Ground Water Report No. 34

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WATER RESOURCES DEPARTMENT

WILLIAM H. YOUNG
Director

HYDROGEOLOGY OF THE ONTARIO AREA MALHEUR COUNTY, OREGON

By
Marshall W. Gannett

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HYDROGEOLOGY OF THE ONTARIO AREA, MALHEUR COUNTY, OREGON

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ABSTRACT

The Ontario area is in the far eastern part of Oregon at the confluence of the Snake and Malheur Rivers. The broad river valleys and parts of the adjacent uplands are cultivated for a number of crops including onions, potatoes, sugar beets, wheat, corn, and alfalfa. Virtually all the cultivated area is irrigated using surface water. Surface water is supplied primarily from Owyhee Reservoir and reservoirs on the Malheur River and Bully Creek. Water is distributed throughout the area by a vast network of canals and ditches.

The valleys are underlain by an extensive shallow alluvial aquifer consisting of 10 to 40 feet of unconsolidated sand and gravel. This aquifer is overlain by 10 to 50 feet of silt. The aquifer is underlain by siltstones which were deposited in a large lake which occupied the region within the last several million years. Sampling by state and federal agencies has verified widespread contamination of this shallow aquifer by agricultural chemicals, specifically nitrate and Dacthal. This aquifer is the main source of drinking water for most of the area. The primary purpose of this study was to characterize the hydrogeology of the area to aid in understanding and solving the contamination problem. A secondary purpose was to evaluate the ground water supply.

This study included the field location of approximately 150 wells. Information from these wells was used to delineate the sub-surface geology and to create a map of the water table. The water table map provided information on the directions of ground water flow. The water level was closely monitored in a number of wells in order to understand how ground water responds to climatic events and irrigation activities. Five aquifer tests were conducted to gain information on the hydraulic properties of the aquifer and overlying silt. Reconnaissance geologic mapping was conducted to understand the nature of the lake sediments underneath the shallow aquifer and the regional hydrologic setting.

Results of this study indicate that the silt overlying the shallow sand and gravel aquifer is somewhat permeable and does not provide the aquifer protection from surface activities. The observed rapid rise in ground water levels in response to melting snow and irrigation canal leakage, and the use of drainage wells indicates a direct hydraulic connection between the soil zone and the shallow aquifer. In addition, aquifer testing results indicate that the overlying silt is permeable and the saturated portion contributes water to the aquifer during well pumping.

The largest source of recharge to the shallow aquifer is from canal and ditch leakage, and deep percolation of irrigation water. According to records from the Owyhee Irrigation District, approximately four acre-feet of water per acre are delivered to farms. This water is applied to fields predominantly by surface spreading methods. Nitrate and Dacthal are most likely being introduced into the ground water through deep percolation and through seepage from tail water ditches and canals. Once water has percolated below the soil zone, it enters the shallow aquifer by traveling through the silt overlying the aquifer.

Reducing contamination in the shallow aquifer will require reducing deep percolation or reducing the amount of nitrate and Dacthal in water lost to deep percolation. The amount of these chemicals in tail water running off of fields must also be reduced.

Current production of ground water from the shallow aquifer is less than one quarter of the estimated annual recharge to the system. This suggests that the shallow aquifer could support additional development.

HYDROGEOLOGY OF THE ONTARIO AREA
MALHEUR COUNTY, OREGON

INTRODUCTION

An extensive shallow alluvial aquifer underlies much of the area around the city of Ontario in northern Malheur County, Oregon. This shallow aquifer is the main source of drinking water for most of the population in this agricultural area. Water quality sampling has delineated widespread contamination of this shallow aquifer by nitrate and pesticide. Between 1983 and 1986, the Oregon Department of Environmental Quality (DEQ) tested water from 107 wells in a 180 square-mile area in the vicinity of the cities of Ontario, Nyssa and Vale. Elevated nitrate concentrations were found on about 67% of the wells tested. Nitrate concentrations exceeded the federal drinking water standard in 35% of the wells tested. Two thirds of the wells tested had detectable levels of Dacthal, a pesticide commonly used in the area. Land use in the area is primarily irrigated row crop farming. Irrigation is almost exclusively by surface spreading methods. The largest potential source of nitrate in the area is agricultural fertilizers.

The contaminated aquifer is a deposit of sand and gravel which blankets the valley floor. This deposit ranges in thickness from 10 to 40 feet thick. This aquifer is poorly confined by an overlying layer of fluvial and eolian silt which averages about 25 feet thick. The water table in the valley is generally 5 to 15 feet below land surface.

Results of this investigation indicate that the silt overlying the sand and gravel aquifer is permeable and does not provide the aquifer protection from surface activities. Contaminants are most likely being carried into the ground water by deep percolation of irrigation water and by seepage of contaminated water from tail water ditches.

PURPOSE AND SCOPE

The primary purpose of this investigation was to gain an understanding of the hydrogeological factors influencing the introduction of contaminants into the ground water and influencing contaminant movement. A secondary purpose was to evaluate ground water supplies.

Specific objectives were to identify individual aquifers and define their geologic framework, hydrologic properties and boundary conditions, and to describe the overall ground water flow system. Additional objectives were to evaluate the potential for over pumping or depleting ground water supplies and to determine the effects, if any, of ground water withdrawals on water quality.

This project included the efforts of one primary investigator for a period of two years. Several individuals assisted with field work. Data collection in the field took place over a period of 18 months. The investigation covers the area from Vale, east to Ontario and south to Nyssa (Figure 1). Effort was concentrated in the valley areas and uplands adjacent to the Valleys where agricultural activity is concentrated.

ACKNOWLEDGMENTS

The author gratefully acknowledges the cooperation and assistance of the many Ontario area residents who allowed access to their wells for periodic water level measurements. Mr. Roland Pennington allowed a continuous water level recorder to be set up on his well and allowed an aquifer test to be conducted on the same well. Dr. Clinton Shock of the Oregon State University

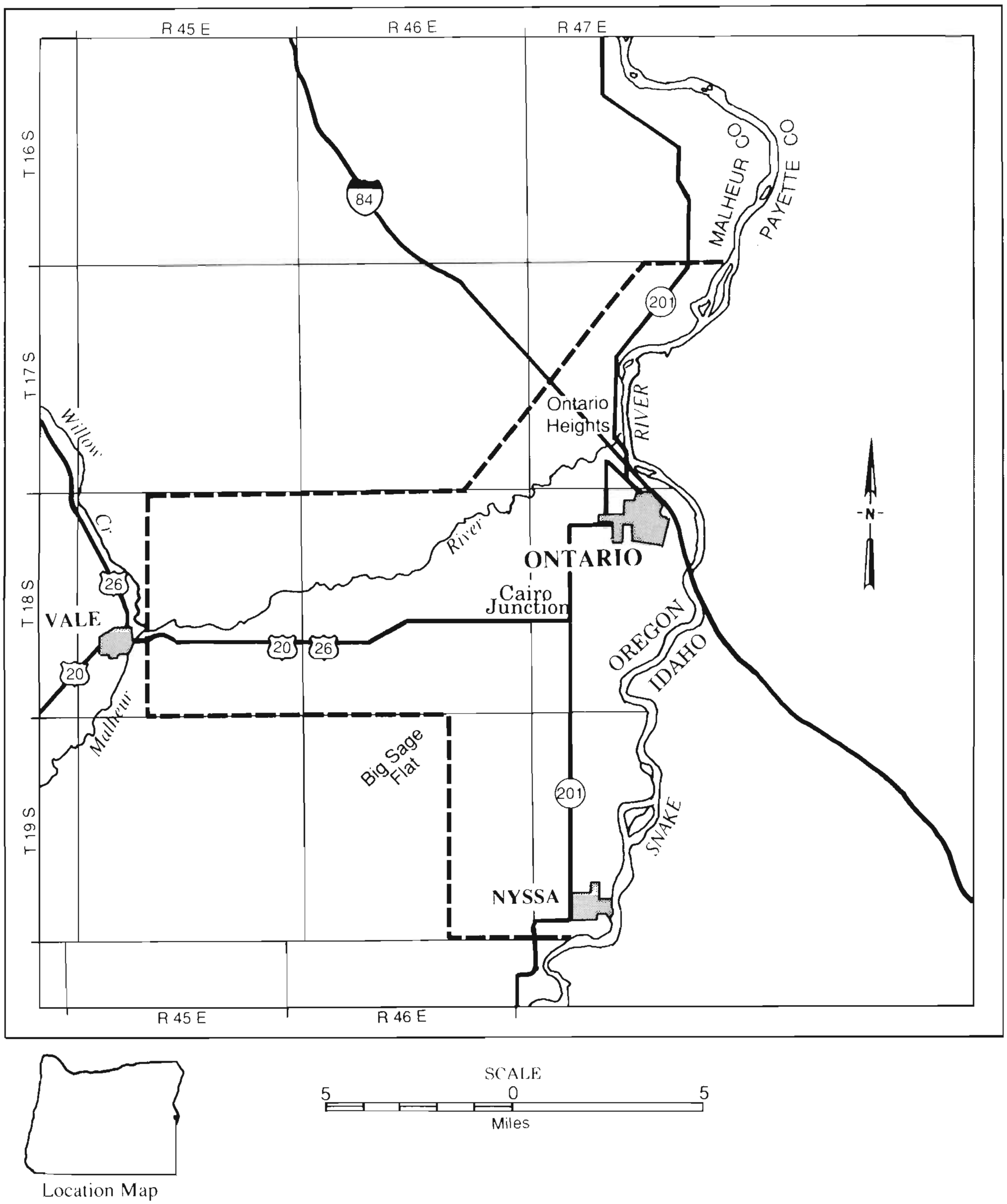


Figure 1. Location map of the Ontario area. The study area is bounded by the dashed line and the Snake River.

Malheur Experiment Station allowed access to wells on the station for aquifer testing and continuous water level recorder placement. Mr. Min Okuda made his irrigation well available for aquifer testing. Mr. Louis Wettstein allowed access to the LDS farm wells for aquifer testing.

The author also gratefully acknowledges the direct and indirect assistance of other professionals in this project. Ken Lite, Susan Hartford, Jerry Grondin and Mike Zwart helped with the field work. Dr. Gerald Smith of the University of Michigan identified a number of fossils and helped verify the age of the lake sediments in the study area. Mark Ferns of the Oregon Department of Geology and Mineral Industries provided valuable discussion on the Geology of the region along with equally valuable encouragement.

This report benefited greatly from the critical reviews by numerous staff members of the Oregon Water Resources Department and the Department of Environmental Quality (DEQ). Special thanks go to Ken Lite, Fred Lissner, Sam Allison and Susan Hartford. Greg Pettit of DEQ provided valuable suggestions relative to water quality and contaminant transport.

INVESTIGATION METHODS

The investigation included compilation and review of existing geologic and ground water information pertinent to the study area. Many reports on areas adjacent to the actual study area, including parts of Idaho, were reviewed.

Approximately 150 wells were field located in the study area. Only wells for which water well reports (well logs) could be found were field located. All field located wells were precisely plotted on 1:24,000 scale maps. These wells were used for stratigraphic control (mapping the thickness and extent of geological units in the sub-surface) and for water table mapping. About 100 of these wells were selected for periodic water level measurement.

All field located wells were measured in three separate "synoptic" measuring rounds. These synoptic rounds consisted of measuring all located wells within a period of four days. This allowed "snapshot" determinations of the water table elevation throughout the area. Such rounds were conducted in September 1988, March 1989 and August 1989. The March synoptic round was timed to roughly correspond to the lowest annual water levels. The August round was timed to correspond with high water levels.

A subset of eighteen wells was measured every four to eight weeks. The more frequent water level tracking allowed an evaluation of the timing and magnitude of water level fluctuations throughout the year.

Two wells were instrumented with continuous water level recorders to provide detailed information on water table fluctuations. This information allowed an understanding of how the water table responds to such short term influences as climatic events, nearby pumping and irrigation activities.

Reconnaissance geologic mapping was conducted in the study area to better understand the geologic controls on ground water flow. In addition, samples of drill cuttings from several water wells were analyzed to determine the nature of the geologic materials in the sub-surface.

Five aquifer tests were conducted during this investigation. An aquifer test is a controlled field experiment which consists of pumping a well at a constant rate and measuring the aquifer response to this stress in nearby wells. Aquifer tests provide information on the hydraulic characteristics of the aquifer and confining materials.

GEOGRAPHY

Physical Geography

The Ontario area is in the Western Snake River Plain physiographic province adjacent to the Owyhee Uplands province in the far eastern part of Oregon (McKee, 1972; Baldwin 1981). The area includes the confluence of the Snake and Malheur Rivers. The Snake River is the boundary between Oregon and Idaho in this area. The rivers occupy alluvial valleys ranging in width from less than two to over five miles wide in Oregon. Other important streams in the study area are Bully Creek and Willow Creek, which both enter the Malheur River near Vale.

The valley floors are relatively flat with slopes ranging from nearly zero to generally less than one percent. There are a number of distinct terraces in the valleys which are most likely related to changes in river levels during glacial periods (Othberg 1989, personal communication). Major terraces are shown on Plate 1. In general, the older, higher terraces have greater slopes and are more incised by drainages. Some of these terraces are characterized by specific soil types (Lovell, 1980). The average valley floor elevation ranges from about 2120 feet north of Ontario to about 2250 feet near Vale.

The upland areas adjacent to the valleys are generally 200 to 600 feet above the valley floor. The average elevation of the upland areas ranges from 2200 feet to 2700 feet with some peaks in excess of 3000 feet. The uplands range from nearly level and flat with slopes of one to two percent, to relatively dissected rolling hills with little or no level area. Most of the level portions of the uplands occur on Ontario Heights, northwest of Ontario, and on Big Sage Flat southwest of Cairo Junction.

The Ontario area is high desert with hot, dry summers and cold winters. Mean annual precipitation is 9.6 inches at weather stations in Vale and Ontario. Much of the precipitation falls as snow from November to February (Figure 2). The driest months are July through September. January is generally the coldest month with a mean daily maximum temperature of 36.7 degrees Fahrenheit and a mean daily minimum of 20.5. July is the hottest month with a mean daily maximum temperature of 96.4 degrees Fahrenheit and a mean daily minimum of 57.1. There are generally 139 frost-free days a year. All climatological information presented is based on the period from 1951 to 1980.

A variety of soils are present in the study area. The soils in northeastern Malheur County have been characterized by Lovell (1980). Most of the study area is typified by four soil series: Owyhee, Greenleaf, Umapine and Stanfield. Owyhee and Greenleaf soils are well-drained silt loams which occur on low to intermediate terraces in the main valley. Umapine and Stanfield soil series occur in the bottom lands and on low terraces. Umapine soils are poorly-drained, strongly alkaline, deep silt loams. Stanfield soils are very strongly alkaline, moderately well-drained, deep silt loams over a silica cemented hardpan.

Higher terraces, including the Ontario Heights area, are dominated by the Nyssa and Virtue soil series. These are both well-drained silt loams which occur over a calcium and silica cemented hardpan.

In the western part of the study area, between White Settlement and Vale, the soils are dominated by the Powder, Turbyfill and Garbutt series. These are well-drained, deep silt loams and fine sandy loams which occur in bottomlands and on alluvial fans.

The soil survey by Lovell (1980) provides a detailed description of the characteristics and distribution of surface soils in most of the study area.

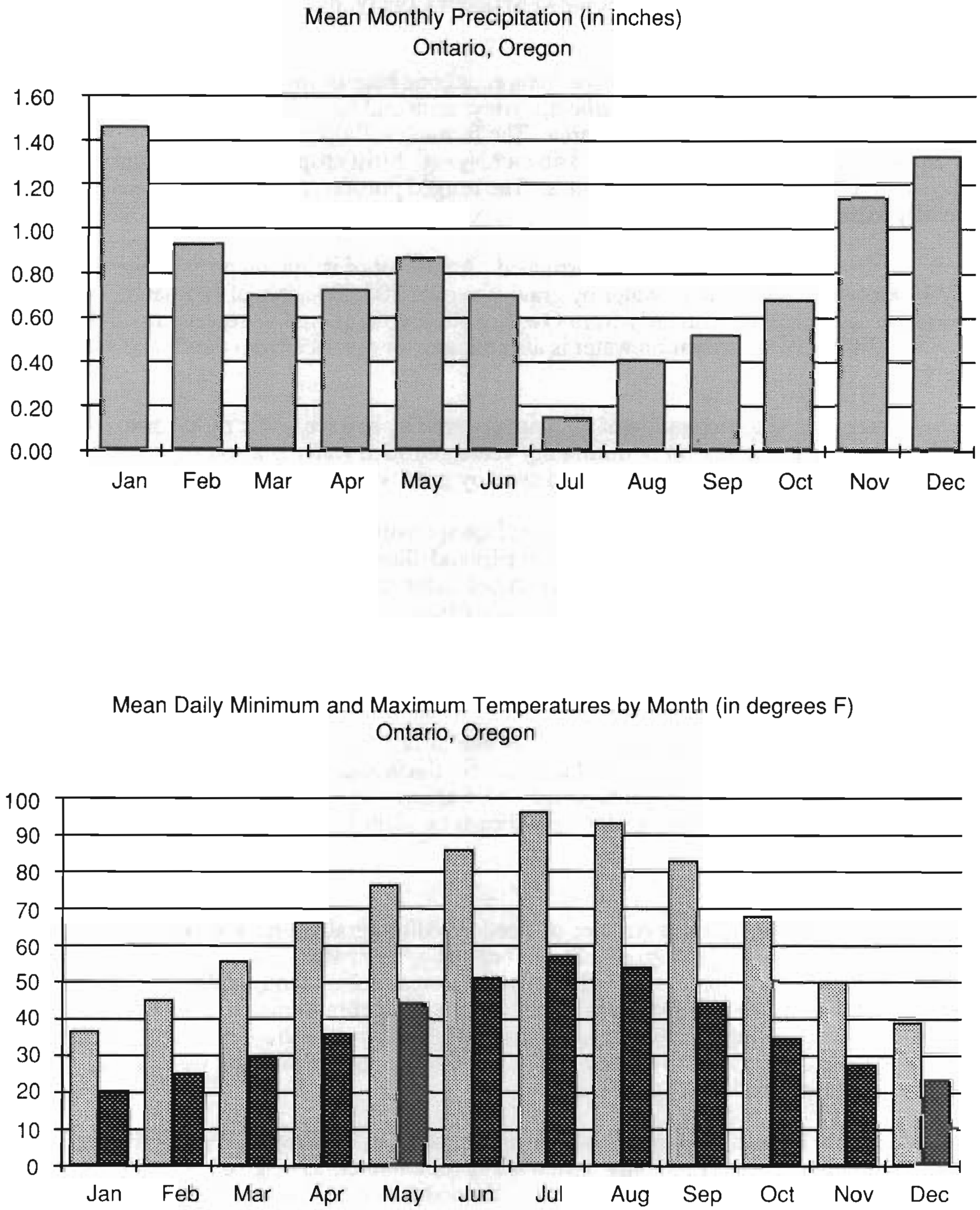


Figure 2. Mean monthly precipitation and mean daily minimum and maximum temperatures at Ontario, Oregon.

Cultural Geography

Major cities in the study area are Ontario (population 9758), Nyssa (population 2820) and Vale (population 1615). Of the 26,900 people in Malheur County, over half live within the study area.

Agriculture and related industries are the main economic base of the area. Major crops include onions, potatoes, sugar beets, corn, wheat, barley, mint and hay. There are also a number of dairy and beef operations in the study area. The farming activities support major sugar, potato and onion processing operations in Ontario and Nyssa. Most crop production occurs in the valleys and level areas of adjacent uplands. The rugged portions of the upland areas are used primarily as range land.

Almost all the agriculture in the area is irrigated. A number of irrigation projects were built in the early 1900s which now deliver water by gravity to over 200,000 acres of farmland. Water for these projects is supplied primarily from Owyhee Reservoir, as well as reservoirs on the Malheur River and Bully Creek. Irrigation water is also pumped or diverted from the Snake and Malheur Rivers.

Ground water is used for irrigation of land not covered by surface water rights or to supplement surface water late in the season or during dry years. Ground water is also used to irrigate land above the main canals which cannot be irrigated by gravity flow.

Almost all irrigation in the study area is by surface spreading methods. In these methods water is applied to the ground directly into furrows or rills and allowed to spread across the field by gravity. Very little sprinkler irrigation is practiced in the area as a whole, however, it is widely practiced on irrigated bench lands above the main canals.

GEOLOGIC FRAMEWORK

The geology of the study area consists of lacustrine tuffaceous siltstones and fine sandstones overlain locally by Quaternary silt, sand and gravel. Surface distribution of the major geologic units is presented on Plate 1. Figures 3, 4, 5 and 6 are geologic cross sections through the study area. The locations of the cross sections are shown on plate 1.

Lacustrine Sediments

The lacustrine material typically consists of fine to medium-grained tuffaceous siltstones. In outcrop, the sediments range from massive to bedded or laminated. Bioturbated horizons are common in the outcrops observed. Sedimentary features such as scour and fill structures appear common in the sandy zones. On the surface, this unit is light brownish to light brownish gray. When encountered during well drilling, the unit appears very dark gray to very dark bluish gray. The difference in color is due to the reducing conditions at depth below the water table. Local drillers refer to these sediments as "blue clay".

The siltstones are typically composed of varying proportions of lithic and crystal fragments and volcanic glass shards, and commonly have trace to minor amounts of greenish brown flexible mica. The material locally contains fish and gastropod fossils. Diatoms were collected from one outcrop. Diatoms were abundant in cuttings from some wells.

Earliest scientific explorers in the region, such as King (1878) recognized vast areas of lacustrine sediments in the Western Snake River Plain. Kirkham (1931) clarified the age, distribution and stratigraphic relationships of major units in the Snake River Plain. He recognized two major depositional sequences which he termed the Idaho and Payette Formations.

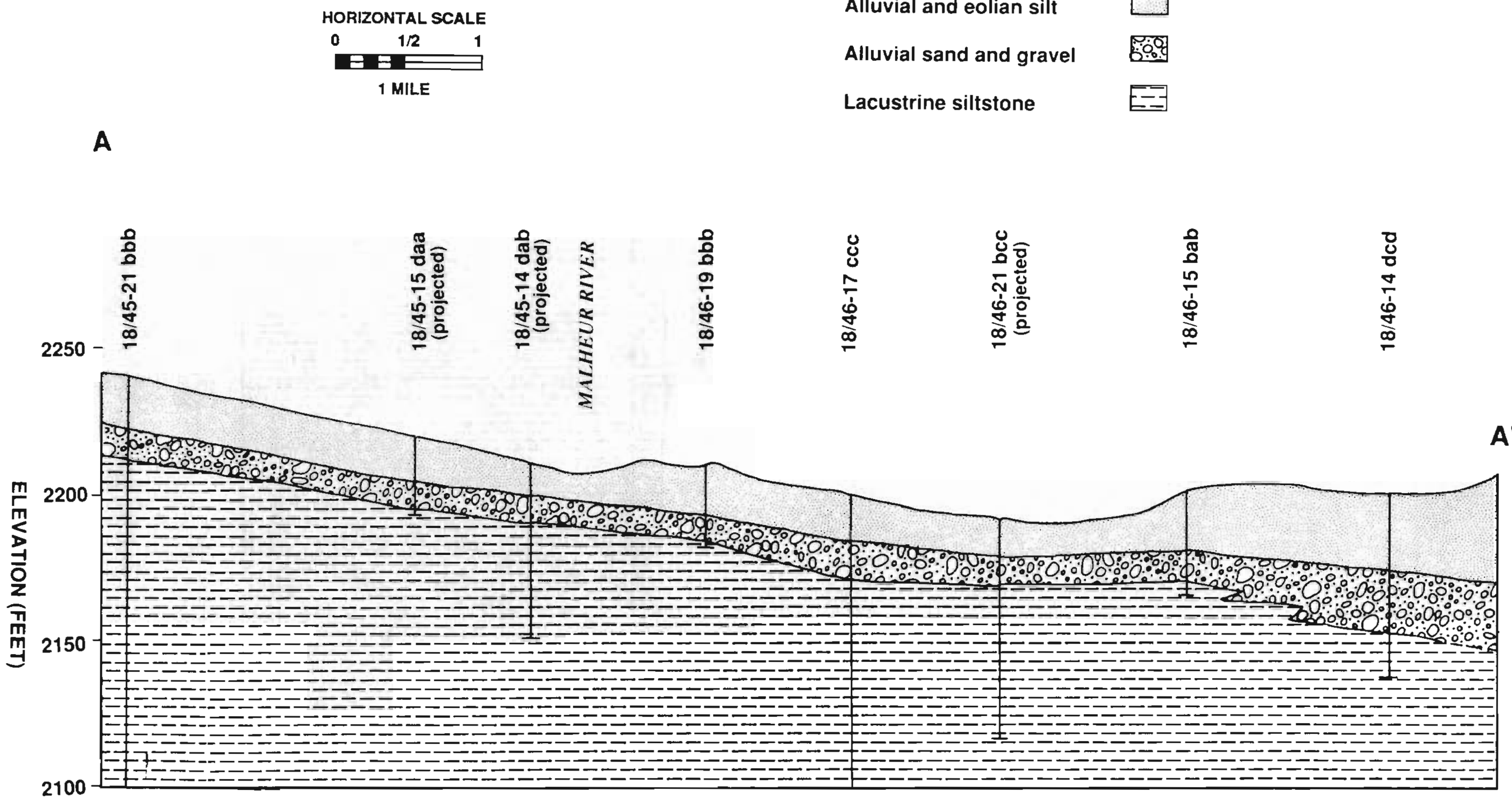


Figure 3. Generalized geologic cross section A to A'. See Plate 1 for section location.

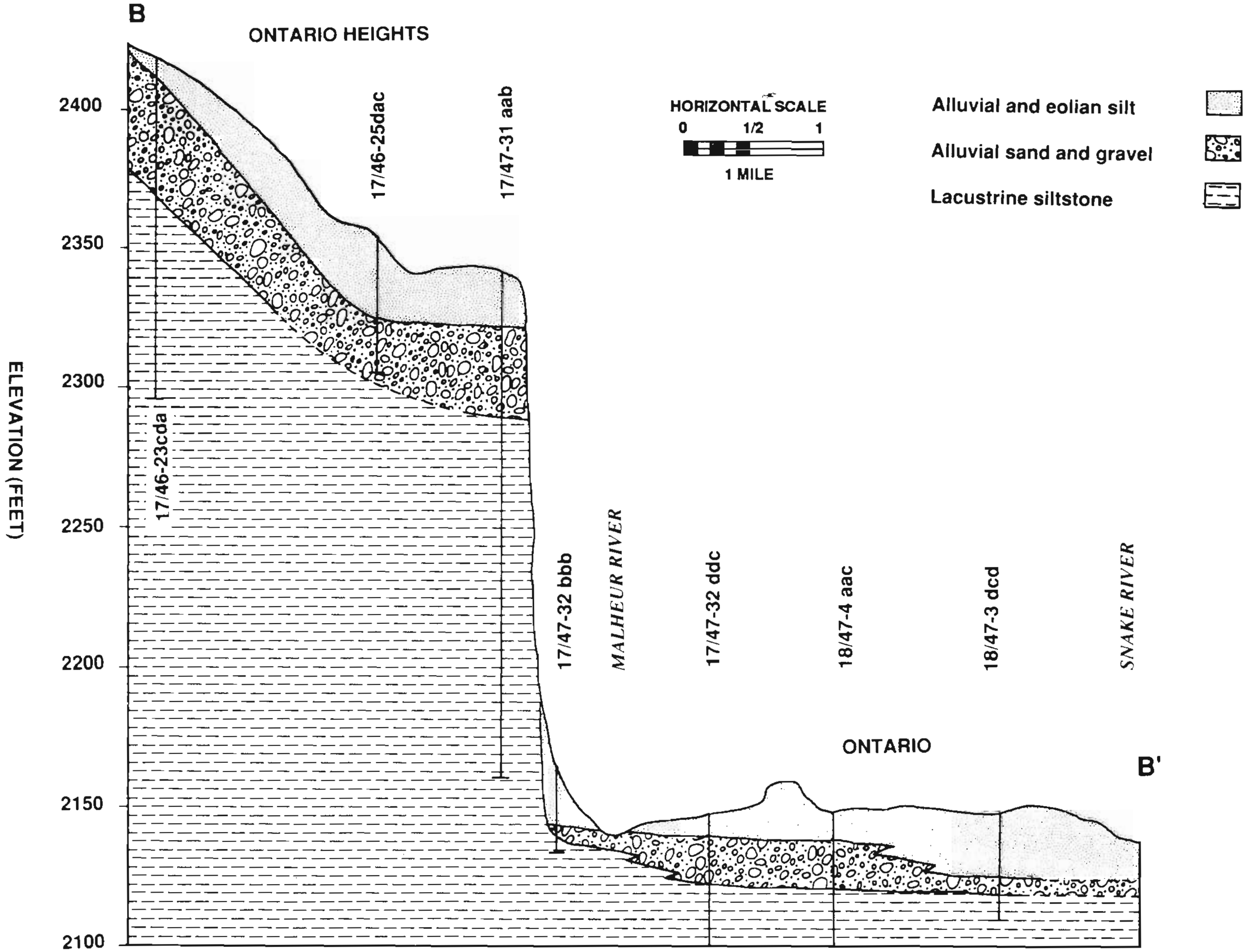


Figure 4. Generalized geologic cross section B to B'. See Plate 1 for section location.

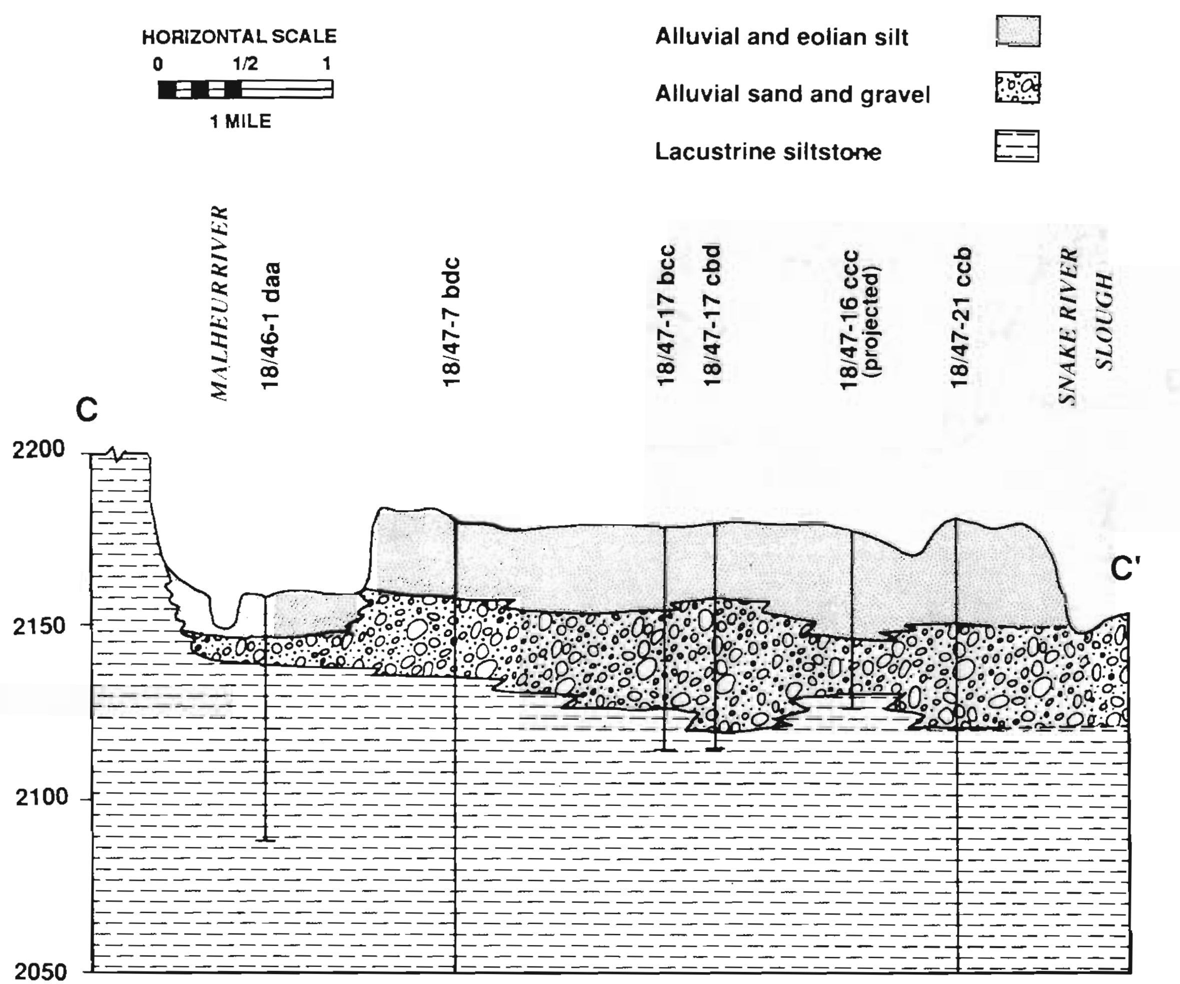


Figure 5. Generalized geologic cross section C to C'. See Plate 1 for section location.

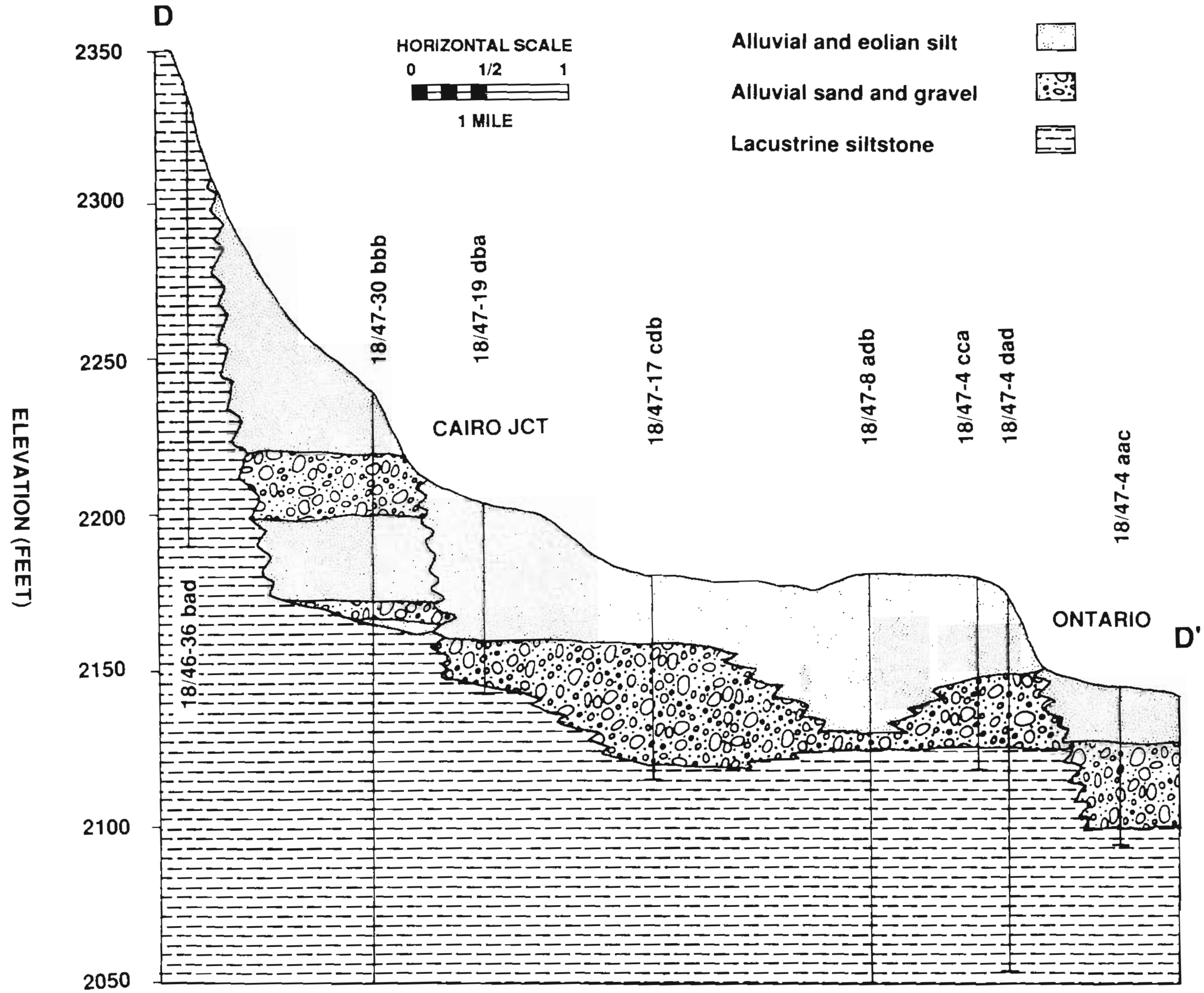


Figure 6. Generalized geologic cross section D to D'. See Plate 1 for section location.

Bryan (1928) presented a detailed geologic map of the area around the then proposed Owyhee Dam in Oregon. In this work, he defines a number of new geologic units, but sticks with the established nomenclature assigning some sedimentary units in the area to the Payette and Idaho Formations.

Malde and Powers (1962) further refined the classification of geologic units in the western Snake River Plain. They they did away with the name Payette Formation, raised the Idaho Formation to group status and identified seven formations within that group. The two major sedimentary sequences are represented by the Miocene Chalk Hills Formation and the Pliocene to Pleistocene Glenns Ferry Formation, both of the Idaho Group. Malde and Powers state that paleontological evidence indicates that sediments near Ontario may be stratigraphically equivalent to the Glenns Ferry Formation.

The only geologic map available for most of the study area in this report is by Corcoran and others (1962). They did not assign sediments to the Idaho or Payette Formations as did Bryan (1928) , but created new formation names. They placed sediments mapped by Bryan (1928) as Idaho Formation in a new formation they called the Deer Butte Formation. Units that Bryan had placed in the Payette Formation were placed into two new formations the Kern Basin Formation and the Chalk Butte Formation. The sediments in the Ontario study area are mapped by Corcoran and others (1962) as Chalk Butte Formation.

Brooks and others (1976) produced a geologic map of the Oregon Part of the Baker 1° by 2° quadrangle. This is the only published geologic map available for the northern part of the study area. Because of the large scale of this map, it has somewhat limited detail. The only major units presented in the study area are Quaternary alluvium and Tertiary tuffaceous sedimentary rocks.

Kittleman and others (1967) expanded the mapping in the Owyhee Region in Oregon and combined Corcoran and others' (1962) Chalk Butte Formation into the Deer Butte Formation.

Smith (1975) described in detail the fossil fish fauna of Malde and Power's (1962) Glenns Ferry Formation. He concluded that most of the Glenns Ferry Formation is Pliocene in age. Kimmel (1975) described the fish of the Deer Butte Formation south of Adrian Oregon. He noted close affinities of the fauna from the Deer Butte Formation, particularly that portion stratigraphically above the Blackjack Basalt, with the fauna of the Glenns Ferry Formation.

Swirydczuk and others (1982), Kimmel (1982), and Smith and others (1982) have further refined the understanding of the stratigraphy, age, depositional history and biostratigraphy of the Chalk Hills and Glenns Ferry Formations in the western Snake River Plain. Kimmel (1982) identified the contact between the Miocene Chalk Hills Formation and the Pliocene Glenns Ferry Formation in a measured section several miles south of Adrian Oregon. Ferns (1989) also shows this contact his geologic map of the Adrian Quadrangle. Ferns and Urbanczyk (1990) mapped lacustrine sediments on the Mitchell Butte Quadrangle several miles west of Nyssa as Pliocene and stated that they can be traced southeastward into sediments considered to be equivalent to the Glenns Ferry Formation by Kimmel (1982) and Smith and others (1982).

Disarticulated fossils of several fish species collected during this study from localities in the Ontario Heights area and from the Willowcreek Valley near Jamieson have been identified as typical of the Pliocene Glenns Ferry Formation (Gerald Smith, written communication, 1990). A few species from each of these localities are unique to the Glenns Ferry Formation. A preliminary check of diatoms from samples of siltstone in cuttings from a water well in Vale indicate the material is Glenns Ferry Formation (J. Platt Bradbury, U.S. Geological Survey, written communication).

Recent detailed mapping by Ferns (1989) and Ferns and Urbanczyk (1990) shows that the Chalk Butte Formation of Corcoran and others (1962) includes sediments from both the Pliocene and Miocene sequences. This also appears to be the case with the Deer Butte Formation as mapped by Kittleman and others (1967). Therefore, for the purposes of this report, these names are rejected and the lacustrine sediments in the Ontario area are considered to be part of the Glenns Ferry Formation as defined by Malde and Powers (1962) and Smith and others (1982).

Malde and Powers (1962) state that the Glenns Ferry Formation is about 2000 feet thick in the type area in Idaho. Its exact thickness in the study area is unknown. At least 4600 feet of continuous fine sediments were penetrated by a geothermal test well in Ontario, but it is not known how much of this section is Glenns Ferry Formation and how much might be older lake sediments of the Miocene Chalk Hills Formation.

The Glenns Ferry Formation is overlain locally by Quaternary deposits of silt, sand and gravel. These unconsolidated deposits occur in two settings: capping the Glenns Ferry Formation on the uplands above the valley or as alluvial deposits on the present-day valleys.

Upland Gravels

On the upland adjacent to the valleys in the Ontario area, lake sediments of the Glenns Ferry Formation are unconformably overlain by fluvial sands and gravels. The upland gravels range in thickness from a few feet to over 40 feet. They appear to be thickest in the eastern part of the study area near the edge of the uplands above the Snake River and appear to thin toward the west. Only a very thin layer of gravel appears to be present in the hills north of Henry Gulch west of Ontario Heights.

The upland gravels are best exposed in the Ontario Heights area and up on Big Sage Flat, southwest of Cairo Junction. Where exposed, the gravel is moderately well sorted and consists of well-rounded to sub-rounded boulder to cobble sized clasts of mixed lithology in a coarse sand matrix. There are occasional one foot layers of coarse sand interbedded with the gravel. Crude bedding and scour and fill structures are common.

The gravels are overlain by a varying thickness of finer-grained silts and sands which locally exhibit considerable lamination, bedding, cross bedding and scour and fill structures. Approximate thickness of this overlying material ranges from a few feet to 40 feet, being less than 20 feet in most places. The gravels are cut by numerous east-west to east-southeast trending normal faults in the Ontario Heights area.

Gravels are also exposed in many road cuts in the lower parts of the uplands near the valley south of the Malheur River. The gravels exposed at these lower elevation portions of the uplands probably represent lag deposits or reworked material deposited in channels or alluvial fans by small tributaries of the Malheur and Snake Rivers. It is also possible that some of these deposits represent an ancient terrace intermediate between the present valley and the higher portions of the uplands.

Gravel deposits are also common capping the Glenns Ferry Formation in Idaho (Malde and Powers, 1962; Kimmel, 1982). It is thought that these represent deposition by rivers onto the lake bed after the lake which formed the Glenns Ferry Formation drained. The upland gravels in the Ontario area may be equivalent to the Tenmile gravel as mapped in adjacent parts of Idaho by Mitchell and Bennett (1979)

The upland gravel deposits are the major source of commercial sand and gravel in the Ontario area. There are a number of operating quarries in the study area, mostly in the Ontario Heights area.

Quaternary Alluvium

In the valleys, the Glenns Ferry Formation is covered by deposits of Quaternary alluvium. The Quaternary alluvium consists of a lower layer of unconsolidated sand and gravel 10 to 40 feet thick overlain by a layer of silt which ranges from about 10 to 50 feet. The lower layer consists of interbedded sand and gravel in varying proportions. In some places the lower layer may be entirely sand or gravel. The silt which overlays the sand and gravel is typically described on driller's logs as "brown sandy clay". Microscopic examination of samples of this material obtained from drilling samples indicates this silt is composed of crystal and lithic fragments and contains very little actual clay.

At least two distinct erosional terraces exist in the main valleys above the modern flood plain. The stratigraphy of the lowest of these two terraces is as described above. The stratigraphy of the upper terrace is less well known and appears to be more complex. The present flood plain and the lowest terrace represent most of the valley floor.

In general, the sand and gravel deposits in the valley are much younger than the gravels capping the Glenns Ferry Formation on the uplands. The alluvium in the valley shows no signs of faulting.

GROUND WATER FLOW SYSTEM

Very little has been published on the ground water flow system in the study area. Russell (1903) made brief reference to wells in the Ontario and Vale areas in a report on artesian basins in southwestern Idaho and southeastern Oregon. Collins (1979) tabulated basic ground water data from field located wells and well logs for Baker and northern Malheur Counties. Bruck (1986) summarized ground water quality data and gives a brief description of the shallow flow system based on well logs. Smyth (1988) conducted a geostatistical analysis of the pesticide and nitrate contamination. Walker (1989) presented a numerical model of ground water flow in the Ontario area based largely on work done during this study.

There are three major water bearing units in the study area. These are the unconsolidated Quaternary sands and gravels in the main valleys, saturated parts of the upland gravels above the valleys, and occasional sand and gravel layers within the Glenns Ferry Formation which occur locally throughout the entire area. The Quaternary sand and gravel aquifer is the most widely used source of ground water for domestic and irrigation purposes, and is where the contamination occurs. This aquifer is the focus of this report.

A schematic representation of the ground water flow system is presented in Figure 7. Ground water in the valley moves primarily in the Quaternary sand and gravel. This ground water comes from precipitation, deep percolation of irrigation water, canal and ditch leakage and inflow from the highlands to the valley. Ground water generally flows toward the rivers where it is discharged from the system. This ground water discharge to the river is known as "baseflow". In areas where there are no reservoirs to provide water to streams during the dry times of the year, stream flow is often entirely from baseflow.

AQUIFER UNITS

Quaternary Sand and Gravel Aquifer

Saturated sand and gravel layers in the Quaternary alluvium in the valley comprise the Quaternary sand and gravel aquifer. The Quaternary sand and gravel aquifer underlies the entire valley area

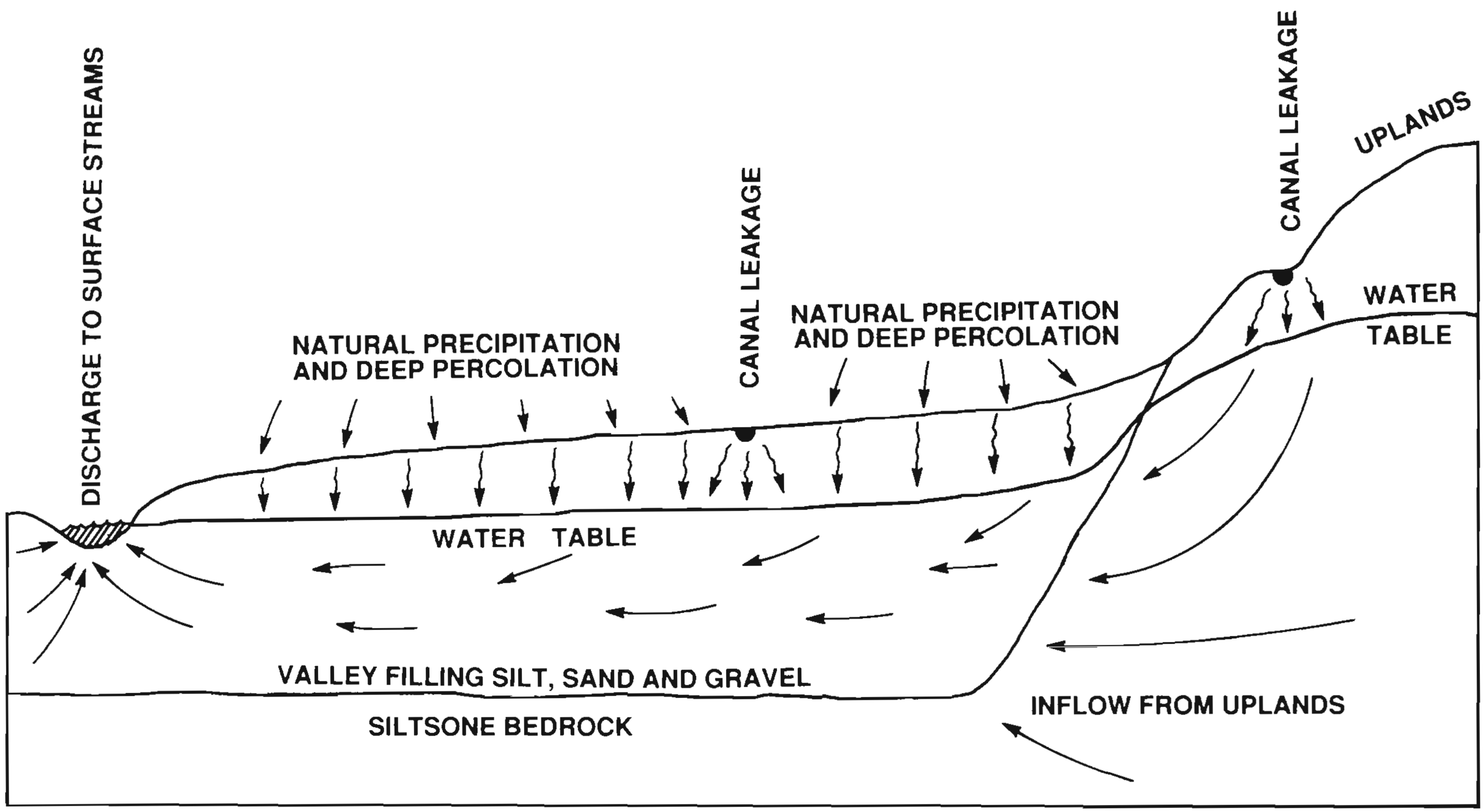


Figure 7. Conceptual diagram of the shallow ground water flow system in the Ontario area.

and is generally a very reliable source of water, yielding in excess of four hundred gallons per minute to wells in many places.

The shallow gravel aquifer is bounded on the sides and underlain by siltstones of the Glenns Ferry Formation. The gravel is overlain by fluvial and eolian silts. The Malheur and Snake Rivers are generally not directly connected to the shallow aquifer. Water in this aquifer flows toward and discharges to the rivers through the overlying silts.

The shallow gravel aquifer is poorly confined to unconfined. The nature of the overlying silt varies with location. In places the silt is very permeable and the aquifer is essentially unconfined. In other places, the permeability of the silt is low enough that the aquifer shows some characteristics of a confined aquifer such as barometrically induced water level fluctuations. In most places in the valley the water table resides in the overlying silt.

Continuous water level recorder charts provide some insight into the hydrology of the shallow gravel aquifer. Figures 8 and 9 are hydrographs of the water level in two wells from continuous water level recorders. It can be seen that water levels were declining steadily after the end of the irrigation season in October 1988. One of the wells showed a rise of the water level in November probably due to cessation of drainage well operation. Low water levels occurred in mid to late February. This corresponds to very cold conditions when maximum daily temperatures were barely above zero degrees Fahrenheit. According to records from the OSU Malheur Experiment Station, there was an accumulation of about twelve inches of snow on the ground during most of February. Starting in late February, maximum daily temperatures were typically above freezing. Starting in early March minimum daily temperatures were also near or above freezing. The snow melted during the last week in February and the first week in March. Coincident with the melting of the snow was a rise in the water levels in the two wells monitored of 1.8 and 3.4 feet in a period of several days. The rapid response of water level to snow melt indicates that the materials overlying the shallow gravel aquifer allow fairly rapid downward percolation of water on the surface.

There is a local practice that also indicates that the overlying silt is permeable. This is the practice of pumping wells to drain fields and basements. Several such wells are operated by the Malheur Drainage District. The fact that standing water in fields and basements can be removed by pumping the shallow gravel aquifer indicates that there is a direct hydraulic connection between the surface and the aquifer.

Plate 2 is a contour map of the elevation of the water table surface in the shallow aquifer. The approximate directions of ground water flow can be determined from this map. Ground water generally flows perpendicular to the contour lines toward lines of lower elevation (assuming the system is isotropic). It can be seen from this map that ground water flows from the edges of the valley toward the main rivers. Where the valley is narrow, ground water flows directly toward the rivers. In the area between Cairo Junction and Ontario where the valley broadens out and the Malheur and Snake Rivers come together, the gradient flattens and ground water flows parallel to the rivers.

Upland Gravel Aquifer

The upland gravel aquifer comprises saturated portions of gravel deposits which occur at or just below the surface in the uplands adjacent to the main valleys (Figure 4). The upland gravels are overlain by fluvial and eolian silt deposits a few feet to 30 feet thick.

The upland gravels are underlain by siltstones and sandstones of the Glenns Ferry Formation. In many places the base of the terrace gravel is above the water table and the gravels are unsaturated. There are other places, particularly the Ontario Heights area, where the gravels are saturated. Saturation of the terrace gravels is thought to be largely artificial, resulting primarily

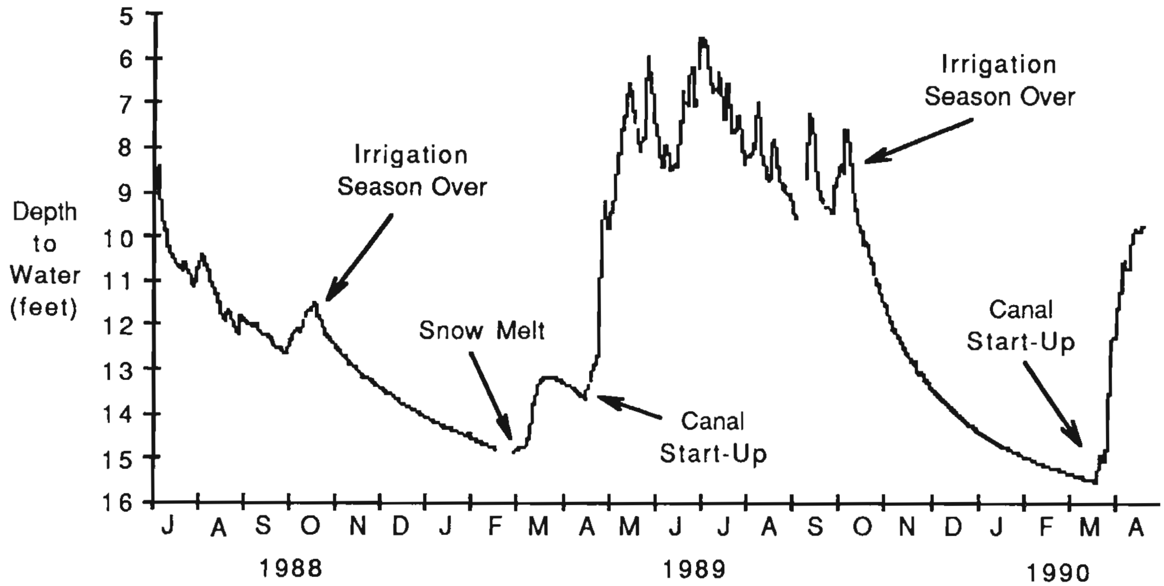


Figure 8. Continuous water level recorder hydrograph of the Pennington well, 18S/46E-19bbb

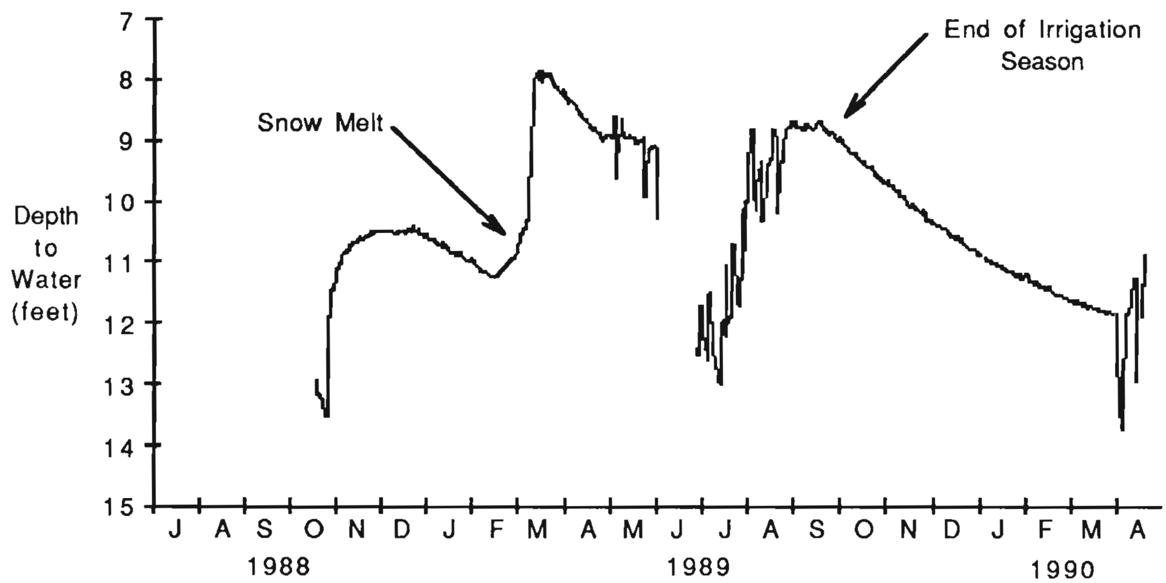


Figure 9. Continuous water level recorder hydrograph of the OSU Malheur Experiment Station north well, 18S/47E-19bcc.

from canal leakage and deep percolation of irrigation water. There is no predevelopment water level data to substantiate this theory, however the lake sediments immediately below the gravels are described by drillers as brown or yellow clay rather than blue clay as in the valleys. The lack of blue (actually very dark gray) color suggests that the sediments have not historically been in a saturated, reducing environment. There is also anecdotal evidence suggesting that wells did not encounter water in the terrace gravels in places prior to completion of the Owyhee Project.

There is probably leakage of water from the upland gravels to the underlying sediments. The amount of leakage is unknown.

The upland gravels appear to be poorly confined similar to the Quaternary gravels in the valley. The silts overlying the upland gravels probably do not represent a significant confining layer. There are no aquifer tests or water level recorder data available to evaluate the nature of the confining silt.

Plate 1 shows the head distribution in the uplands in the Ontario Heights area north of Ontario. It can be seen that heads are 150 to 200 feet higher than in the adjacent valley. Ground water in the upland gravels in this area generally flows away from the North Canal and toward the canyons cutting the bench. The upland gravels discharge water to the numerous canyons which cut the uplands. Evidence of this discharge exists in the form of springs, running surface water, and abundant wetland vegetation, such as cattails, in the canyons.

Glenns Ferry Formation

The Glenns Ferry Formation is composed largely of lacustrine siltstone. This fine-grained material generally yields only very small amounts of water to wells, often barely adequate for domestic use. However, in places there are layers of sand one to several feet thick interbedded with the siltstone which are more productive. In the southern part of the study area there are sand layers at depth which will yield water to wells in amounts sufficient for irrigation.

No cuttings were available for this study from wells which penetrated deep water bearing zones within the Glenns Ferry Formation. Water bearing sand layers in the Glenns Ferry Formation may be volcanic ash beds, beach deposits or deltaic deposits within the lake sediments. Water bearing sands apparently occur throughout the Glenns Ferry Formation, but appear in the valley to be more common at depths greater than 150 feet. These water bearing units are somewhat discontinuous, and there is insufficient drill hole information to delineate lateral boundaries. It was not possible to trace individual sand layers in the subsurface using well logs.

No lateral boundaries of the Glenns Ferry Formation exist in the study area. The unit extends tens of miles in each direction from the study area including toward the east, across the Snake River into Idaho.

There is not enough data available to create a potentiometric surface map of the deep aquifers within the Glenns Ferry Formation. Deep wells are not too common in the valley and are not evenly distributed. In addition, the vast majority of deep wells in the valley are open to the shallow gravel aquifer as well as deep water bearing zones. Therefore, the water levels in those wells represent some intermediate level between the two aquifers.

There is evidence which suggests that head in the water bearing zones in the Glenns Ferry Formation is higher than in the shallow gravel aquifer. This indicates that there is a vertical pressure gradient which would tend to cause upward movement of water from deep zones to the shallow zone. Such an upward gradient is to be expected in the lower part of a large basin near major surface streams. The area is one of regional discharge.

Evidence of an upward gradient in the valley comes in part from temperature profiles of deep wells. The normal geothermal gradient in the area is about 4 to 5 °F/100 feet (Blackwell and others, 1978). This means that the temperature will increase at that rate with depth in a well if there is no vertical flow of water. If there is vertical flow of water from one water bearing zone to another, the gradient in the part of the hole between the two zones will be reduced and may be isothermal. Isothermal sections will have the temperature of the zone that the water is coming from. Figure 10 shows temperature/depth profiles in a number of wells in the study area. It can be seen that nearly all the holes have less than normal gradients for all or part of their depths. One well is isothermal. The temperatures in these holes are always higher than the temperature in the shallow aquifer indicating that the flow is uphole rather than downhole.

The vertical pressure gradient does not appear to be high. There are no records of flowing artesian wells in the study area. There are two places in the study area where there are wells which are sealed into water bearing zones within the Glenns Ferry Formation very close to wells which penetrate only the shallow gravel aquifer. In both these places the water level in the deep aquifer is within a few tenths of a foot of that in the shallow aquifer.

Water levels in wells which produce from the Glenns Ferry Formation outside the valley are substantially higher than water levels in the valley. Plate 2 shows wells south of the valley (19S/46E-Sec. 4 and 18S/46E-Sec. 26 and Sec. 35) which have water levels over 100 feet higher than wells in the valley one to three miles to the north. This indicates that there is ground water flow within the Glenns Ferry Formation from the uplands toward the valley.

AQUIFER TESTING RESULTS

Five aquifer tests were conducted for this study. All involved only the shallow gravel aquifer in the valley since it is the focus of this investigation. Two of the tests were single well tests, while the remaining three included one or more observation wells. Pumping rates varied between the tests from 77 to 417 gallons per minute.

Log-log time-drawdown curves generally did not follow the typical Theis type curve for confined aquifers (Theis 1935). The time-drawdown curves exhibited a variety of shapes which can generally be attributed to hydrogeological conditions near the well. In general, the shape of the curves was influenced by the properties of the semi-confining layer.

The most usable data were obtained from observation wells. Data from the pumped wells were of limited usefulness because well inefficiency caused exaggerated drawdown in the well bore. The three tests with observation wells are discussed below.

The shallow ground water system is essentially two-layered, consisting of a semi-confining silt layer with low hydraulic conductivity overlying a sand and gravel aquifer with high hydraulic conductivity. Testing indicates the conductivities of the two layers differ by about one to two orders of magnitude. The water table is always in the upper silt layer and did not drop into the gravel during any of the tests. When a well in this aquifer is pumped, water moves toward the well primarily through the gravel layer. This causes a lowering of the pressure in the gravel layer in the vicinity of the well. This lower pressure in the gravel causes water to drain by gravity from the overlying silt layer into the gravel layer, probably in a mostly vertical direction. This gravity drainage is relatively slow in comparison to the movement of water in the gravel. This phenomena causes a departure from the Theis type curves for confined aquifers. The shape of the drawdown curve is controlled largely by rate of drainage from the overlying silt. It is possible that some water may be contributed to the aquifer through upward leakage from the underlying siltstone.

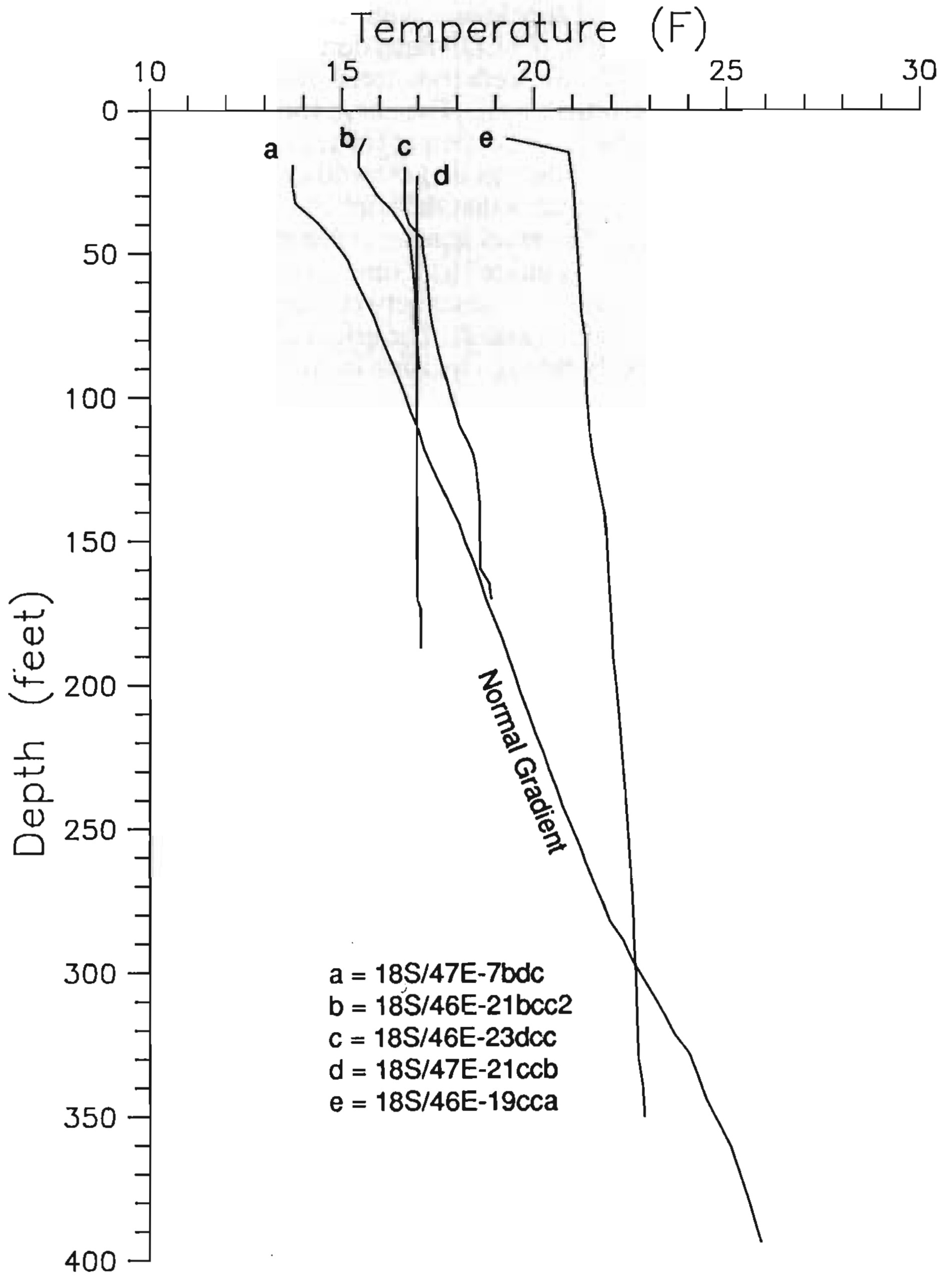


Figure 10. Temperature versus depth graphs for selected wells in the Ontario area.

LDS Farm Irrigation Well Test

The LDS farm irrigation well (18S/47E-17bcc1) was pumped at 400 gallons per minute (gpm) for 1835 minutes. Two observation wells, the LDS farm domestic well (18S/47E-17bcc2) and the Uchida irrigation well (18S/47E-17cbd), were monitored during the test. These wells are 79 and 1500 feet respectively from the pumped well. The curve for the close observation well follows the Theis type curve during the early portion of the test, but then flattens out in the later portion (Figure 11). This flattening out indicates that drawdown was less than would be expected for a confined aquifer. This indicates that the aquifer is receiving recharge. The predominant source of this recharge to the gravel aquifer is drainage from the overlying silt. If the drawdown of both observation wells is plotted as a function of time over the distance squared (Figure 12), it can be seen that there is vertical offset between the two data sets. This indicates that the drawdown at distance is less than expected. The effect also indicates that the gravel aquifer is receiving recharge, most likely through leakage from the overlying silt.

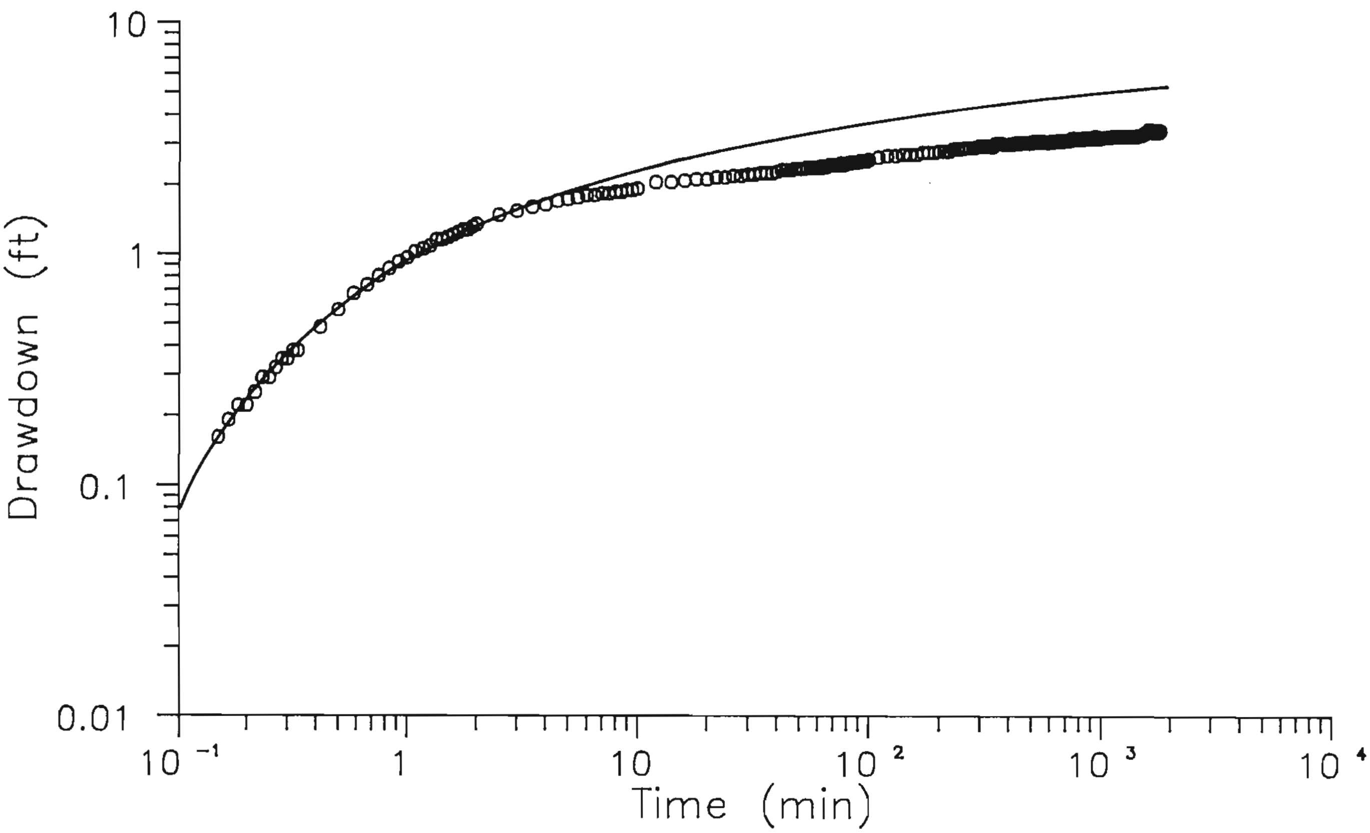


Figure 11. Plot of drawdown versus time for the LDS domestic well (18S/47E-19bcc2) as it responds to pumping of the LDS irrigation well (18S/47E-19bcc1) 79 feet away. The open circles are water level measurements, the solid line is the Theis type curve for comparison.

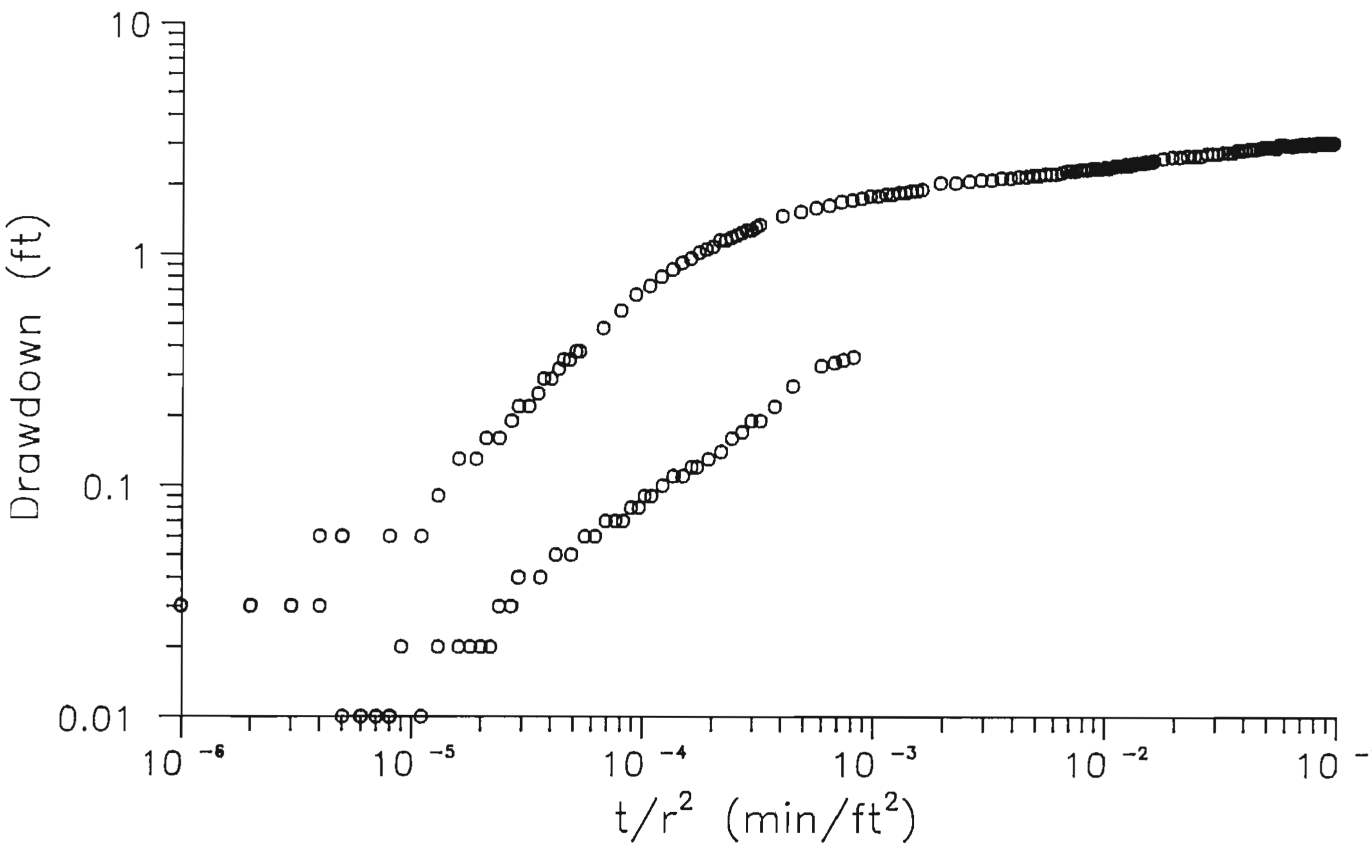


Figure 12. Plot of drawdown versus t/r^2 (time divided by the square of the distance from the pumping well) for the LDS domestic well (18S/47E-17bcc2) and the Uchida irrigation well (18S/47E-17cbd) as they respond to pumping of the LDS irrigation well. The two wells are 79 and 1500 feet respectively from the pumping well.

Analysis of early-time drawdown data from the LDS farm domestic well using the Theis curve resulted in a transmissivity of 9400 ft^2/day. A more appropriate method for analyzing a test of an aquifer with an overlying water table aquitard is the method of Cooley and Case (1973) which employs the delayed yield type curves of Boulton (1963). This method accounts for the desaturation of the overlying material. This latter method yielded transmissivity estimates of 12,250 to 14,600 ft^2/day. The method of Hantush (1960, 1961) for leaky confined aquifers was also employed although not all of the assumptions of this method are met. The Hantush method yielded a transmissivity of 10,000 ft^2/day. The Hantush method and the Cooley and Case method yielded storage coefficients of 0.001 which is typical of a partially confined aquifer. Dividing the transmissivities obtained by the Cooley and Case method by the thickness of the sand and gravel aquifer results in a hydraulic conductivity of 440 to 520 feet per day.

Okuda Irrigation Well Test

The Okuda irrigation well (18S/46E-24dad) was pumped at a rate of 417 gpm for 709 minutes. The OSU north well (18S/47E-19bcc), which is 370 feet from the Okuda well, was the only observation well. For the first minute of the test the water level rose in the observation well. After one minute, the water level dropped. This non-typical early-time behavior may be an effect of the elastic response of the aquifer, or may be an effect of partial penetration of the pumping well (Langguth and Treskatis, 1989). No well log was available for the pumping well. The owner indicated that the well is 40 feet deet which suggests it only penetrates about 15 feet into the 45 foot-thick sand and gravel aquifer. The recovery curve for the observation well (Figure 13) shows an excellent delayed yield response typical of an inhomogeneous water table aquifer (Neuman, 1972 and 1975) or an aquifer with an overlying water table aquitard (Cooley, 1972; Cooley and Case, 1973).

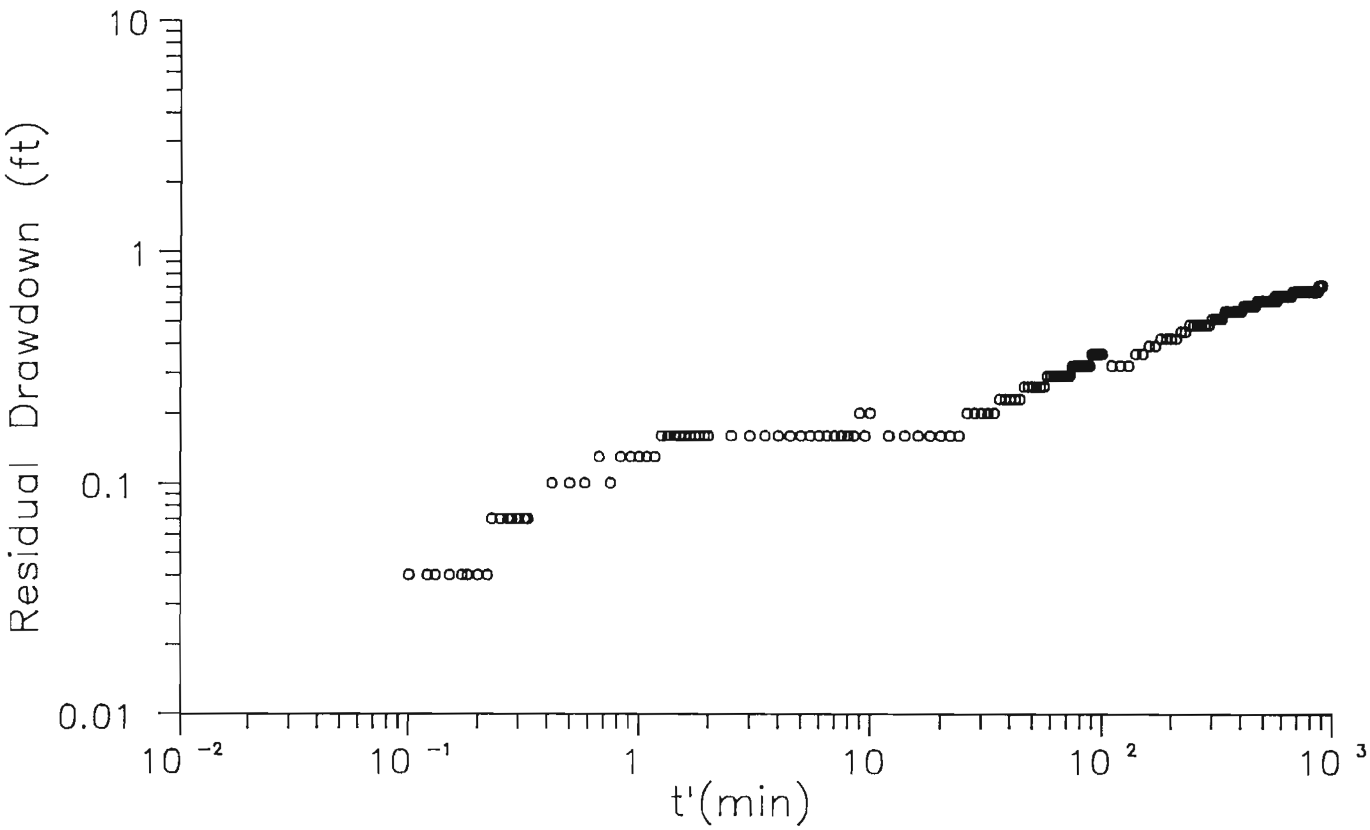


Figure 13. Delayed response of water level recovery in the OSU Malheur Experiment Station north well (18S/47E-19bcc) after pumping the Okuda irrigation well (18S/46E-24dad).

The method of Neuman (1975) yielded a transmissivity value of 29,000 ft^2/day and an elastic storage coefficient (from early-time data) of 0.0001. The late-time data indicated a storage coefficient of 0.011, which suggests a specific yield of 1.1 percent for the overlying silt. The method of Cooley and Case (1973) yielded a transmissivity of 32,300 ft^2/day and storage coefficients similar to the Neuman method. Dividing these transmissivity values by the aquifer thickness results in a hydraulic conductivity of 600 to 670 feet per day for the gravel aquifer.

Pennington Irrigation Well Test

The Pennington irrigation well (18S/46E-19bbb1) was pumped at a rate of 78 gpm for 240 minutes. The Pennington domestic well (18S/46E-19bbb2), 62 feet away from the pumped well, was the only observation well. The time-drawdown curve for this well also appeared to exhibit a delayed-yield response, although not to the extent of well 18S/46E-24dad in the Okuda test. The method of Cooley and Case (1973) yielded a transmissivity of 6000 ft^2/day which when divided by the aquifer thickness results in a hydraulic conductivity of 545 feet per day. The late-time storage coefficient is 0.035 which indicates a specific yield of 3.5 percent for the overlying silt.

Aquifer Testing Discussion

An aquifer such as this with an overlying water table aquitard will demonstrate some properties of an inhomogeneous unconfined aquifer with different horizontal and vertical permeabilities. Neuman (1972, 1974) provides a method for analysis of aquifer tests in such anisotropic water table aquifers. The aquifer will also show some properties of a confined aquifer with a leaky confining layer. The Method of Hantush (1961) for leaky confined aquifers is not entirely appropriate in this case because that method assumes constant head in the confining layer. Head varies in the upper layer of the aquifer in the study area as the water level changes during pumping.

Transmissivity values calculated range from 6000 to 32,300 ft^2/day. The width of this range is due primarily to variations in the thickness of the aquifer. When the transmissivity values are divided by the thickness of the gravel in the aquifer at the test locations, a much narrower range of hydraulic conductivities results, 440 to 670 feet per day. These values are typical for clean sand and gravel aquifers (USBR, 1981; Heath,1983).

Using the Method of Cooley and Case (1973) it was possible to estimate the hydraulic conductivity of the upper silt layer of the aquifer. This method requires a value for the specific yield of the material. The specific yield of mixtures of silt and clay ranges from less than one to over five percent (Johnson, 1967). In unconfined aquifers such as this, the storage coefficient determined from aquifer tests and the specific yield are essentially the same. The most reliable values obtained from the test results range from about one half percent to three percent, which is within the range presented by Johnson (1967). If a specific yield of two percent is used, hydraulic conductivity values estimated for the silt range from 7.4 to 30.6 feet /day. These values are at the high end of the range published for silt and loess (USBR, 1981; Heath,1983).

The results of aquifer tests indicate that the shallow aquifer is essentially unconfined due to permeability in the upper silt layer. The hydraulic conductivity values generated for the gravel portion of the aquifer (440 to 670 feet per day) will allow the calculation of approximate ground water flow velocities. All the aquifer test data and time-drawdown plots are available in an open file report (Gannett, 1990).

GROUND WATER BUDGET

Ground water flow systems are dynamic. Ground water is constantly moving from areas where it enters the ground, known as recharge areas, to areas where it leaves the ground, known as discharge areas. Under natural conditions, ground water systems are generally in a state of equilibrium where the average annual recharge equals the average annual discharge. This is known as a steady-state condition. When the system is perturbed by artificial recharge or artificial discharge through pumping, the recharge may no longer equal discharge. The difference is reflected as a change in storage in the aquifer. If recharge exceeds discharge, more water is stored and there will be a rise in water levels. If discharge exceeds recharge, storage is lost and water levels will decline. If the artificial imbalance between recharge and discharge is not too extreme, the system may attain a new equilibrium and water levels will stabilize at some new level. If too much water is pumped from an aquifer, an equilibrium cannot be reached and water levels will decline until the aquifer is depleted.

Ground Water Recharge

The shallow ground water system in the Ontario area is recharged from a number of sources including precipitation, leakage from irrigation canals and ditches, deep percolation of water applied to fields and infiltration from intermittent streams. There is also minor recharge to ground water from individual on-site sewage disposal systems (drain fields) and municipal sewage lagoons. In addition, individual aquifers may receive recharge from adjacent geologic units.

Available information is insufficient to calculate the amount of recharge from each of these sources to each of the aquifer units. Key information which is lacking includes data on canal losses and deep percolation losses. In addition, the boundary conditions between the major hydrogeologic units are only generally understood.

Precipitation is the most important source of recharge to ground water on a regional scale since it is essentially the only source outside of the irrigated area. In the irrigated area, however, precipitation is relatively insignificant when compared to recharge from canal leakage and deep percolation of irrigation water. Because this study primarily concerns the shallow gravel aquifer in the valley, the discussion on recharge will be largely limited to that unit.

Mean annual precipitation in the lower elevation parts of the study area is approximately ten inches per year. Much of this precipitation is lost through evapotranspiration. Data from Johnsgard (1963) indicates that potential evapotranspiration (PET) exceeds precipitation most of the year (Figure 14). From November to February precipitation exceeds PET. During this period there is an average of 4.1 inches of surplus moisture. This moisture is available to make up any soil moisture deficit. Water in excess of that needed to bring the soil to field capacity is available for ground water recharge.

Recharge from precipitation may occur through seepage from intermittent streams carrying surface runoff or may occur by infiltration of precipitation where it falls. When precipitation occurs as snow and a rapid melt occurs, a relatively large amount of water can infiltrate to the shallow aquifer in a period of several days. The rise in the water table observed coincident with the melting of snow in February and March of 1989 (Figures 8 and 9) demonstrated this phenomenon. The observed rise in the water table corresponds to infiltration of about one half to one and one half inches of water.

The primary source of recharge to the shallow ground water system is from the conveyance, distribution and use of surface water for irrigation. The main study area, which covers parts of seven townships, includes about 125 square miles, or 80,000 acres. About 67,000 acres are irrigated in the area (Figure 15). About 32,800 acres are irrigated in the main valley overlying the shallow gravel aquifer. Water is distributed throughout this area by a network of canals and ditches.

Main supply canals in the valley include the Nevada Canal, the Gellerman-Froman Canal, the Owyhee Ditch and the Ontario-Nyssa Canal. These canals have a combined length of about 42 miles in the study area. Another major canal, the North Canal, runs for about 37 miles through the study area. The North Canal is mainly at higher elevations above the valley.

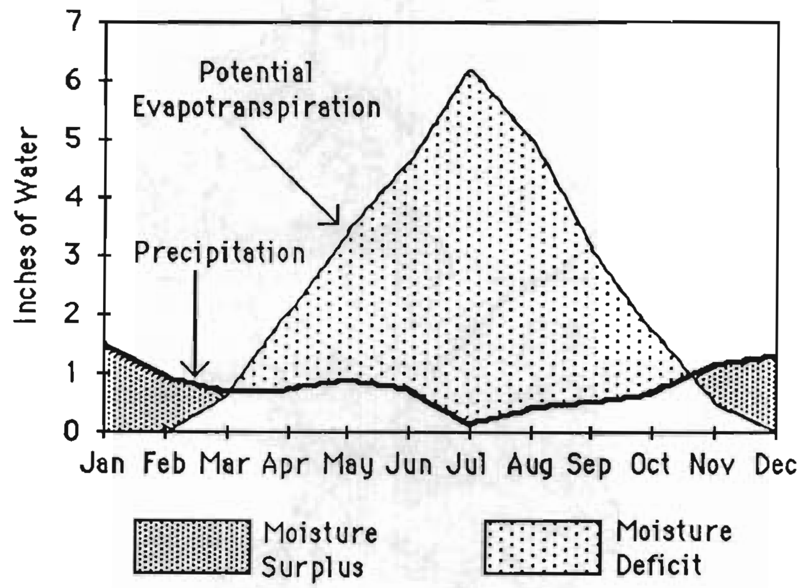


Figure 14. Mean monthly precipitation and potential evapotranspiration at Ontario, Oregon.

With the exception of the North Canal, there is little or no leakage information available for the canals. According to records provided by the Owyhee Irrigation District, there was an average canal loss of about 98,000 acre-feet per year between the years of 1981 and 1988 from the North Canal. This equates to about 1360 acre-feet per mile per year over it's 72 mile length. Although this includes both seepage losses and evaporative losses, the greatest proportion is probably seepage. Some of this seepage is probably lost in turn to evapotranspiration near the canal and to discharge to the surface as seeps and springs. Much of the remaining portion of the seepage moves downward to recharge ground water.

Evidence for canal leakage is seen in continuous well hydrographs. The hydrograph for the Pennington irrigation well (18/46-19bbb) (Figure 8) shows a continuous decline in the water table elevation from the end of the irrigation season to the snow melt event discussed earlier. After the recharge from snow melt, water levels again start to decline until about April 16, when once again water levels rose three feet in a matter of days, and a total of seven feet in about a month. This rapid rise in water level coincides with the initial flowing of the nearby Warm Springs Irrigation District canal that year. Leakage from the unlined canal caused a significant rise in the adjacent shallow aquifer. This high water level was sustained, more of less, for the entire irrigation season indicating continual leakage and aquifer recharge.

Seepage losses from canals in the valley were estimated using the method presented by Ogrosky and Mockus (1964). Canal losses of approximately 185 acre-feet per mile per year were calculated assuming five months of canal operation, a five foot canal width and a soil permeability of two feet per day (soil permeability from Lovell, 1980). This figure is substantially less than the losses reported for the North Canal. This discrepancy is probably due to difference in canal widths.

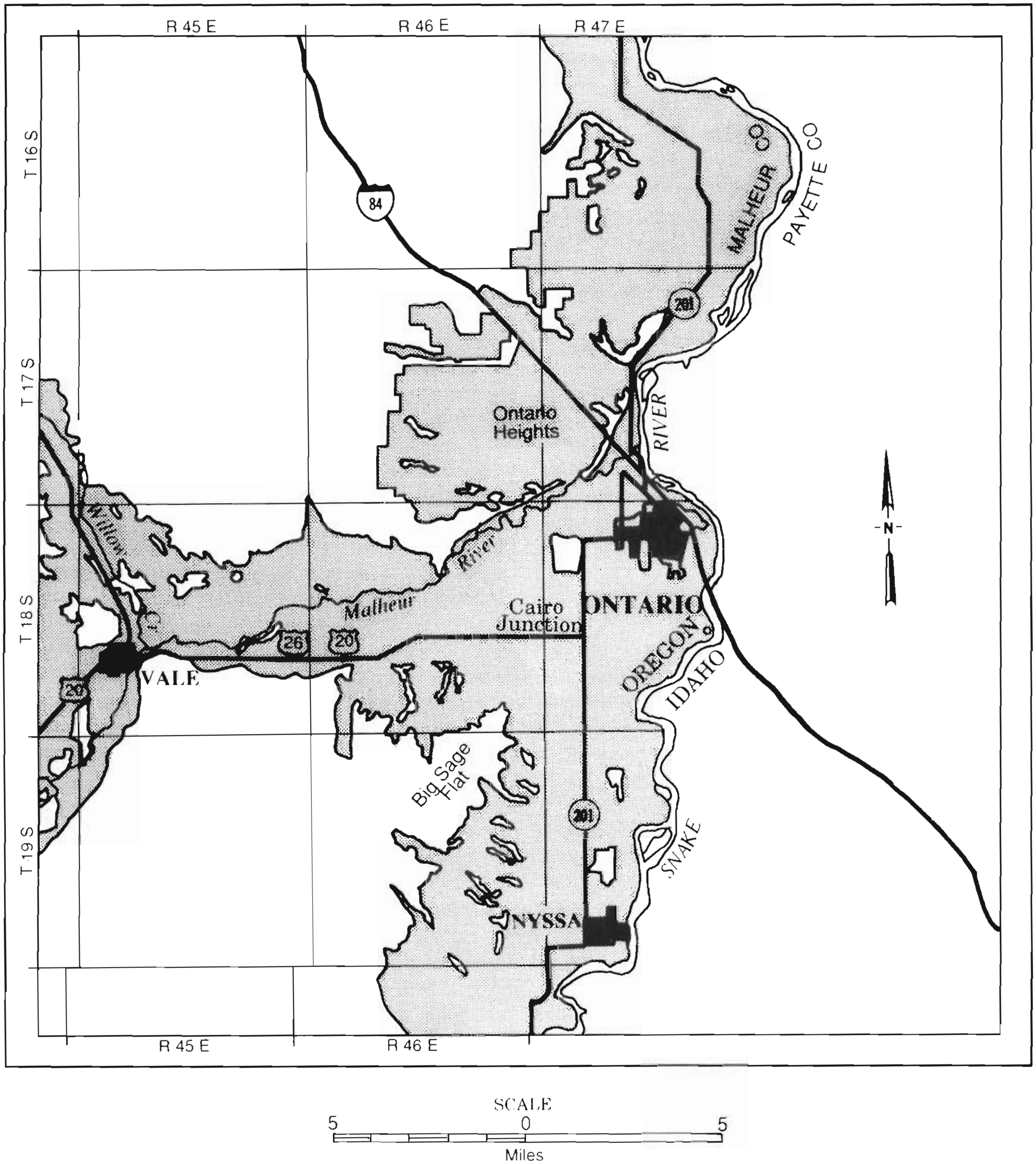


Figure 15. Map showing the irrigated area (shaded) in the Ontario area.

Canal seepage estimates of approximately 185 acre-feet per year per mile, equates to about 6100 acre-feet per year of recharge to the shallow aquifer in the study area south of the Malheur River. This figure only includes losses from the 33 miles of major canals in the valley and not the North Canal or shorter supply canals or tail water canals.

Another source of recharge is deep percolation of irrigation water. Many of the wells in which water levels were monitored monthly exhibited high water levels during the irrigation season. (Figure 16). Irrigation tests conducted by the Soil Conservation Service have shown that under certain conditions deep percolation will occur using the surface spreading irrigation methods practiced in the study area (Herb Futter, SCS, personal communication). There are no data available to determine how much of the observed rise in ground water levels during the irrigation season is due to deep percolation of water applied to fields and how much is due to canal and ditch leakage. The presence of agricultural chemicals in the shallow ground water suggests that deep percolation is occurring. The rise of the water table in response to snowmelt also suggests that water distributed over a wide area can infiltrate.

Another source of recharge to the shallow aquifer is subsurface flow from the adjacent uplands. Along the edges of the valley the shallow sand and gravel aquifer terminates against siltstones of the Glenns Ferry Formation. Water level measurements indicate that the Glenns Ferry Formation silts are saturated at that elevation and that water levels in the Glenns Ferry Formation are higher away from the valley. This suggests that there is movement of ground water through the silts from the uplands to the shallow aquifer. A significant amount of this water may come from leakage of the North Canal. There is not enough information on the hydraulic properties of the Glenns Ferry Formation to determine how significant this source of recharge might be.

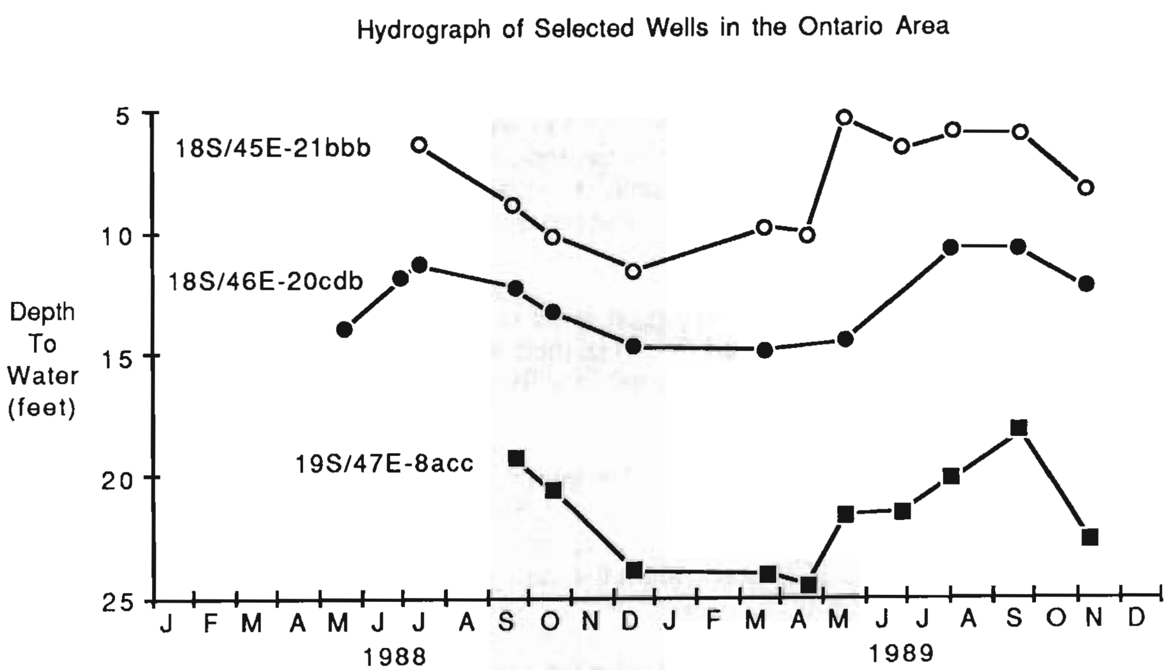


Figure 16. Hydrographs of selected wells in the Ontario area. Note rise in water levels corresponding to irrigation seasons.

Although ground water recharge from various sources cannot be directly calculated due to lack of specific data, it can be estimated by modeling ground water flow with a computer. Walker (1989) created such a computerized ground water flow model for part of the study area. Walker's model covers most of the study area in this report south of the Malheur River. This model utilizes ground water elevations and aquifer hydraulic properties generated as part of this study. Walker's model indicates a total annual recharge of 59,300 acre-feet in the modeled area. Of this amount, 5500 acre-feet is attributed to canal losses in the valley and 9500 is attributed to recharge from upland aquifers (probably mostly from leakage from the North Canal). The remaining 44,300 acre feet per year is attributed to a combination of natural precipitation, seepage from lateral canals and ditches, and deep percolation of water applied to fields. This latter amount equates to about 2 feet per year of recharge for each irrigated acre in the modeled area according to Walker. There are currently no independent data available to verify this figure.

Ground Water Discharge

Water leaves the shallow aquifer by a number of avenues including natural discharge to streams and rivers, discharge to artificial drains, withdrawal through wells and evapotranspiration from wetlands. There are no measurements of actual discharge to surface streams, rivers and artificial drains. However, the amount of discharge through withdrawal by wells can be reasonably estimated.

Ground water is pumped from aquifers in the Ontario area for a number of purposes including irrigation, drainage, domestic use, municipal use and industrial use. Most withdrawal is from the shallow alluvial aquifer.

There are about 855 logs for domestic wells on file for the seven townships around the study area. County health officials estimate that there are approximately 2342 domestic wells in the same area (Ray Huff, personnel communication). This suggests that the state has logs for about 37 percent of the wells in the area.

The Water Resources Department has well logs for 587 wells in the valley part of the study area. If these logs represent 37 percent of the wells in the area, then there are approximately 1587 domestic wells in the valley. Assuming that each domestic well supplies a single household using 500 gallons per day, domestic wells pump approximately 889 acre-feet per year from the shallow alluvial aquifer.

There are 103 wells listed as sources of irrigation water in the water rights records. Of these wells, 87 are in the valley and produce all or part of their water from the shallow gravel aquifer. The remaining 16 are at higher elevations and produce from aquifers within the lake sediment sequence.

According to water right records, there are 3040 acres irrigated in the study area using ground water as a primary water source. Most ground water irrigation, 1751 acres, occurs on the benches above the irrigation canals. Only 1289 acres are irrigated using ground water in the valley. There are an additional 1625 acres, all in the valley, which are irrigated using ground water as a supplemental water source.

Assuming the rates of water application are similar for ground water and surface water rights in the area (about 4 feet per year), approximately 5156 acre feet of water are pumped from wells in the valley for primary irrigation. The vast majority of these wells produce all or part of their water from the shallow gravel aquifer.

Calculating supplemental irrigation pumpage is somewhat problematic since it varies from year to year with the availability of surface water. Supplemental irrigation water is used when the primary source of irrigation water cannot meet needs. Supplemental irrigation use has not been measured. Assuming that supplemental irrigation use is somewhere between one and three feet per year, pumpage for this purpose would be between 1625 and 4875 acre-feet per year.

The cities of Ontario, Nyssa and Vale produce all or part of their municipal water supply from wells. During the 1988/89 water year, the City of Ontario pumped about 2590 acre feet of water from a well field along the banks of the Snake River. An analysis of this pumpage using the method of Jenkins (1970) indicates that the majority of the water produced by these wells comes directly from the Snake River. Water levels in the well field are below river level.

The City of Nyssa pumped about 337 acre-feet from two wells about one mile from the river during the 1988/89 water year.

The City of Vale pumps water for municipal purposes from both deep and shallow wells. Total pumping from the shallow aquifer by the City of Vale is approximately 325 acre feet per year. Most of the shallow pumping is from a sump well about 3000 feet from the Malheur River.

Drainage well operation also results in the withdrawal of a significant amount of ground water from the shallow aquifer. Seven wells area operated by the Malheur Drainage District in the Cairo Junction area. No annual production figures for these wells are available. Annual withdrawal by these wells was estimated to be 1114 acre-feet assuming a pumping rate of 400 gallons per minute per well (based on other wells in the area) and three months of operation per year.

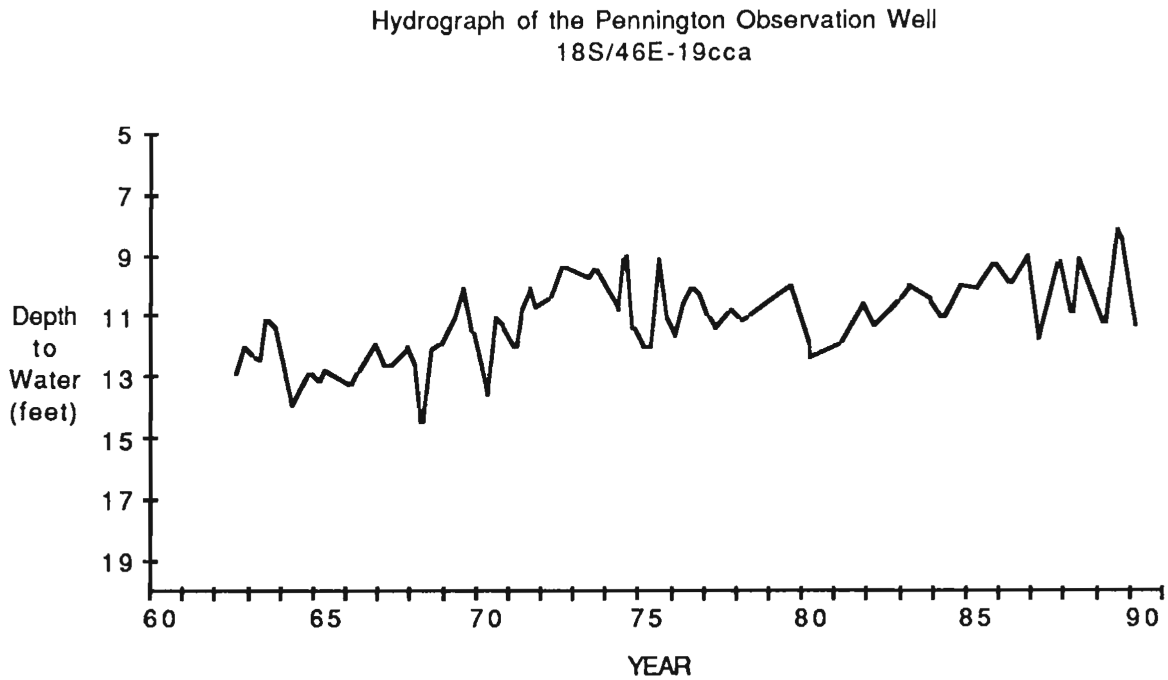
Estimated total ground water withdrawal in the study area is 9446 to 12,696 acre-feet per year. Most of this occurs in the area south of the Malheur River.

Long-Term Water Level Changes

The Oregon Water Resources Department has been monitoring water levels in some wells in the Ontario area since the early 1950s. Some of these wells have exhibited a gradual rise in water level over a long period of time (Figure 17). Most wells show no long term change in water levels. No water level data prior to the early 1950s were found for the study area, but it is probable that water levels may have risen in some places right after the main irrigation projects were completed. A study in the Treasure Valley in Idaho, just across the Snake River, reported water level rises as irrigation development occurred (Thomas and Dion, 1974).

There is little doubt that the ground water flow system as it currently exists in the study area has been dramatically modified by irrigation activities, specifically by canal leakage and deep percolation. For the most part, the system currently appears to be in a nearly steady state condition. The gradual rise occurring in some long term observation wells indicates that the system is still experiencing a slight increase in storage at least in some places.

Considering the physiographic setting of the Ontario area, there is little doubt that it is an area of regional ground water discharge. The upward vertical gradient between the deep and shallow aquifers and the presence of hot springs throughout the area also suggest it is a regional discharge area. This means that the Malheur River is a gaining stream in the study area. Ground water levels are higher than stream levels adjacent to a gaining stream. Most of the gravel aquifer lies below the levels of the Malheur and Snake Rivers. Therefore, the shallow gravel aquifer was saturated prior to irrigation development. Before irrigation development the water level in the shallow aquifer was at or above the elevation of the adjacent rivers. The increase in annual recharge due to irrigation development has raised water levels primarily in the overlying silt, especially toward the edges of the valley. This has increased the gradient of the water table and increased ground water flow velocities. The increased recharge due to irrigation development has not increased storage in the shallow aquifer as much as it has served to greatly increase the annual flow through the system. The shallow gravel is a naturally saturated aquifer and not an artifact of human activity.



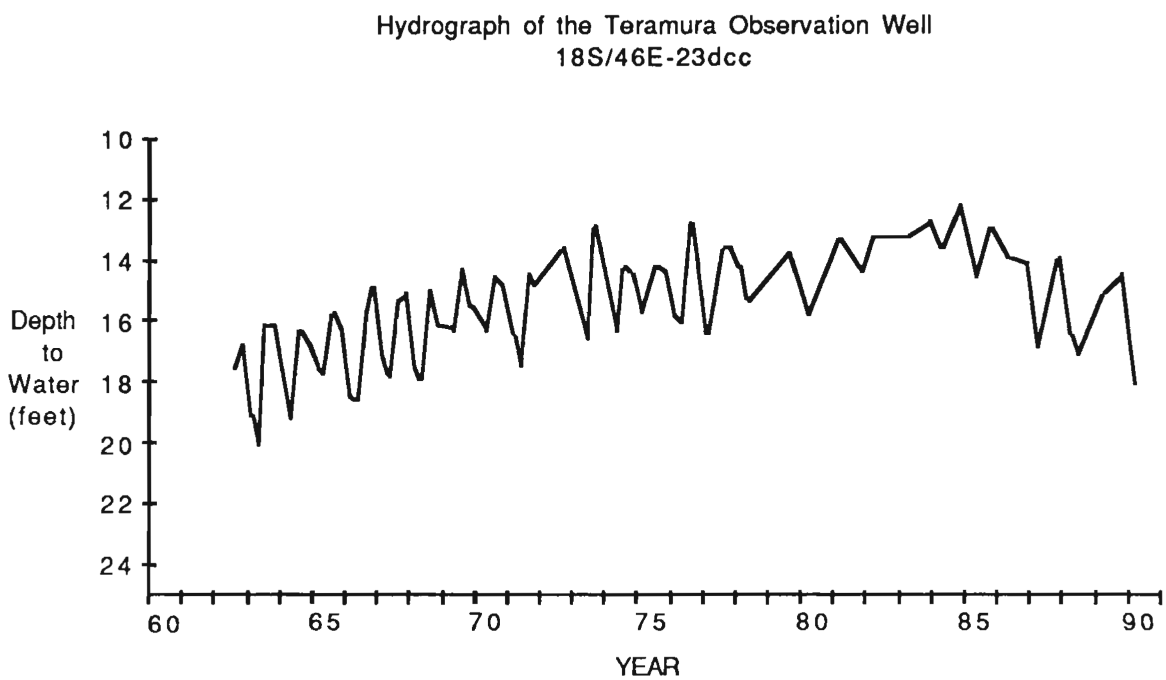


Figure 17. Hydrographs of observation wells in the Ontario area showing long-term rise in the water table.

Ground Water Supply

Assuming the system is at or near steady state, the discharge will approximately equal the recharge. The best available figure for recharge is that provided by Walker (1989). According to Walker, 59,300 acre feet of water are moving into and out of the shallow aquifer each year in the part of the study area south of the Malheur River. It is in this area that virtually all the major ground water pumping occurs.

The estimated annual pumpage from the shallow aquifer is 9446 to 12,696 acre-feet per year. This is less than a quarter of the estimated annual recharge to the system (59,300 acre-feet per year south of the Malheur River). This suggests that some additional development of the shallow aquifer can occur without causing adverse effects to users.

Less is known about deeper aquifers within the lake sediment sequence. Recharge estimates are not available; however, recharge to these deep confined zones is likely to be slower than to the shallow unconfined system. Lower transmissivities and storage coefficients typical of fine-grained confined aquifers increase the chances of interference between wells. Development of deep water bearing zones within the Glenns Ferry Formation should only proceed with that understanding.

GROUND WATER CONTAMINATION

Contamination of the shallow aquifer has been detected in wells within a 180 square-mile area. However, the aquifer is not contaminated under this entire area. The most severe contamination occurs in the much smaller area between Nyssa and Ontario.

Contaminants detected in the shallow aquifer include Nitrate and Dacthal. Nitrate is a component of agricultural fertilizer. Dacthal is an agricultural herbicide commonly used in the area. Although there are many potential sources of nitrate in the area, agricultural fertilizers are the only source which could account for the volume of nitrate known to reside in the aquifer (Greg Pettit, DEQ, personal communication). The presence of Dacthal also indicates that the nitrate has an agricultural source.

Hydrogeological Factors

One of the purposes of this investigation was to determine the most probable route by which the contaminants are entering the aquifer. This information is critical to understanding and solving the contamination problem. Possible routes include deep percolation of irrigation water in fields, seepage of chemical laden water from tail water ditches, and by downward movement of contaminated water through unsealed or poorly sealed wells.

There is compelling evidence to suggest that both deep percolation and ditch seepage occur. As discussed in earlier sections, both aquifer testing and continuous water level recorder data indicate that the silt overlying the shallow gravel aquifer is permeable, and that water moves from it into the shallow aquifer. The effects of canal leakage and precipitation infiltration are clearly shown on recorder charts (Figures 8 and 9). The common use of drainage wells, which pump water from the shallow gravel aquifer to dewater fields and basements, clearly demonstrates a direct hydraulic connection between the very shallow subsurface and the aquifer.

The permeability of the material overlying the shallow aquifer is not the same in all places. The continuous recorder on well 18S/46E-19bbb showed no barometric response suggesting the aquifer is unconfined at that location. However, wells at 18S/47E-19bcc and 18S/47E-17cbd showed water levels which fluctuate with barometric pressure changes indicating partially confined conditions (Figure 18). The permeability of the material overlying the shallow aquifer probably varies between major terraces. The difference in permeability may coincide in part with the major soil types.

Reducing the level of ground water contamination will require reducing the amount of irrigation water lost to deep percolation, reducing the amount of nitrogen in the water that is lost to deep percolation, and reducing the amount of nitrogen in tail water from the fields discharging to ditches. Irrigation and nitrogen application should be managed to ensure that nitrogen in the soil profile is not flushed below the rooting depth of the crop during irrigation.

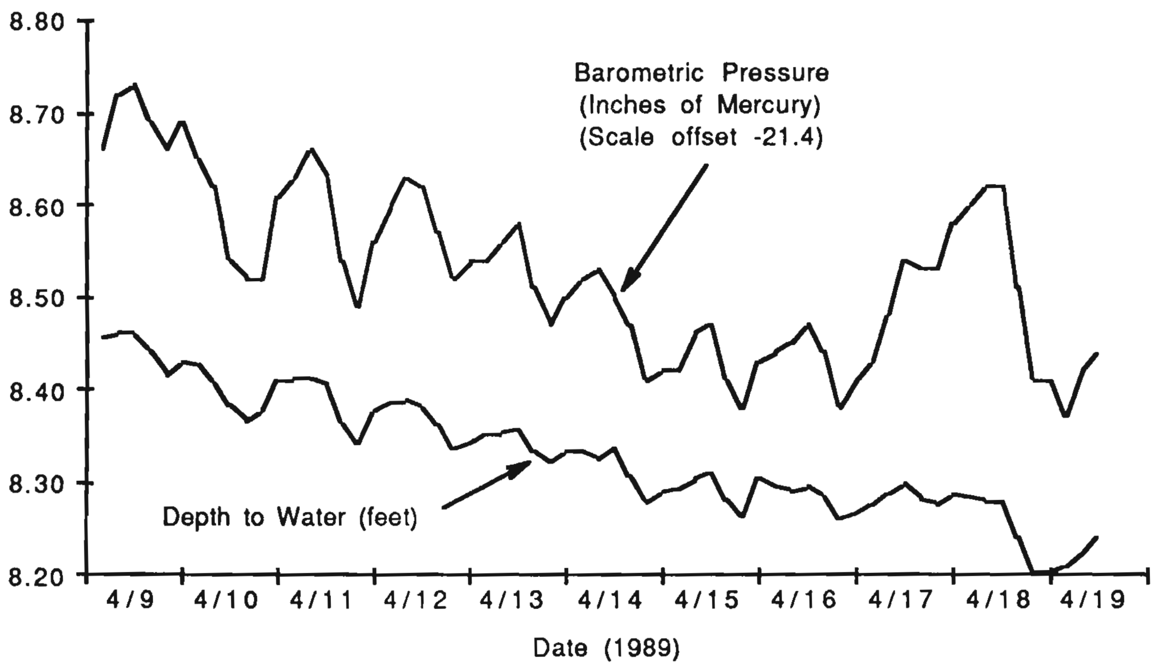


Figure 18. Graph showing correlation between water level and barometric pressure in the OSU Malheur Experiment Station north well (18S/47E-19bcc). The water level data has had a linear, seasonal trend removed to display the correlation.

Well Seals and Well Construction

Contamination of ground water through unsealed wells is probably insignificant for a number of reasons. First, the contaminated water would have to flow to the well either on the surface or in the shallow subsurface. Although a few wells were observed in the study area with visible void spaces around the casing, they were rare. Surface water flowing into the ground around well casings was not observed during this investigation. Results of this investigation indicate that the silt overlying the gravel aquifer has vertical permeability. Water movement in this semi-confining layer undoubtedly has a large vertical component. This suggests that downward percolation of water is occurring throughout most of the area, and the volume of water percolating along unsealed casings would be infinitesimally small in comparison. The unconsolidated silt overlying the aquifer would probably tend to slough into any void spaces around an unsealed casing.

Ground Water Flow Velocity and Contaminant Travel Time

There are many factors which control the rate of contaminant movement in ground water. Among these are the velocity of ground water flow, the solubility of the contaminant and the degree to which the contaminant adsorbs to the framework of the aquifer itself. If the source of contamination is removed, the water quality in the aquifer will improve as contaminated water moves out to the system and is replaced by uncontaminated water. Removing all the contaminated water residing in the system may not entirely clean up the aquifer. Contaminants adsorbed to the aquifer framework may contaminate new water which enters the system even after the original source of the contamination has been removed. However, with highly soluble materials such as nitrate, the water quality should improve greatly as the contaminated water leaves the system. A rigorous analysis of contaminant transport is beyond the scope of this report. The evaluation presented in this section is intended to provide only a rough approximation of nitrate travel times based on average ground water flow velocities.

To determine the time it will take for existing contaminated water to leave the system, it is necessary to know the rate with which ground water moves through the system. The path of contaminated water through the system can be broken into three parts: movement through the unsaturated zone above the water table, movement through the semi-confining layer above the sand and gravel aquifer, and movement through the aquifer itself.

At this time, ground water and contaminant movement through the unsaturated zone in the Ontario area is not sufficiently understood to deal with quantitatively. Therefore, this part of the ground water flow path will not be addressed in detail. However, the rapid response of the water table to snow melt observed by continuous recorders indicates that water movement through the unsaturated zone can be very rapid, perhaps days to weeks.

The rate of water movement through the semi-confining silt can be estimated from the water flux through that layer. Walker (1989) estimated that 2 feet of water are recharged to the aquifer through a combination of deep percolation and leakage from small lateral canals and head ditches. For the purposes of travel-time calculations the assumptions are made that the water movement is vertical through this layer, that the 2 feet of recharge is uniform over the entire irrigated area and that the effective porosity (specific yield) of the semi-confining silt is 5 percent. Specific yield is used in this calculation instead of porosity because in fine-grained materials part of the porosity is taken up by stagnant water which does not move (USBR, 1981; Fetter, 1980). The specific yield is thought to best represent the proportion of rock through which ground water flows. The average saturated thickness of the semi-confining layer in 66 wells in the valley is about 8 feet. The average velocity of ground water flow will be approximately equal to the specific flux (2 feet per year) divided by the specific yield (0.05). This results in an average velocity of 40 feet per year.

The time for water to move through the semi-confining layer would be the thickness (8 feet) divided by the velocity (40 feet per year). Therefore, the travel time through this layer would be between 2 and 3 months. If water movement in the semi-confining layer has a large horizontal component, this time would be increased. After moving through the semi-confining layer, the water would then enter the shallow gravel aquifer where movement is relatively rapid and predominantly horizontal.

Ground water movement through the aquifer is estimated using Darcy's law. The average velocity of ground water movement equals the hydraulic conductivity times the hydraulic gradient and divided by the effective porosity of the aquifer. Aquifer tests indicate that the hydraulic conductivity is about 500 feet per day in the shallow aquifer. Hydraulic gradients average between 5 and 20 feet per mile (0.001 and 0.004). The porosity of sand and gravel mixtures is about 20 percent (0.20). Using these figures, it is estimated that ground water moves through the shallow gravel aquifer at rates ranging from 2 to 10 feet per day over much of the study area.

The distance of the ground water flow path from the Cairo Junction area to the discharge area along the Malheur or Snake Rivers is 2 to 4.5 miles. At an average velocity of 6 feet per day, ground water moves about 0.4 mile per year. Therefore it may take between 5 and 11 years for water in the Cairo junction area to discharge from the system.

A number of simplifying assumptions have been made to arrive at these figures. These estimates are based on average ground water velocities. The velocities will vary in time and space. Velocities of individual water molecules can vary widely. In addition, the effects of ground water pumping for irrigation and drainage have not been considered and may be significant. These figures are very crude and are presented only to give the reader a general sense of the average amount of time necessary for water to move through the shallow ground water system in the Ontario area.

Although it may take close to a decade for water to move through the shallow ground water flow system, the positive effects of changed agricultural practices may be observed in a much shorter time. If the quality of water entering the ground water system through deep percolation is improved, the reduced contaminant loading should result in some improvement of local ground water quality because of dilution. If the ratio of recharge from contaminated sources to recharge from uncontaminated sources is reduced, improved water quality will occur in the aquifer, again through dilution. Some improvement in water quality may be noticeable within a few years after practices are changed.

CONCLUSIONS

The results of this investigation indicate the shallow sand and gravel aquifer in the Ontario area is poorly confined and that water can move from the ground surface into the shallow aquifer with relative ease.

The major sources of recharge to the shallow aquifer in the Ontario area are canal and ditch leakage and deep percolation of irrigation water. The water table rises during the irrigation season in response to this flux of water.

Nitrate and Dacthal in the shallow aquifer are most likely being introduced through deep percolation of irrigation water and through seepage from tail water ditches.

Reducing ground water contamination will require reducing the amount of deep percolation or reducing the amount of nitrate and Dacthal in water which is lost to deep percolation. Reducing ground water contamination will also require reducing the levels of contaminants in tail water running off fields.

The thickness and physical characteristics of the semi-confining silt over the aquifer varies from place to place. These variations should be investigated and considered when developing improved agricultural practices.

It may take close to a decade for ground water in the Cairo Junction area to discharge to the Malheur or Snake River. However, improvements in ground water quality resulting from changes in agricultural practices may be apparent in a few years.

Current ground water withdrawals from the shallow sand and gravel aquifer are only 10 to 20 percent of the annual recharge. The shallow aquifer can support additional development. The impacts of proposed development can be predicted given the current level of knowledge of the system.

Less is known about deeper water bearing zones within the Glenns Ferry Formation. Additional development of deep zones should be approached with caution. Intense pumping of deep water bearing zones could draw contaminated water from the shallow aquifer into those zones through improperly constructed wells.

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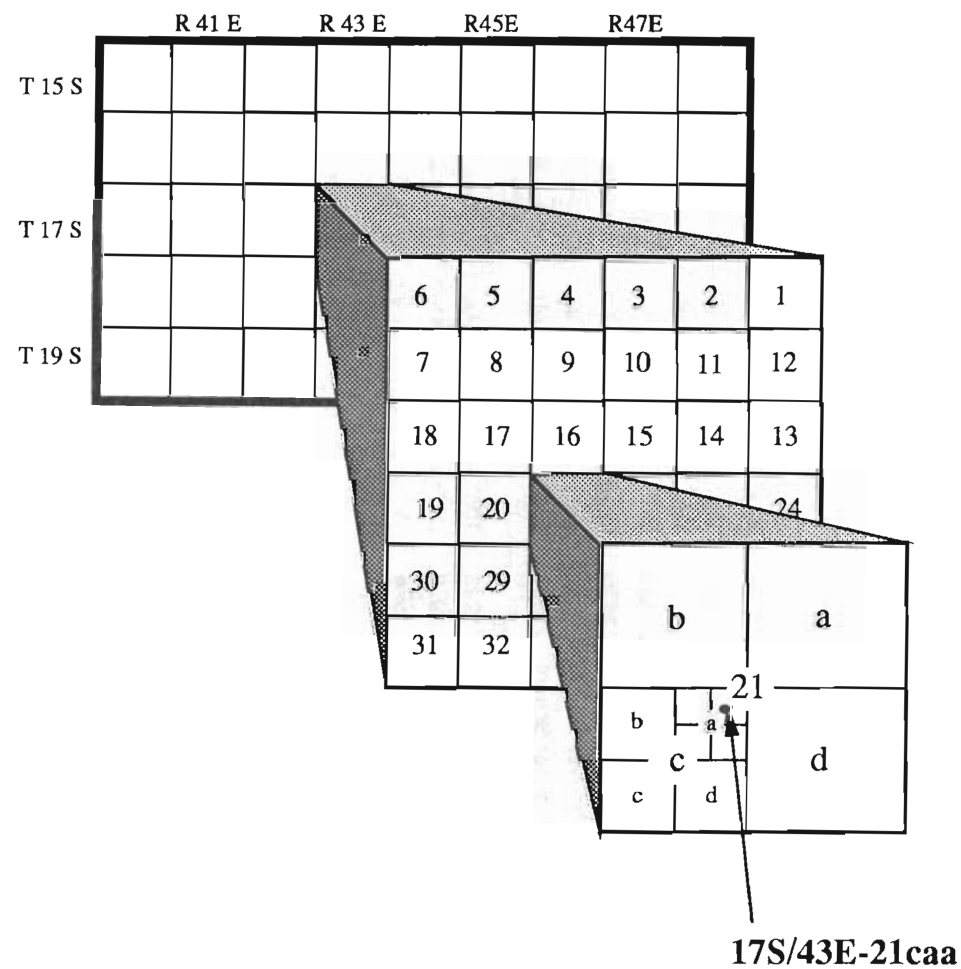
APPENDIX 1

WELL NUMBERING SYSTEM

The well numbering system used in Oregon and in this report is based on the public land survey system. Each well number indicates the geographic location of the well and describes the township, range and section. For example, well number 17S/43E-21caa is in Township 17 South, Range 43 East, and Section 21. The three letters following the section number indicate the location within the section as shown in the figure below. The first letter indicates the quarter section (160 acres), the second letter represents the quarter-quarter section (40 acres) and the third letter represents the quarter-quarter-quarter section (10 acres). Quarters are designated a, b, c or d, starting with the upper right hand quarter and going counterclockwise. If more than one well is located within a 10-acre tract, the three letters are followed by a serial number to identify the specific well.



Use Codes: I = irrigation, D = domestic, S = stock, IN = industrial, DR = drainage, N = none
Test Type Codes: B = bailer, P = pump, A = air lift

Location	Owner	Year drilled	Depth (feet)	Diameter (inches)	Cased Depth (feet)	Perforated Interval (feet)	Aquifer Unit	Static Level (feet)	Yield (gpm)	Draw-down (feet)	Time (hrs)	Test type	Use	Remarks
17/44-7dda	DeLong	1977	106	8	21	none	Tig	20	120	100	1	B	I	
17/44-25dad	Rickard	1980	160	8	29	none	Tig	8	25	10	5	P	D	
17/44-25ada	Durrett	1947	73	12	NA	NA	Qal	46	NA	NA	NA	NA	N	State Obs Well
17/44-36bbd	Guerricogotia	1892	49	8	21	none	Tig	12	16	27	1	P	N	
17/44-36bba	Guerricogotia	1967	247	6	27	none	Tig	28	20	60	2	B	D	
17/46-23cda	Skyline Farms	1968	123	6	49	none	Qtg	42	60	40	2	P	D	
17/46-24aaa	Walt Rodgers	1986	59	6	59	43-59	Qtg	38	22	45	1	B	D	
17/46-24bcc	McCracken	1976	40	40	39	none	Qtg	20	15	5	3	B	D	
17/46-25aaa	Rodgers Dairy	1984	83	10	83	63-78	Qtg	27	20	30	1	B	S	
17/46-25dac	Tshida	1980	50	6	43	37-42	Qtg	40	10	5	1	B	D	
17/47-2cab1	Pioneer School	1963	32	12	32	24-32	Qal	11	100	1	2	P	I	
17/47-2cab2	Pioneer School	1987	145	10	145	90-105 134-139	Tig	16	300	145	8	A	D	
17/47-5cdd	Marler	1983	105	6	60	none	Tig, Qtg	60	28	80	1	A	D	
17/47-9cdd	Reuber	1979	237	6	167	132-142	Tig	83	15	230	NA	A	D	
17/47-10adc	Griffen	1978	47	6	39	34-39	Qal	18	30	11	2	B	D	
17/47-15bbc	Mendiola	1981	55	6	30	none	Qal	15	30	15	3	B	D	
17/47-15aaa	Morishita	1984	54	6	54	none	Qal	10	30	6	2	B	D	
17/47-21cab	Wright	1978	29	6	29	none	Qal	8	122	5	1	B	D	
17/47-29bcc2	Wilson	1980	84	8	67	32-66	Tig, Qtg	40	20	0	1	B	D	
17/47-29bcd	Wilson	1980	435	6	68.5	none	Tig	70	6.5	128	1	B	N	
17/47-29bcc1	Wilson	1978	250	6	51	none	Tig	60	8	90	2	P	N	
17/47-31aab	Gillick	1976	210	6	81	none	Tig	60	20	60	3	P	D	
17/47-32bbb	Gosmeyer	1972	30	6	30	none	Qal	16	15	16	1	B	D	
17/47-32ddc	Edwards	1981	98	8	32	none	Tig, Qal	6	25	45	1	B	D	
17/47-33cbb	Holmes	1988	397	6	97?	none	Tig	15	8	220	1	B	D	
18/45-1ddd	Skinner	1970	160	6	40	none	Tig	67	6	83	1	B	D	

APPENDIX 2 - WELL LOG DATA FROM FIELD LOCATED WELLS

Location	Owner	Year drilled	Depth (feet)	Diameter (inches)	Cased Depth (feet)	Perforated Interval (feet)	Aquifer Unit	Static Level (feet)	Yield (gpm)	Draw-down (feet)	Time (hrs)	Test type	Use	Remarks
18/45-6ccd	DeMeyer	1976	38	6	36	24-31	Qal	14	30	23	1	B	D	
18/45-6dad	Belnap	1979	389	6	60	none	Tig	40	30	50	4	P	D	
18/45-9cda	York	1979	425	6	108	none	Tig	20	10	470	NA	A	D	
18/45-12acc	Patchett	1977	120	6	60	none	Tig?	60	15	55	1	B	S	
18/45-14baa	Patchett	1981	83	6	26.5	none	Tig?	48	20	60	1	A	D	
18/45-14dab	Tamino	1988	50	12	38	21-36	Qal	10	350	65	8	A	I	
18/45-15daa	Kuwahara	1983	35	6	34	29-34	Qal	12	60	30	1	A	D	
18/45-15acc	Netcher	1969	67	8	54	none	Qal, Tig?	20	15	10	1	B	D	
18/45-15bab1	Hagenson	1976	340	6	27	none	Tig	NA	NA	NA	NA	NA	N	Reported Dry
18/45-15bab2	Hagenson	1976	400	6	21	none	Tig	105	5	295	2	B	N	
18/45-15abb	Hagenson	1984	57	6	55	none	Qal	25	24	5	1	B	D	
18/45-17bab	Belnap	1988	31	12	26	18-24	Qal	8	50	0	1	B	N	
18/45-20aac	Stacy	1979	30	6	29	25-30	Qal	14	60	NA	1	B	D	
18/45-20cac	City of Vale	NA	NA	NA	NA	NA	Qal	10	NA	NA	NA	NA	IN	Sump Well
18/45-20dac2	Fuhriman	1977	100	8	42	none	Tig	8	24	37	1	B	D	
18/45-20dac1	Fuhriman	1974	24	6	24	none	Qal?	8	12	10	1	B	D	
18/45-21bbb	Loomis	1960	165	10	40	10 - 40	Qal, Tig?	9	350	12	3.25	P	N	
18/45-21cad	Smith	1983	35	12	35	22-35	Qal	15	100	7	1	P	I	
18/45-22dad	Perry	1979	25	6	25	20-25	Qal	12	10	15	1	B	D	
18/45-28aac	Wheeler	1970	137	6	74	none	Tig	98	10	35	2	B	D	Deepnd to 200
18/45-28aab	Wheeler	1978	230	6	33	none	Tig	90	15	140	1	B	N	
18/45-28acc	Wheeler	1981	63	6	58.5	50-58	Qal	40	30	55	1	A	I	
18/45-29bbc	Vale Sch Dst	1957	35	12	24	14-24	Qal	9	NA	NA	NA	NA	N	
18/45-29bca	Vale Sch Dst	1969	30	12	25	18-25	Qal	10	100	18	2	P	I	
18/46-1daa	Bowers	1979	70	6	23	none	Tig?	8	5	52	1	B	D	
18/46-12aca	Butler	1975	39	6	40	none	Qal	20	20	4	1	B	D	
18/46-12adb	Butler	1981	93	8	39	29-38	Qal	16	45	35	2	A	I	
18/46-12cad	Mooney	1979	80	8	53	none	Qal?	48	21	12	1	P	D	
18/46-13bba	Pennington	1980	65	6	45.8	none	Tig?	28	20	5	2	B	D	
18/46-14dcd2	Hariuchi	1982	40	6	40	37-40	Qal	12	80	40	1	A	D	

APPENDIX 2 - WELL LOG DATA FROM FIELD LOCATED WELLS

Location	Owner	Year drilled	Depth (feet)	Diameter (inches)	Cased Depth (feet)	Perforated Interval (feet)	Aquifer Unit	Static Level (feet)	Yield (gpm)	Draw-down (feet)	Time (hrs)	Test type	Use	Remarks
18/46-14dcd1	Hariuchi	1977	62	12	46	26-46	Qal	20	280	26	2	P	I	
18/46-15bab	Gabiola	1979	25	6	25	20-25	Qal	10	10	12	1	B	D	
18/46-15cdc	Jordan	1979	33	6	31	none	Qal	12	30	21	1	B	D	
18/46-17ccc	Hall	1972	210	6	35	none	Qal, Tig?	10	3	190	1	B	D	
18/46-19bbb1	Pennington	1988	25	16	25	18-25	Qal	8	50	0	1	B	N	
18/46-19bbb2	Pennington	1982	27	6	27	24-28	Qal	5	20	27	1	A	S	
18/46-19cca	Pennington	1961	435	16	28	18-28	Qal, Tig	11	500	85	4	P	I	State Obs Well
18/46-20bcc	Tamino	1988	50	16	41.5	26-40	Qal	11	60	40	1	B	I	
18/46-20cdb	Lee Farms	1976	47	16	33	20-33	Qal	9	504	25	3	P	I	
18/46-20ddd	Lee Farms	1988	125	16	53	20-53	Qal, Tig?	25	50	0	1	B	I	
18/46-21bcc1	Kitamura	1988	35	16	35	20-35	Qal	10	250	25	1	P	I	
18/46-21bcc2	Kitamura	1988	169	10	35	none	Tig, Qal?	10	150	NA	NA	P	I	
18/46-21ccb	Lee Farms	1977	166	16	50	30-50	Qal, Tig	14	446	136	6	P	I	
18/46-22cbb	Baptist Church	1984	177	6	30	none	Tig	12	30	NA	NA	B	D/I	
18/46-22dba	Ito	1972	28	6	28	18-28	Qal	8	60	6	1	B	DR	
18/46-23dcc	Teramura	1958	240	14	54	21-52	Tig, Qal?	21	582	41	4	P	I	
18/46-26ccb	Kennington	1988	180	10	100	none	Tig	21	200	150	3	A	I/S	
18/46-26cdc	Kennington	1980	85	6	30	none	Tig	56	20	12	2	B	S	
18/46-35acd	Kennington	1984	305	6	250	none	Tig	175	12	100	1	B	D	
18/46-35abb	Kennington	1975	160	6	130	none	Tig	90	20	40	2	P	D	
18/46-36bad	OTM	1981	150	8	88	76-86	Tig	52	35	150	2	A	IN	
18/47-3dcd	ODOT	1961	38	12	31	25-30	Qal	NA	NA	NA	NA	NA	I	
18/47-4aac	City of Ontario	1980	50	28	50	18-45	Qal	12	135	8	11.5	P	I	
18/47-4cdd	H R Hospital	1987	400	12	46	none	Tig	31	60	20	8	P	IN	
18/47-4cca	Cruser	1981	63	6	57 1/2	52-57	Qal	38	35	45	1	A	I	
18/47-4dcb	Ontario Sch Dst	1980	32	8	31.7	19-30	Qal	5.5	100	10	4	P	I	
18/47-4dcb	Ontario Sch Dst	1980	255	8	31.7	19-30	Qal, Tig	7	80	250	3	A	I	Deepening
18/47-4dad	Ontario Sch Dst	1980	120	8	48	35-50	Qal, Tig	20	140	120	5	A	I	
18/47-5acb	Laney	1981	63	6	62.5	57-62	Qal	35	40	58	1	A	D	
18/47-5acb	Laney	1985	80	5	66	56-66	Qal	37	25	3	2	B	D	Deepening

APPENDIX 2 - WELL LOG DATA FROM FIELD LOCATED WELLS

Location	Owner	Year drilled	Depth (feet)	Diameter (inches)	Cased Depth (feet)	Perforated Interval (feet)	Aquifer Unit	Static Level (feet)	Yield (gpm)	Draw-down (feet)	Time (hrs)	Test type	Use	Remarks
18/47-6ddc	Wada	1978	65	6	55	50-55	Qal	35	20	20	2	P	D	
18/47-7bdc2	City of Ontario	1985	220	8	50	30-45	Qal, Tig	18	110	NA	NA	P	N	
18/47-7bdc2	City of Ontario	1985	765	8	50	30-45	Qal, Tig	18	110	NA	NA	P	N	Deepening
18/47-7bdc1	City of Ontario	1964	55	11.75	48	36-48	Qal	26	100	20	6	P	D	
18/47-8adb	Pennington	1985	228	6	62	NA	Qal	30	20	25	NA	B	N	
18/47-9bdd	City of Ontario	1962	50	12	38	24-36	Qal	19	250	20	8	P	I	
18/47-9abd	TVCC	1968	100	16	33	21-33	Qal, Tig	16	400	64	15.5	P	I	
18/47-10bda	Minnick	1981	35	6	35	20-25	Qal	12	40	2	2	B	I	
18/47-10bda	City of Ontario	1968	128	12	32	20-32	Qal, Tig	14	100	26	6	P	N	
18/47-11baa	City of Ontario	1974	49	12	49	32-37	Qal	23	200	9	16	P	N	
18/47-15acd	Lopez	1984	74	6	34	none	Qal?	15	10	45	2	B	D	
18/47-16ccc	Kameshige	1987	51	6	48	29-45	Qal	14	25	16	1	B	D	
18/47-17aca	Gabiola	1967	65	8	65	60-65	Qal	22	40	2	2	P	D	
18/47-17bcc	LDS Farm	1988	65	12	58	40-53	Qal	10	400	60	5	A	I	
18/47-17cdb	Uchida Bros	1968	65	16	60	30-60	Qal	7	550	55	2	P	I	
18/47-19aba	Winegar	1975	61	6	62	55-60	Qal	22	20	9	1	B	D	
18/47-19ccb	ODFW	1968	124	8	114	none	Tig?	17	40	4	2	P	D	
18/47-19aba	Hasebe	1972	60	6	59	53-58	Qal	17	20	13	1	B	D	
18/47-19bcc	OSU Exp Stn	1988	90	12	60	35-58	Qal	13	185	50	5	P	N	
18/47-21ccb	Easterly	1952	177	12	60	40-60	Qal	32	700	100	NA	P	I	
18/47-20ccc	Langdon	1978	40	6	40	35-38	Qal	12	18	0	2	B	I	
18/47-21cac	Easterly	1947	50	12	48	16-47	Qal	20	NA	NA	NA	NA	I	
18/47-29cdc	Wettstein	1963	88	11.75	52	23-52	Qal, Tig?	21	500	31	4	P	I	
18/47-30bbb1	OSU Exp Stn	1986	220	6	134	none	Tig	29	45	220	2	A	D	
18/47-30bbb2	OSU Exp Stn	1981	83	6	80	70-80	Tig, Qal?	35	30	60	1	A	D	
18/47-30abc	OSU Exp Stn	1988	90	12	70	55-67	Qal	20	574	55	5	P	I	
18/47-32aca	Wettstein	1981	85	6	51	36-46	Qal, Tig?	25	40	85	2	A	D	
18/47-32bab	Wettstein	1961	58	8	58	52-58	Qal	22	50	4	NA	B	I	
19/46-13cdb	McGowen	1978	395	8	60	none	Tig	74	10	125	2	P	D	
19/46-13cdc	McGowen	1978	333	6	21	none	Tig	10	5	300	1	B	D	

APPENDIX 2 - WELL LOG DATA FROM FIELD LOCATED WELLS

Location	Owner	Year drilled	Depth (feet)	Diameter (inches)	Cased Depth (feet)	Perforated Interval (feet)	Aquifer Unit	Static Level (feet)	Yield (gpm)	Draw-down (feet)	Time (hrs)	Test type	Use	Remarks
19/46-13ddc	Haney	1966	71	8	47	none	Qtg	32	30	10	1	B	D	
19/46-36daa	Ward	1986	27	6	27	21-26	Qal	8	24	5	1	B	D	
19/47-7bbb	Bakker	1983	103	6	103	none	Qal?	40	20	100	1	A	D	
19/47-8acc	Hart	1967	145	24	110	27-47 70-110	Qal, Tig	24	586	96	12	P	D	
19/47-8cbb	Albertson	1984	44	10	44	25-40	Qal	17	30	4	1	B	D	
19/47-20ccd	Hiatt	1985	29	6	29	23-28	Qal	10	24	4	1	B	N	
19/47-32acb	Owyhee ID	1986	40	10	40	18-40	Qal	12	25	2	1	B	IN	

APPENDIX 2 - WELL LOG DATA FROM FIELD LOCATED WELLS

APPENDIX 3 - SYNOPTIC WATER LEVEL DATA

Comment Codes: C = well recently cycled but reading stable, R = well recovering, P = well pumping
Water level measurements are in feet below ground level. Elevations are in feet.

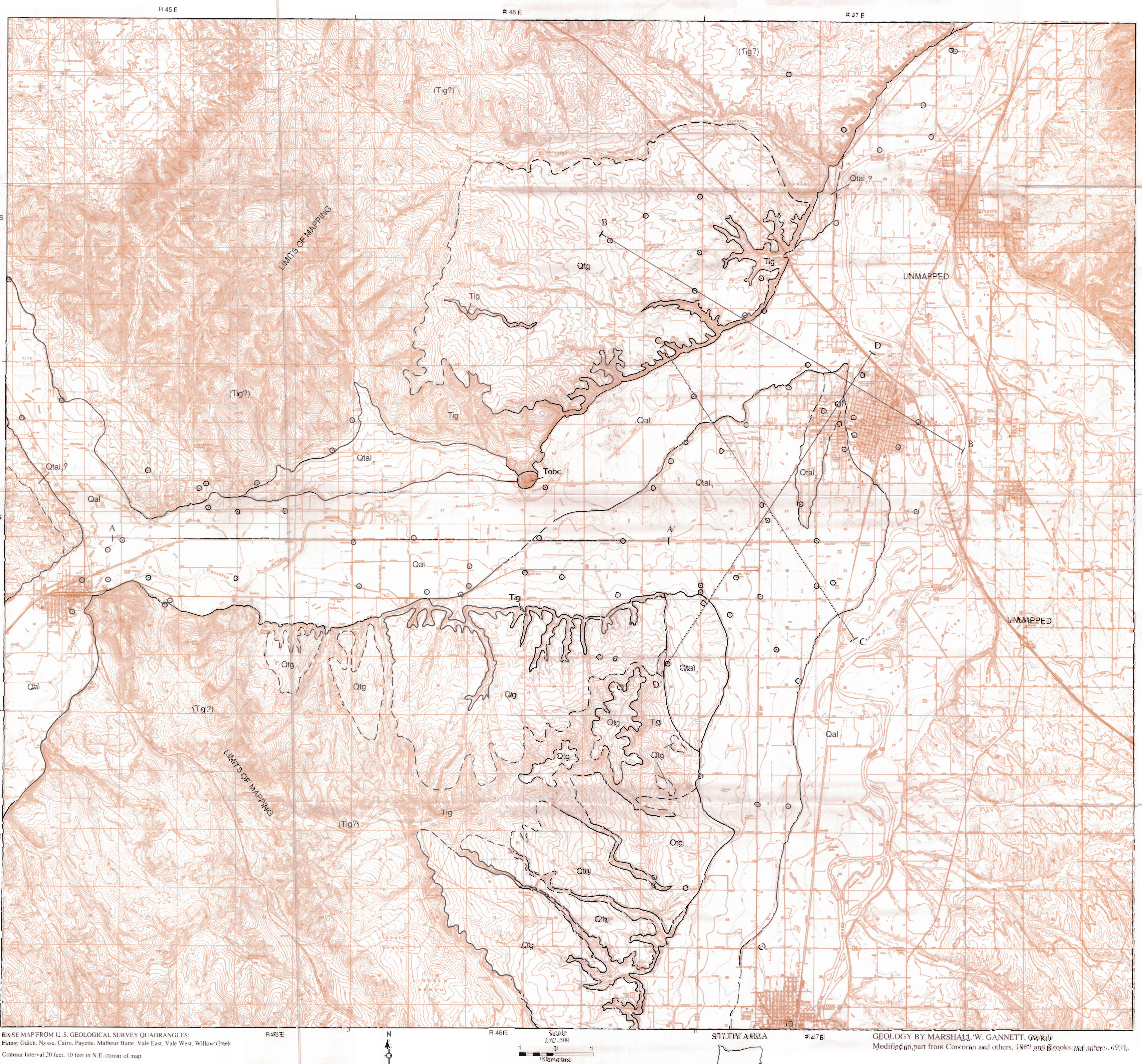
			Water Level Measurements			
WELL NAME	LOCATION	ELEVATION	Sep-88	Mar-89	Aug-89	COMMENTS
DON DELONG	17S/45E-7 DDA	2470	23.80	24.29	17.27	
LEO RICKARD	17S/44E-25 DAD	2300	8.36	7.93	5.27	9/88-C
C. N. DURRETT WELL	17S/44E-25 ADA	2340	46.33	47.31	42.63	
GUERRICOGOTICE TEST WELL	17S/44E-36 BBD	2315	11.31	8.25	7.83	
GUERRICOGOTICE HOUSE WELL	17S/44E-36 BBA	2325	33.40	28.31		9/88-R, 3-89-R
SKYLINE FARMS WELL	17S/46E-23 CDA	2420	33.19			9/88-P
WALT ROGERS	17S/46E-24 AAA	2365	35.55	38.51	36.37	9/88-R
LAWRANCE MCCRACKEN	17S/46E-24 BCC	2390	22.38	24.67	23.00	9/88-C, 3/89-C, 8.89-R
ROGERS DAIRY	17S/46E-25 AAA	2350	31.10	33.63	38.25	3/89-R, 8/89-R
DAN TSCHIDA	17S/46E-25 DAC	2355	22.67	25.43	21.12	3/89-C
PIONEER SCHOOL OLD WELL	17S/47E-2 CAB1	2130	9.73	10.51	9.90	
PIONEER SCHOOL NEW WELL	17S/47E-2 CAB2	2133	11.86	12.50	11.76	
RAYMOND MARLER WELL	17S/47E-5 CDD	2343	42.87	47.63	53.00	8/89-R
HENRY RUEBER WELL	17S/47E-9 CDD	2335	50.86	65.57	54.00	
HAROLD GRIFFIN WELL	17S/47E-10 ADC	2135	9.96	12.70	8.44	
STEVE MENDIOLA WELL	17S/47E-15 BBC	2139	12.90	13.36	12.80	3/89-C, 8/89-R?
RICH MORISHITA WELL	17S/47E-15 AAA	2133	10.79	10.06	10.54	3/89-R
NORWOOD WRIGHT WELL	17S/47E-21 CAB	2135	8.19			
LEM WILSON WELL 3	17S/47E-29 BCC2	2300	41.10	42.98		9/88-R, 3/89-C
LEM WILSON WELL 2	17S/47E-29 BCD	2320	55.19	57.68	57.41	
LEM WILSON WELL 1	17S/47E-29 BCC1	2330	48.51	45.70	48.45	
JAMES GILLICK WELL	17S/47E-31 AAB	2345	46.02	47.73	48.60	
GARY EDWARDS WELL	17S/47E-32 DDC	2145	6.12	3.88	4.75	
JOE GOSMEYER WELL	17S/47E-32 BBB	2170	11.47	10.55	10.06	
DEAN HOLMES WELL	17S/47E-33 CBB	2143	7.29	54.95		3/89-R
DARREL SKINNER WELL	18S/45E-1 DDD	2380	42.35	54.47		
FRED DEMEYER WELL	18S/45E-6 CCD	2270	17.91	17.68	9.80	
RAY BELAP DOMESTIC WELL	18S/45E-6 DAD	2295	90.16	87.53	62.50	9/88-R, 8/89-R
MARION YORK WELL	18S/45E-9 CDA	2320	27.60	45.82		
K. PATCHETT SO. DAIRY WELL	18S/45E-12 ACC	2340	84.82	90.92		3/89-P
RAY TAMENO IRRIGATION WELL	18S/45E-14 DAB	2220	14.40	13.24	11.62	
KENNETH PATCHETT	18S/45E-14 BAA	2330	44.50	54.82	48.41	
FRED KUWAHARA WELL	18S/45E-15 DAA	2233	14.84	14.01	11.45	
DANIAL NETCHER WELL	18S/45E-15 ACC	2250	17.29	22.60	16.38	
HAGENSON (HILEMAN WELL)	18S/45E-15 BAB1	2360	80.14	79.39	75.01	
HAGENSON (HILEMAN WELL)	18S/45E-15 BAB2	2360	56.85	76.25	71.33	
HAGENSEN DOMESTIC WELL	18S/45E-15 ABB	2290	20.82	19.90	15.58	9/88-P
RAY BELNAP IRRIGATION WELL	18S/45E-17 BAB	2249			7.31	
JIM STACY WELL	18S/45E-20 AAC	2240	7.70	8.42	4.25	
CYRIL FUHRIMAN EAST WELL	18S/45E-20 DAC2	2230	11.38	10.98	8.77	
CYRIL FUHRIMAN NORTH WELL	18S/45E-20 DAC1	2230	11.08	10.03	7.98	
CITY OF VALE RAILROAD WELL	18S/45E-20 CAC	2243	11.86	9.16	10.37	
K.T. LOOMIS WELL	18S/45E-21 BBB	2240	8.93	9.85	5.96	
JAMES & LINDA SMITH WELL	18S/45E-21 CAD	2230	9.98	12.47	7.53	
LARRY PERRY (USSING WELL)	18S/45E-22 DAD	2215	10.76	10.17	6.66	9/88-C, 8/89-R?
DARREL WHEELER WELL 2	18S/45E-28 AAB	2295	72.52	69.96	72.77	
DARREL WHEELER WELL 3	18S/45E-28 ACC	2262	46.42	48.66	38.43	
VALE ELEM SCH WELL (UNUSED)	18S/45E-29 BBC	2240	7.28	4.87	6.18	
KENT BOWERS WELL	18S/46E-1 DAA	2160	9.14	7.92	7.72	9/88-R
TOM BUTLER DOMESTIC WELL	18S/46E-12 ACA	2185	20.84	24.04		
TOM BUTLER IRRIGATION WELL	18S/46E-12 ADB	2170	11.92	14.56	10.68	
CHRIS AND TOM MOONEY WELL	18S/46E-12 CAD	2193	34.23	37.62		
ROLAND PENNINGTON	18S/46E-13 BBA	2190	25.73	27.87	25.67	
HARIUCHI DOMESTIC WELL	18S/46E-14 DCD2	2203	11.84	11.49		9/88-R
HARIUCHI IRRIGATION WELL	18S/46E-14 DCD1	2203	9.50	9.35	9.93	
ROSIE GABIOLA	18S/46E-15 BAB	2180	10.70	8.01	9.75	
MARK JORDAN	18S/46E-15 CDC	2197	10.67	9.54	9.07	

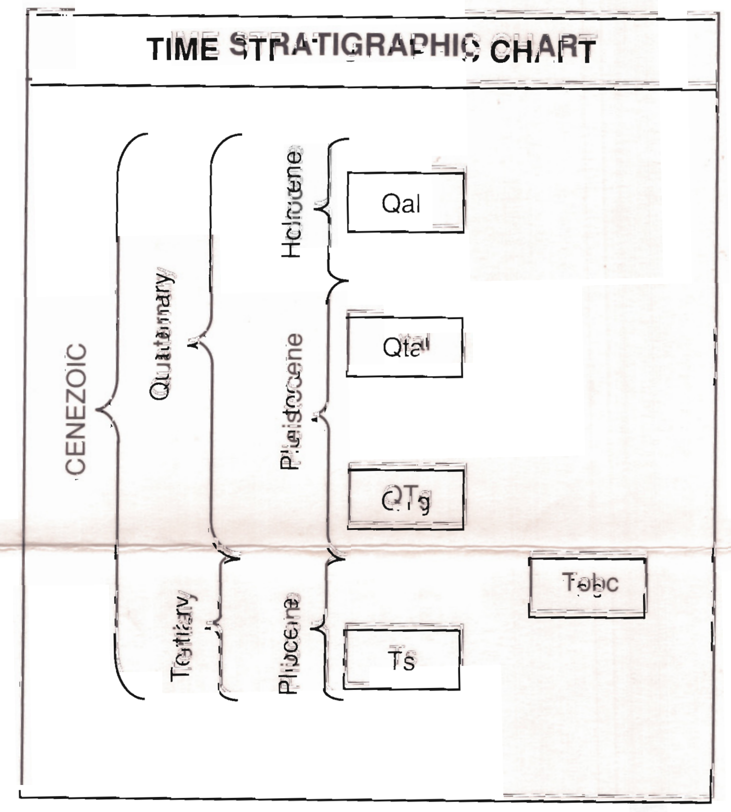
APPENDIX 3 - SYNOPTIC WATER LEVEL DATA

WELL NAME	LOCATION	ELEVATION	Water Level Measurements Sep-88	Mar-89	Aug-89	COMMENTS
MARION HALL	18S/46E-17 CCC	2195	7.35	10.22	4.85	
PENNINGTON (HUTCHINSON)	18S/46E-19 CCA	2210		11.93	9.12	
PENNING IRR.	18S/46E-19 BBB1	2211	10.67	12.70	6.35	
PENNINGTON SHOP WELL	18S/46E-19 BBB2	2211	9.51	10.54		
RAY TAMINO UNUSED WELL	18S/46E-20 BCC	2200			10.81	
LEE FARMS 1976 WELL	18S/46E-20 CDB	2215	19.00	6.99	4.33	9/88-P
LEE FARMS 1988 WELL	18S/46E-20 DDD	2230	15.45	18.70	13.90	
GEORGE KITAMURA WELL SHALLOW	18S/46E-21 BCC1	2205		10.14	8.74	
GEORGE KITAMURA WELL DEEP	18S/46E-21 BCC2	2205		9.89	8.46	
LEE FARMS 1977 WELL EAST	18S/46E-21 CCB	2220	12.29	14.88	10.73	
MALHEUR BUTTE BAPTIST CHURCH	18S/46E-22 CBB	2220	13.06	13.24	13.57	
TOM ITO WELL	18S/46E-22 DBA	2229	7.07	7.80	5.19	9/88-R
KAY TERAMURA WELL	18S/46E-23 DCC	2250	16.36	17.67		
KENNINGTON IRRIGATION WELL	18S/46E-26 CCB	2340			18.47	
KENNINGTON DAIRY WELL	18S/46E-26 CDC	2390	57.08	58.30	58.08	
BRAD KENNINGTON WELL	18S/46E-35 ACD	2585	232.22	231.23		
CLINT KENNINGTON WELL	18S/46E-35 ABB	2430	74.85	75.92	74.87	
MUSHROOM PLANT WELL	18S/46E-36 BAD	2340	52.25	51.77	52.16	
OR HWY COMM NE WELL	18S/47E-13 DCD	2150	15.94	13.60	14.89	
BECK PARK WELL	18S/47E-4 AAC	2155	12.49	10.83		
HOLY ROSARY HOSPITAL WELL	18S/47E-4 CDD	2165	24.92	24.02	30.07	
DWANE CRUSER WELL	18S/47E-4 CCA	2183	35.31	35.47	35.83	
ONTARIO JR HIGH SCH (DEEP)	18S/47E-4 DCB	2150	7.69	6.68	7.83	
ONTARIO HIGH SCHOOL	18S/47E-4 DAD	2170	24.24	23.68	24.47	
STEVE LANEY (OLD FORESTER)	18S/47E-5 ACB	2180	33.88	35.55	34.04	
SHINGO WADA WELL	18S/47E-6 DDC	2185		33.30	32.05	
ONTARIO GOLF COURSE OG-5	18S/47E-7 BDC2	2180	18.40	18.55	18.68	
ONTARIO GOLF COURSE OG-6	18S/47E-7 BDC1	2180	18.36	18.58	18.65	9/88-C, 3/89-C
PENNINGTON SUNSET DR. WELL	18S/47E-8 ADB	2185			28.24	
ONTARIO CITY CEMETARY NE WELL	18S/47E-9 BDD	2165	19.35	17.54	19.61	
TREASURE VALLEY COLL AD BLDG	18S/47E-9 ABD	2150	9.63			
LENNIE MINNICK WELL	18S/47E-10 BDA	2150	10.65	9.78	10.60	
EASTSIDE PARK WELL	18S/47E-10 BDA	2149	12.80	9.07		
ONTARIO WATER TR PLANT #7	18S/47E-11 BAA	2146	19.62	18.34	20.31	
GUS LOPEZ WELL	18S/47E-15 ACD	2150	13.38	9.80	12.60	8/89-R
I. KAMESHIGE (JOHNSON WELL)	18S/47E-16 CCC	2177	9.89	9.97	10.33	
HENRY GUBIOLA	18S/47E-17 ACA	2190	18.08	20.47	22.32	3/89-R?
LDS WELFARE FARM	18S/47E-17 BCC1	2187	5.06		10.70	
UCHIDA BROS. IRRIGATION WELL	18S/47E-17 CBD	2183	4.83	2.63	9.15	
GAME COMMISSION WELL	18S/47E-19 CCB	2230	15.23	13.53	13.68	
ROY HASEBE WELL	18S/47E-19 ABA	2203	15.61	16.08	18.04	
OSU EXP STN	18S/47E-19 BCC	2219	9.35	5.61	6.63	
CECIL LANGDON IRRIGATION WELL	18S/47E-20 CCC	2196	10.77	9.14	10.36	
EASTERLY (MENDIOLA WELL)	18S/47E-21 CCB	2180	17.73	16.51	16.86	
EASTERLY (MENDIOLA WELL)	18S/47E-21 CAC	2178	17.97	20.29	19.03	
LOUIS WETTSTEIN IRRIGATION WELL	18S/47E-29 CDC	2192	19.25	20.22	19.44	
OSU EXP STN	18S/47E-30 BBB2	2255	35.66	37.46	36.39	
OSU EXP STN	18S/47E-30 ABC	2209	12.76	13.40		
JOHN WETTSTEIN	18S/47E-32 ACA	2175	15.44	16.22	16.13	
L. WETTSTEIN (SCHARTNER WELL)	18S/47E-32 BAB	2193	20.25			
KEN MCGOWEN UPPER WELL	19S/46E-13 CDB	2360	65.42	69.01	64.93	
KEN MCGOWEN LOWER WELL	19S/46E-13 CDC	2300	20.89	17.53		9/88-C, 3/89-R
LARRY GLEN	19S/46E-13 DDC	2260	32.94	37.00	33.29	
RON WARD	19S/46E-36 DAA	2196	7.91	8.16	8.38	
BAKKER KENTAL HOUSE WELL	19S/47E-7 BBB	2240	16.10	19.32	17.81	3/89-R
C. HART (K S & D FARMS WELL)	19S/47E-8 ACC	2182	19.29	24.05	20.17	
ALBERTSONS (MURAKAMI FARMS)	19S/47E-8 CBB	2180	9.20	8.73	8.82	
EVERETT HIATT	19S/47E-20 CCD	2178	6.83	5.90	6.76	
OWYHEE IRR. DIST.	19S/47E-32 ACB	2175	11.57	9.77	10.62	8/89-R

PLATE I

RECONNAISSANCE GEOLOGIC MAP OF THE ONTARIO AREA MALHEUR COUNTY, OREGON





EXPLANATION

Qal — **QUATERNARY ALLUVIUM** Unit typically consists of 10 to 20 feet of fluvial and eolian silt (loess) overlying 10 to 50 feet of fluvial sand and gravel. This unit generally corresponds to the present-day flood plains of the Snake and Malheur Rivers and Willow Creek. The gravel portion of this unit is an important aquifer which yields moderate to large amounts of water to wells.

Qtal — **(Qtal$_1$ and Qtal$_2$): TERRACE ALLUVIUM** Silt, sand and gravel deposits of older stream terraces and alluvial fan/terrace combinations. This unit typically consists of 10 to 40 feet of fluvial and eolian silt (loess) overlying 10 to 50 feet of fluvial sand and gravel. At least two terrace levels above the present-day flood plain are discernible. These are identified by subscript numbers. The lowest of these terraces (Qtal$_1$) is relatively undissected by erosion. Changes in the elevation or thickness of the gravel corresponds to terrace margins at many locations suggesting that development of younger terraces includes a period of erosion followed by a period of deposition. Gravel deposits underlying the lowest terrace (Qtal$_1$) generally yield moderate to large amounts of water to wells. Conditions in the upper terrace (Qtal$_2$) are less predictable.

QTg — **UPLAND GRAVELS AND OVERLYING SILTS** Deposits of gravel a few feet to 40 feet thick overlying Tig on uplands, generally thinning toward the west. Gravel is composed of well rounded to subrounded pebble to boulder size clasts of mixed composition in a coarse sand matrix. The gravel is composed of mixed volcanic and silicic intrusive clasts in the Ontario Heights area north of Ontario but appears to contain predominantly basaltic volcanic material southwest of Ontario on Big Sage Flat. The gravel is overlain by fluvial and eolian silt (loess) a few feet to 30 feet thick over most of the area. In the Ontario Heights area this unit appears to be cut by several E-W to ESE trending faults. This unit corresponds in part to Qtg "terrace gravels" of Corcoran and others (1962), Qtg "terrace and fan deposits" of Brooks and others (1976), and may be correlative in part with Qtm "Tenmile Gravel" mapped in adjacent Idaho by Mitchell and Bennett (1979a, 1979b). The upland gravel is generally not saturated except in parts of Ontario Heights. Where saturated, this unit appears to yield amounts of water sufficient for domestic and stock use.

Tobc — **BASALTIC ERUPTIVE CENTER** Remnant of a small basaltic eruptive center which forms Malheur Butte. This material appears to have intruded sediments of unit Tig.

Tig — **GLENNS FERRY FORMATION** Primarily massive to bedded, very fine sandstone to medium siltstone with occasional interbedded coarser sand layers. This unit is very light brown to brownish gray in outcrop, but appears very dark gray in drill cuttings. This material is usually referred to as "blue clay" on water well reports. The unit is composed of varying proportions of crystal and lithic fragments and volcanic glass shards, and commonly has trace to small amounts of dark greenish to brownish flexible mica (chlorite?). Fossil fish from T17S, R47E, Sec. 31cbb, T17S, R46E, Sec. 34bcb and from T18S, R43E, Sec. 5caa (outside the mapped area) have been identified by Gerald Smith, University of Michigan (personal communication) as characteristic of the Glenns Ferry Formation (Malde and Powers, 1962; Smith and Kimmel, 1982; Smith and others, 1982; and Smith, 1975). This unit corresponds in part with Tic "Chalk Butte Formation" of Corcoran and others (1962) and with Tst "Tuffaceous Sedimentary Rocks" of Brooks and others (1976). Where present, sand layers within these sediments often yield moderate to large amounts of water to wells, particularly in the southern portions of the study area. Information does not exist to accurately predict the location and depth of productive water bearing zones within the sediments.

MAP SYMBOLS

Geologic Contact and Alluvial Terrace Margins- approximately located, dashed where poorly defined or inferred from aerial photographs and not field checked

Field Located Wells

A — A'

Cross Section Locations-Sections located in report

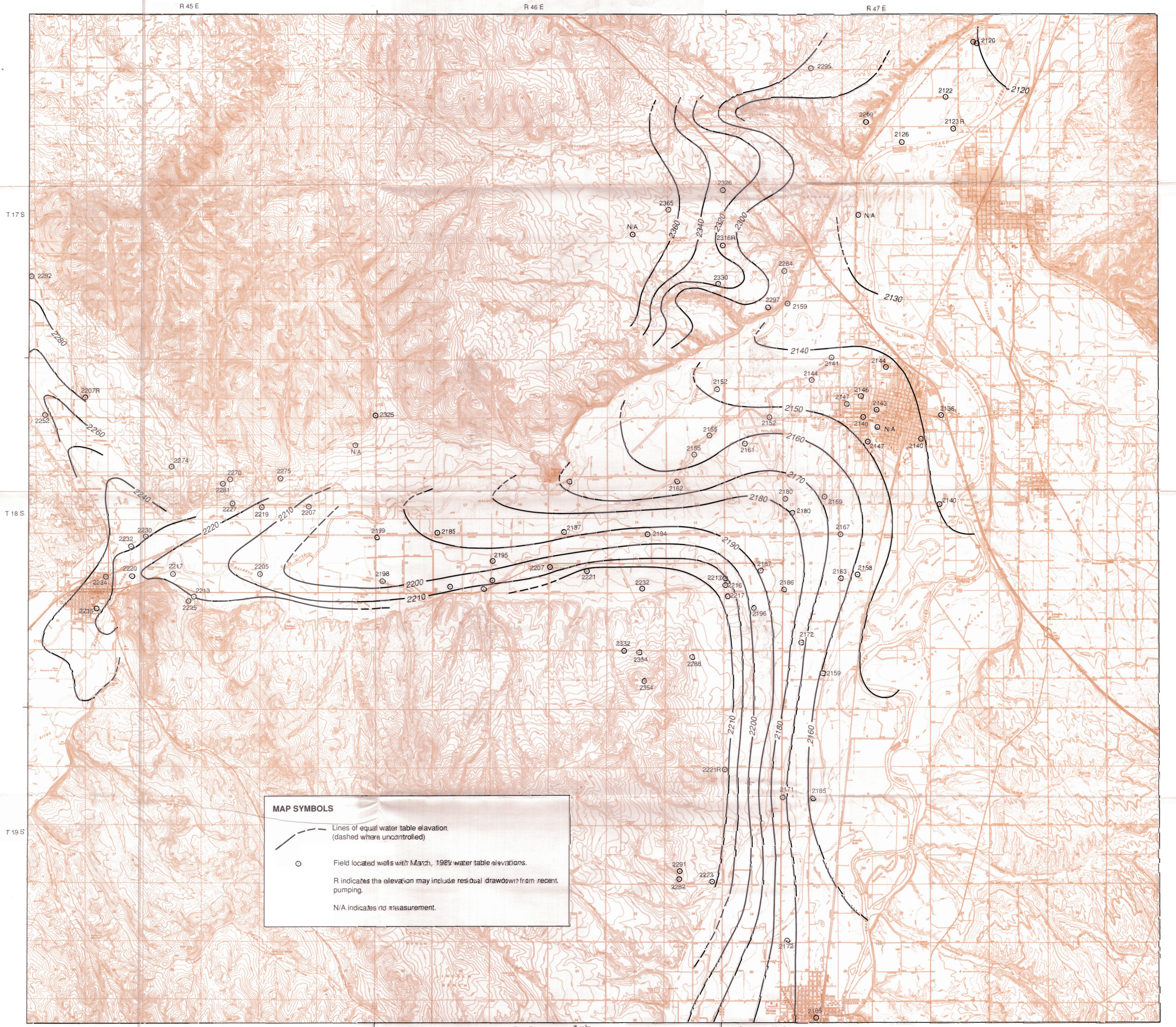
BASE MAP FROM U.S. GEOLOGICAL SURVEY QUADRANGLES:
Henry Gulch, Nyssa, Cairo, Payette, Malheur Butte, Vale East, Vale West, Willow Creek

Contour Interval 20 feet, 10 feet in N.E. corner of map.

GEOLOGY BY MARSHALL W. GANNETT, OWRD
Modified in part from Corcoran and others, 1962 and Brooks and others, 1976.

WATER LEVEL ELEVATION MAP OF THE SHALLOW ALLUVIAL AQUIFER IN THE ONTARIO AREA MALHEUR COUNTY, OREGON

PLATE 2



BASE MAP FROM U. S. GEOLOGICAL SURVEY QUADRANGLES:
Henry Gulch, Nyssa, Cairo, Payette, Malheur Butte, Vale East, Vale West, Willow Creek.

Contour Interval 20 feet, 10 feet in N.E. corner of map.

R 45 E R 46 E R 47 E

Scale 1:62,500

Kilometers

Miles

STUDY AREA

Ground Water Report No. 34

ERRATA SHEET

Figure 3: Well 18/46-15bab should read 18/46-15cdc

Figure 6: Well 18/47-4dad should read 18/47-4cad

Figure 13: The vertical axis should be labeled "Recovery (ft)"

Appendix 3: Well location 18/47-4dad (The Ontario High School well) should be 18/47-4cad.

Plate 2: The following minor errors in the water level contour lines should be noted:

the 2150 foot contour should curve just north of well 18/46-1daa, which has a 2252 foot water level elevation,

the 2170 foot contour should curve to the east of well 18/46-15bab which has a 2172 foot water level elevation,

the 2180 foot contour should curve closer to wells 18/47-17bcc and 17bcd, which have water level elevations of 2180 feet,

the 2220 foot contour should go between wells 8/45-28aab and 28acc,

the 2260 foot contour should curve just west of well 18/45-6ccd which has a water level elevation of 2252 feet.

The water level elevation of well 19/47-8acc should read 2158 not 2185.