Appendix A
Scoping Newsletter

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Naknek Electric Association, Inc.

February 19, 2010
Volume 1, Issue 5

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Mission Statement

Naknek Electric Association is committed to the mission of providing superior electric service, accomplished through the efforts of a highly skilled, motivated and safety conscious work force with the support services, technologies and facilities to ensure the association's members enjoy its benefits at the lowest price consistent with sound management.

Call for Comments for Naknek Enhanced Geothermal Systems (EGS) Project with the US Department of Energy (DOE)

EGS Project Overview and Benefits / Scoping for Environmental Assessment (EA)

This is part of NEA's Southwest Alaska Regional Geothermal Energy Project which is designed to provide a sustainable, affordable and clean alternative to the rising costs of diesel generated electricity. A geothermal resource could stabilize electric rates in Naknek, King Salmon and South Naknek by displacing up to 5.4 million gallons of diesel fuel currently used for electricity and space heating, potentially avoiding over $15,000,000 per year in fuel costs. In support of its goals to develop geothermal power, NEA and DOE in a cost sharing arrangement will drill up to two deep, full-diameter wells via Congressionally Directed Project (CDP) funds and competitively awarded ARRA EGS funds. EGS incorporates stimulation techniques to increase the productivity of a low-permeability geothermal reservoir.

Stimulation Techniques

If natural permeability is not sufficient for commercial production, water may be injected into the well to open micro-fractures and allow greater quantities of water to circulate through the hot rock.

During the process of creating an underground heat exchanger by opening permeable space in the rock or during subsequent circulation of water to recover the heat, stress patterns in the rock may change and produce microseismic events (known as induced seismicity). In almost all cases, these events in the deep reservoir have been of such low magnitude and have so little energy relative to natural earthquakes that they pass unnoticed.

The difference between microseismic events created directly by fluid injection and a natural earthquake is significant: To the extent that they are sometimes felt, induced seismicity usually falls into the category of a nuisance, like a pneumatic hammer or the passing of a train or large truck, whereas a natural earthquake may cause extensive damage. For example, experience and scientific data indicate that the vibration at depth from a micro earthquake related to fluid injection is unlikely to cause any damage to modern buildings. However, large induced seismic events have occurred. In particular, a series of induced seismic events resulting from an EGS program in Basel, Switzerland led to the project's cancellation after a seismic hazard evaluation was performed. Additional information regarding induced seismicity can be located from the Lawrence Berkeley National Laboratory at

http://esd.lbl.gov/research/projects/induced_seismicity/

DOE requires EGS awardees to collect stress data, background seismicity, and geologic data prior to actual field stimulation. Once the data are collected, the awardee should use predictive stimulation models to estimate and forecast potential induced seismicity magnitude and potential radius of seismicity. Information submitted by awardees is used to develop site specific risk mitigation strategies.

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A DOE team of experts will review these results as part of a go/no-go decision point. If judged satisfactory, awardees will be given the go-ahead to conduct field work with adequate permits from local authorities. Otherwise, they will be asked to gather more data and conduct more analysis.

In addition, DOE requires awardees to implement special conditions of approval for stimulations (if necessary) including: placement of ground motion sensors, monitoring and reporting of operational data and events, and instituting procedures for mitigating emerging seismic events up to complete shutdown, if necessary.

DOE requires adherence to induced seismicity protocol detailed in the "PROTOCOL FOR INDUCED SEISMICITY ASSOCIATED WITH ENHANCED GEOTHERMAL SYSTEMS" established by the International Energy Agency-Geothermal Implementing Agreement. An array of seismographs surrounding the drill site will be established to detect the response of the formation, including possible micro-earthquakes due to the EGS stimulation. This array will allow EGS to be safely managed. Properly monitored and analyzed, EGS has been valuable in the development of geothermal resources around the world.

http://www.iea-gia.org/documents/ProtocolforInducedSeismicityEGS-GIADoc25Feb09.pdf

U.S. Department of Energy Funding and National Environmental Policy

DOE has conditionally awarded $12,376,000 to NEA for a competitive ARRA award to use EGS technologies to develop a geothermal resource on Pikes Ridge. Before releasing the funds, the National Environmental Policy Act (NEPA) requires an Environmental Assessment (EA) to be conducted to evaluate any potential environmental impacts, including induced seismicity. In addition, NEA will receive CDP funds totaling $5,354,500 federal funds which will be cost shared.

Opportunities to comment

As part of the EA, the U.S. Department of Energy (DOE) is requesting scoping comments regarding the proposed Southwest Alaska Regional Geothermal Energy Project from people and entities that are likely to be impacted by the project. Your feedback is welcome – if you have any concerns or questions, the DOE wants to hear from you.

THERE ARE TWO OPPORTUNITIES TO COMMENT – NOW (comments must be received by March 5, 2010) and **LATER** (comments on the Draft EA – date TBD).

Comments regarding the project and this Special Edition Newsletter may be sent to:

ASRC Energy Services Alaska, Inc.
ATTN: Naknek Geothermal Project
2700 Gambell Street, Suite 200
Anchorage, Alaska 99503

response@naknekgeothermalproject.com

OR www.naknekgeothermalproject.com

For More Information

Please go to the following websites to find more information:

http://www.nea.coop/about/geothermal.shtml OR

http://www.eere.energy.gov/golden/Reading_Room.aspx

http://www1.eere.energy.gov/geothermal

RATES

RESIDENTIAL:	
Consumer Charge	$15.00
First 1000 kwh	.18
Over 1000 kwh	.165
COMMERCIAL:	
Consumer Charge	$30.00
Consumer 3 Phase	$60.00
First 1000 kwh	.18
Over 1000 kwh	.165
LARGE POWER Year-Round:	
Consumer Charge	$100.00
Demand per kw	10.00
All kwh	.15
LARGE POWER Seasonal:	
Consumer Charge	$200.00
Demand per kw	12.00
All kwh	.135
WHOLESALE:	
Minimum Bill	$15,000.00
All kwh	.1363
FUEL SURCHARGE:	
All KWH/ All Members	.191

METER READING SAFETY

Every NEA Member shares in the responsibility of preserving the safety of NEA's line crew. In order to fulfill this responsibility, members need to make sure that meters are easily accessible during days of NEA meter reading.

- Clear brush or clutter to allow for access to electrical meters for reading
- Ensure pets are secured on days of meter readings

Naknek Electric Association conducts meter readings either the last two or first two days of each month. If you need to know a specific month's meter reading schedule for planning purposes, please feel free to contact NEA's office staff which is always happy to be of assistance. Safety of NEA Employees is a first priority of the utmost importance. NEA's Membership effort to ensure employee safety is sincerely appreciated.

Appendix B
Wetlands Report

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Geothermal Project
King Salmon, Alaska

Proposed Road Corridor and Naknek Electrical Association Property
Wetland Determination

April 2009

Prepared for:

Alaska Earth Sciences
11401 Olive Lane
Anchorage, AK 99515

Prepared by:

HDR Alaska, Inc.
2525 C Street, Suite 305
Anchorage, Alaska 99503

1.0 Introduction and Purpose

The purpose of this report is to identify and describe wetlands at a location approximately 5 miles northeast of King Salmon, Alaska. The general location of the site is in southwestern Alaska, near the northeastern end of Bristol Bay on the north side of the Naknek River, between King Salmon and Naknek Lake. Approximately 154 acres of Naknek Electrical Association (NEA) property is proposed for geothermal exploration. The site includes a proposed 100-foot-wide road corridor beginning at approximately 3 miles west along an unimproved road from Naknek II Recreation Camp (also known as Lake Camp) on Naknek Lake. The road corridor extends north and northeast approximately to the NEA property. The NEA property boundary and the proposed 100-foot road corridor are shown on Figure 1. Both the NEA property and the proposed road corridor are within the following land survey sections: Sections 14, 26, and 23 of Township 17S, Range 44W, Seward Meridian.

This report describes locations within each area that may be subject to the jurisdiction of the U.S. Army Corps of Engineers (USACE) under authority of Section 404 of the Clean Water Act. By federal law (Clean Water Act) and associated policy, it is necessary to avoid project impacts to wetlands wherever practicable, minimize impact where impact is not avoidable, and in some cases compensate for the impact.

This office-based Wetland Determination (WD) describes the wetland identification process and describes the findings of an analysis of aerial photography and existing mapping resources. The focus of this document is on identification of wetlands; project design and impacts are not discussed in this report. Wetlands, Waters of the U.S., and uplands (non-wetlands), as referenced in this report, are defined as:

Wetlands: "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 Code of Federal Regulations [CFR] Part 328.3(b)). Wetlands are a subset of "waters of the U.S." Note that the "wetlands" definition does not include unvegetated areas such as streams and ponds.

As described in the 1987 Wetlands Delineation Manual and in the Alaska Regional Supplement to the 1987 Wetland Delineation Manual (USACE 1987, USACE 2007), wetlands must possess the following three characteristics:

1. *Hydrophytic Vegetation:* Vegetation community dominated by plant species that are typically adapted for life in saturated soils.

2. *Wetland Hydrology:* Inundation or saturation of the soil during the growing season.

3. *Hydric Soils:* Soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions.

Waters of the U.S: Waters of the U.S. include other waterbodies regulated by the USACE, including navigable waters, lakes, ponds, and streams, in addition to wetlands.

Uplands: Non-water and non-wetland areas are called uplands.

2.0 Methods

The area of investigation, hereafter referenced as the project area, includes the NEA property and a 600-foot-wide corridor centered on the 100-foot proposed access road easement. This WD is office-based. Aerial photographs and existing mapping and documentation were reviewed to determine the presence or absence of wetlands; no field verification of wetland areas was conducted. The following datasets were reviewed to identify potential wetlands and other waters of the U.S. occurring within the project area:

- U.S. Geological Survey topographic map Naknek (C-2) at a scale of 1:63,360 (Figure 1).
- Color digital orthophoto taken on September 27, 2008 at 1-foot pixel resolution.
- Color stereoscopic pairs of aerial photographs taken on September 27, 2008.
- U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) mapping for USGS topographic map Naknek (C-2) at a scale of 1:60,000 (Figure 2).

Aerial photographs were analyzed under a stereoscope to identify topographic features (i.e., depressions and steepness of slopes) that may support or inhibit wetlands from occurring. Delineating wetlands from aerial photography includes using the following methods:

> *Vegetation clues:* On aerial photography, scientists look for saturation-adapted vegetation communities such as those dominated by shrub or herbaceous vegetation, stunted plant growth forms, and presence of plant species known to tolerate saturated soils.
>
> *Evidence of soil saturation:* Visible evidence of wetland hydrology is sought, including surface water, channel features, and darker areas of photos indicating surface saturation. A site's elevation relative to streams, open water, and marshes may indicate shallow subsurface water.
>
> *Topography:* Evidence of topographic high points and sloped surfaces that would allow soils to drain is used to support classifying those areas as upland. Topographic depressions, toes of slopes, and flat topography serve as indicators of potentially poor soil drainage. Geomorphic features may also give clues about the substrate's drainage characteristics.

Wetland boundaries were then digitized into a GIS database on the orthorectified aerial photograph. Wetland polygons were drawn in GIS within the project area. NWI mapping codes were assigned to wetland polygons based on the USFWS "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin *et al.*, 1979).

Additional information used to identify potential wetlands and waters of the U.S. included local soil reports and site photos taken in the winter. No soil survey maps have been completed for the vicinity. Soil data from the report "Soils of the King Salmon-Naknek Area, Alaska," (Furbush and Wiedenfeld, 1970) covering the area between Naknek and King Salmon, 5 miles to the east, was interpreted for the purposes of this WD. Vegetation descriptions were based on "The Alaska Vegetation Classification" (Viereck *et al.*, 1979) and the "User's Guide for Bristol Bay Land Cover Maps" (Wibbenmeyer *et al.*, 1982). Individual plant species' wetland indicator status is listed in "1988 National List of Plant Species that Occur in Wetlands Alaska" (USFWS, 1988).

3.0 Summary of Wetland Indicators

The vegetation, soil, and hydrology conditions gathered from existing datasets, aerial photography interpretation, and site photos are summarized for each mapped area below.

Vegetation

Five cover types occur in the project area. These include mixed broadleaf/needleleaf woodland, lichen tundra, stunted needleleaf scrub/shrub, shrub/sedge wet meadow, and broadleaf scrub/shrub thickets. Vegetation types were recognizable on aerial imagery and contact prints by evaluating vegetation signatures for color, plant height, texture, and pattern. Despite the winter conditions in site photos, vegetation was easily observed because snow cover was light.

Mixed broadleaf/needleleaf woodland and lichen tundra are found on low rises and ridges in the project area. Mixed broadleaf/needleleaf woodland occurs mainly on high areas and is typically dominated by a mixed overstory of paper birch (*Betula papyrifera* – FACU), balsam poplar (*Populus balsamifera* – FACU), and white spruce (*Picea glauca* – FACU). Mixed broadleaf/needleleaf forest is generally not dominated by hydrophytes and is recorded to occur on moderately well-drained soils (Wibbenmeyer *et al.*, 1982). Lichen tundra occurs on higher areas and ridges and is dominated by white lichen (*Cladonia* spp., *Cladina* spp. – NL), scattered willows (*Salix* sp*.),* and white spruce. Bare ground or exposed gravel was observed throughout the project area and has a vegetation signature similar to lichen tundra. These cover types typically do not indicate saturated soil conditions.

Stunted needleleaf scrub/shrub and shrub/sedge wet meadow are found in depressional areas and drained lake beds typical of wetlands in the project area. The overstory of stunted needleleaf scrub/shrub is typically dominated by stunted black spruce (*Picea mariana* – FACW). The small size of spruce trees is often a result of suppressed growth in response to the saturated soils (Viereck *et al.*, 1992; Post, 1996). The understory of stunted needle leaf scrub/shrub is comprised of dwarf birch (*Betula nana* – FAC), other ericaceous shrubs (*Ledum decumbens* – FACW, *Vaccinium uliginosum* – FAC*,* and *Empetrum nigrum* – FAC), and sphagnum moss (*Sphagnum* sp. – NL). Shrub/sedge wet meadow is typically dominated by sedges (*Carex* sp. – OBL or FACW), sphagnum moss, and ericaceous shrubs and occurs on very poorly drained organic soils (Wibbenmeyer *et al.*, 1982). Both of these plant community types are generally dominated by hydrophytes.

Broadleaf scrub/shrub thicket is scattered throughout the project area and commonly occurs in moderately well-drained areas (Wibbenmeyer *et al.*, 1982). Broadleaf scrub/shrub thicket is dominated by an overstory of willow (*Salix* sp.) and green alder (*Alnus sinuata* – FAC). This plant community type is also generally dominated by hydrophytes.

Soils

The closest soil survey to the area is of the King Salmon-Naknek area, 5 miles to the east (Furbush and Wiedenfeld, 1970). Soils of the project area are likely either well drained, upland soils similar to the Kvichak Series or poorly drained wetland soils similar to the Nk Series. The soil survey of the King Salmon-Naknek area describes those soils series as:

> *Kvichak series:* consists of well drained soils formed in volcanic ash over strata of loam, sandy loam, and sand. A typical profile has a thin layer of comparatively recent volcanic ash at the surface, thick dark upper horizons, and a dark grayish brown to dark reddish brown stratified subsoil. The soils occur on terraces, on some low hills and areas bordering small lakes. Slopes range from 0 to 30 percent, but are dominantly less than 7 percent. Vegetation consists of a sparse forest of spindly white spruce, willows, and alder, and ground cover of dwarf birch, ericaceous shrubs, sedges, mosses, and lichens.

> *Nk Series:* The Nk series consists of poorly drained mottled brown and olive gray loam, sandy loam, and silt loam. The soils have at most a very thin organic mat at the surface. They are

strongly acidic. They are probably perennially frozen at depths greater than 42 inches but, because of the absence of a thick surface mat of organic material, thaw to at least that depth in the summer. The Nk soils occupy the beds of naturally drained thaw lakes. Slope gradients are generally less than 1 percent. Vegetation is dominantly sedges, willows, and small patches of grass.

Based on their descriptions as well drained or poorly drained, the Kvichak series would be non-hydric soils, and the Nk series would be hydric.

Soils similar to those described in the soil survey likely occur within the project area, and have similar associations with certain vegetation types, geographical position, topography, and slope. Soils similar to the Kvichak series are typically non-hydric, and are likely associated with broadleaf/needleleaf woodland, lichen tundra, and broadleaf scrub/shrub thicket in high areas. Soils similar to the Nk Series are typically hydric and are likely associated with needleleaf scrub/shrub and shrub/sedge wet meadow in low areas.

Hydrology

In general, landforms such as ridges tend to shed water downslope where it may pool at toeslopes and in depressions. Between topographic highs and depressions are flat areas with subtle changes in elevation that may be well drained or hold water depending on the soil type.

The project area is located on a terminal moraine known as Pike Ridge, suggesting glacial activity has contributed to the topography and drainage of the area (Mancuso, 2009). Terminal moraines consist of unsorted, coarsely graded material that is typically less compacted than those areas covered by the glacier, resulting in higher permeability and better soil drainage. Landforms of the area with well-drained soils include ridges and low rises which are remnant glacial features associated with the terminal moraine. Kettles – formed when blocks of glacial ice remain in the terminal moraine, melting later and leaving a steep hole – leave behind depressions where water may accumulate, or where the ground surface may intersect the water table. These depressions may be poorly-drained or may be poorly drained only in the spring but then well drained after the seasonal frost dissipates.

No stream channels are visible on the aerial photography in the mapped area. There is no visible ponding, and no exposed soils that appear dark, which might indicate saturation. To the contrary, there may be substantial areas of exposed soil, implying excessive drainage.

The project area is not likely within a region of discontinuous permafrost (USDOI, BLM, 2007). In areas with shallow (less than two feet below the surface) frozen soils, wetland hydrology may be present because the frozen layer acts as a restrictive layer, perching water upon it. No detailed permafrost mapping exists for the area, but a local surveyor did not report permafrost being found during exploratory sampling conducted at the area (Mancuso, 2009).

In summary, the high areas and low rises are likely to be well drained; the low areas at toeslopes or concave areas are likely to be poorly drained. Flat areas may be either well drained or poorly drained.

4.0 Mapping and Classification Results

Wetlands

After stereoscopic evaluation of the aerial photography and review of the NWI mapping, areas most likely to contain hydrophytic vegetation, hydrologic indicators, and hydric soils were mapped as wetlands. These are displayed in Figure 3. Table 1 summarizes the types of wetlands identified in this office-based WD. Since no field work was completed in conjunction with this WD, wetlands were mapped conservatively with the intent to include a greater wetland area than might be determined by field investigations, rather than exclude areas that may actually be wetlands.

Table 1. Wetland Summary

Proposed Road Corridor and NEA Property		
Mapping Code	**Description**	**Landform**
PSS1B	Saturated broadleaved deciduous scrub/shrub wetland	Depression, Flat, Toeslope
PSS1/EM1B	Saturated broadleaved deciduous scrub/shrub/persistent emergent wetland	Flat, Toeslope
PEM1B	Saturated persistent emergent wetland	Depression, Toeslope
PEM1C	Seasonally flooded persistent emergent wetland	Depression
PEM1/SS1B	Saturated persistent emergent/broadleaved deciduous scrub/shrub wetland	Depression, Flat, Toeslope
PUBH	Permanently flooded waterbody	Depression

Throughout the project area, vegetation types indicating wetlands are typically stunted needleleaf scrub/shrub and shrub/sedge wet meadow. These vegetation types typically occur in depressions, on flats, and on toeslopes. Some broadleaf scrub/shrub thickets were also mapped as wetlands where they occur on toeslopes and flats. Soils in the mapped wetlands are assumed to be poorly drained soils similar to the Nk series. Hydrology indicators for mapped wetlands are likely present as saturation and seasonal or permanent inundation. Two waterbodies exist in the project, which are waters of the U.S., but not strictly "wetlands." The mapped wetlands and waterbodies shown in this conservative delineation are the areas that may be subject to Corps of Engineers jurisdiction. Placement of dredged or fill material within them, or grading of soil within them, might be subject to regulation under Section 404 of the Clean Water Act.

There is some discrepancy between the existing large-scale NWI mapping (Figure 2) and the wetlands mapping presented in this WD (Figure 3). In some places, NWI mapping has indicated wetlands in areas that this WD has considered to be uplands and *vice versa*. It is important to note that NWI mapping shown on Figure 2 was completed using late 1970s 1:60,000-scale aerial photography and limited ground-truthing. Wetland mapping shown on Figure 3 used detailed topographic mapping and aerial photographs printed at a 1:14,400 scale, and gives in-depth consideration to variations in vegetation aerial signature and the complex topography.

Uplands

Areas not mapped as wetlands in the project area are assumed to be uplands because vegetation, soil, or hydrology lacks wetland indicators. Vegetation types of uplands are mainly mixed broadleaf/needleleaf woodland, broadleaf scrub/shrub thicket, and lichen tundra. These are found on ridges and low rises. Soils in uplands are presumably well-drained and similar to the Kvichak Series. These areas would not be subject to the Corps of Engineers' jurisdiction.

Office-Based Determination Made By:

Ann Claerbout
Wetland Scientist
HDR Alaska, Inc.
Date: April 3, 2009

5.0 References

Cowardin L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Furbush, C. E. and C.C. Wiedenfeld. 1970. Soils of the King Salmon-Naknek Area, Alaska. Soil Conservation Service and U.S. Department of Agriculture. Palmer.

Mancuso, Ralph. April 31, 2009. Coastal Surveyors, LLC, Naknek, AK, personal communication.

Post, R.A. 1996. Functional Profile of Black Spruce Wetlands in Alaska. Alaska Department of Fish and Game, Fairbanks, Alaska. Report EPA910/R-96-006 prepared for U.S. Environmental Protection Agency, Region 10.

U.S. Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. p. 143.

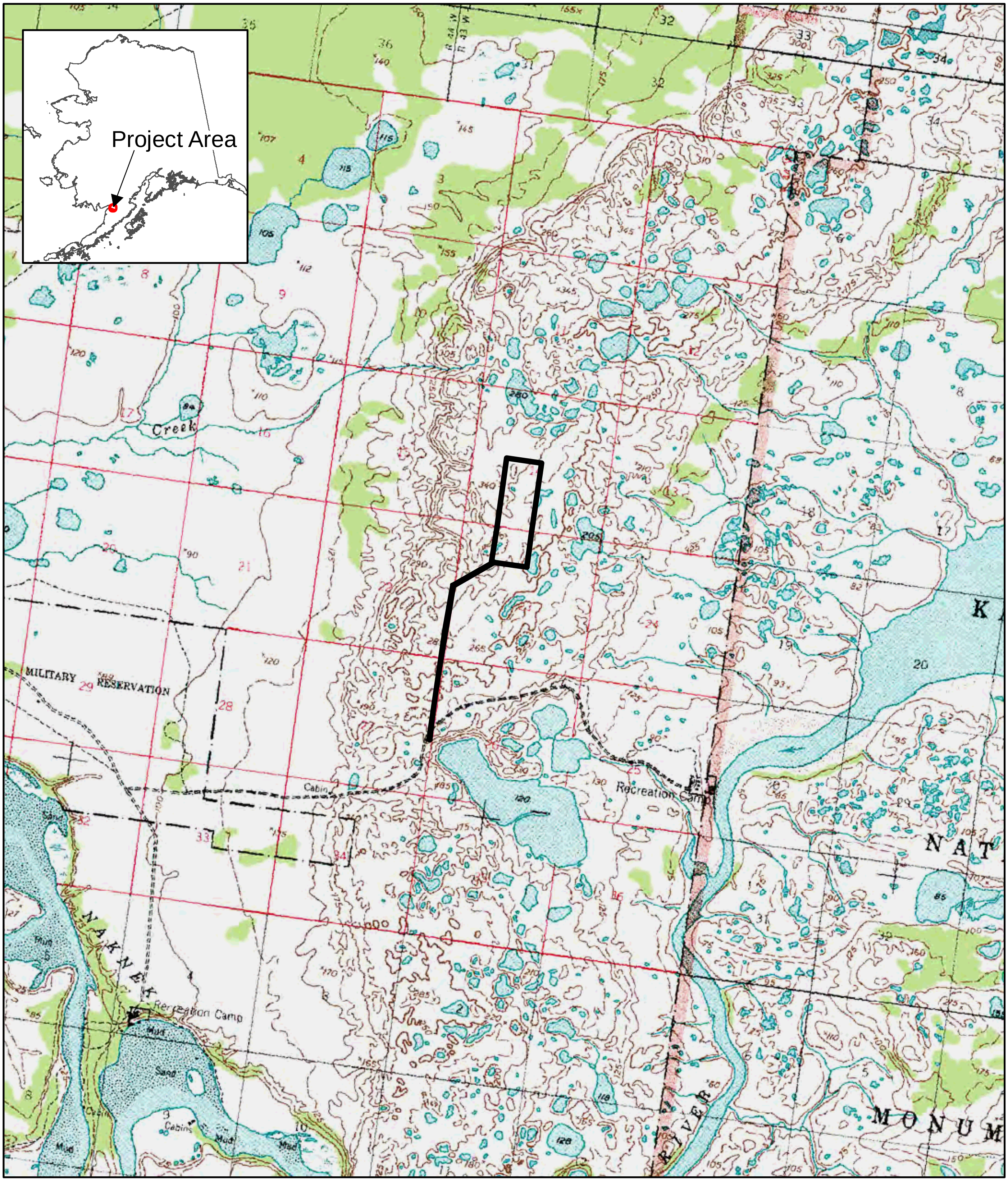
U.S. Department of the Interior (USDOI), Bureau of Land Management (BLM). 2007. Bay Proposed Resource Management Plan/Final Environmental Impact Statement. Available at: http://www.blm.gov/ak/st/en/prog/planning/bay_rmp_eis_home_page/bay_feis_documents.html (Accessed April 1, 2009).

U.S. Department of the Interior (USDOI), Soil Conservation Service (SCS). n.d. Soils of the King Salmon-Naknek Area, Alaska.

U.S. Fish and Wildlife Service. 1988 National List of Plant Species that Occur in Wetlands Alaska (Region A). U.S. Department of the Interior. Biological Report 88 (26.11).

Viereck L. A., C. T. Dyrness, A.R. Batten, and K.J. Wenzlick. 1992. The Alaska Vegetation Classification. U. S. Department of Agriculture.

Wibbenmeyer, M., J. Grunblatt, and L. Shea. 1982. User's Guide for Bristol Bay Land Cover Maps. Bristol Bay Cooperative Management Plan. Alaska Department of Natural Resources and Alaska Department of Fish and Game, Anchorage, AK.



MAP NOTES:
1. Wetland mapping is based on an office study. No field verification has occurred.
2. Mapping is shown in Alaska State Plane (feet) 6, North American Datum of 1983, feet.
3. USGS Quad 1:63,360 Naknek C-2

0 0.5 1 Miles

LEGEND

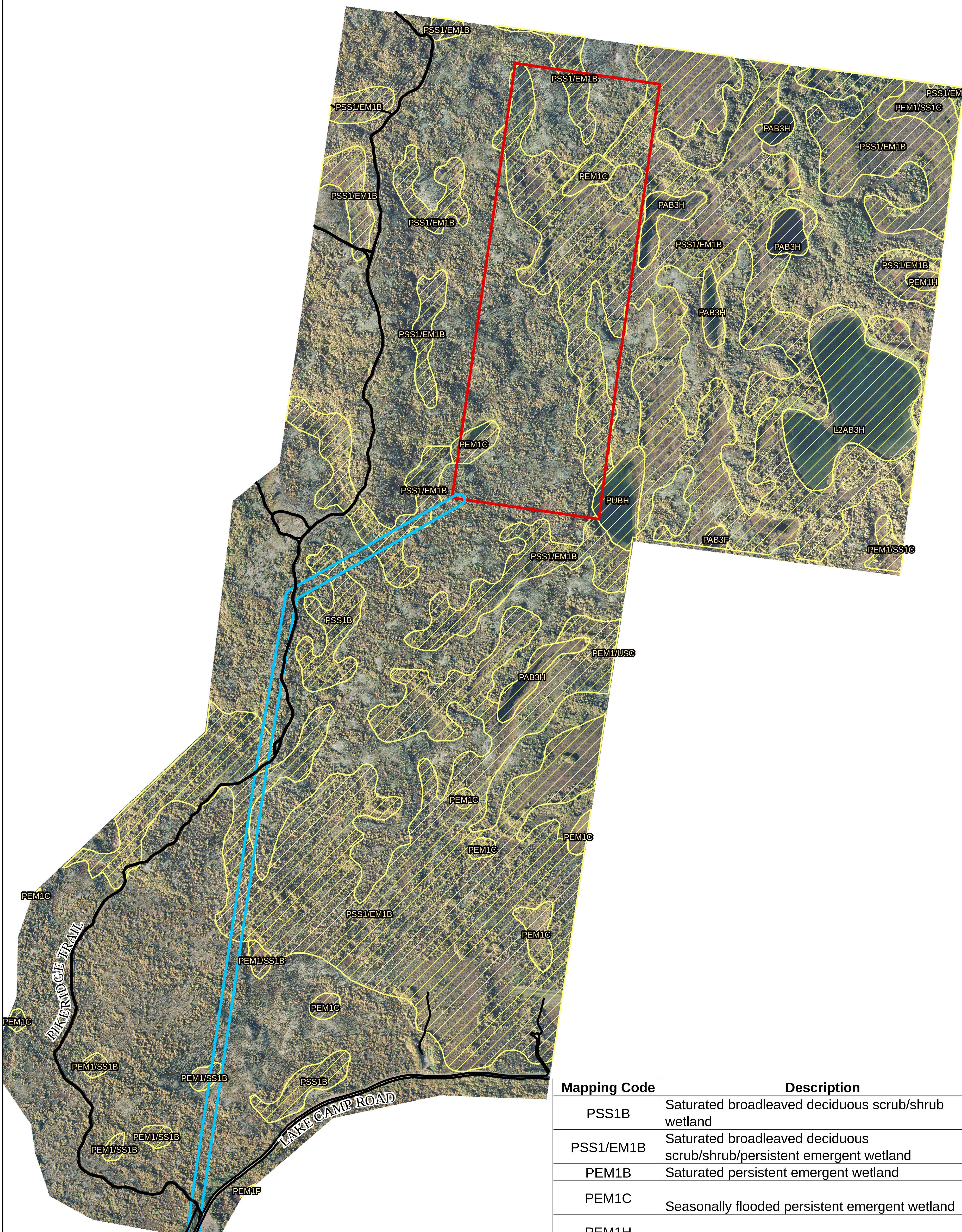
Project Area

N

Vicinity Map

Proposed Road Corridor and NEA Property
Geothermal Project near King Salmon, Alaska
Alaska Earth Sciences
Wetland Determination

FIGURE 1



Mapping Code	Description
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PSS1/EM1B	Saturated broadleaved deciduous scrub/shrub/persistent emergent wetland
PEM1B	Saturated persistent emergent wetland
PEM1C	Seasonally flooded persistent emergent wetland
PEM1H	Permanently flooded persistent emergent wetland
PEM1/SS1B	Saturated persistent emergent /broadleaved deciduous scrub/shrub wetland
PUBH	Permanently flooded waterbody
PAB3H	Permanently flooded aquatic bed waterbody
PAB3F	Semipermanently flooded aquatic bed waterbody
L2AB3H	Permanently flooded aquatic bed lake

MAP NOTES:
1. Wetland mapping is based on an office study. No field verification has occurred.
2. National Wetland Inventory (NWI) wetland units by US Fish & Wildlife Service
3. Aerial photograph taken September 2008.
4. Mapping is shown in Alaska State Plane (feet) 6, North American Datum of 1983, feet.

0 500 1,000
Feet

LEGEND

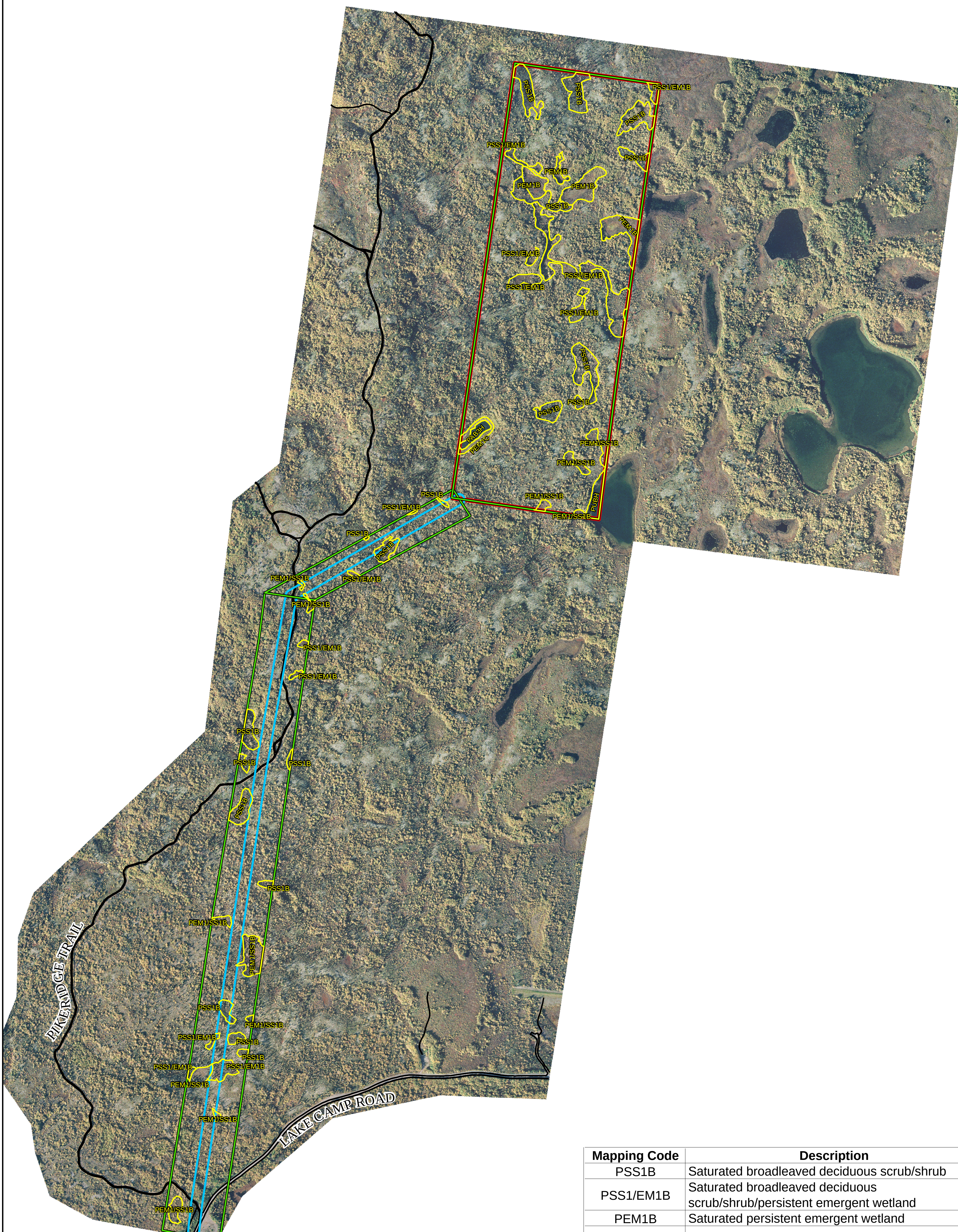
- Existing Roads and Trails
- Proposed Road Corridor
- NEA Property
- NWI - Mapped Wetlands

N

Existing NWI Map

Geothermal Project near King Salmon, Alaska
Alaska Earth Sciences
Wetland Determination

FIGURE 2



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PUBH	Permanently flooded waterbody
PAB3H	Permanently flooded aquatic bed waterbody

MAP NOTES:
1. Wetland mapping is based on an office study. No field verification has occurred.
2.. Aerial photograph taken September 2008.
3. Mapping is shown in Alaska State Plane (feet) 6, North American Datum of 1983, feet.

0 500 1,000 Feet

LEGEND

- Potential Wetlands and Waterbodies
- HDR Mapping Extent
- Proposed Road Corridor
- NEA Property

N

Wetlands & Waterbodies

Proposed Road Corridor and NEA Property
Geothermal Project near King Salmon, Alaska
Alaska Earth Sciences
Wetland Determination

FIGURE 3

Geothermal Project
King Salmon, Alaska

Proposed Road Corridor and Naknek Electric Association Property
Amendment to April 3, 2009 Office-based Wetlands Determination

April 22, 2009

Prepared for:

Alaska Earth Sciences
11401 Olive Lane
Anchorage, AK 99515

Prepared by:

HDR Alaska, Inc.
2525 C Street, Suite 305

1.0 Introduction and Purpose

The purpose of this amendment is to incorporate the results of field investigations completed on April 17, 2009 as a supplement to the office-based wetlands determination (HDR, April 3, 2009) for the proposed road corridor and geothermal well pads near King Salmon, Alaska. The proposed project area of visited during field investigations includes Rev 1 of the road alignment and north and south pads, which was sent to HDR on April 15, 2009 from Steve Roland at Recon LLC.

The field investigations were completed outside of the growing season, which limits the observation of some wetland indicators, according to the 2007 USACE Regional supplement (USACE, 2007). Growing season is estimated as the time from the onset of vegetation green-up in the spring until the time in late fall when woody deciduous species lose their leaves and/or the last herbaceous plants cease flowering and their leaves become dry or brown. Since these field investigations were completed in April before the vegetation green-up had occurred, wetland determinations were limited by winter vegetation, hydrologic, and soil conditions.

2.0 Methods

Study Site Selection

Aerial photographs and HDR's office-based wetland mapping and report were reviewed to determine which areas had been mapped as wetlands based on office-available information. Aerial photographs were analyzed in GIS to identify vegetation clues, evidence of soil saturation, and topographic features that may support or inhibit wetlands from occurring. Areas of potential wetlands and other waters of the U.S. were selected prior to the field visit as field targets for ground truthing. Additional field targets were identified on-site as time allowed.

Data Collection Methods

On April 17, 2009, HDR investigators visited the study area for ground truthing of field targets. Investigators accessed study area by ATV and collected information on vegetation, hydrology, and soil at pre-determined field targets and additional sites selected by investigators on the ground. Vegetation was observed in areas where snow had been blown clear or where snow was scraped away with a shovel. Hydrologic characteristics of the site were observed in the field by walking the perimeter of a 1/10 acre study plot. Soils characteristics were observed from soil pits dug by a backhoe to a depth of at least 36 inches. Plot locations were recorded with a Garmin Etrex GPS unit with an accuracy of 10 feet. Digital photos of each site were recorded.

3.0 Summary of Wetland and Upland Indicators

Overall, 17 sites were verified with ground truthing. At five sites, wetland determination forms were completed. All sites were documented with digital photos and field notes describing presence or absence of wetland indicators. Most study sites were covered in 12-36 inches of snow with soils frozen to at least 12 inches, but vegetation, soils, and hydrology indicators were still observable. Vegetation was observed at all sites by identifying winter characters of vegetation above snow cover and in areas cleared of snow. Hydrologic characteristics, such as geomorphic position, inundation, and soil saturation were observed at all sites. At sites where soil pits were dug, soil profile descriptions were completed to include the descriptions of depth of organic mat, soil color and textures. Field investigations confirmed the wetland indicators discussed in the April 3, 2009 wetland delineation.

4.0 Mapping and Classification Results

The accuracy of this determination is limited since this field work was completed outside of the growing season with snow cover and frozen ground. Although, HDR has made the most accurate determination that they can based on available information and winter ground truthing, determinations of wetlands and uplands should really be based on field data gathered during the growing season. HDR is confident in their wetland mapping of the project area based on the given information, but it is possible that circumstances during the growing season could produce evidence that areas mapped as uplands are subject to the regulation under Section 404 of the Clean Water Act.

Wetlands

After field investigations, evaluation of the aerial photography and review of the NWI mapping, areas most likely to contain hydrophytic vegetation, hydrologic indicators, and hydric soils were mapped as wetlands. These are displayed in Figure 3. Areas near the north pad site previously mapped as wetlands and assumed to be unmistakable in the field were confirmed as wetlands with ground truthing. Table 1 summarizes the types of wetlands identified in the refined wetlands mapping displayed in Figure 1.

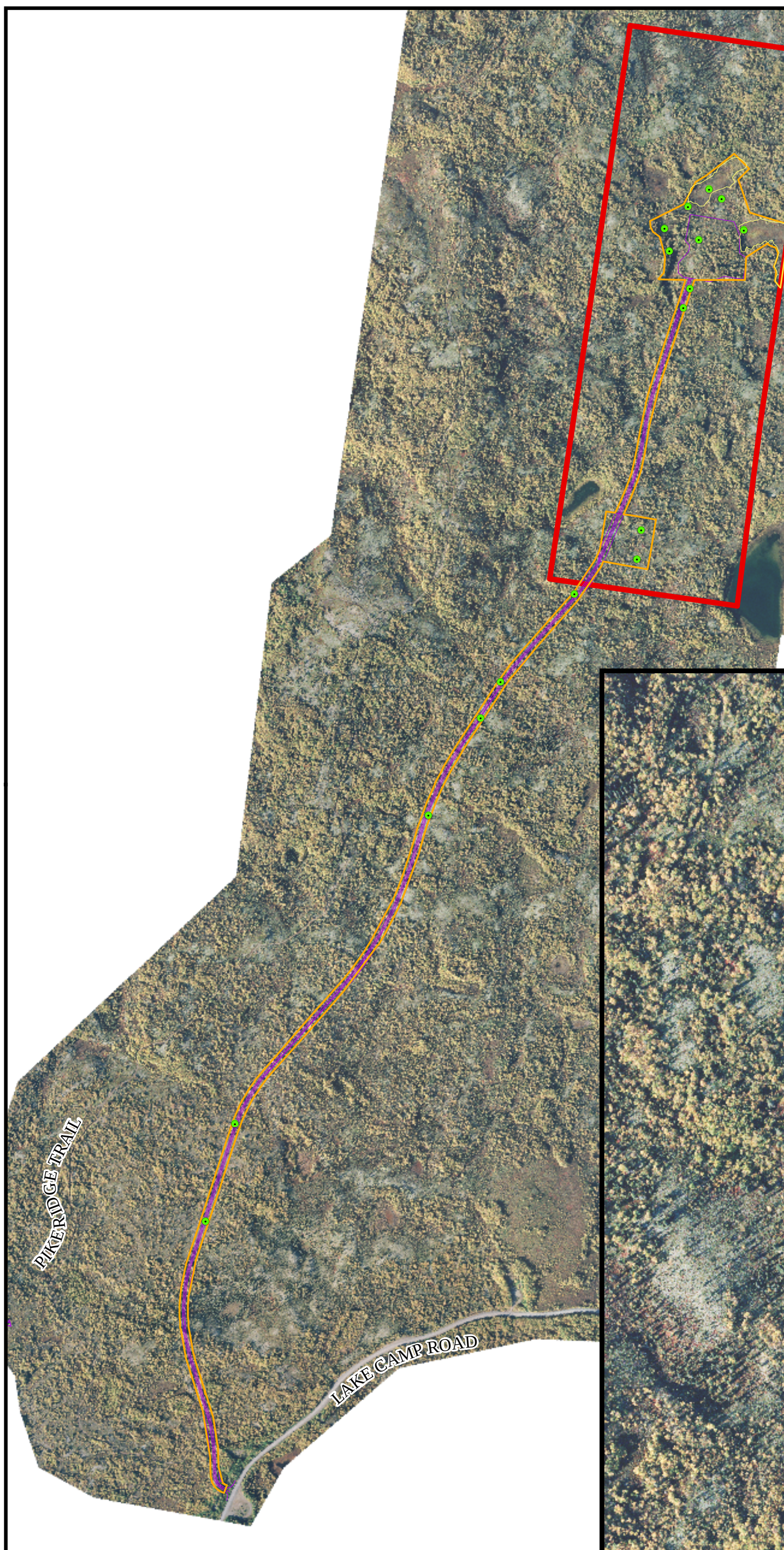
Table 1. Mapped wetlands for the proposed road corridor and geothermal drill pads near King Salmon, AK.

Wetland Types for the Proposed Road Corridor (Rev1) and Drill Pad Sites		
Wetland Type	**Description**	**Landform**
PEM1B	Saturated persistent emergent wetland	Depression, Toeslope

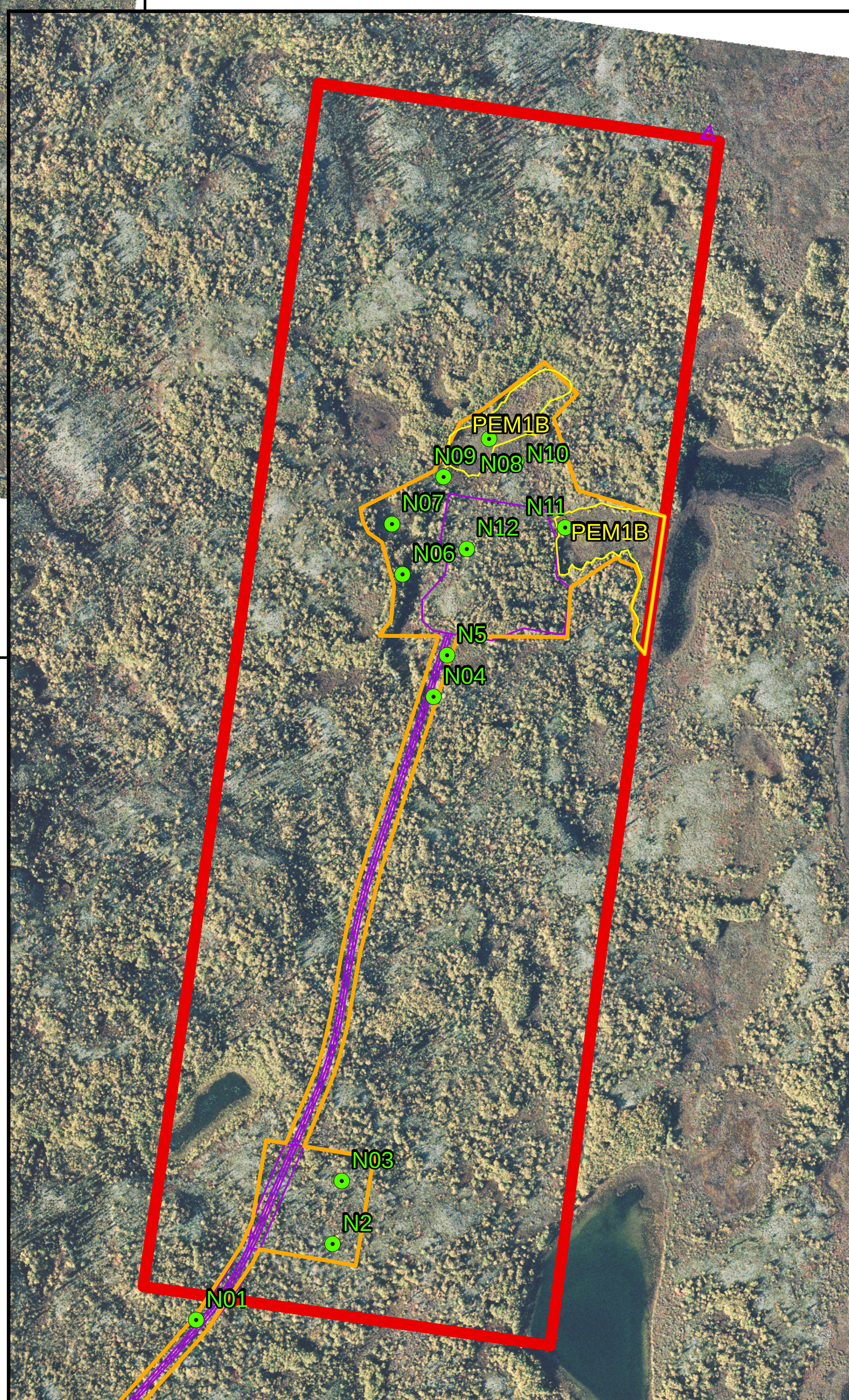
The mapped wetlands occur in persistent emergent vegetation in depressions with concave surfaces. Soils in the mapped wetlands were poorly drained with thick organic mats. Mapped wetlands were saturated with water or flooded. The mapped wetlands shown are the areas that may be subject to Corps of Engineers jurisdiction. Placement of dredged or fill material within them, or grading of soil within them, might be subject to regulation under Section 404 of the Clean Water Act.

Uplands

Areas not mapped as wetlands in the project area are assumed to be uplands because vegetation, soil, or hydrology lacks wetland indicators. Vegetation types of uplands are mainly mixed broadleaf/needleleaf woodland, broadleaf scrub/shrub thicket, and lichen tundra. These are found on ridges and terraces. Soils in uplands are well-drained, moderately well-drained, and somewhat poorly drained with thin organic mats.



Wetland Type	Description
PEM1B	Saturated persistent emergent wetland



MAP NOTES:
1. Aerial photograph taken September 2008.
2. Mapping is shown in Alaska State Plane (feet) 6, North American Datum of 1983, feet.

Feet
0 150 300 600

- Field Truth Points
- Wetlands
- Limits of Field-verified Wetland Determination & Mapping
- Road Alignment and Pad Sites (Rev1)
- NEA Property

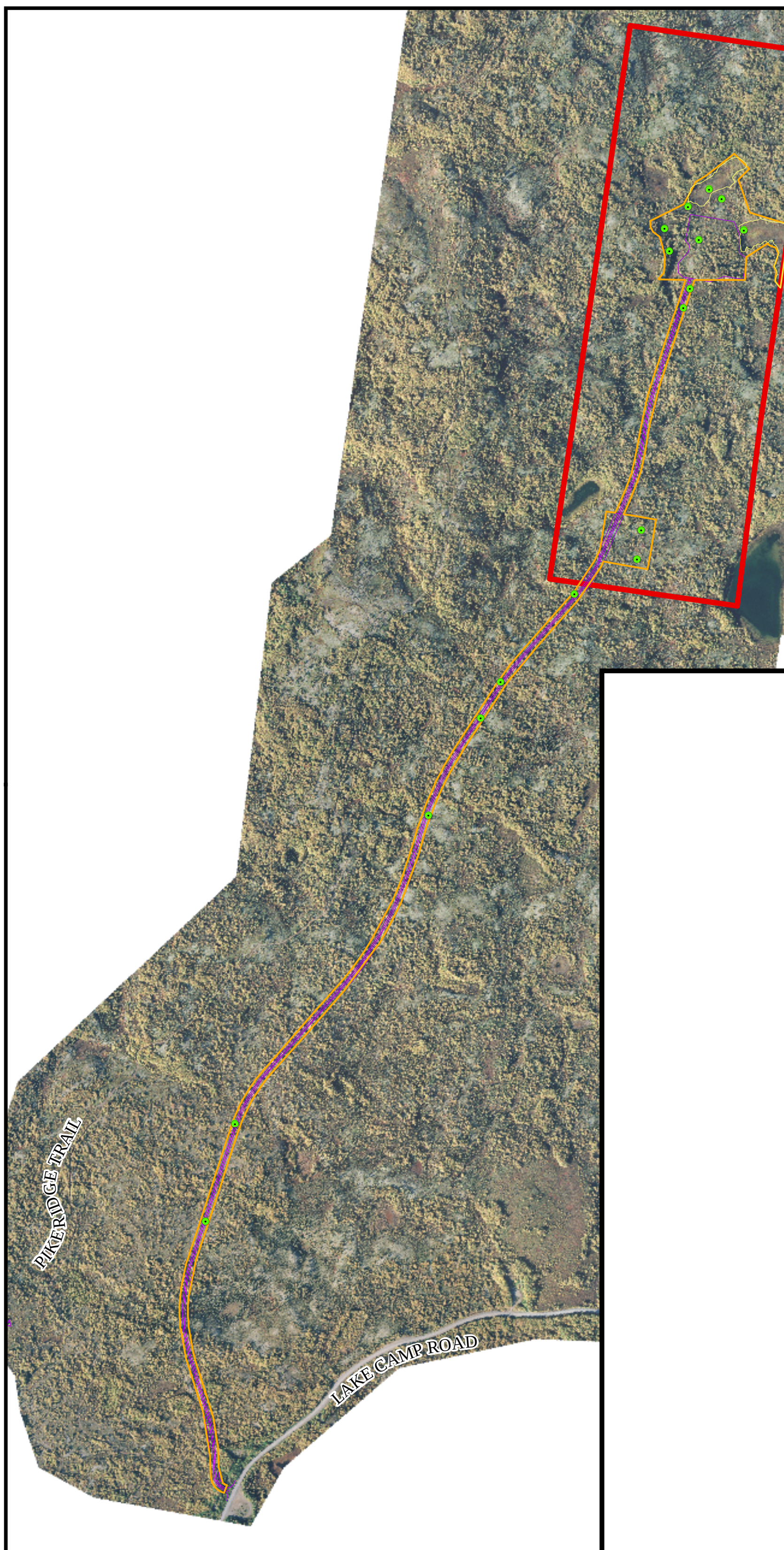
N

Wetlands

Proposed Road Corridor and Pad Site
Geothermal Project near King Salmon, Alaska
Alaska Earth Sciences

Amendment to the Office-based Wetland Determination

FIGURE 1a



Wetland Type	Description
PEM1B	Saturated persistent emergent wetland

MAP NOTES:
1. Aerial photograph taken September 2008.
2. Mapping is shown in Alaska State Plane (feet) 6, North American Datum of 1983, feet.

Feet
0 175 350 700

- Field Truth Points
- Wetlands
- Limits of Field-verified Wetland Determination & Mapping
- Road Alignment and Pad Sites (Rev1)
- NEA Property

N

Wetlands

Proposed Road Corridor and Pad Site
Geothermal Project near King Salmon, Alaska
Alaska Earth Sciences
Amendment to the Office-based Wetland Determination

FIGURE 1b

Appendix C
Agency Consultation Letters

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Department of Energy
Golden Field Office
1617 Cole Boulevard
Golden, Colorado 80401-3393

3130-1R DOE
RECEIVED
MAR 3 0 2010
OHA

March 23, 2010

Ms. Judith E. Bittner
State Historic Preservation Officer
Alaska Office of History and Archaeology
550 West 7th Avenue, Suite 1310
Anchorage, Alaska 99501-3565

No Historic Properties Affected
Alaska State Historic Preservation Officer
Date: 4/9/10
File No.. 3130-1R DOE
cjk

Dear Ms. Bittner,

The Department of Energy (DOE) is proposing to fund a geothermal project (the construction, operation, drilling, well logging, completion, and testing of two exploratory geothermal wells (G2 and G3) with associated roads, and stimulation of one well (G1, G2, or G3), if feasible) proposed by Naknek Electric Association. The project is located in Sections 14 and 23 of Township 17S, Range 44W of the Seward Meridian and can be seen on the Naknek C-2 USGS 1:63,360 quadrangle (Figure 1). Accordant to 36 CFR 800(d)(1), implementation of Section 106 of the National Historic Preservation Act (NHPA), DOE has found that no historic properties would be affected by the proposed project and recommends, following concurrence from the State Historic Preservation Officer, that the proposed undertaking be allowed to proceed.

Cumulative impacts would include future plans by Naknek, including associated construction, and drilling another two exploratory wells (six in total). If exploration proves to be feasible then a power plant and associated facilities would be constructed on the 120-acre parcel of land owned by NEA. A 1.8 mi (2.9 km) single-lane gravel road currently connects the parcel to the existing Lake Camp road to the south. Future plans include expansion of the road from 40 ft (12 m) to 100 ft (30.5 m), the width of NEA's Right of Way, to accommodate construction access and installation of a power line along the road side.

The Area of Potential Effect (APE) consists of the 120-acre parcel, formerly a Native allotment, and the 100 ft (30.5 m) by 1.8 mi (2.9 km) corridor between the parcel and Lake Camp Road (Figure 2). The land surrounding the 120-acre parcel and gravel road is undeveloped. Activities related to the construction of the geothermal power plant will be contained to the 120-acre parcel, which already contains two gravel pads, each measuring approximately 300 ft (91 m) by 350 ft (107 m).

The Native allotment was surveyed by the BIA in 1998 (Biddle 1998, enclosed) prior to its transfer to NEA. BIA archaeologists found no historic or archaeological resources on the parcel and made a recommendation of No Historic Properties Affected. In January 2010, Dr. Mark Cassell of Territory Heritage Resource Consulting conducted background research and a literature review of the project area (Cassell 2010, enclosed). Dr. Cassell's research indicates that no known or potential cultural resources can be identified within 2 mi (3.2 km) of the APE.

Based on these findings and the enclosed reports (Biddle 1998 and Cassell 2010), the DOE concludes that there are no historic properties present within the APE. We request your concurrence on our finding that the proposed undertaking will result in no effect to historic properties. If you have any questions, comments or concerns, please contact Shawna Rider at 907-334-1545 or Shawna.Rider@asrcenergy.com.

Sincerely,

Steve Blazek
Department of Energy, Golden Field Office
1617 Cole Blvd
Golden, CO 80401

Enclosures:

Section 106 Review of the Alaska Native Allotment Parcel of Rebecca M. Reeves (AA-007906, Parcel B), Located on the Naknek River, Near King Salmon, Alaska. Prepared by K. Gregory Biddle, Bureau of Indian Affairs Alaska Region. 1998

Naknek Geothermal Power Plan Cultural Resource Letter Report. Prepared by Mark S. Cassell, Territory Heritage Resource Consulting. 2010

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Anchorage Fish & Wildlife Field Office
605 West 4th Avenue, Room G-61
Anchorage, Alaska 99501-2249

In reply refer to:
AFWFO

April 8, 2009

Steve Blazek
Dept of Energy, Golden Field Office
1617 Cole Blvd
Golden, CO 80401

Re: Naknek Electric Association Geothermal Project (*Consultation number 2010-0081*)
Dear Mr. Blazek,

On March 19, 2010 we received a request for concurrence with your determination that a proposed exploratory geothermal project located approximately on private property five miles northeast of King Salmon will have no effect on species listed under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq., as amended, ESA). The Department of Energy (DOE) is proposing to fund this geothermal exploration project. If approved, Naknek Electric Association (NEA) will drill up to five wells to evaluate geothermal resources. The project will utilize existing infrastructure, including a gravel road to the area, two gravel pads, and an existing exploratory geothermal well, currently being drilled. The proposed exploration activities include site clearing, drilling, and testing of up to five additional wells. Geothermal conditions will be investigated at various depth intervals to evaluate the potential for commercial production of geothermal fluids by conventional means. If the geothermal resources are adequate, Enhanced Geothermal System (EGS) techniques will be used to stimulate the rock formation to create flow paths between wells through which water can be circulated and heated. Stimulation of one well and drilling of up to five additional geothermal wells will establish the components to set up a convective hydrothermal system.

If the geothermal resource is determined to be of sufficient size and temperature to make a generation facility feasible, the project will ultimately expand to include a power plant, switch yard, and a tie into the current NEA energy grid. The current proposal includes only well drilling and stimulation and does not include development of the power plant, transmission lines, and other associated facilities. Impacts to ESA-listed species from development of energy production facilities will be evaluated after energy generation has been determined to be feasible.

Our records indicate that the following species, listed under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq., as amended), may be found in the vicinity of the project area: the North American breeding Steller's eiders (*Polysticta stelleri*, listed as threatened in 1997); spectacled eider (*Somateria fischeri,* listed as threatened in 1993); Kittlitz's murrelet (*Brachyramphus brevirostris* listed as a candidate species in 2004); and the yellow-billed loon (*Gavia adamsii*, listed as a candidate species in 2009). Steller's eiders winter in south-central and southwestern Alaska and they breed in northern Alaska. These birds migrate through Bristol Bay en route to and from breeding and wintering grounds, and can be found in coastal marine areas near Naknek and King Salmon during migration and molting in spring and fall. They do not use upland habitat during these periods but individuals may fly over the uplands. This project is not expected to obstruct the flight path of birds through area. The spectacled eider, Kittlitz's murrelet, and the yellow-billed loon may potentially move through the area from time to time, but occur so infrequently that projects in this area are expected to have no effect on them. As a result, the Service concurs with your determination that the proposed action will have no effect on listed species.

In view of this, requirements of section 7 of the ESA have been satisfied. However, obligations under section 7 of the ESA must be reconsidered if new information reveals project impacts that may affect listed species or critical habitat in a manner not previously considered, if this action is subsequently modified in a manner which was not considered in this assessment, or if a new species is listed or critical habitat is determined that may be affected by the proposed action. If the proposed project changes, please contact us again to verify there is no effect on listed species or critical habitat.

For more information on the distribution of threatened and endangered species and the consultation process in Alaska, please see the US Fish and Wildlife Service Threatened and Endangered Special Consultation Guide, available on-line at: http://alaska.fws.gov/fisheries/endangered/consultation_guide.htm.

This information relates only to federally listed or proposed species, and/or designated or proposed critical habitat, under the jurisdiction of the US Fish and Wildlife Service. This letter does not address species under the jurisdiction of the National Marine Fisheries Service, or other legislation or responsibilities under the Fish and Wildlife Coordination Act, Clean Water Act, National Environmental Policy Act, Marine Mammal Protection Act, Migratory Bird Treaty Act, or Bald and Golden Eagle Protection Act.

Thank you for your cooperation in meeting our joint responsibilities under the ESA. If you have any questions, please contact me at (907) 271-2066 and refer to consultation number 2010-0081.

Sincerely,

Kimberly Klein

Kimberly Klein
Endangered Species Biologist

Appendix D
Induced Seismicity Report

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Final Report

Evaluation of the Environmental Impacts of Induced Seismicity at the Naknek Geothermal Energy Project, Naknek, Alaska

Prepared for
ASRC Energy Services Alaska, Inc.
Regulatory & Technical Services
2700 Gambell Street, Suite 200
Anchorage, AK 99503

12 May 2010

Prepared by
Michael Andrew Hasting
Seismic Consultant
648 La Paloma
Ridgecrest, CA 93555

Table of Contents

List of Figures: Page

Acronyms and Abbreviations

μ	Rock Rigidity
AES AK	ASRC Energy Services Alaska, Inc.
AEIC	Alaska Earthquake Information Center
EGS	Enhanced Geothermal System
gpm	Gallons per minute
ka	Thousand of years ago
Ma	Million of years ago
M_b	Body wave Magnitude
M_d	Coda Magnitude
M_L	Richter Local Earthquake Magnitude
M_O	Seismic Moment
MT	Magnetotellurics
M_W	Moment Magnitude Scale
MEQ	Micro-Earthquake
MMI	Modified Mercalli Intensity Scale
NEA	Naknek Energy Association
NEIC	National Earthquake Information Center
NEPA	National Environmental Policy Act
NGEP	Naknek Geothermal Energy Project
PDE	Preliminary Determination of Epicenters
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
PSHA	Probabilistic Seismic Hazard Analysis
USGS	United States Geologic Survey

1.0 Introduction

At the request of ASRC Energy Services Alaska, Inc, Regulatory & Technical Services (AES AK), the following report presents the evaluation for the environmental impact due to induced seismicity of an Enhanced Geothermal System (EGS) near King Salmon, Alaska. This study is part of Environmental Assessment (DOE/EA-1759) being prepared by the U.S. Department of Energy, in accordance with the National Environmental Policy Act (NEPA) of 1969. The potential for induced seismicity at EGS sites has been identified as a possible environmental impact and as such this report presents the Naknek Geothermal Energy Project (NGEP) area and the possible impact of induced seismicity from EGS operations to the surrounding area.

The NGEP site is a new geothermal prospect and as such little is known about the induced seismicity in the region and the potential risks associated with an EGS project in this region. Also, due to the poor seismic station coverage of the area the seismic catalogues for the region around the NGEP site are incomplete, and as such make it hard to determine the true local seismicity and seismic risk for the region.

For this report to determine the potential for induced seismicity due to injection testing of the Naknek G1, G2 or G3 wells, here after referred to as “the NGEP site”, the geological setting of the area, known faults, and the seismicity catalogues from both the USGS, and Alaska Earthquake Information Center (AEIC) event catalogues were collected. This report applies known equations to calculate the maximum expected event during the injections testing at the NGEP site and related this to ground shaking in the region and their impact to local residents and key structures in the area.

1.1 Scope of Work

The following tasks have been performed as part of this study:

Task 1. Review of available geological and seismic data relevant to the NGEP site.

Task 2. Evaluation of the historic and regional seismicity of the region at various distance and magnitude ranges.

Task 3. Estimate Attenuation Models for the NGEP Site

Task 4. Assess the potential for local resident disturbance and property damage from ground shaking as a result of induced seismicity.

Task 5. Prepare a final report describing the results of these analyses.

2.0 Geological/Seismotectonic Setting and Faults

The following section describes the geological/seismotectonic setting of the region and known faults near the well sites and surrounding region. Much of the geological information is from the Ellis (2009) report provided to NEA.

2.1 Geological/Seismotectonic Setting

There are several tectonic elements present in this region that form the basis of the geologic framework around the NGEP site. The Bristol Bay basin lies in a back-arc tectonic setting bounded on the south by the Alaska Peninsula, and associated active volcanic arc, the result of the active subduction along the northeast-trending Aleutian trench (Ellis, 2009), Figure 1. In the Naknek lake area, the geology mapped immediately north and east of the moraine covering the project area are Meshik age mafic volcanics. Along the east side of Naknek Lake, they are sitting unconformably on lower Jurassic Talkeetna formation sediments, and volcaniclastics. The Talkeetna is considered the basement along with some older Triassic metamorphics. The basement has been intruded extensively by mid-Jurassic granitic bodies and locally by mid-Tertiary granitic bodies.

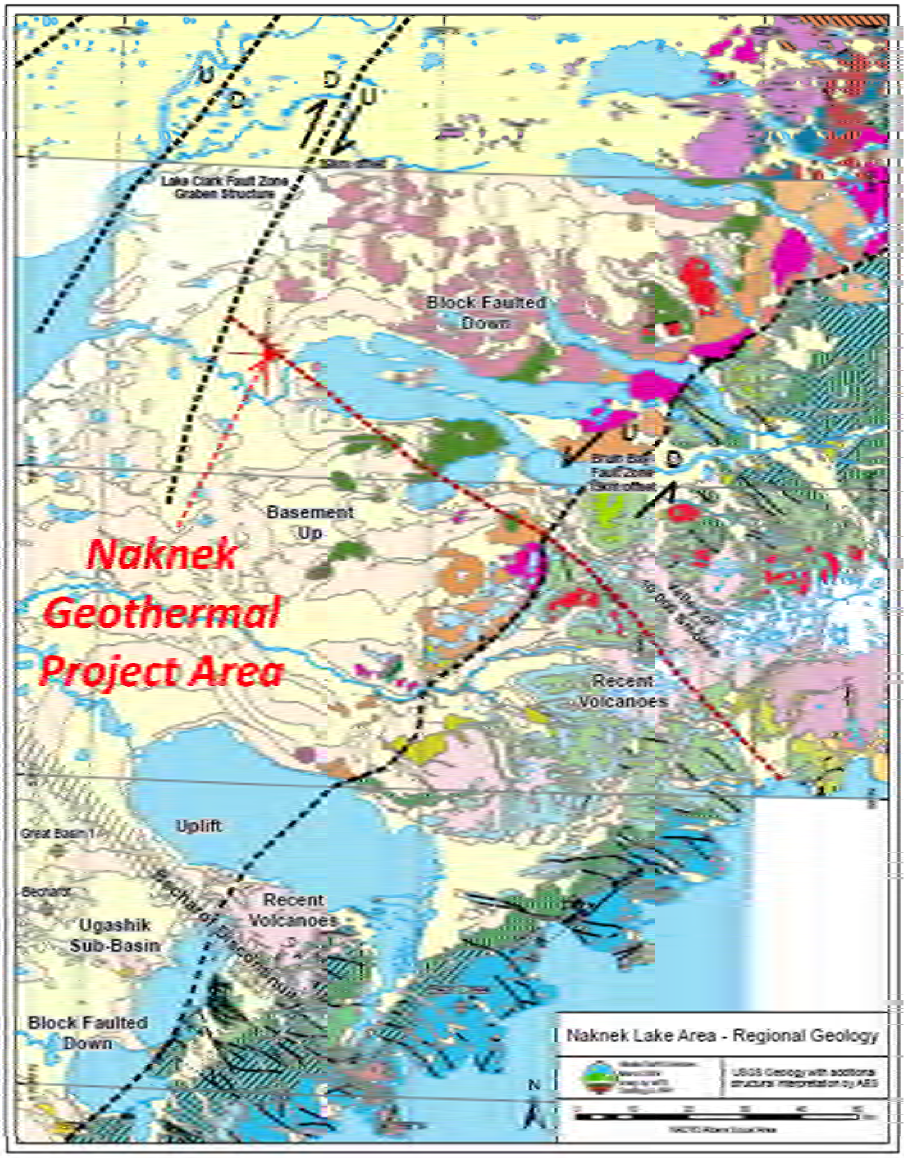

Figure 1, Geological Map of the Region (Ellis 2009)

In the Ugashik Lake area, ~150km south of Naknek Lake area, various seismic studies and boreholes document an approximate 3 km thick sub-basin that is flanked on the south by a thick Meshik volcanic center (Decker et al, 2008). The sub-basin is filled with marine to non-marine locally coaly sediments of the Stepovak Formation (Meshik volcanics age-equivalent) sitting on Jurassic or older crystalline basement overlain by younger Bear Lake and Milky River Formation, Figures 2 and 3.

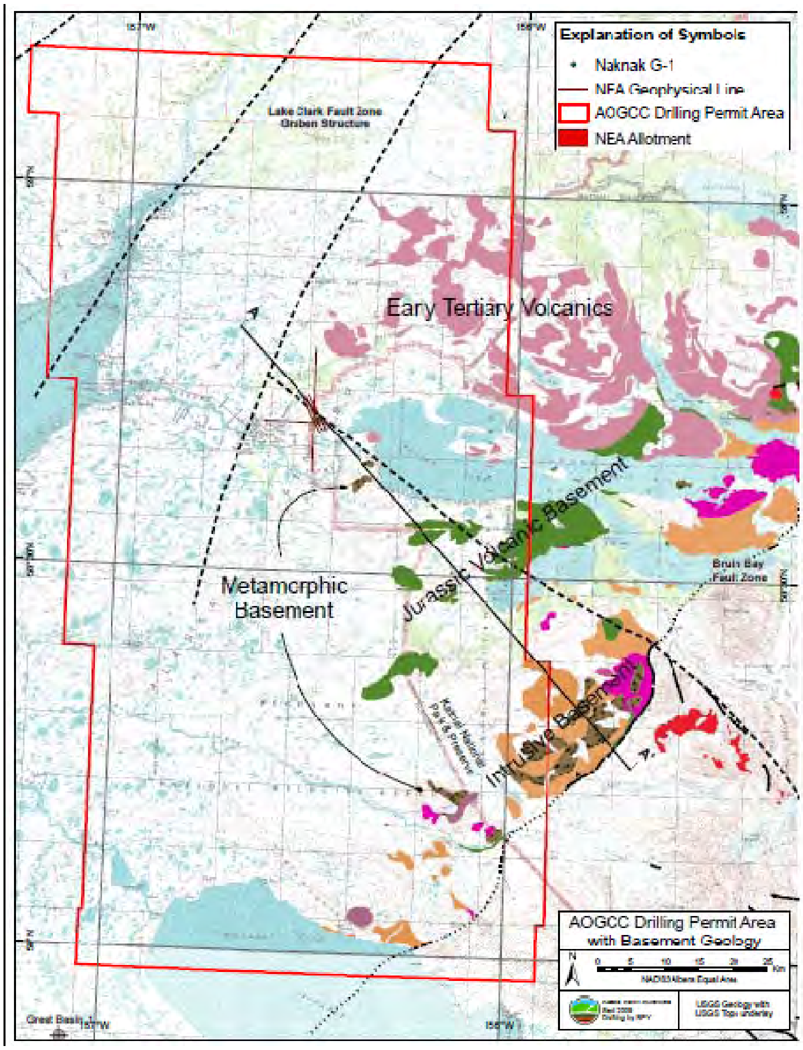

Figure 2, Geological Map of Local Area (Ellis, 2009)

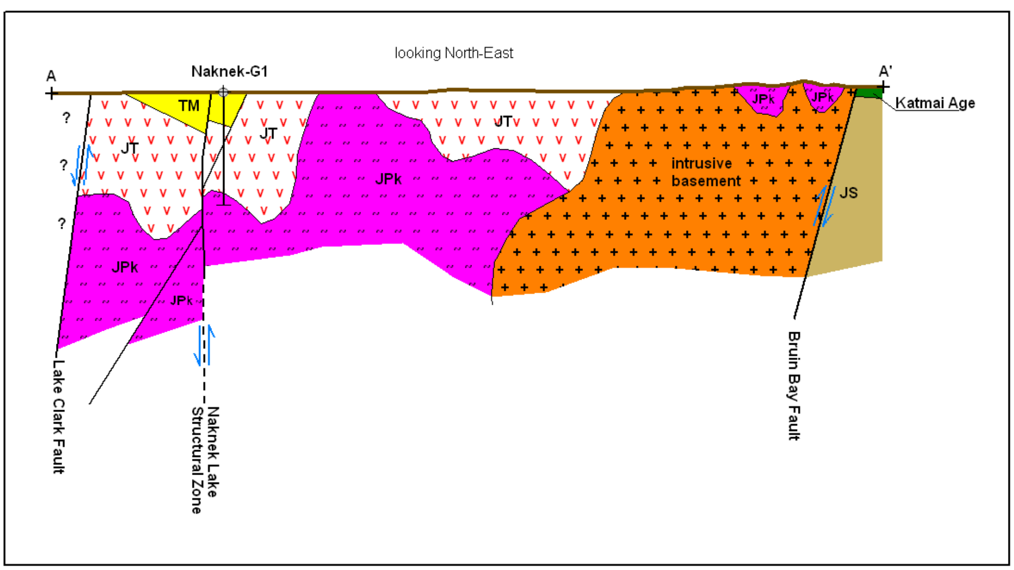

Figure 3, Cross section from Figure 2, A to A' view looking northeast (Ellis, 2009)

North-vectored convergence throughout the Tertiary has created a series of northwest fault zones that are perpendicular to the arc that have accommodated differential subsidence. These zones have created sub-basins and Eocene-Oligicene (Meshik age) volcanic highs. A series of northwest trending fault structures and very young Holocene dikes are present south of a sharp bend in the Bruin Bay Fault in the Valley of Ten Thousand Smokes (the center of the famous eruptive event at the beginning of the last century). This northwest trend strikes into the Pikes Ridge study area and is strikingly analogous to the Ugashik Lake study area that predicted the basinal development to the south and uplift to the north at a northwest bend in the Bruin Bay fault complete with a recent volcano. Ellis (2009) argues that a northwest trending bounding structure has an uplifted basement on the south and down-dropped and preserved the Meshik volcanics to the north. That interpretation is corroborated by the apparent break in the geophysical signature along MT line 4 at ~ 9500N which can be interpreted as bringing the basement up on the south end of the line, Figure 4.

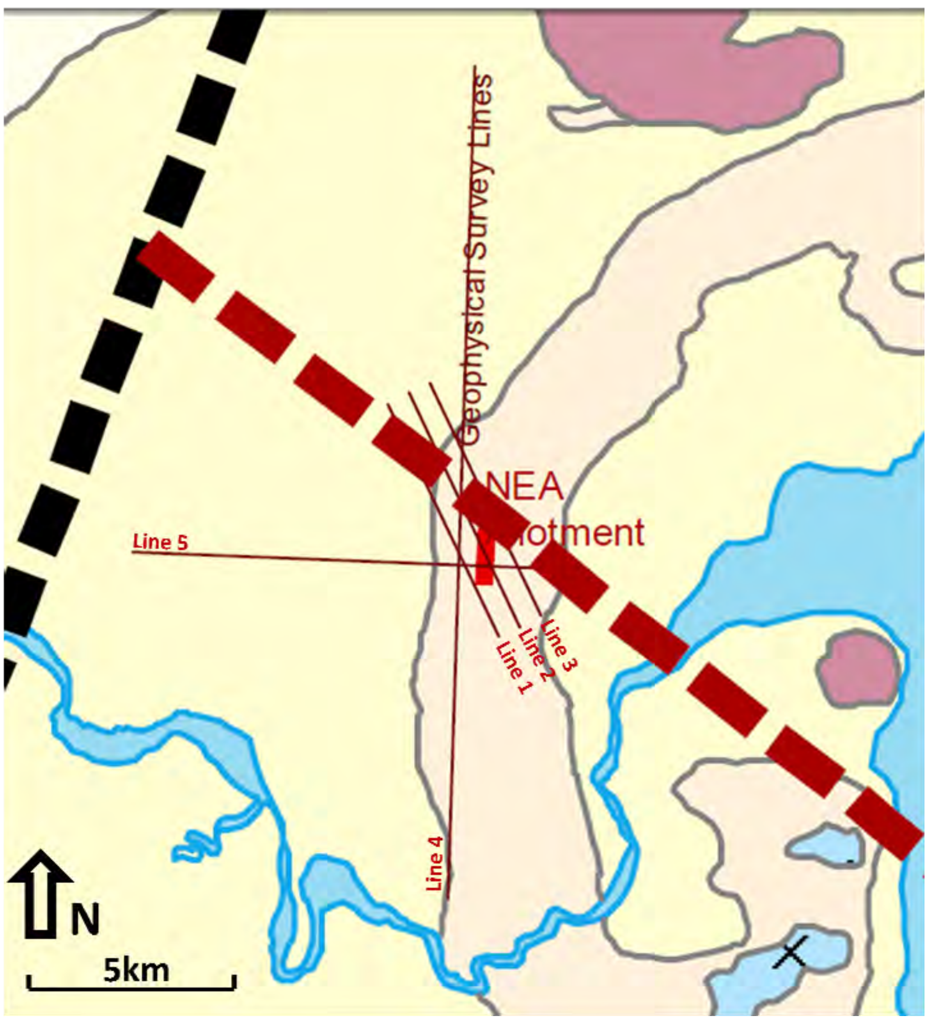

Figure 4, Location of Geophysical Line, solid red lines, Interpreted Fault or Dike, red, dashed Line.

The Meshek volcanics exhibit a noisy magnetic signature and have variable conductivity. They appear to thicken from 0 on line 3 & 4 to ~ 1 km thick and dip gently to the south and east. Several conductive breaks are present on line 4 that could be interpreted as northwest trending block faults with a thickening basin (Stepovak sediments below Meshik volcanics) developing to the north of 9500 on line 4, Figure 4.

There is another distinctive north-northwest trending feature observed on several of the geophysical lines, Figure 4. It is a distinctive 300-400m wide, magnetic, shallow (<200m) resistive dike-like feature that extends through the entire survey area. At 5000W on line 5 it domes the conductive unit, on line 2 it is at 5000NW, and on line 4 it is at 12,400N.

2.2 Faults

There are two major northeast-trending bounding fault zones in the region, the Bruin Bay and the Lake Clark fault systems, Figure 1. The Bruin Bay fault is located along the crest of the Aleutian Range to the southeast, and is the most seismically active, while the Lake Clark fault system is located to the northwest. Both of these regional faults converge in upper Cook Inlet where they are named the Castle Mountain fault system.

The Bruin Bay fault represents a major, long-lived, tectonic boundary that has accommodated crustal-scale stresses generated by the subduction of oceanic lithosphere beneath the continental North American plate since Middle to Late Jurassic time (Gillis, R. et al., 2008). The Bruin Bay fault exerted a fundamental control of the forearc basin structure of the region (Gillis, R. et al., 2008). This fault extends along the west side of the Cook Inlet from near Mount Susitna to the northeast and extends southwest to Becharof Lake, about 515 km. The sense of displacement is reverse and bedded rocks in the downthrown block which are commonly upturned against the fault. Less than 10 km of sinistral displacement is inferred along several places of the fault (Detterman and Hartsocks, 1966). A review of the seismic catalogues, to be discussed later in this report, shows this is an active fault and produces thousands of earthquakes per year.

The Lake Clark fault is a graben-like extensional structure ~225 km long striking northeast. It is predominately a reverse fault that is along the strike from the Castle Mountain fault and is located on the northwest side of the Cook Inlet (Detterman et al., 1976a). Using aeromagnetic data Haeussler and Saltus (2004) show up to 26 km of right-lateral displacement has occurred along the Lake Clark fault in the past 34-39 Ma. The Bruin Bay fault system has as much as 3 km reverse motion (up-to-northwest) and 19 km of left-lateral displacement along it. The age of displacement is mainly Late Tertiary based on an offset of the 38 Ma old quartz monzonite near Lake Clark and juxtaposition of Miocene strata against Eocene beds on the Chuitna River; however, there is no evidence of Holocene movement (Dettermann and Hartsocks, 1966).

Detterman et al. (1976b) estimated the northwest-side-up vertical offset on the fault as 500–1000 m on the basis of the juxtaposition of the late Miocene Beluga Formation with the early Eocene West Foreland Formation west of Tyonek. Plafker et al. (1975) found no evidence for vertical Quaternary movement, but found 561 km of net post–late Eocene dextral slip. In contrast, Schmoll and Yehle (1987) reported some evidence for Pleistocene, but not Holocene, movement on the fault. Schmoll and Yehle (1987) referred to a 6-km-long to 25- m-tall, south-facing scarp along the Lake Clark fault as the Lone Ridge fault. They found that it appears to offset three Quaternary moraines in a northwest-side-up sense, but the youngest moraine, dated as ca. 15 ka, was not offset. A review of the seismic catalogues, to be discussed later in this report, shows this is a relatively inactive fault over the past few decades but still should be considered an active fault.

Ellis (2009) also shows a possible northwest to southeast trending fault, or dike, that crosses the local area just north of the NGEP site, approximately 500m, and terminating at the Lake Clark Fault Zone, Figures 1 through 4. This possible fault is interpreted from magnetic data, and does not show any surface manifestations. Since this fault does not cross the Lake Clark Fault Zone it may be an old, non-active, fault that has been offset by the Lake Clark Fault but could be of concern during the stimulation process due to its proximity to the NGEP.

3.0 Alaska Historical Seismicity

This section covers the background seismicity for the area dating back to 1890's up to the present. This report compiled data from both the USGS National Earthquake Information Center (NEIC) and the Alaska Earthquake Information Center (AEIC) catalogues and used Google Earth Pro to plot these events.

3.1 Overview

Alaska is the most seismically active state in the USA and the site of the second-largest earthquake ever recorded, the 1964 magnitude M_w9.2 earthquake in Prince William Sound. This earthquake killed 132 people, more than the recent Loma Prieta and Northridge earthquakes combined, and generated a tsunami that killed people as far south as California. The subduction of the Pacific Plate created both the string of volcanoes known as the Aleutian mountain range and the associated Aleutian trench. The collision of the Pacific plate with Alaska produces over 20,000 locatable earthquakes in Alaska each year that are recorded and located by the AEIC. However the area around the NGEP site is poorly covered by the Alaska Seismic Network and as such the catalog of seismic events for this area is minimal. The minimum magnitude threshold for the area is about a M_L2.5 with a location and accuracy of about 10 km. Figure 5 shows a plot of all seismic activity along the Aleutian area centered on the NGEP site since 1990. Figure 5 shows that deeper events occur continuously to the north-west where the Pacific Plate is subducting beneath Alaska.

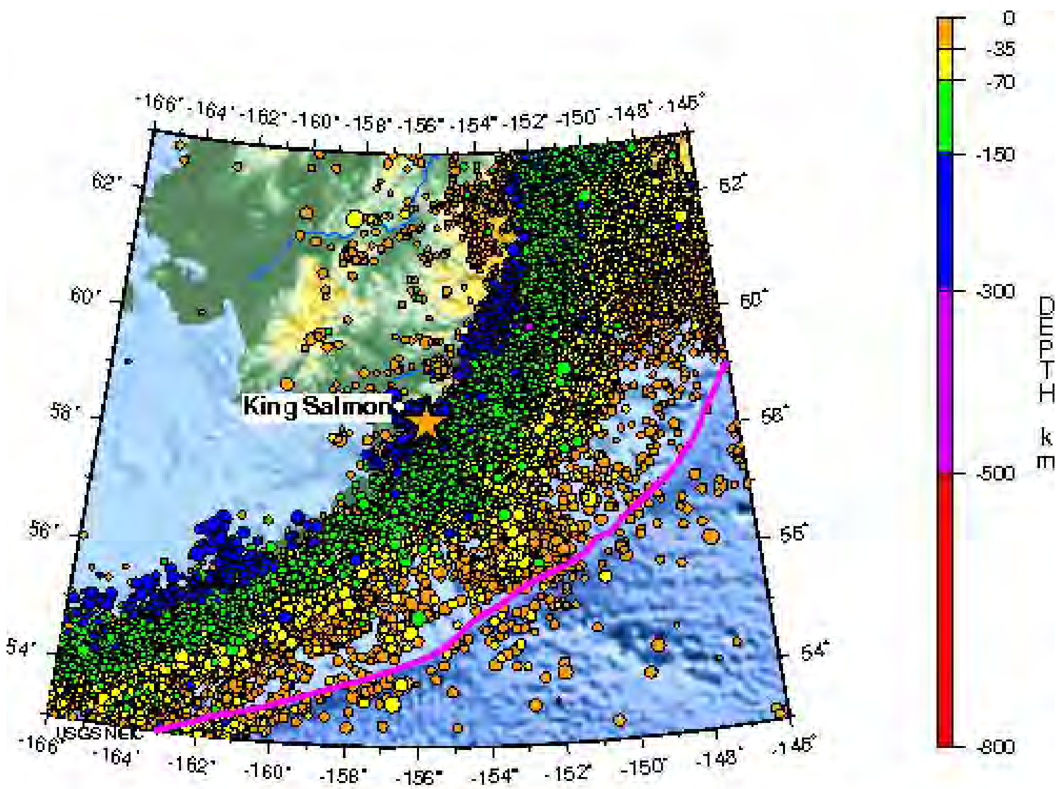

Figure 5, Plot of all seismic events occurring in Alaska since 1990 color coded to depth. This plot is from the USGS National Earthquake Information Center (NEIC) website in Golden CO.

3.2 Large Historical Alaska Events

Besides the 1964 Prince William Sound event there have been over 280 earthquakes registering a Magnitude 6 or higher since 1899 recorded within 1000 km of the NGEP site. Figure 6 is a plot of these events and shows that most of these events are occurring along the subduction zone; those events that occur inland take place at great depth along the subducting slab. Figure 7 shows a generalized cross section view of a volcanic arc system associated with a subduction zone and the development of the various features associated with such plate boundaries.

Figure 6, Magnitude 6.0 and Higher, 1899 to present, data from the USGS NEIC event catalog.

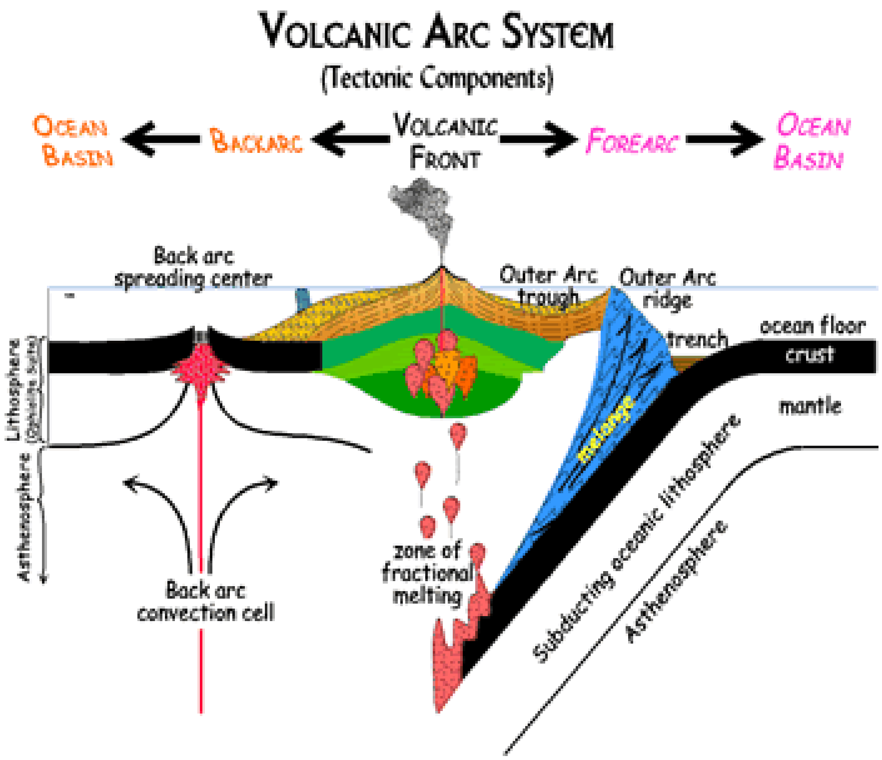

Figure 7, Generalized cross section of a volcanic arc system associated with a subduction zone, image from USGS, http://earthquake.usgs.gov/learn/glossary/?term=forearc

3.3 Regional Events

Regional events examined in this study were collected using a circular search pattern out to 250 km from the NGEP site; over 5500 events of M_L >2.5 occurred since 1970 with over 300 events taking place within 100 km of the NGEP site. Most, if not all, of the events occurring within the 100 km radius of the NGEP site have hypocentral depths of over 150 km, indicating they are occurring in the subduction zone. Figures 8, 9 and 11show plots of these events as located by various seismic networks and reported to the USGS. Also provided are 3D views, Figures 10 and 12 are 3D views of the data showing the depth of seismic activity under the NGEP study area. Views are looking obliquely towards the northeast along strike of the subduction zone.

Many of the events in Figures 8, 9 and 11 occur south of the NGEP site under Becharof Lake, approximately 90 km away. The largest seismic event in the Becharof Lake area was a M_L5.4 that occurred in 1998; there were over 18 events with a magnitude M_L4.0 or larger in this area between May 9th and June 4th. Figures 10 and 12 shows that many of these events have a reported depth 0 to 1 km depth, however the location quality for these events is reported in the C and D categories where A is the best location error, i.e. less than ~500m location error. As such while the events did occur the depths and locations can be off by several kilometers. This 1998 swarm was associated with magma intrusion beneath Mount Peulik, detected via InSAR, which may have triggered the swarm (Lu et al., 2002).

Figure 8, 250km ring of events, data from the USGS NEIC and AEIC Online Seismic Catalogues. Blue Dots = NGEP, King Salmon and Naknek

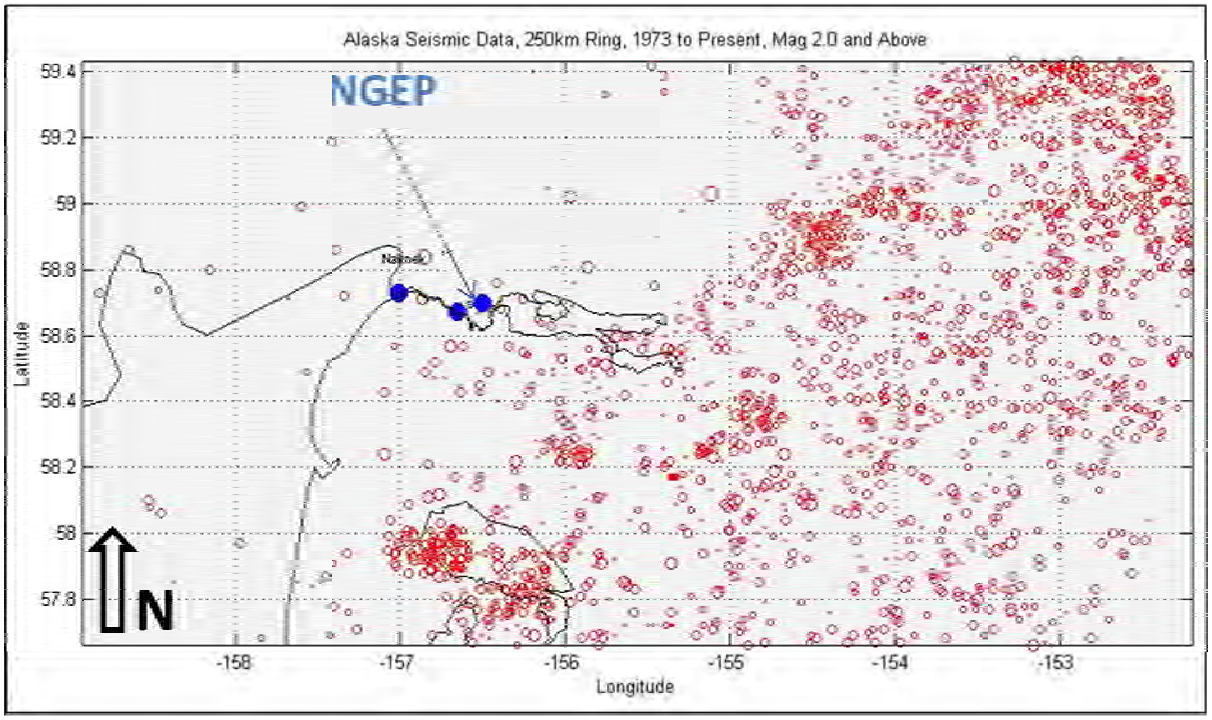

Figure 9, Zoomed area from Figure 8.

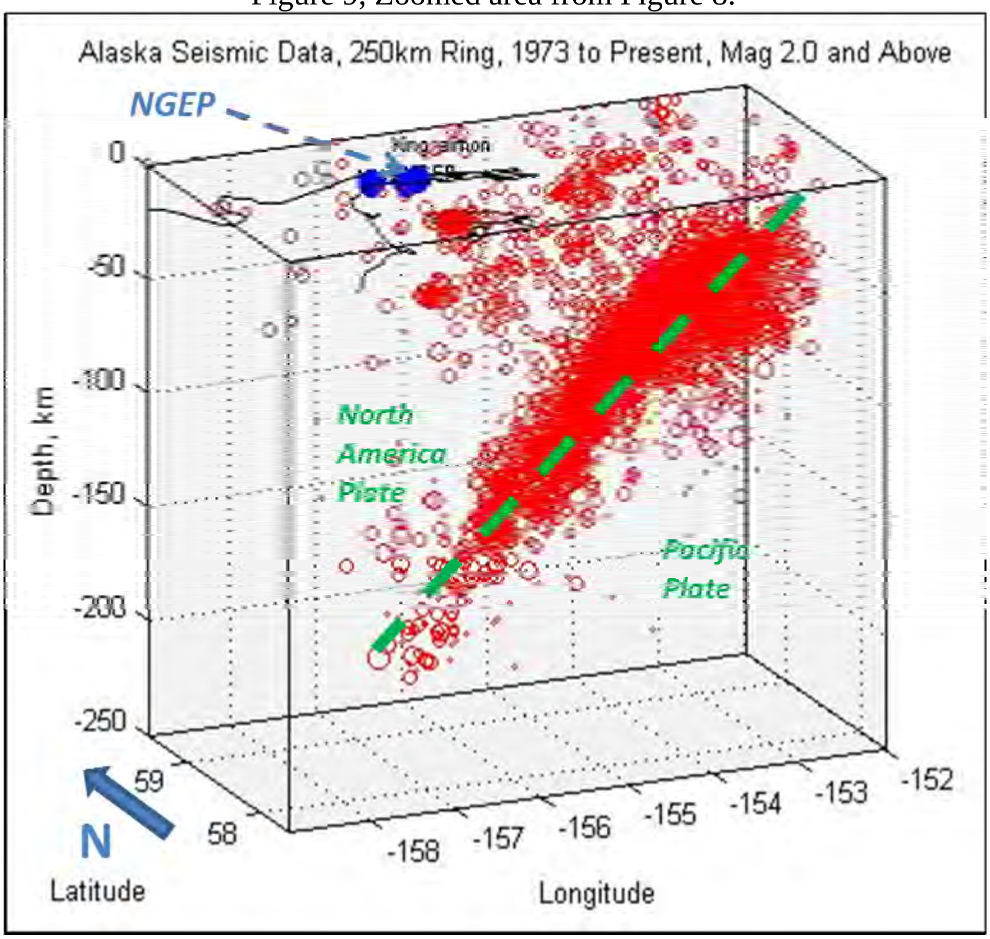

Figure 10, Oblique 3D view of Figure 9, view looking northeast, along strike of plate boundary.

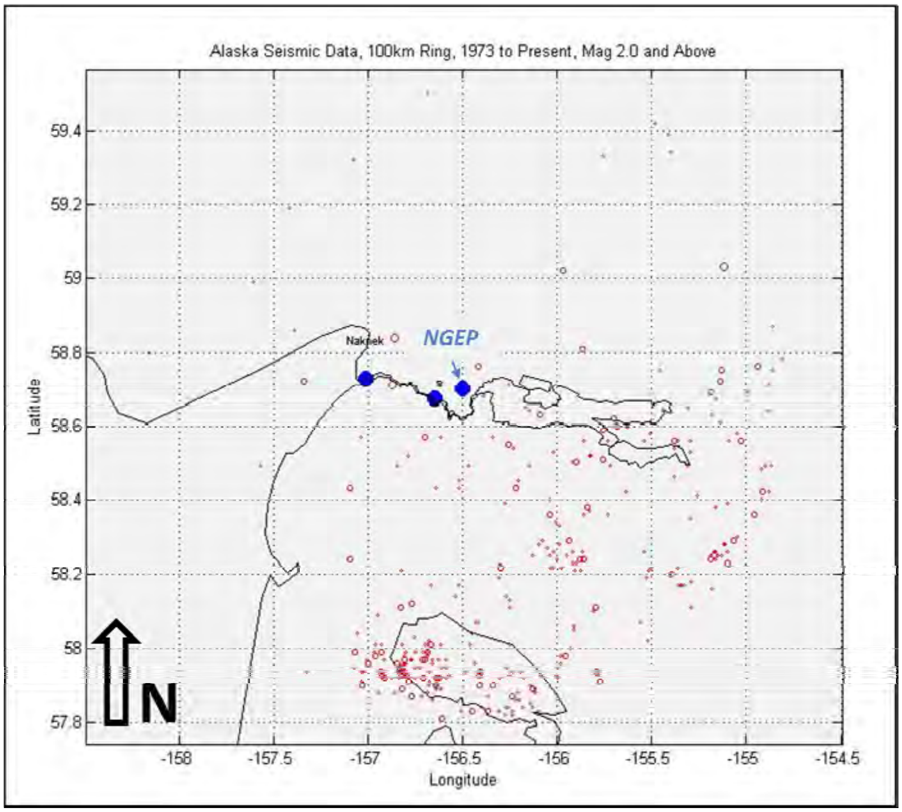

Figure 11, 100km ring events, data from the USGS NEIC and AEIC Online Seismic Catalogues.

Figure 12, Oblique 3D image of Figure 11, view looking northeast along strike of plate boundary.

3.4 Local Seismic Events

Between 1973 and April 20th 2010 only 12 events occurred within 20km of the NGEP site, Figure 13. All of these events had a focal depth of over 150km and a maximum magnitude of M_L4.6 which occurred on the 19th of November 1984. Table 1 is a list of these events as catalogued by the NEIC Preliminary Determination of Epicenters (PDE) database. Most of these events were felt by the local communities of Naknek, South Naknek and King Salmon and according to local people caused little to no damage (personal conversation with locals). Again, it should be noted that due to the poor seismic station coverage in this region the locations of the events plotted in Figure 13 can be off by tens of kilometers. This location uncertainty is primarily due to having only a few seismic phase stations to locate the event since most of the stations being used to locate the events are east of the NGEP site.

Figure 14 shows the location of all AEIC seismic stations in Alaska. The closest seismic stations are located approximately 70km east of the NGEP site in the Katmai National Park along the Bruin Bay fault. Because of the large station spacing the program uses to locate earthquakes, large correction factors are applied and the system can only locate seismic events in the NGEP area to within tens of kilometers with any certainty. Depending on the velocity model used by the program, events can also have a large station residual, or error, due to the uncertainty in the velocity structure of the region and distance between the stations. Since there are few stations in the region, and seismic signals decay as a function of $1/r^3$, more events less than M_L3.0 may have occurred in the region that were not detected by the AEIC seismic network and as such are not in the catalogue. Based on a review of the catalogues of the seismic data set for the region around the NGEP site the “completeness” for earthquakes greater than aM_L3.0 in size, can be seen in Table 1, as compared to M_L2.0 near the Bruin Bay fault in Katmai National Park. Therefore, the events as plotted in Figure 13 may not represent a complete list of the actual seismicity rate for events less than M_L3.0 in the area around the NGEP site.

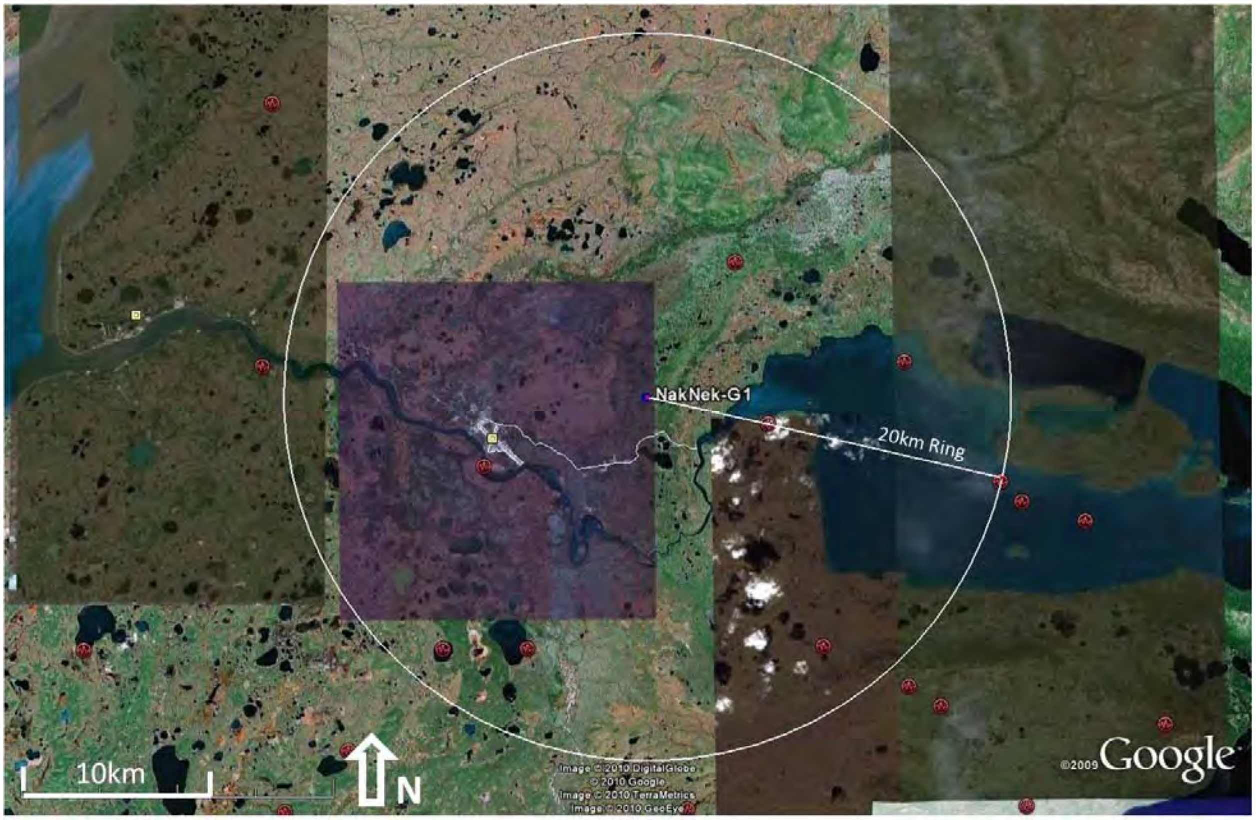

Figure 13, 20km ring around the NGEP site, white circle, event locations are the red circles, data from the USGS NEIC and AEIC Online Seismic Catalogues.

Figure 14, All NEIC seismic stations in Alaska

NEIC: Earthquake Search Result

U. S. GEOLOGICAL SURVEY
EARTHQUAKE DATA BASE

FILE CREATED: Fri Apr 23 23:03:20 2010
Circle Search Earthquakes= 12
Circle Center Point Latitude: 58.699N Longitude: 156.504W
Radius: 20.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data

CAT	YEAR	MO	DA	ORIG TIME	LAT	LONG	DEP	MAGNITUDE	IEM NFO TF	DTSVNWG	DIST km
PDE	1984	11	19	004427.22	58.57	-156.70	205	4.6 mbGS	2F.	....	18
PDE	1990	06	12	134717.11	58.71	-156.26	204	3.6 mbGS	...	....	14
PDE	1995	01	08	025320.65	58.72	-156.25	201		...	....	14
PDE	1995	06	19	144432.35	58.57	-156.62	192	3.9 mbGS	...	....	15
PDE	1995	10	29	024009.76	58.68	-156.17	175		...	....	19
PDE	1996	07	11	145427.50	58.67	-156.53	180		...	....	3
PDE	1998	11	12	200934.94	58.69	-156.72	202		...	....	12
PDE	2001	03	24	033147.53	58.57	-156.34	172	3.0 mbGS	...	....	17
PDE	2004	01	13	215554.69	58.66	-156.66	198	4.2 mbGS	...	....	10
PDE	2004	10	19	064129.07	58.69	-156.45	195		...	....	3
PDE	2006	03	25	093810.78	58.76	-156.42	191	4.2 mbGS	...	....	8
PDE	2007	10	31	103758.37	58.68	-156.39	212	3.2 UKAEIC	...	....	6

Table 1, Historical and Preliminary Data from the USGS NEIC PDE for a 20km circular search around the NGEP site, 1973 to Present. Note that not all events have a Magnitude assigned, indicating these were poorly located. Far Right Column is the approximate epicentral distance from the actual NGEP location.

4.0 Induced Seismicity

As noted in the Introduction, the Naknek Geothermal Project is the first geothermal well to be drilled in this part of the World. As such there are no records of Induced Seismicity in this region. No history can be presented at this time, therefore this report reviews Causative Mechanisms of induced seismicity, as they relate to geothermal wells, the "Predicted" induced seismicity, and the maximum earthquake size for the Naknek Geothermal Energy Project.

4.1 Causative Mechanisms

Greensfelder and Parsons (1996) concluded that there are multiple causes of induced seismicity in a geothermal field. They involve both increases and decreases in the reservoir rock strength caused by the changes in confining pressure, i.e. the normal stress across cracks, or in the coefficient of friction. These increases and decreases would be due to the injection of fluids into the fracture system under pressure that can weaken the rock and apply differential stress in local areas.

According to Greensfelder and Parson (1996), during steam withdrawal, induced seismicity may be caused by an increase in rock strength and then a decrease in rock strength during water injection. These seem contradictory but appear to operate independently over distinct reservoir volumes out to about 1km from a well (Greensfelder and Parson, 1996). One can assume that during fluid withdrawal fractures are closed and the rock is strengthened due to the increase in the friction along preexisting fractures. These fractures can support higher stress levels which would then lead to a seismic event upon failure or slip. During fluid injection fractures can be lubricated and as such cannot support high stress levels and slip much easier, which may not be recorded by the seismic network or may even slip aseismically. However, Rutquist and Oldenburg (2007) point out that the most important cause for injection-induced seismicity is due to the cooling and the associated thermal-elastic shrinkage that alters the rock's stress state causing mechanical failure of the rock. The cooling of the local rock causes shrinkage due to the thermal coefficient of expansion of the rock, thus inducing an unloading and a loss of shear strength of the rock. Rutquist and Oldenburt (2007) modeling for The Geysers shows an agreement with observations that most of the injection seismicity occurs near injection and production wells and can spread several kilometers below injection wells. The deeper seismicity may be due to both thermal-elastic cooling and increased pore pressure in the rock at depth.

4.2 Predicted Induced Seismicity at the NGEP Site

If injection or stimulation is conducted at the NGEP site, it would be difficult to estimate the level of induced seismicity since the physical properties and the state of current stress levels in the rock at depth are unknown. Currently a temporary ten station micro-earthquake (MEQ) network has been deployed around the NGEP site to record the "background" seismicity in the region with much greater resolution than the AEIC network currently provides. Figure 15 shows the layout of this temporary network around the NGEP site. The MEQ network should provide a detection threshold level of about $M_L0.5$ for the NGEP area. This network will be deployed for up to six months to evaluate the baseline level of seismic activity around the NGEP site, and to measure the naturally occurring background seismicity prior to any injection testing. This network would also help to determine if any induced seismic events are occurring during the drilling and/or cementing process of the casing, as was seen in Basel, and most recently at the

Paralana-2 borehole in South Australia. Based on the results of the background study, estimating the probability of induced seismic activity during well stimulation would be more accurate.

Other factors that can influence the rate of induced seismic activity are the injections rates and pressures. Greensfelder (2003) estimated that injection rates at 480 to 950 gallons per min (gpm) would induce earthquake activity in The Geysers. Since the G1 well has just been completed, and G2 and G3 wells still need to be drilled, NEA is not able to provide estimations as to the injection rates at the writing of this report but initial indications may be that injections rates could be as high as 500 to 750 gpm. While the NGEP site is in a different tectonic setting and the rock type are different it would still be expected that the NGEP site will induce seismic events during injection tests at any of the wells but the rate of seismicity would be at a different rate as that of The Geysers.

Figure 15, Naknek MEQ Network Layout, station layout is based on access to the sites both during the winter and summer months when access to the sites is very limited.

4.3 Predicted the Maximum Earthquake at the NGEP Site

A stimulation plan has yet to be worked out for the NGEP site, and neither the current in situ stress state of the reservoir rock at depth nor the existence of faults, or micro-faults, at depth are yet known. However, by applying Brune's (1968) formula where the seismic moment released during an earthquake must equal the rigidity of rock times the length, width and displacement along a fault, an estimate of maximum earthquake size generated by EGS stimulation at the NGEP site can be estimated as follows.

$$\mathbf{M_O = \mu\ (L*W*D)}$$

Assuming that the length, width and displacement must equal the injected volume of fluid then we can replace the L * W * D with the injected Volume (V_I):

$$\mathbf{M_O = \mu\ V_I}$$

If a fracture with a radius of 500m, similar to the Basel and Cooper Basin rupture areas, is created with an average opening of 1cm along the entire fracture surface area a volume change of about 7,900 cubic-meters, or about 2.1 million gallons of injection volume, would be required. Assuming a rigidity of rock at $3\text{x}10^{11}$dyne/cm^2, a typical value for a hard rock at 5 to 10 km depth, a "Total" seismic moment release of 2.356 x 10^{21} dyne-cm would be needed. If we use more conservative rigidity estimations, i.e. 2 x 10^{11}dyne/cm^2 or 1 x 10^{11}dyne/cm^2 which are more typical for the rock at the depth of stimulation at the NGEP site, the seismic moment would be much lower. However for this report the estimation on seismic moment is based on a worse case calculation and as such the larger value is used for the calculations below.

To convert the seismic moment to a "Magnitude" scale there are several to choose from, M_L, M_b, M_d, M_S and M_W and all vary in size but can be related to the seismic moment. The most common scales used by seismologist today are the M_L and M_W scales, local Richter and moment magnitude respectively. To relate the total seismic moment to a local Richter magnitude, M_L, developed in 1935 by Drs Charles Richter and Beno Gutenberg, and is good for local earthquakes out to distances of about 150km we can use the Wyss and Brune (1968) formula:

$$\mathbf{\log M_O = 1.4\ M_L + 17.0}$$

or

$$\mathbf{M_L = ((\log M_O)-17.0)/1.4}$$

This formula yields a local Richter magnitude of M_L3.1 for the above estimated seismic moment. Over the past few years, as instrumentation for recording earthquakes has advanced, the USGS has adopted a newer relationship for reporting the magnitude of an earthquake that is more applicable to estimating the magnitude and is based on the recorded seismic moment. This new formula, M_W =2/3 log(M_O) -10.7, where M_W is the "moment magnitude", is based on work done by Hanks and Kanamori (1979) and yields higher magnitude numbers than the M_L scale for the same seismic moment for the Brune formula. From the above estimation of seismic moment we can estimate the moment magnitude, M_W or M, as follows:

$$\mathbf{M = (\log 2.356\ x\ 10^{21}\ dyne\text{-}cm)/1.5\text{-}10.7}$$

$$\mathbf{M = 3.7}$$

It should be pointed out that this estimation is for the "entire" seismic moment released during the fracturing process. It is highly unlikely that a single rupture of this size would take place and that it is more likely, as has been seen in the past, that there would be thousands of micro-earthquakes to accommodate the total seismic moment that would equal the M3.7 estimated above. Based on the Brune (1968) and Hanks and Kanamori (1979) formulas, even if the injection volume is doubled, thereby doubling the rupture area or opening, the NGEP site would only generate a M_W4.1 size event.

As a single large event is not expected to occur but rather thousands of smaller ones, these MEQ events are likely to occur over many days during the injection testing and even for some weeks after the injection testing has stopped while the shut in pressure bleeds off. For example, the Basel injection test recorded over 20,000 seismic events and over 35,000 for the Cooper Basin injection testing. As discussed in Section 5, most of these events would be too small to be felt at the surface or in the local communities of King Salmon, Naknek and South Naknek.

Given these assumptions and estimations above, a maximum "creditable" event size during any injection testing at the NGEP site should be on the order of a M3.5 to M3.7 in size. Though it is possible that a larger event could be triggered on an adjacent fault that is near failure already, there is no conclusive evidence at this time that a fault exists near the site. The only indication of a fault near the NGEP site is from the geophysical data which has not been conclusively determined to be a fault or a fault under current stress. While drilling logs indicate fractures at injection depth, faults or fault zones have not been identified as of the writing of this report. The nearest known fault is the Lake Clark fault, which is over ten kilometers from the NGEP area, and it would be unlikely that a M3.7 event could trigger an earthquake on this fault.

5.0 Estimating Ground Shaking From Induced Seismicity

For any EGS system the most significant environmental impact from induced seismicity would be from ground shaking. Ground motions are normally recorded by seismometer in either velocity or acceleration units and can either be differentiated or integrated to go between units, or even to displacement. For ground shaking studies the most common unit of measure by engineers is the peak horizontal ground accelerations (PGA) but the peak ground velocity (PGV) is also commonly used. Both the PGA and PGV can be correlated to shaking or intensity using the classifications of Wald et al (1999). They have classified the following levels of ground shaking, Table 2, and the levels are used as part of the USGS ShakeMaps generated for all earthquakes recorded by the NEIC in the United States. Figure 16 shows an example shake map result for a M_W 3.7 event near Anchorage, Alaska, similar in size to the maximum expected event size for the NGEP site.

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	[illegible]	[illegible]

Table 2, Perceived Shaking vs. Instrumental Intensity as related to PGA, Caltech

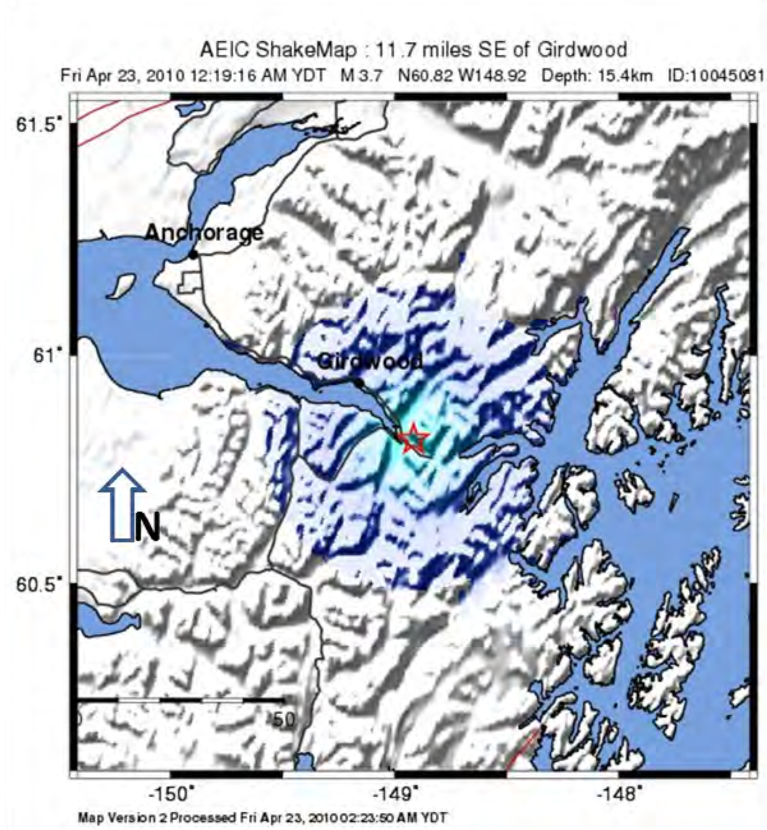

Figure 16, Shake Map Results for a M_W3.7 near Anchorage, 23 April 2010.

While the Richter Magnitude, PGA and PGV values are good for seismologists to work with, the Modified Mercalli Intensity (MMI) scale is a descriptive scale that tries to relate the level of ground shaking to property damage and is more applicable to the general population. As the effects of any one earthquake can vary greatly from place to place the MMI scale tries to normalize these effects based on the following relatively subjective scale of descriptions**:**

Modified Mercalli Intensity Scale

I. People do not feel any Earth movement.

II. A few people might notice movement if they are at rest and/or on the upper floors of tall buildings.

III. Many people indoors feel movement. Hanging objects swing back and forth. People outdoors might not realize that an earthquake is occurring.

IV. Most people indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. The earthquake feels like a heavy truck hitting the walls. A few people outdoors may feel movement. Parked cars rock.

V. Almost everyone feels movement. Sleeping people are awakened. Doors swing open or close. Dishes are broken. Pictures on the wall move. Small objects move or are turned over. Trees might shake. Liquids might spill out of open containers.

VI. Everyone feels movement. People have trouble walking. Objects fall from shelves. Pictures fall off walls. Furniture moves. Plaster in walls might crack. Trees and bushes shake. Damage is slight in poorly built buildings. No structural damage.

VII. People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.

VIII. Drivers have trouble steering. Houses that are not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Tree branches break. Hillsides might crack if the ground is wet. Water levels in wells might change.

IX. Well-built buildings suffer considerable damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.

X. Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas. Railroad tracks are bent slightly.

XI. Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed. Railroad tracks are badly bent.

XII. Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

Table 3, MMI Scale

5.1 Seismic Attenuation

The actual relationship between any single ground motion parameter and intensity are highly uncertain, as there are many variables to consider. Some of the variables include the type of structures, soil conditions, depth to bedrock, type and the height of the structure to name a few. Where numerous strong ground motion data are available empirical attenuation relationships can be developed to help model a site's response to an earthquake. By applying statistical regression methods to the strong motion data, an attenuations model can be developed for a given region, though it is only applicable to that given region. As no strong ground motion sensors are located in the study area, the values to assign to the region are hard to estimate.

Traditionally in predicting ground shaking at a site you would use the attenuation relationship derived from the empirical relationship mentioned above. Attenuation is defined as the decrease in amplitude, or intensity, of the seismic wave over a distance. The decrease in amplitude is the result of numerous factors, such as geometrical spreading, damping by the earth, scattering and reflecting off of structural layers as well as refraction, diffraction and wave conversion. Given the soil conditions, moraine and saturated soils, and depth to bedrock, ~150 meters, an elevated level of ground motion for the local area would be expected as compared to a hard rock/bedrock site. Section 5.2 is presented to estimate the level of ground motion for the area around the NGEP site.

To help record actual strong motion data, during the injection/stimulation study at the NGEP site it has been proposed that at least two strong motion stations be set up in the region to help develop the attenuation model for the area. Additionally, it may be possible after the six month MEQ deployment to develop a model within the footprint of the MEQ array, which could be used as estimations for the local communities, assuming enough natural seismic data is recorded.

5.2 Estimation of PGA and MMI for the NGEP Site

As mentioned in section 5.1 no strong motion data is available for the NGEP area. As such only estimations of ground motions can be made at this time. While there are standard formulas for estimating ground motion Field et al. (2003) have provided a JAVA based program for estimating ground motion using several models and methods, e.g. OpenSHA. For this report we look at only the USGS ShakeMap 2003 model for estimating PGA and the MMI from the NGEP area out to a distance of 50 km. For the modeling parameter a worse case soil condition, C, is used for the area based on Wills et al. (2000) soils classifications, Table 4. For these calculations magnitudes between M_W2.5 and M_W4.0 were used to estimate the ground shaking in both PGA and MMI units. The results from the OpenSHA program are plotted in Figures 17 and 18. Figure 17 shows the PGA vs. Distance while Figure 18 overlays the results for a M_W3.5 event onto a Google Earth image for the area. Note in Figure 17 that even at the Lake Camp site, the closest facility to the NGEP site, a PGA of only 3% of *g* is estimated for M_W4.0 size event, which equates to a MMI of only IV, by King Salmon the MMI is only III and at Naknek an II. Table 4 is a description of the MMI scale as published by the U.S. Federal Emergency Management Agency (FEMA).

Map Category	Expected V_s Range
B	>760
BC	555–1000
C	360–760
CD	270–555
D	180–360
DE	90–270
E	<180

Table 4, Wills et al Soils Classifications

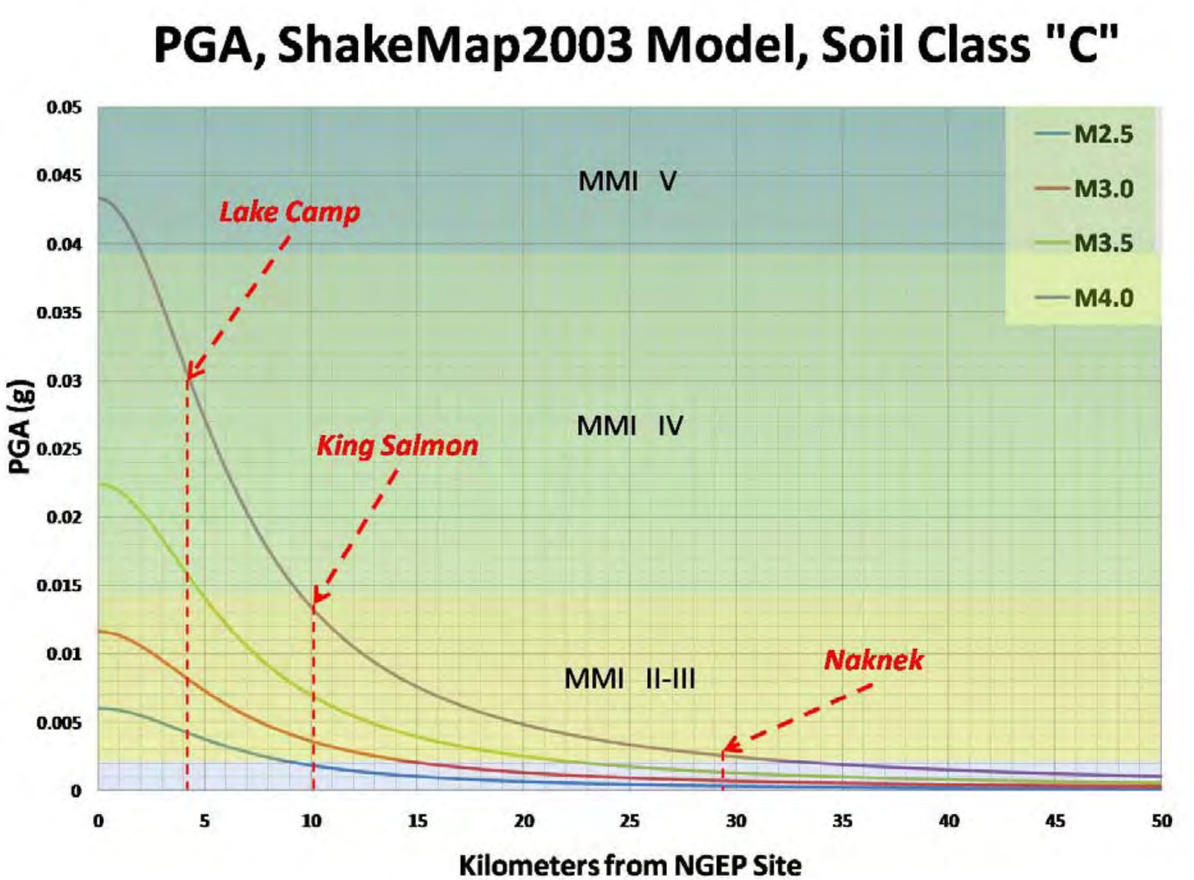

Figure 17, Estimation of PGA for NGEP site using OpenSHA, Shaded area show MMI values, red arrows and line show approximate distance to key points.

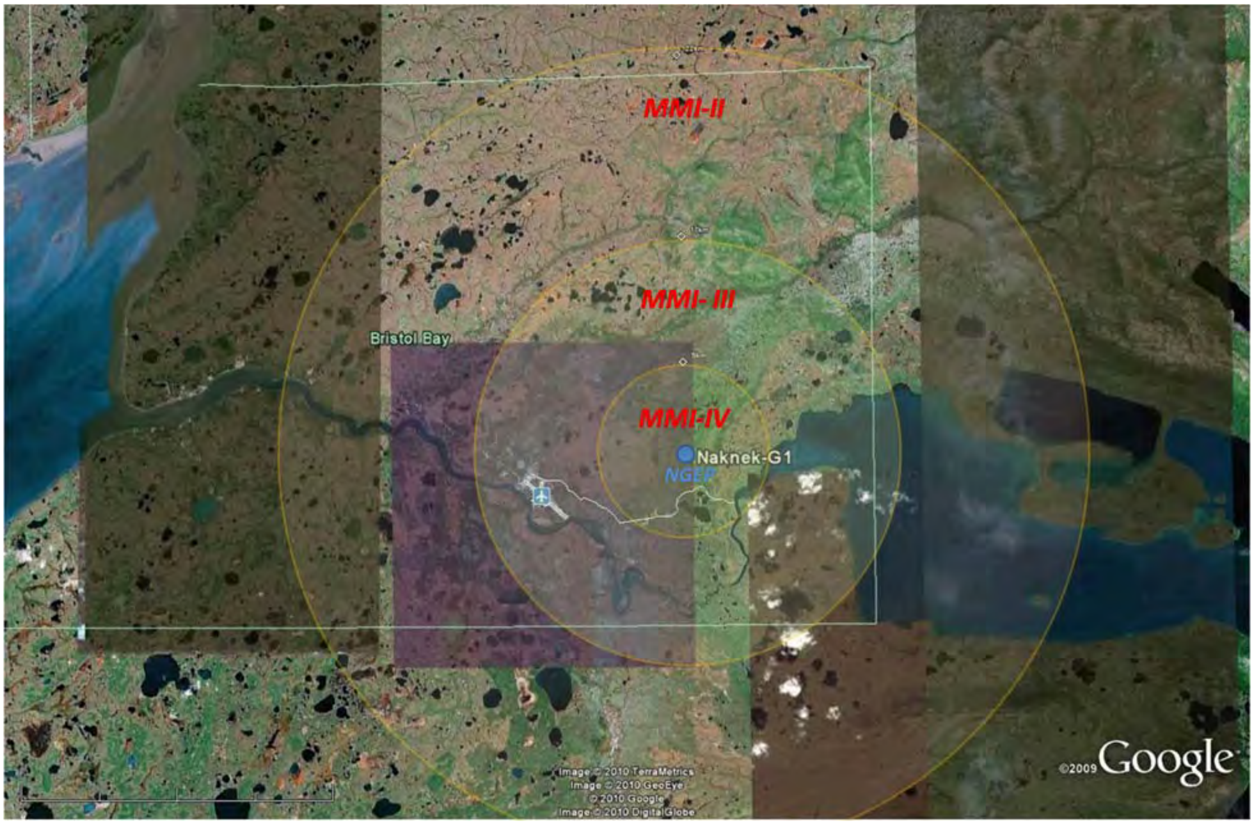

Figure 18, Estimated MMI Zones relative to a M_W3.5 earthquake based on OpenSHA results for the NGEP Site

While these results are only estimations they help provide a basic overview of what to expect from induced seismicity at the NGEP site.

6.0 Impact of the NGEP Operations to Local Community

Any injection testing, or stimulation, at the NGEP site may result in a large induced seismic event that could be felt by the local communities around the area, as has been seen at other such sites around the world. For example, a M_L3.4 occurred in Basel (Switzerland), at the Cooper Basin (Australia) events up to M_L3.7 were recorded, at the Soultz-sous-Forêts (France) EGS development a M_L2.9 event was recorded and at Rosemanowes (UK) an observed magnitude of M_L3.1 was recorded though M_L3.5 size events had been predicted (Bromley and Mongillo, 2008). All these event sizes are within the predicted estimation for the NGEP site.

The largest "Local" earthquakes that have been recorded in the region over the past 35 years were the M_W6.8, which occurred on the 28th of July 2001 at a distance of 85km from the NGEP and the M_W6.3 occurring on the 1st of May 1990 at a distance of only 25 km, neither of which caused any significant damage to the local infrastructure. There were also several magnitude M_W5.0 to M_W5.9 size events during this timeframe as well. It should be pointed out that while the Richter Scale is a base 10 log scale for one order of magnitude increase there is an increase of ~33.3 times in the energy released during an earthquake. Given this the M_W6.8 and M_W6.3 events each respectively released over 350,000 and 30,000 times more energy than is expected for an induced seismic event at the G1 site of M_W3.5 in size or that has been seen at other such projects around the world.

Intensity decays with distance at a rate of $1/r^3$, where "r" is the radius. Comparing estimated intensities levels from OpenSHA and ShakeMap results for the NGEP site; i.e. a M_W3.1 to M_W3.5, a PGA on the order of about 0.7% g (MMI zone III) may be felt at King Salmon (~10 km) and 0.2% g (MMI zone I) at Naknek and South Naknek (~29 km), Figure 17. From Tables 2 and 3, these fall into the "Light to Not Felt" perceived shaking with "Little to No" potential for damage to occur. Some homes close to the NGEP site, i.e. within 5km, could see PGAs on the order of 1.5% to 2% of g which would still have only a "Light" perceived shaking but with "Very Light to Light" potential of damage to occur. Given this a M_W3.5 to M_W3.7 or even up to a M_W4.1 size events occurring at the G1 site should do little to no damage to any of the local infrastructure.

For the injection testing the Institute of Earth Science and Engineering (IESE) at the University of Auckland in New Zealand has been contracted to deploy a ten station seismic monitoring network around the NGEP site. Data from each station would be radioed back to a central site in real-time where a data acquisition computer would acquire all data and process the data for event detection. Location and magnitude calculations would occur within 30 to 60 seconds of any detected seismic event. Other advanced analysis would be carried out in near real-time such as stress drop calculations, moment tensor inversion, spectral density calculations to name a few. In addition to the ten seismic stations at least two strong motion seismometers would be deployed in the region to monitor key facilities. These strong motion stations may, or may not, be included into the real-time network but at a minimum after any felt event the data would be extracted and analyzed to determine the exact PGA for the event.

During the injection testing, the Senior IESE field seismologist on site would interface with both NEA and the Contractor performing the injection testing. From the real-time data, the seismologist would observe for signs of an increased rate of larger seismic events in the region. The seismologist would provide both NEA and the Contractor with hourly updates on the rate of seismicity, pattern(s) of seismicity and any changes to the pattern(s) of seismicity. The seismologist would immediately notify the Contractor and NEA if any events are occurring away from the intended injection area, i.e. on other faults in the area, which could indicate the potential for triggering of an event out of the intended study area. This real-time input should help mitigate the risk potential for damage from induced seismic events by allowing NEA, and the Contractor to modify their injection parameters before a large event is triggered, thus lessening the impact on the local community (Cypser and Davis, 1994).

The following protocols have been developed for the monitoring of seismicity at that NGEP site.

1) Before any injection testing takes place the local communities will be informed of the possibilities of induced seismicity and to take appropriate actions to reduce the potential for damage at their homes and offices. This includes the removal of glass items from shelving and possibility the anchoring of book cases to the walls. Given that the region is a highly seismically active area, most residents should have already taken these precautions, however reinforcing these and other precautions would be good practice.

2) IESE will provide real-time monitoring of seismic activity in and around the NGEP site during any stimulation, including rates of seismicity in the area as well as estimating the cumulative seismic moment.

3) In the event of a significant earthquake occurring in the area of study IESE will notify NEA and the stimulation contractor immediately. Significant events are those $M_W2.5$ and up, or events of $M_W3.0$ and up that occur outside the area of study, i.e. on or near the Clark Lake fault.

4) NEA and its contractor will take the following actions:

    a. In the event of an earthquake of $M_W2.0$ to $M_W3.4$ the rate of injection will be decreased by at least 50%, and injection will cease if additional earthquakes of this magnitude are recorded, until earthquake activity subsides below $M_W2.0$.

    b. In the event of an earthquake of $M_W3.5$ or higher, injection will cease until earthquake activity subsides below $M_W2.0$.

Since the NGEP site is still at an exploration level, the data collected will help characterize the reservoir response to injection during the first test of the G1 well. Data collected during this first test can be applied to other tests that may take place at a later date or for future wells. By monitoring induced seismicity during injection testing in real-time, NEA will be able to respond quickly and mitigate the level of induced seismic events.

While the potential risk from induced seismicity is low, NEA is committed to taking every precaution to manage and mitigate the effects an EGS stimulation could have on the region.

7.0 References

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