Golder Associates Inc.
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August 14, 2007

Our Ref.: 073-95024

CRW Engineering Group, LLC
3900 Arctic Boulevard, Suite 203
Anchorage, Alaska 99503

Attention: David Yanoshek

RE: GEOPHYSICAL INVESTIGATION OF SUBSURFACE HYDROLOGY AND GROUNDWATER EXTRACTION AT THE PROPOSED MERTARVIK TOWN SITE NEWTOK, ALASKA

Dear David:

Golder Associates Inc. (Golder) is pleased to present CRW Engineering Group, LLC (CRW) this geophysical investigation of subsurface hydrology and groundwater extraction at the proposed Mertarvik town site. The results of the investigation indicate that there are at least three viable alternatives for a water source for the public water system for Mertarvik. The spring below the proposed town site flows at a rate that greatly exceeds the potential demand of the proposed town site. In addition, the geophysics investigation results indicate that there are potential well sites above the spring area that could be developed into a public water source for the proposed village.

1. INTRODUCTION

Golder has been subcontracted by CRW to perform a groundwater investigation of a proposed new village site (Mertarvik). This is part of a larger effort to relocate the existing village, Newtok, Alaska, in which CRW was originally contracted by the Village Safe Water (VSW) office and the Newtok Tribal Council (NTC) (CRW project # 81201.00, VSW project # 02EH74).

1.1 Purpose and Objectives

Golder's chief objective is to propose groundwater well locations that will likely produce maximum yield. This report presents Golder's scope of work including:

- Review of existing data/aerial photo interpretation.
- Initial site reconnaissance.
- Geophysical survey.
- Water source evaluation and reporting.

The current Newtok village location is directly threatened by erosion from the Ningluk River. Mertarvik has been selected as the new village site on Nelson Island, nine miles to the south on the south shore of the Ningluk River (Figure 1).

2. METHODOLOGY

2.1 Background Review

A limited body of literature exists to address the geology and hydrology of the proposed new town site. This is compiled here, primarily from previous reports from Woodward Clyde Consultants (WWC, 1984)[1], U.S. Army Corps of Engineers (USACE, 2002; USACE, 2006)[2,3] and R&M Consulting (2005)[4] as well as regional aerial photographs in stereo pairs.

2.2 Geophysics

A combination of electrical resistivity imaging (ERI) and very low frequency (VLF) surveys were used to map subsurface conditions. Seven geophysical lines were collected (Figure 2). Three of these lines have both ERI and VLF data (Lines 1 through 3), one of these lines has just ERI data (Line 4), and three of these lines have just VLF data (Lines 5 through 7). Lines 1 through 4 were collected with a west to east orientation and nearly parallel with the topographic contours. Lines 5 through 7 were collected north to south, approximately perpendicular to the topographic contours. Figure 2 shows the line locations with respect to local topography. Table 1 provides latitude/longitude coordinates for various site features referenced in this report, collected by global position satellite (GPS) instruments.

2.2.1 Electrical Resistivity Imaging

The ERI method maps differences in the electrical resistivity of geologic materials including soils and rock. Most soils and rock minerals are electrical insulators or highly resistive. The flow of current in these materials is primarily conducted through moisture filled pore spaces. Therefore, the resistivity of soils and rock is primarily controlled by the porosity and permeability of the medium, the amount of pore water (degree of saturation) and the concentration of dissolved solids (ionic solutions) in the pore water. For the purpose of this study, areas of low resistivity may indicate the presence of groundwater.

ERI survey involves transmitting an electric current into the ground between two current electrodes and measuring the voltage between two separate potential electrodes. Many combinations of "soundings" are conducted to produce a cross section showing apparent resistivities. The resistivity cross section is presented as a color contoured cross section that highlights stratigraphic features or

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[1] Woodward-Clyde, 1984, "Ningluk River Erosion Assessment, Woodward-Clyde Consultants, Anchorage, AK

[2] U.S. Army Corps of Engineers, 2002, "Preliminary Geotechnical Overview Village Relocation Site, Newtok, AK", p. 1-12

[3] U.S. Army Corps of Engineers, 2006, "Newtok Environmental Baseline Data Studies," p. 175-192

[4] R&M Engineering, 2005, "Newtok Airport Site Reconnaissance Study, Nelson Island, AK," Appendix B: Soils, AKSAS Project #

other features (e.g., contact between alluvium and bedrock, etc.) where there is a variation in subsurface resistivity.

The resistivity data were collected using an IRIS Syscal R1 Plus switch system. This system was used to control up to 72 electrodes spaced 16.4 ft (5 meters) apart. Data were collected using a Wenner array and processed using commercially available RES2DINV software.

2.2.2 Very Low Frequency

The VLF electromagnetics survey uses the magnetic components of the electromagnetic field generated by military radio transmitters to identify electrically conductive subsurface features. Transmitters are distributed globally and transmit at a frequency range of 15 kHz to 30 kHz. Electrically conductive structures above, below or at the surface of the earth locally affect the direction and strength of the field generated by the transmitted radio signal. VLF survey measures two electromagnetic fields: the primary field produced by the transmitter and a secondary field that occurs when the transmitted signal induces electrical current in subsurface conductors (such as water).

VLF equipment measures both the local field strength of the primary field (conductivity, milliSiemens) and phase displacement of the secondary field generated by the conductor (phase percent). The two values are plotted vs. distance along the geophysical line. Divergence of the two values and/or values greater than background values constitutes an anomaly and may be indicative of a subsurface conductive body.

VLF data were acquired using an ABEM Wadi VLF receiver. Transmitting stations used for this survey were located in Washington and Hawaii.

3. REGIONAL GEOLOGY

Nelson Island consists of multiple Quaternary basalt flows overlaying a base of Cretaceous sedimentary rocks of the Yukon-Kuskokwim Delta. Sediments of the Yukon-Kuskokwim Delta are commonly fine grain eolian, fluvial, estuarine and beach-worked deposits. No sedimentary outcrops are documented on the north side of Nelson, although sedimentary layers may exist between basalt flows.

The combined thickness of the estimated eight to 20 basalt flows exceeds 200 ft, and beds have been observed to dip gently to the east and northeast. The island has gentle to moderately sloping surface topography and frequent, gentle 5 ft to 15 ft benches appear to be a surface expression of basalt flows. The basalt on Nelson Is. is observed to range from massive and columnar to highly vesicular in areas. In the vicinity of the proposed new village site, vesicular basalt was found to have unfilled pore spaces of 25% to 30%. In between flows, this may produce alternating layers of high and low hydraulic conductivity.

Permafrost on Nelson Island and the general Mertarvik area is expected to be present but discontinuous. At the site of well location recommendations in this study, permafrost extent is unknown but expected to be limited. The presence of year-round groundwater flow and seepage suggests that subsurface temperatures are not cold enough to freeze water in pore spaces which would inhibit groundwater flow.

The presence of permafrost should not be discounted, because the site is located on a north-facing slope which is prone to the presence of permafrost conditions. Generalized maps of permafrost distribution in Alaska suggest discontinuous to continuous permafrost throughout the region. Ferrians (1965)[5] suggests that the ground surface of the region is continuously underlain by thin to thick permafrost. Brown (1995)[6] suggests discontinuous permafrost on Nelson Island, where 50% to 90% of the area is underlain by a ground-ice-content of 10% to 20% by volume, at depths greater than 16 ft to 33 ft.

4. FIELD ACTIVITIES

4.1 Reconnaissance Fieldwork

In coordination with CRW and Village Safe Water (VSW) a field reconnaissance was done in mid-June of 2007 to determine the technical and logistical requirements to characterize local hydrogeology. During this time, discharge of the spring in the main channel was estimated based on measured flow velocities using a small wood float through the main channel area. Basic field mapping of the area was done to identify appropriate target locations for the geophysical survey.

4.2 Geophysical Survey

From June 18, 2007 to June 22, 2007, ERI and VLF geophysical surveys were conducted on the slope above the spring with the goal of characterizing subsurface conditions, local hydrogeology and identifying appropriate groundwater well targets.

5. RESULTS AND FINDINGS

5.1 Surface Hydrology

The spring flow originates/daylights about 400 ft to 500 ft from Baird Inlet as a series of major and minor seeps near the elevation of 30 ft above MSL across an area that is approximately 175 ft wide. A few of the majors seeps appear to be discharging at a relatively high rate of 0.5 cubic feet per second (CFS), but no measurements were made. These major and minor seeps eventually join in a ponded area, resulting from local topography and a beaver dam that is currently breached. The flow becomes a single channel a short distance below the beaver dam breach before it reaches Baird Inlet.

During reconnaissance fieldwork in June of 2007, total spring discharge estimates were made by measuring the channel cross sectional area in a fairly straight section of the channel and the flow velocity using a small wooden block as a float. Flow rates within the channel ranged from 4.2 to 5.8 CFS and averaged 5.1 CFS (Table A-1, Appendix A).

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[5] Ferrians, O., 1965, Permafrost Map of Alaska, U.S. Geological Survey, Map I-455.

[6] Brown, J., Ferrians, O., Heginbottom, J., Melnikov, E., 1995, Circum-Arctic map of Permafrost and Ground-Ice Conditions.

5.2 Geophysics

5.2.1 Electrical Resistivity Imaging

Figures 3 through 6 show the resistivity models for Lines 1 through 4. Resistivity values between 100 ohm-meters and about 800 ohm-meters are interpreted as representing bedrock. Resistivity values greater than about 800 ohm-meters (warm colors) occur in the shallow subsurface and are interpreted to represent unsaturated soils and/or bedrock. Resistivity values less than 100 ohm-meters (cool colors) near the bottom of the resistivity model are interpreted as influenced by groundwater. White areas occur where data is absent due to a faulty instrument reading.

Figure 6 (Line 4) depicts the shallow geology of this site. Warm colors (brown to yellow) are interpreted as representing a relatively continuous basalt flow. Above this zone are areas of relatively high electrical resistivity that are interpreted as representing relatively dry surface soils. At the base of the section, resistivity values drop to less than 100 ohm-meters indicating relatively (electrically) conductive material.

The most significant feature to note is the lack of lateral continuity in resistance on lines 1 and 2. A layer of high resistivity is present in the west and is interpreted to be a basalt flow, but resistivity decreases in the east. On Line 1, an area of low resistivity values of less than 100 ohm-meters exists along the ERI line from about 425 ft to 1,180 ft from the origin at an elevation of 150 ft (Figure 3). On Line 2 (Figure 4) a low resistivity zone is interpreted between 510 ft and 1,080 ft. On both lines, the area of low resistivity occupies a depth of 60 ft to 100 ft below ground surface, which is at elevations ranging from 140 ft to 50 ft. These low resistivity areas are interpreted as regions of higher porosity, permeability, water content or dissolved solids along this elevation range, which is likely the source of groundwater for the seeps that occur at the lower elevation of approximately 30 ft. These low resistivity areas on the ERI Profiles are the proposed targets for future wells.

5.2.2 Very Low Frequency

The VLF data are shown as a series of 1-dimensional profiles (Figures 3, 4, 5, 7, 8, and 9). These 1-dimensional profiles have been extracted from a 2-dimensional model at a depth of 16, in order to correspond to the interpreted depth of the basalt layer in the ERI data. Both the in-phase and the conductivity response are shown on these profiles. The background VLF response for this site is less than 5% for the in-phase response and 5 milliSiemens per meter for the electrical conductivity response.

The primary VLF anomaly is located at the beginning/south of Line 6 (Figure 8). Here, the peak in-phase response is 15% and the peak conductivity response is almost 30 milliSiemens per meter. This zone is interpreted as being heavily influenced by groundwater conditions versus being influenced by bedrock.

Lesser VLF anomalies occur on Line 3 between 730 ft and 950 ft, where the peak in-phase response is almost -8%. This zone is interpreted as one where water has greater impact on the bulk electrical properties of the zone than does the bedrock.

6. CONCEPTUAL HYDROGEOLOGIC MODELS

Several groundwater seep areas combine flows to produce the spring area and a small but robust creek which flows year-round, low on the slope to the northwest of the proposed town site (Figure 2; Appendix B Photo log). Three potential conceptual hydrologic models were initially considered to explain the source of the water for the spring as listed below:

- Local precipitation as recharge into a local catchment basin.
- Regional groundwater flow discharges at the spring.
- Combination of significant regional groundwater flow and local recharge.

In the first model, the spring flow is a result of local recharge consisting of rain and snowmelt infiltration into the approximately 0.37 square mile catchment area above the spring (Figure 2). In the second model, the spring water is fed solely by regional groundwater originating outside the catchment and is not dependent on recharge from the local catchment area. This groundwater may be arriving at the slope via flow along hydraulically conductive basalt layers or lava tubes. In the third model, both of the first two scenarios occur together and spring water draws from both upslope surface infiltration and from regional groundwater.

The local recharge in the slope above the spring area does not appear to support the local recharge only hydrologic model. The relatively small catchment area could not account for the relatively large year-round flow of the spring, although the spring area certainly has some local recharge from direct infiltration on the slope above the spring area. The area above the spring receives a total annual precipitation in the form of snow or rain of about 17 inches (USACE, 2006). Assuming an average coefficient for surface water runoff of 25%, the local catchment area could generate 1.5×10^7 cubic ft (CF) on an annual basis. If this water were released through out the year at a consistent rate to the spring, the flow would be approximately 0.35 CFS. This supply is far less than the observed average discharge of 5.1 CFS in June, 2007.

May through June is likely the peak spring melt period, and the June, 2007 spring channel flow rate measurements likely represent an annual peak flow following infiltration of spring snow melt water. However, even this peak infiltration period cannot account for the flow of the spring. We estimate the maximum volume of water that could be supplied by peak infiltration alone (Table A-2, Appendix A) to be 1.4 CFS, only a quarter of the observed spring discharge. Long-term monitoring of the channel flows below the spring area would be required to further understand the seasonal variation of the spring flow.

7. WATER SOURCE ALTERNATIVES

Three alternatives for developing a Public Water System (PWS) source appear to be viable:

- Vertical wells: Drill one to two groundwater wells located above the spring area between elevations 125 ft to 200 ft with well depths ranging from 60 ft to 100 ft to reach groundwater, or just above the spring area between elevations 50 ft to 75 ft, with well depths of about 20 ft to 50 ft to reach groundwater.
- Well at spring: Drill a horizontal/sloping well into the slope just above the spring to drain water into a collection tank, from which water is pumped to a treatment facility.

- Infiltration Gallery: Construct an infiltration gallery and water collection system to collect surface water in the spring area.

Alternatives 1, with wells in the 125 ft to 200 ft elevation are assumed to be the preferred option because the source well will be closer to the planned location of the town site and the groundwater supply systems are typically less costly to operate than surface water sources (i.e. less monitoring, fewer freezing problems, less infrastructure to maintain. Alternatively, a vertical well closer to the spring area seems like a reasonable alternative along ERI line 4 near 50 ft to 75 ft elevation contour. This obviously increases pumping distance to the town site and may increase the lift requirements of the well pump depending on the static water level n the well. All these wells would not be considered under the influence of surface water.

Alternative 2, drilling into the slope above the spring, could potentially be accepted by the regulatory agencies as a water source not under the influence of surface water. This does reduce operating costs for the water system but, the source well is farther away from the town site than alternative 1. However, the drilling operation would have to be placed directly into or directly above the spring discharge area, which may results in some technical difficulties with soft ground and steep slopes. A more detailed geotechnical review of the competency of the spring area would need to be completed to fully understand the difficulties in drilling into or just above the spring area.

Alternative 3 is probably the least preferred option because of the potential higher cost to operate a surface water supply system, and these systems typically have higher risk of freezing problems. The advantage of alternative 3 is obviously that the water is readily accessible and in large quantities. The disadvantage is construction would take place at the spring and there would be visible infrastructure at the spring that would have to be periodically accessed for maintenance.

It is possible that any well constructed at locations 1 through 3 may be flowing artesian wells, depending on the hydrostatic pressure in the confined aquifer. This is unlikely in wells constructed at recommended locations 1 and 2 because of their higher elevations. In the case of a flowing well in the presence of permafrost, it may be necessary to pack and seal the well casing to prevent the well water level from rising above the lower bounds of permafrost, as a precaution against freezing of the well.

Well construction upslope of the recommended drilling area (Figure 3) and geophysical survey may still yield a productive well and the threat of a flowing well would be decreased. There is a decrease in the confidence of encountering water, however, because subsurface data and/or observations do not exist and the subsurface water flow routing is not thoroughly understood. The depth to water table is likely greater. Because there may be a relation between the presence of flowing groundwater and the apparent slump feature in the local hillside (Figure 2), drilling above the south scarp may miss this groundwater.

8. CONCLUSIONS

8.1 Geophysics

Figure 10 summarizes the geophysical investigation of this site by highlighting individual anomaly areas. Two VLF anomalies and a large area of low resistance (ERI) occur at the intersections of Lines 1 and 6. This cluster of small areas is interpreted as the most reliable area of high groundwater content and a preferred area for well location. ERI also identifies an area of low resistivity in the mid section of Line 2. The shaded area in Figure 11 encompasses these anomalies and presents a generalized area recommended for groundwater well drilling.

In mid-slope, water-bearing areas are interpreted to occur at depths of 60 ft to 100 ft below ground surface, based on Line 1 and 2 ERI profiles. Water-bearing areas are interpreted to occur shortly upslope of the spring at depths of 20 ft below ground surface, and again at about 25 ft below sea level, which would have the potential for seawater intrusion problems.

8.2 Hydrologic Model

The spring area appears to represent a discharge area for regional groundwater since the local precipitation on the hillside above the spring area could not sustain the relatively high flows of the spring. This suggests that the recharge for the regional groundwater originates in another drainage or drainages south of the spring. The actual recharge area could be the relatively large drainage directly south of the proposed town site. It is beyond the scope of this work to investigate this issue further.

8.3 Public Water System Source

A vertical groundwater well has a high chance of success as a water supply for Mertarvik. Such a well can be capped and closed to the outside environment, preventing external contamination. Further, a vertical well in mid-slope will require a shorter pipeline to the village and incur lesser expense. The two other options would both require a collection/holding tank at the collection site, which has increased vulnerability to freezing problems, and increased operation and monitoring costs.

9. RECOMMENDATIONS

- Groundwater should be developed as the first alternative for a source of water for the PWS for Mertarvik.

- Proposed well locations are shown on Figure 11. The first recommended well location is at the 1000-ft station of Line 1. However, a minimum of two wells should be drilled to provide a back up in the event that the yield of the first well is insufficient, or has a mechanical breakdown while in operation. The second proposed location is the 1000-ft station of Line 2. The anticipated depth of these wells would be approximately 100 ft, but for planning purposes a depth of 200 ft should be considered for bidding purpose for a drilling contractor.

- A third well should be considered if the first proposed wells are unsuccessful. This well should be drilled above the spring along ERI line 4, and the proposed depth would be about 40 ft.

- Further investigation to identify the regional groundwater recharge areas should be considered to identify groundwater protection areas. This investigation does not seem like it is a priority unless there is development in the drainage south of the ridge under the proposed town site.

possible that anomalies on the geophysical data that are interpreted to be soil units, boundaries, bedrock, etc. may upon intrusive sampling prove to be misinterpreted.

11. CLOSING

We appreciate the opportunity to work on this project. If you have questions or require additional information, please contact us at (907) 344-6001.

GOLDER ASSOCIATES

Hiram Henry
Staff Engineer

Jan F. Deick, P.G.
Senior Hydrogeologist

Robert G. Dugan, C.P.G.
Principal & Senior Engineering Geologist

Attachments: Table 1 – Mertarvik Site Feature Coordinates

Figures:
- Figure 1 – Project Location
- Figure 2 – Vicinity Map
- Figure 3 – Line 1 ERI and VLF Data
- Figure 4 – Line 2 ERI and VLF Data
- Figure 5 – Line 3 ERI and VLF Data
- Figure 6 – Line 4 ERI Data
- Figure 7 – Line 5 VLF Data
- Figure 8 – Line 6 VLF Data
- Figure 9 – Line 7 VLF Data
- Figure 10 – Recommended Well Locations
- Figure 11 – Interpreted Area of Geophysical Anomalies

Appendix A:
- A-1 – Estimation of Average Infiltration & Peak Seasonal Surface Recharge to Spring
- A-2 – Spring Flow Estimate June 14, 2007

Appendix B:
- Photo Log of Geophysical Survey at Mertarvik Town Site

HH/JFD/lcm

TABLES

TABLE 1
MERTARVIK SITE FEATURE COORDINATES
NEWTOK GROUNWATER INVESTIGATION

	Latitude				Longitude				Approximate Elevation (feet above MSL)
Feature Description	Degrees	Minutes	Seconds/Decimal		Degrees	Minutes	Seconds/Decimal		
South Margin of Spring Source	60	49	7.54	N	164	31	23.32	W	41
Old Beaver Dam	60	49	25.09	N	164	28	21	W	13
Original Proposed Well Location	60	48	56.09	N	164	31	21.39	W	150
Recommended Well Locations									
Site 1	60	48	52.38	N	164	31	4.53	W	199
Site 2	60	48	57.01	N	164	31	10.21	W	134
Site 3	60	49	7.21	N	164	31	21.74	W	47
Line 1, Start ERI and VLF	60	48	52.23	N	164	31	17.09	W	205
Line 1, Mid ERI and VLF	60	48	52.38	N	164	31	5.25	W	211
Line 1, End ERI and VLF	60	48	52.5	N	164	30	54.05	W	232
Line 2, Start ERI and VLF	60	48	56.07	N	164	31	22.69	W	154
Line 2, Mid ERI and VLF	60	48	56.95	N	164	31	11.34	W	146
Line 2, End ERI and VLF	60	48	57.8	N	164	30	59.8	W	154
Line 3, Start ERI and VLF	60	48	58.16	N	164	31	26.6	W	
Line 3, Mid ERI and VLF	60	48	58.39	N	164	31	15.05	W	110
Line 3, End ERI and VLF	60	48	59.59	N	164	31	3.78	W	
Line 4, Start ERI	60	49	1.97	N	164	31	27.77	W	
Line 4, End ERI	60	49	2.37	N	164	31	20.06	W	
Line 5, Start VLF	60	48	52.17	N	164	31	21.72	W	
Line 5, End VLF	60	49	4.89	N	164	31	25.15	W	
Line 6, Start VLF	60	48	52.34	N	164	31	5.35	W	
Line 6, End VLF	60	49	5.12	N	164	31	7.84	W	
Line 7, Start VLF	60	48	52.54	N	164	30	49.48	W	
Line 7, End VLF	60	49	6.65	N	164	30	53.69	W	

Notes:

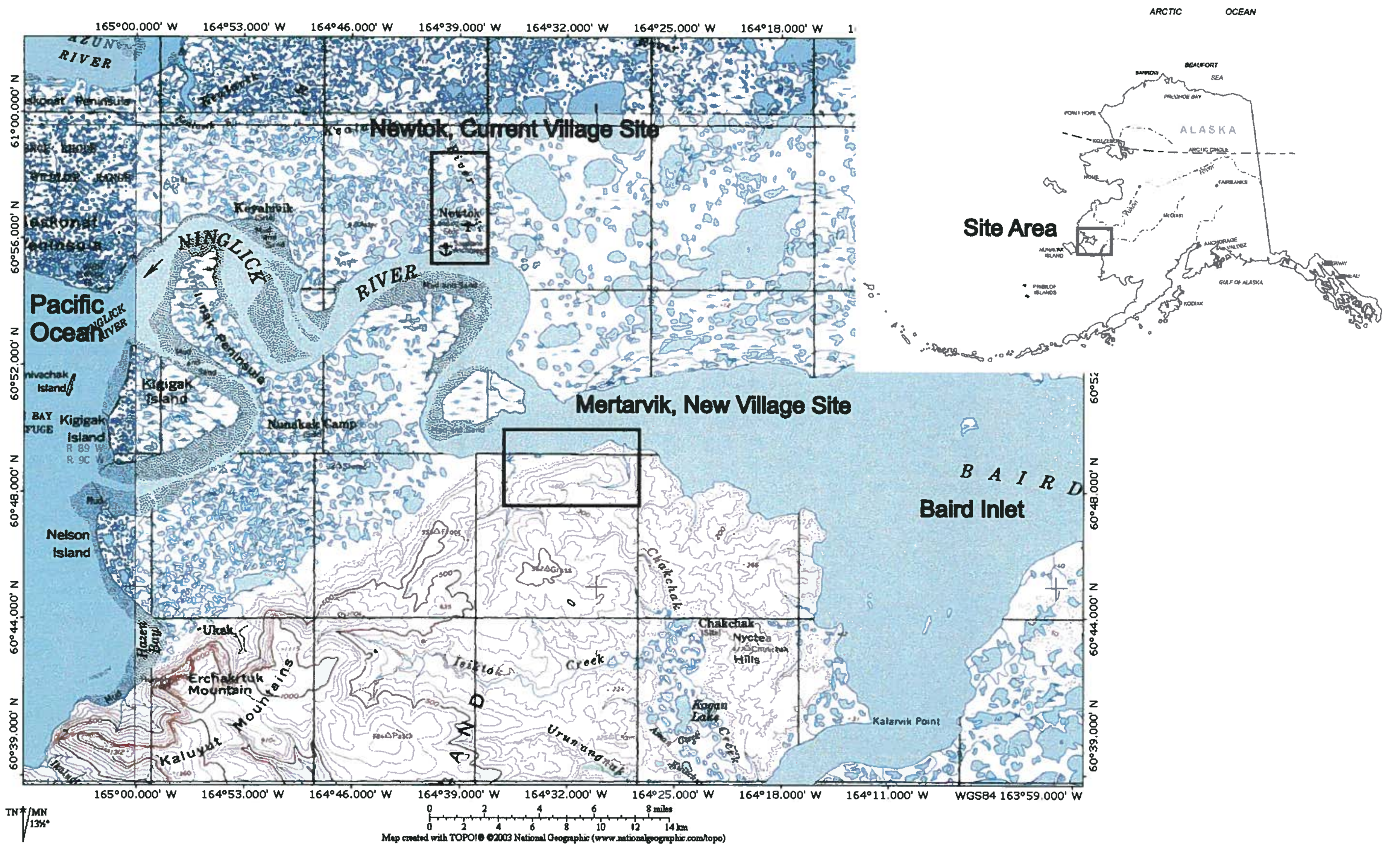
All coordinates taken using handheld GPS, using NAD83 datum

MSL represents mean sea level

ERI represents Electrical Resistance Imaging, geophysical survey

VLF represents Very Low Frequency, geophysical survey

FIGURES



Golder Associates
Anchorage, Alaska

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	DATE 07/13/07		
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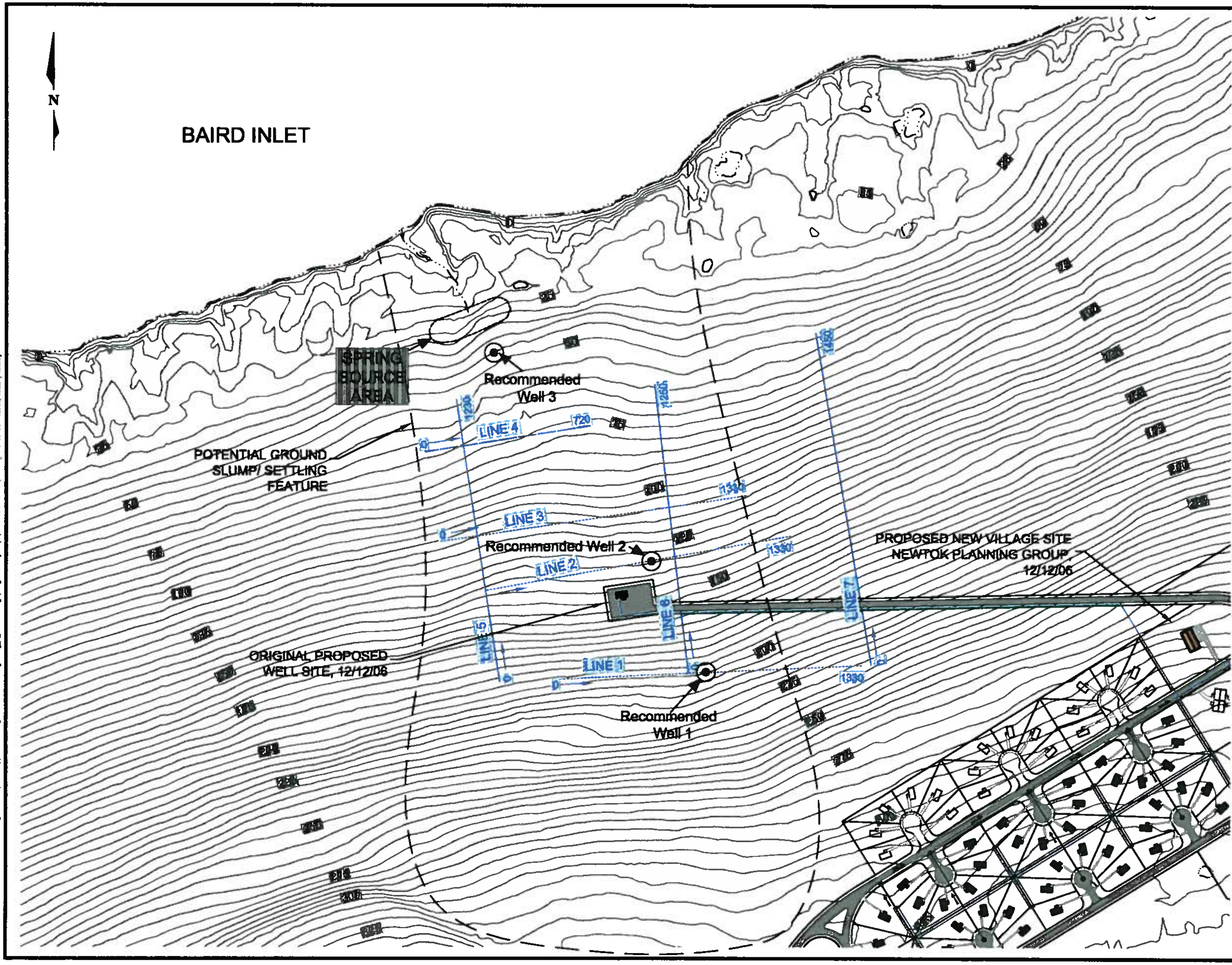
	DATE 08/14/07	CRW/NEWTOK 073-95024 / WESTERN AK	FIGURE 1
	REV. 0		



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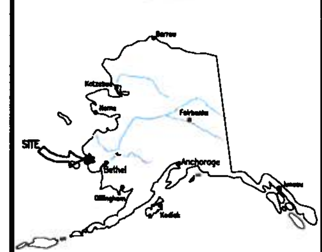

LEGEND

- MINOR CONTOUR @ 5ft
- MAJOR CONTOUR @ 25ft
- VLF LINE ONLY
- ERI LINE ONLY
- VLF & ERI LINE

0 400 800

SCALE IN FEET

NOTES

-ABEN WADI: VLF System
-IRIS Electrical Resistivity System

GEODETIC PARAMETERS

VERT. DATUM: - NAVD 88
HORIZ. DATUM: - Alaska State Plane, Zone 8, Feet
PROJECTION: -

Golder Associates

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SUBMITTED TO:

CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:

CRW / NEWTOK GROUNDWATER INVESTIGATION / AK

TITLE:

VICINITY MAP

PROJECT	073-95024	DESIGN	DH	7/10/07
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REV.	0	CHECK	HMH	8/12/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 2

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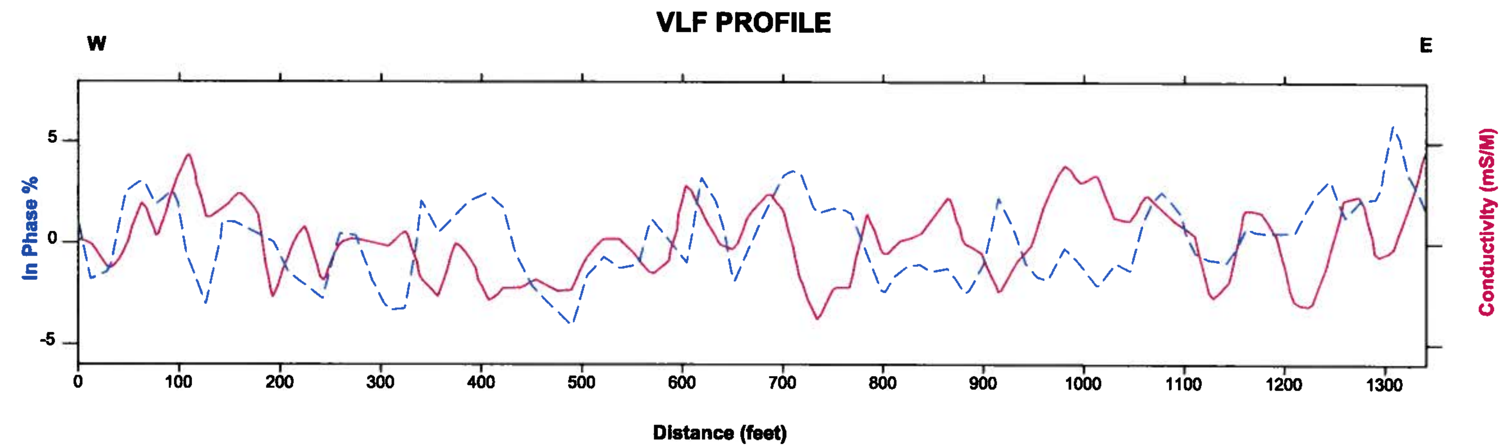

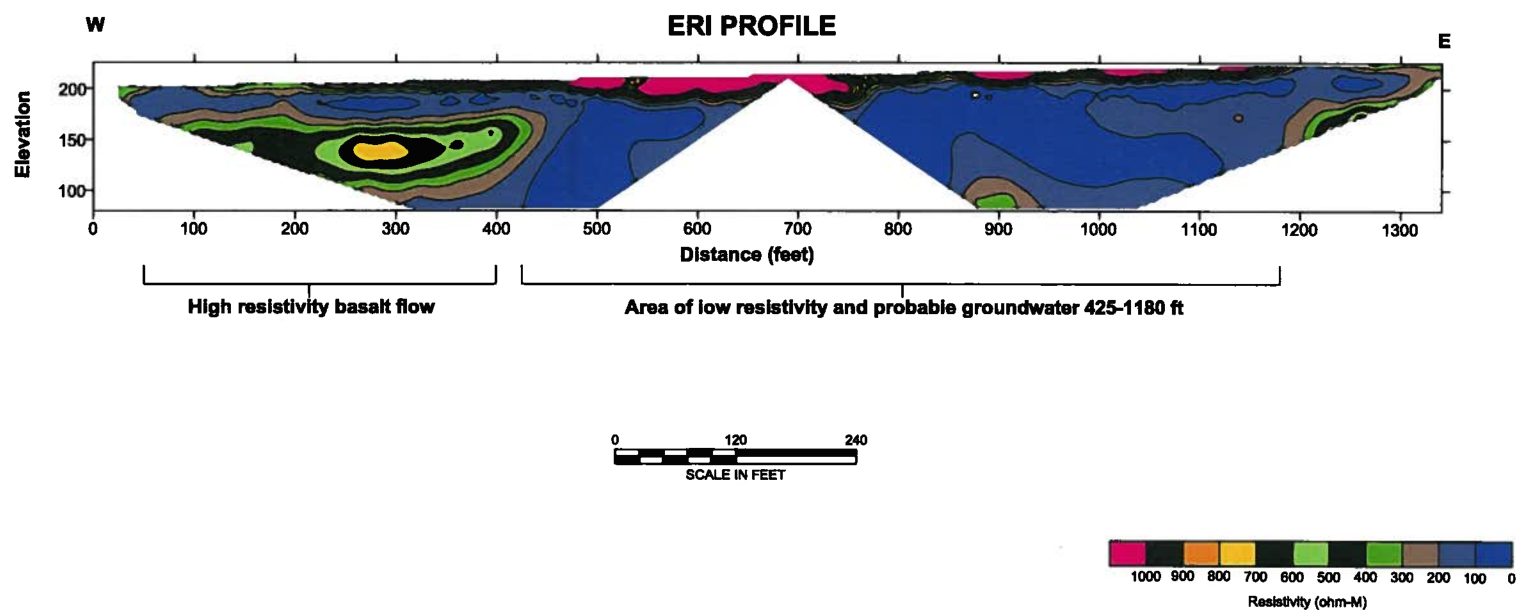

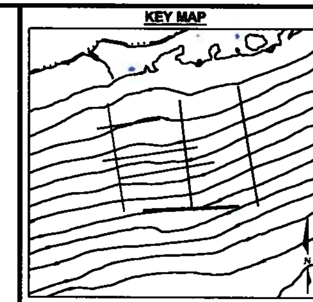

LEGEND

INPHASE VALUE IN %

CONUCTIVITY mS/M

ERI CONTOUR
CI = 100 ohm-M

NOTES

- Data collected June 17-21, 2007
- ASEN WADI VLF System
- IRIS Electrical Resistivity System
- See Figure 2 for line location
- Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: - MSL
HORIZ. DATUM: -Alaska State Plane, Zone 8, Feet
PROJECTION: -

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SUBMITTED TO:
CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

TITLE:
LINE 1 ERI AND VLF

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ACF	7/10/07
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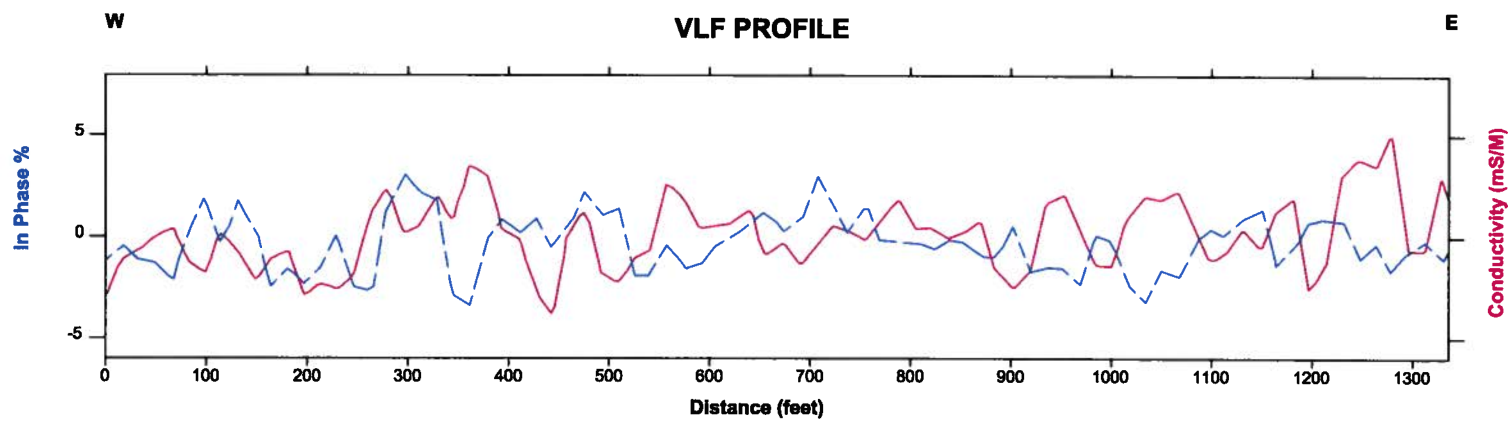
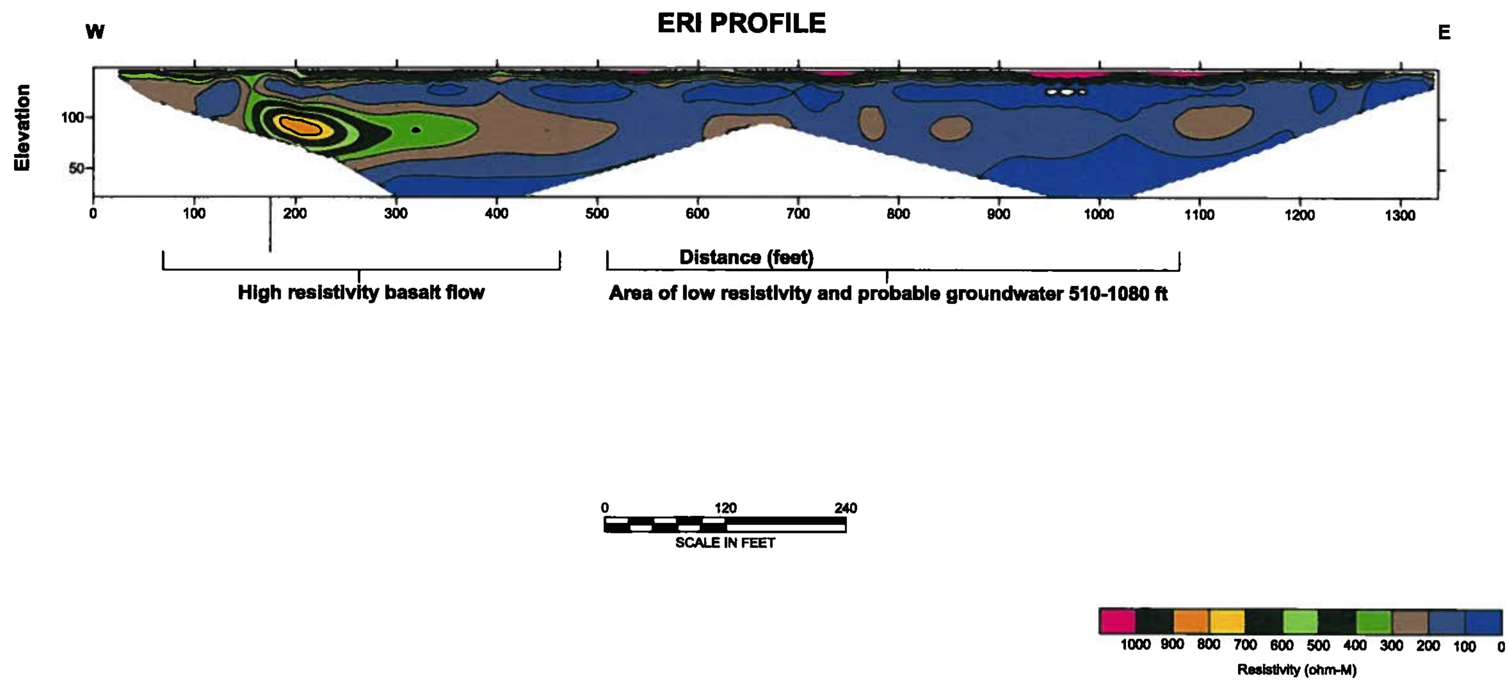
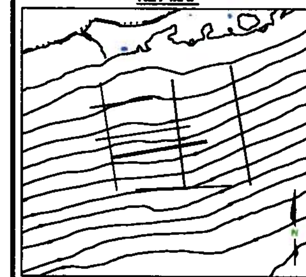
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 3





KEY MAP



LEGEND

INPHASE VALUE IN %

CONUCTIVITY mS/M

ERI CONTOUR
CI = 100 ohm-M

NOTES

-Data collected June 17-21, 2007
-ABEN WADI VLF System
-IRIS Electrical Resistivity System
-See Figure 2 for line location
-Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: -MSL
HORIZ. DATUM: -Alaska State Plane, Zone 6, Feet
PROJECTION: -

GOLDER ASSOCIATES INC.
1750 ABBOTT ROAD, SUITE 200
ANCHORAGE, AK USA 99507
TEL: (907) 344-6001
FAX: (907) 344-6011

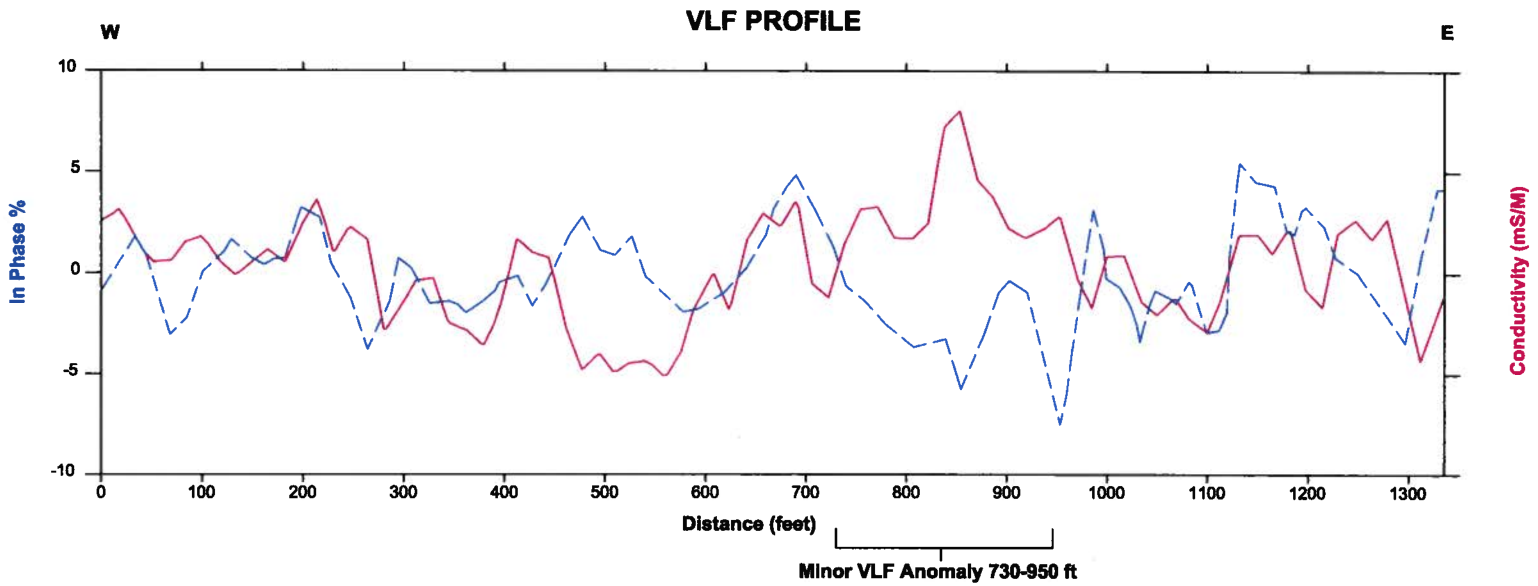
SUBMITTED TO:
CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

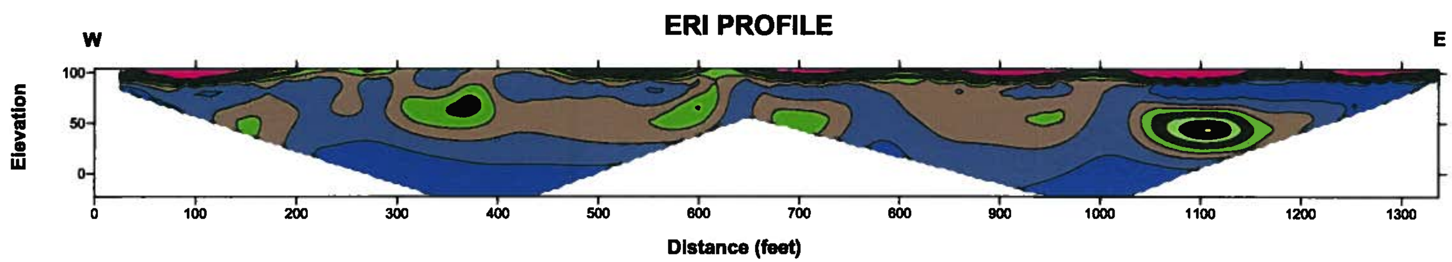
PROJECT:
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

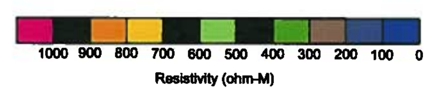
TITLE:
LINE 2 ERI AND VLF

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ACF	7/10/07
REV.	0	CHECK	HMH	7/13/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

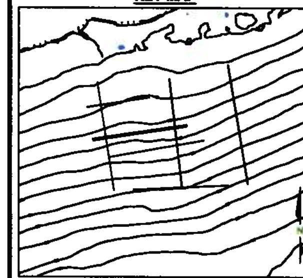
FIGURE 4







KEY MAP



LEGEND

- INPHASE VALUE IN %
- CONUCTIVITY mS/M
- ERI CONTOUR
  CI = 100 ohm-M

NOTES

- -Data collected June 17-21, 2007
- -ABEN WADI VLF System
- -IRIS Electrical Resistivity System
- -See Figure 2 for line location
- -Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: - MSL
HORIZ. DATUM: -Alaska State Plane, Zone 8, Feet
PROJECTION: -

GOLDER ASSOCIATES INC.
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ANCHORAGE, AK USA 99507
TEL: (907) 344-6001
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SUBMITTED TO:
CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

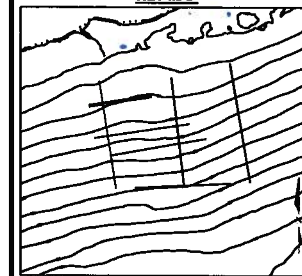
PROJECT:
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

TITLE:
LINE 3 ERI AND VLF

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ACF	7/10/07
REV.	0	CHECK	HMH	7/13/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 5

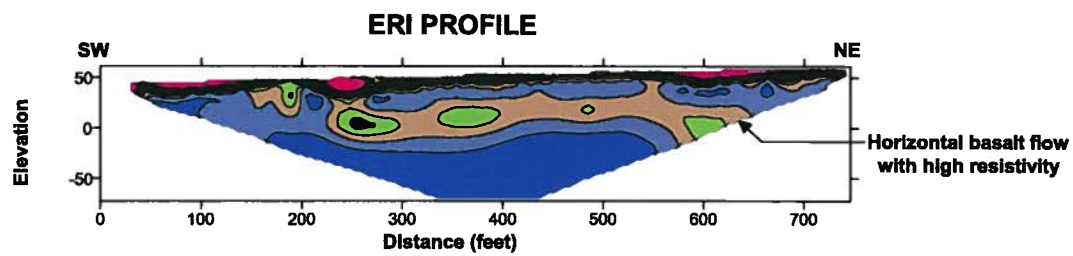
KEY MAP

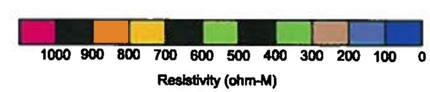


LEGEND

ERI CONTOUR
CI = 100 ohm-M

ERI PROFILE





NOTES

- Data collected June 17-21, 2007
- ABEN WADI VLF System
- IRIS Electrical Resistivity System
- See Figure 2 for line location
- Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: - MSL
HORIZ. DATUM: - Alaska State Plane, Zone 8, Feet
PROJECTION: -

Golder Associates
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CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

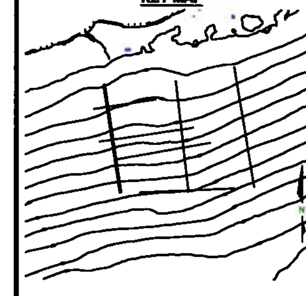
PROJECT:
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

TITLE:
LINE 4 ERI

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ACF	7/10/07
REV.	0	CHECK	HMH	7/13/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 6

KEY MAP

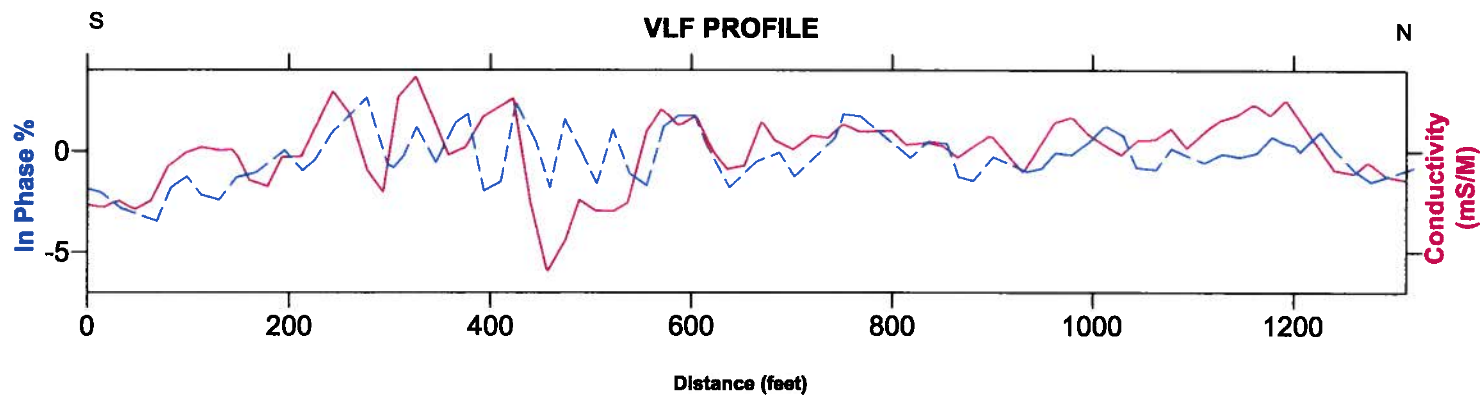


LEGEND

- - - INPHASE VALUE IN %

—— CONUCTIVITY mS/M

VLF PROFILE



NOTES

- -Data collected June 17-21, 2007
- -ABEN WADI VLF System
- -IRIS Electrical Resistivity System
- -See Figure 2 for line location
- -Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: - MSL
HORIZ. DATUM: -Alaska State Plane, Zone 6, Feet
PROJECTION: -

Golder Associates

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SUBMITTED TO:

CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:

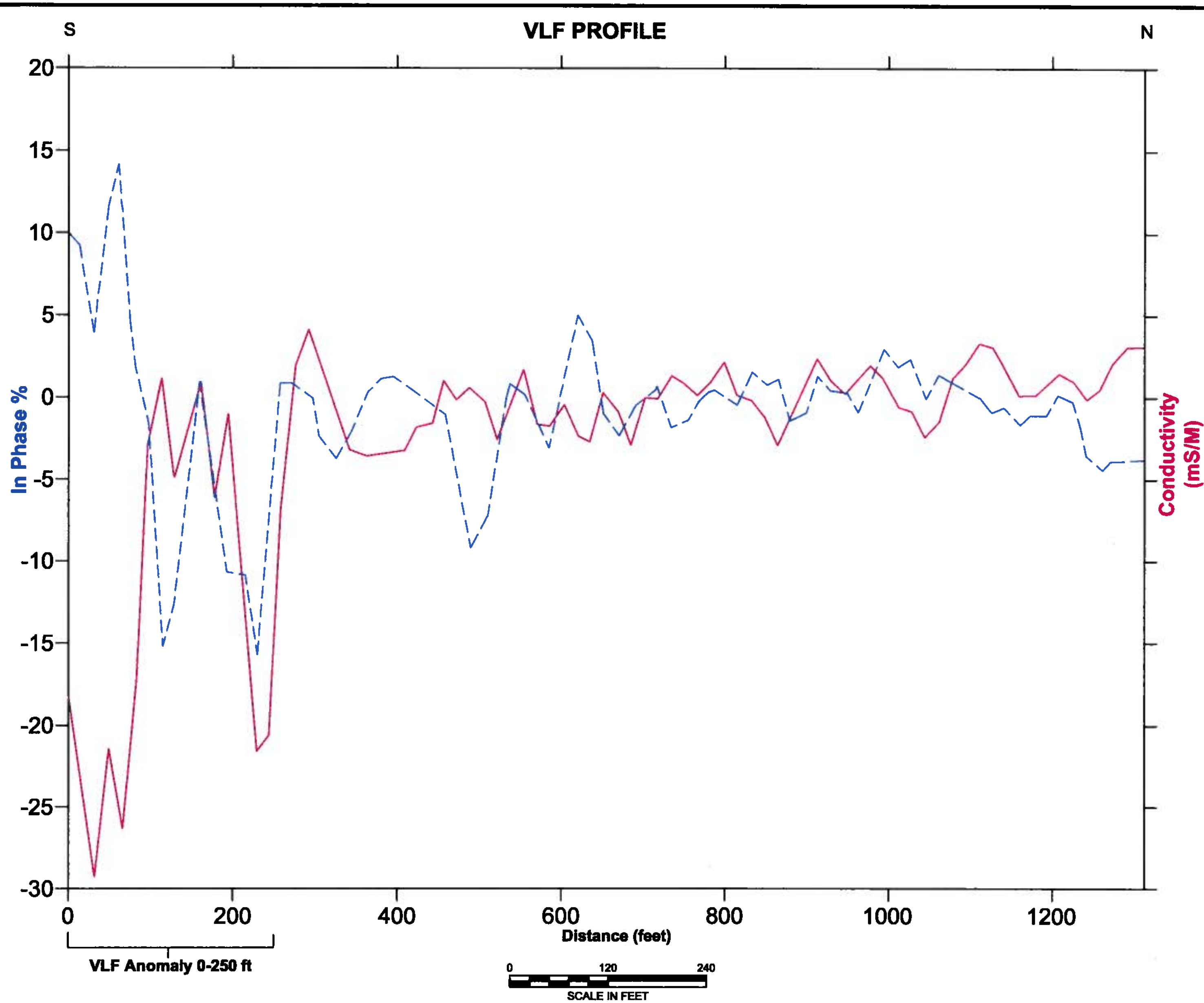
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

TITLE:

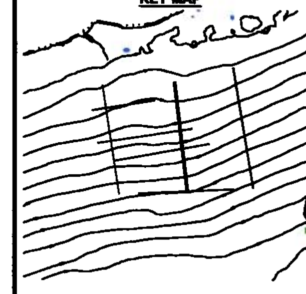
LINE 5 VLF

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	EDC	7/12/07
REV.	0	CHECK	HMH	7/13/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 7



KEY MAP



LEGEND

- INPHASE VALUE IN %
- CONUCTIVITY mS/M

NOTES

- -Data collected June 17-21, 2007
- -ABEN WADI VLF System
- -IRIS Electrical Resistivity System
- -See Figure 2 for line location
- -Elevations in MSL are different than base map contours provided by client (NAVD 88)

GEODETIC PARAMETERS

VERT. DATUM: - MSL
HORIZ. DATUM: -Alaska State Plane, Zone 8, Feet
PROJECTION: -

Golder Associates

GOLDER ASSOCIATES INC.
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TEL: (907) 344-6001
FAX: (907) 344-6011

SUBMITTED TO:

CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:

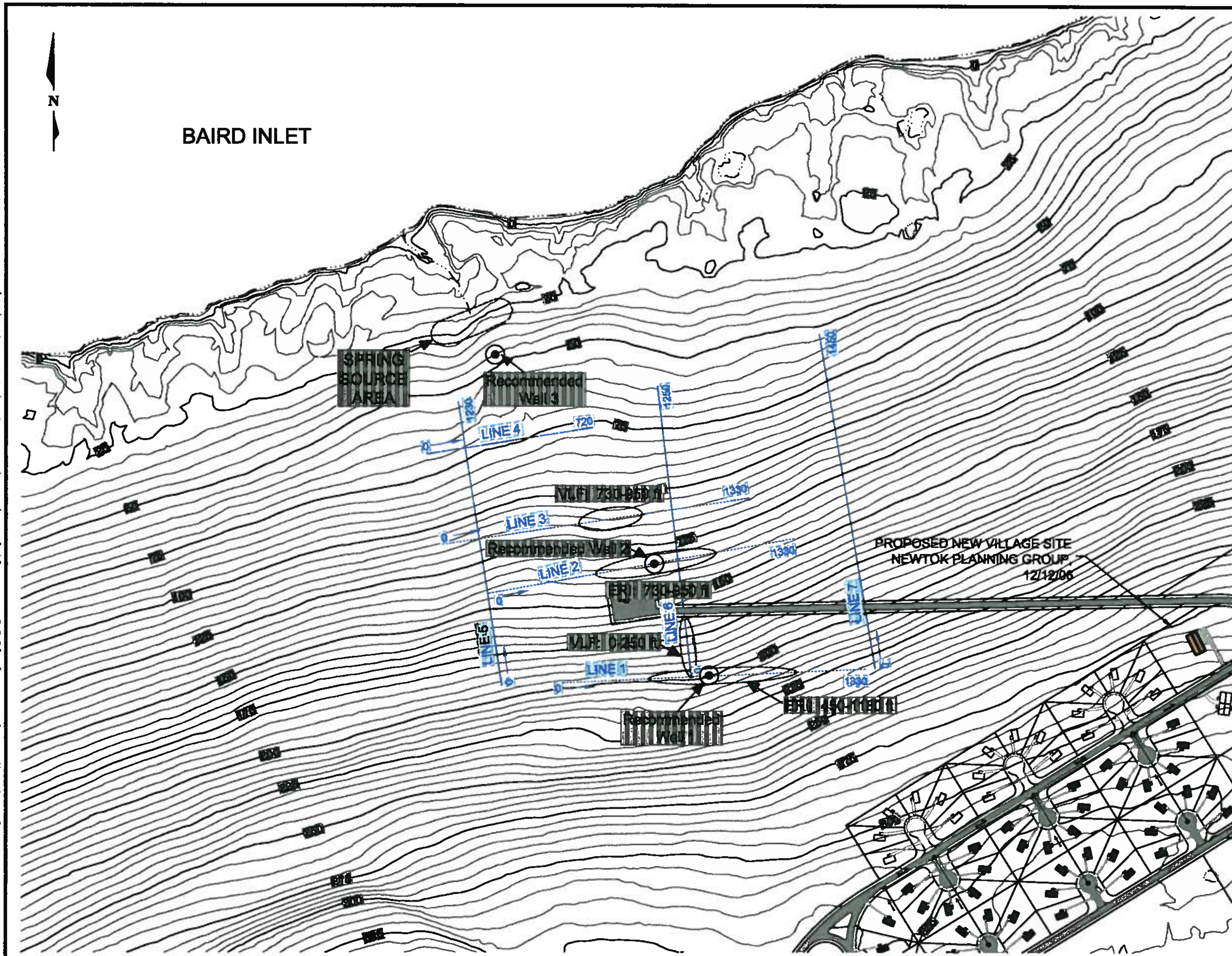
CRW/NEWTOK GROUNDWATER INVESTIGATION/AK

TITLE:

LINE 6 VLF

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ECC	7/12/07
REV.	0	CHECK	HMH	7/13/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 8



LEGEND

- MINOR CONTOUR @ 5ft
- MAJOR CONTOUR @ 25ft
- VLF LINE ONLY
- ERI LINE ONLY
- VLF & ERI LINE

ERI: 450-1180 ft VLF & ERI ANOMALIES (DISTANCE RANGE ALONG PROFILE IN FT)

0 400 800

SCALE IN FEET

NOTES

-ABEN WADI VLF System

-IRIS Electrical Resistivity System

GEODETIC PARAMETERS

VERT. DATUM: - NAVD 88

HORIZ. DATUM: - Alaska State Plane, Zone 8, Feet

PROJECTION: -

Golder Associates

GOLDER ASSOCIATES INC.
1750 ABBOTT ROAD, SUITE 200
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TEL: (907) 344-6001
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SUBMITTED TO:

CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:

CRW / NEWTOK GROUNDWATER INVESTIGATION / AK

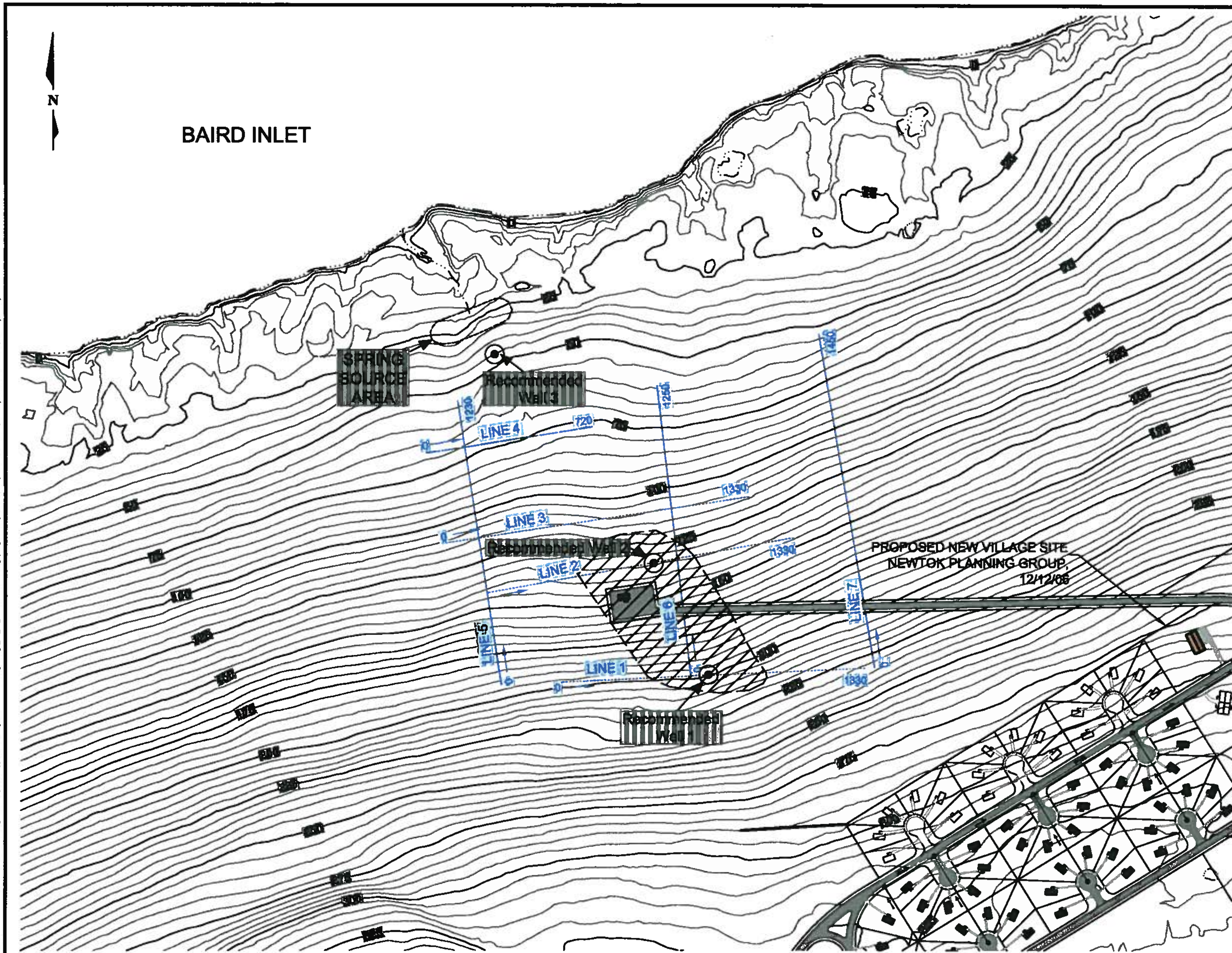
TITLE:

RECOMMENDED WELL LOCATIONS

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ECC	8/10/07
REV.	0	CHECK	HMH	8/12/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 10

J:\2007\073-95024 CRW Newtok Water Investigation\Reports\Appendices\Figures\CAD Drawings\Figs_10_11_Newtok-REV1A.dwg | Fig10 Anomaly Locations | Mod: 08/14/2007, 08:44 | Plotted: 08/14/2007, 10:34 | hheny



KEY MAP

LEGEND

- MINOR CONTOUR @ 5ft
- MAJOR CONTOUR @ 25ft
- VLF LINE ONLY
- ERI LINE ONLY
- VLF & ERI LINE
- INTERPRETED AS BEST LOCATION FOR WATER SUPPLY WELL

0 400 800

SCALE IN FEET

NOTES

-ABEN WADI VLF System

-IRIS Electrical Resistivity System

GEODETIC PARAMETERS

VERT. DATUM: - NAVD 88

HORIZ. DATUM: - Alaska State Plane, Zone 8, Feet

PROJECTION: -

Golder Associates

GOLDER ASSOCIATES INC.
1750 ABBOTT ROAD, SUITE 200
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TEL: (907) 344-6001
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SUBMITTED TO:

CRW ENGINEERING GROUP, LLC
3940 ARCTIC BLVD, SUITE 300
ANCHORAGE, AK 99503

PROJECT:

CRW / NEWTOK GROUNDWATER INVESTIGATION / AK

TITLE:

INTERPRETED AREA OF GEOPHYSICAL ANOMALIES

PROJECT	073-95024	DESIGN	DH	7/10/07
FILE No.	07395024000F02	CADD	ECC	8/10/07
REV.	0	CHECK	HMH	8/10/07
SCALE	AS SHOWN	REVIEW	JFD	8/13/07

FIGURE 11

APPENDIX A

TABLE A-1
SPRING FLOW ESTIMATE
JUNE 14, 2007
NEWTOK GROUNDWATER INVESTIGATION

Test no.	Distance (ft)	Time (sec)	Measured Float Velocity (ft/sec)	Calculated Flow Rate (CFS)	Flow Rate Adjusted 10% lower	Flow Rate Adjusted 20 % lower	gpm
1	8	3.01	2.66	6.4	5.7	5.1	2290
2	8	3.16	2.53	6.1	5.5	4.9	2182
3	8	3.69	2.17	5.2	4.7	4.2	1868
4	8	3.02	2.65	6.4	5.7	5.1	2283
5	8	2.67	3.00	7.2	6.5	5.8	2582
6	8	3.01	2.66	6.4	5.7	5.1	2290
7	8	2.95	2.71	6.5	5.9	5.2	2337
8	8	2.64	3.03	7.3	6.5	5.8	2611
9	8	3.22	2.48	6.0	5.4	4.8	2141
10	8	2.9	2.76	6.6	6.0	5.3	2377
		Average	2.66	6.4	5.8	5.1	2296
		Low	2.17	5.2	4.7	4.2	1868
		High	3.03	7.3	6.5	5.8	2611

Note:

Assumes cross-sectional area of 2.4 ft based on field measurements every 0.5 ft across stream section. Actual velocity is likely 10% to 20% less.

TABLE A-2
ESTIMATION OF AVERAGE INFILTRATION AND PEAK SEASONAL SURFACE RECHARGE TO SPRING
NEWTOK GROUNDWATER INVESTIGATION

Recharge area (upslope)

Map Scale 1 in = 775 ft
1 in^2 = 600625 ft^2

Catchment area = 17.4 in^2
10450875 ft^2
0.37487356 mi^2

Annual Avg Precip

Bethel	16.8	in
Newtok	17	in
1 cfs=	448.831	gpm

Annual Infiltration (assuming 100% infiltration)

17 in/yr = 1.41666667 ft/yr

Annual precip volume = Annual Precip x Area

14805406.3 ft^3/yr (assuming no loss due to ET)

Avg annual infiltration

Avg recharge = vol/days/hours/min/sec

0.46947635 cfs

210.715541 gpm

Effective Recharge (ER) accounting for Evapotranspiration (ET)

ET = ro * R

ro = runoff coef = 0.25

R = recharge rate = R

ET = 0.11736909 cfs

ER = 0.35210726 cfs Average effective recharge to spring

158.036656 gpm

This estimate represents the avg water supply to the spring from just precip recharge. Precip is averaged over entire year, not accounting for peak recharge from storms or spring snow melt. For peak recharge, see below.

Peak seasonal recharge

Assume: Snowpack at end of winter represents 6 months of snow accumulation

Spring melt occurs over a perios of 2 months, during which time the soil recieves snowmelt form the past 6 months of precip. ET is minimal during melt season

Then: A peak volume of water will be delivered groundwater and the spring

Melt Vol of water released from snow = Annual precip vol / 2 (6 mo of pricip)

7402703.13 ft^3

Peak Seasonal Recharge = Melt vol / 2months/hour/min/sec

1.42799057 cfs

640.926436 gpm

Note:
This estimate is the max rate of surface recharge water supplied to the spring by precipitation and snowmelt, which is likely to occur in early summer.

APPENDIX B

PHOTO 1: VIEW SOUTH EAST

ACROSS POND BELOW GROUNDWATER SPRING AND ABOVE BEAVER DAM

PHOTO 2:

VIEW NORTH WEST ACROSS SLOPE WHERE SPRING SEEPAGE OCCURS

Golder Associates	Drawn:	HMH	**PHOTO LOG OF GEOPHYSICAL SURVEY AT MERTARVIK TOWN SITE** **NELSON ISLAND, ALASKA**
	Date:	7/12/07	
	Check:	JFD	
	Date:	8/13/07	
Project No.: 073-95024 File: j:/2007/07395024/field/photo	Rev:	0	CRW / NEWTOK VILLAGE RELOCATION / AK — FIGURE: B-1

PHOTO 3: VIEW NORTH DOWN SLOPE WHERE GROUNDWATER SPRING EXITS

PHOTO 4: VIEW SOUTH OF SPRING CREEK BELOW BEAVER DAM

Golder Associates	Drawn:	HMH	**PHOTO LOG OF GEOPHYSICAL SURVEY AT MERTARVIK TOWN SITE** **NELSON ISLAND, ALASKA**
	Date:	7/12/07	
	Check:	JFD	
	Date:	8/13/07	
Project No.: 073-95024 File: j:/2007/07395024/field/photo	Rev:	0	CRW / NEWTOK VILLAGE RELOCATION / AK — FIGURE: B-2

PHOTO 5: VIEW SOUTH UPSLOPE TO SPRING CREEK ENTERING POND

PHOTO 6: VIEW WEST NORTH WEST ALONG STAKES OF LINE 1

(SOUTHERNMOST AND HIGHEST GEOPHYSICAL LINE ABOVE SPRING)

Golder Associates	Drawn:	HMH	**PHOTO LOG OF GEOPHYSICAL SURVEY AT MERTARVIK TOWN SITE** **NELSON ISLAND, ALASKA**
	Date:	7/12/07	
	Check:	JFD	
	Date:	8/13/07	
Project No.: 073-95024 File: j:/2007/07395024/field/photo	Rev:	0	CRW / NEWTOK VILLAGE RELOCATION / AK — FIGURE: **B-3**

PHOTO 7: ERI EQUIPMENT SETUP ON LINE 1 OF SURVEY

PHOTO 8: ERI MEASUREMENT STATION WITH CABLE AND WIRE LEADING TO STEEL STAKE IN GROUND FOR ELECTRICAL CONDUCTANCE

Golder Associates	Drawn:	HMH	**PHOTO LOG OF GEOPHYSICAL SURVEY AT MERTARVIK TOWN SITE** **NELSON ISLAND, ALASKA**
	Date:	7/12/07	
	Check:	JFD	
	Date:	8/13/07	
Project No.: 073-95024 File: j:/2007/07395024/field/photo	Rev:	0	CRW / NEWTOK VILLAGE RELOCATION / AK — FIGURE: B-4

PHOTO 9: VIEW NORTH WEST OF DAVE HRUTFIORD CONDUCTING VLF GEOPHYSICAL SURVEY

PHOTO 10: BASALT BOULDER ON HILLSLOPE ABOVE SPRING

Golder Associates	Drawn:	HMH	PHOTO LOG OF GEOPHYSICAL SURVEY AT MERTARVIK TOWN SITE NELSON ISLAND, ALASKA
	Date:	7/12/07	
	Check:	JFD	
	Date:	8/13/07	
Project No.: 073-95024 File: j:/2007/07395024/field/photo	Rev:	0	CRW / NEWTOK VILLAGE RELOCATION / AK — FIGURE: B-5