TECHNICAL MEMORANDUM

MOONLIGHT WELLS PROTECTION AREA

NOME, ALASKA

BEESC Project No. 25071

June 2005

Prepared for:

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ACRONYMS AND ABBREVIATIONS

BEESC	Bristol Environmental & Engineering Services Corporation
bgs	below ground surface

TECHNICAL MEMORANDUM

The City of Nome obtains drinking water from a groundwater source located at Moonlight Springs. Moonlight Springs is located approximately 3 miles north of the Nome airport (see Figure 1). The City of Nome currently obtains water from three wells located in a fractured marble formation.

The purpose of this technical memorandum is to define the protection area of the marble aquifer associated with the three drinking water wells and to identify potential activities that could impact the aquifer within the protection area. Prior to 2001, Nome obtained drinking water from a collection gallery located at Moonlight Springs. Previous studies had defined recharge areas for the Moonlight Springs collection gallery. While the two water sources are within the marble formation, the critical recharge area defined in this report reflects the recharge associated with the deeper aquifer that the wells penetrate.

The protection area is based on review of available geologic data as well as hydrologic data for the area. Bristol Environmental & Engineering Services Corporation (BEESC) retained Stevens Exploration Management Corporation to review the geologic data and ground truth activities were performed by Don Stevens, Ph.D., in October 2004. Dr. Stevens' report is presented as Appendix A and BEESC concurs with the findings of the report.

The three wells are completed in a fractured marble groundwater flow system. The wells are completed as open hole wells cased typically to a depth of between 75 and 93 feet below ground surface (bgs) with the total depths of the wells ranging from 80 to 122 feet bgs. Static water levels range between 20 and 35 feet bgs in the three wells. Table 1 provides a summary of well completion details and Appendix B presents the well logs for the three wells.

A review of the available information about the three wells shows that the wells are completed in a confined aquifer as evidenced by the water levels in the wells being much higher than the depth at which water was encountered in the borehole.

Groundwater flow through fractured bedrock systems is complex, and aquifer properties can vary greatly over the large scale of the aquifer system. The aquifer properties are highly dependent on the fracture density, fracture aperture, and the interconnectedness of the fractures. The expected range of hydraulic conductivity of the fractured marble aquifer system ranges over 6 orders of magnitude with values ranging from 10^{-2} to 10^{-8} centimeters per second and values of storativity ranging from 0.005 to 0.00005 (Freeze and Cherry, 1979). The wide range in values is related to the nature of the fractures present. The fractures are related to the degree of faulting, folding, and weathering that has occurred in the past.

Table 1 Moonlight Wells Information

	Groundsurface Elevation (feet)	Water Level Elevation (feet)	Bottom of Casing Elevation (feet)	Bottom of Hole Elevation (feet)	Bottom of Casing Depth (feet bgs)	Bottom of Hole Depth (feet bgs)	Water Level Depth (feet bgs)
Well 1	161	125.15	68	39	93	122	35.85
Well 2	139.7	117.85	64	59	75.7	80.7	21.85
Well 3	150.8	130.49	62	56.5	88.8	94.3	20.31

Notes: Water level elevation from 1:30 p.m. on August 24, 2004, following approximately 4 hours of no pumping in the three wells.

bgs = below ground surface

Because of the low storativity values, groundwater flows in fractured bedrock typically have high groundwater velocities. This means that groundwater will move more quickly and travel farther in a bedrock aquifer than in a porous media aquifer (sand and gravel) with the same hydraulic conductivity.

The aquifer properties at the Moonlight Wells area are not known. In general, the aquifer system is conceptualized to be one where groundwater recharges at various locations away from the wells. These recharge areas are most likely areas where the marble formation outcrops (refer to massive marble on Figure 2). These outcrops may provide a direct conduit into the aquifer and are areas that are critical to maintaining good water quality and quantity. Precipitation and snowmelt within the recharge area eventually provide the water that supplies the wells.

The Moonlight Wells protection area is presented on Figure 2. The protection area is based on review of available geologic and geophysical information of the Moonlight Springs area. Appendix A presents a report on the geology and geophysics of the Moonlight Wells area. The area immediately adjacent to the wells to the south was added into the recharge protection area in order to provide an area of additional wellhead protection close to the wells.

In general, the area delineated as the aquifer protection area is bounded on the west, north, and east by faulting. The structural features are believed to play a large part in the occurrence and movement of groundwater in the aquifer. Groundwater flow across the Anvil fault does not occur. Figure 3 presents a cross section running east-west across the Anvil fault and through the marble aquifer.

The top of the aquifer is exposed in places where the marble formation outcrops at the ground surface. In other portions, the marble is covered by unconsolidated material. This material varies in nature from reworked placer gravels to naturally placed materials. Permafrost may be present in areas. The permafrost may act as a barrier to infiltration as well as a confining layer for the groundwater; although there are no specific examples of this occurring, it is a possibility. Figure 4 presents a cross section running north-south through the Moonlight Wells area to the north through the marble outcrops.

Activities that take place where the aquifer is exposed present the greatest potential threat to the quality and quantity of groundwater in the aquifer. Figure 5 presents the recharge protection area with the land status and areas previously mined.

Protection of the groundwater aquifer requires minimizing the potential for contaminants to enter the aquifer from surface and subsurface activities. There are two issues of concern relating to protecting the groundwater resource.

The first issue is the proper storage, use, and disposal of potential sources of contamination and the second is conduits into the aquifer.

Storage of petroleum hydrocarbons in underground and aboveground storage tanks is a potential source of contaminants. The risk of an unknown release occurring is greatest from underground storage tanks. Another consideration for protection of the groundwater resource is the quantity of fuel stored. Bulk fuel storage stations represent a greater risk than small quantities of fuel stored for domestic use.

Waste disposal activities represent a wide range of potential sources of contaminants with various degrees of risks to degrade the groundwater quality.

Waste disposal activities include landfills, snow disposal areas, honey bucket disposal areas, single or multiple family septic systems, cesspools, outhouses, wastewater holding tanks, and open hole and vaulted pit toilets.

Conduits into the aquifer can take several different forms and can include items such as domestic water wells, soil borings, and other activities that provide a short circuit directly into the aquifer or that would allow contaminants to flow into the subsurface at depths that would more readily allow impacts to the aquifer.

Actions that could adversely impact the aquifer include such activities as quarries and underground mining through the aquifer. These activities could potentially destroy all or part of the aquifer system.

Injection wells by nature provide a conduit into the aquifer and, depending on the nature of the material being injected; have the direct potential to contaminate the aquifer. Examples of this include Class V injection wells for large capacity septic systems, wastewater treatment plant, stormwater drainage, and untreated sewage waste disposal.

Placer mining could produce a potential conduit into the aquifer if the mining activities expose the aquifer at the ground surface.

The activities described above by themselves and in combination may present various risks to the quality and quantity of the water supply from the Moonlight Wells aquifer. BEESC recommends that the City of Nome maintain the integrity of the aquifer within the Moonlight Wells protection area through a permitting process.

REFERENCE

Freeze, R. Allen and John A. Cherry. 1979. *Groundwater*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

FIGURES

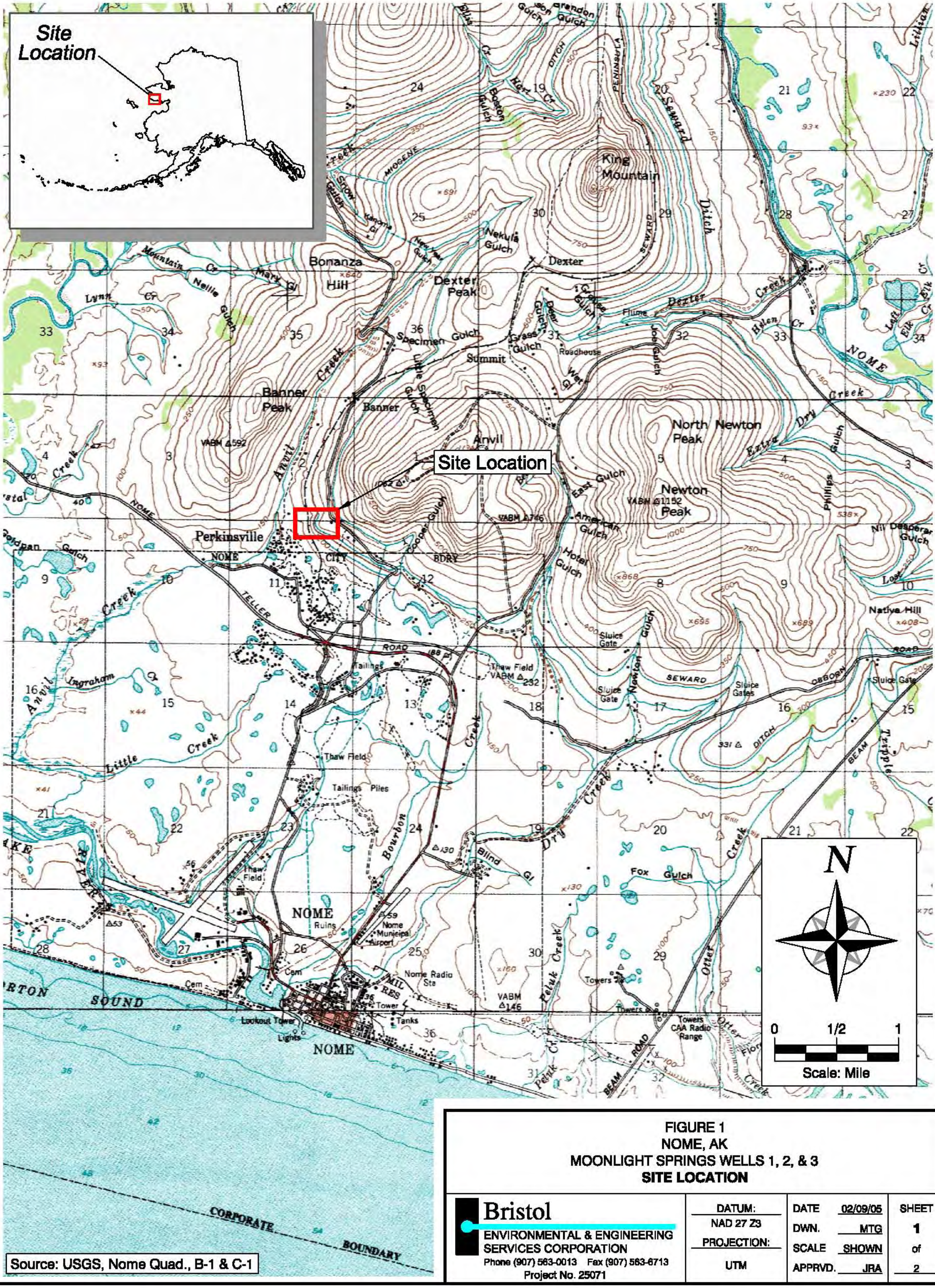
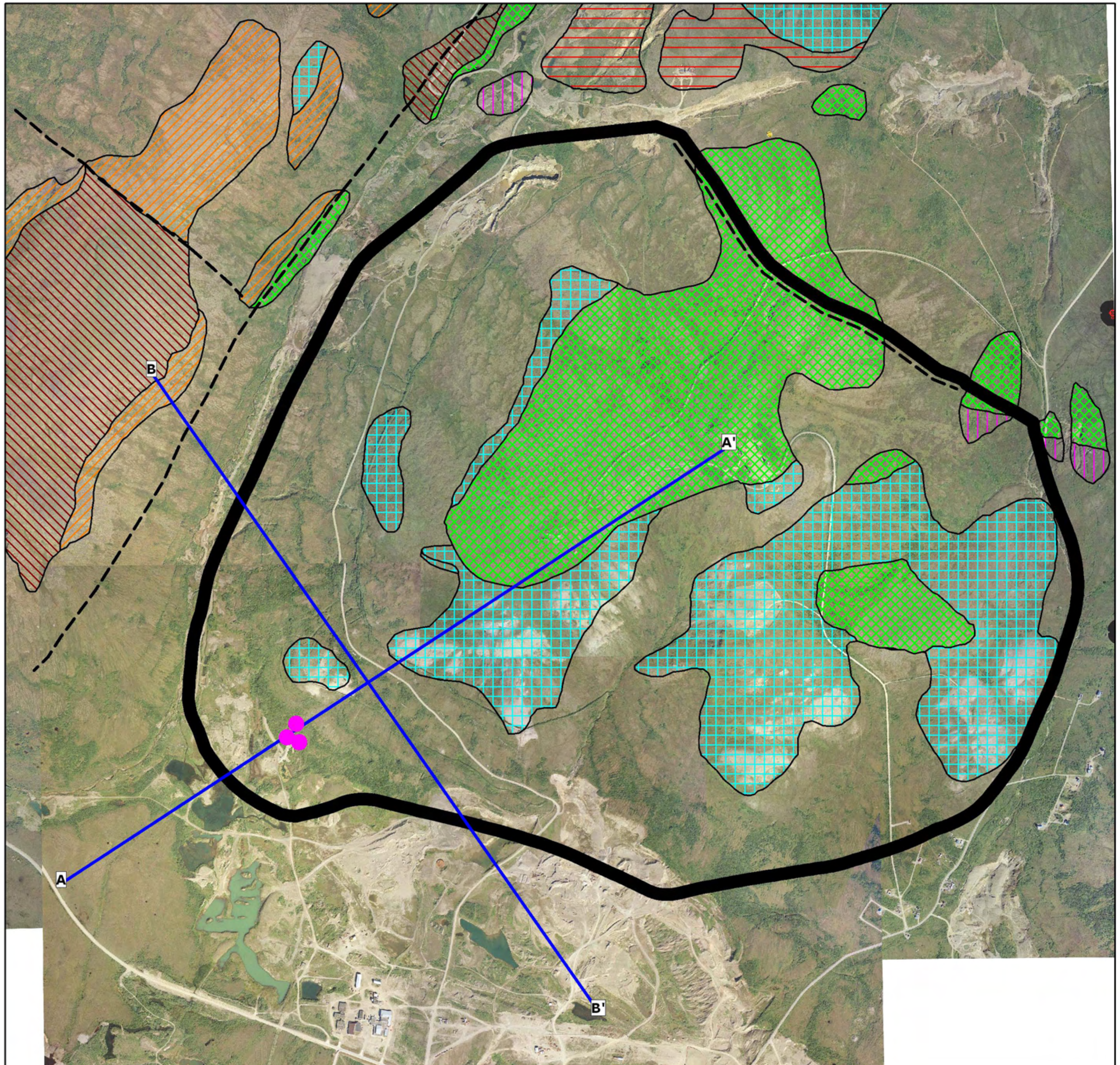


FIGURE 1
NOME, AK
MOONLIGHT SPRINGS WELLS 1, 2, & 3
SITE LOCATION

Bristol
ENVIRONMENTAL & ENGINEERING SERVICES CORPORATION
Phone (907) 563-0013 Fax (907) 563-6713
Project No. 25071

DATUM:	DATE	02/09/05	SHEET
NAD 27 Z3	DWN.	MTG	1
PROJECTION:	SCALE	SHOWN	of
UTM	APPRVD.	JRA	2

Drawing: I:\25071 MLS PROJECT SUPPORT\ACAD-ENVIRO\FIGURES\DWG\25071_V1.DWG - Layout: V1
User: BGALM Feb 17, 2005 - 4:03pm Xrefs: - Images: C64165A1.TIF I64165C1.TIF I64165E1.TIF



Legend

- Moonlight Wells
- Cross Section Lines
- Well Protection Area
- Faults

Geology by UNIT

- Feldspathic, Orthogneiss And Metavolcanic Schist
- Massive Marble
- Massive Marble ?
- Felsic, Muscovite, Metavolcanic Schist
- Graphitic Schist And Quartzite
- Pelitic, Porphyroclastic, Micaceous, Graphitic Schist
- Chlorite Rich, Metaturbidite Schist, And Marble

0 500 1000 1500 2000 2500
Survey Feet

N

Notes:

Air photo from AeroMap, taken August 6, 2003

Bedrock outcrops and faults present in the area are shown on the map. Unconsolidated materials are not shown for clarity. Geology based on Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress Report on the Geology and Mineral Resources of the Nome Mining District: Alaska Division of Geological and Geophysical Surveys Public Data File 94-39, 19 pages, 2 maps.

pCPzm Massive Marble (Light to medium gray, massive, blocky, medium to coarse grained marble composed almost entirely of calcite rhombohedrons. Locally unmapped lenses or crosscutting dikes of chlorite-amphibole-garnet metabasite found in outcrop. pCPzm unit thought to be in thrust contact with underlying pelitic Schist (pCPzpm) in Aurora Creek and at other locations in western portion of map area, where sheared dolomite boudins and mylonite 1 to 2 m thick mark contact zone. pCPzm is resistant to very resistant, and forms conspicuous gray hillslopes barren of vegetation).

pCPzsf Felsic, Muscovite, Metavolcanic Schist (heterogeneous unit of (1) zircon rich, muscovite quartzose schist; (2) feldspar-rich, porphyroblastic muscovite schist with minor quartz; and (3) tourmaline enriched, muscovite-chlorite-feldspar schist, referred to as "tourmalite" beds, and denoted as 't' on sheet 1. In latter rock type, tourmaline rosettes are interwoven into bundles and layers of muscovite and phengite. The "tourmalite" zones are spatially related to massive sulfide-barite deposits at Aurora Creek, and may indicate premetamorphic, submarine (?) hydrothermal activity elsewhere in the study area. Generally nonresistant due to very high muscovite-tourmaline content, and form subdued rubble on ridgetops and in stream cuts).

pCPzspm Pelitic, Porphyroclastic, Micaceous, Graphitic Schist (Distinctively dark gray, massive to layered, medium to coarse grained, biotite, chlorite, muscovite, porphyroclastic "lumpy" schist, the provenance of which is thought to be pelitic, coarse metasandstone and metaconglomerate. Composed of up to 15 percent graphite, 35 to 40 percent white mica, 20 percent chlorite (usually a retrograde product of biotite), 5 percent pink garnet, 10 percent retrograded and inclusion-charged albitic plagioclase, and minor clinozoisite. Lozenge-shaped masses of albite grains and muscovite-chlorite bundles up to 1.5 cm in long dimension are thought to represent pelitic sedimentary clasts prior to regional metamorphism. pCPzpm is very resistant and forms the most rugged mountain landscape in the study area-particularly in the upper Aurora Creek drainage).

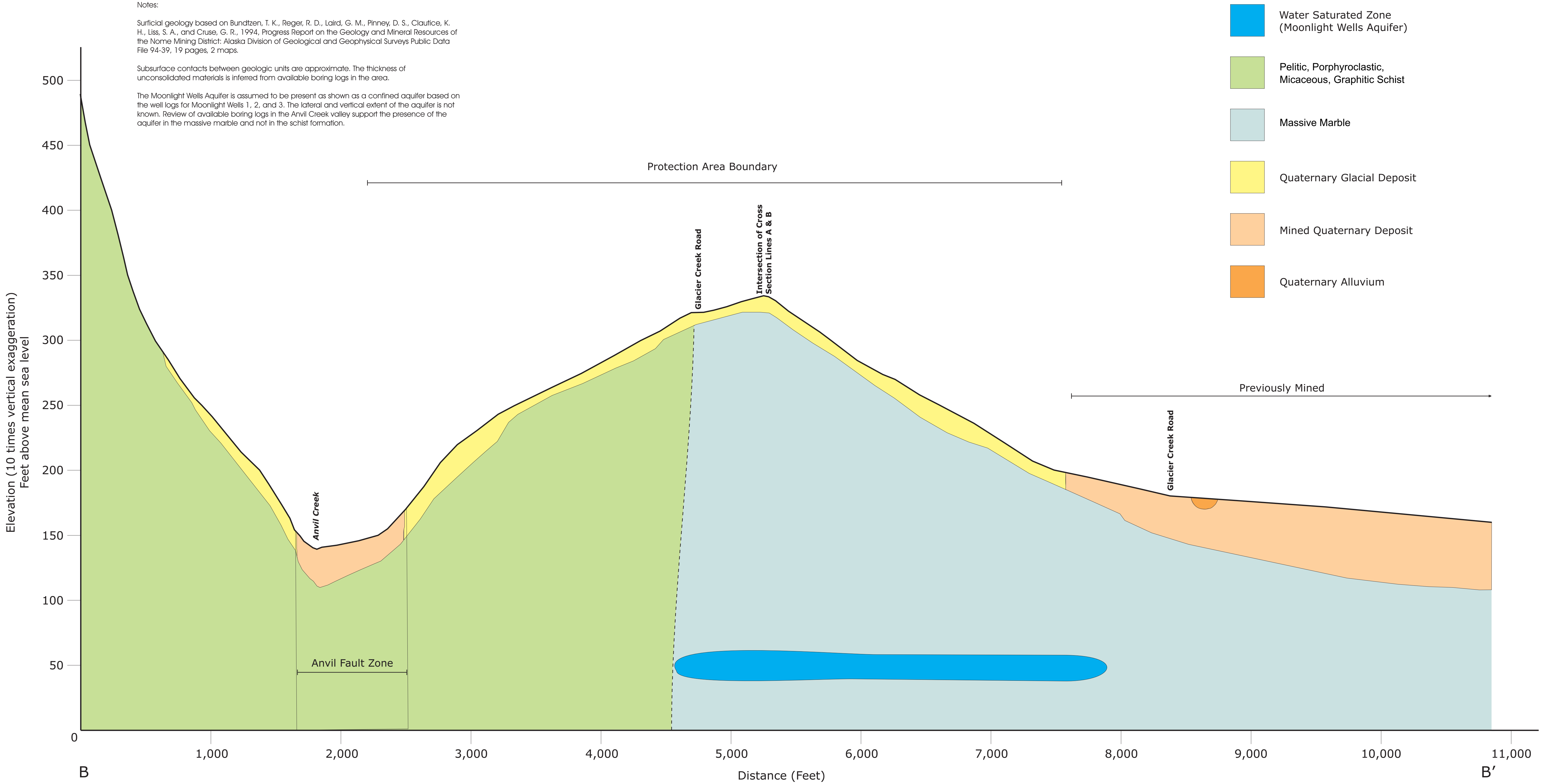
Scale: 1:19,400	CITY OF NOME MOONLIGHT WELLS PROTECTION AREA	Date: Oct. 6, 2006		Figure 2
Datum: NAD27		Drawn by: ME	Checked By: SJ	BEESC No: 25071
Projection: AK State Plane, Z8				

Notes:

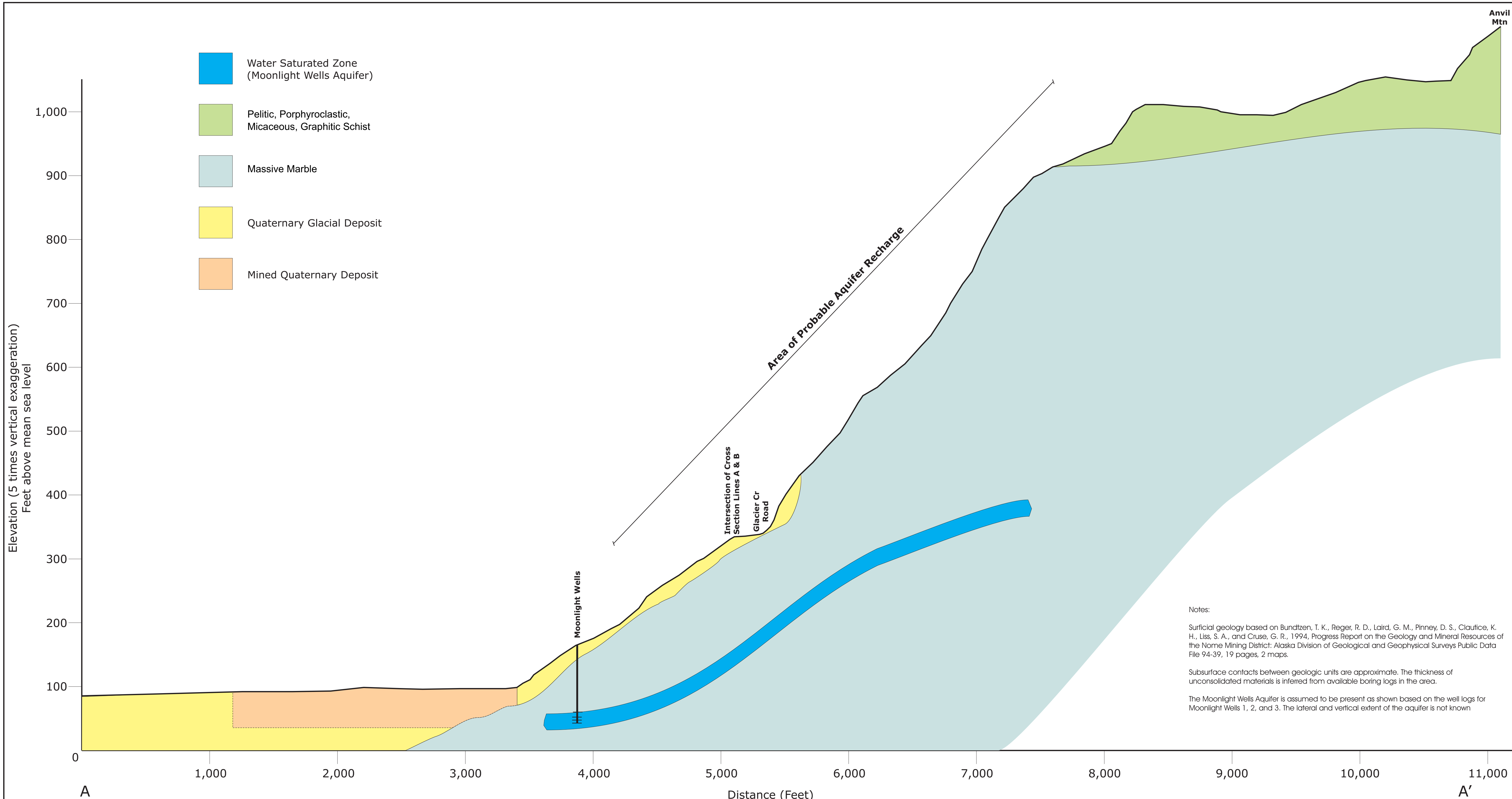
Surficial geology based on Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress Report on the Geology and Mineral Resources of the Nome Mining District: Alaska Division of Geological and Geophysical Surveys Public Data File 94-39, 19 pages, 2 maps.

Subsurface contacts between geologic units are approximate. The thickness of unconsolidated materials is inferred from available boring logs in the area.

The Moonlight Wells Aquifer is assumed to be present as shown as a confined aquifer based on the well logs for Moonlight Wells 1, 2, and 3. The lateral and vertical extent of the aquifer is not known. Review of available boring logs in the Anvil Creek valley support the presence of the aquifer in the massive marble and not in the schist formation.



Scale:	CITY OF NOME	Date Drawn: April 5, 2005	Figure 3
Viewing: Northeast	MOONLIGHT WELLS PROTECTION AREA	Drawn By: ME / Checked By: SJ	BEESC Project No: 25071
Note: see figure 2 for section location	B - B' CROSS SECTION		



Notes:

Surficial geology based on Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress Report on the Geology and Mineral Resources of the Nome Mining District: Alaska Division of Geological and Geophysical Surveys Public Data File 94-39, 19 pages, 2 maps.

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The Moonlight Wells Aquifer is assumed to be present as shown based on the well logs for Moonlight Wells 1, 2, and 3. The lateral and vertical extent of the aquifer is not known

Scale:

Viewing: Northwest

Note: see figure 2 for section location

CITY OF NOME
MOONLIGHT WELLS PROTECTION AREA
A - A' CROSS SECTION

Date Drawn: April 5, 2005

Figure 4

Drawn By: ME

Checked By: SJ

BEESC
Project No: 25071

Scale:	NTS
Datum:	NAD 1927
Projection:	Alaska State Plane Zone 8

MOONLIGHT WELLS
PROTECTION AREA AND LAND STATUS

Date Drawn: March 30, 2005		Figure: 5
Drawn By: MTG	Checked By: SJ	BEESC Project No: 25071

APPENDIX A

Geology and Geophysics of the Moonlight Wells Area

Geology and Geophysics of the
Moonlight Springs Wells Area,
Nome, Alaska

Prepared for:
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2000 West International Airport Road, Suite C-1
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907.563.0013

May 26, 2005

Prepared by:
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907.561.1991
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RECOMMENDATIONS AND CONCLUSIONS

A single recharge zone is recommended. The proposed boundary is based upon the most recent geologic mapping and airborne 900 Hz resistivity data published by the Alaska Division of Geological and Geophysical Surveys.

The south and west boundaries follow the geologic contact between the marble unit, which serves as the recharge area of the wells, and the schist unit. This contact is clearly shown on the Alaska Division of Geological and Geophysical Surveys 900 Hz resistivity map, a portion of which is enclosed as Figure 3.

The northwestern boundary of the recharge area is along the linear trend defined by Specimen Gulch. This linear feature is most likely the trace of an ENE-trending fault.

The northeastern boundary follows a northwest-trending fault that runs from Specimen Gulch to the eastern boundary.

The eastern boundary is along the roughly linear trend defined by the valley east of Anvil Mountain through which the Dexter ByPass road is routed.

These boundary changes are based upon geologic features which affect the recharge area in the marble unit in which the Moonlight Springs wells are located. The recharge area delineated provides a high level of confidence that the boundary will provide strict protection for the recharge area for the wells, and will not restrict present economic activities.

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INTRODUCTION

SCOPE

This report will present the current state of knowledge about the geology and resistivity geophysics of the Moonlight Springs wells area and the likely recharge area for the wells.

PURPOSES

The water wells near Moonlight Springs are the sole source of water for the City of Nome. This study will present geological and geophysical data needed on which to base decisions to protect this valuable resource.

AUTHORIZATION

The preparation of this report was authorized by Steven A. Johnson, P.E., Senior Engineer for Bristol Environmental & Engineering Services Corporation on November 23, 2004.

LOCATION

The City of Nome is located in the Nome B-1 and C-1 quadrangles on the south side of the Seward Peninsula of northwest Alaska. The City of Nome is Alaska's oldest continuous first class city, incorporated on April 9, 1901. The boundaries of the City extend about 4.3 miles in an east-west direction and an average of about 3.7 miles north-south. Nome is physically situated along the north side of Norton Sound, adjacent to the beach, and on the gently sloping coastal plain.

The geographic coordinates for the city area are 64º 30' North latitude, 165º 24' West longitude. Most of the city is situated in Township 11 South, Range 34 West, Sections 25, 26, 35, and 36, Kateel River Meridian. See Figure 1.

HISTORY OF MOONLIGHT SPRINGS FACILITY

Moonlight Springs served as a source of good water for Nome residents and local miners as far back as gold rush days just after the turn of the century. A brief history of the Moonlight Springs well facility is given in the Operations and Maintenance Manual prepared by CE2 Engineers in December, 2003.[1]

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[1] CE2 Engineers, 2003, Operation and Maintenance Manual for Moonlight Springs Wells Number 1, 2, and 3; Transmission Lines; and Collection Structure, Nome, Alaska: Prepared for the Nome Joint Utility System.

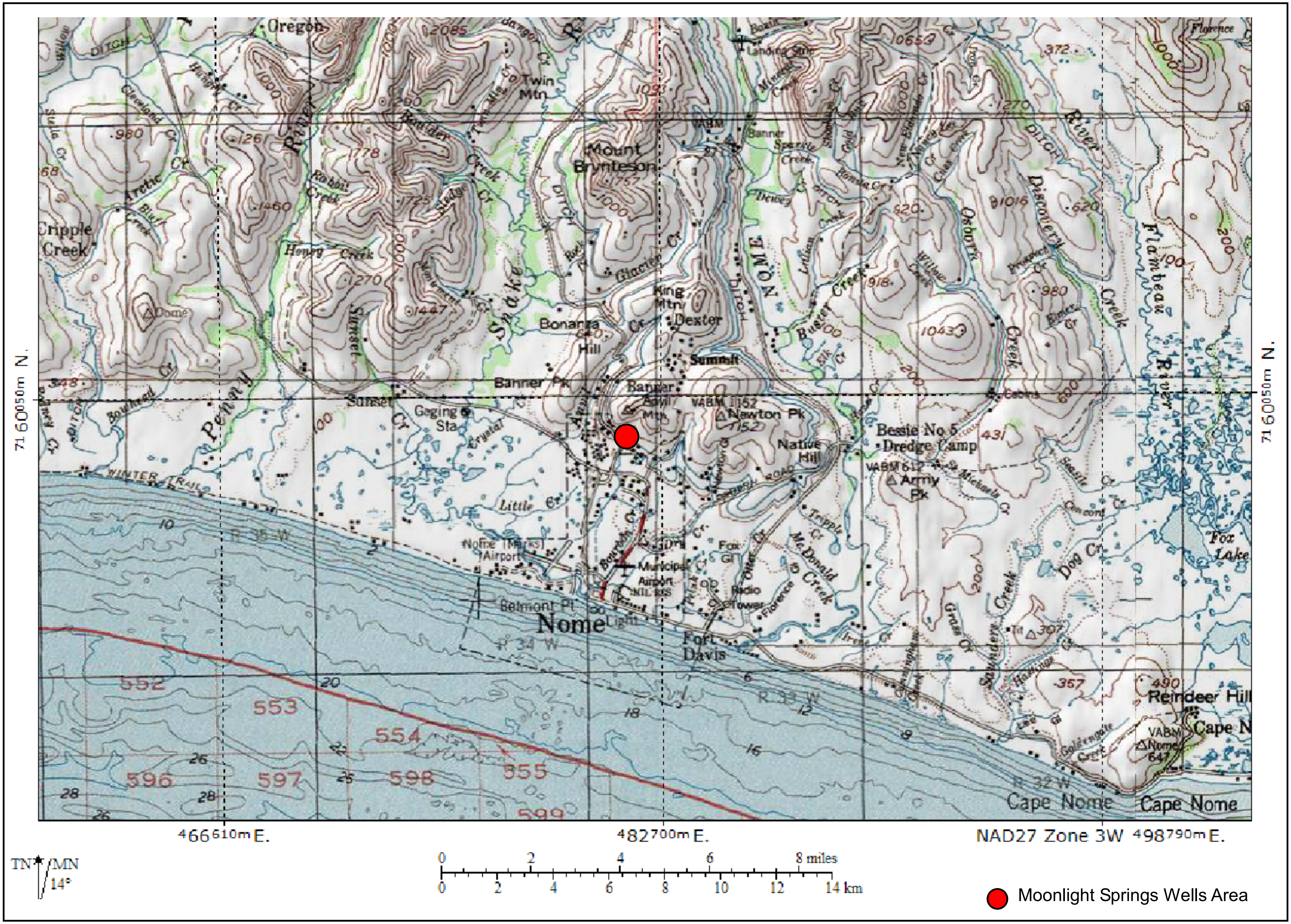

Figure 1 Nome, Alaska area showing location of Moonlight Springs Wells

PREVIOUS WORK

GEOLOGY

The most recent geologic report on the Moonlight Springs area is by Bundtzen, et al.[2]

Lithologies

Bundtzen et al. described the lithologies of the study area which included Moonlight Springs and the areas to the north and east of the wells in their report as quoted verbatim below. The many literature citations in the quoted text are identified in the bibliography in Appendix A of this report.

Nome Group

> *The regionally metamorphosed rocks of the Nome mining district were first described by Brooks and others (1901), whose work was supplanted by more detailed mapping and petrographic studies by Collier (1902), Knopf (1908), Smith (1910), and Moffit (1913). The high-grade regionally metamorphosed rocks of the central Kigluaik Mountains were referred to by Moffit (1913) as the Kigluaik Group; he defined the lower rank, regionally metamorphosed units in the Nome mining district as the Nome Group. Moffit (1913) and Smith (1910) first identified glaucophane in the Nome Group, which is now regarded as one of the largest, high P-low T, blueschist facies metamorphic terranes in the world. Many modern workers including Sainsbury and others (1970), Forbes and others (1984), Thurston (1985), Evans and Patrick (1989), Till (1980), Sturnick (1984), Patrick and Evans (1989), Miller and Hudson (1991), and Miller and others (1992) have published detailed petrographic and radiometric age dating studies of metamorphic rocks in and near the study area. Nokleberg and others (1993) include the Nome Group into the Seward Terrane, an offset continental margin ranging in age from PreCambrian(?) to Late Paleozoic.*
>
> *All regionally metamorphosed rocks in the study area have been assigned to the Nome Group, although some small metamorphosed intrusions may be unrelated to the other units. We have benefited from geologic map studies completed by the previously mentioned early workers and by Herreid (1970) and Hummel (1962a,b). Till and others (1986) and Till and Dumoulin (in press) believe that the Nome Group constitutes a coherent lithostratigraphic succession, which consists of four units: (1) a basal, complexly deformed quartz-rich pelitic schist, which may be correlative with the Solomon Schist of Smith (1910) and Moffit (1913); (2) a "mixed unit" of mafic and pelitic schists and marble; (3) a mafic-dominated schist package, which may be correlative with the Casadepaga Schist of Smith (1910); and (4) an "impure marble unit". We have tentatively subdivided the Nome Group rocks of the study area into the first three units of Till and others (1986), which, in the study area, are locally repeated by thrust faults.*

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[2] Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress Report on the Geology and Mineral Resources of the Nome Mining District: Alaska Division of Geological and Geophysical Surveys Public Data File 94-39, 19 pages, 2 maps.

Smith (1910) and Moffit (1913) believed the Nome Group is Paleozoic in age. However, Sainsbury and others (1970) regarded all Nome Group lithologies as Precambrian in age, on the basis of inferred stratigraphic position and limited Rb-Sr isotopic-age determinations. Till and others (1986) have reported Ordovician to Devonian conodonts from marble units in the Nome Group. We assign a Precambrian-Paleozoic age to all Nome Group rocks mapped in the study area pending results of U-W isotopic-age dating of felsic metavolcanic rocks in the mixed unit and further geological mapping to the east of the study area in 1994.

Summary Of Surficial Geology

Most of the area is covered by drift laid down during past glaciations. Drift of the oldest advance, the Sinuk glaciation of early Pleistocene(?) age, is exposed in the vicinity of Cape Nome in the southeastern comer of the map area. The most extensive surface drift sheet was deposited during the Nome River glaciation of middle Pleistocene age. Ice of this advance flowed southward out of cirques in the Kigluaik Mountains and coalesced with local ice from cirques and small ice caps in the uplands north of Nome. Ice of the Nome River glaciation filled the major trunk streams near Nome and extended southward several kilometers into present day Norton Sound (Hopkins and others, 1960, Nelson and Hopkins, 1972, Kaufman and Hopkins, 1989; Kaufman and others, 1991).

The subsequent Stewart River Glaciation spread out of the Kigluaik Mountains as far as 10 km beyond the mountain front. Ice from Kigluaik Mountain sources joined with local ice, from small, north-facing cirques in the uplands immediately south of Kigluaik Mountains. The Stewart River glaciation is thought to be older than the last major interglaciation (Kaufman and Hopkins, 1986; Kaufman and others, 1988).

Slightly modified drift of the Salmon Lake glaciation forms lobate moraines that nearly reach as far south as the Stewart River terminal moraines (Kaufman and Hopkins, 1989). Radiocarbon dating indicates that this ice expansion occurred more than 33,000 years ago (Kaufman and others, 1989).

During and after these ice expansions, fluvial, colluvial, and marine processes modified the landscape, formed gravel-rich alluvial valley fills, and beach and terrace sediments. Fine-grained estuarine deposits were laid down in lower streams close to the present coast of Norton Sound.

STRUCTURE

All bedrock geologic units have been subjected to blueschist-facies metamorphism, which in turn was retrograded to T-P conditions of the greenschist facies. In the study area, earlier high P-low T mineral assemblages are frequently altered due to the strong, retrogressive greenschist metamorphism. Earlier metamorphic minerals such as garnet, chloritoid, glaucophane, hornblende, and calcic plagioclase are frequently rolled in a granoblastic fabric. Axial-plane schistosity parallel to compositional banding is the dominant "S 1" surface measured in outcrop; later "S 2" cleavage or foliation is transposed at low angles in a westward vergence across lithologic or compositional banding, indicating that low-angle thrusting or recumbent folds have deformed the Nome Group in the study area. Stretched mineral lineations, isoclinal fold plunges, and mica crenulations (sheet 1) record deformation that postdates original schistosity developed during the prograde, blueschist-facies event.

Lithostratigraphic units of the mixed unit are repeated by probable late synmetamorphic thrust faults south of Aurora Creek and east of Mount Distin. In the *former area, metaturbidite schist (pCPzt), felsic metavolcanic schist (pCPzsf), black quartzite (pCPzsg), and "lumpy", porphyroclastic schist (pCPzpm) exposed in the Aurora Creek area are repeated in the Hungary Creek drainage implying a low-angle throw of approximately 7 km. In the Basin Creek drainage, albite mafic schist and metabasite of the Casadepaga Schist(?) are thrust over the upper portion of the mixed unit. Other thrust faults are mapped on the basis of sheared contacts, low-angle mylonite zones, and outcrop-scale discontinuities, but the significance of offset along these faults is unknown.*

Large-scale, younger structures include me north-trending Twin Mountain anticline, and northeast-trending high-angle faults. Pelitic, felsic, mafic, and carbonate-dominated lithologies of the mixed unit at Aurora Creek on the west are repeated at Dexter Mountain and Goldbottom Creek on the east by the Twin Mountain anticline, which largely defines the distribution of Nome Group lithologies in the study area.

The well known Anvil Creek fault trends north 40 to 55 degrees east up Anvil Creek (sheet l), and juxtaposes metaturbidite schists on the west with pelitic, graphitic, metavolcanic, and calcareous lithologies on the east. A significant metafelsite center and interbedded pelitic schist and marble on Dexter Creek are equivalent to felsic metavolcanic schists and exhalite at Aurora Creek. The lithostratigraphic correlation indicates that the amount of postulated vertical movement along the Anvil fault is about 1.5 km.

The Penny River fault (after Herreid, 1970) right laterally offsets the metavolcanic schist section at Aurora Creek about 4 km from an equivalent section on the east side of Penny River (sheet 1).

Other significant northeast-trending high-angle faults include the Rodine fault (after Hawley and Buxton, oral comm., 1993), and the Oregon Creek-Charley Creek fault, both of which show right-lateral throws ranging from 1 to3 km.

Smaller less well defined, northwest-trending high-angle faults such as the Boulder Creek fault also cut the metamorphic rocks throughout the map area, and are probably more extensive than shown on the geologic map (sheet 1).

The detailed descriptions of the key geologic units[3] relevant to the Moonlight Springs follows:

Qh Primarily Placer-Mine Tailings*—Water-washed pebble-cobble gravel with trace to some sand; moderate to well sorted; surface smooth or slightly irregular to symmetrical ridges and cones.*

Qd2 Modified Drift Of Nome River Glaciation*—Heterogeneous blankets of pebble-cobble gravel with trace to some sand and silt and few to numerous subangular to subrounded boulders deposited directly from glacial ice and reworked by mass-movement processes; locally sorted into circles and nets by frost action; generally massive bedded; surface smooth to slightly irregular, lobed, and terraced.*

Qaf Alluvial Fan Deposits*—Fan-shaped, heterogeneous mixtures of pebble-cobble gravel, sand, and silt with few to numerous, subangular to subrounded boulders, especially in proximal areas; may include deposits of slushflows and debris flows in proximal areas; thick to thin bedded; surface smooth, except for numerous shallow networks of interconnected channels.*

[3] Ibid.

Qa Floodplain Alluvium*—Elongate deposits of pebble-cobble gravel and sand with few to numerous boulders beneath modern floodplains; well sorted and medium to thick bedded, locally crossbedded; surface smooth, except for local low scarps.*

pCPzm Massive Marble *(Light to medium gray, massive, blocky, medium to coarse grained marble composed almost entirely of calcite rhombohedrons. Locally unmapped lenses or crosscutting dikes of chlorite-amphibole-garnet metabasite found in outcrop. pCPzm unit thought to be in thrust contact with underlying pelitic Schist (pCPzpm) in Aurora Creek and at other locations in western portion of map area, where sheared dolomite boudins and mylonite 1 to 2 m thick mark contact zone. pCPzm is resistant to very resistant, and forms conspicuous gray hillslopes barren of vegetation.)*

pCPzspm Pelitic, Porphyroclastic, Micaceous, Graphitic Schist *(Distinctively dark gray, massive to layered, medium to coarse grained, biotite, chlorite, muscovite, porphyroclastic "lumpy" schist, the provenance of which is thought to be pelitic, coarse metasandstone and metaconglomerate. Composed of up to 15 percent graphite, 35 to 40 percent white mica, 20 percent chlorite (usually a retrograde product of biotite), 5 percent pink garnet, 10 percent retrograded and inclusion-charged albitic plagioclase, and minor clinozoisite. Lozenge-shaped masses of albite grains and muscovite-chlorite bundles up to 1.5 cm in long dimension are thought to represent pelitic sedimentary clasts prior to regional metamorphism. pCPzpm is very resistant and forms the most rugged mountain landscape in the study area-particularly in the upper Aurora Creek drainage.)*

pCPzsc Calcareous Schist, Felsic Schist, And Chlorite Schist *(Heterogeneous unit composed of distinctly brown weathered, medium grained, calcareous chlorite-white mica schist, albite-rich muscovite felsic porphyroblastic schist, and mica bearing dolomitic marble. The felsic porphyroblastic schists contain zircon and minor pink grossular garnet similar to mineralogical content of felsic metavolcanic schists of pCPzf unit. Nonresistant, and forms rare, rounded outcrops and rubble in stream cuts and on slopes.)*

pCPzf Feldspathic, Orthogneiss And Metavolcanic Schist *(Light tan-gray, fine to medium grained, subfoliated to phaneritic, K-spar rich, felsic orthogneiss (probably regionally metamorphosed metavolcanic flows or shallow hypabyssal intrusions related to premetamorphic volcanism. pCPzf units contain abundant white mica (both muscovite and phengite(35 percent)), feldspar (20 percent), albite (10 percent), quartz (30 percent), and subordinate chlorite, carbonate, and sericitic alterations products. pCPzf flanking Dexter mountain is believed to be a felsite center related to submarine volcanism at, and stratigraphically equivalent to felsic schists at Aurora and Goldbottom Creeks. Moderately resistant and forms large talus along hillslopes.)*

pCPzsf Felsic, Muscovite, Metavolcanic Schist *(heterogeneous unit of (1) zircon rich, muscovite quartzose schist; (2) feldspar-rich, porphyroblastic muscovite schist with minor quartz; and (3) tourmaline enriched, muscovite-chlorite-feldspar schist, referred to as "tourmalite" beds, and denoted as 't' on sheet 1. In latter rock type, tourmaline rosettes are interwoven into bundles and layers of muscovite and phengite. The "tourmalite" zones are spatially related to massive sulfide-barite deposits at Aurora Creek, and may indicate premetamorphic, submarine (?) hydrothermal activity elsewhere in the study area. Generally nonresistant due to very high muscovite-tourmaline content, and form subdued rubble on ridgetops and in stream cuts.)*

> ***pCPzsg Graphitic Schist And Quartzite*** *(Dark gray, massive to laminated, blocky, graphitic quartzite. Composed of laminated layers of interlocking quartz anhedra (80 percent), and graphite (20 percent). Occasionally thin sections contain 1-3 percent white mica. pCPzsg represent either (1) carbonaceous fine grained mudstones; or (2) mylonites. Very resistant and forms distinctive, black-lichen-colored, coarse talus.)*

> ***pCPzt Chlorite Rich, Metaturbidite Schist, And Marble*** *(medium green, medium grained, well foliated, locally banded, chlorite, muscovite, feldspathic, quartzose schist and phyllitic schist. Locally contains thin marble beds ("m" on sheet 1), and up to 3 percent calcite in groundmass. Also contains variable amounts of clinozoisite, garnet, and chloritoid, the latter two minerals from a prograde metamorphic event. Glaucophane reported from similar units in Salmon Lake area by Thurston (1985). Plagioclase porphyroblasts inclusion charged with sericite and clinozoisite. "m" denotes marble bed. pCPzt thought to originally be clastic sediments deposited by turbidity currents on the basis of gross outcrop textures (relict graded bedding ?), and major oxide chemistry, which is similar to lithic sandstone. Generally resistant and forms eroded smooth talus and persistent outcrops in stream canyons.)*

A careful analysis of the geologic map accompanying the above report provides detailed information pertinent to understanding the apparent recharge area for the Moonlight Springs wells. The physical location of the Moonlight Springs wells is in the southwestern corner of a large marble unit (pCPzm). This unit is terminated to the west of the Moonlight Springs by the Anvil Creek fault which controls the NNE trend of Anvil Creek. This fault is probably a zone consisting of several sub-parallel faults collectively known as the Anvil Creek fault. A normal characteristic of such a fault zone is that it is a barrier to ground water movement across the fault due to the fine-grained fault gouge (finely comminuted rock) along the surfaces of the vertical fault. Another characteristic of fault zones is that they induce subparallel to parallel fractures and joints in the country rock adjacent to the fault zone with a tighter spacing closer to the fault zone. This fracture set is probably one of several that could provide the aquifers necessary for the flow of ground water to the Moonlight Springs wells.

Another factor influencing the hydrology of the area is the schist unit (pCPzspm) which caps the Massive Marble (pCPzm) unit in many exposures on Anvil Mountain and to the east and north. This schist unit likely has much lower porosity and permeability than the marble unit and fewer vertical fractures, and most likely restricts surface water recharge of aquifers in the underlying marble unit. See the Cross Section on Figure 2.

The southern margin of the marble unit is covered by a variety of surficial materials including glacial till, colluvium, alluvium, fluvial gravel, marine sediments and placer mine tailings, which obscures the contact with the bedrock unit to the south. However, the airborne resistivity data clearly delineates the southern margin of the marble unit and shows why Moonlight Springs is located where it is.

GEOPHYSICS

In 1994, the Alaska Division of Geological and Geophysics published the results of an airborne geophysical survey of the Nome area in a series of about 10 maps and related digital products. The survey area included the Moonlight Springs, Anvil Mountain, Dexter and adjacent areas and included previously flown private data. The airborne surveys are flown with the sensor slung below a helicopter and with the sensor at a specified distance above the terrane and along a precisely controlled flight path array. The data published included maps showing total field magnetics and derivative presentations, resistivity data at two frequencies with derivative presentations, as well as the raw digital data. The 3D spatial accuracy of data points is very high due to reference to both the Russian and U.S. global positioning systems, and rigorous quality control procedures imposed by the State geophysicist, Dr. Laurel Burns.

Magnetics

The magnetics data generally show the magnetic susceptibility of the underlying rocks[4]. The Anvil Creek fault zone is represented by a magnetic “low” probably due to hydrothermal destruction of magnetite in the rocks. The schist unit to the west of Moonlight Springs on the west side of the Anvil Creek fault is a magnetic “high” and the schist unit overlying the marble unit on Anvil Mountain and Newton Peak also shows a weak high, probably because the schist unit is not very thick, and is underlain by the marble unit which is much less magnetic so there is an “averaging” effect related to the relative thicknesses of the two units in the vertical direction.

Resistivity

Of all the physical properties of rocks and minerals, electrical resistivity shows the greatest variation, and ranges from 10^{-8} to 10^{16} Ωm. The Nome airborne geophysical surveys measured the resistivity at 7200 and 900 Hz. At both frequencies, the Moonlight Springs area plots on the southwestern-most tip of the high resistivity zone. The marble unit which hosts the site of Moonlight Springs and nearby wells correlates with the highest resistivity zones so well that resistivity can be used to define the contacts of the marble unit where direct observation is not possible. See the 900 Hz map[5] in Figure 3.

The resistivity data, particularly the 900 Hz map, shows that Moonlight Springs is located less than 400 feet from the southern contact of the marble unit.

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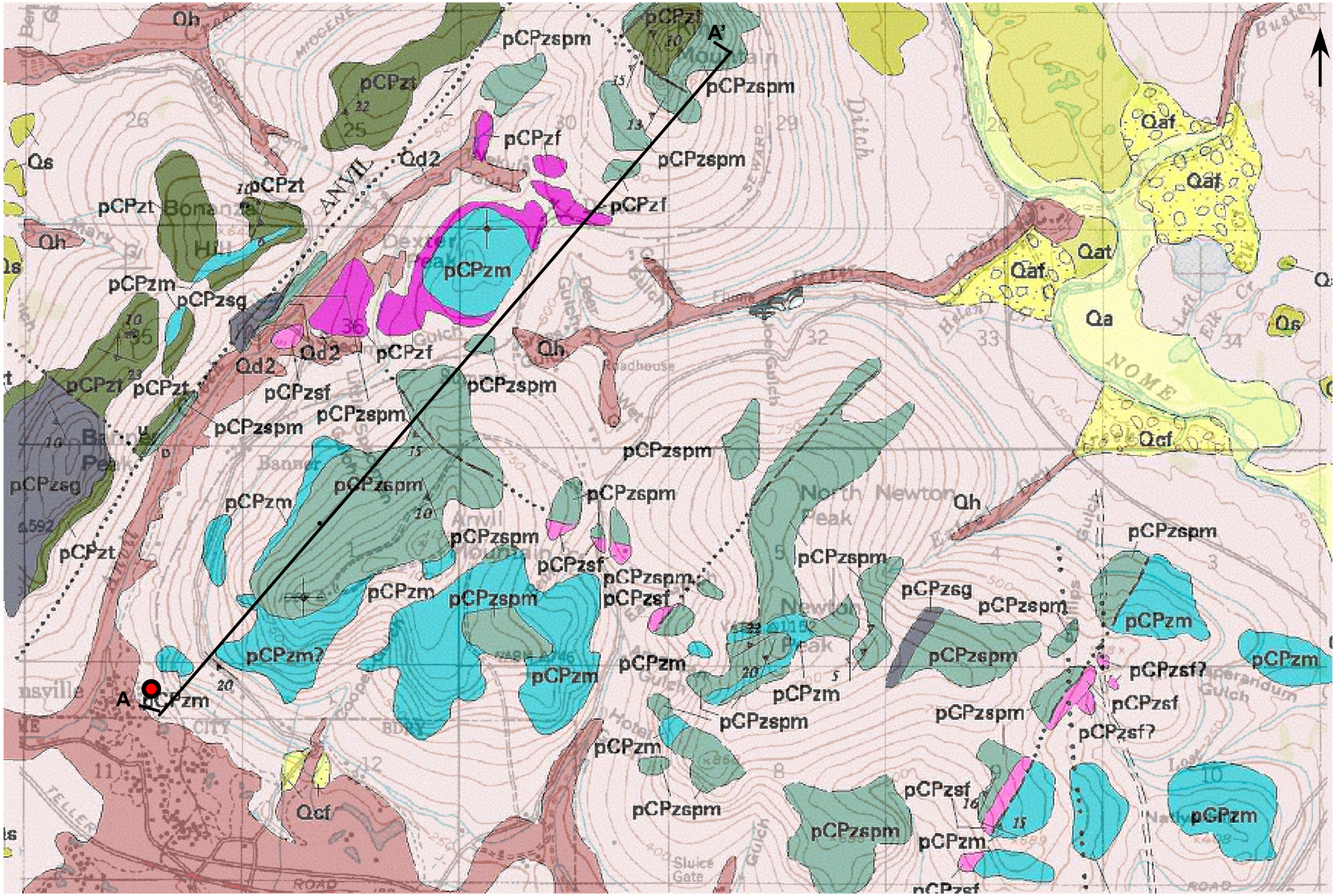
[4] Staff, Dighem, and WGM, 1994 Color shadow total field magnetics of the Nome mining district, Alaska Division of Geological and Geophysical Surveys Report of Investigations 94-11, 1 sheet, scale 1:63,360.

[5] Staff, WGM, and Dighem, 1994, 900 Hz resistivity contours of Nome mining district, Alaska Division of Geological and Geophysical Surveys Pubic-Data File 93-2, 1 sheet, scale 1:63,360.

R. 34 W. R. 33 W.

T. 10 S.
T. 11 S.



LEGEND

Qd2	Drift of Nome R. Glaciation
Qaf	Alluvial Fan Deposits
Qa	Floodplain Alluvium
Qh	Placer Mine Tailings
pCPzm	Massive Marble
pCPzspm	Pelitic Micaceous Graphite Schist
pCPzf	Orthogneiss & Metavolcanic Schist
pCPzsf	Felsic Metavolcanic Schist
pCPzsg	Graphitic Schist & Quartzite
pCPzt	Metaturbidite Schist & Marble
●	Moonlight Springs Wells
—	Fault
- - -	Fault, inferred
↑	True North Magnetic North 17° E.

Scale : 1" = 2,640 feet = ½ mile

Drawn by DLS

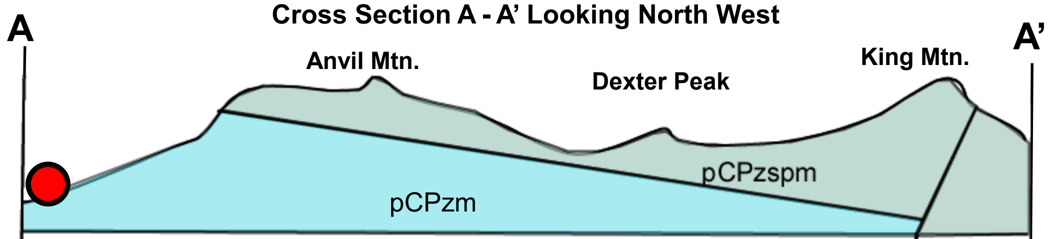
Topography from: All Topo Maps V7 Professional: Alaska R2; Nome C-1, Alaska quadrangle.

Geology from: Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress report on the geology and mineral resources of the Nome mining district, Alaska DGGS PDF 94-39, 21 pages, 2 sheets, scale 1:63,360.

For detailed descriptions of the lithologic units, see the Geology Section of this report.

Land lines are based upon Kateel River Meridian Datum: NAD 27; Projection: UTM Zone 3

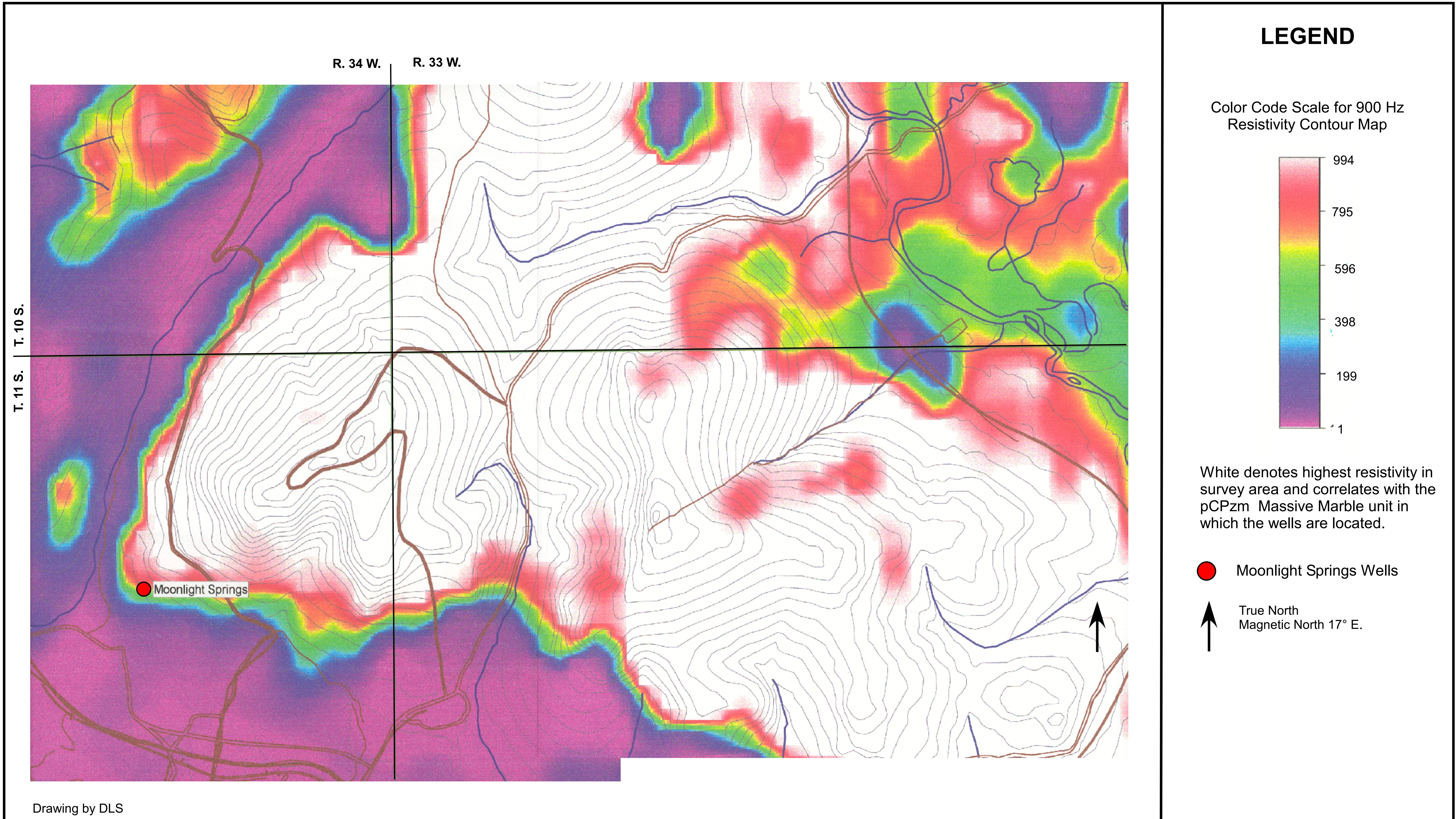
Cross Section A - A' Looking North West



Cross Section after Munter, J. A., et al., 1992.

Figure 2

Geology of the Moonlight Springs Wells Area Near Nome, Alaska



Drawing by DLS

Resisitivity map from: Staff, WGM, and Dighem 1994, 900 Hz resistivity contours of Nome mining district, Alaska Division of Geological and Geophysical Surveys Public-Data File 94-2, 1 sheet, scale 1:63,360

Land lines are based upon Kateel River Meridian

Datum: NAD 27; Projection: UTM Zone 3

Scale : 1" = 2,640 feet = ½ mile

Figure 3

900 Hz Resistivity of the Moonlight Springs Wells Area near Nome, Alaska

GEOCHEMISTRY

Water Quality Analyses

Munter, et al.[6] reported water quality data as follows:

> *All water sample collected during this investigation are classified as fresh. The specific conductance of water is an indication of its degree of mineralization. The specific conductance of Moonlight Springs and nearby surface and ground waters ranges from 47 to 651 µS/cm, which is considered acceptable for domestic and other water uses. Three ground-water sites, the spring near Lindblom Creek, Beltz School well, and M. Desalernos well, have a conductivity value >400 µS/cm. Schist is predominant near the spring near Lindblom Creek, and the two wells are in unconsolidated coastal plain deposits that appear to have been placer mined.*
>
> *Iron and manganese are the only inorganic constituents in the sampled water with concentrations that exceed Alaska Drinking Water Standards [Alaska Department of Environmental Conservation (ADEC), 19911. The highest dissolved iron concentration is 5.1 mg/l in water from a well adjacent to the Snake River at the Teller Highway. The highest dissolved manganese concentration is 1.4 mg/l from a seep in Specimen Gulch.*
>
> *Gross alpha and gross beta radioactivity of Moonlight Springs and nearby waters is very low, (<0.3 to 3.7 pCi/l). The Alaska Drinking Water Standard is 15 pCi/l for gross alpha radioactivity and 50 pCi/l for gross beta radioactivity (ADEC, 1991).*
>
> *The accuracy of dissolved ion values, based on the calculated cation-anion balance, shows that all 17 samples have an acceptable sample error of <4 percent. All surface and ground waters examined are classified as calcium-bicarbonate waters. Results of the common dissolved ion analyses from selected ground-water sites are shown in figure 7. Note the subtle but consistent difference between water from areas where schist is the predominant rock type and water from areas where marble is the predominant rock type. Water from schist areas typically has higher sulfate levels and lower calcium and bicarbonate levels.*

In summary, the water from the Moonlight Springs wells is of excellent quality and is a valuable asset for the City of Nome.

RESULTS OF THIS STUDY

DISCUSSION OF DATA

GEOLOGY AND GEOPHYSICS

This writer field checked the geologic map by Bundtzen, et al. and confirmed the general accuracy of the key contacts, structures, and lithologic descriptions in area of interest to this

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[6] Munter, J.A., Maurer, M.A., Ingraham, M.G., and Petrik, W.A., 1992, Recharge Area Evaluation for Moonlight Springs, Nome, Alaska: Alaska Div. of Geological and Geophysical Surveys Report of Investigations 92-2, pg. 9.

report. The high resistivity zone defines the contacts between the marble and the adjacent geologic units where the contacts are near vertical and therefore is of value where recent sediments cover the contact making it possible to determine the location of those contacts.

As shown on the cross section on Figure 2, on the northern ¾ths of the section line, a pelitic micaceous graphite schist caps the massive marble thought to be the country rock for the main aquifer for the spring and the wells. This schist unit is highly foliated roughly parallel to the underlying contact, and significantly reduces the amount of surface water which could enter aquifers in the highly fractured marble unit lying underneath it.

A traverse across the south-facing slope of Anvil Mountain showed that the marble unit is thoroughly fractured on the surface probably from a combination of tectonic factors, original fabric of the marble, and freeze-thaw action. These mechanisms have produced extensive rubble-crop that extends downslope at least as far as the point where fluvial and/or marine gravels cover the surface, and to an unknown depth below the surface. This observation leads support to the theory that one of the aquifers for the spring water is in surficial materials. This concept is supported in part by the rapid response of the water level in the collection gallery at the spring to rainfall and snow melt episodes and the correlation between surface temperature and spring water temperature[7]. The wells, however, are drilled to greater depths than the spring and thus derive their water from deeper aquifers than the spring.

The spring is located at the lowest elevation where the marble rubble-crop is exposed.

The high-quality 900 Hz resistivity data clearly shows the vertical contacts of the massive marble with the adjacent schists, since the marble is very resistive in character compared to the schists. The massive marble unit is clearly the aquifer for the water at both the spring and in the wells.

[7] Ibid.

RECOMMENDED PROTECTIVE MEASURES

The geology and resistivity data presented above provide a high level of confidence that the necessary zoning boundary to protect the recharge area of the Moonlight Springs wells can be drawn based upon sound scientific principles. This approach ensures that the boundaries for the recharge area do not encompass too much land, to the detriment of the Nome economy and community relationships, and yet provides absolute protection for the water supply to the community.

RECHARGE AREA BOUNDARY

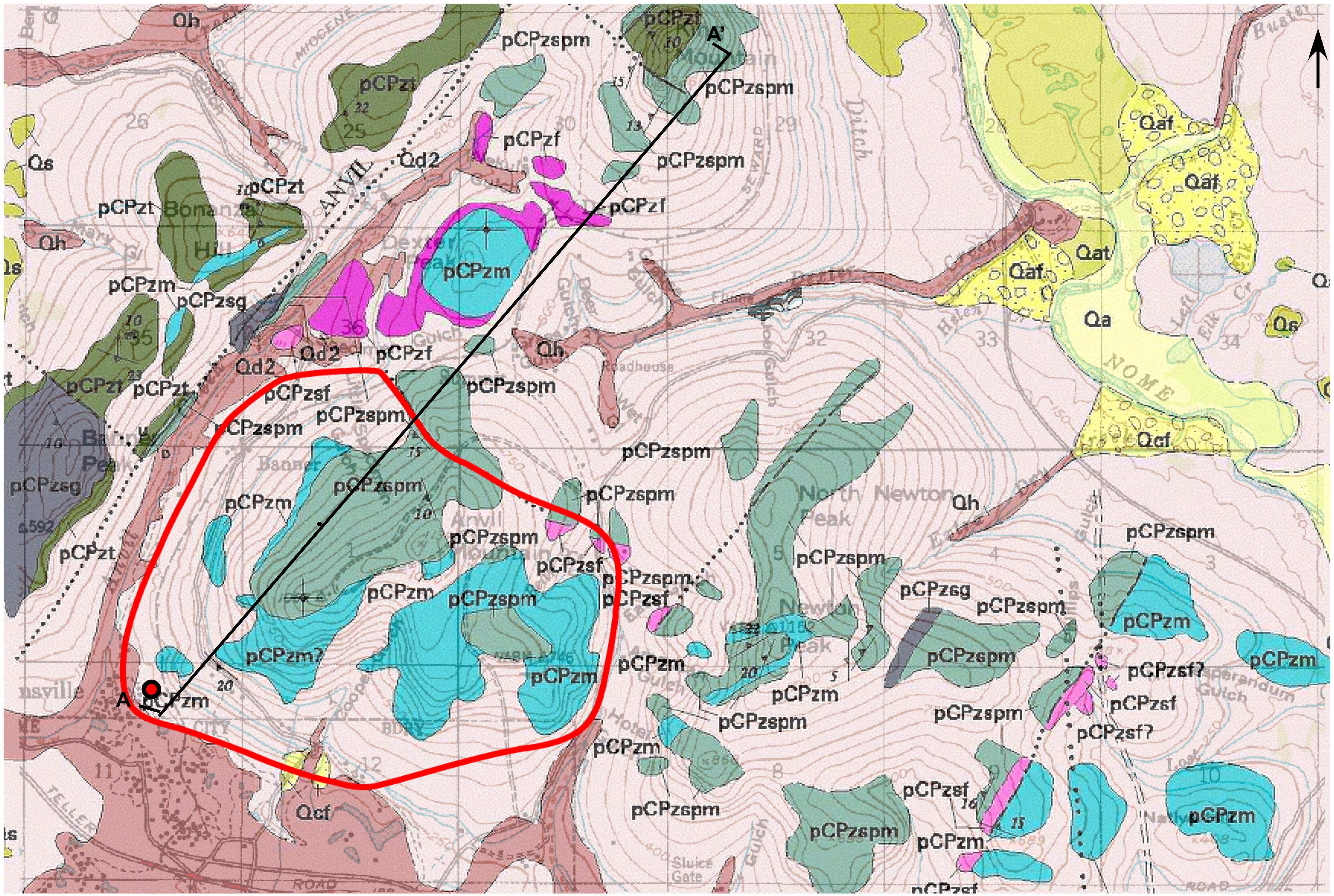
The resistivity map (Figure 3) clearly shows the geologic contacts of the marble unit and the adjacent schist units. Along the southern and western margins of the marble unit near the Moonlight Springs wells, the low resistivity boundary defined by the dark blue color (199 Ωm) serves to delineate where the recharge boundary should be positioned.

The linear topographic feature defined on the west by the orientation of Specimen Gulch and on the east by the orientation of upper Dexter Creek is most likely controlled by an unexposed and therefore unmapped ENE-trending vertical fault. This fault will restrict any flow of water through the bedrock from one side of the fault to the other.

Between Anvil Mountain and Newton Peak, the Dexter By-Pass road between the Nome-Teller road and the Nome – Kougarok Road, is situated in the roughly north-south valley and over the saddle at the north end of the valley. This valley most likely is developed along a north-south fault. This fault would serve as the east boundary as far north as the northwest-trending fault that continues to Specimen Gulch. This northwest-trending fault forms the northeast boundary of the recharge area.

Figure 4 on the next page shows the recommended recharge area boundary placed on the geologic map of the area.

Donald L. Stevens, Ph. D., CPG



Drawn by DLS

LEGEND

Qd2	Drift of Nome R. Glaciation
Qaf	Alluvial Fan Deposits
Qa	Floodplain Alluvium
Qh	Placer Mine Tailings
pCPzm	Massive Marble
pCPzspm	Pelitic Micaceous Graphite Schist
pCPzf	Orthogneiss & Metavolcanic Schist
pCPzsf	Felsic Metavolcanic Schist
pCPzsg	Graphitic Schist & Quartzite
pCPzt	Metaturbidite Schist & Marble

Moonlight Springs Wells

Fault

Fault, inferred

True North
Magnetic North 17° E.

Recommended boundary of Recharge Area

Scale : 1" = 2,640 feet = ½ mile

Topography from: All Topo Maps V7 Professional: Alaska R2; Nome C-1, Alaska quadrangle.

Geology from: Bundtzen, T. K., Reger, R. D., Laird, G. M., Pinney, D. S., Clautice, K. H., Liss, S. A., and Cruse, G. R., 1994, Progress report on the geology and mineral resources of the Nome mining district, Alaska DGGS PDF 94-39, 21 pages, 2 sheets, scale 1:63,360.

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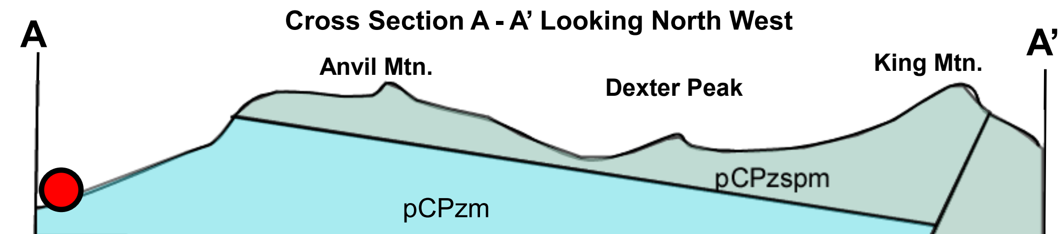

Cross Section after Munter, J. A., et al., 1992.

Figure 4

Recommended Recharge Area Boundary for the Moonlight Springs Wells Near Nome, Alaska

APPENDIX

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APPENDIX B

Well Logs

2.1.2 Drill Log and Test Pump Information

WELL #1 - WELL LOG INFORMATION

(MUNICIPAL 'CLASS A SYSTEM' WATER SUPPLY -- NORTH 64°33'12.4", WEST 165°24'42.7")

DRILLED BY: JIM THRASHER

DRILLERS ASSISTANT: UNKNOWN

INSPECTED BY: GARY EDDY, P.E.

TYPE OF DRILL RIG: UNKNOWN

HEIGHT OF CASING ABOVE THE GROUND: 2.0

DEPTH[1] OF SCREENS: NONE

CASING: 6" Ø SCH. 40 STEEL

DEPTH[1] OF WELL/CASING: 122.0 93.0

DEPTH[1] OF PUMP INTAKE: 92.0

DATE STARTED: UNKNOWN

DATE COMPLETED: SEPTEMBER 28, 1993

EXISITNG GROUND ELEV: 161.0

METHOD OF DRILLING: AIR ROTARY

DEPTH[1] TO STATIC WATER LEVEL: 32.5

DATE: AUGUST 10, 1996

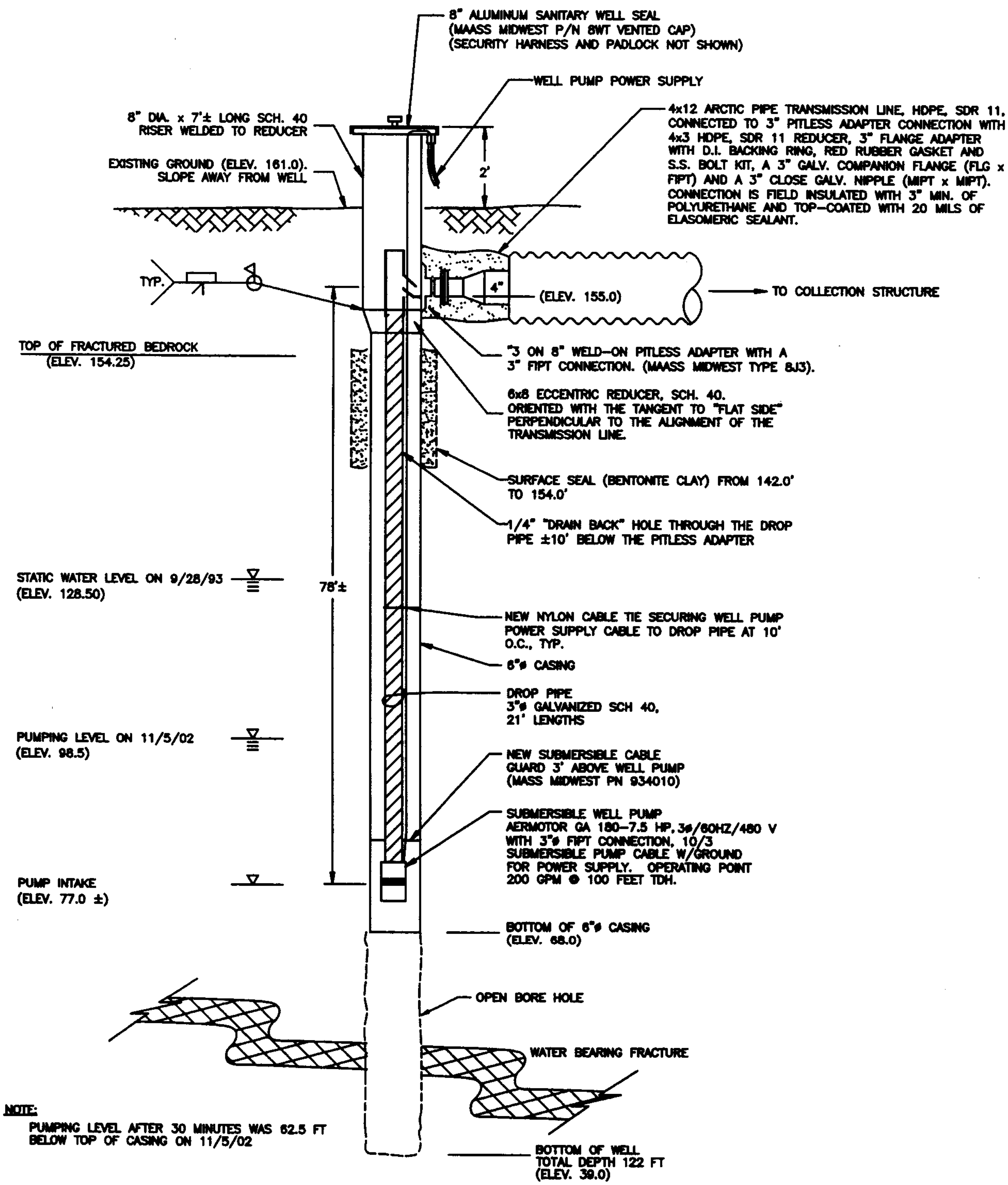
MAXIMUM YEILD: ± 285 GPM

DEVELOPMENT: SURGED & PUMPED TO WASTE FOR 14-DAYS @ 250 GPM

LAYER	FROM[1.]	TO[1.]	THICKNESS (FT)	SOIL DESCRIPTION
1.	0	1.5	1.5	LOAM
2.	1.5	4	2.5	ROCKS AND DIRT
3.	4	6.75	5.75	FRACTURED BEDROCK
4.	6.75	23	16.25	HARD LIMESTONE WITH SOME QUARTZ
5.	23	28	5	SOFT BROWN
6.	28	76	48	HARD
7.	76	95	19	MEDIUM SOFT WHITE
8.	95	98	3	HARD
9.	98	103.25	5.25	SOFT ORANGE CLAY AND ROCK
10.	103.25	105.75	2.5	HARD
11.	105.75	117	11.25	FRACTURED ROCK W/ LOTS OF WATER 56'
12.	117	122	5	HARD

NOTE:
1. IN FEET FROM THE GROUND SURFACE (POSITIVE DOWN).

2.1.3 Well #1 Profile



WELL #1 PROFILE
NTS

2.2.2 Drill Log and Test Pump Information

WELL #2 - WELL LOG INFORMATION

(MUNICIPAL 'CLASS A SYSTEM' WATER SUPPLY -- NORTH 64°33'12.3", WEST 165°24'42.6")

DRILLED BY: ROY LONGBOTHAM, JR.

DRILLERS ASSISTANT: ROY LONGBOTHAM, IV

INSPECTED BY: LLOYD PERSSON, P.E.

TYPE OF DRILL RIG: BUCYRUS ERIE CABLE TOOL

HEIGHT OF CASING ABOVE THE GROUND: 2.0

DEPTH[1] OF SCREENS: NONE

CASING: 10" Ø SCH. 40 STEEL

DEPTH[1] OF WELL/CASING: 80/66 75.66

DEPTH[1] OF PUMP INTAKE: 67.2

DATE STARTED: MAY 27, 2000

DATE COMPLETED: JUNE 18, 2000

EXISITNG GROUND ELEV: 139.7 FEET

METHOD OF DRILLING: CABLE TOOL W/CHANNEL BIT

DEPTH[1] TO STATIC WATER LEVEL: 18.66 FEET

DATE: JUNE 18, 2000

MAXIMUM YEILD: ± 300 GPM

DEVELOPMENT: SURGED & PUMPED TO WASTE FOR 4-DAYS @ 320 GPM

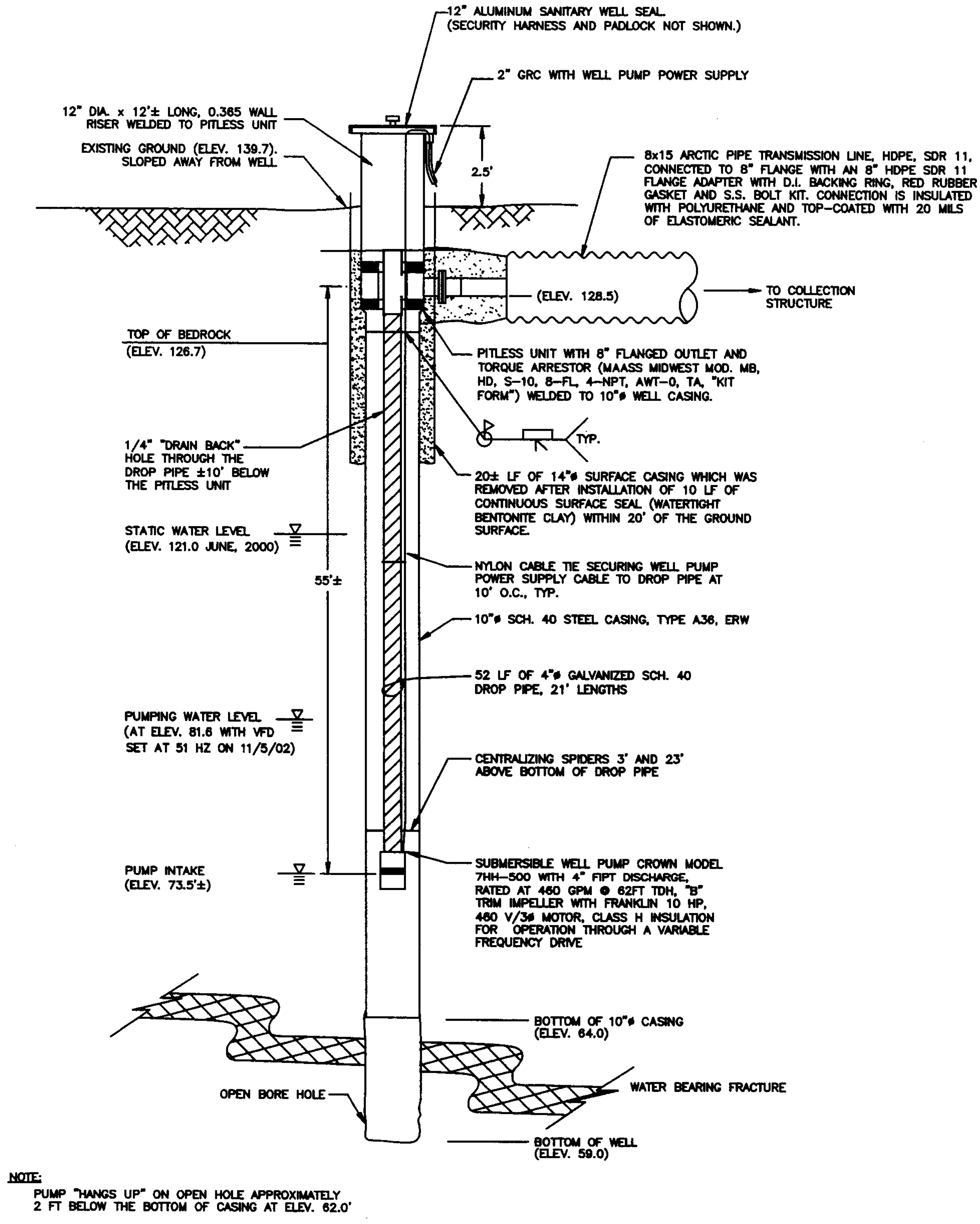
LAYER	FROM[1]	TO[1]	THICKNESS (FT)	SOIL DESCRIPTION
1.	0	13	13	COARSE GRAVEL WITH SOME CLAY (FROZEN)
2.	13	16	3	EXTREMELY HARD LIMESTONE WITH SOME QUARTZ
3.	16	18	2	SOFT LIMESTONE WITH SOME QUARTZ
4.	18	21	3	MEDIUM HARD LIMESTONE WITH QUARTZ AND MICA
5.	21	26.5	5.5	HARD LIMESTONE WITH QUARTZ AND MICA
6.	26.5	35	8.5	HARD LIGHT BROWN LIMESTONE WITH QUARTZ AND MICA
7.	35			VERY SMALL CRACK OF WATER. STATIC LEVEL IS 27'-10"
8.	35	38	3	HARD BROWN LIMESTONE WITH QUARTZ AND MICA
9.	38	43	5	HARD WHITE LIMESTONE WITH QUARTZ AND MICA
10.	43	48	5	HARD LIGHT BROWN LIMESTONE WITH QUARTZ AND MICA
11.	48	50	2	HARD WHITE LIMESTONE WITH QUARTZ AND MICA
12.	50	54.5	4.5	HARD BROWN LIMESTONE WITH QUARTZ AND MICA
13.	54.5	57	2.5	SOFT LIMESTONE WITH QUARTZ AND MICA
14.	57	59.5	2.5	VERY HARD LIMESTONE WITH QUARTZ AND MICA
15.	59.5	63	3.5	SOFT LIMESTONE WITH QUARTZ AND MICA
16.	63	69.5	6.5	HARD LIMESTONE WITH QUARTZ AND MICA
17.	69.5	79	9.5	HARD BROWN LIMESTONE
18.	79	80.67	1.67	VERY HARD ORANGE FORMATION, WATER AT 80'

60'

NOTE:

1. IN FEET FROM THE GROUND SURFACE (POSITIVE DOWN).

2.2.3 Well #2 Profile



WELL #2 PROFILE
NTS

2.3.2 Drill Log and Test Pump Information

WELL #3 - WELL LOG INFORMATION

(MUNICIPAL 'CLASS A SYSTEM' WATER SUPPLY --- NORTH 64°33'12.3", WEST 165°24'42.8")

DRILLED BY: ROY LONGBOTHAM, JR.
DRILLERS ASSISTANT: ROY LONGBOTHAM, IV
INSPECTED BY: LLOYD PERSSON, P.E.
TYPE OF DRILL RIG: BUCYRUS ERIE CABLE TOOL
HEIGHT OF CASING ABOVE THE GROUND: 2.0
DEPTH[1] OF SCREENS: NONE
CASING: 10" ø SCH. 40 STEEL
DEPTH[1] OF WELL/CASING: 94.25 / 87.0
DEPTH[1] OF PUMP INTAKE: 66.3

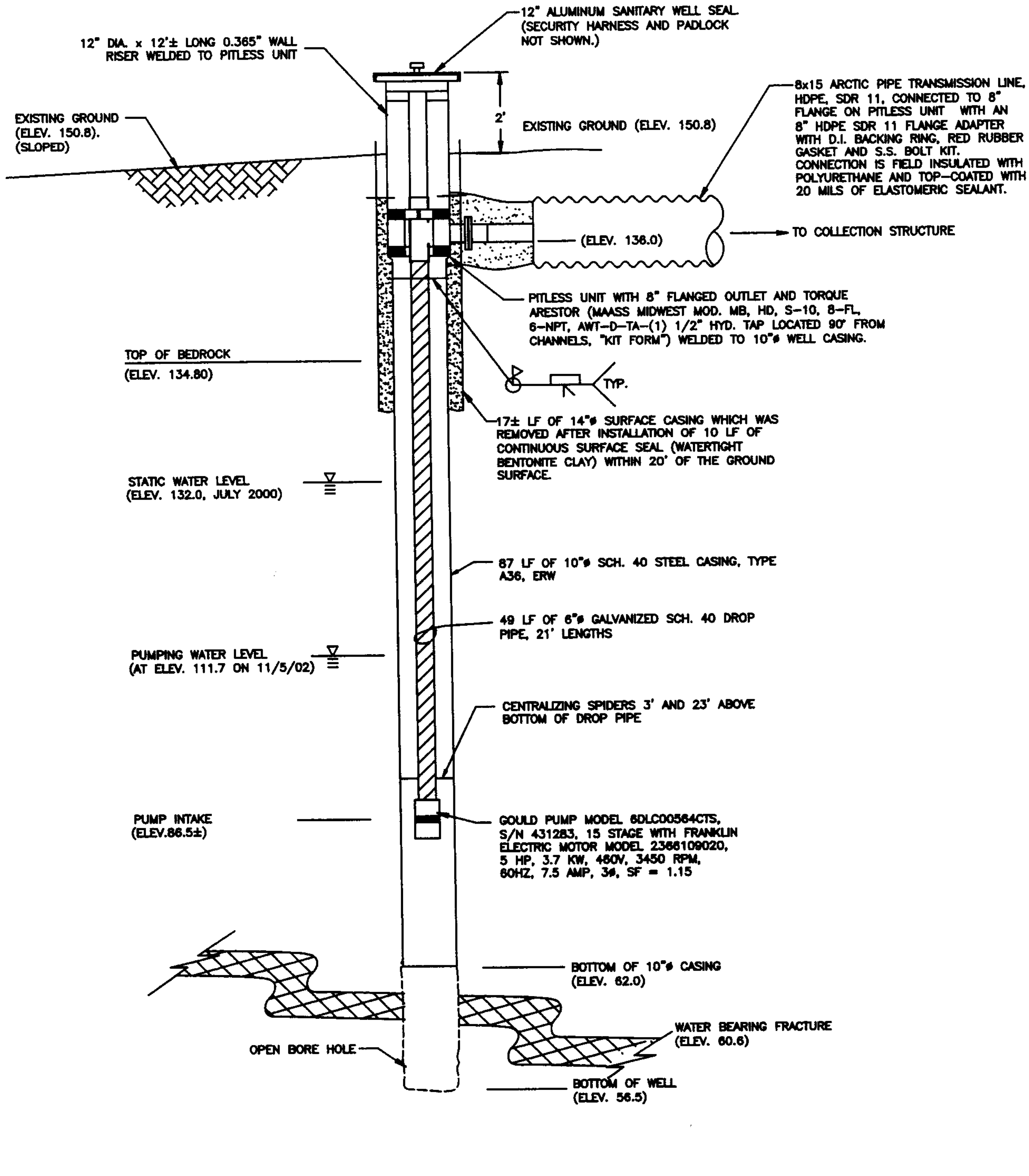
DATE STARTED: JUNE 19, 2000
DATE COMPLETED: JULY 1, 2000
EXISITNG GROUND ELEV: 150.8 FEET
METHOD OF DRILLING: CABLE TOOL W/CHANNEL BIT
DEPTH[1] TO STATIC WATER LEVEL: 18.79 FEET
DATE: JULY 1, 2000
MAXIMUM YEILD: ± 650 GPM
DEVELOPMENT: SURGED & PUMPED TO WASTE FOR 10-DAYS @ 300 GPM TO 700 GPM

LAYER	FROM[1]	TO[1]	THICKNESS (FT)	SOIL DESCRIPTION
1.	0	3	3	FROZEN
2.	3	12	9	GRAVEL AND CLAY
3.	12	16	4	MORE GRAVEL WITH CLAY
4.	16	20	4	BEDROCK AT 16'. VERY HARD LIMESTONE.
5.	20			CRACK OF WATER. STATIC LEVEL IS 16' 7"
6.	20	25	5	MEDIUM HARD LIMESTONE
7.	25	30	5	ORANGE FORMATION WITH QUARTZ AND MICA
8.	30	34	4	RED CLAY WITH FINE GRAVEL
9.	34	35	1	MEDIUM HARD LIMESTONE
10.	35	36	1	SOFT LIMESTONE
11.	36	37	1	MEDIUM HARD LIMESTONE
12.	37	51	14	VERY HARD LIMESTONE
13.	51	62.5	11.5	SOFT LIMESTONE WITH QUARTZ AND MICA
14.	62.5	68	5.5	MEDIUM HARD LIMESTONE WITH QUARTZ AND MICA
15.	68	78	10	VERY HARD LIMESTONE
16.	78	82	4	EXTREMELY HARD LIMESTONE
17.	82	86	4	MEDIUM HARD LIMESTONE WITH SILT
18.	86	89.75	3.45	EXTREMELY HARD LIMESTONE
19.	89.75	90.25	.5	HARD ORANGE FORMATION
20.	90.25			WATER
21.	90.25	94.25	4	VERY HARD FORMATION

60'

NOTES:
1. IN FEET FROM THE GROUND SURFACE (POSITIVE DOWN).

2.3.3 Well #3 Profile



WELL #3 PROFILE
NTS