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LNG FACILITIES ONSHORE HYDROGEOLOGIC REPORT

USAL-FG-GRZZZ-00-002016-007

Rev	Date	Revision Description	Originator	Reviewer / Endorser	Response Code	Approver
A	21-Nov-16	Issued for Review	D. Sadoff	P. Wong	2	J. Alexander
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FUGRO CONSULTANTS, INC.

Alaska LNG™

LNG FACILITIES ONSHORE HYDROGEOLOGIC REPORT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

AKLNG REPORT NO. USAL-FG-GRZZZ-00-002016-007

FUGRO REPORT NO. 04.10160001-8

EXXONMOBIL ALASKA LNG LLC (EMALL)
HOUSTON, TEXAS

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A	21-Nov-16	Issued for Review	D. Sadoff	K. Emery	J. Alexander
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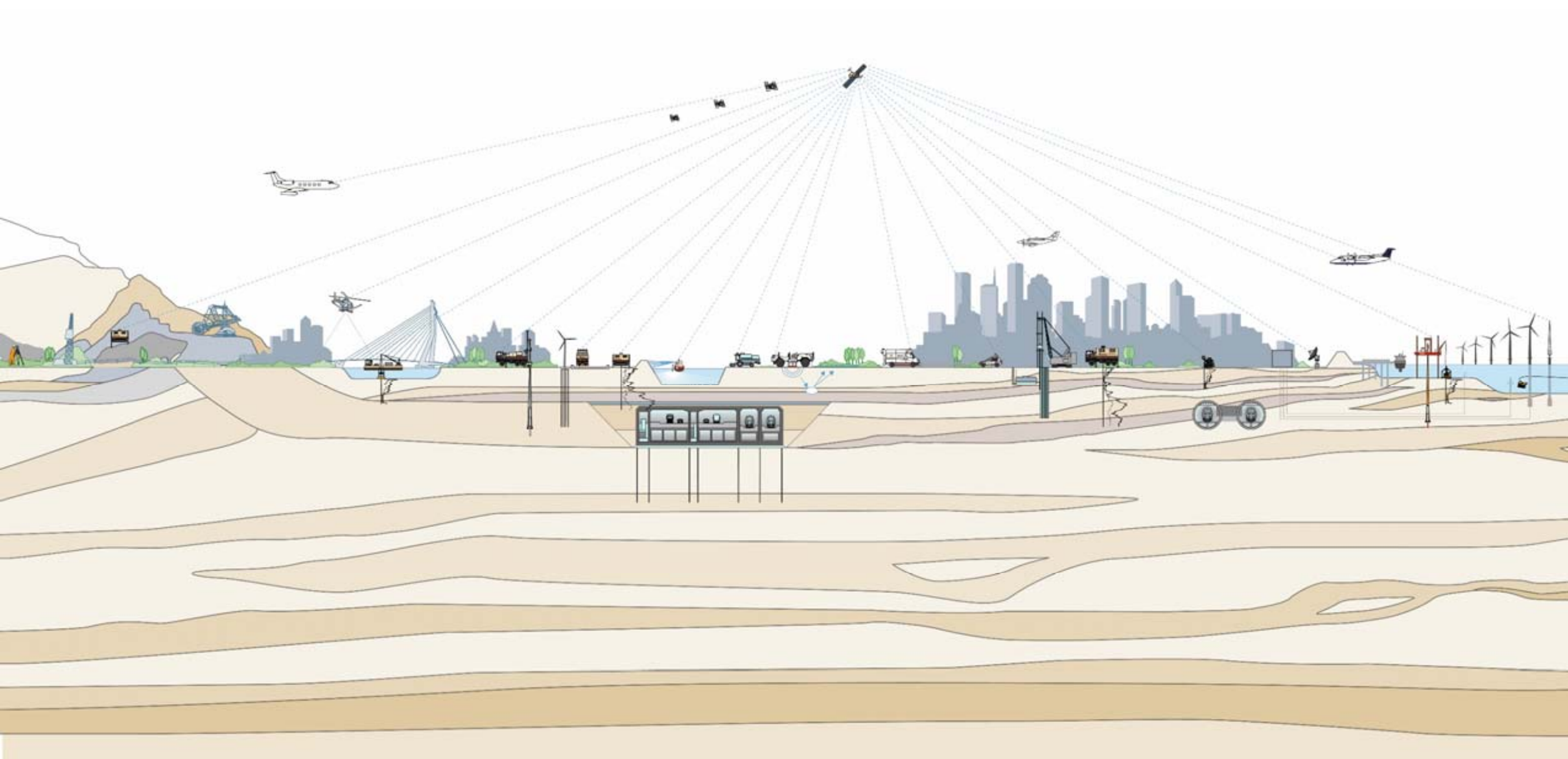

REVISION MODIFICATION LOG

Revision	Section	Description

January 6, 2017
Report No. 04.10160001-8

ExxonMobil Alaska LNG LLC (EMALL)
10613 W. Sam Houston Pkwy N, Suite 500
Houston, TX, 77064

Attention: Patrick Wong
Geotechnical Engineering Advisor Alaska LNG/Technical POC

Subject: **LNG Facilities Onshore Hydrogeologic Report, Onshore LNG Facilities, Alaska LNG Project, Nikiski, Alaska**

Dear Patrick Wong:

Fugro Consultants, Inc. (Fugro) is pleased to present this hydrogeologic report for the onshore facilities of the Alaska LNG Project (AKLNG) located in Nikiski, Alaska. Our services were authorized under Service Work Order No. AKLNG-FUG-US-005 Rev 0, dated March 2, 2016 in accordance with the Service Agreement No. A2275592 between Fugro and ExxonMobil Global Services Company, dated October 29, 2012. Fugro has been contracted by ExxonMobil Alaska LNG LLC (EMALL) under the service order to provide site investigation services for the proposed AKLNG Project. Fugro has been providing services to EMALL since 2014.

We appreciate the opportunity to be of service to EMALL. Please call Mr. Abhishek Shethji, P.E., Fugro's Project Manager at (713) 369-5431, if you have any questions or comments concerning this report, or when we may be of further assistance.

Sincerely,

FUGRO CONSULTANTS, INC.
TBPE Firm Registration No. 299

Dave Sadoff, P.G., C.P.G.
Associate Geologist/Project Hydrogeologist

Jeriann Alexander, P.E. R.E.P.A
Principal Engineer/Project Hydrologist

Copies Submitted: Aconex Document Control System

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

APPENDICES

1.0 INTRODUCTION

1.1 Project Description

The Alaska Gasline Development Corporation, BP Alaska LNG LLC, ConocoPhillips Alaska LNG Company, and ExxonMobil Alaska LNG LLC (Applicants) plan to construct one integrated liquefied natural gas (LNG) Project (Project) with interdependent facilities for the purpose of liquefying supplies of natural gas from Alaska, in particular from the Point Thomson Unit (PTU) and Prudhoe Bay Unit (PBU) production fields on the Alaska North Slope (North Slope), for export in foreign commerce and opportunities for in-state deliveries of natural gas.

The Natural Gas Act (NGA), 15 U.S.C. § 717a(11) (2006), and Federal Energy Regulatory Commission (FERC) regulations, 18 C.F.R. § 153.2(d) (2014), define "LNG terminal" to include "all natural gas facilities located onshore or in State waters that are used to receive, unload, load, store, transport, gasify, liquefy, or process natural gas that is ... exported to a foreign country from the United States." With respect to this Project, the "LNG Terminal" includes the following: a liquefaction facility (Liquefaction Facility) in Southcentral Alaska; an approximately 804-mile gas pipeline (Mainline); a gas treatment plant (GTP) on the North Slope; an approximately 62-mile gas transmission line connecting the GTP to the PTU gas production facility (PTU Gas Transmission Line or PTTL); and an approximately 1-mile gas transmission line connecting the GTP to the PBU gas production facility (PBU Gas Transmission Line or PBTL). All of these facilities are essential to export natural gas in foreign commerce.

The new Liquefaction Facility would be constructed on the eastern shore of Cook Inlet just south of the existing Agrium fertilizer plant on the Kenai Peninsula, approximately 3 miles southwest of Nikiski and 8.5 miles north of Kenai (Plate 1). The Liquefaction Facility would include the structures, equipment, underlying access rights, and all other associated systems for final processing and liquefaction of natural gas, as well as storage and loading of LNG, including terminal facilities and auxiliary marine vessels used to support Marine Terminal operations (excluding LNG carriers [LNGCs]). The Liquefaction Facility would include three liquefaction trains combining to process up to approximately 20 million metric tons per annum (MMTPA) of LNG. Two 240,000-cubic-meter tanks would be constructed to store the LNG. The Liquefaction Facility would be capable of accommodating two LNG carriers. The size of LNGCs that the Liquefaction Facility would accommodate would range between 125,000–216,000-cubic-meter vessels.

EMALL contracted Fugro to investigate the site conditions of the onshore LNG facilities, marine LNG Terminal, and marine pipeline corridors. Overview of overall project facilities described above are presented on Plate 2. Completed onshore explorations and the proposed LNG Facilities plant layout are presented on Plate 3. This report presents the results of the onshore hydrogeologic studies conducted during the 2016 geophysical and geotechnical site investigation (G&G) program at the Alaska LNG site (Site) near Nikiski, Alaska (see Plate 1).

A list of the reports (including the superseded reports) that are generated by Fugro as part of the 2014, 2015 and 2016 G&G programs are presented in the table below. A copy of the below table is also separately submitted to AKLNG under document number USAL-FG-BRCTL-00-000001-000[1].

[1] Fugro Consultants, Inc. (Fugro), 2016, A Roadmap to Fugro G&G Reports Covering Site Investigation Campaigns in 2014, 2015 & 2016, Alaska LNG Project, Nikiski, Alaska, AKLNG Document No. USAL-FG-BRCTL-00-000001-000, Rev.0, dated December 22, 2016.

Table 1.1: Summary of Fugro Reports Developed for 2014, 2015 and 2016 G&G Programs

G&G Program	Report Title (Superseded Reports in Gray)	AKLNG Document Number	Fugro Report Number
2014	Project Execution Plan for 2014 Onshore and Marine G&G	USAL-FG-GPZZZ-00-000001-000	04.10140094-1
	Geologic Mapping Report	USAL-FG-GRZZZ-00-000001-000	04.10140094-2
	Marine Survey Report Pipeline Corridor Route 1	USAP-FG-GRZZZ-10-000001-000	04.10140094-3
	Marine Survey Report Pipeline Corridor Route 2	USAP-FG-GRZZZ-10-000002-000	04.10140094-4
	Marine Survey Report Nearshore LNG Facilities and Approach Channel	USAL-FG-GRZZZ-90-000003-000	04.10140094-5
	Probabilistic Seismic Hazard Analysis Report(1)	USAL-FG-GRHAZ-00-000001-000	04.10140094-6
	Geophysical Survey Report	USAL-FG-GRZZZ-00-000002-000	04.10140094-7
	Geotechnical Data Report Onshore LNG Facilities	USAL-FG-GRZZZ-00-000003-000	04.10140094-8
	Geologic Hazard Report(2)	USAL-FG-GRHAZ-00-000002-000	04.10140094-9
	Hydrogeologic Report(3)	USAL-FG-GRZZZ-00-000004-000	04.10140094-10
	Groundwater Monitoring Well Installation Report	USAL-FG-GRZZZ-00-000007-000	04.10140094-10A
	Liquefaction Potential Evaluation Report(4)	USAL-FG-GRZZZ-00-000005-000	04.10140094-11
	Integrated Site Characterization and Engineering Report(5)	USAL-FG-GRZZZ-00-000006-000	04.10140094-12
2015	Project Execution Plan for 2015 Onshore and Marine G&G Program	USAL-FG-GPZZZ-00-000002-000	04.10140334-1
	LNG Facilities Onshore Geologic Field Mapping Report	USAL-FG-GRZZZ-00-002015-004	04.10140334-2
	Pipeline Marine Geophysical Survey Report - Route 1	USAP-FG-GRZZZ-10-002015-013	04.10140334-3
	Pipeline Marine Geophysical Survey Report - Route 2	USAP-FG-GRZZZ-10-002015-014	04.10140334-4
	LNG Facilities Marine Geophysical Survey Report	USAL-FG-GRZZZ-90-002015-010	04.10140334-5
	LNG Facilities Probabilistic Seismic Hazard Analysis (PSHA) Report(1)	USAL-FG-GRHAZ-00-002015-001	04.10140334-6

G&G Program	Report Title (Superseded Reports in Gray)	AKLNG Document Number	Fugro Report Number
2015	LNG Facilities Onshore Geophysical Survey Report	USAL-FG-GRZZZ-00-002015-005	04.10140334-7
	LNG Facilities Onshore Geotechnical Data Report	USAL-FG-GRZZZ-00-002015-006	04.10140334-8
	LNG Facilities Marine Geotechnical Data Report	USAL-FG-GRZZZ-90-002015-011	04.10140334-9
	LNG Facilities Geologic Hazard Report(2)	USAL-FG-GRHAZ-00-002015-002	04.10140334-10
	LNG Facilities Onshore Groundwater Monitoring Well Installation Report	USAL-FG-GRZZZ-00-002015-007	04.10140334-11
	LNG Facilities Onshore Hydrogeologic Report(3)	USAL-FG-GRZZZ-00-002015-008	04.10140334-12
	LNG Facilities Seismic Engineering Report(4)	USAL-FG-GRZZZ-00-002015-003	04.10140334-13
	LNG Facilities Onshore Integrated Site Characterization and Geotechnical Engineering Report(5)	USAL-FG-GRZZZ-00-002015-009	04.10140334-14
	LNG Facilities Marine Integrated Site Characterization and Geotechnical Engineering Report	USAL-FG-GRZZZ-90-002015-012	04.10140334-15
2016	Project Execution Plan for 2016 Onshore and Marine G&G Program	USAL-FG-GPZZZ-00-002016-001	04.10160001-1
	LNG Facilities Groundwater Quality Sampling and Testing Report – Event 1	USAL-FG-GRZZZ-00-002016-003	04.10160001-2
	LNG Facilities Groundwater Quality Sampling and Testing Report – Event 2	USAL-FG-GRZZZ-00-002016-004	04.10160001-3
	LNG Facilities Aquifer Pump Test Well and Groundwater Observation Well Installation Report	USAL-FG-GRZZZ-00-002016-002	04.10160001-4
	LNG Facilities Onshore Geotechnical Data Report	USAL-FG-GRZZZ-00-002016-001	04.10160001-5
	LNG Facilities Onshore Hydrogeologic Report(3)	USAL-FG-GRZZZ-00-002016-007	04.10160001-8
	LNG Facilities Seismic Engineering Report(4)	USAL-FG-GRZZZ-00-002016-008	04.10160001-9
	Pipeline Marine Shallow Geotechnical Report	USAP-FG-GRZZZ-10-002016-011	04.10160001-10

G&G Program	Report Title (Superseded Reports in Gray)	AKLNG Document Number	Fugro Report Number
2016	LNG Facilities Marine Survey Report	USAL-FG-GRZZZ-90-002016-010	04.10160001-11
	LNG Facilities Onshore Integrated Site Characterization and Geotechnical Engineering Report(5)	USAL-FG-GRZZZ-00-002016-009	04.10160001-12
	LNG Facilities Rigs Tenders Wharf Siltation Survey Report	USAL-FG-CRZZZ-90-002016-001	04.10160001-13

Notes: (1) Fugro Report No. 04.10140334-6 supersedes Fugro Report No. 04.10140094-6.
(2) Fugro Report No. 04.10140334-10 supersedes Fugro Report No. 04.10140094-9.
(3) Fugro Report No. 04.10160001-8 supersedes Fugro Report Nos. 04.10140094-10 and 04.10140334-12.
(4) Fugro Report No. 04.10160001-9 supersedes Fugro Report Nos. 04.10140094-11 and 04.10140334-13.
(5) Fugro Report No. 04.10160001-12 supersedes Fugro Report Nos. 04.10140094-12 and 04.10140334-14.

1.2 General Scope of Work

Fugro prepared this report to document the hydrogeologic conditions at the onshore AKLNG project site (Site). These conditions are interpreted based on a review of available historic geologic and hydrogeologic reports and data, as well as data collected during Fugro's Site investigations conducted in 2014 (Phase I), 2015 (Phase 2), and 2016 (Phase 3). Fugro has observed geologic and hydrogeologic conditions encountered in 130 onshore borings; and during installation and monitoring of twenty-six (26) groundwater monitoring wells, four (4) observation wells (OW), and three (3) aquifer pump test (APT) wells; and a review of groundwater quality data collected in 2016. Locations of the borings and wells are depicted on Plate 4 – Investigation Plan.

The groundwater monitoring wells were installed using subsurface lithological information from nearby co-located borings. Groundwater quality data and elevations were used to delineate aquifers and aquitards across the Site; and to provide means to develop an understanding of aquifer characteristics including artesian conditions, hydraulic conductivity, occurrence, elevation fluctuation, tidal impacts, gradient, and flow direction.

Observation and aquifer pump test wells were installed in the eastern portion of the proposed facility footprint. The wells were installed to enable water withdrawal and aquifer monitoring to assess the nature of groundwater flow, yield, quality, and interconnectedness of three observed water bearing units. Well installations and associated activities such as well development and surveying were completed in general conformance with the approved Project Execution Plan (PEP) (USAL-FG-GPZZZ-00-002016-001), an Aquifer and Observation Well Installation Method Statement, and an Air Rotary Rig and Generator Refueling Method Statement. Specific deviations from the PEP, which were discussed with the EMALL representatives prior to implementation, included the following:

- A planned 10-day aquifer pump test and subsequent 8-hour aquifer pump test were not performed.
- Well development water was contained and disposed at an approved disposal facility.

The Groundwater Monitoring Well Installation Report (Fugro Report No. 04.10160001-4) for 2016 is submitted separately as AKLNG Report Number USAL-FG-GRZZZ-00-002016-002. Installation of wells completed in 2014 and 2015 are discussed in AKLNG Report Number USAL-FG-GRZZZ-00-002015-007.

1.3 Limitations

Fugro makes no claim or representation concerning any activity or condition falling outside the specified purposes to which this report is directed. We have conducted our work using the standard level of care and diligence normally practiced by recognized engineering firms now performing similar services under similar circumstances. We intend for this report, including all illustrations, to be used in its entirety. The information presented in this report may not apply to locations not explored by borings or areas outside the project boundaries. This information should be made available to prospective users for information only, and not as a warranty of subsurface conditions.

1.4 Unit Conversions and Elevation Datums

The data presented herein are based on the Imperial Unit System. Table 1.4.1 provides a quick reference for conversion from Imperial Units to SI.

Table 1.4.1. Conversion Units

From SI System	To Imperial System	Multiply by
Kilo Newtons – kN	Kips – k	0.224809
Mega Newtons – MN	Kips – k	224.809
Kilo Newtons/meter^2 – kN/m^2 (kPa)	Pounds/feet^2 - psf	20.885
Kilo Newtons/meter^3 – kN/m^3	Pounds/feet^3 - pcf	6.3659
Meters – m	Feet – ft	3.2808
Millimeters – mm	Inches – in.	0.03937

All coordinates are reported in Zone AK4 North, NAD83 (NSRS 2007), and are in feet. Topographic elevations for onshore areas are referenced to NAVD88. It should be noted that the marine survey report uses Mean Lower Low Water (MLLW) as the vertical datum. The following conversion formula is used to convert the elevations from MLLW to NAVD88:

- Elevation, in feet (NAVD88) = Elevation, in ft (MLLW) – 7.32 ft

Please note that this conversion formula is only applicable at the Nikiski Area. Elevations presented in this report, and the corresponding illustrations and engineering plates are all referenced to the NAVD88 datum, unless noted otherwise.

2.0 EVALUATION OF SITE DATA

2.1 Regional Data Review

Stratigraphy descriptions by others of the Site area are dominated by discussions of the occurrence, movement, and deposition of glacial and glaciofluvial sediments during the late Pleistocene Naptowne glaciation period. The two main lithologic formations at the Site include the stratigraphically higher Killey Unit and the stratigraphically lower Moosehorn Unit. The transition zone between the Killey

Unit outwash deposits and the late Moosehorn Unit subestuarine deposits are generally marked by rust discoloration of the underlying late Moosehorn deposits. The finer-grained and more compact (i.e., lower permeability) upper Moosehorn deposits act as a leaky aquitard for iron-rich groundwater descending through the Killey sands, which leaves behind a characteristic iron staining.

Locally, the unconsolidated sediments that make up the regional aquifer system consist of discontinuous clay, silt, sand, gravel and boulders deposited primarily by glaciers, but also by alluvial and colluvial processes. The sediments are complexly interbedded, with lenses and thin beds of sand and gravel interfingering with beds of clay, silt, and till. This complexity and the high variability in grain size distribution of the sediments causes discontinuity and variability in their hydraulic characteristics (USGS Ground Water Atlas of the United States, Publication HA 730-N).

There are three regional aquifers noted by researchers in the Nikiski area. The uppermost aquifer, referred to herein as Water Bearing Unit 1 is unconfined. The next encountered aquifer (Water Bearing Unit 2) is confined or semi-confined, and the last encountered aquifer (Water Bearing Unit 3) is confined. Reportedly, the unconfined aquifer (Water Bearing Unit 1) is hydraulically connected to Beaver and Bishop Creeks and other lakes in the area (United States Department of the Interior Geological Survey, Water Resources Division, Alaska District, Water Resources of the Kenai-Soldotna Area, Alaska, 1972).

The base of the unconfined aquifer (Water Bearing Unit 1) is comprised of discontinuous layers of silt and clay within the Killey-Moosehorn transition zone. Water Bearing Units 2 and 3 receive recharge from upland sources to the east and to a lesser extent from water percolating through the Killey-Moosehorn transition zone from the overlying Water Bearing Unit 1. A lower confined aquifer (not encountered during the investigation described in this report) is separated from the Water Bearing Units 2 and 3 by a silt and clay unit, and reportedly consists of many interconnected lenses and layers of sand, gravel, silt and clay at depths greater than 400 feet below ground surface (bgs) (United States Department of the Interior Geologic Survey, 1981, Hydrology and the Effects of Industrial Pumping in the Nikiski Area, Alaska).

2.2 Offsite Production Wells

A review of the sparse publicly available documentation (USAKL-PT-PROPT-00-0001) regarding offsite production wells has identified several such wells at and near the Site (Plate 5). Most of these wells are located in the industrialized northwest portion of the peninsula, and are associated with various local plant operations. Pertinent data regarding these wells is presented in the following table.

Table 2.2.1. Industrial Well Summary

Well ID	Owner	Casing Diameter	Pump Rate	Well Depth	Static Water Level
		(inches)	(GPM)	(feet, approximate)	(feet, approximate)
TW-9	Tesoro	10"/14"	550	351	113
T2-A	Tesoro	8"	1300	200	Unavailable
PW 5-8	UNOCAL	Unavailable	1000	319	Unavailable
Kasilof River Plant	Trans-Aqua Int.	10"	1700 (Artesian)	335	Unavailable
Kasilof River Plant	Trans-Aqua Int.	8" Dis. Pipe	1400	335	Unavailable
Production Well 10	Collier Carbon & Chem.	16"	1250	75	15
Production Well 12	Collier Carbon & Chem.	16"	725	68	27
Production Well 9	Collier Carbon & Chem.	12"	1000	90	15
PW 5A	Collier Carbon & Chem.	16"	Unavailable	296	Unavailable
Production Well 1	Litwin Corporation	12"	525	140	50
Production Well 1	Collier Carbon & Chem.	16"	4000	340	110
Well Number 2	USGS	12"	700	215	58
Phillips Number 1	Phillips Petroleum	6"	900	245	72
Well 16	Unocal Chemicals	10"	520	198	65
2167	Seward Fish	8"	250 (Salt Water)	108	20-30 Var. w/ Tide
2166	Seward Fish	6"	150 (Salt Water)	107	25-30 Var. w/ Tide
Well 2	City of Soldotna	6"	Unavailable	197	Unavailable
Well 1	City of Soldotna	6"	Unavailable	210	Unavailable
PW 6	Union Chemicals	16"	1200	160	62

Source: USAKL-PT-PROPT-00-0001, MVE, Alaska SCLNG Project, Technical Evaluation of Water Cooled LNG Plan, September 13, 2013; and MW Drilling (Tesoro TW-9)

Production wells in the nearby vicinity (within approximately 2 miles) of the Site vary in diameter from 6 to 16-inches, in depth from 160 to 350.5 feet, and in production rates from 520 to 4,000 gallons per minute (gpm). Based on the depths of the wells and reported static water levels, it may be assumed that most of these wells targeted the first and/or second encountered aquifers (Water Bearing Units 1 and/or 2, respectively). Based upon their relatively deeper well depths and static water levels, it may also be assumed that Tesoro Well TW-9, Trans-Aqua Int. Kasilof River Plant Well, and Collier Carbon & Chemical Production Well 1 are most likely screened within the third encountered aquifer (Water Bearing Unit 3).

Tesoro Well TW-9 is located approximately 9,000 feet northeast of the recently installed APT and OW well locations. A review of the log of boring of TW-9 (Plate 6) shows three large, discrete sand and gravel zones, separated by two discrete clay units, at depths which correlate well with our regional understanding of the three uppermost aquifers (Water Bearing Units 1, 2 and 3) and the two aquitards that separate them.

2.3 Lithologic Relationships with Groundwater

Based on a review of the data collected to date, the Site is underlain by glacially derived deposits of Late Pleistocene age. Lithology in the study area is very complex and spatially varies due to the episodic glacial nature of sediment deposition. Groundwater occurrence and flow is controlled by these lithologic strata.

Sandy and gravelly bedded outwash deposits of the Killey Unit (Water Bearing Unit 1) extend to depths of approximately 60 (+/- 25) feet beneath the Site. Local rain water and snow melt percolate through these poorly consolidated sediments, until reaching the Killey-Moosehorn transition zone. The transition zone ranges between 25 to 50 feet thick and undulates with variable depth and thickness across the Site. The transition zone is characterized by the less dense lithologies of the Killey Unit (Water Bearing Unit 1) transitioning to the denser subestuarine deposits of the Moosehorn Unit (Water Bearing Units 2 and 3). The transition zone acts as leaky barrier between Water Bearing Units 1 and 2. Within the transition zone, one to several dense silt beds interfinger with sandier materials. Individual silt beds, observed in the sea cliff exposures, are observed to be laterally continuous over hundreds of feet, and locally form barriers to impede percolating water from reaching Water Bearing Unit 2. Water Bearing Units 2 and 3 are recharged predominately by upland, distal sources to the east. Based on field observations, the transitional contact zone between the two deposits represents a prominent surface present throughout the Kenai-Nikiski area. Details regarding these exposed units may be found in Fugro's LNG Facilities Onshore Geologic Field Mapping Report, USAL-FG-GRZZZ-00-2015-004, August 21, 2015.

For reference, existing upland surface elevations vary from approximately +94 to about +135 feet (NAVD88). In general, the surface topography dips slightly to the west and south.

A Site Investigation Plan showing locations of cross sections, and cross sections depicting variations in observed conditions across the Site, groundwater monitoring well schematics, groundwater measurements, and the locations of the water bearing units are presented in Appendix A. The cross section lines shown in Plate A-1 were selected to show lithologic and hydrologic trends both parallel to general coastal topography (northwest-southeast) and perpendicular to topography (northeast-southwest, and generally parallel to groundwater flow regimes). The cross sections reflect the highly heterogeneous nature of sediments at the Site. The thickness and elevation variabilities of the strata can be observed on all cross sections, and in many cases there is no horizontal connectivity between strata as shown on the borehole logs. A summary of cross section observations is presented below. Additional cross sections are presented in the Fugro Geotechnical Data Report, Onshore LNG Facilities, Alaska LNG Project, Report No. 04.10140334-8, USAL-FG-GRZZZ-00-002015-006, and in the Fugro Geotechnical Data Report, Onshore LNG Facilities, Alaska LNG Project, Report No. 04.101400001-5, USAL-FG-GRZZZ-00-002016-001.

Cross sections A1-A1' and A2-A2'

These cross sections (Plates A-2 and A-3) depict lithology encountered during drilling of boreholes along the Nikiski Beach. All borings shown on these sections depict borings completed solely within Water Bearing Unit 2. The length of this cross section necessitated splitting it into two parts, a northern cross section (A1-A1') and a southern cross section (A2-A2'). These cross sections highlight the discontinuous nature of clay units, as evidenced by the lack of observed clay in boring B-127 and boring B-126 in the northwest portion of the Site. Artesian conditions were observed in the southeast portion of the Site, at the locations of boring B-117 (non-flowing artesian condition) and boring B-136 (flowing artesian condition). The artesian aquifer was encountered in a gravelly sand unit, found beneath an approximately 50-foot-thick layer of a competent clay unit (aquitard) at a depth of 99 feet below ground surface in B-117 and beneath an approximately 20-foot-thick layer of competent clay unit (aquitard) at 94 feet bgs in B-136. A northeast-southwest trending geologic structure/feature extending from the proposed well field area southwest to the vicinity of boring B-117 is observed by the preponderance of Killey-Moosehorn contact points, and the U-shape of the transition zone exposure visible in the bluff face on section A2-A2'.

Cross sections B1-B1' and B2-B2'

These cross sections (Plates A-4 and A-5) are located along the bluff, just inland from the Nikiski beach area. As with the beach cross section described above, the length of this cross section necessitated splitting it into two parts, a northern cross section (B1-B1') and a southern cross section (B2-B2'). The discontinuous nature of sedimentary strata is observed by the lack of significant clay units at similar elevations in nearby borings (e.g., an approximately 15-foot thick clay layer at an elevation between 2 and 17 feet (NAVD88) in boring B-114 is not observed in nearby boring B-135 located about 750 feet to the south).

Cross section C-C'

This cross section (Plate A-6) trends through the middle of the Site and is approximately perpendicular to the general groundwater flow direction. The Killey-Moosehorn transition zone appears to dip in elevation in the northern portion of this cross section, between the locations of borings B-66 and B-151. Surface water levels observed between borings B-101 and B-42 correlate to the regional northeast-southwest trending geologic feature described previously. The potentiometric (i.e., piezometric) water surface level observed in Water Bearing Unit 2 wells is significantly higher (by 13.35 feet) in well MW-74A as compared with the potentiometric water surface measured in well MW-62A. Both wells are located a similar distance from the Cook Inlet, and in general, one would expect potentiometric surface increments to approximately parallel the coastline. The reason for this apparent anomaly is unknown.

Cross section D-D'

This cross section (Plate A-7) is the most inland northwest-southeast trending cross section in the current onshore facilities study area. The slight dip in topography at the locations of wells OW-1, OW-2, APT-1, and APT-3 represents a surface expression of the northeast-southwest trending geologic feature. The relatively thick sequences of clay and silt beginning at approximately 30 feet elevation (NAVD88) in well APT-3 do not extend to the location of well OW-2, further evidence of the discontinuous nature of lithologic strata at the Site. Groundwater surface elevations observed in wells completed in Water Bearing Unit 1 near surface water bodies (wells MW-82B, OW-1, and OW-3) are noted to be higher than Water Bearing Unit 1 water surface elevations in wells which are not located near the surface water bodies. The higher water surface elevations near surface water bodies may be attributed to surface water recharge to Water Bearing Unit 1.

Cross section E-E'

This cross section (Plate A-8) is the northernmost northeast-southwest trending cross section. The decrease in the groundwater surface elevation in Water Bearing Unit 1 as it flows from an inland point toward the Cook Inlet is graphically shown, as evidenced by the difference in groundwater elevation observed in well MW-50B and the lack of water observed in well MW-62B (bottom screened interval terminates at a depth of approximately 80 feet bgs, above the Killey-Moosehorn transition zone). The water within Water Bearing Unit 2 is also noted to decrease in elevation as it flows from inland areas toward the Cook Inlet, as observed by the declining potentiometric water surface between wells MW-50A and MW-62A.

Cross section F-F'

This cross section (Plate A-9) is an east/northeast-west/southwest trending cross section located in the northern portion of the Site. The water elevation in Water Bearing Unit 1 is observed decreasing from east to west, as shown in wells MW-14B and MW-74B. The relative steep northeast to southwest trending gradient of the potentiometric surface in Water Bearing Unit 2 is shown in the relative elevations observed in wells MW-74A and MW-77A.

Cross section G-G'

This cross section (Plate A-10) is a northeast-southwest trending cross section located in the approximate northern third of the Site. The Water Bearing Unit 1 water surface elevation is observed decreasing as groundwater flows to the southwest, as shown in the decrease in elevation observed between wells MW-14B and MW-80B. Based on our understanding of approximate water bearing unit elevations at the Site, we infer that the Water Bearing Unit 2/Water Bearing Unit 3 demarcation is at an elevation of approximately -120 feet at the location of boring B-198.

Cross section H-H'

Cross section H-H' (Plate A-11) extends from a surface water body at the northeast end, to Cook Inlet at the southwest end. This cross section is located within and subparallel to the major regional northeast-southwest trending geologic feature discussed previously. The Water Bearing Unit 1 water surface elevation observed in well MW-98B is noted to be anomalously high when compared with the Water Bearing Unit 1 water surface elevations in nearby wells, likely reflecting a perched water condition. It is unknown if the perched condition is associated with the northeast-southwest trending geologic feature.

Cross section I-I'

This cross section (Plate A-12) which trends northeast-southwest, is also located subparallel to the regional geologic feature. The large body of surface water observed on the southern half of this plate is a surface expression of the regional geologic feature. The water surface elevation in Water Bearing Unit 1 wells, and the potentiometric water surface in Water Bearing Unit 2 wells are noted to decline in elevation as the water flows toward the Cook Inlet to the southwest.

Cross section J-J'

This cross section (Plate A-13) is the southernmost northeast-southwest trending cross section. An approximately 10-foot-thick clay is observed near elevation 50 feet (NAVD88) in boring B-38, and it may be inferred that this clay unit extends to and thickens at the locations of borings B-40 and B-42 to the southwest. The thinning of the water column in Water Bearing Unit 1 is evidenced by the lack of captured water observed in well MW-112B, located near the bluff and screened above the Killey/Moosehorn transition zone.

2.4 Groundwater Bearing Units

Three (3) distinct water bearing units have been identified and observed during subsurface field activities. These units are discussed in the following subsections. Micro Diver devices have been installed in all wells at the Site to provide data collection of changes in depth to groundwater. The static water surface (Water Bearing Unit 1) and potentiometric surface elevations (Water Bearing Units 2 and 3) in Site wells, as recorded on September 22, 2016, are presented in Table 2.4.1. The wells cover a large spatial area, and top of well casing elevations vary from 97.99 feet (NAVD88) at well MW-39A in the southern portion of the site to 136.24 feet (NAVD88) at well MW-14B, about 5,000 feet to the north.

Table 2.4.1. Observed Static Water Elevations

Water Bearing Unit	Well ID	Year Installed	Water Elevation [1,2]
1	MW-14B	2015	91.64
1	MW-27B	2014	92.54
1	MW-39B	2014	72.62
1	MW-50B	2014	89.47
1	MW-62B	2015	Dry
1	MW-74B	2015	72.92
1	MW-77B	2015	Dry
1	MW-80B	2015	84.69
1	MW-82B	2015	99.21
1	MW-86BA	2016	71.23
1	MW-87B	2015	79.56
1	MW-91B	2015	Dry
1	MW-98B	2015	91.30
1	MW-112B	2015	Dry
1	MW-138B	2015	82.84
1	OW-1	2016	96.94
1	OW-3	2016	97.00
2	MW-39A	2014	33.48
2	MW-50A	2014	69.00
2	MW-62A	2015	50.01
2	MW-74A	2015	63.36
2	MW-77A	2015	28.69
2	MW-82A	2015	94.84
2	MW-86A	2015	56.83
2	MW-91A	2015	15.71
2	MW-98A	2015	26.81
2	MW-112AA	2015	19.50
2	MW-138A	2015	61.28
2	OW-2	2016	74.62
2	OW-4	2016	75.09
2	APT-1	2016	72.22
2	APT-2	2016	74.35
3	APT-3	2016	45.86

Notes:
1. Measured September 22, 2016 at 18:00 hours
2. Datum: NAVD88

2.4.1 Water Bearing Unit 1

The first encountered groundwater (designated Water Bearing Unit 1) is found in the Killey Unit, and is unconfined. Groundwater monitoring wells installed in 2014 and 2015 with a “B” suffix in their designation were designed and installed for screening within Water Bearing Unit 1. Observation wells OW-1 and OW-3 were also screened within Water Bearing Unit 1. This unit consists of sands, gravels, and silts.

Four of the groundwater monitoring wells targeting Water Bearing Unit 1 remain dry, consistent with observations made following well installation. The dry wells (MW-62B, MW-77B, MW-91B, and MW-112B) are located in the western, coastal portion of the Site. This confirms that perched water conditions were observed during well installation, and suggests that groundwater elevations in Water Bearing Unit 1 decrease with the top of the Killey-Moosehorn transition zone as that zone becomes exposed along the western face of the shoreline bluff. The four dry wells were all screened in a perched water zone, sufficiently above the Killey-Moosehorn transition zone, such that the well screens do not capture the static water level. This perched water well condition was confirmed by observations made during and subsequent to the installation of replacement well MW-86BA, which was installed very close to abandoned well MW-86B. The elevation of the bottom of the well screen interval of well MW-86B was approximately 92 feet (NAVD88), and this well was found to not contain water after construction. The elevation of the bottom of the well screen interval of the replacement well (MW-86BA) was set into the Killey-Moosehorn transition zone at approximately 64 feet (NAVD88). The water surface elevation in replacement well MW-86BA, as measured in September 2016, was 71.23 feet (NAVD88).

The water surface for Water Bearing Unit 1 was observed at elevations ranging between 99.21 feet (NAVD88) at the location of well MW-82B and 71.23 feet (NAVD88) at the location of well MW-86BA. This water unit was observed present at higher elevations in proximity to surface water bodies. Water elevations, gradient, and flow direction as measured in wells installed within Water Bearing Unit 1 are shown on Plate 7. Groundwater is inferred to flow in a west/southwest direction at a gradient of approximately 0.008 to 0.01 feet per foot (ft/ft).

Plate 8 shows water surface elevations in each of the 13 Water Bearing Unit 1 wells bearing water. The water level for wells installed in the 2014 campaign are shown from December 2014 to September 2016; the water level for wells installed during the 2015 field campaign commenced in August and September 2015 (depending upon Micro Diver installation and activation date), and are shown through September 2016. A review of this plate shows water elevations decline approximately 2 and 5 feet from data recording inception in December 2014 through approximately October 2015, at which time elevations are at their nadir. Water elevations then commence recovery in response to surface water recharge to the aquifer, and reach their apex in February 2016, at which time water elevations are noted to begin their seasonal decline. An overall decrease of approximately 1 foot in water elevation is observed in wells MW-27B, MW-39B, and MW-50B from December 2014 to December 2015.

Approximately 4.13 inches of rain fell at Nikiski during the last week of September and first week of October, 2015. The water elevations were observed to rise during the first week of October 2015 in wells MW-39B, MW-138B, MW-50B, MW-27B and MW-82B. This relatively fast water level rebound is likely attributable to high transmissivity and well established hydraulic connectivity between these well locations and nearby surface water bodies. Conversely, the absence of fast rebound in the other wells is likely due to low transmissivity and poorly established hydraulic connectivity between those well locations and nearby surface water bodies. Groundwater recovery for the winter of 2015/2016 peaked in February 2016.

Water levels within Water Bearing Unit 1 wells are not influenced by cyclic Cook Inlet tidal levels (in contrast with Water Bearing Units 2 and 3, see below). The absence of correlation is graphically presented on Plates 9 through 21.

The water elevation within well MW-98B has consistently been substantially higher than water elevations in nearby Water Bearing Unit 2 wells, which is likely the result of locally perched water conditions due to lithologic units. However, between November 2015 and March 2016, this well showed a significant decrease in water elevation, which may be attributed to nearby groundwater withdrawal/use.

2.4.2 Water Bearing Unit 2

Water Bearing Unit 2 is present within the Moosehorn Unit beneath the first encountered confining lithologic stratum (Killey-Moosehorn transition zone), and is confined or semi-confined. Groundwater monitoring wells installed in 2014 and 2015 with an "A" suffix in their designation were designed and installed for screening within Water Bearing Unit 2. Aquifer pump test wells APT-1 and APT-2, and observation wells OW-2 and OW-4 were also screened within Water Bearing Unit 2.

The potentiometric water surface elevations (the surface to which water in a confined aquifer will rise within a well to reach hydrostatic equilibrium) were observed ranging between 94.84 feet (NAVD88) at the location of well MW-82A and 15.71 feet (NAVD88) at the location of well MW-91A in September 2016. The variability in potentiometric water surface is influenced by the complex heterogeneous nature of the lithology which comprises the matrix of Water Bearing Unit 2. These lithologic units include numerous sand and silt layer pinch-outs, which act to spatially inhibit and modify the physical groundwater conditions within Water Bearing Unit 2.

Water elevations, gradient, and flow direction are depicted on Plate 22. Groundwater is inferred to flow in a west/southwest direction at a gradient of approximately 0.008 to 0.06 ft/ft. The potentiometric groundwater gradient is noted to steepen as it approaches the Cook Inlet.

Plate 23 displays the potentiometric water surface elevations in the Water Bearing Unit 2 wells between December 2014 and September 2016. The water level for wells installed in the 2014 campaign are shown from December 2014 to September 2016; the water level for wells installed during the 2015 field campaign commenced in August and September 2015 (depending upon Micro Diver installation and activation date), and are shown through September 2016. The water level data acquisition for wells installed in 2016 commenced upon their Micro Diver installation dates in August and September. The gap in data collection for well MW-39A approximately between March and June 2015 is attributable to Micro Diver failure. The failed device was replaced in June 2015, and data collection resumed.

Water levels in instrumented wells declined approximately 2 to 3 feet between December 2014 and November 2015. Water levels were observed to have recovered by May 2016. There is no discernable reduction in water levels year-over-year, 2014 to 2015, in the Water Bearing Unit 2 wells.

Water levels within a majority of Water Bearing Unit 2 wells are influenced by cyclic Cook Inlet tidal levels. This influence is graphically presented on Plates 24 through 38. In general, this correlation is stronger at well locations in proximity to the Cook Inlet, and weaker in wells located further inland. It may be inferred that Cook Inlet water influences Water Bearing Unit 2 wells at the Site, and that this influence is generally more pronounced in wells adjacent to the coast. We do note some departures from this general relationship, and attribute these outliers to the heterogeneous nature of the lithologies at a given well. Tidal influence is observed in wells MW-82A, OW-2 and OW-4, wells located most distal from the coast, and near the eastern boundary of the Facilities Study Area. The correlation between Cook Inlet tides and potentiometric water surfaces within Water Bearing Unit 2 likely terminates at some distance to the east, beyond the current area of study.

The static water surface and potentiometric surface elevations in select co-located wells within Water Bearing Unit 1 and Water Bearing Unit 2 are depicted on Plate 39.

Table 2.4.2. Static Water Elevations at Selected Co-Located Well Pairs

Well ID	Water Elevations (ft) [1]	Water Level Elevation Difference (ft)[2]	Separating Aquitard Thickness (Approximate, ft) [3]
MW-39A	33.48	39.14	15 - 20
MW-39B	72.62		
MW-50A	69.00	20.47	10 - 30
MW-50B	89.47		
MW-74A	63.36	9.56	40 - 50
MW-74B	72.92		
MW-82A	94.84	4.37	20 - 40
MW-82B	99.21		
MW-138A	61.28	21.56	15 - 20
MW-138B	82.84		
OW-1	15.29	22.19	10 - 30
OW-2	37.48		
OW-3	34.26	21.44	10 - 30
OW-4	55.70		

Notes:
1. Datum: NAVD88, measured September 22, 2016 at 18:00 hours
2. Water Bearing Unit 1/ Water Bearing Unit 2
3. Aquitard thickness based on boring logs (either co-located or nearby).

No correlation between separating aquitard thickness and magnitude of the water elevation difference is apparent at these co-located wells (Table 2.4.2). There also is no observed correlation between groundwater elevation differences in wells located within a regional northeast-southwest trending geological feature characterized by surface water bodies and relatively shallow groundwater (wells MW-39A and MW-39B, and MW-82A and MW-82B) as compared with those outside of this feature (wells MW-50A and MW-50B, and MW-74A and MW-74B).

2.4.3 Water Bearing Unit 3

Water Bearing Unit 3 is found beneath a second encountered confining lithologic stratum in the Moosehorn Unit. This water bearing unit extends at least as deep as the maximum drilled depth (437 feet bgs within boring well APT-3) and water within the unit was observed to be confined or under pressure. During the drilling of well APT-3, no sequences of lithologies conducive to produce a sustainable well yield were encountered within the depth explored through Water Bearing Unit 3. In contrast, at Tesoro Well TW-9 (located approximately 9,000 feet to the northeast of well APT-3) a medium to coarse gravel was encountered from 328 to 352 feet bgs within Water Bearing Unit 3 (see Plate 6). The TW-9 well log documents a field well yield of 550 gallons per minute. The difference in lithologies and well yields between well APT-3 and TW-9, support the theory that there is a geologic formational feature between these two well locations which is a limiting factor to well recharge and yield at well APT-3.

Well APT-3 was screened within Water Bearing Unit 3. The potentiometric water surface elevation measured on September 22, 2016 at the location of well APT-3 was 45.86 feet (NAVD88). There is insufficient data upon which to provide comment regarding water flow and direction in Water Bearing Unit 3.

The water level within well APT-3 is shown to be influenced by Cook Inlet tidal fluctuations. This influence is graphically presented on Plate 40. The magnitude of the cyclic response wave pattern observed at well APT-3 is greater than those observed at co-located well APT-1.

2.5 Effect of the January 24, 2016 Kenai Earthquake on Groundwater

A magnitude 7.1 earthquake, located in the Iniskin area of Alaska, approximately 60 miles west of Homer, occurred on January 24, 2016. Groundwater elevations in five of the Water Bearing Unit 1 and two of the Water Bearing Unit 2 wells exhibited a response based upon Micro Diver data retrieved from the wells. Graphic depictions of the groundwater elevations in Water Bearing Units 1, 2, and selected co-located pairs are presented on Plates 41, 42, and 43, respectively.

The Micro Divers are programmed to collect water depth data every 30 minutes, and therefore instantaneous post-earthquake responses were not recorded. Water levels may have responded and subsequently recovered to their pre-earthquake levels between data recording intervals in wells which showed no measured response.

No discernable spatial correlation (such as, proximity to Cook Inlet or surface water bodies) is observed in the responsive wells. Likewise, no correlation in lithologies of the responsive wells, as compared to lithologies of the non-responsive wells, is observed. A discussion regarding the seven wells which showed a response to the earthquake are discussed below by water bearing unit.

2.5.1 Water Bearing Unit 1

The water elevations within wells MW-39B, MW-74B, MW-82B and MW-87B were observed to decrease between approximately 3-inches to 1-foot, and then rebounded to their pre-earthquake levels within approximately 1 hour. The water level within well MW-50B was observed to increase approximately 3-inches, and then returned to its' pre-earthquake level in approximately 1 hour. A decrease in water elevation may be indicative of increased pore space made available in the saturated zone by the shaking motion; conversely, an increase in water elevation may be indicative of decreased pore space made available in the saturated zone by the shaking motion.

2.5.2 Water Bearing Unit 2

The water elevation within well MW-74A was observed to drop approximately 3-feet, then rebounded and sustained an approximately 2-feet rise above its' pre-earthquake elevation. The water elevation within well MW-86A was observed to rise and sustain approximately 1-foot in elevation. The factors which caused the sustained responses of water elevation change at these locations is unknown.

2.6 Former Quarry Pit Area Limited Environmental Assessment and Mitigation

A former quarry located near the proposed well field, has been considered as a repository for aquifer pump test discharge waters. A Limited Phase II Site Assessment conducted by URS/AECOM in January 2015 (USAI-UR-SRZZZ-00-000034-005, URS Environmental Due Diligence Limited Phase II Site Assessment Analytical Soil Sample Results Peterkin Parcel, January 30, 2016) identified several recognized environmental conditions (RECs) within the former quarry, including areas of surficial petroleum staining and bluish-green sand. We understand that AECOM was subsequently tasked by AKLNG with conducting additional environmental assessment and mitigation. This work is documented in an AECOM Memorandum dated September 7, 2016 (USAI-UR-SRZZZ-00-000092-000, Aconex #JV-TRN-002947).

3.0 HYDROLOGIC SETTING

3.1 General

Water falling to the land surface as rain or snow percolates into underlying soils down to the water table, where it recharges Water Bearing Unit 1. Groundwater in this unconfined aquifer flows toward springs on the coastal bluffs where it was observed to be discharging during the 2014 and 2015 field investigations. Groundwater in Water Bearing Unit 1 is also reported to leak through the clay units to recharge deeper aquifers. Groundwater in Water Bearing Unit 2 flows towards the west (United States Department of the Interior Geologic Survey, 1981, Hydrology and the Effects of Industrial Pumping in the Nikiski Area, Alaska).

Lakes in the area are recharged by precipitation, snowmelt, and by groundwater inflow. Groundwater levels adjacent to lakes correlate to lake water levels and fluctuations based on hydrologic processes. Similarly, as distance away from lakes increases, groundwater levels are expected to rise or fall to meet stabilized groundwater levels in an area.

Several factors contribute to seasonal and annual fluctuations in groundwater aquifer levels. Recharge is influenced by the amount of precipitation received both locally and regionally, evapotranspiration rates, and the rate of surface water runoff.

3.2 Precipitation

The mean annual precipitation for Nikiski between 1980 and 2010 was 19.01 inches per year according to Nikiski data compiled by the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service. The average annual precipitation, as measured at the Nikiski Airport monitoring station from 2010 to 2015, was 19.96 inches per year.

Much of the water available for aquifer recharge falls during the winter season and is stored as snow and ice.Recharge to lakes, streams, and aquifer units occurs as the snow and ice melt..

3.3 Artesian Conditions

Artesian groundwater conditions in select wells are observed at the Site in Water Bearing Units 2 and 3 with potentiometric water surfaces measured above the aquitard formed by the Killey-Moosehorn transition zone. A majority of potentiometric water surface elevations recorded in wells installed within Water Bearing Unit 2 are all noted to rise above the corresponding top of the Killey-Moosehorn transition zone (see Appendix A, Plates A-6, A-7, A-8, A-9, A-11, and A-12). Well APT-3 is screened between 253 and 283 feet bgs and beneath a substantial clay and silt strata within Water Bearing Unit 3. The potentiometric water surface elevation within this well was observed at approximately 72 feet bgs, also rising above the Killey-Moosehorn transition zone.

Artesian groundwater conditions were also observed in two of the completed Alaska LNG beach borings during the 2015 campaign. At these locations (B-117 and B-136), artesian conditions were encountered at elevations of approximately -84 feet (NAVD88) and -78 feet, respectively. These two borings, are located in the southern area of the onshore geotechnical investigation program. A review of the two referenced beach boring logs, as well as other nearby boring logs, show a wide variation in lithology. It appears that the widely varied, lenticular, and heterogeneous properties of the sediments are acting as confining layers, controlling the presence and nature of these artesian conditions. The artesian condition has been observed to be flowing (where enough hydraulic pressure exists to push the groundwater up to the ground surface) at boring B-136. Artesian conditions were also observed in one offshore boring, MB-24. At this location a flowing artesian condition was encountered at an elevation of approximately -100 feet (NAVD88).

3.4 Proposed Well Field Conditions

Wells APT-1, APT-3, OW-1, and OW-2 are clustered within a regional northeast-southwest trending geological feature characterized by clustered surface water bodies and relatively shallow depth to groundwater in Water Bearing Unit 1. Wells APT-2, OW-3, and OW-4 are situated approximately 1,000 feet to the southeast, and are either on the margin or just beyond the regional subsurface geologic feature which has been observed to limit water recharge and yield locally in the proposed well field. A discussion regarding hydrologic conditions within each water bearing unit follows below. Well development summaries are presented in Appendix B.

3.4.1 APT Well Development Effects on Water Bearing Unit 1

Depth to water within this unit varies depending on proximity to the subsurface geologic feature. Static water depth within well OW-1 is approximately 15.29 feet below top of casing (BTOC) (corresponding elevation of 96.94 feet NAVD88); the static water depth within well OW-3 is approximately 34.26 feet BTOC (corresponding elevation of 97.00 feet NAVD88).

Well APT-1, completed in Water Bearing Unit 2, was developed on September 12, 2016 by pumping approximately 7,540 gallons of water in two intervals. The development of well APT-1 consisted of originally pumping at approximately 100 gpm, and subsequently increasing the pumping rate in increments to approximately 300 gpm. Well APT-1 was dewatered to the pump intake level (approximately 23 feet elevation NAVD88) during development. None of the nearby wells (within 1,000 feet of well APT-1) screened within Water Bearing Unit 1 (e.g., wells MW-27B, OW-1, and OW-3) showed any discernable water level response to the water extraction during well APT-1 development activities (Plate 44).

Well APT-2, also completed in Water Bearing Unit 2, was developed on September 19, 2016 by pumping approximately 7,059 gallons of water in two intervals. During development, water was originally pumped at a rate of approximately 200 gpm, and stepped up in one increment to approximately 250 gpm during the first pumping interval. Well APT-2 was dewatered to the pump intake level (approximately 33 feet elevation NAVD88) during the first interval. Pumping was maintained at approximately 200 gpm during the second development interval for 11 minutes. Well APT-2 was not dewatered to the pump intake level during the short second pumping interval.

The closest well to well APT-2 (well OW-3, located approximately 500 feet north) is screened within Water Bearing Unit 1, and did not show a discernable water level response to the water extraction during the development activities (Plate 45).

Although there is likely communication between water within Water Bearing Unit 1 and Water Bearing Unit 2 at the Site, there was no measurable decrease in water elevation in nearby Water Bearing Unit 1 wells during the pumping of water from wells screened within Water Bearing Unit 2. This may be attributable to several factors including the limited nature of the well development activities, and the presence of a relatively competent aquitard separating Water Bearing Unit 1 and Water Bearing Unit 2 in this area, or a combination of these and other possible factors.

3.4.2 APT Well Development Effects on Water Bearing Unit 2

During well APT-1 development activities, water elevations recorded within wells OW-2 (located approximately 550 feet east/northeast of well APT-1) and OW-4 (located approximately 1,000 feet east/southeast of well APT-1) were observed to quickly respond to the pumping, with two discrete decreases recorded in water elevations (Plate 44). Water elevations within the wells quickly recovered subsequent to cessation of pumping activities. Given the quick responses to pumping and cessation of pumping, it is evident that good hydraulic communication within Water Bearing Unit 2 exists between the locations of wells APT-1, OW-2, and OW-4.

There was no discernable response to well APT-1 development pumping recorded at well MW-82A (located approximately 1,450 feet northeast of well APT-1); indicating that either this well is located outside of the limited radius of influence of the well development activities, or there is an impediment to hydraulic communication somewhere between wells APT-1 and MW-82A.

During well APT-2 development activities, the water elevation recorded within well OW-4 (located approximately 500 feet north of well APT-2) was observed to quickly respond to the pumping, with two discrete decreases recorded in groundwater elevations (Plate 45). The water elevation within this well quickly recovered subsequent to cessation of pumping activities.

Water elevations within well OW-2 (located approximately 1,225 feet north-northwest of well APT-2) did not show a discernable response to well APT-2 water development pumping activities; indicating that either this well is located outside the limited radius of influence of the well development activities, or there is an impediment to hydraulic communication somewhere between wells APT-2 and OW-2.

Water was pumped at a continuous rate of approximately 200 gpm during the second interval of development of well APT-2. During that interval, the rate of water drawdown was observed to slow over time, and did not reach the pump intake elevation. The slowing of the rate of drawdown at 200 gpm may signify that this pumping rate may be close to the well's sustainable yield.

3.4.3 APT Well Development Effects on Water Bearing Unit 3

During development water removal from co-located well APT-1, no discernable response was noted in the potentiometric water surface elevation at well APT-3. This may be attributable to the limited nature of the well development activities, a relatively competent aquitard separating Water Bearing Unit 2 and Water Bearing Unit 3 in this area, or a combination of these or other possible factors.

Well APT-3, completed in Water Bearing Unit 3, was developed on September 3, 2016 by pumping groundwater at a continuous rate of approximately 25 gpm. The well was completely dewatered to the pump intake depth of 231 feet bgs; indicating that a sustained groundwater yield would be less than 25 gpm.

3.4.4 Hydraulic Conductivity

Data collected during well development activities were analyzed, and hydraulic conductivity estimated utilizing the Hvorslev Method of analysis. Charts depicting changes in water elevations (drawdown and recovery) and temperature data (collected to graphically illustrate conductivity) during the development of wells APT-1, APT-2, and APT-3 are presented as Plates 46, 47, and 48, respectively. Hydraulic conductivity at wells APT-1, APT-2, and APT-3 is calculated at 30.4, 49.9, and 0.12 feet per day, respectively.

3.5 Generalized Hydrogeologic Conceptualized Model

Hydrogeology within the study area is complex in nature. This complexity is due to the heterogeneous and sporadic spatial occurrence of sediments comprising the three water bearing units observed at the Site. General site lithologies with water bearing units and fence diagrams are graphically depicted as Plates A-14 and A-15 in Appendix A.

The interactions between precipitation, surface water bodies, and water percolation through the diverse identified glacial and glaciofluvial formations have created unconfined, semi-confined and confined aquifers at the Site. The three aquifers are separated by discontinuous aquitards (typically between Water Bearing Units 1 and 2), and a generally more continuous aquitard (between Water Bearing Units 2 and 3). There appears to be significant hydraulic communication between surface water bodies and Water Bearing Unit 1, and a lesser degree of hydraulic communication between Water Bearing Units 1 and 2. This is likely attributable to the discontinuous nature of the aquitard separating these units.

Groundwater within Water Bearing Unit 1 is recharged by percolation of local precipitation through overlying sediments, and from local surface water bodies. The predominant recharge source of water within Water Bearing Units 2 and 3 is distal, and to the east.

Groundwater in both Water Bearing Units 1 and 2 flows to the west, at relatively flat gradients. Groundwater with Water Bearing Units 2 and 3 are influenced by Cook Inlet tides. This influence may be due to hydraulic connectivity with Cook Inlet waters, by increased hydrostatic pressure due to increased load during high tides, or a combination of both.

The quick response in water levels observed within nearby wells screened within Water Bearing Unit 2 during development water removal from wells APT-1 and APT-2 indicate good hydraulic communication within Water Bearing Unit 2 in the well field area.

A review of the recovery graph generated from well APT-3 development data (Plate 48, Chart D) shows an upward curve at the end of recovery. This indicates influence of an impermeable geologic barrier near this well. As there are no known geologic structures (e.g., folds, faults, joints) in this area, it may be inferred that very stiff sedimentary strata in this area could be acting as a barrier to groundwater flow.

4.0 GROUNDWATER QUALITY

Two groundwater quality sampling events have been conducted in 2016 to evaluate groundwater quality in Site wells. The groundwater sampling program activities and results are documented in Fugro's LNG Facilities Groundwater Sampling and Testing Report – Event 1 Report, USAL-FG-GRZZZ-

00002016-003; and LNG Facilities Groundwater Sampling and Testing Report – Event 2 Report, USAL-FG-GRZZZ-00002016-004. Major findings of the sampling program are summarized below by water bearing unit.

4.1 Water Bearing Unit 1 Groundwater

Detected total and dissolved metal concentrations were below respective Alaska Department of Environmental Conservation (ADEC) Table C groundwater cleanup levels, where established. For wells OW-1 and OW-3, detected concentrations of select total and/or dissolved metals including aluminum, chromium, copper, iron, manganese, and/or nickel exceeded respective ADEC Water Quality Standards for Designated Uses. Of particular note, Arsenic was not detected at concentrations above regulatory thresholds, as compared with Water Bearing Unit 2 and Water Bearing Unit 3 (see below).

Petroleum hydrocarbons, including diesel range organics, gasoline range organics, and residual range organics have been detected in several Water Bearing Unit 1 wells, at concentrations below regulatory thresholds.

Values of pH in groundwater collected during Event 1 ranged between 6.40 and 7.93 (average of 7.14) Standard Units (SU), and between 4.82 and 7.30 (average of 6.86) SU in groundwater collected during Event 2.

No VOCs, PCBs, pesticides, fecal coliform, or Chlorophyll-A were detected in samples submitted for analyses.

4.2 Water Bearing Unit 2 Groundwater

Analyses detected arsenic at concentrations ranging from 0.0077 milligrams per Liter (mg/L) to 0.131 mg/L, exceeding the ADEC Table C groundwater cleanup level of 0.01 mg/L in wells MW-39A, MW-50A, MW-62A, MW-74A, OW-2, OW-4, APT-1, and APT-2. Arsenic was not detected above this regulatory threshold in samples collected from wells MW-82A and MW-91A.

For wellsOW-2, OW-4, APT-1, and APT-3, detected concentrations of select total and/or dissolved metals including aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, nickel, vanadium, and/or zinc exceeded respective ADEC Water Quality Standards for designated uses.

No VOCs were detected in any of the six (6) wells sampled during Event 1. With the exception of trichloroethene, toluene, and chloromethane, no VOCs were detected in any of the ten (10) wells sampled during Event 2. Analyses detected trichloroethene in three (3) of ten (10) wells (wells OW-2, OW-4, and APT-1) at concentrations ranging between 0.00047 mg/L and 0.057 mg/L, exceeding ADEC Table C groundwater cleanup level of 0.005 mg/L in wells OW-4 and APT-1. Analyses detected toluene at 0.0027 mg/L (well APT-2) and chloromethane at a concentration of 0.00039 mg/L (OW-2 and OW-4), all below ADEC Table C groundwater cleanup criteria.

Detected petroleum hydrocarbon concentrations were well below respective ADEC Table C groundwater cleanup levels. Analyses detected gasoline range organics in one (1) of the six (6) wells sampled during the Event 1 monitoring event (well MW-39A) at a concentration of 0.0539 mg/L. Analyses detected gasoline range organics in one (1) of the ten (10) wells sampled during the Event 2 monitoring event (well APT-1) at a concentration of 0.0497 mg/L. Diesel range organics were detected in eight (8) out of ten (10) samples collected during the Event 2 monitoring event at concentrations ranging between 0.24 mg/L and 0.486 mg/L (wells MW-39A, MW-50A, MW-62A, MW-74A, MW-82A, OW-4, APT-1, and APT-2). Diesel range organics were not detected in any wells sampled during Event 1. Residual range organics were detected in one (1) of six (6) wells collected during the Event 1 monitoring event (MW-74A) at a concentration of 0.352 mg/L; and at two (2) of the ten (10) wells sampled during the Event 2 monitoring event at concentrations of 0.192 mg/L (well OW-2) and 0.476 mg/L (well OW-4). All of these concentrations are below ADEC Table C groundwater cleanup criteria.

Values of pH in groundwater collected during Event 1 ranged between 8.37 and 9.99 (average of 9.04) SU, and between 7.08 and 8.67 (average of 8.13) SU in groundwater collected during Event 2.

4.3 Water Bearing Unit 3 Groundwater

The second groundwater quality sampling event (Event 2) represented the first opportunity to collect groundwater quality data from Water Bearing Unit 3, and at only one (1) location, well APT-3.

Detected concentrations of select total and/or dissolved metals including, aluminum, arsenic, boron, chromium, copper, iron, lead, manganese, molybdenum, nickel, and/or zinc exceeded respective ADEC Water Quality Standards for designated uses.

With the exception of trichloroethene, no VOCs were detected during this event. Analyses detected 0.015 mg/L of trichloroethene, exceeding the ADEC Table C groundwater cleanup level of 0.006 mg/L.

Petroleum hydrocarbons were detected at concentrations well below respective ADEC Table C groundwater cleanup levels. Analyses detected diesel range and residual range organics at concentrations of 0.518 mg/L and 0.165 mg/L, respectively.

The pH value was measured at 9.03 SU in a groundwater sample collected from well APT-3.

4.4 Comparison of Water Quality Data Between Water Bearing Units

Groundwater within Water Bearing Units 2 and 3, including groundwater in the vicinity of the quarry and the APT wells, has been shown to contain total and dissolved metals and select VOCs at higher concentrations than values detected in Water Bearing Unit 1. Of particular note is the presence of total arsenic and trichloroethene concentrations that were detected at an order of magnitude higher in Water Bearing Units 2 and 3 wells than in Water Bearing Unit 1 wells. Detected concentrations of these analytes in select wells screened within Water Bearing Units 2 and 3 exceed ADEC groundwater cleanup levels, whereas these analytes, if detected, are below ADEC levels in Water Bearing Unit 1. Additionally, Water Bearing Units 2 and 3 also have higher pH levels than Water Bearing Unit 1.

With the exception of bis(2-ethylhexyl)phthalate in well MW-74B, detected analytes in groundwater samples within Water Bearing Unit 1 have all been below ADEC groundwater cleanup levels. During the September monitoring event, bis(2-ethylhexyl)phthalate was detected in well MW-74B at 0.0077 mg/L, exceeding the ADEC groundwater cleanup level of 0.006 mg/L.

In general, no PCBs or pesticides were identified in any of the groundwater samples analyzed from the three water bearing units underlying the site. Between the two monitoring events, gasoline range, diesel range, and residual range organics have been detected within all three water bearing units, at similar concentrations, and below ADEC groundwater cleanup levels.

Cations and anions from wells sampled during the two monitoring events were plotted on Piper Diagrams by Water Bearing Unit. Based on the data, with the exception of well MW-39B, water within

Water Bearing Unit 1 is calcium bicarbonate rich, indicative of a shallow fresh water environment. Water in the vicinity of well MW-39B is slightly more calcium sulfate rich than other wells screened within the shallow water bearing unit. With the exception of groundwater in the vicinity of MW-50A, MW-82A, and OW-2, groundwater within Water Bearing Unit 2 is also calcium bicarbonate rich, indicative of a shallow fresh water environment. Water in the vicinity of wells MW-50A, MW-82A, and OW-2 tends to be more sodium bicarbonate rich, which may be indicative of a deep groundwater environment influenced by ion exchanges. Similar to wells MW-50A, MW-82A, and OW-2, cations and anions for well APT-3, screened within Water Bearing Unit 3, are also indicative of a deep groundwater environment influenced by ion exchanges.

4.5 Conditions in the Proposed Well Field Area

Groundwater sample analyses has detected antimony at concentrations ranging from 0.000362 mg/L to 0.00775 mg/L, exceeding the ADEC Table C groundwater cleanup level of 0.006 mg/L in OW-4. Detected total arsenic concentrations varied between 0.00131 mg/L and 0.131 mg/L, exceeding ADEC Table C ground water cleanup level of 0.01 mg/L, and the ADEC Alaska General Permit AKG003000 for Discharge of Aquifer Pump Test (Table 3) in samples obtained from wells OW-2, OW-4, and APT-1 through APT-3. It should be noted that most total metals also exceeded ADEC Water Quality Standards for Designated Uses in most wells.

Analyses detected trichloroethene at concentrations ranging from 0.00047 mg/L (well OW-2) to 0.057 mg/L (well OW-4), exceeding the ADEC Water Quality Standard for Designated Use criteria of 0.005 mg/L in samples collected from OW-4, APT-1, APT-2, and APT-3.

For wells OW-2, OW-4, APT-1, APT-2, and APT-3, detected concentrations of select dissolved metals including arsenic, copper, lead, and zinc also exceeded respective ADEC Water Quality Standards for Designated Uses.

Gasoline range organics were detected in well APT-1 at 0.0497 mg/L. Analyses detected diesel range organics in all three APT wells and in well OW-4 at concentrations ranging from 0.24 mg/L (well APT-2) to 0.518 mg/L (well APT-3). Residual range organics were detected in all four OW wells and in well APT-3 at concentrations ranging from 0.155 mg/L to 0.476 mg/L. All detected hydrocarbons were well below respective ADEC Table C groundwater cleanup levels.

Given the regulatory concentration threshold exceedances of antimony, arsenic, and trichloroethene found in groundwater samples in the proposed well field area, any discharge must be managed in accordance with regulatory agency requirements to mitigate any potential impacts.

4.6 Conditions in the Vicinity of the Former Quarry Pit

Groundwater monitoring wells MW-27B and MW-87B, and three (3) third-party wells (wells PQW-1, TPW-1, and TPW-2) are located in the general vicinity of the former quarry pit.

Various total metals were detected in all wells located in the vicinity of the quarry. With the exception of arsenic, detected total metals were well below respective ADEC Table C groundwater cleanup levels, where established. Analyses detected arsenic up to 0.0149 mg/L, exceeding ADEC's Table C groundwater cleanup level and APT General Discharge Permit criteria of 0.01 mg/L in TPW-2. Various dissolved metals were also detected in the two (2) monitoring and the three (3) third-party wells at concentrations below respective ADEC Table C groundwater cleanup levels, where established.

Petroleum hydrocarbons including gasoline range (0.359 mg/L, PQW-1) and diesel range (up to 0.354 mg/L, well MW-87B) have been identified in groundwater samples collected within the quarry area. Analyses also detected the presence of benzene up to 0.0677 mg/L, exceeding ADEC's Table C groundwater cleanup level of 0.005 mg/L.

It is likely that a future discharge of a significant volume of water associated with a potential aquifer pump test would mobilize the documented petroleum hydrocarbons, benzene, and arsenic which are found in groundwater above regulatory thresholds at and near the former quarry pit. Any potential discharge will need to be managed in accordance with regulatory agency guidance.

5.0 CONCLUSIONS

Studies completed during the 2014, 2015 and 2016 field investigations have provided good coverage and data collection for the Site. Groundwater monitoring wells, aquifer pump test wells and observation wells installed to date span an area of approximately 9,000 feet in the north/south direction by approximately 5,700 feet in the west/east direction. Based on the data collected to date, we conclude the following:

- Three (3) groundwater bearing units have been identified at the Site, an unconfined Water Bearing Unit 1 within the upper Killey formation, and a confined or semi-confined Water Bearing Unit 2 and a confined Water Bearing Unit 3 within the underlying Moosehorn formation.
- Shallow groundwater is influenced by surface water bodies, and is found to recharge quickly relative to proximity to those bodies after rain events.
- Four (4) of the wells completed within Water Bearing Unit 1 were dry during both monitoring events completed in 2016, consistent with observations made following initial well installation. This confirms that perched water conditions were present during well installation, and suggests variable depth to water conditions exist within Water Bearing Unit 1. All of the dry wells are located in the western, coastal portion of the Site, where the shallow water column decreases in elevation as it approaches its' discharge point at the bluff.
- The water elevation observed at well MW-98B appears to represent a localized perched condition within Water Bearing Unit 1.
- Water elevations within Water Bearing Unit 1 wells declined approximately 2 to 5 feet from data recording inception in December 2014 through approximately October 2015, at which time elevations are observed at their lowest. Water elevations then commence recovery in response to surface water recharge to the aquifer, and reach their apex in February 2016, at which time water elevations are noted to begin their seasonal decline. An overall decrease of approximately 1 foot in water elevation is observed in the 2014-installed wells from December 2014 to December 2015, likely in response to lower year-to-year seasonal precipitation.
- Water Bearing Unit 1 is observed not to be tidally influenced.
- Water Bearing Units 2 and 3 are observed to be tidally impacted at various degrees of correlation. In general, a higher degree of correlation exists closer to the coastline. There are some departures from this general relationship; we attribute these outliers to the heterogeneous nature of the lithologies across the Site. A stronger correlation between Cook

Inlet tides and potentiometric groundwater elevation is noted in water within well APT-3 (Water Bearing Unit 3) than at co-located well APT-1 (Water Bearing Unit 2).

- There is no discernable reduction in water elevations year-over-year, 2014 to 2015, in the Water Bearing Unit 2 wells.
- Groundwater within Water Bearing Unit 1 and Water Bearing Unit 2 flows at a relatively flat gradient to the west-southwest. There is insufficient data upon which to provide a comment regarding water flow and direction in Water Bearing Unit 3.
- The differences in water surface and potentiometric elevations in co-located wells within Water Bearing Unit 1 and Water Bearing Unit 2 vary significantly. No correlation was noted between the magnitude of the differing co-located water level readings and the thickness of the aquitard separating the units, nor by geographic location.
- Water elevations in five (5) of the Water Bearing Unit 1 wells and two (2) of the Water Bearing Unit 2 wells exhibited a response to a January 2016 magnitude 7.1 earthquake located in Iniskin area of Alaska, approximately 60 miles west of Homer, based upon Micro Diver water level data retrieved from the wells. Most of the water levels decreased and rebounded to their pre-earthquake elevations within an hour. However, the water level in MW-50B was noted to increase slightly. The response was greatest at the location of well MW-74A, which was noted to drop approximately 3 feet, then rebounded and sustained an approximately 2 feet rise above its' pre-earthquake level.
- A review of the recovery graph generated from well APT-3 development data shows an upward curve at the end of recovery, indicating influence of an impermeable barrier near this well. As there are no known seismic structures in this area, it may be inferred that very stiff sedimentary strata in this area could be acting as a barrier to groundwater flow.
- Although there is likely communication between water within Water Bearing Unit 1 and Water Bearing Unit 2 at the Site, there was no measurable decrease in water elevation in nearby Water Bearing Unit 1 wells during the development water removal from wells screened within Water Bearing Unit 2. This may be attributable to the limited nature of the pumping activities, the presence of a relatively competent aquitard separating Water Bearing Unit 1 and Water Bearing Unit 2 in this area, or a combination of these or other possible factors.
- It is evident that good hydraulic communication within Water Bearing Unit 2 exists between the locations of wells APT-1, OW-2, and OW-4. There was no discernable water elevation response at well MW-82A (located approximately 1,450 feet northeast of well APT-1); indicating that there is an impediment to hydraulic communication somewhere between the locations of wells APT-1 and MW-82A and/or the lack of response is a reflection of the shortened development activities which did not stress the aquifer system sufficiently.
- During development water removal from well APT-2, the water elevation recorded within well OW-4 (located approximately 500 feet north of well APT-2) was observed to quickly respond to the water removal activities. Groundwater elevations within well OW-2 (located approximately 1,225 feet north-northwest of well APT-2) did not show a discernable response to well APT-2 groundwater development activities; indicating that there may be an impediment to hydraulic communication somewhere between the locations of wells APT-2 and OW-2, and/or the lack of response is a reflection of the shortened development activities which did not stress the aquifer system sufficiently.

- Water quality found within the three (3) water bearing units varies by unit and laterally within the unit. Total arsenic concentrations within Water Bearing Unit 2 and Water Bearing Unit 3 are up to two orders of magnitude greater than concentrations within Water Bearing Unit 1. Trichloroethene has been detected in Water Bearing Unit 2 and Water Bearing Unit 3 groundwater samples, but not in Water Bearing Unit 1 groundwater samples. pH values measured in Water Bearing Unit 1 groundwater is slightly acidic to neutral; pH Values in Water Bearing Unit 2 and Water Bearing Unit 3 groundwater are neutral to alkaline.
- Groundwater in the proposed well field area is impacted by concentrations of antimony, arsenic, and trichloroethene that exceed the concentrations allowed by the regulatory water quality standards. It is likely that groundwater treatment would be required prior to discharge during a potential future aquifer pump test.
- Groundwater in the former quarry pit area is impacted by concentrations of petroleum hydrocarbons, benzene, and arsenic above regulatory water quality standards. Any potential groundwater discharge will need to be conducted in accordance with regulatory agency review and approval.
- During the installation and development of wells APT-1 and APT-3, no sequences of lithologies conducive to high groundwater yield were encountered within Water Bearing Unit 2 or 3 to the total drilled depth. This may be reflective of geologic processes and conditions found within the northeast-southwest trending geological feature found in this area.

6.0 RECOMMENDATIONS

The Site hydrogeology is a direct result of the complex depositional environment, and subsurface groundwater conditions vary significantly, both vertically and laterally. Although some hydrogeological parameters of Water Bearing Units 1, 2, and 3 have been observed, evaluated, and documented herein, a full-scale long duration (approximately 10 day) aquifer pump test, as originally planned, is necessary to properly evaluate properties of the water source aquifers below the Site and their ability to meet LNG project design criteria needs.

Limited groundwater recharge capacity has been observed in the currently proposed production well field area due to a subsurface geologic feature. In addition, the chemical contaminant trichloroethene has been detected in the well field area, and a source has not been identified. Water removal from the currently proposed well field area during well development activities generated contaminated water which was unsuitable for upland discharge and would require additional treatment for long term use. Long term pumping would continue to move the contamination source toward the Site. As a result, Fugro recommends that the location of the LNG project production well field be moved to another location. Areas further to the north, beyond the subsurface geologic feature, may provide better water quality and capacity. New aquifer pump test and observation wells will need to be installed, and the previously planned long-duration (approximately 10 day) aquifer pump test for Water Bearing Unit 2 should be conducted.

Investigations in the proposed well field area have not provided evidence of a water bearing unit with sufficient capacity capable to satisfy the design criteria/demand use for the LNG Plant. In addition, groundwater collected from Water Bearing Units 2 and 3 was observed to possess elevated arsenic and trichloroethene concentrations. .Before deciding whether Water Bearing Units 2 or 3 should be further evaluated for design criteria/demand use, ADEC should be consulted..

Fugro recommends that efforts for the permitting of any new wells and subsequent pump testing water discharge start early. Fugro understands that ADEC may agree to allow the pump testing water to be discharged to the Cook Inlet. However, this would require consultation with ADEC and may require additional water data collection, testing, and evaluation prior to aquifer pump testing activities.

Fugro further recommends that subsequent groundwater monitoring events be conducted to provide additional data upon which to develop a trend analysis. Data to collect during future monitoring events may include depth to groundwater, chemical concentration, as well as general climatic and/or hydrologic cycle data which may be available including precipitation, snow fall and near-by lake level fluctuations. Fugro suggests that all wells on-site be resurveyed prior to subsequent monitoring events; as it is possible that well casings may have shifted due to ground shaking as a result of the January 2016 Iniskin area earthquake.

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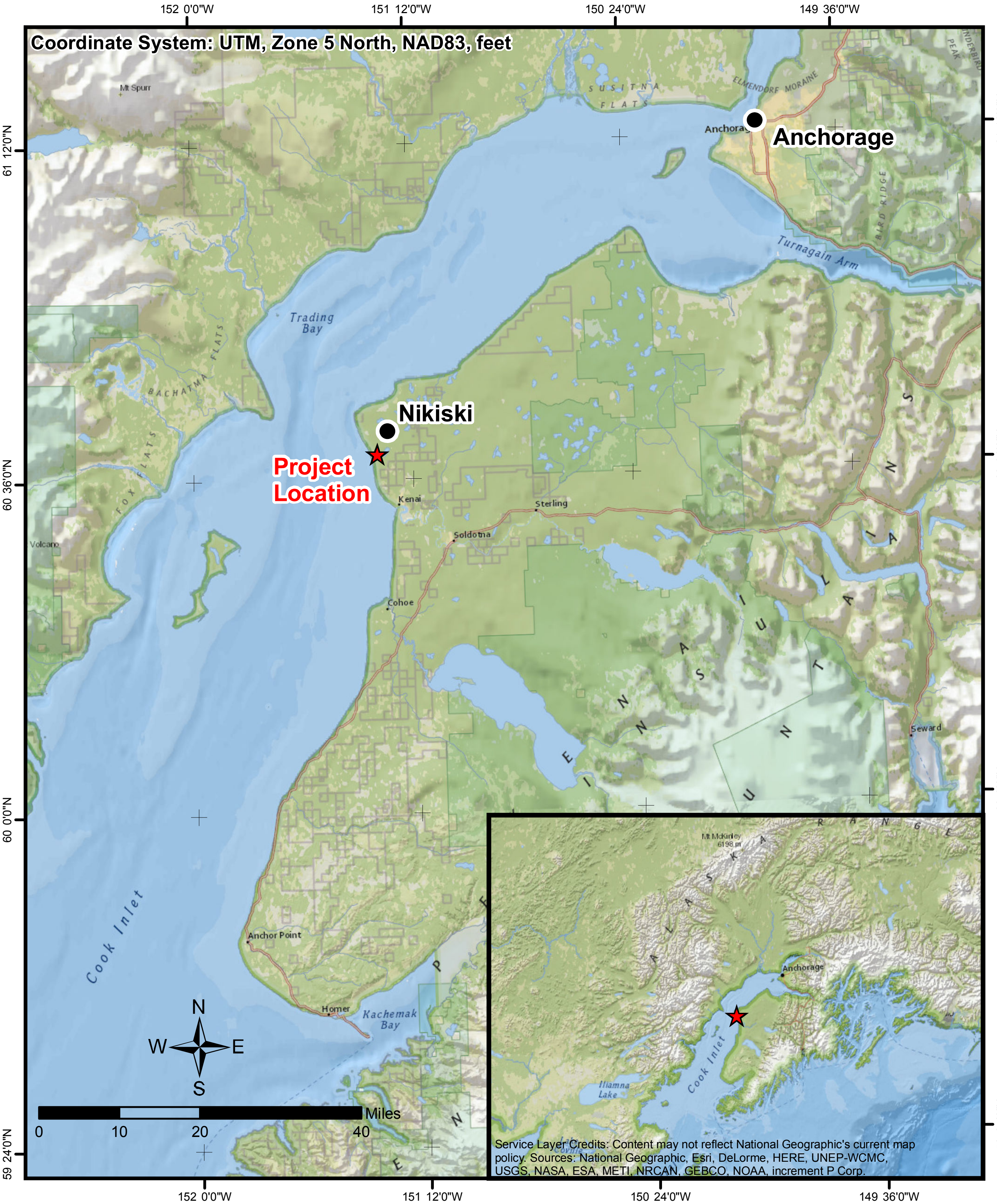
ILLUSTRATIONS



VICINITY MAP
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 1

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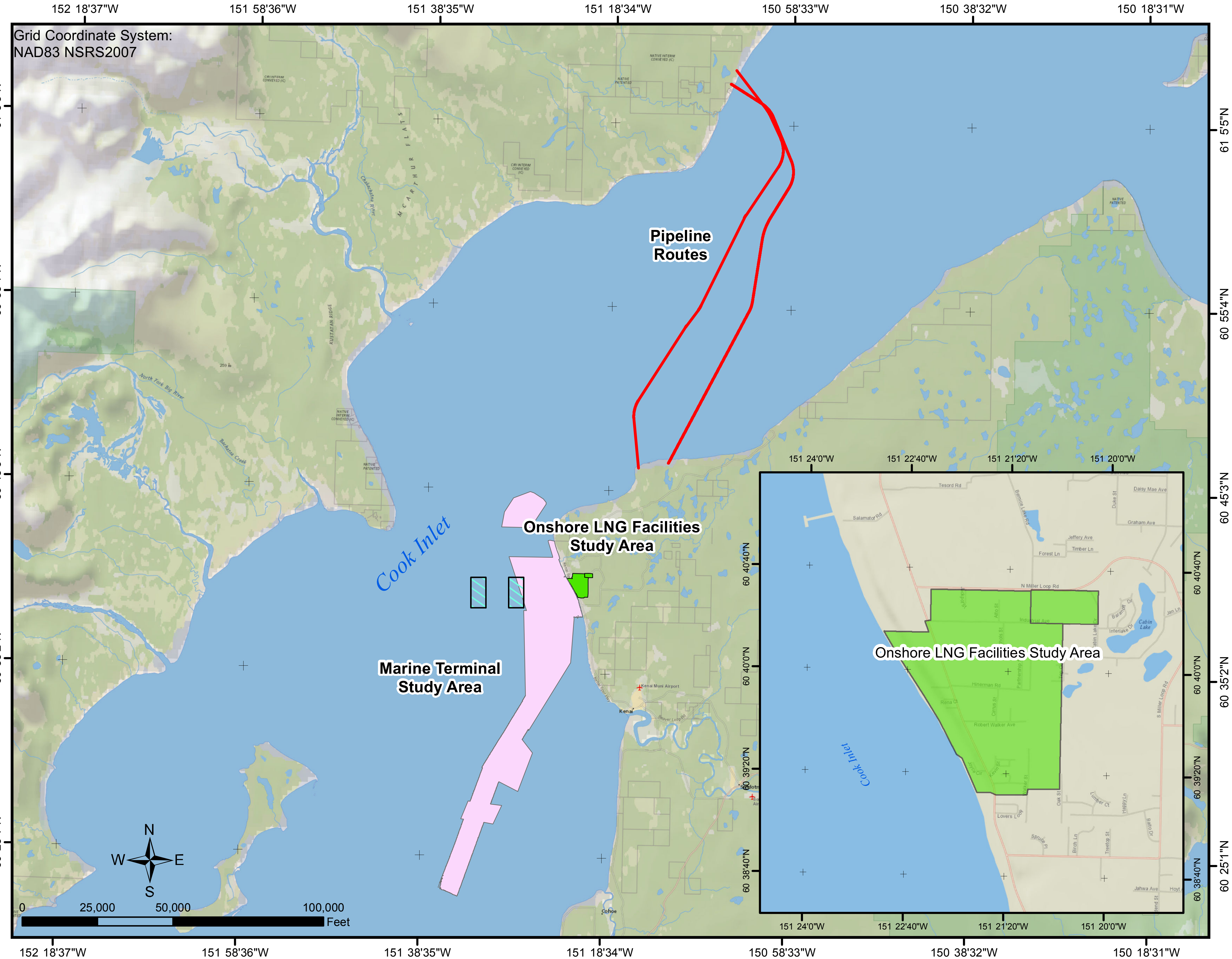
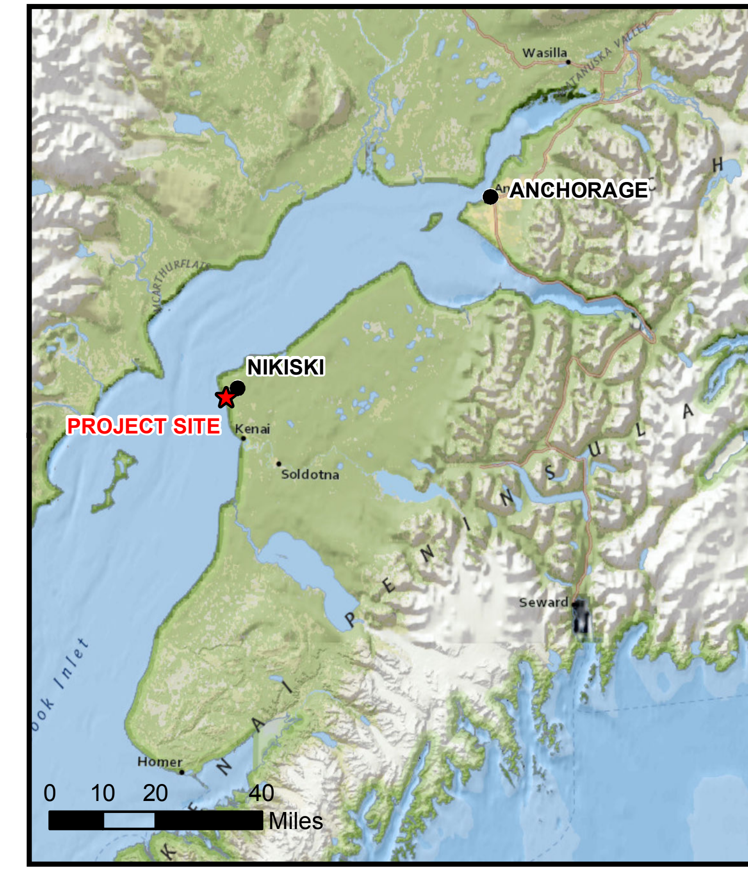
Alaska LNG





KEY MAP

LEGEND

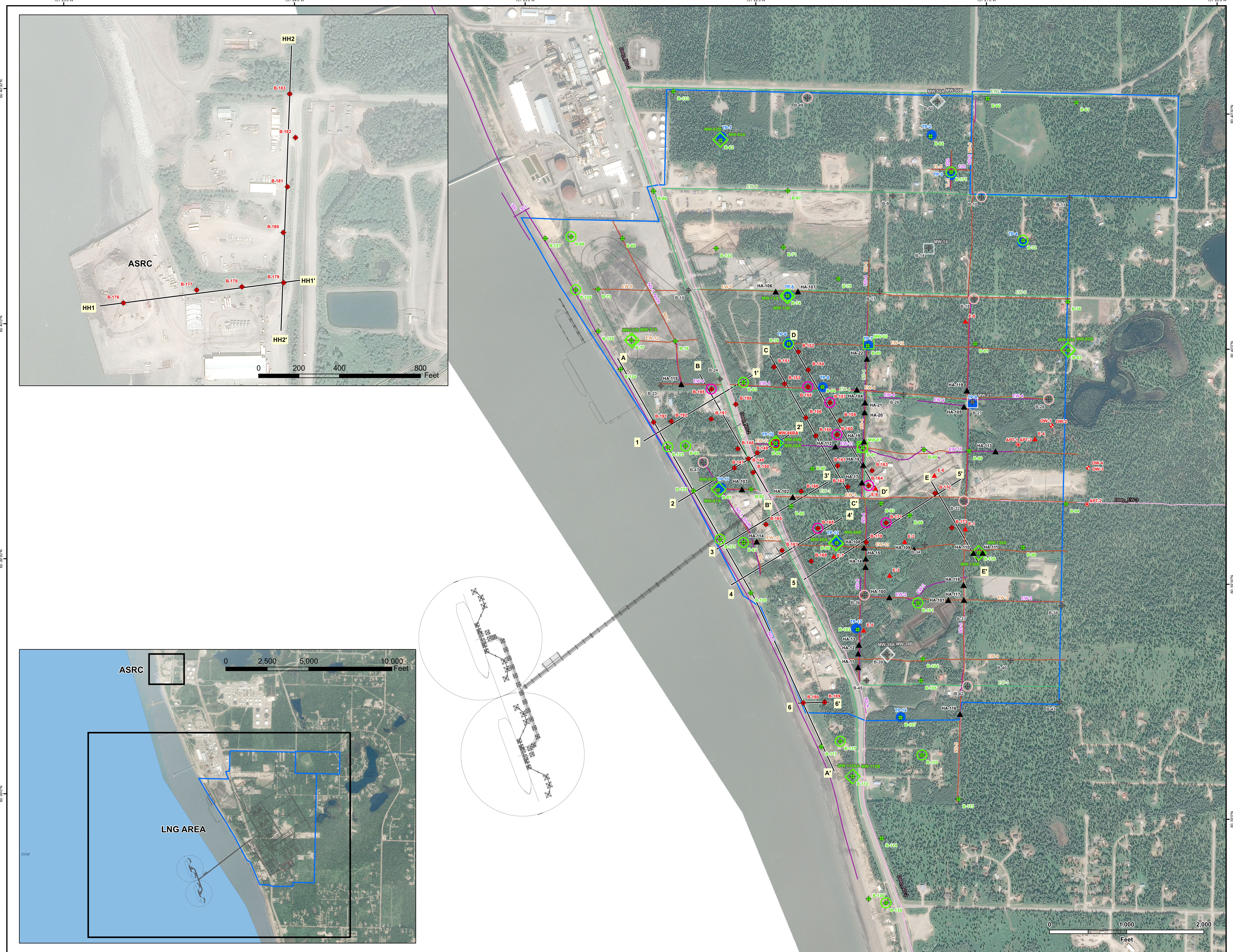
- Onshore LNG Facilities Study Area
- Marine Terminal Study Area
- Dredge Disposal Area
- Pipeline Routes

NOTE:

1. Onshore LNG Facilities Study Area boundary provided by AKLNG.

OVERALL SITE PLAN
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 2



LEGEND

- Onshore LNG Facilities Study Area
- Cross Section Lines

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Boring (2014)
- APT Well (2016)
- Observation Well (2016)
- VES Location (2016)
- Hand Auger (2015)
- Test Pit (2015)
- Monitoring Well - Shallow (2016)
- Monitoring Well - Shallow (2015)
- Monitoring Well - Shallow&Deep (2015)
- Monitoring Well - Shallow (2014)
- Monitoring Well - Shallow&Deep (2014)
- Downhole Geophysics (2016)
- Downhole Geophysics (2015)
- Downhole Geophysics (2014)

GEOPHYSICAL SURVEY LINES

- Deep Seismic (2015)
- ERT (2015)
- Shallow Seismic (2015)
- Shallow Seismic (2014)

Borings	As-Built Elevation (NAVD88, ft)	Depth, ft	As-Built Coordinates (NAD83 - NSRS2007)		DH[(1)]	MW[(2)]	TP[(3)]	Borings	As-Built Elevation (NAVD88, ft)	Depth, ft	As-Built Coordinates (NAD83 - NSRS2007)		DH[(1)]	MW[(2)]	TP[(3)]
			Longitude, deg	Latitude, deg							Longitude, deg	Latitude, deg			
B-9	132.25	100.50	-151.35640930	60.67185419				B-105	95.54	101.00	-151.35368353	60.65469558			
B-10	132.80	103.00	-151.35002130	60.67188199	1			B-107	96.04	101.00	-151.35545580	60.65337380			1
B-11	136.36	101.30	-151.34366490	60.67192943				B-110	117.07	155.70	-151.35348741	60.65205636	1		
B-14	133.40	110.70	-151.35375740	60.67003682		1		B-112	109.09	101.00	-151.35846843	60.65124872		2	
B-15	122.96	101.00	-151.37105710	60.66836028				B-113	112.53	113.50	-151.35080438	60.65052782			
B-17	131.21	101.50	-151.35723250	60.66845974				B-114	114.99	126.00	-151.35629452	60.64907498			
B-18	131.25	101.50	-151.35041260	60.66826252	1			B-117	7.60	99.30	-151.36078845	60.65228123			
B-23	124.63	186.50	-151.37288540	60.66494561				B-120	15.41	101.00	-151.36601528	60.65771551			
B-24	120.40	101.00	-151.36864010	60.66523854				B-121	16.38	120.40	-151.36825549	60.65946757	1		
B-26	125.54	100.50	-151.35535980	60.66481307				B-122	16.52	101.00	-151.37037895	60.66120614			
B-27	124.35	101.50	-151.35039120	60.66461107		1		B-123	15.78	139.00	-151.37209000	60.66279044	1		
B-28	118.89	103.00	-151.34486220	60.66475620	1			B-124	13.68	78.50	-151.37584730	60.66551173			
B-32	122.99	101.50	-151.35084730	60.66109265	1			B-125	14.43	101.00	-151.37751496	60.66684480			
B-34	111.83	101.00	-151.35361470	60.65951893				B-126	14.43	127.00	-151.37914509	60.66831013	1		
B-36	111.70	103.00	-151.35789050	60.65768300	1			B-127	15.98	101.00	-151.38141047	60.67012169			
B-37	106.27	27.00	-151.35022180	60.65717918				B-131	133.25	91.00	-151.35225744	60.67274798	1		1
B-38	123.47	151.30	-151.34359640	60.65746298				B-132	122.90	111.00	-151.36911316	60.66986806			
B-39	95.51	151.50	-151.35615280	60.65559414		2		B-133	125.63	105.50	-151.37244708	60.67540767			
B-40	120.84	101.50	-151.34721580	60.65547709				B-135	112.66	150.50	-151.35586806	60.64679349	1		
B-42	118.85	101.50	-151.35029920	60.65453131	1			B-136	13.42	94.00	-151.35727753	60.64689374			
B-43	121.14	102.80	-151.34362450	60.65405368				B-137	116.64	115.50	-151.35941780	60.65248997	1		
B-45	109.09	101.50	-151.35759480	60.65465742				B-138	103.22	146.00	-151.34969539	60.65926678		2	
B-47	119.73	151.00	-151.36972090	60.66227016	1			B-146	111.74	217.30	-151.36648264	60.66243655	1		
B-49	127.76	101.50	-151.36274610	60.67526763	1			B-147	119.69	200.30	-151.36747798	60.66209855			
B-50	131.66	151.50	-151.35335930	60.67524580		2		B-148	122.26	206.10	-151.36726271	60.66278039			
B-60	135.49	81.00	-151.34970518	60.67539889				B-149	126.30	223.00	-151.36585008	60.66265279			
B-61	137.58	96.00	-151.34332584	60.67530860				B-150	110.97	200.20	-151.36610352	60.66195569			
B-62	127.66	101.30	-151.36898112	60.67372335		2	1	B-151	125.85	201.00	-151.36476522	60.66571099			
B-64	133.91	86.00	-151.35383276	60.67397590			1	B-152	125.79	150.40	-151.36303312	60.66626550			
B-66	127.44	105.00	-151.37372952	60.67185480				B-153	126.81	150.60	-151.36397783	60.66511871			
B-67	124.49	110.50	-151.36405465	60.67196390				B-154	127.46	151.00	-151.36228714	60.66562743			
B-68	122.47	202.00	-151.37961780	60.67016196	1			B-155	126.76	151.00	-151.36228399	60.66502805	1		
B-69	123.86	105.50	-151.37590717	60.67015134				B-156	124.84	151.00	-151.36239760	60.66393399			
B-71	116.20	101.00	-151.36427266	60.66996116				B-157	124.51	151.00	-151.36066599	60.66448827	1		
B-72	135.28	86.30	-151.34710070	60.67027771	1		1	B-158	120.63	150.50	-151.36163461	60.66329807			
B-73	122.34	111.00	-151.37753990	60.66852118				B-159	118.84	150.30	-151.35991084	60.66385187			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B-92	118.03	99.80	-151.36624365	60.66135905				B-180	77.76	76.00	-151.39342768	60.68827819			
B-93	118.69	101.00	-151.35681706	60.66095091				B-181	87.19	76.50	-151.39334051	60.68889704			
B-94	127.39	101.00	-151.34346988	60.66106965				B-182	85.60	50.50	-151.39314642	60.68956559			
B-95	96.73	101.00	-151.36332415	60.66078281				B-183	98.76	101.10	-151.39333025	60.69015403			
B-96	97.65	101.00	-151.35473390	60.66054881				B-189	119.97	201.00	-151.36061126	60.65385926			
B-97	109.47	203.00	-151.36669900	60.65946066	1			B-190	20.56	97.10	-151.36215168	60.65382001			
B-98	115.67	101.00	-151.35997475	60.65951243		2	1	B-191	20.50	114.20	-151.37337267	60.66365831			
B-99	123.82	151.00	-151.34652491	60.65948995				B-192	123.19	239.30	-151.37209739	60.66371093			
B-101	94.98	152.00	-151.35402409	60.65744590	1			B-195	119.97	226.00	-151.36924661	60.66487249	1		
B-102	97.95	101.00	-151.35833603	60.65645887			1	B-197	122.74	249.60	-151.36922005	60.66381855			
B-104	95.22	105.90	-151.35258202	60.65547421				B-198	117.99	300.50	-151.36747007	60.66435767			

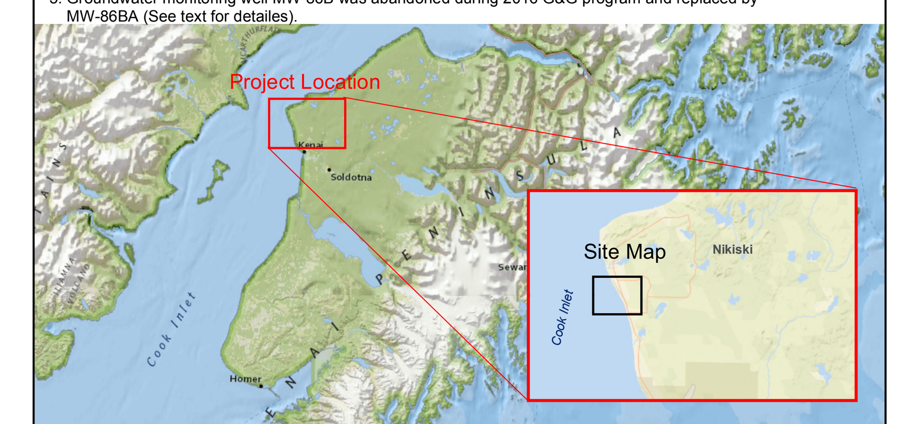
Notes:
(1)DH = Downhole Seismic Test
(2)MW = Monitoring Well
(3)TP = Test Pit

Monitoring Wells	As-Built Elevation (NAVD88, ft)	Depth, ft	As-Built Coordinates (NAD83 - NSRS2007)	
			Longitude, deg	Latitude, deg
MW-14	133.70	56.00	-151.35376440	60.67001489
MW-27	124.30	57.00	-151.35037410	60.66459539
MW-39A	95.50	147.00	-151.35615710	60.65557926
MW-39B	95.30	40.00	-151.35613450	60.65560508
MW-50A	132.60	146.00	-151.35331470	60.67523060
MW-50B	132.20	55.50	-151.35336650	60.67526072
MW-62A	127.36	145.40	-151.36900760	60.67372740
MW-62B	127.63	47.00	-151.36896370	60.67373020
MW-74A	111.70	159.00	-151.36390300	60.66825110
MW-74B	111.53	81.00	-151.36390170	60.66822290
MW-77A	116.31	146.00	-151.37507200	60.66655740
MW-77B	116.25	61.00	-151.37506340	60.66654210
MW-80	130.99	61.70	-151.35796510	60.66660890
MW-82A	118.58	150.00	-151.34354410	60.66651740
MW-82B	119.22	52.00	-151.34358260	60.66654600
MW-86A	124.44	146.00	-151.36452040	60.66301340
MW-86B	124.48	42.00	-151.36451240	60.66299700
MW-87	106.91	52.50	-151.35826080	60.66293920
MW-91A	117.27	146.00	-151.36859480	60.66133530
MW-91B	117.31	64.00	-151.36858380	60.66131500
MW-98A	122.17	116.00	-151.36000880	60.65949110
MW-98B	122.26	43.00	-151.36003290	60.65952300
MW-112AA	115.55	119.00	-151.35844950	60.65126000
MW-112B	115.76	61.00	-151.35847780	60.65124200
MW-138A	103.22	146.80	-151.34969540	60.65926680
MW-138B	103.33	43.30	-151.34973370	60.65927620
APT-1	117.09	138.00	-151.34706092	60.66315390
APT-2	126.99	137.00	-151.34195457	60.66107404
APT-3	115.83	437.00	-151.34698760	60.66312928
OW-1	109.56	79.00	-151.34463703	60.66385170
OW-2	109.09	150.00	-151.34460741	60.66382579
OW-3	128.26	70.00	-151.34191656	60.66235654
OW-4	128.29	137.00	-151.34194479	60.66238108
MW-86BA	124.73	66.00	-151.36456512	60.66299257

Hand Augers	As-Built Elevation (NAVD88, ft)	Depth, ft	As-Built Coordinates (NAD83 - NSRS2007)	
			Longitude, deg	Latitude, deg
HA-11	104.53	2.8	-151.3582393	60.65512561
HA-12	93.98	4.3	-151.3582455	60.65560946
HA-13	97.62	2.3	-151.3582056	60.65592101
HA-14	121.19	1.6	-151.3578491	60.65868729
HA-15	121.09	3.2	-151.3578434	60.65898341
HA-17	116.12	2.5	-151.3582332	60.66167632
HA-18	108.69	5.5	-151.3581713	60.66230348
HA-19	106.92	6.9	-151.3581512	60.66313564
HA-20	119.04	2.6	-151.3581436	60.66416493
HA-21	123.32	2.8	-151.3581355	60.66451619
HA-22	130.06	2.8	-151.3580616	60.66606764
HA-100	97.71	4.3	-151.3560797	60.65762929
HA-101	88.78	2.0	-151.3518266	60.65757639
HA-102	104.23	4.0	-151.3632097	60.6611113
HA-103	117.69	3.0	-151.3668833	60.66134432
HA-104	124.01	3.8	-151.3587445	60.6649634
HA-105	124.7	2.2	-151.3509738	60.66444029
HA-106	118.92	1.8	-151.3647449	60.66838243
HA-107	118.88	3.7	-151.3631376	60.66840602
HA-108	123.01	1.5	-151.3579906	60.65936729
HA-109	111.12	1.5	-151.3543773	60.65935399
HA-110	100.45	4.0	-151.3500841	60.65926121
HA-111	102.15	2.0	-151.3494033	60.65927181
HA-112	106.13	2.0	-151.3602101	60.662931
HA-113	125.64	2.4	-151.3486347	60.66288061
HA-114	105.52	2.7	-151.365746	60.65950795
HA-115	121.16	3.3	-151.371427	60.6650298
HA-116	109.59	5.0	-151.350813	60.65354365
HA-117	90.06	3.0	-151.3507027	60.65758828
HA-118	94.46	2.0	-151.3507445	60.65811632
HA-119	123.19	2.0	-151.350797	60.66501537

Test Pits	As-Built Elevation (NAVD88, ft)	Depth, ft	As-Built Coordinates (NAD83 - NSRS2007)	
			Longitude, deg	Latitude, deg
TP-01	127.2	8	-151.36890605	60.67382958
TP-02	133.08	8	-151.35371804	60.67405024
TP-03	134.43	5	-151.35223907	60.67264108
TP-04	134.56	8	-151.34703124	60.67029871
TP-05	111.72	8	-151.36376102	60.66825015
TP-06	122.7	8	-151.36376305	60.66658642
TP-07	130.61	8	-151.35798402	60.66653967
TP-08	127.05	8	-151.36120253	60.66502775
TP-09	123.74	8	-151.35036700	60.66453403
TP-10	124.36	8	-151.36432332	60.66300351
TP-11	117.18	8	-151.36840024	60.66138217
TP-12	122.53	8	-151.35995040	60.65957943
TP-13	97.98	8	-151.35843823	60.65650048
TP-14	97.02	11	-151.35507881	60.65339243

Notes:
1. Base imagery provided by EXP Geomatics (EXP).
2. Onshore LNG Facilities Study Area provided by AKLNG.
3. Onshore Facilities plot plan is provided by CB&I/CHIYODA on drawings USAL-CB-LDLAY-00-000003-000 Rev.6 dated June 30, 2016.
4. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc. (2015, 2016).
5. Groundwater monitoring well MW-86B was abandoned during 2016 G&G program and replaced by MW-86BA (See text for detailes).



GEODETIC INFORMATION

PROJECTION:	Transverse_Mercator
FALSE EASTING:	1640416.666666666
FALSE NORTHING:	0.0
CENTRAL MERIDIAN:	-150.0
SCALE FACTOR:	0.9999
LATITUDE OF ORIGIN:	54.0
LINEAR UNIT:	US Foot
SPHEROID:	GRS 1980
SEMI-MAJOR AXIS:	6,378,137.000
SEMI-MINOR AXIS:	6,356,752.314140356
INVERSE FLATTENING:	298.257222101

N W E S

Coordinate Grid: NAD 1983 (NSRS 2007), Degrees Minutes Seconds

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Houston, Texas 77081
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Fax: 713.369.5518
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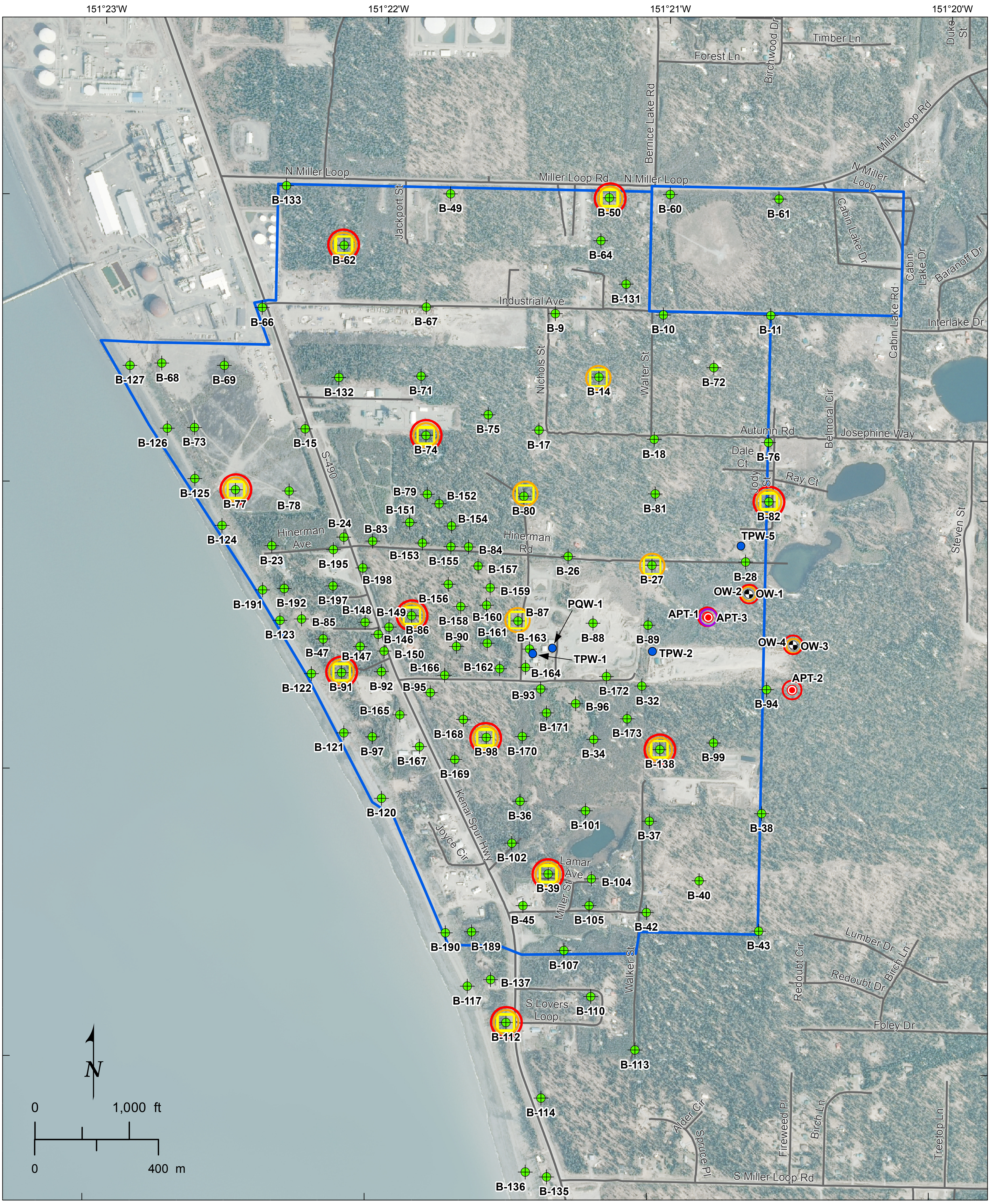
Alaska LNG

PLANT LAYOUT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

REV NO:	DATE:	DESCRIPTION:	DRAWN:	CHKD:	APPR:
0	11/10/2016	Onshore LNG Facilities Plan of Exploration	KIMK	BB	

JOB NUMBER: 04.10160001-8
DRAWING NO: PLATE 3



LEGEND

- Onshore Borings (completed)
- Monitoring Well Locations
  Note: co-located well pairs are present at locations B-39, B-50, B-62, B-74, B-77, B-82, B-86, B-91, B-98, B-112, and B-138
- Onshore LNG Facilities Study Area
- APT Well
- Observation Well Pair
- Third Party Well
- Shallow Well - Water Bearing Unit 1
- Intermediate Well - Water Bearing Unit 2
- Deep Well - Water Bearing Unit 3

INVESTIGATION PLAN
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 4

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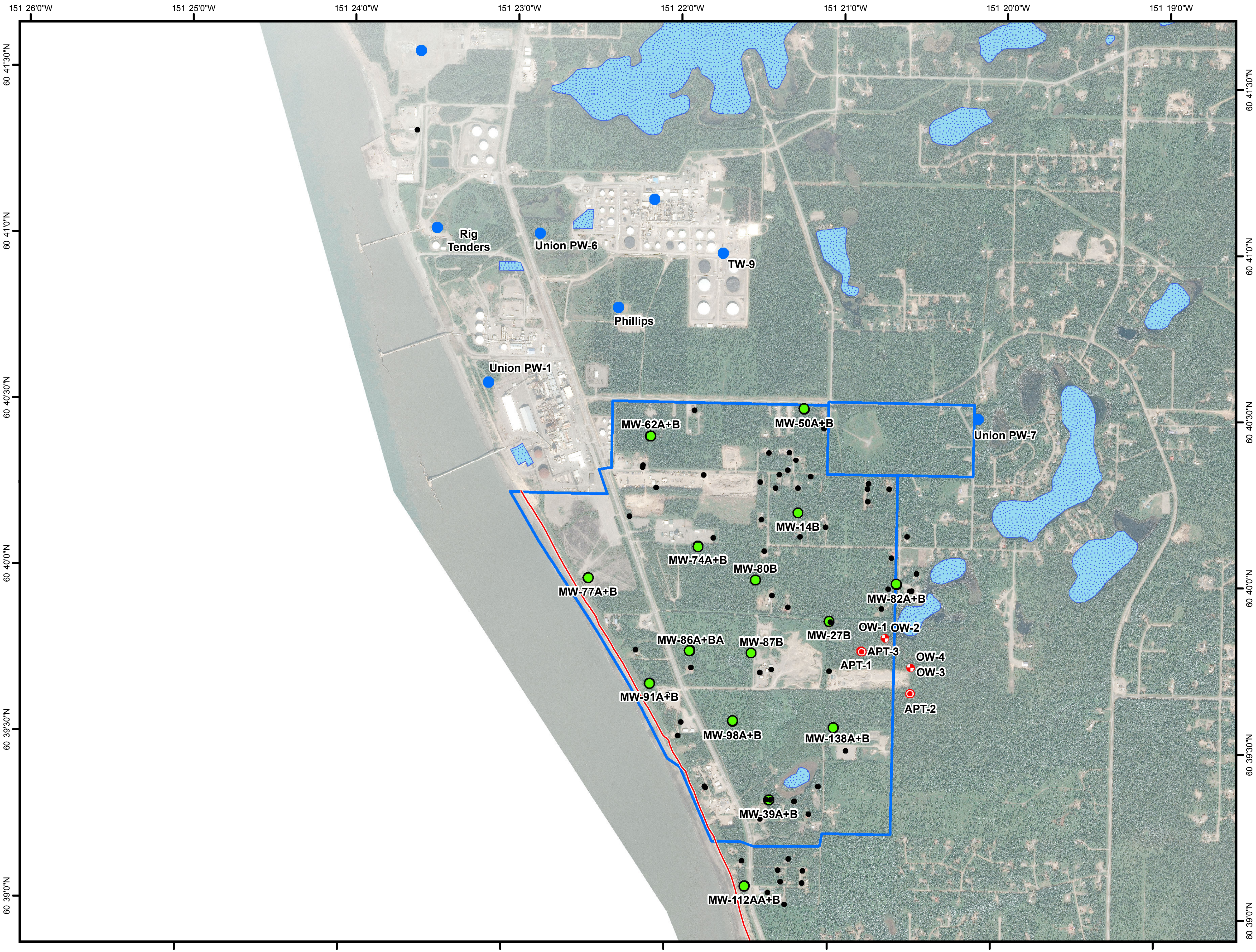


Legend

- Monitoring Wells (Fugro 2014, 2015, 2016)
- Production Water Wells
- Existing Private Wells
- APT Wells (2016)
- Observation Wells (2016)
- Toe of Bluff
- Surface Water Body
- Onshore LNG Facilities Study Area

NOTE

1. Production water wells source is from MVE, Alaska SC LNG project, technical evaluation of water cooled LNG plan, September 13th, 2013 with well designation if known.
2. Existing water wells identified by AKLNG and surveyed by McLane, Inc.

0 1,000 2,000 4,000 Feet

OFFSITE PRODUCTION WELLS
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 5

R:\04100\2016 Projects\0001-0099\04.10160001 - AKLNG\07_GIS\Outputs\01_REPORTS\HydroReport\MXD\Plate-5_ContaminatedAreas_rev_20161107.mxd, 11/21/2016, kimk

Well Owner:	Tesoro Refinery				**Use of Well:**	Commercial		
Legal Description:	TW-9							

CONSTRUCTION

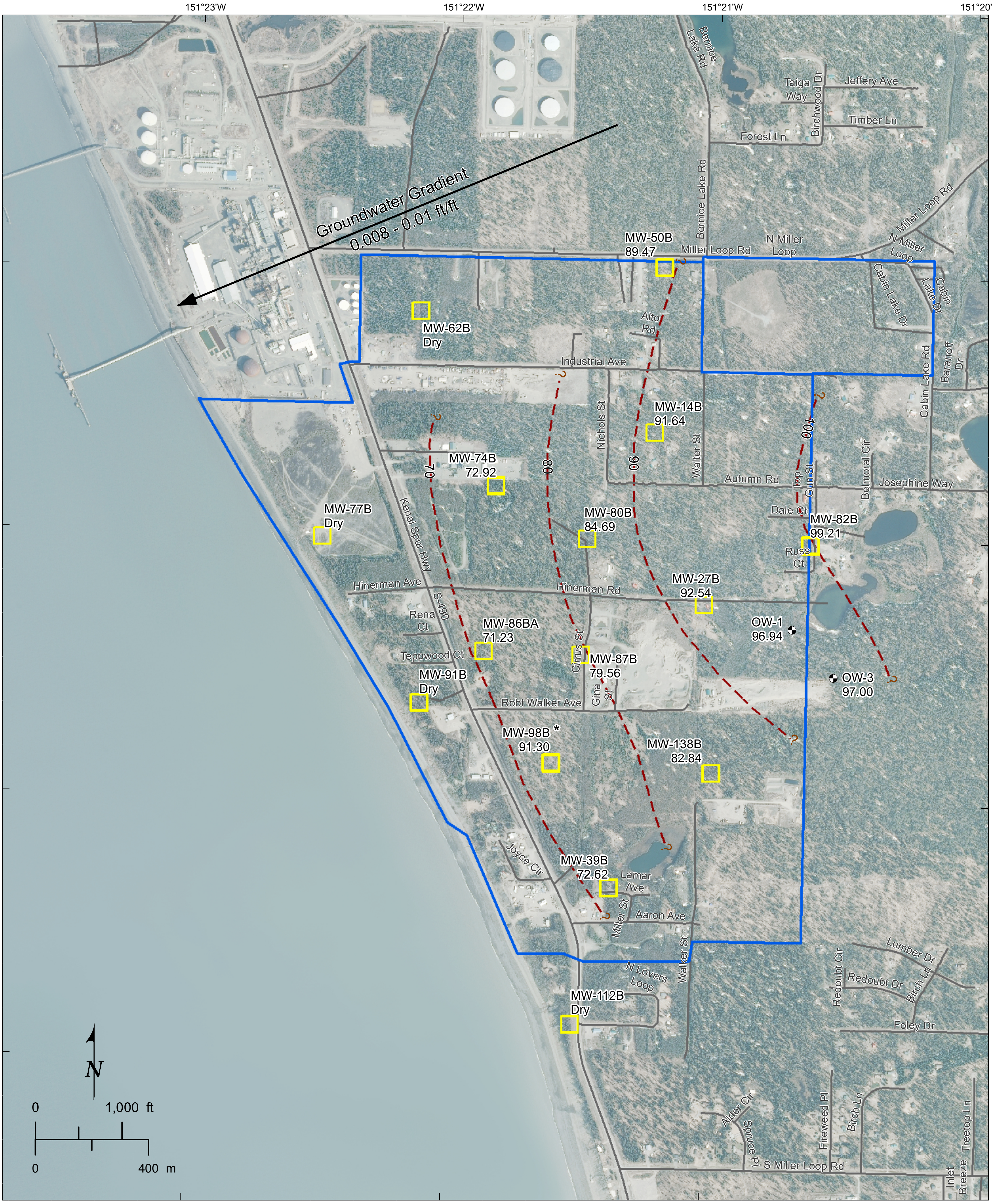
Drill Method:	Air rotary			**Hole Size:**	10"	**Hole Depth:**	352'	
Casing Size:	10"	**Cased to:**	331.34'	**Material:**	A53 B	**Wall:**	0.322	
	14"		91.74'					
Well Completion:	**Open end**		**Screen**	X	**Perforated**		**Method:**	
Screen/Perforation description:	K-packer & riser pipe from 326' to 329.6', 8" telescope .100 slot screen from 329.6' to 350.5', tailpipe from 350.5' to 351.5'							
Grout Notes:	Liquid bentonite grout installed in annulus between 14" casing & 8" casing from 91.74' to top of 14" casing							
Well Development:	Air jetting/air lift							
Well Notes:	14" surface casing installed to 91.74'							
Yield test at	550	**GPM for**	9	**hour(s) with**	212'	**of drawdown (DD) from static level(SWL).**		
Method:	Submersible pump				**Static Water Level (SWL):**	113.4'		
Start Date:	6/28/11			**Completion Date:**	7/23/11			
Test Pump Date:	7/23/11			**Final Pump Install Date:**				

WELL LOG

Depth in feet from top of casing.			Details of formations penetrated, size of material, color and miscellaneous details.
0	TO	3	Casing Stick Up
3	TO	78	Gravel: loose, very cobbly, dry
78	TO	89	Gravel: cobbly, wet
89	TO	111	Clay: gray, some gravel
111	TO	136	Gravel: sandy, runny, silty
136	TO	247	Sand: runny, mucky, heaving
247	TO	328	Clay: sandy, silty
328	TO	352	Water gravel: medium to coarse
	TO		
	TO		
	TO		
	TO		
	TO		
	TO		
	TO		
	TO		

LOG OF TESORO WELL TW-9
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 6



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LEGEND

MW-39B 72.64 — Well Locations (labeled with well ID and groundwater elevation, NAVD88, feet, measured September 2016) (* Omitted from contouring)

OW-1 96.94 — Observation Well

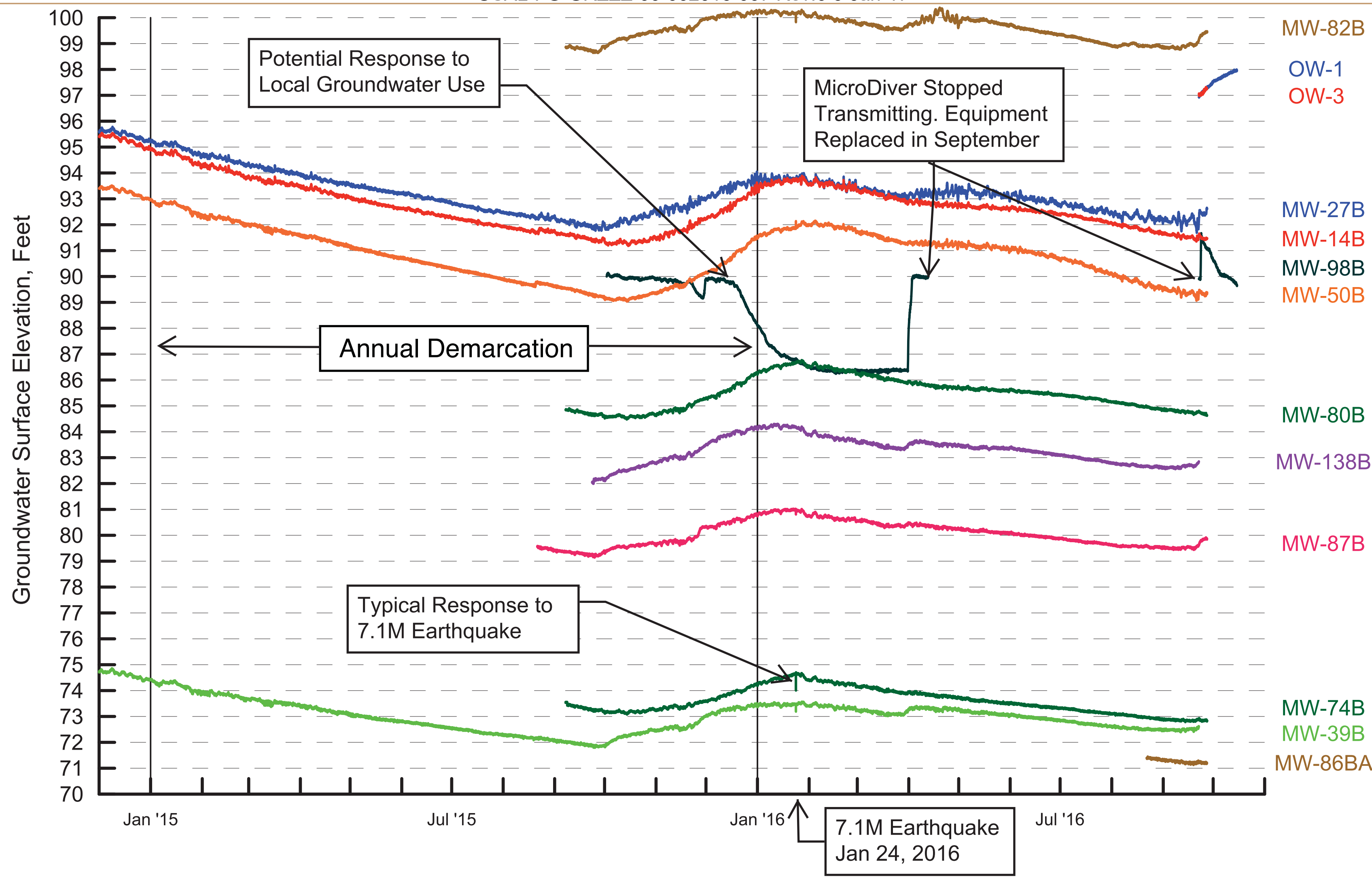
80 — Water Bearing Unit 1 Contour Elevations

Onshore LNG Facilities Study Area

Groundwater Flow Direction and Gradient

WATER BEARING UNIT 1
GROUNDWATER ELEVATIONS AND GRADIENT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 7

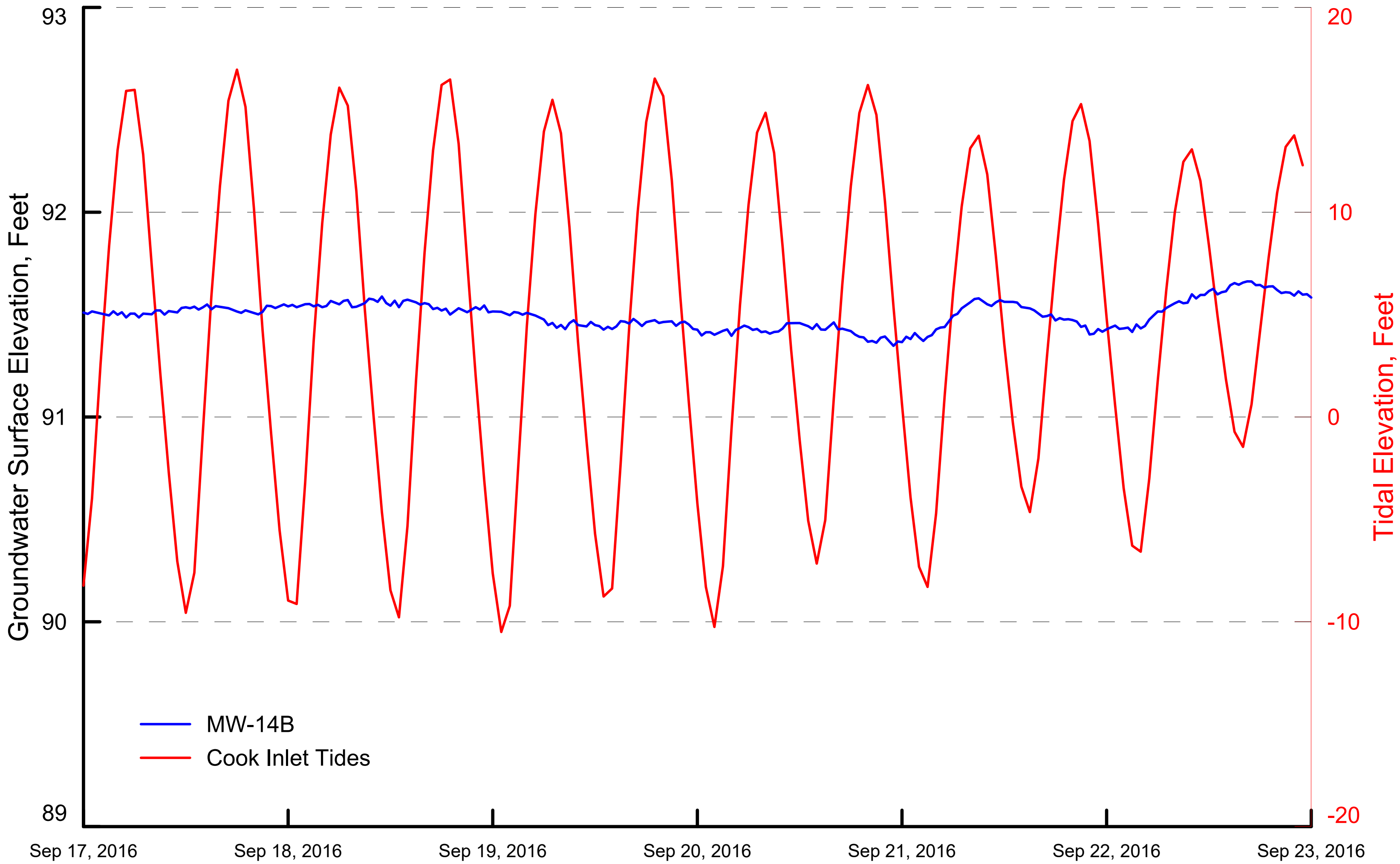


WATER BEARING UNIT 1 GROUNDWATER SURFACE ELEVATIONS SINCE 2014

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

Elevation in Feet, NAVD88

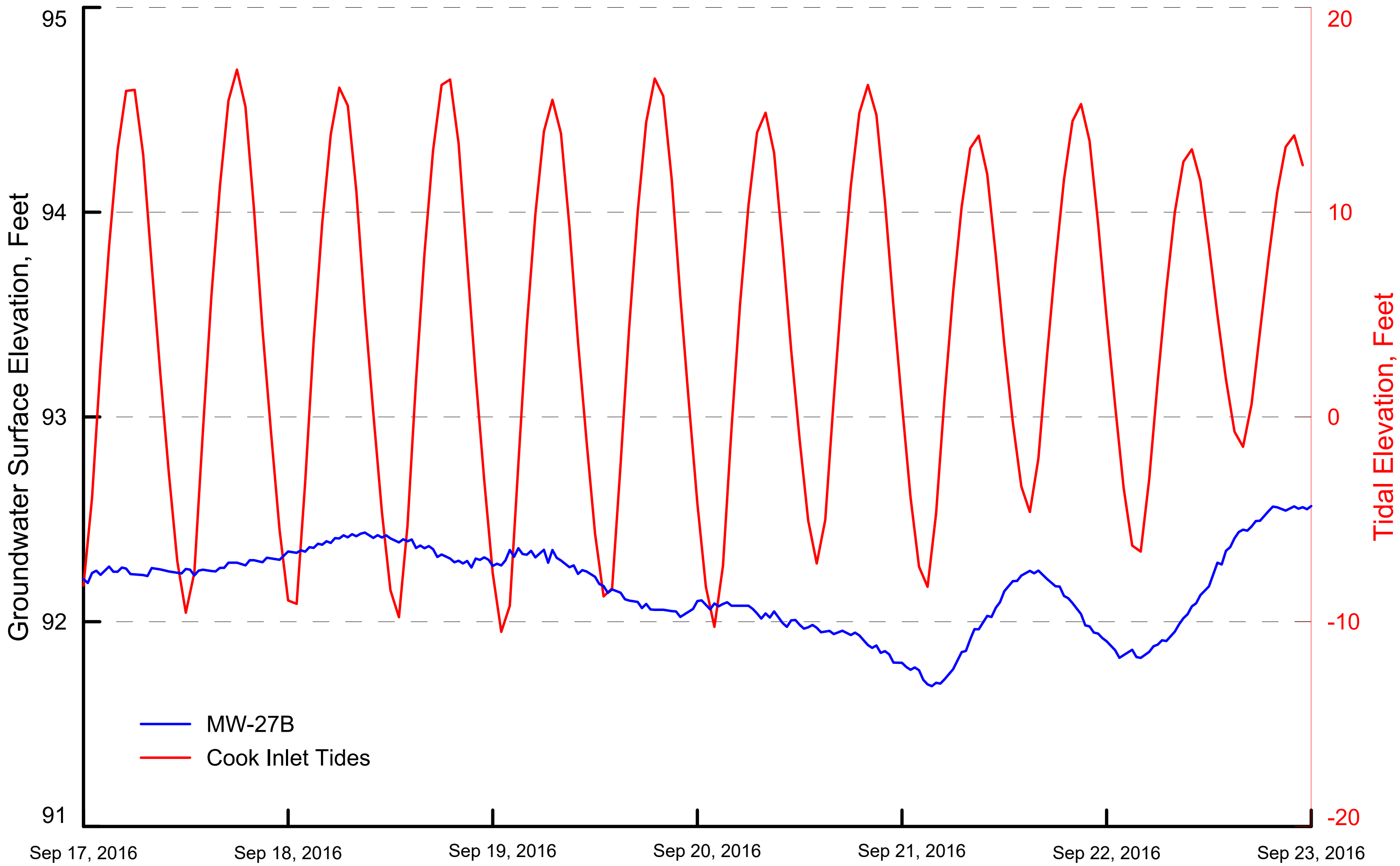
PLATE 8



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-14B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

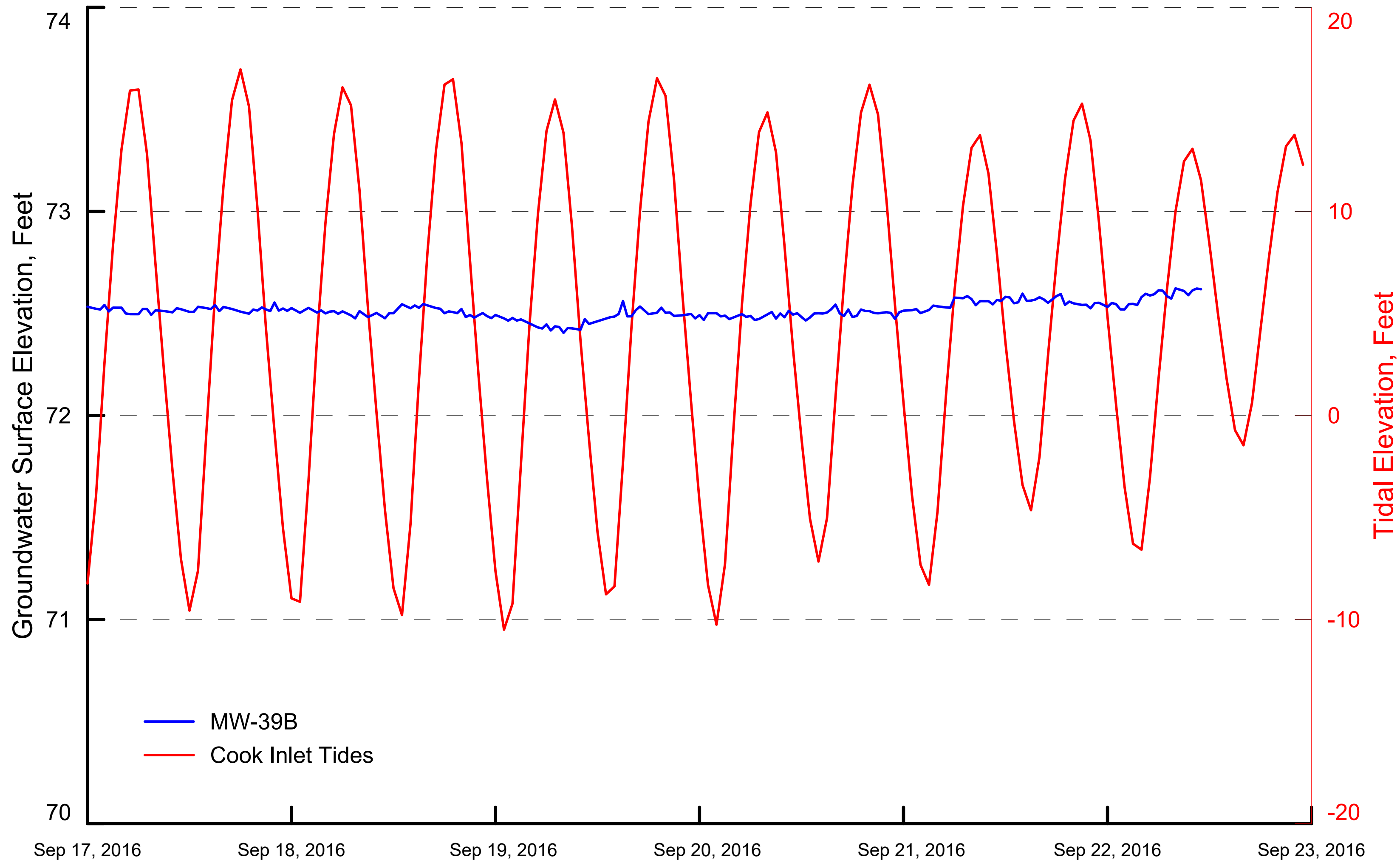
PLATE 9



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-27B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

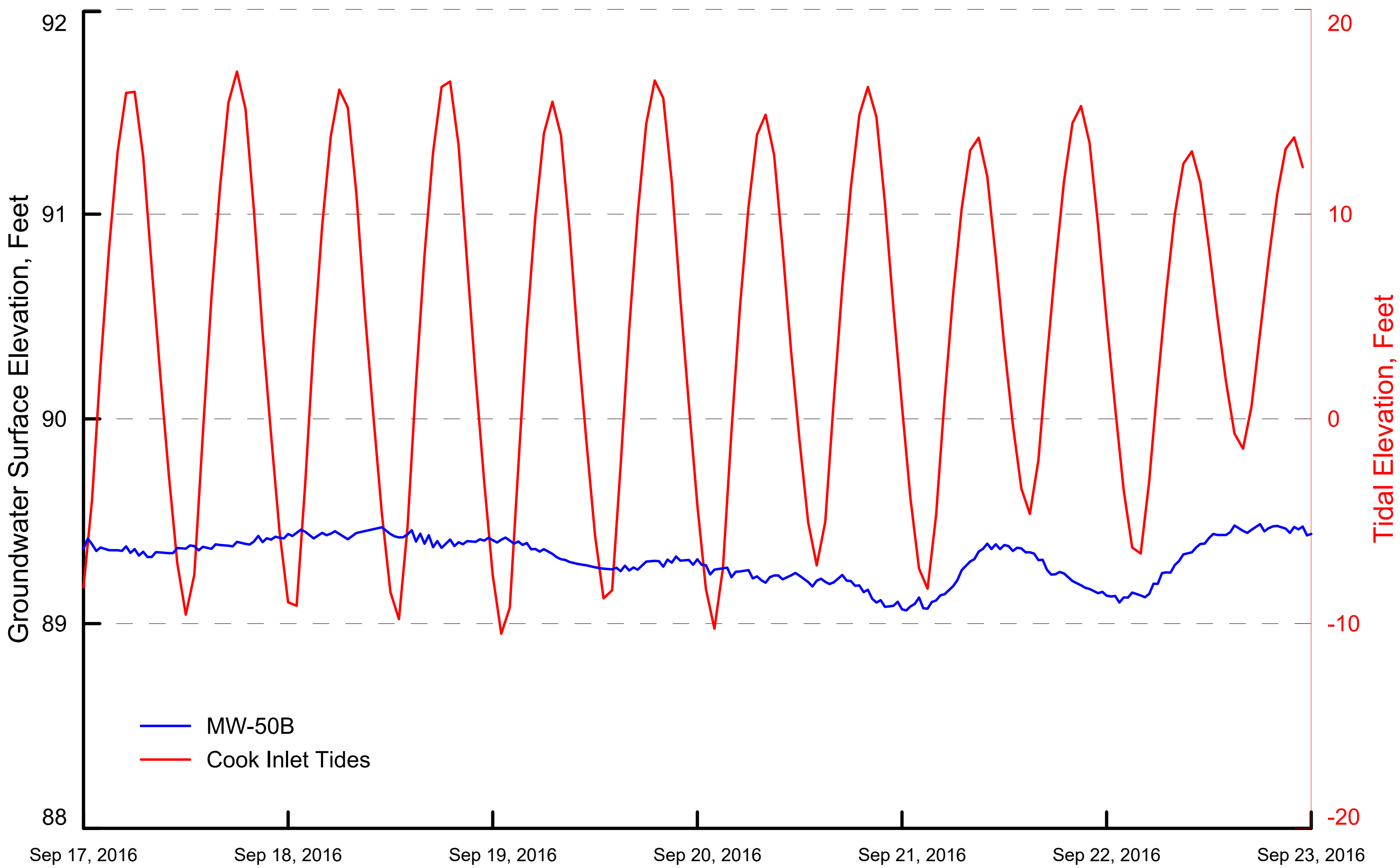
PLATE 10



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-39B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

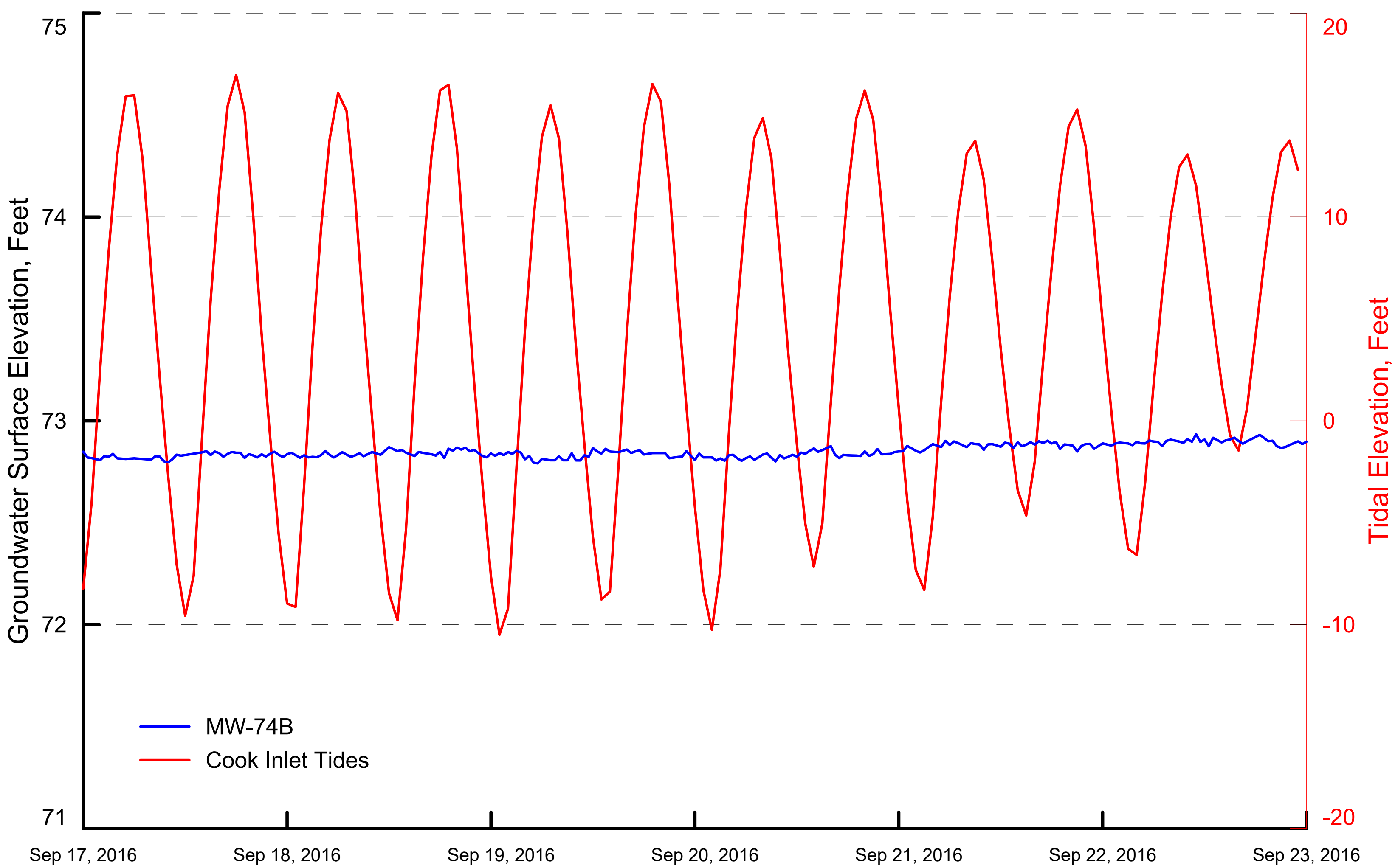
PLATE 11



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-50B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

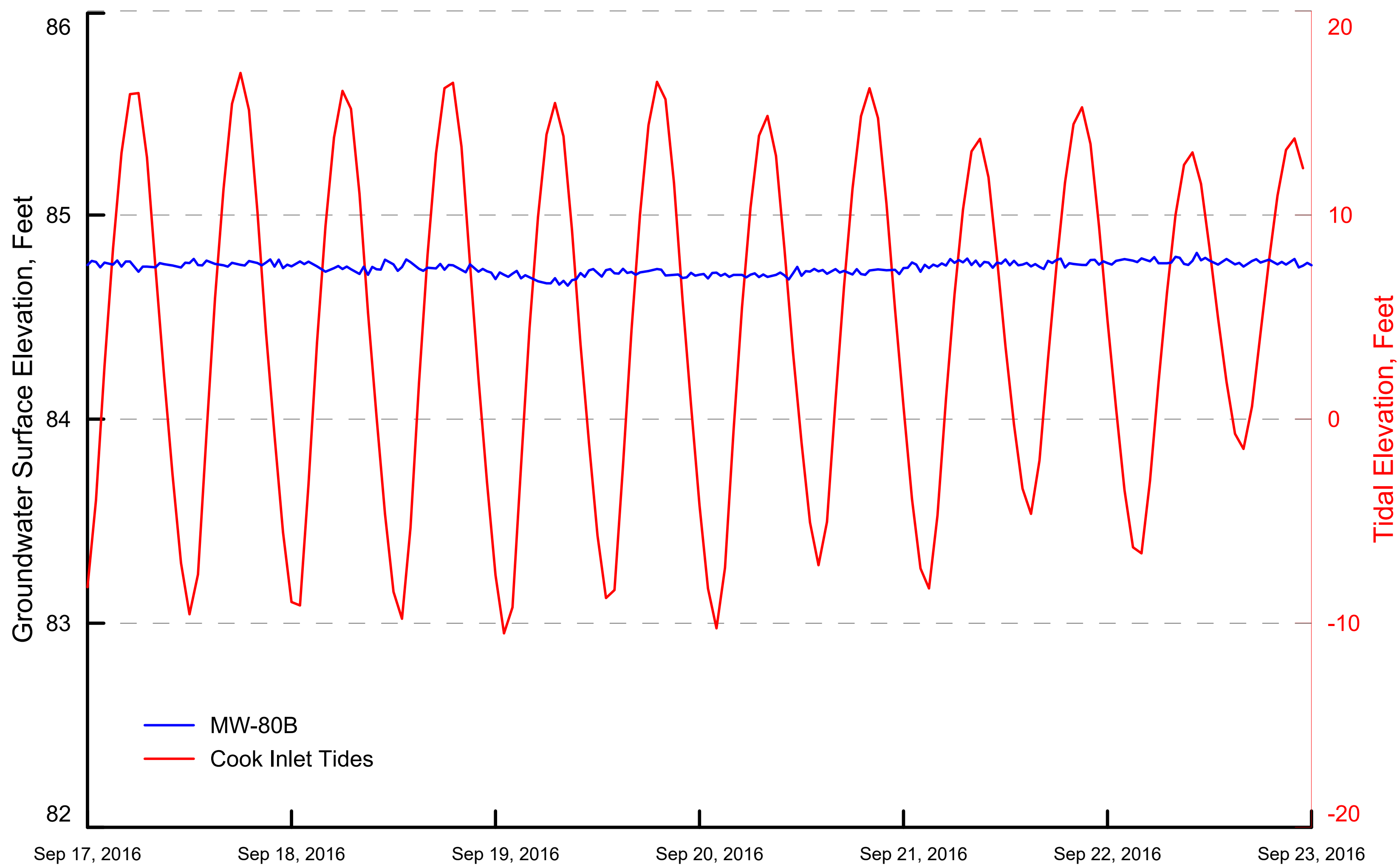
PLATE 12



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-74B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

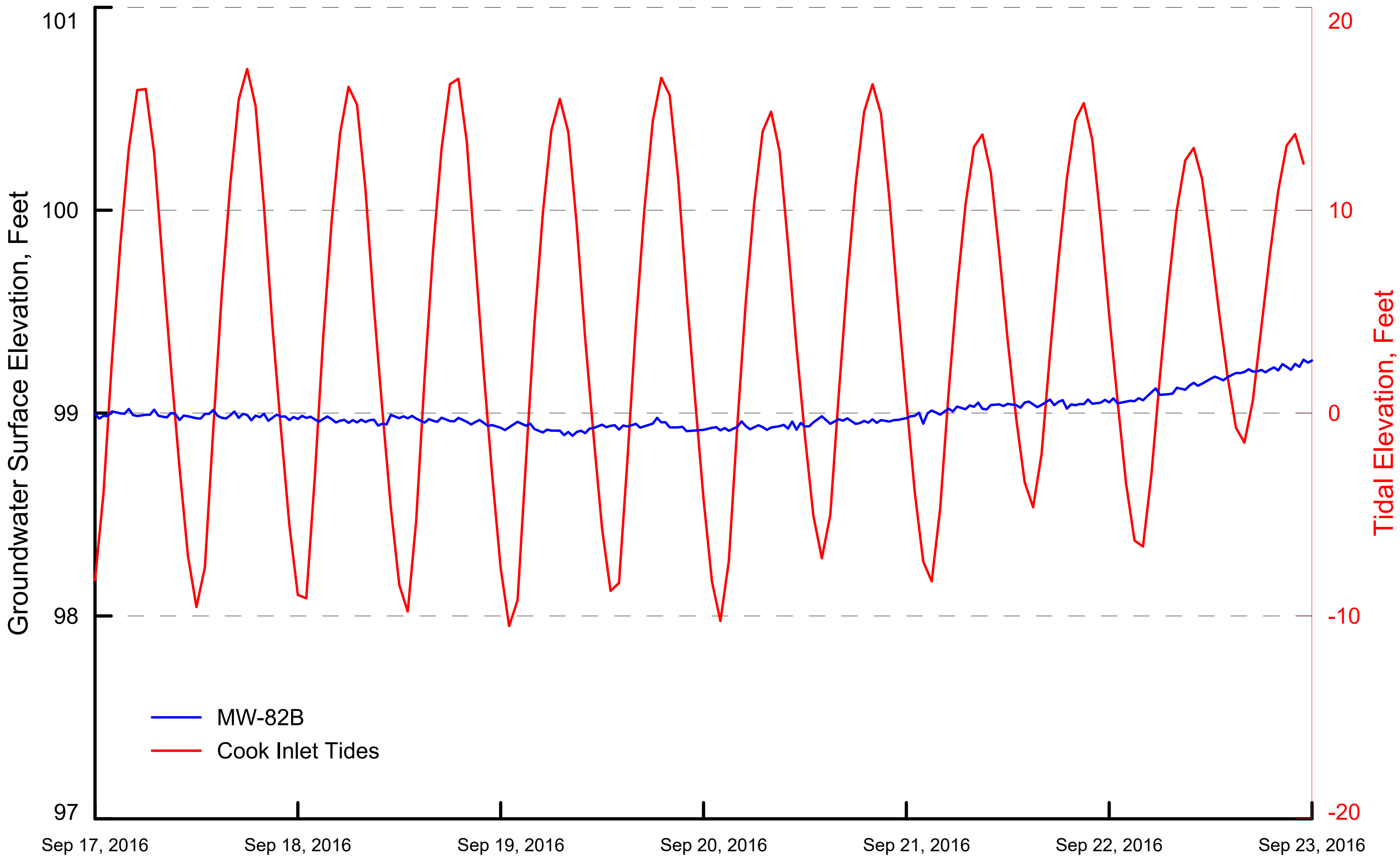
PLATE 13



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-80B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

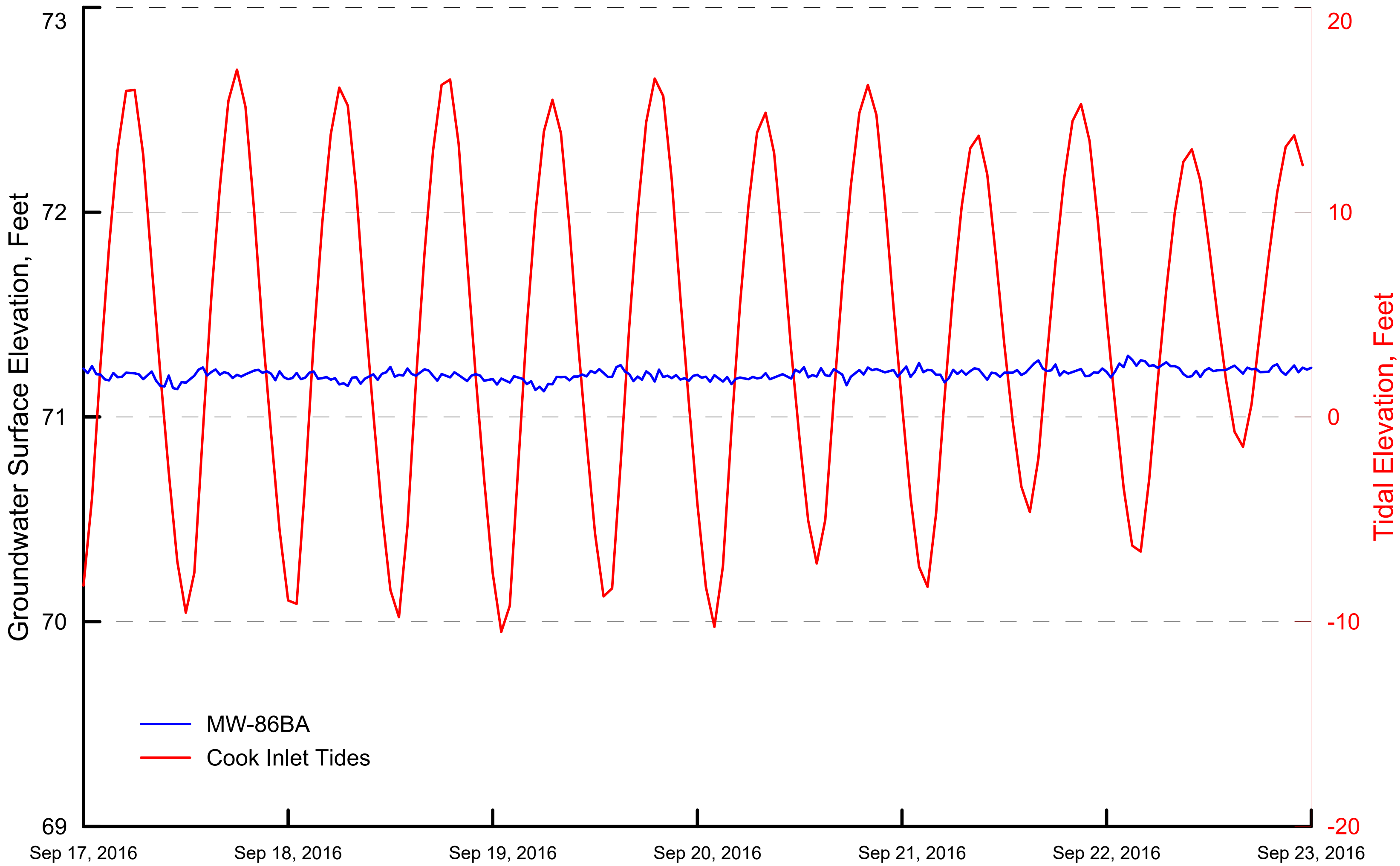
PLATE 14



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-82B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

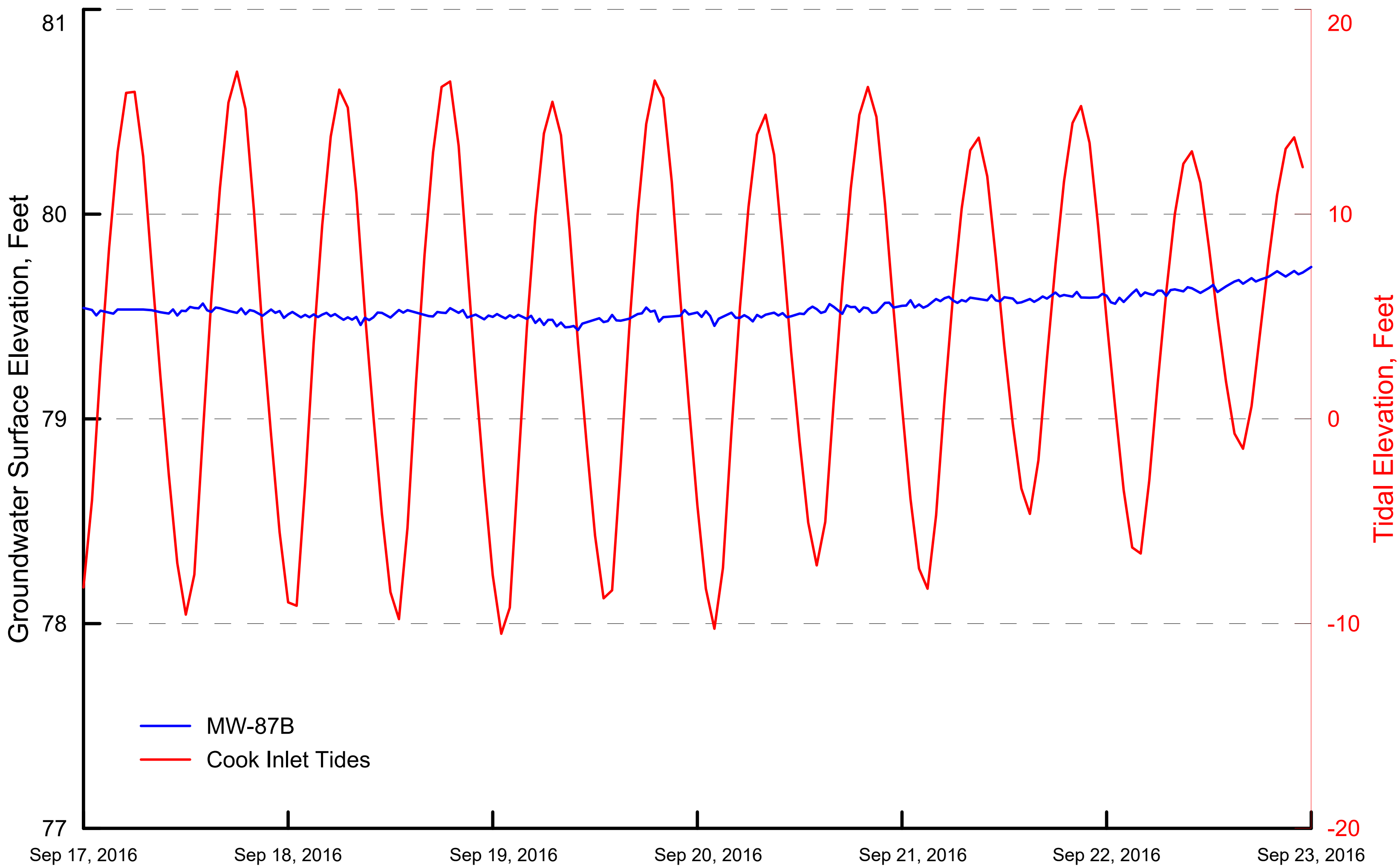
PLATE 15



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-86BA
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

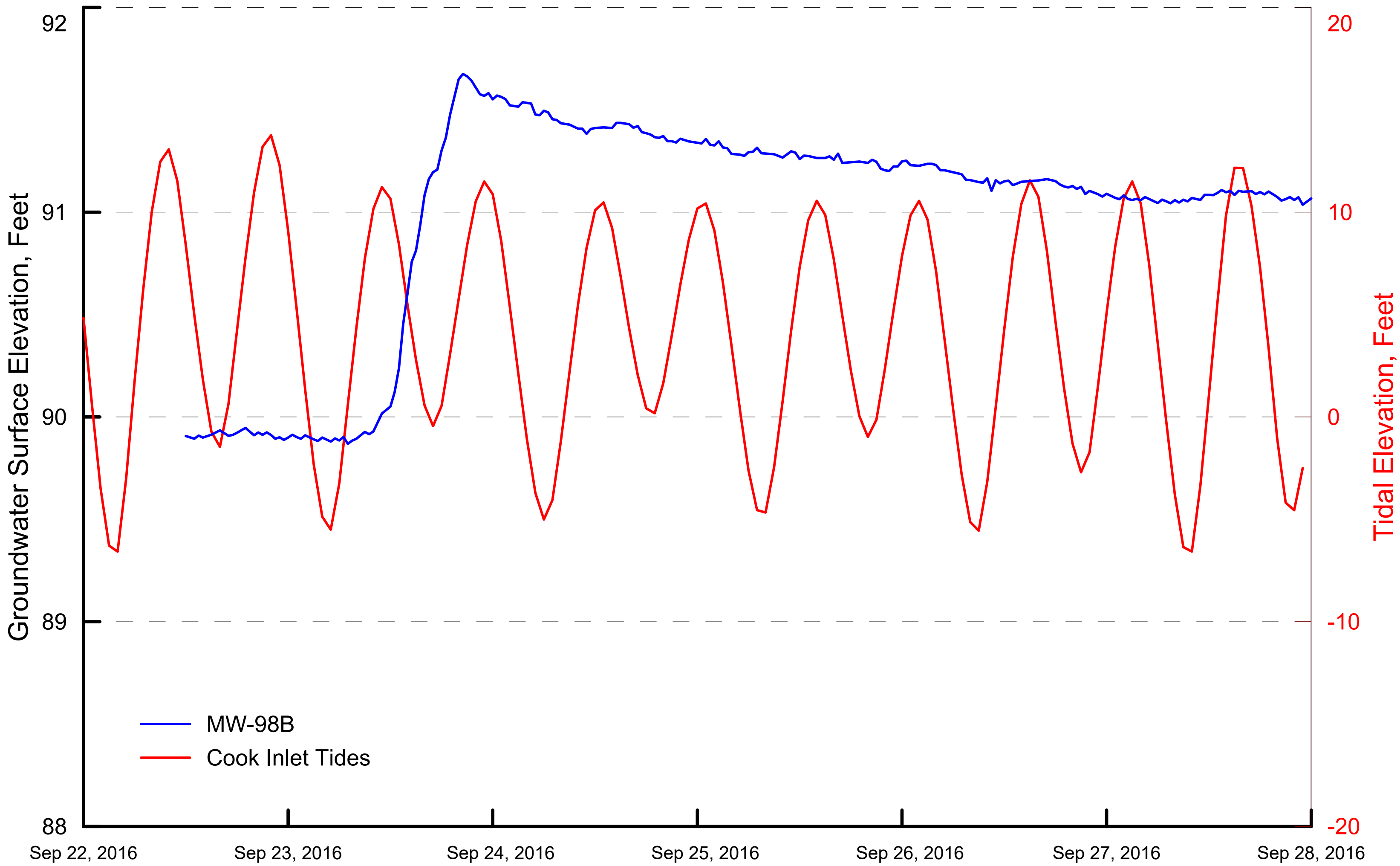
PLATE 16



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-87B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

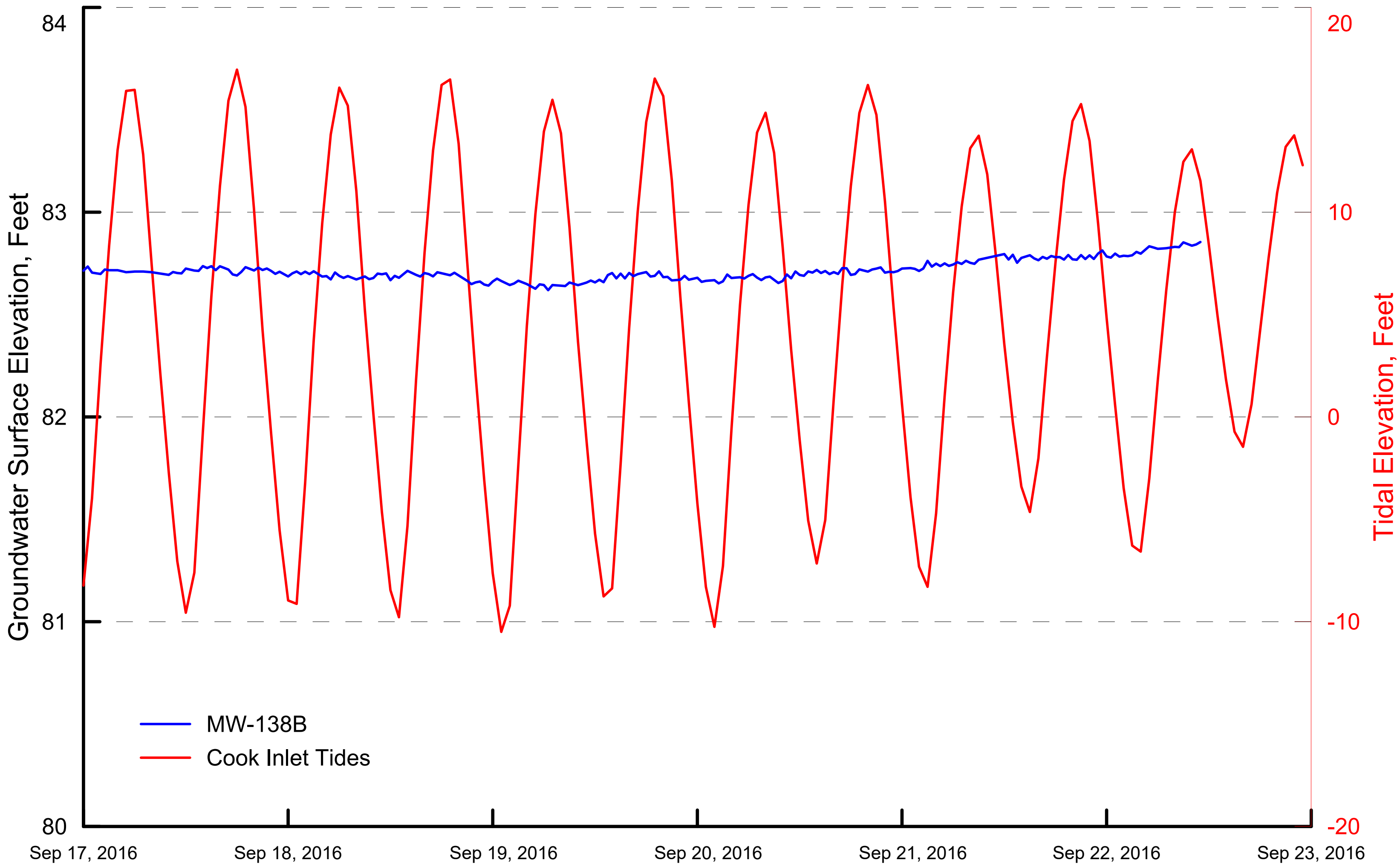
PLATE 17



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-98B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

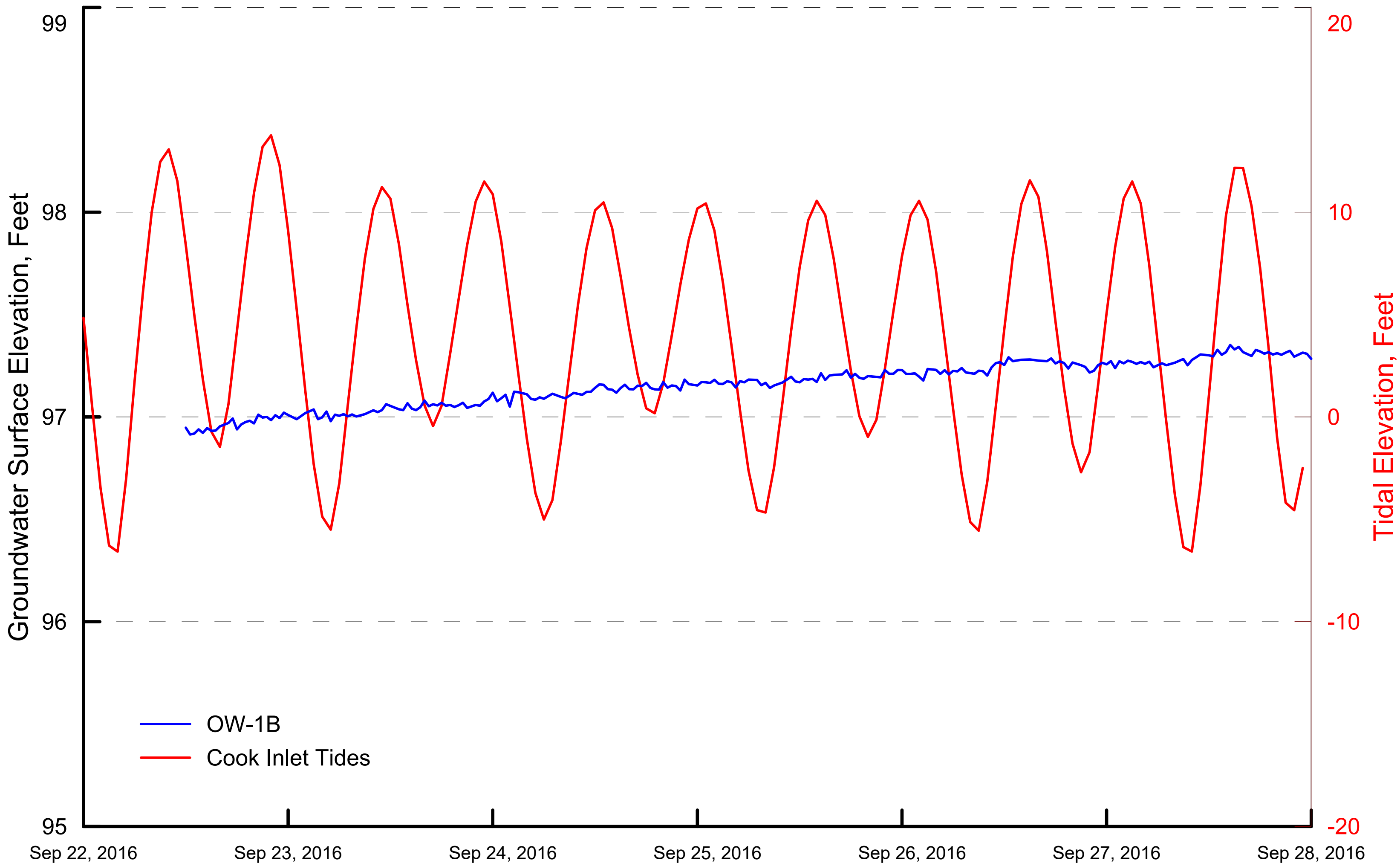
PLATE 18



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
MW-138B
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

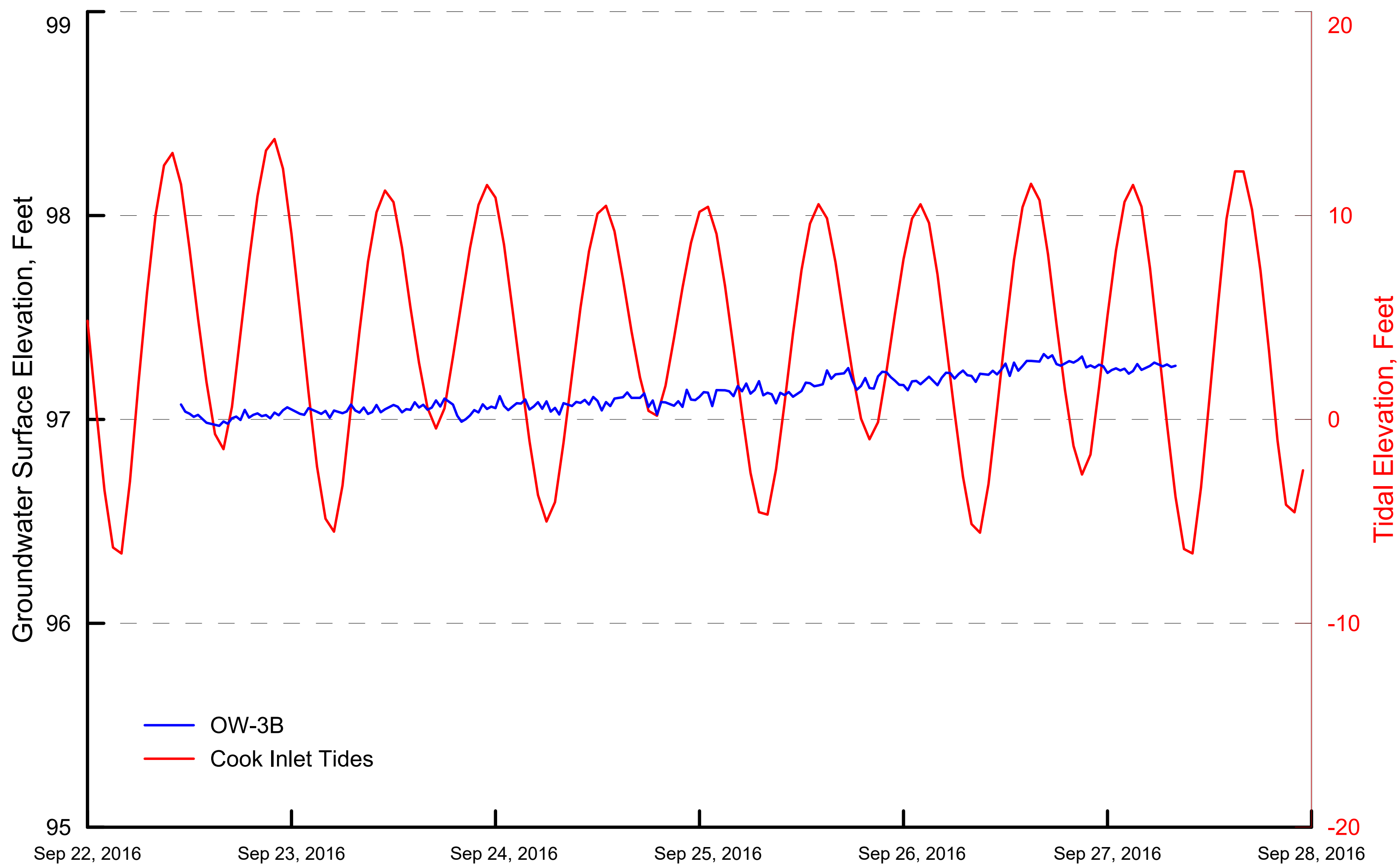
PLATE 19



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
OW-1
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

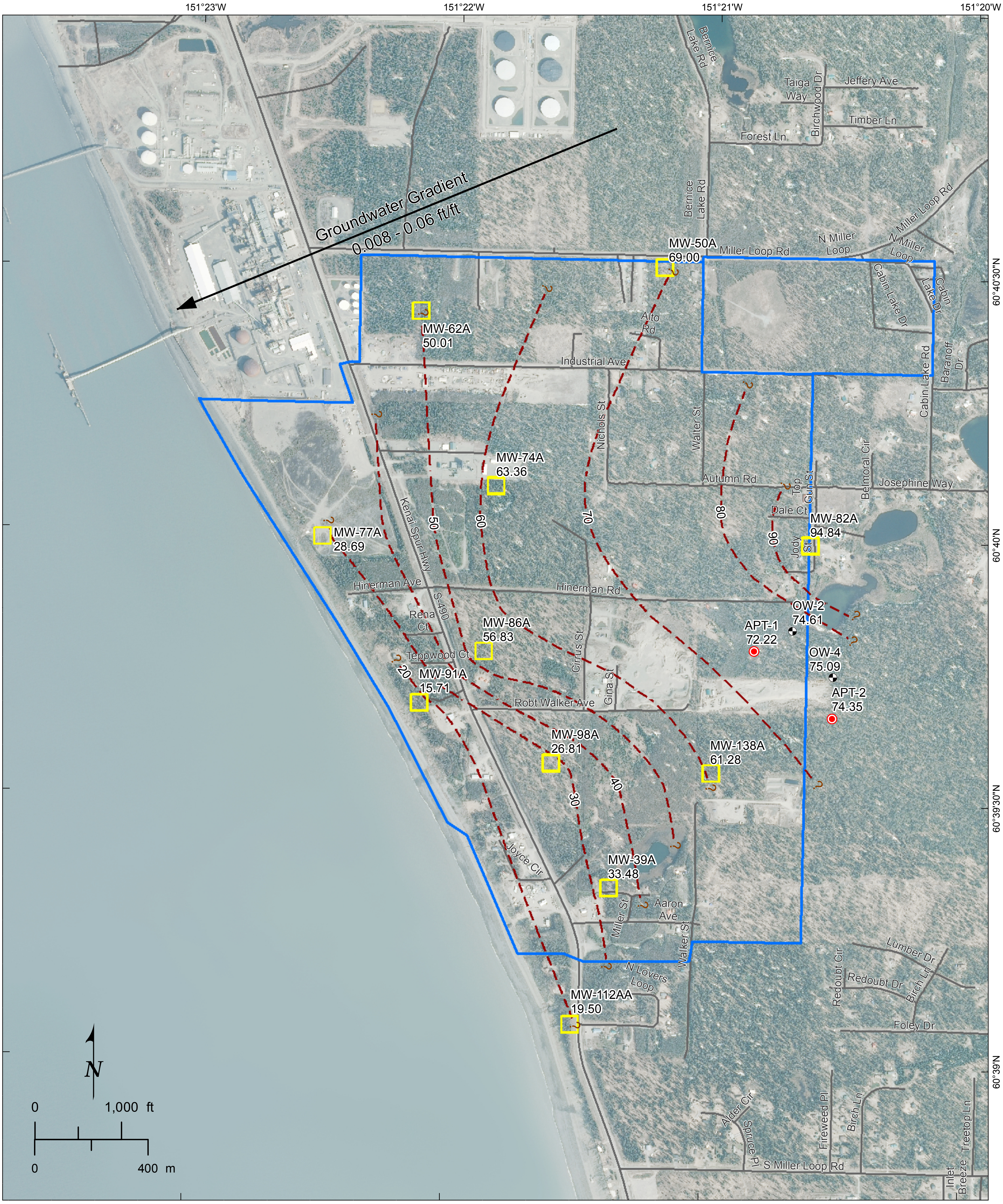
PLATE 20



Elevation in feet, NAVD88

GROUNDWATER SURFACE - WATER BEARING UNIT 1
OW-3
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, AKLASKA

PLATE 21



LEGEND

MW-39A 33.48 — Well Locations (labeled with well ID and groundwater elevation, NAVD88, feet, measured September 2016)

APT-1 72.22 — APT Well

OW-2 74.61 — Observation Well Pair

80 — Water Bearing Unit 2 Contour Elevations

Onshore LNG Facilities Study Area

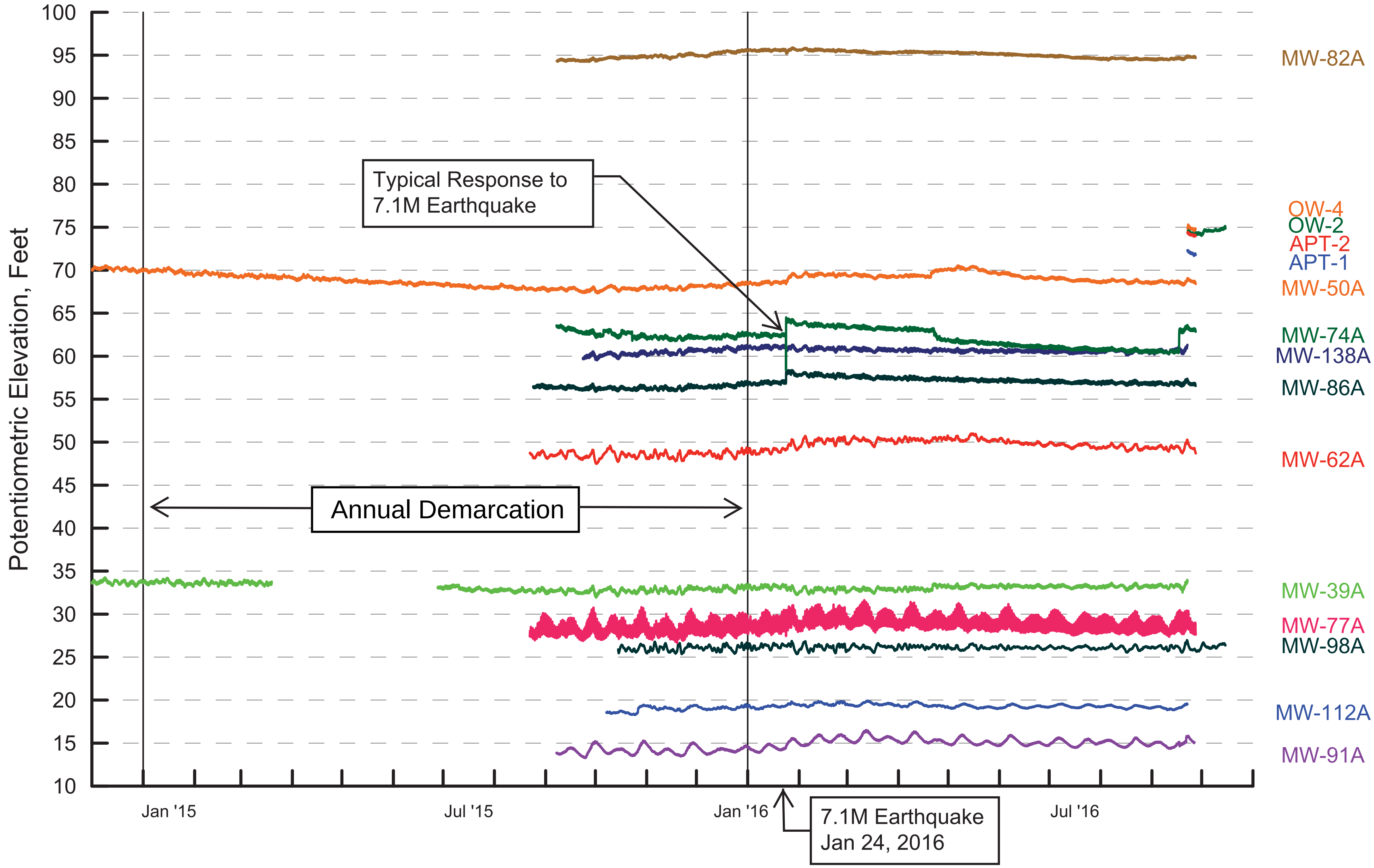
Groundwater Flow Direction and Gradient

WATER BEARING UNIT 2
POTENTIOMETRIC SURFACE
ELEVATIONS AND GRADIENT

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 22

P:\Projects\10_0000\10_160001_AKLNG_2016\04_GIS\MXD\Figures\AKLNG_Plate_22_WaterBearing_U2_Sept.mxd, m.tocci, 11/21/2016

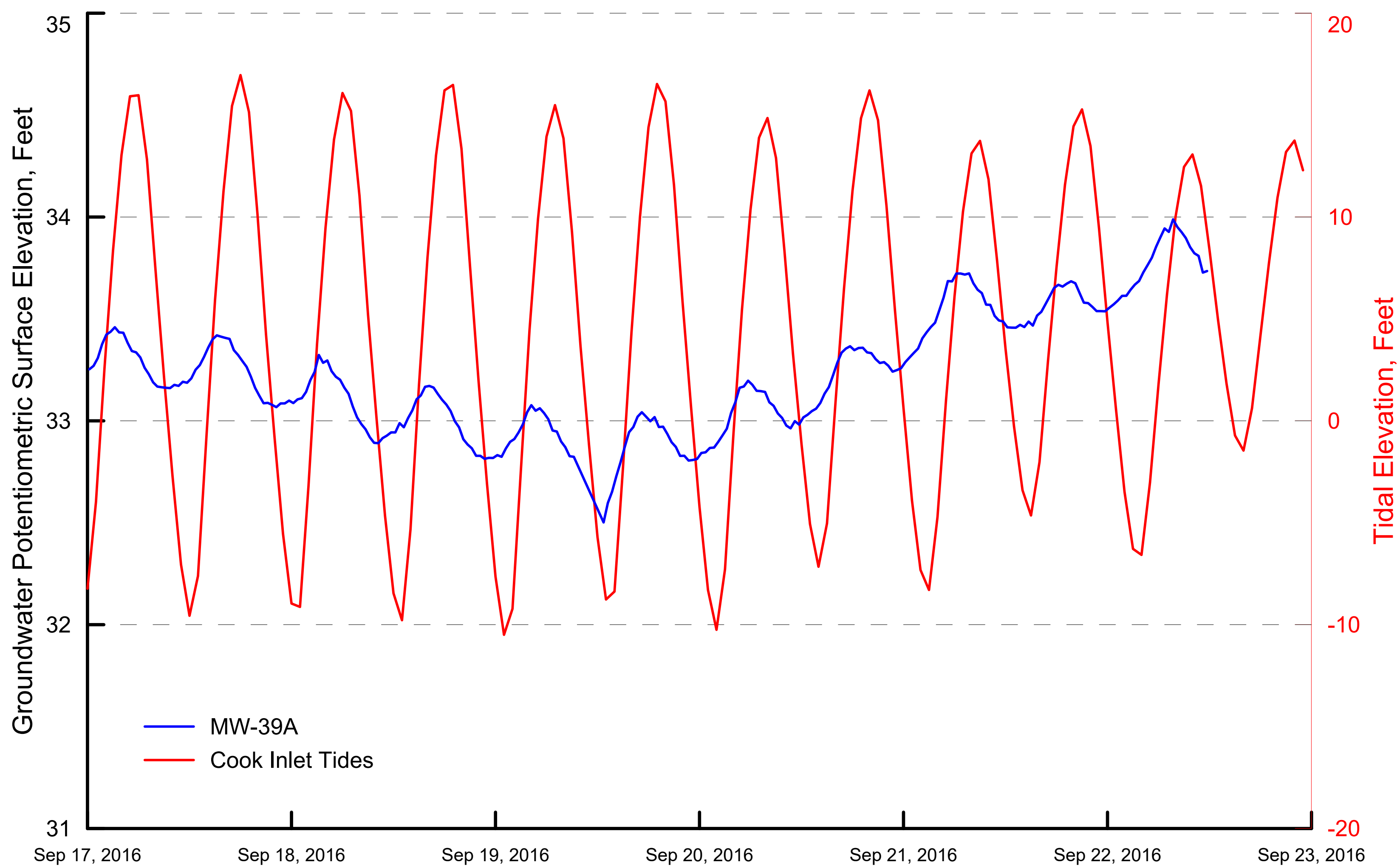


WATER BEARING UNIT 2 GROUNDWATER POTENTIOMETRIC SURFACE ELEVATIONS SINCE 2014

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

Elevation in feet, NAVD88

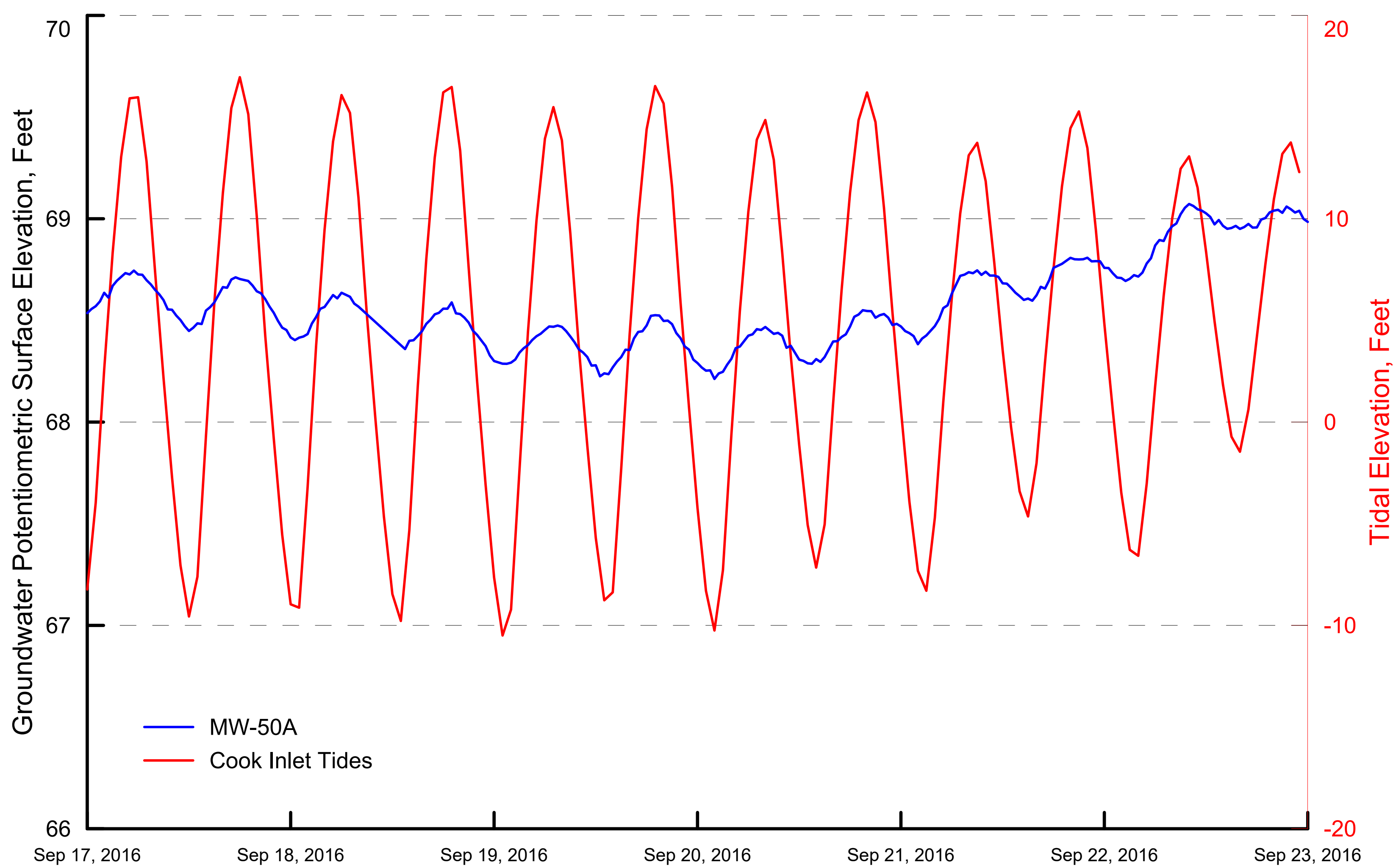
PLATE 23



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-39A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

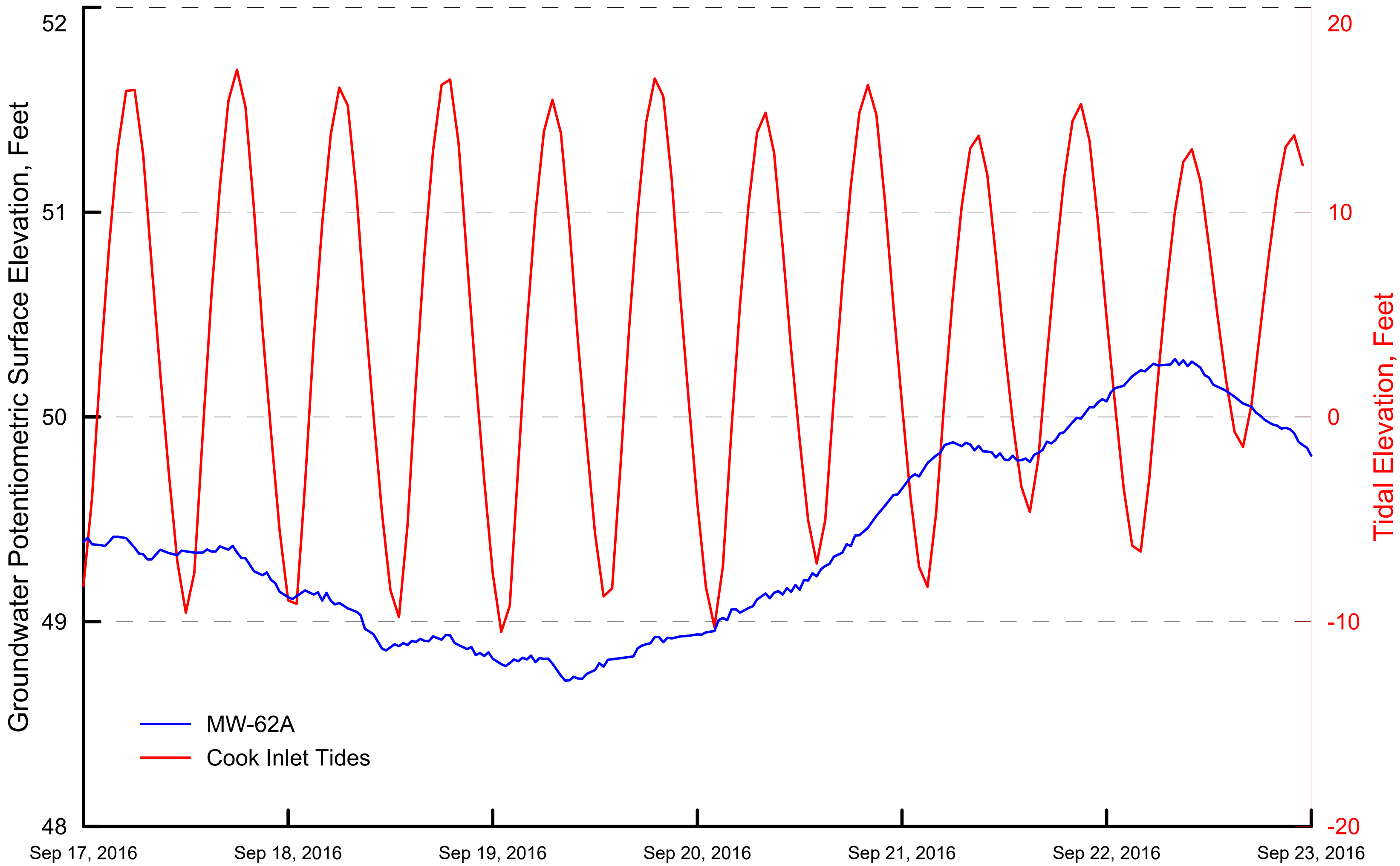
PLATE 24



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-50A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

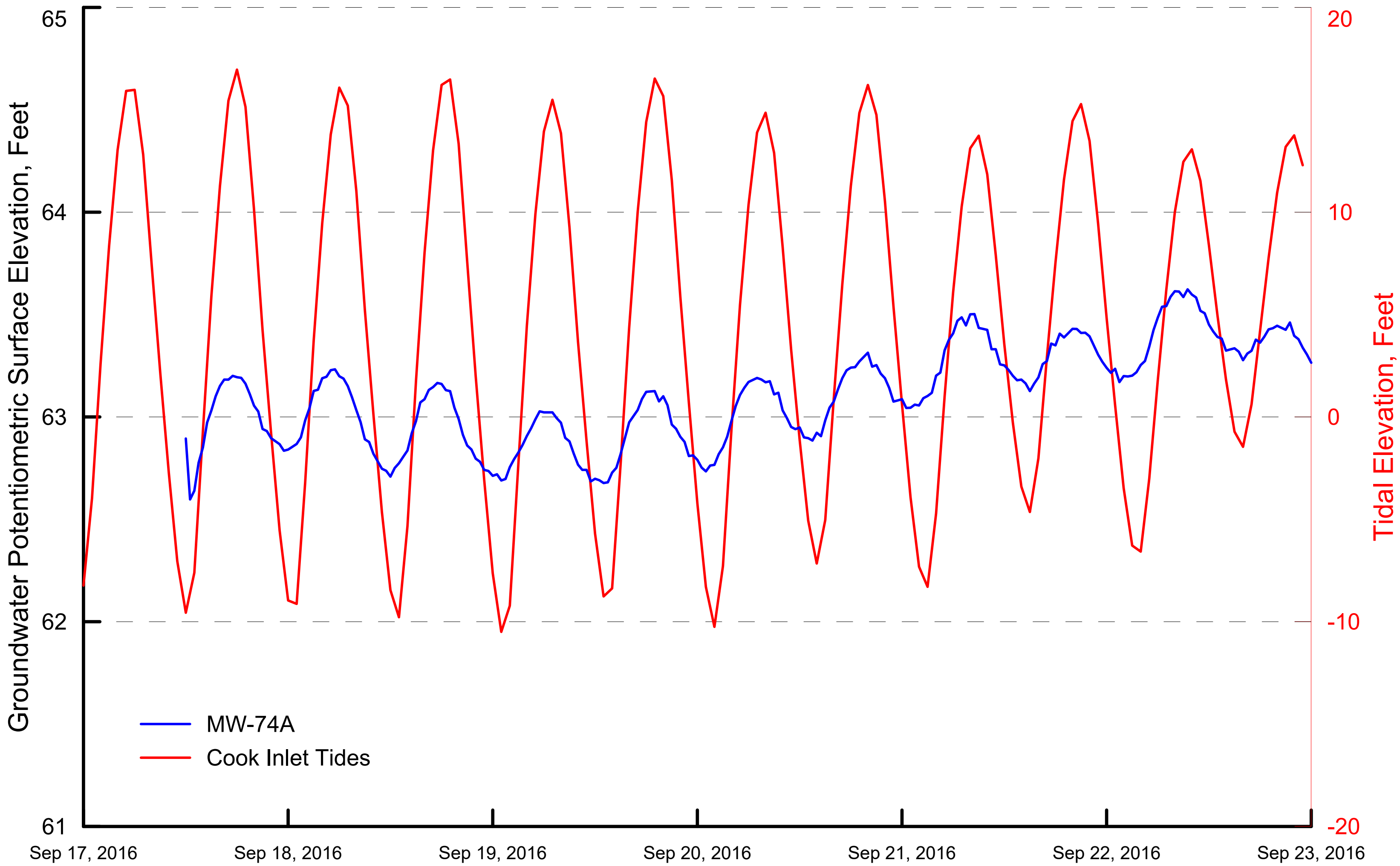
PLATE 25



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-62A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

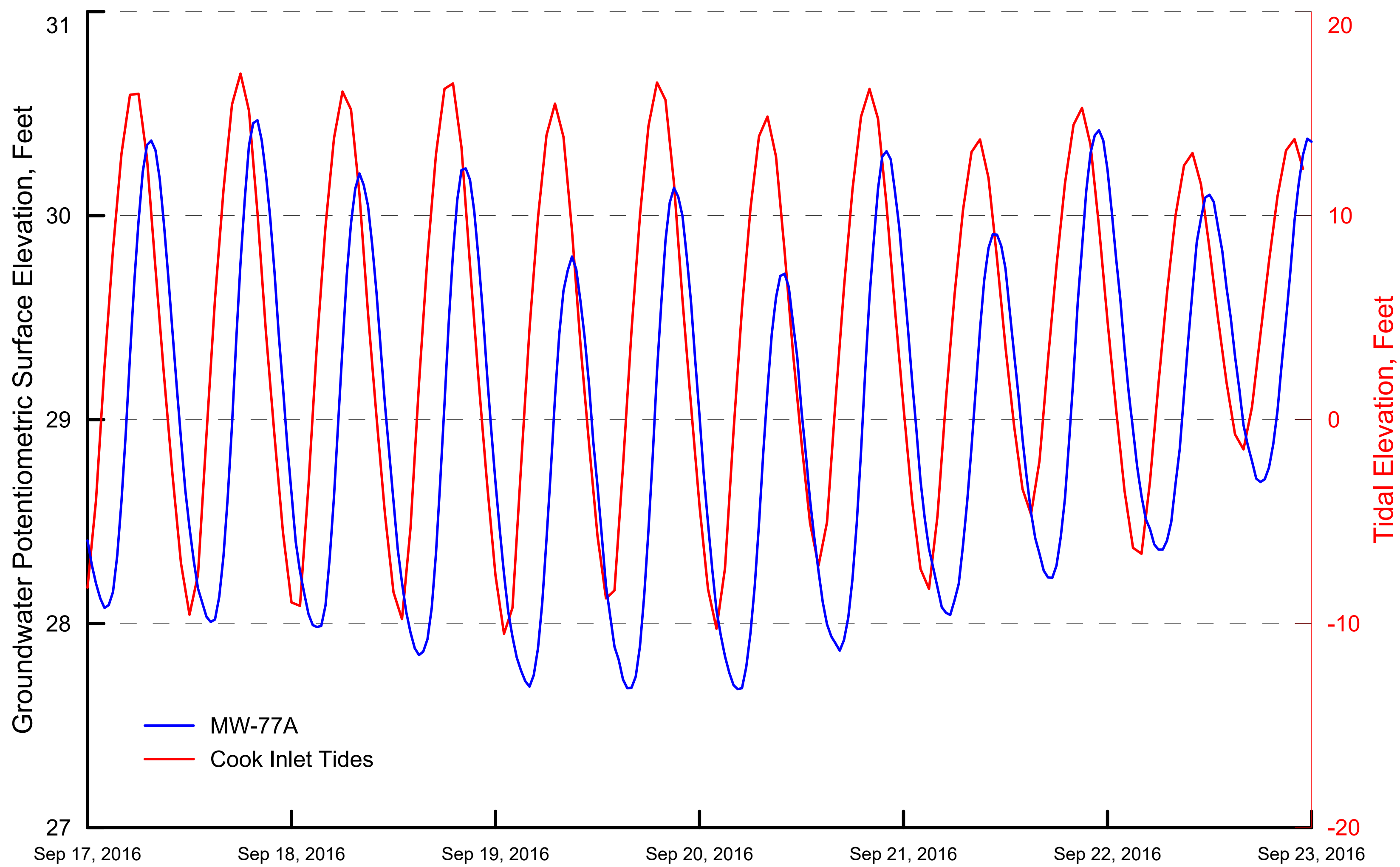
PLATE 26



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-74A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

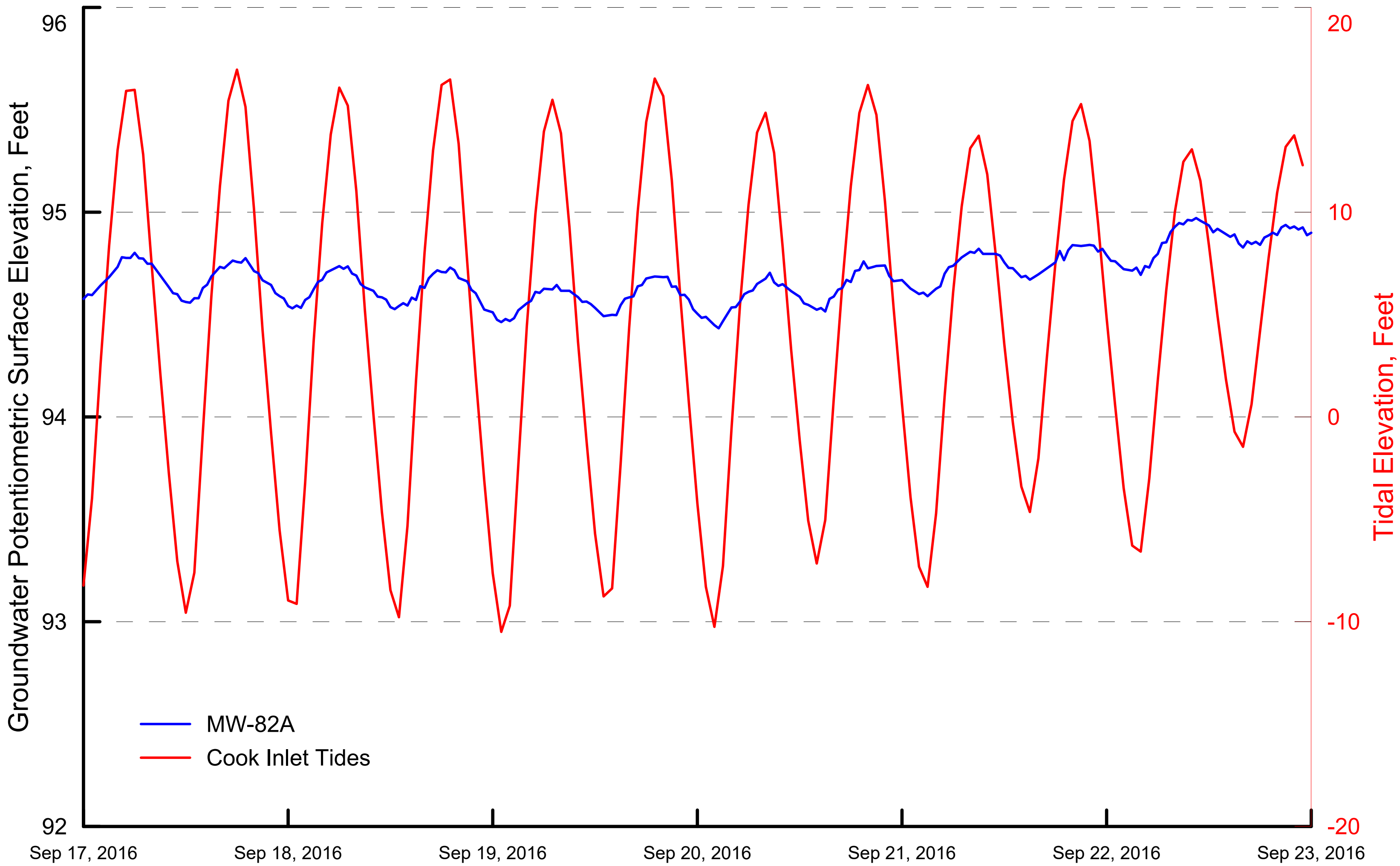
PLATE 27



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-77A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

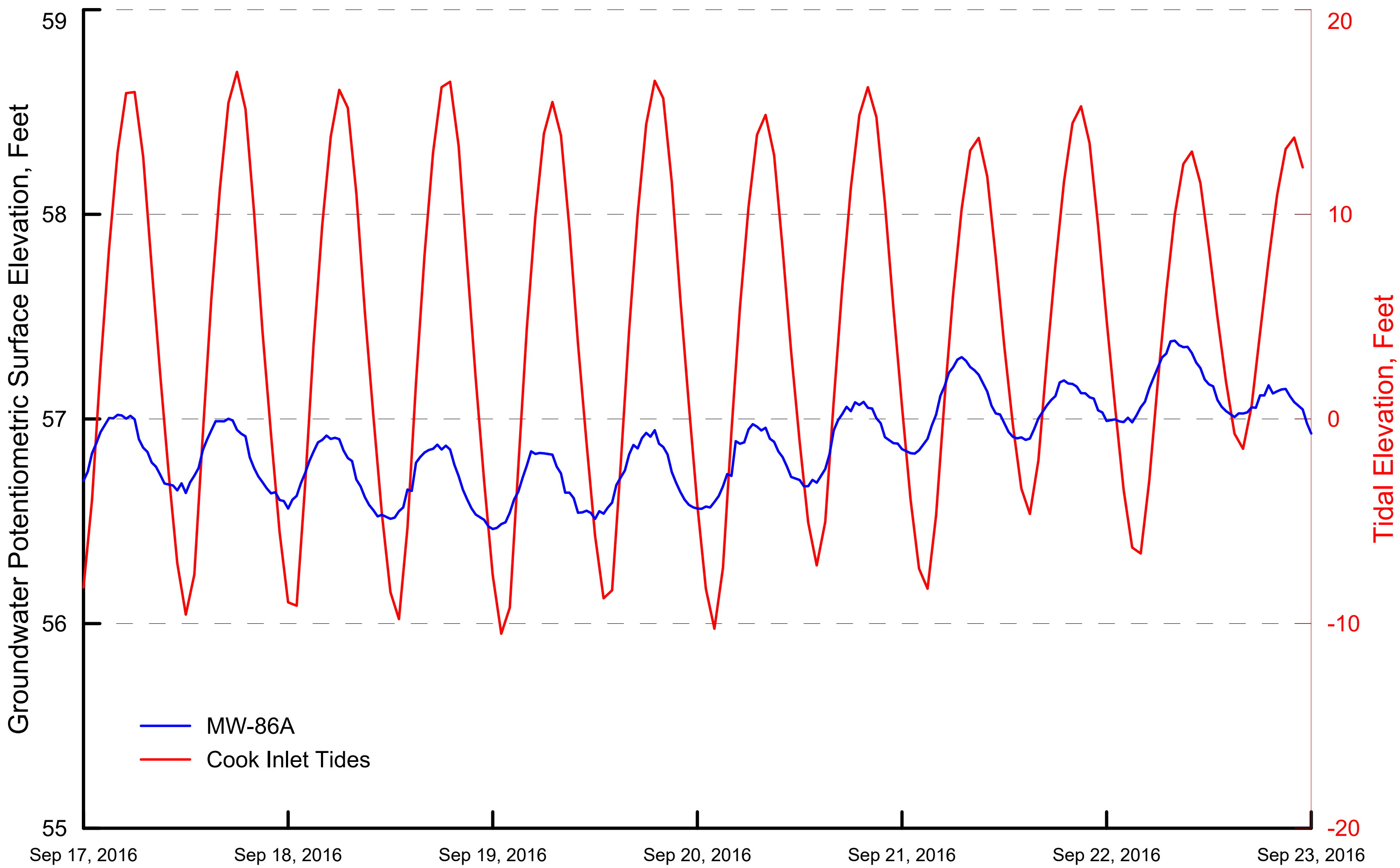
PLATE 28



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-82A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

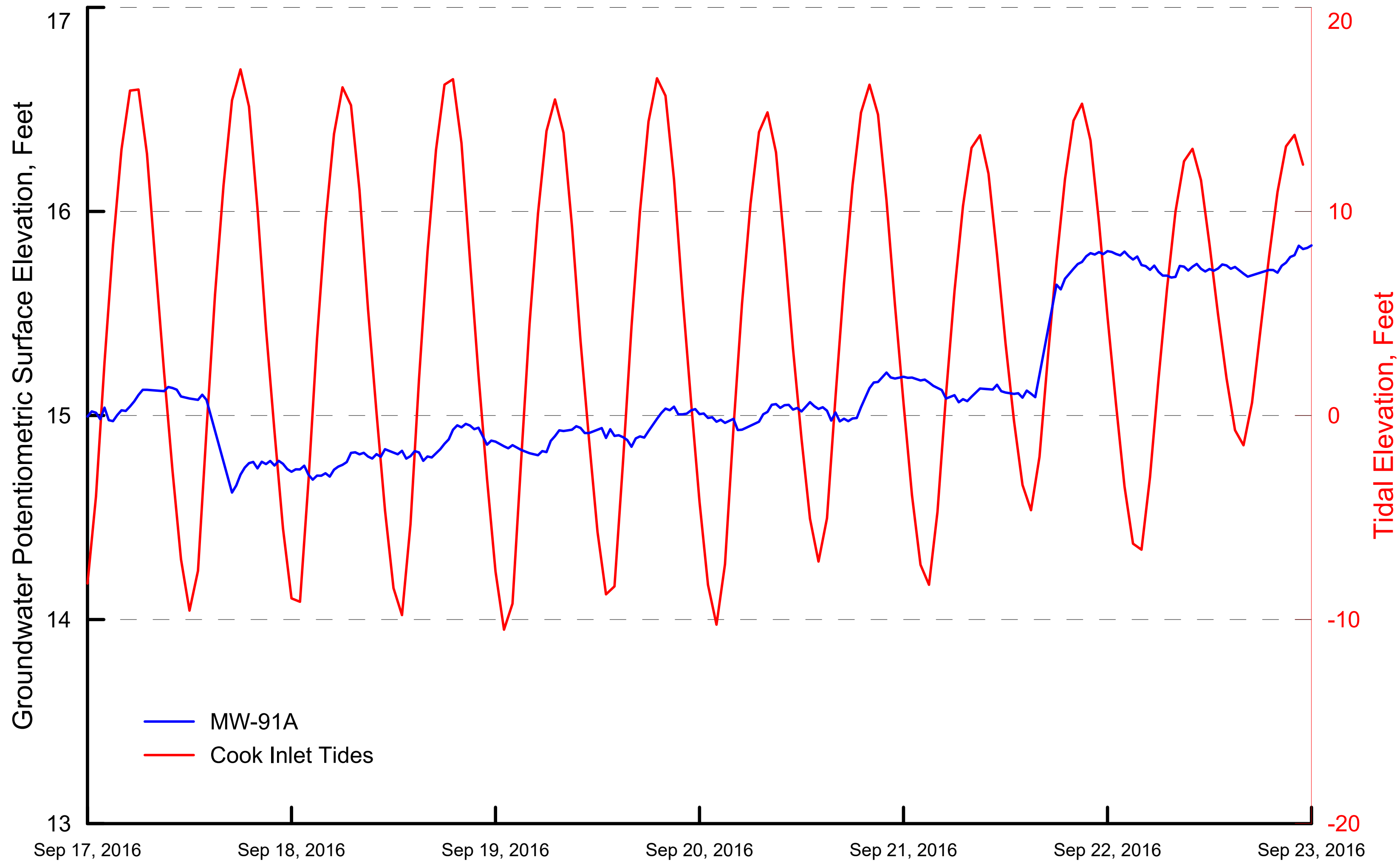
PLATE 29



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-86A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

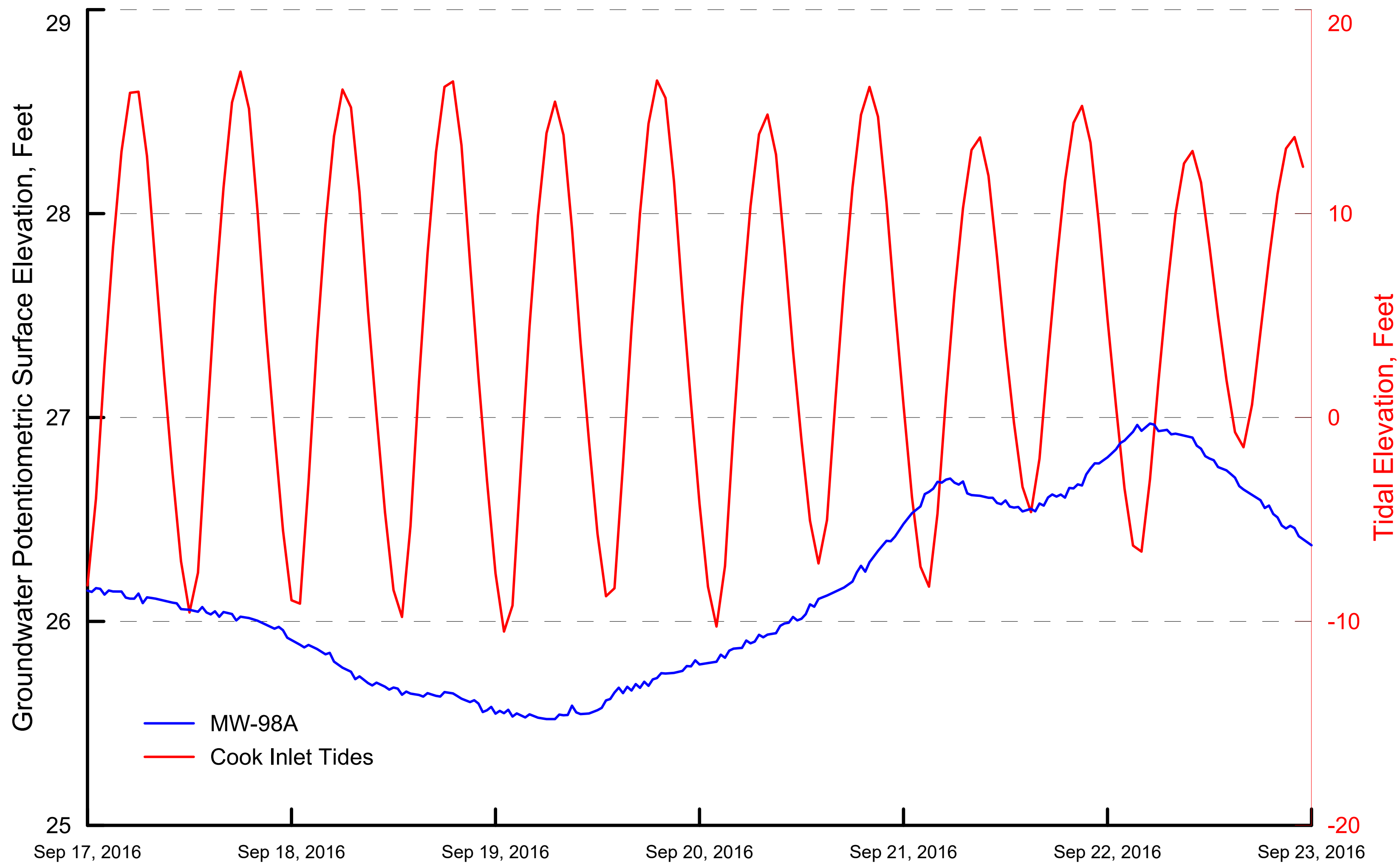
PLATE 30



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-91A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

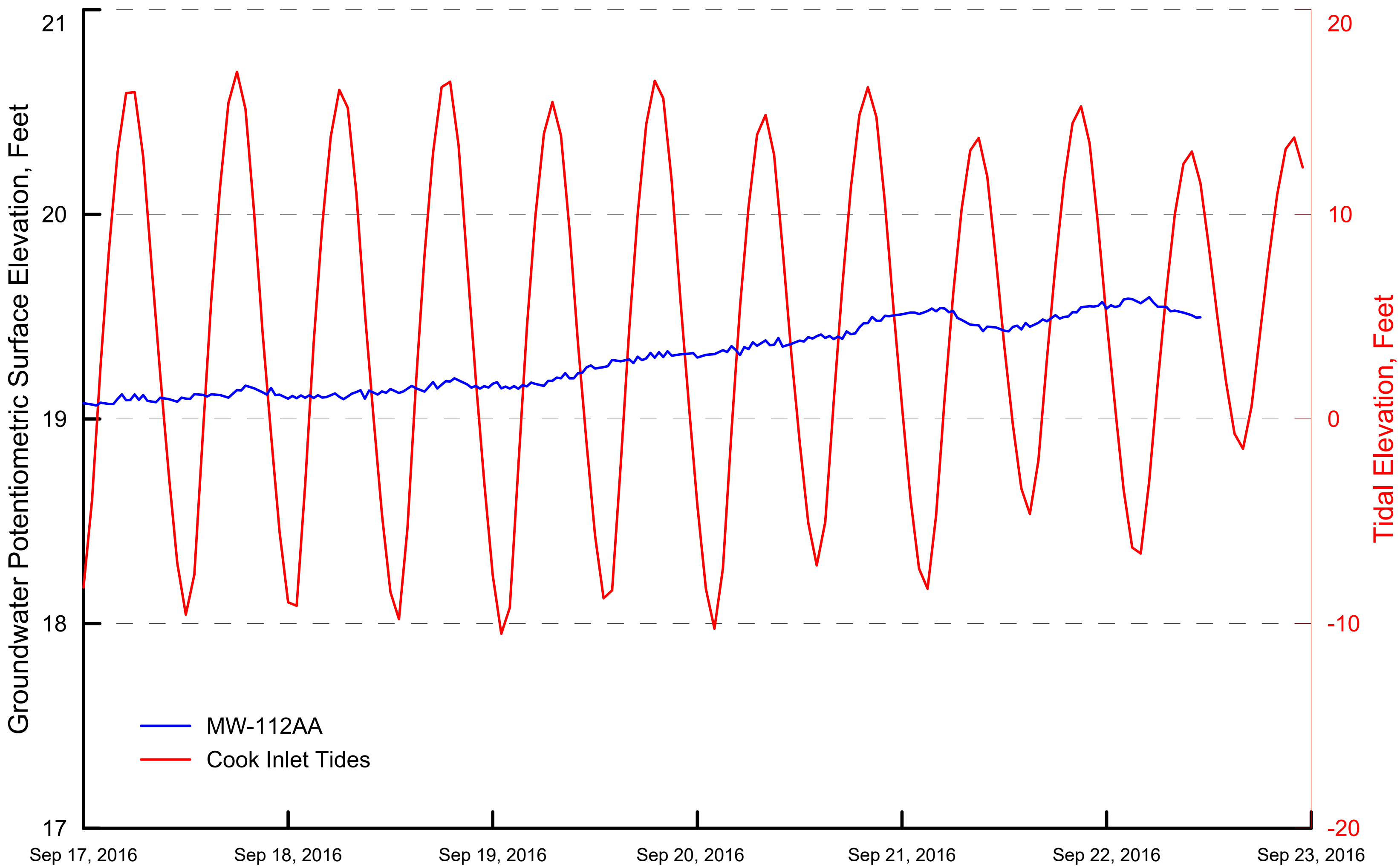
PLATE 31



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-98A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

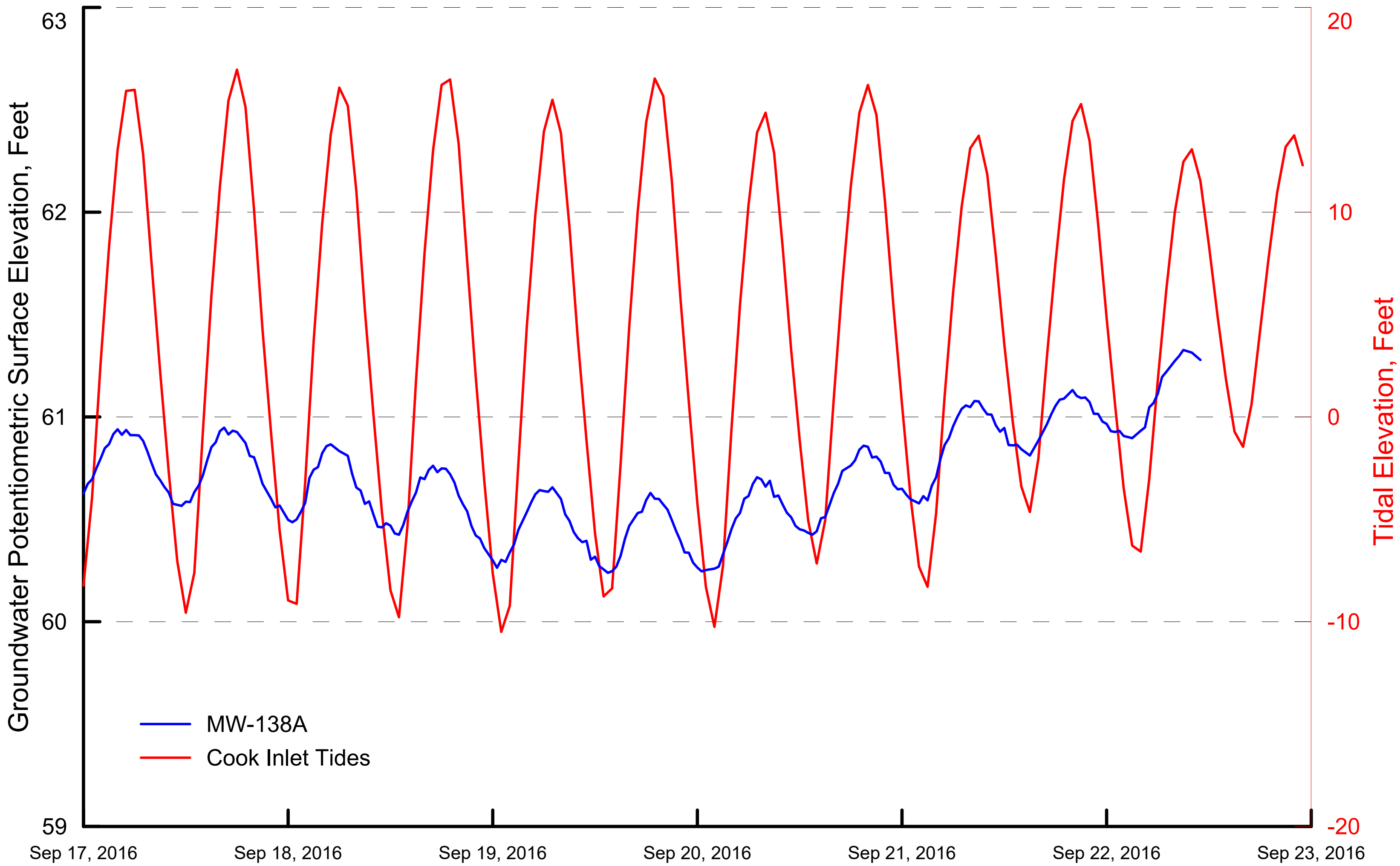
PLATE 32



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-112AA
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

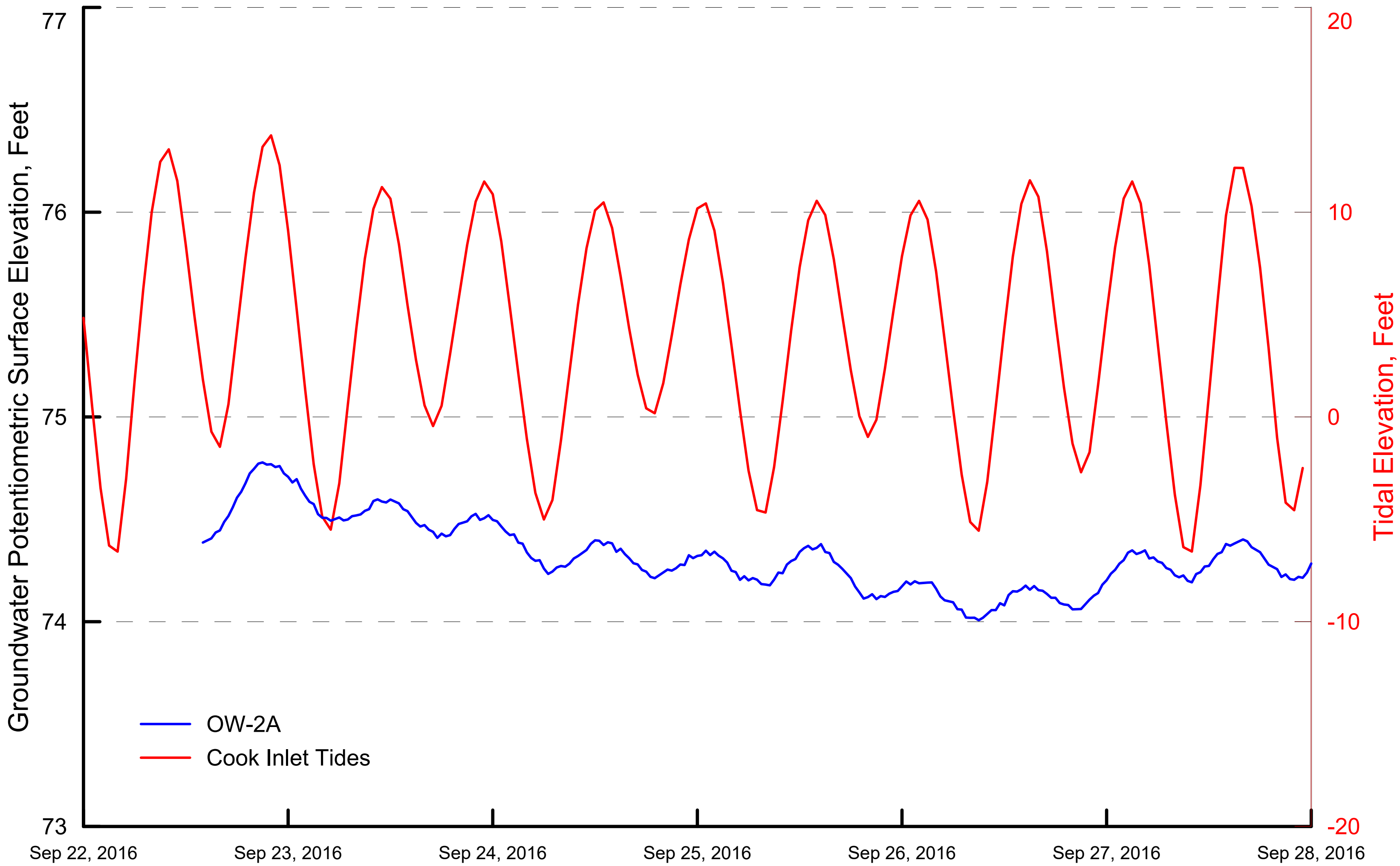
PLATE 33



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
MW-138A
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

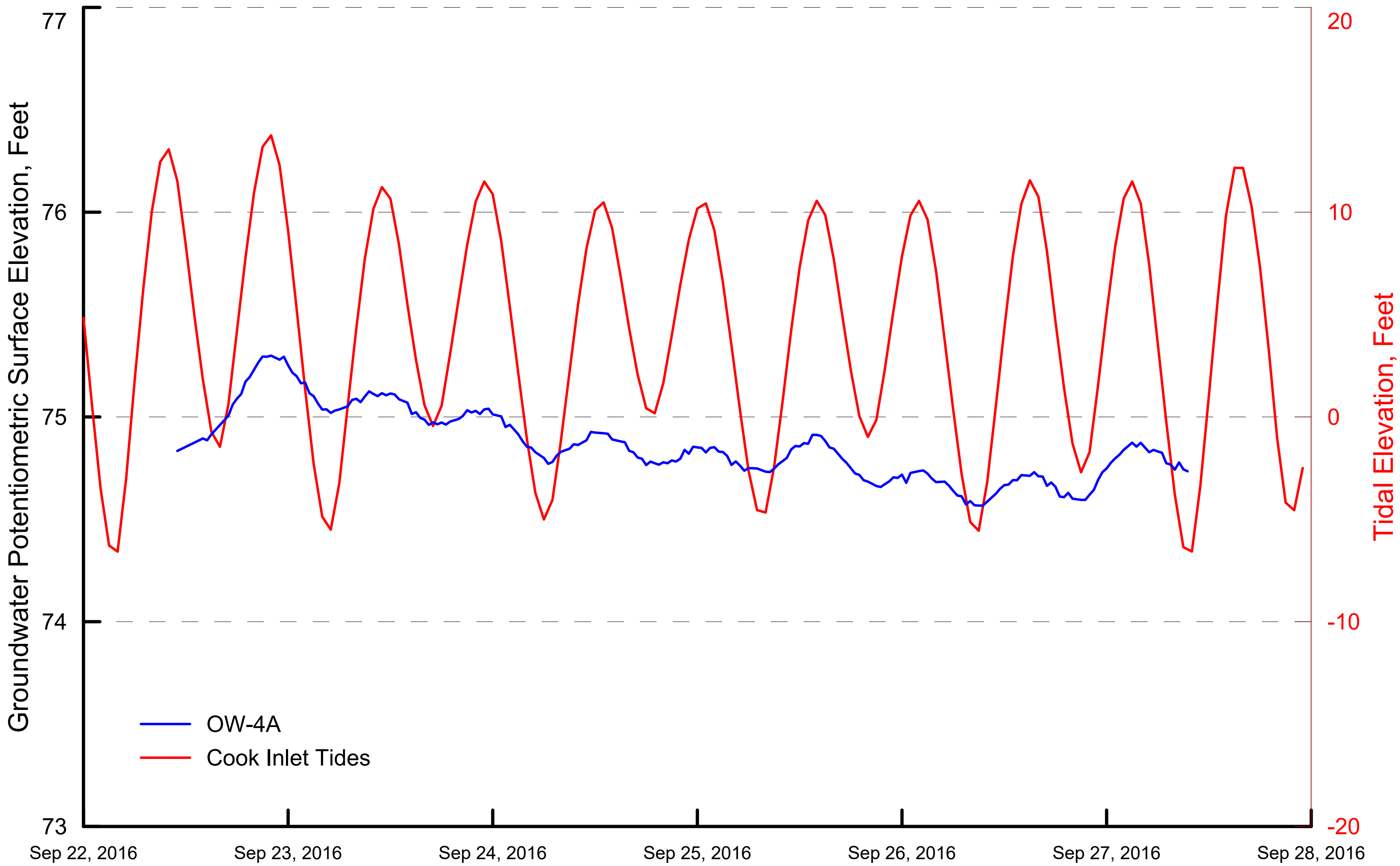
PLATE 34



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
OW-2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

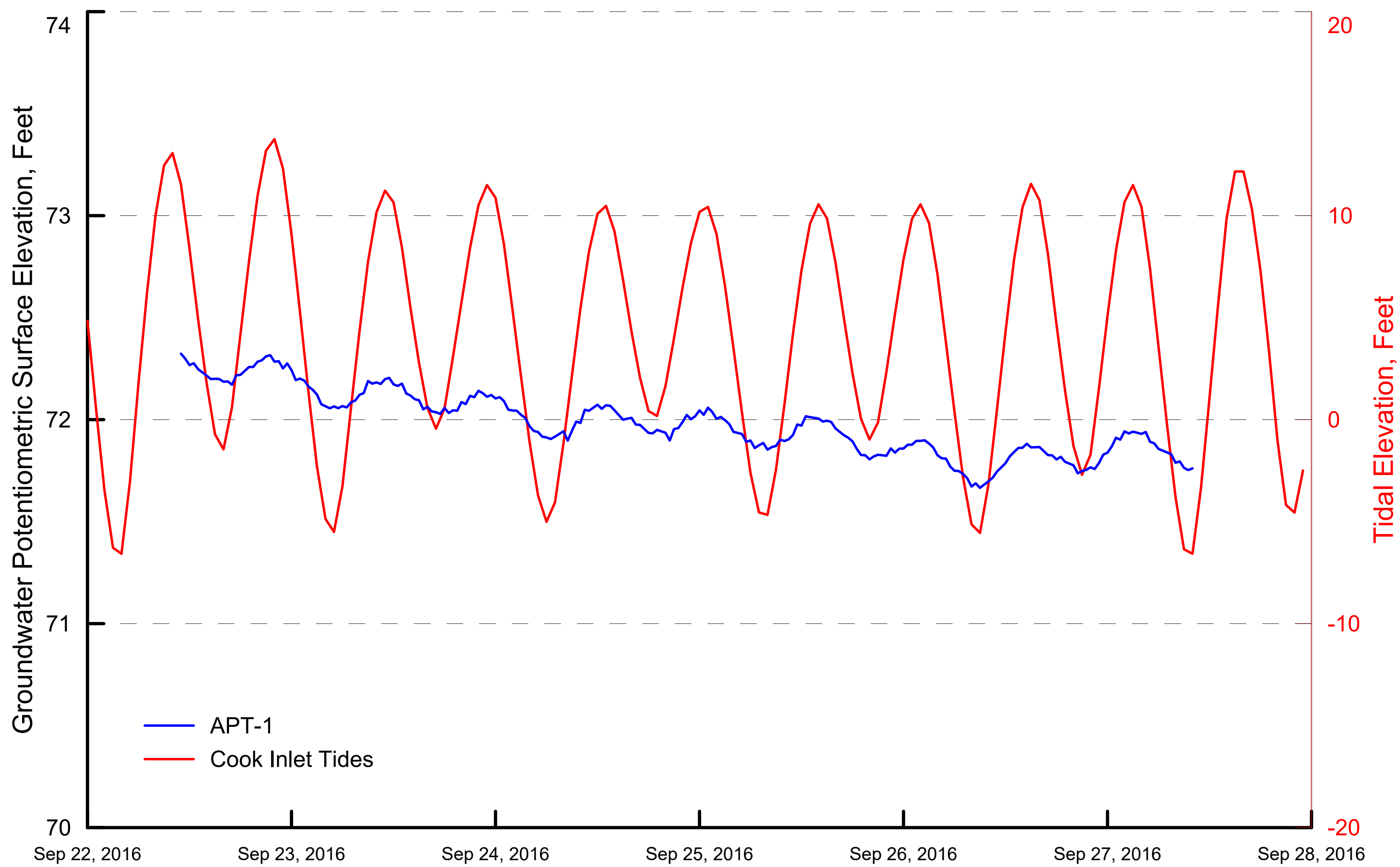
PLATE 35



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
OW-4
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

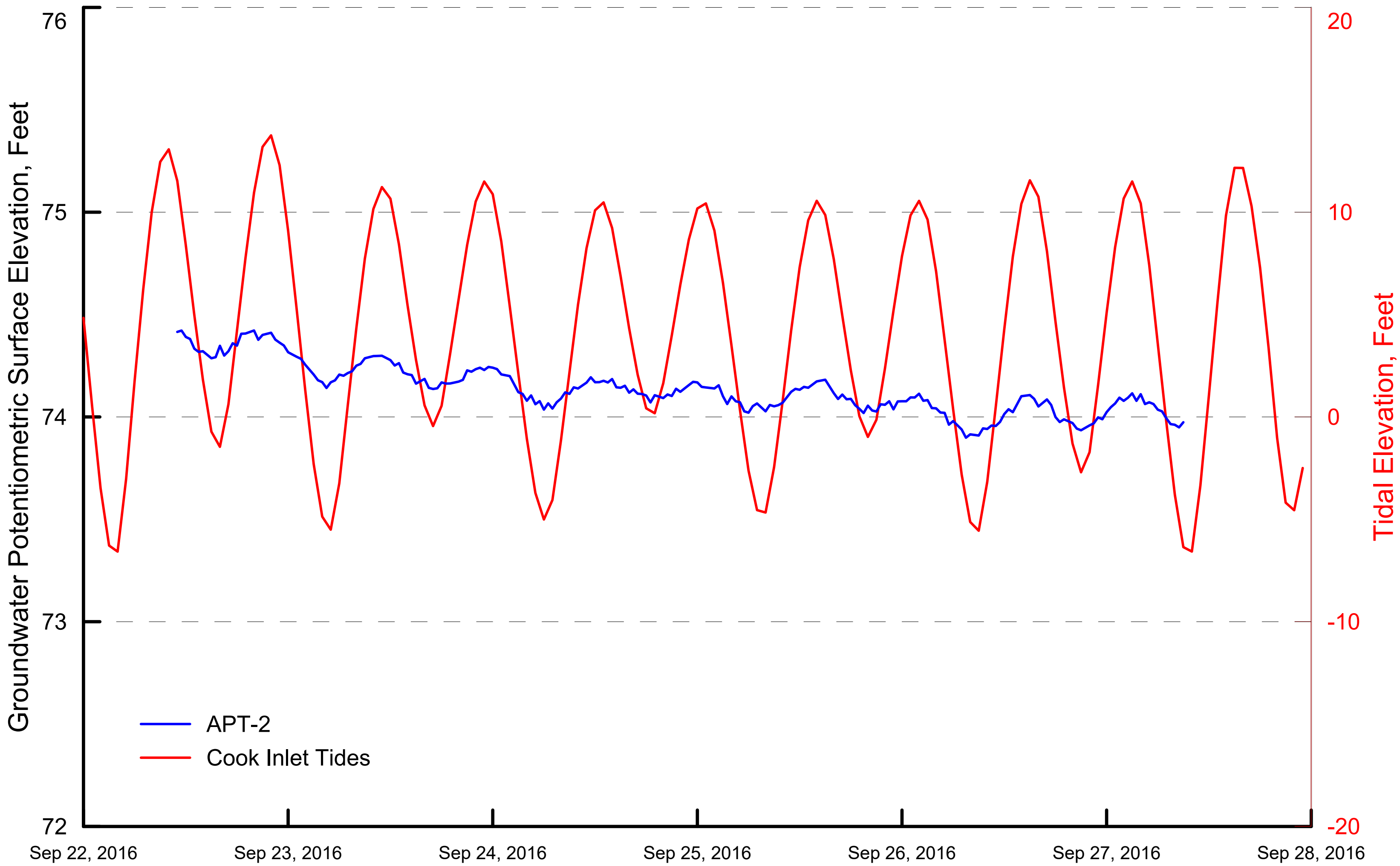
PLATE 36



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
APT-1
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

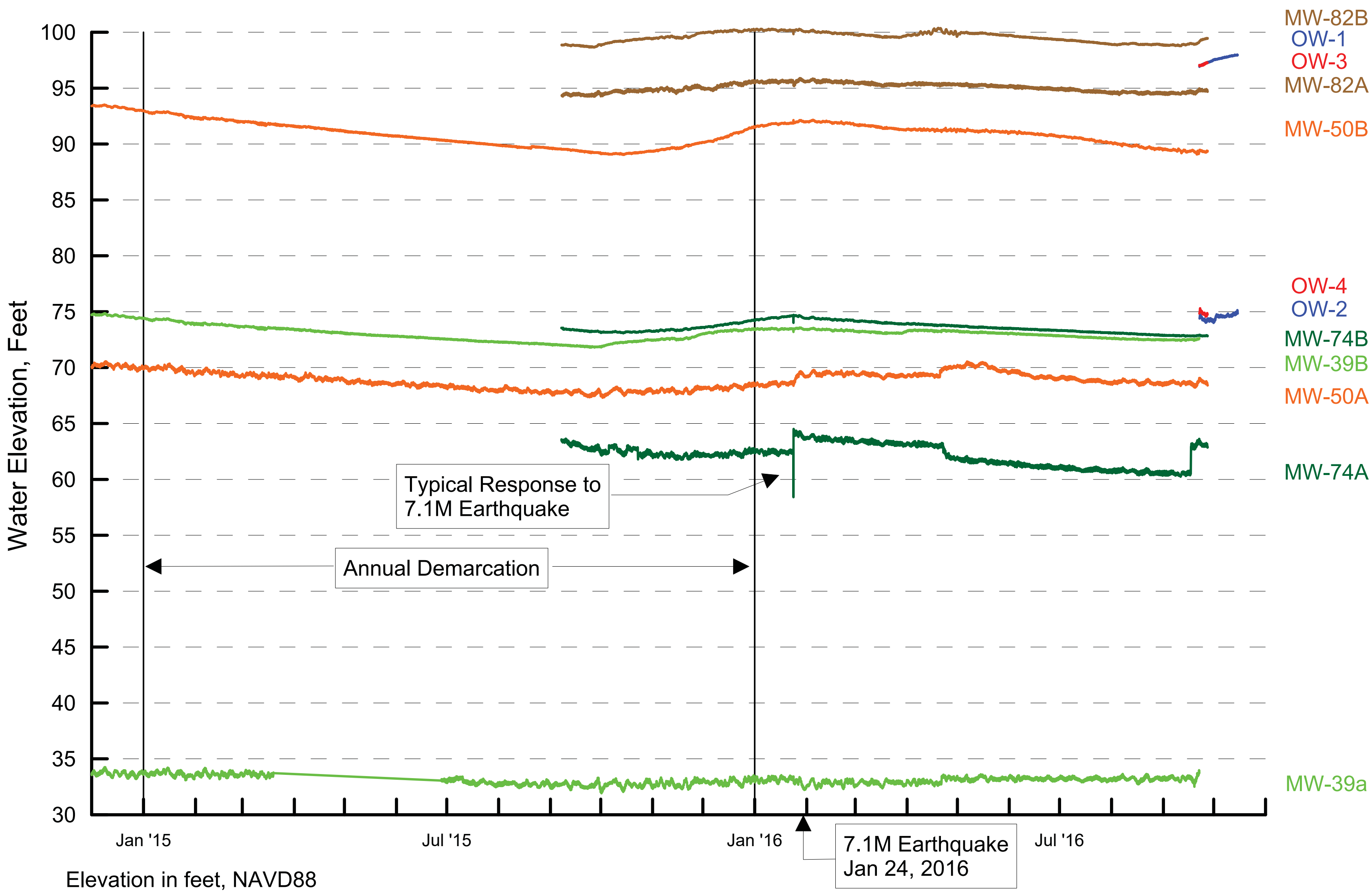
PLATE 37



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 2
APT-2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 38

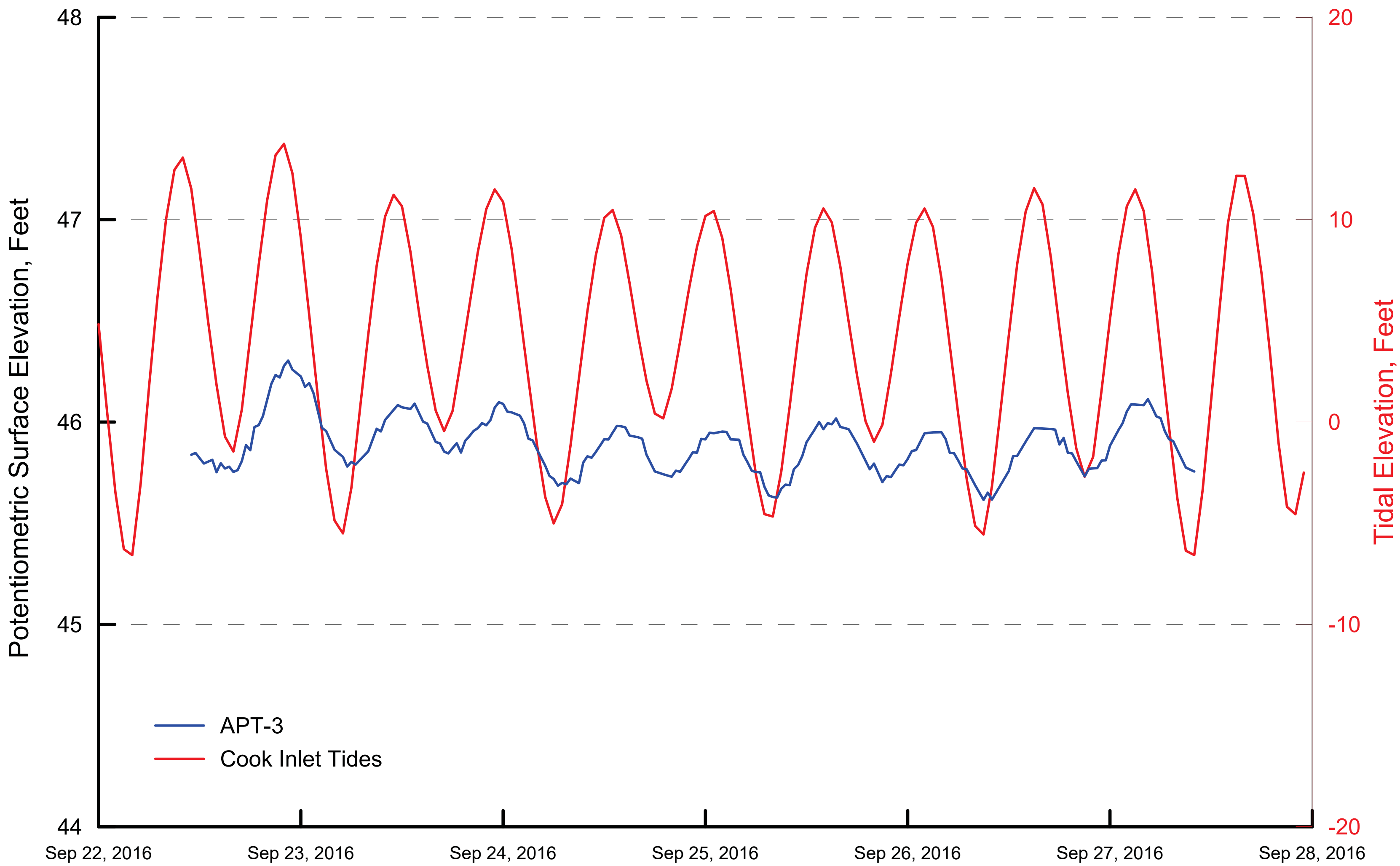


Elevation in feet, NAVD88

WATER ELEVATIONS AT CO-LOCATED WELLS WATER BEARING UNITS 1 AND 2

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

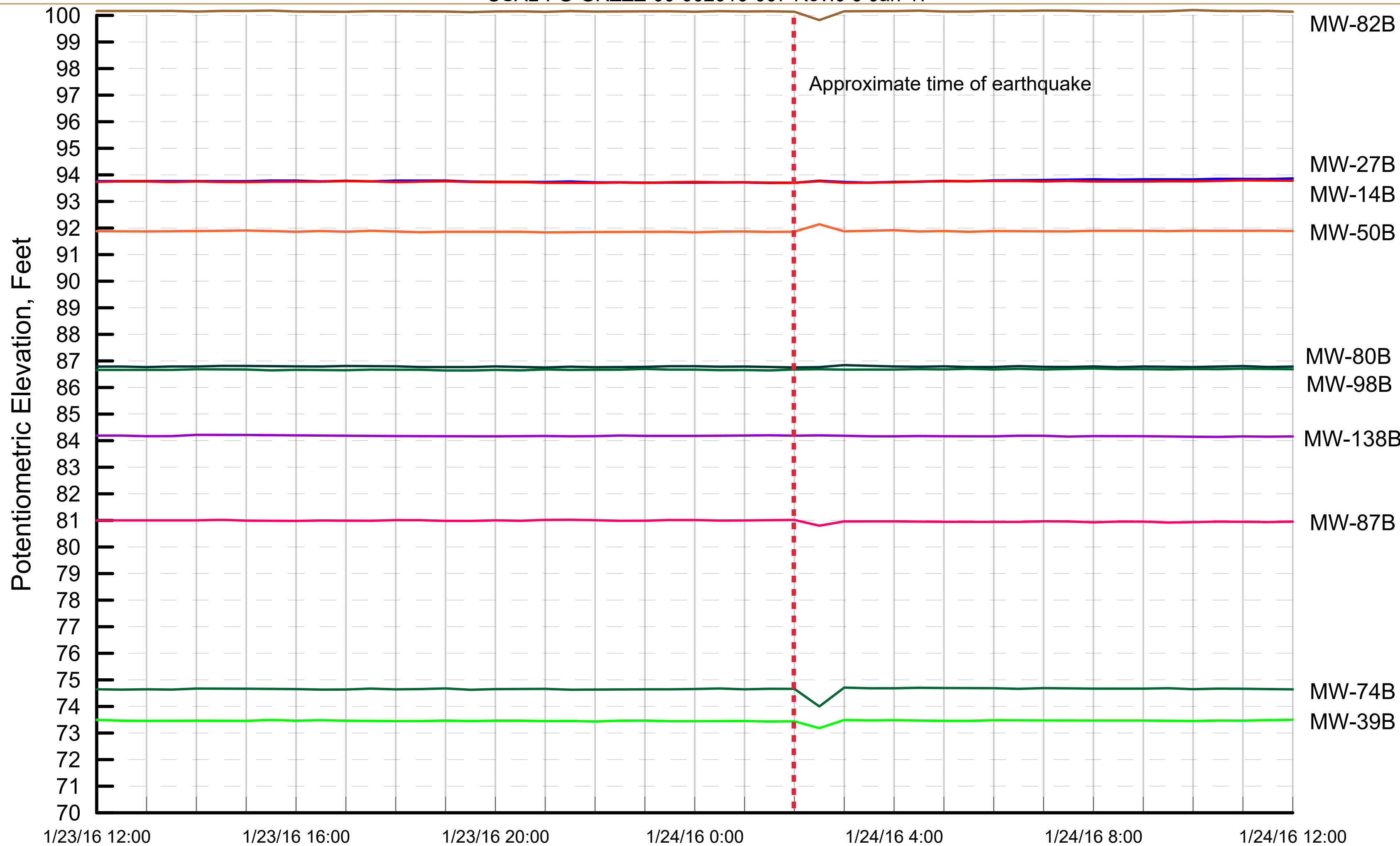
PLATE 39



Elevation in feet, NAVD88

POTENTIOMETRIC SURFACE - WATER BEARING UNIT 3
APT-3
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 40

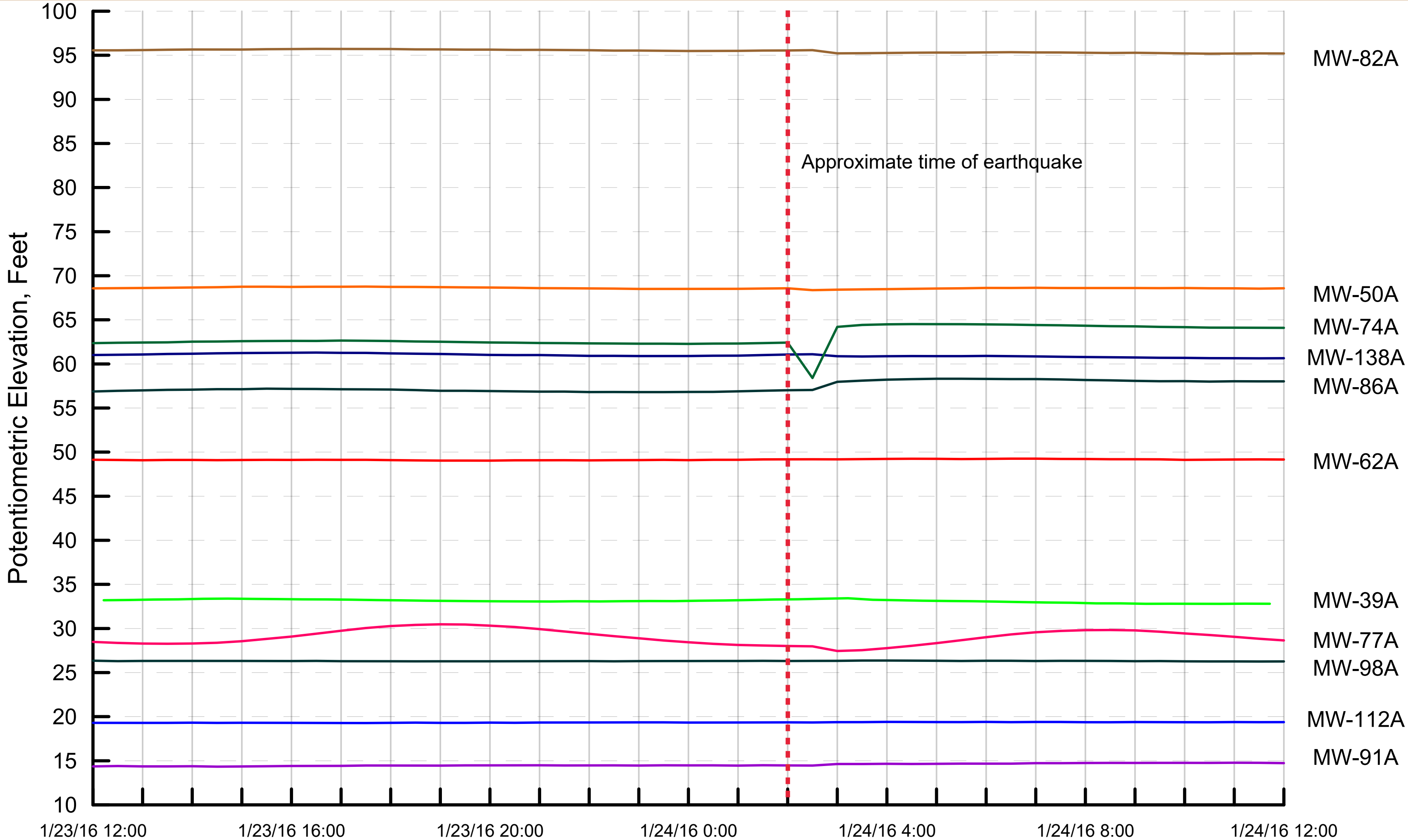


JANUARY 24, 2016 EARTHQUAKE EFFECT ON WATER BEARING UNIT 1

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

Elevation in feet, NAVD88

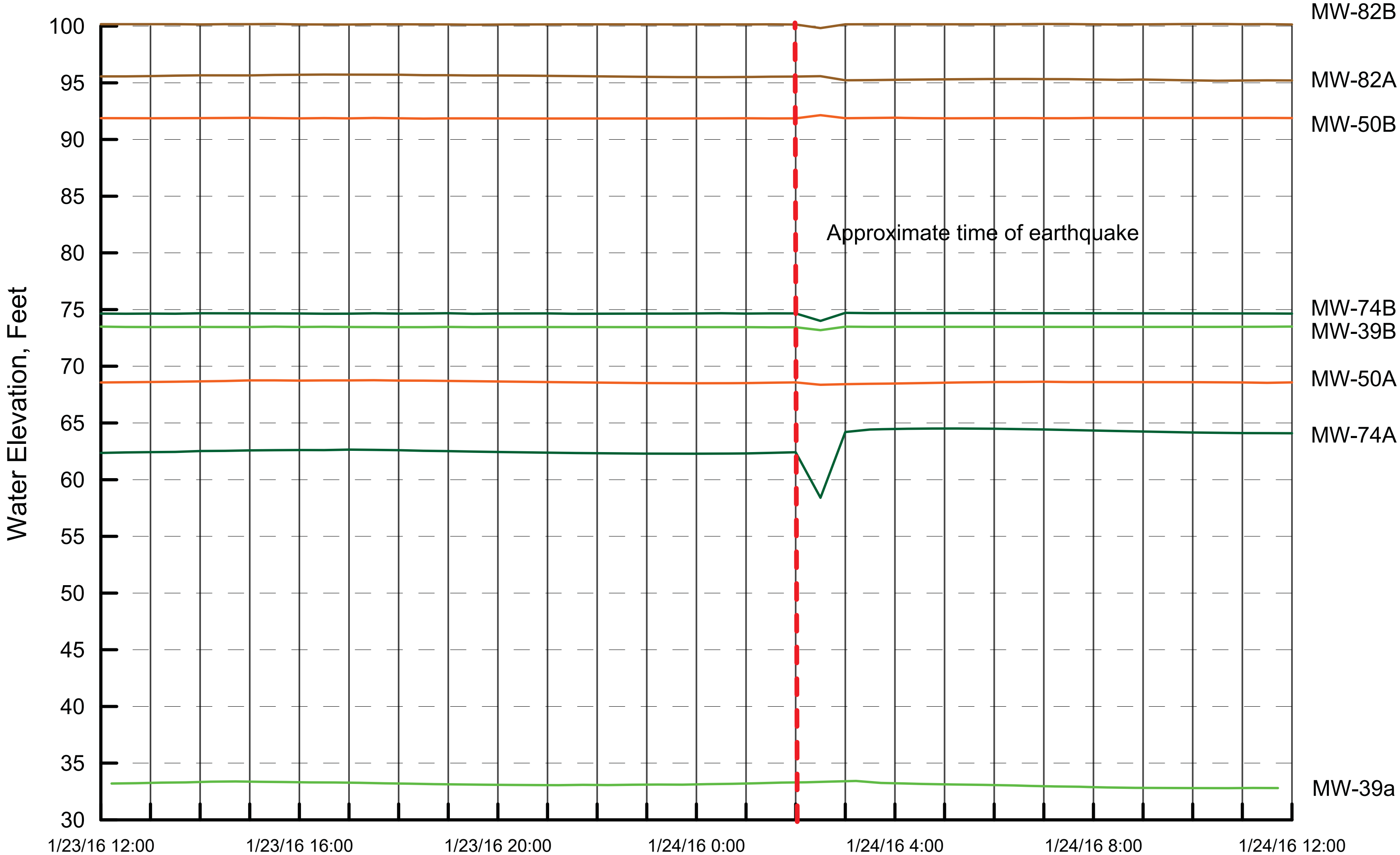
PLATE 41



JANUARY 24, 2016 EARTHQUAKE EFFECT ON
WATER BEARING UNIT 2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

Elevation in feet, NAVD88

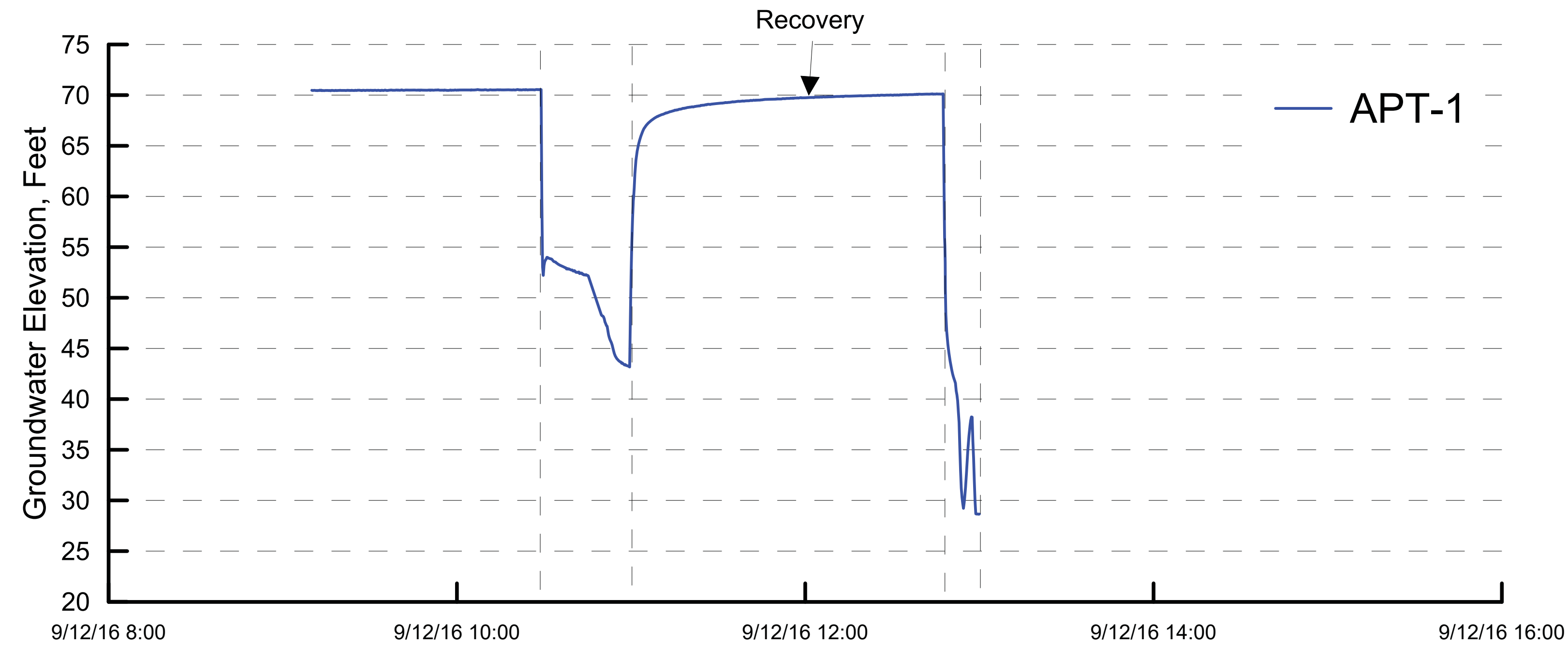
PLATE 42

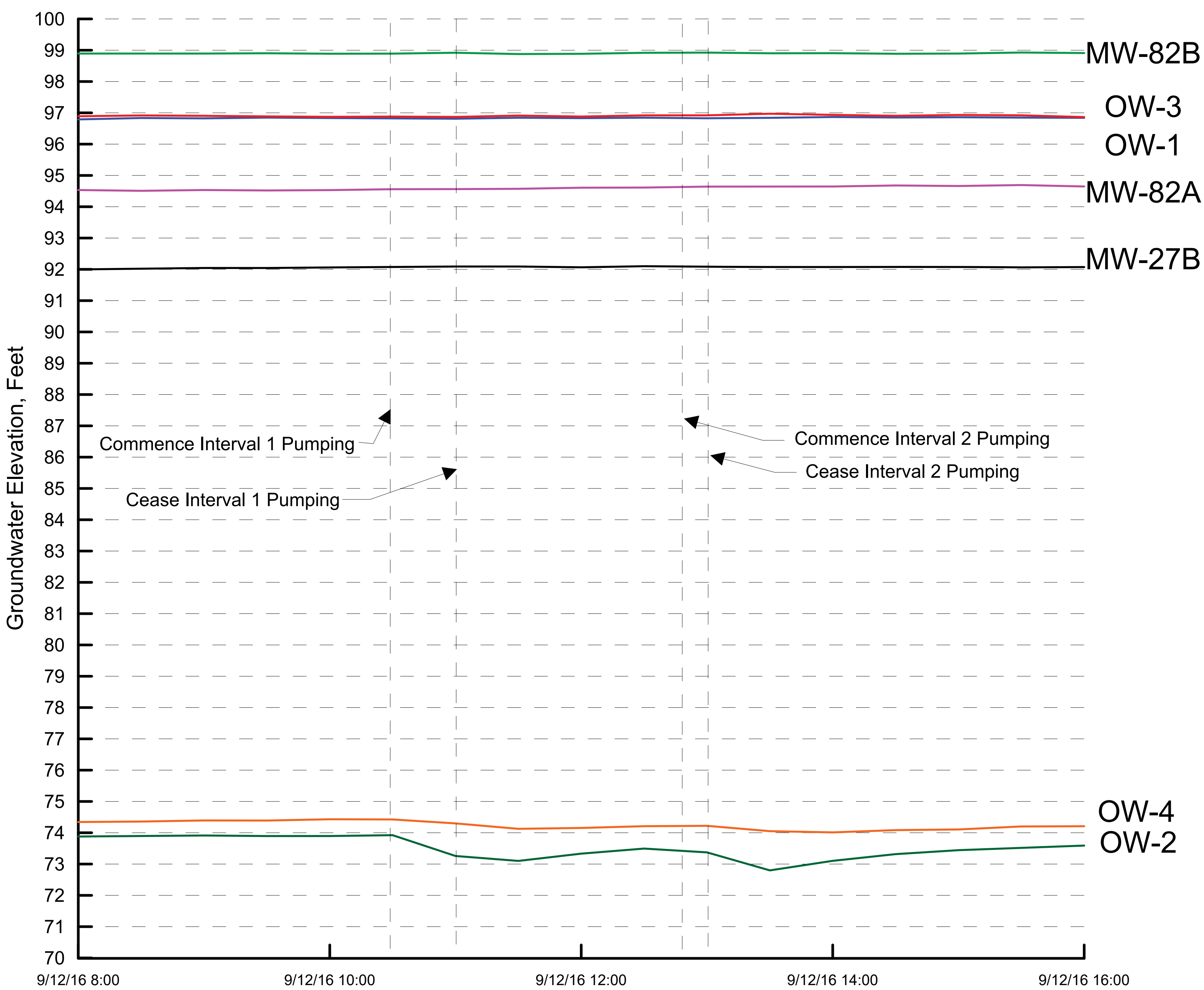


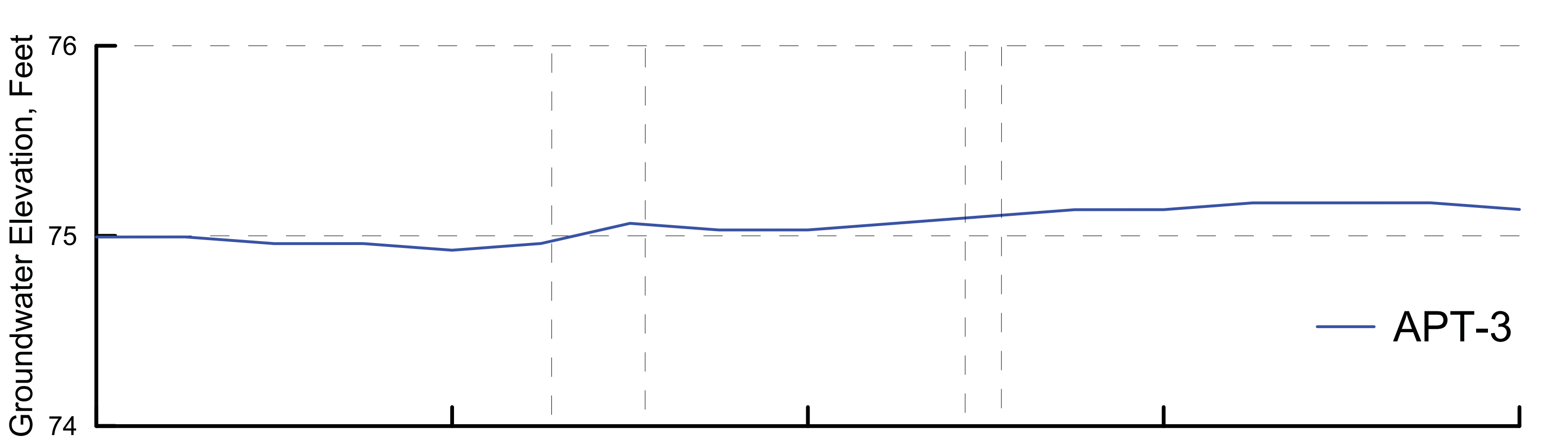
Elevation in feet, NAVD88

JANUARY 24, 2016 EARTHQUAKE EFFECT ON
WATER ELEVATIONS AT SELECTED CO-LOCATED WELLS
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 43



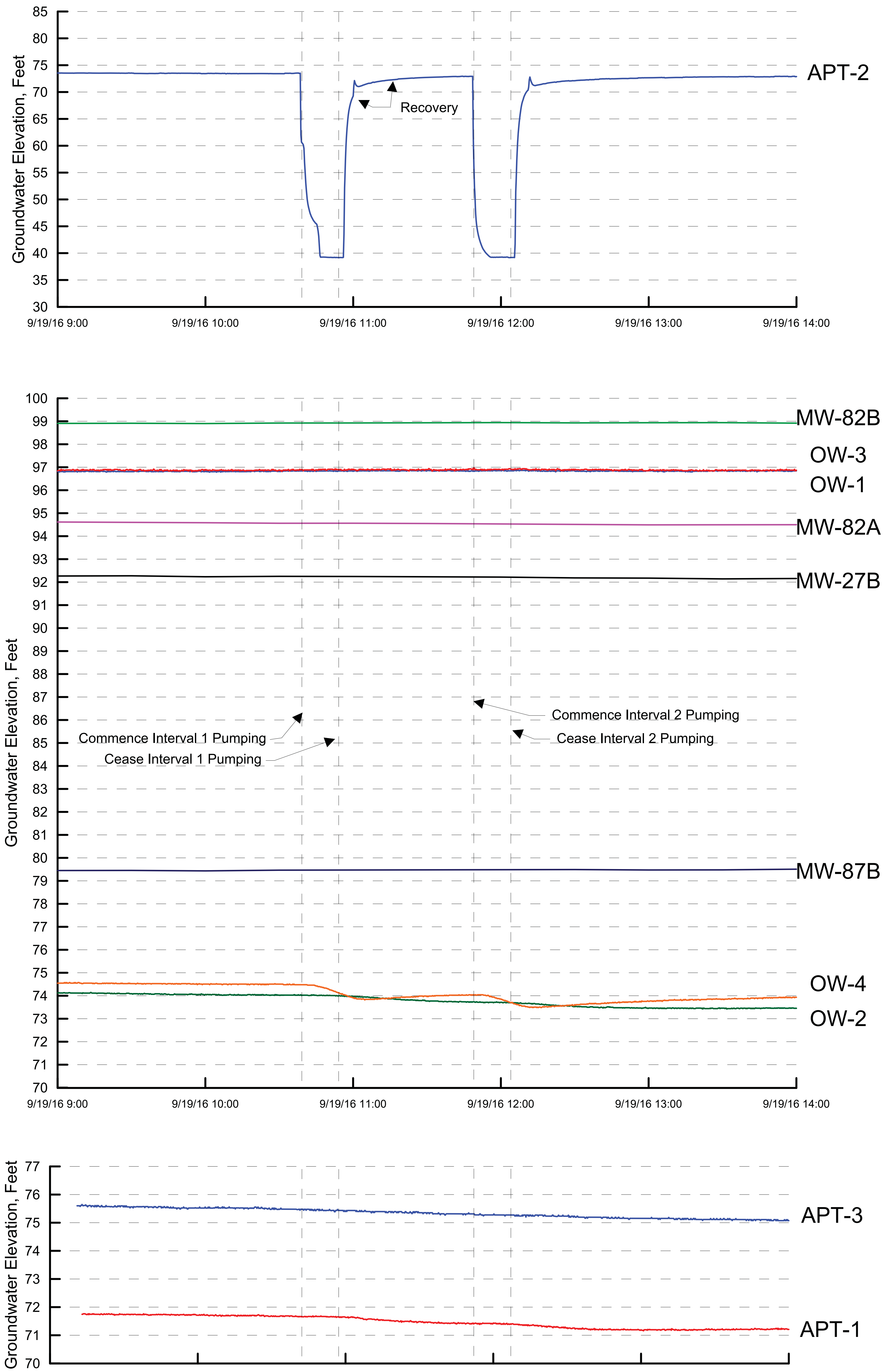




Note: Apparent water level rise due to hydraulic pressure differential.

WATER ELEVATIONS IN SELECT WELLS DURING APT-1 DEVELOPMENT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

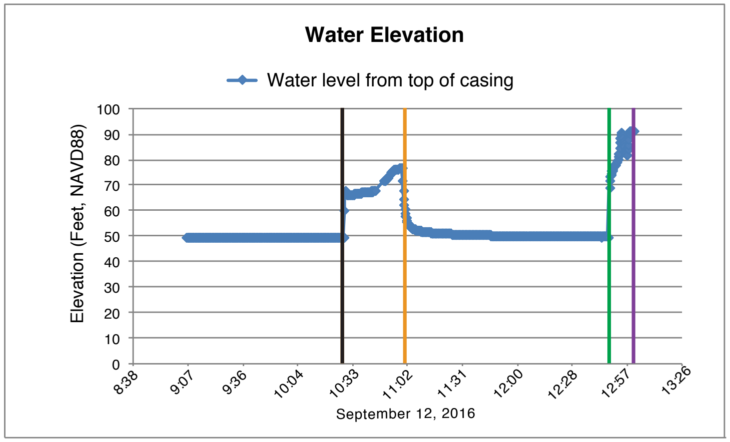
PLATE 44



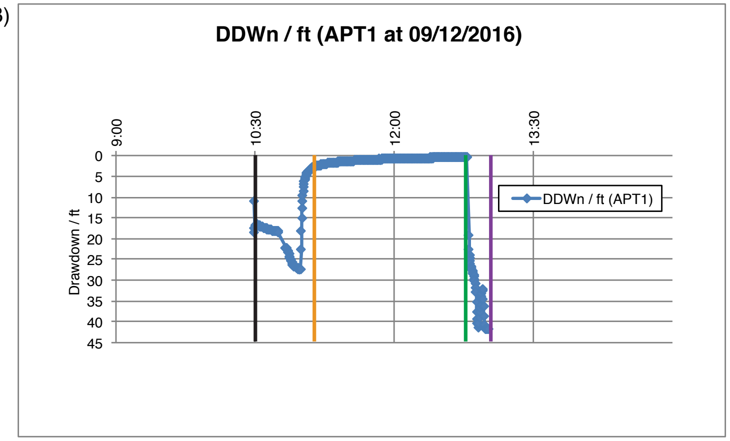
WATER ELEVATIONS IN SELECT WELLS DURING APT-2 DEVELOPMENT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 45

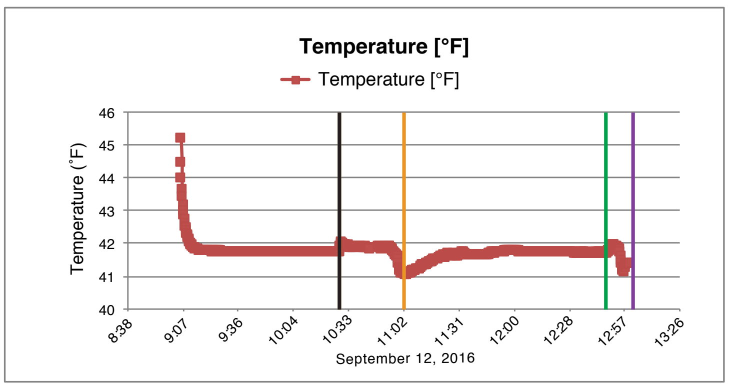
A)



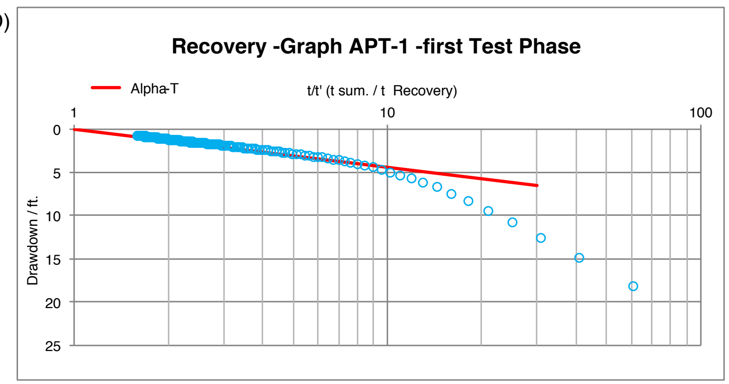
B)



C)



D)

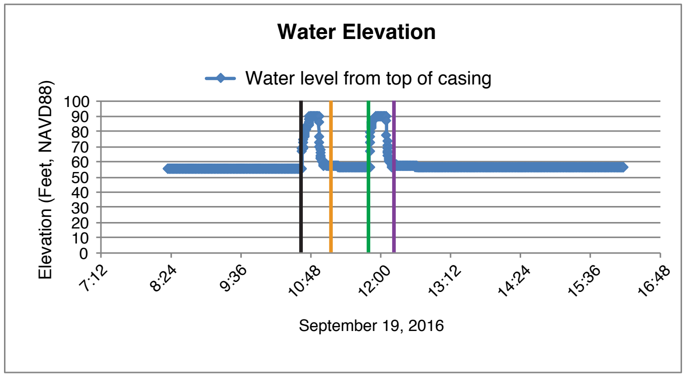


Legend

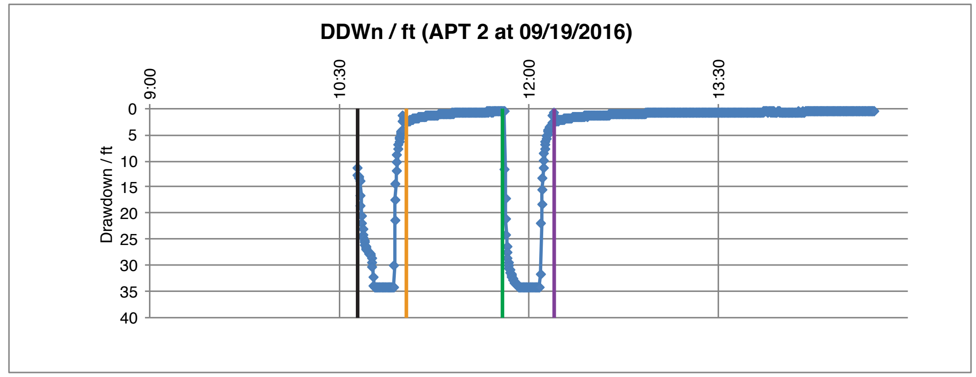
- Commence pumping, interval 1
- Cease pumping, interval 1
- Commence pumping, interval 2
- Cease pumping, interval 2

APT-1 WELL DEVELOPMENT DATA CHARTS
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

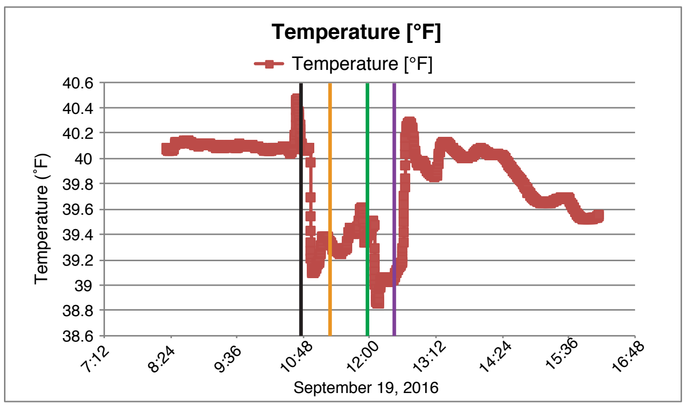
A)



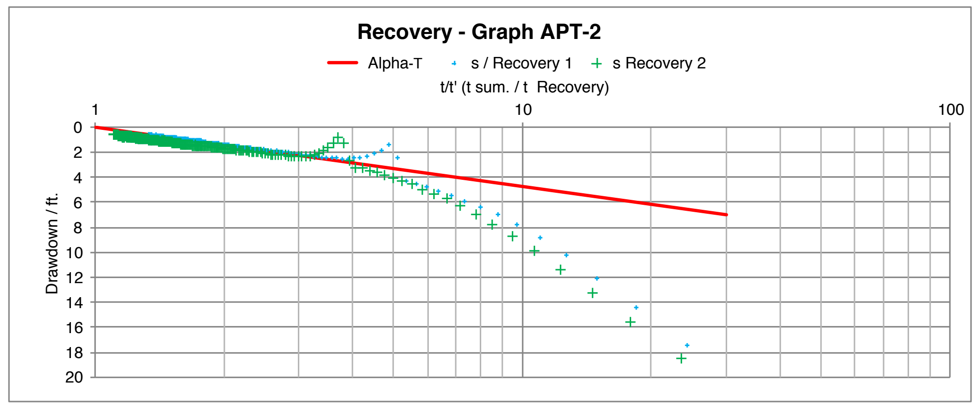
B)



C)



D)



Legend

Commence pumping, interval 1

Cease pumping, interval 1

Commence pumping, interval 2

Cease pumping, interval 2

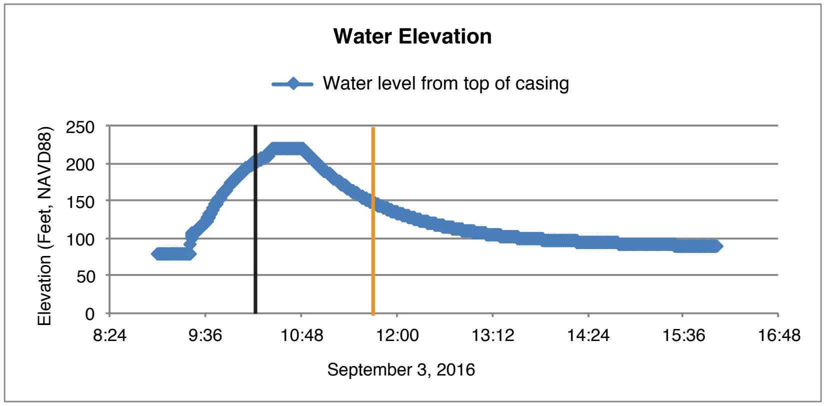
APT-2 WELL DEVELOPMENT DATA CHARTS

ONSHORE LNG FACILITIES

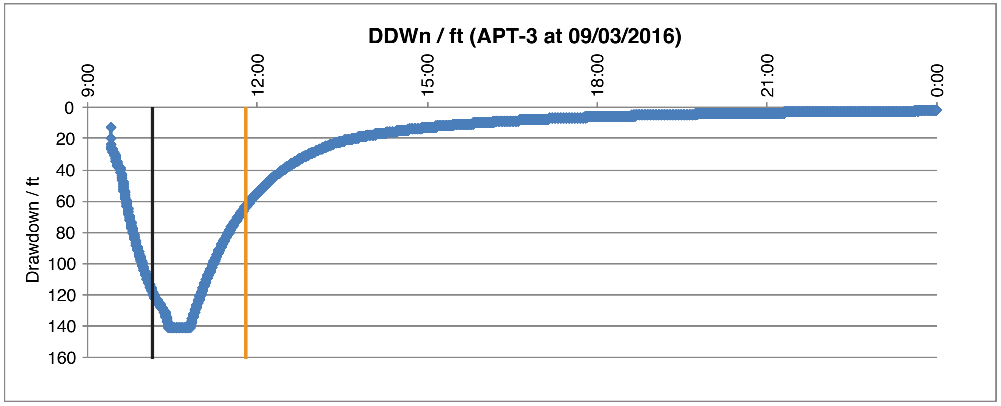
ALASKA LNG PROJECT

NIKISKI, ALASKA

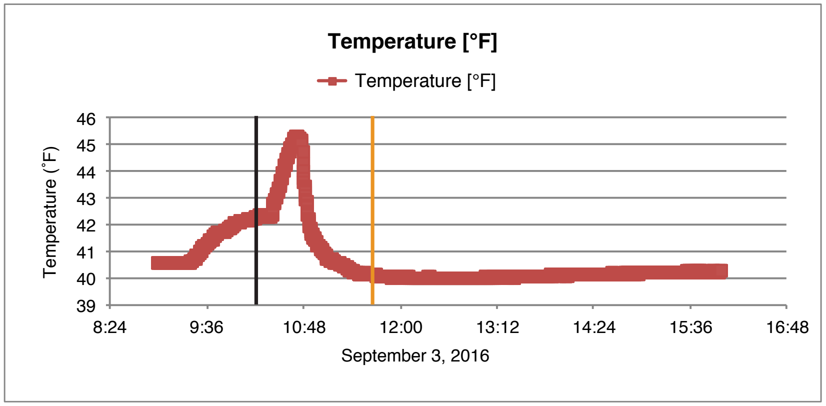
A)



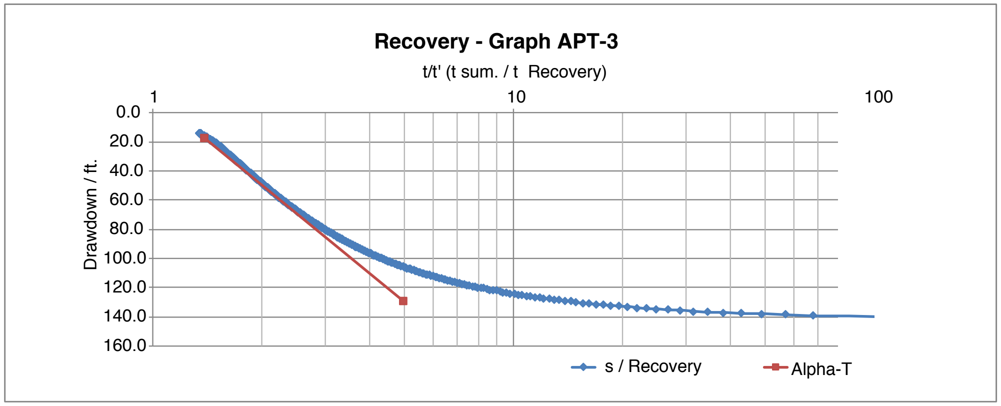
B)



C)



D)



Legend

Commence pumping, interval 1

Cease pumping, interval 1

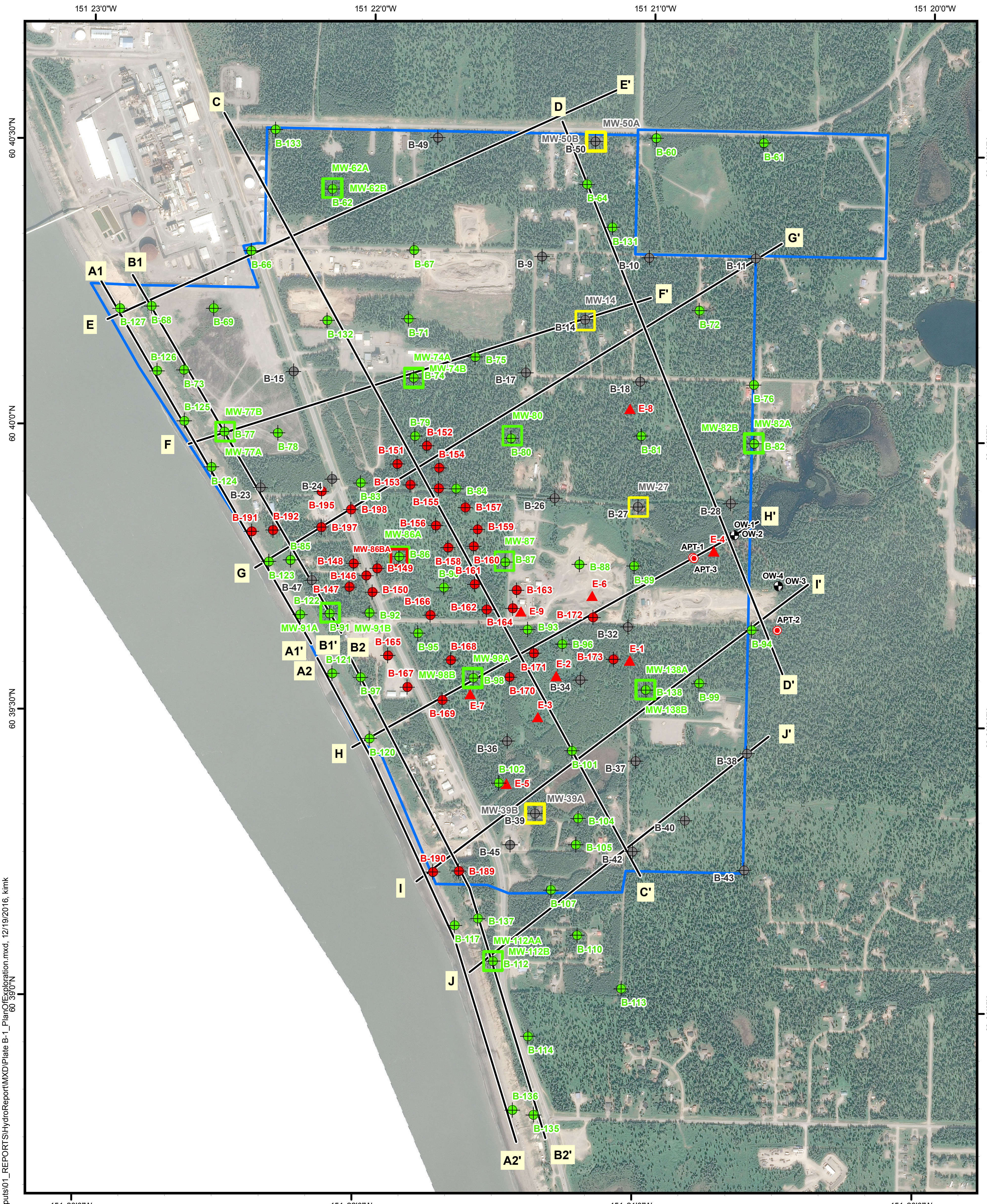
APT-3 WELL DEVELOPMENT DATA CHARTS

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 48

APPENDIX A

LITHOLOGIC CROSS SECTIONS
AND
GENERAL SITE LITHOLOGY AND WATER BEARING UNITS FENCE DIAGRAMS



LEGEND

EXPLORATION

- Boring (2016)
- Boring (2015)
- Boring (2014)
- VES Location (2016)
- Monitoring Well (2016)
- Monitoring Well (2015)
- Monitoring Well (2014)
- APT Well (2016)
- Observation Well (2016)

Onshore LNG Facilities Study Area

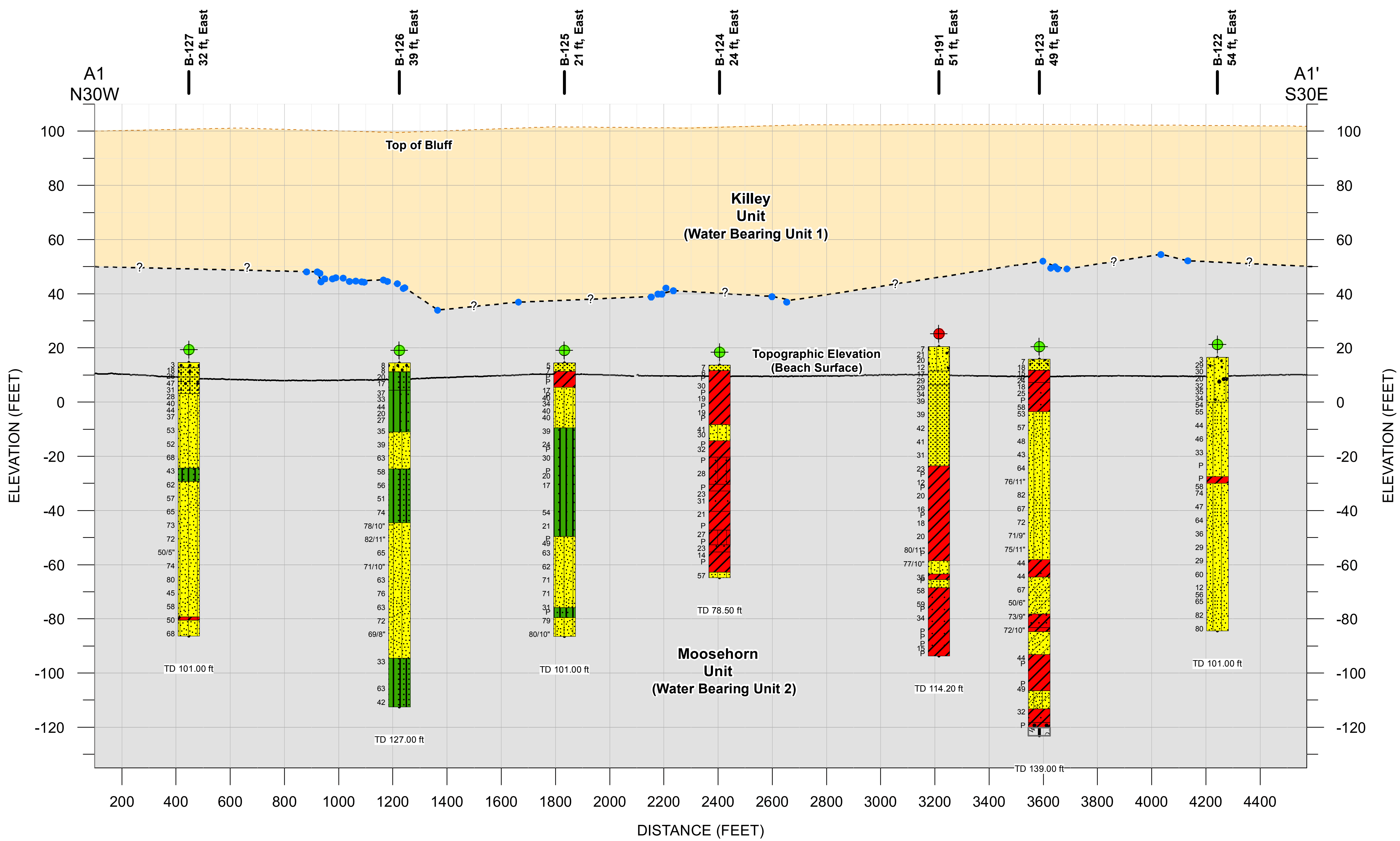
1 Cross Section Lines

0 500 1,000 2,000 Feet

PLAN OF EXPLORATIONS

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-1



LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Topographic Elevation (Ground LiDAR)
- KM Contact Points Observed in Bluff

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Silty CLAY with Sand (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Gravelly Lean CLAY (CL)
- SILT with Sand (ML)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Clayey SAND (SC)
- Clayey to Silty SAND (SC-SM)
- Silty SAND (SM)
- Poorly-Graded GRAVEL with Sand (GP)
- Sandy GRAVEL with Silt (GP-GM)
- Sandy GRAVEL (GP)

40 ft

400 ft

Vertical Exaggeration = 10.0X

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

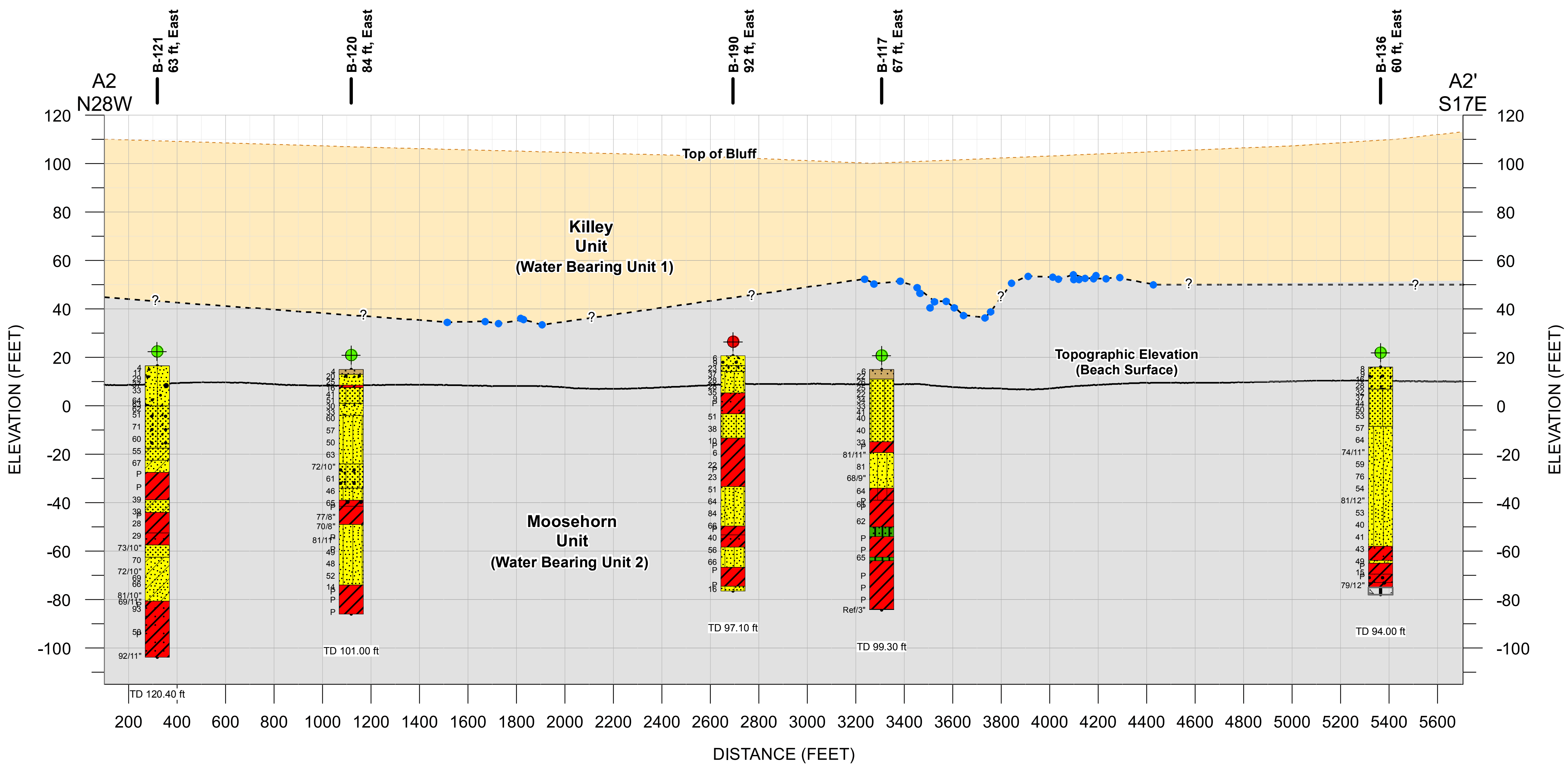
NOTES:

1. Topographic source data is provided by McLane Consulting, Inc.(2015) and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88.
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

SUBSURFACE CROSS SECTION A1 - A1'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-2

R:\04100\2016 Projects\0001-0099\04.10160001 - AKLNG\07_GIS\Outputs\01_REPORTS\HydroReport\MXD\Xsect_A1.mxd, 1/5/2017, kimk



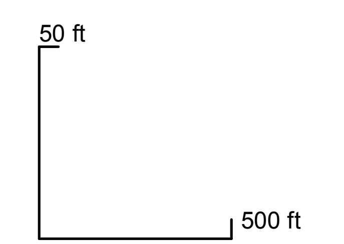
LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Topographic Elevation (Ground LiDAR)
- KM Contact Points Observed in Bluff

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Sandy, Gravelly Lean CLAY (CL)
- Gravelly Lean CLAY (CL)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Clay (SP-SC)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Silty SAND (SM)
- Topsoil



Vertical Exaggeration = 10.0X

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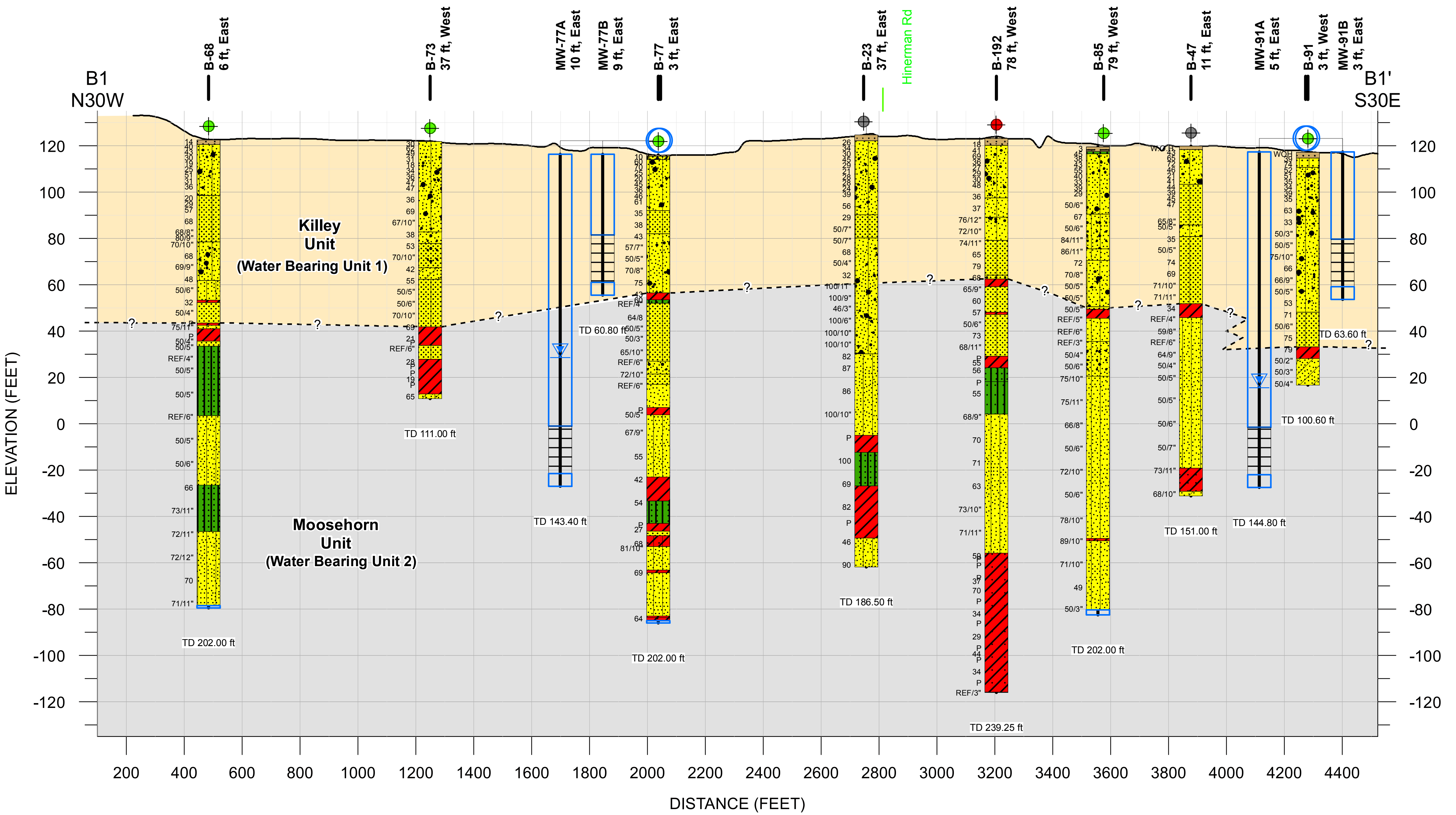
TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is provided by McLane Consulting, Inc.(2015) and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88.
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

SUBSURFACE CROSS SECTION A2 - A2'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Boring (2014)
- Topographic Elevation
- Monitoring Well
- Water Level Reading During Drilling
- Water Level Reading from Monitoring Well on 9/22/16 at 6pm
- Slotted Screen Section of Monitoring Well
- Cross Section Road Crossing

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY with Sand (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- SILT with Sand (ML)
- Sandy, Gravelly SILT (ML)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND (SW)
- Well-Graded SAND with Silt (SW-SM)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Clayey to Silty SAND (SC-SM)
- Silty SAND (SM)
- Gravelly Silty SAND (SM)
- Topsoil
- Sandy Well-Graded GRAVEL (GW)
- Sandy, Silty GRAVEL (GM)
- Low-Plasticity Organic (OL)

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is provided by McLane Consulting, Inc.(2015) and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88.
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

50 ft
400 ft
Vertical Exaggeration = 8.0X

SUBSURFACE CROSS SECTION B1 - B1'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-4

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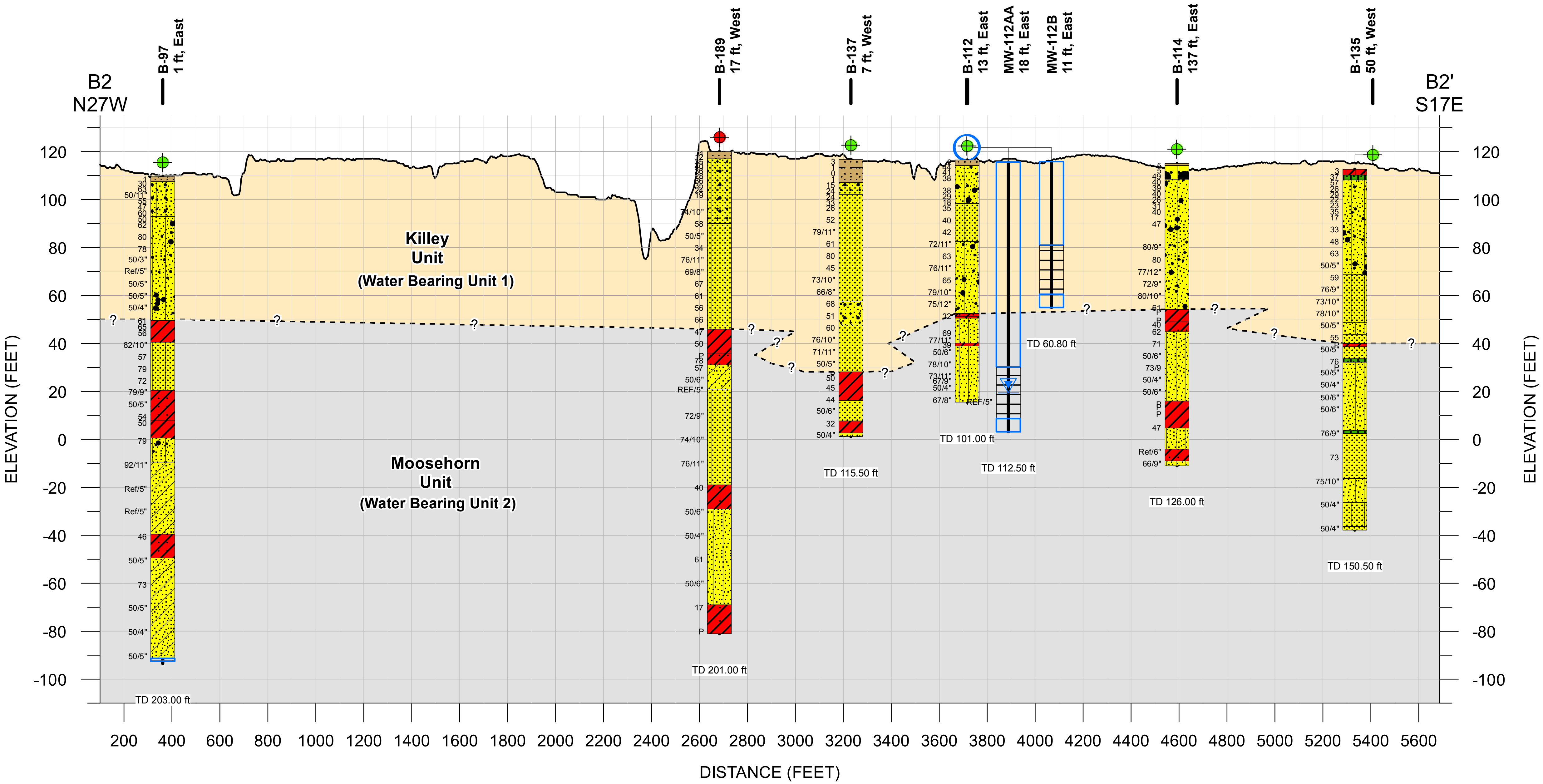

LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Boring (2014)
- Topographic Elevation (KPB, 2008)
- Monitoring Well
- Water Level Reading During Drilling
- Water Level Reading from Monitoring Well on 9/22/16 at 6pm
- Slotted Screen Section of Monitoring Well

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Sandy, Gravelly SILT (ML)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt (SW-SM)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Silty SAND (SM)
- Gravelly Silty SAND (SM)
- Topsoil
- Well-Graded GRAVEL with Silt and Sand (GW-GM)

50 ft
500 ft
Vertical Exaggeration = 10.0X

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

SUBSURFACE CROSS SECTION B2 - B2'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-5

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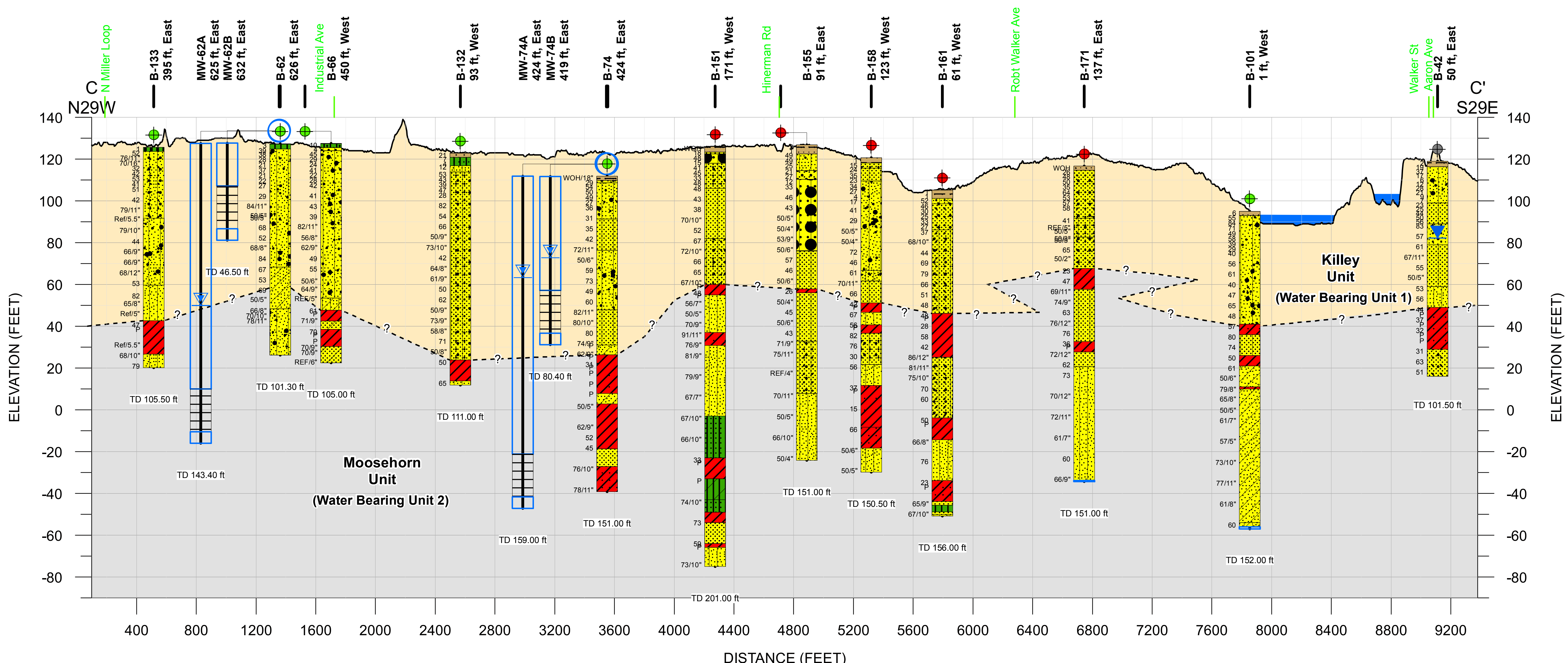

LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2016)
- Boring (2015)
- Boring (2014)
- Topographic Elevation (KPB, 2008)
- Monitoring Well
- Cross Section Road Crossing
- Water Level Reading During Drilling
- Water Level Reading from Monitoring Well on 9/22/16 at 6pm
- Slotted Screen Section of Monitoring Well
- Surface Water Body (shown for graphical purposes)

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Silt (ML)
- Clayey SILT (ML)
- Sandy, Gravelly SILT (ML)
- Sandy SILT (ML)
- Elastic Silt (MH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Clay (SP-SC)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Clayey to Silty SAND (SC-SM)
- Clayey to Silty SAND with Gravel (SC-SM)
- Silty SAND (SM)
- Gravelly Silty SAND (SM)
- Topsoil
- Poorly-Graded GRAVEL with Sand (GP)
- Sandy GRAVEL (GP)
- Well-Graded GRAVEL with Silt and Sand (GW-GM)

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

50 ft
700 ft
Vertical Exaggeration = 14.0X

SUBSURFACE CROSS SECTION C - C'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-6

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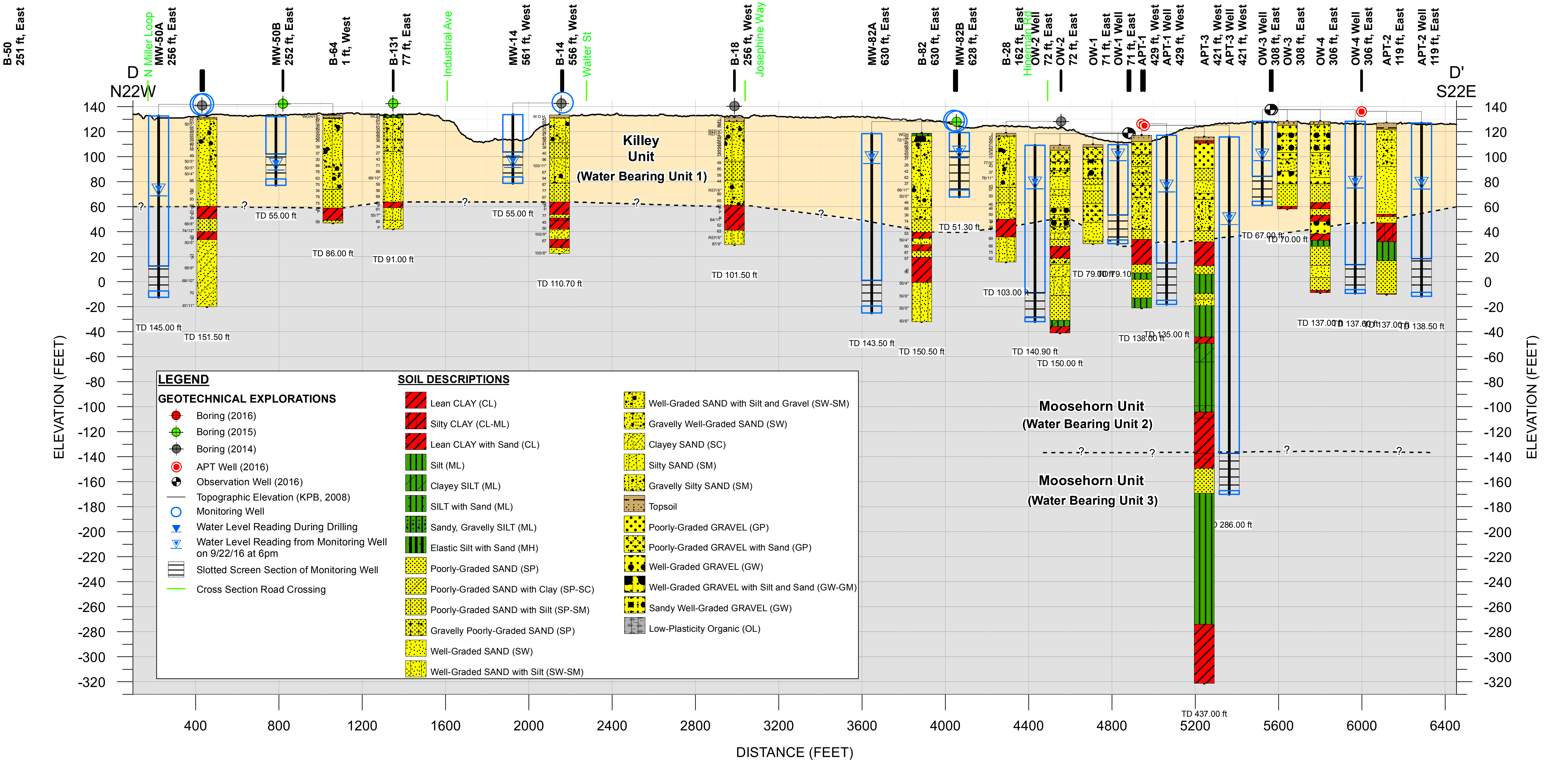

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" seating.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

80 ft

480 ft

Vertical Exaggeration = 6.0X

SUBSURFACE CROSS SECTION D - D'

ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA

PLATE A-7

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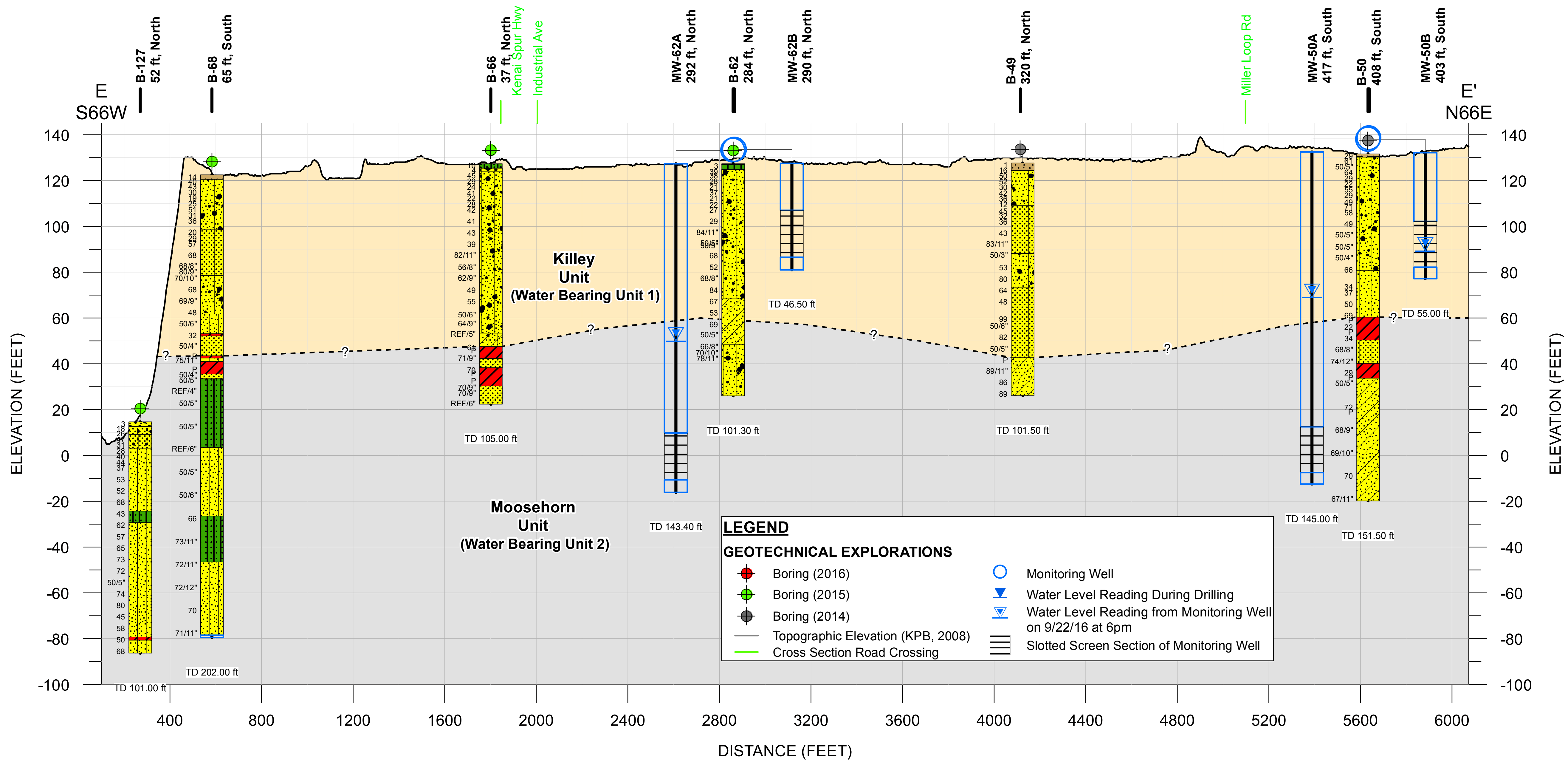


SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Silt (ML)
- Sandy, Gravelly SILT (ML)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Clay (SP-SC)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt (SW-SM)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Clayey SAND (SC)
- Clayey to Silty SAND with Gravel (SC-SM)
- Silty SAND (SM)
- Topsoil
- Poorly-Graded GRAVEL with Sand (GP)
- Sandy GRAVEL (GP)
- Well-Graded GRAVEL with Silt and Sand (GW-GM)

TUBE AND SPT SAMPLES

P	Push thin-walled 3'' tube.
20	Number of blows to produce 12'' of penetration after the initial 6'' of seating.
86/11''	Number of blows required to produce the indicated penetration after an initial 6'' seating.
Ref/3''	50 blows produced the indicated penetration during the initial 6'' interval.
W.O.H.	Weight of Hammer

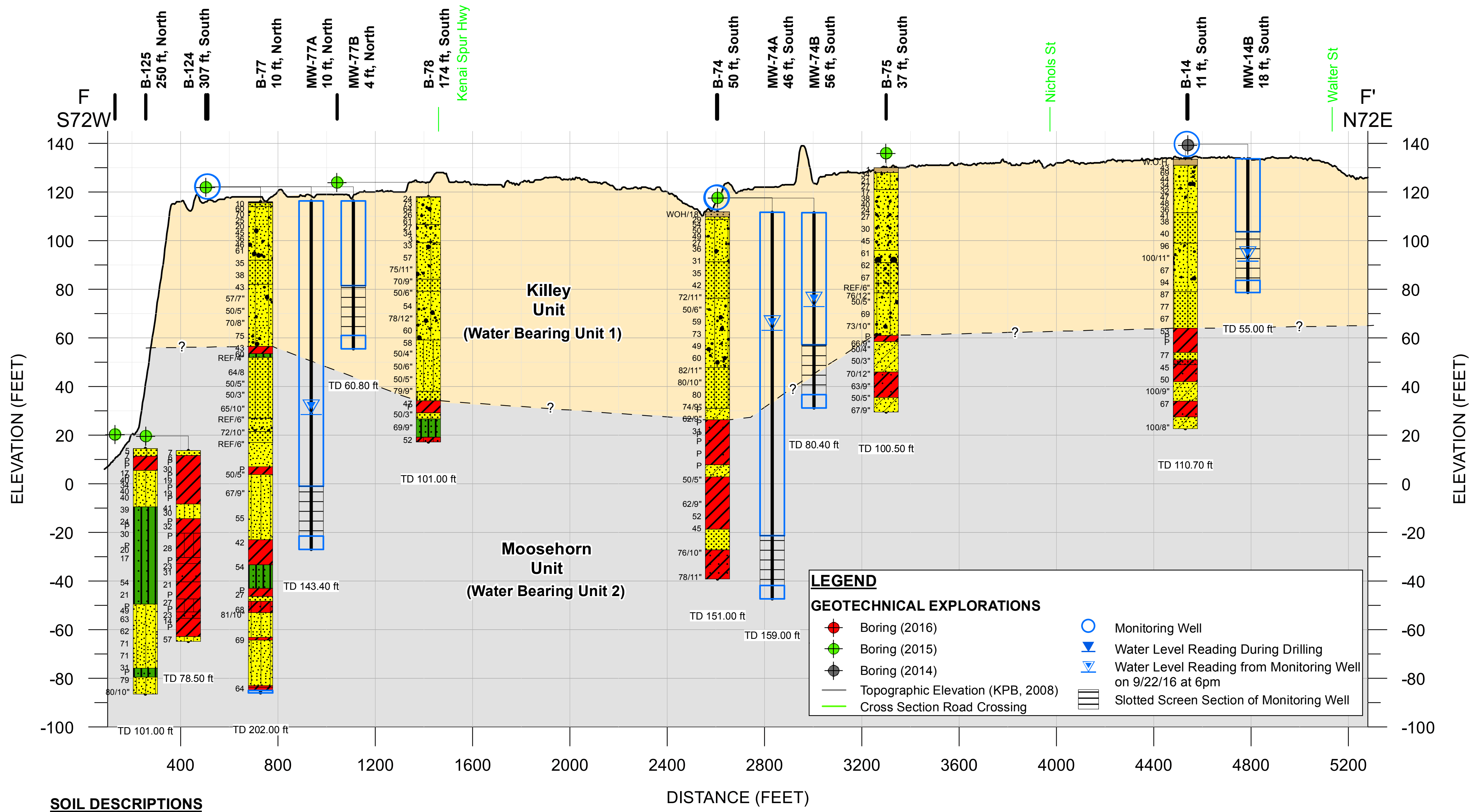
NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

50 ft
500 ft
Vertical Exaggeration = 10.0X

SUBSURFACE CROSS SECTION E - E'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-8



SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Silty CLAY with Sand (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- SILT with Sand (ML)
- Sandy SILT (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND (SW)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Silty SAND (SM)
- Gravelly Silty SAND (SM)
- Topsoil
- Sandy Well-Graded GRAVEL (GW)

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

50 ft
500 ft
Vertical Exaggeration = 10.0X

SUBSURFACE CROSS SECTION F - F'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-9

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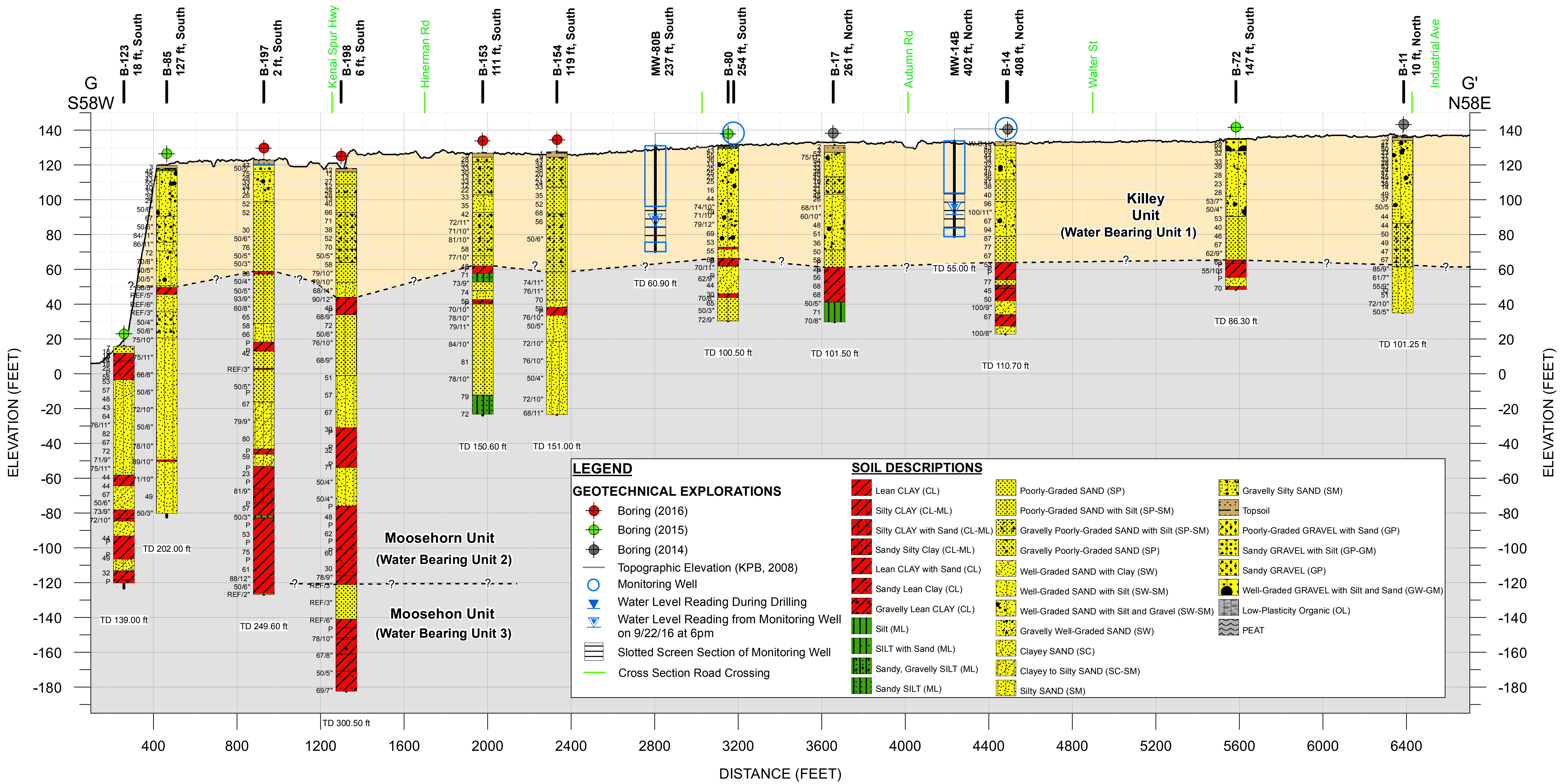

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

60 ft

500 ft

Vertical Exaggeration = 8.3X

SUBSURFACE CROSS SECTION G - G'

ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA

PLATE A-10

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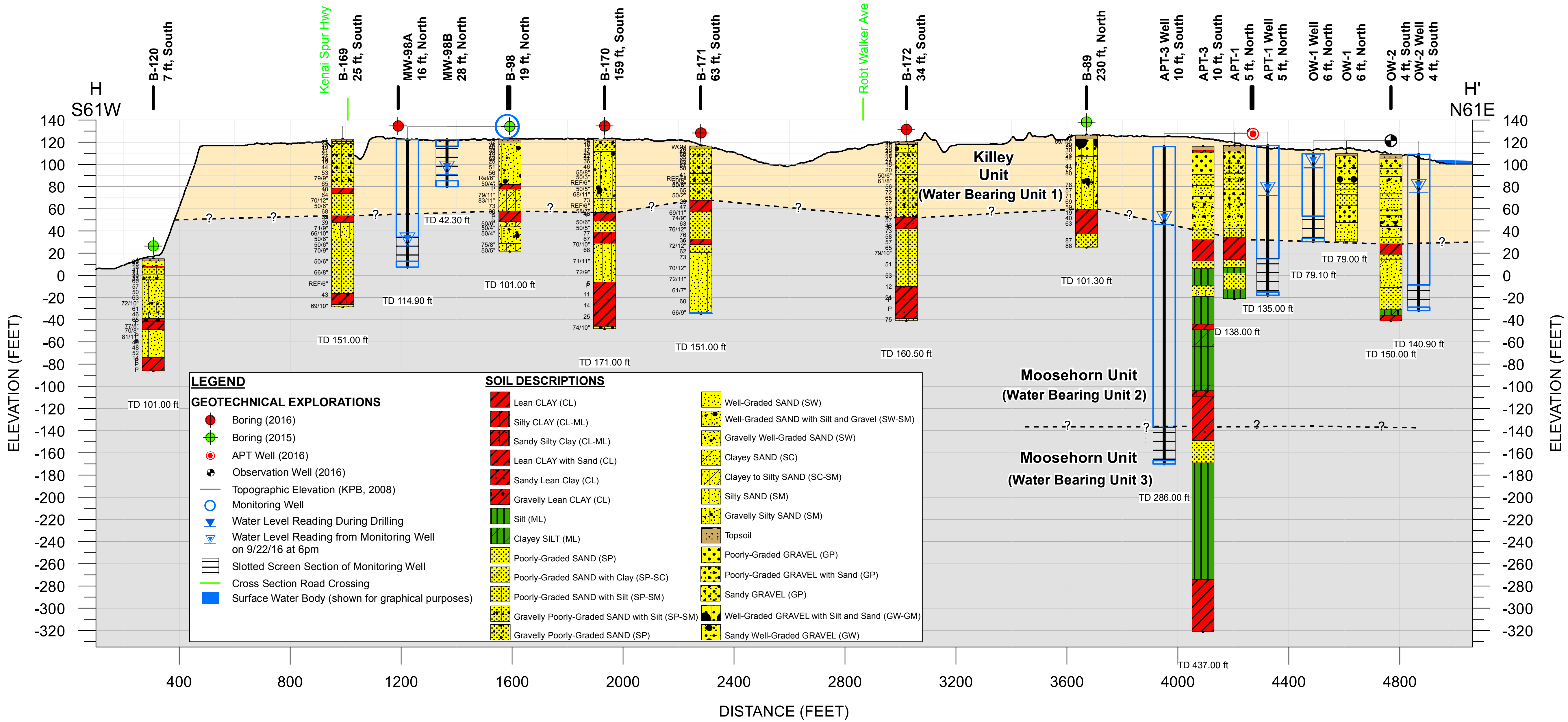

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

100 ft

400 ft

Vertical Exaggeration = 4.0X

SUBSURFACE CROSS SECTION H - H'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

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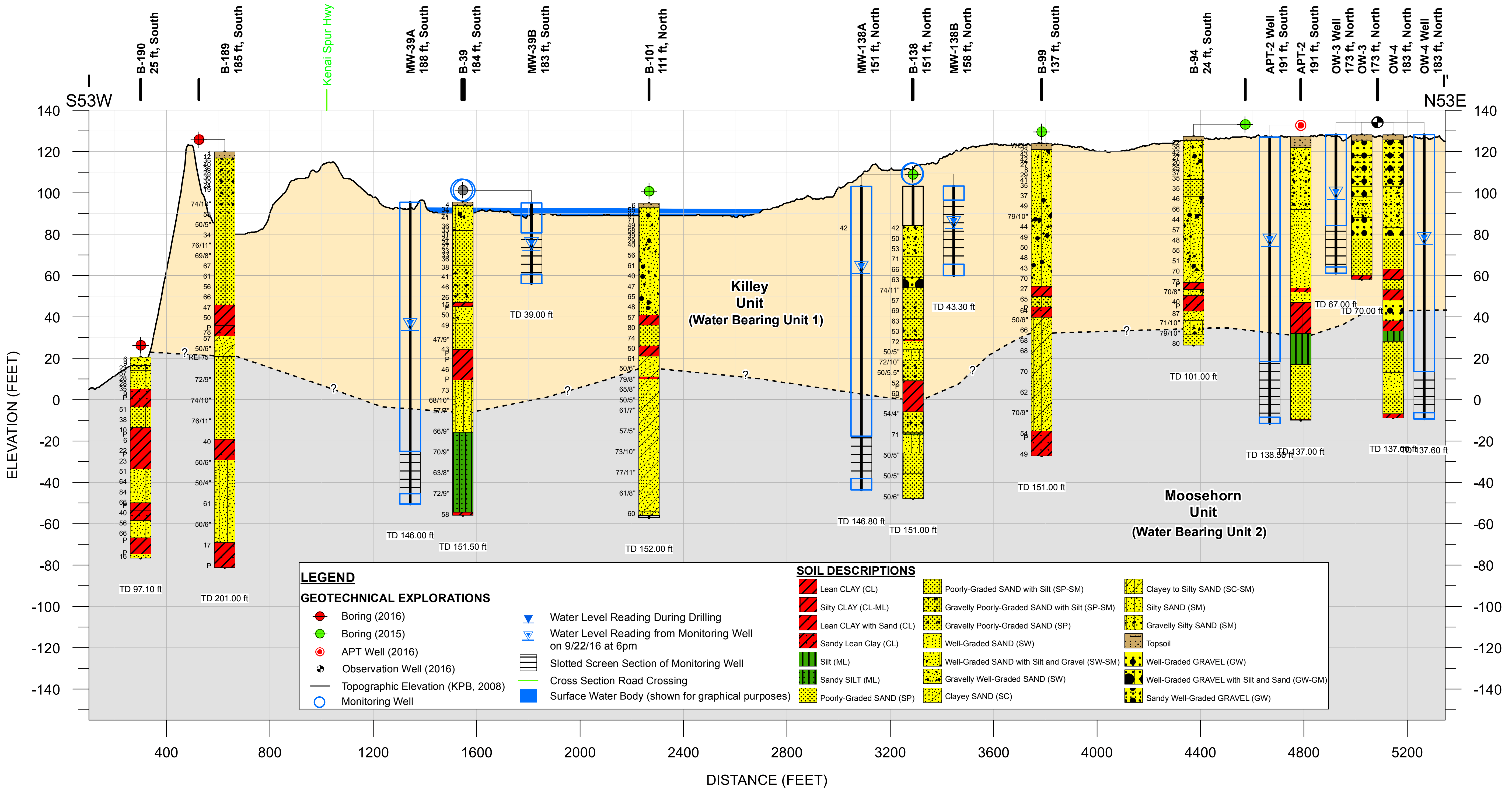

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

50 ft
400 ft
Vertical Exaggeration = 8.0X

SUBSURFACE CROSS SECTION I - I'
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-12

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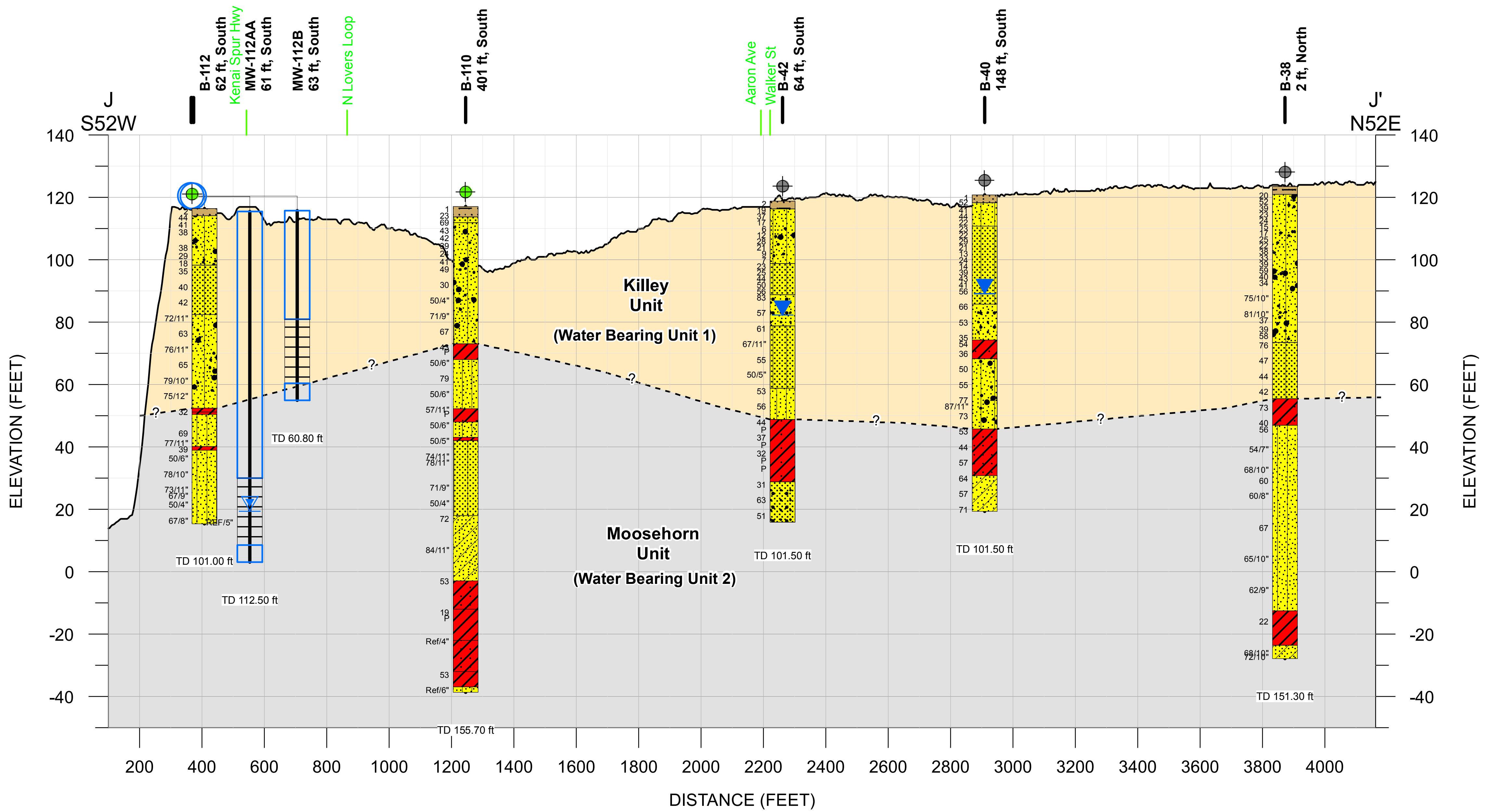


LEGEND

GEOTECHNICAL EXPLORATIONS

- Boring (2015)
- Boring (2014)
- Topographic Elevation (KPB, 2008)
- Monitoring Well
- Water Level Reading During Drilling
- Water Level Reading from Monitoring Well on 9/22/16 at 6pm
- Slotted Screen Section of Monitoring Well
- Cross Section Road Crossing

SOIL DESCRIPTIONS

- Lean CLAY (CL)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt (SW-SM)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Clayey SAND (SC)
- Silty SAND (SM)
- Topsoil

40 ft

400 ft

Vertical Exaggeration = 10.0X

TUBE AND SPT SAMPLES

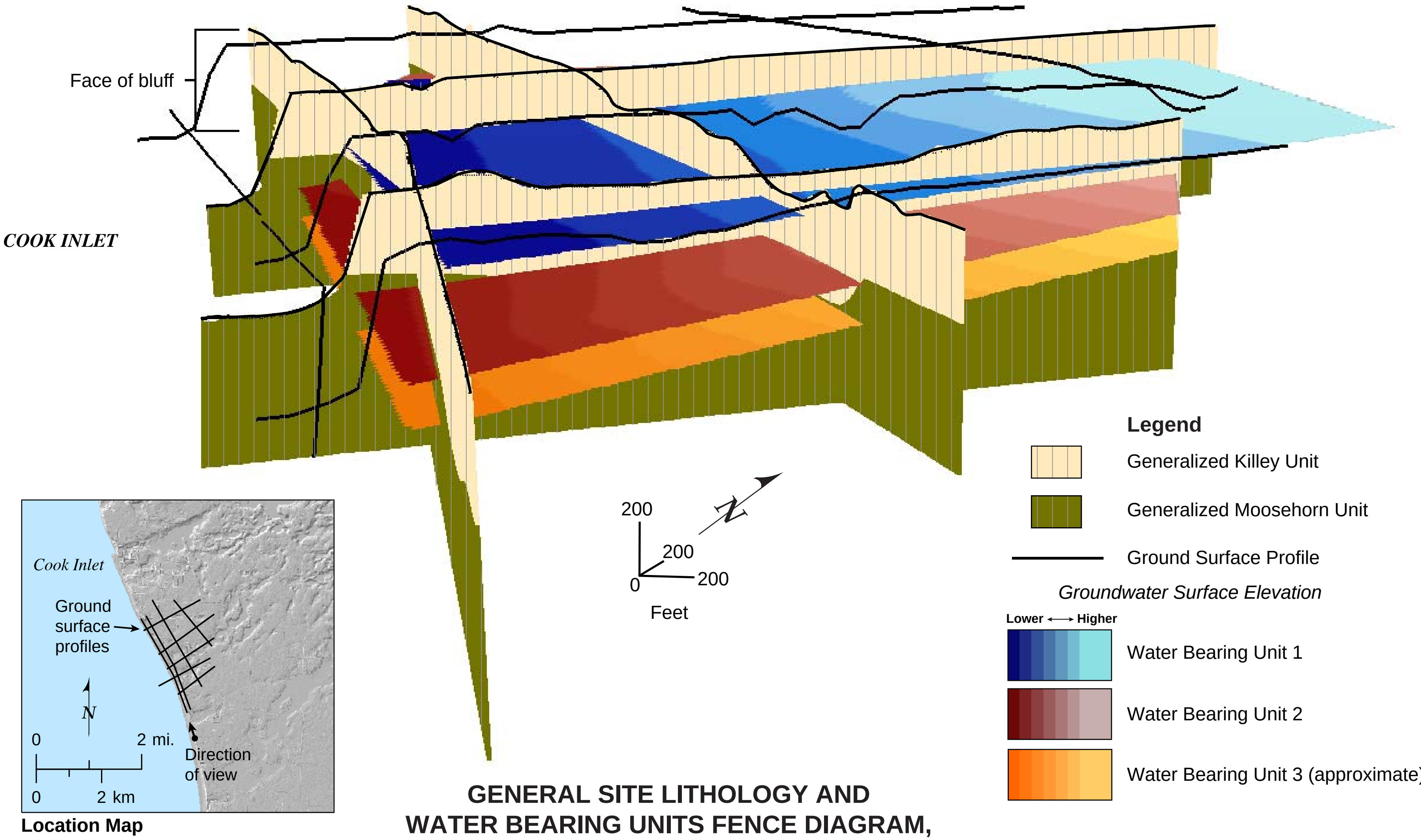
P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. Topographic source data is from Kenai Peninsula Borough LiDAR, collected in 2008 and processed using 4 foot bin interval. Topographic elevation is referenced to NAVD88. Data provided by EXP Geomatics (EXP).
2. As-built coordinates of exploration locations provided by JOA Surveying Services, Inc. (2014) and McLane Consulting, Inc.(2015, 2016).
3. Stratigraphic contacts are approximate, and interpreted from borings and field observations. Refer to USAL-FG-GRZZZ-00-002015-004 LNG Facilities Onshore Geologic Field Mapping Report for description of contact. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
4. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
5. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
6. See Plate B-1 for location of explorations and cross section lines.
7. See USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report for boring logs.
8. NAVD88 is converted to MLLW using the following equation: MLLW = NAVD88 + 7.32 ft.

SUBSURFACE CROSS SECTION J - J'

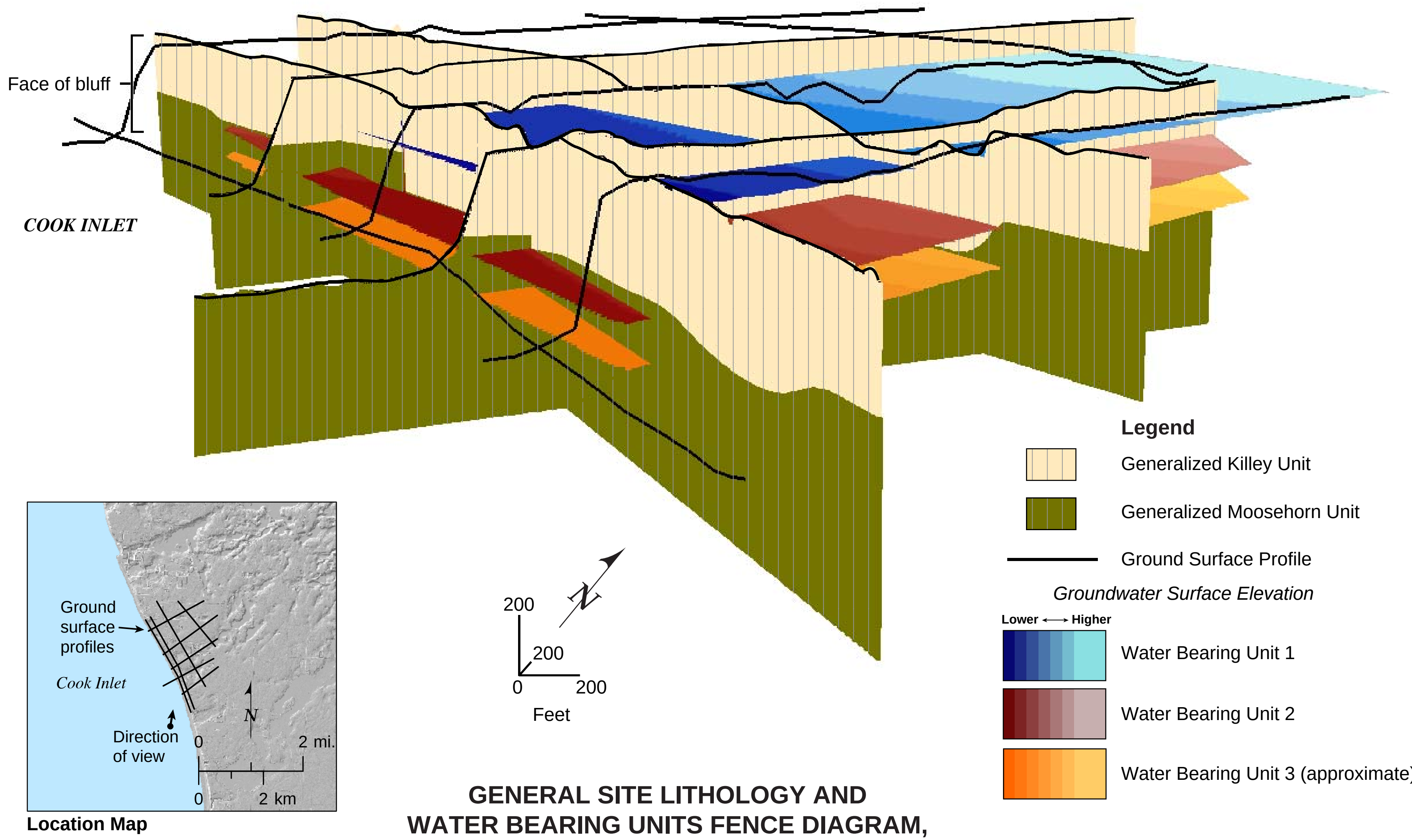
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



GENERAL SITE LITHOLOGY AND WATER BEARING UNITS FENCE DIAGRAM, VIEW TOWARD N/NW FROM BLUFF, SOUTH OF PROJECT AREA

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-14



GENERAL SITE LITHOLOGY AND WATER BEARING UNITS FENCE DIAGRAM, VIEW TOWARD N/NE FROM COOK INLET, SOUTH OF PROJECT AREA

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-15

APPENDIX B

WELL DEVELOPMENT SUMMARIES

APT1 Well Development Summary

Date: September 12, 2016

Borehole Diameter:	12 inches
Well Diameter:	8 inches
Bottom of casing:	105 feet BTOC
Screen Interval:	105 to 135 feet BTOC
Pump Setting Depth:	97 feet BTOC (water inlet depth)
Micro Diver Depth:	91 feet BTOC

Flow meter reading prior to pumping:	20,819,035 gallons
Flow meter reading after pumping:	20,825,575
Total Gallons of water pumped:	7,540 gallons (in two intervals)

First Pumping Interval:

Groundwater pumping commenced:	10:30 AM
Groundwater pumping terminated:	11:00 AM
Initial groundwater elevation:	49.31 feet BTOC
End of pumping groundwater elevation:	76.75 feet BTOC
Gallons of water pumped:	3,795 gal

Second Pumping Interval:

Groundwater pumping commenced:	12:48 PM
Groundwater pumping terminated:	1:04 PM
Initial groundwater elevation:	49.75 feet BTOC
End of pumping groundwater elevation:	96.98 feet BTOC
Gallons of water pumped:	3,745 gal

Notes:

Groundwater pumping was conducted in two intervals, constrained by the approximately 4,000-gallon capacity of a water truck used 1) as a temporary repository for pumped groundwater, and 2) for transportation and discharge of the contained groundwater to a poly tank staged at the nearby Peterkin Quarry. Discharged development water was pumped via hose directly into the water tank staged approximately 50 feet from the well head.

For the first interval, pumping commenced at 10:30 AM. The Initial pumping was approximately 200 GPM. The pump valve was adjusted until the target rate of approximately 100 GPM was reached at approximately 10:35 AM. This pumping rate continued until approximately 10:47 AM, at which time the pump valve was adjusted to reach and maintain 150 GPM. A pumping rate of approximately 150 GPM was maintained until 11:00 AM, at which time the pump was shut off and the first pumping interval terminated.

The water truck was then dispatched to the Peterkin Quarry. Approximately 3,795 gallons of development water collected during the first pumping interval was discharged into a 6,900-gallon poly tank staged at the quarry. The water truck then returned to the APT1 pad.

For the second interval, pumping commenced at 12:48 PM. The initial pumping rate was approximately 400 GPM. The pump valve was adjusted until the target rate of 200 GPM was reached at approximately 12:49 PM. This pumping rate continued until approximately 12:59 PM, at which time the pump valve was adjusted in an attempt to reach and maintain 300 GPM. Difficulties were encountered, and the pump rate is estimated to have briefly risen to approximately 400 GPM, until a relatively stable pump rate of approximately 300 GPM was achieved at approximately 1:00 PM. A pumping rate of approximately 300 GPM was maintained until 1:04 PM, at which time the pump was shut off and the second pumping interval terminated.

The water truck was then dispatched to the Peterkin Quarry. Approximately 3,000 gallons of development water collected during the second pumping interval was discharged into the same 6,900-gallon poly tank used for storing the first pumping interval water staged at the quarry. The remaining water collected during the second interval was staged within the water truck, and was transported for disposal at NRC's permitted disposal facility in Anchorage, Alaska on September 21, 2016. Development water waste manifests are included in the LNG Facilities Aquifer Pump Test Well and Groundwater Observation Well Installation Report (Appendix A).

APT2 Well Development Summary

Date: September 19, 2016

Borehole Diameter:	12 inches
Well Diameter:	8 inches
Bottom of casing:	141.5 feet BTOC
Screen Interval:	111.5 to 138.5 feet BTOC
Pump Setting Depth:	97 feet BTOC (water inlet depth)
Micro Diver Depth:	91 feet BTOC

Flow meter reading prior to pumping:	20,826,576 gallons
Flow meter reading after pumping:	20,833,635 gallons
Gallons of water pumped:	7,059 gallons (in two intervals)

First Pumping Interval:

Groundwater pumping commenced:	10:39 AM
Groundwater pumping terminated:	10:55 AM
Initial groundwater elevation:	57.02 feet BTOC
End of pumping groundwater elevation:	94.95 feet BTOC
Gallons of water pumped:	3,474 gal

Second Pumping Interval:

Groundwater pumping commenced:	11:49 AM
Groundwater pumping terminated:	12:06 PM
Initial groundwater elevation:	57.62 feet BTOC
End of pumping groundwater elevation:	93.37 feet BTOC
Gallons of water pumped:	3,585 gal

Notes:

Groundwater pumping was conducted in two intervals, constrained by the approximately 4,000-gallon capacity of a water truck used 1) as a temporary repository for pumped groundwater, and 2) for transportation and discharge of the contained groundwater to a poly tank staged at the nearby Peterkin Quarry. Discharged development water was pumped via hose directly into the water tank staged approximately 50 feet from the well head.

For the first interval, pumping commenced at 10:39 AM. The Initial pumping rate was approximately 300 GPM. The pump valve was adjusted until the target rate of approximately 200 GPM was reached at approximately 10:40:30 AM. This pumping rate continued until approximately 10:45:30 AM, at which time the pump valve was adjusted to reach and maintain 250 GPM. A pumping rate of approximately 250 GPM was maintained until 10:50:30 AM, at which time the pump valve was adjusted to reach 200 GPM. This pumping rate was maintained until approximately 10:55:30, at which time the pump was shut off and the first pumping interval terminated.

The water truck was then dispatched to the Peterkin Quarry. Approximately 3,474 gallons of development water collected during the first pumping interval was discharged into a 6,900-gallon poly tank staged at the quarry. The water truck then returned to the APT2 pad.

For the second interval, pumping commenced at 11:49 AM. The initial pumping rate was approximately 200 GPM. This pumping rate was maintained for the duration of this pumping interval. The pump was shut off at approximately 12:06 PM, and the second pumping interval terminated.

The water truck was then dispatched to the Peterkin Quarry. Approximately 3,585 gallons of development water collected during the second pumping interval was discharged into the same 6,900-gallon poly tank used for storing the first pumping interval water staged at the quarry. The remaining water collected during the second interval was staged within the water truck, and was transported for disposal at NRC's permitted disposal facility in Anchorage, Alaska on September 27, 2016. Development water waste manifests are included in the LNG Facilities Aquifer Pump Test Well and Groundwater Observation Well Installation Report (Appendix A).

APT3 Well Development Summary

Date: September 3, 2016

Borehole Diameter:	12 inches
Well Diameter:	8 inches
Bottom of casing:	289 feet BTOC
Screen Interval:	256 to 286 feet BTOC
Pump Setting Depth:	234 feet BTOC
Micro Diver Depth:	220 feet BTOC

Flow meter reading prior to pumping:	20,817,200 gallons
Flow meter reading after pumping:	20,819,035 gallons
Gallons of water pumped:	1,835 gallons

Pumping Interval:

Groundwater pumping commenced:	10:25 AM
Groundwater pumping terminated:	11:45 AM
Initial groundwater elevation:	79 feet BTOC
End of pumping groundwater elevation:	234 feet BTOC

Notes:

Pumping commenced at 10:25 AM. Initial pumping rate was approximately 100 GPM until approximately 10:26 AM. Valve was adjusted in an attempt to reach and maintain 25 GPM. Achieved approximately 25 GPM rate by 10:31 AM.

Maintained approximate pump rate of 25 GPM until approximately 11:26 AM, at which time (based upon a review of Micro Diver erratic water level indications); the water level had dropped to the pumping elevation of 231 feet BGS. Noticeable pump cavitation was observed at the wellhead at approximately 11:41 AM. Pumping activities ceased at approximately 11:45 AM. It appears that residual water in the pump riser pipes then cascaded back into the well casing. Micro Diver water level recovery data commenced at approximately 11:48 AM.

Discharged development water was pumped via hose directly into a water tank staged approximately 50 feet from the well head. After completion of pumping, the water truck transported the 1,835 gallons of development water to a poly tank staged at the Peterkin Quarry pending water sampling, profiling and disposal.

All downhole equipment remained overnight to allow uninterrupted collection of water level recovery data. The pump, associated riser pipe, and flow meter were removed from the casing on September 4th. The remaining water collected during the second interval was staged within the water truck, and was transported for disposal at NRC's permitted disposal facility in Anchorage, Alaska on September 15, 2016. Development water waste manifests are included in the LNG Facilities Aquifer Pump Test Well and Groundwater Observation Well Installation Report (Appendix A).