PACIFIC groundwater GROUP

WRIA 44/50
GROUNDWATER ELEVATION MONITORING REPORT
2009 WATER YEAR
EXEMPT WELL WATER USE STUDY PHASE 2

January 2010

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TABLE OF CONTENTS

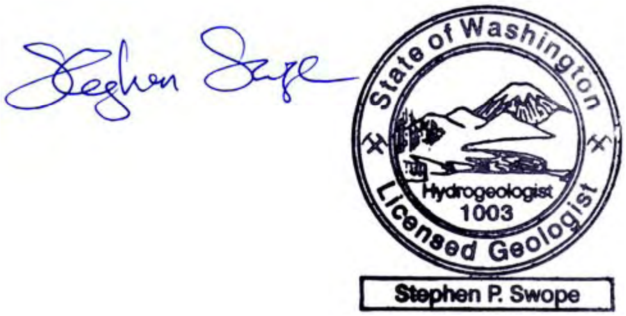
TABLES

FIGURES

APPENDICES

SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.



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Foster Creek:
Charles Hammons
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Lee Hemmer
Ray Henton
Terry Hunt
Barry Watson (Malone well)

1.0 SUMMARY OF FINDINGS

Groundwater elevations in Water Resource Inventory Area (WRIA) 44/50 fluctuated seasonally between a high spring elevation and low late summer to fall elevation in most monitored wells. Seasonal fluctuations ranged from an apparent 20 feet to less than 1 foot. In general, shallow wells within the alluvial aquifer or basalt wells completed in recharge areas (Badger Mountain) displayed the largest seasonal fluctuations, while deeper wells within the basalt aquifer and away from recharge areas displayed little seasonal fluctuation. Groundwater within the basalt aquifer is influenced by a more regional source; and therefore, groundwater elevations are less responsive to local recharge events.

Precipitation was significantly greater than the previous two years but still below average. Groundwater declines previously attributed to low precipitation continued this year, suggesting an alternate cause. Declines were noted in the following monitoring areas and wells:

- Lower Moses Coulee: Linville South, PID, and Biram
- Upper Moses Coulee: Mayer, Johncox, TNC, Johnson, Downes, Rimrock, PGG-2
- Jameson and Grimes: None
- Foster Creek: Hemmer
- Chelan Hills/Chelan Springs: Nystrom
- Badger Mountain: Moulton, Murray, Robbins

Groundwater elevation increases are noted in the Matthiesen and Hanford wells.

2.0 INTRODUCTION

The subsequent sections provide an introductory discussion on the following: (1) the purpose of this study and this report; (2) background on the exempt well water use study; (3) a summary of the hydrogeology of the area; and (4) a description of the monitoring system and method of well selection.

2.1 PURPOSE OF STUDY AND REPORT

Many areas across Washington State are experiencing growth in the number of houses with exempt wells and septic tanks. This growth is unregulated and can result in declines in groundwater quantity and quality.

The purpose of this study is to monitor long-term trends in groundwater elevations in areas identified during the Phase 1 Exempt Well Water Use Study as having potential for future groundwater level declines. These areas include Chelan Springs, Chelan Hills, Rimrock Meadows, and Badger Mountain. Existing monitoring wells in the Foster Creek basin and the Lower and Upper Moses Coulee were also added to the long-term monitoring program. These wells were instrumented during previous studies and continued monitoring will provide useful information on long-term trends in groundwater elevations throughout WRIA 44/50. All long-term groundwater monitoring areas are shown in **Figure 1**.

The purpose of this report is to provide a summary of groundwater elevation trends observed at the monitoring sites through the end of the 2009 Water Year (October 2009). Monitoring began as early as 2003 in some wells and as late as 2007 in other wells.

This work was performed, and this report prepared, using generally accepted hydrogeologic practices used at this time and in this vicinity, for exclusive application to the WRIA 44/50 Watershed Planning process and for the exclusive use of the Foster Creek Conservation District, the WRIA 44/50 Planning Unit, and their agents. This is in lieu of other warranties, express or implied.

2.2 PREVIOUS STUDIES

To address the issue of exempt well water use, the WRIA 44/50 Watershed Planning Unit proposed an Exempt Well Water Use Study in 2004. Pacific Groundwater Group (PGG) performed an initial Phase 1 Exempt Well Water Use Study in 2005 in three areas of Douglas County: Chelan Springs/Chelan Hills, Rimrock Meadows/Sagebrush Flats, and Badger Mountain (**Figure 1**). These areas were identified as high growth in exempt well water use. The Phase 1 Study involved the following elements:

- A water balance calculation comparing current and future groundwater use to recharge.
- A synoptic groundwater level survey to compare current groundwater levels to levels at the time of drilling.
- A nitrate loading calculation to assess the effects of full build-out conditions on water quality.

The results of the Phase 1 Study suggested the potential for groundwater level declines exists in all study areas except for Chelan Springs, and that nitrate loading at full build-out conditions should have minimal impacts on groundwater quality in all areas except possibly Rimrock Meadows, an area that could experience relatively dense development (PGG, 2006a).

Based on these results, a Phase 2 Exempt Well Water Use Study was initiated. The primary component of the Phase 2 Study is monitoring long-term trends in groundwater elevations. Wells in four areas were initially instrumented for long-term monitoring: Lower Moses Coulee, Upper Moses Coulee, Jameson/Grimes Lake Area, and Foster Creek (**Figure 1**). Surface water elevations are also monitored at the Jameson/Grimes Lake site. The first annual report on long-term groundwater elevations summarized monitoring up to October 2005 at these four monitoring areas (PGG, 2006b). Since then three additional areas (Chelan Hills, Chelan Springs, and the Badger Mountain) were added to the monitoring program (**Figure 1**). As of December 2009, the monitoring program for the Phase 2 Exempt Well Use Study consists of six areas with a total of 26 monitored wells and 2 lake stations (**Table 1**). Well logs for all actively monitored wells are provided in **Appendix A.**

2.3 HYDROGEOLOGY

The hydrogeology of the study area is described in the WRIA 44/50 Final Phase 2 Basin Assessment (PGG, 2003a) and in the WRIA 44/50 Foster Creek and Lower Moses Coulee Level 2 Hydrogeologic Assessment (PGG, 2003b). The following summary is drawn predominantly from those reports.

WRIA 44/50 is underlain primarily by the Miocene basaltic rocks of the Columbia River Basalt Group. The basalt sequence is generally 2,000 to 3,000 feet thick in the area and is made up of numerous individual basalt flows ranging from a few tens of feet to about 300 feet thick; the average thickness is about 100 feet. Interbed deposits, often consisting of mudstones, siltstones, and sandstones, separate many of the individual basalt flows. The tops and bottoms of the flows are typically more permeable than flow interiors because of rubble zones, vesicles, and fractures. These zones form the principal aquifers within the basalt. Flow interiors are generally dense and less permeable. Openings caused by minor vertical cooling fractures provide some limited, primarily vertical, permeability in the central part of the flows.

In the Chelan Hills and Chelan Springs area, the Columbia River Basalt Group thins in the direction of the Cascade Mountains. In this area along the Columbia River valley, older, light-colored granitic rocks underlying the Columbia River Basalt can be seen in outcrops. Water saturated fractures in these older rocks provide some water supply to wells in this area.

The Ellensburg Formation and other unconsolidated deposits, consisting of sand and gravel with varying amounts of clay and silt overlie the basalts in many areas. These deposits are generally less than 50 feet thick on the plateau but may be as much as 300 feet thick on the banks of the Columbia River and in Moses Coulee. In these areas the unconsolidated deposits form a productive aquifer referred to as the alluvial aquifer.

All wells included in this analysis are completed in either the basalt aquifer or alluvial aquifer, except for the Corcoran and Nystrom wells in the Chelan Hills and Chelan Springs area, which are completed in the older fractured granitic rocks (**Table 1**).

2.4 MONITORING SYSTEM

The following criteria were used in selecting monitored wells:

- Favorable location in study area.
- Permission granted by well owner.
- Well head accessibility (pitless adaptor versus top seal). Instrumenting wells with pitless adaptors is preferred, but modifications to the top seal is possible with owner's permission.
- Water levels in well recover to static conditions between pumping periods.

These criteria limit the number of potential wells available for monitoring in each area. For example, in the Chelan Hills and Chelan Springs area, the preferred number of wells (3 at each study area) could not be achieved because the above criteria could not be met.

The monitoring system uses Solinst LT Leveloggers transducers to measure and record groundwater levels and barometric pressure at six different study areas within WRIA 44/50 (**Figure 1**). The wells are all privately owned domestic, irrigation, or stock watering wells. Monitoring in Lower Moses Coulee and Foster Creek area began in 2003. Monitoring in Upper Moses Coulee and Jameson Lake began in 2004. Monitoring in the Chelan Springs, Chelan Hills, and Badger Mountain areas began in 2006.

Transducers are downloaded in the spring each year with a Solinst Leveloader and imported into a Microsoft Access database and managed as needed. Water levels are corrected for barometric pressure because the transducers are not vented to the atmosphere.

3.0 RESULTS OF LONG-TERM GROUNDWATER ELEVATION MONITORING

The following subsections provide a brief summary of annual precipitation records during the monitoring period followed by results of the long-term groundwater elevation monitoring through the end of the 2009 Water Year (October 1, 2009) at each site. Site maps and hydrographs are provided in **Figures 2-33**.

3.1 PRECIPITATION RECORDS

The Western Regional Climate Center (WRCC) operates a number of Remote Automated Weather Stations (RAW), which record daily values of total precipitation. There are RAW stations at the town of Douglas, located in the central portion of WRIA 44/50, and at the town of Nespelem, just north of WRIA 44/50 (**Figure 1**). Time series plots of precipitation for both stations are presented in **Appendix B**. The plots were constructed from data available at http://www.raws.dri.edu/wraws/waF.html.

The precipitation records indicate that 2009 was significantly wetter than the previous two years but still below average levels.

3.2 LOWER MOSES COULEE

Lower Moses Coulee (**Figure 2**), from Rattle Snake Springs to the Columbia River, is approximately 20 miles long and 1 mile wide with steep basalt cliffs rising up to 1,500 feet above the valley floor. The surface elevation of the valley floor ranges from 1,100 feet (relative to mean sea level, msl) near McCarteney Creek to 850 feet msl near the Columbia River.

3.2.1 Monitoring Network

Groundwater elevation monitoring in Lower Moses Coulee commenced in late spring of 2003. Monitored wells include: Palisades Irrigation District (PID), Biram, Linville N, and Linville S (**Table 1, Figure 2**). Groundwater elevations were also monitored in the King well from May 2003 to December 2003, when monitoring in this well was terminated. Monitoring continues in the remaining wells. None of the wells are currently used for water supply.

Driller's logs indicate that the Linville S and PID wells are completed within the alluvial aquifer. A driller's log is not available for the Biram monitored well; however, based on its depth and a driller's log for Biram's second well 50 feet away, the Biram well is likely completed within the alluvial aquifer.

3.2.2 Historical Seasonal Fluctuations

Groundwater elevations in all monitored wells in the Lower Moses Coulee display distinct seasonal fluctuations (**Figures 3-6**). In all monitored wells, groundwater elevations increase during the wet winter months, reaching their peaks in March or April after the spring snow melt. Groundwater elevations decrease during the dry summer months, reaching their lows in September or October before the start of the wet winter months.

Seasonal fluctuations in groundwater elevations result from seasonal cycles in local groundwater recharge. Local recharge in the Lower Moses Coulee is derived from infiltrating precipitation and snow melt within the coulee itself and from infiltrating surface water sources, both of which contribute more recharge during the wet winter and spring months. Surface water sources include Douglas and McCarteney Creeks, which enter the Coulee near its upper reaches and lose all their water to the highly permeable alluvial aquifer. However, during exceptionally large runoff events, Douglas Creek has been known to flow all the way to the Columbia River.

In general, the seasonal fluctuations in groundwater elevations are most pronounced in the shallow alluvial aquifer where recharge lag times are short. Seasonal fluctuations observed in these wells range from over 11 feet in the Linville South well to about 7 feet in the PID and 5 feet in the Biram well. The larger seasonal fluctuations observed in the Linville South well may be related to heterogeneities within the aquifer, bedrock slope, and/or irrigation withdrawals.

3.2.3 Summer Fluctuations

Groundwater elevations in the Linville N, Linville S, and Biram wells also display smaller, shorter time-scale fluctuations during the summer months in addition to the seasonal fluctuations described above. These smaller fluctuations are not observed in the PID well, which is located in the upper reaches of the coulee.

The smaller fluctuations observed during the summer months are likely in response to variable groundwater withdrawal during summer irrigation. The Palisades Irrigation District near Palisades in the upper reaches of the coulee uses surface water from Douglas Creek for irrigation and may explain the lack of summer fluctuations observed in that well.

3.2.4 Long Term Trends

Six complete years of monitoring have now been collected in the Lower Moses Coulee and preliminary long-term trends can begin to be assessed (**Figures 3 through 6)**.

Initially, groundwater elevations appeared to generally correlate with precipitation. However during 2009 when precipitation increased over the previous two years, groundwater elevations continued to decline in the two alluvial wells, Linville S and PID. Groundwater elevations in the Biram well are consistent with 2008, although an overall pattern of decline is still evident. Groundwater elevations in the Linville N well appear stable. Statistical analysis is required to evaluate the validity and source of the declines.

3.3 UPPER MOSES COULEE

Upper Moses Coulee from Jameson Lake to Lower Moses Coulee is approximately 20 miles long and follows McCarteney Creek (**Figure 7**). The surface elevation along the Upper Moses Coulee ranges from 850 feet msl near the upper reaches of Lower Moses Coulee to 1,800 feet msl near Jameson Lake.

3.3.1 Monitoring Network

Groundwater elevation monitoring in the Upper Moses Coulee was initiated in the summer of 2004. Groundwater elevation time series plots are presented in **Figures 8-14**. Initially monitored wells included Bechtol, Mayer, and The Nature Conservancy [TNC] (**Table 1)**. Monitoring of the Bechtol well was terminated in May 2005. The Johnson well was added in 2006, the NAAC, Downes, Johncox, and Rimrock wells were added in 2007. All of the wells are completed in the basalt aquifer except for the Johnson well, which is completed in the overlying alluvial aquifer.

3.3.2 Observations

Static groundwater levels in the Mayer well at the end of the 2009 Water Year were approximately 1 foot lower than previously monitored (**Figure 8**), despite the increase in precipitation. In previous years, the decline has been attributed to declines in precipitation. However, since precipitation increased during the 2009 water year, the decline is likely due to other influences such as local usage.

The scatter evident in the Johncox groundwater elevation record (**Figure 9**) is due to pumping and recovery of the well. Data loss from November 2008 to April 2009 obscured the full range of water level variation during the year. However, the minimum groundwater elevation appears to have fallen approximately 1.5 feet continuing the pattern of decline evident from previous years.

Groundwater elevations in the TNC well (**Figure 10**) indicate a seasonal variation of approximately two feet. Groundwater elevations have declined consistently for the three years the well has been monitored.

The groundwater elevation record for the Johnson well (**Figure 11**) is typical for an irrigation well. Groundwater elevations rise from October until the beginning of the irrigation season in April of each year. During the irrigation season, groundwater elevations decline in response to pumping. The two sets of readings for the irrigation season indicate the groundwater elevations during pumping and non-pumping periods. Seasonal groundwater elevation changes are approximately three feet. As with other monitored wells in the Upper Moses Coulee, groundwater elevations have decreased by approximately a half to one foot per year since 2007.

The seasonal groundwater elevation change in the Downes well (**Figure 12**) evident in 2007 was greatly reduced in 2008 and 2009. Groundwater elevations did not recover during the wet season but continued to decline. The total measured decline is approximately one to two feet per year.

Only two years of data have been collected at the Rimrock (**Figure 13**). However, groundwater elevations appear consistent with the pattern of decline evident in other Upper Moses Coulee wells.

3.4 JAMESON AND GRIMES LAKE

Jameson and Grimes Lake are contained behind a glacial moraine in the upper most reaches of Moses Coulee (**Figure 14**). Grimes Lake is approximately 2 miles upgradient of Jameson Lake and approximately 40 feet higher in elevation than Jameson Lake. Discharge to the lakes and the surrounding alluvial aquifer is derived mainly from precipitation, snow melt, runoff from storm events, and upward flow from the underlying basalt aquifer.

Throughout the first part of the 20th century, the lake level in Jameson Lake rose, apparently as a result of agricultural practices in the surrounding watershed. The lake water elevation is now controlled by ditch and culvert structures at the south end of the lake. Details on the historical and current lake water quality can be found in *WRIA 44/50 Water Quality Assessment Jameson and Grimes Lakes* (Pacific Groundwater Group and Water Quality Engineering, 2004) and a more detailed discussion on the hydrogeology of the Jameson Lake area can be found in *WRIA 44/50 Jameson Lake and Moses Coulee Flood Mitigation Hydrogeologic Assessment* (PGG, 2006c).

3.4.1 Monitoring Network

Lake level monitoring in Jameson and Grimes Lakes began in May 2004. Lake levels are monitored at the northern end of Jameson Lake and at the south-western end of Grimes Lake (**Figure 14**). The transducers are housed in 2-inch diameter PVC pipes attached to steel fences posts within the lakes.

The Grimes Lake station is located at the southern end of the lake. The transducer must be removed each winter because flows into Grimes are not sufficient to keep the transducer ice free in the winter. The transducer is reinstalled at the original location and removed each fall.

Groundwater level monitoring of the shallow alluvial aquifer was initiated in March 2005 at the Matthiesen Resort (Matthiesen well) adjacent to Jameson Lake. Groundwater level monitoring of the deep alluvial aquifer was initiated in August 2006 in a deep groundwater monitoring well (PGG-1) at the north end of Jameson Lake. PGG-2 was added in 2008. Hydrographs for all five stations are shown in **Figures 15-18.**

3.4.2 Observations

Water level elevations of Jameson and Grimes Lakes display similar seasonal fluctuations of about 2 feet (**Figures 15 and 16**). Both lakes reach their peak levels by early May and declined to their lows by early October before the start of the wet winter months. Seasonal fluctuations during the period of record were fairly similar for both lakes. Lake stage elevations have been generally stable over the period of record.

The water level in Grimes Lake is about 40 ft higher than Jameson Lake throughout the year indicating a hydraulic gradient (slope) of 0.004 ft/ft between the two lakes.

Groundwater elevations in the Mattheisen water supply well (**Figure 17**) are closely tied to the Jameson Lake elevation indicating a strong hydraulic connection between the shallow alluvial aquifer and the lake in this vicinity. Seasonal variation in the Mattheisen well is approximately two feet.

Groundwater elevations in deep monitoring well PGG-1 indicate approximately one foot of seasonal variation since monitoring began (**Figure 18**). The groundwater elevation in PGG-1 is about 8.5 feet higher than the Jameson Lake and shallow aquifer levels, indicating an upward groundwater gradient at the north end of the lake. The upward vertical gradient between PGG-1 and Jameson Lake is approximately 0.05 ft/ft. Continued monitoring will indicate if there are any seasonal or long term trends.

Only two years of data have been collected from the PGG-2 wells (**Figure 19**). However, groundwater elevations appear consistent with the pattern of decline evident in the Upper Moses Coulee wells.

3.5 FOSTER CREEK

Foster Creek drains approximately 660 square miles and lies north of Jameson and Grimes Lake. The Foster Creek monitoring network is presented in **Figure 20**.

3.5.1 Monitoring Network

Groundwater monitoring of six wells in the Foster Creek area began in the summer of 2003 (**Table 1**). Three monitored wells (Malone, Henton and Hanford), completed within the alluvial aquifer, are located in the Foster Creek valley and three monitored wells (Hammons, Hemmer, and Hunt) are located along the uplands above Foster Creek. The Hunt and Hemmer wells are completed within the basalt aquifer and the Hammons, Hanford, Henton, and Malone wells are completed in the alluvial aquifer. Upland elevations are approximately 1000 feet higher than the valley.

Hydrographs for all monitored Foster Creek wells are shown in **Figures 21** through **26**. The barometric pressure transducer malfunctioned from December 2004 to February 2005 and was subsequently replaced in June of 2005.

3.5.2 Valley Observations

Groundwater elevations in monitored wells in the Foster Creek valley (Malone, Henton, and Hanford) display variable amounts of seasonal fluctuations (**Figures 21, 22, and 23**). Fluctuations are generally between 1 and 2 feet, although higher fluctuations are apparent in the Henton well due to pumping of the well. Peak water level elevations are highly variable and range from December to April. Groundwater lows occur between July and October. In general, seasonal peaks and lows in the Malone well occur about two months later than the Hanford and Henton wells.

The 2009 peak groundwater elevation is slightly higher (about 0.2 feet) in the Malone well compared to 2008, likely a result of increased precipitation. The 2009 peak groundwater elevation in the Henton well is obscured by data loss. The 2009 peak groundwater elevation in the Hanford well is not discernable from 2008.

The seasonal fluctuations in the valley monitored wells result from cycles in local recharge derived from infiltrating precipitation, snow melt, and storm runoff. The higher 2009 peak groundwater elevations in the Malone and wells are likely due to the wetter 2009 water year.

Groundwater elevations in the Hanford well were consistent with 2008, although previously they have increased every year since monitoring began in 2003. The source of the increased groundwater elevations in the Hanford well is unknown, although it may be related to changes in surface water flow.

3.5.3 Upland Observations

Trends in groundwater elevations along the upland wells (Hammons, Hunt, and Hemmer) are variable. Unlike the monitored wells in the Foster Creek valley, the groundwater elevations in the Hammons and Hunt wells increase rapidly in the early spring, likely in response to snow melt, and then gradually decline during the summer and fall before leveling off during the winter months. Rapid changes in groundwater elevations are common in uplands which are typically considered recharge areas for aquifer systems.

In the Hammons well, seasonal fluctuations range from 2 feet to over 9 feet (**Figure 24**). The 2009 minimum groundwater elevations were approximately 1 foot lower than in 2008.

Seasonal variability in the Hunt well (**Figure 25**) is approximately 2 to 4 feet. Groundwater elevations during the 2009 Water Year were comparable to previous years.

Groundwater elevations in the Hemmer well (**Figure 26**) have declined since monitoring began in 2003 except for spring of 2006 through spring 2007. The total decline is approximately 6-7 feet.

3.6 CHELAN HILLS AND CHELAN SPRINGS

Chelan Hills and Chelan Springs were added to the long term groundwater monitoring program in 2006. The sites are located about 30 miles north of Wenatchee along the Columbia River near Chelan Falls (**Figure 1**). Chelan Springs is a 6,731 acre area in the McNeil Canyon area and Chelan Hills is a 7,637 acre area immediately south and adjacent to the Chelan Springs (**Figure 27**). Both sites occur along the eastern slopes of the Columbia River valley. Many springs emanate within the study area indicating that it is a groundwater discharge area fed by more than water recharging directly within it, likely from upland recharge. Both areas have experienced relatively consistent population growth since 1988.

3.6.1 Monitoring Network

Four domestic wells were instrumented with pressure transducers in the Chelan Hills and Chelan Springs area. In the Chelan Hills area, the Luce and Sandum wells were instrumented on May 9, 2006. Monitoring of the Sandum well was discontinued because the water level did not recover between pumping periods. In the Chelan Springs area, the Nystrom well was instrumented on May 9, 2006 and the Cocoran well was instrumented on November 8, 2006 (**Table 1**).

All monitored wells except the Luce well are completed in fractured granite. The Luce well is completed in the basalt aquifer.

3.6.2 Observations

Time series plots of groundwater elevations for the Chelan Hills/Chelan Springs wells are presented in **Figures 28-30**. Groundwater elevations in the Luce well (**Figure 28**) indicate a 3-foot annual variation with the highest water levels in March or April and lowest in October. The data dispersion evident in the first half of Water Year 2007 is likely due to instrument error. The summer peak groundwater elevation was about 0.5 feet higher in 2009 that 2008; winter minimums were similar.

Groundwater elevations in the Nystrom well (**Figure 29**) indicate a decline of approximately 2.5 feet during the three year monitoring period. The scatter in the Nystrom well hydrograph reflects the influence of pumping.

Groundwater elevations in the Cocoran well (**Figure 30**) show high seasonal variability. During the fall of 2008 and 2009, the water level dropped over 15 feet and apparently below the data logger, causing the flat-line effect observed in hydrographs. No trend in the winter low is discernible because of the censored data. However, the spring/summer peak in 2009 was approximately 3 feet lower than in 2008.

3.7 BADGER MOUNTAIN

Badger Mountain was added to the long term groundwater monitoring program in 2006. The site is located northeast of East Wenatchee, between East Wenatchee and Waterville (**Figure 1**). Badger Mountain is located on a local topographic high and therefore has no up-gradient recharge area. As such, it may be susceptible to groundwater declines if development of the area continues.

3.7.1 Monitoring Network

Four domestic wells were instrumented with pressure transducers at the Badger Mountain site on May 9, 2006: the Murray, Moulton, Robins and Wilcox wells (**Figure 31** and **Table 1**). The Murray, Moulton, and Robins wells are currently used for domestic water supply. The Wilcox well is a domestic water supply well that is currently unused. All wells are completed within the basalt aquifer.

3.7.2 Observations

Time series plots of groundwater elevations for the Badger Mountain wells are presented in **Figures 32-35**. Peak groundwater elevations occur in April to June while annual minimums occur in October to February. Groundwater elevations in the Moulton well (**Figure 32**) vary by 10 to 20 feet annually. Groundwater elevations have declined approximately 15 feet since 2007. The groundwater level may have dropped below the bottom of the transducer at the end of 2008 and 2009, causing the flat effect seen in **Figure 32**. On December 21, 2009, a new logger with 65 feet of range was installed.

The Murray well (**Figure 33**) indicates up to 9 feet of annual water level variation. Each subsequent spring freshet has resulted in about half as much elevation rise as the previous year since 2007. Minimum groundwater elevations have declined approximately 3 feet since monitoring began in 2006.

The Robins well (**Figure 34**) indicates over 10 feet of water level change annually, with the peak water levels occurring in June. Three feet of groundwater decline have occurred since the end of 2007.

Groundwater elevations in the Wilcox well (**Figure 35**) remained essentially constant throughout the 2007 and 2009 Water Years, although they exhibit higher variability during the winter months. Much of the variability appears to be associates with barometric changes more than water level variation.

4.0 REFERENCES

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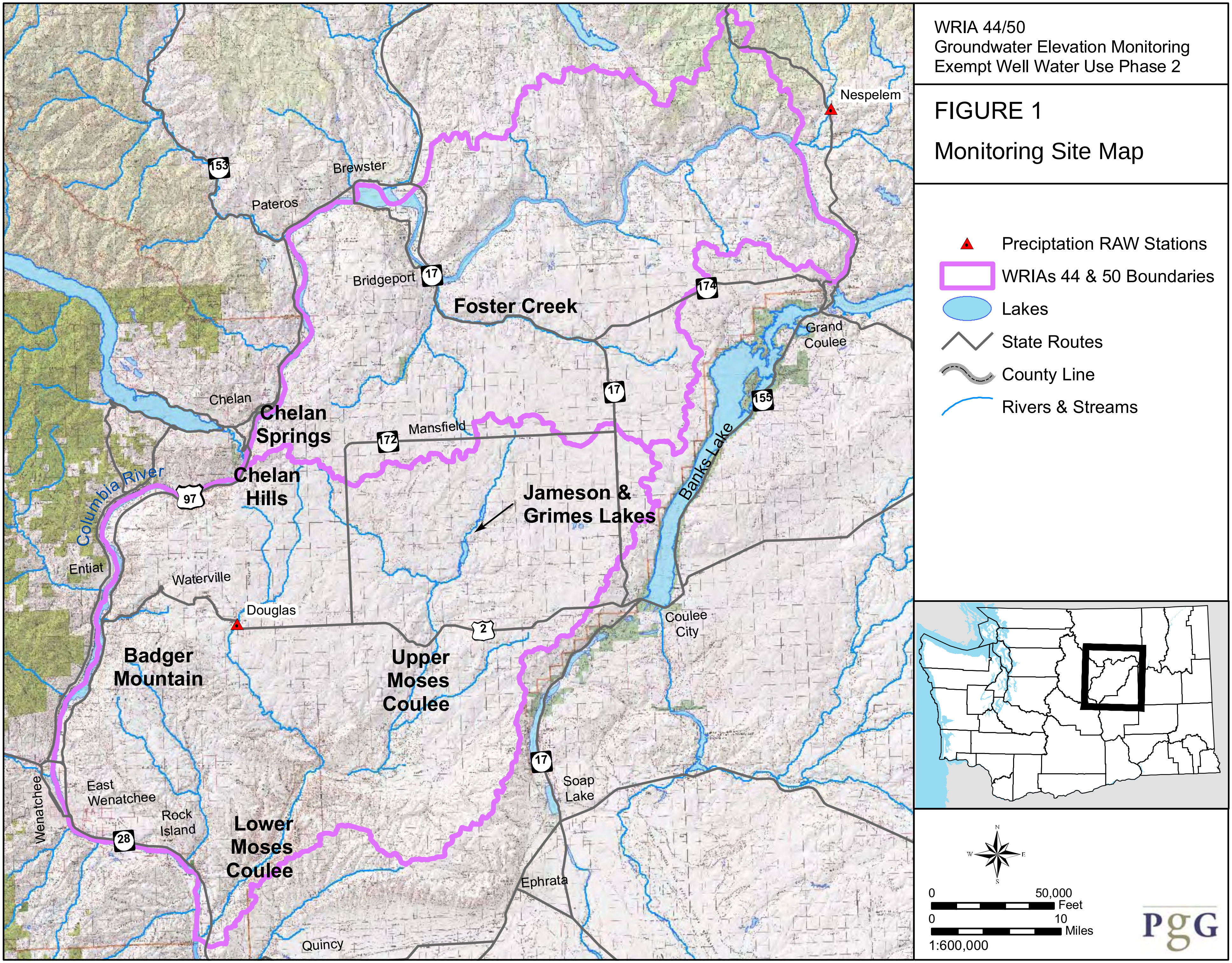
TABLE 1: Groundwater and Surface Water Monitoring Sites (WRIA 44/50)

Lower Moses Coulee	Well Use	Aquifer	*MP Elevation (ft)	Well Depth (ft)	Start of Data Collection	Status
Biram	Unused	Alluvial	920.3	135	5/6/2003	
Linville N	Unused	Basalt	906.5	240	5/6/2003	
Linville S	Unused	Alluvial	849.0	249	6/25/2003	
PID (Palisades Irrigation Di:	Unused	Alluvial	1029.4	160	5/7/2003	
King	Unused	Basalt	981.7	139	5/6/2003	discontinued 12/3/03
Upper Moses Coulee						
Downes	Domestic	Basalt	1640	200	11/27/2006	
Johncox	Domestic	Basalt	1600	150	3/8/2006	
Johnson (aka Peterson)	Irrigation	Alluvial	1554	191	9/19/2006	
Mayer	Domestic	Basalt	1569	80	8/10/2004	
Rimrock	Community	Basalt	1570	738	1/18/2007	
TNC	Unused	Basalt	1888	705	2/9/2005	
Bechtol	Livestock	Unknown	2050	>195	8/10/2004	discontinued 5/31/05
Jameson Lake						
Grimes Lake	NA	NA	1836.63	NA	4/28/2004	
Jameson Lake	NA	NA	1797.71	NA	4/28/2004	
PGG-1 (Jameson Test Well	Monitoring Well	Alluvial	1805.41	152	8/31/2006	
PGG-2 (Jameson Test Well	Monitoring Well	Alluvial	1778.00	198	1/10/2008	
Matthiesen	Domestic	Alluvial	1800.86	41	3/2/2005	
Foster Creek						
Hammons	Unused	Alluvial	2126	57	7/9/2003	
Handford	Unused	Alluvial	896	45	7/9/2003	
Hemmer	Livestock	Basalt	2178	200	7/9/2003	
Henton	Irrigation	Alluvial	971	90	7/9/2003	
Hunt	Old Domestic	Basalt	2087	290	8/5/2003	
Malone	Unused	Alluvial	1663	64	7/9/2003	
Chelan Hills/Chelan Springs						
Corcoran	Domestic	Granite	1978	165	11/8/2006	
Luce	Domestic	Basalt	1913	59	5/9/2006	
Nystrom	Domestic	Granite	2247	205	5/9/2006	
Sandum	Domestic	Granite	967	485	5/9/2006	discontinued 10/20/06
Badger Mountain						
Moulton	Domestic	Basalt	3881	299	5/10/2006	
Murray	Domestic	Basalt	3659	140	5/9/2006	
Robins	Domestic	Basalt	4078	125	5/11/2006	
Wilcox	Unused	Basalt	4053	210	5/9/2006	

*Measuring Point Elevations (execpt Jameson Lake Area) survyed with GPS hand held reciever (vertical accuracy estimated to be +/- 10-ft).
Jameson Lake Stations professionally surveys (vertical accuracy +/- 0.10-ft)
Grimes Lake Station Moved in Sept. 2006 (elevation in table is for new station site)
Datum: NAVD88



WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

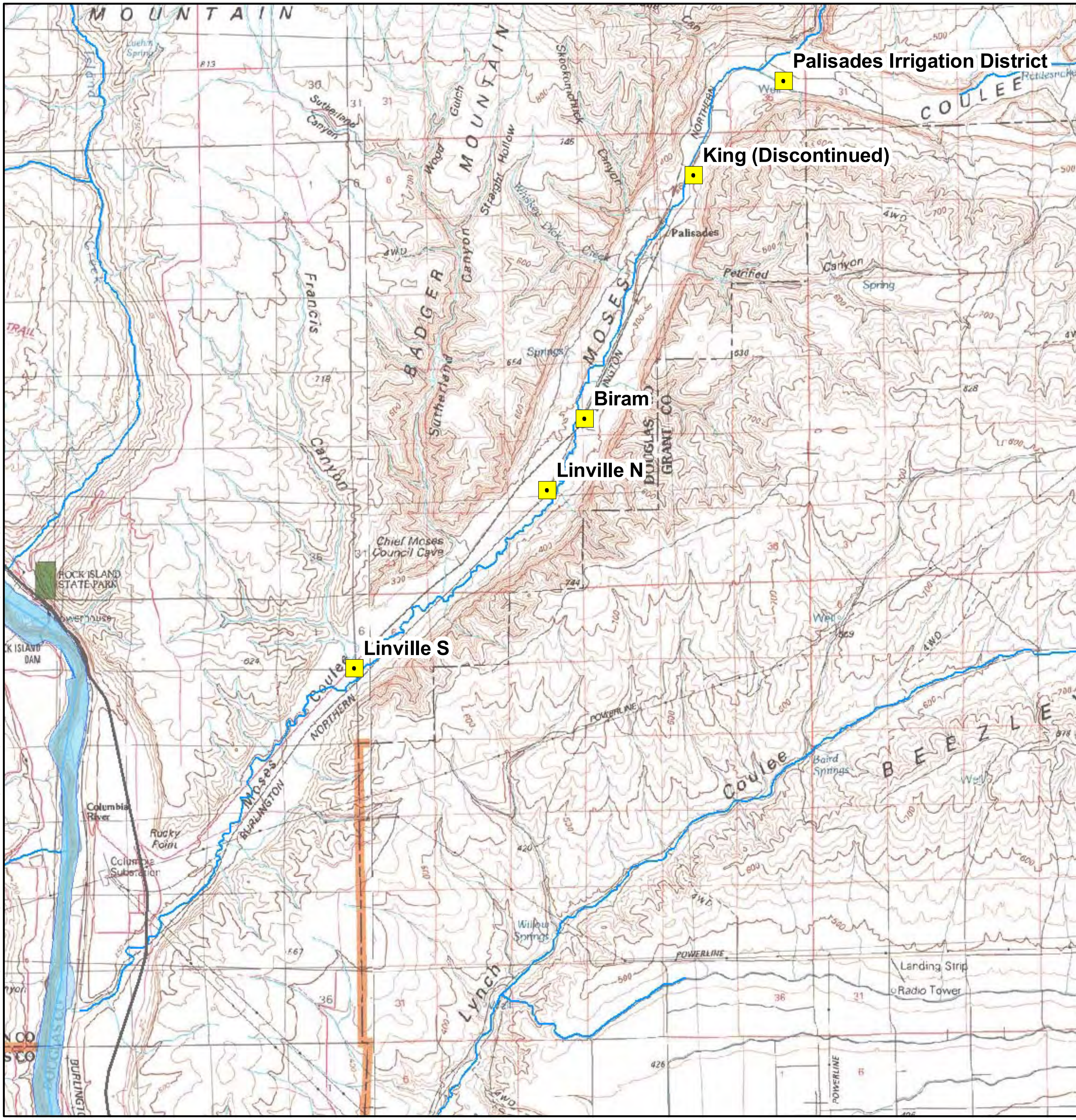
FIGURE 1
Monitoring Site Map

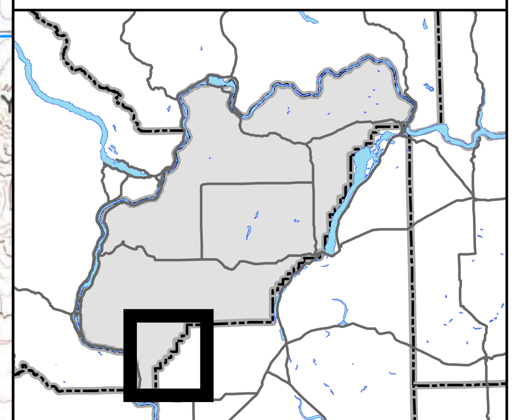
K:\Steve\DouglasCountyExemptUsePhase2\gis\mxd\2006\Douglas_County_EU_P2_Vicinity.mxd - 01/8/2007

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 2

Lower Moses Coulee Monitoring Locations



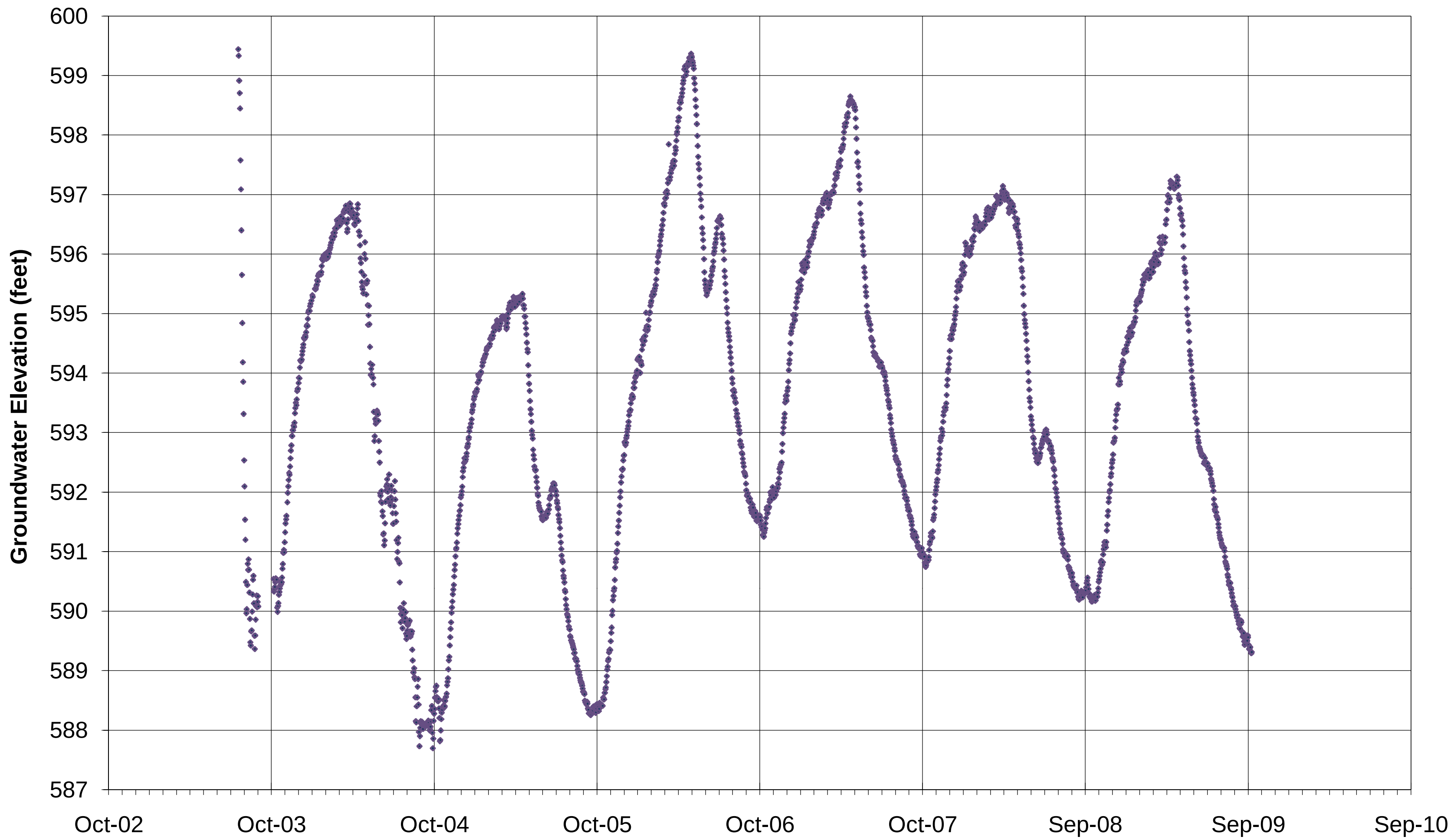


Groundwater Level Monitored Well

0 10,000 Feet
0 2 Miles
1:120,000

PGG

K:\Steve\DouglasCountyExemptUsePhase2\gis\mxd\Douglas_County_EU_P2_Lower_MC_Monitoring_Sites.mxd - 04/14/2006



Note: Scale modified from standard report scale

Figure 3
Linville South Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

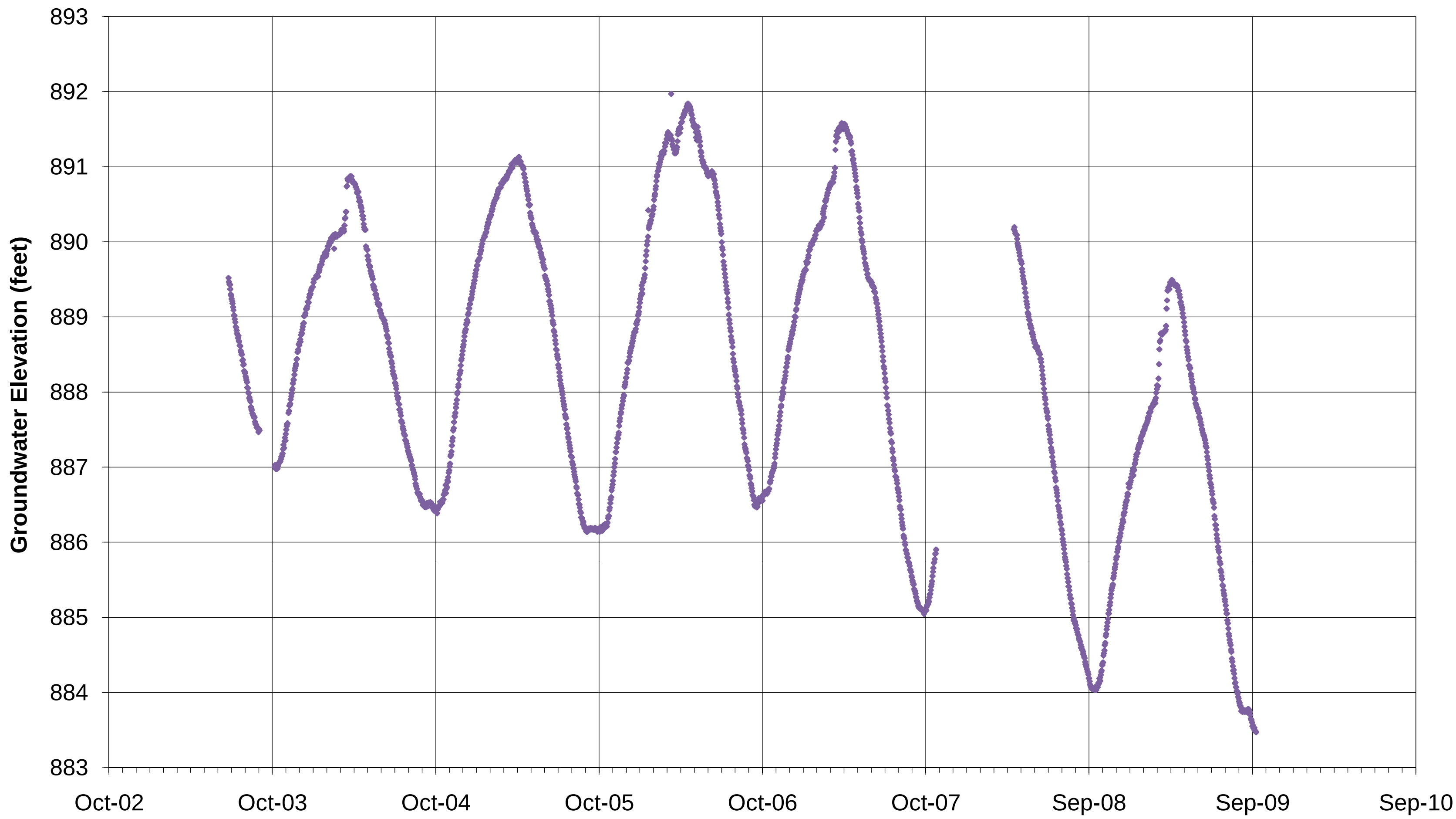


Figure 4
Palisades Irrigation District (PID) Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

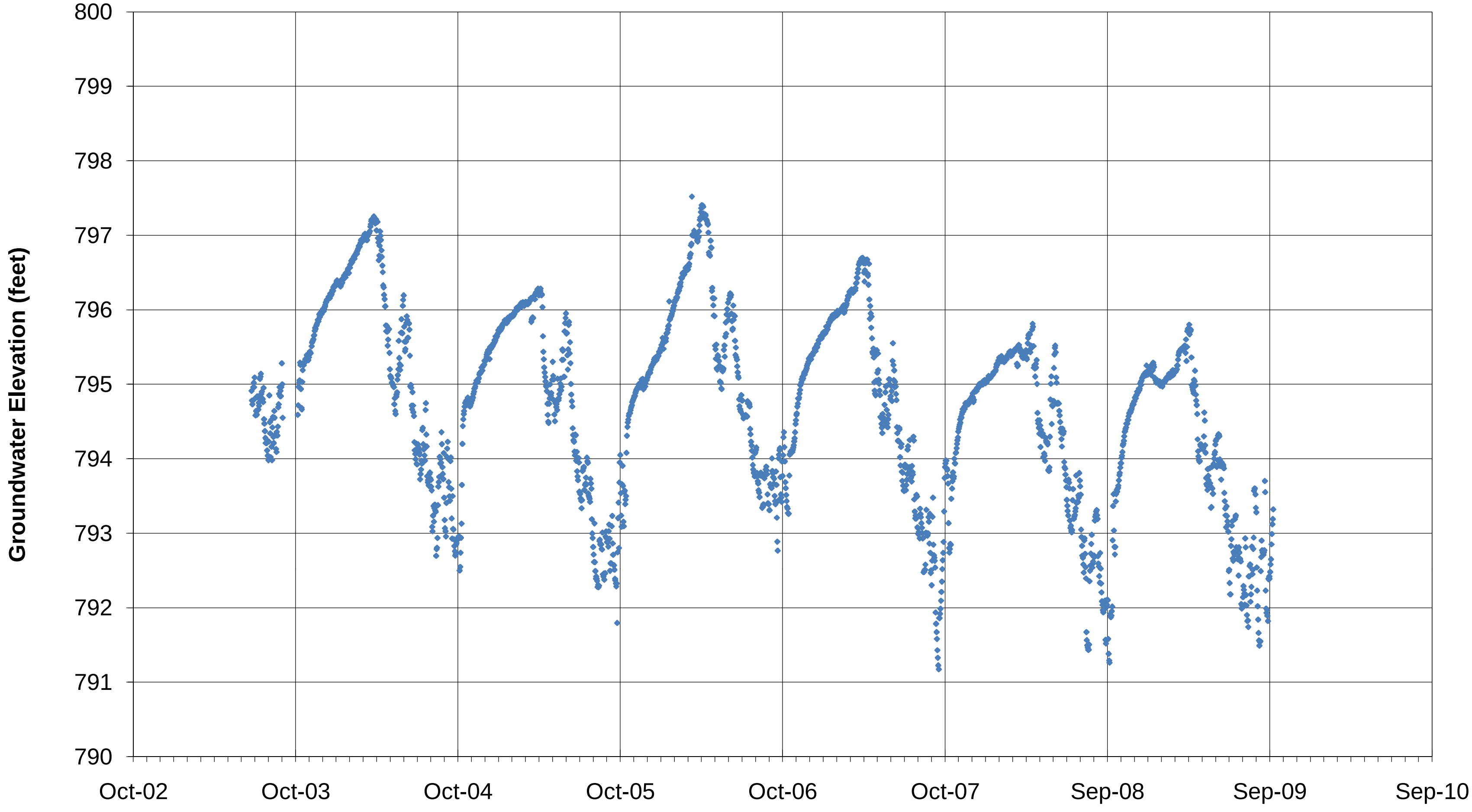


Figure 5
Biram Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

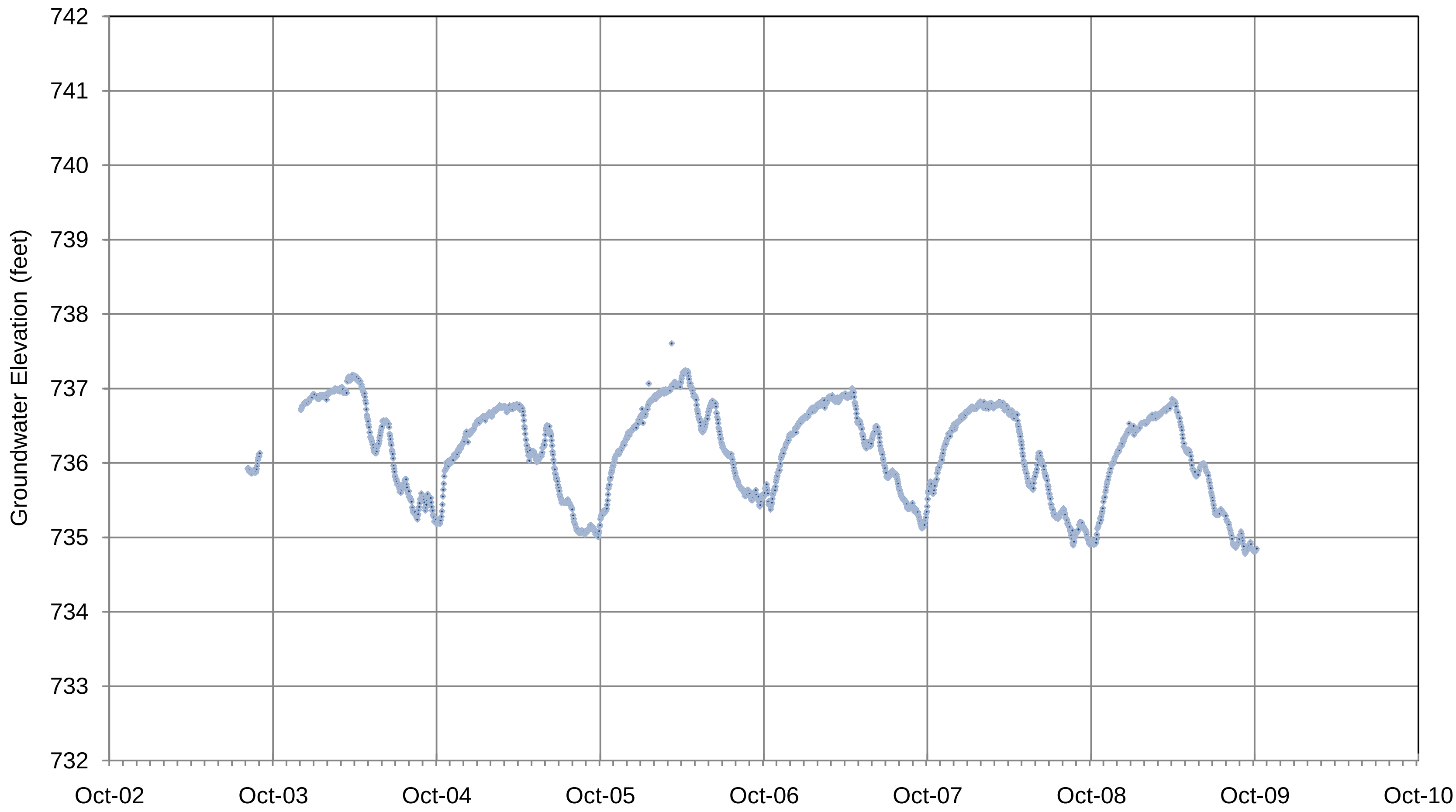


Figure 6
Linville North Well Hydrograph

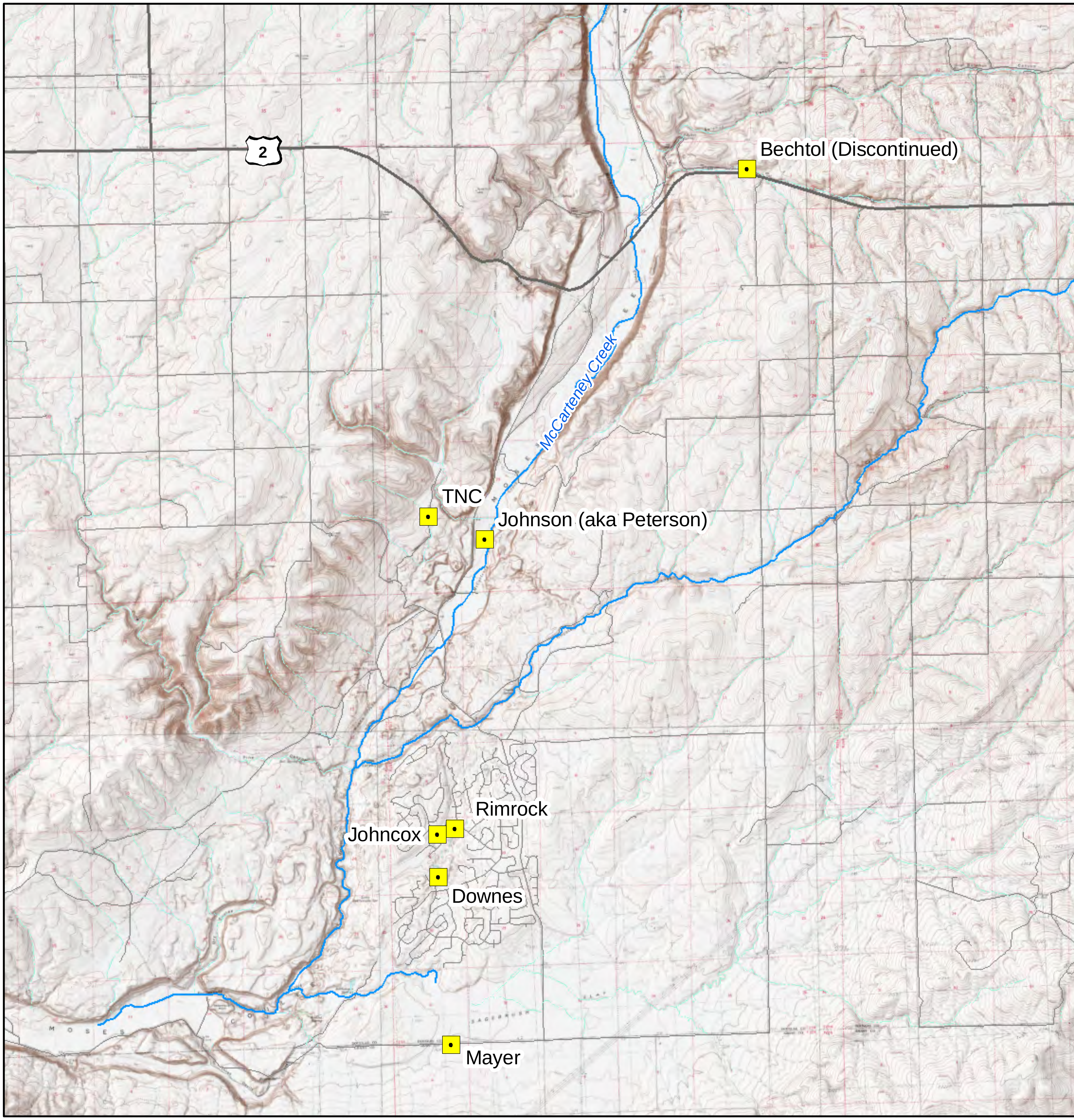
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

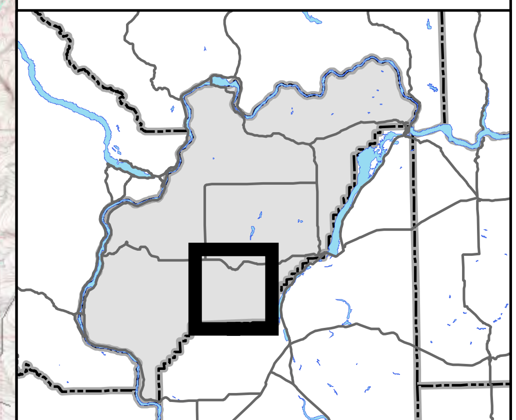
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 7

Upper Moses Coulee Monitoring Sites



Groundwater Level Monitored Well



N
W E
S

0 10,000 Feet

0 2 Miles

1:120,000

PGG

K:\Steve\DouglasCoData\GIS\mxds\Douglas_County_EU_P2_UMC_Monitoring_Sites.mxd - 1/2010

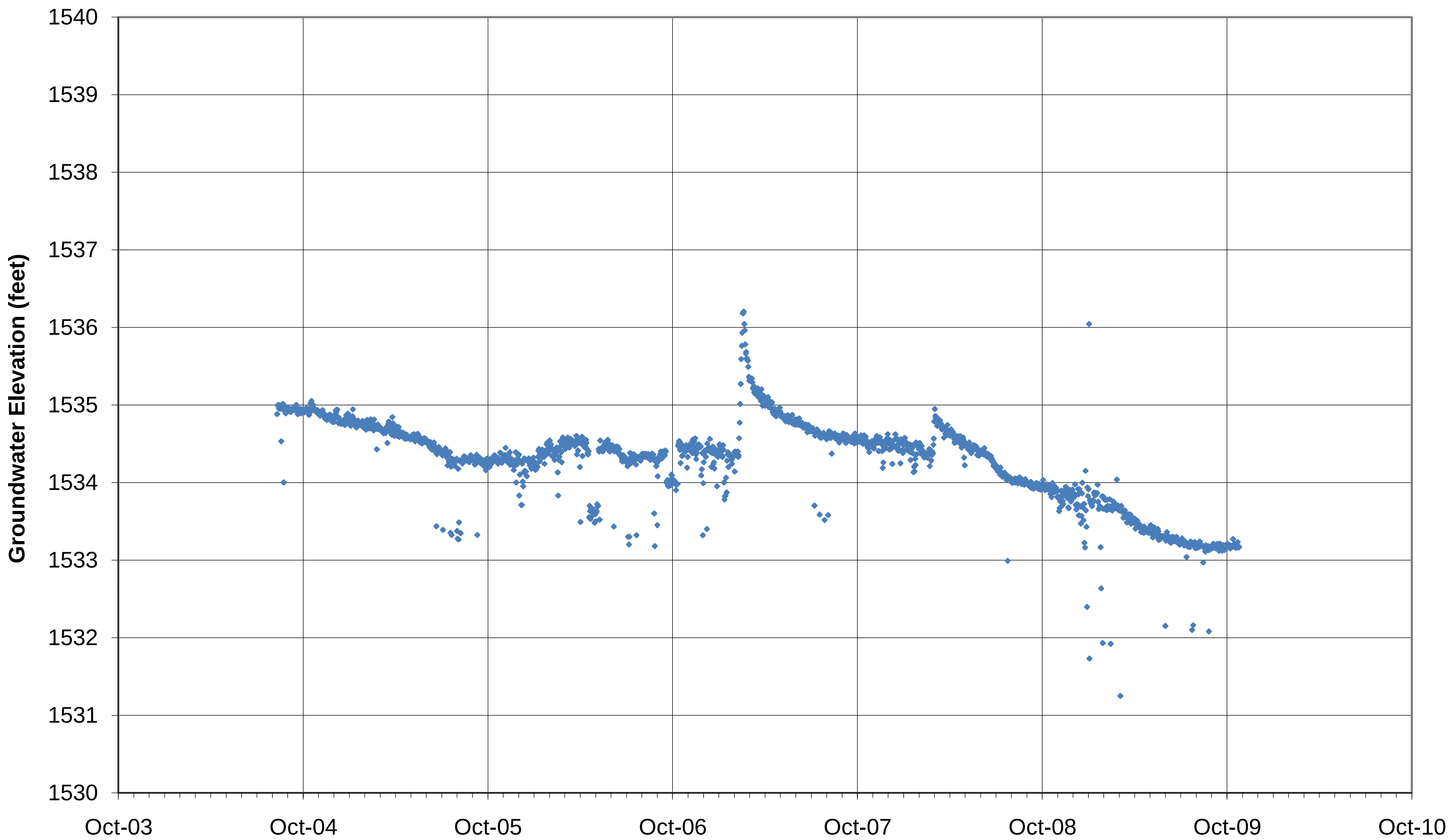
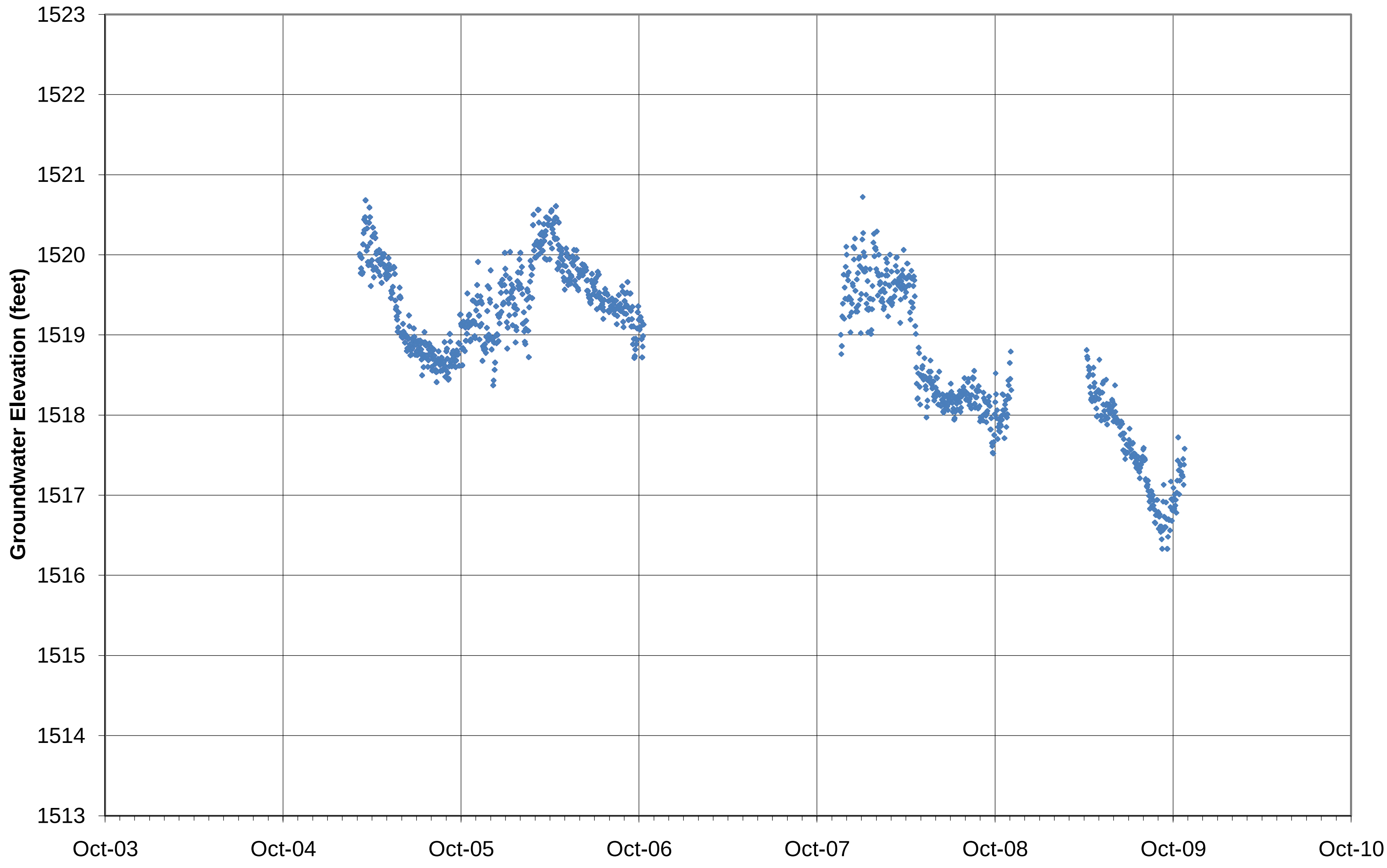


Figure 8
Mayer Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

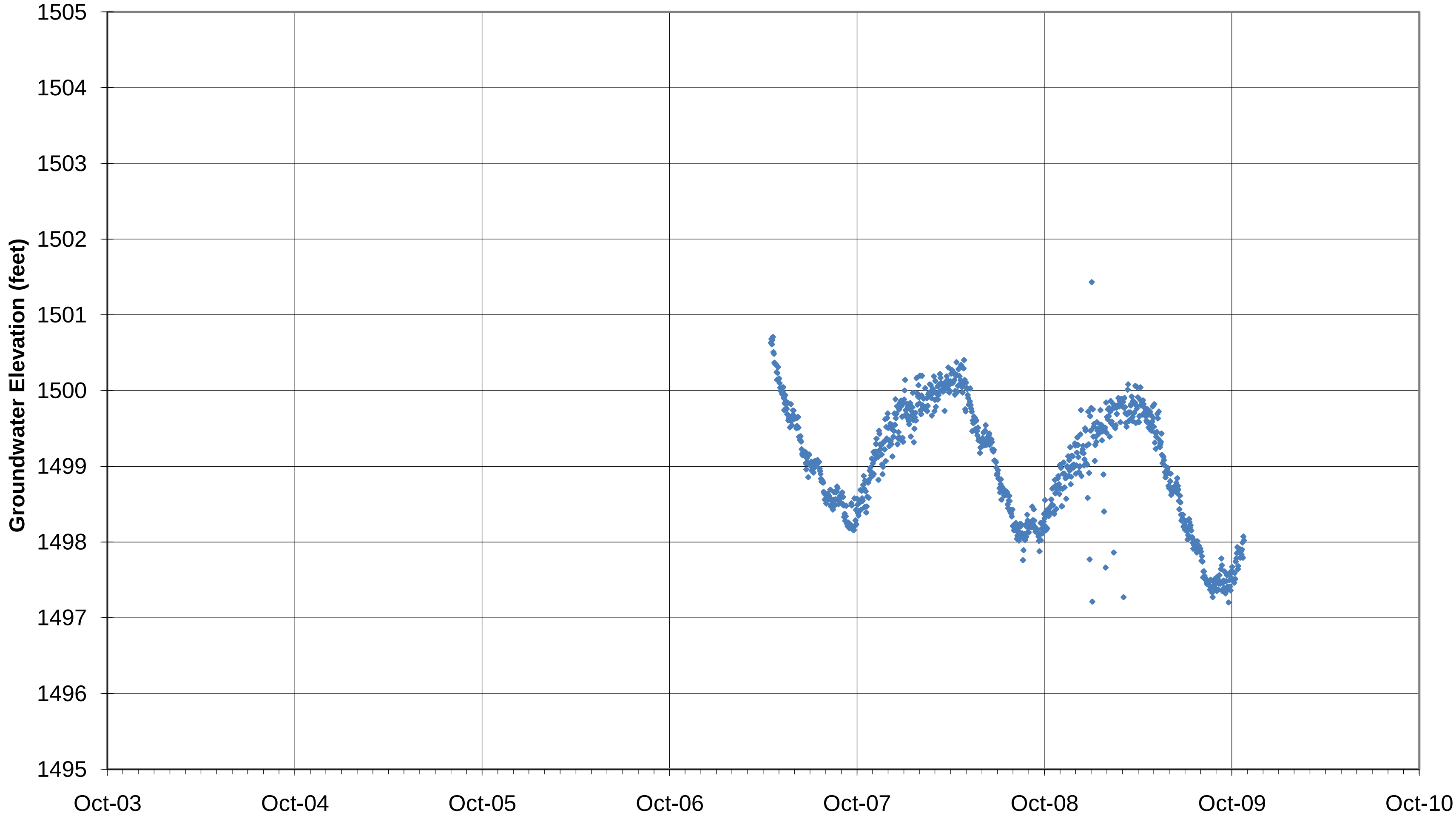


Notes
No data are available for October 2006 - October 2007 due to well head maintenance.
No data are availiable for November 2008 to April 2009 due to data loss

Figure 9
Johncox Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG



Data before 4/17/2007 is not valid because the logger was likely above water level based on hand measurements

Figure 10
TNC Observation Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

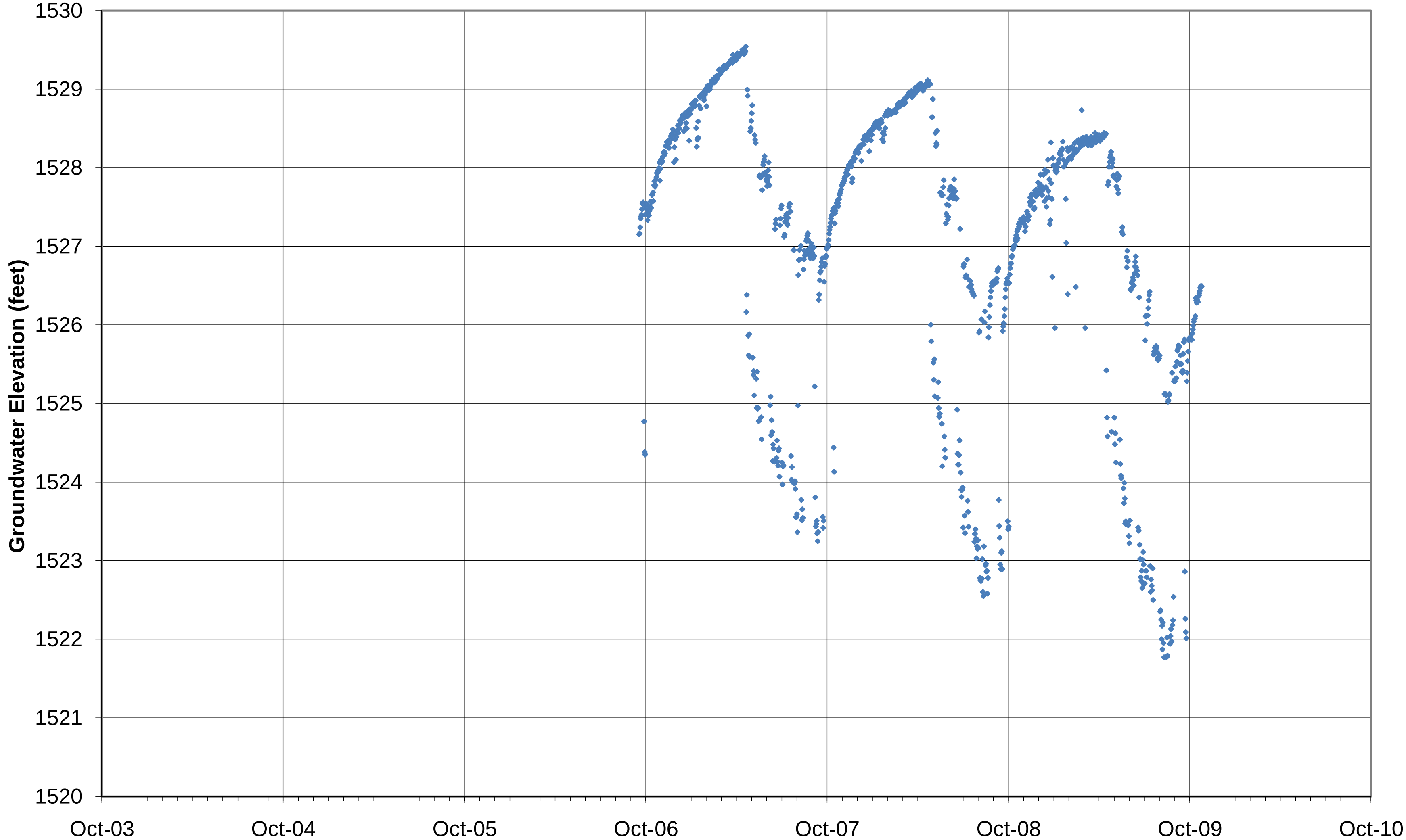


Figure 11
Peterson (aka Johnson) Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

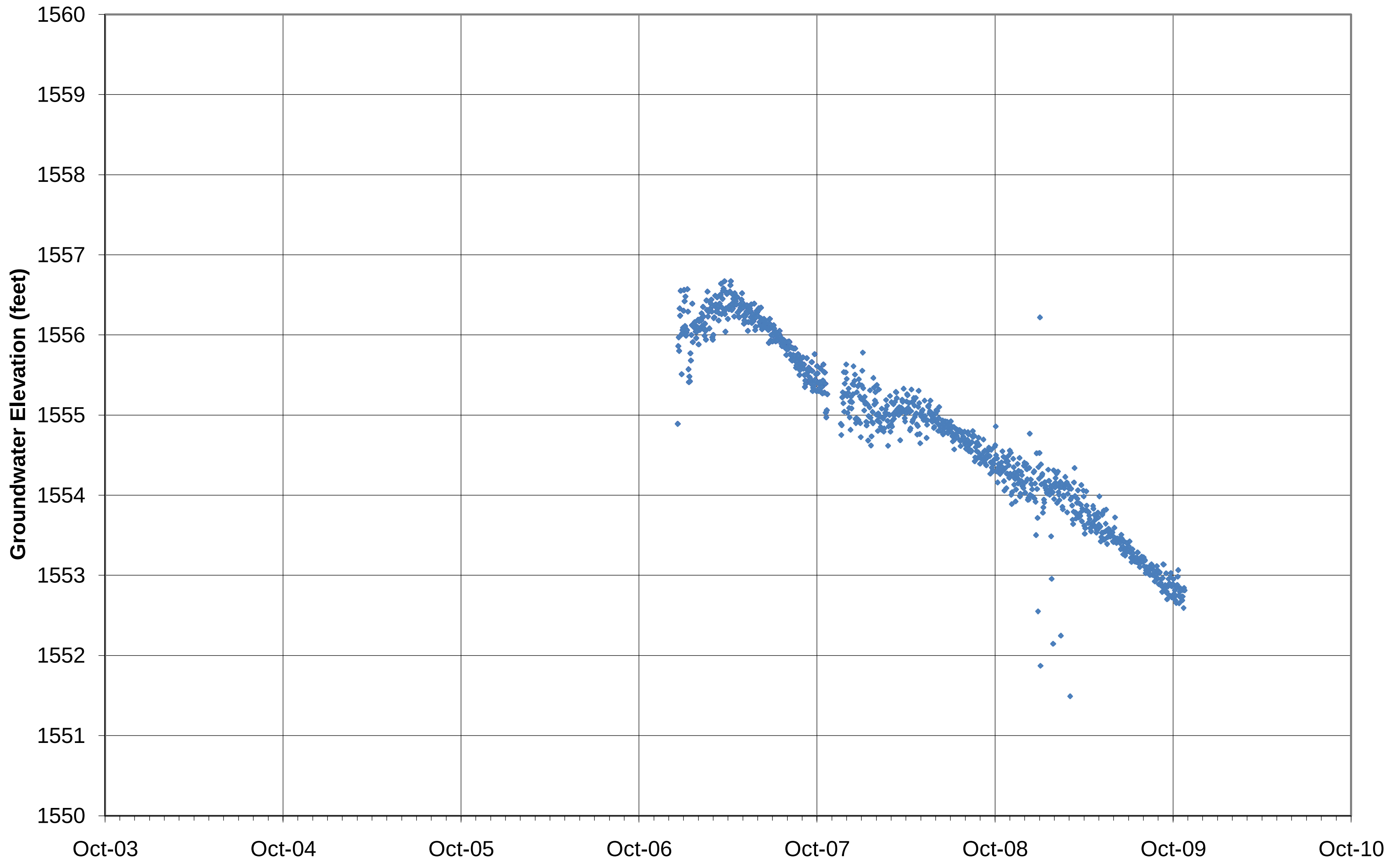


Figure 12
Downes Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

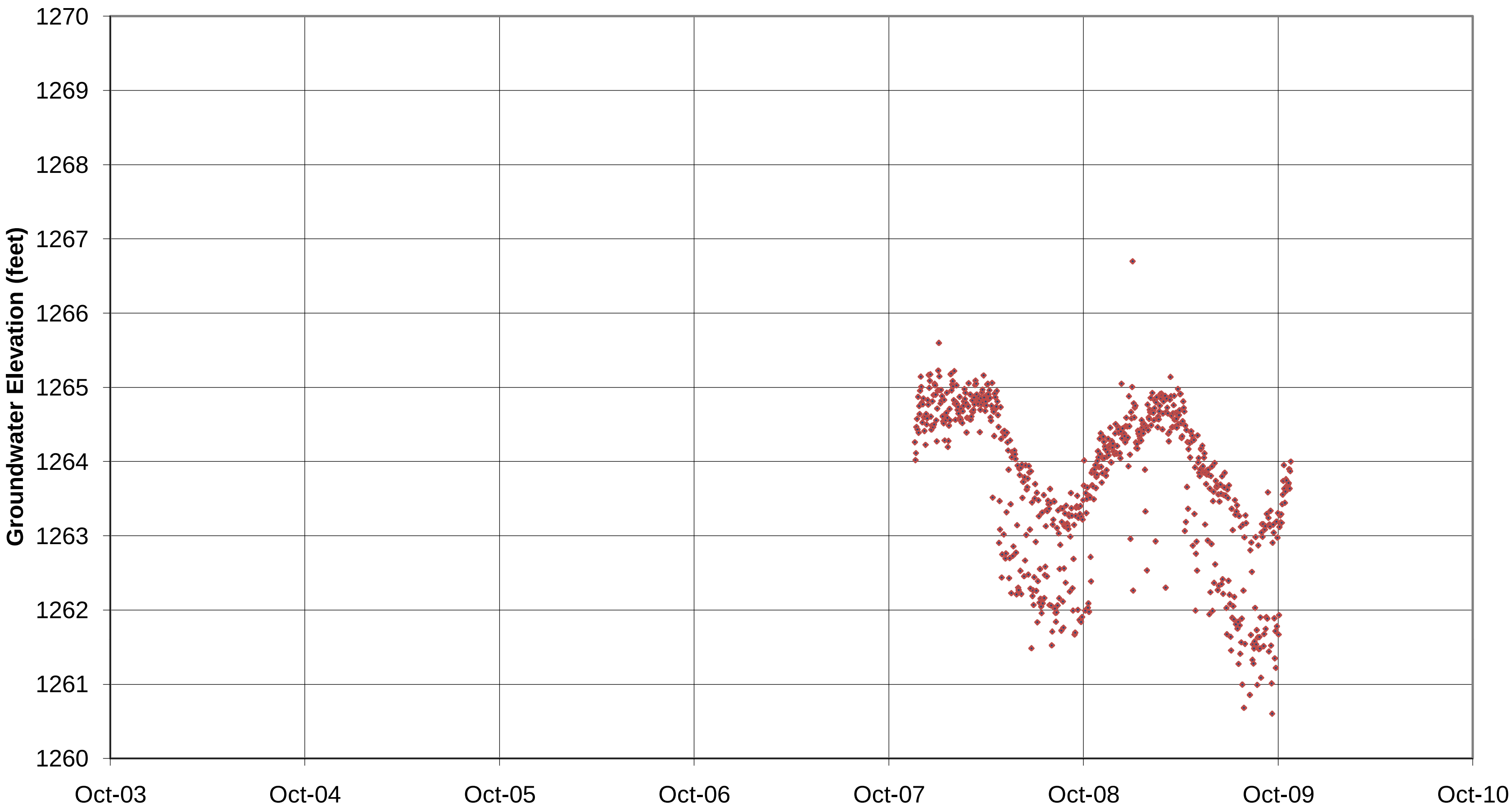


Figure 13
Rimrock Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

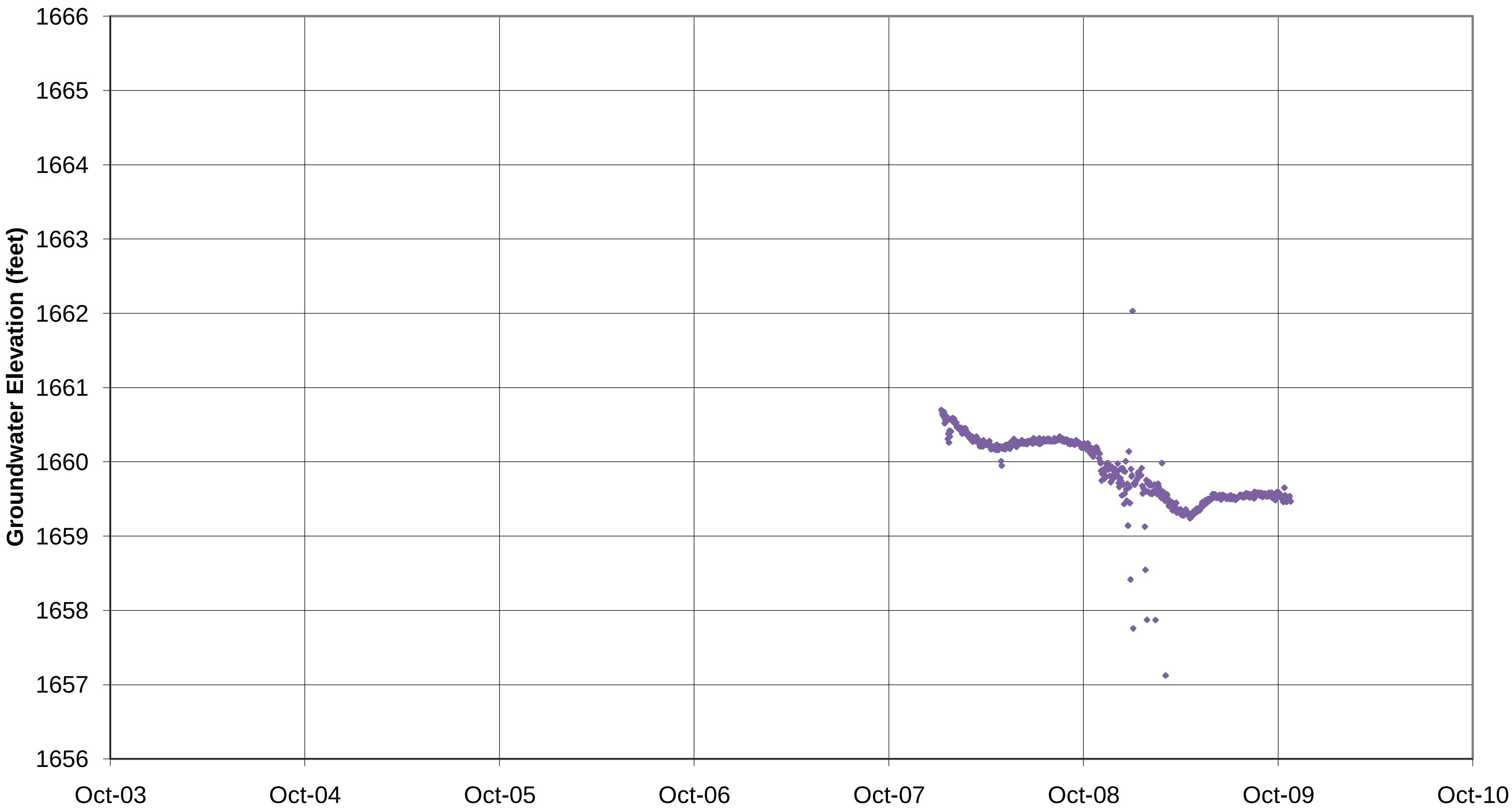


Figure 14
PGG-2 Hydrograph

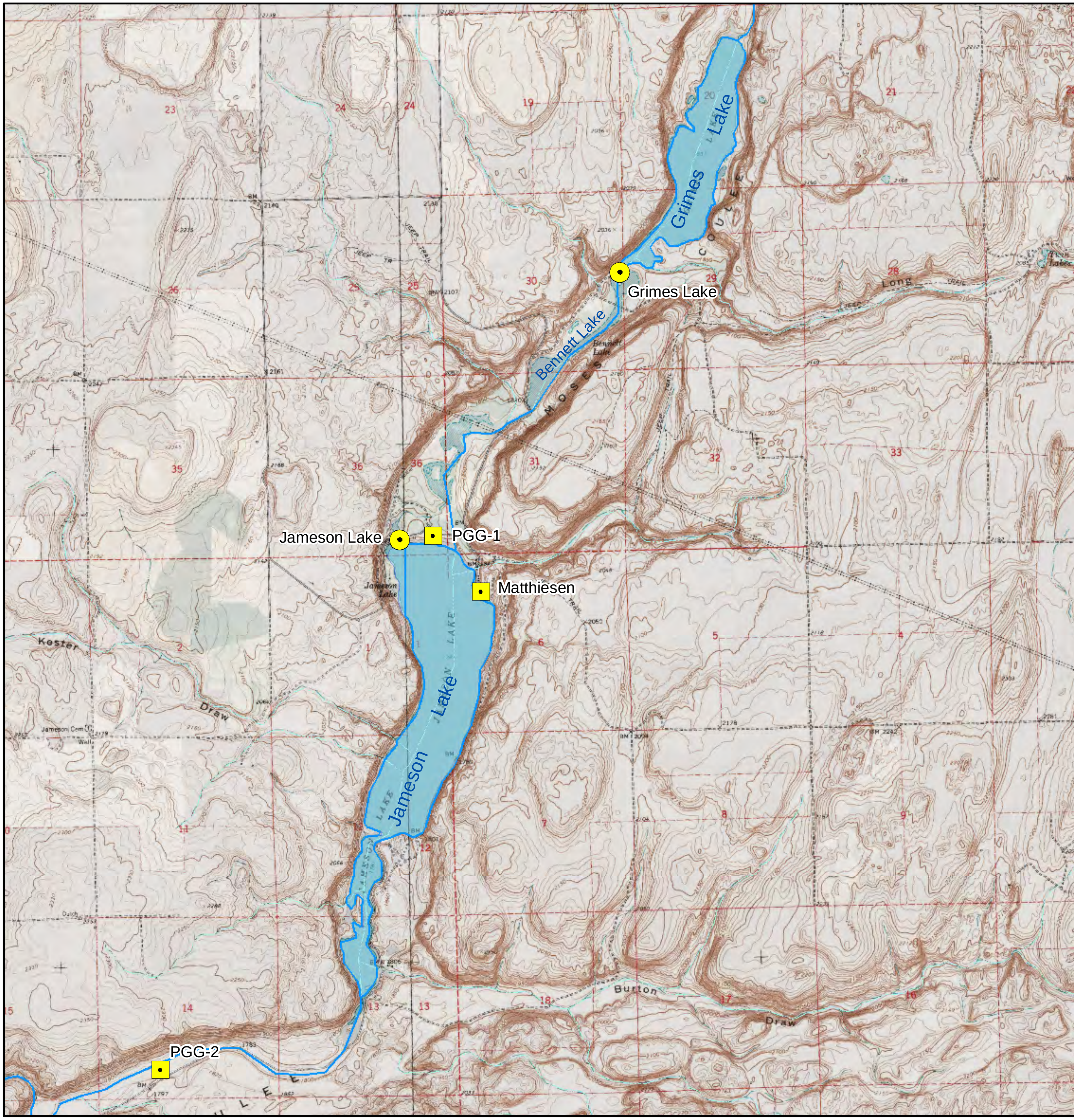
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 15

Jameson & Grimes Lake Monitoring Sites



Surface Water Level Monitoring Station

Groundwater Level Monitored Well

0 5,000 Feet

0 1 Miles

1:50,000

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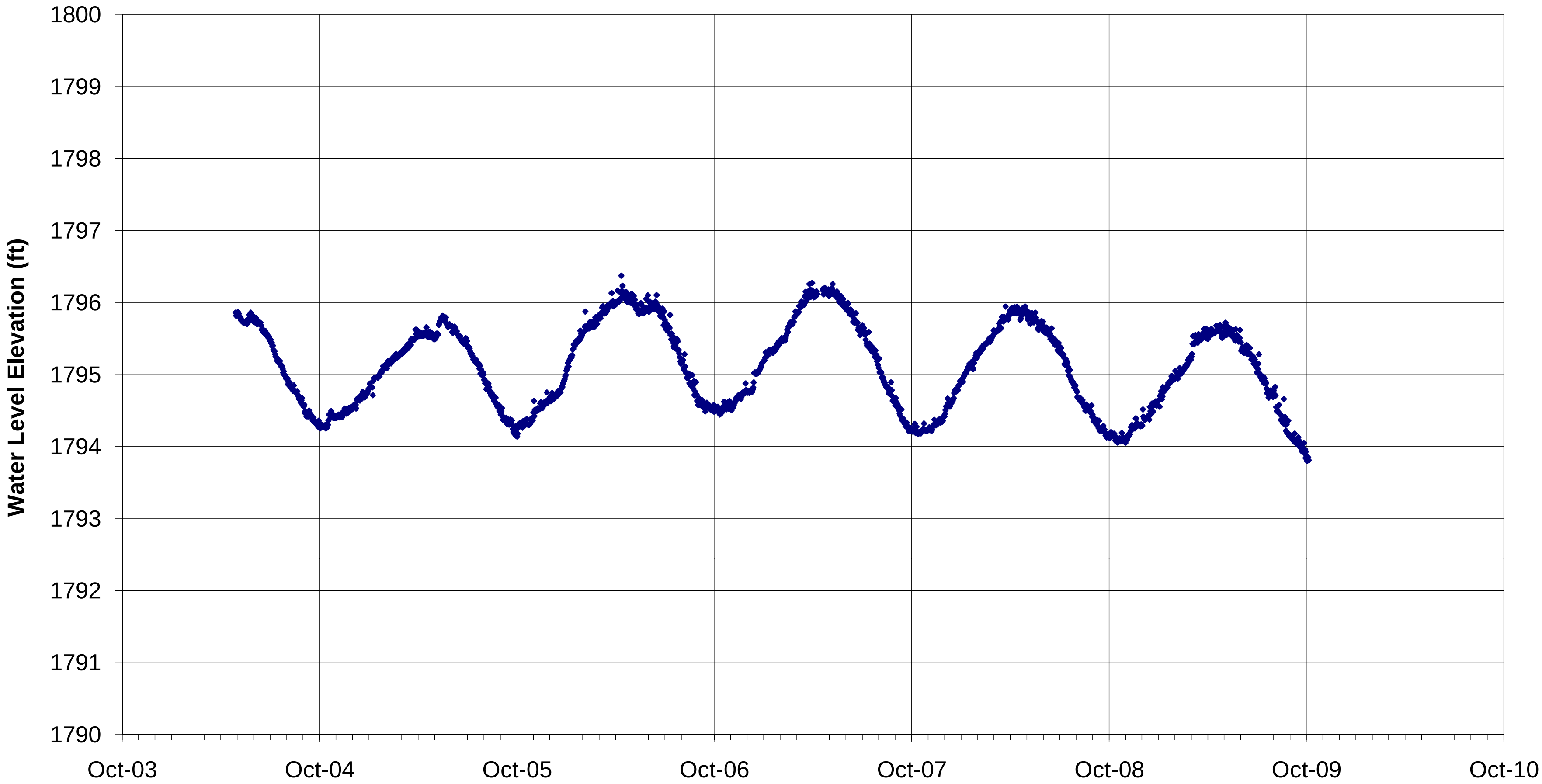
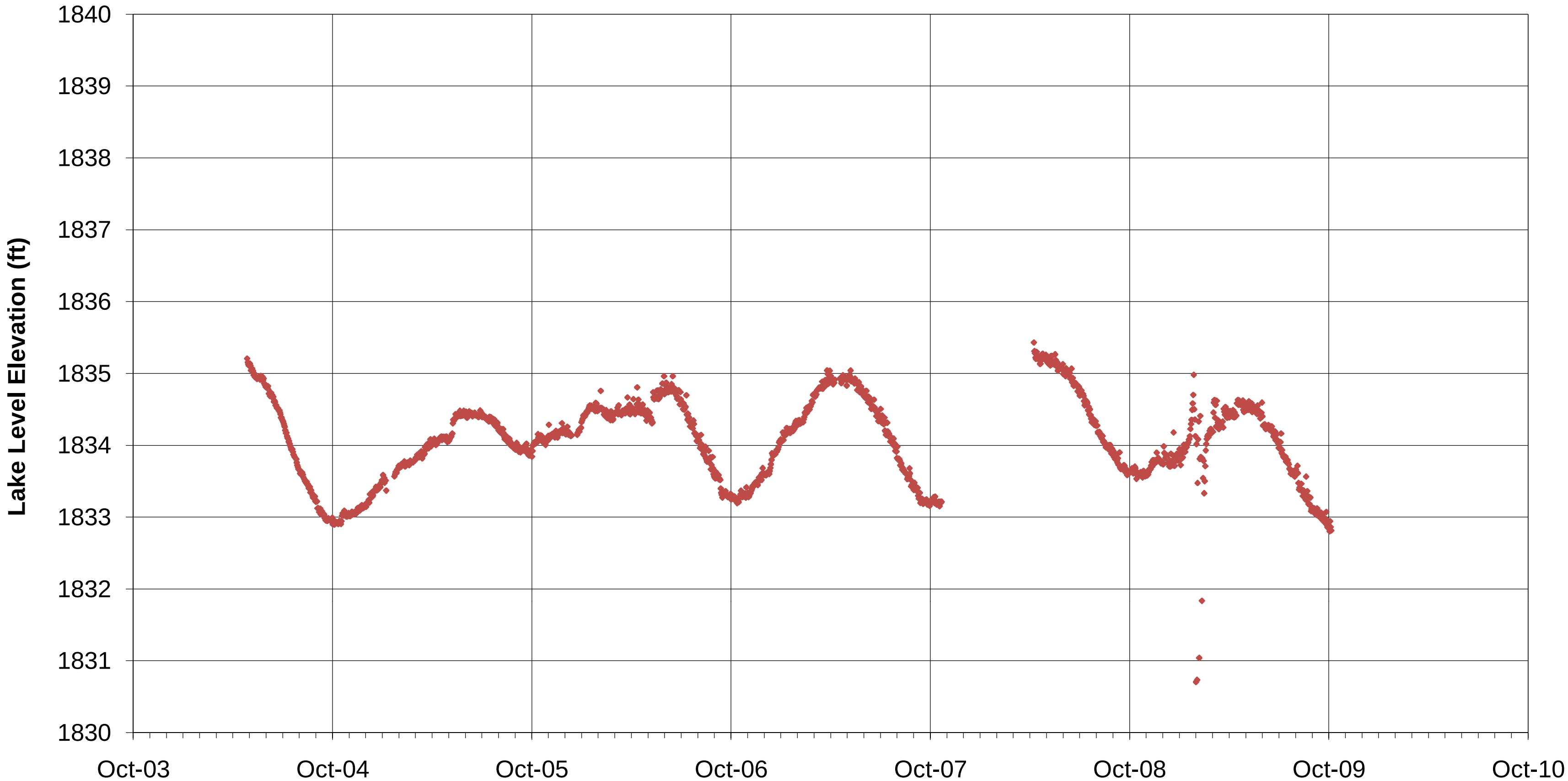


Figure 16
Jameson Lake Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG



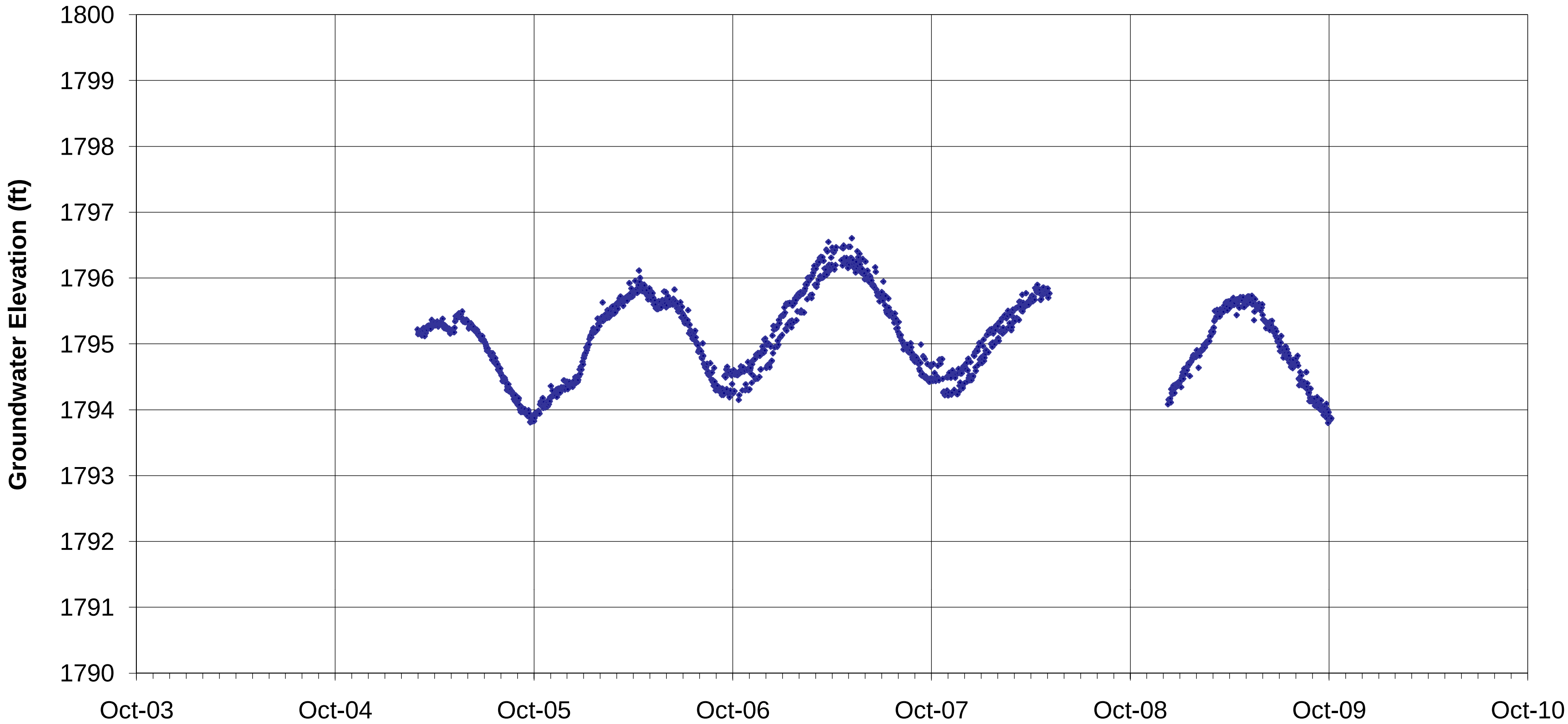
Notes

Originally 7.87' below Bench Mark (BM) = 1836.6
Spring 05 moved up 0.25 (7.62' below BM) = 1836.9
Spring 06 moved up another 0.47' (7.15' below BM) = 1837.4
Station Moved 9/12/06 to new location where less ice expected. = 1837.5715
Data logger removed from October 2007 to April 2008 due to freezing conditions,the logger was re-installed at the original location and elevation in the spring of 08 and will be removed each fall due to movement when frozen in the ice

Figure 17
Grimes Lake Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG



Notes
Data missing from March to December 2008 due to logger damage during wellhead maintenance

Figure 18
Matthiesen Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

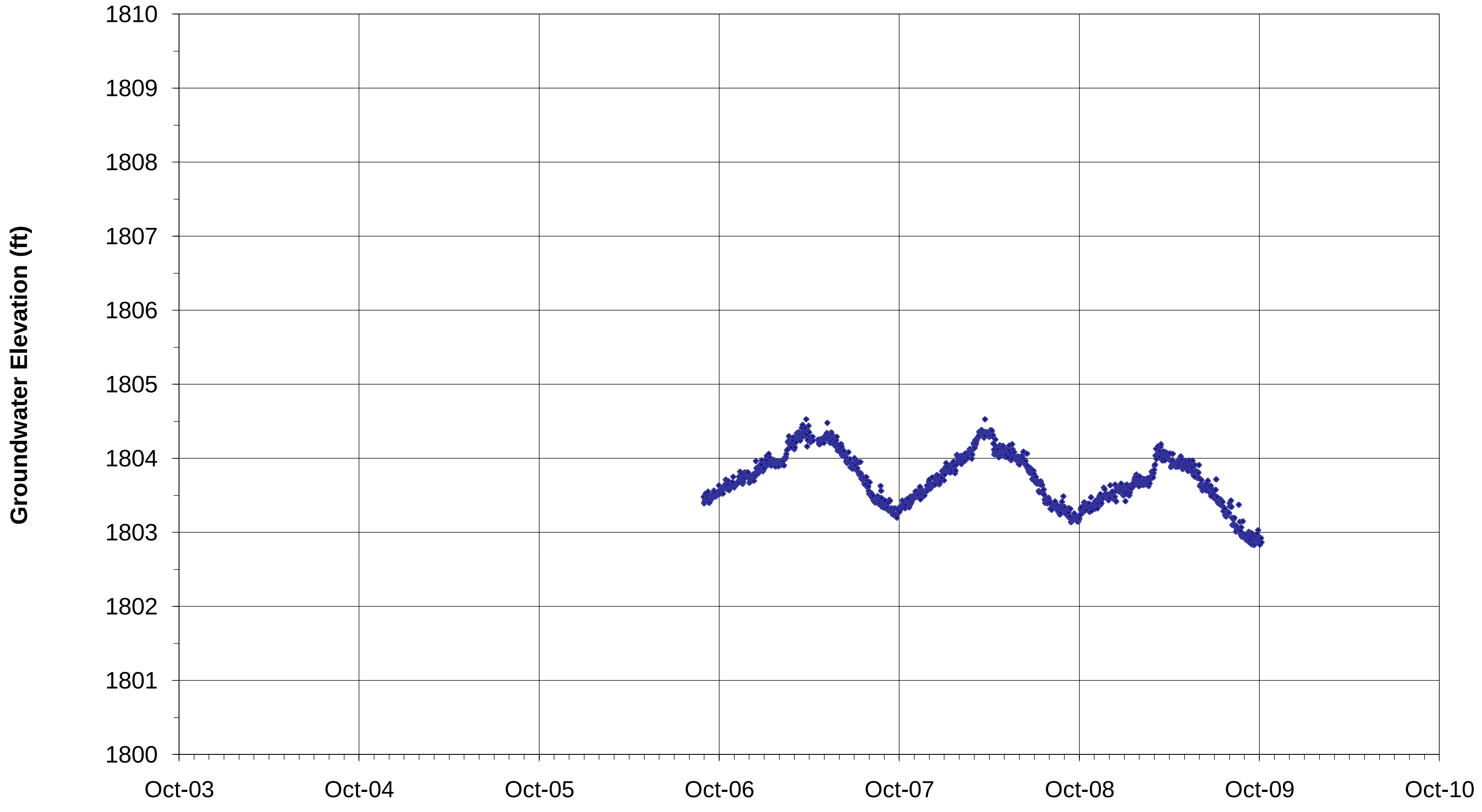


Figure 19
PGG-1 Well Hydrograph

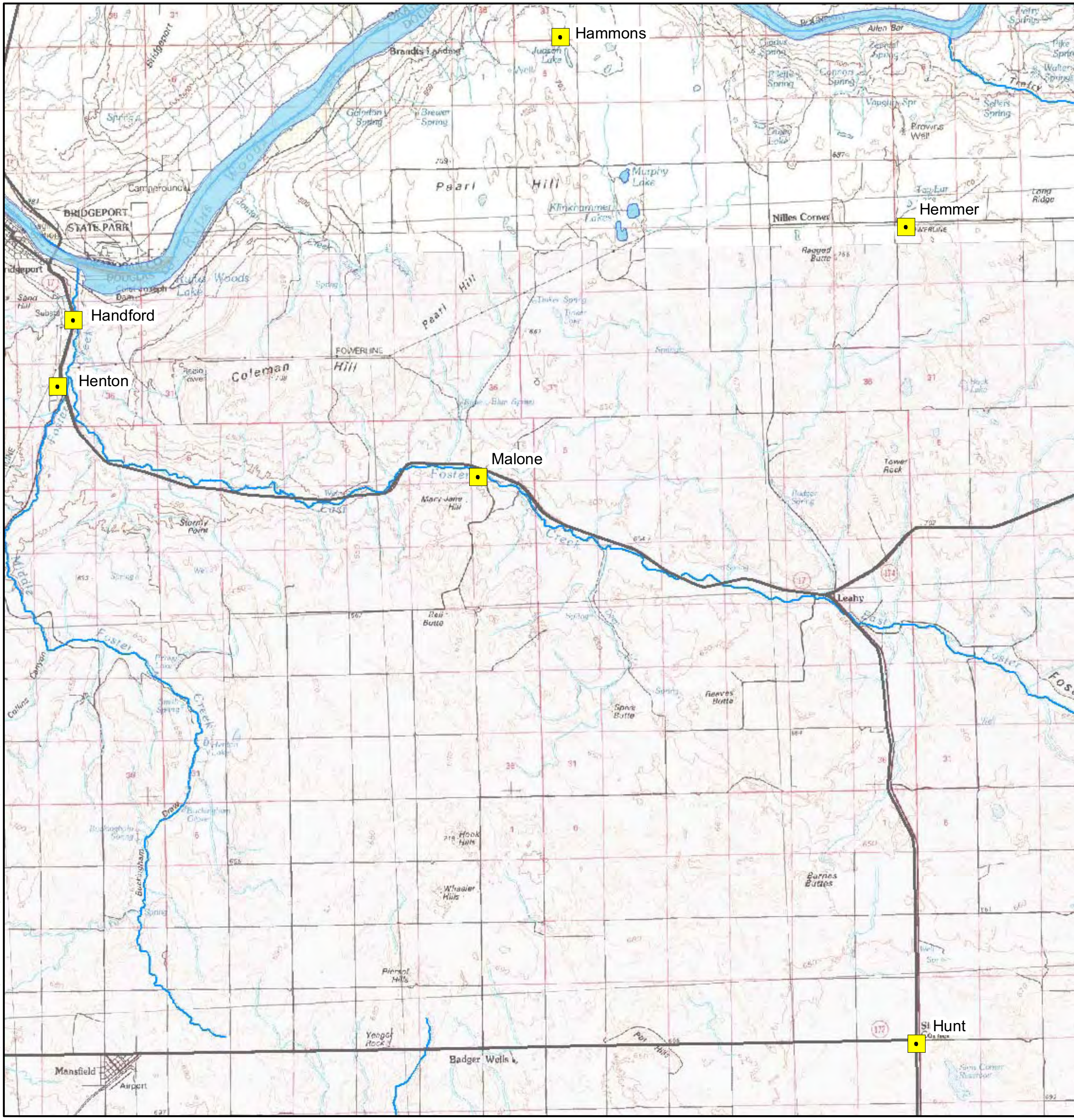
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

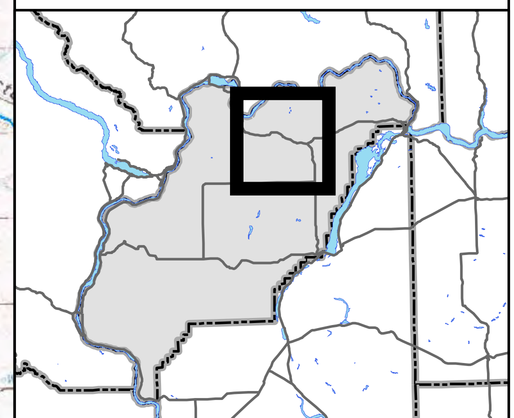
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 20

Foster Creek Monitoring Locations



Groundwater Level Monitored Well



0 12,000 Feet
0 2 Miles
1:144,000

PGG

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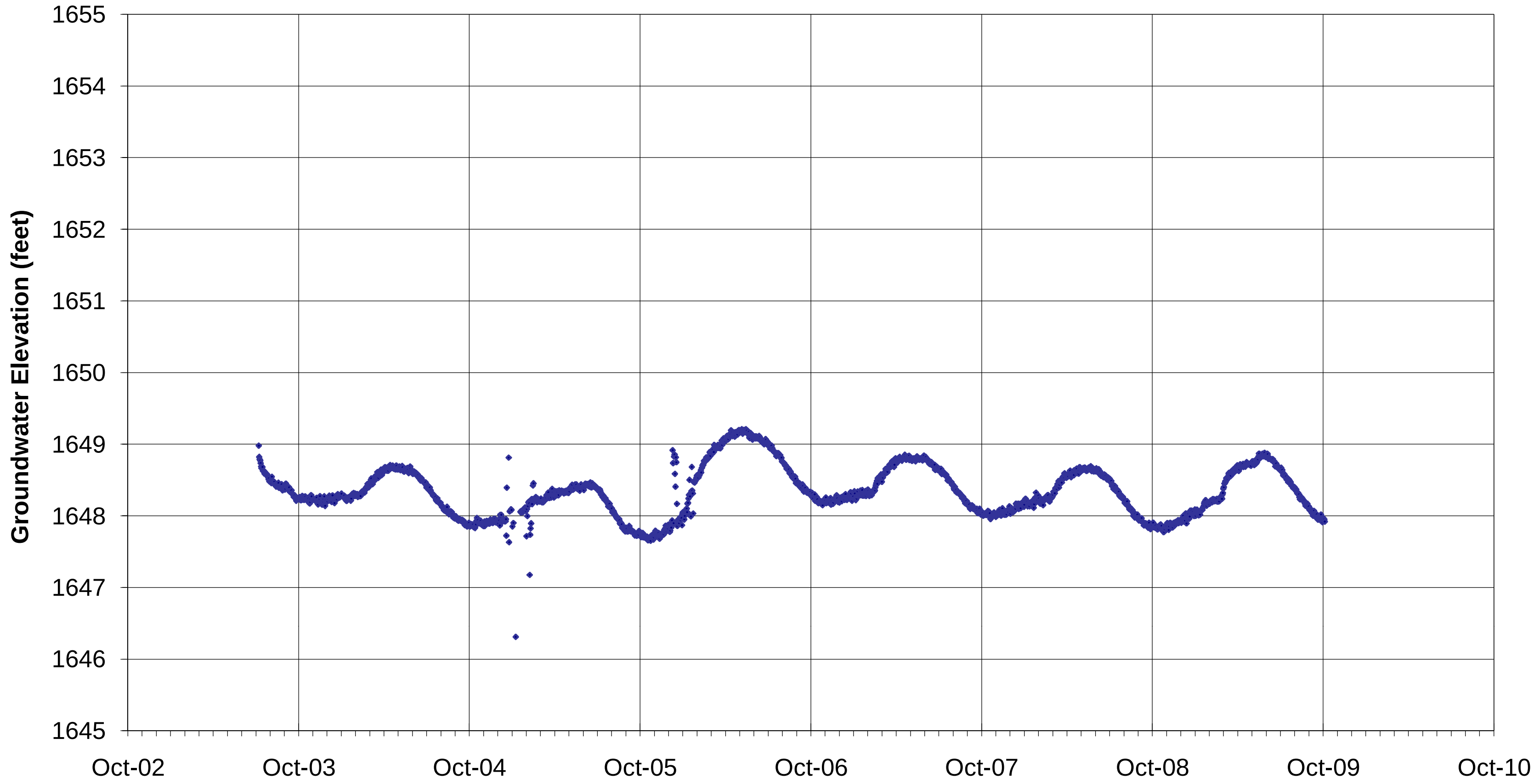
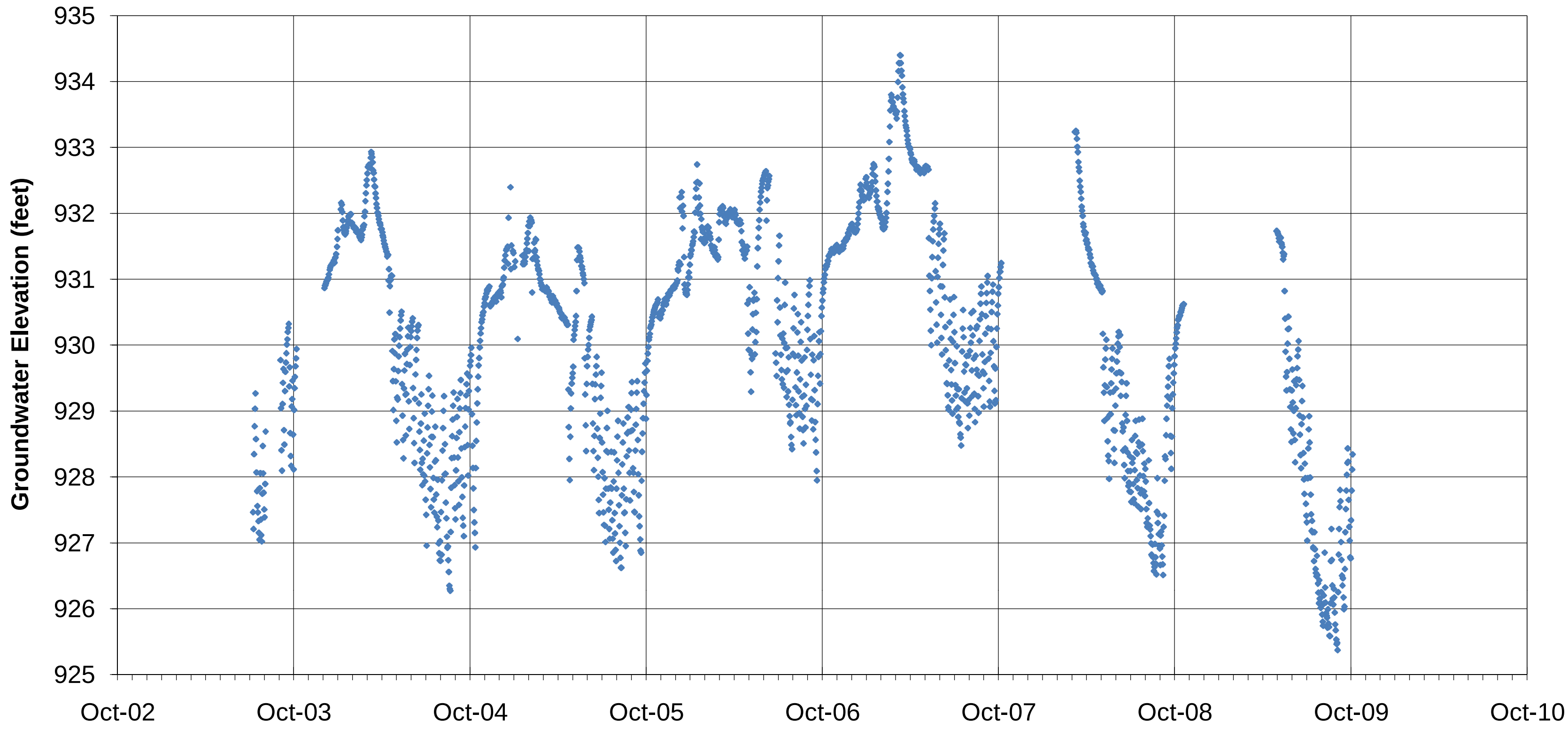


Notes
Spurious data variability is related to barometer malfunction.
On May 15, 2009, there a was an unexplained pressure decrease of 1.85 feet, which was corrected in the data

Figure 21
Malone Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

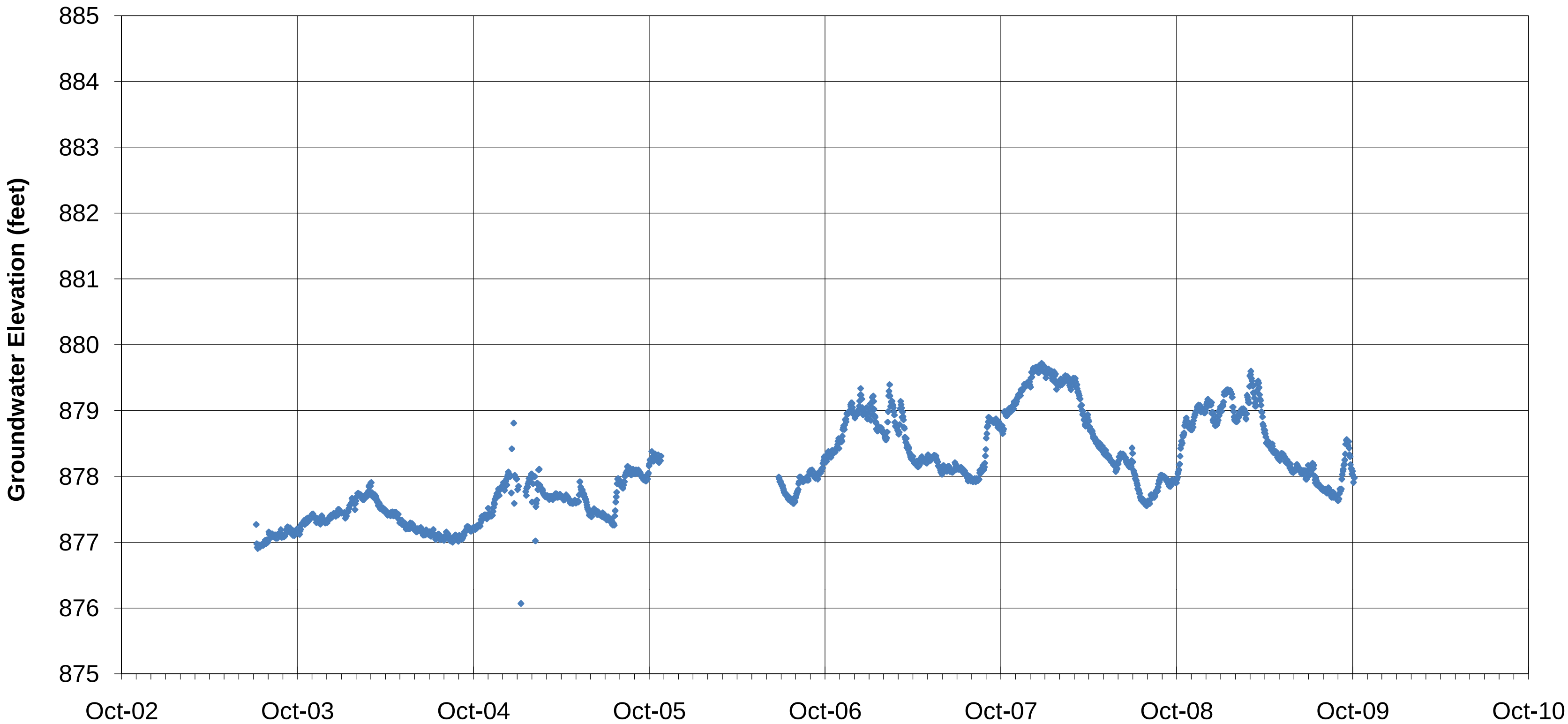


Notes
Spring 2009 data gap due to accidental data erasure.
Data gap between 10/07 and 3/08 due to wellhead maintenence.
Jumps between 12/04 and 2/05 due to the barometer logger malfunctioning.
Small gap in data (5/4/05 to 6/10/05)occured while logger was replaced.
Possible logger malfunction 6/15/06 to 6/28/06 (data not included).
Data missing from 10/07 to 3/08 due to well head maintenance.

Figure 22
Henton Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

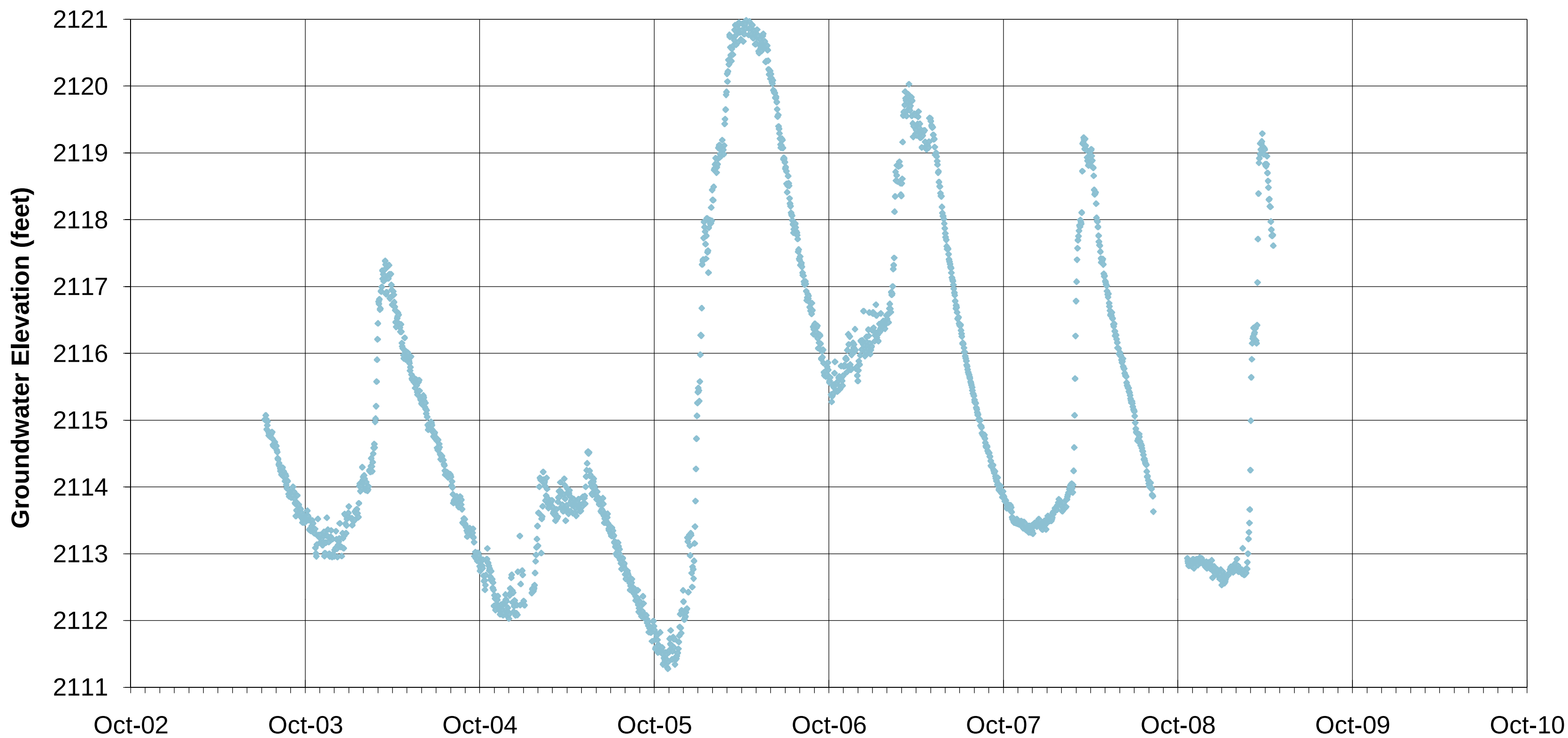


Notes
Jumps between 12/04 and 2/05 due to the barometer logger malfunctioning.
Small gap in data (5/4/05 to 6/10/05) while logger was replaced.
October 2005 to May 2006 data inadvertently overwritten during the May 2006 download. The logger was temporarily removed and was reinstalled in late June 2006.

Figure 23
Hanford Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

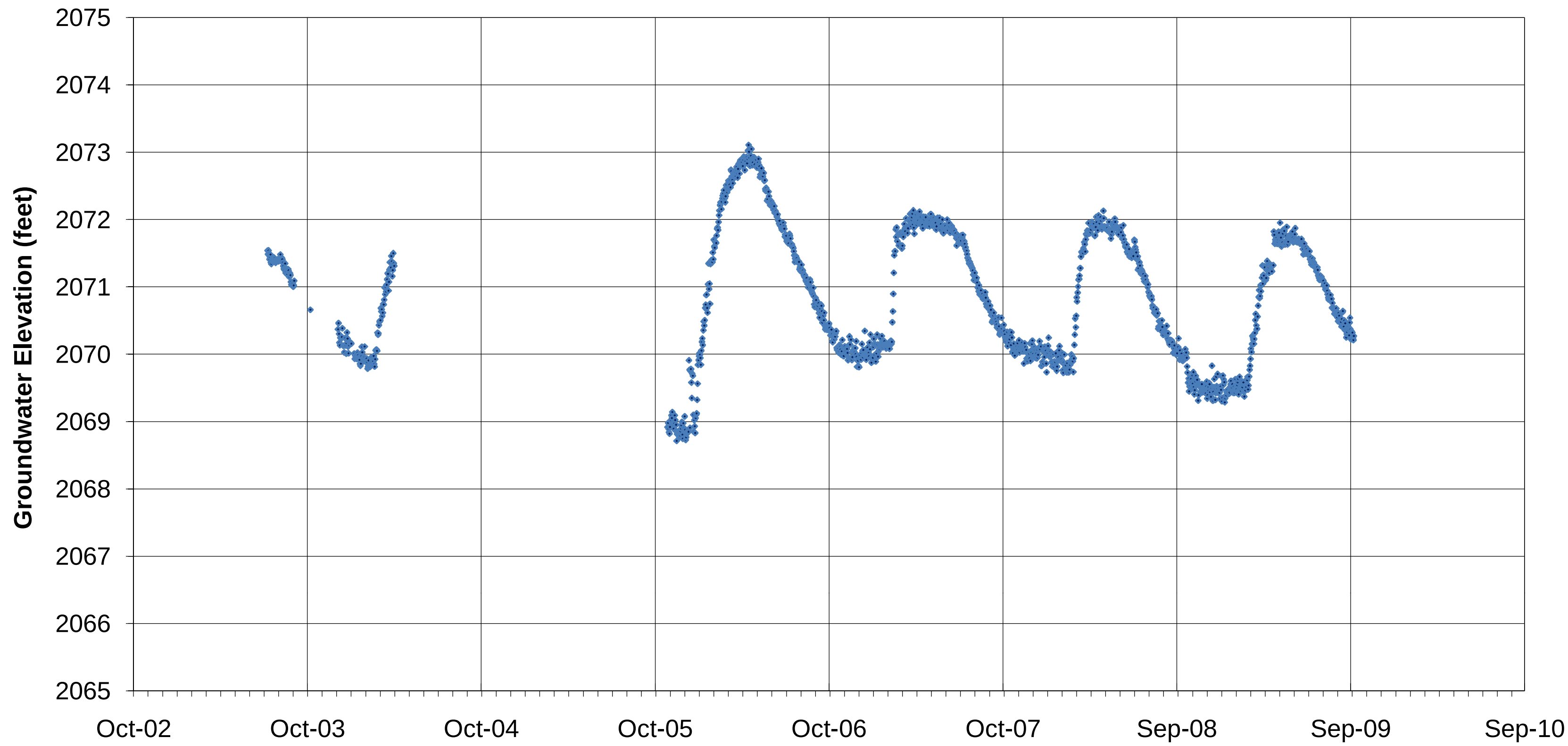


Notes
Jumps between 12/04 and 2/05 due to the barometer logger malfunctioning.
Small gap in data (5/4/05 to 6/10/05) while logger was replaced.
This well has no pump in it.
Data collected June 22, 2006 to October 1, 2006 unreliable due to firm ware issues.
Data gap in Fall of 2008 due water level rise of 3.49 feet resulting from animal influence

Figure 24
Hammons Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

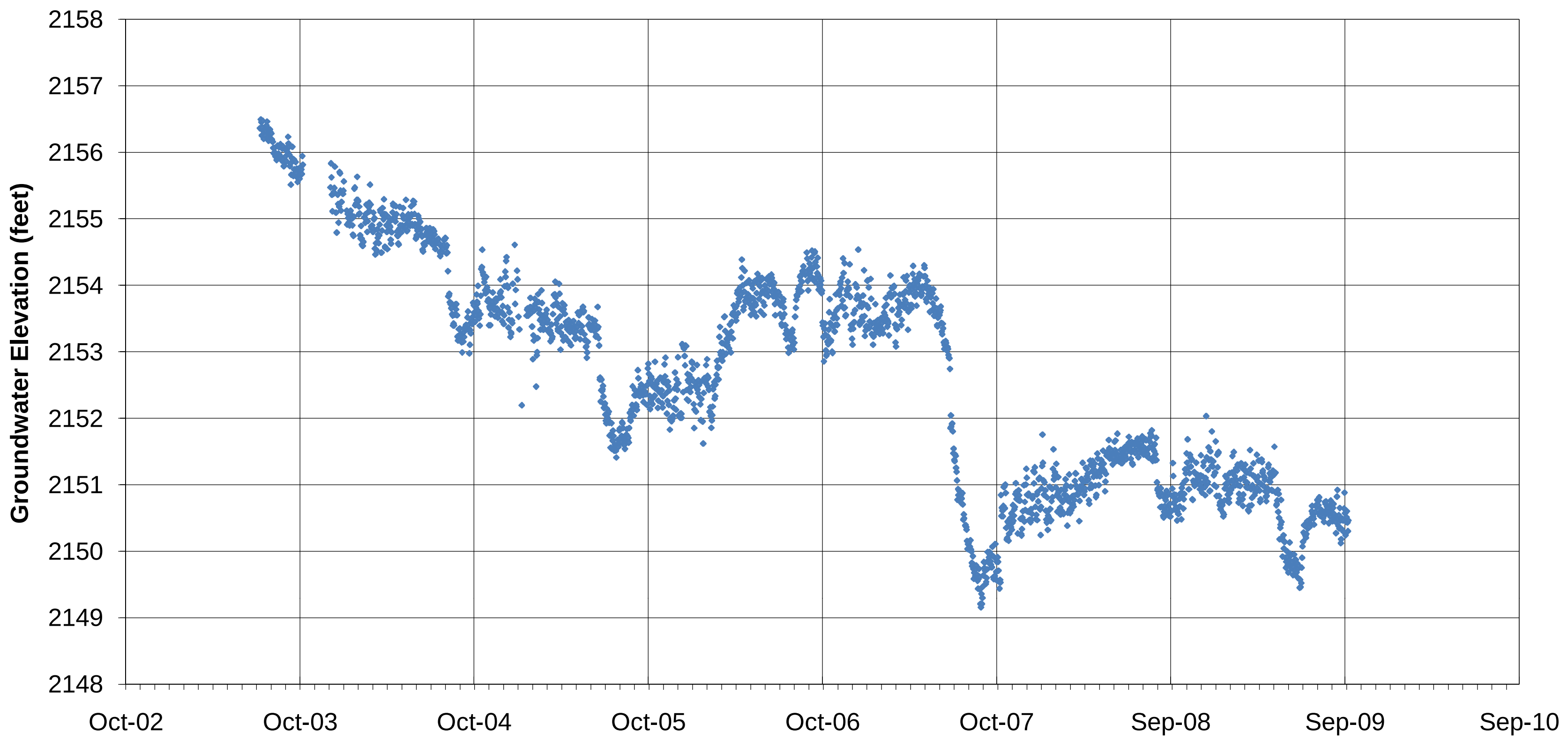


Notes
Data from April 2004 to June 2005 is unreliable because of logger malfunction and is therefore not displayed. The logger was replaced in June 2005.

Figure 25
Hunt Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG



Notes
Jumps between 12/04 and 2/05 due to the barometer logger malfunctioning.
Small gap in data (5/4/05 to 6/10/05) while logger was replaced.

Figure 26
Hemmer Well Hydrograph

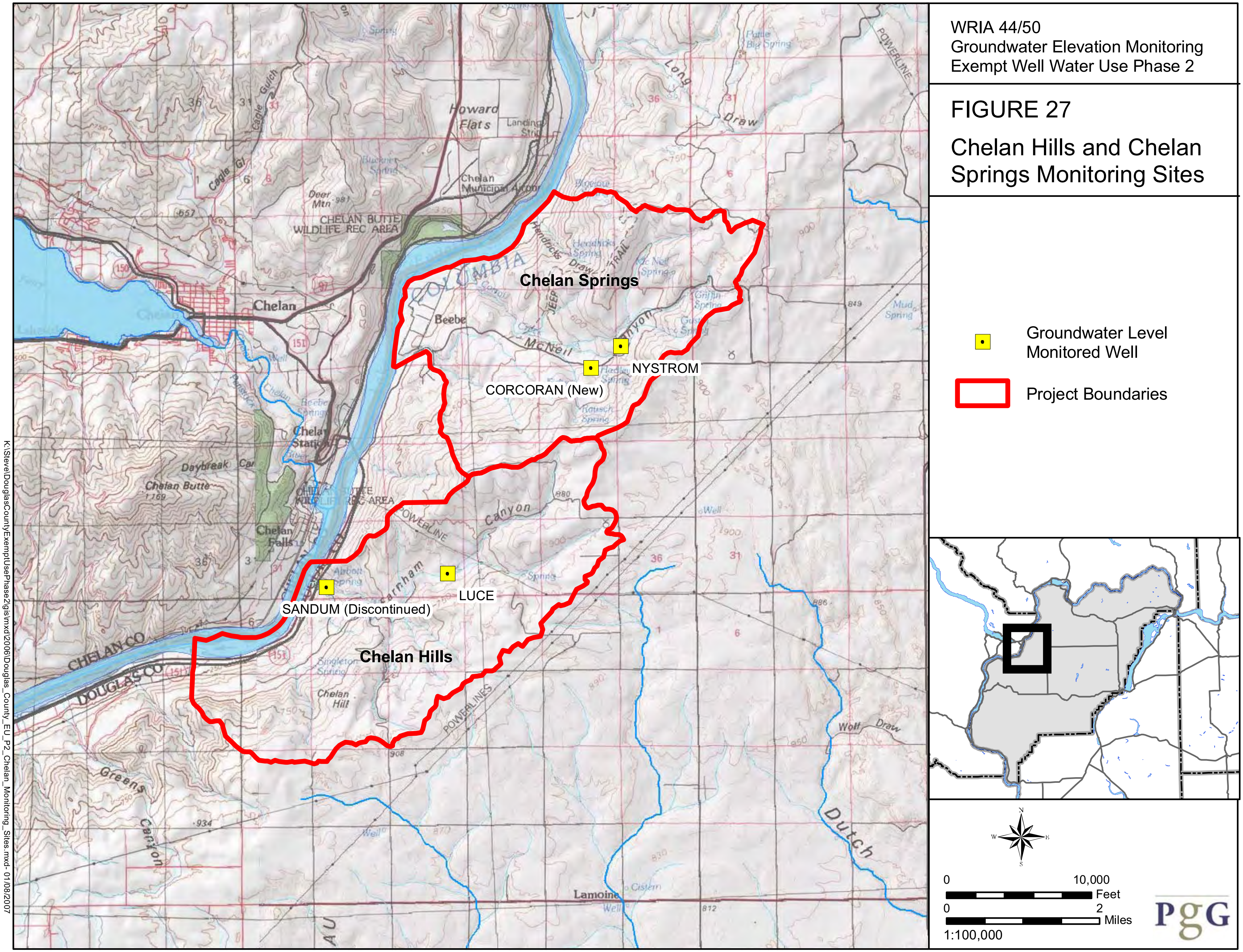
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 27

Chelan Hills and Chelan Springs Monitoring Sites



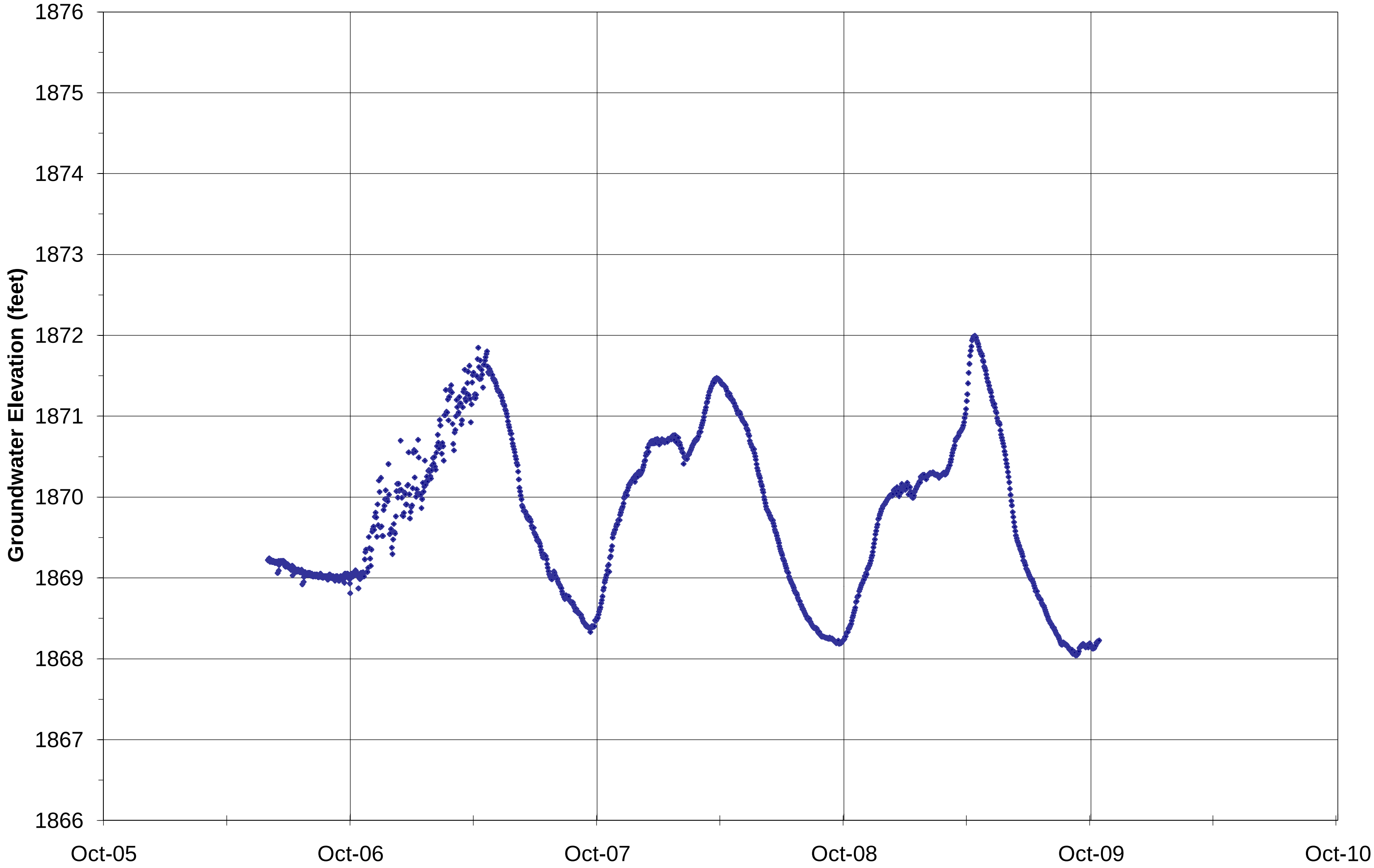


Figure 28
Luce Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

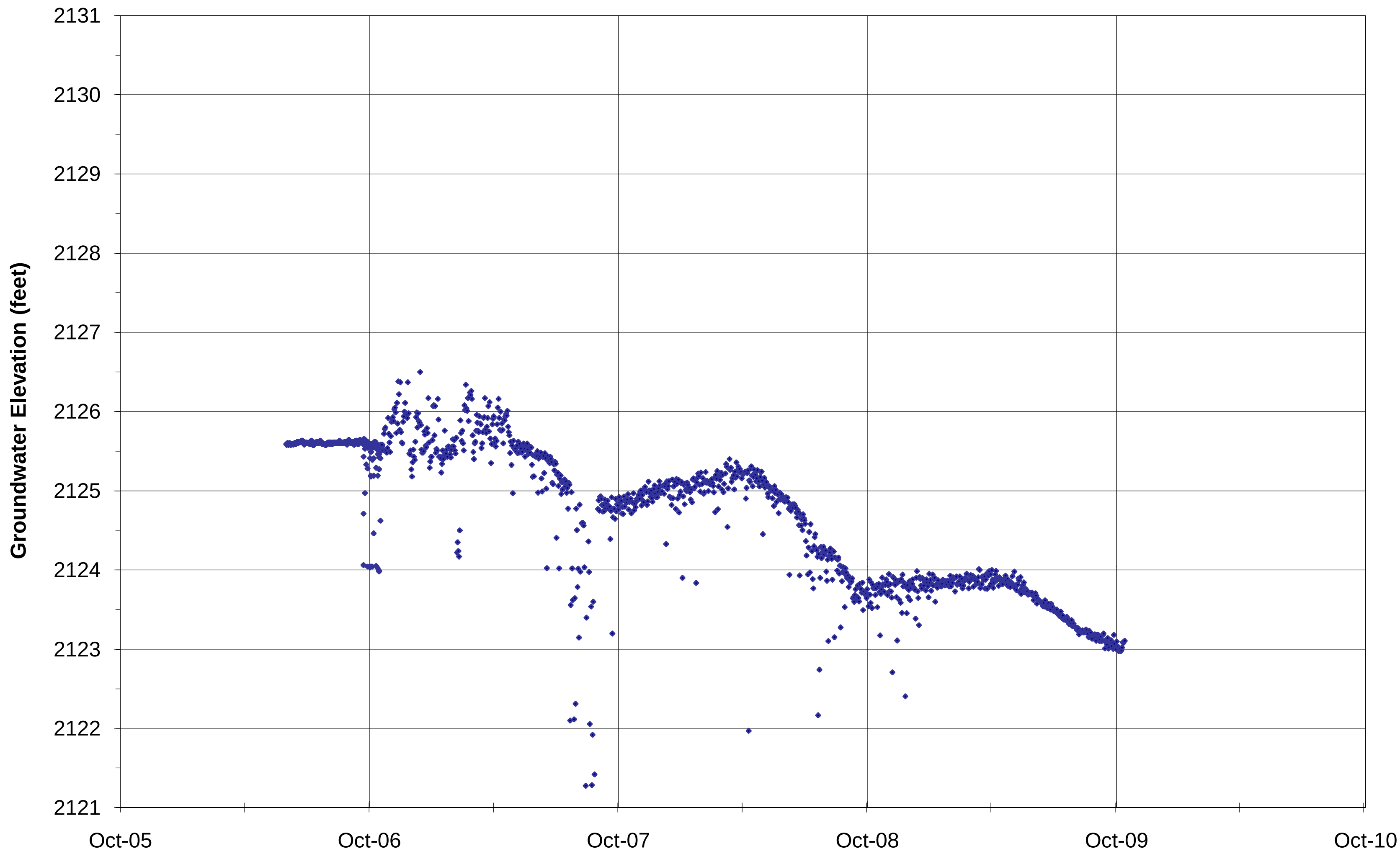
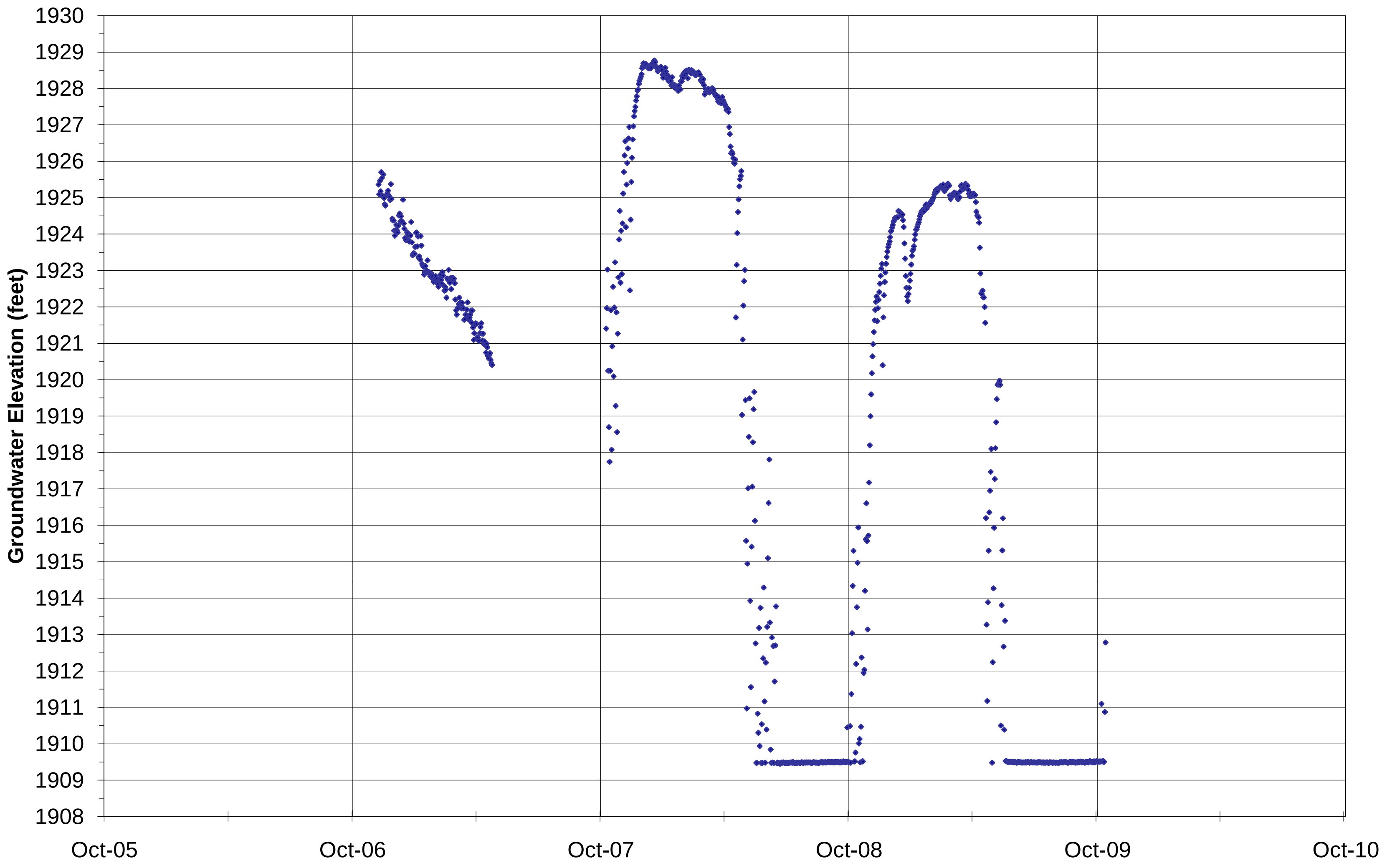


Figure 29
Nystrom Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG



Notes
Faulty logger in Fall 2007
Flat line plots in the fall of 2008 and 2009 are due to groundwater elevations falling below the data logger.

Figure 30
Cocoran Well Hydrograph

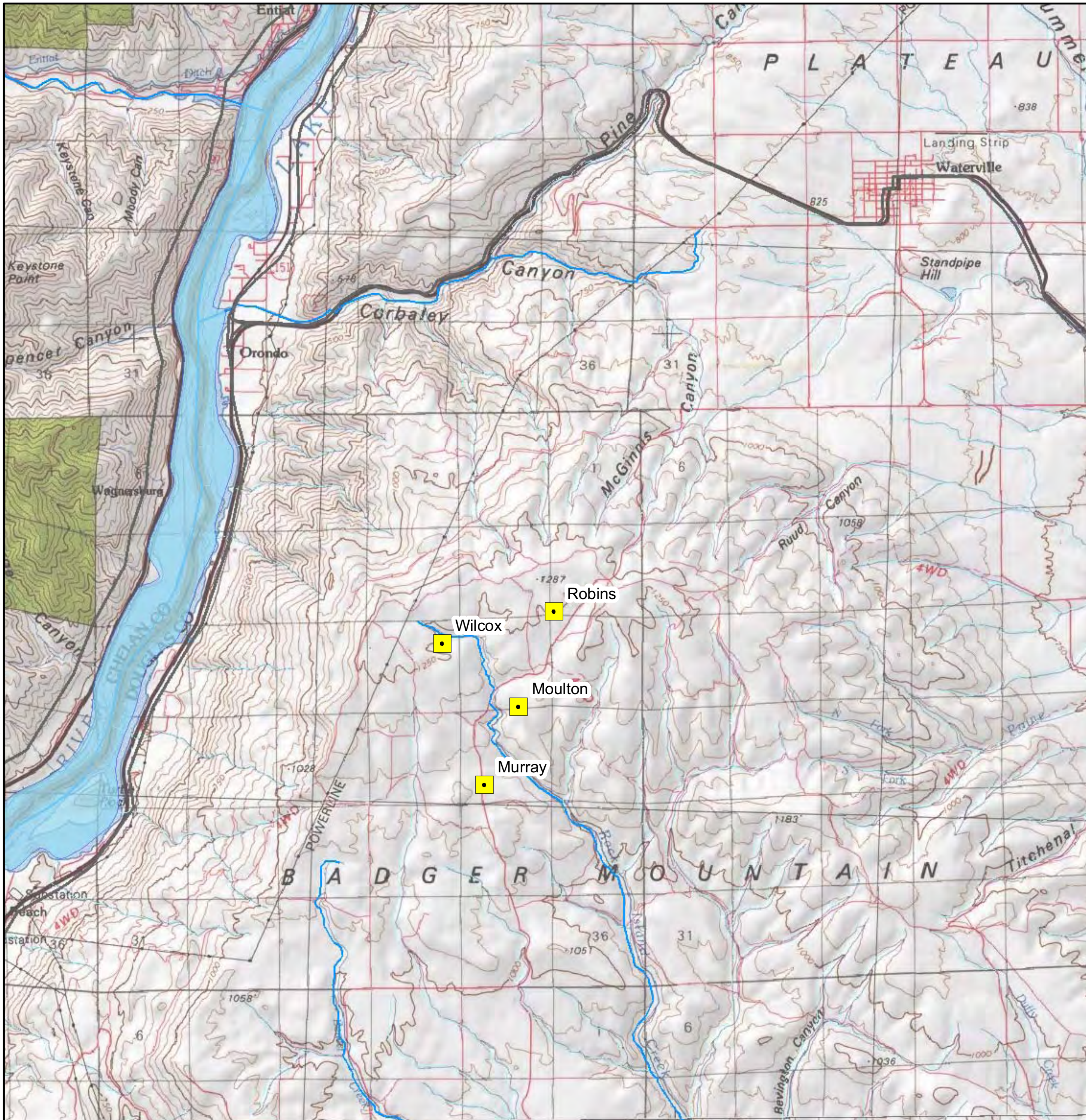
WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

FIGURE 31

Badger Mountain Monitoring Locations



Groundwater Level Monitored Well

0 10,000 Feet

0 2 Miles

1:100,000

PgG

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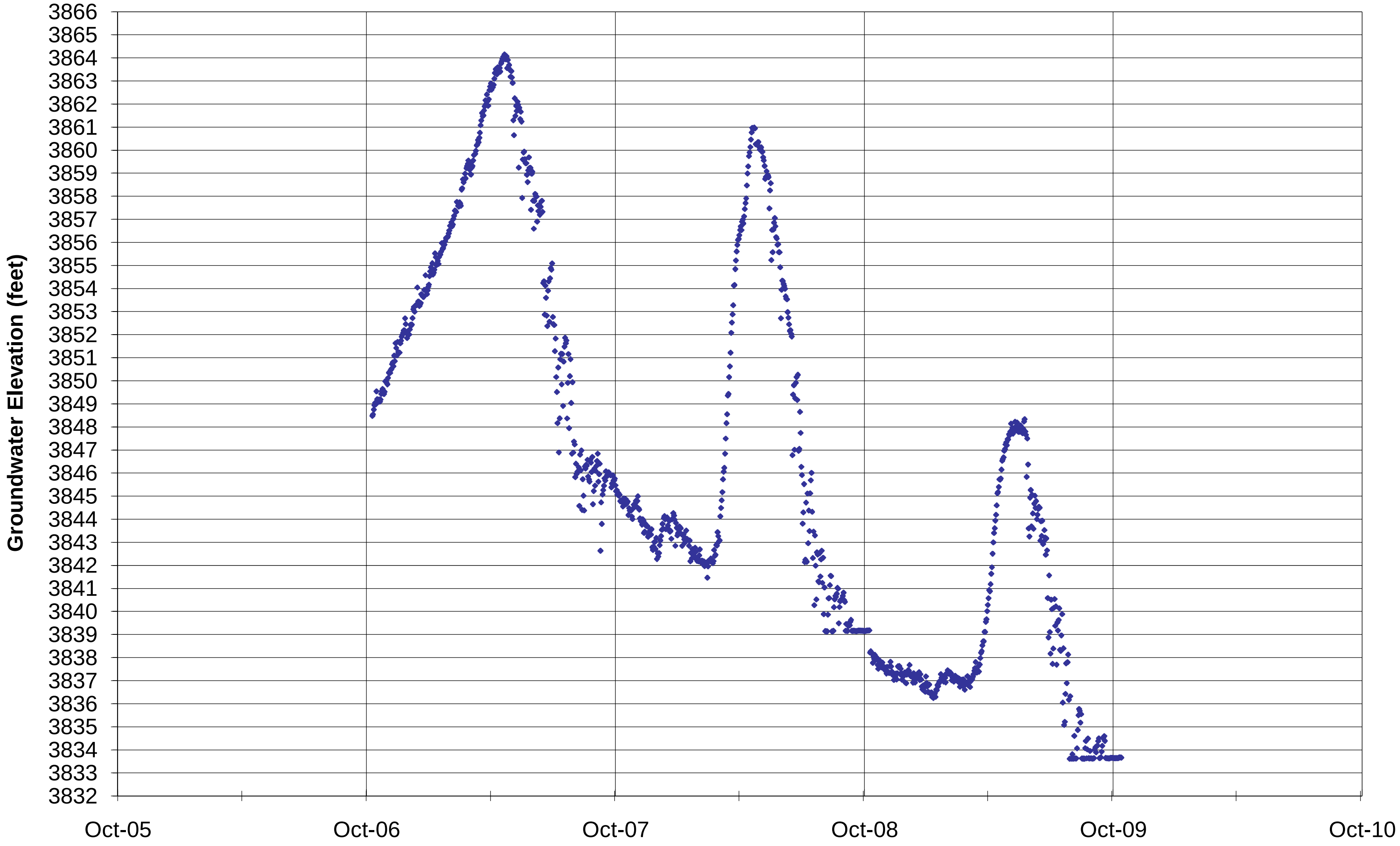
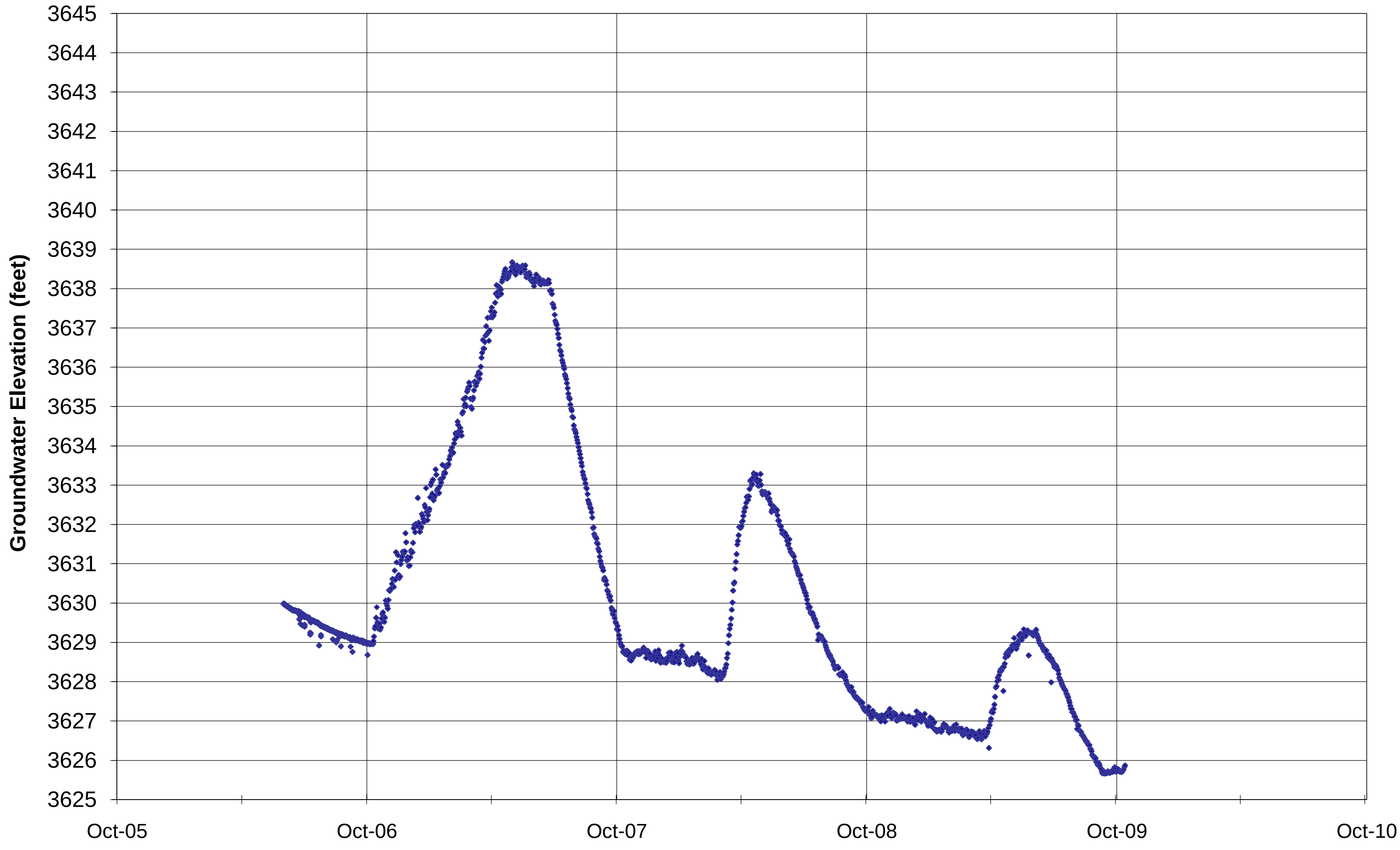


Notes
Scale modified from standard report scale

Figure 32
Moulton Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

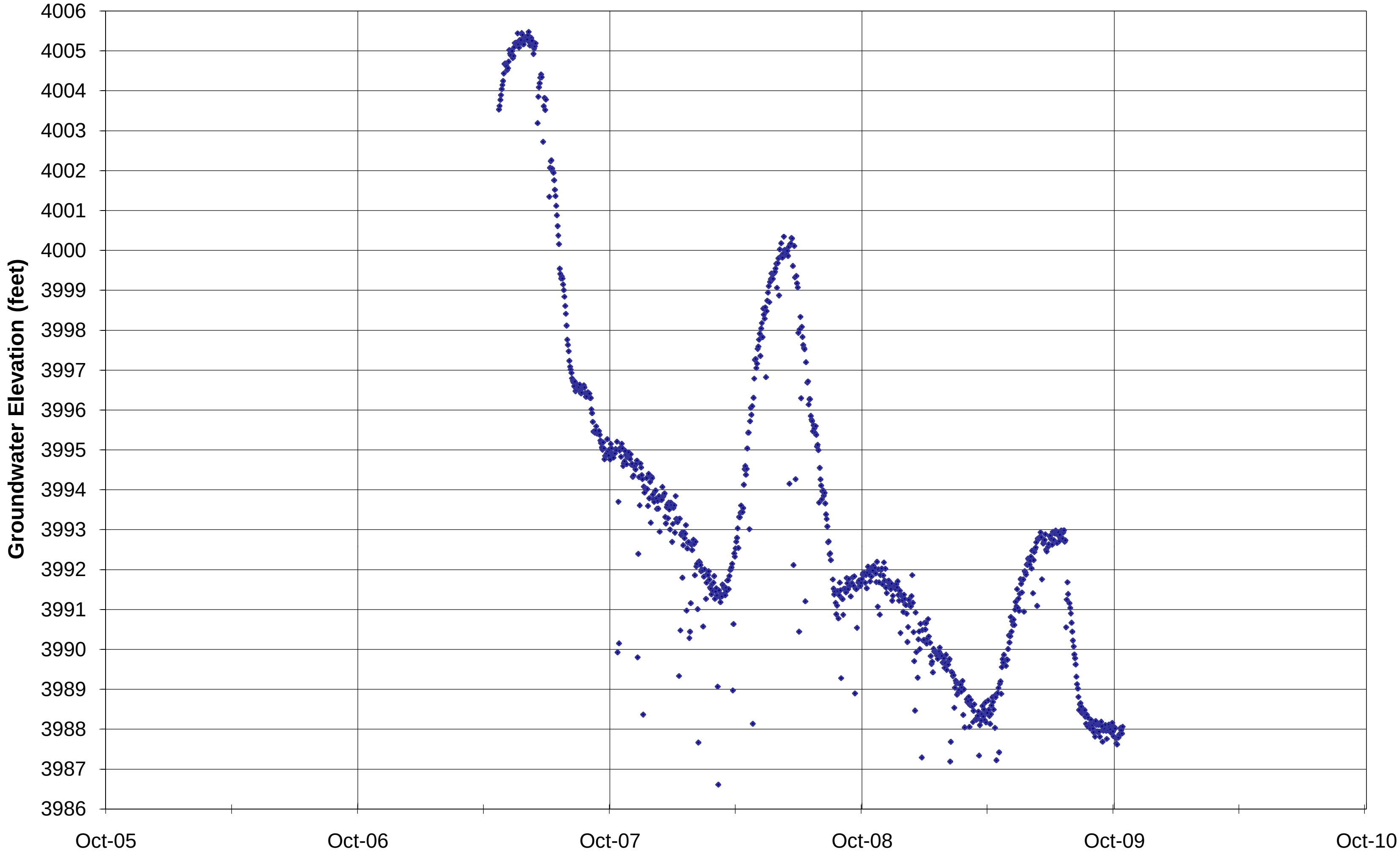


Notes

Figure 33
Murray Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

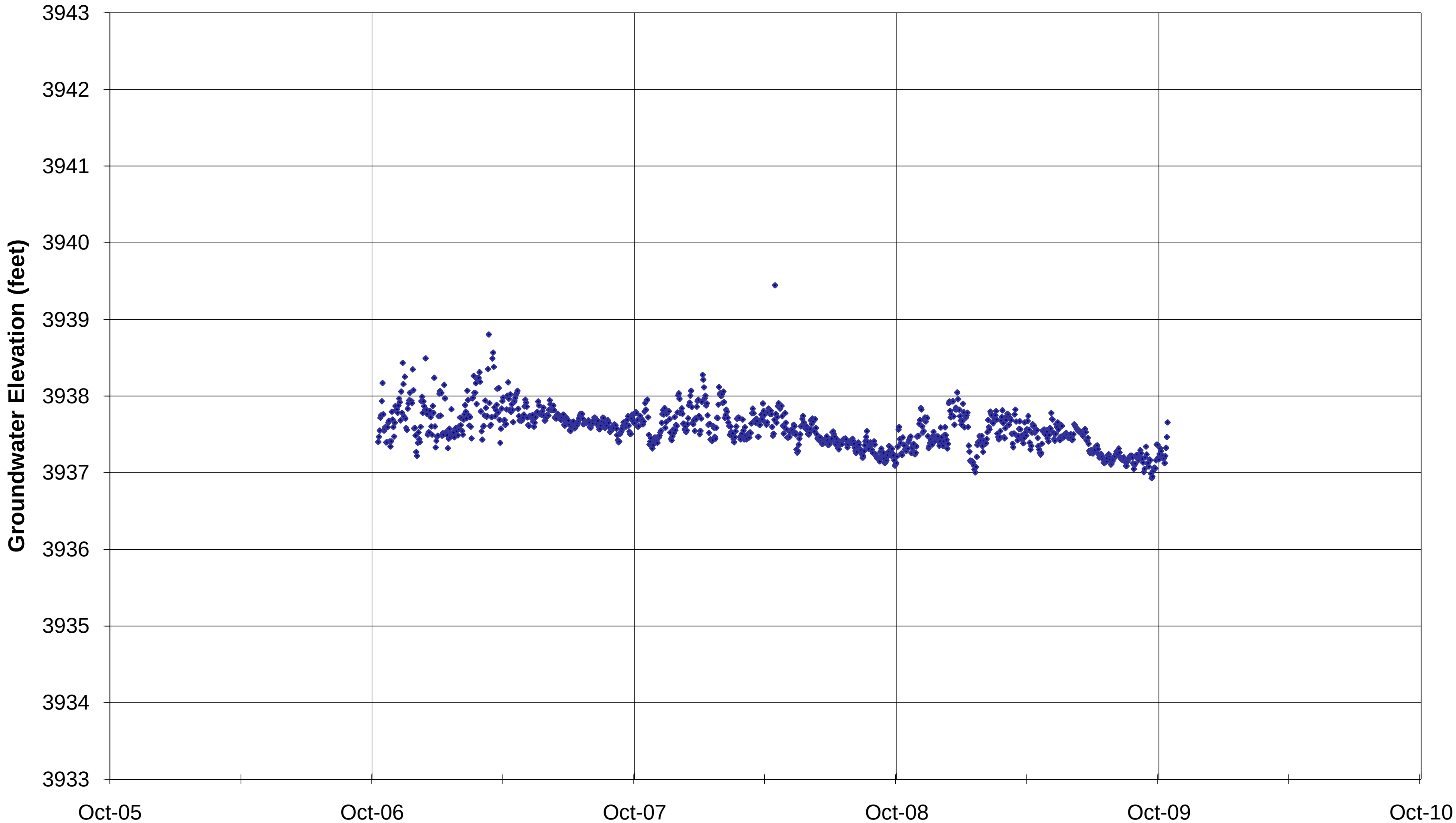


Notes
Scale modified from standard report scale

Figure 34
Robins Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PgG



Notes

Figure 35
Wilcox Well Hydrograph

WRIA 44/50
Groundwater Elevation Monitoring
Exempt Well Water Use Phase 2

PGG

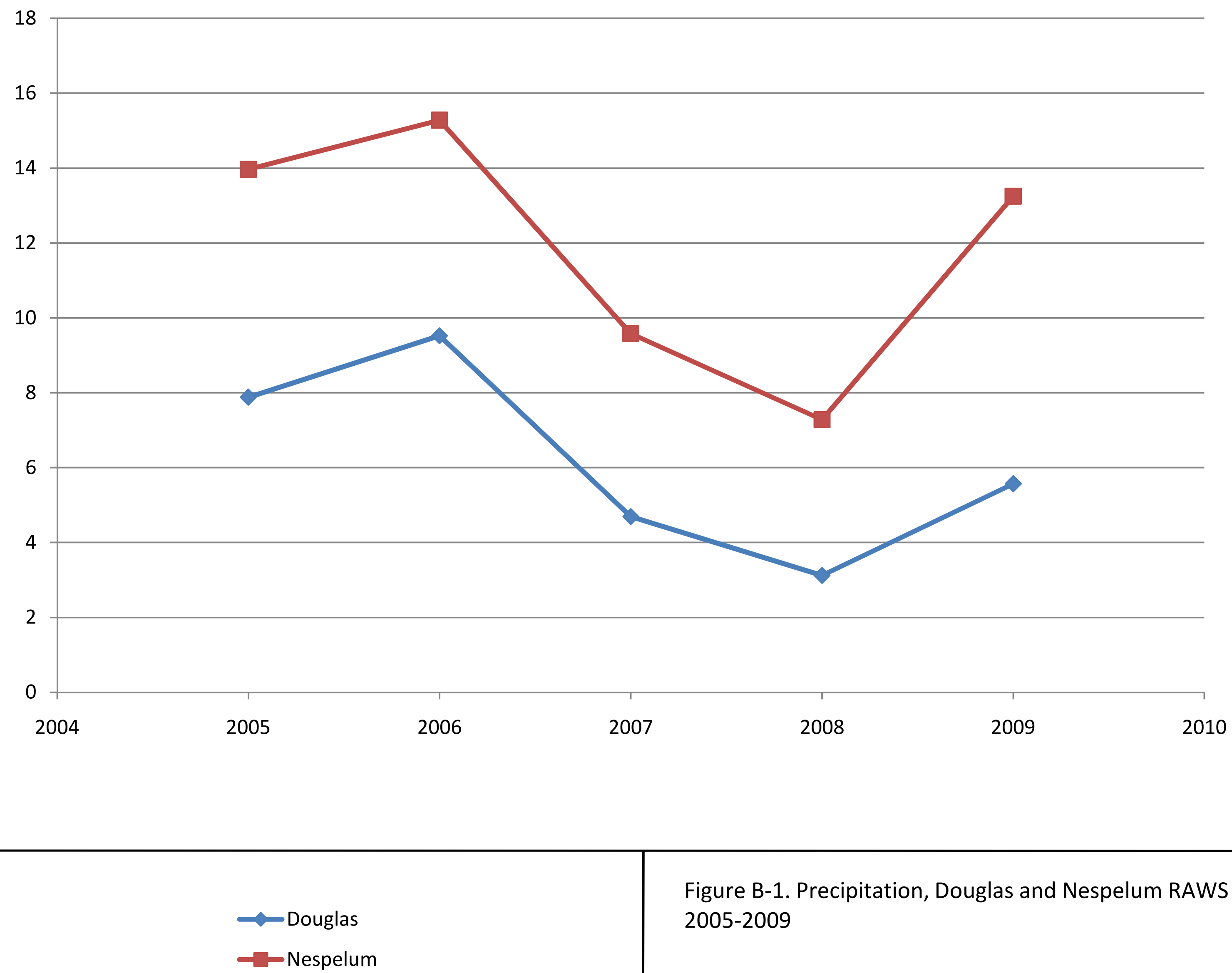


Figure B-1. Precipitation, Douglas and Nespelum RAWS Stations, 2005-2009