APPENDIX J

Shallow Groundwater Level Trends

C-089073

State of California
Department of Water Resources
Central District

Shallow Groundwater Level Trends in the Northwest Portion of Ryer Island, Sacramento-San Joaquin Delta

Geology and Groundwater Section

January 1999

C-089074

Introduction

This report presents the results of hydrologic monitoring and analysis on and near Ryer and Prospect Islands in the Sacramento-San Joaquin River Delta. Monitoring and analysis was conducted primarily to determine the cause of high groundwater levels occurring on the northeast side of Ryer Island. Some of these tasks were requested in a letter, dated October 20, 1997, from Edward Solbos of the U.S. Bureau of Reclamation's Mid-Pacific Regional Office to Emil Calzascia, Chief of the Water Management Branch. Additional monitoring was requested by the USBR in October 1998 to measure groundwater levels on Ryer Island as Prospect Island was pumped out. This is the summary report requested by USBR in their letter.

Hydrologic Data Sources

The following sections discuss the data sources used in the hydrologic analysis of Ryer Island groundwater level changes. These sources include groundwater levels measured on Ryer and Prospect Islands, the level of water on Prospect Island during the 1996 and 1998 pumpouts, water levels in Miner Slough, and precipitation records from three nearby stations. This section also includes a short discussion on the elevations used for well and surface water data.

Ryer Island Groundwater Monitoring Network

The Ryer Island groundwater monitoring network consists of five wells built in the spring of 1996 by a geophysical survey company at the request of Tom Hester, a Ryer Island landowner and a board member of Reclamation District 501. The network originally included six wells, R-1 through R-6, but well R-2 was destroyed before monitoring began. Well locations are shown on Figure 1. Each well is about ten feet deep. The well casing is polyvinyl chloride with a diameter of about two inches. Wells R-1, R-3, and R-4 are built with a thin-walled casing perforated throughout the length with 1/4-inch diameter holes. Wells R-5 and R-6 are constructed with schedule 40 PVC casing. The perforated interval and type of perforation in these two wells are unknown. The subsurface portion of all wells was wrapped with geotextile fabric, which acts as a filter. The wells sit in fields planted with crops such as safflower, corn, and milo.

DWR staff measured water levels in the five Ryer Island piezometers, when they were accessible, at least once a week from April 2, 1996 to July 3, 1996 and October 3, 1996 to the present. At times during the winter, wells were inaccessible due to wet and muddy field conditions. Monitoring frequency was raised to twice a week from October 2, 1998 until December 1, 1998. These water level measurements are plotted as elevations in Figure 2.

In addition to weekly measurements, water levels in well R-1 were measured and recorded hourly with an In-Situ Hermit datalogger and pressure transducer over two periods. These periods, April 1, 1996 to June 3, 1996 and October 7, 1998 to the present, spanned the periods when water impounded on Prospect Island was pumped to Miner

C-089075

Slough. The water levels recorded with a datalogger in R-1 during the 1996 pumpout are shown on Figure 4. The water levels recorded with a datalogger in R-1 during the 1998 pumpout are shown on Figure 5.

DWR's Central District staff used an electric sounder to measure the depth to water in the Ryer Island wells. At each well, a technician measured from a marked reference point at the top of the well casing to the water surface in the well. Water level measurements were made with a precision of 0.01 feet. Since the datalogger was placed at R-1 in 1998, the same electric sounder has been used for all measurements to maintain the calibration of the pressure transducer.

The minimum, maximum, and range of groundwater elevations at each Ryer Island well over the period of record are listed in the following table.

Minimum, Maximum, and Range of Groundwater Levels - Ryer Island Wells April 2, 1996 to November 6, 1998

	R-1	R-3	R-4	R-5	R-6
Ground surface elevation	-2.3	-3.2	-1.0	-1.1	-4
Minimum water level, feet	-4.9	-5.6	-5.4	-6.1	-8.0
Dates of minimum water levels	10/11/96	8/28/98	10/11/96 9/4/98	10/11/96	8/13/98
Maximum water level, feet	-2.7	-3.0	-1.1	-3.0	-4.2
Dates of maximum water levels	1/3/97 2/13/98	2/13/98 2/20/98 2/26/98	1/3/97 1/10/97	4/2/96	2/20/98
Water level range, feet	2.2	2.6	4.3	3.1	3.8

In 1997 and 1998, the groundwater levels in the Ryer Island wells reached their maximum elevations in January or February and reached their minimum elevations sometime from July to September.

Prospect Island Groundwater Monitoring Network

USBR geologists built four shallow wells, P-1A, P-1B, P-2, and P-3, on Prospect Island. Each well is constructed of two-inch diameter schedule 40 PVC casing. The wells are about ten feet deep.

USBR staff measured water levels in the Prospect Island wells at least once a week from May through August 1996. DWR staff measured these water levels several times in November and December 1996 and resumed measuring levels in three of these wells, P-1A, P-1B, and P-2, in November 1998 when water levels on Prospect Island receded and the wells could be accessed. The water impounded on Prospect Island flooded the base of these wells after the 1997 floods, but not in the preceding flood. The water levels measured in these wells are shown as elevations in Figure 3.

Level of Water Impounded on Prospect Island

Water flooded Prospect Island from south to north on March 14 and 15, 1995 after levees on the Port of Sacramento's Prospect Island property failed. The island's cross-levee was breached shortly thereafter. Those floodwaters were pumped from Prospect Island in May and June 1996. The island flooded again when the levee along Miner Slough was breached on January 1 and 2, 1997. The levees on Miner Slough were repaired and water was pumped from the island in October 1998.

USBR staff measured the level of water impounded on Prospect Island during the two periods it was pumped out to Miner Slough. Water levels were measured daily from May 8, 1996 to June 11, 1996. In 1998, USBR staff installed an In-Situ Troll datalogger/pressure transducer alongside the steel pump deck at the permanent drainage pumps on Prospect Island. The datalogger recorded water levels once every two hours from October 13, 1998 through December 1998. Figure 4 shows the water level record from 1996. Figure 5 shows the water level record from 1998.

The beginning water level on Prospect Island was higher in 1998 than in 1996. According to Chris Reeves of the USBR, the starting water level in 1996 was 0.0 feet (NGVD 29), and in 1998 the starting water level was 1.7 feet (NGVD 29). The Prospect Island water level at the end of the pumpout period was six to seven feet lower in 1996 than in 1998. In 1998, funds allocated to the pumping task ran out before the water level was fully drawn down.

Tide Gage at Five Points on Miner Slough

DWR installed a tide gage on Miner Slough at Arrowhead Harbor Marina in 1996. The tide gage record includes the periods from April 1, 1996 to December 13, 1996; from July 27, 1997 to December 9, 1997; from January 2, 1998 to January 7, 1998; and from August 3, 1998 to January 20, 1999. The gage is currently operating, and DWR plans to raise the height of the gage so it can operate during flood conditions. The datalogger at the gage was flooded twice resulting in the gaps in the data record.

The tide at this gage ranges over approximately three feet in a day. The maximum water level recorded in 1998 was 5.39 feet (NGVD 29). No minimum levels below approximately 0.8 feet (NGVD 29) were recorded, and successive readings at the low end of the tidal cycle did not change during especially low tides. On November 16, 1998, the gage was inspected, and several feet of sediment, which had obstructed the gage float, was cleaned from the bottom of the gage housing. Therefore, minimum readings of less than one foot elevation may not be actual minimum water levels in Miner Slough unless they occurred after November 16, 1998. The complete record of water levels from this tide gage is shown on Figure 6.

Precipitation Records

Precipitation records near Ryer and Prospect Islands are available for three locations, Ryer Island, Liberty Island, and Georgiana Slough. DWR maintains precipitation records of a gage at well R-1 that was installed on October 4, 1996. That gage was checked weekly to biweekly from October 1997 to the present. Records from a tip bucket rain gage on Liberty Island, 4.3 miles northwest of well R-1, are maintained by the California Data Exchange Center. The Liberty Island record starts on December 18, 1997. Sacramento County maintains a station at Georgiana Slough, 7.3 miles southwest of R-1. The records of accumulated precipitation at Georgiana Slough since October 1, 1995 are available through CDEC. Figures 7, 8, and 9 show the weekly precipitation at Ryer Island, the daily precipitation at Liberty Island, and the daily precipitation at Georgiana Slough.

Monitoring Network Elevation

The water levels in this report are presented as elevations. However, the elevation of each site may not be referenced to the same datum. Also, different benchmarks were used in the various surveys and the precision of the surveys is not necessarily known. The following section discusses the elevation references used for the data in this report.

USBR surveyed wells on Ryer and Prospect Islands in 1996 with a Global Positioning System survey and trigonometric leveling. The crew used a DWR survey control point, NB-1, for vertical control. According to Rosie Mendoza, of the DWR survey group, the elevation of that point is referenced to the NGVD 1929 datum. Wells on Ryer and Prospect Islands and the pumping station deck on Prospect Island were assigned elevations with that survey. In the summer of 1997, DWR staff ran a trigonometric level loop from benchmark "W965" on the south side of the Ryer Island bridge. The elevation of "W965" is also referenced to the NGVD 1929 datum. The elevations of the Ryer Island wells determined in the two different surveys, shown in the table below, may not be truly related to the same datum, due to physical changes experienced by the different benchmarks over time. The Ryer Island groundwater elevations shown in the figures in this report were calculated from the top of casing elevations determined by DWR using "W965."

The elevation of the tide gage at Five Points on Miner Slough was also determined by differential leveling from "W965."

Ryer Island Well Elevations

	Reference	R-1	R-3	R-4	R-5	R-6
Ground surface, USBR survey	NB-1	-2.4	-3.3	-1.9	-3.9	-4.1
Casing stickup measured by USBR	Hubs at wells	NA	1.25	1.60	2.03	NA
Casing stickup measured by DWR	Ground	2.00				
Top of casing elevation, USBR	NB-1	-0.4	-2.0	-0.3	-1.9	NA
Top of casing, DWR 7/25/97	W965	-0.28	-1.94	0.60	-0.92	-1.94

Data Analysis

The data listed in the first sections of this report were reviewed to determine which hydrologic conditions affect Ryer Island groundwater levels. This section presents the findings of the data analysis.

Weekly Water Level Changes in Ryer Island Wells

The water level elevations in Ryer Island wells, measured on a weekly basis, show a predictable seasonal trend (Figure 2). In general, the water levels rise from late summer into the winter, and drop from late winter into the summer. This pattern is typical of groundwater levels elsewhere in the Central Valley.

During the winter months, water level rises of one foot over a one-week period are occasionally seen in individual wells. These increases appear to coincide with precipitation, as measured at the Ryer Island gage.

The Effect of Drainage Ditch Water Levels on Water Levels in Well R-1

The data collected with a datalogger on an hourly basis from well R-1 provides the best information regarding the factors controlling water levels in this near surface groundwater system. One portion of the 1998 record, shown in Figure 10, indicates that the water level in Ryer Island ditches has a significant effect on shallow groundwater levels. One of the primary purposes of the ditches is to maintain the groundwater below the root zone of crops.

During the week before the 1998 pumpout began on Prospect Island, water levels in well R-1 were being drawn down by about two feet on a repeating daily pattern. The lowest daily water level from October 8 through 13 usually occurred at 3:20 p.m. Pacific Daylight Time, and the highest water level usually occurred at 8:20 p.m. PDT.

The cause of the water level drawdown pattern was determined through discussions with Gary Rook, superintendent of Reclamation District 501. There are three drainage-pumping stations on Ryer Island. Two operate regularly and a third operates during those periods when two are insufficient to drain the island. One regularly operating pumping station is near the reclamation district office. The other is about one-half mile to the south. According to Rook, flashboards in the islands drainage ditches were set in October 1998 so that the pumps at the reclamation district office drained the central and western portions of the island. The pumping station to the south drained the eastern portion of the island. This area includes the drainage ditch adjacent to well R-1. Rook said each pump was controlled with a float and a timer. The timers were set so the pumps remained off from noon to 6 p.m., the peak electric rate period. The water level recovery period, shown in the R-1 record on Figure 10, is the same six-hour pump shutoff period delayed by a few hours.

The water level changes in well R-1 follow the drainage pumping pattern with a delay caused by the distance between the well and the pumps. The well is about 5.4 miles on a straight line from the pumping station, and the drainage channel length between the well and pumping station is greater. Figure 10 shows water levels in the well decline about two hours after pumping starts at 6 p.m. PDT. Water levels in the well begin to rise rapidly about three hours after pumping stops at noon PDT.

The rate of water level decline in well R-1 changes after the first 12 hours of pumping. The initial 12 hours of water level decline is relatively slow, several hundredths of a foot each hour. After approximately 12 hours from the previous day's point of water level recovery, the rate of decline in R-1 increases to as much as one-half foot per hour. This change in the rate of water level decline probably occurs when the ditches near the pumps empty and cannot contribute as much flow to the system as during the initial 12 hours of pumping. As the furthest ditches, such as the ditches next to R-1, contribute more of the percentage of the total flow at the pumping station, water levels in them recede at an accelerated rate.

Pumps draining the Ryer Island drainage system probably caused the major water level changes in well R-1 from October 7 to October 13, 1998. The well appeared to reliably reflect the water level in nearby ditches. As estimated from Figure 10, drainage pumping for this portion of Ryer Island, at least with the noon to 6 p.m. shutoff schedule, was probably discontinued for the season at about 8 p.m. on October 13, 1998.

Tidal Effects Observed in Well R-1

After the drainage pumping ceased and water level fluctuations of up to two feet per day stopped, the hourly record at well R-1 shows a pattern that suggests the well's water levels were varying with the tidal fluctuations in Miner Slough. This is similar to the pattern observed when the datalogger was recording water levels in R-1 in 1996. Figure 11 compares the water level in Miner Slough and the water level in R-1 over the period October 21, 1998 to October 31, 1998. The water level peaks in the tidal record occur at the same frequency as the water level peaks in the record of well R-1. As expected, there is some delay in the timing of the peak in the well. The water level in Miner Slough changed the water levels in the well, but it may have done so by changing the water level in the ditch next to R-1. Whether transmitted directly through groundwater or through the ditch and then through groundwater, the water levels in Miner Slough helped control the water level in R-1.

The Effect of Precipitation on the Water Level in R-1

Another notable change in R-1 water levels apparent in Figure 11 is the rise in the average water level in the well on October 24 that is maintained through October 30. On October 24, 0.48 inch of precipitation was measured at the Liberty Island gage and 0.67 inch was measured at Georgiana Slough. These two stations lie northwest and southeast of well R-1.

Groundwater levels in R-1 rise after precipitation events. That water level response is apparent in the hourly record of R-1 water levels. The R-1 hourly record is plotted in Figure 12 with the daily precipitation values for the station at Liberty Island. Significant daily precipitation totals, generally greater than one-quarter inch, result in a slight rise in the average daily water level in R-1. The rise may occur either because the ditch water level rises or because rainfall percolates through the soil and raises the shallow groundwater levels.

The Effect of Lowering the Level of Water Impounded on Prospect Island on the Water Level in R-1

The level of water impounded on Prospect Island during the 1998 pumpout is also plotted on Figure 12. It shows the water level on Prospect Island declines steadily from October 15 through October 31. The total water level decline over the period is about 2.8 feet. There appears to be no overall decline in the water level of R-1 over this same period.

The water level in R-1 over this period appears to rise and fall in response to the tide in Miner Slough and to rise in response to rainfall. Figure 12 shows no apparent drop in R-1 water levels resulting from the dropping water levels on Prospect Island.

Conclusions

Weekly groundwater level measurements on Ryer Island indicate groundwater levels follow a seasonal trend on the northwest portion of the island. Groundwater levels rise from late summer through winter and decline from late winter through summer.

Hourly groundwater level measurements show that shallow groundwater levels on Ryer Island change continuously due to several nearby hydrologic conditions. The changes are best observed on an hourly basis, as monitored by DWR in well R-1, because the groundwater level can vary by up to two feet in one day.

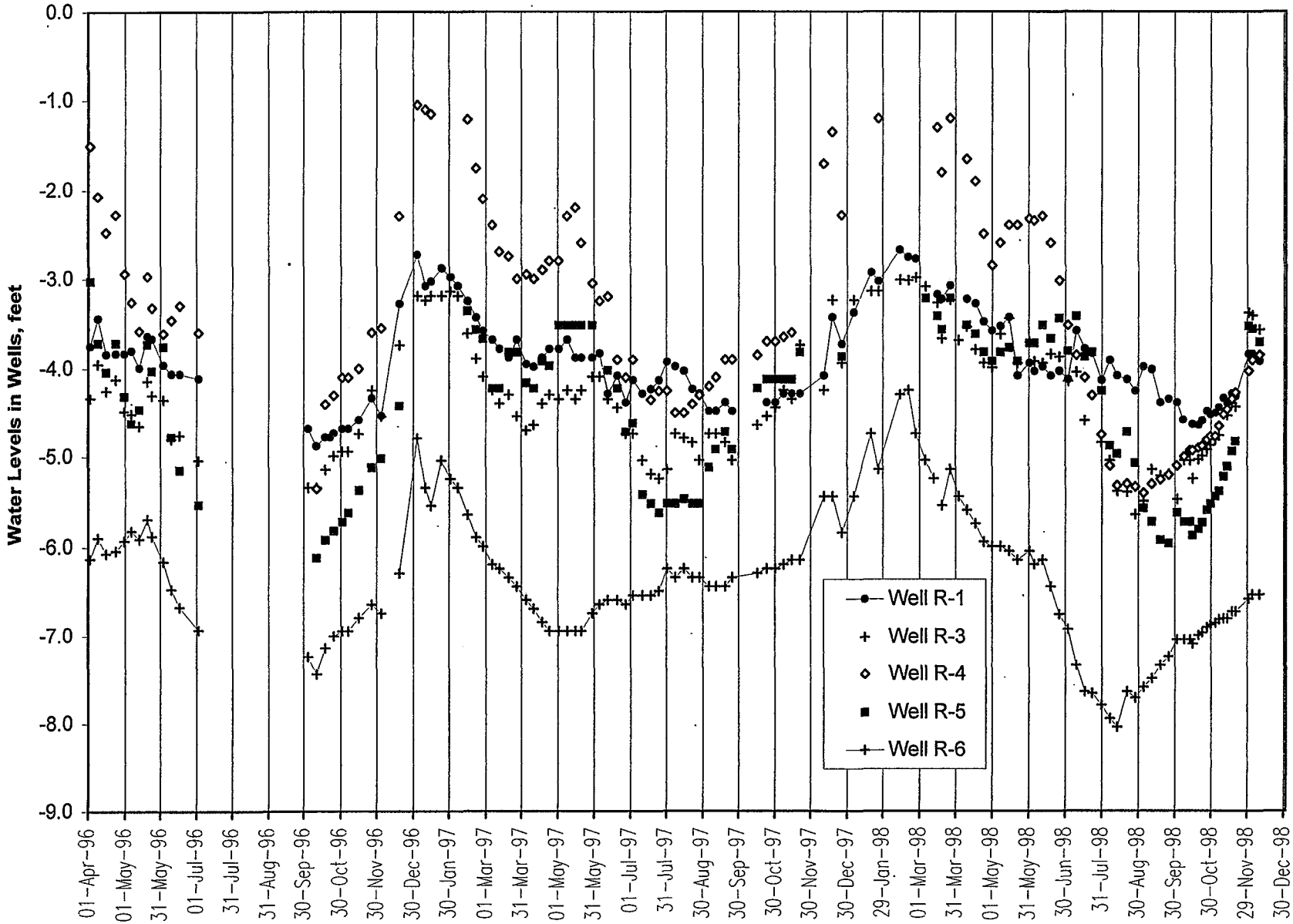
The water level in Ryer Island drainage ditches appears to be the primary control on the shallow groundwater level in the northwest corner of the island. The water level in Miner Slough and rainfall also affect the water level in the shallow groundwater, but to a lesser degree. The level of water impounded on Prospect Island does not appear to affect the shallow groundwater levels in this part of Ryer Island.

Water levels on Prospect Island were 1.7 feet higher when the 1998 pumpout began than when the 1996 pumpout began. Water levels on Prospect Island after the 1998 pumpout were six to seven feet higher than after the 1996 pumpout.

The existing shallow groundwater monitoring network, especially well R-1, responds significantly to drainage ditch water levels. The monitoring system should be modified by placing piezometers in an array that can distinguish between the different hydrologic causes for change in shallow groundwater levels.

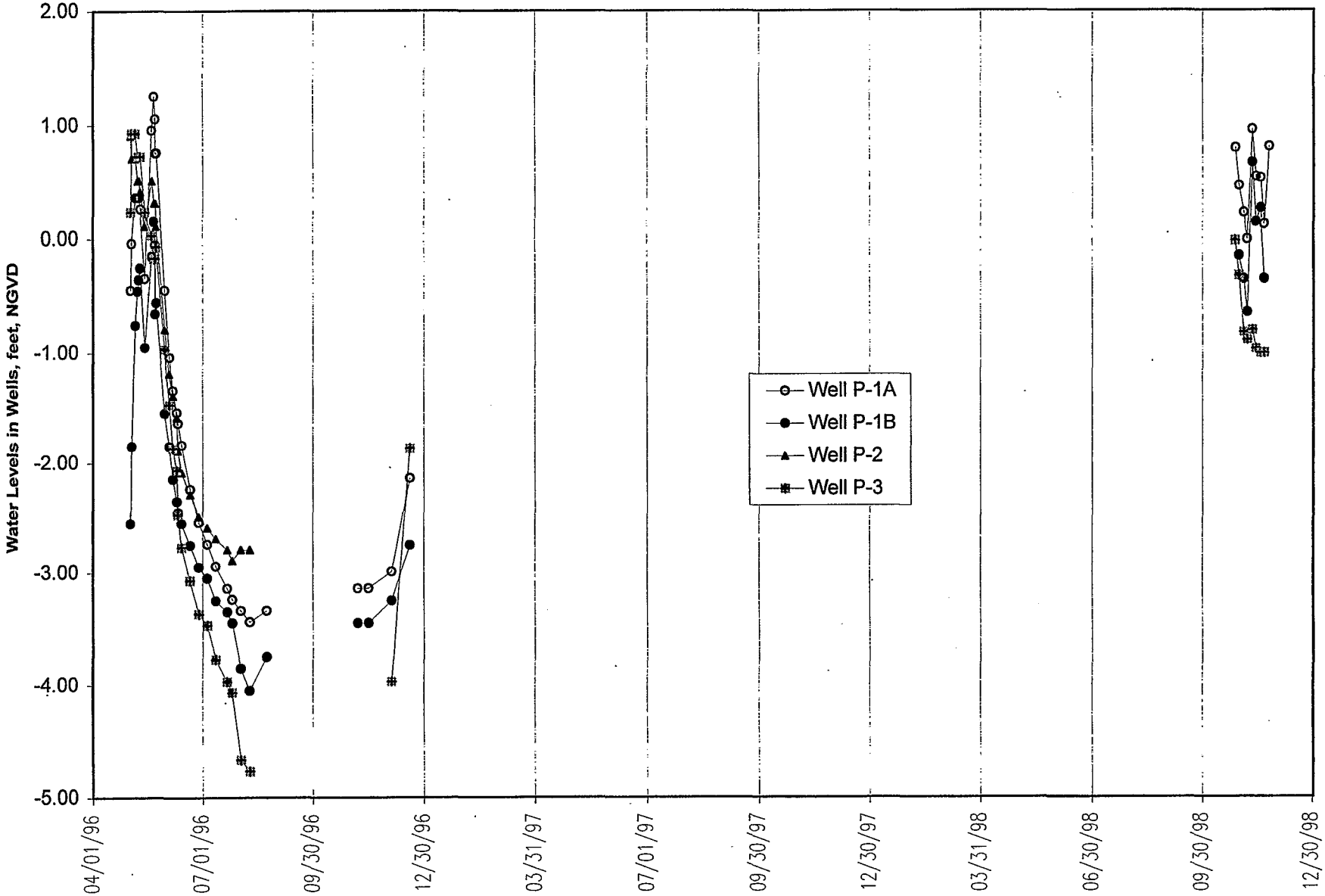
Figures

Figure 2
Water Levels in Ryer Island Wells



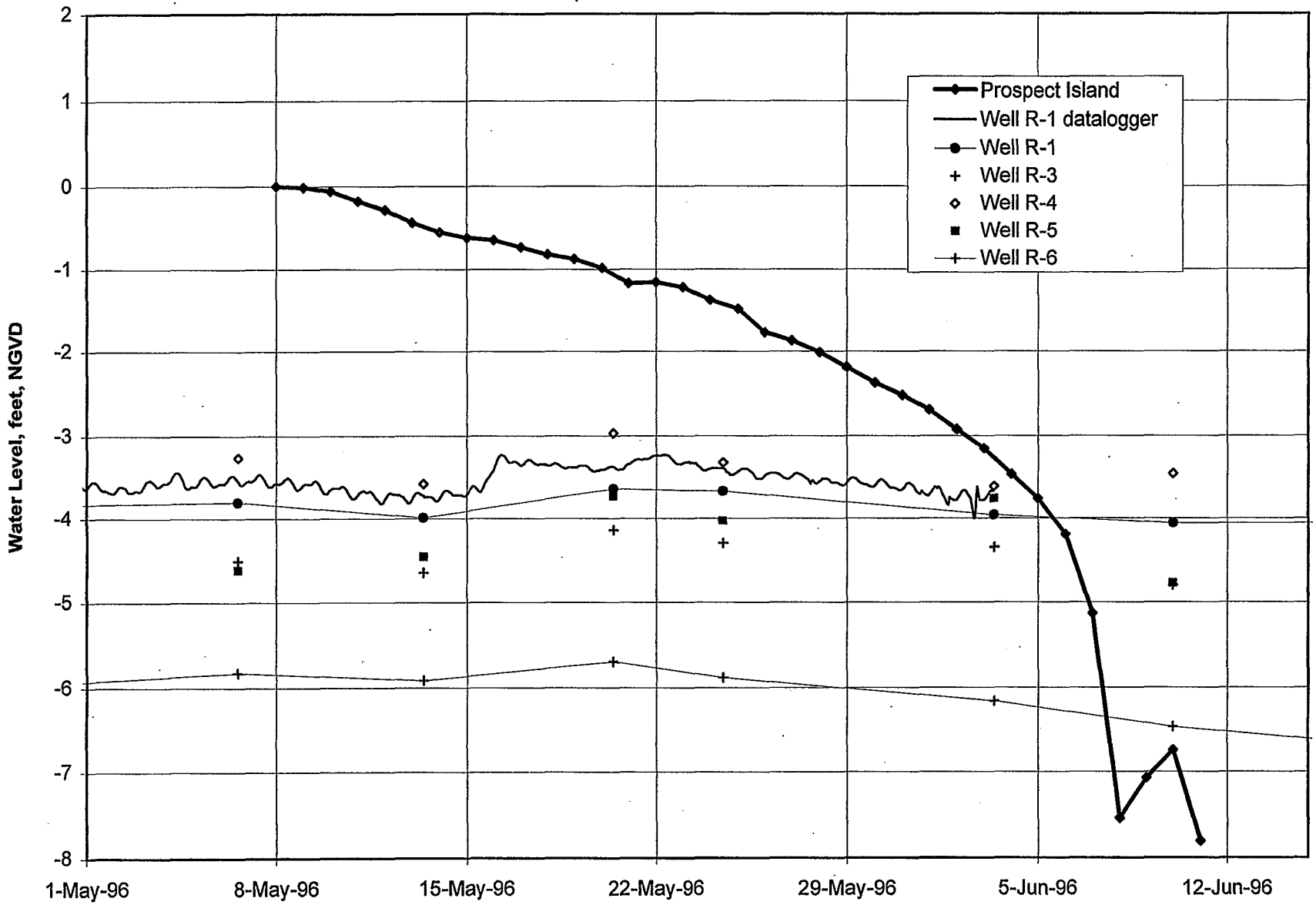
DWR, Central District, Geology and Groundwater, RLN ryer wells.xls/chart 1/21/99

Figure 3
Water Levels in Prospect Island Monitoring Wells



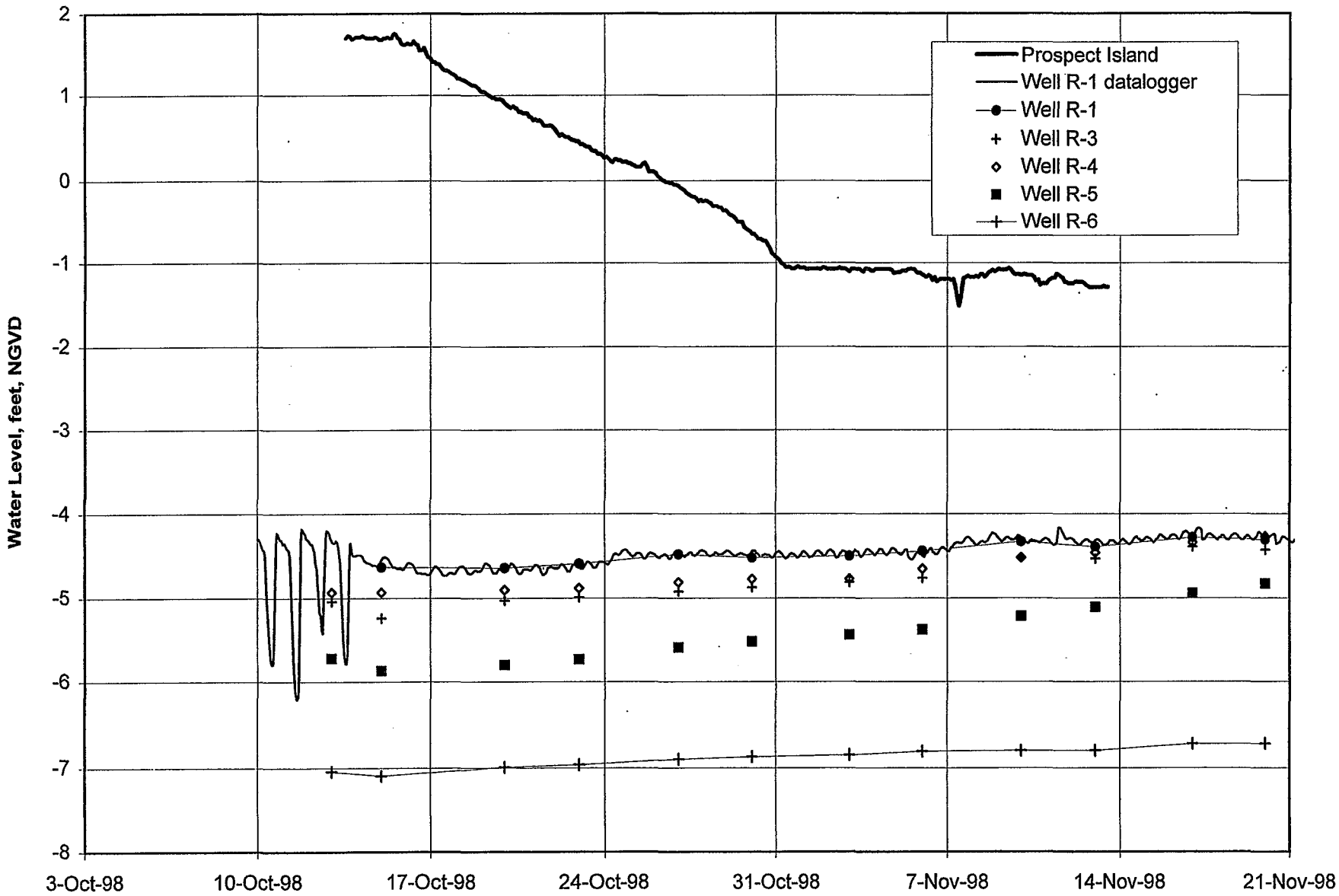
DWR, Central District, Geology and Groundwater, RLN prospect wells.xls/chart 1/21/99

Figure 4
Water Levels in Ryer Island Wells and on Prospect Island during Pumpout in May and June 1996



DWR, Central District, Geology and Groundwater, RLN Pumpouts w dataloggers.xls/1996ch 1/21/99

Figure 5
Water Levels in Ryer Island Wells and on Prospect Island during Pumpout in October 1998



DWR, Central District, Geology and Groundwater, RLN Pumpouts w dataloggers.xls/1998ch 1/21/99

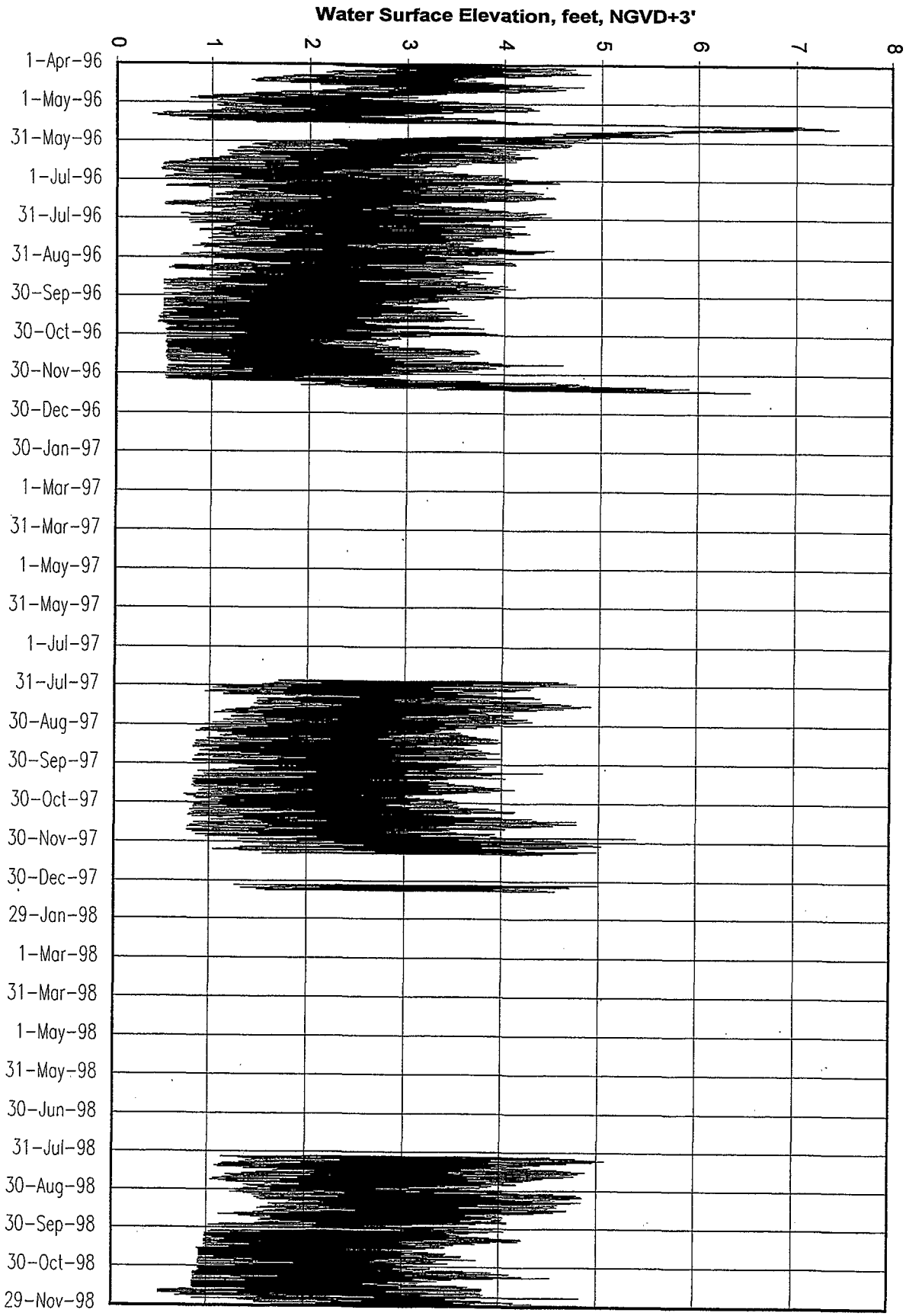


Figure 6
Record from theTide Gage at Five Points in Miner Slough

DWR Central District, Geology and Groundwater, RLN

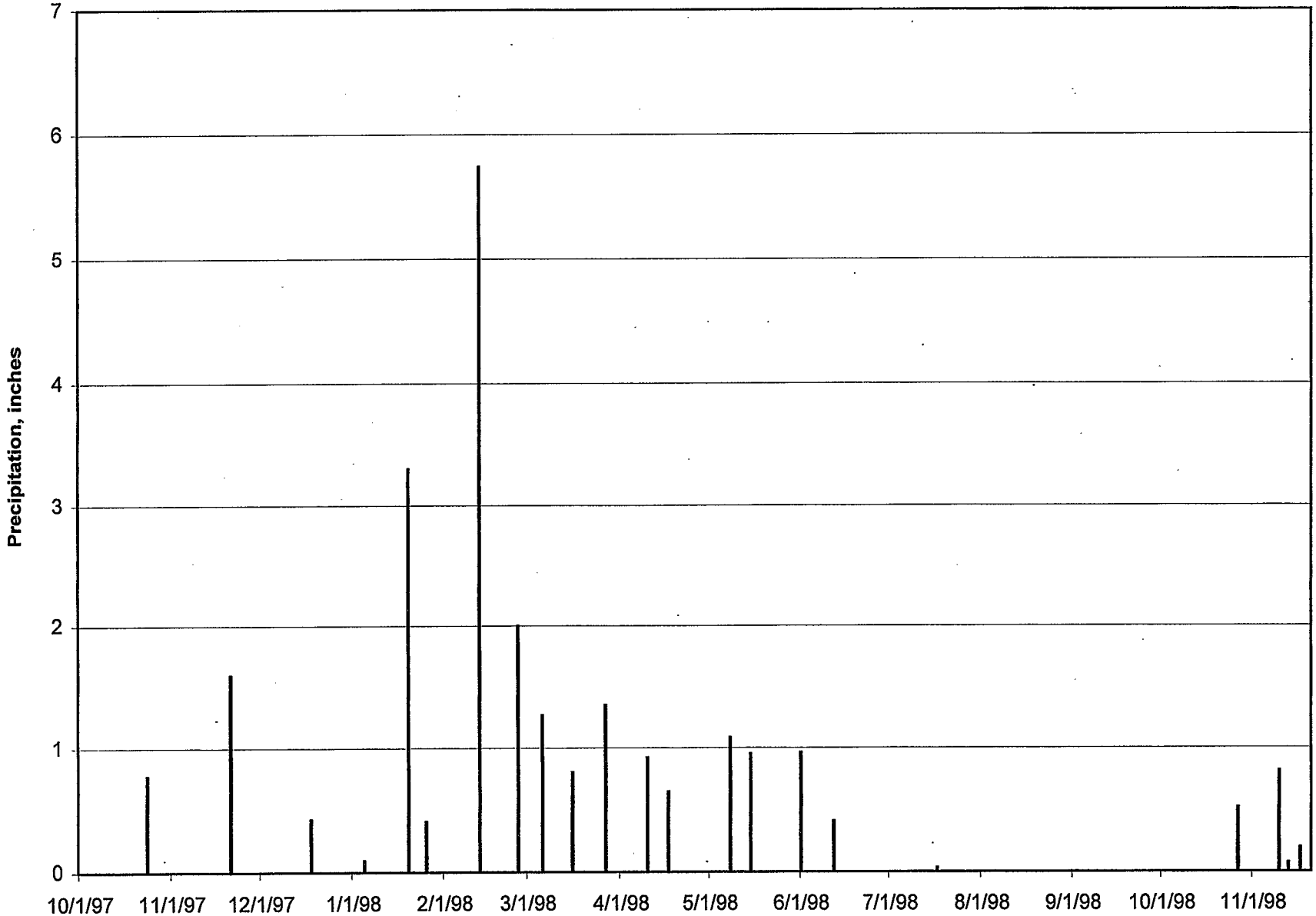
miner stage.xls/totalch

1/21/99

C-089087

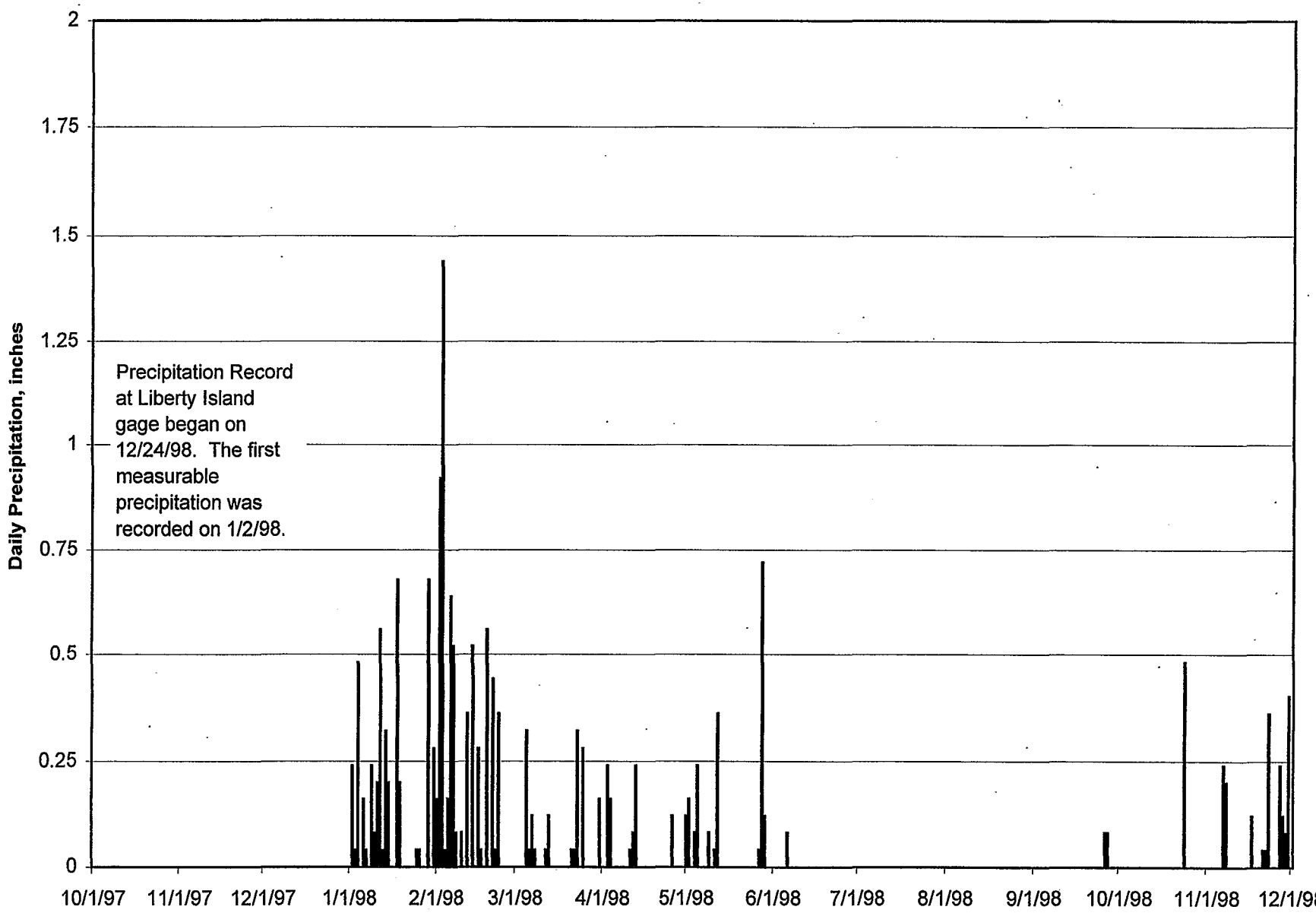
C-089087

Figure 7
Weekly Precipitation at Gage near Well R-1 on Ryer Island



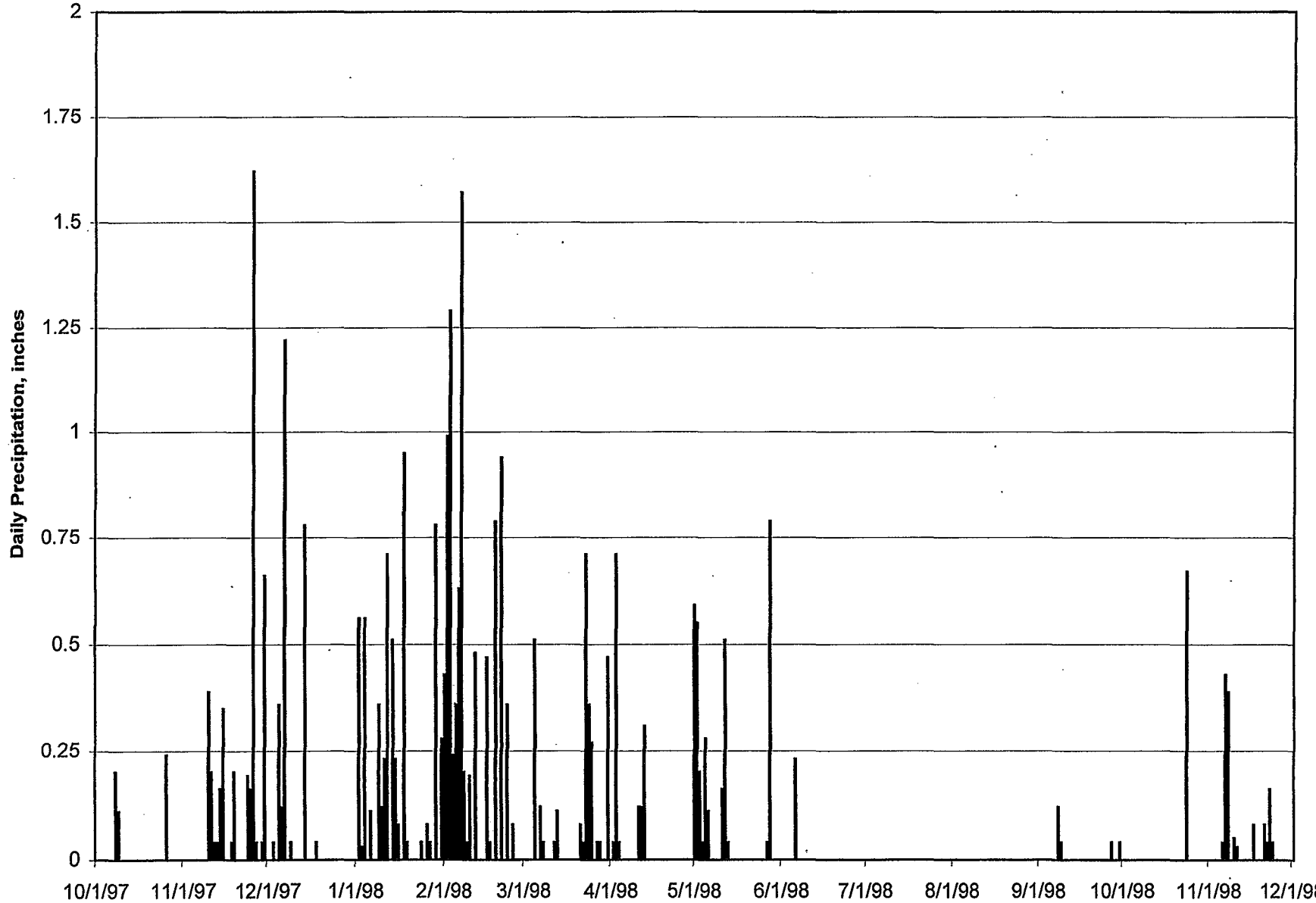
DWR, Central District, Geology and Groundwater, RLN c:\ryer\RIG.xls\chart 1/21/99

Figure 8
Daily Precipitation at Liberty Island Station (LIR)



DWR, Central District, Geology and Groundwater, RLN LIR.xls/CHART 1/21/99

Figure 9
Daily Precipitation at Georgiana Slough (GGS)



DWR, Central District, Geology and Groundwater, RLN GGS.xls/daily 1/21/99

Figure 10
Water Levels in Well R-1 Affected by Ryer Island Drainage Pumping

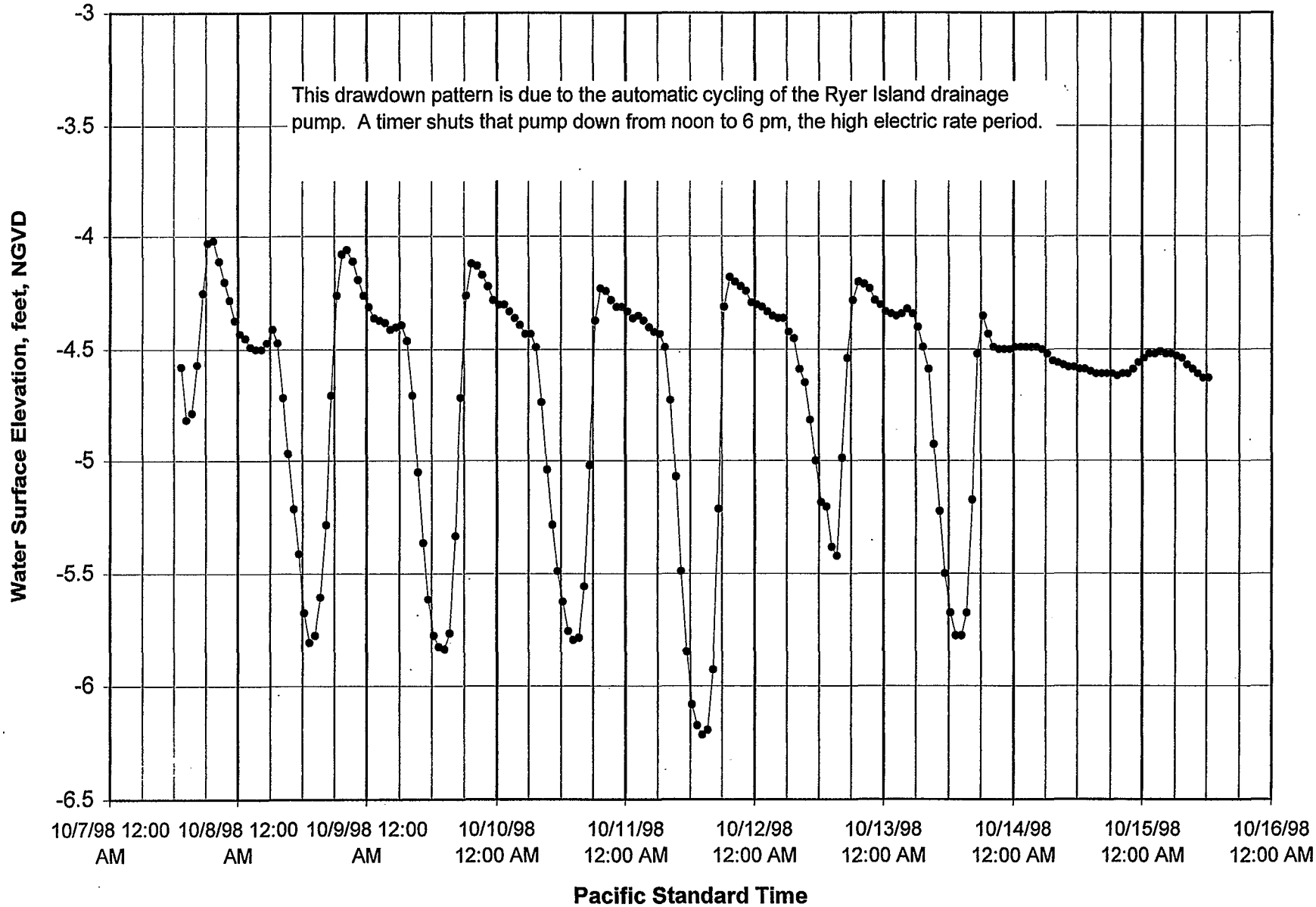
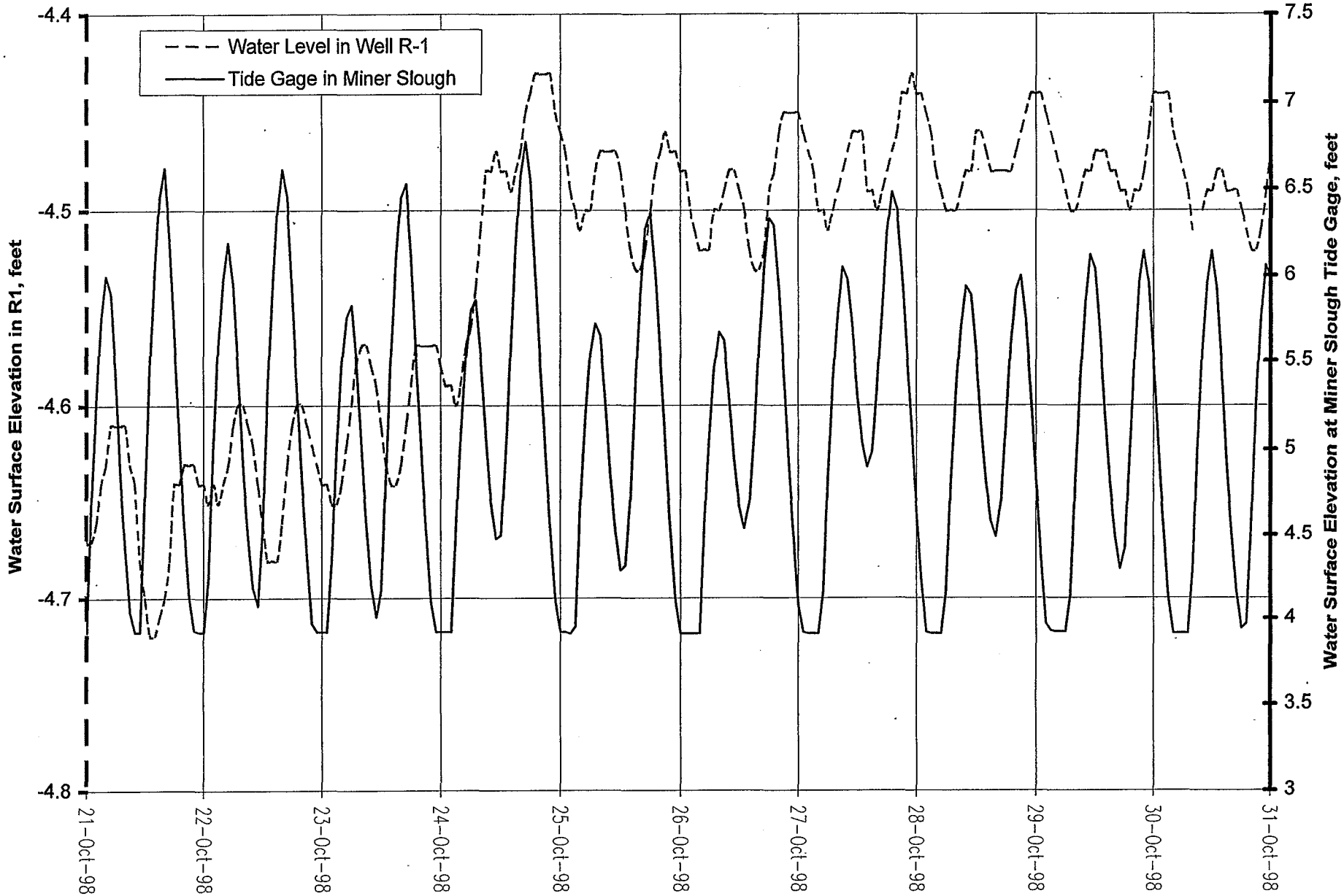


Figure 11
Comparison of Tide in Miner Slough and Water Level in Well R-1



DWR, Central District, Geology and Groundwater, RLN well one log98.xls\R1 vs tide CHART 1/21/99