

GEOHERMAL INVESTIGATIONS IN IDAHO

**GEOHERMAL RESOURCE ANALYSIS
IN TWIN FALLS COUNTY, IDAHO**

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**GEOHERMAL RESOURCE ANALYSIS
IN TWIN FALLS COUNTY, IDAHO**

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Geologic Map

ABSTRACT

Increased utilization of the geothermal resource in the Twin Falls - Banbury area of southern Idaho has resulted in noticeable declines in the artesian head of the system. In order to determine the nature of the declines, a network of wells was identified for monitoring shut-in pressures and temperatures. In addition, a compilation of data and reconnaissance of the areal geology was undertaken in order to better understand the geologic framework and its relationship to the occurrence of the thermal waters in the system.

The geothermal resource of the Twin Falls - Banbury system is characterized by temperatures between 30° and 70°C (86° to 158°F) and shut-in well pressures of 14 to 250 psi. The thermal water occurs in rhyolitic ash-flow tuffs and lava flows of the Tertiary Idavada Volcanic Group. Permeability of the reservoir rocks results from tectonic and cooling fractures, intergranular porosity of the non-welded tuffs and voids left between successive flows. The system is recharged by rain and snow falling on the Cassia Mountains to the south. Northward dipping volcanic strata channel the water toward the center of the Snake River Plain and into northwest trending structure zones which cross the area from Hollister to Banbury Hot Springs. The heat source is thought to be the regionally high heat flow supplemented in parts of the system by deep circulation in structure zones.

The results of the monitoring indicate that while water temperatures have remained constant, the system shows a gradual overall decline in artesian pressure superimposed on fluctuations caused by seasonal use of the system. Well testing and the similarity of hydrographs resulting from well monitoring throughout the area suggest that there are no major hydrologic barriers to thermal water movement in the system and that wells are affected by increases and decreases in utilization of nearby wells.

DISCLAIMER

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INTRODUCTION

The low to moderate geothermal resource base of the Snake River Plain, Idaho is extensive. Estimates of mean reservoir energy of over 455×10^{18} J have been made by Mabey (1983) and energy offset of over 26 MW thermal were made by Bloomquist and others (1985). The hydrothermal resources range in temperature from 30 to 70° C (86 to 158°F) and well depths range between 80 and 3000 feet. Most flowing wells have high yields (2000 gpm) and shut-in pressures (250 psi). The focus of this report is the geothermal resources of southern Idaho's Twin Falls County, Figure 1.

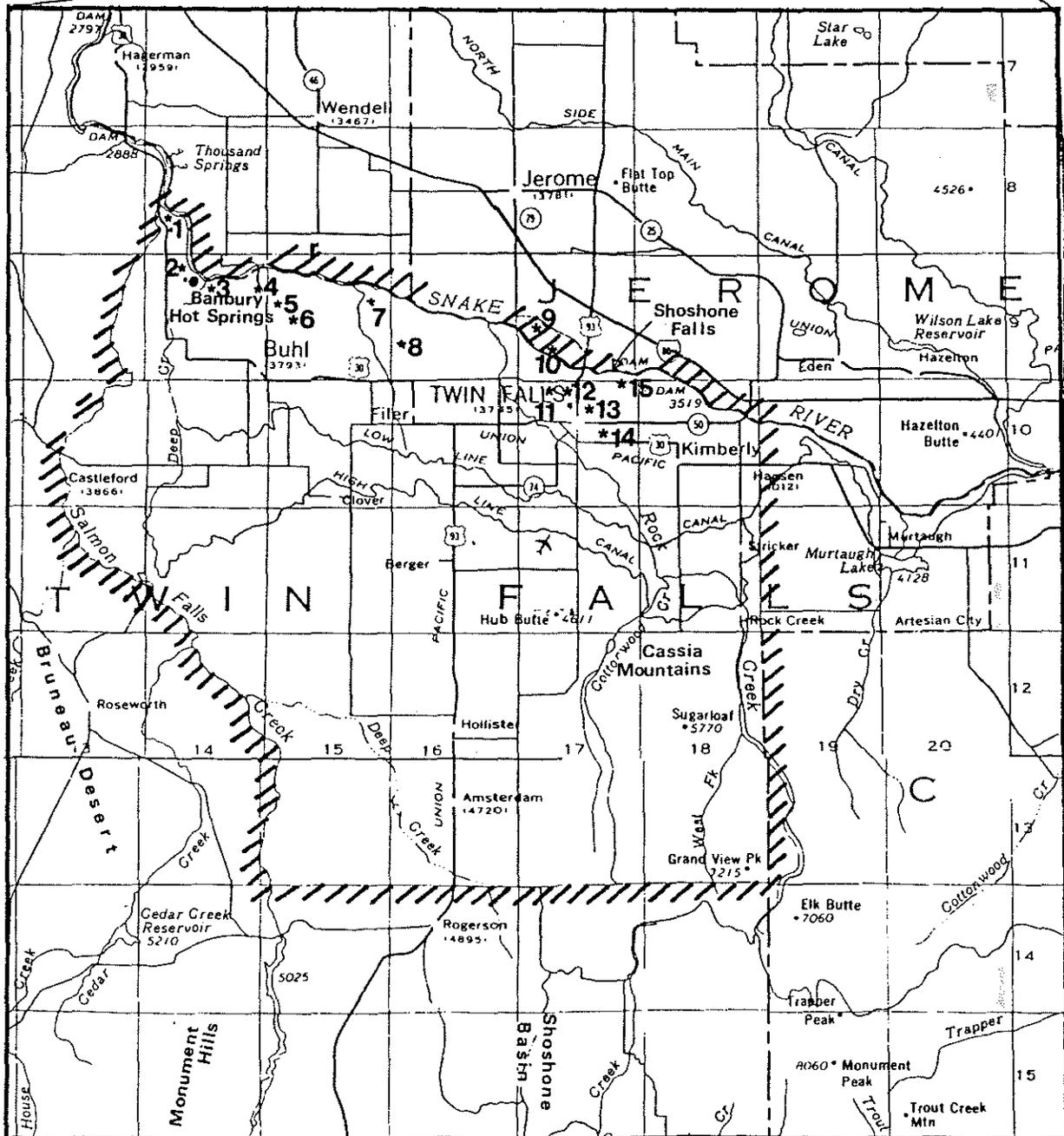
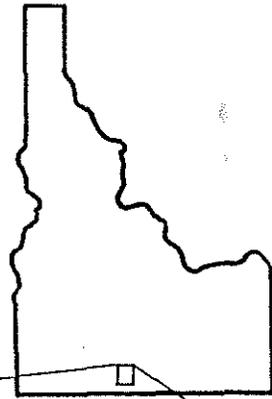
Artifacts found in the vicinity of Banbury and other hot springs in Twin Falls County are evidence that thermal waters were known and used by Indians and early settlers. In 1938, a 1154 foot well was drilled by the City of Twin Falls (T10S, R17E, Sec 14 SESWSW) that encountered the geothermal resource. The well continues to be used for irrigation. Further development did not ensue until the early 1970's when concern for energy was heightened. Drilling continued until the early 1980's when projects for low-head hydro-power production, space heating, irrigation and aquaculture were developed. The increased demands on the resource have resulted in noticeable declines in pressure in existing artesian wells. These declines have caused concern among the resource owners, and in some cases have led to litigation.

In the study area, there are more than seventy-five thermal wells. For the convenience of discussion and ease of reference, the wells have been assigned an arbitrary number. The locations of selected wells referred to in this study are shown on Figure 1 and driller's logs for these wells and others are found in Appendix A.

FIGURE 1.

Index Map - Showing Study Area (Inside Hachures),
Surrounding Region and Selected Wells

10 Miles



Purpose and Approach

This study was initiated to provide baseline resource data for the thermal system in Twin Falls County and to develop a model that would describe the relationship between the geothermal resource and the regional geologic framework. Methods selected to complete the objectives were: 1) compile data for existing wells; 2) analyze well logs for thermal water levels and subsurface geology; 3) compile and interpret geologic mapping in relation to regional stratigraphy and structural controls of the system and possible recharge areas; 4) establish a monitoring network using existing thermal wells to record pressure and temperature measurements on a regular basis; and 5) collect samples of the suspected rhyolite reservoir rock for geochemical analysis and comparison.

Previous Work

Geologic Studies

Geologic mapping within the study area has been limited to reconnaissance studies. For the southern part of Twin Falls County, virtually no published geologic maps exist at a scale of less than 1:250,000. Also, the nature and stratigraphy of the Idavada rhyolites exposed throughout the area are largely unknown.

The early geologic work in the Snake River Plain included reconnaissance level studies of geology by King (1878), Lindgren (1898), Russell (1902), Schrader (1912), and Buwalda (1924). Stearns and others (1938) published a report on eastern Snake River Plain geology and groundwater resources that included descriptions of the basalts of the lava plains and the Tertiary volcanic rocks at Shoshone Falls. Stearns, in a later publication (1955), described the mud flow associated with the Shoshone Falls volcanic rocks. Youngquist and Haegele (1956) published a

report and very general geologic map of the Cassia Mountains. Malde and Powers (1962) studied and defined the stratigraphic framework for the western Snake River Plain and developed much of the stratigraphic terminology and nomenclature currently in use. As part of their reconnaissance of the western Snake River Plain, Malde and others (1963) included much of the western portion of the study area on a geologic map at a scale of 1:125,000. Malde and Powers (1972) published a more detailed geologic map of a part of the previously mapped area, which included the Banbury Hot Springs area, at a scale of 1:48,000. Covington (1976), published a 1:24,000 scale geologic map which focused on geologic hazards along the Snake River Canyon in the Twin Falls area. Stratigraphic relations of Paleozoic and Mesozoic marine sedimentary rocks in the Cassia Mountains were presented by Mytton and others (1983). A study and morphometric analysis of basalt volcanoes in the southern and western portion of the study area was conducted by Jenks in 1984.

Geothermal Studies

The geothermal resources of the Banbury and Artesian City areas were first described by Stearns, and others (1938). Young and Mitchell (1973) sampled hot springs and wells in Twin Falls County as part of a statewide reconnaissance of geologic setting and chemical characteristics of thermal waters. Lewis and Young in 1980 and 1987 (in press) investigated hydrologic conditions of thermal waters in the Banbury and Twin Falls area using geophysical studies and water chemistry. The geothermal resources in the Artesian City area were studied by Struhsacker and others (1983).

Climate

The climate of the area is characterized by hot, dry summers [$>32^{\circ}\text{C}(90^{\circ}\text{F})$] and cold winters [$<7^{\circ}\text{C}(20^{\circ}\text{F})$]. The mean annual temperature at Twin Falls is $9^{\circ}\text{C}(49^{\circ}\text{F})$ (U.S. Department of Commerce, 1973). Mean annual precipitation ranges from 9.5 inches at Twin Falls (U.S. Department of Commerce, 1973) to over 40 inches (Wilson and Carstens, 1975) in the mountainous areas to the south. The majority of the precipitation falls as rain or snow during the winter.

Physiography

The Twin Falls - Banbury Study Area is within the Snake River Plain subdivision of the Columbia Plateaus physiographic province (Fenneman, 1946). The Snake River Plain is an arcuate structural and topographic depression extending across southern Idaho from Weiser on the west to Yellowstone National Park on the east. Recent workers have further subdivided the plain as consisting of a western graben, eastern downwarp, and central transition zone (Mabey, 1982). The Twin Falls - Banbury Study Area lies within the transition zone between the eastern and western subdivisions. Topography of the plain is subdued and includes extensive lava plains and numerous constructional volcanic features including basaltic cinder cones and broad shield volcanoes. Elevations of the Snake River Plain range from 2,000 feet on the west to 5,000 feet near the eastern end.

The area in and around Twin Falls County, like much of the eastern Snake River Plain, is characterized by a gently rolling lava plain from which rise scattered shield volcanoes such as Hansen, Stricker, Hub, Sonnichsen and Flat Top Buttes (see Plate 1). These volcanic shields generally rise from 150 to 400 feet above the surrounding plain (Jenks, 1984). Many of the younger Pleistocene lavas on the north side of the Snake River Canyon

still preserve features such as pressure ridges and aa and pahoehoe lava surfaces. On the south side of the river the lavas are earlier Pleistocene and Pliocene and most original features have been removed by erosion or obscured by loess (Covington, 1976).

Within the study area the plain extends south from the Snake River approximately 15 miles to the Cassia Mountains (locally known as the South Hills or Rock Creek Hills). The Cassia Mountains are a broad domal uplift that rise from a base elevation of 4200 feet at the point where Rock Creek enters the plain to a maximum of over 8000 feet at Monument Peak. The uplift contains a core of Paleozoic marine sedimentary rocks that are unconformably mantled by a sequence of outwardly dipping Tertiary ash-flow tuffs. The dome is deeply dissected by numerous drainages.

The southwest and western portion of the Twin Falls - Banbury Study Area is a gently rolling lava plain broken by low shield volcanoes. In addition, these areas are transected by a series of low (50 to 100 foot) northwest trending fault scarps and low elongate shield-like ridges formed by basaltic fissure eruptions.

The Snake River is the primary drainage for the study area. Through the Twin Falls reach, the river has incised a nearly vertical walled canyon 500 to 600 feet deep and 1475 to 4900 feet in width. Important tributaries within the study area include Rock Creek and Salmon Falls Creek. Rock Creek is the primary drainage of the Cassia Mountains where it has carved a canyon in excess of 1450 feet deep. Numerous other less dramatic but deeply incised drainages issue from the Cassia Mountains in a radial pattern. Between the Cassia Mountains and the Snake River, Rock Creek Canyon is relatively shallow (30 to 50 feet) but steep walled. The canyon of Salmon Falls Creek, which borders the study area on the west, is deeply incised with depths in excess of 500 feet. The remaining drainage for the area

consists of a series of shallow drainageways that have developed along fault scarps and in the creases between lava flows and shield volcanoes.

GEOLOGIC FRAMEWORK

Rocks exposed in the Snake River Plain are predominantly the products of bimodal basalt-rhyolite volcanism during the past 12 million years (Leeman, 1982). These volcanics were erupted onto a region of probable low relief which was underlain by folded and faulted pre-Cenozoic sedimentary, volcanic, and plutonic rocks (Armstrong, 1978). Inception of volcanism in any one area of the plain was characterized by voluminous explosive eruptions of rhyolitic ash which resulted in extensive sheets of welded tuff. These were followed by extrusions of rhyolite lavas with some minor intercalated basalts. The final phase of volcanism for an area was the eruption of basalt lavas. Based on radiometric dating (Armstrong, 1975; Armstrong and others, 1975; Armstrong and others, 1980; Honjo and others, 1986), volcanism has progressed along the axis of the eastern plain from the Owyhee Plateau area on the southwest to Yellowstone on the northeast. Recent evidence, including measurements of flow directions in welded tuffs along the margin of the plain (DeTar and Street, unpub. data; Leeman, unpub. data) and additional radiometric dating (Honjo and others, 1986), points to the probability that this general progression was interrupted by regressions or coeval activity at more than one eruptive center.

Stratigraphy

General Statement

The oldest rocks in the study area are Paleozoic and Mesozoic marine sediments that form the core of the Cassia Mountains on the southern margin of the Snake River Plain (Rember and Bennett, 1979; Mytton and others, 1983). Tertiary rhyolitic volcanic rocks of the Idavada group mantle the pre-Cenozoic sediments in the Cassia Mountains and underlie most of the Snake River basalts. Tertiary rhyolites comprise the known basement rock within the Snake River Plain portion of the study area and are the reservoir rocks for the Twin Falls - Banbury geothermal system. The Tertiary rhyolite is overlain by 500-700 feet of Tertiary and Quaternary basalts. Lacustrine and fluvial sedimentary rocks of the Glens Ferry and Bruneau formations are interbedded with and overlie the basalts in the western portion of the study area (Malde and Powers, 1962). The following description of the major rock units focuses on rocks of the Idavada Volcanic Group because of their relationship to the Twin Falls - Banbury geothermal system. Descriptions of the other rock units are more generalized and are included to provide a more complete picture of the stratigraphic framework of the study area.

Pre-Cenozoic Rocks (MPz)

Paleozoic and Mesozoic sedimentary rocks are exposed both on the northern and southern margins of the eastern Snake River Plain and probably formed a continuous terrain across the area prior to the inception of the Miocene rhyolite volcanism (Armstrong, 1978). Within the study area, the pre-Cenozoic sediments are exposed in the core of the Cassia Mountain uplift. Based on these exposures the pre-volcanic topography was probably

a gently rolling to mountainous upland (Struhsacker and others, 1983). Numerous pre-Tertiary episodes of tectonic deformation have resulted in the sediments being folded and thrust faulted.

The units in the Cassia Mountains consist of limestone, dolomitic limestone, siltstone, quartzite, and chert. The limestones and dolomitic limestones range from light to dark gray and fine to medium grained and occur in thick massive beds several to several tens of feet thick. Chert occurs as thin interbeds, as major members of formations, and as nodules and pods up to several feet across within limestone units. Siltstones show a wide range of colors including reddish brown, yellow, and gray, and commonly occur as a series of thin laminar beds. Quartzites are buff, reddish and gray-green, fine to medium grained and massively bedded.

Tertiary Idavada Volcanic Group

The oldest volcanic rocks in the study area have been mapped as part of the Tertiary Idavada Volcanic Group (Rember and Bennett, 1979; Malde and Powers, 1962). The Idavada Group is a loosely defined aggregation of predominately rhyolitic welded ash-flow tuffs with subordinate amounts of rhyolite lava and intercalated tuffaceous lacustrine sediments (Malde and Powers, 1962). Rocks of the Idavada Group are exposed in the study area within the Snake River Canyon near the City of Twin Falls, in the Cassia Mountains 10 to 15 miles to the south, and in various stretches of Salmon Falls Creek to the west. Idavada rocks have also been mapped in areas along the northern margin of the Snake River Plain (Malde and others, 1963). While rocks of the Idavada group are clearly related genetically, they probably represent numerous as yet undifferentiated episodes of volcanism ranging in age from 12 million years to as young as 6 million years (B. Bonnicksen, personal communication).

Idavada Ash-Flow Tuffs in the Cassia Mountains (Tiv)

Unconformably overlying the Paleozoic and Mesozoic sediments in the Cassia Mountains are a sequence of welded vitric and vitric-crystal rhyolite ash-flow tuff sheets of Miocene age (J. W. Mytton and others, unpub. geologic map). The sequence consists of seven or more distinct cooling units, most of which are separated by variable amounts of poorly consolidated airfall, water-lain, and non-welded ash-flow tuff (DeTar and Street, unpublished data). Thicknesses of the welded tuffs range from 15 feet to over 200 feet. The densely welded units are distinctly zoned, consisting, in ascending order, of: (1) gray bedded surge deposits; (2) gray to black basal vitrophyre; (3) brown, reddish-brown, red and purple massive to platy thick densely welded central lithoidal zones; and (4) an upper lithoidal zone containing abundant primary flow marks and secondary flow folds. Thin gray to black vitrophyre also occurs irregularly at the tops of some units. Phenocryst assemblages and percentages are variable from unit to unit but are generally dominated by plagioclase with minor amounts of pyroxene, quartz, and opaque oxides (probably magnetite and ilmenite) (DeTar and Street, unpub. data).

A generalized stratigraphic section for the Cassia Mountains sequence is presented as Appendix B and is based on a reconnaissance level investigation of exposures along Goat Springs Creek (T13S, R17E, Sec 17) and Dry Gulch (T12S, R18E, Sec 2 & 3).

Older Rhyolite (Not Exposed)

All of the wells in the Snake River Plain portion of the study area that have been drilled deep enough to completely penetrate the Cenozoic basalts encounter Idavada rhyolite. Data for these rhyolites are generally meager, consisting primarily of well cuttings, driller's logs, and discussions with drillers. The descriptions in this report are based primarily on information

from wells. Direct correlation of these units with the welded tuff sequence of the Cassia Mountains is not possible because of the extensive basalt cover between the wells and the mountains, the possibility of intervening subsurface structures between the two areas, and the lack of detailed stratigraphic information for the subsurface units in the study area.

Cuttings from the USGS test well at Filer were examined for this study. The cuttings were sand to pebble size making it impossible to determine the large scale features of the rocks. However, it was possible to identify vitric and lithoidal phases of rhyolitic composition. Constituents include abundant glass shards and clear glassy feldspar. Glass shards are cusped and platy and commonly show bubble wall structure. Other constituents include black and brown 0.01 inch rounded obsidian fragments which are similar to the "apache tears" that commonly occur in perlitic vitrophyres of the Idavada welded tuffs in the Cassia Mountains. Fragments in some intervals, both crystals and glass, are partially to completely coated with a white chalky encrustation. Also noted in the cuttings were minor amounts (less than 1%) of pumice fragments and masses of glass shards welded together.

Lacustrine Sediments

Wells drilled in the Filer (No. 8, Figure 1) and the City of Twin Falls area (No.'s 11, 12, 13, 14 and 15) encounter a 50 to 100 foot section of white to tan tuffaceous probable lacustrine siltstone and clay-stone overlying the Idavada rhyolites. Cuttings from the USGS test well contain abundant calcareous oolites or coated grain sands similar to exposed Tertiary and Quaternary lacustrine sediments in the western Snake River Plain (Swirydczuk and others, 1979; W. Burnham, personal communication). The oolites or coated sand grains make up approximately 20 to 40 percent of the sample.

The lower part of the lacustrine section as encountered in the USGS test well is a white sugary, vitreous, highly silicified unit containing scattered 0.02 to 0.03 inch masses of opaque oxides, some of which have a halo of limonite. Because the samples were limited in quality and quantity, little else is known about this unit.

Subsurface Alteration and Mineralization

In the subsurface rhyolite and lacustrine sediments described above, evidence of alteration and mineralization was noted including the white chalky encrustation, fragments and coatings of opal and chalcedony occurring within rhyolite, and magnetite within a probable silicified sedimentary unit. The opal, chalcedony, magnetite, and silicification are the products of hydrothermal activity. However, based on the existing samples it is not possible to determine whether the occurrences are related to the present thermal system or to hydrothermal activity associated with volcanism. The white chalky encrustation may represent paleo-episodes of duricrust formation.

Shoshone Falls Rhyolite

A silicic volcanic unit of Idavada affinity is exposed in the Snake River Canyon from the Canyon Springs Golf Course (T9S, R17E, Sec 33 NW) to approximately 1/2 mile west of Twin Falls dam (T10S, R18E, Sec 4) and is identified as a single rhyolite lava flow. The rock is light to dark gray on fresh surfaces and weathers to a dark reddish brown. Fracturing occurs throughout the unit. Zones of sheeted or platy fractures are common. Sheets or plates within the zones are generally from 0.5 to 2 inches thick and the zones may be quite extensive covering

several hundreds of square feet. Columnar jointing isn't pronounced, but strong vertical fractures are abundant. The bottom of the flow is not exposed but well drilling has shown the flow to be as much as 600 feet thick.

Microscopic examination, as reported by Stearns and others, (1938), and confirmed in this study, has revealed no definitive criteria on which to distinguish this unit as a lava or tuff. Bonnicksen (1982 a & b) has found that many of the tuffs and lavas of the Idavada group are petrographically indistinguishable. Phenocrysts in the porphyritic rock are predominately plagioclase with minor amounts of pyroxene and opaque oxides. The plagioclases are milky white in hand specimen and are up to 0.2 inch in length. The pyroxenes and oxides are commonly closely associated and phenocryst aggregates of plagioclase, pyroxene and oxides, are common but widely scattered. Bonnicksen (1982b), notes that phenocryst aggregates in general tend to be more abundant in lava flow rocks than in welded tuffs, but more detailed statistical analysis will be needed to establish the greater abundance of the aggregates in this unit.

These rocks have been classified (Stearns, 1955; Stearns and others, 1938) as an andesite lava flow. Classification of this unit as a lava flow was based on the abundance of glass near the top of the unit, the abundant vesicles, and the common flow structures. However, all of these characteristics can also be found in the ash-flow tuffs of the Idavada group in areas north and south of the Snake River Plain. Further evidence suggesting that this unit is a lava flow rather than an ash-flow tuff, is the lobate morphology, irregular upper surface of the unit, the irregular distribution of vitrophyre and breccia zones within the unit, the lack of typical ash-flow tuff zonation, and the lack of the characteristic ash-flow tuff tabular aerial distribution.

While Stearns' classification of this unit as a lava flow can be supported, it is believed his classification of the rock as andesite is incorrect within the context of current classification schemes. Based on the phenocryst assemblage, which is typical of Idavada group rocks, and geochemical analyses (see Appendix C, samples SF1 and SF2) these rocks should be classified as rhyolite or silicic latite genetically related to the Idavada group.

Tertiary and Quaternary Basalts (Tb, QTb and Qb)

A sequence of Tertiary and Quaternary basalt lava flows overlies the Tertiary rhyolites. The oldest of these basalts includes the type Banbury Basalt of Stearns and others, (1938) which has yielded radiometric ages of 4.4 to 4.9 million years and possibly as old as 6.2 million years, (Armstrong, 1975, contains a good discussion of Banbury Basalt and its various ages and correlations). Near the type locality (Stearns and others, 1938), Banbury Basalt lies unconformably on Idavada rhyolitic rocks (Malde and Powers, 1962). While contact between Banbury and Idavada rocks is not exposed in the Snake River Canyon near the City of Twin Falls, Banbury Basalt is believed to overlie Idavada volcanics over much of the area to the west. However, where the Shoshone Falls rhyolite is exposed in the Snake River Canyon it is not overlain by Banbury Basalt but rather by younger basalts of Glens Ferry (Plio-Pleistocene) and Snake River (Pleistocene-Holocene) age (Covington, 1976). Therefore, the Shoshone Falls rhyolite marks the eastern limit of Tertiary basalt flows in this area. Banbury Basalt is also exposed in the uplands of the Snake River Plain in the southwest part of the study area and within the Salmon Falls Creek Canyon (Malde and others, 1963).

Banbury Basalt within the study area consists of a series of thin olivine basalt flows which are locally interbedded with minor stream and lake sediments (Malde and Powers, 1972). The basalts are gray to dark gray to gray-green, both dense and vesicular, fine to coarse grained and diktytaxitic (Malde and others, 1963). These older basalts generally are altered. Phenocrysts include amber to brown olivine crystals and clusters of plagioclase 0.01 inch in diameter and laths of plagioclase averaging 0.08 inch in length.

A series of similar appearing, but younger and unaltered basalts, overlie Banbury Basalt in the City of Twin Falls area. These basalts include units assigned to the Glens Ferry Formation (Malde and others, 1962 and 1963) in the western part of the study area and the younger Snake River Group (Malde and others, 1962; Covington, 1976) of lava flows which were erupted from vents north, south and northeast of Twin Falls. These basalts represent the surface units at the City of Twin Falls and are well exposed along the canyon wall of the Snake River and Rock Creek.

Geochemistry of Idavada Rhyolites

In order to establish baseline geochemistry for the known and related geothermal reservoir rocks of the area, nineteen samples of ash-flow tuff, airfall tuff and rhyolite lava were analyzed for major element compositions. Of these, nine samples were analyzed for the following trace elements: Sr, Ba, Co, Cu, Pb, Zn, Sb, Li, Be, Fr, La, Ce, and F. The variable compositions of the rocks fall within a range comparable to other rhyolitic rocks of the Idavada Volcanic Group (Bonnichsen, 1982a and b; Bonnichsen and Citron, 1982; Ekren and others, 1982; Leeman, 1982). A discussion of analytical techniques and the results of the analyses are presented in Appendix C.

Tectonics and Structure

Mabey (1982) states that "...the Snake River Plain remains one of the least understood geologic structures in the United States. It has been described as a depression, downwarp, graben, rift, and lateral rift." The plain is clearly related to, and the partial result of the propagation of, bimodal basalt-rhyolite volcanism from southwest to northeast across southern Idaho. Mabey (1982) divides the plain into three subdivisions; an eastern, western, and central segment. The western Snake River Plain graben is clearly expressed topographically and is distinctly bounded by normal faults along its southwest and northeast margins. The eastern Snake River Plain, Mabey concludes, is "likely a downwarp containing a complex of calderas." Ekren and others (1984) considered the eastern Snake River Plain to be part of a tectonic-structural trend extending from the Idaho-Oregon-Nevada border area to Yellowstone National Park and possibly beyond. Within the central segment, graben bounding structures of the western Snake River Plain, but not the pronounced topographic expression, are superimposed on the eastern Snake River Plain trend. The Twin Falls - Banbury Study Area is located within this central segment.

Not only is the gross structure of the Snake River Plain poorly understood, but the local structures within the plain are similarly enigmatic. Basement and subsurface structures are probably complex because of the complex geologic and volcanic history of the area. However, these structures are difficult to completely delineate because they are covered by Cenozoic basalts.

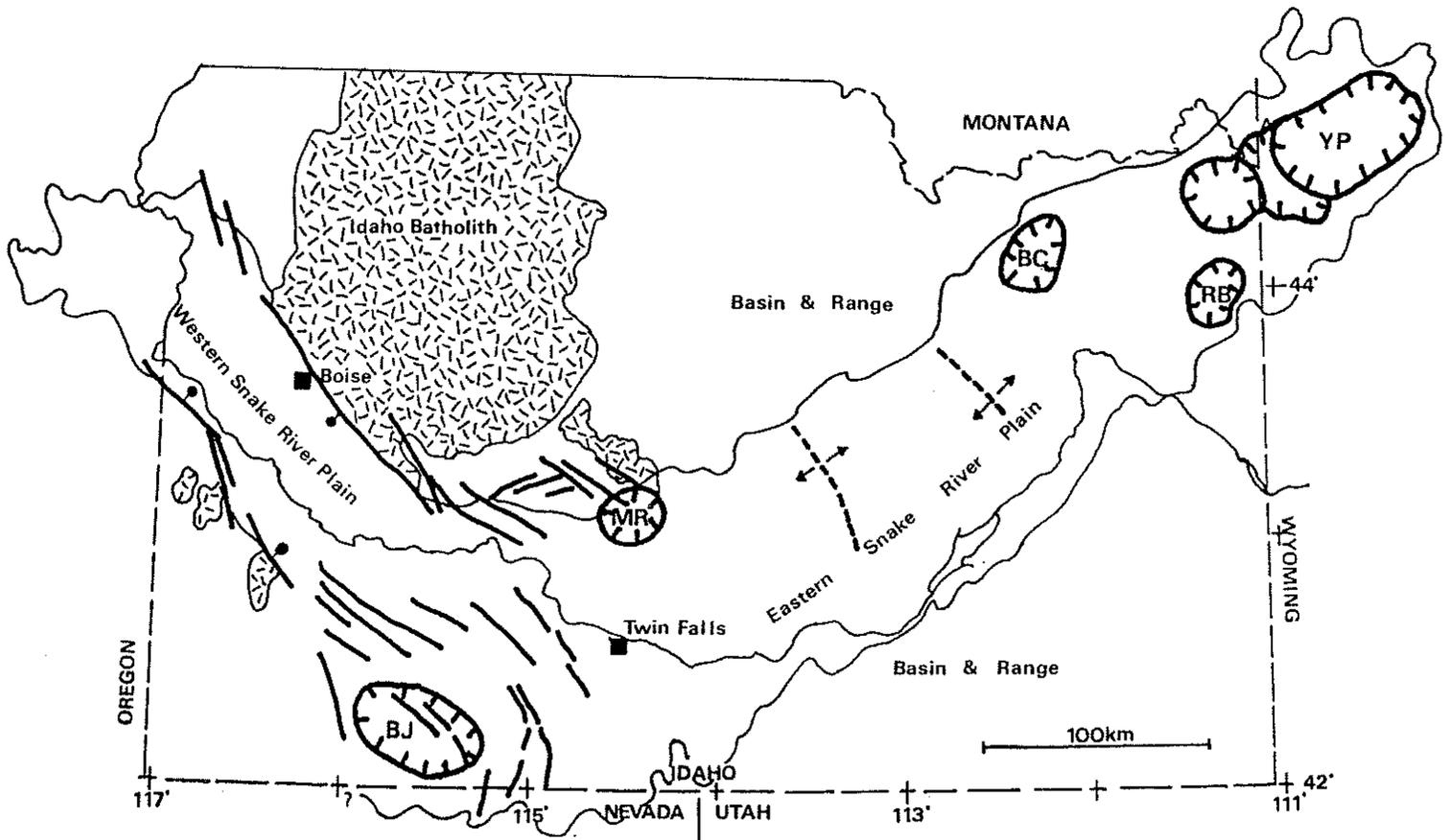
Structural features characteristic of both the eastern and western Snake River Plain occur within the study area. Idavada volcanic strata along the southern margin of the plain, within the study area, dip into the plain and disappear beneath basalt

without any clear evidence of down-faulting. A review of the depth at which the top of Idavada rocks is encountered in wells south of the City of Twin Falls demonstrates that this trend continues beneath the basalt cover (Street and DeTar, unpub. data). This is consistent with interpretation of the eastern Snake River Plain as a downwarp.

Western Snake River Plain structures are represented within the southwest part of the study area by a series of northwest trending small displacement (<100 ft.) normal faults and small scale grabens that fan out from the Salmon Falls Creek area across the Bruneau Desert to merge with the fault zone on the southwest margin of the western plain at the base of the Owyhee Mountains (see Figure 2 and Plate 1). These northwest-trending fault zones are characteristic of the structural style within the western part of the study area. The northwest trending faults of the Bruneau Desert and Salmon Falls Creek area form a broad zone of normal faulting which appears to be related to Basin and Range extension. This zone crosses the southwest portion of the study area from Hollister to Buhl and is sub-parallel to rift zones normal to the eastern plain. The rift zones are also thought to be related to Basin and Range extension, (Kuntz, 1977).

The northeastern most trend of the Bruneau Desert - Salmon Falls Creek zone is here informally designated the Buhl-Berger Structure Zone (BBSZ). This N 35° W trending structure zone traverses the area from southeast of Buhl to southeast of Hollister, and is delineated based on the occurrence and trend of fault scarps and associated basaltic eruption fissures, and aligned vents (see Plate 1).

The principal fault scarps within the BBSZ are recognized in the field and on topographic maps as somewhat rounded northwest trending linear ridges which are steepest on the northeast side and slope gradually away to the west indicating a northeast side down sense of movement. There are two primary scarps within the



Compiled from Ekren and Others (1982), Protska and Embree (1978) and Leeman (1982).



Known or Inferred Calderas or Eruptive Centers

Caldera Designations

YP - Yellowstone Complex

RB - Rexburg Complex

MR - Magic Reservoir Caldera

BJ - Bruneau-Jarbidge Eruptive Center

BC - Blue Creek Caldera



Selected Faults - Ball on downthrown side



Granitic Rocks of the Owyhee Mountains and Idaho Batholith



Rift Zone

Figure 2
Tectonics and Structure

zone, one, 50 to 75 feet high, extending from the southeast corner of Buhl to about Berger (Plate 1) and the second, 150 to 175 feet high, from Clover to just north of Hollister (Malde and others, 1963).

Basaltic fissure eruptions are associated with both of the fault scarp segments, evidence that the BBSZ is probably a deep seated structure. Southeast of Hollister, three aligned basaltic shield volcanoes lie on trend with the BBSZ and appear to represent an extension of the zone. The zone cannot be traced with any certainty into the Cassia Mountains. A graben which forms the Shoshone Basin (Figure 1) is a possible southeast extension of the zone, but this interpretation is complicated by a possible east-northeast trending structural zone that has been identified trending across the northern margin of the Monument Hills and into a zone of concentrated and possibly faulted basaltic vents including Salmon Falls Butte (Figure 1), (Covington, U.S. Geological Survey, unpublished mapping; Bonnicksen & Jenks, Idaho Geological Survey, personal communications). This east-northeast trending zone may offset structures in the Cassia Mountains and Monument Hills (Figure 1) from those in the plain and it appears to at least mark a change in structural style and trend.

On the northwest the BBSZ can be traced to a zone of northwest trending faults mapped by Malde and others, (1963) through the Banbury Hot Springs - Melon Valley area. The BBSZ and the extension mapped by Malde and others, (1963) coincide with a major bend in the Snake River and the sense of movement (down to the northeast) is appropriate for fault control of this deflection of the river.

In some areas of the Snake River Plain alignment of basaltic cinder cones and/or shields can be used to delineate structures such as the BBSZ. Probably most basalt volcanoes in the Snake

River Plain are related to deep seated fractures. However, basaltic vents in the area northeast of the BBSZ area show no clear pattern of alignment.

The stratigraphy of the study area is summarized in Figure 3. Structurally, the area is complex with a dominant northwest-trend. The stratigraphy and structures both play important roles in understanding the nature and occurrence of the geothermal resource. The following hydrogeology sections discuss the relationship between the geothermal resource and the geologic framework.

HYDROLOGY OF THERMAL SYSTEMS

Aquifer Characteristics

The geothermal aquifer of the Twin Falls - Banbury area is a confined artesian system with shut-in pressures ranging from 14 to 250 psi depending upon the elevation of the well. Based upon the drillers' logs, well cuttings and chemistry of thermal water, it is apparent that the system is contained in the Idavada volcanics with the upper units acting as the confining layer. Permeability of the volcanic rocks is the result of structural fractures related to tectonic movements, sheeted cooling joints and fractures developed during emplacement, intergranular porosity of the non-welded ash flows and air fall tuffs, and voids left between successive flows.

Where Idavada pyroclastic rocks are exposed, they are composed of a heterogeneous assemblage of rocks. In heterogeneous rocks, it is difficult to accurately calculate transmissivity and storativity values without long-term flow tests. The following section describes the data obtained from the only long-term flow test on the aquifer near Twin Falls.

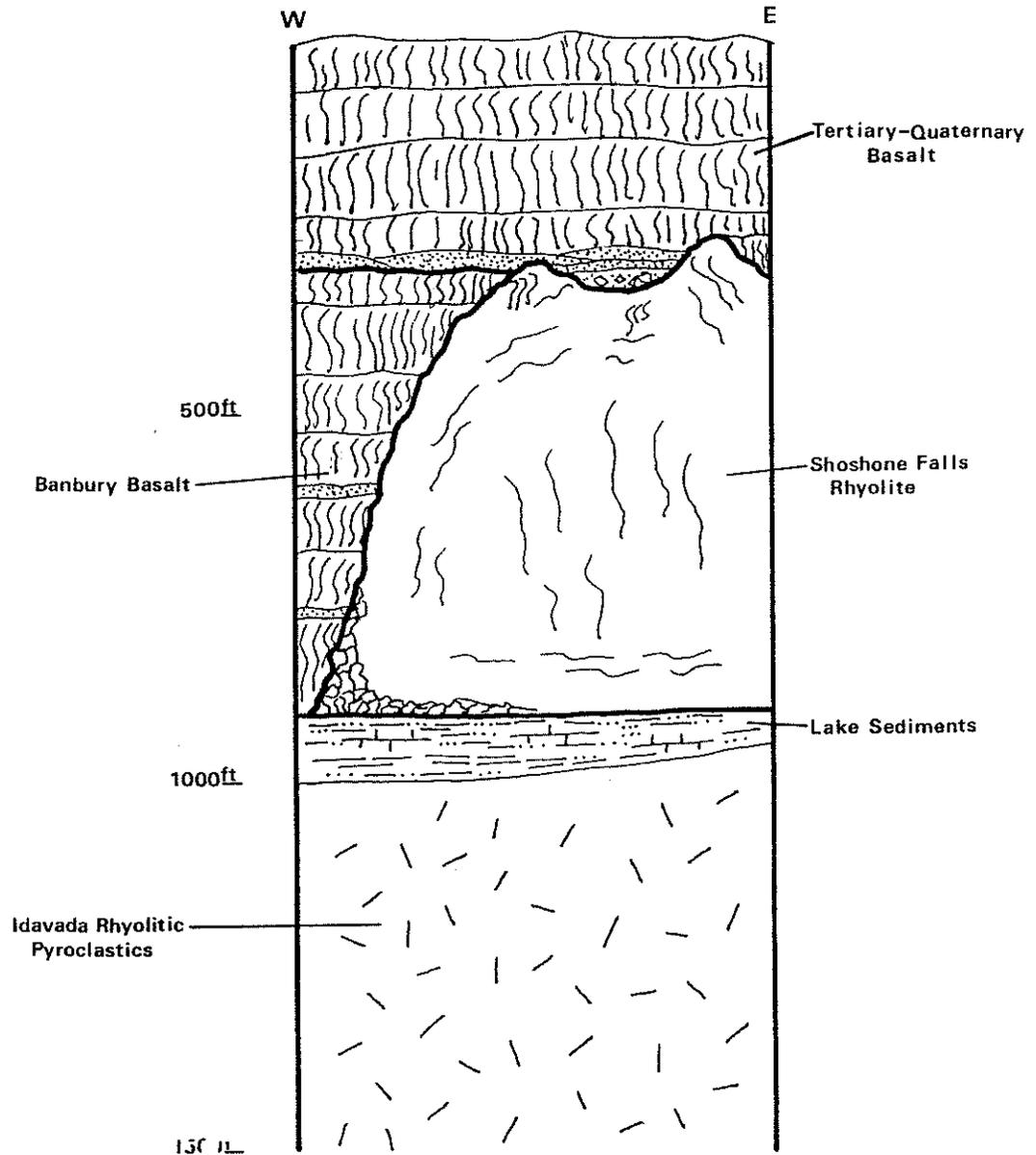


Figure 3

Generalized Stratigraphy of the Study Area

Aquifer Testing

A 1000 hour (41.7 days) aquifer test was conducted by CH₂M Hill (unpub. report, 1982) for the developer of the well in T9S, R17E, Sec 33 NWNWNW (Well No. 10) from July 22 to September 2, 1982. During the test, the well-head pressure was maintained at 150 psi which was the pressure that was to be used for production. Periodic measurements of the flow indicated that it remained relatively constant at 2,920 GPM throughout the test.

During the test, shut-in pressures were recorded on the wells in T10S, R17E, Sec 4 (Wells No.'s 11 and 12). At the end of the test, pressures were recorded in the two monitoring wells and the test well for 46 days to determine the rate of recovery. Nearly complete recovery to original static heads was noted in all three wells.

Based on this test, the transmissivity (permeability) and storativity (volume of water taken into or released from storage) were calculated for both recovery and drawdown and are as follows:

<u>Well</u>	<u>Data Type</u>	<u>Transmissivity</u> <u>(GPD/FT)</u>	<u>Storativity</u>
9S 17E 33 #10	Recovery	74,300	-
10S 17E 4 #12	Recovery	46,400	-
	Drawdown	45,200	5.8 x 10 ⁻⁴
10S 17E 4 #11	Recovery	58,600	-
	Drawdown	44,600	6.2 x 10 ⁻⁴

From this test and subsequent time drawdown analyses, CH₂M Hill concluded that no hydrologic boundaries exist between the wells and that the development of the well would affect the water levels in nearby thermal wells.

Water Chemistry

Detailed analyses of thermal water chemistry were not conducted during this study. Previous analyses have shown that the thermal water in the study area is low in Ca, Mg and high in Si, HCO_3 and F in comparison to other geothermal waters in the state with different aquifer rock types (Young and Mitchell, 1973).

It has been determined that the Idavada ash flow tuffs are high in SiO_2 , F and low in Ca and Mg (Appendix C). It is apparent from this that the chemistry of the thermal water reflects the geochemistry of the flowpath and Idavada host rock.

Monitoring of Thermal Wells

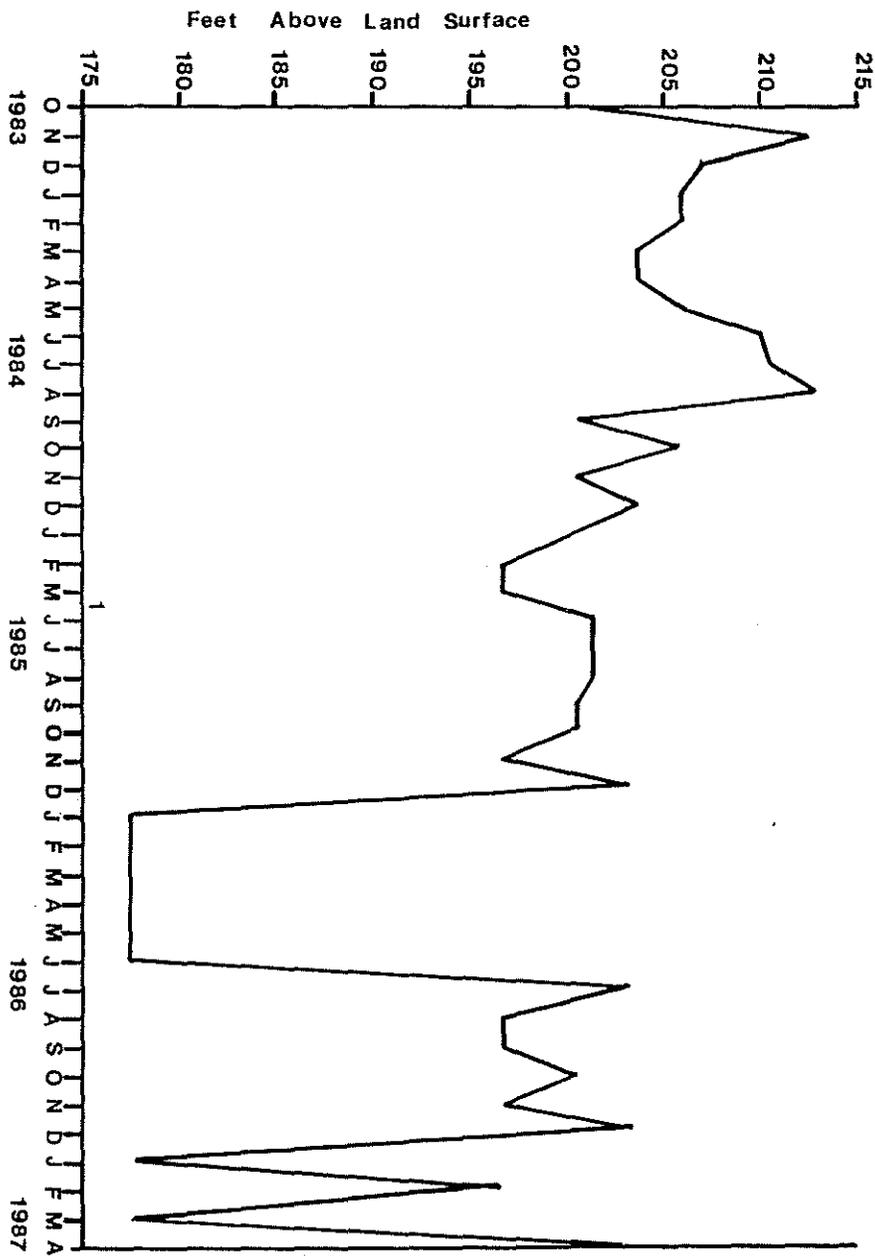
A monitoring network of five wells in the Banbury Hot Springs area was established in the fall of 1983. A similar network of four wells was established for the Twin Falls area in the spring of 1984. A standard method was employed to determine pressure and temperature measurements. The procedure included completely shutting in each well for ten minutes and at the end of this time recording pressure and temperatures. Record was also kept of other information, such as how many valves were opened or comments made by the owner regarding well performance.

The locations of the monitoring wells and other wells discussed in this section are shown in Figure 1. Frequency of measurements and pertinent well information for both the monitored wells and other wells discussed in the text are found in Table 1. The results of the monitoring effort are illustrated by hydrographs (Figures 4 through 12). Temperatures remained constant during the monitoring.

TABLE 1. WELL INFORMATION AND FREQUENCY OF MEASUREMENTS

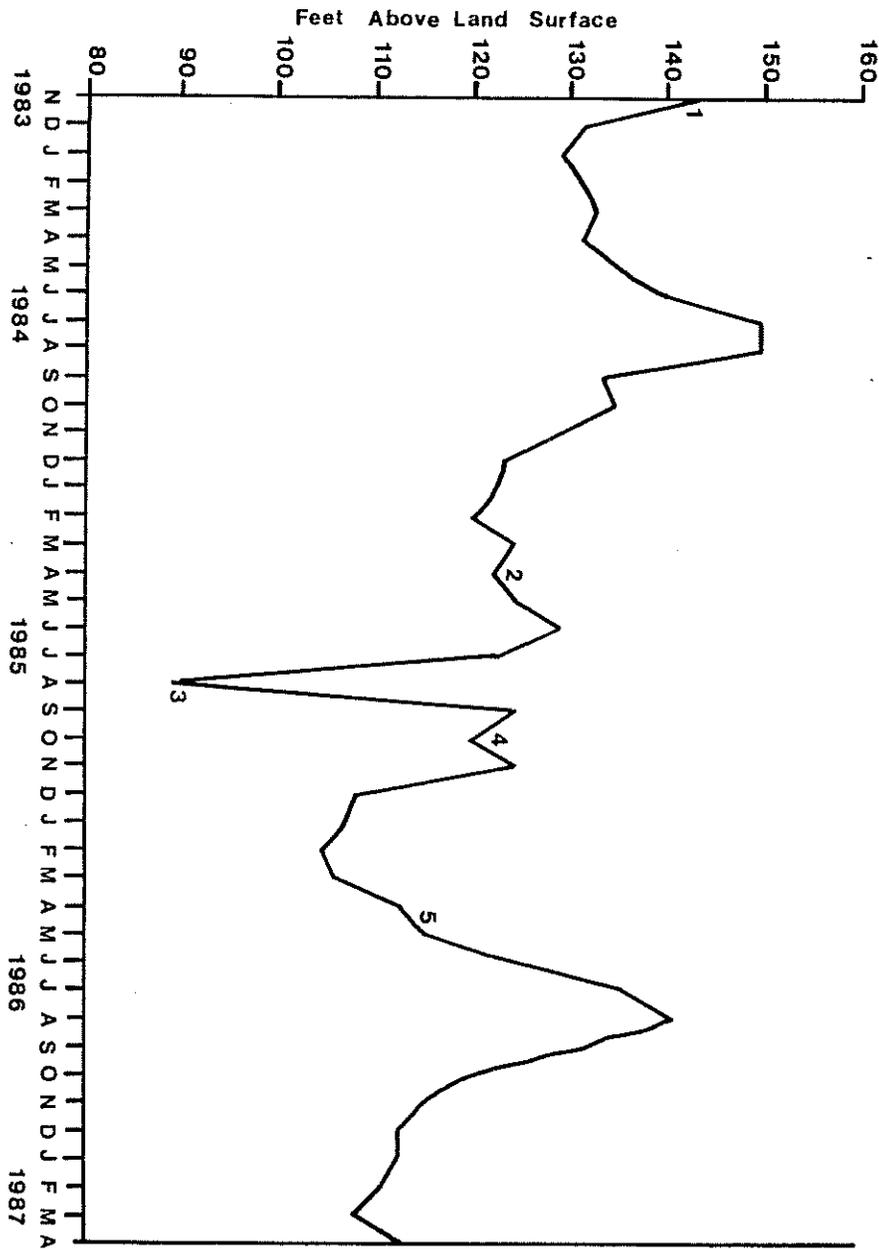
WELL NO.	LOCATION	ELEVA- TION	FLUID	DEPTH	*FRE- QUENCY	PRESENT USE
			TEMP. °C/°F			
1	8S 14E 30 NESWSE	2897	68°/154°	760'	M	Heating
2	8S 14E 33 SWNWSE	2907	47°/117°	800'	M	Greenhouse Heating
3	9S 14E 04 NWNWNW	2959	41°/106°	700'	M	Space Heating
4	9S 14E 09 NESESW	2996	32°/90°	850'	M	Tropical Fish
5	9S 14E 14 NWSENW	3146	34°/93°	906'	M	Irrigation
6	9S 14E 14 NENESW	3200		1300'		Catfish Propagation
7	9S 15E 12 SWSWNE	3064	42°/108°	1420'	M	Irrigation
8	9S 16E 20 NESESE	3530		1247'		USGS-Observation Well
9	9S 17E 29 NWSWSE	3154		743'		Cat Fish Propagation
10	9S 17E 33 NWNWNW	3174		750'		Low-Head Power Gen.
11	10S 17E 04 SWNWNE	3662	37°/99°	1453'	W	Campus Space Heating
12	10S 17E 04 SWSENE	3668	37°/99°	1191'	W	Campus Space Heating
13	10S 17E 10 NWSENW	3717	37°/99°	1700'	W	Space Heating
14	10S 17E 14 SWSESE	3786		1154'		Irrigation
15	10S 18E 06 NWNWNW	3585		1300'		Domestic Space Heating

* Frequency of Measurements (M=monthly, W=weekly)



1. No reading possible for April and May

Figure 4
 Well #1 Hydrograph
 T8S, R14E, Sec. 30, NESWSE

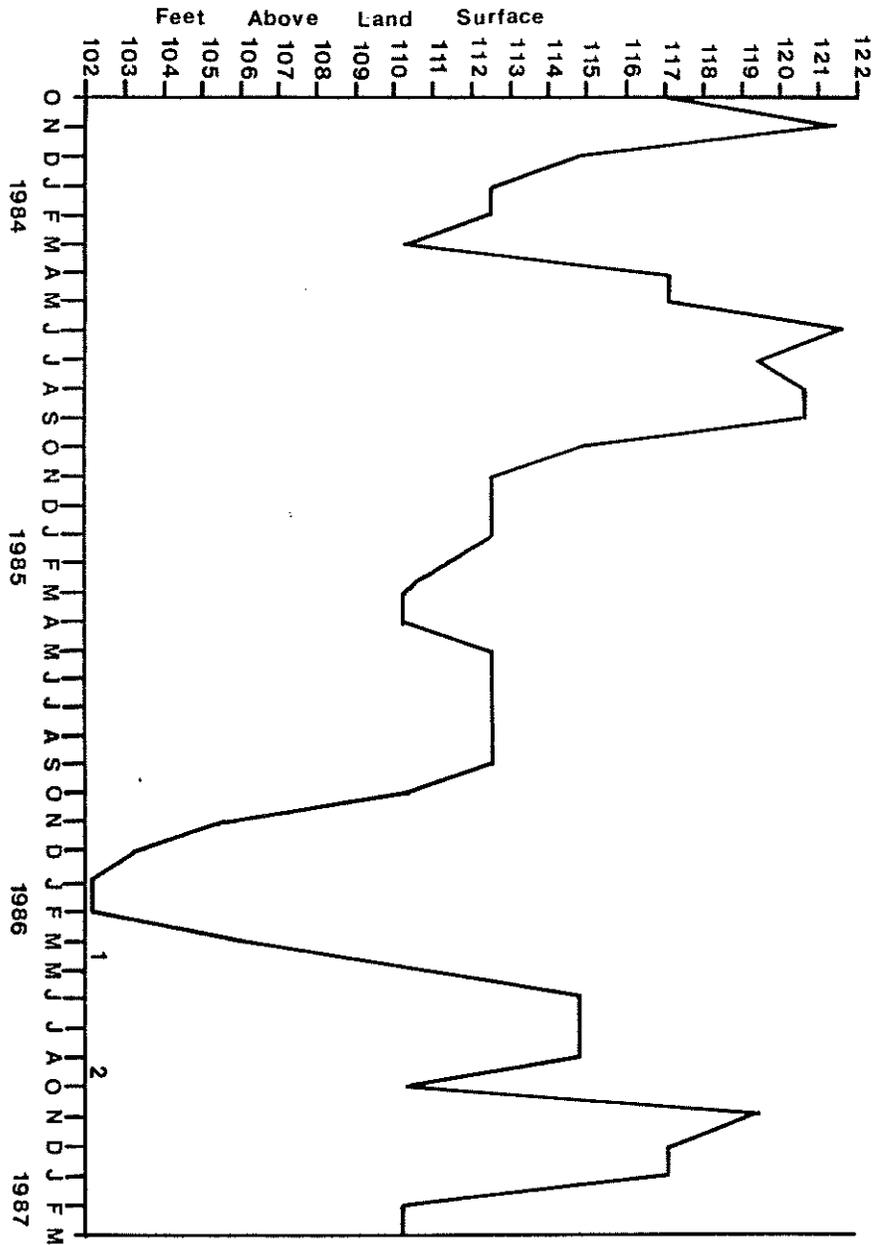


1. Well not in use
2. Greenhouses on line
3. New well being drilled
4. Developing system - adding greenhouses
5. Used for domestic from April through July

Figure 5

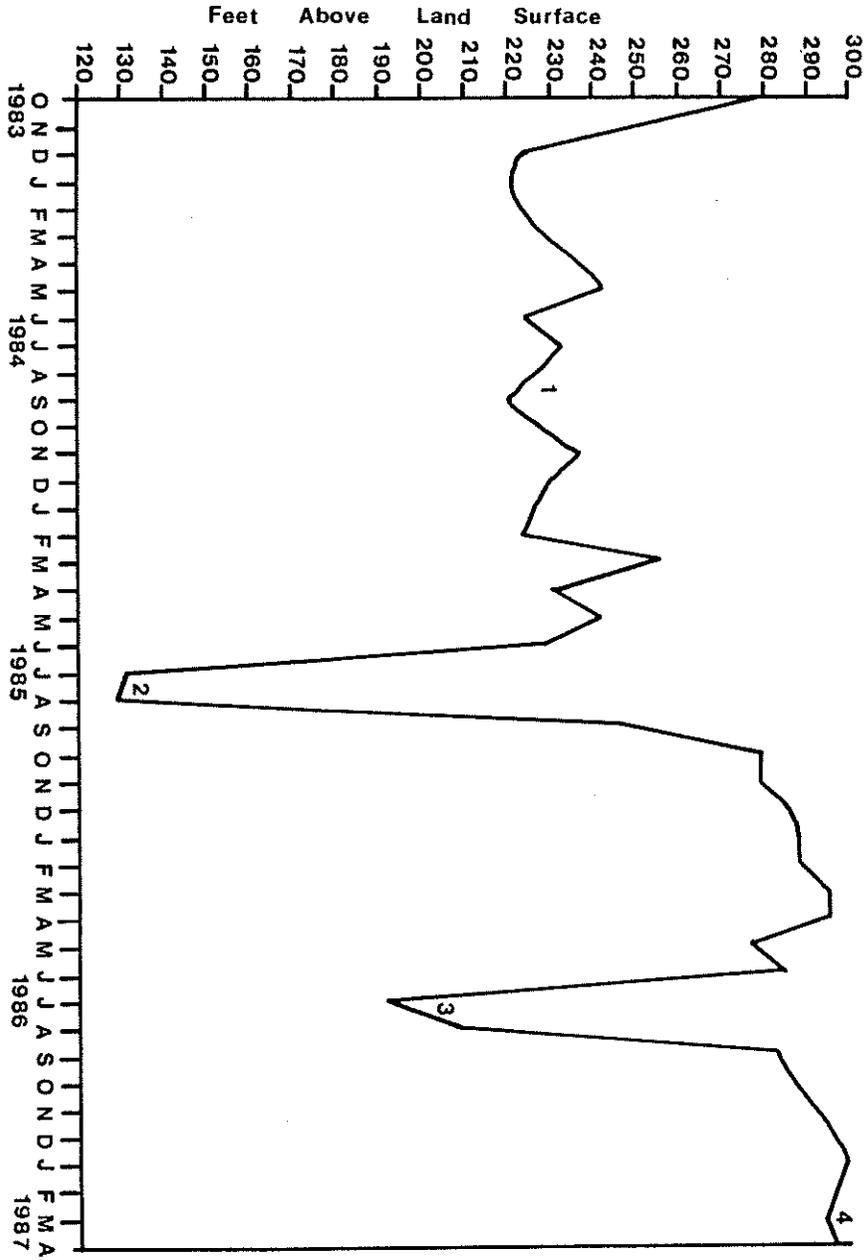
Well #2 Hydrograph

T8S, R14E, Sec. 33, SWNWSE



1. No reading for April, 1986
2. No reading for September, 1986

Figure 7
 Well #4 Hydrograph
 T9S, R15E, Sec. 12, SWSWNE

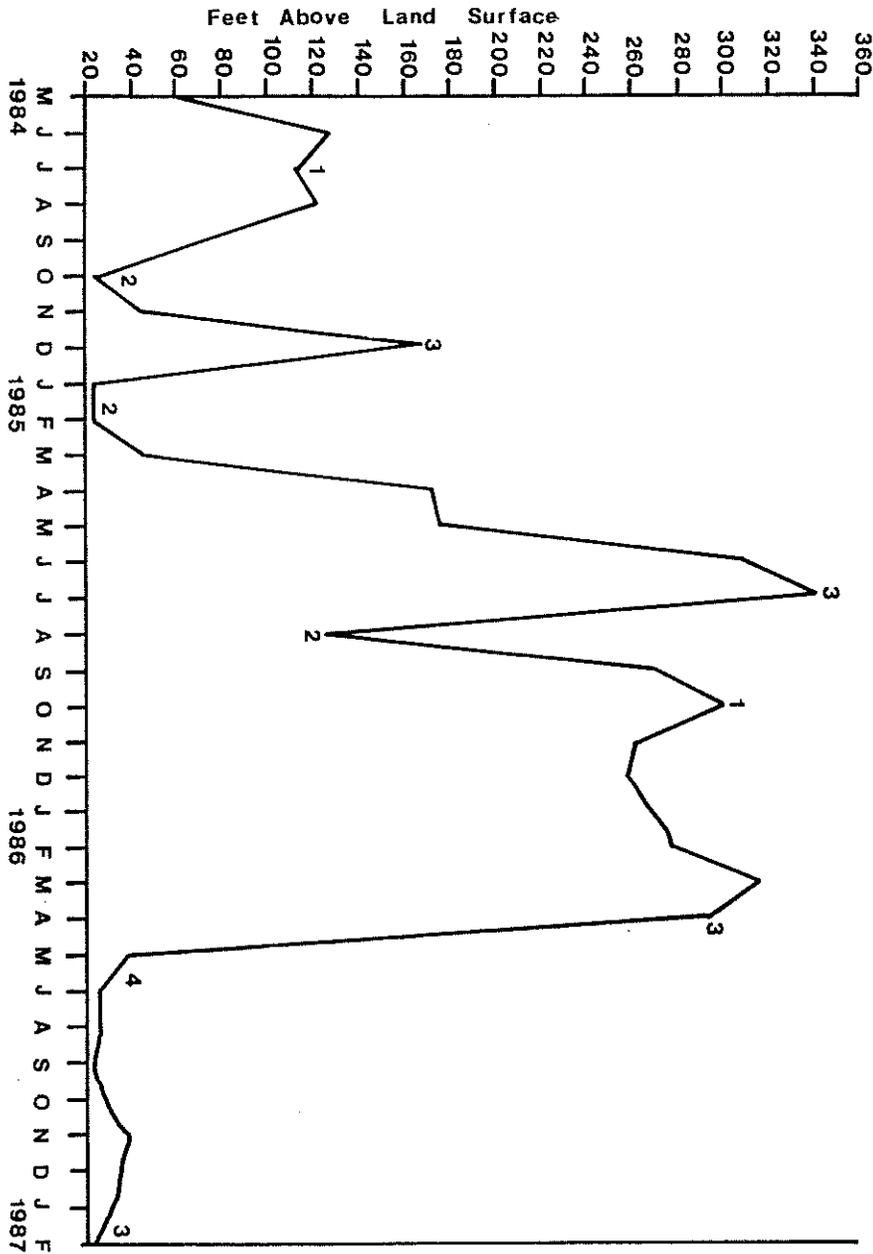


1. Irrigation
2. Irrigation
3. Irrigation
4. Wells in adjacent area
are open

Figure 8

Well #5 Hydrograph

T9S, R14E, Sec. 14, NWSNW

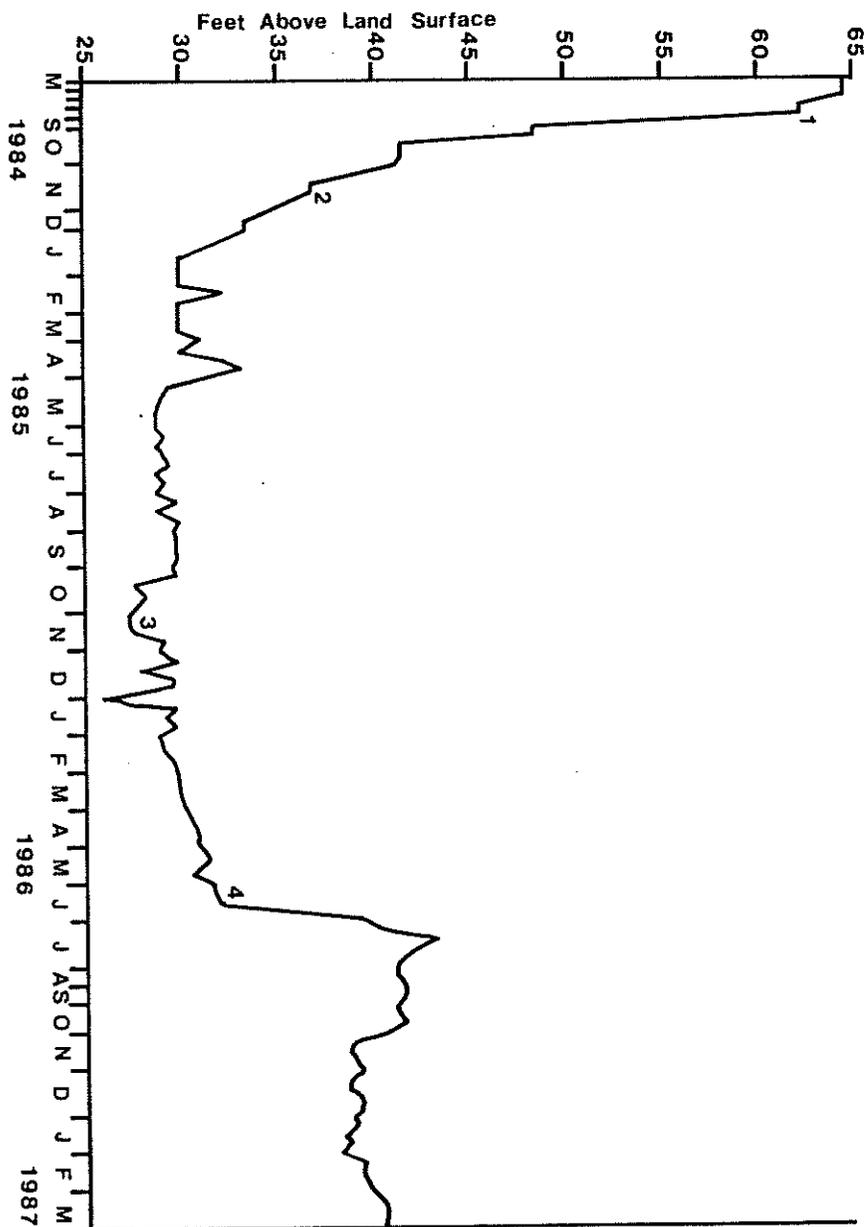


1. Small amount flowing
2. Completely open
3. Shut-in
4. Well cleaned out

Figure 9

Well #7 Hydrograph

T9S, R15E, Sec. 12, SWSWNE

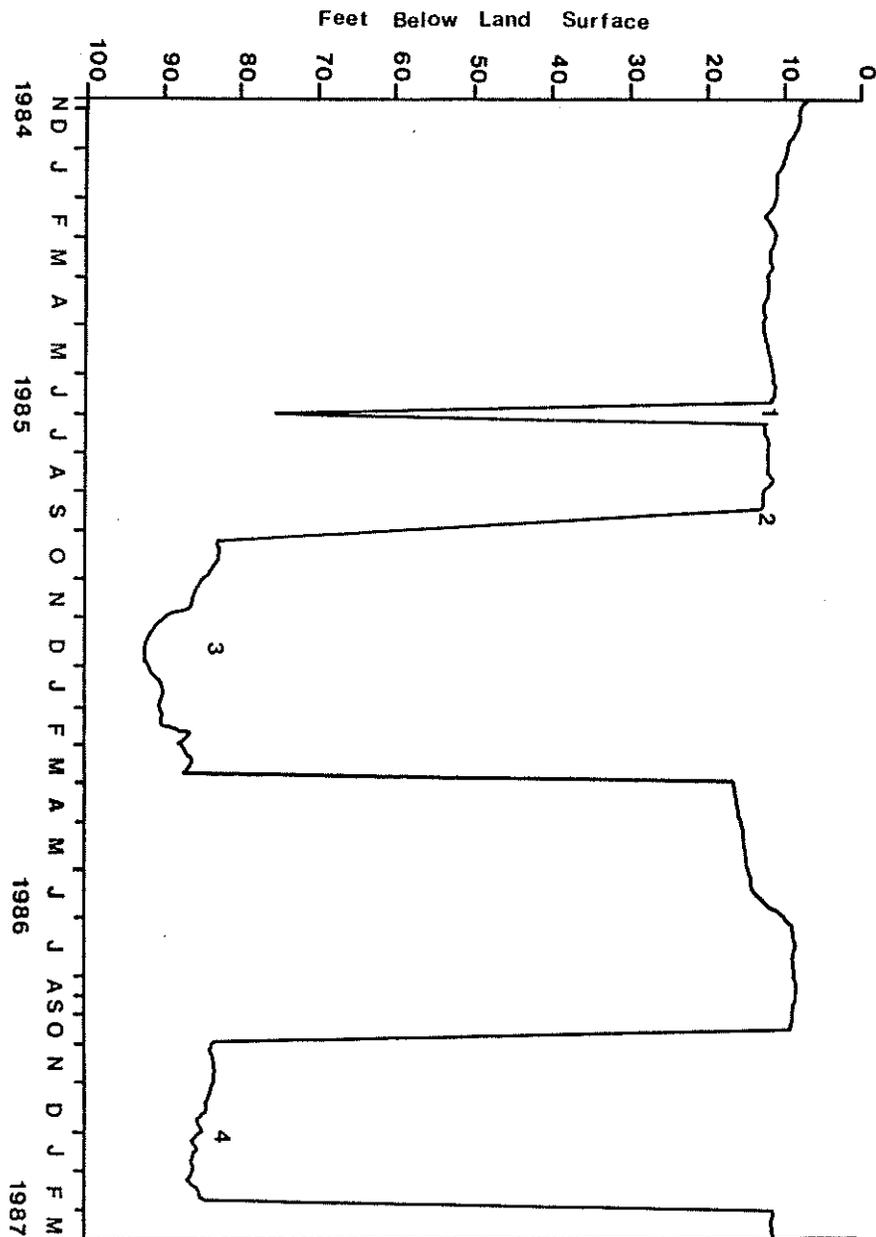


1. Low head power production goes on line from Well #10
2. Well #13 being developed
3. Well #13 goes on line
4. Well #9 repaired

Figure 11

Well #12 Hydrograph

T10S, R17E, Sec. 04, SWNE



1. Pump test
2. Well being used for heating.
3. Pumping levels
4. Pumping levels

Figure 12

Well #13 Hydrograph

T10S, R17E, Sec. 10, NWSNW

Seasonal fluctuations are shown in the hydrographs of wells No.'s 1, 3, and 4 (Figures 4, 6 and 7 respectively). Typically, demand is the greatest during the winter months and recovery occurs in the late summer, early fall. The sharp decline in the months of January and February of 1985 reflects the harsh winter which resulted in increased usage of the geothermal resource.

Well No. 2 (Figure 5) was not used until April, 1984. The record from November, 1983, until that date reflects a shut-in period. The sharp drop in the fall of 1985 represented the time when the owner was testing the system for use in an additional greenhouse. The effect of a new geothermal domestic well drilled in October of 1985 is shown as a depression. From April to the end of June in 1986, the use of the monitored well was expanded to irrigation and domestic consumption because the cold water supply to the area was under repair. This can be seen as a break in the slope of the seasonal recovery.

Well No. 5 (Figure 8) is primarily used for irrigation, hence the deep declines during the summer months. From July to December, 1986, an increase in pressure is shown. This increase was caused by the shut-in of four wells in the adjacent area (T9S, R14E, Sec 14, all 4 wells are shown as No. 6 on Figure 1) that used approximately 4300 gpm from 1983 until late fall, early winter of 1985. Two of the wells were opened and have been utilized since January, 1987 for fish propagation. This subsequent usage is shown by the decline of the water level in the monitored well.

The hydrograph of well No. 7 (Figure 9) is erratic. The well is 1420 feet deep and is cased to 621 feet in poorly consolidated sediments or ash layers. These units continue below the casing where they have the tendency to cave, thus clogging the well. The well was cleaned out during June and July, 1986. Additional casing was not added, therefore the clay continues to clog the well. The well has not been utilized over a continuous

period of time. When the well was flowing freely, the 10 minute shut-in pressures were low, as compared to when the well was completely shut-in over a period of time, the pressures were high. This is evident in the reading of June, 1985. At that time, the pressure had increased to the point where water was leaking from the bolts on the well head. Most of the time the well is either opened completely or is running a small amount; rarely is it completely shut in.

During September, 1984, well No. 10 was opened and used for power production. The well produces at a constant rate of 2470 GPM, and has rarely been shut-in for more than a few hours. When production for the power project commenced the response in wells 11 and 12 was immediate as indicated in Figures 10 and 11. The decline continued until the end of the 1984 heating season. Fluid pressure recovery did not return to pre-production levels. Well 13 was drilled and completed in August, 1984 and was pumped at 280 GPM starting October 1, 1985. Both events show effects on the other two wells. Well 13 was included in the monitoring network in November, 1984 (Figure 12). A pump test was performed in June, 1985, and is shown on the hydrograph. Water levels during the fall and winter months reflect pumping levels. In all three hydrographs, a dramatic increase in shut-in pressure is evident in July, 1986. At that time, well 9 was rehabilitated with an attendant reduction in leakage.

Well 9 had been flowing for several years at 1500 GPM at the surface and was believed to flow a considerable amount in the subsurface. When drilled in 1970, the flow was estimated to be 2750 GPM and the shut-in pressure was 212 psi. The well was 730 feet deep, completed in rhyolite and was cased to 518 feet in "gray shale and sandstone". There were 300 perforations from 220 to 230 feet and 200 perforations between 460 and 485 feet. The 16 inch steel casing was welded to an 8 inch steel casing at 222 feet. When the well was shut-in during June, 1986, the sound of running water was heard, the well remained warm to the touch, and

no response was recorded in wells 11 and 12. All of the above were indications that the well was leaking in the subsurface. It was thought that over the years the pressurized water had eroded the formations around the bottom of the casing and at the perforated intervals. In addition, perforations cut where the 8" casing was welded to the 16 inch casing may have resulted in partial failure of that joint. Cement was pumped into the well to seal the eroded intervals. The well was then redrilled to 743 feet. Casing was set to 640 feet and was pressure-grouted. As soon as the well was controlled at depth, the thermal wells in the vicinity immediately responded. The responses can be seen in the hydrographs of wells 11, 12 and 13 (Figures 10, 11 and 12).

Another well, No. 15, was drilled and completed in December, 1986 and the effects of development are shown in the hydrographs of wells 11, 12 and 13 (Figures 10, 11 and 12). Present usage is less than 10 GPM from this new well. Thus this well has an insignificant effect on the overall system.

Annual Discharge

To determine the annual discharge from the thermal aquifer, water rights files and field exam reports were reviewed to determine the maximum permitted usage. Based on discussions with well owners pertaining to seasonal and daily consumption, adjustments were made to the maximum permitted amount. Current annual withdrawal of the aquifer within the Twin Falls - Banbury Study Area was estimated to be 23,600 acre feet per year, (4,364 acre feet for the immediate Twin Falls vicinity and 19,326 for the Banbury area).

PRELIMINARY CONCEPTUAL MODEL OF THE THERMAL SYSTEM

In general, it appears that there are two main directions of flow movement converging in the Twin Falls area: from south to north and from east to west (Young, 1987, personal communication). From the Rock Creek area water follows a generally west-northwest flow path and from the Rogerson area flow is generally to the north. Both flow components encounter the Buhl - Berger Structure Zone in a poorly defined zone southeast of Buhl.

Permeability of the Idavada, both along the flow path and within reservoir rocks, results from fractures related to tectonic movement, sheeted joints and cooling fractures developed during emplacement, intergranular porosity of the non-welded ash flows and air fall tuffs, and voids left between successive flows. Fractures in the BBSZ facilitate the deep circulation of and heating of the water by the regionally high temperature gradient. The heated water is then pushed to the surface in the Banbury area to the northwest by the continued inflow of colder more dense water from the southeast.

It is the authors' opinion based on well testing, similarity of monitoring results, responses to changes in discharge and water chemistry that there appear to be no barriers to thermal water movement within or between the Twin Falls and Banbury portions of the system. While the Twin Falls and Banbury portions of the system are hydrologically connected the source of the heat component at Twin Falls is not clear. The study area is within a zone of regionally high heat flow which extends from northern Nevada to Yellowstone National Park. Heat flow over the zone is generally about 2.5 Heat Flow Units (HFU) (Brott, 1976; Smith, 1980). Lewis and Young (1987, in press) determined heat flow values within the study area to be between 2.2 and 2.5 HFU based on data from thermal gradients derived from bottom hole temperature evaluations. The thermal anomaly over the region is believed to be related to the Cordilleran Thermal Tectonic Anomaly

of Eaton and others (1976) and local thinning of the crust related to Basin and Range extension (Mabey, 1983, p. 13). Heat could be conducted through the aquifer from the Banbury area at a greater rate than the inflow of colder water from the southeast. There could also be inflow of thermal water from other systems from the east and northeast, Figure 13.

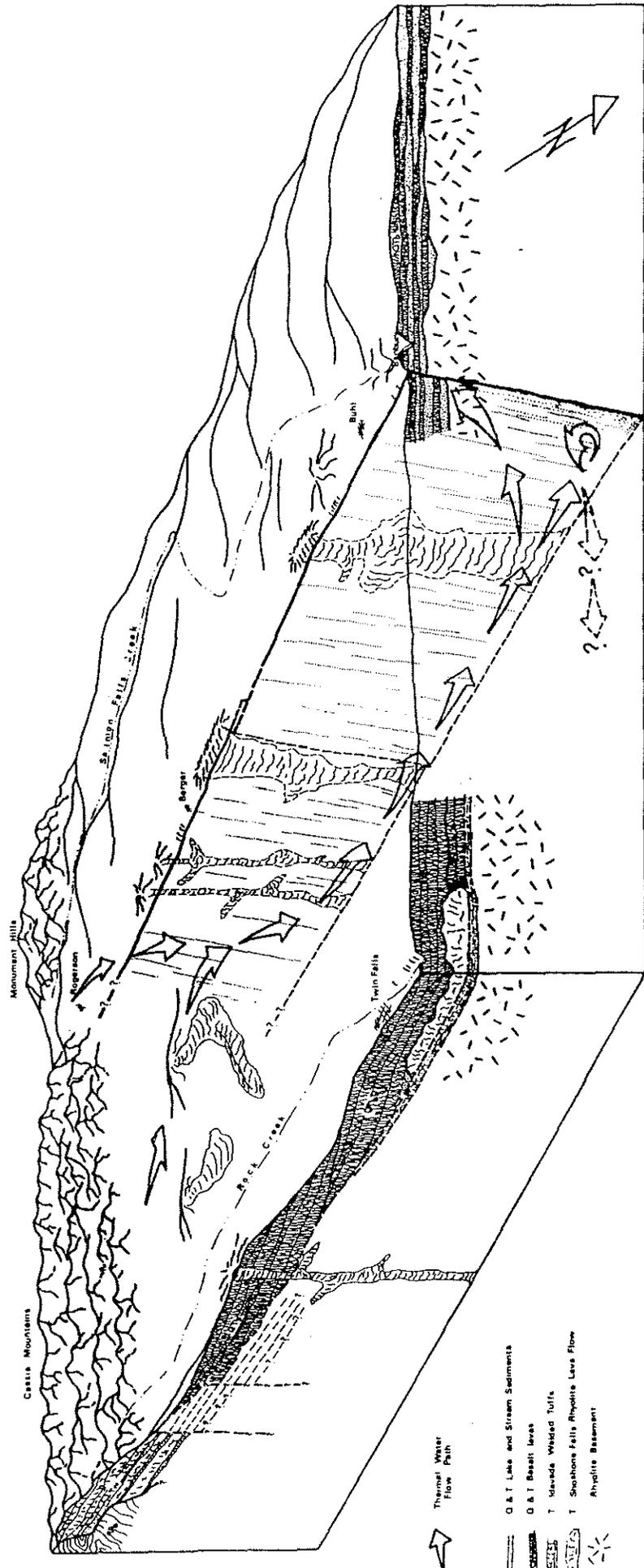


Figure 13. Conceptual Model of the Twin Falls - Banbury Thermal System

SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDIES

The geothermal resource in the Twin Falls - Banbury area is characterized by temperatures between 30°C and 70°C (86°F to 158°F) and is confined to the Tertiary Idavada rhyolitic rocks. The probable recharge area is the Cassia Mountains where water could circulate to depths via the regional dip of volcanic strata and structure zones and be heated by the regional thermal gradient.

Increased utilization for heating, irrigation, low-head hydro-power production and fish propagation has led to substantial declines in water levels. Monitoring of the aquifer has shown that temperatures remained constant while water levels are still declining and have not reached equilibrium. The seasonal fluctuations indicate response to the decrease in discharge, not necessarily to recharge. The monitoring also demonstrated that the aquifer responds rapidly to the development and usage of new wells or to the repair and shut-in of existing wells, thus indicating good hydraulic interconnection within the Banbury and Twin Falls portions of the system.

This study was initiated to provide baseline data and to develop a preliminary geologic model of the thermal system. During the course of this investigation, several topics for further study were identified:

1. Continued monitoring of the water levels and temperatures of the Twin Falls - Banbury system to expand understanding of the nature and magnitude of declines;
2. Additional chemical analyses of thermal waters to determine if changes have occurred over time as a result of withdrawals.
3. Comparison of regional thermal water chemistries to determine if there are relationships between the Twin Falls - Banbury and adjacent systems.

4. Regional and detailed geologic mapping to: further define the Buhl - Berger Structure Zone, determine if other structures exist that may be related to thermal systems and determine if there are other geologic relationships or boundaries between the Twin Falls - Banbury and neighboring systems.
5. Selected geophysical studies to determine structures at depth and extent of thermal system.

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APPENDIX A

DRILLER'S LOGS

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 30, NESENW (Casing: 8-inch steel 1 to 204 feet)			
Elevation: 2906			Water - Y/N
Quaternary Alluvium			
Brown Clay and Gravel.....	3	0	
Heavy Gravel and Brown Clay.....	62	3	Y
Banbury Basalt			
Grey Basalt.....	26	65	
Grey Clay.....	4	91	
Brown Clay.....	13	95	
Grey Basalt.....	30	108	
Red Clay.....	9	138	
Grey Basalt.....	32	147	Y
Brown Basalt.....	12	179	
Grey Basalt.....	35	191	
Green Shale w/Grey Basalt.....	19	226	
Green Shale w/Grey Clay.....	118	245	
Grey Basalt.....	112	363	Y
Idavada Undifferentiated			
Grey Shale (major field).....	5	475	Y
Total Depth.....		480	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 30, NENWSE (Casing: 8-inch steel 1 to 80 feet; 6-inch steel 1 to 501 feet)			
Elevation: 2902			Water - Y/N
Quaternary Alluvium			
Brown Sandy Clay.....	12	0	
Gravel.....	4	12	Y
Gravel and Clay.....	16	16	Y
Gravel.....	23	32	Y
Banbury Basalt			
Grey Basalt.....	9	55	
Brown Scoria and Clay.....	2	64	
Black Basalt.....	19	66	
Brown Basalt.....	3	85	
Grey Basalt.....	9	88	
Brown Clay.....	5	97	
Brown Basalt w/Thin Layers of Sticky Clay.....	40	102	
Grey Basalt.....	31	142	
Grey Basalt (Very Hard).....	17	173	
Red Clay w/Thin Layers of Clay.....	7	190	
Grey Clay.....	8	197	
Grey Basalt w/Thin Layers of Grey Clay.....	22	205	
Brown Basalt.....	20	227	
Grey Basalt.....	11	247	
Grey Basalt (Very Hard).....	10	258	
Grey Basalt w/Green Clay Seams, Small Flow, 2 GPM at 268	19	268	Y
Grey Clay and Sand.....	8	287	
Coarse Sand and Layers of Shale, Flow Increased to 5 GPM	47	295	
Grey-Brown Clay.....	23	342	
Green Clay.....	25	365	
Tan Clay.....	11	390	
Grey Clay.....	8	401	
Tan Clay.....	11	409	
Grey Clay.....	22	420	
Tan Clay.....	4	442	
Grey Clay.....	9	446	Y
Flow picks up to 30 GPM Then Dwindles to 5 GPM			
Light Grey Clay.....	60	455	
Grey Clay.....	32	515	
Grey Sand Stone.....	31	547	
Grey Brown Sand Stone.....	12	578	

Idavada Undifferentiated			
Black Igneous Rock.....	22	590	Y
Grey-Brown Igneous Rock.....	21	612	Y
Black Igneous Rock.....	67	633	
Total Depth.....		700	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 30, NWNWSE (Casing: 12-inch steel 0 to 35 feet; 8-inch steel 1 to 145 feet)			
Elevation: 2900			Water -Y/N
Quaternary Alluvium			
Top Soil.....	15	0	
Medium Hard Rock and Gravel.....	10	15	
Clay and Rock.....	60	25	
Banbury Basalt			
Medium Hard Black Rock.....	25	85	Y
Clay and Black Rock.....	10	110	
Rock and Clay Mix.....	60	120	
Hard Solid Lava.....	35	180	
Clay and Water Strips.....	220	215	Y
Clay and Rock Mix.....	5	435	Y
Idavada Undifferentiated			
Hard Black Rock.....	10	440	
Total Depth.....		450	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 32, SWSENE (Casing: Not on File)			
Elevation: 2950		Water - Y/N	
Quaternary Alluvium			
Brown Sandy Clay.....	3	0	
Boulders.....	27	3	
Grey Sand.....	5	30	
Boulders, Cobble Stones & Gravel.....	11	35	
Boulders.....	6	46	Y
Brown Clay.....	6	52	
Grey Clay & Gravel.....	6	58	
Gravel.....	12	64	
Brown Clay and Gravel.....	9	76	
Banbury Basalt			
Grey Basalt.....	18	85	
Brown Clay.....	5	103	
Grey Basalt.....	5	108	
Brown Clay.....	6	113	
Grey Basalt.....	38	119	
Brown Basalt.....	4	157	
Red Clay.....	8	161	
Black Basalt.....	26	169	
Grey Basalt.....	15	195	
Grey Basalt.....	4	210	
Grey Clay & Basalt.....	11	214	
Grey Clay.....	16	225	
Grey Basalt.....	43	241	
Dark Grey Clay.....	8	284	
Grey Shale w/Layers of Sand.....	8	292	
Grey-Black Basalt.....	12	300	Y
Dark-Grey Clay.....	48	312	
Black Basalt.....	15	360	
Sticky Clay.....	15	375	
Grey Shale Clay & Rocks.....	17	390	
Green Clay.....	19	407	
Basalt.....	2	426	
Grey Clay & Shale.....	12	428	Y
Idavada Undifferentiated			
Black Rhyolite.....	31	440	
Grey Sand Stone.....	40	471	
Grey-Brown Rhyolite.....	34	511	
Brown-Grey Sandstone Shale & Rocks			
Grey-Green Shale, Rock & Clay...	15	545	Y
Main Flow			

Grey Rhyolite.....	9	560	Y
Grey Clay.....	3	569	
Light Grey Rhyolite w/Layers of Green Shale.....	27	572	Y
Light Grey Rhyolite w/Layers Shale.....	24	599	
Grey Clay Sticky.....	6	623	
Light Grey Rhyolite.....	16	629	
Total Depth.....		645	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 32, SENENE			
(Casing: 12-inch steel 0 to 49 feet;			
8-inch steel 1.5 to 447 feet;			
6-inch steel 400 to 815 feet)			
Elevation: 2906		Water - Y/N	
Quaternary Alluvium			
Sand.....	5	0	
Sand & Clay.....	43	5	
Banbury Basalt			
Black Basalt.....	78	48	
Sandstone.....	24	126	Y
Sandstone.....	40	150	Y
Sand, Lots of Water.....	10	190	Y
(Sandstone) Layer of Sand.....	120	200	Y
Sand.....72°	6	320	Y
Sandstone.....74°	54	326	
Sandstone.....80°	20	380	Y
Sand.....74°	11	400	
Rock.....	11	411	
Sandstone.....74°	13	422	
Clay.....74°	12	435	
Banbury Basalt.....69°	33	447	
Clay & Basalt.....	10	480	
Sandstone.....69°	30	490	Y
Sand.....82°	10	520	
Sandstone.....93°	105	530	Y
Sand.....104°	2	635	
Grey Shale.....	3	637	
Sandstone.....	30	640	
Idavada Undifferentiated			
Black or Dark Grey Rhyolite.....	8	670	
Grey Shale.....	4	678	
Sandstone.....	18	682	
Grey Shale.....	42	700	
Black Rhyolite.....	4	742	
Grey Shale.....	14	746	
Sandstone.....	30	760	
Black Rhyolite.....	70	790	Y
Green-Blue Shale.....108°	30	860	
Grey Shale.....	40	890	
Grey-Black Rhyolite.....	15	930	
Grey Shale.....	2	945	
Grey-Black Rhyolite.....	7	947	
Grey-White Shale.....	4	954	
Dark Grey Shale w/Some of Lighter Grey.....	62	958	

Grey-Green Shale.....	10	1,020
Grey Rhyolite w/Layers of Grey Shale.	50	1,030
Grey Shale & Clay.....	5	1,080
Grey Rhyolite w/Grey Clay.....	15	1,085
Grey Shale.....	20	1,100
Grey Rhyolite w/Layers of Clay.....	30	1,120
Grey Shale.....	30	1,150
Grey Shale w/White Soft Clay.....	2	1,180
Grey Shale.....	38	1,182
Grey/Green Shale.....	60	1,220
Grey Shale w/Clay Layers.....	20	1,280
Grey Shale w/Thin Clay Layers.....	80	1,300
Total Depth.....		1,380

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 30, NENESW (Casing: 16-inch steel 1 to 23 feet; 12-inch steel 1 to 47 feet; 6-inch steel 1 to 444 feet)			
Elevation: 2940			Water-Y/N
Quaternary Alluvium			
Tan Clay.....	15	0	
Dark Grey Clay.....	9	15	
Dark Grey Clay w/ ?.....	30	24	Y
Tertiary Basalt			
Black Basalt (Hard).....	20	54	
Grey Shale.....	6	74	
Red-Brown Clay.....	6	80	
Black Basalt.....	18	86	
Red-Brown Silty Clay.....	7	104	Y
Red & Black Cinders.....	11	111	Y
Grey Clay.....	84	122	
Red Clay w/Rock Layers.....	16	206	
Grey Basalt w/Clay.....	18	222	
Grey Basalt (Hard).....	18	240	
Grey-Brown Clay.....	8	258	
Grey-Brown Basalt.....	6	266	
Grey Basalt.....	24	272	
Grey Shale.....	11	296	
Grey Basalt.....	2	307	
Grey Shale w/Stick Clay.....	17	309	
Light Tan Shale.....	11	326	
Grey Clay & Shale.....	27	337	
Dark Grey Basalt.....	3	364	Y
Grey Green Shale.....	18	367	
Grey Shale.....	7	385	
Green Shale.....	7	392	
Grey Clay.....	33	399	
Tan Clay.....	9	432	
Grey-Green Clay w/Rock Layers.....	9	441	
Grey-Green Shale w/Rock Layers.....	12	450	
Idavada Undifferentiated			
Grey Rhyolite.....	7	462	Y
Grey Shale w/Rock Layer.....	15	469	Y
Black Rhyolite.....	40	484	Y
Grey Clay.....	4	524	
Grey Shale w/Rock Layers.....	37	528	Y
Black Rhyolite.....	22	565	Y
Grey Shale w/Clay Layers.....	13	587	Y
Decomposed Brown Rhyolite.....	10	600	Y
(Major Flow)			
Total Depth.....		610	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 32, NENWSE (Casing: 10-inch steel 1 to 299 feet)			
Elevation: 2931			Water - Y/N
Quaternary Alluvium			
Brown Sandy Clay.....	6	0	
Boulders & Gravel.....	61	6	
Boulders.....	16	67	
Brown Clay.....	2	83	
Tertiary Basalt			
Grey Basalt (Hard).....	48	85	
Grey Basalt.....	5	133	
Red Clay.....	6	138	
Grey Basalt w/Clay Layers.....	16	144	
Grey Basalt (Hard).....	32	160	
Brown Clay.....	11	192	
Grey-Green Clay or Shale.....	14	203	
Black Basalt.....	26	217	Y
Grey Clay, Shale & Basalt.....	8	243	
Grey Basalt.....	16	251	Y
Grey Brown Shale.....	11	267	Y
Black Basalt w/Shale Layers.....	5	278	
Gravel.....	10	283	
Idavada Undifferentiated			
Green Shale & Clay.....	22	293	
Grey Rhyolite.....	21	315	
Grey Rhyolite & Shale Layered.....	27	336	
Grey-Brown Rhyolite.....	46	363	
Grey Rhyolite.....	4	409	
Grey Rhyolite (at 435' Small Flow)...	105	413	Y
Light Shale w/Rhyolite Layered.....	5	518	
Grey Rhyolite.....	59	523	Y
Grey Rhyolite w/Clay Layers.....	30	582	Y
Grey Rhyolite.....	26	612	
Grey Rhyolite w/Clay Layers.....	13	638	
Green Shale w/Layers of Rhyolite.....	12	651	
Brown Clay (Sticky).....	6	663	
Black-Brown Rhyolite.....	16	669	
Grey Rhyolite.....	11	685	
Grey Rhyolite w/Green Shale.....	23	696	
Black Rhyolite.....	35	719	
Green Cinders.....	4	754	Y
Black Rhyolite.....	15	758	
Grey Rhyolite.....	5	773	Y
Grey Rhyolite.....	4	778	
Brown Rhyolite.....	24	782	Y
Grey Rhyolite.....	26	806	Y
Grey-Brown Rhyolite.....	16	832	Y

Grey Rhyolite.....	178	848	
Black Rhyolite w/clay seams.....	13	1,026	
Grey Clay.....	5	1,039	
Black Rhyolite.....	8	1,044	
Brown Clay (Sticky).....	14	1,052	Y
Grey Rhyolite w/Layers Sticky Clay...	9	1,066	
Grey Rhyolite.....	5	1,075	
Total Depth.....		1,080	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 32, NWNWSE (Casing: 12-inch steel 1 to 39 feet; 8-inch steel 2 to 591 feet)			
Elevation: 2975			Water - Y/N
Quaternary Alluvium			
Top Soil.....	22	0	
Gravel.....	4	22	
Clay.....	8	26	
Banbury Basalt			
Red Lava, (16" to 38').....	67	34	
Grey Lava.....	124	101	
Lava & Clay.....70°...	6	225	Y
Grey Lava.....	127	231	
Grey Lava, Strips Blue Clay.....	167	358	
Blue Clay.....80°...	12	525	Y
Grey Lava.....	35	537	
Blue Clay.....86°...	17	572	Y
Grey Lava (12" to 591').....	35	589	
Idavada Undifferentiated			
Broken Grey Rhyolite.....110°...	2	624	Y
Hard Red-Brown Rhyolite.....	64	626	
Hard Grey Rhyolite.....	183	690	
Broken Grey Rhyolite.....120°...	4	873	Y
Hard Grey Rhyolite.....	25	877	
Soft Grey Rhyolite.....	93	902	
Broken Grey Rhyolite.....140°...	15	995	Y
Total Depth.....		1,010	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 33, NWNENW (Casing: 6-inch steel 1 to 361 feet)			
Elevation: 2900		Water - Y/N	
Quaternary Alluvium			
Clay.....	31	0	
Gravel.....	2	31	
Clay.....	92	33	
Sand.....	15	125	
Banbury Basalt			
Black Basalt.....	33	140	Y
Clay.....	47	173	
Sand.....	25	220	Y
Clay.....	55	225	
Black Basalt.....	35	280	
Conglomerate.....	4	315	
Black Basalt (Medium to Hard).....	36	319	
Black Basalt (Very Hard).....	100	355	
Blue Clay.....	117	455	
Blue Shale.....	86	572	
Broken Blue Shale.....	12	658	
Blue Clay.....	145	670	Y
Blue Shale (Hard).....	120	815	
Blue Clay.....	214	935	
Blue Shale.....	53	1,149	
Blue Clay.....	40	1,202	
Idavada Undifferentiated			
Reddish Brown Rhyolite.....	33	1,242	Y
Total Depth.....		1,275	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 33, NWNWSW			
(Casing: 10-inch steel 1 to 199 feet;			
8-inch steel 148.5 to 497.5 feet;			
6-inch steel liner 494 to 694 feet;			
Liner is perforated:			
40 perforations - 497 to 505 feet			
32 perforations - 674 to 682 feet)			
Elevation: 2918			Water - Y/N
Quaternary Alluvium			
Sandy Clay.....	13	0	
Clay w/Light Grey Sand.....	11	13	
Sand w/Clay.....	19	24	Y
Brown Sand w/Small Gravel.....	5	43	Y
Boulders w/Sand.....	4	48	Y
Grey Clay.....	67	52	
Banbury Basalt			
Black Basalt (Hard).....	3	119	
Basalt, Broken w/Clay.....	17	122	
Basalt, Broken w/Clay.....	5	139	
Basalt, Broken w/Clay.....	20	144	
Black Basalt (Hard).....	2	164	
Grey Clay.....	2	166	
Brown Clay.....	10	168	
Black Basalt, Fractured w/Clay.....	2	178	
Tan Clay.....	9	180	
Blue-Grey Clay.....	3	189	
Blue Shale (First Artesian Flow).....	7	192	Y
		(Above Flows Grouted Off)	
Blue Shale.....	3	199	
Black Basalt (Hard).....	1	202	
Blue Shale.....	10	203	
Black Basalt (Hard).....	8	213	
Brown Shale.....	2	221	
Basalt, Broken w/Clay.....	12	223	
Tan Clay.....	5	235	
Green Clay.....	11	240	
Green Shale.....	13	251	
Grey Clay.....	17	264	
Idavada Undifferentiated			
Black & Green Rhyolite.....	4	281	
Light Brown Shale.....	4	285	
Dark Green Shale.....	11	289	
Light Grey Clay.....	30	300	
Green Clay.....	4	330	
Shale & Green Clay.....	37	334	
Grey Shale.....	13	371	
Green Shale.....	18	384	

Grey Shale.....	24	402	Y
Brown Clay.....	14	426	
Brown Basalt.....	4	440	
Shale & Green Clay.....	8	444	
Blue Shale.....	24	452	
Grey Shale.....	12	476	
Dark Blue Shale.....	14	488	
Black Basalt.....	8	502	
Red-Brown Rhyolite.....	9	510	
Black Rhyolite.....	3	519	
Brown Rhyolite.....	5	522	
Black Rhyolite.....	9	527	
Sandstone.....	4	536	
Black Rhyolite.....	7	540	
Decomposed Rhyolite, Alternating Hard & Soft Layers.....	111	547	
Black Rhyolite (Hard).....	3	658	
Grey Clay.....	2	661	
Rhyolite (Very Hard).....	31	663	
Total Depth.....		694	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 33, SENWSW (Casing: 12-inch steel 1 to 119 feet; 8-inch steel 1.5 to 278 feet; 6-inch steel 185 to 470 feet)			
Elevation: 2907			Water - Y/N
Quaternary Alluvium			
Brown Clay.....	8	0	
Brown Sand.....	27	8	Y
Tertiary Basalt			
Grey Basalt.....	13	35	
Grey-Brown Clay.....	19	48	
Grey Basalt.....	5	67	
Brown Clay.....	20	72	
Grey Basalt.....	45	92	
Brown Basalt.....	5	137	
Grey Basalt.....	26	142	
Dark Brown Clay.....	7	168	
Grey Basalt.....	34	175	
Brown Clay & Brown Basalt.....	4	209	
Brown Basalt.....	6	213	
Brown Basalt.....	34	219	
Green Clay.....	4	253	
Tan Clay w/Thin Layers of Basalt.....	13	257	
Tan Clay w/Shale Layers.....	36	270	
Hard Grey Shale.....	21	306	Y
Grey-Brown Clay w/Shale in Layers....	25	327	Y
Grey-Brown Shale w/Clay in 1' to 2' Layers.....	26	352	
Grey Clay.....	31	378	
Light Tan Clay.....	7	409	
Dark Green Shale.....	4	416	
Light Green Clay.....	21	420	
Grey-Brown Shale.....	9	441	
Grey Shale.....	20	450	
Dark Grey Shale.....	17	470	
Light Grey Shale.....	20	487	
Idavada Undifferentiated			
Black Rhyolite.....	3	507	Y
Brown Rhyolite.....	46	510	Y
Black Rhyolite.....	22	556	Y
Grey Shale.....	6	578	Y
Black Rhyolite.....	48	584	Y
Black Rhyolite w/Thin Layers of Sticky Clay.....	50	632	Y
Brown Rhyolite.....	61	682	Y
Grey-Brown Rhyolite.....	57	743	Y
Total Depth.....		800	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 8S, R 14E, Sec. 33, NWNWSW (Casing: 8-inch steel 1 to 259 feet) 6-inch steel 171 to 482 feet)			
Elevation: 2912		Water - Y/N	
Quaternary Alluvium			
Brown Sandy Clay.....	33	0	
Brown Clay.....	3	33	
Brown Sandy Clay.....	20	36	
Gravel & Sandy Clay.....	17	56	Y
Grey Sand.....	39	73	Y
Gravel & Boulders.....	30	112	Y
Grey Sandy Clay.....	3	142	Y
Banbury Basalt			
Grey Basalt.....	3	145	
Gravel.....	8	148	
Brown Clay.....	5	156	
Gravel & Clay.....	25	161	
Grey Basalt.....	42	186	
Brown Basalt & Clay.....	11	228	
Grey Basalt w/Clay.....	3	239	
Grey Basalt.....	29	242	
Grey Shale.....	14	271	
Brown Clay.....	16	285	
Grey-Green Shale & Clay.....	57	301	Y
Green Shale w/Sand & Gravel.....	21	358	
Gravel.....	5	379	
Green Shale.....	9	384	
Green Clay.....	24	393	
Grey Clay.....	31	417	
Dark Grey Shale.....	6	448	
Grey Clay.....	16	454	
Grey Shale.....	48	470	
Shale & Sand in Thin Layers.....	11	518	Y
Idavada Undifferentiated			
Black Rhyolite.....	53	529	
Grey Shale.....	5	582	
Brown Rhyolite.....	53	587	
Grey Shale.....	14	640	
Black Rhyolite.....	14	654	Y
Black Rhyolite.....	19	668	Y
Brown Rhyolite.....	13	687	Y
Total Depth.....		700	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 14E, Sec. 4, NWNWNW (Casing: 8-inch steel 0 to 95 feet; 6-inch steel 1 to 215 feet)			
Elevation: 2959		Water - Y/N	
Tertiary Basalt			
Sand & Dirt.....	35	0	
Decomposed Lava (Medium-Hard).....	30	35	
Clay & Gravel (Water ?).....	75	65	Y
Idavada Undifferentiated			
Black Rock (Hard).....	110	140	
Black Rock (Medium-Hard).....	100	250	
Grey Rhyolite (Hard).....	75	350	Y
Broken Spot.....			
Grey Rhyolite (Hard).....	155	425	
Broken Rhyolite.....	5	580	Y
Black Rock (Hard) w/Clay Seams.....	55	585	
Black Rock (Hard).....	260	640	
Total Depth.....		900	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 14E, Sec. 4, NESESW (Casing: 8-inch steel 1 to 41 feet; 6-inch steel 1 to 380 feet)			
Elevation: 2996			Water - Y/N
Tertiary Basalts			
Dirt & Rock.....	6	0	
Brown Basalt.....	14	6	
Grey Basalt.....	70	20	
Black Basalt & Clay.....	5	90	
Black Basalt.....	25	95	
Brown Clay.....	11	120	
Grey Silt.....	42	131	
Undifferentiated Idavada Volcanics			
Grey Shale (Hard).....	2	173	
Grey Sandy Clay.....	50	175	
Grey Clay.....	23	225	Y
Grey Shale (Hard).....	3	248	
Grey Clay.....	19	251	
Grey Shale.....	110	270	
Brown Shale.....	27	380	
Grey Shale.....	91	407	
Black Rhyolite.....	104	498	Y
Grey Rhyolite.....	248	602	
Total Depth.....		850	Y

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 15E, Sec. 12, SWNESW (Casing: 8-inch steel 2 to 110 feet; 6-inch steel 30 to 621 feet)			
Elevation: 3065			Water - Y/N
Tertiary Basalts			
Top Soil.....	3	0	
Boulders & Gravel.....	7	3	
Grey Lava.....	123	10	
Brown Clay.....	8	133	
Blue Clay.....	19	141	Y
Brown Sandstone.....	44	160	Y
Idavada Pyroclastics			
Red Lava.....	4	204	Y
Black Lava.....	60	208	Y
Brown Lava & Red Ash.....	11	268	Y
Black Lava.....	49	279	Y
Grey Sand & Blue Clay.....	39	328	Y
Black Lava.....	39	367	Y
Reddish Brown Lava Ash.....	14	406	Y
Black Lava.....	50	420	Y
Brown Lava.....	130	470	Y
Reddish Brown Lava Ash.....	50	600	Y
Sandstone & Clay.....	50	650	Y
Grey Lava (Hard).....	50	700	Y
Blue Clay.....	10	750	Y
Grey Lava.....	75	760	Y
Soft Blue Clay.....	203	835	Y
Hard Rock.....	37	1,038	Y
Broken Rock.....	45	1,075	Y
Clay.....	155	1,120	Y
Clay.....	9	1,275	Y
Hard Black Rock.....	16	1,284	Y
Black Rock, Layers, Broken.....	120	1,300	Y
Total Depth		1,420	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 17E, Sec. 29, NWNWSE (Casing: 6-inch steel 0 to 640 feet) Well has been reconstructed.			
Elevation: 3154			Water - Y/N
Tertiary Basalts			
Brown Sand.....	7	0	
Tan Sandy Clay.....	5	7	
Boulders in Gravel.....	26	13	
Loose Basalt.....	12	39	Y
Basalt Boulders.....	7	51	
Cinders & Clay.....	2	53	Y
Basalt Boulders.....	10	60	
Cinders & Clay.....	11	70	Y
Basalt Boulders.....	6	81	
Basalt (Soft).....	37	87	
Grey Basalt.....	24	124	
Brown Basalt.....	16	148	
Grey Basalt.....	29	164	
Brown Clay & Rock.....	9	193	
Brown Basalt.....	17	202	
Grey Basalt.....	34	219	Y
Brown Clay w/Rock.....	20	253	
Grey Basalt.....	39	273	
Brown Clay.....	9	312	
Grey Basalt.....	40	321	
Grey Clay w/Rock.....	21	361	
Grey Basalt.....	6	382	
Brown Basalt.....	8	388	
Grey Basalt.....	38	396	
Grey Clay.....	10	434	
Grey Basalt.....	15	444	
Lake Sediments			
Tan Clay.....	8	459	
Grey Sandy Clay w/Layered Shale.....	11	467	
Grey Sand.....	2	478	Y
Idavada Pyroclastics			
Tan Shale.....	6	480	
Grey Shale & Sandstone.....	32	486	
Consolidated Black Shale or Rock(?)..	5	518	
Grey Shale.....	24	523	Y
Brown Rhyolite w/Layers of ?.....	58	547	Y
Green Rhyolite (Soft).....	25	605	Y
Green Rhyolite (Hard).....	20	630	Y
Brown Rhyolite (Very Hard).....	35	650	Y
Pink Rhyolite (Very Hard).....	15	685	Y

Black & Pink Rhyolite (More Water)...	2	700	Y
Black & Pink Rhyolite (More Water	3	702	Y
125 to 175 GPM).....	5	705	Y
Pink & Black Rhyolite.....	15	710	Y
Brown & Pink Rhyolite.....	18	725	
Total Depth.....		743	Y

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 17E, Sec. 32, NESESE (Casing: 12-inch steel 1 to 71 feet; 8-inch steel 2 to 493 feet)			
Elevation: 3637			Water - Y/N
Quaternary/Tertiary Basalts			
Top Soil.....	5	0	
Lava Boulders.....	5	5	
Grey Lava.....	23	10	
Cements (?). Gravel.....	11	33	
Grey Lava.....	9	46	
Brown Sandy Clay.....	4	55	
Grey Lava.....	12	59	
Lava Cinders & Gravel.....	22	71	Y
Brown Lava Cinders.....	7	93	
Brown Lava Cinders & Clay.....	40	100	
Grey Lava (Hard).....	40	140	
Brown Clay.....	6	180	
Grey Lava.....	20	186	
Reddish Brown Lava.....	49	206	
Brown Sandy Clay w/Gravel.....	24	255	
Tan Sticky Clay.....	39	279	
Grey Lava (?).....	20	318	
Brown Sandy Clay.....	17	338	
Grey Lava.....	37	355	
Brown Sandy Clay.....	63	392	
Blue Sticky Clay.....	39	455	Y
Grey Lava (Hard).....	75	494	
Reddish Brown Clay.....	8	569	
Brown Clay.....	48	577	
Grey Sandy Clay.....	29	625	
Brown Sandy Clay.....	29	654	
Idavada Pyroclastics			
Grey Rhyolite (Hard).....	63	683	
Reddish Brown (?).....	14	746	
Grey Rhyolite (Very Hard).....	30	760	
Black Rhyolite (Hard).....	15	790	
Rhyolite (Slightly Softer).....	15	805	
Brown Lava & Clay.....	20	820	
Black Rhyolite (Hard).....	20	840	
Decomposed Lava.....	20	860	
Broken Black Rhyolite (Hard).....	80	880	
Sandstone.....	12	960	
Sandstone (Very Soft).....	2	972	
Sandstone, Brown Shale.....	53	974	
Black Lava.....	33	1,027	
Black Rhyolite (Very Hard).....	10	1,060	
Rhyolite (Slighter Softer).....	30	1,070	

Softer Form Again.....	7	1,100	
Black Rhyolite (Very Hard).....	8	1,107	
Red & Black Rhyolite.....	35	1,115	
Red & Black Rhyolite (Broken).....	15	1,150	
Medium-Hard Strips of Soft Broken Rhyolite.....	40	1,165	
Soft White Shale.....	20	1,205	Y
Rhyolite, Broken (Medium-Hard).....	10	1,225	Y
Red Rhyolite, Broken (Soft).....	5	1,235	
Red Rhyolite, Broken (Hard).....	40	1,240	
Total Depth.....		1,280	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 9S, R 17E, Sec. 33, NWNWNW (Casing: 24-inch steel 1 to 26 feet; 16-inch steel 1 to 128 feet; 12-inch steel 1 to 261 feet; 8-inch steel 1 to 592 feet)			
Elevation: 3174			Water - Y/N
Bonneville Flood Deposits			
Sand & Dirt.....	8	0	
Grey Lava Boulders & Sand.....	18	8	
Grey Lava Boulders & Sand.....	30	26	
Grey Rhyolite Boulders & Cinder Mix..	23	56	
Tertiary Basalts			
Grey Basalt (Hard).....	7	79	
Grey Rhyolite & Cinders (Soft).....	30	86	Y
Grey Lava & Some Clay.....	7	116	Y
Blue Clay & Lava (Some Caving).....	17	123	
Grey Lava (Hard).....	17	140	
Grey & Brown Clay/Grey Rhyolite.....	10	157	
Grey Rhyolite w/Layers of Clay.....	36	167	
Grey Rhyolite & Clay.....	23	203	
Grey Basalt (Hard).....	34	226	
Grey Basalt (Very Hard).....	14	260	
Brown Basalt (Hard).....	6	274	
Black Basalt (Hard).....	32	280	
Broken Basalt (Crevice).....	2	312	
Black Basalt - Some Brown.....	1	314	
Black Basalt - Big or Broken Boulders.....	14.5	315	
Grey Basalt (Very Hard) Andesite?....	47.5	329.5	
Black Basalt (Andesite?), Broken.....	12	377	
Black Basalt? Andesite?.....	5	389	
Black Basalt, Broken.....	19	394	
Grey Basalt (Very Hard).....	25	413	
Broken Basalt (Softer) - Trace of Cold Flowing Water.....	14	438	
Solid Basalt.....	8	452	
Lake Sediments			
Layers of Sandstone & Clays - Some Warmer Water.....	92	460	Y
Layers of Clay & Rock - Water Increasing - About 150 GPM Temp. Increase from 80° to 92° F.	40	552	Y

Idavada Pyroclastics

Broken Rhyolite w/Shale Layers - Water Increased about 600 GPM Temp. 99°.....	78	592	Y
Broken Rhyolite w/Shale Layers -Big Increases in Water Temp., Increased 102°-103°.....	80	670	Y
Total Depth		750	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 10S, R 13E, Sec. 20, NESENE			
(Casing: 20-inch steel 0 to 25 feet;			
16-inch steel 0 to 100 feet;			
12-inch steel 1 to 255 feet)			
Elevation: 3428			Water - Y/N
Idavada Pyroclastics			
Boulders.....	25	0	Y
Brown Rhyolite.....	37	25	
Red Clay.....	26	62	
Loose Rock.....	12	88	Y
Brown Rhyolite.....	48	100	
Loose Rock & Clay.....	107	148	
Brown Rhyolite.....	145	255	
Grey Rhyolite (Hard).....	62	400	
Brown Rhyolite.....	18	462	Y
Grey Rhyolite.....	178	480	
Blue Clay (Sticky).....	37	658	
Brown Rhyolite.....	35	695	Y
Brown & Grey Loose Rhyolite.....	120	730	Y
Grey Rhyolite.....	70	850	
Red Rhyolite (Loose).....	55	920	Y
Grey Rhyolite (Hard).....	65	975	
Grey Brown (Loose).....	45	1,040	Y
Red Brown (Loose).....	20	1,085	Y
Grey Rhyolite (Hard).....	135	1,105	
Loose.....	27	1,240	Y
Hard Rhyolite.....	88	1,267	
Rhyolite (Broken).....	35	1,355	Y
Rhyolite (Hard).....	70	1,390	
Total Depth.....		1,460	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 10S, R 17E, Sec. 4, NESESW (Casing: 16-inch steel 1 to 367 feet; 12-inch steel 2 to 1611 feet;			
Elevation: 3668			Water - Y/N
Quaternary Basalts			
Brown Clay.....	9	0	
Black Basalt.....	11	9	
Brown Silt.....	4	20	
Black Basalt.....	11	24	Y
Brown Silt.....	8	35	
Broken Basalt.....	4	43	Y
Black Basalt.....	32	47	
Brown Clay.....	3	79	
Black Basalt.....	21	82	
Grey Basalt.....	17	103	
Brown Basalt.....	33	120	
Grey Basalt.....	9	153	
Brown Basalt.....	25	162	
Grey Basalt (Very Hard).....	40	187	
Brown Clay.....	5	227	
Grey Basalt.....	3	232	
Brown Clay.....	9	235	
Gravel & Brown Clay.....	39	244	
Grey Clay.....	22	283	
Brown Clay w/Some Gravel.....	30	305	
Grey Basalt.....	3	335	
Grey Clay.....	5	338	
Grey Basalt.....	74	343	
Grey Basalt (Crevediced).....	8	417	
Grey Clay.....	8	425	
Grey Basalt (Crevediced & Hard).....	12	433	
Grey Basalt (Hard).....	50	445	
Grey Basalt w/Clay Layers.....	68	495	
Grey Basalt (Very Hard).....	7	563	
Grey Basalt w/Clay Seams.....	13	570	
Grey Basalt (Hard).....	2	583	
Grey Clay.....	10	585	
Grey Basalt.....	15	595	
Grey Basalt (Hard).....	15	610	
Brown Clay.....	8	625	
Shoshone Falls Rhyolite			
Grey Andesite (Very Hard).....	30	633	
Grey Andesite (Very Hard).....	15	663	
Brown Clay.....	9	678	
Grey Basalt w/Clay Layers.....	11	687	
Grey Clay.....	7	698	
Brown Clay & Rocks.....	28	705	

Grey Basalt.....	17	733	
Grey Clay.....	35	750	
Grey Andesite (Very Hard).....	75	785	
Grey Clay.....	10	860	
Grey Rock.....	31	870	
Grey Clay.....	2	901	
Grey Rock.....	4	903	
Clay & Rock in Thin Layers.....	49	907	
Grey Clay.....	7	956	
Grey Clay (Hard).....	15	963	
Grey Rock.....	3	978	
Grey Clay (Hard).....	11	981	
Grey Andesite (Very Hard).....	19	992	
Sticky Clay.....	1	1,011	
Grey Andesite (Very Hard).....	8	1,012	
Lake Sediments			
Brown Clay.....	10	1,020	
Tan Clay.....	15	1,030	
Brown Sand.....	5	1,045	
Grey-Brown Sand.....	20	1,050	
Dark Grey Sand w/Some Clay Seams.....	15	1,070	
Dark Grey Sand w/Some ?.....	20	1,085	
Grey Rock.....	2	1,105	
Grey Shale.....	3	1,107	
Grey Rock.....	13	1,110	
Clay & Sand (First Flow).....	2	1,123	Y
Idavada Pyroclastics			
Brown Rhyolite.....	30	1,125	Y
Broken Brown Rhyolite & Sand.....	15	1,155	Y
Brown Rhyolite.....	45	1,170	Y
(1215 was end of major ?)			
Red-Brown Rhyolite.....	335	1,215	
Grey-Brown Rhyolite.....	105	1,550	
Grey Rhyolite.....	85	1,655	
Grey Rhyolite.....	60	1,740	
(Reduced hole to 8" at 1760')			
Grey Rhyolite.....	20	1,800	
Brown Rhyolite.....	17	1,820	
Grey Rhyolite.....	45	1,837	
Grey-Brown Rhyolite.....	25	1,882	
Brown Rhyolite.....	21	1,907	
Grey Rhyolite.....	34	1,928	
Brown Rhyolite.....	91	1,962	Y
Grey Andesite.....	43	2,053	
Olivine.....	9	2,096	
Grey Andesite.....	16	2,105	
Light Brown Andesite.....	66	2,121	
Light Brown Rhyolite Crevised.....	33	2,187	
Total Depth.....		2,220	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)
T 10S, R 17E, Sec. 4, SENWSW		
(Casing: 16-inch steel 1 to 512 feet; 12-inch steel 1 to 1248 feet; 10-inch steel 1184 to 1345 feet; 8-inch steel 1293 to 1453)		
(Perforations: 16 rows per foot 1293 to 1333; 12 rows per foot 1333 to 1353; 8 rows per foot 1353 to 1453; Size of perforations: 1/4" x 3")		

Elevation: 3662 Water - Y/N

Quaternary and Tertiary Basalt			
Brown Clay.....	15	0	
Clay & Broken Rock.....	7	15	Y
Grey Basalt.....	23	22	Y
Brown Clay.....	4	45	
Grey Basalt.....	14	49	
Clay.....	13	63	
Grey Basalt.....	9	76	
Clay.....	13	85	
Grey-Brown Basalt.....	32	98	Y
Grey Basalt.....	34	130	
Brown Basalt.....	17	164	
Grey Basalt.....	37	181	
Talc.....	2	218	
Grey Basalt.....	21	220	
Brown Sandy Clay w/Gravel.....	137	241	
Soft Brown Conglomerate.....	8	378	
Grey Basalt.....	30	386	
Brown Clay.....	32	416	
Grey Clay.....	14	448	
Brown Clay.....	37	462	
Grey Clay.....	9	499	
Grey Basalt (Hard).....	27	508	
Brown Clay.....	8	535	
Brown Sandy Clay.....	97	543	
Grey Sandy Clay.....	28	640	
Grey Sandy Clay.....	46	668	
Grey Sandy Clay.....	8	714	
Grey Basalt.....	26	722	
Reddish Brown Clay.....	8	748	
Grey Basalt.....	22	756	
Brown Basalt w/Layers of Sticky Clay.	5	778	
Brown Clay.....	5	783	

Grey Basalt (Hard).....	65	788
Brown Basalt.....	5	853
Grey Basalt.....	38	858
Grey Clay (Sticky).....	16	896
Tertiary Basalt		
Grey Basalt (Very Hard).....	76	912
Grey Clay.....	2	988
Grey Basalt.....	5	990
Grey Clay (Sticky).....	28	995
Grey Basalt.....	5	1,023
Clay & Shale w/Fine Gravel.....	34	1,028
Black Basalt.....	8	1,062
Brown Clay (Sticky).....	12	1,070
Grey Clay & Shale (Sticky).....	8	1,082
Grey Brown Shale.....	21	1,090
Grey Basalt.....	2	1,111
Grey Clay.....	1	1,113
Grey Basalt.....	8	1,114
Grey Clay & Rock Layered.....	22	1,122
Black Basalt.....	13	1,144
Grey Clay & Shale.....	19	1,157
Grey Basalt.....	5	1,176
Grey Shale.....	5	1,181
Grey Basalt w/Thin Clay Layers.....	12	1,186
Grey Basalt.....	4	1,198
Grey Basalt w/Thin Clay Layers.....	7	1,202
Brown Clay.....	6	1,209
Grey-Brown Basalt.....	15	1,215
Grey Basalt (Hard).....	3	1,230
Grey-Brown Basalt.....	15	1,233
Lake Sediments		
Grey Andesite (Very Hard).....	19	1,248
Brown Shale (Caved In).....	48	1,267
Brown Shale.....	6	1,315
Layers of Sand, Shale & Clay.....	14	1,321
Light Brown Clay.....	15	1,335
Brown Rhyolite Chips & Clay.....	7	1,350
Idavada Pyroclastics		
Red-Brown Rhyolite.....	123	1,357
(Broken 1409-1455)		
1455 on Broken, Creviced and Caving Formation		
Total Depth.....		1,480
Main Flow - 1422' to 1455'		

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 10S, R 17E, Sec. 5, NENESE (Casing: 12-inch steel 1 to 18 feet; 8-inch steel 2 to 1091 feet; 6-inch steel 1080 to 1200 feet)			
Elevation: 3647			Water - Y/N
Quaternary and Tertiary Basalts			
Top Soil.....	3	0	
Hard Pan.....	13	3	
Grey Lava (16" to 19').....	12	16	
Brown Ash.....	5	28	
Brown Lava.....	18	33	
Brown Cinder.....	5	51	
Brown Lava (54°).....	84	56	Y
Red Lava.....	14	140	
Brown Lava.....	32	154	
Grey Lava (54°).....	68	186	
Brown Sandy Clay & Gravel.....	124	254	
Grey Lava (54°).....	26	378	
Brown Clay (55°).....	23	404	
Blue Clay.....	105	427	
Grey Lava & Rock.....	13	532	
White Clay.....	3	545	
Brown Sandstone.....	6	548	
Grey Lava.....	104	554	
Brown Sandstone.....	12	658	Y
Grey Lava (Very Hard).....	55	670	
Lake Sediments			
Brown Clay.....	10	725	
Blue Clay Shale.....	14	735	
Idavada Pyroclastics			
Black Rhyolite (63°).....	166	749	
Black Lava (Softer).....	23	915	
Black Lava (Hard) (63°).....	63	938	
Decomposed Lava or Rhyolite.....	74	1,001	
Brown & Red Sandstone, Broken			
Rhyolite (85°).....	10	1,075	Y
Red Rhyolite (12" to 1091').....	35	1,085	
Broken Red Rhyolite (90°).....	3	1,120	Y
Red Rhyolite.....	27	1,123	
Red Rhyolite Sand (90°).....	15	1,150	Y
Broken Red Rhyolite.....	15	1,165	
Red Rhyolite (8" to 1200').....	69	1,180	Y
Broken Rhyolite (91°).....	3	1,249	Y

Solid Red Rhyolite.....	48	1,252	
Broken Red Rhyolite.....	5	1,300	
Solid Red Rhyolite.....	70	1,305	
Broken Red Rhyolite.....	7	1,375	
Solid Red Rhyolite.....	68	1,382	Y
Total Depth.....		1,450	
Started Flowing 20 GPM at 1,075'			
Main Flow From 1180' to 1,252'			

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)
T 10S, R 17E, Sec. 10, NWSENW (Casing: 16-inch steel 1 to 23 feet; 12-inch steel 2 to 900 feet)		
Elevation: 3717		Water - Y/N
Quaternary Basalt		
Top soil.....	12	0
Grey Lava.....	36	12
Lava Ash.....	5	48
Grey Lava.....	77	53
Red Lava.....	7	130
Brown Lava.....	8	137
Red Lava.....	5	165
Grey Lava.....	68	170
Brown Lava.....	20	238
Brown Lava.....	5	258
Shoshone Falls Rhyolite		
Brown Rhyolite.....	11	263
Grey Rhyolite.....	41	274
Grey Rhyolite.....	123	315
Softer Grey Rhyolite (More Water)....	20	438
Red & Grey Broken Rhyolite - Water...	13	458
Red & Grey Broken Rhyolite - Lots of Water.....	47	471
Brown Rhyolite.....	10	518
Broken Grey Rhyolite - Water.....	3	528
Hard Grey Rhyolite.....	26	531
Broken Softer Red Rhyolite.....	26	557
Solid Grey Rhyolite.....	4	583
Grey Rhyolite (Very Hard).....	19	587
Broken Brown Rhyolite - Water.....	6	606
Solid Grey Rhyolite.....	13	612
Broken Grey Rhyolite - More Water....	13	625
Grey Rhyolite (Hard).....	60	638
Grey Shale (Some Black Rock) - More Water.....	16	698
Black Rhyolite, Broken - Water.....	83	714
Lake Sediments		
Broken Brown Rock.....	6	797
Brown Clay.....	6	803
Green Clay & Shale.....	33	809
Idavada Pyroclastics		
Broken Black Rock.....	28	842
Soft Red Rhyolite.....	9	870
Medium Black Rock.....	31	879

Hard Black Rock.....	16	910
Soft Brown Rock.....	6	926
Hard Black Rock.....	59	932
Soft Brown Sandstone.....	64	991
Grey Decomposed Rhyolite - Hit 81° Water.....	30	1,055
Grey Decomposed Rhyolite.....	36	1,085
Red Rhyolite.....	125	1,121
Broken Red Rhyolite - 89°.....	38	1,246
Solid Brown Rhyolite.....	124	1,284
Red Rhyolite.....	8	1,408
Broken Green & Pink Rhyolite - Some Water.....	4	1,416
Solid Brown Rhyolite.....	85	1,420
Grey Rhyolite.....	195	1,505
Total Depth.....		1,700

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)
T 10S, R 17E, Sec. 14, SESWSW (Casing: 6-inch steel 1 to 580 feet)		
Elevation: 3786		Water - Y/N
Quaternary Basalt		
Soil.....	10	0
Hard Pan.....	2	10
Lava.....	37	12
Lava Red.....	2	49
Lava.....	10	51
Clay & Shale, Medium Flow.....	12	61
Lava.....	4	73
Lava (Hard).....	14	77
Lava Red, Medium Flow.....	3	91
Lava (Hard).....	11	94
Lava.....	16	105
Loose Formation - Small Flow.....	3	121
Lava.....	12	124
Lava Red.....	5	136
Lava.....	50	141
Lava Red - Small Flow.....	14	191
Lava.....	60	205
Piller Falls Mud Flow		
Boulders - Small Flow.....	28	265
Shoshone Falls Rhyolite		
Lava.....	17	293
Reaming well from 6 1/4 to 8 1/4		
Lava (Hard).....	92	310
Crevice & Talc.....	1	402
Lava (Hard) - More Water.....	9	403
Clay.....	4	412
Broken Formation of Hard Rock.....	2	416
Lava.....	2	418
Clay.....	2	420
Lava (Hard).....	36	422
Clay.....	2	458
Lava (Hard).....	15	460
Lava (Soft).....	3	475
Lava (Hard).....	22	478
Lava (Soft).....	10	500
Lava (Hard).....	68	510
Clay.....	4	578
Blue Clay.....	6	582
Lava.....	12	588
Red Lava - More Water.....	5	600
Black Lava.....	22	605
Clay.....	2	627
Lava.....	9	629

Clay.....	3	638
Lava.....	7	641
Lava (Soft) - More Water.....	3	648
Lava (Hard).....	21	651
Blue Mud & Clay - More Water.....	6	672
Lava.....	9	678
Blue Mud & Boulders.....	23	687
Rock.....	28	710
Blue Clay - More Water.....	1	738
Lava (Hard).....	21	739
Lava (Hard) - Reaming Out Wall.....	70	760
Lava (Hard).....	100	830
Lava (Hard) - More Water.....	5	930
Lava (Hard).....	45	935
Lake Bed		
Limestone.....	45	980
Quartz Crystals.....	6	1,025
Shale.....	24	1,031
Lake Bed.....	30	1,055
Idavada Pyroclastics		
Red Granite.....	46	1,085
Sandstone - Water Strong.....	4	1,131
Sandstone - Water Strong.....	19	1,135
Total Depth.....		1,154

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)
T 10S, R 18E, Sec. 6, NWNWNW (Casing: 10-inch steel 1 1/2 to 6 1/2 feet; 8-inch steel 1 to 149 feet; 6-inch steel to 1173 feet)		
Elevation: 3585		Water - Y/N
Quaternary Basalts		
Brown Clay.....	1	0
Quaternary Basalt (Hansen Butte).....	29	1
Light Clay.....	6	30
Brown Basalt.....	14	36
Grey Basalt.....	14	50
Brown Clay.....	2	64
Red-Brown Basalt.....	6	66
Grey Basalt.....	38	72
Grey Silty Clay and Gravel.....	15	110
Brown Basalt.....	5	125
Basalt (Slightly Green).....	5	130
Gravel, Silt & Sand.....	15	135
Shoshone Falls Rhyolite		
Decomposed Rhyolite.....	17	150
Brown Rhyolite.....	202	167
Grey-Brown Rhyolite.....	16	369
Grey Rhyolite.....	60	385
Grey-Brown Rhyolite.....	20	445
Brown Rhyolite.....	27	465
Grey Rhyolite.....	11	492
Dark Sand.....	4	503
Black Rock (Soft & Shiny).....	11	507
Lake Sediments		
Rock and Clay in Layers.....	19	518
Brown Clay.....	9	537
Idavada Pyroclastics		
Brown Rhyolite.....	4	546
Brown Clay.....	3	550
Grey Rhyolite.....	45	553
Red-Brown Clay.....	4	598
Black Rhyolite.....	24	602
Red-Brown Clay.....	5	626
Brown Rhyolite.....	4	631
Tan and Green Shale.....	21	635
Andesite (Very Hard).....	89	656
Black Rhyolite & Grey Clay in Layers.	34	745
Brown Clay (Sticky).....	4	779
Andesite & Grey Clay Layered (Very Hard).....	97	783
Grey Clay & Shale.....	13	880

Andesite & Grey Clay Layered (Very Hard).....	22	893	
Brown Clay.....	5	915	
Andesite (Very Hard).....	35	920	
Brown Clay.....	3	955	
Grey Rhyolite.....	31	958	
Grey Clay (Sticky).....	6	989	
Grey Rock & Clay Seams.....	39	995	
Brown Clay.....	6	1,034	
Grey Rhyolite.....	3	1,040	
Brown Clay.....	7	1,043	
Tan Clay.....	15	1,050	
Greenish-Grey Shale & Clay.....	72	1,065	
Black Rhyolite.....	13	1,137	
Clay & Sand Layers.....	18	1,150	
Black Rhyolite.....	22	1,168	
1st Flow, Very Small.....		1,180	Y
Black Rhyolite w/Thin Layers of Grey Shale.....	45	1,190	
Grey-Black Rhyolite.....	65	1,235	
Total Depth.....		1,300	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 10S, R 19E, Sec. 1, SESESE			
(Casing: 8-inch steel 0 to 47 feet;			
6-inch steel 0 to 1460 feet;			
5-inch steel 13 to 1925 feet;			
3-inch steel 1900 to 2160 feet			
Perforations: 50 - 1400 to 1925 feet;			
150 - 2100 to 2160 feet)			
Elevation: 3952		Water - Y/N	
Quaternary Basalt			
Brown Clay.....	42	0	
Grey Basalt.....	10	42	
Grey Scoria.....	31	52	
Grey Basalt.....	32	83	
Grey Scoria.....	21	115	
Brown Cinders.....	34	136	
Caving Rock.....	10	170	
Grey Basalt.....	20	180	
Black Basalt.....	30	200	
Brown Scoria.....	20	230	
Grey Scoria.....	18	250	
Grey Basalt (Hard).....	6	268	
Grey Scoria.....	23	274	Y
Grey Basalt.....	11	297	Y
Grey Scoria.....	66	308	Y
Grey Basalt.....	6	374	Y
Grey Scoria.....	23	380	Y
Grey Basalt & Clay.....	12	403	Y
Brown Basalt.....	50	415	Y
Grey Basalt.....	17	465	Y
Brown Clay.....	4	482	
Brown Basalt.....	36	486	
Brown Clay.....	3	522	
Brown Scoria.....	3	525	
Brown Basalt w/Clay Layers.....	13	528	
Brown Clay.....	8	541	
Brown Basalt.....	18	549	
Brown Clay w/Layers of Basalt.....	7	567	
Brown Basalt.....	31	574	
Grey-Brown Basalt.....	36	605	
Red Clay & Brown Basalt.....	23	641	Y
Grey-Brown Basalt.....	16	664	
Grey Basalt.....	63	680	
Grey Sand.....	4	743	
Grey Basalt.....	17	747	
Brown Basalt.....	13	764	

Idavada Pyroclastics

Grey-Brown Rhyolite.....	27	777	
Brown Rhyolite.....	92	804	
Grey Rhyolite.....	215	896	
Black Rhyolite.....	11	1,111	
Brown Shale.....	11	1,122	
Brown Rhyolite.....	9	1,133	
Brown Clay.....	3	1,142	
Brown Rhyolite.....	7	1,145	
Grey Rhyolite.....	13	1,152	
Andesite (Very Hard).....	9	1,165	
Red Clay.....	2	1,174	
Grey Rhyolite.....	7	1,176	
Brown Clay.....	19	1,183	
Grey Rhyolite.....	12	1,202	
Brown Clay.....	3	1,214	
Grey Clay & Rhyolite.....	14	1,217	
Grey Rhyolite.....	2	1,231	
Grey Clay.....	42	1,233	
Grey Rhyolite.....	11	1,275	
Grey Clay & Shale.....	16	1,286	
Grey Rhyolite.....	59	1,302	
Grey Clay (Sticky).....	7	1,361	
Grey Sand.....	5	1,368	
Dark Grey Clay (Sticky).....	40	1,373	
Grey Sandy Clay.....	27	1,413	
Tan Clay (Sticky).....	6	1,440	
Grey Clay (Sticky).....	14	1,446	
Andesite (Very Hard).....	69	1,460	
Brown Clay (Sticky).....	4	1,529	
Sandy Clay.....	5	1,533	Y?
Red-Brown Sandy Clay.....	17	1,538	
Grey Clay (Sticky).....	20	1,555	
Grey Shale.....	4	1,575	
Grey Shale (Sticky).....	11	1,579	
Grey Clay (Sticky).....	5	1,590	
Grey Sandy Clay.....	5	1,595	Y?
Grey Shale.....	18	1,600	
Grey Clay & Shale.....	10	1,618	
Black Rhyolite.....	42	1,628	
Red Clay.....	15	1,670	
Grey Shale & Clay Layered.....	15	1,685	
Grey Rhyolite.....	5	1,700	
Grey Shale.....	10	1,705	
Grey Rhyolite.....	5	1,715	
Grey Clay (Sticky).....	115	1,720	
Light Grey Pumice Clay.....	8	1,835	
Light Green Pumice Clay.....	10	1,843	
Light Grey Clay (Sticky).....	22	1,853	
Grey Shale (Caving).....	75	1,875	
Dark Grey Clay w/Thin Shale Layers...	39	1,950	
Grey Shale.....	2	1,989	
Dark Grey Clay w/Thin Layers of Shale	21	1,991	
Light Blue-Grey Clay.....	33	2,012	

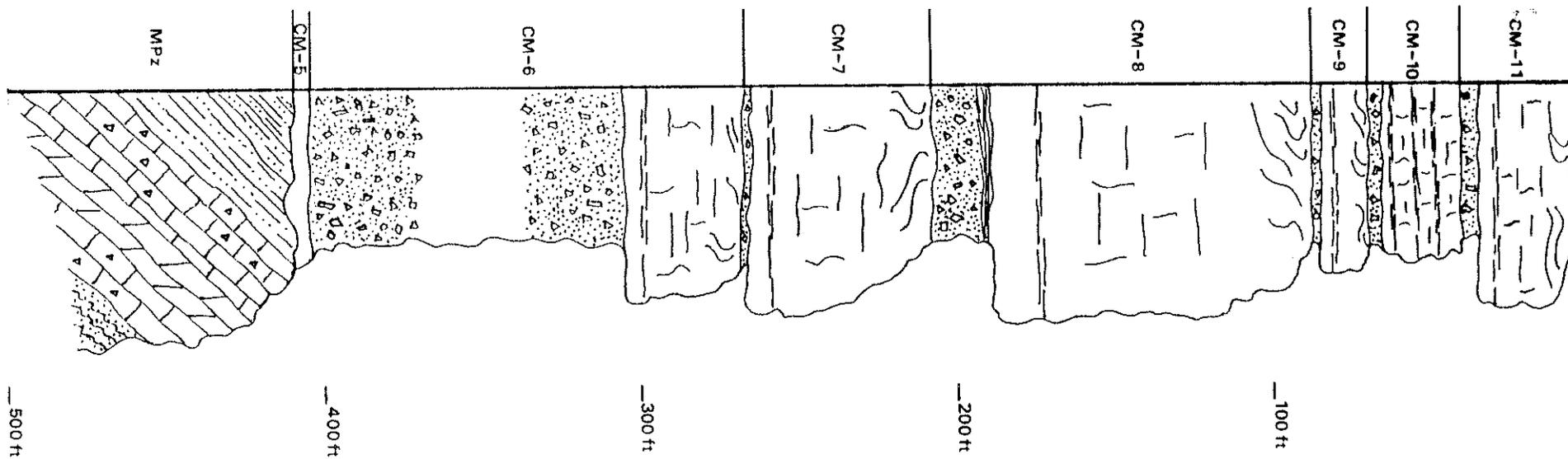
Dark Grey Clay.....	12	2,045	
Dark Grey Shale.....	6	2,057	
Light Grey Clay.....	49	2,063	
Light Grey Sand.....	7	2,112	
Grey Shale w/Alternating Layers of Green Sand.....	37	2,119	Y
Grey-Green Rock (Rock is fine grained and Very Hard).....	4	2,156	
Total Depth.....		2,160	

LOGS OF WELLS

Material	Thickness (feet)	Depth (feet below land surface)	
T 14S, R 15E, Sec. 16, SESWSE (Casing: 8-inch steel 2 to 143 feet)			
Elevation: 4931			Water - Y/N
Tertiary Basalts			
Top Soil.....	5	0	
Grey Lava.....	22	5	
Red-Brown Sandy Clay.....	32	27	
Grey Lava.....	56	59	
Red-Brown Lava Ash & Cinders.....	48	115	
Brown Clay & Gravel.....	72	163	
Brown Sandy Clay.....	45	235	
Black Lava Cinders.....	32	280	
Black Lava (Hard).....	11	312	
Idavada Pyroclastics			
Brown Rhyolite.....	147	323	
Broken Brown Rhyolite.....	65	470	
Red Cinders & Talc.....	33	535	
Grey Rhyolite.....	7	568	
Broken Red Rhyolite.....	43	575	
Hard Red Rhyolite.....	17	618	
Broken Red Rhyolite.....	57	635	
Brown Clay.....	12	692	
Broken Brown Rhyolite & Grey Clay....	112	704	
Solid Red Rhyolite.....	109	816	
Solid Grey Rhyolite.....	51	925	
Tan Clay.....	24	976	
Broken Red Rhyolite & Clay.....	60	1,000	
Hard Red Rhyolite.....	22	1,060	
Red Clay.....	56	1,082	
Hard Red Rhyolite.....	95	1,138	
Broken Red Rhyolite.....	19	1,233	
Black Lava.....	8	1,252	
Red Lava Ash.....	15	1,260	
Brown Clay & Lava.....	32	1,275	
Black Sandy Clay.....	6	1,307	
Brown Rhyolite.....	152	1,313	Y
Grey Rhyolite.....	45	1,465	
Red Rhyolite.....	30	1,510	
Void	11	1,540	
Crevice and Broken Rock.....	10	1,551	
Hard Rock.....	49	1,561	
Total Depth.....		1,610	

APPENDIX B

GENERALIZED STRATIGRAPHIC SECTION
FOR THE
CASSIA MOUNTAINS



B-1

APPENDIX B
 Generalized Stratigraphic Section for the Cassia Mountains

Units identified as CM-5 through CM-11 each includes a densely welded rhyolitic ash-flow tuff and the underlying non-welded pyroclastics. All geochemistry samples were taken from densely welded units.

MPz - Pre-Cenozoic marine sedimentary rocks.

APPENDIX C

CHEMICAL ANALYSIS OF IDAVADA PYROCLASTICS
AND THE SHOSHONE FALLS RHYOLITE
TECHNIQUES AND RESULTS

CHEMICAL ANALYSES TABLES

Samples CM10-1, CM10-2, CM9-1, CM9-2, CM11-3, CM11-2, CM11-1, CM10-4 and CM10-3 were analyzed at the University of Utah Research Institute Earth Science Laboratory. The samples were crushed and split in a tungsten carbide shatterbox, pulverized to -200 mesh. The samples were then fused with lithium borate followed by the appropriate dilutions. Major elements, except silica were then analyzed by Inductively Coupled Spectrometry. Silica and the trace elements were analyzed by inductively coupled plasma spectrometry.

Samples CM8-1, CM8-2, CM8-3, CM8-4, CM8-5, CM7, CM5, SF1, SF2 and WC1 were analyzed at Rice University Department of Geology and Geophysics. The samples were crushed and prepared for analysis in the form of lithium metaborate fusion followed by appropriate dilutions. Six of the samples were prepared in duplicate. Major element concentrations were analyzed using Inductively Coupled Spectrometry.

	CM 11-3	CM 11-2	CM 11-1	CM 10-4	CM 10-3
% oxide					
SiO ₂	70.70	73.05	66.80	65.87	73.41
Al ₂ O ₃	13.00	12.24	14.87	11.83	11.71
TiO ₂	0.53	0.49	0.63	0.61	0.47
Fe as Fe ₂ O ₃	4.24	3.96	4.86	4.23	3.21
MnO	0.08	0.07	0.10	0.07	0.05
CaO	1.61	1.19	1.87	4.74	1.06
MgO	0.32	0.29	0.97	0.50	0.24
K ₂ O	5.27	2.91	3.88	4.10	4.00
Na ₂ O	3.18	3.32	2.11	2.86	2.61
P ₂ O ₅	<u>0.08</u>	<u>0.08</u>	<u>0.61</u>	<u>0.11</u>	<u>0.06</u>
Total	99.01	97.60	96.70	94.92	96.82
LOI	1.48	.44	2.87	3.00	1.62
Ba (% oxide)	0.14	0.14	0.11	0.12	0.14
Sr	103.	95.	149.	143.	68.
Co	34.	12.	7.	8.	13.
Cu	6.	10.	24.	10.	6.
Pb	11.	14.	20.	11.	18.
Zn	105.	93.	103.	105.	75.
Sb	L30.	L30.	33.	L30.	31.
Li	20.	9.	34.	12.	16.
Be	3.	3.	4.	2.	3.
Zr	545.	462.	470.	312.	480.
La	98.	91.	92.	87.	93.
Ce	173.	160.	163.	143.	167.
F	670.	90.	540.	340.	310.

Minor elements in parts per million.

	CM 8-5	CM 8-4	CM 8-3	CM 8-2	CM 8-1
% oxide					
SiO ₂	73.70	74.62	73.76	71.81	73.21
Al ₂ O ₃	11.84	11.64	11.90	12.71	12.21
TiO ₂	0.31	0.30	0.28	0.64	0.49
Fe as Fe ₂ O ₃	2.42	2.46	2.23	4.56	2.93
MnO	0.04	0.02	0.02	0.07	0.03
CaO	0.59	0.46	0.27	1.70	0.68
MgO	0.13	0.07	0.06	0.49	0.17
K ₂ O	5.66	5.28	5.34	4.38	5.91
Na ₂ O	2.72	3.23	3.07	3.28	2.10
P ₂ O ₅	<u>0.07</u>	<u>0.07</u>	<u>0.05</u>	<u>0.15</u>	<u>0.10</u>
Total	97.48	98.15	96.98	99.79	97.83
LOI	2.55	0.41	0.37	0.56	3.01

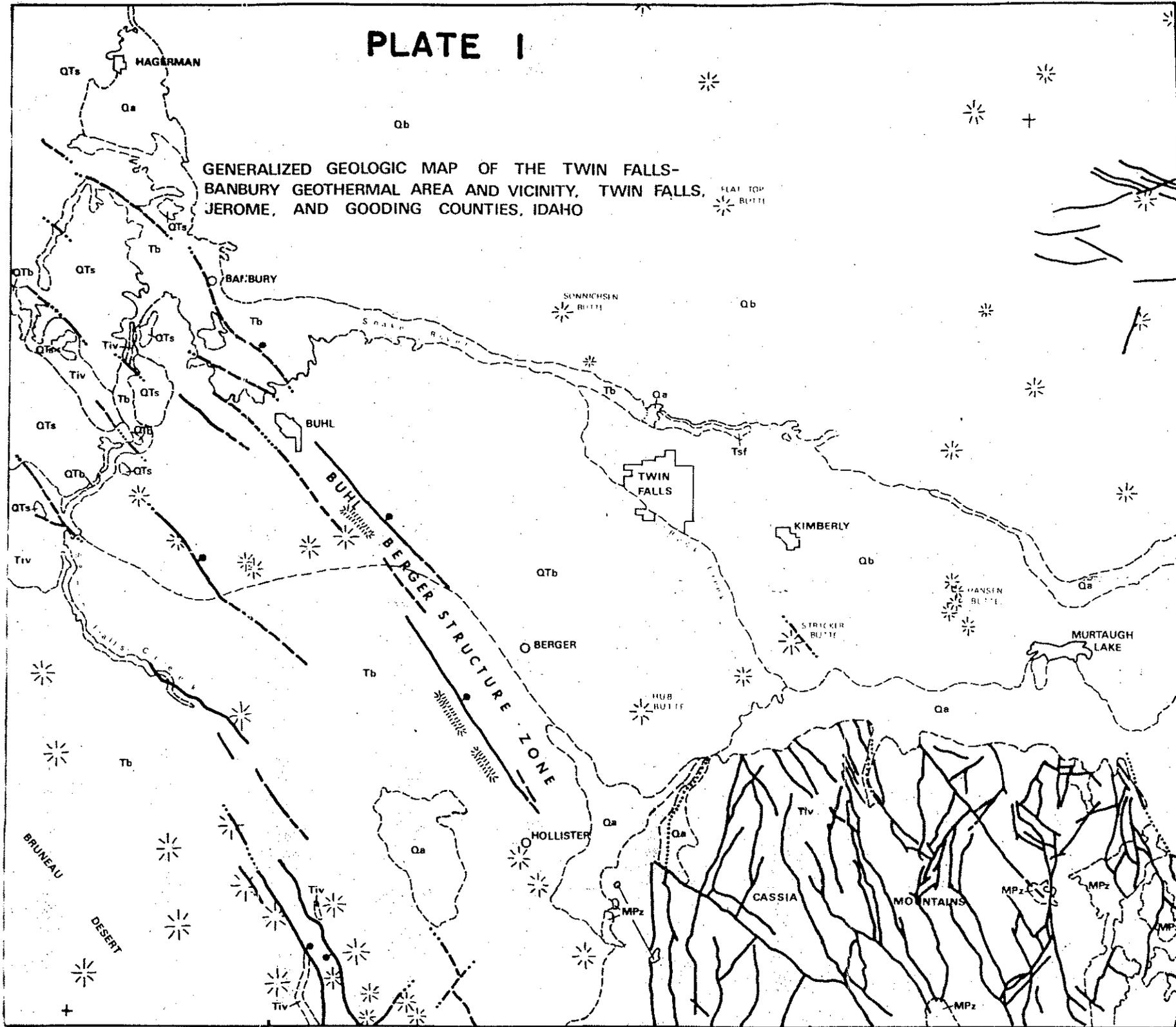
	CM 10-2	CM 10-1	CM 9-2	CM 9-1
% oxide				
SiO ₂	72.30	72.41	71.40	68.80
Al ₂ O ₃	11.39	11.67	12.20	12.63
TiO ₂	0.51	0.48	0.47	0.56
Fe as Fe ₂ O ₃	3.20	3.25	4.03	4.73
MnO	0.05	0.05	0.07	0.08
CaO	1.28	1.10	1.38	1.87
MgO	0.42	0.24	0.27	0.39
K ₂ O	4.79	5.32	3.35	4.95
Na ₂ O	2.33	2.69	3.02	2.96
P ₂ O ₅	0.03	0.06	0.08	0.11
Total	96.30	97.27	96.27	97.08
LOI	2.62	1.50	1.70	1.28
Ba (% oxide)	0.12	0.14	0.13	0.14
Sr	88.	68.	82.	112.
Co	33.	41.	11.	32.
Cu	6.	6.	6.	7.
Pb	15.	18.	18.	L10.
Zn	65.	93.	93.	103.
Sb	L30.	L30.	33.	L30.
Li	17.	16.	18.	9.
Be	3.	3.	3.	3.
Zr	436.	481.	567.	554.
La	81.	92.	95.	94.
Ce	141.	164.	167.	163.
F	210.	310.	540.	120.

Minor elements in parts per million.

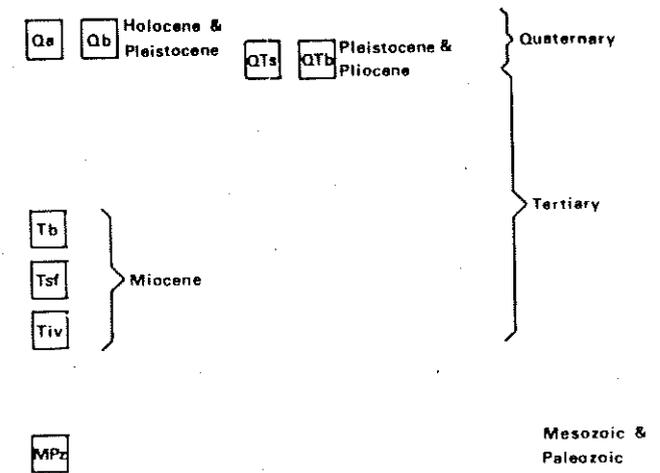
	CM 7	CM 5	SF 1	SF 2	WC 1
% oxide					
SiO ₂	65.21	71.93	71.54	68.65	74.72
Al ₂ O ₃	13.04	12.02	13.72	13.48	12.35
TiO ₂	0.77	0.43	0.69	0.69	0.36
Fe as Fe ₂ O ₃	5.34	3.57	4.66	4.69	2.95
MnO	0.08	0.04	0.07	0.07	0.05
CaO	2.45	0.87	1.82	1.98	0.61
MgO	0.74	0.20	0.72	0.67	0.17
K ₂ O	4.77	5.54	4.71	4.93	4.92
Na ₂ O	2.88	2.44	3.53	3.17	3.39
P ₂ O ₅	<u>0.22</u>	<u>0.08</u>	<u>0.18</u>	<u>0.16</u>	<u>0.06</u>
Total	95.50	97.12	101.64	98.49	99.58
LOI	1.87	2.95	.36	1.75	.26

PLATE I

GENERALIZED GEOLOGIC MAP OF THE TWIN FALLS-BANBURY GEOTHERMAL AREA AND VICINITY, TWIN FALLS, JEROME, AND GOODING COUNTIES, IDAHO

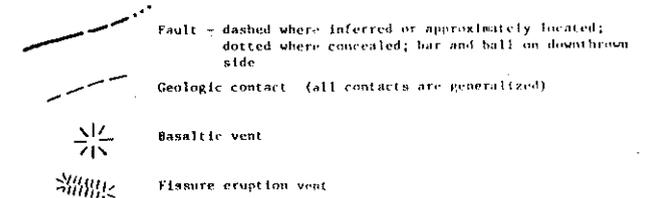


Correlation of Map Units



Description of Map Units

- Qa - Quaternary Sedimentary Rocks - Holocene and Pleistocene gravels, sands, silts and clays. Includes Melon Gravel along the Snake River in the western part of the area and Snake River deposits in the east. Also includes large areas of stream and lake deposits along the northern margin of the Cassia Mountains.
- Qb - Quaternary Olivine Basalt Lava Flows - Includes flows from Hansen Butte and flows of Snake River Group Basalt from numerous vent areas north of the Snake River Canyon. Many flows show young constructional features such as aa and pahoehoe lava surfaces and pressure ridges.
- QTs - Lower Pliocene to Upper Pleistocene Continental Sedimentary Units - Includes stream and lake sediments primarily of the Glenns Ferry Formation. Composed of gravel, sand, silt, clay and interbedded volcanic ash beds.
- QTb - Lower Pliocene to Upper Pleistocene Olivine Basalt Lava Flows - Includes flows from Hub Butte and other vents in the southwestern and western part of the area. Some units within the Glenns Ferry Formation are included. Constructional features generally removed by erosion or obscured by loess.
- Tb - Lower Miocene to Upper Pliocene Banbury Basalt - Consists of lava flows of olivine basalt locally interbedded with stress and lake sediments. Basalts are commonly altered to greenish brown saprolite with residual spheroids of undecomposed rock. Sediments composed of lenticular channel deposits of sand and pebble gravel and light colored silt, clay and diatomite in massive lake deposits.
- Tsf - Rhyolite Lava Flow of Shoshone Falls - Porphyritic light gray devitrified single lava flow. Contains zones of sheeted or platy fractures. Columnar jointing isn't pronounced but strong vertical fractures are abundant. Phenocrysts are predominantly plagioclase with minor amounts of pyroxene and opaque oxides.
- Tiv - Welded Ash-Flow Tuff Sheets of the Idavada Volcanic Group - Predominantly densely welded units separated by airfall, water-lain and non-welded ash-flow tuff. Densely welded units are typically zoned from base to top: bedded base surge clastics, basal vitrophere, thick massive central devitrified lithoidal zone, and a thin upper lithoidal vapor phase zone showing prominent flow structures and scattered vitrophere.
- MPz - Mesozoic and Paleozoic Marine Sedimentary Rocks of the Cassia Mountains - Includes limestone, dolomitic limestone, siltstone, chert, and quartzite. Formations include lower Triassic Dinwoody, lower Permian Phosphoria and Grandeur Tongue of the Park City and several other locally delineated Permian and possible Ordovician units.



Scale 1:250,000

