G. HYDROGEOLOGY

Additional Information Regarding the
Phase 5 - Hydrologic Investigation Report
GeoLogic Associates:
October 18, 1998

Phase 5 - Hydrogeologic Investigation
GeoLogic Associates:
December 1997

Leachate Generation Analysis
GeoLogic Associates:
December 18, 1998

Two-Dimensional Groundwater Flow Model
GeoLogic Associates:
October 23, 1995

GeoLogic Associates
Geologists, Hydrogeologists and Engineers

October 18, 1998
Job No. 9539

Gregory Canyon Ltd.
14249 Via Baroda
San Diego, CA 92130

Attention: Mr. Richard Chase

RE: ADDITIONAL INFORMATION REGARDING THE PHASE 5 - HYDROLOGIC INVESTIGATION REPORT PROPOSED GREGORY CANYON LANDFILL, SAN DIEGO COUNTY, CALIFORNIA

This letter contains supplementary data to our Phase 5 - Hydrogeologic Investigation report, as requested by the County of San Diego in the October 2, 1998. Reference is made to sections and pages in the original report.

Comment # 1. *State the proposed base elevation of the landfill and contrast it with the surface elevation of the San Luis Rey River flood plain (page 3).*

Addendum # 1. The base elevation of the proposed landfill (370 to 440 feet amsl), is at least 50 feet higher than the maximum surface elevation of the San Luis Rey River flood plain (320 feet amsl). *Text to augment the information provided in page 3, section on Location and Topography.*

Comment # 2. *State the significance of the triple junction of lineaments 2, 3 and 9 (page 8).*

Addendum # 2. Lineaments 2, 3, and 9 appear to form a triple "junction" at a significant distance south of Gregory Canyon, which demonstrates that none of these lineaments is a through-going fault. *Text to augment the information provided in page 8, paragraph 4, which is a part of the section on Structural Geology.*

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Comment # 3. *Provide further information on lineament 6 (page 8).*

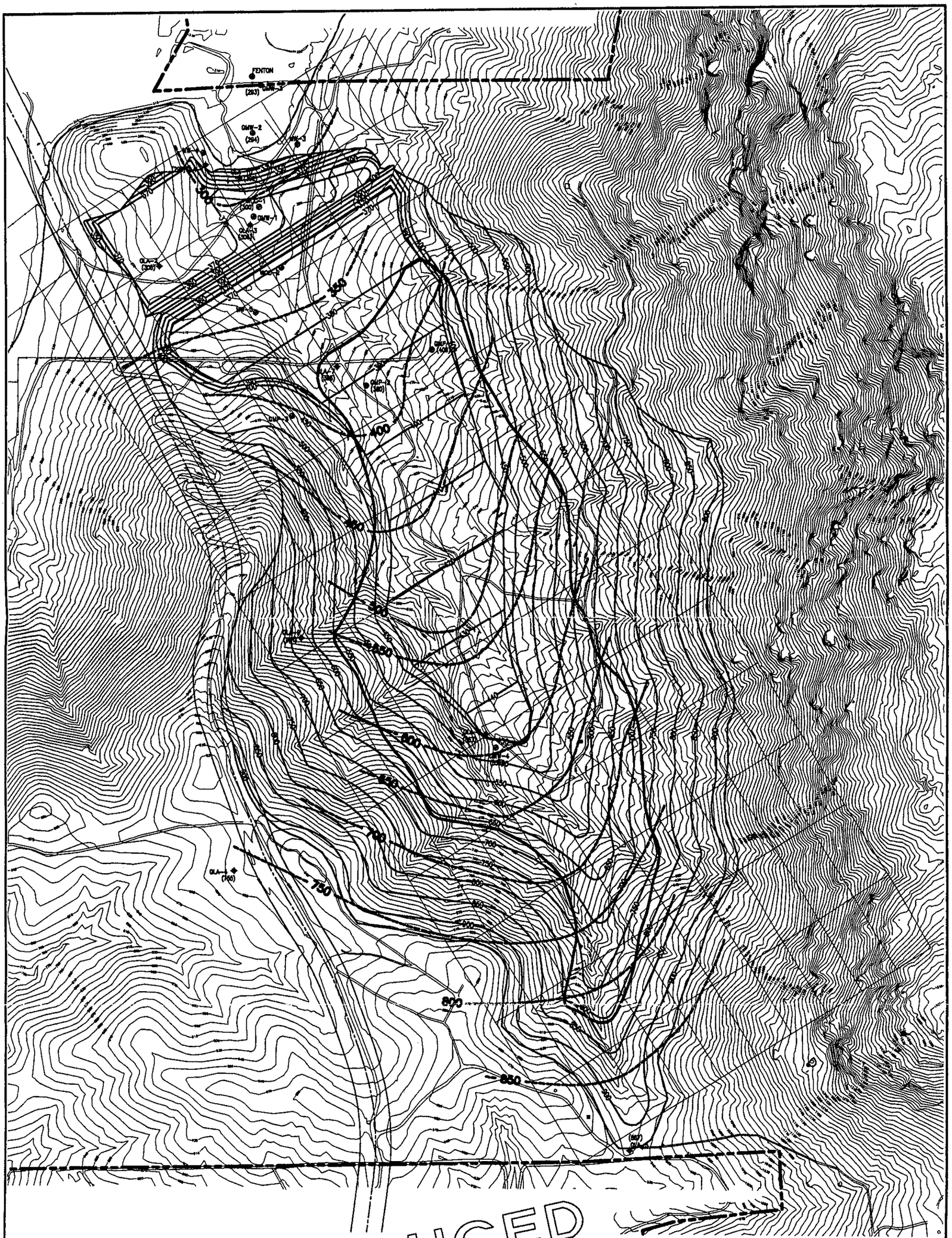
Addendum # 3. Lineaments 6 and 7 appear to be erosional features, formed by lateral migration of the San Luis Rey River. Lineament 6 was further investigated because its projection to the southwest would intercept the thalweg of Gregory Canyon immediately south of the ancillary facilities area (the projection of the lineament does not cut across the lined refuse disposal area). Six geophysical survey lines were measured with a very-low frequency electromagnetic field receiver (lines E, F, F_{NLK}, G, H, and N) across the projection of the lineament. Weak anomalies along these lines could be constrained as permissive evidence of the existence of a zone of secondary fracture permeability aligned with lineament 6. Well GLA-10 was installed over the most prominent zone of geophysical anomaly, but analysis of its structural data (e.g., Figure 16) did not disclose preferential fracturing in a northeast orientation. *Text to augment the information provided in page 8, section on Structural Geology.*

Comment # 4. *The off-site wells listed should be summarized as to their current uses. These uses should be defined as follows: municipal, domestic, agricultural, industrial, not in use and unknown.*

Addendum # 4. Figure 1, enclosed to this addendum, summarizes the known uses of nearby offsite wells. *This figure to complement Figure 20 in the report.*

Comment # 5. *The groundwater model was based on Sheet 4 (Master Excavation Plan) of the January 1998 plans. The Master Excavation Plan was slightly modified for the April 1998 submittal. Does the groundwater flow model need to be re-evaluated?*

Addendum # 5. GLA re-evaluated the after-grading low-permeability (GREG2) and high permeability (GREG4) models, with the slightly modified Master Excavation Plan of the April 1988 submittal. Figure 2 shows the August 1998 Master Excavation Plan, the boundary of the area of the excavation that could be expected to be below the piezometric level, and the model domain. The August 1998 plan reduces slightly the depth of excavation along the eastern flank of the canyon, so the area below the piezometric level is slightly narrower than what would have been using the January 1998 grading plan. The modified models are labeled GREG2b (results summarized in Figure 3) and GREG4b (results summarized in Figure 4), respectively. The results are comparable in magnitude to those of the original models, so no major impacts are anticipated with regard to the design of the sub-drain system. *These figures to complement Figures 24, 27, and 29 in the report.*



REDUCED

PLATE 5

LEGEND:

- 700 — Bottom grade contours
- 700 — Contours of the piezometric surface
- Outline of area where the bottom grade is below the piezometric surface
- MODFLOW model grid

GRAPHIC SCALE

300 0 100 200 400

(IN FEET)

1 inch = 200 ft.

N

COMPARISON BETWEEN ELEVATION OF THE PIEZOMETRIC SURFACE AND BOTTOM GRADING PLAN, AND MODFLOW MODEL GRID

GREGORY CANYON LANDFILL

GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	SEPTEMBER 1997	9539

PHASE 5
HYDROGEOLOGIC INVESTIGATION

PROPOSED GREGORY CANYON LANDFILL
SAN DIEGO COUNTY, CALIFORNIA

December, 1997

PREPARED FOR:

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Appendix B. Report of the VLF survey
Appendix C. Report of BIPS and HydroPhysical™ logging

INTRODUCTION

This project was undertaken in support of the Environmental Impact Report that will be submitted for the proposed construction of a landfill in Gregory Canyon, north San Diego County, California. The main objectives of this phase of the investigation were to map the distribution of bedrock types within the footprint of the site, characterize the bedrock in terms of fracture density and orientation, identify potential water-yielding zones within the bedrock, characterize the geometry of the piezometric surface, assess the monitorability of the site, quantify potential inflow volumes into the excavation, and assess whether a subdrain could be designed to accommodate these inflow volumes and provide a minimum separation of 5 feet between groundwater and the waste. Previous investigations include those of Geotechnical Consultants (1989) (Phase 1), Geraghty & Miller (1988, 1990) (Phases 2 and 3), and Woodward-Clyde (1995) (Phase 4).

REGIONAL GEOLOGIC SETTING

Gregory Canyon is located in the central portion of the Peninsular Ranges province, which is characterized by northwesterly trending mountains and intervening valleys. This geomorphic province extends from the Los Angeles Basin into Baja California, Mexico. Major drainage systems generally traverse the province in a westerly direction and in northern San Diego County include, from north to south, those of the Santa Margarita, San Luis Rey and San Dieguito Rivers.

Throughout the northern part of San Diego County there are exposures of Mesozoic intrusive crystalline rocks of the Southern California batholith, and metamorphosed screens of pre-batholitic rocks. These granitoid and older metamorphic rocks have been weathered to various degrees, and are often covered by residual soils, colluvium, or alluvium. The colluvial deposits are typically found on and at the base of slopes and are the result of the downslope movement of soil and rock by the force of gravity. The alluvial deposits are found in most drainages, with deposits of considerable thickness present in major river valleys.

GEOLOGIC UNITS

Pre-batholithic, metasedimentary and metavolcanic rocks outcrop throughout the Peninsular Ranges. Examples include the outcrops of Paleozoic limestone in Riverside County, and a thick sequence of altered Jurassic (?) gneisses in the San Jacinto Mountains. In San Diego County one finds the Triassic/Jurassic Bedford Canyon sedimentary sequence, and the overlying Jurassic Santiago Peak volcanics.

The Southern California batholith is formed by plutons that range in age between 120 and 90 Ma. In order of declining age they include gabbros, quartz diorites or tonalites (the most common type), and granodiorite. Examples include the San Marcos Gabbro, the Bonsall Tonalite, and the Woodson Mountain Granodiorite. Intrusion of these plutons led to contact metamorphism of the pre-batholithic rocks. In general, mafic or intermediate magmas (gabbro to tonalite) are typically emplaced at higher temperatures than silicic magmas (granodiorite), so the contacts between the former and the host rock tend to be anatectic (i.e., with partial melting of the pre-existing rock), whereas those of the latter tend to be abrupt and largely due to the effect of forceful injection. The pre-metamorphic rock fabric

can be completely obliterated by migmatization (i.e., development of a banded aspect in the rock as a result of partial melting), but in many instances is recognizable as a relict volcanic or sedimentary texture in the metamorphic rock.

Late Cretaceous sedimentary rocks are not exposed in the immediate vicinity of the site. In the Camp Pendelton area they include the largely nonmarine Trabuco Formation, and the marine Williams Formation. In the San Luis Rey and Encinitas areas the Cretaceous rocks are grouped in the Lusardi and Point Loma Formations.

Post-Cretaceous rocks lie unconformably on either the Cretaceous rocks or the crystalline basement, but are largely confined to coastal margins some distance from the site.

STRUCTURAL GEOLOGY

The tectonic regime of the region has changed significantly between the time of emplacement of the intrusions of the Southern California batholith and the present. During the Mesozoic a subduction zone was active off the coast of California, and the tectonic stress regime was probably not unlike that observed today off the coast of Central or South America. Here, underthrusting of the Pacific plate beneath the continental plate has led to partial melting, batholith intrusion, and volcanic activity. The resulting heating of the crust creates an extensional regime perpendicular to the direction of subduction (e.g., the Central America graben, the Quito graben of the Andes, or the High Cascades graben in Oregon), which to some extent controls the location of individual intrusions and dikes stemming from these intrusions. In the case of the Mesozoic Southern California batholith, the direction of minimum stress would be parallel to the direction of subduction (to the northeast), and dikes would have a preferential strike orientation to the northwest, perpendicular to the direction of minimum stress. As will be discussed later, the measured orientations of dikes at the site conform well to this general pattern.

Tectonic conditions changed during the Cenozoic, when the East Pacific Rise reached the subduction zone, and the convergent margin was replaced by the transform margin of the San Andreas fault system. Transform, strike-slip motion started between 25 and 20 million years ago in the San Diego region (Atwater, 1970), and since then the tectonic "grain" of the Peninsular Ranges province has been dominated by strike-slip faulting along northwest-trending faults like the San Andreas, San Jacinto, Elsinore, and Rose Canyon faults. The Elsinore fault zone runs about five miles northeast of Gregory Canyon, and is thus the closest of these large structural discontinuities to the site. Like the rest of the mentioned faults, the Elsinore fault zone is the result of the right-slip motion between the North American and Pacific plates, although the individual fault strands within the Elsinore fault zone may have strike-slip, normal or thrust fault motions as a result of complex local geometries (Lamar and Rockwell, 1986). The northwest-trending fabric of the fault zone also results in distinctive structural features, including large-scale structural depressions like the Elsinore Trough, and structural highs such as the Agua Tibia Mountains.

Of more immediate interest to the structural setting of Gregory Canyon is the fact that the "block" between the Elsinore fault zone to the northeast and the Rose Canyon fault zone to the southwest is under a shear stress regime (Figure 1). In effect, the area between both fault zones is being

"wrenched" clockwise by the relative motion along these faults. Under these conditions, north-oriented extensional fractures would form, as shown in the stress diagram of Figure 1. As discussed in later sections, this is the most likely explanation for the predominance of north-striking fractures on the site, and for the dominant orientation of topographic lineaments in the region.

LOCAL GEOLOGIC SETTING

LOCATION AND TOPOGRAPHY

The proposed landfill site is located in Gregory Canyon, a north-draining tributary canyon above and to the south of the San Luis Rey River valley (Figure 2).

East of the canyon Gregory Mountain rises steeply to a maximum elevation of 1844 feet amsl. The western ridge is less steep, and rises to a maximum elevation of only 940 feet amsl. The thalweg of the canyon itself drops in elevation from 920 ft amsl at the head of the canyon on the south, to 320 ft amsl on its northern terminus. The slopes are about 5:1 (horizontal:vertical) on the lower area of the canyon, become 2:1 at the east edge of the landfill footprint, and are 1:1 and steeper on the upper part of the eastern slope above the site. The western flank of the canyon is defined by a rounded ridge line, with rather uniform slopes at inclinations of 2:1 to 3:1.

GEOLOGIC UNITS

Surficial soils

Woodward-Clyde (1995) and Geragthy & Miller (1990) excavated several test pits to expose shallow soil profiles. According to Woodward-Clyde (1995), the topsoil units encountered varied in thickness from about six inches to one foot and were composed of silty sand, silty sand with clay, and silty sand with cobbles and boulders. The topsoil was dry to moist and contained roots, pores and varying amounts of organic matter. Underlying the topsoil were residual soil horizons or weathered rocks.

The residual soils encountered in the test pits were composed of sandy lean clays and clayey sands with local cobbles and boulders. The thickness of the residual soil layers varied in the test pit exposures from about two to three feet. In general, one would expect the steeper, upper slope area of the landfill site to have slightly thinner soil accumulations than the intermediate or lower slope areas.

Alluvium

Two alluvial units have been mapped at the lower elevations of the site, near the mouth of Gregory Canyon. The younger unit, Qal-1 is formed by overbank deposits from the active San Luis Rey river channel, which are interbedded with channel deposits from the Gregory Canyon drainage. These deposits are relatively thin and contain gravels, cobbles and boulders, supported by a sandy silt matrix. The older alluvial subunit, Qal-2, is a terrace remnant of older alluvium from the Gregory Canyon drainage.

The alluvial wedge pinches out to the south, before reaching the footprint of the proposed development. In other words, the buttress at the foot of the landfill, and all of the refuse prism, will be founded on bedrock, and not on alluvium. The wedge thickens to the north until eventually it merges with the channel deposits of the San Luis Rey River. Well GMW-2, near the mouth of the canyon, cut through a 50-foot section of alluvial deposits before reaching the underlying bedrock.

Colluvium

Colluvium forms a veneer over most of the surface of the proposed landfill site. It is typically formed by silty sand with rock clasts that range in size from gravel to very large boulders. Finer-grained deposits, largely devoid of rock clasts, were encountered in test pits located at the southern end of the canyon. Older colluvium was encountered in some of the test pits, consisting of clayey sand to sandy clay with varying rock content and slight to moderate cementation.

Rock clasts exposed at the surface of the colluvial veneer vary from gravel- to boulder-size material. Boulders of leucogranodiorite, some in excess of 20 feet in maximum dimension, are present along much of the eastern sideslopes. Based on borings drilled during previous investigations, it appears that boulders are extensive in the subsurface.

The thickness of the colluvial deposits in the landfill site area is highly variable. Cross-section interpretations by Geragthy & Miller (1990) show thickness variations from 2 to 50 feet. The weathered bedrock surface on which the colluvium is deposited was described as a surface with high relief by Woodward-Clyde (1995), who thought that areas of deep colluvium were likely to be present in the lower slope area of the canyon. They stressed, however, their belief that these deposits were laterally discontinuous due to the presence of local bedrock highs, as inferred from isolated surface outcrops. The upper slope area is likely to be underlain by thin colluvial deposits and surficial soils formed on highly weathered crystalline rock. Debris chutes and drainage channels may be locally backfilled with colluvium of moderate thickness, but in general, the upper slopes are not likely to be underlain by thick, laterally continuous deposits of colluvium.

Bedrock

The area of the proposed landfill was included in the regional map of Larsen (1948), who used the term Bonsall Tonalite to describe the rocks underlying the western ridge, and the term Indian Mountain Leucogranodiorite to describe the light-colored, bold outcrops of granitic rock that form the ridge to the east of the proposed development area. Larsen (1948) also mapped an intervening screen or band of metamorphic rock along the lower slopes of the eastern ridge, which he correlated with the sedimentary Triassic/Jurassic Bedford Canyon Formation; rocks of this unit have relict volcanic textures, however, and are probably best correlated with the Jurassic Santiago Peak volcanics.

Metamorphic rocks (TJm)

The metamorphic rocks present along the easterly slopes of Gregory Canyon form a north-south-trending belt, or screen, of older rock that was intruded by batholithic rocks (Plate 1).

Specifically, the tonalite intruded and intermingled with the metamorphic rock, and both units were subsequently intruded by the leucogranodiorite.

The metamorphic rock screen includes amphibolites and metavolcanic rocks, in some locations with migmatitic structure that resembles gneissic banding. The rocks are generally dark blueish gray, hard, and only slightly weathered. They have aphanitic to porphyroblastic textures, but relict porphyritic textures suggest a volcanic protolith for some of the units.

As mentioned above, Larsen (1948) correlated these metamorphic rocks with the Bedford Canyon Formation (a sequence of mildly metamorphosed sedimentary rocks represented by deformed slates, schists, quartzites and localized occurrences of limestone), which is widespread in the Santa Ana Mountains. At Gregory Canyon, however, there are no outcrops of slates, quartzites or marbles, and there is a preponderance of metavolcanic rocks. It seems more reasonable to correlate the Gregory Canyon sequence with the Jurassic Santiago Peak volcanics, a unit composed of metavolcanic and metasedimentary rocks exposed elsewhere in San Diego County.

Tonalite (Kbt)

The tonalite that underlies the western slopes and the central portion of Gregory Canyon is an extensive rock unit in the area (Plate 1). Larsen (1948) referred to this rock unit as the Bonsall Tonalite. The tonalite is a dark gray, phaneritic rock, with medium- to coarse crystallinity, that includes a variety of related rock types such as gabbro. Other common variations noted in the tonalite are the locally veined and streaked appearance, and the migmatitic fabric that is observed near its contact with the metamorphic rocks.

The rock is also characterized by rare inclusions of the metamorphic rocks, and by numerous leucogranodiorite dikes that include fine-grained aplites and coarse-grained pegmatites.

The tonalite is moderately to intensely weathered in most outcrops, although small cores of only slightly weathered tonalite form boulder knobs in the western flank of Gregory Canyon. Moderately weathered tonalite still preserves its phaneritic texture, but the cohesion of the rock is considerably weakened, and the constituent minerals are slightly altered to oxides and clays, particularly along the edges. The intensely weathered tonalite has a granular texture that only vaguely recalls the original phaneritic texture, and is oxidized throughout. The constituent minerals are partially altered to oxides and clays, and disaggregate easily under pressure. Depth of weathering, as determined from exploratory drilling by Geraghty & Miller (1990), ranges between 65 feet (GMP-3) and 95 feet (GMW-2).

The tonalite comes in contact with the metamorphic rocks along the easterly side slopes of Gregory Canyon, although the contact is typically covered by colluvium or obscured by surficial soils. Based on its map position, as inferred from isolated outcrops of both rock types, the contact appears to dip to the east at angles of 20° to 25°, but the contact is somewhat transitional because of the effects of partial melting. Mafic or intermediate magmas (gabbro to tonalite) are emplaced at a relatively high temperature (1,200° to 900° C), so the

contacts between them and the host rock tend to be anatectic (i.e., with partial melting of the pre-existing rock). The pre-metamorphic rock fabric can be completely obliterated by migmatization (i.e., development of a banded aspect in the rock as a result of partial melting), so along the contact zone it is not always easy to discriminate between the intrusion and the host rock.

Leucogranodiorite (Kglgd)

The leucogranodiorite map unit is a light-colored, biotite-bearing granodiorite that forms the prominent mountain flanking the eastern side of Gregory Canyon (Plate 1). This prominent mountain is referred to as Gregory Mountain, but Larsen (1948) referred to it as Indian Mountain and to the light-colored rock as the Indian Mountain Leucogranodiorite. In hand specimen, the rock has a phaneritic texture with medium- to coarse-crystallinity, is light gray to buff, and has less than 5% dark minerals (biotite and Fe-Ti oxides). Quartz, plagioclase, and potassium feldspar are the dominant felsic minerals.

Besides forming the core of Gregory Mountain, the leucogranodiorite also forms dikes that cut older units. The dikes vary in thickness from less than an inch up to five feet, and in most instances are pegmatitic (i.e., coarsely crystalline). On account of their coarse texture and superimposed fracturing, some of these dikes may constitute preferential paths for water flow.

The degree of weathering of the leucogranodiorite is generally slight, as can be inferred from the bold outcrops of Gregory Mountain. The dikes, on the other hand, vary in degree of weathering from slight to moderate. Moderately weathered dikes are pervasively oxidized and have "cloudy" feldspars, but still preserve their phaneritic texture.

The main body of the leucogranodiorite is in intrusive contact with the metamorphic screen midway along the easterly side slope of Gregory Canyon. The contact zone is narrow and abrupt where it can be observed, but is generally buried under talus. Based on its map position, as inferred from the abrupt change in topography, the contact is nearly vertical, and "wraps around" Gregory Mountain, suggesting that the latter is a high level stock intruded by forceful emplacement.

STRUCTURAL GEOLOGY

Lineaments

Historical aerial photographs of the area were inspected, in order to identify potential structural discontinuities in the area of the proposed Gregory Canyon Landfill. Six sets of aerial photographs were used in the lineament analysis of the site:

Frame identification	Flight/Date	Scale	Source	Comments
Two frames without ID or fiduciary marks	Unknown, but probably ca. 1993. Dry vegetation suggests summer.	1:13,000 Probably an enlargement from a negative at a smaller scale (to judge from the lack of fiduciary marks)	San-Lo Aerial Surveys on behalf of San Diego Co. Land Use Dept. (619) 694-3160	Color stereopair with excellent resolution
1-3, 1-4, 1-5	WAC-89CA 3/30/89	1:35,000	WAC Corporation (503) 342-5169	Black and white set
305-57, 305-58, 305-59	HAP 84 F 331608 2/24/85	1:65,000	USGS Western Mapping Center (415) 329-4309	Color infrared
1836-022, 1836-023, 1836-024,	NAPP 1836 8/15/89	1:42,500	USGS Western Mapping Center (415) 329-4309	Color infrared with excellent resolution
7A,7B,8A,8B	Gregory LF 10/16/91	1:7,200	San Diego Co. Department of Environmental Health	Black and white set
1,2	Gregory LF Study 11/2/92	1:24,000	San Diego Co. Department of Environmental Health	Black and white set

The large-scale lineaments identified on and around the proposed footprint of the landfill are shown on Plate 3, in which the different colors identify the characteristics of any given lineament. Blue lines are used to indicate lineaments defined by single stretches of a ravine, and accordingly many of them are simple "shortest and steepest" paths for surface water drainage. The green lines indicate lineaments defined on the base of geomorphology (e.g., alignment of topographic saddles, linear cliff scarps) or tonal differences. Finally, the red lines indicate lineaments related to well defined fractures (as in Gregory Mountain), or dikes.

In the small scale photographs (1:42,500 to 1:65,000), Gregory Canyon seems to be anomalously straight, but in the large scale photographs it does not appear to be truly "linear". At the large scale of Plate 3, one can identify a very short linear segment near the head of the canyon (A on Plate 3), a tonal lineament off the thalweg of the canyon to the west (B), and a longer linear segment near the mouth of the canyon (C). There is also a set of three lineaments that are subparallel to the canyon,

off the thalweg to the east (D).

Perpendicular to the length of the canyon one finds, on the north, the geomorphologic lineaments defined by the cut of the San Luis Rey River (E), and a tonal lineament defined by the transition from grass to scrub vegetation (F). Toward the middle of the canyon, on the west flank, there are four steep ravines (G through J), but they do not seem to have corresponding lineaments east of the thalweg.

There is little doubt that the leucogranodiorite, which crops out along the eastern portion of Gregory Canyon, is criss-crossed by joints, but there no lineaments were identified in the photographs that might suggest that the joints extend into the metamorphic wedge or the weathered tonalite to the west.

Figure 3 summarizes some of the lineaments observed in small scale photographs outside of the footprint of the proposed landfill. Of immediate interest to this project is the general alignment of the thalweg of Gregory Canyon (hereafter referred to as the Gregory Canyon alignment). As discussed above, this alignment is actually formed by several "segments" that are closely, but not precisely aligned. If structurally controlled, it would appear to indicate the presence of subparallel fracture zones of limited length (100's of feet).

South of the project site, lineaments 1and 10 are defined by very straight, north-trending canyons; these lineaments "dominate" the fabric of the small scale photographs and satellite images, and as discussed in the introduction may be related to the extension induced by the shearing of the "wedge" between the Elsinore and Rose Canyon faults. Because of their distance from the project site, none of these lineaments is likely to be of hydrogeologic significance to the proposed landfill. Lineament 2 is somewhat parallel to the Gregory Canyon "alignment", but appears to terminate against lineament 3. In fact, lineaments 2, 3, and 9 appear to form a triple "junction" at a significant distance south of Gregory Canyon. Lineament 5 is defined by saddles that cut across the topography, and is therefore the only regional lineament that is not defined by a single, straight canyon segment. Lineament 5 is of secondary interest to the landfill, since it runs east of Gregory Mountain.

On the north, the two strands of lineament 4 appear to be the surface expression of dikes. Although similar in trend to the Gregory Canyon lineament, it would project west of the aqueduct, too far to be of immediate interest to the landfill. Lineaments 6 and 7 appear to be erosional features, formed by lateral migration of the San Luis Rey River.

"Lineament" 8 is not really expressed as a linear feature in any of the photographs, but corresponds to the only nearby fault depicted in the 1994 Fault Activity Map of California (Jennings, 1994).

The lineament analysis has not disclosed regional, through-going discontinuities across the footprint of the site. The short alignments of stretches of Gregory Canyon, however, justify geophysical exploration of a 30 feet-wide swath along both sides of the thalweg. Other lineaments (e.g., D) appear to converge toward the Gregory Canyon alignment, and no lineaments have been identified that diverge from it. It would then appear reasonable to suggest installation of the main monitoring points for the site along this alignment.

Discontinuities at outcrop level

Colluvium forms a veneer over most of the proposed landfill site, but inspection of the limited bedrock exposures indicates that structural discontinuities (joints, dikes) are common in the rocks that form the substrate of the canyon. In order to evaluate orientation, type, and characteristic spacing of these discontinuities, three "lines" were cleared of vegetation and cover soil (Figure 4), and the structural attitude of all observed discontinuities along them was measured. Line 1 was exposed along the floor of the north-trending road that runs mid-slope along the west flank of the canyon, and had a total length of 530 feet. Line 2 was excavated along the wall of the east-trending road that descends on a straight line from the western flank into the thalweg of the canyon; the wall could not be properly cleaned and this 75-foot line is thus of limited use in characterizing spacing. Line 3 was cleared along the floor of the same road, and had a total length of 220 feet.

The orientation of a plane in space can be fully defined by measuring the maximum dip angle and dip direction of the plane (Figure 5). The dip angle refers to the maximum inclination of the plane below the horizontal. The dip direction of a plane is defined as the azimuth (the angle from the north direction, measured clockwise) at which the maximum dip angle is measured. A related parameter is the strike direction of the plane, which is the azimuth of a horizontal line contained in the plane. The dip direction and the strike direction form an angle of 90° with respect to each other.

The first step in the interpretation of structural orientations requires the use of stereographic projections, to represent and analyze the three-dimensional data in two dimensions. Stereographic presentations remove one dimension by "projecting" the relevant geometric relations onto a plane. Because of the steps involved in the projection, stereographic analysis considers only angular relations between planes and lines, but provides no information with regard to position or relative importance of any given feature. The fundamental operations of stereographic projection assume a reference hemisphere that has a fixed orientation of its axis relative to the north, and of its equatorial plane to the horizontal (Figure 5). Planar features are positioned so that the plane passes through the center of the reference hemisphere. Next, it is assumed that a line perpendicular to the plane also passes through the center of the reference hemisphere. The plane can then be uniquely represented by a single point (the pole to the plane) defined by the projection of this line onto the surface of the hemisphere. The reference hemisphere is itself projected as a circle that is parallel to the equatorial plane, and this projection is referred to as a stereonet. In the stereonet, then, a plane that dips steeply to the southwest will be represented by a point close to the edge on the NE quadrant, whereas a plane that dips gently to the northwest will appear as a point near the center in the SE quadrant.

Structural mapping data of discontinuities are plotted in the pole format in order to detect the presence of preferred orientations, thus defining discontinuity sets, and to determine mean values for the orientations of these sets. This process can be facilitated by contouring to accentuate and distinguish the repetitive features from the random or unique features.

Figure 6 is a contoured pole plot of all fractures and dikes measured along lines 1 through 3 in Gregory Canyon (424 measurements). On first inspection, there seem to be data points "scattered" throughout the plot area (except perhaps for a paucity of points in the central portion of the stereonet, where horizontal discontinuities would plot). Looking at the frequency contours, there is a maximum

on the east half of the stereonet, which corresponds to a family of planes dipping between 50° and 80° to the west (dip direction between 260° and 280° or strike between 350° and 10°). This maximum merges with two secondary clusters on the northeast and southeast quadrants of the stereonet. The range of orientations of the first of these secondary clusters is 220° to 250° of dip direction (310° to 340° strike) and 50° to 70° of dip angle. The second cluster has dip directions between 320° and 340° (50° to 70° strike) and dip angles of 55° to 70°. Finally, there is a secondary maximum along the western edge of the stereonet, representing discontinuities with dip directions between 80° and 100° (350° to 10° strike) and dip angles of 75° to 90°. In summary, the combined structural data suggests the existence of four directions of preferred orientation:

	Dip direction	Strike direction	Dip angle	Dominant feature
Direction 1	270°	360°	65°	Fractures
Direction 2	90°	360°	80°	Fractures
Direction 3	255°	345°	60°	Dikes
Direction 4	330°	60°	65°	Dikes

The intersection of each pair of planes defines a line in 3-dimensional space, whose orientation can be expressed in terms of plunge direction (the azimuth of the projection of the line on the horizontal plane) and plunge angle (the vertical angle of the line with respect to the horizontal), as follows:

	Plunge direction	Plunge angle	Formed by the intersection of
Intersection line A	180°	0°	Direction 1 and Direction 2
Intersection line B	222°	55°	Direction 1 and Direction 3
Intersection line C	300°	62°	Direction 1 and Direction 4
Intersection line E	176°	19°	Direction 2 and Direction 3
Intersection line F	16°	56°	Direction 2 and Direction 4
Intersection line I	286°	57°	Direction 3 and Direction 4

The structural attitudes of fractures and dikes are plotted separately on Figures 7 and 8. The stereonet plot for the fractures (Figure 7) has primary maxima that correspond to Directions 1 and 2 in the table above, whereas the plot for dikes (Figure 8) has maxima that correspond to Directions 3 and 4. The four directions are perhaps better visualized in rose diagrams of the strike directions (Figures 9 through 11). These predominant orientations are consistent with the overall tectonic stress regime of the area, as described in the introductory section:

The tectonic regime of the region has changed significantly between the time of emplacement of the intrusions of the Southern California batholith and the present. During the Mesozoic a subduction zone was active off the coast of California, at which time the direction of minimum stress would have paralleled the direction of subduction, to the northeast. Under these conditions, dikes are preferentially emplaced perpendicular to the direction of minimum stress (Direction 3 in the table above), or parallel to it (Direction 4 in the table above).

Tectonic conditions changed during the Cenozoic, when the convergent margin was replaced by the transform margin of the San Andreas fault system (including the San Andreas, San Jacinto, Elsinore, and Rose Canyon faults). The "block" between the Elsinore fault zone to the northeast and the Rose Canyon fault zone to the southwest is thus under a shear stress regime (Figure 1). In effect, the area between both fault zones is being "wrenched" clockwise. Under these conditions, north-oriented extensional fractures would form, as shown in the stress diagram of Figure 1. This is the most likely explanation for the predominance of north-striking fractures on the site (Directions 1 and 2 in the table above).

Spacing between discontinuities, and patterns of spatial distribution, can be characterized through the use of standard statistical techniques. The discontinuity data of Gregory Canyon were tested for randomness and uniformity as follows:

Randomness in a data set means that the occurrence of an event (e.g., a discontinuity) does not affect the probability of occurrence of other events. For spatially distributed events this would result in irregular clusters, like the stars in the sky, rather than in a homogenous distribution. The frequency distribution of random data can often be expressed with the Poisson model, which has one parameter (γ) that describes the average density of points. The test for goodness of fit to the Poisson model can be done with the χ^2 test, as described by Swan and Sandilands (1995, p.222-226). The data from Line 1, which has a general north-south orientation, fit the Poisson distribution, and thus appear to be randomly distributed. The data from east-trending Line 3, on the other hand, do not fit the random distribution. The difference may be related to the orientation of the lines, and the general dominance of north-trending discontinuities. For one thing, the east-trending Line 3 had a better chance of intersecting the more abundant north-trending discontinuities than Line 1.

Uniformly distributed events are likely to result from geological processes in which the occurrence of one event influences the probability of another. In contrast with random events, then, uniformly distributed events tend to be more homogeneously distributed. Uniformity can be qualitatively assessed by constructing a cumulative occurrence plot, in which the cumulative proportion of discontinuities (number of discontinuities up to a certain point in the line normalized with respect to the total number of discontinuities) is plotted against relative distance (distance from the start of the line up to a certain point normalized to the total length of the line). Figures 12 and 13 are uniformity plots for Lines 1 and 3. In these plots, uniformly distributed events would plot close to the 1:1 line, whereas randomly distributed or clustered events would depart from this line (in all cases the lines start at the (0,0) point and converge toward the (1,1) point due to the normalization procedure). Consistent with the results of the randomness test, the data for Line 1 show a pronounced departure from the 1:1 line (Figure 12), whereas those of Line 3 straddle it (Figure 13). We conclude, hence, that discontinuities along Line 3 appear to be uniformly distributed.

Figures 14 and 15 are simple frequency histograms of spacing between discontinuities in Lines 1 and 3. In the case of Line 1, 57% of the spacings are less than, or equal to, 2 feet, and 9% of the spacings are larger than, or equal to, 9 feet. For Line 2, in contrast, 91% of the spacings are less than, or equal to, 2 feet.

In conclusion, the apparent predominance of north-striking discontinuities (Figure 9), and the relative paucity of east-striking discontinuities, could have considerable significance on the patterns of local groundwater flow. For example, if the frequency orientation in the measured data set is representative of the site, one would expect a higher uniformity in the distribution of north-striking discontinuities, which in turn might favor preferential groundwater flow along them. The presence of a significant number of discontinuities with other orientations would enhance interconnection of the flow paths, however, so reasonable assurance can be had that any given well can "sample" water representative of large portions of the aquifer.

Discontinuities in boreholes

As discussed in detail in the next section, 15 boreholes have been drilled into the crystalline bedrock at the site (Plates 1 and 5). Twelve of these boreholes were logged with an optical borehole imaging probe (BIP). The BIP system provides the highest resolution available for fracture and feature analysis in boreholes. This technique is based on direct optical observation of the wall of the borehole. Figure 16 summarizes the structural data for the 12 logged wells (see also Appendix C), and the following table summarizes the interpretations derived from these plots:

Well	Comments
GMP-3	Based on 50 fractures, the pole-plot shows a predominance of low angle fractures, and a secondary maximum with a dip azimuth and dip intensity of 260°/70°. Accordingly, the rose diagram shows a dominant strike azimuth of 350°, and secondary directions with azimuths 30°, 45°, and 70°.
GMW-1	The number of fractures is small (32 fractures), so the maximum in the density pole-plot is based on few observations and may not be representative. The maximum has a dip azimuth and dip intensity of 270°/45°. Accordingly, the rose diagram shows a dominant strike azimuth of 355°.
GMW-4	Based on 191 fractures, the pole-plot shows a predominance of fractures with a dip azimuth and dip intensity of 265°/60°. Accordingly, the rose diagram shows a dominant strike azimuth of 355°. Secondary maximum have dip azimuths and dip intensities of 325°/55° and 20°/40°.
GLA-1	Based on 191 fractures, the pole-plot shows a maximum with a dip azimuth and dip intensity of 20°/30°, but also an overall scatter pattern in the northeast and southwestern quadrants. Accordingly, the rose diagram shows a spread of strike azimuths between 280° and 330°, with a secondary maximum at an azimuth of 10°. This is a low-yield well.

GLA-2	Based on 230 fractures, the pole-plot shows a maximum with a dip azimuth and dip intensity of 330°/30°. The rose diagram shows a spread of strike azimuths between 35° and 85°. This is a low-yield well.
GLA-3	Based on 80 fractures, the pole-plot shows a predominance of low angle fractures, and an overall scatter pattern in the east-west direction. Accordingly, the rose diagram has a prominent maximum at 20° of strike azimuth, and secondary maxima at azimuths of 90°, 290°, 310°, and 340°. This is a well with average yield.
GLA-4	Based on 264 fractures, the pole-plot shows a well-defined scatter pattern in the northwest and southeast quadrants. Accordingly, the rose diagram shows a prominent maximum at 50° strike azimuth. This well produces very low yields, but its fracture pattern is very similar to that of GLA-8, which had comparatively high yield.
GLA-5	Based on 154 fractures, the pole-plot shows a maximum with a dip azimuth and dip intensity of 10°/70°. The rose diagram hence shows a well-defined maximum at 280° strike azimuth, and secondary maxima at 10° and 70° strike azimuth. This is a well with intermediate yield.
GLA-7	Based on 92 fractures, the pole-plot shows considerable scatter. The rose diagram shows a maximum at 330° strike azimuth, and a secondary maximum at 40° strike azimuth. This is a well with average yield.
GLA-8	Based on 576 fractures, the pole-plot shows a well-defined scatter pattern in the northwest and southeast quadrants. Accordingly, the rose diagram shows a tight clustering of strike azimuths between 30° and 70°. The fracture pattern of this average-yield well is very similar to that of the low-yield well GLA-4.
GLA-9	Based on 193 fractures, the pole-plot shows considerable scatter, with a modest maximum defined by low-angle fractures. The rose diagram shows clustering of strike azimuths between 300° and 340°. This is a dry well.
GLA-10	Based on 120 fractures, the pole-plot shows a predominance of low angle fractures, and an overall scatter patterns in the east-west direction. Accordingly, the rose diagram has a prominent maximum at 360° of strike azimuth, and a secondary maximum at 290° strike azimuth. This is a well with average yield.

Although the interpretation of the structural information is not straightforward, the following patterns are reasonably common:

- Even though the predominant strike orientation of high angle fractures differs from point to point, at any given location they appear to cluster in one or two of 4 dominant strike azimuths: 340° to 10°, 40° to 50°, 80° to 110°, and 330° to 340°. Three of these directions are similar to those identified in the study of outcrop fractures (360°, 60°, and 345°), and can be adequately explained by the tectonic setting of the site. The remaining strike direction (80°

to 110°), although not coincident with an identified structural trend, could be the compressive counterpart of the tension fractures represented by the 360° direction.

- Low-yield wells GLA-1, GLA-2 and GLA-4, and dry well GLA-9, share in common fractures with strike azimuths of 330° to 340° or 40° to 50°, and have comparatively low proportions of north-striking fractures. In the previous section the argument was made that the former fracture directions are probably related to a stress regime that ceased to be active 20 to 25 million years ago, thus increasing the probability of annealing of the fractures by deposition of mineral matter within them. (The converse condition is not true, for average-yield wells in several instances include fractures with similar strike orientations). All low-yield wells have in common the fact that they are located along the ridge that borders the site to the west.

- The fractures in average-yield wells GMW-1, GMW-4, GLA-3 and GLA-10 have strike azimuth maxima in the 360° to 20° range, and in about 50% of the cases have dip angles of less than 45°. In contrast, the fractures in average-yield wells GLA-7 and GLA-8 generally have dip angles in excess of 45°, and strike azimuth maxima in the 330° to 340° or 40° to 50° directions. All average-yield wells have in common the fact that they are located within Gregory Canyon itself.

Spacing between discontinuities and patterns of spatial distribution in the boreholes were tested using the same techniques used for analyzing the surface data. Randomness in a data set was tested by means of the χ^2 test, as described by Swan and Sandilands (1995, p.222-226), with the following results:

Well	Result of χ^2 test
GMP-3	Reject Ho*
GMW-1	Cannot reject Ho
GMW-4	Cannot reject Ho
GLA-1	Cannot reject Ho
GLA-2	Reject Ho
GLA-3	Cannot reject Ho
GLA-4	Cannot reject Ho
GLA-5	Reject Ho
GLA-7	Cannot reject Ho
GLA-8	Cannot reject Ho
GLA-9	Cannot reject Ho
GLA-10	Cannot reject Ho

* Ho = fractures are randomly distributed with a Poisson distribution

As can be seen from this listing, the null hypothesis, which assumes that the fractures are randomly distributed, cannot be rejected at the 95% confidence level in 9 of the 12 wells. This a good indication of randomness, but the possibility of a different underlying distribution (e.g., a clustered distribution) cannot be discounted.

Uniformity was assessed by constructing cumulative occurrence plots, in which the cumulative proportion of discontinuities (number of discontinuities up to a certain depth in the well normalized with respect to the total number of discontinuities) is plotted against relative depth in the borehole (depth to a certain point normalized to the total depth of the borehole). Figure 17 has uniformity plots for the 12 logged boreholes. In these plots, uniformly distributed events would plot close to the 1:1 line, whereas randomly distributed events would depart from this line (in all cases the lines start at the (0,0) point and converge toward the (1,1) point due to the normalization procedure). Wells GMP-3, GLA-2, and GLA-5, for which the randomness hypothesis was rejected at the 95% confidence level by the χ^2 test, show significant departures from the 1:1 line, suggesting that fractures are distributed in clusters, and that these clusters are not randomly distributed. The cumulative fracture distribution in wells GMW-4, GLA-4, GLA-8, and GLA-10 straddles the 1:1 line, so even though the randomness hypothesis could not be rejected at the 95% confidence level by the χ^2 test, the uniformity test suggests that the fractures in these wells are uniformly distributed. Finally, wells GLA-1, GLA-3, GLA-5, GLA-7, and GLA-9 show departure patterns consistent with the random distribution hypothesis.

Figure 18 summarizes frequency histograms of spacing between discontinuities in twelve of the logged boreholes. In most cases, over 40% of the fractures have spacings of less than 0.5 feet, and 60% of the fractures have spacings of less than 1 foot.

COLOG did a visual assessment of all fractures logged, rating them on a scale of 0 to 5 developed by Vernon et al. (1993):

Rank	Observation	Evaluation
0	Weak, parallel features continuously imaged around the borehole.	Probable foliation.
1	Weak feature - not continuously imaged around the borehole.	Partial crack with thin (<0.1 mm), discontinuous apertures. Possibly annealed.
2	Clean, distinct feature with no discernible aperture.	Continuous crack with thin (<0.1 mm), aperture. Possibly annealed.
3	Distinct feature with apparent aperture.	Continuous crack with aperture larger than 0.1 mm.
4	Multiple features, interconnected	Probable fracture zone.
5	Swarm of interconnected features; large voids are discernible.	Major fracture zone.

Of the 2,273 of the fractures imaged, none were ranked in categories 4 and 5, and only 20 were ranked in category 3. Of these, only 4 correlate with water-yielding intervals. With such few features it is not possible to make a meaningful correlation of fracture aperture with depth, orientation, or yield.

In conclusion, structural orientation and spatial distribution patterns are consistent with the analysis and conclusions reached for the outcrop data. Abundance of north-striking discontinuities has a moderate correlation with the occurrence of high yields in wells, and the presence of a significant number of discontinuities with other orientations could be expected to enhance interconnection of the flow paths.

HYDROGEOLOGY

In slightly weathered granitic rocks it is reasonable to assume that the hydraulic conductivity of the unfractured rock is very low ($<10^{-9}$ cm/sec), and that significant groundwater flow can only occur through fracture systems. Recent reviews of the current understanding of groundwater flow in fractured rock include those of Gale (1982) and Bear et al. (1993). In general, flow through fractured rock masses is determined by fracture orientation, spacing, fracture interconnection, and fracture aperture. At the individual scale of a single fracture, it can be demonstrated that flux is a function of the cube of the aperture of the fracture, so it is not uncommon to find that a few fractures with wider apertures convey a large proportion of the groundwater flow. Still, a "master" fracture can only sustain a large flux if a large number of interconnected, "tributary" fractures feed into it.

VLF GEOPHYSICAL SURVEY

In order to further understand the geometry of the fractured-rock aquifer of Gregory Canyon, and to assist in the location of test monitoring wells, a geophysical survey was conducted. The Geophysics Group surveyed a total of 24,000 linear feet along 14 lines with a very low frequency (VLF) receiver (Appendix B and Figure 19).

The VLF method relies on the fact that the U.S. and other coastal nations operate long wavelength, or very low frequency, radio stations for communication with submarines. These stations operate at high power, up to 1000 kw, at assigned frequencies in the range 15 to 28 kHz. The electromagnetic emissions from the VLF antennas propagate as air-, water-, and groundwaves, with magnetic and an electric field components. The majority of the signal power in the ground is provided by the magnetic component of these electromagnetic waves.

At a large distance from the transmitter, the VLF field can be regarded as a uniform electromagnetic field that is oriented parallel to the surface of the ground and perpendicular to the bearing of the transmitter. In the ground, the primary (source) field propagates vertically away from the transmitter. Upon encountering an electrical conductor, the propagation of the source field causes the flow of secondary electrical currents, which in turn generate a secondary magnetic field. The total magnetic field is then the vector sum of the primary and secondary magnetic fields.

It can be demonstrated that in the absence of lateral changes in conductivity the secondary field is parallel to the primary field, and thus that the total field is horizontal and linearly polarized. In the presence of a lateral change in conductivity, the secondary field is tilted relative to the primary field, and shifted in phase; the resulting total magnetic field vector will then trace an ellipse in the vertical plane over time.

The basic parameters measured by the VLF receiver are the strength of the total magnetic field, the tilt angle (i.e., the inclination of the major axis of the total field ellipse), and the eccentricity of the ellipse (also referred to as ellipticity). From these last two measurements one can calculate the proportion of the secondary field that is in-phase with the primary field, and the proportion that is 90° out-of-phase (quadrature) with the primary field. To the extent that the observed VLF anomalies are caused by relatively vertical and narrow structures elongated parallel to the bearing to the transmitter, the interpretation of the data is straightforward: the surface trace of the structure is inferred to be where there is a positive anomaly in the total magnetic field, and where the in-phase or quadrature response changes sign (the crossover point). Interpretation is complicated, however, by non-geologic conditions (e.g., power lines or grounded metal fences), topography, or departures from the ideal assumption that the conductor is narrow, steeply dipping, and parallel to the bearing to the transmitter.

The plots of Appendix B also include "Fraser-filter" curves. These curves are calculated following the algorithm proposed by Fraser (1969), which converts proper crossovers to "Fraser-filter" maxima. The utility of this approach is that systematic bias of the VLF response due to, for example, large scale topographic effects, is substantially reduced.

Figure 19 indicates the location of the field traverses, and Figures B-1 through B-28 show plots of the VLF data along these traverses. The solid line shows the total field, the solid with circles line shows the in-phase proportion, and the dashed line shows the 90° out-of-phase (quadrature) proportion. Traverses A through H are oriented in an east-west direction, and are thus best suited to detect north-trending structures. Traverses K through Q, on the other hand, are oriented north-south, and are best suited to detect east-trending structures. At the time the first stage of the survey was performed, in June 1996, the only operating VLF stations were the ones in Cutler, Maine, and Lualualei, Hawaii, which are best suited to detection of east-trending anomalies. The north-bearing station, at Jim Creek, Washington, was not transmitting at the time. A second survey was conducted in July, 1996, when the Jim Creek station again became operational.

As shown on Plate 4, some lines identified a considerable number of anomalies, whereas others had homogeneous responses. For example, line N, along the lower thalweg of Gregory Canyon, had several anomalies; these anomalies do not extend into parallel line G, from which we infer that they either result from east-trending zones of very limited extend or, more likely, represent north-trending zones of secondary permeability (as suggested by the fact that the trend correlates with the anomaly identified in the central portion of line E). Similarly, line P has several anomalies, which in some instances correlate with those on parallel line M as would be expected from an east-trending zone of secondary permeability. A similar correlation is observed between the south portion of line K and parallel line J, which in addition show good correlation with lineaments along the axis of the tributary canyons (Plate 3).

GLA drilled nine exploration boreholes, to further investigate the footprint and periphery of the landfill. The borehole locations were selected based on geophysical VLF anomalies, inferred structural lineaments, prominent geologic or topographic features that might reflect a deeper ground water pathway, and to make use of existing wells as possible observation wells for cross-hole testing. Specifically, the borehole locations were selected as follows:

Well	Comments
GLA-1	Located over a VLF anomaly along the western ridge.
GLA-2	Located along the western ridge, over the coincidence of a VLF anomaly and the westward projection of lineament E.
GLA-3	Located along the main alignment of Gregory Canyon, and within 30 feet of existing well GMW-1.
GLA-4	Located along the western ridge, over the coincidence of a VLF anomaly and the westward projection of a spur of lineament H.
GLA-5	Location based on the intersection of the thalweg of the canyon and the southern ridge.
GLA-7	Located off the main alignment of Gregory Canyon, over a VLF anomaly and within 100 feet of existing well GMP-2.
GLA-8	Geotechnical borehole based on the existing design plan. Located off the main alignment of Gregory Canyon and within 20 feet of existing well GMW-4.
GLA-9	Located along the western ridge, along lineament G (the most prominent lineament in the whole canyon).
GLA-10	Located along the main alignment of Gregory Canyon, over a minor VLF anomaly and within 200 feet of well GLA-1.

WELLS

Onsite wells

The following thirteen wells and piezometers were installed by previous consultants (Plate 1, Figures 22 and 23):

Well	Screened or open hole interval	Material in which well is screened	Depth to water table (12/16/96)	Elevation of piezometric level (feet amsl)
MW-3	? to 24.6 ft	Alluvium	23.20 ft	306 ft
MW-4	? to 20.3 ft	Alluvium	Dry	
MW-5	? to 12.35 ft	Colluvium	Dry	
FENTON	? to 23.9 ft	Alluvium	15.97 ft	296 ft
GMW-1	48 to 90 ft	Tonalite	21.89 ft	305 ft
GMW-2	50 to 106 ft	Tonalite	20.46 ft	295 ft
GMW-3	9.5 to 49.5 ft	Alluvium	16.52 ft	293 ft
GMW-4	55 to 116 ft	Tonalite	65.72 ft	556 ft
GMP-1	41.1 to 81ft	Tonalite	56.21 ft	409 ft
GMP-2	45 to 87.5 ft	Tonalite	69.54 ft	360 ft
GMP-3	40 to 81 ft	Tonalite	Dry	
WCC-1	8 to 30 ft	Alluvium	Dry	
WCC-2	12 to 22.5 ft and 22.5 to 34 ft	Colluvium	Dry	

To these, **GLA** added nine new wells (Appendix A):

Well	Screened or open hole interval	Material in which well is screened	Depth to water table (12/16/96)	Elevation of piezometric level (feet amsl)
GLA-1	20 to 300 ft	Tonalite	37.10 ft	298 ft
GLA-2	10 to 250 ft	Tonalite	69.73 ft	305 ft
GLA-3	45 to 150 ft	Tonalite	23.84 ft	306 ft
GLA-4	30 to 240 ft	Tonalite	149.93 ft	755 ft
GLA-5	30 to 190 ft	Tonalite	42.57 ft	887 ft
GLA-7	30 to 160 ft	Tonalite	34.82 ft	368 ft

GLA-8	15 to 300 ft	Tonalite	62.40 ft	558 ft
GLA-9	20 to 300 ft	Tonalite	Dry	
GLA-10	50 to 150 ft	Tonalite	22.20 ft	303 ft

Although the tonalite is moderately to intensely weathered in most outcrops, *cores of only slightly weathered tonalite form boulder knobs throughout the western flank of Gregory Canyon.* This surface observation holds true for all the wells drilled along the western ridge (GLA-1, GLA-2, GLA-4, and GLA-9), which after going through a thin interval of weathered rock encountered hard, unaltered, and very sparsely fractured tonalite. It appears, thus, that the geomorphic expression of the western ridge results from an underlying core of comparatively pristine tonalite.

Based on their estimated recovery rates when blowed dry, the eight wells that encountered water can be divided into low-yield and average-yield categories (GLA-9 did not intersect any water-yielding fractures). Those with low recovery rates (< 5 gpm) include GLA-1, GLA-2, and GLA-4 (including dry well GLA-9), which are located on the western ridge. The low-yield of these wells, coupled with the observation made before regarding the hard and sparsely fractured nature of the substrate, suggests that the western and southern ridges act as low permeability barriers along the periphery of the site.

Boreholes drilled within the canyon encountered tonalite with various degrees of hydrothermal alteration (epidote-albite-chlorite facies and perhaps also an overprinting zeolite facies), with a significant amount of fractures. These wells have estimated yield rates of 5 to 20 gpm, without apparent correlation to VLF anomalies or geomorphic lineaments. Quite simply, the underlying rock substrate seems to be pervasively fractured, and this facilitates groundwater flow.

Offsite wells

The locations of known offsite wells are shown on Figure 20. The filled circles are wells identified by Geraghty & Miller (1990), and those identified by filled squares were identified during a two-day survey performed as part of the activities summarized in this report. Clearly, the largest concentration of wells is in the alluvial basin of the San Luis Rey River, with a few additional domestic wells serving dwellings in Couser Canyon. According to the interviewed operators of the orchards south of Gregory Canyon, irrigation water for these orchards is derived from the San Diego Aqueduct rather than from wells.

HYDROPHYSICAL LOGGING

Ambient flow conditions

The horizontal average linear velocity of groundwater water moving through a fracture, or group of fractures, can be estimated using the borehole dilution method (Drost et al., 1968; Freeze and Cherry, 1979). The method relies on the introduction of a "tracer" in an isolated interval of the well, and periodic measurements of the concentration as the tracer is diluted by groundwater flowing

through that interval. The rate of concentration decay is related to the average velocity of groundwater moving through the formation and across the borehole. COLOG, Inc. adapted the borehole dilution method, using de-ionized water as the tracer and fluid electric conductivity as a measure of "concentration" of the tracer, so C_{obs} and C_f in the following discussion actually represent observed and formation fluid electric conductivity values. Because the tracer is de-ionized water, the borehole "dilution" will actually be an enrichment in fluid electrical conductivity.

The method of analysis can be summarized as follows: Consider a "tracer" (i.e., de-ionized water) that has been introduced uniformly into a section of an open borehole. Let the observed concentration of the tracer be C_{obs}. Once introduced, the concentration of the tracer is modified by formation water flowing into the borehole at a velocity $\tilde{u}^*$, as illustrated in Figure 21a. Let the concentration of the tracer in the formation water be C_f. By balancing the net rate of mass into the borehole with the rate of change of C_{obs} (Figure 21b), we get the following first-order differential equation:

$$\tilde{u}^*C_fA-\tilde{u}^*C_{obs}A = W\frac{dC_{obs}}{dt} \qquad (1)$$

where A is the cross-sectional area of the borehole ($A = 2\pi L$), and W is the corresponding volume ($W = \pi r^2 L$). Upon integration we obtain

$$\tilde{u}^* = -\frac{\pi r \ln(C_2/C_1)}{2(t_2-t_1)} \qquad (2)$$

where t_2 and t_1 are times corresponding to values of C_1 and C_2.

The velocity given by equation 2 is the velocity through the borehole, which may be slightly larger than the velocity of groundwater in the formation because flow lines tend to converge toward the borehole (Figure 21c). Corrections for this convergence have been given by Drost et al. (1968) as

$$\tilde{u} = \frac{\tilde{u}^*}{n\alpha} \qquad (3)$$

where $\tilde{u}$ is the average linear velocity in the formation away from the borehole (Figure 21c), n is the porosity, and α is an adjustment factor that depends on the nature of the formation and the geometry of the well. The usual range of α for tests in sand or gravel aquifers is between 0.5 and 4 (Drost et al., 1968), but there is no information available on fractured aquifers. In interpreting the data, COLOG, Inc. set α to 2.5.

Knowing from Darcy's law that $\tilde{u} = v/n$; where n is porosity and v is the specific discharge (or Darcyan velocity), then

$$v = \frac{\tilde{u}^*}{\alpha} \qquad (4)$$

Since specific discharge is also defined as $v = Q/A$, restating this relation in terms of Q, and equating it to Darcy's law [i.e., $Q = vA = KA(dh/dl)$; so $v = K(dh/dl)$], leads to the equation

$$K = v/(dh/dl) \quad (5)$$

where dh/dl is the hydraulic gradient.

The results obtained by COLOG, Inc. after applying this technique in the logging of 13 wells can be summarized as follows (Appendix C):

1. In shallow wells (e.g., GMW-1, GMW-4, and GMP-2), or in the shallow portions of wells GLA-5 and GLA-7, the transmissive intervals are broad and continuous, in a way characteristic of a porous medium. This behavior is consistent with the deeply weathered nature of the tonalite, which for all practical purposes behaves like a silty sand.

Well	Depth to water (feet)	Depth of transmissive interval (feet)	"Saturated" interval (feet)	Percent of "saturated" interval	Specific discharge (ft/day)
GMW-1	21.89	65-71	68	NA#	0.31
GMW-1	21.89	71-78	68	NA#	0.26
GMW-1	21.89	78-83	68	NA#	0.31
GMW-4	65.72	66-74	50	NA#	0.12
GMP-2	69.54	70-76	18	NA#	0.14
GLA-5	42.57	43-66	147	16%	0.05
GLA-7	34.82	35-72	125	30%	0.2

The "saturated" section of this borehole is within heavily weathered tonalite, and is too short to allow for a meaningful percentage comparison with deeper, unweathered tonalite.

2. In the deeper portion of the GLA wells, where the tonalite is only slightly weathered, there are very few transmissive intervals. They range in thickness between 2 and 8 feet, and represent between 1% and 5% of the total length of the bedrock section. This behavior is characteristic of a fracture-flow regime.

Well	Depth to water (feet)	Depth of transmissive interval (feet)	"Saturated" interval (feet)	Percent of "saturated" interval	Specific discharge (ft/day)
GLA-1	37.10	ND	263	NA	ND
GLA-2	69.73	83-85	180	1.1%	0.17
GLA-3	23.84	66-70	126	3.2%	0.23
GLA-3	23.84	82-84	126	1.6%	0.29

GLA-4	68*	70-72	172*	1.2%	0.03
GLA-4	68*	126-134	172*	4.7%	0.07
GLA-5	42.57	96-99	147	2.0%	0.06
GLA-8	62.40	175-180	238	2.1%	
GLA-10	22.20	58-64	128	4.6%	0.002

* The static depth to water was 149.93 feet bgs, but the transmissivity of the well was so low that water added during testing did not drain. Thus, the reported transmissive intervals and specific discharge values are transient.

3. For the deep GLA wells, in all but one instance the intervals of groundwater flow are within 60 feet of the piezometric surface. In other words, groundwater flow is largely concentrated in shallow fracture zones; deeper fractures seem to have a much lower transmissivity, perhaps on account of larger compressive stresses. This is significant because grading operations will remove between 50 and 150 feet of the bedrock, thus eliminating the shallow porous-flow regime through the weathered tonalite, and most of the shallow, transmissive fractures.

4. Taking into account the fact that the intervals of groundwater flow are within 60 feet of the piezometric surface, and that grading operations will remove most of the shallow, transmissive fractures, we have assumed that the porosity of the deeper intervals is on the order of 1%. Given that specific discharge values calculated for the deeper transmissive intervals range between 0.3 and 0.02 ft/day, and the assumption of 1% porosity, the equivalent specific discharge for a porous-medium would be between 0.003 and 0.0002 ft/day. Using equation 5 above, and an average dh/dl value of 0.15 ft/ft, determined from the contour map of the piezometric surface, the hydraulic conductivity for an equivalent porous-medium would range between 0.02 and 0.0013 ft/day (7.1×10^{-6} cm/sec to 4.6×10^{-7} cm/sec).

For comparison, packer testing estimates of the hydraulic conductivity of the weathered bedrock ranged from 0.3 to 0.03 ft/day (10^{-4} to 10^{-5} cm/sec) (Geraghty & Miller, 1990).

Cross-hole aquifer tests

COLOG, Inc. also performed three cross-hole aquifer tests to assess the interconnectivity of the bedrock aquifer, using the following well pairs:

Pumping well	Observation well	Distance between wells	General location in the canyon
GMW-1	GLA-3	51 feet N36E	Lower reach
GMP-2	GLA-7	167 feet N56W	Middle reach
GMW-4	GLA-8	30 feet N10E	Upper reach

For cross-hole flow assessment, the formation water in the observation well is replaced with deionized water (DI) while the nearby well is pumped. A series of fluid electric conductivity (FEC) and temperature logs are then run in the observation well as pumping continues, to identify changes in the fluid conductivity as a result of fluid flow. In effect, formation water coming into the observation well "enriches" the electric conductivity of the DI "tracer", so that inflow velocities can be estimated through the borehole dilution method discussed above.

The hydraulic connection between the pumping and observation wells is estimated by comparing the flow conditions in the observation well under ambient flow conditions (discussed above) and under cross-hole pumping conditions. By comparing the horizontal flow velocities of transmissive intervals under these two different pressure states, a qualitative evaluation of which intervals are hydraulically connected can be achieved. Quite simply, those intervals which display the greatest change in flow between the two pressure conditions can be reasonably assumed to be hydraulically connected.

For the cross-hole test in which GMW-1 was the pumping well and GLA-3 was the observation well, COLOG concluded that significant change occurred at three distinct depth intervals within GLA-3: 48 to 56 feet, 66 to 68 feet, and 82 to 84 feet. Applying equation 2 to the data yielded borehole horizontal fluid velocities of 0.93, 0.70, and 1.25 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specific discharge (or Darcyan velocity) in the aquifer of 0.37, 0.28, and 0.50 ft/day, respectively. The interval from 48 to 56 feet had negligible horizontal flow under ambient conditions, and so had the greatest change during cross-hole pumping conditions; in effect, this interval was "opened" by the stress imposed by pumping. The interval of 66 to 68 feet experienced an increase of 22% with respect to the ambient flow condition. Finally, the interval from 82 to 84 feet experienced a 72% increase in the average flow velocity with respect to the ambient flow condition. For this well pair, then, the "capture radius" extends at least 51 feet in the horizontal direction and 60 feet vertically into the aquifer (i.e., the distance between the depth of the piezometric surface, 24 feet, and the depth of the 82-84 feet transmissive interval).

For the cross-hole test in which GMP-2 was the pumping well and GLA-7 was the observation well, COLOG concluded that significant change occurred at numerous zones over the interval from 34 to 91 feet. To discretize the specific intervals for horizontal flow analysis, the results of the ambient and cross-hole tests were evaluated in the following discrete intervals: 33-42 feet, 42-48 feet, 48-52 feet, 52-58 feet, 58-62 feet, 62-69 feet, 69-72 feet, 72-76 feet, 76-79 feet, 79-88 feet, and 88-94 feet. Borehole dilution algorithms applied to these data yielded horizontal fluid velocities between 0.60 and 1.05 ft/day. Correcting for convergence of flow at the wellbore, these velocities equate to a range in specific (or Darcyan velocity) in the aquifer of 0.24 to 0.42 ft/day. The intervals between 33 and 62 feet experienced increases in horizontal flow velocity of 13% to 79%, while the intervals at 62 to 69 and 69 to 72 feet displayed a 102% and 146% increase, respectively. The intervals between 72 and 94 feet did not display observable horizontal flow under ambient flow conditions, so a percent change cannot be calculated; again, these intervals were "opened" by the stress imposed by pumping. In summary, the data suggest that the intervals from 33 to 72 feet in well GLA-7 have a significant hydraulic connection to pumping well GMP-2. For this well pair, then, the "capture radius" extends at least 167 feet in the horizontal direction and 60 feet vertically into the aquifer (i.e., the distance between the depth of the piezometric surface, 35 feet, and the lower-bound depth of the transmissive

interval, 94 feet).

For the cross-hole test in which GMW-4 was the pumping well and GLA-8 was the observation well, COLOG concluded that significant change occurred at numerous zones over the interval from 70 to 90 feet, and at a discrete interval at a depth of 178 to 182 feet. The results of the cross-hole test for the 70 to 90 feet inflow zone were evaluated as four discrete intervals: 70-75, 75-80, 80-85, and 85-90 feet. Borehole dilution algorithms applied to these data suggest the fluid velocities for these intervals were similar and ranged from 0.67 to 0.72 ft/day. Correcting for convergence of flow at the wellbore, these velocities equate to a range in specific discharge (or Darcyan velocity) in the aquifer from 0.27 to 0.29 ft/day (this same interval had operated as a zone of outflow under ambient flow conditions, so calculation of an percent increase rate in flow is not meaningful). The inflow at the 178 to 182 feet interval under cross-hole pumping conditions was 19% larger than under ambient flow conditions. These data suggest that the "capture radius" of this well pair extends at least 30 feet in the horizontal direction and 120 feet vertically into the aquifer (i.e., the distance between the depth of the piezometric surface, 62 feet, and the lower-bound depth of the lower transmissive interval, 182 feet).

In conclusion, all three cross-hole tests documented hydraulic connectivity between the pumping and the observation well. Doubling the 167-foot capture radius documented by the pair GMP-2 / GLA-7, we conclude that monitoring wells at an average spacing of 300 feet can be reasonably expected to detect potential groundwater impacts under the proposed landfill. The wells would need to be submitted to cross-hole testing to confirm the extent of their capture zones, and the spacing between the wells reduced or extended based on the pumping test data. Also, the purgeing protocols may need to be modified (e.g., by pumping a volume significantly larger than the traditional three borehole volumes), to impose enough "stress" in the aquifer to force convergence into the borehole of water carried by distant fractures.

CONFIGURATION OF THE WATER TABLE

Figure 22 shows a contour map of the water table in the alluvial aquifer based on data collected on 12/16/96. This aquifer most likely merges with the San Luis Rey alluvial aquifer to the north. Its extent to the south is limited, however, as indicated by the dry wells MW-4, WCC-1, WCC-2, and MW-5. The data suggest groundwater flow is to the north, under a gradient of about 0.045 ft/ft.

The transmissivity of the alluvial aquifer was estimated by Geraghty & Miller (1990) through a pumping test performed in well GMW-3. Transmissivity was calculated, using the Cooper-Jacob method, at 700 gpd/ft, and from this value the hydraulic conductivity was estimated to be approximately 1.47 ft/day (5×10^{-4} cm/sec).

Figure 23 shows a contour map of the piezometric surface in the fractured-rock aquifer, based on the depth to water level measurements made on 12/16/96. A piezometric surface is slightly different than a water table, in that the bulk of the aquifer is dry and water is only present where an open continuous fracture lies below the piezometric level. A dry well could thus indicate that the piezometric level is below the bottom of the well, but it can also indicate that the borehole did not intersect any open fractures (our preferred explanation for the dry condition of GLA-9 and GMP-3). Using standard

contouring and hydrogeologic procedures, the available data suggest groundwater flow toward and down the axis of Gregory Canyon. In the upper reaches of the canyon the gradient is comparatively steep (0.25 ft/ft to the north). The gradient becomes shallower toward the mouth of the canyon (0.1 ft/ft to the north), and it appears that the pressure contours "open" to the west in the area of GLA-2.

COMPARISON BETWEEN GRADING PLAN AND THE PIEZOMETRIC SURFACE

The proposed grading plan is compared with the bedrock piezometric surface in Figure 24 and on Plate 5. A simple visual comparison of both surfaces indicates that, over the central portion of the proposed landfill, the floor of the excavation would be below the piezometric level. At the location of GMW-4, for example, the difference in elevation is nearly 150 feet.

This condition will require installation of a subdrain system to maintain the required separation of 5 feet between refuse and groundwater. This subdrain system could consist of draining geonet on the slopes, with collector pipes or gravel drains along the benches, to carry collected groundwater toward the toe of the landfill by gravity. The basal subdrain could consist of a gravel blanket with dendritic collector pipes, to again convey water to the toe.

The subdrain systems may provide a unique opportunity to monitor potential impacts of the landfill on groundwater, since they would provide an areally extensive "sample" of the quality of groundwater immediately below the liner system. If the collector pipes draining different sectors of the footprint were to be brought separately to the toe of the landfill, then sampling and analysis of these waters would allow early detection of discrete problem areas.

The subdrain system will have to be sized so that 200% of the inflow volume can be easily accommodated by the subdrain, thus guaranteeing that groundwater will not exert hydrostatic lift under the liner system. To calculate this inflow volume **GLA** constructed a groundwater flow model, in which the substrate is simulated by a three-dimensional group of flow cells, and the excavation is represented by drain cells. The following paragraphs describe the setup of the model.

Approach

For the analysis of the head distribution in the bedrock aquifer of Gregory Canyon we constructed a computer-based numerical model, which simulates groundwater flow by means of governing equations that represent the physical processes that occur in the system, together with equations that describe the flux of water along the boundaries of the model (boundary conditions).

The centerpiece of the software used to prepare the groundwater flow model was the program MODFLOW developed by U.S. Geological Survey (McDonald and Harbaugh, 1988). MODFLOW solves an algebraic approximation of the 3-dimensional differential flow equations to estimate the value of hydraulic head at the center nodes (block-centered) of a 3-dimensional grid of cells. The use of the differential flow equation presumes that the large volume of the model cells allows for groundwater flow to be simulated as equivalent to flow through a porous medium. Once the distribution of hydraulic head values has been estimated, cell-by-cell fluxes are calculated using Darcy's law.

MODFLOW was selected because of its availability, active use in groundwater research (which in turn has provided extensive validation of the program), and a relatively large pool of experienced users. The input data files were prepared through Visual Modflow ®. The Visual Modflow pre-processor provides a convenient computer-aided design environment for setting the initial conditions of the models, and checks the input for consistency before translating the information into the FORTRAN input files used by MODFLOW. Visual Modflow also has useful post-processing capabilities, such as contouring of hydraulic heads, display of calibration correlations, and display of mass balance summaries.

Model orientation, dimensions, and units

To optimize the match between the natural flow system and a numerical model, it is always better to try to match natural and model boundaries. For the Gregory Canyon model the obvious boundaries are the west ridge hydrogeologic barrier, the east flank inflow boundary, and the north outflow boundary into the alluvial aquifer. To best match these boundaries, the model grid was rotated counter-clockwise with respect to geographic coordinates by 32° (Plate 5).

The domain of the model is defined by a 3-dimensional grid of cells that for convenience are grouped first in layers, and then in rows and columns. For modeling the Gregory Canyon groundwater system 7 horizontal layers, each 100-foot thick, were assumed. These layers are sequentially numbered from top to bottom. Each layer was divided in 12 rows, spaced at 400-foot intervals, numbered sequentially from north to south. Finally, each row was divided in 10 columns, spaced at 200-foot intervals, and numbered sequentially from west to east.

MODFLOW does not "make" any assumptions about units of measurement, so it is necessary that all parameters are expressed in internally consistent units. For this project, the unit of linear measurement is feet, and the unit of time is days. Areas are thus expressed in ft^2, volumes in ft^3, flux in ft^3/day, hydraulic conductivity and velocities in ft/day, recharge in ft/day, transmissivity and conductance in ft^2/day, and conductance coefficients in day^{-1}. By convention, inflow flux (e.g., recharge) is considered positive, and outflow flux is considered negative.

Boundary conditions

By the nature of the algorithms, the edges of the model are treated as impermeable boundaries so, to account for inflow and outflow of groundwater, sources and sinks need to be placed along some of the boundary cells. These sources and sinks are described in the following paragraphs as drains, constant head boundary cells, and constant flux cells.

> Drains: MODFLOW was initially developed in response to the needs of hydrogeologists working in the regional aquifers of the Atlantic coastal plain, which are hosted by sedimentary units with dip angles of less than 5°. Under these conditions the simplifying assumption can be made that model layers are parallel to the stratigraphy, and that groundwater flow is subparallel to stratigraphic boundaries. In the case of Gregory Canyon, however, the topography is too steep to justify these simplifying assumptions, and it becomes necessary for the model layers to cut across the topography. A provision then has to be taken for the water

table not to rise above the topographic surface. This can be accomplished by placing "drains" at the surface, which would remove water if the water table were to rise to that level. MODFLOW "removes" water from the drains only when the calculated hydraulic head exceeds the elevation of the drain, at a rate proportional to the hydraulic conductance. The location of each of the drains used in the model, and their elevations are shown in Figures 25 and 26. Hydraulic conductance has been uniformly set at 10 ft^2/day for all of the drains.

Constant head boundary cells: Constant head boundary cells have been placed in layer 10 at the north edge of the model domain, to establish "reference points" for the model. Only very few constant head boundary cells were included in the model, because MODFLOW treats them as infinite sources (or sinks) of water, and having too many of them could lead to unrealistic fluxes into and out of the model domain. The elevations of the constant head cells were estimated from the map of piezometric surface elevations shown in Figure 27.

Constant flux cells: Constant flux boundaries allow for better control of the amount of water entering or leaving a system, and thus are more realistic than constant head boundaries. In general, mass balances are more realistic, although some tradeoff may need to be accepted with lower convergence rates and/or larger calibration errors. Inflow boundaries are set by locating imaginary recharge wells at inflow nodes. For the Gregory Canyon model, inflow boundaries are set at the east and south edges of the model, to simulate inflow from Gregory Mountain to the east. Flux values were calculated using Darcy's law and the hydraulic gradient of Figure 27.

Hydraulic conductivities

For the Gregory Canyon flow model we used hydraulic conductivities calculated following the procedure described in the section on hydrophysical logging (7.1×10^{-6} cm/sec to 4.6×10^{-7} cm/sec). We have used these values for both horizontal and vertical hydraulic conductivity for construction of the groundwater flow model. Our base model uses the low permeability value for the simulation of existing and after-grading conditions (models GREG1 and GREG2 respectively). As an extreme sensitivity case, we then used the high range of hydraulic conductivities for all cells within Gregory Canyon itself (the cells along the western ridge were kept at their base case low permeability value, as suggested by field observations). The models for the existing and after-grading conditions are referred to as GREG3 and GREG4, respectively.

Model calibration

Calibration was performed in three stages. First, boundary conditions were varied over relatively wide ranges to achieve hydraulic head configurations that made good hydrogeologic sense in light of the piezometric surface map of Figure 22. The second step was to further screen those combinations that yielded reasonable configurations, to make sure that the mass balance calculated by the model was realistic given the thickness of the saturated section and the hydraulic gradient. In this second step constant head nodes were problematic, as expected, in that in some solutions they either "generated" or "consumed" more than 50% of the flux through the model. Cutoffs of 15% for outflow, and less than 1% mass balance discrepancy between inflow and outflow balances were set as acceptable levels

for the calibration. The third step in the calibration involved comparing hydraulic head elevations measured in the site monitoring wells during December of 1996, with the heads predicted by the model. Several of the models that had passed the second stage of screening had good fits with respect to wells screened in the lower reaches of the canyon, but in almost all cases the models under-predicted the head in the western ridge. The fit could be improved by allowing for some localized recharge along the western ridge but there are no obvious sources of recharge in this area. Rather, the most likely explanation for the higher-than-predicted heads near the west ridge is a lower hydraulic conductivity than for the rest of the model domain.

After the third stage of refinement, the current-conditions base model (GREG1) had a mass balance of:

		Values in ft^3/day	
IN:			
STORAGE	=	0.00000E+00	0%
CONSTANT HEAD	=	0.00000E+00	0%
CONSTANT FLUX	=	356.98	100%
DRAINS	=	0.00000E+00	0%
RECHARGE	=	0.00000E+00	0%
TOTAL IN	=	356.98	
OUT:			
STORAGE	=	0.00000E+00	0%
CONSTANT HEAD	=	53.75	15.06%
CONSTANT FLUX	=	0.00000E+00	0%
DRAINS	=	303.22	84.94%
TOTAL OUT	=	356.97	
IN - OUT	=	0.017	
PERCENT DISCREPANCY	=	0.005%	

The loss of 303.2 ft^3/day to drains in the current-conditions model is reasonable considering that the drains were located along the thalweg of the canyon (Figure 26), where evapotranspiration by the riparian plant community can be expected to be large. Considering the surface area of the drains (640,000 ft^2), the average rate of removal of 0.0005 ft/dy (or 2.2 inches/year, or 0.004 gpd/ft^2) is well within the range of potential evapotranspiration at the site.

Model results for the after-excavation condition

The base model was modified by the introduction of drains with a high conductance (100 ft^2/day) throughout the footprint of the excavation, at an average elevation coincident with the proposed excavation grades. The location of the drains and their elevations are indicated in Figure 27. The after-

excavation model (GREG2) had a mass balance of:

		Values in ft^3/day	
IN:			
STORAGE	=	0.00000E+00	0%
CONSTANT HEAD	=	0.00000E+00	0%
CONSTANT FLUX	=	289.92	100%
DRAINS	=	0.00000E+00	0%
RECHARGE	=	0.00000E+00	0%
TOTAL IN	=	289.92	
OUT:			
STORAGE	=	0.00000E+00	0%
CONSTANT HEAD	=	20.77	7.16%
CONSTANT FLUX	=	0.00000E+00	0%
DRAINS	=	269.13	92.84%
TOTAL OUT	=	289.91	
IN - OUT	=	0.014	
PERCENT DISCREPANCY	=	0.005%	

The total flux into the system is lower because draining by the excavation would reduce the piezometric level, and thus the saturated section of the constant flux nodes. Given the area of the active drains (2,640,000 ft^2), the 269.13 ft^3/day into drains equates to an average rate of flux into the floor of the excavation of 0.0001 ft/dy (or 0.44 inches/year, or 0.00075 gpd/ft^2). Figure 27 gives the specific inflow rate for the different drain cells.

Model sensitivity

The model described is sensitive to both the hydraulic conductivity of the substrate, and the rate of inflow through constant flux nodes. These parameters were varied over reasonable ranges, and the resulting models were subjected to the same calibration procedure described above. Figures 28 and 29 summarize the results for existing and after-grading conditions (GREG3 and GREG4, respectively), of models in which the hydraulic conductivity of all cells within Gregory Canyon itself was increased to 0.02 ft/day, and in which the rate of mass influx was increased by a factor of 10 with respect to the base case. The rates of flux into the floor of the excavation indicated in Figure 29 are conservative by a factor of 10 over the most likely average conditions. These values are recommended for use in design of a reasonably conservative subdrain system for the landfill.

SUMMARY AND CONCLUSIONS

Regional geologic setting

The proposed landfill site is located in Gregory Canyon, a north-draining tributary canyon above and to the south of the San Luis Rey River valley. Two alluvial units have been mapped at the lower elevations near the mouth of Gregory Canyon. The younger unit, Qal-1 is formed by overbank deposits from the active San Luis Rey river channel, which are interbedded with channel deposits from the Gregory Canyon drainage. These deposits are relatively thin and contain gravels, cobbles and boulders, supported by a sandy silt matrix. The older alluvial subunit, Qal-2, is a terrace remnant of older alluvium from the Gregory Canyon drainage.

Colluvium forms a veneer over most of the proposed landfill site. In most instances is formed by silty sand with rock clasts that range in size from gravel to very large boulders. Rock clasts exposed at the surface of the colluvial veneer vary from gravel- to boulder-size material. Boulders of leucogranodiorite, some in excess of 20 feet in maximum dimension, are present along much of the eastern sideslopes. The thickness of the colluvial deposits in the landfill site area is highly variable. Cross-section interpretations by Geragthy & Miller (1990) show thickness variations from 2 to 50 feet.

The area of the proposed landfill was included in the regional map of Larsen (1948), who used the term Bonsall Tonalite to describe the rocks underlying the western ridge, and the term Indian Mountain Leucogranodiorite to describe the light-colored, bold outcrops of granitic rock underlying the eastern ridge of the site area. Larsen (1948) also mapped an intervening screen or band of metamorphic rock along the lower slopes of the eastern ridge, which he correlated with the sedimentary Triassic/Jurassic Bedford Canyon Formation; rocks of this unit have relict volcanic textures, however, and are probably best correlated with the Jurassic Santiago Peak volcanics.

The metamorphic rocks present along the easterly slopes of Gregory Canyon form a north-south-trending belt, or screen, of older rock that was intruded by batholithic rocks. Specifically, the tonalite intruded and intermingled with the metamorphic rock, and both units were subsequently intruded by the leucogranodiorite. The metamorphic rock screen includes amphibolites and metavolcanic rocks, in some locations with migmatitic structure that resembles gneissic banding. The rocks are generally dark blueish gray, hard, and only slightly weathered. They have aphanitic to porphyroblastic textures, but relict porphyritic textures suggest a volcanic protolith for some of the units.

The tonalite that underlies the western slopes and the central portion of the Gregory Canyon area is an extensive rock unit in the area. The tonalite is a dark gray, phaneritic rock, with medium- to coarse crystallinity, that includes a variety of related rock types such as gabbro. Other common variations noted in the tonalite are the locally veined and streaked appearance, and the migmatitic fabric that is observed near the contact with the metamorphic rocks. The tonalite is moderately to intensely weathered in most outcrops. Depth of weathering, as determined from exploratory drilling by Geraghty & Miller (1990), ranges between 65 feet (GMP-3) and 95 feet (GMW-2).

The tonalite comes in contact with the metamorphic rock along the easterly side slopes of Gregory Canyon, although the contact is typically covered by colluvium or obscured by surficial soils. Based on

its map position, as inferred from isolated outcrops of both rock types, the contact appears to dip to the east at angles of 20° to 25°. The contact is somewhat transitional because of the effects of partial melting.

The leucogranodiorite map unit is a light-colored, biotite-bearing granodiorite that forms the prominent mountain flanking the eastern side of Gregory Canyon. In hand specimen, the rock has a phaneritic texture with medium- to coarse-crystallinity, is light gray to buff, and has less than 5% dark minerals (biotite and Fe-Ti oxides). Quartz, plagioclase, and potassium feldspar are the dominant felsic minerals.

Besides forming the core of Gregory Mountain, the leucogranodiorite also forms dikes that cut older units. The dikes vary in thickness from less than an inch up to five feet, and in most instances are pegmatitic. On account of their coarse crystallinity and superimposed fracturing, some dikes may constitute preferential paths of water flow.

The degree of weathering of the leucogranodiorite is generally slight, as can be inferred from the bold outcrops of Gregory Mountain. The dikes, on the other hand, vary in degree of weathering from low to moderate. Moderately weathered dikes are pervasively oxidized and have "cloudy" feldspars, but still preserve their phaneritic texture.

The main body of the leucogranodiorite is in intrusive contact with the metamorphic screen midway along the easterly side slope of Gregory Canyon. The contact zone is narrow and abrupt where it can be observed, but is generally buried under talus. Based on its map position, as inferred from the abrupt change in topography, the contact is nearly vertical, and "wraps around" Gregory Mountain, suggesting that the latter is a high level stock intruded by forceful emplacement.

Structural geology

A lineament analysis performed in small- and large-scale aerial photographs of the site and its surroundings has not disclosed regional, through-going discontinuities across the footprint of the site. The short alignments of stretches of Gregory Canyon, however, justify geophysical exploration of a 30 feet-wide swath along both sides of the thalweg. Other lineaments appear to converge toward the Gregory Canyon alignment, and no lineaments have been identified that diverge from it. It would then appear reasonable to suggest installation of the main monitoring points for the site along this alignment.

Field measurements of the attitude of structural discontinuities (fractures and dikes) suggests the existence of four directions of preferred orientation:

	Dip direction	Strike direction	Dip angle	Dominant feature
Direction 1	270°	360°	65°	Fractures
Direction 2	90°	360°	80°	Fractures
Direction 3	255°	345°	60°	Dikes
Direction 4	330°	60°	65°	Dikes

These predominant orientations are consistent with the overall tectonic stress regime of the area. The tectonic regime of the region has changed significantly between the time of emplacement of the intrusions of the Southern California batholith and the present. During the Mesozoic a subduction zone was active off the coast of California, at which time the direction of minimum stress would have paralleled the direction of subduction, to the northeast. Under these conditions, dikes are preferentially emplaced perpendicular to the direction of minimum stress (Direction 3 above), or parallel to it (Direction 4 above).

Tectonic conditions changed during the Cenozoic, when the convergent margin was replaced by the transform margin of the San Andreas fault system (including the San Andreas, San Jacinto, Elsinore, and Rose Canyon faults). The "block" between the Elsinore fault zone to the northeast and the Rose Canyon fault zone to the southwest is thus under a shear stress regime. In effect, the area between both fault zones is being "wrenched" clockwise. Under these conditions, north-oriented extensional fractures would form. This is the most likely explanation for the predominance of north-striking fractures on the site (Directions 1 and 2 above).

Twelve boreholes were logged with an optical borehole imaging probe (BIP), which provides the highest resolution available for fracture and feature analysis in boreholes. The following patterns are noted:

- Even though the predominant strike orientation of high angle fractures differs from point to point, at any given location they appear to cluster in one or two of 4 dominant strike azimuths: 340° to 10°, 40° to 50°, 80° to 110°, and 330° to 340°. Three of these directions are not that dissimilar to those identified in the study of outcrop fractures (360°, 60°, and 345°), and can be adequately explained by the tectonic setting of the site. The remaining strike direction (80° to 110°) could be the compressive counterpart of the tension fractures represented by the 360° direction.

- Low-yield wells GLA-1, GLA-2 and GLA-4, and dry well GLA-9, share in common fractures with strike azimuths of 330° to 340° or 40° to 50°, and have comparatively low proportions of north-striking fractures. The former fracture directions are probably related to a stress regime that ceased to be active 20 to 25 million years ago, thus increasing the probability of annealing of the fractures by deposition of mineral matter within them. All low-yield wells have in common the fact that they are located along the ridge that borders the site to the west.

- The fractures in average-yield wells GMW-1, GMW-4, GLA-3 and GLA-10 have strike azimuth maxima in the 360° to 20° range, and in about 50% of the cases have dip angles of less than 45°. In contrast, the fractures in average-yield wells GLA-7 and GLA-8 generally have dip angles in excess of 45°, and strike azimuth maxima in the 330° to 340° or 40° to 50° directions. All average-yield wells have in common the fact that they are located within Gregory Canyon itself.

With respect to spatial distribution, there is a predominance of north-striking discontinuities at the site, so one would expect preferential groundwater flow along them. The presence of a significant number

of discontinuities with other orientations would enhance interconnection of the flow paths, however, so reasonable assurance can be had that any given well can "sample" water representative of large portions of the aquifer.

VLF geophysical survey

To assess potential paths of groundwater flow, a total of 24,000 linear feet along 14 lines were surveyed with a very low frequency (VLF) receiver. Some lines identified a considerable number of anomalies, whereas others had homogeneous responses. For example, line N, along the lower thalweg of Gregory Canyon, had several anomalies; these anomalies do not extend into parallel line G, from which we infer that they may represent north-trending zones of secondary permeability. Similarly, line P has several anomalies, which in some instances correlate with those on parallel line M as would be expected from an east-trending zone of secondary permeability. A similar correlation is observed between the south portion of line K and parallel line J, which in addition show good correlation with lineaments along the axis of the tributary canyons (Plate 3).

Of the existing wells, GMW-1 is aside an anomaly along line N, GMW-3 is aligned with an anomaly on line H, and GMP-2 is within a cluster of anomalies along line P. The locations of GMW-2 and GMW-4 do not appear to coincide with VLF anomalies.

Hydrogeology

There are 15 bedrock monitoring wells within the proposed landfill footprint and along the periphery of the site. Boreholes drilled within the canyon encountered tonalite with various degrees of hydrothermal alteration (epidote-albite-chlorite facies and perhaps also an overprinting zeolite facies), with a significant amount of fractures. Wells drilled in the footprint of the landfill have estimated yield rates of 5 to 20 gpm, without apparent correlation to VLF anomalies or geomorphic lineaments. Quite simply, the underlying rock substrate seems to be pervasively fractured, and the aquifer appears thus to be comparatively homogeneous.

Although the tonalite is moderately to intensely weathered in most outcrops, *cores of only slightly weathered tonalite form boulder knobs throughout the western flank of Gregory Canyon.* This surface observation holds true for all the wells drilled along the western ridge (GLA-1, GLA-2, GLA-4, and GLA-9), which after going through a thin interval of weathered rock encountered hard, unaltered, and very sparsely fractured tonalite. It appears, thus, that the geomorphic expression of the western ridge results from an underlying core of comparatively pristine tonalite. The low-yield of these wells, coupled with the observation made before regarding the hard and sparsely fractured nature of the substrate, suggests that the western and southern ridges act as low permeability barriers along the periphery of the site.

The horizontal average linear velocity of groundwater water moving through a fracture, or group of fractures, can be estimated using the borehole dilution method. COLOG, Inc. adapted the borehole dilution method, using de-ionized water as the tracer and fluid electric conductivity as a measure of "concentration" of the tracer. The results obtained by COLOG, Inc. after applying this technique in the logging of 13 wells can be summarized as follows:

- In shallow wells (e.g., GMW-1, GMW-4, and GMP-2), or in the shallow portions of wells GLA-5 and GLA-7, the transmissive intervals are broad and continuous, in a way characteristic of a porous medium. This behavior is consistent with the deeply weathered nature of the tonalite, which for all practical purposes behaves as a silty sand. In the deeper portion of the GLA wells, where the tonalite is only slightly weathered, there are very few transmissive intervals. They range in thickness between 2 and 8 feet, and represent between 1% and 5% of the total length of the bedrock section. This behavior is characteristic of a fracture-flow regime.

- For the deep GLA wells, in all but one instance the intervals of groundwater flow are within 60 feet of the piezometric surface. In other words, groundwater flow is largely concentrated in shallow fracture zones; deeper fractures seem to have a much lower transmissivity, perhaps on account of larger compressive stresses. This is significant because grading operations will remove between 50 and 150 feet of the bedrock, thus eliminating the shallow porous-flow regime through the weathered tonalite, and most of the shallow, transmissive fractures.

- Taking into account the fact that most intervals of groundwater flow are within 60 feet of the piezometric surface, and that grading operations will remove most of the shallow, transmissive fractures, we have assumed that the porosity of the deeper intervals is on the order of 1%. Given that specific discharge values calculated for the deeper transmissive intervals range between 0.3 and 0.02 ft/day, and the assumption of 1% porosity, the equivalent specific discharge for a porous-medium would be between 0.003 and 0.0002 ft/day. The hydraulic conductivity for an equivalent porous-medium would range between 0.02 and 0.0013 ft/day (7.1×10^{-6} cm/sec to 4.6×10^{-7} cm/sec).

COLOG, Inc. also performed three cross-hole aquifer tests to assess the interconnectivity of the bedrock aquifer, using the following well pairs:

Pumping well	Observation well	Distance between wells	General location in the canyon
GMW-1	GLA-3	51 feet N36E	Lower reach
GMP-2	GLA-7	167 feet N56W	Middle reach
GMW-4	GLA-8	30 feet N10E	Upper reach

For cross-hole flow assessment, the formation water in the observation well is replaced with deionized water (DI) while the nearby well is pumped. After emplacement, a series of fluid electric conductivity (FEC) and temperature logs are run in the observation well as the pumping continues, to identify changes in the fluid column associated with fluid flow. In effect, formation water coming into the observation well "enriches" the electric conductivity of the DI "tracer", so that inflow velocities can be estimated through the borehole dilution method discussed at the beginning of this section.

The hydraulic connection between the pumping and observation wells is estimated by comparing the flow conditions in the observation well under ambient flow conditions and under cross-hole pumping conditions. By comparing the horizontal flow velocities of transmissive intervals under these two

different pressure states, a qualitative evaluation of which intervals are hydraulically connected can be achieved. Quite simply, those intervals which display the greatest change in flow between the two pressure conditions can be reasonably assumed to be hydraulically connected.

All three cross-hole tests documented hydraulic connectivity between the pumping and the observation well. Doubling the 167-foot capture radius documented by the pair GMP-2 / GLA-7, we conclude that monitoring wells at an average spacing of 300 feet can be reasonably expected to detect potential groundwater impacts under the proposed landfill. The wells would need to be submitted to cross-hole testing to confirm the extent of their capture zones, and the spacing between the wells reduced if needed based on the pumping test data. Also, the purgeing protocols may need to be modified (e.g., by pumping a volume significantly larger than the traditional three borehole volumes), to impose enough "stress" in the aquifer to force convergence into the borehole of water carried by distant fractures.

Configuration of the water table

Figure 22 shows a contour map of the water table in the alluvial aquifer based on data collected on December 16, 1996. This aquifer most likely merges with the San Luis Rey alluvial aquifer to the north. Its extent to the south is limited, however, as indicated by the dry wells MW-4, WCC-1, WCC-2, and MW-5. The available data suggest groundwater flow is to the north, under a gradient of 0.045 ft/ft.

Figure 23 shows a contour map of the piezometric surface in the fractured-rock aquifer, based on the depth to water level measurements made on December 16, 1996. A piezometric surface is slightly different than a water table, in that the bulk of the aquifer is dry and water is only present where an open continuous fracture lies below the piezometric level. Using standard contouring and hydrogeologic procedures, the available data suggest groundwater flow toward and down the axis of the canyon. In the upper reaches of the canyon the gradient is comparatively steep (0.25 ft/ft to the north). The gradient becomes shallower toward the mouth of the canyon (0.1 ft/ft to the north).

Comparison between grading plan and the piezometric surface

Comparison of the proposed grading plan with the bedrock piezometric surface indicates that over a large portion of the footprint the bottom grade is below the piezometric level. At the location of GLA-8, the difference in elevation is nearly 150 feet. This condition will require installation of a subdrain system to mantain the required separation of 5 feet between the refuse and groundwater. The subdrain system may consist of draining geonet on the slopes, with collector pipes or gravel drains along the benches that will carry collected groundwater toward the toe of the landfill by gravity. The basal subdrain may consist of a gravel blanket with dendritic collector pipes that again will convey water to the toe.

The subdrain systems may provide a unique opportunity to monitor potential impacts of the landfill on groundwater. In effect, they would collect all water that comes within 5 feet of the refuse, thus providing an areally extensive "sample" of the quality of groundwater immediately below the liner system. If the collector pipes draining different sectors of the footprint were to be brought separately to the toe of the landfill, then sampling and analysis of these waters would allow early detection of

discrete problem areas.

To properly design the subdrain system an estimate was made of the potential groundwater inflow into the floor of the excavation. A conservative design model yielded seepage rates of 0.00063 to 0.0012 ft/day into the excavation (equivalent to 0.0047 and 0.009 gpd/ft^2, respectively). We believe that these rates of flux into the floor of the excavation are conservative by a factor of 10 over the most likely average conditions. These values are recommended for use in design of a reasonably conservative subdrain system for the landfill.

CLOSURE

This report is based on available public data, and on field observations made in the course of this investigation. Our firm should be notified if conditions are found that differ from those described in this report, since this may require a re-evaluation of the conclusions and recommendations. This report has not been prepared for use by parties and projects other than those named or described on the cover page. It may not contain sufficient information for other parties or other purposes.

This report has been prepared in accordance with generally accepted geologic practices and makes no other warranties, either expressed or implied, as to the professional advice or data included in it.

GeoLogic Associates

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CEG # 2018

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REFERENCES

Atwater, T., 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, p.3513-3536.

Bear, J., Tshang,C.-F., de Marsily, G. (eds.), 1993, Flow and Contaminant Transport in Fractured Rock: Academic Press, Inc. (New York, NY), p.237-266.

Davis, S.N., Turk, L.S., 1964, Optimum depth of wells in crystalline rocks: Ground Water, v.2, no. 2, p.6-11.

Drost, W., Klotz, D., Koch, A., Moser, H., Neumaier, F., Rauert, W., 1968, Point dilution methods of investigating groundwater flow by means of radioisotopes: Water Resources Research, v. 4, p.125-146.

Freeze, R. A., Cherry, I. A., 1979, Groundwater: Prentice Hall (Englewood Cliffs, NY) 604p.

Gale, J.E., 1982, Assessing the permeability characteristics of fractured rock: Geological Society of America Special Paper 189, p.163-181.

Geraghty & Miller, 1988, Phase I hydrogeologic investigation - Proposed North County Landfill, San Diego, California: Consultant's report to Waste Management of North America, Western Region.

Geraghty & Miller, 1990, Phase II investigation - Proposed Gregory Canyon Class III Landfill, San Diego County, California: Consultant's report to Waste Management of North America, Western Region.

Huntley, D, Pollack, J., Pierce, S.W., McHugh, J.A., 1991, Relations between well yield, fracturing, and depth in crystalline rock systems, San Diego County, California: in Environmental Perils, San Diego Region.

Lamar, D.L., Rockwell, T.K., 1986, An overview of the tectonics of the Elsinore fault zone: in Neotectonics and Faulting in Southern California - Guidebook and Volume: Geological Society of America Cordilleran Section, 82nd Annual Meeting, p.149-158.

Larsen, E.S., 1948, Batholith and associated rocks of the Corona, Elsinore and San Luis Rey quadrangles, Southern California: Geological Society of America Memoir 29, 182 pp.

Swan, A.R.H., Sandilands, M., 1995, Introduction to Geological Data Analysis: Blackwell Science (Oxford, England), 446pp.

Woodward-Clyde, 1995, Geology and hydrogeology report, Gregory Canyon Landfill, Pala, San Diego County, California: Consultant's report to Gregory Canyon Ltd. (March, 1995).

FIGURES

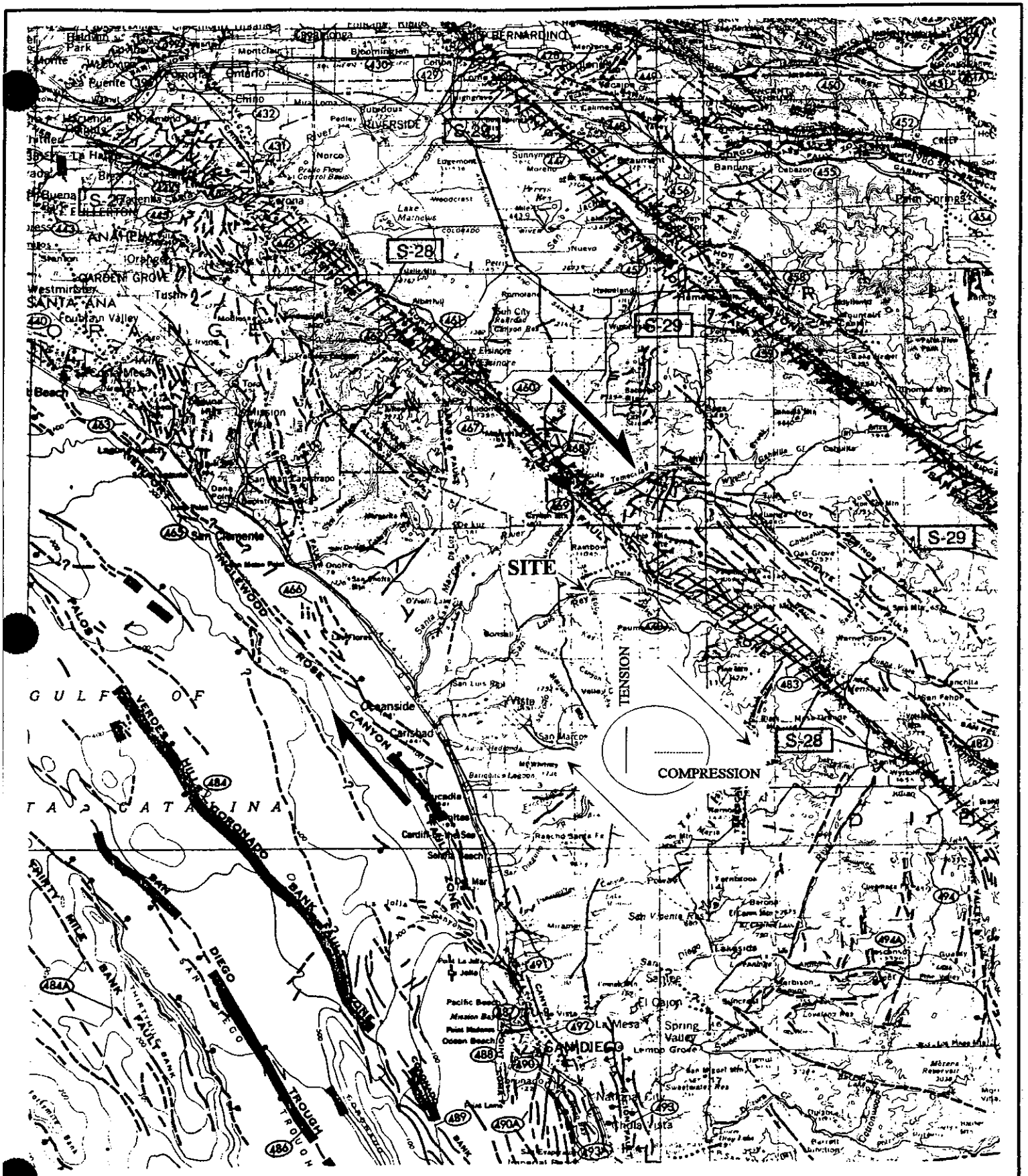

Figure 1. Regional tectonic stress regime.
Base map from Jennings (1994).

GeoLogic Associates

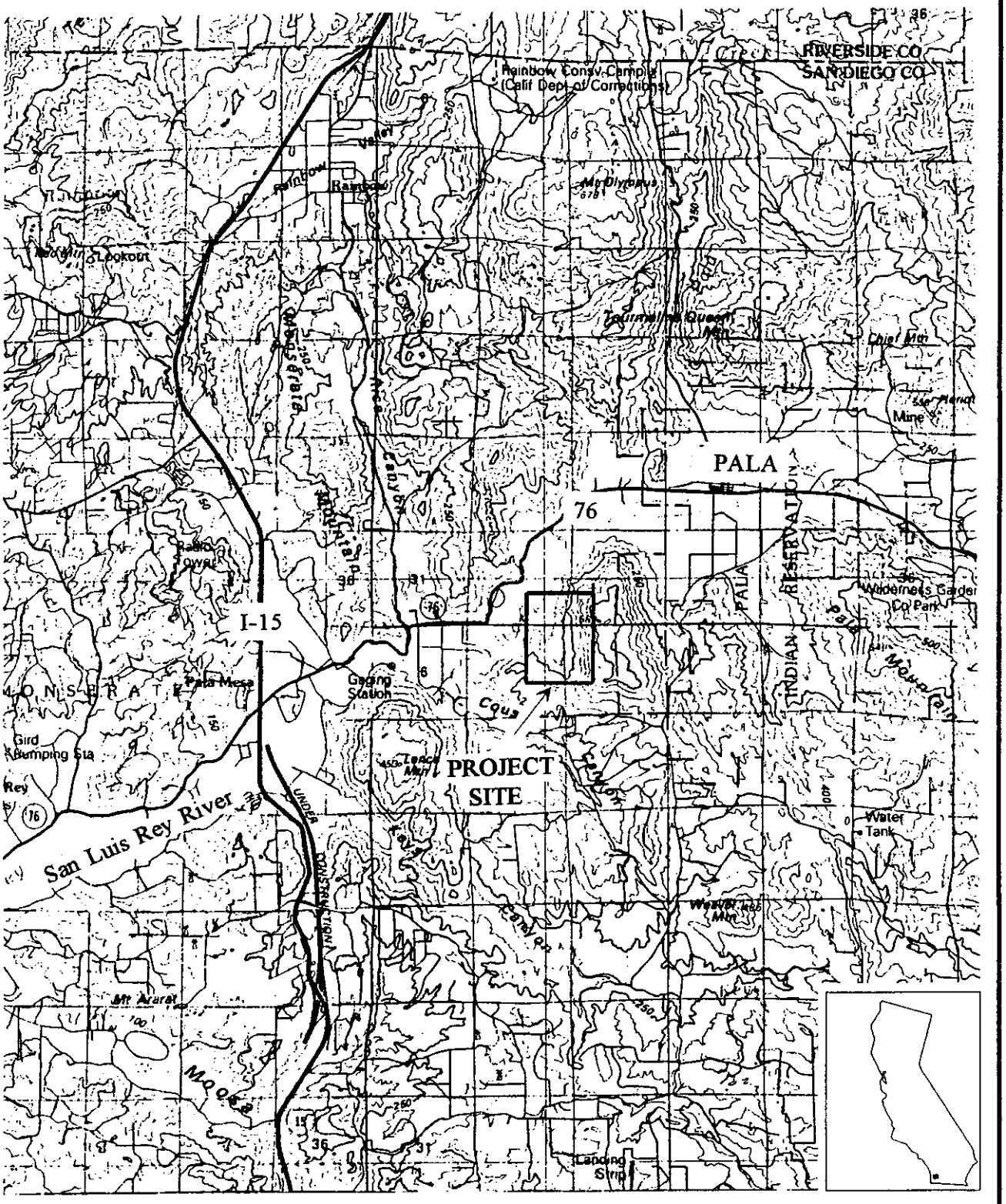

Figure 2. Location map

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Linear drainage

Geomorphologic or tonal lineament

Fractures or dikes

Fault depicted on CDMG fault map (Jennings, 1994)

2,000 feet

Figure 3. Regional lineaments.

GeoLogic Associates

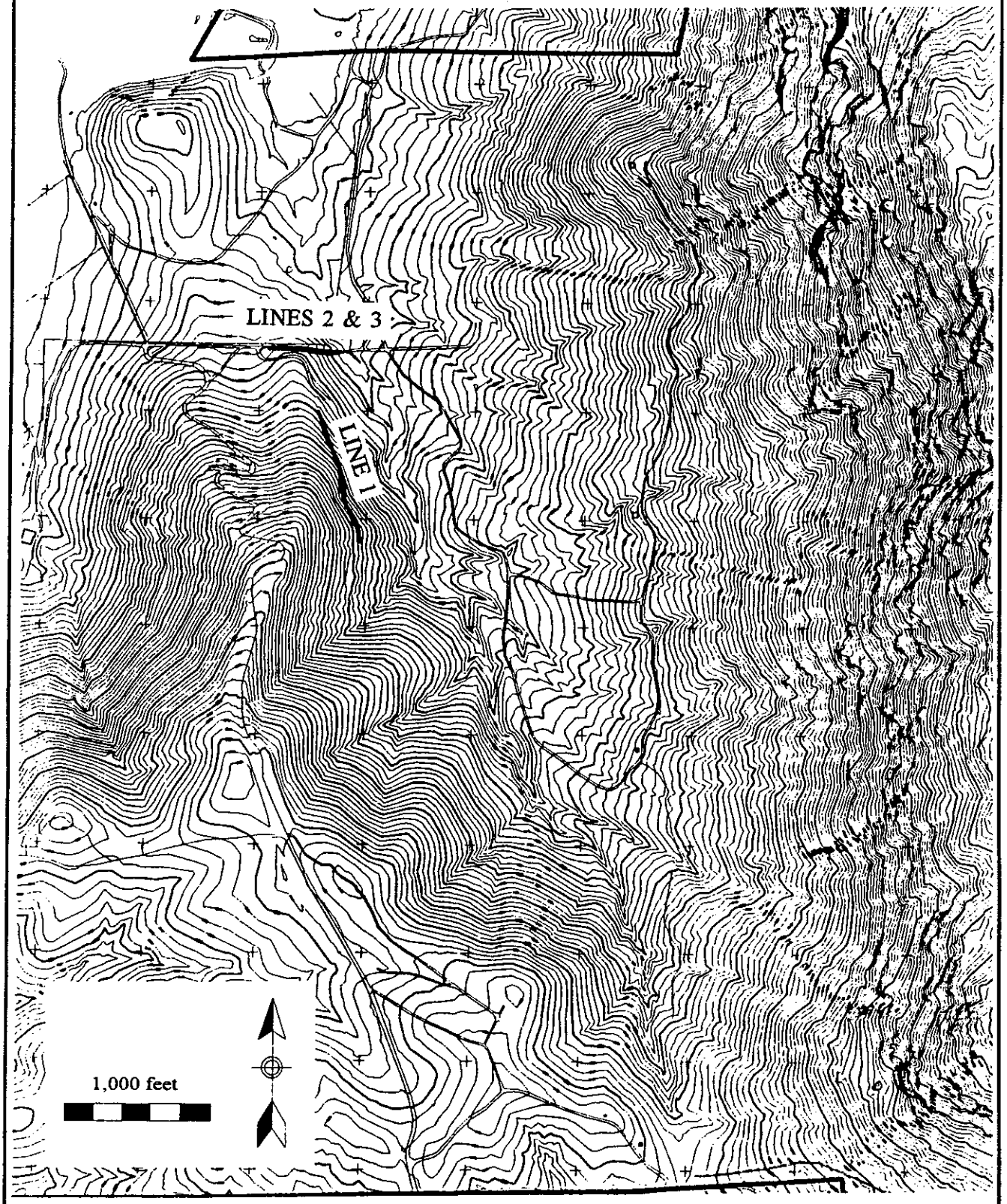

Figure 4. Location of survey lines mapped for discontinuities.

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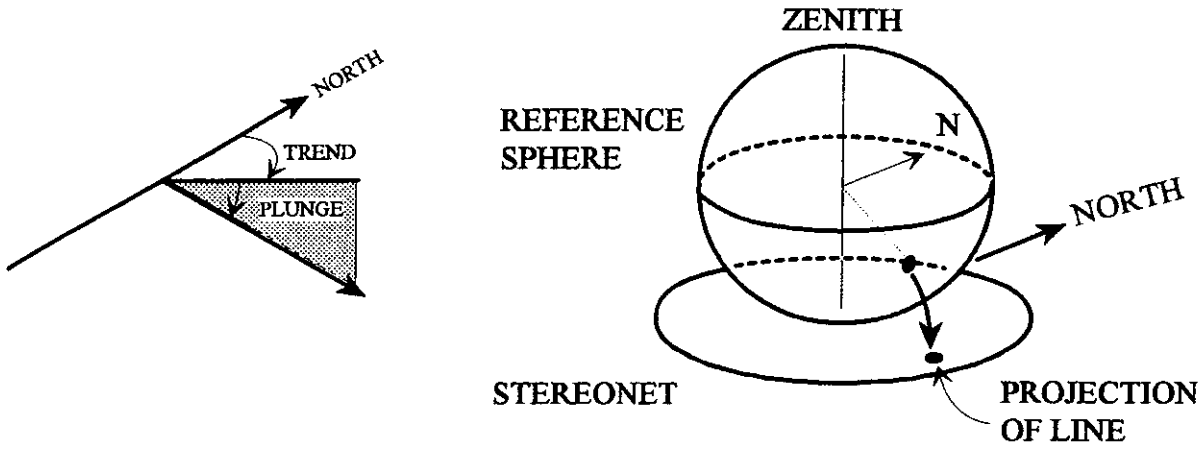
TERMS OF DESCRIPTION AND PROJECTION OF LINES



TERMS OF DESCRIPTION AND PROJECTION OF PLANES

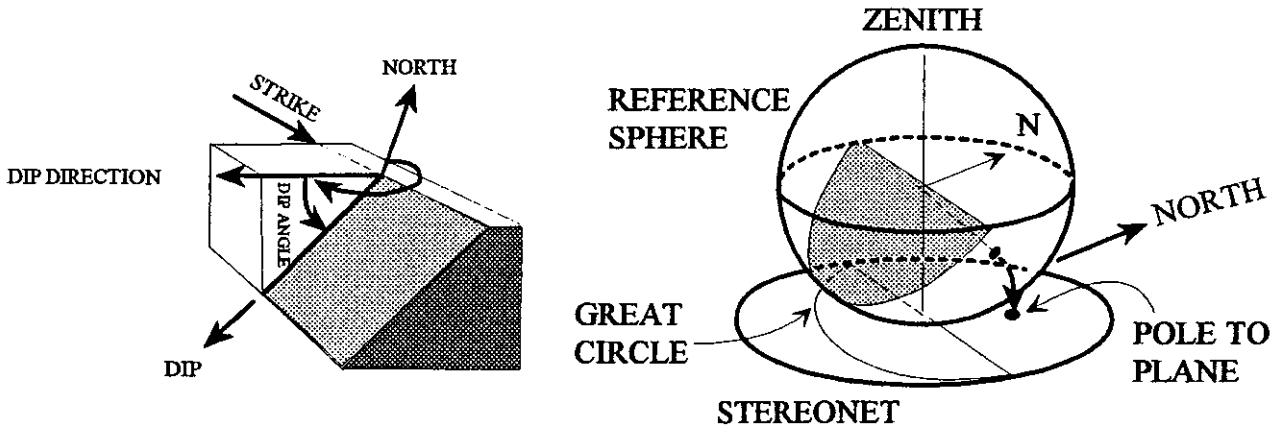
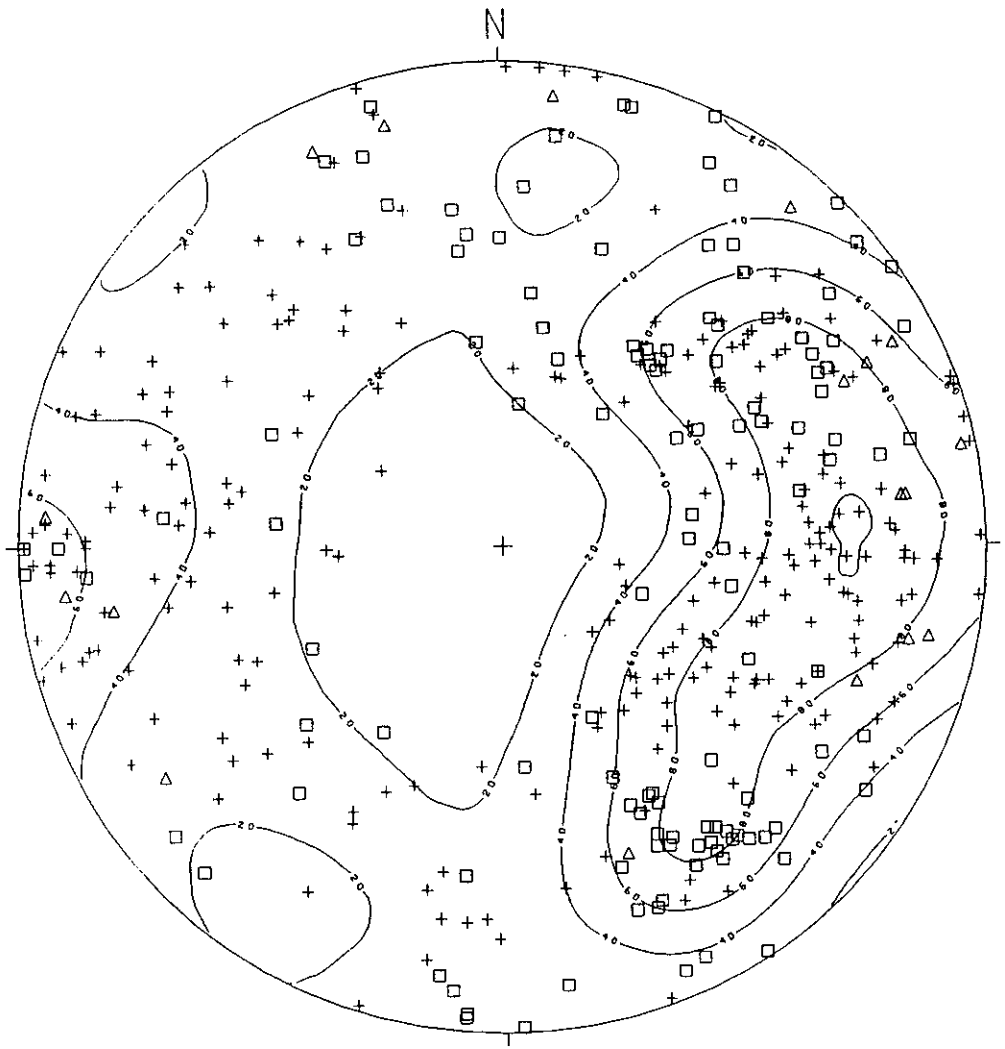


Figure 5. Definition of structural terms and system of stereographic projection.



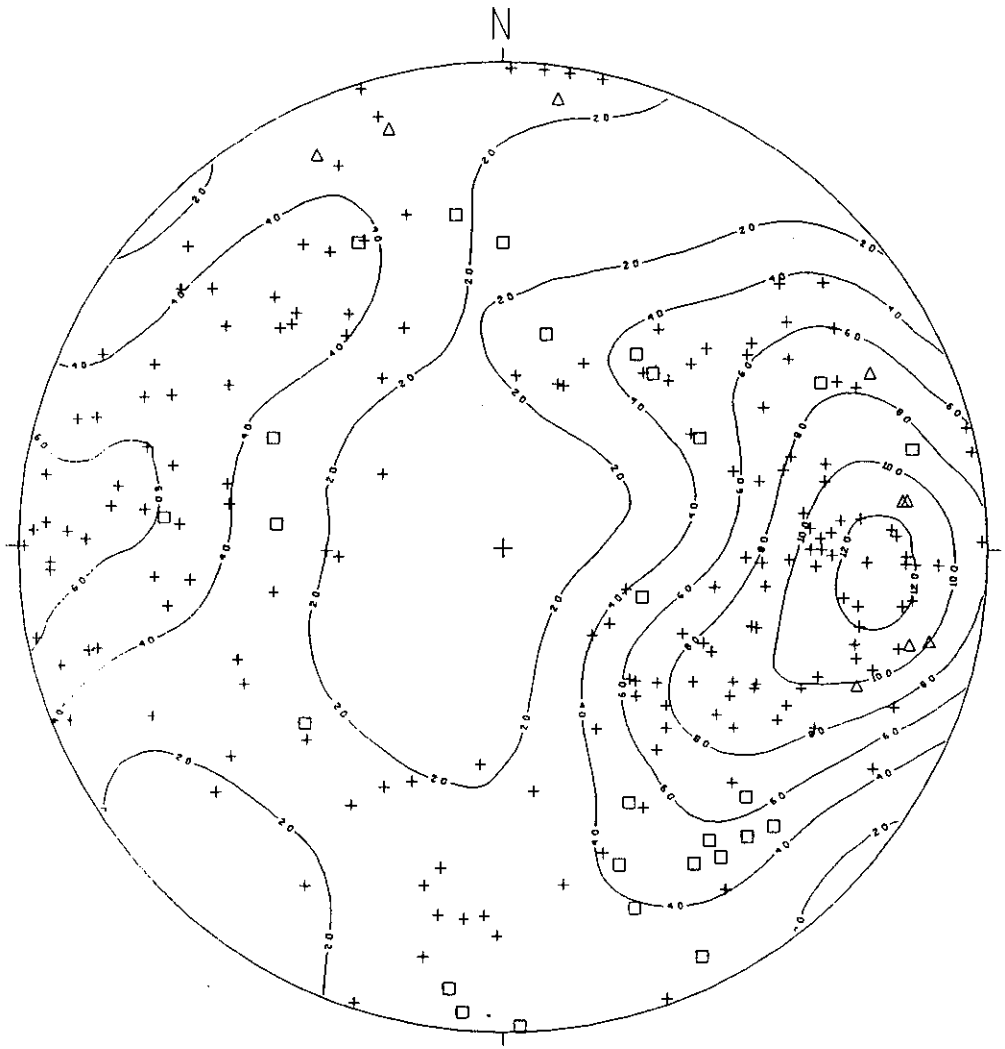
ATTITUDE OF FRACTURES AND DIKES

Projection	Schmidt
Number of Sample Points	424
Mean Lineation Azimuth	94 5
Mean Lineation Plunge	27 2
Great Circle Azimuth	6 1
Great Circle Plunge	27 3
1st Eigenvalue	0 504
2nd Eigenvalue	0 276
3rd Eigenvalue	0 220
LN (E1 / E2)	0 602
LN (E2 / E3)	0 224
(LN(E1/E2)] / (LN(E2/E3))	2 682
Spherical variance	0 4874
Rbar	0 5126

□ LINE 1
△ LINE 2
+ LINE 3

Figure 6. Stereographic plot of structural attitudes of all discontinuities

GeoLogic Associates



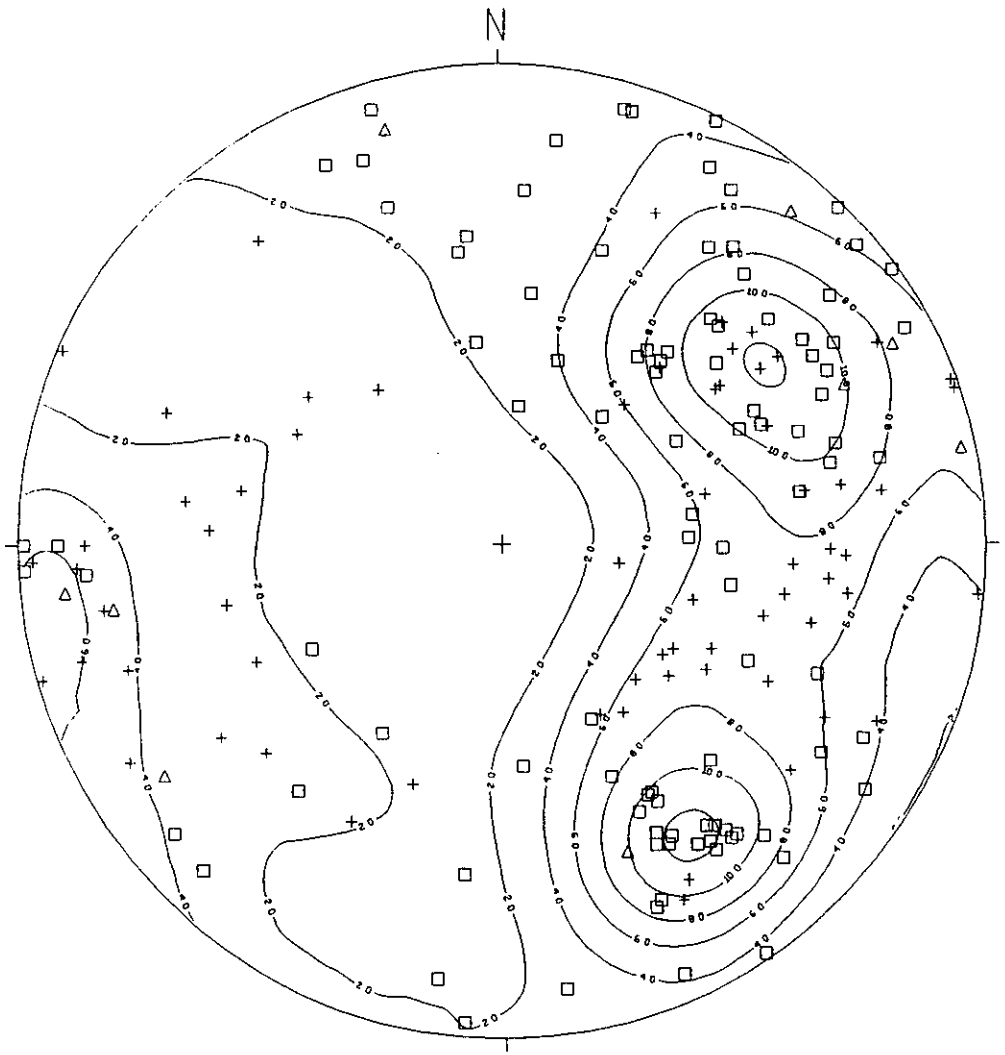
ATTITUDE OF FRACTURES

Projection	Schmidt
Number of Sample Points	243
Mean Lineation Azimuth	100 5
Mean Lineation Plunge	21 2
Great Circle Azimuth	308 2
Great Circle Plunge	39 9
1st Eigenvalue	0 515
2nd Eigenvalue	0 249
3rd Eigenvalue	0 236
LN (E1 / E2)	0 726
LN (E2 / E3)	0 056
(LN(E1/E2)] / (LN(E2/E3)]	12 861
Spherical variance	0 5034
Rbar	0 4906

□ LINE 1
△ LINE 2
+ LINE 3

Figure 7. Stereographic plot of structural attitudes of fractures

GeoLogic Associates



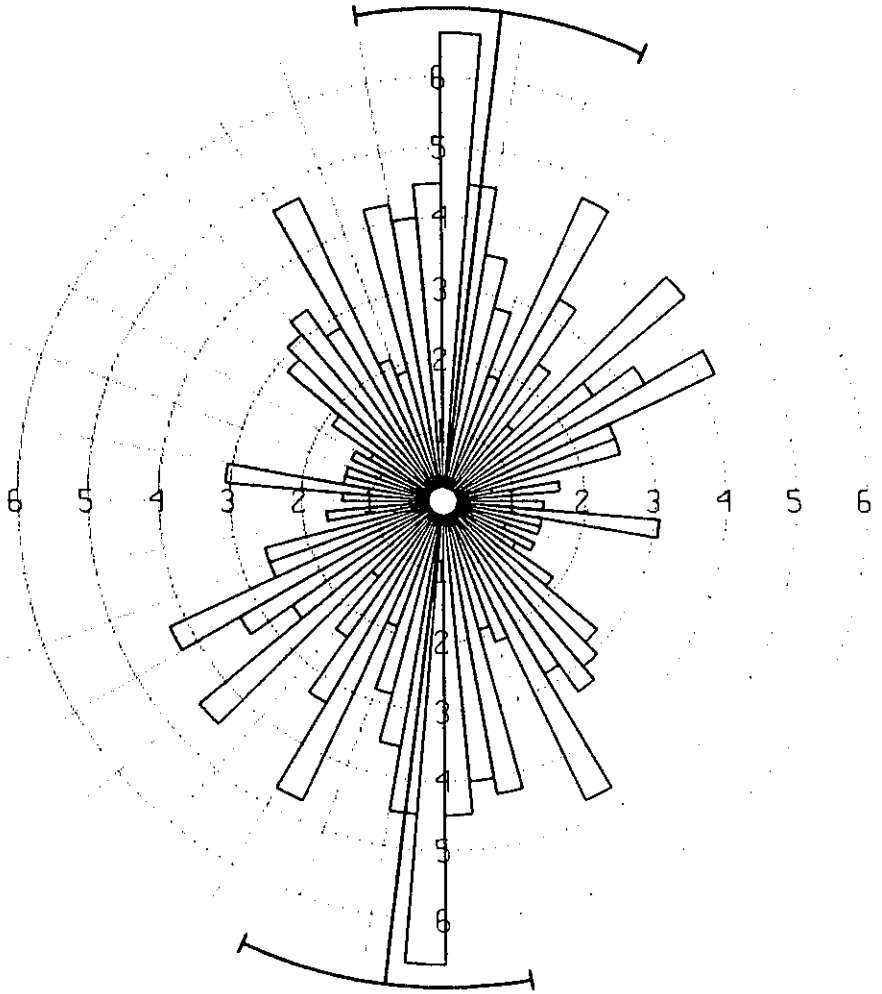
ATTITUDE OF DIKES

Projection	Schmidt
Number of Sample Points	180
Mean Lineation Azimuth	82 9
Mean Lineation Plunge	33 4
Great Circle Azimuth	18 0
Great Circle Plunge	36 1
1st Eigenvalue	0 505
2nd Eigenvalue	0 312
3rd Eigenvalue	0 183
LN (E1 / E2)	0 480
LN (E2 / E3)	0 533
(LN(E1/E2)] / (LN(E2/E3))	0 901
Spherical variance	0 4569
Rbar	0 5431

□ LINE 1
△ LINE 2
+ LINE 3

Figure 8. Stereographic plot of structural attitudes of dikes

GeoLogic Associates



STRIKE OF DIKES AND FRACTURES

Calculation Method	Frequency
Class Interval	5 Degrees
Filtering	Deactivated
Data Type	Bidirectional
Rotation Amount	0 Degrees
Population	424
Maximum Percentage	6 6 Percent
Mean Percentage	2 8 Percent
Standard Deviation	1 38 Percent
Vector Mean	7 19 Degrees
Confidence Interval	17 15 Degrees
R-mag	0 22

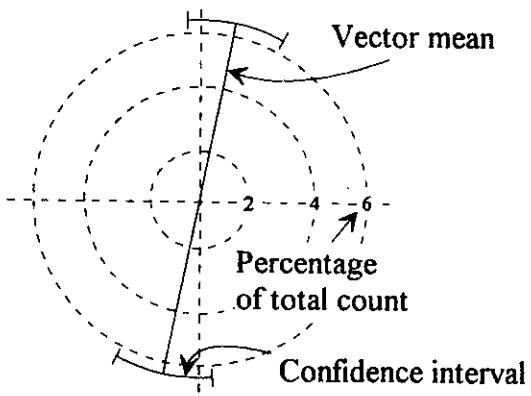
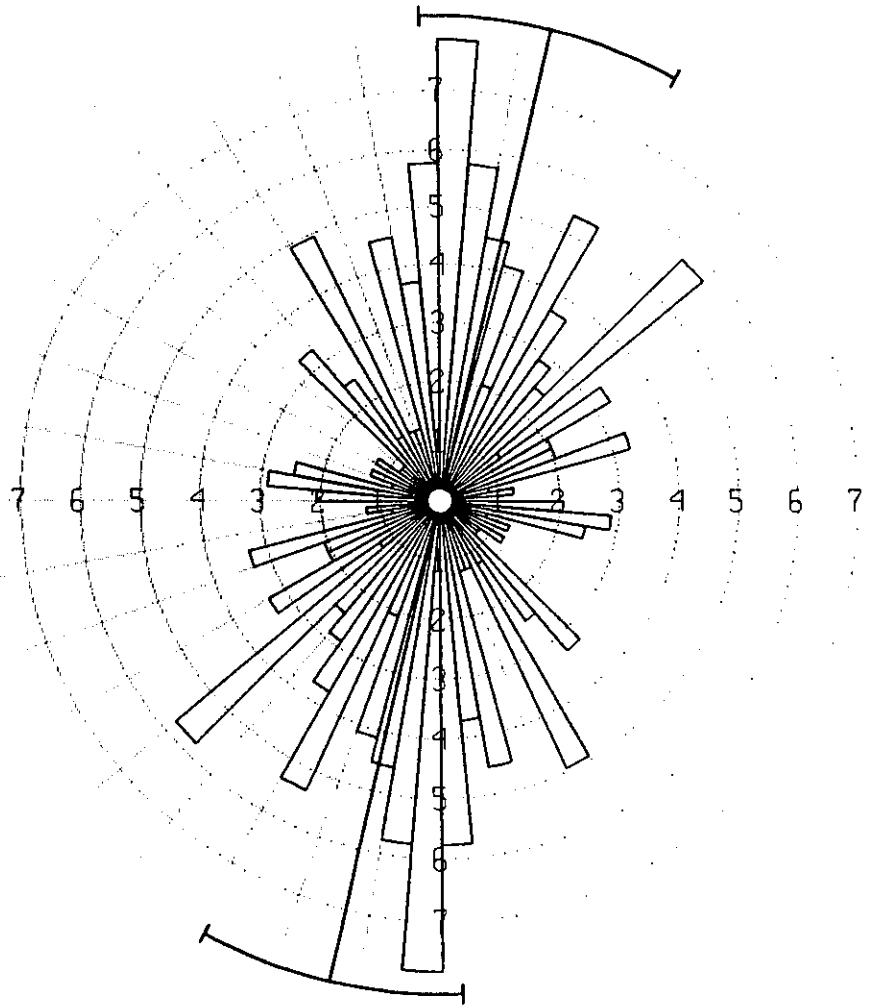


Figure 9. Rose diagram of strikes of all discontinuities

GeoLogic Associates



STRIKE OF FRACTURES

Calculation Method	Frequency
Class Interval	5 Degrees
Filtering	Deactivated
Data Type	Bidirectional
Rotation Amount	0 Degrees
Population	243
Maximum Percentage	7 8 Percent
Mean Percentage	2 8 Percent
Standard Deviation	1 83 Percent
Vector Mean	13 34 Degrees
Confidence Interval	15 61 Degrees
R-mag	0 32

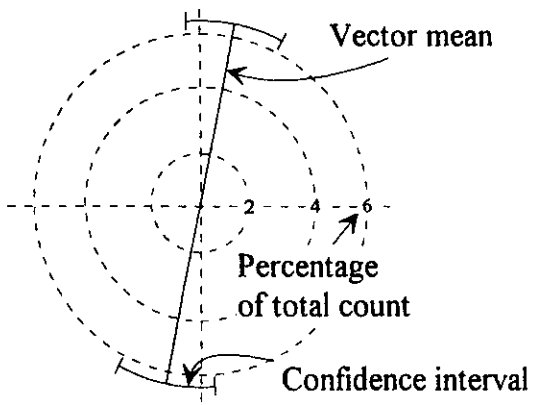
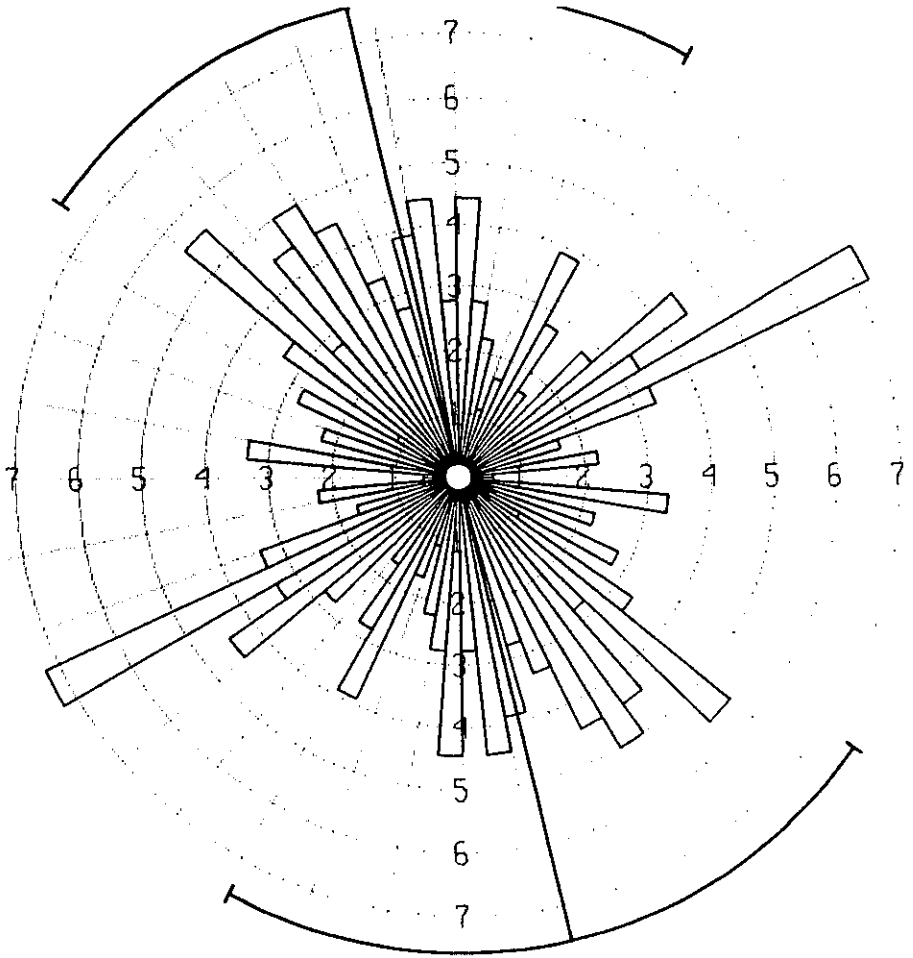


Figure 10. Rose diagram of strikes of fractures

GeoLogic Associates



STRIKE OF DIKES

Calculation Method	Frequency
Class Interval	5 Degrees
Filtering	Deactivated
Data Type	Bidirectional
Rotation Amount	0 Degrees
Population	180
Maximum Percentage	7 2 Percent
Mean Percentage	2 9 Percent
Standard Deviation	1 54 Percent
Vector Mean	347 13 Degrees
Confidence Interval	42 1 Degrees
R-mag	0 14

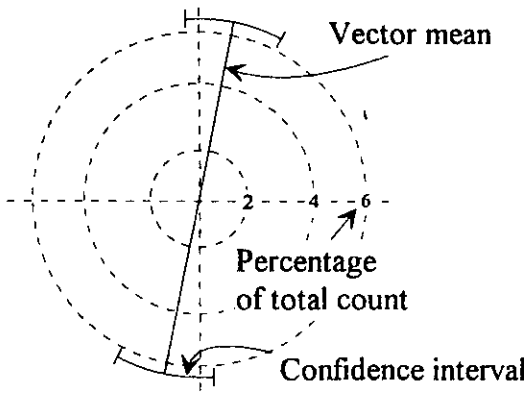


Figure 11. Rose diagram of strikes of dikes

GeoLogic Associates

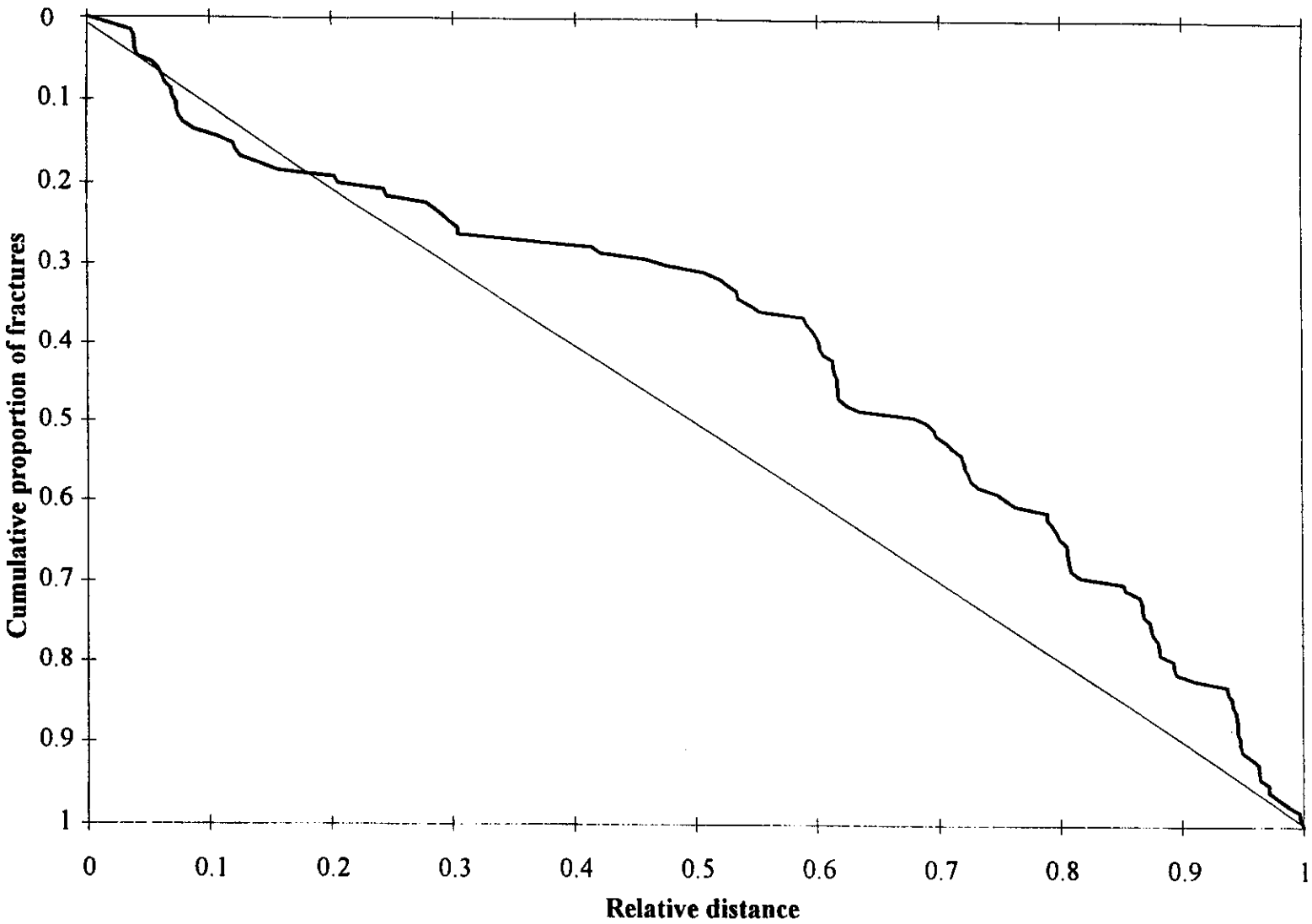


Figure 12. Uniformity test for the spacing of discontinuities along Line 1

GeoLogic Associates

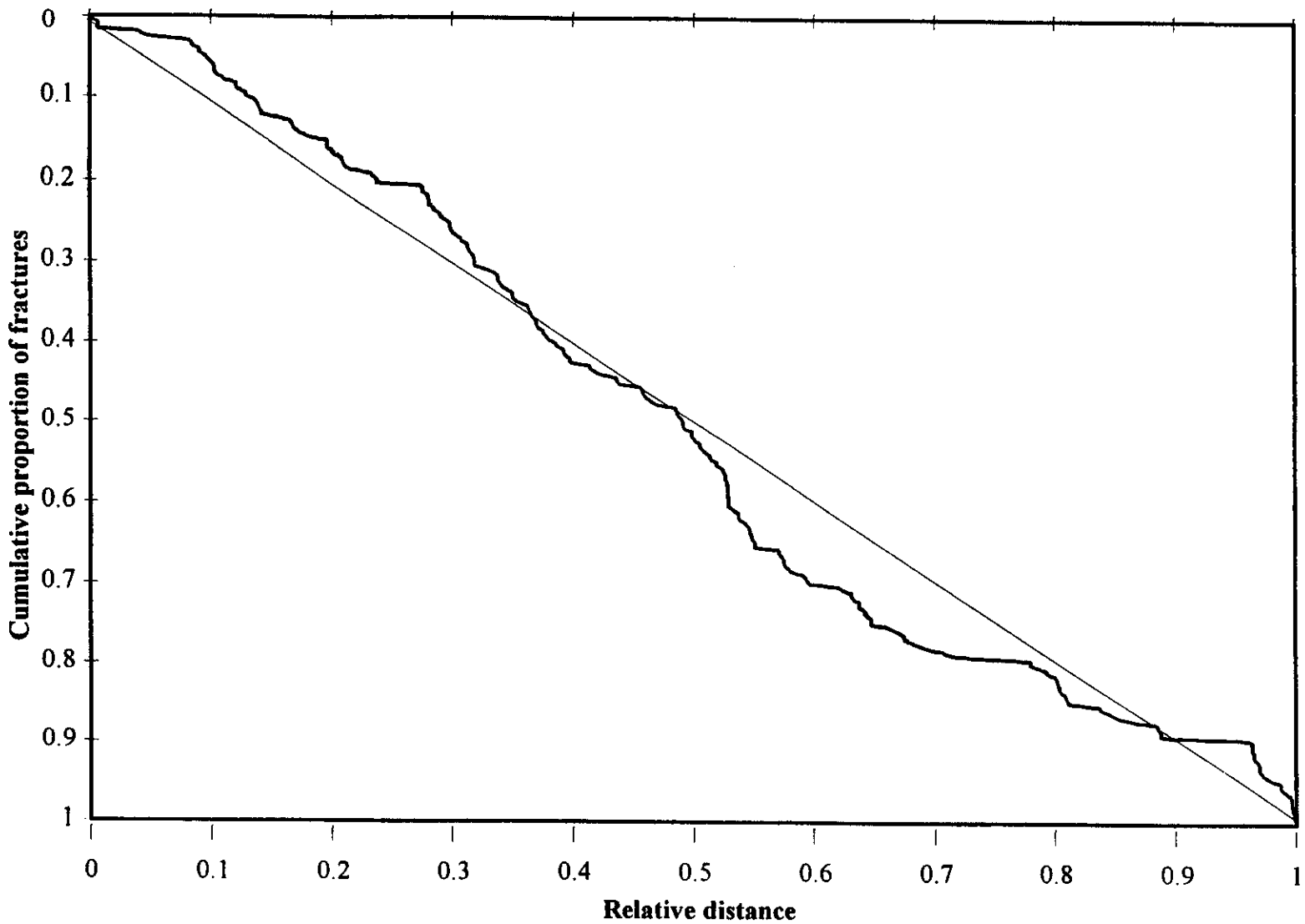


Figure 13. Uniformity test for the spacing of discontinuities along Line 3

GeoLogic Associates

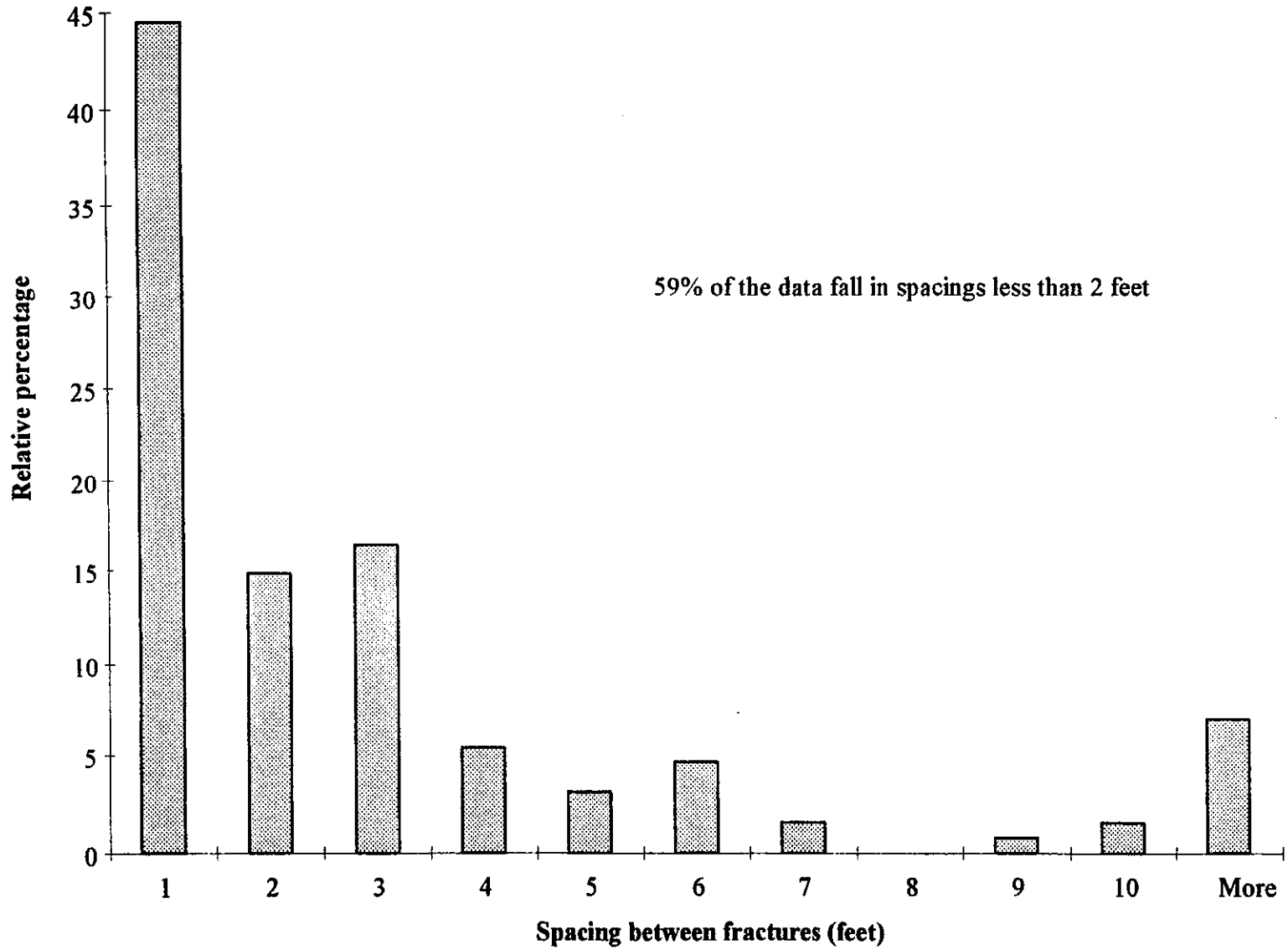


Figure 14. Histogram of spacing of discontinuities along Line 1

GeoLogic Associates

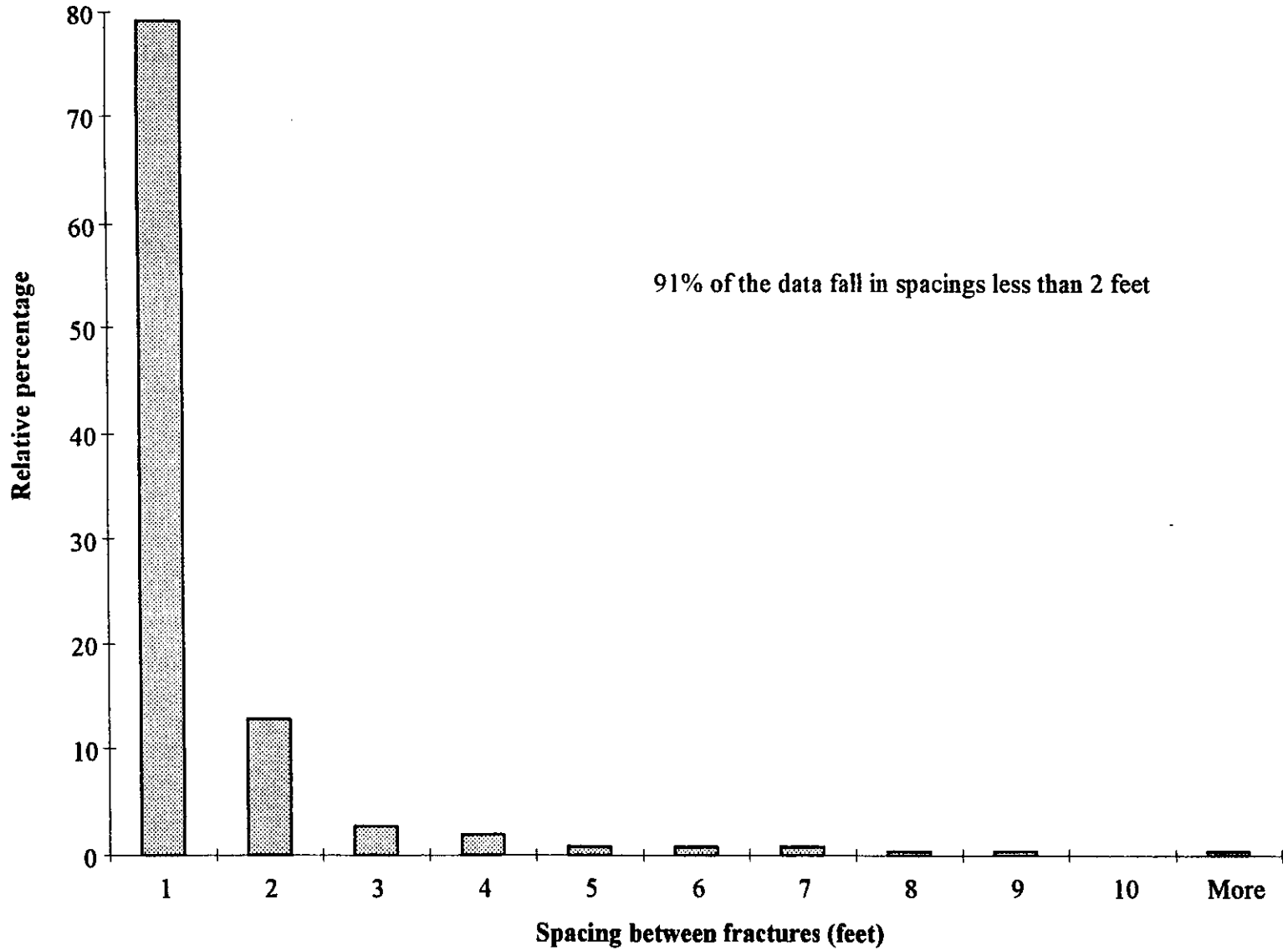


Figure 15. Histogram of spacing of discontinuities along Line 3

GeoLogic Associates

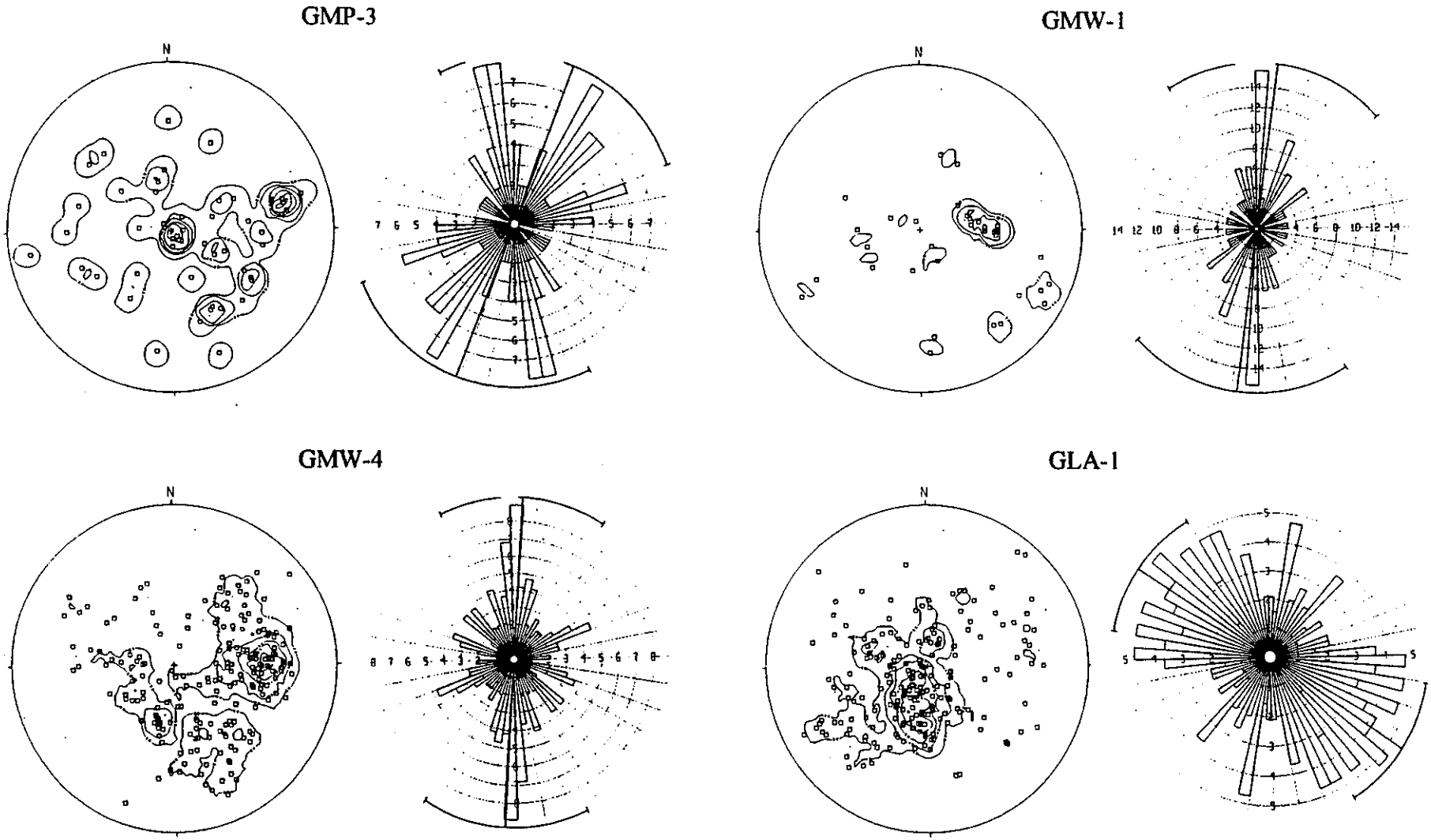


Figure 16. Stereographic pole-plots and rose diagrams for fractures logged in wells.

GeoLogic Associates

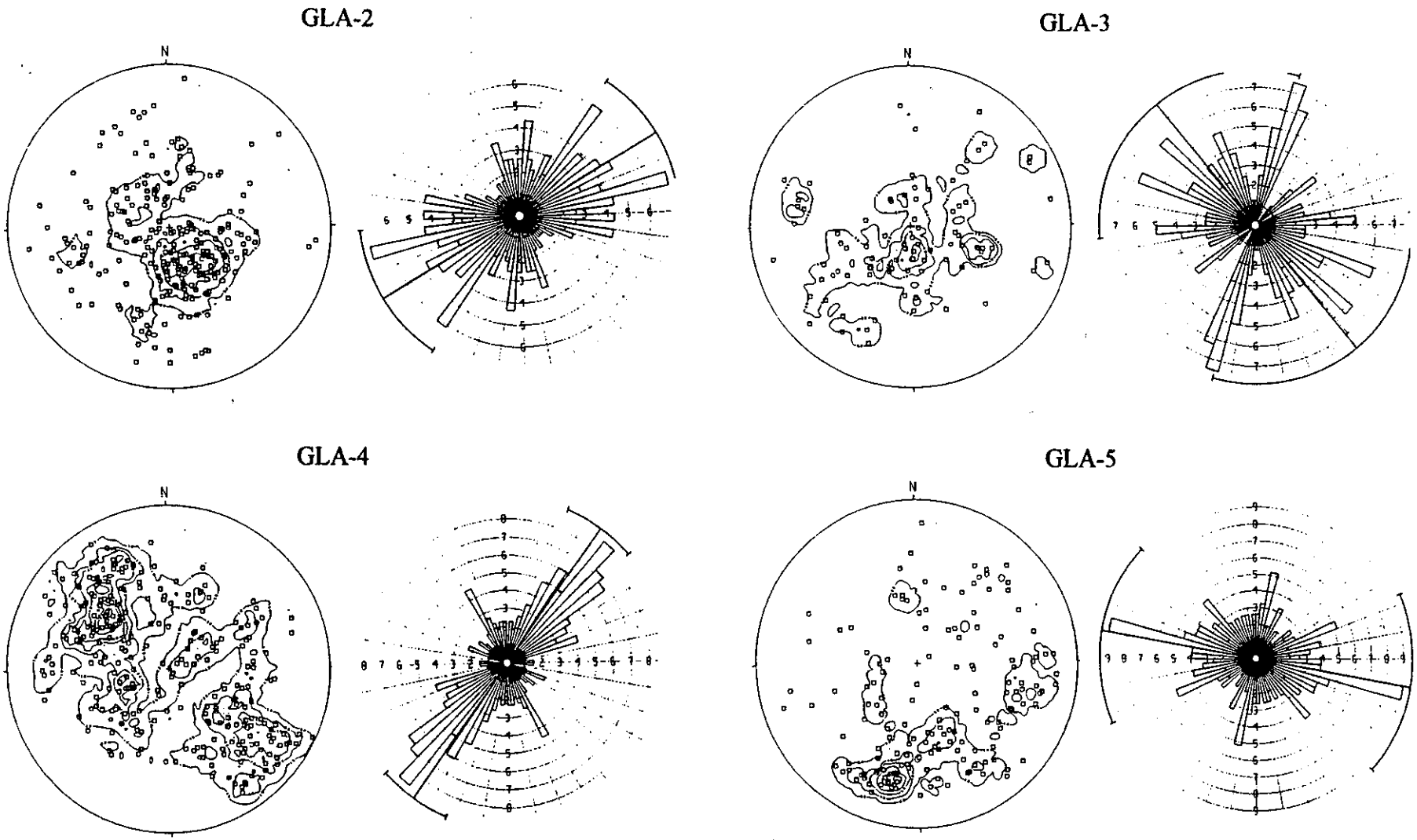
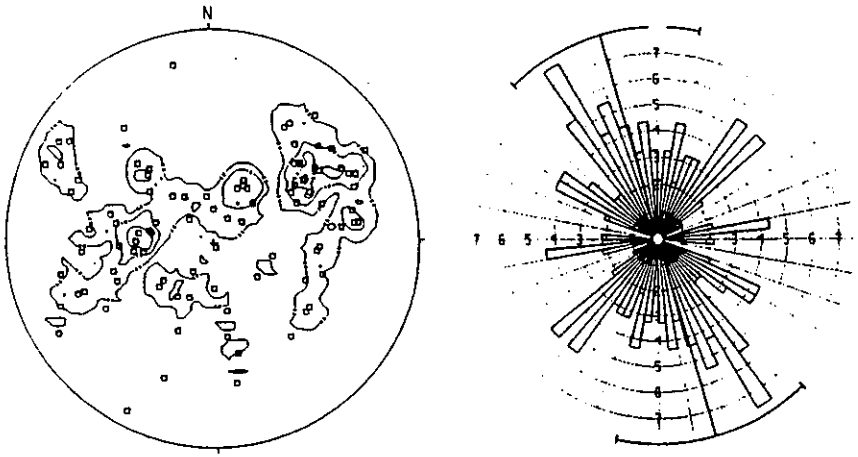


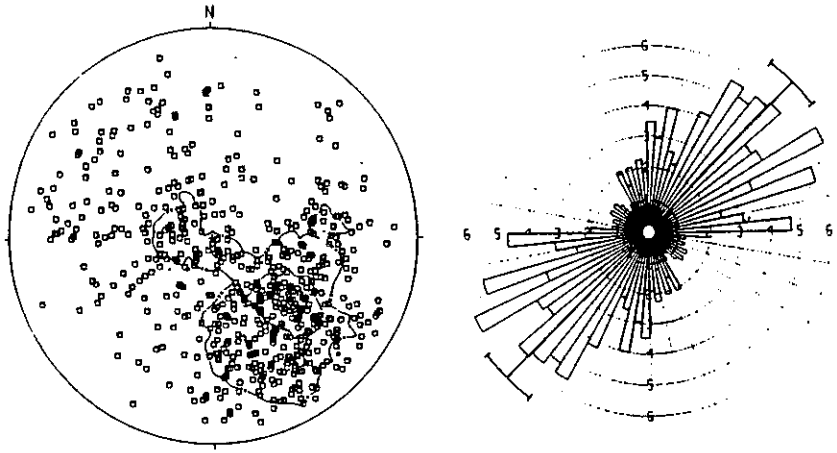
Figure 16. Stereographic pole-plots and rose diagrams for fractures logged in wells (continued)

GeoLogic Associates

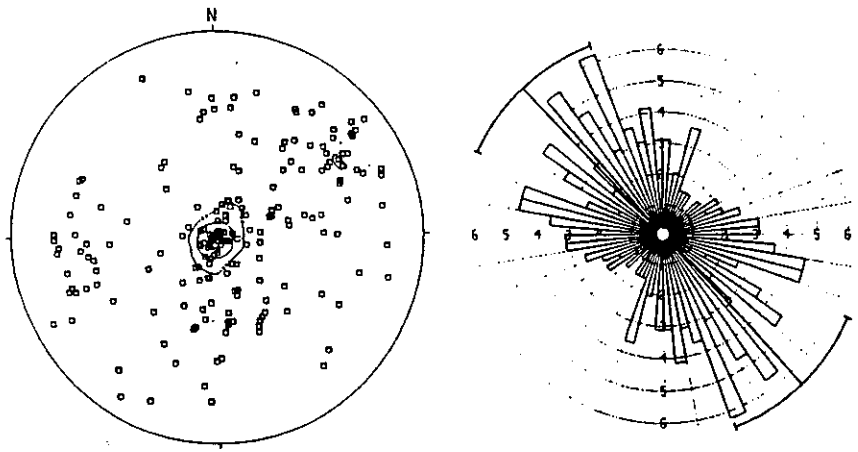
GLA-7



GLA-8



GLA-9



GLA-10

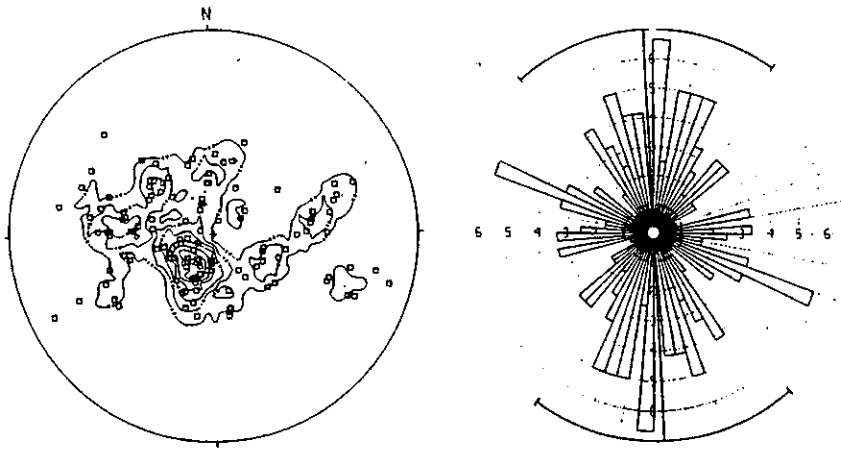
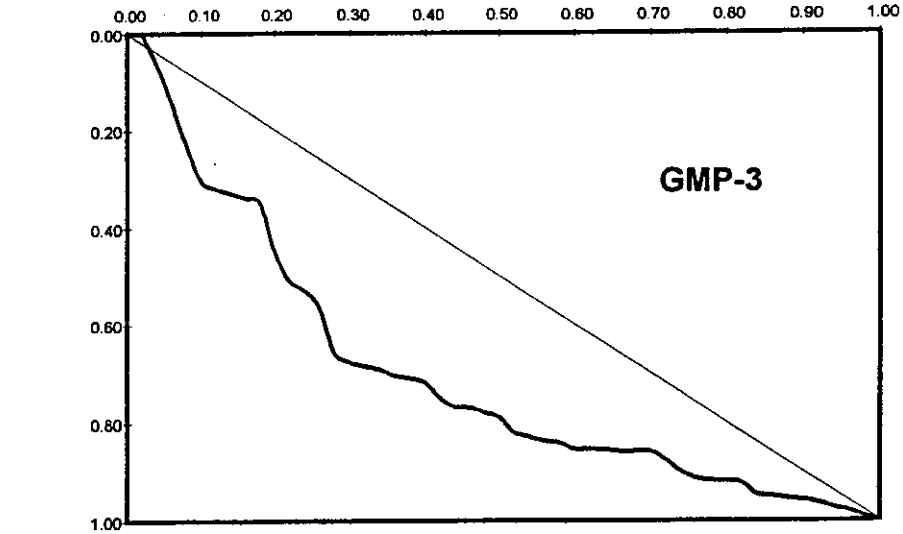
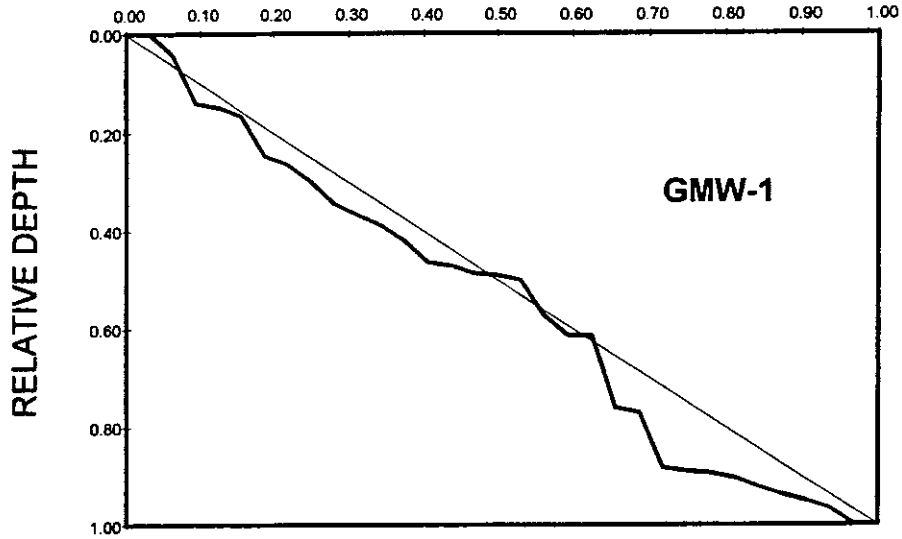
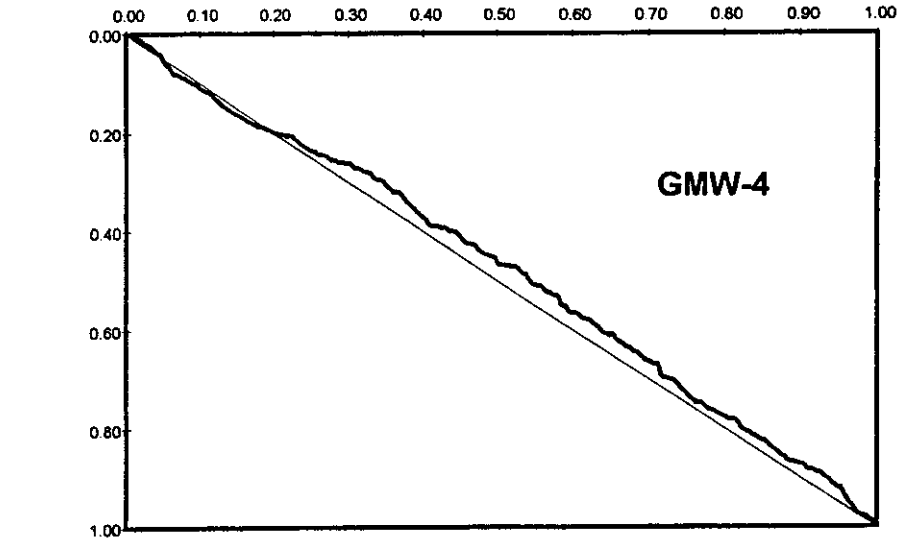


Figure 16. Stereographic pole-plots and rose diagrams for fractures logged in wells (continued)

GeoLogic Associates







RELATIVE DEPTH

RELATIVE NUMBER OF FRACTURES

Figure 17. Uniformity plots for GM wells

GeoLogic Associates

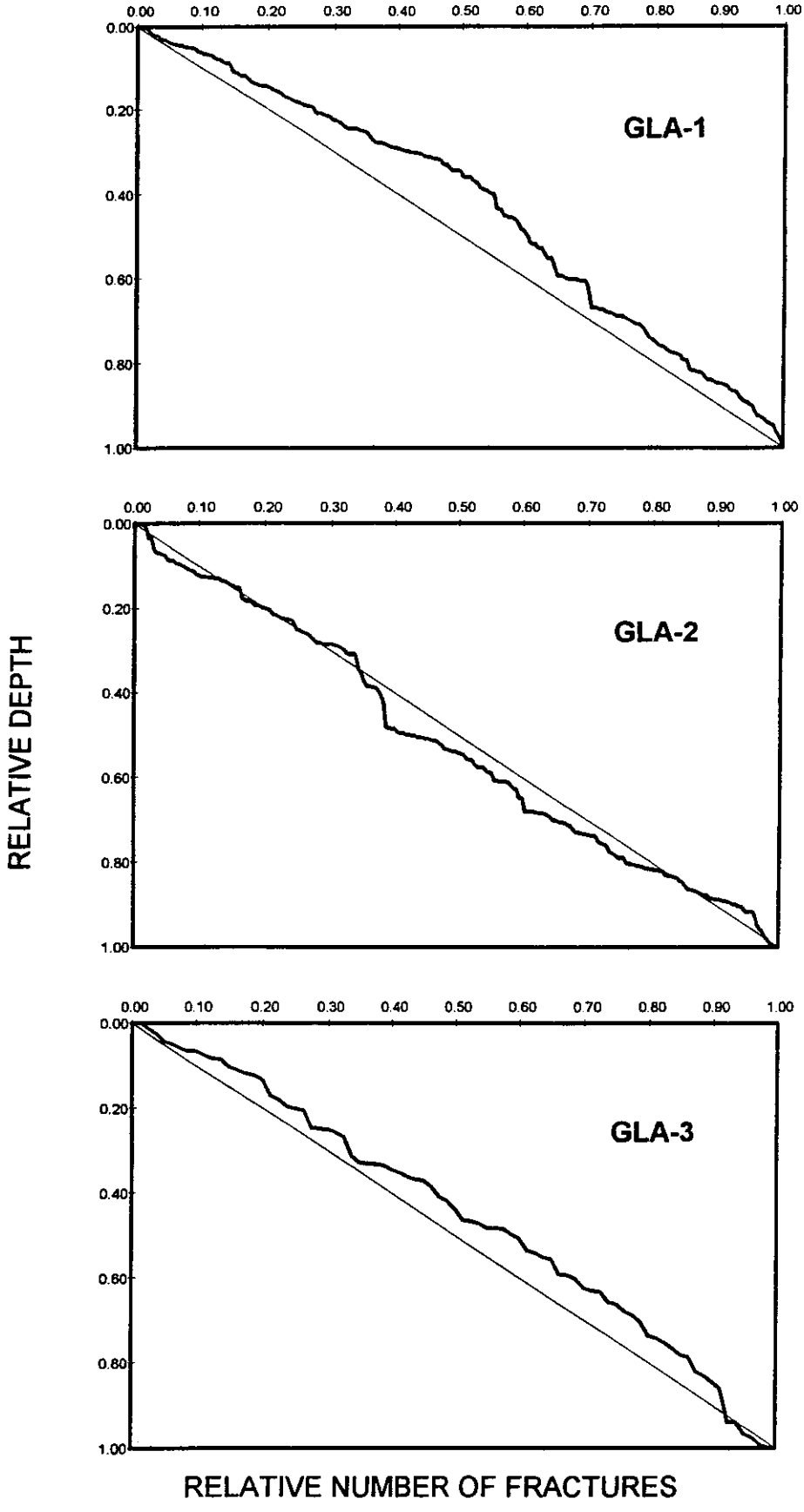
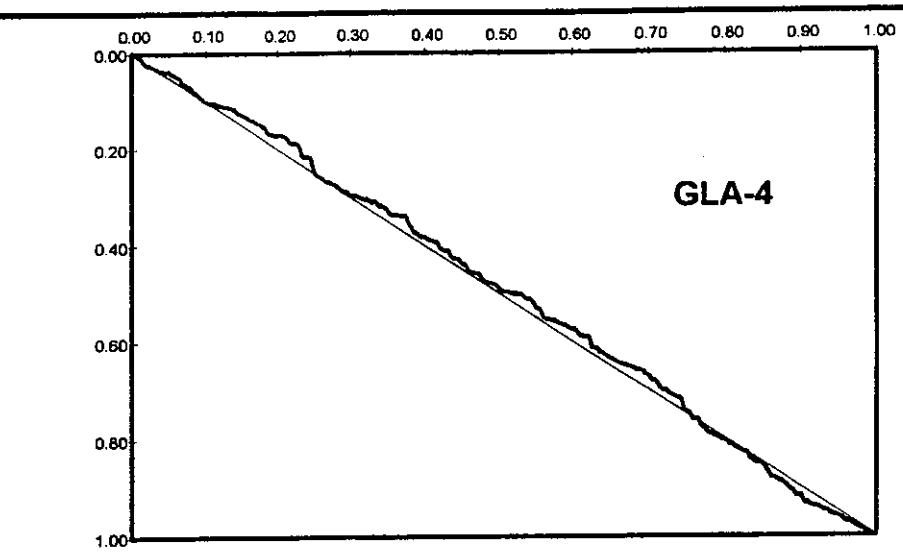
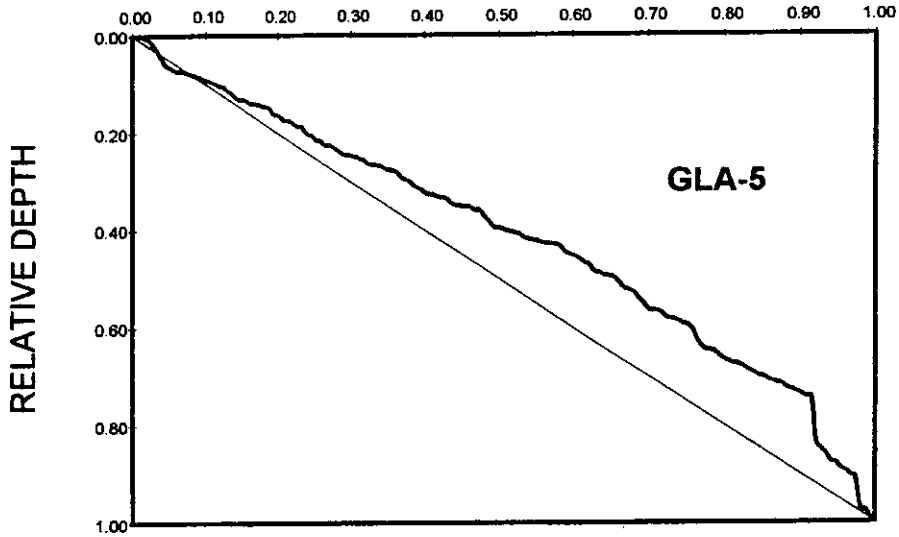
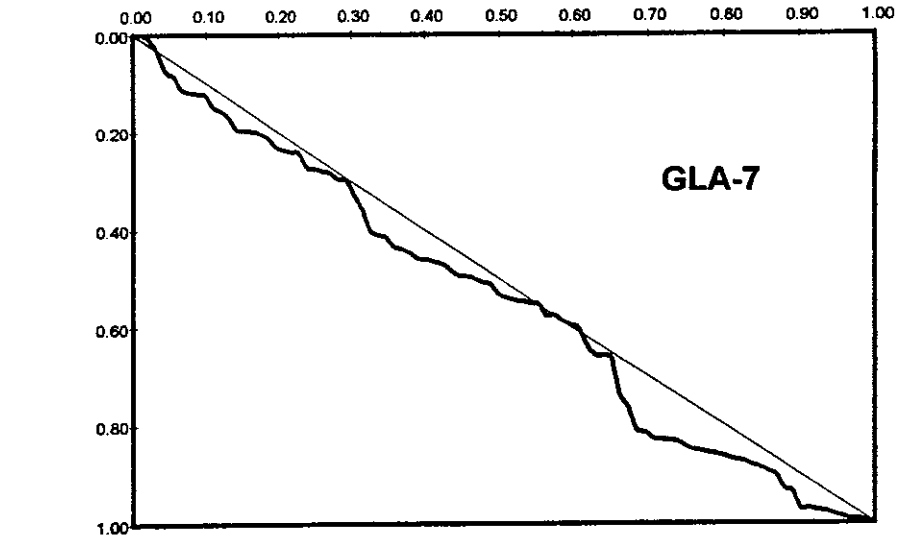


Figure 17. Uniformity plots for GLA wells (continued)

GeoLogic Associates







RELATIVE DEPTH

RELATIVE NUMBER OF FRACTURES

Figure 17. Uniformity plots for GLA wells (continued)

GeoLogic Associates

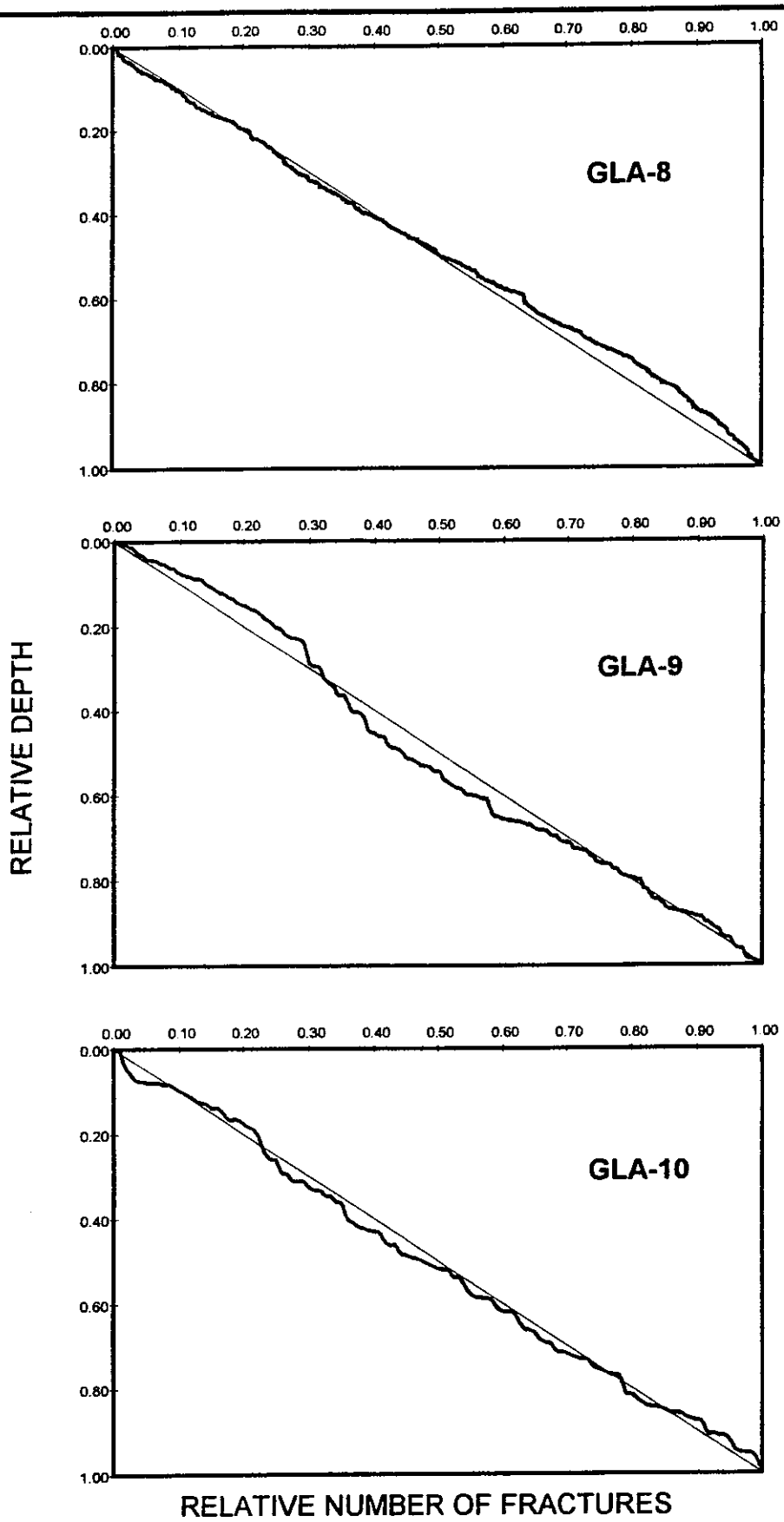


Figure 17. Uniformity plots for GLA wells (continued)

GeoLogic Associates

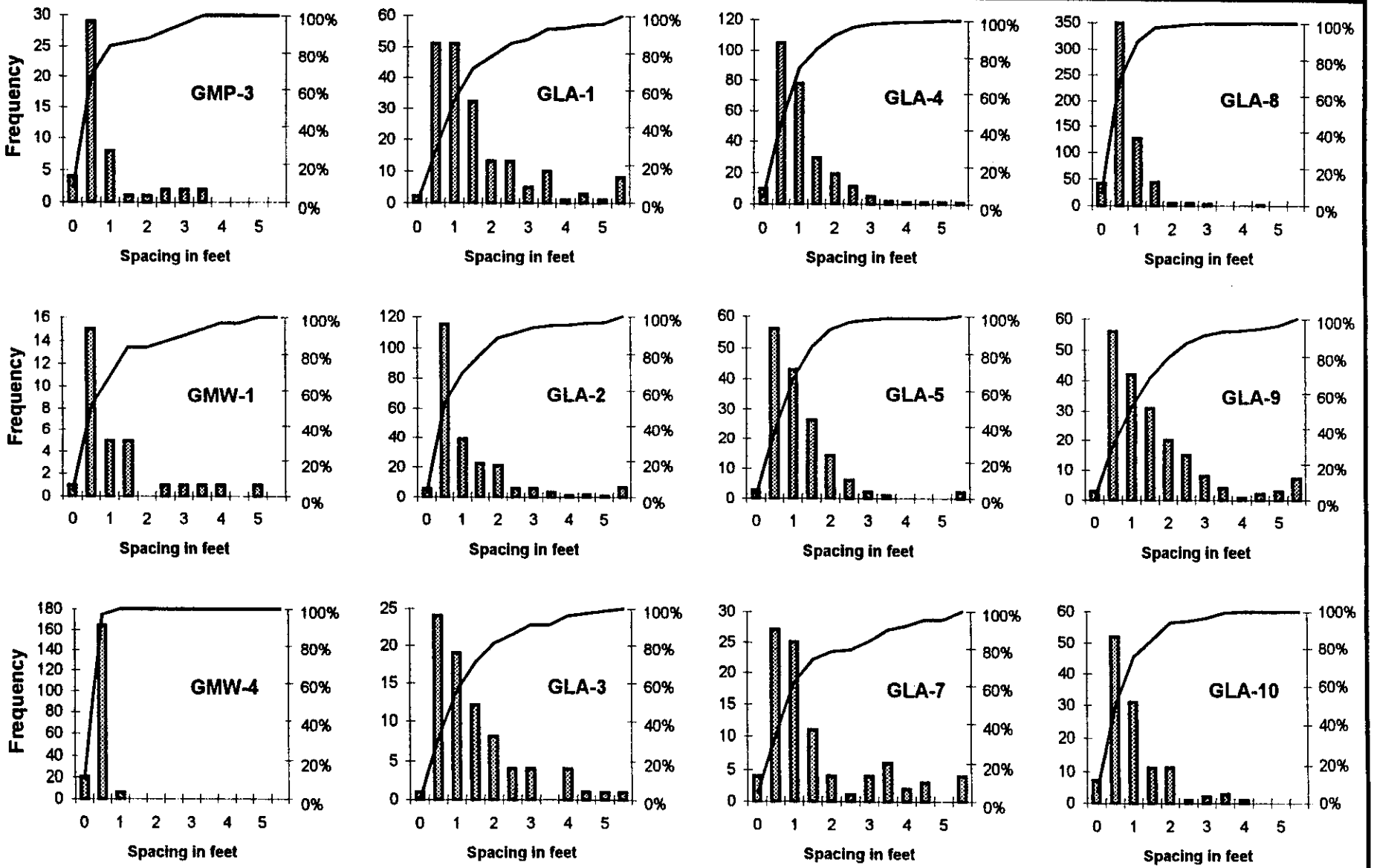


Figure 18. Fracture spacing histograms for wells.

GeoLogic Associates

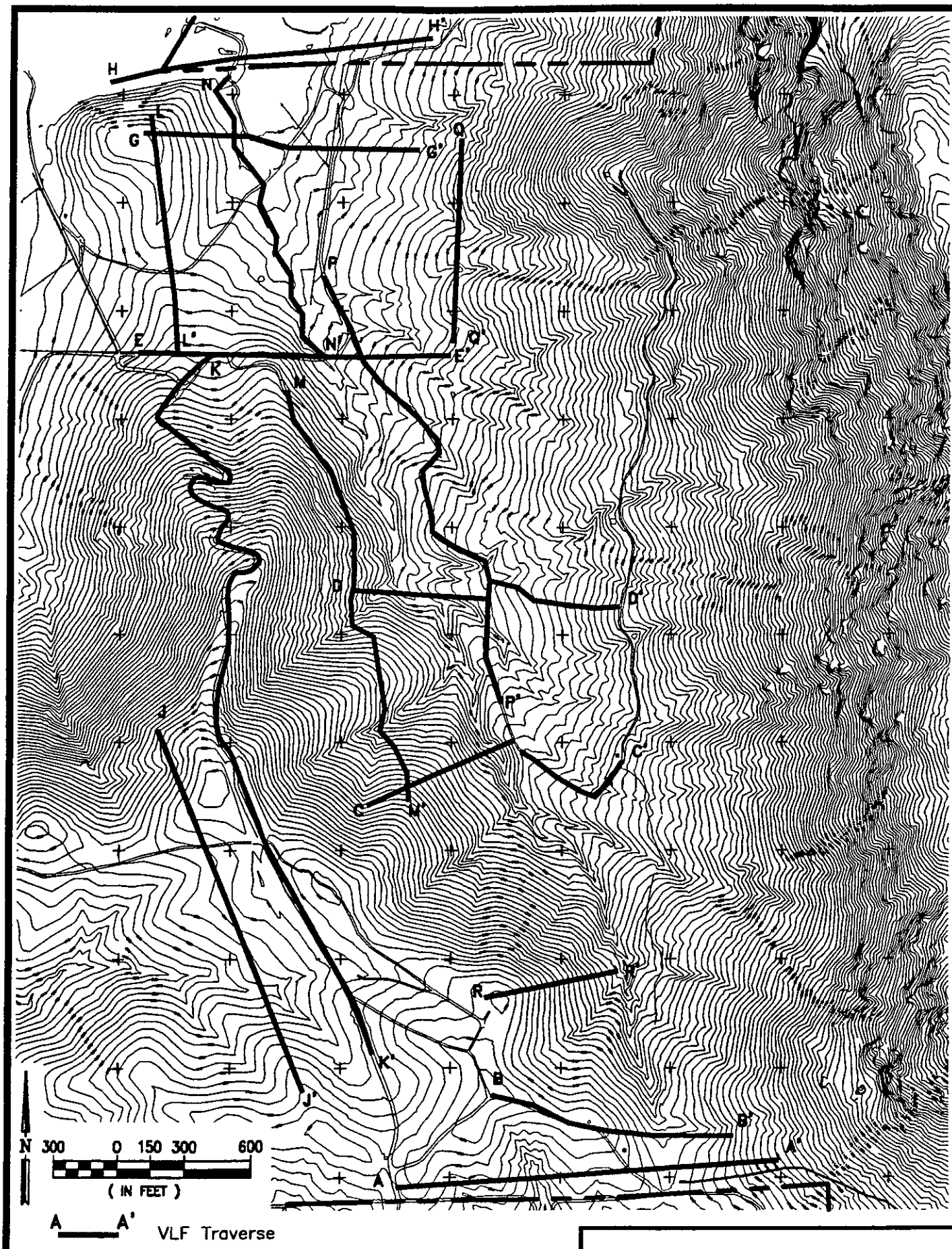


Figure 19. Location of lines for the VLF survey.

GeoLogic Associates

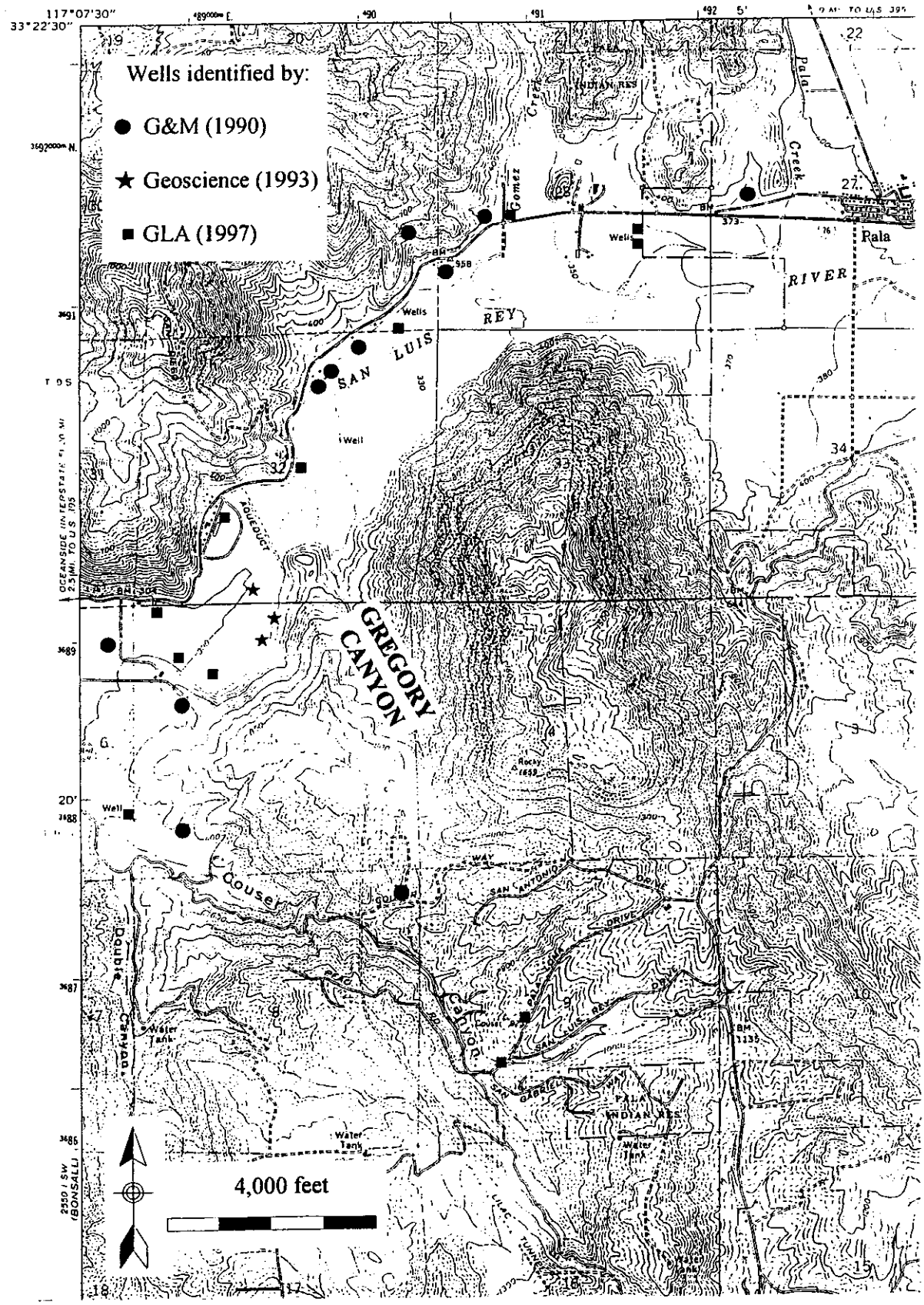
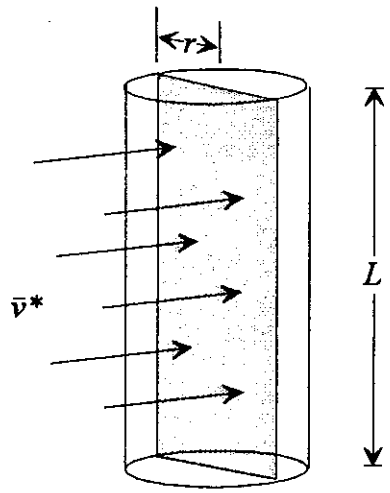
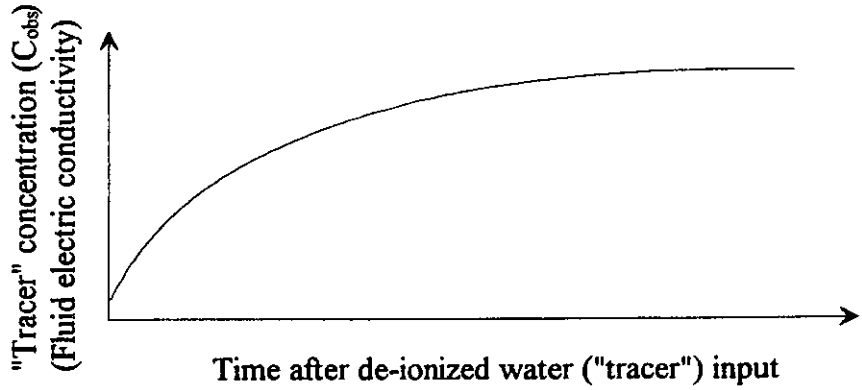


Figure 20. Location of offsite wells.

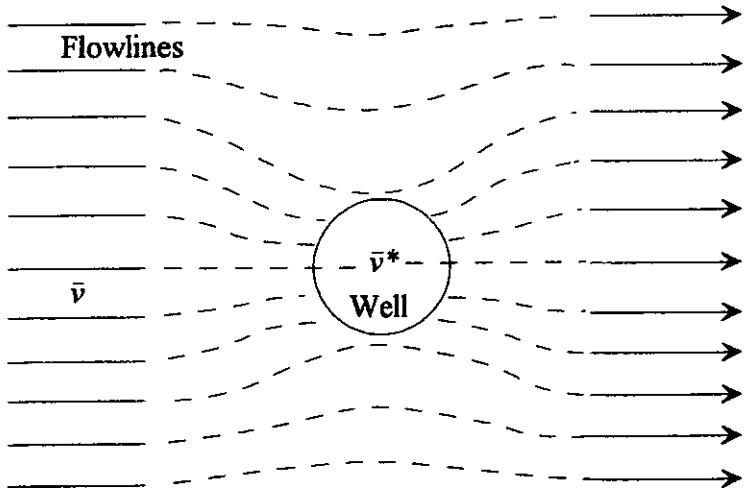
GeoLogic Associates



(a) Schematic of borehole section showing the definition of geometric variables.



(b) Increase in fluid electric conductivity after introduction of de-ionized water "tracer".



(c) Distortion of flow pattern caused by the presence of the well (plan view).

Figure 21. Principles of borehole dilution theory.

GeoLogic Associates

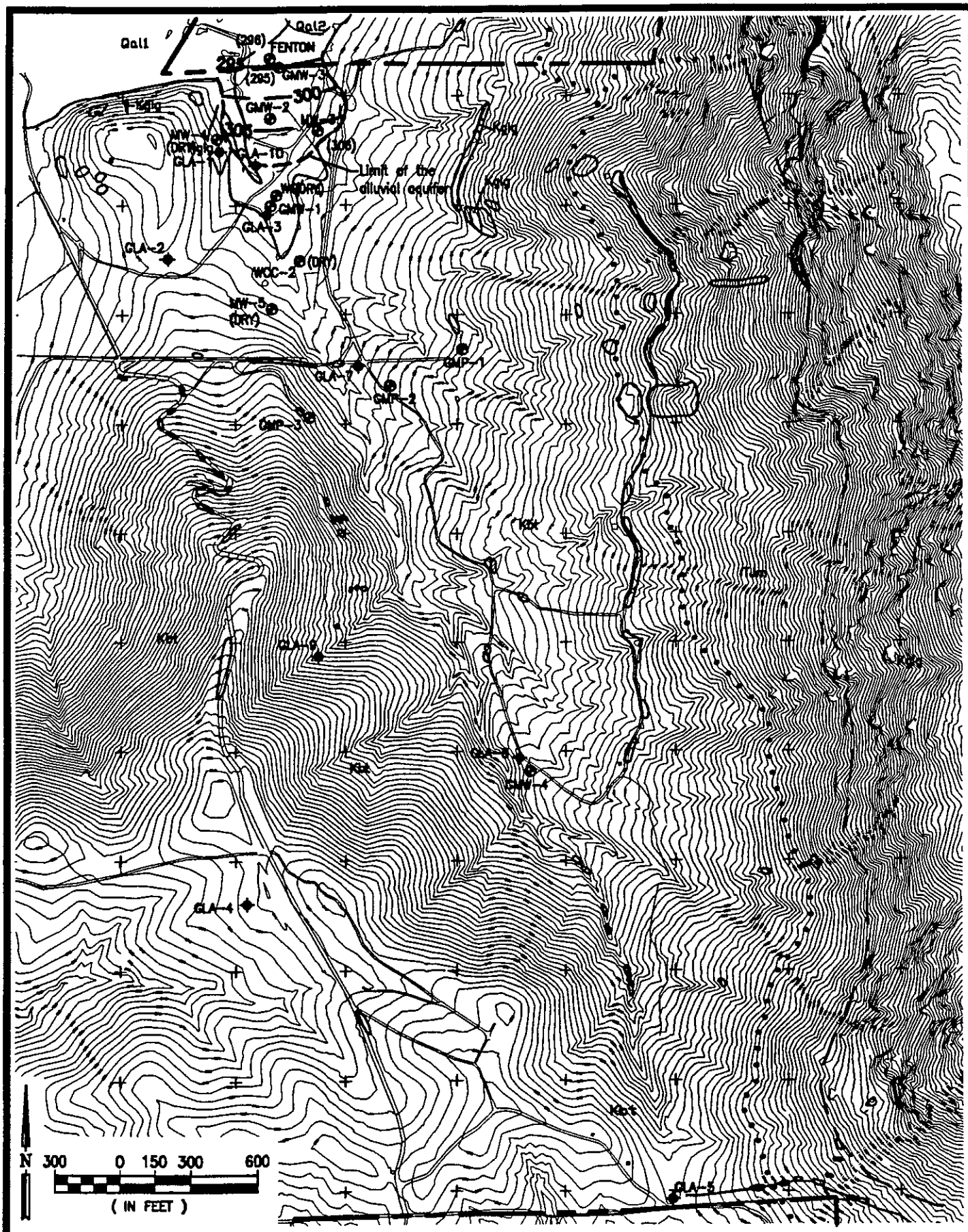


Figure 22. Contour map of elevations of the water table in the alluvial aquifer.

GeoLogic Associates

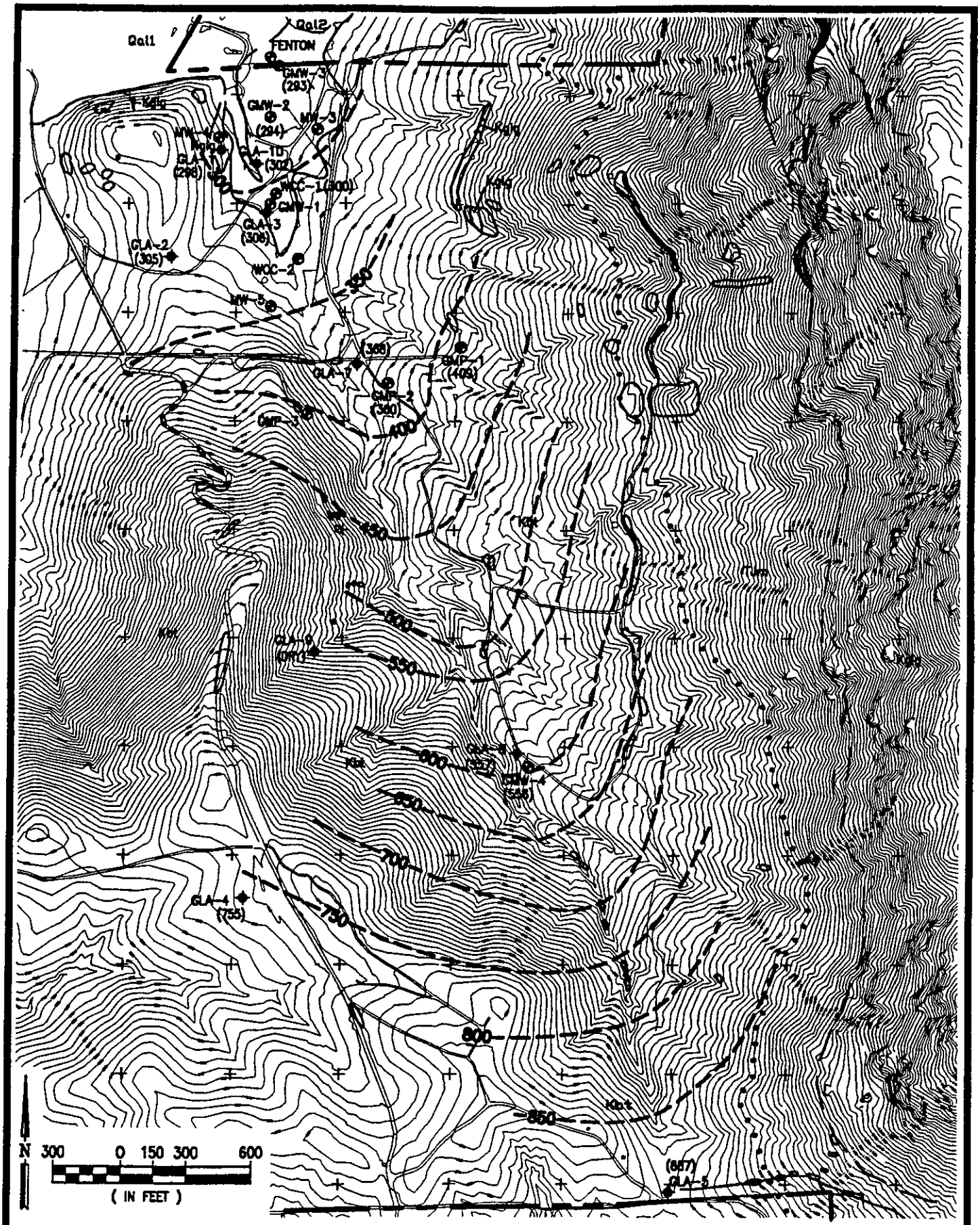


Figure 23. Contour map of elevations of the piezometric surface of the fractured bedrock aquifer.

GeoLogic Associates

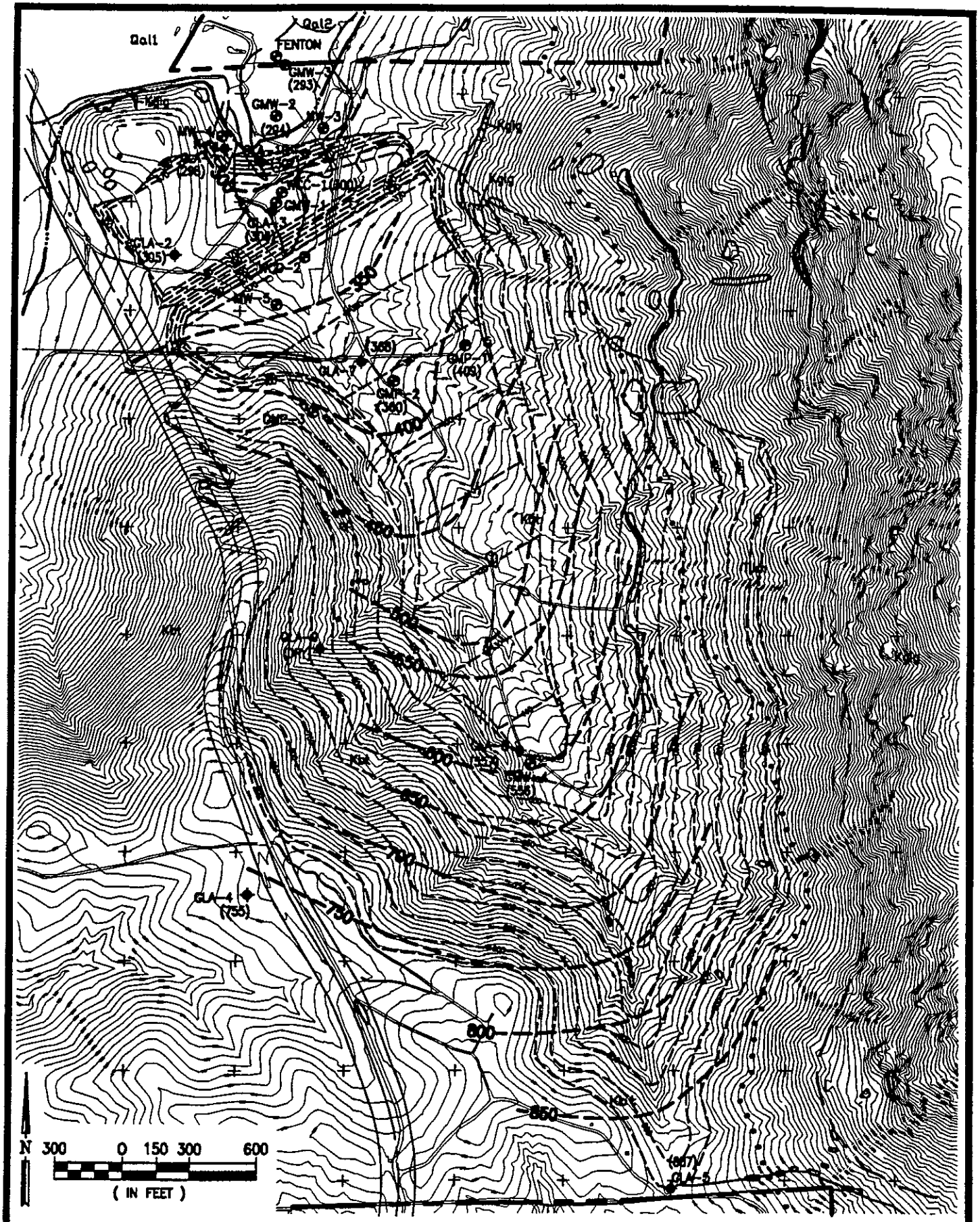


Figure 24. Comparison between elevation of the piezometric surface and grading plan.

GeoLogic Associates

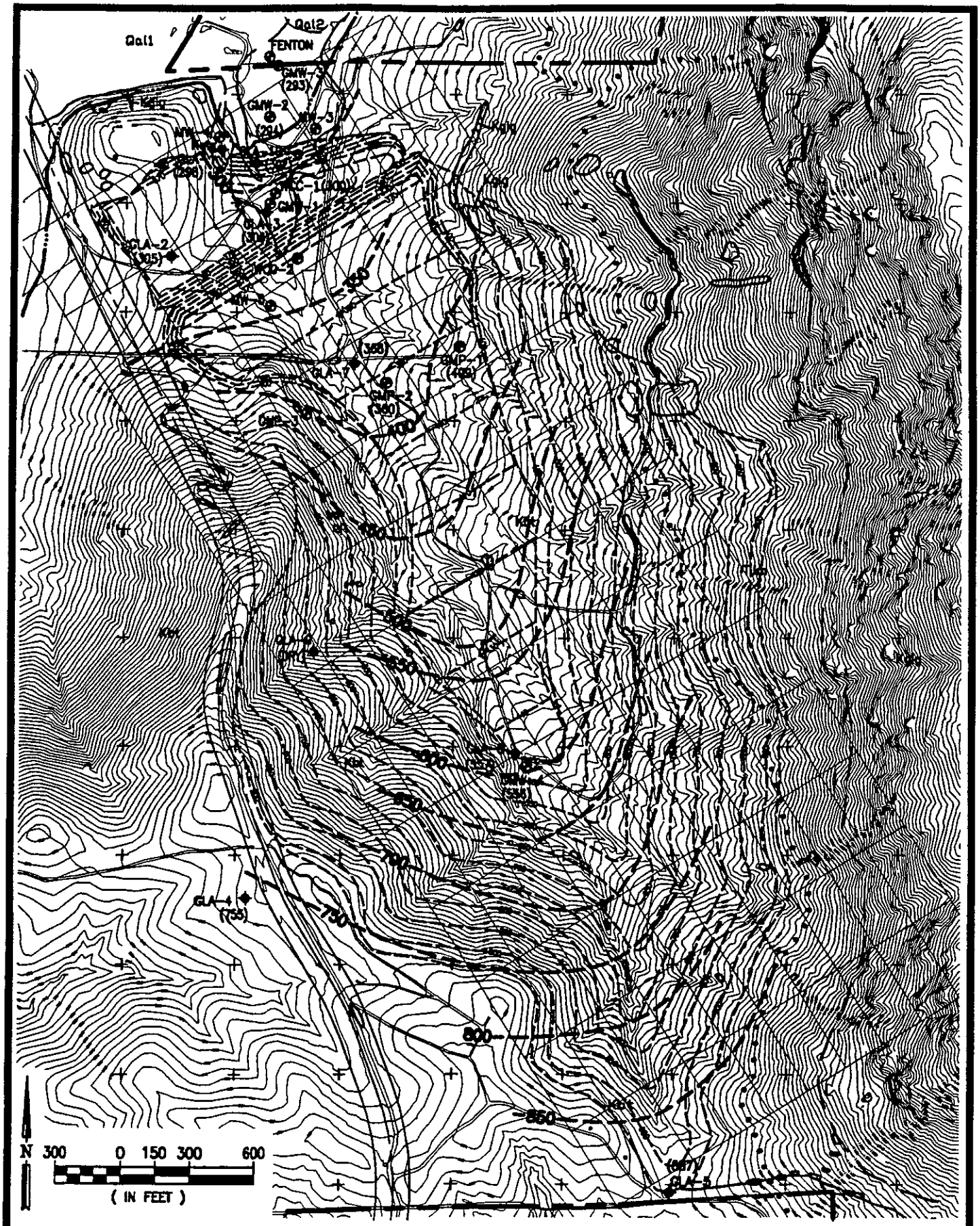


Figure 24. Comparison between elevation of the piezometric surface and grading plan.

GeoLogic Associates

	1	2	3	4	5	6	7	8	9	10
1	375	380	385	375	350	330	360			2
2										6 (4)
3										6 (4)
4										8 (6)
5										8 (6)
6										15 (13)
7										24 (20)
8										30 (25)
9										35 (30)
10										35 (30)
11	18 (15)									35 (30)
12	18 (15)	18 (15)	12 (10)	12 (10)	12 (10)	12 (10)	12 (10)	12 (10)	30 (25)	35 (30)

Figure 25. Location of constant head nodes (with head elevation in feet amsl) shown by double outlines. Location of constant flux nodes shown in bold outlines. Numbers on the left are the inflow in cubic feet/day (model GREG1); numbers in parenthesis are the reduced fluxes after the excavation has drained the aquifer.

	1	2	3	4	5	6	7	8	9	10
1	375	380	385	375	350	330	360	370	390	415
2	490	475	440	380	380	**375** (0.00048)	410	440	450	500
3	625	560	550	475	**400** (0.00048)	425	440	460	525	570
4	750	700	600	**450** (0.00055)	455	475	500	540	555	620
5	675	600	540	**475** (0.00055)	510	560	580	625	650	675
6	710	650	590	**500** (0.00055)	525	580	600	645	710	750
7	725	690	620	**580** (0.00046)	590	600	650	710	770	825
8	800	710	640	**640** (0.00043)	650	675	700	750	825	925
9	850	800	710	**660** (0.00043)	700	750	800	850	920	975
10	950	890	790	750	800	800	850	950	975	975
11	925	880	850	860	900	950	975	975	975	975
12	960	910	925	975	975	975	975	975	975	975

Figure 26. Existing topography and location of drains for the current-conditions, low-permeability base model (GREG1). Bold numbers indicate elevation in feet amsl, and numbers in parenthesis indicate flux into the drains in ft/day.

	1	2	3	4	5	6	7	8	9	10
1	375	380	390	390	390	390	390	390	390	415
2	490	475	378	378	378	378	378	378	400	500
3	625	560	550	460	390 (0.000075)	390 (0.000075)	390 (0.000075)	390 (0.000075)	450	525
4	750	700	600	510	403 (0.00015)	403 (0.00015)	403 (0.00015)	410 (0.00015)	500	600
5	700	600	525	450 (0.00015)	415 (0.00015)	415 (0.00015)	415 (0.00015)	475 (0.00015)	570	660
6	650	560 (0.0)	460 (0.00015)	425 (0.00015)	425 (0.00015)	425 (0.00015)	475 (0.00015)	550 (0.00009)	650	710
7	700	600 (0.00009)	500 (0.00015)	438 (0.00015)	438 (0.00015)	500 (0.00015)	590 (0.00009)	670	750	840
8	735	650 (0.0)	580 (0.00009)	525 (0.00009)	490 (0.00015)	560 (0.00009)	650 (0.0)	740	845	925
9	850	800	730	640 (0.00003)	600 (0.00009)	685 (0.00003)	750	850	920	975
10	950	885	790	690 (0.00003)	710 (0.0)	775 (0.0)	850	950	975	975
11	920	850	780 (0.0)	825 (0.0)	885	950	975	975	975	975
12	960	895	900	975	975	975	975	975	975	975

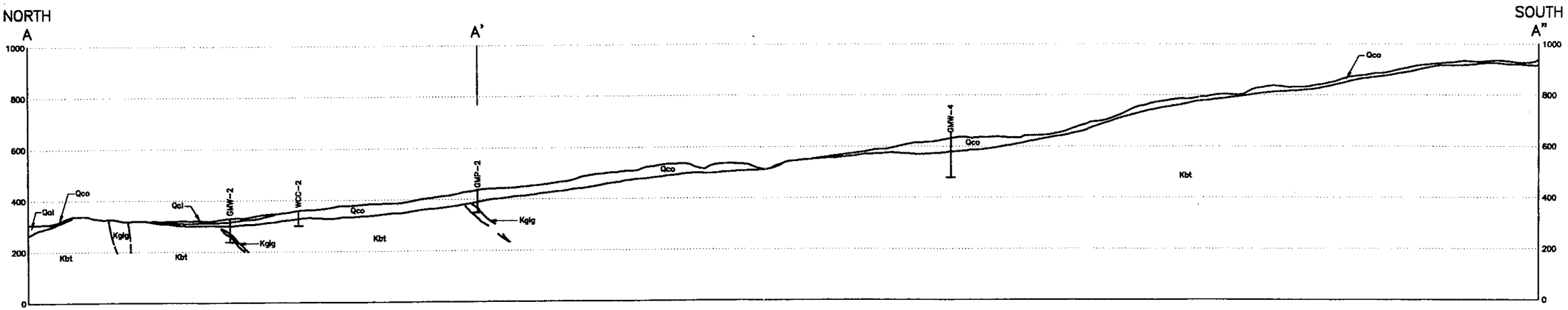
Figure 27. Excavation topography and location of drains for the after-grading, low-permeability model (GREG2). Simple numbers indicate elevation in feet amsl, and numbers in parenthesis indicate flux into the drains in ft/day. Double lines mark the perimeter of the excavation.

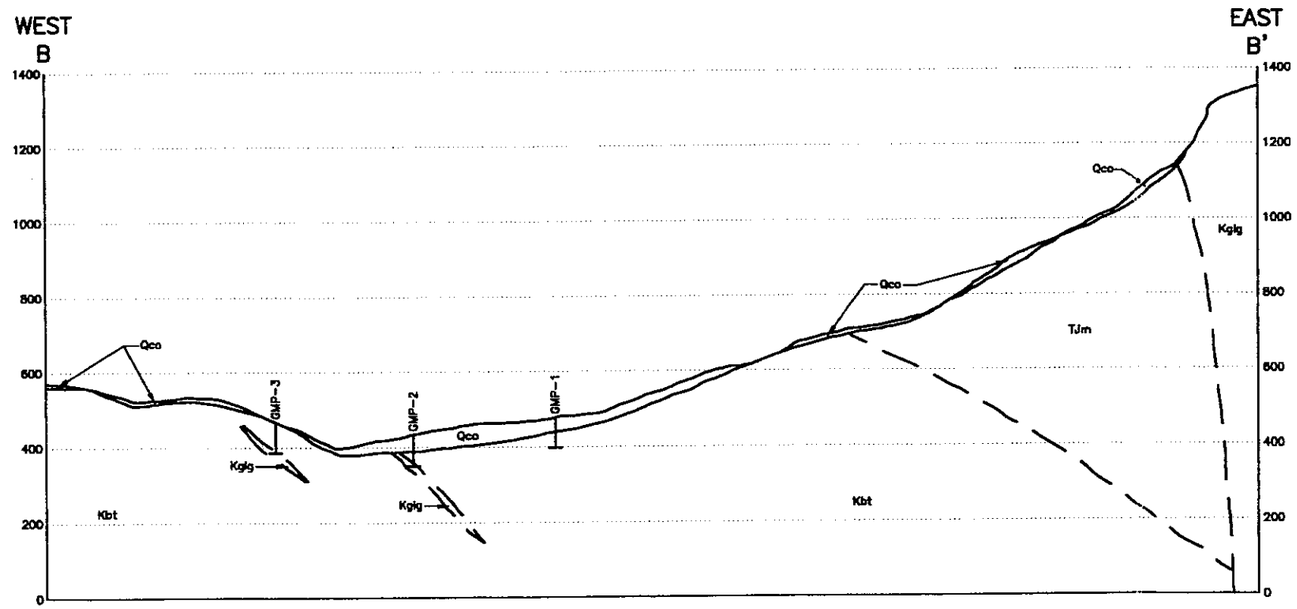
	1	2	3	4	5	6	7	8	9	10
1	375	380	385	375	350	330	360	370	390	415
2	490	475	440	380	380	375 (0.0051)	410	440	450	500
3	625	560	550	475	400 (0.0051)	425	440	460	525	570
4	750	700	600	450 (0.0043)	455	475	500	540	555	620
5	675	600	540	475 (0.0043)	510	560	580	625	650	675
6	710	650	590	500 (0.0043)	525	560	600	645	710	750
7	725	690	620	580 (0.0041)	590	600	650	710	770	825
8	800	710	640	640 (0.003)	650	675	700	750	825	925
9	850	800	710	660 (0.003)	700	750	800	850	920	975
10	950	890	790	750	800	800	850	950	975	975
11	925	880	850	860	900	950	975	975	975	975
12	960	910	925	975	975	975	975	975	975	975

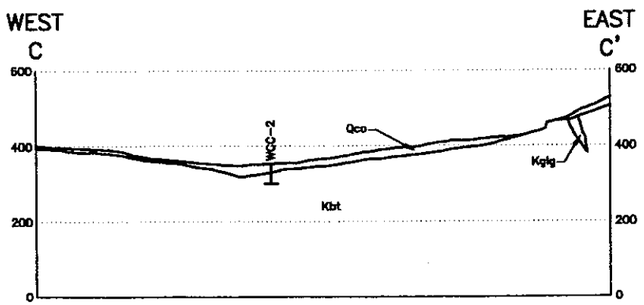
Figure 28. Existing topography and location of drains for the current-conditions, high-permeability base model (GREG3). Bold numbers indicate elevation in feet amsl, and numbers in parenthesis indicate flux into the drains in ft/day.

	1	2	3	4	5	6	7	8	9	10
1	375	380	390	390	390	390	390	390	390	415
2	490	475	378	378	378	378	378	378	400	500
3	625	560	550	460	390 (0.0008)	390 (0.0008)	390 (0.0008)	390 (0.0008)	450	525
4	750	700	600	510	403 (0.0012)	403 (0.0012)	403 (0.0012)	410 (0.0012)	500	600
5	700	600	525	450 (0.0012)	415 (0.0012)	415 (0.0012)	415 (0.0012)	475 (0.0012)	570	660
6	650	560 (0.0)	460 (0.0012)	425 (0.0012)	425 (0.0012)	425 (0.0012)	475 (0.0012)	550 (0.0)	650	710
7	700	600 (0.0)	500 (0.0012)	438 (0.0012)	438 (0.0012)	500 (0.0012)	590 (0.00063)	670	750	840
8	735	650 (0.0)	580 (0.00063)	525 (0.00063)	490 (0.0012)	560 (0.00063)	650 (0.0)	740	845	925
9	850	800	730	640 (0.0)	600 (0.00063)	685 (0.0)	750	850	920	975
10	950	885	790	690 (0.00013)	710 (0.0)	775 (0.0)	850	950	975	975
11	920	850	780 (0.0)	825 (0.0)	885	950	975	975	975	975
12	960	895	900	975	975	975	975	975	975	975

Figure 29. Excavation topography and location of drains for the after-grading, high-permeability model (GREG4). Simple numbers indicate elevation in feet amsl, and numbers in parenthesis indicate flux into the drains in ft/day. Double lines mark the perimeter of the excavation.







REDUCED

GRAPHIC SCALE
200 0 100 200 400
(IN FEET)
1 inch = 200 ft.

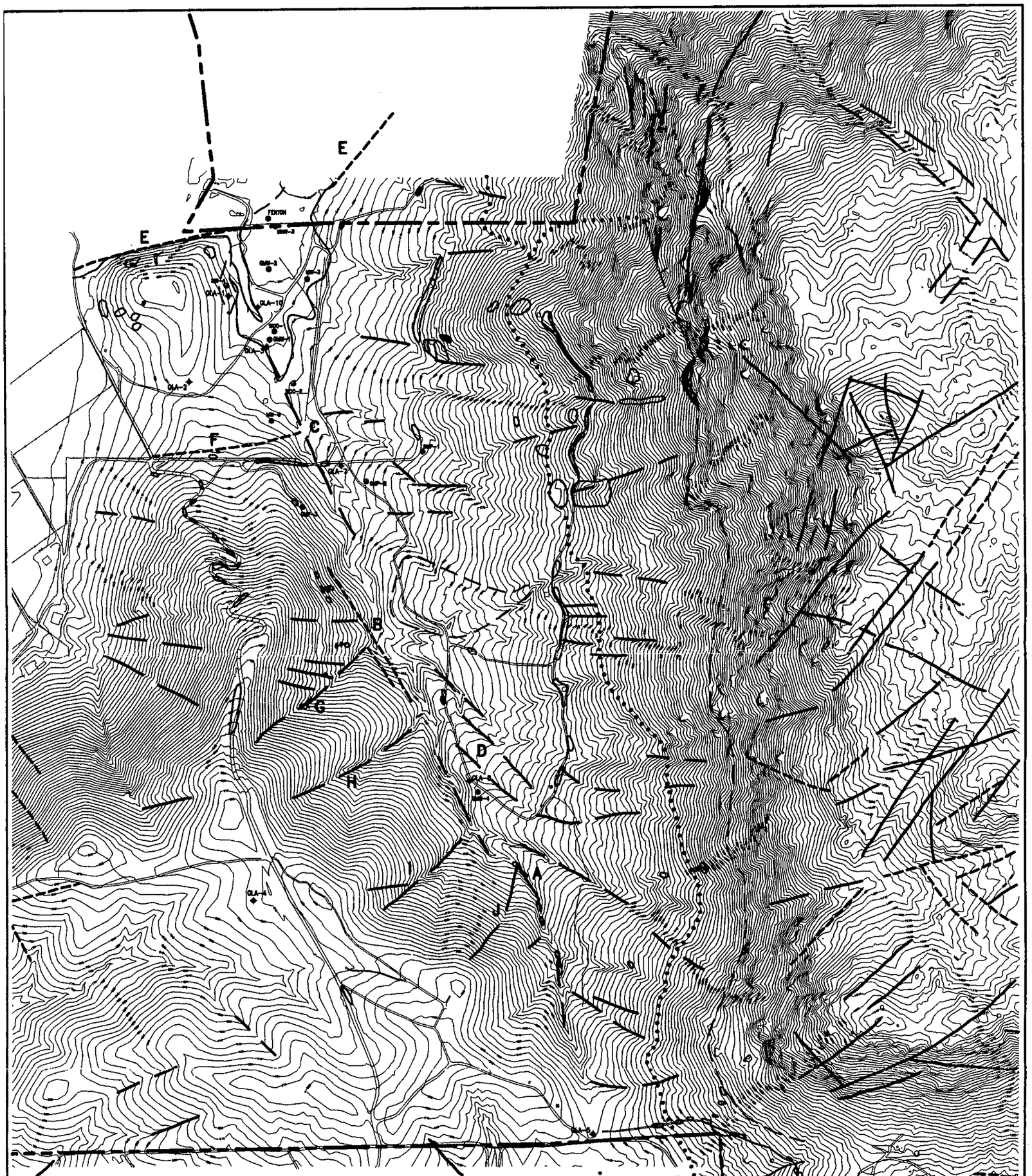
PLATE 2

GEOLOGIC CROSS-SECTIONS

GREGORY CANYON LANDFILL

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	DECEMBER 1997	9539



LEGEND:

Qal1 — Recent alluvium deposited by the San Luis Rey river. Unconsolidated deposits of sand, silt and gravel with variable amounts of cobbles and boulders.

Qal2 — Older alluvium. Remnants of alluvial sediments deposited in the mouth of Gregory Canyon. Weakly stratified silt and sand.

Qca — Colluvium, slope wash and talus deposits that form a veneer over most of the area shown in the map. On the east flank of the canyon they comprise cobbles and boulders of leucogranodiorite set in a locally consolidated matrix of sand and silt. On the west flank of the canyon they include mostly sand and silt derived from weathered tonalite. Includes Qd(?) in the center portion of the map, which appears to be a debris flow deposit with cobbles in a matrix of sand and silt.

Kgig — Gregory Mountain Leucogranodiorite. Phaneritic texture with medium to coarse crystallinity. Light gray to buff with less than 5% dark minerals. Forms the core of Gregory Mountain, and also forms dikes that cut older units. Outcrops shown by solid outline; inferred extent of outcrop under a veneer of colluvium shown by pink hatching.

Kbt — Bonsall Tonalite. Phaneritic texture with medium to coarse crystallinity. Dark gray. Typically deeply weathered and friable. Outcrops shown by solid outline; inferred extent of outcrop under a veneer of colluvium shown by green hatching.

Tjm — Metamorphic rocks. Amphibolites and metavolcanic rocks, in some locations with migmatitic structure that resembles gneissic banding. Aphanitic to porphyroblastic texture; relict porphyritic textures suggest a volcanic protolith for some of the units. Medium to dark bluish gray. Generally massive and hard.

Photolineaments defined by single stretches of a drainage.

Photolineaments defined on the basis of geomorphology (e.g., alignment of topographic saddles, linear cliff scarps) or tonal differences.

Photolineaments related to recognizable fractures or dikes.

Brecciated bedrock

Outcrop of bedrock

Geologic contact

Buried geologic contact

MW-3 — Monitoring well by others

GLA-8 — Monitoring well by GLA

REDUCED

GRAPHIC SCALE

(IN FEET)

1 inch = 200 ft.

PLATE 3

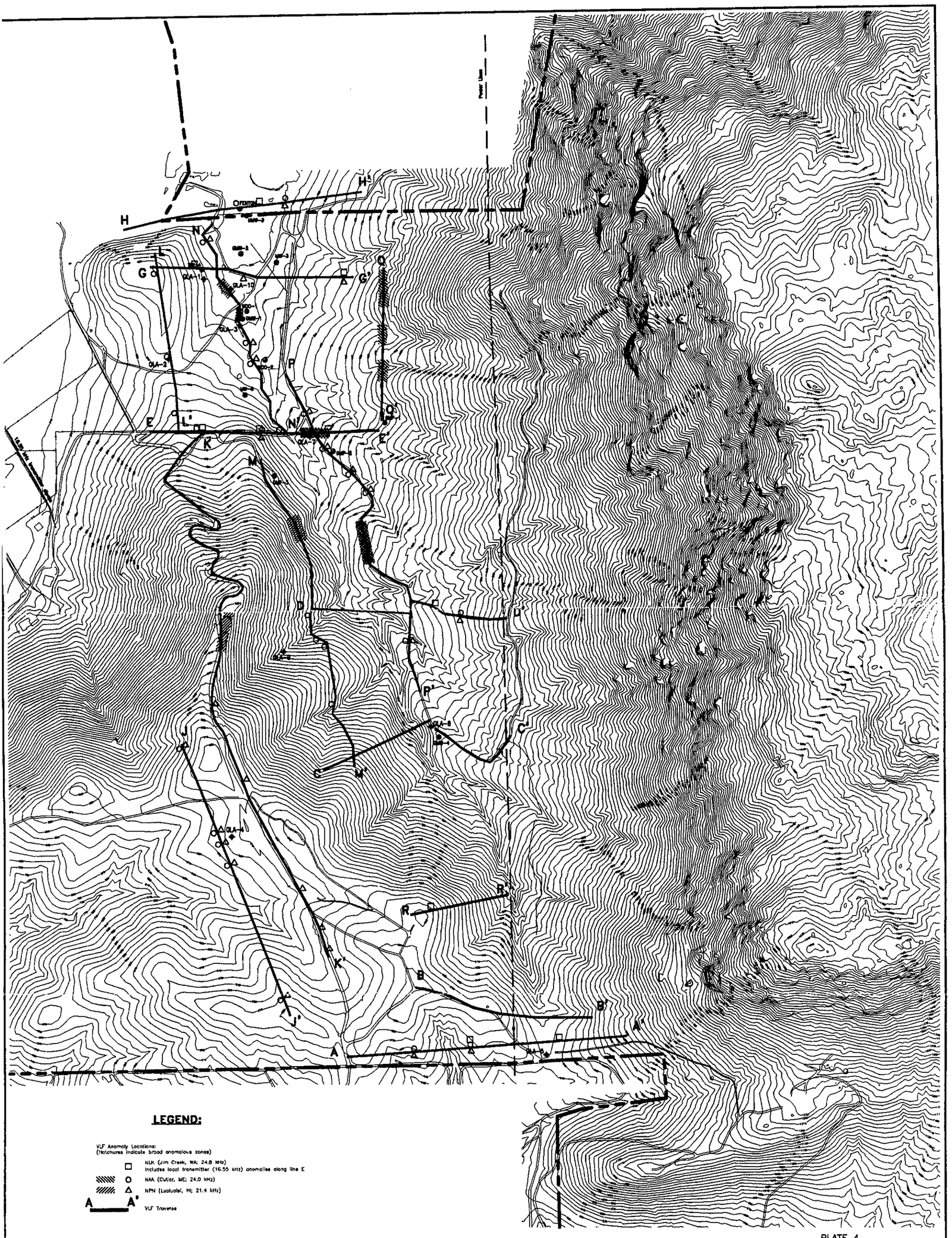
GEOLOGIC MAP WITH LINEAMENTS

GREGORY CANYON LANDFILL

GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	DECEMBER 1997	9539



LEGEND:

VLF Anomaly Locations:
(Hatchures indicate broad anomalous zones)

- □ NLK (Jim Creek, WA; 24.8 kHz) Includes local transmitter (16.55 kHz) anomalies along line E
- ○ NAA (Cutler, ME; 24.0 kHz)
- △ NPN (Lualualei, HI; 21.4 kHz)
- A — A' VLF Traverse

PLATE 4

REDUCED

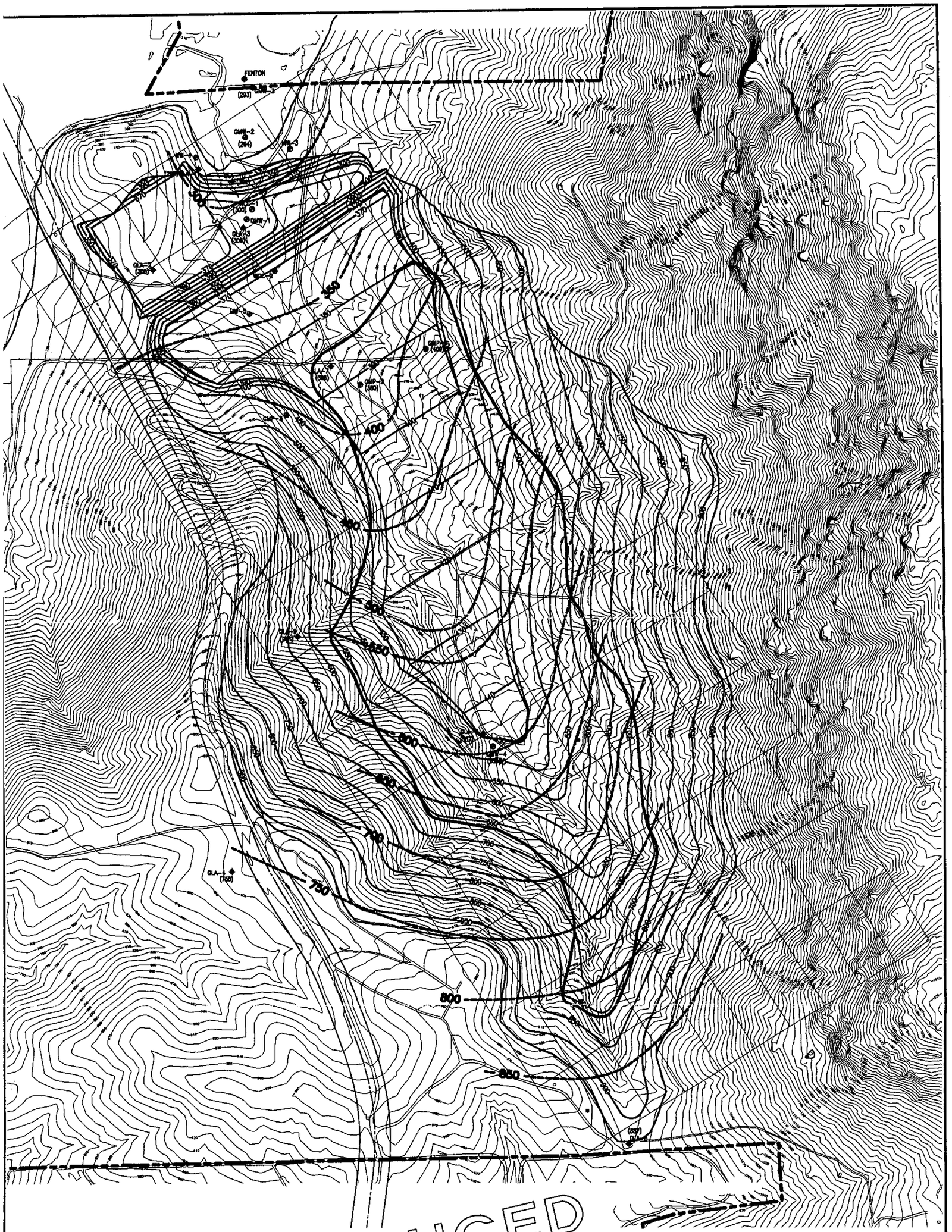
GRAPHIC SCALE
(IN FEET)
1 inch = 200 ft.

VLF ANOMALIES

GREGORY CANYON LANDFILL

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	DECEMBER 1997	9539



REDUCED

PLATE 5

LEGEND:

700 — Bottom grade contours

700 — Contours of the piezometric surface

Outline of area where the bottom grade is below the piezometric surface

MODFLOW model grid

GRAPHIC SCALE

300 0 100 200 400

(IN FEET)

1 Inch = 200 ft.

N

COMPARISON BETWEEN ELEVATION OF THE PIEZOMETRIC SURFACE AND BOTTOM GRADING PLAN, AND MODFLOW MODEL GRID

GREGORY CANYON LANDFILL

GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	SEPTEMBER 1997	9539

APPENDIX A

BORING LOGS

GeoLogic Associates

BORING LOG

BORING NO.: GLA-1

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/19/96
DATE FINISHED: 11/20/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 99.5 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/19 10:12						0			SP GP	RESIDUAL SOIL mixed with decomposed rock. Yellowish brown (10R5/4). Drills as a coarse SAND. Moderately to highly weathered. Dominant lithic fragments are decomposed LEUCOGRANODIORITE with iron oxide staining.	Dry.
						10				Decomposed GRANODIORITE with quartz. Light brownish gray (2.5Y6/2) to brown (10YR5/3). Oxidized with altered biotite and some pink (7.5YR7/4) potassium-feldspar. Cut by quartz feldspar dikes.	Damp.
						15				BONSALL TONALITE. Gray (2.5Y5/1). Drills as a fine to medium sand with some coarse fragments. Highly to moderately weathered; some iron oxide staining; altered micas.	Damp.
						20				...(20') - slightly less weathered (moderately weathered) and more felsic.	
						25					
						30				...(30') - TONALITE drills as a fine sand with minor coarse sand - fine gravel size fragments. Color changes to gray (2.5Y6/1).	
						35	12/16/96				
12:14	10:36					40					
		1.17				45				GRANODIORITE/TONALITE lithic fragments. Slightly weathered and oxidized. Gray (N6); many fragments display foliation; rare pinkish white (5YR8/2) potassium feldspar, probably as dikes.	
						50				GRANODIORITE. Increase in felsic lithic fragments. Gray (10YR6/4) to light gray (10YR7/1). More quartz and feldspar dikes; foliation is less common. Iron oxide staining on quartz and feldspar.	
						55					
12:35	12:31					60				GRANODIORITE/TONALITE. Less felsic fragments. Color change to gray (5Y5/1 to N5); with very minor pinkish white to reddish yellow (5YR8/2 to 7.5YR7/6) potassium feldspar; very minor iron oxide staining.	

CONTINUED ON NEXT PAGE

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/19/96
DATE FINISHED: 11/20/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 99.5 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
12:35						60				GRANODIORITE/TONALITE. Less felsic fragments. Color change to gray (5Y5/1 to N5); with very minor pinkish white to reddish yellow (5YR8/2 to 7.5YR7/6) potassium feldspar; very minor iron oxide staining.	
						65				TONALITE. Gray (N6). Slightly weathered. Mineralogy is hornblende, pyroxene, feldspar (plagioclase), and minor quartz.	
						70				...(70') - slightly darker; less potassium feldspar.	
						75					
	12:57	0.91				80					
12:59											...(80') - dry.
						85					
		0.91				90					
						95				...(95') - mixed TONALITE and GRANODIORITE. Darker gray (N5) and light gray (N7) (TONALITE inclusions in GRANODIORITE?).	
	13:21					100					
13:24											
						105					
		1.05				110				...(110') - less segregated GRANODIORITE/ TONALITE.	
						115				...(115') - slightly more felsic lithic fragments. GRANODIORITE/TONALITE with slightly oxidized quartz/feldspar dikes.	
	13:43					120					
13:46										...(120') - More uniform appearance. Felsic fragments absent - no dikes.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-1

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/19/96
DATE FINISHED: 11/20/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 99.5 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
13:46						120				...(120') - More uniform appearance. Felsic fragments absent - no dikes.	
						125				...(125') - same as above. GRANODIORITE/ TONALITE. Gray (N5). Slight foliation on some fragments.	Dry.
		0.91				130				GRANODIORITE/TONALITE. Gray (N5).	
						135					
	14:08					140					
14:12						145					
						150					
						155					
	14:33	0.95				160				...(160') - slightly more felsic fragments, possibly dikes in the TONALITE.	
14:37						165				...(165') - less felsic fragments; more mafics.	
						170					
						175					
	14:56	1.05				180					
15:25											

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-1

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/19/96
DATE FINISHED: 11/20/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 99.5 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
15:25						180					
						185					
						190				...(190') – some very minor iron oxide staining along fractured surfaces.	
						195				GRANODIORITE/TONALITE. Gray (N5). Slightly weathered to fresh.	
15:50	15:47	0.91				200					
						205				...(205') – increase in felsic minerals (quartz and feldspar); probably GRANODIORITE dikes in the TONALITE. White (N8) felsic fragments represent approximately 35–40% of material.	
						210	▽				...(210') – dampness on outside of drill stem.
						215				...(215') – felsic fragments increase to 50%.	
16:12	16:09	1.05				220				LEUCOGRANODIORITE. White (N8 to 10YR8/1) with minor inclusions of TONALITE. Slightly weathered; minor iron oxide staining; with pinkish white (5YR8/2) potassium feldspar.	
						225				GRANODIORITE/TONALITE with felsic dikes. Gray (N5) TONALITE with approximately 30% LEUCOGRANODIORITE dikes.	...(223') – damp.
						230				...(230') – 5% felsic fragments.	
						235				...(235') – felsic fragments increase to 40%. LEUCOGRANODIORITE dikes in TONALITE. Light gray (N6). Slightly oxidized.	
11/20 7:35	16:30	1.11				240				...(240') – felsic fragments represent approximately 50% of the material (QUARTZ GRANODIORITE?).	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-1

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/19/96
DATE FINISHED: 11/20/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 99.5 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/20 7:35						240				...(240') - felsic fragments represent approximately 50% of the material (QUARTZ GRANODIORITE?).	
						245				...(245') - felsic fragments less than 5% (GRANODIORITE with 30%+ quartz and feldspar). Light gray (N6); with pink (5Y7/4) potassium feldspar; some epidote and chlorite alteration.	Wet.
7:41	7:47	0.83				250				...(250') - no pink potassium feldspar. Increase in GRANODIORITE/TONALITE fragments foliation.	
						255				...(255') - darker. TONALITE with little felsic fragments. Gray (N5). Very minor quartz/ feldspar dikes.	Dry.
8:08	7:59	0.56				260				TONALITE. Dark gray (N5). Hard; minor foliation of mafic minerals.	
						265					...(265') - enough water flowing into the hole to wet sample when adding rod.
8:17	8:16	1.25				270				...(270') - Migmatitic texture on some fragments. GRANODIORITE/TONALITE with minor epidote and chlorite alteration. Slightly more felsic than above.	
						275					
8:42	8:29	0.83				280					
						285				...(285') - white zeolite coating on fracture surface on one lithic fragment. Very minor iron oxide staining on some fragments. Minor chlorite and epidote alteration.	Damp.
	8:53	0.91				290				...(290') - very minor pinkish white (5Y8/2) potassium feldspar. ...(295') - no visible potassium feldspar (5YR8/2).	
						295				NOTES: 1. Total depth of borehole 300 feet. 2. Conductor casing set to 20 feet. 3. Open hole interval (exposed bedrock) between 20 and 300 feet below ground surface. 4. Groundwater first encountered between 200 and 220 feet. 5. Depth to water on 12/16/96 measured at 37.10 feet.	
	9:07					300					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-2

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/18/96
DATE FINISHED: 11/19/96
ELEVATION: 375 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 70 feet
TOTAL DEPTH: 250 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/18 11:20						0			SM	RESIDUAL SOIL. Loose, non-cohesive, with coarse SAND to fine GRAVEL-sized rock fragments. Yellowish-brown (10YR5/4).	Dry.
						5				BONSALL TONALITE. Strongly weathered (probably "C" horizon). Brown (10YR5/3). Drills as a fine silty sand.	Damp.
						10				...(10') - becomes coarser with fine sand to medium gravel-sized fragments; coarser fragments are dominantly composed of quartz and feldspar (probably derived from a LEUCOGRANODIORITE dike).	
		0.67				15					
11:42	11:50					20				...(20') - slightly coarser.	Drier.
						25				GRANODIORITE. Gray (2.5Y5/1) to grayish brown (2.5Y5/2). Drills as a loose fine sand with minor coarse sand-size fragments of quartz and feldspar.	Dry.
						30				LEUCOGRANODIORITE dike (?). Color changes to light gray (2.5Y7/1) to gray (2.5Y6/1). Drills as a very fine sand; minor coarse sand-size fragments; rare gravel-size fragments. Increase in felsic minerals (quartz and feldspar); decrease in mafics. ...(35'-40') - sample consists only of coarse fragments. Pale red (2.5YR7/2).	Dry. Drilling becomes more difficult from this depth on.
12:26	12:05	0.87				35					
13:25	12:48					40				...(40') - LEUCOGRANODIORITE dike (?). Gray (2.5Y7/1). Very felsic.	Dry.
						45				...(45') - GRANODIORITE. Slightly darker, but still gray (2.5Y7/1).	
						50				...(50') - darker gray (2.5Y6/1. Increase in mafics (biotite).	Dry.
						55				...(55') - slightly darker gray (2.5Y6/1 to 2.5Y5/1). Drills as a very fine sand, with minor coarse sand and medium gravel fragments.	
13:40	13:37	1.67				60				...(60') - iron oxide staining on fragments (probably weathered fracture). Gray (7.5YR5/1).	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-2

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/18/96
DATE FINISHED: 11/19/96
ELEVATION: 375 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 70 feet
TOTAL DEPTH: 250 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
13:40						60				...(60') - iron oxide staining on fragments (probably weathered fracture). Gray (7.5YR5/1).	
						65				GRANODIORITE. Gray (7.5YR5/1). Moderately weathered with iron oxide staining, probably along fractures. Some GRANODIORITE fragments display foliation.	
							12/16/96				
						70				...(70') - less oxidation. GRANODIORITE/ TONALITE.	
						75					
14:02	13:58	1.11				80				...(80') - slightly weathered. Very little iron oxide staining. Color change to gray (N6 to N5) with some bluish gray (5B5/1).	
						85				...(85') - less weathered. No iron oxide staining.	
						90					
						95				...(95') - slightly less mafic. Pronounced foliation on many fragments.	
14:24	14:20	1.11				100					
						105					
						110					
						115					
14:44	14:41	1.18				120				GRANODIORITE. Gray (N5). Slightly weathered.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-2

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/18/96
DATE FINISHED: 11/19/96
ELEVATION: 375 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 70 feet
TOTAL DEPTH: 250 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
14:44						120				GRANODIORITE. Gray (N5). Slightly weathered.	
						125					
						130				GRANODIORITE with minor quartz feldspar dikes. Gray (N5). Slightly weathered.	
						135				...(135') - lighter color; gray (N6) to light gray (N7). Less mafics; more quartz and feldspar.	
15:02						140					...(140') - damp.
						145					
						150	▽				...(150') - moist.
						155					
	15:25	0.87				160					...(160') - possibly moist; will let hole sit 15 minutes to see if water seeps into the hole.
15:36						165					...(165') - wet.
						170					...(170') - drilling dry again; probably very low seepage into hole.
						175					
	15:59	0.87				180					...(180') - moist; will let hole sit 15 minutes before putting in next stem. Refuel.
16:13											

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-2

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/18/96
DATE FINISHED: 11/19/96
ELEVATION: 375 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 70 feet
TOTAL DEPTH: 250 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
16:13						180				...same as above.	...(180') - moist; will let hole sit 15 minutes before putting in next stem. Refuel. ...(181') - wet. ...(185') - damp.
						185					
						190				TONALITE. Darker gray (N5 to N4), with white (N8) fragments mixed in composed of quartz and feldspar (probably derived from quartz/feldspar dikes in TONALITE).	
11/19 6:45						195				TONALITE. Gray (N5) to dark gray (N4), with white (N8) fragments of quartz/feldspar mixed in (<10%) (probably derived from quartz/feldspar dikes in TONALITE).	
6:54						200					
						205					
						210				...(210') - pink (5YR8/3) potassium feldspar fragments present in mix. Increase in felsic fragments up to 15-20% of material (TONALITE with feldspathic dikes). Some chlorite alteration of mafics.	
						215				...(215') - decrease in felsic fragments to approximately 5%. No obvious potassium-feldspar fragments.	
7:24	7:18	0.83				220					...(220') - still drilling damp. ...(223') - very minor water in hole when adding rod.
						225					
						230				...(230') - same as above.	Drilling drier to just slightly damp.
						235					...(235') - drilling wet again; driller thinks there is water pressure; material is clogging up cyclone.
8:04	7:50	0.77				240				TONALITE/DIORITE. Mafic fragments are dark gray to very dark gray (N4 to N3) when wet. Less than 3% felsic fragments.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-2

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/18/96
DATE FINISHED: 11/19/96
ELEVATION: 375 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 70 feet
TOTAL DEPTH: 250 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
8:04						240				TONALITE/DIORITE. Mafic fragments are dark gray to very dark gray (N4 to N3) when wet. Less than 3% felsic fragments.	
						245					
	8:19	0.67				250				...(250') - some epidote alteration of plagioclase; some chlorite alteration of mafics.	
						255				NOTES: 1. Total depth of borehole 250 feet. 2. Conductor casing set to 10 feet. 3. Open hole interval (exposed bedrock) between 10 and 250 feet below ground surface. 4. Groundwater first encountered at 150 feet. 5. Depth to water on 12/16/96 measured at 69.73 feet.	
						260					
						265					
						270					
						275					
						280					
						285					
						290					
						295					
						300					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-3

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/25/96
DATE FINISHED: 11/26/96
ELEVATION: 330 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 21 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/25 12:15						0			SM SP	TOPSOIL/COLLUVIUM: SILTY SAND with GRAVEL; sub-angular clasts of TONALITE and LEUCOGRANODIORITE; loose. Dark grayish brown (10YR4/3).	Moist.
						5			SW	ALLUVIUM: SAND, medium- to coarse-grained, minor fines, with fine- to coarse-grained angular gravel-size fragments of mostly LEUCOGRANODIORITE with some TONALITE. Brown (10YR5/3).	...(5') - damp.
						10				SAND with minor fine- to coarse-grained GRAVEL. Light yellowish brown (2.5Y6/4) to very pale brown (2.5Y7/3).	...(10') - damp.
						15					
						20			SW		
						25	12/16/96				
						30				DECOMPOSED LEUCOGRANODIORITE (GRUSS). Light olive brown (2.5Y5/6), highly weathered; Fe-oxide staining. Drills as a fine- to coarse-grained sand/silty sand; soft, loose.	...(30') - damp.
						35				DECOMPOSED LEUCOGRANODIORITE. Olive (5Y5/3) with Fe-oxide staining. Highly weathered and decomposed.	
						40				DECOMPOSED LEUCOGRANODIORITE. Light olive brown (2.5Y5/4). Drills as fine- to coarse-grained sand with minor gravel. Highly weathered and decomposed.	...(40') - damp.
						45				...(45') - color change to olive brown (2.5Y4/4).	
						50				DECOMPOSED LEUCOGRANODIORITE. Pale brown (10YR6/3) to yellowish brown (10YR5/4). Drills as loose, soft, medium- to coarse-grained sand. Potassium feldspar is reddish yellow (7.5YR6/6-6/8) with Fe-oxide staining.	...(50') - damp.
						55				...(60') - cuttings change in color to pale olive (5Y6/3); larger lithic fragments are gray (10YR6/1) to light brownish gray (10YR6/2); decrease in oxidation staining; color intensity of potassium feldspar decreases to pink (7.5YR8/3) to pinkish gray (7.5YR7/2).	
15:33	12:45	2				60					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-3

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/25/96
DATE FINISHED: 11/26/96
ELEVATION: 330 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 21 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
15:33						60				...(60') - cuttings change in color to pale olive (5Y6/3); larger lithic fragments are gray (10YR6/1) to light brownish gray (10YR6/2); decrease in oxidation staining; color intensity of potassium feldspar decreases to pink (7.5YR8/3) to pinkish gray (7.5YR7/2).	
						65	▽			LEUCOGRANODIORITE. Weathered and decomposed. Cuttings are mixed yellow (10YR7/6) and grayish brown (10YR5/2) with minor reddish yellow (7.5YR7/6) potassium feldspar.	...(65') - groundwater first encountered. Moderately wet.
						70				...(70') - cuttings are light olive brown (2.5Y5/4).	...(70') - damp.
						75				...(75') - cuttings are olive brown (2.5Y4/3).	Hole produces water at a rate of about 15 gpm.
						80					
						85				...(85') - slightly darker, more mafic.	
						90				GRANODIORITE/TONALITE. Composed mostly of plagioclase, quartz and mafics. Slightly weathered. Dark greenish gray (5B4/1); larger lithic fragments are gray (N5); potassium feldspar is reddish yellow (7.5YR6/6). Less than 3% Fe-oxide staining on some quartz and feldspar dikes.	...(90') - moist.
						95					
	16:01	1.43				100					
16:03						105				TONALITE. Relatively unweathered. Gray (N5) with little Fe-oxide staining.	
						110					
						115					
	16:31	0.71				120				...(120') - minor (less than 5%) potassium feldspar.	
11/26											

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-3

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/25/96
DATE FINISHED: 11/26/96
ELEVATION: 330 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 21 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/26						120				...(120') - minor (less than 5%) potassium feldspar.	
						125					
						130				TONALITE. Gray (N5). Slightly weathered with less than 1% feldspar. Minor quartz/feldspar dikes.	
						135					
7:25	7:19	1.67				140				...(140') - color change to dark gray (N4).	
						145					
	7:31					150				Notes: 1. Total depth of borehole 150 feet. 2. Conductor casing set to 45 feet. 3. Open hole interval (exposed bedrock) between 45 and 150 feet below ground surface. 4. Groundwater first encountered at 65 feet. 5. Depth to water on 12/16/96 measured at 23.84 feet.	
						155					

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.

GeoLogic Associates

BORING LOG

BORING NO.: GLA-4

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER / M. VINCENT, CEG

DATE STARTED: 11/26/96
DATE FINISHED: 11/27/96
ELEVATION: 905 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 103.2 feet
TOTAL DEPTH: 240 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/26						0			SM SC	TOPSOIL: SILTY SAND with CLAY to CLAYEY SAND. Reddish brown (5Y3/3) to dark brown (7.5YR3/3), soft, loose. Less than 6" thick.	Moist.
						5			SP	ALLUVIUM: Coarse SAND with fine GRAVEL and angular felsic clasts. Pale yellow (2.5Y7/4) to very pale brown (10YR7/4).	...(0.5') - damp.
						10				TONALITE: Moderately weathered with minor quartz/ feldspar dikes.	Damp.
						15				TONALITE with less than 30% of quartz/ feldspar dikes. Gray (N5).	
						20				...(20') - increase in felsic cuttings to 50%.	
						25				LEUCOGRANODIORITE DIKE. Yellow (10YR7/6) with Fe-oxide staining. Cuttings are approximately 40% TONALITE and 60% LEUCOGRANODIORITE.	Damp.
						30				LEUCOGRANODIORITE DIKE (30-35%) in TONALITE. Weathered potassium feldspar is pink (5Y7/4). Cuttings are somewhat oxidized.	
						35					
11/27 6:58						40				TONALITE. Greenish gray (5GY6/1), phaneritic with fine crystallinity and anhedral to subhedral crystals. Moderately weathered and hydrothermally altered. Hornblende and biotite phenocrysts show moderate chlorite-epidote hydrothermal alteration.	
						45					
						50				...(49') - color change to greenish gray (10BG6/1).	
						55				TONALITE. Bluish gray (10B5/1), phaneritic with fine crystallinity and anhedral to subhedral crystals; biotite- and hornblende-rich. Weak alteration to chlorite-epidote.	
7:27		~0.7				60				...(61') - slightly higher mafic mineral content than above.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-4

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER / M. VINCENT, CEG

DATE STARTED: 11/26/96
DATE FINISHED: 11/27/96
ELEVATION: 905 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 103.2 feet
TOTAL DEPTH: 240 feet

TIME START	TIME STOP	RATE, FT/MIN	DEPTH IN FEET	DESCRIPTION	COMMENTS
7:27			80	...(61') - Slightly higher content of biotite than above. ...(61'-65') - weak limonite staining on fracture surfaces. Slightly more chloritized biotite than above. ...(65') - weak foliation as evidenced by preferred orientation of biotite crystals.	
			85		
			70		...(70') - dry.
			75	...(72') - slightly more felsic than above, with slight increase in crystal size from fine- to medium-crystallinity feldspar and hornblende phenocrysts. ...(75') - same as above.	
7:51		~0.95	80	...(80') - same as above.	Dry.
			85	...(85') - same as above. ...(86'-92') - fracture zone with minor limonite and pyrolusite mineral coatings on fracture surfaces.	
8:03			90		...(90') - dry.
			95	...(94') - aplite dike(s) consisting mostly of potassium feldspar with minor quartz. ...(95'-100') - minor limonite staining visible on fracture surfaces.	
			100	...(100'-105') - no visible oxidation.	Dry.
					...(103.2') - groundwater sounded on 12/02/96.
8:50			105		
			110	...(110'-115') light bluish gray (5B8/1), feldspar- and quartz-rich felsic dike(s). ...(116'-120') - no visible dikes.	Dry.
9:22			115	...(120'-137') - abundant fragments of medium- to coarse-grained potassium-feldspar and minor quartz dike(s). Host rock TONALITE shows evidence of moderate chlorite-epidote hydrothermal alteration. Fractures show possible zeolite veining with minor oxidation staining on non-mineral filled fractures. Host rock TONALITE is bluish gray (5PB5/1), aphanitic to phaneritic (very fine- to fine-crystallinity) with abundant biotite and hornblende.	
			120		Dry.

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-4

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER / M. VINCENT, CEG

DATE STARTED: 11/26/96
DATE FINISHED: 11/27/96
ELEVATION: 905 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 103.2 feet
TOTAL DEPTH: 240 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						120				...(120'-137') - abundant fragments of medium- to coarse-grained potassium-feldspar and minor quartz dike(s). Host rock TONALITE shows evidence of moderate chlorite-epidote hydrothermal alteration. Fractures show possible zeolite veining with minor oxidation staining on non-mineral filled fractures. Host rock TONALITE is bluish gray (5PB5/1), aphanitic to phaneritic (very fine- to fine-crystallinity) with abundant biotite and hornblende.	...(120') - dry.
						125					
						130					...(130') - dry.
											Moderately hard drilling.
						135					Groundwater sounded at 103.2' below ground surface on 12/02/96 at 6:55.
8:08						140					No free groundwater while drilling or stacking rods.
						145					Hard drilling. No free groundwater while drilling or stacking rods.
8:24						150	▼				...(149.93') - groundwater sounded on 12/16/96.
						155				...(154') - color change to bluish gray to dark bluish gray (10B4.5/1) with increase in felsic mineral content and increase in crystal size to fine- to medium-crystallinity; anhedral to subhedral feldspar crystals. Cuttings show a weak foliation as evidenced by the segregation of mafic and felsic minerals, and by the preferred orientation of biotite crystals. No visible oxidation of fractures. Rock is unfractured to weakly fractured. No chlorite-epidote alteration visible.	Hard to very hard drilling. No free groundwater encountered.
8:36						160					
						165					Hard to very hard drilling. No free groundwater encountered.
						170					
						175				...(175') - same as above.	Hard to very hard drilling. No free groundwater encountered.
9:10						180					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-4

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER / M. VINCENT, CEG

DATE STARTED: 11/26/96
DATE FINISHED: 11/27/96
ELEVATION: 905 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 103.2 feet
TOTAL DEPTH: 240 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
9:10						180					
						185				...(185') - same as above.	
						190				...(190') - better developed foliation with depth. No visible jointing or fracturing.	Hard to very hard drilling. No free groundwater encountered.
						195				...(195'-240') - same as above.	
9:43						200					Hard to very hard drilling. No free groundwater encountered.
						205					
						210					Hard to very hard drilling. No free groundwater encountered.
						215					
10:23						220					Hard to very hard drilling. No free groundwater encountered.
						225					
						230					Hard to very hard drilling. No free groundwater encountered.
						235					
	11:08					240				Notes: 1. Total depth of borehole 240 feet. 2. Conductor casing set to 30 feet. 3. Open hole interval (exposed bedrock) between 30 and 240 feet below ground surface. 4. Groundwater first encountered between 103 and 140 feet. 5. Depth to water on 12/16/96 measured at 149.93 feet.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-5

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/20/96
DATE FINISHED: 11/21/96
ELEVATION: 930 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 41 feet
TOTAL DEPTH: 190 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/20 11:20						0			SM SW SP	COLLUVIUM/RESIDUAL SOIL: SILTY SAND with coarse-grained SAND and fine-grained GRAVEL and minor CLAY; sub-angular sand and gravel size clasts of TONALITE and LEUCOGRANODIORITE. Dark reddish brown (5YR3/3).	Damp.
						15				WEATHERED TONALITE. Light olive brown (2.5Y5/3). Drills as a medium- to coarse-grained sand. Minor quartz and feldspar dikes.	Damp.
						20					...(20') - damp.
						25				TONALITE. Gray (2.5Y6/1) to light brownish gray (2.5Y6/2). Moderately weathered. Drills as a fine- to coarse-grained sand with minor fine-grained gravel size fragments. Minor quartz/feldspar dikes.	Less damp.
						35					
15:57						40	11/21/96			TONALITE/QUARTZ DIORITE. Olive (5Y5/3) cuttings, with black (N2.5) and dark gray (N4) lithic fragments. More mafic than above. Drills as a fine-grained sand.	
						45	12/16/95				
						50				...(50'-55') - color change to light brownish gray (2.5Y6/2) to olive gray (5Y6/2).	
						55					
						60				TONALITE. Gray (5Y6/1). Moderately weathered. Less mafic than above.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-5

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/20/96
DATE FINISHED: 11/21/96
ELEVATION: 930 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 41 feet
TOTAL DEPTH: 190 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						60				TONALITE. Gray (5Y6/1). Moderately weathered. Less mafic than above.	
						65					
						70					
						75				...(75'-80') - slightly more felsic, gray (2.5Y6/1) TONALITE; cuttings are sand-size with quartz/feldspar fragments.	
	16:24					80					
16:27										TONALITE/QUARTZ DIORITE. Gray (N5) lithic fragments. More mafic than above; chlorite alteration of mafics.	
						85				...(85'-90') - felsic cuttings increase to 20% (probably indicates quartz/potassium feldspar dikes in the TONALITE/QUARTZ DIORITE). Felsic fragments have pink (5YR7/4) potassium feldspar. Chlorite alteration of mafics in the TONALITE.	
						90					
						95					...(93'-96') - "soft" drilling.
						100	▽			GRANODIORITE. Bluish gray (5B6/1 to 5/1) with minor reddish yellow (5YR7/6); potassium feldspar and quartz cuttings. GRANODIORITE fragments are chloritized. White coatings on some fractures (zeolite?). ...(100') - decrease in felsic cuttings to less than 10%. Majority of cuttings are of TONALITE with granodiorite dikes; some feldspar and chlorite alteration of mafics; gray (N5).	...(100') - moist.
						105					
11/21										TONALITE. Gray (N5). Moderate to slightly weathered and fractured.	...(105') - damp.
						110				...(110') - very minor fragments of quartz/feldspar with minor mafics as veins/dikes in TONALITE.	
						115					
	7:35					120					...(120') - water coming up hole.

CONTINUED ON NEXT PAGE

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-5

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/20/96
DATE FINISHED: 11/21/96
ELEVATION: 930 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 41 feet
TOTAL DEPTH: 190 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
7:35						120					...(120') - water coming up hole.
						125					
						130				TONALITE. Gray (N5). Slightly weathered; fractured. Chlorite alteration of mafics. Less than 1% quartz/feldspar fragments from dikes, and a few rare fragments of zeolite(?) from fracture infilling; minor iron oxide staining.	
						135					
						140					
						145					
						150					
						155					
						160					
						165				...(165') - increase in felsic fragments to 40%.	Sample is wet.
9:08	9:07	0.54				170				...(170') - increase in quartz/feldspar dikes. Decrease in chlorite alteration.	Drier.
						175				...(175') - decrease in felsic fragments to less than 10%.	
9:27	9:23	0.67				180				TONALITE/QUARTZ DIORITE. ...(180') - less than 3% felsic fragments.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-5

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/20/96
DATE FINISHED: 11/21/96
ELEVATION: 930 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 41 feet
TOTAL DEPTH: 190 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
9:27						180				...(180') - less than 3% felsic fragments.	
	9:47	0.50				190				...(190') - increase in felsic fragments to 10%.	Lost bit downhole.

Notes:

1. Total depth of borehole 190 feet.
2. Conductor casing set to 30 feet.
3. Open hole interval (exposed bedrock) between 30 and 190 feet below ground surface.
4. Groundwater first encountered at 100 feet.
5. Depth to water on 12/16/96 measured at 42.57 feet.

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-7

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/21/96
DATE FINISHED: 11/21/96
ELEVATION: 403 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 50 feet
TOTAL DEPTH: 160 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/21 13:55						0			SM SW	COLLUVIUM: SILTY SAND, coarse-grained; contains fine gravel fragments. Yellowish brown (10YR5/7).	Damp.
						5			SW	SAND (DG?). Light yellowish brown (2.5YR6/4). May be boulder of decomposed leucogranodiorite.	
						10				DECOMPOSED ROCK (TONALITE?): Olive (5Y5/3). Drills as a fine- to medium-grained sand. Oxidized fragments of brownish yellow (10YR6/8) quartz/ potassium feldspar.	...(10') - damp.
						15					
						20				TONALITE/DIORITE. Very dark gray (5Y3/1). Sub-angular to subrounded oxidized fragments.	
						25				TONALITE. Gray (N5). Highly weathered and decomposed. Drills as an olive (5Y5/3), fine- to coarse-grained sand.	...(25') - damp.
						30					
						35	12/16/96				
						40				...(40') - color change to olive gray (5Y5/2 to 4/2).	
						45					
						50					...(50') - groundwater encountered.
						55					
	14:20					60				TONALITE. Olive (5Y4/3). Highly weathered. Drills as a fine- to coarse-grained sand. Large fragments are gray (N5).	...(60') - abundant water coming out of hole on 11/22/96.
11/22 8:25											

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-7

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/21/96
DATE FINISHED: 11/21/96
ELEVATION: 403 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 50 feet
TOTAL DEPTH: 160 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
8:25						60				TONALITE. Olive (5Y4/3). Highly weathered. Drills as a fine- to coarse-grained sand. Large fragments are gray (N5).	...(60') - abundant water coming out of hole on 11/22/96.
						65				...(65') - moderately weathered TONALITE.	...(65') - damp.
8:35	8:31	1.67				70				...(70') - color change to olive gray (5Y4/2). Lithic fragments are larger and appear less weathered.	...(70') - moist.
						75					
						80					
						85				...(85') - approximately 35% of lithic fragments are of white (N8) quartz/feldspar dikes. TONALITE fragments are very dark gray (N3).	...(85') - moist.
						90					
						95					
8:52	8:50	1.33				100				...(100') - color of cuttings change to dark gray (N4). Lithic fragments of TONALITE are very dark gray (N3); less than 5% felsic fragments. Slight weathering.	...(100') - wet.
						105					
						110					
						115				...(115') - color of cuttings changes to very dark gray (N3). TONALITE fragments are very mafic with dark gray (N4) plagioclase (borderline GABBRO). Slightly weathered. Tonalite fragments are black (N2.5).	
9:24	9:21	0.69				120					...(120') - abundant water in hole.

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-7

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 11/21/96
DATE FINISHED: 11/21/96
ELEVATION: 403 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 50 feet
TOTAL DEPTH: 160 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
9:24						120				...same as above.	...(120') - abundant water in hole.
						125					
						130					
						135					
9:54	9:49	0.80				140				...(140') - increase in felsics to 40% (probably derived from quartz/feldspar dikes in TONALITE).	
						145				GRANODIORITE. Gray (N6) with pale red (2.5YR7/2) orthoclase feldspars. Olive (5Y4/4) chlorite/epidote alteration of some clasts, particularly along fracture surfaces.	
						150				TONALITE. Dark gray (N4) with less than 5% felsic fragments.	
						155					
	10:21	0.74				160				GRANODIORITE. Gray (N6) with only rare pale red (2.5YR7/2) potassium feldspar.	
						165				Notes: 1. Total depth of borehole 160 feet. 2. Conductor casing set to 30 feet. 3. Open hole interval (exposed bedrock) between 30 and 160 feet below ground surface. 4. Groundwater first encountered at 50 feet. 5. Depth to water on 12/16/96 measured at 34.82 feet.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-8

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG; T. REEDER

DATE STARTED: 11/24/96
DATE FINISHED: 11/25/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 61 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/24 9:20						0				WEATHERED BEDROCK - TONALITE. Light yellowish brown (10YR6/4). Phaneritic with fine-crystallinity, amphibole-rich and biotite-rich. Some hydrothermal alteration to chlorite-epidote facies.	
						5				...(6') - color change to light gray (10YR7/1).	
						10				...(10') - color change to gray (2.5Y6/1). Less oxidation of biotite than above.	
						15					Conductor casing set to 15'. Begin drilling 5-inch diameter with downhole carbide button hammer.
						20					
						25				...(24') - color change to gray (5Y6/1) to light olive gray (5Y6/2). Increase in chlorite-epidote alteration products and minor increase in iron-oxide alteration products.	Slightly damp.
						30					
						35					
						40					
11:45						45				UNWEATHERED BEDROCK - TONALITE. Gray (5Y6/1). Phaneritic with fine-crystallinity, subhedral crystals, biotite and hornblende-rich. Pervasive, moderate to weak chlorite-epidote hydrothermal alteration.	
						50					
						55				...(53'-56') - color change to light brownish gray (2.5Y6/2). Increase in jointing/fracturing as evidenced by increase in oxidation products and weathered feldspar phenocrysts.	
						60				11/25/96	
										12/16/96	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-8

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG; T. REEDER

DATE STARTED: 11/24/96
DATE FINISHED: 11/25/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 61 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						60					
						11/25/96					
						12/16/96					
						65				...(64') - color change to light yellowish brown (2.5Y6/3.5).	
						70				...(67'-78') - possible weathered joints as evidenced by alternating zones of light yellowish brown (10YR6/4) weathered rock and greenish gray (10BG5/1) unweathered rock. Contains fragments of dark gray (N4) to greenish gray (10BG5/1), micaceous and amphibole-rich TONALITE with fine- to medium-crystallinity phenocrysts of weak red (10R4/3) feldspar.	
						75					...(75') - slightly damp.
12:08						80				...(78') - color change to greenish gray (5BG5/1).	
	12:28					85				...(81'-86') - TONALITE to GRANODIORITE. Phaneritic with medium crystallinity; subhedral to euhedral, white to light red (2.5YR6.5/8) potassium feldspar phenocrysts. Minor amounts of white to light red (2.5YR6.5/8) 1/32-inch thick mineral vein infilling (zeolite?) on some fracture surfaces. Mineral veins show some reaction with the host rock, as evidenced by epidote alteration envelopes.	...(83') - larger pieces of sample expelled from the cyclone.
12:53										...(86') - groundwater encountered in weathered fracture zone. Weathered rock is pale olive (5Y6/3) in color.	...(85') - stop at 12:28 to trip rods out of hole to repair downhole hammer. ...(86') - groundwater encountered. Mineral vein materials do not appear to react to weak HCl solution.
						90					...(90') - very dry.
						95					
						100				...(98') - decrease in amount of weathered fracture zones. Abundant healed fractures showing shear structures in possible hydrothermal (zeolite) mineral veins approximately 1/2-inch thick.	...(100'-105') - somewhat abundant groundwater.
						105					
						110					
						115					
13:26		1.17				120					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-8

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG; T. REEDER

DATE STARTED: 11/24/96
DATE FINISHED: 11/25/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 61 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
13:26						120					
						125				...(128') - increase in mafic minerals with associated color change to brownish gray (10B5/1).	
13:38						130				...(135'-140') - healed fractures showing shear structures in possible hydrothermal (zeolite) mineral veins approximately 1/2-inch thick. Veins contain 1/32-inch to 1/16-inch diameter TONALITE fragments as inclusions. Vein materials are typically greenish gray (5BG6/1) in color with less than 1/64-inch thick iron-oxide and pyrolusite coatings between the vein material and the host-rock.	
	13:45					135					...(135') - stop drilling at 13:45 to trip out rods due to blockage in the downhole hammer. Begin drilling with tri-cone bit.
14:25											
14:42						140					
	15:10	0.22				145				...(143') - abundant olive gray to light red (2.5YR5/8), euhedral feldspar phenocrysts. A weak foliation is evidenced by the partial segregation of mafic and felsic minerals and by the preferred orientation of platy feldspar and biotite phenocrysts. No visible signs of mineral veining on fracture surfaces.	...(145') - stop drilling at 15:10. Trip out rods and replace tri-cone bit with downhole hammer.
15:32											
						150				...(150') - minor occurrence of mineral veining along fracture surfaces, along with non-mineralized fractures.	
15:44		1.11				155					
						160				...(160') - same as above.	
						165				...(165') - same as above.	
										...(169') - decrease in the amount of feldspar phenocrysts with light red (2.5YR5/8) coloration. Most phenocrysts are white.	
16:01		1.43				170				...(172') - increase in amount of mineral veining with associated increase in chloritization. Possible fracture zone.	
16:10						175				...(177') - most feldspar phenocrysts are colored light red (2.5YR5/8).	
						180				...(180'-185') - decrease in light red colored feldspar phenocrysts and increase in white colored feldspar.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-8

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG; T. REEDER

DATE STARTED: 11/24/96
DATE FINISHED: 11/25/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 61 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						180				...(180'-185') - decrease in light red colored feldspar phenocrysts and increase in white colored feldspar.	
						185					
						190				...(190') - same as above.	
						195				...(195') - same as above.	
						200					
						205				TONALITE - dark gray (N4), weathered, with some epidote alteration of feldspar, quartz and granodiorite veins.	...(205') - wet.
						210				CONTACT ZONE: mixed TONALITE and LEUCOGRANODIORITE - mineralogy includes: greenish gray (5G6/1), altered plagioclase; pale red (2.5YR7/2) to light red (2.5YR7/6) orthoclase; white (N8) quartz and plagioclase; dark gray (N4) to dark greenish gray (5GY4/1) mafics (pyroxene, hornblende and biotite). Quartz-filled veins in some of the cuttings.	
						215				...(215') - increase to 80% of cuttings of LEUCOGRANODIORITE with potassium-feldspar and some mafics.	
						220				...(220') - equal proportions in cuttings of greenish gray (5G6/1) TONALITE(?) to pale red (2.5YR7/2) LEUCOGRANODIORITE.	
						225				...(225') - mix of dark gray (N4) TONALITE and light red (2.5YR7/2) LEUCOGRANODIORITE.	
						230				...(230') - approximately 70% greenish gray (5G6/1), altered TONALITE and 30% pale red (2.5YR7/2) GRANODIORITE.	
						235				...(235') - cuttings become darker due to increase in dark gray (N4) mafics.	
						240				...(240') - TONALITE is dark gray (N4) with greenish gray (5G6/1), altered plagioclase and dark gray (N4) mafics. Decrease in potassium-feldspar/LEUCOGRANODIORITE fragments to less than 15%.	
11/25 8:14											

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-8

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG; T. REEDER

DATE STARTED: 11/24/96
DATE FINISHED: 11/25/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: 61 feet
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11/25 8:14						240				...(240') - TONALITE is dark gray (N4) with greenish gray (5G6/1), altered plagioclase and dark gray (N4) mafics. Decrease in potassium-feldspar/LEUCOGRANODIORITE fragments to less than 15%. ...(245') - increase in LEUCOGRANODIORITE fragments to about 30%; color intensifies to light red (2.5Y7/6). ...(250') - TONALITE color becomes lighter - gray (N5). Less than 5% LEUCOGRANODIORITE fragments. ...(255') - same as above, with minor greenish gray (5G6/1 to 5GB6/1), altered (chloritized?) plagioclase. ...(260') - approximately 10% LEUCOGRANODIORITE fragments.	
	8:35	0.95				260				TONALITE/GRANODIORITE - gray (N5) to dark gray (N4), with some greenish gray (5G6/1), altered (chloritized?) plagioclase, and LEUCOGRANODIORITE dikes with less than 2% pale red (2.5YR7/2) to light red (2.5YR7/6) orthoclase. ...(265') - mix of LEUCOGRANODIORITE and GRANODIORITE cuttings. Some greenish gray (5G6/1) altered plagioclase. ...(275') - same as above. ...(280') - orthoclase feldspar/ leucogranodiorite fragments decrease to less than 5%. ...(285') - increase in LEUCOGRANODIORITE fragments to approximately 35%. ...(300') - decrease in orthoclase feldspar to approximately 15%; increase in greenish gray (5G6/1), altered plagioclase.	
8:38						265					
						270					
						275					
	8:54	1.25				280					
8:58						285					
						290					
						295					
	9:17	1.05				300				NOTES: 1. Total depth of borehole 300 feet. 2. Conductor casing set to 15 feet. 3. Open hole interval (exposed bedrock) between 15 and 300 feet below ground surface. 4. Groundwater first encountered at 86 feet. 5. Depth to water on 12/16/96 measured at 62.40 feet.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						0				DECOMPOSED TONALITE. Olive gray (5Y4/2). Highly weathered and decomposed. Drills as a fine-grained sand to silty sand with coarse-grained sand to fine-grained gravel size fragments.	Drilling on cut - all topsoil removed. Damp.
						5					
						10				LEUCOGRANODIORITE DIKE. Light yellowish brown (2.5Y6/4) to pale yellow (2.5Y7/4). Highly weathered and decomposed. Fe-oxide staining, and oxidation and chloritization of mafics.	Damp.
						15					
						20					
						25				TONALITE. Dark gray (5Y4/1) to very dark gray (5Y3/1). Moderately weathered. Minor Fe-oxide staining; some chloritization of mafics.	Damp.
						30					
						35				...(35') - quartz veins in TONALITE.	
14:00						40				GRANODIORITE dike in TONALITE (about 60% GRANODIORITE). Light gray (2.5Y7/2) to pale yellow (2.57/3). Oxidized; weathered; some epidote alteration of feldspar and chloritization of mafics.	
						45				DIORITE/TONALITE. Black (N2.5) to very dark gray (N3). Slightly to moderately weathered. Altered biotite on some fragments; minor epidote alteration of some feldspars. Cuttings include fragments of GRANODIORITE; oxidized with some epidote and chlorite alteration. ...(50') - very minor quartz/feldspar fragments in cuttings.	Damp.
						50					
						55				GRANODIORITE dike in TONALITE. White (N8) and black (N2.5) mafics. Approximately 30% GRANODIORITE and 70% TONALITE.	
14:22	14:20	1				60				DIORITE/TONALITE. Very dark gray (N3) to black (N2.5) with GRANODIORITE fragments in cuttings. Slightly weathered to fresh. Zeolite(?) and chlorite as fracture infillings; minor disseminated pyrite in veins and in host rock at contact.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
14:22						60				DIORITE/TONALITE. Very dark gray (N3) to black (N2.5) with GRANODIORITE fragments in cuttings. Slightly weathered to fresh. Zeolite(?) and chlorite as fracture infillings; minor disseminated pyrite in veins and in host rock.	
						65				DIORITE. Very dark gray (N3) to black (N2.5). Slightly weathered to fresh; minor chloritization. No quartz/feldspar fragments.	...(65') - damp to dry. Hard drilling.
						70					
						75					
	14:43	0.95				80					
14:46											
						85					...(85'-90') - very hard drilling. Broke tooth off bit.
						90					
						95					
	15:19	0.61				100					
15:24										DIORITE. Very dark gray (N3) to black (N2.5) with minor quartz/feldspar veins with some zeolite(?) alteration/infillings along fractures and chloritization.	
						105					
						110					
						115					
						120					

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BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
14:22						60				DIORITE/TONALITE. Very dark gray (N3) to black (N2.5) with GRANODIORITE fragments in cuttings. Slightly weathered to fresh. Zealite(?) and chlorite as fracture infillings; minor disseminated pyrite in veins and in host rock.	
						65				DIORITE. Very dark gray (N3) to black (N2.5). Slightly weathered to fresh; minor chloritization. No quartz/feldspar fragments.	...(65') - damp to dry. Hard drilling.
						70					
						75					
	14:43	0.95				80					
14:46						85					...(85'-90') - very hard drilling. Broke tooth off bit.
						90					
						95					
	15:19	0.61				100					
15:24						105				DIORITE. Very dark gray (N3) to black (N2.5) with minor quartz/feldspar veins with some zeolite(?) alteration/infillings along fractures and chloritization.	
						110					
						115					
						120					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
16:02	15:58	0.59				120 125				...(125') - no apparent quartz/feldspar dikes.	
						130 135				DIORITE. Very dark gray (N3) to black (N2.5). Fresh; hard. Quartz/feldspar fragments with altered biotite and some epidote alteration of feldspars. Very minor disseminated pyrite. ...(135') - no apparent quartz/feldspar fragments.	Rock is fractured, but very hard - breaking buttons off bit. Dry.
12/06 8:20						140 145					
						150 155				DIORITE. Very dark gray (N3) to black (N2.5). Fresh; very hard; mostly unaltered. Very minor quartz/feldspar fragments with some chloritized biotite.	
	8:46	0.77				160 165					
						170 175				...(175') - DIORITE with GRANODIORITE/ TONALITE dikes. Chlorite alteration, especially along contact of dikes with DIORITE.	
9:20						180				Altered GRANODIORITE and quartz/feldspar dikes in TONALITE. Greenish gray (5G5/1). Chloritization of some fractures, and thin coatings of zeolite(?) along some fracture surfaces.	Dry.

CONTINUED ON NEXT PAGE

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
9:20						180				Altered GRANODIORITE and quartz/feldspar dikes in TONALITE. Greenish gray (5G5/1). Chloritization of some fractures, and thin coatings of zeolite(?) along some fracture surfaces.	Dry.
						185				...(185') - TONALITE without felsic fragments.	
						190				...(190') - more mafic - DIORITE.	
						195				...(195') - minor quartz/feldspar fragments in cuttings.	
10:22	9:46	0.77				200				...(200') - DIORITE/TONALITE. Dark gray (N4); increase in felsic fragments in cuttings.	Wait 20 minutes for water. No water.
						205					
						210				...(210') - minor quartz/feldspar fragments in cuttings.	
						215				...(215') - some chloritized fragments - look like fracture coatings; very dark gray (N3).	
10:51	10:47	0.80				220				TONALITE/DIORITE. Very dark gray (N3). Hard; fresh. Very minor granodiorite fragments with some disseminated pyrite(?).	
						225				...(225') - some chloritized fragments, dark greenish gray (5G4/1 to 5BG4/1).	
						230				...(230') - DIORITE. Dark gray (N4) to gray (N5). Less mafics.	
						235					
11:20	11:15	0.83				240					

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-9

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: T. REEDER

DATE STARTED: 12/05/96
DATE FINISHED: 12/07/96
ELEVATION: ND
NORTHING: ND
EASTING: ND

GW DEPTH: Not encountered
TOTAL DEPTH: 300 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
11:20						240					
						245					
	11:35	0.67				250				...(250') - cuttings are very dark gray (N3) to gray (N4); minor quartz/feldspar fragments.	Changing bit. Fuel up. Let hole sit over one hour - end of sounder is moist, but no free water in hole.
14:27						255				...(255') - DIORITE with no apparent quartz/feldspar dikes. More mafic; darker.	
	14:48	0.48				260					
14:53						265					
						270				...(270') - very minor quartz/feldspar fragments in cuttings.	
						275					
	15:50	0.35				280					
12/07 8:30						285				TONALITE. Minor quartz/feldspar dikes with chloritized mafics along contact with TONALITE.	Change bit. About 0.5" of water at bottom of hole on 12/07 (condensation?).
						290				TONALITE/GABBRO. Very dark gray (N3). Fresh; hard; tight. Minor quartz/feldspar dikes. Minor chloritization of some mafics.	Used up 4 bits (last one only made it 20 feet) - too many carbide fragments in hole. Rubber fitting on bit broke.
						295					
	8:57	0.74				300				NOTES: 1. Total depth of borehole 300 feet. 2. Conductor casing set to 30 feet. 3. Open hole interval (exposed bedrock) between 20 and 300 feet below ground surface. 4. No free groundwater encountered.	

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GeoLogic Associates

BORING LOG

BORING NO.: GLA-10

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG / T. REEDER

DATE STARTED: 12/03/96
DATE FINISHED: 12/05/96
ELEVATION: 325 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 33 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
12/03 11:57						0				ALLUVIUM: SAND to SILTY SAND - very fine- to medium-grained with minor coarse sand to pebbles, with boulders of granodiorite and lesser amounts of tonalite. SAND is poorly sorted, micaceous and feldspathic. Dark brown (7.5YR3/3.5).	Dry to damp.
						5			SW SM		
						10				...(10'-20') - gradational color change to pinkish gray to brown (7.5YR5/2) with associated decrease in silt and micaceous minerals.	...(10') - dry to damp.
						15					...(15') - dry to damp.
											...(17') - groundwater encountered.
						20	12/16/96				
12:35	12:16	1.32				25			SW	GRAVELLY SAND - poorly sorted, medium- to very coarse-grained, arkosic. Abundant subrounded to sub-angular, tonalitic and granodioritic GRAVEL to BOULDERS.	...(25') - stop drilling to repair rig at 12:16. Start drilling again at 12:35.
						30					
						35				WEATHERED BEDROCK - TONALITE: Dark gray (2.5Y4/1) to dark grayish brown (2.5Y4/2). Phaneritic with fine- to medium- crystallinity. Biotite- and hornblende-rich. Weakly weathered with moderate to strong oxidation of biotite and hornblende to chlorite, and with minor alteration of feldspar crystals to clay.	...(33') - wet.
						40					...(40') - wet.
						45				...(45'-50') - predominantly fine-crystallinity.	...(45') - damp.
						50					...(50') - moist to dry. Set conductor casing to 50' below ground surface.
						55				...(53') - color change to olive gray (5Y5/2).	...(55') - dry.
						60					...(60') - dry.

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VLF SURVEYING AT THE PROPOSED GREGORY CANYON LANDFILL SITE, SAN DIEGO CO., CA

Final Report

for

GeoLogic Associates
426 Fourteenth Street
Modesto, CA 95354

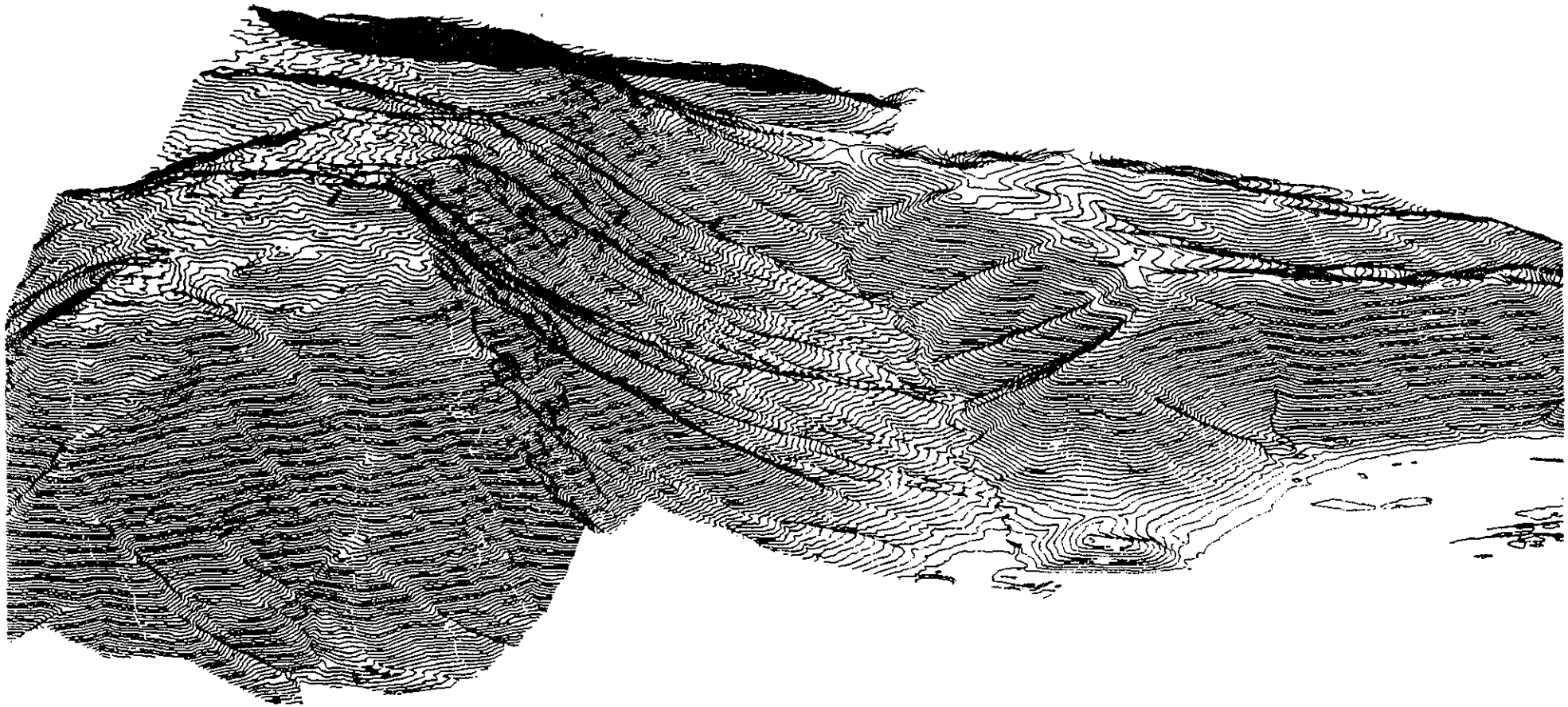
by

The Geophysics Group
260 S. Orange Street, Suite 10
Escondido, CA 92025

Edward P. Gustafson

Edward P. Gustafson, CA Reg. GP974
Chief Geophysical Analyst

April, 1997



Fronticepiece: Gregory Canyon and neighboring terrain.

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VLF SURVEYING AT THE PROPOSED GREGORY CANYON LANDFILL SITE, SAN DIEGO CO, CA.

1.0 SUMMARY

Very-Low Frequency (VLF) data were acquired along approximately 24,700 ft of traverse at the proposed Gregory Canyon Landfill site in San Diego County, CA. The purpose of the survey was to determine the locations of fractures, which possibly provide controls on the local groundwater flow patterns, on the basis of the perturbations of the VLF response due to lateral changes in electrical conductivity.

The sets of fractures detected could be grouped in three general trends. The most sriking VLF anomalies were observed at or near the floor of the main N30W drainage of the canyon. A second trend, bearing N50E was generally associated with drainages on the west side of the canyon. A third set, trending N70W, was observed along the east side of the canyon.

The San Diego Aqueduct ran along the west side of the study area (along Line K-K'). High-voltage power lines ran along the eastern edge of the study area. Because of the large amount of cultural interference in the proximity of these features, meaningful data could not be obtained.

Topography can perturb VLF response in a way that mimics the response of fractures. While the topography at the site was in some areas extreme, no positive correlation between the VLF anomalies and the topography was observed. Thus, we conclude that the observed anomalies, when not due to culture, represent true lateral variations in the electrical conductivity of the subsurface.

2.0 INTRODUCTION

The Geophysics Group, at the request of **GeoLogic Associates, Inc.**, and **Gregory Canyon Partners, Ltd.**, performed a geophysical survey at the proposed landfill site at Gregory Canyon in San Diego CO., CA (Figure 1). The purpose of the survey was to remotely detect the presence and trends of relatively high-permeability fault or fracture zones which may influence the groundwater flow at the site.

Very Low Frequency (VLF) methods were used to perform this investigation. VLF methods were employed because of the sensitivity of this technique to the presence of long, linear changes in the electrical conductivity of the rocks resulting from chemical alteration of the minerals in fractures. **The Geophysics Group** have been using this and other techniques with much success in similar terraines in San Diego and Riverside Counties for the purposes of siting high-yield water wells necessary for cost-effective crop irrigation.

VLF data were acquired over the following dates; May 21 through May 26, July 2 through July 5, and July 8 through July 10, 1996. Because the VLF transmitter north of the site at Jim Creek, WA was down for unscheduled maintenance, a local transmitter was deployed on July 5. All data were acquired by Messrs. Leopold L Mairesse, Edward P. Gustafson and John Patskan of **The Geophysics Group**.

3.0 EQUIPMENT AND DATA ACQUISITION

3.1 RECEIVER AND TRANSMITTER EQUIPMENT

In the VLF method the perturbations to otherwise horizontally oriented electromagnetic fields, caused by lateral variations in the earth's electrical properties, are monitored and interpreted. The VLF receiver records the magnitude, orientation and phase of the magnetic field at a specific frequency; that of the transmitter. The frequencies used are typically in the 10 KHz to 25 KHz band. A discussion of some of the more technical aspects of the VLF method is included as Appendix A.

Relatively high-power VLF transmitters, used for military communication, are located at a number of places around the world. In the continental United States, three transmitters are typically used: NLK (24.8 KHz) at Jim Creek (Seattle), WA; NPN (21.4 KHz) at Lualualei, HI; and NAA (24.0 KHz) at Cutler, ME. While the VLF receivers can sense anomalies due to lateral geologic inhomogeneities striking in arbitrary directions, NLK is most useful for detecting structures striking in a roughly north-south direction, and NPN and NAA are most useful for detecting structures striking in an east-west direction. The response to all three of these transmitters was monitored during the survey, provided the transmitters were operating.

The NLK transmitter was not operating during the initial portion of the survey, through July 8, 1996. To optimally illuminate possible structures striking in a roughly north-south direction, a local VLF transmitter was deployed. The transmitter used was a Geonics Ltd. EM27, operating at a frequency of 16.55 KHz. The location of the local transmitter dipole is indicated on the included Interpretation Map.

During the initial portion of the survey, signals from the remote VLF transmitters were monitored using an OMNI Plus VLF receiver. The sensor of this instrument comprises three orthogonal coils to sense the total time-varying magnetic field at the selected frequencies. The unit records the magnetic field at three specific frequencies simultaneously, and reports the total field, the percent in-phase (or dip angle), and the percent quadrature field.

During the second portion of the survey, the Geonics Ltd. EM16 VLF receiver was used. This unit was chosen because it was the only available receiver which was guaranteed to be compatible with the EM27 local transmitter, used to provide an optimal signal while the NLK transmitter was down. The orientation of the VLF magnetic field is determined by physically orienting the EM16 and reading the dip angle on an inclinometer. Dip angle (in-phase) and quadrature field measurements are available with the EM16. A comparison was made of the data along Line E acquired using the local transmitter source and NLK. While the data from the two sources did not overlay precisely, the anomalous responses occurred at the same locations, and the interpretations of the two datasets are equivalent (see Appendix B, Line E).

3.2 DATA ACQUISITION

3.2.1 Profile Lines

Data were collected along 15 traverses as shown on the included Interpretation Map. The total

linear coverage was approximately 24,700 feet. When the OMNI receiver was being used, measurements were taken at 10-foot intervals. When the EM16 receiver was being used, measurements were taken at 25-foot intervals. Profile locations were marked at 100-foot intervals with survey ribbon. Distances and orientations were reckoned through compass and pacing. Paced distances were found to be accurate along roads and clear ground. Paced distances were less accurate in areas of steep terrain and heavy brush, thus locations in the field should be based on the existing flags in these areas.

3.2.2 Transmitter Schedules

The NLK transmitter was not operating during the initial portion of the survey, which prompted the use of the EM27 local transmitter. However, NLK was operating as of July 8, 1996, and was used in lieu of the local transmitter thereafter. Each of the military transmitters are shut down periodically for scheduled maintenance: NLK on Thursdays, NPN on Wednesdays, and NAA on Mondays. In addition, it is not uncommon for a transmitter to be off the air due to unscheduled maintenance. The data in the profile plots included as Appendix B represent all of the measurements available from the transmitters operating at the time of field data acquisition.

4.0 INTERPRETATIONS

4.1 INTERPRETATION PROCEDURES

Interpretations of the VLF data were made primarily on the basis of the character of the in-phase response and the total field. The presence of conductive material in a fracture (such as clay) results in the generation of anomalous electric currents that, in turn, causes an anomalous magnetic field. This serves to 1) tilt the surface VLF field from the horizontal resulting in an anomalous in-phase response, and 2) increase the magnitude of the total VLF field. This characteristic VLF response is described in more detail in Appendix A.

The characteristic in-phase response is commonly referred to as a crossover, where (by convention) the in-phase field values increase as the structure is approached, decrease rapidly as the structure is crossed, and increase gradually again to the background level away from the structure. This is usually associated with a local maximum of the total VLF field. Where there are several fractures in proximity to each other, the responses combine to produce a composite anomaly. Some examples of typical VLF anomalies observed at the site are shown in Figure 2.

4.2 OBSERVED VLF ANOMALIES

4.2.1 East-West Lines

Line H: Low-amplitude in-phase and total field anomalies were observed at location 900 ft on all stations monitored. In addition, low-amplitude in-phase anomalies were observed at locations 640 ft and possibly 900 ft in the NLK data, and at 1050 ft in the NPN data.

Line G: A strong in-phase anomaly at location 140 ft, and a low-amplitude anomaly at 1180 ft were observed in the NLK data. A broad anomaly observed in the NAA data can be resolved into two separate total field and in-phase anomalies located at 325 ft and 1010 ft, suggesting possibly that two fractures are being crossed at a grazing angle.

Line E: Well-formed anomalies at 350 ft and 1080 ft, and a less compelling anomaly at 600 ft, were observed in the NLK data. Low-amplitude anomalies occurred at 960 ft and 1310 ft in the NAA data. A weak but well-formed anomaly occurs at 1080 ft in the NPN data, which correlates with the anomaly observed in the NLK data.

Line F: Line F actually comprises two lines: the NLK data were collected along a traverse that was parallel to, but approximately 340 feet to the south of, the traverse along which the NPN and NAA data were collected. Along the southern (NLK) traverse, a broad in-phase anomaly was observed at 350 ft. Another anomaly was observed at 1070 ft. Along the northern traverse, similar anomalies were observed in both the NPN and NAA data. These occurred at locations 480 ft, 930 ft and 1270 ft. The in-phase response is subtle, and the sense of the cross-overs are reversed from what one would normally expect. This is not surprising since the profile is oriented in an east-west direction, and the criteria that the VLF receiver uses to assign a sign to the data are invalid.

Line D/Dext: A strong in-phase and total field anomaly in the NLK data was observed along the west extension of Line D (Dext) at 800 ft along the axis of the main canyon. The NLK data from 700 ft to 750 ft were also anomalous and possibly represent a composite response of fractures running in a roughly east-west direction. No significant anomalies were observed along Line D. No NPN or NAA data were acquired along Line Dext.

Line C/Cext: Strong in-phase anomalies were observed on Cext in the NLK data. These anomalies are at 810 ft and 860 ft, and likely represent the response of fracturing associated with the main canyon axis. No significant anomalies were observed along Line C. NPN and NAA data were not acquired along Line Cext.

Line R: A low-amplitude in-phase anomaly was observed at location 500 ft in the NLK data. NPN and NAA data were not acquired along Line R

Line B: No significant anomalies were observed in the data from any of the three frequencies monitored that could not be attributed to power line interference.

Line A: The largest anomaly along Line A is attributed to power line interference. Low-amplitude anomalies were observed in the NLK data at locations 2060 ft and 2720 ft.

4.2.2 North-South Lines

Line L: Low-amplitude in-phase and total field anomalies were observed at locations 130 ft, 450 ft and 1050 ft in the NPN data.

Line N: In-phase and total field anomalies were observed at 580 ft, 800 ft and 1020 ft in the NPN and NAA data.

Line Q: In-phase and total field anomalies were observed at 250 ft, 450 ft and 780 ft in the NPN and NAA data.

Line P: In-phase and total field anomalies were observed in the NPN and NAA data at locations -110 ft, -300 ft, -480 ft and -1450 ft. The zone between -750 ft and -1050 ft is characterized by a broad total field anomaly and several distinct in-phase anomalies, and likely indicated the presence of numerous (three or more) fractures.

Line M/Mext: A broad, low-amplitude in-phase and total field anomaly may indicate fracturing at -390 ft along Line M. Along Line Mext (the southern extension of Line M), significant in-phase anomalies occur at -1910 ft, -1400 ft and -1320 ft in the NPN data. A relatively low-amplitude in-phase crossover occurs at -1070 ft in the NPN data along Line Mext.

Line K: Line K was a traverse made along an access road for the San Diego Aqueduct. Many of the VLF anomalies along this line can be attributed to the response of the pipeline beneath the road. This

is particularly evident in the VLF response between
-900 ft and -1400 ft.

In-phase and total field anomalies located at -3950 ft, -3750 ft and -3530 ft in the NAA data appear to be the response of geologic structure and not the response of the aqueduct.

Line J: In-phase and total field anomalies were observed in the NAA data at locations -4060 ft, -3680 ft, -3060 ft and possibly at the traverse end at -2500 ft. The in-phase anomalies between locations -2700 ft and -2900 ft may represent a zone of multiple fractures.

4.3 INTERPRETED FRACTURE TRENDS

Fracture trends, determined on the basis of linear correlations of VLF anomalies and correlations of VLF anomalies with linear geomorphic trends (drainages) are shown on Plate I. Fractures were not interpreted when VLF anomalies could not be correlated between two traverse lines or geomorphic evidence. In addition, VLF anomalies that were clearly the result of culture (power lines, buried aqueducts, etc.) were not plotted on Plate I.

Three general fracture azimuths were observed. The first, trending at a roughly N30W direction, is primarily represented by strong NLK anomalies associated with the main drainage of the canyon. The second trend consists of a set of fractures bearing in a roughly N50E direction. These show up most clearly as VLF anomalies associated with drainages along the west side of the canyon. A third set, bearing N70W, was evident in the VLF data along the east side of the canyon.

5.0 CONCLUSIONS

The interpreted fractures shown in PLATE I were identified on the basis of line-to-line correlations of the VLF anomalies along with geomorphic evidence (generally linear drainages.) While a linear drainage does not in itself provide unequivocal evidence of a fracture, correlation between physical property anomalies and topographic anomalies certainly strengthen the interpretation of both the geophysical and geomorphic observations.

Topographic variations can, in principle, produce VLF anomalies that mimic those due to subsurface resistivity variations. The magnitude of the topographic effect increases with increasing bulk conductivity of the subsurface. Also, the form of the VLF anomaly, due strictly to a topographic low (such as a canyon or drainage), would be opposite to that due to a linear subsurface conductor associated with a fracture. While there is significant topography in the study area, there is little indication that the observed VLF anomalies are *caused* strictly by topography. To the extent that the VLF anomalies correlate with topography, we can attribute this correlation to a common underlying cause, namely fracturing.

The most compelling VLF anomalies observed at the site were those observed along the main north-south axis of the canyon (the N30W trend.) Weaker anomalies were generally observed over the N50E-trending structures. Still weaker anomalies were observed along the N70W structures. On this basis, one possible conclusion that can be drawn is that the N30W structures at one point had higher permeability, thus conducting the flow of larger amounts of groundwater. This would increase the amount of chemical alteration of the minerals in the fracture zone, yielding a larger volume of electrically-conductive alteration products (primarily clays).

6.0 ACKNOWLEDGMENTS

The Geophysics Group would like to thank **GeoLogic Associates Inc.**, and **Gregory Canyon Partners, Ltd.** for inviting us to participate in this interesting study. Invaluable information and support during the field study was provided by Horacio Ferriz, Ph.D. of **GeoLogic Associates Inc.**

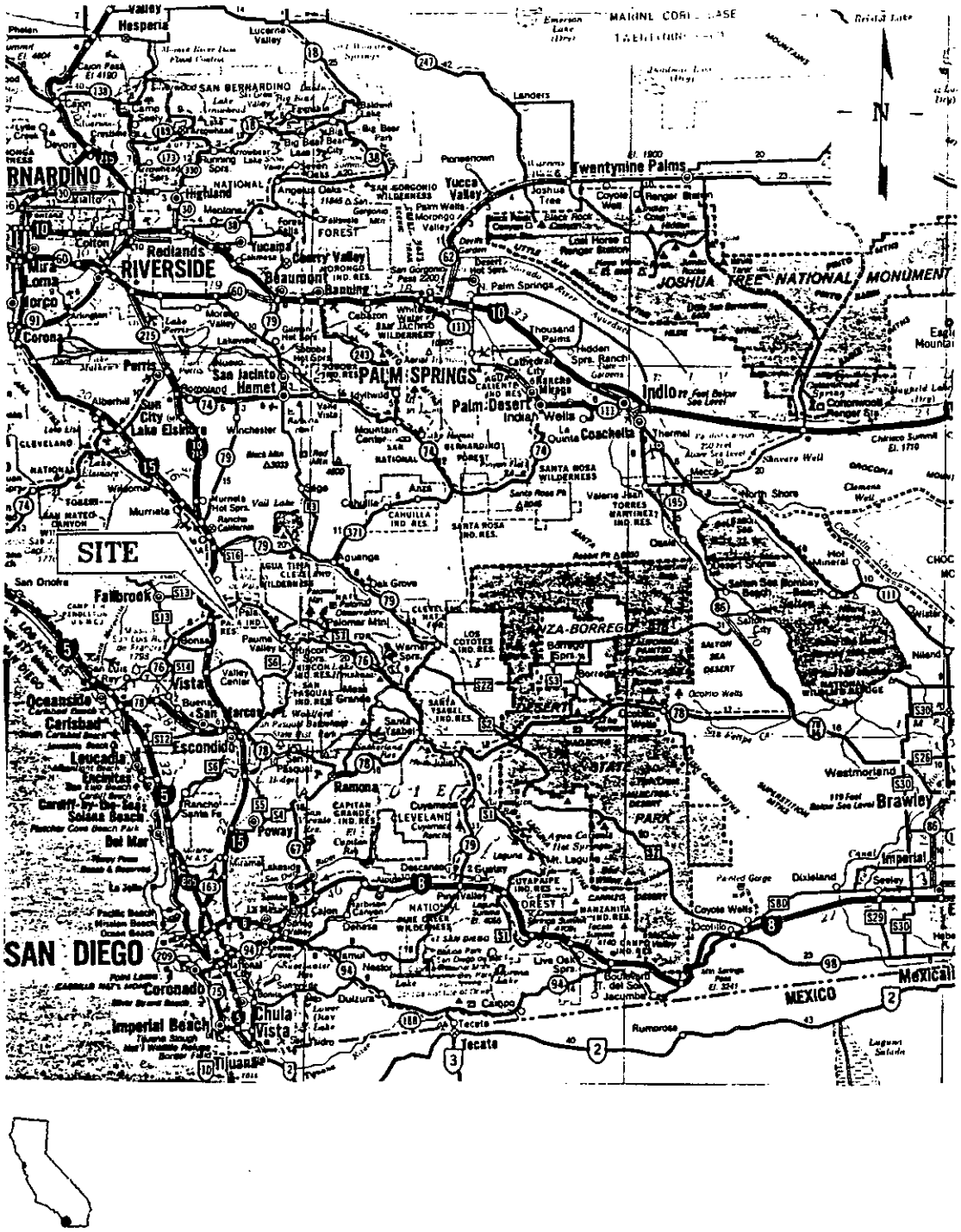
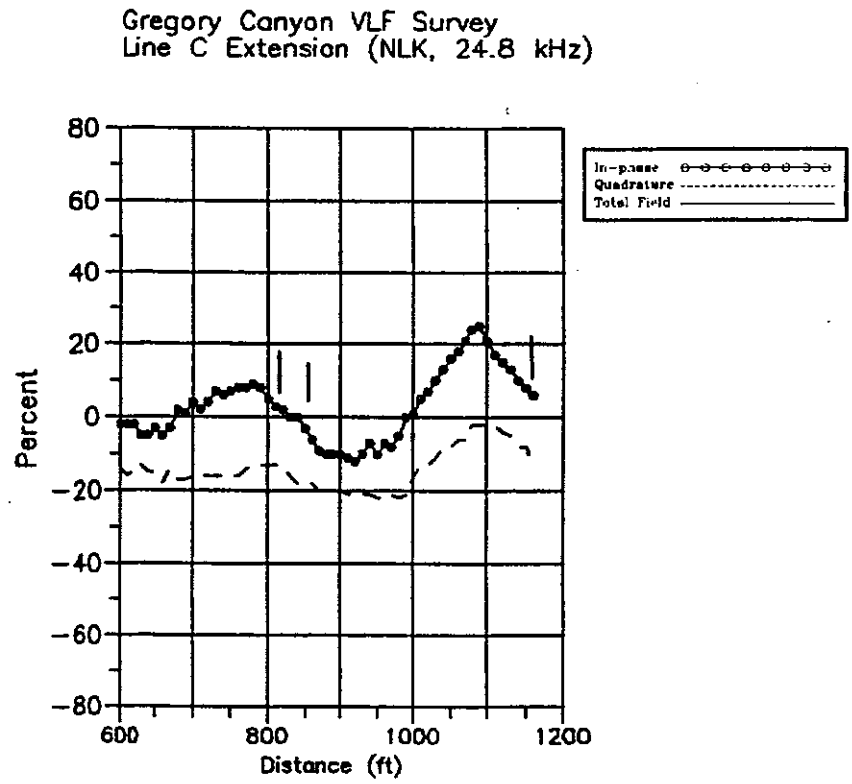


Fig. 1: General site location map.



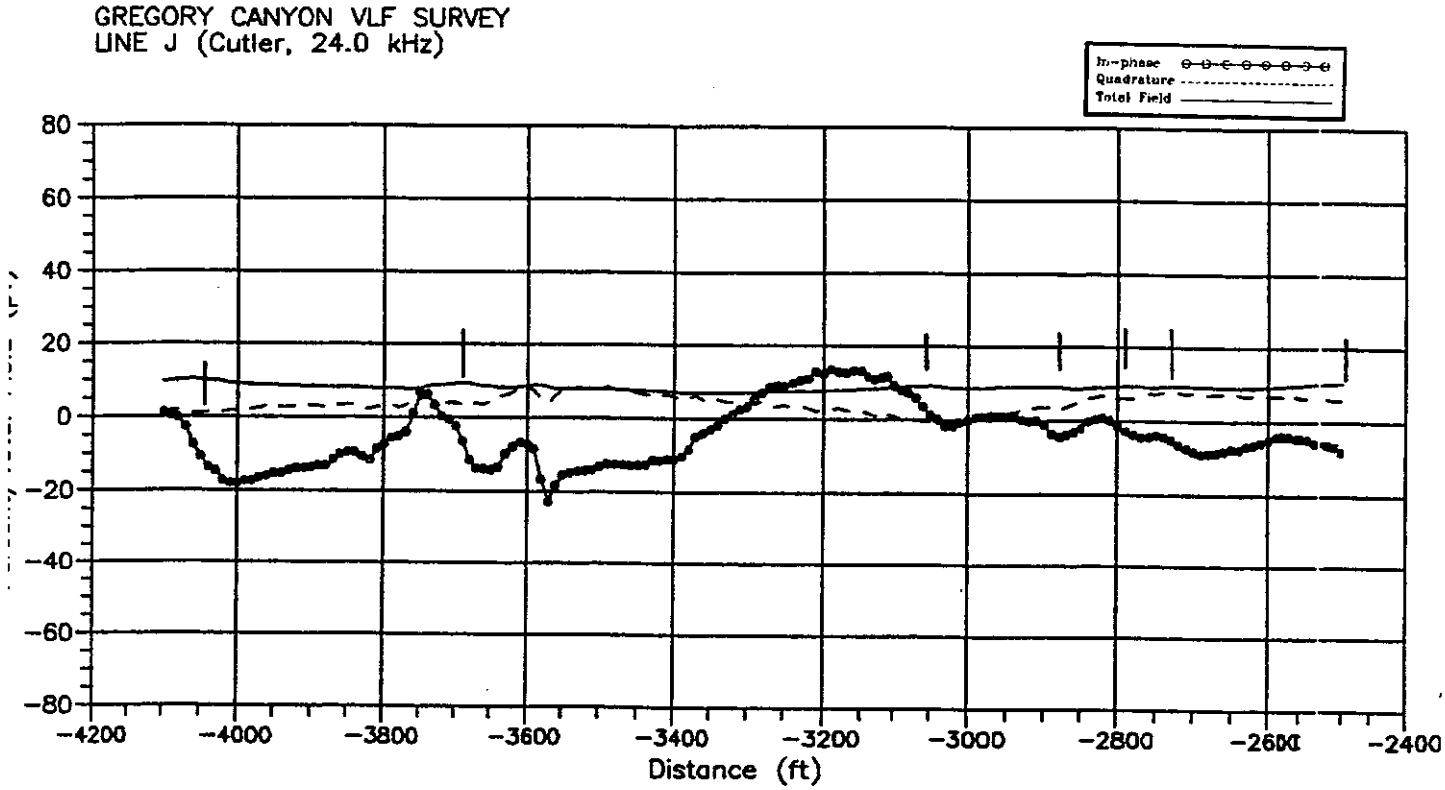


Fig 2: Examples of typical VLF anomalies observed at the site. Vertical ticks above the data curves indicate the presence of possible fractures.

Table 1. Summary of transmitters used in the VLF study.

	Line	Orientation	Transmitter
Figure B-1	A-A'	West-East	NLK - Jim Creek, Washington
Figure B-2	A-A'	West-East	NPM - Lualualei, Hawaii
Figure B-3	A-A'	West-East	NAA - Cutler, Maine
Figure B-4	B-B'	West-East	NPM - Lualualei, Hawaii
Figure B-5	B-B'	West-East	NAA - Cutler, Maine
Figure B-6	C-Cext	West-East	NPM - Lualualei, Hawaii
Figure B-7	C-Cext	West-East	NAA - Cutler, Maine
Figure B-8	Cext-C'	West-East	NLK - Jim Creek, Washington
Figure B-9	D-Dext	West-East	NLK - Jim Creek, Washington
Figure B-10	Dext-D'	West-East	NLK - Jim Creek, Washington
Figure B-11	E-E'	West-East	NLK - Jim Creek, Washington & local transmitter
Figure B-12	E-E'	West-East	NPM - Lualualei, Hawaii
Figure B-13	E-E'	West-East	NAA - Cutler, Maine
Figure B-14	F(NLK)-F(NLK)'	West-East	NLK - Jim Creek, Washington
Figure B-15	F-F'	West-East	NPM - Lualualei, Hawaii
Figure B-16	F-F'	West-East	NAA - Cutler, Maine
Figure B-17	G-G'	West-East	NLK - Jim Creek, Washington
Figure B-18	H-H'	West-East	NLK - Jim Creek, Washington
Figure B-19	J-J'	North-South	NAA - Cutler, Maine
Figure B-20	K-K'	North-South	NAA - Cutler, Maine
Figure B-21	L-L'	North-South	NPM - Lualualei, Hawaii
Figure B-22	M-Mext	North-South	NPM - Lualualei, Hawaii
Figure B-23	Mext-M'	North-South	NPM - Lualualei, Hawaii
Figure B-24	M-Mext	North-South	NAA - Cutler, Maine
Figure B-25	N-N'	North-South	NPM - Lualualei, Hawaii
Figure B-26	N-N'	North-South	NAA - Cutler, Maine
Figure B-27	P-P'	North-South	NAA - Cutler, Maine
Figure B-28	P-P'	North-South	NPM - Lualualei, Hawaii
Figure B-29	Q-Q'	North-South	NPM - Lualualei, Hawaii
Figure B-30	Q-Q'	North-South	NAA - Cutler, Maine
Figure B-31	R-R'	North-South	NLK - Jim Creek, Washington

APPENDIX A:

Principles of the VLF method

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VLF METHOD: BASIC PRINCIPLES

INTRODUCTION

The VLF (Very Low Frequency) method is an electromagnetic technique wherein certain types of geologic structures are detected on the basis of response to radio signals in the 10 to 25 kHz frequency band. Portable VLF receivers, designed specifically for geophysical exploration, detect the local perturbations of the VLF signals caused by geologic structure. VLF methods are typically used to detect high-angle geologic structures (faults, fractures, mineralized veins) and abrupt lateral changes in the electrical conductivity of the ground.

The results of experiments in the application of radio waves to geophysical prospecting were published as early as 1908. The techniques that are used today were initially developed in the early 1960's when receivers were developed to take advantage of the signals emitted by VLF transmitters used for military communications. Early instruments were relatively crude; the operator being required to physically align the instrument with the desired component of the field. Currently available VLF instruments typically measure three orthogonal components of the VLF field so no orientation of the instrument is required.

SIGNAL SOURCES

The VLF method utilizes signals from military transmitters used primarily for submarine communication. These transmitters are high-power (typically several hundred kW) and are located at various places around the world (Figure 1). Thus, VLF signals can be detected from most locations on land. In addition, the broadcast signal does not vary in strength significantly with time. VLF transmitting facilities operate continuously except for scheduled maintenance periods. Rarely, a VLF transmitter will be off the air for unscheduled (and usually unannounced) maintenance.

For surveying in the continental U.S., there are four useful VLF transmitters; NLK/NPG near Seattle, WA (24.8 kHz), NPM at Lualualei, HI (23.4 kHz), NAA at Cutler, ME (24.0 kHz), and NSS at Annapolis, MD (21.4 kHz).

In rare cases where military VLF transmitters are inappropriate, portable VLF transmitting equipment is available.

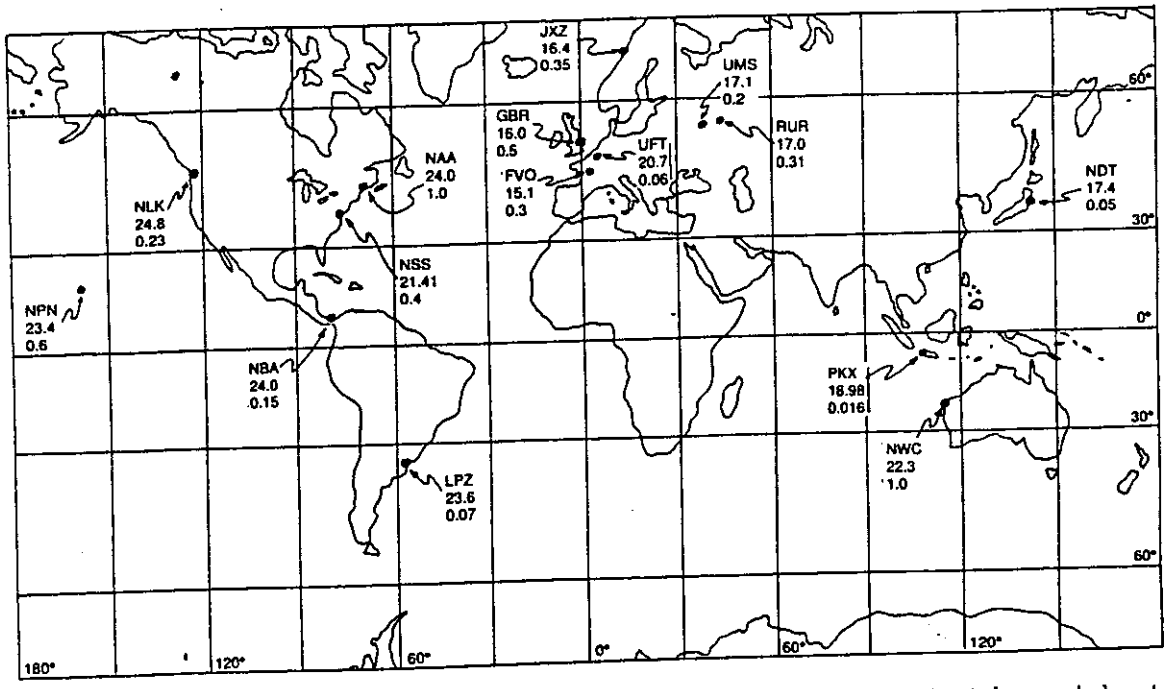


Figure 1: VLF transmitter locations, including station identification, operating frequency in kHz and power in MW (from Milsom, 1989).

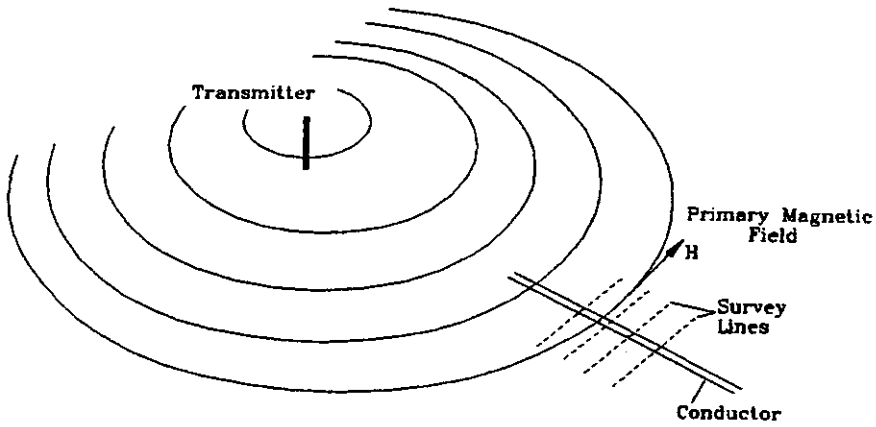


Figure 2: Diagram showing the optimum orientations of a conductive target and survey lines relative to a VLF signal and transmitter.

In the absence of a secondary field, the total field is linearly polarized in the horizontal direction. The addition of the secondary field causes the total field to be elliptically polarized. The two parameters that characterize this ellipse are its ellipticity (the ratio of the major and minor axes), and the angle between the major axis and the horizontal (known as the dip angle). Older VLF receivers allowed direct measurement of the dip angle and ellipticity. Newer VLF receivers report percent in-phase values, quadrature phase values and the magnitude of the total field. The in-phase value is the ratio (to the primary field) of the portion of the vertical component of the secondary field which is in phase with the primary field. The quadrature value is the ratio (to the primary field) of the portion of the vertical component of the secondary field which is 90 degrees out of phase with the primary field. It can be shown (e.g. Paterson and Ronka, 1971) that (for small secondary fields) the in-phase value is equal to the tangent of the dip angle. Likewise, the quadrature values are equal to the ellipticity of the polarization ellipse. The sign of the in-phase value indicates whether the major axis is tilted above or below the horizontal. The sign of the quadrature value indicates the sense of rotation of the total field vector as it traces out the ellipse (clockwise vs. counterclockwise).

VLF Response Over a Thin Vertical Conductor

The typical VLF target is the conductive vein or fracture, so this will be used to illustrate the character of observed VLF response. The presence of the VLF signal will cause an excess of electric current to flow within the conductive body. This will happen for two reasons; 1) eddy currents will be generated in the body directly by the primary magnetic field through electromagnetic induction and 2) galvanic effects will cause currents flowing nearby to be channeled into the conductor. The first cause will be important only when the conductor is striking toward the transmitter. The second cause is less dependant on the strike of the conductor, and may be responsible for most of the observed VLF anomalies (McNeill and Labson, 1990).

The geometry of the perturbations of the VLF field near such a conductor is shown in Figure 4. The sense of direction of the secondary vertical magnetic field reverses as the conductor is crossed. This results in a change in the sign of the dip angle and, thus, the in-phase portion of the field. This behavior is called a crossover, and is diagnostic of the presence of a thin tabular conductor. Associated effects involve a crossover in the quadrature field, and a local peak in the total field.

Interpretation of the canonical VLF response shown in Figure 4 is straightforward. A number of complications can arise, however. VLF signals attenuate rapidly with depth in the ground, especially when the ground is highly conductive. Thus, the detection of targets beneath sufficiently thick, conductive overburden may be problematic. VLF anomalies caused by geologic contacts produce a response which the inexperienced interpreter may mistake as a

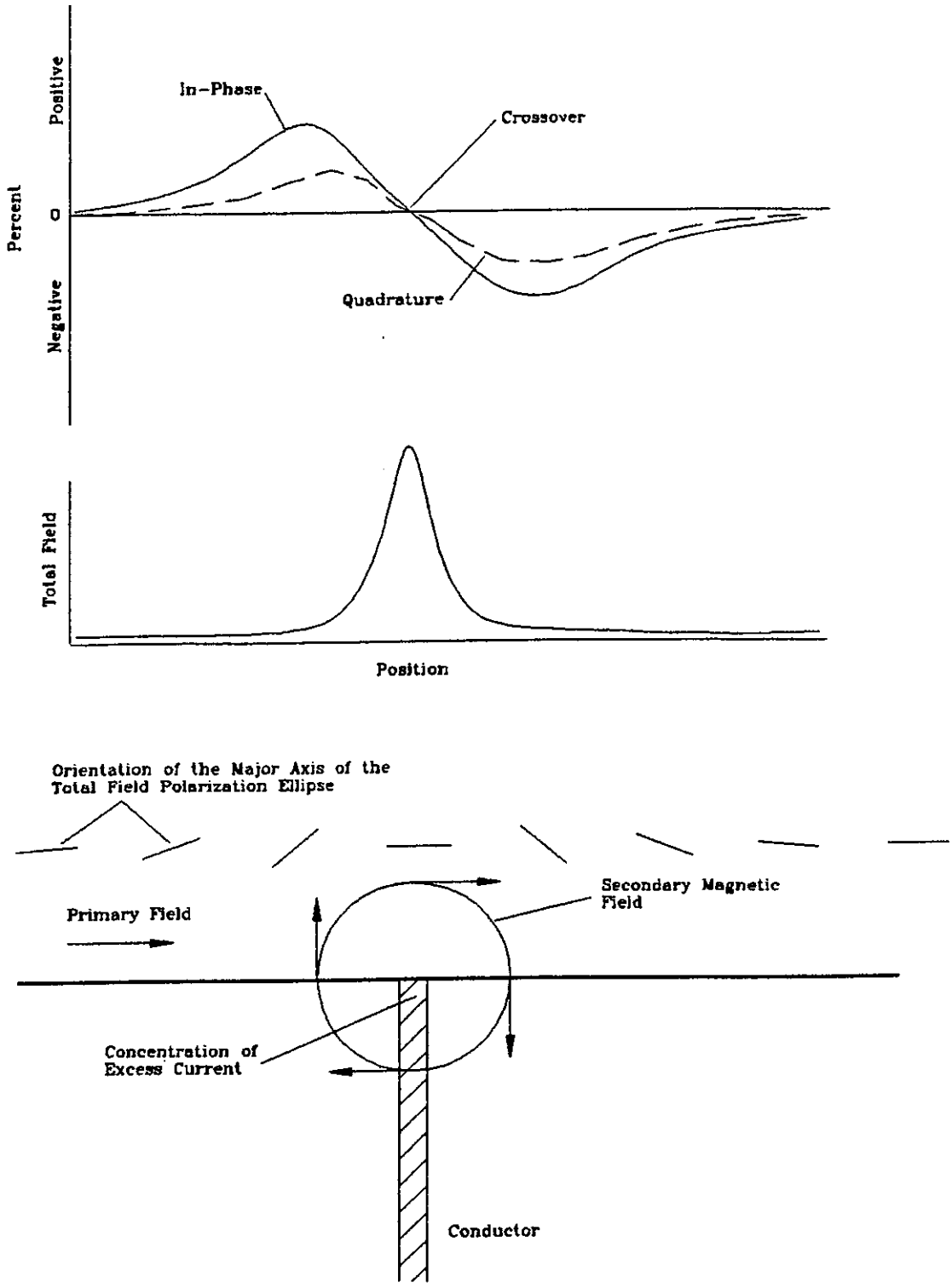


Figure 4: Relationships between measured VLF response and the magnetic field distortions near a conductive body.

narrow conductor. Also, topography can cause a response that may be mistaken as a change in conductivity of the subsurface.

INTERPRETATION ALGORITHMS

The interpretation of the raw VLF data is relatively straightforward. Certain types of data reduction, however, are useful for preparing VLF data contour maps or depth sections.

The Fraser filter (Fraser, 1969) is a simple algorithm which converts dip angle (or in-phase) crossovers to peaks for contouring. The more elaborate approach of Karous and Hjelt (1983) affords first-order depth estimations. Examples are shown in Figure 5.

REFERENCES

Fraser, D. C., 1969, Contouring of VLF data: Geophysics, v. 34, p. 958 - 967.

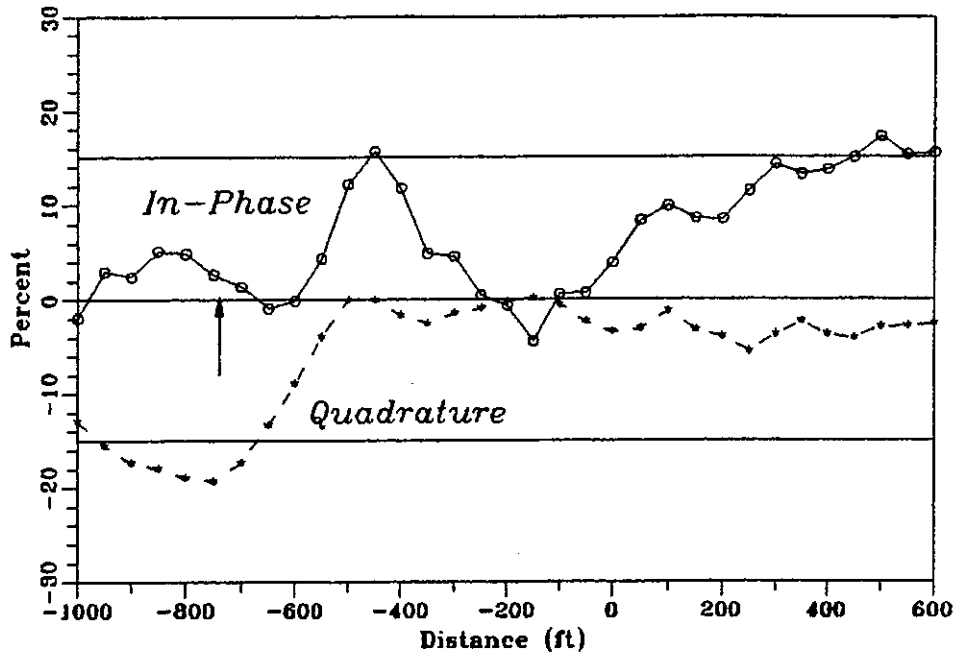
Karous, M., and Hjelt, S. E., 1983, Linear filtering of VLF dip-angle measurements: Geophysical Prospecting, v. 31, p. 782 - 794.

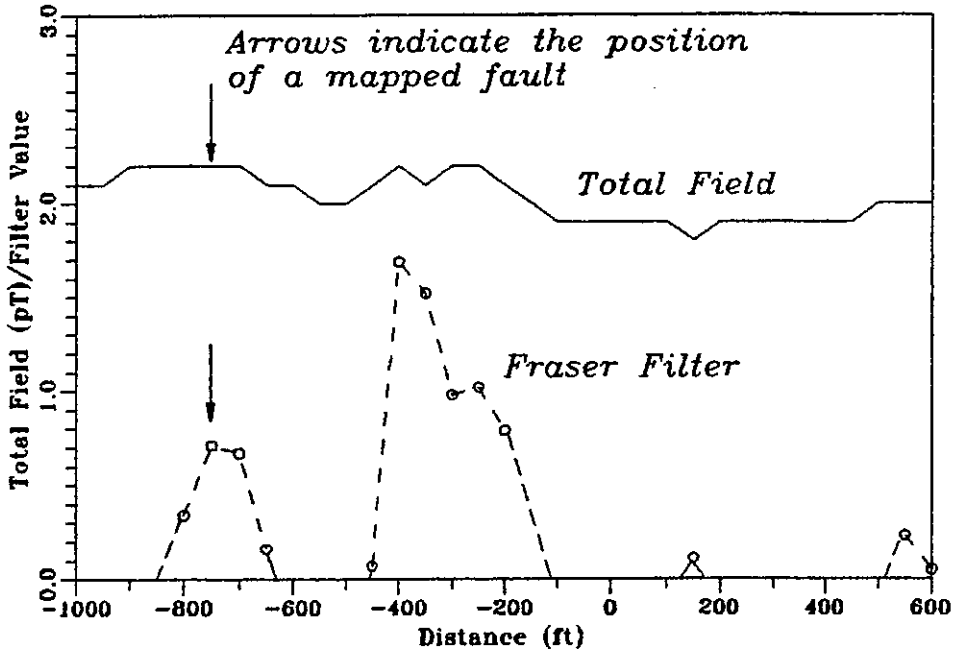
McNeill, J. D., and Labson, V., 1990, Geological mapping using VLF radio waves: in Nabighian, M. N., Ed., Electromagnetic methods in applied geophysics, Vol. 2, Soc. Expl. Geophys.

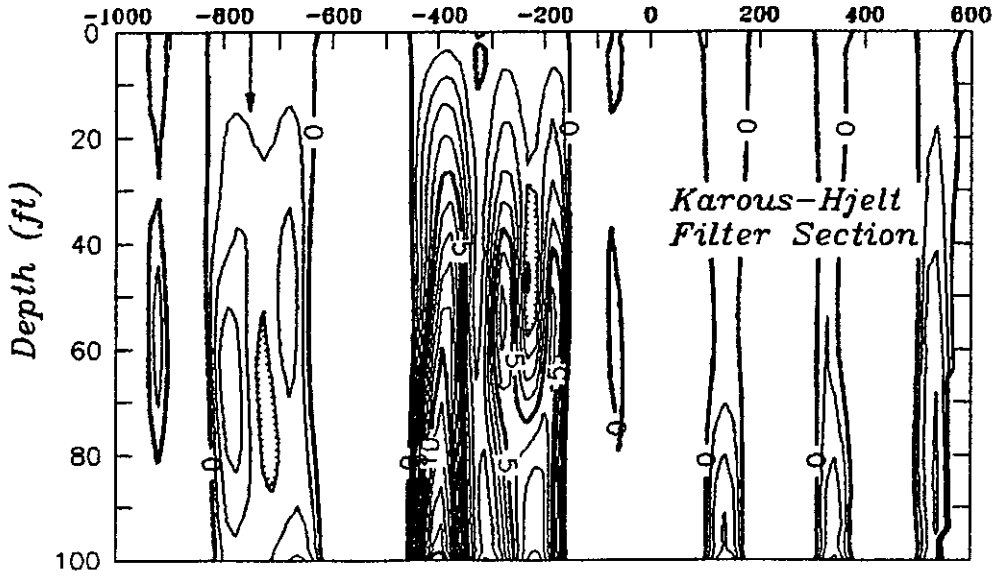
Milsom, J., 1989, *Field Geophysics*, John Wiley & Sons, New York, 182 p.

Paterson, N. R., and Ronka, V., 1971, Five years of surveying with the VLF electromagnetic method: Geoexploration, v. 9, p. 7-26.

Figure 5 (next page): Relationships between observed VLF in-phase, quadrature and total field values. These data were acquired over an area of known faulting. The arrows indicate the position of the only mapped fault along this profile. *Top*: Observed in-phase and quadrature data. *Middle*: Comparison of the observed total field and the Fraser filter values calculated from the in-phase response. Fraser filter peaks correlate with the total field peaks and the in-phase field crossovers. Note that the in-phase crossover at -400 ft represents a compound anomaly caused by multiple conductors. *Bottom*: Karous-Hjelt filter section derived from the in-phase data. Contours represent the estimated relative contribution of anomalous current flow to the observed anomaly. The major anomalies near -400 and -800 ft have been resolved into multiple vertical conductors.


In-Phase
Quadrature
Percent
Distance (ft)


Arrows indicate the position of a mapped fault
Total Field
Fraser Filter
Total Field (pT)/Filter Value
Distance (ft)


Karous-Hjelt Filter Section
Depth (ft)

APPENDIX B:

VLF data profile plots.

WEST

EAST

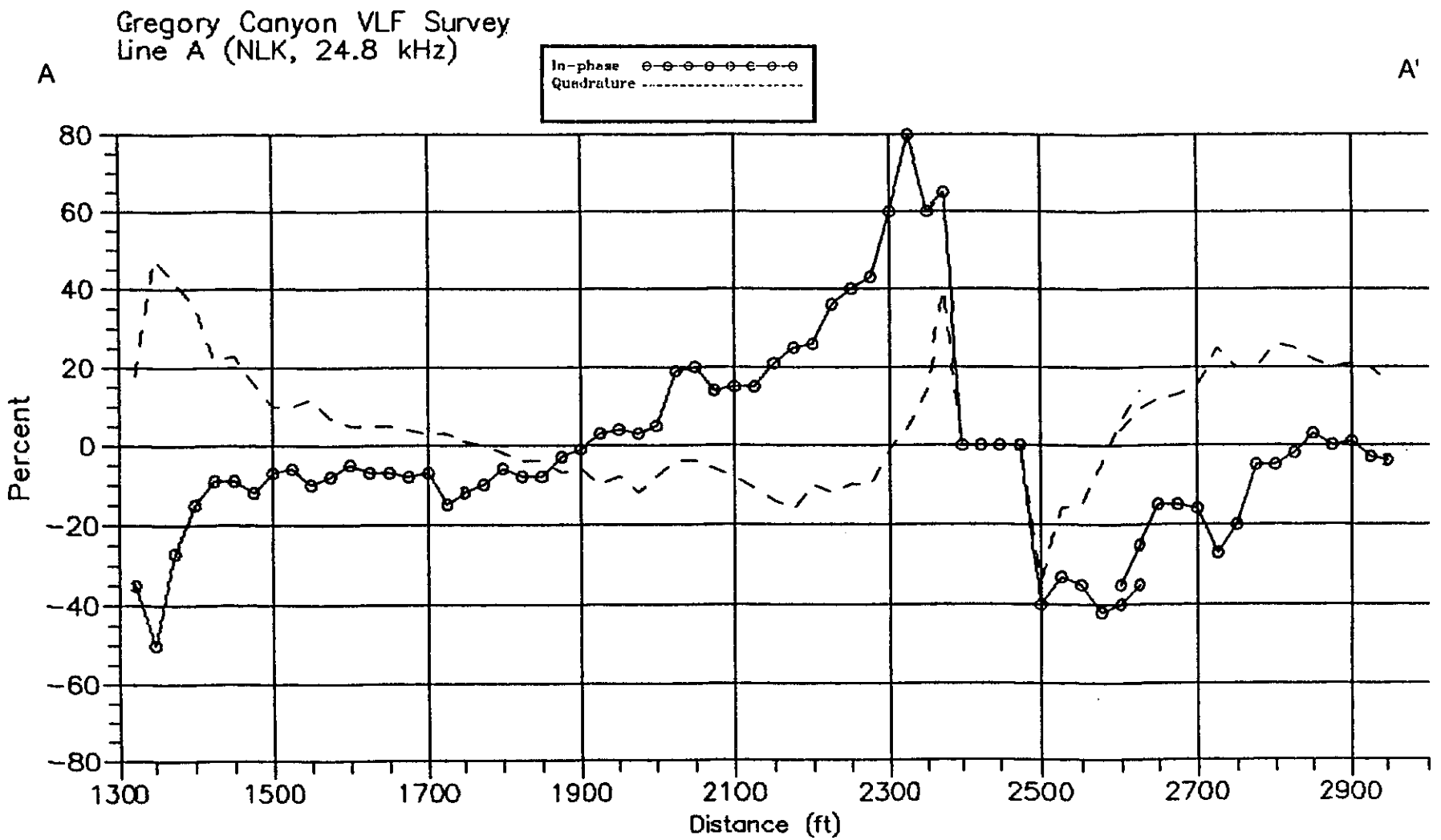


Figure B-1

WEST

EAST

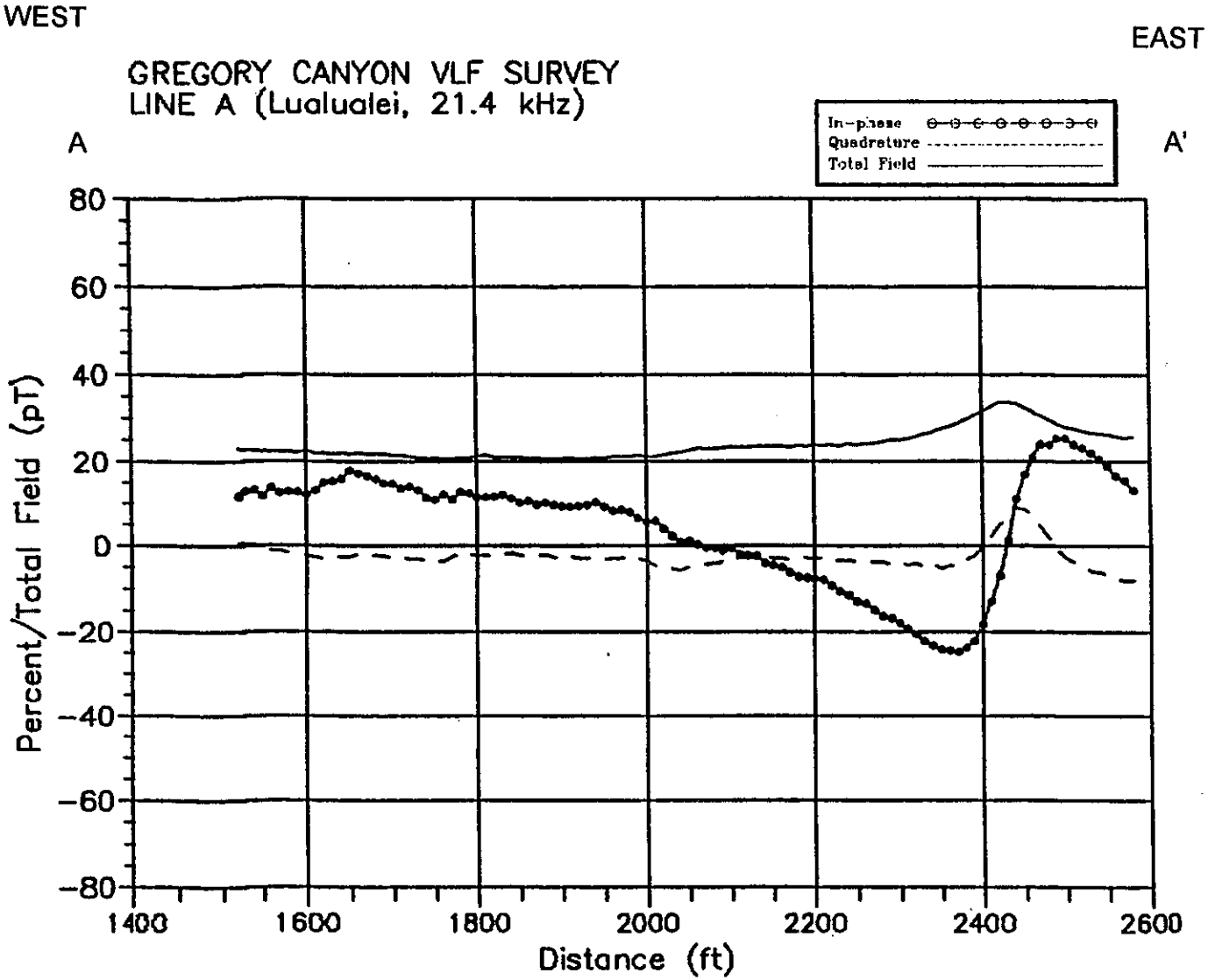


Figure B-2

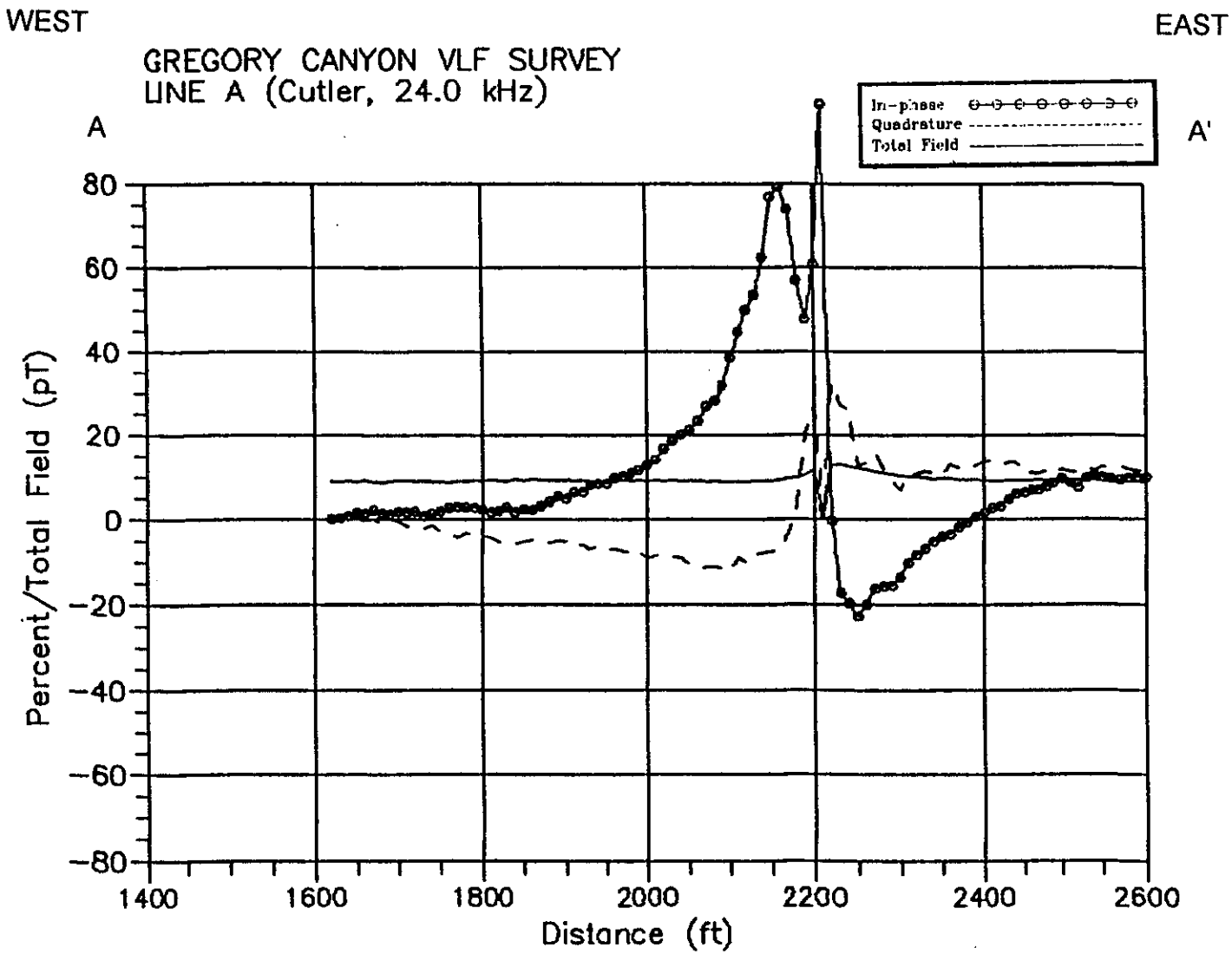

WEST
EAST
GREGORY CANYON VLF SURVEY
LINE A (Cutler, 24.0 kHz)
A
A'
In-phase
Quadrature
Total Field
Percent/Total Field (pT)
80
60
40
20
0
-20
-40
-60
-80
1400
1600
1800
2000
2200
2400
2600
Distance (ft)

Figure B-3

WEST

EAST

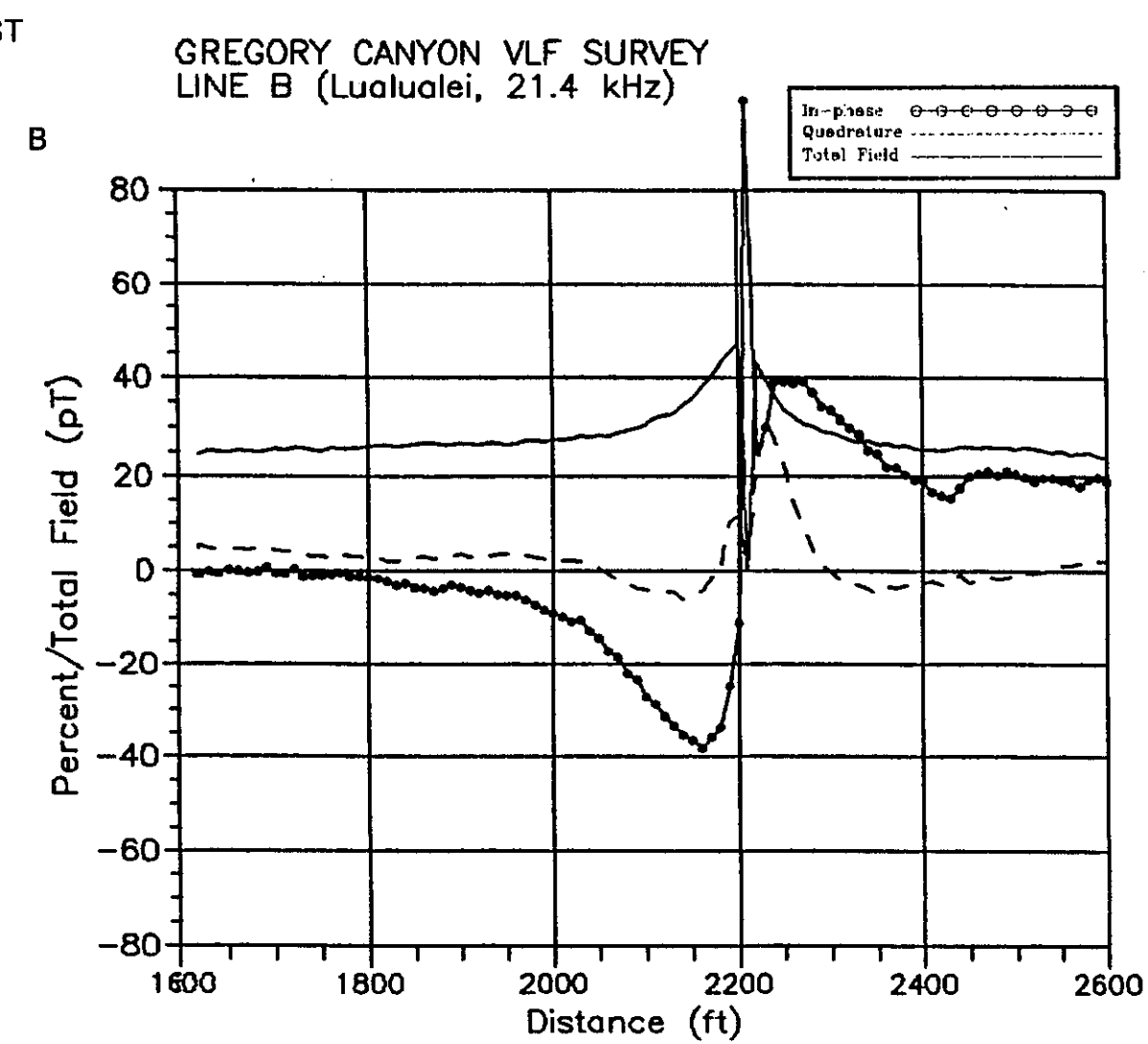


Figure B-4

WEST

EAST

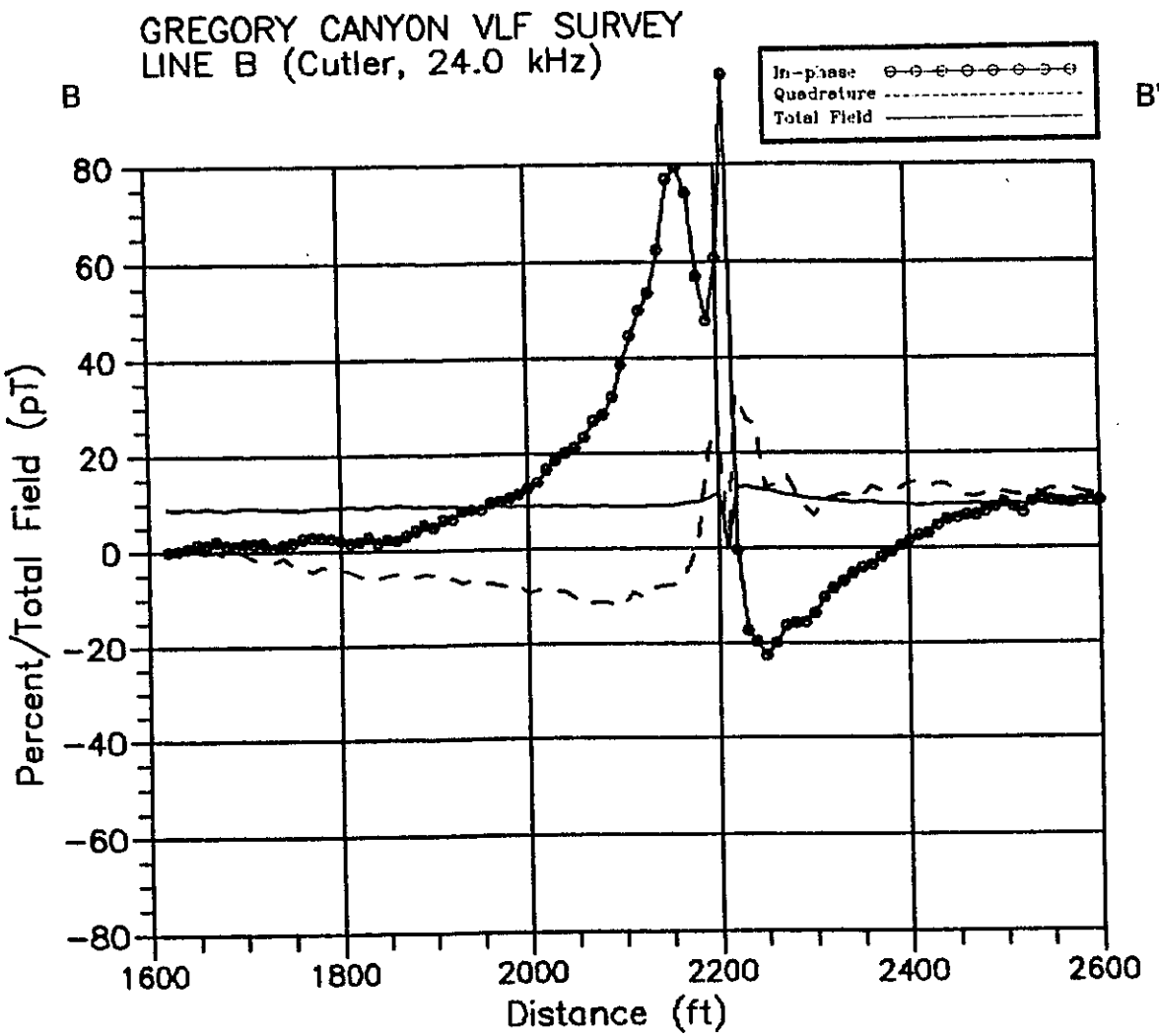


Figure B-5

WEST

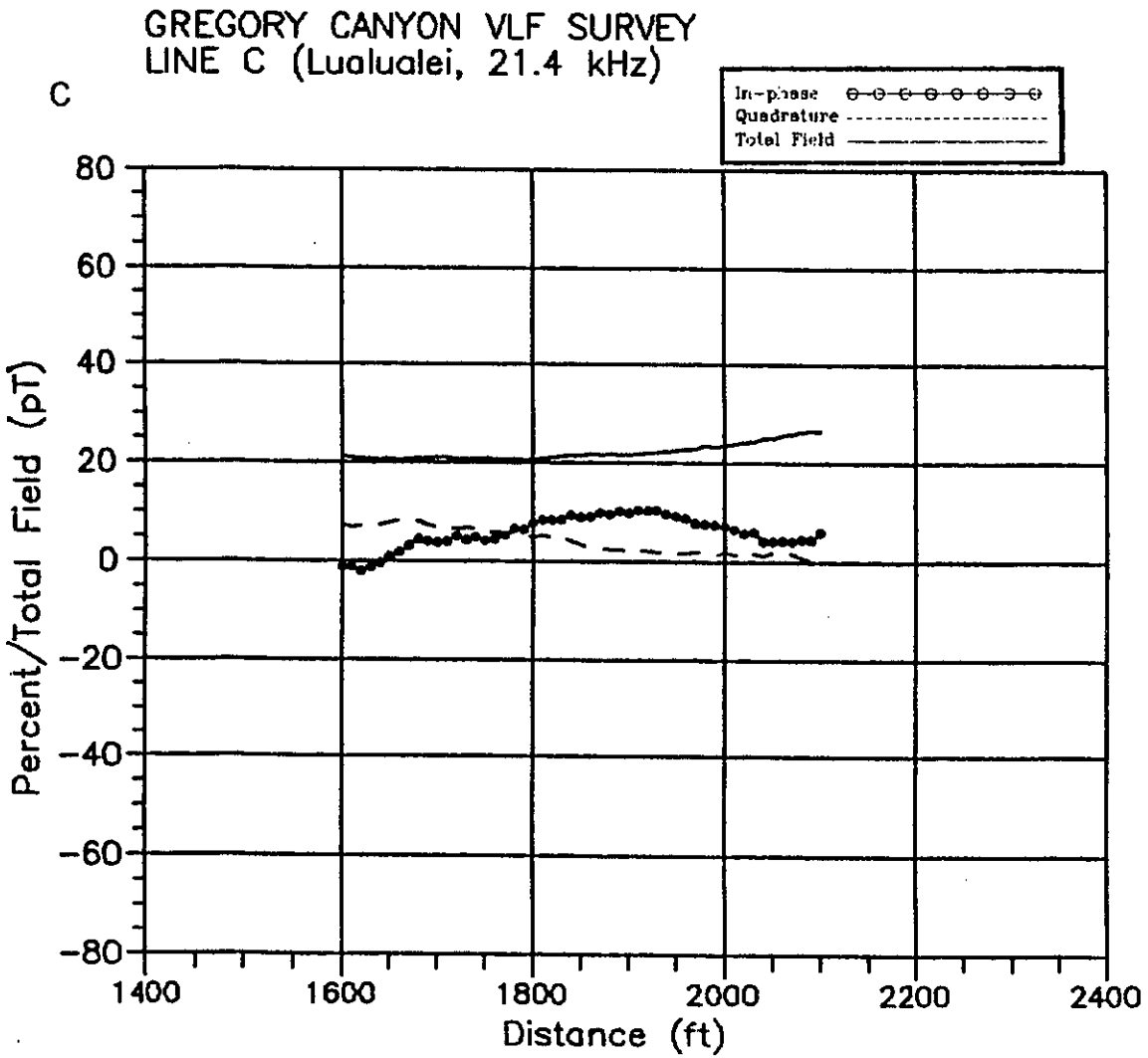


Figure B-6

WEST

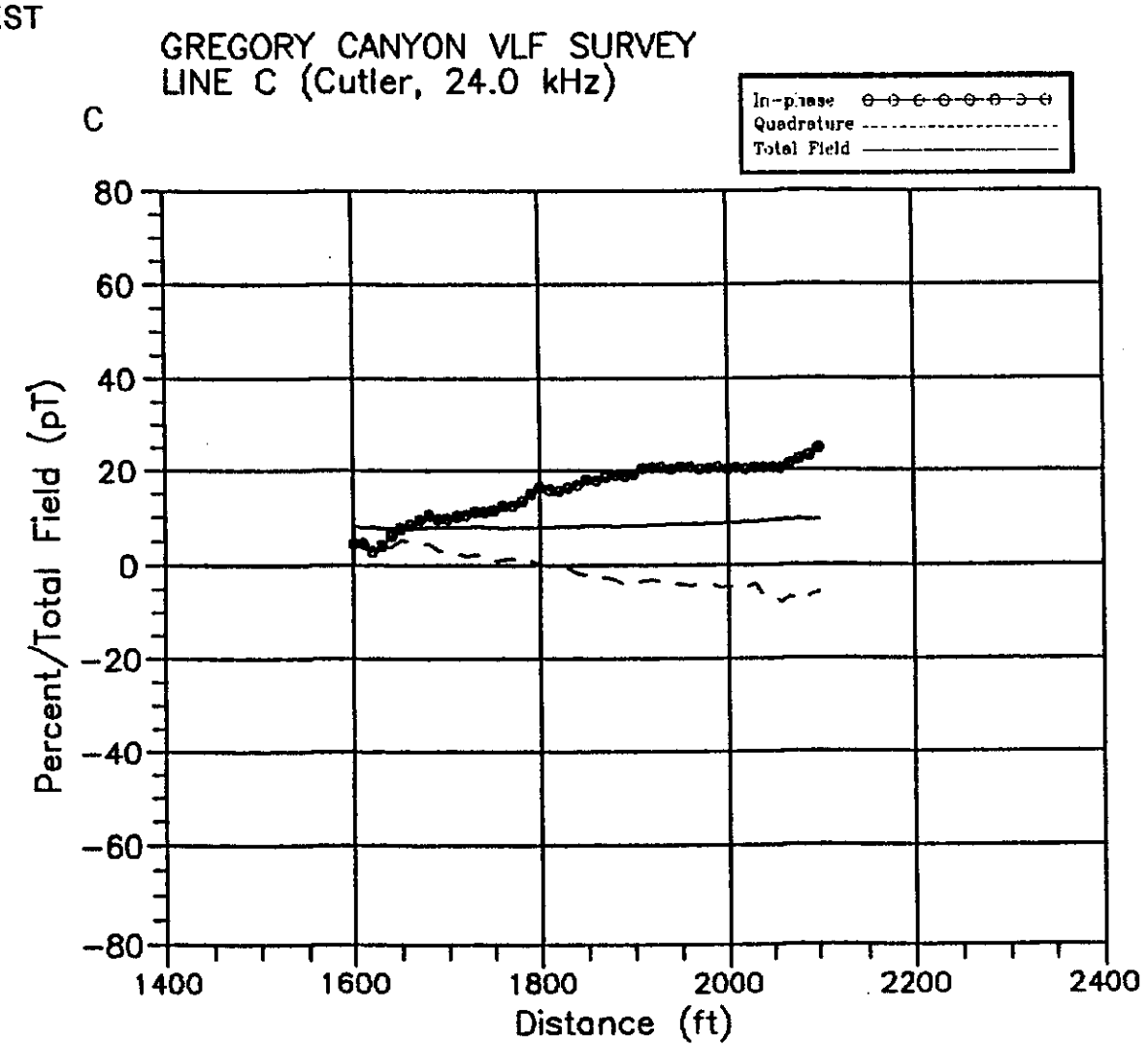


Figure B-7

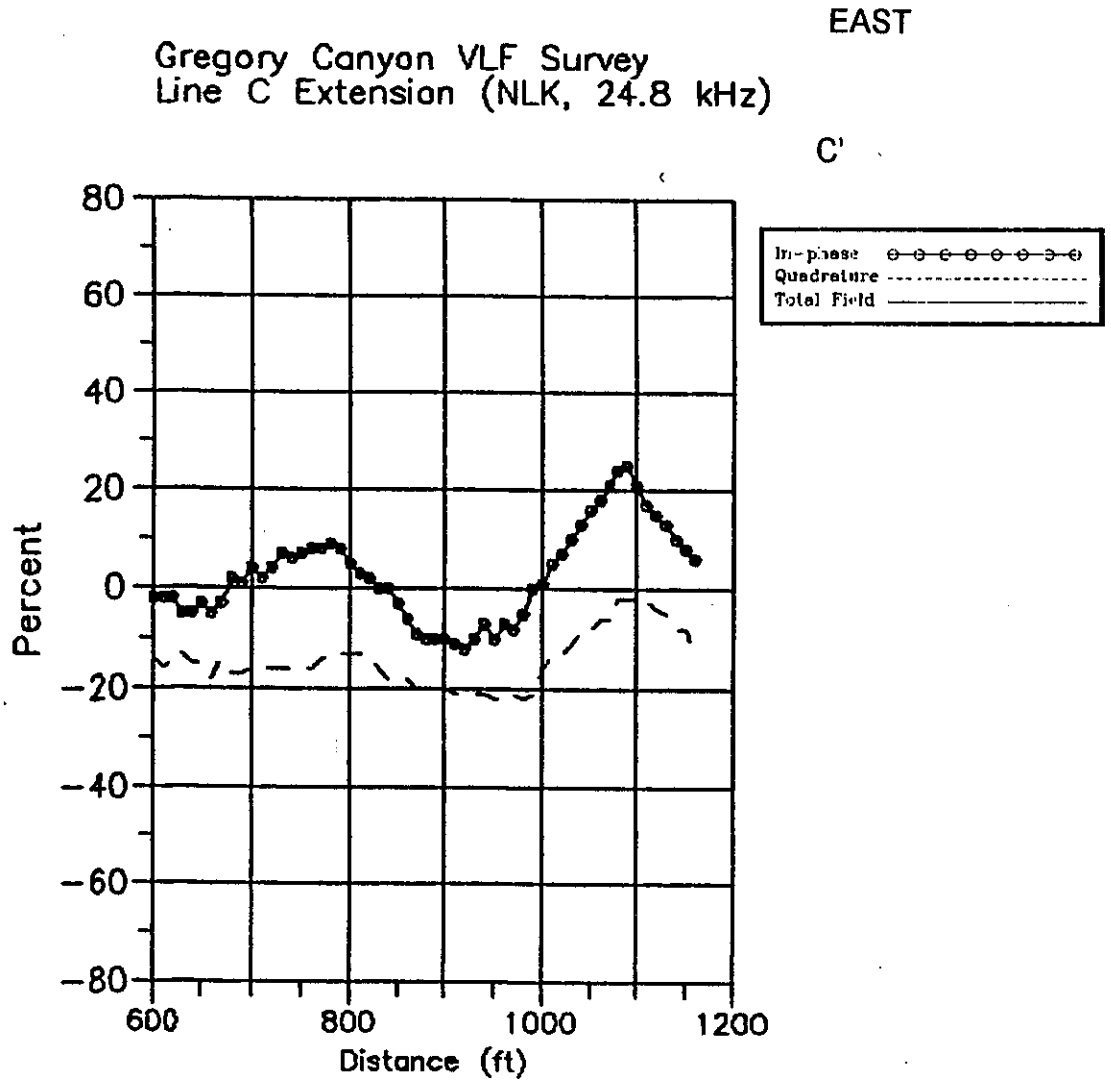
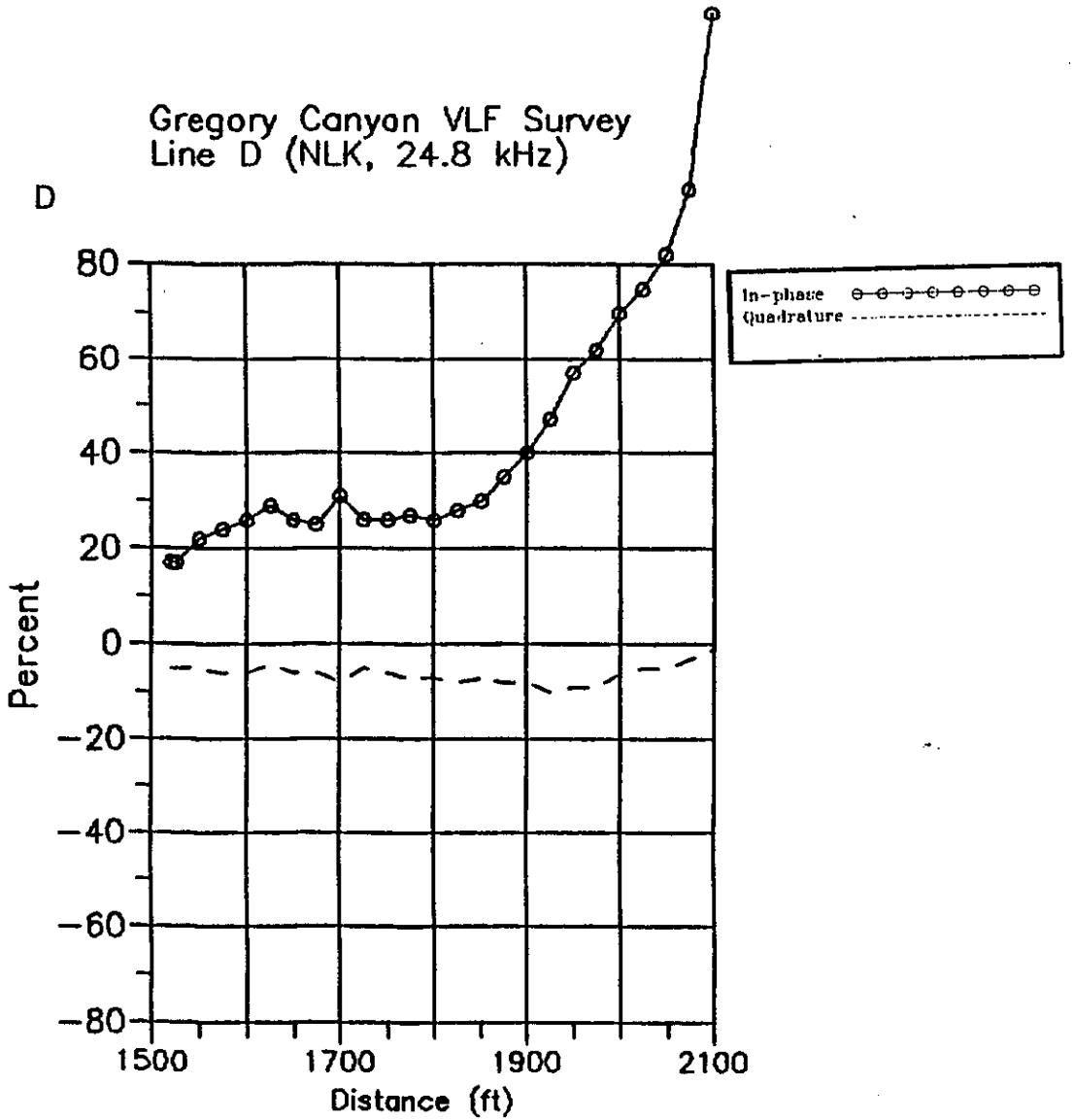

EAST
Gregory Canyon VLF Survey
Line C Extension (NLK, 24.8 kHz)
C'
In-phase
Quadrature
Total Field
80
60
40
20
0
-20
-40
-60
-80
Percent
600
800
1000
1200
Distance (ft)

Figure B-8

WEST



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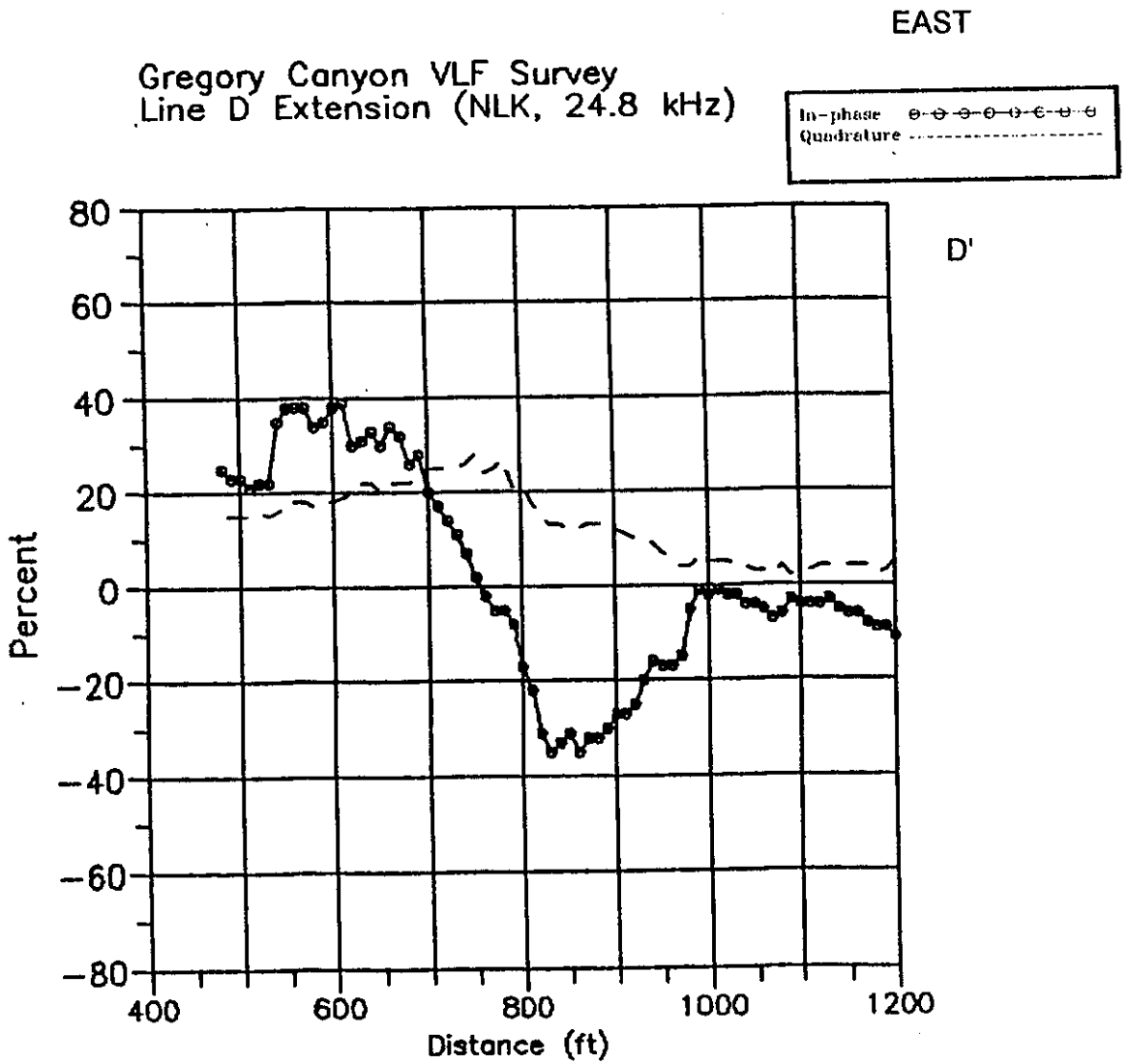

EAST
Gregory Canyon VLF Survey
Line D Extension (NLK, 24.8 kHz)
In-phase
Quadrature
D'
80
60
40
20
0
-20
-40
-60
-80
Percent
400
600
800
1000
1200
Distance (ft)

Figure B-10

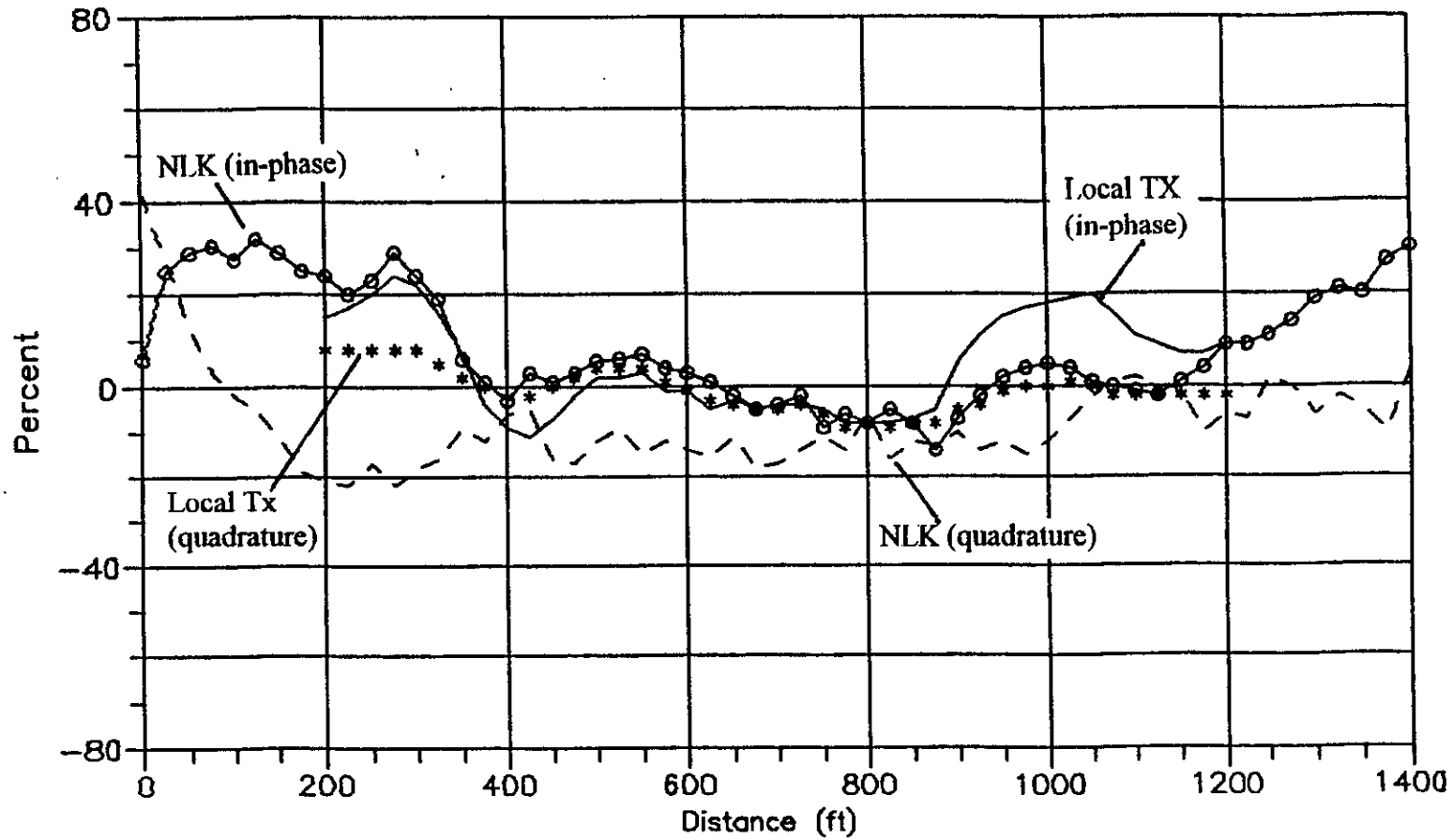
WEST

EAST

Gregory Canyon VLF Survey
Line E; (Local Tx, 16.55 kHz; NLK, 24.8 kHz)

E

E'



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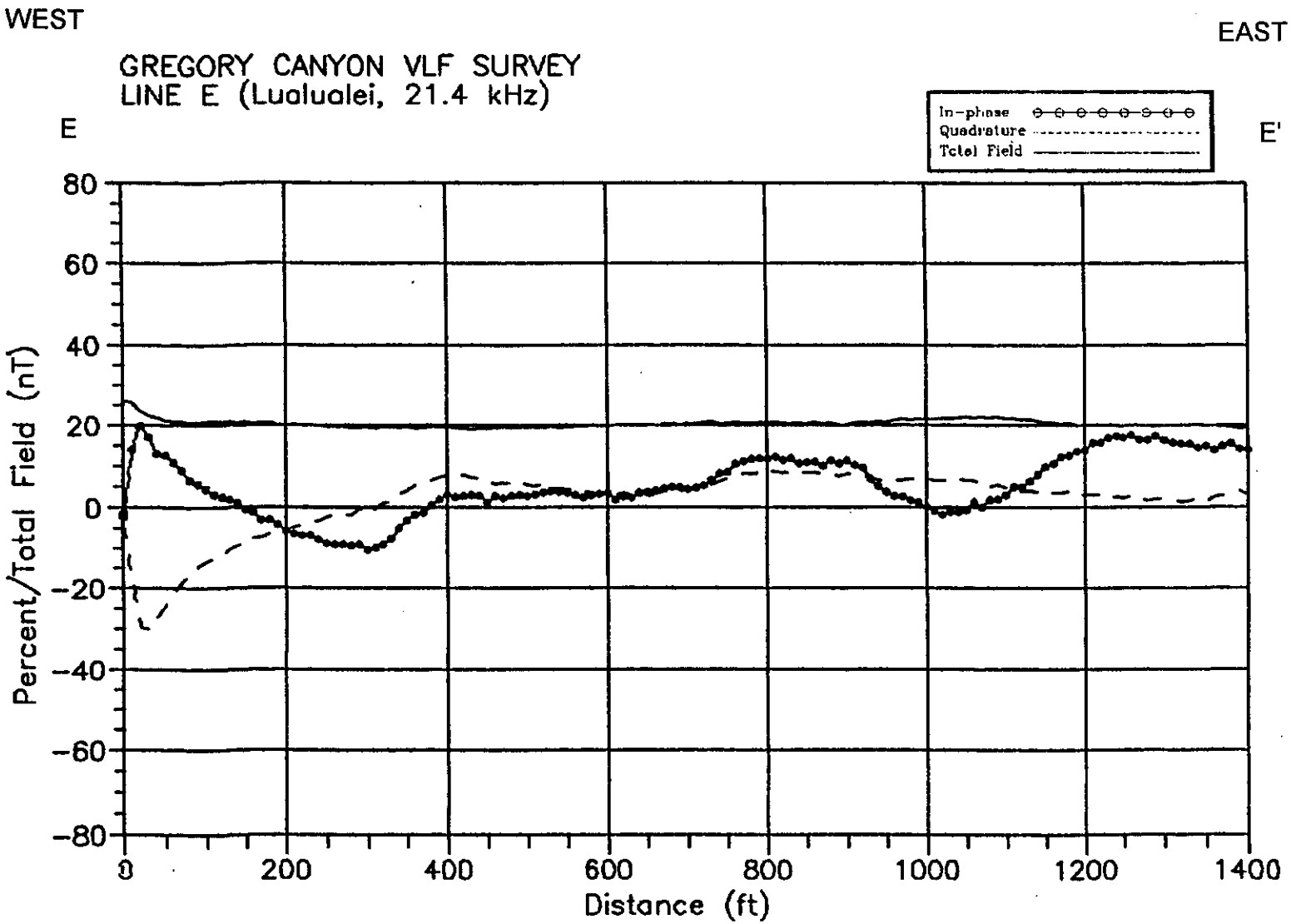
WEST
EAST
GREGORY CANYON VLF SURVEY
LINE E (Lualualei, 21.4 kHz)
E
E'
In-phase
Quadrature
Total Field
Percent/Total Field (nT)
80
60
40
20
0
-20
-40
-60
-80
0
200
400
600
800
1000
1200
1400
Distance (ft)

Figure B-12

GeoLogic Associates

BORING LOG

BORING NO.: GLA-10

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG / T. REEDER

DATE STARTED: 12/03/96
DATE FINISHED: 12/05/96
ELEVATION: 325 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 33 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USGS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
						60					...(60') - dry.
										...(62') - color change to dark greenish gray (10Y4/1).	
						65					
						70				...(70') - color change to pale olive to olive (5Y5.5/3).	
										...(73') - color change to greenish gray (5GY5.5/1).	
						75					
										...(77') - color change to gray (N5).	
12/05 8:54	13:04					80					...(80') - stop drilling to set conductor casing to 50' below ground surface.
						85				TONALITE/DIORITE. Very dark gray (N3). Weathered and moderately decomposed. Fe-oxide stained with altered mica and/or pyrite on oxidized pieces; chloritization of some mafics.	...(87') - water production from borehole while drilling approximately 5-6 gpm.
						90				GRANODIORITE dikes in TONALITE. White (N8). Contains black (N2.5) mafic minerals (biotite, hornblende and pyroxene). Very slight chloritization of some mafics (pyroxene) in very dark gray (N3), weathered and moderately decomposed TONALITE.	...(90') - wet.
						95				...(95') - less than 10% GRANODIORITE dike fragments in TONALITE.	
9:27	9:25	0.65				100				...(100') - 40% GRANODIORITE in TONALITE.	
						105				...(105') - dark gray (N4) mixed TONALITE and GRANODIORITE.	Moist.
						110				Gray (N5 to N6) GRANODIORITE.	
						115				Gray (N5 to N6) GRANODIORITE/TONALITE.	...(115') - wet.
10:05	10:02	0.57				120				...(120') - same as above.	Wet.

CONTINUED ON NEXT PAGE

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.

GeoLogic Associates

BORING LOG

BORING NO.: GLA-10

JOB NO.: 9539
SITE LOCATION: GREGORY CANYON
DRILLING METHOD: DUAL-WALL REVERSE, AIR
CONTRACTOR: LAYNE - ENVIRONMENTAL
LOGGED BY: M. VINCENT, CEG / T. REEDER

DATE STARTED: 12/03/96
DATE FINISHED: 12/05/96
ELEVATION: 325 feet
NORTHING: ND
EASTING: ND

GW DEPTH: 33 feet
TOTAL DEPTH: 150 feet

TIME START	TIME STOP	RATE, FT/MIN	WATER SAMPLE INTERVAL	SAMPLE SIZE, INCHES	SAMPLE NO.	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
10:05						120				...(120') - same as above.	Wet.
						125				...(125') - less than 5% orthoclase feldspar.	
						130				...(130') - no potassium-feldspar; less than 5% GRANODIORITE dikes in TONALITE.	
						135				...(135') - increase in GRANODIORITE to approximately 50% of cuttings; moderately weathered, with minor pink potassium-feldspar.	
10:47	10:44	0.51				140				...(140') - moderately weathered TONALITE with GRANODIORITE dikes.	
						145				Gray (N6), moderately weathered TONALITE/ GRANODIORITE with some epidote/chlorite alteration.	...(145') - wet.
	11:06	0.53				150				...(150') - less than 1% epidote or zeolite alteration and fracture infillings.	
						155				Notes: 1. Total depth of borehole 150 feet. 2. Conductor casing set to 50 feet. 3. Open hole interval (exposed bedrock) between 50 and 150 feet below ground surface. 4. Groundwater first encountered at 33 feet. 5. Depth to water on 12/16/96 measured at 22.20 feet.	

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.

APPENDIX B

REPORT ON THE VLF SURVEY
(The Geophysics Group, 1997)

The Geophysics Group
260 S. Orange St., Ste. 10 • Escondido, CA 92025
(619) 747-3404

VLF SURVEYING AT THE PROPOSED GREGORY CANYON LANDFILL SITE, SAN DIEGO CO., CA

Final Report

for

GeoLogic Associates
426 Fourteenth Street
Modesto, CA 95354

by

The Geophysics Group
260 S. Orange Street, Suite 10
Escondido, CA 92025

April, 1997

WEST

EAST

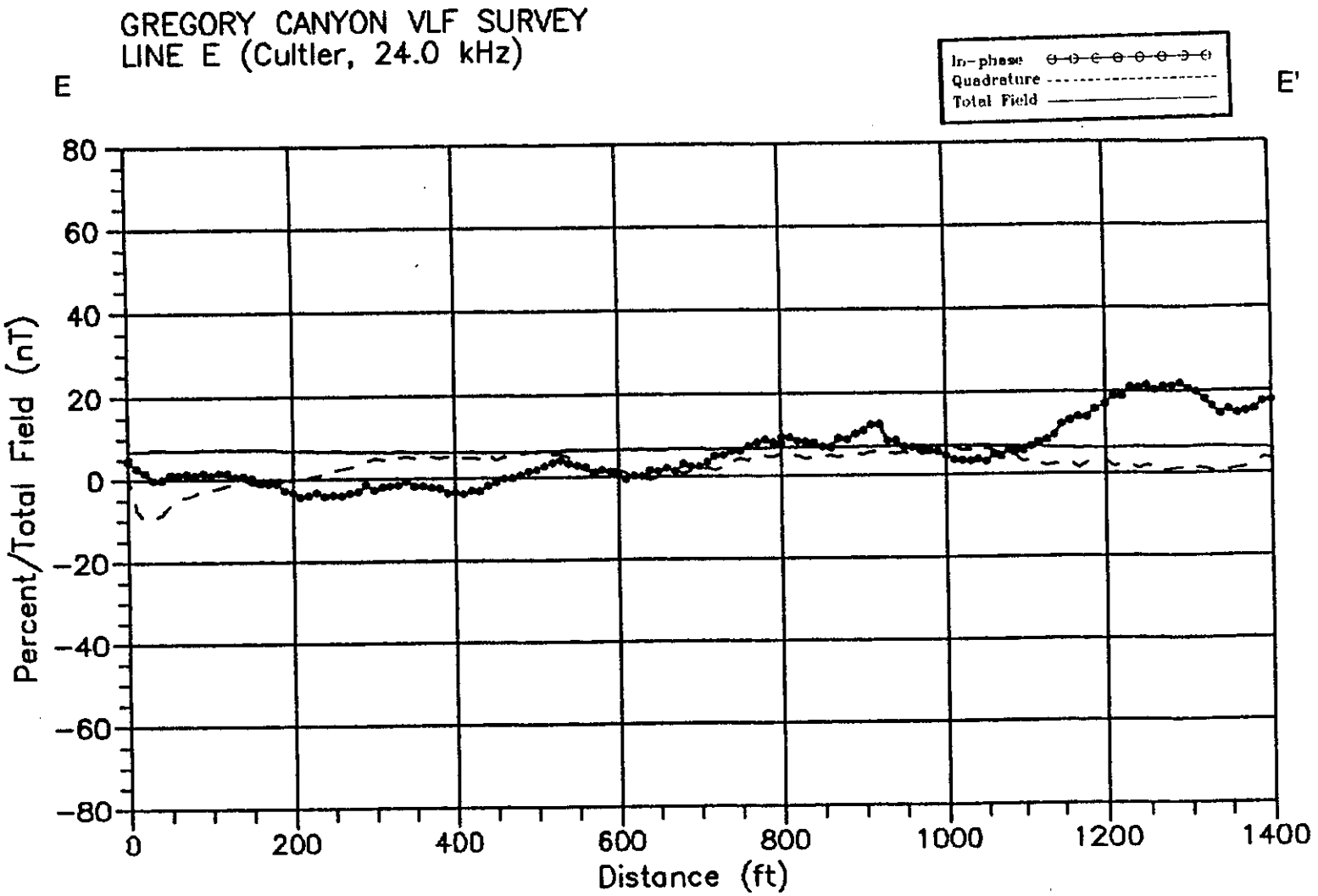

Figure B-13

WEST

EAST

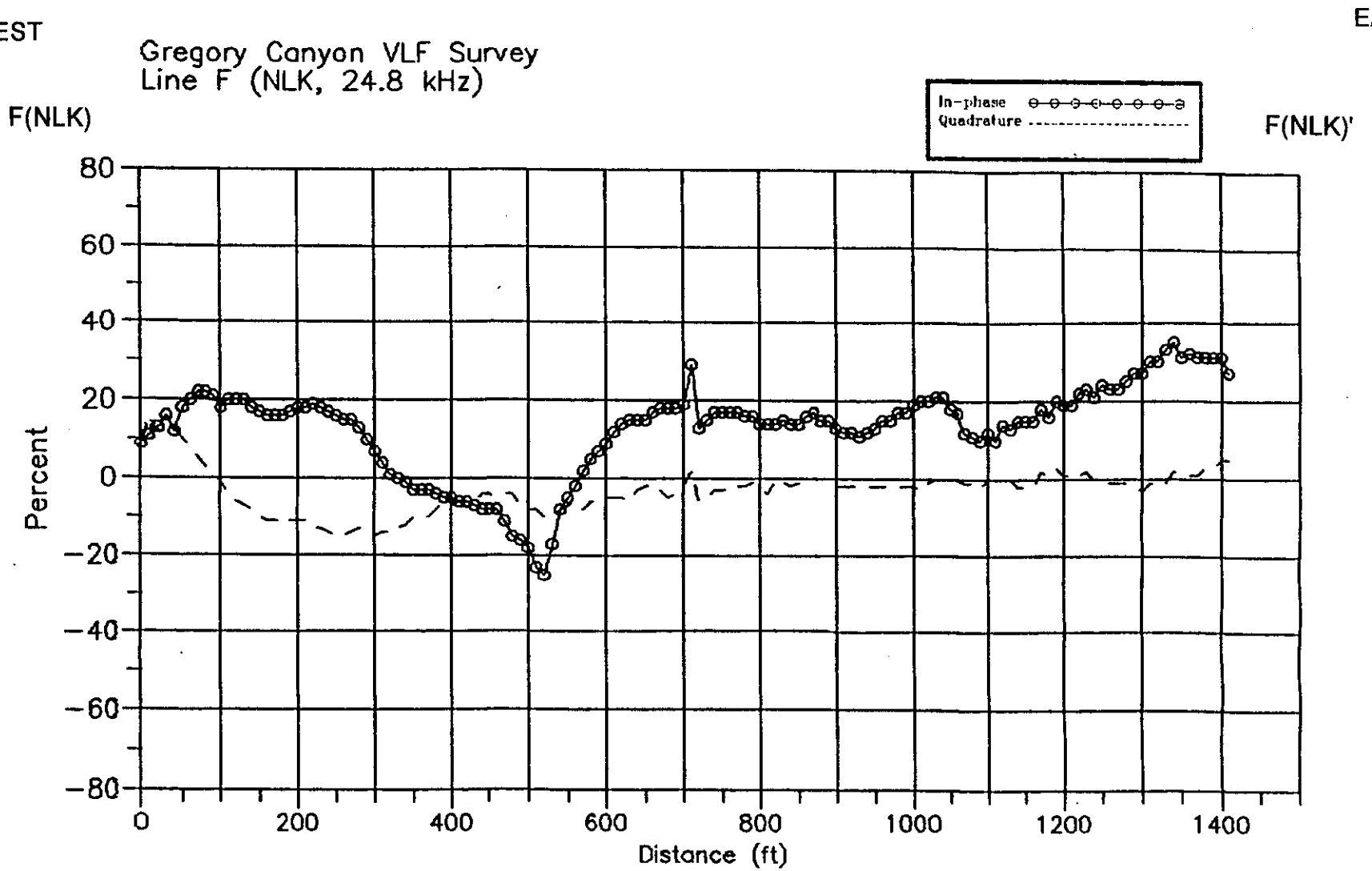

Figure B-14

WEST

EAST

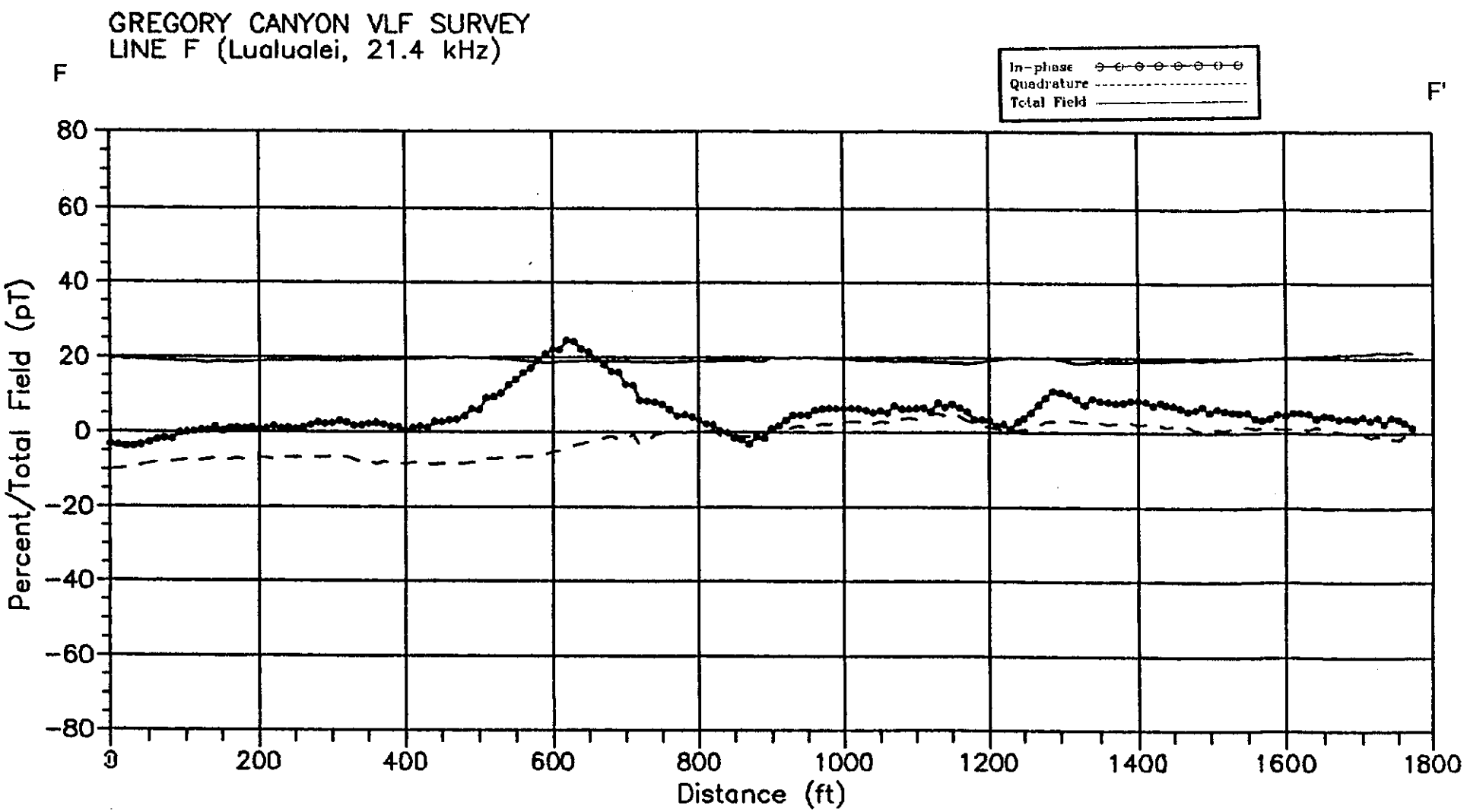

Figure B-15

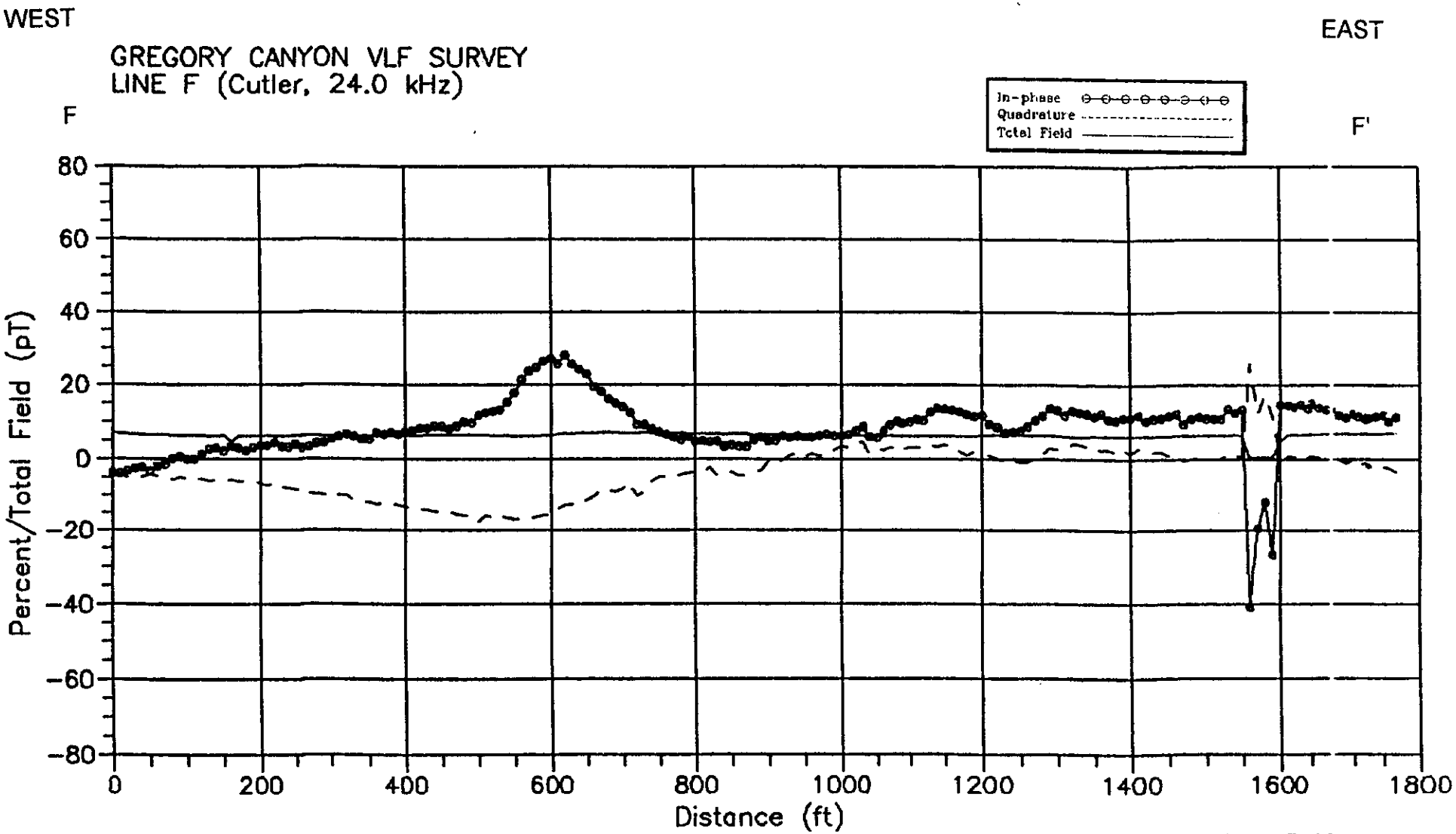
WEST
EAST
GREGORY CANYON VLF SURVEY
LINE F (Cutler, 24.0 kHz)
F
F'
In-phase
Quadrature
Total Field
Percent/Total Field (pT)
80
60
40
20
0
-20
-40
-60
-80
0
200
400
600
800
1000
1200
1400
1600
1800
Distance (ft)

Figure B-16

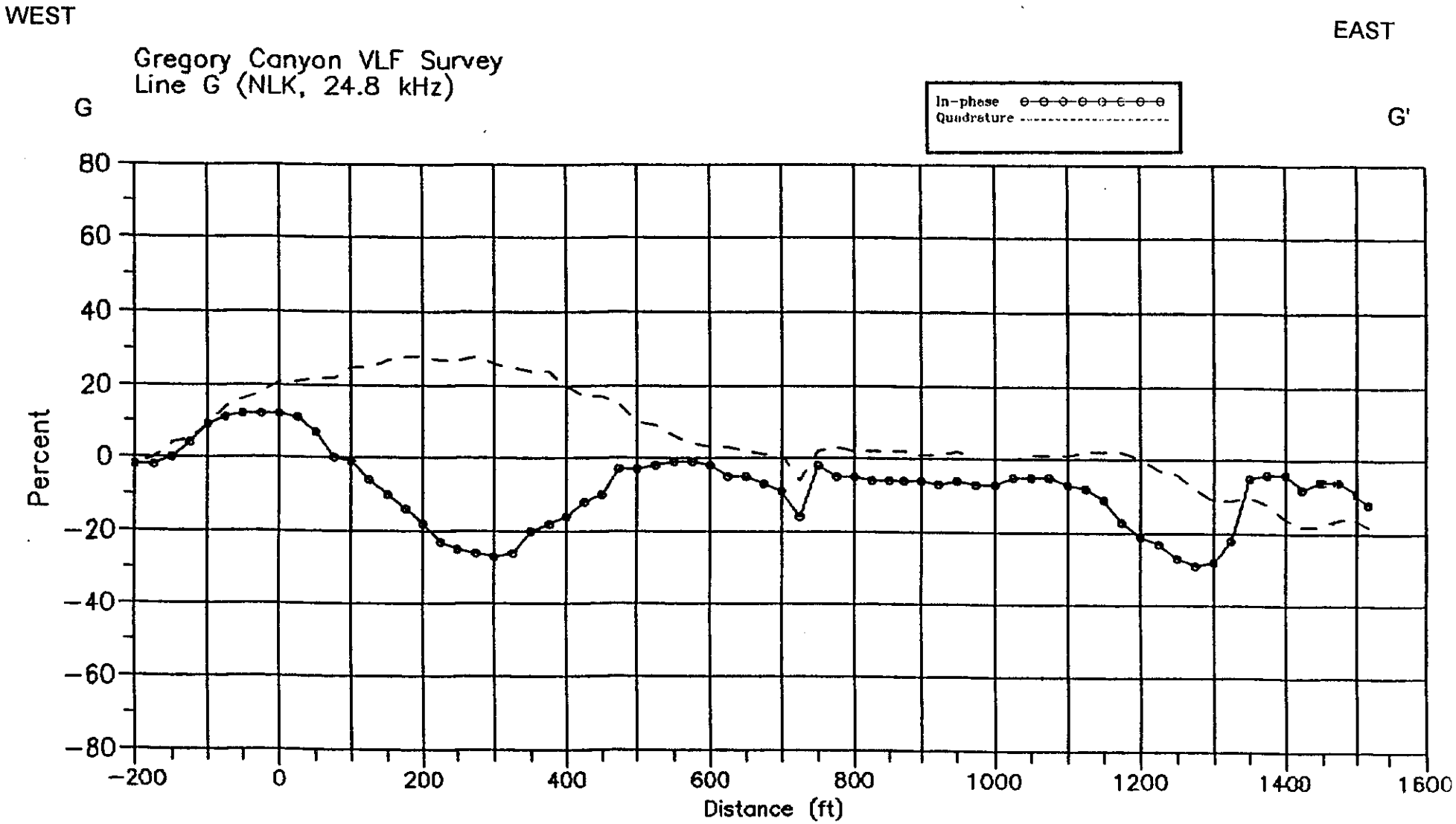
WEST
EAST
Gregory Canyon VLF Survey
Line G (NLK, 24.8 kHz)
G
G'
In-phase
Quadrature
80
60
40
20
0
-20
-40
-60
-80
Percent
-200
0
200
400
600
800
1000
1200
1400
1600
Distance (ft)

Figure B-17

WEST

EAST

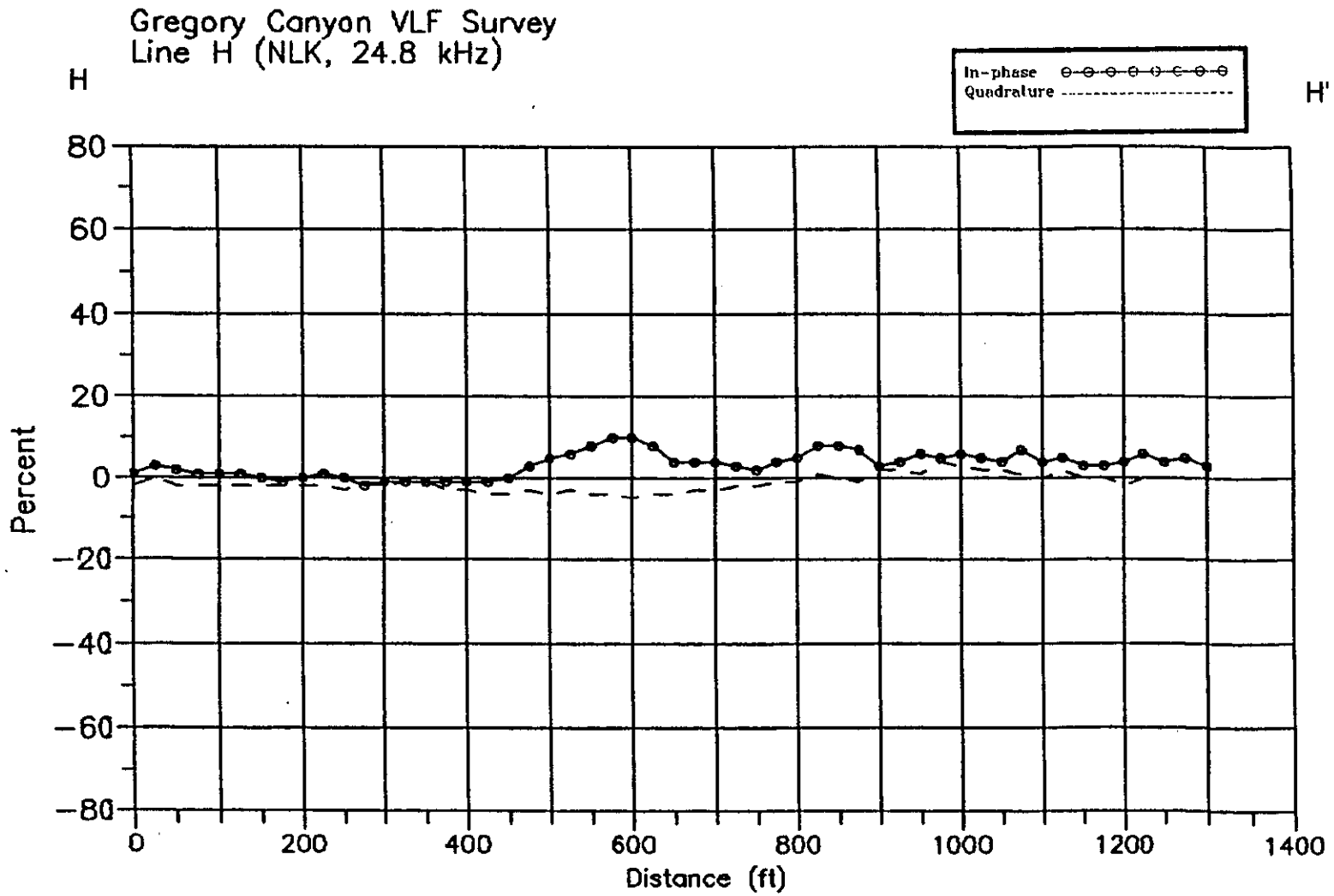

Figure B-18

NORTH

SOUTH

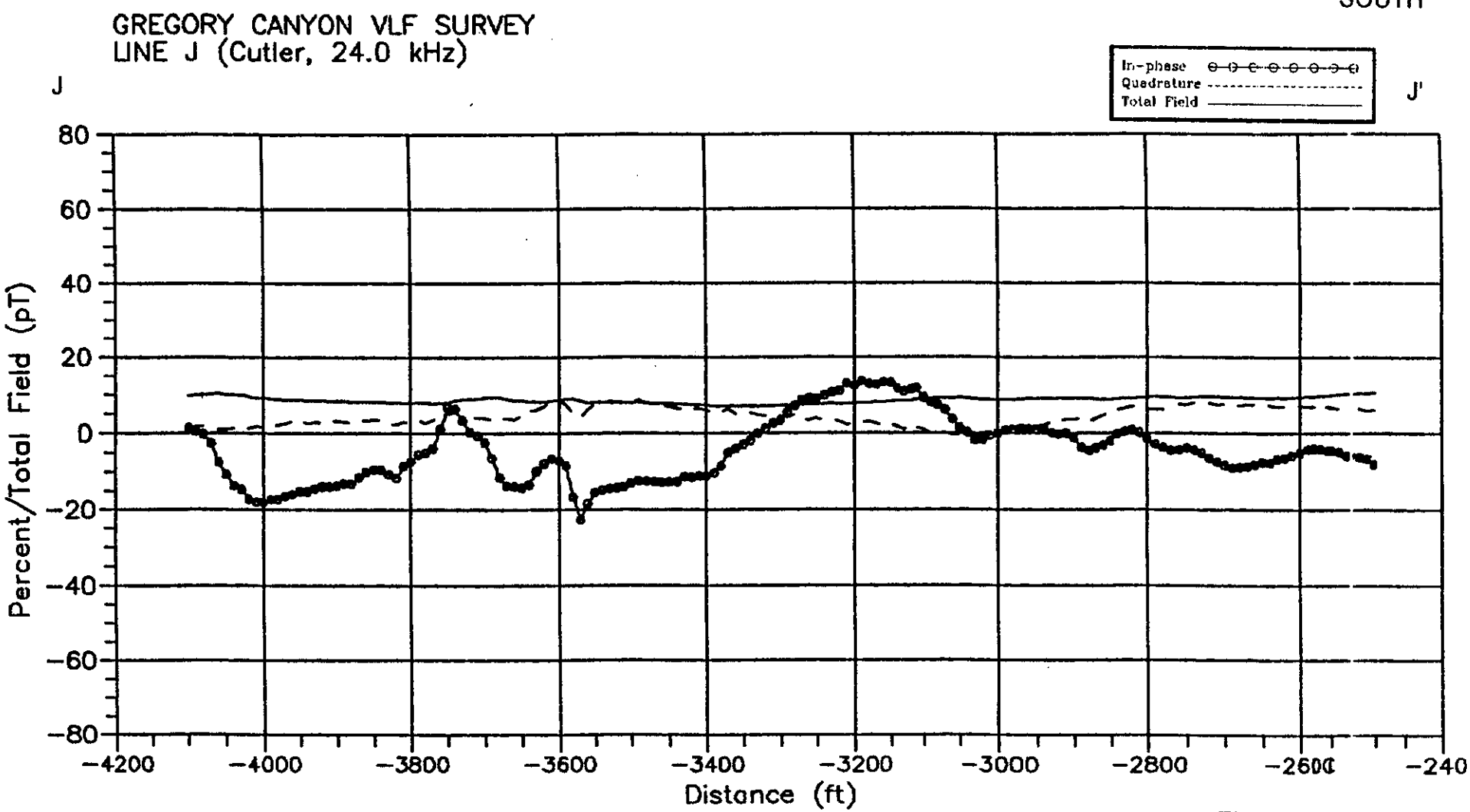

Figure B-19

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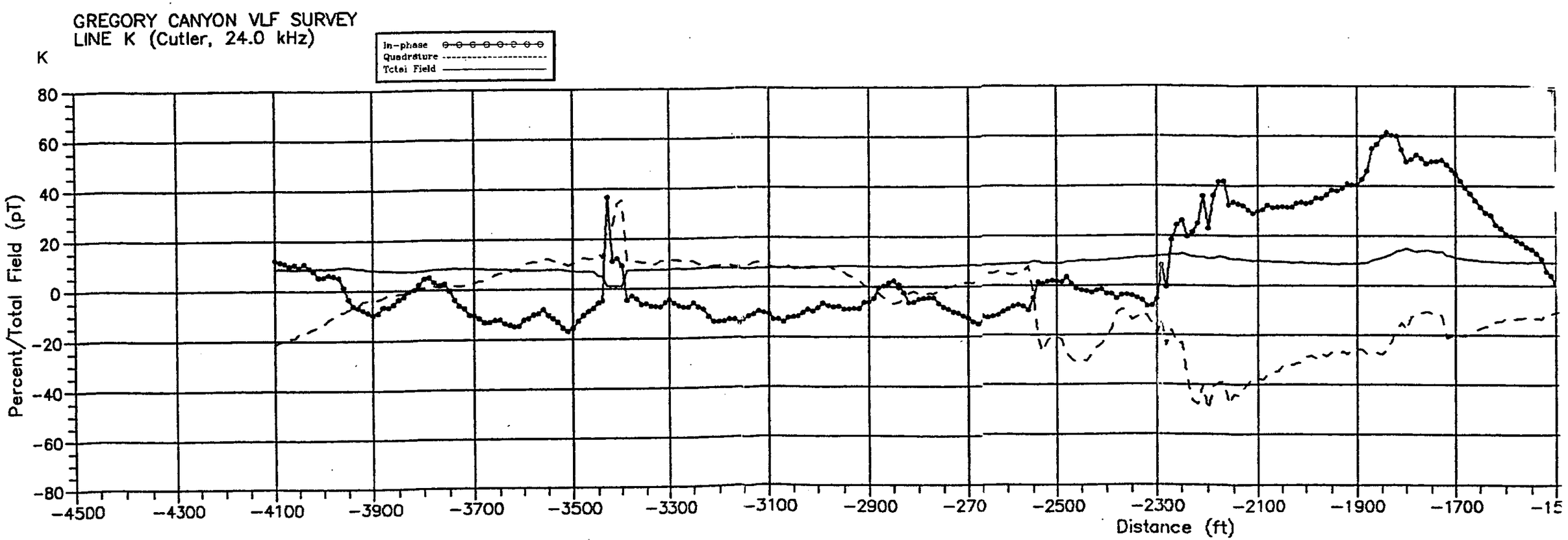

Figure B-20a

SOUTH

K'

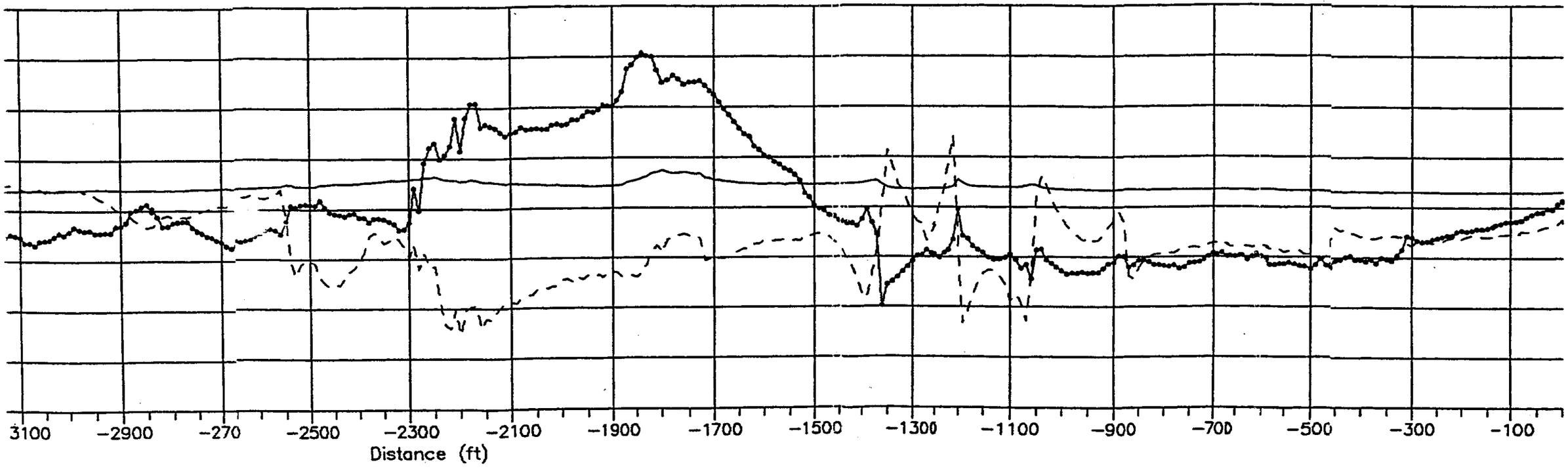

Figure B-20b

NORTH

SOUTH

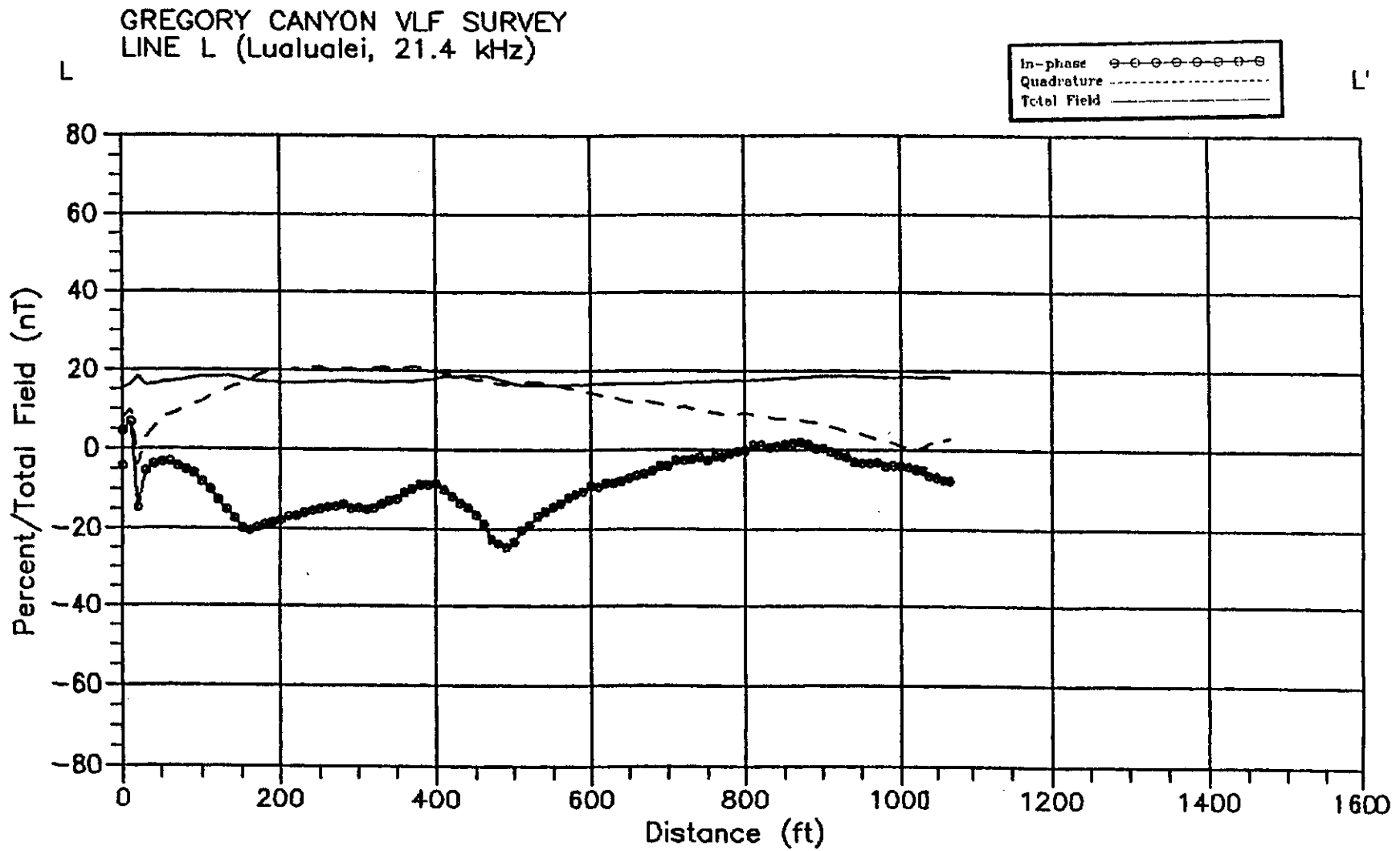

Figure B-21

NORTH

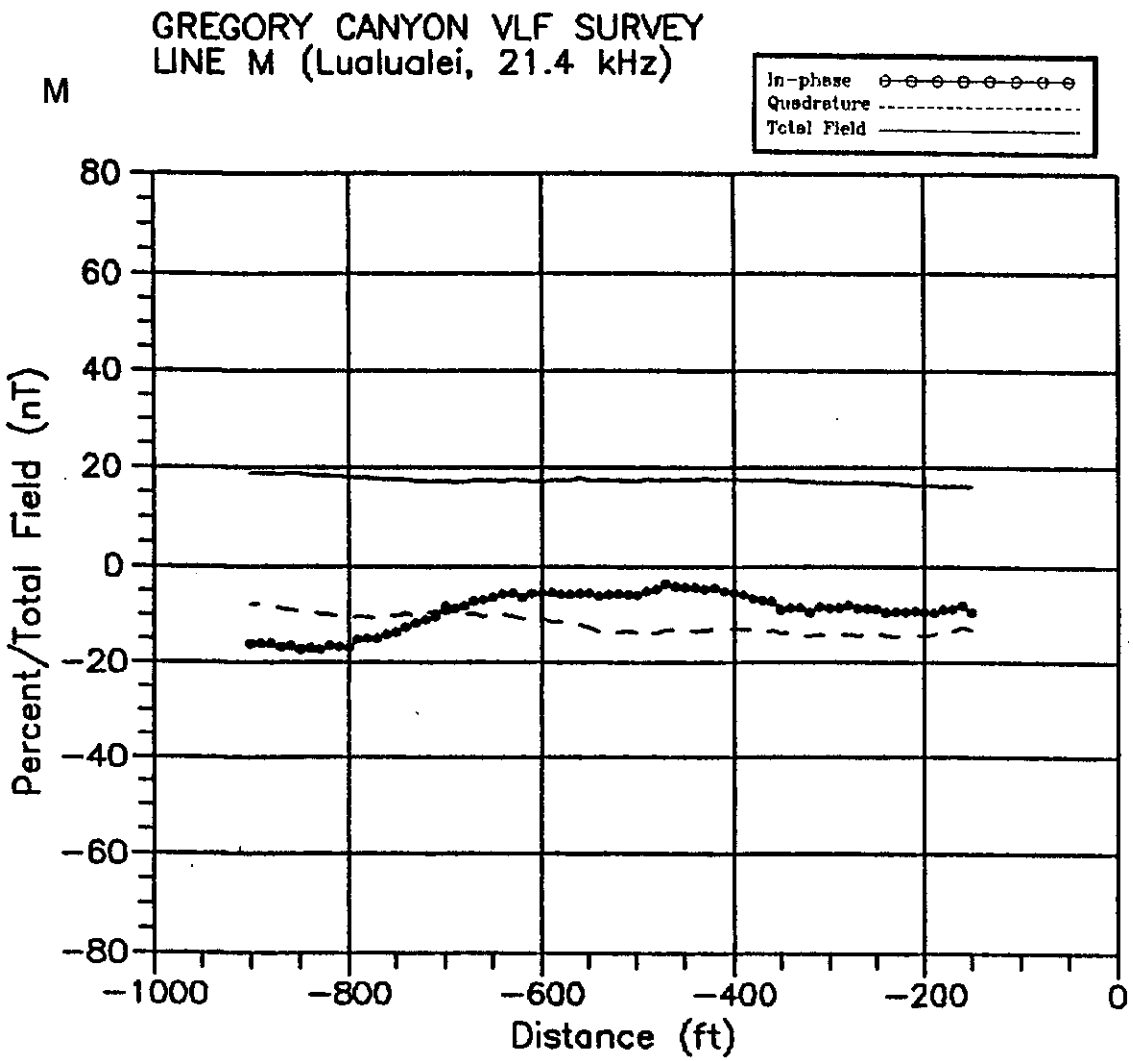

Figure B-22

SOUTH

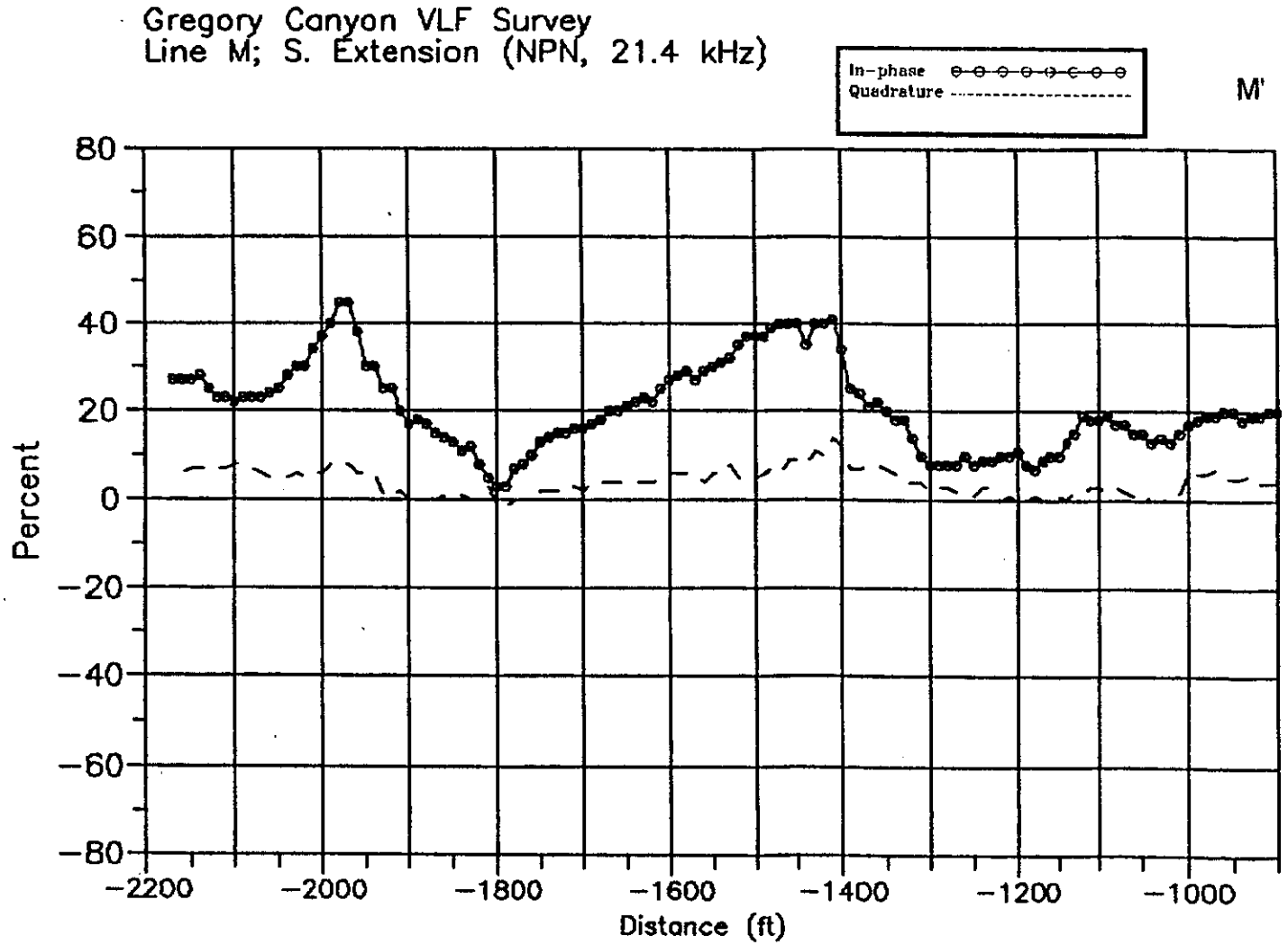

Figure B-23

NORTH

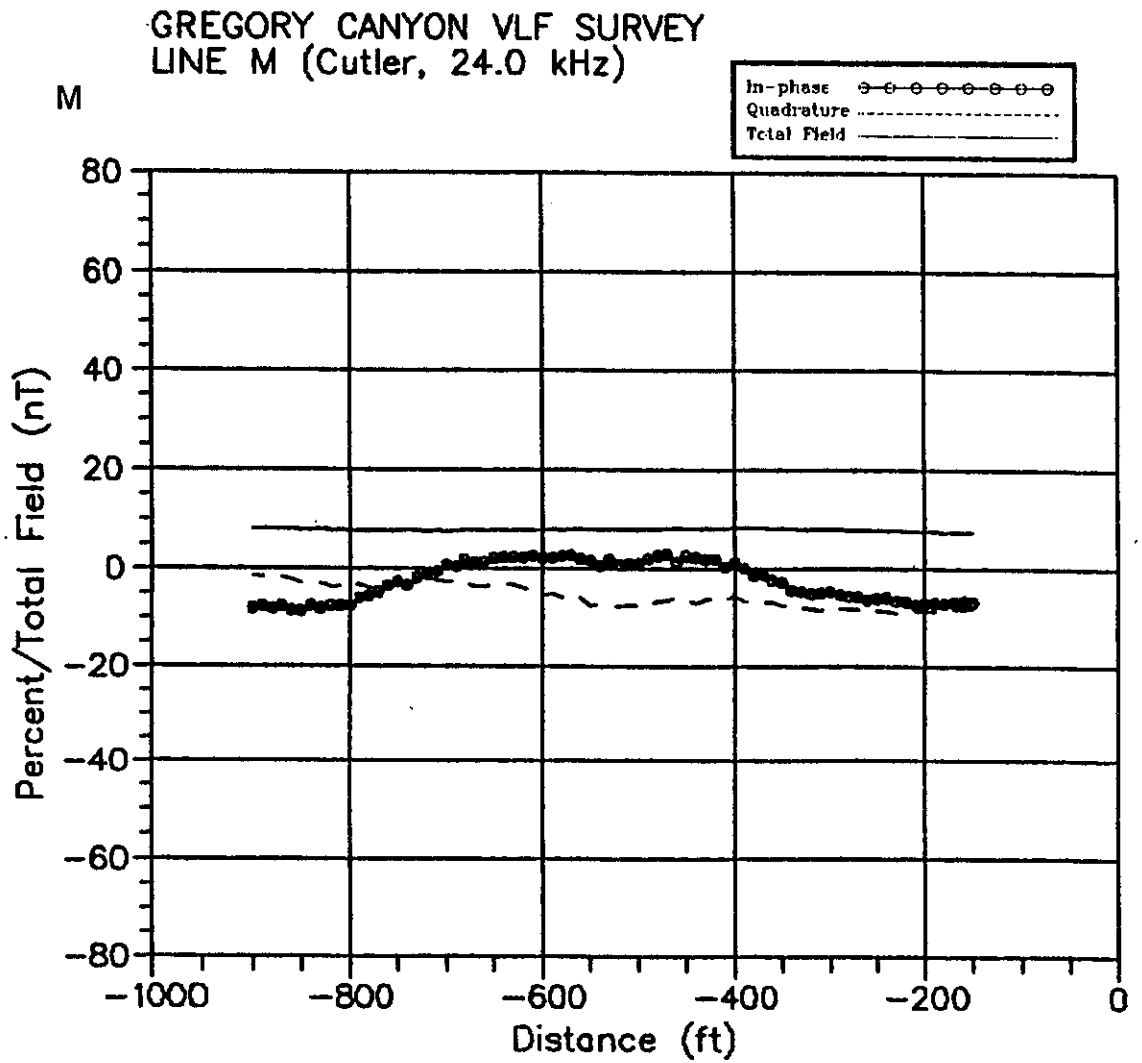

Figure B-24

NORTH

SOUTH

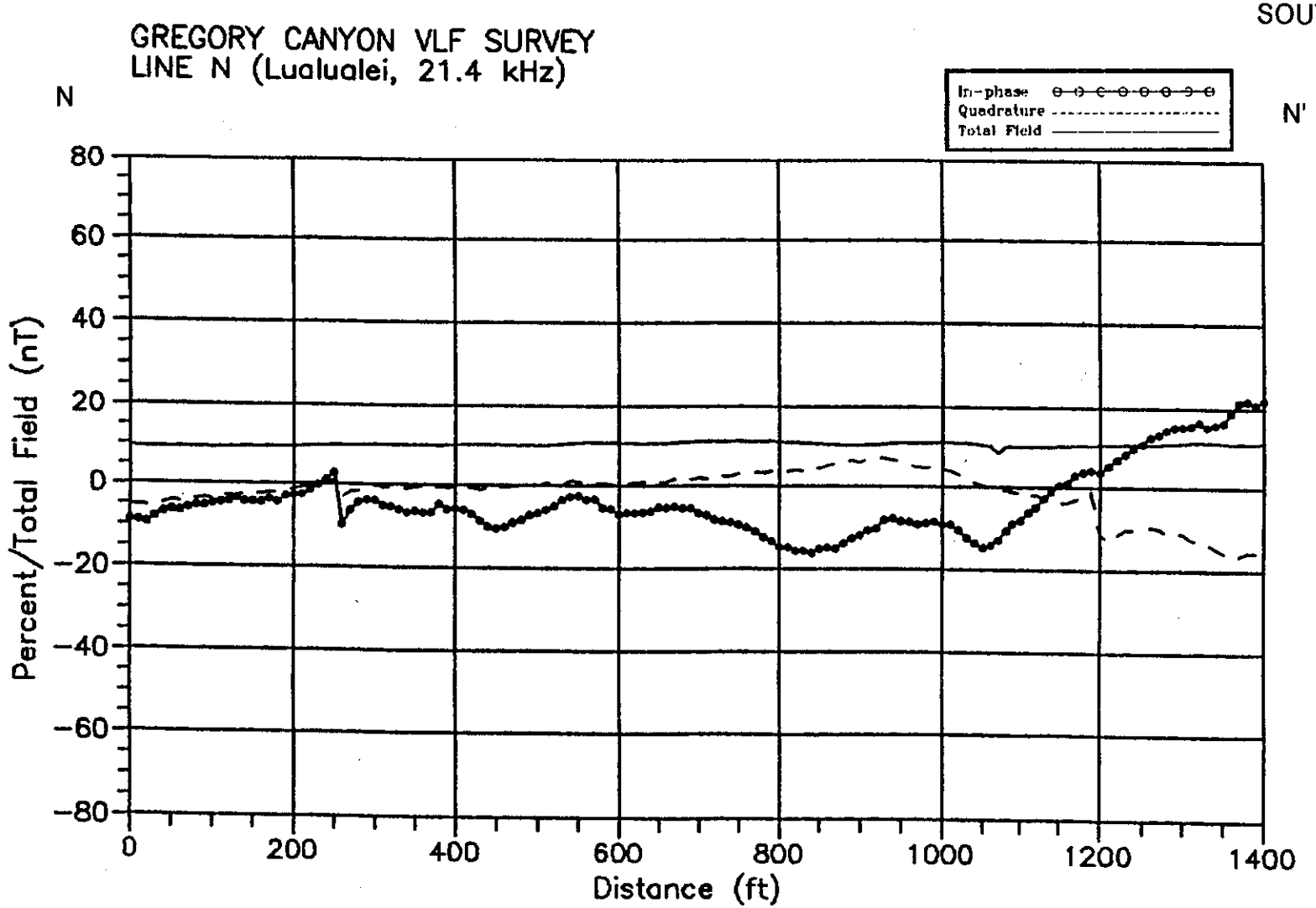

Figure B-25

NORTH

SOUTH

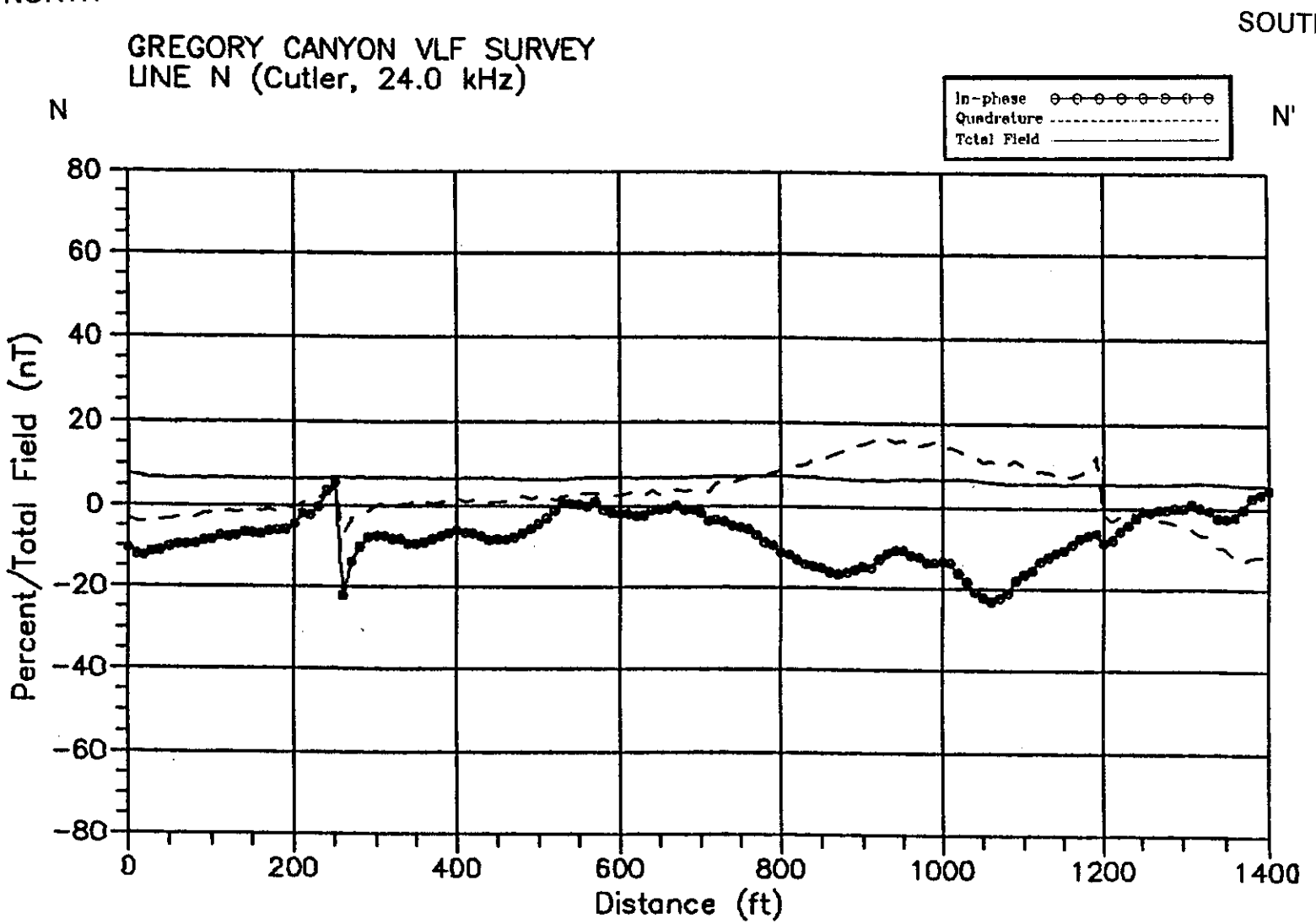

Figure B-26

NORTH

SOUTH

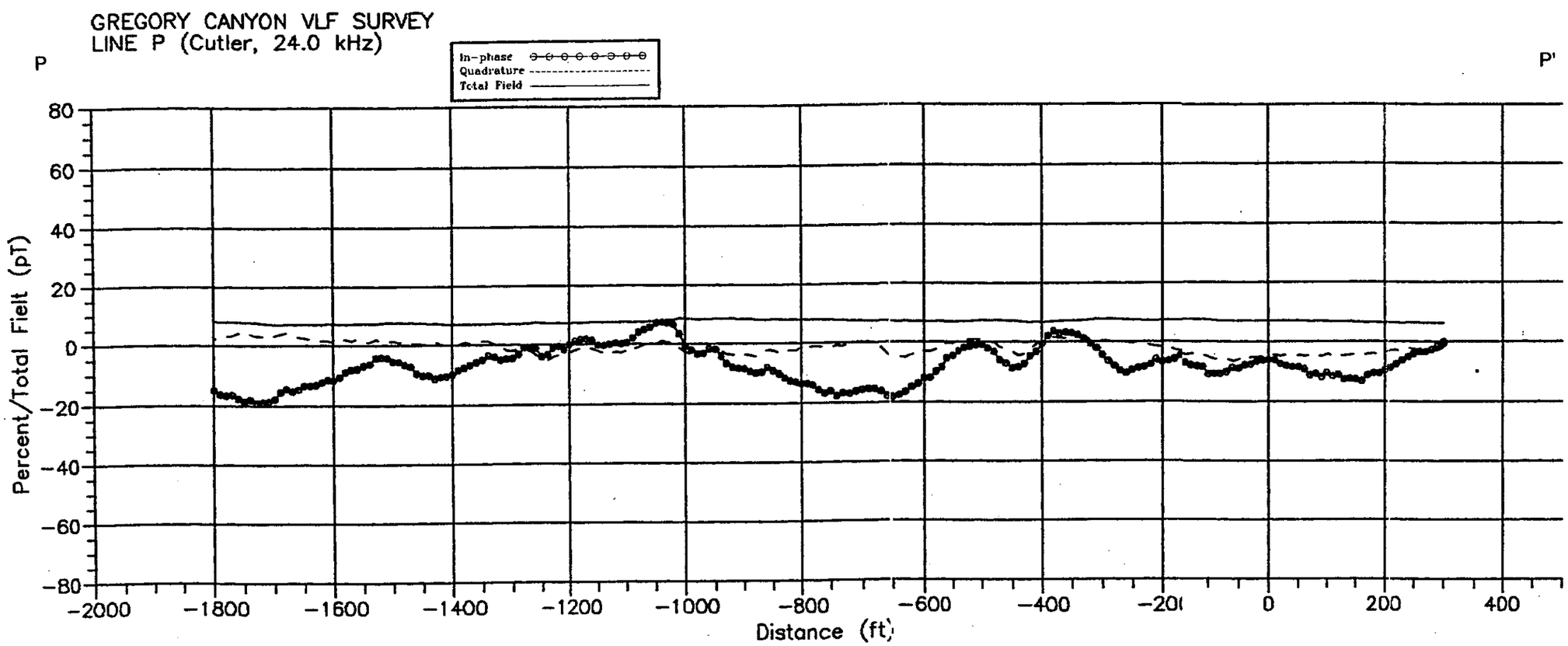

Figure B-27

NORTH

SOUTH

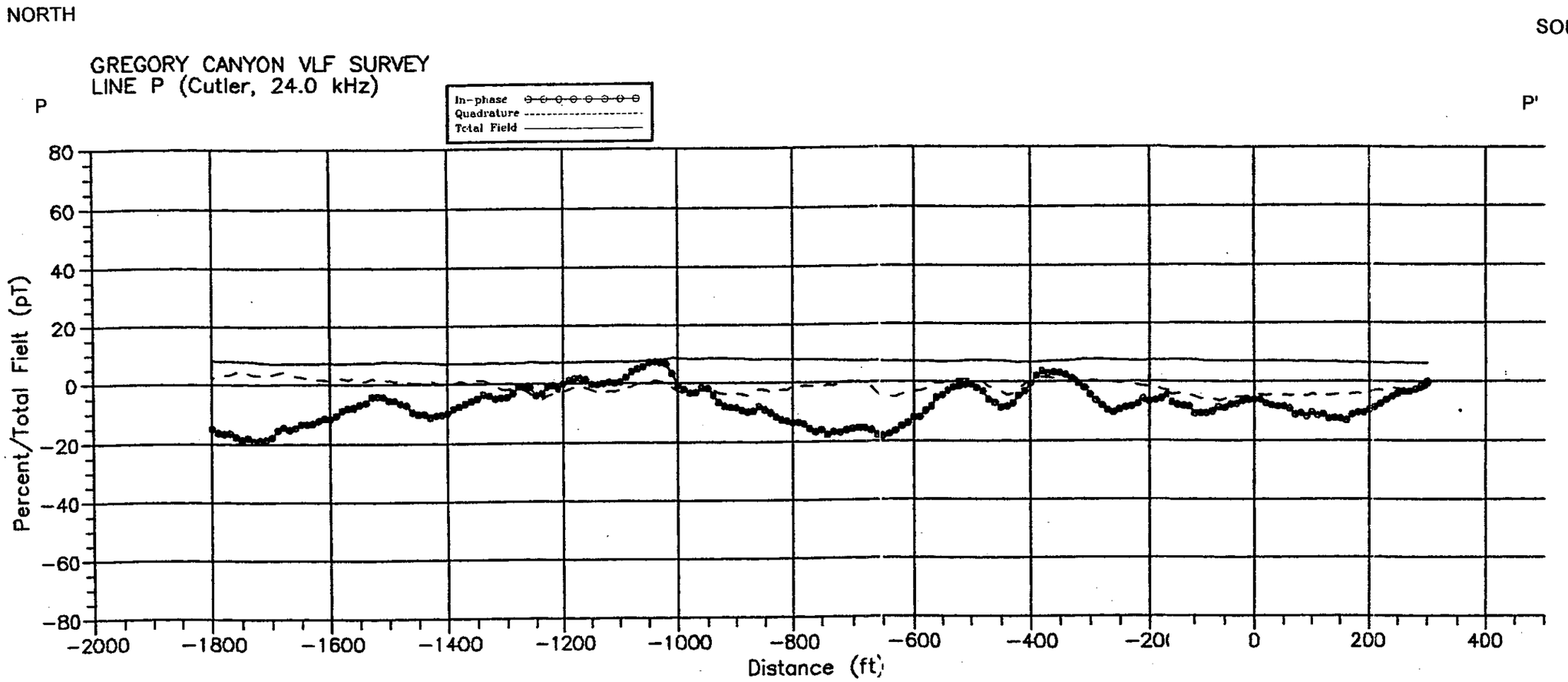

Figure B-27

NORTH

SOUTH

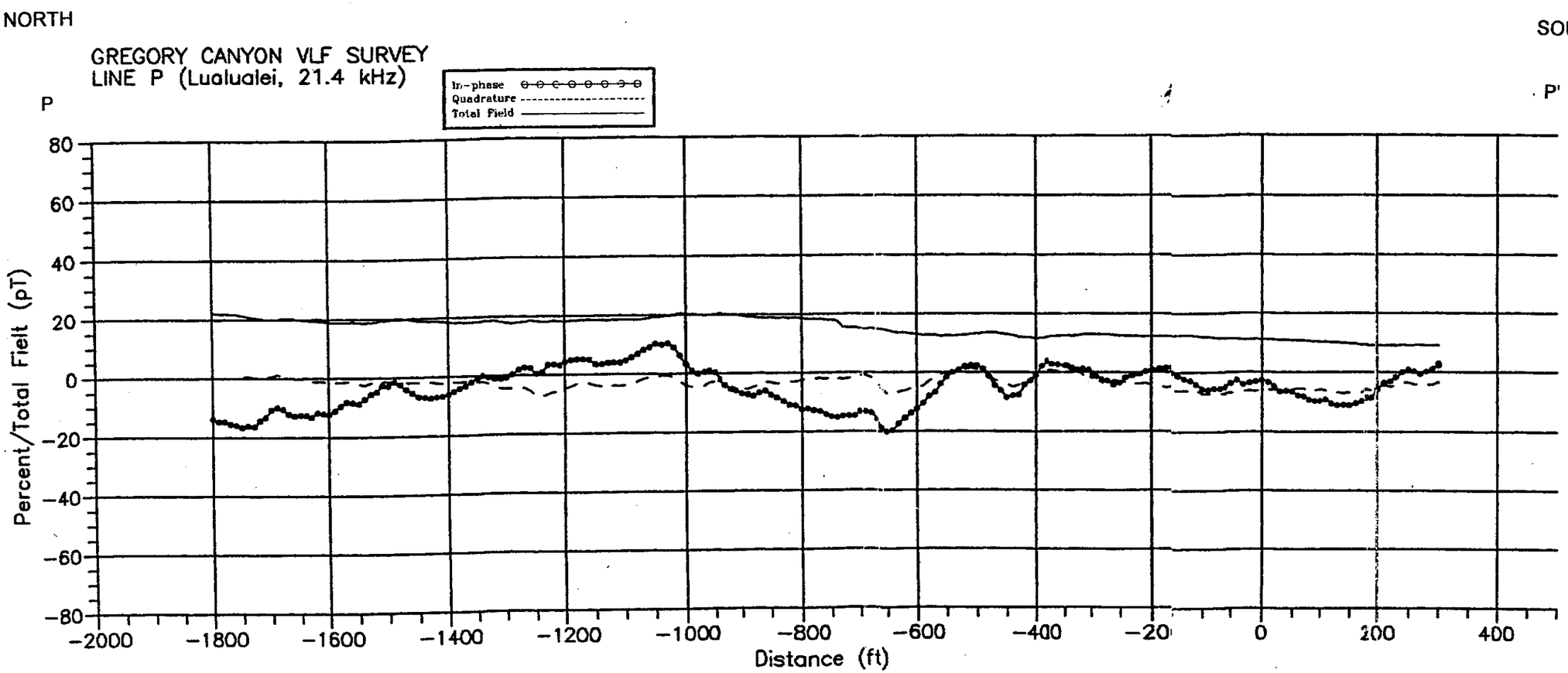

Figure B-28

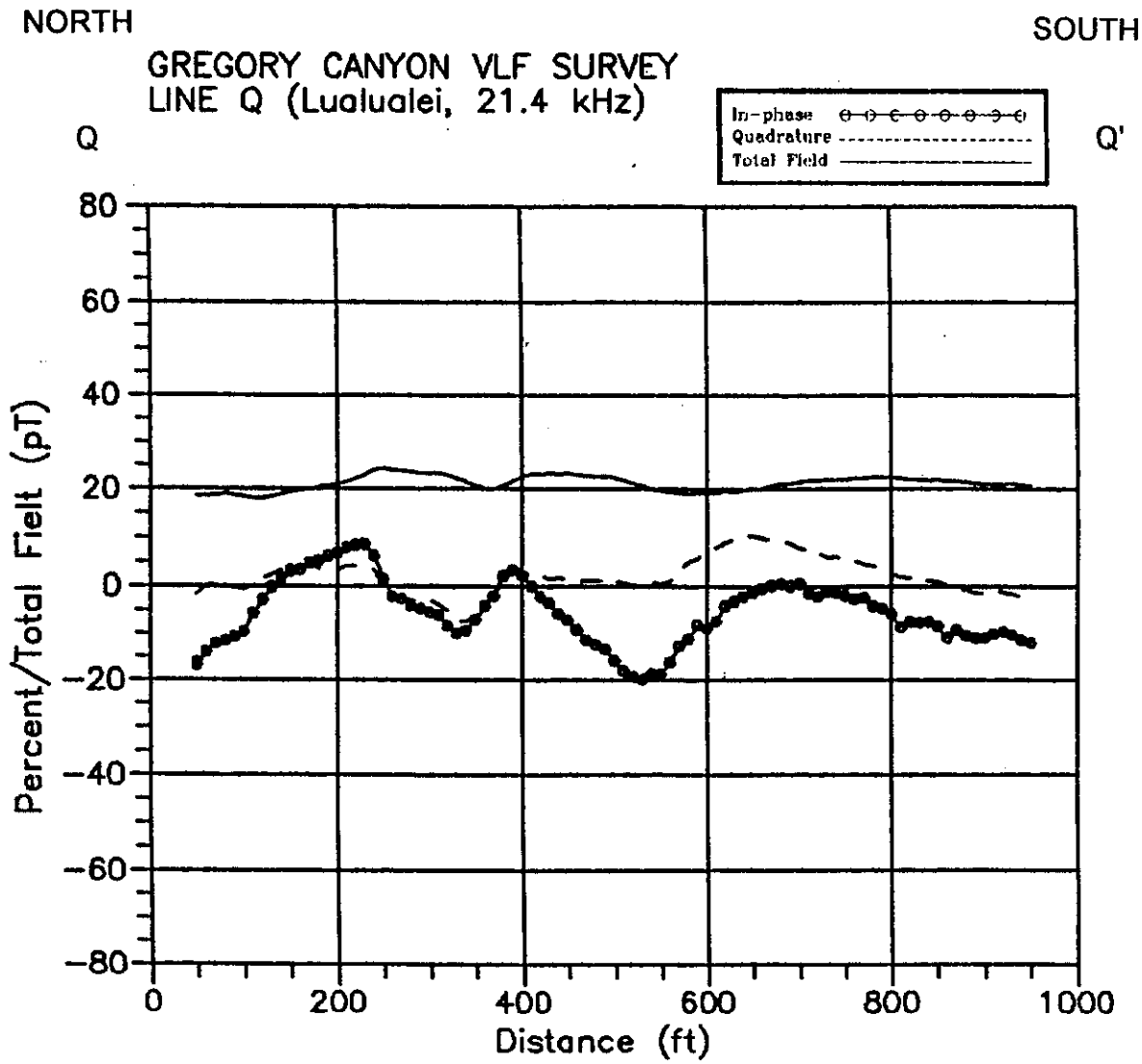
NORTH
SOUTH
GREGORY CANYON VLF SURVEY
LINE Q (Lualualei, 21.4 kHz)
Q
Q'
In-phase
Quadrature
Total Field
80
60
40
20
0
-20
-40
-60
-80
Percent/Total Field (pT)
0
200
400
600
800
1000
Distance (ft)

Figure B-29

NORTH

SOUTH

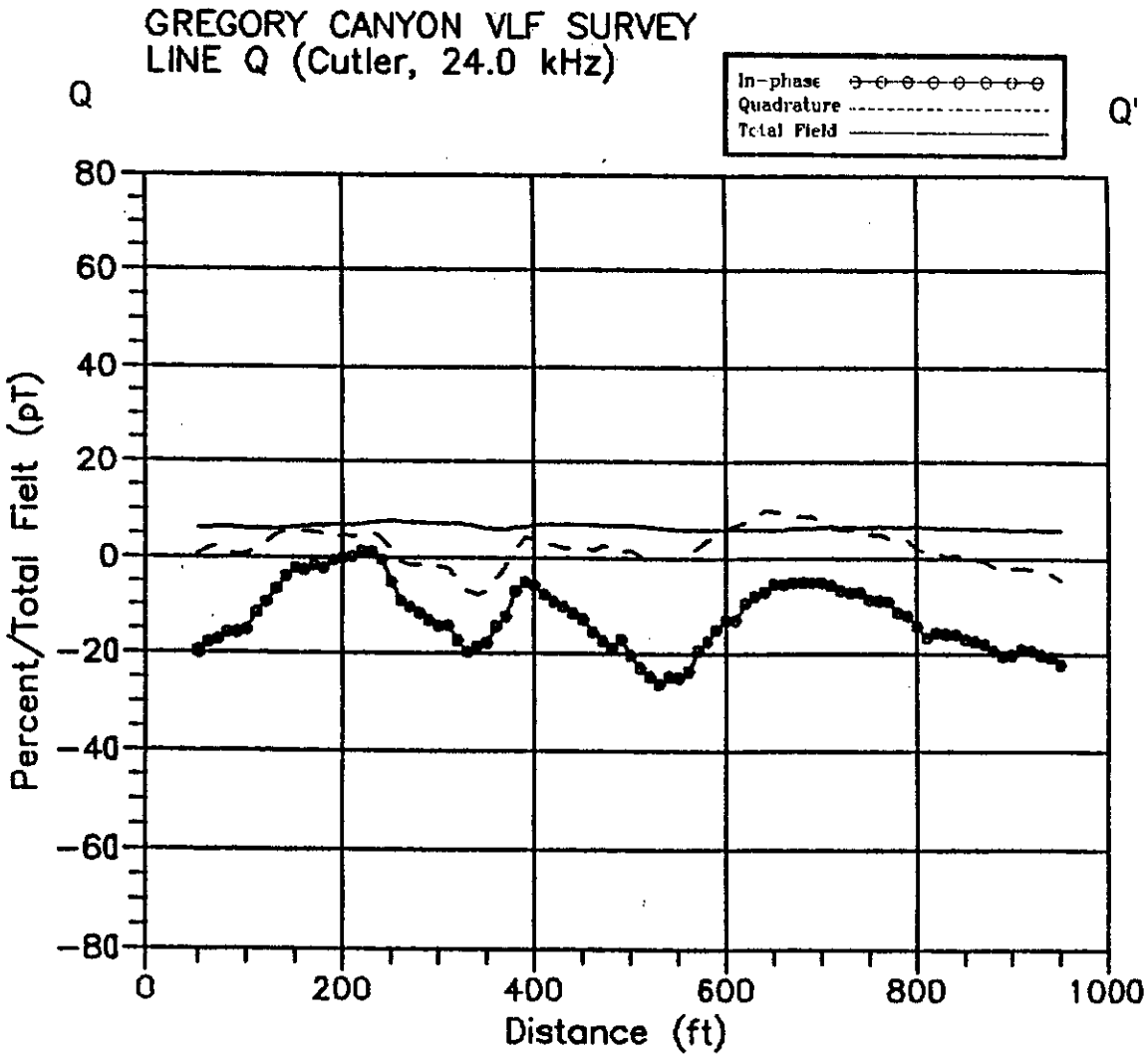

Figure B-30

NORTH

SOUTH

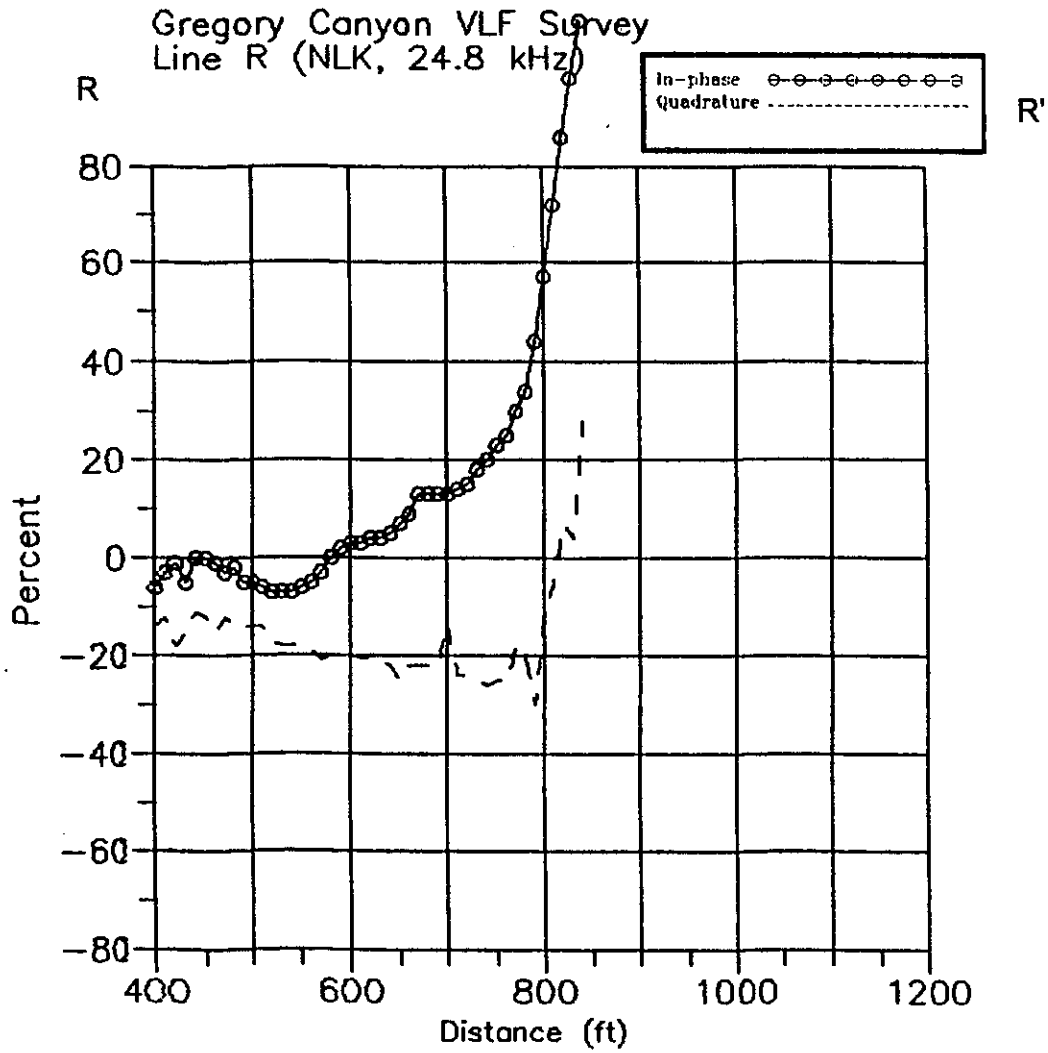

Figure B-31

LEGEND:

Qal1 Recent alluvium deposited by the San Luis Rey river. Unconsolidated deposits of sand, silt and gravel with variable amounts of cobbles and boulders.

Qal2 Older alluvium. Remnants of alluvial sediments deposited in the mouth of Gregory Canyon. Weakly stratified silt and sand.

Qco Colluvium, slope wash and talus deposits that form a veneer over most of the area shown in the map. On the east flank of the canyon they comprise cobbles and boulders of leucogranodiorite set in a locally consolidated matrix of sand and silt. On the west flank of the canyon they include mostly sand and silt derived from weathered tonalite. Includes Qu(?) in the center portion of the map, which appears to be a debris flow deposit with cobbles in a matrix of sand and silt.

Kglg Gregory Mountain Leucogranodiorite. Phaneritic texture with medium to coarse crystallinity. Light gray to buff with less than 5% dark minerals. Forms the core of Gregory Mountain, and also forms dikes that cut older units. Outcrops shown by solid outline; inferred extent of outcrop under a veneer of colluvium shown by pink hatching.

Kbt Bonsall Tonalite. Phaneritic texture with medium to coarse crystallinity. Dark gray. Typically deeply weathered and friable. Outcrops shown by solid outline; inferred extent of outcrop under a veneer of colluvium shown by green hatching.

Tjm Metamorphic rocks. Amphibolites and metavolcanic rocks, in some locations with migmatitic structure that resembles gneissic banding. Aphanitic to porphyroblastic texture; relict porphyritic textures suggest a volcanic protolith for some of the units. Medium to dark brown to gray. Generally massive and hard.

B B' Location of geologic cross-section.

- 51 Strike and dip of foliation
- 15 Strike and dip of joints
- 73 Strike and dip of dike
- Brecciated bedrock
- Outcrop of bedrock
- Geologic contact
- Buried geologic contact
- MW-5 Monitoring well by others
- GLA-5 Monitoring well by GLA

REDUCED

N

GRAPHIC SCALE
200 0 100 200 400
(IN FEET)
1 inch = 200 ft.

PLATE 1

GEOLOGIC MAP

GREGORY CANYON LANDFILL

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	DECEMBER 1997	9539

PLATE I

GREGORY CANYON

March, 1997

VLF ANOMALY/INTERPRETATION MAP

THE GEOPHYSICS GROUP (760) 747-3404
for
GeoLogic Associates, Inc.

APPENDIX C

REPORT OF BIPS AND HYDROPHYSICAL LOGGING (COLOG, 1997)

HYDROPHYSICAL™ AND BIPS LOGGING RESULTS FOR GEOLOGIC ASSOCIATES GREGORY CANYON PROJECT TEMECULA, CA

Prepared for
Geologic Associates
October 9, 1997

Prepared by

COLOG, INC.
17301 W. Colfax Avenue
Suite 265
Golden, Colorado 80401
(303) 279-0171

BOREHOLE GEOPHYSICS
COLOG
INC.
GOLDEN, COLORADO

October 9, 1997
ref. no. 68-0236

Horacio Ferriz, Ph.D.
Geologic Associates
426 Fourteenth Street
Modesto, California 95354

Re: Final HydroPhysical™ and BIPS Logging Report, Gregory Canyon Project, Temecula, CA

Dear Dr. Ferriz,

Enclosed please find the final HydroPhysical™ and BIPS Logging Report from the above referenced site. This final report incorporates revisions based on your letter of May 27, 1997, and our telephone conversation on August 5, 1997. I have included an introductory page addressed to you regarding several issues you had brought to our attention.

COLOG appreciates the opportunity to provide you with these revisions.

Please call with any questions pertaining to this project.

Sincerely,
COLOG, Inc.

Gregory D. Bauer
Associate Hydrogeologist

William H. Pedler
HydroPhysical™ Division Manager
Research Hydrogeologist
Reviewer

cc: Lacey Williams, COLOG, Inc

17301 W. Colfax, Suite 265 • Golden, CO 80401 • (303) 279-0171 • 1-800-753-0855 • FAX (303) 279-2730

HYDROPHYSICAL™ AND BIPS LOGGING RESULTS FOR GEOLOGIC ASSOCIATES GREGORY CANYON PROJECT TEMECULA, CA

Prepared for
Geologic Associates
October 9, 1997

Prepared by

COLOG, INC.
17301 W. Colfax Avenue
Suite 265
Golden, Colorado 80401
(303) 279-0171

TABLE OF CONTENTS

EXECUTIVE SUMMARY

HYDROPHYSICAL ™ LOGGING RESULTS FOR GMW-1

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GMW-1:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GMW-1:2 Summary of HydroPhysical Logs for Ambient Flow
Figure GMW-1:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GMW-1:4 Horizontal Flow Analysis During Ambient Conditions
Figure GMW-1:5 Horizontal Flow Analysis During Ambient Conditions
Figure GMW-1:6 Horizontal Flow Analysis During Ambient Conditions
Figure GMW-1:7 Horizontal Flow Analysis During Ambient Conditions

Figure GMW-1 BIPS Fracture Table for Well GMW-1

Figure GMP-1 BIPS Fracture Table for Well GMP-1

HYDROPHYSICAL ™ LOGGING RESULTS FOR GMP-2

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GMP-2:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GMP-2:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GMP-2:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GMP-2:4 Horizontal Flow Analysis During Ambient Conditions
Figure GMP-2:5 Horizontal Flow Analysis During Ambient Conditions
Figure GMP-2:6 Horizontal Flow Analysis During Ambient Conditions Well
Figure GMP-2:7 Horizontal Flow Analysis During Ambient Conditions
Figure GMP-2:8 Horizontal Flow Analysis During Ambient Conditions

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Figure GMP-2 BIPS Fracture Table for Well GMP-2

Figure GMP-3 BIPS Fracture Table for Well GMP-3

HYDROPHYSICAL ™ LOGGING RESULTS FOR GMW-4

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GMW-4:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GMW-4:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GMW-4:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GMW-4:4 Horizontal Flow Analysis During Ambient Conditions
Figure GMW-4:5 Horizontal Flow Analysis During Ambient Conditions

Figure GMW-4 BIPS Fracture Table for Well GMW-4

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-1

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GLA-1:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-1:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-1:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization

Figure GLA-1 BIPS Fracture Table for Well GLA-1

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-2

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GLA-2:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-2:2 Summary of HydroPhysical Logs for Ambient Flow

	Characterization
Figure GLA-2:3	Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-2:4	Horizontal Flow Analysis During Ambient Conditions
Figure GLA-2	BIPS Fracture Table for Well GLA-2

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-3

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions
1.3 Flow Characterization During Pumping After DI Water Emplacement: GLA-3
1.4 Cross Hole Testing; GLA-3 and GMW-1
1.4.1 Cross Hole Flow Evaluation During Stressed Well Condition
1.5 Summary of Cross-Hole Flow Evaluation: Wells GMW-1 and GLA-3

Figure GLA-3:1	Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-3:2	Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-3:3	Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-3:4	Horizontal Flow Analysis During Ambient Conditions
Figure GLA-3:5	Horizontal Flow Analysis During Ambient Conditions
Figure GLA-3:6	Pump and Drawdown Data for 4 GMP Production Test
Figure GLA-3:7	Summary of HydroPhysical Logs for Pump After Emplacement Test
Figure GLA-3:8	Field Fluid Electrical Conductivity vs. Code Bore Results for Pump After Emplacement Test
Figure GLA-3:9	Pump and Drawdown Data During Cross Hole Testing
Figure GLA-3:10	Summary of HydroPhysical Logs for Ambient Flow Characterization Cross Hole Test Pumping GMW-1 at 5 GPM
Figure GLA-3:11	Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-3:12	Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-3:13	Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-3:14	Chromographic Tessellation of FEC Logs for Ambient Flow Characterization Cross Hole Test
Table GLA-3:1	Code Bore Results for Pumping After Emplacement Test
Figure GLA-3	BIPS Fracture Table for Well GLA-3

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HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-4

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions

Figure GLA-4:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-4:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-4:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-4:4 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-4:5 Horizontal Flow Analysis During Ambient Conditions

Figure GLA-4 BIPS Fracture Table for Well GLA-4

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-5

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions
1.3 Flow Characterization During Slug Testing; GLA-5
1.4 Sensitivity to Inflows

Figure GLA-5:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-5:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-5:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-5:4 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-5:5 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-5:6 Drawdown Data During Slug Test
Figure GLA-5:7 Summary of HydroPhysical Logs for Slug Test
Figure GLA-5:8 Field Fluid Electrical Conductivity vs. Code Bore Results for Slug Test

Table GLA-5:1 Code Bore Results for Slug Test

Figure GLA-5 BIPS Fracture Table for Well GLA-5

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-7

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

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1.2 Ambient Flow Evaluation During Stable Well Field Conditions
1.3 Flow Characterization During Well Production: GLA-7
1.4 Cross Hole Testing; GLA-7 and GMP-2
1.4.1 Cross Hole Flow Evaluation During Stressed Well Condition: GLA-7
1.5 Summary of Cross-Hole Flow Evaluation: Wells GLA-7 and GMP-2
1.6 Sensitivity to Inflows

Figure GLA-7:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-7:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-7:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-7:4 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:5 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:6 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:7 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:8 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:9 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:10 Horizontal Flow Analysis During Ambient Conditions
Figure GLA-7:11 Pump and Drawdown Data for 5 GMP Production Test
Figure GLA-7:12 Summary of HydroPhysical Logs During 5 GPM Production Test with Interval Specific Flow Rates
Figure GLA-7:13 Field Fluid Electrical Conductivity vs. Code Bore Results for 5 GPM Production Test
Figure GLA-7:14 Pump and Drawdown Data During Cross Hole Testing
Figure GLA-7:15 Summary of HydroPhysical Logs for Ambient Flow Characterization Cross Hole Test
Figure GLA-7:16 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-7:17 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:18 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:19 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:20 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:21 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:22 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:23 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:24 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:25 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:26 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-7:27 Horizontal Flow Analysis During Cross Hole Testing

Table GLA-7:1 Summary of Horizontal Flow, Stable and Stressed Wellfield Conditions

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Table GLA-7:2 Code Bore Results for 5 GPM Production Test

Figure GLA-7 BIPS Fracture Table for Well GLA-7

HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-8

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions
1.3 Flow Characterization During Well Production: GLA-8
1.4 Cross Hole Testing; GLA-8
1.4.1 Cross Hole Flow Evaluation During Stressed Well Condition: GLA-8
1.5 Summary of Cross-Hole Flow Evaluation: Wells GLA-8 and GMW-4
1.6 Special Conditions
1.7 Sensitivity to Inflows

Figure GLA-8:1 Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-8:2 Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-8:3 Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-8:4 Pump and Drawdown Data for 4 GMP Production Test
Figure GLA-8:5 Summary of HydroPhysical Logs During 4 GPM Production Test
Figure GLA-8:6 Field Fluid Electrical Conductivity vs. Code Bore Results for 3.8 GPM Pumping During Injection Test
Figure GLA-8:7 Pump and Drawdown Data During Cross Hole Testing
Figure GLA-8:8 Summary of HydroPhysical Logs for Ambient Flow Characterization Cross Hole Test
Figure GLA-8:9 Chromographic Tessellation of FEC Logs for Cross Hole Flow Characterization: Stressed Wellfield Conditions
Figure GLA-8:10 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-8:11 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-8:12 Horizontal Flow Analysis During Cross Hole Testing
Figure GLA-8:13 Horizontal Flow Analysis During Cross Hole Testing

Table GLA-8:1 Code Bore Results for 3.8 GPM Pumping During Injection Test

Figure GLA-8 BIPS Fracture Table for Well GLA-8

Figure GLA-9 BIPS Fracture Table For Well GLA-9

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HYDROPHYSICAL ™ LOGGING RESULTS FOR GLA-10

1.1 Ambient Fluid Electrical Conductivity and Temperature Log
1.2 Ambient Flow Evaluation During Stable Well Field Conditions
1.3 Flow Characterization During Pumping After DI water Emplacement; GLA-10
1.4 Sensitivity to Inflows

Figure GLA-10:1	Ambient Temperature and Fluid Electrical Conductivity
Figure GLA-10:2	Summary of HydroPhysical Logs for Ambient Flow Characterization
Figure GLA-10:3	Chromographic Tessellation of FEC Logs for Ambient Flow Characterization
Figure GLA-10:4	Horizontal Flow Analysis During Ambient Conditions
Figure GLA-10:5	Pump and Drawdown Data for 1.5 GMP Pump After Emplacement Test
Figure GLA-10:6	Summary of HydroPhysical Logs for Pump After Emplacement Test
Figure GLA-10:7	Field Fluid Electrical Conductivity vs. Code Bore Results for 1.7 GPM Pump After Emplacement Test
Table GLA-10:1	Code Bore Results for 1.6 GPM Pump After Emplacement Test
Figure GLA-10	BIPS Fracture Table for Well GLA-10

APPENDICES

APPENDIX A	STANDARD OPERATING PROCEDURES HYDROPHYSICAL™ LOGGING FOR AQUIFER CHARACTERIZATION
APPENDIX B	STANDARD OPERATING PROCEDURES FOR BIPS
APPENDIX C	ESTIMATION OF HORIZONTAL FLOW FROM FLUID ELECTRICAL CONDUCTIVITY LOGS ACQUIRED AT GREGORY CANYON, TEMECULA, CALIFORNIA
APPENDIX D	SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL ™ LOGGING RESULTS
APPENDIX E	RANKING SYSTEM FOR BIPS FEATURES

EXECUTIVE SUMMARY OF HYDROPHYSICAL™ LOGGING

COLOG, Inc. conducted HydroPhysical™ and BIPS logging on 11 wells at the Gregory Canyon site near Temecula, California over the periods of December 12-21, 1996, January 2-11, 1997 and January 16-20, 1997. HpL™ testing was done in accordance with the Standard Operating Procedures (SOPs) provided in Appendix A. The BIPS logging was done in accordance with SOPs in Appendix B. At the request of one or more consultants, COLOG used a spinner-type flow meter in three wells (GLA-3, GLA-7 and GLA-8) along with the standard HydroPhysical™ Logging to quantify vertical flow. COLOG expressed its concern to Geologic Associates that the detection range of the spinner-type flow meter is well above the flow rates expected in the three wells. The data collected using the spinner-type flow meter did not suggest the presence of any flow. It is the opinion of COLOG that the flow in the well was below the detection limit of that particular spinner-type flow meter. COLOG has presented the results of the spinner flow meter in comparison to the HpL™ data for wells GLA-3, GLA-7 and GLA-8. These figures can be found in Appendix D.

For ambient flow assessment, COLOG incorporated the use of an experimental algorithm, when applicable, to evaluate horizontal flow. As the application of this algorithm is considered experimental, the velocities and specific discharge values reported should be considered qualitative until independently confirmed by traditional methods. Please refer to Appendix C for a discussion of this methodology.

HYDROPHYSICAL™ LOGGING RESULTS FOR GMW-1

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On January 10, 1997, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to figure GMW-1:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On January 10, 1997, at 1031 hours (T=0.00 minutes), dilution of the fluid column was complete. Due to the silty nature of the water being pumped, the extraction flowmeter could not accurately record extraction flow during dilution of the borehole. However, it is estimated that approximately 10 gallons of DI were lost to the formation during dilution procedures. During the 5.06 hours following dilution, multiple logs were conducted. Of these logs, 30 are presented in Figure GMW-1:2. These logs illustrate significant change throughout the interval from 65 to 83 feet. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring over the zone from 65 to 83 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GMW-1.3. FEC of 0 μ S/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 400 μ S/cm.

The data suggest that horizontal flow was occurring over the following intervals: 65-68, 68-71, 71-78, and 78-83 feet. Experimental algorithms applied to these data suggest that the fluid velocities in the wellbore for these intervals were approximately 0.75, 0.77, 0.66, and 0.78 ft/day, respectively. Correcting for convergence of flow at the wellbore, this velocity equates to a specific discharge of groundwater in the aquifer of 0.30, 0.31, 0.26, 0.31 ft/day, respectively. Please refer to Figures GMW-1:4 through GMW-1:7 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GMW-1.1: AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.

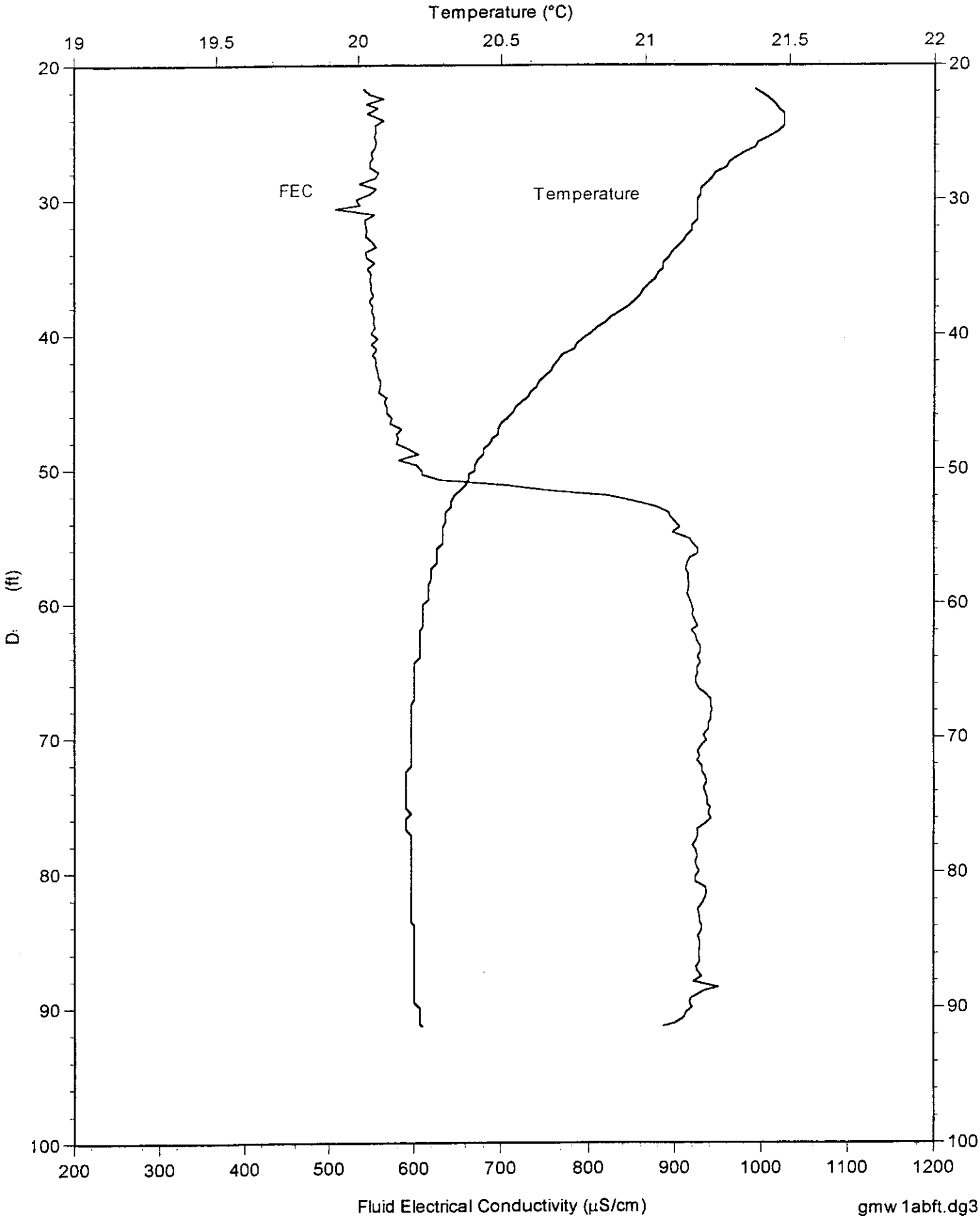


FIGURE GMW-1:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.

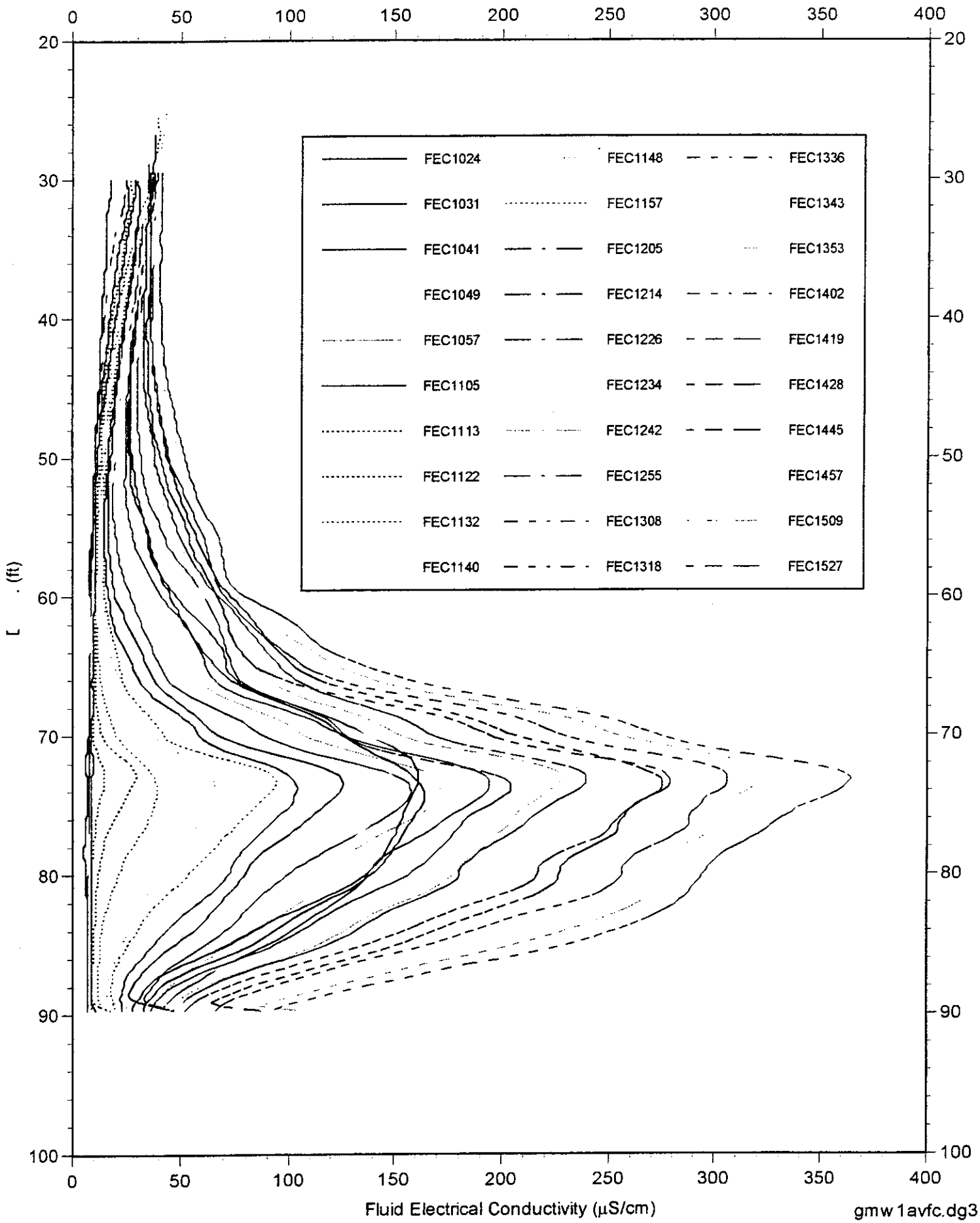
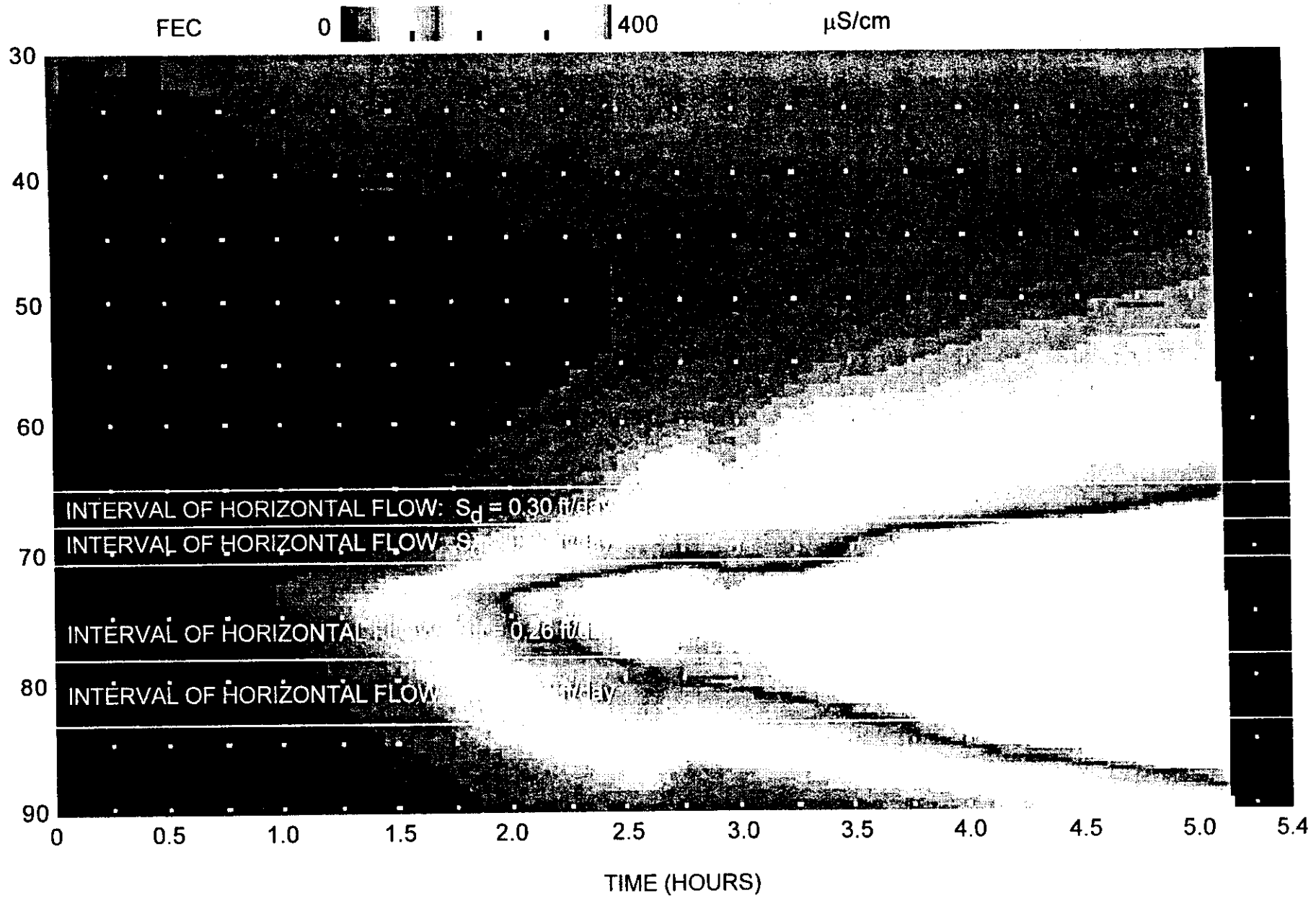
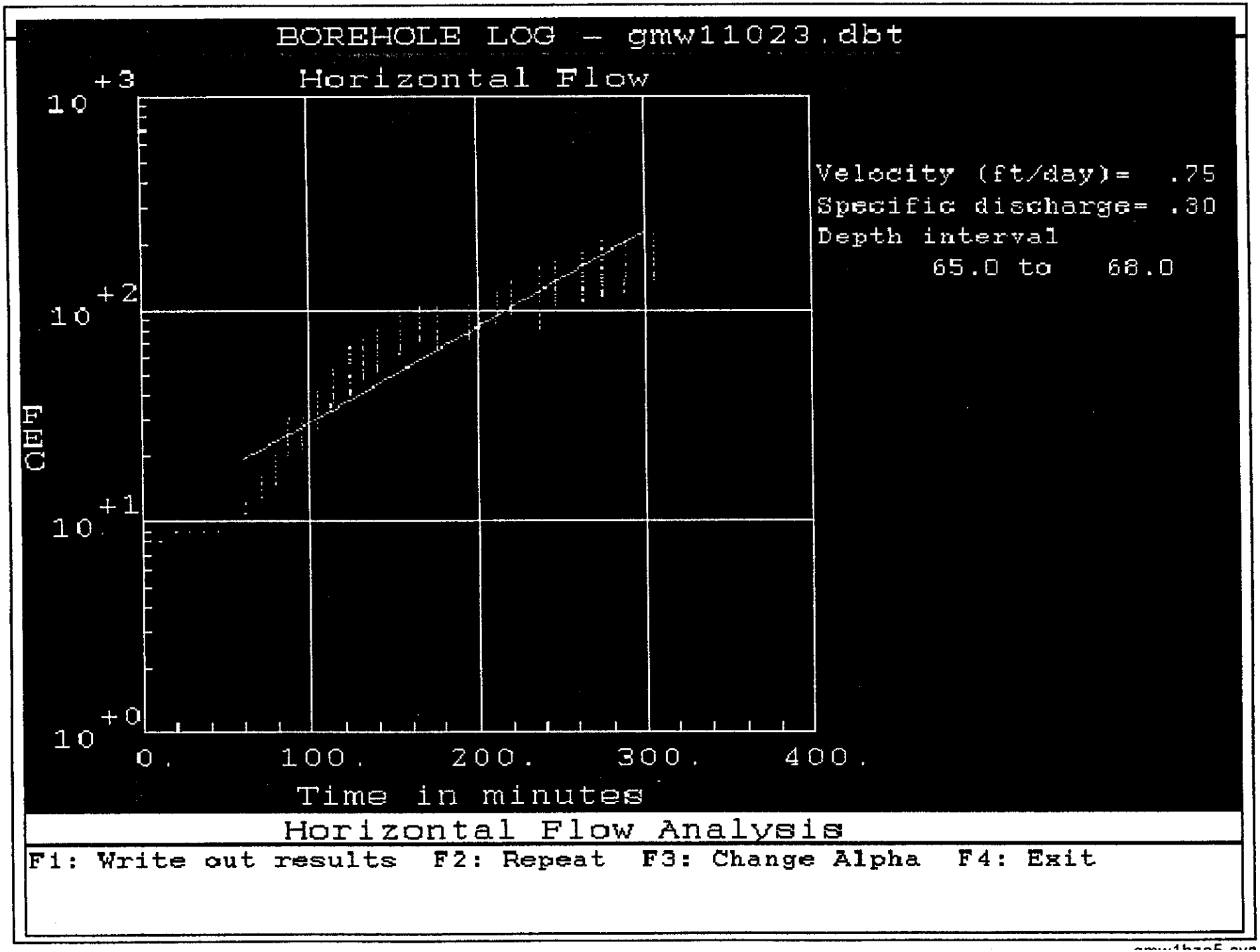


FIGURE GMW-1:3. CHROMOGRAPHIC TESSELATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.

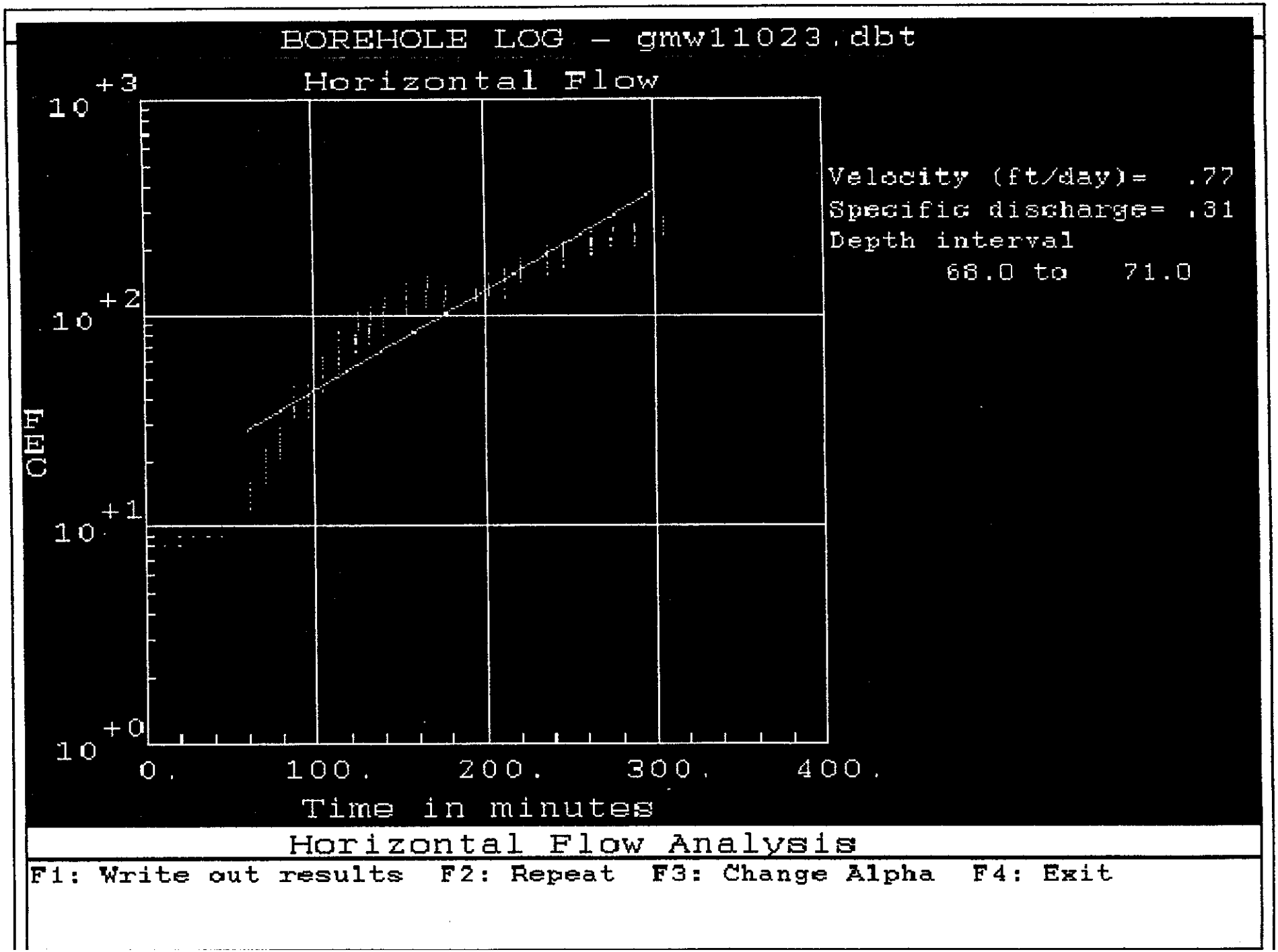


gmw1avfc.cvs

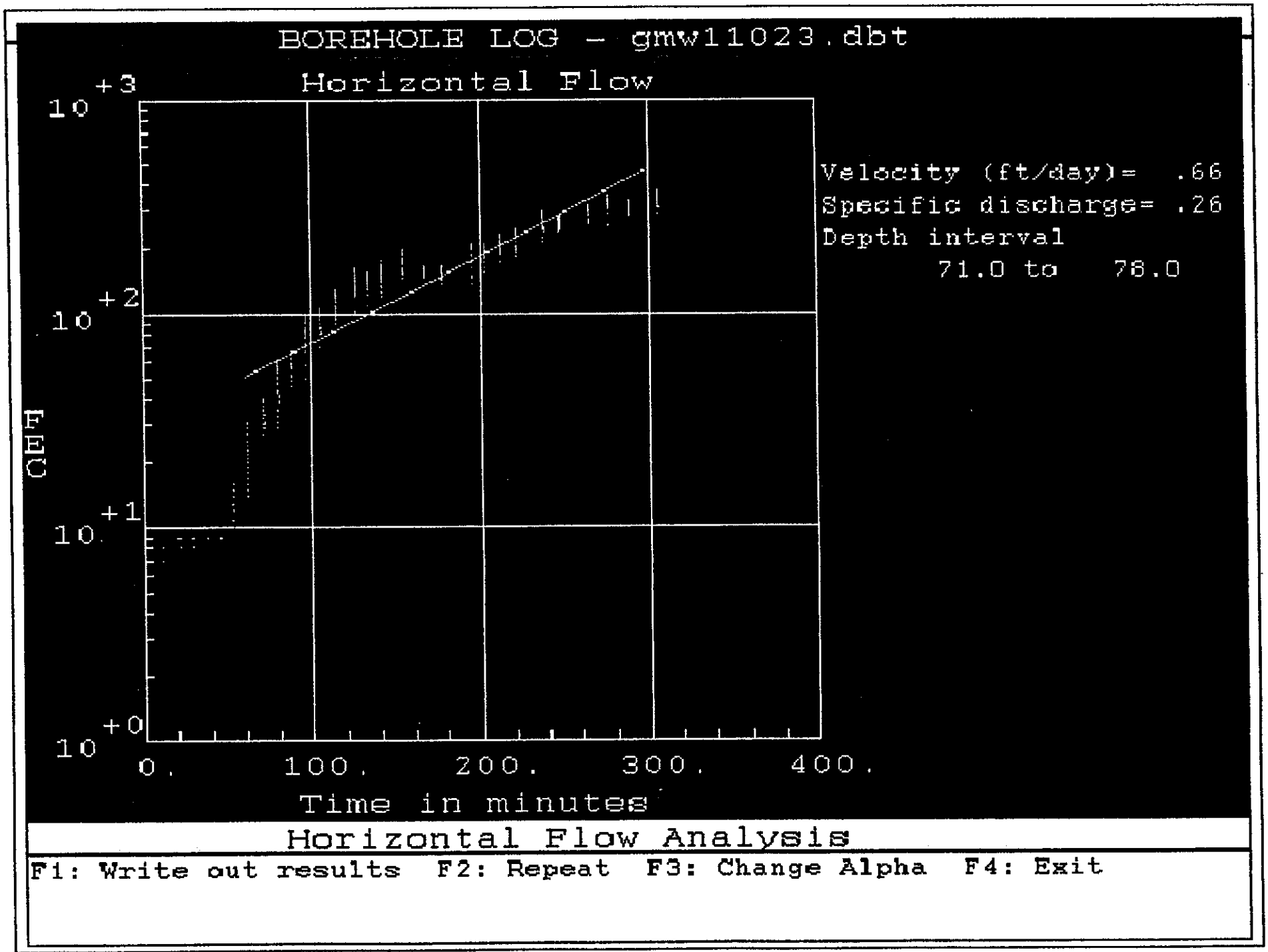
FIGU GMW-1:4. HORIZONTAL FLOW ANALYSIS DURING 3IENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.



FIGU GMW-1:5. HORIZONTAL FLOW ANALYSIS DURING BIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.



FIGU GMW-1:6. HORIZONTAL FLOW ANALYSIS DURING BIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.



gmw1hz07.cvs

FIG[illegible] GMW-1:7. HORIZONTAL FLOW ANALYSIS DURING [illegible]BIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-1.

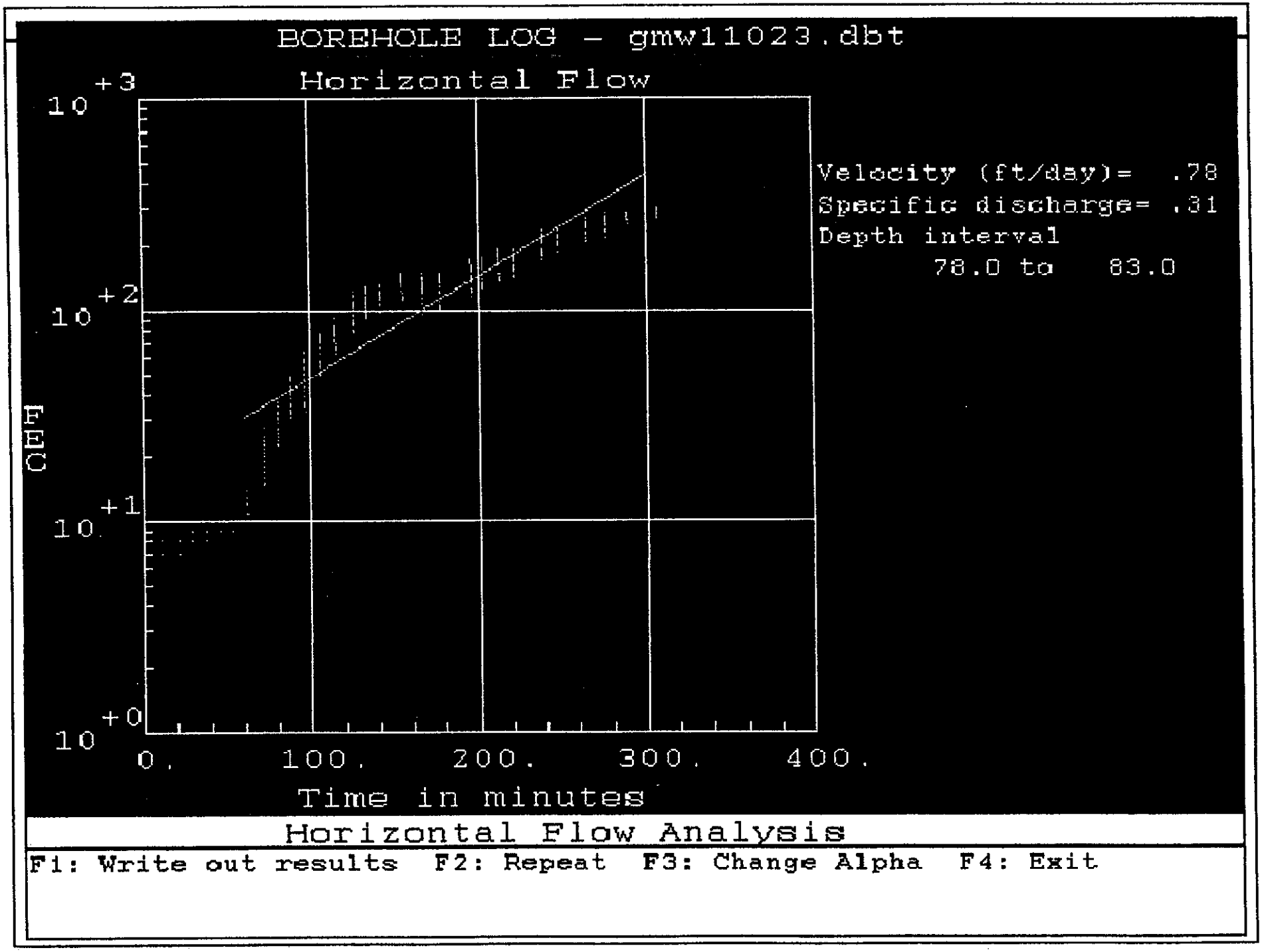


FIGURE GMW-1: BIPS FRACTURE TABLE FOR WELL GMW-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	56.1	17.10	N67E	5S	157	2
2	57.5	17.51	N33W	23SW	237	2
3	60.6	18.46	N74W	40S	196	1
4	60.9	18.57	N1E	32E	91	1
5	61.4	18.73	N38W	31NE	52	2
6	64.0	19.52	N31E	79NW	301	1
7	64.5	19.66	N27E	73W	297	1
8	65.6	19.99	N53E	64NW	323	1
9	67.1	20.44	N26E	66W	396	1
10	67.8	20.66	N50E	66NW	320	1
11	68.5	20.87	N34E	63NW	304	1
12	69.5	21.19	N23E	76W	293	1
13	70.9	21.62	N8W	57W	363	1
14	71.1	21.68	N23E	16E	113	2
15	71.6	21.83	N24E	42E	114	2
16	71.7	21.87	N21E	21E	111	2
17	72.0	21.95	N1E	39W	271	2
18	74.3	22.65	N17W	28E	73	2
19	75.6	23.04	N29W	74E	61	1
20	75.6	23.04	N25W	61E	65	1
21	80.3	24.49	N13E	66W	283	1
22	80.6	24.57	N60W	39S	210	2
23	84.2	25.67	N61E	18N	331	1
24	84.4	25.72	N55E	10NW	325	1
25	84.5	25.77	N8W	30W	262	1
26	84.8	25.83	N3W	40W	267	1
27	85.4	26.03	N4E	39W	274	1
28	85.9	26.19	N1E	33W	271	1
29	86.3	26.31	N2E	38W	272	1
30	86.8	26.44	N13W	26W	257	1
31	87.8	26.75	N17W	25W	253	1
32	87.9	26.782	N6W	26W	264	1

All directions are with respect to magnetic north.

FIGURE GMP-1: BIPS FRACTURE TABLE FOR WELL GMP-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	44.4	13.55	N34E	24NW	304	0
2	44.7	13.62	N39E	21NW	309	0
3	49.9	15.21	N70E	31S	160	0

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GMP-2

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On January 9, 1997, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GMP-2:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On January 9, 1997, at 1403 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 5 gallons of DI water were lost to the formation during dilution procedures. During the 2.95 hours following dilution, multiple logs were conducted. Of these logs, 21 are presented in Figure GMP-2:2. These logs illustrate significant change in the FEC profile. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring at the interval from 70 to 86 feet. The uniform increase in FEC throughout the length of the borehole is a result of horizontal flow.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GMP-2:3. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 170 µS/cm.

The data suggest that horizontal flow was occurring over the following intervals: 70-76.4, 76.4-80, 80-82, 82-84, and 84-86 feet. Experimental algorithms applied to these data suggest that the fluid velocities in the wellbore for these intervals were approximately 0.36, 0.41, 0.43, 0.46, and 0.43 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specific discharge of groundwater in the aquifer of 0.14, 0.17, 0.17, 0.18, and 0.17 ft/day, respectively. Please refer to figures GMP-2:4 through GMP-2:8 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GMP-2:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

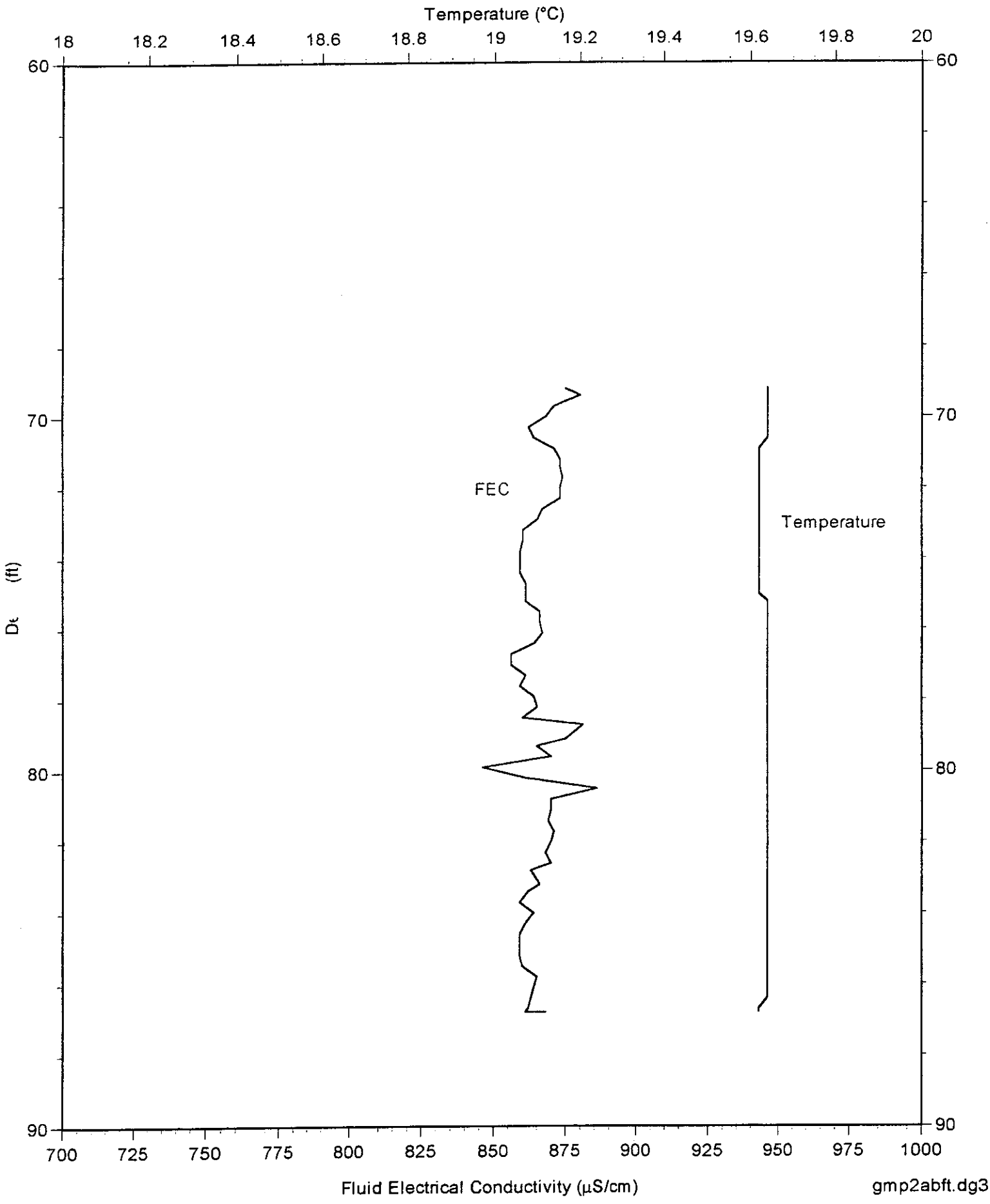


FIGURE GMP-2:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

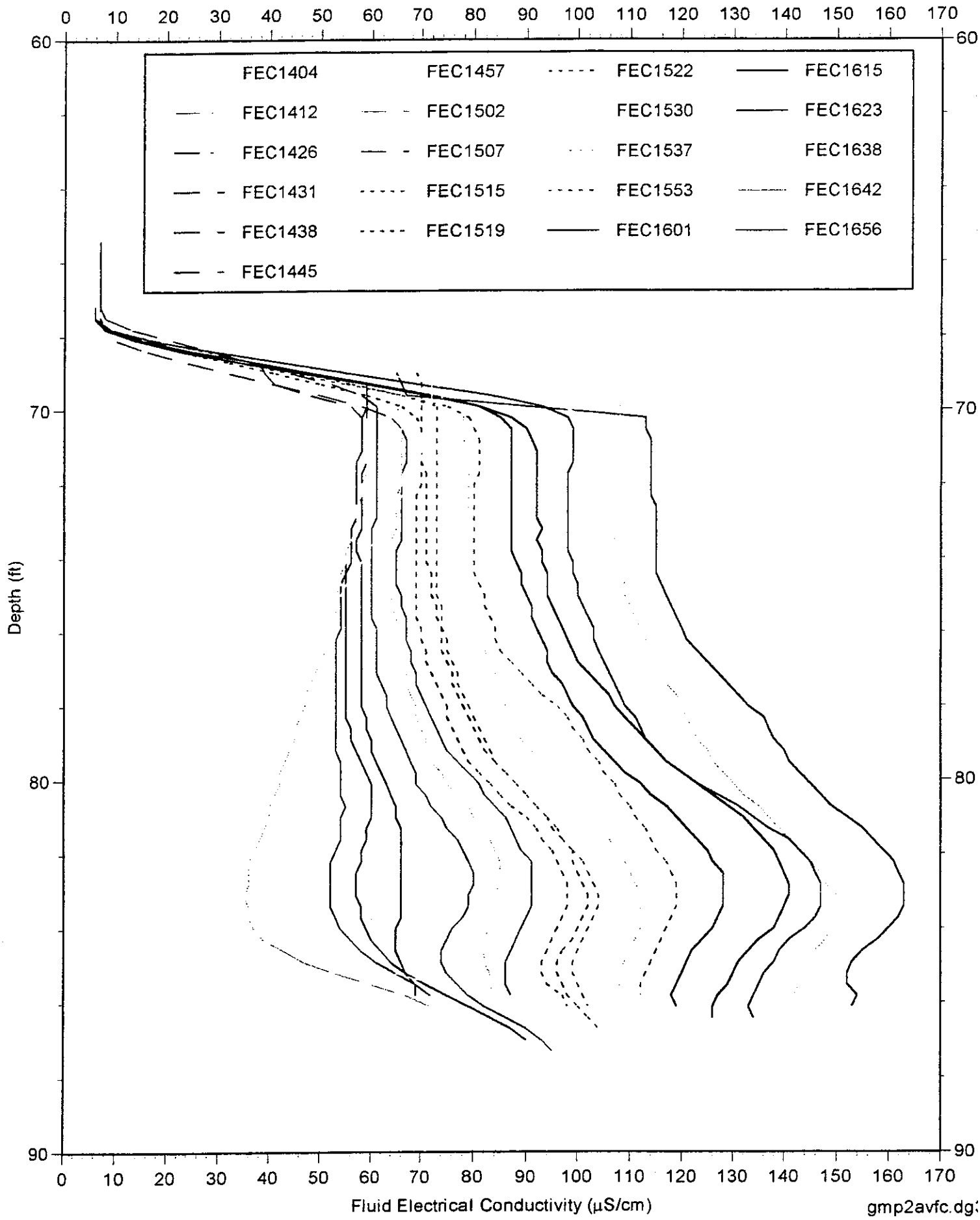


FIGURE GMP-2:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

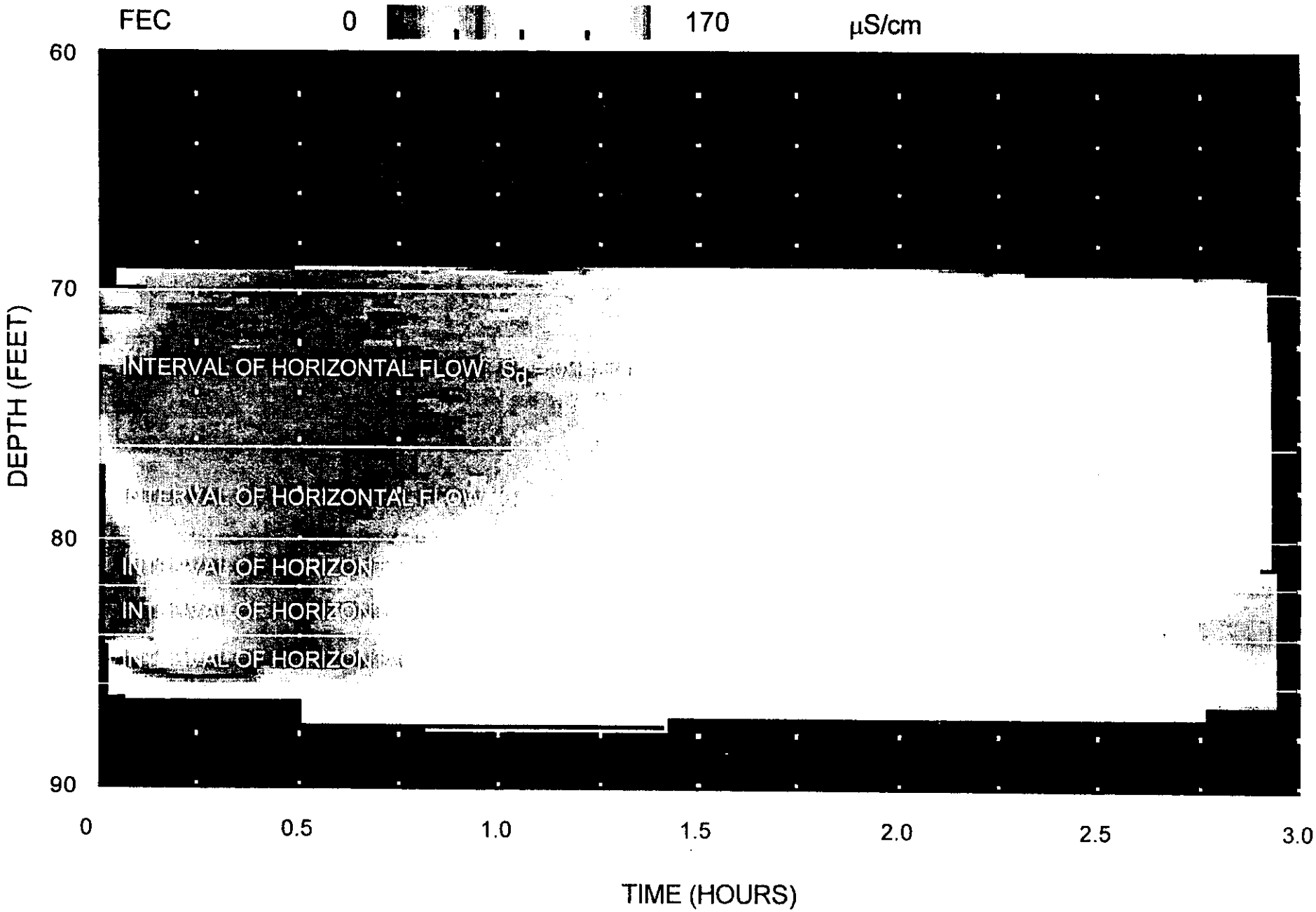


FIGURE GMP-2:4. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

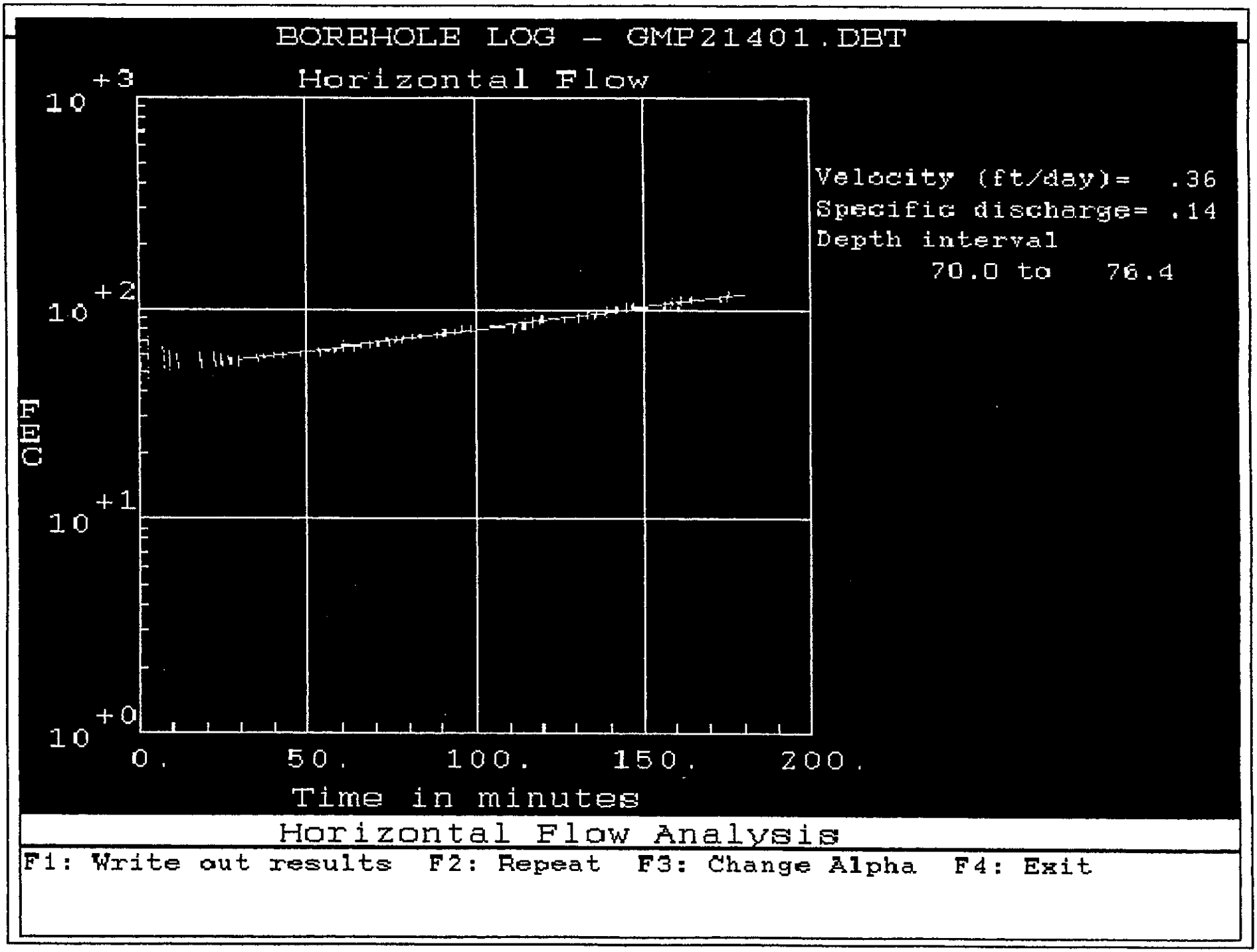


FIGURE GMP-2:5. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

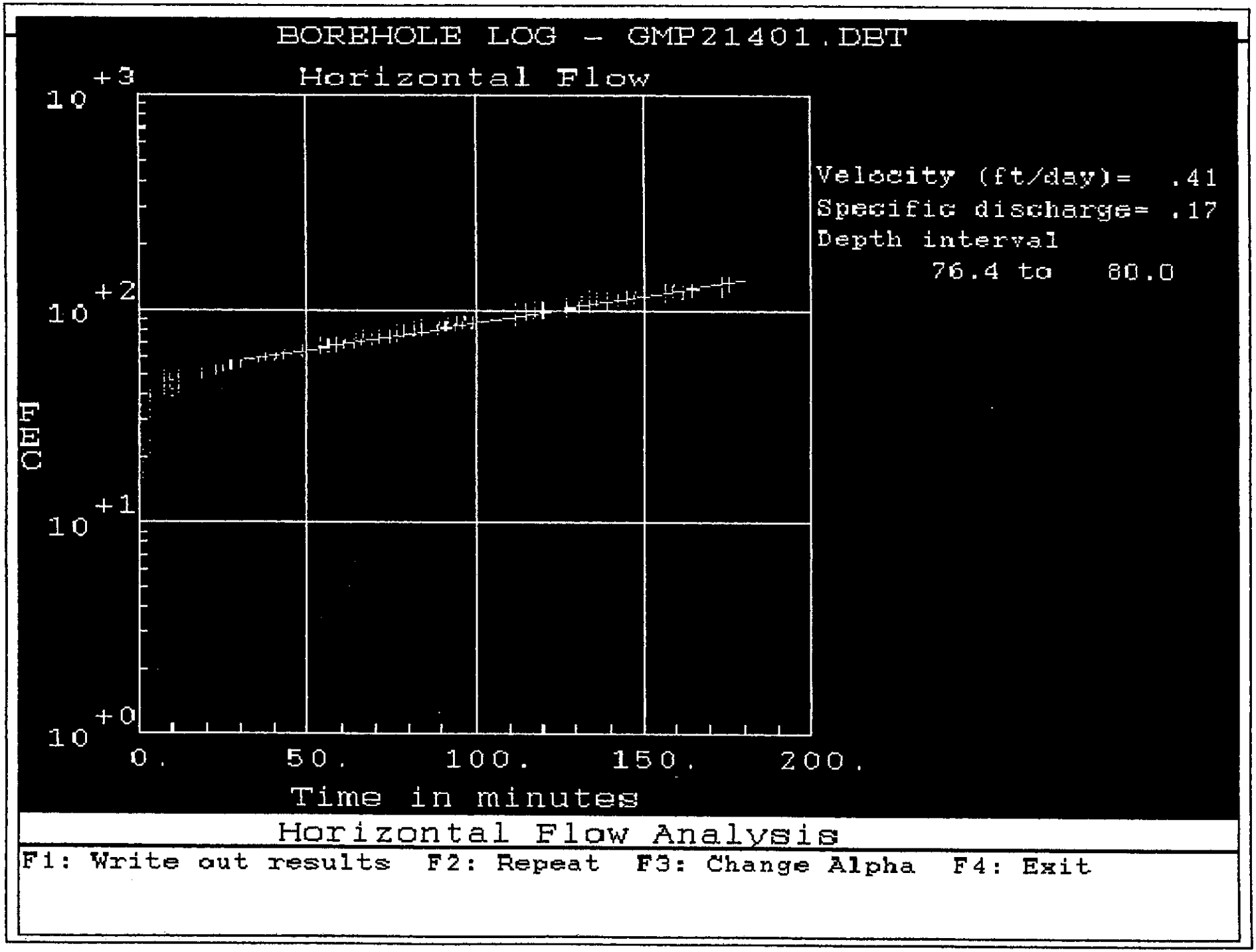


FIGURE GMP-2:6. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

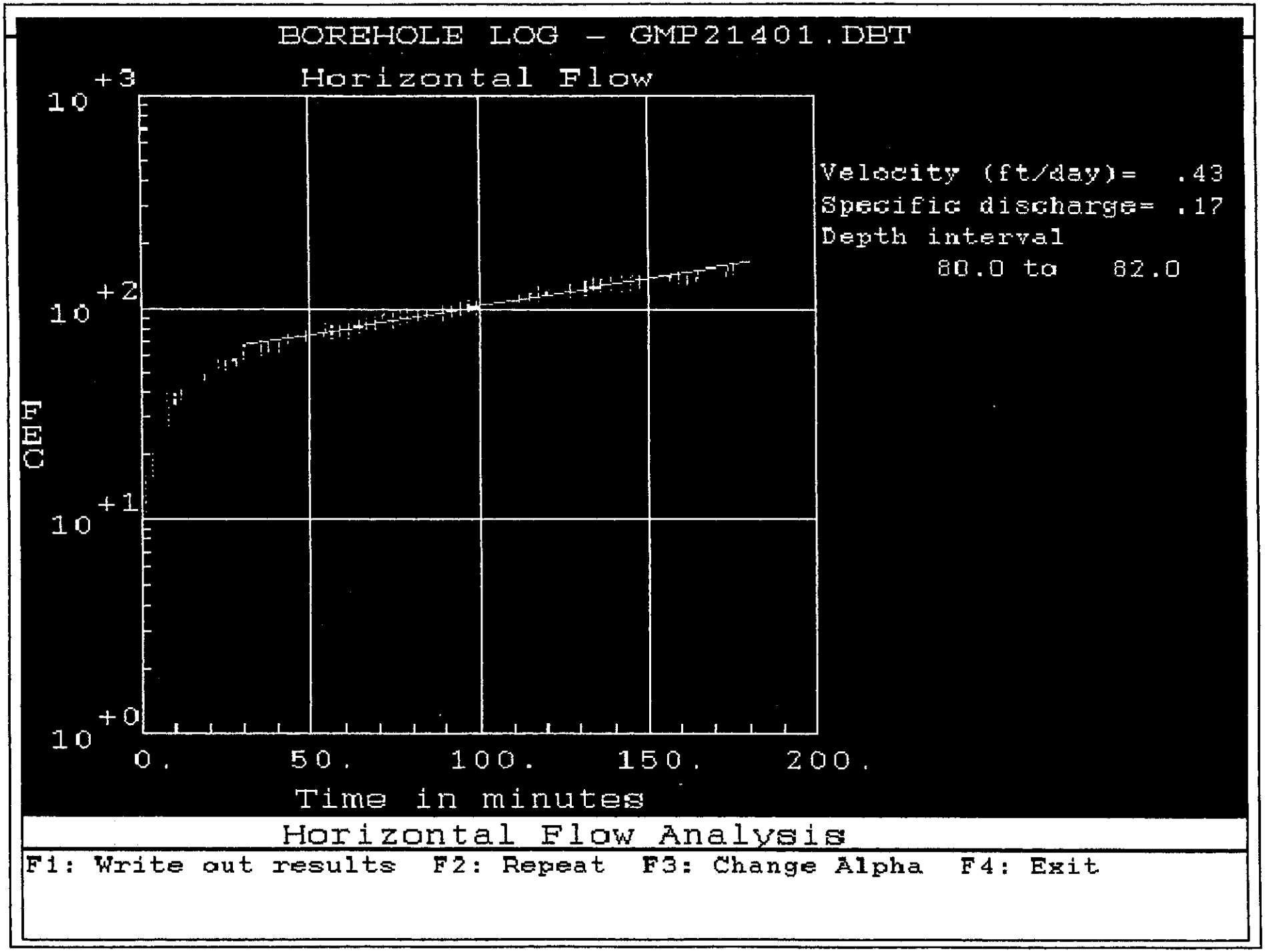
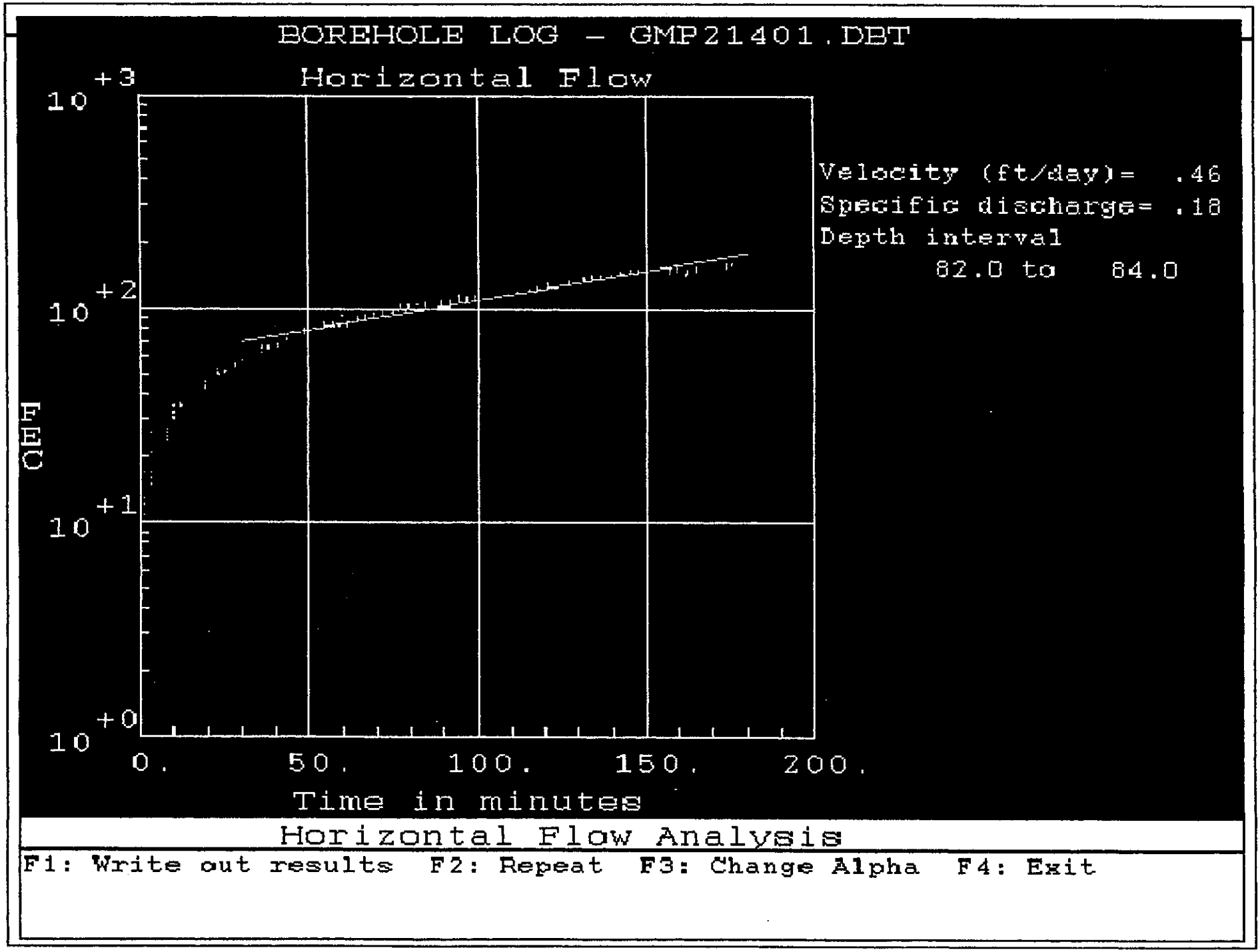


FIGURE GMP-2:7. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.



FIGUR. .MP-2:8. HORIZONTAL FLOW ANALYSIS DURING AM ENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2.

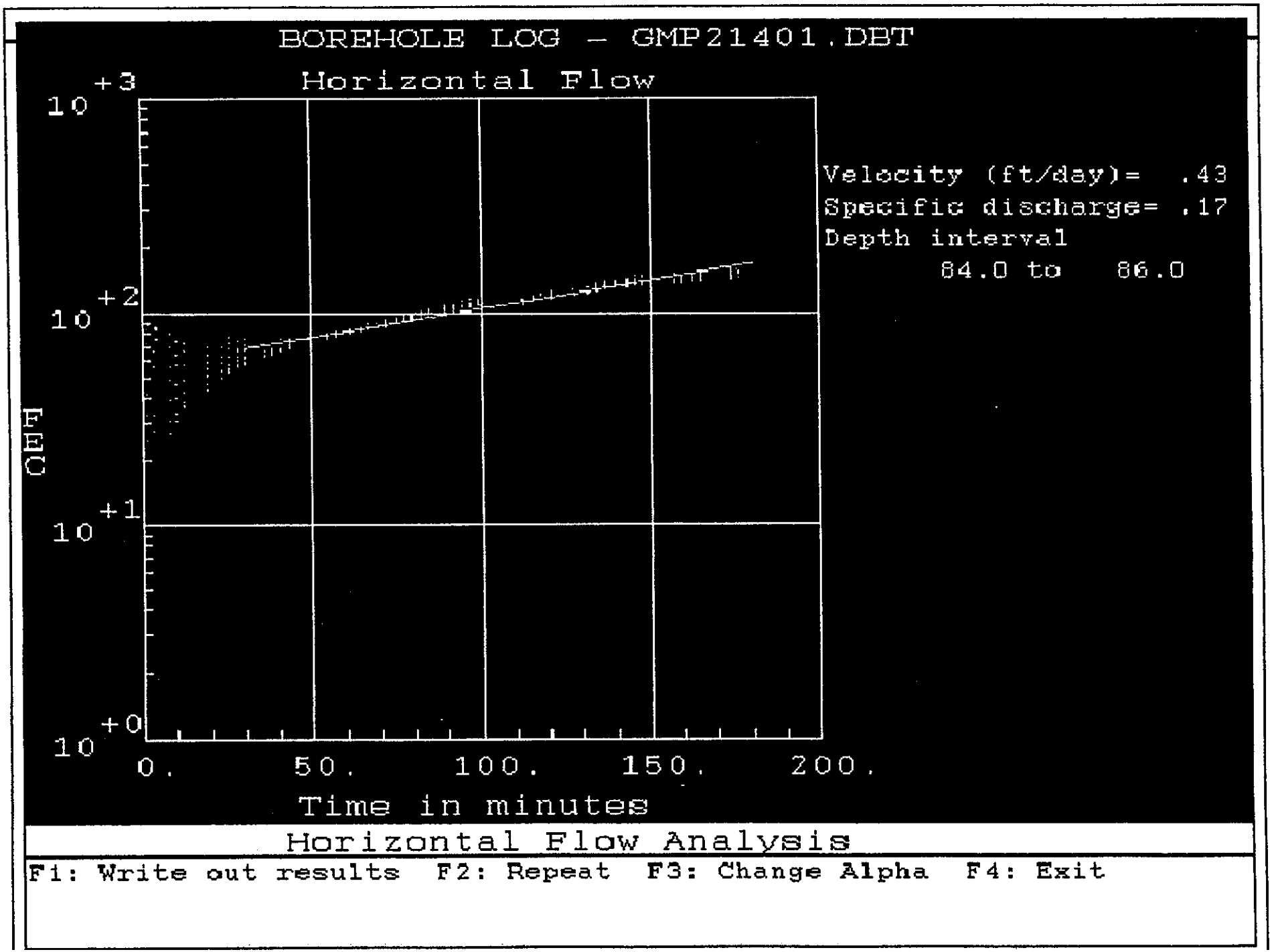


FIGURE GMP-2: BIPS FRACTURE TABLE FOR WELL GMP-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	52.1	15.87	N55E	56SE	145	1
2	60.0	18.29	N51E	3NW	321	0
3	60.1	18.31	N85E	3N	355	1
4	60.6	18.47	N45W	60SW	225	1
5	61.5	18.75	N3W	14W	267	1
6	62.0	18.90	N28W	78E	62	0
7	63.7	19.42	N35W	9NE	55	1
8	64.1	19.53	N18E	13E	108	2
9	64.4	19.64	N59E	30NW	329	0
10	65.6	20.00	N34W	54SW	236	1
11	67.0	20.41	N23W	66W	247	2
12	68.9	21.00	N3W	66W	267	1
13	69.5	21.17	N59W	77NE	31	0
14	69.6	21.22	N57W	47NE	33	1
15	69.9	21.31	N35W	41NE	55	0
16	70.7	21.56	N28W	62W	242	1
17	71.0	21.65	N58W	51SW	212	0
18	73.6	22.42	N15E	33W	285	1
19	75.0	22.85	N81E	8S	171	2
20	75.5	23.00	N63W	2N	27	1
21	77.0	23.48	N57E	30NW	327	1
22	78.1	23.79	N9W	31W	261	2
23	78.5	23.92	N73E	25N	343	1
24	78.7	24.00	N2W	29E	88	0
25	79.1	24.12	N17E	66W	287	0
26	79.3	24.16	N5W	40E	85	1
27	79.4	24.19	N22W	60W	248	2
28	80.1	24.42	N45W	44SW	225	2
29	80.9	24.67	N3W	53E	87	1

All directions are with respect to magnetic north.

FIGURE GMP-3: BIPS FRACTURE TABLE FOR WELL GMP-3, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	44.8	13.64	N15W	73W	255	0
2	47.0	14.34	N26W	36W	244	2
3	49.6	15.12	N15W	61W	255	0
4	52.5	16.01	N16E	49E	106	0
5	54.9	16.74	N16W	55W	254	2
6	55.4	16.89	N9W	62W	261	0
7	55.7	16.99	N7W	59W	263	1
8	56.0	17.08	N13W	61W	257	0
9	56.3	17.16	N15W	55W	255	1
10	59.6	18.15	N51W	28NE	39	1
11	61.6	18.77	N40E	32SE	130	1
12	62.3	18.99	N58W	41NE	32	0
13	63.4	19.33	N74E	50N	344	1
14	66.6	20.31	N9W	77E	81	2
15	67.2	20.48	N70E	21S	160	1
16	67.5	20.56	N22E	18W	292	0
17	67.7	20.64	N64W	49S	206	2
18	68.1	20.76	N6W	40W	264	1
19	68.3	20.83	EW	56S	180	2
20	68.6	20.90	N31W	29SW	239	1
21	69.6	21.21	NS	54E	90	2
22	70.2	21.38	N32E	48NW	302	1
23	70.3	21.42	N33E	49NW	303	1
24	70.6	21.52	N46E	52NW	316	1
25	70.9	21.61	N59E	48NW	329	1
26	71.9	21.92	N50E	52SE	140	2
27	72.2	22.01	N70E	71N	340	2
28	72.5	22.10	N22W	50E	68	2
29	72.6	22.13	N6E	16E	96	2
30	73.0	22.25	N85E	31S	175	2
31	73.0	22.26	N30E	43NW	300	2
32	73.1	22.28	N63E	45N	333	2
33	73.2	22.30	N31W	45NE	59	1
34	73.2	22.31	N82W	65N	8	2
35	73.2	22.32	N77E	26S	167	1
36	73.8	22.50	N2W	6W	268	2
37	74.6	22.75	N77E	4N	347	2
38	75.0	22.86	N10E	48W	280	1
39	75.2	22.92	N46E	5SE	136	2
40	75.2	22.93	N65E	46N	335	2
41	75.3	22.95	N85E	8N	355	2
42	76.1	23.20	N18W	22W	252	1
43	76.2	23.21	N40E	54SE	130	2
44	76.4	23.28	N50W	9SW	220	1
45	76.5	23.31	N41E	4NW	311	2
46	76.7	23.39	N49E	6NW	319	1
47	77.0	23.46	N68E	26N	338	1

All directions are with respect to magnetic north.

FIGURE GMP-3: BIPS FRACTURE TABLE FOR WELL GMP-3, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	77.2	23.52	N30E	25NW	300	1
49	77.6	23.64	N2E	47W	272	2
50	77.9	23.76	N22E	29W	292	0

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GMW-4

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On January 11, 1997, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GMW-4:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On January 11, 1997, at 1047 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 21 gallons of DI water were lost to the formation during dilution procedures. During the 6.06 hours following dilution, multiple logs were conducted. Of these logs, 24 are presented in Figure GMW-4:2. These logs illustrate significant change in the FEC profile. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring over the interval from 65 to 74 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GMW-4:3. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 760 µS/cm.

The data suggest that horizontal flow was occurring over the intervals from 65-68 feet and 68-74 feet. Experimental algorithms applied to these data suggest that the fluid velocities in the wellbore for these intervals were approximately 0.32 and 0.26 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specific discharge of groundwater in the aquifer of 0.13 and 0.11 ft/day, respectively. Please refer to figures GMW-4:4 and GMW-4:5 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GMW-4:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-4.

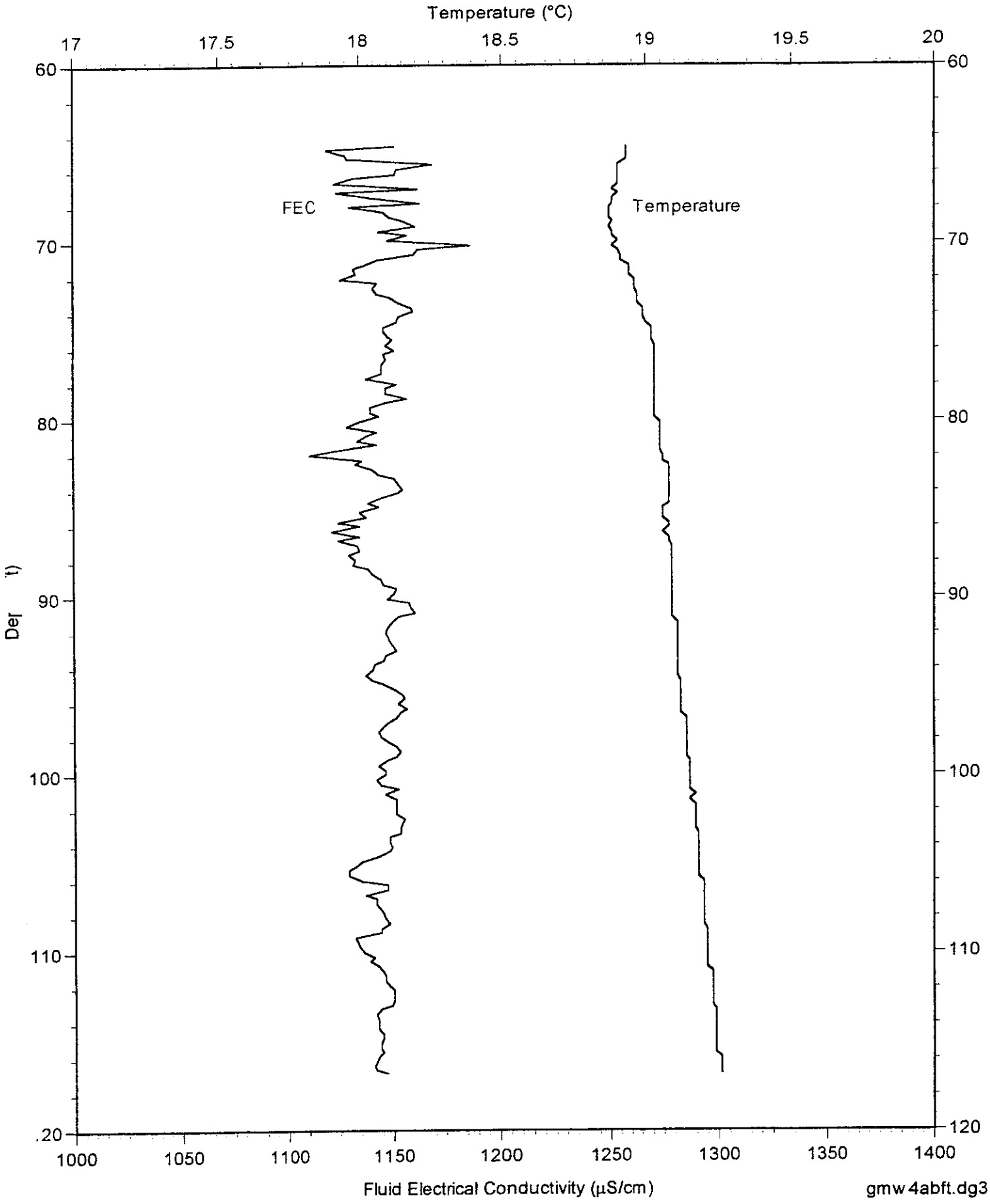


FIGURE GMW-4:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-4.

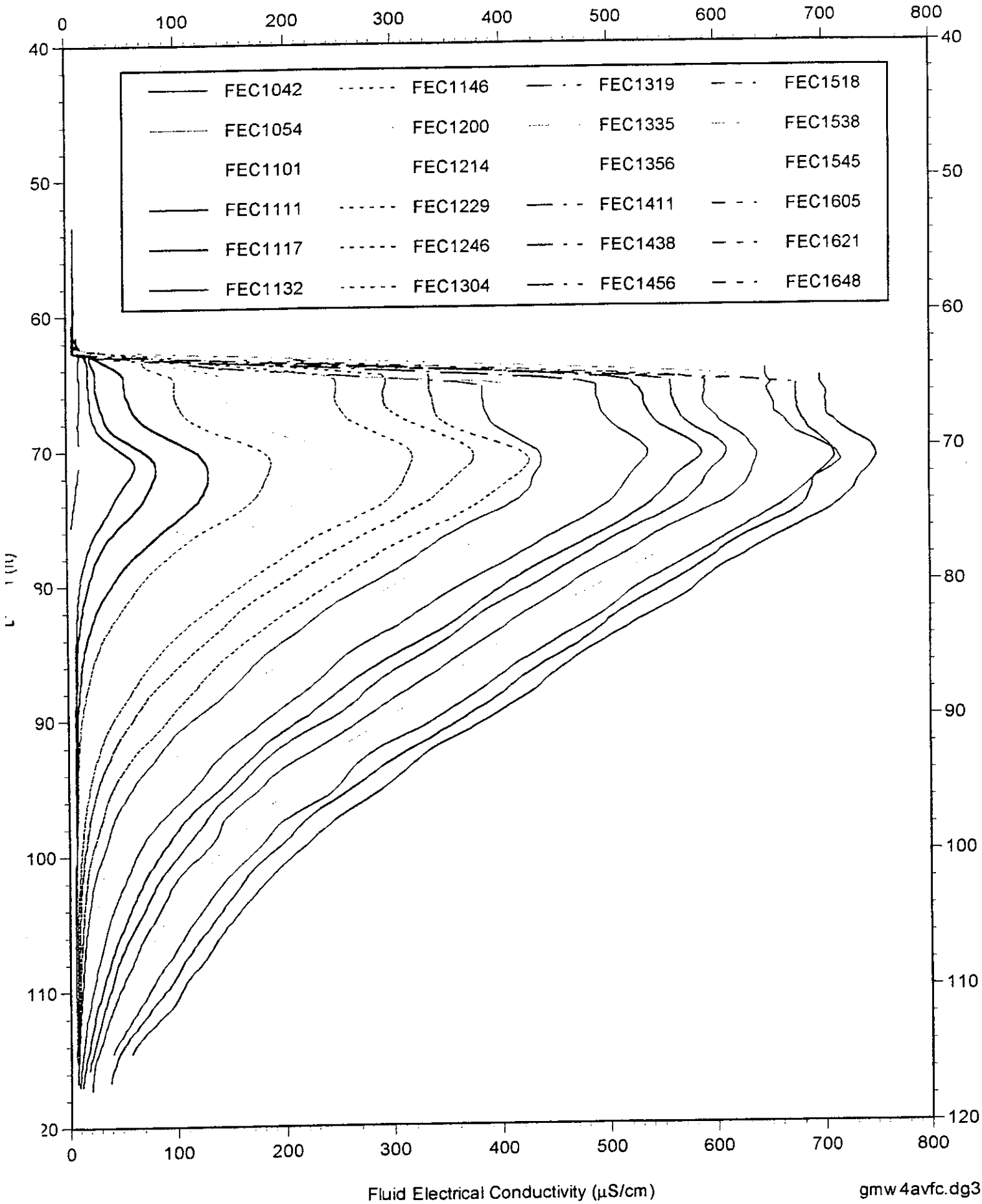
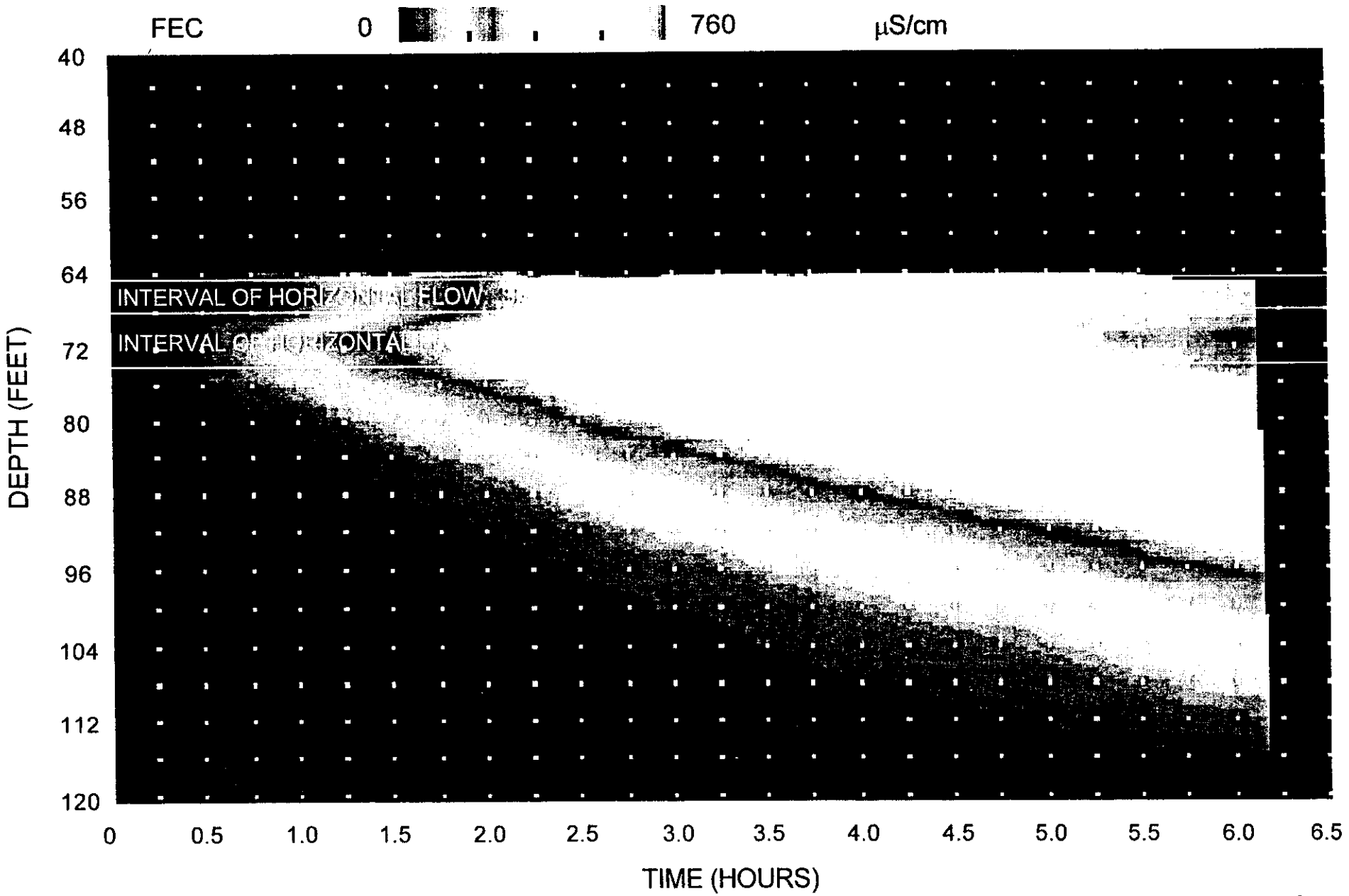
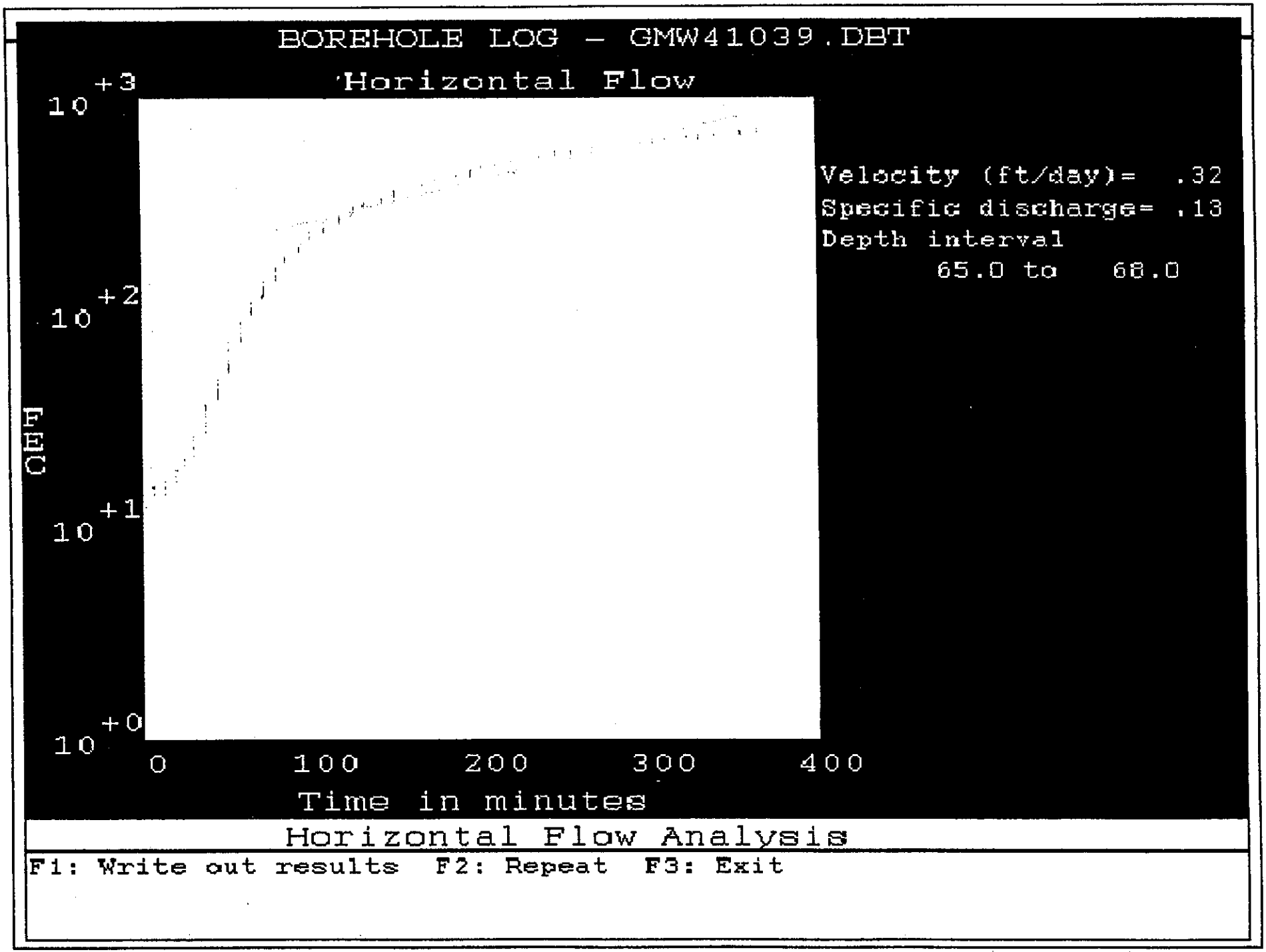


FIGURE GMW-4:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-4.



FIGU. . GMW-4:4. HORIZONTAL FLOW ANALYSIS DURING / 3IENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-4.



FIGU. . GMW-4:5. HORIZONTAL FLOW ANALYSIS DURING , BIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMW-4.

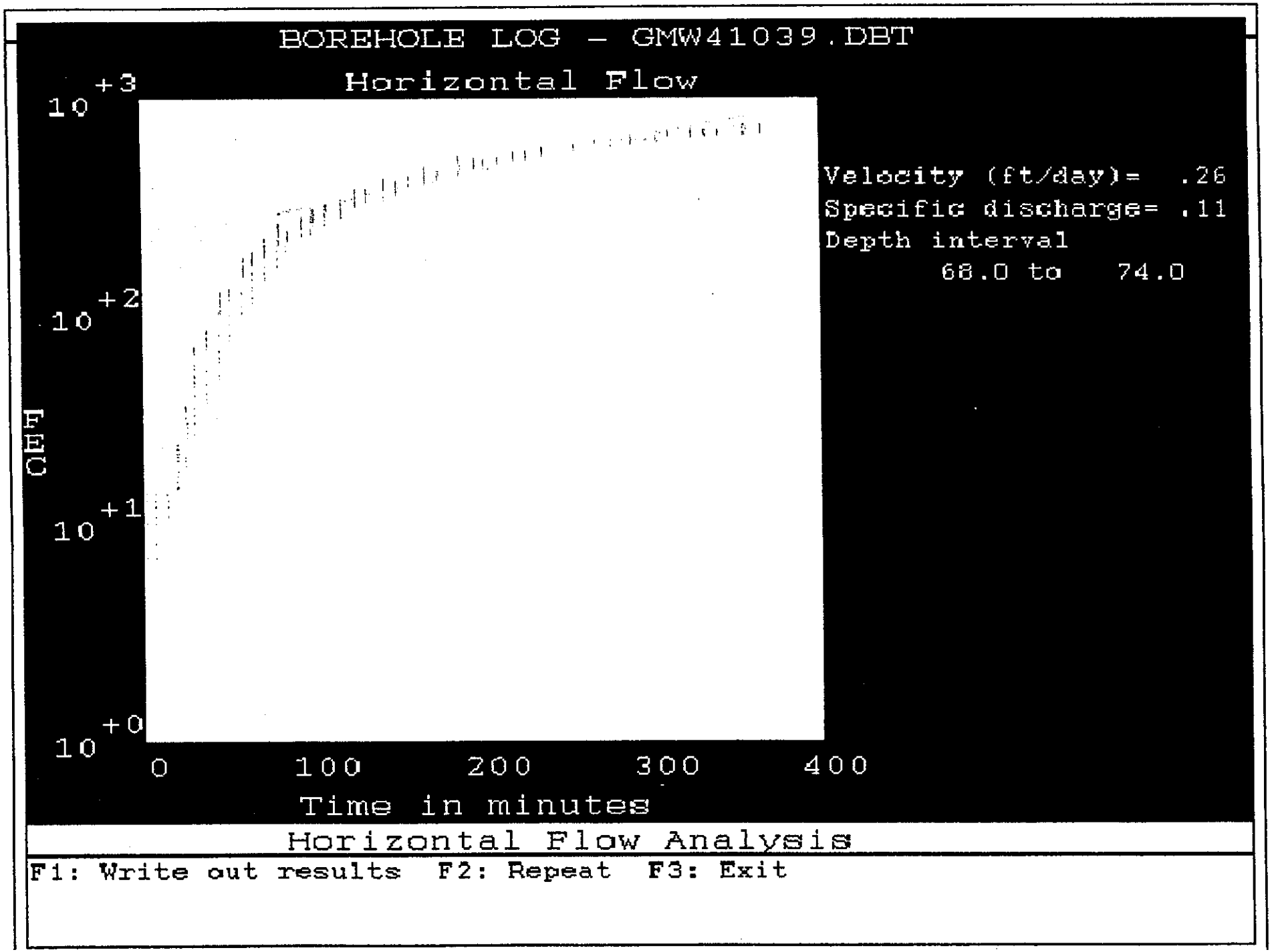


FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	62.5	19.05	N86W	35N	4	2
2	63.0	19.20	N22W	58W	248	1
3	63.5	19.35	N88E	56W	358	1
4	63.8	19.43	N77E	44W	347	2
5	63.9	19.47	N82W	68N	8	1
6	64.1	19.54	N7W	44E	83	2
7	64.4	19.64	N57E	64NW	347	1
8	64.9	19.77	N50E	47NW	320	2
9	65.0	19.80	N5W	66W	265	1
10	65.1	19.85	N58E	34NW	328	1
11	65.8	20.05	N5W	27W	265	1
12	65.8	20.05	N5W	27W	265	1
13	66.0	20.11	N75W	56N	15	1
14	66.0	20.12	N39W	35NE	51	2
15	66.8	20.35	N82E	25N	352	1
16	66.9	20.38	N79E	31N	349	2
17	67.4	20.53	N84E	38N	354	1
18	67.5	20.58	N80E	41N	350	2
19	67.8	20.66	N57E	37NW	327	1
20	68.1	20.77	N81E	36N	351	1
21	68.4	20.85	N88E	28N	358	2
22	68.5	20.89	N72E	29N	342	1
23	68.8	20.96	N39W	16SW	231	1
24	68.8	20.98	N56W	24NE	34	1
25	69.2	21.09	N9E	36W	279	1
26	69.2	21.11	N17W	65W	253	1
27	69.7	21.24	N22E	72W	292	2
28	70.0	21.35	N4E	27W	274	1
29	70.1	21.37	N8W	56W	262	1
30	71.0	21.64	N74W	33N	16	1
31	71.6	21.82	N44W	51NE	46	1
32	71.7	21.87	N24W	35N	246	1
33	71.9	21.92	N30W	36SW	240	1
34	71.9	21.92	N63W	55N	27	1
35	72.3	22.03	N64W	22N	26	2
36	72.5	22.09	N81E	32N	351	2
37	72.9	22.21	N15W	59W	255	3
38	72.9	22.22	N18E	20E	108	1
39	73.1	22.30	N10W	60W	260	2
40	73.2	22.32	N8W	63W	262	1
41	73.5	22.41	N6E	60W	276	1
42	73.8	22.50	N10E	59W	280	0
43	74.0	22.56	N16E	56W	286	0
44	74.5	22.72	N70E	61N	340	1
45	74.8	22.79	N60E	59N	330	1
46	75.1	22.88	N52E	55NW	322	1
47	75.4	22.99	N59E	48NW	329	0

All directions are with respect to magnetic north.

FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	75.9	23.12	N55E	45NW	325	1
49	76.1	23.19	N44E	42NW	314	0
50	76.2	23.22	N46E	40NW	316	1
51	76.4	23.29	N32E	25NW	302	1
52	76.7	23.37	N17W	51W	253	1
53	76.8	23.41	N9W	53W	261	1
54	77.1	23.49	N2E	56W	272	0
55	77.4	23.58	NS	61W	270	1
56	77.6	23.65	N5E	62W	275	0
57	78.3	23.87	N4E	56W	274	2
58	78.5	23.93	N16E	55W	286	2
59	79.0	24.08	N9E	34W	279	2
60	79.1	24.12	N7E	29W	277	1
61	79.3	24.18	N13E	35W	283	1
62	79.4	24.20	N43W	26NE	47	1
63	79.6	24.25	N13E	49W	283	1
64	79.8	24.31	N19E	48W	289	0
65	79.9	24.37	N27E	47W	298	0
66	80.2	24.44	N47E	42NW	317	1
67	80.4	24.50	N65E	41N	335	2
68	80.5	24.55	N59E	41NW	326	1
69	80.7	24.60	N46W	40SW	224	1
70	81.1	24.72	N36W	59SW	234	1
71	81.3	24.79	N40W	48SW	230	1
72	81.6	24.87	N31W	47SW	236	0
73	81.8	24.94	N32W	43SW	238	0
74	82.0	25.00	N33W	36SW	237	0
75	82.2	25.05	N46W	32SW	224	0
76	82.3	25.09	N45W	30SW	225	0
77	82.5	25.14	N37W	32SW	233	0
78	82.7	25.20	N3E	27W	273	0
79	82.9	25.27	NS	29W	270	0
80	83.0	25.29	N73E	45S	163	2
81	83.2	25.36	N61E	40S	151	0
82	83.2	25.37	N69W	20S	201	1
83	83.4	25.42	N17E	24W	287	0
84	83.5	25.46	N36W	43SW	234	1
85	83.7	25.51	N77W	37N	13	1
86	83.8	25.53	N73W	26S	197	1
87	83.9	25.56	N48W	67SW	222	1
88	83.9	25.57	N69W	78N	21	2
89	84.0	25.61	N4W	42W	266	0
90	84.0	25.62	N46W	23NE	44	1
91	84.3	25.70	N11W	38W	259	1
92	84.6	25.78	N61W	53S	209	1
93	84.8	25.85	N51W	54SW	219	0
94	85.0	25.92	N2W	21W	268	0

All directions are with respect to magnetic north.

FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	85.2	25.95	N21E	22W	291	0
96	85.3	25.99	N44E	28NW	314	1
97	85.5	26.06	N76E	64N	346	1
98	85.5	26.06	N86E	21N	356	0
99	85.6	26.10	N78W	19N	12	1
100	85.9	26.19	N85W	29N	5	1
101	85.9	26.19	N59W	47SW	211	0
102	86.1	26.25	N69E	30N	339	1
103	86.1	26.25	N67E	17S	157	1
104	86.2	26.27	N49W	59SW	221	1
105	86.2	26.27	N84E	6N	354	2
106	86.6	26.40	N48W	52SW	222	1
107	86.6	26.40	NS	50E	90	1
108	86.8	26.45	N64W	37S	206	0
109	86.9	26.48	N21W	50W	249	0
110	87.0	26.52	N17W	56W	253	1
111	87.4	26.63	N5W	53W	265	1
112	87.5	26.66	N73E	54N	343	0
113	87.6	26.71	N6E	45W	276	1
114	88.0	26.83	N27W	50W	243	1
115	88.3	26.91	N21W	47W	249	1
116	88.5	26.97	N18W	52W	252	1
117	88.5	26.99	N73W	10S	197	1
118	88.8	27.08	N15W	54W	255	2
119	89.2	27.20	N7W	42W	263	1
120	89.5	27.29	N9W	33W	261	1
121	89.8	27.38	N5W	40W	265	2
122	90.1	27.47	N3E	49W	273	1
123	90.4	27.56	N21E	52W	291	2
124	90.6	27.61	N2E	16E	92	2
125	91.1	27.76	N20W	23E	70	2
126	91.2	27.81	N4E	27E	94	1
127	91.3	27.84	N75W	31N	15	1
128	92.0	28.05	N75W	28N	15	1
129	92.6	28.22	N4W	42W	266	0
130	91.2	27.81	N14E	23E	104	1
131	91.3	27.84	N70W	31N	20	0
132	91.6	27.91	N34W	30NE	56	0
133	91.6	27.92	N35E	55SE	125	0
134	91.7	27.95	N39W	28NE	51	0
135	92.0	28.05	N69W	27N	21	2
136	92.4	28.16	N11E	54E	101	1
137	92.6	28.22	N2W	53E	88	1
138	92.6	28.22	N7W	42W	263	0
139	92.8	28.28	N11E	44E	101	0
140	93.2	28.40	N72E	34N	342	1
141	93.4	28.47	N5W	39W	265	0

All directions are with respect to magnetic north.

FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	93.5	28.49	N1E	45W	271	0
143	93.6	28.52	N33E	37NW	303	0
144	93.7	28.57	N72W	28N	18	1
145	94.2	28.71	N11E	39E	101	0
146	94.3	28.74	N23W	36E	67	1
147	94.3	28.75	N75E	39N	345	1
148	94.4	28.79	N5W	53W	265	1
149	94.4	28.79	N53E	81NW	323	1
150	94.6	28.84	N80W	40N	10	1
151	94.9	28.92	N78E	36N	348	1
152	95.1	28.97	N76E	45N	346	1
153	95.5	29.10	N84E	29N	354	1
154	95.8	29.21	N1E	48W	271	0
155	95.9	29.22	N30W	29NE	60	0
156	96.0	29.25	N16E	46W	286	0
157	96.4	29.37	N68E	74N	338	0
158	96.5	29.40	N87E	45N	357	1
159	96.7	29.48	N58W	33NE	32	1
160	96.8	29.52	N74E	68N	344	0
161	97.5	29.70	N75W	33N	15	1
162	97.6	29.75	N61E	12N	331	1
163	98.1	29.90	N34E	67SE	124	1
164	98.1	29.90	N10W	58W	260	1
165	98.2	29.93	N40W	21NE	50	1
166	98.5	30.02	N68E	65N	338	1
167	98.6	30.05	N4W	49W	266	1
168	98.7	30.09	N3W	49W	267	1
169	99.0	30.17	N13E	46W	283	2
170	99.2	30.24	N6W	52W	264	1
171	99.6	30.36	N63E	64N	333	0
172	99.8	30.42	N25E	64E	115	2
173	99.9	30.44	N63E	51N	333	1
174	99.9	30.46	N81W	59N	9	0
175	100.3	30.56	N88E	55N	358	0
176	100.5	30.64	N77E	58N	347	2
177	100.8	30.73	N67E	22S	157	1
178	100.9	30.75	N61E	57N	331	0
179	101.2	30.84	N82E	21N	352	2
180	101.3	30.88	N30E	57SE	120	0
181	101.6	30.98	N33E	41SE	123	0
182	101.9	31.07	N17W	64W	253	1
183	102.0	31.09	N73E	39N	343	0
184	102.2	31.16	N14E	18E	104	2
185	102.3	31.19	N4E	15E	94	1
186	103.2	31.46	N15E	41W	285	2
187	103.3	31.49	N8E	53W	278	1
188	103.4	31.52	N61E	58N	331	1

All directions are with respect to magnetic north.

FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	103.5	31.54	N2W	27W	268	1
190	103.8	31.64	N1E	35E	91	1
191	104.2	31.76	N59E	35NW	329	1
192	104.5	31.86	N67E	32N	337	2
193	104.8	31.94	N16E	42W	286	1
194	105.1	32.04	N21E	30W	291	0
195	105.3	32.09	N22E	18W	292	0
196	105.3	32.09	N62E	68N	332	2
197	105.6	32.19	N4E	51W	274	0
198	105.8	32.26	N6E	32E	96	2
199	105.9	32.28	N68E	44S	158	0
200	106.1	32.34	N66W	3N	24	1
201	106.3	32.39	N69E	29S	159	0
202	106.4	32.42	N68W	23N	22	0
203	106.6	32.48	N1W	57W	269	0
204	106.6	32.49	NS	44W	270	0
205	106.7	32.53	N3W	51W	267	1
206	107.3	32.70	N12W	36W	258	2
207	107.5	32.76	N6W	42W	264	2
208	107.6	32.79	N17E	32W	287	2
209	107.9	32.89	N87W	54N	3	1
210	108.0	32.93	N54W	38SW	216	0
211	108.2	32.98	N44W	53SW	226	0
212	108.3	33.02	N75W	30N	15	0
213	108.6	33.10	N53W	47SW	217	0
214	108.9	33.19	N3E	43W	273	1
215	109.1	33.26	N21W	30W	249	2
216	109.4	33.33	N15W	33W	255	1
217	109.6	33.41	N18W	17E	72	0
218	109.9	33.48	N70W	28N	20	1
219	110.0	33.51	N79W	33N	11	1
220	110.1	33.55	N50E	40NW	320	0
221	110.2	33.59	N2E	40W	272	2
222	110.3	33.63	N10E	44W	280	2
223	110.6	33.70	N6E	41W	276	1
224	110.6	33.72	N46W	11NE	44	1
225	110.8	33.76	N17W	24W	253	2
226	110.9	33.80	N3W	47W	267	1
227	111.2	33.89	N27E	19W	297	2
228	111.4	33.94	N51E	7NW	321	2
229	111.7	34.04	N85E	51N	355	1
230	112.0	34.14	N56E	51NW	326	0
231	112.1	34.16	N7E	19E	97	0
232	112.7	34.35	N80E	45N	350	2
233	113.2	34.49	N55E	54NW	325	1
234	113.5	34.60	N46E	56NW	316	1
235	114.1	34.77	N42E	52NW	312	0

All directions are with respect to magnetic north.

FIGURE GMW-4: BIPS FRACTURE TABLE FOR WELL GMW-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
236	114.2	34.82	N17E	61W	287	1
237	114.5	34.89	N47E	52NW	317	0
238	114.3	34.84	N29E	16W	39	2
239	114.8	34.99	N42E	54NW	312	1
240	115.2	35.12	N39E	39SE	129	2

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-1

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 13, 1996, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-1:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow.

On December 13, 1996, at 1023 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 8 gallons of deionized water was lost to the formation during dilution procedures. Prior to the pumps being turned off, a baseline log (FEC1018) during emplacement was acquired. During the 5.87 hours following dilution, multiple logs were conducted. Of these logs, 11 are presented in Figure GLA-1:2. These logs illustrate little change throughout the length of the borehole. This lack of any significant change in the FEC profiles with respect to time indicates no observed horizontal or vertical ambient flow. As such, a discussion of horizontal or vertical ambient flow is not necessary.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-1:3. FEC of 0 μ S/cm is represented on this figure by the dark blue color, with a spectral color progression to yellow as the values increase linearly to 100 μS/cm.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GLA-1:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-1.

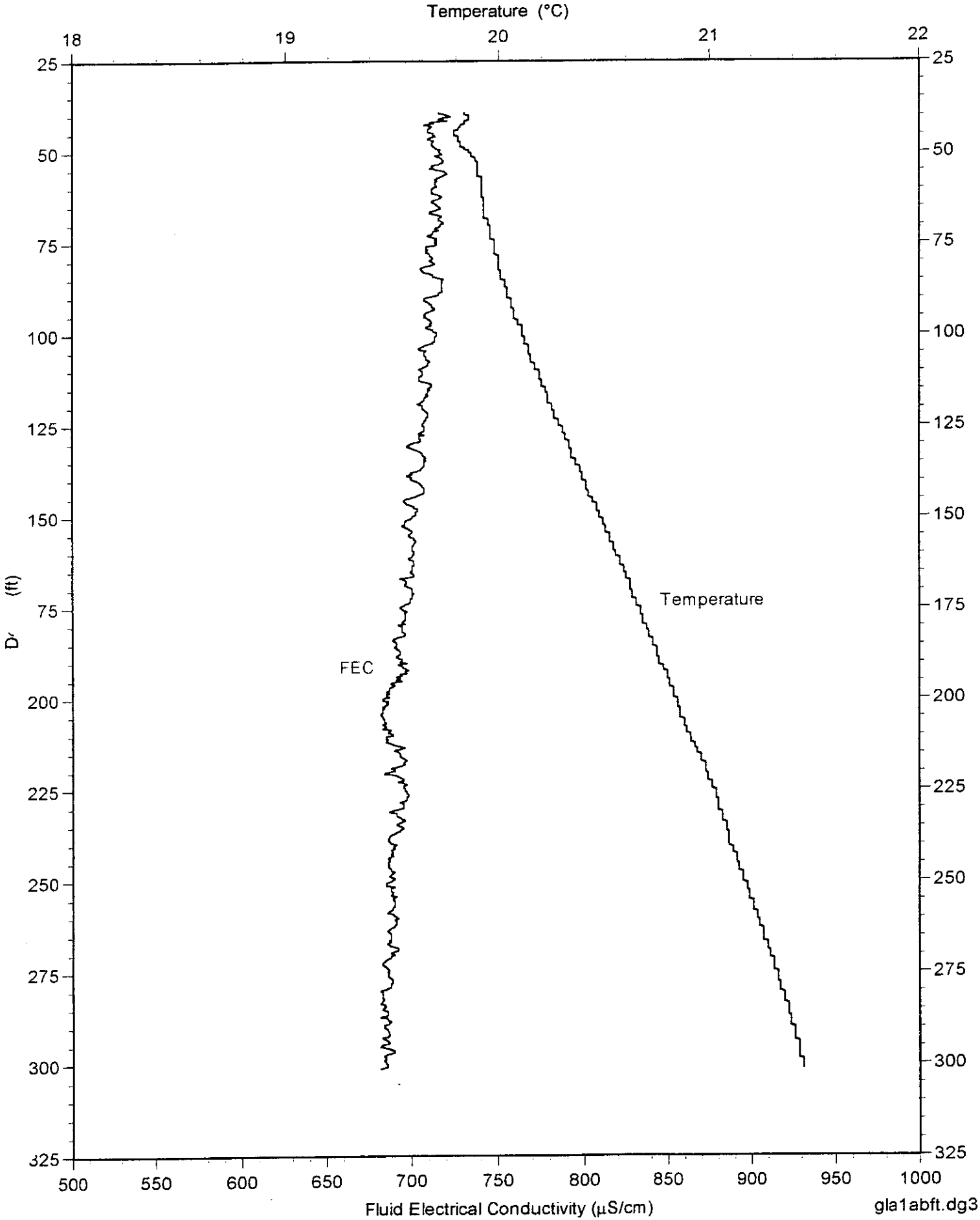

FIGURE GLA-1:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA.; WELL GLA-1.

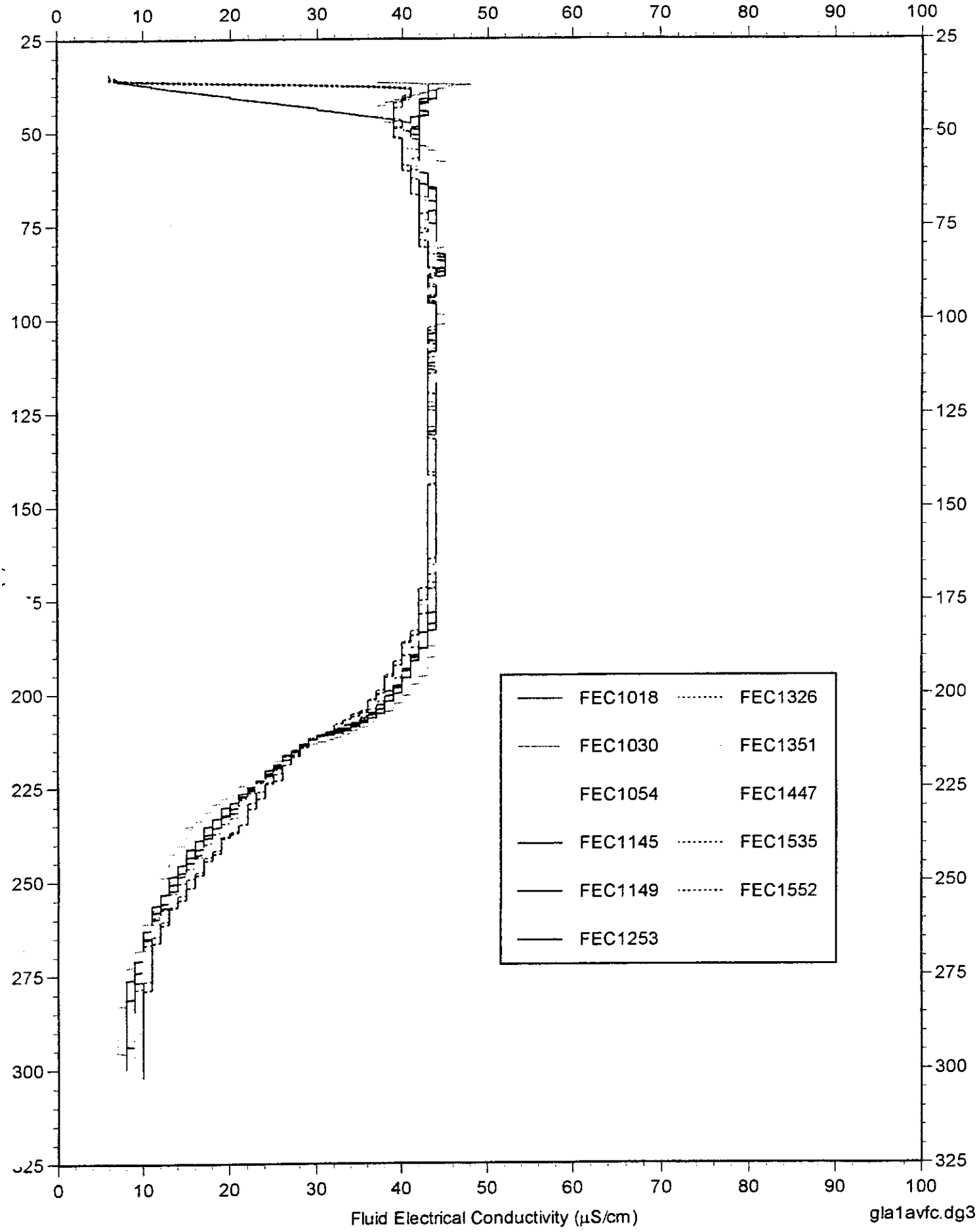

FIGURE GLA-1:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-1.

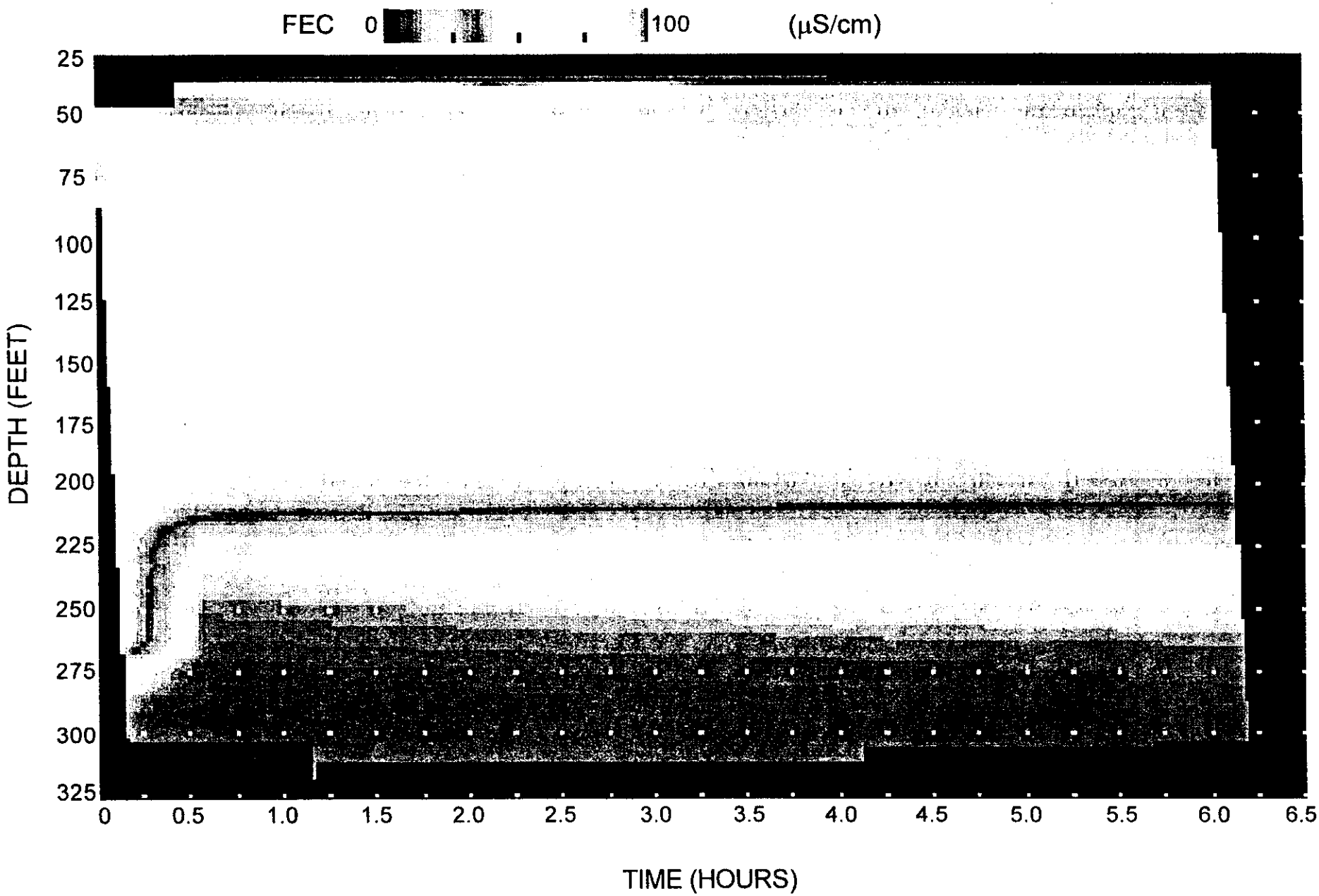

FIGURE GLA-1: BIPS FRACTURE TABLE FOR WELL GLA-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	22.9	6.97	N55W	6NE	35	1
2	23.4	7.14	N13E	12W	283	2
3	24.8	7.57	N66W	43S	204	2
4	27.0	8.23	N12W	50E	78	0
5	28.2	8.60	N12E	62E	102	0
6	28.8	8.79	N30W	57NE	60	0
7	31.2	9.50	N63W	13S	207	0
8	31.7	9.67	N36W	17SW	234	0
9	32.8	9.98	N11W	10E	79	0
10	33.9	10.35	N28W	68E	62	0
11	34.5	10.51	N27W	65E	63	1
12	35.0	10.66	N26W	63E	64	0
13	35.1	10.71	N11W	55W	259	0
14	36.1	11.01	N26W	51W	244	0
15	36.5	11.12	N79W	21S	191	1
16	36.8	11.21	N74E	58N	344	0
17	37.5	11.42	N86E	31S	176	0
18	39.5	12.05	N78W	17S	192	0
19	40.1	12.21	N57W	49NE	33	0
20	41.2	12.57	N87W	30S	183	0
21	41.7	12.70	N62E	39S	152	0
22	42.3	12.89	N65W	13N	25	0
23	44.6	13.58	N69E	5N	339	0
24	44.7	13.63	N65W	15S	205	0
25	46.3	14.10	N18W	60W	252	0
26	47.2	14.39	N89E	42N	359	0
27	47.3	14.43	N56W	31NE	24	0
28	52.6	16.02	N53E	33NW	212	0
29	53.2	16.22	N59W	22NE	21	1
30	55.0	16.78	N32W	54NE	58	0
31	55.1	16.80	N28W	77E	62	0
32	56.4	17.19	N25W	26E	65	0
33	59.6	18.18	N54W	42SW	216	2
34	60.5	18.43	N76W	32N	14	0
35	61.0	18.61	N57W	31NE	33	0
36	61.8	18.84	N38W	52NE	52	0
37	62.1	18.92	N49W	50NE	41	0
38	62.6	19.08	N39W	41NE	51	1
39	64.0	19.50	N47W	42NE	43	1
40	65.2	19.86	N48W	23NE	42	2
41	65.8	20.05	N48W	83SW	222	1
42	68.0	20.73	N88E	37N	358	1
43	69.5	21.20	N31W	66NE	59	0
44	70.2	21.39	N51W	68NE	39	1
45	71.4	21.75	N52W	15NE	38	0
46	72.5	22.10	N59W	58NE	31	0
47	73.3	22.34	N82W	19S	188	1

All directions are with respect to magnetic north.

FIGURE GLA-1: BIPS FRACTURE TABLE FOR WELL GLA-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	74.1	22.59	N56W	62NE	34	1
49	75.2	22.91	N79E	29S	169	0
50	75.3	22.97	N88W	34S	182	1
51	76.3	23.27	N47W	64NE	43	0
52	79.9	24.34	N35E	60NW	305	0
53	79.9	24.36	N29E	67W	299	0
54	80.9	24.67	N44E	58NW	314	0
55	81.4	24.80	N66W	32N	24	0
56	82.1	25.02	N72W	27N	18	0
57	84.6	25.80	N68W	38S	101	0
58	84.9	25.88	N88W	14S	182	0
59	86.5	26.38	N66W	39N	24	0
60	87.8	26.75	N54W	48NE	36	0
61	89.4	27.24	N4E	3E	94	0
62	89.8	27.36	N82W	23N	8	0
63	89.9	27.40	N51W	81SW	219	0
64	90.1	27.46	N64E	11N	334	1
65	91.0	27.73	N41W	28SW	229	1
66	91.9	28.01	N64W	46N	26	0
67	92.7	28.27	N80W	42N	10	0
68	95.1	29.00	NS	62W	270	0
69	97.8	29.81	N1W	55W	269	1
70	98.9	30.13	N45W	27NE	45	0
71	99.0	30.17	N51W	25NE	39	1
72	99.6	30.35	N63W	44S	207	0
73	100.5	30.64	N87W	40N	3	1
74	101.3	30.87	N85W	24N	5	1
75	102.0	31.09	N86E	34N	356	1
76	102.7	31.30	N87W	34N	3	1
77	103.2	31.44	EW	24N	0	0
78	103.7	31.60	N71W	40N	19	1
79	104.1	31.74	N7W	52E	83	0
80	104.7	31.91	N70E	25N	340	1
81	105.0	32.00	N55E	26NW	325	0
82	105.6	32.19	N71E	30N	341	0
83	106.0	32.30	N86E	37N	356	0
84	107.1	32.66	N82W	29N	8	1
85	107.7	32.84	N86W	29N	4	2
86	108.2	32.99	N60W	18N	30	0
87	108.8	33.15	N50W	19NE	40	0
88	109.3	33.31	N82W	33N	8	0
89	110.1	33.56	N71W	30N	19	1
90	112.6	34.31	N75W	32N	15	1
91	112.9	34.40	N32W	67SW	238	0
92	115.9	35.32	N27E	47E	117	0
93	116.1	35.40	N21W	44E	69	1
94	116.6	35.53	N10E	26E	100	1

All directions are with respect to magnetic north.

FIGURE GLA-1: BIPS FRACTURE TABLE FOR WELL GLA-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	117.1	35.69	N59W	25NE	31	0
96	120.2	36.65	N80W	29N	10	0
97	120.4	36.70	N84E	22N	354	1
98	121.1	36.92	N84E	21N	354	1
99	123.1	37.51	N51W	26NE	39	0
100	124.1	37.83	N87W	35N	3	1
101	127.4	38.84	N39W	35NE	51	0
102	128.5	39.17	N81E	15N	351	0
103	129.3	39.40	N76W	25N	14	0
104	131.3	40.03	N76W	25N	14	0
105	131.7	40.15	N56W	26NE	34	0
106	140.7	42.90	N22W	21E	68	1
107	141.8	43.22	N73W	14N	17	1
108	145.0	44.19	N64W	38N	26	1
109	146.4	44.63	N65W	12S	205	1
110	146.9	44.77	N82W	24N	8	1
111	147.4	44.92	N50W	18NE	40	0
112	149.6	45.59	N36E	59SE	126	0
113	153.9	46.90	N88E	13S	178	0
114	156.2	47.61	N56E	20NW	326	2
115	159.0	48.47	N10E	29E	100	0
116	163.4	49.82	N8E	31E	98	1
117	163.7	49.89	N14E	23E	104	0
118	166.5	50.74	N6E	43W	276	1
119	166.8	50.85	N71W	11N	19	0
120	170.2	51.88	N70W	40S	200	0
121	173.4	52.84	N13E	30W	283	0
122	173.4	52.86	N3E	36W	273	2
123	178.6	54.44	N80W	13N	10	0
124	184.4	56.20	N49W	12NE	41	0
125	184.7	56.30	N23W	10E	67	1
126	185.8	56.64	N11E	17E	101	0
127	186.6	56.88	N85E	20N	355	0
128	186.8	56.95	N79E	55S	169	0
129	187.0	56.99	N46W	17NE	44	0
130	187.5	57.14	N77W	13N	13	0
131	188.0	57.30	N39E	5SE	129	1
132	188.3	57.41	N20E	4E	110	1
133	193.9	59.10	N67E	17N	337	0
134	204.8	62.42	N36W	10NE	54	0
135	204.9	62.45	N35W	9NE	55	1
136	205.9	62.75	N22W	10E	68	2
137	206.3	62.87	N21W	8E	69	2
138	207.6	63.29	N20E	15E	110	2
139	208.2	63.45	N66W	5N	24	1
140	209.1	63.74	N66W	6S	204	0
141	210.4	64.14	N11W	2E	79	0

All directions are with respect to magnetic north.

FIGURE GLA-1: BIPS FRACTURE TABLE FOR WELL GLA-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	210.7	64.23	N43E	25SE	133	1
143	210.9	64.30	N26E	13W	296	1
144	212.3	64.71	N46E	15SE	136	1
145	213.4	65.03	N5W	40E	85	1
146	214.3	65.31	N13E	30E	103	0
147	215.4	65.65	N12W	21E	78	1
148	216.0	65.83	N27W	60W	243	0
149	218.0	66.45	N45W	32SW	225	1
150	221.3	67.45	N76E	58N	346	0
151	224.6	68.44	N28W	45W	242	0
152	225.6	68.77	N28W	31W	242	0
153	227.5	69.36	N14W	53W	256	0
154	229.5	69.96	N5W	47W	265	0
155	230.2	70.17	N8E	11E	98	0
156	231.6	70.60	N25W	42E	65	1
157	233.3	71.10	N33W	65NE	57	0
158	234.2	71.38	N81W	12S	189	2
159	234.6	71.50	N14W	43E	76	1
160	236.0	71.92	N37W	45SW	233	2
161	238.5	72.71	N50W	54SW	220	1
162	238.9	72.83	N52E	31SE	142	0
163	244.6	74.54	N50E	52SE	140	1
164	245.6	74.84	N44E	57NW	314	1
165	246.3	75.07	N42E	79SE	132	1
166	246.7	75.19	N21E	55W	291	0
167	248.0	75.59	N50E	42NW	320	1
168	250.7	76.42	N21W	15W	249	1
169	251.2	76.57	N47E	30NW	317	1
170	252.3	76.89	N77E	27N	347	1
171	253.1	77.16	N55E	28NW	325	0
172	253.7	77.32	N57E	19NW	327	0
173	254.3	77.51	N44E	14NW	314	1
174	255.2	77.80	N19E	32E	109	0
175	257.6	78.52	N29E	56E	119	0
176	258.7	78.86	N38W	22NE	52	1
177	259.5	79.10	N19E	51E	109	1
178	263.0	80.16	N25W	37E	65	0
179	265.3	80.88	N88W	12N	2	0
180	266.0	81.09	N36E	28SE	126	0
181	267.8	81.63	N37W	17NE	53	1
182	269.4	82.10	N34W	48NE	56	1
183	274.4	83.64	N44E	20SE	134	1
184	275.5	83.98	N24E	35E	114	1
185	276.6	84.30	N39W	55NE	51	1
186	279.0	85.04	N4W	17E	86	0
187	279.9	85.33	N2E	19E	92	1
188	281.3	85.73	N68W	18N	22	1

All directions are with respect to magnetic north.

FIGURE GLA-1: BIPS FRACTURE TABLE FOR WELL GLA-1, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	285.8	87.12	N72E	13S	162	1
190	289.1	88.12	N42E	39NW	312	0
191	295.4	90.05	N26E	30E	116	0

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-2

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 12, 1996, after field calibration of the fluid electrical conductivity (FEC) and temperature logging tool (see Appendix A for details), the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-2:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On December 12, 1996, at 1220 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 10 gallons of deionized water were lost to the formation during dilution procedures. During the 6.76 hours following dilution, multiple logs were conducted. Of these logs, 15 are presented in Figure GLA-2:2. These logs illustrate significant change throughout the interval from 70 to 100 feet. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring over the interval from 83 to 85 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-2:3. FEC of 0 μ S/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 220 μ S/cm.

The data suggest that horizontal flow was occurring over the interval from 83 to 85 feet. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for this interval was approximately 0.43 ft/day. Correcting for convergence of flow at the wellbore, this velocity equates to a specific discharge of groundwater in the aquifer of 0.17 ft/day. Please refer to Figure GLA-2:4 for the estimated horizontal velocity and specific discharge calculated for this interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GLA-2:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-2.

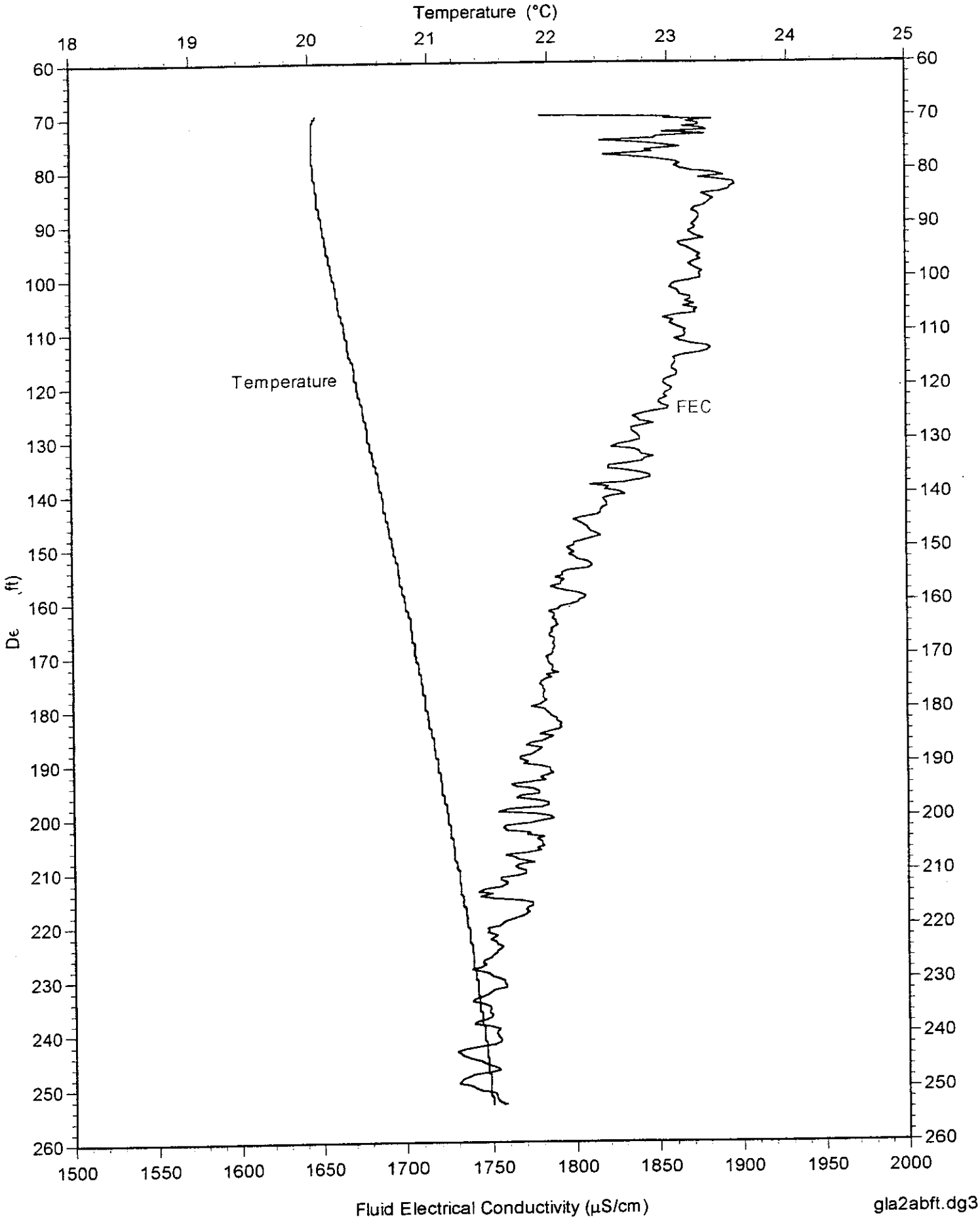


FIGURE GLA-2:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-2.

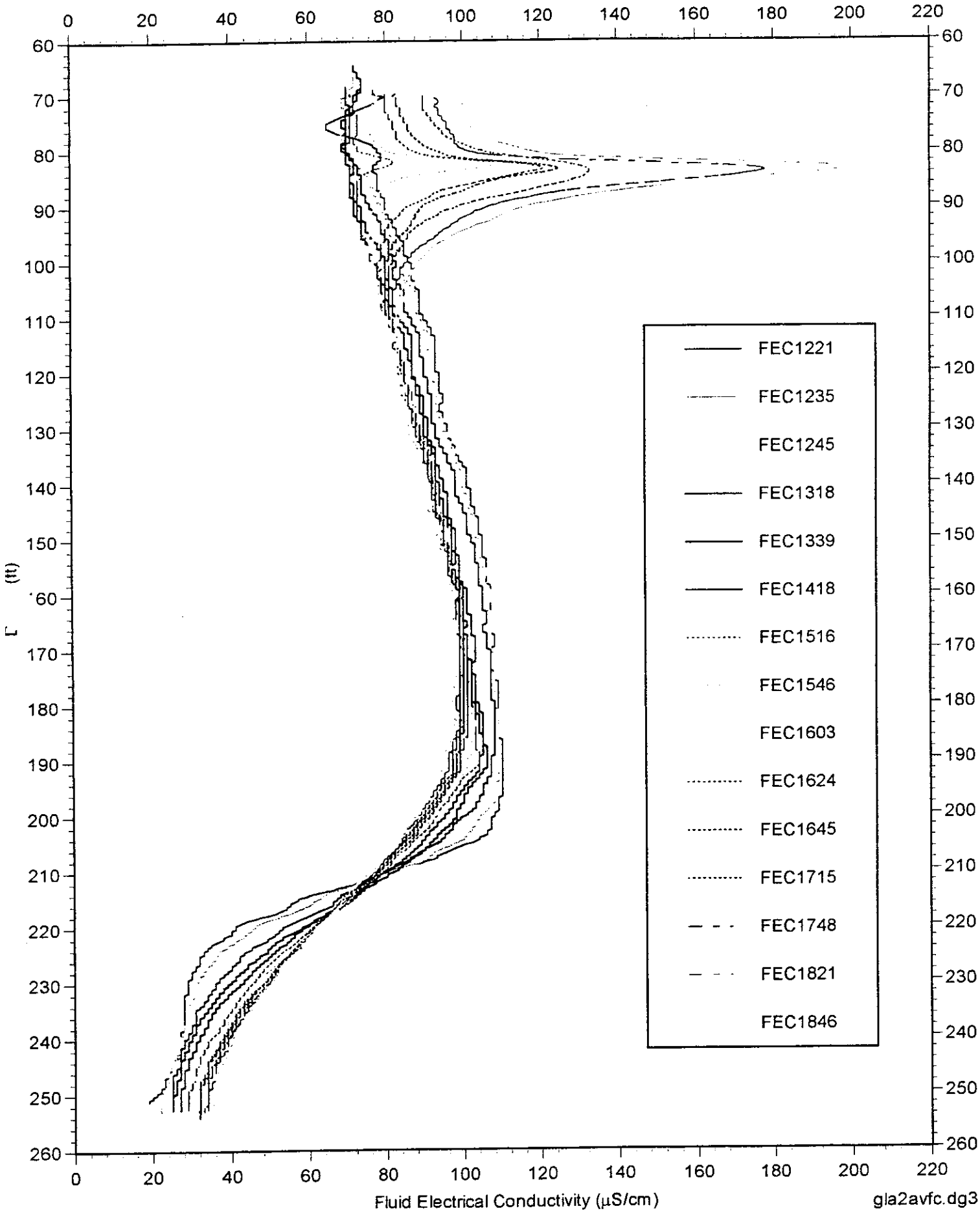
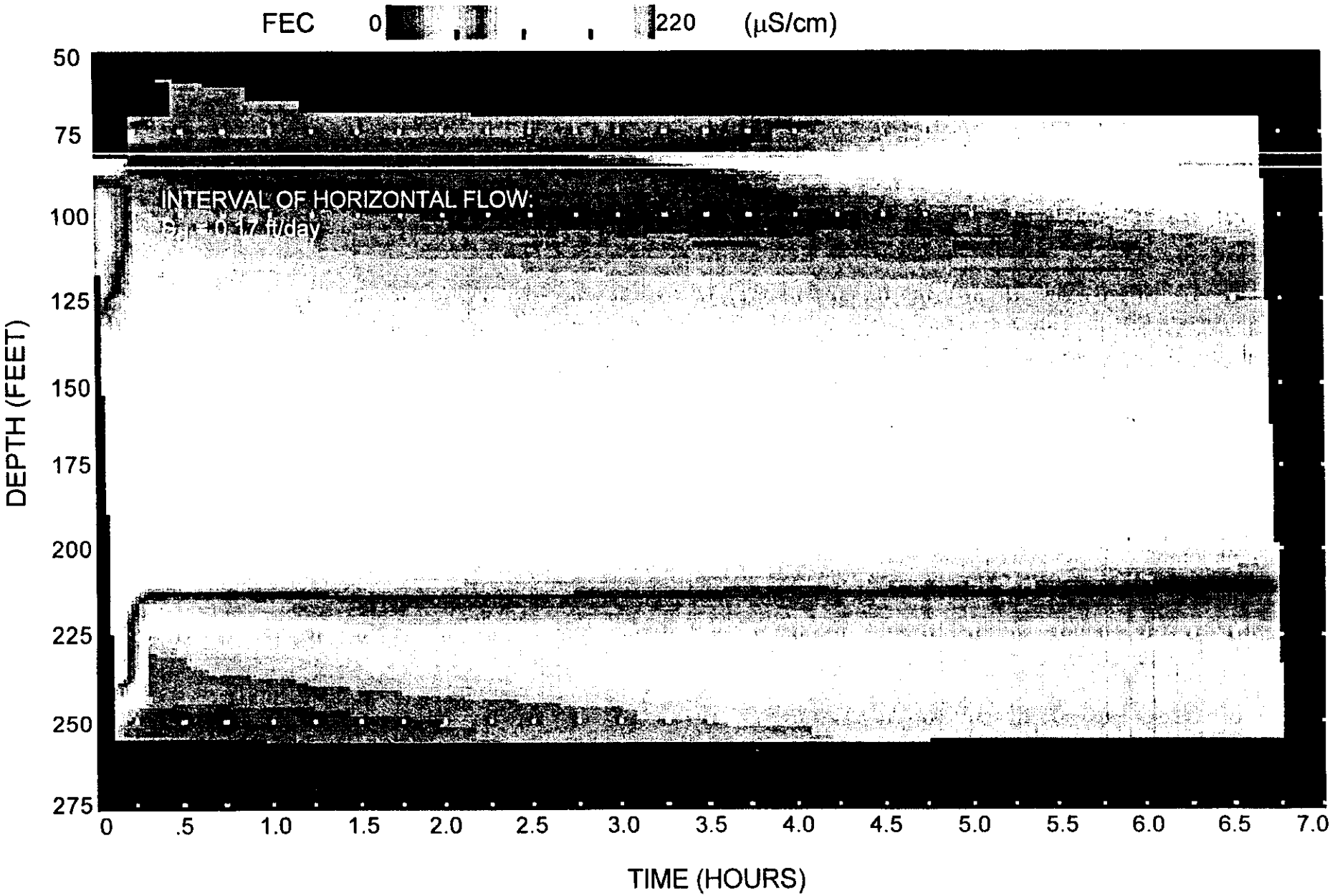
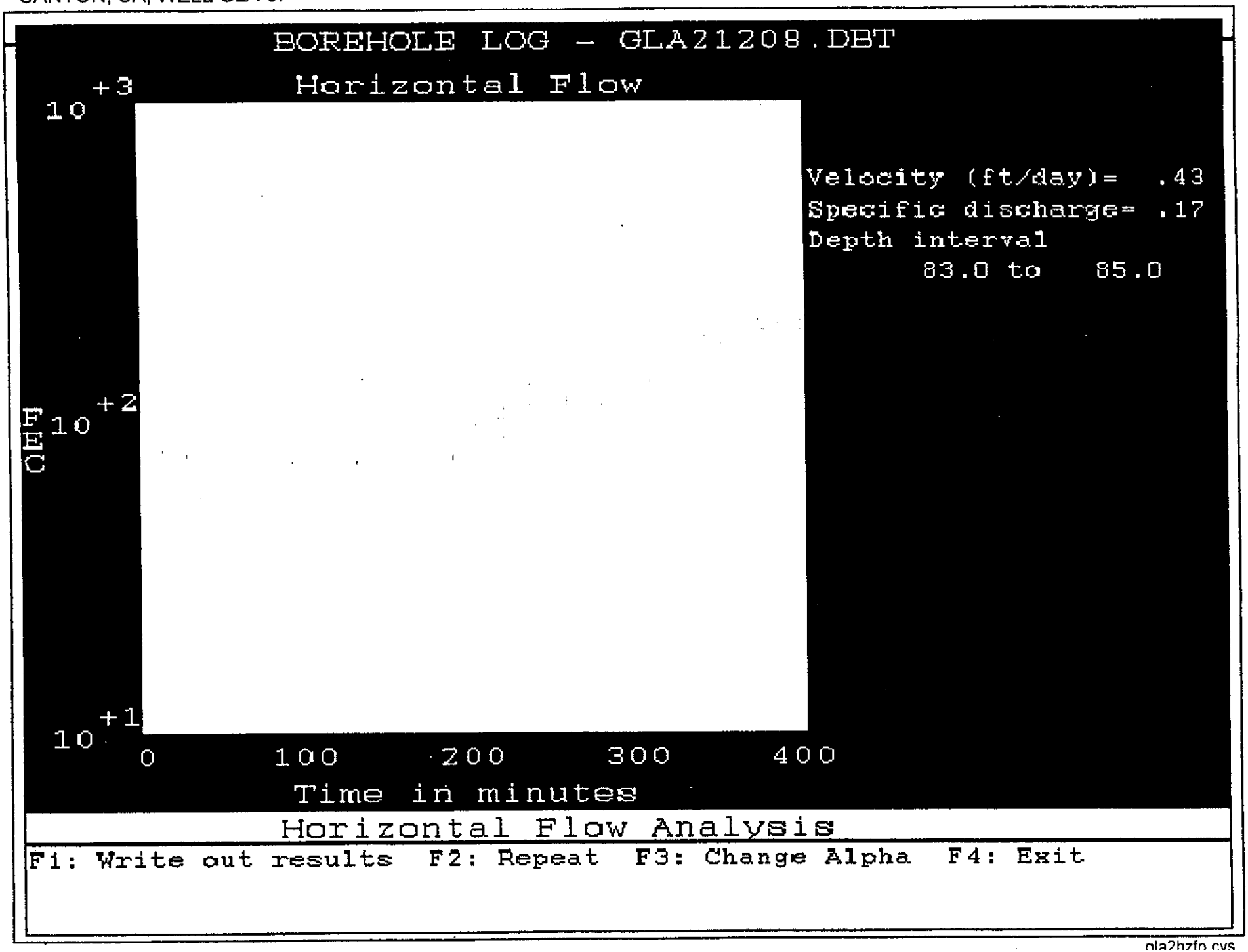


FIGURE GLA-2:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-2.



gla2avfc.cvs

FIGURE _A-2:4. HORIZONTAL FLOW ANALYSIS DURING AME .T CONDITIONS; GEOLOGIC ASSOCIATES; GREGOF CANYON, CA; WELL GLA-5.



gla2hzfo.cvs

FIGURE GLA-2: BIPS FRACTURE TABLE FOR WELL GLA-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	13.3	4.07	N68W	30S	202	0
2	13.5	4.12	N67W	33S	203	0
3	14.6	4.44	N69E	29S	159	0
4	15.7	4.79	N89W	74N	1	0
5	21.0	6.39	NS	65E	91	0
6	21.3	6.49	N61E	22S	151	0
7	28.0	8.55	N83W	82S	187	0
8	29.8	9.07	N80W	42S	190	0
9	30.1	9.17	N74W	41S	196	0
10	30.9	9.42	N74W	65N	16	0
11	31.6	9.63	N56W	49NE	34	0
12	33.7	10.26	N87W	44S	183	0
13	33.9	10.34	N88E	16S	178	0
14	34.1	10.38	EW	66N	1	0
15	35.6	10.86	N84E	65S	174	2
16	36.1	11.00	N79E	62S	169	0
17	36.9	11.25	N89E	28S	179	2
18	37.1	11.31	N83W	46S	187	0
19	38.7	11.79	N74E	64S	164	1
20	39.5	12.04	N61E	26N	331	0
21	40.2	12.24	N56E	61SE	146	0
22	41.8	12.75	N63E	60S	153	0
23	42.3	12.90	N76E	60S	166	0
24	42.9	13.07	N67E	42S	157	1
25	43.2	13.18	N78E	38S	168	0
26	43.5	13.26	N76E	45S	166	0
27	43.9	13.38	N45E	30SE	135	1
28	44.1	13.44	N25E	29E	115	1
29	44.5	13.55	N58W	24SW	212	0
30	44.5	13.56	N18W	23E	72	0
31	45.6	13.91	N71E	21S	161	0
32	45.8	13.96	N5W	55E	85	1
33	47.0	14.32	N14W	65E	76	1
34	47.8	14.58	N64W	16S	206	0
35	49.0	14.95	N44W	58NE	46	0
36	49.5	15.10	N63W	22S	207	0
37	49.6	15.12	N19W	56E	71	0
38	54.9	16.75	N46W	37SW	224	2
39	56.4	17.18	N50E	35NW	320	0
40	56.5	17.22	N48E	33NW	318	0
41	56.7	17.29	N69E	35N	339	1
42	59.0	17.98	N84E	47N	354	1
43	59.3	18.09	N78W	39N	12	0
44	59.9	18.27	N44W	62SW	226	0
45	60.4	18.40	N82W	65N	8	0
46	60.7	18.51	N60E	29N	330	1
47	61.4	18.70	N36E	26NW	306	0

All directions are with respect to magnetic north.

FIGURE GLA-2: BIPS FRACTURE TABLE FOR WELL GLA-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	62.7	19.11	N33W	31NE	57	0
49	63.6	19.40	N/A	Vert.	N/A	0
50	64.7	19.73	N11E	71E	101	0
51	64.9	19.79	N1E	30W	271	0
52	65.9	20.09	N77E	9N	347	1
53	66.4	20.24	N87W	35N	3	0
54	67.1	20.46	N80E	71N	350	1
55	67.6	20.60	N75E	69N	345	1
56	67.8	20.65	N74E	70N	344	0
57	69.5	21.20	N40E	22NW	310	0
58	72.7	22.16	N34W	40NE	56	1
59	73.2	22.32	N10W	25E	80	1
60	74.2	22.61	N77E	70N	347	1
61	74.7	22.77	N8W	78E	82	1
62	75.5	23.02	N23W	42W	247	2
63	76.9	23.45	N20W	19E	70	1
64	78.7	24.00	N37E	26SE	127	1
65	80.1	24.40	N23E	34W	293	0
66	80.2	24.46	N6E	35W	276	0
67	80.8	24.64	N7E	37W	277	0
68	81.0	24.68	N9E	41W	279	0
69	81.2	24.74	N26E	38W	296	0
70	81.3	24.78	N30E	32NW	300	0
71	81.5	24.85	N38E	29NW	308	0
72	81.9	24.98	N6E	26W	276	0
73	82.3	25.09	N25E	28W	295	1
74	83.2	25.36	N55E	19NW	325	0
75	84.5	25.76	N78E	27N	348	0
76	86.3	26.30	N60E	16N	330	0
77	86.5	26.36	N81E	12N	351	1
78	86.7	26.44	N13W	10W	257	0
79	86.9	26.48	N5E	11W	275	0
80	92.9	28.32	N/A	Vert.	N/A	0
81	94.7	28.87	N10E	21E	100	0
82	97.0	29.57	N21E	24E	111	1
83	101.2	30.85	N27W	11E	63	0
84	104.1	31.72	N7W	27E	83	0
85	104.3	31.78	N42W	15NE	48	0
86	104.9	31.99	N6E	20E	96	0
87	105.4	32.12	N64E	55S	154	0
88	106.6	32.49	N80W	37S	190	0
89	109.3	33.33	N60E	39N	330	1
90	112.7	34.35	N/A	Vert.	N/A	2
91	113.4	34.56	N39W	79SW	231	2
92	127.2	38.78	N33E	22SE	123	0
93	127.9	38.97	N36E	33SE	126	1
94	128.2	39.07	N6W	9E	84	0

All directions are with respect to magnetic north.

FIGURE GLA-2: BIPS FRACTURE TABLE FOR WELL GLA-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	128.5	39.17	N19W	18E	71	0
96	130.3	39.72	N73E	24N	343	0
97	131.0	39.92	N56E	20NW	326	1
98	131.1	39.97	N71E	15N	341	0
99	131.5	40.08	N79W	18N	11	0
100	131.7	40.14	N80W	13N	10	0
101	132.0	40.22	N84W	23N	6	0
102	132.2	40.29	N68E	19S	158	0
103	133.0	40.54	N87W	27N	3	0
104	133.2	40.59	N86W	23N	4	1
105	133.5	40.69	N76W	26N	14	0
106	133.6	40.73	N80E	24N	350	0
107	134.0	40.84	N57E	23NW	327	0
108	134.4	40.97	N76E	53N	346	0
109	134.9	41.12	N86E	30N	356	0
110	135.1	41.17	N85E	31N	355	0
111	135.8	41.40	N/A	Vert.	N/A	1
112	136.4	41.58	N89E	13N	359	0
113	137.9	42.04	N40W	64NE	50	1
114	139.6	42.56	N3W	30E	87	0
115	140.2	42.72	N16W	32E	74	0
116	140.6	42.85	N53W	15NE	37	0
117	141.1	43.00	N83E	19N	353	0
118	141.3	43.07	N87W	19N	3	0
119	142.2	43.35	N62E	21N	332	1
120	142.4	43.40	N84E	15S	174	1
121	143.1	43.63	N55E	25NW	325	1
122	145.2	44.24	N4W	5E	86	1
123	145.9	44.47	N9E	19W	279	0
124	146.1	44.53	N25E	26W	295	1
125	148.7	45.34	N62W	21N	28	0
126	149.9	45.68	N58W	10NE	32	0
127	150.0	45.72	N20W	16E	70	0
128	150.2	45.79	N47E	39NW	317	2
129	151.9	46.29	N4E	45W	274	0
130	153.1	46.67	N68E	50N	338	2
131	153.6	46.81	N62E	40N	332	0
132	157.3	47.94	N35E	6SE	125	0
133	157.4	47.99	N56E	19SE	146	0
134	157.6	48.04	N79E	18N	349	0
135	157.6	48.05	N85E	17N	355	0
136	157.8	48.11	N58E	29NW	328	2
137	158.4	48.28	N27E	18W	297	0
138	160.1	48.78	N88W	23S	182	1
139	161.9	49.35	N74W	57N	16	1
140	162.3	49.48	N76W	53N	14	0
141	167.1	50.95	N51E	56SE	141	1

All directions are with respect to magnetic north.

FIGURE GLA-2: BIPS FRACTURE TABLE FOR WELL GLA-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	167.3	51.01	N14W	32W	256	0
143	174.3	53.12	N51W	34SW	219	0
144	174.5	53.18	N12E	16W	282	0
145	174.7	53.25	N27E	15W	297	1
146	174.8	53.29	N37E	17NW	307	0
147	175.1	53.38	N80E	12S	170	0
148	175.5	53.48	N71E	23N	341	0
149	175.6	53.54	N39E	25NW	309	1
150	175.8	53.60	N49E	31NW	319	0
151	177.0	53.95	N5E	12W	275	1
152	177.7	54.15	N36E	41NW	306	0
153	179.4	54.68	N39E	24NW	309	1
154	179.8	54.79	N3E	27W	273	1
155	180.0	54.86	N6W	11W	264	0
156	180.6	55.06	N34E	23NW	304	0
157	180.9	55.14	N39E	17NW	309	0
158	182.0	55.48	N14E	9W	284	1
159	182.5	55.62	N46E	23NW	316	0
160	184.7	56.30	N6E	81W	276	0
161	186.1	56.73	N47E	3NW	317	0
162	186.4	56.82	N45E	29NW	315	0
163	186.9	56.98	N39E	36NW	309	0
164	187.2	57.06	N36E	35NW	306	0
165	187.4	57.11	N65E	16N	335	1
166	187.9	57.27	N45E	34NW	315	0
167	188.1	57.34	N52E	48NW	322	0
168	188.4	57.43	N56E	33NW	326	0
169	191.4	58.33	N14E	39W	284	3
170	192.1	58.55	N19E	41W	289	0
171	193.1	58.87	N12W	44E	78	0
172	193.9	59.10	N83W	21N	7	0
173	197.3	60.13	N11W	51E	79	0
174	198.1	60.37	N32W	62NE	58	0
175	198.9	60.62	N8W	54E	82	1
176	200.0	60.97	N21W	49E	69	1
177	200.2	61.03	N17W	47E	73	0
178	200.6	61.15	N3W	41E	87	1
179	203.4	61.99	N79W	28N	11	0
180	203.6	62.06	N78E	36N	348	0
181	204.1	62.22	N77E	21N	347	0
182	204.6	62.35	N74E	48N	344	0
183	204.9	62.45	N74E	39N	344	0
184	205.2	62.53	N79E	38N	349	0
185	205.4	62.61	N70W	22N	20	0
186	206.5	62.94	N21W	51E	69	0
187	206.6	62.97	N33W	44NE	57	0
188	206.9	63.06	N86W	51N	4	0

All directions are with respect to magnetic north.

FIGURE GLA-2: BIPS FRACTURE TABLE FOR WELL GLA-2, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	207.2	63.15	N21E	25E	111	0
190	207.4	63.23	N20E	27E	110	1
191	207.7	63.30	N71W	48N	19	0
192	208.1	63.43	N15E	30E	105	1
193	209.8	63.93	N36E	35SE	126	1
194	210.7	64.21	N48W	19NE	42	0
195	210.8	64.27	N83W	36N	7	0
196	211.0	64.31	N79E	48N	349	0
197	211.4	64.44	N46E	16SE	136	2
198	213.1	64.94	N78W	40N	12	0
199	213.8	65.17	N57E	30NW	327	0
200	215.7	65.76	N11E	45W	281	1
201	217.7	66.36	N2E	26W	272	0
202	218.2	66.51	N29E	31W	299	0
203	218.6	66.64	N15E	24W	285	1
204	219.0	66.74	N41E	23NW	311	0
205	219.5	66.90	N84E	17N	354	0
206	220.3	67.14	N89W	33N	1	0
207	221.1	67.38	N68E	16S	158	0
208	221.1	67.41	N46W	39SW	224	0
209	222.9	67.93	N37E	21NW	307	1
210	223.3	68.05	N63E	39N	333	0
211	223.4	68.08	N2E	5W	272	0
212	223.4	68.09	N30E	7NW	300	0
213	223.7	68.19	N19W	7E	71	0
214	224.6	68.45	N71E	32N	341	1
215	224.8	68.51	N78E	33N	348	0
216	225.2	68.64	N80E	22N	350	0
217	226.0	68.89	N31E	58SE	121	0
218	226.2	68.95	N78E	30N	348	1
219	227.2	69.26	N58W	50NE	32	1
220	227.4	69.32	N16E	42E	106	0
221	228.3	69.58	N21W	63E	69	0
222	230.4	70.24	N52W	37NE	38	0
223	230.4	70.24	N78W	57N	12	0
224	230.6	70.30	N68W	46N	22	0
225	231.3	70.49	N68W	52N	22	0
226	237.3	72.34	N75W	76N	15	0
227	240.0	73.15	N9E	77W	279	0
228	241.6	73.64	N70W	31S	200	0
229	244.7	74.59	N63E	26S	153	0
230	246.5	75.13	N55E	27SE	145	0
231	248.4	75.70	N28W	48W	242	0
232	250.1	76.22	N19E	45E	109	1
233	250.1	76.22	N12W	38W	258	0
234	250.3	76.30	N2W	30W	268	0

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-3

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 14, 1996, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-3:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-dilution levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On December 14, 1996, at 1016 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 4 gallons of deionized water were lost to the formation during dilution procedures. During the 6.10 hours following dilution, multiple logs were conducted. Of these logs, 22 are presented in Figure GLA-3:2. These logs illustrate significant change throughout the interval from 40 to 120 feet. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring in the intervals from 66 to 70 feet, and 82 to 84 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-3:3. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 300 µS/cm.

The data suggest that horizontal flow was occurring over the interval from 66 to 70 feet and 82 to 84 feet feet. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for these intervals was approximately 0.57 and 0.71 ft/day, respectively. Correcting for convergence of flow at the wellbore, this velocity equates to a specific discharge of groundwater in the aquifer of 0.23 and 0.29 ft/day, respectively. Please refer to Figures GLA-3:4 and GLA-3:5 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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1.3 Flow Characterization During Pumping After DI Water Emplacement; GLA-3

Initial evaluation of well production indicated that the subject well had only sufficient yield to maintain the lowest measurable flow rate (approximately 1.5 gpm). As such, a pump after DI emplacement approach was applied to identify water bearing intervals and estimate hydraulic properties of these intervals (Tsang et. al. 1988, 1990 and Pedler et. al. 1989, 1990). Please refer to the Standard Operating Procedures in an attached Appendix A for a detailed discussion.

Pumping after DI emplacement was conducted to establish the inflow locations and evaluate the interval specific inflow rates during low rate pumping. DI emplacement was performed by replacing the wellbore fluids with DI. Care was exercised during this procedure so as to minimize the volume of DI lost to the formation. Approximately 40 gallons of deionized water were lost to the formation during dilution procedures. After emplacement, a baseline FEC log was conducted. Immediately following the baseline log, low rate pumping of the wellbore fluids and continuous FEC logging were conducted. During the low rate pumping, water level elevations, instantaneous flow rates and total gallons pumped were recorded with respect to time. The resulting FEC logs are evaluated to identify the inflow locations and interval specific flow rate during recovery.

On December 21, 1996, at 0947 hours, replacement of the wellbore fluids with DI (emplacement) was complete. Prior to the installation of the pumping equipment, the ambient water level was recorded at 23.80 feet (referenced to top of protective casing). All drawdown values are referenced to this elevation. Immediately following emplacement, a baseline FEC log FEC0946 was performed. At 0955 hours, (T=0.00 minutes, elapsed time of testing), low rate pumping of the wellbore fluids was initiated. During the 3.0 hours of testing, the time average extraction flow rate was 1.2 gpm. During this period a maximum drawdown of 1.1 feet was observed. Refer to Figure GLA-3:6 for the pumping and drawdown data. During the 3.00 hours of pumping, 27 FEC logs were collected and are presented in Figure GLA-3:7. These logs clearly illustrate specific intervals of dramatic increase in FEC with respect to time. The depth at which the peak FEC value for a given interval occurs is indicative of a water bearing interval. The data presented in Figure GLA-3:7 suggest the presence of hydraulically conductive intervals at 55 to 67 feet, 68 to 80 feet and 81 to 85 feet. Numerical modeling of the reported field data was performed using code BORE (Hale and Tsang, 1988, Pedler et. al. 1990, Tsang et.al. 1990). This modeling was performed to estimate the rate of inflow for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Figure GLA-3:8 and Table GLA-3:1.

1.4 Cross Hole Testing; GLA-3 And GMW-1

Additional HydroPhysical™ testing was performed in well GLA-3 while pumping was conducted in well GMW-1. Well GLA-3 is located approximately 51 feet N36°E from well GMW-1. The objective of this testing was to evaluate the "cross hole" hydraulic connection between wells GMW-1 and GLA-3. The hydraulic connection between these wells was estimated by evaluating the flow conditions in well GLA-3 during a stable wellfield condition (see section 1.2) and during a stressed wellfield condition. The stressed wellfield condition was achieved by pumping well GMW-1. By comparing the flow conditions during these two pressure states, a qualitative evaluation of which intervals are hydraulically connected can be achieved. Quite simply, those intervals which display the greatest change in flow between the two pressure conditions are assumed to be more hydraulically connected. Further evaluation of the logging data to quantify the horizontal flow velocity and associated specific discharge has been conducted using experimental coding developed by others. This coding is discussed in Appendix C.

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1.4.1 Cross Hole Flow Evaluation During Stressed Well Field Condition

For cross-hole flow assessment, the formation water in the observation well was diluted with deionized water (DI) while maintaining pumping in well GMW-1. After emplacement, the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded for both the observation well and the pumping well. Cross-hole flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with fluid flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

To estimate the hydraulic connection between pumping well GMW-1 and observation well GLA-3, pumping in GMW-1 was performed and contemporaneously the flow was evaluated in well GLA-3. Pumping in well GMW-1 was initiated on January 17, 1997, at 2235 hours (T=0.00 minutes, elapsed time of testing), at a flow rate of about 5 gpm. A reasonably stable drawdown of about 3.0 feet was observed in well GLA-3 prior to initiating DI emplacement. On January 18, 1997, at 1021 hours, (T=775 minutes, elapsed time of testing), dilution of the fluid column was complete. This emplacement was performed after pumping for approximately 11.5 hours at approximately 5 gpm. Refer to Figure GLA-3:9 for water level elevations during this testing. During the emplacement procedures, no appreciable DI was lost to the formation. During the 3.18 hours following dilution, multiple logs were conducted and 21 are presented in Figure GLA-3:10. The first log presented was conducted during emplacement. These traces illustrate significant change over the interval from 48 to 84 feet. Review of these data suggest three distinct intervals where horizontal flow is occurring. These intervals are 48 to 56 feet, 66 to 68 feet, and 82 to 84 feet. Experimental algorithms applied to the data suggest that the fluid velocity in the wellbore for these intervals was 0.93, 0.70, and 1.25 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specific discharge of groundwater in the aquifer of 0.37, 0.28, and 0.50 ft/day, respectively. Please refer to Figures GLA-3:11, GLA-3:12 and GLA-3:13 for the estimated horizontal velocity and specific discharge calculated for each interval. These dramatic changes in the FEC profiles with respect to time are associated with strong horizontal flow occurring within this wellbore.

A tessellated chromographic summary of all downward FEC traces is presented in Figure GLA-3:14. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 700 µS/cm.

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1.5 Summary of Cross-Hole Flow Evaluation: Wells GMW-1 and GLA-3

Review and comparison of Figures GLA-3:3 and GLA-3:14 clearly illustrate a dramatic change in flow characteristics between the two pressure conditions. Comparison of the flow evaluation between the stable and stressed (i.e. pumping) conditions suggest that the intervals from 48 to 56 feet and 82 to 84 feet demonstrated the greatest change in flow properties during testing. These data suggest that the interval from 48 to 56 feet did not demonstrate any appreciable flow during the stable wellfield condition in contrast to the stressed condition when this zone inflows at 0.93 ft/day. This reflects a very significant change between the two testing (i.e. pressure) conditions. The data also suggest that the interval from 82 to 84 feet was inflowing at a velocity of 0.71 ft/day during stable wellfield conditions in contrast to the stressed wellfield condition when this interval inflows at 1.25 ft/day. This reflects an increase of 176%.

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FIGURE GLA-3:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

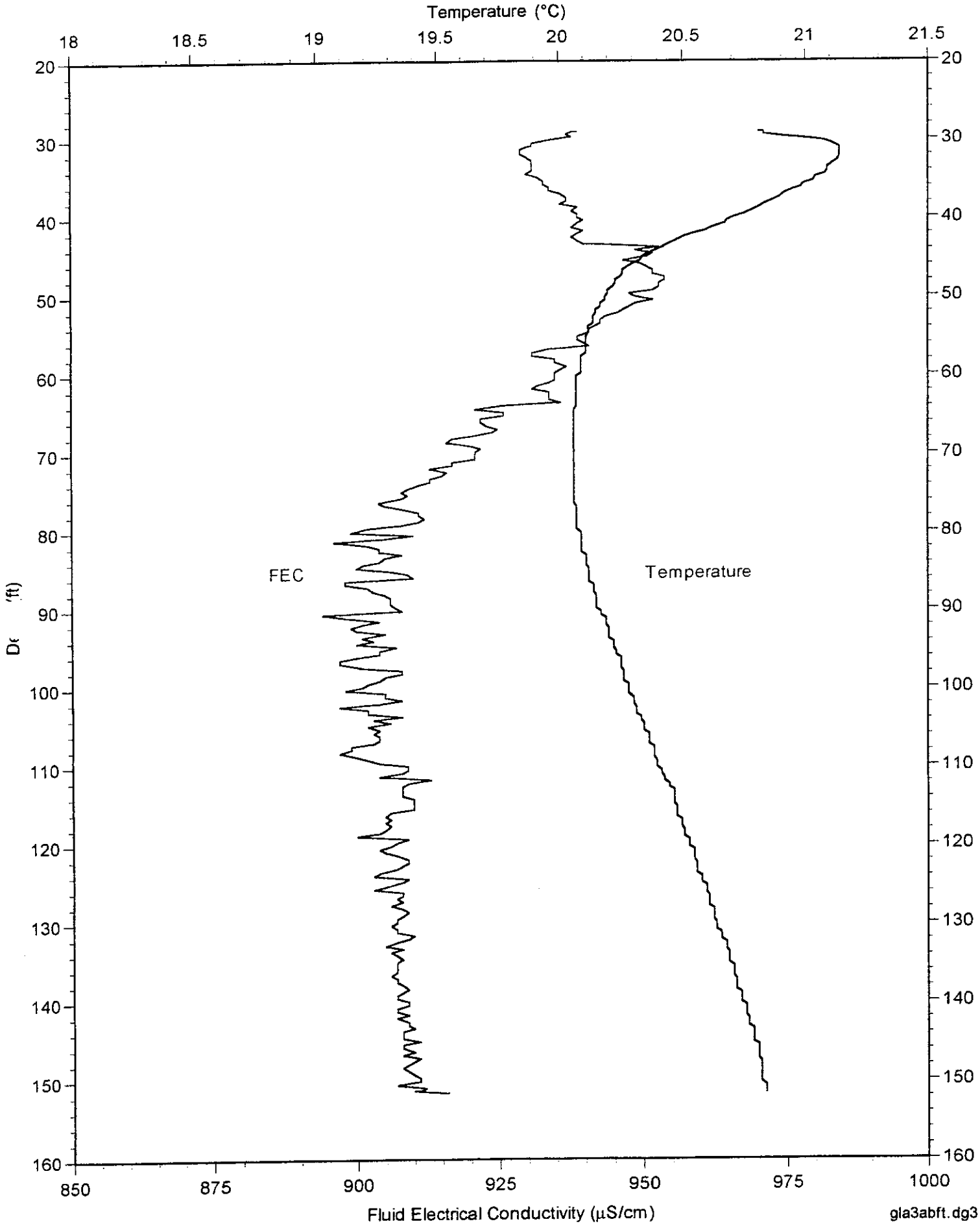

FIGURE GLA-3:2: SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

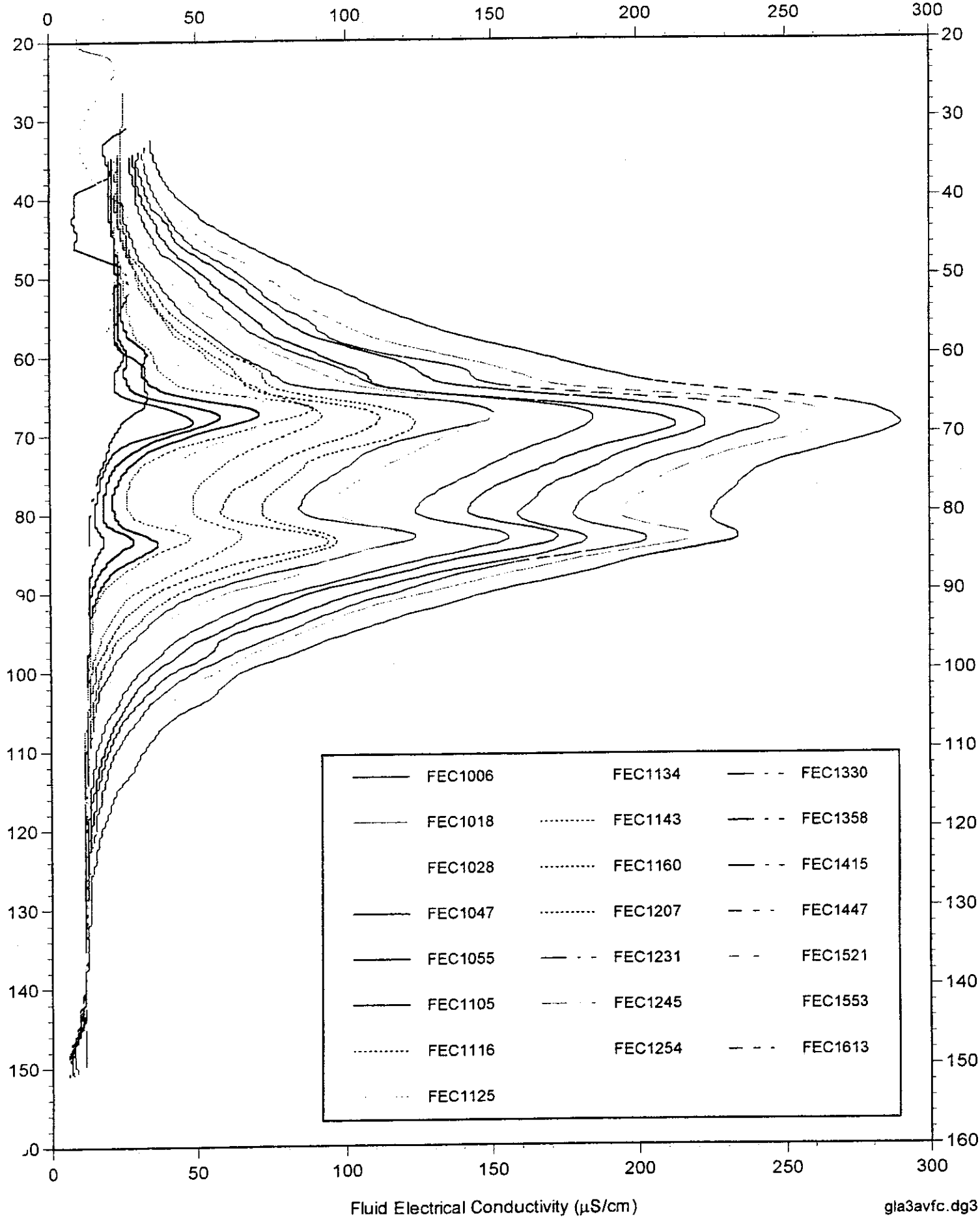

FIGURE GLA-3:3. CHROMOGRAPHIC TESSELATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-3.

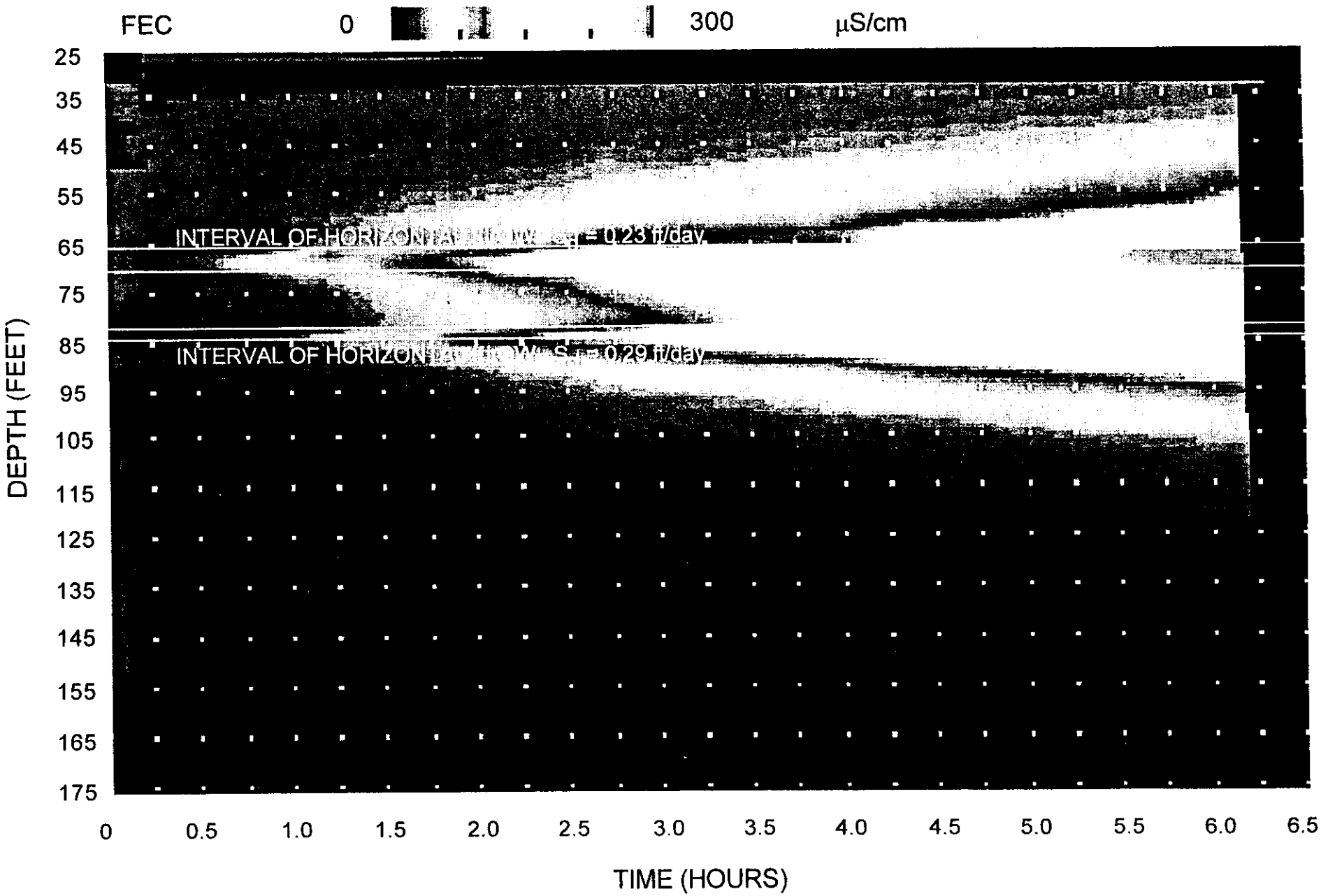

FIGURE GLA-3:4. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

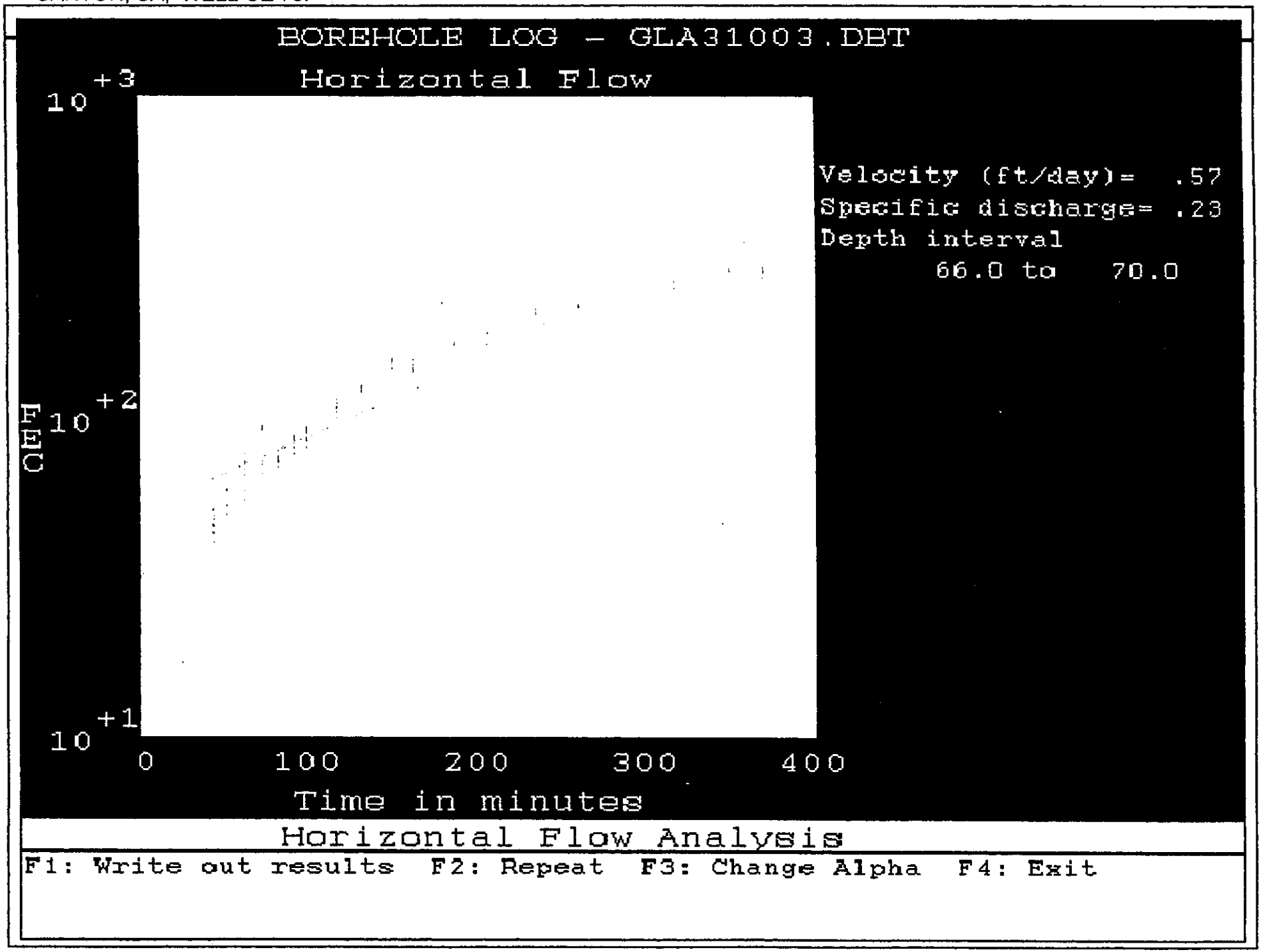

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FIGURE GLA-3:5. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

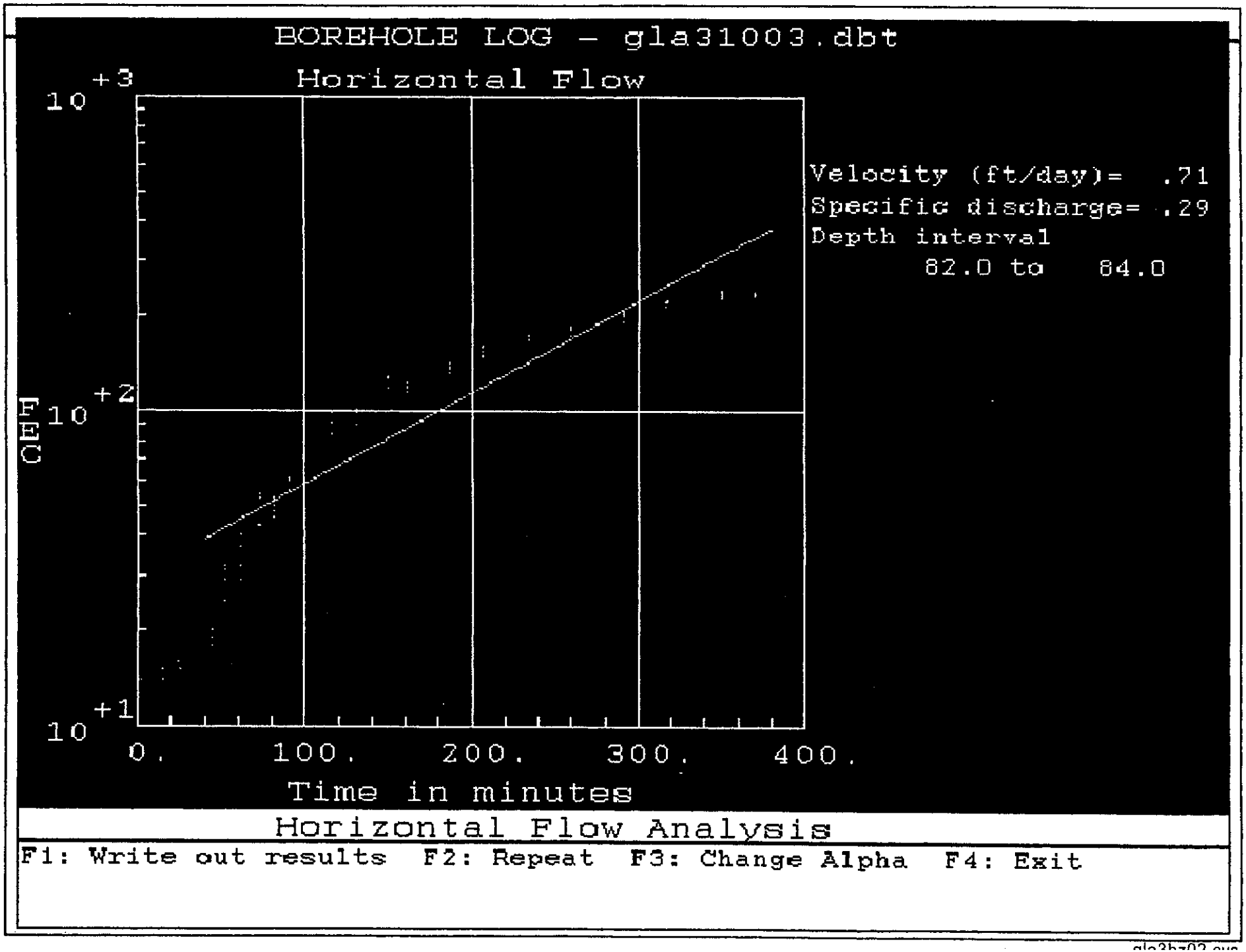


FIGURE GLA-3:6. PUMP AND DRAWDOWN DATA FOR 4 GPM PRODUCTION TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

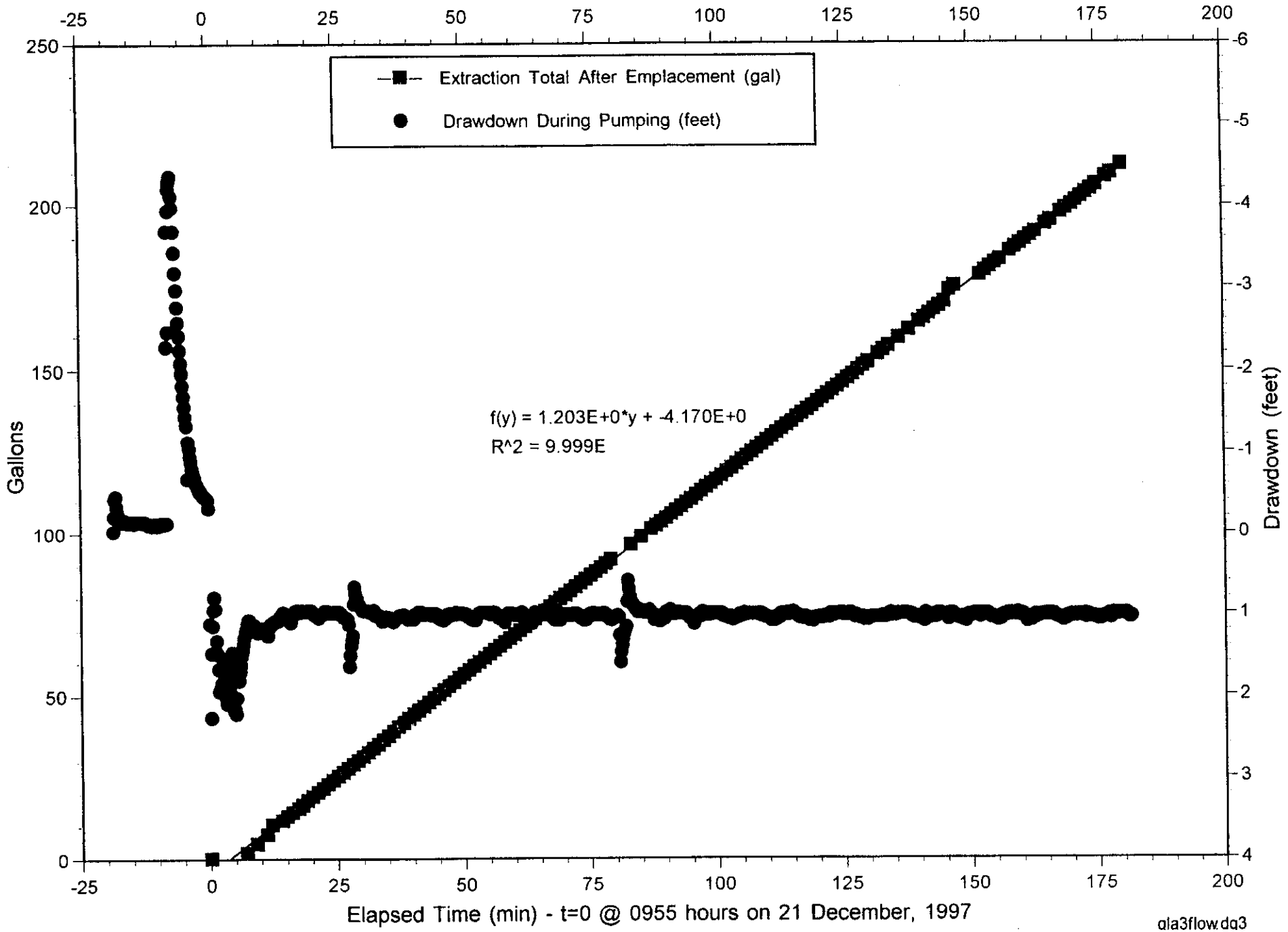


FIGURE GLA-3:7. SUMMARY OF HYDROPHYSICAL LOGS FOR PUMP AFTER EMPLACEMENT TEST WITH INTERVAL SPECIFIC FLOW RATES; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

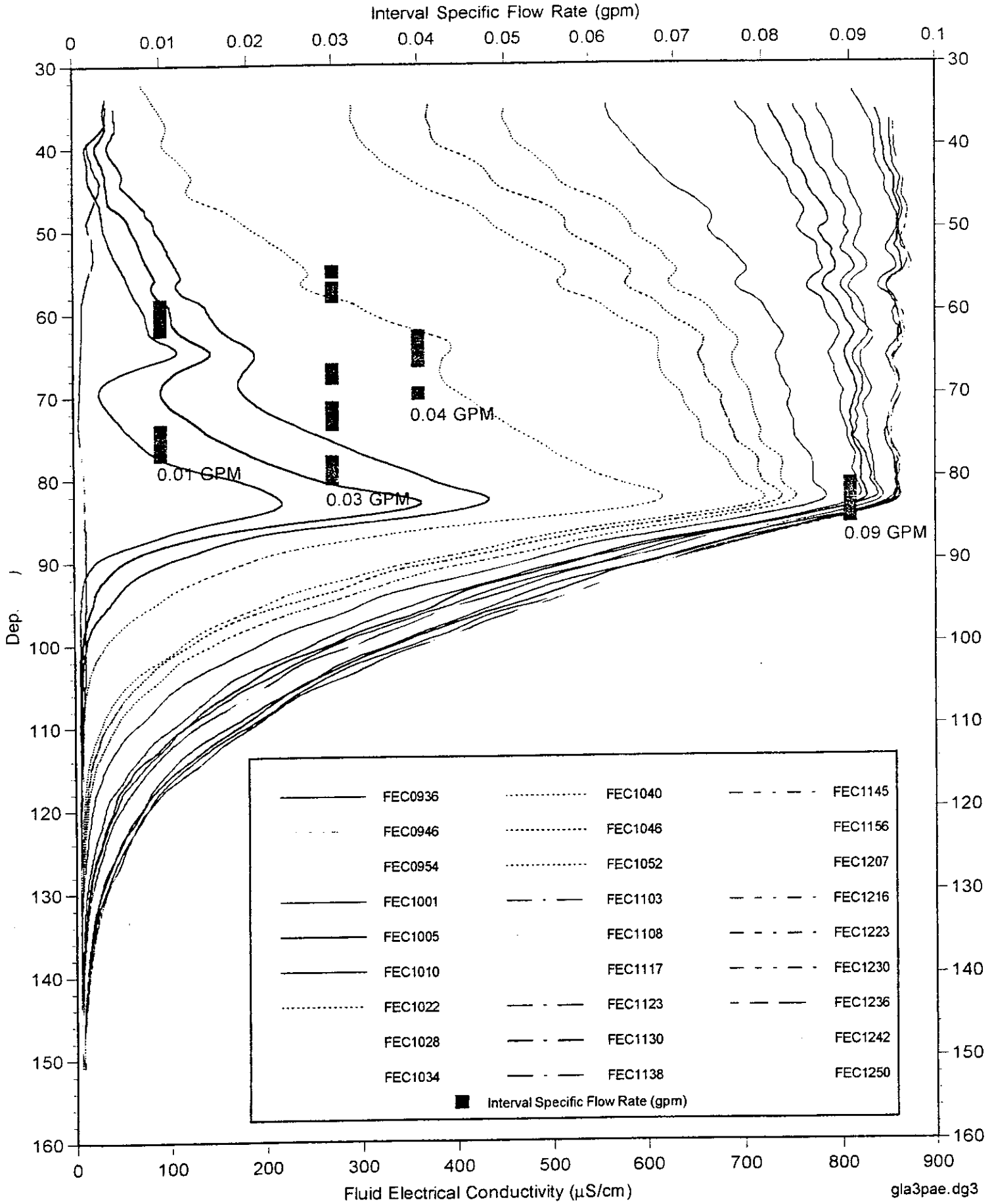
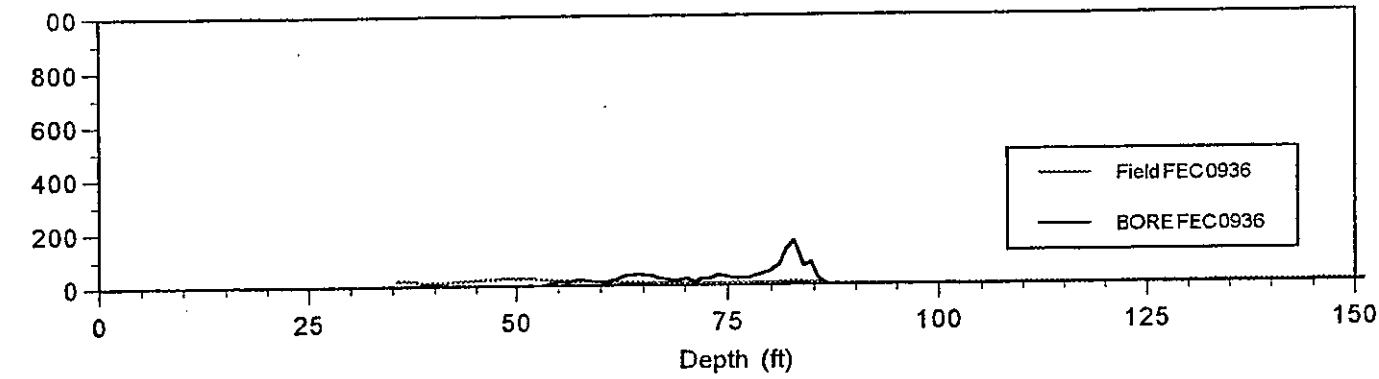
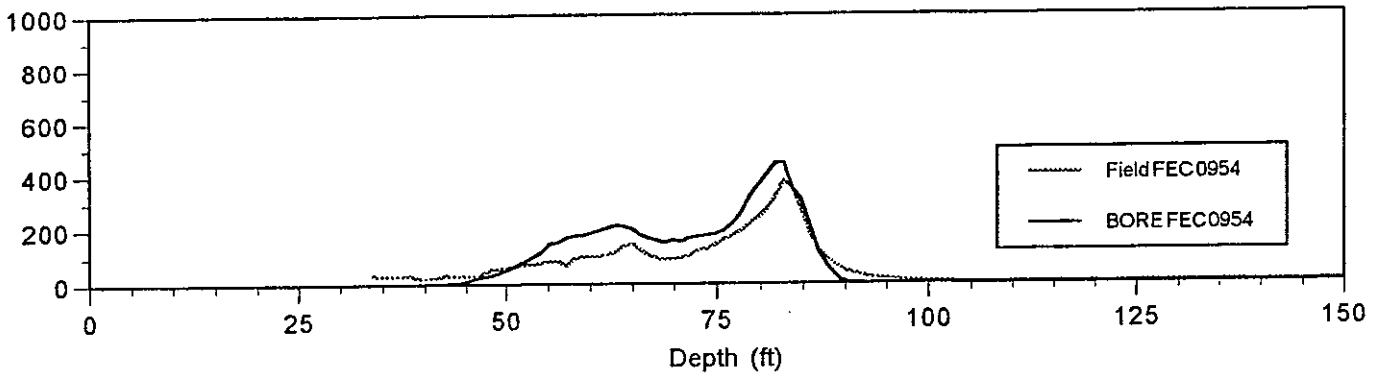
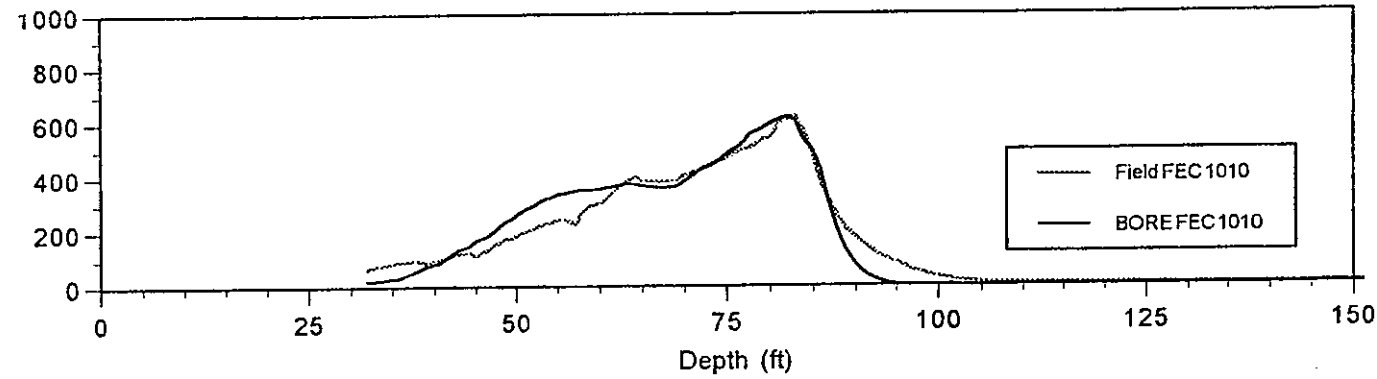


FIGURE GLA-3:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-3.







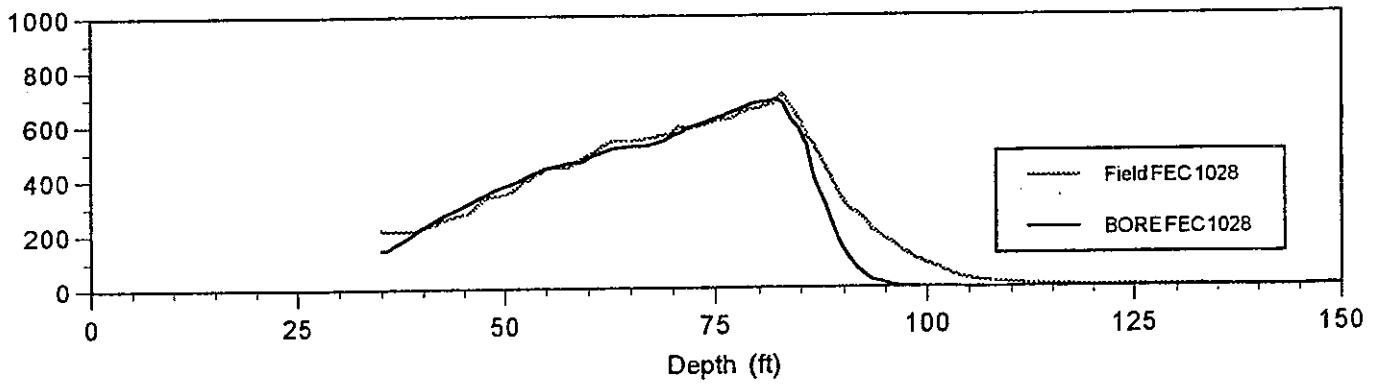


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FIGURE GLA-3:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-3.

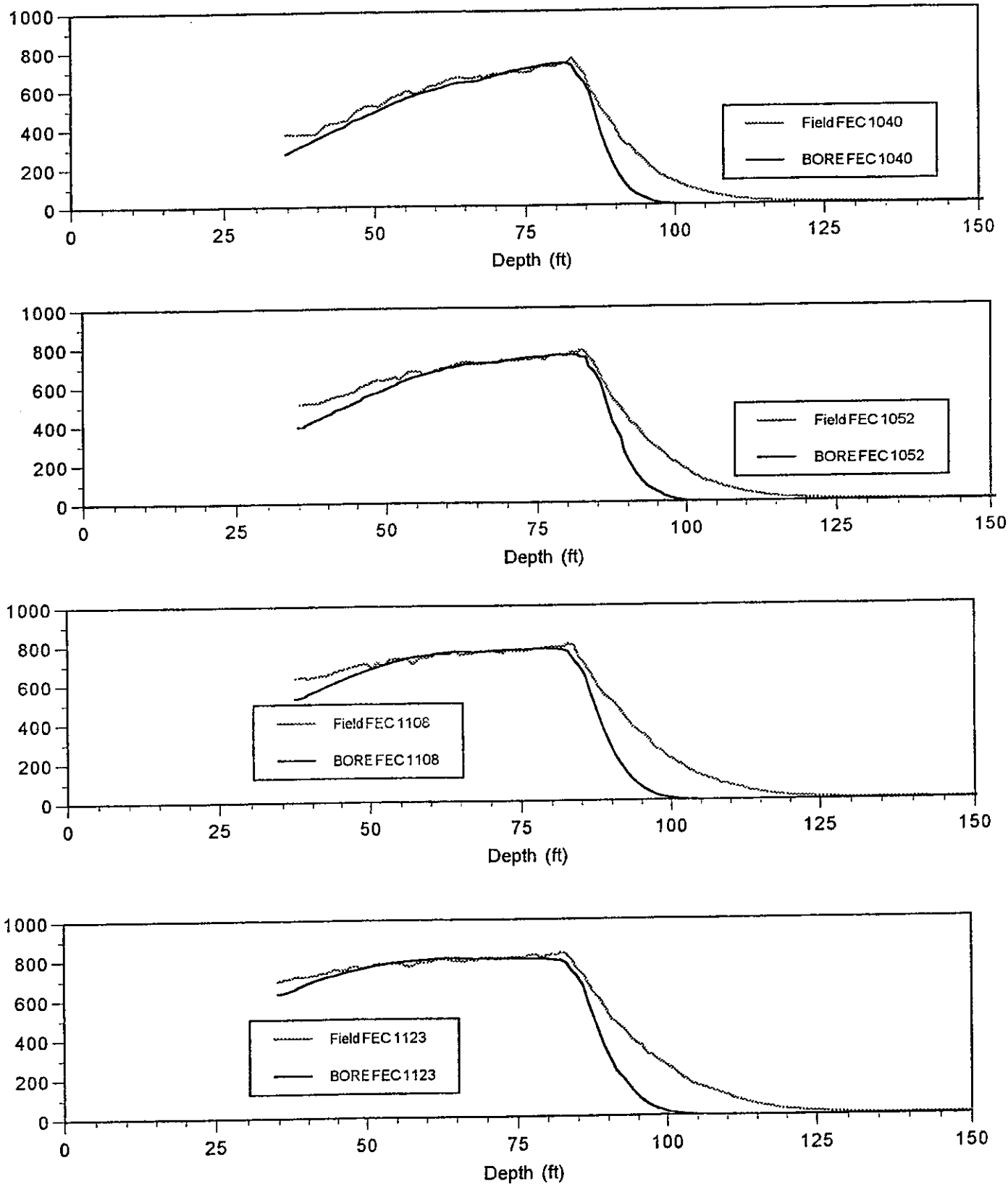
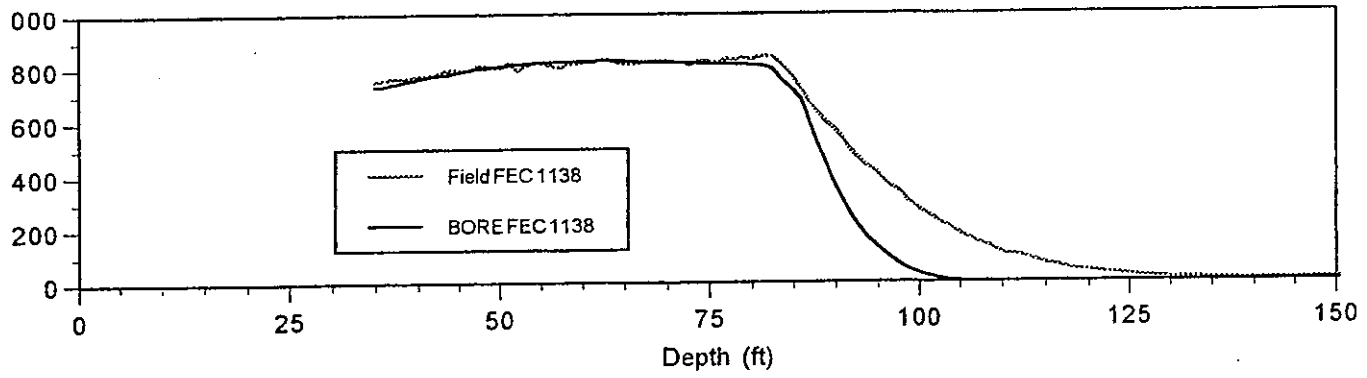
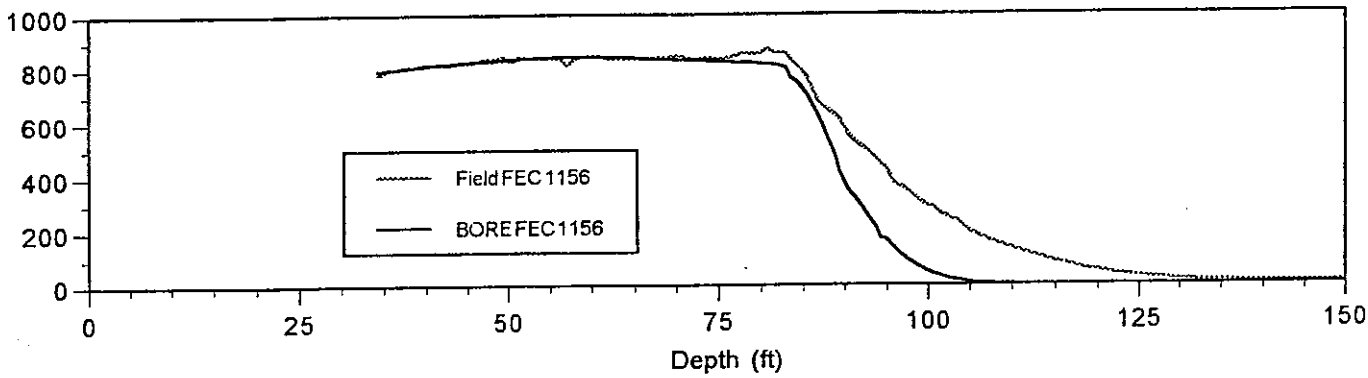
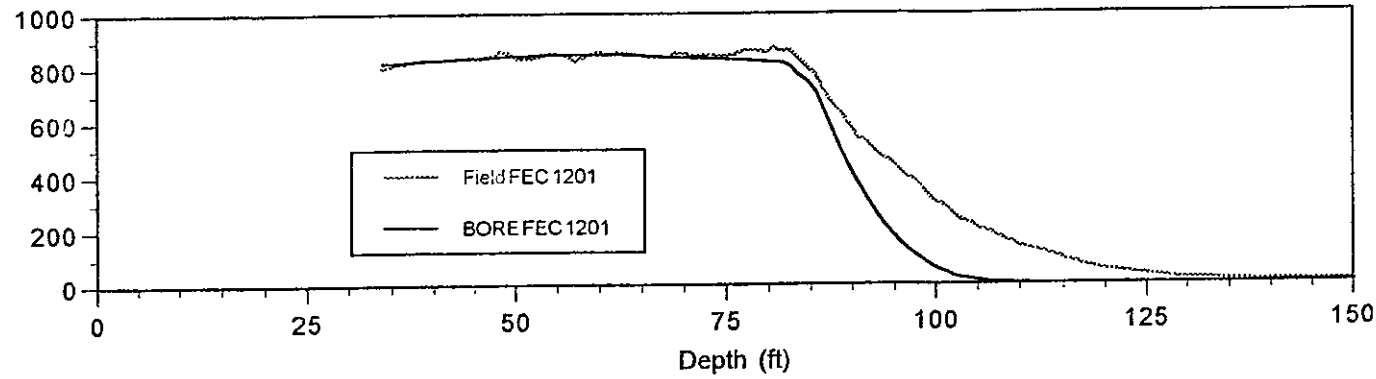


FIGURE GLA-3:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-3.







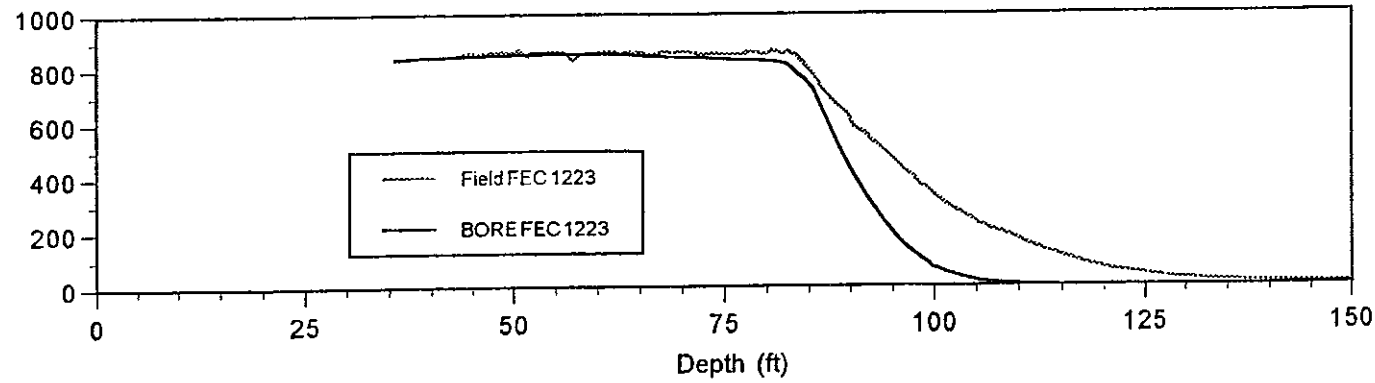
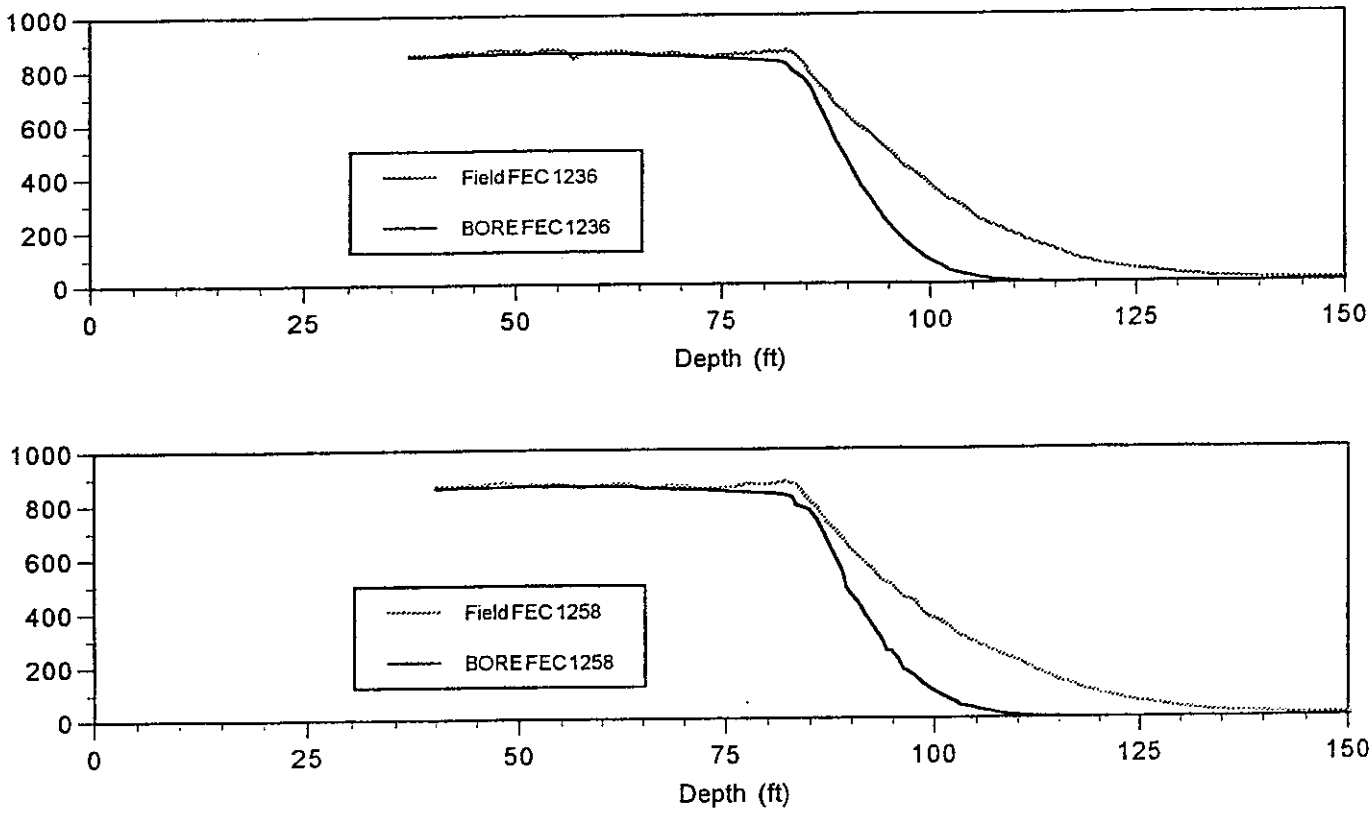


FIGURE GLA-3:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-3.



F. RE GLA-3:9. PUMP AND DRAWDOWN DATA DURIN ROSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GMW-1 AND GLA-3.

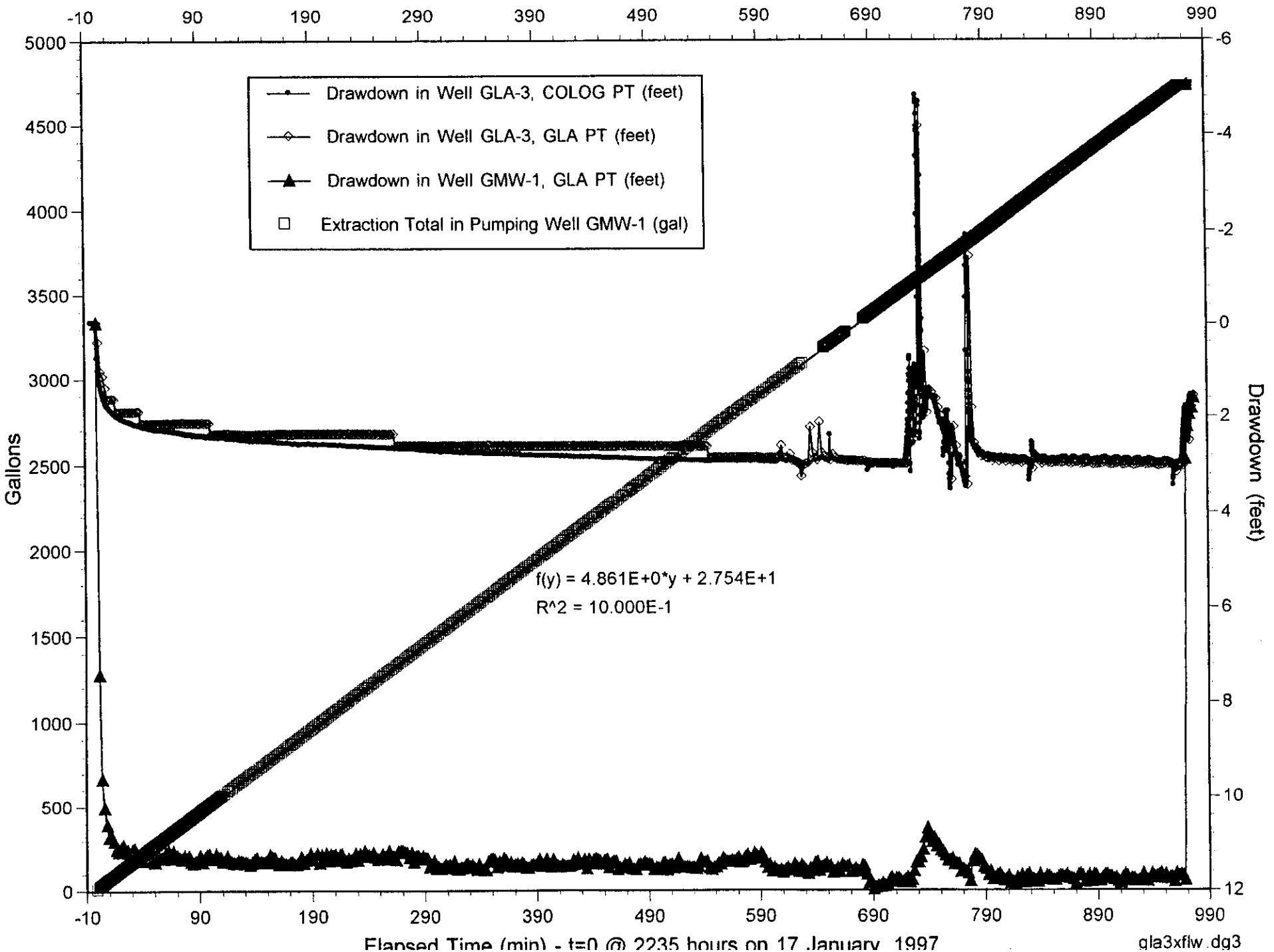
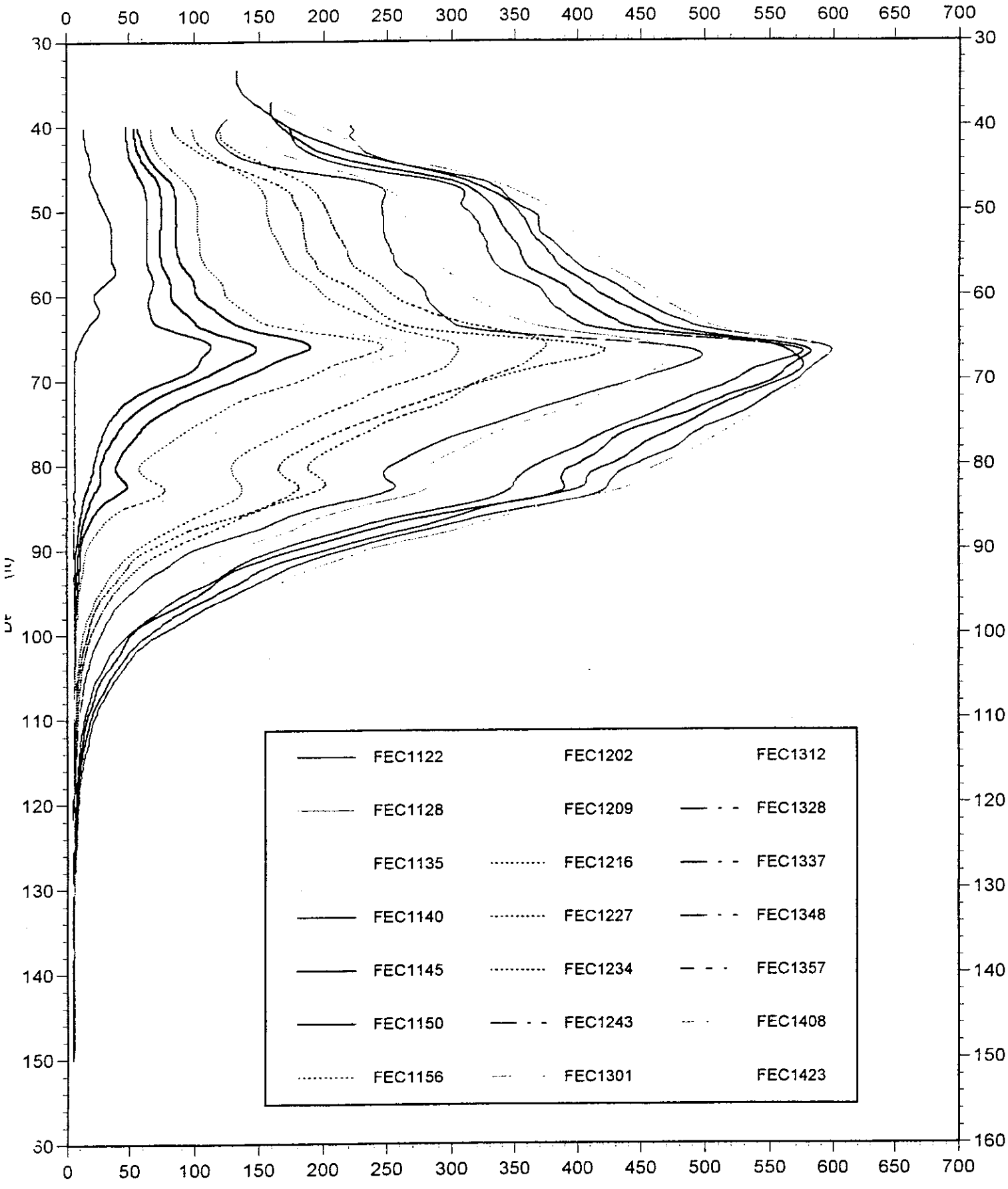
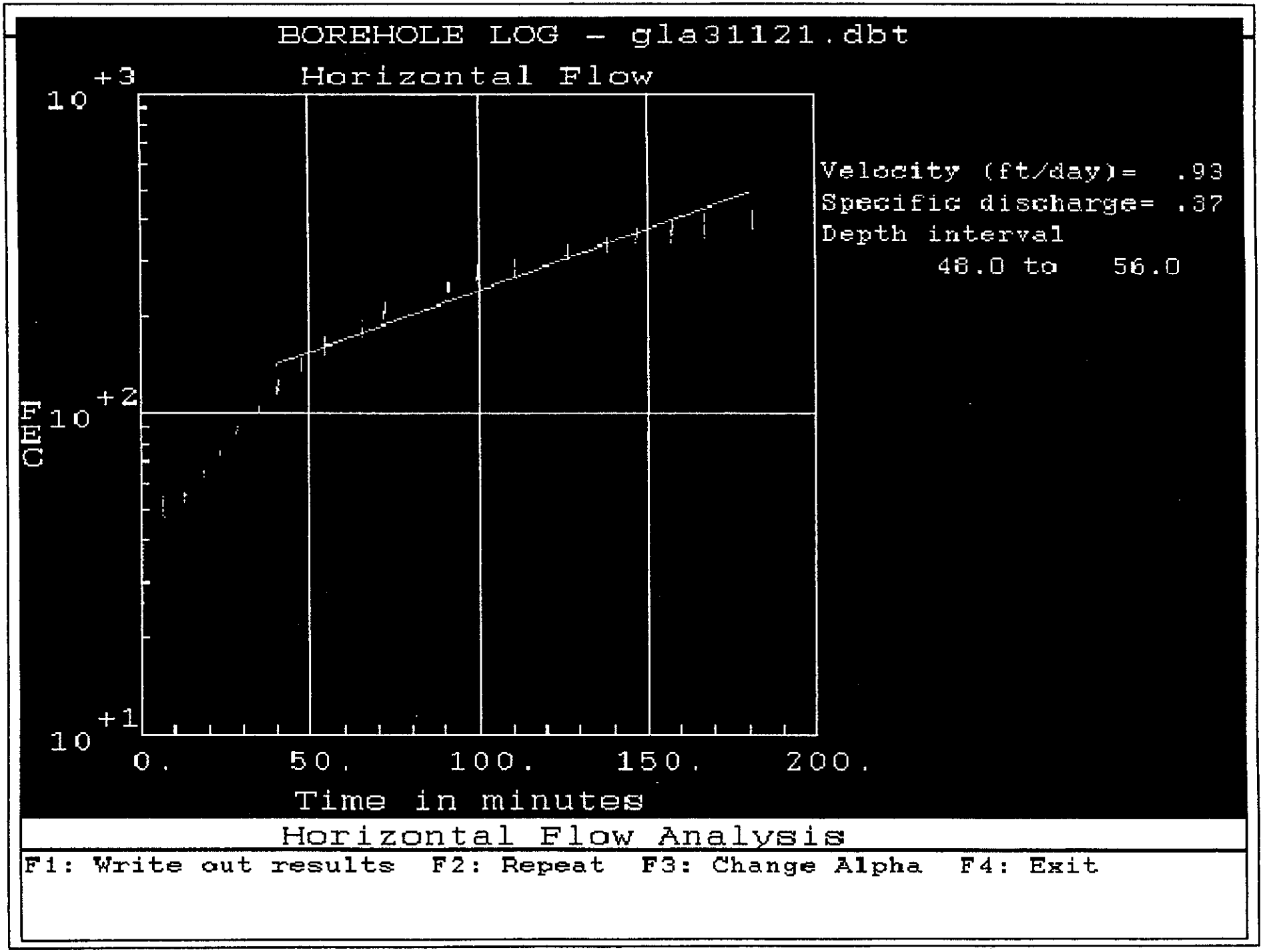


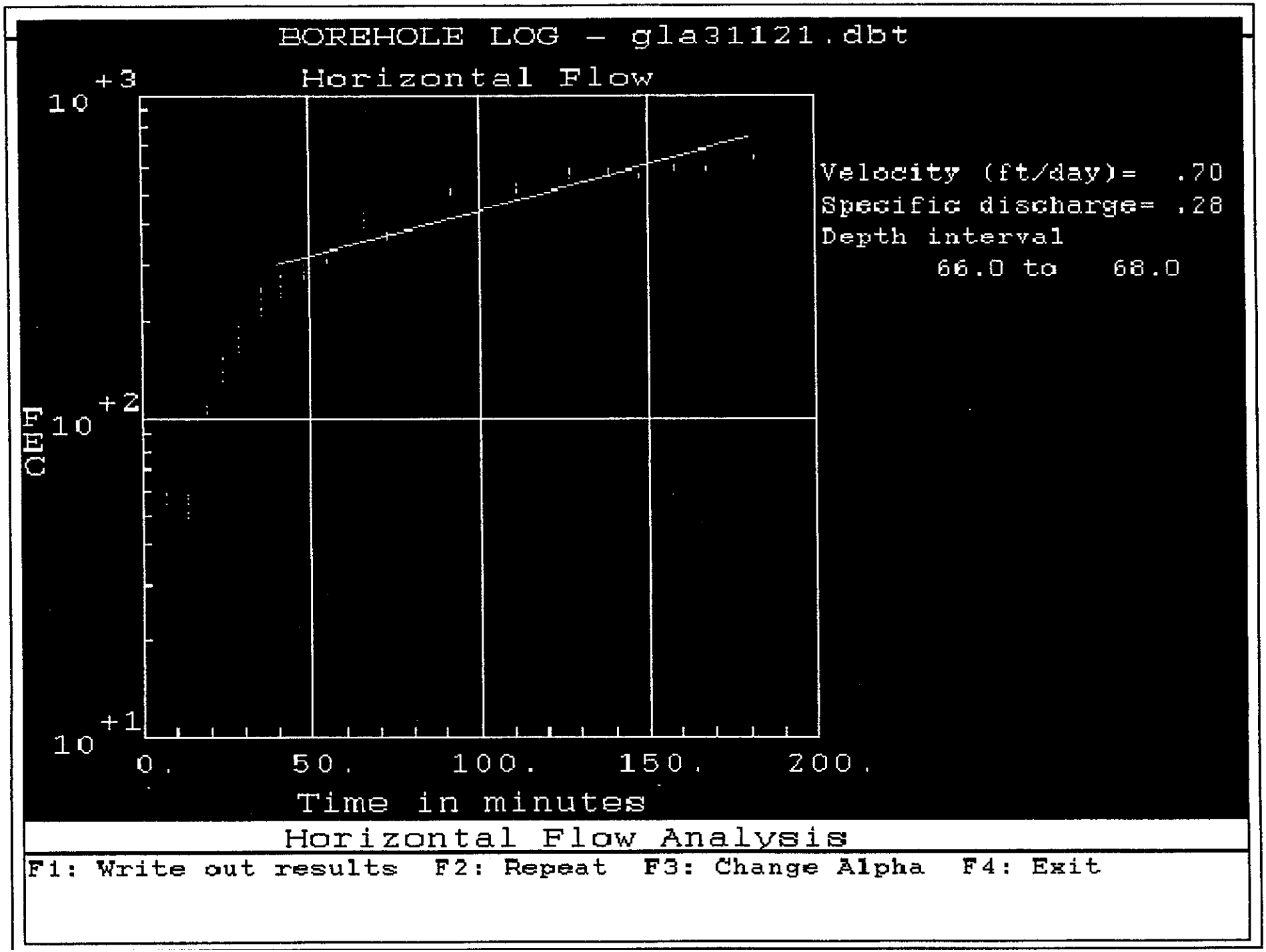
FIGURE GLA-3:10. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION CROSS HOLE TEST PUMPING GMW-1 AT 5 GPM; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.



FIGU GLA-3:11. HORIZONTAL FLOW ANALYSIS DURING .OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GR ORY CANYON, CA; WELLS: GLA-3 AND GMW-1.



FIGU. . GLA-3:12. HORIZONTAL FLOW ANALYSIS DURING .OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GR. ORY CANYON, CA; WELLS: GLA-3 AND GMW-1.



FIGU. _ GLA-3:13. HORIZONTAL FLOW ANALYSIS DURING .OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GR JRY CANYON, CA; WELLS: GLA-3 AND GMW-1.

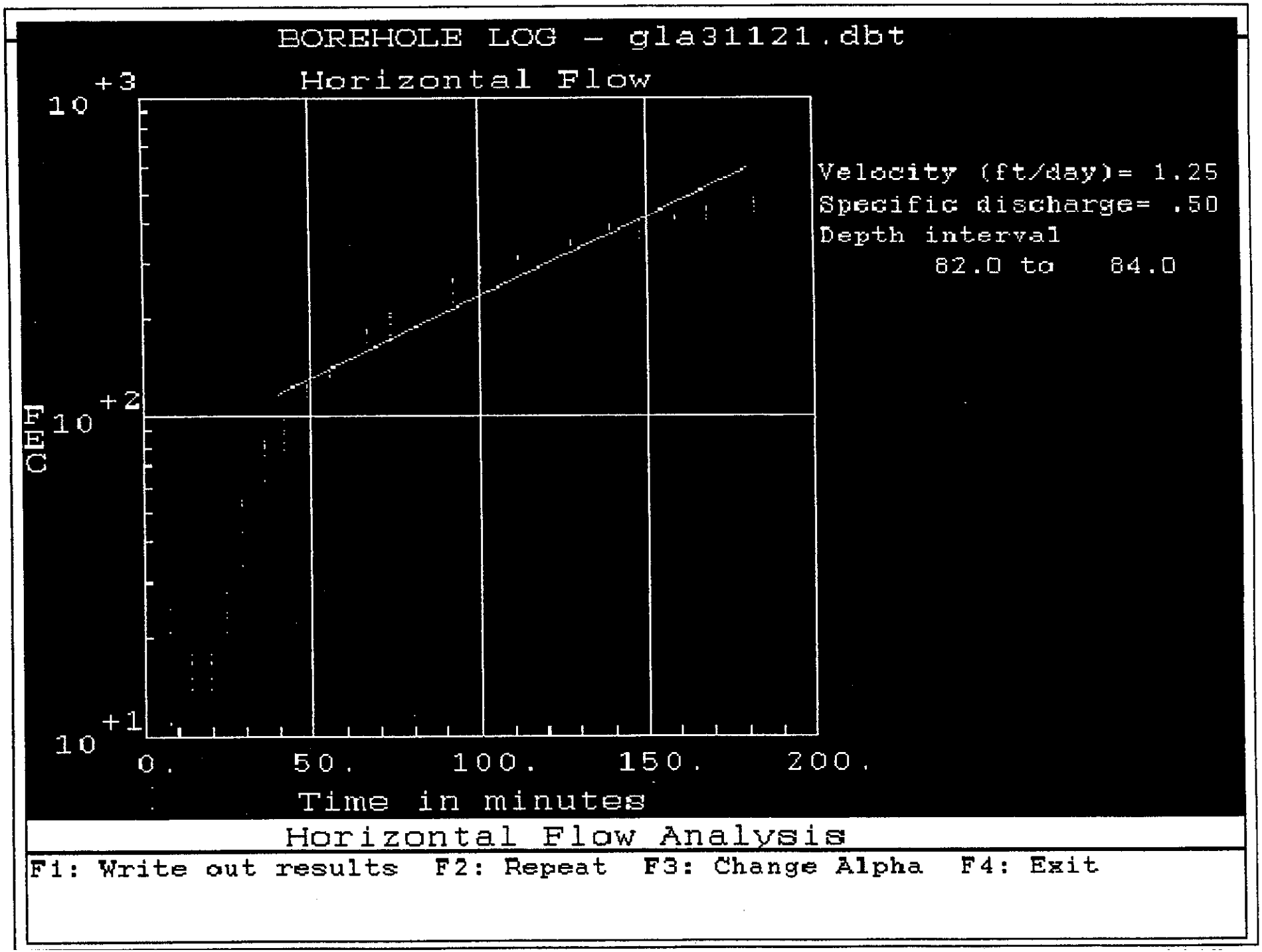


FIGURE GLA-3:14. CHROMOGRAPHIC TESSELATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION CROSS HOLE TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS: GLA-3 AND GMW-1.

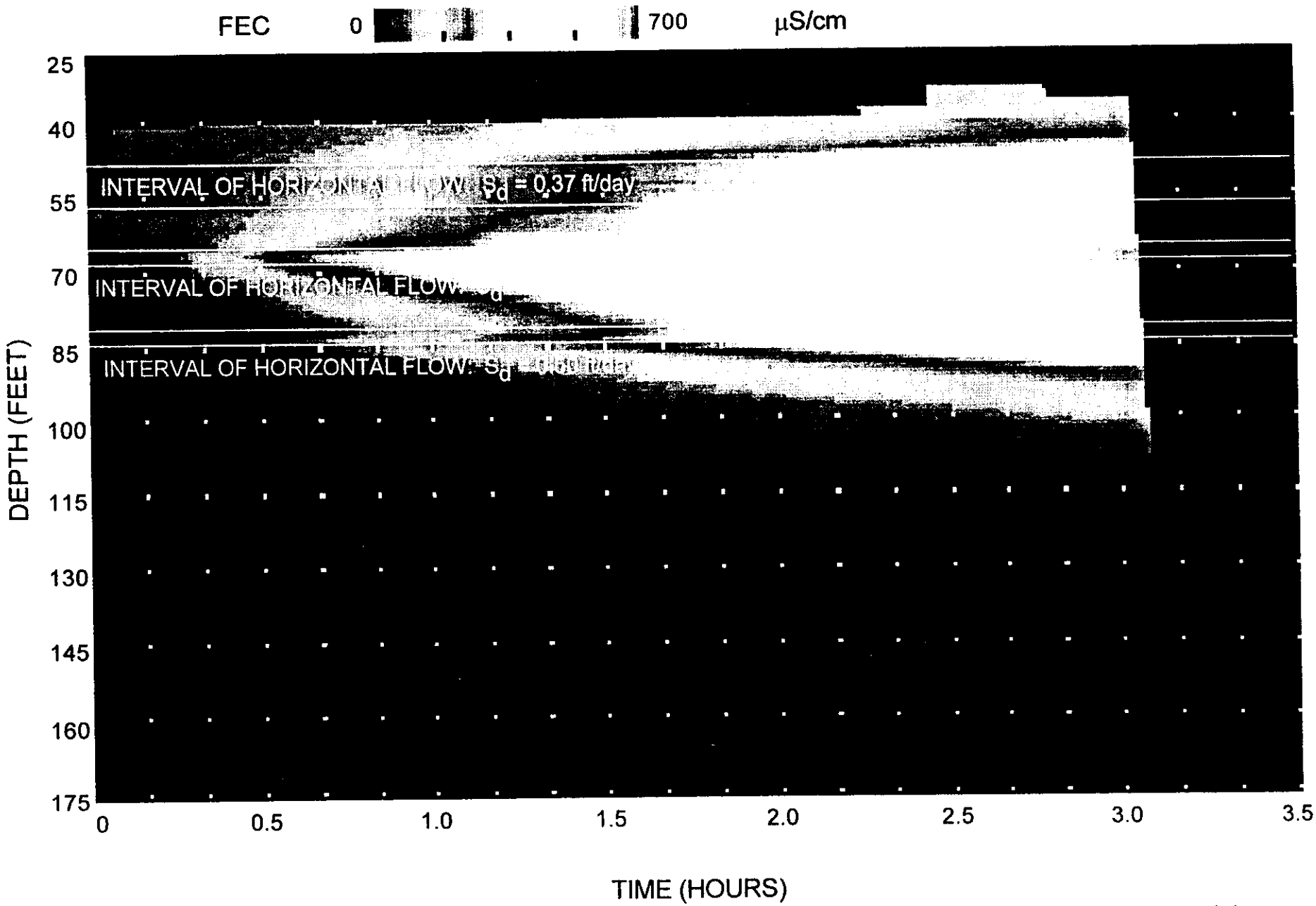


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TABLE GLA-3:1. CODE BORE RESULTS FOR PUMPING AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-3.

Depth (meters)	Depth (feet)	Flow Rate (m^3/s)	Flow Rate (lpm)	Flow Rate (gpm)	FEC (gram/l)	FEC (µS/cm)
16.8	55.12	1.67E-06	1.00E-01	0.03	0.44	913
17.4	57.09	1.67E-06	1.00E-01	0.03	0.44	913
17.7	58.07	1.67E-06	1.00E-01	0.03	0.44	913
18	59.06	8.33E-07	5.01E-02	0.01	0.44	913
18.3	60.04	8.33E-07	5.01E-02	0.01	0.44	913
18.6	61.02	8.33E-07	5.01E-02	0.01	0.44	913
18.9	62.01	8.33E-07	5.01E-02	0.01	0.44	913
19.2	62.99	2.50E-06	1.50E-01	0.04	0.44	913
19.5	63.98	2.50E-06	1.50E-01	0.04	0.44	913
19.8	64.96	2.50E-06	1.50E-01	0.04	0.44	913
20.1	65.94	2.50E-06	1.50E-01	0.04	0.44	913
20.4	66.93	1.67E-06	1.00E-01	0.03	0.44	913
20.7	67.91	1.67E-06	1.00E-01	0.03	0.44	913
21.3	69.88	2.50E-06	1.50E-01	0.04	0.44	913
21.8	71.52	1.67E-06	1.00E-01	0.03	0.44	913
22.1	72.51	1.67E-06	1.00E-01	0.03	0.44	913
22.4	73.49	1.67E-06	1.00E-01	0.03	0.44	913
22.6	74.15	8.33E-07	5.01E-02	0.01	0.44	913
22.7	74.48	8.33E-07	5.01E-02	0.01	0.44	913
22.9	75.13	8.33E-07	5.01E-02	0.01	0.44	913
23.2	76.12	8.33E-07	5.01E-02	0.01	0.44	913
23.5	77.10	8.33E-07	5.01E-02	0.01	0.44	913
23.8	78.08	1.67E-06	1.00E-01	0.03	0.44	913
24.1	79.07	1.67E-06	1.00E-01	0.03	0.44	913
24.4	80.05	1.67E-06	1.00E-01	0.03	0.44	913
24.7	81.04	5.50E-06	3.31E-01	0.09	0.44	913
25	82.02	5.50E-06	3.31E-01	0.09	0.44	913
25.3	83.01	5.50E-06	3.31E-01	0.09	0.44	913
25.6	83.99	5.50E-06	3.31E-01	0.09	0.44	913
25.9	84.97	5.50E-06	3.31E-01	0.09	0.44	913
TOTAL ESTIMATED FLOW RATE - BORE RESULTS =				1.05 gpm		
TOTAL OBSERVED FLOW RATE =				1.20 gpm		

FIGURE GLA-3: BIPS FRACTURE TABLE FOR WELL GLA-3, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	45.4	13.83	N30W	55NE	60	1
2	46.8	14.27	N13W	37E	77	0
3	47.9	14.60	N56W	68NE	34	0
4	50.1	15.28	N65W	24N	25	0
5	50.5	15.41	N58W	73SW	212	0
6	51.5	15.71	N29W	76W	241	0
7	52.2	15.92	N78E	31N	248	0
8	52.4	15.97	N85W	23N	5	3
9	53.3	16.23	N43W	77NE	47	0
10	54.1	16.48	N34W	66NE	56	0
11	54.3	16.55	N20W	14E	70	2
12	56.2	17.14	N24W	25E	66	2
13	57.1	17.41	N87E	17N	357	1
14	57.8	17.62	N77E	35N	347	0
15	58.2	17.74	N84W	36N	6	1
16	59.4	18.10	N10E	57E	100	1
17	61.2	18.65	N/A	Vert.	N/A	0
18	63.2	19.28	N19E	37W	289	0
19	64.2	19.58	N19E	36W	289	0
20	66.0	20.12	N54E	17SE	144	0
21	66.3	20.21	N24E	58E	114	0
22	66.9	20.38	N14E	61E	104	1
23	71.2	21.71	N21E	73E	111	0
24	71.3	21.72	N76W	12N	14	0
25	71.7	21.86	N12E	25W	282	1
26	72.2	22.01	N48W	45SW	222	1
27	73.4	22.36	N49W	33NE	41	2
28	78.1	23.80	N10W	79W	260	0
29	79.6	24.27	N2E	62E	92	1
30	79.9	24.36	N22E	28W	292	2
31	80.1	24.43	N18E	39W	288	2
32	80.4	24.49	N16E	44W	286	4
33	81.4	24.82	N9E	23W	279	2
34	82.1	25.02	N5W	38E	85	1
35	83.0	25.30	N40E	34NW	310	0
36	83.8	25.54	N40W	60NE	50	0
37	83.9	25.57	N39W	67NE	21	0
38	85.5	26.07	N64W	26N	26	1
39	87.9	26.78	N27W	74W	243	0
40	88.8	27.07	N70W	10N	20	0
41	91.0	27.73	N84E	13N	354	3
42	93.7	28.57	N18W	35E	72	0
43	94.0	28.64	N39W	26NE	51	1
44	94.3	28.74	N45W	30NE	45	0
45	95.5	29.12	N70E	19N	340	1
46	95.6	29.15	N11E	61E	101	0
47	95.8	29.21	N78E	24N	348	0

All directions are with respect to magnetic north.

FIGURE GLA-3: BIPS FRACTURE TABLE FOR WELL GLA-3, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	97.0	29.57	N45E	25NW	315	1
49	98.2	29.94	N15E	4W	285	0
50	101.2	30.83	N86E	65S	176	0
51	101.7	31.01	N86W	51S	184	2
52	102.9	31.36	N47W	54SW	223	2
53	103.2	31.46	N47W	59SW	223	0
54	107.0	32.60	N68E	47N	338	0
55	107.1	32.65	N57W	4SW	213	2
56	108.1	32.94	N16E	78W	286	0
57	110.4	33.66	N82E	6N	352	1
58	111.0	33.84	N87E	37N	357	2
59	111.3	33.92	N52W	60NE	38	1
60	113.9	34.73	N13W	78E	77	0
61	114.2	34.82	N37W	42NE	53	0
62	116.1	35.40	N31W	45NE	59	0
63	116.9	35.64	N52E	16NW	322	0
64	118.5	36.13	N89E	44N	359	0
65	122.1	37.20	N23W	50E	67	1
66	122.6	37.36	N21E	71W	291	0
67	123.7	37.69	N68W	53N	22	0
68	125.2	38.17	N21E	39W	291	0
69	126.8	38.64	N47E	57NW	317	0
70	127.2	38.76	N69E	10N	339	2
71	130.8	39.88	N8E	23E	98	0
72	131.8	40.19	N77W	14S	193	1
73	133.3	40.62	N80E	16S	170	0
74	134.9	41.13	N18W	23W	252	0
75	143.0	43.58	N66W	19N	24	2
76	143.0	43.59	N63W	31S	207	0
77	145.9	44.48	N21W	27W	249	1
78	146.8	44.73	N87W	26S	183	1
79	148.4	45.22	N53E	16SE	143	0
80	149.1	45.43	N66W	60N	24	1
81	149.2	45.48	N46W	32SW	224	1

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-4

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On January 21, 1997, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-4:1.

1.2 Ambient Flow Evaluation During Stabilized Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On January 21, 1997, at 1055 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 11 gallons of DI were lost to the formation during dilution procedures. During the 5.50 hours following dilution, multiple logs were conducted. Of these logs, 13 are presented in Figure GLA-4:2. These logs illustrate significant change throughout the interval from 68 to 170 feet. These dramatic changes in the FEC profiles with respect to time are associated with ambient horizontal flow at 70 to 72 and 126 to 134 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-4:3. FEC of 0 μS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 100 μ S/cm.

The data suggest that horizontal flow was occurring over the interval from 70 to 72 feet and 126 to 134 feet. The precise location of water bearing intervals cannot be further defined due to the extremely low inflow velocities. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for these intervals was approximately 0.06 ft/day and 0.18 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specified discharge of groundwater in the aquifer of 0.03 ft/day and 0.07 ft/day respectively. Please refer to Figures GLA-4:4 and GLA-4:5 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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FIGURE GLA-4:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-4.

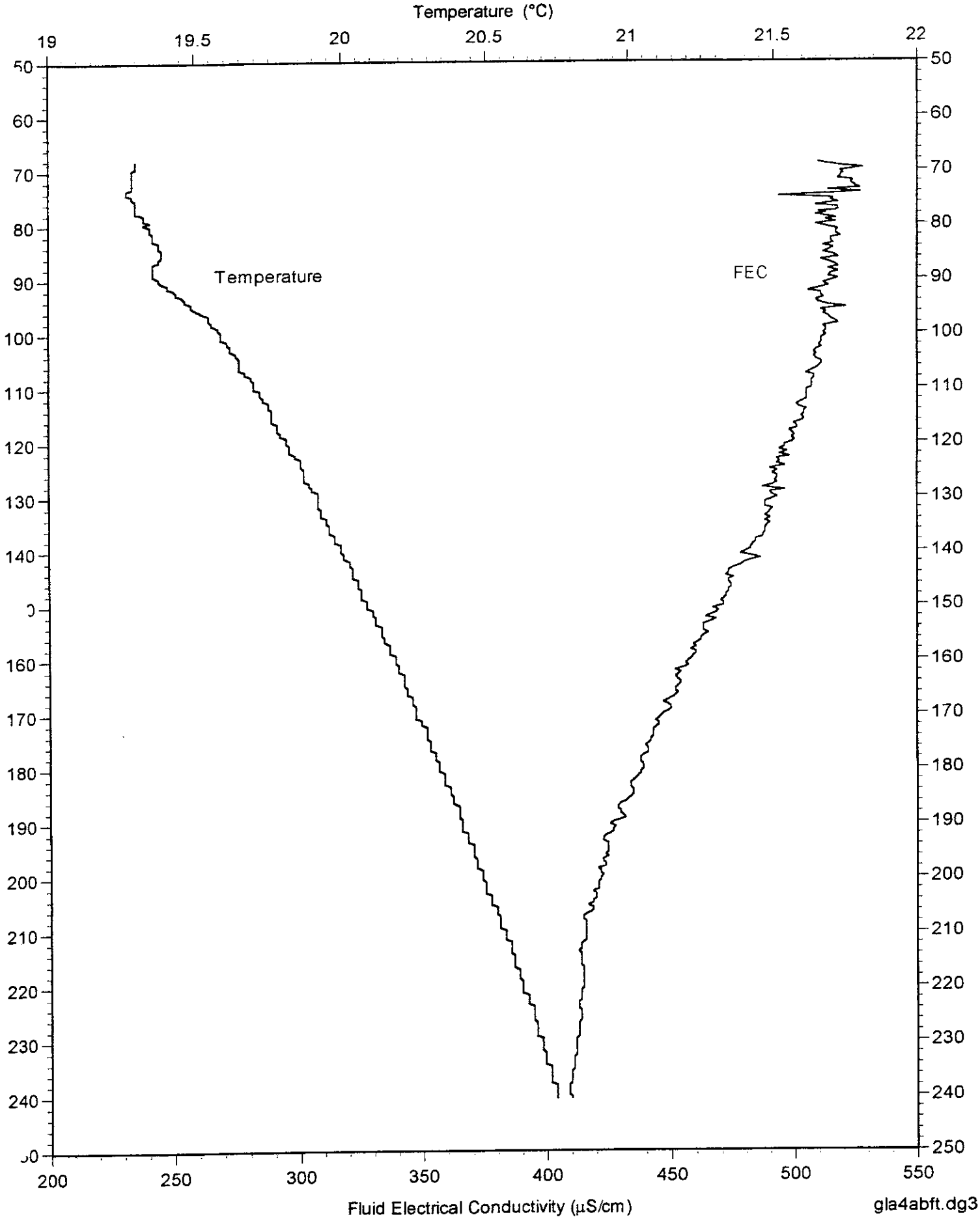


FIGURE GLA-4:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-4.

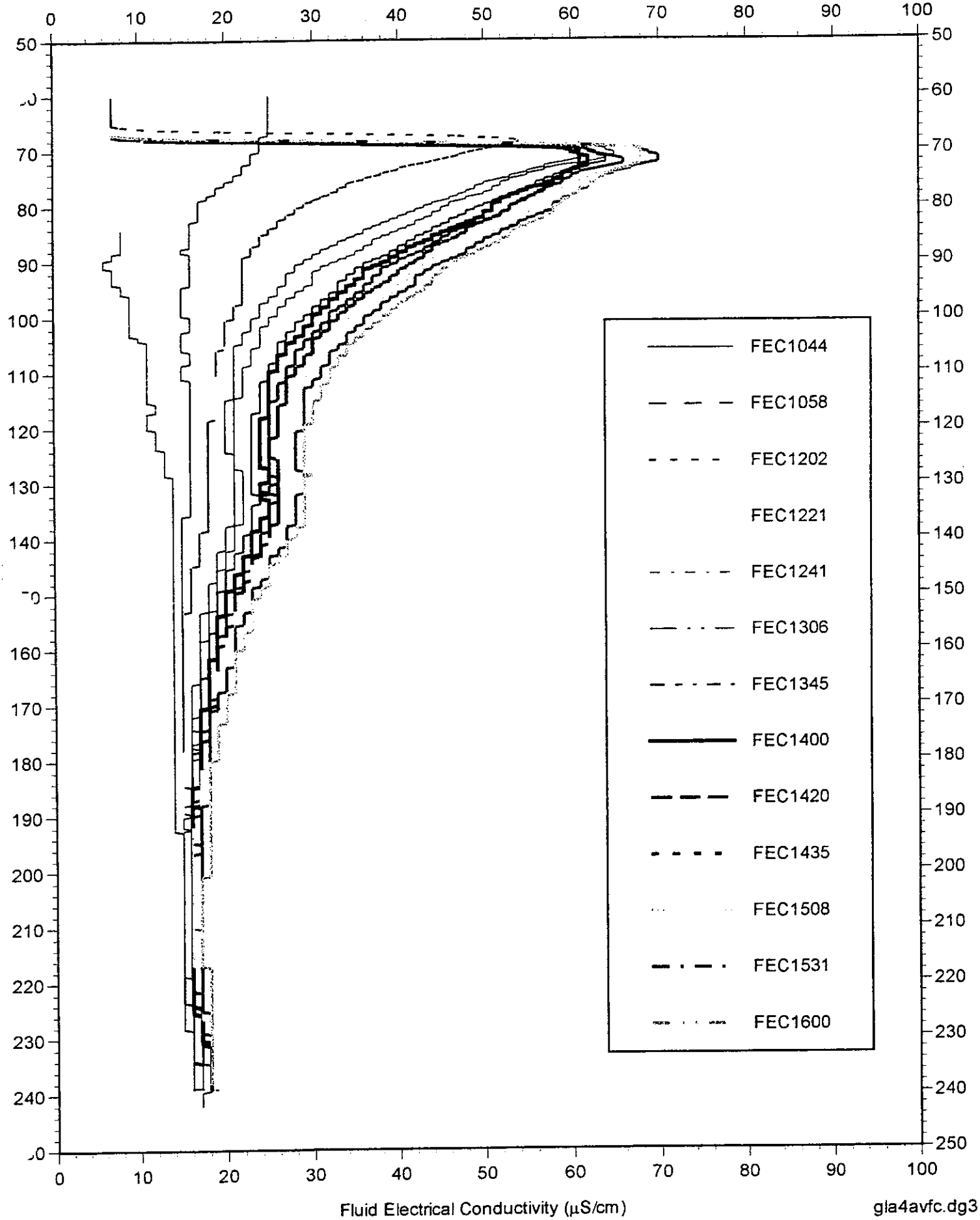
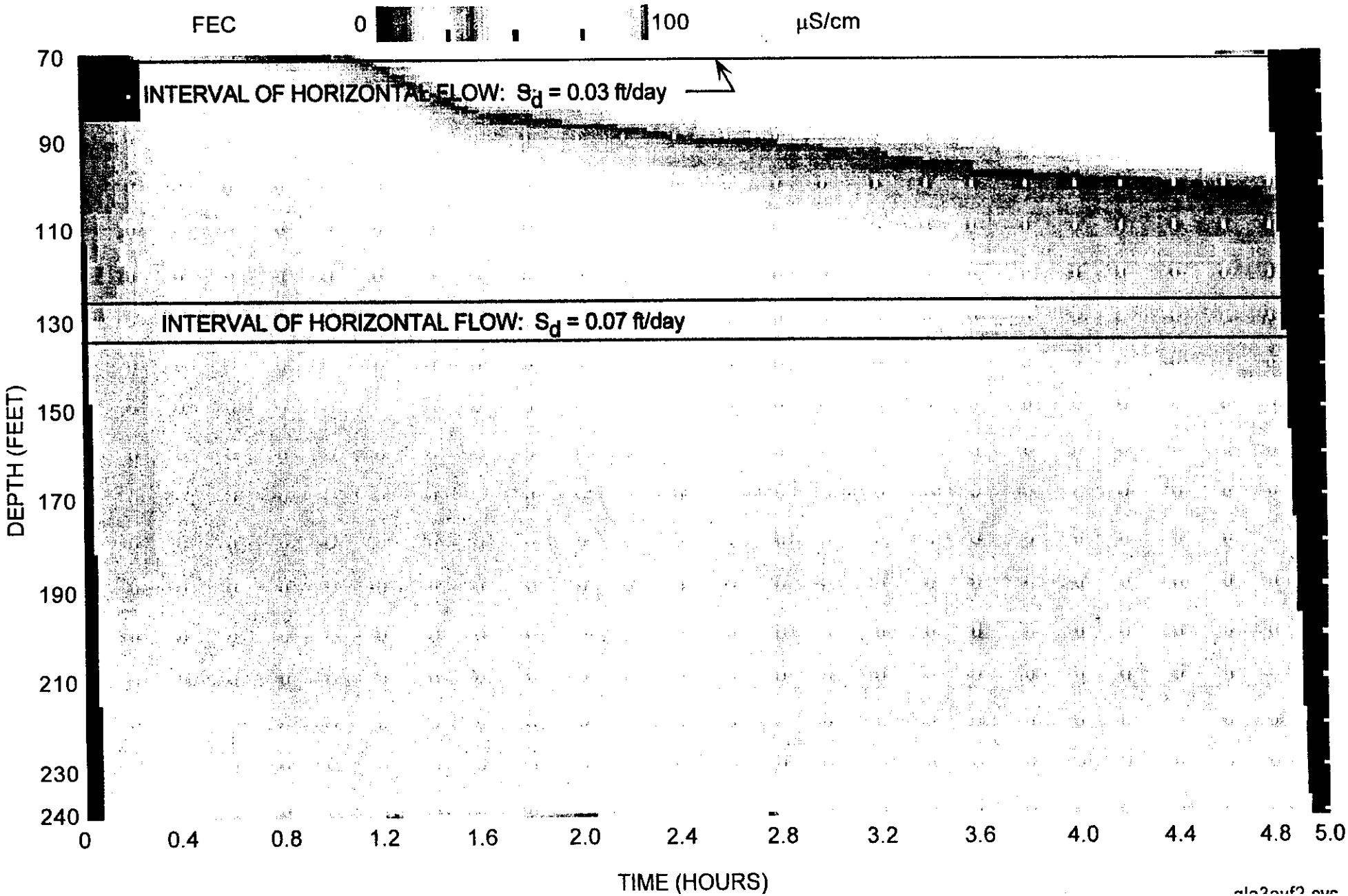
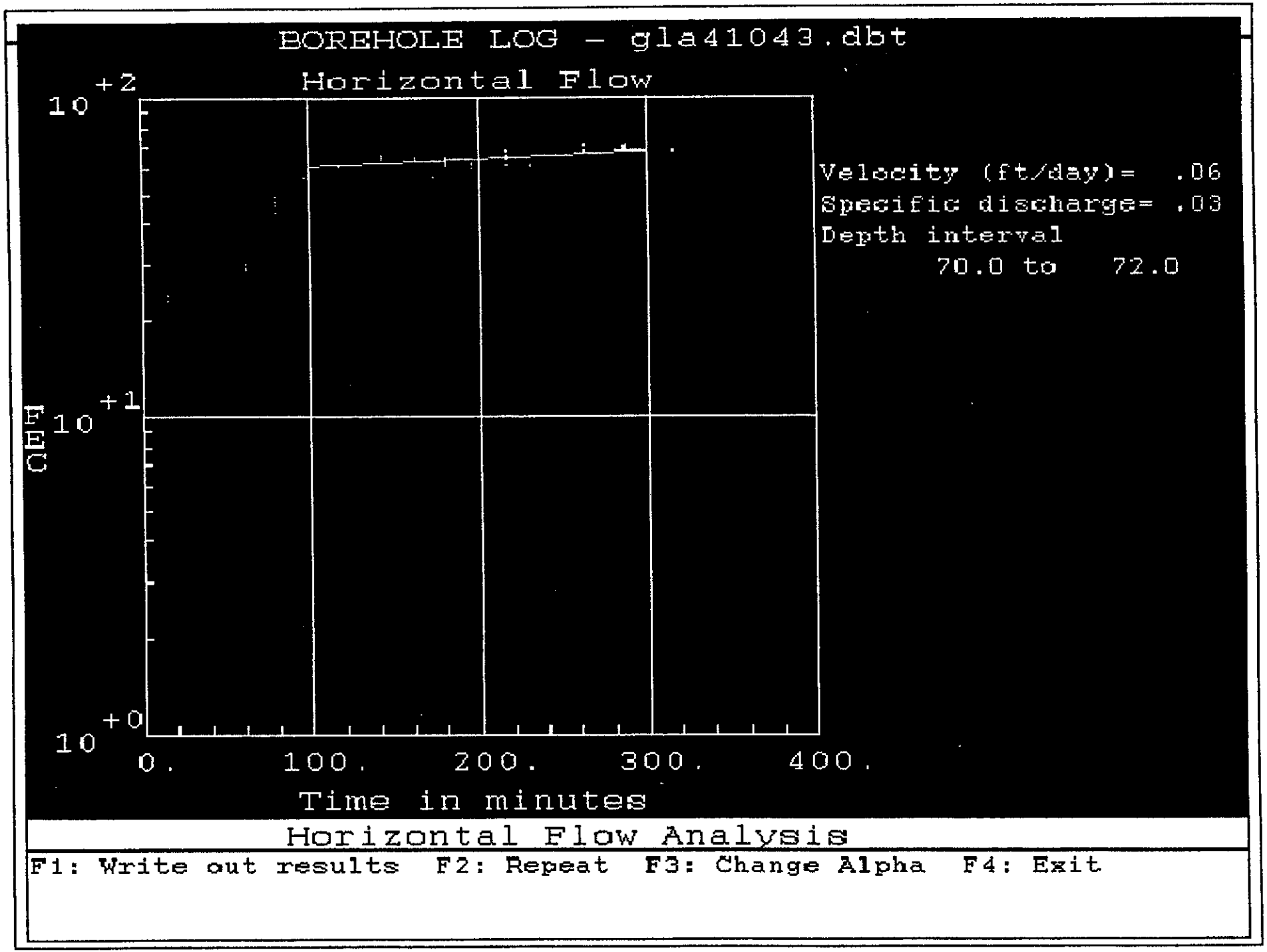


FIGURE GLA-4:3. CHOMOGRAPHIC TESSELATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-4.



FIGU GLA-4:4. HORIZONTAL FLOW ANALYSIS DURING Ai ENT CONDITIONS, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-4.



FIGU. GLA-4:5. HORIZONTAL FLOW ANALYSIS DURING A ENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-4.

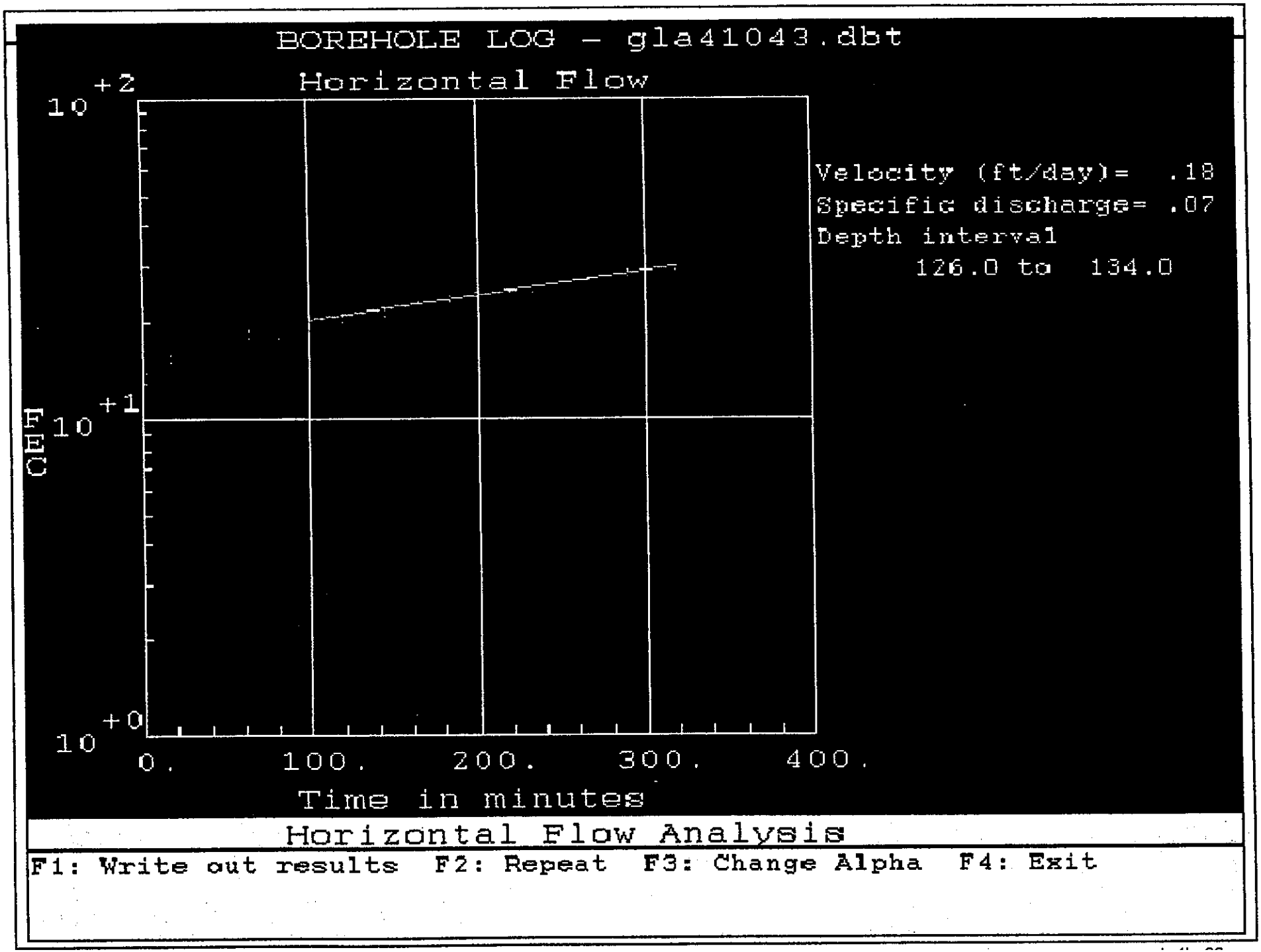


FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	12.2	3.72	N49E	47SE	139	1
2	13.6	4.14	N61W	35N	29	1
3	14.4	4.38	NS	68E	90	1
4	16.3	4.97	N70W	44N	20	1
5	17.3	5.28	N11E	33E	101	1
6	17.9	5.47	N40E	42SE	130	0
7	18.4	5.60	N11E	38E	101	0
8	19.2	5.84	N5E	40E	95	1
9	19.7	6.01	N30W	40NE	60	0
10	20.3	6.20	N/A	Vert.	N/A	2
11	20.4	6.23	N36W	34NE	54	0
12	20.7	6.30	N50W	29NE	40	2
13	20.8	6.34	N3W	28E	87	2
14	20.9	6.38	N19E	48E	109	1
15	21.8	6.64	N28E	47E	118	2
16	22.2	6.78	N24E	43E	114	1
17	23.2	7.06	N48E	49SE	138	1
18	24.3	7.40	N42E	79NW	312	1
19	26.5	8.07	N29E	42E	119	1
20	27.0	8.24	N52E	48SE	142	1
21	27.8	8.48	N72E	47S	162	0
22	28.4	8.65	N6E	56W	276	1
23	30.4	9.26	N27E	80W	297	1
24	31.0	9.46	N21E	47E	111	1
25	32.9	10.02	N33W	56SW	237	1
26	33.9	10.34	N55W	54NE	35	1
27	34.9	10.63	N26W	52W	244	1
28	35.5	10.81	N71E	4N	341	1
29	35.6	10.84	N27W	21E	63	1
30	36.0	10.96	N42W	23SW	228	2
31	36.1	11.01	N45W	14SW	225	0
32	36.9	11.26	N46E	16SE	136	2
33	36.9	11.26	N70W	56S	200	1
34	37.4	11.40	N27W	56W	243	1
35	37.8	11.52	N32W	5SW	238	1
36	38.1	11.62	N33E	76NW	303	1
37	38.4	11.70	N43E	65SE	133	0
38	38.7	11.79	N45E	56SE	135	0
39	40.5	12.36	N48W	37NE	42	2
40	41.1	12.54	N31E	27NW	301	1
41	41.9	12.77	N52E	10NW	322	0
42	42.5	12.96	N86W	21N	4	0
43	43.6	13.30	N87W	48N	3	0
44	44.2	13.47	N48E	54NW	318	0
45	44.7	13.63	N70E	61S	160	0
46	45.3	13.80	N51E	62SE	141	0
47	45.9	14.00	N53W	26NE	37	0

All directions are with respect to magnetic north.

FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	46.9	14.30	N54E	34NW	324	1
49	47.3	14.43	N67E	44N	337	2
50	49.8	15.17	N42E	65NW	312	1
51	50.2	15.29	N55E	70SE	145	0
52	50.9	15.51	N9W	13W	261	1
53	51.0	15.55	N88E	37S	178	1
54	51.0	15.55	N69W	47N	21	1
55	51.1	15.58	N25E	70E	115	0
56	51.6	15.71	N26W	45E	64	1
57	52.2	15.91	N27W	28W	243	2
58	54.1	16.48	N1W	62E	89	1
59	54.6	16.65	N60W	12N	30	4
60	54.7	16.67	N9W	65E	81	0
61	54.8	16.71	N27W	47W	243	2
62	57.0	17.37	N31E	81NW	301	2
63	60.7	18.50	N/A	Vert.	N/A	3
64	61.0	18.61	N87E	35S	177	1
65	61.2	18.66	N79E	23S	169	0
66	61.2	18.66	N31E	78SE	121	1
67	62.9	19.18	N72W	35S	198	1
68	63.3	19.30	N/A	Vert.	N/A	1
69	67.7	20.63	N65W	47S	205	1
70	69.7	21.26	N3E	62E	93	1
71	70.7	21.54	N23W	28E	67	2
72	71.4	21.77	N44E	4SE	134	2
73	72.7	22.15	N74W	39S	196	3
74	73.0	22.25	N/A	Vert.	N/A	3
75	73.2	22.30	N85E	41S	175	2
76	73.4	22.37	N71E	44S	161	2
77	74.3	22.65	N27W	53E	63	0
78	74.6	22.75	N53W	53NE	37	1
79	75.4	22.99	N79E	42N	349	3
80	77.2	23.53	N70E	49N	340	2
81	77.5	23.61	N71E	43N	341	2
82	77.7	23.68	N43E	29NW	313	1
83	77.8	23.70	N/A	Vert.	N/A	0
84	79.1	24.11	N59W	42SW	211	2
85	79.3	24.18	N58W	34SW	212	1
86	79.5	24.24	N61E	71N	331	1
87	79.7	24.31	N53W	22SW	217	2
88	80.6	24.55	N19W	43W	251	1
89	80.9	24.67	N25W	25W	245	1
90	81.1	24.73	N62E	66N	332	2
91	82.0	25.00	N45E	54NW	315	0
92	82.2	25.06	N47E	58NW	317	1
93	82.2	25.06	N50E	78NW	320	1
94	83.8	25.53	N57E	75NW	327	1

All directions are with respect to magnetic north.

FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	84.0	25.60	N57E	71NW	327	1
96	84.9	25.87	N59E	75NW	329	2
97	85.5	26.07	N51E	29NW	321	1
98	87.6	26.71	N28W	31W	242	1
99	87.8	26.76	N53E	73NW	323	1
100	87.9	26.80	N/A	Vert	N/A	1
101	88.2	26.89	N65W	35N	25	2
102	88.3	26.92	N58E	53NW	328	1
103	88.7	27.02	N67E	55N	337	1
104	88.7	27.03	N69E	61N	339	1
105	88.8	27.08	N40E	76NW	310	1
106	91.4	27.85	N/A	Vert.	N/A	1
107	91.9	28.02	N41E	71NW	311	1
108	94.2	28.71	N41E	75SE	131	1
109	94.7	28.85	N/A	Vert.	N/A	2
110	96.4	29.39	N45E	73NW	315	0
111	96.7	29.47	N57E	69SE	147	1
112	98.1	29.89	N33W	42SW	237	1
113	98.2	29.93	N28W	43W	242	2
114	98.6	30.05	N47E	76NW	317	1
115	99.7	30.39	N87W	33S	183	1
116	100.1	30.50	N35E	73NW	305	2
117	100.7	30.70	N50W	18SW	220	1
118	101.3	30.89	N16W	40W	254	0
119	103.6	31.58	N20W	45W	250	0
120	104.4	31.81	N36W	53NE	54	1
121	105.1	32.04	N13E	42W	283	2
122	105.3	32.11	N32E	77NW	302	0
123	107.8	32.87	N23E	24E	113	2
124	108.7	33.13	N40E	31NW	310	1
125	108.7	33.14	N17W	32E	73	2
126	109.6	33.41	N2W	67E	88	0
127	111.3	33.91	N40E	45NW	310	2
128	111.7	34.06	N32E	64SE	122	1
129	114.7	34.95	N14W	26E	76	2
130	114.8	35.00	N23W	24E	67	2
131	115.6	35.23	N17E	20E	107	1
132	115.8	35.29	N8W	45E	82	0
133	116.4	35.47	N1W	50E	89	1
134	118.4	36.10	N6E	35E	96	0
135	119.6	36.46	N45E	42NW	315	1
136	120.1	36.61	N58E	43NW	328	2
137	120.4	36.71	N68E	58S	158	0
138	120.8	36.82	N20E	30W	290	1
139	121.4	37.02	N37E	35SE	127	1
140	123.2	37.55	N53E	62NW	323	0
141	124.0	37.80	N50E	50NW	320	1

All directions are with respect to magnetic north.

FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	124.2	37.85	N50E	64SE	140	1
143	124.2	37.85	N13W	9W	257	2
144	124.8	38.04	N22E	46W	292	0
145	125.0	38.10	N37E	49NW	307	0
146	125.1	38.14	N40E	55NW	310	0
147	125.5	38.24	N34E	48NW	304	1
148	125.5	38.24	N54E	33NW	324	1
149	127.0	38.71	N30E	71NW	300	1
150	127.6	38.90	N36E	67NW	306	1
151	127.7	38.93	N18E	50E	108	0
152	128.9	39.28	N46E	72SE	136	2
153	131.0	39.93	N39E	55SE	129	2
154	132.2	40.31	N10W	32E	80	2
155	133.3	40.62	N47W	44NE	43	3
156	135.7	41.35	N/A	Vert.	N/A	1
157	136.2	41.53	N57E	50NW	327	1
158	136.5	41.60	N/A	Vert.	N/A	3
159	136.9	41.74	N31E	50NW	301	1
160	137.1	41.80	N52E	48SE	142	0
161	137.6	41.95	N14E	36W	284	2
162	137.8	42.00	N28E	39W	298	1
163	138.9	42.35	N42E	32NW	312	1
164	139.1	42.41	N40E	39NW	310	1
165	139.8	42.61	N35E	52NW	305	1
166	139.9	42.65	N47E	38NW	317	1
167	141.2	43.03	N34E	67NW	304	0
168	141.6	43.15	N52E	58SE	142	1
169	141.7	43.19	N26E	59W	296	1
170	143.0	43.59	N23W	23E	67	2
171	144.6	44.08	N56E	58SE	146	1
172	145.1	44.23	N61E	47S	151	1
173	145.2	44.25	N29E	55W	299	1
174	145.3	44.27	N32E	40SE	122	1
175	149.6	45.61	N37W	57SW	233	1
176	150.4	45.86	N6E	64E	96	2
177	150.7	45.94	N28E	64W	298	1
178	152.4	46.44	N89W	21S	181	1
179	152.8	46.58	N46E	50SE	136	1
180	153.9	46.92	N73W	27N	17	1
181	155.1	47.26	N36E	37SE	126	1
182	155.5	47.39	N35E	38SE	125	0
183	156.1	47.57	N43E	34SE	133	1
184	157.1	47.89	N27E	44W	297	1
185	157.6	48.05	N44E	39SE	134	0
186	157.9	48.11	N29E	44E	119	1
187	158.3	48.24	N37E	55SE	127	0
188	158.8	48.40	N75E	52S	165	0

All directions are with respect to magnetic north.

FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	159.4	48.57	N56E	55SE	146	0
190	160.2	48.82	N45E	27NW	315	2
191	160.7	48.99	N7E	54W	277	0
192	160.8	49.00	N15E	39W	285	0
193	161.2	49.13	N30E	58NW	300	0
194	162.7	49.59	N31E	63NW	301	1
195	163.8	49.94	N83E	54S	173	0
196	165.5	50.45	N35E	35SE	125	1
197	166.0	50.61	N74E	37S	164	0
198	167.8	51.14	N66E	70S	156	1
199	169.4	51.62	N87E	48N	357	0
200	169.9	51.80	N74E	20N	344	2
201	170.4	51.94	N49E	59NW	319	0
202	171.8	52.35	N60E	78N	330	1
203	172.4	52.56	N74E	44N	344	1
204	173.1	52.77	N52W	23SW	218	0
205	174.0	53.03	N45E	35SE	135	0
206	174.3	53.13	N26E	43E	116	1
207	179.0	54.545	N64E	73S	154	1
208	180.5	55.02	N59E	80SE	149	0
209	181.2	55.239	N34W	8SW	236	2
210	183.2	55.849	N34E	64NW	304	1
211	183.7	55.977	N45E	54SE	135	0
212	184.0	56.077	N19W	26W	251	0
213	186.6	56.878	N21W	16W	249	1
214	187.6	57.177	N41E	82SE	131	1
215	189.5	57.756	N43E	64SE	133	1
216	190.5	58.051	N50E	58SE	140	2
217	190.8	58.157	N52E	59SE	142	2
218	191.6	58.401	N41E	42SE	131	2
219	191.9	58.491	N36E	56SE	126	1
220	192.8	58.76	N17E	48E	107	1
221	193.1	58.87	N64E	62S	154	1
222	194.2	59.18	N64E	65S	154	2
223	195.3	59.522	N62E	60S	152	1
224	195.6	59.621	N63E	62S	153	1
225	196.8	59.975	N72E	58S	162	1
226	197.3	60.123	N65E	56S	155	1
227	198.5	60.508	N60E	48S	150	1
228	198.9	60.61	N66E	58S	156	1
229	199.1	60.697	N83E	68S	173	1
230	201.9	61.552	N69E	24S	159	1
231	202.5	61.711	N41E	25SE	131	1
232	203.6	62.063	N66W	43S	204	2
233	203.9	62.154	N24E	26E	114	1
234	204.5	62.33	N66W	42S	204	1
235	205.4	62.595	N84W	45S	186	1

All directions are with respect to magnetic north.

FIGURE GLA-4: BIPS FRACTURE TABLE FOR WELL GLA-4, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
236	207.7	63.32	N44W	32NE	46	1
237	210.3	64.113	N33E	24SE	123	1
238	210.8	64.26	N40E	35SE	130	1
239	211.4	64.438	N21E	38E	111	1
240	212.1	64.658	N48E	35SE	138	2
241	212.6	64.813	N50E	45SE	140	1
242	213.8	65.167	N35W	36NE	55	1
243	214.6	65.395	N26W	42E	64	1
244	216.3	65.918	N20W	40E	70	2
245	216.5	65.991	N36E	47SE	126	0
246	218.7	66.661	N43E	48SE	133	1
247	219.0	66.755	N23E	53E	113	1
248	219.0	66.762	N12E	61E	102	2
249	222.2	67.712	N4W	44W	266	0
250	222.3	67.747	NS	44W	270	0
251	223.4	68.107	N15W	69W	255	2
252	223.6	68.149	N18E	58E	108	1
253	223.8	68.204	N8W	52W	262	1
254	224.5	68.424	N25E	37W	295	1
255	225.3	68.669	N12W	20W	258	0
256	225.7	68.799	NS	18E	90	1
257	226.1	68.921	N28E	34E	118	0
258	227.5	69.353	N23E	51E	113	1
259	227.8	69.427	N17E	56E	107	1
260	228.0	69.508	N33E	37SE	123	2
261	228.7	69.7	N52E	42SE	142	2
262	229.4	69.932	N38E	40SE	128	2
263	230.7	70.332	N41E	61NW	311	1
264	230.9	70.369	N26W	20E	64	2
265	231.6	70.605	N72E	57S	162	0
266	232.5	70.852	N47E	38NW	317	1
267	233.2	71.092	N53E	36SE	143	1
268	234.1	71.351	N67W	14N	23	2
269	234.5	71.463	N9W	22E	81	1
270	235.2	71.695	N21W	20E	69	1
271	236.1	71.965	N7E	26E	97	1
272	236.6	72.114	N1W	41W	269	1
273	237.4	72.361	N13W	69E	77	1
274	237.5	72.389	N21W	72W	249	0

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-5

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 16, 1996, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-5:1.

1.2 Ambient Flow Evaluation During Stabilized Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On December 16, 1996, at 1155 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 14 gallons of DI were lost to the formation during dilution procedures. During the 6.26 hours following dilution, multiple logs were conducted. Of these logs, 15 are presented in Figure GLA-5:2. These logs illustrate minor change over the interval from 42 feet to 99 feet. These minor changes in the FEC profiles with respect to time are associated with horizontal flow occurring from 42 to 66 feet and 96 to 99 feet.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-5:3. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 90 µS/cm.

The data suggest that horizontal flow was occurring over the following intervals from 42 to 66 feet and 96 to 99 feet. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for these intervals was approximately 0.13 and 0.15 ft/day, respectively. Correcting for convergence of flow at the wellbore, these velocities equate to a specified discharge of groundwater in the aquifer of 0.05 and 0.06 ft/day, respectively. Please refer to figures GLA-5:4 and GLA-5:5 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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1.3 Flow Characterization During Slug Testing; GLA-5

Initial evaluation of well production indicated that the subject well did not have sufficient yield to maintain the lowest measurable flow rate (approximately 1.5 gpm). As such, a slug test approach was applied to identify water bearing intervals and estimate hydraulic properties of these intervals (Pedler and Urish, 1988; Pedler et. al. 1989, 1990). Please refer to the Standard Operating Procedures in Appendix A for a detailed discussion.

Slug testing after DI emplacement was conducted to establish the inflow locations and evaluate the interval specific inflow rates during well recovery. DI emplacement was performed by replacing the wellbore fluids with DI. Care was exercised during this procedure so as to minimize the volume of DI lost to the formation. After emplacement a baseline FEC log was conducted. Immediately following the baseline log, a slug of wellbore fluids was removed and the pump was withdrawn from the wellbore. During the recovery period, water level elevations were recorded with respect to time and periodic FEC logs were obtained. The resulting FEC logs and the water level recovery data are evaluated to identify the inflow locations and interval specific flow rate during recovery.

On January 16, 1997, at 1201 hours, replacement of the wellbore fluids with DI (emplacement) was complete. Approximately 24 gallons of DI were lost to the formation during dilution procedures. Prior to the installation of the pumping equipment, the ambient water level was recorded at 42.21 feet, referenced to top of protective casing. All drawdown values are referenced to this elevation. Immediately following emplacement, a baseline FEC log FEC1208 was performed. At 1240 (T=0.00 minutes, elapsed time of recovery) a near instantaneous withdrawal of wellbore fluids was performed and the pump was removed from the wellbore. This instantaneous withdrawal of wellbore fluid corresponded to approximately 6 feet of drawdown. Refer to Figure GLA-5:6 for the water level recovery data. The random steps seen in Figure GLA-5:6 are a result of the logging tool entering and exiting the wellbore fluid, thereby raising and lowering fluid level. During the 3.83 hours of recovery, 20 FEC logs were collected. Of these 20, 11 are presented in Figure GLA-5:7. These logs clearly illustrate specific intervals of dramatic increase in FEC with respect to time. The depth at which the peak FEC value for a given interval occurs is indicative of a water bearing interval. The data presented in Figure GLA-5:7 suggest the presence of five hydraulically conductive intervals at 44, 54, 61, 80 and 97 to 99 feet. The data also suggest the possibility of a water bearing interval at or above the water surface (i.e. perched water bearing interval). Numerical modeling of the reported field data was performed using code BORE (Hale and Tsang, 1988, Pedler et. al. 1990, Tsang et.al. 1990). This modeling was performed to estimate the rate of inflow for each identified hydraulically conductive interval during the recovery period. The results of the modeling and analysis are presented in Figure GLA-5:8 and Table GLA-5:1.

1.4 Sensitivity to Inflows

The HpL™ technique is based on measuring induced electrical changes in a dynamic (i.e. flowing conditions) wellbore fluid column. As such, the sensitivity with which "downstream" inflow points (those closest to the pump, where the flow rate is the greatest) can be identified as directly proportional to the flow rate and FEC of both the upward flowing wellbore fluids and the formation inflow location. Given the conditions observed in the well during our testing, the HpL™ technique would have detected any inflow greater than 0.01 gpm with FEC of 1200 μS/cm, during the testing described in this report.

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FIGURE GLA-5:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.

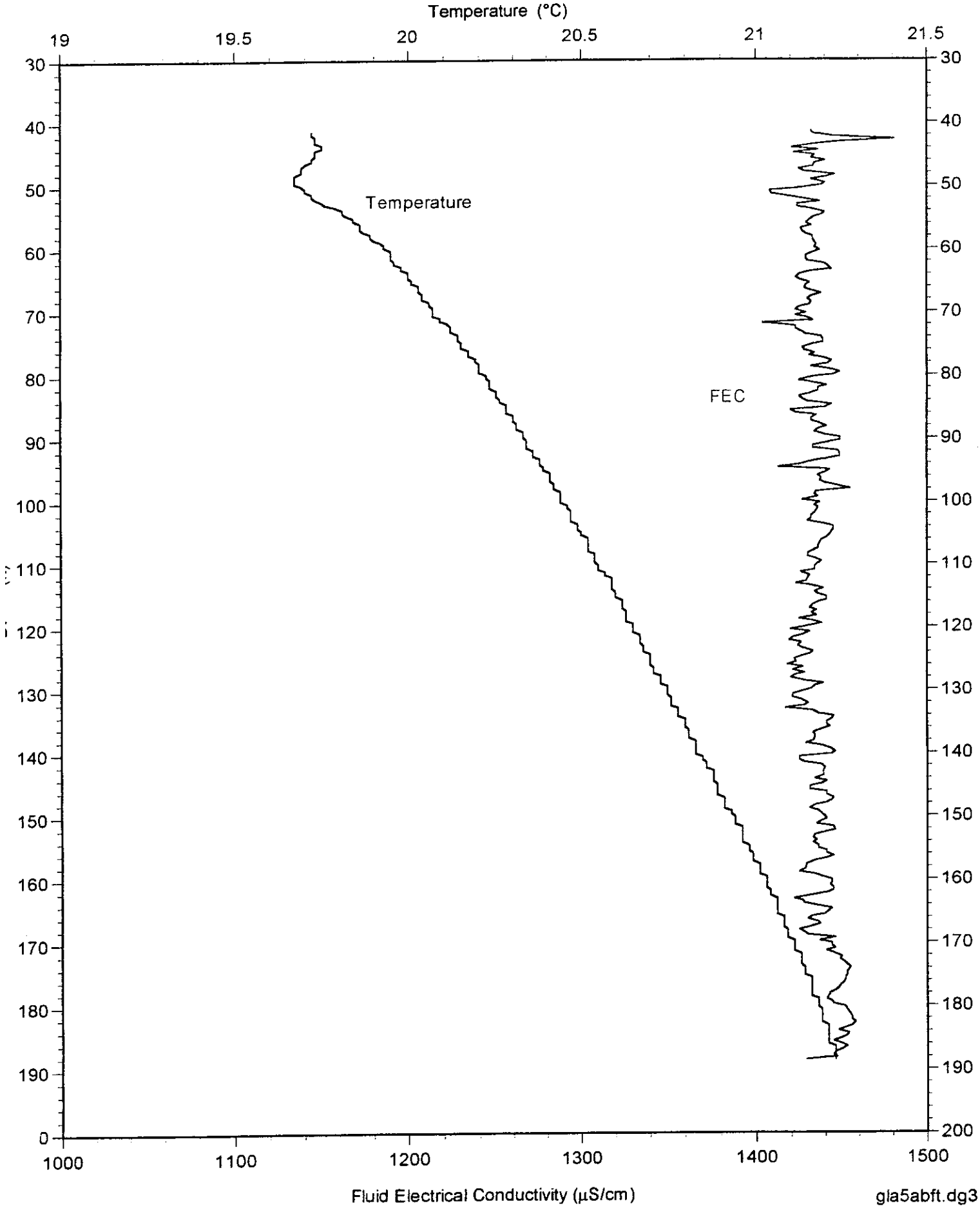


FIGURE GLA-5:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-5.

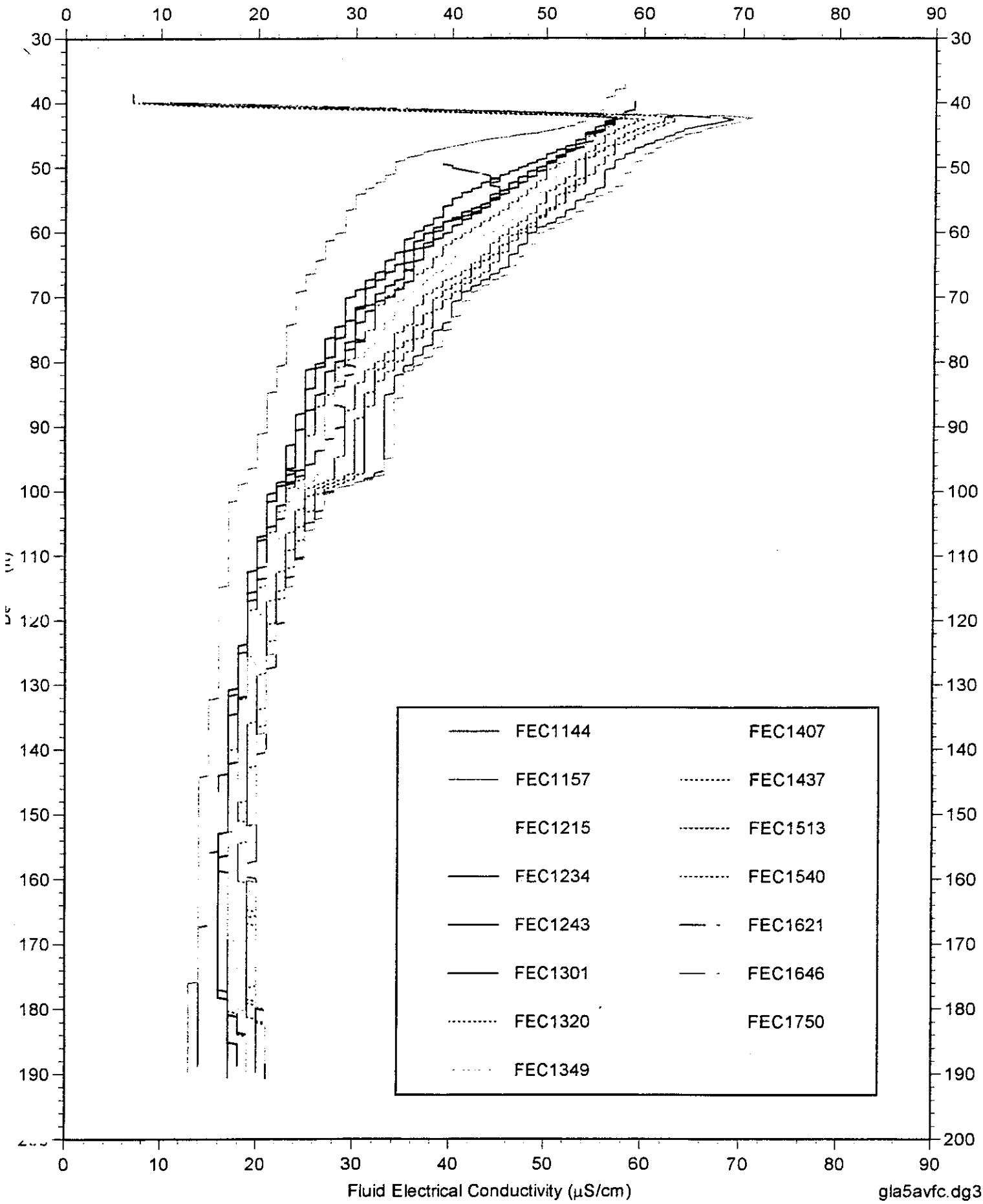
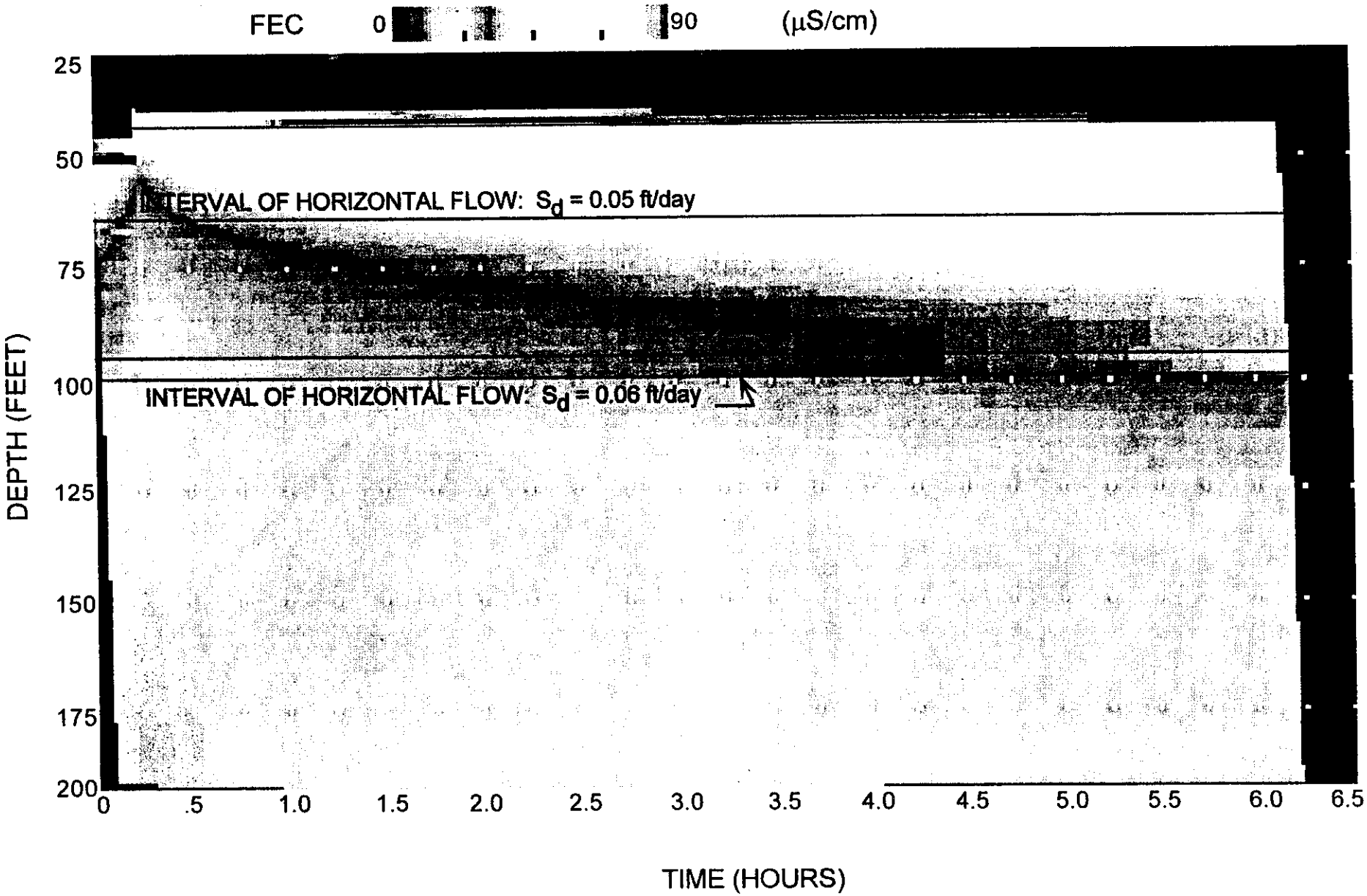


FIGURE GLA-5:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-5.



gla5avfc.cvs

FIGURE GLA-5:4. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.

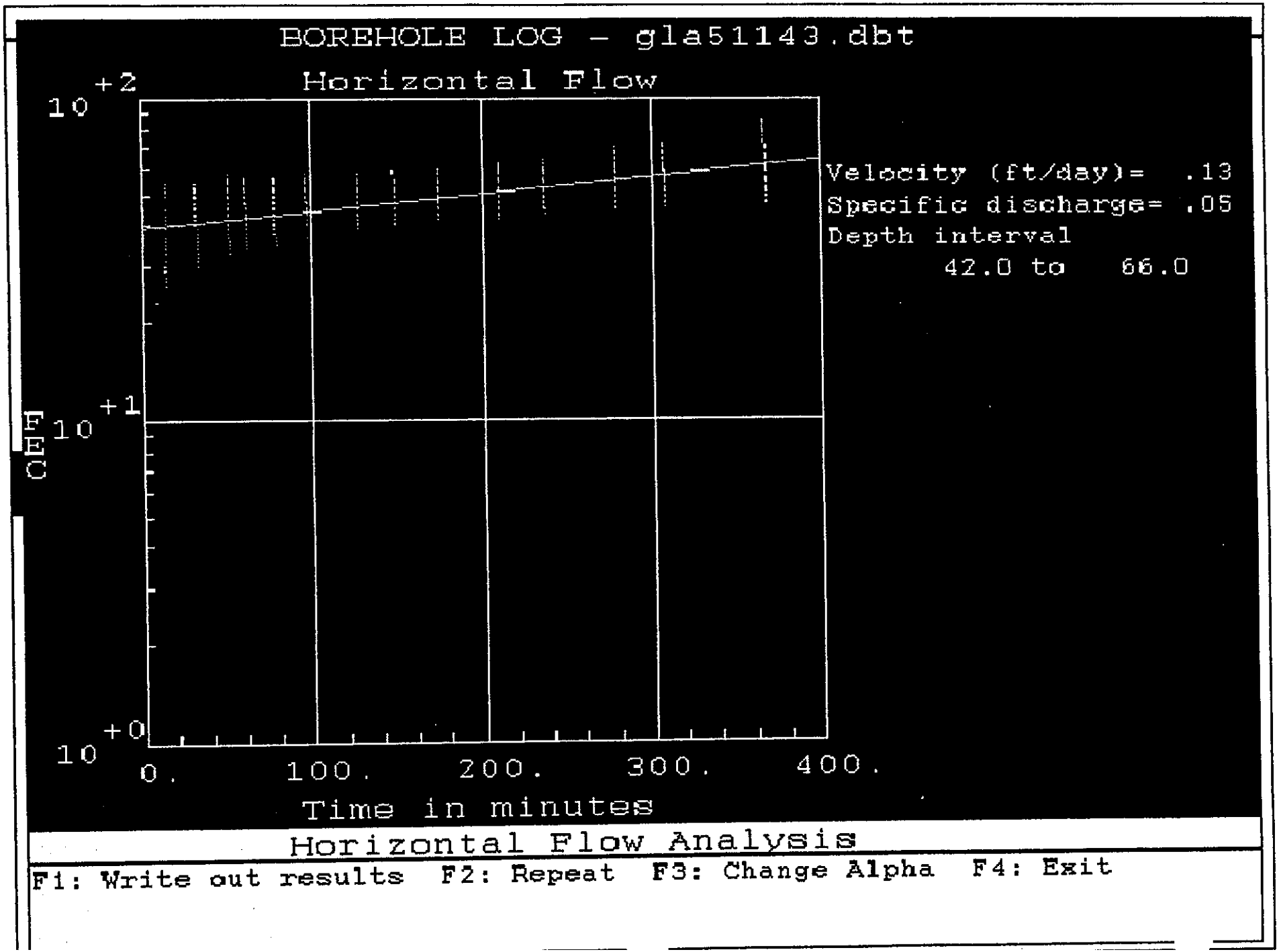


FIGURE GLA-5:5. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.

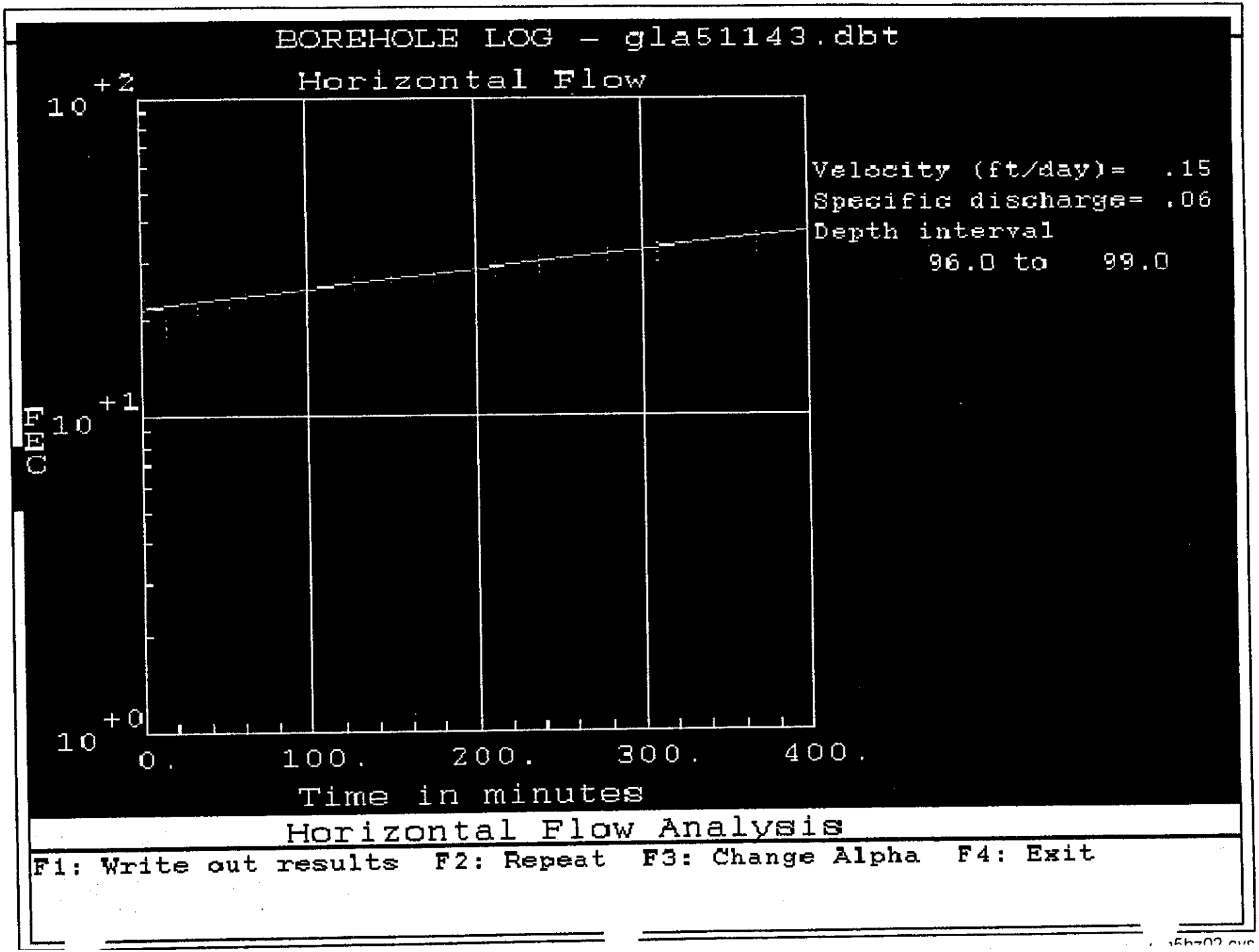


FIGURE GLA-5:6. DRAWDOWN DATA DURING SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.

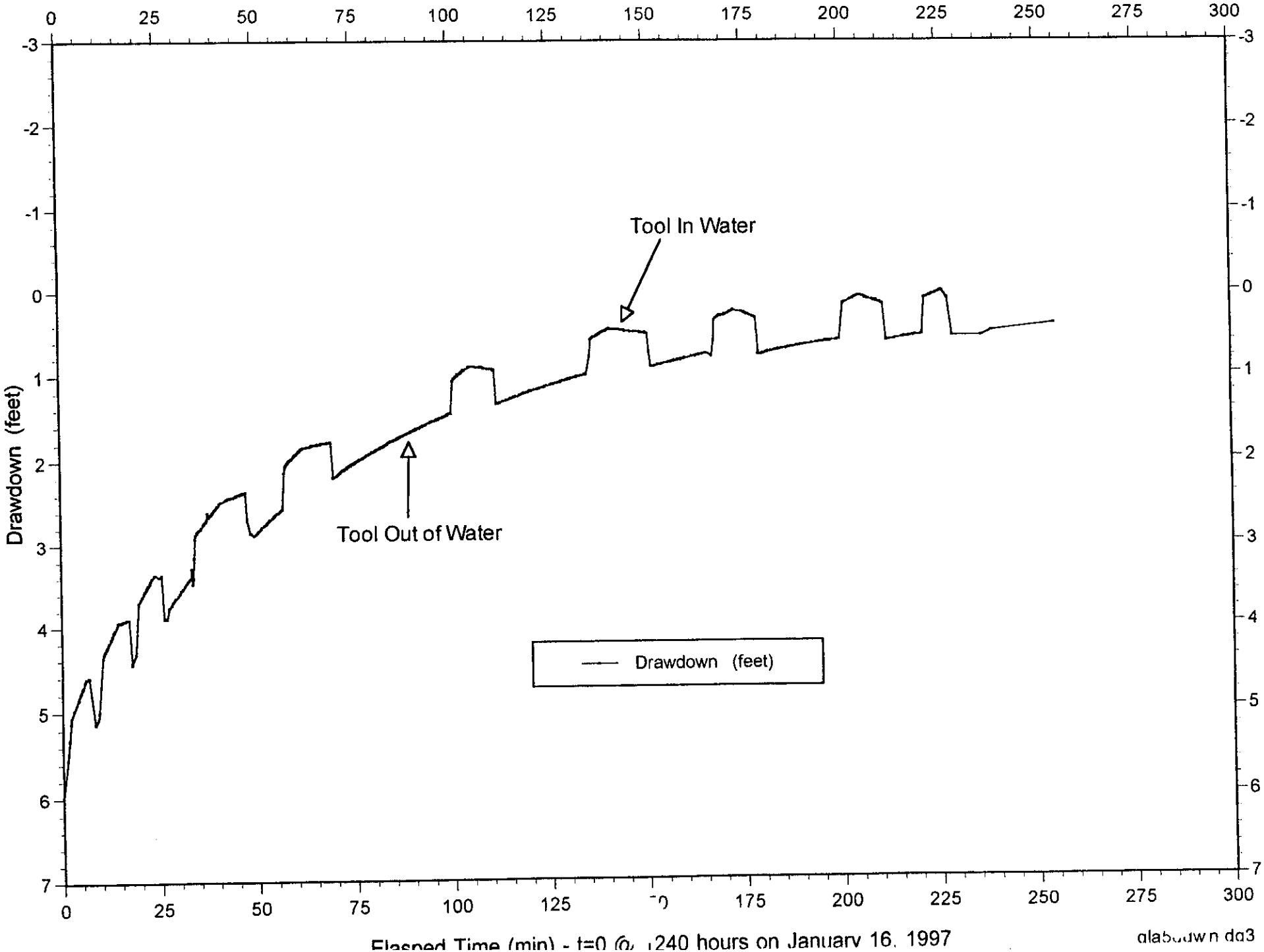


FIGURE GLA-5:7. SUMMARY OF HYDROPHYSICAL LOGS FOR SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.

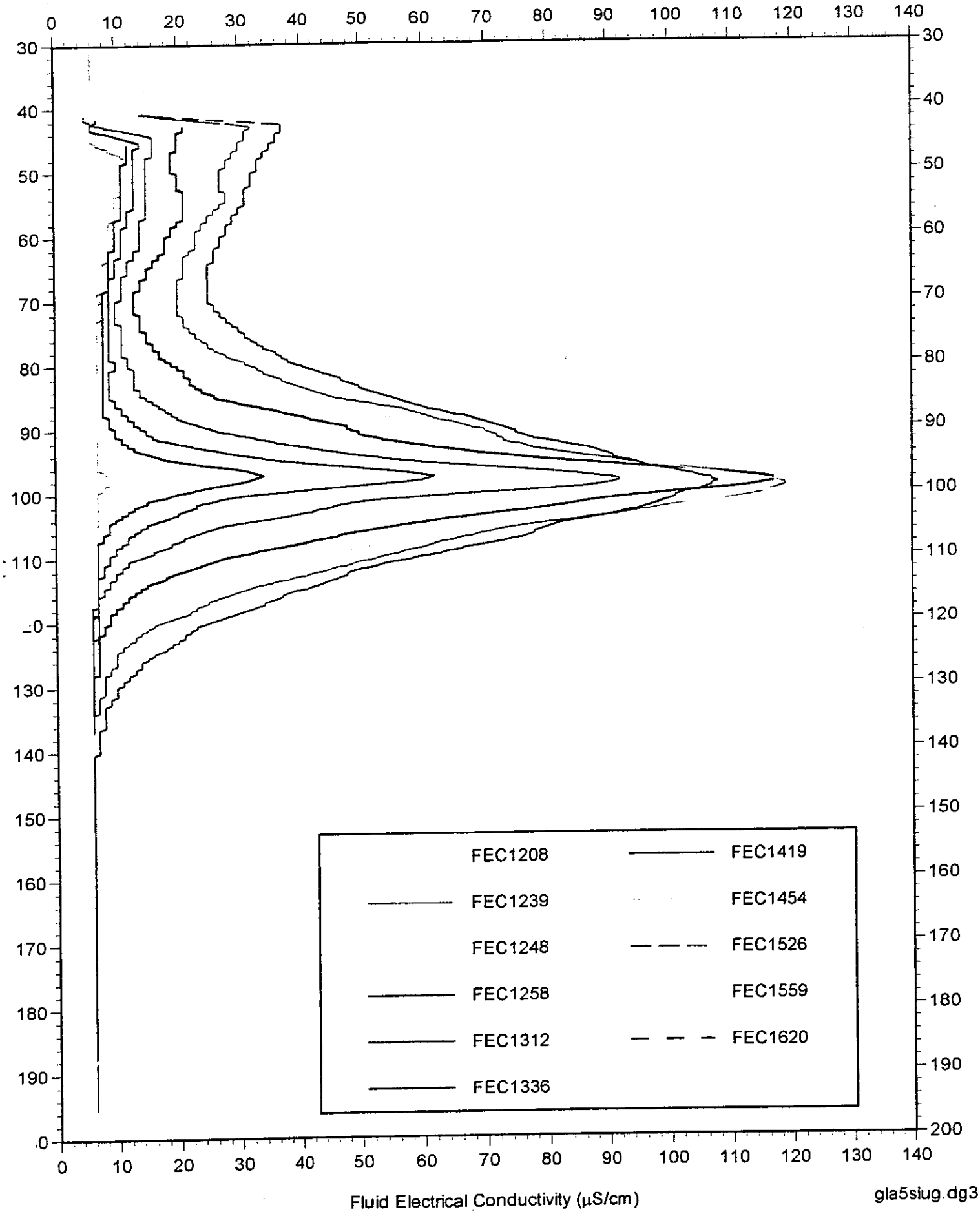
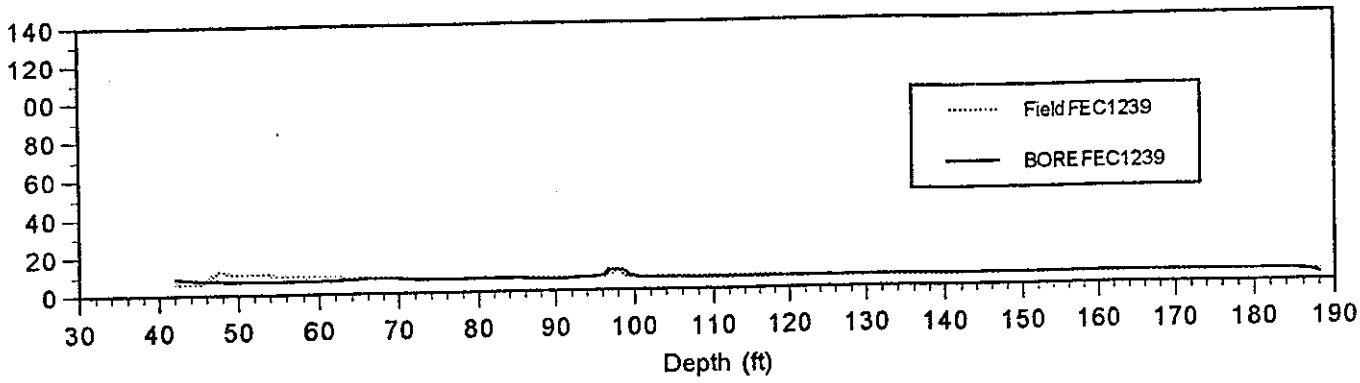
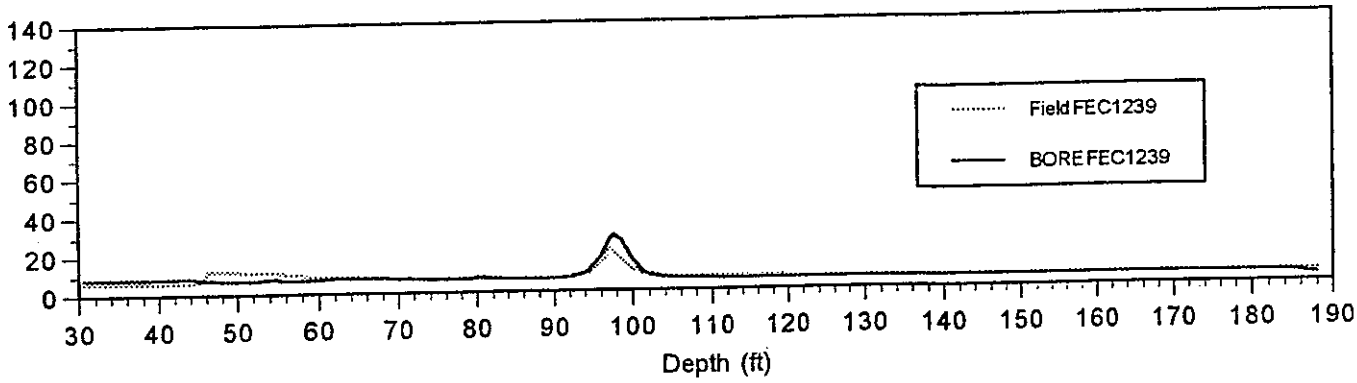
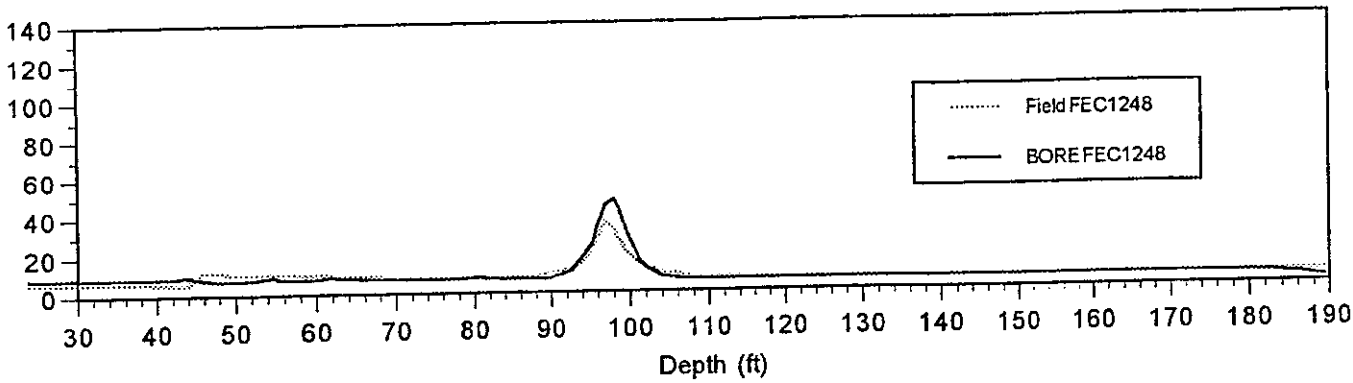


FIGURE GLA-5:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.







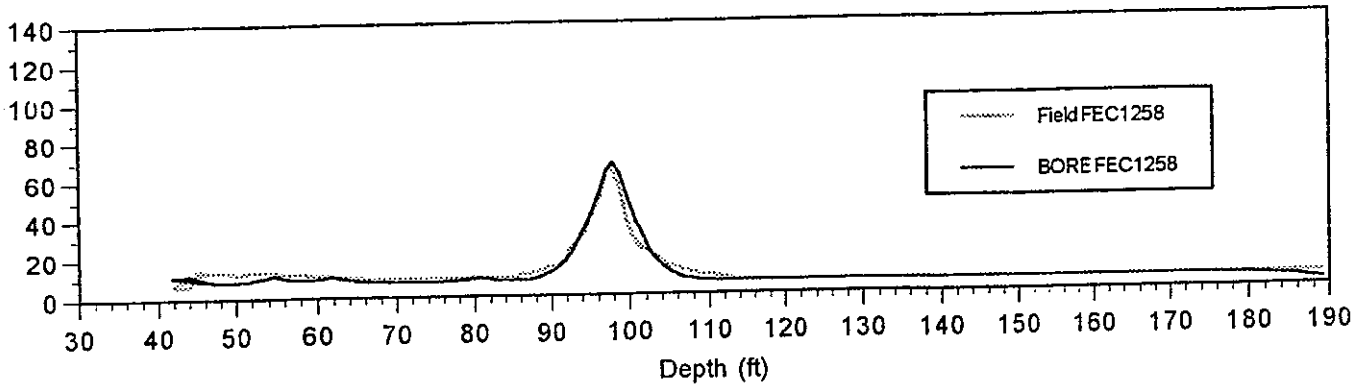


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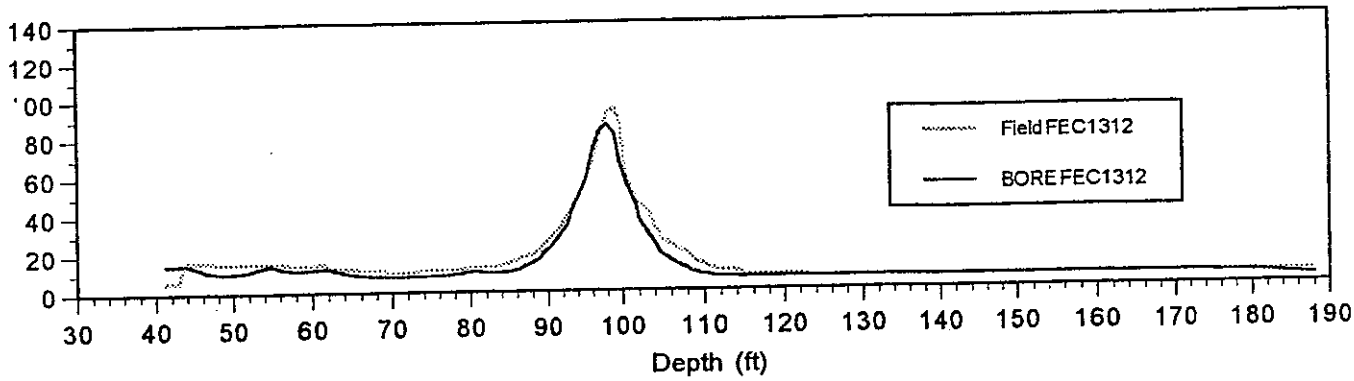
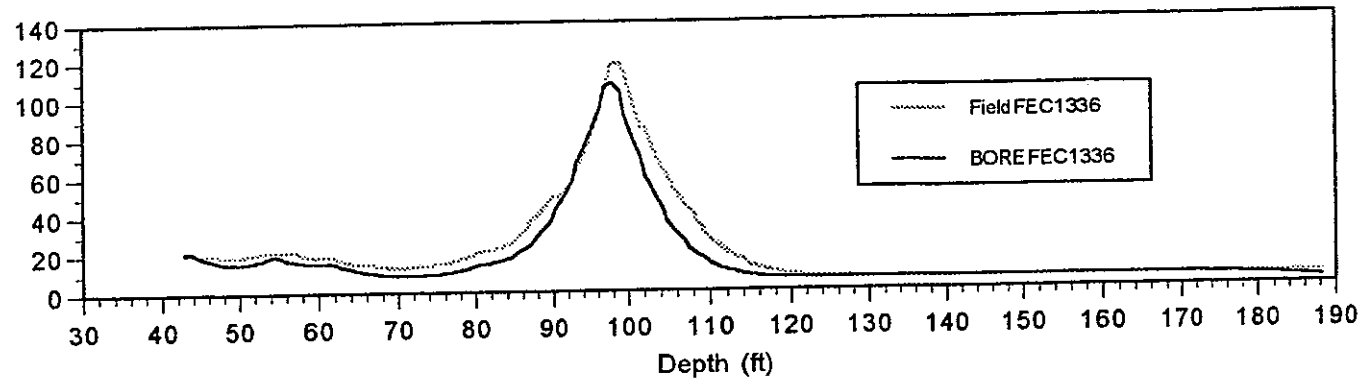
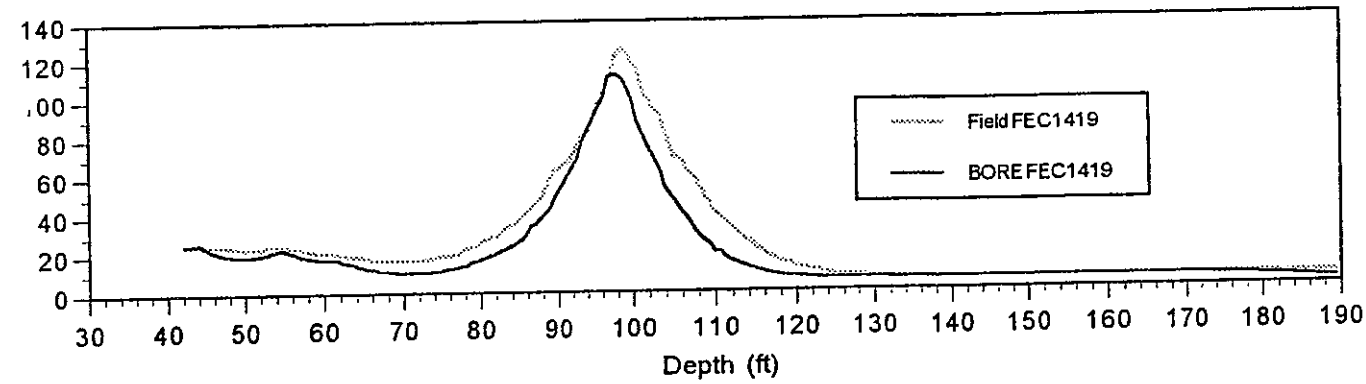
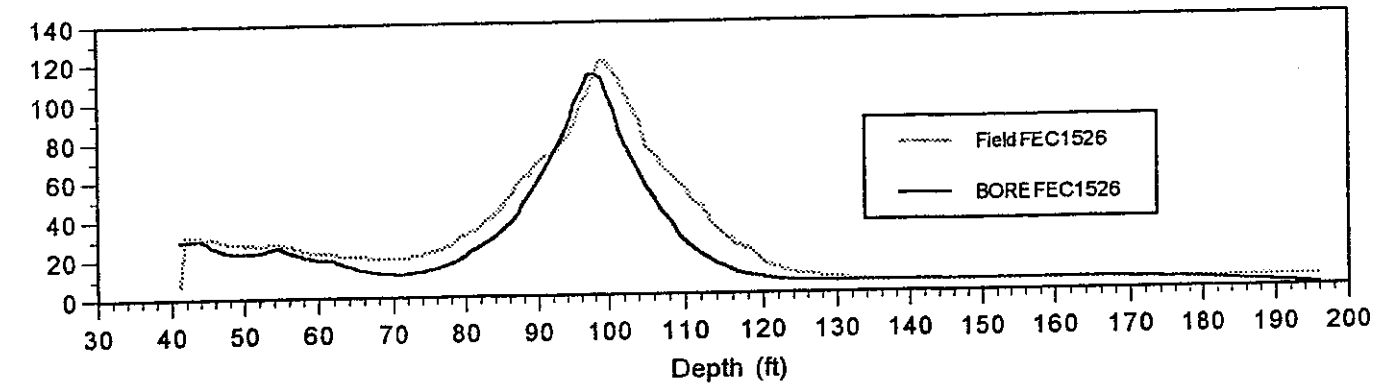
FIGURE GLA-5:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.



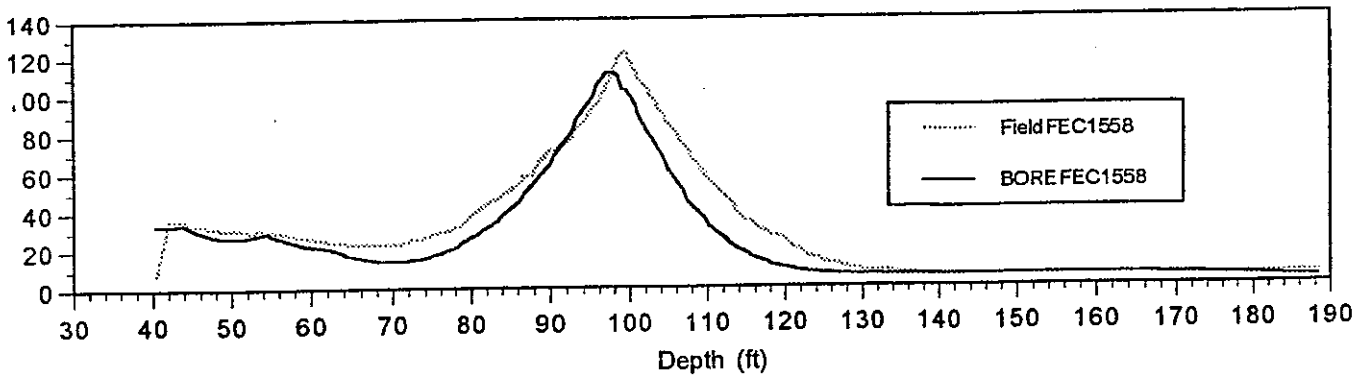






gla5comp.dg3

FIGURE GLA-5:8. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-5.



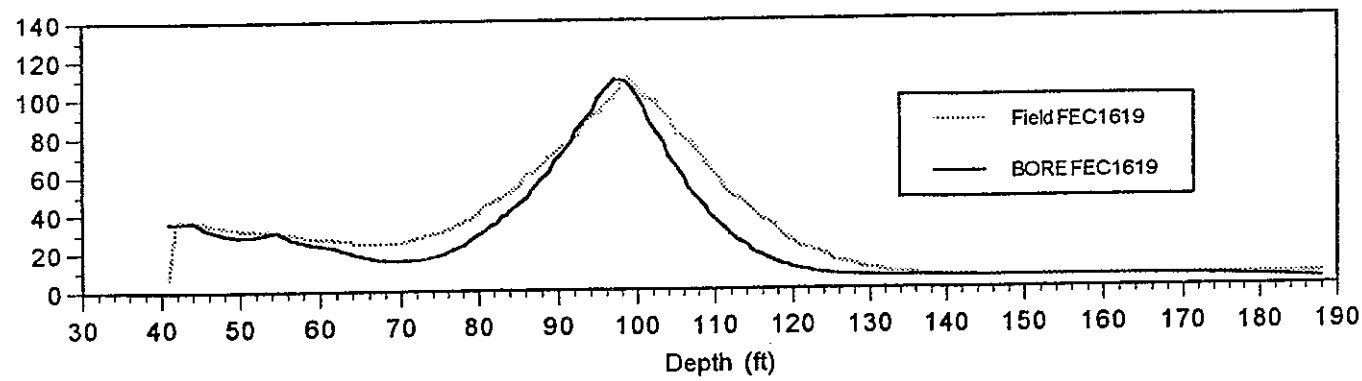


TABLE GLA-5:1. CODE BORE RESULTS FOR SLUG TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-5.

Depth (meters)	Depth (feet)	Flow Rate (m^3/s)	Flow Rate (lpm)	Flow Rate (gpm)	FEC (gram/l)	FEC (µS/cm)
13.4	43.96	2.02E-07	0.01	0.003	0.500	1038
16.5	54.13	2.52E-07	0.02	0.004	0.500	1038
18.7	61.35	1.50E-07	0.01	0.002	0.500	1038
24.4	80.05	1.50E-07	0.01	0.002	0.500	1038
29.5	96.78	2.23E-06	0.13	0.035	0.500	1038
29.8	97.77	2.23E-06	0.13	0.035	0.500	1038
30.1	98.75	2.23E-06	0.13	0.035	0.500	1038
TOTAL ESTIMATED FLOW RATE - BORE RESULTS =				0.118 gpm		

FIGURE GLA-5: BIPS FRACTURE TABLE FOR WELL GLA-5, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	30.2	9.19	N61W	70N	29	0
2	30.7	9.37	N56W	67NE	34	0
3	31.3	9.53	N75W	65N	15	0
4	32.6	9.95	N78W	65N	12	0
5	34.6	10.54	N75W	59N	15	0
6	37.2	11.35	N46W	72SW	224	0
7	39.8	12.12	N79W	63N	11	0
8	40.7	12.41	N72W	67N	18	0
9	41.4	12.62	N13E	26E	103	0
10	41.5	12.64	N77W	67N	13	1
11	42.0	12.82	N79W	67N	11	0
12	42.5	12.95	N75W	64N	15	0
13	43.2	13.17	N78W	61N	12	0
14	43.6	13.30	N73W	62N	17	0
15	44.4	13.53	N78W	58N	12	1
16	44.8	13.65	N78W	59N	12	0
17	45.5	13.87	N77W	58N	13	0
18	46.3	14.11	N78W	58N	12	0
19	46.7	14.23	N80W	61N	10	0
20	47.8	14.56	N85E	65N	355	0
21	48.9	14.92	N6E	20W	276	1
22	50.6	15.42	N62W	66N	28	0
23	50.9	15.53	N40W	65SW	230	0
24	51.0	15.55	N54W	64NE	36	0
25	52.1	15.87	N64W	67N	26	1
26	52.1	15.87	N44W	54SW	226	0
27	52.5	16.00	N26W	61W	244	0
28	53.2	16.20	N42W	25NE	48	0
29	53.4	16.29	N3W	75W	267	0
30	55.3	16.85	N27E	33W	297	0
31	55.7	16.97	N61E	46N	331	2
32	57.1	17.42	N22W	24E	68	0
33	57.5	17.53	N8E	15E	98	0
34	58.3	17.78	N50W	70NE	40	1
35	59.4	18.10	N17W	77E	73	0
36	59.4	18.11	N45W	39NE	45	0
37	61.6	18.77	N65E	37N	335	1
38	62.2	18.97	N26E	55W	296	0
39	63.7	19.41	N18E	49W	288	0
40	64.0	19.51	N63W	65N	27	0
41	65.2	19.86	N12W	18E	78	1
42	65.3	19.89	NS	19E	90	0
43	66.3	20.19	N69W	73N	21	0
44	67.4	20.54	N54W	70NE	36	0
45	68.3	20.80	N17W	45E	73	1
46	68.5	20.88	N73E	36S	163	2
47	69.0	21.02	N71E	36N	341	0

All directions are with respect to magnetic north.

FIGURE GLA-5: BIPS FRACTURE TABLE FOR WELL GLA-5, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	69.3	21.12	EW	48N	0	0
49	70.1	21.36	N75W	18S	195	0
50	71.2	21.71	N82E	46N	352	0
51	71.3	21.73	N40W	39SW	230	1
52	71.7	21.86	N57E	26NW	327	0
53	72.5	22.09	N13E	69W	283	0
54	73.1	22.27	N23W	28E	67	0
55	73.5	22.39	N38W	32NE	52	2
56	74.2	22.61	N44W	29NE	46	0
57	76.0	23.18	N82W	47N	8	1
58	76.4	23.28	N79E	35S	169	0
59	77.4	23.58	N71W	58N	19	1
60	78.7	24.00	N83W	52N	7	0
61	79.6	24.26	N24E	43E	114	0
62	80.8	24.62	N30W	25SW	240	0
63	81.1	24.71	N71E	34N	341	0
64	81.6	24.87	N29E	38E	119	0
65	82.1	25.03	N88E	58S	178	0
66	82.2	25.05	N79E	36N	349	1
67	83.7	25.50	N68W	40N	22	1
68	84.4	25.73	N86W	38N	4	1
69	84.7	25.82	N58W	60SW	212	0
70	84.8	25.85	N86E	55N	356	0
71	85.0	25.91	N87W	76S	183	0
72	86.1	26.25	EW	10N	0	0
73	86.2	26.28	N43E	78NW	313	1
74	87.9	26.80	N52E	78NW	322	0
75	89.8	27.37	N53W	51SW	217	0
76	91.5	27.90	N50E	75NW	320	1
77	91.8	27.98	N61E	61N	331	0
78	92.3	28.14	N57E	54NW	327	0
79	92.9	28.31	N36E	52NW	306	0
80	93.3	28.43	N81E	50S	171	1
81	93.5	28.50	N82E	35N	352	0
82	93.5	28.50	N/A	Vert.	N/A	0
83	94.6	28.85	N79E	43N	349	0
84	95.1	28.98	N69E	30N	339	1
85	95.5	29.12	N77W	31N	13	0
86	95.9	29.22	N79W	27S	191	1
87	96.4	29.39	N78E	33S	168	0
88	96.8	29.50	N56W	43SW	214	2
89	97.1	29.61	N11W	70E	79	1
90	97.2	29.62	N52W	62SW	218	2
91	97.8	29.81	N69W	41S	201	2
92	99.5	30.33	N76W	47N	14	1
93	100.2	30.55	N68W	61N	22	0
94	101.0	30.78	N53W	31NE	37	0

All directions are with respect to magnetic north.

FIGURE GLA-5: BIPS FRACTURE TABLE FOR WELL GLA-5, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	101.7	31.00	N81W	18N	9	2
96	103.1	31.41	N69E	30N	339	1
97	103.7	31.62	N52E	32NW	322	1
98	105.9	32.29	N12W	42W	258	1
99	106.2	32.38	N86W	25S	184	0
100	107.1	32.63	N66W	53N	24	0
101	107.3	32.71	N25E	63E	115	0
102	107.9	32.90	N66E	63N	336	0
103	109.4	33.34	N3W	70W	267	0
104	111.1	33.85	NS	62W	270	1
105	111.7	34.05	N85E	40N	355	0
106	112.6	34.31	N60E	68N	330	1
107	114.6	34.93	N77E	66N	347	0
108	116.0	35.35	N65E	63N	335	1
109	118.0	35.96	N83W	41N	7	0
110	118.4	36.09	N66E	49N	336	0
111	118.5	36.13	N70E	38N	340	0
112	119.6	36.44	N81E	61N	351	1
113	120.7	36.79	N37W	62SW	233	2
114	120.9	36.86	N43W	54NE	47	0
115	121.6	37.08	N64W	36N	26	0
116	122.4	37.31	N84W	54N	6	0
117	122.7	37.39	N80W	53N	10	1
118	124.8	38.04	N41W	26SW	229	2
119	128.0	39.00	N20W	60E	70	1
120	130.0	39.63	N16E	54W	286	1
121	130.5	39.77	N3E	28W	273	2
122	131.0	39.92	N6E	29W	276	2
123	132.2	40.30	N65E	55N	335	1
124	133.5	40.68	N2W	64W	268	0
125	134.1	40.89	N14E	57W	284	0
126	134.9	41.11	N64W	48N	26	0
127	135.0	41.16	EW	70N	0	0
128	135.8	41.39	N56E	63NW	326	0
129	136.9	41.74	N40E	47NW	310	0
130	137.6	41.94	N16W	46W	254	1
131	138.6	42.26	N11E	56W	281	1
132	139.1	42.41	N62E	39NE	332	0
133	140.0	42.67	N77E	45N	347	1
134	140.6	42.87	N52E	65NW	322	0
135	141.1	43.02	N68E	43N	338	0
136	141.5	43.14	N12E	49W	282	0
137	142.8	43.53	N38E	38NW	308	1
138	143.2	43.64	N11E	65W	281	0
139	144.0	43.89	N5E	77W	275	0
140	144.8	44.14	N29W	7W	241	0
141	145.6	44.38	N38E	55NW	308	0

All directions are with respect to magnetic north.

FIGURE GLA-5: BIPS FRACTURE TABLE FOR WELL GLA-5, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	145.6	44.38	N82E	32S	172	0
143	160.1	48.80	N67W	69N	23	0
144	162.3	49.47	N48E	59NW	318	1
145	163.9	49.96	N83W	42S	187	0
146	166.3	50.68	N26E	54W	296	1
147	166.8	50.83	N21E	60W	291	1
148	168.4	51.34	N45W	23SW	225	1
149	169.3	51.61	N3E	51W	273	0
150	170.6	52.00	N1W	50W	269	0
151	171.3	52.22	N14E	68W	284	1
152	181.6	55.37	N14W	65W	256	0
153	181.7	55.38	N9E	77W	279	1
154	184.2	56.13	N12E	58E	102	0
155	185.7	56.59	N19E	67W	289	1

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-7

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 19, 1996, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-7:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On December 19, 1996, at 0945 hours (T=0.00 minutes), dilution of the fluid column was complete. Approximately 6 gallons of DI water was lost to the formation during dilution procedures. During the 6.3 hours following dilution, multiple logs were conducted. Of these logs, 16 are presented in Figure GLA-7:2. These logs illustrate significant change throughout the interval from 33 (top of water column) to 88 feet. These dramatic changes in the FEC profiles with respect to time are associated with horizontal flow occurring primarily over this same interval.

A tessellated[1] chromographic summary of all downward FEC traces are presented in Figure GLA-7:3. FEC of 0 μ S/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 160 μS/cm.

The data suggest that horizontal flow was occurring over the interval from 33 to 72 feet. To discretize the specific intervals for horizontal flow analysis, review of these data and the results of the production test were evaluated. Based on review of these data, the following intervals were selected for horizontal flow analysis: 33 to 42 feet, 42 to 48 feet, 48 to 52 feet, 52 to 58 feet, 58 to 62 feet, 62 to 69 feet, and 69 to 72 feet. The data suggest that the change in FEC for the interval from 72 to 88 feet was associated with dispersion rather than horizontal flow. As such, the interval was not analyzed. Review of these data suggests a decrease in velocity and specific discharge with depth. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for these intervals ranged from 0.41 to 0.53 ft/day. Correcting for convergence of flow at the wellbore, these velocities equate to a specific discharge of groundwater in the aquifer of 0.16 to 0.24 ft/day. Please refer to Figures GLA-7:4 through GLA-7:10, and Table GLA-7:1 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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1.3 Flow Characterization During Well Production; GLA-7.

Pumping of wellbore fluids and simultaneous DI injection was conducted at one pumping rate to establish the inflow locations and evaluate the interval specific inflow rates. Pumping at a given rate was conducted until reasonably constant drawdown was observed. When constant drawdown was observed, DI injection was initiated at about 54% of the pumping rate and the extraction pumping rate was adjusted to maintain a constant total formation production rate (i.e. pumping rate prior to DI injection). These procedures were conducted at one formation production rate, about 5 gpm.

On January 2, 1997, at 1220 hours (T=0.00 minutes, elapsed time of testing), pumping was initiated at about 5 gpm. Prior to initiating pumping, the depth to water was recorded at 35.05 feet (referenced to the top of protective casing). Time dependent depth to water, totals and flowrate information was recorded and is presented in Figure GLA-7:11. Pumping was maintained at a time averaged rate of 5.09 gpm until 1351 hours (T=91 minutes, elapsed time of testing). DI injection was initiated at 1351 hours at a time averaged rate of 2.74 gpm, total extraction was increased to a time averaged rate of 7.82 gpm, resulting in a total formation time averaged production rate of 5.08 gpm. A brief power failure at 1455 hours (T=155 minutes, elapsed time of testing) resulted in loss of power to the pumps and the data acquisition system. At 1500 hours (T=160 minutes, elapsed time of testing) power was restored and the testing resumed. The time averaged flow rates were calculated from this point until the conclusion of the test. These flow conditions were maintained until 1704 hours (T=284 minutes, elapsed time of testing). A reasonably constant drawdown of about 6.2 feet was observed during DI injection. During this period, multiple loggings were conducted, and ten selected FEC traces (FEC1320, FEC1326, FEC1331, FEC1338, FEC1604, FEC1610, FEC1616, FEC1622, FEC1628 and FEC1634) are presented in Figure GLA-7:12. These logs illustrate a reasonably stable, diluted condition of the fluid column with local inflow locations identified by incremental step increases. Each of these step changes indicates hydraulically conductive intervals at that depth. Numerical modeling of the reported field data was performed using code BORE (Hale and Tsang, 1988, Pedler et. al. 1990, Tsang et.al. 1990). This modeling was performed to estimate the rate of inflow for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Figures GLA-7:12 and GLA-7:13 and Table GLA-7:2. In summary, flow during the 5 gpm production test is located at one continuous hydraulically conductive interval from 56 to 99 feet. This hydraulically conductive interval is illustrated in Figures GLA-7:12 and GLA-7:13 and summarized in Table GLA-7:2.

1.4 Cross Hole Testing; GLA-7 and GMP-2.

Additional HydroPhysical™ testing was performed in well GLA-7 while pumping was conducted in well GMP-2. Well GLA-7 is located approximately 167 feet N56°W from well GMP-2. The objective of this testing was to evaluate the "cross hole" hydraulic connection between wells GMP-2 and GLA-7. The hydraulic connection between these wells was estimated by evaluating the flow conditions in well GLA-7 during a stable wellfield condition (see section 1.2 above) and during a stressed wellfield condition. The stressed wellfield condition was achieved by pumping well GMP-2. By comparing the flow conditions during these two pressure states, a qualitative evaluation of which intervals are hydraulically connected can be achieved. Quite simply, those intervals which display the greatest change in flow between the two pressure conditions are assumed to be more hydraulically connected. Further evaluation of the logging data to quantify the horizontal flow velocity and associated specific discharge has been conducted using experimental coding developed by others. This coding is discussed in Appendix C.

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1.4.1 Cross-Hole Flow Evaluation During Stressed Well Field Condition: GLA-7.

For cross-hole flow assessment, the formation water in the observation well was diluted with deionized water (DI) while maintaining pumping in well GMP-2. After emplacement, the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded for both the observation well and the pumping well. Cross-hole flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with fluid flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

To estimate the hydraulic connection between pumping well GMP-2 and observation well GLA-7, pumping in GMP-2 was performed and contemporaneously the flow was evaluated in well GLA-7. Pumping in well GMP-2 was initiated on January 18 1997, at 1650 hours (T=0.00 minutes, elapsed time of testing), at a flow rate of about 11 gpm. A reasonably stable drawdown of about 0.7 feet was observed in GLA-7 prior to initiating DI water emplacement. On January 19, 1997 at 1021 hours, (T=1,051 minutes, elapsed time of testing), dilution of the fluid column was complete. This emplacement was performed after pumping 11 gpm for approximately 16.5 hours. Refer to Figure GLA-7:14 for water level elevation during this testing. During the emplacement procedures, no appreciable DI water was lost to the formation. During the 4.86 hours following dilution, multiple logs were conducted and 20 are presented in Figure GLA-7:15. The first log presented was conducted during emplacement. These traces illustrate significant change throughout the interval of 33 to 94 feet. These dramatic changes in the FEC profiles with respect to time are associated with strong horizontal flow occurring within this interval.

A tessellated chromographic summary of all downward FEC traces is presented in Figure GLA-7:16. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 450 µS/cm.

The data suggest that horizontal flow was occurring at numerous zones over the interval from 34 to 94 feet. To discretize the specific intervals for horizontal flow analysis, these data and the results of the production test were evaluated. Based on review of the data the following intervals were selected for horizontal flow analysis: 33-42 feet, 42-48 feet, 48-52 feet, 52-58 feet, 58-62 feet, 62-69 feet, 69-72 feet, 72-76 feet, 76-79 feet, 79-88 feet, and 88-94 feet. Experimental algorithms applied to this data suggest that the fluid velocity in the wellbore for these intervals ranged from 0.60 to 1.05 ft/day. Correcting for convergence of flow at the wellbore, these velocities equate to a range in specific discharge of groundwater in the aquifer of 0.24 to 0.42 ft/day. Please refer to Figures GLA-7:17 through GLA-7:27, and Table GLA-7:1 for the estimated horizontal velocity and specific discharge calculated for each interval. Refer to Appendix C for a complete discussion of the methodology used to calculate the values.

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1.5 Summary of Cross-Hole Flow Evaluation: Wells GLA-7 and GMP-2

Review and comparison of Figures GLA-7:3 and GLA-7:16 clearly illustrate a significant change in flow characteristics between the two pressure conditions. Comparison of the flow evaluation between the stable and stressed (i.e. pumping) conditions suggests that all the intervals demonstrated some change in flow properties during testing. These data suggest that the four intervals from 72 to 94 feet displayed the greatest change in horizontal velocity. These intervals did not display observable horizontal flow in the stable wellfield condition so a percent change could not be calculated. However, the intervals at 62 to 69 and 69 to 72 feet displayed a 102 and 146, percent increase, respectively. As such, the data suggest that the intervals from 62 to 94 feet have a significant hydraulic connection to pumping well GMP-2.

1.6 Sensitivity to Inflows

The HpL™ technique is based on measuring induced electrical changes in a dynamic (i.e. flowing conditions) wellbore fluid column. As such, the sensitivity with which "downstream" inflow points (those closest to the pump, where the flow rate is the greatest) can be identified as directly proportional to the flow rate and FEC of both the upward flowing wellbore fluids and the formation inflow location. Given the conditions observed in the well during our testing, the HpL™ technique would have detected any inflow greater than 0.07 gpm with FEC of 900 µS/cm, during the testing described in this report.

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FIGURE GLA-7:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

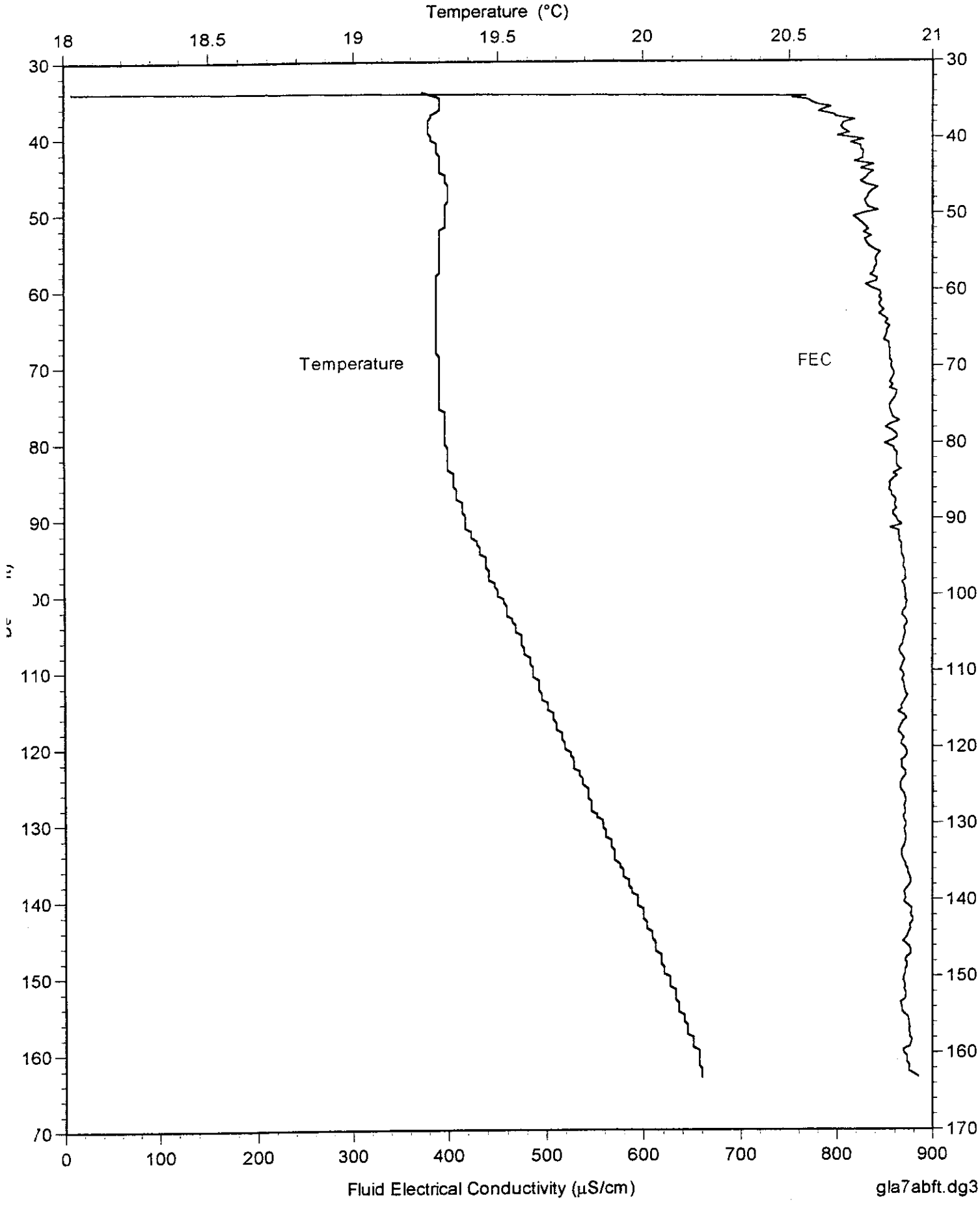


FIGURE GLA-7:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION, STABLE WELLFIELD CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

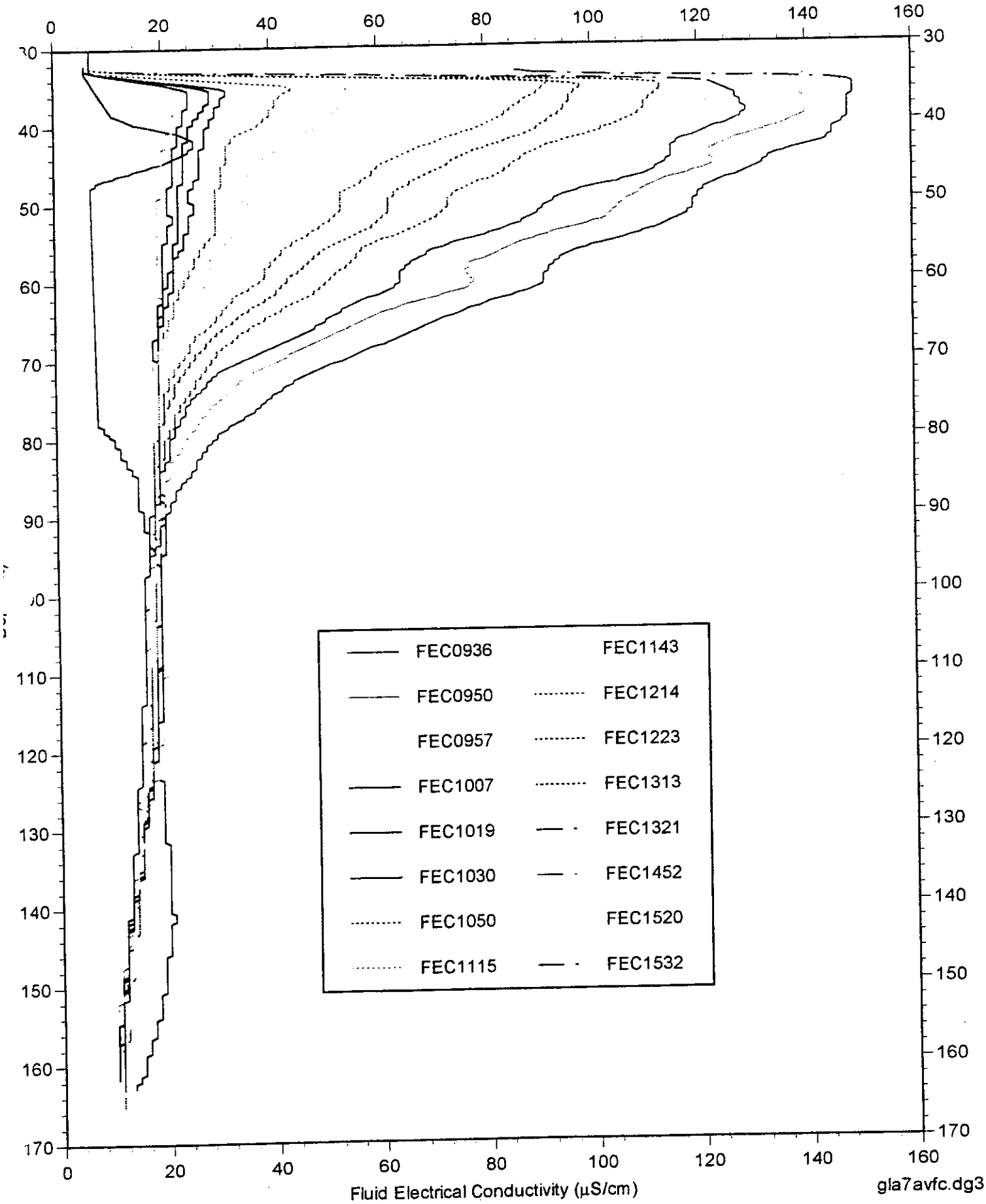
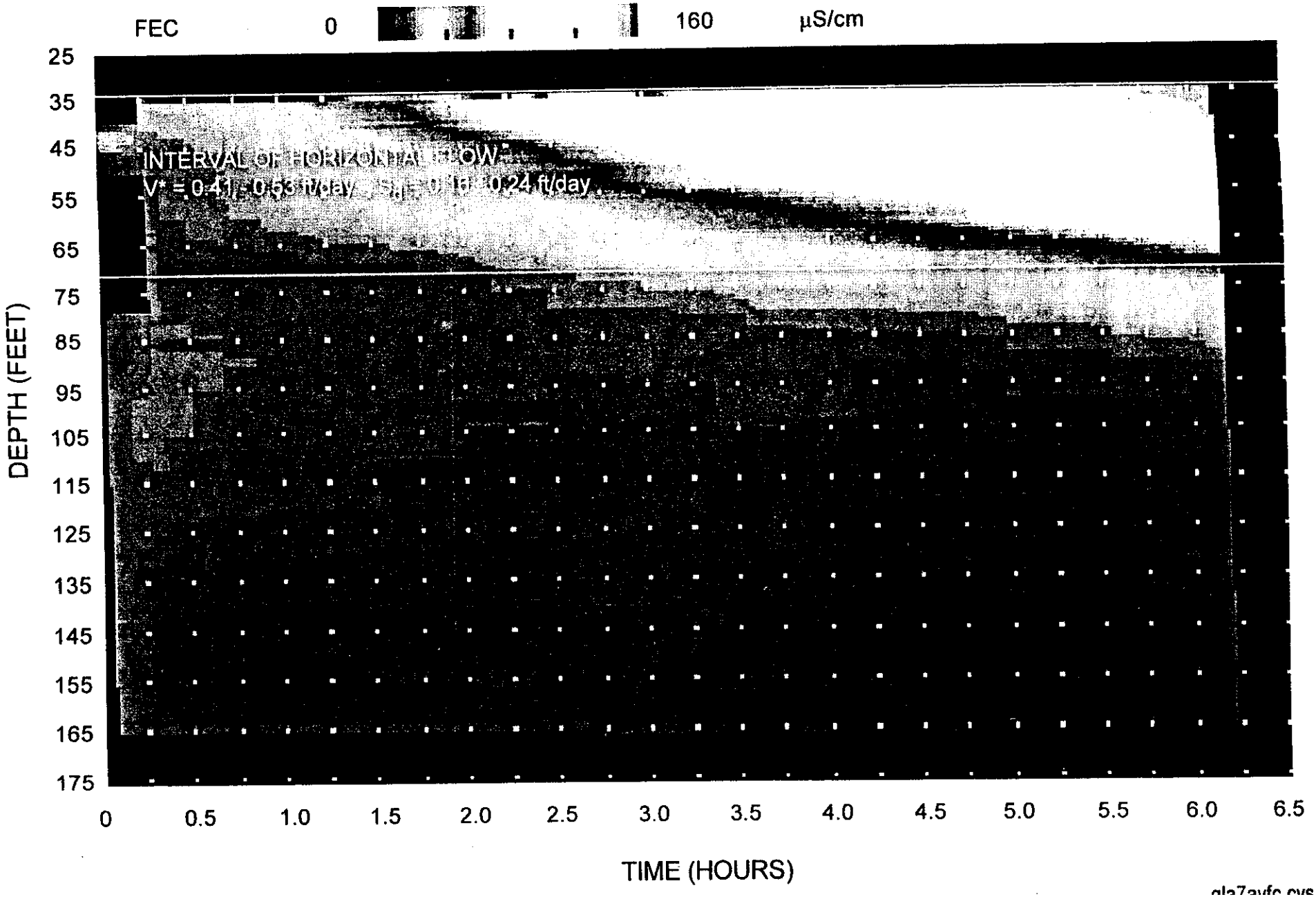
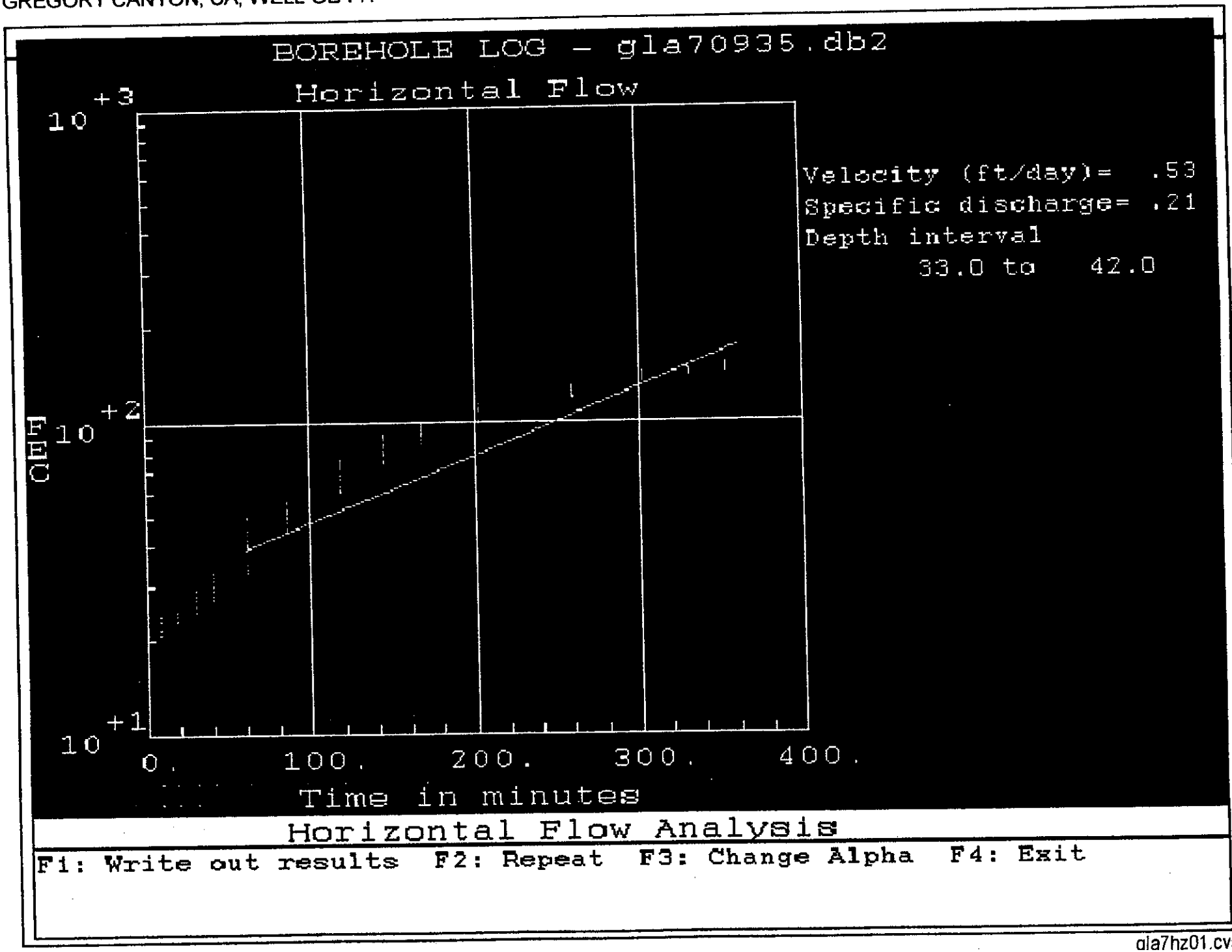


FIGURE GLA-7:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.



FIGU GLA-7:4. HORIZONTAL FLOW ANALYSIS DURING A ENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.



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FIGU GLA-7:5. HORIZONTAL FLOW ANALYSIS DURING A IENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

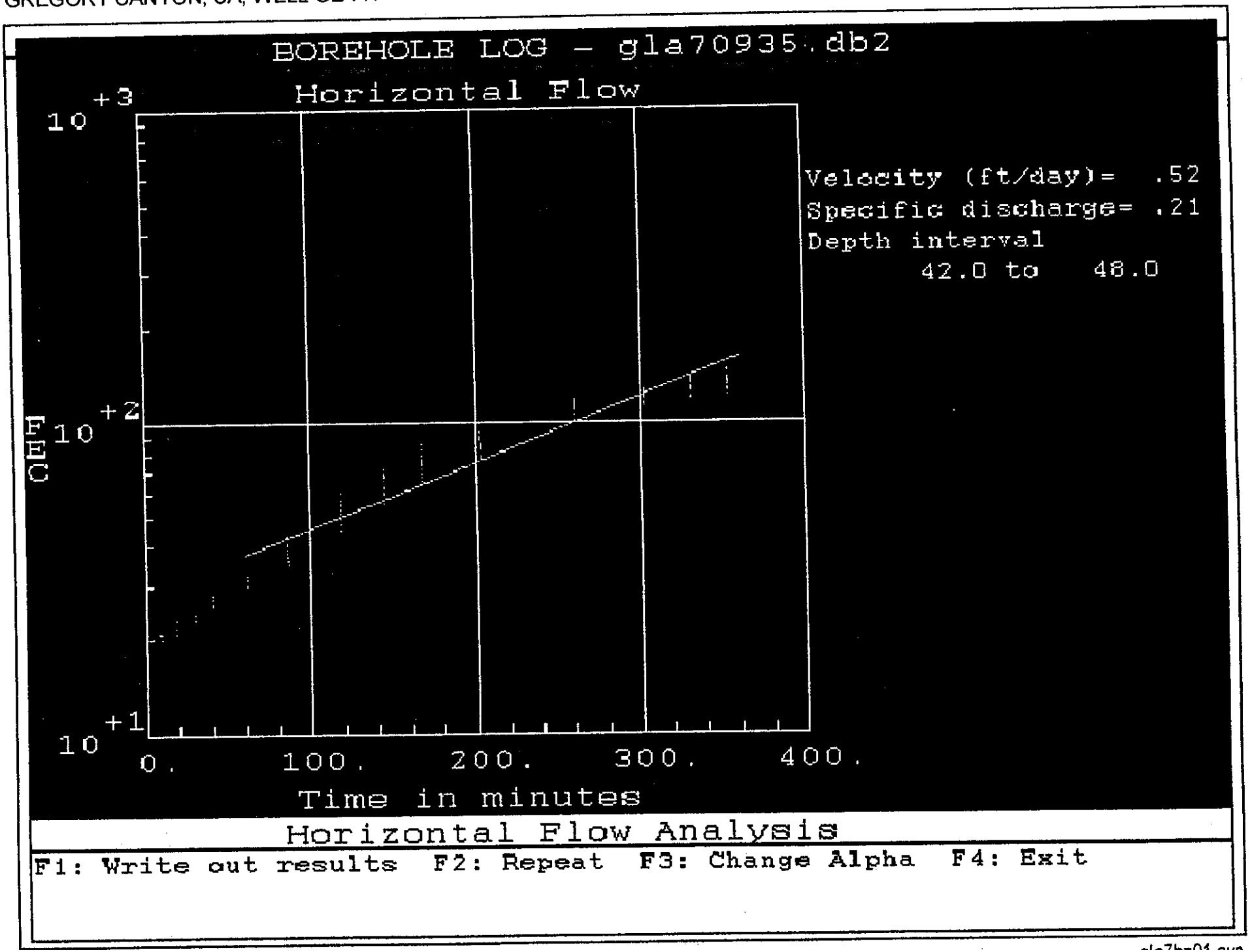
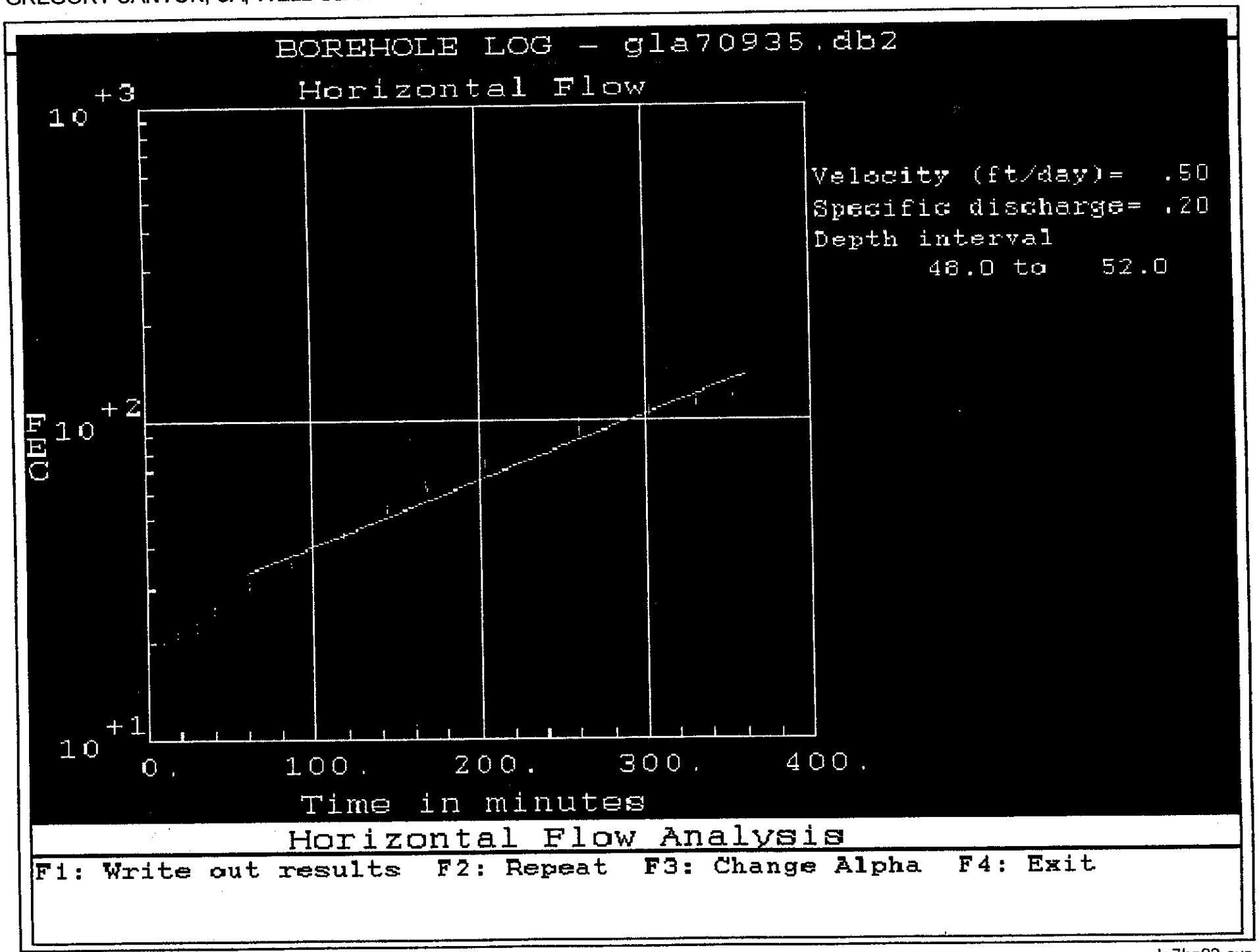


FIGURE GLA-7:6. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELL GLA-7.



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FIGU[illegible]GLA-7:7. HORIZONTAL FLOW ANALYSIS DURING A[illegible]ENT CONDITIONS, [illegible]
GREGORY CANYON, CA; WELL GLA-7.

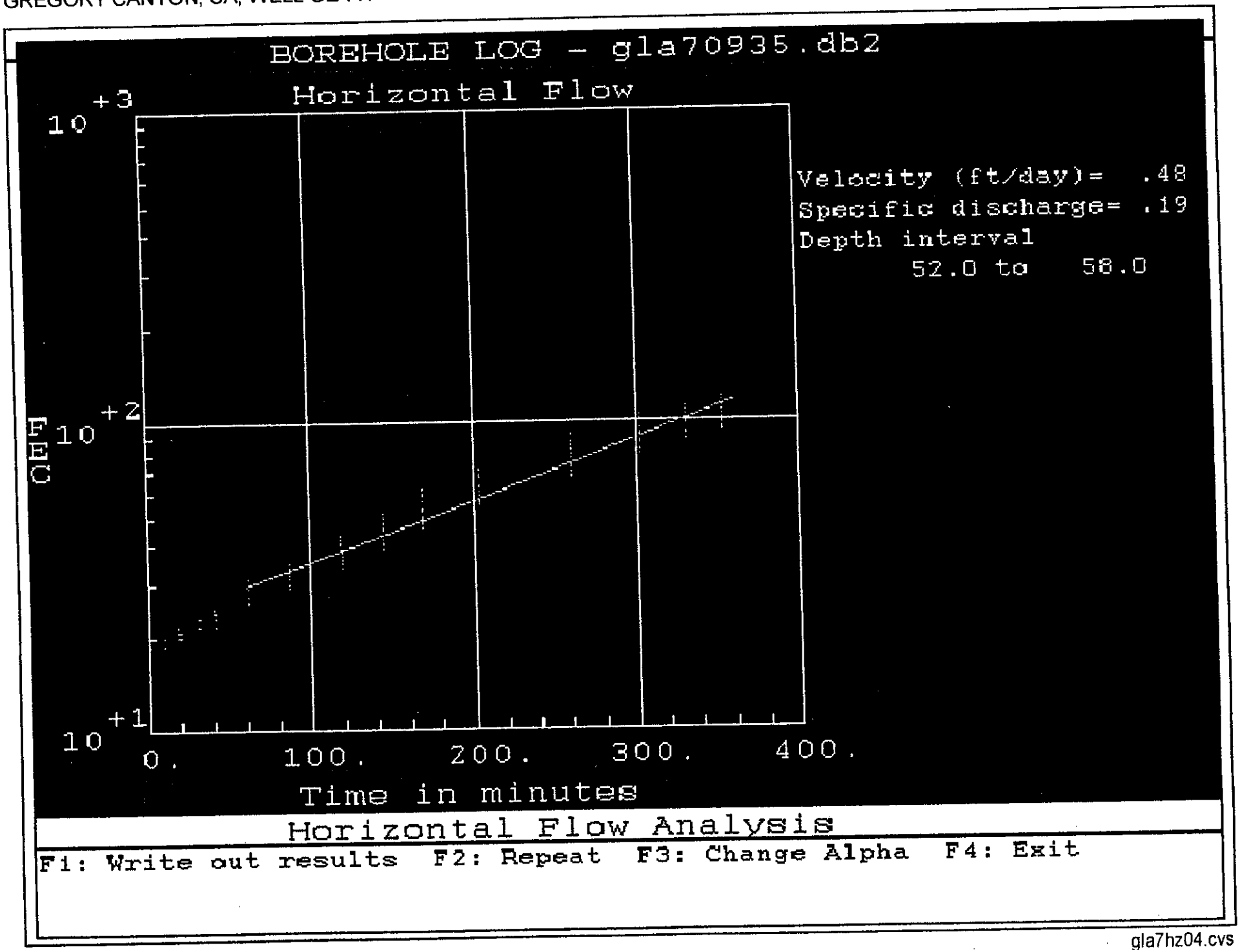

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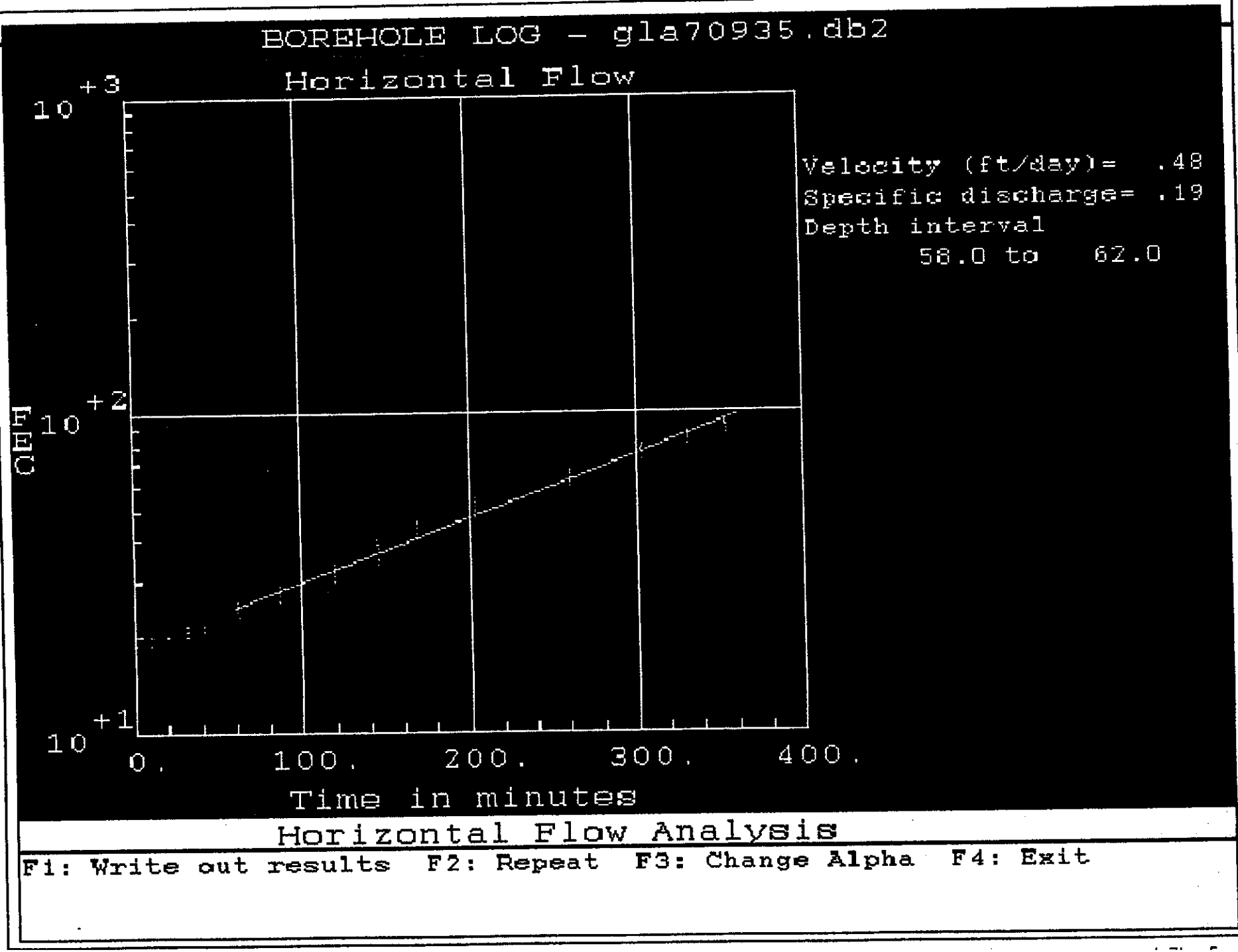
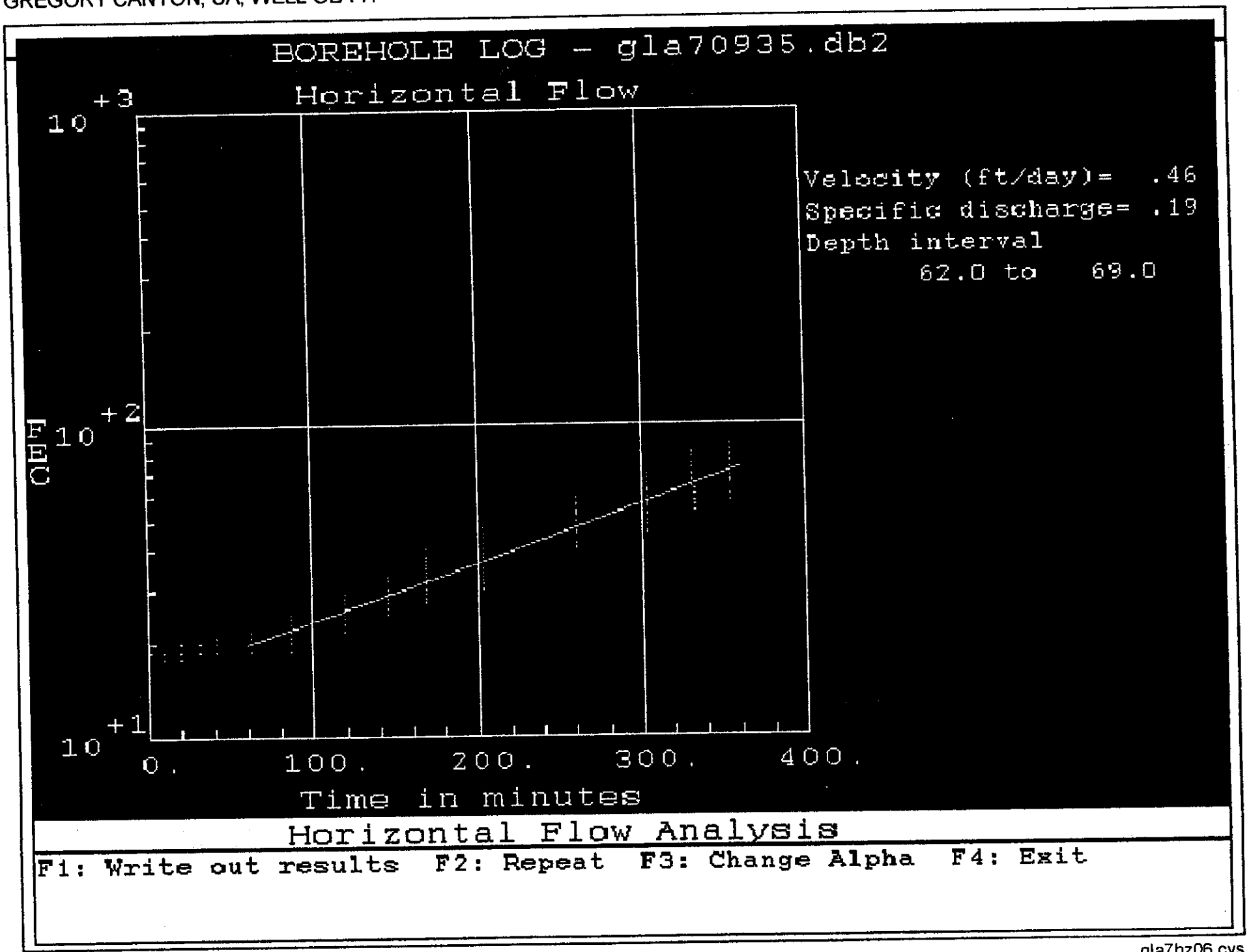
FIGURE GLA-7:8. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.



FIGU GLA-7:9. HORIZONTAL FLOW ANALYSIS DURING A ENT CONDITIONS, GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELL GLA-7.



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FIGU GLA-7:10. HORIZONTAL FLOW ANALYSIS DURING BIENT CONDITIONS, GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELL GLA-7.

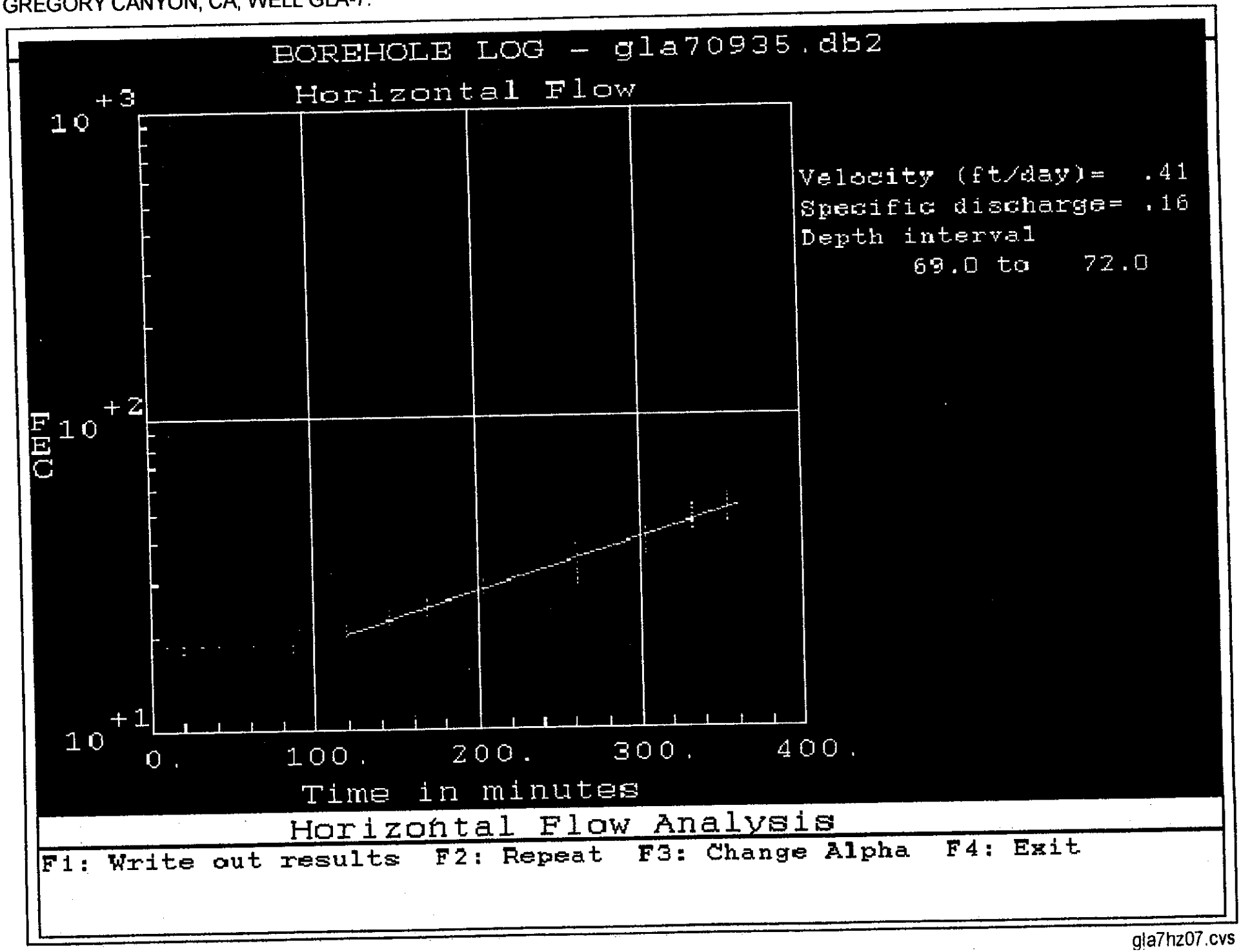

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FIGURE GLA-7:11. PUMP AND DRAWDOWN DATA FOR 5 ... M PRODUCTION TEST; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELL GLA-7.

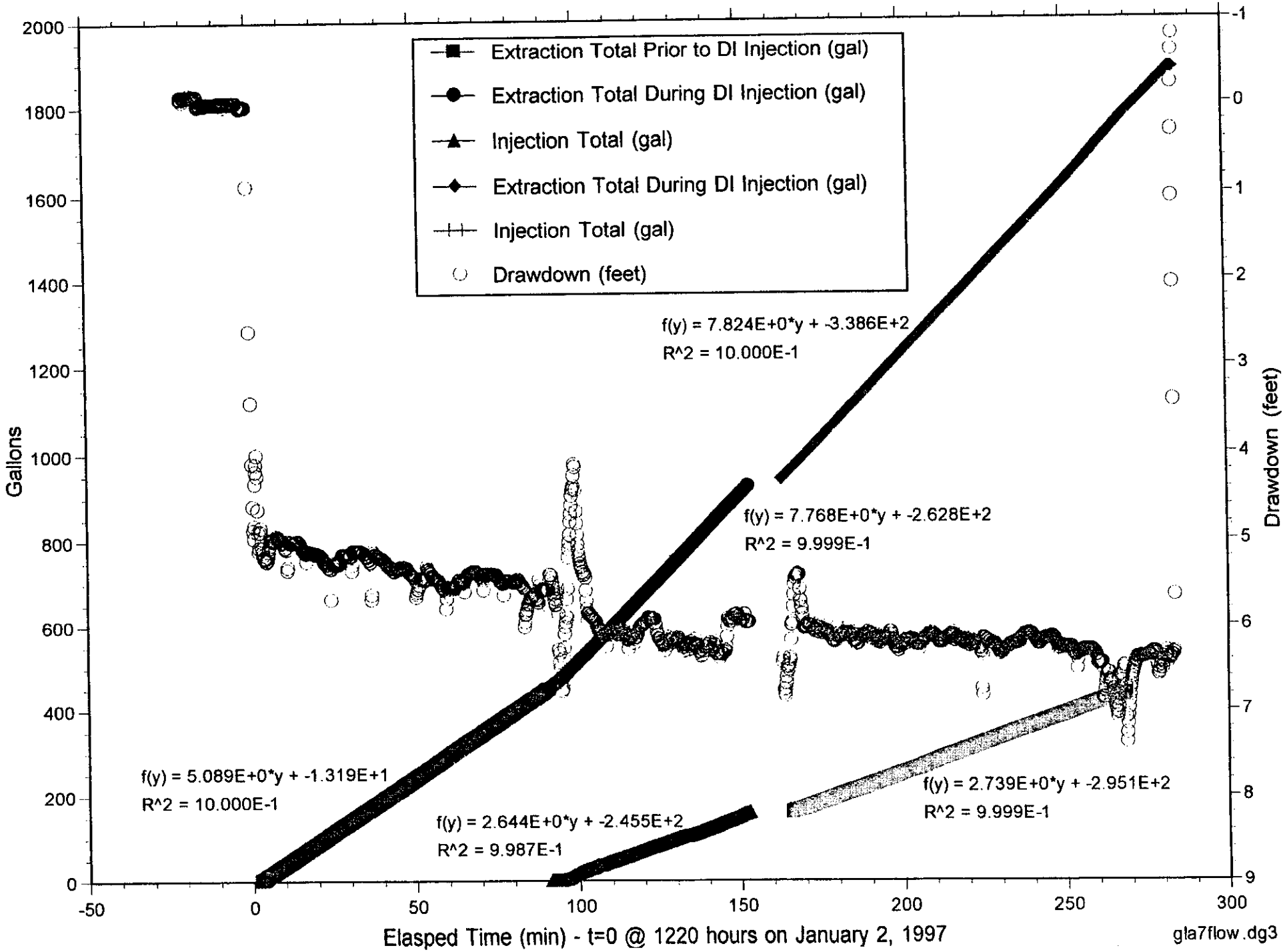


FIGURE GLA-7:12. SUMMARY OF HYDROPHYSICAL LOGS DURING 5 GPM PRODUCTION TEST WITH INTERVAL SPECIFIC FLOW RATES; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

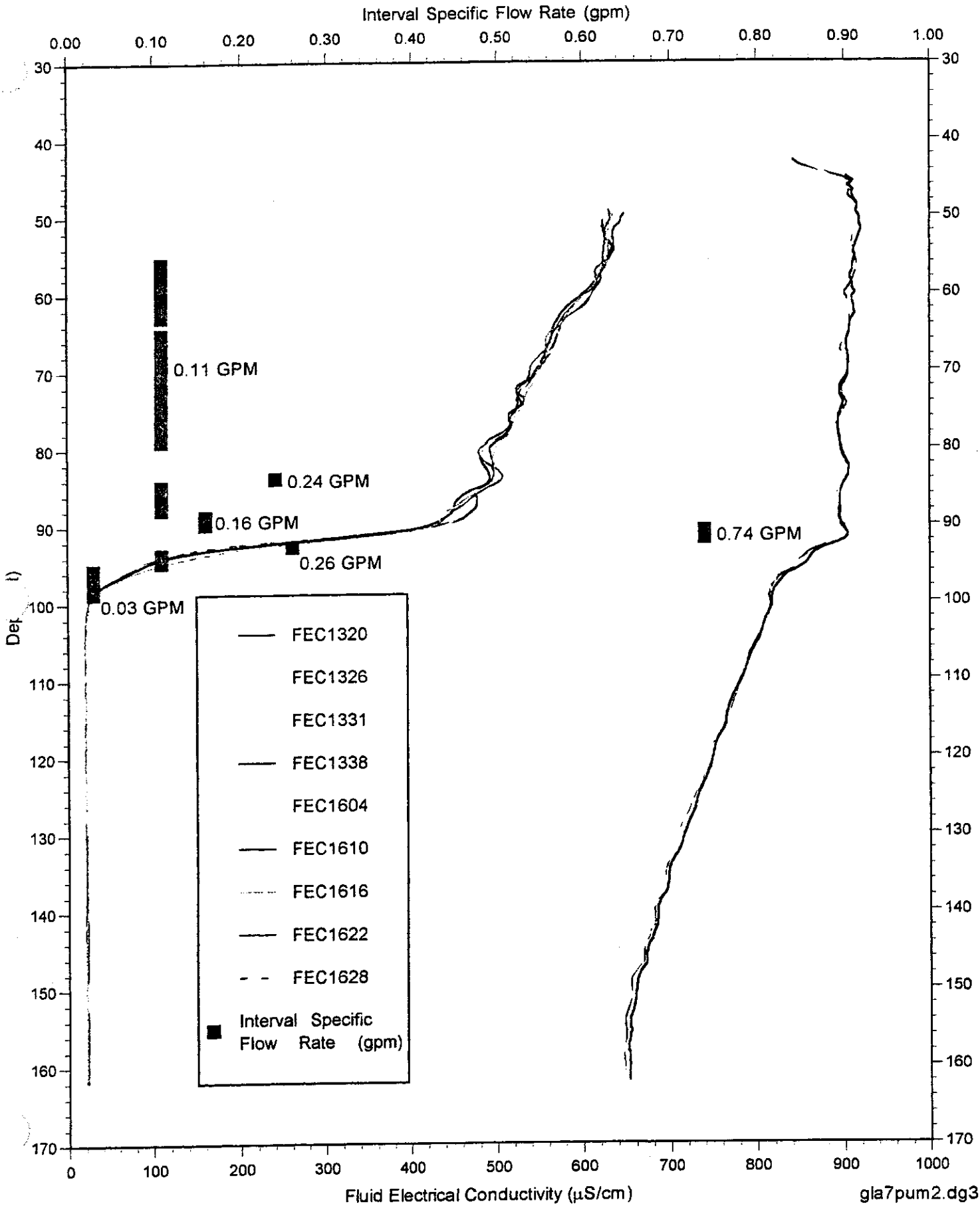
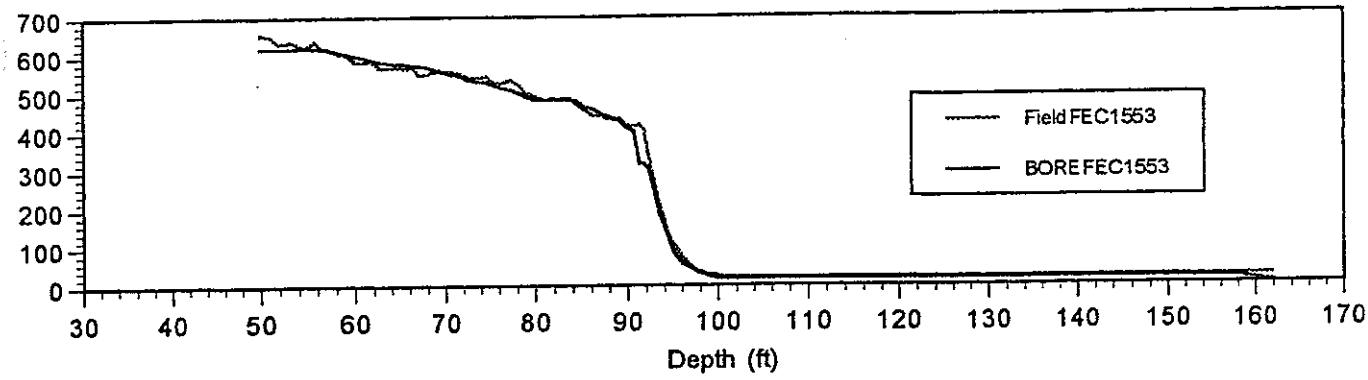
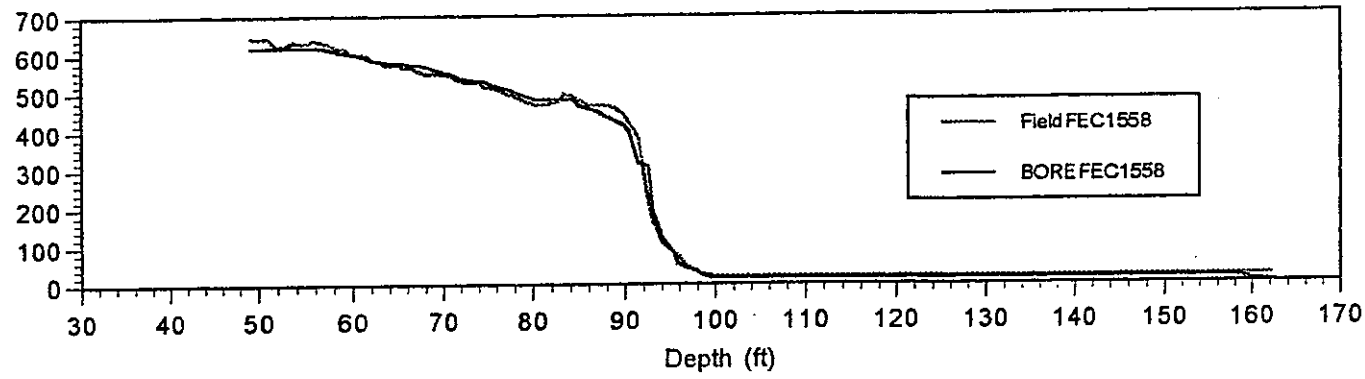
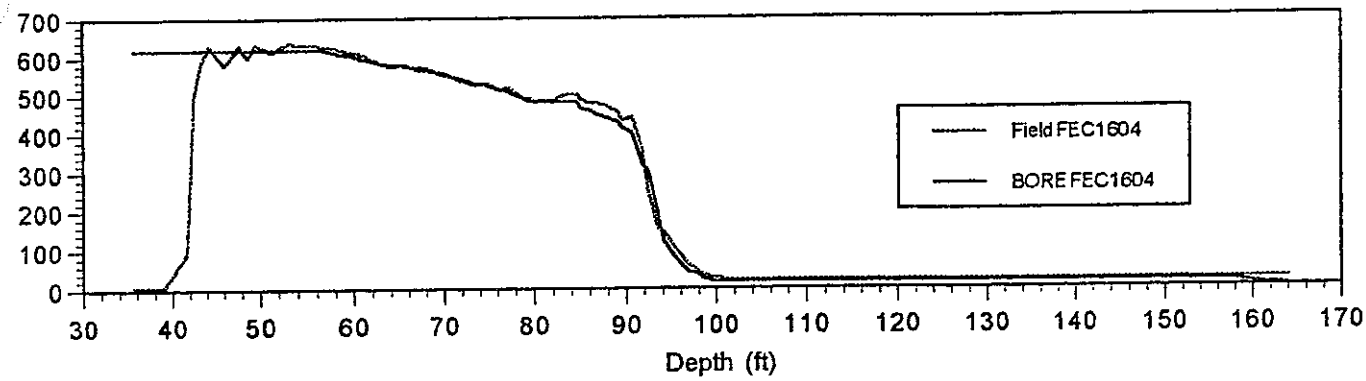


FIGURE GLA-7:13. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR 5 GPM PRODUCTION TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.







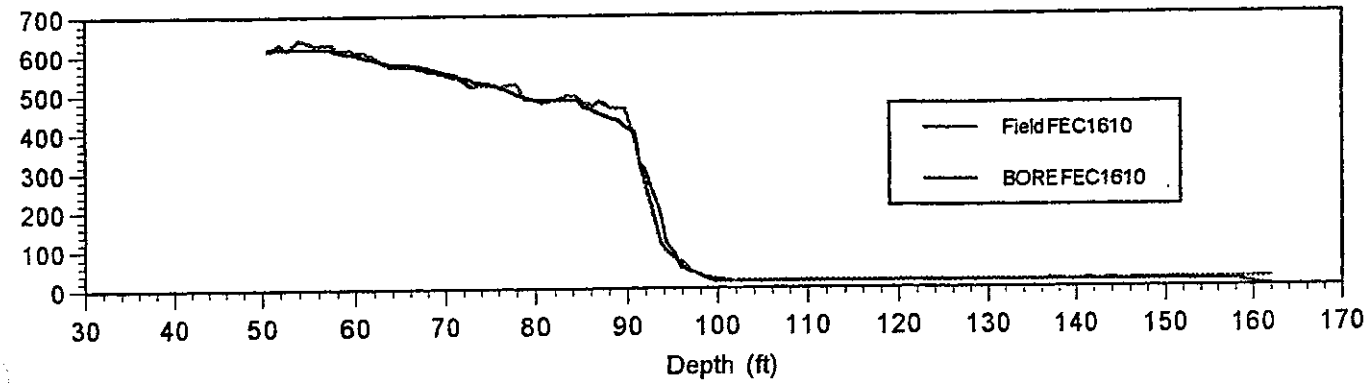


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FIGURE GLA-7:14. PUMP AND DRAWDOWN DATA DURING CROSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.

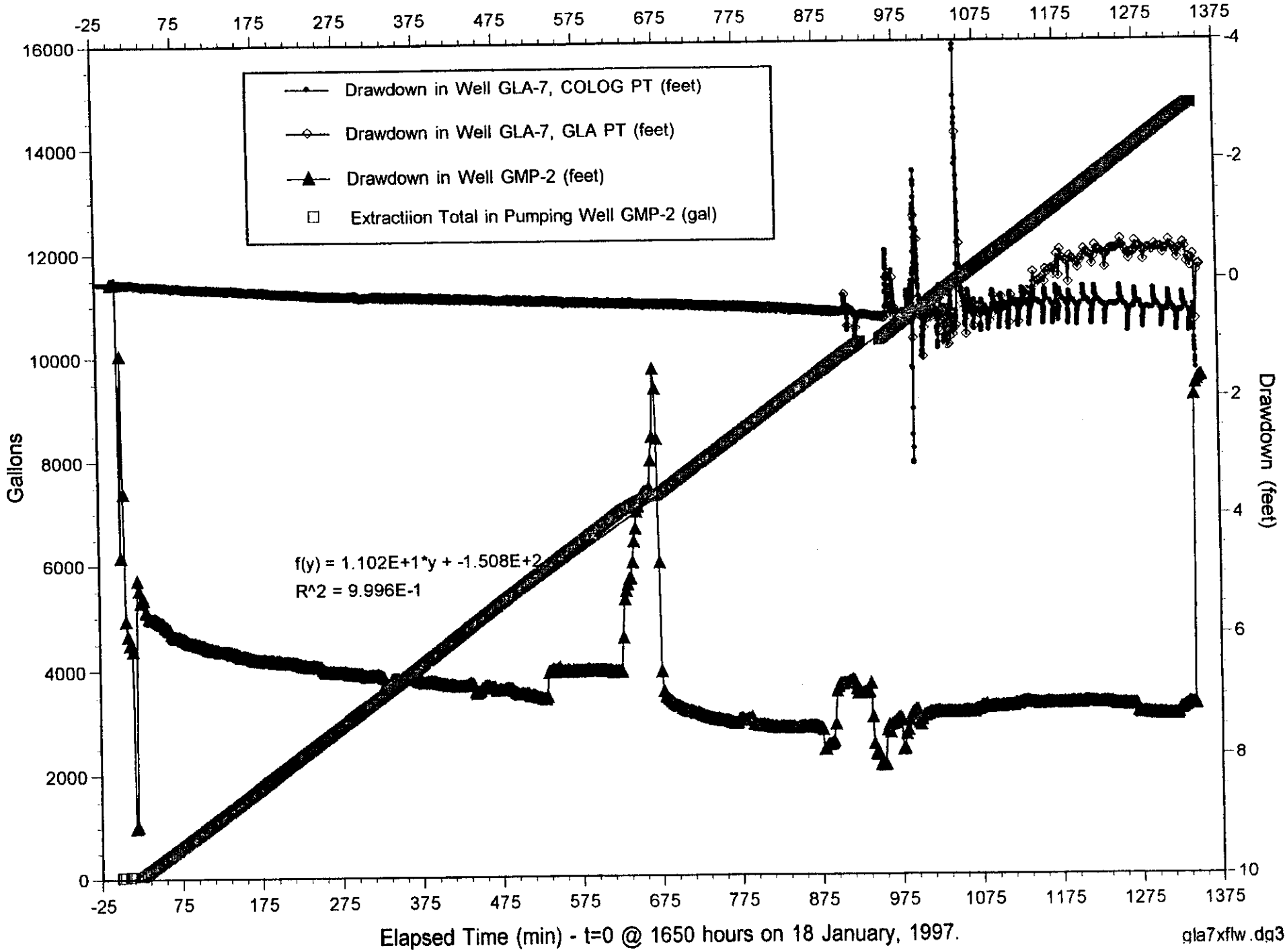

FIGURE GLA-7:15. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION CROSS HOLE TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GMP-2 AND GLA-7.

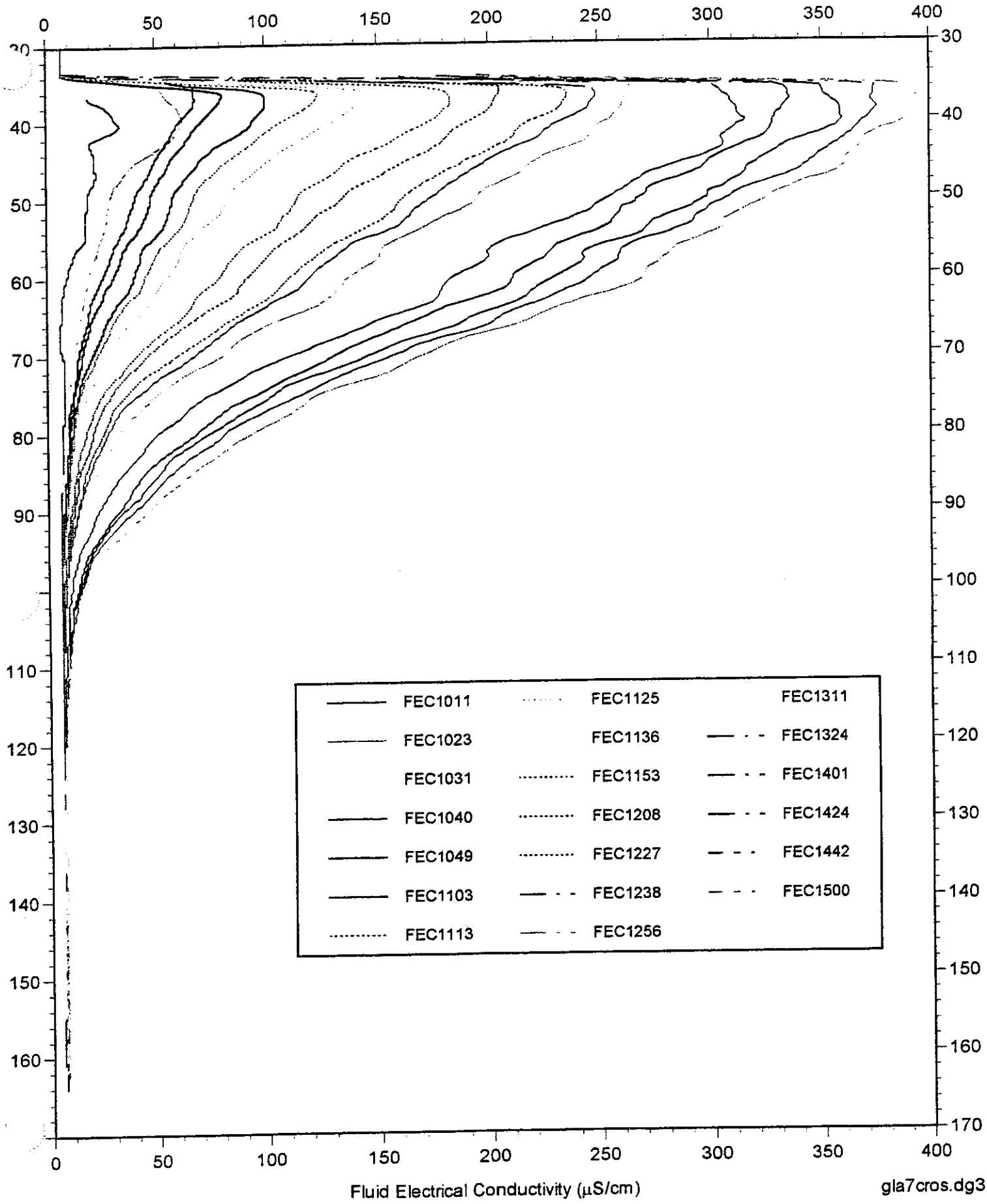

FIGURE GLA-7:16. CHROMOGRAPHIC TESSELATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION CROSS HOLE TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7 AND GMP-2.

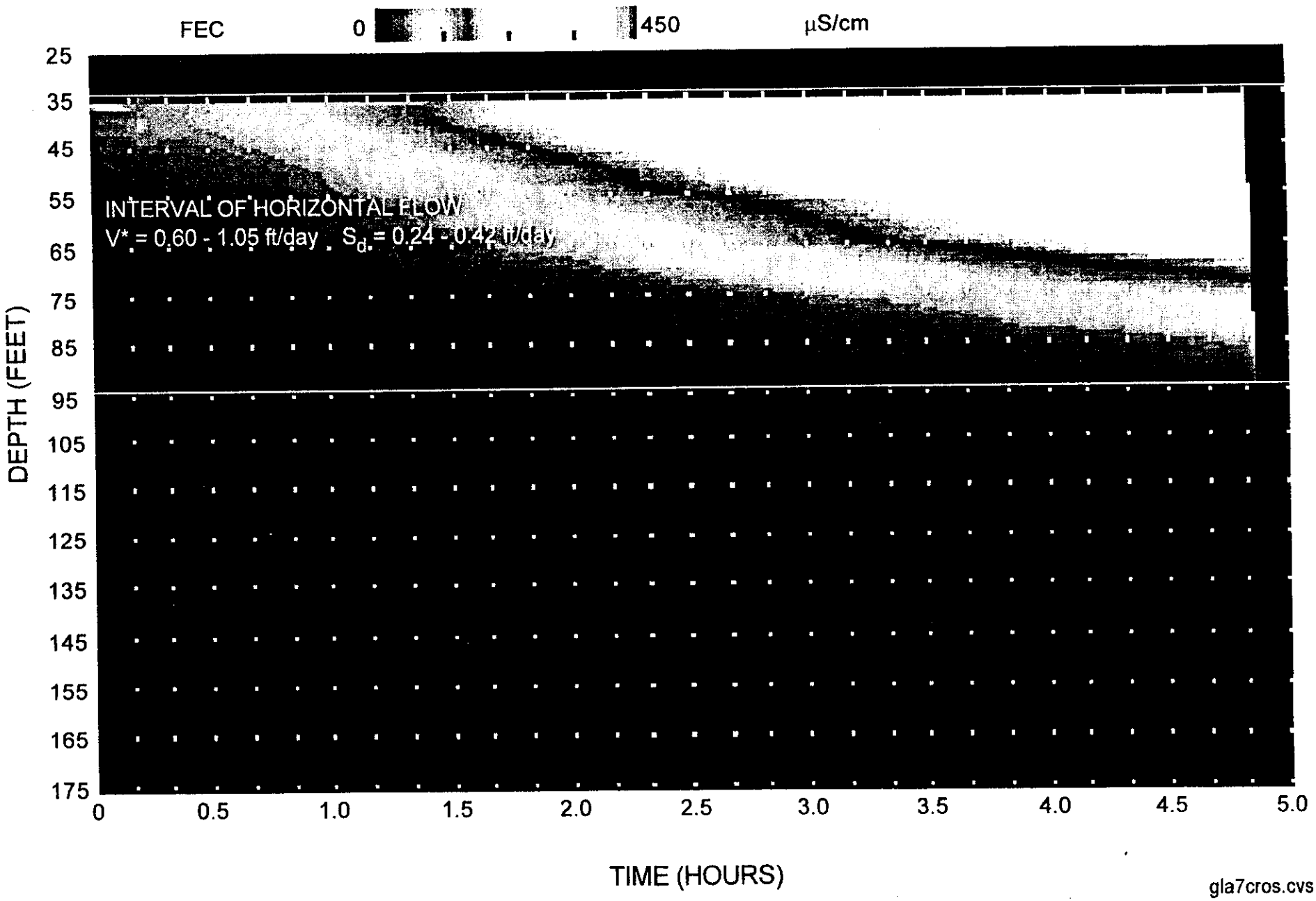

FIGURE GLA-7:17. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.

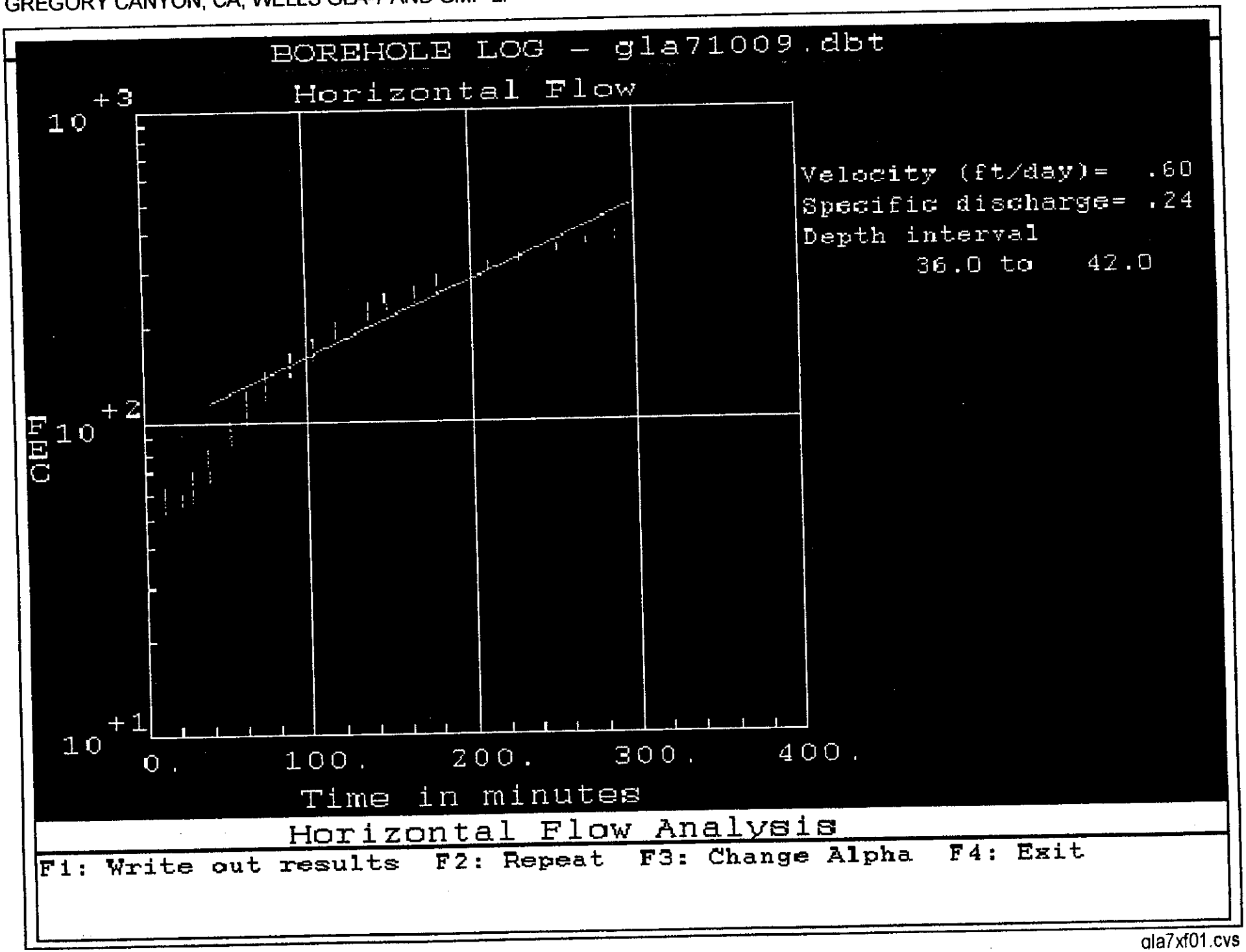

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FIGURE GLA-7:18. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.

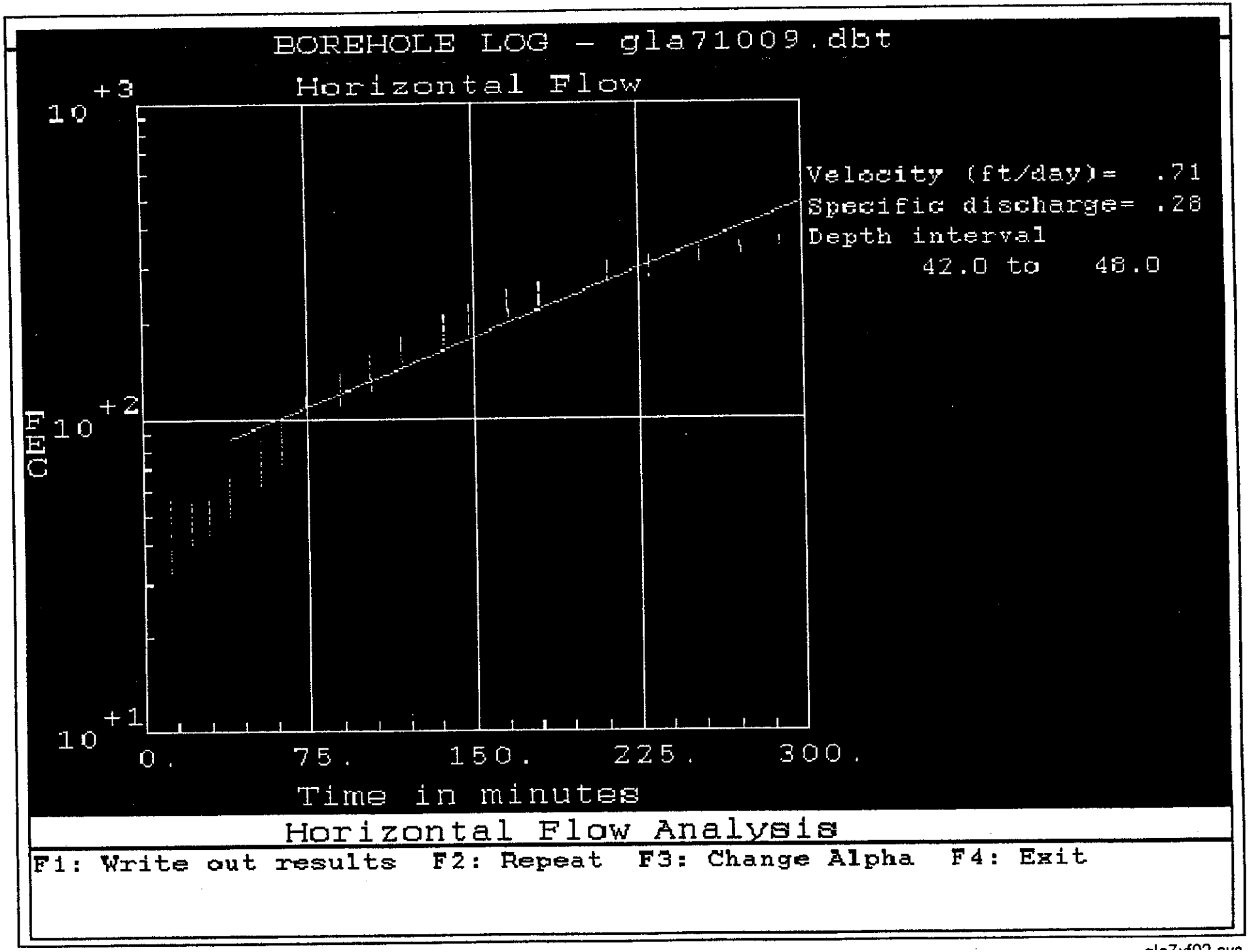
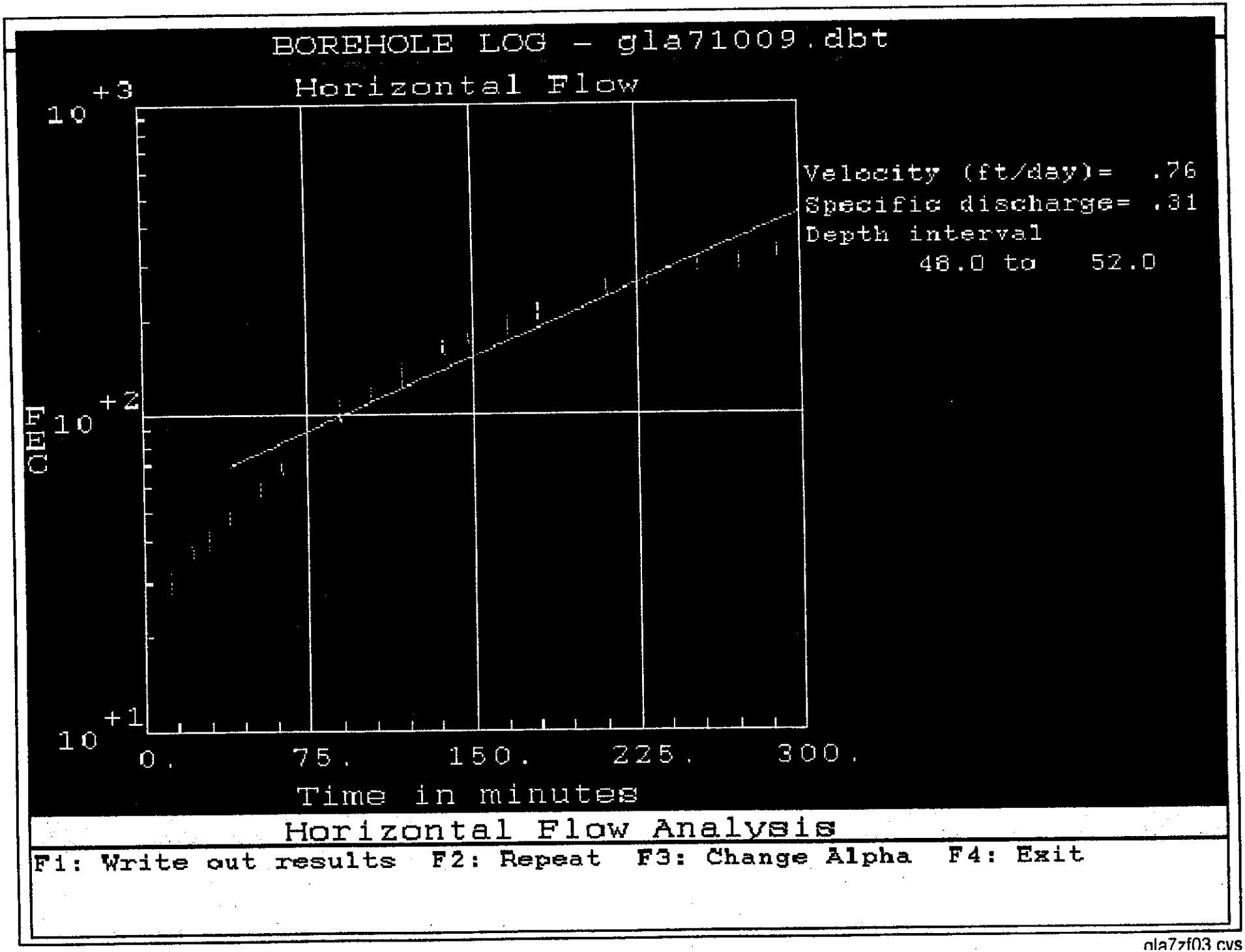
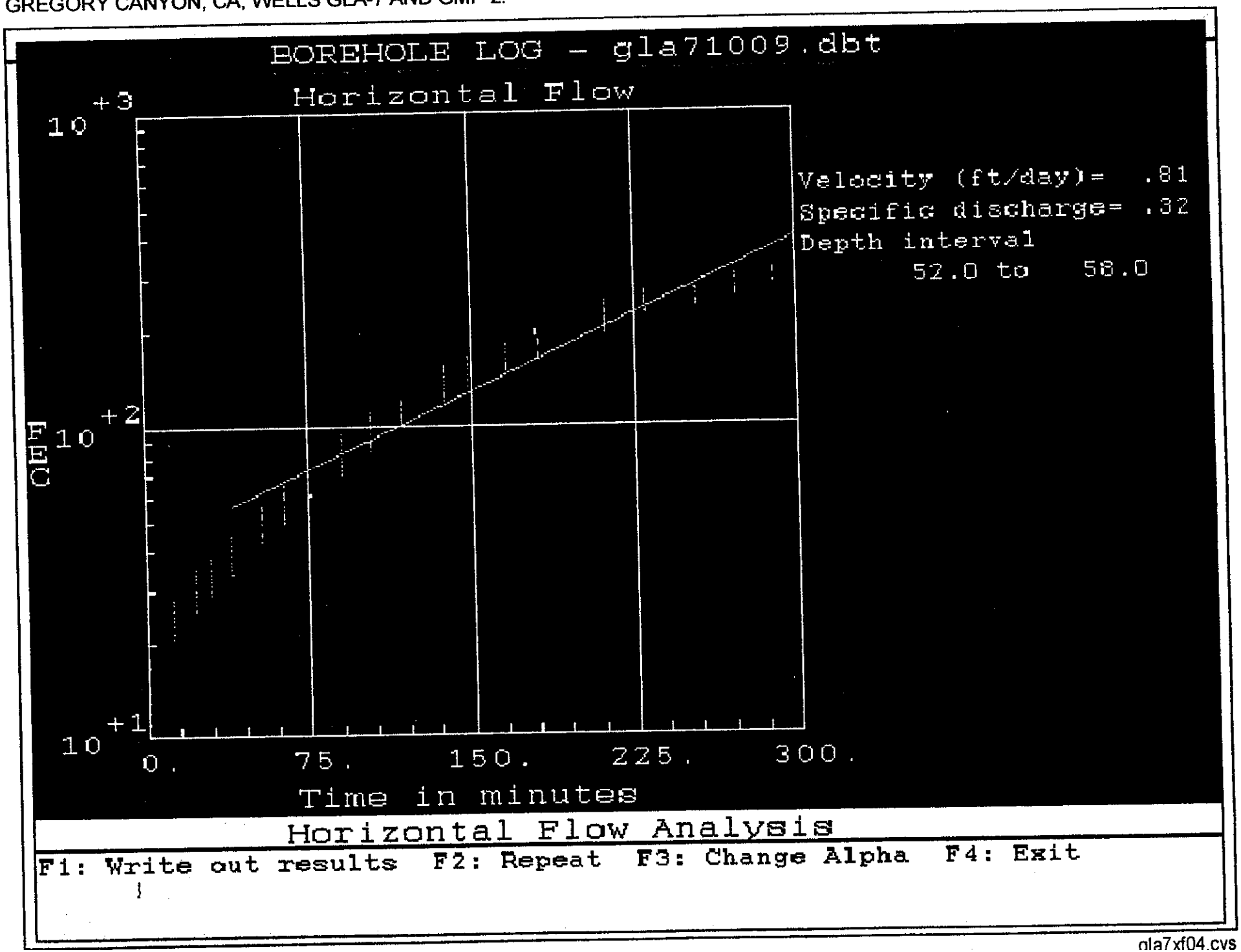


FIGURE GLA-7:19. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING, GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



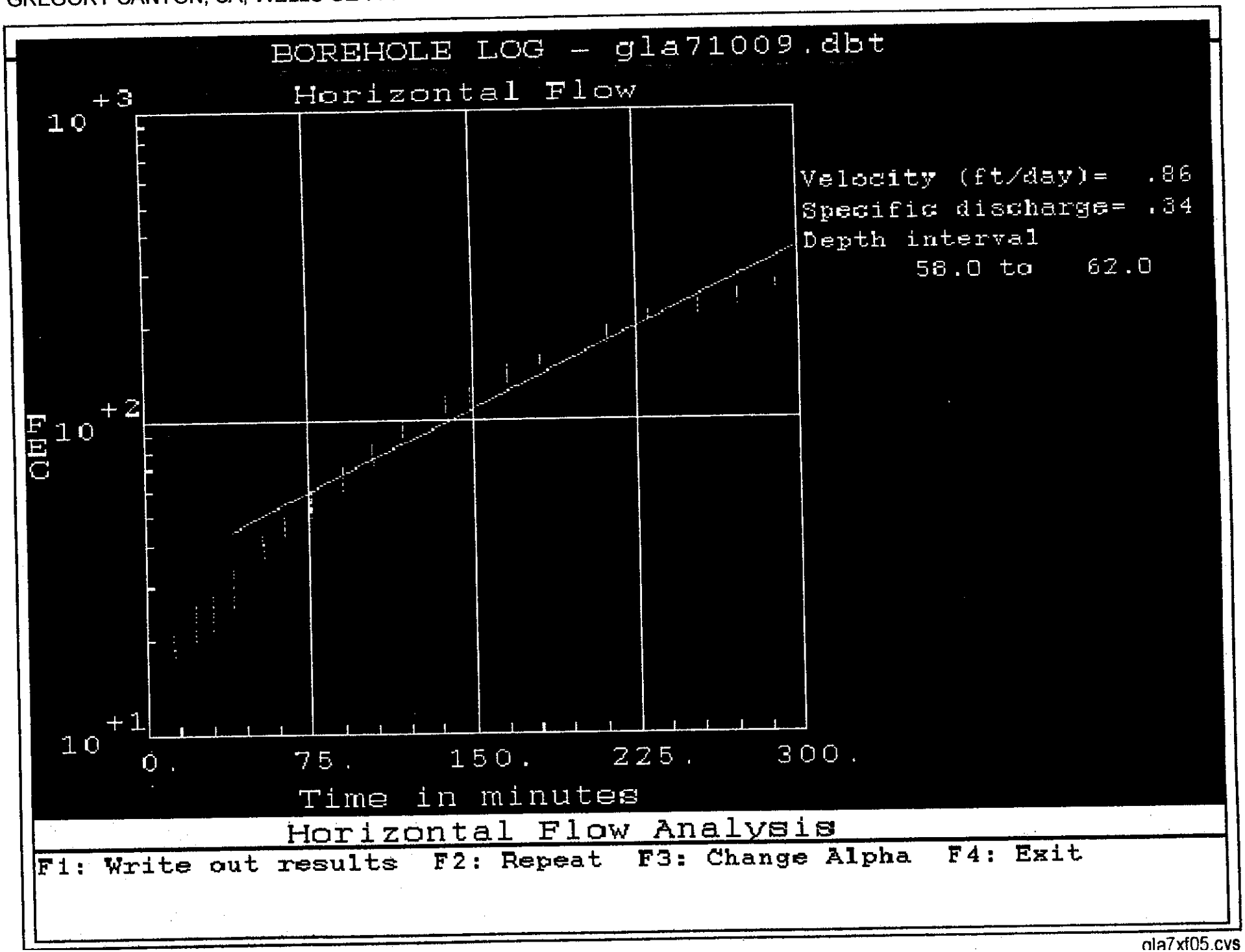
gla7zf03.cvs

FIGU GLA-7:20. HORIZONTAL FLOW ANALYSIS DURING OSS HOLE TESTING; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



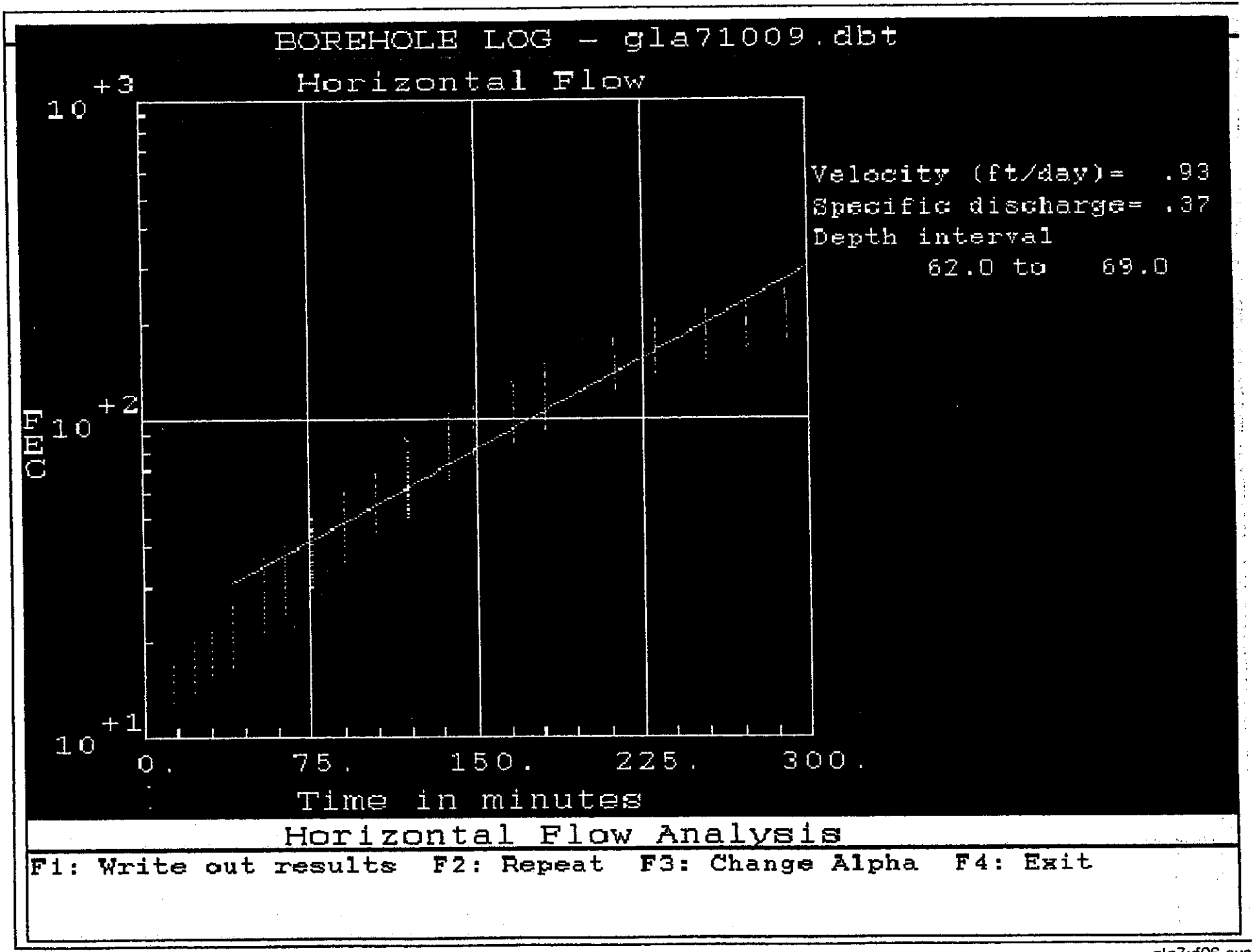
gla7xf04.cvs

FIGURE GLA-7:21. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



gla7xf05.cvs

FIGU.. GLA-7:22. HORIZONTAL FLOW ANALYSIS DURING ..OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



gla7xf06.cvs

FIGU. GLA-7:23. HORIZONTAL FLOW ANALYSIS DURING OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.

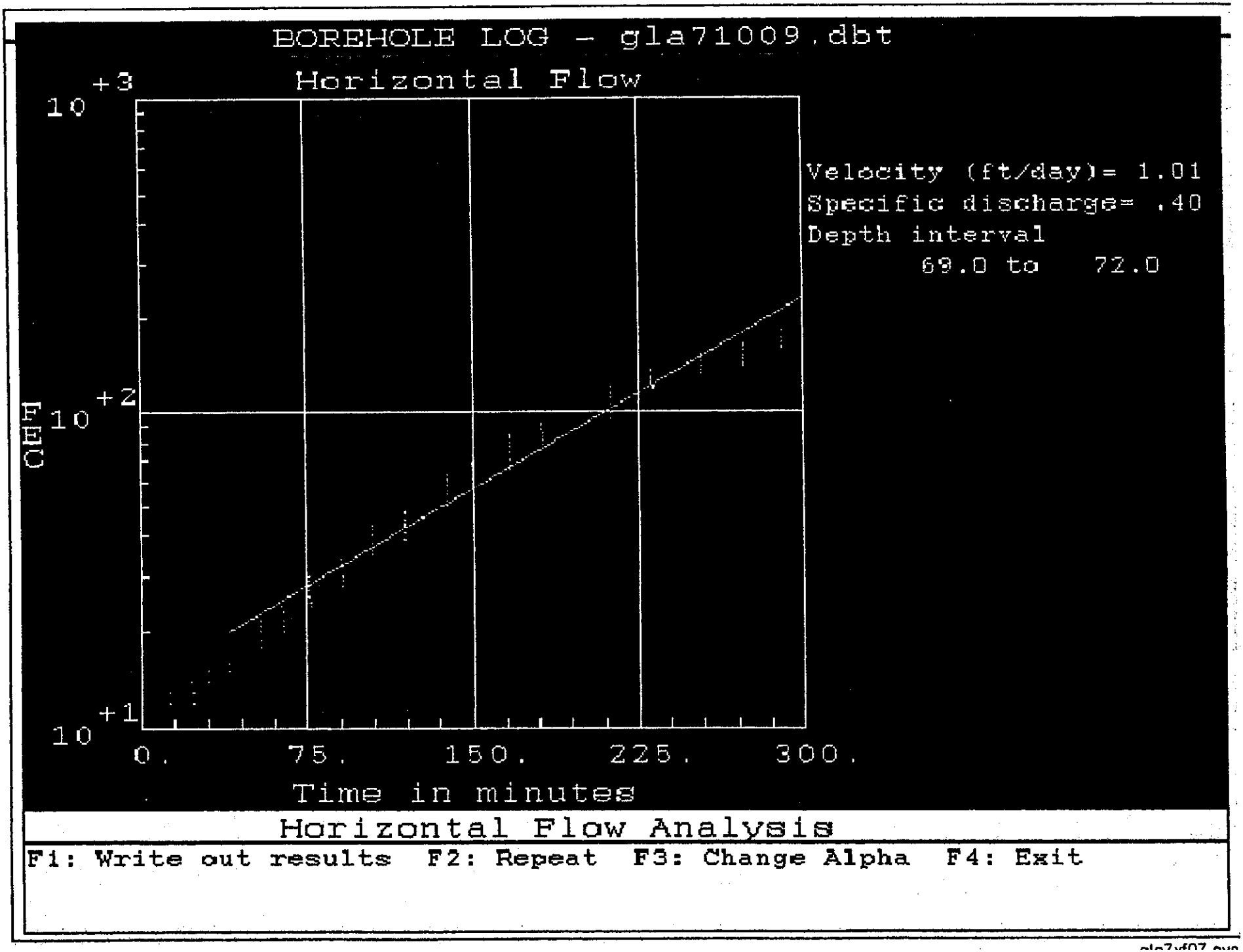
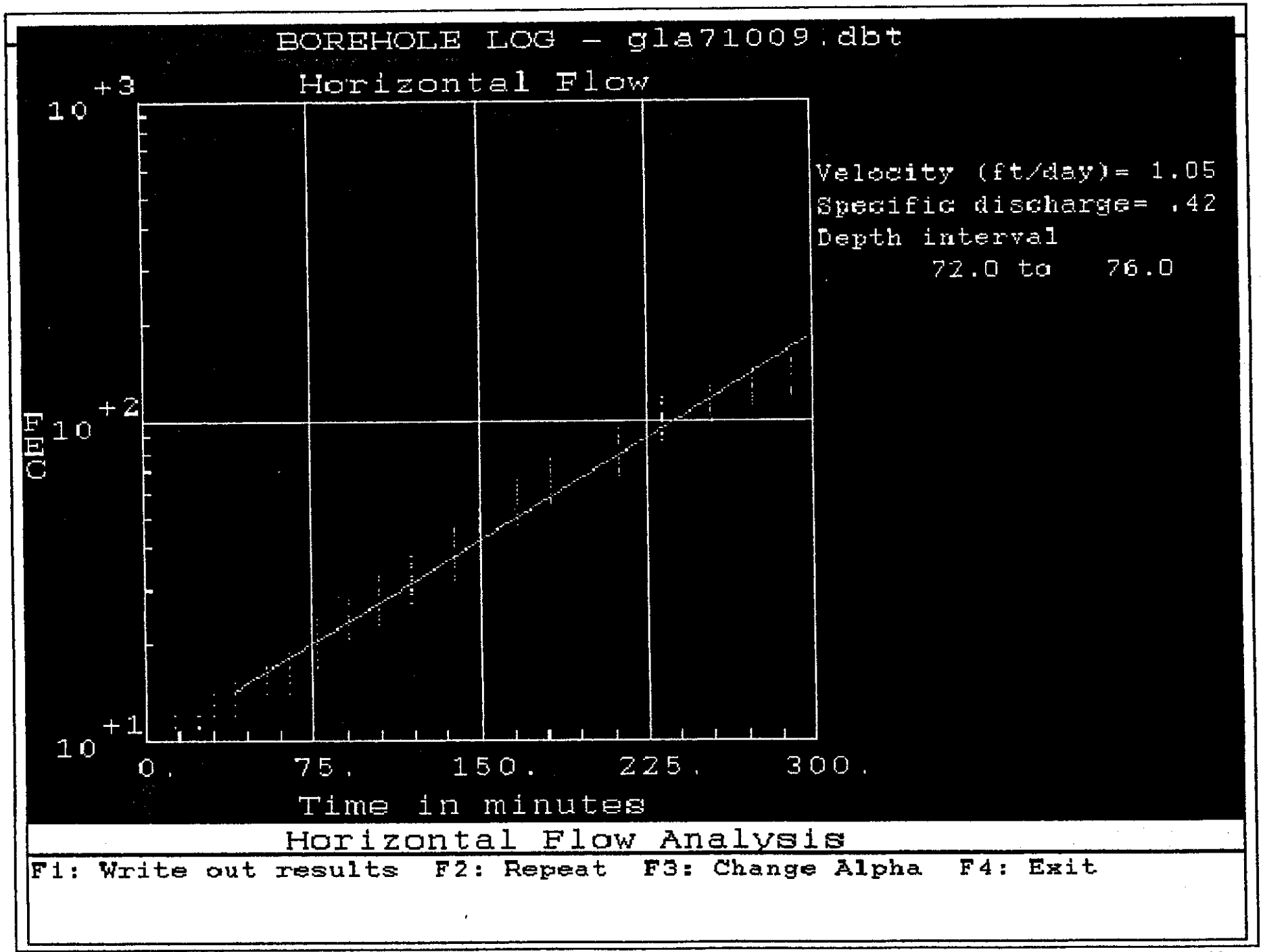


FIGURE GLA-7:24. HORIZONTAL FLOW ANALYSIS DURING C[illegible]SS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



gla7xf08.cvs

FIGU[illegible] GLA-7:25. HORIZONTAL FLOW ANALYSIS DURING [illegible]OSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.

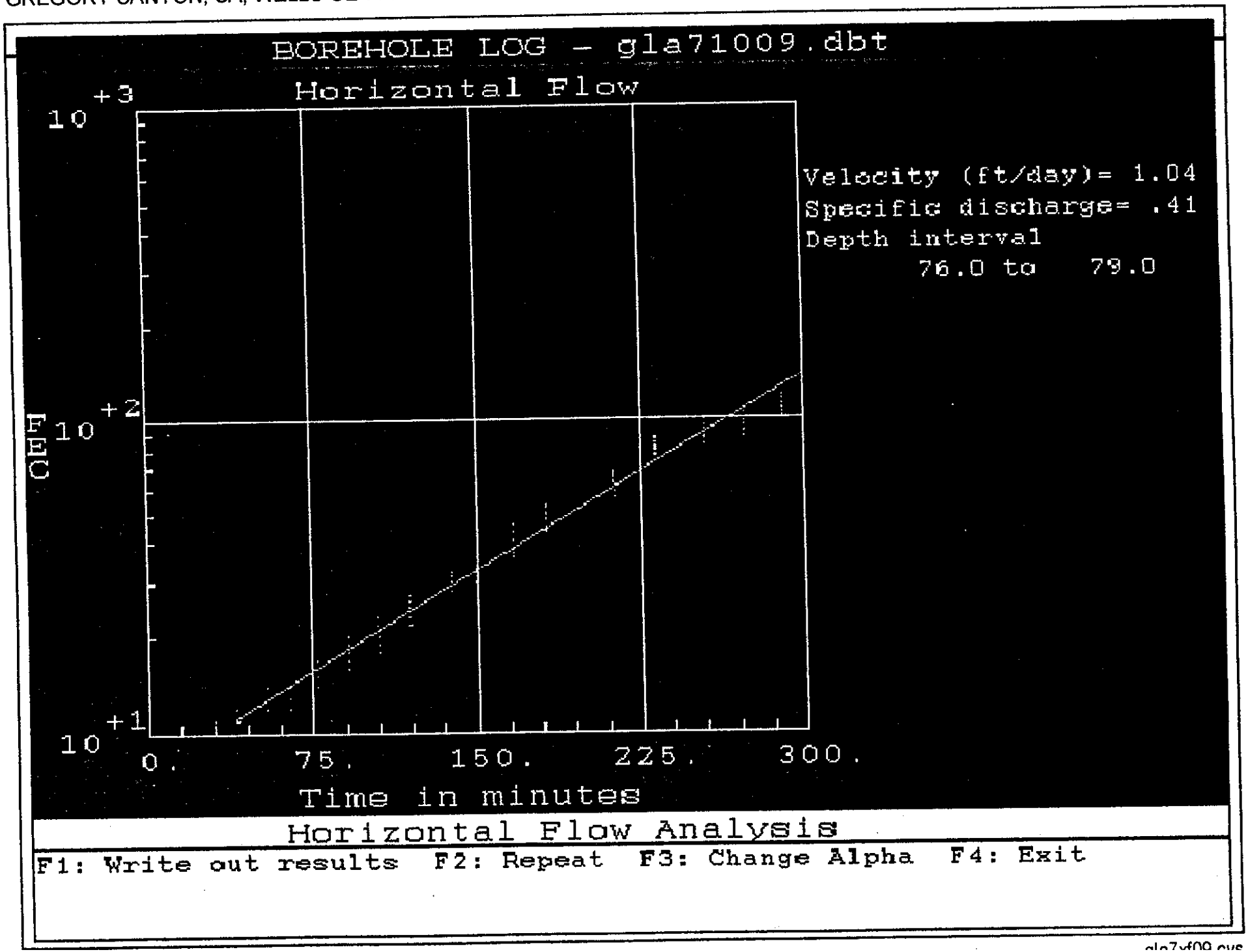
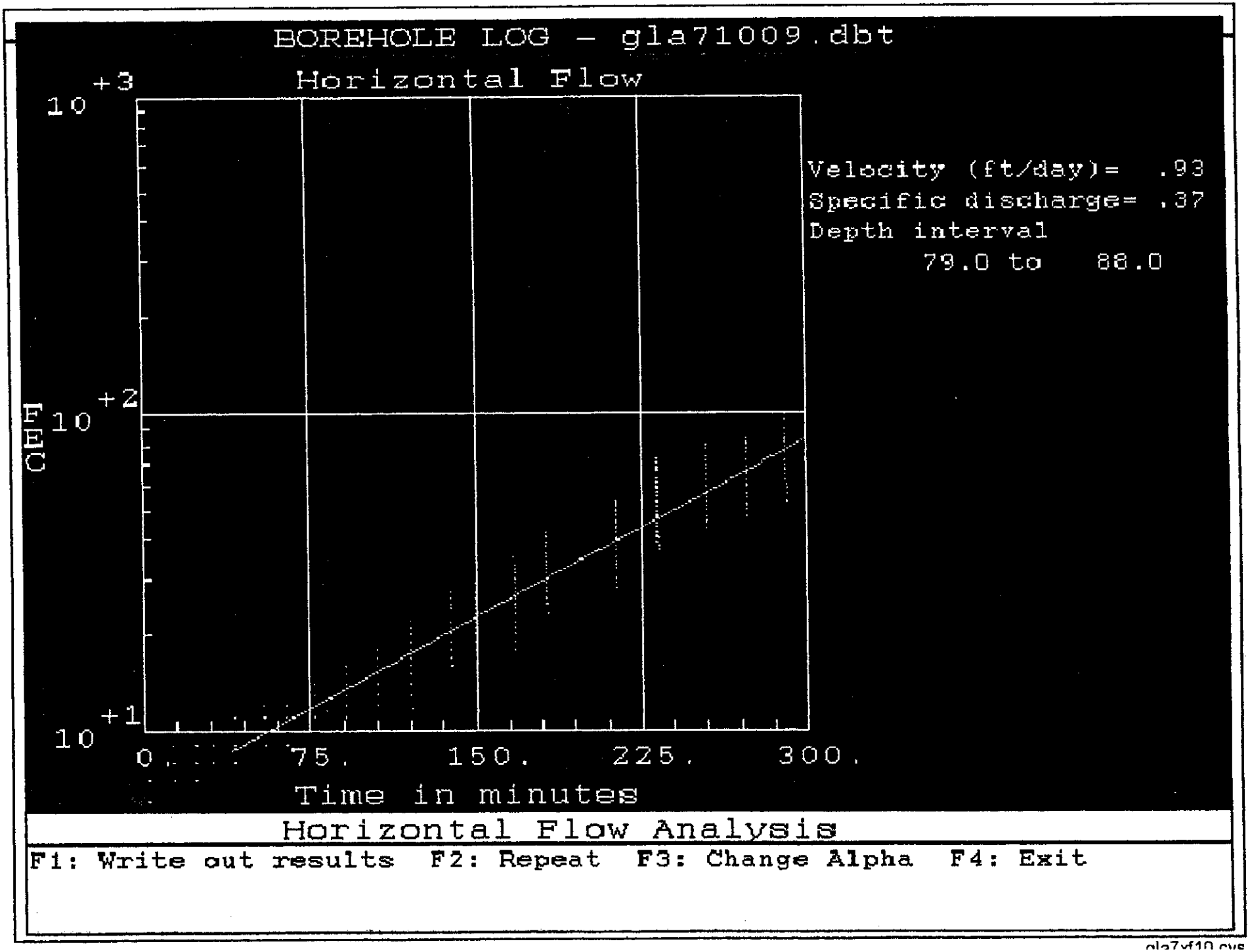
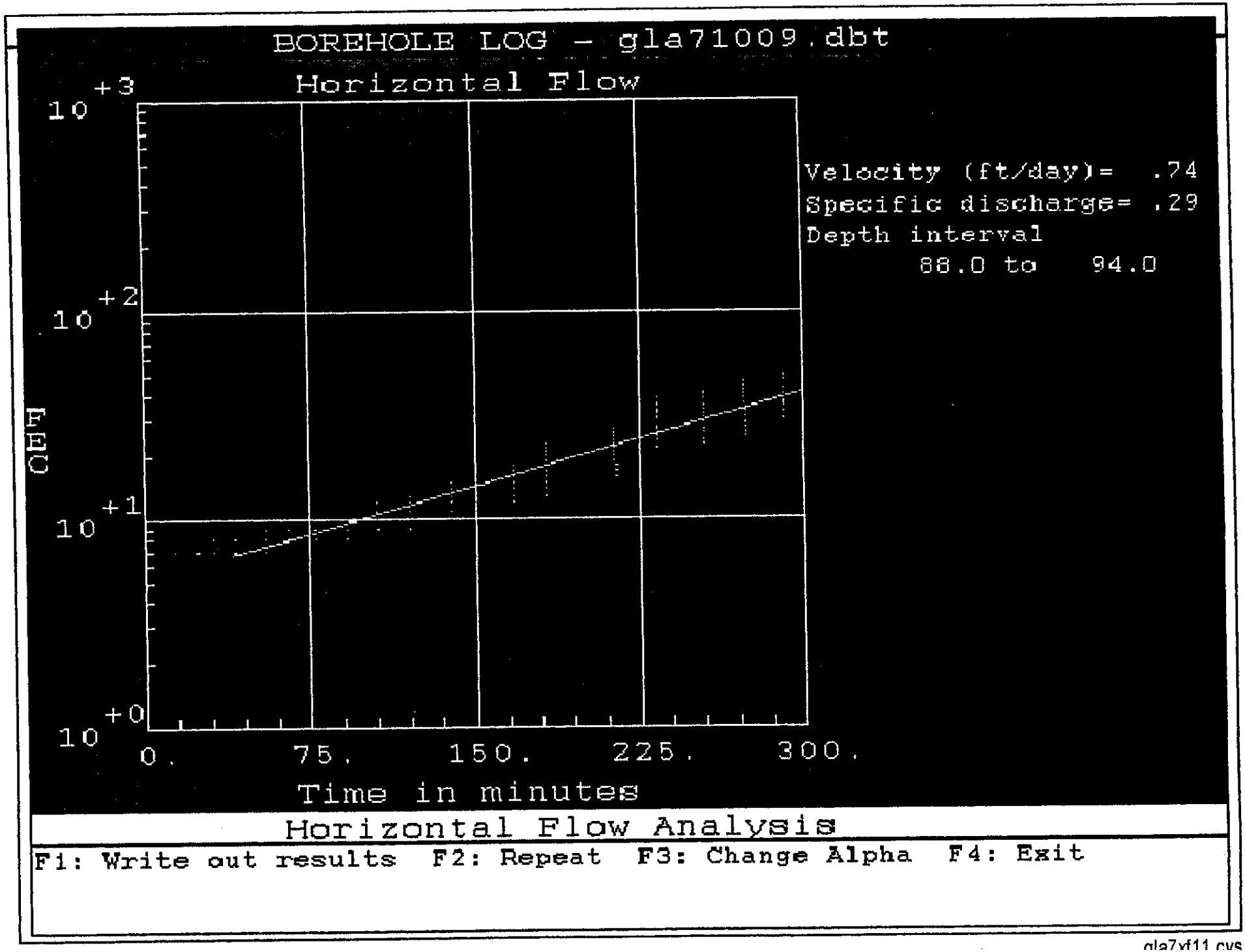


FIGURE GLA-7:26. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING, GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



FIGU. GLA-7:27. HORIZONTAL FLOW ANALYSIS DURING ...OSS HOLE TESTING; GEOLOGIC ASSOCIATES, GREGORY CANYON, CA; WELLS GLA-7 AND GMP-2.



gla7xf11.cvs

TABLE GLA-7:1. SUMMARY OF HORIZONTAL FLOW, STABLE AND STRESSED WELLFIELD CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

	Stable Wellfield Conditions		Stressed Wellfield Conditions[1]		Percent
Interval	v*[2]	Sd[3]	v*	Sd	Change
(ft)	(ft/day)	(ft/day)	(ft/day)	(ft/day)	(%)
33 - 42	0.53	0.21	0.60	0.24	13
42 - 48	0.52	0.21	0.71	0.28	37
48 - 52	0.50	0.20	0.76	0.31	52
52 - 58	0.48	0.19	0.81	0.32	69
58 - 62	0.48	0.19	0.86	0.34	79
62 - 69	0.46	0.19	0.93	0.37	102
69 - 72	0.41	0.16	1.01	0.40	146
72 - 76	NA[4]	NA	1.05	0.42	ND[5]
76 - 79	NA	NA	1.04	0.41	ND
79 - 88	NA	NA	0.93	0.37	ND
88 - 94	NA	NA	0.74	0.29	ND

[1] Stressed conditions created by pumping GMP-2 at approximately 11 gallons per minute (gpm).
[2] Horizontal flow velocity estimated using algorithm discussed in an attached appendix.
[3] Specific discharge estimated using a convergence factor (α) of 2.5.
[4] Not applicable. The HydroPhysical ™ logging data did not suggest horizontal flow was occurring in this interval during the stable wellfield condition.
[5] Non-determinable. These intervals did not display horizontal flow during stable wellfield conditions and therefore, no percent change could be calculated. However, the data suggest that these intervals demonstrated significant horizontal flow during stressed wellfield conditions. As such, these intervals should be considered more hydraulically connected to pumping well GMP-2.

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TABLE GLA-7:2. CODE BORE RESULTS FOR 5 GPM PRODUCTION TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-7.

Depth (meters)	Depth (feet)	Flow Rate (m^3/s)	Flow Rate (lpm)	Flow Rate (gpm)	FEC (gram/l)	FEC (μS/cm)
17.1	56.10	7.17E-06	0.43	0.11	0.455	944
17.4	57.09	7.17E-06	0.43	0.11	0.455	944
17.7	58.07	7.17E-06	0.43	0.11	0.455	944
18	59.06	7.17E-06	0.43	0.11	0.455	944
18.3	60.04	7.17E-06	0.43	0.11	0.455	944
18.6	61.02	7.17E-06	0.43	0.11	0.455	944
18.9	62.01	7.17E-06	0.43	0.11	0.455	944
19.2	62.99	7.17E-06	0.43	0.11	0.455	944
19.9	65.29	6.90E-06	0.42	0.11	0.455	944
20.3	66.60	6.90E-06	0.42	0.11	0.455	944
20.6	67.59	6.90E-06	0.42	0.11	0.455	944
20.9	68.57	6.90E-06	0.42	0.11	0.455	944
21.3	69.88	6.90E-06	0.42	0.11	0.455	944
21.6	70.87	6.90E-06	0.42	0.11	0.455	944
21.9	71.85	6.90E-06	0.42	0.11	0.455	944
22.2	72.83	6.90E-06	0.42	0.11	0.455	944
22.6	74.15	6.90E-06	0.42	0.11	0.455	944
22.9	75.13	6.90E-06	0.42	0.11	0.455	944
23.2	76.12	6.90E-06	0.42	0.11	0.455	944
23.5	77.10	6.90E-06	0.42	0.11	0.455	944
23.8	78.08	6.90E-06	0.42	0.11	0.455	944
24.1	79.07	6.90E-06	0.42	0.11	0.455	944
25.6	83.99	1.50E-05	0.90	0.24	0.435	903
25.9	84.97	6.67E-06	0.40	0.11	0.435	903
26.2	85.96	6.67E-06	0.40	0.11	0.435	903
26.5	86.94	6.67E-06	0.40	0.11	0.435	903
26.8	87.93	6.67E-06	0.40	0.11	0.435	903
27.1	88.91	1.00E-05	0.60	0.16	0.435	903
27.4	89.90	1.00E-05	0.60	0.16	0.435	903
27.7	90.88	4.67E-05	2.81	0.74	0.435	903
28	91.86	4.67E-05	2.81	0.74	0.435	903
28.3	92.85	1.67E-05	1.00	0.26	0.435	903
28.6	93.83	6.67E-06	0.40	0.11	0.435	903
28.9	94.82	6.67E-06	0.40	0.11	0.435	903
29.2	95.80	1.67E-06	0.10	0.03	0.435	903
29.5	96.78	1.67E-06	0.10	0.03	0.435	903
29.8	97.77	1.67E-06	0.10	0.03	0.435	903
30.1	98.75	1.67E-06	0.10	0.03	0.435	903
TOTAL ESTIMATED FLOW RATE - BORE RESULTS =				5.49 gpm		
TOTAL OBSERVED FLOW RATE =				5.09 gpm		

FIGURE GLA-7: BIPS FRACTURE TABLE FOR WELL GLA-7, GEOLOGIC ASSOCIATES; GREGORY CANYON , CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	30.3	9.25	N49E	38SE	139	1
2	31.6	9.63	N25W	63W	245	1
3	34.9	10.64	N62W	83N	28	2
4	40.0	12.20	N49E	24SE	139	1
5	41.3	12.57	N46E	37SE	136	0
6	44.7	13.62	N25E	61E	115	0
7	45.7	13.93	N69W	61N	21	1
8	46.1	14.04	N36W	25NE	54	0
9	46.4	14.13	N36W	62SW	234	0
10	49.5	15.08	N43W	22SW	227	0
11	50.5	15.39	N23E	40W	293	1
12	52.4	15.97	N79E	47N	349	1
13	55.5	16.91	N39E	32SE	129	1
14	55.7	16.97	N80E	28N	350	1
15	56.0	17.07	N67W	39N	23	0
16	56.7	17.27	N20E	62E	110	0
17	57.8	17.61	N49W	67SW	221	0
18	60.0	18.30	N25E	78E	115	2
19	60.7	18.49	N33E	77SE	123	2
20	61.4	18.70	N6W	53W	264	1
21	61.5	18.75	N35E	73SE	125	0
22	65.4	19.94	N38E	47NW	308	1
23	65.8	20.05	N27E	71E	117	0
24	66.5	20.26	N17E	46W	287	1
25	67.0	20.43	N35E	47NW	305	1
26	68.8	20.96	N11W	65E	79	1
27	68.8	20.99	N78E	75S	168	1
28	72.9	22.23	N52E	50NW	322	1
29	76.6	23.36	N53W	14NE	37	1
30	82.0	25.00	N33W	40SW	237	1
31	83.4	25.41	N31W	37SW	239	1
32	84.0	25.61	N13E	24W	283	1
33	86.6	26.40	N83E	39N	353	1
34	87.2	26.57	N64W	23S	206	1
35	88.1	26.85	N24W	37W	246	2
36	89.6	27.32	N61E	2N	331	1
37	89.9	27.40	N58W	11SW	212	1
38	90.5	27.58	N62W	27S	208	2
39	91.0	27.72	N56W	25SW	214	2
40	92.7	28.26	N60W	25S	210	1
41	94.2	28.71	N35W	14SW	235	1
42	94.5	28.81	N83E	18S	173	1
43	95.0	28.96	N65W	24N	25	1
44	96.0	29.25	N45E	13SE	135	2
45	96.5	29.42	N88W	13S	182	2
46	99.1	30.21	WE	18N	0	2
47	100.0	30.48	N58E	21SE	148	1

All directions are with respect to magnetic north.

FIGURE GLA-7: BIPS FRACTURE TABLE FOR WELL GLA-7, GEOLOGIC ASSOCIATES; GREGORY CANYON , CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	100.7	30.70	N21W	42E	69	1
49	101.0	30.79	N15W	42E	75	2
50	101.4	30.92	N39E	22NW	309	1
51	101.7	30.99	N7E	51E	97	2
52	104.6	31.87	N6W	28E	84	2
53	104.6	31.89	N30W	77NE	60	1
54	106.0	32.32	N20W	57E	70	1
55	107.1	32.63	N82E	60N	352	1
56	108.0	32.92	N3E	43W	273	1
57	112.3	34.21	N24W	66W	246	1
58	115.1	35.09	N7W	61W	263	1
59	115.2	35.11	N48W	51SW	222	2
60	116.0	35.36	N26W	44W	244	1
61	125.5	38.25	N12E	40E	102	2
62	129.0	39.32	N31W	52NE	59	1
63	134.9	41.13	N32W	52SW	238	1
64	135.4	41.28	N22W	70E	68	2
65	137.1	41.79	N34W	51SW	236	1
66	137.5	41.91	N12W	59W	258	2
67	137.7	41.98	N18W	47W	252	2
68	138.1	42.08	N16E	43E	106	1
69	139.3	42.47	N55W	26NE	35	2
70	140.1	42.69	N3W	54E	87	2
71	140.5	42.81	N28W	61W	242	2
72	141.0	42.96	N42W	45SW	228	1
73	141.6	43.17	N33W	44SW	237	2
74	142.1	43.32	N40W	58SW	230	1
75	142.7	43.48	N55W	57SW	215	2
76	143.1	43.61	N56W	54SW	214	1
77	144.2	43.96	N40W	47SW	230	2
78	144.8	44.14	N5E	42W	275	1
79	145.9	44.46	N29W	75W	241	1
80	146.9	44.77	N20W	63W	250	1
81	150.4	45.83	N7W	59W	263	1
82	151.1	46.05	N20W	60E	70	2
83	155.6	47.42	N46E	43SE	136	1
84	155.6	47.43	N20E	24E	110	2
85	156.0	47.55	N10E	25E	100	2
86	156.4	47.66	N38W	28NE	52	1
87	157.0	47.86	N1W	38E	89	1
88	157.6	48.03	N8E	30E	98	2
89	158.4	48.28	N52E	58SE	142	1
90	158.4	48.29	N5W	32E	85	2
91	158.9	48.44	N2E	31E	92	1
92	159.5	48.62	N11E	26E	101	1

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-8

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 18, 1996, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-8:1.

1.2 Ambient Flow Evaluation During Stable Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow.

On December 18, 1996, at 1051 hours (T=0.00 minutes), dilution of the fluid column was complete. During the 5.32 hours following dilution, multiple logs were conducted. Of these logs, 17 are presented in Figure GLA-8:2. These logs illustrate significant change throughout the interval from 85 to 200 feet. These dramatic changes in the FEC profiles with respect to time are associated with ambient vertical flow.

A tessellated[1] chromographic summary of all downward FEC traces is presented in Figure GLA-8:3. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 860 µS/cm.

Wellbore formation water migration caused by vertical flow within the fluid column is indicated by the chromatically defined lineament in Figure GLA-8:3 for the interval from 125 to 178 feet. Direct interpretation of these data for this interval suggest that inflow (flow from the localized aquifer into the well) appears to be occurring at 178 feet, then moving upward and exiting the wellbore at about 70 to 95 feet. The rate of this upward flow appeared reasonably constant during the period of testing at an estimated 0.28 ft/min (0.42 gallons per minute in nominal 6 inch diameter casing) for this interval over the period of testing.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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1.3 Flow Characterization During Well Production; GLA-8

Pumping of wellbore fluids and simultaneous DI injection was conducted at one pumping rate to establish the inflow locations and evaluate the interval specific inflow rates. Pumping at a given rate was conducted until reasonably constant drawdown was observed. When constant drawdown was observed, DI injection was initiated at about 30% of the pumping rate and the extraction pumping rate was adjusted to maintain a constant total formation production rate (i.e. pumping rate prior to DI injection). These procedures were conducted at one formation production rate, about 4.0 gpm.

On January 17, 1997, at 1545 hours (T=0.00 minutes, elapsed time of testing), pumping was initiated at about 4.0 gpm. Prior to initiating pumping, the depth to water was recorded at 61.90 feet (referenced to protective casing). Time dependent depth to water, totals and flowrate information was recorded and is presented in Figure GLA-8:4. Pumping was maintained at a time averaged rate of 4.04 gpm until 1702 hours (T=77 minutes, elapsed time of testing). During this period, multiple logs were conducted, and three selected FEC traces (FEC1622, FEC1632, and FEC1649) are presented in Figure GLA-8:5. DI injection was initiated at 1702 hours at a time averaged rate of 1.8 gpm, total extraction was increased to a time averaged rate of 5.6 gpm, resulting in a total formation time averaged production rate of 3.8 gpm. These flow conditions were maintained until 2000 hours (T=255 minutes, elapsed time of testing). During this period, multiple logs were conducted, and four selected FEC traces (FEC1909, FEC1918, FEC1928, and FEC1949) are presented in Figure GLA-8:5. These logs illustrate a reasonably stable, diluted condition of the fluid column with local inflow locations identified by incremental step increases. Each of these step changes indicates hydraulically conductive intervals at that depth. Numerical modeling of the reported field data was performed using code BORE (Hale and Tsang, 1988, Pedler et. al. 1990, Tsang et.al. 1990). This modeling was performed to estimate the rate of inflow for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Figure GLA-8:6 and Table GLA-8:1. In summary, flow for the 3.8 gpm production test is located at two distinct intervals. The first interval can be seen on Figure GLA-8:5, from approximately 179 to 182 feet. Code BORE results indicate that 1.92 gpm is being produced in this interval. The remaining 1.88 gpm is being produced above the logged interval for this test, and can be seen on Figure GLA-8:8 to be at 70 to 90 feet.

1.4 Cross Hole Testing; GLA-8

Additional HydroPhysical™ testing was performed while pumping in nearby well GMW-4. This well was located approximately 21 feet NW from well GLA-8. The objective of this testing was to evaluate the "cross hole" hydraulic connection between wells GLA-8 and GMW-4. The hydraulic connection between these wells was estimated by evaluating the flow conditions in well GLA-8 during a stable wellfield condition and during a stressed wellfield condition. The stressed wellfield condition was achieved by pumping well GMW-4. By comparing the flow conditions during these two pressure states, a qualitative evaluation of which intervals are hydraulically connected can be achieved. Quite simply, those intervals which display the greatest change in flow between the two pressure conditions are more hydraulically connected. Further evaluation of the logging data to quantify the horizontal flow velocity and associated specific discharge has been conducted using experimental coding developed by others. This coding is discussed in Appendix C.

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1.4.1 Flow Evaluation During Stressed Well Field Condition; GLA-8

For cross-hole flow assessment, the formation water in the observation well was diluted with DI while maintaining pumping in well GMW-4. After emplacement, the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded for both the observation well and the pumping well. Cross-hole flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with fluid flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

To estimate the hydraulic connection between pumping well GMW-4 and observation well GLA-8, pumping in GMW-4 was performed and contemporaneously the flow was evaluated in well GLA-8. Pumping in well GMW-4 was initiated on January 19, 1997, at 1720 hours (T=0.00 minutes, elapsed time of testing), at a flow rate of about 0.8 gpm. A reasonably stable drawdown of about 7.0 feet was observed in observation well GLA-8 prior to initiating DI emplacement. DI emplacement was complete on January 20, 1996 at 1150 hours. This emplacement was performed after pumping GMW-4 for approximately 1000 minutes. Refer to Figure GLA-8:7 for water level elevation during this testing. Due to pumping of GMW-4 at approximately 0.8 gpm, the water level elevation continued to slightly decrease in GLA-8 during the period of testing by about 1.0 feet. During the emplacement procedures, no appreciable DI was lost to the formation. During the 3.25 hours following dilution, multiple logs were conducted, and 25 are presented in Figure GLA-8:8. The first log presented was conducted during emplacement. These traces illustrate significant change over the interval from 70 to 225 feet. These dramatic changes in the FEC profiles with respect to time are associated with vertical and horizontal flow occurring within this wellbore.

A tessellated chromographic summary of all downward FEC traces is presented in Figure GLA-8:9. FEC of 0 µS/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 900 µS/cm.

The data suggest that horizontal flow was occurring over the interval from 70 to 90 feet. For the purpose of processing these data, this interval was divided into four- 5 feet intervals; 70-75, 75-80, 80-85, and 85-90 feet. Experimental algorithms applied to these data suggest the fluid velocities for these intervals were reasonably similar and ranged from 0.67 to 0.72 ft/day. Correcting for convergence of flow at the wellbore, these velocities equate to a range in specific discharge of groundwater in the aquifer from 0.27 to 0.29 ft/day. Please refer to Figures GLA-8:10 through GLA-8:13 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

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Wellbore formation water migration caused by vertical flow within the fluid column is indicated by the chromatically defined lineament in Figure GLA-8:9 for the interval from 120 to 175 feet. Direct interpretation of these data for this interval suggests that inflow (flow from the localized aquifer into the well) appears to be occurring at 178 feet, then moving upward and exiting the wellbore at about 90 to 95 feet. The rate of this upward flow appeared reasonably constant during the period of testing at an estimated 0.33 ft/min (0.50 gallons per minute in nominal 6 inch diameter casing) for this interval over the period of testing.

1.5 Summary of Cross-Hole Flow Evaluation; Wells GLA-8 and GMW-4.

Review and comparison of Figures GLA-8:3 and GLA-8:9 illustrate a significant change in flow characteristics between the two pressure conditions. Comparison of the flow evaluation between the stable and stressed (i.e. pumping) conditions suggest that the intervals from 70 and 95 feet demonstrated the greatest change in flow properties during testing. These data suggest that the inflow at 178 feet was inflowing at 0.42 gpm during the stable wellfield condition in contrast to the stressed condition when this zone inflowed at 0.50 gpm. This reflects an increase of 0.08 gpm or 19 percent. Review of these data and the HydroPhysical™ Logging data for ambient flow characterization in well GMW-4 (see previous section for this discussion) suggest that a hydraulically conductive interval is present in both wells at a similar depth (65 to 74 feet). These data suggest the dominant hydraulic connection between these wells is via this interval. In addition, the data suggest that the deeper hydraulically conductive interval at 178 feet, while a significant hydraulically conductive interval, does not appear to have the same degree of hydraulic connection as the uppermost zone.

1.6 Special Conditions

On the night of January 19, 1997, during overnight pumping associated with the cross-hole testing, the water level in pumping well GMW-4 dropped below the depth of the pressure transducer. This pressure transducer was installed by Geologic Associates and was placed at a depth of 87 feet. When COLOG arrived on site the next morning the situation was observed and manual water level elevations were recorded. These data are presented in Figure GLA-8:7. In addition, at elapsed time of 575 to 825 minutes the COLOG flow meter "silted up" and incorrectly recorded that no flow occurred. However, pumping never stopped. As such, during this period, the extraction totals on Figure GLA-8:7 show that no pumping had taken place. The curve fits on Figure GLA-8:7 have been adjusted to compensate for this time period.

1.7 Sensitivity to Inflows

The HpL™ technique is based on measuring induced electrical changes in a dynamic (i.e. flowing conditions) wellbore fluid column. As such, the sensitivity with which "downstream" inflow points (those closest to the pump, where the flow rate is the greatest) can be identified is directly proportional to the flow rate and FEC of both the upward flowing wellbore fluids and the formation inflow location. Given the conditions observed in the well during our testing, the HpL™ technique would have detected any inflow greater than 0.05 gpm with FEC of 900 µS/cm, during the testing described in this report.

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FIGURE GLA-8:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-8.

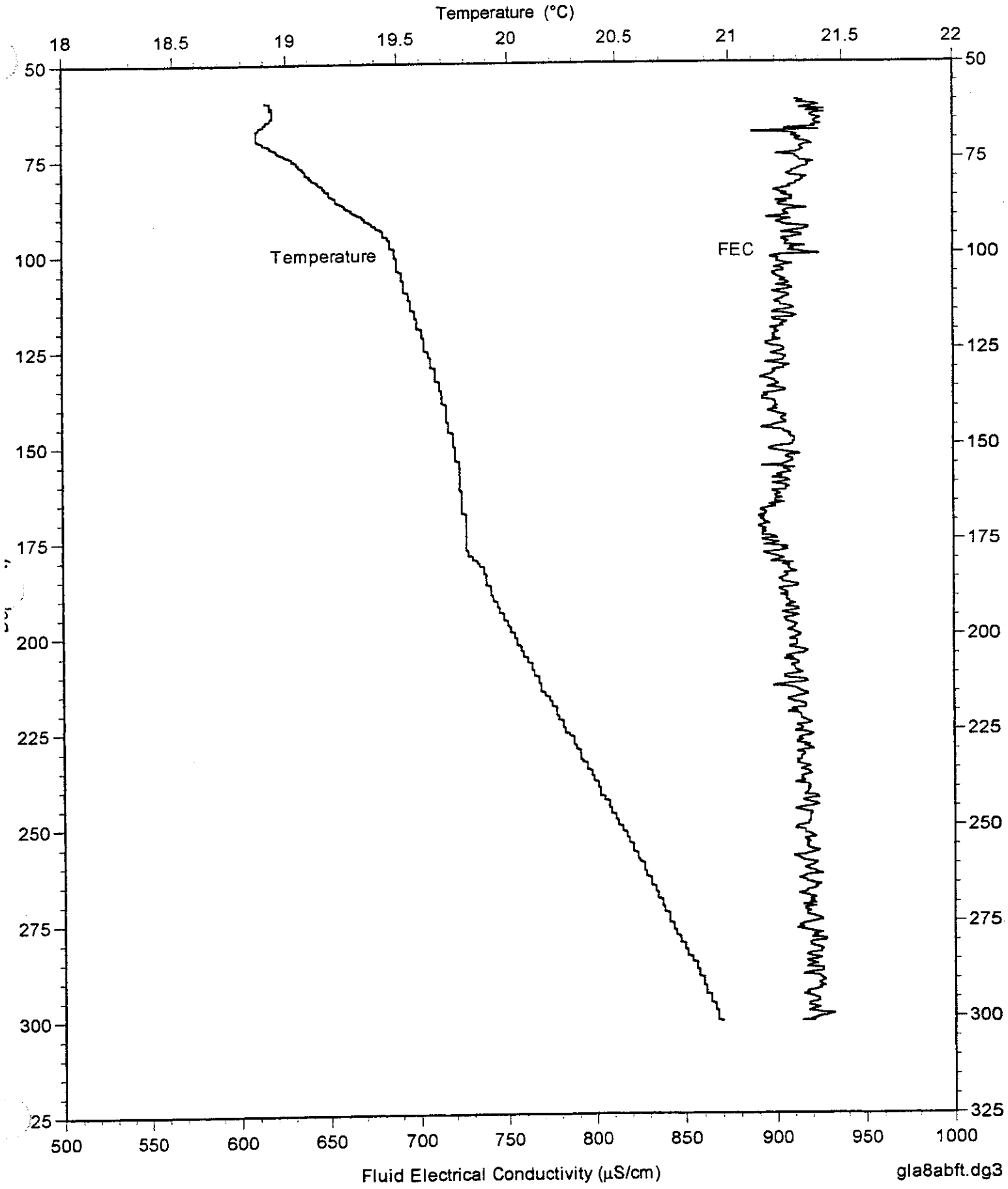
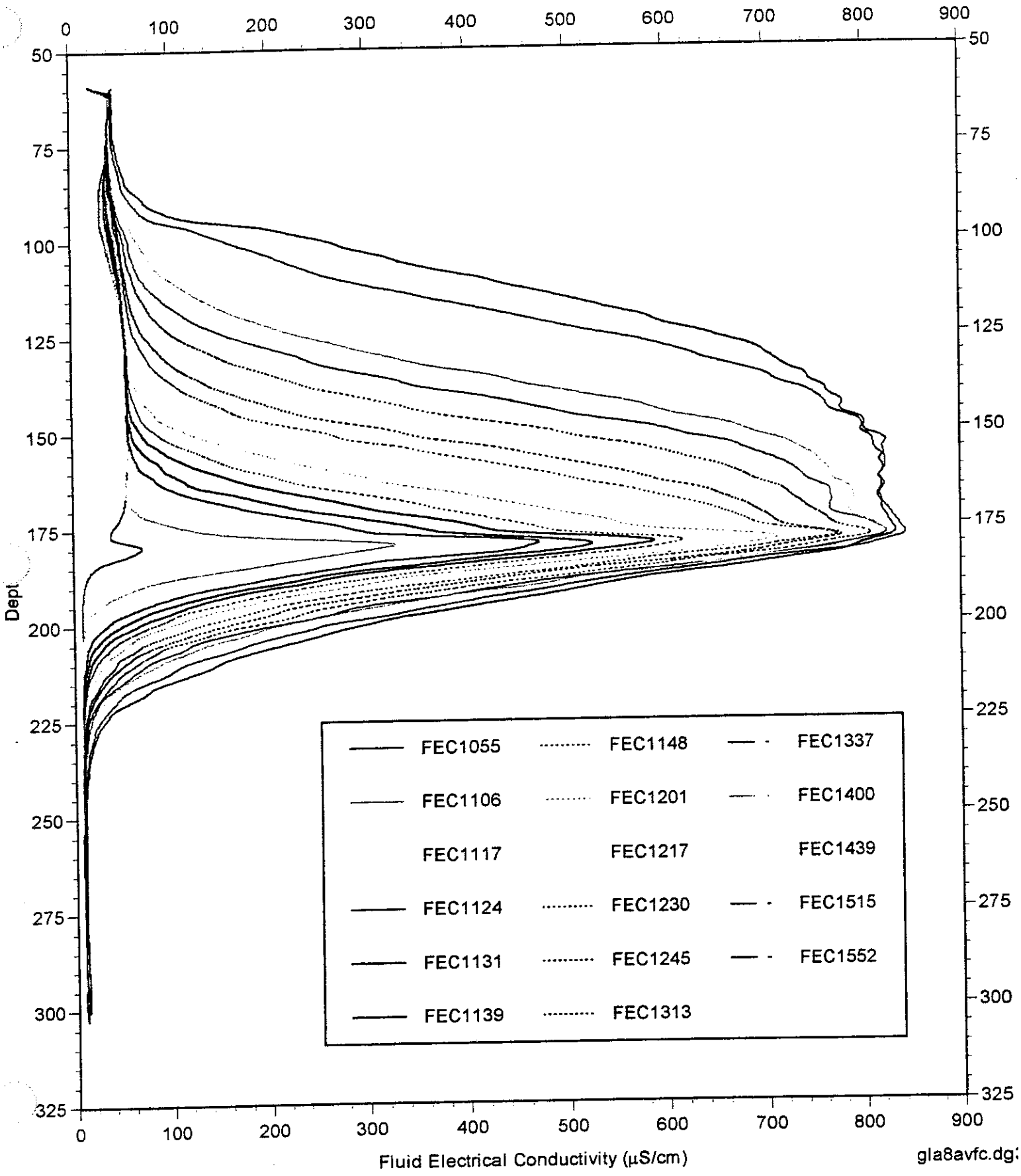


FIGURE GLA-8:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-8.



URE GLA-8:3. CHROMOGRAPHIC TESSELLATION FEC LOGS FOR AMBIENT FLOW CHARACTERIZATI
GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-8.

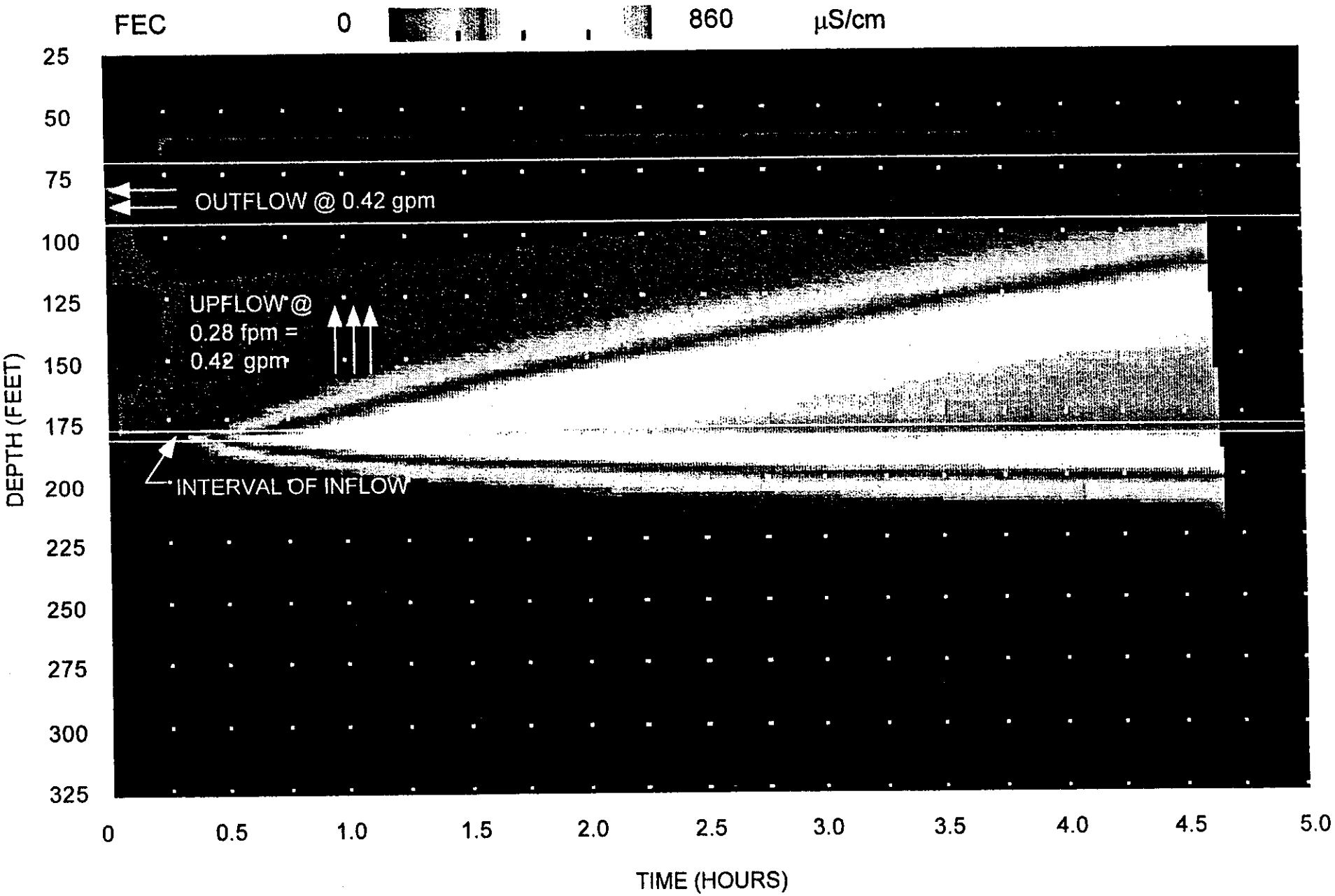


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FIGURE GLA-8:4. PUMP AND DRAWDOWN DATA FOR 4 [illegible]M PRODUCTION TEST, GEOLOGIC ASSOCIATES, GORY CANYON, CA; WELL GLA-8.

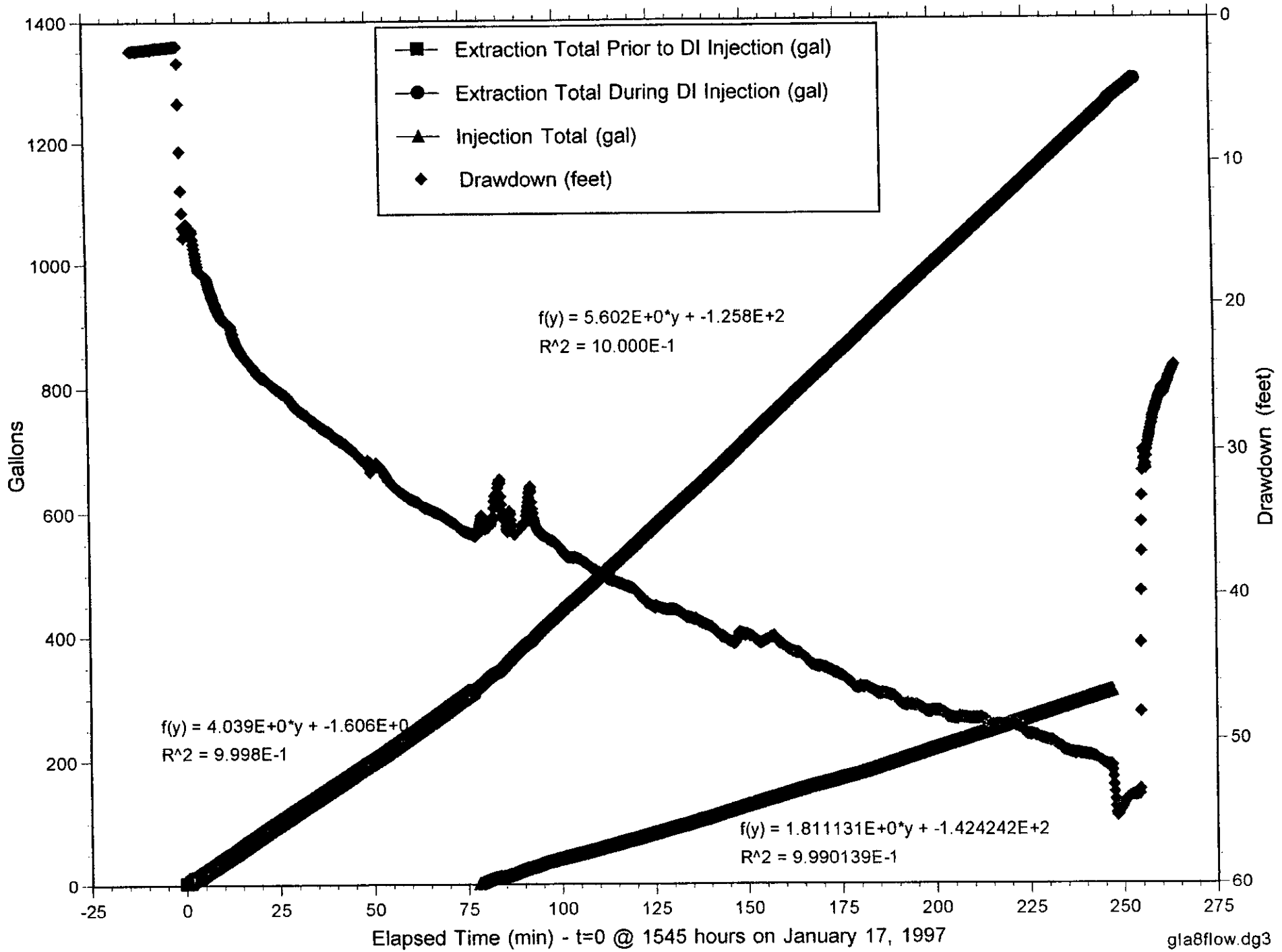


FIGURE GLA-8:5. SUMMARY OF HYDROPHYSICAL LOGS DURING 4 GPM PRODUCTION TEST WITH INTERVAL SPECIFIC FLOW RATES; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-8.

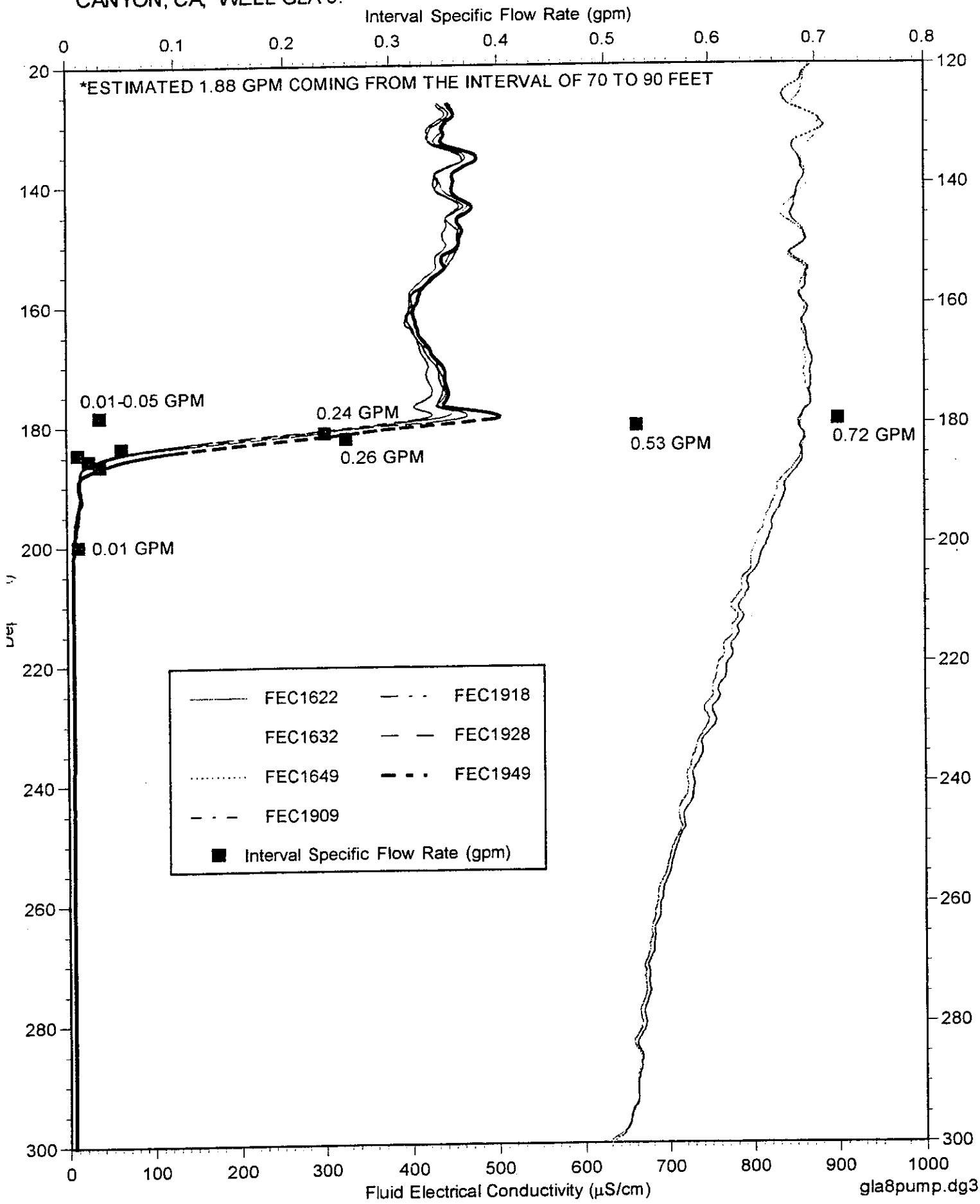
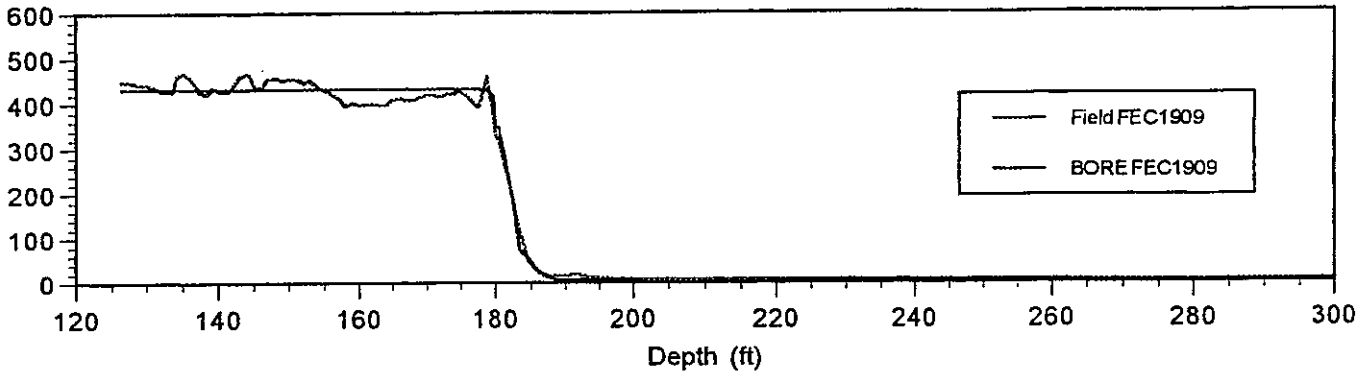
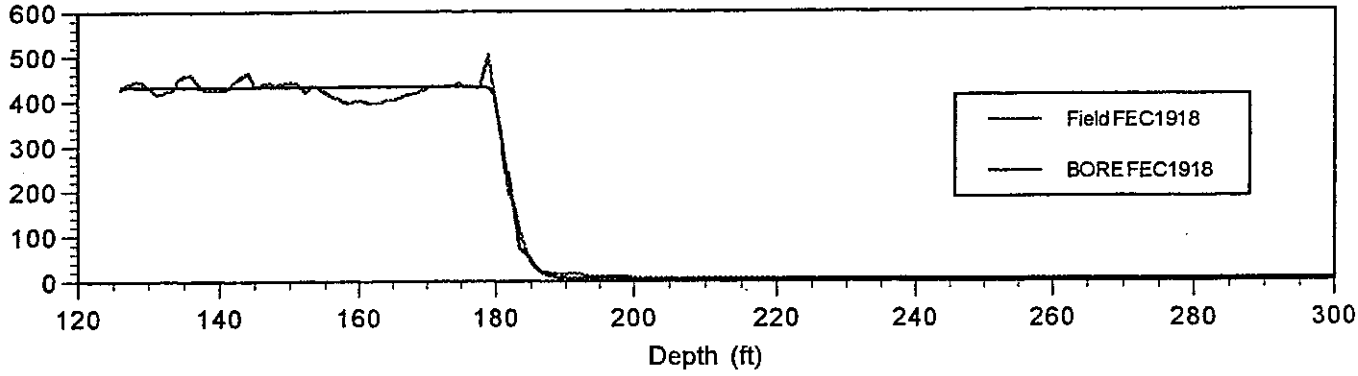
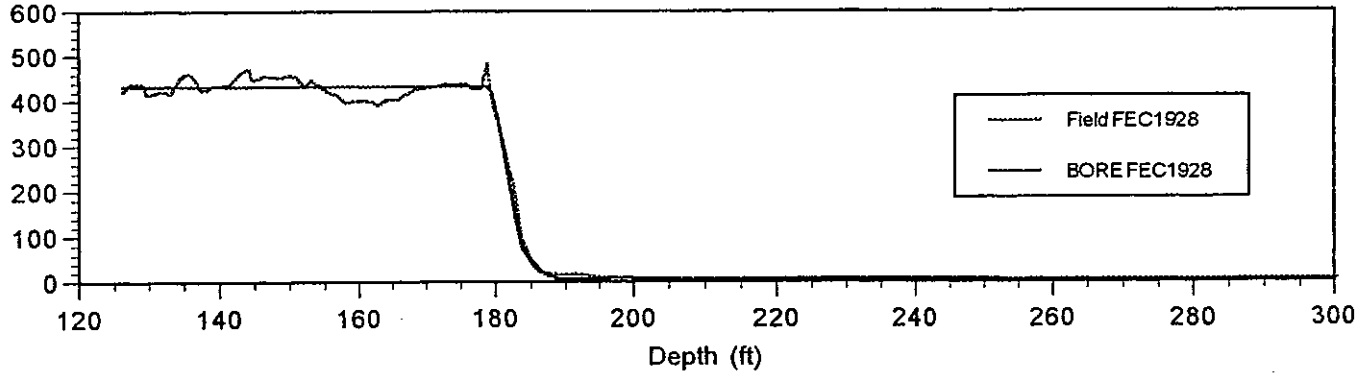
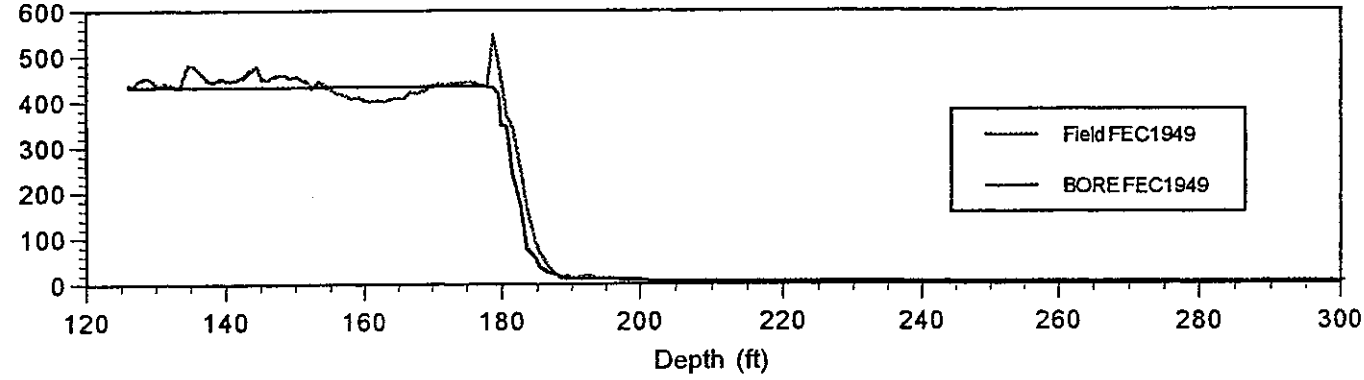


FIGURE GLA-8:6. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR 3.8 GPM PUMPING DURING INJECTION TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-8.









F 'RE GLA-8:7. PUMP AND DRAWDOWN DATA DURIN' 'ROSS HOLE TESTING; GEOLOGIC ASSOCIATES; G\ ⊂GORY CANYON, CA; WELLS GLA-8 AND GMW-4.

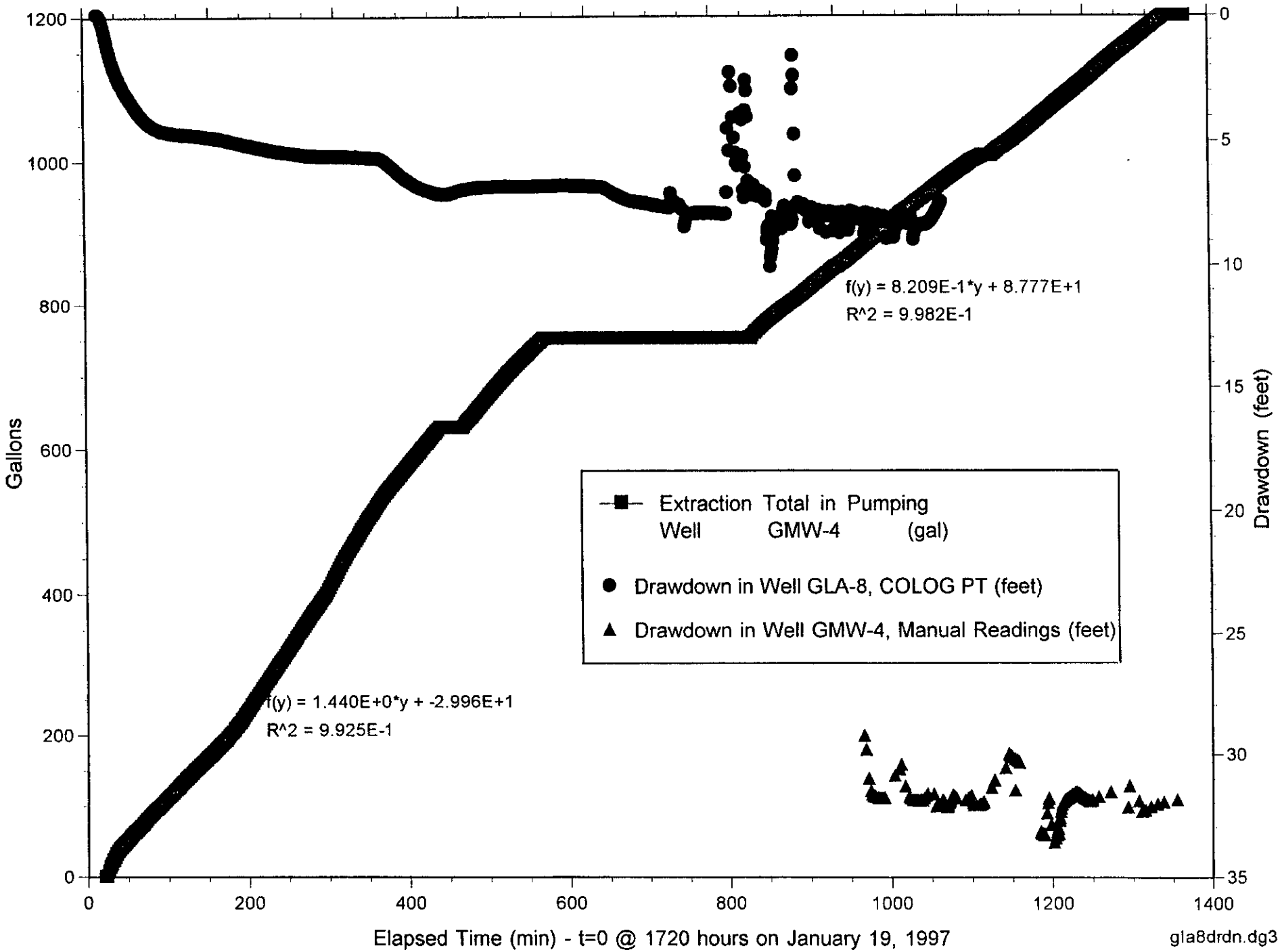


FIGURE GLA-8:8. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION CROSS HOLE TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS GLA-8 AND GMW-4.

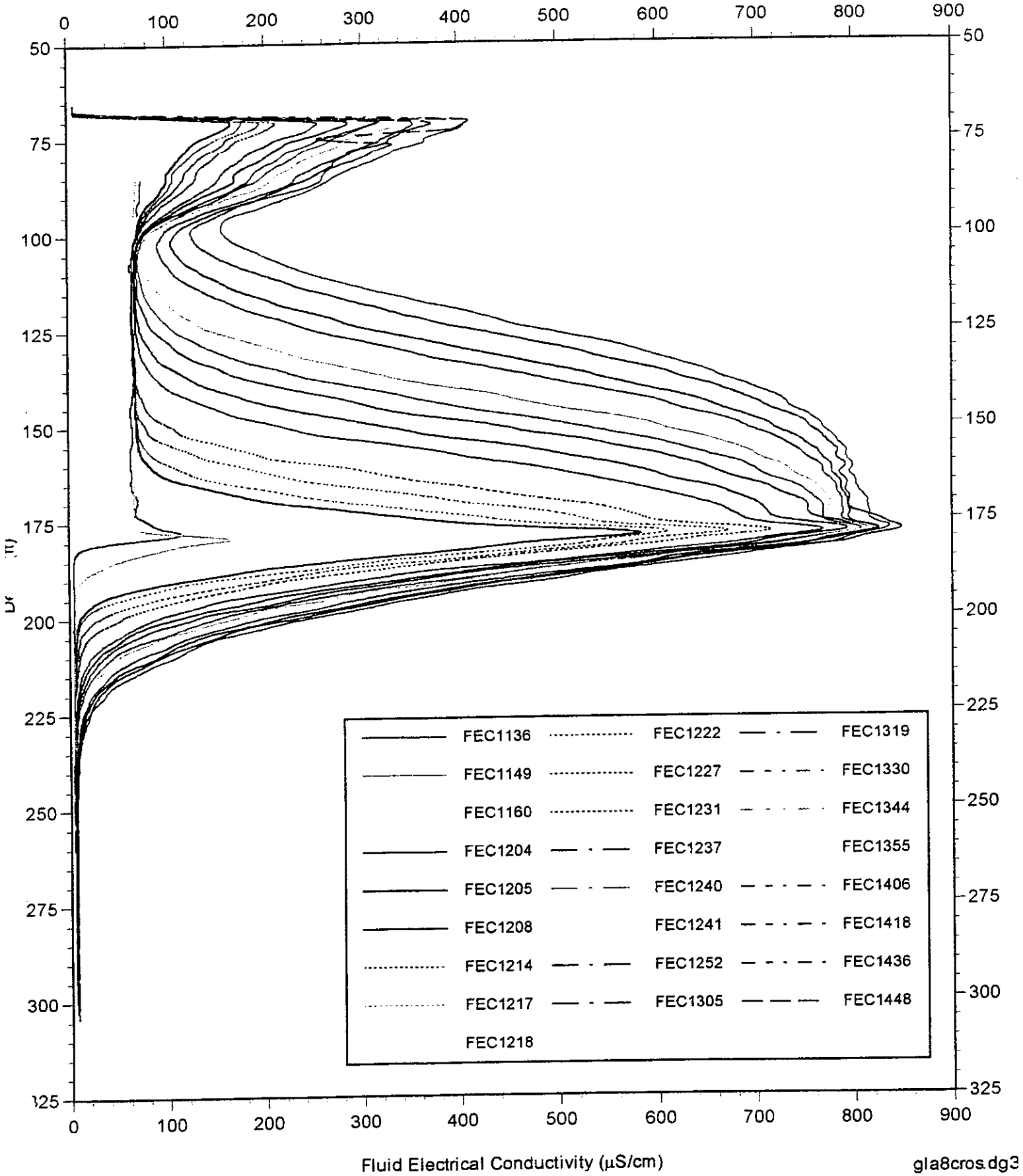


FIGURE GLA-8:9. CHROMOGRAPHIC TESSELATION OF EC LOGS FOR CROSS HOLE FLOW CHARACTERIZATION: STRESSED WELLFIELD CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON,

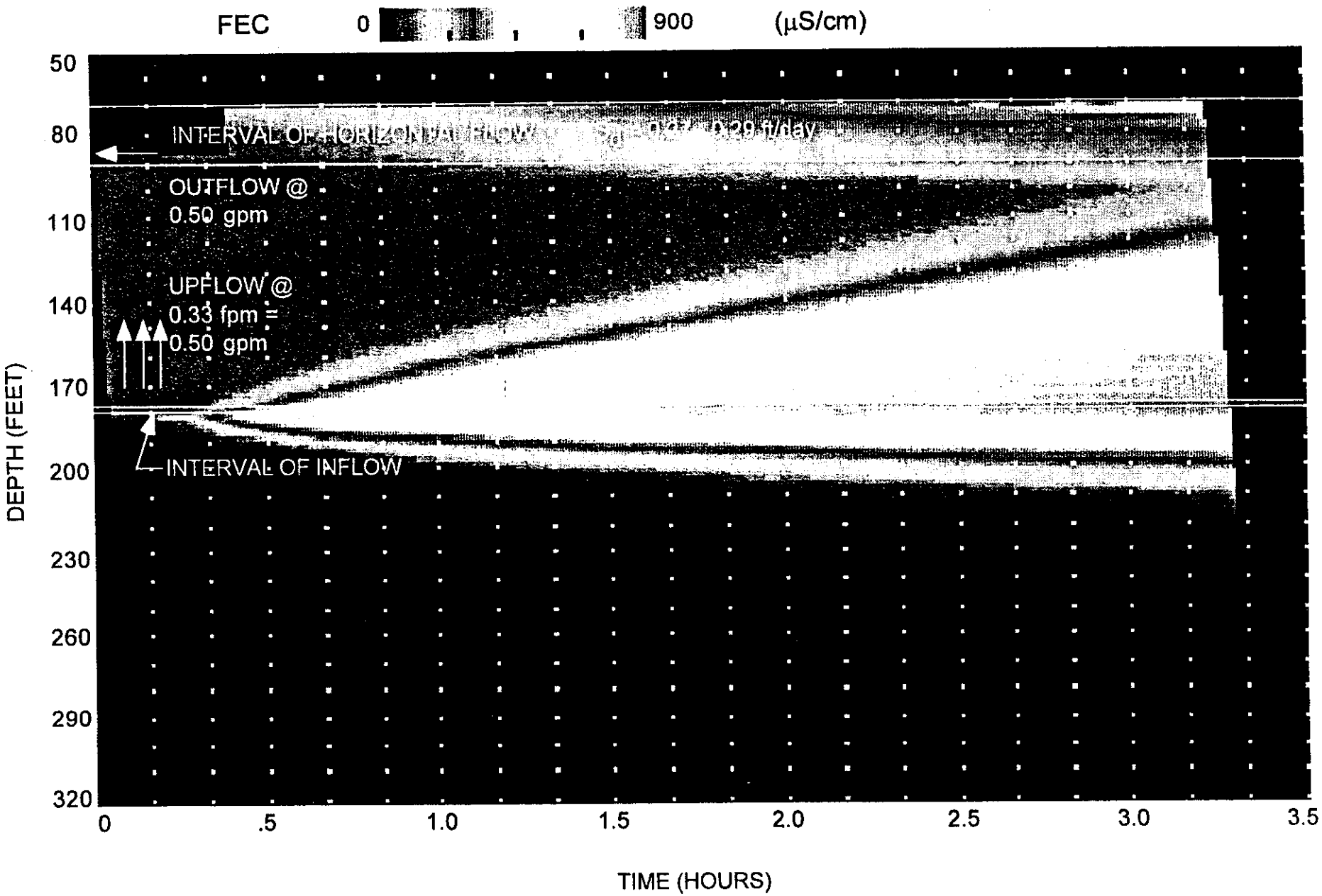


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FIGURE GLA-8.10: HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING, GEOLOGIC ASSOCIATES, CRESCENT CITY, CALIFORNIA; WELLS: GLA-8 AND GMW-4.

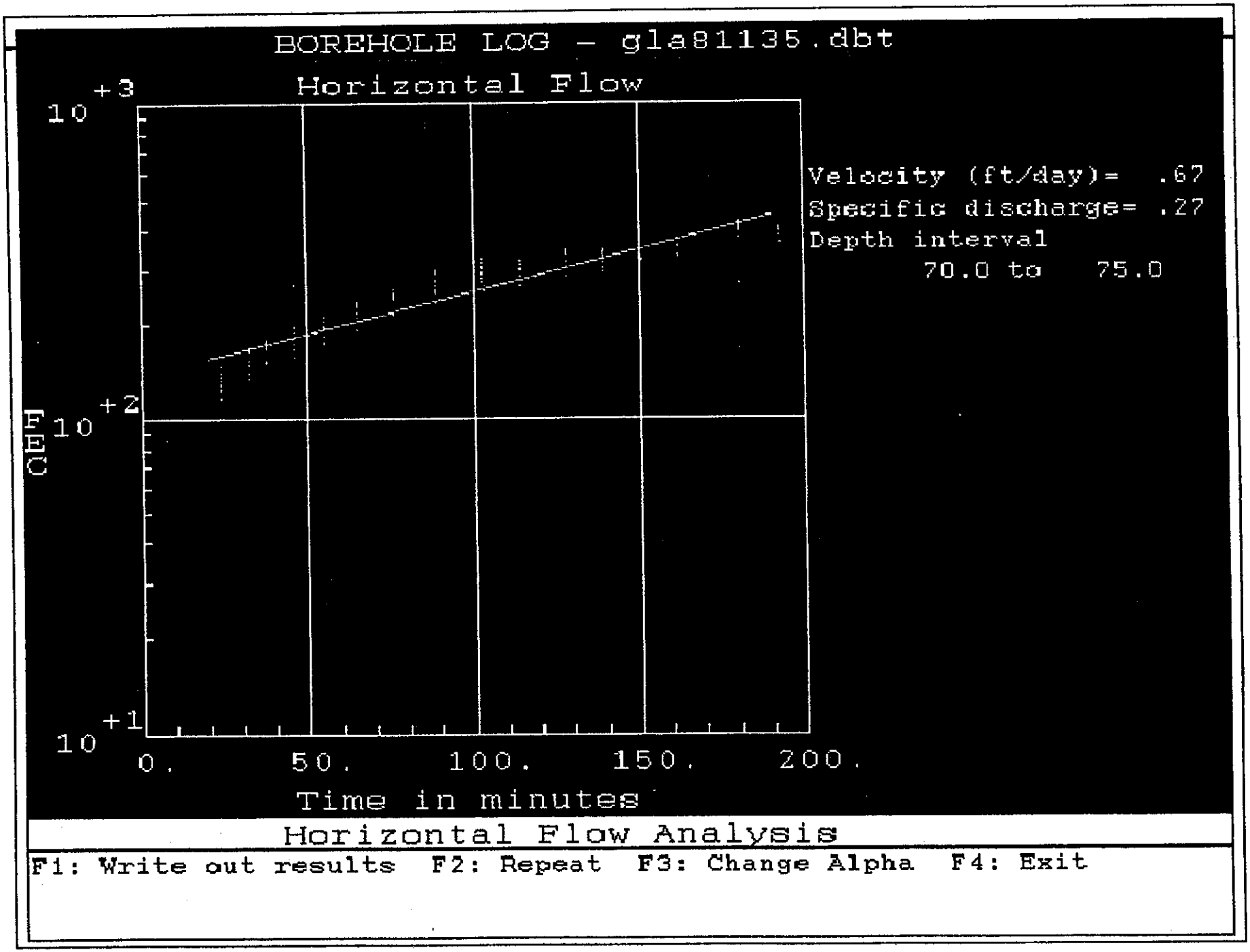

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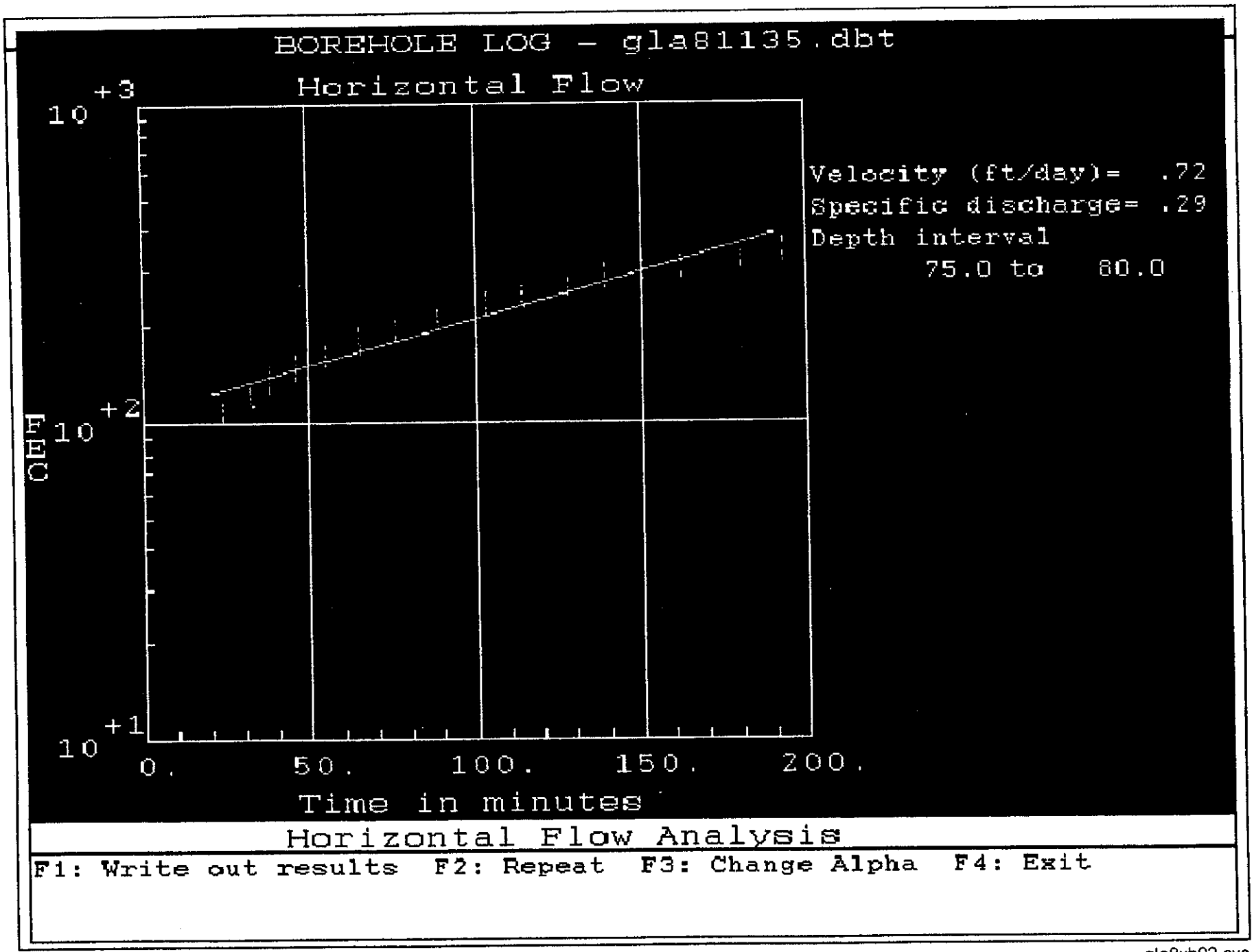
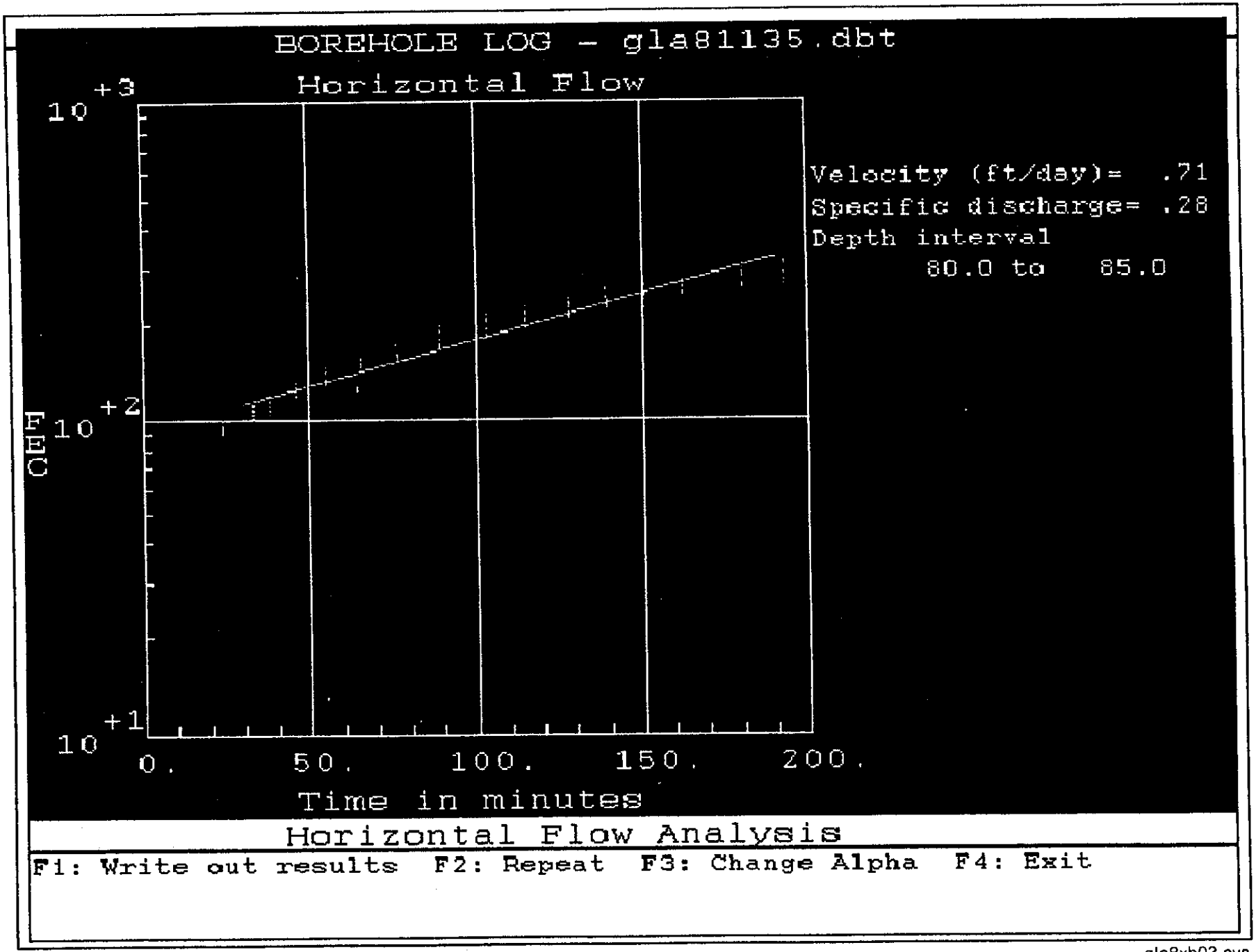
FIGURE GLA-8.11: HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING, GEOLOGIC ASSOCIATES, [illegible]
CAN I, CA; WELLS: GLA-8 AND GMW-4.



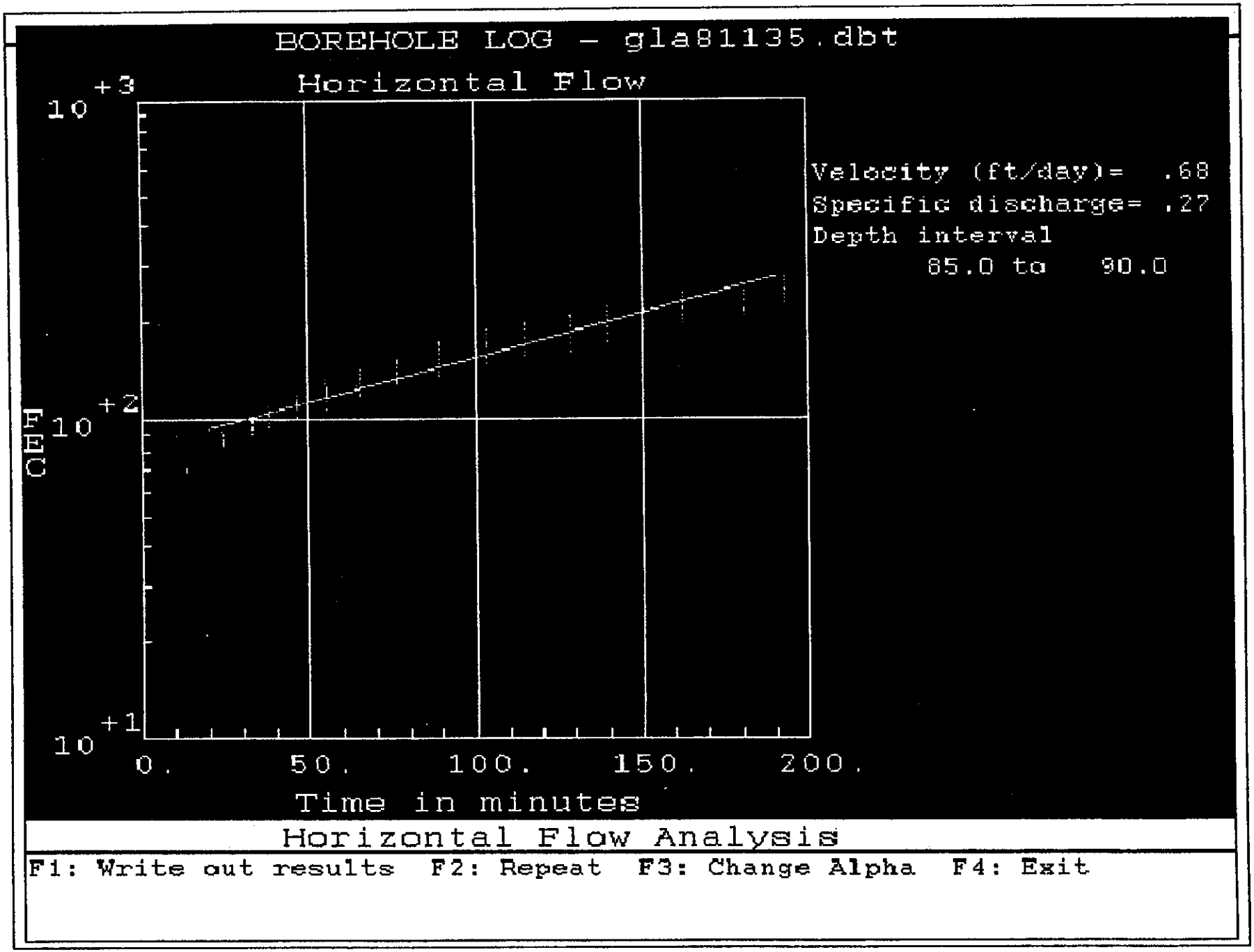
gla8xh02.cvs

FIGURE GLA-8:12. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING, GEOLOGIC ASSOCIATES, GREGORY CAN I, CA; WELLS: GLA-8 AND GMW-4.



gla8xh03.cvs

FIGURE GLA-8:13. HORIZONTAL FLOW ANALYSIS DURING CROSS HOLE TESTING; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELLS: GLA-8 AND GMW-4.



gla8xh04.cvs

TABLE GLA-8:1. CODE BORE RESULTS FOR 3.8 GPM PUMPING DURING INJECTION TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-8.

Depth (meters)	Depth (feet)	Flow Rate (m^3/s)	Flow Rate (lpm)	Flow Rate (gpm)	FEC (gram/l)	FEC (µS/cm)
	70 - 90			1.88		861
54.1	177.49	1.67E-06	0.10	0.03	0.415	861.1
54.4	178.48	1.67E-06	0.10	0.03	0.416	863.2
54.7	179.46	4.50E-05	2.71	0.72	0.416	863.2
55	180.45	3.33E-05	2.00	0.53	0.416	863.2
55.3	181.43	1.50E-05	0.90	0.24	0.416	863.2
55.6	182.41	1.67E-05	1.00	0.26	0.416	863.2
56	183.73	3.33E-06	0.20	0.05	0.416	863.2
56.3	184.71	1.67E-09	0.00	0.00	0.416	863.2
56.6	185.70	1.50E-06	0.09	0.02	0.400	830.0
56.9	186.68	1.67E-06	0.10	0.03	0.400	830.0
61	200.13	8.33E-07	0.05	0.01	0.400	830.0
TOTAL ESTIMATED FLOW RATE - BORE RESULTS =				3.80 gpm		
TOTAL OBSERVED FLOW RATE =				3.80 gpm		

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	15.8	4.81	N35E	59NW	305	1
2	15.9	4.85	N45E	41NW	315	0
3	17.0	5.18	N4W	62W	266	2
4	17.6	5.38	N7W	57W	263	1
5	20.3	6.18	N62E	73N	332	1
6	20.9	6.38	N45E	56NW	315	2
7	21.6	6.60	N83E	55N	353	1
8	22.0	6.71	N61E	57N	331	1
9	23.7	7.23	N48E	12NW	318	1
10	24.7	7.54	N89E	35N	359	2
11	24.8	7.55	N68E	45S	158	1
12	25.7	7.83	N73E	36S	163	1
13	26.1	7.95	N59E	33NW	329	1
14	26.2	7.99	N73E	28N	343	1
15	26.4	8.04	N77W	27S	193	1
16	27.2	8.29	N73E	27N	33	2
17	27.6	8.42	N58E	46NW	328	1
18	28.7	8.74	N25E	33W	295	1
19	29.1	8.88	N2E	41E	92	1
20	29.8	9.09	N33W	17NE	57	2
21	30.4	9.27	N37E	58SE	127	1
22	31.5	9.59	N5W	50W	265	1
23	31.5	9.59	N6E	37E	96	1
24	32.1	9.80	N76E	35N	346	1
25	32.9	10.02	N53E	31NW	323	1
26	33.0	10.05	N69E	9S	159	1
27	33.2	10.11	N43E	44NW	304	1
28	33.3	10.16	N53W	14SW	217	2
29	33.8	10.29	N74E	34S	164	3
30	34.2	10.44	N28W	24E	62	2
31	34.7	10.56	N43E	46NW	313	2
32	35.1	10.69	N81E	11N	351	2
33	35.4	10.78	N6W	26W	264	2
34	35.5	10.83	N85E	14N	355	1
35	36.4	11.08	N45E	51NW	315	0
36	36.6	11.15	N41E	55NW	311	2
37	37.6	11.45	N48E	38NW	318	1
38	37.6	11.45	N40E	66NW	310	1
39	37.7	11.49	N47E	42NW	317	2
40	38.1	11.61	N39E	76SE	129	1
41	38.3	11.66	N45E	58SE	135	1
42	38.3	11.67	N43E	79NW	313	1
43	38.4	11.72	N3E	48W	273	1
44	38.8	11.83	N20E	47W	290	1
45	39.9	12.16	N46E	80NW	316	1
46	40.4	12.30	N41E	47NW	311	2
47	40.7	12.41	N42E	11NW	312	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	40.8	12.43	N47E	77NW	317	1
49	41.4	12.62	N19W	53E	71	1
50	41.7	12.70	N60E	72N	330	1
51	43.1	13.13	N57E	77NW	327	1
52	43.4	13.24	EW	44N	0	1
53	43.9	13.37	N88W	23N	2	1
54	44.0	13.43	N2E	67E	92	1
55	45.2	13.77	N16E	48W	283	2
56	45.6	13.89	N11E	53W	281	2
57	45.7	13.92	N47E	59SE	137	2
58	46.5	14.18	N80E	55N	350	1
59	46.6	14.21	N21W	58W	249	1
60	47.8	14.57	N32E	82SE	122	1
61	48.8	14.89	N9E	60W	179	2
62	49.2	15.00	N80E	33N	350	1
63	50.1	15.26	N71E	61N	351	1
64	51.5	15.70	N62E	79N	332	1
65	51.8	15.79	N42E	70NW	312	1
66	53.0	16.16	N64E	6N	334	2
67	53.2	16.22	N48W	40NE	42	1
68	53.3	16.24	N55W	23NE	35	2
69	53.3	16.25	N25E	78W	295	0
70	53.6	16.33	N62E	82N	332	1
71	54.5	16.60	N18W	33E	72	0
72	55.9	17.03	N74E	68N	344	0
73	56.2	17.12	N88E	42NW	358	1
74	57.1	17.40	N83W	9S	187	2
75	57.5	17.52	N74E	70N	344	0
76	57.8	17.63	N80E	62N	350	1
77	58.1	17.71	N72E	63N	342	0
78	58.4	17.80	N74W	18N	16	2
79	58.7	17.90	N70E	51N	340	1
80	59.2	18.04	N66E	58N	336	0
81	59.6	18.17	N53W	11NE	37	2
82	60.0	18.29	N18W	20E	72	2
83	60.2	18.35	N13E	60E	103	0
84	60.4	18.40	N53E	60NW	323	0
85	60.8	18.53	N24W	20E	66	2
86	60.8	18.53	N40E	63NW	310	0
87	61.8	18.84	N78E	49N	348	0
88	61.9	18.86	N69E	35N	339	2
89	62.2	18.97	N77E	44N	347	1
90	62.8	19.14	N40E	8NW	310	1
91	62.9	19.16	N60E	48N	330	1
92	62.9	19.17	N63E	9N	333	1
93	63.3	19.29	N55E	50NW	25	2
94	63.6	19.40	N68E	45N	338	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	63.7	19.42	N66E	5N	336	2
96	64.1	19.54	N75E	13S	165	1
97	64.3	19.61	N72W	62S	198	0
98	64.4	19.64	N64E	44N	334	1
99	64.7	19.72	N62E	14S	152	2
100	65.1	19.86	N72W	33N	18	1
101	65.6	19.99	N70E	74N	340	0
102	65.7	20.04	N64W	33N	26	1
103	66.1	20.15	N54W	23NE	36	2
104	66.2	20.17	N82E	73N	352	2
105	66.2	20.18	N70E	61N	340	1
106	66.2	20.18	N40E	61SE	130	0
107	67.1	20.46	N75E	56N	345	2
108	68.1	20.75	N51E	63NW	321	0
109	68.3	20.82	N59E	60NW	329	1
110	69.3	21.14	N64E	22N	334	0
111	70.5	21.48	N10E	46W	280	2
112	70.7	21.55	N20E	49W	290	1
113	70.9	21.63	N21W	39E	69	2
114	71.2	21.70	N38E	53NW	308	1
115	71.5	21.80	N66W	40NE	24	2
116	71.5	21.80	N46W	16NE	44	1
117	71.9	21.93	N65E	35S	155	1
118	72.2	22.02	N67E	56S	157	2
119	72.4	22.06	N36E	12NW	306	1
120	72.5	22.09	N53E	52NW	323	1
121	72.5	22.10	N65E	56S	155	2
122	73.4	22.38	N42E	50SE	132	2
123	77.6	23.65	N58E	62NW	328	2
124	77.7	23.68	N39E	20NW	309	2
125	78.1	23.82	N29E	13W	299	1
126	78.2	23.82	N58E	59NW	328	1
127	78.6	23.95	N13E	38W	283	0
128	78.8	24.03	N9E	29W	279	1
129	78.9	24.06	N1W	49W	269	0
130	79.5	24.22	N31E	73NW	301	0
131	79.8	24.32	N6W	21E	84	2
132	80.3	24.47	N8W	34W	262	2
133	80.5	24.53	NS	59E	90	1
134	81.0	24.68	N16E	54E	106	2
135	81.3	24.77	N7E	67E	97	1
136	82.9	25.26	N29W	31E	61	1
137	83.3	25.38	N49W	8NE	41	0
138	83.6	25.47	N40E	56NW	310	2
139	84.2	25.67	N58E	64NW	328	1
140	84.9	25.88	N50E	60NW	320	0
141	85.0	25.91	N41W	60SW	229	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	85.9	26.17	N29W	28E	61	1
143	87.4	26.63	N20W	69W	250	2
144	87.4	26.64	N35W	64SW	235	2
145	88.4	26.95	N28E	71W	298	1
146	89.2	27.19	N24W	49W	246	0
147	89.7	27.35	N14E	31W	284	1
148	90.5	27.59	N5W	67W	265	1
149	90.7	27.66	N72W	33S	198	0
150	91.2	27.81	N70E	24S	160	0
151	92.3	28.14	N13E	61W	283	2
152	94.7	28.87	N81E	50N	351	2
153	95.1	28.99	N88E	50N	358	1
154	96.2	29.33	N87W	79N	3	0
155	96.7	29.46	N86W	62S	184	0
156	97.0	29.57	N88E	59S	178	0
157	97.5	29.73	N6E	54W	276	2
158	97.7	29.78	N3E	52W	273	1
159	99.0	30.16	N9W	53W	261	1
160	99.6	30.37	N21W	50W	249	1
161	99.8	30.41	N27W	49W	243	3
162	100.7	30.70	N27E	50W	297	1
163	101.3	30.88	N53W	28SW	217	2
164	101.7	31.01	N40E	68NW	310	1
165	101.8	31.02	N65W	10S	205	1
166	102.4	31.21	N6E	61E	96	0
167	102.8	31.34	N3E	64E	93	1
168	102.8	31.35	N29W	55E	61	2
169	102.9	31.35	N26E	78W	296	0
170	103.4	31.50	N17W	67W	253	1
171	103.9	31.66	N30W	34NE	60	1
172	104.1	31.74	N43E	79NW	313	0
173	106.1	32.35	N40E	34NW	310	1
174	106.4	32.44	N41E	57NW	311	1
175	106.6	32.48	N60E	49N	330	2
176	106.7	32.52	N56E	24SE	146	2
177	107.0	32.60	N89E	29N	359	1
178	107.1	32.65	N9W	42W	261	1
179	107.7	32.84	N72E	66N	342	0
180	107.8	32.87	N11E	71E	101	0
181	108.3	33.02	N12W	47W	258	2
182	109.1	33.26	N88W	49N	2	0
183	110.3	33.61	N10E	35W	280	2
184	110.6	33.71	N11W	31W	259	1
185	110.9	33.80	N78E	37S	168	2
186	111.4	33.95	N4E	36W	274	1
187	111.5	33.98	N61E	75N	331	0
188	112.0	34.15	N16W	44W	254	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	112.7	34.34	N50E	72NW	320	2
190	113.1	34.47	N24W	52W	246	1
191	113.3	34.55	N20W	59W	250	1
192	113.4	34.57	N60E	67N	330	2
193	114.2	34.80	N53E	61NW	323	1
194	114.3	34.84	N39E	32NW	309	1
195	115.0	35.05	N8W	46W	262	2
196	115.1	35.09	N1E	58E	91	0
197	115.7	35.27	N89W	14S	181	1
198	115.9	35.34	N54E	66NW	324	0
199	116.3	35.45	N56E	79NW	326	0
200	116.9	35.63	N21W	52E	69	1
201	117.4	35.80	N16W	48W	254	2
202	118.1	35.99	N14W	23W	256	1
203	118.4	36.10	N19E	24W	289	0
204	119.0	36.26	N15W	40W	255	0
205	119.3	36.37	N33E	45NW	303	1
206	120.5	36.73	N26E	41E	116	2
207	120.6	36.76	N74E	30N	344	0
208	120.9	36.85	N9E	32W	279	2
209	121.0	36.88	N5E	37W	275	2
210	121.1	36.93	N34E	77NW	304	1
211	121.5	37.03	N27E	20W	297	1
212	122.2	37.23	N60E	61N	330	0
213	123.1	37.51	N71E	37N	341	1
214	124.2	37.87	N29E	76W	299	0
215	124.8	38.03	N12E	40W	282	2
216	125.0	38.11	N43E	63SE	133	0
217	125.9	38.37	N53E	46NW	323	0
218	126.4	38.52	N60E	42N	330	0
219	126.6	38.59	N10E	40W	280	2
220	127.6	38.88	N24E	31W	294	2
221	127.8	38.95	N87E	42N	357	2
222	128.0	39.02	N42E	37NW	312	1
223	128.1	39.05	N15E	45W	285	2
224	128.5	39.17	N55E	26SE	145	1
225	128.6	39.19	N77E	18S	167	0
226	128.9	39.28	N67E	24S	157	2
227	129.2	39.37	N64E	67S	154	0
228	129.5	39.47	N86E	59N	356	1
229	129.6	39.51	N57E	35NW	327	2
230	130.3	39.70	N89E	64NW	359	0
231	130.4	39.73	N48W	40SW	222	1
232	130.4	39.75	N23E	24W	293	1
233	131.4	40.04	N76E	35N	346	2
234	132.0	40.23	N73E	51N	343	0
235	132.0	40.25	N63E	64N	333	0

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
236	132.1	40.25	N74E	79S	164	0
237	132.9	40.51	N50E	27NW	320	1
238	133.5	40.70	N2W	41W	268	2
239	134.1	40.86	N71E	62N	341	2
240	134.1	40.89	N9W	56W	261	1
241	134.6	41.03	N89E	47S	179	0
242	135.8	41.40	N89E	48N	359	1
243	136.4	41.58	N82E	53N	352	1
244	136.7	41.67	N83W	58N	7	1
245	137.4	41.87	N87W	68N	3	1
246	137.7	41.97	N12W	47W	258	0
247	137.9	42.04	N82W	35N	8	0
248	138.2	42.11	N83W	70N	7	0
249	139.0	42.35	N74E	57N	344	0
250	139.5	42.51	N63E	73N	333	1
251	139.6	42.54	N71E	59N	341	1
252	140.4	42.79	N86W	69N	4	0
253	140.4	42.80	N6E	40E	96	1
254	141.2	43.02	N65W	29S	205	1
255	141.7	43.18	N69E	66S	159	0
256	141.7	43.20	N64W	80N	26	0
257	142.1	43.31	N17E	41E	107	1
258	142.2	43.36	N12W	55E	78	1
259	142.8	43.51	NS	51W	270	2
260	143.3	43.69	N68E	76N	338	0
261	143.4	43.71	N33E	37NW	303	1
262	144.6	44.07	N39W	14SW	231	1
263	144.6	44.07	N53E	67NW	323	1
264	144.8	44.13	N77W	31S	193	2
265	145.2	44.25	N52E	25NW	322	1
266	145.2	44.26	N45W	79SW	225	1
267	145.3	44.30	N82E	43N	352	1
268	145.5	44.34	NS	69E	90	1
269	145.7	44.41	N23E	32E	113	1
270	147.0	44.80	N38E	66NW	308	2
271	147.5	44.95	N15E	18W	285	0
272	147.9	45.09	N44E	64NW	314	0
273	148.4	45.22	N70E	58S	160	0
274	148.6	45.30	N68E	67N	338	0
275	149.1	45.46	N75E	54S	165	0
276	149.3	45.52	N38E	59NW	308	0
277	149.7	45.61	N14E	50E	104	1
278	149.7	45.64	N43E	39NW	313	0
279	150.4	45.84	N60E	70S	150	0
280	151.1	46.07	N75W	42S	195	1
281	151.5	46.17	N81E	32N	351	1
282	151.8	46.28	N41E	33NW	311	2

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
283	152.3	46.42	N20E	38W	290	0
284	152.5	46.48	N40W	24E	70	0
285	152.6	46.52	N33E	13SE	123	1
286	153.5	46.79	N6W	32W	264	1
287	155.3	47.33	N9E	56W	279	2
288	156.0	47.56	N24E	79W	294	1
289	156.6	47.72	N33E	22SE	123	1
290	157.1	47.88	N40E	17SE	130	2
291	157.8	48.08	N48E	26SE	138	2
292	157.8	48.09	N76W	21S	194	1
293	158.3	48.25	N75E	18S	165	0
294	158.3	48.26	N65E	61S	155	0
295	158.7	48.36	N9W	52W	261	0
296	158.8	48.42	N26W	14E	64	1
297	158.9	48.44	N26E	13E	116	2
298	159.3	48.55	N19E	13E	109	2
299	159.6	48.65	N47E	75SE	137	1
300	159.8	48.72	N19E	42W	289	1
301	160.0	48.76	N32E	5SE	122	1
302	160.3	48.86	N12E	46W	282	1
303	160.6	48.94	N6E	16E	96	1
304	161.1	49.10	N24E	46E	114	1
305	161.2	49.12	N38E	26NW	308	0
306	161.7	49.30	N43W	9NE	47	2
307	161.8	49.32	N85E	58N	355	1
308	161.9	49.34	N37E	73SE	127	1
309	163.2	49.75	N8W	41W	262	0
310	163.5	49.84	N62E	38N	332	2
311	163.8	49.93	N33E	37NW	303	1
312	164.0	49.98	N32W	8NE	58	2
313	164.2	50.04	N63E	57N	333	1
314	164.7	50.20	N16W	22E	74	0
315	165.2	50.35	N6W	10E	84	1
316	165.2	50.36	N13E	57W	283	2
317	166.0	50.59	N45E	48NW	315	0
318	166.7	50.80	N37E	79NW	307	0
319	166.8	50.83	N3W	40W	267	0
320	166.9	50.86	N75E	62N	345	1
321	167.0	50.89	N64E	38S	154	1
322	168.2	51.26	N46W	56NE	44	1
323	168.6	51.40	N82E	27N	352	0
324	169.3	51.59	N84E	55N	354	1
325	170.8	52.06	N33E	64NW	303	1
326	171.3	52.22	N73E	59N	343	1
327	171.7	52.34	N41E	39SE	131	1
328	172.2	52.48	N54E	23NW	324	1
329	172.5	52.57	N85E	46N	355	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
330	172.9	52.70	N52E	30NW	322	0
331	173.4	52.85	N43E	48NW	313	0
332	173.5	52.89	N32E	21NW	302	1
333	173.7	52.93	N81E	66N	351	1
334	174.0	53.03	N63E	30N	333	0
335	174.7	53.24	N56E	45NW	326	1
336	174.7	53.26	N53E	32NW	323	1
337	175.0	53.35	N55E	23NW	325	0
338	175.6	53.54	N46E	37SE	136	0
339	175.7	53.55	N39E	43NW	309	0
340	176.3	53.73	N6E	46W	276	0
341	177.2	54.01	N13E	18E	103	2
342	177.4	54.07	N12E	30W	282	1
343	177.4	54.08	N37E	65NW	307	1
344	178.2	54.31	N45E	33NW	315	1
345	178.3	54.35	N46E	25NW	316	0
346	178.8	54.51	N47E	26NW	317	1
347	179.1	54.60	N7E	2W	277	0
348	179.2	54.63	N25E	58E	115	0
349	179.9	54.83	N21E	45W	291	1
350	179.9	54.84	N5E	59W	275	1
351	180.4	54.99	N66E	59N	336	0
352	180.9	55.14	N34E	45NW	304	0
353	181.1	55.21	N46E	36NW	316	0
354	181.3	55.25	N2E	66E	92	0
355	181.3	55.25	N61E	50N	331	0
356	181.3	55.27	N57E	40NW	327	0
357	181.5	55.33	N42E	55NW	312	0
358	181.9	55.44	N45E	16SE	135	1
359	182.2	55.52	N39E	9SE	129	1
360	182.3	55.56	N63E	37N	333	1
361	182.5	55.63	N30E	69NW	300	1
362	182.5	55.64	N37E	32NW	307	1
363	183.3	55.87	N12W	38W	258	1
364	183.4	55.89	N2W	26E	88	0
365	183.8	56.01	N18E	12E	108	1
366	184.5	56.25	N/A	Vert.	N/A	3
367	188.3	57.40	N9W	23W	261	0
368	188.5	57.44	N66E	67N	336	1
369	189.6	57.79	N64E	75N	334	0
370	190.8	58.16	N58E	67SE	148	0
371	191.6	58.40	N11E	11E	101	1
372	191.6	58.41	N3W	79W	267	0
373	192.0	58.51	N46E	33NW	316	2
374	192.9	58.78	N39E	56NW	309	2
375	193.4	58.94	N81W	65N	9	1
376	194.2	59.21	N29E	47W	299	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
377	194.3	59.23	N67E	76N	337	1
378	195.4	59.55	N32E	34NW	302	0
379	195.6	59.63	N41E	43NW	311	1
380	196.4	59.88	N29E	46W	299	0
381	196.7	59.97	N25E	67W	295	0
382	196.8	60.00	N4E	26W	274	0
383	197.3	60.14	N38E	41NW	308	0
384	197.7	60.27	N37E	38NW	307	2
385	197.8	60.28	N57E	68NW	327	2
386	198.5	60.52	N85E	75N	355	1
387	198.7	60.57	N32E	66SE	122	1
388	199.2	60.70	N85E	76N	355	1
389	199.3	60.76	N53E	55SE	143	2
390	200.2	61.02	N87W	67N	3	0
391	200.4	61.09	N56W	13NE	34	1
392	200.5	61.12	N82E	36N	352	1
393	201.2	61.32	N63E	28N	333	1
394	201.8	61.52	N84E	48N	354	0
395	201.9	61.54	N51W	64NE	39	1
396	202.5	61.73	N71E	51N	341	1
397	202.7	61.78	N28W	64E	62	1
398	202.7	61.79	N21W	80E	69	1
399	203.1	61.91	N55E	61NW	325	0
400	204.3	62.26	N46E	40NW	316	2
401	204.3	62.26	N63W	62N	27	0
402	204.4	62.29	N27W	52E	63	0
403	204.6	62.35	N36E	32NW	306	1
404	204.8	62.41	N41E	19NW	311	2
405	205.0	62.48	N39E	40NW	309	2
406	205.1	62.50	N87E	28N	357	1
407	205.3	62.57	N77E	78N	347	0
408	206.2	62.85	N33W	41NE	57	2
409	206.2	62.86	N58E	35NW	328	1
410	206.3	62.89	N73E	71N	343	1
411	207.0	63.08	N34E	12NW	304	2
412	207.4	63.20	N86E	65N	356	0
413	207.5	63.24	N71W	5N	19	2
414	207.7	63.31	N30W	30SW	240	1
415	207.7	63.32	N48E	65NW	318	0
416	207.9	63.36	N81E	6N	351	1
417	208.3	63.49	N64E	63N	334	2
418	209.8	63.94	N55E	60NW	325	0
419	210.5	64.18	N53E	71NW	323	1
420	211.1	64.35	N61E	63N	331	0
421	211.7	64.53	N25E	60W	295	2
422	212.4	64.75	N14E	46W	284	2
423	212.7	64.85	N28E	43W	298	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
424	212.9	64.89	N26E	40W	296	1
425	213.2	64.97	N40E	47NW	310	1
426	213.3	65.02	N33E	64NW	303	1
427	214.4	65.34	N47E	29NW	317	1
428	214.5	65.38	N72E	47N	342	1
429	215.2	65.60	N48E	72NW	318	1
430	215.7	65.75	N14E	47E	104	1
431	215.9	65.80	N14E	29W	284	0
432	216.1	65.87	N24E	44W	294	1
433	217.0	66.13	N88E	48N	358	1
434	217.0	66.14	N30E	55NW	300	2
435	217.2	66.21	N34E	38NW	304	2
436	217.5	66.29	N36E	34NW	306	1
437	217.9	66.42	N36E	30NW	306	2
438	218.0	66.46	N52E	45NW	322	1
439	218.6	66.64	N18E	44W	288	2
440	218.9	66.72	N29E	46W	299	2
441	219.3	66.83	N33E	42NW	303	2
442	219.8	66.99	N28E	47W	298	1
443	220.0	67.04	N44W	70SW	226	1
444	220.0	67.06	N40E	41NW	310	1
445	220.2	67.13	N31E	40NW	301	2
446	220.4	67.17	N26E	40W	296	1
447	221.1	67.40	N39E	46NW	309	1
448	221.4	67.48	N44E	43NW	314	1
449	221.6	67.55	N29E	60E	119	1
450	222.0	67.66	N26E	27W	296	2
451	222.2	67.73	N23E	29W	293	1
452	222.7	67.87	N35E	60NW	305	1
453	222.7	67.89	N10E	41W	280	1
454	223.5	68.12	N59E	32NW	329	2
455	224.0	68.28	N38E	49NW	308	2
456	224.2	68.35	N35E	48NW	305	1
457	224.4	68.39	N32E	29NW	302	1
458	224.4	68.40	N2W	47E	88	1
459	224.6	68.46	N25W	45E	65	1
460	225.1	68.60	N72E	55N	342	1
461	225.4	68.70	N71E	23N	341	2
462	225.7	68.80	N53E	40NW	323	1
463	226.5	69.03	N45E	32NW	315	0
464	227.3	69.29	N71E	78N	341	2
465	228.6	69.69	N76E	83N	346	1
466	229.4	69.91	N32E	37NW	302	1
467	229.9	70.07	N3W	16E	87	2
468	230.5	70.24	N30W	7SW	240	0
469	230.5	70.27	N27E	64W	297	0
470	231.0	70.40	N22E	70E	112	1

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
471	232.0	70.70	N73E	51S	163	1
472	232.0	70.72	N5E	27E	95	1
473	232.4	70.84	N58E	54NW	328	2
474	233.0	71.01	N15E	77E	105	0
475	233.2	71.07	N1E	44E	91	2
476	233.8	71.26	N49E	32NW	319	0
477	234.5	71.49	N31E	66SE	121	1
478	234.6	71.52	N64E	25N	334	2
479	236.7	72.15	N9E	55E	99	2
480	236.8	72.16	N2E	48E	92	0
481	237.2	72.31	N87E	35N	357	0
482	238.1	72.56	N58E	36NW	328	1
483	238.2	72.59	N87E	79N	357	0
484	238.7	72.75	N56E	46NW	326	1
485	239.6	73.03	N53E	72NW	323	1
486	239.7	73.06	N17W	27E	73	2
487	240.2	73.21	N47E	51NW	317	1
488	240.7	73.37	N13E	73E	103	1
489	241.3	73.54	N39E	57NW	309	1
490	242.5	73.91	N31E	54NW	301	2
491	242.2	73.82	N47E	56NW	317	1
492	242.5	73.93	N72E	46N	342	0
493	242.9	74.02	N83E	44N	353	0
494	243.1	74.08	N8E	28E	98	2
495	243.5	74.21	N18E	43E	108	1
496	243.8	74.31	N71E	10N	341	1
497	244.1	74.40	N44E	48NW	314	2
498	244.3	74.47	N27E	26E	117	2
499	244.6	74.55	N31E	56NW	301	1
500	245.0	74.67	N70E	57N	340	1
501	245.6	74.86	N88E	68N	358	0
502	245.7	74.90	N51W	30NE	39	1
503	246.9	75.25	N46E	46NW	316	0
504	247.0	75.30	N/A	Vert.	N/A	1
505	247.1	75.30	N17E	71E	107	0
506	249.4	76.00	N31E	82NW	301	1
507	249.4	76.02	N77W	29N	13	0
508	249.9	76.18	N50E	56NW	320	0
509	250.4	76.32	N86W	23N	4	1
510	251.0	76.49	N1E	13E	91	2
511	251.8	76.75	N74E	43N	344	1
512	252.0	76.82	N88E	51N	358	0
513	253.1	77.13	M87E	38N	357	1
514	254.5	77.59	M64E	28N	334	2
515	254.9	77.68	M58E	47NW	328	1
516	255.1	77.75	N68E	65N	338	2
517	255.7	77.93	N62E	40N	332	2

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
518	257.8	78.58	N61E	44N	331	1
519	257.9	78.61	N88E	58S	178	2
520	258.6	78.81	N59E	66NW	329	2
521	260.1	79.28	N76E	41N	346	0
522	260.4	79.36	N33E	47SE	123	2
523	261.1	79.57	N29W	17E	61	2
524	261.2	79.60	N46W	72SW	224	0
525	261.6	79.72	N85E	32N	355	2
526	261.6	79.73	N47E	22SE	137	2
527	262.0	79.86	N40E	46NW	310	1
528	262.5	80.02	N62E	30N	332	1
529	262.7	80.08	N64E	24N	334	1
530	263.1	80.21	N48E	59NW	318	3
531	263.2	80.22	N4E	21E	94	1
532	264.1	80.50	N9E	80E	99	1
533	264.3	80.55	N58W	43NE	32	1
534	264.8	80.70	N2E	75W	272	1
535	265.7	80.98	N20E	19E	110	3
536	266.4	81.19	N53E	57NW	323	1
537	266.8	81.31	N3E	34E	93	1
538	267.9	81.64	N54E	51NW	324	1
539	267.9	81.64	N33E	58SE	123	2
540	269.0	82.00	N70W	34N	20	1
541	270.2	82.35	N31W	38NE	59	2
542	270.3	82.39	N43W	39SW	236	1
543	270.9	82.58	N58W	83NW	328	1
544	271.6	82.78	N19W	43W	251	1
545	272.1	82.94	N68E	76W	338	2
546	272.4	83.03	N51W	10NE	39	2
547	273.1	83.24	N88W	37N	2	2
548	275.8	84.06	N39E	53NW	309	1
549	276.8	84.38	N13E	26E	103	3
550	276.9	84.38	N41W	37NE	49	2
551	277.6	84.60	N4E	25W	274	1
552	277.9	84.71	N75E	70S	165	0
553	278.2	84.80	N30E	27NW	300	1
554	279.4	85.15	N72E	51N	342	1
555	280.7	85.57	N82W	42N	8	1
556	280.8	85.60	N79W	27N	11	1
557	281.1	85.69	N63W	52N	27	2
558	282.6	86.15	N82W	50N	8	2
559	282.7	86.16	N34E	15SE	124	2
560	282.9	86.23	N89E	52S	179	1
561	283.9	86.53	N45E	16NW	315	1
562	284.2	86.62	N40E	30NW	310	2
563	284.9	86.84	N34E	39NW	304	2
564	285.8	87.12	N19E	28E	109	0

All directions are with respect to magnetic north.

FIGURE GLA-8: BIPS FRACTURE TABLE FOR WELL GLA-8, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
565	287.1	87.51	N17E	59W	287	2
566	287.3	87.57	N21E	76W	291	1
567	289.9	88.35	N36E	55NW	306	1
568	290.6	88.57	N17E	17E	107	1
569	290.9	88.67	N81E	24S	171	2
570	292.5	89.16	N66E	52N	336	1
571	293.7	89.53	N73W	65N	17	2
572	294.3	89.69	N60E	52S	150	2
573	294.5	89.77	N73E	50S	163	2
574	294.8	89.85	N4E	57E	94	1
575	294.9	89.89	N50E	71NW	320	2
576	295.4	90.04	N38E	39NW	308	1
577	297.5	90.69	N50E	74SE	140	2
578	297.9	90.79	N2W	58W	268	2

All directions are with respect to magnetic north.

FIGURE GLA-9: BIPS FRACTURE TABLE FOR WELL GLA-9, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	20.3	6.20	N73E	26N	343	0
2	21.3	6.49	N10E	37E	100	0
3	22.5	6.86	N84W	28N	6	1
4	23.5	7.16	N83E	49S	173	1
5	24.2	7.38	N26W	31E	64	1
6	26.4	8.05	N81W	35N	9	1
7	28.3	8.61	N50W	41NE	40	1
8	29.0	8.85	N53W	71NE	37	1
9	30.9	9.42	N64W	32N	26	0
10	31.7	9.65	N23W	67W	247	0
11	32.1	9.79	N16W	52E	74	0
12	32.4	9.88	N4W	44E	86	0
13	33.9	10.33	N32W	51NE	58	0
14	34.6	10.55	N6W	57E	84	0
15	35.5	10.82	N25W	65W	245	0
16	36.7	11.18	N11W	52E	79	1
17	36.9	11.24	N9W	54E	81	2
18	38.9	11.87	N33W	63SW	237	1
19	40.5	12.35	N42W	67SW	228	2
20	41.3	12.59	N57E	14SE	147	0
21	41.8	12.75	N86E	40N	356	0
22	42.2	12.88	N74E	24N	344	1
23	43.6	13.28	N66E	75S	156	1
24	43.6	13.29	N32W	54SW	238	1
25	44.1	13.45	N59W	15NE	31	1
26	44.6	13.60	N73W	15S	197	0
27	47.1	14.36	N49E	25NW	319	2
28	48.2	14.70	N82W	59S	188	1
29	49.4	15.06	N81E	36N	351	2
30	50.9	15.51	N52E	71NW	322	1
31	52.5	16.02	N79W	18N	11	1
32	52.8	16.10	N83W	54S	187	1
33	54.0	16.45	N37W	72SW	233	2
34	55.6	16.93	N53W	45SW	217	2
35	56.2	17.14	N40W	64SW	230	3
36	58.1	17.72	N36W	72SW	234	1
37	59.1	18.02	N37W	75SW	233	1
38	60.1	18.32	N83E	32N	353	2
39	60.5	18.45	N84E	36N	354	1
40	61.9	18.87	N8W	29W	262	1
41	63.1	19.24	N17W	24E	73	1
42	63.6	19.39	N26W	8E	64	1
43	65.5	19.97	N54W	24NE	36	1
44	66.9	20.39	N17E	12E	107	2
45	68.9	21.02	N39E	34NW	309	1
46	70.5	21.49	N20W	22W	250	1
47	71.8	21.88	N20W	23W	250	1

All directions are with respect to magnetic north.

FIGURE GLA-9: BIPS FRACTURE TABLE FOR WELL GLA-9, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	74.1	22.58	N30W	72NE	60	2
49	74.7	22.77	N49W	15SW	221	1
50	76.8	23.42	N31E	49NW	301	2
51	79.0	24.08	N60E	37N	330	2
52	80.5	24.54	N24W	3W	246	1
53	80.9	24.66	N52E	36SE	142	1
54	81.2	24.75	N47E	67NW	317	1
55	82.3	25.10	N20E	1W	290	1
56	83.7	25.51	N17E	7E	107	1
57	85.3	26.00	SPIRAL	FROM	DRILLING	
58	89.6	27.33	N45W	38SW	225	2
59	96.9	29.55	N28W	81E	62	1
60	98.5	30.01	N18E	12W	288	2
61	98.9	30.15	N41W	30SW	229	1
62	100.3	30.58	N49E	42NW	319	1
63	105.6	32.20	N58W	81NE	32	1
64	108.5	33.06	N87W	70N	3	1
65	109.9	33.50	N74W	63S	196	0
66	111.9	34.11	N15E	49E	105	1
67	116.5	35.49	N68E	43N	338	3
68	116.8	35.61	N67E	41N	337	2
69	117.1	35.70	N24W	56W	246	1
70	120.2	36.63	N76W	39N	14	1
71	126.0	38.41	N56E	37SE	146	0
72	127.4	38.83	N52W	66SW	218	3
73	127.8	38.96	N57W	62SW	213	1
74	128.7	39.23	N40W	58SW	230	1
75	131.7	40.16	N54W	48SW	216	1
76	138.1	42.11	N60W	10N	30	1
77	140.2	42.75	N84E	37N	354	2
78	140.8	42.93	N84W	28N	6	1
79	142.3	43.37	N10E	3E	100	2
80	143.0	43.60	N23E	62E	113	1
81	143.3	43.69	N24E	61E	114	1
82	147.8	45.06	N9E	62E	99	1
83	149.8	45.67	N37E	4NW	307	2
84	150.0	45.72	N19W	2E	71	2
85	150.6	45.91	N4W	17W	266	1
86	152.2	46.39	N10E	17W	280	1
87	155.0	47.26	N19E	56E	109	1
88	156.8	47.80	N63W	50N	27	1
89	157.0	47.86	N58W	63SW	212	1
90	158.1	48.19	N65E	39N	335	1
91	159.6	48.65	N32W	51SW	238	1
92	160.9	49.04	N84W	63N	6	1
93	161.2	49.12	N89E	51N	359	1
94	161.5	49.23	N45W	43SW	225	2

All directions are with respect to magnetic north.

FIGURE GLA-9: BIPS FRACTURE TABLE FOR WELL GLA-9, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	162.1	49.39	N85W	6N	5	1
96	164.4	50.10	N77W	2N	13	2
97	164.5	50.15	N71E	4N	341	2
98	165.5	50.44	N71W	28S	199	1
99	170.0	51.80	N4E	72W	274	1
100	170.8	52.05	N15E	75W	285	1
101	172.5	52.57	N80E	62S	170	1
102	174.0	53.03	N51W	51SW	219	2
103	175.0	53.33	N13W	36W	257	1
104	175.3	53.43	N74W	12N	16	1
105	177.1	53.97	N68W	20N	22	1
106	179.2	54.61	N29W	60W	241	3
107	179.4	54.67	N33W	56SW	237	2
108	179.8	54.79	N32W	60SW	238	3
109	180.0	54.85	N32W	65SW	238	2
110	181.3	55.26	N10W	39W	260	1
111	181.9	55.45	N23W	55W	247	2
112	182.0	55.47	N22W	59E	68	1
113	187.8	57.24	NS	14E	90	1
114	192.5	58.68	N10E	8W	280	1
115	192.8	58.78	N7W	6W	263	1
116	194.2	59.19	N22W	54E	68	1
117	194.4	59.27	N38W	44SW	232	1
118	195.2	59.49	N68W	42S	202	1
119	195.4	59.56	N22W	64E	68	1
120	195.8	59.67	N54W	5NE	36	1
121	196.1	59.77	N87W	6S	183	1
122	196.3	59.84	N75W	40N	15	1
123	197.2	60.11	N44W	54SW	226	1
124	198.1	60.38	N30E	19NW	300	1
125	198.1	60.39	N89E	10S	179	1
126	200.2	61.02	N89E	7N	359	1
127	201.0	61.27	N64E	13N	334	1
128	201.5	61.43	N58E	14NW	328	1
129	201.9	61.54	N28E	4W	298	1
130	202.3	61.65	N25E	6E	115	1
131	204.4	62.30	EW	53S	180	1
132	205.0	62.48	N71W	15S	199	1
133	205.4	62.61	N77W	43S	193	1
134	208.1	63.41	N80W	8N	10	1
135	209.1	63.74	N1W	43W	269	1
136	209.3	63.78	N11W	43W	259	1
137	209.8	63.96	N12W	29W	258	0
138	213.0	64.93	N74W	10N	16	2
139	213.3	65.02	N77E	16N	347	1
140	213.7	65.14	N47W	5NE	43	0
141	214.2	65.30	N85E	52S	175	0

All directions are with respect to magnetic north.

FIGURE GLA-9: BIPS FRACTURE TABLE FOR WELL GLA-9, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
142	214.8	65.46	N59W	17SW	211	1
143	217.5	66.31	N15W	56W	255	2
144	218.8	66.68	N80W	13S	190	1
145	221.6	67.55	N14W	65E	76	1
146	222.3	67.74	N20W	65E	70	2
147	222.8	67.92	N21W	67E	69	2
148	223.0	67.97	N68W	9S	202	1
149	223.1	67.99	N10W	71W	260	1
150	225.8	68.83	N36W	14SW	234	1
151	226.3	68.97	N78W	31N	12	1
152	228.8	69.74	N17E	61E	107	2
153	230.0	70.10	N41W	3NE	49	1
154	230.7	70.31	N31E	58NW	301	1
155	231.5	70.55	N44E	28SE	134	1
156	231.5	70.56	N55E	33NW	325	2
157	232.8	70.95	N77W	18N	13	1
158	233.0	71.03	N63E	38N	333	1
159	237.8	72.47	N89E	58S	179	1
160	238.7	72.77	N56W	16NE	34	0
161	242.0	73.77	N53W	6NE	37	2
162	244.4	74.48	N73W	2S	197	1
163	244.5	74.54	N61W	7S	209	1
164	246.3	75.08	N29E	5W	299	1
165	248.0	75.58	N38W	82SW	232	2
166	250.6	76.39	N76W	29S	194	1
167	251.0	76.49	N10W	13W	260	2
168	251.3	76.60	N66W	13S	204	1
169	252.0	76.81	N34W	3NE	56	1
170	252.8	77.07	N31W	8NE	59	1
171	252.9	77.10	N77E	1S	167	2
172	253.7	77.34	N46W	2SW	224	1
173	253.9	77.40	N1E	2E	91	2
174	255.3	77.82	N40W	76SW	230	1
175	255.7	77.93	N71E	2N	341	2
176	255.9	78.00	N1E	69E	91	1
177	258.3	78.72	N71E	24N	341	1
178	259.2	79.02	N4W	67E	86	1
179	261.3	79.65	N39W	2NE	51	2
180	262.8	80.09	N6W	68E	84	3
181	263.7	80.39	NS	49W	270	2
182	267.5	81.55	N67W	76N	23	1
183	268.6	81.87	N25W	24W	245	2
184	268.7	81.91	N25W	27W	245	3
185	271.1	82.65	N1E	59E	91	1
186	274.6	83.70	N16E	61W	286	1
187	275.4	83.94	N22W	76W	248	2
188	275.8	84.06	N20W	75W	250	2

All directions are with respect to magnetic north.

FIGURE GLA-9: BIPS FRACTURE TABLE FOR WELL GLA-9, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
189	281.4	85.78	N51W	72SW	219	1
190	282.0	85.95	N29W	6E	61	1
191	282.7	86.16	N37W	57SW	233	0
192	283.3	86.35	N3W	54E	87	1
193	284.1	86.58	N89W	52N	1	1
194	285.9	87.15	N1W	69E	89	1

All directions are with respect to magnetic north.

HYDROPHYSICAL™ LOGGING RESULTS FOR GLA-10

1.1 Ambient Fluid Electrical Conductivity and Temperature Log

On December 15, 1996 the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure GLA-10:1.

1.2 Ambient Flow Evaluation During Stabilized Well Field Conditions

For ambient flow assessment, the formation water in the wellbore was diluted with deionized water (DI) and the well was left in an undisturbed state to allow any natural flow to occur. Prior to this period and throughout all HpL™ testing, water levels were monitored and recorded. Ambient flow evaluation is reported for the period after the water surface returned to near pre-emplacement levels. A series of FEC and temperature logs was then conducted to identify changes in the fluid column associated with ambient flow. In addition to vertical flow characterization, horizontal flow was evaluated using an experimental algorithm.

On December 15, 1996, at 0940 hours (T=0.00 minutes), dilution of the fluid column was complete. Due to unknown circumstances, the logging tool was unable to pass by the pump during emplacement procedures, therefore no baseline log during the emplacement was acquired. During the 6.5 hours following dilution, multiple logs were conducted. Of these logs, 19 are presented in Figure GLA-10:2. These logs illustrate minor changes in the FEC profile throughout the interval from 50 to 90 feet. These minor changes in the FEC profiles with respect to time are associated with horizontal flow occurring at the interval from 59 to 61 feet.

A tessellated[1] chromographic summary of all downward FEC traces are presented in Figure GLA-10:3. FEC of 0 μ S/cm is represented on this figure by the dark blue color, with a spectral color progression to red as the values increase linearly to 85 μS/cm.

The data suggest that horizontal flow was occurring over the interval from 59 to 61 feet. Experimental algorithms applied to these data suggest that the fluid velocity in the wellbore for this interval was approximately 0.05 ft/day. Correcting for convergence of flow at the wellbore, this velocity equates to a specific discharge of groundwater in the aquifer of 0.02 ft/day. Please refer to Figure GLA-10:4 for the estimated horizontal velocity and specific discharge calculated for each interval. Please refer to Appendix C for a complete discussion of the methodology used to calculate these values.

[1] Referring specifically to the mosaic coloration of FEC values between traces.

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1.3 Flow Characterization During Pumping After DI Water Emplacement; GLA-10

Initial evaluation of well production indicated that the subject well had only sufficient yield to maintain the lowest measurable flow rate using surface flow meters (approximately 1.5 gpm). As such, a pump after DI water emplacement approach was applied to identify water bearing intervals and estimate hydraulic properties of these intervals (Tsang et. al. 1988, 1990 and Pedler et. al. 1989, 1990). Please refer to the Standard Operating Procedures in Appendix A for a detailed discussion.

Pumping after DI emplacement was conducted to establish the inflow locations and evaluate the interval specific inflow rates during low rate pumping. DI emplacement was performed by replacing the wellbore fluids with DI. Care was exercised during this procedure so as to minimize the volume of DI lost to the formation. After emplacement, a baseline FEC log was conducted. Immediately following the baseline log, low rate pumping of the wellbore fluids and continuous FEC logging was conducted. During the low rate pumping, water level elevations, instantaneous flow rate and total gallons pumped were recorded with respect to time. The resulting FEC logs are evaluated to identify the inflow locations and interval specific flow rate during recovery.

On January 7, 1997, at 1043 hours, replacement of the wellbore fluids with DI (emplacement) was complete. Approximately 15 gallons of DI were lost to the formation during emplacement. Prior to the installation of the pumping equipment, the ambient water level was recorded at 22.12 feet (referenced to top of protective casing). All drawdown values are referenced to this elevation. Immediately following emplacement, a baseline FEC log FEC1038 was performed. At 1050 hours (T=0.00 minutes, elapsed time of testing), low rate pumping of the wellbore fluids was initiated. During the 4.92 hours of testing, the time average extraction flow rate was 1.67 gpm. During this period, a maximum drawdown of 9.3 feet was observed. Refer to Figure GLA-10:5 for the pumping and drawdown data. During the 4.92 hours of pumping, 30 downward FEC logs were collected and are presented in Figure GLA-10:6. These logs clearly illustrate specific intervals of dramatic increase in FEC with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water bearing interval. The data presented in Figure GLA-10:6 suggest the presence of a continuous hydraulically conductive zone of multiple intervals from 51-87 feet. Numerical modeling of the reported field data was performed using code BORE (Hale and Tsang, 1988, Pedler et. al. 1990, Tsang et.al. 1990). This modeling was performed to estimate the rate of inflow for each identified hydraulically conductive interval during pumping. The results of the modeling and analysis are presented in Figure GLA-10:7 and Table GLA-10:1.

1.4 Sensitivity to Inflows

Given the conditions observed in the well during our testing, the HpL™ technique would have detected any inflow greater than 0.01 gpm with FEC of 1000 µS/cm, during the testing described in this report.

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FIGURE GLA-10:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-10.

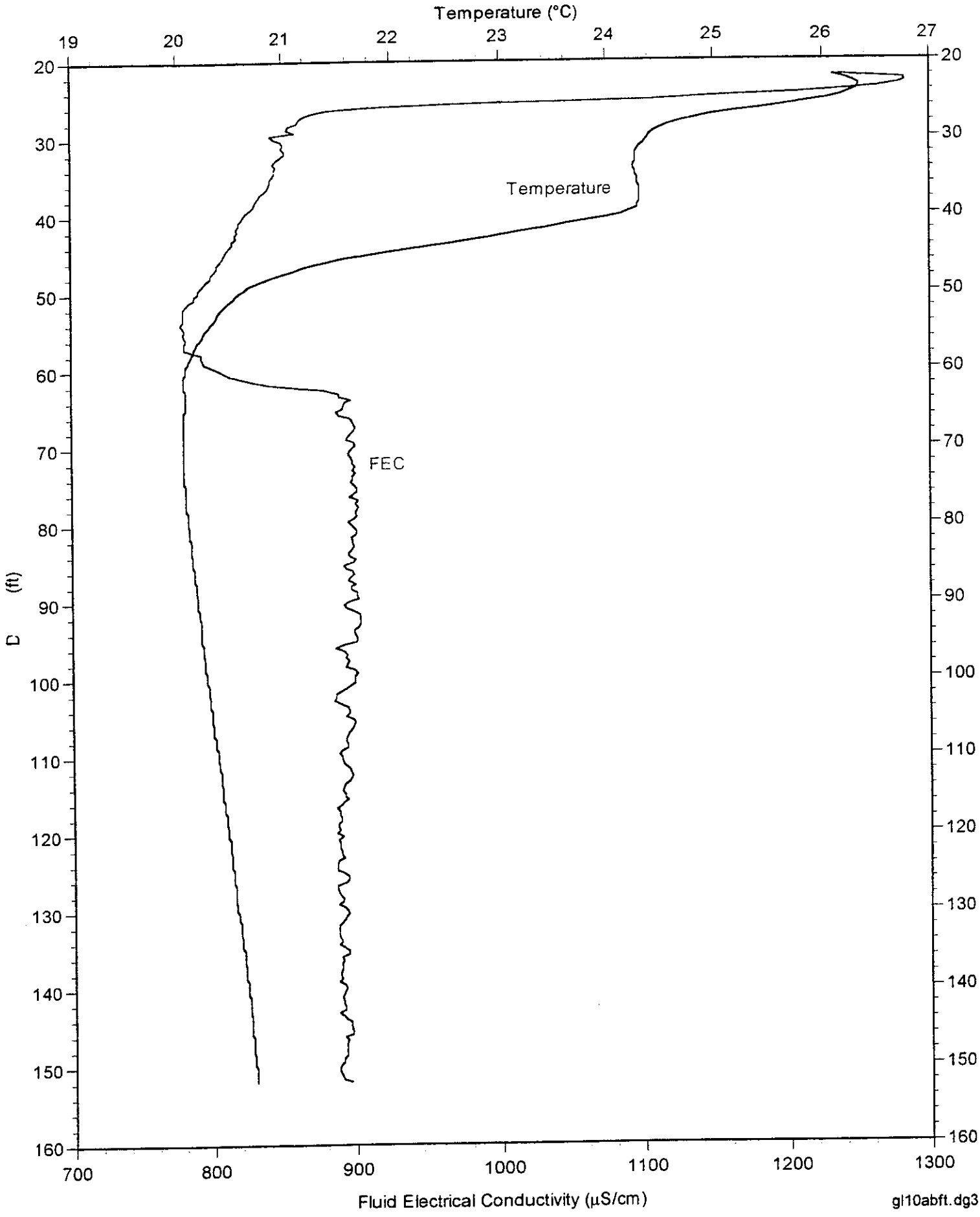

FIGURE GLA-10:2. SUMMARY OF HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL GLA-10.

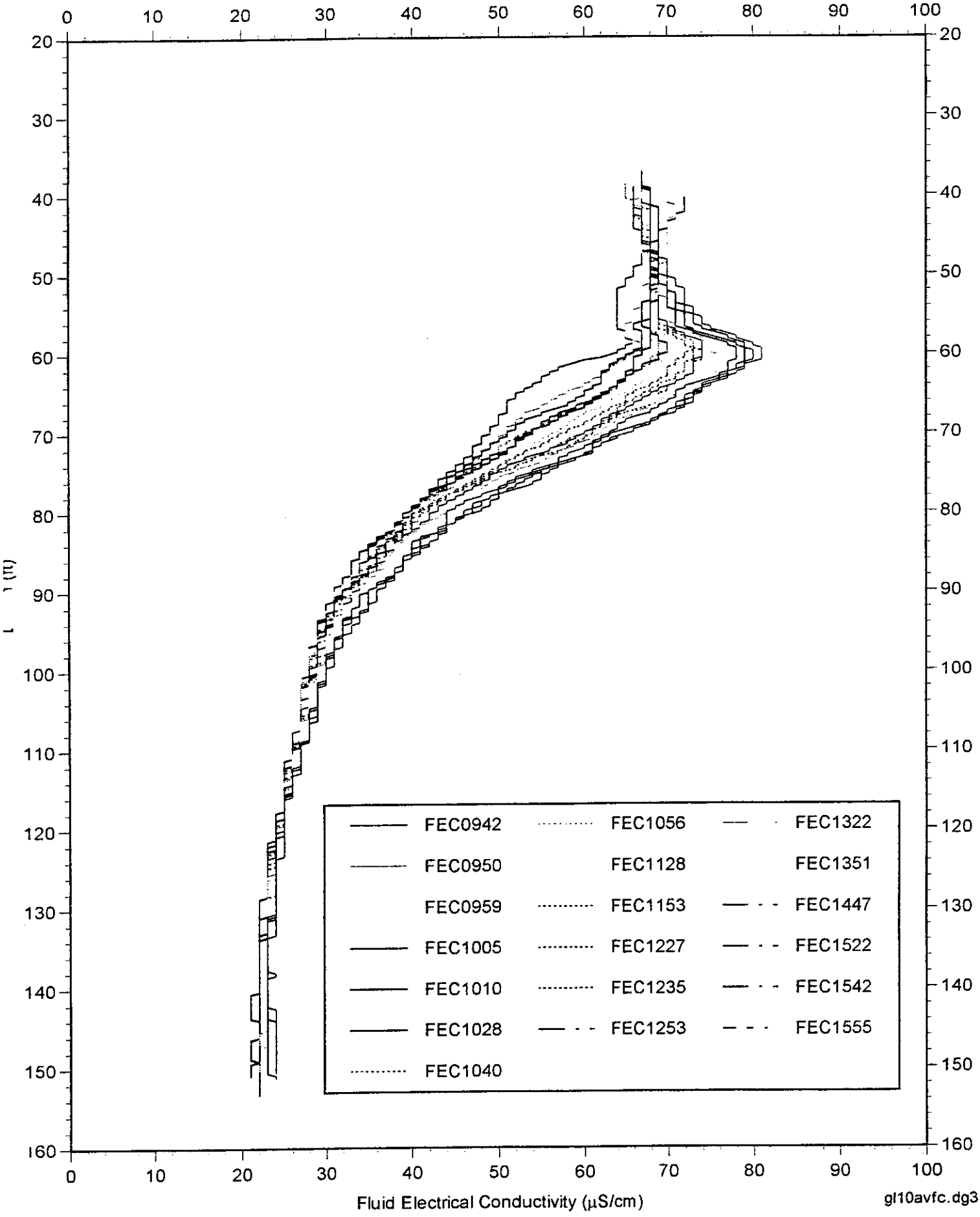

FIGURE GLA-10:3. CHROMOGRAPHIC TESSELLATION OF FEC LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON; WELL: GLA-10.

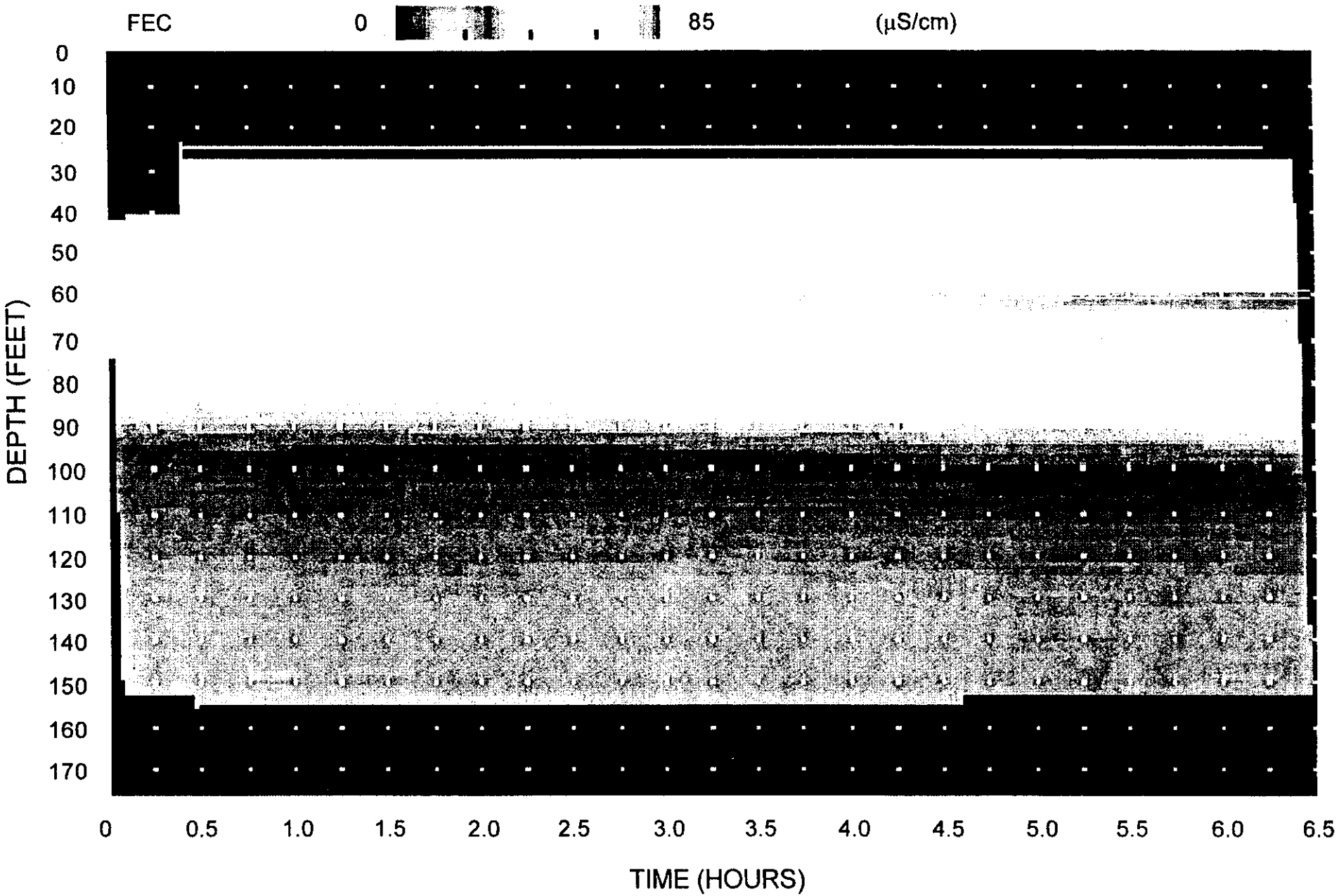

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FIGURE GLA-10:4. HORIZONTAL FLOW ANALYSIS DURING AMBIENT CONDITIONS; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-10.

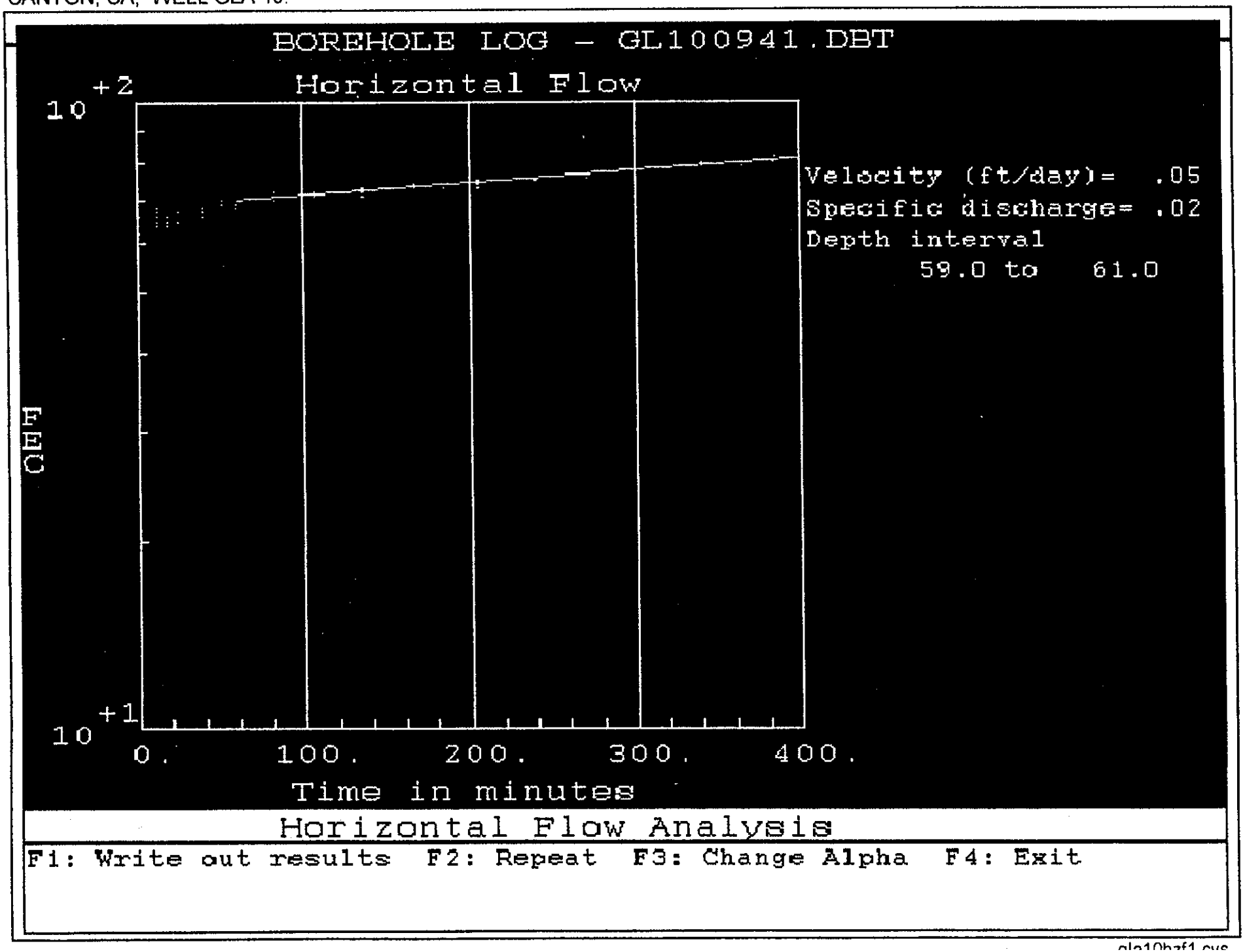


FIGURE GLA-10:5. PUMP AND DRAWDOWN DATA FOR 1.5 GPM PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-10.

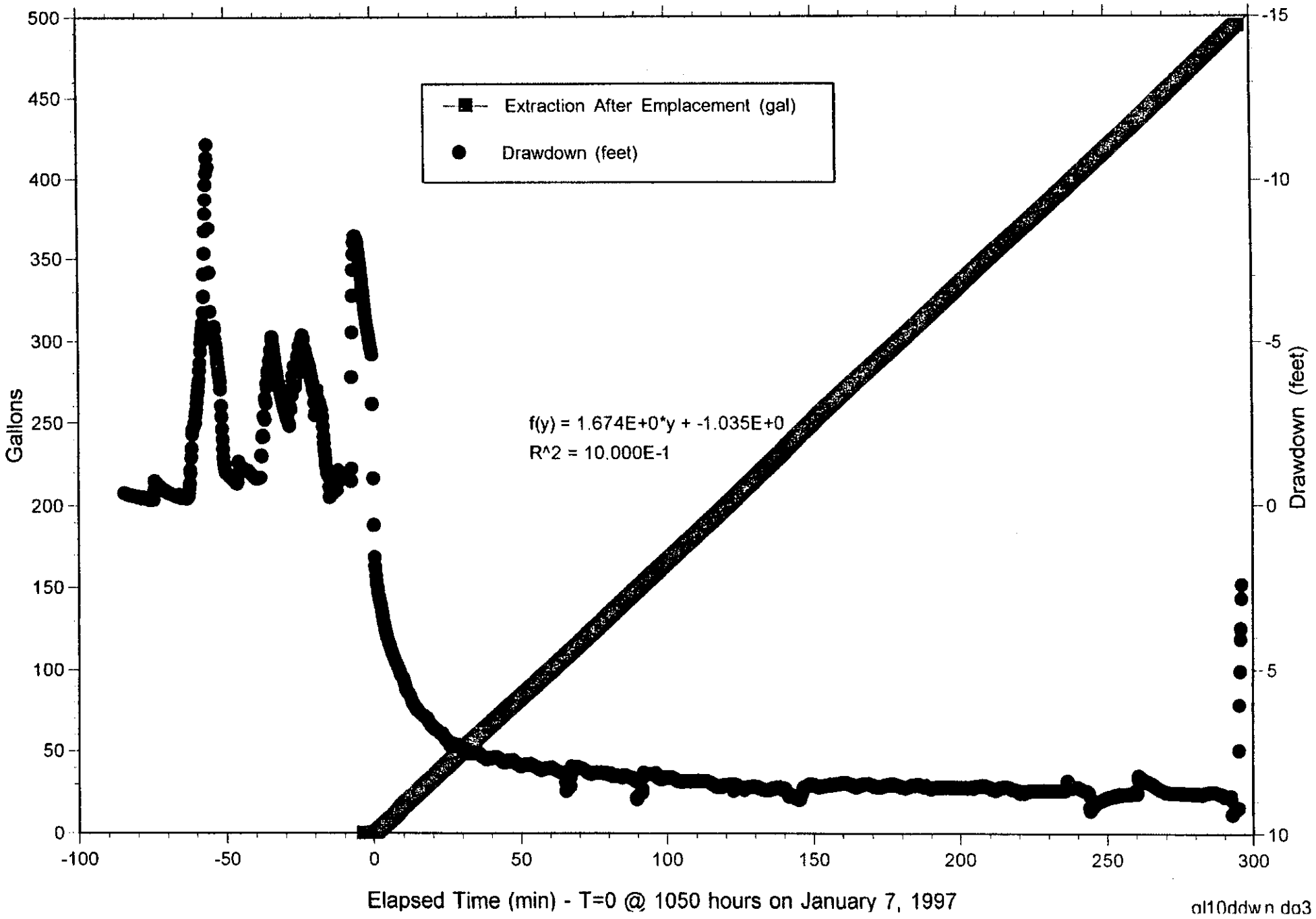


FIGURE GLA-10:6. SUMMARY OF HYDROPHYSICAL LOGS FOR PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-10.

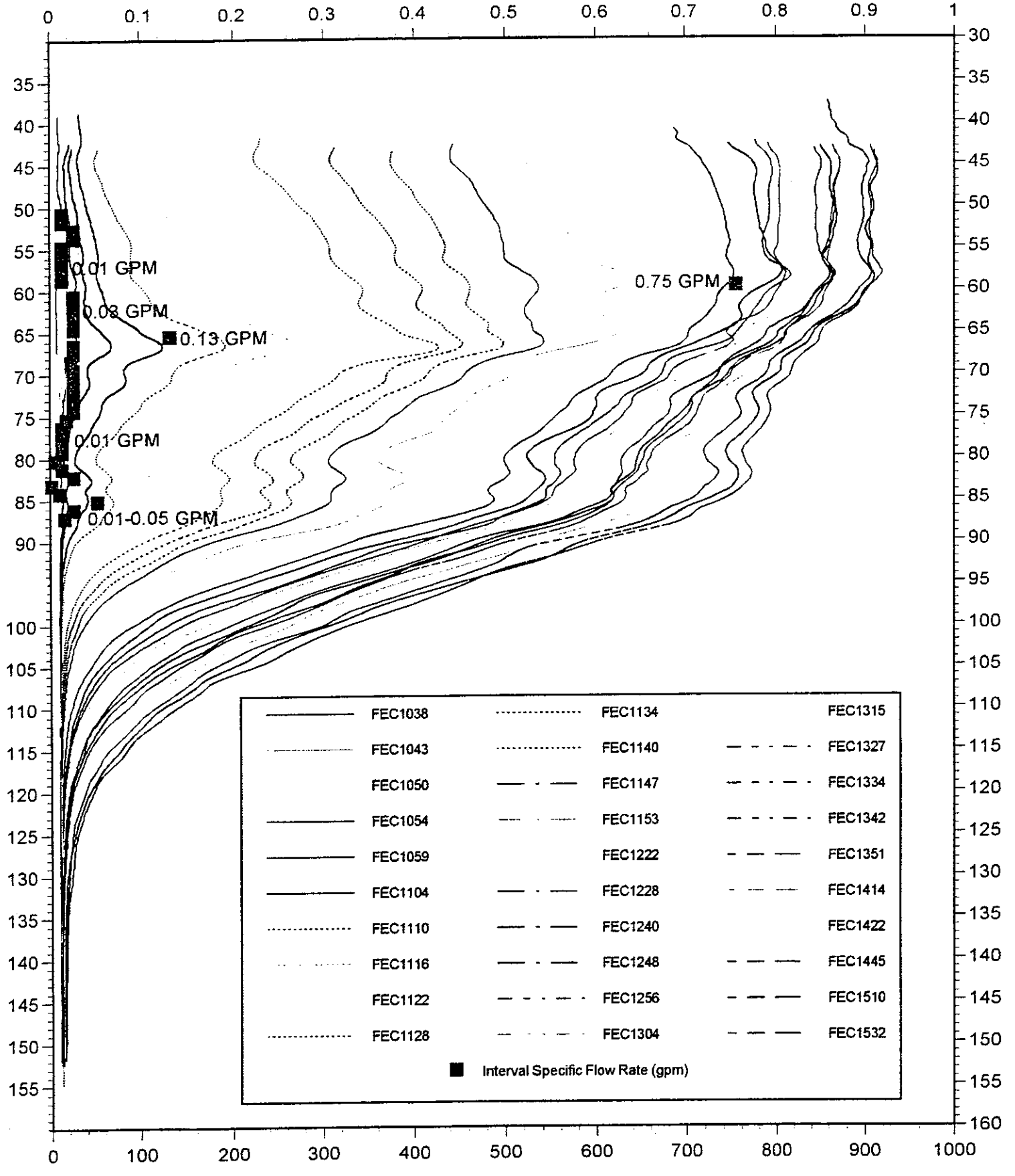
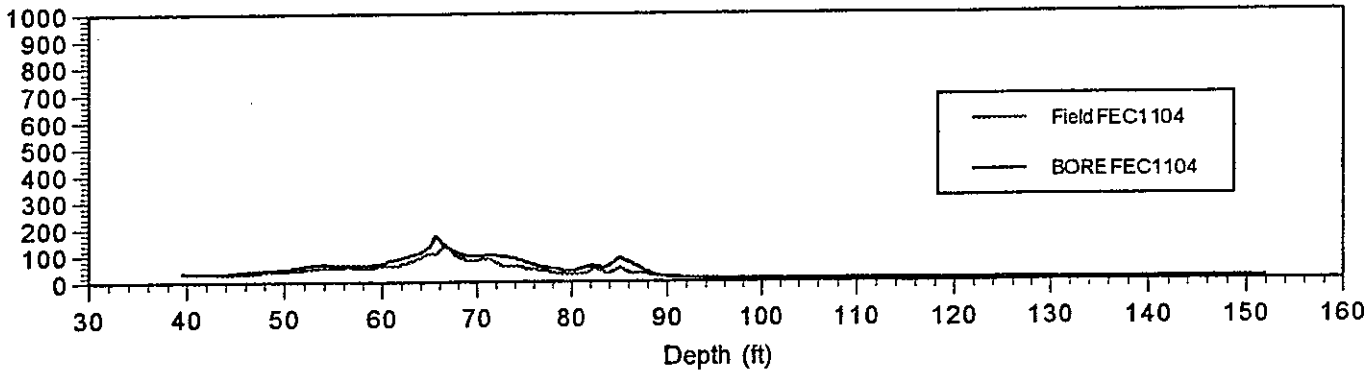
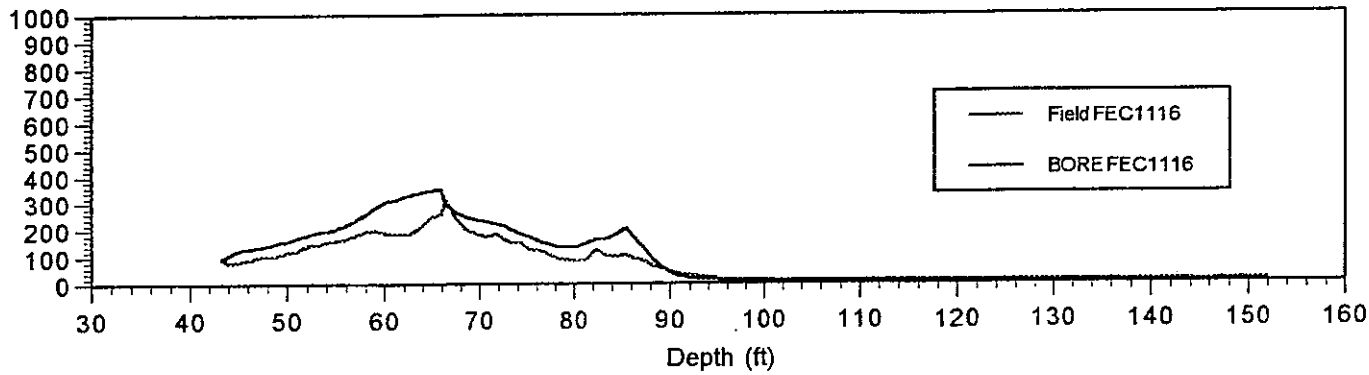
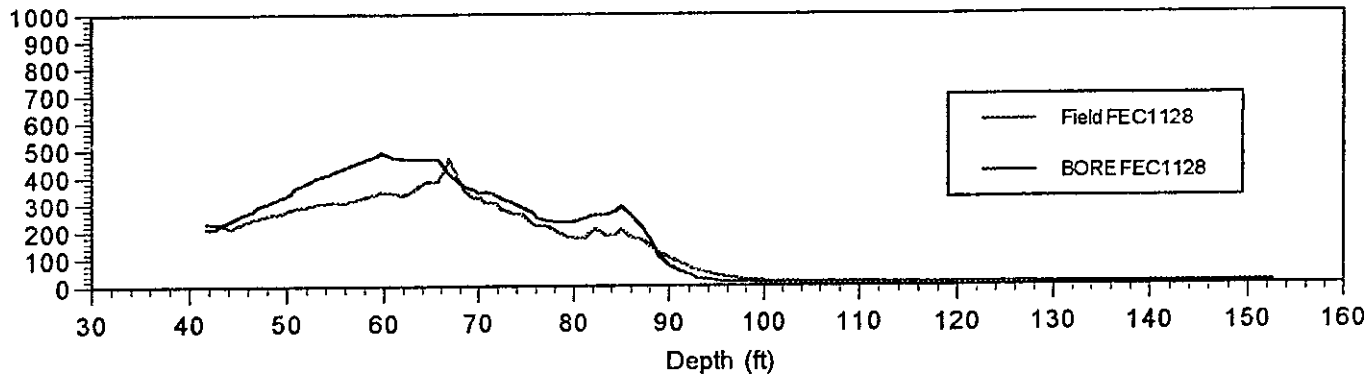
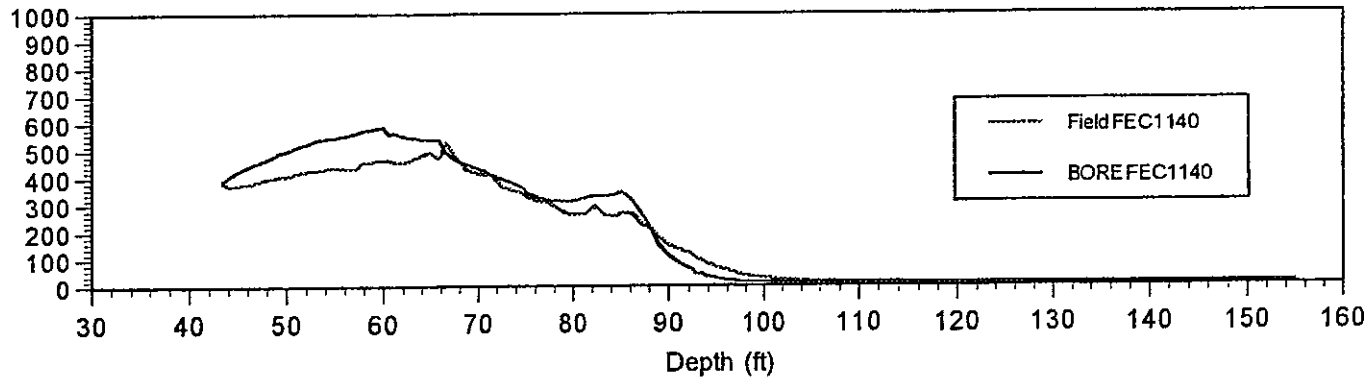


FIGURE GLA-10:7. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR 1.7 GPM PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-10.



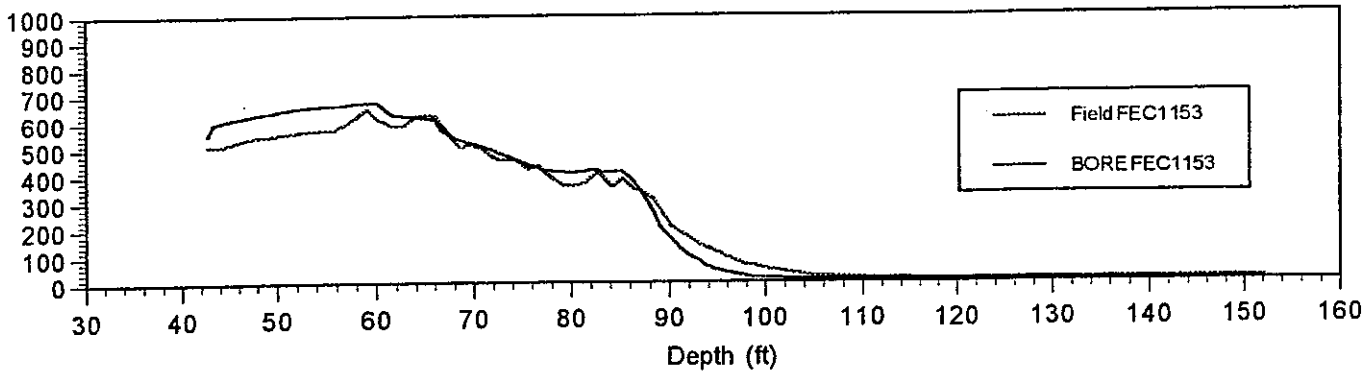


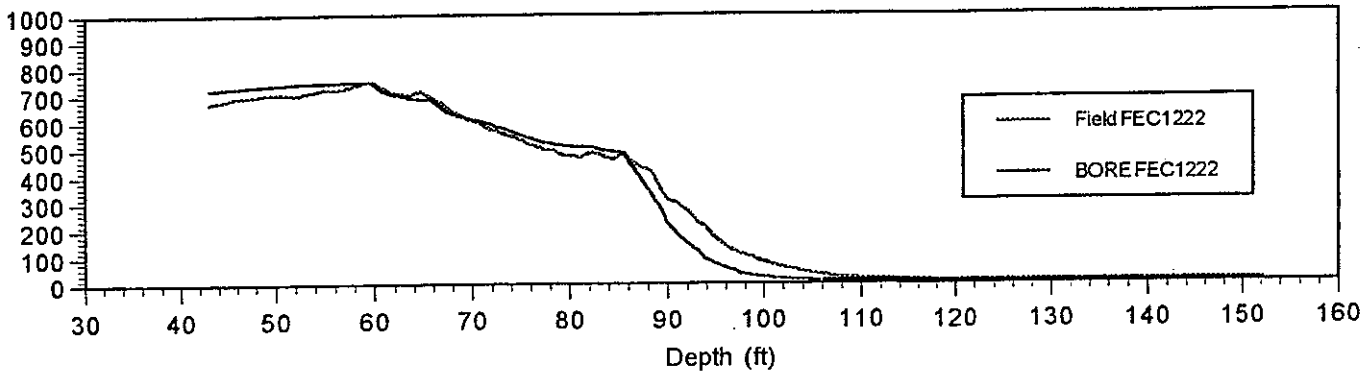


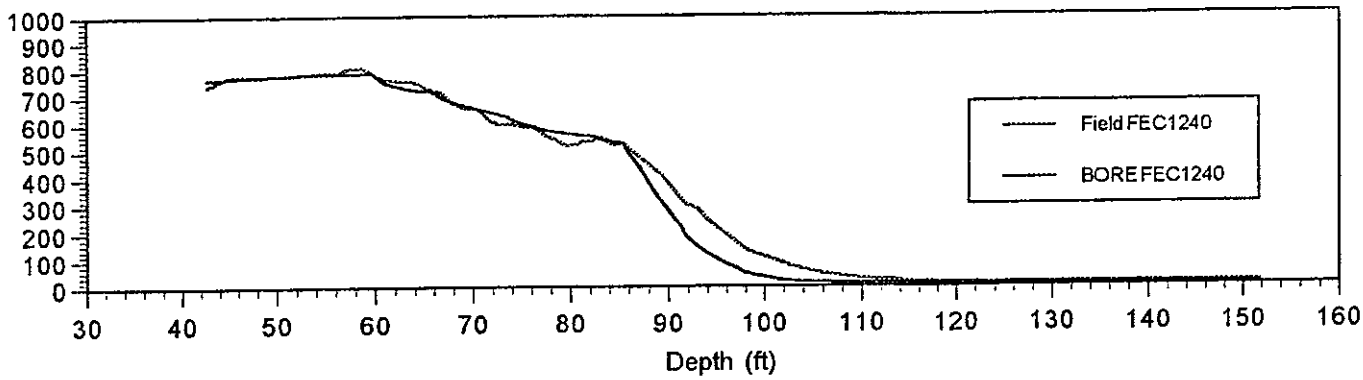


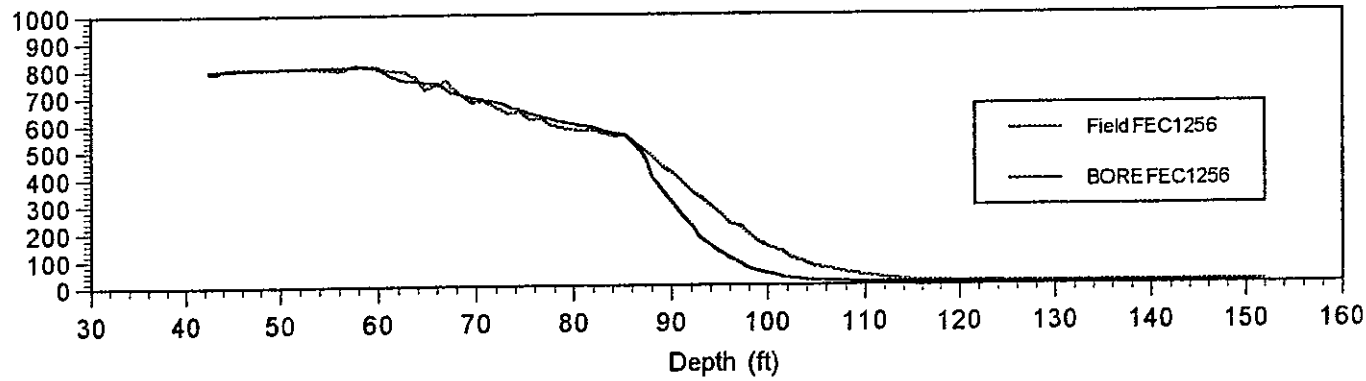
gl10comp.dg3

FIGURE GLA-10:7. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR 1.7 GPM PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-10.



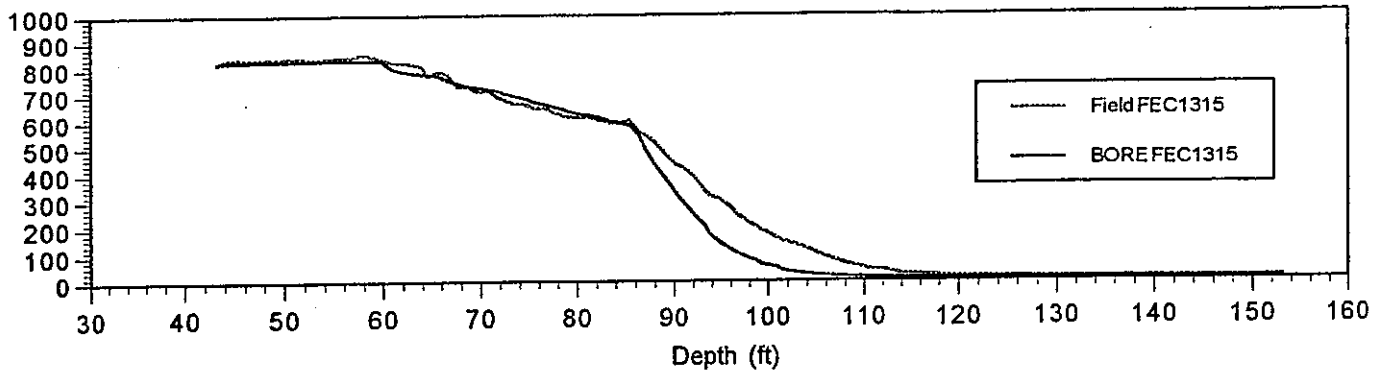


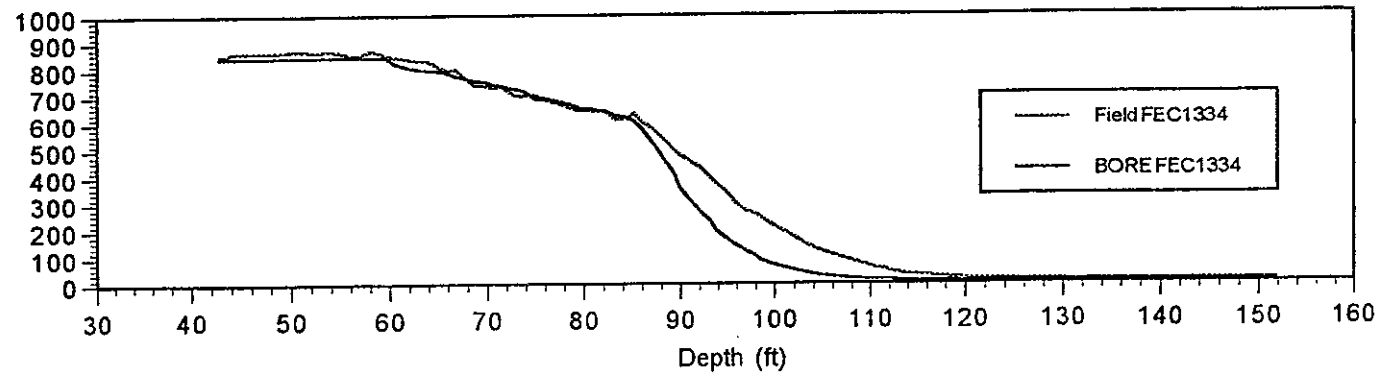


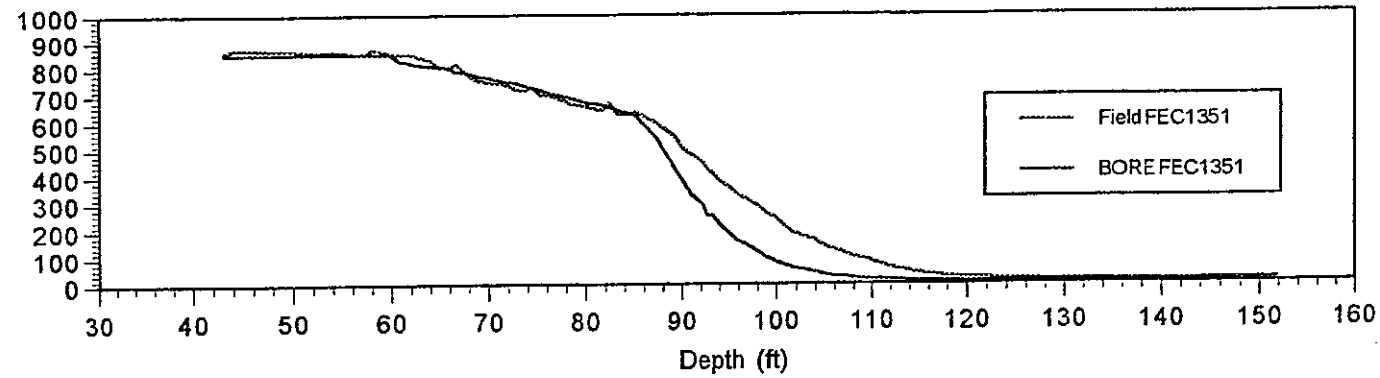


gl10comp.dg3

FIGURE GLA-10:7. FIELD FLUID ELECTRICAL CONDUCTIVITY VS. CODE BORE RESULTS FOR 1.7 GPM PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL: GLA-10.







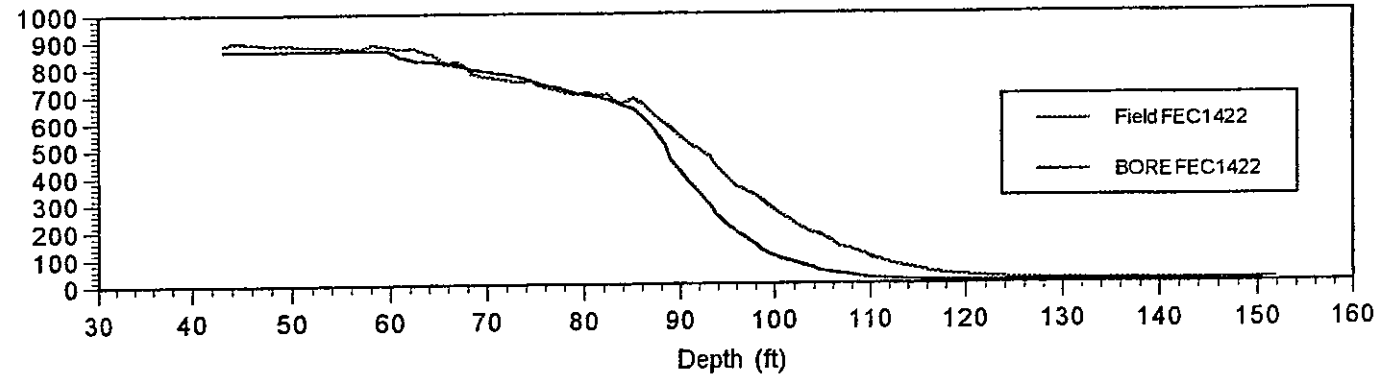


TABLE GLA-10:1. CODE BORE RESULTS FOR 1.6 GPM PUMP AFTER EMPLACEMENT TEST; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-10.

Depth (meters)	Depth (feet)	Flow Rate (m^3/s)	Flow Rate (lpm)	Flow Rate (gpm)	FEC (gram/l)	FEC (µS/cm)
15.5	50.85	8.33E-07	0.05	0.01	0.438	909
15.8	51.84	8.33E-07	0.05	0.01	0.438	909
16.1	52.82	1.67E-06	0.10	0.03	0.438	909
16.4	53.81	1.67E-06	0.10	0.03	0.438	909
16.7	54.79	8.33E-07	0.05	0.01	0.438	909
17.0	55.77	8.33E-07	0.05	0.01	0.438	909
17.3	56.76	8.33E-07	0.05	0.01	0.438	909
17.6	57.74	8.33E-07	0.05	0.01	0.438	909
17.9	58.73	8.33E-07	0.05	0.01	0.438	909
18.2	59.71	4.75E-05	2.86	0.75	0.438	909
18.5	60.70	1.67E-06	0.10	0.03	0.438	909
18.8	61.68	1.67E-06	0.10	0.03	0.438	909
19.1	62.66	1.67E-06	0.10	0.03	0.438	909
19.4	63.65	1.67E-06	0.10	0.03	0.438	909
19.7	64.63	1.67E-06	0.10	0.03	0.438	909
20.0	65.62	8.33E-06	0.50	0.13	0.438	909
20.3	66.60	1.67E-06	0.10	0.03	0.438	909
20.6	67.59	1.67E-06	0.10	0.03	0.438	909
20.9	68.57	1.50E-06	0.09	0.02	0.438	909
21.2	69.55	1.67E-06	0.10	0.03	0.438	909
21.5	70.54	1.67E-06	0.10	0.03	0.438	909
21.8	71.52	1.67E-06	0.10	0.03	0.438	909
22.1	72.51	1.67E-06	0.10	0.03	0.438	909
22.4	73.49	1.67E-06	0.10	0.03	0.438	909
22.7	74.48	1.67E-06	0.10	0.03	0.438	909
23.0	75.46	1.17E-06	0.07	0.02	0.438	909
23.3	76.44	8.33E-07	0.05	0.01	0.438	909
23.6	77.43	8.33E-07	0.05	0.01	0.438	909
23.9	78.41	8.33E-07	0.05	0.01	0.438	909
24.2	79.40	8.33E-07	0.05	0.01	0.438	909
24.5	80.38	3.33E-07	0.02	0.01	0.438	909
24.8	81.36	8.33E-07	0.05	0.01	0.438	909
25.1	82.35	1.67E-06	0.10	0.03	0.438	909
25.4	83.33	8.33E-08	0.01	0.00	0.438	909
25.7	84.32	6.67E-07	0.04	0.01	0.438	909
26.0	85.30	3.33E-06	0.20	0.05	0.438	909
26.3	86.29	1.67E-06	0.10	0.03	0.438	909
26.6	87.27	1.00E-06	0.06	0.02	0.438	909
TOTAL ESTIMATED FLOW RATE - BORE RESULTS =				1.62 gpm		
TOTAL OBSERVED FLOW RATE =				1.67 gpm		

FIGURE GLA-10: BIPS FRACTURE TABLE FOR WELL GLA-10, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
1	56.8	17.32	N14E	71W	284	1
2	60.4	18.40	N21E	58E	111	0
3	62.2	18.96	N17E	79W	287	0
4	63.5	19.36	N44E	32SE	134	2
5	63.9	19.48	N53E	37SE	143	1
6	64.2	19.56	N58W	12NE	32	1
7	64.2	19.58	N10E	37E	100	2
8	64.4	19.61	N12E	36E	102	0
9	64.6	19.68	N8W	10E	82	1
10	64.6	19.70	N27W	78E	63	3
11	65.3	19.91	N41E	27SE	131	0
12	66.0	20.12	N29W	13W	241	2
13	66.7	20.32	N40E	32NW	310	0
14	67.3	20.51	N15E	25E	105	1
15	68.3	20.81	N14E	47E	104	0
16	68.6	20.90	N77E	32S	167	1
17	68.9	21.01	N2E	47E	92	0
18	69.7	21.25	N15E	59W	285	0
19	69.7	21.26	N11E	66E	101	1
20	70.6	21.52	N9E	51E	99	2
21	72.2	22.00	N15W	52W	255	0
22	72.3	22.04	N25E	65W	295	0
23	72.4	22.07	N34W	32SW	236	0
24	73.1	22.28	N35W	16SW	235	0
25	73.9	22.51	N2E	42E	92	2
26	74.5	22.71	N56E	18NW	326	1
27	76.5	23.32	N22E	51W	292	0
28	79.6	24.28	N44E	62SE	134	3
29	81.0	24.70	N28E	12E	118	2
30	81.4	24.82	N39E	32SE	129	2
31	84.0	25.60	N31W	7NE	59	2
32	84.4	25.73	N75E	15S	165	2
33	85.8	26.17	N26E	62W	296	1
34	85.9	26.19	N69W	32N	21	3
35	85.9	26.19	N87E	21S	177	2
36	87.2	26.58	N80W	30S	190	0
37	87.9	26.78	NS	42E	90	1
38	88.1	26.86	N2E	43E	92	1
39	89.1	27.16	N24E	51W	294	0
40	89.2	27.20	N12W	42W	258	2
41	90.5	27.57	N26W	63E	64	2
42	90.9	27.71	N37W	49NE	53	1
43	94.2	28.70	N67W	6S	203	2
44	95.0	28.94	N13E	30W	283	0
45	95.9	29.23	N63W	21S	207	1
46	96.3	29.35	N74W	31S	196	0
47	96.9	29.52	N87W	33S	183	0

All directions are with respect to magnetic north.

FIGURE GLA-10: BIPS FRACTURE TABLE FOR WELL GLA-10, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
48	97.1	29.60	N1W	38W	269	2
49	97.3	29.65	N1E	34W	271	2
50	99.2	30.25	N17W	54W	253	2
51	100.1	30.51	N20W	63W	250	2
52	100.1	30.52	N20E	21W	290	0
53	102.0	31.10	N22W	55W	248	0
54	102.3	31.19	NS	47W	270	0
55	102.8	31.33	N10W	49W	260	2
56	103.1	31.43	N6W	40W	264	1
57	103.5	31.53	N65E	11S	155	0
58	104.1	31.74	N21E	28W	291	1
59	104.6	31.89	N30E	23NW	300	1
60	105.2	32.08	N46E	31NW	316	2
61	105.5	32.14	N38E	22NW	308	0
62	105.6	32.20	N55E	22NW	325	1
63	107.1	32.65	N52W	14NE	38	1
64	107.3	32.70	N48W	15NE	42	0
65	109.0	33.21	N72W	17N	18	2
66	110.8	33.78	N14W	23E	76	1
67	111.5	33.98	N19E	5E	109	1
68	111.7	34.05	N88W	12N	2	1
69	111.9	34.10	N88E	11N	358	0
70	112.2	34.19	N68W	14N	22	0
71	113.9	34.70	N52W	24NE	38	0
72	114.7	34.97	N34E	29SE	124	0
73	114.8	35.00	N70W	21N	20	0
74	115.0	35.06	N66W	20N	24	2
75	116.8	35.59	N80E	34N	350	1
76	118.4	36.08	N51W	17NE	39	1
77	118.8	36.20	N7E	30E	97	0
78	119.4	36.40	N30E	29SE	120	2
79	120.9	36.85	N13W	37E	77	0
80	121.6	37.05	N16W	15E	74	0
81	121.9	37.16	N23W	19E	67	1
82	123.4	37.62	N76E	24N	346	2
83	123.6	37.69	N78E	31N	348	1
84	123.9	37.76	N29W	20E	61	1
85	124.6	37.97	N44W	14NE	46	0
86	125.0	38.09	N14W	20E	76	0
87	125.2	38.15	N84W	11N	6	0
88	125.4	38.24	N64W	26N	26	0
89	126.9	38.67	N48E	42SE	138	2
90	127.5	38.86	N29E	57E	119	0
91	128.0	39.02	N32W	18NE	58	0
92	128.5	39.18	N62W	12N	28	1
93	128.6	39.21	N54E	29SE	144	1
94	129.2	39.37	N40W	10NE	50	1

All directions are with respect to magnetic north.

FIGURE GLA-10: BIPS FRACTURE TABLE FOR WELL GLA-10, GEOLOGIC ASSOCIATES; GREGORY CANYON, CA

Feature No.	Depth (feet)	Depth (meters)	Strike Direction (degrees)	Dip Angle (degrees)	Dip Direction (degrees)	Rank
95	132.7	40.45	N88E	25S	178	2
96	133.0	40.52	N85E	21S	175	1
97	134.0	40.84	N19W	45E	71	2
98	134.8	41.10	N25W	49E	65	2
99	135.5	41.29	N81W	15N	9	0
100	135.7	41.37	N6E	24E	96	0
101	135.9	41.43	N8W	13E	82	0
102	136.2	41.53	N16W	13E	74	1
103	136.9	41.71	N68W	19N	22	0
104	137.0	41.76	N73W	24N	17	2
105	137.2	41.81	N78W	34N	12	0
106	138.0	42.06	N48E	29SE	138	0
107	138.4	42.18	N72E	30S	162	0
108	138.6	42.23	N87W	15N	3	0
109	139.1	42.40	N45E	32SE	135	1
110	141.6	43.16	N21E	45E	111	1
111	141.6	43.17	N73W	29N	17	1
112	142.0	43.27	N15E	37E	105	2
113	142.0	43.30	N3E	32E	93	0
114	143.2	43.65	N3E	33E	93	1
115	145.1	44.23	N70W	40S	200	2
116	145.7	44.40	N16E	21W	286	1
117	145.8	44.45	N33W	49NE	57	0
118	145.9	44.48	N8W	41W	262	2
119	147.4	44.93	N62W	27N	28	1
120	150.2	45.77	N17W	35E	73	0

All directions are with respect to magnetic north.

Appendix A

Standard Operating Procedures HydroPhysical™ Logging for Aquifer Characterization

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STANDARD OPERATING PROCEDURES
HYDROPHYSICAL™ LOGGING FOR AQUIFER CHARACTERIZATION

1. Purpose

Application of the HydroPhysical™ (HpL™) logging method to analyze and determine:

- The location of hydraulically conductive intervals within a wellbore
- The interval specific rate of inflow during well production, in conjunction with the drawdown data, can be used to estimate interval specific hydraulic conductivity or transmissivity
- Ambient (non-pumping) flow conditions (inflow and outflow rates, and locations)

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- The hydrochemistry (pH, fluid electrical conductivity (FEC), oxidation-reduction potential, temperature) of the associated formation waters

In addition, when downhole, discrete point fluid sampling is coupled with the HydroPhysical™ Logging technique, analysis of the actual contaminant concentrations associated with each identified conductive interval is accomplished for any aqueous phase contaminant.

2. Equipment and Materials

This SOP specifically applies to application of the technique using COLOG's HydroPhysical™ Logging Truck 16, which has been specially configured to handle those field conditions associated with small diameter, low-moderate yield wells The maximum capability of the van is to a total depth of 700 ft and 350 ft total drawdown (maximum depth to water) . In the event of high yield wells, the wireline capability of Truck 16 can be used to accompany fluid management equipment (subcontracted from others) in wells to a 1500 ft total depth. Deeper wells can be tested using subcontracted pumping/plumbing services and the appropriate logging vehicle.

- HydroPhysical™ logging van field equipment includes:

- Fluid management system
  - Back Pressure Regulator or orifices
  - Rubber hose (0.75-inch i.d.) for injection
  - Submersible Pump
  - Evacuation Line
  - Storage tanks (as required) with inlet/outlet valves
  - Surface Pump
  - Fluid management manifold/Monitoring Panel
  - Mechanical hose spoolers (pump, injection)
  - Data Acquisition System (for recording volumes, flow rates, time)
  - Wireline System
  - Cable
  - Power supply
    - Wireline winch unit
    - Boom and drawworks
  - Depth encoder
  - Water level indicator
  - Computer System
    - HydroPhysical™ Logging tool
    - Downhole Fluid Sampler

- Deionized water (prepared with wellbore fluids or transported on-site)

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- Standard Reference Solutions - Orion low ionic strength pH reference solution 4, 7, and 10 (no others are acceptable) and electrical conductivity reference solutions (set of 4 solutions).
- Appropriate water sample containers (typically provided by client)
- Steam Cleaner (for logging/sampling tools)
  - High density floppy disks
- Deionizing Units

3. Procedures

1.) Review well construction details and complete general well information sheet. The HydroPhysical™ logging technique involves dilution of the wellbore fluids with DI water and profiling of the wellbore dynamics using a HydroPhysical™ logging tool. Significant aberrations or reductions in the borehole diameter should be identified as the downhole equipment can become lodged in the borehole. Additionally, application of the technique requires certain wellbore conditions:

- In open bedrock boreholes, casing must be installed through the overburden and grouted at the rock/alluvium interface to inhibit water leakage into the borehole from the saturated alluvium. For cased boreholes, the well should be fully cased and gravel packed with single or multiple screened intervals;

- The diameter of the borehole must be 4 inches or greater for application with the slim-tool (1.5-inch o.d.) and at least 6 inches or greater for application with the large diameter tool (3.5-inch o.d.). Two inch i.d. boreholes may be tested using the slug test approach described in Section 5.

- For newly drilled wells, cuttings and drill fluids must be removed from the affected fractures by standard well development procedures.

2.) Review and record additional wellbore construction/site details and fill out the general well information form which includes the following information:

- Ambient depth-to-water

- Depth of casing

- Total depth of well

- Lithology (if available)

- Estimated well yield and any available drawdown data

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- Standard Reference Solutions - Orion low ionic strength pH reference solution 4, 7, and 10 (no others are acceptable) and electrical conductivity reference solutions (set of 4 solutions).
- Appropriate water sample containers (typically provided by client)
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- Type and concentration of contamination

3.) Prepare the deionized (DI) water. Consult with DI water tank firm for assistance if necessary. If DI water has not been transported to the site, surface or groundwater may be used if it is of suitable quality Generally source water containing less than 1000 micro Siemens per centimeter (μS/cm) and less then 200 ppb VOCs will not significantly affect the deionizing units, but this should be confirmed with DI water firm. If the groundwater from the well under construction cannot be used for DI water generation, then DI water must be transported to the site and containerized at the wellhead.

Depending on the amount of HydroPhysical™ testing to be performed (ambient and/or during production) the typical volume of DI water required for each borehole is approximately three times the volume of the standing column of formation water in the wellbore per type of HydroPhysical™ characterization.

If preparation takes place on site, pump the source water through a pre-filter, to the deionizing units, and into the storage tanks.

Monitor the FEC of the DI water in-line to verify homogeneity; the target value is 5 to 25 μS/cm.

4.) Calibrate the HydroPhysical™ logging tool using standard solutions prepared and certified by a qualified chemical supply manufacturer. Fill out tool calibration form.

When using the large diameter tool, use the calibration cup provided with the tool and follow the instructions, Part 3, Scout H-20 Operating Manual. Record the value of the standards used and the corresponding tool value for the respective standard.

When using the slim tool, follow the steps defined in the software program, "tools" under the directory, calibration. Also use a separate field temperature / FEC / pH meter to support calibration data.

Record the results of the tool calibrations, specifically noting any problems on the tool calibration form. Also record the certification number of the standard solutions.

5.) Set datum on the depth encoder with the FEC sensor on the tool as 0 depth at the top of casing. If inadequate space is available at the wellhead, measure 10 feet from the FEC sensor up the cable (using measuring tape) and reference with a wrap of electrical tape. Lower the tool down the hole to the point where the tape equals the elevation at the top of the casing and reference that as 10 feet depth on the depth encoder.

6.) Place the top of the tool approximately 3 feet below the free-water surface to allow it to achieve thermal equilibrium. Monitor the temperature output until thermal stabilization is observed at approximately ± .02 °C.

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7.) After thermal stabilization of the logging tool is observed, log the ambient conditions of the wellbore (temperature, FEC, pH, and oxidation-reduction potential). Fill out the water quality log form. During the logging run, the data are plotted in real time in log format on the computer screen and, the data string is simultaneously recorded on the hard drive. At the completion of each logging run, *immediately* copy the recorded data onto a back up floppy disk (high density disk).

Log the ambient fluid conditions in both directions (i.e. record down and up). The ideal logging speed is 5 feet per minute (fpm). For deeper wells the logging speed can be adjusted higher, but the fpm should not exceed 20.

At completion of the ambient log, place the tool approximately 10 feet below the free water surface. The tool will remain there during equipment set up as long as borehole conditions permit. Establish and record ambient depth to water using top of protective casing as datum.

8.) Attach back pressure regulator or orifice, if used, and weighted boot, to end of emplacement line and secure. Insure that the injection line is of adequate length to reach the bottom of the wellbore.

9.) Lower the flexible emplacement line to the bottom of the well allowing one foot of clearance from the well bottom to the outlet of the injection line.

10.) Lower tool about 10 feet below the water surface. The tool will be stationed beneath the submersible pump during non-logging times.

11.) Lower submersible pump in the well to a depth just above the logging tool. Record approximate depth of the pump location.

12.) Record all initial readings of gauges at elapsed time 0.0 minutes. Fill out well testing data form.

13.) Mark hoses with a round of electrical tape for reference. In addition, establish datum for tool depth to the nearest foot and mark on wire with wrap of tape. Reset datum on optical encoder for this depth.

14.) When vertical flow characterization is to be conducted, it should be done now, before disturbing the aquifer (i.e. by pumping). Fill out ambient vertical flow characterization (AVFC) form. Skip to Section 17 for procedures.

15.) After AVFC, if performed, conduct a controlled, short term well production test (pump test) to characterize the overall hydraulics of the wellbore (drawdown at given pumping rate provides total well transmissivity or yield) and to make an initial assessment of formation water hydrochemistry. Begin pumping at a total extraction flow rate appropriate for wellbore under investigation (see Section 4 Special Notes). During this

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period, record elapsed time of pumping, depth to water, total gallons extracted, and extraction flow rate at approximately one minute intervals.

During extraction, log the fluid column continuously until at least three wellbore volumes have been extracted from the wellbore, or a stabilized water level elevation is obtained.

Review fluid logging results to verify that true formation water is present within the affected borehole interval and that the vertical distribution of water quality parameters within this interval is stable.

16.) Review data obtained during the pumping test to determine DI water emplacement and pumping/logging procedures. Extraction procedures for detection and characterization of hydraulically conductive intervals and the formation water hydrochemistry are determined based on the pumping test information. The emplacement, testing and pumping procedures will differ depending upon well yield and determined lengths of intervals of interest. In wellbore situations where intervals of interest are small (less than 30 feet) and hydraulic characteristics observed during borehole advancement and preliminary hydraulic testing indicate hydraulically conductive intervals with extremely low flow rates (i.e. <0.10 gpm/foot of drawdown), a slug testing procedure can be employed. In wellbore cases where the preliminary hydraulic testing indicates low to moderate total yield (i.e. $0.10 < Q < 4$ gpm/foot of drawdown), constant low flow rate pumping after DI water emplacement procedures can be employed. In wellbore situations where intervals of interest are large, and high total yield (i.e. > 4 gpm/foot of drawdown) is observed, constant pumping during DI water injection procedures will be employed.

17.) When the fluid column is to be replaced with DI water, (vertical flow characterization, slug testing, logging during pumping after DI water emplacement) the following emplacement procedures apply:

Pump the DI water to the bottom of the wellbore using the surface pump and the injection riser. Simultaneously use the submersible pump to maintain a stable, elevated total head by extracting groundwater from near the freewater surface. When groundwater from the subject well is used for DI water generation, generate DI water from the extracted formation water and recirculated to the well bottom via the solid riser.

Use the water level meter to observe the elevated total head during emplacement. If borehole conditions permit (i.e. the absence of constricted borehole intervals), the logging tool is used to monitor the advancement of the fluid up the borehole as it displaces the standing formation water. Draw the logging tool up the wellbore in successive increments as the DI water is emplaced. Monitor the electrical conductivity of the fluid expelled from the evacuation pump during emplacement procedures. When FEC values are representative of the DI water, or sufficiently diluted formation water, terminate emplacement procedures.

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Emplacement is complete when DI water, or sufficiently diluted formation water, is observed from the evacuation pump or when logging tool stationed near the pump indicates DI water or sufficiently diluted formation water.

Upon completion, turn off the evacuation pump. Then turn off the injection line.

18.) Record volumes of extracted and injected fluids on the well testing data form. Calculate the volume of DI water lost to the formation.

19.) Take initial background HydroPhysical™ log, or begin continuous logging depending upon extraction method (i.e. slug vs. continuous).

20.) Pumping and testing procedures vary depending upon wellbore hydraulics and construction detail.

21.) Continuous logging is conducted until stabilized and consistent diluted FEC logs are observed. If inflow characterization at a second pumping rate is desired, increase extraction rate and assure the proper DI water injection rate. Perform continuous logging until stabilized and consistent FEC logs are observed and all diluted formation water is resaturated with formation water.

22.) After stabilized and consistent FEC traces are observed, terminate DI water injection. Reduce the total extraction flow rate to the net formation rate and conduct continuous logging. Conduct logging until stable and consistent FEC values are observed.

23.) Conduct depth specific sampling at this time.

24.) At the conclusion of the above procedures, assess the wellbore fluid conditions and compare them with those observed during the original pumping (Step 14).

25.) Turn all pumps off. First remove the extraction pump from the borehole. During removal, thoroughly clean the evacuation line (2-inch o.d.) with a brush and oxydal and rinse using the steam cleaner and DI water. Also clean the outside of the pump. Place the pump in a drum of DI water and flush DI water through the system.

Remove the tool. Clean the wireline for the tool in a similar manner during its withdrawal from the borehole.

Remove the injection line from the well. Follow the same procedures when cleaning the injection line as for the evacuation line.

Store the pumps and logging tools properly for transport.

Place cover on well and lock (if available).

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4. Special Notes

On-site pre-treatment of groundwater using activated carbon, can be conducted prior to DI water generation, if there is a contaminated groundwater source. In addition, on-site treatment can also be considered to handle extracted fluids that would require containerization and treatment prior to disposal.

The rate(s) of pumping are determined by drawdown information previously obtained or at rate(s) appropriate for the wellbore diameter and saturated interval thickness. The appropriate extraction rate is a function of length of saturated interval, borehole diameter, and previous well yield knowledge. The appropriate pumping procedures to be employed are also dictated by the length of the exposed rock interval. In general, the extraction flow rate should be sufficient to induce adequate inflow from the producing intervals. The concern is that the extraction flow rate does not cause extreme drawdown within the well i.e. lowering the free water surface to within the interval of investigation.

5. Discussion

LOW YIELD: Extraction Slug Test After DI water Emplacement

In wells with very low total flow capability (i.e. < 0.10 gpm/foot of drawdown), perform a slug test in accordance with procedures developed by Hvorslev (1951). Rapidly extract a small volume of water from near the free water surface using the extraction riser and pump. A drop in piezometric head of about 2 feet should be adequate for the initial test. Record the rise in the free water surface with time and develop a conventional time-lag plot.

When the free water surface has recovered to a satisfactory elevation, log the wellbore fluid conditions. Repeat the procedures described above with successive increases in the drop of piezometric head (or volume extracted). Let the wellbore recover and record the rise in the free water surface. Repeat logging of the wellbore fluid after the free water surface has recovered to a satisfactory elevation. The number of slug tests performed is determined in the field after review of previous logging results.

MODERATE YIELD: Time Series HydroPhysical™ Logging During Continuous Pumping After DI water Emplacement

In the case of moderate yield wells (i.e. 0.10 < Y < 4 gpm/foot of drawdown), maintain a constant flow rate from the evacuation pump and record the total volume of groundwater evacuated from the wellbore. Employ a continuous reading pressure transducer (or equivalent device) to monitor the depressed total head during pumping, along with the associated pumping rate.

Hold the flow rate from the evacuation pump constant at a rate determined for the specific borehole. Drawdown of the free water surface produced during pumping should not

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overlap any identified water producing interval. Conduct hydrophysical logging continuously. The time interval is a function of flow rate and is specific to each well. The number of logging runs and the length of time required to conduct all loggings is a function of the particular hydraulic conditions. Logging and pumping is continued until the fluid column is resaturated with formation water (i.e. all DI water is removed from the borehole).

HIGH YIELD: Time Series Wellbore Fluid Logging During Continuous Pumping and Simultaneous DI Water Injection

When wells exhibit high yield (> 4 gpm/foot of drawdown), as determined by a review of the interval of interest, the borehole diameter and the results obtained from previous information and preliminary hydraulic testing, the appropriateness of time series fluid logging during continuous pumping and simultaneous DI water injection is determined.

In this case, maintain a constant flow rate from the evacuation pump and record this rate and the associated drawdown. During this period, conduct hydrophysical logging until reasonably similar HydroPhysical™ logs are observed and stabilized drawdown is achieved. After reasonably similar downhole fluid conditions are observed and simultaneous with extraction pumping, inject DI water at the bottom of the well at a constant rate of 10 to 20% of that employed for extraction. Increase the total rate of extraction to maintain total formation production reasonably similar to that prior to DI water injection (i.e. increase the total extraction by amount equal to the DI water injection rate).

Periodically record the total volume and flow rate of well fluids evacuated and the total volume and flow rate of DI water injected. Use a continuous reading pressure transducer or similar device to monitor the depressed total head during pumping. Record the depressed total head (piezometric surface) periodically, with the associated pumping and injection data.

The evacuation and DI water injection flow rates are held constant at a rate determined for the specific wellbore. Drawdown of the free water surface during pumping must not overlap any identified water producing intervals. HydroPhysical™ Logging is conducted continuously. The number of logging runs and the length of time required to conduct all loggings is a function of the particular hydraulic conditions exhibited by the well under investigation.

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Appendix B

Standard Operating Procedures for BIPS

Technical Procedure and Work Instructions for

Borehole Image Processing System (BIPS)
TP-2

Prepared by: Joseph T. Nelson Date: 7/31/97

Approved by: _____ Date: _____

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CONTROL DOCUMENT No. Colog, Inc.

TP-2
Revision History

Revision Level	Issue Date	Change Summary
0	4/22/97	New procedure, issued as TP-14.
1	7/31/97	Changes to original draft, renamed to TP-2.

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing BIPS measurements to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of BIPS logging, the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure includes by reference those sections of TP-1 which are common to all measurements.

1.1.4 In applying this procedure to the BIPS measurement, the requirements of this procedure shall supersede those stipulated in TP-1.

1.2 Applicability

1.2.1 This procedure applies to all personnel who perform work referred to in paragraph 1.1.).

1.2.2 This procedure applies to video image data acquisition using the Borehole Image Processing System (RaaX Model BPR-551).

1.2.3 All data derived from this procedure, and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-95, October, 1995.

2.4 SPWLA Reprint Series, BOREHOLE IMAGING, 1990

2.5 RaaX, Co., Ltd., BIP-300 Field Subsystem Operation Manual

2.6 RaaX, Co., Ltd., Analyzing Subsystem Operation Manual

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D 5753-95. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 BIPS downhole probe

The BIPS (Borehole Image Processing System) consists of a downhole probe containing a light source, a video camera, and focusing equipment which acquires and transmits a video image of the borehole wall to surface processing and recording equipment. (Appendix 1).

3.2 Surface recording equipment

The surface recording equipment mounted in the logging truck provides DC power to the probe, which is otherwise entirely self-contained and runs independently of the surface system. The surface electronics receives and displays the video signal and orienting pulses and processes them for digital data acquisition and display.

3.3 Fluxgate magnetometer orientation

The downhole probe contains in addition to the BIPS electronics a fluxgate magnetometer which provides an orienting pulse at a known azimuth with respect to magnetic north, and a reference mark for use in magnetically active materials. A mechanical compass is mounted at the center of the conical mirror which should not be used in a quantitative manner.

3.4 Raw signal

The raw signal is identical to the unprocessed video signal transmitted up the cable, with a superimposed radial line which serves as an orientation mark. The orientation mark is either the azimuth of an arbitrary reference within the downhole probe or at a fixed orientation relative to the magnetometer orientation. The signal looks like a disk and contains an image of a compass at its center which does not provide a quantitative orientation but is provided for qualitative assessment of tool function. A raw image is shown in Appendix 7.2.

3.5 Processed signal

The processed signal is obtained by extracting a circular scan from the raw signal using a user-selectable radius. This signal is re-displayed and stored

so as to provide an image for interpretation which represents the borehole as a rectangular image with the left-hand margin aligned with magnetic North determined by the fluxgate magnetometer. Vertical position in the borehole varies along the "y axis" of the image, and orientation varies along the "x axis". An example is shown in Appendix 7.3.

3.6 Personnel

Personnel are as defined in TP-1.

3.7 COLOG

COLOG, Inc., located in Golden, CO, is the sole source provider of BIPS services.

4.0 REQUIREMENTS

4.1 Prerequisites

In addition to the prerequisites stipulated in TP-1:

4.1.1 The borehole shall be either dry and air-filled or filled with optically clear water. If necessary, the borehole fluid shall be replaced by optically clear water prior to logging. The choice of fluids is not quality affecting, provided that the replacement fluid is optically clear and colorless. The method shall be approved by the project geochemist.

4.1.2 The borehole wall shall not be obscured by mud cake or optically opaque materials.

4.1.3 The borehole shall be clear of restrictions which prevent entry of the tool (including centralizers).

4.2 Tools, Material, Equipment

The RaaX Borehole Image Processing System is an oriented digital video system. It visualizes the borehole wall with an axial view camera lens looking down upon a special conical mirror and includes a light source to illuminate the well bore. The data is transmitted from the probe to the surface on a coaxial wireline as a raw NTSC video image. This image is displayed on a monitor in the logging truck. Appendix 7.2 shows a typical raw image. The raw NTSC video signal (raw signal) is stored on VHS video tape during logging.

To produce a digital image of the well bore which is undistorted, a circular disk with a user-selected radius and centralization is extracted from the raw

NTSC video image every 0.5 mm vertically along the well. This disk is sampled 360 times around its circumference to produce RGB values at each point. The resulting data is stacked vertically to produce an image of the well as if it were sliced along magnetic South and laid flat. This digital image is displayed on a second monitor, and the individual traces are also stored on magneto-optical disk.

The raw signal recorded on videotape can be played back and reprocessed where regeneration of the digital data is needed or required.

4.2.1 COLOG utilizes a BIPS probe Model BPR-551 manufactured by RaaX Company, Ltd.

4.2.2 The BIPS shall be run on a coaxial logging cable.

4.2.3 Recording Equipment: The raw NTSC image shall be recorded on VHS video tape. If desired, the processed video image may also be recorded (in real time) on VHS video tape. This requires two video tape recorders.

The processed data is recorded on magneto-optical disks in the field then transferred to a personal computer to be processed with RaaX's BIP Analysis Software. The final data is then transferred to CD-ROM for archiving. The raw NTSC video may later be replayed and redigitized using the same processing and recording unit.

4.2.4 Portable aluminum cradle or down hole tool stand to facilitate assembly and breakdown of the probe.

4.2.5 Sprayer and a clean water supply to clean drilling fluid from tool after use.

4.2.6 BIPS centralizers

4.2.7 Calibration tube (Appendix 7.4)

The calibration tube consists of a cylinder large enough for the BIPS probe to fit inside. The cylinder shall be fitted with a cap on the top with a hole just large enough for the probe to pass through. This cap is designed to restrict outside light from entering the tube creating glare on the inner surface of the tube. Inside the cylinder is a removable color palette with eight color bars (including black and white) covering the full circumference of the tube. The color bars are aligned axially with the tube along with two reference lines annotated "N" and "S" with which to orient the tube to magnetic

North. A black reference line inside the tube is aligned with the "North" reference line on the color palette.

4.2.8 Brunton compass or equivalent for orientation of calibration tube.

4.2.9 Data information, calibration sheets, and operating procedures.

4.2.10 Reference calibration image, for comparison to the image(s) recorded in the field. This image shall be a processed image played back on a standard printer using standard software and settings.

4.2.11 The BIPS probe shall be calibrated for the following purposes:

1) To verify system operation in terms of image color, clarity and stability.

2) To verify (and re-orient if necessary) the stability of the digital compass used to provide image orientation.

3) To provide a color reference to aid in analysis of the wellbore image.

4.2.12 Pre-log Calibration Procedure

Calibration of the digital compass shall be performed under controlled conditions in a laboratory when calibration checks indicate a problem or after probe repair.

During pre-log calibration, the digital compass may be adjusted (if necessary) to align with the reference lines of the calibration tube oriented with a Brunton compass to magnetic North and South. After that time, and until the post-log calibration check is completed, no further adjustment of the digital compass shall be made.

Calibrations shall be performed before leaving the home office for the logging location.

In the field, the probe shall be calibrated prior to logging and the calibration shall be checked following logging every borehole.

4.2.12.1 Set up the calibration apparatus with a minimum of two feet lateral clearance from any magnetic objects as shown in Appendix 7.4. Use a Brunton compass to orient the North and South reference lines in the calibration tube to magnetic North and South.

4.2.12.2 Attach the BIPS tool to the cable.

4.2.12.3 Hang the tool vertically in the calibration tube with the recording window just inside the light restricting cover. Be sure to attach the temporary (rubber) to the bottom of the probe prior to hanging it in the tube (see Appendix 7.4). The calibration tube shall be dry and air-filled.

4.2.12.4 Attach the probe to the downhole cable and connect the cable to the surface recording equipment. Open the "centering" window in the acquisition program and turn power on to the probe. Set all of the video adjustment knobs on the dual monitors to the neutral position. Monitor power settings and the raw signal on the color monitor to ensure correct operation.

4.2.12.5 Set up the BIPS acquisition system to record a data file as described in Reference 2.5.

4.2.12.6 Set logging depth to zero.

4.2.12.7 Record the calibration.

Start recording a data file, but prior to moving the tool down into the calibration tube, adjust the digital magnetometer needle to align with the black reference line oriented to magnetic North. Use the winch to begin lowering the probe in a downward direction past the color palette at approximately 0.7 m/min (*Note:* The "Logging Too Fast" warning will come on if the speed exceeds 0.7 m/min).

The digital data shall be recorded on magneto optical disc, while the raw NTSC video signal shall be recorded on VHS tape.

Acquire data over the length of the calibration image.

4.2.12.8 Check proper image orientation, color, and resolution on the processed image displayed on the color monitor.

4.2.12.9 Compare the processed image to the reference calibration image (Appendix 7.5).

4.2.12.10 Make adjustments to match the reference image if necessary.

4.2.12.11 Complete the pre-log portion of the "BIPS BPR-551 Checkout/Calibration" form (Appendix 7.6) to document the calibration.

4.2.12.12 In the field, if the hole to be logged contains fluid, the calibration may be repeated after filling the calibration tube with clear water.

4.2.13 Calibration Check Procedure

A calibration check is identical to a calibration except that no adjustment of the tool shall be made. The purpose of the calibration check is to verify that no change in system performance has occurred during logging.

4.2.14 Calibration Records

Calibration data shall be recorded on the form specified for both the pre-log calibration and the post-log check. These shall be performed prior to and at the completion of "continuous" logging operations for a particular well. The calibration forms shall include the probe identification number, well location, date and time calibration was performed, person executing calibration procedure, and any pertinent observations.

Calibration and calibration check data shall be recorded as raw data on videotape and as processed data on optical disc.

4.3 Precautions and Limits

4.3.1 The BIPS log shall be recorded in an uncased hole unless the condition of casing is to be investigated. When logging in casing, steel casing may necessitate turning off the automatic digital compass resulting in non-oriented images.

4.3.2 The quality of the image depends on the optical properties of the fluid in the borehole and the condition of the borehole wall.

4.3.3 The image is interpreted as if the tool is perfectly centralized. If the tool is eccentered, the geometry of the observed features will be distorted.

4.3.4 During analysis, the tool axis is assumed to be aligned with the axis of the borehole.

4.3.5 The maximum length of cable on which the tool can be run is 5000 ft.

4.3.6 The operational temperature and pressure limits for the BIPS system provided by the manufacturer should be adhered to while running the log. The maximum operating pressure is approximately 2400 PSI (165 bars). The practical operational temperature range is from 0 to 46°C (32 to 140°F).

4.3.7 The recommended minimum borehole diameter is 60 mm (2.36"). The recommended maximum diameter is 230 mm (9.0"). In ideal circumstances, BPR-551 can be run successfully in holes as large as 16".

4.3.8 Washout zones will affect the resolution of the photographic image if the zones extend beyond 230 mm (9.0").

4.3.9 Bridges or constrictions in the borehole diameter will make it impossible to lower the probe into the borehole and difficult to retrieve the probe.

4.3.10 The magnetometer is approximately 3 feet above the image measurement point. Thus, if the borehole is cased with magnetically active material, the uppermost approximately 4 feet of image immediately below casing will be more difficult to orient.

4.3.11 The log shall be recorded with the tool moving down the borehole.

4.4 Acceptance Criteria

This log shall be accepted for use based on the expectation that the results will be interpreted quantitatively.

The following acceptance criteria shall be evaluated using the digital data recorded on magneto-optical disk.

4.4.1 The orientation of the pre- and post-logging calibration images shall be within 5°.

4.4.2 The orientation of features on the repeat section shall be within 5° of their orientation recorded during the main logging run.

4.4.3 The pre-log calibration shall result in an acceptable level of color matching and resolution to the reference image.

4.4.4 The post-log calibration check shall result in an acceptable level of similarity of the color and resolution to that of the pre-log calibration.

4.4.5 The image quality of the digitized data shall be evaluated by the Logging Engineer for resolution.

4.4.6 The orientations and characteristics of features observed in the repeat log shall be similar to those observed in the main log. However, it should be kept in mind that the quality of the repeat log may be degraded due to loss of fluid clarity caused by the initial log.

4.4.7 After Survey Depth Error (A.S.D.E.) shall be within required tolerances.

4.4.8 The processed image should be compared by the on-site geologist to core from the well or from a nearby core hole, if available, to establish if an adequate level of resolution of color variations and other features is present in the log images.

5.0 DETAILED PROCEDURE

The processed BIPS image shows the borehole wall as if it were split vertically and laid flat. Vertical fractures appear as vertical straight lines, while bedding and fractures dipping between vertical and near horizontal appear as sinusoidal traces.

The vertical distance between digitized video scans is typically 0.5 mm. The angular distance subtended by each color value is (360°/number of points).

The BIPS images can be used:

- To evaluate the stratigraphic, structural, diagenetic, weathering, textural and mineralogical features detectable in the borehole wall.
- To locate and orient fractures and bedding planes to aid in the analysis and interpretation of in situ physical and hydrologic properties.
- To perform direct comparison between BIPS log and recovered core from the same well.
- To locate and orient any stress-induced wellbore failure (breakouts) for determination of the orientation and magnitude of in situ stresses.
- To locate and orient any drilling induced hydraulic and other tensile fractures for determination of the orientation and magnitude of in situ stresses.

BIPS logs are typically run as one of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival as described here pertain only to the specific requirements of the BIPS. Where they do not conflict with the procedures detailed here, all of the procedures specified in TP-1 shall also be adhered to.

5.1 Prior to arrival

In addition to those procedures detailed in TP-1.

5.1.1 Select the appropriate centralizers for use in the well.

5.1.2 Assure that the logging truck has a coaxial cable of sufficient length to perform the log.

5.2 On arrival

No added procedures are necessary beyond those detailed in TP-1.

5.3 While Logging

Throughout the logging process, two sets of data shall be obtained. The first is a raw videotape of the data provided by the logging tool. The second is digital files recorded on magneto-optical disk of the digital data.

5.3.1 The BIPS shall be run centralized in the borehole. Adjust the probe centralizer for optimal centralization in the interval to be logged.

5.3.2 Visually inspect all joints on the BIPS to be sure they are tight, and check the clear lens to verify that it is free of scratches.

5.3.4 Verify the integrity of the coaxial cable as specified in TP-1.

5.3.5 Prepare optical disk media for data storage.

5.3.6 Perform a pre-log calibration.

5.3.7 Set the software depth counter to read zero when probe measuring point is depth referenced to the measurement datum (land surface, top of casing, etc.). The depth zero should be taken with tension on the wireline similar to that expected while logging, to prevent slack in the cable from biasing the datum.

5.3.8 Lower the probe to the top of the interval to be logged.

5.3.9 Begin logging at approximately 0.7 meters per minute to the bottom of the hole (or interval to logged). The raw signal shall be recorded to VHS videotape, while the digital data shall be recorded on optical disc. Tool operation is verified by observing the raw and projected (2D) video images on dual monitors.

5.3.11 Even if the logged interval extends to the bottom of magnetically active casing, no attempt shall be made to adjust the magnetometer orientation during the logging of the complete interval. If it is

desired to obtain a more stable image in this section of the hole, a repeat log shall be obtained for this purpose.

5.3.12 If logging needs to be stopped for any reason a brief overlap interval should be recorded, to ensure that no data are missed.

5.3.13 After completion of the log, a 50 ft repeat section of the hole shall be logged with the tool moving downward at a rate of 0.7 m/min. Proper tool operation is verified by monitoring the video images on the dual monitor.

5.3.14 After completion of logging and acceptance of the logged data, a VHS copy of the projected image shall be recorded by playing back the digital data. This videotape shall be labeled as to well, logged interval, date, etc.

5.3.15 Unless otherwise noted all azimuth orientation data shall be recorded on magnetic north orientation. Field plots unless otherwise noted shall be based upon magnetic north.

5.3.16 Determine after survey depth error.

5.3.17 Record a Post-log calibration check.

5.4 Prior to departure

In addition to the requirements of TP-1:

5.4.1 Immediately after logging the well, the digital data recorded on magneto optical disk during the log (see 5.3) shall be replayed and an oriented 2D video image shall be generated, monitored, and recorded on VHS tape. This video image is necessary to verify that the digital data recorded on optical disc is valid.

6.0 RECORDS

Records shall be provided as detailed in TP-1. In addition the following records shall be provided:

6.1 Completed "BIPS BPR-551 Checkout/Calibration" Forms (Appendix 7.5).

6.2 Observer's logs (or records) of all pertinent information, including data, time, recording parameters, borehole data, water level casing information, unusual conditions, etc.

6.3 The VHS videotape (5.4.1) containing the 2D oriented image.

6.4 Color paper copies of all of the requested BIPS images (see 5.5.2).

6.5 Data Deliverables

The data provided by the BIPS system cannot be presented using the standard database software. However, the processed digital data may be on CD-Rom upon client's request.

7.0 APPENDICES

7.1 BIPS Tool Diagram.

7.2 Example Raw BIPS Image.

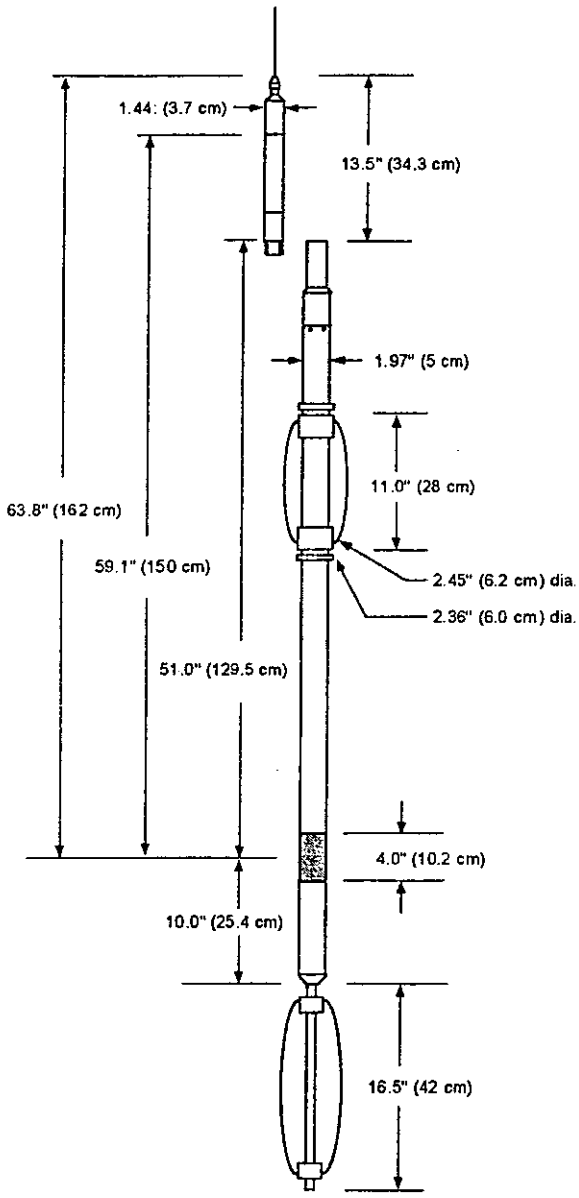
7.3 Example Processed BIPS Image.

7.4 Calibration Apparatus and Set-up

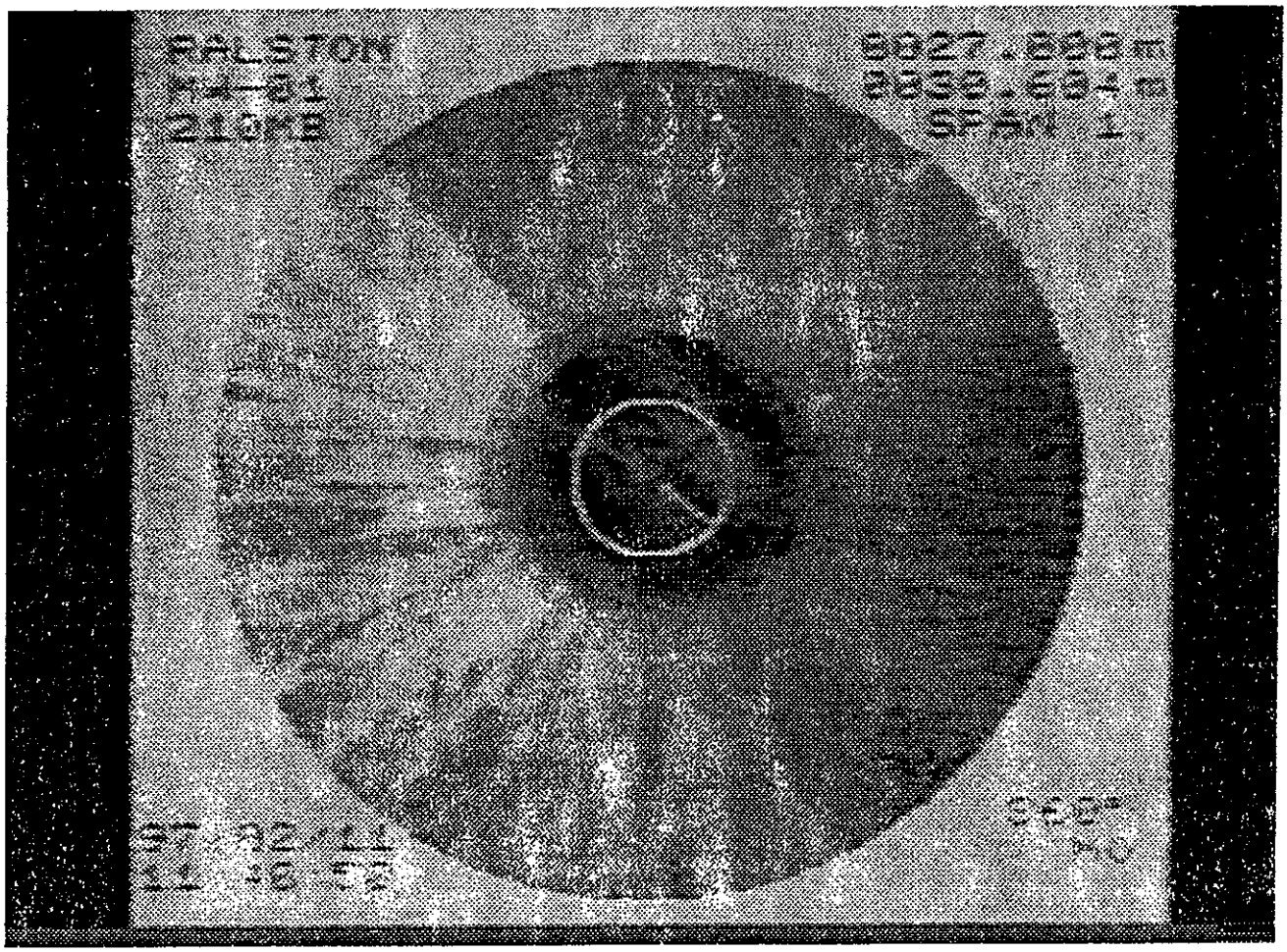
7.5 "BIPS BPR-551 Checkout/Calibration" Form.

Appendix 7.1

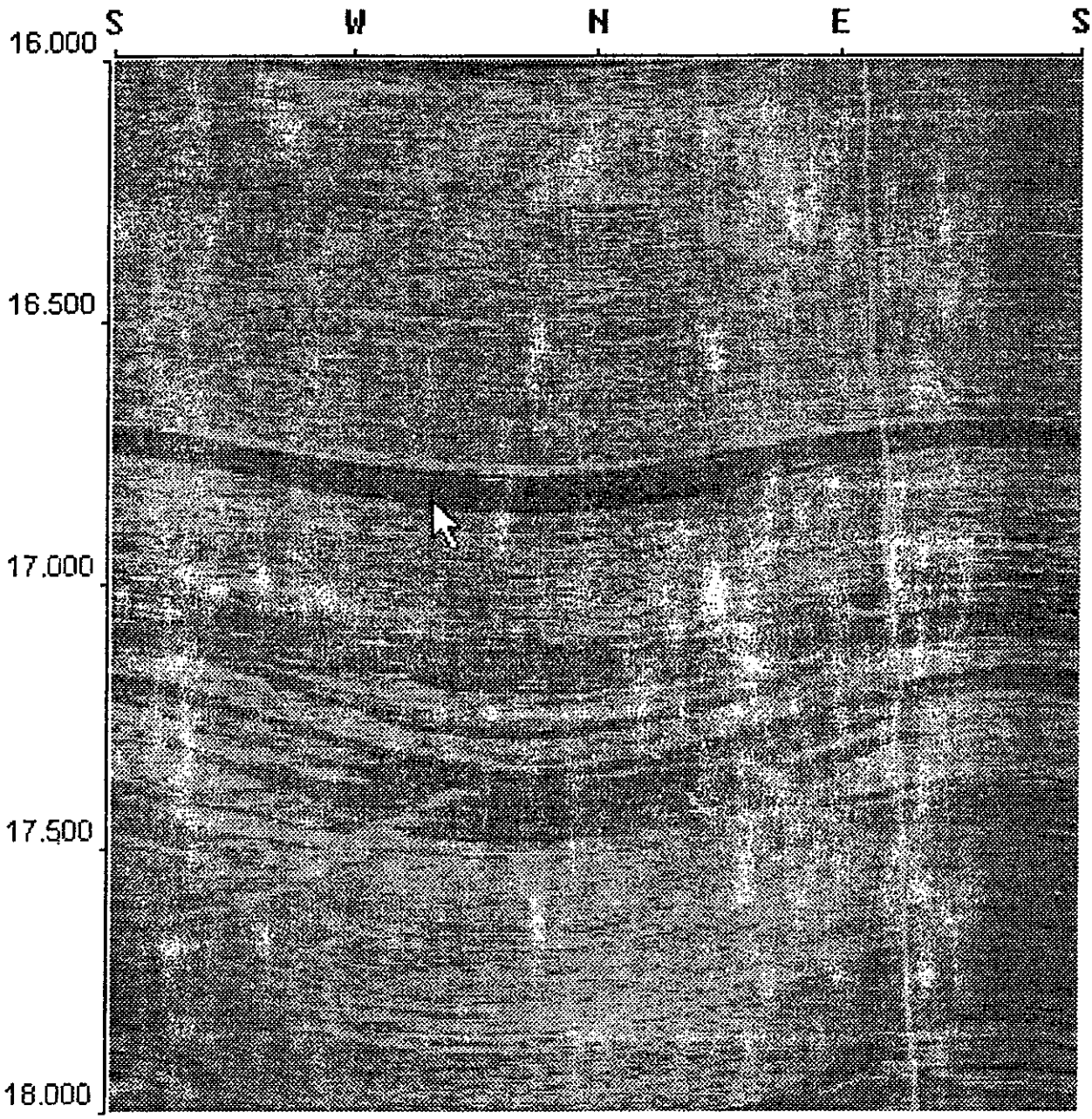
Borehole Image Processing System, Model: BPR-551



Appendix 7.2 Example Raw Image Recorded During a BIPS Log



Appendix 7.3 Example Processed BIPS Image



Appendix 7.4 Calibration Apparatus and Set-up

Appendix 7.5 Reference Calibration Image

Appendix 7.6

BIPS BPR-551
Checkout/Calibration

Engineer:_____ Location or Well Name:_____ Truck/Unit No:_____

Probe Serial No:_____

Pre-Log Calibration:

Date:_____ Time:_____

Calibration tube filled with: AIR / WATER

Calibration Filename:_____

Post-Log Check:

Date:_____ Time:_____

Calibration tube filled with: AIR / WATER

Calibration Filename:_____

COMPARE IMAGES TO:

"Reference Calibration Image" (Image generated from the Calibration Tube in air)

Calibration Standards:

1.) Calibration Tube oriented to North and South using a Brunton compass set clear of metal objects.

Appendix C

Estimation of Horizontal Flow From Fluid Electrical Conductivity Logs Acquired at Gregory Canyon, Temecula, California

ESTIMATION OF HORIZONTAL FLOW FROM FLUID ELECTRICAL CONDUCTIVITY LOGS ACQUIRED AT GREGORY CANYON, TEMECULA, CALIFORNIA

INTRODUCTION

COLOG, Inc. has examined the fluid electrical conductivity (FEC) logs that were acquired in several open wellbores related to the hydrogeologic investigation at Gregory Canyon, Temecula, Califonia. This examination and processing was conducted with experimental computer codes developed by Radon Abatement Systems, Inc., of Golden, Colorado. The goal of the interpretation is to estimate the magnitude of horizontal groundwater velocity in discrete zones of the aquifer. The zones used in this analysis were delineated from these FEC data sets. The results of this analysis is provided for each identified horizontal cross-flow zone, for a given well, in the main body of the report.

The data analyzed were obtained in both a reasonably stable ambient wellfield condition and during cross-hole testing. No effort was made to correct the data for a possible disturbance to the aquifer by any other outside influence. In addition, this coding is considered experimental and the results generated should be considered as such until independently confirmed by traditional methods.

The computer code developed for analysis of flow rates through each zone is based largely on borehole dilution theory in which a mixing model is used to infer horizontal groundwater flow velocity through a borehole. The borehole dilution technique is summarized in the textbook by Freeze and Cherry (1979) and is based on the work of Drost *et al.* (1968). Although the theory for such analysis is well established, its use in hydrophysical logging experiments is innovative. Special considerations apply in using the theory with such applications; nonetheless, the theory provides promising results in such applications.

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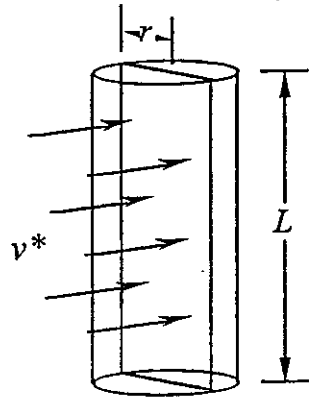
THEORY

Consider a tracer (e.g., de-ionized water) that has been introduced uniformly into a section of a screened borehole. Let the observed concentration of the tracer be $C_{obs.}$ Once introduced, the concentration of the tracer is modified by formation water flowing into the borehole at a velocity v^*, as illustrated in the sketch below. Let the concentration of tracer in formation water be C_f . In hydrophysical logging we can substitute fluid electrical conductivity (FEC) for concentration (so $C_{obs.}$ and C_f actually represent observed and formation FEC values). Because the tracer is de-ionized water, the borehole "dilution" will actually be an enrichment in fluid electrical conductivity.



Sketch 1. Schematic of borehole dilution process showing the definitions of geometric variables

By balancing the net rate of mass into the borehole with the rate of change of C_{obs}, we get the following first-order differential equation:

$$v^* C_f A - v^* C_{obs} A = W \frac{dC_{obs}}{dt} \tag{1}$$

where A is the cross-sectional area of the borehole ($A = 2rL$), and W is the corresponding volume ($W = \pi r^2 L$). If we make the following change of variable

$$C = C_f - C_{obs} \tag{2}$$

we get a somewhat simplified equation

$$v^* C = -\frac{W}{A}\frac{dC}{dt} \tag{3}$$

that we can solve for C:

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$$C = C_0 \exp(-\frac{2t}{\pi r} v^*) \tag{4}$$

where $C_0 = (C_f - C_{obs}(t = 0))$. Taking the log of both sides of (4) we get

$$\ln(C/C_0) = -\frac{2v^*}{\pi r} t \tag{5}$$

Thus the ratio C/C_0 should plot as a linear change with time on semi-log paper. The slope of this line is proportional to the velocity of groundwater flowing through the well. Specifically,

$$v^* = -\frac{\pi r \ln(C_2/C_1)}{2(t_2 - t_1)} \tag{6}$$

where t_1 and t_2 are times corresponding to values of C_1 and C_2 on the straight-line segment of the semi-log plot.

The velocity given by equation (6) is the velocity through the borehole, which may be different from the velocity of groundwater in the formation because flow lines tend to converge toward the borehole. Corrections for this convergence have been given by Drost *et al.* (1968) as

$$q = \frac{v^*}{\alpha} \tag{7}$$

where q is the specific discharge of groundwater in the aquifer and α is a factor that accounts for convergence of flow lines. In general, calculating α requires detailed knowledge of the hydraulic properties of the screen, the gravel pack (or annulus around the screen if the well is naturally developed), and the hydraulic properties of the aquifer. It turns out, however, that the value of α is relatively insensitive to the hydraulic properties provided the screen and gravel pack are considerably more permeable than the aquifer. However, to the knowledge of RAS these corrections have never been validated for the fractured open hole environment. While these values have been calculated using a convergence factor of 2.5, these results should be considered experimental until confirmed by traditional methods.

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INTERPRETATION AND RESULTS

In order to apply the borehole dilution technique to the appropriate logs, the data acquired in each zone was isolated. We then plotted all of the data for a particular zone against time on a semi-log graph. These graphs are shown for each identified zone in a given well in the main body of the report. Using slope of the lines plotted, we calculated groundwater velocity through each zone using equation (6). The results of these calculations are given on the figures in the main body of the report.

In most of the logs the early-time FEC data do not fit a linear trend, presumably because de-ionized water was forced into the formation during the fluid exchange and/or the pressure had not stabilized; thus the water flowing into the well at early times is diluted formation water. As such the early time data was not considered in the slope calculations[1].

Please refer to the main body of the report for a brief discussion of the results for each well.

REFERENCES

Freeze, R. A. and J. A. Cherry, 1979. *Groundwater*, Prentice Hall, Englewood Cliffs, 604p.

Drost, W., D. Klotz, A. Koch, H. Moser, F. Neumaier, and W. Rauert, 1968. Point dilution methods of investigating groundwater flow by means of radioisotopes, *Water Resour. Res.*, **4**, 125-146.

[1] Personal communication with COLOG representatives indicated that during the early time data, the pressure had not stabilized.

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Appendix D

Spinner Flow Meter Results vs. HydroPhysical™ Logging Results

SUMMARY OF SPINNER FLOW METER RESULTS

On December 20, 1996, at the request of one or more consultants, COLOG logged wells GLA-3, GLA-7 and GLA-8 with a spinner-type flow meter to quantify vertical flow for comparison to the HydroPhysical™ data. COLOG expressed its concern to Geologic Associates that the detection range of the spinner-type flow meter is well above the flow rates expected in the three wells. The data collected using the spinner-type flow meter did not suggest the presence of any flow. It is the opinion of COLOG that the flow in the well was below the detection limit of that particular spinner-type flow meter. . COLOG was pleased the results of the spinner flow meter was in comparison to the HpL™ data. Please see the following figures and tables for a comparison of the spinner flow meter data with the HydroPysical™ data. The spinner flow meter data has been plotted as impeller speed as a function of depth. The lack of any significant change in the impeller speed with depth is an indication of no observable flow within the range of that particular spinner flow meter.

FIGURE GLA-3:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

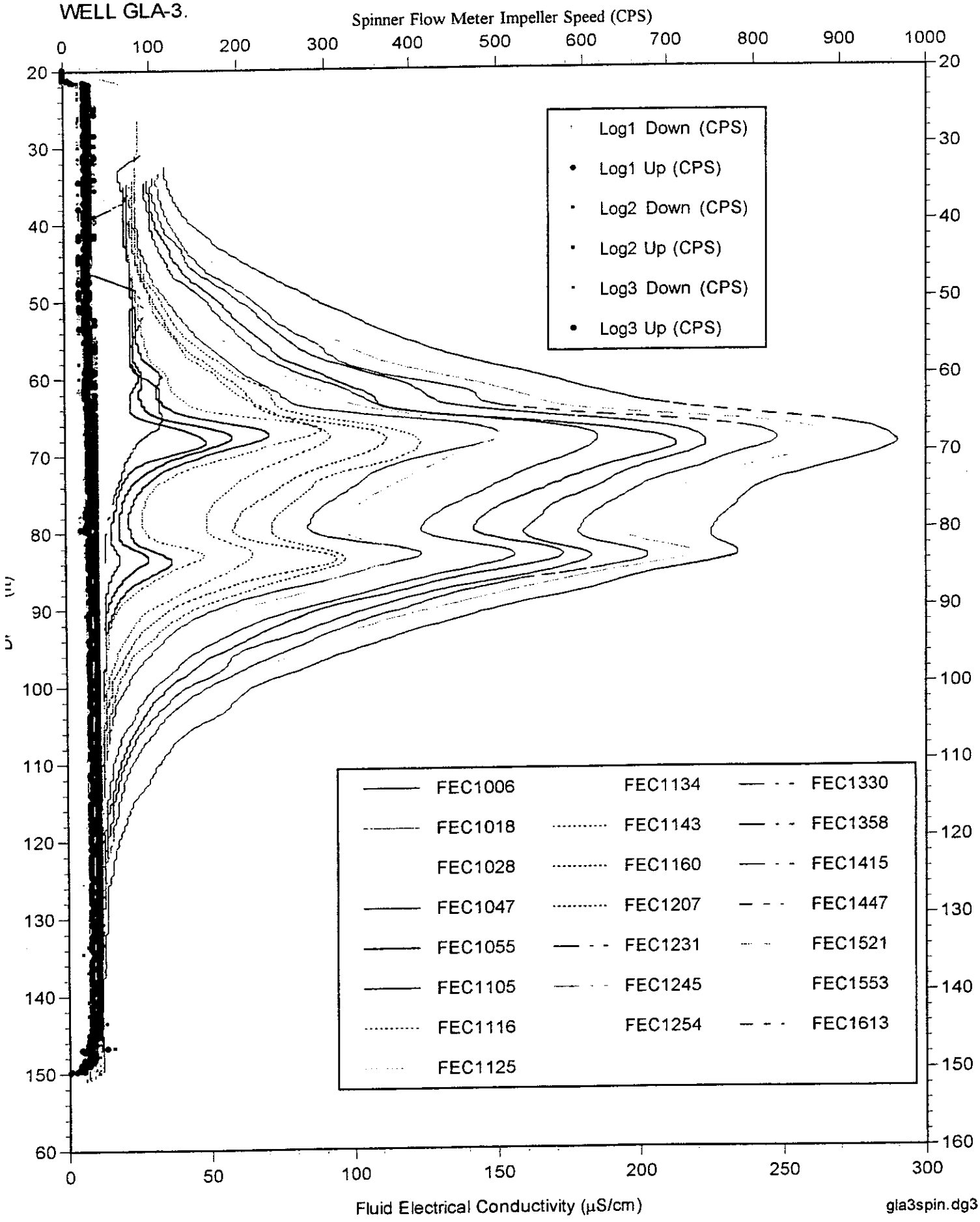

TABLE GLA-3:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL RESULTS DURING AMBIENT CONDITIONS; GOELOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-3.

		Ambient Flow Characterization Test				
Water Bearing Interval #	**Upper Boundary of Interval (feet)** [1]	**Lower Boundary of Interval (feet)** [1]	**Length of Interval (feet)**	**Direction of Flow**	**Specific Discharge Determined from HpL™ (ft/day)**	**Results of Spinner Flow Meter Logging**
1	66	77	11.0	Horizontal	0.23	No Detection
2	82	84	2.0	Horizontal	0.29	No Detection

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[1]Depths are referenced to top of inner PVC casing.

FIGURE GLA-7:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

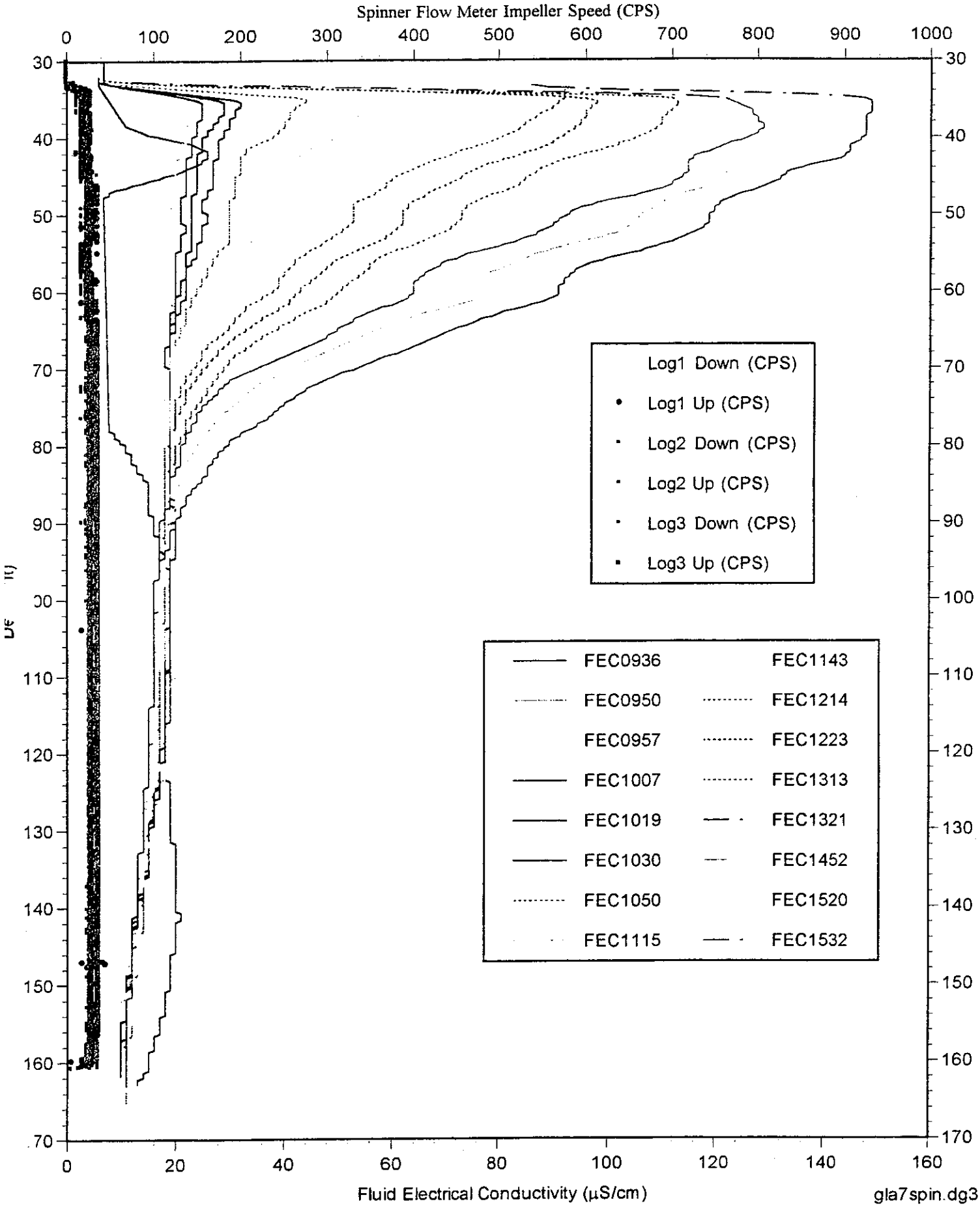

TABLE GLA-7:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL RESULTS DURING AMBIENT CONDITIONS; GOELOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-7.

		Ambient Flow Characterization Test				
Water Bearing Interval #	Upper Boundary of Interval (feet) [1]	Lower Boundary of Interval (feet) [1]	Length of Interval (feet)	Direction of Flow	Specific Discharge Determined from HpL™ (ft/day)	Results of Spinner Flow Meter Logging
1	33	42	9	Horizontal	0.21	No Detection
2	42	48	6	Horizontal	0.21	No Detection
3	48	52	4	Horizontal	0.20	No Detection
4	52	58	6	Horizontal	0.19	No Detection
5	58	62	4	Horizontal	0.19	No Detection
6	62	69	7	Horizontal	0.19	No Detection
7	69	72	3	Horizontal	0.16	No Detection

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[1]Depths are referenced to top of inner PVC casing.

FIGURE GLA-8:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL LOGS FOR AMBIENT FLOW CHARACTERIZATION; GEOLOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-8.

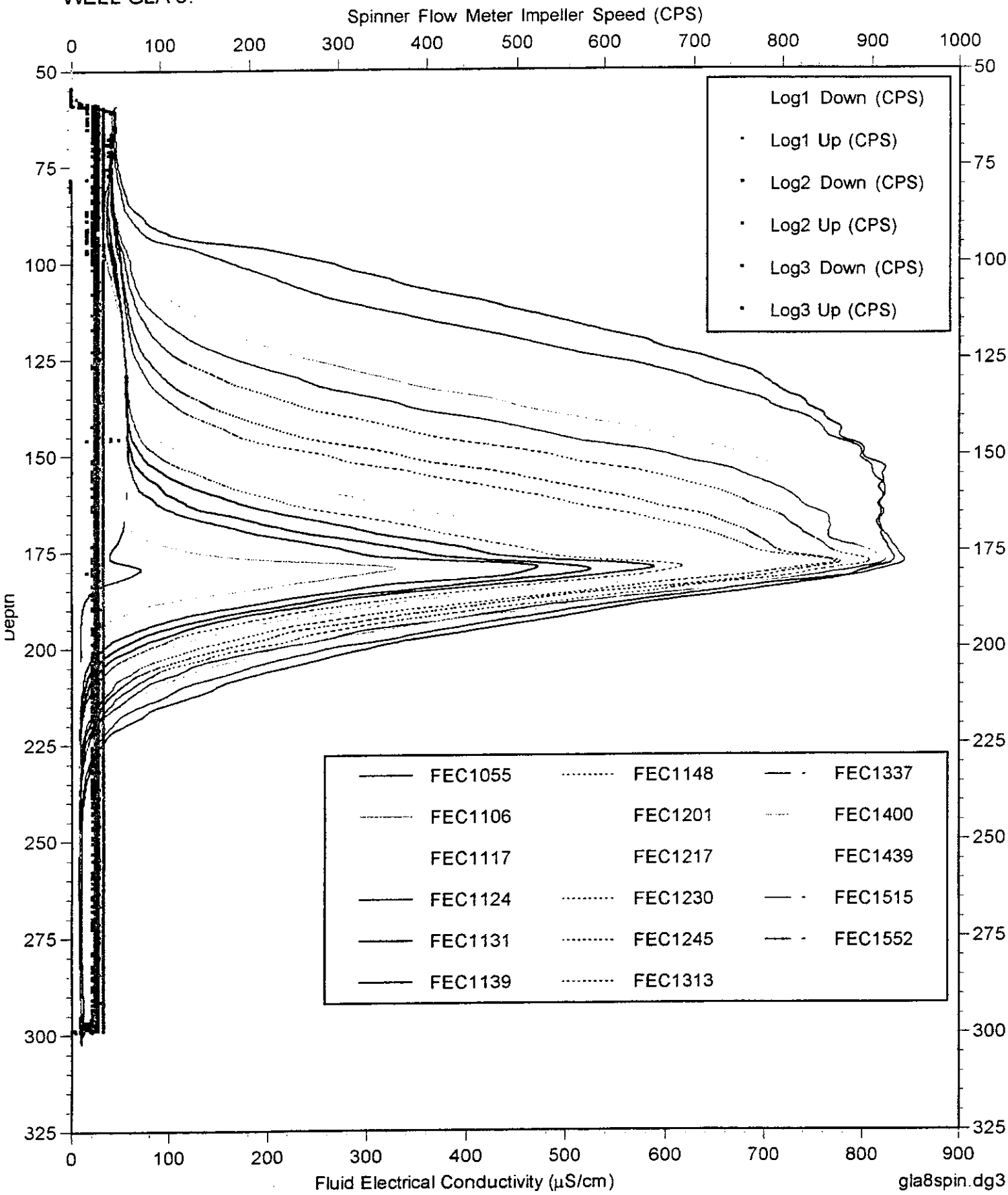

TABLE GLA-8:SP1. SPINNER FLOW METER RESULTS VS. HYDROPHYSICAL RESULTS DURING AMBIENT CONDITIONS; GOELOGIC ASSOCIATES; GREGORY CANYON, CA; WELL GLA-8.

		Ambient Flow Characterization Test				
Water Bearing Interval #	**Upper Boundary of Interval (feet)** [1]	**Lower Boundary of Interval (feet)** [1]	**Length of Interval (feet)**	**Direction of Flow**	**Interval Specific Flow Rate Determined from HpL™ (gpm)**	**Results of Spinner Flow Meter Logging**
1	178	178	NA	Upward	0.42	No Detection

[1]Depths are referenced to top of inner PVC casing.

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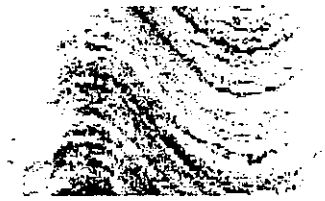
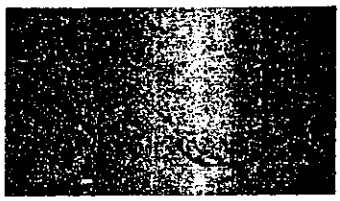
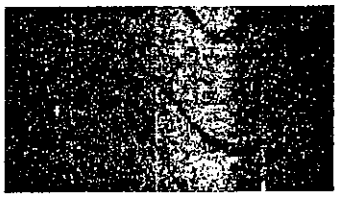
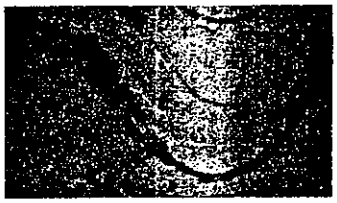
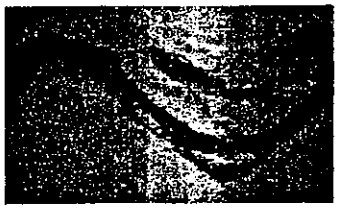
Appendix E

Ranking System For BIPS Features

Ranking System For BIPS Features

	Rank	Observation	Flow Rating System
	0	Probable bedding feature or foliation	Sealed - no flow
	1	Weak feature (possibly bedding) - not continuous around the borehole	Partial open crack
	2	Clean distinct feature	Continuous open crack
	3	Distinct feature with apparent aperture	Wide open crack or cracks
	4	Very distinct, wide fracture or fractures, possibly interconnected	Very wide crack or multiple inter-connected fractures
	5	Major fracture zone with large openings.	Major fracture zone

This ranking system is based on a system developed and applied by Paillet (USGS, WRD, Borehole Geophysics Research Project) as a subjective evaluation of permeability potential. In general, the higher the rank, the greater the likelihood of fracture interconnection and subsequent increased permeability.

GeoLogic Associates
Geologists, Hydrogeologists and Engineers

December 18, 1998
Job No. 9539

Gregory Canyon Ltd.
14249 Via Baroda
San Diego, CA 92130

Attention: Mr. Richard Chase

RE: LEACHATE GENERATION ANALYSIS
PROPOSED GREGORY CANYON LANDFILL

Modeling of potential leachate generation was performed using the United States Army Corps of Engineers HELP 3 (Hydrologic Evaluation of Landfill Performance) computer program, which uses representative rainfall and evapo-transpiration data to determine the amounts of leachate that might be generated in municipal solid waste landfills. The program takes into account the total area landfilled, representative precipitation patterns, representative evapo-transpiration, and the hydraulic conductivity of various construction materials to calculate leachate generation and accumulation.

Climate

The initial climate properties were selected from a table of default values included in the HELP 3 model. These default values were selected for the city of San Diego and were corrected for the latitude of the proposed Gregory Canyon Landfill.

Precipitation data were adjusted to a 50-year annual average of 18 inches, with a minimum yearly total of 4.40 inches and a maximum yearly total of 24.79 inches.

Material properties

The engineering and hydraulic properties of materials were determined from HELP3 default values, as follows:

Layer	USCS	Porosity	Saturated hydraulic conductivity (cm/s)
Vegetative cover	SM	0.473	5.20E-04
Low permeability layer	CH	0.4	7.80E-07

Interim/daily cover	SM	0.473	5.20E-04
Refuse	--	0.671	1.00E-03
Operations layer	SM	0.473	5.20E-04
LCRS layer	GP	0.397	3.00E-02
60 mil HDPE	--	--	2.00E-13
Low permeability layer	CH	0.4	7.80E-07

In calculating the potential percolation through the future liner area, a pinhole density and installation defect densities of 1 per acre were assumed.

The hydraulic conductivities and other engineering properties of materials utilized in the analysis are shown in the HELP3 model output sheets presented in Appendix I.

Model configuration

Modeling of the proposed Gregory Canyon Landfill was performed by subdividing the 186-acre landfill into sixteen zones, based on the Master Plan developed by Bryan A. Stirrat & Associates. Eight zones were defined for the "floor" area (40.6 acres), and another eight zones were defined for the "slope" areas (145.8 acres).

Modeling of refuse placement was performed taking into account the anticipated timing and volumes of refuse that will be placed, as well as the footprint areas and elevations that are expected as the landfill incrementally approaches capacity. During active phases of landfilling at any given zone, it was conservatively assumed that refuse was left uncovered, but it was also assumed that an interim cover was placed at the conclusion of refuse placement on that zone.

Leachate drains in the LCRS system were positioned at 500-foot intervals within the bottom LCRS gravel. Along the side slopes, drains were assumed to be positioned at 100-foot intervals (measured along the slope).

Closure of the proposed Gregory Canyon Landfill was modeled using a prescriptive low-permeability final cover (Title 27 of the California Code of Regulations).

Modeling period

Using the climatic and material values described above, and taking the changing configuration of the landfill into account, the HELP 3 analysis was performed iteratively for a simulated 30-year period and a 20-year post-closure period. Table 5 shows the modeled refuse placement history. Precipitation records for these 50 years were generated synthetically by repeating the 10-year history of the Lake Hodges Station. Average annual leachate generation, peak daily leachate generation, and peak daily head on the liner were recorded.

Results

The results of the HELP 3 analysis indicate generally low values for both the total leachate generation and peak daily leachate generation during the 30-year life of the facility, except for significant "spikes" associated with the heavy precipitation of years 3, 16, and 22 (Figure 1). After the final cover is placed in year 31, leachate generation would be expected to decrease to almost zero. The amount of leachate generated reaches a maximum value on the 16th year, when the projected total leachate generation is estimated at 53,984 ft^3, of which 8,187 ft^3 are generated from the floor area and 45,797 ft^3 are generated from the slope area. The peak daily leachate generation is estimated to be 142 ft^3 for the floor areas and 1,094 ft^3 for the slope areas during the 16th year.

Calculated peak daily head on the liner reaches a maximum at 0.25 inches during the 16th year (Figure 1). This is within the 12-inch range allowed by regulations (e.g., Section 258.40 of Subpart D of Title 40 of the Code of Federal Regulations), so we conclude that the proposed LCRS design meets the standard of practice regarding leachate removal.

CLOSURE

This report is based on our interpretation of the modeling data described above. Our firm should be notified of any pertinent change in the project or if conditions are found to differ from those described herein, since this may require reevaluation of our conclusions. This report has not been prepared for use by parties or projects other than those named or described above. It may not contain sufficient information for other parties or other purposes. It has been prepared in accordance with generally accepted geotechnical practices and makes no other warranties, either express or implied, as to the professional advice or data included in it.

GeoLogic Associates

Horacio Ferriz

Horacio Ferriz, Ph.D., C.E.G.
Senior Engineering Geologist

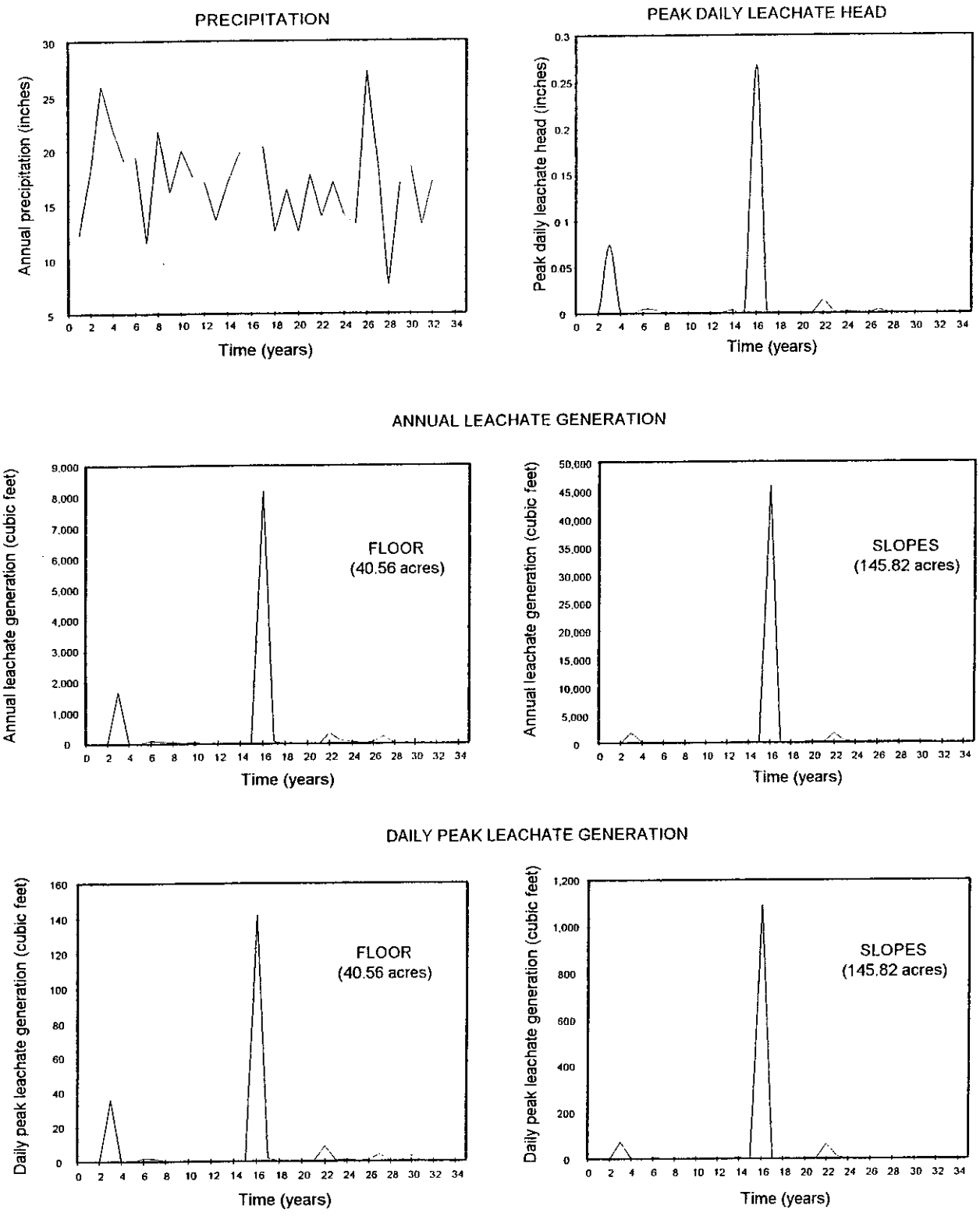


Figure 1. Results of the leachate generation analysis.

GeoLogic Associates

APPENDIX 1

EXAMPLE CALCULATIONS FOR LEACHATE GENERATION ANALYSIS

```
**********************************************************************
**********************************************************************
**                                                                  **
**                                                                  **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE        **
**                HELP MODEL VERSION 3.06   (17 AUGUST 1996)        **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY            **
**                   USAE WATERWAYS EXPERIMENT STATION              **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY      **
**                                                                  **
**                                                                  **
**********************************************************************
**********************************************************************

PRECIPITATION DATA FILE:     \HELP3\DATA4.D4
TEMPERATURE DATA FILE:       \HELP3\DATA7.D7
SOLAR RADIATION DATA FILE:   \HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA:     \HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE:   \HELP3\4GCS13.D10
OUTPUT DATA FILE:            \HELP3\APPX1.OUT

TIME:  13:48     DATE:  12/17/1998

**********************************************************************
     TITLE:  Gregory Canyon
**********************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                              LAYER  1
                              --------
                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
          THICKNESS                     =     18.00   INCHES
          POROSITY                      =      0.4730 VOL/VOL
          FIELD CAPACITY                =      0.2220 VOL/VOL
          WILTING POINT                 =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.1106 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.520000001000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                              LAYER  2
                              --------
                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  18
          THICKNESS                     =   4800.00   INCHES
          POROSITY                      =      0.6710 VOL/VOL
          FIELD CAPACITY                =      0.2920 VOL/VOL
          WILTING POINT                 =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.2913 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC


                              LAYER  3
                              --------
                TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   7
          THICKNESS                     =     24.00   INCHES
          POROSITY                      =      0.4730 VOL/VOL
          FIELD CAPACITY                =      0.2220 VOL/VOL
          WILTING POINT                 =      0.1040 VOL/VOL
```

INITIAL SOIL WATER CONTENT	=	0.2220	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.5200000001000E-03	CM/SEC
SLOPE	=	50.00	PERCENT
DRAINAGE LENGTH	=	100.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 27

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3660	VOL/VOL
WILTING POINT	=	0.2880	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.779999993000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-SPECIFIED CURVE NUMBER OF 96.7, A SURFACE SLOPE OF 29.% AND A SLOPE LENGTH OF 700. FEET.

SCS RUNOFF CURVE NUMBER	=	96.80	
FRACTION OF AREA ALLOWING RUNOFF	=	95.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	43.040	ACRES
EVAPORATIVE ZONE DEPTH	=	32.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.103	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	17.908	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.950	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	1415.253	INCHES
TOTAL INITIAL WATER	=	1415.253	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM SAN DIEGO CALIFORNIA

STATION LATITUDE	=	33.30	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	0	
END OF GROWING SEASON (JULIAN DATE)	=	367	
EVAPORATIVE ZONE DEPTH	=	32.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	6.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	65.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	69.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%

AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 66.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SAN DIEGO CALIFORNIA
NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.22	2.86	3.20	1.56	0.48	0.12
0.02	0.22	0.38	0.66	2.20	2.72

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SAN DIEGO CALIFORNIA
NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
56.80	58.40	59.00	61.20	63.40	66.30
70.30	72.20	71.30	67.50	61.60	57.40

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SAN DIEGO CALIFORNIA
AND STATION LATITUDE = 33.30 DEGREES

ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.53	2113862.500	100.00
RUNOFF	6.085	950707.562	44.97
EVAPOTRANSPIRATION	7.646	1194557.750	56.51
DRAINAGE COLLECTED FROM LAYER 3	0.0002	36.032	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000001	0.229	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0001		
CHANGE IN WATER STORAGE	-0.201	-31449.201	-1.49
SOIL WATER AT START OF YEAR	1415.694	221181280.000	
SOIL WATER AT END OF YEAR	1415.493	221149824.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	10.077	0.00

ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.00	2655998.500	100.00
RUNOFF	5.661	884386.750	33.30
EVAPOTRANSPIRATION	10.758	1680835.500	63.28
DRAINAGE COLLECTED FROM LAYER 3	0.0000	6.888	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000001	0.165	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	0.581	90781.203	3.42
SOIL WATER AT START OF YEAR	1415.493	221149824.000	
SOIL WATER AT END OF YEAR	1416.074	221240608.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0001	-11.970	0.00

ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	19.77	3088769.750	100.00
RUNOFF	7.362	1150140.250	37.24
EVAPOTRANSPIRATION	11.557	1805618.620	58.46
DRAINAGE COLLECTED FROM LAYER 3	0.0001	13.116	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000001	0.211	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	0.851	132986.828	4.31
SOIL WATER AT START OF YEAR	1416.074	221240608.000	
SOIL WATER AT END OF YEAR	1416.925	221373600.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	10.810	0.00

ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	19.93	3113768.000	100.00
RUNOFF	9.040	1412436.000	45.36
EVAPOTRANSPIRATION	11.424	1784815.620	57.32
DRAINAGE COLLECTED FROM LAYER 3	0.0978	15278.588	0.49
PERC./LEAKAGE THROUGH LAYER 5	0.000048	7.454	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0228		
CHANGE IN WATER STORAGE	-0.632	-98753.164	-3.17
SOIL WATER AT START OF YEAR	1416.925	221373600.000	
SOIL WATER AT END OF YEAR	1416.293	221274832.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0001	-16.480	0.00

ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.29	3170013.000	100.00
RUNOFF	9.655	1508388.120	47.58
EVAPOTRANSPIRATION	11.423	1784680.620	56.30
DRAINAGE COLLECTED FROM LAYER 3	0.0000	0.002	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000000	0.014	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	-0.788	-123069.555	-3.88
SOIL WATER AT START OF YEAR	1416.293	221274832.000	
SOIL WATER AT END OF YEAR	1415.505	221151776.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	13.841	0.00

ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.47	1948252.870	100.00
RUNOFF	4.061	634546.062	32.57
EVAPOTRANSPIRATION	8.524	1331716.500	68.35
DRAINAGE COLLECTED FROM LAYER 3	0.0000	0.951	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000001	0.112	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	-0.115	-18003.666	-0.92
SOIL WATER AT START OF YEAR	1415.505	221151776.000	
SOIL WATER AT END OF YEAR	1415.390	221133760.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-6.949	0.00

ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.36	2556008.250	100.00
RUNOFF	6.149	960675.937	37.59
EVAPOTRANSPIRATION	9.006	1407064.370	55.05
DRAINAGE COLLECTED FROM LAYER 3	0.0000	7.308	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000001	0.159	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	1.205	188256.562	7.37
SOIL WATER AT START OF YEAR	1415.390	221133760.000	
SOIL WATER AT END OF YEAR	1416.595	221322016.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	4.081	0.00

ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.51	1954502.370	100.00
RUNOFF	4.930	770184.250	39.41
EVAPOTRANSPIRATION	8.575	1339744.750	68.55
DRAINAGE COLLECTED FROM LAYER 3	0.0000	0.001	0.00
PERC./LEAKAGE THROUGH LAYER 5	0.000000	0.009	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
CHANGE IN WATER STORAGE	-0.995	-155434.203	-7.95
SOIL WATER AT START OF YEAR	1416.595	221322016.000	
SOIL WATER AT END OF YEAR	1415.600	221166592.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	7.664	0.00

GeoLogic Associates
Geologists, Hydrogeologists and Engineers

October 23, 1995
Job No. 9529

Gregory Canyon Ltd.
15025 Paso del Sol
Del Mar, CA 92014

Attention: Mr. Richard Chase

TWO-DIMENSIONAL GROUNDWATER FLOW MODEL
PROPOSED LANDFILL AT GREGORY CANYON

INTRODUCTION

The San Luis Rey Water District has requested from Gregory Canyon Ltd., an assessment of potential impacts of a release from the proposed Gregory Canyon Landfill on the San Luis Rey (SLR) groundwater basin, and an estimate of remediation costs that would need to be incurred to mitigate the effects of such a release.

GeoLogic Associates has performed computer model simulations of groundwater flow for the San Luis Rey River Basin in the vicinity of the proposed landfill, estimated worst-case leakage from the landfill, identified wells within the basin that could be impacted by a release, and estimated costs of treating the water from these wells.

Hydrogeologic setting

The SLR groundwater basin is situated in a meandering, coarse-grained alluvial valley that is bounded by moderately incised granitic and metamorphic rocks of the Peninsular Ranges geomorphic province. The valley has an average width of 2,600 feet and a maximum depth of about 240 feet (average thickness of 150 feet). The groundwater gradient in the basin is approximately 0.004 feet/feet, which is similar to the topographic gradient of the ground surface. Depths to water range from less than five feet to approximately 10 feet below ground surface (GeoScience, 1993). The average hydraulic conductivity of the alluvial sediments is estimated to be about 80 to 100 feet/day, with higher conductivity materials in the main river channel and lower conductivity materials (8 feet/day) skirting the edges of the valley (NBS Lowry, 1994; Geraghty & Miller, 1988). The meandering San Luis Rey River flows at an average rate of about 18.6 cubic feet per second (Geraghty & Miller, 1988).

Setting of the proposed landfill

The proposed landfill will cover an area of approximately 185 acres within the Gregory Canyon watershed and will consist of a sequence of composite lined "cells". The composite liner system will be constructed to U.S. EPA Subtitle D standards and will include the following elements

(from bottom to top):

- Bedrock - The subgrade of the landfill will be competent bedrock. Existing alluvium, colluvium and weathered bedrock are expected to be removed in order to achieve design grades.

- Sub-liner dewatering system - Current regulations for a Class III municipal solid waste landfill (Chapter 15 and Title 14) require that a five foot separation exist between the base of refuse and groundwater. The sub-liner dewatering system will ensure that groundwater does not rise to within five feet of the base of refuse. Water from this system will drain into a sump and could act as a fail-safe leachate collection system in the unlikely event of a liner system breach.

- Inert fill - This layer will consist of random fill soils and will act as a separator between the refuse cell and the sub-liner dewatering system.

- Low permeability soil liner - This layer will consist of fine-grained soils that have low hydraulic conductivity, and will act as the secondary containment system.

- HDPE liner - The HDPE liner will consist of thick plastic sheets seamed together to form a barrier with a very low hydraulic conductivity.

- Leachate Collection and Recovery System (LCRS) - The system will consist of a network of perforated drain pipes surrounded by high conductivity gravel. The purpose of the system is to keep leachate from ponding upon the liner. The leachate collection system will be sized to assure that the maximum leachate head build-up on the liner system be less than 6 inches during the lifetime of the landfill.

- Random soil layer - This layer acts as a buffer to ensure that large objects that might occur in the waste stream do not penetrate the LCRS and liner system. Refuse is placed directly upon this layer.

Modern Class III municipal solid waste landfill liner systems are constructed under very stringent Quality Assurance and Quality Control guidelines. However, even under the best Quality Assurance and Quality Control measures there could be defects in the liner system that could lead to leakage of leachate from the refuse cell. Leakage from the landfill was estimated following the guidelines of U.S. EPA (1987) and Gireaud and Bonaparte (1989a, 1989b) at 1 to 10 gallons per day per acre.

GROUNDWATER FLOW MODEL ELEMENTS

General

The following is a general discussion of elements incorporated into the two-dimensional groundwater flow model developed using the finite difference computer program Flowpath (Franz

and Guiguer, 1992). A grid composed of squares or rectangles is superimposed over the modeled area to partition the system into grid cells that are small compared to the spatial extent of the entire aquifer. The program models groundwater flow in two-dimensions and takes into consideration hydraulic head and saturated thickness to calculate flux between the cells.

Constituent transport modeling with the Flowpath computer program is accomplished with the use of particle tracking techniques, which simulate constituents as "particles" that follow the groundwater flowlines. The particle tracking method is a case of simple advective transport where no dispersion, absorption or decay are allowed. Particles are tracked until they are pulled into a modeled pumping well, or until they stagnate and are overwhelmed by a much larger flux of groundwater.

Known head values were derived from the Geohydrologic Basemap of the San Luis Rey MWD Area (Geoscience, 1993). Pumping rates are estimated values based on the basin wide mass balance prepared by Don Owen & Associates (1995).

The groundwater flow simulations were created using a mesh of nodes spaced 250 to 260 feet apart, which included nearly the entire SLR Water District area both up- and down-gradient from the proposed landfill site. Water flow into the modeled simulation is controlled by the use of constant flux nodes (a function of the hydraulic conductivity, saturated thickness, and hydraulic gradient), and water flow out of the modeled area is controlled using constant head nodes. The river was modeled by applying a known hydraulic head in conjunction with a leakance factor that is a function of the river bed thickness, hydraulic conductivity and area of recharge. Table 1 lists the parameters that were included in the model.

Table 1

Model Element	Q (cu. ft./day)	K (ft./day)	i (gradient)	A (sq. ft.) saturated section	How modeled
San Luis Rey Channel (Entering)	+123,000	80 to 100	0.004	375,000	Constant flux
San Luis Rey Channel (Exiting)	-676,029	80 to 100	0.004	375,000	Constant head
Gregory Cyn. Channel	+247	8	0.08	2,400	Worst case landfill liner leakage
San Luis Rey River	+1.6 million (Potential)	NA	0.004	NA	River node (leakance and head input)
Consump. Use	-60,650	NA	NA	NA	Pumping wells
Precip-ET	-5972				

Modeled conditions

Two conditions were simulated using the groundwater flow model. The first (Figure 1) was to simulate groundwater flow under existing conditions with a worst case leakage through the liner of 10 gallons per day per acre (1,850 gallons per day for the entire site) and head conditions in the SLR basin at levels approximately equal to those shown on the Geoscience (1993) hydrogeologic basemap. The release is assumed to be a point source and is modeled as an injection well. The second simulation (Figure 2) involved dropping groundwater approximately 20 feet below ground surface in the southwest corner of the basin as could happen if increased pumping took place during extended drought periods.

Modeling results

Steady-state groundwater flow in the SLR basin generally follows the topography, with flow lines following the general trend of the river (Figure 1). Owing to slightly increased recharge in the vicinity of the river, groundwater velocities are higher immediately adjacent to the trace of the river. Figure 1 also shows the predicted pathways of particles released from the proposed landfill. The particle pathways are shown to extend past wells #41 and #42 (SLR Water District designations) when allowed to flow under steady state conditions. The particle pathways then extend along the southern perimeter of the canyon along the embayment until the particles intercept the point of constriction within the canyon. The particles do not extend beyond this point because the computer program stops tracking the particles when they enter a model cell with much higher flux, as under these circumstances, the liquid release would be strongly diluted (from the computational standpoint, the path of a particle entering a cell with large flux gets distorted beyond the accuracy required for tracking).

Figure 2 shows the second groundwater flow simulation for the case where groundwater head levels have been reduced in the southwest part of the basin to a level approximately 20 feet below ground surface. Owing to the reduced groundwater head levels in the downgradient part of the model, a steeper groundwater gradient is induced. The net effect is slightly higher groundwater flow velocities in the central portion of the basin. The modest change in the trajectories of particles is very small, however, as demonstrated by almost identical particle tracks calculated for the second simulation (Figure 2).

Water District concerns

Currently, all of the wells of the SLR Water District are utilized for agricultural purposes and no routine chemical analyses are performed. The historic record of chemical analyses available for the basin is limited to analysis for total dissolved solids (TDS), hydroxide ion, calcium and several other constituents that could have adverse effects on normal crop growth. The SLR Water District is concerned that a liquid release that might enter the groundwater basin from the landfill could be detrimental to agricultural and private land owner interests.

According to Mr. Don Owen (personal communication, 1995), the SLR Water District has not

established any basin objectives, nor has it estimated the Waste Assimilation Capacity for the SLR basin. However, the District is requesting that the landfill control the effluent and leachate so as to keep the quantities of deleterious compounds below drinking water levels and the levels required for normal agricultural use. The Water District is more concerned with the total quantities of chemical compounds that might enter the basin, than with relative chemical concentrations (in light of the relatively small amounts of landfill-derived fluids when compared to the total amount of water entering the basin upgradient from the landfill).

Typical landfill leachate chemistry

Although landfill leachate chemistry varies on a site by site basis, certain compounds are common to many of the facilities. Table 2 below shows a typical landfill leachate sample along with concentrations of each of the analytes. Based on typical analyte concentrations and estimated quantities of leachate generation, the total chemical contribution from the landfill can be calculated. The following landfill leachate chemical concentrations are from samples collected at a typical Class III sanitary landfill:

Analyte	Concentration	Concentration	Rate of accumulation
Sodium	292 mg/L	5.0e-04 pounds/gallon	0.925 pounds/day
TDS	2400 mg/L	4.0e-03 pounds/gallon	7.4 pounds/day
Chloride	375 mg/L	6.4e-04 pounds/gallon	1.18 pounds/day

The rate of accumulation assumes a worst case scenario of 10 gallons per day per acre leakage through the liner for a 185 acre site. Total accumulation of dissolved solids at the rates given above is of approximately 3,000 pounds/year

LEACHATE AND GROUNDWATER TREATMENT

The leachate control system designed for the Gregory Canyon Landfill will include: leachate collection, leachate disposal and/or treatment, and groundwater monitoring. The leachate collection component includes a gravel blanket between the HDPL liner and the operations layer, and perforated pipes embedded within the gravel blanket to maintain the head of leachate over the liner at less than 12 inches. The pipes will convey the leachate into a holding tank at the toe of the landfill, where it will be collected for treatment (e.g., air-stripping) and reuse onto various landfill areas for dust suppression. The groundwater monitoring component will include monitoring wells situated in various upgradient and downgradient locations. Groundwater samples will be collected quarterly and analyzed for general ionic compounds, metals, and volatile organic compounds.

The sub-liner dewatering system (Figure 3) will collect groundwater before it rises to within five feet of the base of refuse. The system consists of dendritic array of perforated pipes, surrounded by gravel, located below the low-permeability clay layer of the liner. Water from this system will drain into a sump, sampled for general water quality parameters, treated if need be (e.g., reverse osmosis), and reused onto various landfill areas for dust suppression. The sub-liner dewatering

system could act as a fail-safe leachate collection system in the unlikely event of a liner system breach.

In any case, design calls for reuse of collected leachate and/or groundwater within the footprint of the landfill, so as not to impare water quality in the San Luis Rey groundwater basin.

CONCLUSIONS

- The leachate containment systems incorporated in the design of the Gregory Canyon Landfill meet the requirements for environmental protection mandated by U.S. EPA and the California Environmental Protection Agency. However, even under the best Quality Assurance and Quality Control measures there could be defects in the liner system that could lead to leakage of leachate from the refuse cell. Leakage from the landfill was estimated following the guidelines of U.S. EPA (1987) and Gireaud and Bonaparte (1989a, 1989b) at 1 to 10 gallons per day per acre.

- The potential impact of a hypothetical release of leachate into the San Luis Rey groundwater basin was evaluated by simulating groundwater flow under existing conditions with a worst case leakage through the liner of 10 gallons per day per acre (1,850 gallons per day for the entire site) and head conditions in the SLR basin at levels approximately equal to those shown on the Geoscience (1993) hydrogeologic basemap. The model (Figure 1) shows that the predicted pathways of particles released from the proposed landfill extend past wells #41 and #42 (SLR Water District designations) when allowed to flow under steady state conditions. Under increased pumping conditions, well #37 could also be impacted.

- Impact to the wells could manifest itself in the detection of volatile organic compounds, or in increased concentrations of sodium, chloride, and total dissolved solids. Based on typical analyte concentrations and estimated quantities of leachate generation, we estimate that as much as 1 pound/day of sodium, 7.5 pounds/day of total dissolved solids, and 1.2 pounds/day of chloride could be added to the basin by a worst case scenario of 10 gallons per day per acre leakage through liner rate for a 185 acre site.

RECOMMENDATIONS

For the purpose of providing environmental and financial assurance to the San Luis Rey Water District we recommend:

- Including wells 37, 41, and 42, and an upgradient basin well, in the regular quarterly monitoring program of the landfill. We also recommend that monitoring starts immediately, so that a baseline of spatial and seasonal variations in water chemistry can be established.

- Providing financial assurance to the San Luis Rey Water District that the water of these three wells will be treated and disposed off adequately, and that enough treatment capacity will be implemented to guarantee removal of an amount of dissolved solids equal or greater than the worst case scenario of leachate release. Figure 4 shows a flow diagram of a water treatment system that would achieve the goals stated in the previous paragraph. As shown in the enclosed calculation sheet (Table 3), this water treatment system can be constructed for a capital outlay of $195,543 and annual operating cost of $168,300 (1995 dollars). We thus recommend these figures as goals for the financial assurance instruments.

CLOSURE

This report is based on the numerical modeling described above, and standard engineering cost estimates. Our firm should be notified of any pertinent change in the project or if conditions are found to differ from those assumed herein, since this may require reevaluation of our conclusions. This report has not been prepared for use by parties or projects other than those named or described above. It may not contain sufficient information for other parties or other purposes. It has been prepared in accordance with generally accepted geotechnical practices and makes no other warranties, either express or implied, as to the professional advice or data included in it.

GeoLogic Associates

Horacio Ferriz

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Senior Geologist

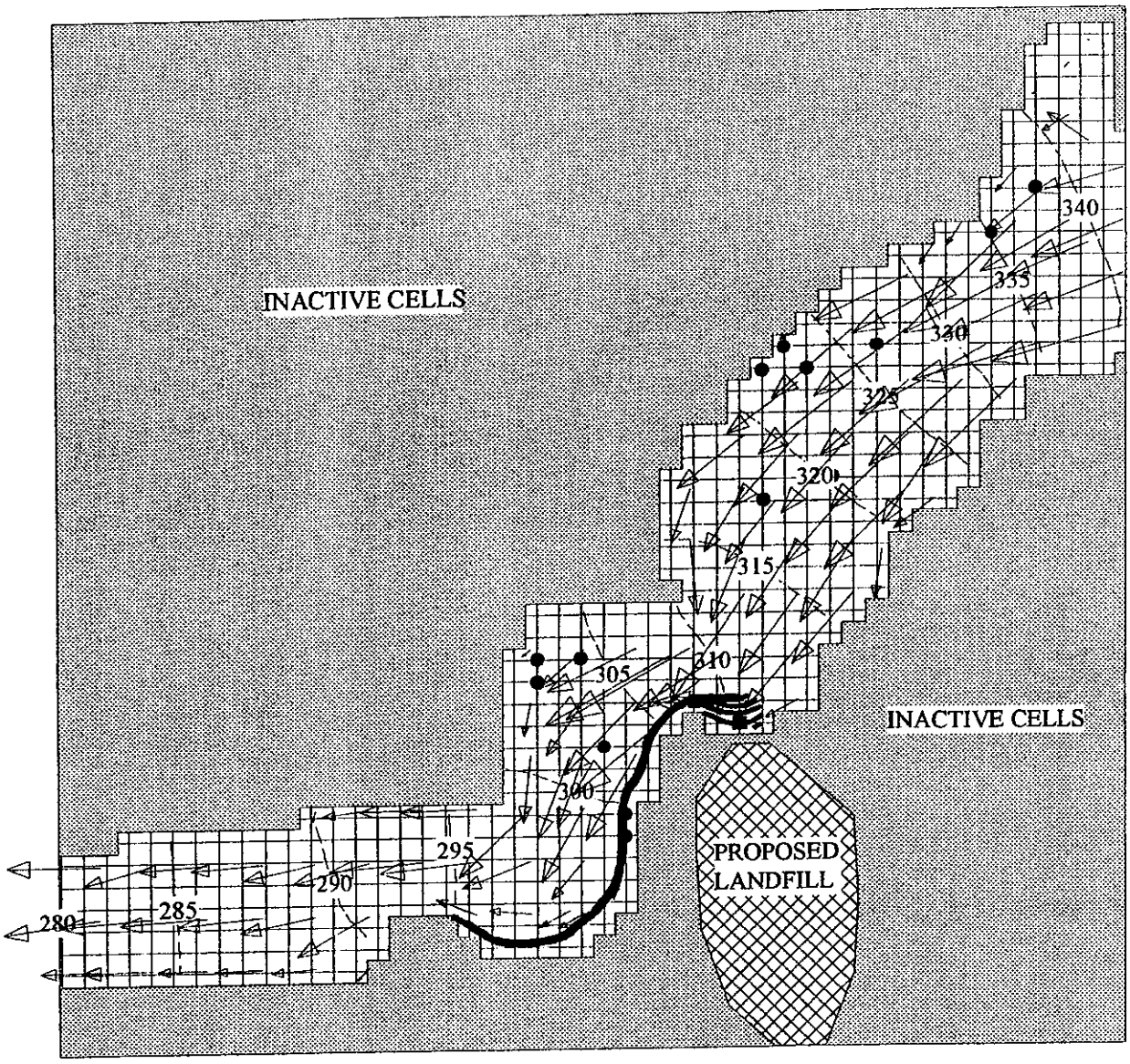
Reviewed by: Gary Lass, Principal

REFERENCES

Gireaud, J.P., Bonaparte, R., 1989a, Leakage through liners constructed with geomembranes-Part I. Geomembrane liners: Geotextiles and Geomembranes, v.8, p.27-67.

Gireaud, J.P., Bonaparte, R., 1989a, Leakage through liners constructed with geomembranes-Part II. Composite liners: Geotextiles and Geomembranes, v.8, p.27-67.

U.S. EPA, 1987, Background document: Bottom liner performance in double-lined landfills and surface impoundments: EPA 530-SW-87-013, 301pp.



Case 1. Equipotential levels similar to the ones measured currently

- Pumping well
- Hypothetical point of release
- 315 Equipotential line (in feet amsl)
- Groundwater flow velocity vectors
- Release pathway

2,000 feet

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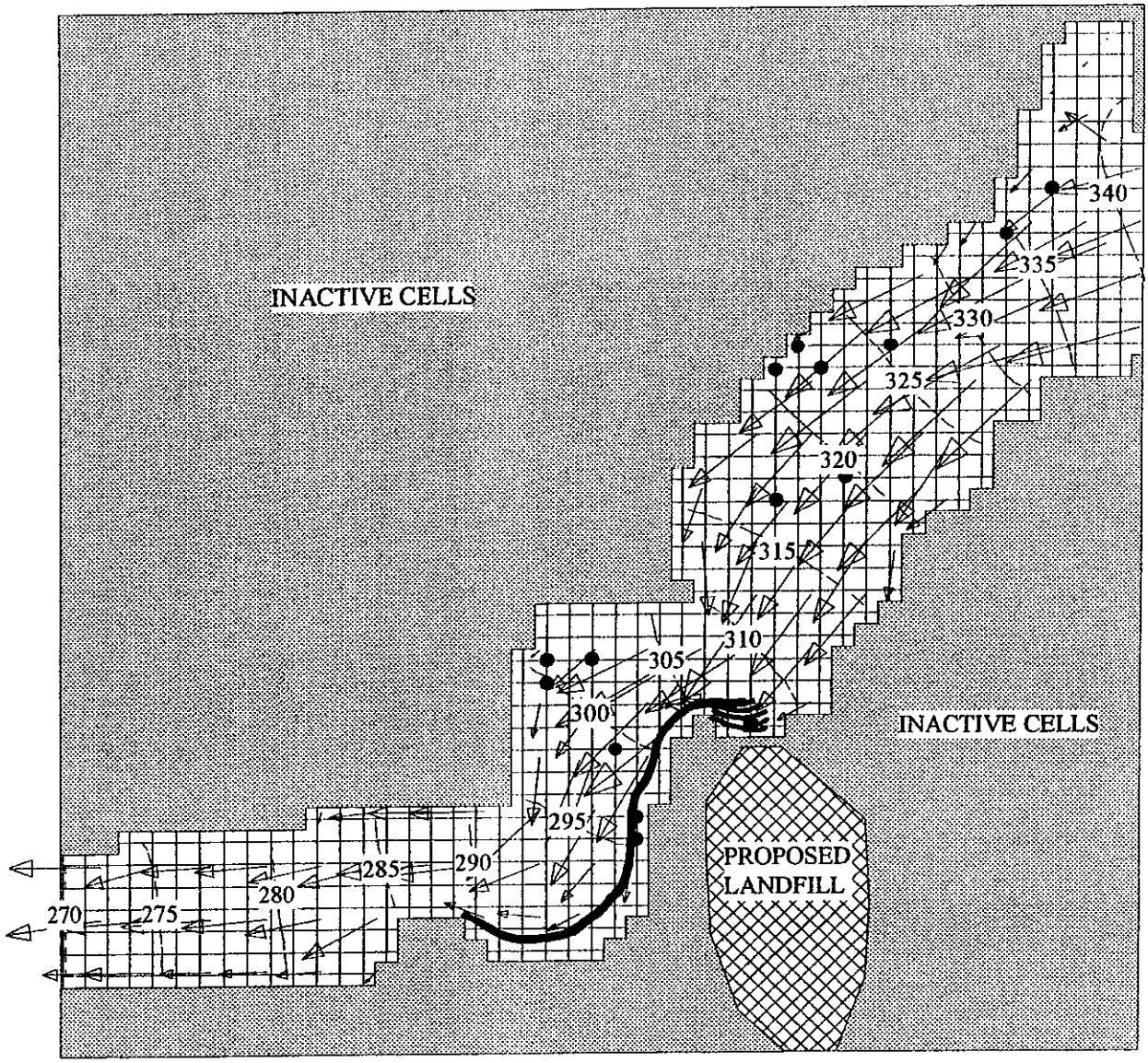

Case 2. Equipotential levels 20 feet lower than ground surface along the western edge of the model

- Pumping well
- Hypothetical point of release
- 315 Equipotential line (in feet amsl)
- Groundwater flow velocity vectors
- Release pathway

2,000 feet

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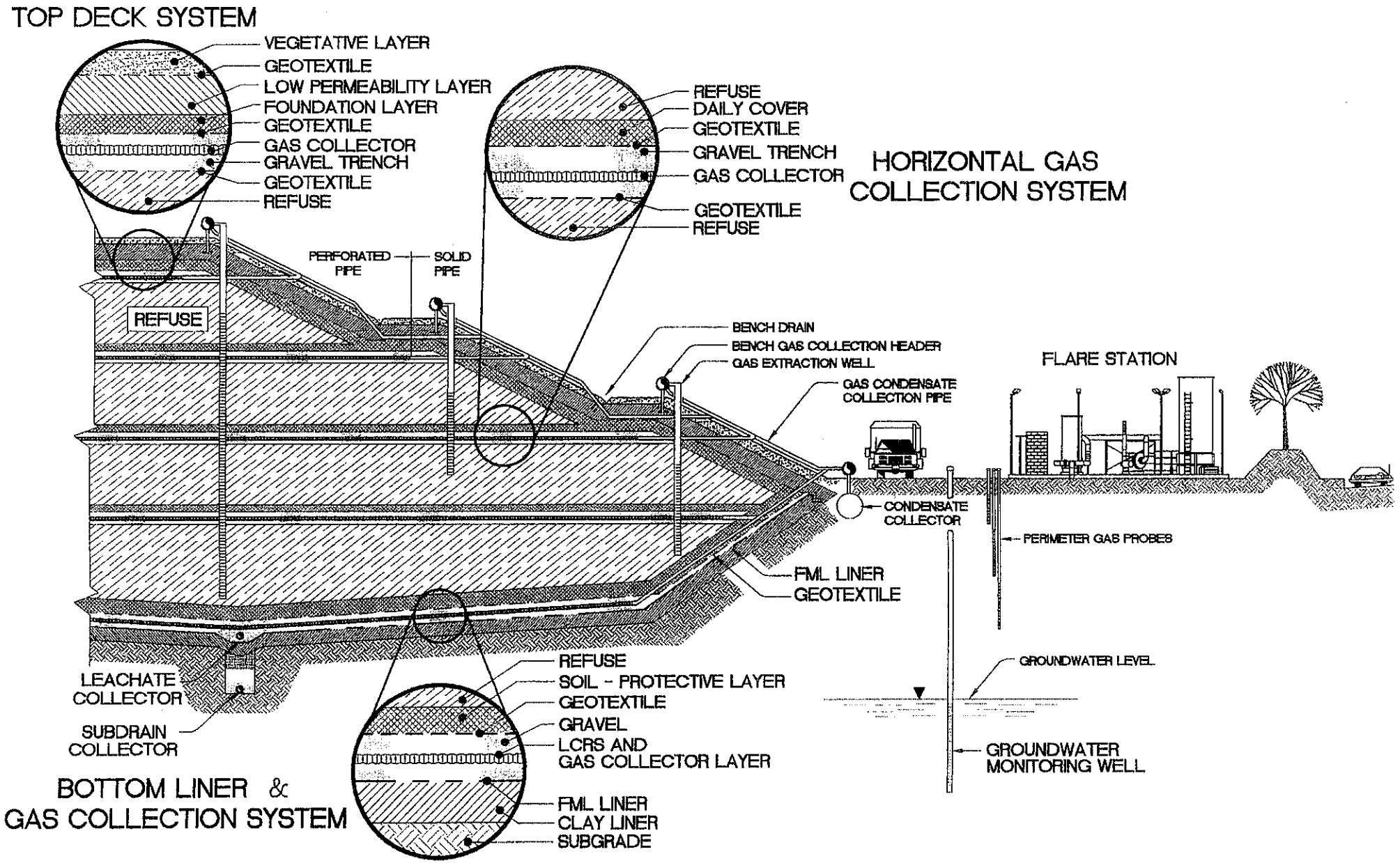

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BAS

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TYPICAL LANDFILL CROSS - SECTION

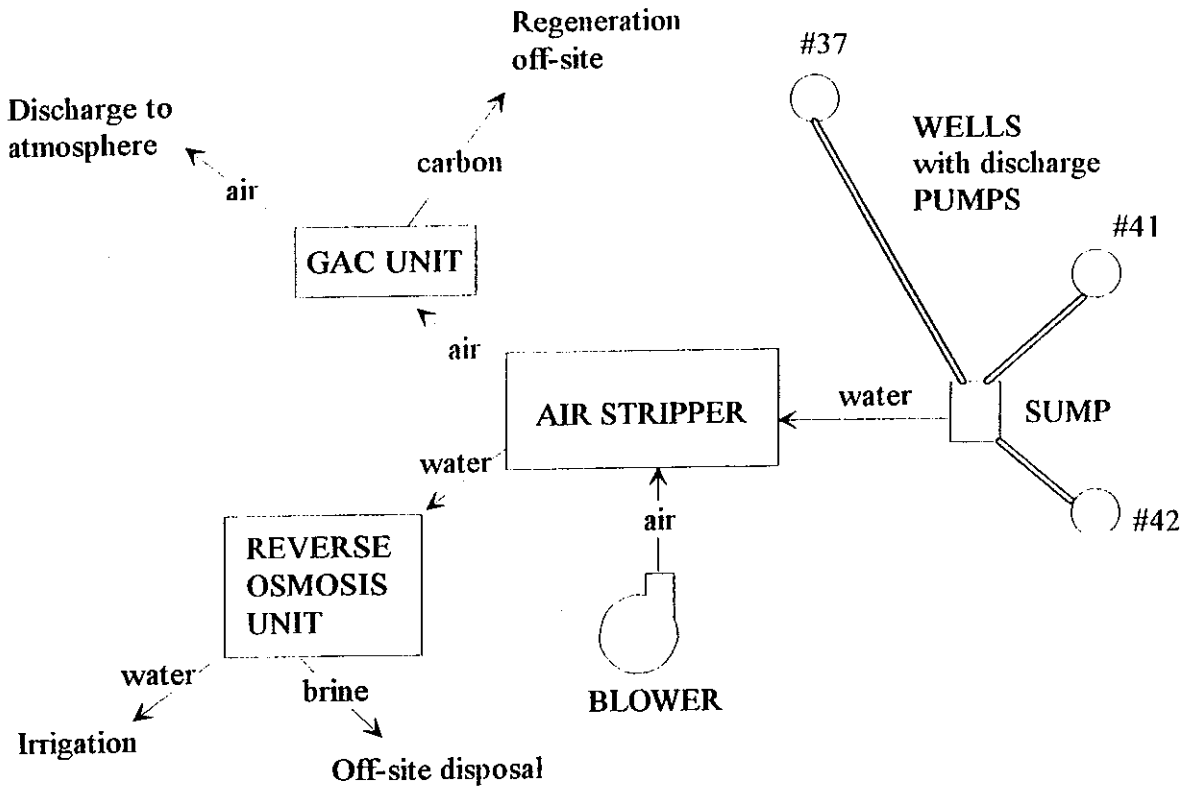

Figure 4. Schematic flow diagram of the treatment system.

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Table 3. Cost estimate for treatment system for wells 37, 41, and 42

ENGINEER'S ESTIMATE		
PROJECT: Water treatment of three agricultural wells		
ASSUMPTIONS: The three wells have pumps, and the total distance to a common sump is 1,500 feet. Total VOC content is 15 ppb, and the goal is to reduce it to less than 5 ppb. Total dissolved solids content is 1,000 ppm, and the goal is to reduce it to 600 ppm. A secondary goal is to remove a grand total of at least 3,000 lbs/yr of TDS.		
It is assumed that the total discharge of the three wells is 50 to 90 gpm.		
EQUIPMENT		COSTS
1. EXTRACTION WELLS		$ -
Already in place		
2. DISCHARGE PUMPS		$ -
Already in place		
3. PIPING		$ 9,000
4" PVC, schedule 40 with valves and fittings.		
2,000 feet at $4.50/foot		
4. SUMP		$ 2,500
5. AIR STRIPPER	$ 75,000	$ 93,581
50-90 gpm. Model 2600 Poly Services	8.5% sales tax	
Three trays and sump tank.	15% installation (FOB)	
Industrial blower 10 HP/230/3		
1,800 cfm @ 12"WC with control		
panel, sampling ports, alarms		
flow indicators.		
Booster blower 2,400 cfm @ 22"WC		
6. GRANULAR ACTIVATED CARBON UNIT	$ 22,500	$ 28,074
2,400 cfm	8.5% sales tax	
VSC - 4,000 lbs carbon	15% installation (FOB)	
(Two canisters of 2,000 lbs each)		
7. REVERSE OSMOSIS	$ 50,000	$ 62,388
50-90 gpm.	8.5% sales tax	
	15% installation (FOB)	
TOTAL CAPITAL OUTLAY		$ 195,543
OPERATION COSTS		COSTS
8. GAC REGENERATION		$ 24,300 per year
@ $1.90 per pound of carbon		
plus $500 chemical profiling		
3 regenerations per year		
9. OFF-SITE DISPOSAL OF BRINE		$ 144,000 per year
Transport at $0.80 per gallon		
15,000 gallons per month (est.)		
TOTAL YEARLY OPERATION COSTS		$ 168,300 per year
Estimate prepared by: Eugene Lacey, PE		