Oregon Water Resources Department Memorandum

Date: 15 June 2015

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To: Ivan K. Gall -- Manager, OWRD Groundwater Section

Subject: Harney Basin: Permitted Groundwater Rights and Groundwater Budget

Introduction

This memo summarizes a preliminary assessment that compares the Harney Basin groundwater budget to permitted groundwater rights using currently available data. The assessment was conducted to help evaluate the cause of groundwater level declines and help provide information useful for future groundwater allocation decisions. The assessment includes the entire Harney Basin comprised of three major watersheds. The assessment results indicate permitted annual groundwater use in the "Greater Harney Valley Area" exceeds available groundwater.

Harney Basin Geographic Area

The 5,243 square-mile Harney Basin is located mostly in northern Harney County. It is the northern portion of the Malheur Lake Administrative Basin (figure 1 and plate 1). Piper and others (1939) define the basin as "… the relatively high, semi-arid plateau of southeastern Oregon, in Harney and Grant Counties. It constitutes the drainage area of the Malheur and Harney Lakes, which have no outlet to the sea." The basin is divided into three major watersheds (table 1 and plate 2). The Oregon State Water Resources Board (1967) identified those watersheds as Silver Creek, Silvies River, and Donner und Blitzen River. Harney Valley resides within the central portion of the basin. Waring (1909) described the valley as "…a wide, flat area in which lie Malheur and Harney lakes, and… which comprises roughly 700 square miles of plain, marsh, and lake surface…"

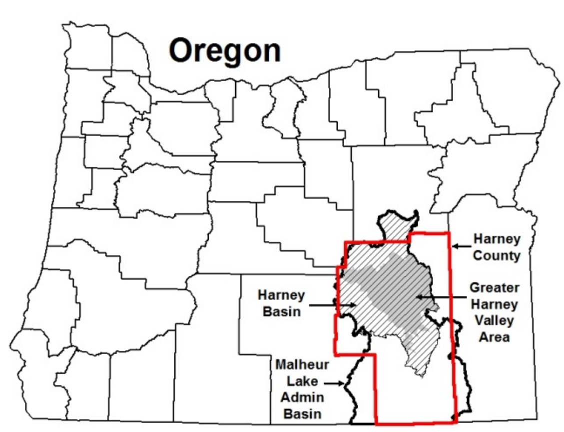


Figure 1. Locations of Harney County, Malheur Lake Administrative Basin, Harney Basin, and the "Greater Harney Valley Area

An area of significant interest to OWRD due to existing and proposed groundwater development is the "Greater Harney Valley Area." In this memo, the "Greater Harney Valley Area" is defined for the first time informally and unofficially as the area that includes Harney Valley, adjoining valleys, and lower elevation flanks of uplands facing those valleys. The area's approximate 2,385 square-mile surface area is noted in table 1 and shown in plate 3. That surface area was delineated selecting hydrologic units (HU12s) from the USGS Watershed Boundary Dataset (WBD) that are within Harney Valley, or within adjoining valleys, or along the lower elevation flanks of uplands facing those valleys.

Table 1: Surface Area of Harney Basin and Watersheds		
Watershed	**Area (acres)**	**Area (sq.-mi.)**
Silver Creek	1,345,900	2,103
Silvies River	1,381,270	2,158
Donner und Blitzen River	628,515	982
Entire Harney Basin Area	**3,355,685**	**5,243**
"Greater Harney Valley Area" Harney Valley and adjoining Valleys and Bounding Uplands	**1,526,830**	**2,386**
Note: Each surface area was derived by using GIS geometry calculation		

Harney Basin Precipitation

The average annual precipitation in the basin varies with location. The lowest annual precipitation occurs within the valleys, and the highest occurs in the uplands, particularly the Steens Mountain crest. Table 2 and plate 4 show average annual precipitation distribution across the basin.

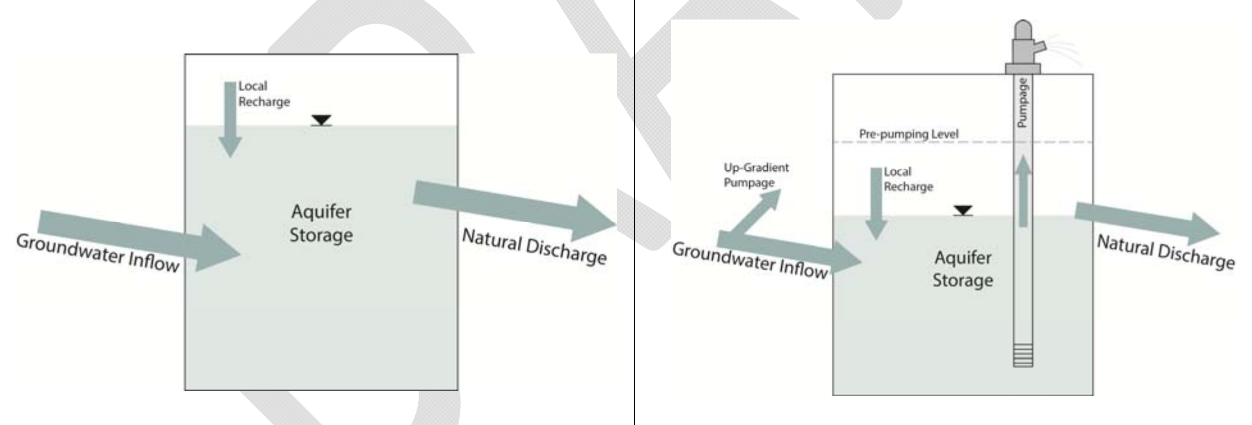
Table 2: Average Annual Precipitation				
Watershed	**Minimum (inch)**	**Maximum (inch)**	**Range (inch)**	**Mean (inch)**
Silver Creek	9.09	29.13	20.04	11.51
Silvies River	8.86	41.43	32.48	14.25
Donner und Blitzen	8.98	56.57	47.59	19.92
Entire Harney Basin	8.86	56.57	47.72	14.25
Burns, Oregon			Leonard (1970) LaMarche (2015)	10.96 11.23
Note: The average annual precipitation values for the Harney Basin and the three watersheds were derived from GIS statistical analysis of OSU PRISM Climate Group data for each area. The distribution of the average annual precipitation across the basin can be seen in plate 4. **Note:** Leonard (1970) used 1938 to 1970 data **Note:** LaMarche (2015) used 1940 to 2015 data				

Groundwater Budget Fundamentals

Groundwater budgets are based on the law of conservation of mass: water is neither created nor destroyed. Water moving into a given area, temporarily "stored" in the area as it moves through the area, and exiting the area can be fully accounted with enough data. That is true for the entire hydrologic cycle and its various components including groundwater.

Figure 2 is a simplified conceptual diagram illustrating a groundwater budget for pre-development conditions and post-development conditions. Groundwater systems are dynamic, not static. Water in various ways enters a groundwater system, moves through the system, and exits the system.

Most pre-development groundwater systems are (were) fully established and in dynamic equilibrium. A certain component of water in the groundwater system is "stored" water. That "stored" water is not motionless. It flows through the system from areas of recharge to areas of discharge. Natural discharge areas include streams, springs, lakes, and vegetation. The "stored" water component gets replenished by local recharge and groundwater inflows from adjacent and distal areas. Natural recharge to a system include stream losses to groundwater, groundwater inflows from various areas, and deep percolation of precipitation water that remains available after runoff, evaporation, and vegetation uptake. Once established, the volume of water entering and exiting a pre-developed groundwater system is equal over the long-term and the "stored" water component is stable, which is reflected by stable groundwater levels over the long-term. With enough data, the water in each component of the system can be accounted and the average annual water "gained" and "lost" will balance.



A. Pre-Development **B. Post-Development**

Figure 2: Groundwater Budget Conceptual Diagram

Developed groundwater systems add engineered withdrawals to the system, primarily through wells. Water removed by wells is often at the expense of the "stored" water component and/or the natural discharge component of the groundwater system. This is reflected over the long-term by lower groundwater levels and decreased discharge to streams, springs, lakes, and vegetation. Groundwater removed from the inflow component of the groundwater system reduces the amount of replenishment water entering the system. If development is within the capacity of the groundwater resource, a new equilibrium is established where the average annual water "gained" and "lost" balances, but a smaller volume of “stored” water is maintained. This is reflected by a stable lower groundwater level and less water discharging naturally from the system. If development exceeds the capacity of the groundwater resource, the average annual water “gained” and “lost” does not balance. The imbalance is at the expense of the “stored” groundwater component which shrinks over time (reflected by groundwater level declines over the long-term) and at the expense of the natural discharge component which shrinks and may stop over the long-term. Exceeding the capacity of the groundwater resource can cause long-term injury to existing groundwater and surface water rights and to the local groundwater and surface water resource.

Natural Groundwater Recharge Estimate

The OWRD effort to compare total permitted groundwater rights volume in acre-feet to available groundwater recharge volume in acre-feet for the Harney Basin first required determining a reasonable annual recharge estimate for the Harney Basin groundwater system. Three hydrogeologic reports were found that include average annual groundwater recharge estimates. Two reports, Piper and others (1939) and Leonard (1970), provide recharge estimates primarily for the Harney Valley area (table 3). They note recharge to the valley’s groundwater includes inflow from un-delineated areas surrounding the valley. The third report, Robison (1968), estimates recharge for each of the three Harney Basin watersheds (table 4 and appendix 1).

Piper and others (1939) estimated groundwater recharge in different sub-areas in the Harney Valley area. They used three different methods to estimate groundwater recharge to the basin-fill sediments in a 210 square-mile area in western Harney Valley near the Silvies River (Silvies Sub-area). The methods used were: (1) estimates based on groundwater storage; (2) estimates based on groundwater discharge; and (3) estimates based on soil water budget (water inflow from precipitation and surface water diversion and water outflow from evaporation of free standing water, evapotranspiration by vegetation, and deep percolation to groundwater). The three methods yielded an annual groundwater recharge estimate of 36,500 acre-feet, 42,000 acre-feet, and 40,000 acre-feet respectively (see pgs. 74-82). They estimated about 17,000 acre-feet of additional groundwater recharge in the vicinity of alluvial fans located north of Malheur Lake and east of the Silvies Sub-area (see pgs. 90-91).

Leonard (1970) investigated the groundwater in the basin-fill and the underlying volcanic rocks and sediments in the Harney Valley north of Harney and Malheur Lakes. The area investigated extends to the base of the surrounding uplands and occupies about 400 square-miles. He estimated the groundwater recharge to the basin-fill in the valley by multiplying the potentiometric gradient observed in the valley basin-fill by transmissivity values derived from specific capacity data related to area wells. He estimated groundwater recharge to the underlying volcanic rocks and sediments in the valley by multiplying 0.50 inch of annual water infiltration by the surrounding upland area. He estimated about 60,000 acre-feet total recharge to the Harney Valley north of Harney and Malheur Lakes: 38,000 acre-feet to the basin-fill sediments and 22,000 acre-feet to the underlying volcanic rocks and sediments (see pgs. 25-28). Much of that recharge is from the surrounding uplands: volcanic rocks and sediments conveying water from upland exposures to the valley below the basin-fill after losing water to upland streams; and upland streams losing water to the basin-fill as they enter the valley.

Robison (1968) used surface water base-flow methods to estimate annual groundwater recharge for each watershed. He notes this methodology likely represents conservative values. Table 4 summarizes his results. His estimated annual groundwater recharge for the entire Harney Basin area is 260,000 acre feet. Table 5 converts his results for the basin and each watershed as a percent of the mean average annual precipitation for each area previously shown in table 2. The results indicate that 5 to 10 percent of the mean average annual precipitation in the Harney Basin becomes groundwater recharge. The remaining 90 to 95 percent likely runs-off as surface water, evaporates, or is transpired by vegetation.

The Harney Basin recharge estimates by Robison (1968) were found to be reasonable for OWRD use by comparing his recharge estimates for the nearby Summer Lake watershed in the Goose and Summer Lakes Administrative basin to recharge estimates by other authors for the Fort Rock area that occupies most of that watershed. The Fort Rock area within the Summer Lake watershed is west of the Harney Basin. Like the Harney Basin, it is a high desert basin. Miller (1986) and Newcomb (1953) estimated the average annual recharge to be less than 1.20 inches over the entire Fort Rock area. Conversion of the Robison (1968) estimated average annual recharge for the entire Summer Lake watershed converts to 1.28 inches (appendix 1), which compares favorably.

Table 3: Summary of Previous Groundwater Recharge Estimates for Harney Valley

Piper and others (1939) (see Figure 8 on pg. 73 and text on pgs. 74-94)	**Surface Area (square-miles)**	**Annual Recharge Estimate (acre-feet)**
Silvies Sub-area (basin fill)	About 210	40,000
Minor Sub-areas north of Malheur Lake (alluvial fans north of Malheur Lake & east of Silvies Sub-area)	About 145	17,000
Sage Hen Valley and Sunset Valley		No value, estimated small
Donner und Blitzen Valley		No value
Silver Creek-Warm Spring Valley		No value
Total		**> 57,000**
Leonard (1970) (see pgs. 25-28)	**Surface Area (square-miles)**	**Annual Recharge Estimate (acre-feet)**
Harney Valley north of Malheur Lake	About 400	
Basin-fill		38,000
Volcanic rocks and sediments		22,000
Total		**60,000**

Note: The Piper and others (1939) and Leonard (1970) recharge estimates include inflow from surrounding uplands whose area is not specified or delineated.

Table 4: Annual Groundwater Recharge Estimate for Harney Basin Watersheds (Robison, 1968)

Watershed	**Natural GW Recharge (ac-ft) (Robison, 1968)**	**Surface Area (square-miles) (Robison, 1968)**	**Surface Area (acres) (Robison, 1968)**	**Natural GW Recharge (inches)**
Silver Creek	60,000	2,000	1,280,000	0.56
Silvies River	100,000	2,000	1,280,000	0.94
Donner und Blitzen	100,000	1,000	640,000	1.88
Harney Basin Total	**260,000**	**5,000**	**3,200,000**	**0.98**
Watershed	**Natural GW Recharge (ac-ft) (Robison, 1968)**	**Surface Area (square-miles) (OWRD GIS)**	**Surface Area (acres) (OWRD GIS)**	**Natural GW Recharge (inches)**
Silver Creek	60,000	2,103	1,345,900	0.53
Silvies River	100,000	2,158	1,381,270	0.87
Donner und Blitzen	100,000	982	628,515	1.91
Harney Basin Total	**260,000**	**5,243**	**3,355,685**	**0.93**

Table 5: Annual Groundwater Recharge Estimate for Harney Basin Watersheds (Robison, 1968) Converted to a Percent of the Mean Average Annual Precipitation			
Using Natural Groundwater Recharge in inches Calculated from Robison (1968) Surface Areas			
Watershed	**Natural GW Recharge (inches) Surface Area from Robison (1968)**	**Mean Precipitation (inch)**	**Natural GW Recharge vs. Mean Average Annual Precipitation (percent)**
Silver Creek	0.56	11.51	4.87
Silvies River	0.94	14.25	6.60
Donner und Blitzen	1.88	19.92	9.44
Harney Basin	0.98	14.25	6.88
Using Natural Groundwater Recharge in inches Calculated from OWRD GIS Surface Areas			
Watershed	**Natural GW Recharge (inches) Surface Area from OWRD GIS**	**Mean Precipitation (inch)**	**Natural GW Recharge vs. Mean Average Annual Precipitation (percent)**
Silver Creek	0.53	11.51	4.60
Silvies River	0.87	14.25	6.11
Donner und Blitzen	1.91	19.92	9.59
Harney Basin	0.93	14.25	6.53

The OWRD assessment used the Robison (1968) average annual natural recharge estimate of 260,000 acre-feet for the entire Harney Basin as the best currently available recharge estimate.

Natural Groundwater Discharge Estimate

A significant portion of groundwater naturally discharges to support streams, springs, lakes, and vegetation. This preliminary assessment found data for Harney Basin streams shown in table 6 and appendix 2, springs shown in appendix 3, and Malheur Lake (Hubbard, 1975) which are useful for evaluating groundwater discharge to those water bodies. Quantitative data related to vegetation and evaporation representing the entire Harney Basin was not found. Leonard (1970) noted the potential annual crop evapotranspiration in the Harney Valley is greater than the annual precipitation. Piper and others (1939) reported shallow groundwater levels influenced daily and seasonally by native plants.

The OWRD assessment conservatively estimated the average annual natural groundwater discharge. It used the OWRD "Water Availability" calculated data (Cooper, 2002) for Harney Basin streams only given that data likely includes groundwater discharge to springs (Stahr, 2015). The estimate only used the calculated median natural flow for the lowest flow months (August, September, and October) representing the likely minimum average annual natural groundwater discharge to streams, and it only used the calculated median natural flow at the stream mouth to avoid double counting. Groundwater discharge to Malheur Lake was not added given Hubbard (1975) notes groundwater discharge to Malheur Lake predominantly occurs at Sodhouse Spring which the OWRD assessment assumes is included in the OWRD "Water Availability" calculated median natural flow data for the Donner und Blitzen River.

Table 6: Annual Groundwater Discharge Estimate for Harney Basin Watersheds (Cooper, 2002)		
Watershed	**Average Median Low Flow (cubic-feet per second)**	**Average Annual Volume (acre-feet per year)**
Silver Creek	42.53	30,793
Silvies River	25.91	18,756
Donner und Blitzen	54.73	39,625
Harney Basin	123.17	89,173
Source: OWRD Water Availability Data (Cooper, 2002) using 50% exceedance values. **Note:** The Annual Groundwater Discharge Estimates likely include groundwater discharge to springs (Stahr, 2015).		

The OWRD assessment used the conservative average annual stream flow volume of 89,173 acre-feet for the entire Harney Basin shown in Table 6 and appendix 2 for the estimated average annual natural groundwater discharge in the basin. The difference between the OWRD assessed average annual natural groundwater recharge and discharge for the entire Harney Basin is an unaccounted 170,827 acre-feet.

Permitted Groundwater Use for Irrigation

Permitted groundwater use for irrigation in the Harney Valley area includes both supplemental and primary uses. Table 7 shows the current summary of the total permitted acres and the related total annual groundwater volume permitted in acre-feet for the "Greater Harney Valley Area" only, given that is the area of significant interest to OWRD. Only 138 permitted acres are outside the "Greater Harney Valley Area." To avoid double counting acres, all the delineated permitted place of use (POU) acres for each groundwater right for a given sub-area were united using the GIS ArcMap "dissolve" tool. The permitted place of use (POU) acres is shown in plates 2 to 4. The permitted volume was calculated by multiplying the permitted acres by 3 acre-feet per acre, the annual water volume typically permitted per acre.

Table 7: Permitted Groundwater Use for Irrigation in the "Greater Harney Valley Area"		
Watershed	**Permitted Area (acres)**	**Permitted Volume (acre-feet)**
Silver Creek	22,307	66,921
Silvies River	65,525	212,253
Donner und Blitzen	2,625	7,875
Entire "Greater Harney Valley Area"	**95,683**	**287,049**
Note: To avoid double counting acres, all the delineated permitted place of use (POU) acres for each groundwater right for a given sub-area were united using the GIS ArcMap "dissolve" tool. **Note:** Only 138 permitted acres are outside the "Greater Harney Valley Area."		

Comparing the Harney Basin Average Annual Groundwater Budget to the Annual Groundwater Volume Permitted for Irrigation in the "Greater Harney Valley Area"

The OWRD assessment compared the Harney Basin average annual groundwater budget to the annual groundwater volume permitted for irrigation in the "Greater Harney Valley Area." The comparison is shown in table 8. The annual groundwater volume permitted for irrigation in acre-feet is for the "Greater Harney Valley Area" only, given that is the area of significant interest to OWRD. Only 138 permitted acres in the Harney Basin are outside the "Greater Harney Valley Area."

The total annual groundwater volume permitted for irrigation in acre-feet for the "Greater Harney Valley Area" alone exceeds the groundwater budget for the entire Harney Basin. That indicates the total annual groundwater volume permitted for irrigation exceeds the capacity of the groundwater resource [see OAR 690-400-0010-(4)], and the groundwater resource is over-appropriated [see OAR 690-400-0010-(11)(a)(B)]. That puts the groundwater resource at risk, particularly groundwater storage and groundwater discharge to streams, springs, lakes, wetlands, and vegetation. In turn, that puts senior surface water rights and groundwater rights at risk of injury.

Table 8: Comparison of the Harney Basin Groundwater Budget to the "Greater Harney Valley Area" Permitted Groundwater Use for Irrigation

Watershed	Harney Basin Groundwater Budget			Permitted Groundwater Volume (acre-feet) (OWRD)
	Groundwater Recharge (acre-feet) (Robison, 1968)	Groundwater Discharge (acre-feet) (OWRD)	Unaccounted Difference (acre-feet) (OWRD)	
Silver Creek	60,000	30,793	29,207	66,921
Silvies River	100,000	18,756	81,244	212,253
Donner und Blitzen	100,000	39,625	60,375	7,875
Harney Basin	**260,000**	**89,173**	**170,827**	**287,049**

Note: The total unaccounted difference is 1 acre-foot more than the sum of the unaccounted difference for each watershed due to number rounding.

Note: The total annual groundwater volume permitted in acre-feet is for the "Greater Harney Valley Area" only, given that is the area of significant interest to OWRD.

Note: Only 138 permitted acres are outside the "Greater Harney Valley Area."

Groundwater Level Data

OWRD graphed and reviewed "Greater Harney Valley Area" groundwater level data related to 108 wells. Available groundwater level data are limited, but they clearly show annual groundwater level declines are generally occurring in the "Greater Harney Valley Area" (plate 5). The declines are most obvious in the Weaver Springs area in the western portion of the Harney Valley area and also along the Crane-Buchanan Road corridor in eastern Harney Valley. Limited data for other areas in the "Greater Harney Valley Area" further indicate a widespread annual groundwater level decline is occurring.

The observed groundwater level declines indicate that current permitted annual groundwater use exceeds the capacity of the groundwater resource [OAR 690-400-0010-(4)], and the groundwater resource is over-appropriated [OAR 690-400-0010-(11)(a)(B)]. The groundwater levels are declining because groundwater storage is decreasing due to the capacity of the groundwater resource being exceeded. The Department has begun collecting additional groundwater level data to help further assess the area-wide decline.

Current groundwater level data for the upper Silver Creek area in the vicinity of Riley and for the Donner und Blitzen River watershed is either too limited to assess groundwater level trends or they show no decline due to a likely nearby surface water influence that sustains local groundwater levels. Groundwater use in these areas will likely be at the expense of surface water and/or groundwater storage. Additional groundwater level data are needed for these areas to better define the local groundwater trend and to better assess the local groundwater-surface water relationship.

Conclusion

OWRD conducted a preliminary assessment that compared the Harney Basin groundwater budget to permitted groundwater rights in the "Greater Harney Valley Area" using currently available data. The results indicate the total annual groundwater volume permitted for irrigation in acre-feet for the "Greater Harney Valley Area" alone exceeds the total groundwater budget for the entire Harney Basin. That means the permitted groundwater usage is not sustainable. The total annual groundwater volume permitted for irrigation exceeds the capacity of the groundwater resource [see OAR 690-400-0010-(4)], and the groundwater resource is over-appropriated [see OAR 690-400-0010-(11)(a)(B)]. That puts the groundwater resource at risk, particularly groundwater storage and groundwater discharge to streams, springs, lakes, wetlands, and vegetation. In turn, that puts senior surface water rights and groundwater rights at risk of injury.

OWRD graphed and reviewed "Greater Harney Valley Area" groundwater level data related to 108 wells. Available groundwater level data are limited, but they clearly show annual groundwater level declines are generally occurring in the "Greater Harney Valley Area." The observed groundwater level declines indicate that current permitted annual groundwater use exceeds the capacity of the groundwater resource [OAR 690-400-0010-(4)], and the groundwater resource is over-appropriated [OAR 690-400-0010-(11)(a)(B)]. That means the permitted groundwater usage is not sustainable, which puts senior water rights at risk of injury.

A multi-year hydrogeologic investigation in the Harney Basin is needed to better define the groundwater system, its relationship to surface water, its water budget, and its response to groundwater development.

References Used

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Data Sources Used

The annual precipitation data is from the 1971-2000 30-year “normals” developed by the PRISM Climate Group at OSU.

The delineated Oregon Water Availability Basins (WABs) were delineated over the past 20-years at OWRD in support of the surface water availability project. It began with delineations made on 7.5’ quad maps using the contours as a guide. Hydrographics Section staff currently use the peakflow estimation tool to define or refine the WAB boundaries. The tool uses the 10-meter DEMs produced by the USGS from the 7.5’ quad contours.

The delineated hydrologic units (HU12s) are from the USGS’s Watershed Boundary Dataset (WBD) and have been certified by the program that oversees the data.

Appendix 1: Estimated Natural Annual Groundwater Recharge

Data Source: **J.H. Robison (1968)**
USGS Open File Report 68-232

Malheur Lake Administrative Basin: Harney Basin

Drainage	Area (square-miles)	Area (acres)	Natural GW Recharge (acre-feet)	Natural GW Recharge (inches)
Steens	1,000.00	640,000.00	100,000.00	1.88
Harney	2,000.00	1,280,000.00	60,000.00	0.56
Silvies	2,000.00	1,280,000.00	100,000.00	0.94
Total	5,000.00	3,200,000.00	260,000.00	0.98

Malheur Lake Administrative Basin: Outside Harney Basin

Drainage	Area (square-miles)	Area (acres)	Natural GW Recharge (acre-feet)	Natural GW Recharge (inches)
Alvord	2,000.00	1,280,000.00	50,000.00	0.47
Catlow	3,000.00	1,920,000.00	30,000.00	0.19
Total	5,000.00	3,200,000.00	80,000.00	0.30

Goose-Summer Lakes Administrative Basin: West of Harney Basin

Drainage	Area (square-miles)	Area (acres)	Natural GW Recharge (acre-feet)	Natural GW Recharge (inches)
Goose Lake	1,000.00	640,000.00	60,000.00	1.13
Warner Lake	1,700.00	1,088,000.00	30,000.00	0.33
Abert Lake	900.00	576,000.00	50,000.00	1.04
Summer Lake	4,400.00	2,816,000.00	300,000.00	1.28
Total	8,000.00	5,120,000.00	440,000.00	1.03

Malhuer River Administrative Basin: East of Harney Basin

Drainage	Area (square-miles)	Area (acres)	Natural GW Recharge (acre-feet)	Natural GW Recharge (inches)
Malhuer	3,250.00	2,080,000.00	200,000.00	1.15
Willow	1,600.00	1,024,000.00	100,000.00	1.17
Total	4,850.00	3,104,000.00	300,000.00	1.16

Owyhee River Administrative Basin: East of Harney Basin

Drainage	Area (square-miles)	Area (acres)	Natural GW Recharge (acre-feet)	Natural GW Recharge (inches)
Upper Owyhee	2,000.00	1,280,000.00	50,000.00	0.47
Crooked Creek	1,700.00	1,088,000.00	50,000.00	0.55
Lower Owyhee	1,700.00	1,088,000.00	30,000.00	0.33
Total	5,400.00	3,456,000.00	130,000.00	0.45

Appendix 2: Estimated Natural Annual Groundwater Discharge

Malheur Lake Administrative Basin: Harney Basin Streams

Data Source: OWRD Water Availability Data Tables (Cooper, 2002)

Median Natural Flow

Stream	August Flow (cubic-feet per second)	September Flow (cubic-feet per second)	October Flow (cubic-feet per second)	Average Low Flow (cubic-feet per second)	Average Annual Volume (acre-feet per year)
Donner und Blitzen River Watershed					
Donner und Blitzen River	50.80	51.70	61.70	54.73	39,625.12
			Sub-Total	**54.73**	**39,625.12**
Silvies River Watershed					
Silvies River	27.30	20.40	24.50	24.07	17,423.47
Malheur Slough	2.25	1.53	1.74	1.84	1,332.10
			Sub-Total	**25.91**	**18,755.57**
Silver Creek Watershed					
Silver Creek	28.20	27.40	28.50	28.03	20,295.21
Warm Springs Creek	14.50	14.50	14.50	14.50	10,497.52
			Sub-Total	**42.53**	**30,792.73**
			Basin Total	**123.17**	**89,173.42**

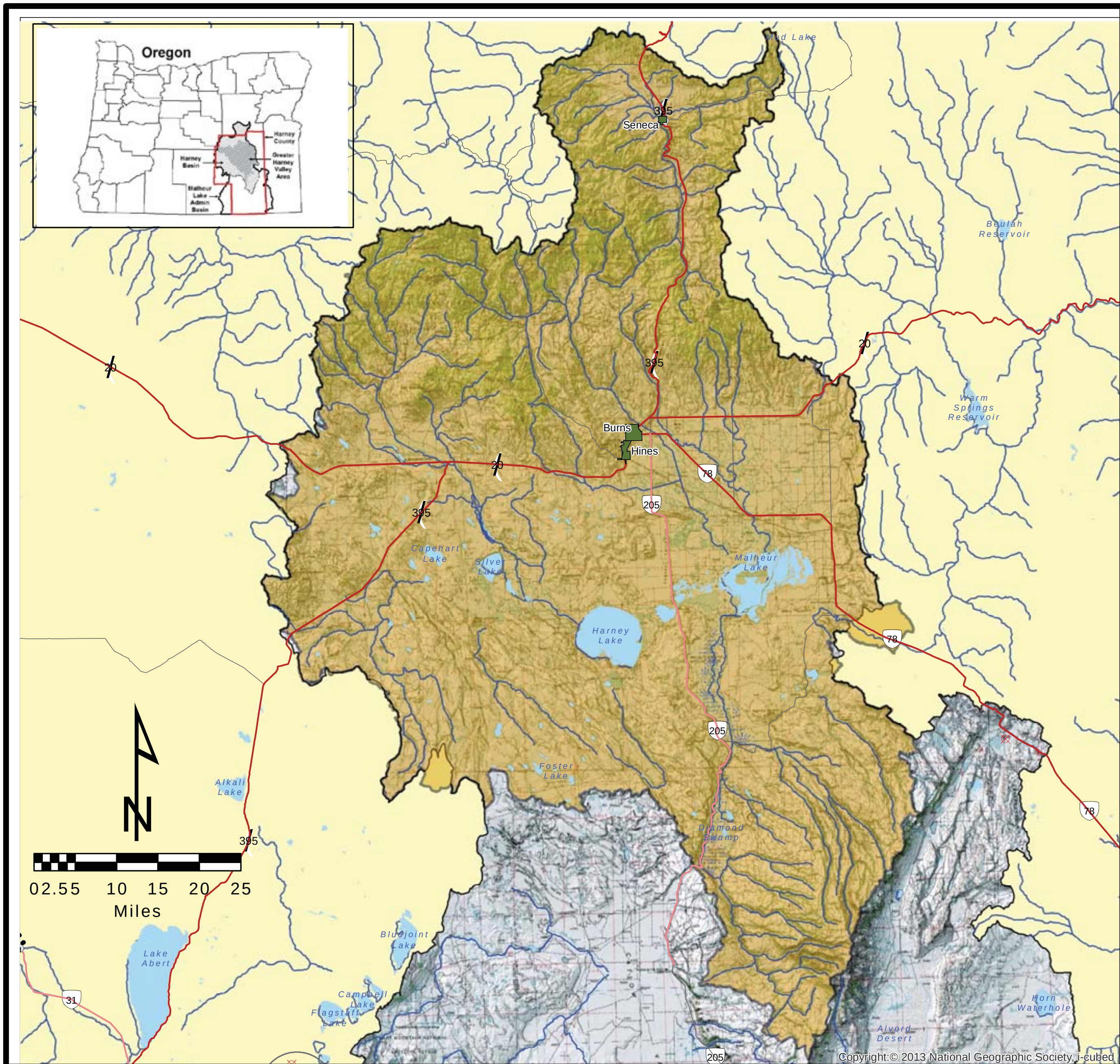
Appendix 3: Estimated Natural Annual Groundwater Discharge

Malheur Lake Administrative Basin: Harney basin Springs

Data Source: Piper, Robinson, and Park (1939), pgs. 184-185
Maximum & Minimum Flows Measured
Groundwater discharge to Harney Basin springs is likely included in the surface water availability natural flow data rather than being an additional discharge

Spring	Area	Maximum Flow Date	Maximum Flow (cubic-feet per second)	Maximum Annual Volume (acre-feet per year)	Minimum Flow Date	Minimum Flow (cubic-feet per second)	Minimum Annual Volume (acre-feet per year)
Donner und Blitzen River Watershed							
Site 317: Sodhouse Spring	Donner und Blitzen River	09/09/1930	11.60	8,398.02	09/20/1907	4.50	3,257.85
Site 379: Hog House Spring	Frenchglen Area	11/01/1907	4.00	2,895.87	08/27/1932	2.00	1,447.93
Site 380: Knox Spring	Frenchglen Area	04/11/1911	1.50	1,085.95	July 1932	1.00	723.97
Site 381: Un-named	Frenchglen Area	06/09/1907	0.50	361.98	06/09/1916	1.40	1,013.55
Site 382: Un-named	Frenchglen Area	08/27/1932	0.20	144.79	08/27/1907	0.04	32.29
		Sub-Total	**17.80**	**12,886.61**	**Sub-Total**	**8.94**	**6,475.59**
Silvies River Watershed							
Site 13: Un-named	Cow Creek drainage	09/06/1930	0.50	361.98	05/08/1931	0.50	361.98
Site 148: Un-named	Sage Hen Valley	09/03/1930	0.73	528.50	05/29/1931	0.56	405.42
Site 150: Roadland Spring	Sage Hen Valley	09/03/1930	1.08	781.88	05/29/1931	0.82	593.65
Site 211: Weaver Spring	Weaver Springs	10/16/1930	0.04	32.29	06/10/1931	0.02	16.14
		Sub-Total	**2.35**	**1,704.65**	**Sub-Total**	**1.90**	**1,377.20**
Silver Creek Watershed							
Site 273: OO Cold Spring	Warm Springs Valley	07/22/1931	1.00	723.97	07/29/1907	0.70	506.78
Site 280: OO Spring	Warm Springs Valley	08/23/1913	20.90	15,130.91	06/10/1918	8.40	6,081.32
Site 281: OO Barnyard Spring	Warm Springs Valley	09/05/1919	9.20	6,660.50	06/10/1918	3.00	2,171.90
Site 285: Basque (East OO) Spring	Warm Springs Valley	07/29/1907	4.00	2,895.87	10/28/1916	1.80	1,303.14
Site 347: Johnson Spring	Warm Springs Valley	10/02/1917	2.00	1,447.93	10/28/1916	1.30	941.16
Site 349: Hughet Spring	Warm Springs Valley	10/28/1916	14.50	10,497.52	04/02/1916	9.20	6,660.50
Site 351: Sizemore Upper Spring	Warm Springs Valley	05/22/1917	2.80	2,027.11	10/28/1916	1.20	868.76
Site 354: Sizemore Lower Spring	Warm Springs Valley	05/22/1917	1.60	1,158.35	10/28/1916	1.30	941.16
Site 361: Un-named	Harney Lake	1902 (no date, year only)	0.80	579.17	08/19/1907	0.40	289.59
		Sub-Total	**56.80**	**41,121.32**	**Sub-Total**	**27.30**	**19,764.30**
		Basin Total	**76.95**	**55,712.59**	**Basin Total**	**38.15**	**27,617.09**

Plate 1



Harney Basin

Entire Harney Basin Area Source: OWRD GIS Basin Map & USGS Watershed Boundary Dataset & Piper and others (1939)

Gerald H. Grondin
Oregon Water Resources Department
June 2015

Explanation

Harney_Basin

Software: ESRI ArcMap ver. 10.1
Source File: S:\groups\gwater\grondin\areas\Harney_Valley\arcview\Harney_Valley_POU_GW_Recharge_2014_Analysis.mxd

Oregon Lambert Projection, NAD 83 (EPSG# 2992)

This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

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