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Environmental
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Project

Groundwater Response to Heavy Precipitation

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Revision History

Revision	*Date*	*Change*
0	14 May 2003	

Authorship

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Authorised	Dr John Harries	Leader, Environmental Management Project		

Groundwater hydrograph analysis for selected bores at Lucas Heights Science & Technology Centre

1. Introduction

An investigation of the groundwater response to heavy rainfall at LHSTC is required under the Conditions of Facility Licence F0001 for the Replacement Research Reactor. Condition 5.7(c) requires: "an investigation of groundwater direction and flow rate at the Site under heavy precipitation conditions is performed and the results submitted to the CEO ARPANSA as soon as is reasonably practicable".

In February 2002, ANSTO submitted to ARPANSA a report on 12 months of monitoring well chemical, radiological, and nutrient data (ANSTO report Attachment D, Garry Seaborne letter to Dr John Loy dated 25-Feb-02). This report including a preliminary assessment of the groundwater response to precipitation based on 12 months of hydrograph data. PPK Environment & Infrastructure in a review of the data queried this hydrograph data and subsequent checking by Groundwater Data Collection Services (GDCS) revealed problems with the initial installation. These problems were rectified by GDCS and the equipment was recalibrated. ARPANSA was advised of the problem and that additional hydrograph data would be collected. The hydrograph data and interpretation of the response to rainfall reported here supersede that in previous report.

2. Hydrograph Data

Four groundwater bores (MW1S, MW1D, MW6S & MW6D) nested in two locations at Lucas Heights Science & Technology Centre (LHSTC) have been instrumented with automatic continuous water level monitoring devices. The locations of MW1 and MW6 are shown in Figure1. Standing water level data have been collected from these loggers between the period August 2002 and March 2003. Bore construction and lithological details, including the hydraulic conductivity values averaged over the bore screened length, are contained in PPK Environment & Infrastructure, 2000. A summary of properties of the bores listed in Table 1.

Table 1. Borehole Properties

Continuous Monitoring Well	Hydraulic Conductivity m/sec	Screen Interval m
MW1S	1.28×10^{-7}	0.5 – 12.5
MW1D	3.89×10^{-7}	18.5 – 24.5
MW6S	7.83×10^{-8}	0.5 – 9.5
MW6D	3.73×10^{-10}	18.5 – 24.5

Hydrograph data for the four boreholes is presented graphically in Figures 2a, 3, 4 and 5 each showing the rainfall recorded during the same period for comparison. Some of the spikes evident in the hydrograph data are responses to purging and sampling for collection of quarterly groundwater chemical parameters. The dates for bore purging and sampling are tabulated in Table 2.

Table 2. Dates of Purging and Groundwater Sampling

Continuous Monitoring Well	Purge date	Sample date	Purge date	Sample date	Purge date	Sample date
MW1S	19-Aug-02	20-Aug-02	9-Jan-03	10-Jan-03	20-Mar-03	21-Mar-03
MW1D	19-Aug-02	20-Aug-02	9-Jan-03	10-Jan-03	20-Mar-03	21-Mar-03
MW6S	23-Aug-02	19-Sep-02	7-Jan-03	8-Jan-03	14-Mar-03	17-Mar-03
MW6D	23-Aug-02	19-Sep-02	7-Jan-03	8-Jan-03	14-Mar-03	17-Mar-03

3. Response to Precipitation Events

After elimination of hydrograph events due to purging and sampling, two events remain that are attributable to heavy rainfall. These rainfall responses were detected in only the shallow piezometers: MW1S with an event on 12 March and MW6S with events on 24 February and 12 March.

Figure 2b is an expanded plot of the bore water level response in MW1S for the period between 10 March to 16 March 2003. A rapid rise in the water level in the bore occurred due to a rain event on the 12 March. The rapid rise can be attributed to the bore being screened from 0.5m depth in high infiltration capacity sandy soil (see Table 1). A weathered sandstone layer at approximately 1-2m depth acts as a barrier at this site which would cause groundwater to drain directly into the bore. The result is observed as an almost immediate response to heavy rainfall. At the conclusion of the rain event, the water level declined according to the characteristic hydraulic conductivity of the aquifer and returned to the longer term standing water level, perhaps slightly higher than prior to the rain event.

MW6S detected a similar although smaller immediate rapid response during the 12 March rain event but this feature was then followed by a longer-term peak over a period of 10 days, Figure 4. The peak in the water level occurred about 2 days after the rain event on the 12 March and the water level then slowly decreased over the following 10 days. This delayed peak is due to groundwater moving down-gradient from the Lucas Heights plateau (which is where the MW1 site is located) towards the lower lying MW6 site. MW6 is situated in a gully producing a concentration of flow in the vicinity of MW6.

The response to the rainfall event on 24 February observed in MW6S is similar to the response observed in this borehole from the 12 March rainfall event.

The hydrograph data for MW1S and MW1D also depict a falling groundwater trend probably due to dry conditions through the assessment period, but also possibly due to effects of excavation for the RRR. Groundwater levels in MW1S fall from approximately 8.4m in August 2002 to 10.1m in March 2003. MW1D follows a similar trend and is slightly lower in groundwater level compared to MW1S by approximately 0.2-0.4m. This indicates that the vertical hydraulic gradient is in a downward direction and characteristic of a semi-confined aquifer.

MW6S and MW6D groundwater trend data over the August 2002 to March 2003 period is primarily at a constant water level depth at approximately 5.7m in MW6S and 6.8m for MW6D. MW6D data shows a much slower water level recovery rate after purging and sampling periods. The slow recovery is due to a low hydraulic conductivity associated with the sandstone around this site. The groundwater in MW6D appears to be not affected by weather conditions, whereas MW6S does respond to individual storm events, above a certain threshold.

Small diurnal groundwater level fluctuations of approximately 0.1-0.2m in MW1S and MW1D can be accounted for by lunar tidal effects (regular fluctuations) or changes in atmospheric pressure (irregular fluctuations).

The groundwater response to heavy rainfall is consistent with our understanding of the groundwater regime as an imperfect multi-layer flow regime with decreasing rate of flow in each layer due to decreasing hydraulic conductivities with depth.

4. Groundwater Flow Regime of LHSTC

The conceptual model of the LHSTC site hydro-geological structure is one in which a thin highly permeable soil layer absorbs rain. Most of this water then rapidly drains laterally to the topographic lows at the heads of the gullies. Percolating rainwater cannot effectively flow downward in the sandstone groundwater system because of zones of low hydraulic conductivity. The contrast in hydraulic conductivity between these layers forms an effective barrier to vertical flow.

LHSTC is situated on top of a gently north-sloping ridge. On the eastern side, several steep gullies drain into the Woronora River, and on the west are the shallow depressions forming the headwaters of Barden and Mill creeks. A significant proportion of LHSTC has building and road cover, with the remainder covered by grass or sparse native vegetation. After heavy rain, the stormwater system accounts for surface flows from roads, buildings and surface drainage lines. Rain falling on the grassed and sparsely vegetated portion of LHSTC is absorbed into the soil. In the days following heavy rain, water seeps from the soil into the top of the gullies surrounding LHSTC. Discharge via the soil into the top of the gullies ceases after a few days.

Discharge via a deeper groundwater path over a much slower time regime lower in the gullies ultimately forms the base-flow of the Woronora River. A rough comparison of the volumetric flow in the Woronora River a few days after rain compared to base-flow shows groundwater discharge to be dominated by discharge from the thin upper moist soil-regolith layer.

A basic three layer hydro-geological structure is suggested from the Coffey seismic refraction survey (Coffey 1998) consisting of:

- a near surface soil and regolith layer, typically <2m;
- a weathered sandstone layer of variable thickness and degree of weathering, <1m - <10m; and
- an unweathered sandstone, >10m.

The seismic survey showed variability for these three layers, both in their thickness and in their degree of definition. In places, there was no clear distinction between the layers. A similar pattern is expected for the hydraulic conductivity, because both the seismic velocity and hydraulic conductivity are correlated with the degree of consolidation for these layers.

5. Conclusion

Groundwater continuous hydrograph monitoring has been used to assess the groundwater response to heavy rainfall at LHSTC. The drought conditions have provided only limited cases where the groundwater responded to a rainfall event. The characteristic response was an immediate local response caused by saturated soil contributing water directly the borehole and the falling head as this water was redistributed into the aquifer in a few hours. Hydrograph data from a borehole near the head of a gully (MW6) showed that ground water flow from the plateau to the gully produced a peak a few days after the rainfall event and that the water level then returned to its original level after about 10 days.

The hydrograph data are consistent with the ground water regime developed from earlier seismic and geophysical data.

References

ANSTO 2002. Report to ARPANSA; Initial 12 months Groundwater Monitoring Results and Interpretation; Groundwater Flow Regime; Groundwater Response to Heavy Precipitation.

Coffey 1998, A report to ANSTO G459/1-AG, Replacement Reactor Site Lucas Heights Hydrogeological and Hydrochemical Study, August 1998

PPK Environment & Infrastructure Pty Ltd (2000) "Groundwater Monitoring and Management Program – Lucas Heights Science & Technology Centre" Consultant report to the Australian Nuclear Science & Technology Organisation. Aug 2000 57L057A.

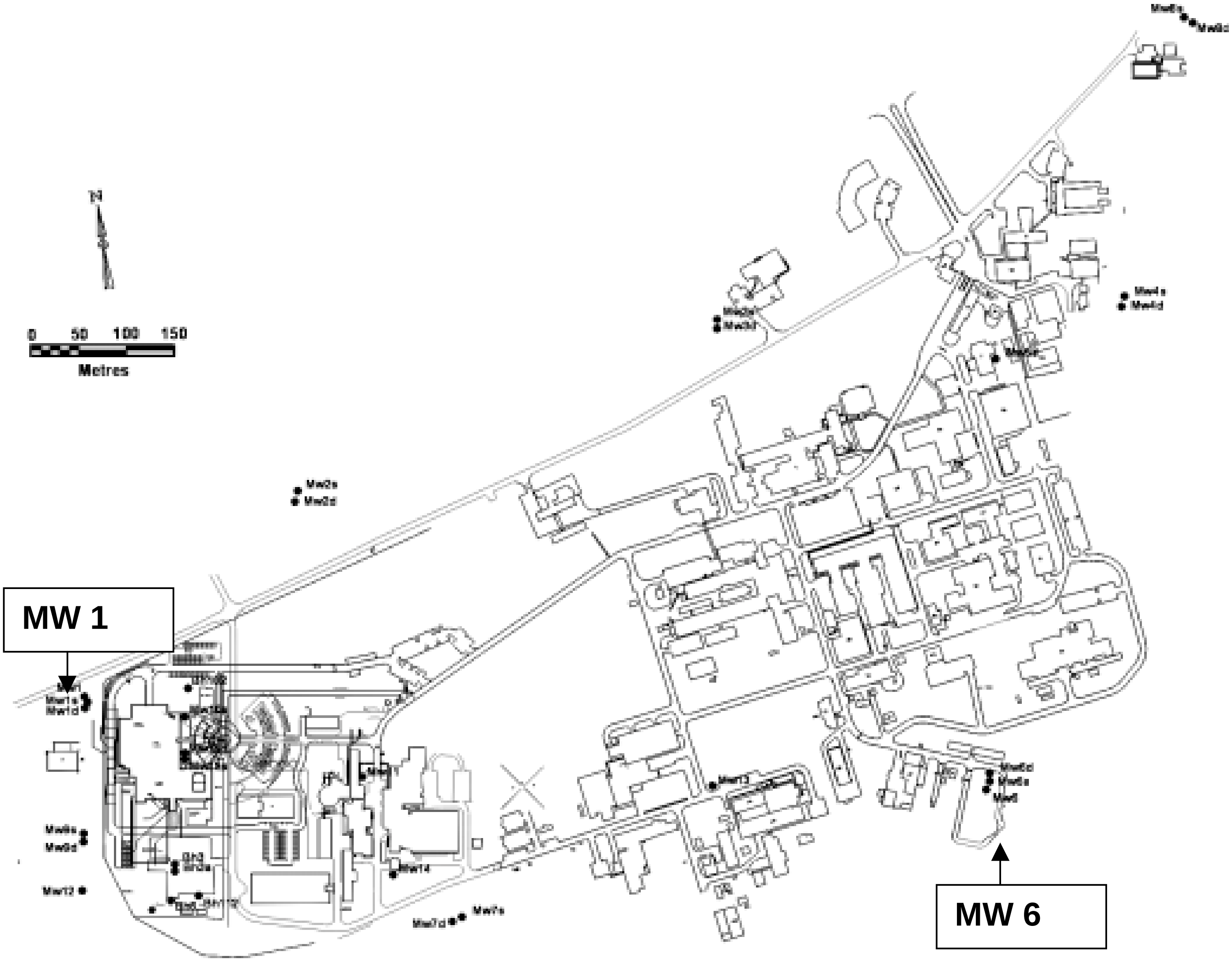


Figure 1. Location of MW 1 and 6

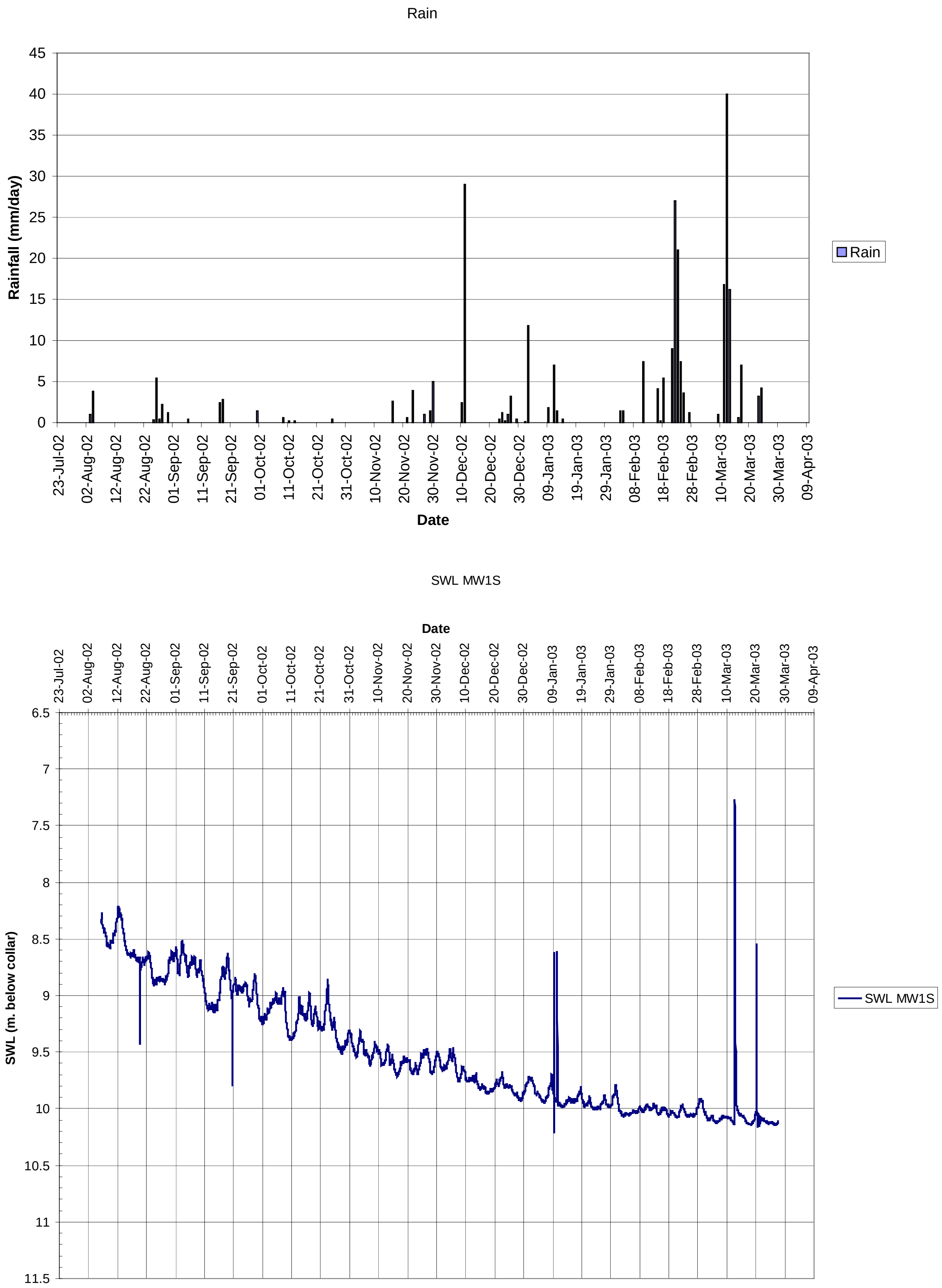


Figure 2a: MW 1S groundwater hydrograph and rainfall.

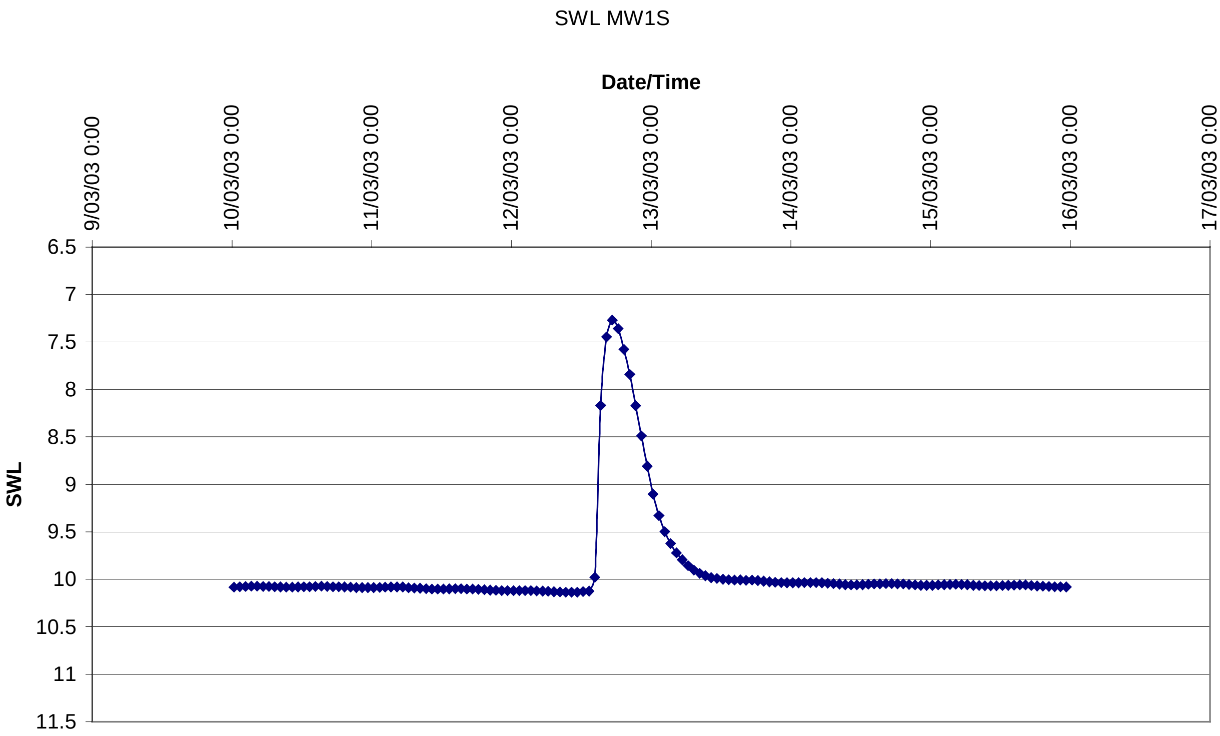


Figure 2b: Excerpt from MW 1S groundwater hydrograph for 10-16th March 2003.

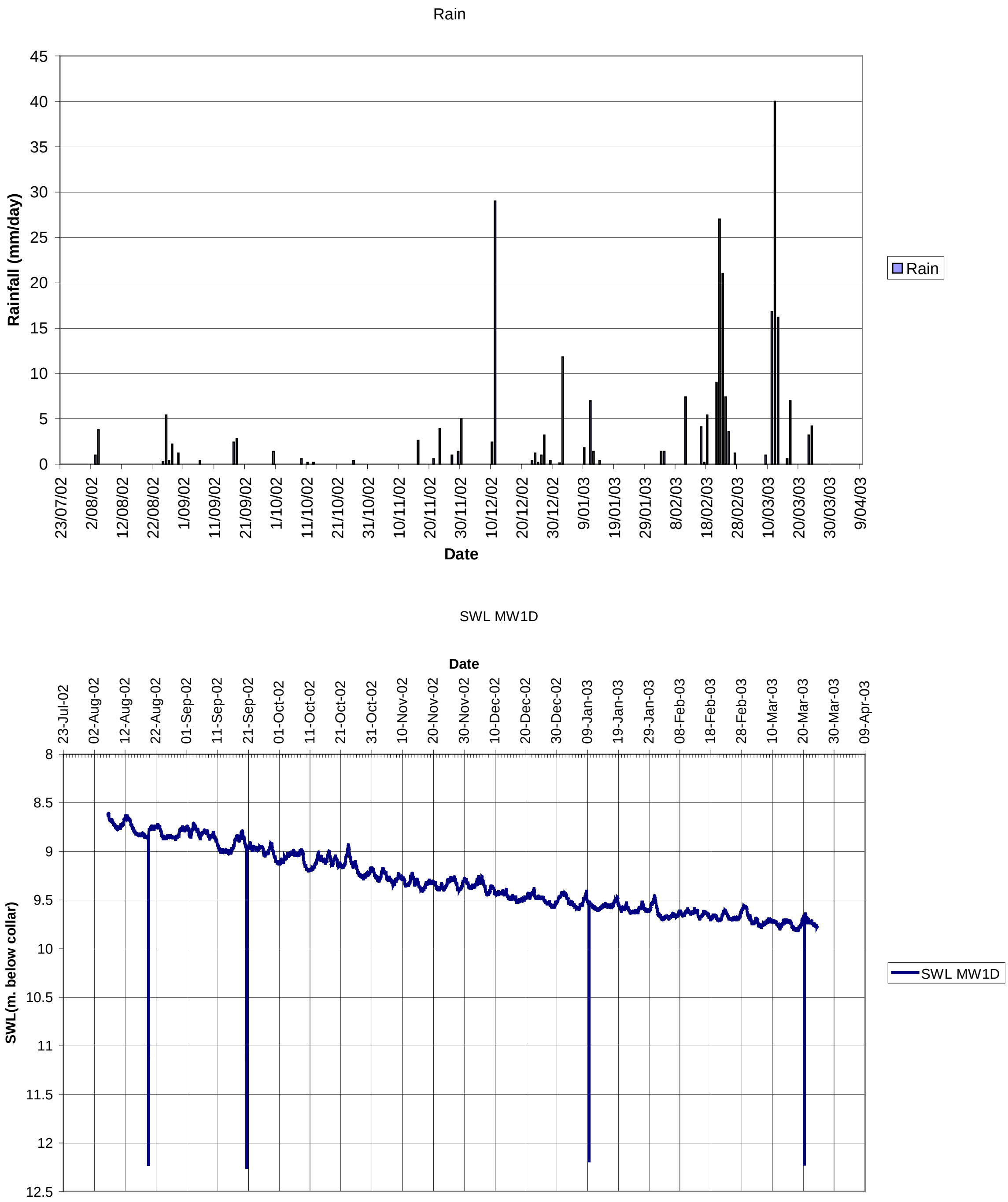
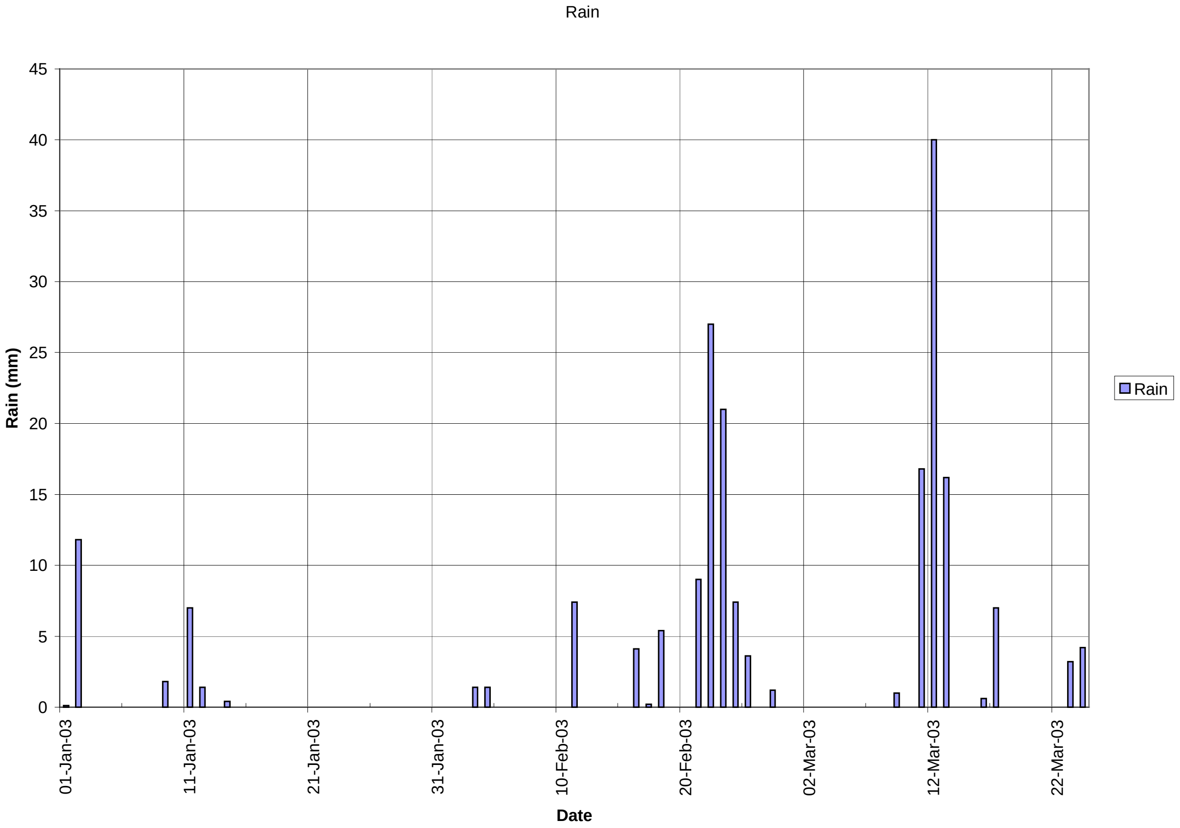


Figure 3: MW 1D groundwater hydrograph and rainfall.


Rain
Rain (mm)
45
40
35
30
25
20
15
10
5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
Date
Rain

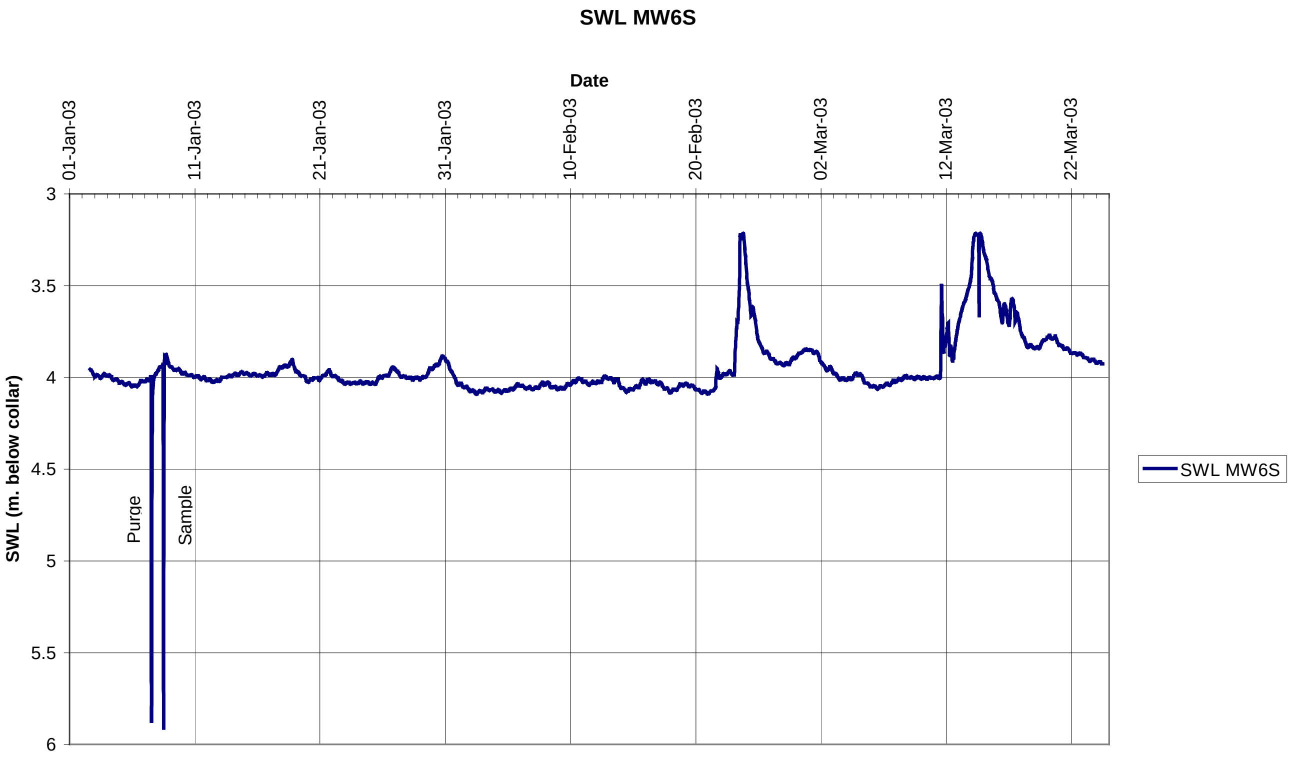


Figure 4: MW 6S groundwater hydrograph and rainfall.

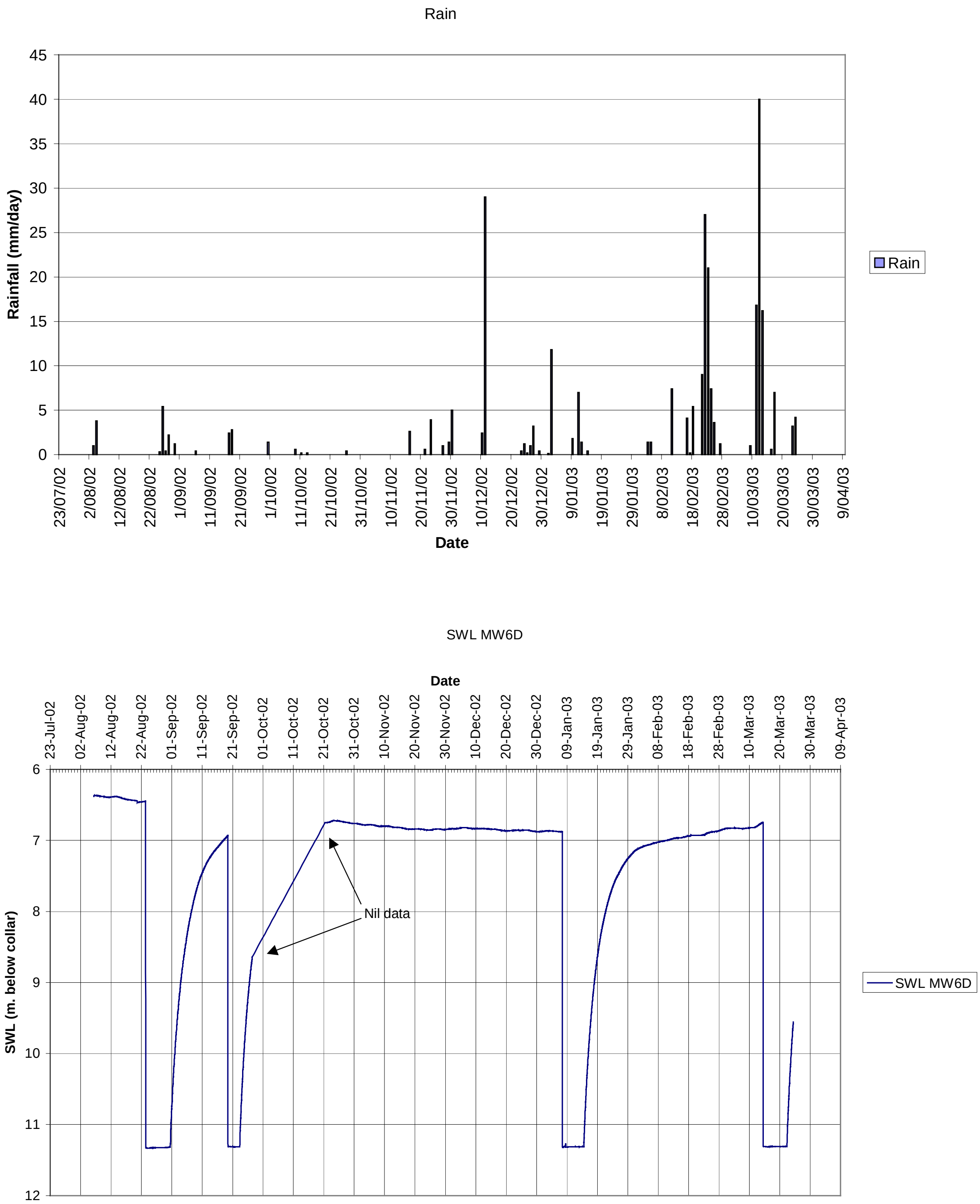


Figure 5: MW 6D groundwater hydrograph and rainfall.