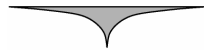

Technical Memorandum
Perennial Yield Update for the
City of Big Bear Lake Department of
Water and Power Service Area

Prepared for City of Big Bear Lake Department of Water and Power

February 2, 2006

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City of Big Bear Lake Department of Water and Power Service Area**

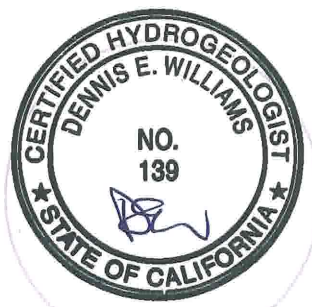
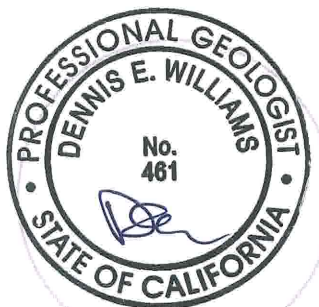
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Prepared for



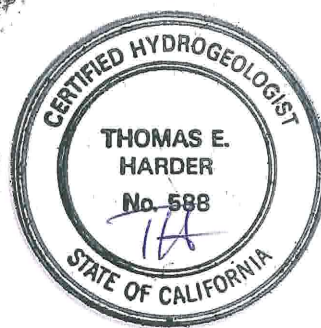
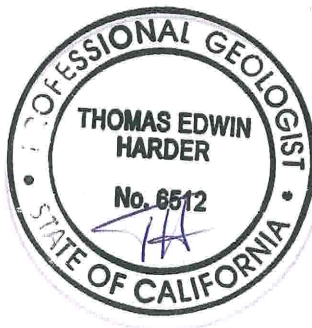
A handwritten signature in blue ink, appearing to read "D Williams".

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**TECHNICAL MEMORANDUM
PERENNIAL YIELD UPDATE FOR THE
CITY OF BIG BEAR LAKE DEPARTMENT OF
WATER AND POWER SERVICE AREA**

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**TECHNICAL MEMORANDUM
PERENNIAL YIELD UPDATE FOR THE
CITY OF BIG BEAR LAKE DEPARTMENT OF
WATER AND POWER SERVICE AREA**

1.0 EXECUTIVE SUMMARY

This technical memorandum provides an update of perennial yield estimates for the ground water basins within the hydrologic subunits of the City of Big Bear Lake Department of Water and Power (BBDWP; Figure 1). The purpose of this update is to refine the previous estimates through incorporation of hydrogeological data collected since the last perennial yield report prepared in August 2001 (GEOSCIENCE, 2001). This technical memorandum also incorporates updated perennial yield studies for the Grout Creek and North Shore subunits (GEOSCIENCE, 2003c) as well as an evaluation of the Lake William tributary subarea of the Erwin Subunit (GEOSCIENCE, 2004a). The scope of work to conduct the study consisted of updating the ground water level and production database, analysis of data collected since 2001 for reevaluation of the perennial yield of each subunit, and preparation of this technical memorandum.

Estimation of perennial yield for the various hydrologic subunits was conducted using three different methods: evaluation of the water balance using a watershed model, ground water underflow analysis, and evaluation of ground water levels and production over time. Of the methods utilized for analysis, evaluation of ground water levels and production history was considered to provide the most reliable estimate of perennial yield for any given subunit. The other methods were utilized for subunits that did not have adequate historical records or where other methods were more appropriate.

In summary, evaluation of data collected since the GEOSCIENCE (2001) maximum perennial yield update has resulted in a revised perennial yield for the hydrologic subunits that encompass the BBDWP service area. The previous range of perennial yield was 3,710 to 3,870 acre-ft/yr including Gray's Landing, and 3,570 to 3,730 acre-ft/yr excluding Gray's Landing.¹ Geohydrologic data collected since 2001 has enabled a more refined range of perennial yield for the BBDWP service area, which is slightly lower than the previous estimate (3,400 to 3,475 acre-ft/yr) (see Table E1). The lower estimate is primarily a result of reductions in the perennial yield estimates for the Mill Creek and Village Subunits, which were reduced based on new data and ongoing monitoring of ground water level trends. Furthermore, based on analysis of updated ground water level and production data in the Rathbone and Erwin Subunits, it is recommended to use the lower end of the previous perennial yield ranges for each of these subunits.

¹ Gray's Landing is no longer included in the perennial yield estimates because it is located in a remote area on granitic bedrock, which makes ground water development and distribution from this area economically unfavorable.

Table E1. Summary of Maximum Perennial Yield Estimates by Subunit

Subunit	SUMMARY OF MAXIMUM PERENNIAL YIELD ESTIMATES BY SUBUNIT (acre-ft/yr)		
	GEOSCIENCE (2001)	GEOSCIENCE (2003)	GEOSCIENCE This Study
Grout Creek	200	280	280
Gray's Landing	140	NA ¹	NA
Mill Creek	330	NA	100-175
Village	290	NA	250
Rathbone	1,100 - 1,200	NA	1,100
Division	500 - 550	NA	540²
North Shore	260	240 ³	240³
Erwin	890 - 900	NA	890
TOTAL	3,710 - 3,870	NA	3,400 – 3,475
TOTAL Available to BBDWP⁴	3,570 - 3,730	NA	3,100 – 3,175

- 1 NA = Not analyzed or not applicable
- 2 Includes North Shore Tributary Subarea F
- 3 Does not include North Shore Tributary Subarea F
- 4 Accounts for BBCSD portion of Erwin Subunit Perennial Yield

	Yellow cells indicate results obtained using a watershed model
	Green cells indicate results obtained using underflow analysis
	Blue cells indicate results obtained through analysis of ground water levels and pumping data

2.0 INTRODUCTION

This technical memorandum provides an update of perennial yield estimates for the ground water basins within the hydrologic subunits of the City of Big Bear Lake Department of Water and Power (BBDWP; Figure 1). The purpose of this update is to refine the previous estimates through incorporation of geohydrological data collected since the last perennial yield report prepared in August 2001 (GEOSCIENCE, 2001). This technical memorandum also incorporates updated perennial yield studies for the Grout Creek and North Shore subunits (GEOSCIENCE, 2003c) as well as an evaluation of the Lake William tributary subarea of the Erwin Subunit (GEOSCIENCE, 2004a).

The scope of this evaluation included:

- Updating the existing geohydrologic database through 2005 with ground water level and ground water production records,
- Reevaluating the maximum perennial yield of each hydrologic subunit within the BBDWP service area using available data, and
- Preparing this technical memorandum of findings from the analysis.

3.0 METHODOLOGY

Maximum perennial yield is defined as:

The maximum quantity of ground water perennially available if all possible methods and sources are developed for recharging the basin. This quantity depends on the amount of water economically, legally, and politically available to the organization or agency managing the basin (Todd, 1980).

By definition, the maximum perennial yield is some portion (i.e. subset) of the total amount of ground water recharge that the aquifers receive from precipitation on an average annual basis. Not all of the water that reaches the ground water aquifer can be developed for beneficial use because either it is not economically feasible, or there is no legal right to the water, or political constraints prevent or inhibit development.

Three different methods have been utilized during historical studies to estimate maximum perennial yield of the various hydrologic subunits within the BBDWP's service area. These methods included:

- Watershed Model. The watershed model is a mathematical tool that assists in solving the water balance, or hydrologic budget, for the watershed. The water balance takes into account all quantifiable hydrologic variables that affect the water resources within the catchment area. These variables include daily precipitation, surface water infiltration, surface water runoff, evapotranspiration, and deep percolation. Maximum perennial yield of aquifers within the watershed is a function of the deep percolation term that occurs on an average annual basis. The watershed model results were used to provide estimates of perennial yield for the North Shore and Grout Creek Subunits.

- Ground Water Underflow. This method utilizes Darcian velocity coupled with the cross sectional flow through the aquifer to provide an estimate of underflow which recharges a particular hydrologic subunit. Inputs required include aquifer hydrogeologic parameters (transmissivity), hydraulic gradient and the area of ground water flow. Hydrogeologic parameters are obtained from well pumping tests. Hydraulic gradients are obtained from ground water level contour maps. Underflow analysis was used to provide an estimate of perennial yield for the Mill Creek Subunit.
- Methods Relating Ground Water Level Changes with Ground Water Production Changes. The potential ground water yield of any particular ground water basin can be assessed by evaluating ground water elevation trends and ground water production for a selected period of time. Ideally, the selected time period should extend over multiple dry and wet precipitation cycles to include climatic variations encountered in the area of interest. If the mean ground water elevations at the beginning of the selected time period match those at the end, the average production during the same time period is considered within the maximum perennial yield of the ground water basin because ground water levels can be maintained within that pumping regime. Analysis of ground water levels and production data were used to provide estimates of perennial yield for the Village, Rathbone, Division, and Erwin Subunits.

Of the methods utilized for analysis, evaluations of ground water levels and production history were considered to provide the most reliable estimate of perennial yield for any given subunit. It was possible to use this method for most of the hydrologic subunits in the BBDWP service area (Village, Rathbone, Division, and Erwin).

For the Mill Creek Subunit, although historical ground water level records are available, no significant ground water pumping has occurred. Accordingly, the perennial yield for this subunit was estimated using the ground water underflow analysis, in order to take advantage of the ground water level record as well as aquifer parameters from recent pumping tests.

For the Grout Creek Subunit, ground water level and pumping records are available but stable ground water level records indicate that pumping has not exceeded the perennial yield. To account for this and the fact that a significant amount of production from this subunit is from the

bedrock aquifer system, the watershed model was employed to estimate perennial yield. The watershed model was also used to estimate perennial yield for the North Shore Subunit because little ground water level and production data were available for this area.

4.0 NORTH SHORE SUBUNIT

4.1 Data Collected Since 2001

The primary ground water resource evaluation work completed in the North Shore Subunit since GEOSCIENCE (2001) was the focused perennial yield study conducted in 2003 (GEOSCIENCE, 2003c). For this study, the North Shore Subunit was subdivided into six tributary subareas (Subareas A through F) to better distinguish portions of the subunit that would be distinct from a water supply perspective given that the aquifer system at the west end of the subunit is not in direct hydraulic communication with the aquifer system at the east end of the subunit. As a result of this work, North Shore Tributary Subarea F is now grouped with the Division Subunit because the aquifer system within this subarea is in hydraulic communication with the aquifer system in the Division Subunit. As such, only Subareas A through E will be reflected in the perennial yield estimates for this subunit. The perennial yield for Subarea F will be discussed with the Division Subunit.

4.2 Updated Perennial Yield Estimate – North Shore Subunit

As reported in GEOSCIENCE (2003c), the revised perennial yield estimate for the North Shore Subunit (Tributary Subareas A through E) is **240 acre-ft/yr**, as estimated using a watershed model. As stated earlier, this estimate does not include North Shore Tributary Subarea F, which is included in the estimate for the Division Subunit.

5.0 GROUT CREEK SUBUNIT

5.1 Data Collected Since 2001

The primary ground water resource evaluation work completed in the Grout Creek Subunit since GEOSCIENCE (2001) was the focused perennial yield study conducted in 2003 (GEOSCIENCE, 2003c). Similar to the North Shore Subunit, the Grout Creek Subunit was subdivided into four tributary subareas (Subareas A through D) to better distinguish portions of the subunit that would be distinct from a water supply perspective. In addition, one exploratory borehole (Cherokee Borehole) has been drilled and tested and four private wells have been tested (GEOSCIENCE, 2004c; GEOSCIENCE, 2004d). However, the results of the testing of these wells did not change the perennial yield estimate (GEOSCIENCE, 2003c).

5.2 Updated Perennial Yield Estimate – Grout Creek Subunit

As reported in GEOSCIENCE (2003c), the revised perennial yield for the Grout Creek Subunit is **280 acre-ft/yr**, as estimated using a watershed model. Tributary Subareas A and B values were removed from the perennial yield estimate because they are remote and located on land under the jurisdiction of the United States Forest Service.

6.0 MILL CREEK SUBUNIT

6.1 Data Collected Since 2001

A significant amount of additional geologic and hydrogeologic data has been collected in the Mill Creek Subunit since the last maximum perennial yield update (GEOSCIENCE, 2001). Two test drilling programs (GEOSCIENCE, 2003a; GEOSCIENCE, 2004b), construction of one production well (GEOSCIENCE, 2005b), and ongoing ground water level monitoring in accordance with the ground water monitoring and management plan (GEOSCIENCE, 2003b) has resulted in the collection of soil lithologic data, geophysical logs, depth-specific ground water quality data, additional ground water level time histories, and aquifer properties. Specific boreholes and wells included:

- Presbyterian Conference Center Borehole,
- Canvasback Borehole and Nested Monitoring Well,
- Mallard Lane Borehole and Nested Monitoring Well, and
- Canvasback Production Well.

6.2 Updated Findings – Mill Creek Subunit

The data collected since 2001 has refined our understanding of the hydrogeology of the Mill Creek Subunit. The lithology observed from the test boreholes provided greater detail regarding the characteristics of sediments and enabled the delineation of the subsurface into two aquifers: a shallow unconfined aquifer and a deep confined aquifer. This characterization is supported by the observation that ground water levels measured in monitoring wells that are perforated in the shallow aquifer are different (generally lower in elevation) than ground water levels measured in monitoring wells perforated in the deep aquifer. At the Canvasback deep nested monitoring well, the ground water level is generally at or above the land surface (flowing artesian), a condition which is also observed at BBDWP's Metcalf Bay monitoring well.

Ground water quality data also support the presence of a two-aquifer system in the Mill Creek Subunit. Analysis of ground water samples collected from deeper aquifer zones during test drilling and from the deeper nested monitoring wells shows elevated total dissolved solids (TDS) concentrations and concentrations of fluoride and arsenic above their respective regulatory limits for drinking water (see Table 1). In addition to supporting the premise that the deeper aquifer system is hydraulically separated from the shallow aquifer system, the fluoride and arsenic data show that ground water from this aquifer would require treatment if future ground water supply wells are perforated within it.

Table 1. Summary of Selected Ground Water Quality Data Mill Creek Hydrologic Subunit.

		Depth-Specific Sample				Shallow Well ²	Deep Well ²	MCL or Action Level
Sample Depth/ Screened Interval	[ft, bgs]	175 ¹	200 ¹	275 ¹	499 ¹	160-315	415-485	
Arsenic	[µg/L]	< 2.0	< 2.0	2.2	88	< 2.0	150	50 ^{3,5}
Fluoride	[mg/L]	0.5	0.4	0.4	3.0	0.5	2.8	2.0 ³
Iron	[mg/L]	< 0.02	< 0.02	< 0.02	0.23	< 0.02	< 0.02	0.3 ⁴
Manganese	[µg/L]	25	14	13	45	<10	15	50 ⁴
Total Dissolved Solids, TDS	[mg/L]	250	310	280	430	310	420	500-1000 ⁴

Shaded cells indicate constituents that are above the present or impending MCLs.

¹ Depth-Specific sample collected during the drilling of Canvasback test boreholes

² Canvasback nested monitoring well

³ California Department of Health Services (DHS) Primary Maximum Contaminant Levels (MCL).

⁴ California DHS Secondary Maximum Contaminant Levels.

⁵ In January 2006 the MCL for arsenic will be reduced to 10 µg/L.

The BBDWP has constructed one production well within the Mill Creek Subunit, the Canvasback Well, located approximately 50 ft from the Canvasback nested monitoring well. Due to the ground water quality issues with the deeper aquifer, the Canvasback production well was perforated within the upper aquifer only. Pumping test results from the completed well show that the upper aquifer system at this site yields up to 46 gallons per minute (gpm) for short periods of time. Long-term operation of the well at this pumping rate will require limiting the pumping duration to a maximum of 14-hr/day cycles to avoid excessive drawdown in the well (GEOSCIENCE, 2005b).

Prior to the construction and testing of the Canvasback Production Well, aquifer properties for the Mill Creek Subunit were unknown. Previous perennial yield studies relied on aquifer properties from pumping tests on wells in the adjacent Village Subunit (1,800 to 3,600 gallons per day per square foot (gpd/ft²)). The aquifer transmissivity estimated from the 24-hr pumping test on the Canvasback Well ranged from 360 to 600 gpd/ft² with an average of approximately 480 gpd/ft² (using two different analysis methods). The updated transmissivity from the Canvasback Well pumping test, which is more representative of the Mill Creek Subunit than previous estimates, is significantly lower than the transmissivity used for the ground water underflow analysis from the 2001 perennial yield evaluation and resulted in a lower perennial yield estimate for this subunit.

6.3 Updated Perennial Yield Estimate – Mill Creek Subunit

The previous estimate of perennial yield was based on an underflow evaluation using ground water levels from private wells (as reported at the time of their construction) and an assumed transmissivity based on pumping tests from wells in the adjacent Village Subunit (as described above). It has not been possible to improve the previous estimate of the ground water flow gradient because the number and location of shallow monitoring wells is not adequate to develop a representative flownet for this aquifer. The transmissivity estimate, on the other hand, is more representative of the area than the transmissivity previously used.

Using the average ground water flow gradient from the 2001 study and the average transmissivity value from the Canvasback well pumping test, an underflow (i.e. perennial yield) of approximately **100 acre-ft/yr** is estimated for the shallow aquifer of the Mill Creek Subunit.

Inclusion of the deeper aquifer in the underflow evaluation would increase the underflow and, therefore, perennial yield estimate for the Mill Creek Subunit. Although a pumping test has not been conducted for this aquifer, review of the geophysical logs show that it is more permeable

than the upper aquifer. Assuming that it is twice as permeable as the upper aquifer and given a lower aquifer thickness of approximately 50 ft, the transmissivity of the combined upper and lower aquifers is estimated to be approximately 800 gpd/ft². This would increase the perennial yield of the Mill Creek Subunit to **175 acre-ft/yr**. However, it should be noted that, based on depth-specific water quality sampling and analysis at the Canvasback Well site, production of ground water from the deeper aquifer would require treatment of the water for both fluoride and arsenic prior to distribution for municipal supply in order to meet regulatory requirements.

7.0 VILLAGE SUBUNIT

7.1 Data Collected Since 2001

Although no new ground water studies have been conducted in the Village Subunit, ongoing ground water level monitoring has been conducted by the BBDWP in accordance with the ground water monitoring and management plan (GEOSCIENCE, 2003b).

7.2 Update of Findings – Village Subunit

Ground water levels in the Village Subunit have been steadily declining since 1988 despite average ground water production at the previous perennial yield estimate of 290 acre-ft/yr (see Figure 2). Ground water levels for the Pennsylvania production well are shown on Figure 2. Ground water levels in this well were (Oct-05) approximately 120 ft lower than they were at the time of well construction. More importantly, ground water levels have been steadily declining through both above-normal and below-normal precipitation conditions and despite the fact that the well was turned off between August 1994 and May 2004. Similar trends are observed at the Middle School, Oak, and Knickerbocker wells (Figure 3). The updated data suggest that the perennial yield of the Village Subunit is lower than previously estimated (290 acre-ft/yr).

7.3 Updated Perennial Yield Estimate – Village Subunit

Based on the ground water level trends observed in wells in the Village Subunit, it is recommended to lower annual ground water production from this subunit to **250 acre-ft/yr** and observe ground water level trends during both dry and wet climatic conditions. If ground water levels stabilize at the average annual production rate, then 250 acre-ft/yr could be considered a more representative perennial yield for the subunit. If ground water levels continue to decline, then the annual ground water production rate will have to be reduced further until levels stabilize.

8.0 RATHBONE SUBUNIT

8.1 Data Collected Since 2001

Studies conducted to collect additional geologic and hydrogeologic data in the Rathbone Subunit since the last maximum perennial yield update (GEOSCIENCE, 2001) included two test drilling programs (GEOSCIENCE, 2003a; GEOSCIENCE, 2004b), construction of two production wells (GEOSCIENCE, 2002; GEOSCIENCE, 2004f), and ongoing ground water level monitoring in accordance with the ground water monitoring and management plan (GEOSCIENCE, 2003b). These studies resulted in the collection of soil lithologic data, geophysical logs, depth-specific ground water quality data, additional ground water level data, and aquifer properties. Specific boreholes and wells included:

- Moonridge Test Borehole,
- Rathbun Test Borehole and Nested Monitoring Well,
- Moonridge Production Well, and
- Sheephorn Production Well.

8.2 Updated Findings – Rathbone Subunit

The relatively long period of available record for ground water level graphs (hydrographs) in the Rathbone Subunit provided the best indicator of available perennial yield for this subunit. The longest available record was from the DWP Yard Monitoring Well (also referred to as “Rathbun”), with ground water level records dating from 1986 to the present (Figure 4). This monitoring well was also useful for evaluating perennial yield because it is at the downgradient end of the subunit and thus ground water levels at this point not only reflect localized pumping but pumping and recharge from the upgradient portions of the subunit.

Changes in ground water levels at the DWP Yard Monitoring Well reflect precipitation trends and ground water production patterns within the Rathbone Subunit. Historical high ground water levels observed in 1993, 1995, and 1998, all corresponded to years of significantly above-normal precipitation (Figure 4). During these times, significantly more water is available from spring sources resulting in lower ground water pumping, which facilitates ground water level recovery. Historically low ground water levels were observed at this well in 1991 and 2002, both of which were preceded by multiple years of below-normal precipitation. During these times, less water was available from spring water sources and ground water pumping was increased, magnifying the ground water level declines. Ground water levels also showed predictable seasonal trends, with lower ground water levels in the summer and fall and higher ground water levels in the winter and spring. During historically low ground water levels in the DWP Yard Monitoring Well, pumping ground water levels in the adjacent Lakeplant Well No. 3 were drawn below the pump intake.

8.3 Updated Perennial Yield Estimate – Rathbone Subunit

Consistent with the historical pattern described above, ground water levels in the DWP Yard Monitoring Well returned to near historical high levels following the 2004-2005 above-average precipitation. Thus, at the average annual ground water production rate of 981 acre-ft/yr, ground water levels fully recover. It should be noted that the average annual production was for the BBDWP only and does not include ground water production from the golf course, which has been estimated to be approximately 120 acre-ft/yr. Thus, the previous perennial yield estimate of **1,100 acre-ft/yr** for the Rathbone Subunit remains a good long-term estimate of the perennial yield. However, during periods of prolonged below-normal precipitation, ground water production may have to be reduced, particularly in the area of the Lakeplant wells, to avoid drawing ground water levels below the pump intakes.

9.0 DIVISION SUBUNIT AND NORTH SHORE F

9.1 Data Collected Since 2001

Studies conducted to collect additional geologic and hydrogeologic data in the Division Subunit since the last maximum perennial yield update (GEOSCIENCE, 2001) have included two test drilling programs (GEOSCIENCE, 2003a; GEOSCIENCE, 2004b), construction of one production well (GEOSCIENCE, 2005a), and ongoing ground water level monitoring in accordance with the ground water monitoring and management plan (GEOSCIENCE, 2003b). These studies have resulted in the collection of soil lithologic data, geophysical logs, depth-specific ground water quality data, additional ground water level data, and aquifer properties. Specific boreholes and wells included:

- Riffenburgh Test Borehole and Monitoring Well,
- McAlister Test Borehole and Nested Monitoring Well, and
- McAlister Production Well.

9.2 Updated Findings – Division Subunit with North Shore F

The relatively long period of available record for hydrographs in the Division Subunit provided the best indicator of available perennial yield for this subunit. The longest available record was from Division Well No. 1; with ground water level records dating from 1955 (Figure 5). Production data from the Division wells were available from as early as 1948.

Changes in ground water levels at Division Well No. 1 reflected precipitation trends and ground water production patterns within the Division Subunit. Ground water levels between 1955 and 1975 dropped during periods of below-normal precipitation (e.g. early to mid 1960s) but recovered to historical high levels during periods of above-normal precipitation (Figure 5). During this period (1955 through 1975), ground water production was primarily from Division Wells 1 through 4, and was maintained at or below 500 acre-ft/yr. Between 1975 and 1990,

ground water production from the Division Wells increased to an average of 834 acre-ft/yr, in large part as a result of the addition of Division Wells 6 and 7, located in North Shore Subarea F. During this time period, ground water levels did not recover fully, including years when precipitation was above-normal. Between 1990 and 2000, the combination of above-normal precipitation and lowered production from the Division Subunit again restored ground water levels to historical highs at Division Well No. 1. However, between 2000 and 2005, below-normal precipitation and increased ground water production resulted in ground water declines in Division Well No. 1.

Although the 2004-2005 precipitation was above-normal, ground water levels have not recovered fully in either Division Well No. 1 or Division Well No. 6 (Figure 6). Given that ground water production from the combined Division Subunit and North Shore F Subarea was maintained above 600 acre-ft/yr during recent years, it appears that this level of production exceeds the perennial yield for the combined areas. The recent data is consistent with the historical data.

9.3 Updated Perennial Yield Estimate – Division Subunit with North Shore F

Based on ground water levels and ground water production patterns described above, we concluded that a perennial yield of **540 acre-ft/yr** (500 acre-ft/yr for the Division Subunit and 40 acre-ft/yr from the North Shore Subarea F) is appropriate for the combined Division Subunit and North Shore Subarea F. The incomplete ground water level recovery following the recent wet season is likely due to sustained ground water production in excess of this perennial yield. While periodic ground water production in excess of the perennial yield can be a normal part of basin management, ground water levels should be allowed to recover periodically by lowering production to levels at or below the perennial yield. The historical record shows that this can be accomplished during periods of above-normal precipitation.

10.0 ERWIN SUBUNIT

10.1 Data Collected Since 2001

Studies conducted to collect additional geologic and geohydrologic data in the Erwin Subunit since the last maximum perennial yield update (GEOSCIENCE, 2001) have included one test drilling program (GEOSCIENCE, 2004b), drilling and testing associated with a pilot artificial recharge test (GEOSCIENCE, 2004e; GEOSCIENCE, 2005e), development of a ground water flow model of the northern Erwin Subunit (GEOSCIENCE, 2005d), revision of the Lake William tributary subarea maximum perennial yield (GEOSCIENCE, 2004a), and ongoing ground water level monitoring in accordance with the ground water monitoring and management plan (GEOSCIENCE, 2003b). These studies resulted in the collection of soil lithologic data, geophysical logs, depth-specific ground water quality data, additional ground water level data, and aquifer properties.

10.2 Updated Findings – Erwin Subunit

Ground water hydrographs in the Erwin Subunit are available with records from 1966 to the present for Lakewood Well No. 27 (1966 to 1987), and Lakewood Well No. 3 (1988 to present; Figure 7). Production data from the Erwin Subunit, including both well production by the BBDWP and well production and spring water diversions by the Big Bear City Community Services District (BBCSD), is available from 1957 to the present (although spring water diversion amounts prior to 1982 are estimated; Figure 8).

Changes in ground water levels at the Lakewood Wells reflected precipitation trends and ground water production patterns within the Erwin Subunit (not including the Lake William Tributary Subarea). Ground water levels were at historical highs in the late 1970s, early 1980s and 1993, all periods of above-normal precipitation (Figure 7). During these times, significantly more water was available from spring sources resulting in lower ground water production, which facilitated ground water level recovery. Noticeable declines in ground water levels were

observed during the period of below-normal precipitation between 1984 and 1991. Following ground water level recovery in 1993, levels generally declined during the period of 1998 to 2004, when below-normal precipitation resulted in reduced spring flow and necessitated increased pumping from wells (Figure 7). Ground water levels have recovered significantly following the winter of 2004-2005. Nonetheless, ground water levels have not recovered to historical highs.

10.3 Updated Perennial Yield Estimate – Erwin Subunit

Based on the historical ground water level trends observed in the Erwin Subunit, it appears that the perennial yield is being fully utilized in this subunit. Thus, at the average annual ground water production rate of approximately 860 acre-ft/yr (1990 to present), ground water levels did not fully recover, suggesting that this production rate may be slightly higher than the perennial yield of the subunit (not including the Lake William area). The perennial yield of the Lake William Tributary Subarea has recently been estimated to be approximately 45 acre-ft/yr (GEOSCIENCE, 2004a). Thus, the perennial yield of the Erwin Subunit is slightly less than 900 acre-ft/yr. The previous estimate of **890 acre-ft/yr** for the perennial yield of the Erwin Subunit appears to be a realistic long-term estimate of the perennial yield for this subunit. Approximately 67 percent of this amount (approximately 590 acre-ft/yr) has historically been assumed to be available to the BBDWP for water supply, and the balance has typically been assigned to the BBCSD, which also produces ground water from the Erwin Subunit.

11.0 SUMMARY OF FINDINGS

In summary, evaluation of data collected since the GEOSCIENCE (2001) maximum perennial yield update has resulted in a revised perennial yield for the hydrologic subunits that encompass the BBDWP service area. The previous range of perennial yield was 3,710 to 3,870 acre-ft/yr including Gray's Landing and 3,570 to 3,730 acre-ft/yr by excluding Gray's Landing.² Geohydrologic data collected since 2001 has enabled a more refined range of perennial yield for the BBDWP service area, which is lower than the previous estimate (3,100 to 3,175 acre-ft/yr; Table 2). The lower estimate is primarily a result of reductions in the perennial yield estimates for the Mill Creek and Village Subunits, which were reduced based on new data and ongoing monitoring of ground water level trends. Furthermore, based on analysis of updated ground water level and production data in the Rathbone and Erwin Subunits, it is recommended to use the lower end of the previous perennial yield ranges for each of these subunits.

It should be emphasized that the perennial yield estimates presented in this technical memorandum represent long-term averages. Practical management of ground water resources within the service area will allow for short-term ground water production above the perennial yield when precipitation conditions are favorable but will also necessitate ground water production below the perennial yield during periods of prolonged below-normal precipitation. This is being accomplished through the ongoing monitoring and analysis of ground water levels in accordance with the ground water monitoring and management plan.

² Gray's Landing is no longer included in the perennial yield estimates because it is located in a remote area on granitic bedrock, which makes ground water development and distribution from this area economically unfavorable.

Table 2. Summary of Maximum Perennial Yield Estimates by Subunit

Subunit	SUMMARY OF MAXIMUM PERENNIAL YIELD ESTIMATES BY SUBUNIT (acre-ft/yr)		
	GEOSCIENCE (2001)	GEOSCIENCE (2003)	GEOSCIENCE This Study
Grout Creek	200	280	280
Gray's Landing	140	NA ¹	NA
Mill Creek	330	NA	100-175
Village	290	NA	250
Rathbone	1,100 - 1,200	NA	1,100
Division	500 - 550	NA	540²
North Shore	260	240 ³	240³
Erwin	890 - 900	NA	890
TOTAL	3,710 - 3,870	NA	3,400 – 3,475
TOTAL Available to BBDWP⁴	3,570 - 3,730	NA	3,100 – 3,175

1. NA = Not analyzed or not applicable
2. Includes North Shore Tributary Subarea F
3. Does not include North Shore Tributary Subarea F
4. Accounts for BBCSD portion of Erwin Subunit Perennial Yield

	Yellow cells indicate results obtained using a watershed model
	Green cells indicate results obtained using underflow analysis
	Blue cells indicate results obtained through analysis of ground water levels and pumping data

12.0 REFERENCES

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FIGURES

LOCATION OF
BIG BEAR VALLEY

EXPLANATION

-  Big Bear Lake Watershed Boundary with Hydrologic Subunits
-  Tributary Subunit of the Northshore Hydrologic Subarea
-  Baldwin Lake Watershed Boundary with Hydrologic Subunits
-  Lake William Tributary Subarea of the Baldwin Lake Watershed
-  City of Big Bear Lake Department of Water and Power Boundary
-  Road
-  Surface Water
-  Playa Lake
-  Creek or River

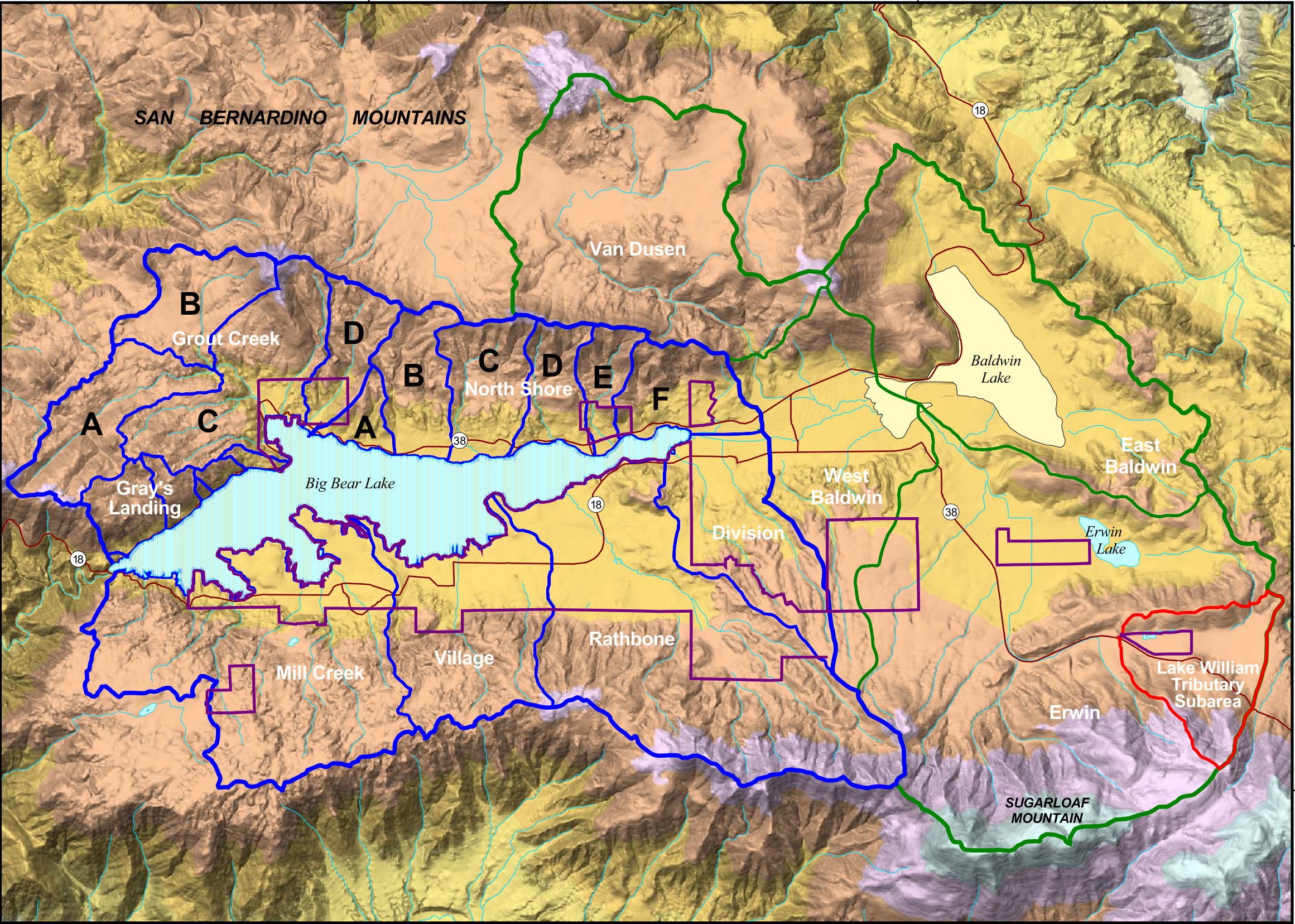
County Inset Map



GEOSCIENCE

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Figure 1



Prepared by: DWB

R.1 W. | R.1 E.

R.1 E. | R.2 E.

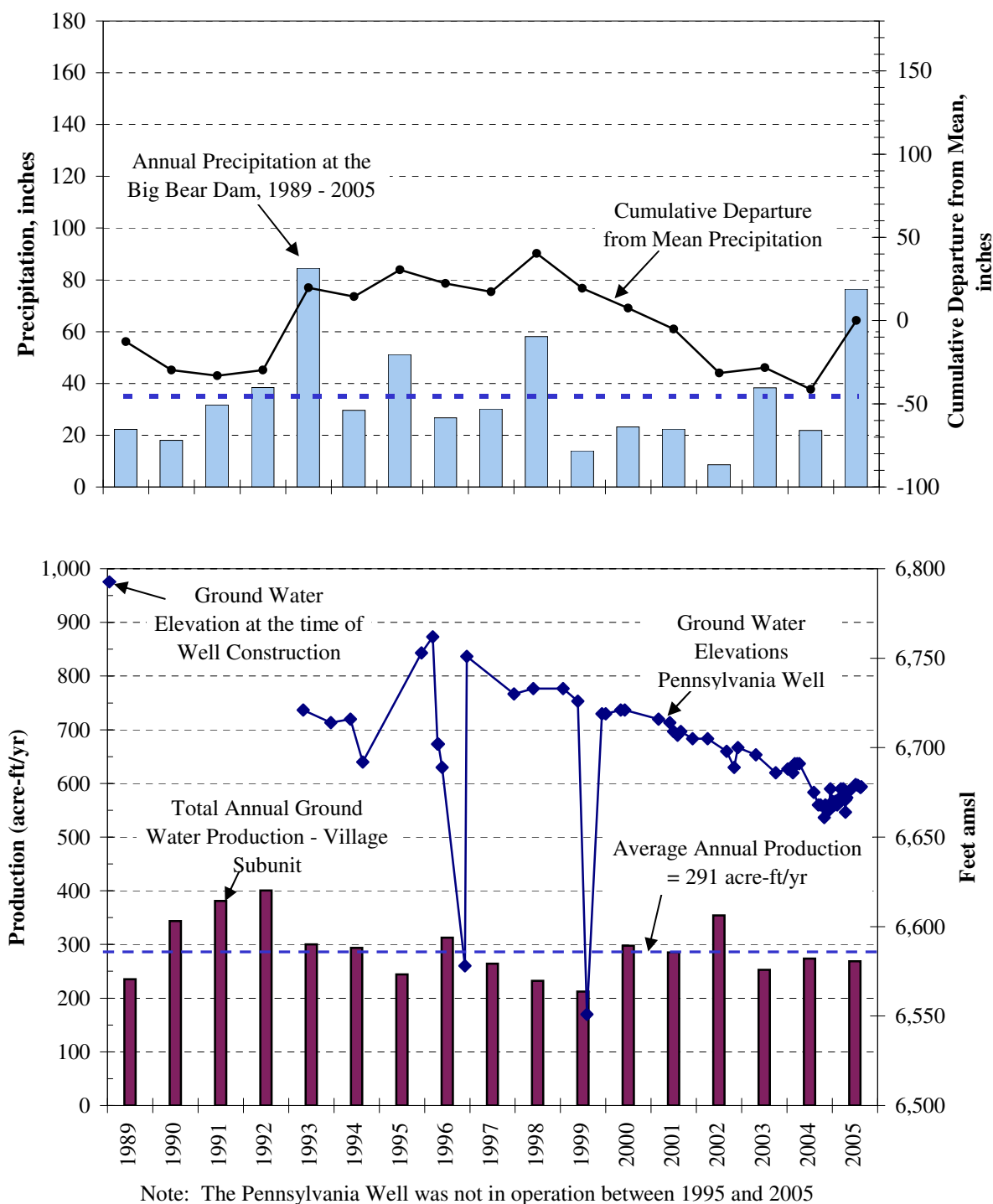
2-FEB-06

Map Projection:
UTM Zone 11, NAD27
Central Meridian: -117 degrees



Figure 2

Precipitation, Ground Water Production and Ground Water Levels Village Subunit



Historical Ground Water Elevations Village Subunit Wells

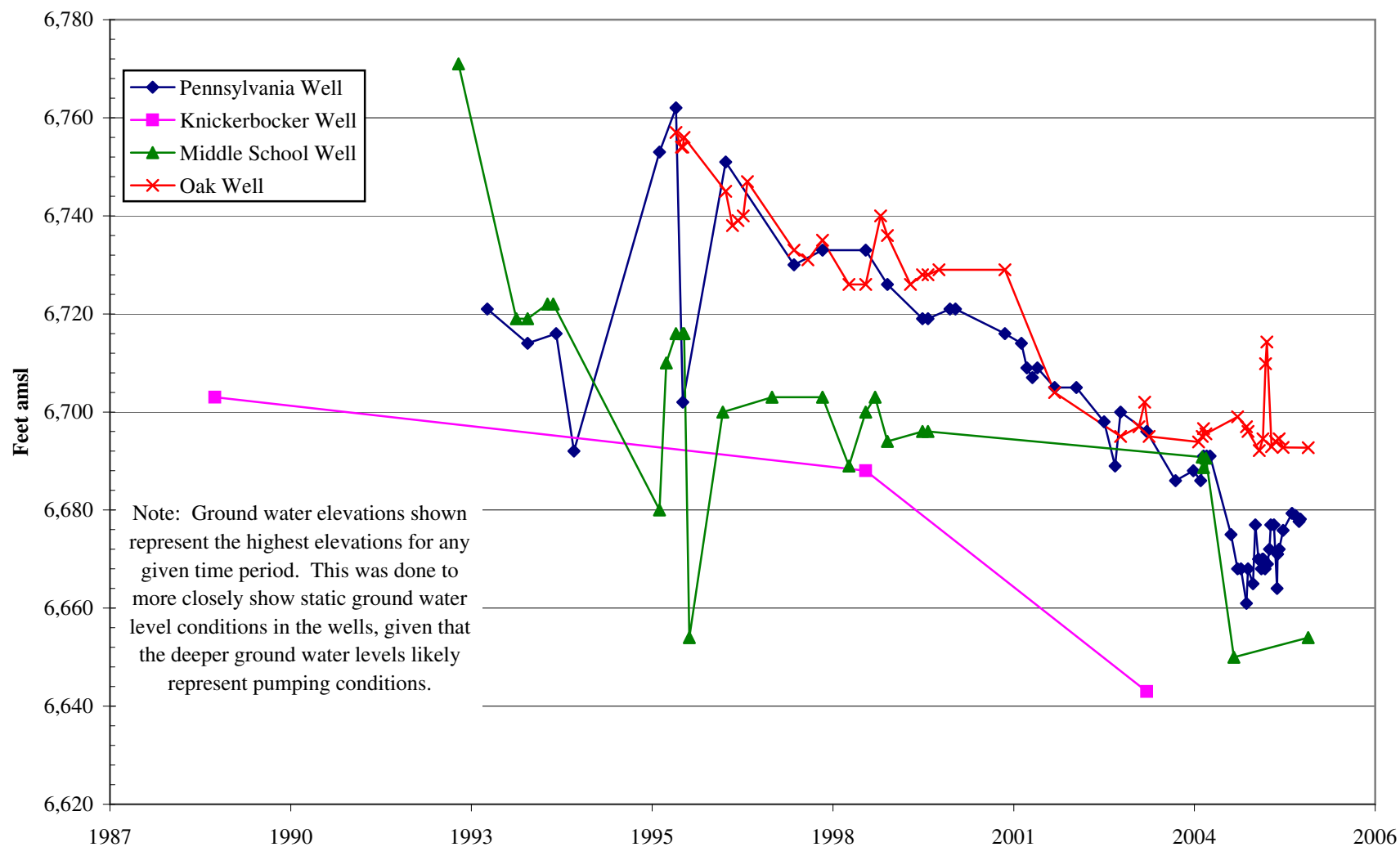
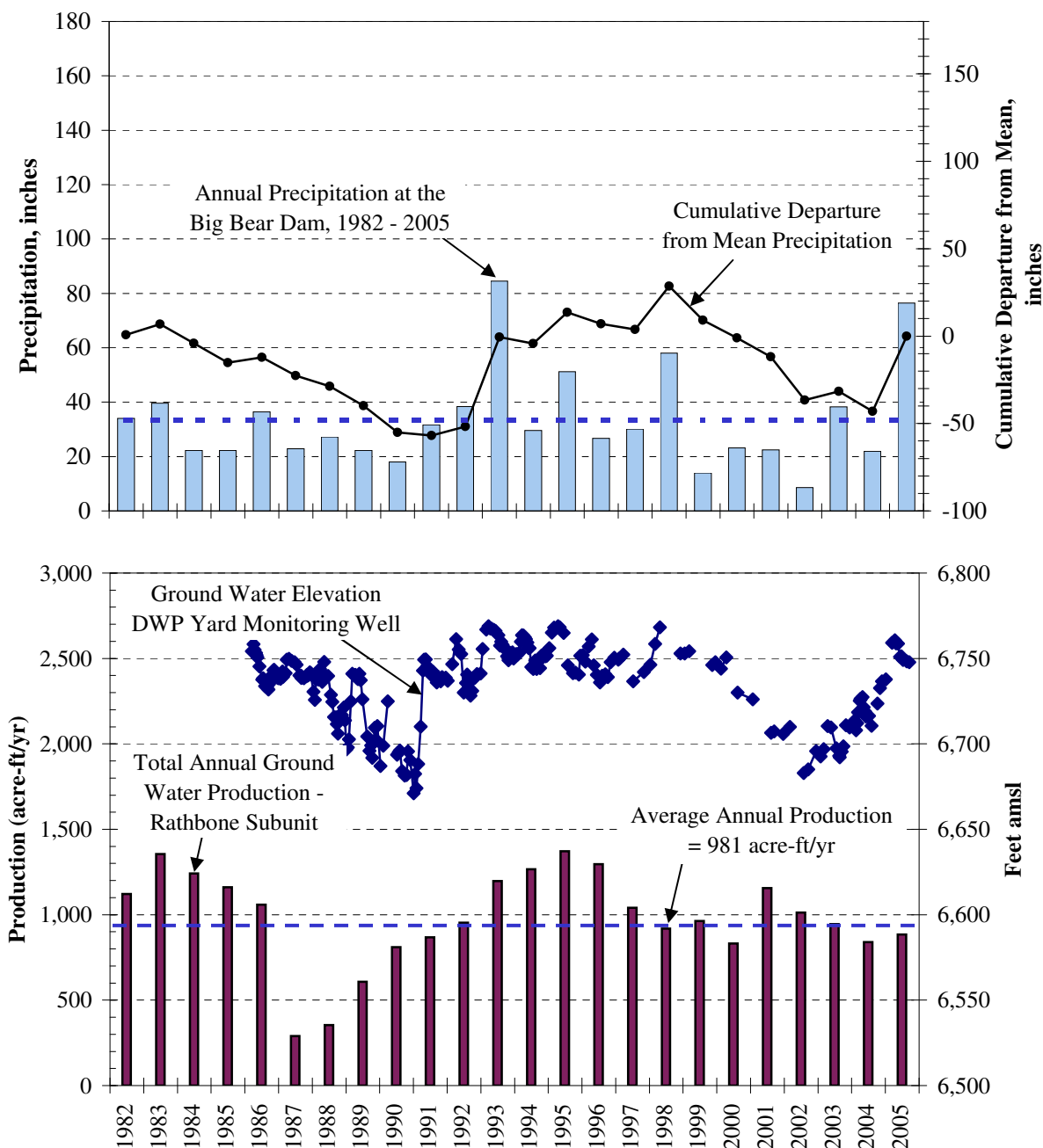
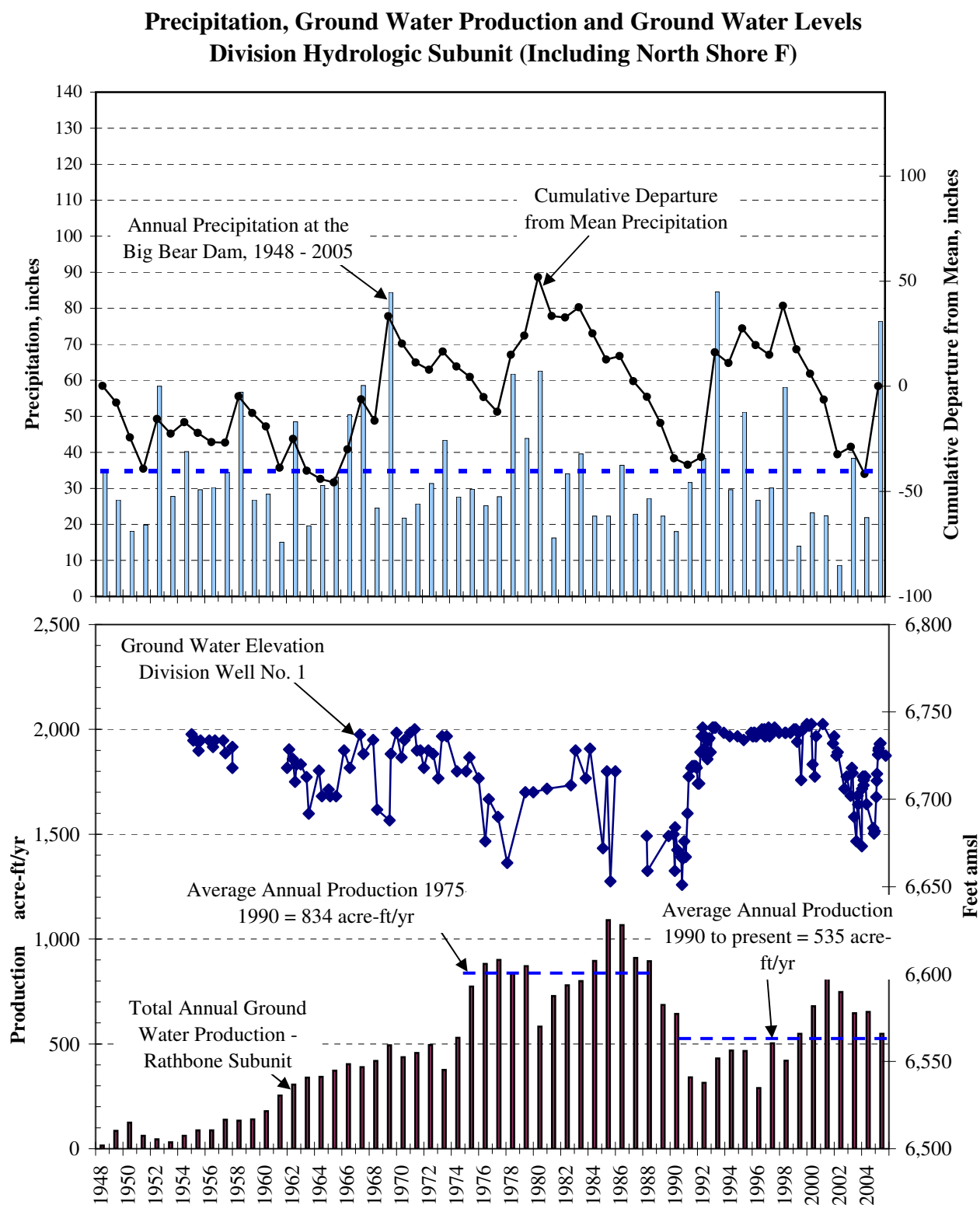


Figure 3

Precipitation, Ground Water Production and Ground Water Levels Rathbone Subunit





Historical Ground Water Elevations Division Wells

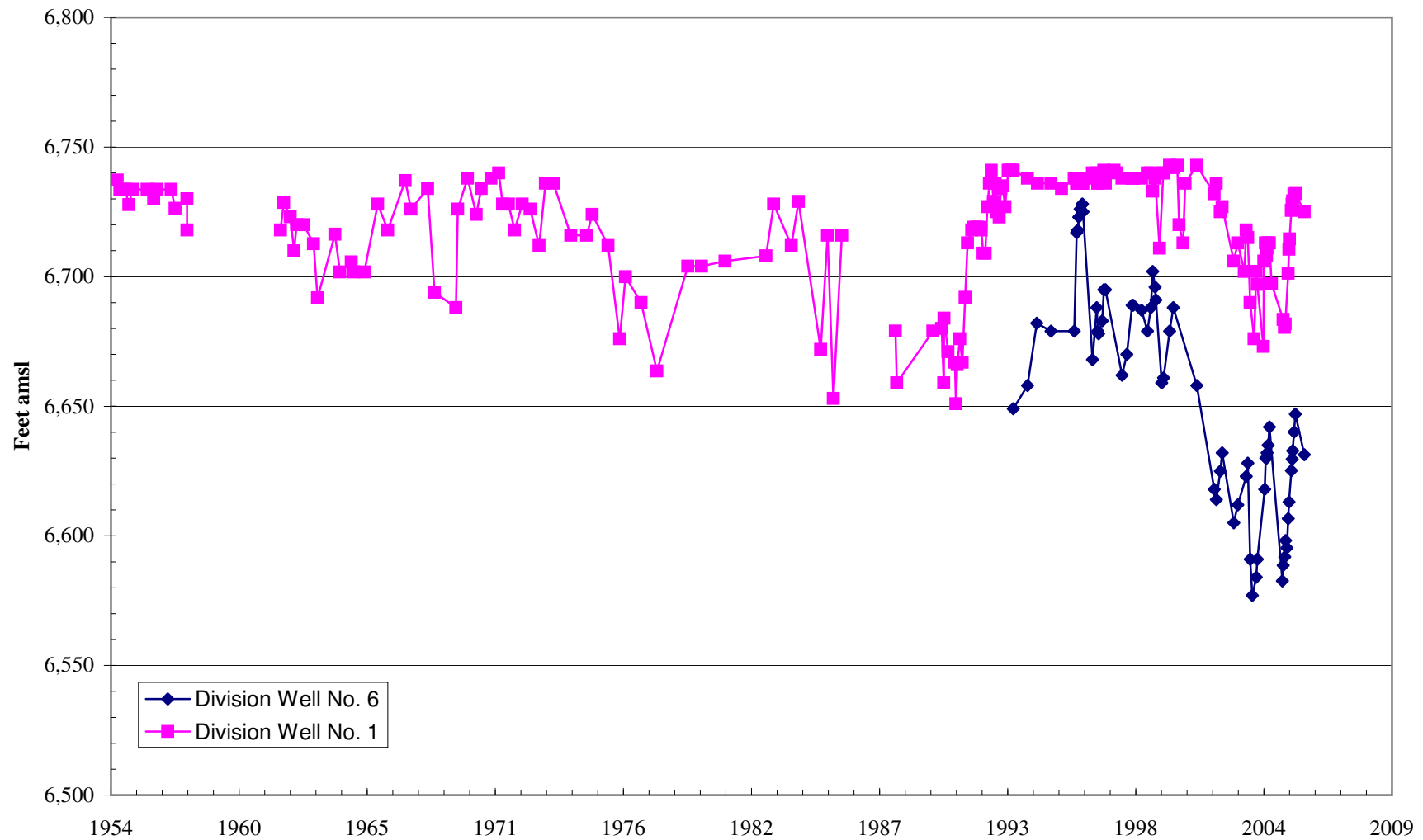
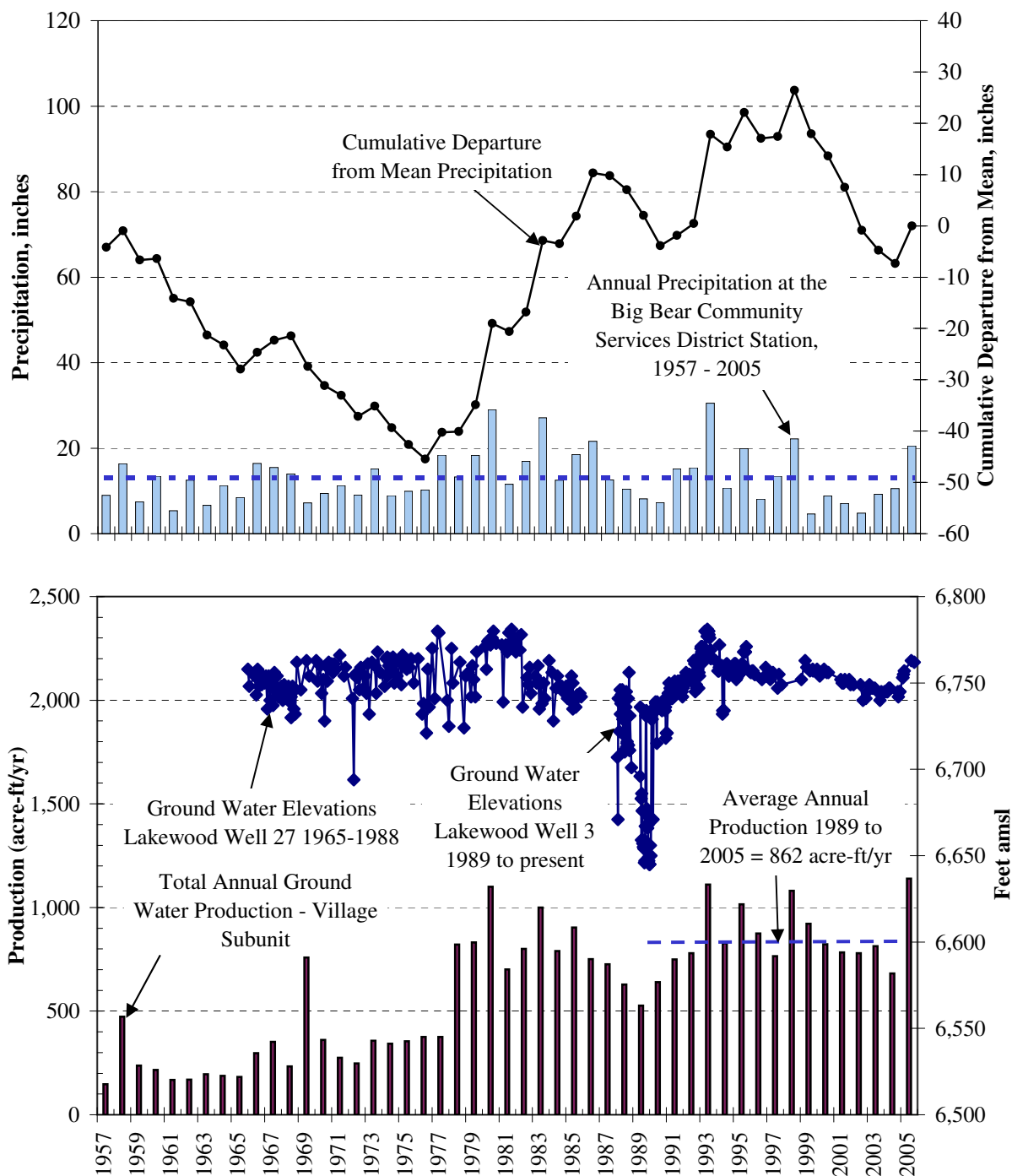


Figure 6

Precipitation, Ground Water Production and Ground Water Levels Erwin Subunit



Historical Production of Erwin Subunit Production Wells and Springs

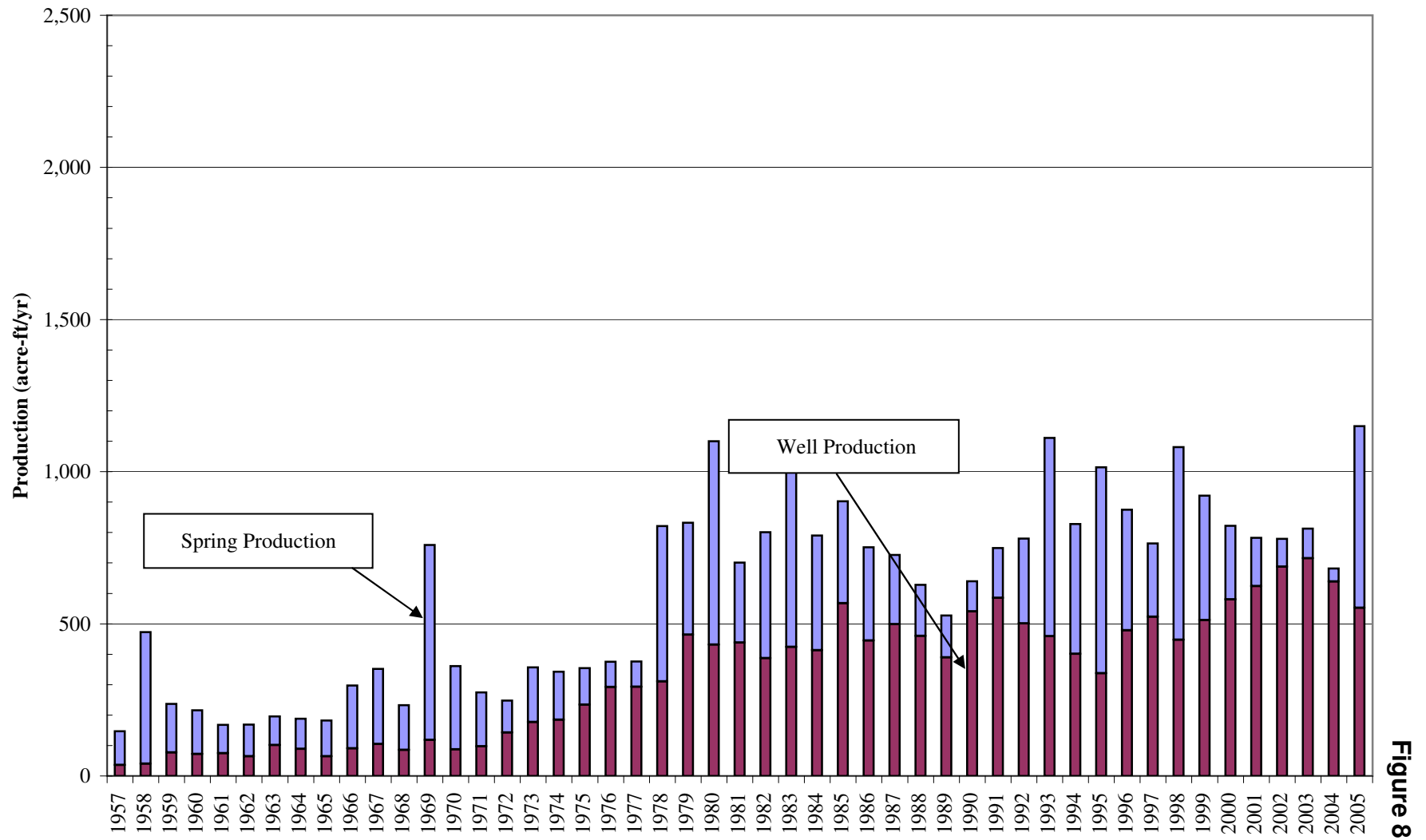


Figure 8