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Geological Consulting • Environmental Restoration • Regulatory Compliance

GROUND WATER

INVESTIGATION

for

Tanana, Alaska

Prepared for:

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VSW?

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FILE COPY

FIGURES

TABLES

APPENDICES

Technical Terms Glossary

Anastomosing stream system - A stream system characterized by multiple network of interfingering channels and associated wetlands (FIGURE 3) whose channels are generally straight and stable, not cutting from side to side. Sediment load of an anastamosing river is high and deposition occurs within the channel, forming longitudinal bars, and along the edges of the channel, forming levees. Bars and levees are built up of multiple layers of sand and silt.

Fining-upward sequence- A geologic formation characterized by coarse-grained sediment at the bottom of the formation and diminishing grain size upward in the geologic formation.

Lacustrine - A depositional environment formed in a lake.

Overbank deposit - Sediment that is deposited over the natural levees of a river at flood stage.

Proglacial deposit - Sediment that is carried by a glacial stream and deposited in front of the glacier.

VES - (Vertical Electrical Sounding) The location of an electrical resistivity sounding.

EXECUTIVE SUMMARY

TERRASAT, INC., was contracted in August of 1996 by Too'gha, Inc., of Tanana, Alaska to investigate ground water resources around Tanana. The work was funded by Village Safe Water, a division of the state of Alaska's Department of Environmental Conservation. Our scope of service was to conduct geophysical logging and surface electrical resistivity programs and to conduct a magnetic survey.

could be useful – want to tap into Yukon – may be more silt than same old channels of Yukon though –

Interpretation of air photos suggests that a glacial meltwater channel exists near the east end of Tanana airport. Interpretation also suggests the presence of two faults in Tanana. One fault has a northeast-southwest trend and cuts diagonally through the city near the city wells. The second has a north-south trend and appears to cut through town near Koyukuk Street. Surface resistivity surveys and magnetic profiles indicate the presence of two faults in Tanana. A GIS map of reported well yields in Tanana suggests that some wells have noticeably higher yields than others. These wells appear to be aligned in trends corresponding to the proposed faults interpreted from the air photos. Surface resistivity surveys and magnetic profiles also suggest that permafrost is thin or nonexistent near the proposed faults where these wells are located.

?

I don't see that

PF could be good

this is what you want (just down bedrock)

Geophysical well logging indicates that four major stratigraphic units are represented in Tanana. The downward sequence may include: proglacial alluvium, lacustrine sediment, river sediment, and bedrock. This sequence is repeated in most of the well logs. The geology across Tanana is generally continuous with the exception of localized discontinuities characteristic of channelized stream deposits.

very hetero!

The local ground water system in Tanana may receive recharge from the Ray Mountains. Water appears to move south toward the Yukon River through fractures and meltwater channels. Evidence of this recharge is seen as springs in the Mission Hill area, where water is discharged to the surface at elevations above those in Tanana. The good quality water in Tanana is also characteristic of recharge that is not influenced by the river.

yes, but for big production → Yukon river

not unless you want a low production bedrock well!

We recommend that additional surface resistivity and magnetic surveys be conducted across the faults identified in this investigation to more accurately locate areas where ground water resources exist. We also suggest that these additional geophysical investigations be conducted at the same time as a pilot drilling program. We further recommend that a drilling program be coupled with geophysical logging of the boreholes. Using this strategy, TERRASAT, INC., has been able to maximize well yields by placing well screens at the best depths to intercept water bearing zones.

hmm...

We recommend that all water wells within 500 feet of the PHS complex and school be tested for petroleum-derived constituents. This concern arises as a result of a study in 1995 by Ecology and Environment, Inc., where soil contamination was discovered. Contamination was suggested to result from a tank farm, UST's, AST's, buried pipelines, and a former drum storage area. E & E suggested that the area around the hospital complex may have contaminated ground water.

We recommend that periodic testing of the water wells be done to confirm the absence of petroleum contamination. Testing should be conducted until a time when the ground water involvement has been established, extent of contamination identified, and threat to the water supply has been eliminated.

SITUATION ANALYSIS

INTRODUCTION

TERRASAT, INC., was contracted in August of 1996 by Too'gha, Inc., Tanana's water/sewer utility, to investigate ground water resources around Tanana, Alaska and determine the potential exploitability of this water. Our work is preparatory to a planned service expansion by Too'gha, Incorporated. Our scope of services for this investigation follows:

- Evaluate existing information compiled by CH2M-Hill and Scott Wheaton (PHS).
- Conduct a geophysical logging program of local water wells.
- Conduct a surface electrical resistivity program to determine the depth to bedrock.
- Conduct magnetometer profiles along surface electrical resistivity transects to determine the relief of the sediment/bedrock interface.

The goals for our study were to:

- Locate subsurface structural trends where buried water-bearing channels or faults are suspected from our reconnaissance investigation of available well yield data and our interpretation of aerial photographs.
- Identify the water producing zones in select area water wells and determine possible correlation of these zones between wells.
- Identify the depths of interfaces between bedrock, permafrost, and thawed sediment.
- Profile the sediment/bedrock interface using electrical resistivity and magnetics to locate and identify buried water bearing-channels or faults.
- Evaluate the aquifers identified by (or suspected from) this study in terms of their potential for future development.

We examined the well log information supplied by CH2M-Hill and Scott Wheaton (PHS) and selected a total of eleven area wells, eight primary and three alternate, to try to log. Five of these wells were out-of-service, and in each case these out-of-service wells were frozen. We were able to defrost one of the frozen wells and log a total of seven wells.

elec resist — 7 holes
Surface elec. resist - along runway
- 1st ave
- 3rd ave

We obtained a total of 37 electrical soundings. Eleven soundings were taken along a transect parallel to the runway. A calibration sounding was obtained next to the BLM office to correlate with the logged BLM well. Nine soundings were taken along a transect down First Avenue beside the Yukon River. Seven soundings were taken along a transect down Third Avenue. An extra nine soundings were obtained from three outlying areas outside the downtown core area.

We obtained three magnetic profiles along the three main electrical sounding transects, the runway, First Avenue and Third Avenue. The spacing of the magnetic surveys were designed to provide high resolution subsurface structural information in the data gaps between electrical soundings.

We obtained several surface and subsurface water conductivity measurements. Surface conductivity measurements were taken at Mission Springs. Subsurface conductivity measurements were collected from two wells; the new city well #3 and the school superintendent's well.

LOCATION

Tanana is located about 140 air miles west northwest of Fairbanks, Alaska. The city sits on the north bank of the Yukon River, about three miles downstream from the confluence of the Yukon and Tanana Rivers (FIGURE 1). The sectional description for the Tanana townsite is the NE and NW 1/4s of the SW 1/4 of Section 17, Township 4 North, Range 22 West, Fairbanks Meridian.

CLIMATE

The city of Tanana has an average elevation of 230 feet above sea level. The climate is characteristic of the interior basin of Alaska with generally dry, cold winters and hot summers. The average lows in winter are near -10°F and the average highs in summer are near 90°F (Leslie, 1989). The area receives about eighteen inches of annual precipitation which arrives in the form of about thirteen inches of rain per year and around 50 inches of snow.

SOIL and GEOLOGY

not always
this simple
— [illegible] well
gravel
sand
silt

The Tanana townsite appears to sit on proglacial alluvial sediment that originated from the Ray Mountains. Our interpretation of the stratigraphy in Tanana is described using five major units (FIGURE 2). The uppermost layer is composed of 5 to 15 feet of silt and sandy silt. This silt appears to have been deposited as overbank river sediment or fine-grained glacial flour. Beneath the silt lies 35 to 65 feet of glacial alluvium, carried by meltwater from the north during the last glacial period. These deposits consist of fine sands to coarse gravels. Below the glacial sediment lie 0 to 60 feet of silt and clay (Geosphere, 1996). This fine-grained sediment is believed to originate in a lacustrine or flooded environment where deposits formed in ponded water. Beneath the silt is a layer of river sediment consisting of medium-grained sands. This sediment appears to be 0 to 10 feet thick and becomes finer-grained toward the top of the layer. We believe that these deposits formed in an anastamosing sedimentation setting (Smith, 1983), (FIGURE 3).

(next to the Yukon River, it's hard to believe anything else could occur!!!)

Bedrock forms the base of the stratigraphic sequence in Tanana. The bedrock is composed of schist, sandstone, limestone and slate. Depth to the bedrock / sediment interface is quite irregular and varies from 24 to 140 feet. The silt and clay (lacustrine) layer typically is thin or non-existent where the interface is shallow.

hospital well – ~88' to rock
no lacustrine silt

REVIEW of WATER WELL DATA

TERRASAT, INC., conducted a well search for the Tanana area. We searched databases from the Department of Natural Resources (DNR) and the Public Health Service (PHS). Lee Ice of Ice Water Wells and CH2M-Hill provided well logs and information about wells in Tanana. A summary of the well information is shown in TABLE 1.

The water supply in Tanana is divided between three systems. The first is the Native Council system. This system consists of a water well, a water plant, and distribution facilities, and was constructed by PHS to serve the former hospital. This system currently supplies water to the school, clinic, tribal council office, and teacher's housing. The second system is administered by the City. This system consists of several water wells and treatment and distribution facilities and provides water to the fire station, power plant, city offices, the laundromat and Head Start building. The third consists of private water wells. These wells were drilled in the sixties and seventies to provide water to individual residences. Private wells also supply water to the Federal Aviation Administration (FAA) and Bureau of Land Management (BLM) complexes.

Available information suggests that there are approximately 80 wells in Tanana. Well locations are plotted in FIGURE 4. Nine wells were drilled in 1996 as part of CH2M-Hill's ongoing investigation of the water resources in Tanana. Approximately seven wells have been drilled to provide water to the community and electrical utility. Some of these wells have been abandoned or are no longer in use. The remaining wells in Tanana are private wells, drilled from 1967 to 1980. The average depth of the wells is about 69 feet. The wells used for municipal and electrical water supplies are deeper and attain depths of 220 feet. Nearly all of the private wells are shallow, and most have depths from 40 to 70 feet. Average yield of the wells in Tanana is approximately 11 gpm. There appears to be a wide range in well yields (FIGURE 4; TABLE 1). Several possible explanations for this include: discontinuous permafrost across the area, resulting in many frozen wells; diminished yield due to iron encrustation of the well casing perforations; and limited extent

agree

of the aquifer(s) intercepted by wells. Static water levels are at an average depth of 28 feet below ground surface.

INTERPRETATION of AERIAL PHOTOGRAPHS & GIS MAPS

TERRASAT, INC., reviewed the aerial photographs for Tanana and the surrounding area. Aerial photographs show that Tanana sits on glacial sediment that originated from the north and was deposited as it was carried toward the Yukon River. The photos suggest that two large scale features may control the water resources in Tanana.

cost [illegible] airport?

The first feature is a group of proglacial alluvial fans and glacial outwash deposits. The pattern and scale of these deposits suggest they originated from the Ray Mountains during a past glacial period. Photo interpretation suggests that channels perpendicular to the Yukon River may have formed as glacial meltwater channels. This type of channel typically produces large quantities of water if it has been filled with coarse-grained sediment. The water in these channels may have come from a recharge area located up gradient in the Ray Mountains. Evidence of recharge in these mountains is indicated by the springs that flow out from the side of the hills north of Tanana.

= discharge

? water!

only if you want a rock well

The second group of features that may control water resources in Tanana are large scale faults. Two major faults may lie northeast of Tanana. The first has a northeast-southwest orientation and may bisect the city (FIGURE 4). The other fault has a north-south orientation. This fault appears to be offset to the west as it gets closer to the city (FIGURE 7). A present day creek that runs near Koyukuk Street may follow the trend of this fault.

?

[illegible]

We drafted a GIS map for Tanana and linked it to the well information database (FIGURE 4). Wells interpreted to have greater probabilities for higher than average area well yields (11 gpm) appear to be aligned and have two general orientations; a northeast-southwest or a north-south trend. This is consistent with observations made from aerial photographs and suggests that wells constructed along these lines may have higher than average yields.

disagree

STATISTICAL ANALYSES

TERRASAT, INC., conducted statistical analyses from available well information in Tanana. Statistical plots are shown in APPENDIX A. A frequency distribution of well depths shows that the average well depth is about 60 feet with about 80% of the wells between 30 and 70 feet. A frequency distribution of depths to bedrock shows that the mean is near 50 feet. Note here that only a small portion (approximately 35%) of the wells in the well depth distribution reportedly encounter bedrock. This suggests that the bedrock surface is generally uneven and deeper than indicated by the depth to bedrock distribution. A frequency plot of well yields shows a log-normal distribution with a median of about seven gpm.

FIELD METHODS

WELL LOGGING

TERRASAT, INC., digitally logged seven wells in Tanana using Century Geophysical well logging tools: DRAWWORKS, COMPU-LOG, and a #9042 logging tool, which combines measurements for stratigraphic natural gamma, high resolution fluid temperature and fluid resistivity. We selected this combination of measurements because they provide complete stratigraphic information from a cased well. We used this equipment to identify the local stratigraphy around each well to determine the intervals where water enters the wells. The logging was done for two purposes: a) to determine the stratigraphy at individual well sites and b) to provide a reference showing the subsurface stratigraphy so that we could calibrate our findings from the electrical resistivity survey.

The stratigraphic natural gamma is a passive sensor that measures the intensity of radiation naturally present in all rocks. This radiation occurs at very low levels from the radiogenic decay of the potassium, thorium and uranium contained in all rocks. It occurs at levels that are far below anything remotely considered harmful and is a natural part of the background radiation we experience every day. We used this measurement to distinguish between fine-grained and coarse-grained sediment. As bedrock erodes it breaks down into smaller particles, and new clay minerals are formed. During this process, potassium, thorium and uranium are preferentially incorporated into the clay minerals because their ionic radii fit well with the clay structure. Consequently, fine-grained sediment has a higher natural gamma signal than sand, gravel, or bedrock. The gamma signal will pass through metal, and the gamma probe can be used to detect the stratigraphy down a boring, or well, even when cased.

The high resolution fluid temperature is a specialized solid-state thermometer that can measure small changes in fluid temperature when it is lowered or raised in a fluid filled well. Ideally, the fluid in the well or boring should be allowed to equilibrate for up to 24 hours before using this probe. If no fluids enter or leave the well, the boring will develop a characteristic thermal profile that is roughly the average of the surrounding temperature gradient. However, if water enters or leaves the well or boring it may disrupt this thermal equilibrium, resulting in a temperature change. Thus, when the probe passes an influx of water, it may record a change in fluid temperature. Sometimes this change will be subtle and at other times it will not. We use these subtle and bold changes to infer where the water enters or leaves a well or boring.

The fluid resistivity measures changes in the apparent electrical resistance of the fluid in a well. The apparent resistance is measured between two reference electrodes on the logging tool. The resistivity is inversely proportional to the conductivity of the fluid. Increasing conductivity is an indication of diminishing water quality. We used this probe in conjunction with the fluid temperature measurements to locate the depths where water enters a well. The water that enters a well mixes with the standing water already in the casing. The water found in a well casing usually has a water quality which is an average for the qualities of all the water entering the well. This value generally differs from the water quality of the water just entering a well from the aquifer, thus, when the electrode passes an influx of water, it may record a change in the resistivity of the water.

RESISTIVITY SOUNDINGS

TERRASAT, INC., conducted a series of 37 resistivity soundings using a STING R-1 Earth Resistivity Instrument. This instrument consists of a specialized voltmeter, a direct current power source, four stainless steel electrodes, two 250 foot cables and two 1000 foot cables. We took electrical soundings using a Schlumberger array spacing. This array pattern is both an accurate and rapid electrode configuration for obtaining soundings at a single location. Our plan was to collect data for current electrode spacings out to 300 feet to a side (600 feet total) and potential electrode spacings out to 15 feet (30 feet total). The orientation of the sounding arrays were generally east-west except for the soundings done along the access road to the former White Alice site and the sounding at Mission Spring. As a rule, the depth obtained by a measurement is approximately equal to 1/5th the distance of the current electrode spacing or a depth of 60 feet for our spacings of 300 feet. This depth is quickly diminished when a strong resistor, such as ice, is encountered at the surface or near the surface of a given site.

Six soundings were collected from locations as close to the logged wells as site conditions permitted (FIGURE 5), that is, an electrical sounding was usually located within 100 feet of a logged well. These soundings were used as background measurements to calibrate and adjust our resistivity models to match the stratigraphy determined from the well logs (APPENDIX B). With the exception of the BLM sounding (VES-12), the remaining background soundings also serve as a site along one or the other of our resistivity cross-sections through Tanana. Since the Native Council Well (a.k.a. Hospital Well) and the school well were so close together only one sounding was collected to serve as a calibration for both wells.

Eleven soundings were collected along a transect parallel to the runway (FIGURE 5). This is an approximately east-west transect that tested for the meltwater channels expected from the aerial photographs. The orientation is designed to maximize contrast of the structures by cutting across them perpendicularly. The structures out here where expected to be deeper from available driller's logs, so the array lengths were increased to 600 feet per side (1,200 feet total) and the expected depths were down to 120 feet.

Nine soundings were collected along the edge of First Avenue along the Yukon River (FIGURE 5). This transect crossed the projected extension of the two faults expected from the aerial photos.

Seven soundings were collected along a transect down Third Avenue (FIGURE 5). This transect crossed at least one possible fault, and investigated the possible permafrost thaw bulb associated with the Yukon River. This transect tested for the lateral continuity to the north of the stratigraphic layers and geologic structures identified in the subsurface along the First Avenue transect.

Nine additional soundings were added to the investigation while we were in the field. These soundings were added as part of a preliminary investigation of three outlying areas where the community expects to see future residential expansion. Each of the three transects followed a general north-south orientation and consisted of three soundings (FIGURE 6). The first transect was along former White Alice Site near the home of Cathy Fliris and is called Cathy's area. The second transect crossed the flat, north of the intersection of White Alice road and Mission Hills road near Pongee's house. This transect is called Pongee's area. The last transect was along the road to Mission Hill. This transect was called the Mission Hill area.

MAGNETOMETER PROFILES

A Geometrics Model G-816 magnetometer was used to collect magnetic survey data along the three main electrical sounding transects: runway, First Avenue and Third Avenue. This magnetometer is a portable proton precession magnetometer. An electrical current is passed through a hydrogen rich fluid, e.g. kerosene, contained within the sensor head. The electrical field aligns the spinning protons in the fluid. When the current is turned off, the protons shift position to line up with the earth's magnetic field. This produces a small current proportional to the strength of the magnetic field. Thus, this instrument measures total magnetic field strength.

The strength of the magnetic field changes as a function depths. Therefore, the magnetometer can be used to measure changes in the magnetic field due to changes in the depth to bedrock. The depth to bedrock can not be determined directly by this method because the magnetometer can only measure relative changes. The magnetic field strength of an area is also affected by the magnetic contrast between different rock types. This means that the magnetometer can be used to locate abrupt lithologic changes such as those across a fault. Magnetometers are often used to locate subsurface structures such as faults or vertical sediment/bedrock interfaces (e.g. buried channels).

FLUID CONDUCTIVITY & TDS

TERRASAT, INC., tested the surface waters at several locations around Tanana in an attempt to measure water quality. We used a portable HACH Conductivity / TDS (Total Dissolved Solid) Meter. This instrument measured the conductivity and TDS content of the water sample. Higher conductivities and/or TDS values indicate poorer water quality. We collected water samples from the new city well #3 and the school superintendent's well #2 and from mission spring at the base of mission hill, east of town.

Project Organization

TERRASAT PERSONNEL and RESPONSIBILITIES

TERRASAT, INC., provided services for Too'gha, Incorporated. Jim Granata of TERRASAT, INC., conducted the surface resistivity, magnetometer, and borehole geophysical surveys. Dan Young and Bill Lawrence of TERRASAT, INC. compiled well information and drafted GIS maps. TERRASAT, INC., evaluated the recorded data from the surface resistivity, magnetometer, and borehole geophysical surveys.

LOCAL HELPERS and LOCAL TRANSPORT SUPPORT

Mary Edwin, of Too'gha, Inc., organized and acquired access to the wells for geophysical logging and made transportation arrangements for Mr. Granata. Dennis Edwin of Tanana, assisted Mr. Granata in conducting the surface resistivity survey. Don Blackwell provided pump removal and installation services. Mr. Blackwell also assisted Mr. Granata with the geophysical well logging.

FINDINGS

WELL LOGGING RESULTS

The stratigraphy in Tanana is highly variable. Wells less than 100 feet apart show little to no correlation. An example of this is the very poor correlation between the School Well and the Native Council Well shown in the geophysical well logs (APPENDIX B). This degree of variability, however, appears to be controlled by local features existing within a larger, fairly consistent sedimentary sequence. Our simplified stratigraphic model of the area contains four major units. We combine the top two units of FIGURE 2 because the constraints of the equipment used in well logging cause data near the top of the well to be less accurate. Results from well logging show that five of the seven wells have similar stratigraphic sequences. APPENDIX B contains the well logs from the geophysical well logging.

The top layer of our stratigraphic model is approximately 25 feet thick and is composed of medium-grained glacial sediment. A layer of fine-grained lacustrine sediment underlies the glacial sediment. A fining upwards sequence of stream-channel deposits underlies the lacustrine sediment and bedrock forms the base of the stratigraphic sequence. We believe that water enters the wells from the channel deposits near the bottom of the wells.

The stratigraphy of the BLM well corresponds to our model (APPENDIX B). Water appears to enter the well from a deposit of a fining upwards sequence near the bottom of the well. The FAA East well is shallow and only shows the top three layers of our model. Water enters this well from the fine-grained layers at the bottom of the well.

The Native Council Well (a.k.a. Hospital Well) fits our model with less certainty. Interpretation of the log for this well suggests that the top layer is about 80 feet thick. This is much greater than the 20-30 foot layer proposed in our model. Also within the top layer are several thin layers of fine-grained sediment, not incorporated into our model. However, like the other wells, the bottom layer is characterized by a fining upward sequence, which appears to be the water production zone for this well.

The school well generally fits the model. The base of the top layer has more fine sediment lenses than the other wells. This well was not drilled deep enough to intercept the bottom layer of our stratigraphic model. The school superintendent's well is very similar to the school well. Subtle differences can be seen in the thickness of the stratigraphic units. Interpretation of the New City Well #3 suggests that the same sequence of three units exists. However, near the top of the well a three foot thick layer of fine-grained material appears that may be attributed to an overbank flood deposit. Josephine's well fits the model for the top and bottom layers. The middle layer, however, shows interbedded lenses of fine and medium-grained sediment. Water enters the well through the layers at the bottom of the well.

RESISTIVITY SOUNDINGS

TERRASAT, INC., constructed interpretive cross-sections along six transects in and around Tanana. We used these cross-sections to interpret the depth to bedrock and to identify areas with a high probability of suitable ground water. Features identified from cross-sections as potential sources of water appear as discontinuities to the subsurface structure. These discontinuities may occur as faults or buried meltwater channels.

From surface resistivity data we constructed interpretive cross-sections for an east-west transect parallel to the runway, west of Tanana (FIGURE 5, APPENDIX B). The cross-sections suggest several stratigraphic layers and structures. Approximately 1000 feet from the west end of the transect a discontinuity exists in the data. We have interpreted this to suggest the presence of a buried fault or scoured meltwater channel. This is consistent with the aerial photograph interpretation that suggests the presence of a meltwater channel. Extremely high data values indicate permafrost at approximately 1600 feet east from the transect base station. The base station for each transect is located at the westernmost sounding location. Permafrost appears to be continuous toward the west with only minor variations in thickness. Data at about 3600 feet east suggest that coarse-grained sediment lies above bedrock. The bedrock surface may also be lower here. Thus the area from 3600 to 4100 feet east may be a source of ground water.

We constructed an interpretive cross-section for an east-west transect along First Avenue (APPENDIX C). Three locations may have structures containing usable quantities of ground water. The first structure occurs at about 1300 feet east and may be a depression in the bedrock surface. The sediment on top of the bedrock is probably coarse-grained. The second and third structures at 2200 and 5650 feet east are interpreted as faults. Faults are generally permeable structures that often channelize the flow of groundwater, thus they represent the highest potential for water along this transect. The bedrock surface depression has the next highest potential for development. Permafrost appears to be continuous along the transect from 1000 to 6510 feet east.

Using surface resistivity data for a transect along Third Avenue, we constructed an interpretive cross-section (APPENDIX C). The cross-section reveals an uneven bedrock surface along the entire length of the transect. A fault is interpreted at about 1100 feet east. Evidence suggests that permafrost is continuous along the transect with the exception of the area with the fault. This area may be a good source of ground water.

We conducted three surface resistivity surveys along north-south transects at outlying areas east of Tanana (APPENDIX C) and constructed interpretive cross-sections for each area. At Cathy's area, the first sounding, 0 north, is interpreted as having a thin sand layer underlain by silt. The 1000 foot north sounding is interpreted as a thick sequence of sand. The 2000 foot north sounding is characterized by near surface permafrost underlain by silt. Permafrost is apparent in the 2000 feet north sounding. The location where water is most likely to be found along this transect is in the thick sandy unit at the 2000 feet north sounding.

At Pongee's area, permafrost is present at both ends of the transect, but does not appear near the middle. Likewise, a layer of fine-grained sediment is present at the ends of the transect, but not at the middle. A thick layer of medium-grained sediment is interpreted to lie near the center of the transect and represents the area with the highest potential for water.

The third outlying transect was run in the area of Mission Hill. Our interpretation suggests that permafrost is continuous to about 735 feet north, which corresponds to the base of Mission Hill. At this point along the transect, there is a flowing spring (Mission Hill Spring) where we suspect the continuity of the permafrost to be disrupted by a possible fault. This fault probably acts as a conduit for significant amounts of ground water and represents the highest potential for water resources in this area.

MAGNETOMETER PROFILES

We prepared profiles from magnetometer data corresponding to the resistivity transects (APPENDIX C). Spikes in the data result from near surface metallic sources such as pipes or culverts, or from above surface metallic objects such as cars, wire fences, or power lines. These objects generate strong local magnetic fields that often hide the more gentle magnetic signature from the sediment/bedrock interface. Valuable information is gained about the subsurface by smoothing the data to remove these local effects thereby enhancing the bedrock features. An abrupt change in the intensity of the magnetic field, which may appear as opposing spikes on the magnetic profile, often represent changes in the subsurface lithology. These changes may indicate the presence of faults.

The magnetic profile along the First Avenue profile shows an uneven bedrock surface (APPENDIX C). The bedrock surface appears deepest at about 1500 feet east. An abrupt change in the magnetic intensity at about 2300 feet east indicates a lithologic change. We have interpreted this feature as a fault.

The Third Avenue profile shows a change in the magnetic intensity at the 1200 foot east location similar to the change observed in the First Avenue profile. This change indicates a lithologic change which is also interpreted as a fault. In addition to the interpreted fault, the profile suggest that there are two lows in the bedrock/sediment interface. These depressions in the bedrock surface are located at 1000 and 2500 feet east along Third Avenue.

The runway profile suggests that the bedrock surface is nearly uniform along this transect. The discontinuity seen at 1000 feet east in the resistivity cross-sections is not evident from the magnetic profile. This suggests that the change in resistivity is within the sediment and is not related to a bedrock structure. However, the magnetic profile suggests a possible structural change at about 2900 feet east along the transect. This corresponds to the axis of the meltwater channel interpreted from air photos.

FLUID CONDUCTIVITIES

We measured the fluid conductivity of two wells in Tanana and at Mission Springs. Water temperatures in the school superintendent's well, the New City well #3 and at Mission Springs were 1.3°C, 3.9°C and 9.6°C respectively. The temperature difference at Mission Springs is probably due to equilibration of the water with the temperature at the ground surface. Water conductivities at the three locations were 0.996, 1.036 and 0.598 ms/cm (microsemens per centimeter), respectively. Total dissolved solids (TDS) for the three sites were 498, 516, and 298 mg/l (milligrams per liter), respectively. These values for conductivity and TDS are low to moderate. This suggests that the quality of local ground water can be expected to range from good to moderate. This also suggests the better quality ground water is obtained from sources that are deep or distant from possible river influence.

CONCLUSIONS

Aerial photographs suggest that two major geologic structures control ground water resources in the Tanana area: glacial meltwater channels and faults. Glacial meltwater channels extend southward like fingers from the Ray Mountains. We believe they formed when meltwater breached a glacial moraine and flowed toward the Yukon River during the last glacial period. Air photo interpretation suggests that a meltwater channel exists near the east end of the airport (FIGURE 7).

Two faults appear to exist in Tanana. The first cuts diagonally through the city and has a northeast-southwest trend. The second has a north-south trend and may be delineated at the surface by the north-south trending segment of the creek, located east of Eamole Street (FIGURE 5).

A map of reported well yields in Tanana suggests that some wells have noticeably higher yields than others (FIGURE 4). The pattern of higher well yields suggests that there are structural controls that influence the local distribution of ground water. These wells form groups that have alignments parallel to northeast-southwest trends observed for one of the faults. These trends are interpreted as being related to the northeast-southeast trending fault.

A synthesis of the geophysical well logs for the seven wells enabled us to create a conceptual stratigraphic model for Tanana (FIGURE 2). This model consists of four major units. From top to bottom the layers are medium-grained proglacial alluvium, fine-grained lacustrine or overbank sediment, medium-grained river sediment and bedrock. Although this conceptual stratigraphic sequence is present in most of the well logs, the beds within individual units are discontinuous. Thus, we were unable to trace individual beds between wells even over distances less than 100 feet (APPENDIX B). We conclude that this type of localized sedimentary setting best fits an anastomosing stream model (FIGURE 3).

Surface resistivity surveys were conducted along three transects in Tanana (APPENDIX C). A transect along the runway suggests a scoured meltwater channel or fault at 1000 feet east of the base station. A topographic low in the bedrock surface may be present at the 3800 feet east position. Both of these structures have potential as water resources, with the meltwater channel having the highest potential.

The resistivity survey along First Avenue suggests faults at 1300 and 5650 feet east along the transect. A fault is also suggested along the Third Avenue transect at 1100 feet east. This Third Avenue fault is interpreted to be a northeastern extension of the 1300 foot east fault indicated from the First Avenue transect. This fault corresponds to the fault interpreted from air photos and is generally aligned with the wells reported to have higher than average yields. This predominance of independent lines of evidence suggests that these two faults offer the highest potential for water resources in Tanana.

Surface resistivity surveys were conducted along three transects in outlying areas near Tanana (APPENDIX C). Transects along the road to the former White Alice Site (Cathy's area) and along a flat just north of the White Alice and Mission Hills road (Pongee's area) show little structural change. We conclude that the highest potential for water resources are located at the center of these two transects. The third transect along the Mission Hill area suggests that a fault is the conduit for the water that feeds the spring. This fault, along the base of Mission Hill, offers the highest potential for water along this transect.

Magnetic profiles along the three main resistivity transects in town confirmed the resistivity structural interpretations in Tanana (APPENDIX C). The profiles suggest that major subsurface changes occur along First Avenue at 2300 feet east and along Third Avenue at 1200 and 2500 feet east. These correspond to the faults interpreted from the resistivity surveys. Major lithologic changes interpreted from the resistivity survey along the runway at 1000 and 2900 feet east are not obvious from the magnetic profiles. We interpret this difference to mean that the features at these two locations are related to changes in the sediment and do not reflect changes in bedrock.

A recharge area in the Ray Mountains to the north-northwest appears to be the source of the local ground water system. Water appears to move toward the Yukon River through fractures and meltwater channels. Springs in the Mission Hill area suggest that water may be coming to the surface through a fault. Intercepting these fractures will provide the highest quality water of this region and should provide ample yield to meet the current and future needs of Tanana.

RECOMMENDATIONS

We have identified several locations in Tanana that may have significant water resources (FIGURE 7). These areas correspond to potential faults and buried channels. We recommend that additional surface resistivity and magnetic surveys be conducted across these structures to more accurately locate areas with ground water. We also suggest that these additional geophysical investigations be conducted at the same time as a pilot drilling program.

We recommend that a drilling program be coupled with geophysical logging of the boreholes. Using this strategy, TERRASAT, INC., has increased well yields up to 50 fold by permitting accurate placement of well screens where the most water will be intercepted.

Ecology and Environment, Inc., conducted a site investigation for the Alaska area Native Health Service Hospital in Tanana, Alaska from August 1994 through April 1995 (Ecology and Environment, Inc. 1995). The investigation showed that 31 of 88 soil borings at the complex contained levels of petroleum-derived constituents that exceeded regulatory guidance levels. They suggested that soil contamination probably exists beyond the fifteen foot depths to which they sampled. They also suggested that the contamination may reach the water table in this area. Data from nearby wells indicated water levels approximately 28 feet below ground level. The report by Ecology and Environment, Inc., indicates that no petroleum contaminants were detected in the two existing inactive wells that they tested. However, the report by Ecology and Environment, Inc., makes no mention of testing any of the wells currently supplying water in Tanana for petroleum contaminants.

We recommend that wells in the vicinity of the contamination mentioned in this report, the school well and the native council well be tested for petroleum contaminants. Although no contamination was detected in the two wells sampled by Ecology and Environment, Inc., it is still possible that the local ground water may be contaminated which could pose a health risk to the water consumers.

Even if the initial testing for petroleum contaminants suggests no contamination, we would still suggest quarterly or semi-annual water testing to ensure the water does not become contaminated in the future. We suggest that this testing continue until the extent of the soil contamination has been identified and any potential source for ground water contamination has been removed.

REFERENCES

Ecology and Environment, Inc., 1995, Site Investigation Report: Alaska Area Native Health Service Hospital, Tanana, Alaska, Ecology and Environment, Inc. Anchorage, AK.

Geoshpere, Inc., 1996, Terrain Unit Analysis. P.,11, Fig. 2, Tab. 4.

Leslie, L.D., 1989, Alaska Climate Summaries, Arctic Environmental Information and Data Center, University of Alaska Anchorage, Anchorage, AK.

Smith, D.G., 1983, Anastomosed fluvial deposits: modern examples from Western Canada. *Spec. Publs int. Ass. Sediment* (1983) **6**, 155-168.

Wheaton, S., 1980, Shallow Groundwater Resources at Tanana, Alaska. Public Health Service.

COLOR INFRA RED AERIAL PHOTOGRAPH

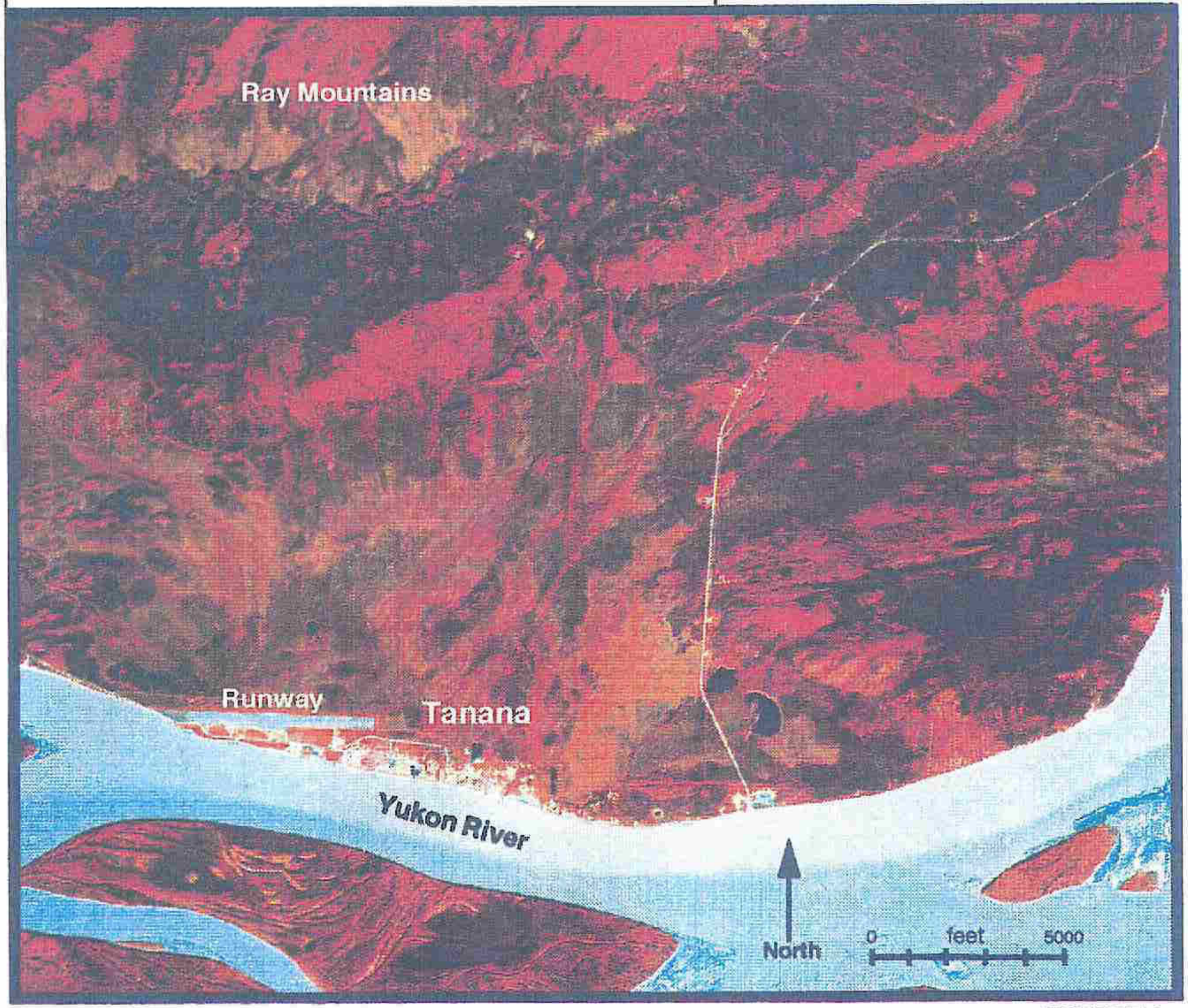
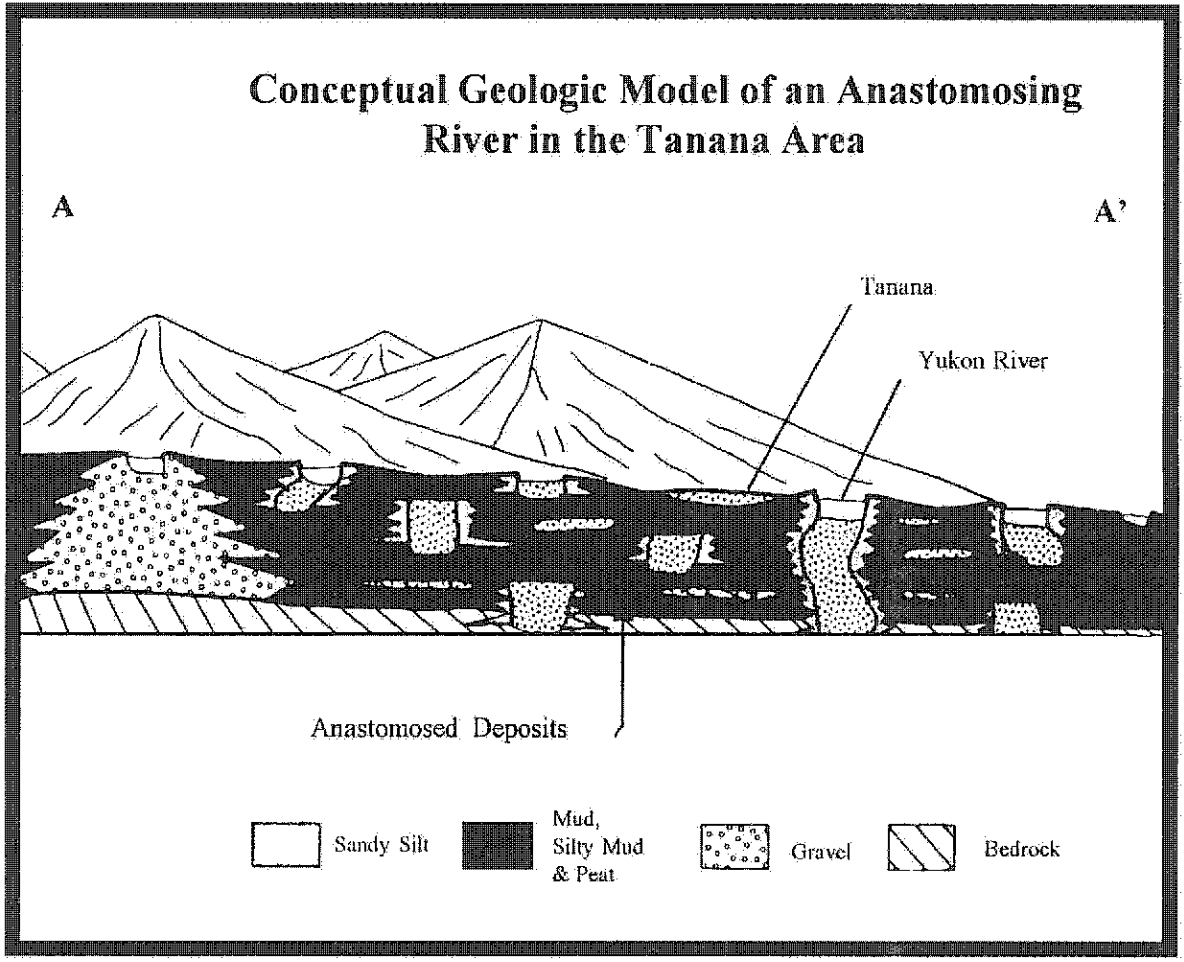


FIGURE 1

Ground Surface	
Fine-Grained Overbank ? Sediment	5 to 15 feet Silt and Sandy Silt
Fine to Coarse-Grained Proglacial Alluvium	35 to 65 feet Fine Sands to Coarse Gravels
Fine-Grained Lacustrine Sediment or River Overbank Deposits	0 to 60 feet Silt and Clay
Medium-Grained River Channel Sediment	Sand 0-10
Bedrock	Schist, Sandstone Limestone, & Slate Depth from 24 to 140'

FIGURE 2



Conceptual Geologic Model of an Anastomosing River in the Tanana Area

FIGURE 3

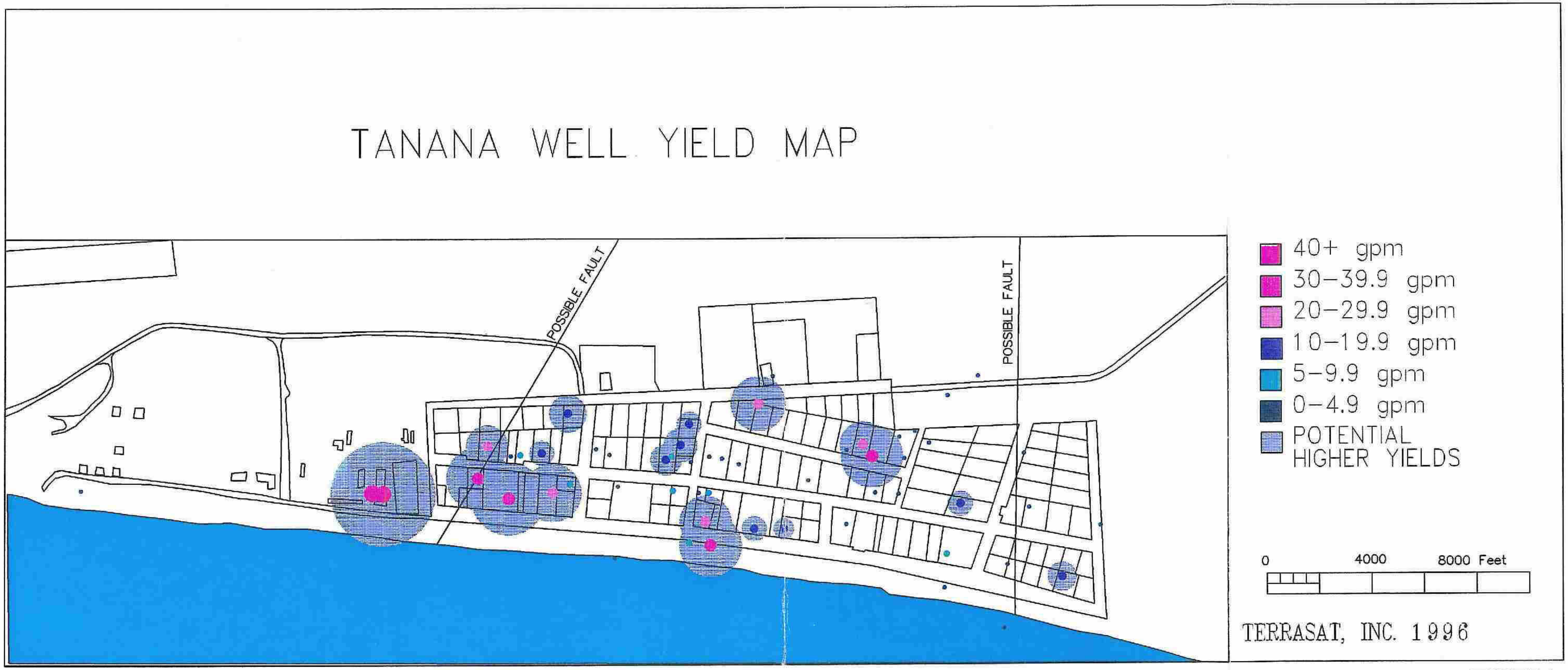

TANANA WELL YIELD MAP
POSSIBLE FAULT
POSSIBLE FAULT
40+ gpm
30–39.9 gpm
20–29.9 gpm
10–19.9 gpm
5–9.9 gpm
0–4.9 gpm
POTENTIAL HIGHER YIELDS
0
4000
8000 Feet
TERRASAT, INC. 1996

FIGURE 4

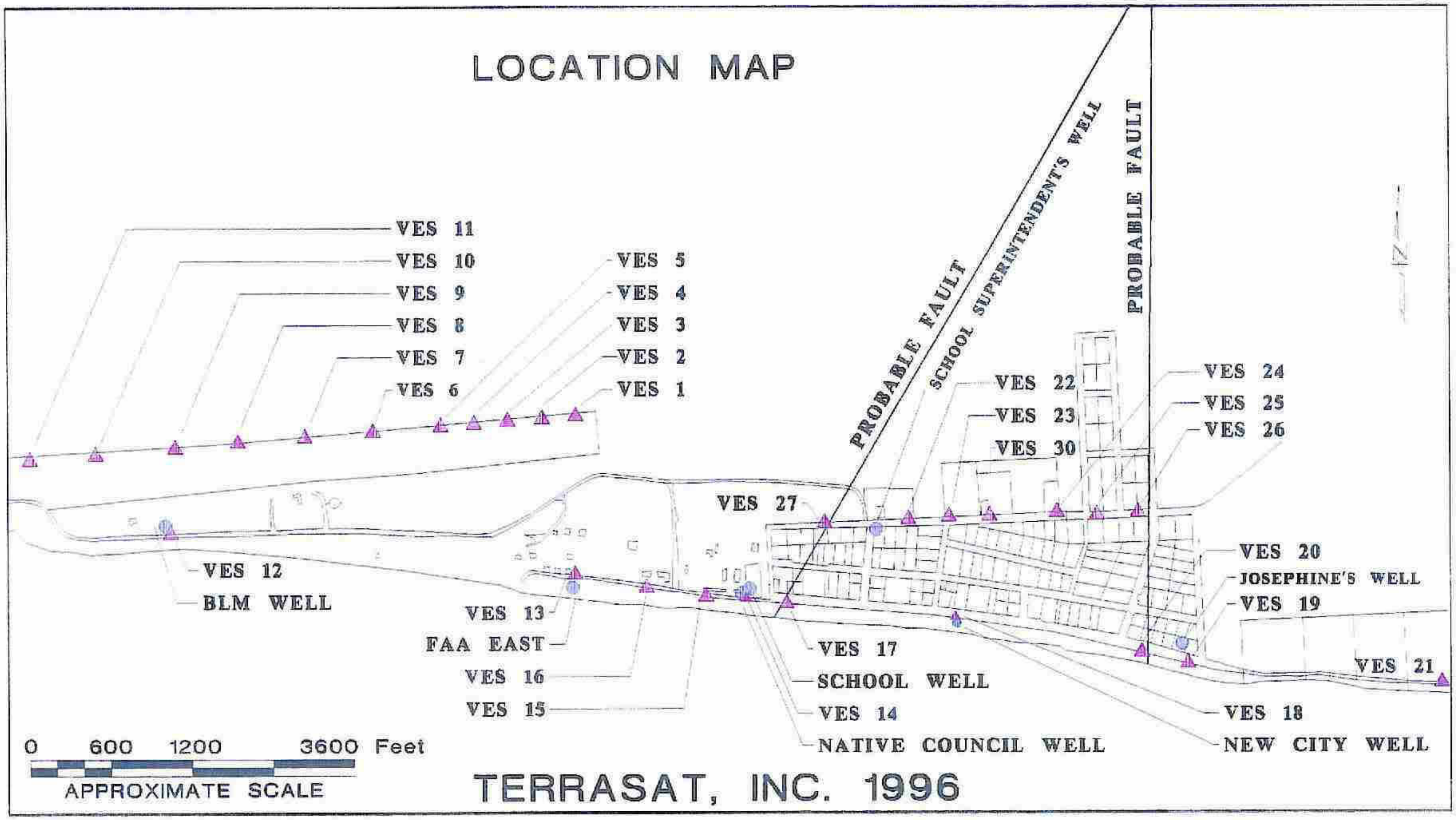

LOCATION MAP
VES 11
VES 10
VES 9
VES 8
VES 7
VES 6
VES 5
VES 4
VES 3
VES 2
VES 1
PROBABLE FAULT
SCHOOL SUPERINTENDENT'S WELL
PROBABLE FAULT
N
VES 22
VES 23
VES 30
VES 24
VES 25
VES 26
VES 27
VES 12
BLM WELL
VES 13
FAA EAST
VES 16
VES 15
VES 17
SCHOOL WELL
VES 14
NATIVE COUNCIL WELL
VES 20
JOSEPHINE'S WELL
VES 19
VES 21
VES 18
NEW CITY WELL
0 600 1200 3600 Feet
APPROXIMATE SCALE
TERRASAT, INC. 1996

FIGURE 5

COLOR INFRA RED AERIAL PHOTOGRAPH

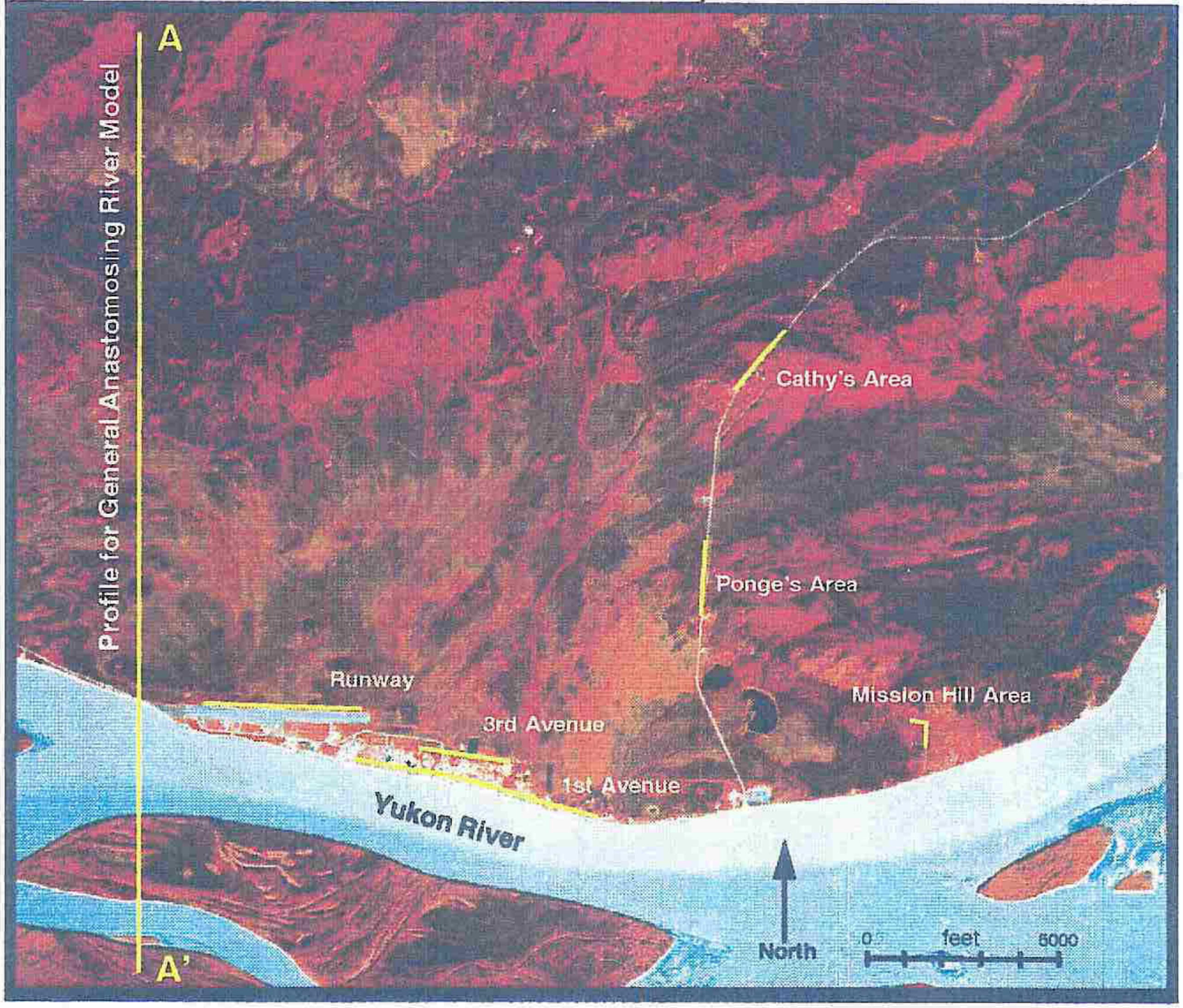


FIGURE 6

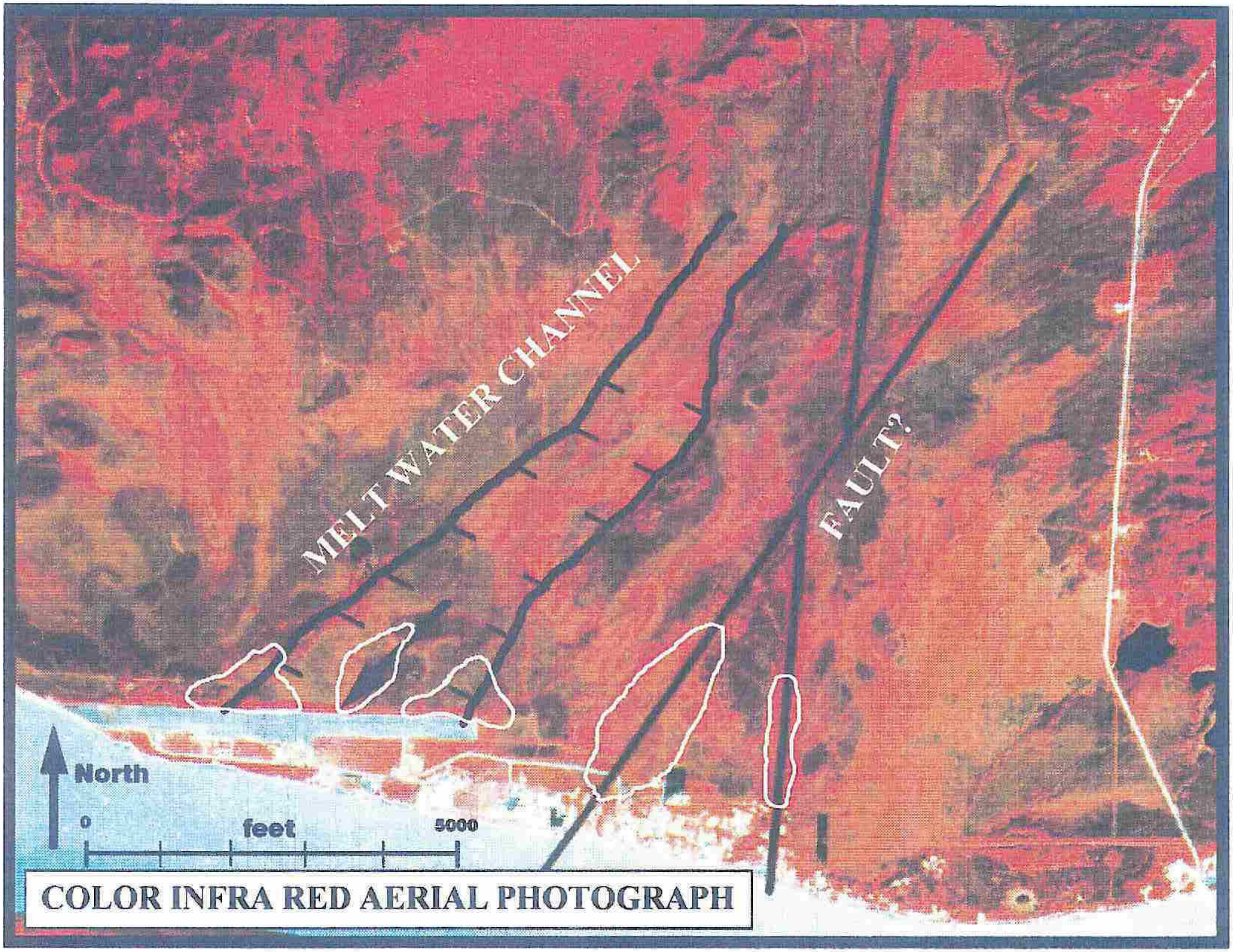

MELT WATER CHANNEL
FAULT?
North
0
feet
5000
COLOR INFRA RED AERIAL PHOTOGRAPH

FIGURE 7

elev? or b.g.s.?

contaminated

Screen 39-49'

Screen? 20'

Screen 38-48'

Screen 20-30'

Screen 45-50'?

Hosp well

Well_ID (map tag)	Year Drilled	Total Depth (ft)	Yield (gpm)	DTW (ft)	Depth to Base of Permafrost (ft)	Depth to rock (ft)	Aquifer Thickness (ft)	Top of Perfs (ft)	Aq_Type	Well Info. (owner)	Comments	
Tan_1	96	46.5			28	28	12		U	Tan_1		
Tan2	96	21.5					10		U	Tan2		
Tan3	96	41.5	0		22.5		19	20	U	Tan3	Dry	
Tan4	96	33.5	0		22.5	32.5	10		U	Tan4	Dry	
Tan5	96	38.7	0		12	38.5	26.5	29	U	Tan5	Dry	
Tan6	96	40.5	26.33 sub?	22	22.5		18	30	U	Tan6		
Tan7	96	22	0		22			12	U	Tan7	Frozen	
Tan8	96	24	0		22.5	24	1.5	19	U	Tan8	Frozen	
Tan9	96	41.5		22.5	4		19	20	U	Tan9		
Hospital	72	206	40	41	20	108	3 ← ?	42		Hospital		
Hospital2	76	155	50	25.5	sub 34	108	10 ?	39		Hospital2		
City #2	81	49	10	32			5 ?	44		City #~~1~~ 2		
Community	67	49	6	22		42	6	35	U	Community		
City #3 old	86			[illegible]	says 15 gpm			20		City #3 old		
City #3 new	91	50	15 ~~30~~	27.9	i think sub	46	10	38	C	City #3 new		
City #4	86	30	50	0			10	20		City #4		
Judy Sommers	81	52	20	31	2		15	45		Judy Sommers		
3256	67	48	30	18			3	42	U	Jason Edwin		
2758	67	51	0.16	20			5	39	U	Bascoe Minook		
745	67	43	28	14			8	37	U	Episcopal Res.		
4974	67	63	0		62					Donald Starr	Dry	
638	67	75	0		47	47				Alfred Grant	Dry	
2181	67	55	12	24				45	U	Lillian Folger		
172	67	46	12	18			2		U	Milton Nicholia		
2576	67	51	8	25			9	43		Sammy Hagg		
1175	67	52	14	23	17		17	45	U	Lawrence Roberts		
Joe Runyan	75	210				47	35		C	Joe Runyan		
Northern C Co.	75	223				41			C	Northern C Co.		
NC35	67	49	62	19						Northern C Co.		
Cliff Eller	75	223		155	50	50	8		C	Cliff Eller		
2095	67	75	0		75				U	Arlie Charle	Dry	
1545	67	51	10	23				42	U	George Edwin		
5084	67	48	20	18			9	42	U	Gus Norder		
5286	67	56	0.67	36		51	3	41		Jake Starr		
5337	67	65	0		65					Todd Kozenikoff	Dry	
437	67	50	0		42					Ted Kozenikoff	Dry	
Kozenikoff	77	160	1	80		50			C	Wilfred Kozenikoff		
5453	67	52	7	16		52	4	46	U	David Elia		
10042	67	65	0		61	61				Phil Kennedy Sr.	Dry	
1016	67	51	7	19	51			43		Ekada		

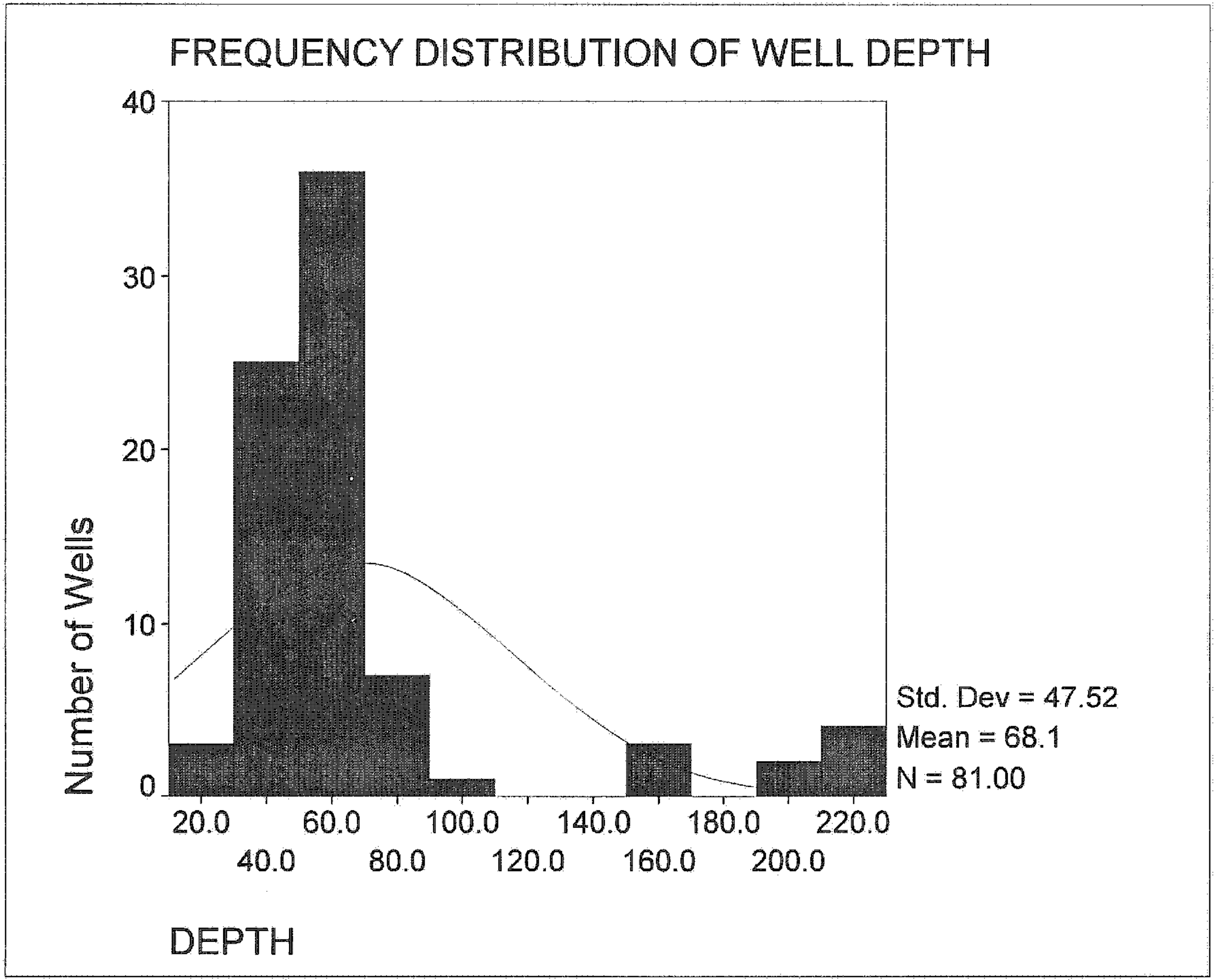
TABLE 1

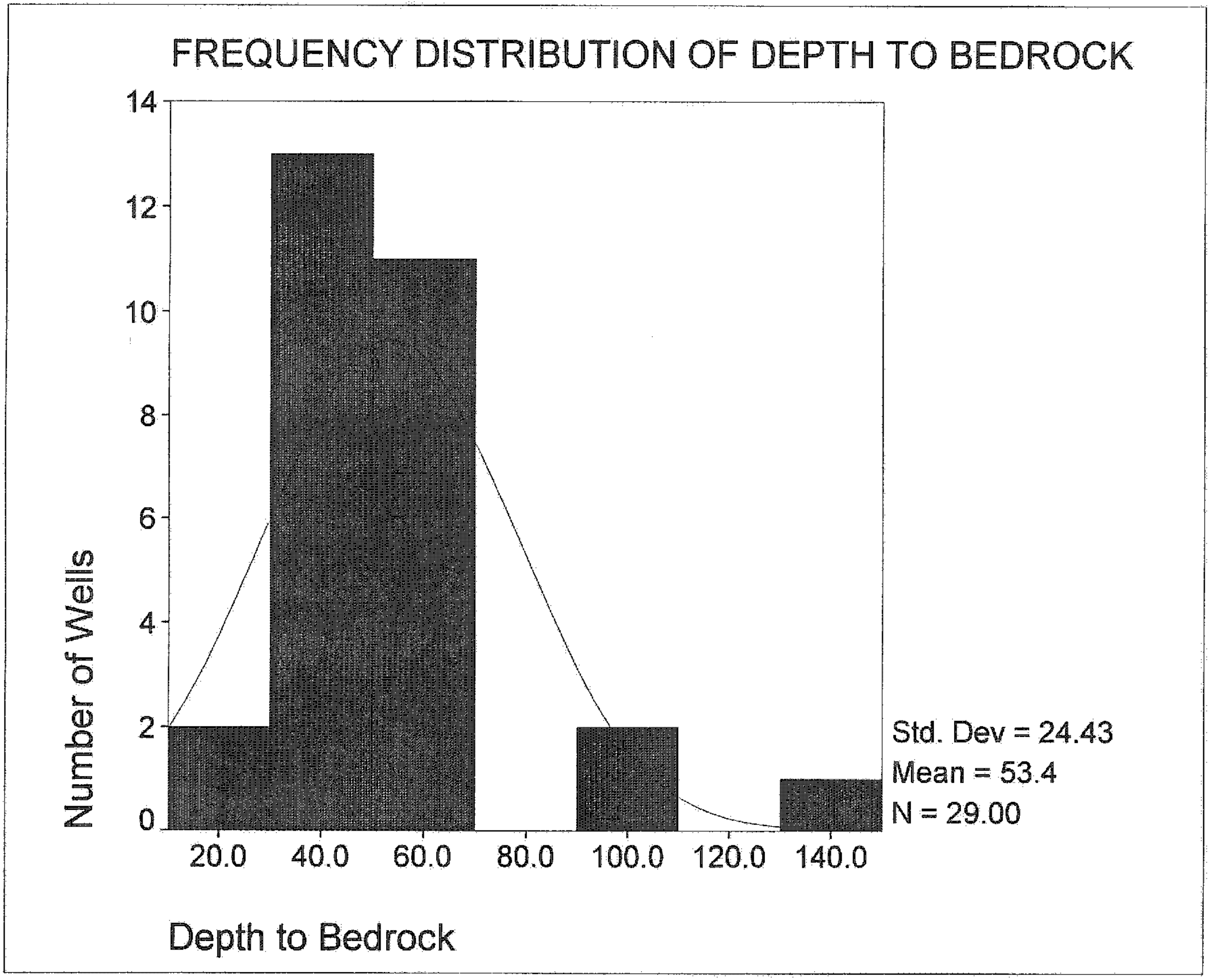
		Total Depth	Yield	DTW	depth to base of aq	depth to bedrock	Aq thick					
1015	67	51	8	17			10	44		Butler/Swanson		
3354	67	56	0		56					Jimmy Albert	Dry	
343	67	50	35	17			4	40		Glenn Gregory		
352	67	48	30	18			4	41	U	Miller		
3613	67	50	30	18		47	6	43	U	Walter Nicholia		
3755	67	51	22	22		48	9	36		Martha Wright		
3864	67	58	0		58	58				Charlie Jorden	Dry	
3953	67	45	0		37	37				David Elia	Dry	
4217	67	42	18	8			3	36	U	Hudson Nicholia		
4314	67	58	0		54					Alan Starr	Dry	
4452	67	43	25	14			4	37	U	Bob Moffat		
4619	67	43	12	16			7	37	U	John George		
4797	67	48	2	22			10	34	U	Arland Dick		
4821	67	72	0		72					Joe John	Dry	
2669	67	60	0		60	44				Haine Sommers	Dry	
2859	67	65	0.25	20	15	51	14	49	C	Maggie Elia		
2960	67	55	1.5	20		50	10	45	U	Don Johnson		
3061	67	57	0.2	34		55	5	49	U	David Henry		
3157	67	50	0.26	19			6	41	U	Abandoned		
1379	67	49	10	22			4	43	U	Christopher Grant		
1430	67	58	16.3	24			4	51	U	Sam Joseph		
1647	67	46	12	22			6	39	U	Warren Thompson		
1724	67	65	0							Edgar Joseph	Dry	
1832	67	50	7	24		46	3	41	U	Arthur Antoski		
1996	67	93	2.5	18	23		8	83	U	Stan Joseph		
2282	67	55	20	25		50	3	47	U	Lester Erhart		
2388	67	75	1.5	25			15	52	U	Lee Albert Sr.		
2490	67	76	0		76					Fred Starr	Dry	
1278	67	44	9	22			3	35	U	Richard Grant		
327	67	47	8	20			4	35	U	Joseph Percy		
531	67	51	12	24		48	6	43	U	Mary Dick		
729	67	50	0		50					Willy Grous	Dry	
823	67	75	0		75					Pete Nicholia	Dry	
936	67	50	0		50					Harry Nicholia	Dry	
226	67	44	15	18			2	31	U	Roy Folger		
FAA		70	1.7	33						FAA		
802	80	55								Eller L12	Dry	
803	80	60								Eller L07	Dry	
C1	80	194	5	45		140	4	58	U	City		
BLM	78	58	51	22			36	48	U	Bureau of L Mgmt.		
PPlant	75	223		155	50	50	8		C	PowerPlant (Eller)		
Greenway		160								Greenway		
AP			100							Airport		

TABLE 1

APPENDIX A

Statistics


FREQUENCY DISTRIBUTION OF WELL DEPTH
40
30
20
10
0
Number of Wells
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
Std. Dev = 47.52
Mean = 68.1
N = 81.00
DEPTH

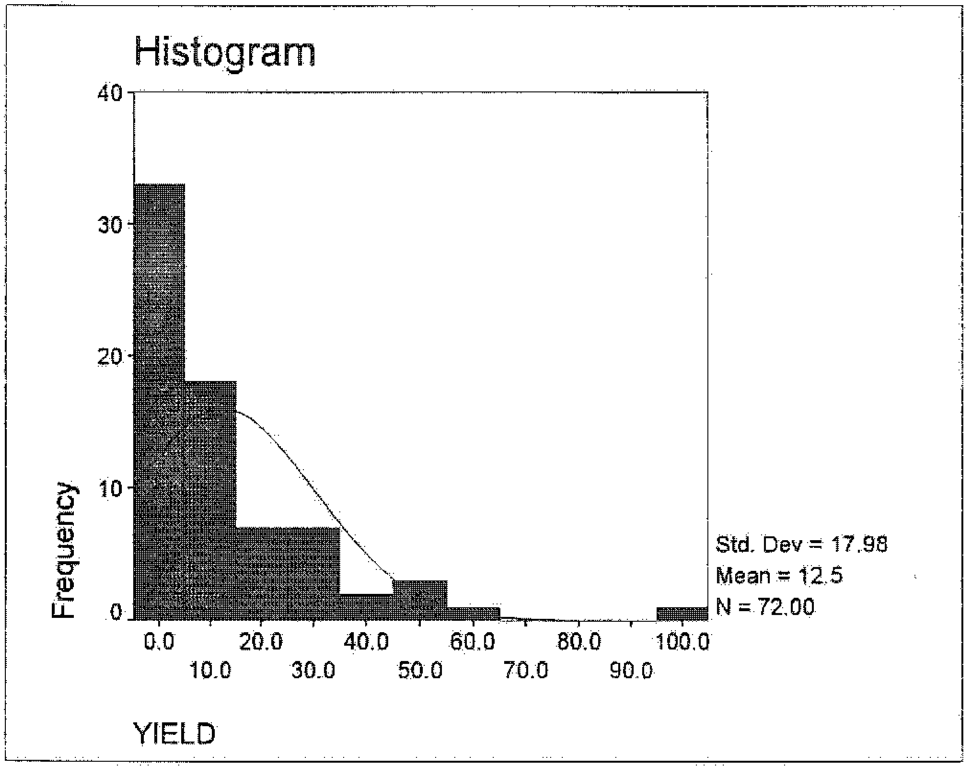


FREQUENCY DISTRIBUTION OF DEPTH TO BEDROCK
14
12
10
8
6
4
2
0
Number of Wells
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Depth to Bedrock
Std. Dev = 24.43
Mean = 53.4
N = 29.00

Frequencies

Statistics

	N		Mean	Median	Std. Deviation	Range	Minimum	Maximum
	Valid	Missing						
YIELD	72	11	12.4913	7.0000	17.9800	100.00	.00	100.00
BX	29	54	53.4483	48.0000	24.4326	116.00	24.00	140.00
DEPTH	81	2	68.0580	51.0000	47.5175	201.50	21.50	223.00

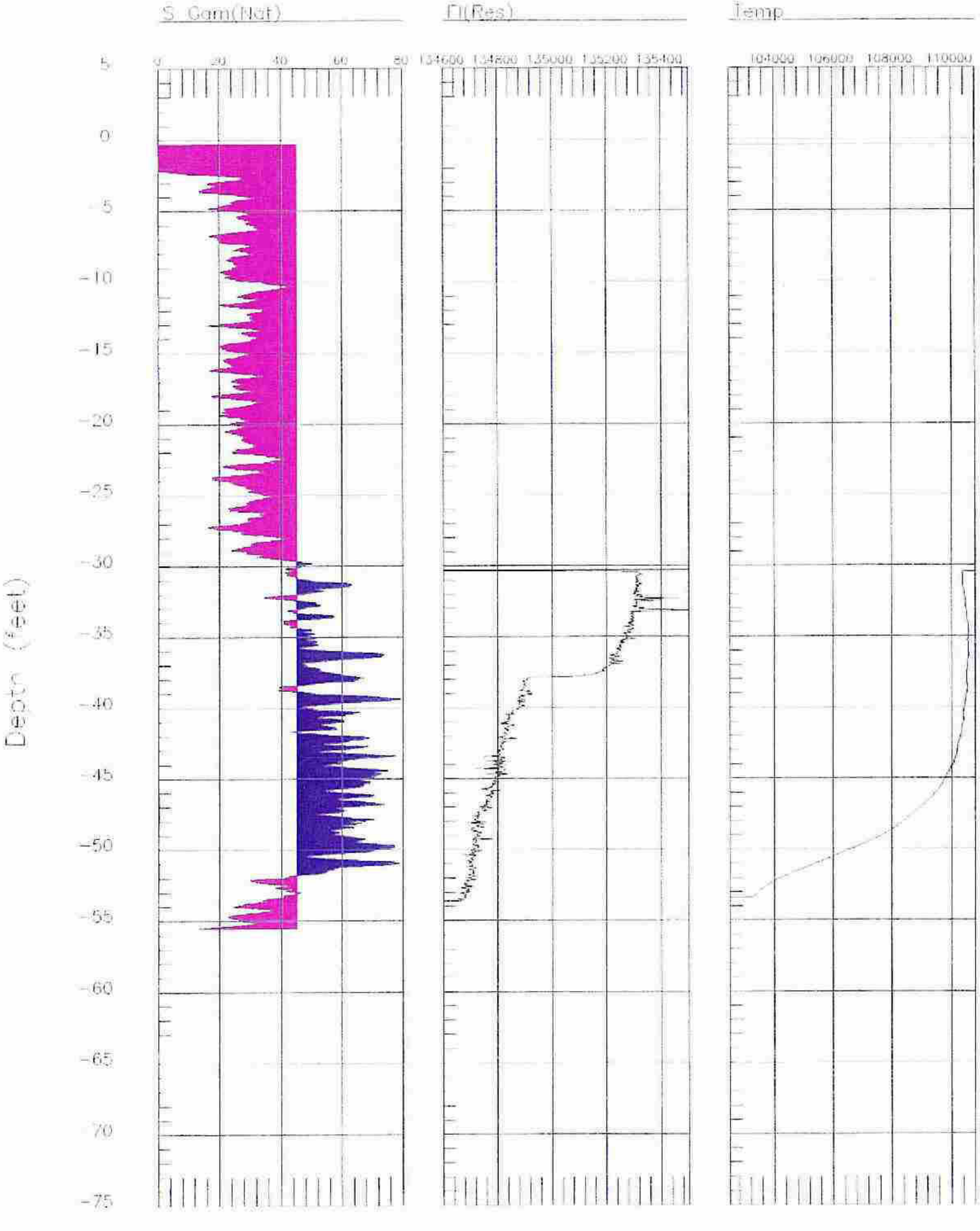


APPENDIX B

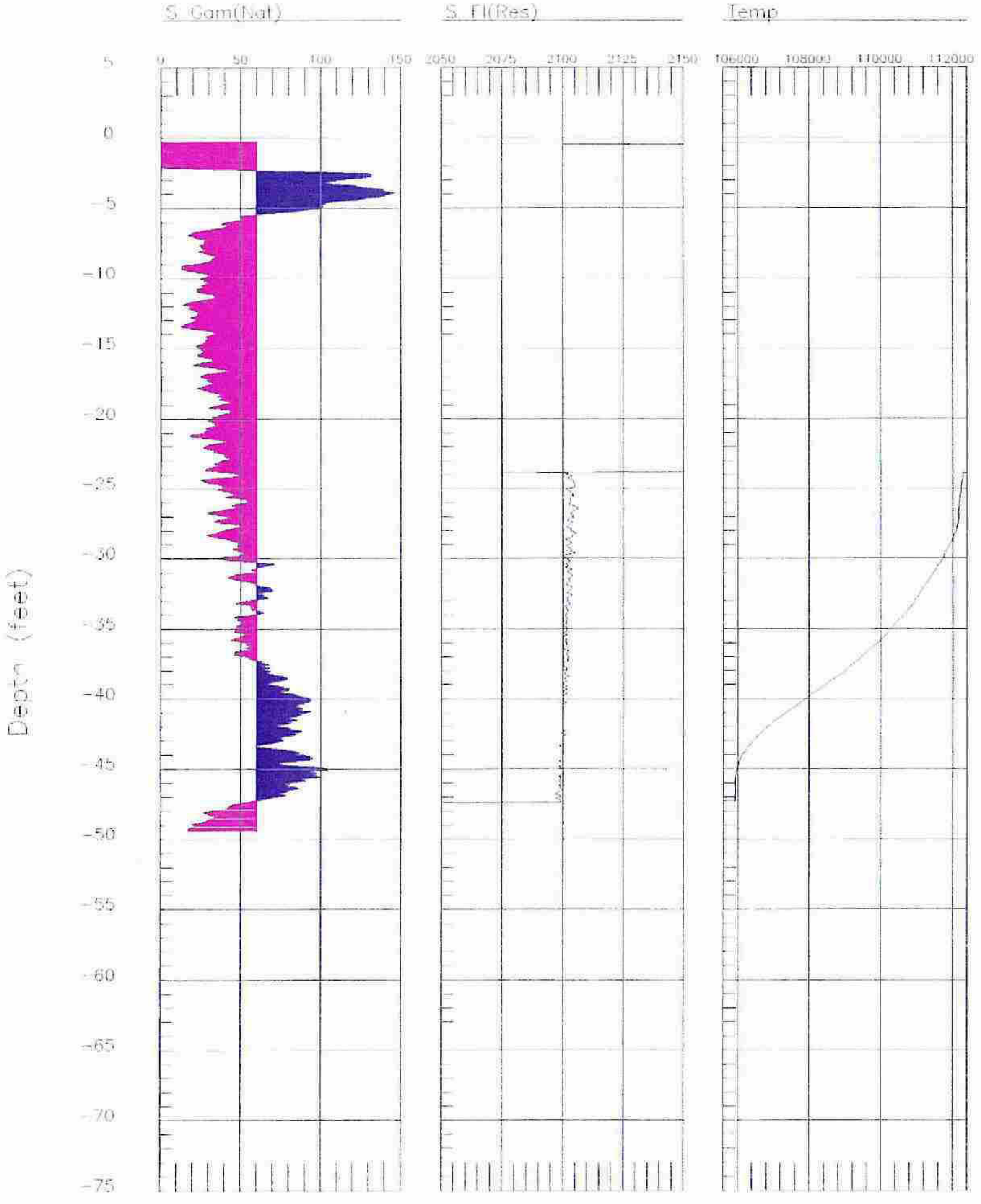
Well Logs

Refer to FIGURE 5 for well locations

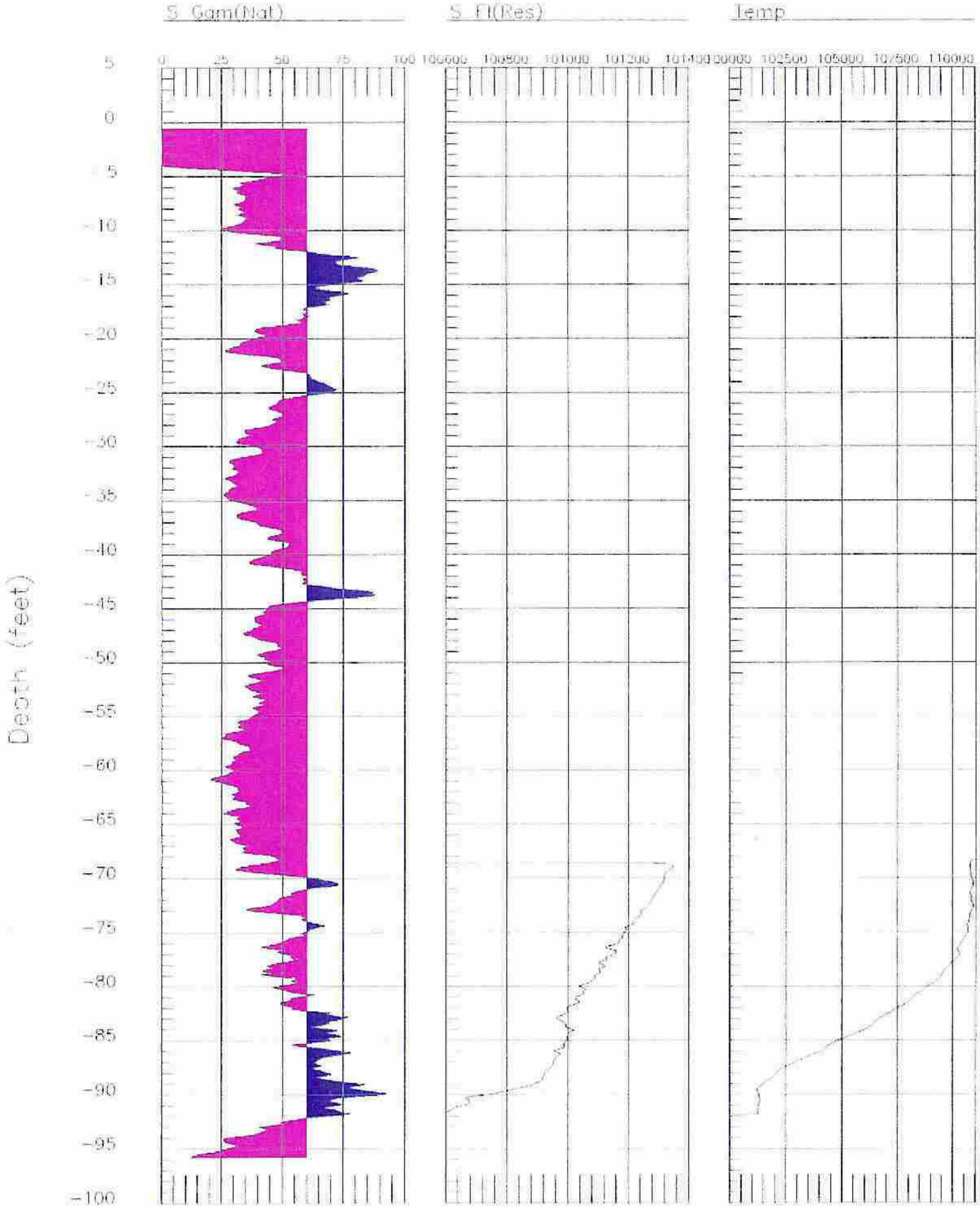
Well Name: BLM Well
File Name: BLM-DN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



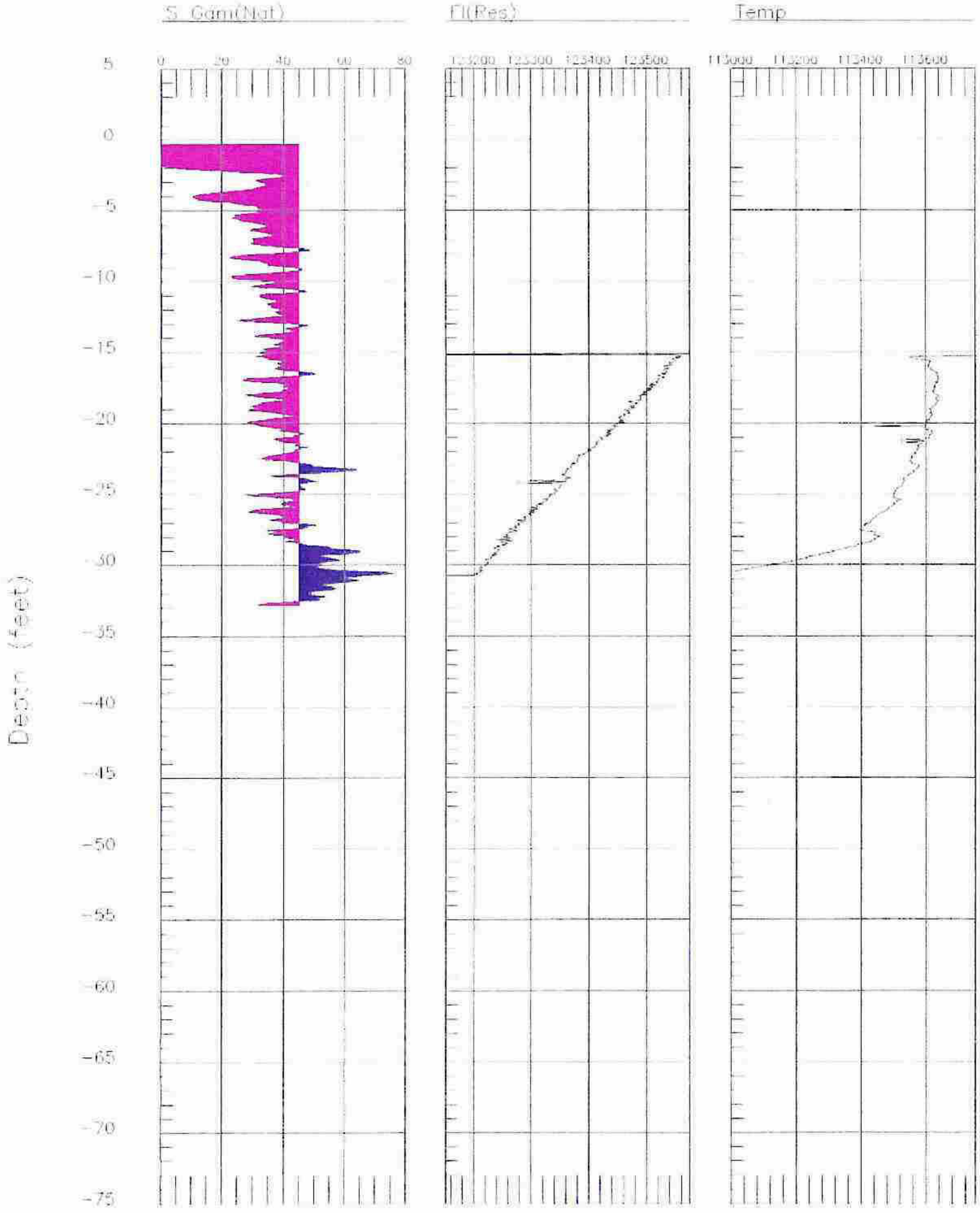
Well Name: New City Well #3
File Name: N-CTY-D1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



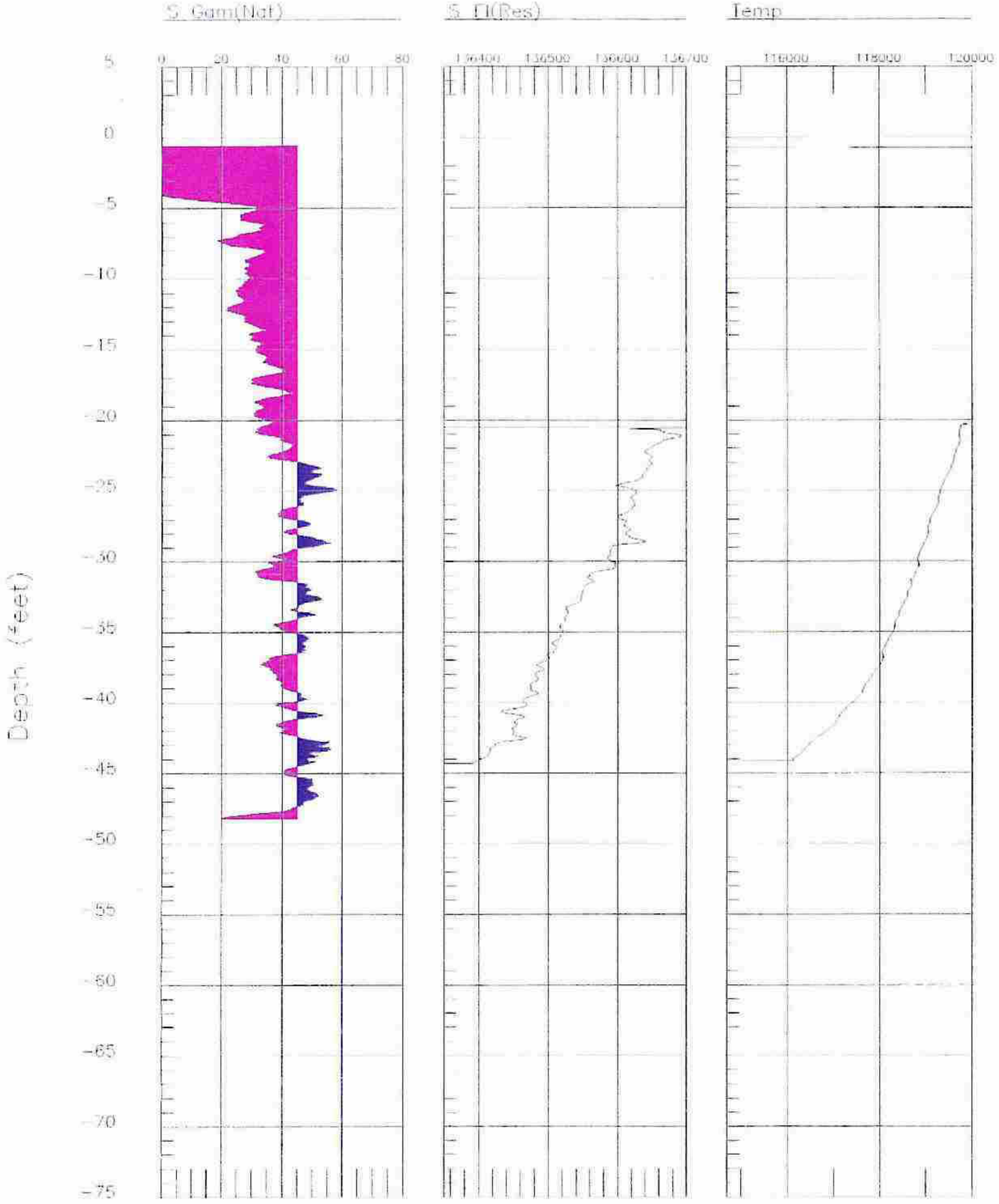
Well Name: Native Council Well
File Name: COUN-DN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



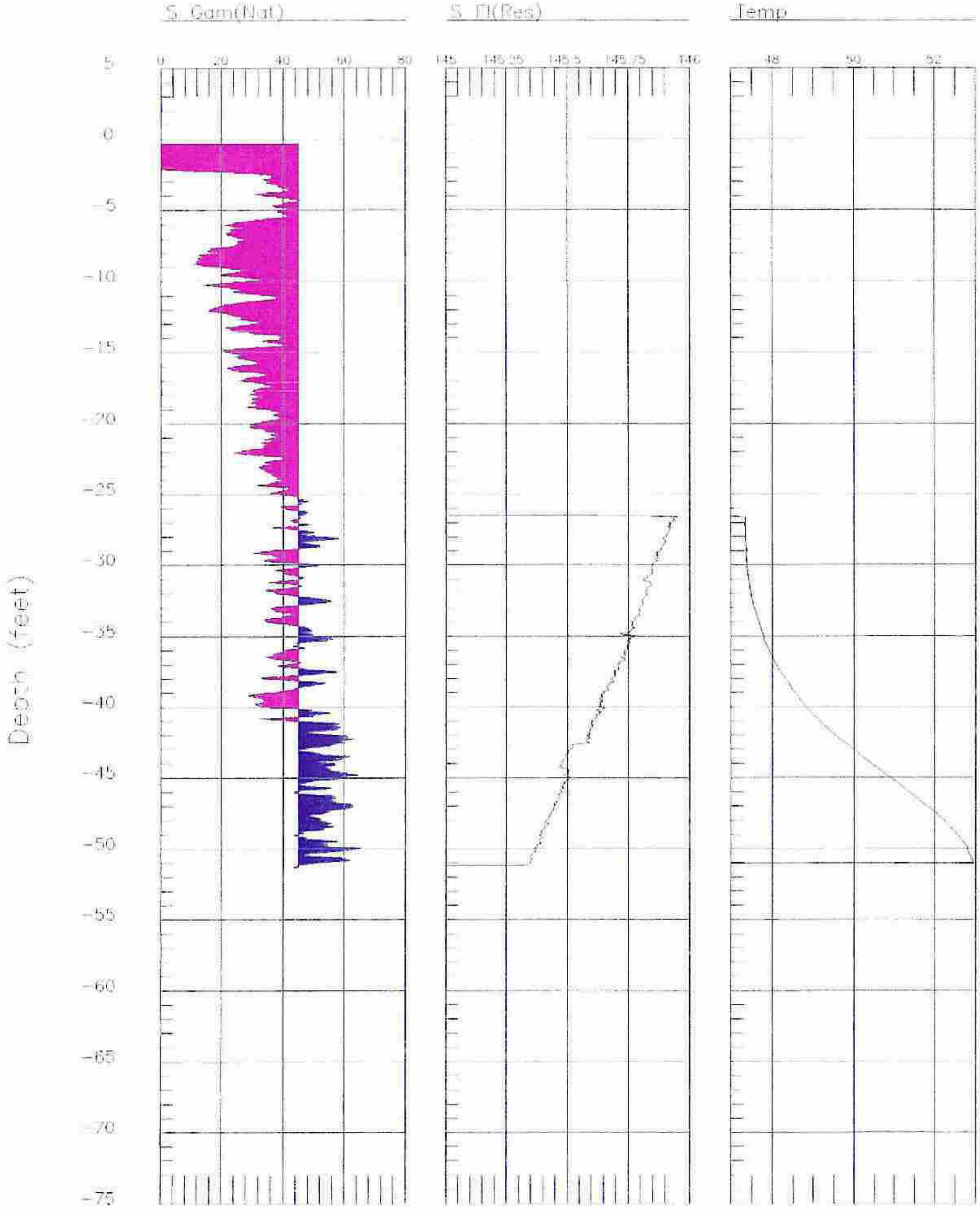
Well Name: FAA East Well
File Name: FAAEDN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



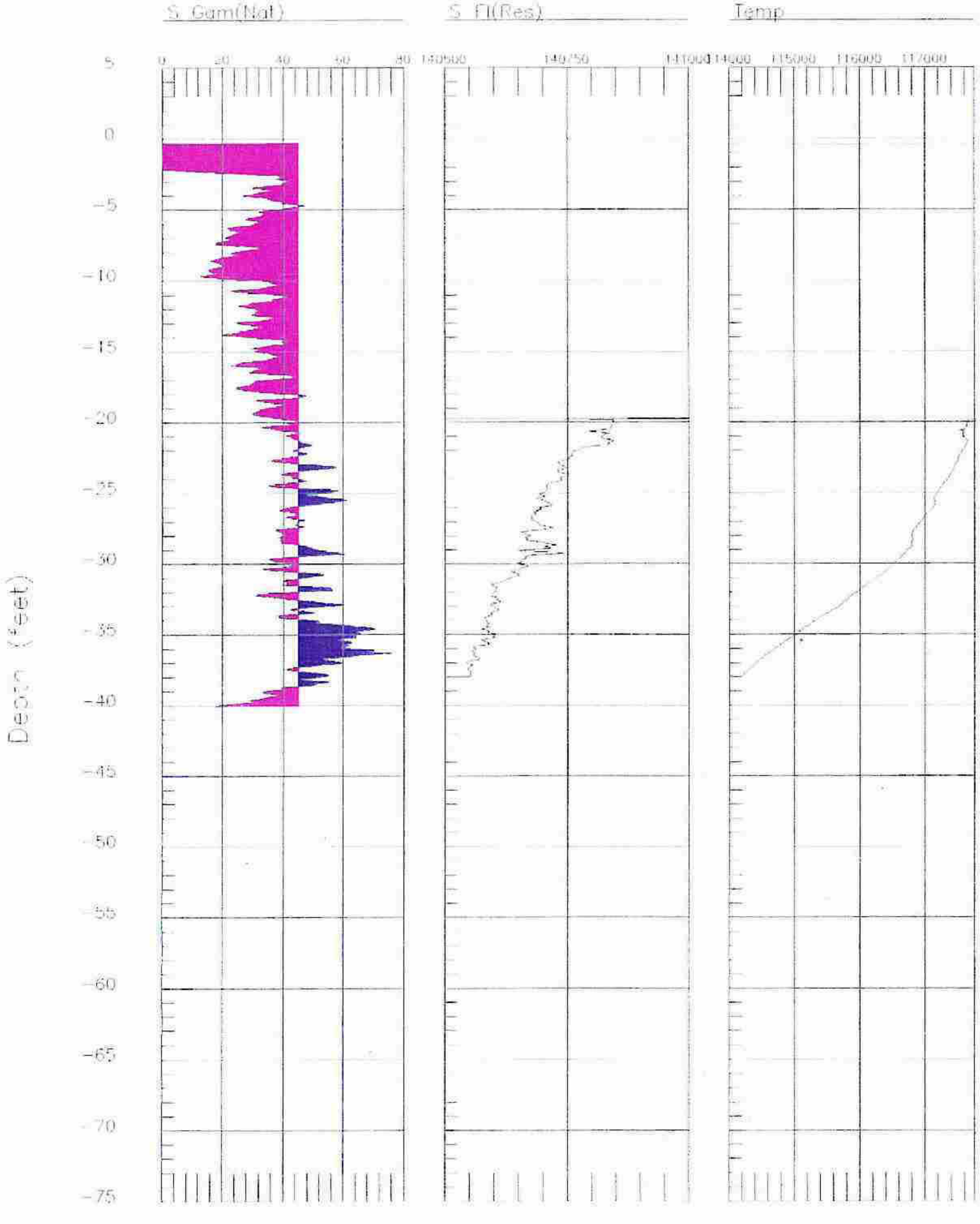
Well Name: Josephine's Well
File Name: JOSE-DN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



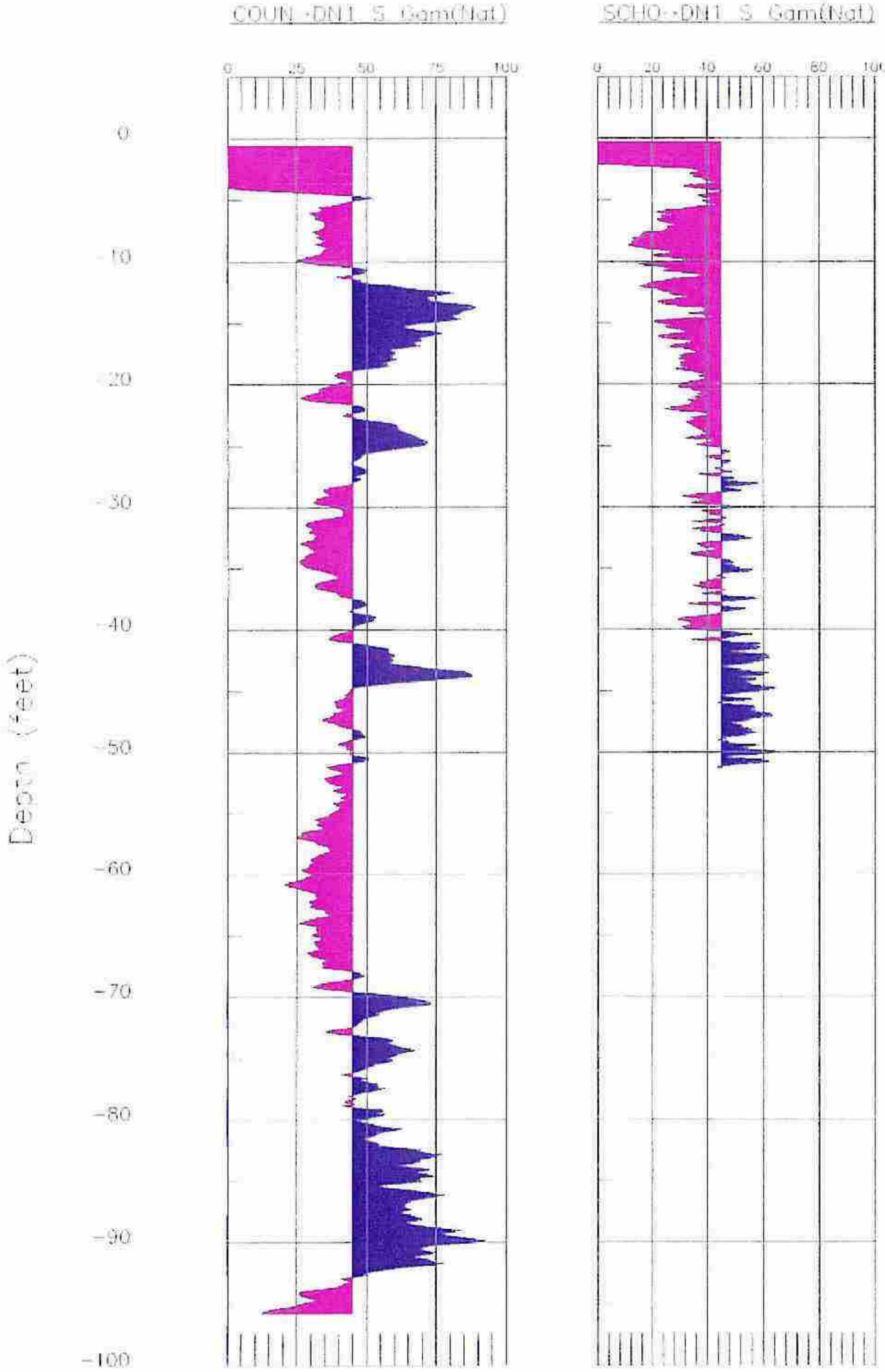
Well Name: School Well
File Name: SCHO->DN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



Well Name: School Superintendent's Well
File Name: SUP2 -DN1
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



Well Name: Native Council Well - School Well Cross Section
File Name: X SECT
Location: Tanana, Alaska
Elevation: 0 Reference: Ground Surface



APPENDIX C

Electrical Resistivity Cross-sections

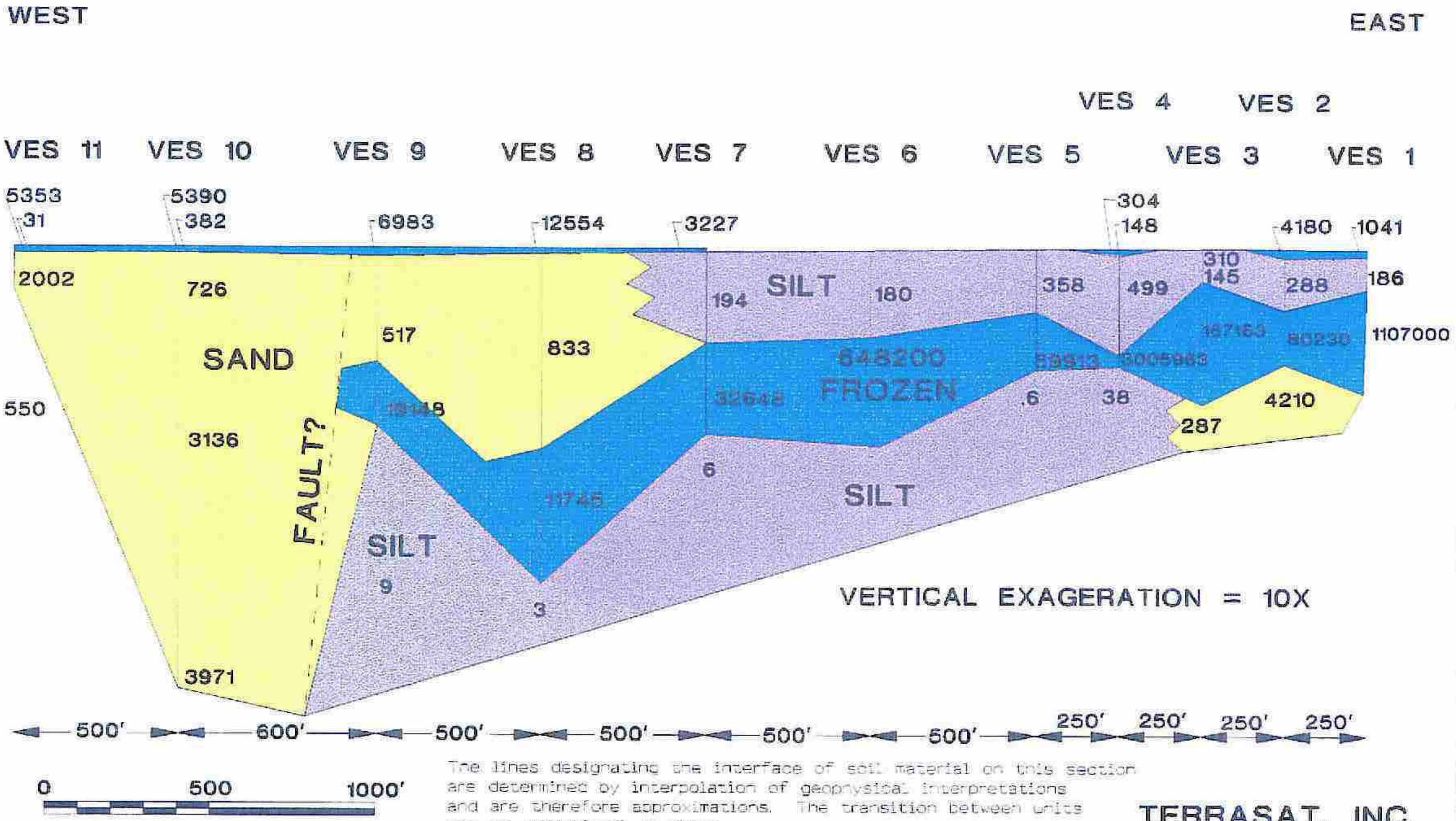
and

Magnetic Profiles

Refer to FIGURE 5 for well locations

Electrical Resistivity Cross-sections

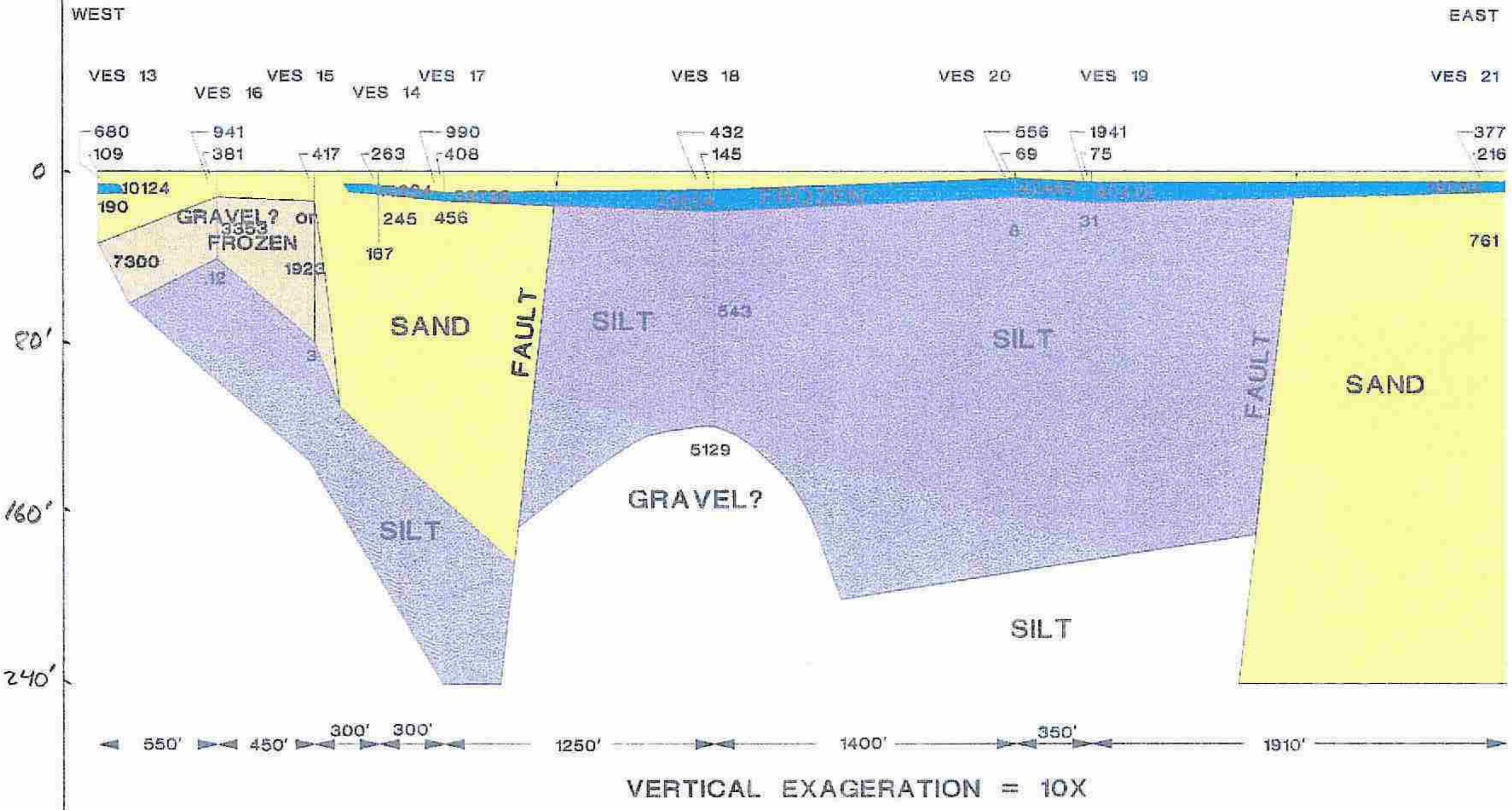
AIRPORT RUNWAY CROSS SECTION



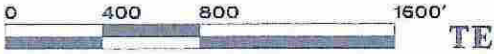
The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.

TERRASAT, INC.

1st AVENUE CROSS SECTION

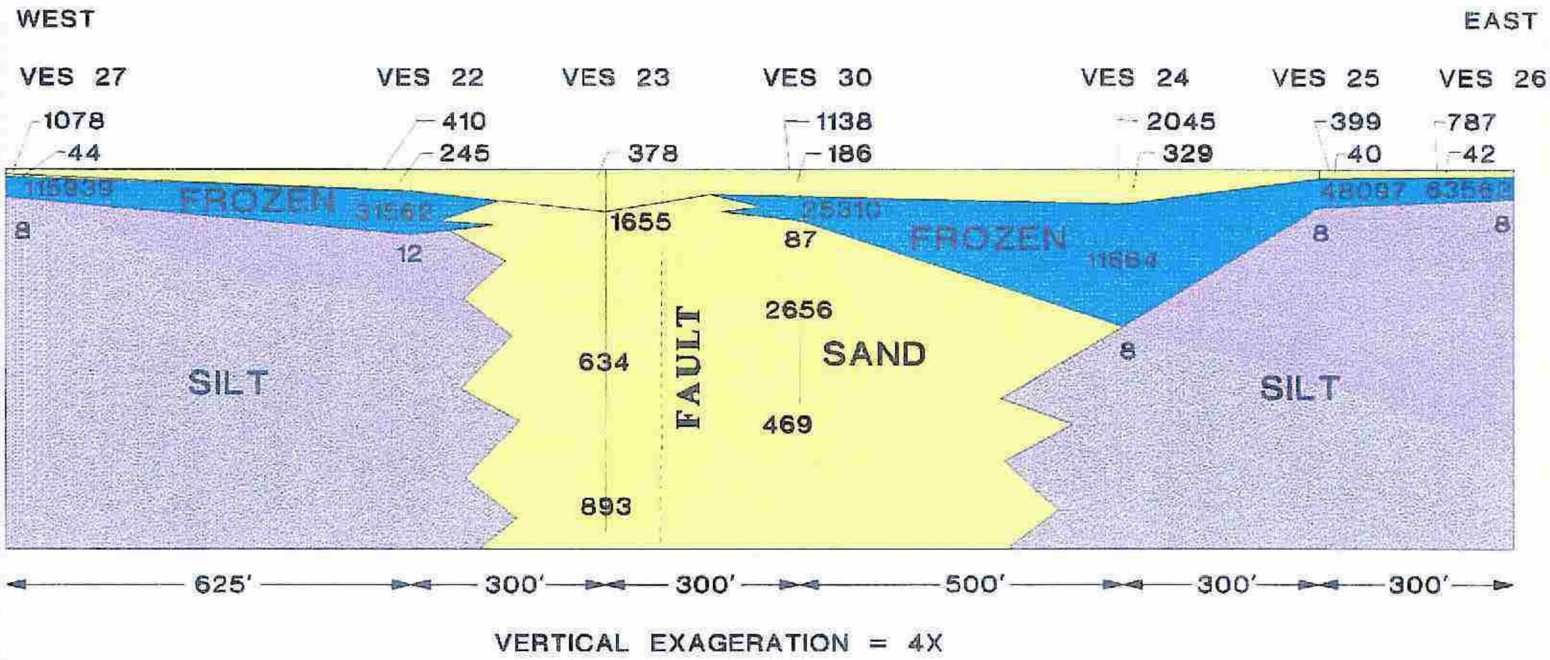


The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.



TERRASAT, INC.

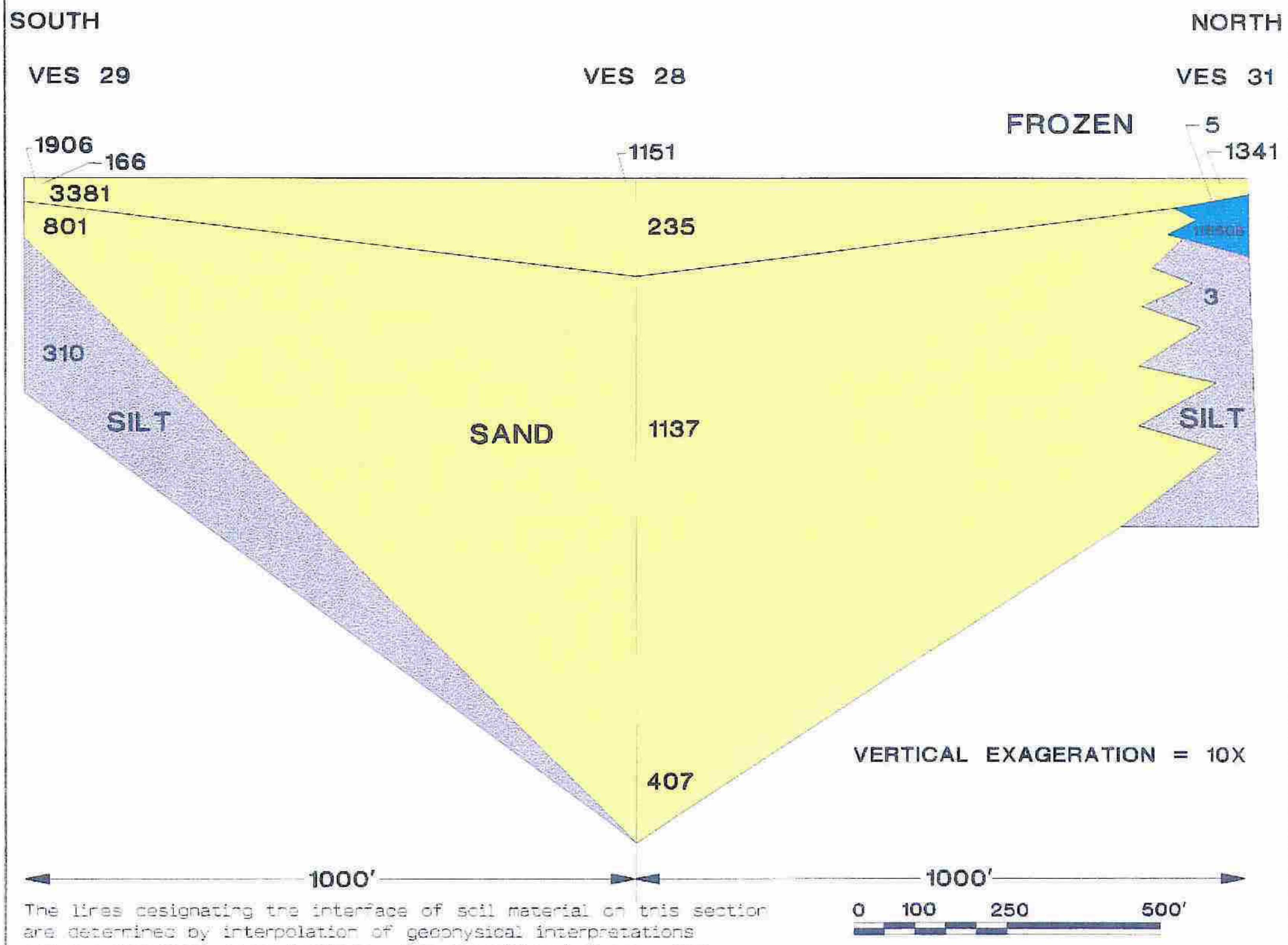
3rd AVENUE CROSS SECTION



The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.

TERRASAT, INC.

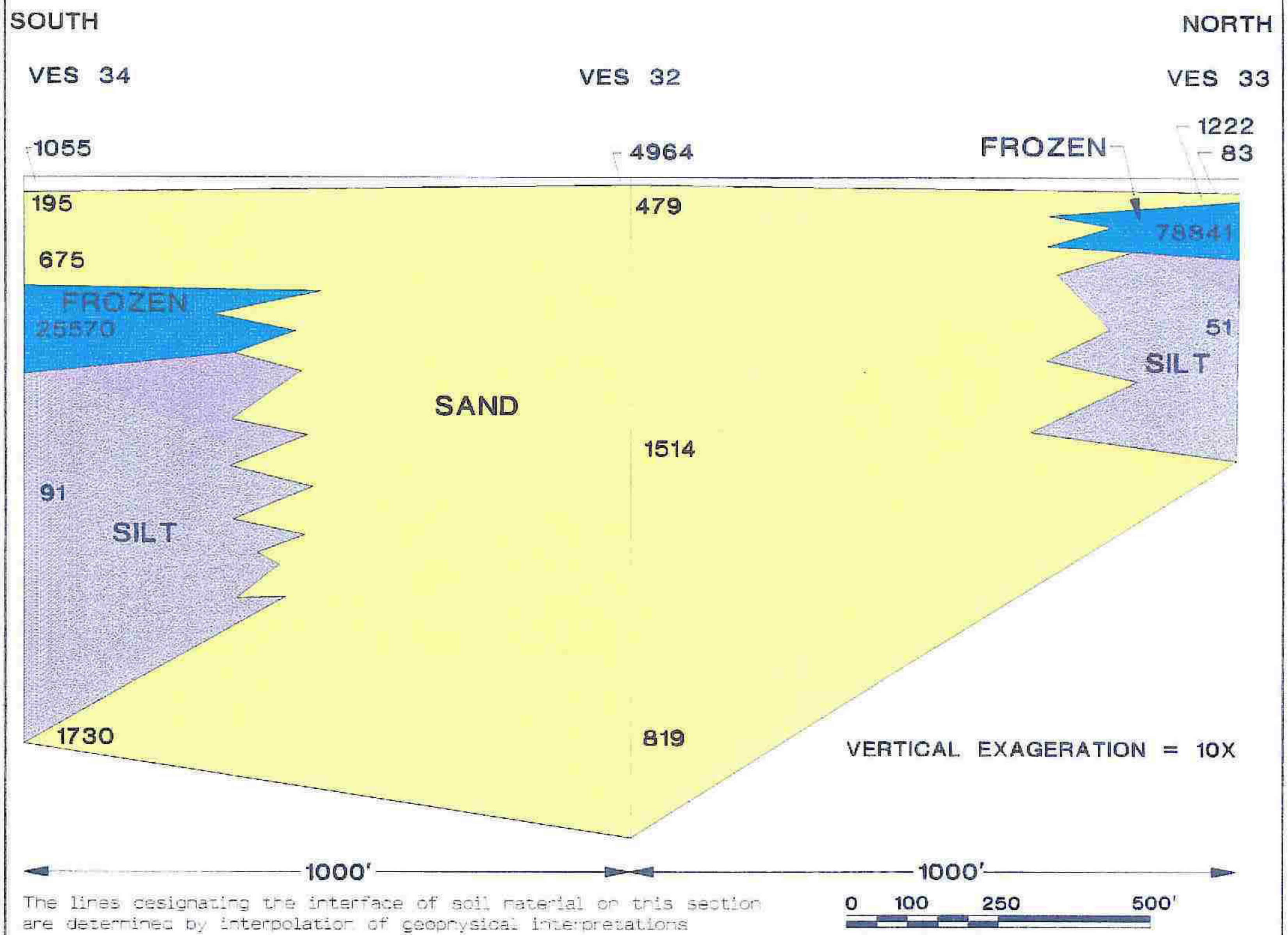
CATHY'S AREA CROSS SECTION



The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.

TERRASAT, INC.

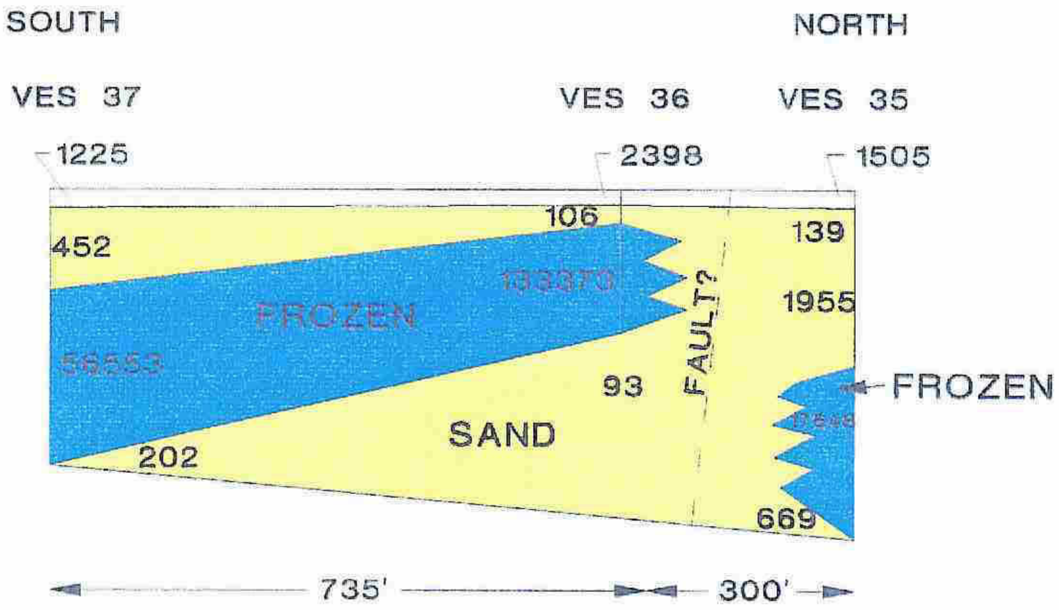
PONGE'S AREA CROSS SECTION



The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.

TERRASAT, INC.

MISSION HILL AREA CROSS SECTION



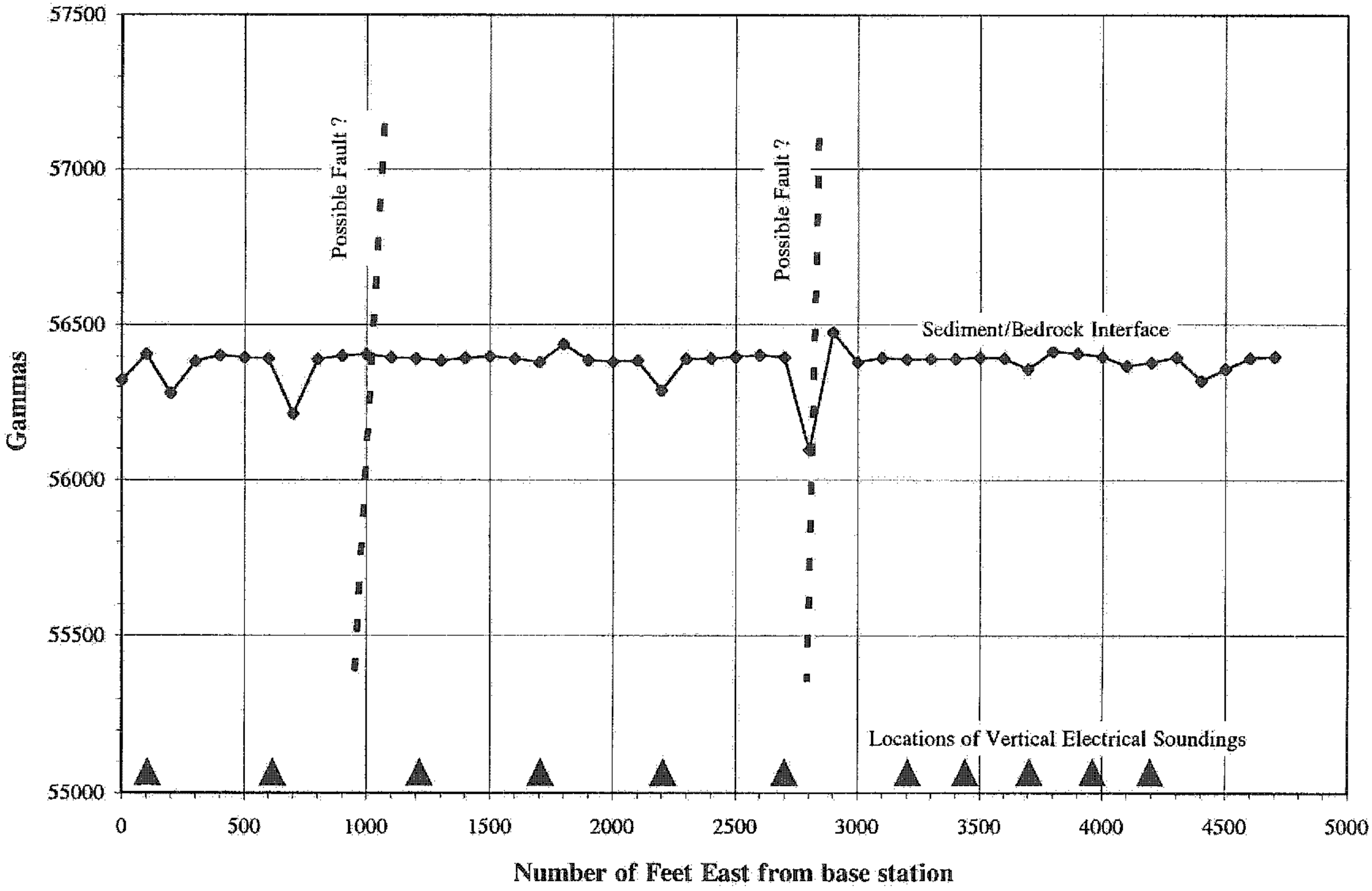
VERTICAL EXAGERATION = 10X

The lines designating the interface of soil material on this section are determined by interpolation of geophysical interpretations and are therefore approximations. The transition between units may be gradational or sharp.

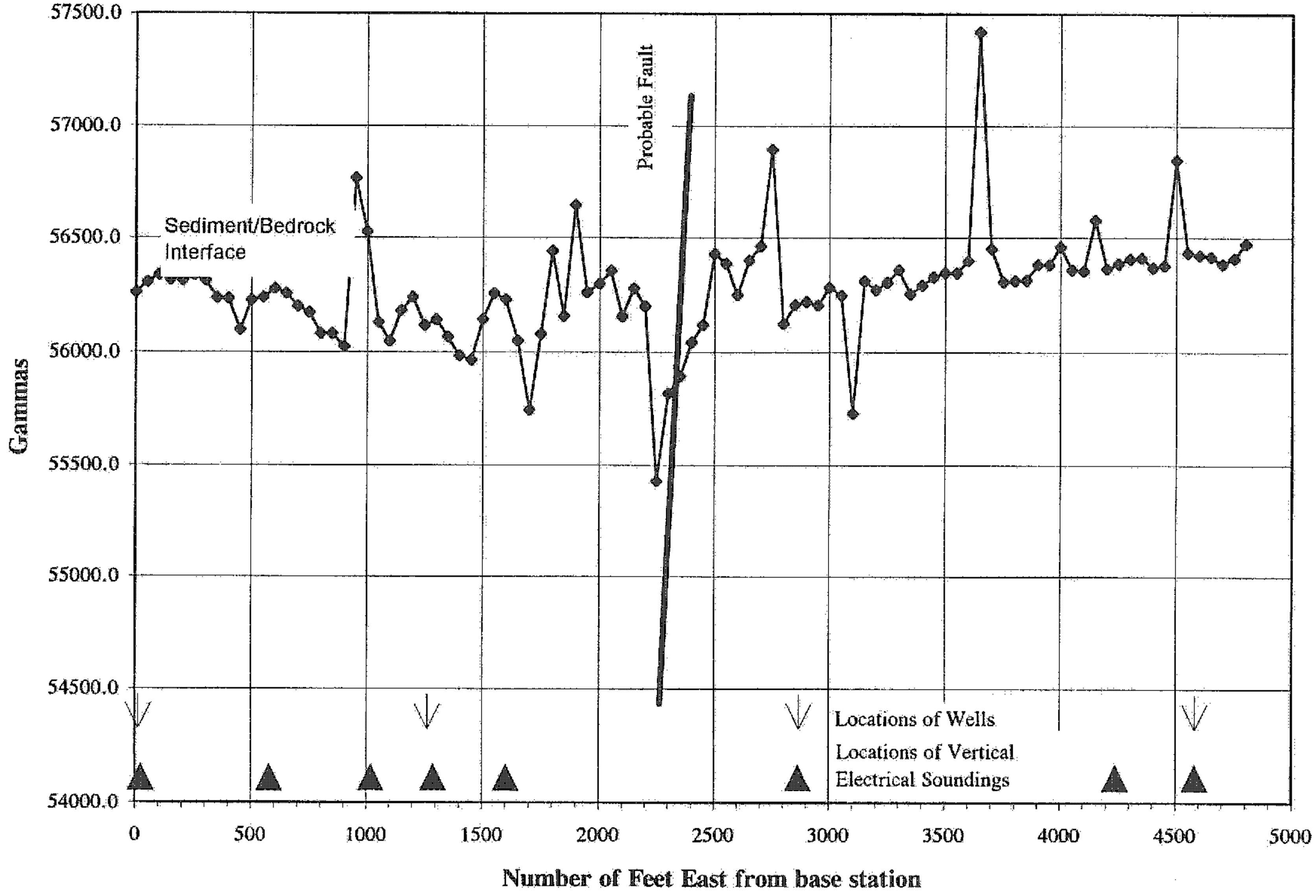
TERRASAT, INC.

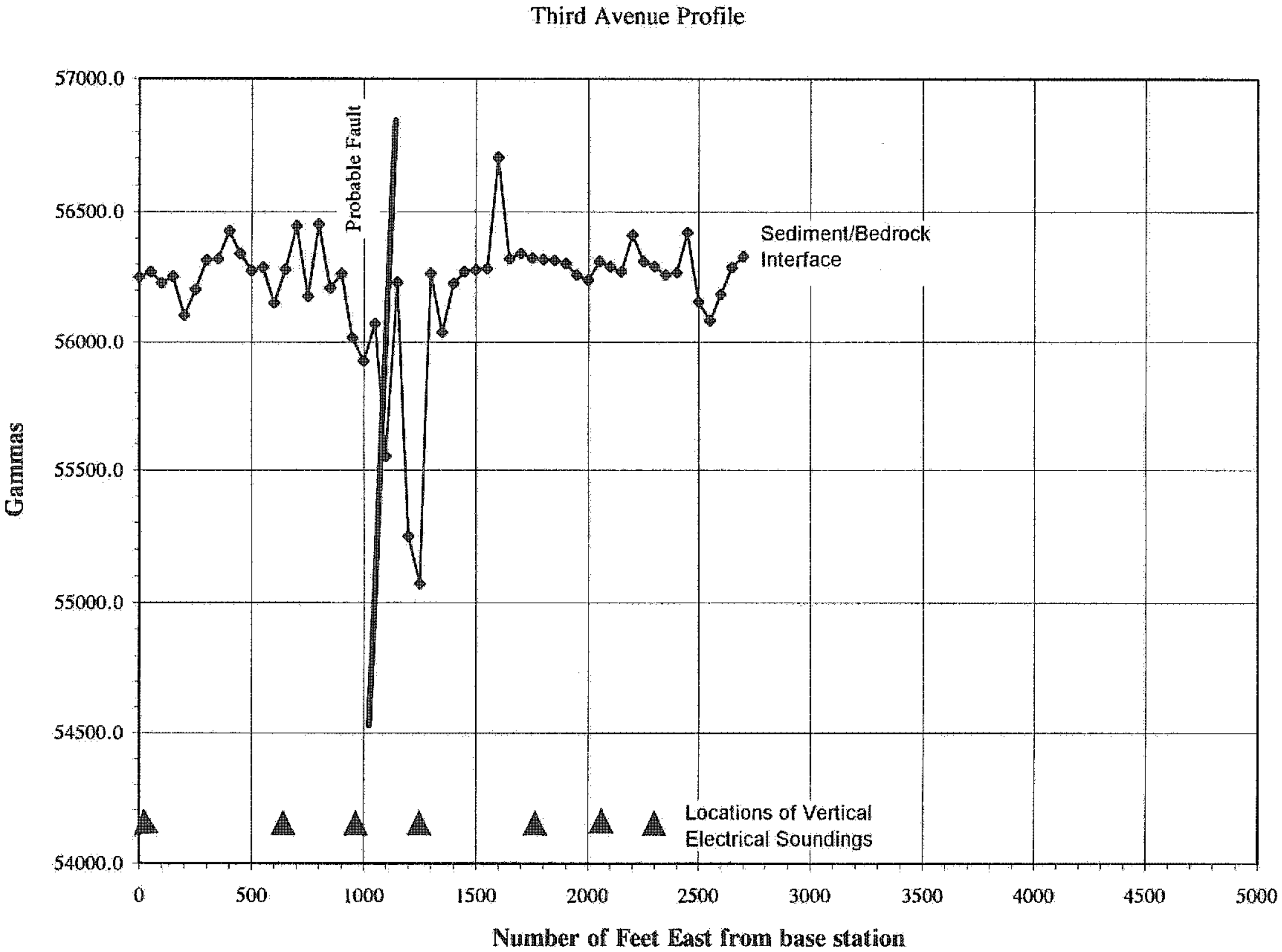
Magnetic Profiles

Runway Profile



First Avenue Profile




Third Avenue Profile
57000.0
56500.0
56000.0
55500.0
55000.0
54500.0
54000.0
Gammas
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Number of Feet East from base station
Probable Fault
Sediment/Bedrock Interface
Locations of Vertical Electrical Soundings