Ground Water Report No 33

STATE OF OREGON

WATER RESOURCES DEPARTMENT

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Director

Hydrogeology of the Basalt Aquifers near Mosier, Oregon: A Ground Water Resource Assessment.

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DEFINITIONS OF SELECTED TERMS

Acre-Foot: The volume required to cover 1 acre to a depth of 1 foot. This is equal to 43,560 cubic feet or 325,851 gallons.

Aphric: A rock texture in which all crystals are fine grained (less than 1mm).

Aquifer: A water bearing layer of rock that will yield water in a useable quantity to a well or spring.

Alluvium: Clay, silt, sand, gravel or similar material deposited by running water.

Andesite: A fine grained, gray to grayish black volcanic rock, typically containing the minerals plagioclase, augite, biotite, or hornblende.

Anticline: A geologic structure where rock strata (layers) are arched upward.

Basalt: A very fine grained, dark gray to black volcanic rock. The minerals it contains (pyroxene, plagioclase, olivine) are relatively high in iron and magnesium.

Confined Aquifer (Artesian Aquifer): An aquifer bounded above and below by material of distinctly lower permeability than the aquifer itself. Ground water in the aquifer is under sufficient pressure to rise above the level at which it is encountered by a well. The water may or may not rise above land surface in a well.

Fault: A fracture or zone of fractures in the earth's crust along which there has been displacement of one side relative to the other.

Geologic Structure: A general term for features created by movement, bending, tilting, or breaking of rock layers or units.

Ground Water Reservoir: A designated body of standing or moving ground water having exterior boundaries which may be ascertained or reasonably inferred [ORS 537.515(4)].

Hyaloclastite: A deposit formed by lava shattering into small glassy angular fragments as it flows into water or water saturated sediments.

Hydraulic Conductivity: A measure of the capacity of a rock to transmit water. It is expressed as the rate (volume/time) at which water moves through a unit area of an aquifer under a unit hydraulic gradient. Its value depends upon the physical properties of the water and the aquifer. Larger values means water can move more easily.

Hydraulic Gradient: A measure of the slope of the potentiometric surface. It is the change in total head per unit distance measured in the direction of steepest change. This gradient drives ground water flow.

$$\text{Hydraulic Gradient} = \frac{(\text{Total Head at Point A}) - (\text{Total Head at Point B})}{\text{Distance Between A \& B}}$$

Lithology: The description of rocks on the basis of color, mineral composition, and grain size.

Paleomagnetism: The intensity and direction of residual magnetization in ancient rocks. The magnetic particles in the rock were oriented by the earth's magnetic field as it existed when the rock was formed.

Phenocryst: A crystal conspicuously larger than most crystals in the rock.

Phyric (porphyritic): A basalt rock texture in which larger crystals (phenocrysts) are set in a matrix of finer grained crystals and glass.

Pillow - Palagonite (Pillow Breccia): Pillow lava surrounded by yellow or orange minerals formed as the pillow lava weathers. Pillow lavas are lobes of lava material stacked one upon another resembling a pile of bed pillows. They are formed by lava flowing into water.

Potentiometric Surface: A surface that represents the total head in an aquifer. It is defined by the elevation at which water stands in cased wells that penetrate the aquifer.

Storativity: The volume of water released from or added to storage in a unit prism of a confined aquifer per unit change in total head. Water released is due to compaction of the aquifer and expansion of water when pressure is relieved. Water added is due to expansion of the aquifer and compaction of water associated with an increase of pressure.

$$\text{Storativity} = \frac{\text{(volume of water released) (aquifer thickness)}}{\text{(volume of aquifer with a unit area base)(unit decline of total head)}}$$

Stratigraphy: Branch of Geology which treats the formation, composition, sequence and correlation of rock layers.

Syncline: A geologic structure where rock layers are bent downward into a trough.

Thrust Fault: A fault with a dip less than or equal to 45° over most of its extent. Rock on one side appears to have moved upward and over the rocks on the other side. Horizontal compression is usually responsible for thrust faults.

Total Head: Total Head = Elevation Head + Pressure Head

Elevation Head: The elevation at a point of interest in an aquifer relative to a measuring point (i.e. sea level)

Pressure Head: The height of a column of water that can be supported by the pressure at a point of interest in an aquifer.

Transmissivity: A measure indicating how easily water can move through an aquifer.

Transmissivity = (hydraulic conductivity)(aquifer thickness)

Tuffaceous: A rock containing up to 50 percent volcanic ash.

Vesicular: A rock texture characterized by abundant small openings formed by gas bubbles trapped during the solidification of lava.

Volcanic Breccia (agglomerate): A rock composed of angular volcanic fragments (larger than 64mm) set in finer volcanic material.

Volcaniclastic: A rock composed of volcanic fragments.

The well and spring numbering system used in Oregon is based on the rectangular system used for subdivision of public land. Each well number indicates the geographic location of the well and describes the township, range, and section. For example, the well number 2N/12E-20aab or T2N/R12E-20aab indicates a well located within Township 2 North, Range 12 East, and Section 20. The letters following the section number indicate the well location within the section as shown in Figure 1. The first letter (a) represents the quarter section (160 acres), the second letter (a) the quarter-quarter section (40 acres), and the third letter (b) the quarter-quarter-quarter section (10 acres). If more than one well is located within a 10-acre tract, a series number is added following the third letter to distinguish each well.

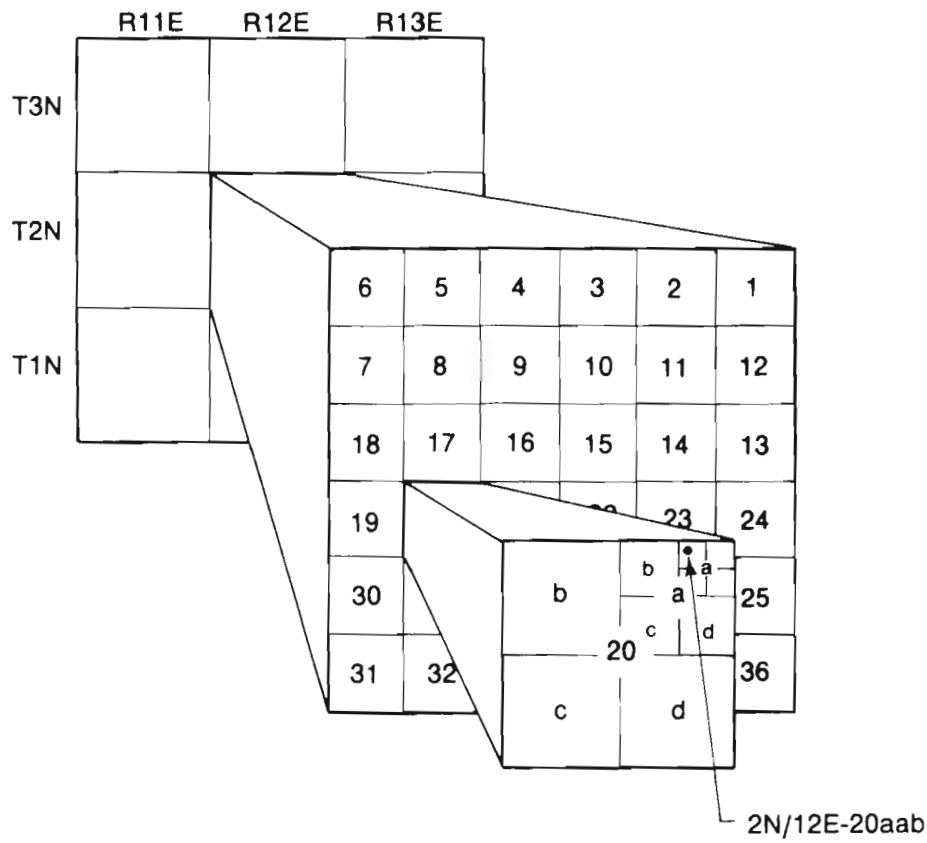

Figure 1. WELL NUMBERING SYSTEM

Table 1. Measurement Conversions

	Multiply	By	To Obtain
Length	feet	3.048×10^{-1}	Meter
	mile	1.609	Kilometer
Area	$feet^2$	9.290×10^{-2}	$Meter^2$
	acre	4.047×10^{3}	$Meter^2$
	acre	4.356×10^{4}	$Feet^2$
	$mile^2$	2.590	$Kilometer^2$
	$mile^2$	640	Acre
Volume	$feet^3$	2.300×10^{-5}	acre-feet
	$feet^3$	2.832×10^{-2}	$Meter^3$
	$feet^3$	7.482	U.S. Gallon
	$feet^3$	28.320	Liter
	$meter^3$	2.642×10^{2}	Gallon
Discharge	U.S. gal/min	1.440×10^{3}	U.S. gal/day
	U.S. gal/min	1.930×10^{2}	ft^3/day
	U.S. gal/min	2.230×10^{-3}	ft^3/second
	U.S. gal/min	4.420×10^{-3}	acre-feet/day
	U.S. gal/min	6.309×10^{-5}	m^3/day
Hydraulic Conductivity	ft/second	3.048×10^{-1}	m/second
	ft/second	6.458×10^{5}	U.S. gal/day/ft
Transmissivity	ft^2/second	9.290×10^{-2}	m^2/second
	ft^2/second	6.460×10^{5}	U.S. gal/day/ft

HYDROGEOLOGY OF THE BASALT AQUIFERS NEAR MOSIER, OREGON:

A GROUND WATER RESOURCE ASSESSMENT

by

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Gerald H. Grondin

ABSTRACT

The Mosier study area is located adjacent to the Columbia River in the northwest corner of Wasco County, in north-central Oregon. The area encompasses approximately 35 square miles in the transitional zone between the High Cascades to the west and the Columbia Plateau to the east. The Mosier area receives an average yearly rainfall of 23 inches.

Northwest-facing slopes predominate in the area. The regional geology controls most slope directions and angles. The Columbia River and three small tributaries drain the area.

Unincorporated areas of the Mosier study area are designated for five and ten acre rural residential, agricultural, and forest land uses. Fruit grown on nearly 1,240 acres is the primary agricultural activity in the Mosier area. Cherry trees are planted on most of the orchard acreage.

Aquifers in five distinct stratigraphic units are identified in the Mosier study area. Ground water occurs in glaciofluvial deposits, within permeable layers of the Chenoweth Formation, and within three aquifers in the Columbia River Basalt Group. The basalt aquifers are informally called the Pomona, Priest Rapids and Frenchman Springs aquifers. The Pomona and Priest Rapids aquifers are the major source of ground water in the Mosier area.

The Columbia Hills anticline and Mosier syncline control the regional ground water flow direction. Local ground water movement is also influenced by an east-northeast trending thrust fault and a northwest trending strike-slip fault.

Two aquifer tests were conducted, and the data collected were analyzed. Transmissivity values calculated for the Pomona aquifer range from 11,500 to 24,000 ft^2/day and storativity values calculated range from 0.00004 to 0.00009. Transmissivity values calculated for the Priest Rapids aquifer range from 9,100 to 29,900 ft^2/day.

Water level declines are documented in some wells isolating the Pomona and Priest Rapids aquifers. The current rate of decline for the Pomona aquifer is 6.9 feet per year. The current rate of decline for the Priest Rapids aquifer is 3.3 feet per year. Recharge replaces approximately 90 percent of the discharge from the Priest Rapids aquifer, and recharge replaces approximately 82 percent of the discharge from the Pomona aquifer. Over 27 percent of the recharge to the Pomona aquifer may come from the Priest Rapids aquifer through wells interconnecting the two aquifers.

Ground water samples were collected from each aquifer and the natural water quality was chemically analyzed. No primary (health related) drinking water standards were exceeded. Two secondary (aesthetic) drinking water standards (iron and zinc) were exceeded in two wells.

INTRODUCTION

PURPOSE AND SCOPE

This is the first of a series of studies to be conducted through the Oregon Water Resources Department's Ground Water Resource Assessment Program. The studies are conducted in an effort to identify and describe all of Oregon's ground water resources. The Ground Water Resource Assessment Program was authorized in 1985, in response to ORS 537.665 and the recognition that responsible management of ground water quantity and quality requires a fundamental knowledge of the resource.

The Mosier area was chosen for the initial study because of an immediate need to define an apparent water supply problem in that area. Water level declines are documented from measurements taken in observation wells near Mosier for the past 24 years. The investigation of the Mosier area was designed to address the declining water level issue while also describing the overall ground water resources of the area. The major emphases of the Mosier study were to:

1. identify the aquifers in which the declines are occurring;
2. describe the local ground water flow system;
3. describe the geologic and hydrologic characteristics of the aquifers;
4. describe the ground water chemistry.

Early in the study, it was recognized that:

1. water level declines are occurring within two basalt aquifers underlying the Mosier area;
2. the two basalt aquifers are the primary source of ground water in the Mosier area.

As a result, this study focused upon characterizing geologic and hydrologic parameters of two basalt aquifers underlying the Mosier area.

LOCATION AND GEOGRAPHY

The Mosier study area is located in the northwest corner of Wasco County, in north-central Oregon (Figure 2). The area encompasses approximately 35 square miles in the transitional zone between the High Cascades to the west and the Columbia Plateau to the east. As indicated on Plate 1, the study area is located within Township 2 North, Range 12 East, and the eastern half of Range 11 East.

The area is drained by the Columbia River and three small tributaries. Only one tributary, Mosier Creek, flows year around. Two intermittent streams drain the area; Rock Creek near the western boundary and Rowena Creek, which forms part of the eastern boundary of the study area.

The topography of the area is characterized by predominately northwest facing slopes. The directions of the slopes are mainly controlled by the regional geology. Elevations within the study area range from about 100 feet near the Columbia River to over 2300 feet at Wasco Butte. Most slopes dip between 3

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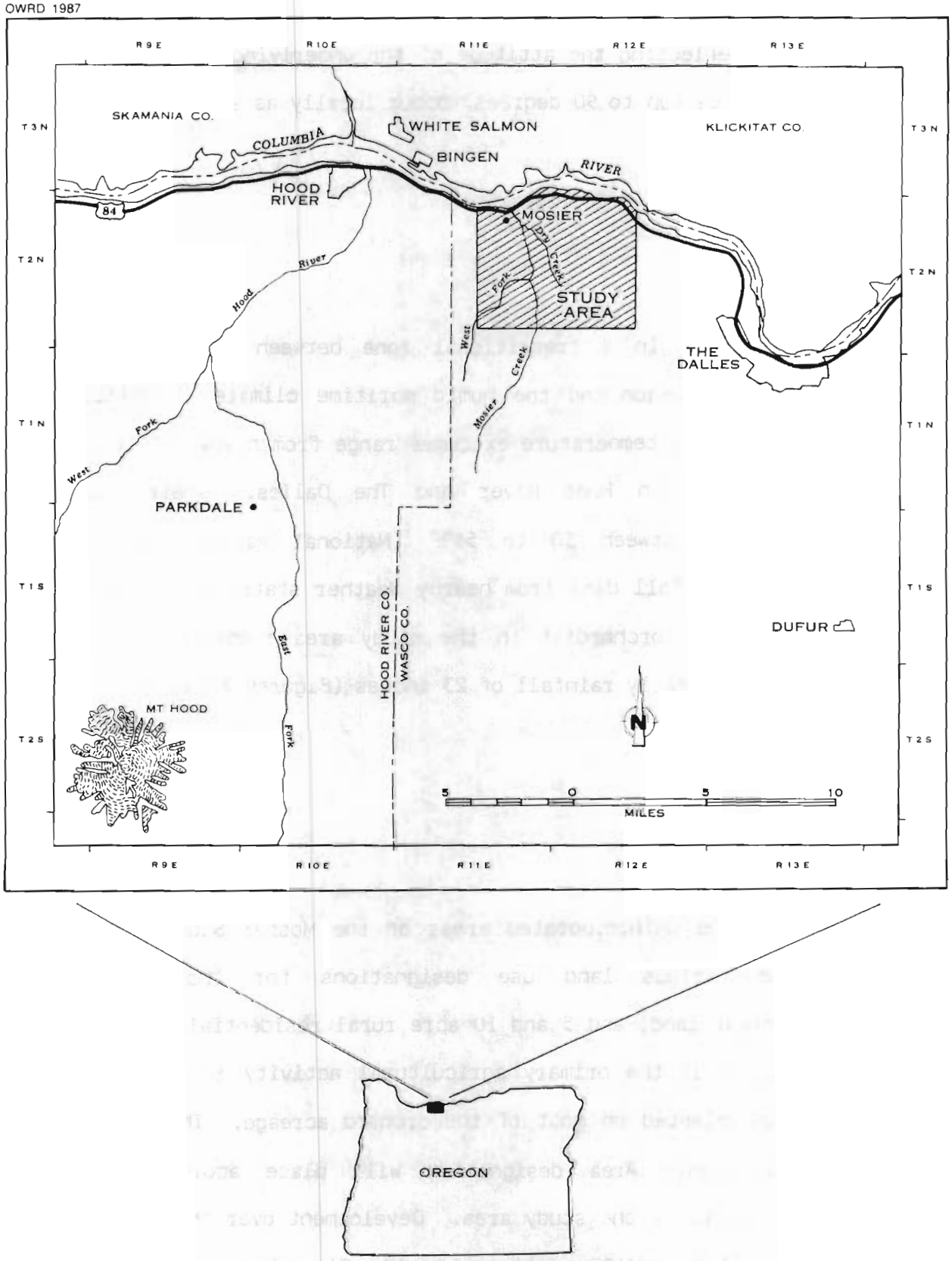

Figure 2. LOCATION MAP OF THE MOSIER STUDY AREA

and 11 degrees, reflecting the attitude of the underlying rock surfaces. Much greater slope angles (up to 90 degrees) occur locally as a result of erosion.

CLIMATE

The study area lies in a transitional zone between the arid continental climate of Eastern Oregon and the humid maritime climate of Western Oregon (Grady, 1983). Yearly temperature extremes range from below 0°F to over 100°F at weather stations in Hood River and The Dalles. Their yearly mean temperatures range between 50 to 55°F (National Weather Service Data). Interpolation of rainfall data from nearby weather stations and precipitation data collected by an orchardist in the study area suggests the study area receives an average yearly rainfall of 23 inches (Figures 3 and 4).

LAND USE

Land use within the unincorporated areas of the Mosier Study Area is quite variable. The various land use designations for the area include: agriculture, forest land, and 5 and 10 acre rural residential. Fruit grown on nearly 1,240 acres is the primary agricultural activity in the Mosier area. Cherry trees are planted on most of the orchard acreage. The Columbia River Gorge National Scenic Area designation will place additional land use restrictions in parts of the study area. Development over the next 5 years is mainly anticipated in 2N/12E sections 16, 17, 21 and 22 (James W. Johnson, personal communication, 1987). The new development will be mostly on 10 acre rural residential plots.

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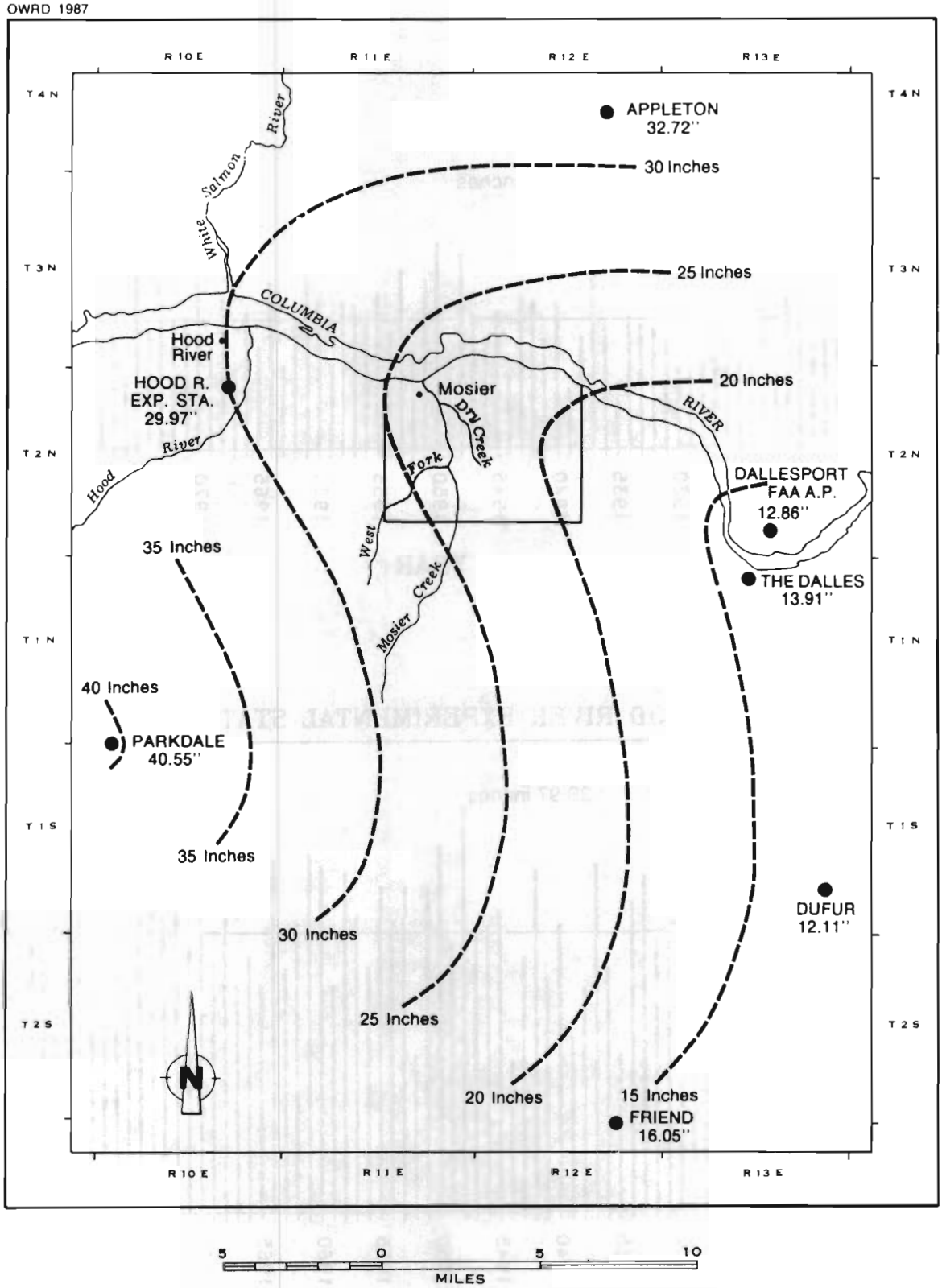
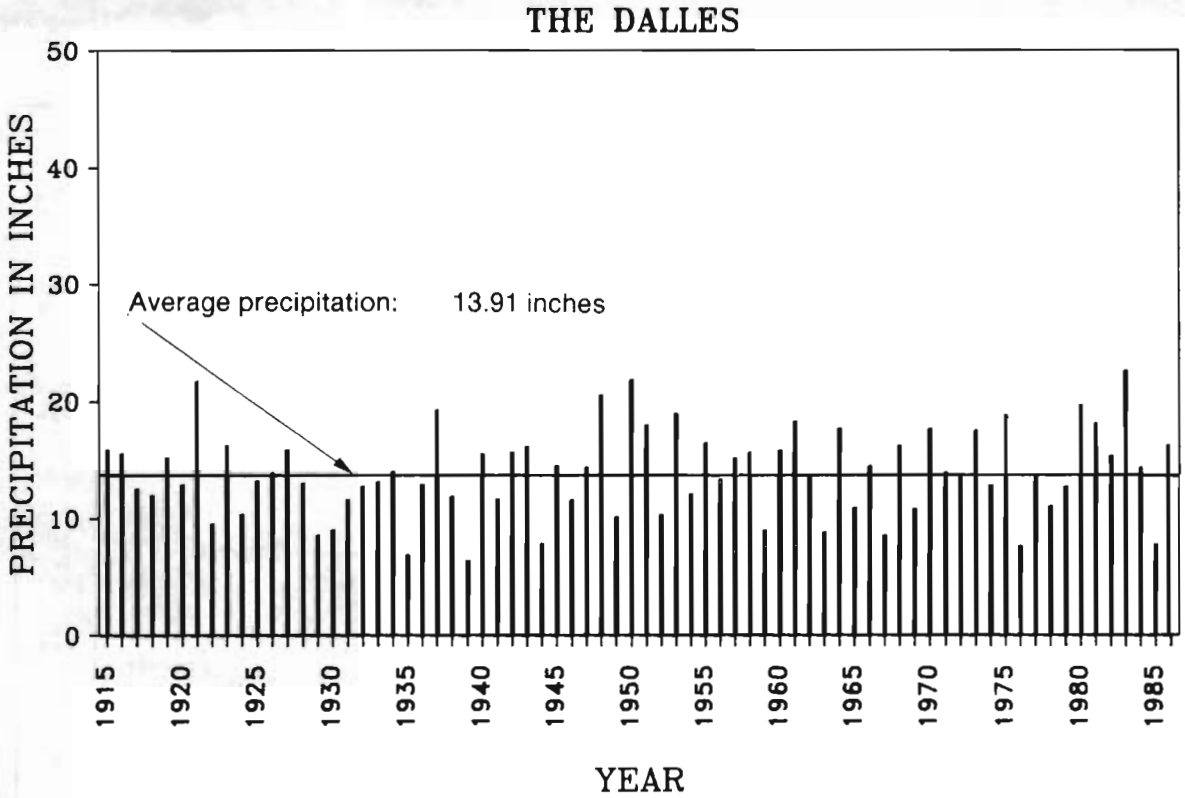


5 0 5 10
MILES

Note: Map based upon National Oceanic and Atmospheric Administration Data

Figure 3. ISOHYETAL MAP SHOWING MEAN ANNUAL PRECIPITATION FOR MOSIER AND SURROUNDING AREAS



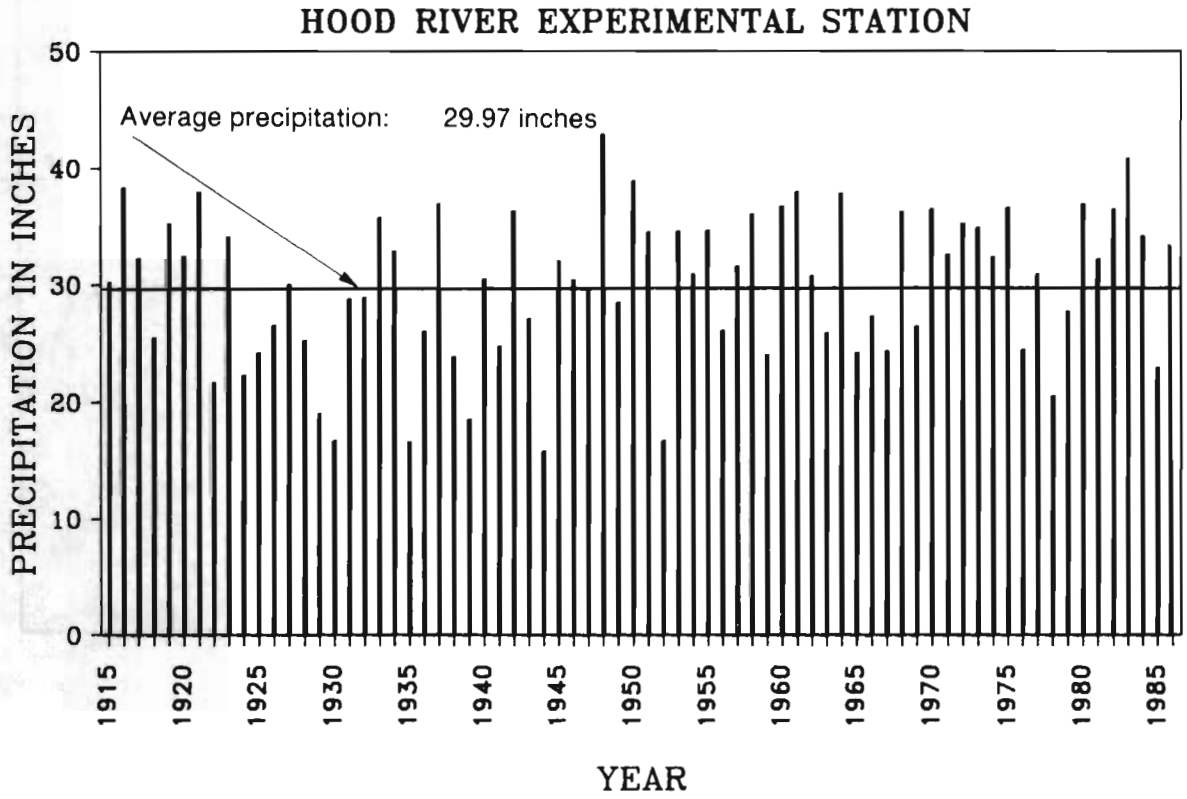


Figure 4. ANNUAL PRECIPITATION AT THE DALLES AND HOOD RIVER EXPERIMENTAL STATION (1915-1986)

GROUND WATER DEVELOPMENT

INTRODUCTION

The historical development of ground water in the Mosier area can be traced from the mid-1920's to the present (Figure 5). The development trend shown on Figure 5 is based upon well log and water right records at the Water Resources Department. According to the recorc, approximately 290 water wells are located within the Mosier study area. Plate 1 shows the location of 139 of those wells. Over ninety percent of the wells in the study area were drilled after 1970 and fifty percent were constructed after 1978.

A large percentage of the wells located in the Mosier area are domestic supply wells. Only 25 of the wells inventoried are used for irrigation, group domestic, or municipal supply.

TREND OF DEVELOPMENT

Ground water development near Mosier began in or near the orchard tract. Approximately seventy percent of the wells drilled prior to 1970, were constructed in 2N/12E sections 5, 6, 7, 8 and 18. Those wells were drilled for both irrigation and domestic use. During the mid to late 1970's, ground water development increased throughout the study area, particularly in the vicinity of Seven Mile Hill (2N/12E-22). Section 22 has more than twice the number of wells (52 wells) as the next most densely developed section

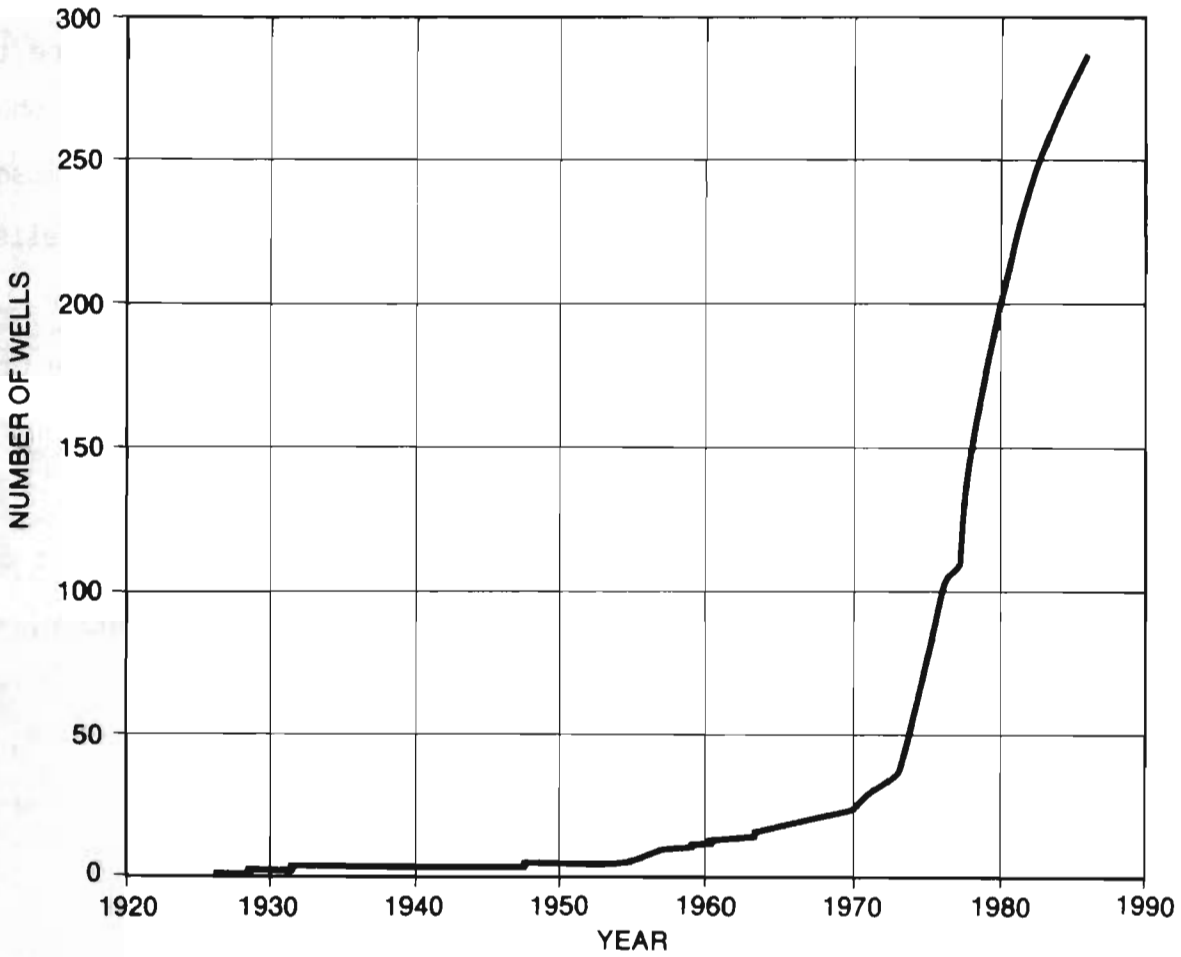


Figure 5. CUMULATIVE NUMBER OF WELLS COMPLETED WITHIN THE MOSIER STUDY AREA BETWEEN 1926 AND 1986

(2N/12E-16). With the exception of two wells in section 22, all of the wells are used for domestic supply. Several unused wells are also located in section 22.

CURRENT GROUND WATER USE

Approximately 250 households in the area rely on ground water from domestic wells for their water supply. The City of Mosier supplies water from a well to approximately 130 additional households in the area. The average household consumption of water in the study area is approximately 790 gallons per day (290 gallons per day per person).

Nearly 500 acres of orchard tract in 2N/12E sections 7 and 18 receive irrigation water from ground water sources. Approximately 90 acres of orchard tract receive supplemental irrigation from ground water sources. A 75 acre orchard tract will soon switch from dry land farming to irrigation farming using ground water. The remaining 275 acres of dry land orchards could also switch to irrigation farming in the future.

Most irrigators water their trees three times per year. They water once in the spring and twice after harvest. Irrigators estimate they apply 5 to 7 inches of water per acre each watering. Agricultural extension agents recommend applying 36 inches of water per acre each year.

AQUIFER RESPONSE TO GROUND WATER DEVELOPMENT

Utilization of water stored in some aquifers has caused water level declines in wells penetrating the aquifers. Figure 6 illustrates the water level decline that has occurred in a well since 1963. The water level in Well 2N/12E-7ada declined approximately 2.0 feet per year from 1963 to 1971. Increased demand accelerated the decline to approximately 6.5 feet per year from 1976 to 1986. The accelerated water level decline in Well 2N/12E-7ada corresponds to the increased number of wells drilled after 1970 (Figure 5) and the increased acreage permitted for irrigation after 1970 (Figure 7). If the present trend continues, pumping levels in 7ada could intercept the aquifer within five years. That means artesian conditions at 7ada would be lost, and the aquifer there could be drained.

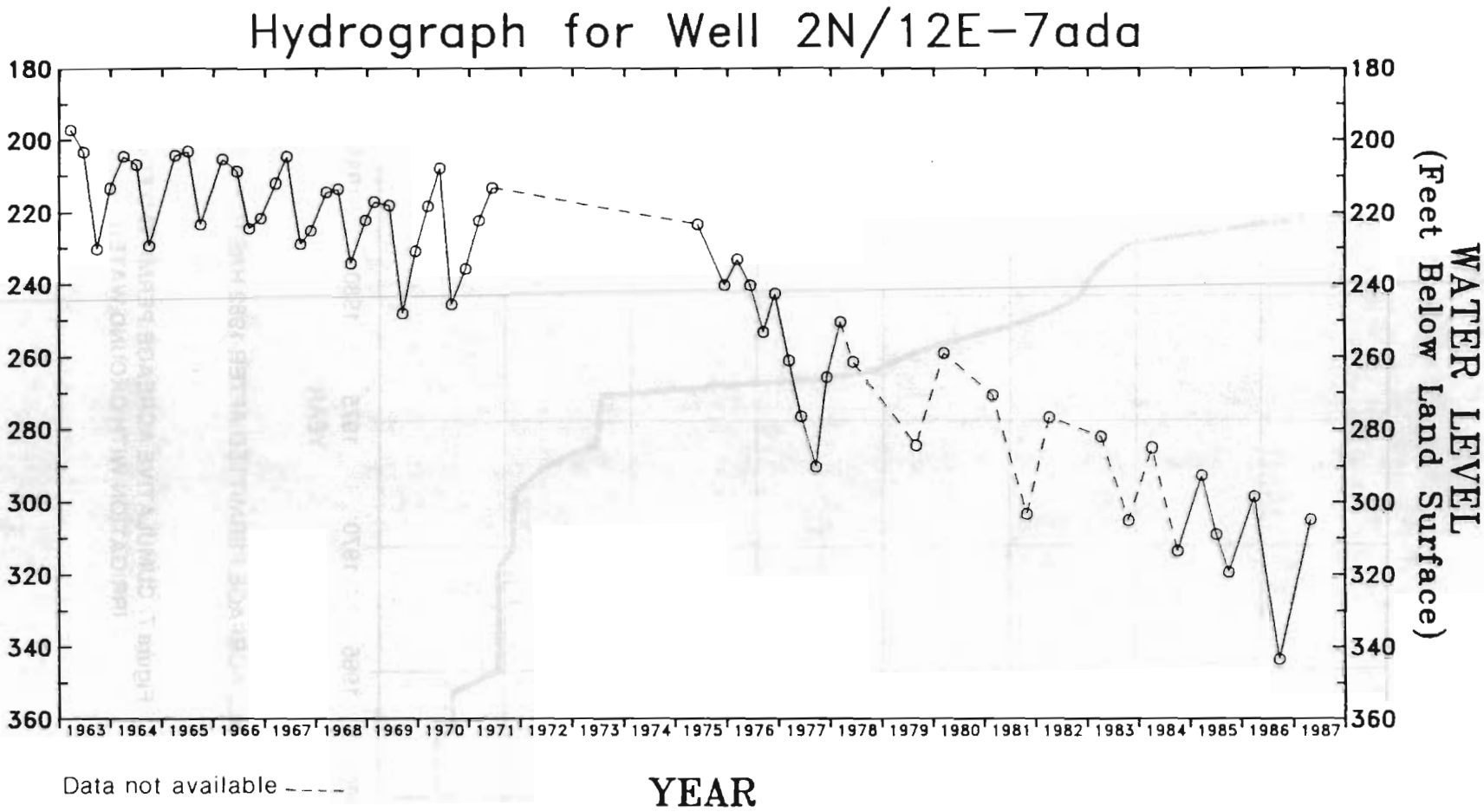
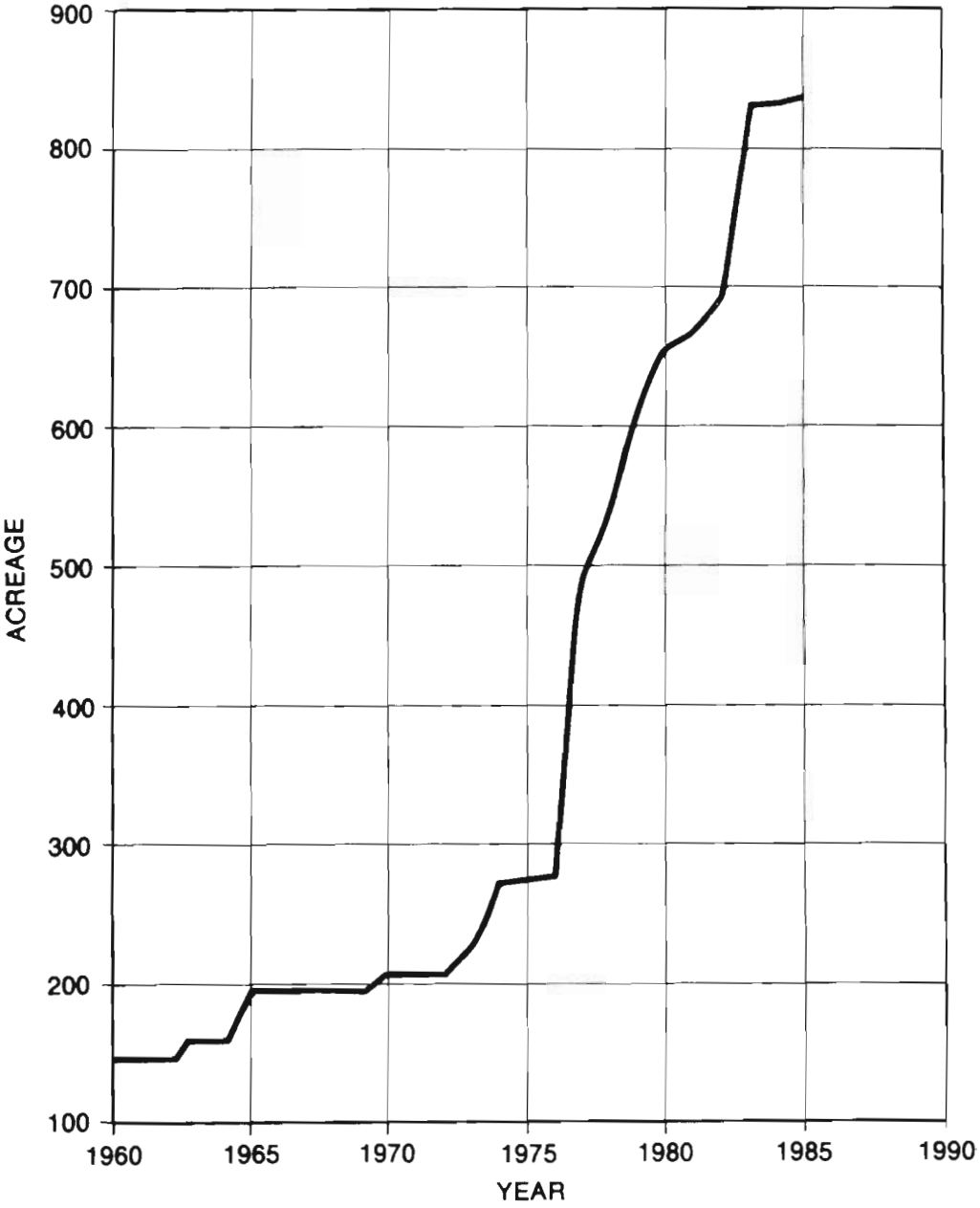


Figure 6. WELL HDYROGRAPH FROM 1963 TO 1987



(NOT ALL ACREAGE PERMITTED AFTER 1982 HAS BEEN IRRIGATED)

Figure 7. CUMULATIVE ACREAGE PERMITTED FOR IRRIGATION WITH GROUND WATER

GEOLOGY

INTRODUCTION

The occurrence and movement of ground water in an area is controlled by the geology. A thorough understanding of the geologic structure and stratigraphy is necessary to evaluate the ground water resource.

The stratigraphy of the Mosier area consists of multiple layers of basalt, mostly overlain by consolidated and unconsolidated layers of volcanic sediment. Both the basalt and volcanic sediment are locally overlain with unconsolidated silt, sand, and gravel. The geologic ages and formal geologic nomenclature for the stratigraphic units described in this report are shown on Figure 8.

Ground water flow within the various stratigraphic units near Mosier is influenced by both regional and local tectonics. Folds and faults within the Mosier area have regionally tilted and locally disrupted the older, once predominately horizontal, lava flows and sedimentary deposits.

Several previous geological and hydrogeological publications of the region include discussions of the geology of the Mosier area (Piper, 1932; Newcomb, 1963, 1969, Swanson and others, 1981; Bela, 1982; Grady, 1983). Geologic maps by Newcomb (1969), and Swanson and others (1981) were especially useful during this investigation.

TIME-STRATIGRAPHIC UNITS			ROCK-STRATIGRAPHIC UNITS	
ERA	PERIOD	EPOCH		
CENOZOIC	QUATERNARY	*		ALLUVIUM
		PLEISTOCENE		GLACIOFLUVIAL DEPOSITS
	TERTIARY	PLIOCENE	DALLES GROUP	? ? CHENOWETH FORMATION
		MIOCENE	COLUMBIA RIVER BASALT GROUP	? ? SADDLE MOUNTAINS BASALT Pomona Member WANAPUM BASALT Priest Rapids Member Roza Member Frenchman Springs Member GRANDE RONDE BASALT

* HOLOCENE

Figure 8. GEOLOGIC AGES AND NOMENCLATURE OF STRATIGRAHIC UNITS WITHIN THE MOSIER STUDY AREA

The geologic map in this report (Plate 2) was prepared with the aid of aerial photographs, analyses of numerous water well reports, and reconnaissance field mapping. The map includes some reinterpretation of the geologic work published by R.C. Newcomb, (1969) and J.L. Anderson (in Swanson and others, 1981).

STRATIGRAPHY

Columbia River Basalt Group

Basalts of the Columbia River Group are the most abundant rock type in the Mosier area and important in terms of the occurrence of ground water. Near Mosier, the Columbia River Basalt Group includes three formations: Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Only the Wanapum Basalt and Saddle Mountains Basalt are pertinent to this study, and are described herein.

Wanapum Basalt The Wanapum Basalt near Mosier consists of three members (Figure 8): Frenchman Springs, Roza, and Priest Rapids (Swanson and others, 1981). The Frenchman Springs and Priest Rapids Members are the only members important as aquifers in the Mosier area.

The Frenchman Springs Member exposed near Mosier is represented by a relatively thin aphyric flow unit overlying a very vesicular phyric flow unit. A similar appearing sequence near The Dalles has been identified as the basalt of Sentinal Gap overlying basalt of Sand Hollow (Marvin H. Beeson, personal communication, 1987). Ground water found within the upper Frenchman Springs Member probably occurs within the very vesicular flow unit.

Both units have normal paleomagnetic polarity, as do all flow units of the Frenchman Springs Member. The areal distribution of the Frenchman Springs Member near Mosier is shown on Plate 2.

The Roza Member is an important marker unit, but apparently is not important as an aquifer near Mosier. The Roza Member is represented by one flow in the area. The abundance of relatively large (less than 1 cm) and uniformly distributed plagioclase phenocrysts makes identification of the flow relatively easy. The Roza Member can also be identified by its rather unique transitional paleomagnetic polarity. In addition, distinct short, stubby colonnade and slender, fanning entablature-like jointing patterns are locally diagnostic of the Roza Member. The Roza Member is present only near Rowena Creek; so apparently, it is not important as an aquifer in the study area. The areal distribution of the Roza Member near Mosier is shown on Plate 2.

The Priest Rapids Member is a very important water bearing unit near Mosier. Regionally, the Priest Rapids Member consists of two rock chemical types, called the Lolo and Rosalia chemical types (Swanson and others, 1979). Both chemical types have been tentatively identified in the Mosier area based on hand specimen lithology. The upper, Lolo chemical type is characteristically dark gray to black, medium to coarse grained, and occasionally contains phenocrysts. In the Mosier area, rock identified as Lolo chemical type often exhibits a platy jointing pattern. The lower, Rosalia chemical type is dark gray to black, fine to medium grained, and aphyric to microphyric. The Rosalia commonly exhibits a blocky jointing pattern where it has been tentatively identified near Mosier.

Hyaloclastites and a pillow-palagonite complex underlie the Rosalia Flow near Mosier and in The Dalles (Tolan and others, 1984). Hyaloclastite and pillow-lava form as a result of hot lava flowing into water. Across the Columbia River from Mosier, the Rosalia Flow is underlain by a hyaloclastite deposit of the same chemical type (Tolan and others, 1984). At two localities along Mosier Creek, a similar appearing pillow-palagonite complex has been identified. The pillow-palagonite complex is thought to represent the base of the Priest Rapids Member in the Mosier area.

The Priest Rapids Member is distinguished from the other Wanapum basalt members by its reversed paleomagnetic polarity. The areal distribution of the Priest Rapids Member near Mosier is shown on Plate 2.

Saddle Mountains Basalt The Saddle Mountains Basalt is represented by the Pomona member in the Mosier area. The Pomona is the only member of the Saddle Mountains Basalt found near the western edge of the Columbia Plateau Region (Swanson and others, 1981). The Pomona Member is an important aquifer in the Mosier area.

The Pomona Member is light to dark gray, fine grained, and porphyritic. The phenocrysts are small (less than 0.5 cm) and occur in both equant and acicular form. This bimodal crystal habit is somewhat diagnostic of the Pomona Member near Mosier. Pomona Member rocks described farther to the west display a similar crystal habit (Anderson, 1980). The Pomona Member is easily recognized in outcrop by its slender, wavy entablature-like jointing pattern. Although the wavy entablature-like jointing pattern is most common in the Mosier area, more massive upper and lower colonnades are also locally exposed.

The upper and lower contacts of the Pomona Member are observed in the Mosier area. The upper contact of the Pomona Member with the overlying Chenoweth Formation is identified at two locations near Mosier. Red and black vesicular flow tops locally exhibiting ropy textures characterize the top of the Pomona at both sites.

The base of the Pomona Member exhibits varying degrees of vesicularity throughout the Mosier area. A vesicular zone up to 20 feet thick was identified at the base of the Pomona Member at two localities near Mosier. Based on water well report information, the thick vesicular zone is limited in areal extent. Wells within 2N/11E, sections 12 and 13, and 2N/12E, sections 7, 8, and 18 presumably penetrate the same vesicular zone. Locally, the vesicular zone is sufficiently weathered or fractured to serve as an aquifer. A weathered zone or interbed is typically present between the Pomona and Priest Rapids Members. The weathered zone is exhibited by a partially decomposed rock contact along Mosier Creek Road near the West Fork of Mosier Creek. The interbed is primarily a weathered volcanic ash deposit where it is exposed along Mosier Creek in 2N/12E, section 19. According to water well report information, the interbed varies from 0 to 170 feet in thickness. More commonly, the interbed is 30 to 50 feet thick. The interbed appears to occur locally within the same 4 to 6 square mile area as the thick vesicular zone. The areal distribution of the Pomona Member in the Mosier area is shown on Plate 2.

Chenoweth Formation

The Chenoweth Formation (also known as Dalles Formation) directly overlies the Columbia River Basalt Group in the Mosier area (Farooqui and others, 1981).

The Chenoweth Formation is one of five formations recently included in the Dalles Group (Farooqui and others, 1981). The Chenoweth Formation consists of volcaniclastic material probably derived from the vicinity of the present Cascade Mountains.

The Chenoweth Formation in the Mosier area consists primarily of volcanic breccia, tuffaceous sandstone, and tuffaceous siltstones. The volcanic breccia consists of large (1-5 feet) angular, andesitic blocks within a fine to coarse tuffaceous matrix. The total thickness of the Chenoweth Formation ranges from zero to over 500 feet in the Mosier area. The areal distribution of the Chenoweth Formation near Mosier is shown on Plate 2.

Glaciofluvial Deposits

Glaciofluvial deposits of sand, gravel, and boulders locally overlie the Chenoweth Formation and Columbia River Basalt Group in the Mosier area. These deposits are the result of the so called Missoula Floods, dated at approximately 13,000 years ago (Baker, 1978). During the last period of glaciation a major drainage in western Montana was impounded behind a lobe of one of the large continental glaciers (Baker, 1978). This ice impoundment periodically failed sending enormous volumes of water down the Columbia drainage, known as the Missoula Floods. Unsorted, massive to poorly bedded sand and gravel with occasional cobbles and boulders characterize these deposits near Mosier. Exposed deposits near Mosier are commonly cross-bedded.

The open-work texture of the deposits make it a good aquifer where it is saturated. The thickness of the glaciofluvial deposits range from zero to approximately 300 feet near Mosier. The areal distribution of the

glaciofluvial deposits in the Mosier area is shown on Plate 2.

Alluvium

Alluvial deposits are found along portions of all streams, and locally overly all bedrock units. The alluvial deposits probably grade into the glaciofluvial deposits where both are present. In the Mosier area, alluvium consists of unconsolidated silt, sand, and gravel. These deposits occur locally as stream channel deposits, flood plain deposits, and terrace deposits.

Along Mosier Creek, the alluvium occurs mainly as stream channel deposits upstream from the West Fork Mosier Creek confluence. Downstream from the confluence, the alluvial deposits occur mainly as flood plain and terrace deposits.

The areal distribution of the alluvial deposits near Mosier are shown on Plate 2. The alluvium is shown only where the deposits are areally and vertically extensive enough to cover the bedrock units.

GEOLOGIC STRUCTURE

The northwest slopes of the Mosier countryside are largely influenced by the northeast trending geologic structures in the area. The combination of the Columbia Hills anticline and the Mosier syncline control the overall geometry and orientation of the land surface and underlying stratigraphic units. The Columbia Hills anticline (also locally called the Ortley anticline) trends approximatey N 45°E and forms the topographic highs from Wasco Butte to the

crest of Seven Mile Hill near Ortley (Plate 2). As a result of the Columbia Hills anticline, the stratigraphic units strike approximately N 40° - 45° E and dip about 4 degrees to the northwest; steepening to approximately 10 degrees near the axis of the anticline. The regional dip in the Mosier area is illustrated on the structure contour map, Plate 3.

The axis of the Mosier syncline forms the lower reach of Rock Creek and a segment of the Columbia River Gorge near Mosier. A north-northeast trending thrust fault apparently prevents ground water flow from moving freely from the Columbia Hills anticline into the Mosier syncline. The thrust fault is informally referred to in this report as the Rocky Prairie thrust fault.

The Rocky Prairie thrust fault was originally described as a tightly folded anticline with associated flexure slippage (Newcomb, 1963, 1969). The structure was later interpreted as a thrust fault (Swanson and others, 1981). Field observations and stratigraphic interpretations of water well report data support the latter interpretation. Geologic section C-C' on Plate 2 illustrates what the Rocky Prairie thrust fault may look like in cross sectional view at that location. The trace of the Rocky Prairie thrust is also shown on Plate 2.

The trace of the Rocky Prairie thrust fault has been superimposed onto the structure contour map (Plate 3) to further illustrate the local disruption of stratigraphic units. The data suggest a major discontinuity is present in the vicinity of the fault trace, although the data are not sufficient to define the precise location of the fault.

A northwest trending fault also influences the flow of ground water in the Mosier area. The fault is informally called the Rowena Creek fault in this report (Plate 2). J.L. Anderson (Swanson and others, 1981) originally mapped the Rowena Creek fault. The location of the Rowena Creek fault on the Reconnaissance Geologic Map is based upon the data presented on the structure contour map (Plate 3). The structure contour map shows an apparent 100-feet vertical offset across the fault. A component of horizontal (strike-slip) movement has also been indicated for this fault (Swanson and others, 1981). The Reconnaissance Geologic map also shows the Rowena Creek fault as possibly branching in the vicinity of the Rocky Prairie thrust fault. Evidence for the branching comes from a strong airphoto lineament observed in that vicinity and from several data points presented on the structure contour map.

The effect of the geologic structures upon ground water flow can be inferred from the Potentiometric Surface Map (Plate 4). The next section discusses those effects.

HYDROGEOLOGY

INTRODUCTION

Geologic conditions control ground water occurrence and the hydraulic characteristics of aquifers (Figure 9). The arrangement of the lithologic units can control how easily water enters and migrates through the ground, the confinement of aquifers, and the occurrence of springs. Folds can form basins in which ground water can accumulate, and faults can be barriers that inhibit or redirect ground water movement. All of these geologic factors that exert controls upon ground water occurrences are present in the Mosier study area.

STRATIGRAPHIC CONTROL

General Discussion

The geology in the Mosier study area controls the distribution of aquifers and the occurrence of springs within five stratigraphic units (Plate 2, cross sections B-B' and C-C'). Aquifers occur in glaciofluvial sand and gravel deposits, within permeable layers of the Chenoweth Formation, near the base of the Pomona Member of the Saddle Mountains Basalt, near the top of the Priest Rapids Member of the Wanapum Basalt and near the top of the Frenchman Springs Member of the Wanapum Basalt. Springs occur in the Mosier study area where water bearing sections are exposed.

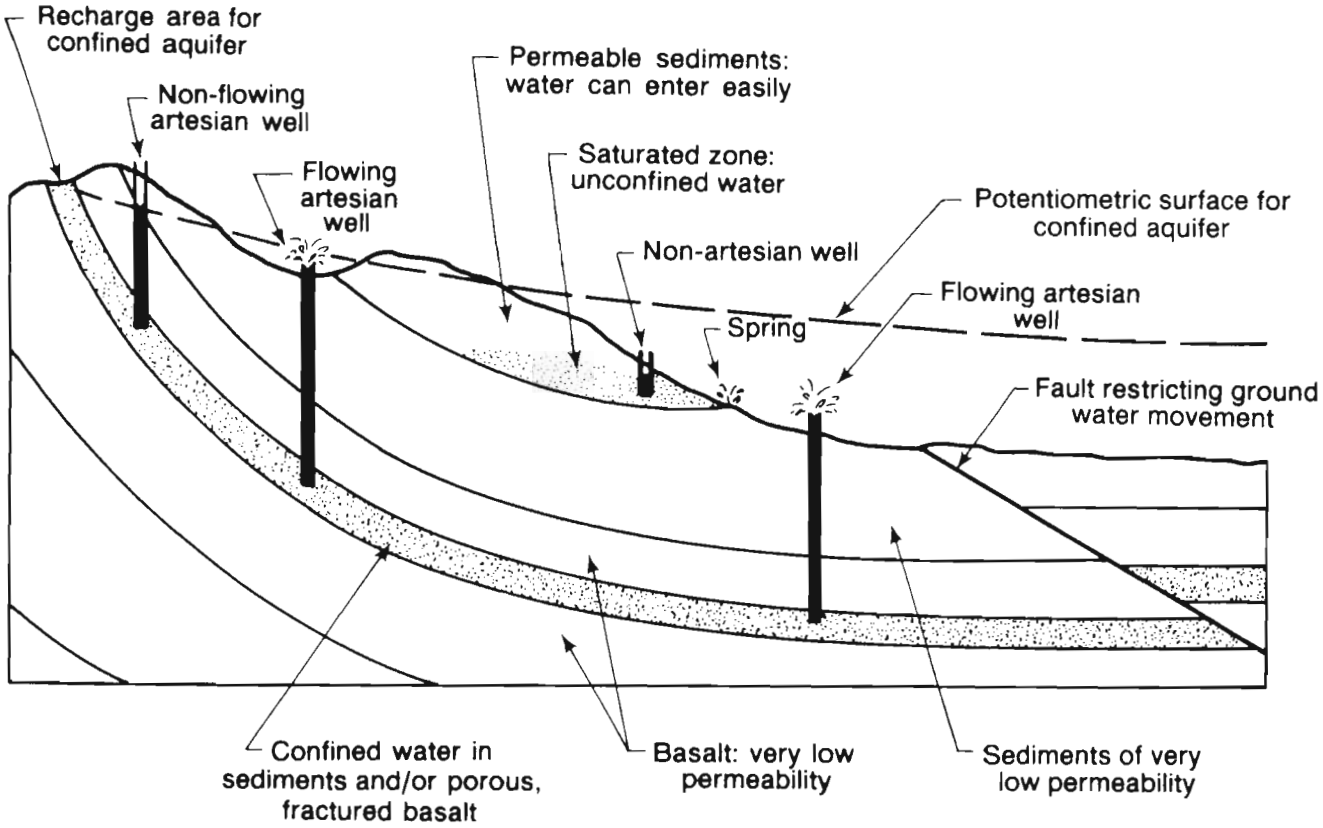


Figure 9. IDEALIZED RELATIONSHIP BETWEEN GROUND WATER HYDROLOGY AND GEOLOGY IN THE MOSIER STUDY AREA

This report will refer to the aquifers introduced in this section by the name of the rock units thought to be associated with them. Thus, the aquifers found in the glaciofluvial deposits and the Chenoweth Formation will be called the glaciofluvial and Chenoweth aquifers. Likewise, the basalt aquifers will be called the Pomona aquifer, the Priest Rapids aquifer and the Frenchman Springs aquifer respectively.

GLACIOFLUVIAL DEPOSITS

The glaciofluvial deposits in the Mosier study area are discontinuous. This creates several small discontinuous glaciofluvial aquifers. These unconfined aquifers rely solely upon local precipitation for recharge (Grady, 1983). Water should easily enter into and migrate through the coarse glaciofluvial deposits. Approximately 95 acres of orchard land obtain water pumped from glaciofluvial aquifers.

CHENOWETH FORMATION

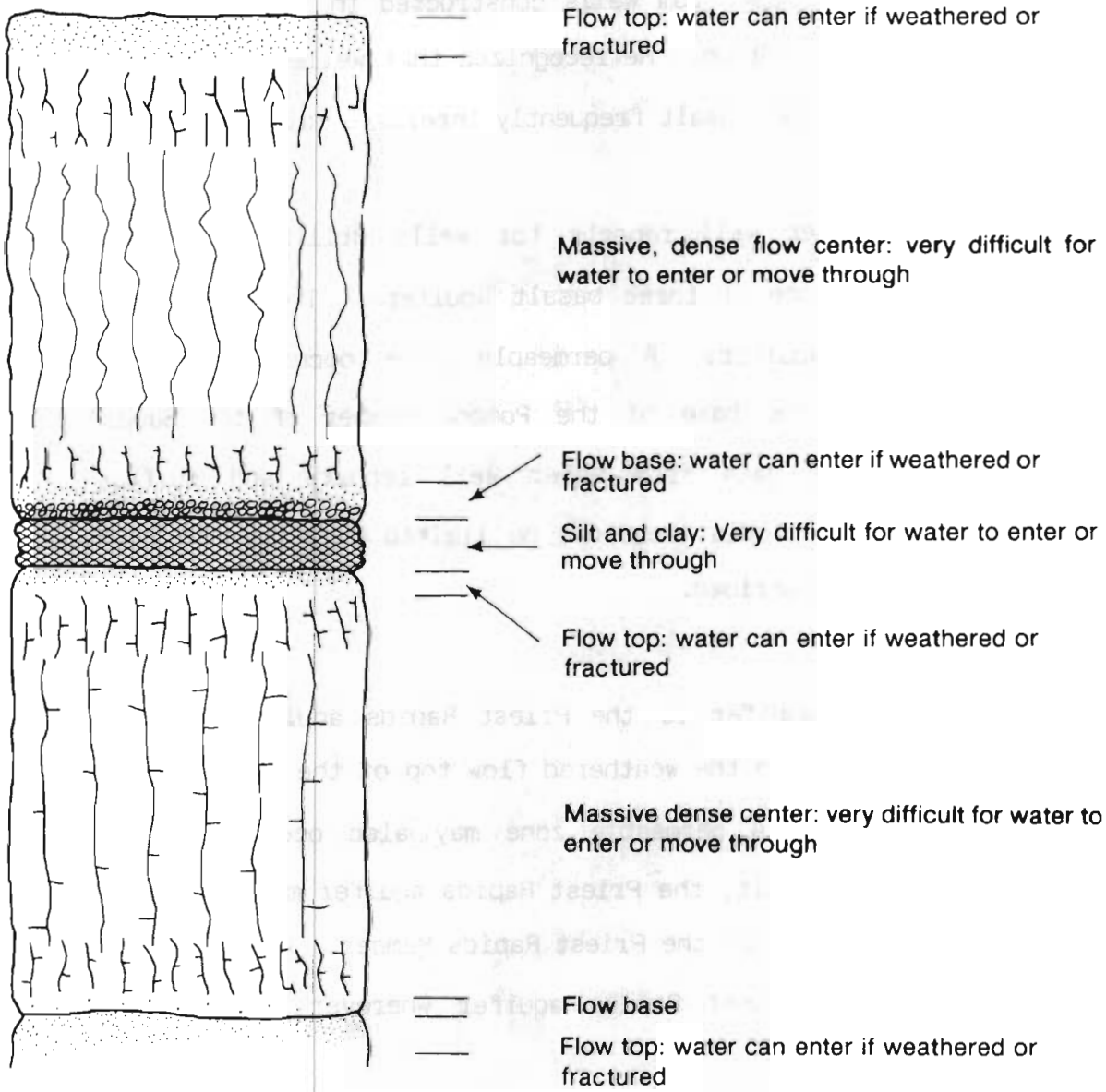
The permeability of the Chenoweth Formation is generally very low. Permeability is the property of a rock, sediment or soil for transmitting a fluid. The occurrence of springs at the contact between the bottom of the glaciofluvial deposits and the top of the Chenoweth Formation shows the general low permeability of the Chenoweth Formation. Piper (1932) and Newcomb (1963) assumed the Chenoweth Formation would yield little or no water. However, the Chenoweth Formation does yield water from permeable layers. Some Mosier area residents draw water from aquifers within the Chenoweth Formation

for domestic use. Generally, Chenoweth aquifers yield water to wells in the region at rates of 0.5 to 55 gallons per minute. However, in a few areas, yields of 150 to 250 gallons per minute occur in a few large production wells (Grady, 1983). Near Mosier, one pear orchard in the southeast corner of 2N/12E-7 obtains water from a Chenoweth aquifer, and several springs discharge water from aquifers within the Chenoweth Formation. One spring is found on a northeast facing slope in the northeast corner of 2N/12E-19.

COLUMBIA RIVER BASALT GROUP

Ground water flow within Columbia River basalt is mainly restricted to permeable zones at vesicular (formerly filled with gas bubbles) flow tops and bottoms (Figure 10). Basalt flow centers are generally solid, but vesicular flow tops and bottoms can become permeable when cooling fractures, flow brecciation (breaking of the lava crust while the flow continues to move) and/or weathering form interconnected spaces (Newcomb, 1982). In the Columbia River Basalt Group rocks, it is more common to find permeable vesicular zones associated with the flow tops. However, a well developed permeable vesicular zone at the base of a flow can be found in places where a flow has been deposited in water or over very moist material. Newcomb (1982) noted that permeable zone thicknesses in Columbia River basalt flow tops range from 1 to 33 feet and that cooling fractures formed most of these zones.

Sediments occasionally found between basalt flows can locally aid or inhibit ground water flow. Water can migrate more easily through coarse sediments then fine sediments. Fine sediments, such as silt and clay, can inhibit water migration, and isolate water in a permeable flow top from water in an overlying permeable flow bottom. This isolation occurs in the Mosier study area.



(Modified from Swanson (1967) and Long and Davidson (1981))

Figure 10. IDEALIZED RELATIONSHIP BETWEEN BASALT STRATIGRAPHY AND THE OCCURRENCE OF GROUND WATER IN THE MOSIER STUDY AREA

Most wells in the Mosier study area rely upon ground water from aquifers within the basalt formations. Newcomb (1963) reported regional well yields from 300 gpm to 800 gpm from wells constructed in various formations of the Columbia River Basalt Group. He recognized that wells in the region producing from the Columbia River basalt frequently intercept multiple aquifers.

Information on water well reports for wells drilled in the Mosier area indicates the presence of three basalt aquifers. The Pomona aquifer is the uppermost basalt aquifer. A permeable zone occurs within a weathered vesicular zone at the base of the Pomona Member of the Saddle Mountains Basalt. Lithologic data from water well reports and surface exposures indicate that the vesicular zone may be limited to a four to six square mile area as previously described.

The middle basalt aquifer is the Priest Rapids aquifer. A permeable zone apparently occurs within the weathered flow top of the Priest Rapids Member of the Wanapum Basalt. A permeable zone may also occur locally within the pillow-lava. As a result, the Priest Rapids aquifer may locally occur within a significant thickness of the Priest Rapids Member. A confining silt or clay layer overlies the Priest Rapids aquifer wherever the Pomona aquifer is present.

The third and lowermost basalt aquifer is the Frenchman Springs aquifer. A permeable zone apparently exists within the weathered vesicular flow top of the Frenchman Springs Member of the Wanapum Basalt.

Variations in hydraulic characteristics within the Pomona and Priest Rapids aquifers appear to coincide with the areal distribution of the Pomona aquifer

and related interbed sediments. First, the basalt aquifers are more transmissive within the four square mile orchard tract area (2N/11E-12; 2N/12E-7, 8, 18) than in the upgradient area. Evidence for this comes primarily from higher specific capacity values found on water well reports. (specific capacity can indicate how easily an aquifer can transmit water if the well fully penetrates the aquifer.) For example, the specific capacity of wells in the orchard tract area and in the upgradient areas is generally greater than 360 gpm/ft (gallons per minute per foot drawdown) and less than 6 gpm/ft, respectively.

Second, the aquifers are more transmissive in the orchard tract area. This results in almost flat hydraulic gradients in the Pomona and Priest Rapids aquifers in that area. For example, the potentiometric surface gradient for the Priest Rapids aquifer in the orchard tract area is approximately 75 feet/mile (Plate 4). The relatively high transmissivity in the orchard tract area also results in near uniform water level fluctuations in wells completed in the same aquifer.

Lastly, the seasonal water level fluctuations in wells within the four square mile orchard tract area differ from wells outside the area. The Pomona aquifer is limited primarily to this area. Within the orchard tract area, water levels rise and decline uniformly in similarly constructed wells. Water levels in wells penetrating the Pomona aquifer currently fluctuate about 38 feet annually. Water levels in wells isolating the Priest Rapids aquifer currently fluctuate about 12 feet annually. Water levels fluctuate annually in response to ground water use and recharge. Water levels in wells upgradient of the orchard tract area, fluctuate less than two feet annually. Comparison of water level data for well 2N/12E-17bcb within the upgradient

area and barometric pressure data collected in Mosier suggest that barometric pressure is the primary influence upon short term water level changes in the upgradient wells (Figure 11). The water level in well 2N/12-17bcb rose and fell in nearly a one-to-one relationship to the fall and rise, respectively, of barometric pressure in Mosier during July and October 1986. This suggests that the aquifer is rigid and any pressure change is absorbed primarily by the ground water.

GEOLOGIC STRUCTURE CONTROL

Folds and faults also control the occurrence and movement of ground water in the Mosier study area. Recharge to the Chenoweth Formation and to the basalt probably occurs where permeable layers in these formations are exposed along the flanks of the Columbia Hills anticline and other upland areas (Newcomb, 1963 and 1969). Then the water moves from these upland areas down dip toward the Mosier syncline under the influence of gravity.

Ground water would move freely from the Columbia Hills anticline to the Mosier syncline if not for the intervening Rocky Prairie thrust fault. The thrust fault apparently impedes ground water movement in the Pomona, Priest Rapids and possibly the Frenchman Springs aquifers. Consequently, artesian pressures are considerably higher on the up gradient side of the fault. Newcomb (1963) reported static water levels 500 feet above sea level in basalt wells south of the thrust fault and 72 feet above sea level in basalt wells north of the thrust fault, a difference of over 400 feet.

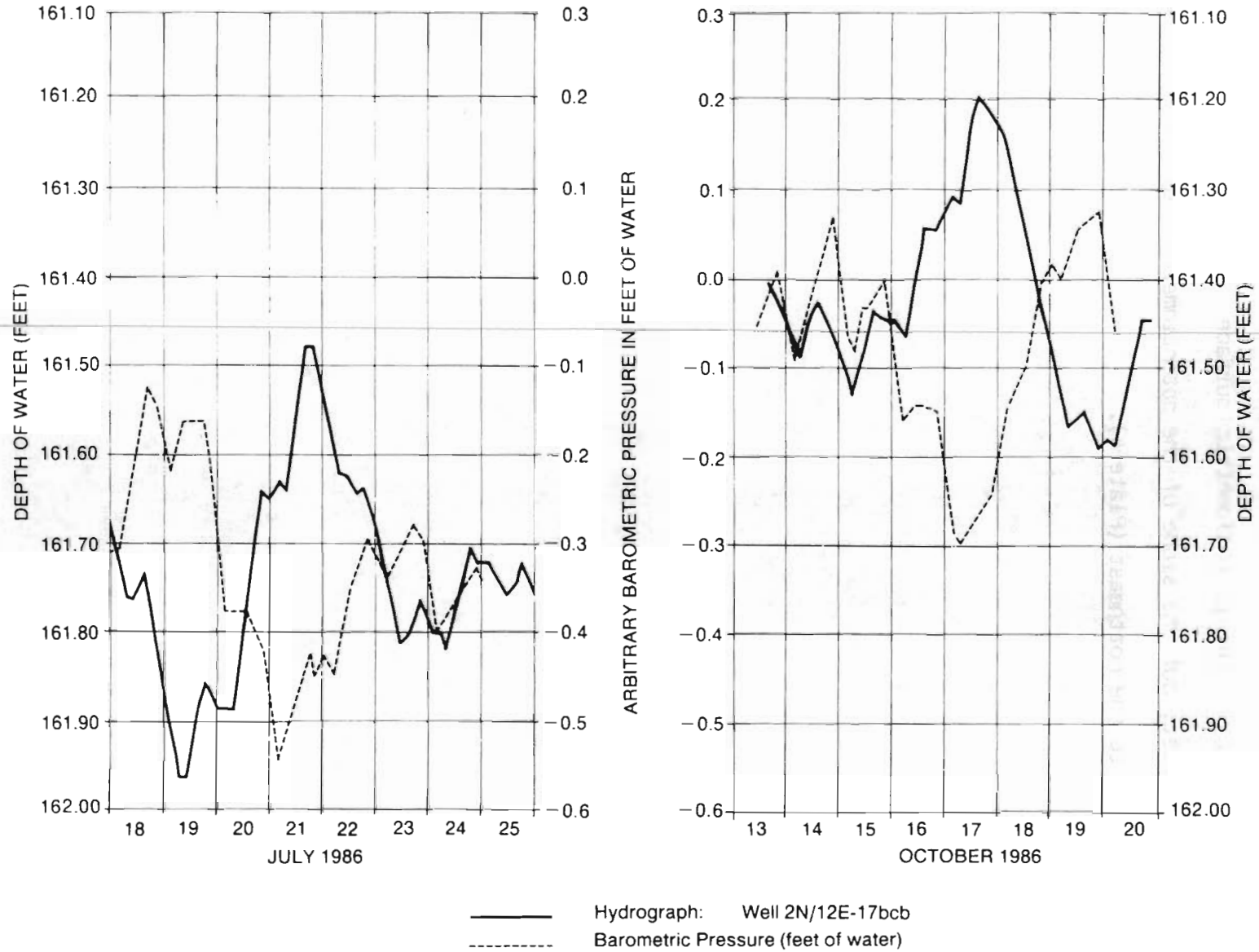


Figure 11. HYDROGRAPH RECORDED AT WELL 2N/12E-17bcb IN THE PRIEST RAPIDS AQUIFER AND BAROMETRIC PRESSURE RECORDED NEARBY

The Rowena Creek fault may also be a barrier to ground water movement. The potentiometric surface changes abruptly across the Rowena Creek fault (Plate 4). The slope of the potentiometric surface southwest of the fault trends to the northwest, but the slope of the potentiometric surface northeast of the fault trends to the northeast (Plate 4).

POMONA AND PRIEST RAPIDS AQUIFERS

INTRODUCTION

The ground water investigation near Mosier focused upon the Pomona and Priest Rapids aquifers in the orchard tract area. These two aquifers received attention because:

1. Both aquifers are the primary source of ground water in the Mosier area.

2. Water level declines are recorded for the Pomona and Priest Rapids aquifers in the orchard tract area over a 10 and 20 year period respectively.

DISTINGUISHING THE POMONA AND PRIEST RAPIDS AQUIFERS

Newcomb (1959) identified the presence of different water-bearing zones in Columbia River basalt by noting zones where drilling progressed more easily and where static water levels changed. A pattern of more easily penetrated zones and corresponding water level changes could help identify the basalt aquifers within an area. Neither Newcomb nor others established a pattern of such zones as a method for aquifer identification in the Mosier area.

Geologic mapping and good water well records were used to help identify the Pomona, Priest Rapids and other aquifers. "Good" water well records include descriptions of the color, hardness, texture and structure of the rock penetrated, descriptions of where water was encountered and where the static water level changes occurred.

The Pomona and Priest Rapids aquifers are distinctive in the Mosier orchard tract area. First, they are both basalt aquifers. This easily distinguished them from the glaciofluvial and the Chenoweth aquifers. Second, the Pomona and Priest Rapids aquifers stratigraphically overlie the Frenchman Springs aquifer which also is in basalt. Nearly the entire thickness of the Priest Rapids Member separates the Pomona and Priest Rapids aquifers from the Frenchman Springs aquifer. Third, the Pomona and Priest Rapids aquifers can be distinguished from each other, because they have different static water levels in wells and different hydrographic records.

Static water level differences best distinguish the Pomona aquifer from the Priest Rapids aquifer in the four square mile orchard tract area. Water level differences reported at four wells near Mosier provide good examples. Two wells drilled less than 50 feet apart at 2N/11E-12dab1 and -12dab2 penetrate the two different basalt aquifers. Well 2N/11E-12dab2 penetrated the Pomona aquifer only, and a static water level approximately 345 feet above sea level (30 feet below land surface) was recorded. Well 2N/11E-12dab1 first penetrated into the Pomona aquifer, and a static water level similar to well -12dab2 was recorded. However, drilling in well -12dab1 continued downward through a green siltstone into the Priest Rapids aquifer, and the static water level rose to 412 feet above sea level (37 feet above land surface) after the Pomona aquifer was sealed off. The static water level in well 2N/11E-12aad also rose above land surface when the well was drilled beyond the Pomona aquifer into the Priest Rapids aquifer. Similarly, the static water level in well 2N/12E-7dbc rose more than 34 feet when the well was deepened beyond the Pomona aquifer into the Priest Rapids aquifer in August 1986. The Pomona aquifer was not sealed off in this last well.

Long-term and seasonal hydrographs of wells completed in the Pomona aquifer and in the Priest Rapids aquifer within the orchard tract area are characteristic and differ considerably from each other. Hydrographs of wells completed in the Pomona aquifer (Figure 12) show greater long-term water level declines than hydrographs of wells completed in the Priest Rapids aquifer (Figure 13). The water level in well 2N/12E-7ada, (Figure 12) declined 76 feet between March 1976 and March 1987, whereas the water level in well 2N/11E-12aad (Figure 13) declined 37 feet during the same period. In addition, seasonal water levels fluctuate more in wells completed in the Pomona aquifer (Figure 14) than in wells completed in the Priest Rapids aquifer (Figure 15). For example, the seasonal water level fluctuations in well 2N/12E-7ada (Figure 14) were more than twice the fluctuations observed in well 2N/11E-12aad (Figure 15) between 1983 and 1987.

Chemical analysis of water from the Pomona aquifer and the Priest Rapids aquifer show slight differences. However, nothing was identified to chemically distinguish Pomona aquifer water from Priest Rapids aquifer water. Ground water chemistry of the different aquifers is discussed in more detail in the water chemistry section.

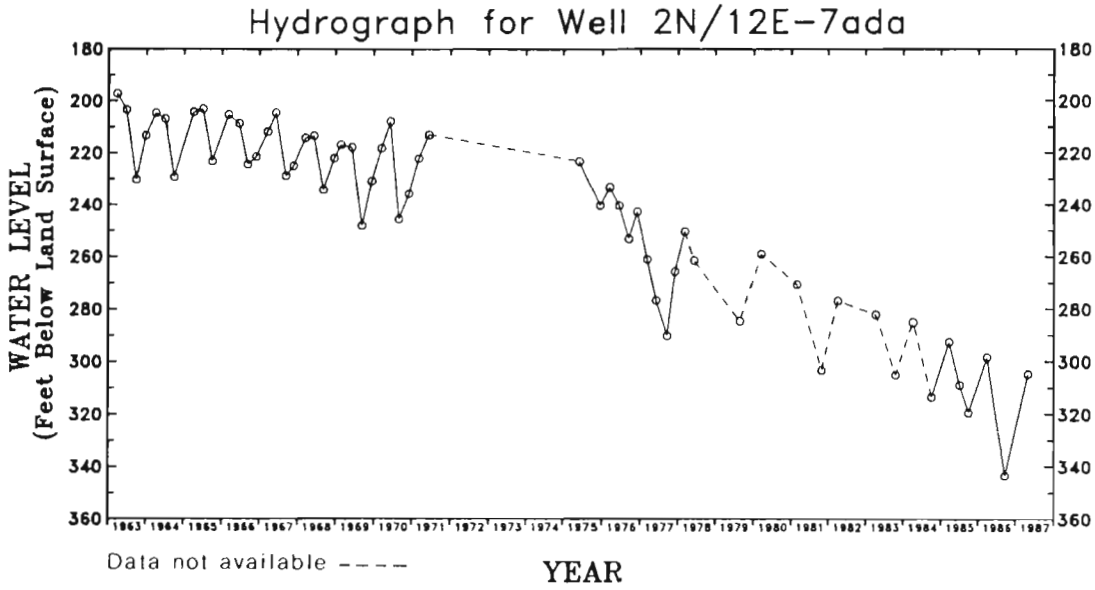


Figure 12. LONG TERM HYDROGRAPH FOR A WELL PENETRATING THE POMONA AQUIFER

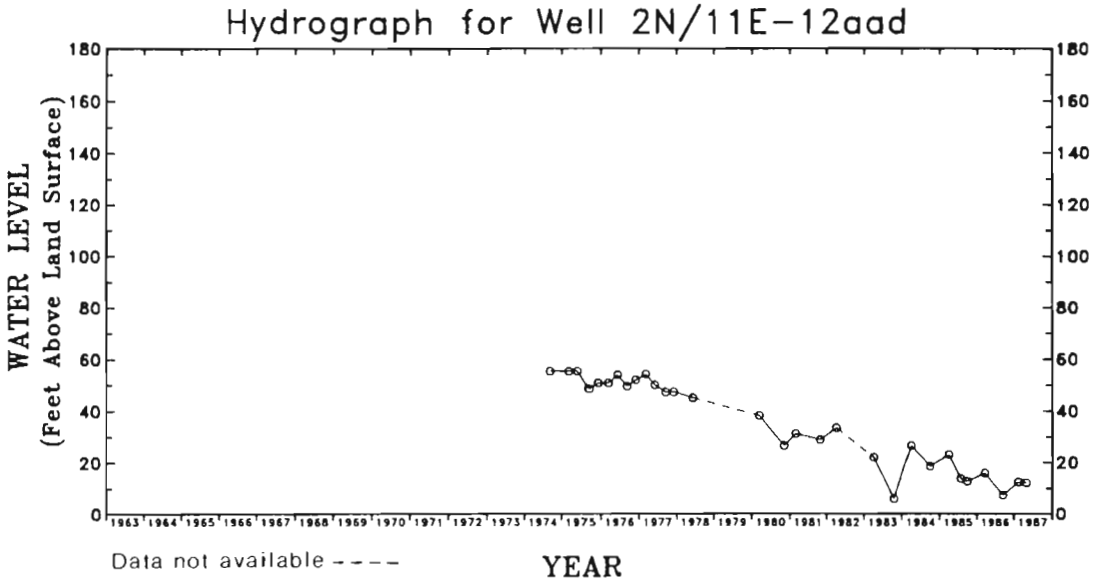


Figure 13. LONG TERM HYDROGRAPH FOR A WELL PENETRATING THE PRIEST RAPIDS AQUIFER

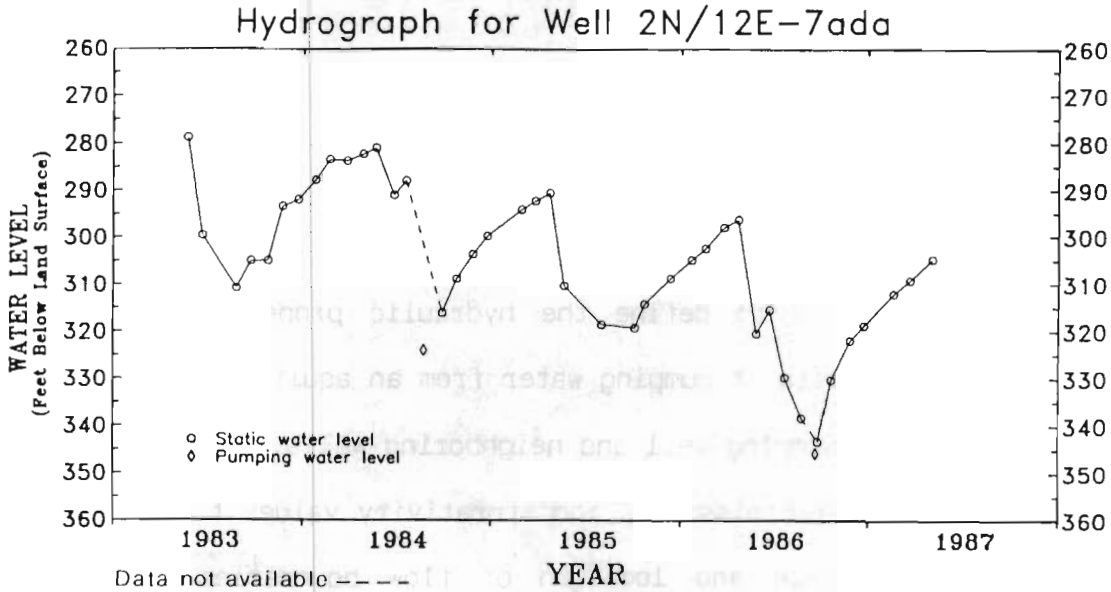


Figure 14. SEASONAL HYDROGRAPH FOR A WELL PENETRATING THE POMONA AQUIFER

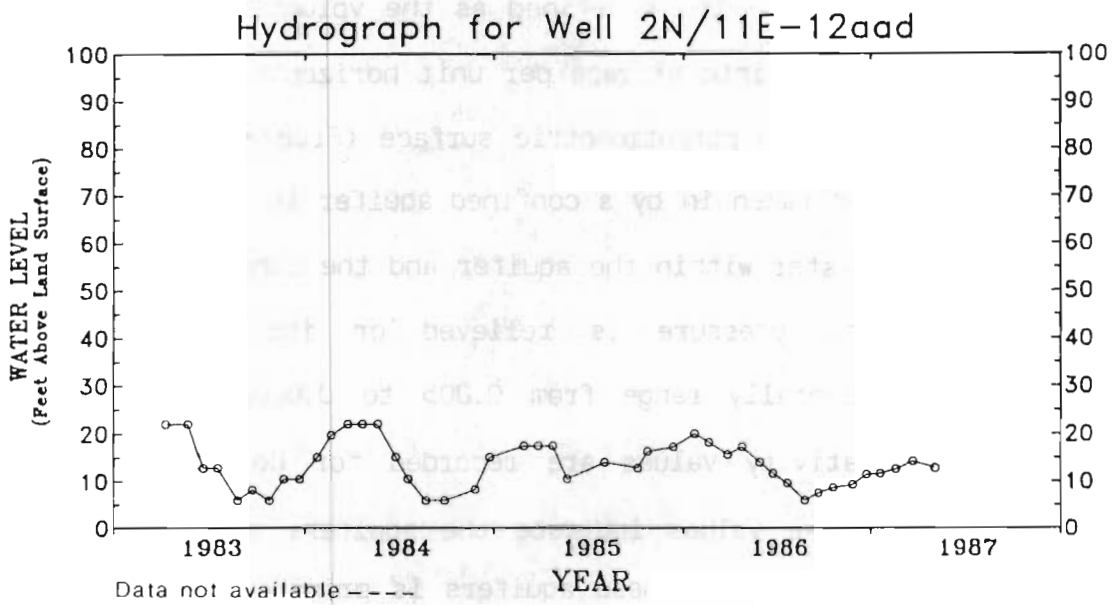


Figure 15. SEASONAL HYDROGRAPH FOR A WELL PENETRATING THE PRIEST RAPIDS AQUIFER

TEST AND ANALYSES OF THE POMONA AND PRIEST RAPIDS AQUIFERS

INTRODUCTION

Aquifer tests are used to define the hydraulic properties of an aquifer. Normally, a test consists of pumping water from an aquifer and recording water level changes at the pumping well and neighboring wells. Analysis of the data includes calculating transmissivity and storativity values for the aquifer and determining the presence and location of flow boundaries. Transmissivity values indicate how easily water moves through an aquifer at a given location. Large transmissivity values indicate a greater capacity to transmit water.

Storativity is a measure of the capacity of an aquifer to release or take in water as pressure changes. It is defined as the volume of water a confined aquifer releases or takes into storage per unit horizontal surface area of an aquifer per unit change in potentiometric surface (Freeze and Cherry, 1979). Water released from or taken in by a confined aquifer is due to the expansion or the compaction of water within the aquifer and the compaction or expansion of the aquifer when pressure is relieved or increased respectively. Storativity values generally range from 0.005 to 0.00005. Newcomb (1982) noted that low storativity values are recorded for Columbia River Basalt aquifers, and that those values indicate the aquifers are generally rigid. Any compaction or expansion in these aquifers is primarily restricted to the ground water.

The presence of flow boundaries can affect the rate of water level change observed during an aquifer test (Figures 16, 17 and 18). There are two common flow boundary types: impermeable (no flow) boundaries and recharge (constant head) boundaries. Impermeable boundaries restrict ground water flow, and its presence can accelerate drawdowns (water level declines) observed during pumping (Figure 17). Faults commonly act as impermeable boundaries. Streams may act as a no flow boundary if the aquifer loses water to the stream. Rivers, streams and lakes losing water to an aquifer commonly act as recharge boundaries. A recharge boundary may reduce the drawdown observed during pumping (Figure 18). Good aquifer test data and careful analysis can yield aquifer boundary locations.

Investigators conducted aquifer tests of the Pomona and Priest Rapids aquifers during this study. One test discharged water from the Pomona aquifer. A second test discharged water from the Priest Rapids aquifer. Water levels at the discharging well and neighboring wells were measured during each test. Analyses of the data yielded transmissivity and storativity values for each aquifer, and the analyses indicated the presence of no flow boundaries for the Pomona aquifer.

PREVIOUS AQUIFER TEST ANALYSES

Newcomb (1961 and 1963) reported a high transmissivity value for the Mosier area, and he assumed a low storativity value of 0.0001 for all Columbia River Basalt aquifers. Newcomb (1963) reported an average transmissivity value of 13,400 ft^2/day for the Mosier area.

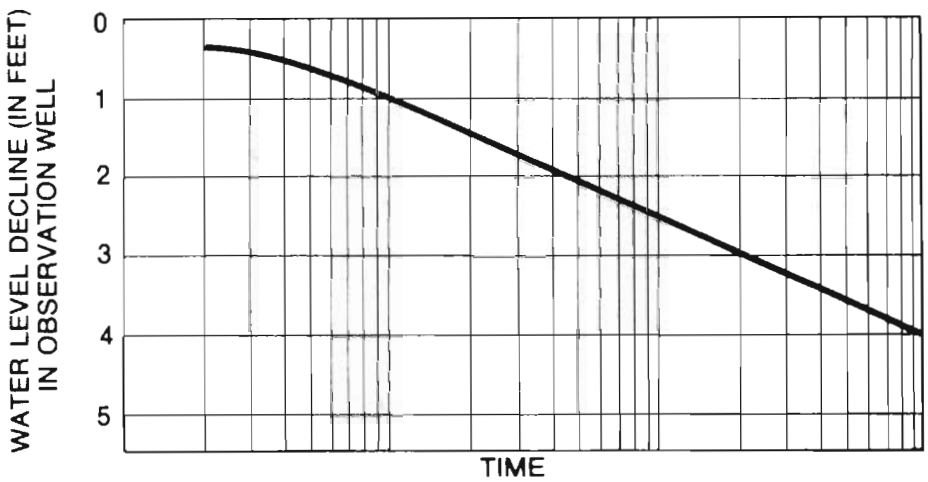


Figure 16. IDEALIZED RESPONSE OF AN OBSERVATION WELL TO A PUMPING WELL

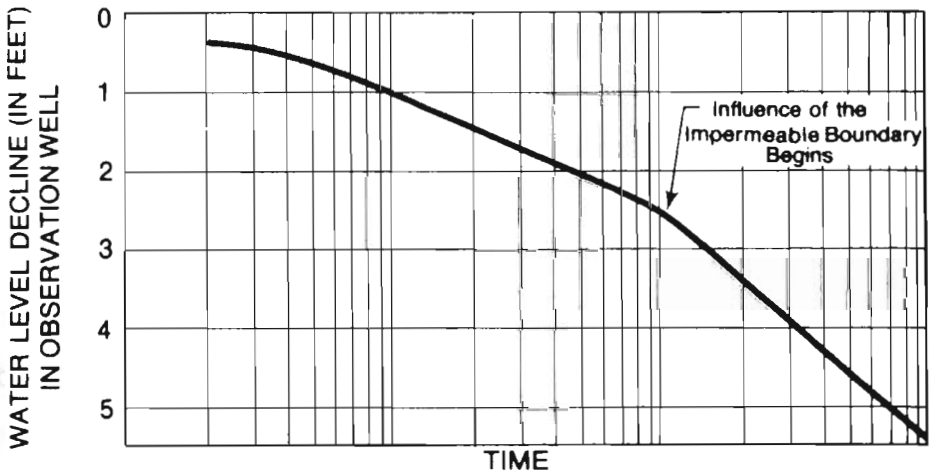


Figure 17. IDEALIZED RESPONSE OF AN OBSERVATION WELL TO A PUMPING WELL WHEN AN IMPERMEABLE BOUNDARY IS PRESENT

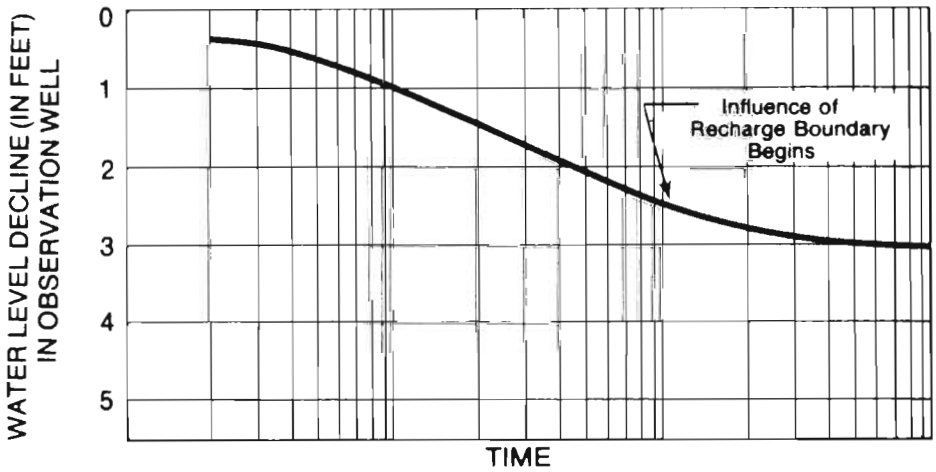


Figure 18. IDEALIZED RESPONSE OF AN OBSERVATION WELL WHEN A RECHARGE BOUNDARY IS PRESENT

TEST AND ANALYSES OF THE POMONA AQUIFER

The Pomona aquifer was tested from June 30 to July 1, 1986. Water was discharged from the Pomona aquifer at 198 gallons per minute for 25 hours at well 2N/12E-7ada. Water levels in the discharging well and two observation wells, 2N/12E-7aac and -7bda, were recorded during the pumping period. Additional water levels in the pumped well were recorded during the first hour of recovery after pumping ended. Water level data collected from the pumping well and the two observation wells (Appendix A_1) were analyzed.

Transmissivity and storativity values were calculated for the Pomona aquifer using the Theis curve method, the Cooper-Jacob time versus drawdown method, the Cooper-Jacob drawdown versus distance method and the recovery method. Ferris and others (1962), Davis and DeWiest (1966), Freeze and Cherry 1979) and Lohman (1972) describe these methods. Tables 2 and 3 list the transmissivity and storativity values calculated and the analytical methods used. The data indicate that transmissivity for the Pomona aquifer probably falls within a range of 11,500 to 24,000 feet^2/day, and storativity for the aquifer is probably within a range of 0.00004 and 0.00009.

The transmissivity values calculated are large, and the storativity values are small. The transmissivity values indicate a large hydraulic conductivity for the Pomona aquifer which ranges in thickness from several feet to tens of feet (Newcomb, 1969 and analysis of water well reports). Hydraulic conductivity can be calculated by dividing the transmissivity of an aquifer by aquifer thickness. A large hydraulic conductivity means water can move easily through a unit cross section of an aquifer. The storativity values indicate that

Table 2. ANALYSIS OF THE POMONA AQUIFER TEST: RESULTS OF TRANSMISSIVITY CALCULATIONS (feet^2/day)

	METHOD OF ANALYSIS		
WELL	Theis	Cooper-Jacob	Recovery
2N/12E-7ada	--	23,300	11,500
2N/12E-7aac	17,900	23,700	--
2N/12E-7bda	43,400	41,600*	--
Elapsed time	Distance vs. Draw Down		
27 min	14,900		
260 min	14,400		

*the $u \leq 0.02$ criteria was not met in these analyses (Therefore, the values are less reliable or unreliable.)

Table 3. ANALYSIS OF THE POMONA AQUIFER TEST: RESULTS OF STORATIVITY CALCULATIONS

	METHOD OF ANALYSIS	
WELL	Theis	Cooper-Jacob
2N/12E-7aac	0.00009	0.00006
2N/12E-7bda	0.00004	0.00004*

*the $u \leq 0.02$ criteria was not met in these analyses (Therefore, the values are less reliable or unreliable.)

water in the Pomona aquifer is confined and that little water will be released from the Pomona aquifer when pressure is relieved. This should be expected. Water compresses very little under pressure, and basalt aquifers are relatively rigid.

Further analysis of the data collected from the Pomona aquifer test indicate the presence of at least one impermeable boundary to the Pomona aquifer. However, the data were inadequate to identify boundary locations and orientation by the image well method described by Ferris and others. (1962), Davis and DeWiest (1966), Freeze and Cherry (1979), and Lohman (1972).

TEST AND ANALYSES OF THE PRIEST RAPIDS AQUIFER

The Priest Rapids aquifer was tested from May 14 to May 15, 1986. A valve was opened at flowing well 2N/11E-12dab1, which receives water from the Priest Rapids aquifer only. Water discharged from the well at an average rate of 357 gallons per minute. The water level at well 2N/11E-12dab2 and the well head pressure at 2N/11E-12dab1 were monitored (Appendix A_2). Plate 1 shows the location of these wells. Well 2N/11E-12dab2 penetrates the Pomona aquifer only. A neighboring well, 2N/11E-12acd, interconnects the Pomona and Priest Rapids aquifers, and during the aquifer test, it continuously discharged approximately 75 gallons per minute to the Mosier City Reservoir. This additional discharge complicated the analysis.

Transmissivity values were calculated for the Priest Rapids aquifer using the Cooper-Jacob Method, the recovery method and the Jacob-Lohman method (Lohman, 1972). Table 4 displays the values calculated. Although each method yielded

different values, the transmissivity values are large and relatively consistent. However, the values may have been biased downward by the analysis procedures used. The discharge values used in the analyses do not include discharge from the Priest Rapids aquifer through well 2N/11E-12acd. The proportion of water supplied by the Pomona and Priest Rapids aquifers to the 75 gallon per minute discharge from well 2N/11E-12acd is unknown. In addition, the average discharge rate of 357 gpm from the flowing Priest Rapids well, 2N/11E-12dab1, was assumed constant for the recovery method and the Cooper - Jacob method of aquifer analysis. In reality, discharge from a flowing well decreases with time. The total decrease in discharge during this aquifer test was less than 15 gallons per minute. The Jacob-Lohman method of analysis incorporates the declining discharge into the analysis.

Table 4. ANALYSIS OF PRIEST RAPIDS AQUIFER TEST: RESULTS OF TRANSMISSIVITY CALCULATIONS (feet ^{2}/day)

WELL	METHOD OF ANALYSIS		
	Cooper-Jacob	Recovery	Jacob-Lohman
2N/11E-12dab1	10,100	9,160	29,900

The water level in well 2N/11E-12dab2 responded very rapidly to water discharging from the Priest Rapids flowing well 2N/11E-12dab1 (Appendix A_2). This response reflects a high hydraulic conductivity within the Priest Rapids and Pomona aquifers. The only connection known between the flowing Priest Rapids well, 2N/11E-12dab1, and the Pomona well, 2N/11E-12dab2, is well 2N/11E-12acd which interconnects the two aquifers. Well 2N/11E-12acd is located 690 feet from wells 2N/11E-12dab1 and -12dab2. The water level in the Pomona well, 2N/11E-12dab2, declined 3.75 feet during the aquifer test.

Review of earlier hydrographs for the Pomona well and hydrographic records of when water flowed from well 2N/11E-12acd indicate that discharge from 2N/11E-12acd may be responsible for up to 1.5 feet of the drawdown observed in the Pomona well. Barometric pressure fluctuated less than 0.10 pounds per square inch (less than 0.23 feet of water) during the two day aquifer test.

DISCHARGE AND RECHARGE ESTIMATES FOR THE POMONA AND PRIEST RAPIDS AQUIFERS

INTRODUCTION

Each year, water enters and leaves most ground water systems. This is true for the Pomona and Priest Rapids aquifers in the approximately 22 square mile area bounded to the north by the Rocky Prairie thrust fault and to the east by the Rowena Creek fault. Most recharge to the Pomona and Priest Rapids aquifers occurs where the aquifers are exposed in the highlands to capture rainfall and runoff. Mosier Creek may provide additional recharge to the Priest Rapids aquifer in section 19 of 2N/12E. The Pomona aquifer receives additional recharge from the Priest Rapids aquifer through interconnecting wells.

Both the Pomona and Priest Rapids aquifers lose water through natural and man-induced discharge. The Pomona aquifer discharges water to Mosier Creek, and some water may leak from both aquifers through fault zones. Both aquifers lose water through wells for domestic and irrigation purposes, and the Priest Rapids aquifer loses water to the Pomona aquifer through interconnecting wells.

Discharge and recharge estimates for the Pomona and Priest Rapids aquifers in 1986 are presented in the following text. Appendix B shows the calculations used. The discharge estimates include: household use; irrigation use; discharge to Mosier Creek from the Pomona aquifer; and discharge from the Priest Rapids aquifer to the Pomona aquifer through interconnecting wells. The estimated household use of water in the study area was based upon estimated household water consumption for the City of Mosier. The estimated

use of water for irrigation was based upon periodic field measurements. The estimated discharge from the Pomona aquifer to Mosier Creek was based upon stream flow measurements. The estimated discharge from the Priest Rapids aquifer to the Pomona aquifer was based upon an analysis of a 23 year hydrograph for the Pomona aquifer. In addition, an analysis of artesian flow from a Priest Rapids well and a neighboring well interconnecting the Pomona and Priest Rapids aquifers was conducted to estimate discharge from the Priest Rapids aquifer to the Pomona aquifer through a single interconnecting well (Appendix B).

Recharge estimates were based upon discharge estimates and hydrographs for wells completed in the Pomona and Priest Rapids aquifers (Appendix C). More investigation over a longer period would help refine or correct the estimates presented in the following text.

DISCHARGE

The Pomona and Priest Rapids aquifers in the area south of the Rocky Prairie thrust fault and west of the Rowena Creek fault discharge water each year. Table 5 presents the estimated discharge in 1986 for each aquifer. The ground water discharge estimates include rural household consumption, water use by the City of Mosier, water applied to orchards, water discharged from the Pomona aquifer to Mosier Creek and water discharged from the Priest Rapids aquifer to the Pomona aquifer through interconnecting wells. Natural subsurface leakage was not determined.

Table 5. ESTIMATED DISCHARGES FROM THE POMONA AND PRIEST RAPIDS AQUIFERS DURING 1986

Recipient	Supplying Aquifer	
	Pomona	Priest Rapids
City of Mosier	?	115 acre-feet
Rural Households	19 acre-feet	78 acre-feet
Orchards	300 acre-feet	270 acre-feet
Pomona Aquifer		153 acre-feet
Mosier Creek	369 acre-feet	
Frenchman Springs Aquifer		undetermined
Subsurface Outflow	undetermined	undetermined
Total	688 acre-feet	616 acre-feet

The estimated ground water use by the City of Mosier in 1986 was based upon discharge meter readings at the city reservoir (Appendix B_1). The 115 acre-feet estimate for the City of Mosier suggests that each person in the Mosier area uses an average of 293 gallons per day. Some water may be lost through leaky pipes. The average daily household use of water for the City of Mosier (approximately 790 gallons) was used to estimate the withdrawal of ground water from the Pomona and Priest Rapids aquifers by 109 rural households in the 22 square mile area.

The estimated ground water withdrawal for irrigation in 1986 was based upon periodic field measurements (Appendix B_2). Those measurements included: the amount of water applied per day at different orchards, the time required

to irrigate each orchard per irrigation cycle, and the number of irrigation cycles each orchard receives each year. Most orchardists irrigate a portion of their orchard per day in a cycle. The amount of water applied per day and the area irrigated varies. It depends upon sprinkler spacing, the number of sprinklers operating, and the elevation of the area irrigated relative to the well head. Less water is delivered per minute when a pump must lift it higher. Currently, 459 acres of orchard in the 22 square mile area are irrigated solely by ground water from the Pomona and Priest Rapids aquifers.

The estimated discharge from the Pomona aquifer to Mosier Creek in 1986 was based upon stream flow measurements (Appendix B_3). Stream flow measurements in 1986 suggest that the Pomona aquifer discharges at least 230 gallons per minute (369 acre-feet per year) to Mosier Creek between section 13aad of 2N/11E and section 18cbb of 2N/12E.

Flow between aquifers through wells can be measured by down hole flow meters. Such measurements were not available during this study. Instead, the estimated discharge of water from the Priest Rapids aquifer to the Pomona aquifer was based upon an analysis of a 23 year hydrograph for the Pomona aquifer (Appendix B_4). The analysis included a comparison of the discharge from and the recharge to the Pomona aquifer before and after 1970. Two wells may have interconnected the aquifers before 1970. Therefore, the analysis does not include water lost to the Pomona aquifer from the Priest Rapids aquifer through these wells. This analysis suggests the Priest Rapids aquifer loses 153 acre-feet per year to the Pomona aquifer through interconnecting wells.

A second analysis was conducted to estimate discharge from the Priest Rapids aquifer to the Pomona aquifer through a single well. Artesian flow rates and well head pressures at two neighboring wells, a Priest Rapids well and a well interconnecting the Priest Rapids and the Pomona aquifers, were compared (Appendix B_4). The discharge values obtained suggest that 225 to 775 acre-feet per year may be lost from the Priest Rapids aquifer through one well interconnecting the two aquifers. This implies that more water may be lost from the Priest Rapids aquifer through interconnecting wells than can be fully accounted within the Pomona aquifer. Locally, leakage to fractures or permeable zones may be possible in wells with significant sections open to the formation. The values from the second analysis were not used to estimate the total loss of water from the Priest Rapids aquifer to the Pomona aquifer through interconnecting wells, because the values represented water lost through one of many interconnecting wells, and because the amount of water lost could not be fully accounted within the Pomona aquifer.

Discharge from the Priest Rapids aquifer to the Frenchman Springs aquifer could not be estimated at this time. However, the Priest Rapids aquifer apparently does lose water to the Frenchman Springs aquifer through interconnecting wells. Evidence for this drainage is based upon water level drops noted when wells penetrated beyond the Priest Rapids aquifer into the Frenchman Springs aquifer. For example, the owner of well 2N/12E-7bcc noted a water level drop from 491 to 463 feet above sea level (46 to 18 feet above land surface) when his well was deepened into the Frenchman Springs aquifer in 1959.

Data in Table 5 indicate that Mosier Creek, the Pomona aquifer and the Priest Rapids aquifer are interconnected. Figure 19 schematically represents how

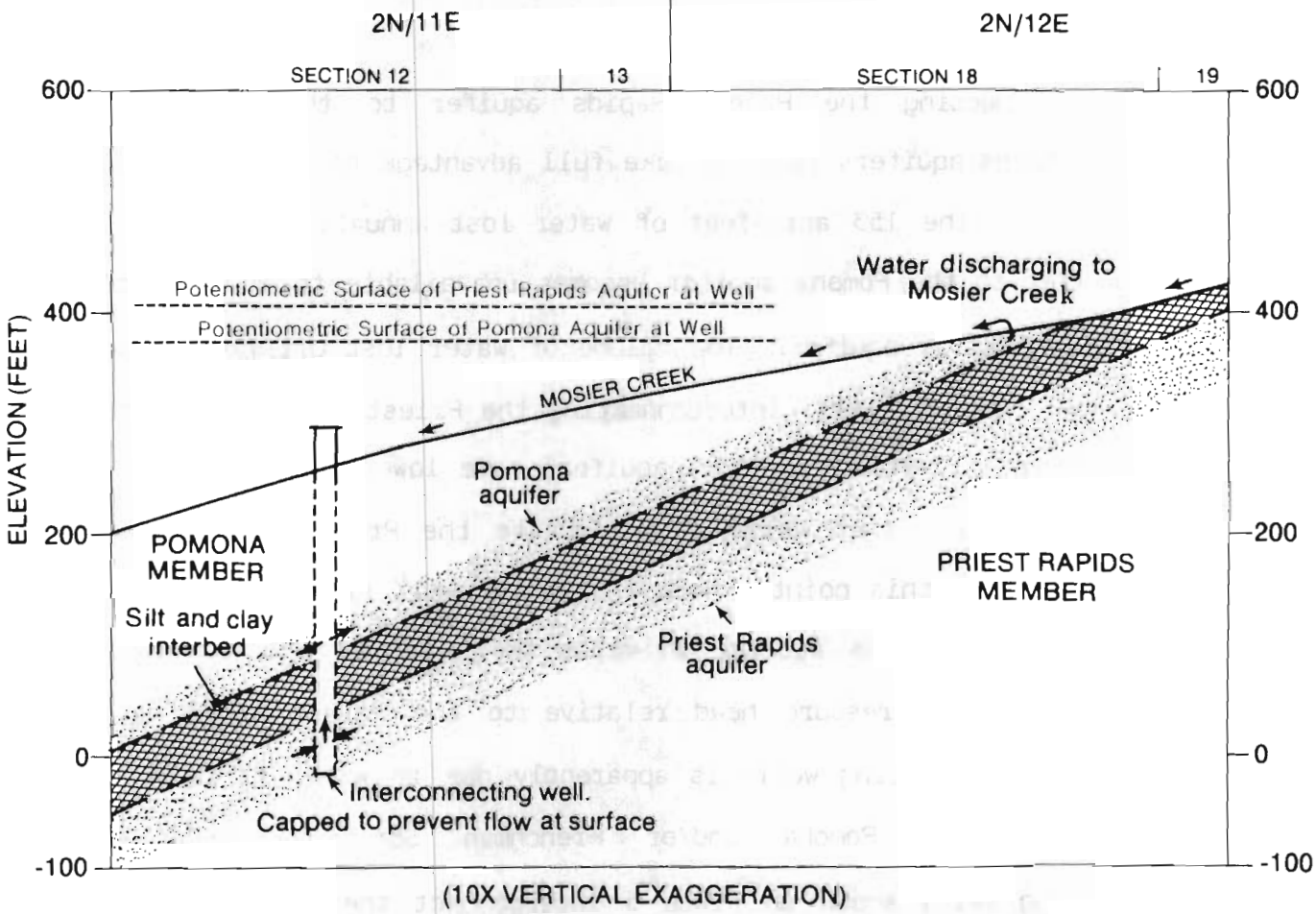


Figure 19. PROFILE OF MOSIER CREEK AND IDEALIZED INTERACTION BETWEEN THE POMONA AQUIFER AND THE PRIEST RAPIDS AQUIFER THROUGH AN INTERCONNECTING WELL

the aquifers and Mosier Creek interconnect. According to Table 5, 25 percent (153 acre-feet) of the discharge from the Priest Rapids aquifer flows into the Pomona aquifer through interconnecting wells. In turn, more than twice that amount of water (369 acre-feet) flows from the Pomona aquifer into Mosier Creek where the Pomona aquifer intersects the creek.

Wells interconnecting the Priest Rapids aquifer to the Pomona and/or Frenchman Springs aquifers fail to take full advantage of the Priest Rapids aquifer. First, the 153 acre-feet of water lost annually from the Priest Rapids aquifer to the Pomona aquifer becomes unavailable to wells completed in the Priest Rapids aquifer. The volume of water lost ultimately goes to Mosier Creek. Second, wells interconnecting the Priest Rapids aquifer with the Pomona and/or Frenchman Springs aquifers have lower static water levels due to pressure loss than wells which isolate the Priest Rapids aquifer. Plate 5 illustrates this point. Note that water will rise higher above the top of the Priest Rapids aquifer in wells that isolate the Priest Rapids aquifer. The lower pressure head relative to the Priest Rapids aquifer within the interconnecting wells is apparently due to water flowing out of the wells to the Pomona and/or Frenchman Springs aquifer. The interconnecting wells shown on Plate 5 interconnect the Pomona and Priest Rapids aquifers only.

RECHARGE

Newcomb (1963) suggested recharge of all the basalt aquifers in the greater Mosier area occurs primarily along the Columbia Hills anticline and valley outcrops. He estimated the overall recharge to the basalt aquifers in the

Mosier area as 2,100 acre-feet per year. Newcomb based his estimate upon water flowing through a four mile arc, down a five feet per mile gradient within aquifers with an average transmissivity of 13,400/ft^2/day. Newcomb, also, noted that the Chenoweth Formation inhibits recharge of the basalt aquifers. He estimated 2.92 inches from the total rainfall over the area of exposed basalt would yield the 2,100 acre-feet of water.

Table 6 presents the 1986 recharge estimates for the Pomona and Priest Rapids aquifers in the area south of the Rocky Prairie thrust fault and west of the Rowena Creek fault. The estimates are based upon discharge estimates found on Table 5 and analyses of hydrographs for the Pomona and Priest Rapids aquifers (Appendix C). Other methods of estimating recharge were considered, but they were not applicable for this study. Analysis of hydrographs from 1983 to 1987 for the Priest Rapids aquifer (Appendix C_2) indicates that recharge replaces an estimated 90 percent (554 acre-feet) of the water discharged (616 acre-feet) from the aquifer annually. The amount of recharge to the Priest Rapids aquifer may be greater than estimated, however, because the discharge estimate for the Priest Rapids aquifer does not include all water lost through interconnecting wells. Analysis of hydrographs from 1983 to 1987 for the Pomona aquifer (Appendix C_1) indicates that recharge replaces an estimated 82 percent (564 acre-feet) of the water discharged (688 acre-feet) annually from the aquifer.

Table 6. YEARLY RECHARGE ESTIMATES FOR THE POMONA AND PRIEST RAPIDS AQUIFERS DURING 1986

Recharge Source	Pomona Aquifer	Priest Rapids Aquifer
Priest Rapids Aquifer	153 acre-feet	----
Mosier Creek		173 acre-feet
Precipitation	411 acre-feet	381 acre-feet
Total to each Aquifer	564 acre-feet	554 acre-feet
Total Priest Rapids Aquifer Recharge		554 acre-feet
Total Pomona Aquifer Recharge		+564 acre-feet
Recharge to the Pomona Aquifers from the Priest Rapids Aquifer		-153 acre-feet
Total combined Recharge to the Aquifers		965 acre-feet

Over 27 percent (153 acre-feet) of the total estimated recharge to the Pomona aquifer comes from the Priest Rapids aquifer through wells interconnecting the aquifers (Appendix B_4). The remaining 411 acre-feet of recharge probably comes from captured rainfall and runoff.

Stream flow measurements (Appendix B_2) indicate that an estimated 173 acre-feet of water may enter the Priest Rapids aquifer annually from Mosier Creek. Inspection of the potentiometric surface contours for the Priest Rapids aquifer near Mosier Creek (Plate 4) suggests two opposing interpretations. The shape of the contour near Mosier Creek suggests that the Priest Rapids aquifer may lose water to Mosier Creek. Newcomb (1969) did suggest that Mosier Creek gains water from the basalt (Priest Rapids Member) exposed along the creek bed in section 19 of 2N/12E. However, the contours also show that the Spring 1986 potentiometric surface of the Priest

Rapids aquifer lies below the surface elevation of Mosier Creek in the northwest quarter of section 19. Therefore, Mosier Creek could lose water to the Priest Rapids aquifer in the northwest quarter of section 19 if the two are hydraulically connected. Perhaps, the potentiometric surface decline of the Priest Rapids aquifer in 2N/12E section 7, 18 and 19 since 1969 changed the relationship between Mosier Creek and the Priest Rapids aquifer. Further investigation is necessary to clarify this ground water/surface water relationship. The remaining 381 acre-feet of recharge to the Priest Rapids aquifer apparently comes from captured rainfall and runoff.

Geologic data and analysis of potentiometric surface data (Plate 4) support Newcomb's hypothesis that recharge to the basalt aquifers occurs primarily along the Columbia Hills anticline and valley outcrops. The geologic map (Plate 2) shows the Pomona and Priest Rapids Members exposed along the flanks of the anticline and within stream valleys. Rainfall and runoff may enter exposed permeable zones of the Pomona and Priest Rapids Members except along very steep valley slopes. Inspection of the contours on the potentiometric surface map (Plate 4) also supports recharge of the Priest Rapids aquifer along the flanks of the Columbia Hills anticline. An area of recharge for the Pomona aquifer could not be determined from the potentiometric surface map due to the few data points available. Approximately one-third (7 inches) of the total rainfall over the exposed Pomona and Priest Rapids Members would yield the estimated recharge by precipitation to each aquifer.

Hydrograph data suggest water in the Pomona and Priest Rapids aquifers bounded to the north by the Rocky thrust fault and to the east by the Rowena Creek fault travels quickly from the area of recharge to the area of discharge. A comparison of hydrograph and local rainfall data suggest that

the lag time between high and low annual rainfall and high and low annual recharge for the Pomona and Priest Rapids aquifers is short; less than a year. This implies that the ground water moves rapidly to an area of discharge after it enters the aquifer.

GROUND WATER CHEMISTRY

INTRODUCTION

A water quality assessment of ground water samples collected from selected wells in the Mosier area was provided by the Oregon Department of Environmental Quality (DEQ). Water quality surveys were conducted between July and September 1986. Twelve wells were selected for water quality monitoring from a network of observation wells established by the Oregon Water Resources Department (OWRD). The sampled wells are shown on Plate 1. The selection of wells for water quality sampling was based on such factors as: the producing aquifer, potential for ground water contamination, well use, and well accessability. Water samples were collected monthly from aquifers within the glaciofluvial deposits; Chenoweth Formation; and Pomona, Priest Rapids, and Frenchman Springs Members of the Columbia River Basalt Group.

Each sample was tested for 35 parameters. Parameters selected include those used as drinking water standards and as water quality indicators. The results of the water chemistry analyses are included in appendix D.

CHARACTERIZATION OF THE AQUIFERS BY WATER CHEMISTRY

Water samples collected from five of the twelve sampling wells were identified as representing the five aquifers in the Mosier area. Those aquifers include the glaciofluvial, Chenoweth, Pomona, Priest Rapids, and Frenchman Springs

aquifers. The samples were selected because those five wells most likely obtain water from individual aquifers. Where possible, the wells were selected in the same general geographic area.

In general, the aquifers are quite similar in water chemistry. Figure 20 shows plots based on average ionic (sodium, potassium, calcium, magnesium, chloride, sulfate, and carbonate/bicarbonate) composition of the samples. As shown, the aquifers are carbonate systems. The Chenoweth aquifer stands out somewhat from the other aquifer units, because it is lowest in calcium, magnesium, and bicarbonate concentrations, and highest in chloride concentrations.

The following contrasts the five aquifers sampled in the Mosier area. It is based on limited data (a maximum of three samples collected in summer 1986). Therefore the findings should be viewed as preliminary.

Glaciofluvial: Water samples from the glaciofluvial aquifer were intermediate in concentration for most parameters.

Chenoweth: Water samples from the Chenoweth aquifer were the lowest in calcium, magnesium, sodium, sulfate, and bicarbonate concentrations, and highest in chloride.

Pomona: Only one water sample was collected from a well that was open only to this aquifer. This sample indicates lower potassium and higher chloride concentrations as compared to other basalt aquifers that were sampled in the area. The sample from the Pomona aquifer was also significantly higher in iron (Table D 1.1 in Appendix D).

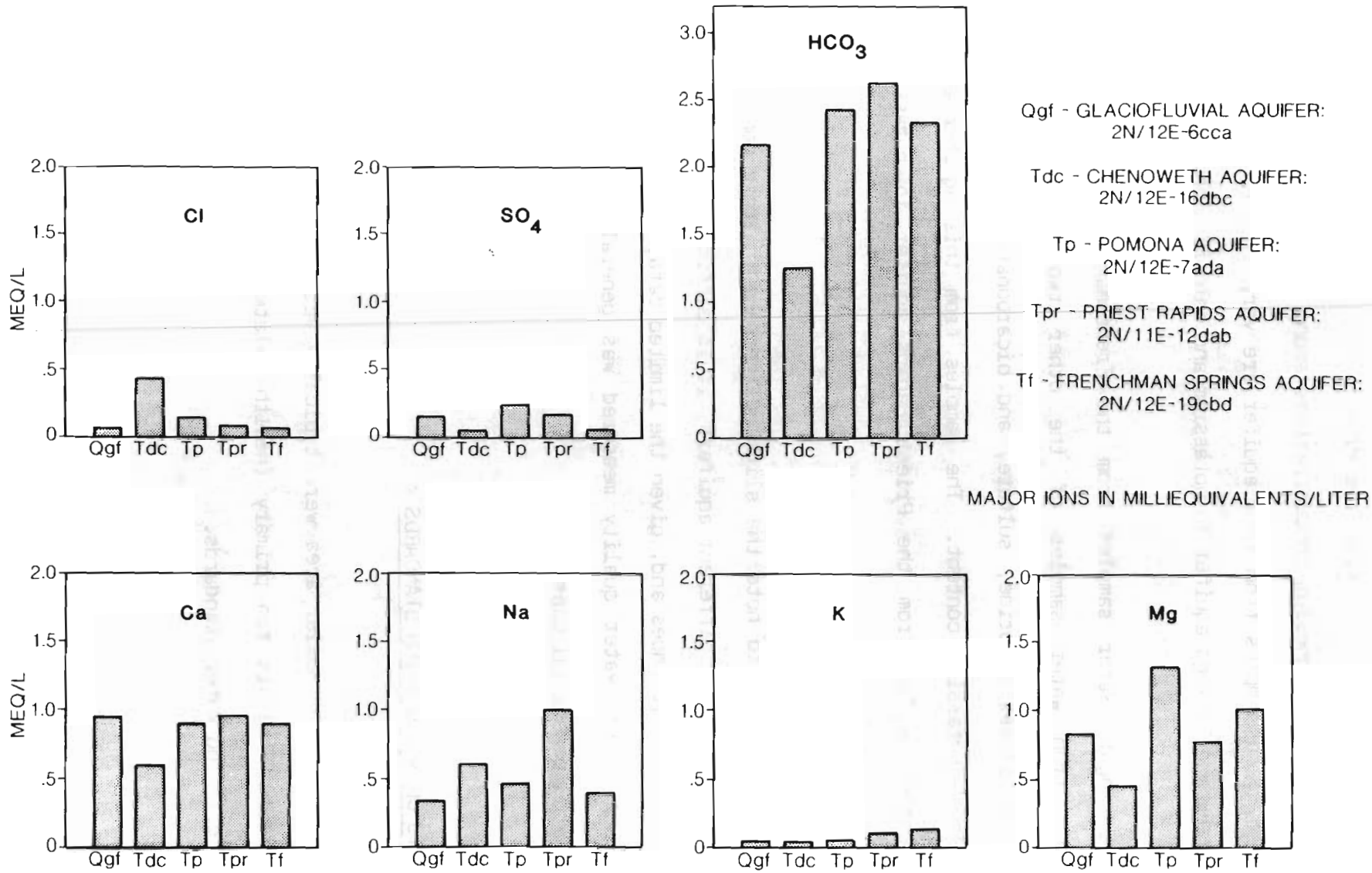


Figure 20. RELATIVE ABUNDANCE OF MAJOR IONS IN REPRESENTATIVE WATER SAMPLES

Priest Rapids: Water samples from the Priest Rapids aquifer were highest in sodium and lowest in magnesium concentrations among the basalt aquifers that were sampled. The samples from this aquifer are very similar to the samples from the Frenchman Springs aquifer in potassium and chloride concentrations.

Frenchman Springs: Water samples from the Frenchman Springs aquifer are distinguished from water samples of the other two basalt aquifers by exhibiting the lowest chloride, sulfate, and bicarbonate concentrations and highest overall potassium content. The samples from this aquifer are very similar to the samples from the Priest Rapids aquifer in potassium and chloride concentrations.

While it is interesting to note the slight difference in ionic concentration of water samples from the different aquifers, it is difficult to determine the reasons for these differences and, given the limited data, the significance of the differences. The water quality measured was generally quite good and suitable for all beneficial uses.

COMPARISON TO DRINKING WATER STANDARDS

Values measured in the Mosier area were typically well within drinking water standards. Table 7 lists ten primary (health related) and eight secondary (aesthetic) drinking water standards.

TABLE 7. Selected Drinking Water Standards

Selected Primary Drinking Water Standards (Health Related)		
Arsenic	0.05	mg/l
Barium	1.0	mg/l
Cadmium	0.01	mg/l
Chromium	0.05	mg/l
Fluoride	1.4-2.4	mg/l
Lead	0.05	mg/l
Mercury	0.002	mg/l
Nitrate (as N)	10.00	mg/l
Selenium	0.01	mg/l
Silver	0.05	mg/l
Selected Secondary Drinking Water Standards (Aesthetic Quality)		
Chloride	250.0	mg/l
Copper	1.0	mg/l
Corrosivity	non-corrosive	
Iron	0.3	mg/l
Manganese	0.05	mg/l
pH	6.5 - 8.5 SU	
Sulfate	250.0	mg/l
Total Dissolved Solids	500.0	mg/l
Zinc	5.0	mg/l

mg/l means milligrams per liter of water

With the exception of nitrate-nitrogen, nine primary (health) drinking water parameters were measured only once during this study. These nine parameters are heavy metals. No values were found to exceed the primary drinking water standards. Rather, they were found below or near detection levels. Arsenic was the only primary drinking water standard metal that was measured at concentrations above detection limits. It was detected in two wells. One well (2N/12E-7ada) penetrates the Pomona aquifer only, and the other well (2N/11E-12acd) interconnects the Pomona and Priest Rapids aquifers.

Many ground water samples contained measureable levels of nitrate (between 0.1-1.0 mg/l) or ammonia nitrogen (above minimum detection levels but well within drinking water standards). No vertical or horizontal pattern was apparent in these data. An interesting trend in nitrate concentration was noted for samples collected from well 2N/12E-6cca where values decreased two orders of magnitude (from 1.2 to <.02 mg/l) in two months. The reason for this trend is unknown.

Only two values exceeded secondary (aesthetic quality) drinking water standards; zinc in well 2N/12E-6cca and iron in well 2N/12E-7ada. The first well is used for irrigation and domestic purposes and the second well is only used for irrigation.

Zinc was found to be slightly above the standard (5.3 vs 5.0 mg/l) in the sample collected from well 2N/12E-6cca. Zinc, at low concentrations, is an essential and beneficial element in human metabolism. At high concentrations, zinc may produce adverse taste and appearance. No health problems would be expected at the level found, but a taste effect may be observed. Zinc is commonly used in galvanized pipe. This may be a factor because the well was drilled during early summer 1986 and presumably a galvanized pipe was installed in the well.

Well 2N/12E-7ada was sampled once, and its water exceeded the secondary drinking water standard for Iron (0.95 vs 0.3 mg/l). The standard was established to minimize taste and staining effects of iron.

Four metals included in the secondary standards were measured above minimum detection levels but within standards at a few wells. Concentrations of copper, manganese, iron, and zinc are shown in some wells (Appendix D).

A corrosivity calculation was made using the Langelier's Index Method. This index uses pH, total dissolved solids, calcium and alkalinity to indicate the potential for corrosivity. In general, the index value obtained for well 2N/12E-6cca indicates that the well water is only slightly corrosive. This may account for the zinc levels detected in that well. Commonly, ground water in Oregon is slightly corrosive.

ORGANIC INDICATORS

Little organic contamination was detected in well water sampled in the Mosier area during the summer months of 1986. Total halogenated organics (TOX), total organic carbon (TOC) and chemical oxygen demand (COD) were measured as indicators of possible organic contamination. Only four samples were found above detection limits. A July TOX value (0.052 mg/l) at well 2N/12E-21cca was the only value considerably above the detection level. A follow-up sample in August was measured below detection.

SUMMARY/CONCLUSION

Aquifers in five distinct stratigraphic units were identified in the Mosier study area. Several discontinuous unconfined aquifers exist in glaciofluvial sand and gravel deposits. Ground water is also found within the more permeable layers of the Chenoweth Formation. Many springs in the Mosier Creek valley occur at locations where the contact between the glaciofluvial deposits and the Chenoweth Formation is exposed and where saturated permeable layers of the Chenoweth aquifer are exposed. Three aquifers are found within the Columbia River Basalt Group. They are identified informally as the Pomona, Priest Rapids and Frenchman Springs aquifers. This study focused upon the Pomona and Priest Rapids aquifers because they are the major source of ground water in the Mosier area.

Aquifer tests were conducted on the Pomona and Priest Rapids aquifers. The transmissivity values obtained indicate that water can move easily through both aquifers. The storativity values obtained indicate the aquifers are confined.

Ground water samples were collected and chemically analyzed in order to characterize the natural water quality of the aquifers. The ground water samples taken in the Mosier area were generally found to be of excellent quality and suitable for all beneficial uses. No primary (health related) drinking water standards were exceeded. Secondary (aesthetic) drinking water standards were exceeded for zinc and iron in two wells. Ground water samples from the various aquifers were quite similar in chemical composition. The Chenoweth aquifer stood out somewhat from the rest by having lower dissolved solids.

The northeast trending Columbia Hills anticline and Mosier syncline influence the occurrence and migration of ground water in the Pomona and Priest Rapids aquifers. Rainfall and runoff enters the two aquifers primarily through exposures on the flanks of the Columbia Hills anticline. Some additional water may enter the Priest Rapids aquifer from Mosier Creek. Water in the aquifers migrates down slope through permeable layers towards the Mosier syncline.

The down slope migration of ground water is impeded by the Rocky Prairie thrust fault. The fault causes water to accumulate under high pressure south of the Rocky Prairie structure in the Pomona and Priest Rapids aquifers. The high pressures cause water to rise in wells penetrating the Pomona and Priest Rapids aquifers in this area. Water rises up to 70 feet higher in elevation in wells completed in the deeper Priest Rapids aquifer than in wells completed in the Pomona aquifer. The discharge of water from the Pomona aquifer to Mosier Creek may be the primary reason why the potentiometric surface (water level in wells) in the Pomona aquifer is less than the potentiometric surface in the Priest Rapids aquifer. Apparently, in the past, the Priest Rapids aquifer also released water to Mosier Creek until its potentiometric surface dropped below the elevation of the creek.

The water levels in wells isolating the Pomona and Priest Rapids aquifers in and near the orchard area are declining. The rate of decline for the Pomona aquifer (6.9 feet/year) is more than twice the rate of decline for the Priest Rapids aquifer (3.3 feet/year). These declines indicate that the average annual discharge from each aquifer is greater than the average annual recharge for each aquifer. Recharge replaces approximately 90 percent of the discharge from the Priest Rapids aquifer, and recharge replaces approximately 82 percent

of the discharge from the Pomona aquifer. However, over 27 percent of the recharge to the Pomona aquifer may come from the Priest Rapids aquifer through wells interconnecting the two aquifers.

Wells interconnecting the Priest Rapids aquifer to the Pomona aquifer and/or Frenchman Springs aquifer cause reduced artesian pressure in the Priest Rapids aquifer. The Priest Rapids aquifer loses water unnecessarily through these wells. This loss increases the overall potentiometric surface decline for the Priest Rapids aquifer. In addition, the amount of water the Pomona aquifer gains from the Priest Rapids aquifer is, in turn, lost to Mosier Creek.

Wells interconnecting the Priest Rapids aquifer to the Pomona aquifer and/or Frenchman Springs aquifer lose a benefit of the Priest Rapids aquifer. That benefit relates to the water level found in a well. Wells that isolate the Priest Rapids aquifer apparently have higher water levels than wells interconnecting the Priest Rapids aquifer to the Pomona aquifer and/or Frenchman Springs aquifer. Water draining from the Priest Rapids aquifer into the other aquifers through an interconnecting well causes a lower composite water level in that well.

Water level declines will continue if current ground water development practices continue. Most remaining flowing wells may cease flowing within the next 10 years. Summer pumping levels in Pomona aquifer wells may soon intercept and drain the Pomona aquifer. Residents using these wells will probably deepen their wells into the Priest Rapids aquifer. If the deepened wells do not isolate the Priest Rapids aquifer, the potentiometric surface decline for the Priest Rapids aquifer will probably accelerate as more water drains into the Pomona aquifer.

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APPENDIX A

AQUIFER TEST DATA

Appendix A_1 : Pomona Aquifer Test Data

Well 2N/12E-7ada was pumped from 10:10 am on June 30, 1986 to 12:10 pm on June 31, 1986
Well 2N/12E-7aac is located 703 feet from Well 2N/12E-7ada
Well 2N/12E-7bda is located 2,275 feet from Well 2N/12E-7ada

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/12E-7ada	2N/12E-7aac	2N/12E-7bda	Discharge Rate (gpm)	Comments
0	0	0	0		pump on
0.2	0.65	----	----		
0.7	0.65	----	----		
1.0	0.92	0	0.03		pressure guage used for 2N/12E-7aac
1.6	1.03	----	----		
2.0	1.09	0.23	0.04		
2.3	1.09	----	----		
2.6	1.16	----	----		
3.0	1.19	0.23	0.04		
3.7	1.24	----	----		
4.0	1.27	0.23	0.06		
4.3	1.24	----	----		
4.8	1.24	----	----		
5.0	----	0.23	0.06		
5.2	1.25	----	----		
6.0	1.29	0.23	0.07		
7.0	1.29	0.23	0.08		
8.0	1.31	0.23	0.09		
9.0	1.32	0.23	0.10		
10.0	1.32	0.23	0.10	206	
11.0	1.44	0.23	0.11		
12.0	1.37	0.23	0.11		
13.0	1.36	0.23	0.12		
14.0	1.36	0.46	0.12		
15.0	1.40	0.46	0.12	203	
16.0	1.41	0.46	0.13		
17.0	1.36	0.23	0.12		
18.0	1.41	0.46	0.13		
19.0	1.40	0.46	0.13		
20.0	1.44	0.46	0.14		
21.0	1.43	0.46	0.14		
22.0	1.44	0.46	0.14		
23.0	1.44	0.46	0.15		
24.0	1.46	0.46	0.15		
25.0	1.47	0.46	0.16		
26.0	1.46	0.46	0.15	204	
27.0	1.47	0.46	0.16		
28.0	1.46	0.46	0.16		
29.0	1.49	0.46	0.17		
30.0	1.48	0.46	0.17	204	
35.0	1.54	0.46	0.18		

Appendix A_1 (continued)

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/12E-7ada	2N/12E-7aac	2N/12E-7bda	Discharge Rate (gpm)	Comments
40.0	1.53	0.69	0.18	204	
45.0	1.55	0.69	0.20	204	
50.0	1.59	0.69	0.20	204	
55.0	1.56	0.69	0.21	204	
60.0	1.60	0.69	0.21	204	
70.0	1.62	----	0.22	204	
75.0	----	0.69	----		
80.0	1.62	----	0.23		
90.0	1.63	0.69	0.25		
100.0	1.65	----	0.26		
105.0	----	0.46	----		
110.0	1.67	----	0.27	204	
120.0	1.68	0.46	0.27		
130.0	----	----	0.38		Well 2N/12E-7aac pump on from 165 to 175 minutes
186.0	1.81	----	----	204	
205.0	----	0.69	----		
260.0	----	----	0.38		
265.0	----	0.69			
272.0	1.82	----	----		
316.0	----	0.69	----		
323.0	----	----	0.46		difficult to get a reading at 2N/12E-7bda
333.0	1.82	----	----		
379.0	----	0.69	----		
383.0	----	----	0.46		
390.0	1.86	----	----	196	
441.0	----	0.69	----		
445.0	----	----	0.46		
450.0	1.93	----	----		Well between 2N/12E-7aac and 2N/12E-7bda on from 465 to 490 minutes
519.0	----	0.69	----		
533.0	----	----	----		
540.0	1.95	----	----		
587.0	----	0.69	----		
596.0	----	----	0.61		
605.0	1.98	----	----	198	
652.0	----	0.92	----		

Appendix A_1 (continued)

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/12E-7ada	2N/12E-7aac	2N/12E-7bda	Discharge Rate (gpm)	Comments
659.0	----	----	0.65		
665.0	2.08	----	----		
712.0	----	1.16	----		
718.0	----	----	0.68		
727.0	2.12	----	----		
770.0	----	1.16	----		
777.0	----	----	0.73		
785.0	2.13	----	----	196	
827.0	----	1.16	----		
833.0	----	----	0.77		
840.0	2.19	----	----		
881.0	----	1.16	----		
887.0	----	----	0.79		
892.0	2.22	----	----		
893.0	----	1.62	----		
945.0	----	----	0.78		
959.0	2.21	----	----	200	
995.0	----	----	0.83		
1,003.0	----	1.39	----		
1,011.0	2.24	----	----	200	
1,062.0	----	----	0.86		
1,068.0	----	1.39	----		
1,073.0	2.28	----	----		
1,122.0	----	----	0.92		
1,123.0	----	1.39	----		
1,129.0	2.31	----	----		
1,175.0	----	----	0.97		
1,183.0	----	1.39	----		
1,189.0	2.38	----	----	196	
1,234.0	----	----	0.99		
1,241.0	----	1.39	----		
1,247.0	2.09	----	----	167	1 valve shut 20 min min. while coupling downhill was replaced, valve opened at 1257 min
1,260.0	2.27	----	----	196	
1,295.0	----	----	1.00		
1,300.0	----	1.39	----		
1,304.0	2.30	----	----	194	
1,354.0	----	----	1.06		
1,358.0	----	1.39	----		

Appendix A_1 (continued)

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/12E-7ada	2N/12E-7aac	2N/12E-7bda	Discharge Rate (gpm)	Comments
1,363.0	2.39	----	----	194	
1,416.0	----	----	1.06		
1,420.0	----	1.62	----		
1,425.0	2.42	----	----		
1,448.0	----	1.39	----		
1,453.0	----	----	1.08		
1,481.0	2.44	----	----	192	
1,494.0	2.47	----	----		pump off at 1,495 minutes
1,495.1	2.12	----	----	0	
1,495.3	1.87	----	----	0	
1,495.6	1.78	----	----	0	
1,495.9	1.65	----	----	0	
1,496.2	1.56	----	----	0	
1,496.6	1.49	----	----	0	1 valve shut 20 min
1,496.9	1.42	----	----	0	
1,497.2	1.39	----	----	0	
1,497.6	1.33	----	----	0	
1,497.9	1.30	----	----	0	
1,498.2	1.27	----	----	0	
1,498.5	1.25	----	----	0	
1,498.8	1.24	----	----	0	
1,499.1	1.24	----	----	0	
1,499.4	1.22	----	----	0	
1,511.0	----	1.16	----	0	
1,517.2	----	----	0.91	0	
1,535.0	0.84	----	----	0	

Appendix A_2 : Priest Rapids Aquifer Test Data

Well 2N/11E-12dab1 flowed from 8:55 am on May 14, 1986 to 1:30 pm on May 15, 1986
Well 2N/11E-12dab2 is completed in the Pomona aquifer, and it is located 50 feet from Well 2N/11E-12dab1

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/11E-12dab1	2N/11E-12dab2	Discharge Rate (gpm)	Comments
0	0	0		valve at well head opened - Pressure guage used at well 2N/11E-12dab1
0.3	15.48	----		
0.5	14.32	----		
1.0	14.78	----		
1.5	14.78	----		
2.0	14.78	----		
2.5	15.02	----		
3.0	15.25	----		
3.5	15.25	----		
4.0	15.25	----	364	
4.5	15.48	----		
5.0	15.48	----		
5.5	15.71	----		
6.0	15.71	----		
6.5	15.71	----		
7.0	15.71	----		
8.0	15.94	----		
9.0	15.94	----	361	
10.0	15.94	----		
12.0	15.94	----		
14.0	15.94	----		
15.0	-----	0.13		
21.0	16.17	----		
25.0	16.17	----	361	
30.0	16.17	0.23		
35.0	16.40	----		
40.0	16.40	----		
45.0	16.40	----	361	
50.0	-----	0.38		
55.0	16.40	----		
60.0	16.40	----		
70.0	16.63	----	358	
75.0	-----	0.58		
80.0	16.40	----		
90.0	-----	0.68	355	
100.0	16.63	----		
110.0	16.63	----		
115.0	16.86	----		
120.0	-----	0.83		
145.0	16.86	----		

Appendix A_2 (continued)

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/11E-12dab1	2N/11E-12dab2	Discharge Rate (gpm)	Comments
150.0	-----	0.93		
160.0	16.86	----		
175.0	16.86	----		
180.0	-----	1.03		
200.0	17.09	----		
210.0	-----	1.11		
240.0	17.09	----		
265.0	16.86	----		
270.0	-----	1.21		
295.0	16.86	----		
330.0	-----	1.31		
355.0	16.86	----		
390.0	-----	1.38		
415.0	16.86	----		
450.0	-----	1.44		
475.0	16.86	----		
510.0	-----	1.50		
535.0	16.86	----		
570.0	-----	1.55		
595.0	16.86	----		
630.0	-----	1.58		
655.0	16.86	----		
690.0	-----	1.61		
715.0	16.86	----		
750.0	-----	1.63		
775.0	16.63	----	352	kink in discharge hose found and corrected
810.0	-----	1.66		
835.0	16.86	----		
870.0	-----	1.69		
895.0	16.86	----		
930.0	-----	1.71		
955.0	16.86	----		
990.0	-----	1.72		
1,015.0	17.09	----	355	
1,050.0	-----	1.74		
1,075.0	17.09	----		
1,110.0	-----	1.75		
1,135.0	17.09	----		
1,170.0	-----	1.76		
1,195.0	17.09	----		
1,230.0	-----	1.77		

Appendix A_2 (continued)

Elapsed Time (minutes)	Water Level Drawdown by Well (feet) 2N/11E-12dab1	2N/11E-12dab2	Discharge Rate (gpm)	Comments
1,255.0	17.09	----		
1,290.0	-----	1.78		
1,315.0	17.09	----		
1,350.0	-----	1.79		
1,375.0	17.09	----		
1,410.0	-----	1.81		
1,435.0	17.09	----		
1,470.0	-----	1.83		
1,495.0	17.09	----		
1,530.0	-----	1.84		
1,555.0	17.09	----		
1,590.0	-----	1.86		
1,638.0	16.86	----		
1,650.0	-----	1.88		
1,695.0	-----	1.89		
1,715.0	17.09	----		valve at well head closed
1,715.3	4.62	----	0.00	
1,715.5	3.93	----	0.00	
1,716.0	3.47	----	0.00	
1,716.5	3.23	----	0.00	
1,717.0	3.00	----	0.00	
1,718.0	2.77	----	0.00	
1,719.5	2.54	----	0.00	
1,722.5	2.31	----	0.00	
1,725.0	2.08	----	0.00	
1,729.0	1.85	----	0.00	
1,731.0	1.61	----	0.00	
1,750.0	1.27	----	0.00	
1,770.0	1.16	----	0.00	
1,790.0	0.92	----	0.00	

APPENDIX B

DISCHARGE CALCULATIONS

Appendix B_1 : ESTIMATING CITY OF MOSIER GROUND WATER USE

TABLE B1.1 - Values Used to Calculate City of Mosier Ground Water Use

Number of households: 130
Population: 350
Persons per household: 2.69

Date	Time	Elasped Time (days)	Total Discharge (acre feet)	Average Discharge Rate (ac ft/day)
07/26/85	12:00	----	----	---
08/14/85	14:00	19.1	8.2	0.4
09/16/85	19:00	33.2	13.4	0.4
10/05/85	16:00	18.9	1.9	0.1
10/23/85	16:00	18.0	2.8	0.2
		meter shut off		
03/21/86	15:00	----	----	---
04/21/86	10:00	20.8	4.0	0.2
05/03/86	12:00	12.1	2.3	0.2
05/16/86	15:00	13.1	3.5	0.3
05/27/86	14:00	10.9	4.2	0.4
06/04/86	10:30	7.9	4.4	0.6
07/07/86	19:00	33.4	18.4	1.0
07/17/86	09:00	9.6	5.4	0.6
08/26/86	14:00	40.2	23.7	0.6
08/27/86	09:00	0.8	0.4	0.5
10/10/86	14:00	44.2	12.3	0.3
11/12/86	14:00	33.0	5.0	0.2
12/08/86	15:00	26.0	4.9	0.2
01/11/87	14:00	33.9	5.3	0.2

Appendix B_1 (continued)

The amount of water used in 1986 by Mosier residents had to be estimated, because the Reservoir flow meter was shut off from January through March, 1986. The estimate was based upon average daily consumption in the Winter (October 1 to April 30), Spring (May), and Summer/Fall (June 1 to September 30). For each season, the average daily consumption was calculated from the data in the previous table by:

$$\text{Average Daily Consumption Per Season} = \frac{\Sigma\ (\text{Discharge Rate})(\text{Elapsed Time})}{\Sigma\ (\text{Elapsed Time})}$$

The amounts obtained were:

Winter	34.00 acre-feet
Spring	10.14
Summer/Fall	+ 70.74
Total	114.88 acre-feet

Appendix B_2 : ESTIMATING IRRIGATION USE OF GROUND WATER

Several methods were used to estimate irrigation use of ground water in the Mosier study area.

The first method of estimation relied upon water use estimates from several orchardists. Most irrigating orchardists consulted estimate they apply 21 inches of water per year to their orchards. They believe they apply seven inches of water each time they irrigate their orchard (once before harvest and twice after harvest). However, one orchardist believes, he applies five inches per watering, and another orchardist said, he irrigated his orchard only twice in 1986. The values in column 7 of Table B2.1 reflect these estimates. The values were calculated by using the following equation:

$$V = nid$$

V = volume of water used in 1986

n = number of waterings per year

i = acreage irrigated in 1986

d = estimated water depth in feet applied per watering

The second method of estimation relied upon water use recommended by OSU Extension. OSU Extension recommends that each orchard receives three feet depth of water each year. The values in column 8 in Table B2.1 reflect the volume of water required if each acre irrigated did receive three feet depth of water. The values were calculated by the following equation:

Volume of Water used in 1986 = (acreage irrigated in 1986) (3 feet)

Appendix B_2 (continued)

TABLE B2.1 - Use of Ground Water for Irrigation in 1986 Estimated by Different Methods

1	2	3	4	5	6	7	8	9	10	11	12
Pomona	2N/12E-7dbc	18.8	1.00	3	7	32.90	56.40	---	---	---	32.90[c]
Pomona	2N/12E-7ada	44.8	1.00	2	7	52.27	134.40	22	178	52	34.67
Pomona	2N/12E-7aac	60.0	1.00	3	7	104.99	180.00	42[a]	206	42	114.57
Pomona	2N/12E-7bda	69.4	1.00	3	5	86.75	208.20	16[b]	405	103	88.83
Total						276.91	579.00				270.97
Priest Rapids	2N/11E-12aad	18.7	0.25	3	7	8.18	14.03	---	---	---	8.18[c]
Priest Rapids	2N/11E-12dab	0.0	0.00	0	0	0.00	0.00	0	0	---	0.00
Total						8.18	14.03				8.18
Interconnected	2N/12E-7dda	41.4	1.00	3	7	72.45	124.20	28[b]	129	36	48.07
		36.8	0.50	3	7	32.20	55.20	25[b]	129	36	21.36
Interconnected	2N/12E-7bcc	24.5	1.00	3	7	42.88	73.50	27[b]	70	22	25.39
		34.7	0.50	3	7	30.37	52.05	19[b]	70	22	17.98
Interconnected	2N/12E-7baa	184.4	1.00	3	7	322.70	533.20	30	371[d]	122	150.08
Interconnected	2N/12E-7bac	16.0	1.00	3	7	28.00	48.00	---	---	---	28.00[c]
Interconnected	2N/12E-7cbc	37.8	0.00	3	7	0.00	0.00	0	0	---	0.00
Total						528.60	906.15				290.88

Corresponding Title to number

1. Aquifer
2. Well
3. Acres Irrigated
4. Ground Water Fraction of Total Water Applied
5. Number of Waterings Per Year
6. Estimated water depth applied per watering (inches)
7. 1986 Ground Water Applied if 5 to 7 inches applied per watering (acre-feet)
8. 1986 Ground Water Applied if 36 inches applied per year.
9. Time to irrigate orchard per watering (days)
10. Average Discharge Rate (gpm)
11. Average number of nozzles operating per day
12. 1986 Ground Water applied based on time to irrigate and pumping rate (acre-feet)

a. 26 days to irrigate 38 acre orchard plus 16 days to irrigate 22 additional acres
b. time estimated by formula presented in the discussion
c. used value in column 6
d. discharge from two wells added together

Appendix B_2 (continued)

The third method of estimation relied upon direct water use measurements and the time to completely water each orchard once. Direct measurement provides the best estimate of water use. Discharge was measured at well heads and sprinkler heads. Well head discharge rates were measured directly at two locations by an intrusive flow rate meter and indirectly at other locations by the following equation:

$$D = \frac{6.60\ P}{(e - w) + L(2.31\ ft/psi)}$$

D = discharge (ft^3/second)

p = horse power of the pump

e = well head elevation (feet)

w = pumping water level (feet below well head)

L = line pressure (psi)

The discharge rate calculated at the sprinkler heads used two techniques. One technique involved measuring the pressure at the sprinkler head and converting that pressure to a discharge rate with a 1972 Rain Bird Conversion Table. The second technique involved collecting a volume of water in a bucket and timing the period of time needed to obtain that volume. The sprinkler flow rate values obtained by each technique were then totaled for each orchard. The sums obtained by each technique differed by less than 15 percent (less than 10 percent in most cases).

The discharge rates measured at the well head by the intrusive flow meter differed from the total discharge rates measured at the sprinkler heads by less than 10 percent. The well head discharge rates, D, calculated by the

equation above were greater than the discharge rates measured at the sprinkler heads by 28 to 52 percent. The average discharge rate in column 10 of Table B2.1 are averages of direct measurements at the well heads and the sprinkler heads. The indirect discharge measurements at the well heads were not used.

All irrigating orchardists irrigate a section of their orchard per day. The time to irrigate three orchards is known (see column 9 in Table B2.1). The time in days to irrigate the other orchards was estimated by the following equation:

$$T = \left[\frac{\sum_{x=1}^{3} (a_x / b_x c_x)}{3} \right] b_y \, c_y$$

T = estimated time in days to completely irrigate once an orchard considered

a_x = known number of days to irrigate once each of the three orchards mentioned above

b_x = total acreage irrigated at each of the three orchards mentioned above

c_x = number of sprinklers used each day at each of the three orchards. This is a function of the well head discharge rate.

b_y = total acreage of orchard for which time is being estimated.

c_y = number of sprinklers used each day in orchard for which time is being estimated.

Once the rate of water use (column 10), the time to completely irrigate each orchard once (column 9), and the number of waterings each orchard receives (column 5) was known or estimated, the volume of water used for each orchard in 1986 (column 12) was calculated by using the following equation:

Appendix B_2 (continued)

$$v = Tdn$$

v = estimated volume of water used in 1986 at the orchard considered

T = estimated time to irrigate once the orchard considered

d = total discharge rate measured at the orchard considered

n = number of waterings the orchard receives each year

Use of this equation was not possible for three orchards irrigated by wells, because discharge and nozzle data were not collected. In these cases, the values in column 7 were used, because the values in column 7 appear to agree best with the values in column 12.

The water use values obtained by the third estimation method described above were used in this report. The values obtained for orchards irrigated by wells interconnceting the basalt aquifers presented a dilemma, however. What percent comes from the Pomona aquifer and the Priest Rapids aquifer respectively? The decision of assigning 10 percent from the Pomona aquifer and 90 percent from the Priest Rapids aquifer was based upon water levels observed in interconnecting wells. The water levels in interconnecting wells are closer to water levels found in wells isolating the Priest Rapids aquifer than in wells isolating the Pomona aquifer. The contribution from each aquifer will remain uncertain until direct measurements can be made.

Appendix B_3 : GROUND WATER DISCHARGE TO MOSIER CREEK

The volume of water estimated to discharge from the Pomona aquifer to Mosier Creek in 1986 was calculated by analyzing stream flow measurements.

TABLE B3.1 - MOSIER CREEK STREAM FLOW MEASUREMENTS

Site	Location	Measurements (ft^3/s) June	August	Comments
1	2N/12E-bbac	----	----	Frenchman Springs - Priest Rapids contact
2	2N/12E-19ccab	2.79	1.30	
3	2N/12E-19bbb	3.22	1.01	Below confluence with West Fork of Mosier Creek providing 1.27 ft^3/s in June and 0.05 ft^3/s in August - also intermittent stream contributes upstream between gauging sites
4	2N/12E-18ccb	----	----	Priest Rapids - Pomona contact
5	2N/12E-18cbbb	2.85	0.98	
6	2N/11E-13aad	2.20	1.49	Pump may be in the area
7	2N/11E-12dddd	2.70	1.05	Intermittent stream contributes upstream between guaging sites
8	2N/11E-12daba	3.15	0.56	
9	2N/11E-12adcb	0.35	0.001	Chenoweth springs and pumps in the area
10	2N/11E-12acad	0.03	0.01	Chenoweth springs and pumps in the area
11	2N/11E-12aacc	3.27	0.73	Chenoweth springs and pumps in the area
12	2N/11E-1acaa	----	----	Pomona - Chemoweth contact
13	2N/11E-1dcdb	4.02	0.91	Confluence with Dry Creek between gauging sites and Chenoweth and glaciofluvial springs in the area

Stream flow was measured in Mosier Creek in June and August 1986. Those measurements are presented in the Table C3.1. The influence of stream and spring inflows and discharge through pumps are reflected in the measurements. The August data was used for calculating the discharge of water from the Pomona aquifer to Mosier Creek, because surface water drainage into Mosier Creek was

Appendix B_3 (continued)

minimal. The August data shows a general stream flow loss except between sites 5 and 6 and below site 10. Below site 10, Mosier Creek gains water from springs within the Chenoweth Formation and the base of the glaciofluvial deposits. No irrigation water was observed running off from the orchards. The 0.51 ft^3/s (229 gpm or 369 acre-ft/yr) stream flow gain between sites 5 and 6 appears to come from the Pomona aquifer only.

Appendix B_4 : ESTIMATING GROUND WATER DISCHARGE FROM THE PRIEST RAPIDS AQUIFER TO THE POMONA AQUIFER

The discharge of ground water from the Priest Rapids aquifer to the Pomona aquifer through interconnecting wells was estimated by two methods. The first method was based upon an analysis of a 23 year hydrograph for the Pomona aquifer. The second method of analysis was based upon comparing artesian flow rates and pressures at two neighboring wells.

The first method of estimating ground water lost from the Priest Rapids aquifer to the Pomona aquifer through interconnecting wells was based upon an analysis of a 23 year hydrograph for the Pomona aquifer. The hydrograph for well 2N/12E-7ada was used (figure 12). The method involved estimating and comparing recharge to the Pomona aquifer before and after 1970. Wells interconnecting the Pomona and Priest rapids aquifers were constructed after 1970. Two wells possibly interconnecting the two aquifers were constructed before 1970. Therefore, calculated recharge to the Pomona aquifer through interconnecting wells may be under estimated.

Annual ground water recharge to the Pomona aqufier from 1963 to 1969 was estimated to be 400 acre-feet per year. This value was calculated by the following equation:

$$R = DP$$

R = estimated average annual recharge to the Pomona aquifer (1963 - 1969)

D = estimated average annual discharge from the Pomona aquifer (1963 to 1969)

P = average annual ratio of water level recovery versus drawdown as determined from the hydrograph

Appendix B_4 (continued)

Average recovery from 1963 to 1969 was approximately 86 percent of drawdown. The annual average discharge from the Pomona aquifer from 1963 to 1969 was calculated by:

annual discharge to Mosier Creek	369.20 acre-feet
annual discharge to domestic use	5.30
annual discharge for irrigation use	+103.73
	478.23 acre-feet

Discharge to Mosier Creek (369 acre-feet per year) was assumed constant from 1963 to present. The method of estimating dischage to Mosier Creek is presented in Appendix B_3. Water use per household was also assumed constant from 1963 to to present as 0.88 acre-feet per year. Six households used water from the Pomona aquifer from 1963 to 1969. Discharge for irrigation use from 1964 to 1969 was calculated by:

$$D_i = \Sigma \text{ adnf}$$

D_i = estimated annual discharge from the Pomona aquifer for irrigation (1963 to 1969)

a = total acreage irrigated for orchard considered

d = estimated depth of water applied to the orchard considered per watering

n = estimated number of waterings the orchard considered receives per year

f = ground water fraction of total irrigation water applied to the orchard considered

It was assumed current irrigation practices were used during the 1963 to 1969 period. Table B4.1 shows the values used.

TABLE B4.1 - DISCHARGE FROM THE POMONA AQUIFER FOR VALUES USED TO CALCULATE ANNUAL IRRIGATION USE 1963-1969

Well	Acreage (acres)	Pomona Ground Water Fraction	Water Depth applied/watering (inches)	Waterings per year	Annual Use (acre-feet)
2N/12E-7bcc	24.5	0.10	7	3	4.29
	34.7	0.05	7	3	3.04
2N/12E-7ada	33.0	1.00	7	2	38.50
2N/12E-7abd	20.0	1.00	5	3	25.00
2N/12E-7dbc	18.8	1.00	7	3	32.90

The estimated recharge for the Pomona aquifer from 1963 to 1969 is 411 acre-feet per year. This is less than the 564 acre-feet per year recharge estimate for the Pomona aquifer from 1983 through 1986. The additional 153 acre-feet per year recharge to the Pomona aquifer was assumed to come from the Priest Rapids aquifer through interconnecting wells. This value was used for the report.

A second method for estimating recharge to the Pomona aquifer from the Priest Rapids aquifer was based upon comparing artesian flow rates and total heads at two neighboring wells. The wells are 690 feet from each other. Well 2N/11E-12dabl isolates the Priest Rapids aquifer. Well 2N/11E-12acd interconnects the Pomona and Priest Rapids aquifers. The method included using the Bernoulli equation for fluid flow.

$$H = (v_1^2/2g) + (p_1/\gamma) + z_1 = (v_2^2/2g) + (p_2/\gamma) + z_2$$

Where: H = total head (L)

v = velocity of flow (L/T)

g = acceleration due to gravity (L/T^2)

$v^2/2g$ = velocity head (L)

p = pressure (F/L^2)

γ = specific weight (F/L^3)

P/γ = pressure head (L)

z = elevation (L)

This is a conservation of energy equation. It states that any change in velocity, pressure or elevation along the path of incompressible fluid flow will lead to a change in the other parameters in such a way to maintain a constant total head. The equation assumes no losses due to friction or gravity. If the point of interest is where water exits the well head or discharge pipe, the pressure is zero which eliminates the pressure head term. Then, the Bernoulli equation can be rewritten as:

$$H = (v_1^2/2g) + z_1 = (v_2^2/2g) + z_2$$

If only one elevation and velocity is considered, the equation can be written as:

$$H = (v^2/2g) + z$$

The velocity can be calculated by rewritting the equation as:

$$v = [2g\ (H - z)]^{1/2}$$

Discharge, Q, can be calculated by multiplying both sides of the equation by the cross-sectional area, A, of the well head or discharge pipe:

$$Q = vA = A[2g\ (H - z)]^{1/2}$$

The equation does not assume losses due to friction or gravity as stated earlier. A loss coefficient, C, can be introduced to account for losses as follows:

$$Q^* = Q\ C = v\ A\ C = A\ C[2g\ (H - z)]^{1/2}$$

The loss coefficient assumes a linear relationship for any loss. The coefficient can be calculated by comparing actual discharge to idealized discharge as follows:

$$C = \frac{Q^*}{Q}$$

A loss coefficient was calculated for wells 2N/11E-12dab1 and 12acd by comparing the artesian flow rates, Q*, found on the water well reports for each well to the idealized flow rates, Q. The idealized flow rates were calculated by using the total head found on the water well reports in the Bernoulli equation. The loss coefficient calculated was tested for well 2N/11E-12dab1. Water was discharged at the well head and pressures and flow rates were measured. The flow rates calculated by the Bernoulli equation using the loss coefficient differed from the flow rates measured by less than ten percent. A similar test for well 2N/11E-12acd was not possible during the study. Table B4.2 presents the results.

Note the larger total head, the lower discharge rate and the smaller loss coefficient for well 2N/11E-12acd in Table B4.2. Water loss from the Priest Rapids aquifer to the Pomona aquifer through the well is apparently responsible. Well construction and local transmissivity differences may also contribute to the lower discharge rate at a higher head for well 2N/11E-12acd.

TABLE B4.2 - LOSS COEFFICIENTS FOR WELL 2N/11E-dabl and 12acd

Well	elevation (feet)	cross sectional area of well (feet)	recorded discharge Q* (ft3/s)	idealized discharge Q (ft3/s)	loss coefficient $C = \frac{Q^*}{Q}$	year drilled	total head (feet)
2N/11E-12dabl	375	0.35	1.11	17.03	0.065	1981	412
2N/11E-12acd	300	0.35	0.89	37.06	0.024	1973	475

Discharge was calculated for wells 2N/11E-12acd and 12dabl using a discharge elevation at 324 feet and the loss coefficients assigned to each well (Table B4.3). Well 2N/11E-12acd does discharge water at that elevation. Water loss to the Pomona aquifer from the Priest Rapids aquifer was assumed to be responsible for any difference. A 777 acre-feet per year difference was calculated.

TABLE B4.3 - CALCULATED DISCHARGE FOR WELLS 2N/11E-12dabl and 12acd USING LOSS COEFFICIENTS ASSIGNED TO EACH WELL

Well	Sept. 1986 Total Head at well (feet)	Discharge Elevation (feet)	Discharge (gpm)	Discharge (ac-ft/yr)
2N/11E-12dabl	392	324	682	1,098
2N/11E-12acd	368	324	199	321

A second approach also applied the Bernoulli equation. Idealized discharges at 324 feet elevation were calculated for each well using September 1986 total head values (Table B4.4). Then, each discharge was multiplied by the loss coefficient for well 2N/11E-12dabl. A discharge difference of 225 acre-feet per year was calculated. Water loss to the Pomona aquifer was assumed responsible for the difference.

TABLE B4.4 - CALCULATED DISCHARGE FOR WELLS 2N11E-12dabl and 12acd USING LOSS COEFFICIENTS FOR WELL 12dabl ONLY

Well	Total Head (feet)	$Q = vA = A[2g(H - z)]^{1/2}$ (ft^3/s)	$Q^* = QC$ (ft^3/s)	Q^* (ac-ft yr.)
2N/11E-12dabl	372	23.22	1.52	1,098
2N/11E-12acd	368	18.48	1.21	873

The analyses based upon the Bernoulli equation were not used, because they focused upon one well only. The method using the 23 year hydrograph, however, includes all wells interconnecting the two aquifers. Other short comings of using the Bernoulli equation include: calculated results differed greatly when different applications of the equation were used, and an inability to account for all water lost from the Priest Rapids aquifer to the Pomona aquifer calculated by this method. Conversely, a benefit of using the Bernoulli equation is the awareness that the volume of water lost from the Priest Rapids aquifer to the Pomona aquifer may be much greater than the estimate used.

APPENDIX C

RECHARGE CALCULATIONS

Appendix C_1 : ESTIMATED RECHARGE OF THE POMONA AQUIFER

Total annual recharge to the Pomona aquifer was estimated by the following equation:

$$R_p = D_p f_p$$

R_p	=	estimated recharge to the Pomona aquifer
D_p	=	estimated discharge from the Pomona aquifer in 1986
f_p	=	average ratio of recovery versus drawdown for well 2N/12E-7ada (1983 to 1987)

The estimated discharge from the Pomona aquifer in 1986 was 688 acre-feet (Table 7). The average ratio of recovery versus drawdown for the Pomona aquifer was 0.82 from 1983 to 1987 (figure 14). The total annual recharge to the Pomona aquifer was calculated as 564 acre-feet. The Priest Rapids aquifer apparently supplies 153 acre-feet per year through interconnecting wells (Appendix B_4). Precipitation is the only other recharge source for the Pomona aquifer known to date. Therefore, precipitation probably provides the remaining 411 acre-feet of water per year entering the Pomona aquifer.

Appendix C_2 : ESTIMATED RECHARGE OF THE PRIEST RAPIDS AQUIFER

Total annual recharge to the Priest Rapids aquifer was estimated by the following equation:

$$R_{pr} = D_{pr}\ f_{pr}$$

R_{pr} = estimated recharge to the Priest Rapids aquifer

D_{pr} = estimated discharge from the Priest Rapids aquifer in 1986

f_{pr} = average ratio of recovery versus drawdown for well 2N/11E-12dab1 and 12-aad (1983 to 1987)

The estimated discharge from the Priest Rapids aquifer in 1986 was 616 acre-feet (Table 7). This volume does not include discharge to the Frenchman Springs aquifer through interconnecting wells or other subsurface outflow which could not be determined. The average ratio of recovery versus drawdown for the Priest Rapids aquifer was 0.90 from 1983 to 1987. Table C2.1 shows the values used to calculate that ratio. The total annual recharge to the Priest Rapids aquifer was calculated as 554 acre-feet.

TABLE C2.1 - VALUES USED TO CALCULATE THE RECOVERY VERSUS DRAWDOWN RATIO FOR THE PRIEST RAPIDS AQUIFER

Well	Average Recovery/Drawdown 1983 to 1987
2N/11E-12dab1	0.85
2N/11E-12aad	0.95

Precipitation and inflows from Mosier Creek appear to be the sole recharge sources for the Priest Rapids aquifer. Stream flow data presented in Appendix B_3 shows a decrease between sites 2 and 3 after the inflow from the

West Fork of Mosier Creek is subtracted. This loss occurs where the Priest Rapids member is exposed within Mosier Creek. The 0.24 ft^3/s loss corresponds to 173 acre-feet per year. It is assumed this amount enters the Priest Rapids aquifer. The 381 acre-feet per year recharge balance to the Priest Rapids aquifer probably comes from precipitation and runoff.

APPENDIX D

GROUND WATER CHEMISTRY DATA

Appendix D_1

TABLE D1.1 - SUMMARY OF CHEMICAL ANALYSES OF GROUND WATER (AVERAGE CONCENTRATIONS)

Well Number	Principal Aquifer(s)	Temperature (°C)	Conductivity (umhos/cm)	pH	Alkalinity	Turbidity (ntu)	Total Dissolved Solids	Ammonia Nitrogen	Nitrate+Nitrite Nitrogen	Total Kjeldahl Nitrogen	Total Phosphorus	Dissolved Hardness	Dissolved Calcium	Dissolved Magnesium	Dissolved Sodium	Dissolved Potassium	Dissolved Chloride	Dissolved Sulfate
2N/12E-12bbb	Glaciofluvial	14.5	215	7.3	108	1	181	ND	0.42	ND	0.129	94	20	11	8.8	2.3	3.4	6.1
2N/12E-6cca	Glaciofluvial	14.2	198	7.3	109	ND	176	0.23	0.70	0.2	0.068	90	19	10	7.9	2.3	3.0	7.6
2N/12E-16dbc	Chenoweth	13.8	174	6.2	64	3	177	ND	0.89	ND	0.062	54	12	5.8	14	1.9	15	2.2
2N/12E-7ada	Pomona	15.5	250	7.3	121	12	190	ND	ND	ND	0.30	110	18	16	11	2.4	5.0	11
2N/11E-12acd	Pomona/ Priest Rapids	16.3	259	8.2	132	ND	203	0.03	0.02	ND	0.042	94	20	11	20	4.0	3.3	10
2N/11E-12dab	Priest Rapids	16.3	256	8.2	131	ND	198	0.03	ND	ND	0.028	88	19	9.6	23	4.1	3.3	8.9
2N/12E-6abd	Priest Rapids	16.0	199	7.7	99	ND	158	ND	0.65	ND	0.067	92	20	10	7.5	1.9	2.9	7.3
2N/12E-18ddd	Priest Rapids	15.7	160	7.0	81	ND	158	ND	0.56	ND	0.260	69	13	8.7	7.7	2.1	3.6	1.9
2N/12E-7bcc	Priest Rapids/ Frenchman Spr.	16.0	261	8.1	132	ND	195	0.02	0.02	0.2	0.050	97	19	12	17	3.4	4.1	10.0
2N/12E-21caa	Basalt Interbed	14.3	289	7.5	159	ND	213	ND	ND	ND	0.051	140	26	18	9.4	5.1	3.5	7.8
2N/12E-19cbd	Frenchman Spr.	14.8	228	7.2	117	ND	186	ND	0.22	ND	0.137	96	18	13	9.2	4.5	3.0	3.4
2N/12E-22acd	Frenchman Spr.	14.8	209	7.3	110	ND	175	0.02	0.36	ND	0.086	96	17	13	7.2	2.8	3.5	4.5

Note: Results are given in milligrams per liter unless otherwise indicated.
ND = Not Detected (See Appendix A for data values and detection limits)

Appendix D_1 (continued)

TABLE D1.1 (continued) - CHEMICAL ANALYSES OF GROUND WATER (AVERAGE CONCENTRATIONS)

	Chemical Oxygen Demand	Total Organic Carbon	Total Organic Halides	Total Silver	Total Arsenic	Total Barium	Total Boron	Total Cadmium	Total Chromium	Total Copper	Dissolved Fluoride	Dissolved Iron	Total Iron	Dissolved Manganese	Total Manganese	Total Lead	Total Selenium	Total Zinc
2N/12E-12bbb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	0.09	ND	ND	ND	ND	0.94
2N/12E-6cca	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	5.3
2N/12E-16dbc	ND	ND	ND									0.07		ND				
2N/12E-7ada	ND	ND	0.008	0.001	0.009	ND	ND	ND	ND	ND	0.2	0.93	0.95	0.06	0.06	ND	ND	ND
2N/11E-12acd	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	0.4	0.08	0.08	0.05	0.05	ND	ND	ND
2N/11E-12dab	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5	0.07	0.08	ND	0.05	ND	ND	ND
2N/12E-6abd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	0.64
2N/12E-18ddd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	1.0
2N/12E-7bcc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	0.11	0.17	0.06	0.06	ND	ND	ND
2N/12E-21caa	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	0.62
2N/12E-19cbd	ND	ND	ND								ND		ND					
2N/12E-22acd	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.013	0.1	ND	ND	ND	ND	ND	ND	0.21

Appendix D_2

TABLE D2.1 - Water Quality Data From Mosier Area, Well 2N/12E-6cca

SITE: 2N/12E-6cca Glaciofluvial Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	14.6	170	7.2	102	1	188	.02	1.2	.2	0.098	94	21	10	8.0	2.2	3.7	6.6
8/19/86	14.0	219	7.2	111	1	180	.02	0.87	.2	0.085	86	18	10	7.6	2.4	2.3	8.1
9/16/86	14.0	205	7.5	114	1	161	0.30	.02	0.3	0.020	90	18	11	8.0	2.2	2.9	8.2
Average	14.2	198	7.3	109	1	176	0.23	0.70	0.2	0.068	90	19	10	7.9	2.3	3.0	7.6

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									.05		.05				
8/19/86	5	1	.005									.05		.05				
9/16/86	5	1		.001	.005	.1	.1	.001	.002	.002	0.2	.05	.05	.05	.05	.01	.005	5.3
Average	5	1	.005									.05		.05				

Appendix D2 (continued)

TABLE D2.2 - Water Quality Data From Mosier Area, Well 2N/12E-12bbb

SITE: 2N/12E-12bbb Glaciofluvial Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	14.5	213	7.3	108	1	184	.02	0.53	.2	0.148	93	19	11	9.0	2.4	3.1	6.2
9/16/86	14.5	216	7.3	108	1	177	.02	0.31	.2	0.110	95	20	11	8.5	2.2	3.8	5.9
Average	14.5	216	7.3	108	1	181	.02	0.42	.2	0.129	94	20	11	8.8	2.3	3.4	6.1

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									.05		.05				
9/16/86	5	1		.001	0.005	.1	.1	.001	.002	.002	0.2	.05	0.09	.05	.05	.01	0.005	0.94
Average	5	1										.05		.05				

Appendix D2 (continued)

TABLE D2.3 - Water Quality Data For Mosier Area, Well 2N/12E-16dbc

SITE: 2N/12E-16dbc Chenoweth Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	12.5	182	6.3	68	3	181	.02	0.80	.2	0.058	54	12	5.9	15	1.8	16	2.1
QA-split	12.0	179	6.3	66	3	183	.02	0.81	.2	0.058	54	12	5.8	15	1.7	17	1.9
8/19/86	15.0	166	6.0	59	2	172	.02	0.99	.2	0.067	54	12	5.8	14	1.9	14	2.3
Average	13.8	174	6.2	64	3	177	.02	0.89	.2	0.062	54	12	5.8	14	1.9	15	2.2

Date	COD	TOC	TOX	Dis Fe	Dis Mn
7/16/86	5	1	.005	0.09	.05
QA-split	5	1	.005	0.08	.05
8/19/86	5	1	.005	0.06	.05
Average	5	1	.005	0.07	.05

Appendix D2 (continued)

TABLE D2.4 - Water Quality Data From Mosier Area, Well 2N/12E-7ada

SITE: 2N/12E-7ada Pomona Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
9/16/86	15.5	250	7.3	121	12	190	.02	0.2	.2	0.30	110	18	16	11	2.4	5.0	11

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
9/16/86	5	1	0.008	0.001	0.009	.1	.1	.001	.002	.002	0.2	0.93	0.95	0.06	0.06	.01	.005	.05

Appendix D2 (continued)

TABLE D2.5 - Water Quality Data For Mosier Area, Well 2N/11E-12acd

SITE: 2N/11E-12acd Pomona/Priest Rapids Aquifers (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	16.5	256	8.1	132	1	211	0.02	.02	.2	0.037	95	20	11	19	4.1	3.7	10
8/19/86	16.5	256	8.2	131	1	201	.02	0.02	.2	0.058	91	20	10	22	4.2	2.6	9.9
9/16/86	16.0	264	8.2	132	1	197	0.04	0.2	.2	0.030	95	20	11	19	3.7	3.6	10
Average	16.3	259	8.2	132	1	203	0.03	0.02	.2	0.042	94	20	11	20	4.0	3.3	10

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									0.07		.05				
8/19/86	5	1	.005									0.08		.05				
9/16/86	5	1	.005	.001	0.005	.1	.1	.001	.002	.002	0.4	0.08	0.08	0.05	0.05	.01	.005	.05
Average	5	1	.005									0.08		0.05				

Appendix D2 (continued)

TABLE D2.6 - Water Quality Data From Mosier Area, Well 2N/11E-12dab

SITE: 2N/11E-12dab Priest Rapids Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
5/15/86		260	8.2	133	1	185	0.05	0.03	.2	0.030	85	19	9.2	24	4.0	3.0	8.2
7/16/86	16.0	254	8.3	130	1	219	0.03	.02	.2	0.027	87	19	9.6	21	4.3	3.1	9.2
8/19/86	18.0	250	7.9	126	1	199	0.02	.02	.2	0.033	87	19	9.5	23	4.4	2.5	9.1
9/16/86	15.0	261	8.3	133	1	190	0.03	.02	.2	0.020	91	20	10	23	3.9	4.5	9.1
Average	16.3	256	8.2	131	1	198	0.03	.02	.2	0.028	88	19	9.6	23	4.1	3.3	8.9

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
5/15/86	5	1										0.07		.05				
7/16/86	5	1	.005									0.09		.05				
8/19/86		1	0.006									0.06		.05				
9/16/86	5	1		.001	.005	.1	.1	.001	.002	.002	0.5	0.07	0.08	.05	0.05	.01	.005	.05
Average	5	1										0.07		.05				

Appendix D2 (continued)

TABLE D2.7 - Water Quality Data From Mosier Area, Well 2N/12E-6abd

SITE: 2N/12E-6abd Priest Rapids Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
8/19/86	16.0	199	7.6	98	1	161	.02	0.87	.2	0.075	90	20	9.8	7.4	2.1	2.6	7.3
9/16/86	16.0	198	7.8	99	1	154	.02	0.44	.2	0.060	93	19	11	7.6	1.8	3.2	7.3
QA-split	16.0	198	7.8	99	1	150	.02	0.44	.2	0.060	89	19	10	8.0	1.9	3.3	7.8
Average	16.0	199	7.7	99	1	158	.02	0.65	.2	0.067	92	20	10	7.5	1.9	2.9	7.3

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
8/19/86	5	1	.005									.05		.05				
9/16/86	5	1	.005	.001	0.005	.1	.1	.001	.002	.002	0.3	.05	.05	.05	.05	.01	.005	0.66
QA-split	5	1	.005	.001	0.005	.1	.1	.001	.002	.002	0.3	.05	.05	.05	.05	.01	.005	0.62
Average	5	1	.005									.05		.05				

Appendix D2 (continued)

TABLE D2.8 - Water Quality Data From Mosier Area, Well 2N/12E-18ddd

SITE: 2N/12E-18ddd Priest Rapids Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	13.5	156	7.0	80	1	166	.02	0.63	.2	0.290	67	13	8.4	7.9	2.1	3.3	0.8
8/19/86	18.5	169	6.8	83	1	155	.02	0.48	.2	0.220	72	14	8.9	7.6	2.4	2.9	3.7
9/16/86	15.0	154	7.1	80	1	154	.02	0.57	.2	0.270	69	13	8.9	7.5	1.9	4.5	1.2
Average	15.7	160	7.0	81	1	158	.02	0.56	.2	0.260	69	13	8.7	7.7	2.1	3.6	1.9

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									.05		.05				
8/19/86	5	1	.005									.05		.05				
9/16/86	5	1		.001	.005	.1	.1	.001	.002	0.003	0.1	.05	.05	.05	.05	.01	.005	1.0
Average	5	1	.005									.05		.05				

Appendix D2 (continued)

TABLE D2.9 - Water Quality Data From Mosier Area, Well 2N/12E-7bcc

SITE: 2N/12E-7bcc Priest Rapids/Frenchman Springs Aquifers (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	16.0	264	8.1	133	1	200	.02	.02	.2	0.050	97	19	12	17	3.6	4.1	10
9/16/86	16.0	258	8.1	131	1	190	0.02	0.02	0.2	0.050	97	19	12	17	3.3	4.1	9.9
Average	16.0	261	8.1	132	1	195	0.02	0.02	0.2	0.050	97	19	12	17	3.4	4.1	10.0

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									0.09		.05				
9/16/86	5	1	.005	.001	.005	.1	.1	.001	.002	0.003	0.4	0.14	0.17	0.06	0.06	.01	.005	.05
Average	5	1	.005									0.11		0.06				

Appendix D2 (continued)

TABLE D2.10 - Water Quality Data From Mosier Area, Well 2N/12E-21caa

SITE: 2N/12E-21caa Basalt Interbed (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	14.0	300	7.6	160	1	220	.02	.02	.2	0.048	140	26	18	9.8	5.2	5.0	8.0
8/19/86	14.5	277	7.3	158	1	216	.02	.02	.2	0.056	140	26	18	9.1	5.3	2.8	7.5
9/16/86	14.5	290	7.6	159	1	204	.02	.02	.2	0.050	140	26	18	9.3	4.8	2.7	7.8
Averge	14.3	289	7.5	159	1	213	.02	.02	.2	0.051	140	26	18	9.4	5.1	3.5	7.8

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	7	1	0.052									.05		.05				
8/19/86	5	1	.005									.05		.05				
9/16/86	5	1		.001	.005	.1	.1	.001	0.002	0.003	0.2	.05	.05	.05	.05	.01	.005	0.62
Average	6	1	0.028									.05		.05				

Appendix D2 (continued)

TABLE D2.11 - Water Quality Data For Mosier Area, Well 2N/12E-19cbd

SITE: 2N/12E-19cbd Frenchman Springs Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	15.0	228	7.3	120	1	175	.02	0.23	.2	0.134	98	18	13	9.6	4.4	3.3	3.8
8/19/86	14.5	228	7.0	114	1	197	.02	0.21	.2	0.140	94	18	12	8.7	4.5	2.8	2.9
Average	14.8	228	7.2	117	1	186	.02	0.22	.2	0.137	96	18	13	9.2	4.5	3.0	3.4

Date	COD	TOC	TOX	Dis F	Dis Fe	Dis Mn
7/16/86	5	1	.005		.05	.05
8/19/86	5	1	.005	0.2	.05	.05
Average	5	1	.005		.05	.05

Appendix D2 (continued)

TABLE D2.12 - Water Quality Data For Mosier Area, Well 2N/12E-22acd

SITE: 2N/12E-22acd Frenchman Springs Aquifer (all values in mg/l unless otherwise noted)

Date	Temp (C)	Cond umhos/cm	pH (su)	Alk	Turb (NTU)	TDS	NH3	NO3+NO2 (as N)	TKN	TPO4	Dis Hard	Dis Ca	Dis Mg	Dis Na	Dis K	Dis Cl	Dis SO4
7/16/86	13.3	211	7.4	110	1	181	.02	0.37	.2	0.086	96	17	13	7.6	2.9	3.8	4.1
8/19/86	16.0	207	7.2	111	1	175	.02	0.36	.2	0.092	92	17	12	6.9	2.9	2.8	5.0
QA-split	16.0	212	7.2	110	1	175	.02	0.37	.2	0.096	92	17	12	7.0	3.0	2.8	4.7
9/16/86	15.0	210	7.4	110	1	169	0.02	0.34	.2	0.080	100	17	14	7.1	2.6	3.9	4.5
Average	14.8	209	7.3	110	1	175	0.02	0.36	.2	0.086	96	17	13	7.2	2.8	3.5	4.5

Date	COD	TOC	TOX	Total Ag	Total As	Total Ba	Dis B	Total Cd	Total Cr	Total Cu	Dis F	Dis Fe	Total Fe	Dis Mn	Total Mn	Total Pb	Total Se	Total Zn
7/16/86	5	1	.005									.05		.05				
8/19/86		1	.005									.05		.05				
QA-split	5	1	.005									.05		.05				
9/16/86	5	1		.001	.005	.1	.1	.001	.002	0.013	0.1	.05	.05	.05	.05	.01	.005	0.21
Average	5	1	.005									.05		.05				

Appendix D_3 : DEQ QUALITY ASSURANCE REPORT AND DATA - MOSIER STUDY

Introduction:

The attached data sheets (Tables D.1-D.4) document the quality assurance and quality control (QA/QC) for the analyses performed by DEQ Laboratories for the Mosier Study. The report summaries include:

1. Field QA duplicate results on the three Mosier sampling runs conducted in June, July and August 1986. (Tables D3.1, D3.2, and D3.3)

2. A summary of the overall field QA duplicate precision along with DEQ Labs' precision and accuracy statements for the data generated in 1986. (Table D3.4)

Discussion:

Definitions of data reported in summaries.

1. Field (QA) Precision The assessment of data variability from the point of sample collection through the analysis. Duplicate samples are collected in the field and analyzed as unique samples. The percent difference (% diff.) is calculated by dividing the difference in analytic results by the mean and expressing as a percent by multiplying by 100.

2. Lab Precision The assessment of analytical variability. Duplicate analyses are performed on the same sample and the percent difference is calculated as above.

3. Lab Accuracy The degree of agreement of a measurement, X, with an accepted reference or true value, T. The result reported is the standard deviation of the percent recovery (100X/T) from spiked (standard addition) samples of similar matrices (river, lake, groundwater, etc.)

Results:

The agreement obtained on the QA sample indicates that the data reported by the DEQ lab is of excellent quality. The precision obtained on the QA samples is better than the overall lab precision obtained in 1986. This result indicates good sampling, preservation and analytic technique with the following exception noted. Results for Mosier 1 indicated elevated chloride in the field blank. The high chloride results indicate samples may have been contaminated in the field. Since chlorides are determined from field filtered samples and the unfiltered blank showed no contamination suggests that contamination resulted from the filtering apparatus. It is uncertain whether the contamination in the blank was a carry over from a previous sample. Results may be elevated by an average of 1.5 mg/l for this sampling run. Data were reported as N/A (not applicable) for those analytes which were below detection limits for all three sampling periods. This was the case for NH3-N, TKN, Fe, Mn, COD, TOC and TOX.

Appendix D_3 (continued)

Summary:

The data reported for the Mosier Study have met DEQ Lab's quality assurance and quality control criteria with the exception of Mosier 1 blank chloride results. The data have the approval of DEQ Laboratories and Applied Research Division's Quality Assurance Section.

Appendix D_3 (continued)

TABLE D3.1 - QUALITY ASSURANCE DATA FOR JULY 1986 SAMPLES

Lab#: 86-0600 Code #: 3260
Run: Mosier #1 Period: July 1986

PARAMETER			SITE	QA	MEAN	DIFF	%DIFF
	P1053	P305			P161		
Station	Field	R360	R010	2N/12E-16dbc	R626		
Storet#	Blank	H163	H656		H627		
Date	7/16/86	DP571	DP570	7/16/86	DP262		
Field PH	6.5		6.3	6.3	6.3	0.0	0.00
Temp	17.0		12.5	12.0	12.3	0.5	4.08
Fld Cond	1		182	179	180.5	3	1.66
Field Alk	2.0		68	66	67.0	2.0	2.99
Lab pH	5.6		6.7	6.6	6.65	0.1	1.50
Lab Alk	1		187	188	187.5	-1	-0.53
Lab Cond	2		70	66	68	4	5.88
Hardness	1		54	54	54	0	0.00
Turb	<1		3	3	3	0	0.00
NH3-N	<0.02		<0.02	<0.02	N/A	N/A	N/A
NO3+NO2-N	<0.02		0.80	0.81	0.80	-0.01	-1.24
TKN	<0.2		<0.2	<0.2	N/A	N/A	N/A
T-PO4	<0.005		0.058	0.058	0.058	0	0.00
Cl-	**1.6		16.0	17.0	16.5	-1.0	-6.06
SO4=	<0.5		2.1	1.9	2.0	0.2	10.00
diss Ca	0.2		12	12	12	0	0.00
diss Mg	<0.1		5.9	5.8	5.85	0.1	1.71
diss Na	<0.1		14.6	14.6	14.60	0.00	0.00
diss K	<0.1		1.8	1.7	1.8	0.1	5.71
Fe	<0.05		<0.05	<0.05	N/A	N/A	N/A
Mn	<0.05		<0.05	<0.05	N/A	N/A	N/A
TDS	9		181	183	182	-2	-1.10
COD	<5		<5	<5	N/A	N/A	N/A
TIC	<1		<1	3	N/A	N/A	N/A
TOX	0.008		<0.005	<0.005	N/A	N/A	N/A

Comments: Elevated Cl- blanks. Data may be elevated by an average of 1.5mg/l.

Appendix D_3 (continued)

TABLE D3.2 - QUALITY ASSURANCE DATA FOR AUGUST 1986 SAMPLES

Lab#: 86-0170 Code #: 3258
Run: Mosier #2 Period: August 1986

PARAMETER		SITE	QA	MEAN	DIFF	%DIFF
		2N/12E-22acd				
Station	Field	P2083		P2082		
Storet#	Blank	R147		R692		
Date	8/19/86	DP905	8/19/86	DP900		
Field pH	6.5	7.2	7.2	7.2	0.0	0.00
Temp	28.0	16.0	16.0	16.0	0.0	0.00
Fld Cond	1	207	212	209.5	-5	-2.39
Field Alk	1.0	111	110	110.5	1.0	0.90
Lab pH	5.7	7.5	7.5	7.5	0	0.00
Lab Alk	N/A	115	109	112	6	5.36
Lab Cond	1	220	220	220	0	0.00
Turb	< 1	<1	<1	N/A	N/A	N/A
NH3-N	< 0.02	<0.02	0.02	N/A	N/A	N/A
NO3+NO2-N	< 0.02	0.36	0.37	0.36	-0.01	-2.74
TKN	< 0.2	<0.2	<0.2	N/A	N/A	N/A
T-PO4	0.007	0.092	0.096	0.094	-0.004	-4.26
Cl-	< 0.5	2.8	2.8	2.8	0.0	0.00
SO4=	< 0.5	5.0	4.7	4.8	0.3	6.19
diss Ca	< 0.2	17	17	17	0	0.00
diss Mg	< 0.1	12	12	12	0	0.00
diss Na	< 0.1	6.9	7.0	6.95	-0.10	-1.44
diss K	< 0.1	2.9	3.0	3.0	-0.1	-3.39
Fe	< 0.05	<0.05	<0.05	N/A	N/A	N/A
Mn	< 0.05	<0.05	<0.05	N/A	N/A	N/A
TDS	7	175	175	175	0	0.00
COD	< 5	N/A	<5	N/A	N/A	N/A
TOC	< 1	<1	<1	N/A	N/A	N/A
TOX	< 0.005	<0.005	<0.005	N/A	N/A	N/A

Appendix D_3 (continued)

TABLE D3.3 - QUALITY ASSURANCE DATA FOR SEPTEMBER 1986 SAMPLES

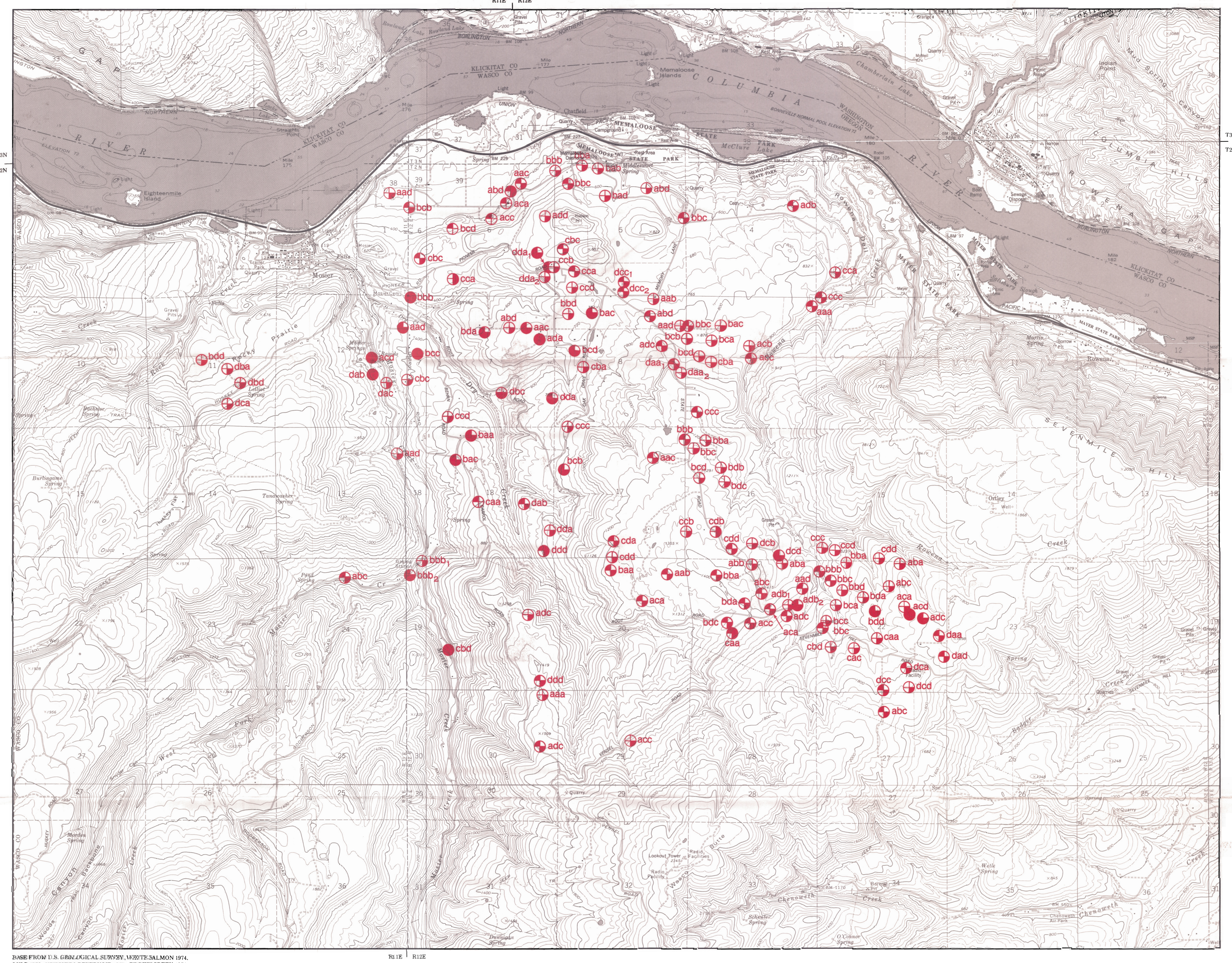
Lab#: 86-0802 Code #: 3258
Run: Mosier #3 Period: September 1986

PARAMETER		SITE	QA	MEAN	DIFF	%DIFF
		2N/12E-6abd				
Station	Field	P150		P2130		
Storet#	Blank	R087		R419		
Date	N/A	DP52	9/16/86	DP528		
Field pH		7.8	7.8	7.8	0.0	0.00
Temp		16.0	16.0	16.0	0.0	0.00
Fld Cond		198	198	198	0	0.00
Field Alk		99.0	99.0	99.0	0.0	0.00
Lab pH		7.9	7.9	7.9	0	0.00
Lab Alk		103	103	103	0	0.00
Lab Cond		202	201	201.5	1	0.50
Turb		1	1	N/A	N/A	N/A
Hardness		93	89	91	4	4.40
NH3-N		0.02	0.02	N/A	N/A	N/A
NO3+NO2-N		0.44	0.44	0.44	0.00	0.00
TKN		0.2	0.2	N/A	N/A	N/A
T-PO4		0.060	0.060	0.06	0	0.00
Cl-1		3.2	3.3	3.3	-0.1	-3.08
F-		0.3	0.3	0.3	0.0	0.00
B		0.1	0.1	N/A	N/A	N/A
SO4=		7.3	7.8	7.6	-0.5	-6.62
diss Ca		19	19	19	0	0.00
diss Mg		11	10	10.5	1	9.52
diss Na		7.6	8.0	7.80	-0.40	-5.13
diss K		1.8	1.9	1.9	-0.1	-5.41
TDS		154	150	152	4	2.63
TOX		0.005	0.005	N/A	N/A	N/A
COD		5	5	N/A	N/A	N/A
TOC		1	1	N/A	N/A	N/A
Ag		0.001	0.001	N/A	N/A	N/A
As		0.005	0.005	0	0	Error
Ba		0.1	0.1	N/A	N/A	N/A
Cd		0.001	0.001	N/A	N/A	N/A
Cr		0.002	0.002	N/A	N/A	N/A
Cu		0.002	0.002	N/A	N/A	N/A
Fe		0.05	0.05	N/A	N/A	N/A
Mn		0.05	0.05	N/A	N/A	N/A
Pb		0.01	0.01	N/A	N/A	N/A
Se		0.005	0.005	N/A	N/A	N/A
Zn		0.66	0.62	0.64	0.04	6.25
Diss Fe		0.05	0.05	N/A	N/A	N/A
Diss Mn		0.05	0.05	N/A	N/A	N/A

Appendix D3 (continued)

TABLE D3.4 - SUMMARY OF QUALITY ASSURANCE DATA

Parameter	Field (QA) Precision (%Diff)	Lab Precision (%Diff)	Lab Accuracy (RSD 100%+-)	(QA/QC) Met	Comments
pH	0.00	2.00	0.50	Yes	
Alkalinity	1.30	2.00	5.00	Yes	
Conductivity	1.35	3.00	2.00	Yes	
Hardness	2.20	7.00	6.00	Yes	
Turbidity	0.00	1.00	5.00	Yes	
NH3-N	N/A	6.00	6.00	Yes	
NO3+NO2-N	1.33	2.00	5.00	Yes	
TKN	N/A	10.00	14.00	Yes	
TPO4-2	1.42	4.60	5.00	Yes	
Chloride	3.00	2.00	7.50	Yes	Mos#1: High Cl- blank
Sulfate	7.60	3.00	6.00	Yes	
Calcium	0.00	3.00	2.00	Yes	
Magnesium	3.70	6.00	5.00	Yes	
Sodium	2.19	1.30	4.00	Yes	
Potassium	4.84	1.00	5.00	Yes	
Iron	N/A	6.00	4.00	Yes	
Manganese	N/A	6.00	11.00	Yes	
TDS	1.24	5.00	4.00	Yes	
COD	N/A	10.00	7.50	Yes	Accuracy at 50 ppm
TOC	N/A	10.00	6.50	Yes	Accuracy at 20 ppm
TOX	N/A	5.00	6.20	Yes	Accuracy at 0.1 ppm



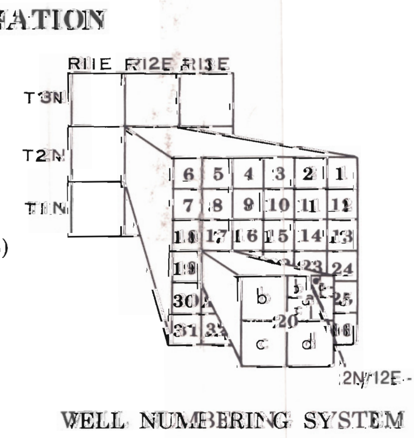
BASE FROM U.S. GEOLOGICAL SURVEY, WHITE SALMON 1974,
LYLE 1978, KETCHUM RESERVOIR 1970, BROWN CREEK 1974.
SCALE 1:24000

R11E R12E

EXPLANATION

WELL SYMBOLS

- Water level reading: monthly (1986)
- Water level reading: semi annual (1986)
- Used for stratigraphic control
- Chemical analysis of water



WELL NUMBERING SYSTEM

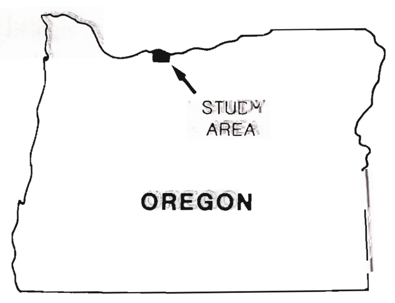


PLATE NO. 1

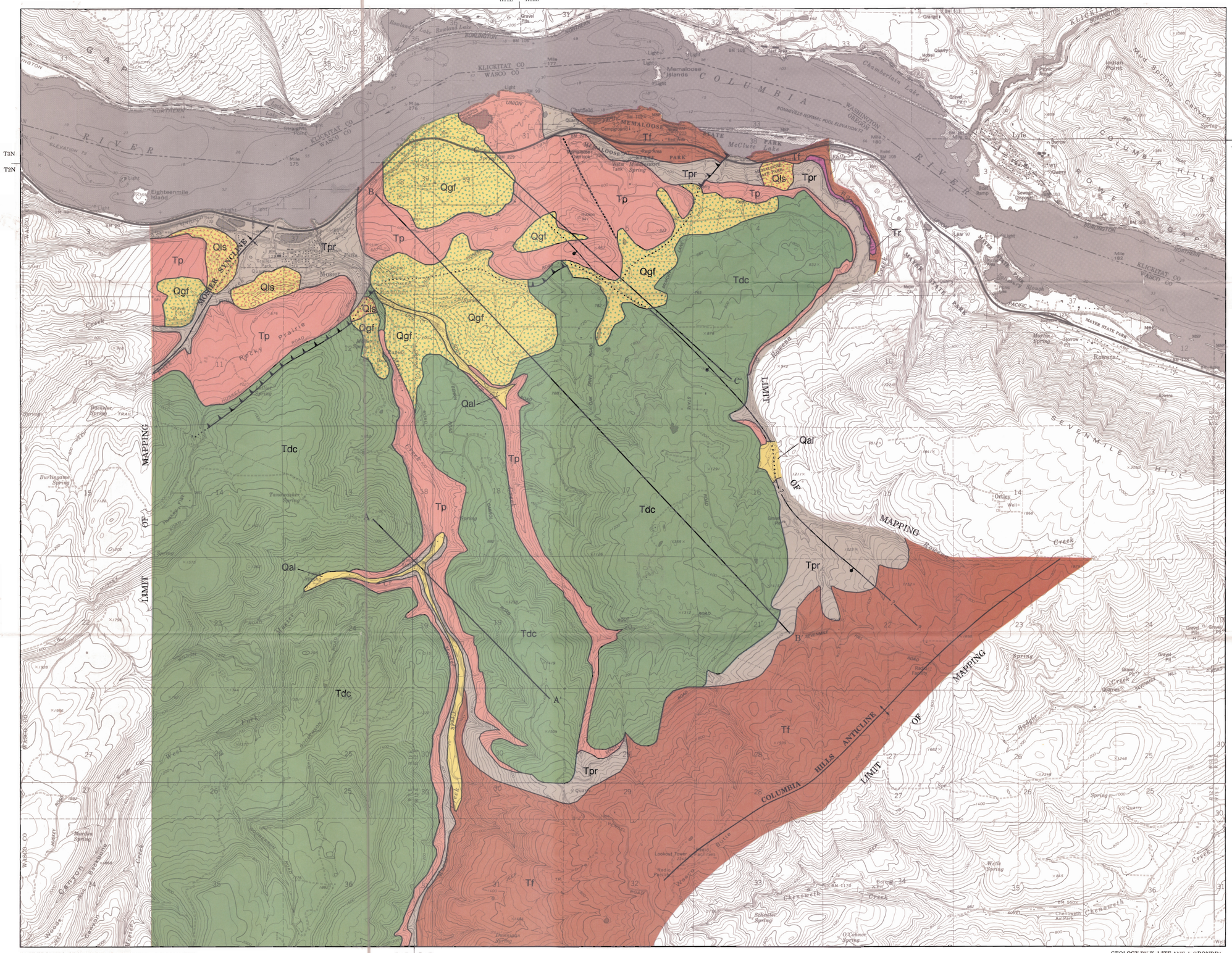
LOCATION MAP OF REPRESENTATIVE WELLS

SCALE 1:24 000

Projection: Lambert Conformal Conic

PLATE NO. 2

RECONNAISSANCE GEOLOGIC MAP AND SECTIONS IN THE MOSIER AREA, WASCO COUNTY, OREGON



BASE FROM U.S. GEOLOGICAL SURVEY, WHITE SALMON 1974, LYLE 1978, KETCHUM RESERVOIR 1970, BROWN CREEK 1974. SCALE 1:24000

GEOLOGY BY K. LITE AND J. GRONDIN, ALSO MODIFIED FROM J.L. ANDERSON (in SWANSON AND OTHERS, 1981) AND NEWCOMB (1969).

SCALE 1:24 000

Projection: Lambert Conformal Conic

EXPLANATION

LITHOLOGIC DESCRIPTIONS

Qal — Alluvium: Unconsolidated silt, sand, and gravel in channels, flood plains, and terraces along intermittent and perennial streams. Predominantly found in Mosier Creek, south of the West Fork confluence. Only shown where alluvium completely covers bedrock.

Qls — Landslide deposits: Mostly unstratified, unsorted mixtures of rock and soil. Two rock slide areas occur adjacent to Rock Creek near Mosier.

Qgf — Glaciofluvial deposits: Coarse, unsorted, chaotically to poorly bedded gravel, sand and silt. Gravels are commonly openwork, with a coarse sand matrix partially filling interstices. Foreset beds are common near Mosier and Rock Creeks. Includes Ql of Newcomb (1969).

Dalles Group

Tdc — Chenoweth Formation: Volcaniclastic and sedimentary rock consisting of laharic deposits of andesitic agglomerate, tuff breccia and fluvial deposits of conglomerate, tuffaceous sandstone and siltstone.

Columbia River Basalt Group

SADDLE MOUNTAINS BASALT

Tp — Pomona Member: Gray to black, fine grained, porphyritic basalt. Easily recognized in surface exposures by its slender, wavy entablature-like jointing pattern. The Pomona Member has reversed paleomagnetic polarity.

WANAPUM BASALT

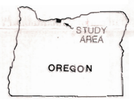
Tpr — Priest Rapids Member: Dark gray to black, fine to coarse grained basalt. The upper part of the member often exhibits a platy jointing pattern. Two flows apparently exist in the Mosier Area. Both flows have reversed paleomagnetic polarity.

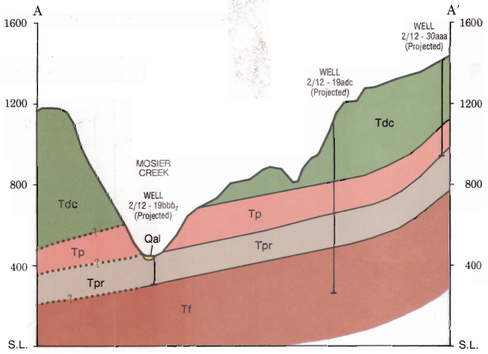
Tr — Roza Member: Dark gray to black, medium grained, porphyritic basalt. Easily recognized by the occurrence of abundant, relatively large (less than 1 cm) plagioclase phenocrysts. The Roza Member has transitional paleomagnetic polarity. Only exposed near Rowena Dell.

Tf — Frenchman Springs Member: Dark gray to black, fine to medium grained, aphyric to porphyritic basalt. Frenchman Springs Member consists of a number of individual units. The upper flow near Mosier is probably part of the aphyric Sentinal Gap unit (Beeson, personal comm., 1986). Frenchman Springs Member has normal paleomagnetic polarity.

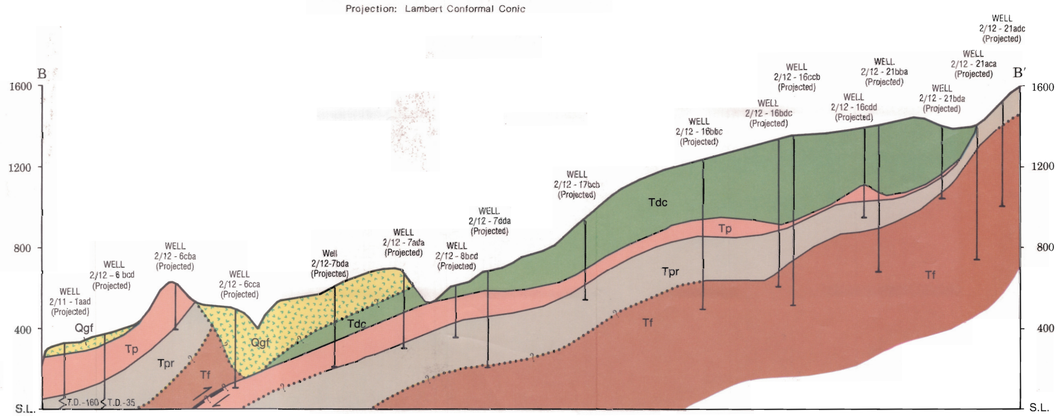
GEOLOGIC SYMBOLS

- Anticline
- Syncline
- Fault: ball on down thrown side; dotted where concealed
- Thrust: teeth on upper side; dotted where concealed
- Photo lineament
- Contact: dotted where inferred
- A—A′ Line of Section A to A′





5X VERTICAL EXAGGERATION



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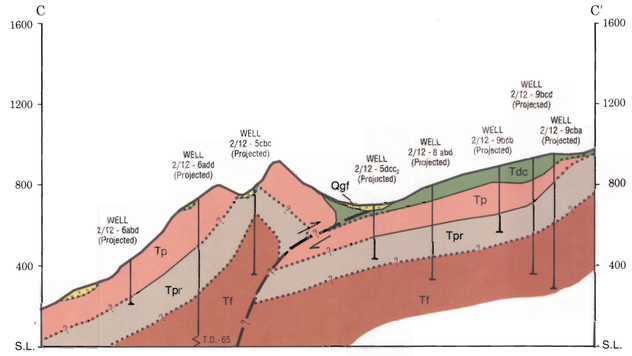
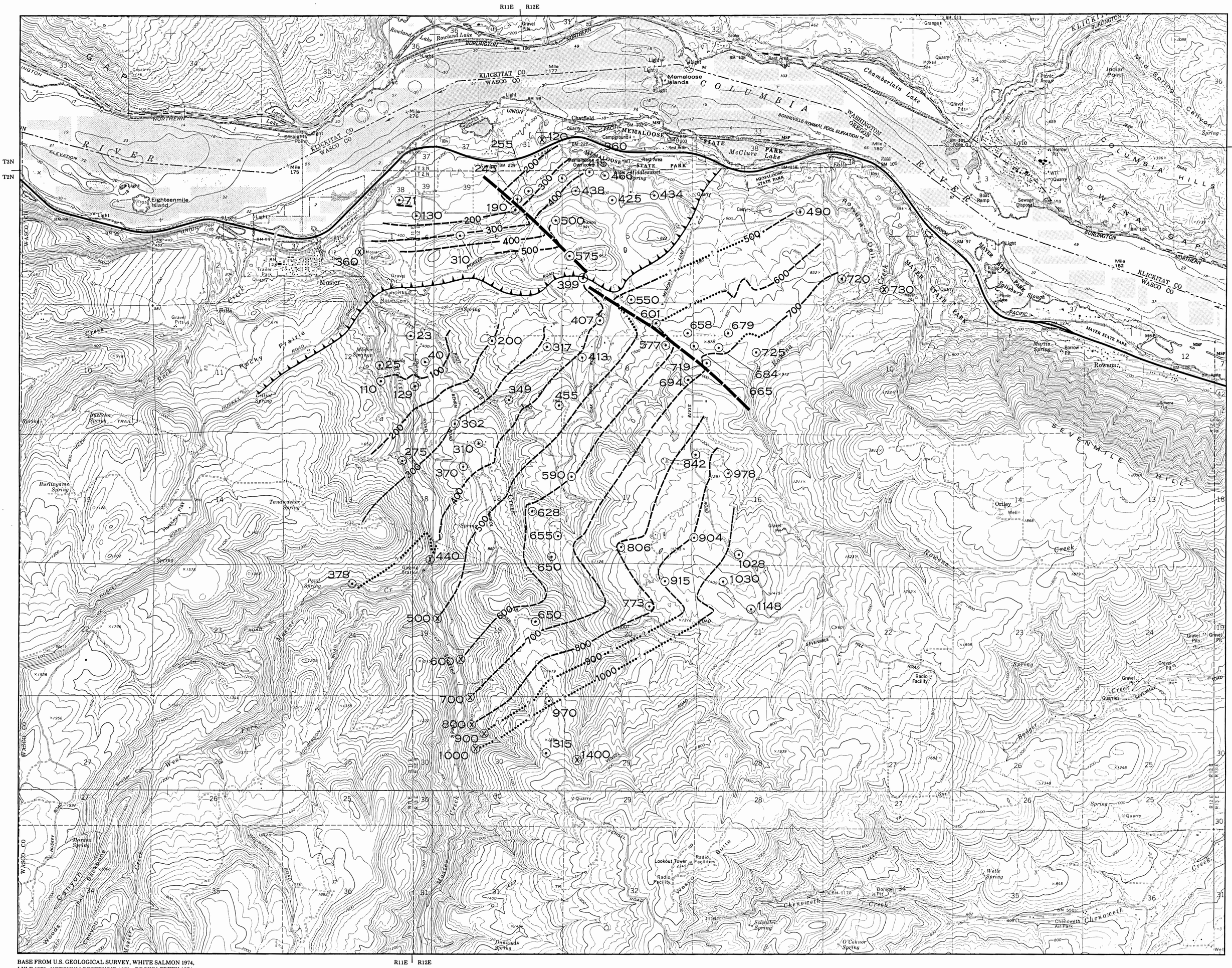


5X VERTICAL EXAGGERATION



BASE FROM U.S. GEOLOGICAL SURVEY, WHITE SALMON 1974, LYLE 1978, KETCHUM RESERVOIR 1970, BROWN CREEK 1974.
SCALE 1:24000

EXPLANATION

LOCATIONS WHERE TOP OF THE PRIEST RAPIDS MEMBER WERE DETERMINED

⊙ 275 — Elevations above sea level determined from well log data[1]

⊗ 440 — Elevations above sea level determined from surface exposure

ELEVATION CONTOUR LINES OF THE TOP OF THE PRIEST RAPIDS MEMBER

—500—•• — Approximate elevation of the top of the Priest Rapids Member: dotted where inferred

Trace of Rocky Prairie thrust fault

Trace of Rowena Creek fault

1 Columbia River Basalt Group units were interpreted from Water Well Reports.

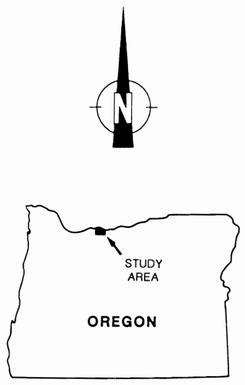


PLATE NO. 3

STRUCTURE CONTOUR MAP: TOP OF THE PRIEST RAPIDS MEMBER

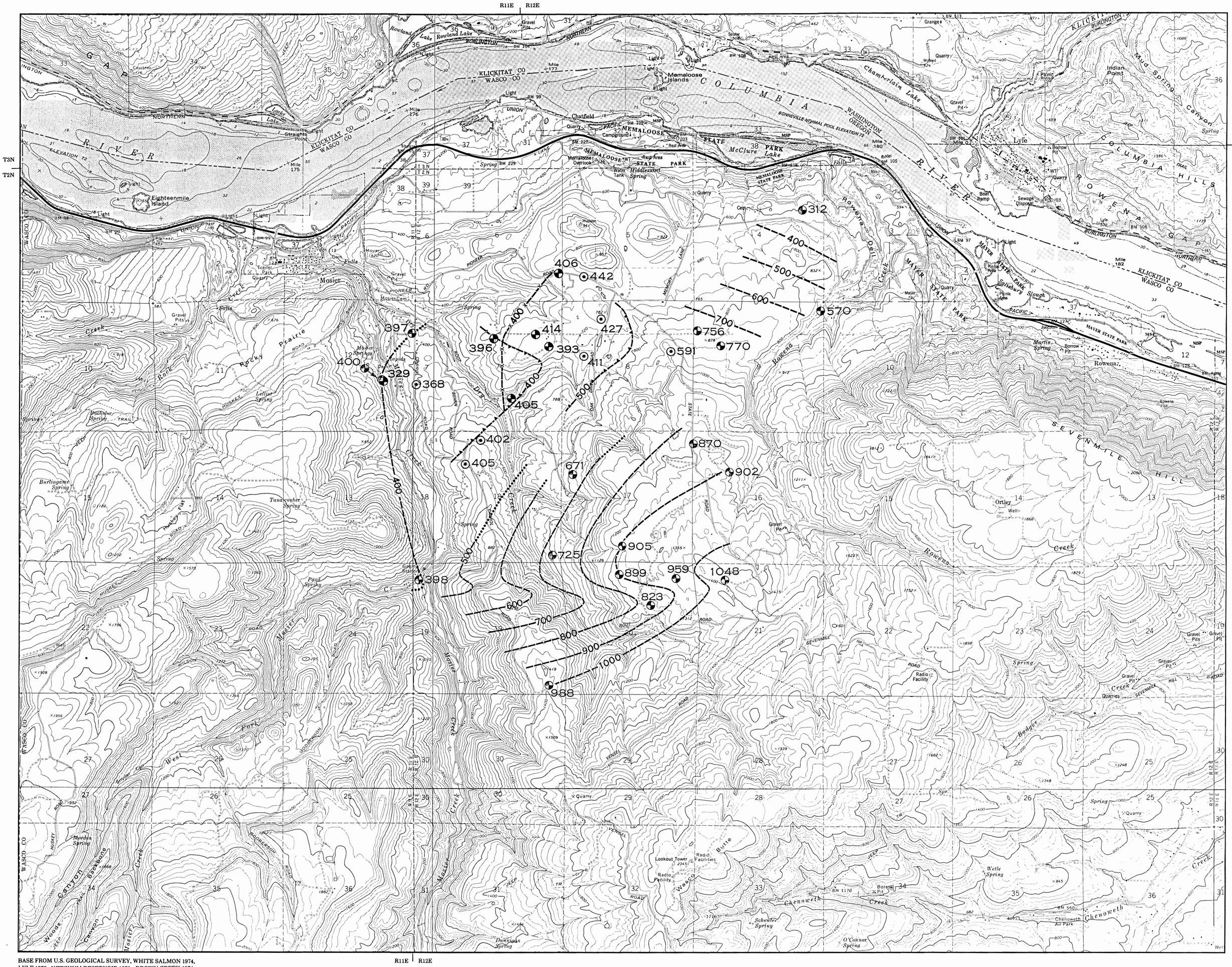
SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

Projection: Lambert Conformal Conic



BASE FROM U.S. GEOLOGICAL SURVEY, WHITE SALMON 1974, LYLE 1978, KETCHUM RESERVOIR 1970, BROWN CREEK 1974.
SCALE 1:24000

EXPLANATION

406	Well location and water level elevation above sea level for the Pomona Aquifer
671	Well location and water level elevation above sea level for the Priest Rapids Aquifer
591	Well location and water level elevation above sea level for where the Priest Rapids Aquifer is interconnected with other aquifers
—x—400—x—	Approximate potentiometric surface elevation above sea level for the Pomona Aquifer
— —500— —	Approximate potentiometric surface elevation above sea level for the Priest Rapids Aquifer
••••500•••••	Inferred potentiometric surface elevation above sea level for the Priest Rapids Aquifer
—▲—500—▲—	Approximate potentiometric surface elevation above sea level for where the Priest Rapids Aquifer is interconnected with the Pomona Aquifer

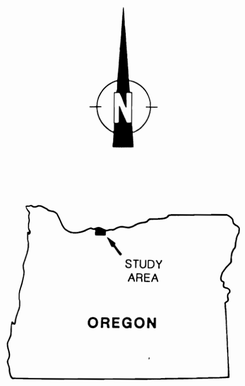


PLATE NO. 4

POTENTIOMETRIC SURFACE MAP OF THE POMONA AND PRIEST RAPIDS AQUIFERS: SPRING 1986

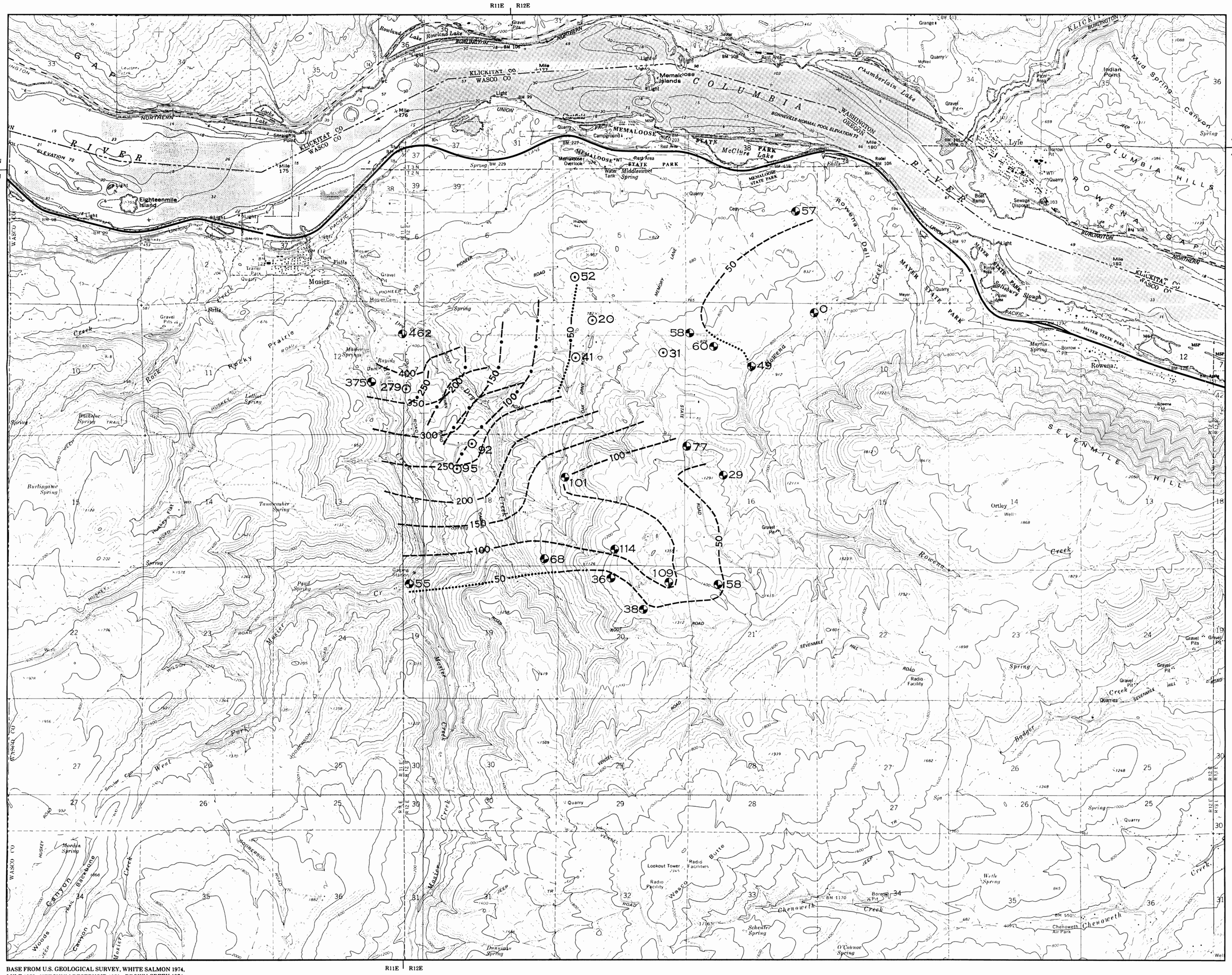
SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

Projection: Lambert Conformal Conic



BASE FROM U.S. GEOLOGICAL SURVEY, WHITE SALMON 1974, LYLE 1978, KETCHUM RESERVOIR 1970, BROWN CREEK 1974.
SCALE 1:24000

EXPLANATION

462	Pressure head in feet of water above the top of the Priest Rapids Aquifer for wells tapping the Priest Rapids Aquifer only
52	Composite pressure head in feet of water above the top of the Priest Rapids Aquifer where wells interconnect the Pomona Aquifer with the Priest Rapids Aquifer
--50--	Pressure head contour in feet of water for the Priest Rapids Aquifer
--50--•	Composite pressure head contour in feet of water above the Priest Rapids Aquifer where wells interconnect the Pomona Aquifer with the Priest Rapids Aquifer

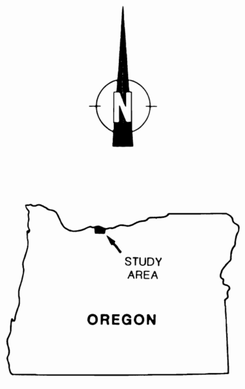


PLATE NO. 5

PRESSURE HEAD MAP FOR THE PRIEST RAPIDS AQUIFER: SPRING 1986

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

Projection: Lambert Conformal Conic