Palouse Basin Aquifer Committee
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September 15, 2011 Meeting Minutes

Moscow UI Facilities Services Center, Jack's Creek Meeting Room

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Attendance

	UI: Michael Holthaus, Water Systems Manager		WSU: Mike Leonas, Director, Capital Planning & Dev.
X	UI: Joe Kline, Director, Utilities and Engineering	X	WSU: Steve Potratz (Vice-Chair), Plant Engineer – Facilities Operations
X	Moscow: Tom Scallorn (Chair), Water Dept Superintendent		Pullman: Mark Workman, Director of Public Works
X	Moscow: Walter Steed, City Council Member		Pullman: Art Garro, Maintenance & Operations Superintendent
X	Moscow: Les MacDonald, Director of Public Works	X	Pullman: Barney Waldrop, City Council Member
	Latah County: Paul Kimmell County Representative	X	Whitman County: Mark Storey, Director of Public Works
	Latah County: Tom Stroschein, County Commissioner		Whitman County: Michael Largent, County Commissioner
	Colfax: Carl Thompson, City Administrator	X	Colfax: Andy Rogers, Public Works Supervisor

Visitors and Others

Kelli Hadley, Moscow-Pullman Daily News; Joe Foote, MSA; Katie Moran, UI; Attila Folnagy, UI; Lauren Carey, UI; Robin Nimmer, Terragraphics; Dale Ralston, Ralston Hydrologic Services; Nathan Moxley, WSU; Kent Keller, WSU; Scotty Cornelius, Whitman County Citizen; Bill Spence, Lewiston Tribune; Steve Robischon, PBAC

Call to Order

Tom Scallorn, PBAC Chair, called the meeting to order at 2:00 PM

1) Approval of the July 21, 2011 Meeting Minutes

Draft July minutes were approved by consensus.

2) Presentations/Discussion –

- **Evaluation of Oxygen and Hydrogen Isotopes in Groundwater of the Palouse Basin and Moscow Sub-basin** – Lauren Carey
  Carey presented the results of her research involving Tritium and Oxygen-18 sampling, and geostatistical modeling of the Moscow Sub-basin. She concludes that mixing is occurring in both the upper and lower aquifers, that the aquifers have distinct oxygen signatures, and that in the upper aquifer areally distributed

precipitation as well as losing streams may play a role in recharge. Carey recommends further study of a strong correlation that was seen between Oxygen-18 depletion and Carbon-14 apparent age.

- **Results of Water Level/Pumping Analysis –** Katie Moran
  Moran presented the results of her (Framework recommended data gap follow-on) project aimed at examining relationships between historical Grande Ronde pumping and water level declines in the basin. She concludes that rates of water level decline have been decreasing since the late 1980's (when pumping began to decline), and a simplified water balance model indicates annual recharge to the lower aquifer is in the range of 1.5 to 2 billion gallons per year. Moran recommends continued monitoring of water level decline, as the quality and completeness of much of the historical data is lacking.

3) Unfinished Business –

- **UI Administration of PBAC Funds**
  Robischon reported the following status items: Funds/costs transfers from UI Research Office accounts to Facilities accounts is in progress; Robischon is now employed by UI Facilities; Joe Kline is his boss; a subcommittee has been created to address Research VP McIver's issues of concern; FY12 PBAC invoices are pending response to McIver issues.

  The group discussed the status, and a motion was passed directing Robischon to send out PBAC invoices the week of September 19.

- **PBAC Goals Review Session Planning**
  The group discussed the logistics of the upcoming (October 20, Pullman, beginning at 1:00 PM) PBAC goals review session. In addition to a review of PBAC goals, the group will discuss the recommendations received from the CAG and the PBAC vision of the future role of the CAG. The session is intended as a PBAC member discussion and decision making forum, and visitors are welcome.

4) New Business – None

5) PBAC Projects Progress Report –

Continuation of Basinwide Aquifer Testing Project
Robischon displayed Folnagy's status report indicating he has been working on water level trend, well connection and compartmentalization analyses. He has also begun planning for a Thanksgiving pumping shutdown, and will be downloading HOBO and datalogger transducers in October.

Enhanced Evaluation of High Priority Data Gaps
Nimmer reported a contract has been signed and work has begun on the project. Nimmer and Ralston are collecting data and have met with Storey and Guy Gregory about potential well locations and well construction funding.

6) Citizens Advisory Group Report – No Report (no meeting)

7) Budget Report – No Report (budget in transition as reported above)

8) Other Reports and Announcements –

Moscow Surface Water Reservoir Feasibility Study

MacDonald reported the draft report of the first project phase is complete, and a city council workshop is tentatively planned for the first week of December to assess the results and discuss how best to proceed.

Moscow Comprehensive Water Systems Plan

MacDonald reported the last chapter of the draft report is nearing completion, with plans to present the report to the city council in October and to complete the process this calendar year. He also reported the comprehensive sewer systems plan has been through a public comment period and will likely be presented to the public works/finance committee later this month.

Moscow Water Conservation Plan

MacDonald reported the draft plan is under review and the goal is to bring the plan to the city council by year's end.

2011 Water Summit Planning

Robischon displayed the flyer and draft agenda for the Water Summit. The Summit is scheduled for (4:00 – 7:00 PM) October 4 in Pullman. The keynote speaker will be Dr. David Wunsch, Director of Science and Technology, National Ground Water Association. Planners are working to firm up the agenda and secure speakers. Advance registration (not required) can be accessed through a link at http://palousewatersumit.org.

Other

Robischon displayed documents related to the Washington watershed plan implementation capital grant program and a proposal submitted by PBAC to construct monitoring wells within the basin. The proposal was not funded through the program, but there may be an opportunity to pursue funding through a different channel. Robischon will contact the appropriate WDOE representative for further discussion of how best to proceed.

Waldrop inquired about whether there are dataloggers in Albion, and if not whether they can or should be installed in the city wells. Rogers volunteered to look into the matter further and report back to the committee.

9) Next Meeting –

The next (PBAC goals review) meeting is scheduled for October 20 in Pullman.

10) Adjournment -

The meeting was adjourned at 3:42 PM.

Submitted for review and approved at the October 20 PBAC meeting.

Steve Robischon, PBAC Executive Manager

Technical Report

Evaluation of the relationship between pumping and water level declines in the Grande Ronde Aquifer of the Palouse Basin

Prepared by Katie Moran, Consulting Hydrogeologist, for the Palouse Basin Aquifer Committee
September 2011

Contents

Introduction

Annual water level declines of 0.9-1.5 feet have been observed in Palouse Basin wells completed in the Grande Ronde aquifer since the aquifer was first developed in the 1890s. Water level declines have decreased slightly during the last fifteen years, possibly as a result of a decrease in annual pumping, but the relationship between water levels and pumping is uncertain. Better understanding of the relationship between water level decline and pumping in the Palouse is important for planning future basin management.

Purpose and Objectives

The overall goal of this research was to investigate the relationship between Grande Ronde pumping rates and measured water levels in order to draw conclusions about historical and future aquifer behavior within the Palouse Basin. Available historical water level and pumping data were compiled and used to calculate long-term rates of water level decline and pumping. Comparisons of changes in water level among different wells within the basin as well as changes in water level per volume pumped over time were performed to identify similarities and differences within the record.

The relationship between pumping and water level decline was also evaluated on a shorter time scale. Water levels collected from the WSU 5 well during 2009 and 2010 were compared to comprehensive HOBO-collected pumping data to identify the relationship between water level decline and pumping on a shorter time scale than the annual averages investigated in the historical data.

The scope of work for this project was identified as a medium-priority data gap in the Palouse Ground Water Basin Framework Project Final Report (TerraGraphics, Inc., 2011, section 6.2.2.4.)

Specific project objectives:

- Identify the quantitative relationship between annual pumping and historic water level declines for the period of record. Evaluate changes in this relationship over time, and consider possible sources for these variations, such as regional recharge/discharge or changing aquifer parameters.
- Investigate WSU 5 well water level responses to changes in basin pumping on shorter time scales, and compare this relationship to the long-term relationship between annual pumping and basinwide declines.

Hydrogeologic Model and Assumptions

Due to the focused nature of this report, it is assumed that the reader has a working knowledge of the study area as well as some understanding of the relevant hydrogeology.

One if the simplest models for an aquifer is the “bathtub” model, in which the change in head (dh) due to withdrawal of a volume of water is a function of aquifer storativity (S), aquifer area (A), and any other existing fluxes (recharge and natural discharge).

Volume Pumped - (Recharge – Natural Discharge) = S * A * dh

Use of this model requires several assumptions, the most significant of which is the assumption that short-term transient effects due to pumping do not affect water levels; the potentiometric surface is assumed to be “flat” within the aquifer. Discounting transient effects is more reasonable over long periods of time, and for high-transmissivity aquifers such as the Grande Ronde, but the assumption that water levels equilibrate quickly across the basin is known to be incorrect on very short time scales (hours-days), and may also be incorrect over time scales of weeks to months.

Additional important assumptions concerning area hydrogeology were necessary due to the limited nature of available historical data as well as uncertainties concerning the spatial extent of the Grande Ronde aquifer.

- Recent work (Moran 2011, McVay 2007, Fiedler 2009) has strongly suggested that hydraulic connections exist between Palouse, Pullman, and Moscow within the Grande Ronde aquifer. This conclusion is supported by recent and historic groundwater elevation data. The similarity of seasonal and annual water level patterns among different wells in these areas indicates that it is not significant which particular well is used for water level analysis, and that historical patterns measured in one well are likely similar across the broader area.
- Hydraulic connection between the Moscow-Pullman pumping centers and Colfax-area wells is uncertain, based on groundwater elevations and the dissimilarities of long-term declines. Correspondingly, Colfax pumping volumes were not included in the calculation of annual pumping totals for the basin. Insufficient groundwater elevation data exists to perform a separate analysis of historical water level declines vs. pumping for the Colfax area. In addition, no conclusive hydrologic conceptual model has been suggested to explain the discrepancies between groundwater elevations in Clay Street and the Glenwood wells.

Within the context of this model, there are multiple reasons that the observed relationship between water level decline and pumping in the Palouse Basin may change over time, including:

- Changes in the magnitude of basin pumping.
- Changing aquifer parameters (S).
- Head-related changes in regional discharge from the basin.
- Decreased recharge due to depletion of the perched or hydraulically connected source (Wanapum aquifer or surface streams).
- Increased recharge due to increase in gradient between hydraulically connected source and the Grande Ronde aquifer.

Description of source data

The evaluation of Grande Ronde aquifer system behavior with respect to Palouse Basin groundwater withdrawals required two types of data: groundwater elevations (water levels) and pumping data.

Water Level Data

Groundwater elevation data for Palouse Basin wells completed into the Grande Ronde aquifer were acquired from several sources. The bulk of this information had been previously compiled or recorded in computer files provided by Steve Robischon, from original data provided directly by Palouse Basin pumping entities, previously-published reports, the data-collection efforts of Farida Leek, and the PBAC well monitoring network. A small amount of historical data was retrieved from the USGS on-line groundwater database. Some recent data were collected by University of Idaho students.

Groundwater elevations used in this project were grouped into three categories: irregular historical water levels, sequential monthly water levels, and high-quality transducer (levelogger) data. Of these, the levelogger data is of the highest quality. For the historical, manually-collected data, multiple factors affect the data quality, including the accuracy of monitoring equipment, changes over time in the monitoring equipment used, and possible changes to wellhead elevations.

Two additional factors also are important for considering the accuracy of water level data. First, water levels in the Palouse Basin exhibit strong seasonal patterns as a result of seasonal demand; in the Grande Ronde aquifer, the maximum head decline measured by comparing each year's maximum and minimum head values may greatly exceed the average decline measured from year to year. Seasonal fluctuations can be significant for calculating annual declines when the elapsed time between measurements is relatively large (more than 1-2 months apart) and irregular. Changes in atmospheric pressure can also cause water levels to fluctuate up to approximately 1 ft. These two factors may be significant sources of error for the manually-measured historic water levels, but are absent in the levelogger data, which were collected on a short increment to correctly register seasonal fluctuations as well as adjusted to account for barometric effects.

Due to the large scope of this project and uncertainties surrounding some historical data, systematic data validation using the original sources was not possible. Professional judgment was used to excise outliers from the data set, as well as exclude portions of the record which appeared to be inaccurate or inconsistent. Selecting outliers to exclude from the data set was done conservatively to preserve as much of the record as possible.

The hydrogeologic assumption that Grande Ronde wells respond similarly over annual time scales allowed some leeway in selecting monitoring wells with “good” records (less noise and/or jumps), which permitted data analysis to focus on the highest-quality existing data.

Pumping data

Pumping data used for this report were obtained from two sources: municipal pumping information recorded by each groundwater utility, and from individual pump monitors (HOBOs). Pumping data recorded by each utility are available on a monthly and annual basis for various periods of time. HOBO data were recorded in real-time, according to the motor on/off times for each well; cumulative pumping totals were then compiled using the pump rating data (gallons per minute, GPM) presented in Moran 2011.

Recorded monthly and annual pumping totals were summed to generate combined basin pumping estimates (Grande Ronde aquifer) for the cities of Pullman, Palouse, and Moscow, as well as UI and WSU. Extreme care was taken to exclude Wanapum pumping from the historical record. As per the hydrogeological assumptions section, Colfax wells or groundwater withdrawals were not analyzed as a part of this project due to hydrogeologic considerations and relatively limited data (amount and quality).

Evaluation of water level declines (Data Analysis)

Presentation of long-term data

Groundwater elevations in the Grande Ronde aquifer have been declining for the full period of record starting in 1935, as shown in Figure 1.

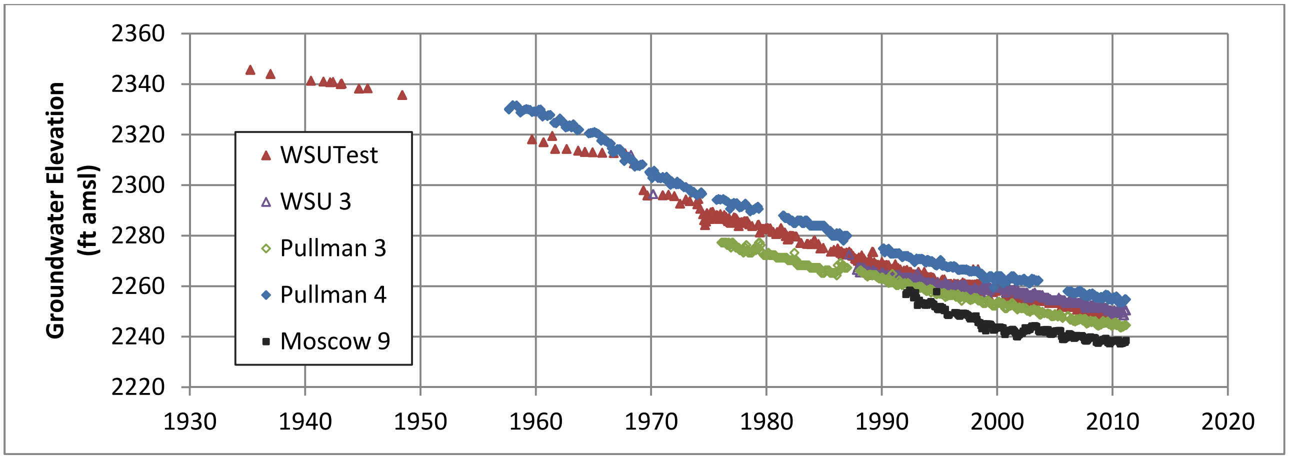

Figure 1. Groundwater elevations for selected Grande Ronde wells, 1935-2011

According to the "bathtub" hydrogeologic model, changes in water level within the basin are linked to cumulative pumping for a given time period. The earliest reliable annual combined basin pumping data used for this project were measured in 1951. Figure 2 compares long-term water levels to total (cumulative) volumes pumped since 1951. It is clear that water levels have continued to decline with continued pumping of the Grande Ronde aquifer.

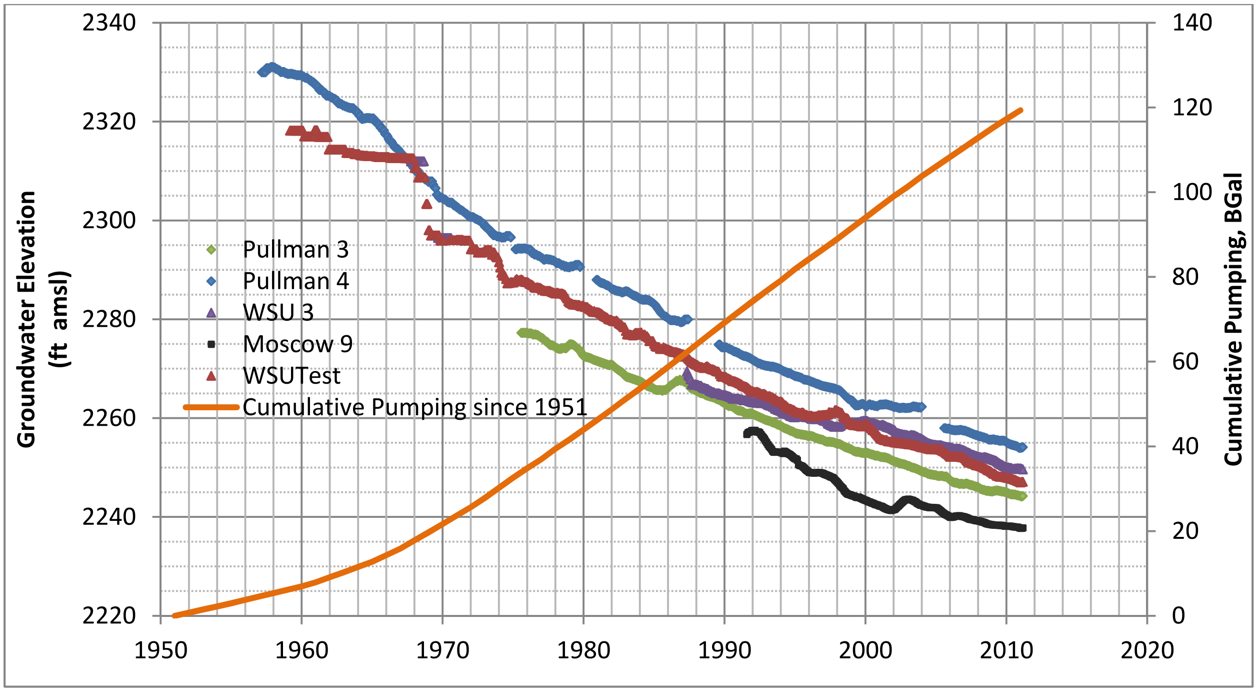

Figure 2. Groundwater Elevations vs. Cumulative Grande Ronde Pumping (BGal since 1951). Water level data is represented by 12-month moving averages to reduce seasonal fluctuations.

Calculation of slope

In order to identify the relationship between pumping and water level decline, it is necessary to determine annual rates of both pumping and water level decline. Due to the cumulative annual accounting of pumping in the Grande Ronde, it is simple to display and analyze changes in basin pumping over time. Figure 3 presents annual Grande Ronde pumping from 1951-2010. As shown, annual pumping rates increased threefold between 1951 and 1974, reached a peak of 2.7 billion gallons (BGal) in 1987, and decreased slowly during the last two decades.

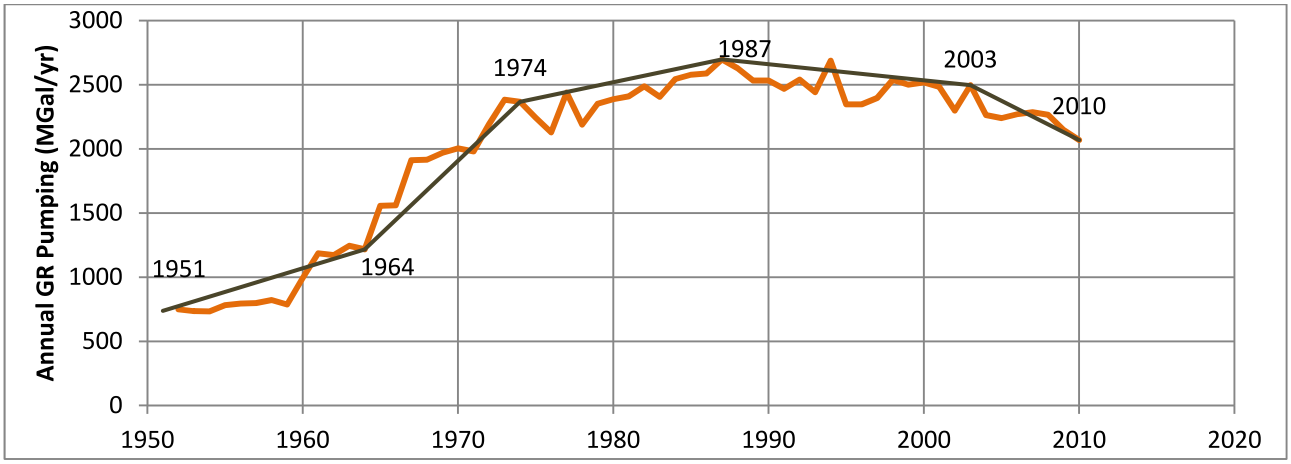

Figure 3. Annual Grande Ronde pumping, 1951-2010.

Annual pumping data is generally accessible and reliable, but it is more difficult to precisely measure annual water level decline directly from existing groundwater elevation data. In addition to error resulting from seasonal fluctuations and barometric influence, the precision and accuracy of water level measurements is not always consistent over time. For this reason, water level declines were calculated by several different methods

Visual Identification

Initial calculation of water level declines were performed by identifying changes in slope of water level decline, and calculating the average yearly declines for the discrete intervening periods. Figure 4 shows water levels for the WSU Test well, broken into periods of discrete slope change, along with the calculated annual head decline for each of the identified time periods. Rates of decline were also calculated for historical data collected in Palouse 1 and Pullman 4. Additional slope estimates for WSU Test were performed by Robischon (2011), by calculating the least-squares-regression-line (LSRL) slope for identified periods of similar behavior.

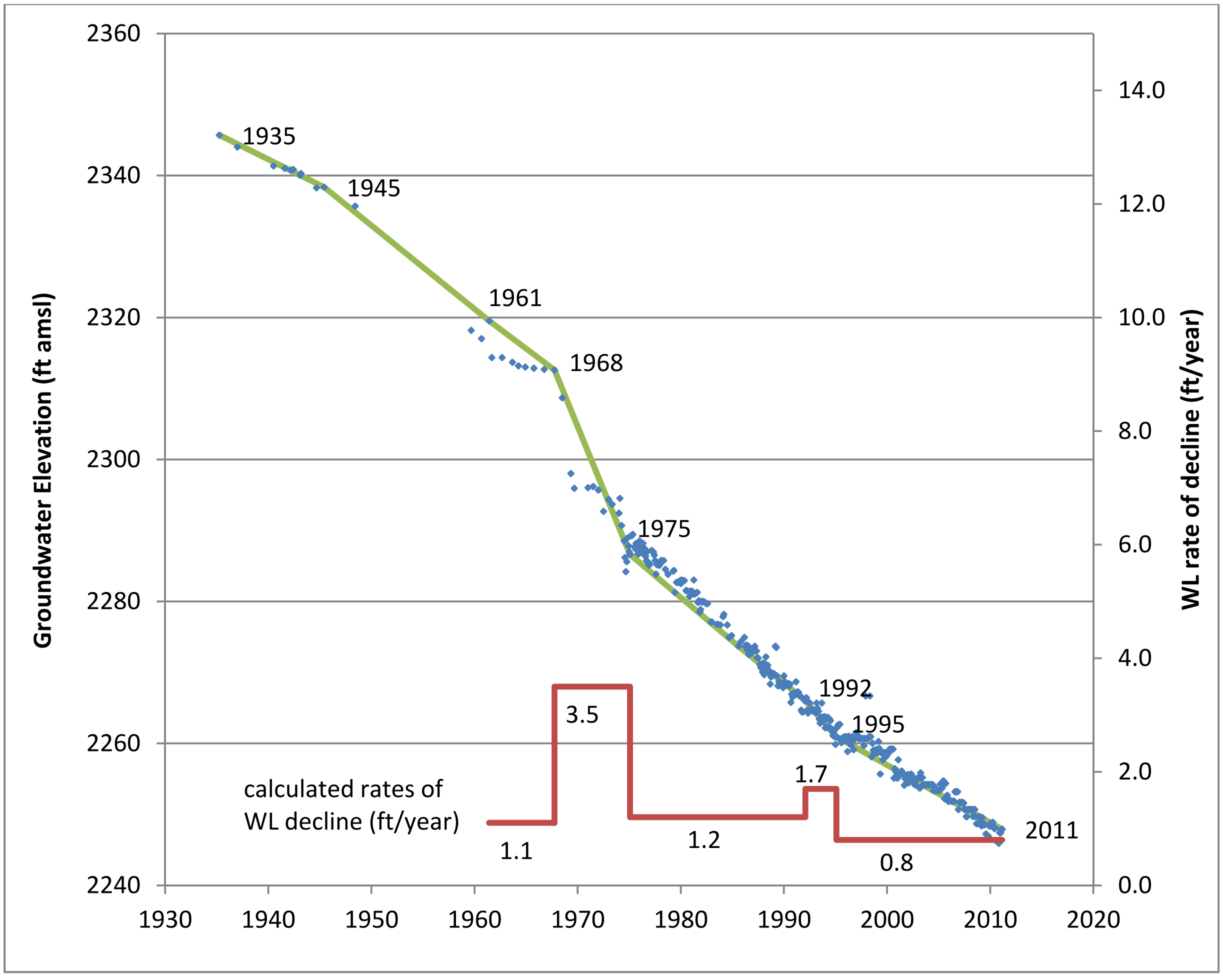

Figure 4. WSU Test water levels with identified periods of constant decline. Calculated rates of annual head decline (ft/year) are shown in red.

Automatic Calculation

Rates of water level decline were also calculated directly from groundwater elevation data (Figure 5). Rates of water level change were calculated as a 5-year slope (LSRL) of 12-month moving averages of measured groundwater elevations. The 12-month moving averages were used to reduce seasonal fluctuations.

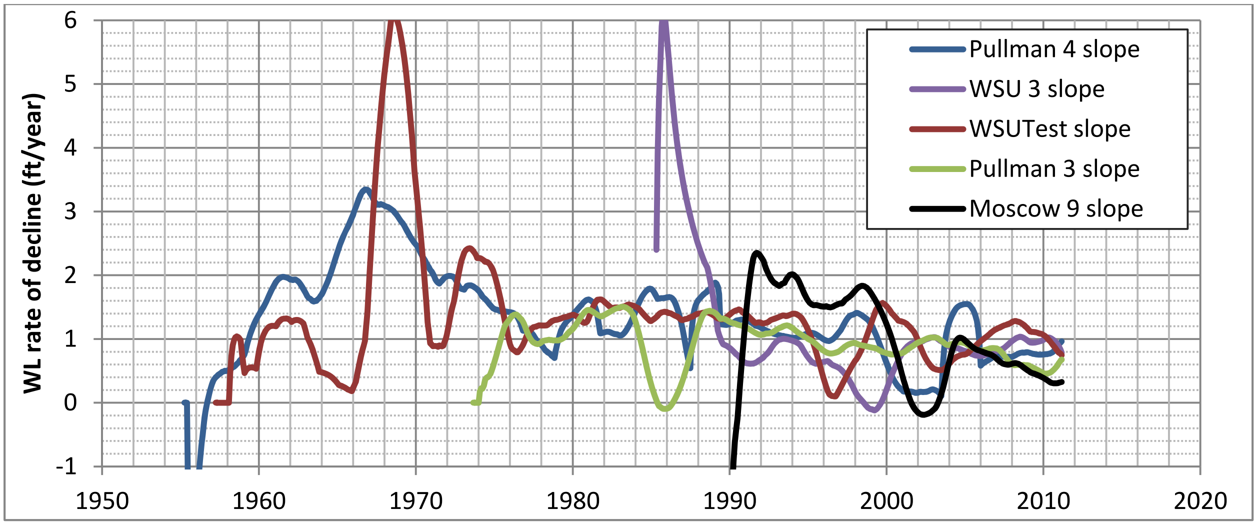

Figure 5. Calculated rates of water level decline (ft/year).

As shown in Figure 5, calculated slopes of groundwater elevations feature a large degree of noise and irregularity; although long-term, monthly groundwater elevation measurements appear to be robust, even a relatively large window for calculating slope (5 years) is susceptible to errors presumably caused by data quality problems. The high and low peaks in the calculated slopes correspond to "jumps" in the historical water level data which were likely caused by inconsistencies in measurement, and may not indicate responses to changes in pumping. The amount of noise in much of these calculated water level declines precludes useful comparison with annual pumping data; however, some of sections of the calculated slopes for WSU Test and Pullman 3 appeared to be sufficiently consistent for comparison with annual pumping (Figure 6). Figure 6 (bottom) presents periods of relatively "clean" water level declines calculated from WSU Test and Pullman 3 groundwater elevation data, along with smoothed annual pumping.

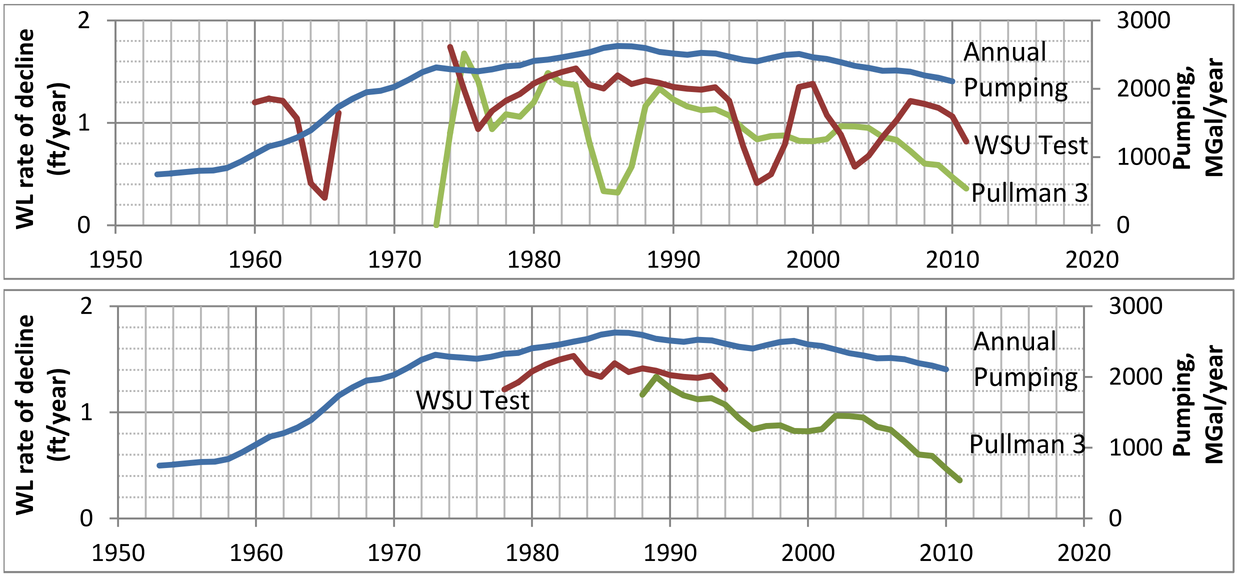

Figure 6. Calculated annual WL declines for WSU Test and Pullman 3, along with annual pumping rates. Rates of water level decline were calculated as the 5-year slopes (linear regression of WL elevations) of 12-month moving averages of measured monthly groundwater elevations, which were then averaged for each calendar year to produce an annual series of WL declines (one data point per year). The annual pumping series was calculated as the moving 5-year slope of cumulative annual pumping.

WSU 5 Regression

Multiple-year rates of water level decline were calculated using the annual maximum and minimum elevations measured by the WSU 5 levelogger (after barometric correction). Regression lines fit through annual maximum and minimum values yielded similar slopes of 0.69 ft/year (mins) and 0.66 ft/year (maxes).

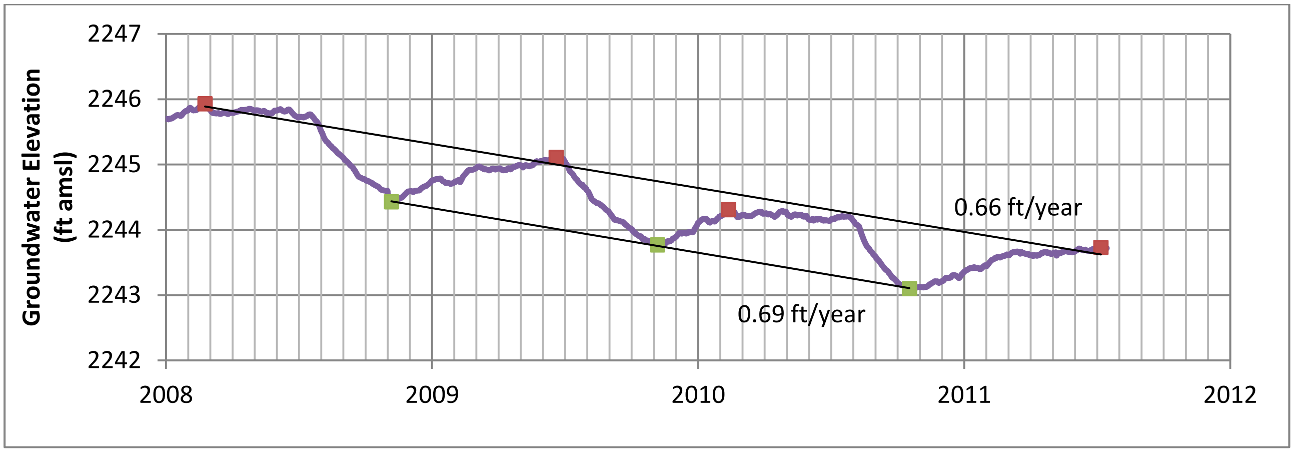

Figure 7. WSU 5 groundwater elevations (levelogger data). Relative minimum and maximum groundwater elevations are denoted by the red and green squares. Displayed rates of decline were calculated from LSRLs fit through the minimum and maximum point series.

Comparison of Calculated Slopes

A compilation of the estimated water level rates of decline calculated by the different methods described above is presented in Table 1. Average annual pumped volumes for each time period were calculated from annual and/or monthly pumping data.

Table 1. Comparison of water level decline and pumping for discrete time periods

Well ID	Method	Start Year	End Year	WL decline (ft/yr)	PV (BGal/yr)
WSUTest	Regression*	1935	1945	0.71	
WSUTest	Regression*	1945	1961	1.45	
WSUTest	Regression*	1961	1967	0.71	1.44
WSUTest	Regression*	1975	1985	1.33	2.39
WSUTest	Regression*	1985	1995	1.37	2.55
WSUTest	Regression*	1992	2007	0.89	2.41
WSUTest	Visual	1961	1967	1.09	1.44
WSUTest	Visual	1967	1975	3.55	2.13
WSUTest	Visual	1975	1985	1.23	2.39
WSUTest	Visual	1985	1992	1.18	2.57
WSUTest	Visual	1992	1995	1.69	2.49
WSUTest	Visual	1995	2010	0.81	2.34
WSUTest	5-year slope of 12-month moving averages	1978	1983	1.39	2.41
WSUTest	5-year slope of 12-month moving averages	1984	1994	1.35	2.57
Pullman 4	Visual	1972	1979	1.32	2.30
Pullman 3	5-year slope of 12-month moving averages	1989	2000	1.04	2.48
Pullman 3	5-year slope of 12-month moving averages	2004	2010	0.72	2.21
Palouse 1	Visual	1975	1993	1.10	2.46
WSU 5	Calculated from levelogger data, maxes	2009	2011	0.66	2.05
WSU 5	Calculated from levelogger data, mins	2009	2010	0.68	2.1

*Regression slopes calculated for visually-identified periods by Robischon (2011)

Figure 8 displays calculated rates of annual water level decline along with annual pumping (data from Table 1). Several obvious outliers exist in the rate of decline data, most noticeably in the older (before 1980) data. Annual rates of water level decline do not correspond particularly well overall among different wells or over time; however, it is clear that the overall rate of water level decline has been decreasing since approximately 1990. This decrease in the rate of water level decline over time corresponds to a similar decrease in annual pumping.

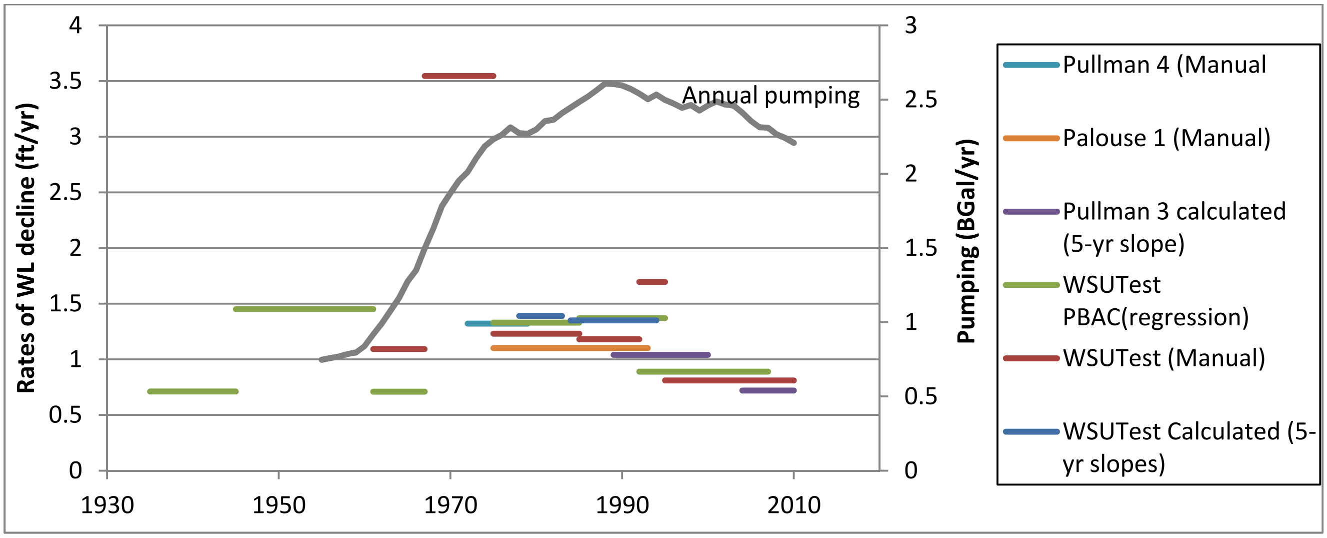

Figure 8. Identified rates of water level decline. Annual pumping is shown as a 5-year moving average (trailing).

Calculation of R and S*A

According to the hydrogeologic model, the calculated annual rates of decline and corresponding annual volumes pumped can be plotted and regressed to estimate R (annual recharge) and S*A (storativity times area).

Comparison of parameters estimated using calculated slopes

Figure 9 shows a plot of calculated annual rates of water level decline vs. annual volumes pumped. The series “Visual ID segments” was created by combining the calculated slopes presented in Table 1. Calculated average annual slopes for WSU Test and Pullman 3 were included with pumping data on an annual scale (one data point for each year) for the time periods designated in the Figure 9 legend.

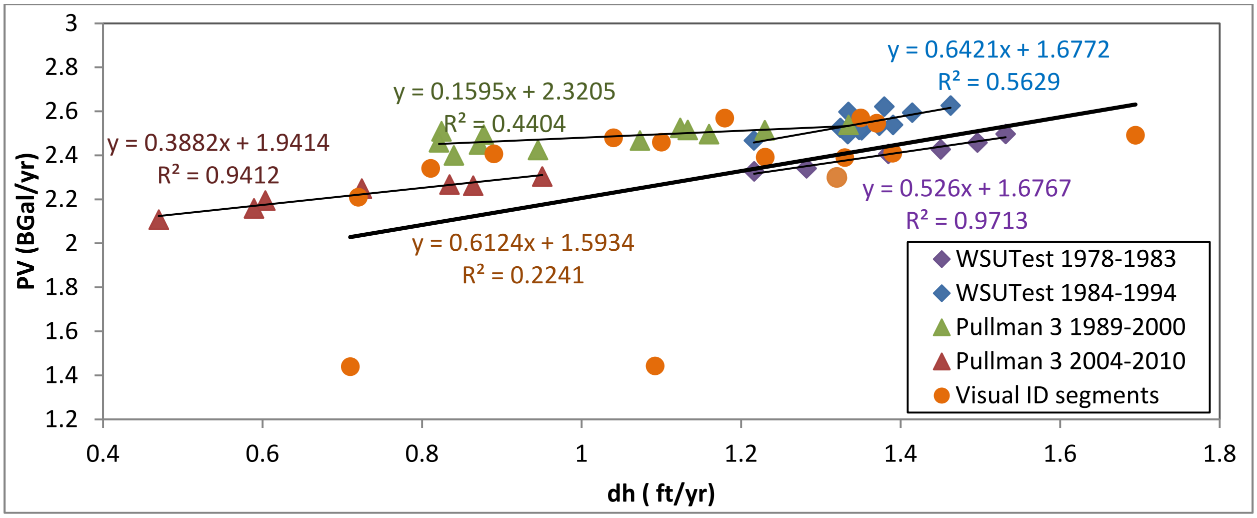

Figure 9. Annual rates of water level decline (ft/year) vs. annual pumped volumes (BGal/year).

Linear trendlines (LSRLs) were calculated for each data series in Figure 9. For each trendline, the intercept represents R, in units of BGal/year, and the slope represents S*A, in units of BGal/feet. Table 2 presents the estimated values of R and S*A. Bush's 500 mi^2 estimate for the size of the basin was also used to generate possible values for aquifer storativity. For this hydrologic model, S and A are inversely related; for a given S*A value, as A increases, S must decrease, and vice versa.

Table 2. Estimated values of S, A, and R

Well ID	Start Year	End Year	S*A (mi^2) (slope)	R (BGal/yr) (intercept)	S (dimensionless) (if A=500 mi^2)
WSUTest	1978	1983	2.52	1.68	5.04E-03
WSUTest	1984	1994	3.08	1.68	6.16E-03
Pullman 3	1989	2000	0.76	2.32	1.53E-03
Pullman 3	2004	2010	1.86	1.94	3.72E-03
Visual ID segments	mixed	mixed	2.94	1.59	5.87E-03

Estimated annual recharge using this relationship is relatively consistent for each of the data sets, with the exception of the Pullman 3 data from 1989-2000. Excepting this data, recharge is estimated between 1.59 BGal/year and 1.94 BGal/year. The storativity values calculated using the 500 mi^2 estimate of basin size are relatively high compared to recent estimates of S from Grande Ronde aquifer test analysis. It's important to note that the S and A estimates are relative, and fairly subjective without conclusive evidence to constrain either parameter.

Despite reasonably good agreement among the estimates of recharge, there is still significant variation in the relationship between PV and dh. Much of this variation of this may be due to the inclusion of imprecise historical groundwater elevation data, but it is impossible to pinpoint the exact cause without additional information. An alternate explanation for differing estimated parameters for water level data collected from different wells is that some of the hydrogeologic assumptions of the model are incorrect, such as connection among these wells. However, regardless of the reason for this variation in estimated parameters, the accuracy and precision of the historical data do not appear to be sufficient for delineating changes in aquifer properties over time.

WSU 5 slope identification and comparison

More detailed examination of water levels over time is possible using high-quality levelogger data. WSU 5 was selected for primary analysis from among the PBAC-monitored Grande Ronde wells because of 1) its excellent data quality and continuity and 2) its ideal character as a "background" well, showing the same weekly-monthly patterns as other wells with minimal "noise" from very short-term transient pumping effects. "Good" levelogger data exists for the period from November 2007 through June 2011. Figure 10 presents groundwater elevations for WSU 5 (after barometric correction) along with cumulative basin pumping during that time period. The barometrically-corrected WSU 5 levelogger data show significant variation from the general declining water level trend on a seasonal (and shorter) basis; cumulative pumping recorded on a monthly scale also shows significant seasonal variation.

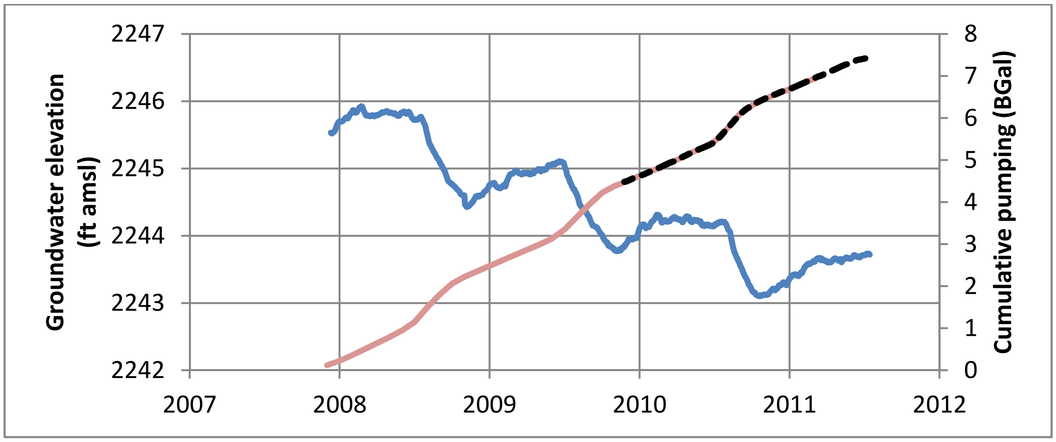

Figure 10. WSU 5 groundwater elevations vs. cumulative basin pumping. Water levels shown are the first measurement recorded for each day; cumulative basin pumping was calculated from monthly data (solid line) as well as HOBO data (dashed line).

WSU 5 groundwater elevations were separated into periods of decline and recovery, in order to compare individual sections of water levels to pumping (Figure 11). Endpoints (time values of water level minima and maxima) were rounded to the most appropriate first day of the month to reduce the error which could result from interpolating monthly pumping totals.

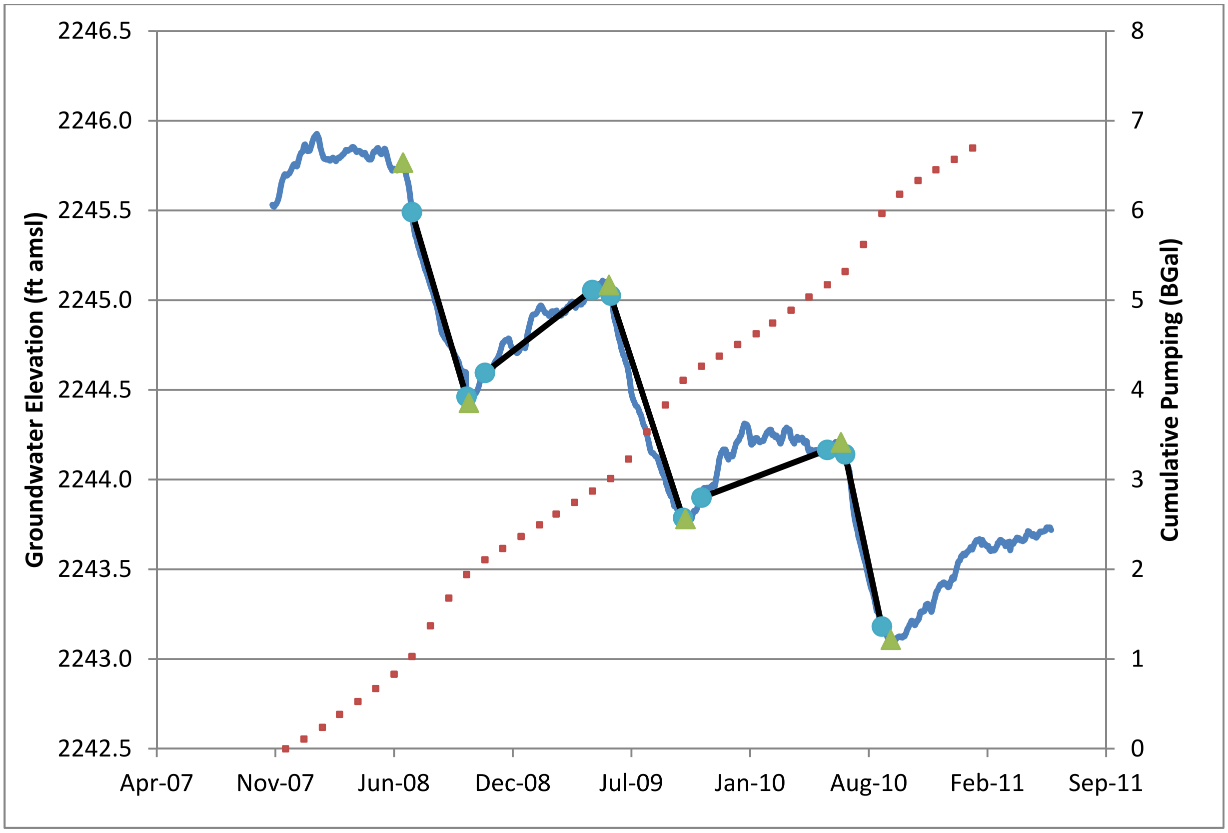

Figure 11. WSU 5 groundwater elevations (daily) with identified periods of decline and recovery. Monthly cumulative pumping is shown in red.

Measured water level declines vs. pumping for the selected periods of decline in recovery shown in Figure 11 were plotted in order to identify estimates of recharge and S*A (Figure 12). Total water level declines and pumping for the identified sections were divided by time to produce "annual" rates of water level decline and pumping. Analysis of seasonal identified decline and recovery periods within the WSU 5 data identified an intercept (R) of 1.82 BGal/year. The slope of the LSRL is in units of BGal/ft; converted to units of square miles, the slope (S*A) is 1.345 mi^2.

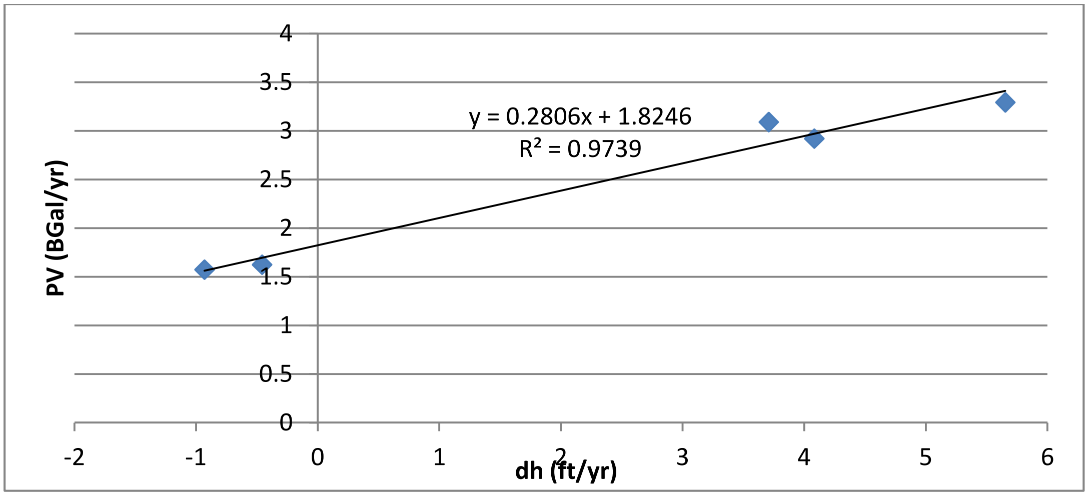

Figure 12. Rates of WSU 5 water level decline (ft/year) vs. pumped volumes (BGal/year). Both water level and pumping slopes were calculated from monthly data.

It is important to note that the data points plotted in Figure 12 were calculated for specific, delineated periods of decline and recovery; to check their validity with the continuous data, these values of R and S*A were used to generate synthetic water levels for comparison with measured WSU 5 water levels on a monthly basis. Figure 13 presents observed WSU 5 water levels, along with synthetic water levels calculated using the parameters estimated for the data in Figure 12 and monthly cumulative pumping.

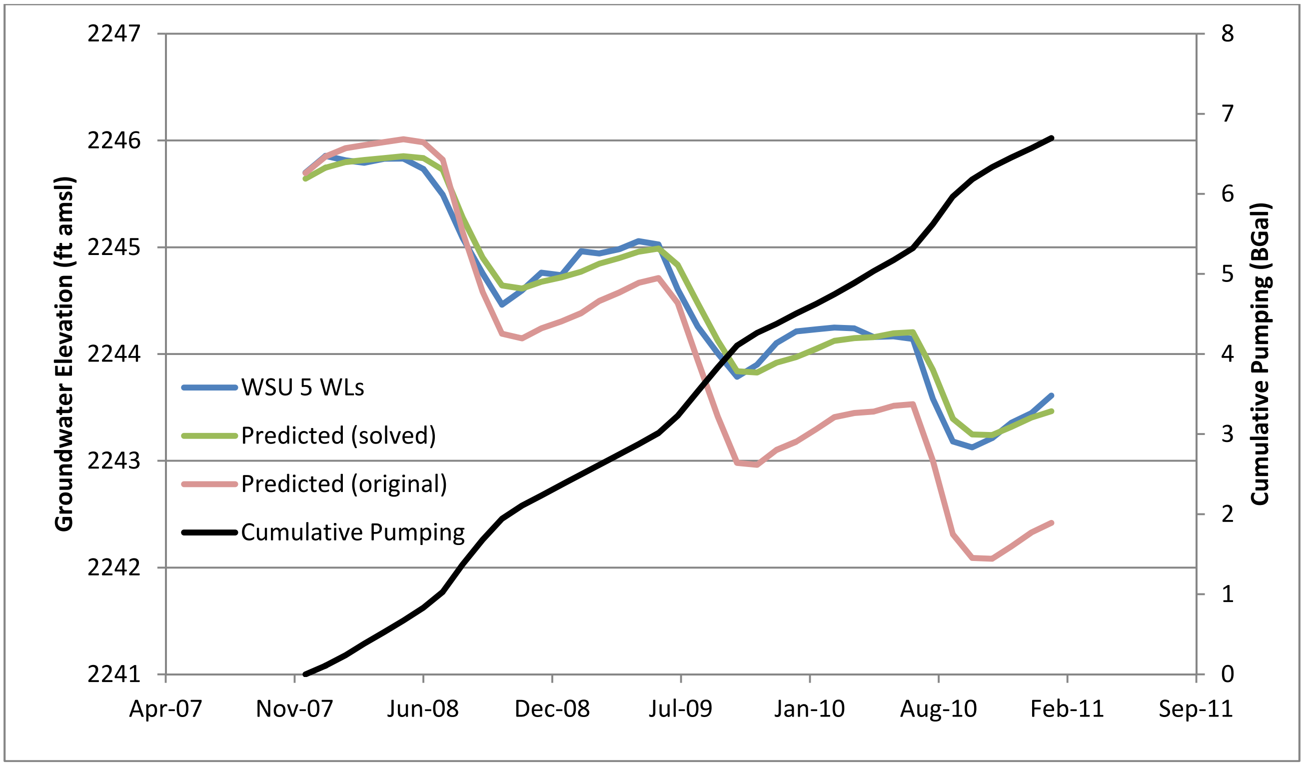

Figure 13. WSU 5 Water levels with cumulative pumping. All data is monthly.

The synthetic water levels generated using the original R and S*A values identified from the decline/recovery segments (denoted as "Predicted (original)") decline at a faster rate than observed WSU 5 water levels. A set of optimized parameters was calculated by directly solving for the S*A and R values which would result in a minimum residual sum of squares (RSS, observed-predicted water levels) for the WSU 5 record; the residual sum of squares was minimized for R=1.8246 BGal/year and S*A=2.02 square miles. These "solved" parameters yield more accurate synthetic water levels than the original parameter values generated from the analysis of decline/recovery segments in WSU 5.

The residuals (observed- predicted water levels) for the optimized parameter values show a strong seasonal pattern, as shown in Figure 14; water levels are over-predicted during the winter and under-predicted during the summer months.

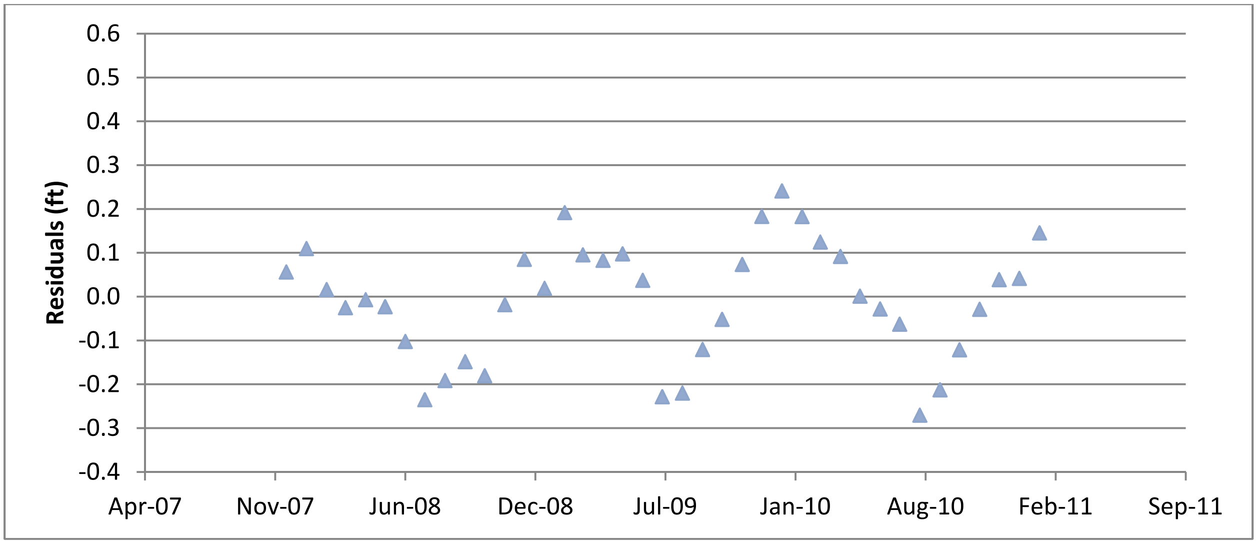

Figure 14. Residuals: Observed WLs – predicted (solved) WLs for monthly water level and pumping data.

The same analysis was performed using a 20-month window of daily water level and pumping data. Daily water levels for WSU 5 were generated by selecting the first water level value measured for each day; cumulative HOBO pumping was averaged for each day. Synthetic water levels were calculated using the original parameters identified from the grouped decline/recovery data, and were also generated using the "solved" parameter values which resulted in the minimized residual sum of squares (Figure 15).

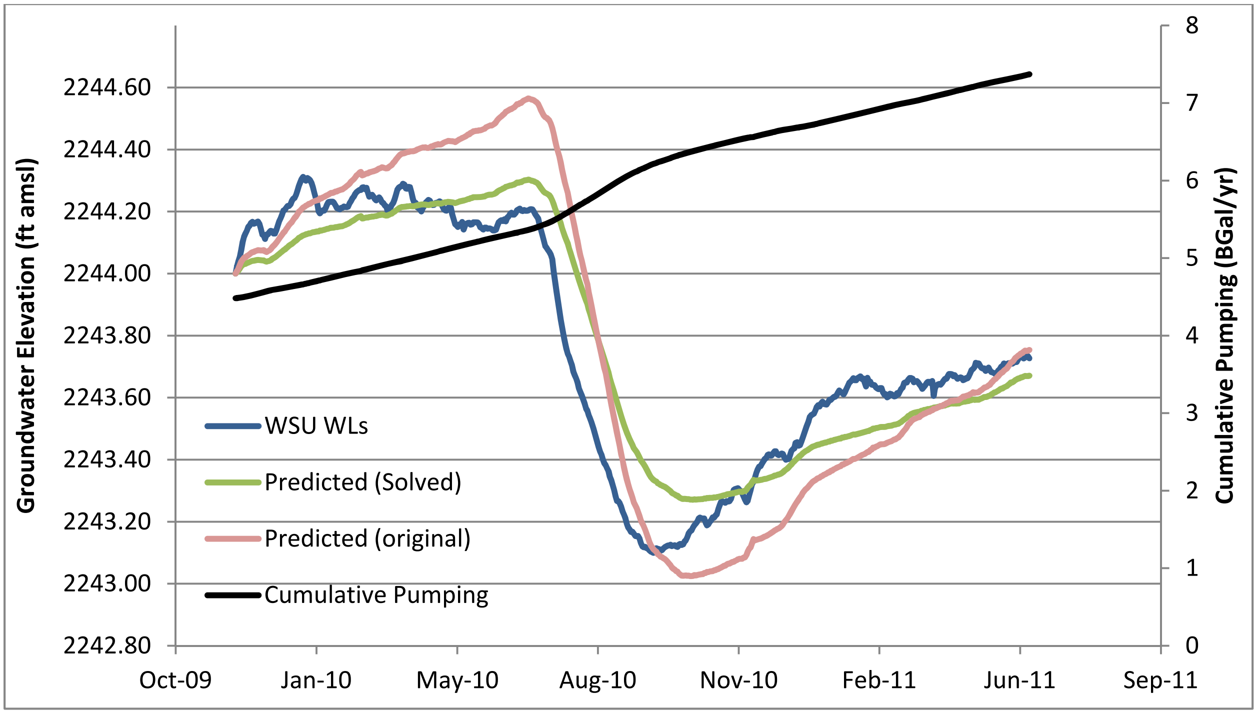

Figure 15. WSU 5 Water levels with cumulative pumping (daily).

The residual sum of squares was minimized for parameter values of R=1.777 BGal/year and S*A=2.08 mi^2, for the daily series of WSU 5 water levels and cumulative pumping. These values are similar to the ones estimated from the monthly WSU 5 data. Still, the “predicted” water levels generated using these optimized values for S*A and R do not mimic observed WSU 5 water levels perfectly. The residuals from the daily data (Figure 16) also indicate that the departures from observed water levels are seasonal.

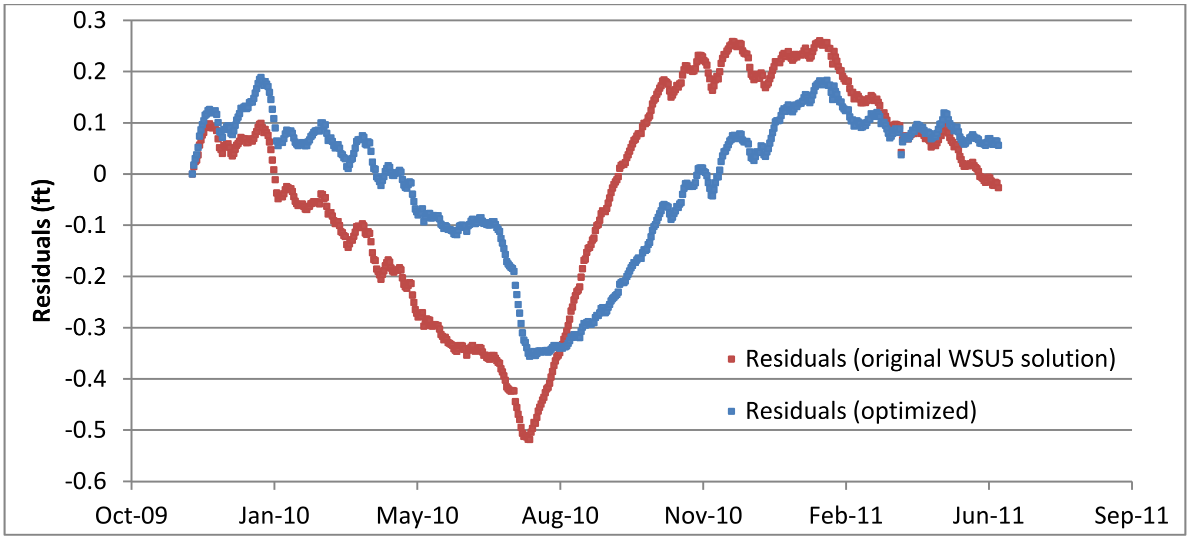

Figure 16. Residuals: Observed WL – predicted (solved) WLs for daily water level and pumping data.

The seasonal trends observed in the residuals for both the monthly and daily WSU 5 data suggest that one or more of the assumptions of the hydrogeologic model are inaccurate over that time scale. One possibility is that annual recharge is not constant, but instead carries a seasonal component; this idea is consistent with models which would tie recharge to streamflow or precipitation, which are greater in the winter and spring. Another possible explanation for the seasonality of the residuals is that water levels may be responding to transient effects, that the “bathtub” model is not adequate over short (day-month) time scales.

However, the relative magnitude of the residuals is small; in general, the optimized parameter estimates are adequate for simulating both the seasonal recovery/decline patterns observed in the WSU 5 water levels, and the magnitude of multi-year declines. It also appears that the monthly pumping data is of sufficient resolution to represent the seasonal and annual behavior of water levels.

WSU 5 seasonal analysis

Seasonal analysis of water level data was conducted using levelogger data collected from WSU 5. WSU 5 was selected from among the wells also instrumented with leveloggers due to its length of record, and its status as a “background” well which is relatively unresponsive to short-term transient pumping effects. The length of record for multiple wells within the basin would be extended if manually-measured monthly water level data were also used; unfortunately, the monthly data are not of sufficient accuracy for seasonal analysis due to the inclusion of barometric effects within the data and other quality control problems.

Figure 11 presented WSU 5 daily water levels, segmented into periods of seasonal water level decline and recovery for comparison of relative changes in head to pumping. These segments, analyzed together using the equation (PV = S*A*dh + R), identified an annual recharge rate of 1.82 BGal/year and an S*A value of 1.345 mi^2. When the decline and recovery segments are grouped by type, however, these estimated parameters are significantly different (Figure 17 and Table 3).

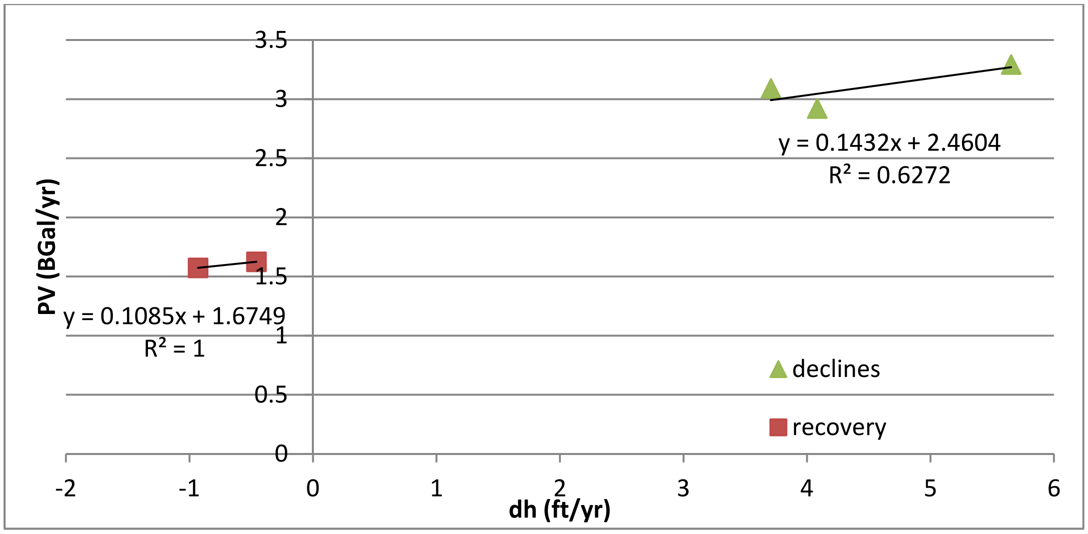

Figure 17. Rates of WSU 5 water level decline (ft/year) vs. pumped volumes (BGal/year), divided into seasonal categories of water level decline and recovery.

Table 3. Seasonal R and S*A estimates

	S*A (mi^2)	R (BGal/year)	S (for A=500 mi^2)
Decline	0.69	2.46	0.0014
Recovery	0.52	1.67	0.001
Combined	1.345	1.82	0.0027

Several interesting points can be made about the estimated parameters presented in Table 3. The S*A values for the seasonal decline and recovery data are similar, but together account for less than half of the estimated S*A value for the combined data set. In addition, not only do the recharge values differ considerably for the seasonal segments, they also suggest that more recharge occurs during the summer months, when water levels are declining, than during the wet winters and springs when water levels recover. This contradicts the hypothesis that recharge is tied to precipitation or streamflow, instead implying that recharge is a function of relative pumping and the corresponding increase in gradient, or controlled by some other factor.

A possible explanation for these disparities is that the sample size for the seasonal analysis is extremely small, a plausible reason for inaccurate parameter estimates. The recovery and decline series consist of only 2 and 3 data points, respectively. This seasonal analysis may be a valuable source of information after several more years of data have been collected, but at this point, the amount of available seasonal data is not large enough for drawing conclusions about seasonal changes in recharge.

Summary, conclusions, and recommendations

Historic and recent Grande Ronde groundwater elevations were compiled and analyzed along with basin pumping in order to delineate rates of water level decline and characterize the relationships between water levels, pumping, and recharge. Water levels in the Grande Ronde aquifer have generally declined at rates between 0.7 and 1.5 ft/year within the historical record. Overall pumping and water level patterns suggest that rates of water level decline have been decreasing since approximately 1987, around the same time that annual pumping began decreasing.

Analysis of historical water levels and cumulative pumping data within the context of the hydrogeologic model (Volume Pumped - Recharge = Storativity*Area*change in head) suggests that annual recharge to the Grande Ronde aquifer may fall between the range of 1.59 BGal/year to 1.94 BGal/year. Estimates of S * A are not very consistent among the historical data. Analysis of recent (2007-2011) WSU 5 water levels (levelogger data) with monthly and daily pumping data yields consistent recharge estimates of approximately 1.8 BGal/year.

The amount and quality of historic water level data was not sufficient to draw meaningful conclusions about changes in R and S*A over time; the degree of variation within S*A estimates alone is an indication of the relatively high “noise” level in measured water levels. The levelogger data collected from WSU 5 is ideal for comparing annual declines and even seasonal trends, however this record is only a few years long, too short for robust analysis.

As with any hydrogeologic study, the applicability of these conclusions is directly tied to the accuracy of the original assumptions, especially in the selection of a hydrogeologic model to represent the system. However, despite the relatively large variation in estimated S*A values, the “bathtub” hydrogeologic model appears to be accurate on an annual scale, and relatively adequate for representing monthly data, based on the accuracy of synthetic monthly water levels generated for WSU 5. Seasonally-controlled errors may be due to a change in R values throughout the year, or related to transient pumping effects discounted by the model.

The following recommendations are offered based on the results of this study:

- While a large monitoring network is useful for individual aquifer test analysis (studying short-term transient effects due to pumping), collecting continuous, high-quality (levelogger) water level data from a few Grande Ronde groundwater wells is more important than monitoring numerous wells within the system for this type of water level/pumping analysis. Continuous, detailed water level records for a handful of wells will provide more useful information for understanding long-term aquifer responses to pumping and predicting future behavior.

- Further investigation into short-term responses to pumping using existing levelogger and HOBO data may allow for characterization of temporal variation in recharge.
- Continued assessment of WSU 5 water levels and monthly pumping totals is essential for understanding how water level declines are related to pumping on multi-year scales. The data used in this study was insufficient for delineating changes in R and S*A over time; further monitoring of monthly water levels and pumping will eventually provide enough data for continuation of this analysis, and indicate whether recharge rates are constant at around 1.8 BGal/year, or vary with other factors.

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