ANALYSIS OF GROUND WATER RECHARGE FROM PARADISE CREEK AT THE UNIVERSITY OF IDAHO GROUND WATER RESEARCH SITE: PART I

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Dale R. Ralston
Professor
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Tong Li
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Prepared for the Pullman-Moscow Water Resources Committee

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I. INTRODUCTION

Purpose and Objectives

The purpose of this report is to increase the understanding of ground water recharge to basalt aquifers in Pullman-Moscow basin. The general objective is to utilize wells at the University of Idaho Ground Water Research Site to study the interrelationship between Paradise Creek and shallow alluvial and basalt aquifers. The specific objectives are as follows:

1) *monitor ground water levels and surface flow discharge in the Paradise Creek at the UI Ground Water Research site.*
2) *analyze the water level and surface flow data with respect to site hydrogeology.*
3) *describe the controls for recharge of shallow aquifers from streams in the area.*

Location and Initial Development of the UI Ground Water Research Site (GRS)

The GRS is located at western edge of University of Idaho campus. Five drilled wells were constructed at the site in 1987. The site is in triangular shape (figure 1) with Paradise Creek along its northern boundary, Perimeter Drive as its eastern boundary and a moderate hill as its southwestern boundary.

Paradise Creek is a tributary of south fork of the Palouse River, originated from Moscow Mountain. The discharge of the creek varied from 0.3 cfs to 50 cfs in 1988. The peak daily discharge usually occurs during snowmelt periods in the spring time. A U.S. Geological Survey gaging station on Paradise Creek is located about 100 feet cross Perimeter Drive from the northeastern corner of the site.

The test wells, named 1-A, 1-B, 1-C, 1-D and 1-E, were constructed with depths of 70, 100, 140, 146 and 80 feet, respectively. All the wells were completed within the Wanapum basalt of Yakima Subgroup of Columbia River Basalt Group with about 10 to 20 feet overburden at ground surface. The water yield of the test wells varies from 5 to 50 gpm. Two piezometers were set up within the overburden to depths of 10 to 12 feet for monitoring water level fluctuations in the shallow alluvial aquifer.

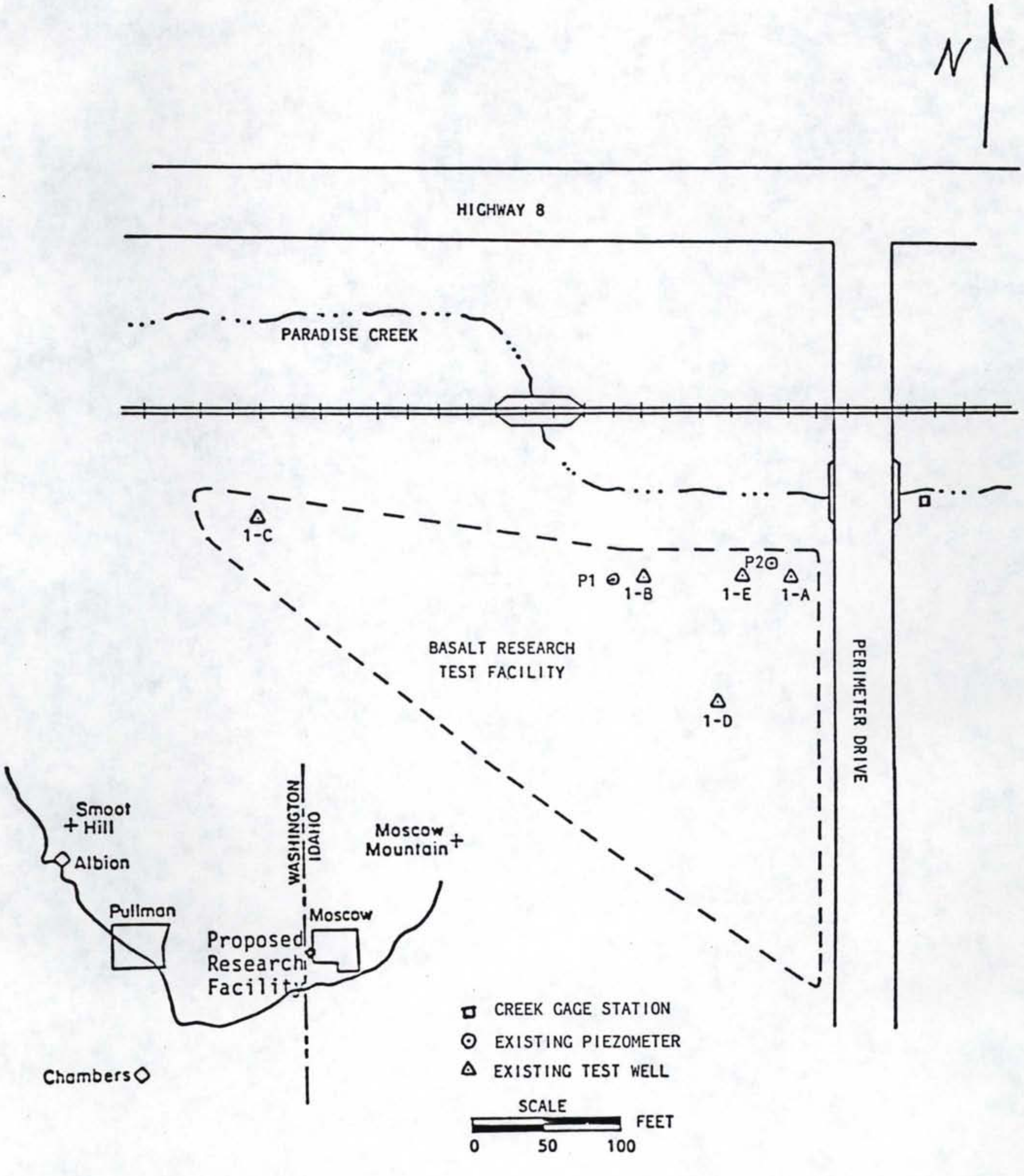


Figure 1. Plan View of Ground Water Research Site

II. GENERAL GEOLOGY AND HYDROGEOLOGY

Geology

Pullman-Moscow Basin lies near the eastern edge of Columbia Plateau within the Palouse Region. The basin base consists of Pre-Tertiary crystalline rocks which are overlain by the Columbia River Basalt with an irregular buried contact surface. The crystalline rocks are primarily granites that are Cretaceous in age and appear to be related to the Idaho Batholith. Some metamorphic rocks occur in the northern part of the Basin (Smoot and Ralston, 1987).

Miocene basalts interbedded with sediments overlie the basement of the crystalline rocks. The total thickness of basalt sequence is as great as 1,500 feet in Moscow and more than 2,200 feet in Pullman. The basalt sequence is classified into the Wanapum and Grande Ronde Formations of Yakima Basalt Subgroup of Columbia River Basalt Group (Swanson et al., 1979). The basalt in the basin is composed of individual flows or layers that were produced by a series eruptions of basalt lava. The thickness of the individual flow range from a few feet up to 200 feet with most flows ranging from 40-100 feet.

Three sets of cooling fractures or joints are generally observed within individual basalt flows. Columnar hexagonal joints that form columns 0.5 to 0.6 feet in width and blocky joints about 0.5 feet in diameter occur in the vertical direction. Platy fractures occur in the horizontal direction (Smoot and Ralston, 1987). The greatest hydraulic conductivity in the basalt sequence occurs at contact zones between individual flows. The outcrops of Wanapum basalt exposed along the Pullman-Moscow Highway illustrate the complexity of the fracture systems (Bush, 1988).

The numerous sedimentary layers that are composed of clay silt, sand and gravel, as well as claystone and siltstone were interbedded with the basalt. Much of the sediments appear to have been deposited in lakes or dammed streams that were formed by eruptions of the basalt lava. The interbeds tend to be thinner in layer thickness and finer in grain size to the west.

The Wanapum and Grande Ronde are two major formations of the basalt in the Basin. They may be differentiated geochemically by the magnesium, titanium and phosphorus concentrations. Wanapum basalt appears to be high in titanium and phosphorus and low in magnesium, whereas Grande Ronde basalt tends to have high magnesium concentrations and low titanium and phosphorus concentrations. The different percentage of concentrations of TiO_2 and P_2O_5 for the two formations is shown in figure 2 (modified from Wood, 1987). The Wanapum basalt is separated stratigraphically from the Grande Ronde basalt by Vantage member of the Ellensburg Formation, which is composed of siltstone, claystone and tuffaceous rocks (Swanson et al. 1979).

Surface of the Wanapum basalt is covered by Pleistocene loess in most part of the Pullman-Moscow Basin. The thickness of loess varies from zero to several hundred feet.

Site Stratigraphy and Hydrology

Understanding of site stratigraphy and aquifer characteristics is based on the drilling cutting logs and borehole geophysical logs as well as water level data and pumping test data. Borehole geophysical logging was conducted on the five test wells using the Washington State University logging unit. Nine logging sondes were used in the study: caliper log, flow meter log, fluid temperature log, fluid resistivity log, natural gamma log, neutron gamma log, gamma-gamma log, neutron-neutron log and spontaneous potential/resistivity log.

The principal findings from the geological, hydrogeological and borehole geophysical investigations of the GRS are as follows:

(1) Five stratigraphic units have been identified at the Ground Water Research site (figure 3). From top to bottom, unit 1 consists of about 6 to 10 feet loam soil and silty clay. Alluvial sand and gravel deposits about 3 to 6 feet thick is considered as unit 2. A broken basalt zone, generally composed of basalt rubbles and highly fractured basalt rock with various thickness of 6 to 16 feet is recognized as unit 3. Unit 4 includes 45 to 110 feet of black, dense basalt with several soft or fractured zones. This unit is the interior of a basalt flow. Underlying the hard basalt is a flow contact zone with thickness of 1 to 5 feet. The flow contact zone, unit 5, is a major water-producing layer on the site.

(2) The sand and gravel layer (unit 2) has a relatively high hydraulic conductivity and appears to be connected hydraulically with the weathered and broken basalt (unit 3). These two layers act as a single aquifer and probably are hydraulically connected with Paradise Creek. Units 2 and 3 form the upper aquifer. The bottom of the upper aquifer occurs at a depth of

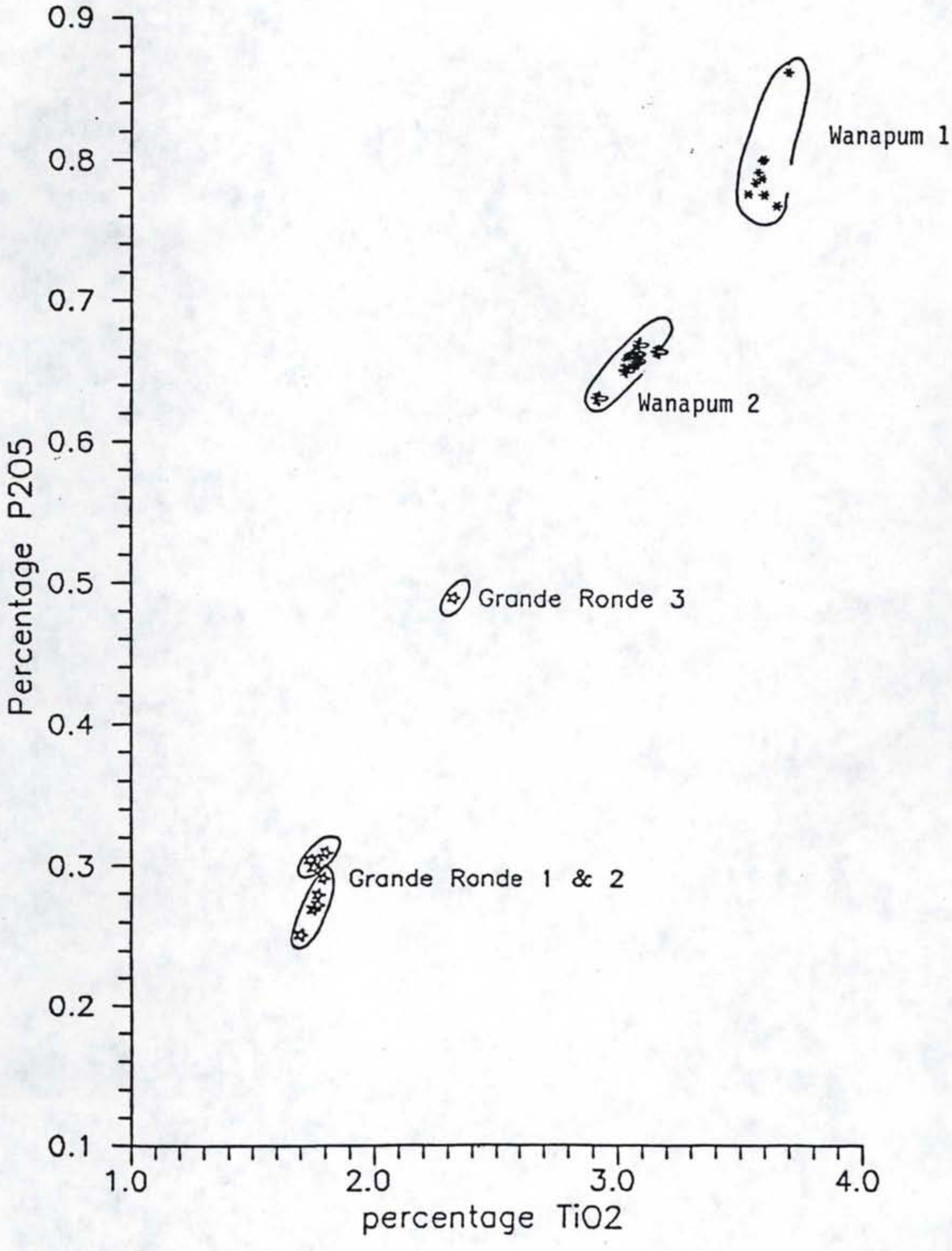
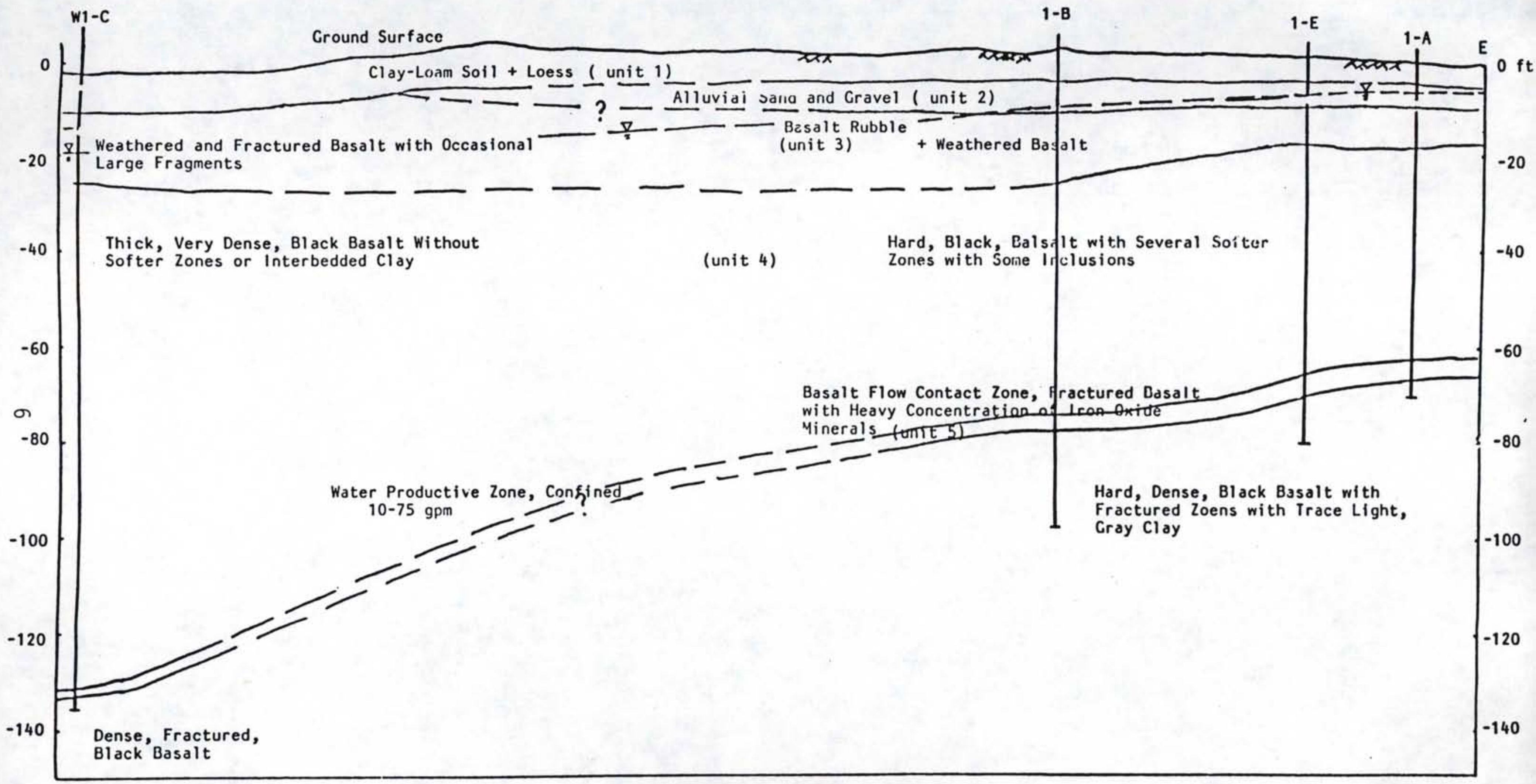


Figure 2. Basalt Chemistry, Percentage of TiO_2 and P_2O_5 of Wanapum and Grande Ronde Formations (modified from Wood, 1987)



SCALE

Horizontal 1:480
Vertical 1:360

Figure 3. Cross-Section of Ground Water Research Site (GRS)

about 30 feet below ground surface. The lateral distribution of this aquifer limited to the east part of the GRS. The grain size and total thickness of the aquifer tend to decrease toward to the southwest. The aquifer disappears at the west end of the site, where well 1-C is located.

(3) The basalt flow contact zone (unit 5) forms the lower aquifer at the GRS. The aquifer lies at depths of 65 to 130 feet from ground surface and is approximately 1 to 5 feet in thickness. The lower aquifer is obviously confined with the hard basalt above it as the confining layer. The aquifer appears to dip to the southwest in an angle less than 10 degree.

(4) Both upper and lower aquifers are very heterogeneous and anisotropic due to complex fracture pattern of the basalt. Based on preliminary analysis of the pumping test data, transmissivity and storitivity of the aquifers generally decrease from the northeast to southwest.

(5) The basalt flow interior (unit 4) that forms the aquitard between the upper and lower aquifers contains 3 to 4 fracture zones. These fracture zones have low hydraulic conductivity but do hydraulically interconnected the upper and lower aquifers. The results of several pumping tests show that a leaky effect exists between the two aquifers. This vertical leaky condition plays an important role in recharge of the lower aquifers. However, these fracture zones do not appear to extend laterally in a great distance and were not logged within the hard basalt at the west end of the site.

III. WATER LEVEL DATA ANALYSIS

Ground Water Hydrograph

Ground water level has been continuously monitored at the five test wells since Dec. 28, 1987 and the two piezometers since April 15, 1988. Relative static water levels of the test wells and piezometers in the different seasons are shown in figure 4. The static water levels shown on the test wells 1-A, 1-B, 1-D and 1-E are average water levels of upper and lower aquifers. These wells are presently open to both aquifers. Piezometers P-1 and P-2 represent the unconfined aquifer which is directly available for recharge from downward infiltration from precipitation or from stream losses.

Well 1-C has the lowest static water level at all times of the year (figure 4). Two possible explanations are that: (a) static water level in well 1-C represents only the lower confined aquifer; or (b) ground water flow at the research site has a significant gradient to the west. Relative water levels from all the wells show that ground water flows generally from the northeast to southwest, which is consistent with the regional flow direction. However, 10 to 15 foot drop of water head in a horizontal distance of about 400 feet is probably too high for the natural ground water gradient in the basalt aquifers.

Figure 4 also shows that the water table of upper aquifer (piezometers) and static water levels in the test wells at the east part of site are lower than the water elevation of Paradise Creek throughout the year. The water level in well 1-C is significantly lower than the Creek elevation.

The changes of static water levels with time in the wells and piezometers are shown in figure 5, 6 and 7. Figure 5 shows static water level hydrographs of four test wells from Jan. 1988 to May 1989. The stage of Paradise Creek at the USGS station is also presented. Figure 6 shows the hydrograph for well 1-C. The hydrographs for the two piezometers are presented on figure 7. A semi-log plot of stream discharge versus time is presented in figure 8 for the period of January-September, 1988.

The basic characteristics of the hydrographs are:

(a) static water levels in the eastern part of the site (all the wells except 1-C) tend to have similar fluctuation patterns; the water level in the west end of the site (well 1-C) is about 10 to 15 feet lower than that in the east end for all period of the year.

(b) water levels in wells 1-A, 1-B, 1-D, and 1-E appear to increase amplitude of fluctuation in the

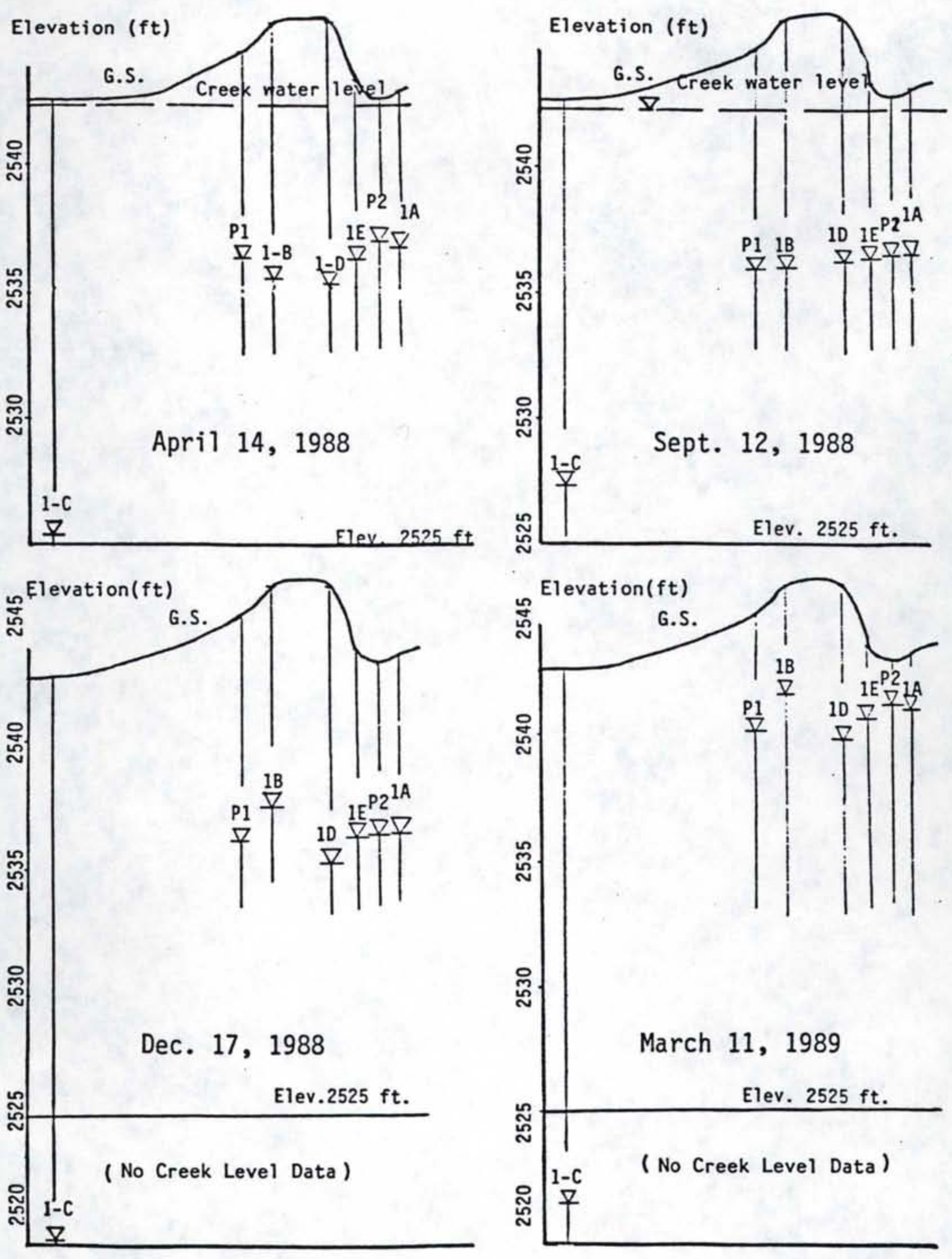


Figure 4. Relative Static Water Levels of Test Wells, Piezometers and Paradise Creek

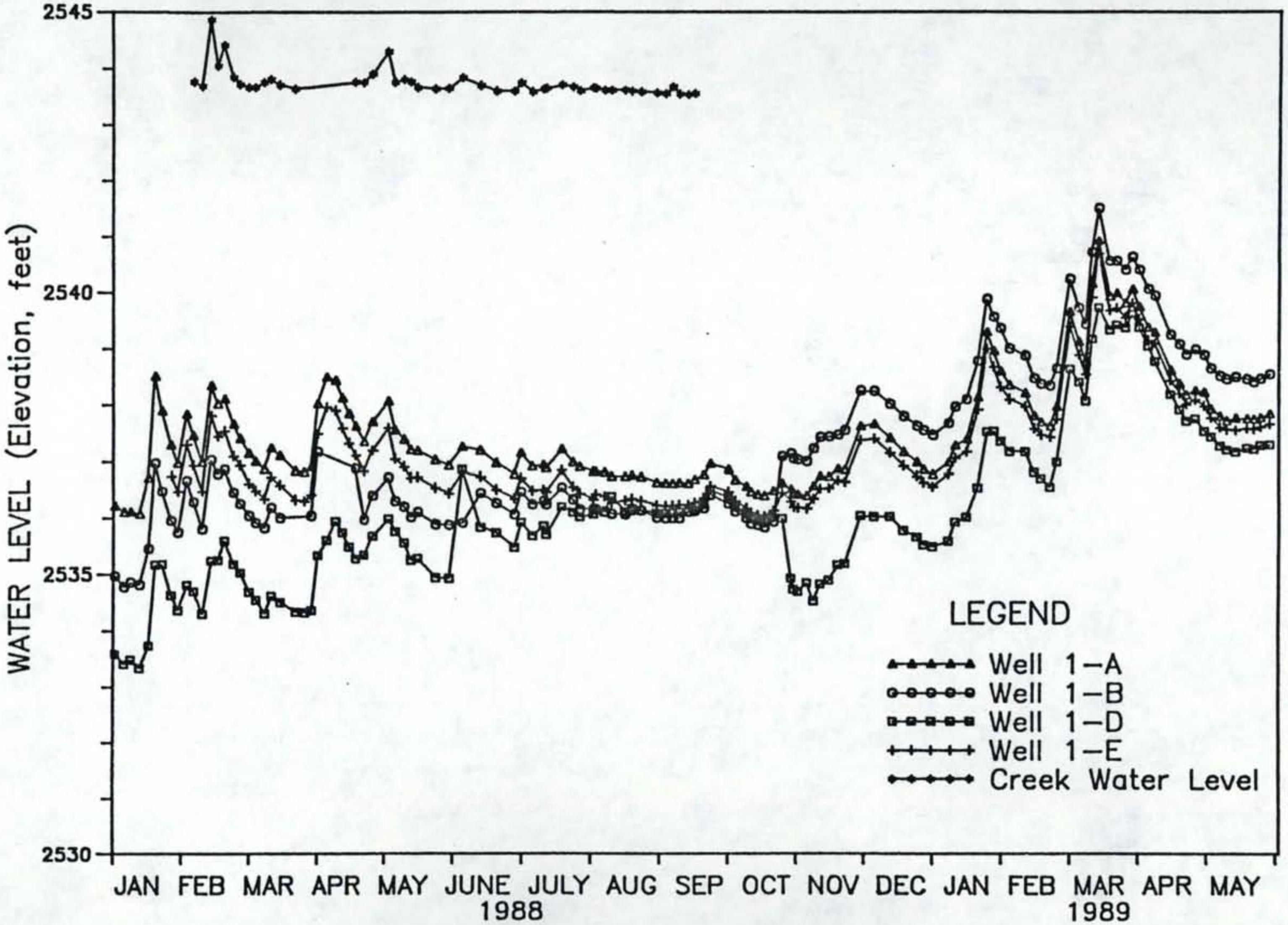


Figure 5. Water Level Records for Wells 1-A, 1-B, 1-D and 1-E Plus the Stage of Paradise Creek, GRS

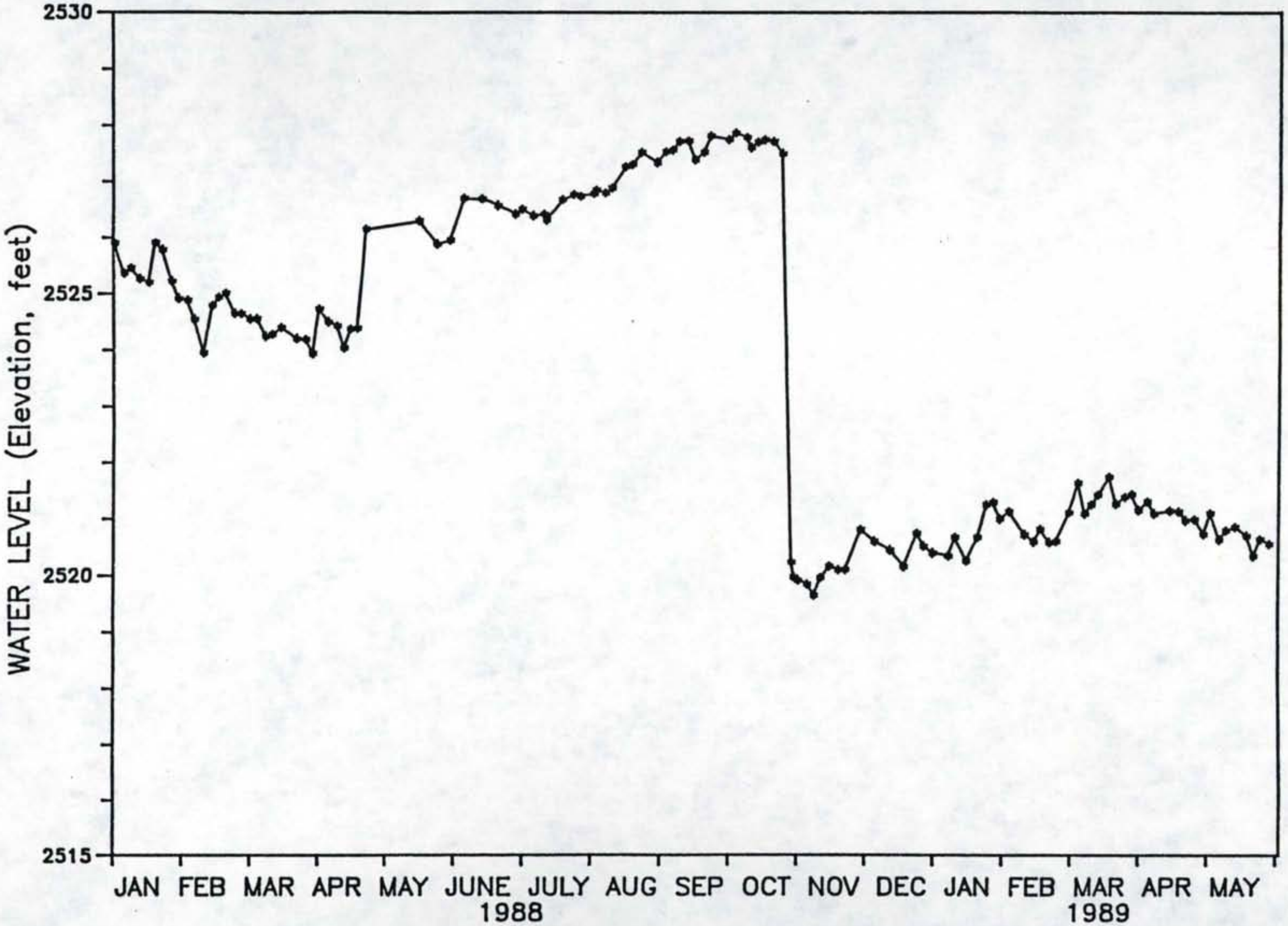


Figure 6. Water Level Record for Well 1-C, GRS

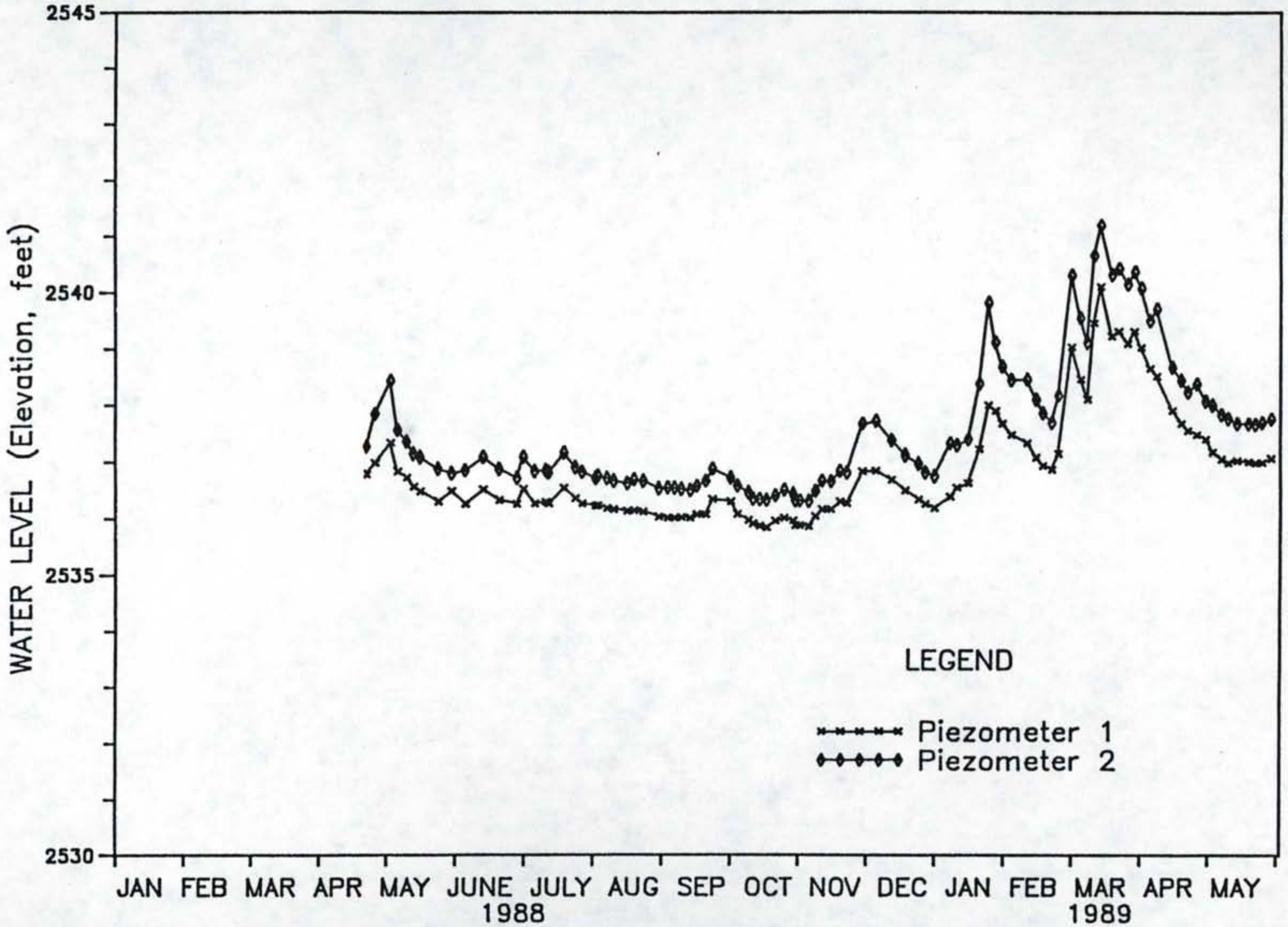


Figure 7. Water Level Records for Piezometer 1 and 2, GRS

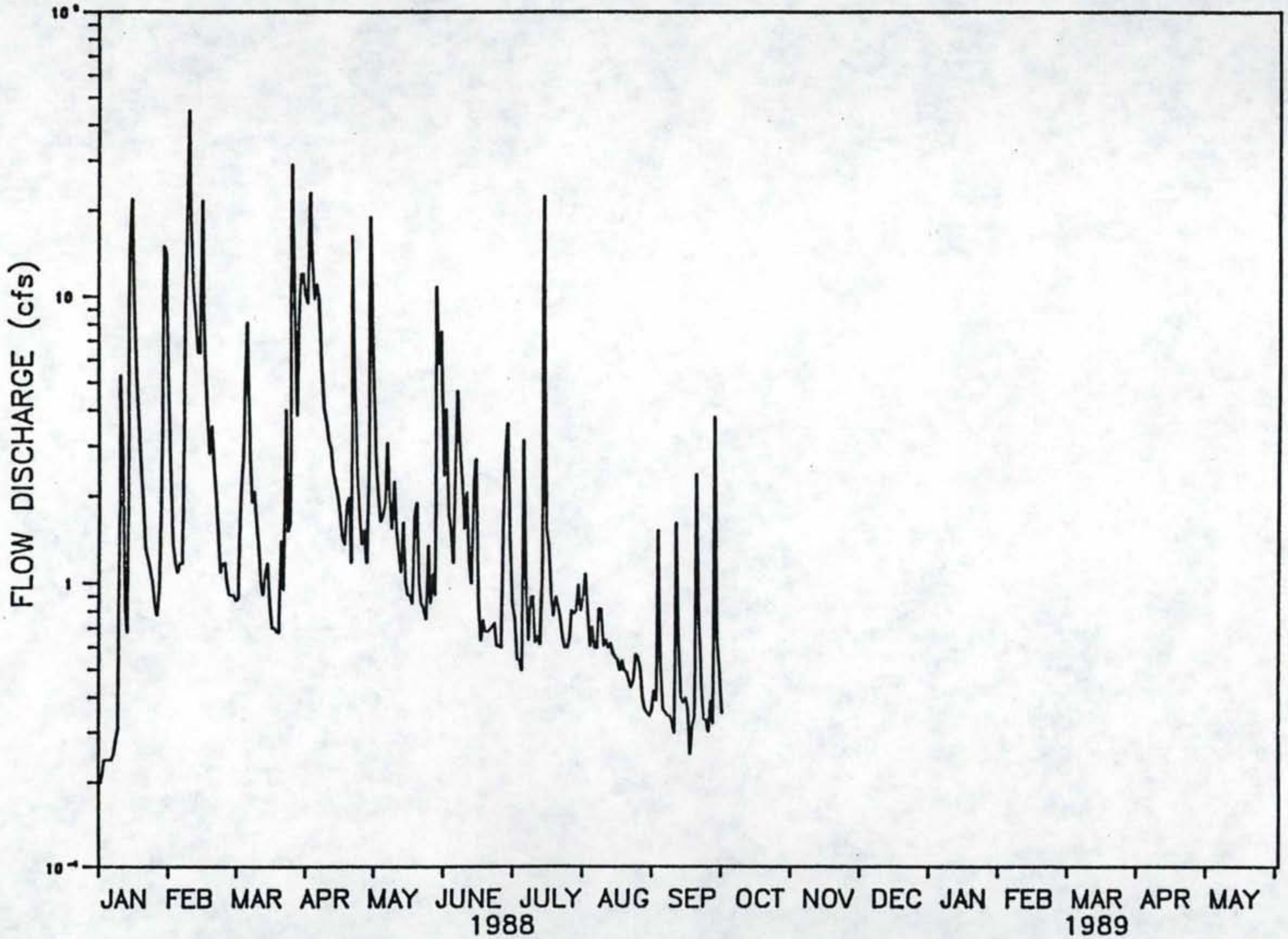


Figure 8. Semi-log Plot of Discharge versus Time for Paradise Creek at GRS, January-September, 1988

spring and to stabilize in the summer and fall without obvious decline;

(c) the hydrograph of well 1-C is significantly different from the other wells; the water level in well 1-C is quite stable during the winter, declines slightly in the spring, and keeps to be stable or slightly rises in the summer and fall; it shows 4 to 6 month time delay as compared to the other wells;

(d) static water levels within well 1-C are generally within 2 feet year around (except two abrupt rise and drop due to the pumping test and well construction); The water levels in other wells have the fluctuations of 3 to 5 feet during the period of record.

The water table levels from the piezometers follow each other very closely (figure 7). The general pattern of these hydrographs is similar to that of the test wells at the eastern part of the site. The piezometer hydrographs are closely correlated to precipitation of the palouse area and the flow of Paradise Creek. The hydrographs for the test wells located at the eastern part of the site similarly correspond with precipitation and streamflow.

Figures 5 and 6 show that there is a discontinuity in the hydrographs of wells 1-B, 1-D and 1-C on October 22, 1988. On this date, the water level of well 1-B rose abruptly about 1 foot while water levels of wells 1-D and 1-C dropped unexpectedly about 1 foot and 7 feet respectively. This was caused by the completion of well 1-B on October 21, 1988. Well 1-B was packed up from bottom to about 80 feet from ground surface with pea gravel, fine sand and bentonite chips in order to install the PVC liner to the open hole. It appears that backfill of lower part of well 1-B sealed part of fractures and reduced the direct connection between the upper and lower aquifers.

Ground Water Recharge and Discharge

Recharge and discharge of the aquifers can be understood from the water level hydrographs (figures 5, 6 and 7). Water levels in wells 1-A, 1-B and 1-E and two piezometers respond to rainfall and snowmelt events with a short time delay of several hours. Well 1-C generally has its water level change several days later. The range of water level change of well 1-C is significantly smaller than that in other wells. The upper aquifer obtains recharge directly from infiltration through the soil during the spring and from stream loss. Rainfall during the other seasons probably does not infiltrate through 6 to 10 feet soil profile to recharge the ground water system.

The lower basalt aquifer appears to get most of its recharge from downward leakage from the upper aquifer. The recharge from leakage is controlled by leaky condition of aquitards and water head difference of two aquifers.

The water level in the upper aquifer is lower than Paradise Creek throughout the year. Most of the stream recharge to the upper aquifer occurs during the peak flow period in the spring.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Basalt stratigraphy and hydrogeology are quite complicated at the GRS. Two aquifers have been identified. The upper aquifer, composed of sand, gravel and weathered basalt, is likely unconfined with a total thickness of 10 to 22 feet. The aquifer is directly below the loam soil and silty clay with its bottom at less than 30 feet from ground surface. It plays an important role in ground water recharge and has a close relation with the Paradise Creek. A basalt flow contact zone forms the lower aquifer. The aquifer is at depth of 65 to 130 feet with a thickness ranging from 1 to 5 feet. It is characterized with great heterogeneity and anisotropy. There are several horizontally extended fractures within the basalt flow interiors above the lower aquifer. These fractures may interconnect the two aquifers.

Hydrographs of the upper aquifer correspond closely with precipitation and with Paradise Creek; the lower aquifer also responds to recharge events. Recharge to the upper aquifer is mainly from infiltration of precipitation and leakage from Paradise Creek, primarily during the spring runoff. Discharge from the upper aquifer probably is to the lower aquifer. Recharge to the lower aquifer is from the upper aquifer.

Recommendations

(1) Hydrologic data collecting should continue at GRS. A longer data record will allow quantitative evaluation of well hydrographs as compared to streamflow.

(2) More hydraulic tests need to be conducted at the GRS for detailed characterization of the aquifer system in the site. Tracer tests should be conducted for understanding of solute transport characteristics of the aquifers.

(3) Completion of existing test wells is very important for further study and confirmation of hydrogeological models. Several of the existing wells interconnect the two aquifers.

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