SUSANVILLE GEOTHERMAL INJECTION WELL NO. 1

SGI-1

WELL COMPLETION REPORT

February 13, 1989

Contract No. 2-G-89

Project 89-46Ø

Prepared for:

CALIFORNIA ENERGY COMMISSION

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1.Ø SUMMARY AND CONCLUSIONS

1. Susanville Geothermal Injection Well No. 1 (SGI-1) was designed to inject 75Ø gallons per minute (gpm) of geothermal effluent from the City of Susanville, California's district space heating system, with a maximum pressure of 65 p.s.i.g. measured at land surface. Target depth for SGI-1 was 65Ø+/- feet. The well was drilled and completed to a depth of 655.5 feet below land surface in August, 1988.

2. Geologic materials penetrated by SGI-1 comprised Recent soil/alluvial deposits and Pleistocene basalt/Lahontan (near-shore) lake deposits. These formation materials were consistent with those encountered in test hole Suzy-6 drilled near the SGI-1 site by the U.S. Bureau of Reclamation in 1979.

3. No formal aquifer stress tests were performed on SGI-1. A first approximation of the specific capacity (productivity index) for the well was advanced from information obtained while bailing the well during initial well development. The value of approximately Ø.1 gallon per minute per foot of drawdown (gpm/ft) is essentially one one-hundredth of that determined for the City's production well, Susan-1.

4. The low specific capacity of SGI-1 indicates that the well is not capable of injecting significant quantities of geothermal effluent back into the geothermal aquifer. Lithologic and geophysical data suggest that permeable horizons in the geothermal aquifer, which are known to exist at similar depths elsewhere, are not present at this locale.

5. Investigations into the disposal of the City's thermal effluent continued beyond the drilling of SGI-1. Most recent studies focused on re-injection at relatively shallow depths near the top of the geothermal reservoir. Chemical data from samples collected from the horizon of interest (depth of approximately 1ØØ feet), in a well near the SGI-1 site, indicate that the water derived from Susan-1, the City's production well, is similar in character to the shallow thermal water.

6. Potential impacts due to re-injection at shallow depths in the geothermal aquifer were investigated by means of an aquifer stress test of an existing shallow geothermal well, referred to as Allen Well No. 2, located approximately 1,5ØØ feet east-southeast of the SGI-1 site. A 24 hour duration constant-discharge test was performed January 17-18, 1989. Aquifer Transmissivity was calculated to be approximately 3,ØØØ gallons per day per foot (GPD/ft), a value which com-

pares closely to the value of 3,400 GPD/ft derived from testing of the nearby Davis-1 well. Coefficient of Storage was calculated to be 0.00006 which is consistent with previously derived values. The shallow geothermal aquifer can be described as a "leaky" artesian aquifer. It is separated from the overlying alluvial aquifer by an aquitard with a vertical hydraulic conductivity of approximately 0.04 gallons per day per square foot (GPD/ft^2).

6. The results of testing Allen #2 suggest that re-injection into the shallow geothermal aquifer in the proximity of SGI-1 is not practical. Because of the moderate Transmissivity of the aquifer materials, excessive injection pressure would be required to re-inject effluent at a rate of 750 gallons per minute. Consequences of this high pressure injection include high energy costs and development of a large upward hydraulic gradient from the basaltic aquifer to the overlying alluvial aquifer. The upward gradient will induce vertical leakage of the injectate and result in degradation of the chemical quality of the alluvial aquifer.

7. Investigations into the disposal of geothermal effluent from the City of Susanville are not complete. Considering the results of this and previous efforts to effect disposal of the geothermal effluent through re-injection, siting a successful injection well which will meet physical and regulatory constraints is no mean task. The well must penetrate sufficiently permeable reservoir materials to keep injection pressure low enough for affordable energy costs and to prevent fracturing of, or leakage into, the overburden. The well must be located to preclude unacceptable impacts on drinking water supplies. It must also be sufficently remote from geothermal production wells to prevent recirculation of the cooled thermal effluent.

2.Ø INTRODUCTION

Susanville Geothermal Injection Well No. 1 (SGI-1) lies within the Susanville Geothermal Anomaly. The well site is located south of the community of Susanville, Lassen County, California within the SE1/4 NW1/4 of Section 5, Township 29 North, Range 12 East, M.D.B.&M. (Figure 1), near the southern margin of the resource. Several geothermal production wells (Figure 2) tap the aquifer including two (Susan-1 and the Naef Well) which are utilized by the City to supply heat to a district space heating system (Figure 3). The extent and nature of the anomaly has been studied extensively (USBR, 1982; Geothermex, 1984; among others) but will not be discussed in detail in this well completion report.

SGI-1 was designed for the purpose of disposing of up to 75Ø gpm of heat-spent thermal effluent from the City's district space heating system via re-injection into the geothermal aquifer at a maximum pressure measured at the land surface of 65 p.s.i.g. (City of Susanville, 1987). Disposal of the effluent is presently accomplished via surface discharge to the Ramsey Ditch. The ditch discharges into Gold Run Creek, thence to the Susan River. The City maintains a comprehensive and expensive program to monitor the impacts of the discharge on the surface-water system.

While the re-injection well's primary purpose is disposal of the thermal effluent, it has two secondary purposes; 1) maintenance of the piezometric head of the aquifer, 2) reduction of the high cost of monitoring the surface water discharge.

The location and design of SGI-1 represented a joint effort on behalf of BGI (the Berkeley Group, Inc.) and the City of Susanville, with input from the California Division of Oil and Gas and the California Energy Commission. The site was constrained by subsurface geology, land ownership, and access (R. Schroeder, BGI, 1988). A target depth of 65Ø feet was selected to penetrate permeable beds in near-shore lake deposits and basalt flows. These drilling targets were identified on the basis of results obtained during the drilling of Suzy-6, a 623 foot deep test well drilled by the Bureau of Reclamation near the site of SGI-1 (USBR, 1982). The targets were known to exist at a depth of approximately 65Ø feet in the nearby well at the Tsuji Nursery (R. Juncal, 1988).

In March of 1988, a contract to drill and test SGI-1 was awarded to the Layne-Western Company, Inc. of Woodland, California with drilling of the well taking place in August. Technical assistance for the proposed drilling and testing of the well, as well as the subsequent monitoring program was provided by the Oregon

(map base: USGS Susanville, CA 15-min. topo. quad.)

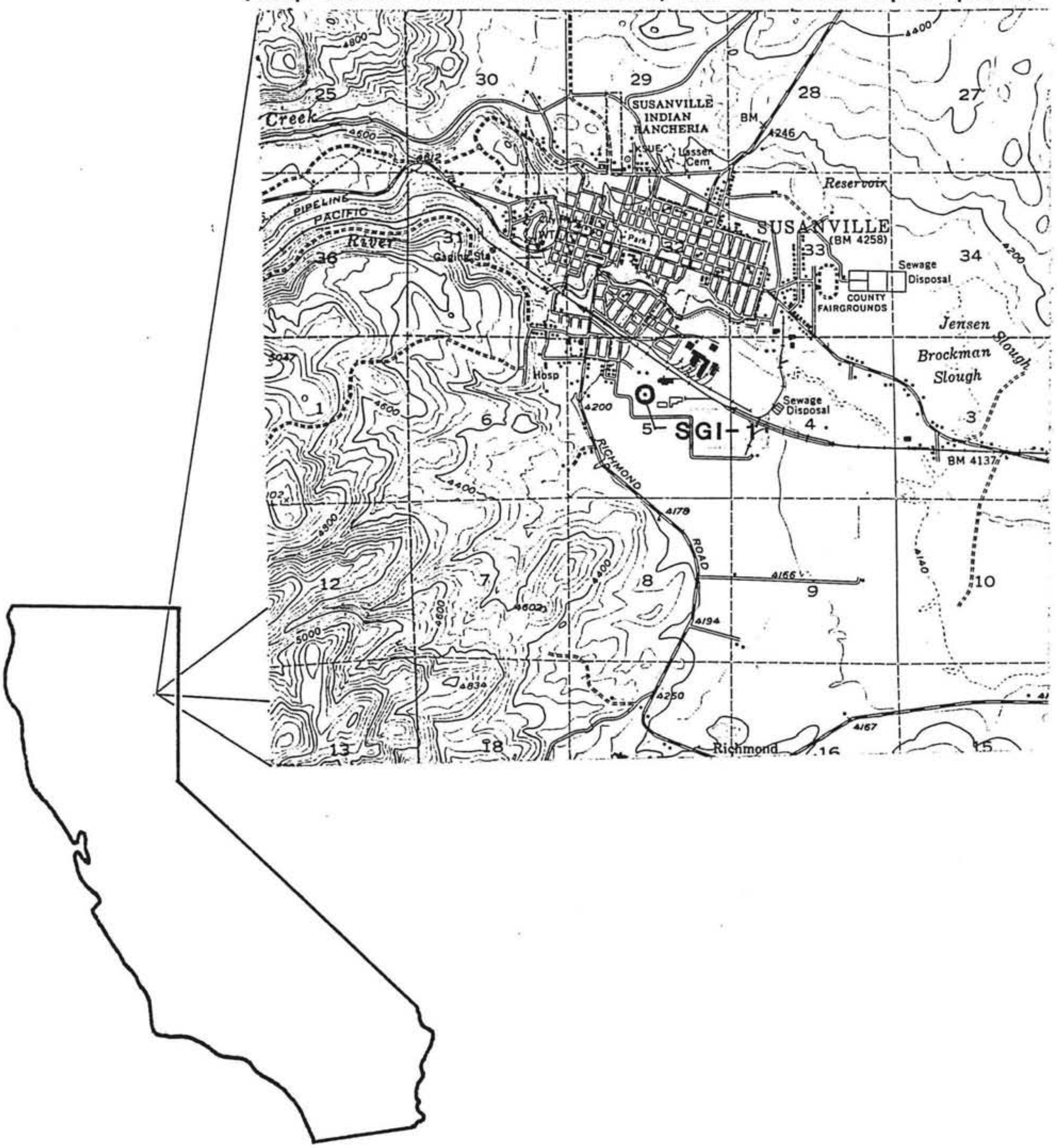


Figure 1. Generalized project location map.

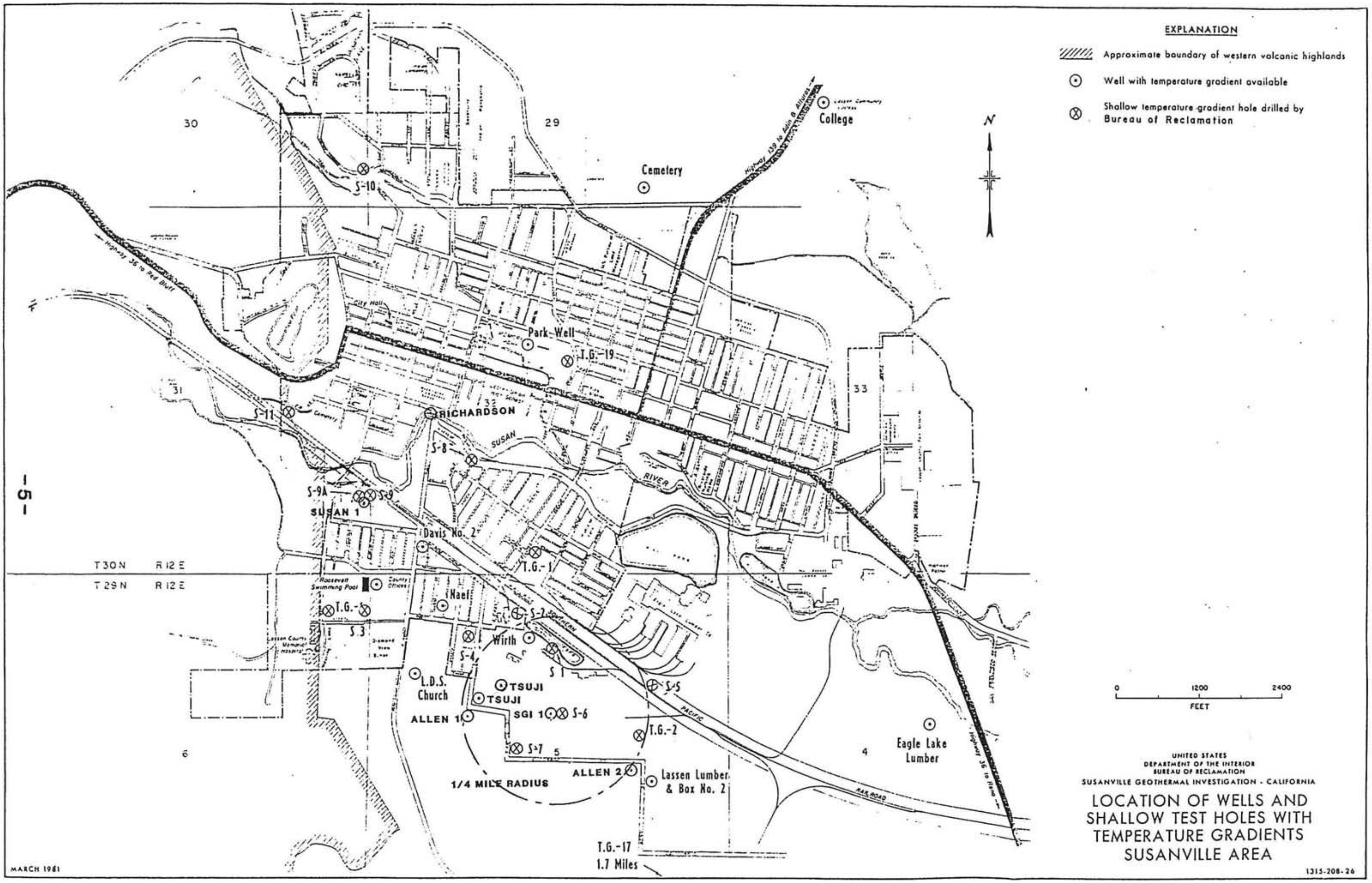


Figure 2. Geothermal wells, Susanville geothermal anomaly.

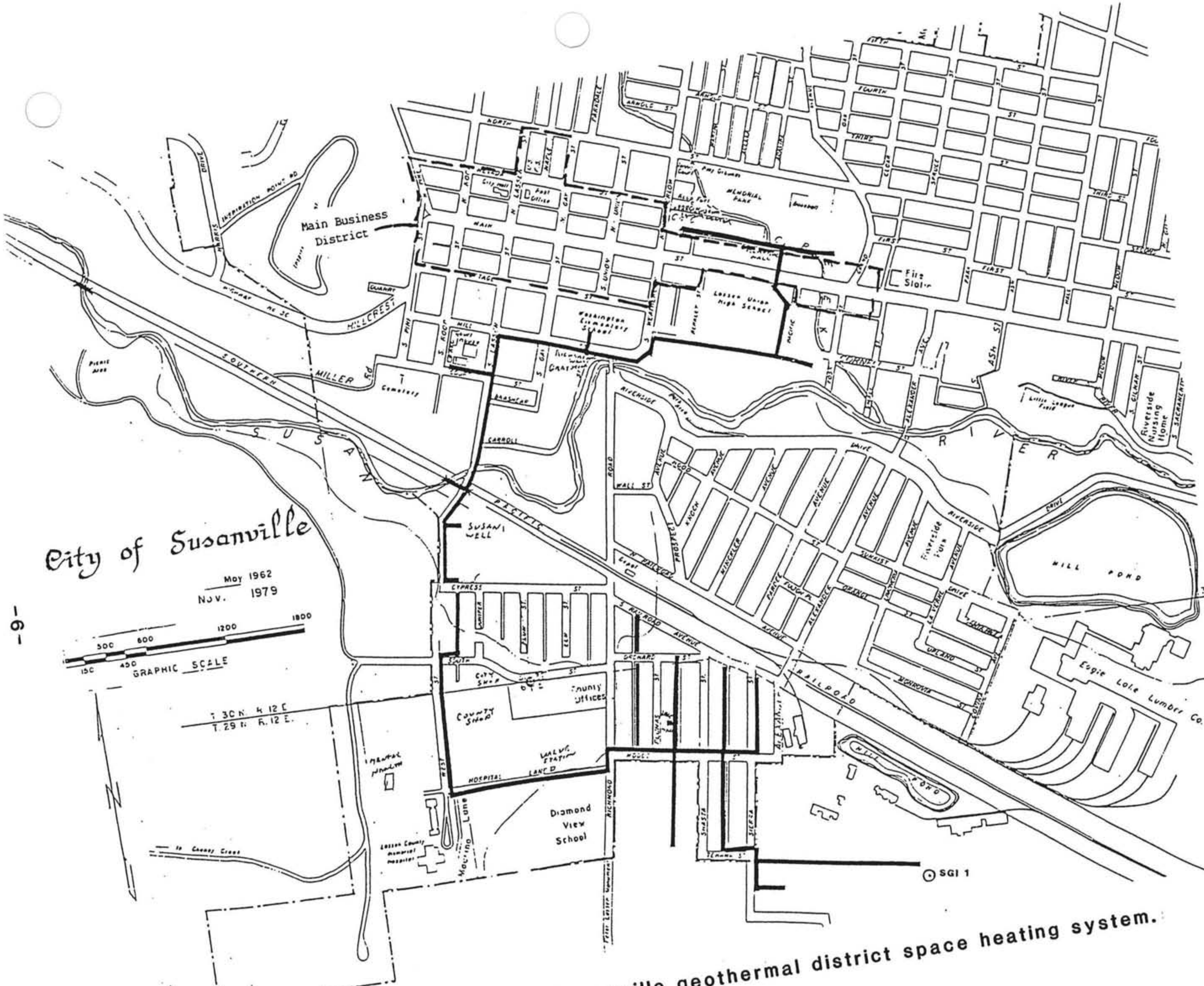


Figure 3. City of Susanville geothermal district space heating system.

Institute of Technology (OIT), under Contract to the California Energy Commission. WILLIAM E. NORK, INC. (WEN, INC.) was contracted by OIT to oversee the drilling operations, provide well-site quality assurance, and geologic consulting services.

This report summarizes the results of the drilling program. It lists several alternatives for disposal of the thermal effluent from the City system and discusses one of these alternatives, that is, re-injection into the geothermal reservoir at relatively shallow depths. It also describes the testing of a shallow geothermal well located southeast of the SGI-1 site which provides information regarding potential impacts of this proposed alternative.

3.0 HYDROGEOLOGY

The hydrogeology of the Susanville Geothermal Anomaly has been discussed in some detail by several investigators, most recently the U.S. Bureau of Reclamation [1982] and Geothermex [1984]. No new insight into the general hydrogeology of the Susanville area was derived as a result of drilling SGI-1. Therefore, the conclusions of these earlier reports are still valid and they will not be reprised herein. However, a few of the salient features of the resource are summarized below.

- The Susanville anomaly comprises a low-temperture resource. The highest recorded temperature is 182°F (83°C).

- The areal extent of the resource is small. It is fault controlled and subdivided into at least five different structural blocks (Figure 4).

- Geothermal aquifer rocks include fractured basaltic lava flows, permeable sediments, and scoriaceous zones at the top and bottom of individual lava flows.

- Hot water upwells in the northwestern portion of the anomaly and cools by mixing and conduction as it moves laterally to the southeast.

- Geothermal reservoir transmissivity ranges from 1×10^6 md-ft/cp (8,000 gallons per day per foot at 70°F) to 4.5×10^6 md-ft/cp (36,000 gpd/ft).

The top of the geothermal reservoir is inferred from borehole temperature survey data for the various wells and test holes (Geothermex, 1984) and is depicted in Figure 5. In the vicinity of SGI-1, the top of the reservoir (geothermal aquifer) is roughly coincident with the bottom of a shallow (65 to 100 feet deep) basalt lava flow sequence.

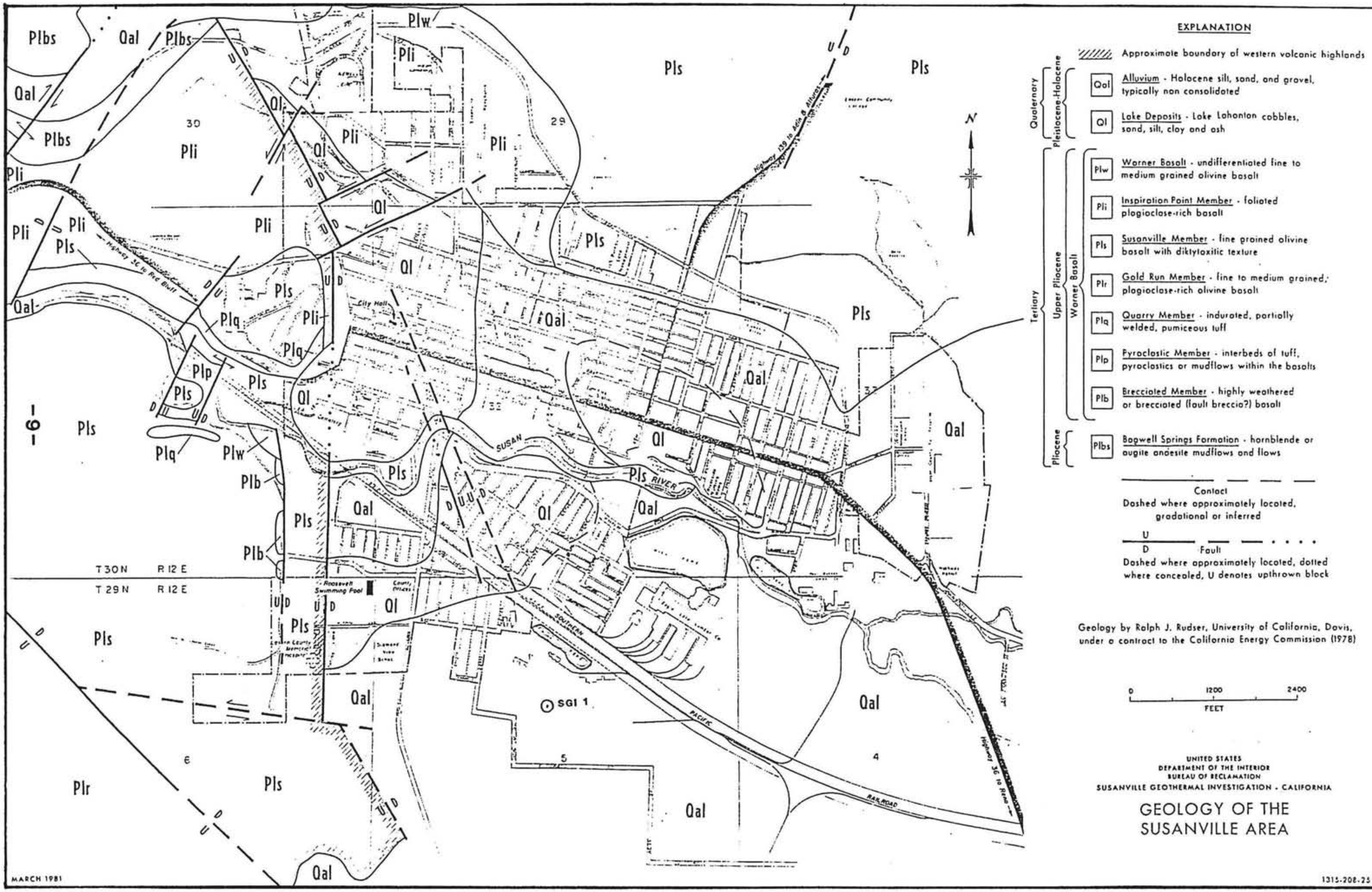
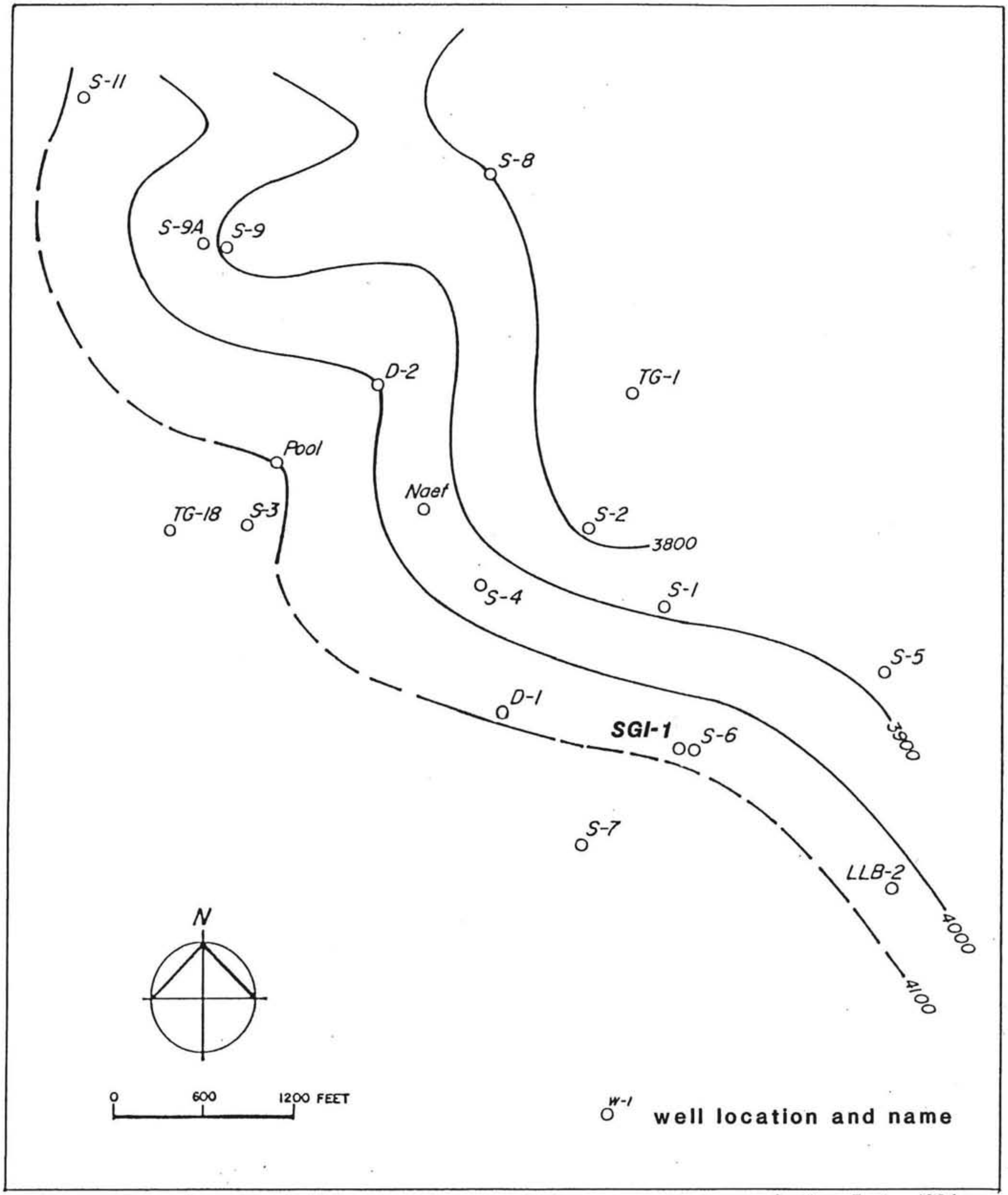


Figure 4. Geology of the Susanville area.



GeothermEx, Inc., 1984

Figure 5. Structural contour map of inferred reservoir top.

4.Ø DRILLING AND CONSTRUCTION SUMMARY

4.1 CHRONOLOGICAL SUMMARY

Actual drilling operations commenced August 7, 1988 and were completed August 26. A chronological summary of the drilling program is presented below.

March 7	Award of contract to drill SGI-1.
May 9	Preconstruction meeting at Susanville.
August 5	Drilling equipment mobilized to site.
August 6	Drilling equipment mobilized to site and equipment set up.
August 7	Drilling equipment set up and pilot hole drilled to a depth of 5Ø feet.
August 8	Borehole hole reamed to a depth of 52 feet.
August 9	Conductor casing installed and cemented in place.
August 1Ø	Pilot hole drilled from a depth of 52 feet to 11Ø feet.
August 11	Pilot hole drilled from 11Ø feet to 21Ø feet.
August 12	Pilot hole drilled from 21Ø feet to 41Ø feet.
August 13	Borehole reamed from 52 feet to 34Ø feet.
August 14	Borehole reamed from 34Ø feet to 412 feet and surface casing installed to a depth of 412 feet.
August 15	Surface casing cemented from bottom to land surface.
August 16	Cellar excavated, Class II diverter assembly fabricated and installed, and cement plug at bottom of surface casing drilled out.
August 17	Drilled borehole from 412 feet to 655.5 feet.
August 18	Ran temperature and electric logs, installed production casing (liner), and ran gamma and neutron logs.
August 19	Moved rig off hole.
August 2Ø	No activity.
August 21	No activity.
August 22	Moved rig back over well. Bailed well to remove drilling fluid, add chlorine solution to break down drilling fluid.
August 23	Bailed well.
August 24	Bailed well, performed borehole television survey.
August 25	Conference to discuss status of well. Attempted to pull production casing.
August 26	Attempted to retrieve production casing. Rigged down and commenced site restoration.
August 27	No activity.
August 29	No activity.
August 3Ø	Rigged down.
August 31	Rigged down.

September 1 through 11	No activity.
September 12	Demobilized equipment from site.
September 13	Demobilized equipment from site.

As of September 14, 1988, site restoration was complete except for disposal of drill cuttings which were stockpiled at the well site pending chemical analyses of the drill cuttings for hazardous substances. Results of the analyses were all negative. Spreading drill cuttings at the site completed site restoration.

4.2 PRELIMINARY WELL DESIGN

The design of SGI-1 called for the well to be constructed in a telescope manner. Basic elements of the preliminary well design (City of Susanville, 1987) included:

- Conductor casing from land surface to 50+/- feet depth with annular space sealed with cement grout.

- Surface casing from land surface to 400+/- feet depth with annular space sealed with cement grout to isolate deeper geothermal production zones from shallow aquifers which are exploited as a source of domestic water supply. Class II diverter assembly attached to the top of surface casing to prevent uncontrolled discharge from the well.

- Production casing (liner) with double factory mill slot perforations from 400+/- feet to total depth (T.D. = 650+/- feet).

The drilling program (ibid.) entailed drilling the well by the direct, mud-rotary method. Fresh-water based bentonite drilling fluids were permitted for drilling the upper portion of the borehole to accommodate the 400+/- feet of surface casing. Below this depth, an inorganic polymer was substituted for bentonite. The polymer was specified in an attempt to eliminate or reduce irreversible damage to the formation due to mud invasion and plugging of permeable zones. These effects appear to have limited the injectivity of the City's first attempt at drilling an injection well, Richardson-1 (Geothermex, 1984). Polymer drilling fluids are easily degraded by the addition of chlorine, which also breaks down the low permeability wall cake that results from drilling. Furthermore, the lower solids content, typical of polymer fluids, reduces drilling fluid weight. This decreases the potential for mud invasion due to differential pressure over and above the formation piezometric head.

4.3 CONSTRUCTION SUMMARY

4.3.a. Lithologic log.

SGI-1 was drilled to a depth of 655.5 feet below land surface. An abbreviated geologic log of the formation materials penetrated is presented below. A more detailed log of the borehole is provided in Appendix A.

Depth Interval (feet)	Description
	<u>Recent soil and alluvial deposits</u>
Land surface - 10	Brown, silty, sandy, gravelly soil.
10 - 15	Red-brown sticky clay.
15 - 35	Sand, gravel, and cobbles; very well rounded.
35 - 50	Clayey, silty sand.
50 - 65	Gravel and cobbles; very well rounded.
	<u>Pleistocene basalt and Lahontan (near-shore) lake deposits</u>
65 - 100	Basalt; black; four individual flows separated by volcanic ash (?) beds.
100 - 412	Conglomerate; rounded to subrounded gravel and cobbles in a matrix of tight clay and silt; some sand interbeds; possible density stratification.
412 - 420	Grey, brittle claystone.
420 - 524	Alternating clay and clayey sands with minor gravel.
524 - 560	Conglomerate; similar to 100 to 412 interval.
560 - 655	Basalt; Dark grey to brown, weathered; amygdular; multiple thin flows separated by volcanic ash (?) beds.

In general, the geologic materials penetrated by SGI-1 resembled those described in the logs for test wells Suzy-6 and Suzy-7. Below approximately 1ØØ feet, these deposits were, for the most part, impermeable. The only detectable fluid loss throughout the target zone occurred opposite relatively clean sand stringers in the interval between 45Ø and 47Ø feet below land surface. The total amount of fluid loss was small, in the range of several tens of gallons, before sufficient filter cake developed to control the loss.

This observation confirms the opinion that minimal but perceptable fluid loss should be expected opposite permeable horizons. Since this fluid loss was relatively isolated and rare, the conclusion that substantial permeable horizons are not present in the target zone is evident.

4.3.b. Geophysical logs.

Upon completion of drilling the borehole to its target depth (T.D.), a suite of borehole geophysical logs was run by WELENCO, a commercial wire-line logging service. Logs, in the order in which they were run, included:

- Temperature - land surface to T.D. four hours after circulation ceased.
- Spontaneous potential, long- and short-normal resistivity, and resistance - uncased portion of hole below surface casing.
- Neutron-neutron and natural gamma - land surface to T.D. after installation of the production casing.

Copies of the geophysical logs are provided in Appendix B and are included in Plate I for ready comparison with geologic materials penetrated by the well bore. Conclusions drawn from the logs are discussed in Section 5.Ø, below.

A second temperature survey of SGI-1 was completed September 12, 1988 by WEN, INC. The temperature profile is also provided in Plate I.

4.3.c. Well completion.

Well construction details for SGI-1 are summarized below.

Borehole diameter

Depth interval (feet)	Diameter (inches)
Land surface to 52 feet	20 inches.
52 to 412 feet	13 1/2 inches.
412 to 655.5 feet	9 7/8 inches.

Casing schedule

Depth interval (feet)	Description
-1 to 52	14 1/2-inch O.D. x 0.250-inch wall thickness steel conductor casing (annulus sealed with cement/sand grout).
-1 to 412.2	10 3/4-inch O.D. x 0.250-inch wall thickness AWWA C200 (equivalent to ASTM A120) steel surface casing (annulus sealed with cement with 2% bentonite to control shrinkage).
401.2 to 655.5	6 5/8-inch O.D. x 0.250-inch wall thickness ASTM A120 steel production casing. Double 1/8-inch x 2 1/2-inch factory mill slot perforations, 24 per foot, from 414.9 to 655.5 feet.

Well construction details, lithologic log, and geophysical logs are all depicted in Plate I. A detailed construction summary for the well is provided in Appendix C.

4.3.d. Well development.

Upon completion of well construction, well development procedures were initiated to prepare the well for test pumping. The well was first bailed to remove a large portion of the residual drilling fluids from the well bore. A total of 10 gallons of sodium hypochlorite solution was then introduced into the well bore and thoroughly mixed by surging with the bailer to promote break down of residual polymer drilling fluid and wall cake which may have formed on the borehole/formation interface.

During the bailing operation, the water level in the well was drawn down to a depth of more than 400 feet below land surface.

Considering that the average withdrawal rate of water from the well was small, less than five gallons per minute, this did not bode well for the capability of the well to function as an injection well.

Results obtained during well development were reviewed at a conference on August 25, 1988 attended by representatives of the California Division of Oil and Gas, the California Energy Commission, OIT, WEN, and City of Susanville. At this time drilling operations were suspended and it was decided to pull the production casing liner from the well in the event there was a desire to deepen the well at a future date if additional funds became available or new information warranted drilling the well deeper. Attempts to retrieve the liner were unsuccessful and the drilling contractor was notified to secure the site and demobilize drilling equipment on August 26.

4.3.e. Well head completion.

SGI-1 was not formally abandoned upon completion of the drilling program. Well head completion consists of a blind flange one foot below land surface with a two-inch diameter steel pipe extending two feet above land surface. Until such time as a decision to formally abandon or deepen the well is made, it will be maintained as a monitoring well. The pipe is fitted with a removable cap which will permit temperature surveys and water sample collection.

5.0 EVALUATION OF DRILLING RESULTS

On the basis of the results obtained from bailing the well, no formal aquifer stress tests were performed on SGI-1. Some information, however, was advanced from the bailing data for comparison with test results for other geothermal wells. In essence, the water level in the well was drawn down approximately 400 feet at a withdrawal rate of nearly five (5) gpm. The specific capacity (productivity index) of the well approximated

$$5 \text{ gpm} / 400 \text{ feet} = 0.125 \text{ gpm/ft}$$

By comparison, the productivity index for Susan-1 is 10.5 gpm/ft at 350 gpm (Geothermex, 1984).

The productivity index (specific capacity), is a measure of a well's overall hydraulic efficiency. It may also be utilized to approximate the Aquifer Transmissivity (the overall ability of an aquifer to transmit ground water) utilizing the relationship

$$\text{Transmissivity, } T = 2{,}000 \times C_s$$

where,

Transmissivity is given in units of gallons per day per foot width of aquifer (GPD/ft), and

C_s is the specific capacity in gallons per minute per foot of drawdown (gpm/ft)

From the available data, the Transmissivity in the vicinity of Susan-1 is approximately 21,000 GPD/ft; in the vicinity of SGI-1 it is 250 GPD/ft. Transmissivity is one of the dominant factors which limits well yield. All other factors being equal, well yield is directly proportional to Transmissivity.

The productivity index for production wells may be thought of as analogous to injectivity index (injection rate per foot rise in water level) for injection wells. In practice, injectivity index is lower than that predicted from productivity index, alone. The causes of this discrepancy may include a loss of hydraulic efficiency of the well resulting from plugging of the formation or perforations by silt, air entrained in the discharge, chemical incrustation, and/or the incompressibilty of water.

Equating the productivity index for SGI-1 to an injectivity index, and assuming 100 per cent efficiency for the well, an injection pressure measured at land surface of 65 p.s.i.g., and a static water level of 20 feet below land surface, SGI-1 could be expected to accept

[65 psig (2.31 ft/psi) + 20 ft] x 0.125 gpm/ft = 21.3 gpm

This low injection rate is only a small fraction of the total discharge from the City system.

There are at least two possible reasons why SGI-1 failed as an injection well. The first is the possibility of extensive formation damage resulting from drilling. The second is that permeability is not well developed in the target zone in this area.

A formation becomes "damaged" in any one of several ways as a consequence of the drilling process. Almost every well is damaged to some degree during drilling. Irreversible damage typically results from poor control of the drilling fluids. The two most common forms of damage are plugging of permeable zones due to invasion of these zones by the drilling fluid or the build up of a thick impermeable mud cake (wall cake) on the borehole/formation interface. Neither of these are plausible in the case of SGI-1.

Mud invasion, the more severe and difficult to remedy of these two types of damage, typically arises from a substantial difference in hydrostatic pressure between the borehole and the formation. This may result from a very deep (low) piezometric head in the aquifer and/or relatively high drilling fluid weight. Neither of these is the case for SGI-1.

Piezometric head in the aquifer is within 10 to 20 feet of land surface at this locale. The drilling fluid utilized in drilling the production zone was comprised of fresh water with added polymer. The mud carried essentially zero solids and mud weight was maintained at only slightly greater than that of water. Therefore, the formation pressure essentially balanced the borehole fluid pressure and the potential to build a substantial hydrostatic head over and above that of the formation pressure did not exist. This is supported by the observation that there was minimal fluid loss to the formation below the 10 3/4-inch diameter surface casing (refer to Section 4.3.a.).

Likewise, the build up of an overly thick wall cake is improbable. This occurs only when there is excessive mud filtrate loss through the wall cake opposite permeable formation material. This results from a large head differential between the well bore and the formation exacerbated by poor-quality drilling fluids. Since there was essentially zero fluid loss detected during drilling, excessive mud cake buildup is also ruled out.

The other alternative, of course, is the likelihood that the permeability of the target zone is poorly developed at this locale. The thermal ground water is known to move laterally in permeable zones along the upper and lower margins of individual lava flows and permeable beds within the sedimentary deposits. At this locale, the upper basalt unit universally transmits large quantities of ground water. The Tsuji Greenhouse well, located less than 1,000 feet west-northwest of SGI-1, derives thermal ground water from highly permeable zones in the lower basaltic unit at a depth of approximately 650 feet (R. Juncal, 1988) but this well is located within a totally different structural block than is SGI-1.

A review of the history for test well Suzy-6 supports the results obtained from SGI-1. Suzy-6 was completed with six-inch diameter casing installed to a depth of 623 feet, was gravel packed and perforated from 103 feet to T.D. The annular space above the top of the perforated interval (above 103 feet) was sealed with cement to inhibit cross-communication between the thermal aquifer and the shallow alluvial aquifer. Upon completion of the cementing job, a test was performed to evaluate the productivity and injectivity of Suzy-6. Test results indicated that Suzy-6 was unsuitable for use as an injection well (ibid.). Two opposing conclusions were drawn: the first that the cement had infiltrated the gravel pack to the bottom of the well and had plugged the production zones; the second that the formation in the lower part of the well was essentially impermeable.

In light of the results obtained from SGI-1, the latter is probably the more correct interpretation. An examination of the borehole geophysical logs completed in SGI-1 support this same conclusion. Several observations are noteworthy,

- The upper and lower basalt flows are clearly delimited by the gamma logs (very low gamma counts).

- Volcanic ash interbeds are present in both basalt flow sequences. The low gamma counts suggest non-potassium clays such as montmorillonite, a major component of volcanic ash.

- The Lahontan near-shore lake deposits between the two basalt flow sequences show very low resistivity (<5 ohm-m^2/m), high gamma counts, and low neutron counts. In combination, these suggest a high clay content (potassium-bearing clay such as illite, perhaps) and high porosity, also typical of clays.

- The resistivity of the lower basalt is low (for a basalt). This unit may be weathered or altered, and as a result, secondary permeability may not be well developed in this unit. The neutron log for this lower basalt unit also suggests low porosity.

6.0 DISPOSAL ALTERNATIVES

There are at least six alternatives for fluid disposal at this time. These are listed below in reverse order of preference:

1. Continue surface discharge. This is not viewed favorably by the Lahontan Regional Water Quality Control Board because the chemical quality of the geothermal effluent is substantially lower than the quality of the receiving waters. It is also undesirable from the perspective of the City because of the high cost of monitoring the impacts of surface discharge.

2. Deepen SGI-1. Funds for drilling SGI-1 have been exhausted and deepening the well would have to be funded at the expense of monies allocated for testing. There is no strong evidence that highly permeable zones exist at some unspecified greater depth at this site. Conversely, existing data do not rule out the possibility that such horizons exist at extreme depth. Drilling blindly ahead in search of an injection zone was not considered prudent. More study was recommended to evaluate whether or not suitable "deep" drilling targets exist at SGI-1.

3. Drill a deep injection well at another site. The selection of an alternate injection well site is beyond the scope of this investigation. Considering that the first two attempts at completing an injection well for the City have been unsuccessful, existing data and information should be reexamined to select a site with a high potential for success of meeting the technical and regulatory constraints on re-injection, additional investigations conducted, or both.

4. Utilize an existing geothermal production well as an injection well. The City may be able to negotiate the use of a well in trade for a heating supply. The mutual benefits are obvious and any disadvantages are not apparent. One likely candidate is Tsuji Well No. 2 which is located approximately 500 feet west-northwest of SGI-1. The subject has not been broached with the well owner, nor has any information concerning well completion and testing been reviewed to determine its suitability for this purpose.

5. Rehabilitate Richardson-1. Geothermex [1984] concluded that the low injectivity of the first injection well drilled for the City could be due to formation damage sustained as a result of invasion and plugging of the formation by drilling fluids during the drilling process. A chemical/physical rehabilitation program was proposed to restore the damage and increase the injectivity of the well. The program was abandoned because of concerns over the possibility of an

accidental chemical spill into the Susan River, and difficulties disposing the spent treatment chemicals. Because the site was highly regarded as an injection well site, it is worth reconsidering this alternative.

6. Drill and utilize a shallow injection well in the vicinity of SGI-1.

Of the six alternatives listed above, the sixth one was rated the highest. There were several reasons for this ranking. Chief among them were a relatively low cost and the ease with which investigations could be carried out in a short period of time. With the City's discharge permit expiring in October, 1988 it was imperative to find an alternative to SGI-1 in a reasonable amount of time. The alternative could be investigated easily using existing wells and relevant data could be generated with funds available from the SGI-1 budget. For these reasons this alternative was incorporated into the SGI-1 program. Results of this investigation are discussed below and in Section 7.

The target for re-injection was a basaltic unit which is widespread in the general vicinity. It is the same unit which was penetrated in SGI-1 between depths of 65 and 100 feet and encountered at depths of between 50 and 100 feet in nearby wells (refer to Section 4.3.a., Plate I, and Geothermex [1984]). The target geothermal horizon is relatively shallow compared to the depths of geothermal wells in the Susanville area but is believed to comprise the upper limit of the geothermal reservoir (refer to Section 3.0 and Figure 5). Scoriaceous and inter-flow zones in the basalt are known to be highly permeable. The nearby Allen No. 1 well reportedly yields up to 400+ gpm of 130°F water with minimal drawdown utilizing a centrifugal pump (L. Allen, 1988). Allen No. 2 also reportedly yields large quantities of warm ground water (ibid.).

Temperature surveys were conducted in the two Allen wells in September 1988. The temperature data for the wells (Figure 6) illustrate a substantial increase in temperature once the basalt is encountered. In Allen No. 1, temperature increases 60.3°F in the interval between 70 and 90 feet depth. In Allen No. 2, the temperature gradient also increases once the basalt is penetrated.

Water samples for chemical analysis were obtained from both of the Allen wells to determine the chemical quality of the shallow geothermal horizon and evaluate the compatibility of the thermal effluent with the prospective host waters. The samples were collected from a depth of 100 feet in Allen No. 1 and 115 feet

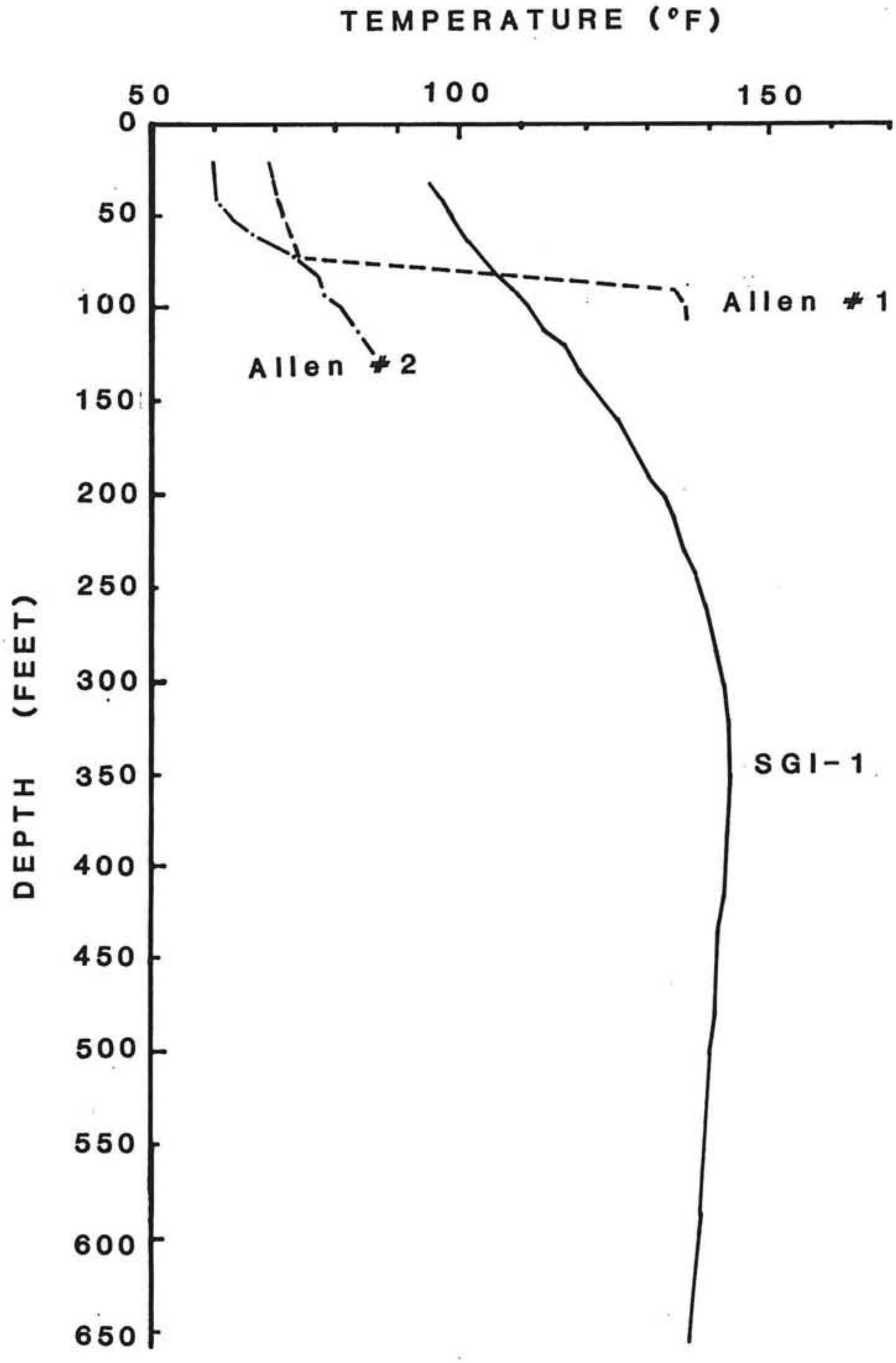


Figure 6. Temperature profiles for Allen wells and SGI-1.

in Allen No. 2 to ensure that the water sampled was representative of the geothermal aquifer. The samples were collected using a Kemmerer-type depth-specific sampling device. Neither well was pumped or bailed prior to sampling in order to preserve stratification of the water in the well.

The sampling device consists of an open brass cylinder that can be sealed with rubber stoppers at each end. It is lowered to the desired depth with both ends open to allow water to pass through until the target depth is achieved. At this point a messenger (weight) is released. When it reaches the sampler, it triggers the release (closure) of the stoppers and a sample of water from the discrete depth is captured.

The results of the chemical analyses of the samples are provided below in Table 1. Also included are water chemistry data for the City's production well, Susan-1 (Geothermex, 1984). Comparison of the waters from the Allen wells and Susan-1 is illustrated in a Piper Tri-linear diagram (Figure 7). From these data, it is apparent that the waters from Allen No. 1 and Susan-1 are of the same general type except that the concentration of total dissolved solids and the major cations and anions of Susan-1 are higher than that for Allen No. 1. It is also apparent that the water from Allen No. 2 is substantially different from either Susan-1 or Allen No. 1 water and likely represents a blend of water of thermal and nonthermal origins as the thermal water moves horizontally away from faults or other vertical conduits.

The available data to date suggest that the shallow basalt aquifer, particularly near the site of SGI-1 where the thermal waters have not yet been diluted by nonthermal waters, had potential as a suitable alternative to surface discharge or a deep injection well. Additional investigations were conducted to determine the feasibility of this alternative (see Section 7). The focus of these investigative efforts included:

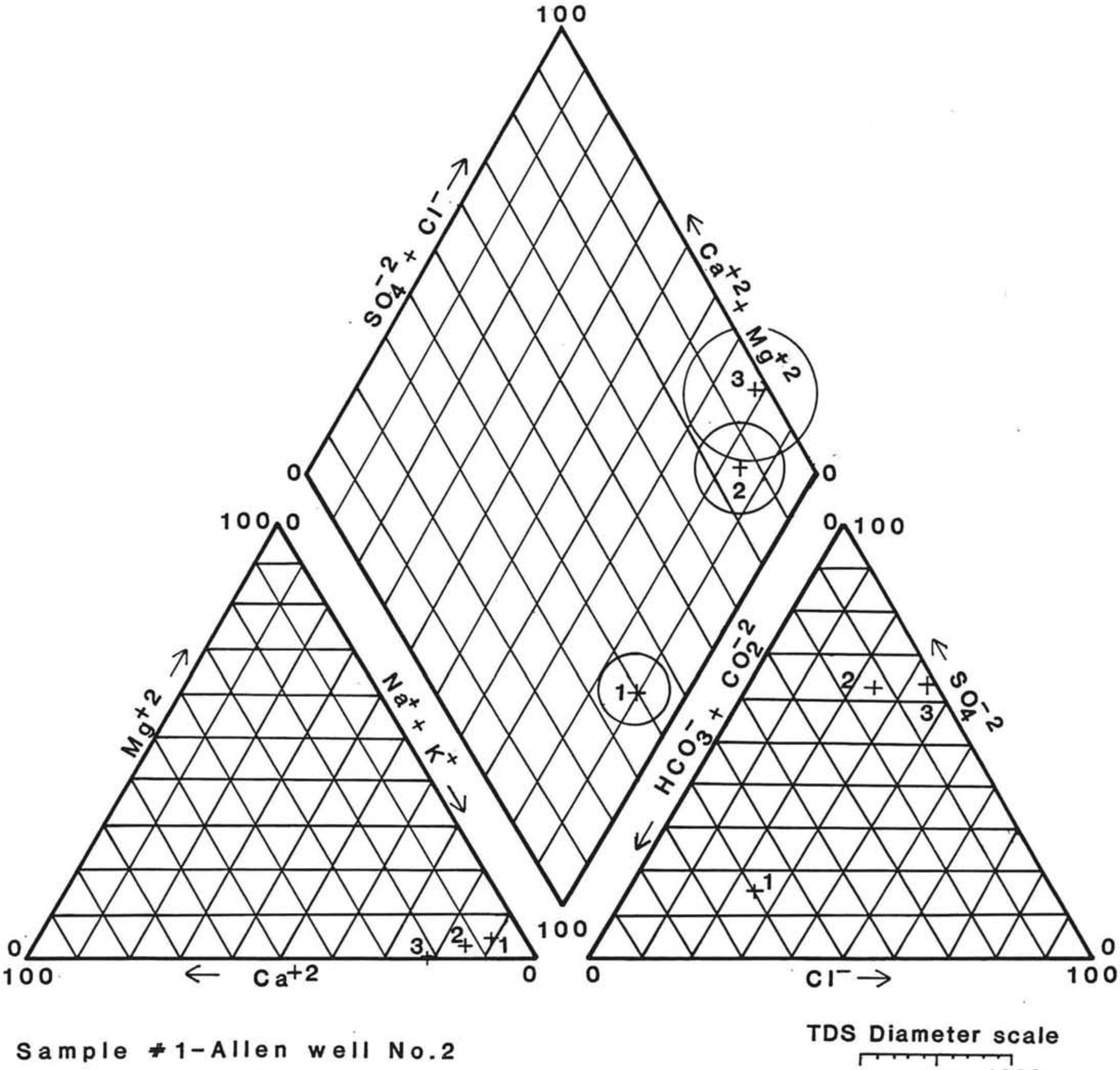
1. The ability of the shallow basaltic unit to accept up to 750 gpm of thermal effluent and the probable injection pressure at this rate.

2. Potential impacts on the overlying alluvial aquifer which is exploited as a source of fresh water supply to individual domestic wells.

Table 1. Water chemistry data, Allen No. 1 and 2, and Susan-1 (reported as milligrams per liter unless otherwise indicated).

Sample source	Allen #1	Allen #2	Susan-1*
Date	9/12/88	9/12/88	10/27/81
Time	1130	1020	0900
Temp (°C)	37.5	26.0	77
E.C. (μmho/cm)	900	550	1400
pH (field, pH units)	7.3	7.5	
pH (lab, pH units)	8.1	7.2	8.4
TDS	614	432	949
Ca	23.7	8.1	28
Mg	2.8	3.4	0.06
Na	160	135	240
K	5	4.5	7.0
HCO_3	56	187	32.9
SO_4	238	76	450
Cl	67	32	130
NO_3	0.2	0.4	
F	1.9	2.1	2.2
As	0.024	0.033	
Ba	<0.4	<0.4	
B	1.8	1.0	2.4
Cd	<0.01	<0.01	
Cr	<0.02	<0.02	
Cu	<0.02	0.03	
Fe	0.03	0.08	
Pb	<0.05	<0.05	
Mn	<0.02	0.02	
Hg	0.0011	<0.0005	
P	0.05	0.18	
Se	<0.005	<0.005	
Ag	<0.01	<0.01	
Zn	0.03	0.09	
SiO_2	62	50	73

* source - Geothermex, 1984.



Sample #1-Allen well No.2

Sample #2-Allen well No.1

Sample #3-Susan 1 (reference: Geothermex, 1984)

Figure 7. Piper Tri-Linear Diagram of water chemistry for Allen wells and Susan-1.

7.Ø TESTING OF ALLEN WELL NO. 2

The feasibility of the sixth disposal alternative (Section 6.Ø, page 21) was investigated in January, 1989 via a 24-hour aquifer stress test performed on Allen Well No. 2. Allen #2 is located approximately 1,5ØØ feet east-southeast of SGI-1 in the NW1/4 SE1/4 Section 5 (refer to Figure 2). It appears to be situated within the same structural block of the geothermal system (Benson, et. al., 198Ø) as Suzy-1, -6, -7, and perhaps, Davis-1. As noted in Section 6, above, this particular well was selected because it provided a relatively inexpensive means with which to determine whether thermal effluent can be re-injected at shallow depths in the general vicinity of SGI-1 without impacting the overlying potable-water aquifer.

Allen #2 is completed to a depth of approximately 125 feet below land surface. It penetrates alluvial deposits to a depth of approximately 6Ø feet and basalt lava flows from 6Ø feet to total depth. The well is cased with blank steel casing to a depth of 65 feet (five feet into the basalt) with the remainder of the well completed as an open borehole (F. Turner, 1989). The blank casing serves to isolate the producing horizons in the basaltic aquifer from the overlying alluvium (refer to Figure 8).

LLB-2 was utilized as an observation well during the testing of Allen #2. It is located 242 feet southeast of Allen #2 and is 5Ø2 feet deep. Little information is available regarding the construction of this well. However, it is believed to be cased through the alluvial deposits and there is some suggestion that production may by limited to the portion of the well above a depth of 13Ø +/- feet.

7.1 ALLEN NO. 2 TEST SUMMARY

A submersible turbine pump was installed to a depth of 82 feet below land surface in Allen #2. The test equipment included a totalizing flow meter to record the pumping rate, a gate valve to regulate pump discharge, and several hundred feet of irrigation pipe to convey the discharge away from the well for surface disposal on the pasture southwest of the well site. Water levels in the pumped and observation wells were measured with electric water level sounders. Testing is summarized below.

Pre-testing water levels -
- Allen #2 - 13.79 feet below top of casing.
- LLB-2 - 13.7Ø feet below top of two-inch diameter coupling.

Testing commenced - 1ØØØ hours, 1/17/89.
Pumping terminated - 1ØØØ hours, 1/18/89.

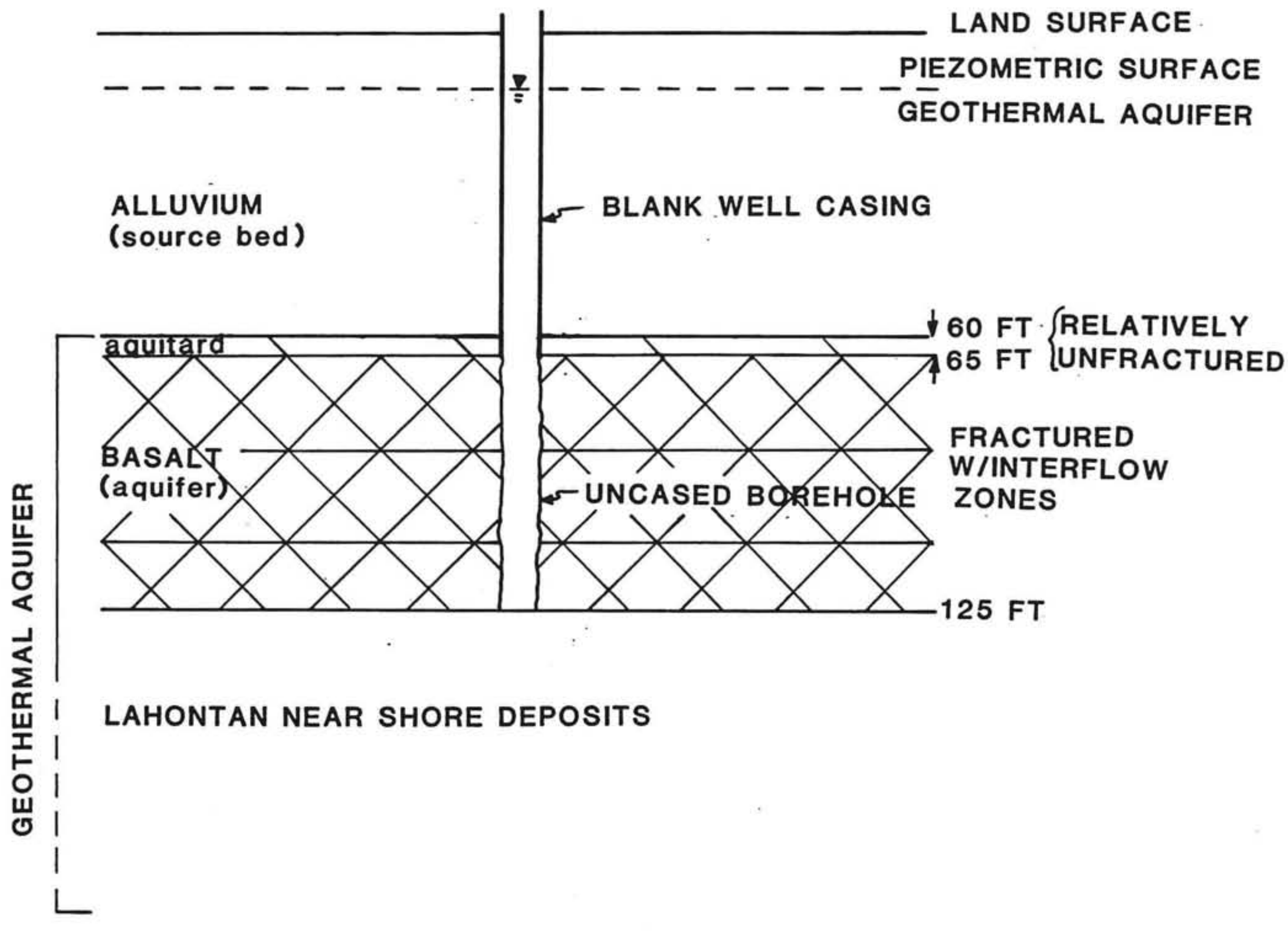


Figure 8. Conceptual model of the shallow geothermal reservoir in the vicinity of SGI-1 and Allen #2.

Average pumping rate - 85.4 gallons per minute.
Water levels at conclusion of pumping -

Allen #2 - 70.3 feet below M.P. (drawdown = 56.51 feet).

LLB-2 - 22.12 feet below M.P. (drawdown = 8.42 feet).

Test terminated - 1400 hrs 1/18/89 (after 4 hours of recovery).

Drawdown and recovery data for the wells are depicted in Figures 9 through 12 and field data sheets are provided in Appendix D.

7.2 ANALYSIS OF AQUIFER STRESS TEST DATA

Drawdown and recovery data for the observation well, LLB-2, were analyzed by the methods of Hantush and Jacob (1955) and Jacob (1946) which apply to an areally extensive isotropic, homogenous, leaky artesian aquifer where flow in the aquifer is augmented by leakage from an overlying source bed through an aquitard. This analytical model also assumes that storage in the aquitard is negligible. These assumptions are clearly approximated by conditions in the vicinity of Allen #2. The basaltic aquifer is separated from the overlying alluvial aquifer (source bed) by several feet of relatively unfractured basalt (aquitard).

In addition to the analytical models above, early-time recovery data (before the effects of leakage became significant) for the pumped well, Allen #2, were analyzed by the Cooper-Jacob approximation of the Theis Equation (Figure 11). Drawdown data for the pumped well (Figure 9) were not analyzed because it was difficult to maintain the discharge from the well at a constant rate. The pumping water levels were very sensitive to small changes in the pumping rate which can lead to inaccuracies in the data analysis. Computerized techniques are available for analysis of these data. However, the quality of the analyses results obtained thus far appear to be good, and additional analysis is not warranted.

The observed data compare closely with the theoretical values for drawdown in a leaky artesian aquifer (Figures 10 and 12) with the exception of the late-time drawdown data for LLB-2. The small increase in drawdown late in the test appears to be related to an outside influence. The most likely cause is interference due to discharge from other geothermal wells in the Susanville area.

Aquifer hydraulic characteristics determined from the Allen #2 test are summarized below.

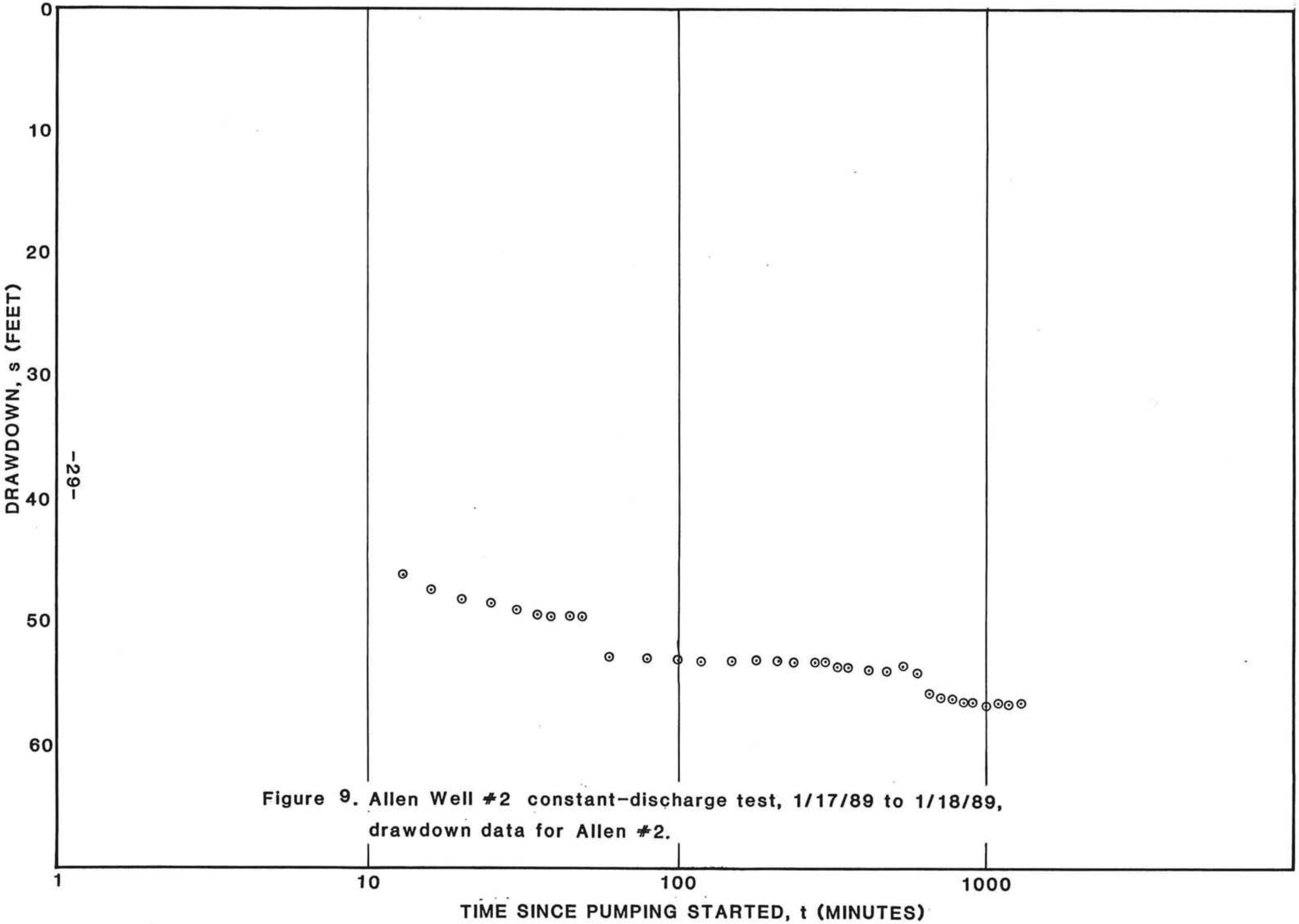


Figure 9. Allen Well #2 constant-discharge test, 1/17/89 to 1/18/89, drawdown data for Allen #2.

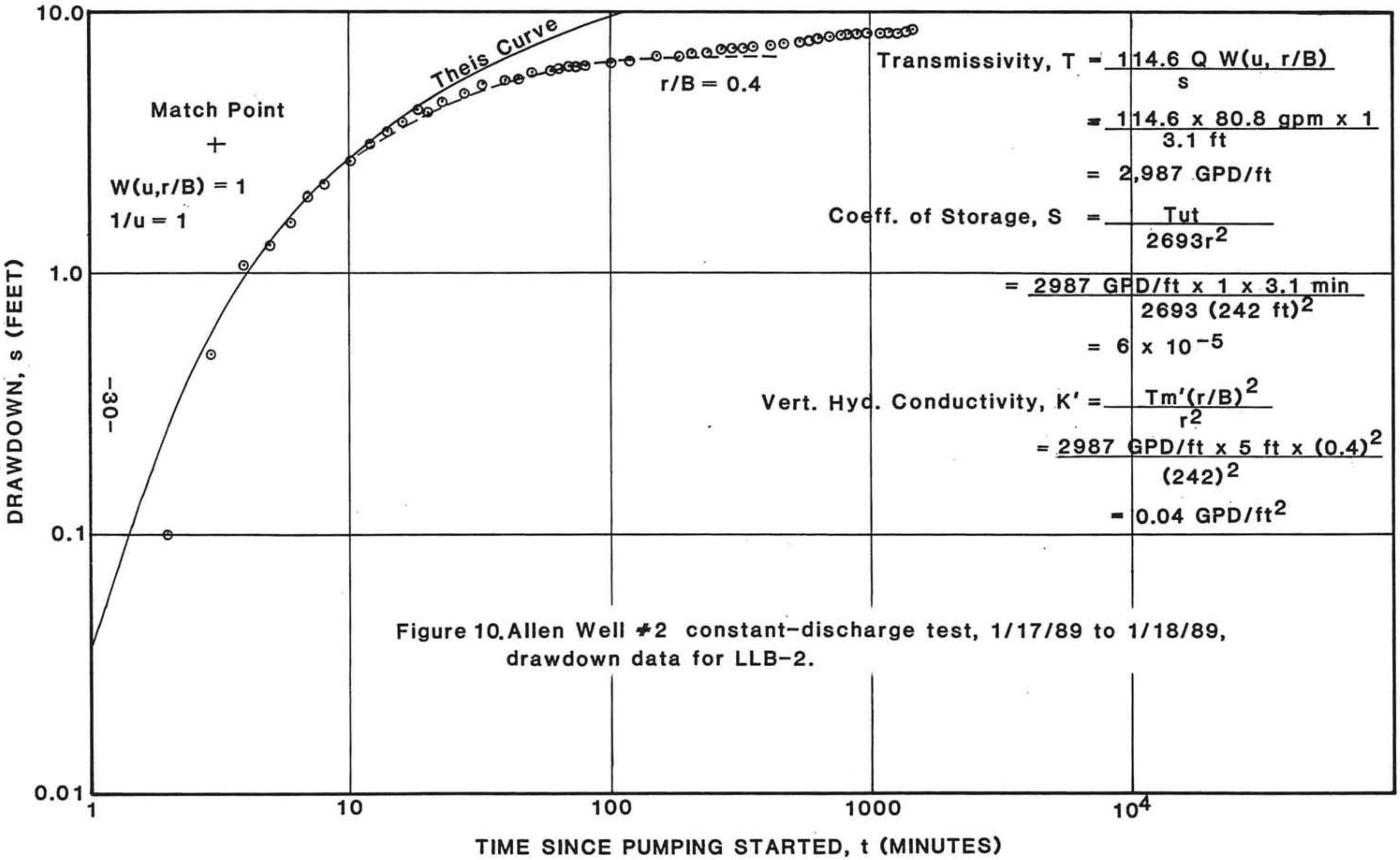


Figure 10. Allen Well #2 constant-discharge test, 1/17/89 to 1/18/89, drawdown data for LLB-2.

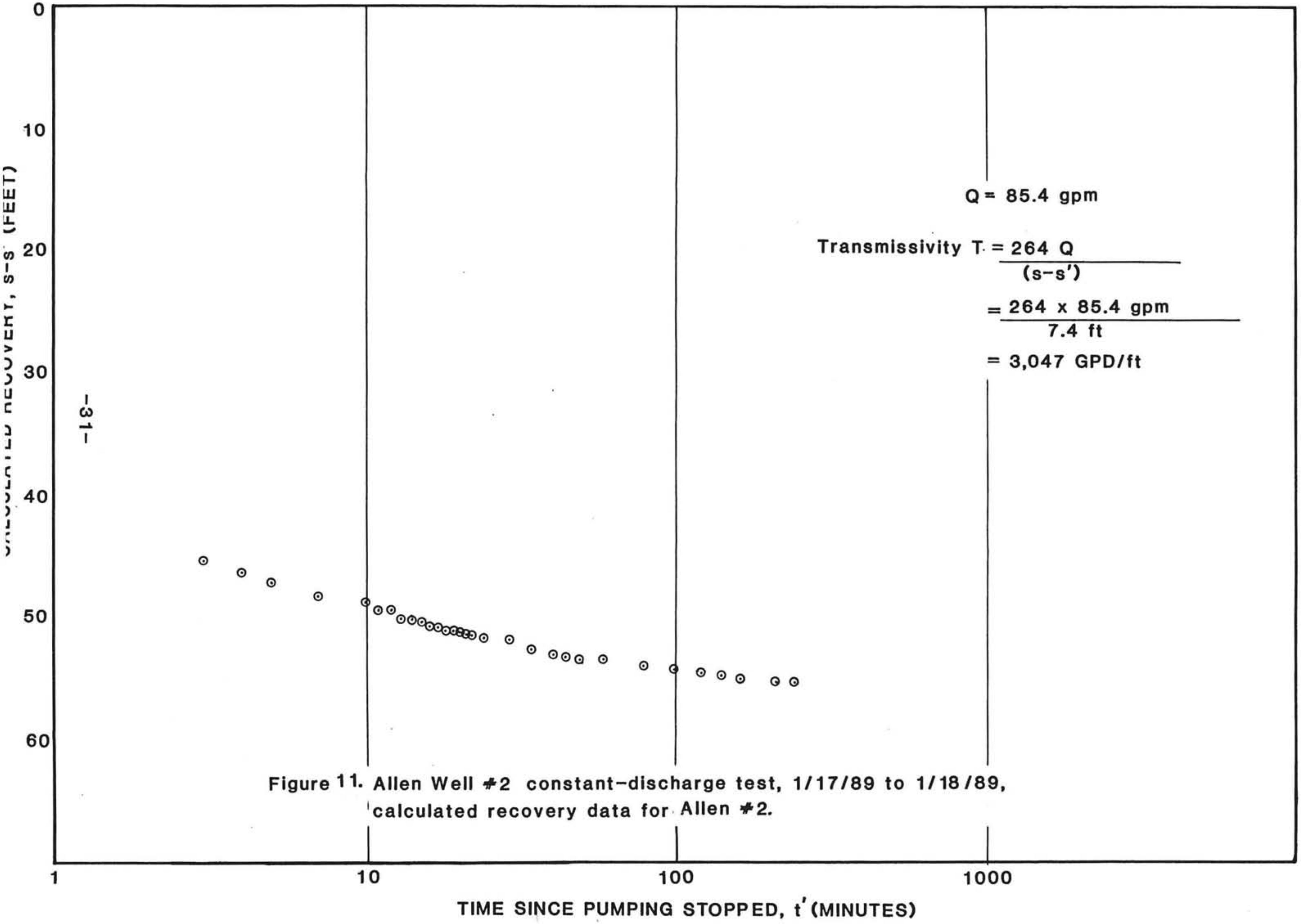


Figure 11. Allen Well #2 constant-discharge test, 1/17/89 to 1/18/89, calculated recovery data for Allen #2.

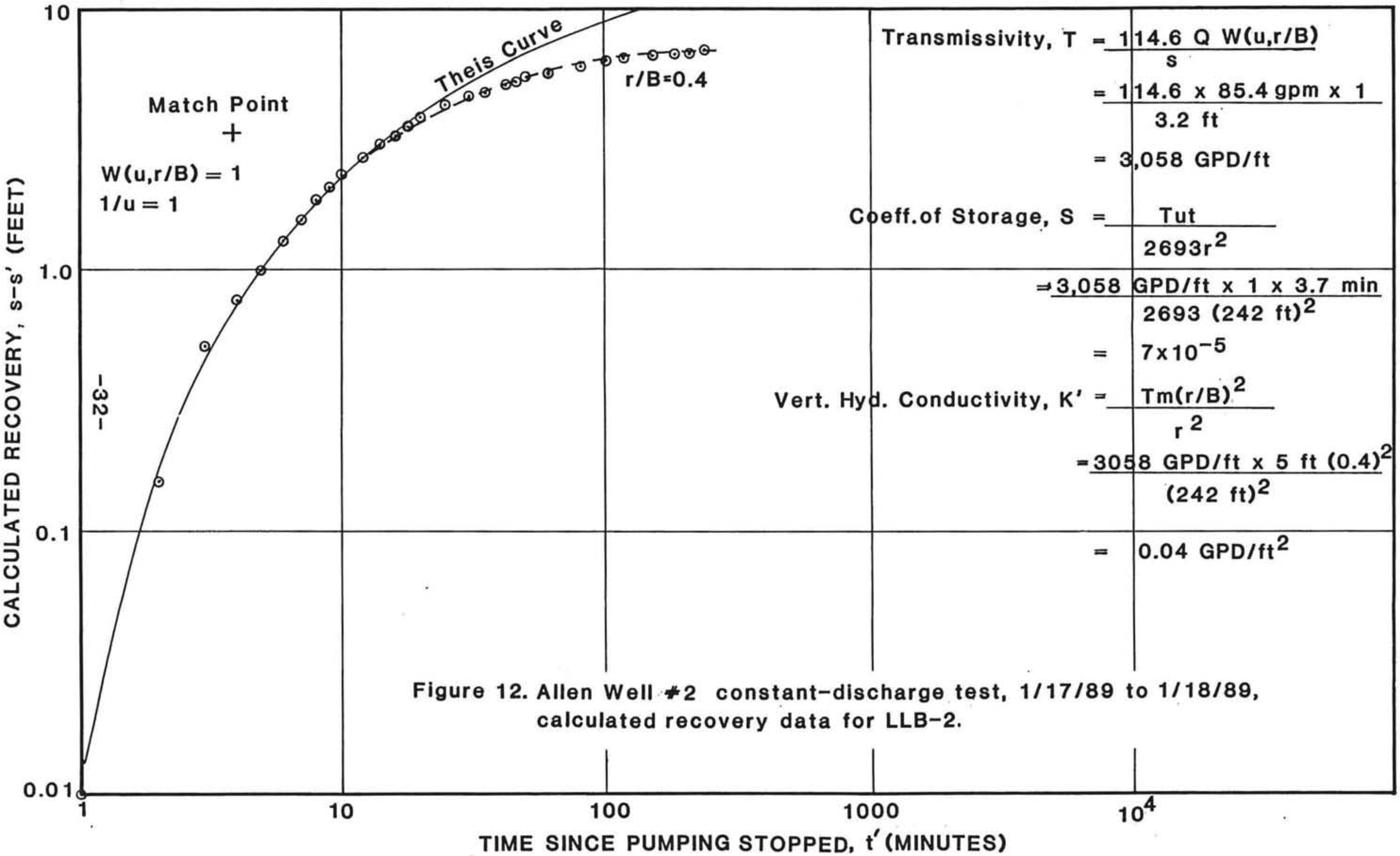


Figure 12. Allen Well #2 constant-discharge test, 1/17/89 to 1/18/89, calculated recovery data for LLB-2.

Table 2. Aquifer hydraulic characteristics, Allen #2 aquifer stress test.

Well	Transmissivity (GPD/ft)	Vertical Hydraulic Conductivity (GPD/ft^2)	Coefficient of Storage
Allen #2	3,047	---	---
LLB-2	2,881-3,058	0.03-0.04	0.00006-0.00007

The average Transmissivity of the aquifer in this general area, as determined from the Allen #2 test data, is similar to a value of 3,400 GPD/ft calculated from a test of Davis-1 (Benson, et. al., 1980) and is approximately one order of magnitude lower than the Transmissivity of the aquifer in the proximity of the Naef Well and Susan-1. The similarity of these values suggests that Davis-1 may be completed in the same structural block as Suzy-1, -6, -7, and Allen #2. If this is the case, then the fault which separates block 3 from blocks 2 and 4 (ibid.) could be positioned west of Davis-1.

The Coefficient of Storage determined from the Allen #2 test data is suggestive of an artesian aquifer and consistent with values generated as a result of the previous investigations.

It is apparent from these new data that injection into the shallow basalt flows near the top of the geothermal aquifer in the vicinity of SGI-1 is not feasible for several reasons. In this area, the aquifer is only moderately transmissive. Assuming a Transmissivity of 3,000 GPD/ft, injection pressures could approach 200 psi for injection rates of 750 gpm. Regulatory agencies would almost certainly not approve an injection pressure this high. Because of the shallow depth of the injection zone, maximum recommended pressure would be closer to 20 psi. Secondly, the energy cost to inject at this pressure is high and not practical.

The third reason is related to potential impacts on the overlying aquifer. High injection pressure in the shallow aquifer would create a large upward hydraulic gradient. Even though the vertical hydraulic conductivity of the aquitard is relatively low, a substantial amount of upward leakage of the injectate into the overlying alluvial aquifer would occur. This may not be acceptable to regulatory agencies because of the potential for degradation of the chemical quality of the ground water in the shallow potable-water aquifer. At the very least, numerous monitoring wells, exhaustive and expensive monitoring would be required. Since one of the reasons that the City is seeking an alternative to surface discharge is the high cost of monitoring this discharge, this alternative has reduced appeal.

Efforts at re-injection which have been completed to date have not met with a major degree of success. Locating a new site, which will accommodate re-injection of the thermal effluent without either impacting the production wells or the chemical quality of the potable water aquifers, would be difficult at best.

8.Ø SOURCES OF INFORMATION

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City of Susanville, CA, 1987. Technical specifications for Susanville Geothermal Injection Well No. 1.

Geothermex, 1984. An assessment of the geothermal resource underlying the City of Susanville and the disposal system for geothermal waste disposal: private consulting report prepared for the City of Susanville, CA.

Hantush, M.S. and C.E. Jacob, 1955. Non-steady radial flow in an infinite leaky aquifer: Trans. Am. Geophys. Union, v. 36(1).

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Other sources

Allen, L., September 1988. Personal communication.

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Schroeder, R., October, 1988. Personal communication.

Turner, F., January, 1989. Personal communication.

WILLIAM E. NORK, Inc.

Reno, Nevada 89503

APPENDIX A

LOG OF BOREHOLE

LOG OF BOREHOLE

BOREHOLE SGI-1

LOC. or COORDS. SE¼ NW¼ Sec. 5, T.29N. R. 12E.

GROUND ELEV. 4130 FT (est.)

TOTAL DEPTH 655.5

BOREHOLE DIAM. 20", 0-52'; 13½", 52-412; 9⅞", 412-T.D.

DRILLER Layne Western Co, 275 Road 73, Woodland CA 95695

RIG Failing 2000 ?? (?)

BIT(S) 12¼ M.T.; 9⅞ M.T.;

FLUID Bentonite & Polymer

	START	FINISH
DATE	7/?/88	8/17/88
TIME	1330	1830

GEOPHYS LOG X YES __ NO

HOW LEFT See Constr. Log

LOCATION Sierra Road, south of Susanville, CA

LOGGED BY DC B

PROJECT 88-460 Susanville Injection well

DEPTH	PENETRATE ft/min	CIRC. RET.	CIRC. LOSS	Rot. Temp. °C	MATERIAL	DESCRIPTION AND COMMENTS
	1.0				silty, sand clay	brown. with coarse sand size volcanic fragments 12¼" ∅ tricone
	0.44					
10					clay	reddish-brown. sticky
					sand, gravel, & cobbles	@ 15' small gravel (granule) & coarse sand varied color volcanics
20				24.0		@ 17' Begin to drill ROUGH. Cobbles; 20-23' Coarse sand & gravel. no cobbles. smoothed out; 23-35' Cobbles ret @ 23'
30	5.1			24.0		Mixture of cobbles, gravel (down to granule size) & sand. Mostly chips. granules are well rounded. tan, brown, green grey & black-volcanics. Add 5" ∅ collar
					clayey, silty sand	@ 35' reddish. fine-med sand. subrounded w/ reddish brown clay
40				25.?		Smooth drilling 1740
	0.5					@ 45' color → to dark brown. similar to above
50				26.0		Ream to 27" ∅ 8/8/88; inst./cement conductor 8/9/88. End 8/?/88 ?51. Start 8/10/88 2-5" ∅ collars
						@ 54.5 fine to coarse sand w/ silt/clay matrix fine- qtz, rounded; coarse- lithic grains
60				26.0		
				27.0	Basalt	@ 65 black. Aphanitic. small chips. ROUGH drilling. Minor lt. grey clay (volc. ash?) drills as if flows are 2-3 ft thick mixed w/ red-brown clay, brittle (ash) 1625
70				27.0		73-75 some ?? breaks
					w/ clay (ash) beds	78-80 Mixture basalt chips, grey ash, & red-brown compacted clay (ash). Interflow(?) zone 78-80' 1649
80				27.0		basalt as above; 82-84 grey volc. ash & red-brown brittle clay (interflow zone) Kelly ?? 1729; basalt as above; clay (ash) lt brown to tan, some green
90				26.0		Difficulty w/ connection due to slough 2200; Mixture clay & basalt chips; 98-100 clay - med-dk-brown with round qtz & lithic sand (paleo-soil?) 2230
100				25.0	Sandy clay	100-?? Mixture of gravel, sand & clay 2230; clay-med. brown, sandy
110				25.0	sandy, gravelly clay	Mixture of volcanic chips, gravel, sand & clay 2305
					gravelly, sandy clay	113-120 chips to ½" 8/11/88; Clay-sandy brown & grey
120				26.0	clayey, sandy gravel	Mixture of gravel sand & clay. gravel to ¾". 0200
						120-130 Sand. fine to coarse. Clay grey less clay than above Cobbles & boulders (?) ROUGH Mostly chips. Chips to 1"
130				26.0		0300; Similar to above, but slight incr in clay
						130-140
140				27.0		0445
						140-150 Mixture of gravel, sand & clay. Similar to above. sm. gravel-rounded grey clay, ?? to med brown ~149. KD. ??20
150				28.0		148 VERY ROUGH @ 148 bit resume @ 1115 hrs

LOG OF BOREHOLE

BOREHOLE SGI-1

LOC. or COORDS. SE¼ NW¼ Sec. 5, T. 29N. R. 12E.	DRILLER LAYNE WESTERN CO 275 Road 93 Woodland, CA 95695		START / FINISH
GROUND ELEV. 4132 (est.)	RIG Failing 3000 CF (#421)	DATE	8/7/88 / 8/12/88
TOTAL DEPTH	BIT(S) 9⅞" Button Tricone	TIME	1330 / 1830
BOREHOLE DIAM. 20"; 9⅞"	FLUID Bentonite & Polymer	GEOPHYS LOG	X YES __ NO
		HOW LEFT	

LOCATION Sierra Rd., South of Susanville

LOGGED BY DAB

PROJECT 88-460 Susanville Injection Well

DEPTH	PENETRATE FT/MIN	CIRC. RET.	CIRC. LOSS	TEMP. °C	MATERIAL	INTERVAL	DESCRIPTION AND COMMENTS	TIME
	1.0				clayey, sandy gravel	150-160	Mixture gravel (mostly chips, sm. gravel rnded.) of grey to black volcs. w/ red-brown volcs. Sand-med-coarse, rounded. Clay - med. grey (sandy) (similar to above)	
160	0.1			31.0	Sandy gravel	160-170	Mixture gravel - (mostly chips, minor sm. gravel) of med to dk grey volcs. Some brown & weathered; Sand - fine to med (5%) minor grey clay (much less than above) (no clay 165-170)	
170				32.0		170	VERY ROUGH	
						170-190	Mixture gravel - (mostly chips, sm-med gravel, rnded) Similar to 160-170 - as above large gravel to cobbles likely, mud thinning slightly	1550
180				32.0			(Mixed mud)	Kelly Down 1630
	0.07							
190				31.0			VERY ROUGH @184	2110
	0.19				sandy, clayey gravel	190-200	Mixture gravel (chips & sm size) of mostly dark volcanics and sandy clay. clay is grey w/ brown cast more clay than above Cobbles(?) noticeably absent sm. gravel is rounded. SMOOTHER DRILLING BELOW 190	2202
200				31.0				
	0.1					200-210	Mixture of gravel (chips & granule to ¼") Sm. gravel is rounded. & brown sandy clay similar to above	
210				31.0	clayey sand & gravel			2345 Kelly Down
						210-220	Mixture of sm. gravel & v. coarse sand. some chips (to ¼") pebbles ? 213-215 cobbles(?) ROUGHER grey sand clay	8/12/88
220				30.0			Added water to mix mud	0115
	0.07					220-230	same as 210-220	
230				31.0	gravelly sandy clay			0250
						230-240	More clay than 220-230. Mixture brown/grey clay, sandy & sm gravel & gravel chips	
240				31.0	sandy clay			0315
						240-250	Mixture blue-grey clay & brown clay plus sand, fine to coarse few chips (little or No gravel)	
250				32.0				0440
	0.25				sandy, clayey gravel	250-260	Mixture of gravel (chips & granules) granules are rounded. grey-brown sandy clay. Sand fine--	
260				32.0				0520
	0.17				silty, clayey sand	260-270	Mixture sands (mostly v. coarse to med.- volc & qtz) silt & clay. few granules. some chips of varied volcanics	
270				32.0	silty, sandy clay	270-280	Mixture lt. brown sandy clay (increased clay) coarse sand, some chips & granules of varied volcanics. Very ROUGH @274' - cobbles?	kelly down 0618/0707
280				33.0				0913
	0.15				sandy, gravelly clay	280-290	Mixture lt. brown clay; sand, up to very coarse (mostly grey volcanics); & gravel (chips & granules, subrounded)	
290				34.0			similar to 270-280 but more gravel	0920
	0.2					290-300	Mixture grey & brown clay; Sand, fine to coarse (mostly volcanics); & gravel. More chips than above (varied color volcanics)	
300				35.0				1125

LOG OF BOREHOLE

BOREHOLE SGI-1

LOC. or COORDS. SE¼ NW¼ Sec. 5, T.29N., R.12E.

GROUND ELEV. 4180 Ft (est.)

TOTAL DEPTH

BOREHOLE DIAM. 20", 2-52; 13½, 52-410; 9⅞" 412 – T.D.

DRILLER LAYNE-WESTERN CO. 275 Road 98 Woodland, CA 95695

RIG Failing 3000 CF (#401)

BIT(S) 9⅞" tricone

FLUID Bentonite & Polymer

	START	FINISH
DATE	3/7/88	3/17/88
TIME	1330	1800

GEOPHYS LOG X YES __ NO

HOW LEFT

LOCATION Sierra Road, South Susanville, CA

LOGGED BY PCB

PROJECT 88-460 Susanville Injection Well

DEPTH	PENETRATE FT/MIN	CIRC. RET.	CIRC. LOSS	TEMP °C	MATERIAL	DESCRIPTION AND COMMENTS	
					sandy, gravelly clay	300-310 Mixture of grey & brown clay; Sand; & gravel similar to 280-300	4 1520 K.D 302.6
310	0.2			36.0		310-320 Mixture of grey & brown clay; Sand, fine to coarse; & gravel (granule & larger (chips)) Mostly grey volcanics	
320				36.0		320-330 Mixture of grey clay; sand, fine to coarse; & gravel (granule & larger), Sand & gravel mostly grey volcanics Gravel is embedded in clay. small gravel is rounded	
330	0.15			38.0		330-340	
340				38.0	sandy, clayey gravel	ROUGH 338'	1600
						340-350 Mixture gravel, sand & minor grey-brown clay Gravel (Chips, granule & larger), subrounded Sand, med. to coarse	
350	0.11			38.0		350-360 similar to above, but w/ more chips (of gravel).	
360				38.0	gravelly, Sandy clay	360-370 Mixture of grey & brown clay sand, mostly coarse-v coarse Large gravel (pebbles &, chips) 362-370 ADDED WATER TO THIN MUD	1825 K.D 1912 1930
370	0.17			35.0	sandy clay interbedded with Sand	370-380 Mixture of grey & brown clay (mostly brown near 380) & sand fine to coarse & v. coarse	
380			slight fluid loss	35.0		slight fluid loss starting w/ ≈380	2146
	0.38					380-390 similar to 370-380, but coarser sand	
390				33.0		390-400 Mixture of brown & grey clay Sand, med-coarse volcanics.	2210
400				33.5		ROUGH @ 399	K.D 2220 2307
	0.43					similar to above but w/ lt. grey ash 'streaks' & possible gravel beds 404-	
410				33.5		surface casing cemented to 412' 8/15/88 commence drilling below casing @ 8/17/88	2330
					sandy claystone	412-420 clay, grey & brittle with angular volcanic sands mostly 1-2mm chips smooth drilling	
420	0.5			32.0		420-430 Mixture gray claystone & med sand: med, subrounded to subangular mostly grey volcanics	0121 KD
430				32.0	Sand	430-440 Mixture of med to coarse sand subrounded to subang; gray claystone & brown clayey sand	0131
						Δ@436	
440				31.5	clay	440-450 Mixture of clay, tan to lt. brown & med. sand	0142
450				32	sand	Δ@449	0201

LOG OF BOREHOLE

BOREHOLE SGI-1 **PAGE** 4 **of** 5

LOC. or COORDS. SE¼ NW¼ Sec 5, T.29N., R.12E	**DRILLER** LAYNE-WESTERN CO. 275 Road 98 Woodland, CA 95695	START / FINISH
GROUND ELEV. 4180 (est.)		**DATE** 8/7/88 / 8/17/88
TOTAL DEPTH	**RIG** Failing 3000 CF	**TIME** 1350 / 1330
BOREHOLE DIAM. 20", 0-52; 13½, 52-412; 9⅞" 412-T.D.	**BIT(S)** 9 ⅞" ⌀ Button Tricone	**GEOPHYS LOG** X YES __ NO
	FLUID Polymer	**HOW LEFT**

LOCATION Sierra Rd, South of Susanville CA

LOGGED BY DCB

PROJECT 88-460 Susanville Injection Well

DEPTH	PENETRATE FT/MIN	CIRC. RET. / LOSS	TEMP. °C	MATERIAL	DESCRIPTION AND COMMENTS	
	0.5			sand	Sand, coarse to very coarse. Volcanics & qtz; 450-460 subrounded to subangular	2201
460		minor loss	31.5		slight fluid loss, added water; △@469	K.D. 0240
	0.7			clayey, silty sand	Sand, medium grained, subrounded & lt. brown clayey, silty sand; clay is ~10%; 460-470 & compacted	0245
470			33.0			
				sand & Gravel	△@471 rougher @ 471' sand coarse as in 450-460' some small gravel	0200
480						1315
	0.5		33.0	interbedded clay & sand	△@482 Clay, light brown & sand, med. to coarse drills like clay w/ sand beds. difficulty making connection, mixed more polymer.	
490			33.0			0328 K.D. 0444 0456
					Note penetration rate improved w/ higher circ. rate	
500	1.8		33.0			
				clay	500-510 clay, lt brown to tan, very soft some red brown compacted clay as well	
510			33.0			
					510-520 Same as 500-510	
520			33.0			0544 K.D.
	0.5				△@524 Clay, brown & grey (soft) small gravel, multi-colored volcanics some very well rounded to chips (added water after cleaning pit)	0616
530			31.0	gravel & clay		
	1.0				530-540 Mixture of lt. brown clay and gravel, variety of volcanics, granules & larger. granules are well rounded plus chips of larger gravel some show round sides	0637
540			31			
					540-550 similar to above. drills as if gravel & clay are interbedded	0647
550			31			
					550-560 Brown clay w/ some silt/fine sand gravel, granules (+ chips) variety of volcanics	0715 K.D. 0800
560			32			
					560-570 Lt. Brown clay w/ minor silt & fine sand gravel, granules & larger (chips) rounded w/ coarse sand △ in rate suggests basalt, chips of basalt.	0820
570			32.0			
					△@575 570-580 Mixture of dark grey to black volcanic. (Aphanitic) red brown & grey clay (ash?) ash & cinders on upper flow surface	0925
580			33.0			
				Basalt w/ ash(?) & cinders	580-590 Dark grey to black volcanic, some qtz (amygdules) vesicular? △587 with red-brown & grey clay (cinders & ash?)	1017
590	0.1		35.0		slight changes @ 587 & 594 suggest breaks between flows; △@594; 590-600	
600			38.0			1320

LOG OF BOREHOLE

BOREHOLE SGI-1

LOC. or COORDS. SE¼ NW¼ Sec. 5, T.29N., R.12E.	DRILLER LAYNE WESTERN CO. 275 Road 98 Woodland CA 95695	START / FINISH
GROUND ELEV. 1180 FT (est.)	RIG Failing 3092 &F (#401)	DATE 8/7/88 / 8/17/88
TOTAL DEPTH 655	BIT(S) 7 7/8" Button Tricone	TIME 1330 / 1330
BOREHOLE DIAM. 20", 0-52'; 13½" 52-412FT; 9 7/8" 412-T.D.	FLUID Polymer	GEOPHYS LOG X YES __ NO
		HOW LEFT

LOCATION Sierra Road, South of Susanville CA

LOGGED BY DCP

PROJECT 88-460 Susanville Injection Well

DEPTH	PENETRATE FT/MIN	CIRC. RET.	CIRC. LOSS	Temp. °C	MATERIAL	SYMBOL	DESCRIPTION AND COMMENTS
	1.0, 0.1				Basalt		600-610 dark grey to black volcanic & dark brown clay (ash). Some silica & Quartz amygdules
610	0.25			39.0			610-620 Similar to above but w/ mottled grey & purple clay (ash?) 1:??
620				39.0			620-630 dark grey, black & brown volcanic, amygdules & brown to red clay (cinders) 1540
630				39.5			630-640 Similar to above 1620
640				40			clay or ash bed 639-642' w/ lt. tan to buff zeoline cuttings 1640
650				39.5			642-55 similar to above but with wet brown clay @648 1658 K.D.
660							T.D. 8/17/88 E-logged 8/18/88
670							
680							
690							
700							
710							
720							
730							
740							
750							

APPENDIX B

GEOPHYSICAL LOGS

APPENDIX C

WELL CONSTRUCTION SUMMARY

WILLIAM E. NORK, Inc.

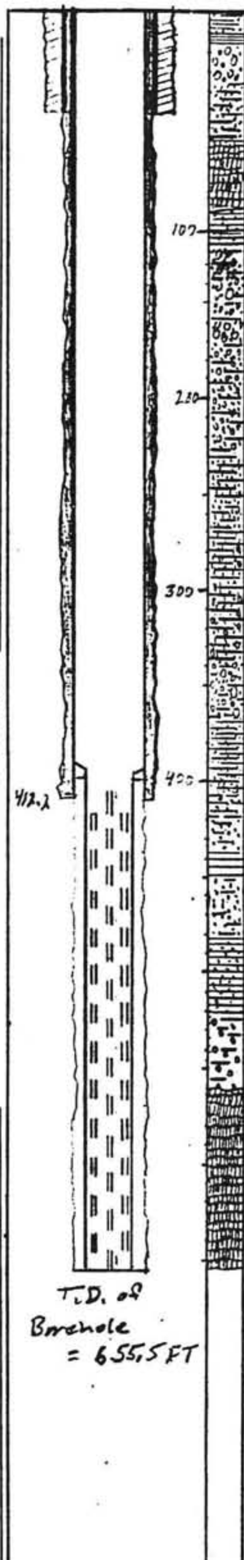
Reno, Nevada 89503

LOCATION Sierra Road, South of Susanville, CA

PERSONNEL DCB

PROJECT 88-460 Susanville Injection Well

CONSTRUCTION SUMMARY FOR WELL SGI-1



T.D. of Borehole = 655.5 FT

LOCATION OR COORDS: SE¼ NW¼ Sec. 5 T.29N., R.12E

ELEVATION: GROUND LEVEL 4180 FT

TOP OF CASING

DRILLING SUMMARY:

TOTAL DEPTH 655.5 FT

BOREHOLE DIAMETER 20"Ø, 0-52 FT; 13½"Ø, 52-412 FT; 9⅞, 412-T.D.

DRILLER [illegible]-WESTERN Co. [illegible] Road [illegible] Woodland, CA 95695

RIG Failing 2500 [illegible] (#401)

BIT(S) 12¼ M.T./TriC.; 20" M.T. reamer; 9⅞" M.T./TriC.; 9⅞" button; 13½" Reamer

DRILLING FLUID Bentonite (added polymer) TO 412 FT.; Polymer below 412 FT

SURFACE CASING [illegible] FT 14½" O.D. [illegible]

WELL DESIGN:

BASIS: GEOLOGIC LOG X GEOPHYSICAL LOG X

CASING STRING(S): C=CASING S=SCREEN

-1.0	412.2	C1
401.2	414.9	C2
414.9	655.5	S1

CASING: C1 10¾" O.D. x 0.250 ASTM A120

C2 6⅝" O.D. x 0.250" w/ 'J' Hook

~~C3~~ Adaptor (13.7 FT L.O.A.)

C4

S1 6⅝ O.D. x 0.250 ASTM A120

~~S2~~ ⅛" x 2½" Double Mill Slots - 24/FT

S3

S4

CENTRALIZERS 3/ROUND EVERY 80 FT; 1½-INCH WIDE (14½" & 10¾" casing)

FILTER MATERIAL NA

CEMENT Type I NEAT CEMENT w/ 2% BENTONITE

OTHER ¼" thick steel plate on bottom of 6⅝" O.D. liner. 'J' hook adapter @ Top of 6⅝". Rubber packer between 6⅝" & 10¾"

CONSTRUCTION TIME LOG:

TASK	START DATE	START TIME	FINISH DATE	FINISH TIME
DRILLING:				
12¼"Ø (first pass)	8/7/88	1330	8/7/88	1759
9⅞"Ø (first pass)	8/10/88	1700	8/12/88	2330
9⅞"Ø (below 10" casing)	8/17/88	2005	8/17/88	1930
GEOPHYS. LOGGING:	8/10/88	0320	8/10/88	1151
CASING:				
Conductor	8/9/88	1250	8/9/88	1330
10¾" O.D.	8/14/88	1210	8/14/88	1700
6⅝" O.D. (liner)	8/18/88	0535	8/18/88	1245
FILTER PLACEMENT:	Not Applicable			
CEMENTING:	8/15/88	0830	8/15/88	0845
DEVELOPMENT:	8/22/88	1700	8/24	1000
OTHER:				
Ream 12¼ to 20"Ø	8/8/88	2530	8/9/88	1450
Cement conductor	8/9/88	1605	8/9/88	1330
Ream 9⅞ to 13½"	8/13/88	0200	8/14/88	0450
Install 12"Ø VALVE	8/10/88		8/11/88	
Attempt to pull liner	8/25/88	1200	8/26/88	1100

WELL DEVELOPMENT:

Bail w/ flap-bottom bailer. Add Chlorine to break down drilling fluid.

COMMENTS:

1. Conductor cemented w/ cement/sand grout pumped thru tremie
2. Cement (412 to LSD) pumped by BJ-TITAN via tremie
3. Casing cut off below L.S.D. Equipped w/ 12"Ø Gate Valve
4. E&T logs before running 6⅝"Ø casing. γ & neutron after
5. T.V. survey showed damage to 'J' tool 8/24/88
6. Attempt to pull liner was unsuccessful.

APPENDIX D

FIELD DATA SHEETS - ALLEN WELL #2 TEST

AQUIFER TEST DATA

Pumping Well Allen #2 **Observation Wells** LLB-2

Owner Les Allen Address ________ County Lassen State CA

Date 1/17/89 Company performing test A1 Pump (Lee Hunter) Measured by JCB

Well No. Allen #2 Distance from pumping well — Type of test Constant-Discharge Test No. 1

Measuring equipment Electric sounder ; Flow meter - Reads AF x 0.0001 · (32.58 x M = Q).

Time Data	Water Level Data	Discharge Data	Comments on factors affecting test data
Pump on: Date 1/17/89 Time 1000 (t_o) Pump off: Date ____ Time ____ (t'_o) Duration of aquifer test: Pumping ____ Recovery ____	Static water level 13.79 Measuring point Top of casing Elevation of measuring point ____	How Q measured Meter Depth of pump/air line 84 Previous pumping? Yes ____ No x Duration ____ End ____	

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change (s or s')		Discharge measurement	$\bar{Q}$ Av Rate	Q Inst Rate	Comments
1/17	1000	0				73.79			0		462535			
	1005	5				—			—		458			Difficulty w/ sounder hanging up
	1011	11				—			—		560			Ditto
	1013	13				65.7?			52.16					Ditto
	1016	16				66.39			52.60		573	77.4		T=94°F
	1018	18										78.1	78.2	65.16 [illegible]
	1020	20				67.18			53.39		585	65		
	1025	25				67.48			53.69					65.16 gal / 50 sec ↓
	1030	30				67.82			54.03				78.2	
	1035	35				68.32			54.53		617.8	77.08	78.2	T=95°F
	1040	40				68.40			54.6					
	1045	45				68.66			54.87		638.8	75	73.5	2.25 rev/min
	1050	50				68.80			55.01				78.2	
	1100	60				66.78			52.99		677	77.1	70	
	1120	80				66.92			53.13		732	80.2	91	96 gpm @ 1017 hrs
	1140	100				66.85			53.06		783	80.8	90	[illegible] T=96°F
	1200	120				67.01			53.22		840	82.8	90	T=96°F
	1230	150				66.98			53.19		462919	83.4	90	T=96
	1300	180				67.0			53.21		3004.5	85	92	T=96
	1330	210				67.23			53.44		3085	85.3	83.4	T=96°F
	1400	240				67.00			53.21		3166		89	T=96°F
	1430	270				67.20			53.41		3247.5		88.5	T=96°F EC=920 µmho/cm pH=7.3
	1500	300				67.16			53.37		3330.5	86.4	90.1	T=95°F EC=920 µmho/cm pH=8.4 30.2 in Hg
	1530	330				67.56			53.77		3412	86.6	88.5	
	1600	360				67.16			53.37		3496.5	86.9	90.7	T=96°F E.C.=930 µmho/cm pH=8.3
	1700	420				67.78			53.99		3657	87.0	87.7	30.36 in Hg
	1800	480				67.72			53.93		3816	86.9	86.2	T=96°F E.C.=924 µmho/cm pH=7.7
	1900	540				67.52			53.73		3969		83.0	T=96°F

AQUIFER TEST DATA

Pumping Well ALLEN #2 **Observation Wells** LLB-2

Owner LES ALLEN Address ____ County LASSEN State CA

Date 1/17/89 Company performing test A1 PUMP (LEE HUNTER) Measured by DCB

Well No. ALLEN #2 Distance from pumping well — Type of test CONSTANT-DISCHARGE Test No. 1

Measuring equipment ELECTRIC SOUNDER · FLOW METER - READS AF x 0.0001 (START 462535 AF)

Time Data
Pump on: Date 1/17/89 Time 1000 (t_o)
Pump off: Date 1/18/89 Time 1000 (t'_o)
Duration of aquifer test:
Pumping 24 HRS Recovery ____

Water Level Data
Static water level 13.79 FT
Measuring point TOP OF CASING
Elevation of measuring point ____

Discharge Data
How Q measured METER
Depth of pump/air line 82 FT
Previous pumping? Yes ____ No X
Duration ____ End ____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	$\bar{Q}$ Av Rate	Q	Comments
1/17	2000	600				67.96			54.17		64114.5	79	78	25 sec [illegible] T = 76°F E.C. = 930 MMHO/cm pH = 7.6
	2100	660				69.70			[illegible]		[illegible]1.9	[illegible]	75	Adj Q
	2200	720				70.70			[illegible]		44 17	[illegible]	[illegible]	T = 76°F
	2300	780				70.08			56.29		4569.6	75	92.9	T = 76°F E.C. = 930 MMHO/cm pH = 7.6
	2400	840				70.40			56.61		4724.6	84.9	84.2	T = 75°F E.C. = 940 MMHO/cm pH = 7.0 (a pH probe)
1/18	0100	900				70.39			56.60		4880	84.9	84.4	
	0240	1000				70.63			56.84		5139.4	84.9	84.5	
	0420	1100				70.28			56.49		5404.7	85.0	86.4	T = 76°F E.C. = 950 MMHO/cm pH = 7.5
	0600	1200				70.30			56.51		5671.5	85.1	86.9	
	0740	1300				70.33			56.59		5938.1	85.3	86.9	
	0920	1400				—			—		6206.3	[illegible]	87.3	sounder stuck @ 63' depth
	1000	1440									466309.1	85.4	83.7	Sample @ 0900 T = 76°F EC = 950 MMHO/cm pH = 6.9

AQUIFER TEST DATA

Pumping Well Allen #2 **Observation Wells** LLR-2

Owner: LES ALLEN | Address: | County: LASSEN | State: CA

Date: 1/18/89 | Company performing test: A1 PUMP (LEE HUNTER) | Measured by: DGB/LH

Well No. ALLEN #2 | Distance from pumping well: — | Type of test: CONSTANT-DISCHARGE | Test No. 1

Measuring equipment: ELECTRIC SOUNDER

Time Data
Pump on: Date 1/17/89 Time 1000 (t_o)
Pump off: Date 1/18/89 Time 1000 (t_o')
Duration of aquifer test: Pumping 24 Recovery ____

Water Level Data
Static water level 13.79 FT
Measuring point Top of Casing
Elevation of measuring point ____

Discharge Data
How Q measured Meter
Depth of (pump)/air line 82 FT
Previous pumping? Yes ____ No X
Duration ____ End ____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'	calc. rec. s-s'	Discharge measurement	Rate		Comments on factors affecting test data
/18	1000	1440	0			70.3			56.51	0				
	10:01	1441				38'		23		42.3				
	10:03	1443	-			35'		25		45.3				
	10:04	1444	4			34'		24		46.3				
	10:05	1445	5			33'		23		47.3				
	1007	1447	7			32'		22		48.3				
	10:09	1449	9			31'4"		21.33		48.97				
	10:11	1451	11			30'11"		20.92		49.38				
	10:12	1452	12			30'5"		20.52		49.48				
	10:13	1453	13			30'2"		20.17		50.13				
	10:14	1454	14			30'		20.0		50.3				
	10:15	1455	15			29'10"		19.83		50.47				
	10:16	1456	16			29'5"		19.52		50.78				
	10:17	1457	17			29'4"		19.33		50.93				
	10:18	1458	18			29'2"		19.17		51.13				
	10:19	1459	19			29½"		19.04		51.26				
	10:20	1460	20			29'		19.0		51.3				
	10:21	1461	21			28'11"		18.92		51.38				
	10:22	1462	22			28'10"		18.83		51.47				Δ Observers
	1024	1464	24			18.46				51.84				
	1029	1469	29			18.31				51.99				
	1034	1474	34			17.78				52.52				
	1040	1480	40			17.50				53.00				
	1044	1484	44			17.10				53.20				
	1049	1489	49			16.90				53.40				
	1059	1499	59			16.71				53.59				
	1118	1518	78			16.26				54.04				
	1138	1438	98			15.92 15.68				54.38				

AQUIFER TEST DATA

Pumping Well ALLEN #2 **Observation Wells** LLB-2

Owner LES ALLEN Address County LASSEN State CA

Date 1/18/89 Company performing test A 1 PUMP (LEE HUNTER) Measured by DCB

Well No. ALLEN #2 Distance from pumping well — Type of test CONSTANT-DISCHARGE Test No.

Measuring equipment

Time Data

Pump on: Date 1/17/89 Time 1000 (t_o)
Pump off: Date 1/18/89 Time 1000 (t'_o)
Duration of aquifer test:
Pumping 24 Recovery

Water Level Data

Static water level 13.79 FT
Measuring point TOP OF CASING
Elevation of measuring point

Discharge Data

How Q measured METER
Depth of (pump)/air line 82 FT
Previous pumping? Yes ____ No x
Duration ____ End ____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'	calc rec s-s'	Discharge measurement	Rate		70.3'
1/18	1158	1558	118			15.68				54.62				
	1229	1589	148			15.42				54.98				
	1259	1619	179			15.21				55.09				
	1329	1649	209			15.07				55.[illegible]				
	1400	1680	240			14.99				55.31				

AQUIFER TEST DATA

Pumping Well Allen #2 **Observation Wells** LLB-2

Owner Les Allen Address County Lassen State CA

Date 1/17/89 Company performing test A1 PUMP SUPPLY Measured by DH / DCB

Well No. LLB-2 Distance from pumping well 242 FT Type of test CONSTANT-DISCHARGE Test No. 1

Measuring equipment Electric sounder

Time Data
Pump on: Date 1/17/89 Time 1000 (t_o)
Pump off: Date ___ Time ___ (t'_o)
Duration of aquifer test:
Pumping ___ Recovery ___

Water Level Data
Static water level 13.70
Measuring point Top of 2" nipple
Elevation of measuring point

Discharge Data
How Q measured meter
Depth of (pump)/air line 84'
Previous pumping? Yes ___ No x
Duration ___ End ___

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change (s) or s'		Discharge measurement	Rate		Comments
1/17	1000	0				13.70			0					
	1001	1				13.70			0					
	1002	2				13.72			0.02					
	1003	3				13.73			0.03					
	1004	4				13.80			0.10					
	1005	5				14.20			0.50					
	1006	6				14.77			1.07					
	1007	7				15.0			1.30					
	1008	8				15.29			1.59					
	1009	9				15.65			1.95					
	1010	10				15.92			2.22					
	1012	12				16.39			2.69					
	1014	14				16.86			3.16					
	1016	16				17.20			3.50					
	1018	18				17.51			3.81					
	1020	20				17.77			4.07					
	1025	25				18.27			4.57					
	1030	30				18.67			4.97					
	1035	35				18.97			5.27					
	1040	40				19.26			5.56					
	1045	45				19.33			5.63					
	1050	50				19.55			5.85					
	1055	55				19.66			5.96					
	1100	60				19.73			6.03					
	1105	65				19.80			6.10					
	1110	70				19.85			6.15					
	1115	75				19.92			6.22					
	1120	80				19.96			6.26					

AQUIFER TEST DATA

Pumping Well Allen #2 **Observation Wells** LLB-2

Owner Les Allen Address ____ County Lassen State CA

Date 1/17/89 Company performing test A1 Pump Measured by PCB

Well No. LLB #2 Distance from pumping well 242 FT Type of test CONSTANT-DISCHARGE Test No. 1

Measuring equipment Electrical sounder

Time Data
Pump on: Date 1/17/89 Time 1020 (t_o)
Pump off: Date ____ Time ____ (t_o')
Duration of aquifer test: Pumping ____ Recovery ____

Water Level Data
Static water level 13.70'
Measuring point Top of 2" pipe
Elevation of measuring point ____

Discharge Data
How Q measured ____
Depth of pump/air line ____
Previous pumping? Yes ____ No ____
Duration ____ End ____

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change (s) or s'		Discharge measurement	Rate		Comments
1/17	1042	122				20.18			6.48					
	1202	122				20.33			6.63					
	1232	152				20.52			6.82					
	1302	182				20.64			6.94					
	1332	212				20.73			7.03					
	1402	242				20.84			7.14					
	1432	272				20.92			7.22					
	1502	302				21.01			7.31					
	1532	332				21.06			7.36					30.3 in Hg
	1602	362				21.13			7.43					
	1702	422				21.23			7.53					30.36 in Hg
	1802	482				21.34			7.64					30.42 in Hg
	1902	542				21.43			7.73					30.41 in Hg
	2004	604				21.52			7.82					30.39 in Hg
	2104	664				21.61			7.91					30.36 in Hg
	2204	724				21.77			8.07					30.62 in Hg
	2304	784				21.84			8.14					30.53 in Hg
1/18	0004	844				21.87			8.17					30.51 in Hg
	0104	904				21.92			8.22					30.44 in Hg
	0246	1006				21.97			8.27					30.44 in Hg
	0424	1104				22.01			8.31					30.28 in Hg
	0604	1204				22.08			8.38					30.33 in Hg
	0744	1304				22.08			8.38					30.29 in Hg
	0830	1350				22.10			8.40					
	0920	1400				22.10			8.40					

AQUIFER TEST DATA

Pumping Well ALLEN #2 **Observation Wells** LLB-2

Owner LES ALLEN Address County LASSEN State CA

Date 1/18/82 Company performing test A1 PUMP (LEE HUNTER) Measured by DCB

Well No. LLB-2 Distance from pumping well 242 FT Type of test CONSTANT-DISCHARGE Test No. 1

Measuring equipment ELECTRIC SOUNDER

Time Data
Pump on: Date 1/17/82 Time 1000 (t_o)
Pump off: Date 1/18/82 Time 1000 (t'_o)
Duration of aquifer test:
Pumping 24 hrs Recovery

Water Level Data
Static water level 13.70 ft
Measuring point Top of 2" coupling
Elevation of measuring point

Discharge Data
How Q measured
Depth of pump/air line
Previous pumping? Yes No X
Duration End

Comments on factors affecting test data

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or (s')	calc. rec s-s'	Discharge measurement	Rate		Comments on factors affecting test data
1/18	1000	1440	0			22.12			8.42	0				
	1001	1441	1			22.11				0.01				
	1002	1442	2			21.96				0.16				
	1003	1443	3			21.70				0.52				
	1004	1444	4			21.44				0.78				
	1005	1445	5			21.11				1.01				
	1006	1446	6			20.80				1.32				
	1007	1447	7			20.54				1.58				
	1008	1448	8			20.25				1.87				
	1009	1449	9			20.01				2.11				
	1010	1450	10			19.78				2.34				
	1012	1452	12			19.40				2.72				
	1014	1454	14			19.05				3.07				
	1016	1456	16			18.80				3.32				
	1018	1458	18			18.54				3.58				
	1020	1460	20			18.28				3.84				
	1026	1466	26			17.75				4.37				
	1031	1471	31			18.45				4.67				
	1036	1476	36			17.19				4.93				
	1042	1482	42			16.94				5.18				
	1046	1486	46			16.80				5.32				
	1051	1491	51			16.62				5.50				
	1101	1501	61			16.42				5.70				
	1120	1520	80			16.07				6.05				
	1140	1540	100			15.80				6.42				
	1202	1562	122			15.61				6.61				30.52 in Hg
	1231	1591	151			15.42				6.79				
	1301	1621	181			15.26				6.86				

AQUIFER TEST DATA

Pumping Well Allen #2 **Observation Wells** LLB-2

Owner: Les Allen Address: ____ County: Lassen State: CA

Date: 1/18/89 Company performing test: A1 Pump Measured by: DCR

Well No.: LLB-2 Distance from pumping well: 242 FT Type of test: ____ Test No.: 1

Measuring equipment: ____

Time Data	Water Level Data	Discharge Data	Comments on factors affecting test data
Pump on: Date 1/17/89 Time 1000 (t_o) Pump off: Date 1/18/89 Time 1000 (t'_o) Duration of aquifer test: Pumping 24 Recovery ____	Static water level 13.70 ft Measuring point Top of 2" coupler Elevation of measuring point ____	How Q measured ____ Depth of pump/air line ____ Previous pumping? Yes ____ No ____ Duration ____ End ____	

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'	calc. rec. s−s'	Discharge measurement	Rate		22.12
1/18	1331	1651	211			15.15			6.97					
	1402	1682	242			15.05			7.07					[illegible].47 in Hg

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