

## Step 2 Surface Groundwater Interaction

### Introduction

The interaction between surface water and groundwater is complex. The interaction is affected by climate, landform, geology, and biotic factors. Precipitation amount and patterns are a critical limiter to the amount of groundwater in the landscape. Vegetation has a significant effect on the ability of precipitation to recharge into the ground through interception of precipitation and recycling water byway of evapotranspiration from the root zone. Landform structure and geology significantly affect the flow path and residence time of groundwater once recharge enters the aquifer system.

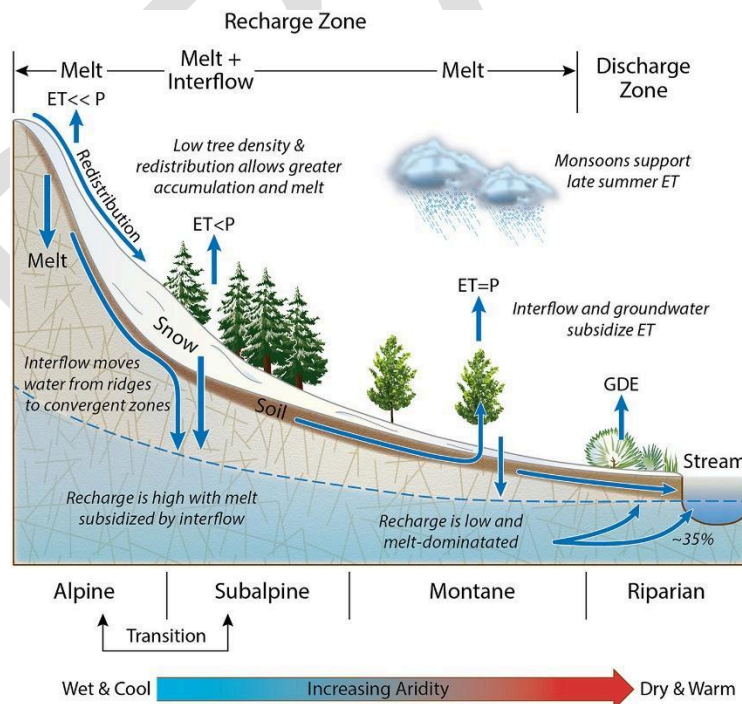
The Groundwater study of the Harney Basin (Gingerich et al., 2022) has a detailed description of the hydrostratigraphic units based on the geology work of Boschmann (2021). The authors (Garcia et al., 2022) conclude “most of the upland recharge reemerges as mountain streamflow upstream of the upland/lowland boundary”.

### Elements of Upland Groundwater Recharge

Once precipitation (either as snow or rainfall) reaches the land surface the soil, geologic characteristics, and soil moisture determine how the groundwater infiltrates and flows in the subsurface. The upland geology results in a topographically driven water table, where the shallow water table reflects the general shape of the topography. Water levels in the upland tend to be the highest in spring after winter snow melt and drops throughout the summer season, discharging to springs and streams. Surface vegetation intercepts and takes up soil and shallow groundwater reducing the amount of water available for either surface or groundwater yield from the catchment.

Headwater contributions to groundwater from snowpack has been explored by Carroll et al. (2019). They

have found that the dominant control on maximum recharge in the upper subalpine is topographically focused interflow transported from the alpine (Figure 1). While Steens Mountain does not have conifer in the subalpine and the Harney Basin does not get monsoon



Recharge and Landscape Position
<b>Alpine</b> Recharges groundwater and generates interflow.
<b>Transition (Upper Sub-alpine)</b> Convergent zone with melt and interflow producing recharge.
<b>Montane</b> Melt occurs early in spring to generate recharge. ET supplemented by interflow and monsoon rains.
<b>Riparian</b> A discharge zone with ET largely supported by monsoon rains and groundwater.

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rains, the model describes headwater contributions to stream flow and down slope recharge. The authors conclude that: “snowmelt transported via interflow from the alpine ridges toward the upper subalpine forms a preferential recharge zone as a function of convergent topography, and this mechanism may buffer groundwater recharge in a drying climate”.

The following is an effort to characterize the groundwater-surface water interactions by general catchments or basins draining towards Malheur and Harney Lakes.

### Harney Basin Surface-Groundwater Interaction from Groundwater Budget Report

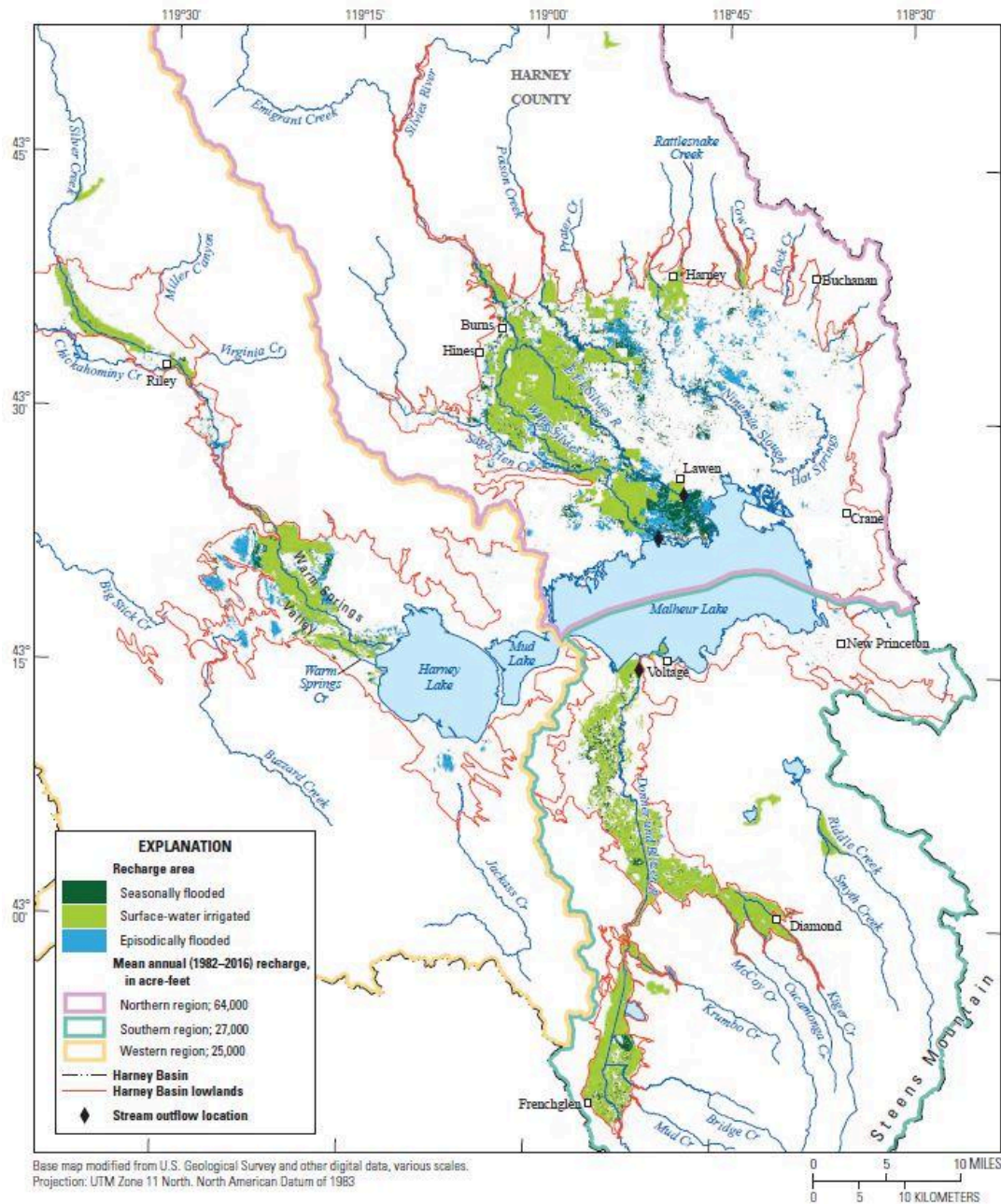
Garcia and others (2022) have measured and estimated the discharge of groundwater in the basin. They have identified some 2,474 springs in the uplands that clearly indicate short flow paths between recharge (precipitation) and discharge. Springs are much less prevalent in the lowlands portion of the basin and are very different in various parts of the basin. The Silvies subbasin has an estimated 2,500 acre-feet/year of spring discharge, mostly at the boundary between uplands and lowlands. The Silver Creek basin has some 24,600 acre-feet/year of estimated discharge, primarily in a group of springs in the Warm Springs Valley along the Brothers Fault Line. Spring discharge in the Blitzen subbasin is around the Page Springs area and lower in the basin adjacent to Malheur Lake (Sodhouse Spring). The discharge is estimated at 20,343 acre-feet/year. Figure 6 displays the local and mean discharge of the known major springs in Harney Basin.

Discharge from groundwater to streams occurs when the stream elevation is lower than the nearby shallow groundwater table. Groundwater can enter by diffuse seepage through the riverbed into streams directly from spring inputs to the river. Groundwater discharge is estimated from measurements of river discharge along the stream where groundwater input or output is suspected, analysis of stream gauge information, or investigation into known springs. The Blitzen River has the greatest discharge of groundwater, estimated at 8,035 acre-feet/year while the Silvies River has only an estimated 4,850 acre-feet/year of groundwater discharge. Silver Creek receives an estimated 6,009 acre-feet/year of groundwater. Groundwater discharge as baseflow accounts for some 60% of the total annual flow of the Blitzen River, 41% of the flow of Silver Creek and 30% of the flow of Silvies River.

Garcia and others (2022) estimated the discharge of groundwater to evapotranspiration to be approximately 119,300 acre-feet/year in the lowland portion of the Harney Basin. No estimate of evapotranspiration from the upland was provided. Figure 6 exhibits where the groundwater evapotranspiration areas are located, which is mostly in the lowlands. Evaluation from the Vegetation Management Work Group has shown that catchment contribution of water can be affected by vegetation cover in the uplands. The significance and relationship between forest cover and groundwater supply requires more study.

Groundwater discharge to Harney and Malheur Lakes was estimated to be relatively insignificant (473 acre-feet/year to Harney Lake and 58 acre-feet/year to Malheur Lake) in the groundwater budget.

Lowland recharge in the northern section of Harney Basin is primarily from surface water infiltration (82%) with the majority occurring due to spring flooding and flood irrigation (70%). Reinfiltration of pumped groundwater and recharge from the uplands makes up the rest of the 18%. Figure 2 shows recharge areas in the Harney Basin. For the southern section of Harney basin, most lowland recharge (56%) occurs from lowland surface water and upland recharge (42%) with very little input from infiltrated pumpage (3%).



## Tributary Interactions

### Silvies River

In general, the groundwater study (Garcia et al., 2022) characterizes the Blue Mountain uplands to the north of the basin as “The Blue Mountain uplands largely are comprised of low-permeability sedimentary, volcanic and metamorphic rocks that promote runoff of rainfall and snowmelt and limit the depth of recharge penetration and length of groundwater flow paths.” The low permeability and relatively steep landscape gradient above Bear Valley results in short flow paths with direct contributions to surface drainage. The Silvies River has a south facing aspect which means there is greater solar

exposure leading to greater solar heating and evapotranspiration than the Blitzen River. The Silvies River also has significant changes in gradient that includes relatively flat slopes through Bear Valley and Silvies Valley before it passes through a canyon reach to the Harney Valley (Figure 2). These lower gradient reaches have a greater potential for both surface and groundwater to interact through the hyporheic zone.

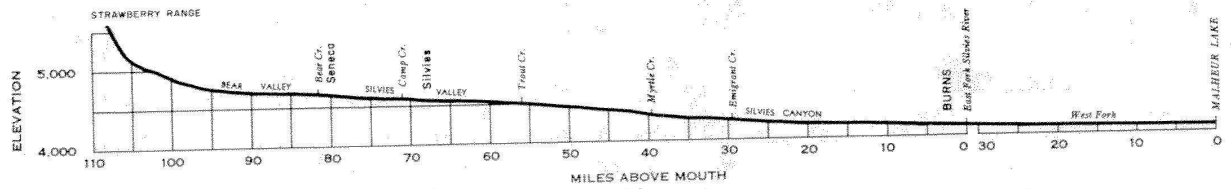


Figure 3: Silvies River Gradient (from OWRD, 1967)

The upslope vegetation of the Strawberry Mountains is conifer forest. Nearly half the basin is forested and some 35% of the basin has sagebrush steppe vegetation. The Silvies Basin has the greatest extent of coniferous forest of all the basins that drain to the lakes. The Vegetation Management Work Group has examined the forest conditions and the literature on the relationship between forest conditions and water yield and have concluded: “The greatest area of potential for influencing Basin water yields through vegetation management appears to be in the Silvies sub-basin based on total area receiving greater than 17.7 inches of precipitation that currently supports dense (>30%) tree cover.” The quantification and evaluation of the effects of forest vegetation management and priority areas for managing forest cover to affect water yield needs further evaluation.

Silvies Valley Ranch has implemented many push-up dams across tributary drainages, both intermittent and perennial, to imitate the effects of beaver (Davee et al., 2017). The potential effect of reintroduction of beaver to build more natural dams to better connect surface water to shallow groundwater through bank infiltration by raising the stream level in incised streams has not been evaluated.

Spring flooding and flood irrigation in the Silvies River floodplain is a significant source of groundwater recharge. Flooding and flood irrigation accounts for some 87% of the recharge from the Silvies basin. Spring flooding and spring stream flows vary greatly year to year depending on snowpack and timing of snow melt.

### Silver Creek

The authors of the groundwater study (Garcia et al., 2022) describe that the Silver Creek drainage “in the western part of the Blue Mountains north and west of Riley, Dry Mountain lavas and High Lava Plains basalt likely have longer groundwater-flow paths” when compared to the Silvies River drainage. The Silver Creek drainage follows the Brothers Fault Zone which could affect groundwater flow along the faulted Rattlesnake tuff and underlying lava rocks.

Silver Creek basin also faces to the south having similar runoff conditions to the Silvies. There is a steep gradient from the top of the catchment to near Riley where the gradient is flat (Figure 3). Silver Creek flows eventually to Harney Lake. Like the Silvies River, the upper portion of the catchment likely has very short flow-paths from the uplands to Silver Creek, however in this portion of the basin there are many playas, depressional features in the landscape that collect local runoff into temporarily ponded sites. The distribution of playas and their role in shallow groundwater recharge is unknown for the northern

Great Basin (Russell et al., 2020).

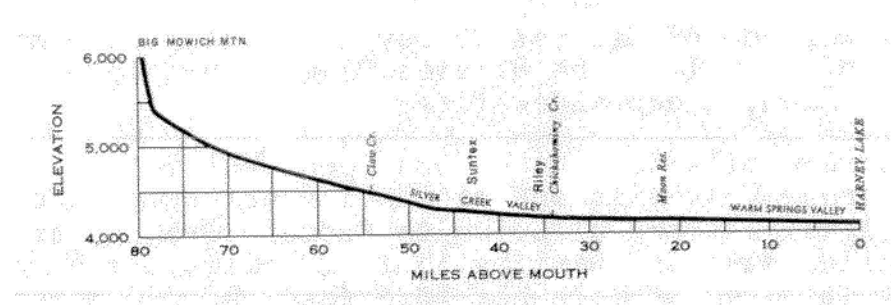


Figure 4: Silver Creek Gradient (from OWRD, 1967)

Only 13% of the Silver Creek basin is forested, while nearly 77% is sagebrush steppe. Forest treatment would have less of an effect on water yield than in the Silvies River basin, however reduction of western juniper (*Juniperus occidentalis*) cover could have an effect on the Silver Creek water yield. Recent evaluation of the hydrological changes from removal of western juniper in central Oregon (Deboodt et al., 2008, Ochoa et al., 2018) has shown that while significant groundwater recharge has not resulted in a paired watershed study, spring flow has increased significantly from the watershed without juniper. Surface water storage in Moon Reservoir and Chickahominy Reservoir which are managed for their fishery. Chickahominy was originally established to provide irrigation water but is not managed by ODFW for its recreational fishery. Both reservoirs are on BLM lands and impound surface water in the Silver Creek drainage that was previously characterized the sinuous channel of Silver Creek and floodplain wetlands. There is no information on the groundwater infiltration associated with the seasonal impoundments of Moon and Chickahominy Reservoirs.

### East side Tributaries

Minor drainages to Malheur Lake include Poison Creek, Prather Creek, Coffeepot Creek, Soldier Creek, Rattlesnake Creek, and Cow Creek. These drainages typically terminate before reaching the Lake. Their lower reaches are characterized as meadow floodplains as they spread out onto the Harney Valley. A number have been impounded for agricultural purposes. Poison Creek is the largest of these small catchments which mostly have headwaters in National Forest lands in King Mountain. The upper portion of the drainages are developed on volcanic flow, dike and vent deposits with thick layers of tuffaceous rocks. The lower portion of the drainages are developed on unconsolidated to partly consolidated alluvial sand and gravel deposits preserved in terraces and floodplains and on alluvial and debris fans. The stream profiles of these streams are similar to Silver Creek except the lower reaches are intermittent but show remnant channel patterns formed during periods of greater precipitation.

There is little information on groundwater relations with the east side tributaries. None of the small streams connect to Malheur Lake so it can be assumed that there is some groundwater recharge in the lower reaches of each of the small streams. Some of the drainages are impounded at their lower end for irrigation. Rock Creek on the east side of the basin and Riddle Creek and Smythe Creek on the north side of the basin are impounded for irrigation at their lower ends. There is little information on the effects on groundwater recharge-discharge from these small impoundments.

## Donner und Blitzen River

Garcia and others (2022) characterize the Steens Mountain groundwater system as “underlain by a thick sequence of moderately permeable northwestward dipping basaltic lava flows that allow for greater recharge through infiltration of rainfall and snowmelt, but a large portion of recharged groundwater on Steens Mountain is intercepted by the streams and springs that occupy deeply incised valleys, many of which were carved by glaciers during the Pleistocene...” Steens Mountain rises sharply above the Harney Valley with steep tributary streams to the Donner und Blitzen River (Figure 4). The lower reach of the river has a broad floodplain on relatively flat gradient.

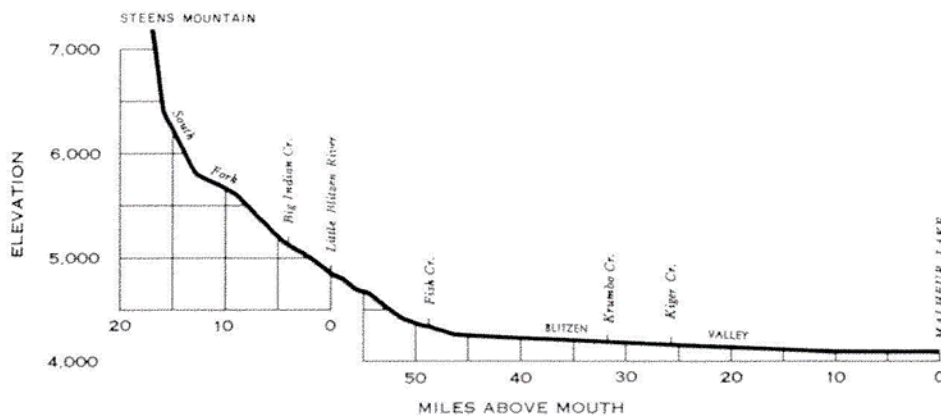


Figure 5: Blitzen River Profile (from OWRD, 1967)

The streams off Steens Mountain have a strong connection to groundwater and are actively recharged from snowmelt runoff. The stream systems are north facing and thus receive less solar insolation. The vegetation of Steens Mountain is significantly less forested than other areas of similar elevation. Aspen groves and a few groves of Sierra white fir are the most abundant forest vegetation. The unique geography and ecology of Steens Mountain provides habitat for over 60 rare plant species. The vegetation cover of the Donner und Blitzen catchment is dominated by wetlands that cover some 50%+ of the surface while sagebrush steppe covers more than 35% and forest is less than 10% of the surface area of the catchment surface.

Garcia states: “Along the Donner und Blitzen River corridor in the southern region, minimal groundwater development and groundwater-level declines indicate capture of  $ET_g$ , and spring discharge is unlikely. Although Sodhouse Spring discharge estimates are based on historical measurements prior to the study period, stable isotope data indicate it is sourced from Donner und Blitzen River water (fig. 2.2; Gingerich and others, 2022) and therefore likely fluctuates with multiyear variations in streamflow.” Which suggests the flow variation in Sodhouse Spring is not directly related to groundwater development.

Since the early 20th century, human activities have transformed the Blitzen River and its valley. Channelization downstream from the Page Springs area has led to “channel scour during floods and large fluctuations in bed elevation” as evaluated by Salant and others (2010). Beckham (1995) provides a history of discovery and mapping of the Blitzen River system with an evaluation of historic river form and conditions. The history of development of the Blitzen Valley and Malheur Lake area is also described by Langston (2003).

## Riddle Creek and North Side Tributaries

Riddle and Smyth Creek drain to Dry Creek Reservoir (also called Riddle Creek Reservoir), an impounded playa. The impounded water is diverted to the west for a limited area of irrigation. Little is known of the flow or recharge/discharge of this system.

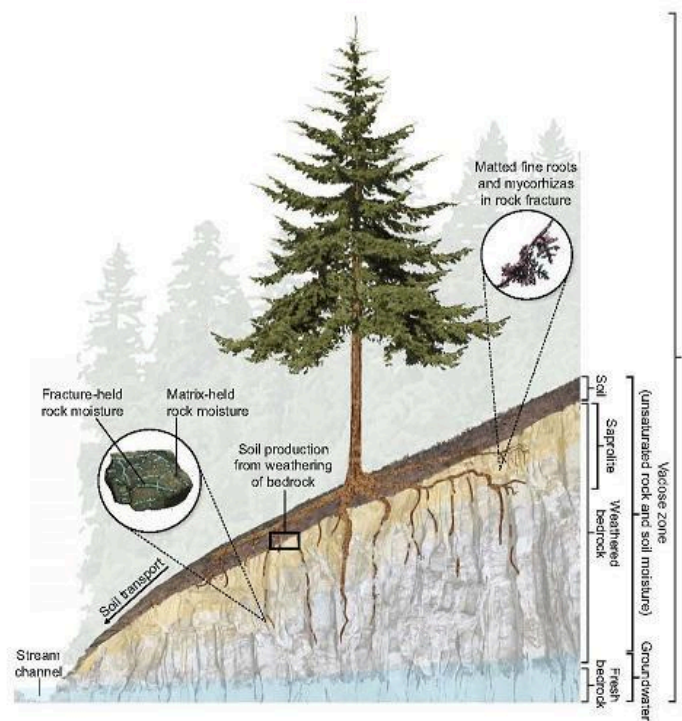
## Critical Zone Research

The critical zone defined as “the living skin of the earth from the top of the vegetation canopy through the soil and down to the fresh bedrock ( figure 5) and the bottom of significantly active groundwater” (Draille et al., 2023) has a significant effect on stream conditions. The research shows the importance of hillslope storage capacity in determining flow timing, duration, and quantity of streams. Applying the concept to the Harney basin it would indicate that the upper Silvies River would have cool, slow flow in the spring recession period and hot, low or no flow during the summer period. These conditions would likely be a result of the limited subsurface plant-assessable water stored in the lower transmissivity rocks of the upper basin characterized by upland volcanic rocks, marine sedimentary rocks, and older basin fill.

The Silver Creek drainage has similar conditions in the headwaters, however much of the basin is composed of High Lava Plains basalt which has somewhat higher transmissivity and lies along the Brothers Fault Zone which may move water with less resistance.

The flows from the Steens Mountain flow from Upland volcanic rocks with low transmissivity to Voltage basalt that has some of the higher

transmissivity and the Blitzen river follows the southern end of the Brothers Fault Zone. Measured base flow in the Donner und Blitzen River indicate more extensive gaining reaches of the river than other streams in the Harney basin. The geological conditions of the Donner und Blitzen River indicate the upper reaches are more likely to be cool, slow flowing at spring recession and hot, low or no flow during summer. The lower river reaches are more likely to have cold, fast flows during spring recession and cool, robust baseflow during the summer season.



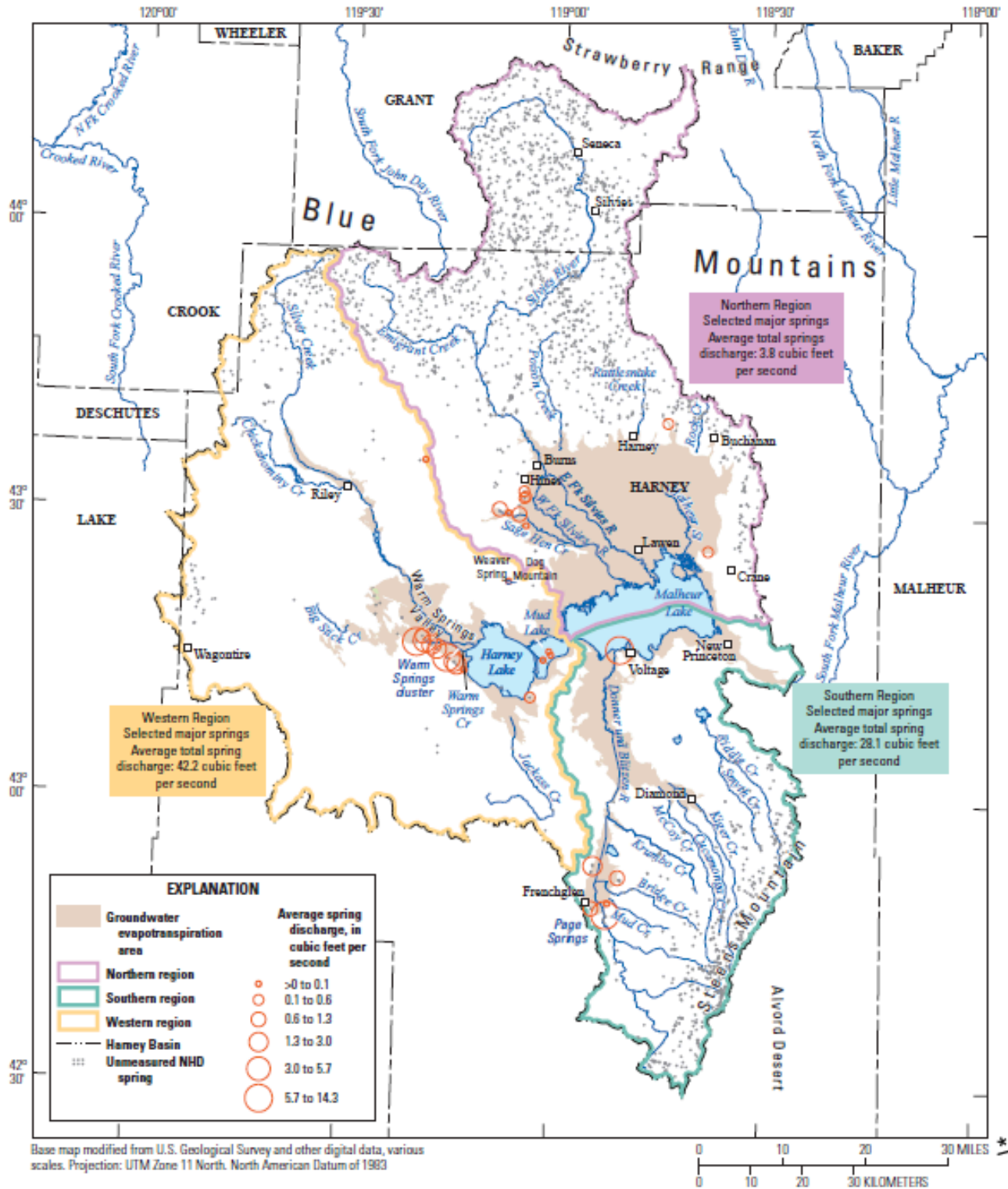


Figure 6: Blitzen River Profile (from USGS report, Groundwater resources of Harney Basin, SE Oregon, 2022)

## Beaver and Shallow Groundwater

In 1925 “a trapper named Antoine Sylvaile with others had been sent by Mr. Ogden to the sources of the Owyhee and Malheur rivers with instructions to rejoin the main party upon its return. Sylvaile however returned to Ft. Vancouver independently reported finding a stream in that quarter **very rich with beaver**, to which the name Sylvaile River was at once given” from The Peter Skene Ogden Journal’s Editorial Notes by T. C Elliott. The 1926 journal documents the taking of 12 beavers on October 11, 65 beavers on October 16, and 134 beavers from the area on October 18. The removal of beaver from the area was part of the effort by the Hudsons Bay Company to “Ruin the Rivers” or establish a “fur desert” (Ott, 2003). From the historical accounts there were significant beaver occupancy in the Silvies River system. Beckham (1995) describes the fur trade as: “Between 1826 and 1832 at least six fur trapping parties entered the Harney Basin. This repeated labor and documented taking of beaver pelts confirms that the region was sufficiently productive of this mammal as to induce regular visits.”

The effect of concentrated beaver trapping can only be estimated but beaver have not returned in the numbers seen before intensive trapping. This change likely has impacts on the surface groundwater relations of the valley floor in low gradient areas of the basin. There is significant recent literature on the potential for beavers to store water in portions of the landscape. For example Scamardo and others (2022) have estimated a 40% loss of surface water and sediment storage across the state of Colorado.

In an extensive review of the effects of beaver (Larsen et al., 2021) the complexities of beaver activities on surface-groundwater dynamics are discussed. They recognize that there is conflicting data on the long-term effect of beaver dams on shallow ground water storage and conclude “Nonetheless, from a long term perspective, as beaver dams are breached or fill with sediment and beavers abandon or decrease activity and allow meadows to develop, interesting results show that although  $S_{surf}$  may decrease, the beaver meadows may still retain significant  $S_{gw}$ , especially relative to the pre-impact landscape”. Burchsted and others (2010) suggest that improved river restoration is dependent on consideration of the role of beaver in structuring stream ecosystems. A similar argument is made by Feiner and Lowry (2015) after modeling the effects of a beaver dam on regional groundwater flow. Beyond shallow groundwater storage, beaver dams affect temperature (Dittbrenner et al., 2022; Majerova et al., 2015). Other researchers (Levine and Meyer, 2019) have identified downstream effects of beaver dams. Researchers looking at climate change have modeled the effect of beaver dams as a moderating effect on likely change (Dewey et al., 2022).

While the potential for beaver reintroduction or the use of beaver dam “analogs” (Davee et al., 2017; Davee et al., 2019) may provide additional upland storage in the Silvies River and Silver Creek drainages. Differences of views on the effect and significance of beavers and beaver dam analogs can be found (Pfaffle et al., 2022). There remain many questions about the potential and significance of such actions. Any evaluation will require region and site specific analysis.

## Groundwater – Surface Water Questions

While the recent groundwater study (Gingerich et al., 2022 and Garcia et al., 2022) has identified many of the surface-groundwater interactions, there remain several questions.

### Upland Questions

- What is the effect of upland vegetation on the water budget, especially water yield?

- What are the likely effects of a changing regime from snow dominated to a rain dominated system on recharge to streams and residence times of stream water?
- How significant can vegetation management affect the water budget for the basin?
- The floodplains of Bear Valley, Silvies River Ranch reach and other low gradient reaches of the Silvies River have not been evaluated as affecting evapotranspiration. Would this level of detail affect the water budget?
- Would the reintroduction of beaver to the upper watersheds change the timing and duration of stream flows?
- Could beaver reintroduction affect water storage in the uplands?
- To what extent has stream channelization affected sediment and flow characteristics of the streams?
- Where would additional stream gauges be important for future water availability evaluation?

#### Lowland Questions

- Are there specific areas where lowland recharge is more effective (greater surface permeability, etc.)?
- How vital is spring flooding to recharge the lowlands? Should/could this be a key component of water management in the Harney basin?
- Are there ways to enhance lowland recharge?
- What is the sustainability of the springs along Warm Springs valley, Sage Hen, West Fork Silvies, and Page Springs?

#### Data Gaps and Needs

A critical need is for additional sites for long-term measurement of stream flow. Without knowledge of changes in flow regime in tributary streams and lower reaches of larger streams it is difficult to accurately understand the interaction between surface and groundwater.

Spatially explicit measurement of lowland recharge under different spring freshet regimes would be a significant help in determining the potential for managing lowland recharge and/or identifying opportunities to increase lowland recharge.

Quantifying the relationship between vegetation conditions of different portions of the catchment and contribution to the surface and groundwater would aid in prioritizing vegetation management for water yield purposes (beyond ecosystem structure and function purposes).

A basin scale evaluation of changing snowpack regime would help to understand the surface and groundwater management needs in the future.

An evaluation of beaver reintroduction and/or the effect of beaver dam analogs (Silvies Valley Ranch) on timing and storage of surface and groundwater would help in determining whether beaver reintroduction is an advisable strategy.

Evaluating the extensive stream simplification and canal system in the lower river systems for effects on recharge and discharge would help to identify if there are reaches important to restore to a more complex pattern.

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