater discharge, and has the potential to reduce flows in hydraulically connected streams/rivers
- Water levels are declining in both aquifer systems, though most notably in the volcanic aquifer system
- New allocations of groundwater from the alluvial aquifer may occur if an approved approach to mitigation is established
- The lack of spatially distributed water level data, as well as data over time, prevents a more complete understanding of characteristics of the aquifers

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