APPENDIX R SEDIMENT CHEMICAL ANALYTICAL DATA FROM WEST DOCK TEST TRENCH SITES

The information in this Appendix is provided for informational purposes as the sediment and benthic test results are used for discussion and analysis in various Resource Reports. However, the actual test trench that was performed near West Dock and proposed dredging activities discussed in the reports are no longer part the Applicant's preferred alternative.

APPENDIX R.1 TABLES 1-5

TABLE 1

2014 Sediment Chemical Data from West Dock Test Trench Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values				
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS											
Ammonia (mg/kg)	0.99	1.12	1.48	0.83	4.55	3.87					
AVS (mg/kg)	0.47	0.46	0.41	0.242	0.49	0.151					
Sulfides (mg/kg)	21.5	38.6	18.0	9.1	16.3	8.4					
TVS (%)	8.99	6.62	4.73	4.51	5.27	4.69					
TOC (%)	1.91	1.37	0.541	0.475	0.736	0.650		0.01	6.42		
Silt/Clay (%)	89.6	70.1	62.7	22.0	43.2	37.3		0.1	100		
Total Solids (%)	60.9	69.4	70.8	73.9	71.2	71.5					
METALS (mg/kg)											
Aluminum	6270	4960	4570	3560	4890	4350					
Antimony	0.133J	0.126J	0.106J	0.101J	0.106J	0.112J	150	0.14	1.14		
Arsenic	9.88	8.23	6.05	7.29	8.34	8.63	57	4.2	28.4	7.24	41.6
Barium	61.4	54.2	46.8	37.0	45.9	45.7		142	863		
Beryllium	0.417	0.302	0.245	0.213	0.297	0.266		0.3	3.6		
Boron	21.5	14.7	8.4	8.9	11.3	10.6					
Cadmium	0.371	0.294	0.222	0.204	0.220	0.195	5.1	0.03	0.82	0.68	4.21
Chromium	17.3	14.7	13.4	11.0	14.3	13.0	260	12.7	104	52.3	160
Cobalt	7.52	6.99	6.04	5.95	6.82	6.56		2.2	18.6		
Copper	19.8	13.2	8.47	6.32	10.6	9.38	390	3.6	50.2	18.7	108
Iron	18400	15600	13900	13700	15800	15100		7000	39000		
Lead	8.76	6.04	4.22	3.74	5.62	5.18	450	3.2	22.3	30.24	112
Manganese	268	220	199	193	217	203		62	898		
Mercury	0.053	0.033	0.025	0.018J	0.027	0.024	0.41	0.003	0.20	0.13	0.70
Nickel	25.4	22.2	19.4	16.0	20.0	18.5		6.0	48.4	15.9	42.8
Selenium	0.50J	0.36J	0.21J	0.18J	0.25J	0.22J	3				
Silver	0.128	0.078	0.044	0.032	0.056	0.043	6.1	0.01	0.44	0.73	1.77
Thallium	0.076	0.069	0.050	0.033	0.045	0.043		0.05	0.92		
Vanadium	24.7	19.8	16.8	14.5	18.8	17.4		25.2	173		
Zinc	67.2	54.9	47.2	40.0	50.8	46.4	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)											
DRO	35 Z	14 J	6.3 J	6.4 J	16 J	11 J	*200*[4]				
RRO	190 Z	73 J	22 J	30 J	56 J	40 J	*2000*[4]				
DRO+RRO	225	87	28.3	36.4	72	51		0.39	104		

[1] Dredge Material Management Program (DMMP) User Manual for sediment Screening Levels (SLs) (Seattle District USACE DMMO, 2015). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects.

[2] Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

[3] ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines (SQG).

[4] ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

[5] Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

TABLE 1

2014 Sediment Chemical Data from West Dock Test Trench Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values				
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		Lower	Upper	TELs[5]	PELs[6]

[6] Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

Underlined values equal or exceed TELs.

TABLE 2
2014 Sediment Pesticide, PCB, SEM, and PAH Data for Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values		
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		TELs[4]	PELs[5]
Chlorinated Pesticides (µg/kg, dry)									
4,4'-DDD	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	16	1.22	7.81
4,4'-DDE	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	9	2.07	374
4,4'-DDT	0.081 J	0.13 J	< 0.078	< 0.091	< 0.078	< 0.078	12	1.19	4.77
Total DDT[6]	0.081	0.13	0	0	0	0		3.89	51.7
alpha-BHC	0.077 J	< 0.064	< 0.064	< 0.064	< 0.064	< 0.064			
beta-BHC	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18			
gamma-BHC (Lindane)	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051		0.32	0.99
delta-BHC	< 0.086	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070			
Aldrin	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056	9.5		
Dieldrin	< 0.083	< 0.12	< 0.083	< 0.083	< 0.083	< 0.083	1.9	0.72	4.3
Endrin	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057			
Heptachlor	< 0.055	< 0.055	< 0.055	< 0.055	< 0.055	< 0.055	1.5		
Heptachlor Epoxide	< 0.23	< 0.23	< 0.23	< 0.23	< 0.23	< 0.23			2.74
gamma-Chlordane	< 0.072	< 0.097	< 0.072	< 0.072	< 0.072	< 0.072			
alpha-Chlordane	< 0.063	< 0.063	< 0.063	< 0.063	< 0.063	< 0.063			
Total Chlordane[6]	0	0	0	0	0	0	2.8	2.26	4.79
Endosulfan I	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060			
Endosulfan II	< 0.091	< 0.091	< 0.091	< 0.091	< 0.091	< 0.091			
Endrin Aldehyde	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061			
Endosulfan Sulfate	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051			
Endrin Ketone	< 0.076	< 0.076	< 0.076	< 0.076	< 0.076	< 0.076			
Methoxychlor	0.16 J	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15			
Toxaphene	< 14	< 14	< 14	< 14	< 14	< 14		0.1	
Polychlorinated Biphenyls (PCBs; µg/kg, dry)									
Arochlor 1016	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1221	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1232	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1242	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1248	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1254	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1		63.3	709
Arochlor 1260	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Total PCBs[6]	0	0	0	0	0	0	130	21.6	189
Acid Volatile Sulfides and Simultaneously Extractable Metals (µMole/g, dry)									
AVS	0.47	0.46	0.41	0.242	0.49	0.151			
Cadmium	0.00333	0.00188	0.0015	0.00099J	0.00155	0.00141			
Copper	0.129	0.0640	0.0375	0.0337	0.0533	0.0450			
Lead	0.0306	0.0162	0.0115	0.0098	0.0169	0.0148			
Mercury (nMole/g)	< 0.021	< 0.017	< 0.017	< 0.015	< 0.018	< 0.017			
Nickel	0.0963	0.0545	0.0442	0.0380	0.0532	0.0429			
Zinc	0.454	0.263	0.216	0.163	0.239	0.210			

TABLE 2
2014 Sediment Pesticide, PCB, SEM, and PAH Data for Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values		
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		TELs[4]	PELs[5]
Total SEM	0.713	0.400	0.311	0.246	0.364	0.314			
Ratio SEM/AVS	1.52	0.87	0.76	1.01	0.74	2.08			
(SEM-AVS)/F_{oc}	12.7	<0	<0	0.7	<0	25.1			
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg, dry)									
Naphthalene	8.3	6.2	2.4 J	1.2 J	3.1 J	3.2 J	2100	34.6	391
2-Methylnaphthalene	19	14	5.6	2.7 J	7.5	7.1	670	20.2	201
Acenaphthylene	< 0.59	< 0.59	< 0.59	< 0.59	< 0.59	< 0.59	560	5.87	128
Acenaphthene	0.85 J	< 0.76	< 0.76	< 0.76	< 0.76	< 0.76	500	6.71	88.9
Dibenzofuran	4.3	3.1 J	1.2 J	< 0.63	1.7 J	1.6 J	540		
Fluorene	3.3 J	2.2 J	0.89 J	< 0.61	1.6 J	1.4 J	540	21.2	144
Phenanthrene	20	15	5.9	2.9 J	8.8	7.6	1500	86.7	544
Anthracene	< 0.58	< 0.58	< 0.58	< 0.58	< 0.58	< 0.58	960	46.9	245
LPAH[6]	55.8	40.5	16.0	6.8	22.7	20.9	5200	312	1442
Fluoranthene	3.5 J	2.9 J	1.3 J	< 0.98	1.8 J	1.4 J	1700	113	1494
Pyrene	4.0 J	3.3 J	1.3 J	0.79 J	2.0 J	1.8 J	2600	153	1398
Benz(a)anthracene	1.1 J	0.98 J	< 0.72	< 0.72	< 0.72	< 0.72	1300	74.8	693
Chrysene	3.7 J	2.9 J	1.2 J	< 0.80	1.7 J	1.6 J	1400	108	846
Benzo(b)fluoranthene	3.6 J	3.3 J	1.1 J	< 0.92	1.9 J	1.7 J	3200		
Benzo(k)fluoranthene	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87			
Benzo(a)pyrene	1.1 J	0.84 J	< 0.76	< 0.76	< 0.76	< 0.76	1600	88.8	763
Indeno(1,2,3-c,d)pyrene	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	600		
Dibenz(a,h)anthracene	< 0.80	< 0.80	< 0.80	< 0.80	< 0.80	< 0.80	230	6.22	135
Benzo(g,h,i)perylene	2.6 J	2.1 J	0.89 J	< 0.85	1.3 J	1.2 J	670		
HPAH[6]	19.6	16.3	5.8	0.8	8.7	7.7	12000	655	6676
Total PAH[6]	75.4	56.8	21.8	7.6	31.4	28.6		1684	16770

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects. Selenium value is bioaccumulation trigger.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

5 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

6 Summed parameters (e.g., Total PAH, Total PCBs, etc.) utilize 0.0 in the calculation where an analyte was ND.

† gamma-Chlordane – For this analyte (CAS Registry No. 5103-74-2), USEPA has corrected the name to be beta-Chlordane, also known as trans-Chlordane.

J Estimated value for concentrations between the MDL and RL and for concentrations that did not meet QC objectives.

< The analyte was analyzed for, but was not detected (ND) at or above the MDL.

TABLE 3

2011 Sediment Chemical Data for Test Trench Sites #1, #2A, and #2B

Parameter	Test Trench Vibracore Samples (Depth Intervals in ft MLLW)					Sediment Screening Values				
	Trench #1 Vibracore 03E		Trench #2A Vibracore 02K		TR #2B Core 02M	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(0-1.5)	(4.0-5.0)	(0-1.5)	(4.0-5.0)	(0-1.0)		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS										
Ammonia (mg/kg)	11.4	13.4	9.31	15.6	<0.06					
Sulfides (mg/kg)	179J	30.7J	114	265	8.4					
TVS (%)	6.53	6.79	4.99	5.72	2.93					
TOC (%)	1.10	1.99	1.24	1.66	0.19		0.01	6.42		
Silt and clay (%)	62	39	45	66	15		0.1	100		
Total Solids (%)	70.2	71.9	73.7	73.0	73.4					
METALS (mg/kg, dry)										
Aluminum	6550	3250	5140	6130	3770					
Antimony	0.10	0.04J	0.06	0.12	0.08	150	0.14	1.14		
Arsenic	7.61	3.75	5.40	8.41	5.49	57	4.2	28.4	7.24	41.6
Barium	63.7	38.0	52.4	52.4	35.5		142	863		
Beryllium	0.338	0.130	0.213	0.302	0.172		0.3	3.6		
Boron	18.6	24.1	10.6	17.5	6.7					
Cadmium	0.294	0.113	0.209	0.264	0.151	5.1	0.03	0.82	0.68	4.21
Chromium	14.5	7.01	9.45	13.4	8.99	260	12.7	104	52.3	160
Cobalt	8.230	2.780	6.700	8.630	4.990		2.2	18.6		
Copper	14.9	4.33	5.40	12.0	4.25	390	3.6	50.2	18.7	108
Iron	17300	7120	15100	16400	13800		7000	39000		
Lead	6.690	3.070	3.610	6.080	3.050	450	3.2	22.3	30.24	112
Manganese	243	57.0	245	254	193		62	898		
Mercury	0.041	0.019	0.017J	0.043	0.012J	0.41	0.003	0.20	0.13	0.70
Nickel	25.7	9.5	16.7	24.4	13.5		6.0	48.4	15.9	42.8
Selenium	0.6J	0.3J	0.4J	0.6J	0.2J	3				
Silver	0.084	0.035	0.040	0.101	0.021	6.1	0.01	0.44	0.73	1.77
Thallium	0.053	0.025	0.036	0.067	0.024		0.05	0.92		
Vanadium	20.8	9.2	17.4	20.8	12.5		25.2	173		
Zinc	75.8	33.0	58.0	69.5	50.4	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg, dry)										
BTEX Compounds	ND	ND	ND	ND	ND					
GRO	<1.6	<1.5	<1.7	<1.5	<1.5	100				
DRO	13J	23J	10J	10J	2.8J	*200*[4]				
RRO	75J	190Z	42J	44J	<40	*2000*[4]				
TPHC (DDR + RRO)	88	210	25	54	2.8		0.39	104		

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects. Selenium value is bioaccumulation trigger.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 ADEC (2011). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

5 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

6 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

TABLE 3

2011 Sediment Chemical Data for Test Trench Sites #1, #2A, and #2B

Parameter	Test Trench Vibracore Samples (Depth Intervals in ft MLLW)					Sediment Screening Values				
	Trench #1 Vibracore 03E		Trench #2A Vibracore 02K		TR #2B Core 02M	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(0-1.5)	(4.0-5.0)	(0-1.5)	(4.0-5.0)	(0-1.0)		Lower	Upper	TELs[5]	PELs[6]

J = Estimated value for concentrations between the MDL and RL.
Z = The chromatographic fingerprint does not resemble a petroleum product.
Underlined values equal or exceed TELs.

TABLE 4

2014 Sediment Grain Size for Test Trench Sites #3A and #3B

Parameter	Trench Site #3A				Trench Site #3B			
	Rep1	Rep2	Rep3	Mean	Rep1	Rep2	Rep3	Mean
Soil Classification								
% Gravel	0	0.01	0	0.003	0	0	0	0
% Coarse Sand	0.05	0.02	0.03	0.033	0.01	0.04	0.03	0.027
% Medium Sand	0.06	0.04	0.03	0.043	0.04	0.04	0.08	0.053
% Fine Sand	2.12	4.53	4.35	3.67	50.9	28.1	42.2	40.4
% Very Fine	7.72	23.6	30.8	20.7	23.9	25.2	19.2	22.8
%Total Sand	10.0	28.2	35.2	24.5	74.8	53.3	61.5	63.2
% Silt	74.4	62.2	57.5	64.7	18.3	31.7	28.7	26.2
% Clay	15.2	7.8	5.2	9.4	3.7	11.6	8.6	8.0
% Fines	89.6	70.1	62.7	74.1	22.0	43.2	37.3	34.2

TABLE 5

2011 Sediment Characteristics for Test Trench Sites #1, #2A, and #2B

Parameter	**Test Trench and Associated 2011 Vibracore Samples and Depth Intervals within Core (ft)**				
	Trench Site #1 Vibracore 03E		**Trench Site #2A Vibracore 02K**		**Trench Site #2B Vibracore 02M**
	(0-1.5)	**(4.0-5.0)**	**(0-1.5)**	**(4.0-5.0)**	**(0-1.0)**
% Solids	72.3	72.0	74.1	72.3	76.2
% TOC	1.10	1.99	1.24	1.66	0.19
Soil Classification	ML	SM	SM	ML	SM
% Gravel	0.0	2.8	0.0	0.0	0.0
% Coarse Sand	0.0	1.3	0.0	0.0	0.0
% Medium Sand	0.2	5.6	0.1	0.1	0.3
% Fine Sand	37.9	51.7	54.9	34.0	84.9
%Total Sand	38.1	58.6	55.0	34.1	85.2
% Silt	44	29	32	43	10
% Clay	18	10	13	23	5
% Fines (<0.075 mm)	62	39	45	66	15
Specific Gravity (20°C)	2.69	2.6	2.71	2.69	2.71
Plasticity Index	2.3	NP	NP	8.2	NP

NP = Non-Plastic

APPENDIX R.2 2014 KLI MARINE SAMPLING PLAN (USAG-EX-SRZZZ-00-0011)

Alaska LNG

2014 Marine Sampling Program

Evaluation of Test Trench Dredging and Disposal Reuse

DOCUMENT NO. USAG-EX-SRZZZ-00-0011

REV	DATE	REVISION DESCRIPTION			ORIGINATOR		REVIEWER/ ENDORSER		APPROVER
A	16 Oct 2014	Draft Document			M. Savoie		J. Savoie		
B	8 Nov 2014				M. Savoie		D. Olivo		
0	19 Nov 2014				M. Savoie				
Document Control No.		**Country**	**Facility**	**Originator**	**Discipline**	**Type**	**Sub-Type**	**Location**	**Sequence**
		US	AG	EX	S	R	ZZZ	00	0011

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
%	Percent
µg/kg	microgram per kilogram
µMole/g	Micro-Moles per gram
µMole/g_{oc}	Micro-Mole per gram of organic carbon
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ANIMIDA	Arctic Nearshore Impact Monitoring in the Development Area Program
APP	Alaska Pipeline Project
ASTM	American Society for Testing and Materials
AVS	Acid volatile sulfides
BP	BP Exploration (Alaska), Inc.
BSMP	Beaufort Sea Monitoring Program
BTEX	Benzene, toluene, ethylbenzene, and xylenes
cANIMIDA	Continuation of ANIMIDA Program
CFR	Code of Federal Regulations
cm	Centimeter
cm/s	Centimeters/second
CoC	Chemical of Concern
CTD	Conductivity, temperature, and depth recorder
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethane
DH	Dock Head
DMMP	Dredged Material Management Program
DO	Dissolved Oxygen
DRO	Diesel Range Organics
EGG	Egg Island disposal site - Site 3
EPA	United States Environmental Protection Agency
ft	Feet or foot
ft^3	Cubic feet
ft^3/yr	Cubic feet/year
g	Grams
GRO	Gasoline Range Organics
GTP	Gas Treatment Plant
Knot	Nautical miles/hour
L	Liter
LNG	Liquefied natural gas
m	Meters
m^2	Square meters
MDL	Method Detection Limit
mg/kg	Milligrams/kilogram
mg/L	Milligrams per liter

MLLW	Mean Lower Low Water
mm	Millimeter
ND	Not detected
NMFS	National Marine Fisheries Service
MSP	Marine Sampling Program
NTU	Nephelometric turbidity units
OBS	Optical backscatter measurement
PAHs	Polycyclic aromatic hydrocarbons
PBU	Prudhoe Bay Unit
PCBs	Polychlorinated biphenyls
PEL	Probable Effects Limit
POP	Persistent Organic Pollutant
ppm	Parts per million
ppt	Parts per thousand
psu	Practical salinity units
PTU	Point Thomson Unit
QC	Quality control
RL	Reporting Limit
SBAY	South Prudhoe Bay disposal site - Site 1
SEM	Simultaneously Extracted Metals
SL	Screening Level
STP	Seawater Treatment Plant
SQL	Sediment Quality Limit guideline
TBTs	Tributyltins
TEL	Threshold effects level
TOC	Total Organic Carbon
TSS	Total suspended solids
US	United States
USACE	United States Army Corps of Engineers
WEST	West Prudhoe Bay disposal site - Site 2
Wet wt	Wet weight
yd^3	Cubic yards

1.0 INTRODUCTION

1.1 ALASKA LNG PROJECT DESCRIPTION

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

With respect to this Project, the planned scope includes a liquefaction facility (Liquefaction Facility) in south central Alaska; an approximately 800-mile, large diameter gas pipeline (Mainline); a gas treatment plant (GTP) on the North Slope; a gas transmission line connecting the GTP to the Point Thomson Unit (PTU) gas production facility (PTU Gas Transmission Line or PTTL); and a gas transmission line connecting the GTP to the Prudhoe Bay Unit (PBU) gas production facility (PBU Gas Transmission Line or PBTL).

The current plan is to transport the GTP modules via barge to the West Dock Causeway at Prudhoe and offload the barges at Dock Head 2 over the course of four summer seasons. This Plan was investigated in detail as part of the Alaska Pipeline Project (APP), a predecessor project to the Alaska LNG Project, which required a barge channel of similar size and location as the one being proposed by the Alaska LNG project. The plan requires construction and maintenance of an approximately 11,000-foot (ft) long and 280-ft wide dredged navigation channel on the east side of West Dock Causeway (Figure 1-1). As currently conceived, the navigation channel will be dredged to a depth of 16 ft below the National Ocean Service (NOS) Mean Lower Low Water (MLLW). An 800-ft x 1000-ft turning basin will be dredged near Dock Head 2 to facilitate vessel maneuverability.

1.2 WEST DOCK WINTER TEST TRENCH PROGRAM

A winter Test Trench Program is currently being planned for the proposed barge channel. Under this program, test trenches will be excavated in the seafloor from the surface of the ice during February 2015. The objectives for the Test Trench Program include:

- Confirmation of the current understanding of sediment in-fill rates;
- Confirmation of through-ice dredging feasibility;
- Assessment of the efficiency and functionality of heavy equipment use proposed for large scale dredging operation through the ice; and
- Evaluation of operational safety issues related to heavy equipment operating on floating sea ice in proximity to excavation activities.

The proposed test trenches will be located east of the West Dock Causeway as shown in the Figure 1-1. An ice road from West Dock will provide access to the test trenches and a second ice road will provide access to the dredged material disposal site. The Project

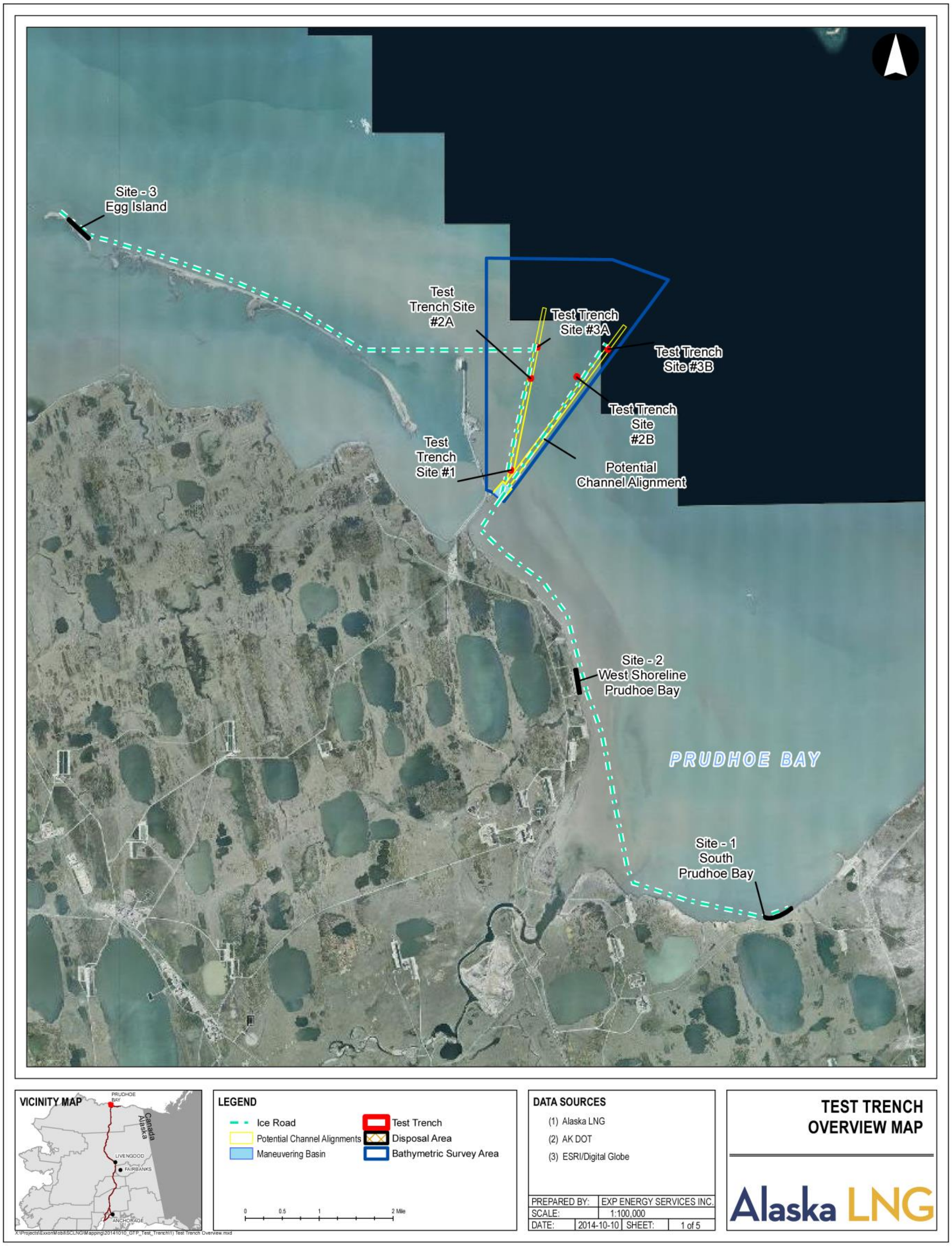

Figure 1-1. General Study Area with Test Trench and Disposal Reuse Sites

will permit five test trench locations; however, only three test trench site locations within the selected channel alignment (A or B) will be selected from five possible alternatives. There will also be one disposal location that will be selected from three possible alternatives.

The ice for the test trenches and the ice roads will be thickened so that it is grounded out to a seafloor depth of -10 ft MLLW. Beyond this depth, the floating ice will be thickened to 10 ft for the test trench pads and 7 ft for the ice roads. Test trench site 1 will be excavated in the bottom fast ice zone, with approximately 5.5 ft of bottom fast ice and 10.5 ft of excavated sediment (Figure 1-2). The ice will be thickened at test trench sites 2A or 2B until it is grounded on the seafloor. Test trench 2 will be floating over water that is approximately 2.5 ft deep; flooding this area to achieve bottom fast ice will be accomplished by sinking the ice mass to the seafloor bottom. Here, the ice will be approximately 8-8.5 ft deep and 7.5-8 ft of sediment will be excavated. Test trench sites 3A or 3B will be located on floating ice. The ice will be thickened to 10 ft to support construction machinery, there will be approximately 2.5 ft of water below the ice, and 3.5 ft of sediment will be excavated. Up to 32,000 cubic yards (yd^3) of dredge material is expected to be excavated from the three selected test trench sites.

Through-ice dredging of the test trenches will be conducted when ice has thickened to the desired depth. Slots will be cut in the ice at test trench locations, ice blocks removed, and bottom sediments excavated to the design depth. Trucks will be used to haul material to the preferred dredge disposal area for placement on the surface of the ice to a depth of approximately 5 ft. Dredge material that is placed on top of the ice would then be deposited in shallow water as ice melts in early summer. Wind and wave action during open water periods would disperse the dredge spoil materials along the nearshore zone.

Three disposal site options in nearshore waters were considered for disposal of the dredged spoils from the test trenches. The Project's preferred alternative is the West Shoreline Prudhoe Bay option (Site 2 – WEST). This site is located adjacent to BP's AGI Pad.

Ice Road Construction

Offshore ice roads will be constructed to connect the test trench sites and the preferred disposal site option. The general construction process will include clearing snow off the sea ice, flooding the ice with saltwater, and capping the ice road with freshwater and fresh ice chips to improve durability. The total length of the proposed ice roads will be approximately 6.1 miles for the preferred alternative.

1.3 DOCUMENT OBJECTIVE

The objective of this document is to provide supplemental data to support the Alaska LNG US Army Corps of Engineers (USACE) Clean Water Act (CWA) Section 404/10 permit application for the dredging and disposal of the test trench material. This report provides the information that will be necessary for regulatory evaluation pursuant to the 40 Code of Federal Regulations (CFR) Part 230 Section 404(b)(1) *Guidelines for Specification of Disposal Sites for Dredged or Fill Material*.

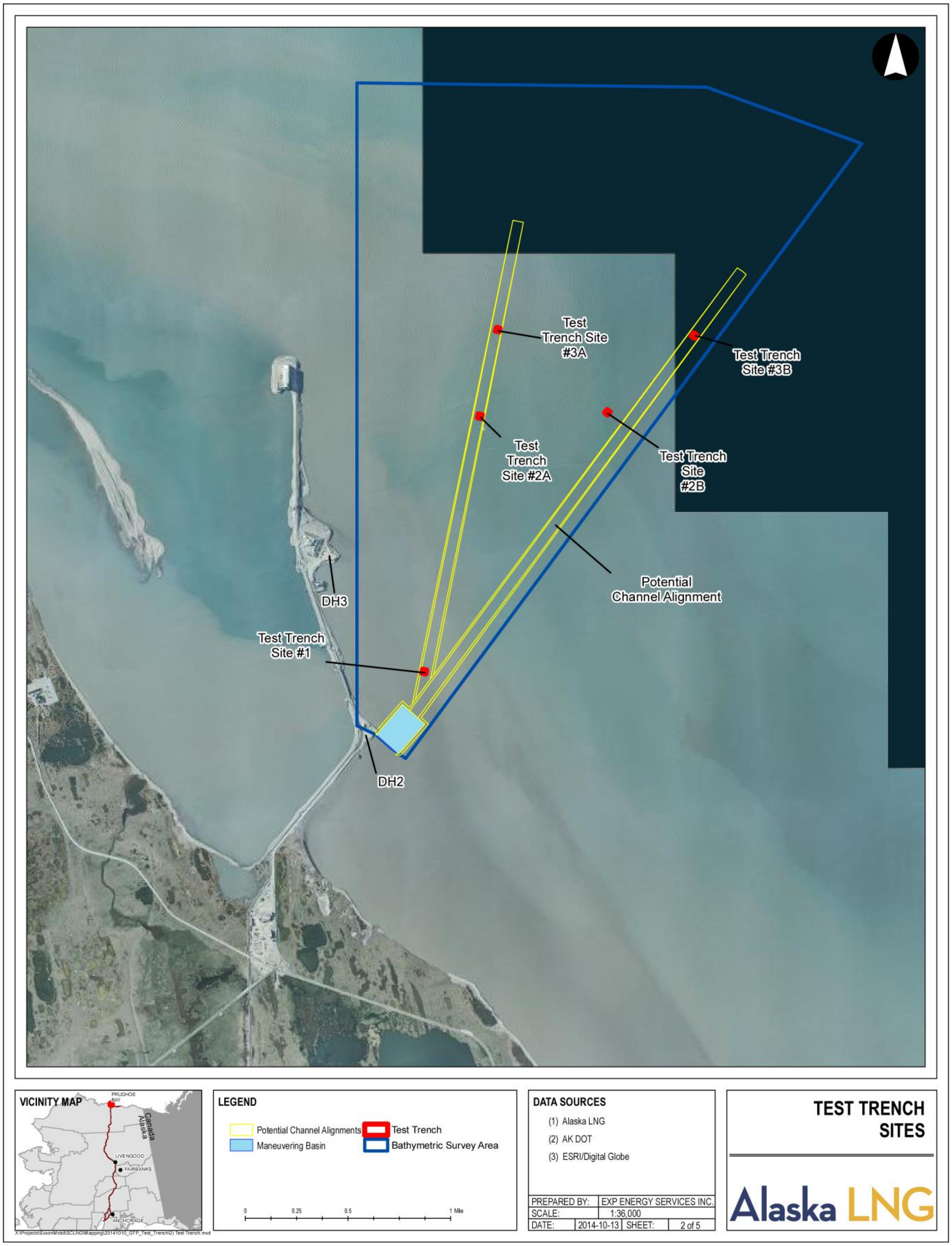

Figure 1-2. Potential Test Trench Sampling Locations

1.4 DOCUMENT STRUCTURE

The structure and content of this document is as follows:

- Section 1 - Provides a description of the Alaska LNG Project, objectives of this document, and an executive summary of the Section 404(b)(1) guideline evaluation.
- Section 2 – Provides a Tier I Evaluation/Site History of the dredge area following Seattle District USACE Guidelines and additional environmental background information for the area that are utilized in the overall dredge evaluation.
- Section 3 – Provides an overview of environmental sampling objectives and methodology that were utilized during the 2011 and 2014 studies that were conducted in the dredge area and the 2014 studies conducted at the three nearshore beneficial reuse sites.
- Section 4 – Presents data and results from both 2011 and 2014 that are associated with the proposed test trench locations and data and results from the 2014 reuse sites.
- Section 5 – Presents evaluation information that addresses the 404(b)(1) Guidelines for Specification of Disposal Sites.
- Section 6 – Presents conclusions in a tabular summary that addresses Section 230.11 Factual Determinations for the permitting of the test trench dredging and disposal.
- Section 7 – References Cited.

1.5 SUMMARY OF COMPLIANCE WITH 404(b)(1) GUIDELINES

This section summarizes the results of the dredge and disposal evaluation and demonstrates that the proposed winter Test Trench Program will comply with Section 404(b)(1) guidelines.

Subpart B – Compliance with Guidelines

It was determined that the material proposed for the test trench disposal program will consist exclusively of clean marine sediments that were found to be below regulatory threshold guidelines/standards and meet criteria for either inland disposal or beneficial re-use for beach nourishment. Thus, the discharge of the dredge at the preferred spoils disposal site will not cause or contribute to any applicable violation of State Water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972.

The only potential effect of the discharge identified was the State of Alaska water quality criteria for sediment and turbidity which would be temporarily exceeded in the immediate vicinity of the disposal activity. It is expected that the Alaska Department of Environmental Conservation's (ADEC's) 401 Water Quality Certification required for the Project would address this issue, and that a short-term variance associated with the placement of dredge or fill material would be granted by ADEC as allowed in the State of Alaska Water Quality Standards (18 AAC 70.200).

Subpart C – Potential Impacts on Physical and Chemical Characteristics

The potential impacts on the physical and chemical characteristics of the aquatic ecosystem have been addressed in this evaluation. It was determined that neither the dredge material nor any of the three potential material reuse sites have any contamination above the regulatory threshold guidelines. Furthermore, the dredge material was found to be suitable for beneficial reuse and, based on grain size, would provide protection to the shoreline at the reuse site. The placement of the dredge material will result in altered currents in its immediate vicinity and increased suspended sediment and turbidity along the receiving beach during the subsequent open-water period as the sea ice melts. This effect will be short lived and will dissipate as the finer-grained particles are winnowed and transported alongshore and into deeper water. It is expected that these increases will primarily occur during storm activity when turbidity and suspended sediment are naturally high, thus masking any project related increases. Additionally it is not expected that the discharge would have any effects on water level fluctuations or salinity gradients nor would it affect water quality parameters other than suspended sediment and turbidity.

Subpart D – Potential Impacts on Biological Characteristics of the Aquatic Ecosystem

The three potential disposal areas that were examined are in very shallow water adjacent to beaches. Biologically, these areas were shown to not be unique, and they were relatively depauperate as a result of winter freezing and annual bottom-fast ice resulting in mortality of most resident benthic marine life. As a result, it is expected that placement of dredge material in these areas will have minimal short-term impact and no long-term impact on resident biological species.

In terms of the dredge area, as with most any dredging, the biological communities within the designated test trench footprint will be eliminated. Since these areas contain typical soft-bottom biological communities, it is expected that the test trench area will recolonized over time. The length of time for this recolonization will depend somewhat on the rate of sediment infill to the trenches as a result of natural sedimentation processes. Overall, the effect on this area would be limited in size and considered short term with no long-term or cumulative impacts or loss to the aquatic ecosystem.

Since the dredging activities will take place during the winter, potential conflicts with fish, marine mammals, and migratory birds will be minimized. Because of the low densities of fish typically present during the winter period, only low numbers are expected to be affected by Project activities (see Project's Essential Fish Habitat Assessment report). Polar bears and ringed seals may be also be in the area but are expected to occur in low numbers. One of the primary concerns for the disposal areas is the potential existence of polar bear maternal dens along the shoreline. Also, ringed seals build subnivian lairs in the offshore area and often take advantage of pressure ridges/cracks in the ice that provide natural cover for their lairs and breathing holes. These and other concerns with respect to marine mammals and threatened or endangered species are addressed in the Project's Wildlife Interaction Plan. This Plan discusses avoidance and mitigation measures that will be followed to avoid or mitigate effects on wildlife from test trench dredging and disposal activities. In addition, no migratory birds are expected to be in the area during test trench construction activities.

During the summer open-water period, birds make extensive use of the marine ecosystem in the Prudhoe Bay area. An estimated 10 million individual birds with over 120 species use the Beaufort Sea coastal area in Alaska (Johnson and Hertner 1989). Nearly all of the species are migratory, occurring from late May during spring breakup through September. Numerous studies have been conducted in the region over the past 40 years that list species likely to occur in the area. Although many of the species may migrate through, rest, and/or feed in the vicinity of the project area, the loss of shallow water habitat at the preferred disposal site location is not expected to adversely affect bird populations based on the relative abundance of shallow water habitat in the general area.

Subpart E – Potential Impacts on Special Aquatic Sites

The potential impact of the dredging activity on special aquatic sites is not an issue since no special aquatic sites exist in the vicinity of the planned operations. The only special aquatic site in the region that has been identified is the "Boulder Patch" which is located 20 miles to the east of West Dock. Other special aquatic sites that are identified in the regulations (40 CFR §230.40-45), including sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes, do not exist in the planned area of operations.

Subpart F – Potential Effects on Human Use Characteristics

For the most part, potential effects on human use characteristics that are addressed in the 404(b)(1) guidance are not applicable to the proposed dredge activity. There are no municipal or private water supplies in the area; recreational and/or commercial fishing activities do not occur in the vicinity of the dredge or any of the disposal sites. Water-related recreation does not occur, it is not expected that the activity would affect aesthetics, and there are no parks, historic monuments, national seashores, research sites, or similar preserves in the area. Aesthetics and visual impacts resulting from the placement of fill material in the nearshore area would be minor given the remote location and limited access to the area. Also, given the limited size of the Test Trench Program, no impacts to any navigational areas or channels are expected to occur. The winter construction timing will also aid in minimizing conflicts with other activities that occur at West Dock such as the tug, barge, and other oil industry support boat traffic prevalent in the summer months.

Alaska native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Since the dredging will occur during the winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

Subpart G – Evaluation and Testing

This section of the regulations requires a general evaluation and testing of the dredge material. The evaluation and testing of the test trench material and surrounding area was extensively studied in both 2011 during the APP project and in 2014 as part of this Marine

Sampling Program (MSP) effort. These sampling programs followed EPA and USACE Seattle District Guidance for dredge material evaluations (USACE 2013). In addition, other sediment data from the immediate area and from the region were utilized for a comparison of both the physical and chemical properties. Sediment chemistry for the dredge material are extensively examined in this report, and based on the chemical concentrations that were seen, there is no evidence that there should be any concern with respect to disposal at any of the potential reuse areas.

Dredge sediments were also examined for potential bioavailability of metals as a result of exposure and oxidation processes at the disposal site. However, due to the low gas permeability of the frozen dredged material and the relatively slow rates of the oxidation reactions at subfreezing temperatures, the overall impacts of oxidation on the toxicity of the dredged material would be negligible, the dredged material is not expected to create any toxic conditions as it disperses in the nearshore waters of Prudhoe Bay, and the tests for bioavailability indicated no risk to the aquatic environment when compared to EPA criteria.

In addition, physical testing of sediment grain size and compatibility determinations were conducted for the test trench sediments versus the potential receiving area locations. The test trench sediments were found to be relatively compatible with the disposal areas and suitable for beneficial reuse as shoreline protection.

Subpart H – Actions to Minimize Adverse Effects

One of the primary actions to minimize adverse impacts is that the test trench dredging and disposal operations will take place during the ice-covered winter months. The winter construction timing ensures that the operations will occur during a period when biological activity in the area is minimal to non-existent in terms of fish, marine mammals, and birds. Also, oceanographic conditions are quiescent and the ice canopy reduces the effective water depth, thus suspended sediments generated by the dredge activities will only be transported a short distance before settling to the bottom. The winter construction will avoid conflicts with other activities that occur near West Dock during the summer such as the tug, barge, and other oil industry activities.

The test trench dredging will be conducted with an excavator from the ice surface which will minimize suspended sediment. As currently planned, all activity will take place from established oil field road surfaces or ice road and pads on the sea ice surface, thus eliminating any impacts to wetlands or the shoreline above the high water line.

In terms of disposal operations, winter disposal will ensure that no suspended sediment or turbidity plumes are generated during the actual placement of the dredge material which will be placed onto the ice at the disposal site. The dredge material will be deposited into shallow water, consolidating as ice melts in early summer, and then will be influenced by wave and current activity during open-water period. The disposal areas have been selected that are in very shallow water adjacent to beaches. Biologically, these areas are not unique; they are relatively depauperate as a result of winter freezing and bottom-fast ice essentially killing most resident marine life on an annual basis. As a result, it is expected that placement of dredge material in these areas will have minimal short-term impact, and there will be no long-term impact on resident biological species. In addition, the planned disposal of the dredge material will be for beneficial reuse as shoreline protection, thus further mitigating any potential adverse effects. Other measures that will be taken to minimize impacts to biological resources are detailed in the Project's Wildlife Interaction Plan.

Subpart I – Planning to Shorten the Permitting Process

The key point that is listed in the regulations (40 CFR §230.80) to shorten the permit processing time is advanced identification of the disposal area(s). Three potential disposal areas were examined in 2014 as part of the MSP including Site 1 in southern Prudhoe Bay (SBAY), Site 2 along the western shore of Prudhoe Bay (WEST), and Site 3 on the outer northern shore of Egg Island (EGG). These three areas have been characterized in terms of their physical, chemical, biological, and general oceanographic characteristics in sufficient detail to allow an evaluation of their appropriateness and suitability for the disposal of dredge material from the proposed test trench activities. Results of these characterizations are included in this report.

Subpart J – Compensatory Mitigation for Loss of Aquatic Resources

The purpose of this section of the regulations is "to establish standards and criteria for the use of all types of compensatory mitigation, including on-site and off-site permittee-responsible mitigation, mitigation banks, and in-lieu fee mitigation to offset unavoidable impacts to waters of the United States." Compensatory mitigation is addressed elsewhere in the permit application.

Preferred Alternative

Of the three potential disposal sites that were examined, Site 2 - WEST along the western shore of Prudhoe Bay is the preferred Project alternative that has been identified as the best in terms of compatibility, need for beneficial reuse, potential interaction with wildlife, and overall costs and timing for ice road construction. Selection of preferred alternative was based on the following:

- This site was found to be the most compatible in terms of sediment grain size distribution; therefore, the beneficial reuse at this site would provide the best use of dredge material for beach nourishment and shoreline protection.
- The shoreline at WEST indicated the greatest immediate need for protection since the southern end of the AGI pad is currently being eroded during storm activity.
- The ice road to this site would be the shortest which would minimize potential interaction with marine mammals, minimize the amount of freshwater needed to cap the ice road, and reduce the ice-road construction window and the overall costs.
- WEST, along with SBAY, was found to be the most compatible in terms of wind/wave energy and the duration that shoreline protection would be effective.
- This site is depauperate of resident marine organisms, thus minimizing any potential adverse impacts to the environment.

2.0 SITE EVALUATION AND BACKGROUND INFORMATION

2.1 Tier 1: Site Evaluation and History

The Tier 1 evaluation presented in this section follows the Seattle District USACE Dredged Material Management Program (DMMP) guidance procedures as outlined in their Dredged Material Evaluation and Disposal Procedures User Manual (USACE 2013). This section presents a comprehensive review and analysis of existing information pertinent to the proposed winter Test Trench Program, including a site history and a summary of previously collected physical, chemical, and biological data.

2.1.1 Past Site Activities

Active petroleum exploration on the barrier islands and mainland shoreline in the Prudhoe area occurred between 1970 and 1982. Available records are incomplete regarding the disposal of drilling muds/cuttings and sanitary and domestic wastewater for all explorations wells; however, permits at the time of drilling typically allowed for ocean discharge of these wastes. Exploration wells typically used reserve pits to store drilling wastes; therefore, it is unlikely that wastes were discharged into the ocean in the vicinity of this project.

West Dock is a multi-purpose, solid-fill gravel structure located northwest of Prudhoe Bay. Originally constructed in the winter of 1974 to 1975, it has since served as a landing facility for heavy marine-borne cargo used in support of the development of oilfields in the Prudhoe Bay area. The first leg of West Dock extends 3,955 ft north-northeast from the shore to Dock Head 2 (DH2). Because of supply difficulties caused by variable sea ice conditions, in early 1976 West Dock was extended 5,274 ft north-northwest to Dock Head 3 (DH3), at a water depth of about 7 ft In the summer of 1981, West Dock was further extended another 5,010 ft north from DH3 to a water depth of about 14 ft. This extension provided all-weather access to the Prudhoe Seawater Treatment Plant (STP) which treats and supplies seawater for enhanced oil recovery processes. Maintenance dredging and screeding has occurred periodically since the 1990s along the West Dock approach channel, at the DH2 and DH3 dock faces, and at the STP intake.

The majority of shipping and marine transportation necessary for support of Prudhoe Bay operations has occurred via West Dock since it was constructed. Construction activity and general maintenance has occurred at DH2 and along the causeway during operations of the Prudhoe Bay facilities. Storage and waste facilities are located onshore and it is unlikely that wastes were discharged into the ocean; however, because of the history of facilities at Prudhoe Bay and the level of activity through West Dock, it is possible that some trace levels of contaminants have entered the water through general activity.

With the possible exception of drilling muds and cuttings, sanitary and domestic wastewater discharged in the 1970s and early 1980s during exploratory drilling, and general facility maintenance of DH2, there are no other known past potential sources of contamination. As of November 2014, no contaminated sites or leaking underground storage tanks for the project area were listed on available databases maintained by the ADEC.

2.1.2 Present Activities

Access to the Prudhoe Bay area by marine vessels is limited to the summer open-water season which, for planning purposes, is estimated to be 60 days in length. As the preferred offloading point for nearly all cargo barged to the North Slope oilfields, West Dock Causeway is busy and congested during the open-water season for travel around Point Barrow to Prudhoe Bay.

As operator of the Prudhoe Bay Unit, BP Exploration (Alaska), Inc. (BP) also manages West Dock, which includes planning and control of all activities that use the facility. BP requires advance notice and application for permission for access and use of the dock. Even during winter, there is substantial traffic along West Dock in support of activities at the STP as well as provision of access to ice roads that serve as transportation corridors to various offshore installations and ongoing projects.

Current permits on file with USACE (2007 and 2008) and ADEC (2008) allow for maintenance dredging of up to 222,000 yd^3 per year of sediment from along the West Dock approach channel, the DH2 and DH3 dock faces, and the STP intake. The dredge material is removed by backhoe or dragline and placed along the sides and roadbed of the West Dock Causeway. If screeding is necessary, the material is back-dragged to the most offshore portions of the permitted dredge areas southwest of the STP and about 4,300 ft northeast of DH3.

2.1.3 Dredge Area – Historic Sampling Results

Existing borehole data near West Dock indicate that material within the proposed dredged sampling area consists of a 0.5 to 6-ft thick layer of sandy and clayey silt at the seafloor, underlain by gravelly to silty sand (McClelland-EBA 1985; McDougall et al. 1986; and Osterkamp and Harrison 1976).

Sediment chemical data collected for past maintenance dredging operations along West Dock (Oasis 2006 and 2008) do not indicate the presence of contamination from metals or petroleum hydrocarbons. Observed metals concentrations were mostly within the natural variability of background values reported for Beaufort Sea coastal sediment (Brown et al. 2005; Exponent 2010; Neff 2010; and Trefry et al. 2003). Sediments were generally found to be very clean within and around West Dock and no evidence of petroleum contamination was seen. All gasoline range organic (GRO) and volatile benzene, toluene, ethylbenzene, and xylenes (BTEX) concentrations in the sediments were found to be below detection limits at all locations (OASIS 2006 and 2008).

2.1.4 Dredge Area General Rankling

Guidance provided in the EPA/USACE Seattle DMMP User Manual (USACE 2013) details a ranking scheme that classifies proposed dredged materials based on the potential for adverse biological effects or elevated concentrations of chemicals of concern (CoCs; Table 2-1).

Table 2-1. Dredged Material Ranking Guidelines

Rank	Guidelines
Low	Few or no sources of chemicals of concern (CoCs). Data are available to verify low chemical concentrations (below Dredged Material Management Program Screening levels), and no significant response in biological tests.
Low-Moderate	Available information indicates a "low" rank, but there are insufficient data to confirm the ranking.
Moderate	Sources exist in the vicinity of the project, or there are present or historical uses of the project site, with the potential for producing chemical concentrations within a range of associated historically with some potential for causing adverse biological impacts.
High	Many known chemical sources, high concentrations of CoCs, and/or biological testing failures in one or both of the two most recent cycles of testing.

A review of the historical data in the dredge study area including the results from the 2011 and 2014 sampling events (discussed later in this report) suggest that the ranking for the dredge material should be low or low-moderate.

2.2 ENVIRONMENTAL BACKGROUND INFORMATION

The environmental background information provided in this section is for the nearshore waters in the Central Beaufort Sea. The information is applicable to the nearshore marine conditions in the vicinity of the proposed test trench project and therefore provides additional information on the physical setting, sediment chemistry, and marine biological resources in the area; this information is provided as a supplement for the Tier 1 evaluation.

2.2.1 Sediment Physical and Chemical Characteristics

The sediment in the nearshore area of the Beaufort Sea is derived primarily from riverine input of suspended material and coastal erosion of tundra cliffs and beaches. The sediments of riverine origin, along with the coastal peat, contribute large amounts of organic carbon, petrogenic source rock, and trace metals to the coastal sediments. Canon (1978) estimated that 80 percent (%) of the terrigenous debris supplied to lagoons in the Beaufort Sea are sediments from fluvial overflow and alongshore transport from river mouths. The major rivers that discharge into Beaufort Sea in order of flow volume include the Mackenzie (~$1x10^{13}$ cubic feet per year [ft^3/yr]), the Colville (~$1x10^{12}$ ft^3/yr), the Sagavanirktok and Kuparuk combined (~$1x10^{11}$ ft^3/yr), and the Canning Rivers (~$3x10^{10}$ ft^3/yr) (AEIDC 1974; Yunker et al. 1995; and USGS 2003). Although the Mackenzie River is much further away in terms of distance, its annual flow is nearly ten times as large as the rest of the rivers discharging into the Beaufort Sea combined. Overall, the Mackenzie River is the fourth largest river in the world discharging into the arctic environment in terms of annual flow and the first largest in terms of organic and inorganic sediments (4.85 $x10^{11}$ lb/yr ; Yunker et al. 1995). More recent work by Trefry et al. (2004 and 2009) on sediment budgets and sourcing of metals in marine sediments from rivers in the Prudhoe area found very similar sediment types in each of the rivers sampled in the region.

A number of studies were performed during the 1970s and 1980s to determine baseline conditions of sediments in the Beaufort Sea prior to oil and gas industry activity in the area. Studies included the determination of hydrocarbons in nearshore sediments (e.g., Shaw 1977) and farther offshore (e.g., Kaplan and Venkatesan 1981), and metals in marine sediments (e.g., Burrell 1977 and 1978; Naidu et al. 1981). Other more recent work include data from the United States Bureau of Ocean Energy Management's (BOEM's) Beaufort Sea Monitoring Program (BSMP), Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA), and continuation of ANIMIDA (cANIMIDA) programs that have extensively documented both the physical and chemical composition of marine sediments in the Beaufort Sea nearshore areas (Exponent 2010 and Neff 2010). These were large multi-year studies that focused on the Central Beaufort Sea nearshore area that could have been impacted by oil and gas exploration and development activities. Other studies include more site-specific monitoring efforts performed in conjunction with oil and gas development activities such as those performed at Endicott, Northstar, Prudhoe Bay, or in the proposed Liberty Development area. Site-specific monitoring was also performed in the vicinity of West Dock as part of the Prudhoe STP's discharge monitoring and for prior dredge activities in the vicinity of DH2 and DH3.

2.2.1.1 Particle Grain Size

Sediment grain size distribution in the Beaufort Sea exhibits a large degree of variability. For example, sediment mud content or % fines (silt + clay) at the BSMP stations ranged between 3 and 86% over a three-year period (Boehm et al. 1987). The sediments on the continental shelf consist predominantly of mud from riverine inputs, with coarser-grained sediments from relict deposits found in nearshore areas on shoals and in the vicinity of the barrier islands (Barnes and Reimnitz 1974). They characterized the bottom sediments in the nearshore waters of the Beaufort Sea as moderate to well-sorted sand and silt (0.08 to 0.25 millimeters [mm]) and documented the importance of ice forcing in reworking and mixing sediments.

Substrates in the West Dock and Prudhoe area were found to vary widely from muddy sand to sandy mud to samples with some samples containing coarse sand and gravel. Although documented elsewhere along the Beaufort Coast, boulders have not been previously found in the vicinity of West Dock or in any of the potential nearshore sediment reuse areas that were examined in 2014.

2.2.1.2 Total Organic Carbon

Total organic carbon (TOC) in marine sediments in the Beaufort nearshore region is mainly of terrigenous origin and derived from inland peat deposits washing down rivers and from coastal erosion of bluffs and tundra. The TOC levels in sediment samples that were sampled adjacent to West Dock near DH2, DH3, and the screed channel were found to range from 0.14 to 3.25% with a mean concentration of 1.2% (Oasis 2006 and 2008). The highest concentrations were typically associated with fine-grained sediments. Data from the BOEM BSMP found TOC to be less variable than the grain size, with a range of 0.34 to 1.8% over a three-year period (Boehm et al. 1987). The ANIMIDA study found TOC values in surficial sediments to range from 0.01 to 3.42% with a mean value of 0.62% (ADL 2001). Data from ANIMIDA and BSMP also indicated a positive relationship between TOC and fine grain sediments since larger surface area sediment can adsorb larger amounts of organic matter (ADL 2001). The TOC adjacent to West Dock in the proposed dredge area is therefore typical of values reported for Beaufort Sea nearshore sediments with a high degree of variability associated with sediment distribution and generally a good agreement between TOC and % fines content.

2.2.1.3 Trace Metals

Concentrations of metals in marine sediments in the nearshore Beaufort Sea area are primarily derived from natural inputs of suspended sediments that are discharged into the marine system from rivers. Probably the most comprehensive examination of metals in marine sediments in the region is from the BOEM-sponsored BSMP (Boehm et al. 1987 and 1990) and the ANIMIDA and cANIMIDA (ADL 2001, Exponent 2010, and Trefry et al. 2003) studies. Each of these studies was large and multi-year that examined nearshore sediment chemistry along the Central Beaufort Sea coastline, concentrating in those areas that would most likely be affected by oil and gas related activities. Other studies include work performed by the University of Alaska that re-examined 20 of the BSMP sites during 1997 (Naidu et al. 2001) and long-term monitoring at two locations as part of NOAA's National Status and Trends (NS&T) Program (Cantillo et al. 1999). The BSMP examined nine metals whereas the ongoing ANIMIDA studies are examining 18 metals from sites located both regionally and in the vicinity of West Dock. Trefry (2003) found that the sediments contained natural levels of metals and that most variability could be predicted as a function of the aluminum content in the sediment. Exceptions to this trend were associated with a couple of sites that indicated a potential pollutant source. Other studies in the region have included the Outer Continental Shelf Environmental Assessment Program (OCSEAP) studies and industry-related site-specific studies for Endicott, Liberty, and Northstar Developments.

Trace metal concentrations in nearshore Beaufort Sea marine sediments including data from the West Dock area show with few exceptions, concentrations are lower than NOAA's effects range low (ERL), State of Washington Sediment Quality Criteria, and USACE screening levels for dredge material evaluation. Differences that were observed in most of these studies can be ascribed to grain size distribution and organic content with higher trace metals concentrations in finer-grained sediments. Except for a couple of site-specific data points, in general these studies have not found any evidence of trace-metal contamination of marine sediments in the Beaufort Sea. Nickel was found to be slightly elevated in many of these studies when compared to the NOAA ERL benchmark criteria, but is actually low when compared to the average for continental crust material of 56 parts per million (ppm) (Wedepohl 1995). Based on these numbers, it would appear that the Beaufort Sea sediments are not contaminated but are actually a combination of eroded continental crust material and sediment from terrestrial sources. Although all metals may be of interest to researchers, only a few are likely to have their concentrations altered by oil and gas development activities. These are barium and chromium, which are likely to be affected by drilling activities (i.e., drilling muds), and lead and vanadium, which are constituents of petroleum and/or refined product.

2.2.1.4 Hydrocarbons

The hydrocarbons found in Beaufort Sea sediments occur naturally and are primarily derived from riverine and terrigenous inputs. The hydrocarbon assemblages in the sediments are dominated by waxy plant inputs, such as peat, and fossil fuel inputs from coal and other source rock formations. The analysis by Boehm et al. (1990) ruled out natural seepage or spills of Prudhoe Bay crude oil as the source of aromatic hydrocarbons in the region, which is supported by earlier OCSEAP studies. Due to seasonal and yearly fluctuations in river flows, there is some variability in sediment hydrocarbon levels in various areas of the Beaufort Sea, but there is little intra-station variability. As with trace metals concentrations, most observed differences between sites are attributed to differences in grain size and TOC, with higher concentrations found in areas with higher percentages of fine-grained sediments and TOC. Work by ADL (2001) found hydrocarbon concentrations that were nearly an order of magnitude higher in the Colville River compared to the offshore areas due to higher TOC content. In addition, the composition of the hydrocarbons in sediments is fairly constant throughout the region.

Extensive work on hydrocarbon concentrations in the marine sediments has been performed as part of both the BSMP, ANIMIDA, and cANIMIDA studies (Boehm et al. 1987 and 1990; ADL 2001; and Exponent 2010). These studies have included the analyses of saturated hydrocarbons (SHC) and polycyclic aromatic hydrocarbons (PAHs). Steranes and triterpanes biomarker analyses were also performed as part of the ANIMIDA and cANIMIDA programs. Similar types of hydrocarbon fingerprint analyses have also been performed for early OCSEAP programs and for site-specific studies associated with the Northstar and Endicott Developments. In the SHC analyses, studies have shown a very strong odd-to-even preference for the straight chain normal alkanes that indicate primarily plant wax sources with lower levels of petroleum hydrocarbons, and also very low levels of unresolved complex mixture (UCM) which is an indicator of oil weathering (ADL 2001; Boehm et al. 1990; and Exponent 2010). The PAH distributions were primarily of a fossil fuel origin (petroleum and coal) with lesser amounts of pyrogenic PAHs and variable amounts of biogenic inputs. Biomarker analysis indicated that the nearshore sediments were very similar to that seen in the Colville River sediments and peat with recent organic matter and similar petroleum hydrocarbon patterns. In summary, the organic geochemical data for the region from these studies indicate that hydrocarbons found in nearshore and offshore sediments originate through natural processes, are primarily from riverine sources, and except for a couple of site-specific samples that were identified, show little evidence of anthropogenic petroleum inputs.

2.2.1.5 Other Pollutants and Constituents

Little area-wide data exist for other pollutants, such as pesticides, herbicides, polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), tributyltins (TBTs), or other pollutants. Scientific work in the Alaskan Beaufort Sea region, including the OSCEAP studies, has concentrated on physical, biological, and chemical properties of the environment, but the chemical components of these programs have generally pertained to hydrocarbons and trace metals. These parameters have received attention because they could potentially be affected by oil and gas activities; i.e., their levels could increase due to releases of petroleum or through drilling activities. Monitoring for these other types of contaminants has generally been made part of an NPDES permit for an industrial discharge rather than the focus of more general research.

For example, NPDES monitoring at the Prudhoe Bay STP at West Dock has included analyses of volatile and semi-volatile organic compounds in sediments collected in the vicinity of the outfall. Results from the 1994 monitoring program failed to show concentrations of these compounds above detection limits (Kinnetic Laboratories, Inc. 1995). Sediment sampling that included the analysis of volatile and semi-volatile organic compounds was performed in 1997 and 1998 in association with the proposed Liberty Island and pipeline routing (Montgomery Watson 1997 and 1998). No volatile organic compounds were detected during either year; however, a number of semi-volatile organic compounds including some phenols and one phthalate were detected during the 1996 sampling.

2.2.2 Biology

2.2.2.1 Fish

A number of surveys have been conducted in the general vicinity of Prudhoe Bay and West Dock that show fish communities, like other Arctic animal communities, have fewer species than do their lower-latitude counterparts. In Alaska coastal waters of the Beaufort Sea, 62 species of fish have been recorded, with additional species presumably found offshore (Craig 1984). Craig describes the fish community of the Alaska Beaufort Sea as typical of the "Inuit fauna," which is a fairly distinct assemblage of diadromous and marine species. Dominant diadromous (anadromous and amphidromous) species are Arctic cisco (*Coregonus autumnalis*), least cisco (*C. sardinella*), and Dolly Varden char (*Salvelinus malma*), which enter previously frozen near-shore waters each summer and feed extensively on an abundant supply of epibenthic crustaceans. Dominant marine species are Arctic cod (or "polar" cod, *Boreogadus saida*) and fourhorn sculpin (*Triglopsis quadricornis*), which enter near-shore waters later in summer as salinities increase. These five dominant species account for over 90% of all fish captured in scientific investigations along the Alaska and western Yukon coastlines. Other species observed include broad (*C. nasus*) and humpback whitefish (*C. pidschian*), rainbow smelt (*Osmerus mordax*), chum salmon (*Oncorhynchus keta*), and pink salmon (*O. gorbuscha*; Craig 1984). Additional marine species include several species of sculpins and eelpouts (Rand and Logerwell 2010).

A biologically important feature of the near-shore Beaufort Sea, including Stefansson Sound and Prudhoe Bay, is the occurrence of a band of relatively warm (5-10 degrees Celsius [°C]) and estuarine water (10-25 parts per thousand [ppt] salinity) that lies adjacent to the shoreline in the summer extending the length of the coast, including Prudhoe Bay (Truett 1981). The band is relatively shallow, narrow, and is often distinctly different from adjacent marine waters. The estuarine band is formed during spring breakup when floodwaters from North Slope rivers flow to sea. In the following weeks, near-shore waters mix with incoming cold marine water to create estuarine systems that prevail along the coast through the summer (Truett 1981). Diadromous fish begin arriving from their overwintering areas with the first signs of spring breakup, disperse along the coastline, remaining in the warmer and low salinity band, and return by fall to river drainages to spawn or overwinter. Many parallel the shore along a narrow corridor often within 100 meters, though a variety of environmental conditions influence the size of the diadromous corridor (Craig and Haldorson 1981). A long history of sampling along shorelines in and near Prudhoe Bay (e.g., Fechhelm et al. 2005 and 2009) has added detail to this understanding of the importance of shoreline areas for fish and the influences of near-shore causeways on movements of these fish.

The distribution of marine species tend to increase in near-shore waters as the open-water season progresses and salinities increase (Craig 1984), though some studies have also noted an offshore movement through the summer (Moulton and Tarbox 1987). These marine fish are not restricted to near-shore waters and probably do not migrate parallel to the coastline. During the winter, most anadromous species return to North Slope freshwater drainages to spawn or overwinter; marine species remain under near-shore ice, but eventually vacate shallow waters, which freeze solid to a depth of approximately 2 meters (m; Craig 1984).

Long-term monitoring of fish in the nearshore Beaufort Sea has been performed over the last 32 years for BP in conjunction with oil industry activities (McCain et al. 2014). The objective of this study was to monitor the distribution, abundance, and health of anadromous and amphidromous fish stocks important to the Native subsistence fishery in the lower Colville River. Fishing took place using stationary fyke nets at various stations stretching from an area east of the Endicott Causeway to the western end of Simpson Lagoon. In 2013, three stations in the Prudhoe Bay area were sampled: one on the western side of West Dock (just outside of Prudhoe Bay proper), one on the western side within Prudhoe Bay, and one at Niakuk/Heald Point at the eastern extreme of Prudhoe Bay. Broad whitefish, Arctic flounder (*Pleuronectes glacilis*), and saffron cod (*Eleginus gracilis*) were the dominant three species captured at all four stations combined in 2013. Arctic flounder was the most dominant species collected at the station in western Prudhoe Bay and the second most dominant species collected in eastern Prudhoe Bay. Other species collected in 2013 included least cisco, rainbow smelt, fourhorn sculpin, Arctic cisco (*Coregonus autumnalis*), and Arctic cod. In 2009, Arctic cisco, fourhorn sculpin, and broad whitefish were the most dominant species at all four stations combined (Fechhelm et al. 2009). Arctic cisco, saffron cod, and fourhorn sculpin were the three most dominant species collected at the western Prudhoe Bay station. Arctic flounder was the fourth most dominant species collected at the western Prudhoe Bay station and, overall, for the combined catch at all four stations. Arctic cod was collected at all four stations in 2009, with the most abundance shown at the western Prudhoe Bay station.

Less information and fewer data are available for offshore portions of Prudhoe Bay and in Stefansson Sound. Craig (1984) listed 40 species that have been documented in coastal areas farther from shore, but sampling effort has been low. Arctic cod, two-horn sculpin (*Icelus bicornis*), and Canadian eelpout (*Lycodes polaris*) were reported to be dominant species. Cannon et al. (1991), studying juvenile Arctic cod, sampled exclusively in the Prudhoe Bay area in a variety of habitats ranging from very shallow near-shore areas (less than 6 ft) in the bay to areas farther out on the shelf (10 to 15 ft) between mid-July and mid-August. This study found that Arctic cod were concentrated in warmer, lower salinity waters closer to shore. Catch was greatest at bottom salinities between 14 and 22 ppt (surface salinities between 10 and 20 ppt) and in relatively shallow waters between 3 and 7 ft. A more recent study in the offshore deeper waters of the Beaufort Sea was performed in 2008 (Rand and

Logerwell 2011). This study documented 32 species of demersal fish, with Arctic cod being the most abundant.

Moulton and Tarbox (1987) trawled both near-shore and offshore locations near Prudhoe Bay (0.3 to 5.5 m [1 to 18 ft] deep) and caught primarily Arctic cod (98% of catch), with minor catches of kelp snailfish (*Liparis tunicatus*), fourhorn sculpin, Pacific sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), rainbow smelt, and least cisco. This study found Arctic cod to be associated with a transition layer between a surface water mass characterized by low salinity and high temperature and a bottom water mass characterized by high salinity and low temperature. The species apparently oriented to the shoreward edge of the marine water mass and redistributed depending upon the location of the shoreward edge. The authors also noted a general offshore movement of cod between July and August sampling periods. The mean bottom depth of capture was about 9 ft in July and 19 ft in August.

A number of studies have conducted offshore investigations during the winter. In Prudhoe Bay winter samples, Tarbox and Thorne (1979) captured four species of fish: Arctic cod, kelp snailfish, fourhorn sculpin, and slender eelblenny. The abundance of these fish was low based on catch rates, diver observations, and hydroacoustic measurements. The study concluded that fish densities were at least an order of magnitude lower than those typically observed in other southern coastal marine environments and that estimated winter densities appeared lower than those recorded in the Beaufort Sea open-water season. Craig et al. (1982) found that Arctic cod were found offshore ("Boulder Patch" and Narwhal Island; 15 to 33 ft in depth) during the winter at higher catch rates than in near-shore habitats (Simpson Lagoon). The highest catch rates during the winter, however, were found in non-coastal areas 175 kilometers offshore.

2.2.2.2 Benthos

Oil and gas exploration activities that have taken place on the Alaskan North Slope since the 1970s have provided, in relationship to these activities, numerous benthic invertebrate studies. Pertinent information concerning Alaskan Arctic benthic communities are provided in numerous Draft or Final Environmental Impact Statement (DEIS or FEIS) documents for the Alaskan Beaufort and Chukchi seas (e.g., MMS 1984, 1987a, 1987b, 1990, and 1996). Additional benthic community data are available from other studies pertaining to oil and gas production activities, such as Envirosphere (1983 and 1985); Feder et al. (1976a and 1976b); USACE and ERT (1984); USACE (1980); and Dames and Moore (1988). Recent reports pertaining to the Northstar Development Project are available in Woodward-Clyde Consultants (1996) and Kinnetic Laboratories, Inc. (2002) and more recently in the synthesis of 1999 – 2007 cANIMIDA data by Neff (2010).

The structures of nearshore and coastal marine benthic communities in the Alaskan Beaufort Sea are complex and generally divided into three zones. The nearshore environment ranges from the shoreline to a depth of 5-6 ft, which corresponds to the bottom-fast ice zone. The coastal (sometimes called inshore) environment ranges from about 6 to 65 ft and includes deeper areas inside the barrier islands as well outside of the islands. Offshore areas include those greater than approximately 66 ft and extending out across the continental shelf. The majority of the Beaufort Sea nearshore and coastal environment consists of large expanses of soft-substrate bottoms (silty muds or sands) that faunal groups adapted to this environment dominate. In addition, limited areas of hard-substrate habitats exist in the Beaufort, supporting kelp communities like those in Stefansson Sound known collectively as the "Boulder Patch."

Benthic communities are an interwoven mosaic of infaunal and epifaunal species. Marine benthic communities in Alaska's Beaufort Sea contain numerous species of surface (epifaunal) and subsurface (infaunal) sediment-dwelling invertebrates, as well as microalgae (diatoms), large and small species of kelp (macrophytic algae), and bacteria (MMS 1987a, 1987b, 1990, and 1996; Thorsteinson 1987; and Dunton and Schonberg 2000). In addition, juveniles and adults of a number of benthic species in the nearshore and coastal waters of the Beaufort Sea do not live in constant association with bottom sediments. Instead, certain species may opportunistically leave the bottom sediments, usually during May to June, to become grazers or predators on epontic (within- or under-ice) communities that are composed primarily of diatoms and meiofauna (Horner 1979). Larvae of some benthic polychaetes and molluscs spend part of their life cycle inside sea ice as members of that epontic community. Juveniles of benthic species may also spend time as members of the zooplankton in the water column and may graze or prey on plankton until reaching their adult stages and retreating to the bottom.

A number of physical factors that influence habitat structure affect the flora and fauna associated with bottom sediments. These physical factors can contribute to spatial and temporal patterns of benthic biota that lead to changes in community structure (Gallagher and Keay 1998). Sediment composition, particularly sediment grain size, is extremely important in influencing infaunal community structure and species composition. In the Alaskan Beaufort Sea, as in many benthic communities, deposit-feeders are characteristic of finer sediments, and suspension-feeders are more typical of coarser sediments.

Ice is another important agent that physically disturbs bottom sediments and limits the abundance and distribution of infaunal and to a lesser extent, epifaunal organisms, as well as kelp. Bottom-fast ice in nearshore waters prohibits over-wintering of most benthic species, resulting in a population dependent upon colonization during ice-free periods (MMS 1990). Because of this process, epifaunal species such as isopods, amphipods, and mysids that are highly mobile and opportunistic characterize these nearshore areas. Outside of nearshore waters, in coastal areas less than 66 ft, both biomass and diversity of the infauna increase with water depth (Feder et al. 1976a and 1976b). In the shear zone, at approximately 50 to 70 ft water depths where shorefast ice and the moving pack ice meet, ice gouging serves to further disturb bottom sediments, limiting infaunal abundances in this area (MMS 1990). In the offshore zone of water depths greater than 65 ft, biomass and diversity of infaunal organisms increase with depth and distance (Carey 1978).

Prevailing currents caused by wind and wave action facilitate the movement and recolonization of invertebrates into the ice-free nearshore shallow areas from offshore (Griffiths and Dillinger 1981). These currents also facilitate transport of organic material from terrestrial sources into the nearshore and coastal environments, influencing biomass and diversity of the local benthic community (Schell et al. 1982). Water quality parameters such as salinity, temperature, dissolved oxygen, and turbidity also directly affect benthic communities. Fluctuations in these parameters, either natural in origin or man-made, may result in extreme stress on benthic organisms. For example, salinities in Simpson Lagoon have been shown to be quite variable, ranging from 1 to 32 ppt during summer and accompanied by water temperatures that fluctuated between 0 and 14°C (Craig et al. 1984). While open-ocean seawater is approximately 34 ppt, hypersaline or brine (highly saline) water of up to 80 ppt occurred naturally in isolated pockets under the ice in winter (Houghton et al. 1984). Open-water conditions during spring breakup may cause hyposaline or brackish conditions (low-salinity water or freshwater) to occur. During this period, water temperatures may reach as high as 13°C (Feder and Jewett 1982).

As noted above, the majority of the Beaufort benthic environment consists of silty muds or sands. These habitats tend to exclude most large plant species (kelp), which generally need a prevalence of cobbles, boulders, or both as suitable substrate for attachment and colonization. The occurrence of this type of hard-substrate habitat in Alaskan Arctic coastal waters is patchy, isolated, and spatially rare when compared to soft-substrate habitats. The best known example of hard-substrate habitats in the Alaskan Beaufort Sea is the large well-studied kelp community in Stefansson Sound known as the Boulder Patch which is located near the proposed Liberty Development. The Boulder Patch was discovered in the early 1970s by geologists but lay unstudied biologically until the late 1970s (Dunton and Schonberg 2000). Researchers have since studied this area extensively and found it to be the most diverse and densely populated benthic community in the Alaskan Beaufort Sea (see Dunton and Schonberg 1981 and 2000; Dunton et al. 1982; Dunton 1984; Martin and Gallaway 1994; MMS 2001; Neff 2010; and Wilce and Dunton 2014).

Epifauna

Epifaunal communities, organisms living on the bottom sediments, are generally more abundant and diverse than the infauna in the nearshore Alaskan Beaufort Sea. Unlike the infauna, these communities exhibit distinct zones in terms of species composition. In Prudhoe Bay, for example, the epibenthos consists of three distinct communities found in the nearshore and offshore areas (Feder and McGee 1982). This is particularly apparent with larger epifauna, because many species distribute themselves in zones parallel to depth contours (Carey et al. 1974). In addition to changes in species composition, the epifauna also exhibited an increase in density and diversity with increasing water depths (Woodward-Clyde Consultants 1984). As noted above, nearshore areas, as winter habitat for epifauna, are eliminated seasonally by bottom-fast ice. This habitat is recolonized every summer and quickly begins to support a variety of benthic species, particularly crustaceans.

Common epifaunal amphipod species in the Alaskan Beaufort Sea include *Onisimus glacialis*, *O. litoralis*, *Gammarus setosus*, and *Monoporeia affinis* (Broad et al. 1977; Envirosphere 1983; Griffiths and Dillinger 1981). The species *O. glacialis* is prevalent in the summer in protected nearshore areas and is much less abundant in deeper areas (Envirosphere 1983). Another species, *Onisimus affinis*, is more prevalent in waters deeper than 7 ft and occurs primarily outside lagoons and protected areas (Envirosphere 1983). As a group, amphipods appear able to occupy a wider range of salinity than mysids (USACE and ERT 1984).

Mysids make up a large proportion of the nearshore epibenthos during summer in Harrison and Prudhoe Bays (Craig and Griffiths 1981) and in Simpson Lagoon (Crane and Cooney 1974; Griffiths and Dillinger 1981); they apparently over-winter in coastal areas (Griffiths and Dillinger 1981). Two common mysids are *Mysis litoralis* and *M. relicta*; of these, *M. litoralis* is widely distributed in nearshore and coastal waters, while *M. relicta* is restricted mostly to coastal waters (Griffiths and Dillinger 1981).

The isopod *Saduria entomon* is also a very common epifaunal organism found in the Beaufort Sea (Broad et al. 1977; Broad et al. 1979; and Griffiths and Dillinger 1981), being nearly ubiquitous in its distribution. Although this species can live at extreme depths in other environments, it appears to be concentrated in depths of less than 16 ft in the Alaskan Beaufort Sea (Robilliard and Busdosh 1979).

Infauna

Benthic infauna, organisms living within the bottom sediments, in the nearshore and coastal environments in the Beaufort Sea exhibit low species diversity and abundance due to the physical and chemical stresses noted earlier. The shallow waters of the nearshore support very low densities of infauna, reflecting the unstable nature of this area (Broad et al. 1977; Carey and Ruff 1977; and Feder et al. 1976a and 1976b).

Early studies along the Alaskan Beaufort Sea coast indicated that annelid worms (polychaetes and oligochaetes) along with bivalve molluscs dominate the infauna in the shallow coastal waters to depths of approximately 35 ft (Broad et al. 1979). At depths of approximately 15 to 25 ft in Prudhoe Bay and Stefansson Sound, polychaetes were the dominant infaunal organisms, with molluscs and crustaceans subdominant members (NORTEC 1981). Moving deeper from the shoreline across the continental shelf and slope, the abundance of infaunal organisms generally increases with depth (Carey et al. 1974).

Past studies conducted in the Alaskan Beaufort Sea indicate that infaunal communities are typically dominated by species from two families of polychaetes, Cirratulidae and Ampharetidae (e.g., *Tharyx* spp., *Chaetozone* spp., and *Ampharete vega*) (Feder and Jewett 1982; Grider et al.1978; Carey et al.1981; and Envirosphere 1983). Bivalve molluscs occur in the nearshore and coastal areas, with either or both *Portlandia arctica* or *Cyrtodaria kurriana* common dominant species of this group (Envirosphere 1983 and Broad et al. 1977). These two species have distinct depth preferences: *P. arctica* appears more frequently in depths greater than about 10 ft, while *C. kurriana* appears to prefer shallower depths of 3 to 10 ft (Envirosphere 1983).

Results from the 1995 Northstar Development sampling program indicated that polychaetes are the dominant species in the area between Endicott and Northstar Island, representing 43% of the total taxa, while crustaceans and molluscs comprised 21 and 26%, respectively (Woodward-Clyde Consultants 1996). There was an obvious increase in the numbers of taxa with increasing depth, but this trend did not occur for abundance. Analyses of their data based on the presence or absence of species showed a clear demarcation between stations at shallow depths of 7 to 15 ft and deeper depths of 23 to 45 ft.

While relatively rare compared to soft-bottom communities, hard-substrate communities supporting algae and epilithic fauna do exist in the Alaskan Arctic. The well-known Boulder Patch community in Stefansson Sound (approximately 15-20 miles east of proposed West Dock test trench sites) provides hard-substrate for invertebrates and the endemic brown kelp *Laminaria solidungula* (Dunton 1984). A recent paper by Wilce and Dunton (2014) describes in detail benthic algae from the Boulder Patch collected in situ from 1977 to 2006. This area also supports a variety of invertebrates, including sponges, soft corals, sea stars, hydroids, anemones, ascidiaceans (sea squirts), bryozoans, and molluscs, such as chitons and nudibranchs (Dunton and Schonberg 1980 and 2000). A variety of small mobile and sessile benthic species, as well as larger organisms like fish, crabs, shrimp, and sea stars, are common inhabitants with the kelp. These fauna are associated with patches of kelp (*Laminaria* spp.) and red algae that are attached to boulders, cobble, or to pieces of shell debris (Toimil and England 1980). Many of the species inhabiting the Boulder Patch do not occur elsewhere in the region due to a lack of suitable hard substrate. Kelp and other large epilithic species can live for many years in a stable relatively undisturbed habitat. Their ability to colonize and re-establish themselves in new suitable habitat following a major disruption is slow and may take as long as 10 years (Toimil and England 1980; Dunton and Schonberg 1980). Additional kelp community information can be found in LGL and Dunton (1992) along with Neff (2010) and Wilce and Dunton (2014).

Other relatively small hard-bottom communities or kelp beds exist or may exist east of the Boulder Patch. These sites include those offshore of Flaxman Island (NOAA 2001; Dunton et al. 1982); southeast of Belvedere Island in the Stockton Island chain (NOAA 2001; Dunton et al. 1982); at Boulder Island Shoal in outer Camden Bay (Dunton et al. 1990); in Demarcation Bay (Dunton et al. 1982); and in Beaufort Lagoon (Truett 1987). No known hard-bottom communities have been found near West Dock or the Prudhoe Bay area.

2.2.2.3 Algae

As noted above, in the early 1970s, a "Boulder Patch" was discovered in Stefansson Sound constituting the first kelp bed discovered in the Alaska Beaufort Sea. This and other accumulations of hard substrate (called "boulder patches") are located 6-8 kilometers off northern Alaska within Stefansson Sound, with some smaller patches found to the east of Prudhoe Bay. These habitats support the most diverse biological community known along the Alaska Arctic coast; they have been subject to considerable study (e.g., Reimnitz and Ross 1979; Dunton and Schonberg 1981; Dunton et al. 1982; Toimil and England 1982; Toimil and Dunton 1983; Busdosh et al. 1985, and Wilce and Dunton 2014).

In these boulder patch areas, localized deposits of gravel, cobble, and small boulders (< 1 m in diameter) provide unique habitat for attached algae and epifauna resulting in an enriched community as compared to the soft-bottom substrate present throughout most of the Beaufort Sea and along the north Alaskan coast. Wilce and Dunton (2014) recently determined that at least 78 species of benthic algae utilize the hard substrate of the Boulder Patch, including 26 species of green, 25 species of brown, and 25 species of red algae. The arctic kelp *Laminaria solidungula* is typical of the boulder patch assemblage, with the other brown kelp species *Saccharina latissima* and *Alaria esculenta* recorded as co-dominants. Numerous species of red algae, such as *Odonthalia dentata* and *Phycodrys fimbriata*, along with red encrusting or coralline algae are also found in the bard-bottom areas. Green algae were noted as not being heavily represented in these hard-bottom areas.

2.2.3 Oceanography and Water Quality

The proposed test trench dredging and the three potential nearshore dredged material reuse sites would occur in relatively shallow waters (less than 20 ft) in Stefansson Sound and Prudhoe Bay area. This region of the Beaufort Sea area has been intensively studied for more than four decades, and the oceanographic characteristics of the region are well understood. Oceanographic conditions in the nearshore Beaufort Sea can be split into two distinct time periods: the summer open-water season which lasts from late June or early July through approximately early-October, and the winter ice-covered time period when the lagoons and nearshore areas freeze solid to shore (fast ice). Offshore of the lagoons, starting in approximately 65 ft of water, the Beaufort Sea is covered by pack ice during the winter months that moves on- and offshore with the winds and other forcing mechanisms and forms a shear zone with the land-fast ice during the winter. In recent years, during the summer open-water period, the pack ice typically recedes up to 100 miles offshore, but may move on and offshore depending on meteorological and large scale forcing mechanisms. Ocean currents during the open water period are primarily governed by wind speed and direction, with astronomical tides, density gradients, bathymetry, coastal morphology, and riverine inputs have a lessor influence. Conditions during the ice-covered winter months are relatively quiescent with very low currents that are driven by tidal and long-shore pressure gradients.

2.2.3.1 Summer Open-Water Conditions

Oceanographic and water quality conditions in the nearshore Beaufort Sea, although complex and highly variable, are fairly well understood having been the subject of numerous investigations over the past 40 years (Kinnetic Laboratories, Inc. 1983; SAIC 1989 and 1993; Savoie and Colonnel 1988; Short et al. 1988; Tekmarine 1983; URS 1999; Weingartner and Okkonen 2001; Weingartner et al. 2009; etc.). Hydrographic (salinity and temperature) conditions of the nearshore waters are strongly influenced by the freshwater runoff and proximity to the rivers, meteorological conditions, seasonal timing, advection due to circulation patterns, and offshore ice conditions. The dominant forcing mechanism in driving the circulation on the inner continental shelf (< 150 ft depth) and in nearshore waters is wind stress, with water level variations and density gradients having a lesser influence. Nearshore currents generally run in an east-west direction, parallel to the local bathymetry and in the same direction as the prevailing wind stress. Water properties are then advected along the coast and redistributed by the regional circulation patterns. These same oceanographic processes affect transport of suspended sediment and sediment quality conditions in the Beaufort nearshore region. These influences, along with regional oceanographic processes such as upwelling and storm surges have been found to be very important in affecting onshore-offshore exchange of water properties.

River discharge is the main source of freshwater input into the nearshore areas of the Beaufort Sea. During late May to early June, rivers on the North Slope breakup and begin to flow into coastal areas. Rivers both overflow and underflow the nearshore land-fast ice which hastens its melting in the immediate area. Following the breakup of the rivers, a warm brackish lens of water between the shore and the offshore ice pack dominates the coastal region. The timing of river breakup and the volume of snow in the watershed determine the amount of fresh water available for diluting the nearshore marine water. During the remainder of the summer, river discharge is highly variable and depends on the amount of precipitation.

At the beginning of the open-water season, during and following breakup of coastal rivers and melting of sea ice, there is a stratified water column with a less saline surface water layer that can be as deep as 13 ft, and which overlays a marine water layer. As the winds from the east increase and temperatures rise following breakup each year, the water column mixes along the project area coastline, creating a brackish water environment. As river flow drops in mid to late summer, water column salinity increases to a more marine condition.

From middle summer until freeze-up, during the late open-water period, the coastal waters become steadily colder and saltier until they are virtually identical to the marine waters. This trend is apparent in all of the time-series records of salinity and temperature from about the end of August through October from numerous studies conducted in the Beaufort Sea nearshore region. Intense storms from both the west and east occur during this period. Salinities usually range from 28 to 31 practical salinity units (psu) throughout the nearshore area and are relatively homogeneous both vertically and horizontally with water temperatures near freezing. An exception to this is during light wind periods when brackish plumes (10-20 psu) from the local rivers may be evident. Freeze-up of the lagoons usually starts in late September or early October with the shallow offshore areas freezing approximately a month later.

Bathymetry is an important parameter with respect to oceanographic conditions along the Beaufort Sea Coast, since nearshore currents generally run in an east-west direction, parallel to the local bathymetry and in the same direction as the prevailing wind stress. Water properties are then transported along the coast following bathymetric bottom contours. The West Dock Causeway interrupts this general east-west flow causing currents to be directed north and has been shown to affect the local hydrographic regime as well as sedimentation patterns in its vicinity. Sedimentation studies that were conducted as part of the Prudhoe Bay Waterflood Environmental Monitoring Program indicated that the causeway redirected the natural east-west transport of sediment resulting in a net accretion of sediment on both the eastern and western sides of the structure. This fact was confirmed in 2011 by the APP project which found the bathymetry on the eastern side West Dock to be substantially shallower than that indicated on historic navigation charts (APP 2012).

2.2.3.2 Winter Ice-Covered Conditions

During winter, the Beaufort Sea is covered by sea ice that begins to form in late September or early October. Freeze-up of the lagoons and nearshore waters is usually completed by the end of October, with ice growing to about 5 ft (1.6 m) thick by April. Ice cover persists on average for 8-9 months until spring warming results in river breakup, and subsequent sea ice melting near the river and stream deltas. Temperature and salinity profiles collected under the sea ice within the Beaufort Sea exhibit uniform near-freezing, temperatures (-1.7°C) and saline (~32 psu) marine waters.

While the current meters employed during under-ice studies are generally insensitive to speeds below 2 centimeters/second (cm/s), the data do not indicate stagnant conditions. Weingartner and Okkonen (2001) measured under-ice currents in Stefansson Sound and found that even though most velocities were less than 5 cm/s, there were periods of time when currents exceeded 15 cm/s. They found that the winter under-ice currents were not correlated with the wind and forcing mechanisms were most likely due to fluctuations in atmospheric pressure or offshore oceanic motions.

Heavy brine formed by the thickening sea ice has been observed to produce a stratified water column in restricted water bodies such as Prudhoe Bay and in stagnant or near-stagnant conditions; however, low current speeds (e.g., less than 5 cm/s) are sufficient to disperse any such brine through the water column and minimize or eliminate resulting under-ice vertical stratification. In nearshore waters, the typical water column structure observed under sea ice in the Beaufort Sea is uniform, with very little temperature, salinity, or density stratification. Although minimal, further offshore on the continental shelf some vertical stratification has been observed during the winter months.

2.2.3.3 Turbidity and Suspended Sediment

Turbidity values and total suspended sediment (TSS) concentrations during the open-water period in the nearshore Beaufort Sea area are very dependent on wind and wave-induced turbulence that re-suspends bottom sediments and on sediment discharge from the rivers. Sediment is introduced naturally to the marine environment through river runoff and coastal erosion and is re-suspended during the summer by wind and wave action. Satellite imagery and suspended particulate matter data suggest that turbid waters are generally confined to depths less than 16 ft (5 m; URS 2001). Storms, wind and wave action, and coastal erosion increase turbidity in shallow waters periodically during the open-water season. Turbid conditions persist in areas where the sea floor consists primarily of silts and clays as opposed to areas having a predominantly sand bottom.

One the most comprehensive studies of turbidity in the region was performed as part of the Endicott Monitoring Program. Data points included turbidity, TSS, and secchi disk measurements (Hachmeister et al. 1987). Correlation between in situ turbidity and laboratory TSS values was found to be low. The highest turbidity values were found during spring breakup, during periods of heavy precipitation when river discharge was high resulting in turbid plumes that were discharged into the nearshore coastal waters, and following storm activity. In contrast, ADL (2001) found very good agreement between turbidity and TSS values measured in the laboratory on the same discrete samples. In the ADL study, turbidity ranged from 1.8 to 75 nephelometric turbidity units (NTU) and TSS ranged from 2.9 to 119 milligrams per liter (mg/L) measured during the open-water period in the vicinity of the Northstar Development and in Foggy Island Bay.

In winter, the presence of ice cover eliminates external effects of river discharge and wave/current activity that increase suspended sediment concentrations and cause turbidity. Under-ice measurements made in Stefansson Sound during the April to June time period found turbidity, optical backscatter, and TSS levels to be very low in the nearshore waters. Turbidity ranged from 0.15 to 1.35 NTU and TSS ranged from 0.14 to 2.0 mg/L, with the lowest levels observed at the more offshore stations (ADL 2001).

3.0 STUDY DESIGN AND METHODOLOGY

During the summer of 2011, the APP, identified previously as a predecessor project to the Alaska LNG Project, conducted extensive sampling to characterize the general vicinity of the proposed barge channel. During 2014 additional sampling of the same area was conducted to supplement these previous sample results. Sampling conducted during 2014 also included three nearshore areas that were examined as potential disposal areas for the beneficial reuse of the dredge material as beach nourishment/shoreline protection. The data collected from these sampling events, presented herein, were used to satisfy the criteria for evaluation of dredge and disposal areas that fall under Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material.*

3.1 STUDY OBJECTIVES

In accordance with the Section 404(b)(1) guidelines, the 2011 APP data and the supplemental data from the 2014 MSP program characterized the marine environmental conditions at the proposed test trench areas (see Figure 1-2). The 2014 MSP sampling program was also designed to characterize the marine environmental conditions at the proposed disposal site options and to evaluate the suitability of the test trench dredge material for disposal, particularly beneficial reuse, at each of the three disposal site options. This information was used to assess potential effects resulting from the disposal action on each of the proposed disposal site options.

Program objectives are as follows:

- Document grain size of the test trench dredge materials and disposal sites. Determine if the sediment grain size at the test trench sites is compatible with the disposal sediments for the reuse of dredge material as beach nourishment for beneficial use.
- Establish existing concentrations of the chemicals, metals, and conventional parameters in sediments at the test trench dredge sites and the disposal sites. Determine if concentrations of dredge materials exceed regulatory screening levels and if they are compatible with the disposal sediments.
- Ascertain information regarding the biological resources in the test trench area and disposal sites. Investigate benthic communities at test trench areas and disposal sites that may be affected by disposal of dredged sediments.
- Gain an understanding of the nature of oceanographic conditions (e.g., temperatures, salinities, stratification) in the test trench and disposal areas.
- Provide data to address Section 404(b)(1) guidelines for the evaluation and testing of dredge material and the specification of disposal sites for dredged or fill material.
- Provide data for planning and design of dredge and disposal operations.

The evaluations presented in this report are intended to provide the information necessary to determine the suitability of the sites for dredge disposal and to predict potential impacts of that action. The parameters measured are those indicative, either directly or indirectly, of the potential immediate and long-term impact of the dredged material on the environment at the disposal sites and on adjacent water areas.

3.2 Study Approach

The 2014 MSP included collection and analysis of water quality, benthos, sediment chemistry, and demersal fish and invertebrates at two of the test trench site locations (i.e., #3A and #3B) and at three proposed disposal site locations (KLI 2014). Data to characterize test trench site locations #1, #2A and #2B were collected during the 2011 APP sampling event (APP 2012). Both study programs (i.e., 2011 APP and 2014 MSP) were designed to characterize the marine sediments and extensively investigate sediment grain size. Grain size is an important parameter for determining if dredge material can be used for beneficial use such as erosion control or beach nourishment.

3.3 Sampling Design and Methodology

To satisfy the objectives of the program of obtaining representative biological, chemical, and physical data for the proposed disposal sites, sampling efforts were heavily allocated to the three proposed disposal areas. The three disposal sites are located where disposal material would be reused to provide beneficial use by providing nearshore beach nourishment and erosion protection along the southern shoreline of Prudhoe Bay (Site 1; SBAY), along the northwestern shore of Prudhoe Bay (Site 2; WEST), and on the outer coast of Egg Island (Site 3; EGG). Locations of the three potential dredge material disposal areas being evaluated in 2014 are depicted in Figure 3-1, Figure 3-2, and Figure 3-3.

To satisfy the objectives of characterizing dredge materials, sampling with a greater degree of chemical characterization was performed at five stations within the targeted test trench area to specifically characterize sediments to be dredged during winter/spring 2015. Two of the potential dredge site locations (#3A and #3B) were sampled in 2014 and were located in approximately 12 ft water depth. The other three potential test trench sites (#1, #2A, and #2B) were sampled in 2011 and were located in shallower water closer to DH2 (refer to Figure 1-2).

3.3.1 Station Selection

Since the nearshore locations were being evaluated for the potential disposal of sediments for beneficial use as beach nourishment, the design of the program utilized both the USACE Seattle District guidelines (2013) and the USACE Los Angeles District guidelines for sampling, testing, and data analysis of dredge material (1989). The Los Angeles guidelines specified that when dredge material is to be placed on a beach that: "At least two profiles should be sampled for a receiving beach one mile or less in length with a least one additional profile for every 1/2-mile of beach affected." For the test-trench program, it is estimated that 32,000 yd^3 will be disposed of over a 4-5 acre area, which translates into an area of approximately 103 ft wide by 2000 ft long covered with an average layer of sediment that is 5 ft deep.

Figure 3-1. Disposal Reuse Site 1 - South Prudhoe Bay (SBAY)

Figure 3-2. Disposal Reuse Site 2 - West Shoreline Prudhoe Bay (WEST)

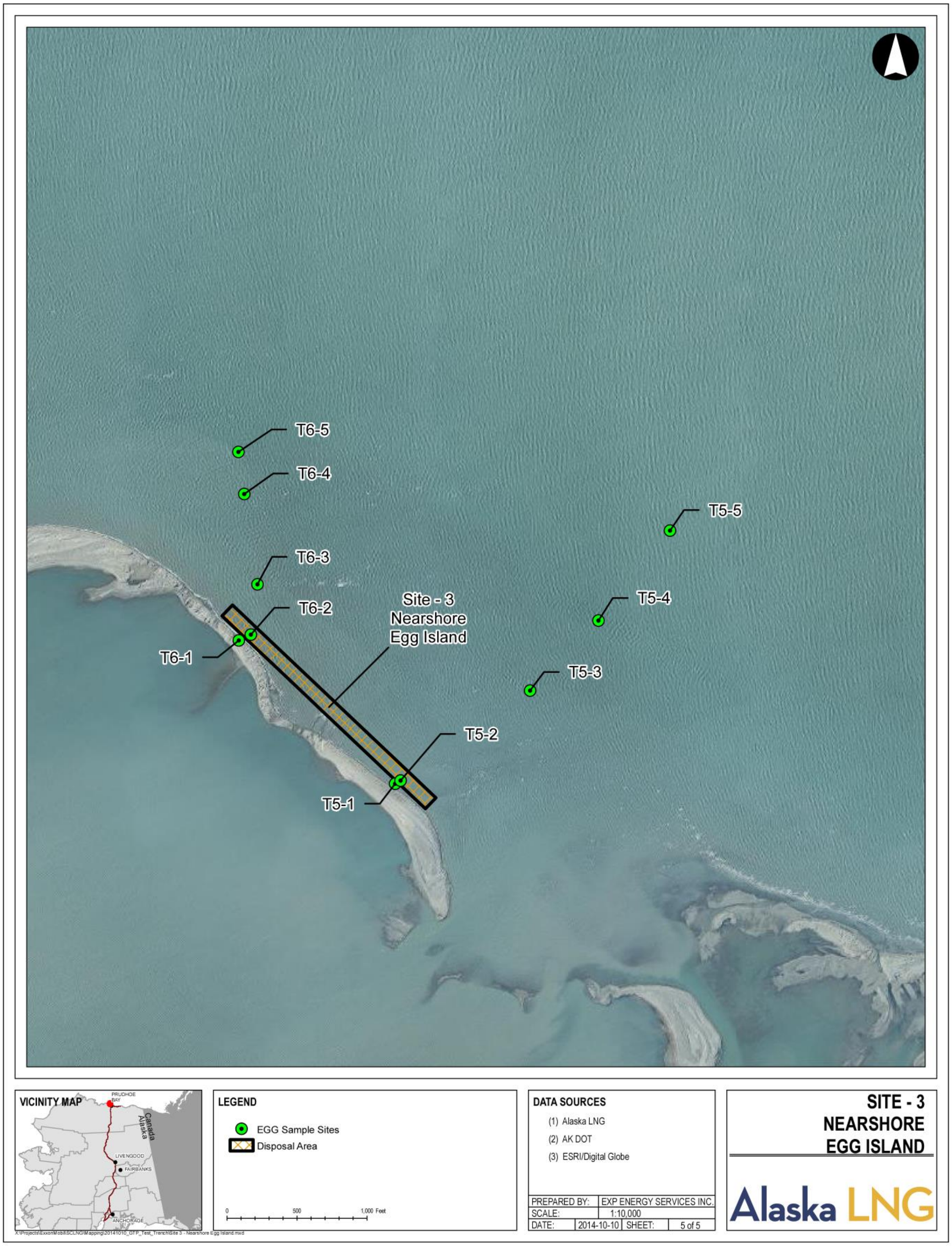

Figure 3-3. Disposal Reuse Site 3 - Nearshore Egg Island (EGG)

Based on this information, the design of the sampling program at each nearshore disposal site included two sample transects (profiles) extending from below the MLLW level to the offshore region beyond the disposal area. Each transect included five sampling stations, with sampling emphasis on collection of sediment grain size (refer to Figure 3-1, Figure 3-2, and Figure 3-3).

3.3.2 Number and Types of Samples Collected

Section 404(b)(1) guidelines for the sampling of dredge material and disposal sites do not include specific numbers and types of samples, but include guidelines on the type of characterization that should take place. Therefore, the numbers and types of samples planned for this study were based on the *Dredged Material Evaluation and Disposal Procedures – User Manual* (USACE 2013) for the Seattle District and on those described above that were developed by the USACE Los Angeles District. A summary of the sample analyses and number of samples that were taken in the dredge area and at the five potential test trench sites is show below in Table 3-1 and at the three disposal sites in Table 3-2.

Some of the analyses that were originally conducted in 2011 were modified, in some instances, from the recommended program outlined in the 2013 Seattle District DMMP guidelines. For example, dioxin is an important parameter that needs to be assessed in Puget Sound, but dioxin is not a concern for the Beaufort Sea in Alaska. These modifications reflect recognition of the unique nature of the oceanography and marine biology of the proposed disposal area and on the type and level of industrial activity that takes place in the

Table 3-1. Summary of 2011 and 2014 Test Trench Area Sampling

Parameter	Number of Samples (excluding QC)					
	2011 APP Sampling[1]				2014 MSP Sampling	
	#1	#2A	#2B	Dredge Area	#3A	#3B
Sediment Quality						
Sediment Grain Size	2	2	1	26	6	6
Conventional Parameters	2	2	1	26	6	6
DRO/RRO	2	2	1	26	6	6
GRO & BTEX[2]	2	2	1	26		
Metals	2	2	1	26	6	6
PAHs				6	6	6
PCBs				6	6	6
Pesticides				6	6	6
AVS with SEM	2	2	1	26	6	6
Biological Monitoring						
Infauna (1.0 mm) fraction				9	6	6
Megafauna (6.4 mm) fraction				9	6	6
Water Quality & Oceanography						
Hydrographic Profiles	1		1	8	1	1
Turbidity/TSS Samples	1		1	8	2	2

1 Some of the analyses in 2011 (e.g., PAHs, PCBs, pesticides, and benthics) were only performed in the greater dredge area since a site specific test trench program was not being considered at that time.

2 The 2014 MSP did not include GRO or BTEX analyses due to a lack of potential sources and the fact that all prior sampling results in the area were non-detect.

Table 3-2. Summary of 2014 Disposal Area Sampling

Parameter	Number of Samples (excluding QC)		
	2014 MSP Disposal Area Sampling		
	Site 1 SBAY	Site 2 WEST	Site 3 EGG
Sediment Quality			
Sediment Grain Size	10	10	10
Conventional Parameters	6	6	6
DRO/RRO	6	6	6
Metals	6	6	6
Biological Monitoring			
Infauna (1.0 mm) fraction	18	18	18
Megafauna (6.4 mm) fraction	18	18	12[1]
Bottom Trawls	4	4	4
Algae	Opportunistic	Opportunistic	Opportunistic
Water Quality & Oceanography			
Hydrographic Profiles	4	4	4
Turbidity/TSS Samples	10	10	10

1 Due to safety concerns as a result of high surf and wave action the two innermost locations at Egg Island could not be sampled for megafauna.

dredge area. In particular, the proposed disposal area is relatively small (~5 acres), shallow (< 4 ft), is ice-covered for about eight months each year, and is located within the bottom-fast ice zone where benthic organisms must recolonize on an annual basis. The shallow depths and generally windy conditions limit the need for detailed examination of depth stratification of oceanographic phenomena. The relatively shallow and flat bathymetry and limited size of the proposed disposal area limits the heterogeneity of the benthic environment and hence the number of samples needed to represent the area.

Sampling of the three potential nearshore reuse disposal areas mirrored each other with the exception of sampling depths where the Prudhoe Bay locations (Sites 1 and 2; SBAY and WEST) were modified to reflect that the disposal areas are much shallower when compared to the Egg Island (EGG; Site 3) site. A total of five sampling stations were sampled on each beach transect as described below, field conditions permitting, resulting in 10 stations per site (five on each of two transects). These stations extended along the length of each transect from the shallow subtidal area where dredge material would be placed during winter to offshore beyond the potential zone of where dredge material would be deposited. Trawling was performed at shallow and deep locations within each of the disposal sites.

3.3.3 Sediment Sampling Design and Methodology

Sediment characterization and chemistry samples that were collected and analyzed for each of three potential disposal sites (SBAY, WEST, and EGG), and five test trench sites (Sites 1, 2A, 2B, 3A and 3B) included the following:

- Sediment grain size distribution
- Total organic carbon (TOC)

- Metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc)
- Hydrocarbons (diesel range organics [DRO] and residual range organics [RRO])

In addition to these sediment parameters, a larger suite of chemical parameters was analyzed at the test trench locations to further characterize the dredge sediments and be consistent between the 2011 APP and 2014 MSP survey efforts:

- Ammonia
- Total sulfides
- Total volatile solids (TVS)
- Acid volatile sulfides (AVS) with simultaneously extractable metals (SEM; cadmium, copper, lead, mercury, nickel, and zinc)
- Polycyclic aromatic hydrocarbons (PAHs)
- Chlorinated pesticides
- Polychlorinated biphenyl compounds (PCBs)

Previous sediment sampling during 2011 also included gasoline range organics (GRO) and benzene, toluene, ethylbenzene, and xylenes (BTEX). These analyses were not included in the 2014 MSP since all BTEX and GRO concentrations found in 2011 were below detection limits and due to the fact that the vast majority of the vessels operating in the West Dock area utilize diesel fuel rather than gasoline.

Sediment samples were collected using three different techniques due to the different water depths and the capabilities of the different sampling vessels (research vessel with hydraulic lifting capability versus a 16-ft inflatable skiff). Techniques included the use of a 0.1-square meter (m^2) stainless steel Smith-McIntyre grab sampler that was utilized on the research vessel and a 4-inch manual hand corer that was utilized in the shallow nearshore sampling effort from the skiff. The third technique was only utilized during 2011 which was the use of a vibracore to obtain sediments cores within the dredge area to the proposed -16 ft dredge depth. Samples were then taken near the surface and near the bottom of each core.

Prior to sampling, all grabs, hand corers, and other non-disposable sampling equipment were scrubbed with dedicated non-metallic bristle brushes and flushed with a deck hose or site rinsed to remove large soil particles. Equipment was cleaned with an Alconox rinsate solution, rinsed with clean seawater, and followed by a final rinse with deionized water. No solvents or other cleaning agents were used since no significant sediment contamination was expected. Samples were processed (collected) using disposable or decontaminated tools in an area that was free of potential contaminant sources (including vessel exhaust) and metal surfaces. Clean nitrile gloves were used during sampling to prevent any contamination of the samples.

3.3.4 Biological Sampling Design and Methodology

Biological samples that were collected and analyzed for the 2011 APP and 2014 MSP include infaunal samples, obtained by collecting whole sediment samples which were sieved to obtain the organisms living in the sediment, and epibenthic samples, which were obtained utilizing an otter trawl to collect or make observations of organisms such as fish and other near-bottom-dwelling organisms and algae.

3.3.4.1 Infauna Sampling Design and Methodology

Infaunal analyses included two size fractions of benthic organisms: the megafaunal fraction was comprised of organisms retained on a 6.4-millimeter (mm) mesh sieve (~1/4 inch), and the macrofaunal fraction contained organisms retained on a 1.0-mm mesh sieve. Infaunal samples were collected at most 2014 MSP stations and at a select few of the 2011 APP dredge area stations, with three replicates of each fraction collected at each station where possible.

Infauna sampling utilized three methods of sampling depending on sampling platform (vessel), water depth, and infaunal fraction. This included the use of the 0.1-m^2 stainless steel Smith-McIntyre or Van Veen grab; a 0.025-m^2 stainless steel petite Ponar grab; and 4-inch hand corer. Samples were sieved to obtain macrofauna (1-mm sieve) and megafauna (6.4-mm sieve) fractions; three replicates of each fraction were collected at each station except as precluded by sediment grain size or field conditions at select stations. Samples from each station were shipped to the taxonomic laboratory for processing and enumeration.

All grabs were visually inspected to ensure they met the outlined acceptability criteria. Once a Smith-McIntyre grab was deemed acceptable, a 0.009-m^2 core was extracted from the center of the grab using the 4-inch hand corer, and this material was screened though a 1-mm sieve to collect macrofauna. Retained material was placed in a pre-labelled plastic sample jar, the organisms were relaxed with propylene phenoxetol, and the sample was preserved in 10% buffered formalin and seawater. The remainder of the grab was sieved through a 6.4-mm sieve for analysis of megafauna, placed in a separate sample container, and handled similarly to macrofauna. For shallower locations where the larger grab could not be utilized, separate Ponar grabs were obtained and composited for the megafauna (6.4-mm) analyses, and a separate 4-inch hand core was collected for the 1-mm macrofauna fraction.

3.3.4.2 Trawl Sampling Design and Methodology

Trawling was performed to further characterize and provide general information regarding the nature and condition of the demersal fish and epibenthic invertebrate assemblages present at the three disposal sites and to determine if any unique hard-bottom areas such as a boulder patch might exist in the these areas.

An otter trawl was employed to collect two replicate nearshore (“Shallow”) and two replicate offshore (“Deep”) trawls at each disposal area for a total of four trawls per disposal site. No trawling was planned or performed at the test trench stations. Trawl samples were collected as 10-minute tows at a speed of approximately 2.5 knots (~750 m). Replicate trawls where performed were run in opposite directions (e.g., east vs. west) parallel to the bathymetry.

Catch was released into an appropriately sized bucket or tote on deck, sorted, and the biota identified and enumerated or estimated. Large fish, algae, and invertebrates were enumerated in the field where possible; in some cases, organisms too numerous to count such as crustaceans were estimated to provide general abundance information. Length was recorded for fish and some larger crustaceans. A limited number of voucher specimens of select unidentified fish and invertebrates as allowed by the Alaska Department of Fish and Game (ADF&G) collection permit were preserved in buffered 10% formalin and returned to the lab for identification. Unidentified voucher algae specimens were retained in chilled seawater for later identification. Any trawl catch that was not retained was released at the sampling site after observations were recorded.

3.3.5 Oceanographic and Water Quality Design and Methodology

Water measurements focused on hydrographic conditions in order to characterize the vertical structure of the water column, and on turbidity and total suspended solids as the parameters that would most likely be affected by the nearshore disposal of dredge sediments. Since the sediment chemistry that was conducted in dredge area in 2011 did not raise any concerns with respect to contaminates and elutriate concentrations during dredge disposal, detailed water chemistry was not warranted. Water observations and samples that were collected during both 2011 and 2014 include the following:

- Hydrographic water column profile of temperature, conductivity, salinity, dissolved oxygen, and turbidity using an in situ SeaBird profiler
- Discrete total suspended solids (TSS) and turbidity samples

Water quality stations were located within each disposal site area and slightly offshore outside of the immediate disposal area in deeper water to serve as reference locations. Due to the shallow water (1-2 ft) at the inshore-most station on each transect, CTD casts were not performed, but water samples were collected for the analysis of TSS and turbidity. Sampling was conducted during 2011 within the general dredge area, whereas in 2014, sampling was performed at the two deeper potential test trench locations.

Because of the relatively undisturbed nature of the disposal areas and the general lack of pollutant sources in the dredge area, no sampling for pollutants in the water column was performed; however, samples were taken for laboratory analysis of TSS and in-field analysis of turbidity during 2014 at two depths (surface and bottom) at two stations within each disposal area and two immediately offshore of each disposal zone. In addition, TSS and turbidity were collected in shallow water at the nearshore-most station along each transect and at surface and bottom at the test trench stations.

Hydrographic profiles were obtained with a high precision SeaBird SEACAT SBE-19 CTD equipped with pressure (depth), conductivity (salinity), temperature, DO, and optical backscatter (turbidity) sensors. Water was collected from near surface and just above the bottom using a standard 5-liter (L) Niskin water sampler. No chemical decontamination of the Niskin bottle was required or performed.

4.0 RESULTS

Analytical results for the 2011 APP (APP 2012) and the 2014 MSP (KLI 2014) are summarized in this section of the report. Data include samples that were collected from four distinct areas that include: (1) five potential test trench site locations that are being characterized for dredge material evaluation, three of which were examined in 2011 (Sites 1, 2A and 2B) and two in 2014 (Sites 3A and 3B); (2) potential dredge sediment disposal reuse along the southern shore of Prudhoe Bay - Site 1 or SBAY; (3) potential dredge sediment disposal reuse along the western shore of Prudhoe Bay – Site 2 or WEST; and (4) potential dredge sediment disposal reuse along the northern shore of Egg Island – Site 3 or EGG. A summary of stations and sampling that was performed at each site was previously presented (see Table 3-1 and Table 3-2). Tabular data are presented in the following sections to summarize data by both area and specific station location. Refer to Figure 1-1, Figure 1-2 and Figure 3-1 through Figure 3-3 for an overview and site specific maps of where sampling took place.

It should be noted that due to the shallow depths at the disposal sites, some of the 2014 sampling locations were adjusted based on how closely the primary survey vessel (draft of 3-3.5 ft) was able to approach shore. This was particularly an issue at EGG since the sampling took place when wave activity restricted the vessel from getting very close to shore. Where possible, sampling activity took place from the primary survey vessel the *R/V Annika Marie* rather than from an inflatable skiff. As a result, the survey transects and stations are not always oriented along a straight perpendicular transect from shore.

4.1 SEDIMENT RESULTS

4.1.1 Sediment Reuse Area Results

4.1.1.1 Reuse Area - Conventional Parameters

Analytical results for conventional parameters, metals, and hydrocarbons are summarized in Table 4-1, Table 4-2, and Table 4-3 for Site 1 - SBAY, Site 2 - WEST, and Site 3 - EGG, respectively. Conventional parameters in the potential dredge material reuse areas include sediment grain size, TOC, and total solids. Where applicable, the data have also been compared to the USACE's Seattle District 2013 DMMP screening levels (USACE 2013) and to ADEC's Arctic Soil Cleanup (18 AAC 75) and recommended sediment quality guideline (SQGs) levels that are based on threshold effects level (TEL) and probable effects level (PEL; ADEC 2013). The TEL represents the concentration below which adverse effects are expected to rarely occur, and the PEL represents the concentration above which adverse effects are frequently expected. A background range is also presented for the Beaufort Sea coastal area that is based on summarized data from BOEM's ANIMIDA and cANIMIDA studies (Exponent 2010 and Neff 2010). In addition to the % fines (silt + clay fraction) that are presented in Table 4-1 through Table 4-3, detailed sediment grain size data for each area and sampling site are presented in Table 4-4.

Table 4-1. Sediment Chemical Data from Site 1 - SBAY Reuse Area

Parameter	Transect #1 Stations and Water Depth (ft)			Transect #2 Stations and Water Depth (ft)			Sediment Screening Values				
	T1-1	T1-3	T1-5	T2-1	T2-3	T2-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(1.7)	(3.8)	(5.7)	(2.7)	(4.0)	(5.5)		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS											
TOC (%)	0.141	0.419	0.443	1.29	0.20	0.182		0.01	6.42		
Silt/Clay (%)	8.16	9.97	10.77	16.67	3.53	4.23		0.1	100		
Total Solids (%)	84.5	77.5	79.9	77.1	78	82.8					
METALS (mg/kg)											
Aluminum	2310	2660	2710	3360	2280	1500					
Antimony	0.081	0.092	0.084	0.088	0.074	0.077	150	0.14	1.14		
Arsenic	3.17	5.16	6.63	4.79	3.97	4.61	57	4.2	28.4	7.24	41.6
Barium	24.4	22.6	26.5	55	20.5	28.5		142	863		
Beryllium	0.134	0.167	0.187	0.19	0.132	0.106		0.3	3.6		
Boron	3.6	6.9	7.4	8.3	4	5.2					
Cadmium	0.113	0.131	0.104	0.162	0.103	0.035	5.1	0.03	0.82	0.68	4.21
Chromium	5.9	7.17	6.95	8.24	5.95	3.75	260	12.7	104	52.3	160
Cobalt	3.15	4.19	4.33	3.72	3.26	2.11		2.2	18.6		
Copper	4.14	5.79	6.17	5.82	3.72	3.44	390	3.6	50.2	18.7	108
Iron	7320	8760	9670	12600	7220	7560		7000	39000		
Lead	2.7	3.75	5.87	3.56	2.65	2.74	450	3.2	22.3	30.24	112
Manganese	91.4	176	156	122	148	56.5		62	898		
Mercury	0.009J	0.014J	0.015J	0.011J	0.008J	0.008J	0.41	0.003	0.20	0.13	0.70
Nickel	9.19	10.6	10.6	13.0	8.72	7.89		6.0	48.4	15.9	42.8
Selenium	0.17J	0.21J	0.25J	0.26J	0.16J	0.12J	3				
Silver	0.023	0.036	0.036	0.034	0.018	0.023	6.1	0.01	0.44	0.73	1.77
Thallium	0.019	0.031	0.032	0.021	0.019	0.017		0.05	0.92		
Vanadium	8	10.6	11.8	11	8.8	7.2		25.2	173		
Zinc	25.2	29.1	30.3	26.8	23.2	17.8	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)											
DRO	3.6JB	42JB	19JB	41Z	8JB	6.3JB	*200*[4]				
RRO	11JB	130Z	58Z	190Z	22JB	18JB	*2000*[4]				
DRO+RRO	14.6	172	77	231	30	24.3		0.39	104		

1 State of Washington Dredged Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects. Selenium value is bioaccumulation trigger.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

5 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

6 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

B = Analyte was found in the associated method blank between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

Underlined values equal or exceed TELs

Table 4-2. Sediment Chemical Data from Site 2 - WEST Reuse Area

Parameter	Transect #3 Stations and Water Depth (ft)			Transect #4 Stations and Water Depth (ft)			Sediment Screening Values				
	T3-1	T3-3	T3-5	T4-1	T4-3	T4-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(1.0)	(2.8)	(5.4)	(1.0)	(2.6)	(5.5)		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS											
TOC (%)	0.457	0.534	3.6	2.2	2.98	0.45		0.01	6.42		
Silt/Clay (%)	12.97	15.53	43.15	19.17	16.29	27.88		0.1	100		
Total Solids (%)	77.9	81.5	68.9	73.5	67.1	80					
METALS (mg/kg)											
Aluminum	3770	3310	4180	2900	2160	2640					
Antimony	0.109	0.106	0.117	0.077	0.047	0.068	150	0.14	1.14		
Arsenic	4.43	4.14	6.02	3.52	3.63	5.28	57	4.2	28.4	7.24	41.6
Barium	49.2	55.9	33.3	57.2	20.6	29.3		142	863		
Beryllium	0.201	0.185	0.27	0.168	0.11	0.168		0.3	3.6		
Boron	3.3	4.4	25.3	7.6	17.1	5.2					
Cadmium	0.246	0.227	0.317	0.198	0.066	0.091	5.1	0.03	0.82	0.68	4.21
Chromium	10	9.16	10.7	7.3	4.92	7.01	260	12.7	104	52.3	160
Cobalt	4.67	3.66	5.89	3.47	2.65	3.87		2.2	18.6		
Copper	8.88	8.12	13.3	5.99	2.99	5.59	390	3.6	50.2	18.7	108
Iron	12600	9150	9930	7950	6890	8710		7000	39000		
Lead	4.14	3.82	5.87	3.39	2.22	4.04	450	3.2	22.3	30.24	112
Manganese	138	215	100	130	131	122		62	898		
Mercury	0.012J	0.009J	0.043	0.011J	0.009J	0.017J	0.41	0.003	0.20	0.13	0.70
Nickel	14.7	13.2	<u>17.6</u>	11.6	7.15	10.5		6.0	48.4	15.9	42.8
Selenium	0.24J	0.22J	0.43J	0.22J	0.15J	0.16J	3				
Silver	0.036	0.037	0.095	0.032	0.023	0.029	6.1	0.01	0.44	0.73	1.77
Thallium	0.032	0.029	0.047	0.027	0.019	0.029		0.05	0.92		
Vanadium	13	12	15.4	10	7.8	11.3		25.2	173		
Zinc	35.8	30.7	42	28	20	28.1	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)											
DRO	5.1J	6.3J	45J	78	41J	21J	*200*[4]				
RRO	12J	32J	360Z	620Z	440Z	78Z	*2000*[4]				
DRO+RRO	17.1	38.3	405	698	481	99		0.39	104		

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

5 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

6 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

B = Analyte was found in the associated method blank between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

<u>Underlined</u> values equal or exceed TELs

Table 4-3. Sediment Chemical Data from Site 3 - EGG Reuse Area

Parameter	Transect #5 Stations and Water Depth (ft)			Transect #6 Stations and Water Depth (ft)			Sediment Screening Values				
	T5-1	T5-3	T5-5	T6-1	T6-3	T6-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(2.5)	(4.2)	(10.4)	(2.4)	(6.7)	(13.2)		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS											
TOC (%)	0.453	0.061	1.21	0.526	0.137	0.492		0.01	6.42		
Silt/Clay (%)	4.45	0.93	48.0	22.2	3.45	25.3		0.1	100		
Total Solids (%)	73.1	79.6	78.9	79.9	87.4	71.2					
METALS (mg/kg)											
Aluminum	2190	1370	2930	1280	1070	3710					
Antimony	0.092	0.087	0.082	0.059	0.054	0.108	150	0.14	1.14		
Arsenic	8.14	5.06	6.23	5.29	4.87	6.92	57	4.2	28.4	7.24	41.6
Barium	24.6	15.5	35.2	18.5	15.6	35.3		142	863		
Beryllium	0.148	0.094	0.201	0.108	0.077	0.219		0.3	3.6		
Boron	6.8	4	11.1	5.7	3	6.9					
Cadmium	0.081	0.018	0.18	0.043	0.028	0.177	5.1	0.03	0.82	0.68	4.21
Chromium	6.92	3.57	8.96	3.38	3.12	11.8	260	12.7	104	52.3	160
Cobalt	5.24	2.8	4.54	2.76	2.29	6.43		2.2	18.6		
Copper	3.77	1.66	8.67	3.34	1.86	6.02	390	3.6	50.2	18.7	108
Iron	9090	6410	9990	6040	5180	12900		7000	39000		
Lead	2.88	1.84	4.05	2.15	1.61	3.53	450	3.2	22.3	30.24	112
Manganese	102	62.2	120	55.4	57.9	145		62	898		
Mercury	0.015J	0.004J	0.028	0.015J	0.006J	0.023	0.41	0.003	0.20	0.13	0.70
Nickel	10.6	5.62	13.6	5.88	4.7	17.8		6.0	48.4	15.9	42.8
Selenium	0.13J	0.06J	0.24	0.08J	0.05J	0.18J	3				
Silver	0.026	0.01J	0.055	0.022	0.013J	0.032	6.1	0.01	0.44	0.73	1.77
Thallium	0.035	0.038	0.042	0.022	0.019	0.039		0.05	0.92		
Vanadium	10	6.4	12.2	6.4	5.2	13.6		25.2	173		
Zinc	25.2	14.8	35.2	15.6	12.7	44.7	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)											
DRO	4.3J	<1.7	8.9J	3.6J	1.8J	4.7J	*200*[4]				
RRO	18J	<3.7	60J	23J	5J	13J	*2000*[4]				
DRO+RRO	22.3	0	68.9	26.6	6.8	17.7		0.39	104		

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

5 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

6 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

Underlined values equal or exceed TELs.

Table 4-4. Sediment Grain Size Summary for Sediment Reuse Areas

Parameter	SBAY (Site 1) Transect #1 Stations					SBAY (Site 1) Transect #2 Stations					Area Mean
	T1-1	T1-2	T1-3	T1-4	T1-5	T2-1	T2-2	T2-3	T2-4	T2-5	
Soil Classification											
% Gravel	3.55	0.57	0.15	6.15	6.24	23.2	15.6	2.25	19.9	21.7	9.93
% Coarse Sand	7.43	4.32	7.95	2.53	12.5	12.3	7.39	8.81	12.2	44.7	12.0
% Medium Sand	33.1	25.5	35.0	9.4	34	16.1	13.5	37.2	20.3	20.6	24.5
% Fine Sand	42.1	52.1	42.7	71.6	35.6	26.4	51.0	41.9	37.0	7.07	40.8
% Very Fine	3.19	6.86	3.95	1.73	0.66	2.58	5.84	1.96	3.08	1.42	3.13
%Total Sand	85.8	88.8	89.6	85.2	82.7	57.4	77.8	89.9	72.6	73.8	80.4
% Silt	5.10	6.16	5.32	2.79	4.83	11.5	2.17	1.68	2.51	2.62	4.47
% Clay	3.06	2.06	4.65	2.35	5.94	5.19	1.13	1.85	1.70	1.61	2.95
% Fines	8.16	8.23	9.97	5.14	10.8	16.7	3.30	3.53	4.21	4.23	7.43
Parameter	**WEST (Site 2) Transect #3 Stations**					**WEST (Site 2) Transect #4 Stations**					**Area Mean**
	T3-1	**T3-2**	**T3-3**	**T3-4**	**T3-5**	**T4-1**	**T4-2**	**T4-3**	**T4-4**	**T4-5**	
Soil Classification											
% Gravel	0.039	38.9	6.08	7.03	10.1	8.73	19.6	23.4	3.72	4.111	12.2
% Coarse Sand	1.24	9.6	7.32	7.47	7.96	9.89	12.7	4.78	12.02	9.49	8.25
% Medium Sand	8.8	12.3	19.2	24.5	17.1	22.6	22.5	27.4	34.7	20.25	20.9
% Fine Sand	60.7	22.3	39.5	37.7	16.7	28.8	26.5	22.4	34.8	25.25	31.5
% Very Fine	15.2	4.07	9.23	8.63	5.03	6.70	3.64	2.63	5.37	11.31	7.18
%Total Sand	85.9	48.3	75.2	78.3	46.8	67.9	65.4	57.3	86.8	66.3	67.8
% Silt	10.2	9.58	11.2	9.86	33.9	13.1	13.6	11.1	4.63	23.8	14.1
% Clay	2.80	2.08	4.29	2.47	9.23	6.12	4.04	5.15	1.30	4.12	4.16
% Fines	13.0	11.7	15.5	12.3	43.2	19.2	17.6	16.3	5.93	27.9	18.3
Parameter	**EGG (Site 3) Transect #5 Stations**					**EGG (Site 3) Transect #6 Stations**					**Area Mean**
	T5-1	**T5-2**	**T5-3**	**T5-4**	**T5-5**	**T6-1**	**T6-2**	**T6-3**	**T6-4**	**T6-5**	
Soil Classification											
% Gravel	4.07	5.44	2.67	26.6	2.35	34.6	0.05	59.8	0.12	0.00	14.0
% Coarse Sand	2.75	2.23	5.95	11.4	10.8	3.63	0.62	6.77	1.98	0.18	4.62
% Medium Sand	10.7	6.89	47.4	14.6	16.3	15.5	7.61	13.4	59.2	0.46	19.2
% Fine Sand	74.3	71.7	40.3	34.7	14.0	24.2	40.3	17.8	31.6	30.3	37.9
% Very Fine	4.42	5.72	0.31	6.62	8.05	1.13	18.0	1.48	2.16	38.6	8.65
%Total Sand	91.5	86.5	94.0	67.3	49.1	44.5	66.5	36.7	94.9	69.6	70.4
% Silt	3.66	2.64	0.34	5.19	43.6	19.0	31.0	2.99	0.89	23.5	13.2
% Clay	0.78	0.89	0.59	0.85	4.41	3.18	1.33	0.47	0.79	1.74	1.50
% Fines	4.45	3.54	0.93	6.04	48.0	22.2	32.3	3.45	1.68	25.3	14.7

Concentrations of TOC for all locations were found to be within the range of those seen for the Beaufort Sea coastal regional, but a fair amount of variability was still seen within each study area as a result of varying peat and detrital content. TOC at SBAY ranged from 0.141 to 1.29% with no clear pattern related to distance from shore. Concentrations of TOC ranged from 0.45 to 3.6% at WEST and from 0.061 to 1.21% at EGG.

Sediment grain size analysis indicated that the sediment compositions at each location were not uniform, but contained varying amounts of fines versus coarser sands and gravels. Percent fines measured as the silt + clay fraction ranged from 3.3 to 16.7% at SBAY, from 5.93 to 43.2% at WEST, and from 0.93 to 48.0% at EGG. In general, sand was the most common size fraction at all locations, with fine sand usually being the most common classification within the sand fraction, although there appeared to be more variability at EGG since the transects extended into deeper water. A number of the stations also were found to have significant amounts of small gravel with concentrations ranging from 0.15 to 23.2% at SBAY, 0.04 to 23.4% at WEST, and 0.0 to 59.8% at EGG.

4.1.1.2 Reuse Area - Total Metals

Analytical results for total metals from the three potential dredge material reuse areas are presented in Table 4-1 through Table 4-3. Analyses included 20 metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Metal concentrations were compared to USACE/EPA 2013 DMMP criteria, ADEC recommended SQGs, and the range of Beaufort Sea background sediments. In all instances, metals at all three of the potential sediment reuse areas (SBAY, WEST, and EGG) were found to below both the DMMP SLs and ADEC's recommended SQG for the PEL. Concentrations were found to be within the range of background sediments for the Beaufort Sea coastal area.

One arsenic and one nickel concentration that were measured at EGG and one nickel concentration measured at WEST did exceed their TELs; however, as noted earlier, Beaufort Sea sediments are naturally high in these metals when compared to some of the low level SQGs. The highest nickel concentration measured was at EGG-Station T5-5 at a concentration of 17.8 milligrams/kilogram (mg/kg) compared to the TEL of 15.9 mg/kg and a value of 56 mg/kg for average continental crust material (Wedepohl 1995). Similarly, for arsenic, the highest concentration measured was at EGG Station T5-1 at a concentration of 8.14 mg/kg compared to the TEL of 7.24 mg/kg and a value of 7.7 mg/kg for typical marine sediments (Trefry et al. 2003). Trefry et al. (2003) and Exponent (2010) have shown that arsenic, copper, and nickel in Beaufort Sea sediments often exceed SQGs, the concentrations are naturally occurring, and suspended sediment introduced by rivers in the region have similar concentrations.

The metals barium, chromium, lead, and zinc that are most often associated with oil exploration and development were found to be typical for the Beaufort area. Similarly, metals associated with refined petroleum products such as lead and vanadium were not found to be obviously elevated in any sample. Based on this comparison, it would appear that the sediments in the three potential dredge material reuse areas should be considered pristine in terms of metals concentrations and that variability seen within and between sites can be explained by variations in % solids, sediment grain size distribution, TOC, and sediment source/mineralogy. Trefry et al. (2003) found that trace metals in the Beaufort coastal area correlated well with both aluminum and iron since most metals are generally low in quartz sand or carbonate shell material and high in the fine-grained metal-bearing alumino-silicates contained in silt and clay.

4.1.1.3 Reuse Area - Petroleum Hydrocarbons

Sediments in the three potential reuse areas were analyzed for diesel range organics (DRO; C_{10}-C_{25}) and residual range organics (RRO; C_{25}-C_{36}). Concentrations of DRO and RRO in all samples and areas were found to be below ADEC-recommended soil cleanup levels for the Arctic. Concentrations of DRO ranged from 6.3 to 42 mg/kg at SBAY, from 5.1 to 78 mg/kg at WEST, and from <1.7 to 8.9J mg/kg at EGG compared to the ADEC cleanup level of 200 mg/kg. (Concentrations below reporting limits were qualified with a "J" flag as estimates.) Concentrations of RRO ranged from 11 to 190 mg/kg at SBAY, from 12 to 620 mg/kg at WEST, and from <3.7 to 60J mg/kg at EGG compared to the cleanup level of 2000 mg/kg. A number of samples appeared to have elevated levels of both DRO and RRO; however, on closer examination of the chromatographic fingerprints by the laboratory, the samples were flagged with a "Z" indicating that chromatograms did not resemble a petroleum product. Most of these same samples also had higher TOC concentrations which indicate high peat levels and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes.

Similar results were seen in the ANIMIDA and cANIMIDA studies which examined hydrocarbons in detail across the entire Central Beaufort Sea coastal area, where the surficial sediments in the Prudhoe region were found to exhibit a mixture of primarily terrestrial biogenic hydrocarbons with lower levels of petrogenic hydrocarbons (Exponent 2010 and Neff 2010). The petrogenic components of the PAH signatures were found to include background concentrations of petroleum and coal with lesser contributions from pyrogenic or combustion related compounds.

4.1.2 Sediment Test Trench Area Results

Three of the five potential test trenches sites coincide with three of the 2011 APP vibracore sampling locations. These locations are identified as 03E for Test Trench Site #1, 02K for Test Trench Site #2A, and 02M for Test Trench Site #2B. There were no 2011 vibracore locations associated with the Test Trench Sites #3A and #3B (designated Stations TTR-3A and TTR-3B). As such, three surface grabs samples were collected at each of these two test trench locations during the 2014 MSP to supplement the 2011 vibracore physical data. Analytical data from 2014 for Sites #3A and #3B are provided in Table 4-5 and Table 4-6. Analytical data from 2011 for Sites #1, #2A, and #2B are provided in Table 4-7. Sediment grain size and physical data are provided in Table 4-8 for 2014 and in Table 4-9 for 2011.

Table 4-5. 2014 Sediment Chemical Data from Test Trench Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values				
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS											
Ammonia (mg/kg)	0.99	1.12	1.48	0.83	4.55	3.87					
AVS (mg/kg)	0.47	0.46	0.41	0.242	0.49	0.151					
Sulfides (mg/kg)	21.5	38.6	18.0	9.1	16.3	8.4					
TVS (%)	8.99	6.62	4.73	4.51	5.27	4.69					
TOC (%)	1.91	1.37	0.541	0.475	0.736	0.650		0.01	6.42		
Silt/Clay (%)	89.6	70.1	62.7	22.0	43.2	37.3		0.1	100		
Total Solids (%)	60.9	69.4	70.8	73.9	71.2	71.5					
METALS (mg/kg)											
Aluminum	6270	4960	4570	3560	4890	4350					
Antimony	0.133J	0.126J	0.106J	0.101J	0.106J	0.112J	150	0.14	1.14		
Arsenic	9.88	8.23	6.05	7.29	8.34	8.63	57	4.2	28.4	7.24	41.6
Barium	61.4	54.2	46.8	37.0	45.9	45.7		142	863		
Beryllium	0.417	0.302	0.245	0.213	0.297	0.266		0.3	3.6		
Boron	21.5	14.7	8.4	8.9	11.3	10.6					
Cadmium	0.371	0.294	0.222	0.204	0.220	0.195	5.1	0.03	0.82	0.68	4.21
Chromium	17.3	14.7	13.4	11.0	14.3	13.0	260	12.7	104	52.3	160
Cobalt	7.52	6.99	6.04	5.95	6.82	6.56		2.2	18.6		
Copper	19.8	13.2	8.47	6.32	10.6	9.38	390	3.6	50.2	18.7	108
Iron	18400	15600	13900	13700	15800	15100		7000	39000		
Lead	8.76	6.04	4.22	3.74	5.62	5.18	450	3.2	22.3	30.24	112
Manganese	268	220	199	193	217	203		62	898		
Mercury	0.053	0.033	0.025	0.018J	0.027	0.024	0.41	0.003	0.20	0.13	0.70
Nickel	25.4	22.2	19.4	16.0	20.0	18.5		6.0	48.4	15.9	42.8
Selenium	0.50J	0.36J	0.21J	0.18J	0.25J	0.22J	3				
Silver	0.128	0.078	0.044	0.032	0.056	0.043	6.1	0.01	0.44	0.73	1.77
Thallium	0.076	0.069	0.050	0.033	0.045	0.043		0.05	0.92		
Vanadium	24.7	19.8	16.8	14.5	18.8	17.4		25.2	173		
Zinc	67.2	54.9	47.2	40.0	50.8	46.4	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)											
DRO	35 Z	14 J	6.3 J	6.4 J	16 J	11 J	*200*[4]				
RRO	190 Z	73 J	22 J	30 J	56 J	40 J	*2000*[4]				
DRO+RRO	225	87	28.3	36.4	72	51		0.39	104		

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.

5 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

6 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

Underlined values equal or exceed TELs.

Table 4-6. 2014 Sediment Pesticide, PCB, SEM, and PAH Data for Sites #3A and #3B

Parameter	Surface Sediment Grabs						Sediment Screening Values		
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		TELs[4]	PELs[5]
Chlorinated Pesticides (µg/kg, dry)									
4,4'-DDD	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	16	1.22	7.81
4,4'-DDE	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	9	2.07	374
4,4'-DDT	0.081 J	0.13 J	< 0.078	< 0.091	< 0.078	< 0.078	12	1.19	4.77
Total DDT[6]	0.081	0.13	0	0	0	0		3.89	51.7
alpha-BHC	0.077 J	< 0.064	< 0.064	< 0.064	< 0.064	< 0.064			
beta-BHC	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18			
gamma-BHC	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051		0.32	0.99
delta-BHC	< 0.086	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070			
Aldrin	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056	9.5		
Dieldrin	< 0.083	< 0.12	< 0.083	< 0.083	< 0.083	< 0.083	1.9	0.72	4.3
Endrin	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057			
Heptachlor	< 0.055	< 0.055	< 0.055	< 0.055	< 0.055	< 0.055	1.5		
Heptachlor Epoxide	< 0.23	< 0.23	< 0.23	< 0.23	< 0.23	< 0.23			2.74
gamma-Chlordane	< 0.072	< 0.097	< 0.072	< 0.072	< 0.072	< 0.072			
alpha-Chlordane	< 0.063	< 0.063	< 0.063	< 0.063	< 0.063	< 0.063			
Total Chlordane[6]	0	0	0	0	0	0	2.8	2.26	4.79
Endosulfan I	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060	< 0.060			
Endosulfan II	< 0.091	< 0.091	< 0.091	< 0.091	< 0.091	< 0.091			
Endrin Aldehyde	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061			
Endosulfan Sulfate	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051	< 0.051			
Endrin Ketone	< 0.076	< 0.076	< 0.076	< 0.076	< 0.076	< 0.076			
Methoxychlor	0.16 J	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15			
Toxaphene	< 14	< 14	< 14	< 14	< 14	< 14		0.1	
Polychlorinated Biphenyls (PCBs; µg/kg, dry)									
Arochlor 1016	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1221	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1232	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1242	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1248	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Arochlor 1254	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1		63.3	709
Arochlor 1260	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1			
Total PCBs[6]	0	0	0	0	0	0	130	21.6	189
Acid Volatile Sulfides and Simultaneously Extractable Metals (µMole/g, dry)									
AVS	0.47	0.46	0.41	0.242	0.49	0.151			
Cadmium	0.00333	0.00188	0.0015	0.00099J	0.00155	0.00141			
Copper	0.129	0.0640	0.0375	0.0337	0.0533	0.0450			
Lead	0.0306	0.0162	0.0115	0.0098	0.0169	0.0148			
Mercury (nMole/g)	< 0.021	< 0.017	< 0.017	< 0.015	< 0.018	< 0.017			
Nickel	0.0963	0.0545	0.0442	0.0380	0.0532	0.0429			
Zinc	0.454	0.263	0.216	0.163	0.239	0.210			
Total SEM	0.713	0.400	0.311	0.246	0.364	0.314			
Ratio SEM/AVS	1.52	0.87	0.76	1.01	0.74	2.08			
(SEM-AVS)/F_{oc}	12.7	<0	<0	0.7	<0	25.1			

Table 4-6. (Continued)

Parameter	Surface Sediment Grabs						Sediment Screening Values		
	Trench Site #3A Station TTR-3A			Trench Site #3B Station TTR-3B			DMMP SLs[1]	ADEC Recommended SQGs[3]	
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3		TELs[4]	PELs[5]
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg, dry)									
Naphthalene	8.3	6.2	2.4 J	1.2 J	3.1 J	3.2 J	2100	34.6	391
2-Methylnaphthalene	19	14	5.6	2.7 J	7.5	7.1	670	20.2	201
Acenaphthylene	< 0.59	< 0.59	< 0.59	< 0.59	< 0.59	< 0.59	560	5.87	128
Acenaphthene	0.85 J	< 0.76	< 0.76	< 0.76	< 0.76	< 0.76	500	6.71	88.9
Dibenzofuran	4.3	3.1 J	1.2 J	< 0.63	1.7 J	1.6 J	540		
Fluorene	3.3 J	2.2 J	0.89 J	< 0.61	1.6 J	1.4 J	540	21.2	144
Phenanthrene	20	15	5.9	2.9 J	8.8	7.6	1500	86.7	544
Anthracene	< 0.58	< 0.58	< 0.58	< 0.58	< 0.58	< 0.58	960	46.9	245
LPAH[6]	55.8	40.5	16.0	6.8	22.7	20.9	5200	312	1442
Fluoranthene	3.5 J	2.9 J	1.3 J	< 0.98	1.8 J	1.4 J	1700	113	1494
Pyrene	4.0 J	3.3 J	1.3 J	0.79 J	2.0 J	1.8 J	2600	153	1398
Benz(a)anthracene	1.1 J	0.98 J	< 0.72	< 0.72	< 0.72	< 0.72	1300	74.8	693
Chrysene	3.7 J	2.9 J	1.2 J	< 0.80	1.7 J	1.6 J	1400	108	846
Benzo(b)fluoranthene	3.6 J	3.3 J	1.1 J	< 0.92	1.9 J	1.7 J	3200		
Benzo(k)fluoranthene	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87			
Benzo(a)pyrene	1.1 J	0.84 J	< 0.76	< 0.76	< 0.76	< 0.76	1600	88.8	763
Indeno(1,2,3-c,d)pyrene	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	< 0.87	600		
Dibenz(a,h)anthracene	< 0.80	< 0.80	< 0.80	< 0.80	< 0.80	< 0.80	230	6.22	135
Benzo(g,h,i)perylene	2.6 J	2.1 J	0.89 J	< 0.85	1.3 J	1.2 J	670		
HPAH[6]	19.6	16.3	5.8	0.8	8.7	7.7	12000	655	6676
Total PAH[6]	75.4	56.8	21.8	7.6	31.4	28.6		1684	16770

1 State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects. Selenium value is bioaccumulation trigger.

2 Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.

3 ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.

4 Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).

5 Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

6 Summed parameters (e.g., Total PAH, Total PCBs, etc.) utilize 0.0 in the calculation where an analyte was ND.

† gamma-Chlordane – For this analyte (CAS Registry No. 5103-74-2), USEPA has corrected the name to be beta-Chlordane, also known as trans-Chlordane.

J Estimated value for concentrations between the MDL and RL and for concentrations that did not meet QC objectives.

< The analyte was analyzed for, but was not detected (ND) at or above the MDL.

Table 4-7. 2011 Sediment Chemical Data for Test Trench Sites #1, #2A, and #2B

Parameter	Test Trench Vibracore Samples (Depth Intervals in ft MLLW)					Sediment Screening Values				
	Trench #1 Vibracore 03E		Trench #2A Vibracore 02K		TR #2B Core 02M	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	(0-1.5)	(4.0-5.0)	(0-1.5)	(4.0-5.0)	(0-1.0)		Lower	Upper	TELs[5]	PELs[6]
CONVENTIONAL PARAMETERS										
Ammonia (mg/kg)	11.4	13.4	9.31	15.6	<0.06					
Sulfides (mg/kg)	179J	30.7J	114	265	8.4					
TVS (%)	6.53	6.79	4.99	5.72	2.93					
TOC (%)	1.10	1.99	1.24	1.66	0.19		0.01	6.42		
Silt and clay (%)	62	39	45	66	15		0.1	100		
Total Solids (%)	70.2	71.9	73.7	73.0	73.4					
METALS (mg/kg, dry)										
Aluminum	6550	3250	5140	6130	3770					
Antimony	0.10	0.04J	0.06	0.12	0.08	150	0.14	1.14		
Arsenic	7.61	3.75	5.40	8.41	5.49	57	4.2	28.4	7.24	41.6
Barium	63.7	38.0	52.4	52.4	35.5		142	863		
Beryllium	0.338	0.130	0.213	0.302	0.172		0.3	3.6		
Boron	18.6	24.1	10.6	17.5	6.7					
Cadmium	0.294	0.113	0.209	0.264	0.151	5.1	0.03	0.82	0.68	4.21
Chromium	14.5	7.01	9.45	13.4	8.99	260	12.7	104	52.3	160
Cobalt	8.230	2.780	6.700	8.630	4.990		2.2	18.6		
Copper	14.9	4.33	5.40	12.0	4.25	390	3.6	50.2	18.7	108
Iron	17300	7120	15100	16400	13800		7000	39000		
Lead	6.690	3.070	3.610	6.080	3.050	450	3.2	22.3	30.24	112
Manganese	243	57.0	245	254	193		62	898		
Mercury	0.041	0.019	0.017J	0.043	0.012J	0.41	0.003	0.20	0.13	0.70
Nickel	25.7	9.5	16.7	24.4	13.5		6.0	48.4	15.9	42.8
Selenium	0.6J	0.3J	0.4J	0.6J	0.2J	3				
Silver	0.084	0.035	0.040	0.101	0.021	6.1	0.01	0.44	0.73	1.77
Thallium	0.053	0.025	0.036	0.067	0.024		0.05	0.92		
Vanadium	20.8	9.2	17.4	20.8	12.5		25.2	173		
Zinc	75.8	33.0	58.0	69.5	50.4	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg, dry)										
BTEX Compounds	ND	ND	ND	ND	ND					
GRO	<1.6	<1.5	<1.7	<1.5	<1.5	100				
DRO	13J	23J	10J	10J	2.8J	*200*[4]				
RRO	75J	190Z	42J	44J	<40	*2000*[4]				
TPHC (DDR + RRO)	88	210	25	54	2.8		0.39	104		

1. State of Washington Dredge Material Management Program (DMMP) sediment Screening Levels (SLs) (Seattle DMMO, 2013). SLs are concentrations of contaminants which at or below are expected to cause no adverse effects. Selenium value is bioaccumulation trigger.
2. Range of sediment concentrations throughout the Beaufort Sea coastal area from 1999 to 2006. Source is from Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies. These ranges are considered background concentrations because of the large spatial and temporal variability in data.
3. ADEC (2013). Memorandum recommending the use of TEL and PEL Sediment Quality Guidelines.
4. ADEC (2011). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.
5. Threshold Effects Levels (TELs) from McDonald et al. (2000) and Buchman (2008).
6. Probable Effects Levels (PELs) from McDonald et al. (2000) and Buchman (2008).

J = Estimated value for concentrations between the MDL and RL.

Z = The chromatographic fingerprint does not resemble a petroleum product.

Underlined values equal or exceed TELs.

Table 4-8. 2014 Sediment Grain Size for Test Trench Sites #3A and #3B

Parameter	Trench Site #3A				Trench Site #3B			
	Rep1	Rep2	Rep3	Mean	Rep1	Rep2	Rep3	Mean
Soil Classification								
% Gravel	0	0.01	0	0.003	0	0	0	0
% Coarse Sand	0.05	0.02	0.03	0.033	0.01	0.04	0.03	0.027
% Medium Sand	0.06	0.04	0.03	0.043	0.04	0.04	0.08	0.053
% Fine Sand	2.12	4.53	4.35	3.67	50.9	28.1	42.2	40.4
% Very Fine	7.72	23.6	30.8	20.7	23.9	25.2	19.2	22.8
%Total Sand	10.0	28.2	35.2	24.5	74.8	53.3	61.5	63.2
% Silt	74.4	62.2	57.5	64.7	18.3	31.7	28.7	26.2
% Clay	15.2	7.8	5.2	9.4	3.7	11.6	8.6	8.0
% Fines	89.6	70.1	62.7	74.1	22.0	43.2	37.3	34.2

Table 4-9. 2011 Sediment Characteristics for Test Trench Sites #1, #2A, and #2B

Parameter	Test Trench and Associated 2011 Vibracore Samples and Depth Intervals within Core (ft)				
	Trench Site #1 Vibracore 03E		Trench Site #2A Vibracore 02K		Trench Site #2B Vibracore 02M
	(0-1.5)	(4.0-5.0)	(0-1.5)	(4.0-5.0)	(0-1.0)
% Solids	72.3	72.0	74.1	72.3	76.2
% TOC	1.10	1.99	1.24	1.66	0.19
Soil Classification	ML	SM	SM	ML	SM
% Gravel	0.0	2.8	0.0	0.0	0.0
% Coarse Sand	0.0	1.3	0.0	0.0	0.0
% Medium Sand	0.2	5.6	0.1	0.1	0.3
% Fine Sand	37.9	51.7	54.9	34.0	84.9
%Total Sand	38.1	58.6	55.0	34.1	85.2
% Silt	44	29	32	43	10
% Clay	18	10	13	23	5
% Fines (<0.075 mm)	62	39	45	66	15
Specific Gravity (20°C)	2.69	2.6	2.71	2.69	2.71
Plasticity Index	2.3	NP	NP	8.2	NP

NP = Non-Plastic

4.1.2.1 Test Trench - Conventional Parameters

The 2011 vibracore logs showed that sediments from most cores within the dredge channel area were physically heterogeneous. Most cores were described with two to six alternating strata of sand (SP-SM), silty sand and gravel (SP/GP), silty sand (SM), sandy silt (ML or MH), and sandy clay (CL) with an occasional thin peat (PT) layer around mid-depth in some cores. Except for the three locations closest to DH2, the surface interval of each core was described as loose silty sand (SM) extending from 0.5 to 6.1 ft below the mudline. The surface interval sediments for the three cores adjacent to DH2 were described as either very soft sandy silt (ML) or clay (CL) up to two ft thick overlying a thin layer of peat (PT). There was no evidence of permafrost in any of the cores

Conditions at the five test trench locations that were examined in 2011 and 2014 were very different in terms of basic sediment characteristics (Table 4-5 and Table 4-7). Test Trench Sites #1, #2A, and #3A were found to contain higher levels of TOC, % fines, and sulfides with lower levels seen at Sites #2B and #3B. TOC ranged from a high of 1.99% at Site #1 to a low 0.19% at #2B. Although sulfides varied between the five sites, overall total sulfides were lower in 2014, ranging from 9.1 to 38.6 mg/kg versus 8.4 to 265 mg/kg seen in 2011. Ammonia was also low, ranging from a low of 0.99 mg/kg at #3A to a high of 3.87 mg/kg at #3B in 2014, with higher levels seen in 2011 where a range of <0.06 to 15.6 mg/kg was seen. Total volatile solid (TVS), which is considered a measure of total organic content, ranged from a low of 4.51% at Site #3B to a high of 8.99% at #3A, with the highest concentrations in those samples that also exhibited higher levels of TOC.

Sediment grain size distribution data from 2011 from within the general dredge area varied somewhat among sampling locations and between upper and lower core interval samples. As verified through observations, sediments closer to DH2 were generally finer in the surface samples with a higher percentage of sand and gravel in the lower core interval samples. The reverse is true for sediments away from DH2, with higher sand and gravel percentages in the surface sediments. The mean sand and gravel content among all dredge area samples was 56%. The mean sand and gravel content among all surface interval samples was 61.8% compared to 48.5% for the bottom core interval sample.

Surface samples from the five test trench areas did not contain much gravel but contained between 10% and 85% sand. The bottom core interval samples (4 to 5 ft below the mudline) at Test Trench Sites #1 and #2A consisted of 58.6% and 34.1% sand and gravel, respectively. Site #1 grain size distributions were consistent with those cores closer to DH2. Of all five potential test trench locations sampled in 2011 and 2014, Site #3A had the highest percentage of fines with a mean concentration 74.1%. The most common size fraction at #3A, surface sediments #1, and bottom sediments at #2A was silt, whereas the most common size fraction at #2B, #3B, bottom sediments from #1, and surface sediments from #2A was fine sand. All five locations were found to have low levels of coarse and medium sand, and only two samples contained gravel.

Atterberg limits were measured in the 2011 dredge area sediments to determine the plastic and liquid limits of the sediments for refining the classification of the sediments. Resulting plasticity indexes determined that most samples (22 out of 31) were non-plastic. Of the remaining, six of the samples were slightly plastic and three had medium plasticity. The bottom core interval sample from Test Trench Site #1 and the surface samples from Sites #2A and #2B were classified as non-plastic. Surface material from Sites #1 and #2B had slight plasticity. Atterberg limits were not ascertained for Sites #3A and #3B sampled in 2014.

4.1.2.2 Test Trench - Total Metals

Analytical results for total metals from the five test trench areas that were examined are presented in Table 4-5 and Table 4-7. Analyses included the same 20 metals that were examined for the dredge material reuse areas. Metal concentrations were compared to USACE/EPA 2013 DMMP criteria, to ADEC's recommended SQGs, and to the range of Beaufort Sea background sediments. In all instances, metals at the five test trench sites were found to below both the DMMP SLs and ADEC's recommended PELs. Concentrations were also found to be within the range of background sediments for the Beaufort Sea coastal area.

Seven of the eleven arsenic samples, one of the eleven copper samples, and nine of the eleven nickel samples that were analyzed for the five test trench sites were found to have concentrations that exceeded their TELs; however, as noted earlier, Beaufort Sea sediments are naturally high in these three metals. The highest nickel concentration measured was at Test Trench Site #1 at a concentration of 25.7 mg/kg compared to the TEL of 15.9 mg/kg and a value of 56 mg/kg for average continental crust material (Wedepohl 1995). Arsenic concentration ranged from 3.75 to 9.88 mg/kg compared to the TEL of 7.24 mg/kg. Trefry et al. (2003) and Exponent (2010) note that arsenic values of typical marine sediments are 7.2 mg/kg and that the Beaufort Sea coastal sediments ranged from 4.2 to 28.4 mg/kg. These Beaufort Sea studies have also shown that both arsenic and nickel in area sediments often exceed SQGs, that the metals are naturally occurring, and that suspended sediments introduced by rivers in the region have similar concentrations. The copper sample that exceeded the TEL was from one sample at Site #3A with a concentration of 19.8 mg/kg compared to the TEL of 18.7 mg/kg, the range seen in the Beaufort Sea of 3.6 to 50.2 mg/kg, and a concentration of 25 mg/kg for average continental crust material.

As previously mentioned, Trefry et al. (2003) found that trace metals in the Beaufort coastal area correlated well with aluminum since most metals are generally low in quartz sand and carbonates and high in the metal-bearing alumino-silicates contained in silt and clay. A comparison of nickel versus aluminum for all of the samples from the test trench and disposal sites that clearly demonstrates this relationship is shown in Figure 4-1.

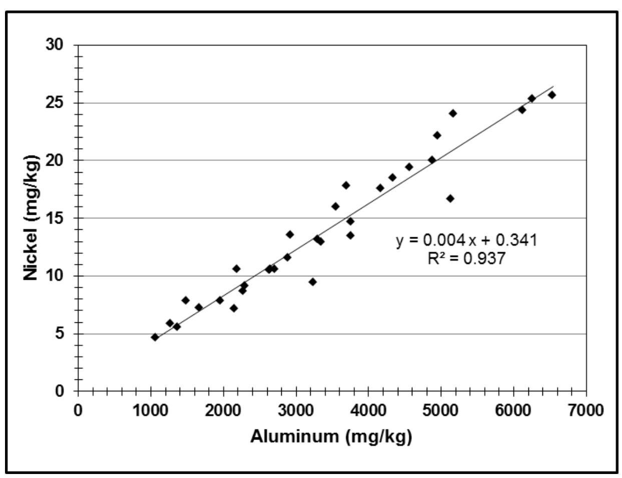

Figure 4-1. Sediment Nickel vs. Aluminum

4.1.2.3 Test Trench - Acid-Volatile Sulfide and Simultaneously Extractable Metals

Total concentrations of divalent metals (e.g., cadmium, copper, lead, nickel, and zinc) in sediments are generally poor predictors of biological effects and toxicity because the bioavailability of the metals depends upon their partitioning between solid and aqueous phases. Metals present in the solid phase are generally less bioavailable and toxic than metals dissolved in the water. In order to better predict bioavailability and potential toxicity of metals in sediments, molar ratios of simultaneously extracted metals to acid volatile sulfides (SEM/AVS) are used to indicate the amount of metals potentially present in the aqueous phase (USEPA 2005). When the molar concentration of AVS exceeds the total molar concentration of the SEM, the concentrations of dissolved metals are generally below toxic levels because of the low solubility of the metal sulfides (Simpson et al. 2012). Metal sulfides are typically very insoluble, and this limits the bioavailability and potential toxicity of the metals.

Sediments at the five test trench sites were analyzed for acid-volatile sulfides (AVS) to evaluate the bioavailability of six divalent metals (cadmium, copper, lead, mercury, nickel, and zinc) which were analyzed by a Simultaneously Extractable Metals (SEM) method. Divalent metals are bound to sulfur compounds in anaerobic sediment, effectively reducing their bioavailability. The ratio of the sum of SEM to AVS was used as a screening criterion for these metals: a ratio greater than 1.0 suggests that the metals are potentially bioavailable, while a ratio less than 1.0 indicates that there is sufficient hydrogen sulfide present to form insoluble metal sulfides that are not bioavailable for uptake by fauna so no toxicity would be expected.

AVS concentrations in surficial sediment samples in 2014 ranged from 0.151 to 0.49 micro Mole per gram (µMole/g). The results for cadmium, copper, lead, nickel, and zinc were above the reporting limits for all six samples that were analyzed. Mercury was not detected above the method detection limit (MDL) in any of the samples from either location. The sum of the detected metals ranged from 0.246 to 0.713 µMole/g. Concentrations of detected metals seen in 2011 were lower, ranging from 0.088 to 0.190 µMole/g. The ratio of SEM to AVS ranged from 0.04 to 2.08 for all five locations (2011 and 2014), with three of the eleven samples exceeding a ratio of 1.0 indicating that the metals may be potentially bioavailable. One of those samples was at #3A and the other two were at #3B. These samples were further evaluated to assess whether the potentially bioavailable metals are reduced through binding to organic carbon. Using EPA guidance for deriving equilibrium partitioning sediment benchmarks for metal mixtures (EPA 2005), each SEM value that exceeded the AVS concentration was normalized to the organic carbon concentration, which is also expected to bind with excess metals. Results less than 130 $\mu Mole/g_{oc}$ indicate that there is little to no risk to aquatic life (EPA 2005). Sample results ranged from less than zero (where AVS exceeds SEM) to 25.1 micro-Mole per gram of organic carbon ($\mu Mole/g_{oc}$), indicating little to no risk.

During the approximately six-month time period that the dredge sediment will be present on the surface of the ice at the disposal site, the surface layer of the sediment pile (windrow) will be exposed to atmospheric oxygen and sunlight which could potentially influence the speciation and bioavailability of metals located at the surface of the pile. Because the material will remain saturated with water and frozen for most of the time that it is on the ice, the gas permeability of the dredged material will remain low, and atmospheric oxygen will only penetrate a few millimeters below the surface. Likewise, immediately after the ice melts, the dredged material is expected to form a pile of water-saturated material on the seafloor; this material will be winnowed and dispersed by natural processes such as wave action and currents. The vast majority of the dredged material in the windrow will be located below the depth of oxygen penetration, sequestered away from atmospheric oxygen and sunlight. Therefore, oxidation reactions that could alter the speciation, bioavailability, and potential toxicity of metals and hydrocarbons in the sediment will occur only in the very small fraction of the material located at the surface. In addition, cold temperatures will limit the rates of the oxidation reactions.

Upon exposure to atmospheric oxygen, a small fraction of the AVS present in the dredged material will oxidize, thereby increasing the overall ratio of SEM/AVS in the material. However, due to the low gas permeability of the dredge material and the cold temperatures, it is not expected that oxidation processes would appreciably change the bioavailability of these metals and create any toxic conditions as the dredge material disperses in the nearshore area.

4.1.2.4 Test Trench - Petroleum Hydrocarbons

Sediments at the five test trench sites were analyzed for DRO and RRO. Concentrations of both DRO and RRO in all eleven samples were found to be below ADEC-recommended soil cleanup levels for the Arctic. Concentrations of DRO were low, ranging from 2.8 mg/kg at Test Trench Site #2B to 35 mg/kg at #3A compared to the cleanup level of 200 mg/kg. Results from ten of the eleven DRO analyses were at concentrations that were below reporting limits and qualified with a “J” flag as estimates. Concentrations of RRO ranged from 22 mg/kg in one replicate at #3A to a high of 190 mg/kg at both #1 and #3A, as compared to the ADEC cleanup level of 2000 mg/kg. One sample from both #1 and #3A appeared to have elevated levels of RRO; however, on closer examination of the chromatographic fingerprints by the laboratory, the samples were flagged with a “Z” indicating that chromatograms did not resemble a petroleum product. These samples also had higher TOC concentrations which probably indicate high peat content and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes. Exponent (2010) presented results from a number of regional peat samples and found that the total petroleum hydrocarbons (TPHC which equals DRO + RRO) ranged from 8.7 to 230 mg/kg as a result of biogenic inputs.

Sediment from Test Trench Sites #3A and #3B were also examined for a suite of PAH components and compared to the 2013 DMMP SLs and to ADEC’s recommended SQGs TELs and PELs. Individual PAHs were found to be low in all samples analyzed with all concentrations well below the DMMP SLs. The TELs and PELs were not exceeded in any of the samples. Total PAH concentration ranged from 7.6 to 75.4 µg/kg, with slightly higher levels seen at #3A which is probably the result of higher TOC and % fine content in those samples. Although not directly comparable as a result of a much longer analyte list, TPAH concentrations for the ANIMIDA and cANIMIDA studies were found to range from 12 to 1,800 µg/kg, with yearly means ranging from 200 to 810 µg/kg (Neff 2010). ANIMIDA and cANIMIDA fingerprint analyses indicated that PAHs seen in the Beaufort Sea coastal sediments are natural background and do not indicate any anthropogenic inputs of crude or petroleum products with the exception of a few samples out of the hundreds that were analyzed for these programs. Concentrations of total low molecular weight PAHs (LPAH) seen at the test trench stations ranged from 6.8 to 55.8 µg/kg, compared to the SL of 5,200 µg/kg and a TEL of 312 µg/kg. Concentrations of high molecular weight PAHs (HPAH) at the #3A and #3B stations ranged from 0.8 to 19.6 µg/kg, compared to the SL of 12,000 µg/kg and a TEL of 655 µg/kg.

Only a limited number of 2011 vibracore samples (three total) were analyzed for PAHs, and since none of these data were obtained at the current potential test trench sites, information must be inferred from these nearby locations for Test Trench Sites #1, #2A and #2B. Low levels of PAH compounds were found in all of the 2011 dredge area samples (both surface and lower) with concentrations that were typical of natural background levels in the Beaufort Sea coastal area. No evidence was seen that any of the samples contained PAHs that were the result of contaminant inputs to the area.

The 2011 APP sediment sampling also included the analysis of gasoline range organics (GRO) and BTEX. All GRO and BTEX concentrations fell below their MDLs for all samples including the larger potential dredge area studied in 2011. Since all 2011 dredge area BTEX and GRO concentrations were below detection limits, these compounds were not included in the analyte list during 2014. Also, all of the marine vessels that utilize West Dock, with the exception of a few skiffs, are powered by diesel engines, so it is not expected that contamination from any gasoline sources would be seen in the sediments.

Overall, concentrations of petroleum hydrocarbons at the five test trench sites are low and well within the range of natural background levels, are well below DMMP guidance and SQG levels, and show no evidence of anthropogenic inputs or contamination.

4.1.2.5 Test Trench - Chlorinated Pesticides and Polychlorinated Biphenyls

Low level pesticides were seen in two of the six samples that were analyzed at the test trench sites in 2014. The first sample was Replicate 1 from Site #3A which had low levels of 4,4'-DDT (0.081 µg/kg), alpha-BHC (0.077 µg/kg), and methoxychlor (0.16 µg/kg), all of which were estimated concentrations that were between the MDL and reporting limit (RL) and flagged with a "J". The second sample with detectable concentrations was also from #3A where 4,4'-DDT was detected at an estimated concentration of 0.13 µg/kg. All other samples and analytes were found to be below detection levels.

Values were compared to the 2013 DMMP guidance levels and ADEC's recommended SQGs. Criteria exist for both 4,4'-DDT and total dichlorodiphenyl-trichloroethane (DDT), but do not exist for either alpha-BHC or methoxychlor. Concentrations of 4,4'-DDT where seen were found at levels that were two orders of magnitude less than the dredge material SLs and an order of magnitude less than the TEL. Similarly, total DDT was low at concentrations of 0.081 and 0.13 µg/kg compared to the TEL of 3.90 µg/kg and the PEL of 51.7 µg/kg.

In 2014, PCBs were analyzed for the seven primary arochlors that were manufactured (Arochlor 1016, 1221, 1232, 1242, 1248, 1254, and 1260). Concentrations of individual arochlors in all samples were found to be below the detection limit of 2.1 µg/kg compared to the 2013 DMMP guidance level for total PCBs of 130 µg/kg; this was also well below the ADEC SQG TEL of 21.6 µg/kg and PEL of 189 µg/kg.

Only a limited number of 2011 vibracore samples (three total) were analyzed for chlorinated pesticides and PCBs, and since none of these data were obtained at the current potential test trench sites, information must be inferred from these nearby locations for Test Trench Sites #1, #2A and #2B. Very low levels of PCB congeners were found in some of the 2011 dredge area samples and in all cases, concentrations of these contaminants were well below SLs established for the Seattle DMMP and well below ADEC recommended SQGs for both the TEL and PEL. It was also noted in the 2011 APP report that the PCB results should be considered maximum possible concentrations since contamination was seen in the laboratory method blanks. One chlorinated pesticide, gamma-BHC (Lindane), was seen in one surface sample at a low level concentration of 0.37 µg/kg, compared to the DMMP SL of 2.8 µg/kg for total chlordane and a TEL of 2.26 µg/kg. All other organochlorine pesticide concentrations were found to below MDLs.

Overall, there appears to be no evidence of any contamination from chlorinated pesticides or PCBs of the test trench sediments including the dredge area sampled in 2011. Most of the compounds that were tested are covered by the Stockholm Convention on Persistent Organic Pollutants (POPs), a global treaty to protect human health and the environment from highly toxic and long-lasting chemicals by restricting their use and ultimately eliminating production and use. POPs are of particular concern in the Arctic as it has been shown that they can travel long distances via a number of pathways, including air transport, and be deposited far from their sources of release, accumulate in living organisms, and cause adverse effects on the environment (AMAP 2002). These organic compounds tend to accumulate in the Arctic and sub-Arctic due to several physical and biological transport processes. The sources of the low-level chemicals measured in this study are believed to be atmospheric in origin as a result of global distillation in the equatorial and temperate regions of the world, followed by cold condensation, resulting in deposition of POPs into the Arctic and sub-Arctic environments; these are often seen in and associated with fine-grained sediments.

4.1.3 Grain Size Compatibility - Test Trench versus Reuse Areas

The preferred dredge disposal scenario is to beneficially reuse the dredged sediments from the test trench locations at one of the three proposed placement areas described previously. The shorelines adjacent to these three reuse areas are all undergoing gradual erosion and therefore could utilize material placed in the shallow areas alongshore to slow down the erosional processes. Grain size characteristics of the test trench dredge sediments are the dominating factor in determining how well these sediments respond to dredging and placement. Fine-grained material is more negatively impacted by the dredging process and is more likely to mobilize after placement. The average fines content of test trench samples collected in 2011 and 2014 is slightly less than 50%. This is somewhat greater than the 7.4%

to 18.3% average fines content in the surface sediments of the three proposed reuse areas. However, the sediments still contain enough coarse material to be beneficial even though much of the finer material may disperse from the immediate disposal area. It is expected that wave and current action will winnow the finer-grained particles, leaving the coarser-grained sediments to provide shore protection. The most common size fraction in the test trench sediments was fine sand, which was also the most common size fraction in the majority of the samples from both SBAY and WEST disposal sites, indicating a fair amount of compatibility.

Besides the average sand and gravel content, another aspect that was evaluated to determine the suitability of reusing the test trench sediments was how well the grain size gradations of the test trench sediments correspond to the grain size gradations of the surface sediments in the proposed reuse areas and adjacent offshore areas. Specifically, the gradation curves of the dredge material were examined to see if they fall within the compatibility envelopes of the reuse areas, including offshore of the direct placement areas, as defined by the fine and coarse limits of each reuse area. Mean gradation curves for each of the test trench sites are provided in Figure 4-2, Figure 4-3, and Figure 4-4 along with the fine and coarse grain limit gradation curves for each of the reuse areas. Except for possibly Test Trench Sites #2B and #3B, the test trench sediments do not fit well within the compatibility envelopes. However, placement of material that does not fit well within a compatibility envelope of a reuse area may be appropriate if the fill material does not cause any issues with aesthetics. Aesthetic issues are not anticipated for any of the reuse areas since the areas are remote and most of the fine material is expected not to migrate onto any beach faces. Also, as mentioned previously, the grain size is compatible in terms of the most common size fraction (fine sands) for the test trench and both the SBAY and WEST reuse areas.

As mentioned previously, sediment descriptions along with grain size data indicated that the fines content at the WEST reuse area was higher in the surface sediments collected farthest offshore in about 5.5 ft of water and about 1,200 ft from shore. These observations did not hold true for the SBAY and EGG reuse areas. As an exercise to see if these WEST offshore sediments were physically similar to the test trench sediments, the test trench average grain size gradations were plotted against the grain size gradations for the WEST Stations T3-5 and T4-5 surface samples. These comparisons are provided in Figure 4-5. Although still on the coarser side of the gradation curves, these figures show that the deeper WEST surface sediment gradations are not that dissimilar to the test trench sediments. Therefore, the further offshore of the WEST reuse area one is located, the more physically compatible the test trench sediments are to those offshore sediments. Thus, over time it is expected that the coarser portion of the dredge material would remain near the beach and provide some continuing shoreline protection, while the finer portion of the material would migrate into deeper water where it would be deposited and also be compatible with the native materials in that area.

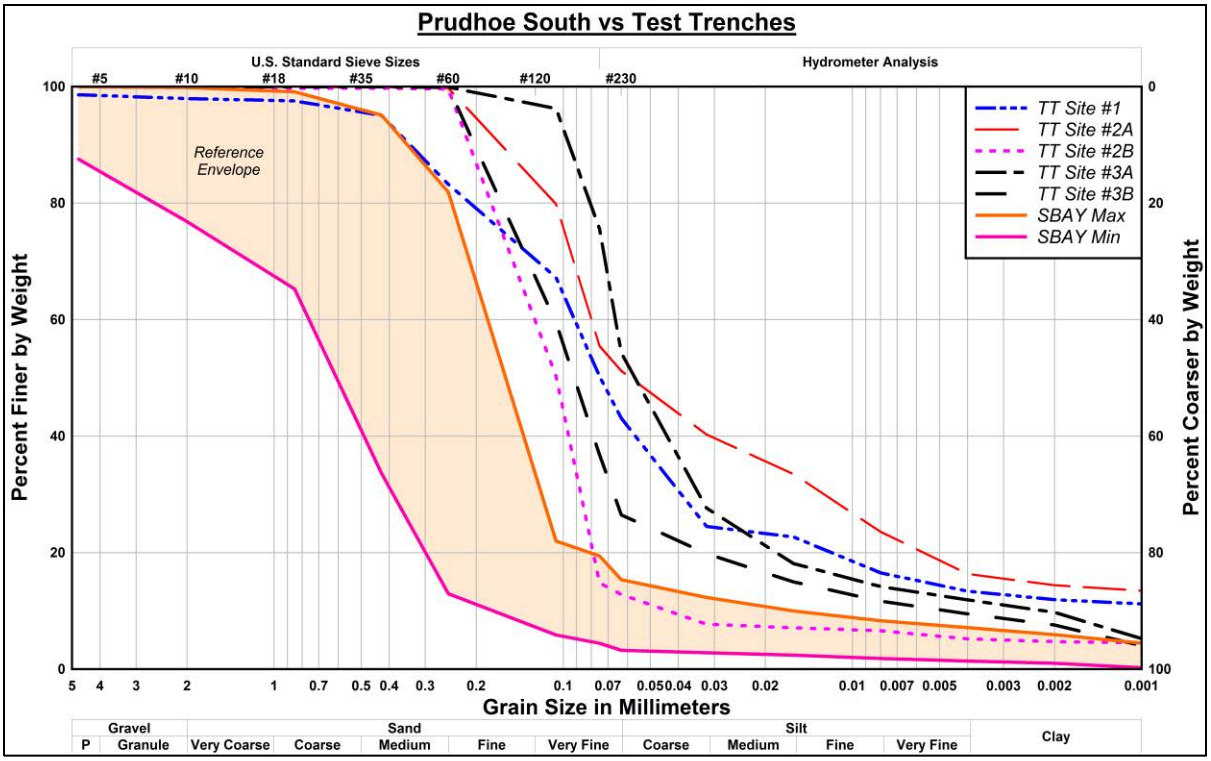

Figure 4-2. Test Trench Grain Size Gradations Compared to SBAY Grain Size

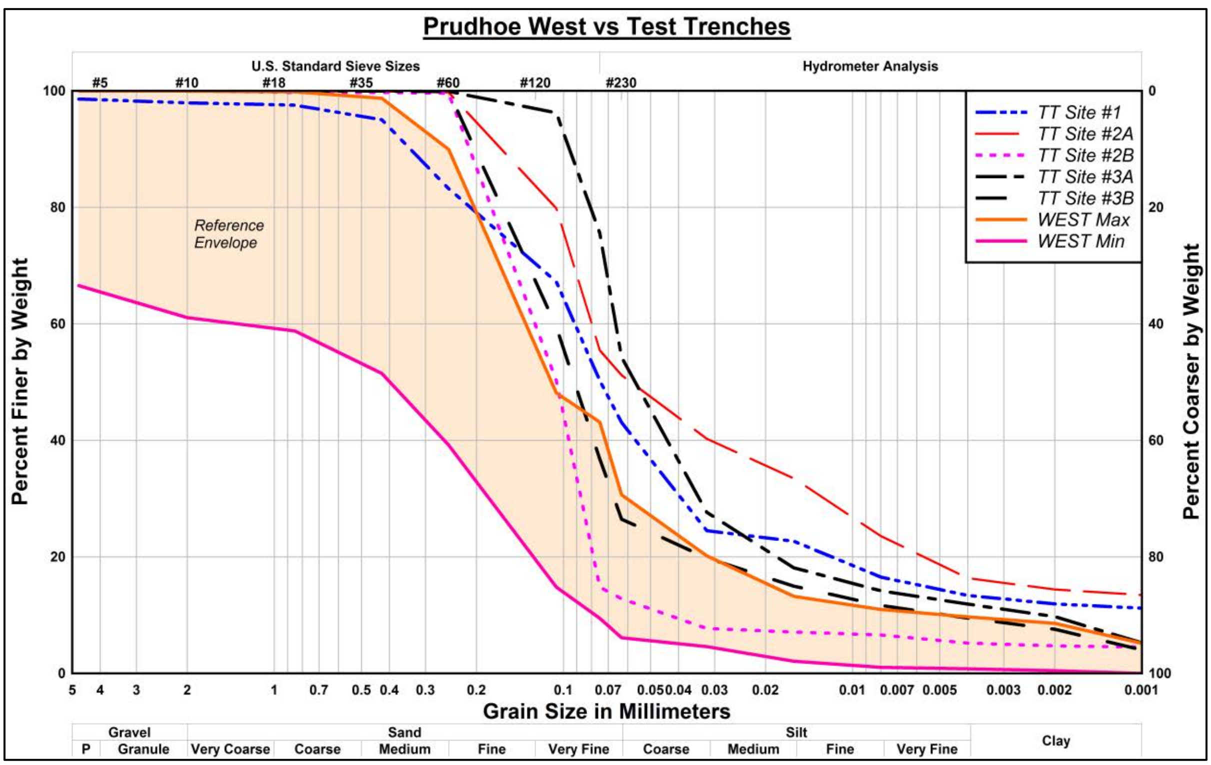

Figure 4-3. Test Trench Grain Size Gradations Compared to WEST Grain Size

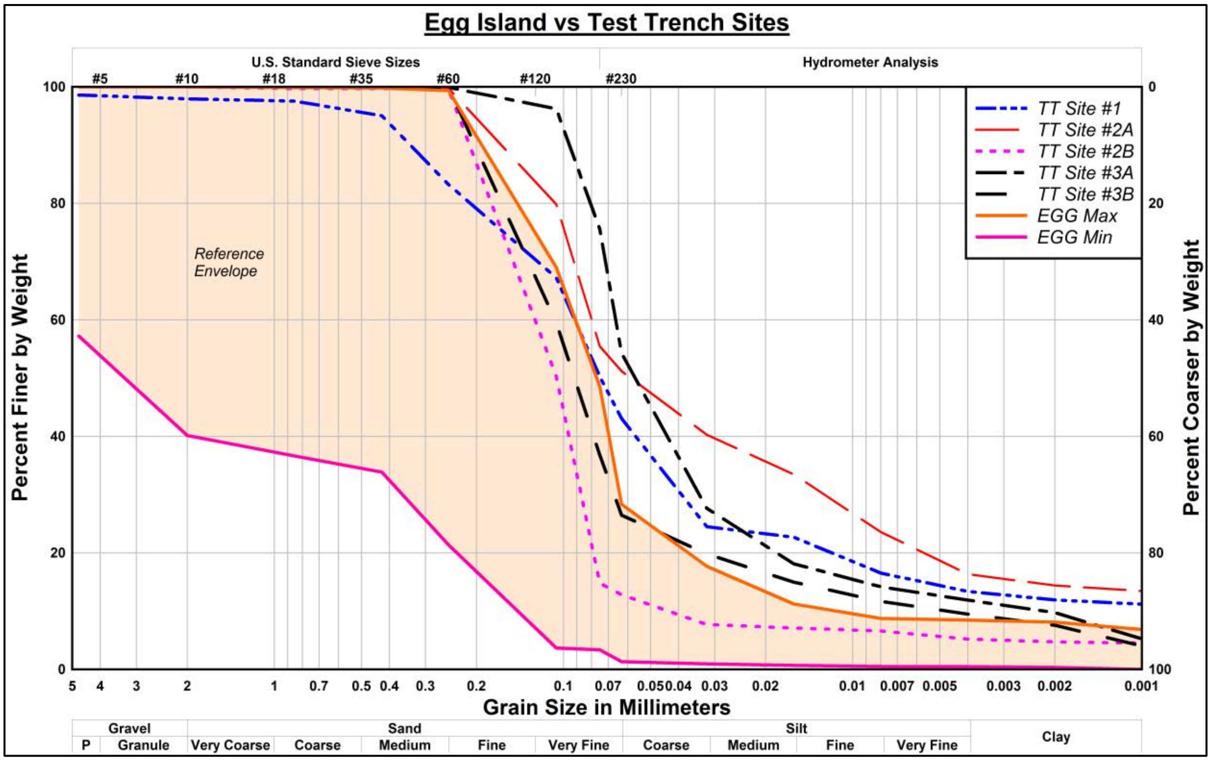

Figure 4-4. Test Trench Grain Size Gradations Compared to EGG Grain Size

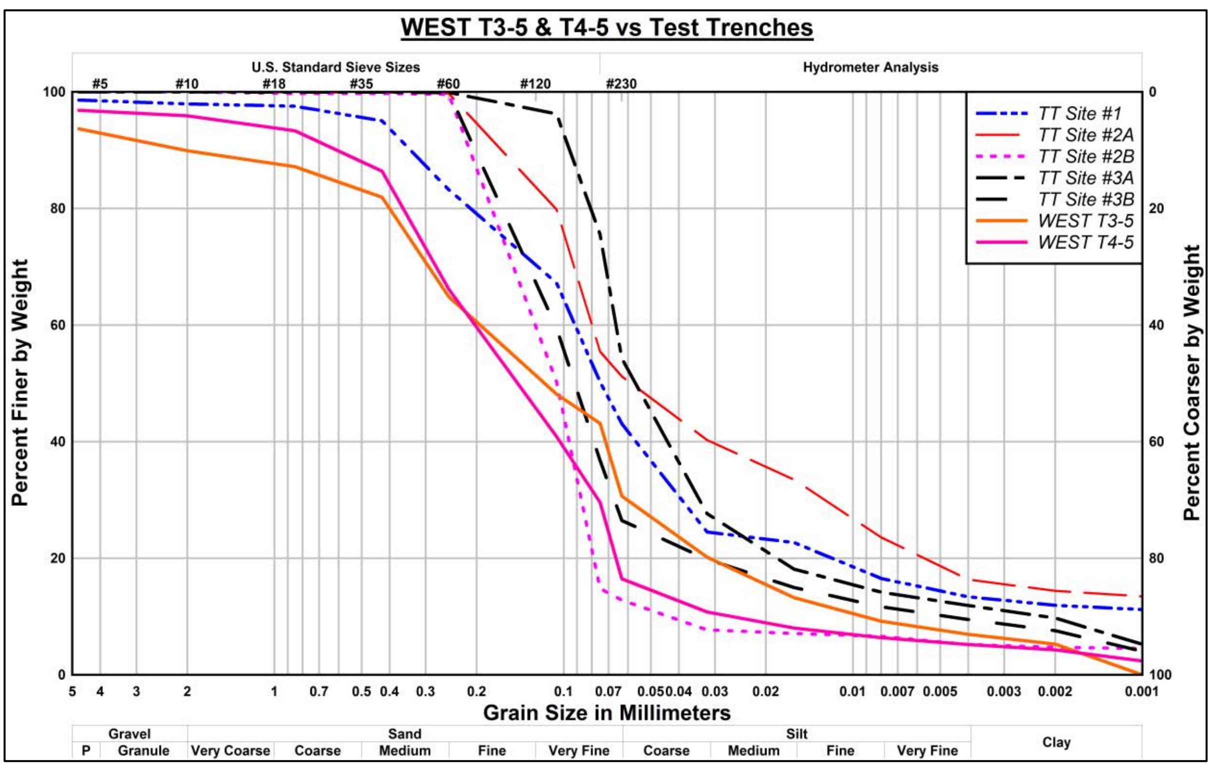

Figure 4-5. Test Trench Grain Size Gradations Compared to Sediments at WEST

A number of photographs are presented below that clearly show the need for beach nourishment and shoreline protection at both Site 1 – SBAY (Figure 4-6) and Site 2 – WEST (Figure 4-7). At SBAY, the tundra is eroding creating a coastal bluff exposing permafrost and an ice lens that can be seen in the photograph. At WEST, the AGI Pad is eroding on the southern end. Based on these photographs, it is clear that beach nourishment and shoreline protection would be beneficial.

4.2 BIOLOGICAL SAMPLING RESULTS

Biological sampling included collection of benthic infauna in sediments using a Smith-McIntyre grab, Ponar grab, or 4-inch hand corer. Benthic samples were separated into two size fractions: the macrofaunal fraction containing small organisms retained on a 1.0-mm sieve, and the megafaunal fraction consisting of organisms retained on a 6.4-mm sieve. Benthic infaunal sampling was attempted at all study sites (SBAY, WEST, EGG, and Test Trench), although two megafauna locations could not be collected at EGG due to high surf conditions and safety concerns in the nearshore area (Table 3-1 and Table 3-2). In addition, otter trawls were performed at the disposal sites SBAY, WEST, and EGG to obtain observations on the biotic assemblages at these areas.

Figure 4-6. Photograph of Site 1 – SBAY Showing Shoreline Erosion

Figure 4-7. Photograph of Site 2 – WEST Showing Erosion of AGI Pad

4.2.1 Disposal Reuse Site – Benthic Infauna Results

Benthic infaunal sampling was conducted at the five 2014 MSP study sites in September 2014. Table 3-2 provides an overview of benthic samples collected at each potential disposal site. Benthic stations were located along two transects at each of the three designated disposal reuse area boundaries at SBAY (T1 and T2), WEST (T3 and T4), and EGG (T5 and T6); refer to Figure 3-1, Figure 3-2, and Figure 3-3 for station locations. Stations along each transect were numbered 1-5 from shallow (nearshore) to deeper water depths for grain size sediment collection; benthic infaunal samples were collected at odd-numbered stations along each transect (i.e., at T1-1, T1-3, and T1-5, and so on). Three replicate grab samples were collected for each infaunal fraction wherever possible.

Estimates of numbers of taxa, abundance (numbers of individuals), and biomass are presented here by major taxonomic group for the disposal sites. Estimates of the number of infaunal taxa found by site and area as an indicator of diversity are presented in Table 4-10; raw sample data by major taxonomic group, site, and station for the 1.0-mm macrofaunal fraction (0.009 m^2/replicate) and the 6.4-mm megafaunal fraction (0.091 m^2/replicate) are presented in Table 4-11. Both abundance and biomass (grams wet weight) data are provided in the table. Abundance and biomass estimates converted to a surface area of 1.0 m^2 to allow comparisons with other studies are presented in Table 4-12.

Samples at the shallowest disposal reuse sites exhibited very low numbers of taxa and abundances of infauna. Site 1 SBAY stations located within the nearshore target reuse zone were Stations T1-1 and T2-1. At Station T1-1, two annelid worms *Pygospio elegans* were found in the macrofaunal fraction, and no organisms were seen in the megafaunal fraction. At Station T2-1, two *P. elegans* worms and one crustacean *Onisimus littoralis* were found in the macrofaunal fraction, and no organisms were found in the megafaunal fraction. Stations with samples taken within the nearshore reuse zone at Site 2 WEST were T3-1, T3-3, T4-1, and T4-3. Among these four sites, only two *P. elegans* were found in the smaller macrofaunal fraction at T3-3. Stations T5-1 and T6-1 were located within the nearshore reuse area zone at EGG; no animals were found in the 1.0-mm fraction at these stations, and megafaunal samples were not collected due to surf conditions and safety concerns. In summary, only seven animals were found in 24 separate samples and two size fractions that were taken within the areas of the three proposed disposal sites where dredged material will be deposited. The total wet weight biomass of these seven organisms found within the disposal area boundaries was only approximately 0.06 grams (g).

Stations further offshore in deeper water at the three disposal reuse sites tended to have more taxa and higher abundance and biomass than the shallower stations. This is particularly evident for both infaunal fractions at the Site 1 SBAY Stations T1-5 and T2-5 located near the outer edge of the bottom-fast ice zone. Abundance for the combined fractions at SBAY Transects T1 and T2 increased dramatically from two to 134 and 83, respectively, with only a small water depth increase of three to four ft. The number of taxa increased from none to as many as eight depending on the fraction. Along these same transects, a dramatic increase in biomass was also observed, with T1-5 and T2-5 having 15.6 and 37.4 g wet weight of biomass, respectively. The majority of the increased abundance along these transects was due to the mollusc *Crytodaria kurriana* and annelid *P. elegans* in the macrofaunal fraction and the mollusc *C. kurriana* and the crustacean *Saduria entomon* in the megafaunal fraction. However, the majority of the observed increase in biomass was due to the megafaunal molluscs and miscellaneous (the priapulid worm *Priapulus caudatus* and the solitary tunicate *Rhizomolgula globularis*) taxa groups. The WEST and EGG sites exhibited a similar but much less distinctive trend, especially at EGG. The macrofaunal dominants of SBAY sites did not occur at all at EGG, and only the worm *P. elegans* was dominant at the WEST sites.

Crytodaria kurriana was the only mollusc found at any of the 18 disposal area stations sampled. SBAY stations exhibited greater abundances of this mollusc at the deeper Stations (T1-5 and T2-5) in both the macrofauna and megafauna fractions. A total of 122 were seen in the three replicates of T1-5, with 60 in the macrofauna and 62 in the megafauna fractions. Station T2-5 had a combined total of 44 individuals. In contrast, only four were seen at the two deeper WEST stations (T3-5 and T4-5) and none were recorded at EGG.

Megafaunal miscellaneous taxa were found only at the two deepest SBAY Stations T1-5 (n=2) and T2-5 (n=7), for a total of nine, and none were found at the WEST or EGG sites. Macrofaunal miscellaneous taxa were also only found at the deepest disposal site transects (total of 3). In terms of unit area, the overall highest abundances for the macrofauna fraction at any disposal reuse station were 2,370 and 1,370/m^2 at T1-5 and T2-5 at SBAY, respectively (Table 4-11). The overall highest abundances for the megafauna fraction were seen at Stations T1-5 and T2-5 at SBAY with 256 and 168/m^2, respectively. Macrofaunal biomass was highest at SBAY Stations T1-5 and T2-5 with 187 and 130 g/m^2, while megafaunal biomass was highest at T2-5 and T1-5 with 124 and 39 g/m^2, respectively.

Table 4-10. 2014 Benthic Infauna Numbers of Taxa per Station

(Number of Taxa)	SBAY							WEST							EGG							Disposal Sites
Taxon Group (Water Depth-ft) -	**T1-1** (1.7)	**T1-3** (3.8)	**T1-5** (5.7)	**T2-1** (2.7)	**T2-3** (4.0)	**T2-5** (5.5)	**SBAY Total**	**T3-1** (1.0)	**T3-3** (2.8)	**T3-5** (5.4)	**T4-1** (1.0)	**T4-3** (2.6)	**T4-5** (5.5)	**WEST Total**	**T5-1** (2.5)	**T5-3** (4.2)	**T5-5** (10.4)	**T6-1** (2.4)	**T6-3** (6.7)	**T6-5** (13.2)	**EGG Total**	**Total**
Macrofauna (1.0-mm)																						
Annelida	1	1	2	1	1	3	3	0	1	1	0	0	2	2	0	0	0	0	0	3	3	5
Crustacea	0	2	2	1	1	2	4	0	0	0	0	0	0	0	0	1	1	0	0	2	3	6
Miscellaneous	0	0	0	0	0	2	2	0	0	0	0	0	2	2	0	1	0	0	0	1	1	3
Mollusca	0	0	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1
Total Number Taxa	1	3	5	2	2	8	10	0	1	2	0	0	5	5	0	2	1	0	0	6	7	15
Megafauna (6.4-mm)																						
Annelida	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0	0	0
Crustacea	0	1	1	0	1	1	1	0	0	1	0	0	1	1		2	1		1	1	2	2
Miscellaneous	0	0	1	0	0	1	2	0	0	0	0	0	0	0		0	0		0	0	0	2
Mollusca	0	0	1	0	0	2	2	0	0	0	0	0	1	1		0	0		0	0	0	2
Total Number Taxa	0	1	3	0	1	4	5	0	0	1	0	0	2	2		2	1		1	1	2	6

Table 4-11. 2014 Benthic Infauna Abundance and Biomass per Station

(numbers or grams wet wt.)	SBAY							WEST							EGG							Disposal
Taxon	**T1-1**	**T1-3**	**T1-5**	**T2-1**	**T2-3**	**T2-5**	**SBAY Total**	**T3-1**	**T3-3**	**T3-5**	**T4-1**	**T4-3**	**T4-5**	**WEST Total**	**T5-1**	**T5-3**	**T5-5**	**T6-1**	**T6-3**	**T6-5**	**EGG Total**	**All Sites**
(Water Depth-ft) -	(1.7)	(3.8)	(5.7)	(2.7)	(4.0)	(5.5)		(1.0)	(2.8)	(5.4)	(1.0)	(2.6)	(5.5)		(2.5)	(4.2)	(10.4)	(2.4)	(6.7)	(13.2)		
Macrofauna (1.0-mm)																						
Annelida	2	8	2	2	4	17	35	0	2	11	0	0	16	29	0	0	0	0	0	4	4	68
Crustacea	0	3	2	1	1	3	10	0	0	0	0	0	0	0	0	1	1	0	0	3	5	15
Miscellaneous	0	0	0	0	0	2	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	3
Mollusca	0	0	60	0	0	15	75	0	0	0	0	0	2	2	0	0	0	0	0	0	0	77
Total Abundance	**2**	**11**	**64**	**3**	**5**	**37**	**122**	**0**	**2**	**11**	**0**	**0**	**19**	**32**	**0**	**1**	**1**	**0**	**0**	**7**	**9**	**163**
Annelida Biomass	0.01	0.03	0.01	0.02	0.02	0.03	0.12	0	0.02	0.02	0	0	0.03	0.07	0	0	0	0	0	0.02	0.02	0.21
Crustacea Biomass	0	0.02	1.7	0.01	0.01	0.1	1.84	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0.01	0.03	1.87
Misc. Biomass	0	0	0	0	0	2.18	2.18	0	0	0	0	0	0.08	0.08	0	0.01	0	0	0.02	0.02	0.05	2.31
Mollusca Biomass	0	0	3.34	0	0	1.19	4.53	0	0	0	0	0	0.42	0.42	0	0	0	0	0	0	0	4.95
Total Biomass	**0.01**	**0.05**	**5.05**	**0.03**	**0.03**	**3.5**	**8.67**	**0**	**0.02**	**0.02**	**0**	**0**	**0.53**	**0.57**	**0**	**0.02**	**0.01**	**0**	**0.02**	**0.05**	**0.1**	**9.34**
Megafauna (6.4-mm)																						
Annelida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	-	0	0	0	0
Crustacea	0	2	6	0	3	3	14	0	0	4	0	0	10	14	-	2	3	-	2	8	15	43
Miscellaneous	0	0	2	0	0	8	10	0	0	0	0	0	0	0	-	0	0	-	0	0	0	9
Mollusca	0	0	62	0	0	29	91	0	0	0	0	0	2	2	-	0	0	-	0	0	0	93
Total Abundance	**0**	**2**	**70**	**0**	**3**	**39**	**114**	**0**	**0**	**4**	**0**	**0**	**12**	**16**	**-**	**2**	**3**	**-**	**2**	**8**	**15**	**145**
Annelida Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	-	0	0	0	0
Crustacea Biomass	0	0.51	2.62	0	0.26	4.48	7.87	0	0	1.28	0	0	2.13	3.41	-	0.49	0.43	-	0.61	1.05	2.58	14.35
Misc. Biomass	0	0	0.35	0	0	21.42	21.77	0	0	0	0	0	0	0	-	0	0	-	0	0	0	21.77
Mollusca Biomass	0	0	7.59	0	0	7.96	15.55	0	0	0	0	0	0.88	0.88	-	0	0	-	0	0	0	16.43
Total Biomass	**0**	**0.51**	**10.56**	**0**	**0.26**	**33.86**	**45.19**	**0**	**0**	**1.28**	**0**	**0**	**3.01**	**4.29**	**-**	**0.49**	**0.43**	**-**	**0.61**	**1.05**	**2.58**	**52.55**

Table 4-12. 2014 Benthic Infauna Abundance and Biomass Estimates per Meter Squared Unit Area

(no/m² or g/m² wet)	SBAY							WEST							EGG							Disposal
Taxon (Water Depth-ft) -	**T1-1** (1.7)	**T1-3** (3.8)	**T1-5** (5.7)	**T2-1** (2.7)	**T2-3** (4.0)	**T2-5** (5.5)	**SBAY Total**	**T3-1** (1.0)	**T3-3** (2.8)	**T3-5** (5.4)	**T4-1** (1.0)	**T4-3** (2.6)	**T4-5** (5.5)	**WEST Total**	**T5-1** (2.5)	**T5-3** (4.2)	**T5-5** (10.4)	**T6-1** (2.4)	**T6-3** (6.7)	**T6-5** (13.2)	**EGG Total**	**All Sites**
Macrofauna (1.0-mm)																						
Annelida	74	296	74	74	148	630	1296	0	74	407	0	0	593	1074	0	0	0	0	0	148	148	2518
Crustacea	0	111	74	37	37	111	370	0	0	0	0	0	0	0	0	37	37	0	0	111	185	555
Miscellaneous	0	0	0	0	0	74	74	0	0	0	0	0	37	37	0	0	0	0	0	0	0	111
Mollusca	0	0	2222	0	0	556	2778	0	0	0	0	0	74	74	0	0	0	0	0	0	0	2852
Total Abundance	**74**	**407**	**2370**	**111**	**185**	**1371**	**4518**	**0**	**74**	**407**	**0**	**0**	**704**	**1185**	**0**	**0**	**0**	**0**	**0**	**259**	**333**	**6036**
Annelida Biomass	0	1.11	0	0.74	0.74	1.11	3.7	0	0.74	0.74	0	0	1.11	2.59	0	0	0	0	0	0.74	0.74	7.03
Crustacea Biomass	0	0.74	62.96	0	0	3.7	67.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67.4
Misc. Biomass	0	0	0	0	0	80.74	80.74	0	0	0	0	0	2.96	2.96	0	0	0	0	0.74	0.74	1.48	85.18
Mollusca Biomass	0	0	123.7	0	0	44.07	167.77	0	0	0	0	0	15.56	15.56	0	0	0	0	0	0	0	183.33
Total Biomass	**0**	**1.85**	**187.04**	**1.11**	**1.11**	**129.63**	**320.74**	**0**	**0.74**	**0.74**	**0**	**0**	**19.63**	**21.11**	**0**	**0.74**	**0**	**0**	**0.74**	**1.85**	**3.33**	**345.18**
Megafauna (6.4-mm)																						
Annelida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	-	0	0	0	0
Crustacea	0	7	22	0	11	11	51	0	0	44	0	0	110	154	-	22	33	-	22	88	429	634
Miscellaneous	0	0	227	0	0	106	333	0	0	0	0	0	22	22	-	0	0	-	0	0	44	399
Mollusca	0	0	7	0	0	26	33	0	0	0	0	0	0	0	-	0	0	-	0	0	0	33
Total Abundance	**0**	**7**	**256**	**0**	**11**	**143**	**418**	**0**	**0**	**44**	**0**	**0**	**132**	**176**	**-**	**22**	**33**	**-**	**22**	**88**	**473**	**1066**
Annelida Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	-	0	0	0	0
Crustacea Biomass	0	1	9.6	0	1	16.41	28.0	0	0	4.69	0	0	7.8	12.49	-	1.79	1.58	-	2.23	3.85	9.45	51.74
Misc. Biomass	0	0	1.28	0	0	78.46	79.74	0	0	0	0	0	0	0	-	0	0	-	0	0	0	79.74
Mollusca Biomass	0	0	27.8	0	0	29.16	56.96	0	0	0	0	0	3.22	3.22	-	0	0	-	0	0	0	60.18
Total Biomass	**0**	**1**	**38.68**	**0**	**0.95**	**124.03**	**164.66**	**0**	**0**	**4.69**	**0**	**0**	**11.03**	**15.72**	**-**	**1.79**	**1.58**	**-**	**2.23**	**3.85**	**9.45**	**191.62**

4.2.2 Test Trench – Benthic Infauna Results

The APP sampling effort in 2011 included benthic sampling of three dredge sites (designated #01F, #01L, and #03B) that were located along and parallel to the inside track of the Test Trench "B" alignment which runs in a north-easterly direction from West Dock. These sites were sampled in a manner similar to the 2014 MSP and are comparable to the two MSP Test Trench Sites #3A and #3B located farther offshore that were sampled in 2014. The three 2011 sites were located in shallower water (5.7 to 7.7 ft) than the 2014 MSP sites and were closer to DH2 along the potential dredge alignment.

A similar number of taxa per site were found between 2011 and 2014 sampling efforts (Table 4-13). The greatest macrofaunal number was seen at Site #01L during 2011 with 11. This was mainly due to a higher number of annelids at that site. The number of taxa for the megafauna was highest at Site #3B sampled during 2014 with nine, and this was also due to a greater annelid presence.

The highest macrofaunal abundances found between 2011 and 2014 were at dredge Site #03B and Test Trench Site #3B, with 2,519/m^2 and 2,741/m^2, respectively (Table 4-14). Site #03B was located in 7.7 ft of water nearest West Dock at the proposed turning basin location in 2011, while station #3B sampled in 2014 was located much farther offshore to the northeast in 11.9 ft of water. The annelid worm *Tharyx* spp. was the dominant organism in 2011, comprising 30% of all individuals, while the annelid worm *Ampharete vega* was the dominant during 2014 and comprised 65%. *Tharyx* spp. was only found during 2011, while *A. vega* was found during both years. During 2011, *A. vega* comprised 21% of all individuals found.

Table 4-13. 2011 APP Dredge Versus 2014 MSP Test Trench Sites Benthic Infauna Numbers of Taxa per Site

Taxon	2011 Dredge Sites			2014 Test Trench Sites	
	#03B	#01F	#01L	#3A	#3B
(Depth in ft)-	(7.7)	(5.7)	(7.6)	(12.3)	(11.9)
Macrofauna (1.0-mm)					
Annelida	4	6	7	3	5
Crustacea	5	1	1	5	2
Miscellaneous	0	0	1	0	0
Mollusca	0	0	2	1	2
Taxa Total	**9**	**7**	**11**	**9**	**9**
Megafauna (6.4-mm)					
Annelida	2	1	1	3	4
Crustacea	1	1	1	1	2
Miscellaneous	1	0	0	0	1
Mollusca	1	1	0	1	2
Taxa Total	**5**	**3**	**2**	**5**	**9**

Table 4-14. 2011 APP Dredge Versus 2014 Test Trench Sites - Benthic Infauna Raw Abundance and Biomass by Fraction, Sample, and by Unit Area

Taxon	2011 Dredge Sites						2014 Test Trench Sites			
	#03B		#01F		#01L		#3A		#3B	
	Raw	m2	Raw	m2	Raw	m2	Raw	m2	Raw	m2
(Depth in ft) -	(7.7)		(5.7)		(7.6)		(12.3)		(11.9)	
Macrofauna (1.0-mm)										
Annelid	53	1963	16	593	15	556	7	333	67	2481
Crustacea	15	556	1	37	3	111	7	259	3	111
Miscellaneous	0	0	0	0	3	111	0	0	0	0
Mollusca	0	0	0	0	16	593	1	37	4	148
Abundance Total	**68**	**2519**	**17**	**630**	**37**	**1370**	**15**	**630**	**74**	**2741**
Annelid Biomass	0.27	10.00	0.03	0.93	0.02	0.74	0.12	4.44	0.87	32.22
Crustacea Biomass	0.50	18.33	0.01	0.19	0.01	0.37	0.81	30.00	0.77	28.52
Misc. Biomass	0.00	0.00	0.00	0.00	0.01	0.37	0	0.00	0	0.00
Mollusca Biomass	0.00	0.00	0.00	0.00	0.04	1.48	0.01	0.37	0.44	16.30
Biomass Total	**0.77**	**28.33**	**0.03**	**1.11**	**0.08**	**2.96**	**0.94**	**34.81**	**2.08**	**77.04**
Megafauna (6.4-mm)										
Annelid	12	44	1	4	1	4	9	29	77	278
Crustacea	6	22	4	15	3	11	10	37	8	29
Miscellaneous	1	4	0	0	0	0	0	0	1	4
Mollusca	1	4	1	4	0	0	7	26	86	77
Abundance Total	**20**	**73**	**6**	**22**	**4**	**15**	**26**	**92**	**107**	**388**
Annelid Biomass	0.23	0.84	0.01	0.04	0.01	0.02	0.31	1.14	1.29	4.73
Crustacea Biomass	0.85	3.11	0.41	1.50	11.69	42.82	11.76	43.08	2.37	8.68
Misc. Biomass	0.02	0.07	0.00	0.00	0.00	0.00	0	0.00	0.12	0.44
Mollusca Biomass	0.69	2.53	0.33	1.21	0.00	0.00	1.76	6.45	4.9	17.95
Biomass Total	**1.79**	**6.56**	**0.75**	**2.75**	**11.70**	**42.84**	**13.83**	**50.66**	**8.68**	**31.79**

1 Estimates of numbers of organisms or grams wet wt.
2 Estimates of number/m^2 or g/m^2 wet wt.

Between the two studies, some macrofaunal taxonomic group differences can be seen with the mollusc taxa being absent at two of the three 2011 dredge sites and present at both 2014 test trench sites. In contrast, the 2011 Site #01L had molluscs present. The miscellaneous taxa were absent from the 2011 #03B and #01F dredge sites as well as the 2014 Test Trench Sites #3A and #3B; only the 2011 Site #01L contained miscellaneous taxa.

Annelids and crustaceans were present at all sites during both years in the macrofaunal fractions. Total macrofaunal biomass was higher during 2014 and appeared to be mainly due to much higher crustacean biomass at both sites and to the much higher annelid and mollusc biomass seen at Site #3B in 2014.

The greatest number of megafaunal taxa found was at Site #3B during 2014 with nine. Similar to the macrofauna, this was mainly due to a higher number of annelids at that site. During 2011, Site #03B contained the most taxa with five.

Megafaunal abundance during 2011 reached a high of 73/m^2 while during 2014 it reached 388/m^2. The crustacean *Saduria entomon* and the worm *A. vega* dominated the 2011 fauna, comprising 80% of all individuals. The latter species was only found at Site #03B of that year. During 2014, *A. vega* dominated the fauna comprising 55% of the individuals. Two species, the mollusc *Portlandia intermedia* and the crustacean *S. entomon*, together comprised another 30% of the fauna. In general, the abundance and biomass for the megafauna was much lower during 2011 than during 2014, which may be due to the fact that the 2014 sampling locations were in deeper water. However, biomass recorded at Site #01L during 2011 was somewhat more comparable to 2014 data.

Both years show the type of variability and patchiness among taxa and major taxonomic group abundance that is expected for the area. The dominant species present for both years and their abundance are consistent with what has been found in these areas historically. The physical environment in the Prudhoe Bay area is subject to many different forces that ultimately create and control the structure of the local benthic communities that exist there. These forces change and therefore influence the benthic community differentially from the shoreline environment out into deeper water in a gradient manner. This gradient of change determines taxonomic diversity and abundance in these areas. This pattern is exhibited in the data that was collected during this study. The harshest and most depauperate areas biologically are the shallowest nearshore areas at the proposed disposal reuse sites as well as the high energy area off Egg Island. The areas offshore of the disposal sites in Prudhoe Bay (at SBAY and WEST) are more biologically diverse than shallower stations or that seen in deeper offshore of EGG. As expected, shallow sites that experience bottom-fast ice were the sites exhibiting the lowest abundances and the fewest numbers of taxa overall.

4.2.3 Reuse Area - Trawling Results

4.2.3.1 Reuse Area – Fish Trawling Results

Nine species of fish plus two unidentified larval fish were collected over the combined 12 otter trawls performed at the disposal reuse sites (SBAY, WEST, and EGG; Table 4-15); no trawling was performed at the dredge or test trench locations in either 2011 or 2014. Overall catch was low, with only 144 fish recorded over all trawls; the majority of fish were recorded at Site 3 - EGG which accounted for 65 % of the total catch at the disposal sites (Table 4-15).

Two species comprised 89% of the overall catch, with Arctic cod (*Boreogadus saida*) making up 53% of the total and fourhorn sculpin (*Myoxocephalus quadricornis*) making up 36% of the total catch. Arctic cod were primarily observed at EGG, where they comprised 97% of the total Arctic cod catch. Of these two species, the fourhorn sculpin displayed a more even distribution over all trawl samples, being the only species that was observed during every trawl at every site. About 15% of the fourhorn sculpin were at SBAY, 60% at WEST, and 25% at EGG sampling sites. The remaining fish comprised only 11% of the total

Table 4-15. Trawl Catch Data for SBAY, WEST, and EGG

Taxon	Site 1 - SBAY				Site 2 - WEST				Site 3 - EGG				Total Ind.
	Shallow		Deep		Shallow		Deep		Shallow		Deep		
Trawl Replicate Number	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	
FISH													
Boreogadus saida-Arctic cod		1					1		11	15	24	24	76
Coregonus autumnalis-Arctic least cisco				2									2
Fish, unidentified	1												1
Liparis spp.-snail fish									1	2	1		4
Lumpenus fabricii-slender ellblenny										1			1
Mallotus villosus-capelin		1		2				1					4
Myoxocephalus quadricornis-fourhorn sculpin	1	3	2	2	5	15	2	9	1	2	5	5	52
Pungitius pungitius-ninespine stickleback							1					1	2
Salvelinus malma-Dolly Varden	1	1											2
CRUSTACEA													
Amphipoda	1		4	4	5	1	1		8	25	7	6	62
Mysid Shrimp													
Mysidae, unidentified	10		90	36	25	30	15	6	50	80	>100	>100	542[1]
Isopoda													
Saduria spp.	1		145	21	30	25	331	250	50	1	55	120	~1029
CNIDARIA													
Tubularians				P[2]			P[2]	P[2]					P[2]
TUNICATA (UROCHORDATA)													
Tunicate, solitary, unidentified			3		14	8	1						26
Tunicate, colonial, unidentified							P[2]						P[2]

[1] estimated as number of organisms too large to quantify; 100 used in calculations

[2] P = "Present" but not enumerated

catch with four capelin (*Mallotus villosus*); four snailfish (*Liparis spp.*); two each of ninespine stickleback (*Pungitius pungitius*); Arctic cisco (*Coregonus autumnalis*) and Dolly Varden (*Salvelinus malma*), one unidentified larval fish; and one slender eelblenny (*Lumpenus fabricii*).

Fish captured in the trawls were generally small, and many specimens were juveniles. All of the fish specimens were enumerated and length recorded. Arctic cod specimens ranged from about 50 to 170 mm in length, with a median of about 62 mm. Overall, about 70% of the Arctic cod measured less than 100 mm in length. Fourhorn sculpin observed in the trawls ranged from 26 to 210 mm in length, with a median of about 90 mm overall. About 50% of the fourhorn sculpin were less than 100 mm in length. Specimens of two larger fourhorn sculpin from SBAY shallow and two specimens from WEST shallow trawl stations were archived for potential chemical analysis of tissue.

4.2.3.2 Reuse Area - Invertebrate Trawling Results

Invertebrates were fairly abundant in the trawls, in some cases too numerous to count with upwards of a hundred small individuals of certain taxonomic groupings. Counts of crustaceans were estimated, where possible, to provide general abundance information.

The benthic isopod *Saduria spp.* and benthopelagic mysid shrimp (Mysidae, unidentified) comprised the majority of the invertebrates observed (Table 4-15), accounting for over 94% of the overall invertebrate catch across all sites. The *Saduria spp.*, estimated at about 1029 individuals or 62% of the overall catch was the most abundant invertebrate found. The *Saduria spp*. were most likely to be *S. entomon*, though *S. sabini* was seen in 2011 and one *S. sibirica* was seen at Test Trench Site #3B in 2014.The taxon *Saduria spp.* was recorded for all trawls except one shallow trawl at SBAY, though abundances were very low (<5) for several trawls, including one shallow replicate each at SBAY and EGG. At the disposal reuse sites SBAY, WEST, and EGG where replicate trawls were performed in both shallow and deep water, a greater concentration of *Saduria spp.* was observed in the deeper trawls as compared to the shallow trawls.

Mysid shrimp were the next most abundant invertebrate observed in the trawl results, accounting for approximately 33% by estimated count, with those too numerous to count estimated at a conservative number of 100 individuals for calculations. In most cases, an estimated number of mysid shrimp was recorded except at the deep sites for EGG where they were too numerous to count. Mysids tend to spend daylight hours associated with the benthos (bottom sediment) but migrate into the water column at night to feed on zooplankton. Being semi-pelagic and smaller than the mesh size of the trawl net, the number of mysid shrimp recorded at each site is likely an underestimate of the true number present at the time of sampling. Both *Mysis relicta* and *Neomysis rayii* were identified in the laboratory from voucher specimens; other mysid species may also be present, including *Mysis littoralis,* a deeper water species that was documented during the 2011 APP sampling. Overall mysid abundance was greater at EGG, though mysids were recorded in all trawls except one at SBAY.

Amphipods were the next most numerous invertebrates captured in the trawl accounting for approximately 4% of the overall catch; again, due to their size and nature, they were likely under sampled in the trawls. An estimate of 62 amphipods was recorded in the field, with the majority seen at EGG. With the exception of one Hyperiid amphipod (*Parathemista libellula*), all voucher amphipod specimens were identified as Gammarid amphipods, including 14 *Gammarus setosus*, *13 Gammaracanthus loricatus*, three *Weyprechtia heuglini*, and one *Anonyx spp.*

An unidentified colonial tunicate was present in one deep trawl from WEST, and 25 solitary tunicates, tentatively identified from voucher specimens as *Rhizomolgula globularis*, were also observed over all trawls. Twenty-two solitary tunicates were observed in the WEST shallow trawls and three from one deep trawl performed at SBAY.

The presence of a "Tubularian" stalked hydroid on pebble substrate, tentatively identified from grab samples or from trawls as *Tubularia indivisa*, was noted at several stations both in the trawls and at the deeper stations where grabs were collected at SBAY and WEST. Unidentified colonial Bryozoans and Hydrozoans were also noted in the EGG trawl samples, along with the incidence of unidentified marine sponges (Porifera).

4.2.3.3 Reuse Area - Algae Trawling Results

Qualitative general observations were made of macroalgae opportunistically collected in the field by trawling, with a few partial specimens retained for later identification. Algae collected during the 2014 MSP appeared to be drift material that was free floating or, in some cases, attached to pebbles (<3 cm). Trawls at most stations exhibited small pieces of detrital algae, unattached algae lacking their holdfasts, broken pieces of algal stipes or blades, or pieces of fine branched or filamentous algae wound around larger pieces of algae or entangled in the trawl net upon retrieval. Though small pieces of seaweed were noted on small pebbles (~2 cm), in no cases were larger pebbles or cobble with attached entire algal specimens with intact holdfasts retained in the trawl. Therefore, there was no indication of the presence of an enriched "boulder patch" environment that might support a community of brown kelps and other hard-substrate flora and fauna as seen in other areas of Stefansson Sound.

Samples from all three disposal stations included pieces of red algae (e.g., *Phycodrys fimbriata*, *Rhodomela spp.*, *Ahnfeltia plicata*, and *Phyllophora truncata* [=*Coccotylus truncates*]). *Dilsea spp.* was also noted. General observations indicated the red algae appeared to be the most numerically abundant algal group in the trawl samples. A few larger pieces of the brown kelp family, including *Laminaria solidingula* and *Saccharina latissimi*, were specifically noted at EGG, including some with holdfasts attached to small pebbles. In general, algae were most abundant at the EGG disposal reuse site, where the field crew noted that some trawls were conducted within a depression in the nearshore area located shoreward of a shoal, where it was likely drift had accumulated.

4.3 OCEANOGRAPHY AND WATER QUALITY RESULTS

Water quality information was collected from each study area and included in situ measurements of conductivity, temperature, salinity, pH, DO, and optical backscatter measurements (OBS; a turbidity-type measurement) as well as discrete samples that were analyzed for TSS and turbidity. Study locations during 2014 included three sites that are being considered for beneficial reuse (Site 1- SBAY, Site 2- WEST, and Site 3 - EGG) and two potential test trench locations (Site #3A and Site #3B).

A summary of the results from the study are summarized in (Table 4-16 and Table 4-17). Since measurements within each general study area were performed on different days and are synoptic in nature, the results are a reflection of the prevailing oceanographic and meteorological conditions on the day that the measurements were made. Therefore, care should be taken in trying to compare measurements between study areas, since conditions at a specific site can change drastically over the course of a short time-span due to the influence and proximity of local rivers and changing wind, wave, and current conditions.

Table 4-16. TSS and Turbidity Water Analysis Results

Area	Station	TSS (mg/L) Surface	TSS (mg/L) Bottom	Turbidity (NTU) Surface	Turbidity (NTU) Bottom
Site 1 SBAY	T1-1	54	-	18.6	-
	T1-3	ND (<5)	11.5	10.7	18.1
	T1-5	7.5	11.5	11.2	22.9
	T2-1	5	-	10.3	-
	T2-3	ND (<5)	16	5.23	25.1
	T2-5	9	9.5	17.1	16.2
Site 2 WEST	T3-1	42	-	52.1	-
	T3-3	37	38.5	43.4	47.1
	T3-5	10.5	20.5	17.7	28.1
	T4-1	41.5	-	54.9	-
	T4-3	48.5	92	62.5	67
	T4-5	37	108	48.1	83.7
Site 3 EGG	T5-1	102	-	66.7	-
	T5-3	49	60	46.3	44.9
	T5-5	56.5	35.5	43.7	30.1
	T6-1	92	-	84.4	-
	T6-3	156	424	156	411
	T6-5	71.5	134	65.8	109
Test Trench (TTR)	#3A	25.5	77	24.9	69.6
	#3B	22	27.5	17.1	24.7

Sampling activities were initiated at SBAY on 16 September 2014 during a period of light easterly wind conditions that extended through 17 September. An examination of the conductivity and salinity measurements revealed that the surface waters at both SBAY and WEST were strongly influenced by the freshwater discharges from the Sagavanirktok River (SBAY and WEST) and, to a lesser extent, the Putuligayuk River (WEST) as seen in the nearly freshwater lens at both of these sites. Surface measurements ranged from 2.10 to 14.31 psu. Bottom measurements were found to be brackish, ranging from 13.28 to 23.68 psu at SBAY and from 13.53 to 23.06 at WEST.

The initial sampling at SBAY and WEST was followed by three days of strong (20-35 knot) easterly winds during which sampling could not be performed. As expected, the easterly winds had a noticeable effect on water levels at West Dock due to the negative storm surge, with water levels dropping by 1-2 ft. Sampling was resumed on 21 September during a southwesterly wind period which eventually rotated around to the northwest causing a positive storm surge in the region. This facilitated getting back into the shallow areas of Prudhoe Bay with the survey vessel. Oceanographic conditions following the three-day easterly storm were found to be cooler and more marine in nature at the two remaining locations (EGG and Test Trench Area) as a result of the general upwelling that occurs along the Beaufort Coast during easterly winds.

Table 4-17. Summary of Hydrographic Data, All Stations

Location	Station	Date	Depth (ft)	Cond (S/m)	Temp (°C)	Salinity (psu)	OBS (NTU)	pH	DO (mg/L)
SBAY	T1-3	9/17/14	0.5	0.41	3.43	3.76	14.9	8.27	12.77
	T1-3	9/17/14	4.0	2.20	2.72	23.68	17.2	7.90	10.27
	T1-5	9/17/14	1.0	0.67	3.62	6.41	21.7	8.27	12.69
	T1-5	9/17/14	4.0	1.89	2.78	20.01	16.9	7.82	10.66
	T2-3	9/17/14	0.5	0.28	3.48	2.51	12.3	8.26	12.91
	T2-3	9/17/14	2.5	1.31	3.25	13.28	22.2	7.93	12.21
	T2-5	9/17/14	0.5	0.60	3.69	5.65	20.6	8.21	12.73
	T2-5	9/17/14	4.0	1.89	2.78	20.01	16.9	7.83	10.66
WEST	T3-3	9/16/14	0.5	0.51	3.88	4.71	24.0	-	12.79
	T3-3	9/16/14	2.5	1.32	2.91	13.53	31.2	-	12.41
	T3-5	9/16/14	1.5	1.41	3.34	14.32	24.4	8.08	12.06
	T3-5	9/16/14	4.0	2.16	2.81	23.06	45.7	7.95	10.61
	T4-3	9/16/14	0.5	1.29	3.63	12.87	49.1	-	12.18
	T4-3	9/16/14	1.0	1.41	2.78	14.54	61.8	-	12.07
	T4-5	9/16/14	1.0	0.23	2.88	2.10	29.0	8.01	11.67
	T4-5	9/16/14	3.5	1.56	2.56	16.31	33.0	7.83	11.46
EGG	T5-3	9/22/14	1.0	2.26	1.87	25.02	46.8	8.00	11.05
	T5-3	9/22/14	5.0	2.54	1.91	28.37	157.4	7.94	10.45
	T5-5	9/22/14	0.5	2.15	1.65	23.85	21.5	7.97	10.92
	T5-5	9/22/14	8.0	2.55	1.86	28.62	26.1	7.89	10.53
	T6-3	9/22/14	0.5	2.29	1.35	25.83	-	7.95	10.19
	T6-3	9/22/14	5.0	4.20	1.52	31.27	-	7.87	9.45
	T6-5a	9/22/14	0.5	1.97	1.63	21.69	-	7.86	10.82
	T6-5a	9/22/14	10.5	2.54	1.89	28.41	-	7.83	9.68
TRENCH	TTR-3A	9/21/14	1.0	2.49	1.90	27.81	17.9	7.90	10.69
	TTR-3A	9/21/14	11.0	2.67	1.49	30.45	46.1	7.87	10.69
	TTR-3B	9/21/14	1.0	2.55	1.90	28.54	17.1	7.96	10.60
	TTR-3B	9/21/14	11.5	2.67	1.41	30.48	71.1	7.94	10.63

Other measurements such as pH were typical for marine waters, ranging from approximately 7.8 to 8.0 pH units with some slightly high measurements seen in the brackish surface waters at both SBAY and WEST as a result of riverine influences. Dissolved oxygen (DO) was found to be high and near or at saturation levels in all measurements with concentrations ranging from 9.45 to 12.91 mg/L as seen in the summary data (Table 4-17).

Measurements of turbidity and suspended sediment were examined with three different methods. Discrete TSS and turbidity samples were collected and analyzed in the laboratory, and OBS measurements were obtained in situ with the SeaBird CTD. TSS measurements ranged from <5 to 156 mg/L at the surface and from 11.5 to 424 mg/L at the bottom, with the highest measurements seen at the EGG stations due the elevated wave and surf activity during the sampling effort. A similar trend was seen for both turbidity and OBS with turbidity levels ranging from 5.23 to 411 NTU and OBS levels ranging from 12.3 to 157.4 NTU, with the highest levels seen at the EGG locations.

As has been seen in numerous other oceanographic studies that have been conducted in the nearshore Prudhoe Bay region over the past 40 years, the hydrographic and water quality conditions that were seen in both 2011 and 2014 reflect recent meteorological and oceanographic conditions. Water quality conditions such as temperature and salinity are dependent on seasonal timing, riverine influences, air temperature, and recent wind activity since easterly winds tend to upwell cooler marine water on to the continental shelf where they mix with nearshore waters. Thus, after the easterly storm that occurred during sampling in 2014, hydrographic conditions were found to be cooler and more marine. Similarly, suspended sediment and turbidity are strongly influenced by wind and wave conditions which result in the re-suspension of bottom sediment, and the effect of riverine plumes which tend to have higher turbidity levels.

5.0 DISPOSAL EVALUATION AND FACTUAL DETERMINATIONS

The data collected from the 2011 and 2014 marine sampling events meet the criteria for evaluation of dredge and disposal areas that fall under Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material.* Components required for the 40 CFR Section 230.11/Section 404(b)(1) factual determination including the short-term or long-term effects of the proposed discharge of dredge material on the physical, chemical, and biological components of the aquatic environment are included in this report and other portions of the application.

It must be reiterated that the material proposed for the test trench disposal program will consist exclusively of clean marine sediments meeting available criteria for either inland disposal or reuse for beach nourishment. Thus, the effects of disposal will be largely related to the physical properties of the sediments and their direct and indirect effects on local habitat and associated ecosystem function. Moreover, the proposed disposal will be in essence a discrete event rather than a recurring activity, as is the case at many disposal sites. Finally, with respect to the test trench disposal program as currently envisioned, the amount of dredge material will be small (~32,000 yd^3), and the disposal area will be approximately 5 acres in size.

5.1 PHYSICAL SUBSTRATE DETERMINATIONS

The design of the sampling program at the three reuse sites utilized a transect approach where two to three locations along each transect were close to shore and within the probable reuse placement areas, leaving two to three locations outside of the probable placement areas. This design allowed biological community analysis to be performed as a function of water depth and allowed some conclusions to be drawn on the effect of bottom fast-ice on those shallow water areas. Also, it is expected that as the deposited dredge material winnows with the wave and current action, the finer-grained sediments will be deposited further from the beach on the outer portions of each transect line. Thus, compatibility with those offshore areas was included in the analysis. Examination of this larger area may also be used long term in the evaluation for handling material from the entire channel dredge footprint rather than just the small amount of material that is proposed to be dredged as part of the 2015 winter Test Trench Program.

Grain size analyses for the three nearshore dredge material reuse areas show differing grain size characteristics. Sediments from the WEST area were on average the finest and therefore most compatible with the test trench locations. Sediments were fairly similar between the Project's preferred WEST and SBAY reuse areas. These sediments were described as either fine sand (SP) or silty fine sand (SM) with occasional gravel. Descriptions indicated that the silt content at WEST tended to increase away from shore.

Physical testing of sediment grain size and compatibility determinations were conducted for the test trench sediments versus the three potential receiving area locations. The test trench sediments were found to be relatively compatible with the reuse areas, and it was determined they would be appropriate for beneficial reuse as shoreline protection. Based on the most common size fraction of fine sand seen at the five test trench sites and at the Site 1 - SBAY and Site 2 - WEST reuse areas, it was determined that these two locations were more compatible than Site 3 at the EGG location. Also, since SBAY and WEST are in a lower energy environment within Prudhoe Bay, it was felt that the increased shoreline protection would last for a longer period of time. Finally, use of SBAY or WEST would result in shorter ice road emplacements than what would be required if the EGG site were to be selected for the disposal materials.

In the near term it is expected that the bottom contours will be affected in the immediate vicinity of the dredge material placement. Since this is a one-time event, the size of the disposal area is relatively small (~5 acres), and the amount of dredge material is also small (32,000 yd^3), it is expected that this shoreline alterations would be minimal and relatively short lived.

5.2 WATER CIRCULATION, FLUCTUATIONS, AND SALINITY DETERMINATIONS

Current patterns will be initially altered in the immediate vicinity of material placement as a result of reduced water depths, but since the size of discharge is relatively small, it is expected that these changes would be short lived. Additionally it is not expected that the discharge would have any effects on normal water level fluctuations or salinity gradients or would affect water quality parameters other than suspended sediment and turbidity.

Given the open coast location and high energy environment of EGG, it is expected that the dredge material would provide less erosional protection to the island as wave and current activity are expected to be much larger at that location than areas within Prudhoe Bay. Although both the SBAY and WEST sites are located within Prudhoe Bay and are afforded some natural protection due to the natural geomorphology of the coastline, both sites are erosional as evidenced by the obvious shoreline erosion and retreat.

Since the test trench material will be spread in a very narrow band (~103 ft wide) along the shoreline, currents will only be affected in the immediate vicinity of the dredge spoils, and the spoils will not be an impediment to fish passage and movements through the area during the open-water period. Additionally, since the distance between any of the three potential disposal areas and the test trenches is at least two miles, it is not expected that any sediment from the disposal area would be re-deposited back into the test trenches.

5.3 SUSPENDED PARTICULATE/TURBIDITY DETERMINATIONS

5.3.1 Test Trench Area Determinations

The dredging of the test trench areas will take place during the winter months and will be conducted through the ice with excavator type equipment, resulting in less impact to the water column at the dredge site than other dredging methods (such as the use of a cutter-head dredge).

Oceanographic conditions during the winter months are quiescent with very small currents that are typically less than 10 cm/s with average current speeds of <5 cm/s (Weingartner and

Okkonen 2001). Under-ice concentrations of TSS are very low and typically less than 0.5 mg/L with turbidity values of less than 1 NTU (Trefry et al. 2009). It is expected that the test trench will generate suspended sediment in the water column and raise turbidity levels in the immediate vicinity of the dredging, but due to the relatively low currents and shallow under-ice water depths, any turbidity plumes that are generated would be short lived and are not expected to travel any significant distance from the dredge area.

Overall, the effects of the dredging operations on the water quality and oceanographic conditions are expected to be minimal. It is expected that the State of Alaska Water Quality Standards (AWQS; 18 AAC 70) for sediment for marine water uses and turbidity for marine water uses will be exceeded in the immediate vicinity of the dredge operation; however, effects will be short lived, will be limited in size, and will not impact any unique biological community. ADEC's sediment criterion for marine water use for the "Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife" is the following:

- No measurable increase in concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method

Applicable turbidity criteria for marine water uses are the following:

- May not exceed 25 nephelometric turbidity units (NTU), or
- May not reduce the depth of the compensation point for photosynthetic activity by more 10%. May not reduce the maximum secchi disk depth by more than 10%.

5.3.2 Disposal Reuse Area Determinations

It is expected that one of the three sediment reuse areas (SBAY, WEST, or EGG) will be utilized for the disposal of the test trench dredge material. Based on the current plan, the dredge material will be transported to the reuse area via an ice road that will be constructed for that purpose. The dredge sediment will then be placed directly on the sea ice in a band that runs parallel to and adjacent to shore. After the sediment has been deposited in the reuse area, it will be graded to a uniform depth and spread over the designated reuse area of approximately 5 acres in size. Since placement of dredge material will occur during the winter months, this will eliminate all issues with sediment and turbidity associated with initial placement of the dredge material.

During spring breakup, it is expected that the dredge spoils will sink to seafloor directly beneath the ice canopy as the ice melts. Since the sediment will present a dark surface compared to the surrounding white snow and ice, the area under and in the vicinity of the dredge spoils will absorb more solar radiation which will hasten the melting process. The much greater weight of the overburden sediment will prevent the ice from lifting off the bottom and carrying any of the sediment from the reuse area. Placement of the dredged materials in the winter and subsequent melting in the spring will give the sediment time to consolidate prior to the open-water season, which will minimize re-suspension from the nearshore area.

Since a greater portion of the dredge material is fine grained compared to any of the potential reuse areas, it is expected that wind and wave activity will begin to winnow and erode the deposited material and will transport that material with the prevailing alongshore currents to be eventually deposited into deeper water. The coarser-grained portion of the test trench sediments is compatible with the reuse areas and will provide shoreline protection against erosion. Sediment plumes will be generated in the reuse areas as fine-grained sediments are re-suspended into the water column, with re-suspension events mainly taking place during storms when wave and currents are greater and when TSS and turbidity are naturally elevated throughout the entire region. It is expected that when sediment plumes are generated during storm activity, they will be masked by natural sediment re-suspension processes that have been shown to increase as a function of wind and wave activity.

5.4 CONTAMINANT DETERMINATIONS

The evaluation and testing of the test trench material and surrounding area was extensively studied in both 2011 during the APP project and in 2014 as part of this MSP effort. These sampling programs followed EPA and USACE Seattle District Guidance for dredge material evaluations (USACE 2013). In addition, other data from the immediate area and from the region were utilized for a comparison of both the physical and chemical properties of the sediment. Since no evidence of contamination was seen in any of the inorganic or organic testing that was performed, and given the limited size of the Test Trench Project, supplemental biological testing was unwarranted and not performed. Sediment chemistry data for the dredge material are extensively examined in this report, and based on the concentrations that were seen, there is no evidence that there should be any concern with respect to disposal at any of the three potential sediment reuse areas.

Likewise, the sediment chemistry data collected for past maintenance dredging operations along West Dock (e.g., Oasis 2006 and 2008) did not indicate the presence of contamination from either metals or petroleum hydrocarbons. All petroleum hydrocarbon data collected between 2002 and 2009 along West dock were reported as non-detect, and metals concentrations were within the natural variability of background values reported for Beaufort Sea coastal sediments.

Similar results were seen during both the 2011 APP and 2014 MSP marine sampling efforts: sediments were generally found to be very clean in the proposed dredge area as well as at a potential disposal sites that were examined. Metals concentrations were all found to be at or near regional background concentrations, all well below SLs established for the Seattle DMMP (USACE 2013), and mostly below ADEC's recommended SQGs consisting of marine threshold effects levels (TELs) developed by MacDonald et al. (2000). (In those instances where an exceedance occurred, the concentration level was within normal regional background levels). There was also no evidence of petroleum contamination. All gasoline range organic (GRO) and volatile BTEX concentrations in the 2011 sediments were found to be below detection limits at all locations.

Diesel range and residual range organic (DRO and RRO) concentrations were detected in several test trench and disposal area samples but at concentrations below ADEC's Arctic

Zone Cleanup Levels (ADEC 2012). On closer examination of the chromatographic fingerprints by the analytical laboratory, it was shown that chromatograms did not resemble a petroleum product or middle distillate pattern. Most of these same samples also had higher TOC concentrations which indicate high peat levels and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes. Similar results were seen in the ANIMIDA and cANIMIDA studies, which examined hydrocarbons in detail, where the surficial sediments in the Prudhoe Bay region were found to exhibit a mixture of primarily terrestrial biogenic hydrocarbons with lower levels of naturally-occurring petrogenic hydrocarbons (Exponent 2010 and Neff 2010).

The dredge area was also examined for PAHs which show low levels. Like the three 2011 dredge channel area samples, low levels of PAH compounds were also found in 2014 at Site #3A and #3B samples and compared to the 2013 DMMP SLs and to ADEC's recommended SQGs (TELs and PELs). Individual PAHs were found to be low in all samples analyzed, with all concentrations well below the DMMP SLs and ADEC's SQGs. Total PAH concentration ranged from 7.6 to 75.4 µg/kg, with slightly higher levels seen at Site #3A resulting from higher TOC and % fine contents in those samples. These concentrations are well within the natural background range for Beaufort Sea sediments.

In general, metals concentrations in the test trench sediments were low and very similar to the overall dredge channel areas and to the three sediment reuse areas. All metals data were well below Seattle DMMP SLs, most metals were well below ADEC recommended SQGs for TEL, and all metals were within the range of background concentrations for the Beaufort Sea coastal area. The only metal concentrations to exceed any screening levels were arsenic and nickel in several samples and copper in a single sample. These metals slightly exceeded TELs but were well below PELs. TELs are concentrations at which toxic effects can be rarely expected, while PELs are concentrations where toxic effects can be expected. As noted earlier in this report, Beaufort Sea sediments are naturally high in these metals and the suspended sediment introduced by rivers in the region has similar concentrations.

Dredge area sediments were also examined to determine whether the metals were bioavailable and potentially toxic by examination of the molar ratios of simultaneously extracted metals to acid volatile sulfides (SEM/AVS). One potential concern is that during the approximate six-month time period when the dredged disposal sediment is present on the ice, the surface layer of the sediment pile will be exposed to atmospheric oxygen and sunlight which could potentially influence the speciation and bioavailability of metals located at the surface of the pile. Upon exposure to atmospheric oxygen, a small fraction of the AVS present in the dredged material will oxidize, thereby increasing the overall ratio of SEM/AVS in the material. However, due to the low gas permeability of the frozen dredged material and the relatively slow rates of the oxidation reactions at subfreezing temperatures, the overall impacts of oxidation on the toxicity of the dredged material will be negligible. The dredged material is not expected to create any toxic conditions as it disperses in the nearshore waters of Prudhoe Bay.

Dredge site samples were further evaluated to assess whether the potentially bioavailable metals are reduced through binding to organic carbon. Using EPA guidance for deriving equilibrium partitioning sediment benchmarks for metal mixtures, each SEM value that exceeded the AVS concentration was normalized to the organic carbon concentration, which is also expected to bind with excess metals. Dredge area sediment indicated no risk to aquatic life with results ranging from less than zero (where AVS exceeds SEM) to 25.1 micro-Mole per gram of organic carbon (μMole/g_{oc}), where a value less than 130 μMole/g_{oc} indicates that there is little to no risk to aquatic life (EPA 2005).

5.5 AQUATIC ECOSYSTEM AND ORGANISM DETERMINATIONS

The potential disposal areas that have been selected are in very shallow water adjacent to beaches. Biologically, these areas were shown to not be unique, and they were relatively depauperate as a result of winter freezing and bottom-fast ice mortality of most resident marine life on an annual basis. Since dredge sediment will be placed on top of the area that contains bottom-fast ice out to approximate 3-ft water depths, short-term effects on this area will be minimal since this soft-bottom area is essentially naturally denuded of most benthic life each winter. As a result, it is expected that placement of dredge material in these areas will have minimal short-term impact and no long-term impact on resident biological species. Other potential impacts to biological communities could result from suspended sediment and turbidity plumes that could in turn reduce light penetration and algae growth. However, no hard-bottom or algae communities which could be affected by turbidity were identified in the vicinity of the potential sediment reuse sites.

In terms of the dredge area, as with most any dredging, the biological communities within the designated test trench footprint will be eliminated. Since these areas contain typical soft-bottom biological communities, it is expected that the test trench area will recolonized over time. The length of time for this recolonization will depend somewhat on the rate of sediment infill to the trenches as a result of natural sedimentation processes. Overall, the effect on this area would be limited in size and considered short term with no long-term impacts or loss to the aquatic ecosystem. Local turbidity of the nearby water column (where the ice is not bottom-fast) may increase during dredging operations which are scheduled to occur in ice-covered winter conditions, but impacts are expected to be minimal in terms of the biota.

Data from the 2011 APP and the 2014 MSP both show the type of variability and patchiness among taxonomic group abundance that is expected in the Prudhoe Bay area. The marine environment in the Prudhoe Bay area is subject to many different physical forces that ultimately control the structure of the local benthic communities that exist there. These forces, such as variable salinity and ice stressing, influence the benthic community differentially from the shoreline environment out into deeper water in a gradient manner, dictating benthic abundance and diversity. This pattern is exhibited in the data that were collected during this study where the harshest and most depauperate areas biologically are in the shallowest water in the nearshore environment, which is subjected to considerable variability in physical conditions. Soft-bottom benthic communities are typically more stable, diverse, and abundant in deeper waters offshore.

Since the dredging activities will take place during the winter, potential conflicts with fish, marine mammals, and migratory birds will be minimized. Because of the low densities of fish typically present during the winter period, only low numbers are expected to be affected by Project activities (see Project's Essential Fish Habitat Assessment report). Polar bears and ringed seals may be also be in the area but are expected to occur in low numbers. One of the primary concerns for the disposal areas is the potential existence of polar bear maternal dens along the shoreline. Also, ringed seals build subnivian lairs in the offshore area and often take advantage of pressure ridges/cracks in the ice that provide natural cover for their lairs and breathing holes. These and other concerns with respect to marine mammals and threatened or endangered species are addressed in the Project's Wildlife Interaction Plan. This Plan discusses avoidance and mitigation measures that will be followed to avoid or mitigate effects on wildlife from test trench dredging and disposal activities. No migratory birds are expected to be in the area during the winter trench construction activities.

During the summer open-water period, birds make extensive use of the marine ecosystem in the Prudhoe Bay area. An estimated 10 million individual birds of over 120 species use the Beaufort Sea coastal area in Alaska (Johnson and Hertner 1989). Nearly all of the species are migratory, occurring from late May during spring breakup through September. Numerous studies have been conducted in the region over the past 40 years that list species likely to occur in the area. Although many of the species may migrate through, rest, and/or feed in the vicinity of the project area, the loss of shallow water habitat at the Project's preferred disposal site location is not expected to adversely affect bird populations based on the relative abundance of shallow water habitat in the general area.

The potential impact of the dredging and disposal activity on special aquatic sites is not an issue since no special aquatic sites exist in the vicinity of the planned operations. The only special aquatic site in the region that has been identified is the "Boulder Patch" which is located 20 miles to the east of West Dock in Foggy Island Bay. This site is a unique hard-bottom biological community that has been the subject of numerous investigations over the past 30 years including impacts of increased turbidity as a result of potential oil development (i.e., the Liberty Project) in its immediate vicinity. Sampling that was conducted as part of the 2014 MSP and other studies that have been conducted in the vicinity of both the proposed test trench dredging and the three potential disposal locations have not identified any other special aquatic site, hard-bottom area, or other unique biological community in any area likely to be affected by the dredging and disposal operations. Other special aquatic sites that are identified in the regulations (40 CFR §230.40-45), including sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes, do not exist in the planned area of operations.

Alaska Native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Since the dredging will occur during the winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

5.6 PROPOSED DISPOSAL SITE DETERMINATIONS

Disposal Site 1 - SBAY and Site 2 - WEST were found to be very similar in terms of coastal geomorphology and exposure to wind and waves with currents being wind driven and parallel to shore. However, WEST is the Project's recommended preferred location for disposal based on sediment compatibility, location in relation to the dredging, and relative need in terms of shoreline protection. The site at Egg Island was found to be much more exposed to wind and wave activity and, based on the more dynamic environment, would not benefit as much from beach nourishment. All three disposal sites are similar in terms of water depths within the deposit zone with depths increasing from zero at the shoreline to approximately 3-4 ft depth at 150 ft from shore. EGG was found to be slightly deeper especially in the area offshore of the potential deposit zone, with depths of 8-15 ft compared to SBAY and WEST where depths increased to 4-5 ft at 1000 ft distance from the beach.

Dispersion of very fine to silty fill material will occur outside the designated placement area during the subsequent open-water period. This widespread dispersion would occur primarily during storm activity by natural means and would result in a thin layer of material that would be transported along and offshore adjacent to the disposal area and would result in no adverse environmental impacts. State of Alaska water quality criteria for sediment and turbidity will be exceeded in the immediate vicinity of the disposal activity. It is expected that ADEC's 401 Water Quality Certification required for the Project would address this issue in terms of a short-term variance for the placement of dredged material and that no other exceedance would occur that would restrict the discharge of dredge materials. Moreover, it was determined that the material proposed for the test trench disposal program will consist exclusively of clean marine sediments meeting regulatory criteria for either inland disposal or reuse for beach nourishment. Thus, the discharge of the dredge spoils at the preferred disposal site would not be expected to cause or contribute to any applicable violation of State Water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972.

A key point that is listed in the regulations (40 CFR §230.80) to shorten the permit processing time is advanced identification of the disposal area(s). Three potential disposal areas were examined in 2014 as part of the MSP that included: Site 1 in southern Prudhoe Bay (SBAY), Site 2 along the western shore of Prudhoe Bay (WEST), and Site 3 on the outer northern shore of Egg Island (EGG). These three areas have been characterized in terms of their physical, chemical, biological, and general oceanographic characteristics in sufficient detail to allow an evaluation of their appropriateness and suitability for the disposal of dredge material from the proposed test trench activities. Results of these characterizations are included in this report.

5.7 DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ECOSYSTEM

No cumulative effects on the aquatic ecosystem were identified in this evaluation.

In terms of the dredge area, as with most any dredging, the biological communities within the designated test trench footprint will be eliminated. Since these areas contain typical soft-bottom biological communities, it is expected that the test trench area will be recolonized over time. The length of time for this recolonization will be dependent upon the rate of sediment infill to the trenches as a result of natural sedimentation processes. Overall, the effect on this area would be limited in size and considered short-term with no long-term or cumulative impacts or loss to the aquatic ecosystem.

In terms of disposal operations, the winter disposal will ensure that no suspended sediment or turbidity plumes are generated during the actual placement of the dredge material. This will allow the sediment to settle and consolidate prior to being influenced by wave and current activity during the subsequent open-water period. The disposal areas have been selected that are in very shallow water adjacent to beaches. These areas are not biologically unique; they are relatively depauperate as a result of winter freezing and bottom-fast ice essentially resulting in the mortality of most resident life on an annual basis. As a result, it is expected that placement of dredge material in these areas will have minimal short-term impacts, and there will be no long-term or cumulative impacts from the Project. In addition, the planned disposal of the dredge material will be for beneficial reuse as shoreline protection which will further mitigate any potential impacts.

5.8 DETERMINATION OF SECONDARY EFFECTS ON THE AQUATIC ECOSYSTEM

No secondary effects on the aquatic ecosystem were identified during this analysis and evaluation.

5.9 OTHER REGULATORY DETERMINATIONS

The only potential restriction on the discharge identified was the State of Alaska water quality criteria for sediment and turbidity would be exceeded in the immediate vicinity of the dredge and disposal activity. However, as stipulated in these criteria (40 CFR §230.10), this violation would only occur after consideration is given to the dilution and dispersion of the discharge. It is expected that ADEC's 401 Water Quality Certification required for the Test Trench Program would address this requirement and that a short-term variance for "a temporary activity associated with the placement of dredged or fill material" (18 AAC 70.200) would be granted; no other exceedance would occur that would restrict the discharge of dredge materials. Moreover, it was determined that the material proposed for the test trench disposal program will consist exclusively of clean marine sediments meeting available criteria for either inland disposal or reuse for beach nourishment. Thus, the discharge of the dredge at the preferred spoils disposal site will not cause or contribute to any violation of State Water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972.

For the most part, potential effects on human use characteristics that are addressed in the 404(b)(1) guidance are not applicable to the proposed dredge activity. There are no municipal or private water supplies in the area; recreational and/or commercial fishing activities do not occur in the vicinity of the dredge or any of the disposal sites. Water-related recreation does not occur, it is not expected that the activity would affect aesthetics, and there are no parks, historic monuments, national seashores, research sites, or similar preserves in the area. Aesthetics and visual impacts resulting from the placement of fill material in the nearshore area would be minor given the remote location and limited access to the area. Also, given the limited size of the Test Trench Program, no impacts to any navigational areas or channels are expected to occur. The winter construction timing will also aid in minimizing conflicts with other activities that occur at West Dock such as the tug, barge, and other oil industry support boat traffic prevalent in the summer months.

Alaska Native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Since the dredging will occur during the winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

One of the primary actions to minimize adverse impacts is the test trench dredging and disposal operations will take place during the ice-covered winter months. The winter construction timing ensures that the operations will occur during a period when biological activity in the area is minimal to non-existent in terms of fish, marine mammals, and birds. Also, oceanographic conditions are quiescent and the ice canopy reduces the effective water depth, thus suspended sediments generated by the dredge activities will only be transported a short distance before settling to the bottom. The winter construction will avoid conflicts with other activities that occur near West Dock during the summer such as the tug, barge, and other oil industry activities.

6.0 CONCLUSIONS: 404 (B)(1) FACTUAL DETERMINATIONS

Information presented in this section and table is based on the 2011 Alaska Pipeline Project (APP) and 2014 Alaska LNG Marine Sampling Programs (MSP). The table summarizes the overall findings of the evaluation that was performed for the proposed test trench dredging program and the disposal of those sediments in one of three disposal areas that were examined for beneficial reuse as beach nourishment and shoreline protection.

Table 6-1. Summary of 404(b)(1) Factual Determinations

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
(a) Physical substrate determinations • Determine the nature and degree of effects that the proposed discharge will have individually and cumulatively on the characteristics of the substrate at the proposed disposal site. • Consider particle size, shape and degree of compaction of the material proposed for discharge and the material constituting the substrate at the disposal site including the duration and physical extent of substrate changes. • Consider possible loss of environmental values and actions to minimize impacts. • Predict potential changes to substrate elevation and bottom contours based on the proposed method, volume, location and rate of discharge of current patterns, water circulation, wind and wave action, and other physical factors that may affect the movement of the discharged material.	*Dredge area* • Predominantly fine sand and silt with some coarser material, with the fine sand fraction being the most common. • No sediment contamination was found at the five potential test trench sites.	2.1 4.1.2 5.1
	Disposal areas • Sediment grain size found to be somewhat coarser than the test trench dredge material, but the most common size fraction was also fine sand. Sediments described as fine sand or silty fine sand with occasional gravel. • No sediment contamination. • Area depauperate of benthic organisms within the disposal areas (within bottom-fast ice zone).	4.1.1 4.2.1 5.1
	Comparison of grain size between dredge site and disposal areas • Site 1 along the western shore of Prudhoe Bay (WEST) was found to be most compatible with the dredge sediments in terms of grain size and is the preferred disposal site. • Site 2 in southern Prudhoe Bay (SBAY) was found to have acceptable compatibility. • Site 3 on the outer coast of Egg Island (EGG) was found to have the least compatibility.	4.1.3 5.1
	Conclusions • Test trench sediments were found to be acceptable for beneficial reuse and will provide beach nourishment/shoreline protection. • Site 1 is the preferred disposal area based on grain size compatibility and level of exposure to wind and wave activity. • No long-term or cumulative loss to the aquatic ecosystem. • Minor short-term changes to the bathymetry and current patterns in the immediate vicinity of the disposal reuse area. • The shoreline geometry will be altered in the immediate vicinity of the disposal area. • Winter dredging will minimize impacts on suspended sediment/turbidity as dredge spoils will consolidate at disposal site prior to being subject to storm activity during later open-water period.	NA

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
(b) Water circulation, fluctuation, and salinity determinations • Determine the nature and degree of effects that the proposed discharge will have individually and cumulatively on water, current patterns, circulation including downstream flows, and normal water fluctuation. • Consider water chemistry, salinity, color, odor, taste, dissolved gas levels, temperature, nutrients and eutrophication plus other appropriate characteristics. • Consider potential diversion or obstruction of flow, alterations of bottom contours, or other significant changes in the hydrologic regime. • Consider possible loss of environmental values and actions to minimize impacts. • Evaluate potential effects on the current patterns, water circulation, normal water fluctuation and salinity based on the proposed method, volume, location and rate of discharge.	*General information* • Current patterns will be initially altered in the immediate vicinity of material placement as a result of reduced water depths, but since the size of discharge is relatively small, these changes would be short lived. Additionally, it is not expected that the discharge would have any effects on normal water level fluctuations, salinity gradients, or water quality parameters other than suspended sediment and turbidity. Since the test trench material will be spread in a very narrow band (~103 ft wide) along the shoreline, currents will only be affected in the immediate vicinity of the dredge spoils; this will not be an impediment to fish passage and movements through the area during the open-water period.	2.2.3 4.3 5.2
	Salinity and Temperature • No effect on either salinity or temperature distribution or stratification.	2.2.3 4.3 5.2
	Water Quality • Other than a short-term increase in suspended sediment and turbidity, no other effects on water quality characteristics were identified.	2.2.3 4.3 5.3
	Circulation and Current Patterns • No effect on under-ice currents at the disposal sites. • Short-term alterations in the immediate vicinity of the dredge spoils during the summer. • No effect on normal water level fluctuations. • No impact to marine navigation.	2.2.3 5.2 5.3
	Conclusions • Short-term impact on bathymetry and currents in the immediate vicinity of the dredge disposal area. • No long-term or cumulative effects to currents or circulation patterns. • No effect on water level fluctuations. • No effect on water quality parameters (including salinity) other than suspended sediment (see below). • No effect on fish migration or passage or on marine navigation.	NA
(c) Suspended particulate/turbidity • Determine the nature and degree of effects that the proposed discharge will have individually and cumulatively in the kinds and concentrations of suspended particulate/turbidity in the vicinity of the disposal site. • Consider grain size of the material proposed for discharge, the shape and size of the plume of suspended	*General information* • As currently envisioned, the dredging of the test trench areas will take place during the winter months and will be conducted through-ice with excavator type equipment which would have less impact to the water column at the dredge site than other dredging methods. • It is expected that the State of Alaska Water Quality Standards (AWQS; 18 AAC 70) for sediment for marine water uses and turbidity for marine water uses will be exceeded in the immediate vicinity of the dredge operation and during the following open-water season at the disposal site; however, effects will be short lived, will be limited in size, and will not impact any unique biological community. • Since a greater portion of the dredge material is fine grained compared to any of the potential reuse areas, it is expected that wind and wave activity will winnow the fine-grain portion of the deposited material to be eventually deposited into deeper water. Sediment plumes will be generated in the reuse areas as fine-grained sediments are re-suspended into the water column, with re-suspension events	4.1.3 4.3 5.3

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
particulates, the duration of the discharge and the resulting plume, and whether the potential changes will cause violations of applicable water quality standards. • Consider possible loss of environmental values and actions to minimize impacts. • Evaluate the proposed method, volume, location and rate of discharge on potential effects to current patterns, circulation and fluctuations, wind and wave action, and other physical factors on the movement of suspended particulates.	mainly taking place during storms when wave and currents are greater and when TSS and turbidity are naturally elevated throughout the entire region.	
	Conclusions • Short-term increase in suspended sediments/turbidity during dredging at the test trench sites that are not within the bottom-fast ice zone. • Short-term increase in suspended sediments/turbidity at the disposal site during the subsequent summer open-water period. • State of Alaska water quality criteria for sediment and turbidity will be exceeded in the immediate vicinity of the dredge and disposal activity. It is expected that ADEC's 401 Water Quality Certification required for the Project would address this issue and that a short-term variance would be granted for the disposal operation; therefore, no exceedance would occur that would restrict the discharge of dredge materials. Moreover, it was determined that the material proposed for the test trench disposal program will consist exclusively of clean marine sediments meeting available criteria for either inland disposal or reuse for beach nourishment. Thus, the discharge of the dredged materials at the preferred site will not cause or contribute to any applicable violation of State Water quality standards or other applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972. • No long-term or cumulative impacts on suspended particulates/turbidity.	NA
(d) Contaminants • Determine the degree to which the material proposed for discharge will introduce, relocate or increase contaminants. To make this determination, consider the material to be discharged, the aquatic environment at the proposed disposal site, and the availability of contaminants.	*Hydrocarbons* • No evidence of hydrocarbon contamination. • Hydrocarbons were not elevated and did not exceed USACE screening level, State of Alaska clean up levels, or ADEC recommended sediment quality guideline criteria. • PAHs were low and at natural background levels. • No evidence of diesel contamination as seen in DRO and RRO levels. • No evidence of any gasoline or volatile range contamination as seen in GRO and BTEX.	2.1 2.2.1 4.1.2 5.4
	Metals • No evidence of any metals contamination. • Metals were not elevated and did not exceed USACE screening levels. • A few samples did exceed ADEC recommended sediment quality guideline TEL criteria for arsenic, copper, and nickel; these levels were shown to be natural occurring. • Metals in the dredge sediments were shown to be not biologically available. • Due to the low gas permeability of the frozen dredged material and relatively slow rates of the oxidation reactions at subfreezing temperatures, the overall impacts of oxidation on the bioavailability of metals in the dredged material was shown to be negligible; it is not expected any toxic conditions will be created as dredged material disperses in the nearshore waters of Prudhoe Bay. • All concentrations were within natural background levels for Beaufort Sea sediments.	2.1 2.2.1 4.1.2 5.4

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
	Conventional Parameters • No evidence of any contamination.	4.1.2 5.4
	Chlorinated Pesticides and PCBs • No evidence of any significant contamination. • Concentrations were well below USACE screening levels and ADEC recommended SQGs. • A few samples showed trace level concentrations that were believed to be due to global distillation processes.	4.1.2 5.4
	Conclusions • No evidence of any contamination in the dredge material that would introduce, relocate, or increase contaminants or create toxic concentrations that would affect the aquatic environment. • No effect on the aquatic environment at the disposal sites.	NA
(e) Aquatic ecosystem and organism • Determine the nature and degree of the effect that the proposed discharge will have individually and cumulatively on the structure and function of the aquatic ecosystem and organisms. • Consider the effects at the proposed disposal site of potential changes in substrate characteristics and elevation, water or substrate chemistry, nutrients, currents, circulation, fluctuation, and salinity, on the recolonization and existence of indigenous aquatic organisms or communities. • Consider possible loss of environmental values and actions to minimize impacts. • Tests as described by 230.61 may be required to provide information on the effect of the discharge material on communities or populations or organisms expected to be exposed.	*Benthic fauna communities at dredge area* • Found to be more numerous and diverse than the disposal sites due to greater water depths. • Typical soft-bottom benthic community that is not unique. • No hard bottom or algal communities were found.	2.2.2 4.2.2 5.5
	Benthic fauna communities at disposal site options • Shallow region within the dredge deposit zone found to be depauperate of benthic life due to annual formation of bottom-fast ice. • Offshore areas adjacent to disposal sites were found to contain more numerous benthic organisms. • Epibenthic organisms primary *Saduria,* mysid shrimp, and amphipods.	2.2.2 4.2.1 4.2.3 5.5
	Fish • Trawling effort indicated low levels of fish usage at the disposal sites. • Winter disposal operations will eliminate impacts. • Fish movements will be slightly altered in the immediate vicinity of the disposal area, but overall fish passage will not be affected. • No important habitat will be eliminated.	2.2.2 4.2.3 5.5
	Algae • No hard-bottom areas that would support an algae community were identified. • Algae that appeared to be drift and not originating in the area was found during the trawling effort.	2.2.2 4.2.3 5.5
	Birds • No impacts to nesting or other use of the disposal area are expected. • The short-term loss of shallow water habitat at the preferred disposal site location is not expected to adversely affect bird populations based on the relative abundance of shallow water habitat in the general area.	5.5
	Threatened & endangered marine mammal species • Ringed Seals – Potential loss of a few breathing holes, but overall no expected impact. Issues are	5.5

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
	addressed in the Wildlife Interaction Plan. • Polar bears – No expected impact, addressed in Wildlife Interaction Plan.	
	Conclusions • No long-term or cumulative impact to benthic communities in the disposal area, since the area naturally dies off on an annual basis as a result of bottom-fast ice. • No overall alteration, long-term impact, or loss to the aquatic biological ecosystem. • No unique biological communities were identified that would be affected by the disposal operations. • Dredge sediments were found to be clean and therefore supplemental biological testing (bioassays, etc.) was not performed.	NA
(f) Proposed disposal sites • For each disposal site, the mixing zone is to be confined to the smallest practicable zone within each specified disposal site that is consistent with the type of dispersion determined to be appropriate. • Where it can be justified that widespread dispersion by natural means will result in no significant adverse environmental effects, the discharged material may be spread naturally in a thin layer over a large area of the substrate rather than be contained within the disposal site. • The permitting authority shall consider the following factors in determining acceptability of a proposed mixing zone:	*General information* • Disposal Site 1 - SBAY and Site 2 - WEST were found to be very similar in terms of coastal geomorphology and exposure to wind and waves with currents being wind-driven and parallel to shore. WEST is the Project's preferred location for disposal based on sediment compatibility, location in relation to the dredging, and relative need in terms of shoreline protection. Site 3 at Egg Island (EGG) was found to be much more exposed to wind and wave activity and, based on the more dynamic environment, would not benefit as much from beach nourishment. • State of Alaska water quality criteria for sediment and turbidity will be exceeded in the immediate vicinity of the disposal activity. It is expected that ADEC's 401 Water Quality Certification required for the Project would address this issue and that a short-term variance would be granted for the placement of the dredged material; therefore, no exceedance would occur that would restrict the discharge of dredge materials. • Dispersion of very fine to silty fill material will occur outside the designated placement area during the subsequent open-water period. This widespread dispersion would occur primarily during storm activity by natural means and would result in a thin layer of material that would be transported along and offshore adjacent to the disposal area and would result in no adverse environmental impacts. • A key point that is listed in the regulations (40 CFR §230.80) to shorten the permit processing time is advanced identification of the disposal area(s). Three potential disposal areas were examined in 2014. These three areas have been characterized in terms of their physical, chemical, biological, and general oceanographic characteristics in sufficient detail to allow an evaluation of their appropriateness and suitability for the disposal of dredge material from the proposed test trench activities.	4.1.1 4.1.3 5.1 5.6
	Conclusions • No adverse environment effects at the disposal site. • No exceedance in State of Alaska water quality standards will occur after consideration is given to natural dilution and dispersion of the dredge material at the disposal site which will require an ADEC 401 Certification of Reasonable Assurance.	NA
(i) *Depth of water at the disposal site*	*Disposal Sites: South Prudhoe Bay, West Shoreline Prudhoe, and outer shoreline of Egg Island* • Shallow from shore out to 3-4 ft water depth.	4.1.1

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
	Conclusions • Proposed disposal area is a band along shore extending from near the beach out to approximately 103ft from shore into 3 to 4 ft water depths.	NA
(ii) Current velocity, direction, and variability at the disposal site	*Disposal Sites* • Minor short-term alteration in currents and circulation in immediate vicinity of disposal.	4.3 5.2
	Conclusions • No significant adverse effect.	NA
(iii) Degree of turbulence	*South Prudhoe Bay* • Low- to medium-energy environment depending on prevailing wind conditions.	4.3 5.2
	West Shoreline Prudhoe Bay • Low- to medium-energy environment depending on prevailing wind conditions.	4.3 5.2
	Nearshore Egg Island • Higher energy environment that is much more turbulent than either of the Prudhoe sites.	4.3 5.2
	Conclusions • Based on wind driven waves and currents, either Site 1 – SBAY or Site 2 – WEST were found to be more compatible than Site 3 - EGG for beneficial reuse of the dredge sediments for beach nourishment and shoreline protection.	NA
(iv) Stratification attributable to causes such as obstructions, salinity or density profiles at the disposal sites	NA	NA
(vi) Rate of discharge	NA	NA
(vii) Ambient concentration of constituents of interest	*Disposal Sites* • TSS and turbidity are dependent on wind/wave activity and found to be highly variable day to day.	4.3 5.3
	Conclusions • Ambient TSS and turbidity levels are highly dependent on prevailing atmospheric and oceanographic conditions. • No effect on other water quality parameters (DO, pH, temperature, salinity, etc.).	NA
(viii) Dredged material characteristics, particularly concentrations of constituent, amount of material (sand, silt, clay, etc.) and settling velocities	*General information* • Some variability seen between test trench locations and depths, but sediment was generally fine-grained sand and silt or silty sand.	4.1.2 4.1.3
	Conclusions • Since disposal will take place on top of the ice during the winter, settling velocities of the dredge sediment are not an issue. The dredge material will consolidate prior to the following open-water period when it will be subjected to wind, wave, and storm activity.	NA
(ix) Number of discharge actions per unit of time	NA	NA

Sec. 230.11: Factual Determinations	Summary of Key Findings	Section No. in Document
(x) Other factors of the disposal site that affect the rates and patterns of mixing	***Conclusions*** • No other factors were identified other than those already discussed.	NA
(g) Determination of cumulative effects on the aquatic ecosystem.	***Conclusions*** • No cumulative effects or long-term loss to the aquatic ecosystem were identified in this evaluation.	5.7
(h) Determination of secondary effects on the aquatic ecosystem.	***Conclusions*** • No secondary effects on the aquatic ecosystem were identified during this evaluation.	5.8

Table 6-2. Other Essential Information for Permitting

Other Essential Information for Permitting	Summary of Key Findings	Section & Page No. in Document.
Subpart E – Potential Impacts on Special Aquatic Sites	*General information* • The potential impact of the dredging activity on special aquatic sites is not an issue since no special aquatic sites exist in the vicinity of the planned operations. The only special aquatic site in the region that has been identified is the "Boulder Patch" which is located 20 miles to the east of West Dock. Other special aquatic sites that are identified in the regulations (40 CFR §230.40-45), including sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes, do not exist in the planned area of operations.	1.5 5.5
	Conclusions • No potential impacts on special aquatic sites as none exist in the area.	NA
Subpart F – Potential Effects on Human Use Characteristics	*General information* • No municipal or private water supplies exist in the dredge or disposal areas. • No recreational and/or commercial fishing activities occur in the vicinity of the dredge or any of the disposal sites. • No impacts on aesthetics and visual impacts will result from the placement of fill material in the nearshore area. • No parks, historic monuments, national seashores, research sites, or similar preserves exist in the dredge or disposal areas. • No impacts to any navigational areas or channels are expected to occur. • Subsistence activities related to bowhead whaling do occur in the general region during late summer. Since the dredging will occur during the winter, conflicts with native subsistence with respect to whaling activity will not occur. Other native subsistence activities such as hunting, fishing, or gathering do not take place in the area. • No other water-related recreation occurs in the area.	1.5 5.9
	Conclusions • No potential effects on human use.	NA

<table>
<tr><th>Other Essential Information for Permitting</th><th>Summary of Key Findings</th><th>Section & Page No. in Document.</th></tr>
<tr><td>(a) Preferred disposal site alternative
Greatest beneficial reuse of material – AGI Pad erosion protection
Compatibility of sediments
Ice road distance minimizes freshwater use.</td><td>West Shoreline Prudhoe Bay – Site 2 (WEST)
The shoreline at WEST indicated the greatest immediate need for protection since the southern end of the AGI pad is currently being eroded during storm activity.
This site was found to be the most compatible in terms of sediment grain size and therefore would provide the best use of dredge material as beneficial reuse for beach nourishment and shoreline protection.
The ice road to this site would be the shortest which minimizes potential interaction with marine mammals and would also minimize the amount of freshwater needed to cap the ice road.
This site along with Site 1 (SBAY) were found to be the most compatible in terms of wind and wave energy and the length of time that the shoreline protection would be effective.
This site is depauperate of benthic infauna that would be affected by disposal.</td><td>1.5
4.1.3
4.2.1</td></tr>
<tr><td>(b) Section 401- Certificate of Reasonable Assurance</td><td>Water Quality
The only potential restriction on the discharge identified was the State of Alaska water quality criteria for sediment and turbidity which would be exceeded in the immediate vicinity of the dredge and disposal activity. However, as stipulated in this criteria (40 CFR §230.10), this violation would only occur after consideration is given to the dilution and dispersion of the discharge. It is expected that ADEC's 401 Water Quality Certification of Reasonable Assurance that is required for the Project would address this requirement, that a short-term variance would be granted for the disposal operations, and therefore, no violation would occur that would restrict the discharge of dredge materials.
The discharge of the dredge material at the preferred spoils disposal site will not cause or contribute to any other applicable violation of State Water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972.</td><td>4.3
5.3
5.9</td></tr>
<tr><td>(c) Endangered Species Act, Section 7 Consultation</td><td>U.S. Fish & Wildlife Service - Polar Bears
Minimize Human & Polar Bear encounters
Project Wildlife Interaction Plan developed
Use Protected Species Observers (PSOs) and Purcell Security during field activities
Avoid disturbance to maternal dens
Survey potentially affected area for active maternal dens area using FLIR technology
Maintain one mile buffer zone around all active dens
Habitat alteration
No effect is expected to ringed seals, the primary prey species for polar bears
National Marine Fisheries Service - Ringed Seal
Loss of breathing holes due to construction of ice roads and pads
Test trench construction will occur in areas of bottom fast ice or floating ice with very little water beneath the ice.</td><td>See Wildlife Interaction Plan</td></tr>
</table>

Other Essential Information for Permitting	Summary of Key Findings	Section & Page No. in Document.
	○ Only one test trench to be constructed in the floating ice zone. ○ Ringed seals maintain multiple breathing holes and the loss of one or two would not adversely affect local seals. • Loss of subnivian lairs ○ Survey for subnivian lairs prior to construction of ice roads and pads. ○ Maintain 500-ft radius buffer zone from subnivian lairs located during the survey. ○ Complete test trench construction prior to ringed seal pupping season (mid-March to late April). • Behavioral disturbance from underwater noise from site activity such as cutting ice blocks, excavating trenches, and truck traffic. ○ Implement use of PSOs, buffer zones, and adherence to MMPA regulations to avoid injurious exposure.	
(d) Essential Fish Habitat Consultation	*National Marine Fisheries Service – Essential Fish Habitat Species* • Arctic Cod - Construction of an ice roads/pads and test trench activity may also displace small numbers of Arctic cod. • Saffron Cod – Not expected to occur in the Project area. Most all of the biomass of this species is in the Chukchi Sea, west of the Project area. • Snow Crab – Not expected to occur in the shallow waters of the Project area.	See Essential Fish Habitat Report

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APPENDIX R.3 2015 KLI MARINE SAMPLING PLAN (USAG-EX-SRZZZ-00-000004-000)

2015 MARINE SAMPLING PROGRAM EVALUATION OF POTENTIAL DISPOSAL REUSE SITES

USAG-EX-SRZZZ-00-000004-000

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1.0 INTRODUCTION

The *Alaska LNG Project – 2015 Marine Sampling Program* (2015 MSP) is a marine environmental monitoring program that was performed to allow for planning and permitting decisions with respect to the dredging of a navigational channel which will be required as part of the Alaska LNG Project (Project), described below. Specifically, the 2015 MSP evaluates four areas being considered for the beneficial reuse of dredged material from dredging to be performed near West Dock on the Alaskan North Slope. These four sites, located along the southern shoreline of Prudhoe Bay, along the western shore of Prudhoe Bay, at Gull Island within Prudhoe Bay, and along the shoreline west of and adjacent to West Dock, will potentially benefit from the use of dredged sediments for nearshore beach nourishment and erosion protection (Figure 1-1).

The 2015 MSP was designed as a standalone study focusing exclusively on evaluating disposal areas that are currently being considered with emphasis on utilization of the dredged sediments for beneficial reuse. The 2015 MSP was designed based on previous marine sampling performed in 2011 as part of the Alaska Pipeline Project (APP) and in 2014 as part of the Project (*2014 Marine Sampling Program* {2014 MSP}), each of which examined a number of potential disposal areas as well as the proposed dredge area itself. It is anticipated that further evaluation of the dredge area and sediments will be part of a detailed program to be performed at a future date.

This report provides information on the 2015 MSP program such as study design, methods, and results, including disposal site evaluation information and dredged materials compatibility in terms of sediment grain size; pertinent data from prior sampling in the dredge area and potential disposal sites; and a summary of applicable regional background and historical data. The data summarized in this report are intended to characterize marine environmental conditions (water quality, surficial sediment chemistry, benthos, and demersal fish) to satisfy the majority of the requirements for permitting of disposal of sediments under the Clean Water Act (CWA) Section 404(b)(1) guidelines for the discharge of dredged material in near-coastal waters, including beach nourishment for beneficial use. Along with providing background and resource information, this report is intended for use as supporting documentation for any dredge permit applications for the North Slope to be submitted in the future in conjunction with the Project.

1.1 ALASKA LNG PROJECT DESCRIPTION

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

The Project scope includes a liquefaction facility in southcentral Alaska; an approximately 800-mile, large-diameter gas pipeline (Mainline); a gas treatment plant (GTP) on the North Slope; a gas transmission line connecting the GTP to the PTU gas production facility (PTU Gas Transmission Line or PTTL); and a gas transmission line connecting the GTP to the PBU gas production facility (PBU Gas Transmission Line or PBTL).

Figure 1-1: General Study Area with Potential Dredging and Disposal Reuse Sites

The current execution plan for construction of the GTP includes a multi-year sealift of component modules to Prudhoe Bay using oceangoing barges and tugs. Modules will be offloaded at Dock Head 2 (DH2) which is located in shallow waters (6 to 7 feet {ft} deep) on the northeast side of the West Dock Causeway. Sealift barges transporting the GTP modules will require a minimum water depth of -16 ft Mean Lower Low Water (MLLW) and thus, a dredged channel from deeper water north of West Dock to DH2 has been proposed to achieve adequate depth for these barges (Figure 1-1). As currently conceived, the navigation channel will be dredged to a depth of 16 ft below the National Ocean Service (NOS) MLLW, and a turning basin will be dredged near DH2 to facilitate vessel maneuverability. It is estimated that over 1 million cubic yards (yd^3) of sediment dredged from the proposed channel and associated turning basin will require disposal.

1.2 2015 MARINE SAMPLING PROGRAM

The 2015 MSP was designed to document the physical, chemical, and biological characteristics of four areas that are being considered on the Project for the beneficial reuse of dredged sediments to provide information necessary for future planning and permitting. The four potential disposal areas examined by the 2015 MSP included the nearshore region in the southern portion of Prudhoe Bay ("SBAY"), the nearshore region along the northwestern shore of Prudhoe Bay ("WEST"), the nearshore area surrounding Gull Island ("GULL"), and the nearshore beach area west of and adjacent to West Dock ("DOCK"; Figure 1-1). Two of these sites were also studied in 2014 (SBAY and WEST), while the remaining two (DOCK and GULL) were evaluated for the first time during 2015. A small portion of the WEST site along the northwestern shore of Prudhoe Bay was utilized for beneficial reuse of dredged materials disposed of during the 2015 Test Trench Project.

Data from this year's sampling event were used in conjunction with data from the two prior studies performed on dredge and disposal site characterization (2011 APP and 2014 MSP) to evaluate the majority of the requirements for permitting of disposal of sediments under the CWA Section 404(b)(1) guidelines for the discharge of dredged material in near-coastal waters, including beach nourishment for beneficial use. Along with providing background and resource information, this report is intended for use as supporting documentation for engineering and planning decisions as well as permitting.

1.3 DOCUMENT OBJECTIVE

The objective of this document is to provide supplemental data that will be necessary to support a United States Army Corps of Engineers (USACE) permit application for the dredging and disposal of the dredged material. This report provides information consistent with 40 Code of Federal Regulations (CFR) Part 230 Section 404(b)(1) *Guidelines for Specification of Disposal Sites for Dredged or Fill Material*. The emphasis of the 2015 MSP was on evaluating potential disposal areas; additional evaluation of the dredged material was not performed.

1.4 DOCUMENT STRUCTURE

The structure and content of this document is as follows:

- Section 1.0 – Provides an introduction to the 2015 MSP, a description of the Alaska LNG Project, objectives of this document, and an executive summary of the Section 404(b)(1) guideline evaluation performed in 2015.
- Section 2.0 – Provides a Tier I Evaluation/Site History of the dredge area following Seattle District USACE guidelines and additional environmental background information for the areas that are utilized in the overall dredge evaluation.

- Section 3.0 – Provides an overview of environmental sampling objectives and methodology utilized during the 2015 MSP.
- Section 4.0 – Presents data and results from the 2015 study along with pertinent information from the prior studies performed in 2011 and 2014.
- Section 5.0 – Presents evaluation information that addresses the 404(b)(1) guidelines for specification of disposal sites.
- Section 6.0 – Acronyms and terms.
- Section 7.0 – References cited.
- Appendix A – 2015 MSP data.
- Appendix B – 2014 MSP data.

1.5 SUMMARY OF EVALUATION CONSISTENT WITH 404(b)(1) GUIDELINES

This section summarizes the results of the dredge and disposal evaluation. For the purpose of organizing this information, the following section has been structured to follow Section 404(b)(1) guidelines. Because at this time it is unknown whether the proposed activities would be permitted under USACE's Nationwide Permits 6 and 13 or under a project-specific permit, this preliminary evaluation consistent with Section 404(b)(1) guidelines is provided as supporting information only.

Subpart B – Compliance with Guidelines

A preliminary assessment has determined that the material proposed for the dredge disposal program will consist exclusively of clean marine sediments that were found to be below regulatory threshold guidelines/standards and that meet criteria for either inland disposal or beneficial reuse for beach nourishment. Thus, the discharge of the dredged material at the preferred spoils disposal site will not cause or contribute to any applicable violation of State of Alaska water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed in the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972.

The only potential effect of the discharge identified was the State of Alaska water quality criteria for sediment and turbidity, which would be temporarily exceeded in the immediate vicinity of any disposal activity. In order for the USACE to permit the dredging project, a water quality certification or waiver of certification, as required by Section 401 of the CWA, must be issued by the Alaska Department of Environmental Conservation (ADEC) to address any potential water quality criteria concerns. No separate permit application effort to the State is required for the Section 401 certification as this requirement will be fulfilled by the USACE as part of their review process.

Subpart C – Potential Impacts on Physical and Chemical Characteristics

The potential impacts on the physical and chemical characteristics of the aquatic ecosystem have been addressed in this evaluation. It was determined that neither the dredged material nor any of the four potential material reuse sites have any contamination above the screening levels (SLs) used as guidance for dredged material evaluations (USACE Seattle District Dredged Material Management Program {DMMP} guidelines {USACE 2014}). Furthermore, the dredged material was found to be suitable for beneficial reuse and, based on grain size, would provide protection to the shoreline at the reuse sites. The placement of the dredged material will result in altered currents in the immediate vicinity and increased suspended sediment and turbidity along the receiving beach during the subsequent open-water periods. This effect will be short-lived and will dissipate as the finer-grained particles are winnowed and transported alongshore and into deeper water. It is expected that these increases will primarily occur during storm activity when turbidity and suspended sediment are naturally high, thus masking any Project-related increases. Additionally, it is not expected that the discharge would have any effects on water level fluctuations or salinity gradients, nor would it affect water quality parameters other than suspended sediment and turbidity.

Subpart D – Potential Impacts on Biological Characteristics of the Aquatic Ecosystem

The four potential disposal areas that were examined are in very shallow water adjacent to beaches. Biologically, these areas were shown to not be unique, and they were relatively depauperate as a result of winter freezing and annual bottom-fast ice resulting in mortality of most resident benthic marine life. As a result, it is expected that placement of dredged material in these areas will have minimal short-term impact and no long-term impact on resident biological species.

In terms of the dredge area, as with most any dredging, the biological communities within the designated footprint will be eliminated. Since these areas contain typical soft-bottom biological communities, it is expected that the dredge area will be recolonized over time. The length of time for this recolonization will depend somewhat on the rate of sediment infill as a result of natural sedimentation processes. Overall, the effect on this area would be limited in size and considered short term with no long-term or cumulative impacts or loss to the aquatic ecosystem.

Since the dredging activities will likely take place during the winter, potential conflicts with fish, marine mammals, and migratory birds will be minimized. Because of the low densities of fish typically present during the winter period, only low numbers are expected to be affected by Project activities. Polar bears and ringed seals may be also be in the area but are expected to occur in low numbers. One of the primary concerns for the disposal areas is the potential existence of polar bear maternal dens along the shoreline. Also, ringed seals build subnivian lairs in the offshore area and often take advantage of pressure ridges/cracks in the ice that provide natural cover for their lairs and breathing holes. These and other concerns with respect to marine mammals and threatened or endangered species will be addressed in the Project's Wildlife Interaction Plan prior to dredge activity. This Plan will discuss measures that will be taken to avoid or mitigate effects on wildlife from dredging and disposal activities. In addition, no migratory birds are expected to be in the area during winter dredging activities.

During the summer open-water period, birds make extensive use of the marine ecosystem in the Prudhoe Bay area. An estimated 10 million individual birds with more than 120 species use the Beaufort Sea coastal area in Alaska (Johnson and Hertner 1989). Nearly all of the species are migratory, occurring from late May during spring break-up through September. Numerous studies have been conducted in the region over the past 40 years that list species likely to occur in the area. Although many of the species may migrate through, rest, and/or feed in the vicinity of the Project area, the loss of shallow-water habitat at the potential disposal site locations is not expected to adversely affect bird populations based on the relative abundance of shallow-water habitat in the general area.

Subpart E – Potential Impacts on Special Aquatic Sites

The potential impact of the dredging activity on special aquatic sites is not an issue since no special aquatic sites exist in the vicinity of the planned operations. The only special aquatic site in the region that has been identified is the "Boulder Patch," which is located 20 miles to the east of West Dock. Other special aquatic sites that are identified in the regulations (40 CFR §230.40-45), including sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes, do not exist in the planned area of operations.

Subpart F – Potential Effects on Human Use Characteristics

For the most part, potential effects on human use characteristics that are addressed in the 404(b)(1) guidance are not applicable to the proposed dredge activity. There are no municipal or private water supplies in the area, nor do recreational and/or commercial fishing activities occur in the vicinity of the dredge area or at any of the disposal sites. Water-related recreation does not occur, it is not expected that the activity would affect aesthetics, and there are no parks, historic monuments, national seashores, research sites, or similar preserves in the area. Aesthetics and visual impacts resulting from the placement of fill material in the nearshore area would be minor given the remote location and limited access to the area. Also, no impacts to any navigational areas or channels are expected to occur. The winter timing will also aid in minimizing conflicts with other activities that occur at West Dock such as the tug, barge, and other oil industry support boat traffic prevalent in the summer months.

Alaska Native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Because dredging will most likely occur during winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

Subpart G – Evaluation and Testing

The evaluation and testing of the dredged material and surrounding area were extensively studied during both the 2011 APP and the 2014 MSP efforts. These sampling programs followed Environmental Protection Agency (EPA) and USACE Seattle District DMMP guidelines (USACE 2013 and 2014). In addition, other sediment data from the immediate area and from the region were utilized for a comparison of chemical and physical properties. Based on the chemical concentrations that were seen in the dredge area, there is no evidence that there should be any concern with respect to disposal at any of the potential reuse areas. It is expected, however, based on DMMP guidelines and agency input, that additional chemical and/or toxicity testing of the dredged material may be required in the future to further address these criteria and support permitting decisions.

Dredge sediments were also examined for potential bioavailability of metals as a result of exposure and oxidation processes at the disposal site. However, due to the low gas permeability of the frozen dredged material and the relatively slow rates of the oxidation reactions at subfreezing temperatures, the overall impacts of oxidation on the toxicity of the dredged material would be negligible. The dredged material is not expected to create any toxic conditions as it disperses in the nearshore waters of Prudhoe Bay, and the tests for bioavailability indicated no risk to the aquatic environment when compared to EPA criteria.

In addition, physical testing of sediment grain size and compatibility determinations were conducted for the dredge sediments versus the potential receiving area locations. The dredge area sediments were found to be relatively compatible with the disposal areas and suitable for beneficial reuse as shoreline protection.

Subpart H – Actions to Minimize Adverse Effects

One of the primary actions to minimize adverse impacts currently planned is to perform dredging and disposal operations during the ice-covered winter months. The winter construction timing ensures that the operations will occur during a period when biological activity in the area is minimal to nonexistent in terms of fish, marine mammals, and birds. Also, oceanographic conditions are quiescent and the ice canopy reduces the effective water depth, so suspended sediments generated by the dredge activities will only be transported a short distance before settling to the bottom. The winter construction will avoid conflicts with other activities that occur near West Dock during the summer such as the tug, barge, and other oil industry activities.

Results from the 2015 Test Trench Program proved the feasibility of conducting dredging during the winter months using excavators from the ice surface. Winter dredging by this method minimizes the creation of suspended sediment when compared to typical open-water methods. As currently planned, all activity will take place from established oil field road surfaces or ice roads and pads on the sea ice surface, thus eliminating any impacts to wetlands or the shoreline above the high water line.

In terms of disposal operations, winter disposal will ensure that no suspended sediment or turbidity plumes are generated during the actual placement of the dredged material which will be placed onto the ice at the disposal site. The dredged material will be placed on the ice in shallow-water areas, will be deposited on the seafloor as ice melts in early summer, and will later be influenced by wave and current activity during subsequent open-water periods. The potential disposal areas that have been selected are in very shallow water adjacent to beaches. Biologically, these areas are not unique; they are relatively depauperate as a result of winter freezing and bottom-fast ice denuding the area of resident marine life on an annual basis. As a result, it is expected that placement of dredged material in these areas will have minimal short-term impact, and there will be no long-term impact on resident biological species. Other measures that will be taken to minimize impacts to biological resources are detailed in the Project's Wildlife Interaction Plan.

Subpart I – Planning to Shorten the Permitting Process

Advanced identification of the potential disposal areas was used to facilitate planning and potentially shorten the dredge application processing time. Four potential disposal areas were examined as part of the 2015 MSP (SBAY, WEST, GULL, and DOCK). One additional potential nearshore disposal site was examined during the 2014 MSP on the outer northern shore of Egg Island ("EGG"), along with an additional offshore optional disposal area in Prudhoe Bay; an additional deep-water disposal area was characterized during the 2011 study. All of these potential disposal areas have now been characterized in terms of their physical, chemical, biological, and general oceanographic characteristics in sufficient detail to allow an evaluation of their appropriateness and suitability for the disposal of dredged material from the proposed dredging activities. Results of the characterizations are detailed in this report for the 2015 sites, and information concerning the potential disposal site characterizations performed in 2011 and 2014 has also been included here where appropriate.

Subpart J – Compensatory Mitigation for Loss of Aquatic Resources

Compensatory mitigation is not addressed in this report as it is expected that this will be addressed as part of the environmental impact statement (EIS) and permitting process.

2.0 SITE EVALUATION AND BACKGROUND INFORMATION

2.1 TIER 1: SITE EVALUATION AND HISTORY

The Tier 1 evaluation presented in this section follows the Seattle District USACE DMMP guidance procedures as outlined in the *Dredged Material Evaluation and Disposal Procedures User Manual* (USACE 2014) for evaluating the dredge site. This section presents a comprehensive review and analysis of existing information pertinent to the proposed dredging activities, including a site history and a summary of previously collected physical, chemical, and biological data.

2.1.1 Past Site Activities

Active petroleum exploration on the barrier islands and mainland shoreline in the Prudhoe area occurred between 1970 and 1982. Available records are incomplete regarding the disposal of drilling muds/cuttings and sanitary and domestic wastewater for all explorations wells; however, permits at that time typically allowed for ocean discharge of these wastes. It is known that exploration wells typically used reserve pits to store drilling wastes; therefore, it is unlikely that wastes were discharged into the ocean in the vicinity of this Project.

West Dock is a multipurpose, solid-fill gravel structure located northwest of Prudhoe Bay. Originally constructed in the winter of 1974–1975, it has since served as a landing facility for heavy marine-borne cargo used in support of the development of oilfields in the Prudhoe Bay area. The first leg of West Dock extends 3,955 ft north-northeast from the shore to DH2. Because of supply difficulties caused by variable sea ice conditions, in early 1976 West Dock was extended 5,274 ft north-northwest to Dock Head 3 (DH3), at a water depth of about (~) 7 ft. In the summer of 1981, West Dock was further extended another 5,010 ft north from DH3 to a water depth of ~14 ft. This extension provided all-weather access to the Prudhoe Seawater Treatment Plant (STP), which treats and supplies seawater for enhanced oil recovery processes. Maintenance dredging and screeding has occurred periodically since the 1990s along the West Dock approach channel, at the DH2 and DH3 dock faces, and at the STP intake.

The majority of shipping and marine transportation necessary for support of Prudhoe Bay operations has occurred via West Dock since it was constructed. Construction activity and general maintenance has occurred at DH2 and along the causeway during operations of the Prudhoe Bay facilities. Storage and waste facilities are located onshore and it is unlikely that wastes were discharged into the ocean; however, because of the history of facilities at Prudhoe Bay and the level of activity through West Dock, it is possible that some trace levels of contaminants have entered the water through general vessel and construction activity.

There is an existing ocean discharge associated with the Prudhoe STP that discharges due north of the STP in ~14 ft of water. This discharge contains low levels of total residual chlorine along with suspended particulates that are removed by the STP processes; in the past, it also included sanitary and domestic wastewater from the small camp facilities at the STP. This discharge is currently active and has been ongoing since 1985; the discharge is regulated by the State of Alaska under an Alaska Pollutant Discharge Elimination System (APDES) permit.

With the exception of the Prudhoe STP discharge and possible discharges of drilling muds and cuttings, sanitary and domestic wastewater discharged in the 1970s and early 1980s during exploratory drilling, and general facility maintenance of DH2, there are no other known past potential sources of contamination in the immediate area. As of October 2015, no contaminated sites or leaking underground storage tanks were listed on available databases maintained by the ADEC in the immediate Project area.

2.1.2 Present Activities

Access to the Prudhoe Bay area by marine vessels is limited to the summer open-water season which, for planning purposes, is estimated to be less than 90 days in length. As the preferred offloading point for nearly all cargo barged to the North Slope oilfields, West Dock Causeway is busy and congested during the open-water season for travel around Point Barrow to Prudhoe Bay and east to Point Thomson.

As operator of the PBU, BP also manages West Dock, which includes planning and control of all activities that use the facility. BP requires advance notice and application for permission for access and use of the dock. Even during winter, there is substantial traffic along West Dock in support of activities at the STP and at the DH3 drill site as well as provision of access to ice roads that serve as transportation corridors to various offshore installations and ongoing projects.

Current permits on file with USACE (2008) and ADEC (2008) allow for maintenance dredging of up to 222,000 yd^3 per year of sediment from along the West Dock approach channel, the DH2 and DH3 dock faces, and the STP intake. The dredged material is removed by backhoe or dragline and placed along the sides and roadbed of the West Dock Causeway. This dredge activity takes place during the summer open-water period. If screeding is necessary, the material is back-dragged to the most offshore portions of the permitted dredge areas southwest of the STP and ~4,300 ft northeast of DH3.

2.1.3 Dredge Area – Historic Sampling Results

Existing borehole data near West Dock indicate that material within the proposed dredge sampling area consists of a 0.5 to 6-ft thick layer of sandy and clayey silt at the seafloor, underlain by gravelly to silty sand (McClelland-EBA 1985; McDougall et al. 1986; and Osterkamp and Harrison 1976).

Sediment chemical data collected for past maintenance dredging operations along West Dock (Oasis 2006 and 2008) do not indicate the presence of contamination from metals or petroleum hydrocarbons. Observed metals concentrations were mostly within the natural variability of background values reported for Beaufort Sea coastal sediment (Brown et al. 2005; Exponent 2010; Neff 2010; and Trefry et al. 2003). Sediments were generally found to be very clean within and around West Dock, and no evidence of petroleum contamination was seen. All gasoline range organics (GRO) and volatile benzene, toluene, ethylbenzene, and xylenes (BTEX) concentrations in the sediments were found to be below detection limits at all locations (OASIS 2006 and 2008).

2.1.4 2011 Alaska Pipeline Project

The 2011 APP West Dock Marine Sediment, Water Quality, and Biological Sampling Program (referred to here as the 2011 APP) was performed to evaluate and characterize the marine sediments, water quality, and biological environment for resource report development and project planning for the Alaska LNG study area. The study was two-pronged, emphasizing the characterization of the dredge area for physical and chemical sediment conditions and the proposed offshore "deepwater" disposal area for oceanographic, chemical, and biological conditions. Stations were sampled along the (then) proposed dredged channel northeast of West Dock, in Stefansson Sound, and in and near a potential deepwater disposal area north of the proposed channel. Data collected in 2011 and information available from previous studies were used to describe current marine environmental conditions in the final report document titled "*2011 West Dock Marine Sampling Program – Marine Sediment, Water Quality, and Biological Sampling*" (APP 2012).

The 2011 sampling included the collection of sediment samples from 16 vibracore stations and three sediment/infaunal grab stations within the proposed dredge area. Water quality sampling (hydrographic profiling) and trawling (for epibenthic assemblage information) was also performed at some of the disposal site locations. Three of these 16 sites were later designated as "Test Trench Sites" that were used extensively for data interpretation during the 2014 MSP program (described below): Site #1 (APP #03E), #2A (APP #02K), and #2B (APP #02M). Results of the vibracore program performed in 2011 indicated that the surface layer of sediments was generally made up of silty sand or sand with a subsurface layer of finer sandy silt or sandy clay. This sandy surface layer was found to often be absent around DH2 where periodic dredging or screeding occur along with propeller wash from tug and barge activity.

In general, the dredge area sediments were found to be clean with no evidence of contamination. Metals concentrations were found to be low and below DMMP SLs and within the range of natural background data for the region. Also, no evidence of petroleum hydrocarbons or other organic contaminants was seen in any of the data, although low levels of diesel range organics (DRO) and residual range organics (RRO) that were attributed to peat and terrigenous plant wax sources were seen. The 2011 program did not include any biological testing of dredged material using toxicity or bioaccumulation procedures.

The evaluation of the potential offshore disposal area in 2011 found that the area was clean with no evidence of contamination. Sediments at the site had a higher percentage of silts and clays when compared to the dredge area sediments. Biologically, the area was found to have much greater abundances, diversity, and biomass of benthic infauna when compared to the dredge area, but overall the infauna sampled in the areas was found to be similar to other studies in the region and did not represent a unique or unusual resource. The trawl data from the offshore disposal site indicated that the area had a relatively low level of biological activity with the catch dominated by Arctic cod (*Boreogadus saida*) and fourhorn sculpin (*Myoxocephalus quadricornis*). Additional information on the 2011 APP is included in the pertinent background and results sections in this report.

2.1.4.1 2014 Marine Sampling Program

The 2014 MSP characterized the marine environmental conditions near the proposed test trench areas in preparation for the 2015 Winter Test Trench Field Study (described in Section 2.1.4.2) and examined three potential dredge disposal sites. It was designed to characterize the marine environmental conditions at three potential disposal sites (located at SBAY, WEST, and EGG) and to evaluate the suitability of the test trench dredged material for disposal, particularly beneficial reuse, at each of those nearshore sites. It was also designed to gain similar characterization data from optional offshore sites in Prudhoe Bay ("PRUD"), although these were not considered as potential disposal sites for the Test Trench Program. Information used to assess potential effects resulting from the disposal action on each of the proposed nearshore disposal reuse site options were presented in the final 2014 MSP report titled "*Alaska LNG 2014 Marine Sampling Program – Evaluation of Test Trench Dredging and Disposal Reuse*" (Alaska LNG 2014).

The 2014 MSP program was also two-pronged in that it was designed to provide information from both the dredge area and the newly proposed potential disposal areas, but the emphasis for the 2014 sampling was on the disposal site characterization, as described previously. During 2014, dredge area sampling was only performed at two sites (#3A and #3B) that had also been subject to vibracoring during the 2011 APP. Sampling was performed at these sites to further characterize the dredge area for the Test Trench Program and other future planning. Otherwise, the 2014 MSP called upon data from the 2011 APP to evaluate the suitability of beneficial reuse of the dredge sediments for the Test Trench Program. As with the earlier 2011 APP, the 2014 data indicated that the two dredge sites evaluated were pristine and that sediment chemistry concentrations were at natural background levels. Benthic infauna were found to be more abundant and diverse in the dredge area compared to the three nearshore disposal areas that were evaluated, which was believed to be due to its greater depth, finer sediment grain size, and due to the fact that the disposal areas are subjected to annual formation of bottom-fast ice. The 2014 program did not include any trawling from the dredge area or any biological testing of dredged material. Additional data on the 2014 MSP is included in the pertinent background and results sections provided below.

2.1.4.2 2015 Winter Test Trench Program

In support of the design phase of the Project, a Test Trench Field Study was performed in winter 2015 to assess the feasibility of winter dredging for the proposed barge navigation channel (Alaska LNG 2015a). The objectives for the Test Trench Field Study included the assessment of the feasibility of winter through-ice dredging and dredged material disposal, including efficiency and functionality of equipment, and the evaluation of operational safety issues related to heavy equipment operating on both grounded and floating sea ice. The study included monitoring of the water column (under the ice) to assess effects of dredging on turbidity. In addition, the study provided the opportunity to obtain information needed to understand the sedimentation in-fill rate during subsequent open-water periods to gauge maintenance dredging requirements.

The two test trenches were located on the east side of West Dock at Sites #1 and #2.5A (Figure 1-1). An ice road from the West Dock Causeway provided access to the test trenches, and a second ice road provided access to the selected dredged material disposal site (WEST) on the western side of Prudhoe Bay adjacent to BP's AGI Pad.

Test Trench Site 1 was excavated adjacent to DH2 in the bottom-fast ice zone in ~5.5 ft of water with 10.5 ft of excavated sediment. The horizontal dimensions at the bottom of the trench at Site 1 were ~100 ft by 100 ft, resulting in an estimated excavation volume of 3,500 yd^3. Test Trench Site 2 was located ~2,000 ft from the northern end of the proposed channel on floating ice in 10.5 ft of water, and 5.5 ft of sediment were excavated. The horizontal dimensions of the trenching at Site #2.5A was 140 ft by 200 ft, with an excavated volume of 7,400 yd^3. Turbidity sampling was performed under the ice near Site #2.5A. At both sites, the ice was thickened to support construction machinery where necessary. Trucks were used to haul material along ice roads to the permitted dredge disposal area at WEST for placement onto the sea ice surface ~50 ft offshore from BP's AGI pad. The total disposal area was estimated to be ~1,800 ft long by 50-80 ft wide, and the dredged materials were consolidated and track-walked to maintain a height of ~5 ft.

In general, the winter dredging methodology was found to be very successful with good production rates, and it was determined that winter dredging could be safely and effectively performed. Turbidity measurements taken in and near Site #2.5A showed that dredging produced a turbidity plume under the ice that was influenced by tidal action but which remained close to the excavation area. Outside the trench itself, turbidity values returned to natural background levels on the day after completion of dredging. Additional information can be found in the final study report (Alaska LNG 2015a). Sediment infill evaluations are currently ongoing and involve multiple bathymetry surveys in 2015 and 2016 as well as oceanographic current meter moorings and sedimentation studies.

2.1.5 Dredge Area General Ranking

Guidance provided in the EPA/USACE Seattle DMMP User Manual (USACE 2014) details a ranking scheme that classifies proposed dredged materials based on potential for adverse biological effects or elevated concentrations of chemicals of concern (CoCs; Table 2-1:).

Table 2-1: Dredged Material Ranking Guidelines

Rank	Guidelines
Low	Few or no sources of chemicals of concern (CoCs). Data are available to verify low chemical concentrations (below DMMP SLs), and no significant response in biological tests.
Low-Moderate	Available information indicates a “low” rank, but there are insufficient data to confirm the ranking.
Moderate	Sources exist in the vicinity of the Project or there are present or historical uses of the project site with the potential for producing chemical concentrations within a range of those historically associated with some potential for causing adverse biological impacts.
High	Many known chemical sources, high concentrations of CoCs, and/or biological testing failures in one or both of the two most recent cycles of testing.

A review of the historical data in the dredge study area, including the results from the 2011 and 2014 sampling events, suggests that the ranking for the dredged material should be low or low-moderate. Sediment chemistry results indicate a low ranking; however, no biological tests have been performed to date which in effect raises the ranking level to low-moderate. These levels are used by the USACE and EPA to determine the amount of additional testing that may be necessary to permit a dredge project and to determine the maximum size of a dredged material management unit (DMMU). It is expected that given the potential size of the dredge project and the amount of dredged material, additional testing in the dredge area will be required within the selected dredge channel and turning basin.

It is recommended that if additional dredged materials testing is conducted, appropriate biological tests be performed to ensure that the dredge sediments do not contain any toxic components that may not have been tested for as part of the chemical testing program. This type of testing will be performed in 2016 or 2017, at a time to be determined based on agency input when dredge materials testing needs will be further defined. For the Prudhoe Bay area, this testing would be considered “safety-net” biological testing to avoid a situation where a CoC not on the analysis list is present at a concentration that could cause adverse biological effects. The DMMP (USACE 2014) recommends that biological testing include the 10-day amphipod test and one other bioassay test from the standard suite and that twenty percent (%) of the project DMMUs be tested; the tested DMMUs must represent the finest grained material. The most common 10-day amphipod mortality test utilizes the species *Eohaustorius estuarius.* This amphipod test is appropriate for the lower salinities that are typically seen in the Prudhoe area during the summer open-water period. The other recommended test would be the 20-day juvenile infaunal growth test which measures chronic rather than acute (fatal) toxicity on the polychaete worm *Neanthes arenaceodentata*. In the absence of a toxic response in the biological tests, the dredged sediments could be ranked “low” based on the DMMP guidelines (see Table 2-1), resulting overall in less chemical testing being required for the Project.

2.2 ENVIRONMENTAL BACKGROUND INFORMATION

The environmental background information provided in this section is for the nearshore waters in the Central Beaufort Sea. The information is applicable to the nearshore marine conditions in the vicinity of the Project and therefore provides additional information on the physical setting, sediment chemistry, and marine biological resources in the area; this information is provided as a supplement for the Tier 1 evaluation.

2.2.1 Sediment Physical and Chemical Characteristics

The sediment in the nearshore area of the Beaufort Sea is derived primarily from riverine input of suspended material and coastal erosion of tundra cliffs and beaches. The sediments of riverine origin, along with the coastal peat, contribute large amounts of organic carbon, petrogenic source rock, and trace metals to the coastal sediments. Canon (1978) estimated that 80% of the terrigenous debris supplied to lagoons in the Beaufort Sea are sediments from fluvial overflow and alongshore transport from river mouths. The major rivers that discharge into Beaufort Sea in order of flow volume include the Mackenzie (~$1x10^{13}$ cubic ft per year {ft^3/yr}), the Colville (~$1x10^{12}$ ft^3/yr), the Sagavanirktok and Kuparuk combined (~$1x10^{11}$ ft^3/yr), and the Canning Rivers (~$3x10^{10}$ ft^3/yr) (AEIDC 1974; Yunker et al. 1995; and USGS 2003). Although the Mackenzie River is much farther away in terms of distance, its annual flow is nearly ten times as large as the rest of the rivers discharging into the Beaufort Sea combined. Overall, the Mackenzie River is the fourth largest river in the world discharging into the arctic environment in terms of annual flow and the first largest in terms of organic and inorganic sediments (4.85 $x10^{11}$ pounds/year {lb/yr}; Yunker et al. 1995). More recent work by Trefry et al. (2004 and 2009) on sediment budgets and sourcing of metals in marine sediments from rivers in the Prudhoe area found very similar sediment types in each of the rivers sampled in the region.

A number of studies were performed during the 1970s and 1980s to determine baseline conditions of sediments in the Beaufort Sea prior to oil and gas industry activity in the area. Studies included the determination of hydrocarbons in nearshore sediments (e.g., Shaw 1977) and farther offshore (e.g., Kaplan and Venkatesan 1981), and metals in marine sediments (e.g., Burrell 1977 and 1978; Naidu et al. 1981). Other more recent work include data from the United States Bureau of Ocean Energy Management's (BOEM's) Beaufort Sea Monitoring Program (BSMP), Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA), and continuation of ANIMIDA (cANIMIDA) programs that have extensively documented both the physical and chemical composition of marine sediments in the Beaufort Sea nearshore areas (Exponent 2010 and Neff 2010). These were large multi-year studies that focused on the Central Beaufort Sea nearshore area that could have been impacted by oil and gas exploration and development activities. Other studies include more site-specific monitoring efforts performed in conjunction with oil and gas development activities such as those performed at Endicott, Northstar, Prudhoe Bay, or in the proposed Liberty Development area. Site-specific monitoring was also performed in the vicinity of West Dock as part of the Prudhoe STP's discharge monitoring and for prior dredge activities in the vicinity of DH2 and DH3.

2.2.1.1 Sediment Grain Size

Sediment grain size distribution in the Beaufort Sea exhibits a large degree of variability. For example, sediment mud content or % fines (silt + clay) at the BSMP stations ranged between 3 and 86% over a three-year period (Boehm et al. 1987). Barnes and Reimnitz (1974) found the sediments on the continental shelf consisted predominantly of mud from riverine inputs, with coarser-grained sediments from relict deposits found in nearshore areas on shoals and in the vicinity of the barrier islands, while bottom sediments in the nearshore waters of the Beaufort Sea were characterized as moderate to well-sorted sand and silt (0.08 to 0.25 millimeters {mm}).

Substrates in the West Dock and Prudhoe area were found to vary widely from muddy sand to sandy mud with some samples containing coarse sand and gravel. Although documented elsewhere along the Beaufort Coast, boulders have not been previously found in the vicinity of West Dock or in any of the potential nearshore sediment reuse areas that were examined in 2011, 2014, or 2015. Grain size seen for the nearshore disposal areas examined in 2014 were also found to have a high amount of variability with % fines ranging from 1.7 to 48.0%, whereas the dredge area sediments had a greater percentage of fines ranging from 22.0 to 89.6%. During the 2011 APP, % fines in the dredge area sediments were similar to that seen in 2014 with a range of 8.0 to 89.6%.

2.2.1.2 Total Organic Carbon

Total organic carbon (TOC) in marine sediments in the Beaufort Sea nearshore region is mainly of terrigenous origin derived from inland peat deposits washing down rivers and from coastal erosion of bluffs and tundra. The TOC levels in sediment samples that were sampled adjacent to West Dock near DH2, DH3, and the screed channel were found to range from 0.14 to 3.25% with a mean concentration of 1.2% (Oasis 2006 and 2008). The highest concentrations were typically associated with fine-grained sediments. Data from the BOEM BSMP found TOC to be less variable than grain size with a range of 0.34 to 1.8% over a three-year period (Boehm et al. 1987). The ANIMIDA study found TOC values in surficial sediments to range from 0.01 to 3.42% with a mean value of 0.62% (ADL 2001). Data from ANIMIDA and BSMP also indicated a positive relationship between TOC and fine-grained sediments because larger surface area sediment can adsorb larger amounts of organic matter (ADL 2001). TOC concentrations adjacent to West Dock in the proposed dredge area are typical of values reported for Beaufort Sea nearshore sediments with a high degree of variability associated with sediment distribution and generally a good agreement between TOC and % fines content. Data from the 2011 APP found TOC concentrations that ranged from 0.13 to 3.33% in the dredge area as compared to the range seen in 2014 of 0.48 to 1.91%.

All concentrations of TOC seen during the 2011 APP and the 2014 MSP were within the range of those seen for the Beaufort Sea coastal region (Neff 2010), though a fair amount of variability was seen due to varying peat and detrital material content.

2.2.1.3 Trace Metals

Concentrations of metals in marine sediments in the nearshore Beaufort Sea area are primarily derived from natural inputs of suspended sediments that are discharged into the marine system from rivers. Probably the most comprehensive dataset on metals in marine sediments in the region is from the BOEM-sponsored BSMP, ANIMIDA, and cANIMIDA programs (Boehm et al. 1987 and 1990; ADL 2001; Exponent 2010; and Trefry et al. 2003). Each of these large multi-year studies examined nearshore sediment chemistry along the Central Beaufort Sea coastline, concentrating in those areas that would most likely be affected by oil and gas related activities. Other studies include work performed by the University of Alaska that re-examined 20 of the BSMP sites during 1997 (Naidu et al. 2001) and long-term monitoring at two locations as part of National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends (NS&T) Program (Cantillo et al. 1999). The BSMP examined nine metals whereas the ongoing ANIMIDA studies examined 18 metals from sites located both regionally and in the vicinity of West Dock. Trefry et al. (2003) found that the sediments contained natural levels of metals and that most variability could be predicted as a function of the aluminum content in the sediment. Exceptions to this trend were associated with a couple of sites that indicated a potential pollutant source. Other studies in the region have included the Outer Continental Shelf Environmental Assessment Program (OCSEAP) studies and industry-related site-specific studies for the Endicott, Liberty, and Northstar developments.

Trace metal concentrations in nearshore Beaufort Sea marine sediments including data from the West Dock area show that, with few exceptions, concentrations are lower than NOAA's effects range low (ERL), State of Washington Sediment Quality Criteria, and USACE SLs for dredged material evaluation. Differences that were observed in most of these studies can be ascribed to grain size distribution and organic content with higher trace metals concentrations in finer-grained sediments. Except for a couple of site-specific data points, in general these studies have not found any evidence of trace-metal contamination of marine sediments in the Beaufort Sea. Arsenic, copper, and nickel were found to be slightly elevated in many of these studies when compared to the NOAA ERL benchmark criteria but are actually low when compared to the average for continental crust material (Wedepohl 1995). Based on these numbers, it would appear that the Beaufort Sea sediments are not contaminated but are actually a combination of eroded continental crust material and sediment from terrestrial sources. Although all metals may be of interest to researchers, only a few are likely to have their concentrations altered by oil and gas development activities. These are barium and chromium, which are likely to be affected by drilling activities (i.e., drilling muds), and lead and vanadium, which are constituents of petroleum and/or refined product.

Sediment metals concentrations seen during the 2011 APP and the 2014 MSP were consistent with the regional background concentrations documented in these other studies referenced above. No evidence of metals contamination was seen in the dredge sediments or any of the disposal area sediments examined during 2011 and 2014. All concentrations were well below USACE SLs and, with the exceptions noted above, all values were below ERL levels. Also, concentrations of most metals were found to be highly correlated with both aluminum and % fines as shown by Trefry et al. (2003).

Testing during both the 2011 APP and the 2014 MSP also included analyses that compared the molar ratio of simultaneously extracted metals (SEM) to acid-volatile sulfides (AVS) to determine the potential bioavailability of metals contained in the dredge area sediments. When the molar concentration of AVS exceeds the total molar concentration of the SEM, the concentrations of dissolved metals are generally below toxic levels because of the low solubility of the metal sulfides, whereas an SEM/AVS ratio greater than 1.0 suggests that the metals are potentially bioavailable (Simpson et al. 2012). The ratio of SEM/AVS ranged from 0.04 to 2.08 for all five locations (2011 and 2014) with three of the eleven samples exceeding a ratio of 1.0, indicating that the metals may be potentially bioavailable. These samples were further evaluated to assess whether the potentially bioavailable metals are reduced through binding to organic carbon. Using EPA guidance for deriving equilibrium partitioning sediment benchmarks for metal mixtures (EPA 2005), each SEM value that exceeded the AVS concentration was normalized to the organic carbon concentration, which is also expected to bind with excess metals. Results less than 130 micro-Moles per gram of organic carbon (µMole/g_{oc}) indicate that there is little to no risk to aquatic life (EPA 2005). Sample results ranged from less than zero (where AVS exceeded SEM) to 25.1 µMole/g_{oc}, indicating that the dredge area sediments had little to no risk of bioaccumulation.

2.2.1.4 Hydrocarbons

The hydrocarbons found in Beaufort Sea sediments occur naturally and are primarily derived from riverine and terrigenous inputs. The hydrocarbon assemblages in the sediments are dominated by waxy plant inputs, such as peat, and fossil fuel inputs from coal and other source rock formations. The analysis by Boehm et al. (1990) and later work during the ANIMIDA and cANIMIDA studies (ADL 2001 and Exponent 2010) ruled out natural seepage or spills of Prudhoe Bay crude oil as the source of aromatic hydrocarbons in the region, which is supported by earlier OCSEAP studies. Due to seasonal and yearly fluctuations in river flows, there is some variability in sediment hydrocarbon levels in various areas of the Beaufort Sea, but there is little intra-station variability. As with trace metals concentrations, most observed differences between sites are attributed to differences in grain size and TOC, with higher concentrations found in areas with higher percentages of fine-grained sediments and TOC. Work by ADL (2001) found hydrocarbon concentrations that were nearly an order of magnitude higher in the Colville River compared to the offshore areas due to higher TOC content. In addition, the composition of the hydrocarbons in sediments is fairly constant throughout the region.

Extensive work on hydrocarbon concentrations in marine sediments has been performed as part of the BSMP, ANIMIDA, and cANIMIDA studies (Boehm et al. 1987 and 1990; ADL 2001; Brown et al. 2005; and Exponent 2010). These studies have included the analyses of saturated hydrocarbons (SHC), polycyclic aromatic hydrocarbons (PAHs), and steranes and triterpanes biomarker analyses. Similar types of hydrocarbon fingerprint analyses were also performed during early OCSEAP programs and for site-specific studies associated with the Northstar and Endicott developments. In the SHC analyses, studies have shown a very strong odd-to-even preference for the straight chain normal alkanes that indicates primarily plant wax sources with lower levels of petroleum hydrocarbons and also very low levels of unresolved complex mixture (UCM), which is an indicator of oil weathering (ADL 2001; Boehm et al. 1990; and Exponent 2010). The PAH distributions were primarily of a fossil fuel origin (petroleum and coal) with lesser amounts of pyrogenic PAHs and variable amounts of biogenic inputs. Biomarker analysis indicated that the nearshore sediments were very similar to that seen in the Colville River sediments and peat with recent organic matter and similar petroleum hydrocarbon patterns. In summary, the organic geochemical data for the region from these studies indicate that hydrocarbons found in nearshore and offshore sediments originate through natural processes, are primarily from riverine sources, and except for a couple of site-specific samples that were identified, show little evidence of anthropogenic petroleum inputs.

Hydrocarbon data from the 2011 APP and the 2014 MSP efforts included analysis for DRO, RRO, and PAHs from the dredge area sediments. Results of all DRO and RRO analyses found low concentrations that were composed of a non-petrogenic signature. Samples with higher concentrations were also found to have higher TOC concentrations, which probably indicated high peat content and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes. Exponent (2010) presented results from a number of regional peat samples and found that the total petroleum hydrocarbons (TPHC which equals DRO + RRO) ranged from 8.7 to 230 milligrams/kilogram (mg/kg, or parts per million {ppm}) as a result of biogenic inputs. Low levels of PAH compounds were found in all of the dredge area samples (both surface and lower) with concentrations that were typical of natural background levels in the Beaufort Sea coastal area. No evidence was seen that any of the samples contained PAHs that were the result of contaminant inputs to the area.

The 2011 APP sediment sampling also included the analysis of GRO and BTEX. All GRO and BTEX concentrations fell below their method detection limits (MDLs) for all samples including the larger potential dredge area studied in 2011. Since all 2011 dredge area BTEX and GRO concentrations were below detection limits, these compounds were not included in the analyte list during either 2014 or 2015. Also, all of the marine vessels that utilize West Dock, with the exception of a few skiffs, are powered by diesel engines, so it is not expected that contamination from any gasoline sources would be seen in the sediments.

2.2.1.5 Other Pollutants and Constituents

Little area-wide data exist for other pollutants such as pesticides, herbicides, polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), tributyltins (TBTs), or other pollutants. Scientific work in the Alaskan Beaufort Sea region, including the OSCEAP studies, has concentrated on physical, biological, and chemical properties of the environment, but the chemical components of these programs have generally pertained to hydrocarbons and trace metals because the levels of these parameters could potentially increase due to releases of petroleum or through drilling activities. Monitoring for these other types of contaminants such as volatiles has generally been made part of an EPA-required National Pollutant Discharge Elimination System (NPDES) or state-required APDES permit for an industrial discharge rather than the focus of more general research.

For example, NPDES/APDES monitoring at the Prudhoe Bay STP at West Dock has included analyses of volatile and semi-volatile organic compounds in sediments collected in the vicinity of the outfall. Results from the 1994 monitoring program failed to show concentrations of these compounds above detection limits (Kinnetic Laboratories, Inc. {KLI} 1995). Sediment sampling that included the analysis of volatile and semi-volatile organic compounds was performed in 1997 and 1998 in association with the proposed Liberty Island and pipeline routing (Montgomery

Watson 1997 and 1998). No volatile organic compounds were detected during either year; however, a number of semi-volatile organic compounds including some phenols and one phthalate were detected during the 1996 sampling.

Both the 2011 APP and the 2014 MSP included the analysis of chlorinated pesticides and PCBs. The 2011 effort included three sediment cores from the dredge area, and six sediment grabs were taken from the dredge area during the 2014 MSP. In 2011, one chlorinated pesticide, gamma-BHC (Lindane), was seen in one surface sample at a low-level concentration of 0.37 micrograms per kilogram (µg/kg), compared to the DMMP screening level (SL) of 2.8 µg/kg for total chlordane and an ADEC Sediment Quality Guideline (SQG) threshold effects level (TEL) of 2.26 µg/kg (ADEC 2013). All other organochlorine pesticide concentrations were found to be below MDLs. In 2014, low-level pesticides were seen in two of the six samples that were analyzed at the test trench sites. One sample had low levels of 4,4'-DDT (0.081 µg/kg), alpha-BHC (0.077 µg/kg), and methoxychlor (0.16 µg/kg), all of which were estimated concentrations that were between the MDL and method reporting limit (MRL) and flagged with a "J." The second sample had low levels of 4,4'-DDT (0.13 µg/kg). All other samples and analytes were found to be below detection levels. Sediment criteria exist for both 4,4'-DDT and total DDT but do not exist for either alpha-BHC or methoxychlor. Concentrations of 4,4'-DDT that were seen were two orders of magnitude less than the SL and an order of magnitude less than the TEL. Similarly, total DDT was low at concentrations of 0.081 and 0.13 µg/kg compared to the TEL of 3.90 µg/kg and the probable effects level (PEL) of 51.7 µg/kg.

In 2014, PCBs were analyzed including the seven primary arochlors that were manufactured (Arochlor 1016, 1221, 1232, 1242, 1248, 1254, and 1260). Concentrations of individual arochlors in all samples were found to be below the detection limit of 2.1 µg/kg compared to the 2013 DMMP guidance level for total PCBs of 130 µg/kg; this was also well below the TEL of 21.6 µg/kg and PEL of 189 µg/kg. Very low levels of PCB congeners were found in some of the 2011 dredge area samples, and in all cases, concentrations of these contaminants were well below SLs established for the Seattle DMMP and well below ADEC-recommended SQGs for both the TEL and PEL. It was also noted in the 2011 APP report that the PCB results should be considered maximum possible concentrations since contamination was seen in the laboratory method blanks.

Overall, there appears to be no evidence of any contamination from chlorinated pesticides or PCBs of the dredge area sediments tested in either 2011 or 2014. Most of the compounds that were tested are covered by the Stockholm Convention on Persistent Organic Pollutants (POPs), a global treaty designed to protect human health and the environment from highly toxic and long-lasting chemicals by restricting their use and ultimately eliminating production and use. POPs are of particular concern in the Arctic as it has been shown that they can travel long distances via a number of pathways, including air transport, and be deposited far from their sources of release, accumulate in living organisms, and cause adverse effects on the environment (AMAP 2002). These organic compounds tend to accumulate in the Arctic and sub-Arctic due to several physical and biological transport processes. The sources of the low-level chemicals measured in this study are believed to be atmospheric in origin as a result of global distillation in the equatorial and temperate regions of the world, followed by cold condensation, resulting in deposition of POPs into the Arctic and sub-Arctic environments; these are often seen in and associated with fine-grained sediments.

2.2.2 Biology

2.2.2.1 Fish

A number of surveys have been conducted in the general vicinity of Prudhoe Bay and West Dock that show fish communities, like other Arctic animal communities, have fewer species than do their lower-latitude counterparts. In Alaska coastal waters of the Beaufort Sea, 62 species of fish have been recorded, with additional species presumably found offshore (Craig 1984). Craig describes the fish community of the Alaska Beaufort Sea as typical of the "Inuit fauna," which is a fairly distinct assemblage of diadromous and marine species. Dominant diadromous (anadromous and amphidromous) species are Arctic cisco (*Coregonus autumnalis*), least cisco (*C. sardinella*), and Dolly Varden char (*Salvelinus malma*), which enter previously frozen nearshore waters each summer and feed extensively on an abundant supply of epibenthic crustaceans. Dominant marine species are Arctic cod (*Boreogadus saida* or "polar" cod) and fourhorn sculpin (*Myoxocephalus* quadricornis) which enter nearshore waters later in summer as salinities increase. These five dominant species account for over 90% of all fish captured in scientific investigations along the Alaska and western Yukon coastlines. Other species observed include broad (*C. nasus*) and humpback whitefish (*C. pidschian*), rainbow smelt (*Osmerus mordax*), chum salmon (*Oncorhynchus keta*), and pink salmon (*O. gorbuscha*; Craig 1984). Additional marine species include several species of sculpins and eelpouts (Rand and Logerwell 2010 and Logerwell and Rand 2010).

A biologically important feature of the nearshore Beaufort Sea, including Stefansson Sound and Prudhoe Bay, is the occurrence of a band of relatively warm (5-10 degrees Celsius {°C}) and estuarine water (10-25 parts per thousand {ppt} salinity) that lies adjacent to the shoreline in the summer extending the length of the coast, including Prudhoe Bay (Truett 1981). The band is relatively shallow, narrow, and is often distinctly different from adjacent marine waters. The estuarine band is formed during spring break-up when floodwaters from North Slope rivers flow to sea. In the following weeks, nearshore waters mix with incoming cold marine water to create estuarine systems that prevail along the coast through the summer (Truett 1981). Diadromous fish begin arriving from their overwintering areas with the first signs of spring break-up, disperse along the coastline, remaining in the warmer and low salinity band, and return by fall to river drainages to spawn or overwinter. Many parallel the shore along a narrow corridor often within 100 meters (m), though a variety of environmental conditions influence the size of the diadromous corridor (Craig and Haldorson 1981). A long history of sampling along shorelines in and near Prudhoe Bay (e.g., Fechhelm et al. 2005 and 2009) has added detail to this understanding of the importance of shoreline areas for fish and the influences of nearshore causeways on movements of these fish.

The distribution of marine species tend to increase in near-shore waters as the open-water season progresses and salinities increase (Craig 1984), though some studies have also noted an offshore movement through the summer (Moulton and Tarbox 1987). These marine fish are not restricted to nearshore waters and probably do not migrate parallel to the coastline. During the winter, most anadromous species return to North Slope freshwater drainages to spawn or overwinter; marine species remain under nearshore ice but eventually vacate shallow waters, which freeze solid to a depth of ~2 m (Craig 1984).

Long-term monitoring of fish in the nearshore Beaufort Sea has been performed over the last 32 years for BP in conjunction with oil industry activities (McCain et al. 2014). The objective of these studies was to monitor the distribution, abundance, and health of anadromous and amphidromous fish stocks important to the Native subsistence fishery in the lower Colville River. Fishing took place using stationary fyke nets at various stations stretching from an area east of the Endicott Causeway to the western end of Simpson Lagoon. In 2013, four stations in the Prudhoe Bay area were sampled: one on the western side of West Dock near the DOCK disposal site, one on the western side within Prudhoe Bay near the WEST disposal site, one at Niakuk/Heald Point at the eastern extreme of Prudhoe Bay, and another on the western nearshore end of the Endicott Causeway. Broad whitefish, Arctic flounder (*Pleuronectes glacilis*), and saffron cod (*Eleginus gracilis*) were the three dominant species captured at all four stations combined in 2013. Arctic flounder was the most dominant species collected at the station in western Prudhoe Bay (near WEST) and the third-most dominant species collected at each of the other three stations. Arctic cod was the dominant species seen at the site near DOCK, and broad whitefish was the dominant species seen at the other two sites. Other species collected in abundance in 2013 included least cisco, rainbow smelt, fourhorn sculpin, and Arctic cisco. In 2009, Arctic cisco, fourhorn sculpin, and broad whitefish were the most dominant species at all stations combined (Fechhelm et al. 2009). Arctic cisco, saffron cod, and fourhorn sculpin were the three dominant species collected at the western Prudhoe Bay station. Arctic flounder was the fourth-most dominant species collected at the western Prudhoe Bay station and, overall, for the combined catch at all four stations. Arctic cod was collected at all three stations in 2009, with the most abundance shown at the western Prudhoe Bay station.

Less information and fewer data are available for offshore portions of Prudhoe Bay and in Stefansson Sound. Craig (1984) listed 40 species that have been documented in coastal areas farther from shore, but sampling effort has been low. Arctic cod, two-horn sculpin (*Icelus bicornis*), and Canadian eelpout (*Lycodes polaris*) were reported to be dominant species. Cannon et al. (1991), studying juvenile Arctic cod, sampled exclusively in the Prudhoe Bay area in a variety of habitats ranging from very shallow nearshore areas (less than 6 ft) in the bay to areas farther out on the shelf (10 to 15 ft) between mid-July and mid-August. This study found that Arctic cod were concentrated in warmer, lower salinity waters closer to shore. Catch was greatest at bottom salinities between 14 and 22 ppt and in relatively shallow waters depths between 3 and 7 ft. A more recent study in the offshore deeper waters of the Beaufort Sea was performed in 2008 (Rand and Logerwell 2010). This study documented 32 species of demersal fish with Arctic cod being the most abundant.

Moulton and Tarbox (1987) trawled both near-shore and offshore locations near Prudhoe Bay (0.3 to 5.5 m {1 to 18 ft} deep) and caught primarily Arctic cod (98% of catch), with minor catches of kelp snailfish (*Liparis tunicatus*), fourhorn sculpin, Pacific sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), rainbow smelt, and least cisco. This study found Arctic cod to be associated with a transition layer between a surface water mass characterized by low salinity and high temperature and a bottom water mass characterized by high salinity and low temperature. The species apparently oriented to the shoreward edge of the marine water mass and redistributed depending upon the location of the shoreward edge. The authors also noted a general offshore movement of cod between July and August sampling periods. The mean bottom depth of capture was ~9 ft in July and 19 ft in August.

A number of studies have conducted offshore investigations during the winter. In Prudhoe Bay winter samples, Tarbox and Thorne (1979) captured four species of fish: Arctic cod, kelp snailfish (*Liparis truncates*), fourhorn sculpin, and slender eelblenny (*Lumpenus fabricii*). The abundance of these fish was low based on catch rates, diver observations, and hydroacoustic measurements. The study concluded that fish densities were at least an order of magnitude lower than those typically observed in southern coastal marine environments and that estimated winter densities appeared lower than those recorded in the Beaufort Sea open-water season. Craig et al. (1984) found that Arctic cod were found offshore (Boulder Patch and Narwhal Island; 15 to 33 ft in depth) during the winter at higher catch rates than in near-shore habitats (Simpson Lagoon). The highest catch rates during the winter, however, were found in non-coastal areas 175 kilometers (km) offshore.

Otter trawling performed as part of the APP 2011 program at the offshore potential disposal site provided additional knowledge of regional biological conditions. Overall fish catch rates in 2011 were low with only three species of fish collected. Arctic cod was the predominant species reported, followed by kelp snailfish and Arctic staghorn sculpin (*Gymnocanthus tricuspis*). All the fish captured in 2011 were small (less than {<} 150 mm total length), and it was noted that the survey was performed in July, fairly early in the open-water period while bottom water temperatures were still cold.

Trawling performed during the 2014 MSP at the Prudhoe Bay optional sites (PRUD) and the three potential disposal sites surveyed (SBAY, WEST, and EGG) showed a predominance of Arctic cod and fourhorn sculpin, which together accounted for more than 86% of the overall catch during 15 trawls. Other species of fish recorded included capelin, Arctic flounder, snailfish, least cisco, eelblenny, Dolly Varden, and ninespine stickleback (*Pungitius pungitius*). Fourhorn sculpin was the only species that was seen in every trawl at all of the sites fished in 2014. As in 2011, fish captured in the 2014 trawls were generally small, and many specimens were juveniles.

2.2.2.2 Benthos

Oil and gas exploration activities that have taken place on the Alaskan North Slope since the 1970s have provided, in relation to these activities, numerous benthic invertebrate studies. Pertinent information concerning Alaskan Arctic benthic communities are provided in numerous Draft or Final Environmental Impact Statement (DEIS or FEIS) documents for the Alaskan Beaufort and Chukchi seas (e.g., Minerals Management Service {MMS} 1984, 1987a, 1987b, 1990, and 1996). Additional benthic community data are available from other studies pertaining to oil and gas production activities, such as Envirosphere (1983 and 1985); Feder et al. (1976a and 1976b); USACE and ERT (1984); USACE (1980); and Dames and Moore (1988). Recent reports pertaining to the Northstar Development Project are available in Woodward-Clyde Consultants (1996) and KLI (2002) and more recently in the synthesis of 1999–2007 cANIMIDA data by Neff (2010).

The structures of nearshore and coastal marine benthic communities in the Alaskan Beaufort Sea are complex and generally divided into three zones. The nearshore environment ranges from the shoreline to a depth of 5-6 ft, which corresponds to the bottom-fast ice zone. The coastal (sometimes called inshore) environment ranges from ~6 to 65 ft and includes deeper areas inside the barrier islands as well outside of the islands. Offshore areas include those greater than ~66 ft and extending out across the continental shelf. The majority of the Beaufort Sea nearshore and coastal environment consists of large expanses of soft-substrate bottoms (silty muds or sands) that faunal groups adapted to this environment dominate. In addition, limited areas of hard-substrate habitats exist in the Beaufort, supporting kelp communities like those in Stefansson Sound known collectively as the "Boulder Patch."

Benthic communities are an interwoven mosaic of infaunal and epifaunal species. Marine benthic communities in Alaska’s Beaufort Sea contain numerous species of surface (epifaunal) and subsurface (infaunal) sediment-dwelling invertebrates, as well as microalgae (diatoms), large and small species of macrophytic algae, and bacteria (MMS 1987a, 1987b, 1990, and 1996; Thorsteinson 1987; and Dunton and Schonberg 2000). In addition, juveniles and adults of a number of benthic species in the nearshore and coastal waters of the Beaufort Sea do not live in constant association with bottom sediments. Instead, certain species may opportunistically leave the bottom sediments, usually during May to June, to become grazers or predators on epontic (within- or under-ice) communities that are composed primarily of diatoms and meiofauna (Horner 1979). Larvae of some benthic polychaetes and molluscs spend part of their life cycle inside sea ice as members of that epontic community. Juveniles of benthic species may also spend time as members of the zooplankton in the water column and may graze or prey on plankton until reaching their adult stages and retreating to the bottom.

A number of physical factors that influence habitat structure affect the flora and fauna associated with bottom sediments. These physical factors can contribute to spatial and temporal patterns of benthic biota that lead to changes in community structure (Gallagher and Keay 1998). Sediment composition, particularly sediment grain size, is extremely important in influencing infaunal community structure and species composition. In the Alaskan Beaufort Sea, as in many benthic communities, deposit-feeders are characteristic of finer sediments, and suspension-feeders are more typical of coarser sediments.

Ice is another important agent that physically disturbs bottom sediments and limits the abundance and distribution of infaunal and to a lesser extent, epifaunal organisms, as well as algae. Bottom-fast ice in nearshore waters prohibits over-wintering of most benthic species, resulting in a population dependent upon colonization during ice-free periods (MMS 1990). Because of this process, epifaunal species such as isopods, amphipods, and mysids that are highly mobile and opportunistic characterize these nearshore areas. Outside of nearshore waters, in coastal areas less than ~65 ft in depth both biomass and diversity of the infauna increase with water depth (Feder et al. 1976a and 1976b). In the shear zone, at ~50 to 70 ft water depths where shorefast ice and the moving pack ice meet, ice gouging serves to further disturb bottom sediments, limiting infaunal abundances in this area (MMS 1990). In the offshore zone of water depths greater than 65 ft, biomass and diversity of infaunal organisms increase with depth and distance (Carey 1978).

Prevailing currents caused by wind and wave action facilitate the movement and recolonization of invertebrates into the ice-free nearshore shallow areas from offshore (Griffiths and Dillinger 1981). These currents also facilitate transport of organic material from terrestrial sources into the nearshore and coastal environments, influencing biomass and diversity of the local benthic community (Schell et al. 1982). Water quality parameters such as salinity, temperature, dissolved oxygen, and turbidity also directly affect benthic communities. Fluctuations in these parameters, either natural in origin or man-made, may result in extreme stress on benthic organisms. For example, salinities in Simpson Lagoon have been shown to be quite variable, ranging from 1 to 32 ppt during summer and accompanied by water temperatures that fluctuated between 0 and 14°C (Craig et al. 1984). While open-ocean seawater is ~33 ppt, hypersaline or brine (highly saline) water of up to 80 ppt occurred naturally in isolated pockets under the ice in winter (Houghton et al. 1984). Open-water conditions during spring breakup may cause hyposaline or brackish conditions (low-salinity water or freshwater) to occur. During this period, water temperatures may reach as high as 13°C (Feder and Jewett 1982).

As noted in Section 2.2.1.1 above, the majority of the Beaufort Sea benthic environment consists of silty muds or sands. These habitats tend to exclude most large algal species (particularly, kelp), which generally need a prevalence of cobbles, boulders, or both as suitable substrate for attachment and colonization. The occurrence of this type of hard-substrate habitat in Alaskan Arctic coastal waters is patchy, isolated, and spatially rare when compared to soft-substrate habitats. The best known example of hard-substrate habitats in the Alaskan Beaufort Sea is the large well-studied kelp community in Stefansson Sound known as the Boulder Patch, which is located near the proposed Liberty Development. The Boulder Patch was discovered in the early 1970s by geologists but lay unstudied biologically until the late 1970s (Dunton and Schonberg 2000). Researchers have since studied this area extensively and found it to be the most diverse and densely populated benthic community in the Alaskan Beaufort Sea (see Dunton and Schonberg 1981 and 2000; Dunton et al. 1982; Dunton 1984; Martin and Gallaway 1994; MMS 2001; Neff 2010; and Wilce and Dunton 2014). Although documented elsewhere along the Beaufort seacoast, boulders have not been previously found in the vicinity of West Dock or in any of the potential nearshore sediment reuse areas that were examined in conjunction with the APP or Alaska LNG Project in 2011, 2014, or 2015.

Epifauna

Epifaunal communities (organisms living on the bottom sediments) are generally more abundant and diverse than the infauna in the nearshore Alaskan Beaufort Sea. Unlike the infauna, these communities exhibit distinct zones in terms of species composition. In Prudhoe Bay, for example, the epibenthos consists of three distinct communities found in the nearshore and offshore areas (Feder and McGee 1982). This is particularly apparent with larger epifauna, because many species distribute themselves in zones parallel to depth contours (Carey et al. 1974). In addition to changes in species composition, the epifauna also exhibited an increase in density and diversity with increasing water depths (Woodward-Clyde Consultants 1984). As noted above, nearshore areas, as winter habitat for epifauna, are eliminated seasonally by bottom-fast ice. This habitat is recolonized every summer and quickly begins to support a variety of benthic species, particularly crustaceans.

Common epifaunal amphipod species in the Alaskan Beaufort Sea include *Onisimus glacialis*, *O. litoralis*, *Gammarus setosus*, and *Monoporeia affinis* (Broad et al. 1977; Envirosphere 1983; Griffiths and Dillinger 1981). The species *O. glacialis* is prevalent in the summer in protected nearshore areas and is much less abundant in deeper areas (Envirosphere 1983). Another species, *Onisimus affinis*, is more prevalent in waters deeper than 7 ft and occurs primarily outside lagoons and protected areas (Envirosphere 1983). As a group, amphipods appear able to occupy a wider range of salinity than mysids (USACE and ERT 1984).

Mysids make up a large proportion of the nearshore epibenthos during summer in Harrison and Prudhoe Bays (Craig and Griffiths 1981) and in Simpson Lagoon (Crane and Cooney 1974; Griffiths and Dillinger 1981); they apparently over-winter in coastal areas (Griffiths and Dillinger 1981). Two common mysids are *Mysis littoralis* and *M. relicta*; of these, *M. littoralis* is widely distributed in nearshore and coastal waters, while *M. relicta* is restricted mostly to coastal waters (Griffiths and Dillinger 1981).

The isopod *Saduria entomon* is also a very common epifaunal organism found in the Beaufort Sea (Broad et al. 1977; Broad et al. 1979; and Griffiths and Dillinger 1981), being nearly ubiquitous in its distribution. Although this species can live at extreme depths in other environments, it appears to be concentrated in depths of less than 16 ft in the Alaskan Beaufort Sea (Robilliard and Busdosh 1979).

Trawl sampling performed in conjunction with the Alaska LNG Project in both 2011 and 2014 indicated that mysids and the isopod *Saduria spp.* were the most abundant epibenthic invertebrates documented in the area. Trawling associated with the offshore disposal site during the 2011 APP indicated that mysids accounted for ~50% of the invertebrates retained by the trawl, while *Saduria* accounted for ~34% of the invertebrate catch. Sampling in 2014 at the three Prudhoe Bay optional sites and the three potential disposal sites (SBAY, WEST, and EGG) also showed high concentrations of mysids and *Saduria,* which together accounted for ~92% of the invertebrate catch at these stations.

Infauna

Benthic infauna, organisms living within the bottom sediments, in the nearshore and coastal environments in the Beaufort Sea exhibit low species diversity and abundance due to the physical and chemical stresses noted earlier. The shallow waters of the nearshore support very low densities of infauna, reflecting the unstable nature of this area (Broad et al. 1977; Carey and Ruff 1977; and Feder et al. 1976a and 1976b).

Early studies along the Alaskan Beaufort Sea coast indicated that annelid worms (polychaetes and oligochaetes) along with bivalve molluscs dominate the infauna in the shallow coastal waters to depths of ~35 ft (Broad et al. 1979). At depths of ~15 to 25 ft in Prudhoe Bay and Stefansson Sound, polychaetes were the dominant infaunal organisms, with molluscs and crustaceans subdominant members (NORTEC 1981). Moving deeper from the shoreline across the continental shelf and slope, the abundance of infaunal organisms generally increases with depth (Carey et al. 1974).

Past studies conducted in the Alaskan Beaufort Sea indicate that infaunal communities are typically dominated by species from two families of polychaetes, Cirratulidae and Ampharetidae (e.g., *Tharyx* spp., *Chaetozone* spp., and *Ampharete vega*) (Feder and Jewett 1982; Grider et al. 1978; Carey et al. 1981; and Envirosphere 1983). Bivalve molluscs occur in the nearshore and coastal areas, with either or both *Portlandia arctica* or *Cyrtodaria kurriana* being the common dominant species of this group (Envirosphere 1983 and Broad et al. 1977). These two species have distinct depth preferences: *P. arctica* appears more frequently in depths greater than ~10 ft, while *C. kurriana* appears to prefer shallower depths of 3 to 10 ft (Envirosphere 1983).

Results from the 1995 Northstar Development sampling program indicated that polychaetes are the dominant species in the area between Endicott and Northstar Island, representing 43% of the total taxa, while crustaceans and molluscs comprised 21 and 26%, respectively (Woodward-Clyde Consultants 1996). There was an obvious increase in the numbers of taxa with increasing depth, but this trend did not occur for abundance. Analyses of their data based on the presence or absence of species showed a clear demarcation between stations at shallow depths of 7 to 15 ft and deeper depths of 23 to 45 ft.

Results from the 2011 APP study also indicated that polychaetes were the most abundant organism in both macrofaunal (1.0 mm) and megafaunal (6.4 mm) fractions sampled in and around the offshore disposal area. Molluscs were noted as accounting for a greater collective biomass, though they were not as abundant. Dredge stations sampled in 2011 for infauna showed markedly lower abundances as well as biomass as compared to the offshore disposal sites, as would be expected based on the shallower water depths where bottom-fast ice occurs each winter. In addition, crustaceans comprised a much larger input and dominated the biomass at each of these shallower stations in both the macrofaunal and megafaunal fractions.

During the 2014 MSP, it was also noted that stations further offshore in deeper water at the disposal sites tended to have higher counts and biomass than the shallower stations. Samples at the shallowest disposal reuse sites exhibited very low numbers of taxa and abundances of infauna. Dramatic increases were seen in biomass with only small water depth increases along some of the study transects. At the deeper test trench sites, the polychaete *A. vega*, dominated the megafaunal samples, comprising 55% of the individuals. Two species, the mollusc *Portlandia intermedia* and the crustacean *S. entomon*, comprised another 30% of the megafauna at the test trench sites.

While relatively rare compared to soft-bottom communities, hard-substrate communities supporting algae and epilithic fauna do exist in the Alaskan Arctic. The well-known Boulder Patch community in Stefansson Sound (~15–20 miles east of the proposed West Dock dredge area) provides hard-substrate for invertebrates and the endemic brown kelp *Laminaria solidungula* (Dunton 1984). A recent paper by Wilce and Dunton (2014) describes in detail benthic algae from the Boulder Patch collected in situ from 1977 to 2006. This area also supports a variety of invertebrates, including sponges, soft corals, sea stars, hydroids, anemones, ascidiaceans (sea squirts), bryozoans, and molluscs, such as chitons and nudibranchs (Dunton and Schonberg 1981 and 2000). A variety of small mobile and sessile benthic species, as well as larger organisms like fish, crabs, shrimp, and sea stars, are common inhabitants with the kelp. These fauna are associated with patches of kelp (*Laminaria* spp.) and red algae that are attached to boulders, cobble, or to pieces of shell debris (Toimil and England 1980). Many of the species inhabiting the Boulder Patch do not occur elsewhere in the region due to a lack of suitable hard substrate. Kelp and other large epilithic species can live for many years in a stable relatively undisturbed habitat. Their ability to colonize and re-establish themselves in new suitable habitat following a major disruption is slow and may take as long as 10 years (Toimil and England 1980; Dunton and Schonberg 1981). Additional kelp community information can be found in LGL and Dunton (1992) along with Neff (2010) and Wilce and Dunton (2014).

Other relatively small hard-bottom communities or kelp beds exist or may exist east of the Boulder Patch. These sites include those offshore of Flaxman Island (NOAA 2001; Dunton et al. 1982); southeast of Belvedere Island in the Stockton Island chain (NOAA 2001; Dunton et al. 1982); at Boulder Island Shoal in outer Camden Bay (Dunton et al. 1990); in Demarcation Bay (Dunton et al. 1982); and in Beaufort Lagoon (Truett 1987). No known hard-bottom communities have been documented near West Dock or the Prudhoe Bay area. There has been no indication of the presence of an enriched boulder patch environment in the vicinity of West Dock or the potential nearshore sediment reuse and offshore disposal areas that have been examined in conjunction with either the APP or Alaska LNG projects in 2011, 2014, or 2015.

2.2.2.3 Algae

As noted above, in the early 1970s, a Boulder Patch was discovered in Stefansson Sound constituting the first kelp bed discovered in the Alaska Beaufort Sea. This and other accumulations of hard substrate (called boulder patches) are located 6–8 km off northern Alaska within Stefansson Sound, with some smaller patches found elsewhere as described above. These habitats support the most diverse biological community known along the Alaska Arctic coast; they have been subject to considerable study (e.g., Reimnitz and Ross 1979; Dunton and Schonberg 1981; Dunton et al. 1982; Toimil and England 1982; Toimil and Dunton 1983; Busdosh et al. 1985, and Wilce and Dunton 2014).

In these boulder patch areas, localized deposits of gravel, cobble, and small boulders (<1 m in diameter) provide unique habitat for attached algae and epifauna resulting in an enriched community as compared to the soft-bottom substrate present throughout most of the Beaufort Sea and along the north Alaskan coast. Wilce and Dunton (2014) recently determined that at least 78 species of benthic algae utilize the hard substrate of the Boulder Patch, including 26 species of green, 25 species of brown, and 25 species of red algae. The arctic kelp *Laminaria solidungula* is typical of the boulder patch assemblage, with the other brown kelp species *Saccharina latissima* and *Alaria esculenta* recorded as co-dominants. Numerous species of red algae, such as *Odonthalia dentata* and *Phycodrys fimbriata*, along with red encrusting or coralline algae are also found in the hard-bottom areas. Green algae were noted as not being heavily represented in these hard-bottom areas.

There has been no indication of the presence of an enriched boulder patch environment that might support a community of brown kelps and other hard-substrate flora and fauna in the Project area to date. Results of the 2011 APP indicated the presence of some benthic algae in association with the offshore deeper disposal sites sampled by trawling; it was noted that the majority of algae seen in 2011 was suspected to be drift material, though some kelp (*L. solidungula*) was attached to pebbles. Algae collected opportunistically by trawling during the 2014 MSP also appeared to be mostly drift material that was free floating or, in fewer cases, were attached to small pebbles. In no cases were larger pebbles or cobble with attached entire algal specimens with intact holdfasts retained in the trawl samples.

2.2.3 Oceanography and Water Quality

The proposed channel dredging and the four potential nearshore dredged material reuse sites that were evaluated in 2015 would occur in relatively shallow waters (less than 20 ft) in Stefansson Sound and Prudhoe Bay area. This region of the Beaufort Sea area has been intensively studied for more than four decades, and the oceanographic characteristics of the region are well understood. Oceanographic conditions in the nearshore Beaufort Sea can be split into two distinct time periods: the summer open-water season which lasts from late June or early July through approximately early-October, and the winter ice-covered time period when the lagoons and nearshore areas freeze solid to shore (fast ice). Offshore of the lagoons, starting in ~65 ft of water, the Beaufort Sea is covered by pack ice during the winter months that moves on- and offshore with the winds and other forcing mechanisms and forms a shear zone with the land-fast ice during the winter. In recent years, during the summer open-water period, the pack ice typically recedes up to 100 miles offshore but may move on- and offshore depending on meteorological and large-scale forcing mechanisms. Ocean currents during the open-water period are primarily governed by wind speed and direction, with astronomical tides, density gradients, bathymetry, coastal morphology, and riverine inputs having a lesser influence.

Conditions during the ice-covered winter months are relatively quiescent with very low currents that are driven by tidal and long-shore pressure gradients.

2.2.3.1 Summer Open-Water Conditions

Oceanographic and water quality conditions in the nearshore Beaufort Sea, although complex and highly variable, are fairly well understood, having been the subject of numerous investigations over the past 40 years (KLI 1983; SAIC 1989 and 1993; Savoie and Colonnel 1988; Short et al. 1988; Tekmarine 1983; URS 1999; Weingartner and Okkonen 2001; Weingartner et al. 2009; etc.). Hydrographic (salinity and temperature) conditions of the nearshore waters are strongly influenced by the freshwater runoff and proximity to the rivers, meteorological conditions, seasonal timing, advection due to circulation patterns, and offshore ice conditions. The dominant forcing mechanism in driving the circulation on the inner continental shelf (<150 ft depth) and in nearshore waters is wind stress, with water level variations and density gradients having a lesser influence. Nearshore currents generally run in an east-west direction, parallel to the local bathymetry and in the same direction as the prevailing wind stress. Water properties are then advected along the coast and redistributed by the regional circulation patterns. These same oceanographic processes affect transport of suspended sediment and sediment quality conditions in the Beaufort nearshore region. These influences, along with regional oceanographic processes such as upwelling and storm surges, have been found to be very important in affecting onshore-offshore exchange of water properties.

River discharge is the main source of freshwater input into the nearshore areas of the Beaufort Sea. During late May to early June, rivers on the North Slope break up and begin to flow into coastal areas. Rivers both overflow and underflow the nearshore land-fast ice, which hastens ice melt in the immediate area. Following the break-up of the rivers, a warm brackish lens of water between the shore and the offshore ice pack dominates the coastal region. The timing of river break-up and the volume of snow in the watershed determine the amount of fresh water available for diluting the nearshore marine water. During the remainder of the summer, river discharge is highly variable and depends on the amount of precipitation.

At the beginning of the open-water season during and following the breakup of coastal rivers and melting of sea ice, there is a stratified water column with a less saline surface water layer that can be as deep as 13 ft and which overlays a marine water layer. As the summer season progresses following break-up each year, winds begin to mix the water column along the coastline, creating a brackish water environment. As river flow drops in mid- to late summer, water column salinity increases to a more marine condition.

From middle summer until freeze-up, during the late open-water period, the coastal waters become steadily colder and saltier until they are virtually identical to the marine waters. This trend is apparent in all of the time-series records of salinity and temperature from about the end of August through October from numerous studies conducted in the Beaufort Sea nearshore region. Intense storms from both the west and east occur during this period. Salinities usually range from 28 to 31 practical salinity units (psu) throughout the nearshore area and are relatively homogeneous both vertically and horizontally with water temperatures near freezing. An exception to this is during light wind periods when nearshore brackish plumes (10-20 psu) from the local rivers may be evident. Freeze-up of the lagoons usually starts in late September or early October with the shallow offshore areas freezing approximately a month later.

Bathymetry is an important parameter with respect to oceanographic conditions along the Beaufort Sea Coast, with nearshore currents generally running in an east-west direction, parallel to the local bathymetry. The West Dock Causeway interrupts this general east-west flow causing currents to be directed north and has been shown to affect the local hydrographic regime as well as sedimentation patterns in its vicinity. Sedimentation studies that were conducted as part of the Prudhoe Bay Waterflood Environmental Monitoring Program indicated that the causeway redirected the natural east-west transport of sediment resulting in a net accretion of sediment on both the eastern and western sides of the structure. This fact was confirmed in 2011 by the APP project, which found the bathymetry on the eastern side of West Dock to be substantially shallower than that indicated on historic navigation charts (APP 2012).

These sedimentation and current patterns at West Dock are currently under investigation by the Alaska LNG Project to assess infill rates within the two test trenches that were constructed through the ice during the Winter of 2015.

2.2.3.2 Winter Ice-Covered Conditions

During winter, the Beaufort Sea is covered by sea ice that begins to form in late September or early October. Freeze-up of the lagoons and nearshore waters is usually completed by the end of October, with ice growing to ~5 ft (1.5 m) thick by April of each year. Ice cover persists on average for 8-9 months until spring warming results in river breakup and subsequent sea ice melting near the river and stream deltas. River break-up along the Beaufort coast typically occurs in mid- to late May. Temperature and salinity profiles collected under the sea ice within the Beaufort Sea exhibit uniform near-freezing temperatures (-1.7°C) and saline (~32 psu) marine waters.

While the current meters employed during under-ice studies are generally insensitive to speeds below 2 centimeters/second (cm/s), the data do not indicate stagnant conditions. Weingartner and Okkonen (2001) measured under-ice currents in Stefansson Sound and found that even though most velocities were less than 5 cm/s, there were periods of time when currents exceeded 15 cm/s. They found that the winter under-ice currents were not correlated with the wind and forcing mechanisms and were most likely due to fluctuations in atmospheric pressure or offshore oceanic motions.

Heavy brine formed by the thickening sea ice has been observed to produce a stratified water column in restricted water bodies such as Prudhoe Bay and in stagnant or near-stagnant conditions; however, low current speeds (e.g., less than 5 cm/s) are sufficient to disperse any such brine through the water column and minimize or eliminate resulting under-ice vertical stratification. In nearshore waters, the typical water column structure observed under sea ice in the Beaufort Sea is uniform, with very little temperature, salinity, or density stratification. Although minimal, some vertical stratification has been observed farther offshore on the continental shelf during the winter months.

2.2.3.3 Turbidity and Suspended Sediment

Turbidity values and total suspended solids (TSS) concentrations during the open-water period in the nearshore Beaufort Sea area are very dependent on wind and wave-induced turbulence that re-suspends bottom sediments and on sediment discharge from the rivers. Sediment is introduced naturally to the marine environment through river runoff and coastal erosion and is resuspended during the summer by wind and wave action. Satellite imagery and suspended particulate matter data suggest that highly turbid waters are generally confined to depths less than 16 ft (5 m; URS 2001). Storms, wind and wave action, and coastal erosion increase turbidity in shallow waters periodically during the open-water season. Turbid conditions persist in areas where the sea floor consists primarily of silts and clays as opposed to areas having a predominantly sand bottom.

One of the most comprehensive studies of turbidity in the region was performed as part of the Endicott Monitoring Program. Data points included turbidity, TSS, and secchi disk measurements (Hachmeister et al. 1987). Correlation between in situ turbidity and laboratory TSS values was found to be low. The highest turbidity values were found during spring break-up, during periods of heavy precipitation when river discharge was high resulting in turbid plumes that were discharged into the nearshore coastal waters, and following storm activity. In contrast, ADL (2001) found during ANIMIDA that there was very good agreement between turbidity and TSS values measured in the laboratory on the same discrete samples. In the ADL ANIMIDA study, turbidity ranged from 1.8 to 75 nephelometric turbidity units (NTU) and TSS ranged from 2.9 to 119 milligrams per liter (mg/L) measured during the open-water period in the vicinity of the Northstar Development and in Foggy Island Bay.

In winter, the presence of ice cover eliminates external effects of river discharge and wave/current activity that increase suspended sediment concentrations and cause turbidity. Under-ice measurements made in Stefansson Sound during the April to June time period found turbidity, optical backscatter, and TSS levels to be very low in the nearshore waters (ADL 2001). Turbidity ranged from 0.15 to 1.35 NTU and TSS ranged from 0.14 to 2.0 mg/L, with the lowest levels observed at the more offshore stations.

During the 2011 APP, turbidity was found to range from 4.5 to 27.4 NTU in the dredge area; no measurements were made in the offshore disposal area, whereas TSS was only measured at the offshore disposal site with a range of 8.0 to 28.5 mg/L. The 2014 MSP found turbidity values that ranged from 5.2 to 411 NTU from samples taken at the test trench site as well as at the three nearshore disposal sites. TSS for these same samples ranged from <5 to 424 mg/L with a high degree of correlation between TSS and turbidity.

3.0 STUDY DESIGN AND METHODOLOGY

The 2015 MSP was designed to document the physical, chemical, and biological characteristics of four disposal areas that are being considered on the Project for the beneficial reuse of dredged sediments. The study design was based on the criteria for evaluation of disposal areas as outlined in Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material.* The two guidelines that are directly applicable to the 2015 MSP are the following:

- Subpart C – Potential impacts on physical and chemical characteristics of the aquatic ecosystem (substrate, suspended particulates/turbidity, current patterns and water circulation, normal water level fluctuations, and salinity gradients).
- Subpart D – Potential impacts on biological characteristics of the aquatic ecosystem (fish, crustaceans, molluscs, and other aquatic organisms in the food web).

The 2015 MSP focused exclusively on the evaluation of four nearshore disposal areas that are being considered for potential beneficial reuse of dredged sediment for shoreline protection and erosional control. The program emphasized the characterization of marine sediments and extensively investigated sediment grain size, which is critical in determining if dredged materials may be reused for beneficial use for erosional control and beach nourishment. As the material proposed for the dredge program will consist exclusively of clean marine sediments meeting available criteria for either inland disposal or reuse for beach nourishment, the effects of disposal will be largely related to the physical properties of the sediments and their direct and indirect effects on local habitat and associated ecosystem function. More information on the program is provided in the *2015 Marine Sampling Program Field Execution Plan* (FEP) that includes the *Quality Assurance Plan* (QAP) prepared for this project (Alaska LNG 2015b; USAG-EX-SRZZZ-00-000002-000).

As noted above, the 2015 program builds on previous marine sampling efforts conducted in 2011 as part of the APP and in 2014 for the Project, each of which examined the dredge area as well as a number of potential disposal areas. Emphasis in 2011 was on the dredge area itself along with a potential offshore disposal site. The 2014 MSP focused more heavily on the characterization of disposal sites; three potential nearshore beneficial reuse disposal sites and three deeper disposal water sites in Prudhoe Bay were sampled. In addition, the 2014 MSP included sampling at two stations within an area targeted for test trenching (subsequently conducted during the winter of 2015) to further characterize dredged materials. The 2015 effort examined two new potential disposal locations as well as re-examined two sites that were sampled in 2014.

3.1 Study Objectives

The goal of the 2015 MSP is to sufficiently characterize marine environmental conditions within the four potential nearshore beach disposal sites to support disposal site permitting, planning, and design of future monitoring programs that may be needed to permit the dredging operations. This program has the following objectives:

- Determine if the sediment grain size at the proposed disposal sites is compatible with the dredge sediments for the placement of dredged material as beach nourishment for beneficial use. Compatibility will be determined by comparing the grain size envelope of each potential receiving beach with the grain size of the dredge area sediments (from previously collected data).

- Gain an understanding of the nature of oceanographic conditions (temperatures, salinities, stratification) in the disposal area.
- Ascertain the biological resources of concern at areas that would be affected by disposal of dredged sediments.
- Establish existing concentrations of the CoCs in surface sediments at the proposed disposal sites and determine whether they exceed regulatory SLs and are compatible with the dredge sediments.
- Provide data to address Section 404(b)(1) guidelines for the specification of disposal sites for dredged or fill material.

In accordance with the Section 404(b)(1) guidelines, this program is intended to provide a synoptic and representative picture of existing conditions in the proposed disposal areas. The observations made and the data obtained are designed to provide the information necessary to evaluate the suitability of the sites for dredge disposal and to predict potential effects of that action. In the longer term, the parameters measured will be those indicative, either directly or indirectly, of the immediate and long-term impact of the dredged material on the environment at the disposal site and on adjacent water areas.

3.2 SAMPLING DESIGN

The 2015 MSP included collection and analysis of water quality, benthos, sediment chemistry, and demersal fish and invertebrates at four proposed nearshore disposal sites (SBAY, WEST, GULL, and DOCK; Figure 1-1). Figure 3-1 through Figure 3-4 depict the individual sites, the sampling stations within each of these sites, and the potential disposal zone at each site. Each of these four nearshore sites was chosen for characterization to determine if they would be suitable candidates for the reuse of dredged material to provide erosion control and/or beach nourishment.

3.2.1 Station Selection

Since the nearshore locations were being evaluated for the potential disposal of sediments for beneficial use, the design of the program utilized appropriate guidelines as described below. In terms of spatial coverage, the USACE Los Angeles District guidelines for sampling, testing, and data analysis of dredged material were used to determine location and frequency of the beach transects (USACE 1989). These guidelines specify that when dredged material is to be placed on a beach that: “At least two profiles should be sampled for a receiving beach one mile or less in length with a least one additional profile for every 1/2-mile of beach affected.” For the purposes of the 2015 MSP, it was assumed that the disposal areas would be ~800–900 ft wide by ~2 miles long. Since two of the disposal areas were previously sampled in 2014, and all samples indicated that the area and region were relatively clean of contaminants, had low infauna populations, and were homogeneous relative to sample depth, it was determined that three transects would adequately cover the region of interest at each disposal site. Based on this information, the design of the sampling program included three sample transects (profiles, labeled “T” followed by a sequential number as in T7) at each site that extended from below the MLLW level to the offshore region beyond the projected areal extent of each disposal area. Transect locations at SBAY, WEST, and DOCK were stretched along the length of the along-shore disposal sites (as proposed in June 2015) with allowances made for the unique configuration of the L-shaped DOCK site; transects were located radially around the Gull Island for the circular GULL site (Figure 3-1 through Figure 3-4).

Figure 3-1: South Prudhoe Bay (SBAY) DIsposal Reuse Site

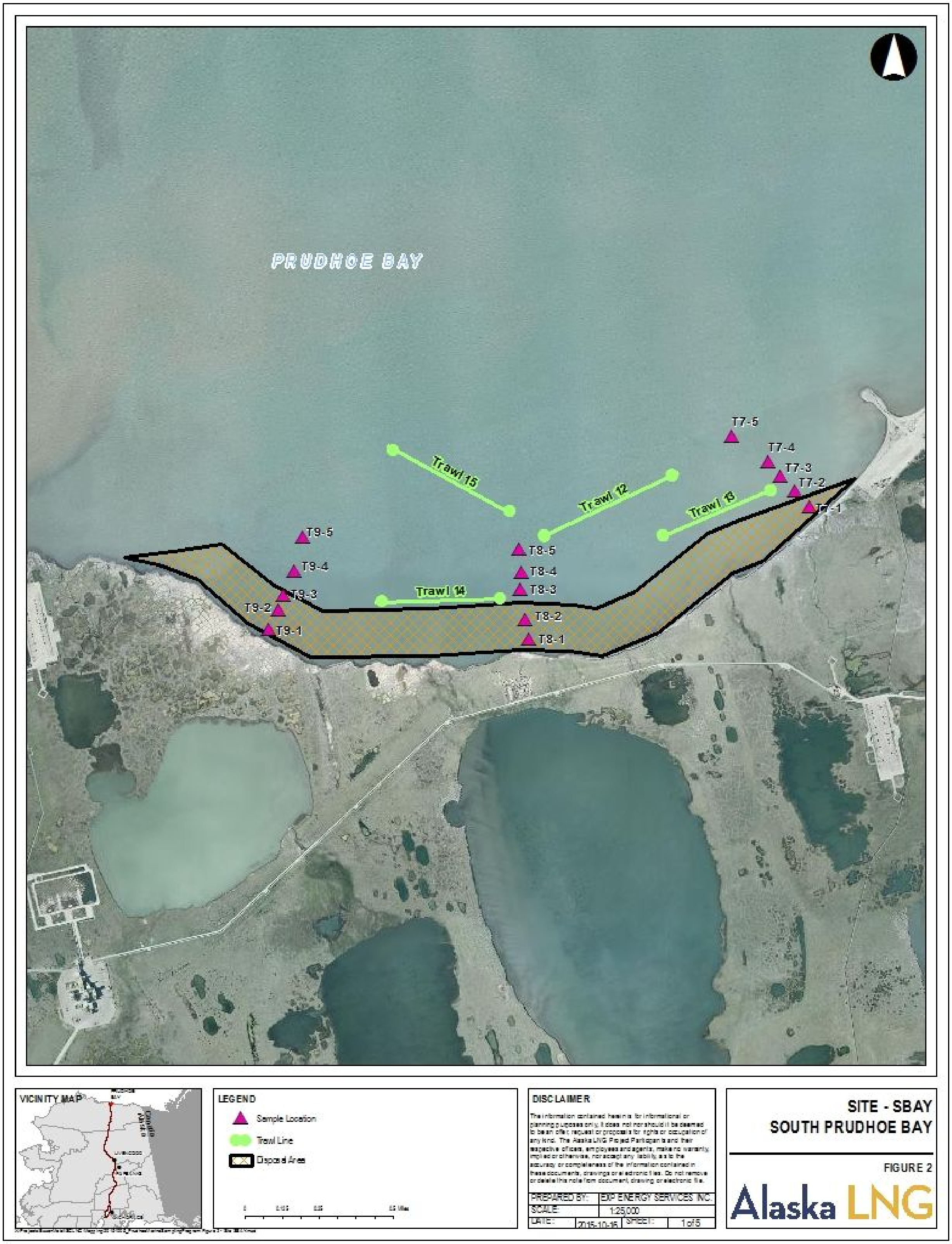


Figure 3-2: West Prudhoe Bay (WEST) Disposal Reuse Site

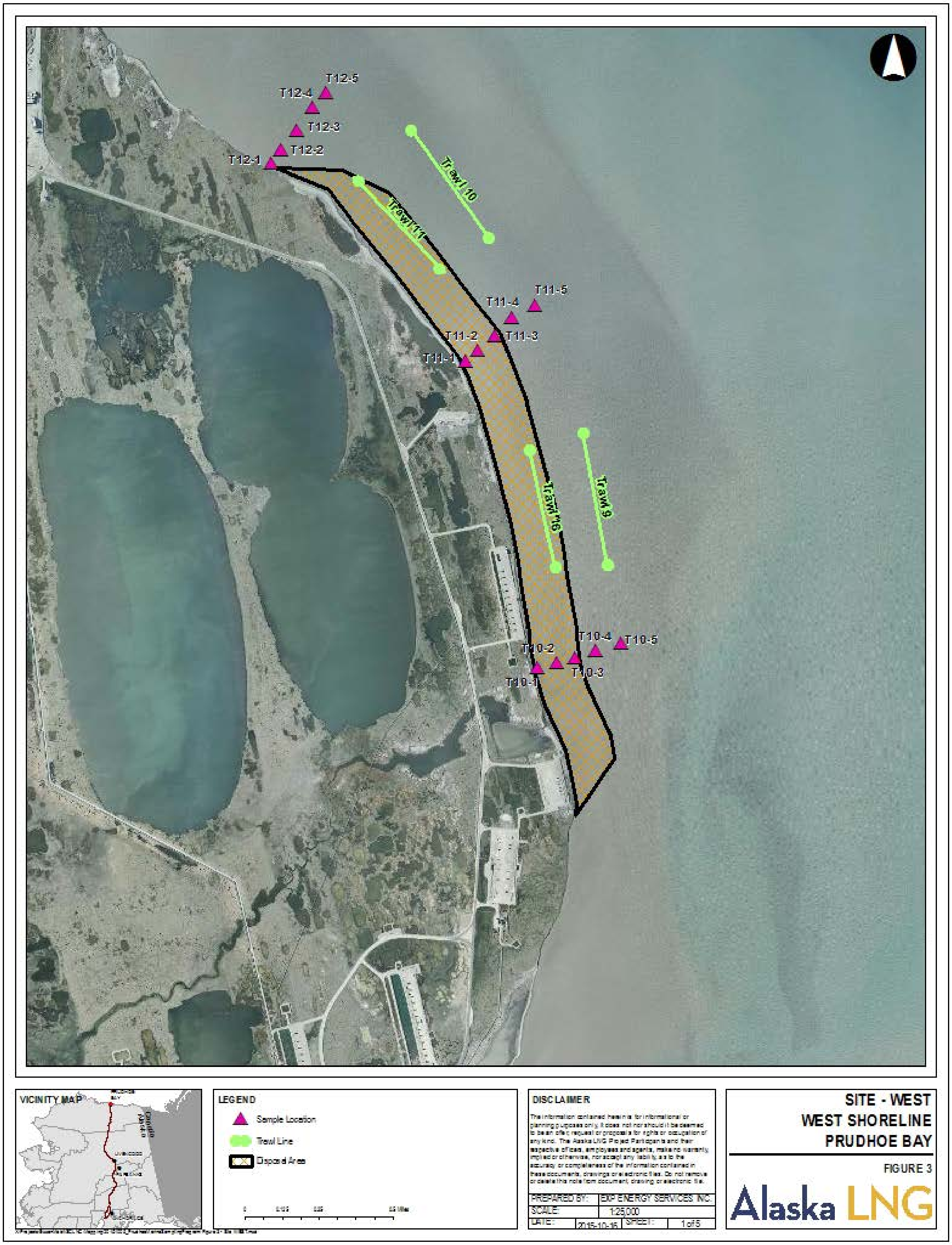


Figure 3-3: Gull Island (GULL) Disposal Reuse Site

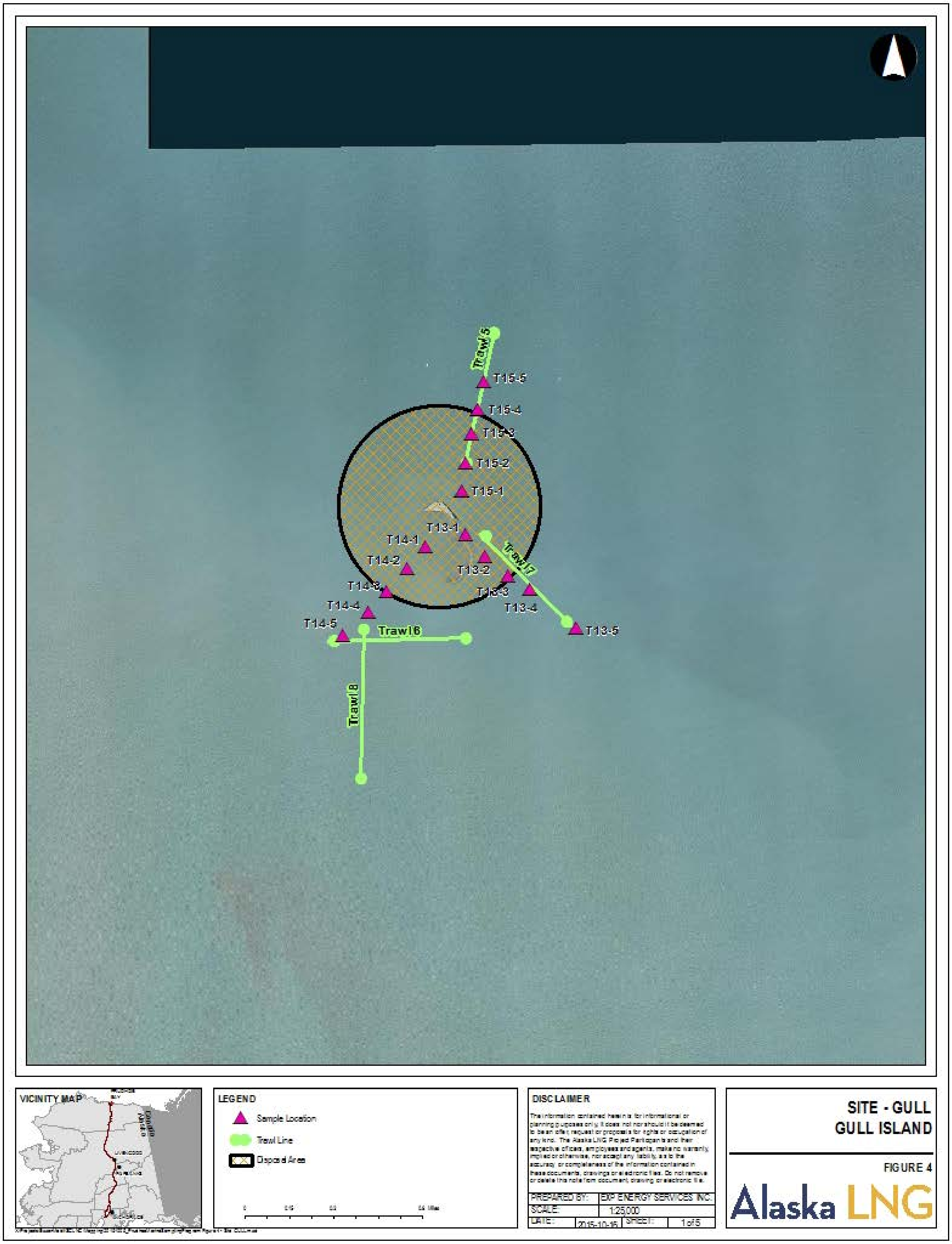
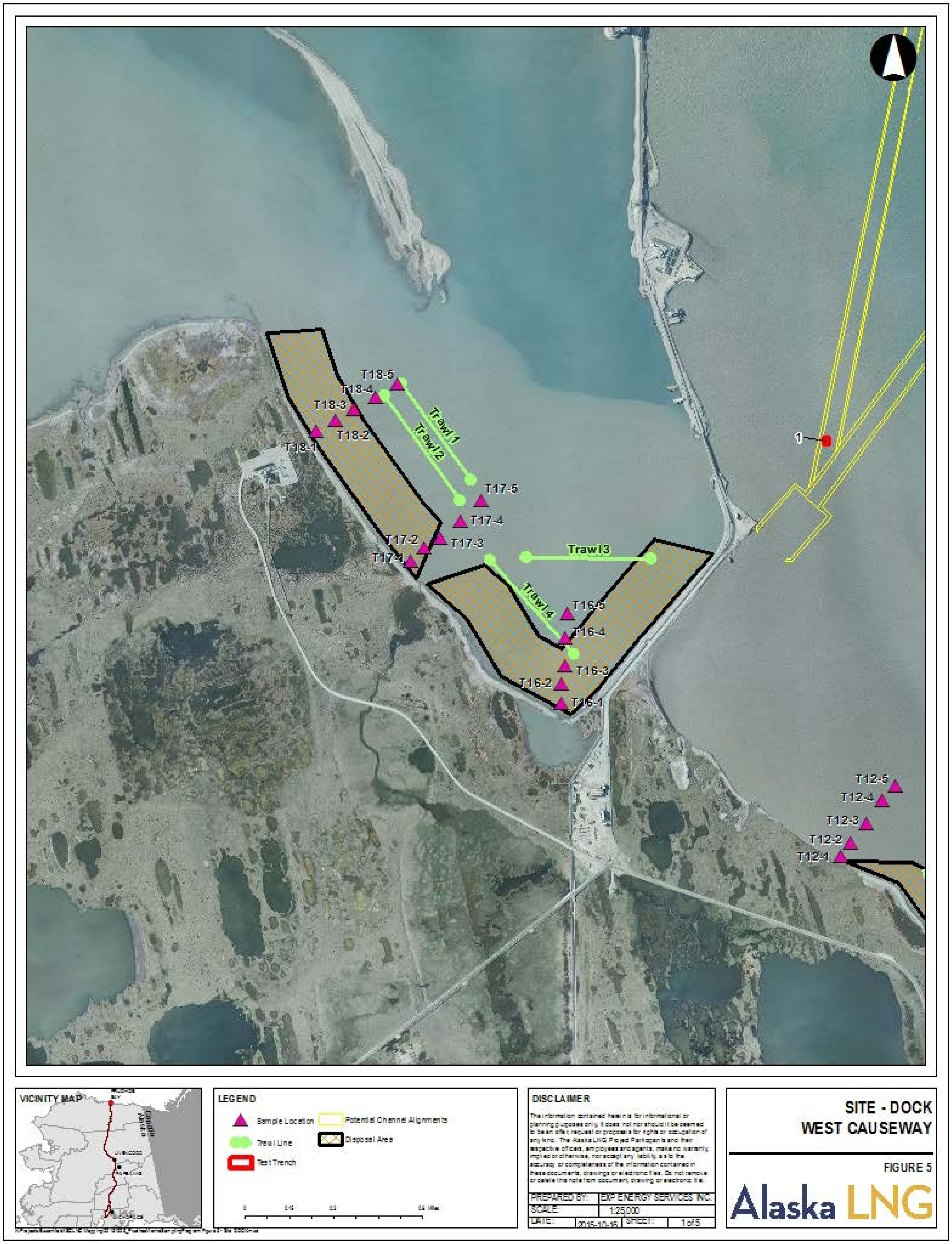


Figure 3-4: West of West Dock (DOCK) Disposal Reuse Site



Each transect included five sampling stations that were sampled for a variety of physical, chemical, and biological properties as detailed below and shown in Section 4.0. Stations extended along the length of each transect from the shallow subtidal area where dredged material would be placed to offshore beyond the zone of where dredged material would be deposited. Stations along each transect were numbered from “1” (most inshore) to “5” (farthest offshore), where the first two to three locations along each transect extended out from shore and were within the probable sediment reuse placement areas, leaving two to three locations outside of the probable placement areas. Therefore, each station was given a designation of “T#-#” to denote transect and station. Each site included 15 sediment collection stations (five along each of three transects), six of which were also used for water quality stations (three along each of the two outer-most transects) and six of which were benthic infauna stations (two stations along each of three transects). In addition, four trawls were collected at each site; trawling was performed at shallow and deep locations within each site.

3.2.2 Number and Types of Samples Collected

Section 404(b)(1) guidelines for the sampling of dredged material and disposal sites do not include specific numbers and types of samples but outline the type of characterization that should take place. As referenced above, the two Section 404(b) guidelines directly applicable to the 2015 MSP include the determination of potential impacts of dredge disposal on physical, chemical, and biological characteristics of the aquatic ecosystem. To satisfy the objectives of this sampling program to obtain representative chemical, physical, and biological data for the proposed disposal sites, sampling efforts were exclusively allocated to the four disposal reuse areas to gather and analyze data on water quality, benthos, surficial sediment chemistry, and demersal fish and invertebrates. No dredge area sampling was performed as part of this year’s program as had been included during the 2011 APP and 2014 MSP studies. It is anticipated that additional sampling of the dredge areas, once fully identified, may take place at the dredge areas in the future to assist in planning and permitting.

Numbers of samples and determination of the parameters sampled for the program were based on the 2014 Seattle District DMMP guidelines, expected level of effort, expected likely contaminants or CoCs in the dredge area, and results from both the 2011 APP and 2014 MSP programs. Modifications in sampling design were made in recognition of the unique nature of the oceanography and marine biology of the dredge area and proposed disposal areas and based on the type and level of industrial activity that takes place in the vicinity. For example, dioxin is an important parameter that needs to be assessed in Puget Sound, but dioxin is not a concern for the Beaufort Sea in Alaska, so dioxins were not analyzed during this program.

All of the Project’s currently proposed disposal areas on the North Slope are shallow (<6 ft depths), ice covered for about eight months each year, and located within the bottom-fast ice zone where benthic organisms must recolonize on an annual basis. The shallow depths and generally windy conditions limit the need for detailed examination of depth stratification phenomena. The relatively shallow and flat bathymetry and the homogenous nature of the bottom sediments in the proposed disposal areas limit the heterogeneity of the benthic environment and hence the number of samples needed to represent the area. Also, as the 2014 effort indicated that little to no benthic organisms were seen at the shallowest locations adjacent to shore, the benthic infauna sampling was eliminated at the shallow-most stations located closest to shore along each transect in 2015.

A summary of sample analyses and number of samples that were collected during the 2015 MSP is shown in Table 3-1. Emphasis was placed on the collection of sediment grain size samples at all five stations along each transect to allow determination of suitability of disposal based on this sediment characteristic. Other parameters were sampled intermittently at targeted stations as outlined below and shown in Section 4.0 (in Table 4-1) to ensure adequate data collection.

Table 3-1: Summary of 2015 MSP Sampling

Parameter	Number of Samples (Exclusive of Quality Control Samples)			
	2015 MSP Sampling			
	SBAY	WEST	GULL	DOCK
Sediment Quality				
Particle Grain Size	15	15	15	15
Total Organic Carbon (TOC)/ Total Solids	9	9	9	9
Diesel Range Organics/Residual Range Organics (DRO/RRO)	9	9	9	9
Metals	9	9	9	9
Biological Monitoring				
Macrofauna (1.0 mm)	18	18	18	18
Megafauna (6.4 mm)	18	18	18	18
Bottom Trawls	4	4	4	4
Water Quality and Oceanography				
Hydrographic Profiles	4	4	4	4
Turbidity/TSS Samples	10	10	10	10

3.2.3 Sediment Sampling and Analysis

Sediment characterization and chemistry samples that were collected and analyzed for each of the four potential disposal sites (SBAY, WEST, GULL, and DOCK) as summarized in Table 3-1 included the following:

- Sediment grain size distribution – (4 sites x 3 transects/site x 5 stations/transect = 60 samples + quality control {QC}).
- Total organic carbon (TOC) – (4 sites x 3 transects/site x 3 stations/transect = 36 samples + QC).
- Metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc) – (4 sites x 3 transects/site x 3 stations/transect = 36 samples + QC).
- Hydrocarbons (diesel range organics {DRO} and residual range organics {RRO}) - (4 sites x 3 transects/site x 3 stations/transect = 36 samples + QC).

Sampling and analysis emphasized the sediment grain size, which was performed at all sediment stations. Chemical analyses of TOC, metals, and hydrocarbons was performed at every other station for a total of three stations per transect (i.e., shallow-most station, mid-depth station, and deepest station along each transect).

The analytical methods selected for use on this program are approved or suggested by the EPA and USACE and are presented in Table 3-2 along with target MDLs and MRLs. Note that actual MDLs and MRLs vary by sample depending on the % solids level since all sediment concentrations are reported on a dry weight basis. More information on method requirements, such as preservation, holding times, container type, quality control procedures, and data quality objectives are provided in the 2015 MSP FEP (including QAP) prepared for this program. Analytical methods identified in this document are referred to by method number or citation. They include, for example, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW846* (EPA 1996); the American Public Health Association's (APHA's) *Standard Methods for the Examination of Water and Wastewater* (APHA 2005); and the Puget Sound Estuary Program's (PSEP's) *Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound, Final Report* (PSEP 1986).

Table 3-2: Sediment Analytical Methods and Detection/Reporting

Analyte	Method	Method Detection Limit (MDL) (mg/kg or ppm)	Method Reporting Limit (MRL) (mg/kg or ppm)
Metals			
Aluminum (Al)	SW 6010C	0.5	2.0
Antimony (Sb)	SW 6020A	0.01	0.05
Arsenic (As)	SW 6020A	0.04	0.5
Barium (Ba)	SW 6010C	0.3	0.8
Beryllium (Be)	SW 6020A	0.005	0.02
Boron (B)	SW 6010C	0.2	4.0
Cadmium (Cd)	SW 6020A	0.007	0.02
Chromium (Cr)	SW 6020A	0.06	0.2
Cobalt (Co)	SW 6020A	0.006	0.02
Copper (Cu)	SW 6020A	0.04	0.1
Iron (Fe)	SW 6010C	2.0	4.0
Lead (Pb)	SW 6020A	0.02	0.05
Manganese (Mn)	SW 6010C	0.02	0.2
Mercury (Hg)	SW 7471B	0.002	0.02
Nickel (Ni)	SW 6020A	0.03	0.2
Selenium (Se)	SW 6020A	0.06	0.8
Silver (Ag)	SW 6020A	0.004	0.02
Thallium (Tl)	SW 6020A	0.002	0.02
Vanadium (V)	SW 6010C	0.2	0.8
Zinc (Zn)	SW 6010C	0.2	1.0
Organics			
Diesel Range Organics (DRO)	AK102	1.0	20
Residual Range Organics (RRO)	AK103	2.9	99
Conventional Parameters			
Total Organic Carbon (TOC)	PSEP/SW 9060	200 mg/kg	50000 mg/kg
Particle Grain Size	PSEP/ASTM D422	Not applicable	0.1%
Total Solids/% Solids	PSEP/SM 2540B	Not applicable	0.1%

AK Alaska Department of Environmental Conservation (ADEC). 1999. 18 AAC 78 UST Regulations, Section 007, Underground Storage Tanks Procedures Manual, Appendix D, November 7, 2002.

ASTM American Society for Testing and Materials (ASTM). 1993. Annual Book of Standards - Water: Volume 11.01, Philadelphia, PA.

PSEP 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency, Seattle, WA.

APHA. 2005. American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater, 21st e American Public Health Association.

SW United States Environmental Protection Agency (EPA). 1996. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. SW-846, 3rd ed. and EPA. 2000. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. SW-846, Draft Update IVB, Chapters 3 and 4.

Sediments in the four potential reuse areas were analyzed for DRO (C_{10}-C_{25}) and RRO (C_{25}-C_{36}). In 2014, these analyses indicated that some of the samples had concentrations of a non-petroleum signature as a result of high peat content. To address this problem in 2015, the sediments were also analyzed for DRO and RRO with the addition of a silicate gel treatment (SGT) cleanup procedure to remove any polar non-petroleum-based hydrocarbons. Concentrations of DRO and RRO obtained by these two methods (with and without SGT) were then compared to help determine contributions from non-petrogenic sources such as peat.

Previous sediment analyses performed during 2011 also included GRO and BTEX. These analyses were not included in the 2014 MSP or 2015 MSP since all BTEX and GRO concentrations found in 2011 were below detection limits and due to the fact that the vast majority of the vessels operating in the West Dock area utilize diesel fuel rather than gasoline. In addition to these sediment parameters, a larger suite of chemical parameters were analyzed at the dredging locations during 2011 APP and 2014 MSP to characterize the dredge sediments and retain consistency between programs. These parameters included: ammonia, total sulfides, total volatile solids (TVS), acid-volatile sulfides (AVS) with simultaneously extracted metals (SEM; cadmium, copper, lead, mercury, nickel, and zinc), polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs). These additional analyses were not required as part of the disposal site characterization and were not performed at the potential disposal site analyses for 2014 and 2015.

Sediment samples were collected in 2015 using two different techniques due to the different water depths and the capabilities of the different sampling platforms (i.e., access with a research vessel with hydraulic lifting capability versus a 16-ft inflatable skiff). Techniques included the use of a 0.1-square meter (m^2) Kynar-coated stainless steel Smith-McIntyre grab sampler that was utilized on the research vessel and a 4-inch diameter stainless steel manual hand corer that was utilized in the shallow nearshore sampling effort from the skiff. These are the same two techniques and types of equipment that were utilized during the 2014 MSP. In addition to these sediment sampling techniques, a vibracore was utilized during the 2011 APP sampling to obtain sediments cores within the dredge area to the proposed -16 ft dredge depth. Samples were then taken near the surface and near the bottom of each core obtained with the vibracore.

Prior to sampling, all grabs, hand corers, and other non-disposable sampling equipment were scrubbed with dedicated non-metallic bristle brushes and flushed with a deck hose or site rinsed to remove large soil particles. Equipment was cleaned with an Alconox® rinsate solution, rinsed with clean seawater, and followed by a final rinse with deionized water. No solvents or other cleaning agents were used since no significant sediment contamination was expected. Samples were processed (collected) using disposable or decontaminated tools in an area that was free of potential contaminant sources (including vessel exhaust) and metal surfaces. Clean nitrile gloves were used during sampling to prevent any contamination of the samples. Appropriate quality assurance (QA) procedures were followed for the program as outlined in the FEP and QAP. Field duplicates were collected in the field at a minimum rate of 10% for sediment grain size and chemistry analysis. Additional sampling, analytical, and QA information is available in the program FEP and QAP.

3.2.4 Biological Sampling Design and Methodology

Biological samples that were collected and analyzed to help characterize biological conditions at the four disposal sites in 2015 include the following:

- Infauna – (4 sites x 3 transects/site x 2 stations/transect x 3 replicates/station = 72 samples of each of 2 size fractions for macrofauna and megafauna).
- Trawls – (4 sites x 2 replicates trawls within and offshore of each disposal area = 16 trawl samples).

No tissue analyses were included in the 2015 MSP based on results of the 2011 and 2014 sediment sampling programs, since contamination of bottom sediments was not seen. Also, tissue from other scientific sampling efforts in the area have indicated that the biota in the region are not elevated in hydrocarbons, metals, or other contaminants and that those concentrations seen in biota represent pristine background levels (Neff 2010).

3.2.4.1 Infauna Sampling Design and Methodology

Infaunal analyses included two size fractions of benthic organisms: the megafaunal fraction was comprised of organisms retained on a 6.4-mm mesh sieve (~1/4 inch), and the macrofaunal fraction of organisms retained on a 1.0-mm mesh sieve. Infaunal sampling was performed at stations selected for sediment grain size and chemical analysis located within each disposal site area (at mid-depths along the three transects) and slightly offshore outside of the immediate disposal area (in deeper water; refer to Table 4-1). Due to the shallow water (1-2 ft) at the extreme inshore station on each transect and the lack of benthic organisms seen at these shallow-most locations during the 2014 MSP, benthic samples were not collected at the shallow-most stations of each transect during 2015 as they were in 2014.

Infauna sampling utilized three methods of sampling depending on sampling platform (vessel), water depth, and infaunal fraction. This included the use of the 0.1-m^2 Kynar-coated stainless steel Smith-McIntyre grab; a 4-inch hand corer; and a 6-inch hand corer. Samples were sieved to obtain macrofaunal (1-mm sieve) and megafaunal (6.4-mm sieve) fractions; three replicates of each fraction were collected at each station. Samples from each station were shipped to the taxonomic laboratory for processing and enumeration.

All grabs were visually inspected to ensure they met the outlined acceptability criteria. Once a Smith-McIntyre grab was deemed acceptable, a subsample was extracted from the center of the grab using the 4-inch hand corer (0.009 m^2 surface area), and this material was screened though a 1-mm sieve to collect macrofauna. Retained material was placed in a pre-labelled plastic sample jar, the organisms were relaxed with propylene phenoxetol, and the sample was preserved in 10% buffered formalin and seawater. The remainder of the grab (0.091 m^2 surface area) was sieved through a 6.4-mm sieve for analysis of megafauna, placed in a separate sample container, and handled similarly to macrofauna. For shallower locations where the grab could not be utilized due to vessel constraints, five separate 6-inch hand cores collected from a skiff were composited for the megafaunal analyses, and a separate 4-inch hand core was collected for the macrofaunal fraction. All biological sampling methods followed PSEP or other appropriate protocols and those outlined in the program FEP.

3.2.4.2 Trawl Sampling Design and Methodology

Trawling was performed to further characterize and provide general information regarding the nature and condition of the demersal fish and epibenthic invertebrate assemblages present at the four disposal sites and to determine if any unique hard-bottom areas such as a boulder patch might exist in the these areas.

An 8-ft otter trawl was employed to collect four replicate trawls at each site. Where bathymetry allowed, two replicate nearshore (“shallow”) and two replicate offshore (“deep”) trawls were performed, but the determination of each trawl line was based on bathymetry, accessibility, weather conditions, and the ability to maneuver the sampling vessel. Trawls were performed as 10-minute tows at a speed of ~2.5 knots (~750 m).

Catch was released into an appropriately sized bucket or tote on deck and sorted; the biota were then identified and enumerated. Large fish and invertebrates were enumerated and identified in the field where possible; in some cases, organisms too numerous to count or colonial in nature were estimated or noted as present to provide general abundance and diversity information.

Algae collected during the trawl effort were also recorded in the field log. Length to the end of the caudal fin was recorded for fish. A limited number of voucher specimens of select fish and invertebrates as allowed by the Alaska Department of Fish and Game (ADF&G) collection permit were preserved in buffered 10% formalin and returned to the lab for identification and verification. Any trawl catch that was not retained was released at the sampling site after observations were recorded. Additional sampling procedure information is available in the program FEP.

3.2.5 Oceanographic and Water Quality Design and Methodology

Water measurements focused on hydrographic conditions in order to characterize the vertical structure of the water column and on turbidity and total suspended solids (TSS) as the parameters that would most likely be affected by the nearshore disposal of dredge sediments. Water observations and samples that were collected during 2015 include the following, as shown in Table 3-3:

- Hydrographic water column profile of temperature, conductivity, salinity, dissolved oxygen (DO), pH, and turbidity using an in situ conductivity, temperature, and depth (CTD) profiler – (4 sites x 2 transects/site x 2 stations/transect = 16 samples + QC).
- Discrete TSS and turbidity samples – (4 sites x 2 transects/site x 2 stations/transect {mid-depth and deepest stations} of surface and bottom samples + 1 station/transect {shallow-most station} with surface samples only} = 40 + QC).

Because the sediment chemistry results from the dredge area in 2011 did not raise any concerns with respect to contaminate and elutriate concentrations during dredge disposal, detailed water chemistry was not warranted during subsequent studies. Conventional water quality parameters were analyzed following standard procedures as outlined in Table 3-3. Field duplicate samples were collected and analyzed at a rate of a minimum of 10% as outlined in the program FEP. Additional sampling, analytical, and QA information is available in the program FEP and QAP.

Water quality samples were collected at two transects per site at sediment stations located at mid-depth and slightly offshore outside of the immediate disposal area in deeper water to serve as reference locations (as shown in Section 4.0 in Table 4-1). Due to the extremely shallow water (1–2 ft) at the inshore station on each transect, CTD casts were not performed, but water samples were collected for the analysis of TSS and turbidity at the surface only.

Table 3-3: Water Analytical Methods and Reporting Limits

Parameter	Type of Measurement	Method	Method Reporting Limit (MRL)
Total Suspended Solids (TSS)	Laboratory	SM2540D	5 mg/L
Dissolved Oxygen	In situ	SM4500-0 G	0.01 mg/L
Turbidity	Field	SM2130B	0.1 NTU
pH	In situ	SM4500-H^+ B	± 0.01 pH units
Salinity	In situ	SM2520B	<0.1 psu
Conductivity	In situ	SM2510B	1 - 100 µSiemens (range dependent)
Temperature	In situ	SM2550B	± 0.01 °C

SM American Public Health Association (APHA). 2012. Standard Methods for the Examination of Water and Wastewater, 22nd ed., American Public Health Association.

Hydrographic profiles were obtained with a high precision SeaBird SeaCAT SBE-19+ V2 CTD equipped with pressure (depth), conductivity (salinity), temperature, DO, pH, and optical backscatter (turbidity) sensors. Water was collected from near the surface (using a bucket) and just above the bottom using a standard 5-liter (L) Niskin water sampler. No chemical decontamination of the Niskin bottle or sampling buckets was required or performed. Field and laboratory QC (e.g., collection of field duplicates, triplicate CTD casts, duplicative turbidity analyses, or field checks) were performed as described in the FEP. Additional sampling procedure information is available in the program FEP and QAP.

3.3 QUALITY ASSURANCE/QUALITY CONTROL

Rigorous quality assurance/quality control (QA/QC) procedures followed for the 2015 MSP have been detailed elsewhere in the FEP and attached QAP. The objectives of the QA/QC program were to fully document the field and laboratory data collected, to maintain data integrity from the time of field collection to storage at the end of the program, and to produce the highest quality data possible. QA for the program was controlled, in part, by adhering to EPA-recommended methods and procedures and performing internal QC checks such analysis of method blanks, matrix spike/spike duplicates (MS/MSDs), and laboratory control spike/laboratory control spike duplicates (LCS/LCSDs). QC in the field included the collection and analysis of duplicate samples where appropriate, adherence to the FEP and SOPs, and the use of formal sample documentation and tracking methodology. All analytical data from ALS Environmental underwent QA/QC evaluation according to EPA National Functional Guidelines for inorganic and low concentration organic data review (EPA 2014). This evaluation is included as part of this interpretive report in Appendix A; the reader is also referred to the appendix for analytical laboratory reports and case narratives.

4.0 RESULTS

Field sampling for the program was performed in July 2015 using the R/V *Ukpik* by field personnel from KLI and a marine mammal observer from Owl Ridge Natural Resource Consultants. All stations were successfully sampled for all the target samples and analyses on the dates shown in Table 4-1. Due to the shallow depths at the disposal sites, some of the 2015 sampling locations were adjusted based on how closely the primary survey vessel (draft of 3.5 ft) was able to approach shore. Where possible, sampling activity took place from the R/V *Ukpik*; shallower areas inaccessible by the *Ukpik* were occupied using inflatable skiffs. As a result, stations along each transect were not always sampled on the same day or in succession based on wind, weather, and tide conditions. Navigational data shown in Table 4-1 and depicted in Figure 3-1 through Figure 3-4 represent the coordinates of the first successful sediment grain size grab collected at a station or, in the case of trawling, the start/end of each trawl. Station depths have been adjusted to Mean Sea Level (MSL) based on water level records from the NOAA tide station located at the Prudhoe Bay STP.

All program procedures followed those outlined in the program FEP and QAP (Alaska LNG 2015b). Sediment grain size and chemistry and laboratory water analyses were performed by ALS Environmental in Kelso, WA. Infaunal benthic analyses were managed by KLI with sorting overseen by Dr. Allan Fukuyama (Edmonds, WA); taxonomy was performed by KLI's Gary Gillingham (Crustacea), Dr. Fukuyama (Mollusca), Gene Ruff (Annelida; Puyallup, WA), and Steve Hulsman (miscellaneous taxa; Seattle, WA).

4.1 SEDIMENT RESULTS

4.1.1 Sediment Reuse Area Results

Results for conventional parameters, metals, and hydrocarbons are summarized in Table 4-2, Table 4-3, Table 4-4, and Table 4-5 for SBAY, WEST, GULL, and DOCK, respectively. Where applicable, the data have also been compared to the USACE's 2014 DMMP SLs (USACE 2014), and ADEC's Arctic Soil Cleanup (18 AAC 75) and recommended SQG levels based on the threshold effects level (TEL) and probable effects level (PEL; ADEC 2013). The TEL represents the concentration below which adverse effects are expected to rarely occur; the PEL represents the concentration above which adverse effects are frequently expected. Background ranges provided are for the Beaufort Sea area based on summarized data from the ANIMIDA/cANIMIDA studies (Exponent 2010 and Neff 2010).

4.1.1.1 Reuse Area – Conventional Parameters

Conventional parameters in the potential dredged material reuse areas include sediment grain size, TOC, and percent total solids. In addition to the % fines (silt plus clay fraction) that are presented in Table 4-2 through Table 4-5, detailed sediment grain size data for each sediment reuse area and sampling site are presented in Table 4-6. Detailed laboratory reports that include case narratives along with QA/QC results are also provided in Appendix A. As comparisons are made to the 2014 MSP data collected at SBAY and WEST, the 2014 data are presented in Appendix B for completeness.

Table 4-1: Station and Sample Collection for the 2015 MSP

Station Information						Type of Sample Collection				
Site/Transect/Station		Date	Depth (ft)	Latitude	Longitude	Sediment Grain Size	Sediment Chemistry	Water Quality	Benthics	Trawl
SBAY										
Transect # 7	**T7-1**	7/23/15	1.3	70º 18.568’	-148º 19.699’	✓	✓	✓		
	T7-2	7/23/15	3.0	70º 18.615’	-148º 19.816’	✓				
	T7-3	7/23/15	3.7	70º 18.659’	-148º 19.939’	✓	✓	✓	✓	
	T7-4	7/23/15	5.7	70º 18.702’	-148º 20.049’	✓				
	T7-5	7/23/15	7.6	70º 18.779’	-148º 20.355’	✓	✓	✓	✓	
Transect #8	**T8-1**	7/24/15	3.7	70º 18.200’	-148º 22.165’	✓	✓			
	T8-2	7/24/15	4.0	70º 18.259’	-148º 22.189’	✓				
	T8-3	7/24/15	3.9	70º 18.348’	-148º 22.224’	✓	✓		✓	
	T8-4	7/24/15	6.4	70º 18.399’	-148º 22.212’	✓				
	T8-5	7/23/15	6.4	70º 18.465’	-148º 22.225’	✓	✓		✓	
Transect #9	**T9-1**	7/24/15	2.5	70º 18.250’	-148º 24.411’	✓	✓	✓		
	T9-2	7/24/15	3.9	70º 18.306’	-148º 24.326’	✓				
	T9-3	7/24/15	4.0	70º 18.348’	-148º 24.285’	✓	✓	✓	✓	
	T9-4	7/24/15	4.8	70º 18.418’	-148º 24.179’	✓				
	T9-5	7/24/15	4.8	70º 18.517’	-148º 24.103’	✓	✓	✓	✓	
Not Applicable	**Trawl 12**	7/27/15	6.7	70º 18.496’	-148º 22.057’					✓
	Trawl 13	7/27/15	4.9	70º 18.622’	-148º 19.996’					✓
	Trawl 14	7/27/15	4.4	70º 18.322’	-148º 22.349’					✓
	Trawl 15	7/27/15	7.0	70º 18.777’	-148º 23.354’					✓
WEST										
Transect # 10	**T10-1**	7/18/15	2.2	70º 20.755’	-148º 27.967’	✓	✓	✓		
	T10-2	7/18/15	2.8	70º 20.768’	-148º 27.803’	✓				
	T10-3	7/19/15	4.0	70º 20.779’	-148º 27.644’	✓	✓	✓	✓	
	T10-4	7/16/15	4.0	70º 20.799’	-148º 27.46’	✓				
	T10-5	7/16/15	4.5	70º 20.817’	-148º 27.238’	✓	✓	✓	✓	
Transect #11	**T11-1**	7/17/15	2.5	70º 21.655’	-148º 28.522’	✓	✓			
	T11-2	7/17/15	3.0	70º 21.685’	-148º 28.421’	✓				
	T11-3	7/17/15	3.9	70º 21.726’	-148º 28.262’	✓	✓		✓	
	T11-4	7/16/15	3.9	70º 21.780’	-148º 28.114’	✓				
	T11-5	7/16/15	4.2	70º 21.814’	-148º 27.911’	✓	✓		✓	
Transect #12	**T12-1**	7/17/15	2.5	70º 22.248’	-148º 30.173’	✓	✓	✓		
	T12-2	7/17/15	3.8	70º 22.286’	-148º 30.085’	✓				
	T12-3	7/17/15	3.0	70º 22.341’	-148º 29.940’	✓	✓	✓	✓	
	T12-4	7/17/15	4.0	70º 22.408’	-148º 29.804’	✓				
	T12-5	7/17/15	4.0	70º 22.450’	-148º 29.681’	✓	✓	✓	✓	
Not Applicable	**Trawl 9**	7/26/15	5.2	70º 21.029’	-148º 27.331’					✓
	Trawl 10	7/26/15	5.2	70º 21.996’	-148º 28.266’					✓
	Trawl 11	7/26/15	3.9	70º 21.911’	-148º 28.688’					✓
	Trawl 16	7/27/15	3.4	70º 21.025’	-148º 27.786’					✓

Table 4-1: Continued

Station Information						Type of Sample Collection				
Site/Transect/Station		Date	Depth (ft)	Latitude	Longitude	Sediment Grain Size	Sediment Chemistry	Water Quality	Benthics	Trawl
GULL										
Transect #13	**T13-1**	7/18/15	2.5	70º 21.861’	-148º 21.768’	✓	✓	✓		
	T13-2	7/18/15	3.6	70º 21.797’	-148º 21.614’	✓				
	T13-3	7/18/15	3.6	70º 21.739’	-148º 21.411’	✓	✓	✓	✓	
	T13-4	7/18/15	3.6	70º 21.696’	-148º 21.228’	✓				
	T13-5	7/18/15	3.8	70º 21.580’	-148º 20.836’	✓	✓	✓	✓	
Transect #14	**T14-1**	7/19/15	3.2	70º 21.830’	-148º 22.122’	✓	✓			
	T14-2	7/19/15	3.6	70º 21.769’	-148º 22.284’	✓				
	T14-3	7/19/15	3.8	70º 21.702’	-148º 22.469’	✓	✓		✓	
	T14-4	7/19/15	4.4	70º 21.642’	-148º 22.639’	✓				
	T14-5	7/19/15	4.4	70º 21.578’	-148º 22.863’	✓	✓		✓	
Transect #15	**T15-1**	7/20/15	4.4	70º 21.990’	-148º 21.798’	✓	✓	✓		
	T15-2	7/20/15	4.4	70º 22.072’	-148º 21.758’	✓				
	T15-3	7/20/15	4.4	70º 22.158’	-148º 21.696’	✓	✓	✓	✓	
	T15-4	7/20/15	4.7	70º 22.226’	-148º 21.636’	✓				
	T15-5	7/20/15	4.6	70º 22.309’	-148º 21.578’	✓	✓	✓	✓	
Not Applicable	**Trawl 5**	7/26/15	4.0	70º 22.056’	-148º 21.774’					✓
	Trawl 6	7/26/15	4.6	70º 21.559’	-148º 23.007’					✓
	Trawl 7	7/26/15	2.9	70º 21.866’	-148º 21.654’					✓
	Trawl 8	7/26/15	3.7	70º 21.608’	-148º 22.679’					✓
DOCK										
Transect #16	**T16-1**	7/25/15	3.0	70º 22.717’	-148º 32.570’	✓	✓	✓		
	T16-2	7/25/15	3.9	70º 22.772’	-148º 32.563’	✓				
	T16-3	7/20/15	5.0	70º 22.825’	-148º 32.526’	✓	✓	✓	✓	
	T16-4	7/25/15	5.0	70º 22.907’	-148º 32.524’	✓				
	T16-5	7/20/15	5.4	70º 22.979’	-148º 32.496’	✓	✓	✓	✓	
Transect #17	**T17-1**	7/25/15	3.2	70º 23.141’	-148º 33.849’	✓	✓			
	T17-2	7/25/15	4.1	70º 23.178’	-148º 33.728’	✓				
	T17-3	7/21/15	3.6	70º 23.206’	-148º 33.596’	✓	✓		✓	
	T17-4	7/25/15	5.1	70º 23.254’	-148º 33.413’	✓				
	T17-5	7/21/15	5.2	70º 23.313’	-148º 33.224’	✓	✓		✓	
Transect #18	**T18-1**	7/25/15	5.3	70º 23.530’	-148º 34.652’	✓	✓	✓		
	T18-2	7/25/15	4.3	70º 23.560’	-148º 34.483’	✓				
	T18-3	7/21/15	4.8	70º 23.589’	-148º 34.316’	✓	✓	✓	✓	
	T18-4	7/25/15	4.6	70º 23.624’	-148º 34.121’	✓				
	T18-5	7/21/15	4.2	70º 23.662’	-148º 33.933’	✓	✓	✓	✓	
Not Applicable	**Trawl 1**	7/25/15	4.6	70º 23.677’	-148º 33.929’					✓
	Trawl 2	7/25/15	4.5	70º 23.643’	-148º 34.079’					✓
	Trawl 3	7/25/15	5.2	70º 23.130’	-148º 31.715’					✓
	Trawl 4	7/25/15	5.0	70º 22.844’	-148º 32.424’					✓

Table 4-2: Sediment Data from SBAY Reuse Area

Parameter	Station and Depth (ft)									Sediment Screening Values				
	T7-1	T7-3	T7-5	T8-1	T8-3	T8-5	T9-1	T9-3	T9-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	1.1	3.6	7.5	3.5	3.6	6.1	2.0	3.8	4.5		Lower	Upper	TEL[5]	PEL[5]
CONVENTIONAL PARAMETERS														
TOC (%)	0.130	0.139	2.23	1.39	0.154	0.393	8.04	3.52	0.176		0.01	6.42		
Silt/Clay (%)	2.65	1.76	97.5	22.7	1.96	11.3	29.7	17.6	2.28		0.1	100		
Solids (%)	76.7	76.8	49.5	70.8	84.2	79.8	48.4	57.5	78.2					
METALS (mg/kg)														
Aluminum	2100	2010	9380	2790	1340	2310	4200	2350	2060					
Antimony	0.049	0.067	0.205	0.090	0.053	0.065	0.112	0.088	0.065	150	0.14	1.14		
Arsenic	2.67	4.13	**12.1**	3.33	3.30	4.71	5.22	3.99	4.80	57	4.2	28.4	7.24	41.6
Barium	22.0	20.1	82.4	41.1	37.1	33.4	41.3	26.1	29.2		142	863		
Beryllium	0.114	0.117	0.678	0.177	0.091	0.159	0.256	0.-148	0.133		0.3	3.6		
Boron	3.2	3.1	28.3	15.8	3.2	4.5	33.3	21.3	4.1					
Cadmium	0.122	0.080	0.307	0.20	0.049	0.137	0.241	0.198	0.048	5.1	0.03	0.82	0.68	4.21
Chromium	6.16	6.21	23.7	7.68	3.52	6.2	9.96	6.38	5.42	260	12.7	104	52.3	160
Cobalt	2.75	3.39	10.5	3.75	2.09	3.68	4.61	3.3	3.82		2.2	18.6		
Copper	3.07	2.92	**27.7**	5.92	2.55	4.1	8.64	4.5	3.47	390	3.6	50.2	18.7	108
Iron	5970	6860	24000	7500	4590	6880	10400	6920	6840		7000	39000		
Lead	1.81	1.98	13.8	2.99	1.90	3.15	4.35	2.54	2.78	450	3.2	22.3	30.24	112
Manganese	93.3	100	288	91.4	45.9	82.3	152	104	117		62	898		
Mercury	0.007J	0.007J	0.063	0.012J	0.005J	0.012J	0.018	0.012J	0.007J	0.41	0.003	0.20	0.13	0.70
Nickel	8.21	7.87	**35.5**	12.9	5.29	9.17	15.8	9.32	7.95		6.0	48.4	15.9	42.8
Selenium	0.10J	0.11J	0.72	0.23J	0.10J	0.16J	0.42J	0.26J	0.14J	3				
Silver	0.021	0.018	0.166	0.035	0.017	0.033	0.052	0.033	0.02	6.1	0.01	0.44	0.73	1.77
Thallium	0.017	0.025	0.087	0.023	0.015	0.035	0.029	0.022	0.019		0.05	0.92		
Vanadium	7.5	8.0	31.3	9.6	5.7	9.5	14.1	9.6	9.2		25.2	173		
Zinc	20.6	20.9	96.4	31.5	13.4	23.9	37.3	25.8	19.8	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)														
DRO	ND	ND	40 J	ND	ND	22J	150 Z	73 Z	ND					
DRO-SGT	ND	ND	26 J	ND	ND	ND	66 Z	31 J	ND	*200[4]*				
RRO	ND	ND	150J	8J	ND	58J	710 Z	360 Z	ND					
RRO-SGT	ND	ND	68J	38J	ND	25J	180J	110 J	ND	*2000[4]*				
DRO+RRO	ND	ND	190 J	96 J	ND	80 J	860J	433 J	ND					
DRO+RRO -SGT	ND	ND	94 J	49 J	ND	35 J	246 J	141 J	ND		0.39	104		

1 State of Washington DMMP Sediment Screening Levels (SLs; Seattle DMMO, 2014). SLs are concentrations at which there are no adverse effects expected.
2 Range of sediment concentrations throughout the Beaufort Sea coastal area 1999-2006. Source is Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies.
3 ADEC (2013). Memorandum recommending the use of TELs and PELs. Sediment Quality Guidelines.
4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.
5 TELs and PELs from McDonald et al. (2000) and Buchman (2008).
J Estimated value for concentrations between the MDL and MRL.
ND Not detected or analyte was <5x the concentration seen in the associated method blank and below the MRL.
Z The chromatographic fingerprint does not resemble a petroleum product.
Bold underlined values equal or exceed TELs.

Table 4-3: Sediment Data from WEST Reuse Area

Parameter	Station and Depth (ft)									Sediment Screening Values				
	T10-1	T10-3	T10-5	T11-1	T11-3	T11-5	T12-1	T12-3	T12-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	1.8	2.8	3.9	2.3	3.1	3.8	2.3	2.3	3.6		Lower	Upper	TEL[5]	PEL[5]
CONVENTIONAL PARAMETERS														
TOC (%)	0.67	0.174	0.457	0.208	0.215	1.01	0.218	0.149	0.439		0.01	6.42		
Silt/Clay (%)	24.0	7.73	14.0	9.70	6.51	47.7	12.9	3.37	17.8		0.1	100		
Solids (%)	80.2	79.3	78.7	80.9	83.5	72.4	82.4	81.8	78.4					
METALS (mg/kg)														
Aluminum	5170	1960	2940	2470	1700	4760	3520	2070	2840					
Antimony	0.073	0.056	0.076	0.065	0.062	0.083	0.061	0.062	0.062	150	0.14	1.14		
Arsenic	4.28	4.25	5.09	2.62	4.41	6.05	3.65	3.74	4.95	57	4.2	28.4	7.24	41.6
Barium	95.4	25.7	31.9	44.6	43.6	50	46	31.4	33.7		142	863		
Beryllium	0.325	0.127	0.189	0.143	0.133	0.304	0.232	0.111	0.178		0.3	3.6		
Boron	6.4	4.4	5.6	2.5	3.7	10.2	5.9	3.5	6.6					
Cadmium	0.223	0.089	0.141	0.244	0.075	0.208	0.213	0.075	0.12	5.1	0.03	0.82	0.68	4.21
Chromium	12	5.17	8.05	7.05	4.5	13.1	8.44	5.11	7.43	260	12.7	104	52.3	160
Cobalt	4.87	3.51	4.09	2.73	3.17	6.55	3.93	3.04	4.66		2.2	18.6		
Copper	11.6	3.54	6.55	6.28	3.56	11.0	7.13	2.95	5.7	390	3.6	50.2	18.7	108
Iron	11700	6340	9070	7640	6720	12400	8810	6210	8460		7000	39000		
Lead	5.28	3.07	4.14	3.07	2.71	5.98	3.6	2.4	4.22	450	3.2	22.3	30.24	112
Manganese	166	125	123	113	85.5	135	139	109	147		62	898		
Mercury	0.013J	0.006J	0.02	0.009J	0.005J	0.025	0.006J	0.005J	0.014J	0.41	0.003	0.20	0.13	0.70
Nickel	**17.1**	7.99	12.2	9.76	8.16	**19.3**	12.2	6.96	10.8		6.0	48.4	15.9	42.8
Selenium	0.25J	0.13J	0.18J	0.16J	0.10J	0.29J	0.17J	0.11J	0.17J	3				
Silver	0.05	0.017	0.035	0.038	0.024	0.063	0.03	0.018	0.036	6.1	0.01	0.44	0.73	1.77
Thallium	0.051	0.027	0.027	0.025	0.021	0.041	0.033	0.022	0.028		0.05	0.92		
Vanadium	16	8.6	11.2	8.7	8.7	16.6	11.8	8.3	11.9		25.2	173		
Zinc	40.2	21.9	32.7	25.1	18.7	51.6	28.5	18.7	29.9	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)														
DRO	22 J	ND	ND	ND	ND	18 J	ND	ND	ND					
DRO-SGT	ND	ND	ND	ND	ND	ND	ND	ND	ND	*200*[4]				
RRO	140 Z	ND	51 J	ND	ND	95 J	ND	ND	48 J					
RRO-SGT	50 J	11 J	21 J	7.1 J	9.2 J	44 J	7.6 J	9.4 J	23 J	*2000*[4]				
DRO+RRO	162	ND	60.8	ND	ND	113	ND	ND	59					
DRO+RRO -SGT	70	18	29.7	13.6	15.2	57	13.9	16.3	32.1		0.39	104		

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2 Range of sediment concentrations throughout the Beaufort Sea coastal area 1999-2006. Source is Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies.
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4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.
5 TELs and PELs from McDonald et al. (2000) and Buchman (2008).
J Estimated value for concentrations between the MDL and MRL.
ND Not detected or analyte was <5x the concentration seen in the associated method blank and below the MRL.
Z The chromatographic fingerprint does not resemble a petroleum product.
Bold underlined values equal or exceed TELs.

Table 4-4: Sediment Data from GULL Reuse Area

Parameter	Station and Depth (ft)									Sediment Screening Values				
	T13-1	T13-3	T13-5	T14-1	T14-3	T14-5	T15-1	T15-3	T15-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	1.7	2.8	3.1	2.1	3.0	3.9	3.6	3.9	4.2		Lower	Upper	TEL[5]	PEL[5]
CONVENTIONAL PARAMETERS														
TOC (%)	0.147	0.218	0.368	0.33	0.391	0.395	0.535	0.291	0.342		0.01	6.42		
Silt/Clay (%)	1.77	26.3	28.5	53.5	29.5	36.0	48.1	24.8	20.0		0.1	100		
Solids (%)	91.6	72.6	73.2	72.0	72.8	73.4	74.0	74.3	77.1					
METALS (mg/kg)														
Aluminum	1250	3330	3600	3890	3670	3680	4140	3670	3720					
Antimony	0.042	0.079	0.086	0.071	0.082	0.077	0.082	0.085	0.107	150	0.14	1.14		
Arsenic	3.37	5.96	6.34	5.63	6.17	6.28	6.43	6.62	***<u>7.52</u>***	57	4.2	28.4	7.24	41.6
Barium	20.9	93.6	105	68.3	114	96.3	56.6	61.2	69.4		142	863		
Beryllium	0.093	0.216	0.242	0.239	0.23	0.225	0.247	0.219	0.241		0.3	3.6		
Boron	4.0	5.7	5.7	7.2	5.5	5.8	8.5	6.5	8.1					
Cadmium	0.074	0.191	0.194	0.195	0.191	0.183	0.211	0.209	0.216	5.1	0.03	0.82	0.68	4.21
Chromium	3.95	10.7	11.4	11.9	11.4	11.0	13.1	12.3	11.5	260	12.7	104	52.3	160
Cobalt	2.03	5.94	6.86	6.17	6.48	6.25	6.58	6.96	7.57		2.2	18.6		
Copper	2.73	5.67	8.62	6.70	6.86	6.69	8.18	6.48	6.66	390	3.6	50.2	18.7	108
Iron	4710	12100	13000	12500	12700	12600	13600	13100	14100		7000	39000		
Lead	1.82	3.74	4.13	3.79	4.14	4.18	4.62	4.23	4.89	450	3.2	22.3	30.24	112
Manganese	48.8	161	286	189	222	194	218	218	255		62	898		
Mercury	0.007J	0.016J	0.016J	0.017J	**<u>0.298</u>**	0.014J	0.021	0.013J	0.018J	0.41	0.003	0.20	0.13	0.70
Nickel	5.88	15.7	**<u>16.8</u>**	**<u>17.6</u>**	**<u>16.5</u>**	**<u>16.4</u>**	**<u>18.8</u>**	**<u>17.6</u>**	**<u>17.3</u>**		6.0	48.4	15.9	42.8
Selenium	0.08J	0.18J	0.20J	0.19J	0.20J	0.20J	0.23J	0.21J	0.22J	3				
Silver	0.021	0.023	0.027	0.030	0.028	0.054	0.038	0.028	0.025	6.1	0.01	0.44	0.73	1.77
Thallium	0.014	0.022	0.026	0.029	0.025	0.026	0.032	0.036	0.034		0.05	0.92		
Vanadium	6.0	13.5	14.9	14.3	14.7	14.6	15.9	14.8	16.2		25.2	173		
Zinc	15.7	43.3	46.6	46.7	45.6	45.3	46.9	44.2	46.6	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)														
DRO	ND	ND	ND	ND	14 J	ND	ND	ND	ND					
DRO-SGT	ND	ND	ND	ND	ND	ND	ND	ND	ND	*200[4]*				
RRO	ND	ND	35 J	ND	43 J	32 J	29 J	24 J	24 J					
RRO-SGT	4.6 J	6.6 J	16 J	11 J	24 J	16 J	ND	ND	ND	*2000[4]*				
DRO+RRO	ND	ND	46	ND	57	41.5	37.8	31.8	31.3					
DRO+RRO -SGT	9.9	14	24.8	19.2	33.5	24.6	ND	ND	ND		0.39	104		

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5 TELs and PELs from McDonald et al. (2000) and Buchman (2008).
J Estimated value for concentrations between the MDL and MRL.
ND Not detected or analyte was <5x the concentration seen in the associated method blank and below the MRL.
Z The chromatographic fingerprint does not resemble a petroleum product.
<u>Bold underlined</u> values equal or exceed TELs.

Table 4-5: Sediment Data from DOCK Reuse Area

Parameter	Station and Depth (ft)									Sediment Screening Values				
	T16-1	T16-3	T16-5	T17-1	T17-3	T17-5	T18-1	T18-3	T18-5	DMMP SLs[1]	Range of Beaufort Sea Background[2]		ADEC Recommended SQGs[3]	
	2.5	3.8	4.4	2.7	3.0	4.6	4.8	4.3	3.9		Lower	Upper	TEL[5]	PEL[5]
CONVENTIONAL PARAMETERS														
TOC (%)	0.311	0.680	0.515	0.199	0.157	1.22	1.56	1.21	1.47		0.01	6.42		
Silt/Clay (%)	12.6	24.1	19.5	2.12	33.3	72.5	40.3	67.0	65.8		0.1	100		
Solids (%)	83.8	75.9	78.9	87.3	82.0	62.9	69.4	65.9	63.3					
METALS (mg/kg)														
Aluminum	3020	3380	3210	1190	1820	5910	4830	5370	6380					
Antimony	0.077	0.064	0.065	0.065	0.043	0.101	0.101	0.097	0.121	150	0.14	1.14		
Arsenic	3.44	3.84	4.46	5.86	3.93	**<u>8.65</u>**	**<u>7.93</u>**	**<u>7.58</u>**	**<u>10.5</u>**	57	4.2	28.4	7.24	41.6
Barium	45.5	36.1	33.8	67.3	23.4	65.5	49.6	53.8	62.5		142	863		
Beryllium	0.146	0.184	0.197	0.126	0.106	0.367	0.305	0.334	0.399		0.3	3.6		
Boron	4.6	6.6	7.2	5.2	3.8J+	12.9	15.3	14.0	16.8					
Cadmium	0.158	0.145	0.162	0.065	0.031	0.246	0.192	0.243	0.283	5.1	0.03	0.82	0.68	4.21
Chromium	7.41	9.03	8.4	3.05	4.19	16.1	13.3	15.1	17.3	260	12.7	104	52.3	160
Cobalt	3.35	3.77	4.08	2.33	2.85	7.82	6.29	7.47	8.3		2.2	18.6		
Copper	4.76	5.93	6.08	3.27	2.40	14.9	11.2	12.9	18.0	390	3.6	50.2	18.7	108
Iron	7190	8970	8770	5670	6000	17600	13500	15800	19200		7000	39000		
Lead	2.66	3.68	3.74	2.30	2.12	7.43	6.21	6.21	8.49	450	3.2	22.3	30.24	112
Manganese	126	108	99.6	42.6	71.5	263	164	229	277		62	898		
Mercury	0.008J	0.012J	0.013J	0.003J	0.005J	0.038	0.026	0.035	0.039	0.41	0.003	0.20	0.13	0.70
Nickel	10.7	12.0	11.8	6.77	5.95	**<u>23.9</u>**	**<u>18.6</u>**	**<u>22.4</u>**	**<u>25.2</u>**		6.0	48.4	15.9	42.8
Selenium	0.15J	0.20J	0.19J	0.09J	0.07J	0.38J	0.34J	0.34J	0.43J	3				
Silver	0.030	0.038	0.040	0.029	0.015J	0.081	0.062	0.072	0.096	6.1	0.01	0.44	0.73	1.77
Thallium	0.03	0.03	0.032	0.016	0.022	0.051	0.04	0.042	0.058		0.05	0.92		
Vanadium	9.4	12.4	12.0	6.1	7.6	21.5	17.8	19.0	23.6		25.2	173		
Zinc	24.2	29.7	30.0	13.4	15.1	62.2	49.2	57.1	67.3	410	14.8	157	124	271
PETROLEUM HYDROCARBONS (mg/kg)														
DRO	ND	17 J	ND	ND	ND	25 J	30 Z	21 J	28 J					
DRO-SGT	ND	ND	ND	ND	ND	ND	ND	ND	ND	*200[4]*				
RRO	41 J	80 J	60 J	ND	ND	100 J	160 Z	100 J	130 J					
RRO-SGT	ND	42 J	31 J	ND	ND	50 J	71 J	54 J	59 J	*2000[4]*				
DRO+RRO	50.1	97	72	ND	ND	125	190	121	158					
DRO+RRO -SGT	ND	54	41	ND	ND	68	90	71	78		0.39	104		

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2 Range of sediment concentrations throughout the Beaufort Sea coastal area 1999-2006. Source is Exponent (2010) which summarizes data from a large number of locations from the ANIMIDA and cANIMIDA studies.
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4 ADEC (2012). Recommended soil cleanup levels for DRO/RRO Arctic Zone. Alaska Administrative Code 18 AAC 75.
5 TELs and PELs from McDonald et al. (2000) and Buchman (2008).
J Estimated value for concentrations between the MDL and MRL.
ND Not detected or analyte was <5x the concentration seen in the associated method blank and below the MRL.
Z The chromatographic fingerprint does not resemble a petroleum product.
<u>Bold underlined</u> values equal or exceed TELs.

Table 4-6: Sediment Grain Size Summary for Sediment Reuse Areas

Soil Classification	SBAY Station and Depth (ft)															Area Mean
	T7-1	T7-2	T7-3	T7-4	T7-5	T8-1	T8-2	T8-3	T8-4	T8-5	T9-1	T9-2	T9-3	T9-4	T9-5	
	1.1	2.8	3.6	5.7	7.5	3.5	3.8	3.6	6.2	6.1	2.0	3.4	3.8	4.3	4.5	
% Gravel	0.00	1.05	0.89	0.00	0.00	6.21	1.60	46.77	13.15	14.46	6.64	33.81	12.32	7.77	1.15	9.83
% Coarse Sand	3.78	4.29	3.34	10.80	0.41	13.51	4.47	19.87	14.64	17.82	13.18	10.65	12.44	6.87	18.89	10.30
% Med Sand	30.17	36.41	43.28	34.45	0.28	23.08	29.83	18.92	21.52	25.79	17.08	15.04	20.62	12.37	39.60	24.46
% Fine Sand	56.46	52.92	50.46	31.10	1.35	28.59	57.95	11.64	28.06	26.47	26.54	21.76	29.54	26.71	37.39	32.30
% Very Fine	6.94	2.46	0.26	0.96	0.44	5.88	2.78	0.84	3.63	4.15	6.87	5.67	7.52	7.47	0.70	3.76
% Total Sand	97.35	96.08	97.34	77.32	2.47	71.06	95.04	51.27	67.85	74.24	63.67	53.12	70.12	53.42	96.57	70.83
% Silt	1.74	2.05	1.19	15.91	74.84	19.75	2.37	1.54	13.12	9.04	24.77	11.65	15.42	29.06	1.46	15.08
% Clay	0.91	0.83	0.58	6.77	22.69	2.98	0.99	0.42	5.89	2.27	4.92	1.42	2.14	9.74	0.82	4.26
% Fines	2.65	2.88	1.76	22.68	97.53	22.73	3.36	1.96	19.00	11.30	29.69	13.07	17.56	38.80	2.28	19.34

Soil Classification	WEST Station Stations and Depth (ft)															Area Mean
	T10-1	T10-2	T10-3	T10-4	T10-5	T11-1	T11-2	T11-3	T11-4	T11-5	T12-1	T12-2	T12-3	T12-4	T12-5	
	1.8	2.4	2.8	3.5	3.9	2.3	2.7	3.1	3.6	3.8	2.3	3.1	2.3	3.4	3.6	
% Gravel	12.93	5.15	0.95	10.18	27.66	3.15	8.68	23.17	8.36	0.64	5.06	21.63	3.14	4.72	1.26	9.14
% Coarse Sand	5.85	5.51	8.12	10.54	10.09	5.62	8.12	14.13	9.89	3.45	5.49	12.45	11.29	8.01	5.85	8.31
% Med Sand	15.83	24.08	46.63	29.30	19.10	20.30	32.69	29.24	16.74	11.12	24.49	29.17	44.82	31.56	27.72	26.83
% Fine Sand	34.03	52.01	32.31	27.17	23.26	52.27	38.01	24.12	24.24	22.23	44.51	25.35	34.25	41.70	41.40	34.37
% Very Fine	7.31	6.25	4.27	4.43	5.87	8.96	5.47	2.84	4.85	14.88	7.56	4.82	3.14	3.91	5.99	6.04
% Total Sand	63.01	87.85	91.33	71.43	58.32	87.14	84.28	70.32	55.72	51.67	82.05	71.79	93.50	85.18	80.96	75.55
% Silt	13.02	5.34	6.88	15.85	11.46	6.50	5.16	5.22	29.14	40.93	8.85	5.20	2.37	7.95	14.46	11.95
% Clay	11.03	1.66	0.85	2.55	2.56	3.20	1.88	1.28	6.77	6.75	4.04	1.38	1.00	2.16	3.32	3.36
% Fines	24.05	7.00	7.73	18.40	14.02	9.70	7.04	6.51	35.92	47.68	12.89	6.58	3.37	10.10	17.78	15.31

Soil Classification	GULL Station and Depth (ft)															Area Mean
	T13-1	T13-2	T13-3	T13-4	T13-5	T14-1	T14-2	T14-3	T14-4	T14-5	T15-1	T15-2	T15-3	T15-4	T15-5	
	1.7	2.8	2.8	2.9	3.1	2.1	2.5	3.0	3.3	3.9	3.6	3.6	3.9	3.9	4.2	
% Gravel	92.62	0.21	0.02	0.03	0.13	0.03	0.05	0.12	0.07	0.05	0.11	0.00	0.00	0.04	0.02	6.54
% Coarse Sand	1.94	0.45	0.12	0.22	0.40	0.17	0.18	0.45	0.25	0.32	0.41	0.06	0.19	0.35	0.30	0.39
% Med Sand	2.22	1.05	0.14	0.17	0.31	0.21	0.07	0.25	0.12	0.18	0.34	0.20	0.52	0.30	0.51	0.45
% Fine Sand	1.05	33.83	46.22	46.14	46.91	18.37	44.33	40.58	40.79	32.69	25.23	40.70	45.37	24.56	54.45	36.00
% Very Fine	0.40	29.39	27.19	29.16	23.71	27.76	32.18	29.04	33.22	30.76	25.77	33.94	29.13	31.34	24.71	27.05
% Total Sand	5.61	64.73	73.67	75.69	71.32	46.50	76.76	70.32	74.38	63.95	51.75	74.90	75.20	56.55	79.98	63.90
% Silt	1.55	32.29	23.89	21.85	25.73	50.66	20.95	27.01	23.13	33.18	43.41	22.74	22.32	38.13	17.79	26.87
% Clay	0.21	2.78	2.42	2.43	2.82	2.81	2.23	2.55	2.42	2.82	4.73	2.36	2.48	5.27	2.21	2.69
% Fines	1.77	35.07	26.31	24.28	28.54	53.47	23.19	29.55	25.55	36.00	48.14	25.10	24.80	43.41	20.00	29.56

Soil Classification	DOCK Station and Depth (ft)															Area Mean
	T16-1	T16-2	T16-3	T16-4	T16-5	T17-1	T17-2	T17-3	T17-4	T17-5	T18-1	T18-2	T18-3	T18-4	T18-5	
	2.5	3.4	3.8	4.5	4.4	2.7	3.6	3.0	4.6	4.6	4.8	3.8	4.3	4.1	3.9	
% Gravel	23.96	1.21	0.66	5.16	1.30	52.36	66.58	0.48	0.30	2.82	0.10	9.00	0.71	0.00	0.51	11.23
% Coarse Sand	6.37	8.40	4.74	9.89	9.63	20.85	10.82	7.09	8.10	1.09	1.72	3.94	0.69	0.51	0.64	6.32
% Med Sand	22.44	24.59	14.28	22.36	22.13	14.82	7.28	33.26	26.58	2.53	6.28	21.45	0.55	0.89	0.95	14.72
% Fine Sand	29.84	38.11	45.46	27.29	39.61	9.10	8.26	25.39	35.06	7.31	33.86	34.66	6.79	8.90	18.37	24.45
% Very Fine	4.81	4.11	10.77	8.23	7.79	0.75	0.93	0.46	9.41	13.75	17.70	10.18	24.29	19.88	13.69	9.73
% Total Sand	63.45	75.22	75.25	67.76	79.16	45.52	27.29	66.19	79.15	24.68	59.56	70.21	32.31	30.17	33.65	55.22
% Silt	9.64	20.92	20.62	22.96	16.05	1.40	4.80	28.92	17.16	63.05	32.26	17.38	56.11	62.23	57.26	28.59
% Clay	2.94	2.65	3.47	4.12	3.50	0.72	1.33	4.41	3.39	9.44	8.09	3.41	10.86	7.59	8.58	4.95
% Fines	12.59	23.58	24.09	27.08	19.54	2.12	6.13	33.33	20.55	72.50	40.34	20.79	66.97	69.83	65.84	33.54

Concentrations of TOC for all locations were found to be within the range of those seen for the Beaufort Sea coastal region, but a fair amount of variability was still seen within each study area as a result of varying peat and detrital content. TOC at SBAY ranged from 0.130 to 8.04% with the highest concentration seen at one the stations that were closest to shore and near the delta of the Putuligayuk River, a tundra river that discharges into Prudhoe Bay. Concentrations of TOC ranged from 0.149 to 1.01% at WEST, from 0.147 to 0.535% at GULL, and from 0.157 to 1.56% at DOCK. Overall SBAY appeared to have the highest TOC content, which is probably the result of tundra inputs and high detritus in the sediments at the site due to riverine inputs from both the Putuligayuk and Sagavanirktok Rivers and from the eroding tundra shoreline. TOC concentrations seen at SBAY and WEST were similar in range to the smaller subareas at both of these locations that were sampled during 2014 as part of the 2014 MSP where concentrations ranged from 0.141 to 1.29% at SBAY and from 0.45% to 3.6% (Alaska LNG 2014; refer to Appendix B for 2014 results)**.**

Sediment grain size analysis indicated that the sediment compositions at each location were not uniform but contained varying amounts of fines versus coarser sands and gravels. Percent fines measured as the silt + clay fraction ranged from 1.76 to 97.5% at SBAY, from 3.37 to 47.7% at WEST, from 1.77 to 53.5% at GULL, and from 2.12 to 72.5% at DOCK. In general, sand was the most common size fraction at most locations, with fine sand usually being the most common classification within the sand fraction, although there appeared to be more variability at DOCK where some nearshore stations had high percentages of gravel and some offshore stations had high percentages of the fine fractions. A number of the stations also were found to have significant amounts of small gravel with concentrations ranging from 0.0 to 46.8% at SBAY, 0.64 to 27.7% at WEST, 0.0 to 92.6% at GULL, and 0.0 to 66.6% at DOCK. The silt + clay fraction seen at SBAY and WEST in 2014 fell within the range of concentrations seen during 2015, with ranges of 3.3 to 16.7% at SBAY and 5.93 to 43.2% at WEST (Alaska LNG 2014). The wider range of sediment grain size seen during 2015 as compared to 2014 at SBAY and WEST was probably the result of looking at a larger area that also encompassed sites farther from shore, which typically included a greater percentage of the fine sediment fractions.

Total solids ranged from 48.4 to 91.6% overall. Total solids ranged from 48.4 to 84.2% at SBAY, 72.4 to 83.5% at WEST, 72.0 to 91.6% at GULL, and 62.9 to 87.3% at DOCK. This parameter is primarily used to determine dry weight concentrations of metals and hydrocarbons and is highly correlated with grain size.

4.1.1.2 Reuse Area – Total Metals

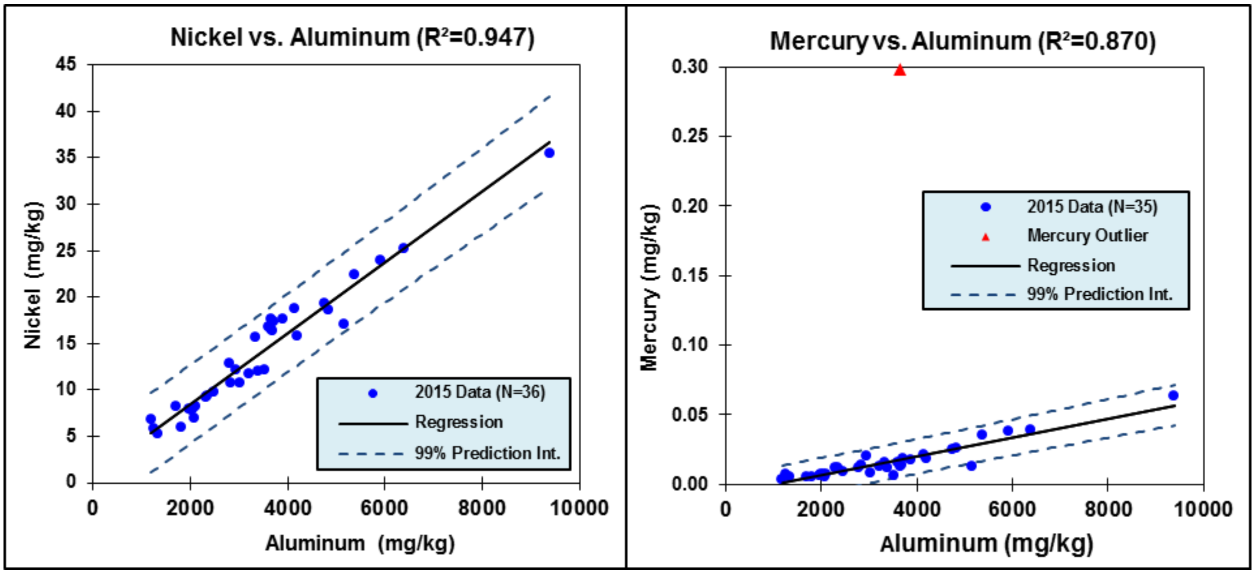
Analytical results for total metals from the four potential dredged material reuse areas that were examined during 2015 are presented in Table 4-2 through Table 4-5. Analyses included 20 metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Metal concentrations were compared to USACE 2014 DMMP criteria, ADEC-recommended SQGs, and the range of Beaufort Sea background sediments. In all instances, metals were found to be below both the DMMP SLs and ADEC's recommended PELs.

TELs were exceeded for some metals at some stations: one arsenic, one copper, and one nickel concentrations at SBAY; two nickel concentrations at WEST; one arsenic, one mercury, and seven nickel concentrations at GULL; and four arsenic and four nickel concentrations at DOCK. However, as noted earlier, with the exception of mercury, Beaufort Sea sediments are naturally high in these metals as compared to the SQGs. The highest nickel concentration measured was at SBAY Station T7-5 at 35.5 mg/kg compared to the TEL of 15.9 mg/kg and a value of 56 mg/kg for average continental crust material (Wedepohl 1995). The highest copper was seen at the same station at 27.7 mg/kg compared to the TEL of 18.7 mg/kg and a continental crust value of 25 mg/kg. Similarly, the highest arsenic (also at this station) was 12.1 mg/kg compared a TEL of

7.24 and a value of 7.7 mg/kg for typical marine sediments (Trefry et al. 2003). Trefry et al. (2003) and Exponent (2010) have shown that arsenic, copper, and nickel concentrations in Beaufort Sea sediments are naturally occurring and often exceed SQGs and that nearby riverine suspended sediments have similar concentrations.

Trefry et al. (2003) also found that trace metals in the Beaufort coastal area correlated well with both aluminum and iron; most metals are generally low in quartz sand or carbonate shell material and high in the fine-grained metal-bearing alumino-silicates contained in silt and clay. A comparison of nickel versus aluminum for all of the 2015 sediment samples from the four reuse sites clearly demonstrates this relationship as shown in Figure 4-1. Even though some sediment samples exceeded the TEL of 15.9 mg/kg for nickel, it can clearly be seen that this is a result of naturally occurring fine grain sediment that is high in aluminum and not the result of any contamination.

Figure 4-1: Nickel and Mercury vs. Aluminum in Sediments



The one mercury concentration that exceeded the TEL occurred at GULL Station T14-3, where a concentration of 0.298 mg/kg was seen as compared to the TEL of 0.13 mg/kg and a range seen in the Beaufort Sea of 0.003 to 0.20 mg/kg. This concentration was nearly an order of magnitude higher than most of the mercury levels seen during 2015. This data point was not included in the regression analysis that indicated that mercury was highly correlated with aluminum (i.e., that data point is shown as an outlier; Figure 4-1). An examination of the other parameters that were sampled at this site revealed that barium levels were also slightly elevated when compared to other locations, which may indicate the presence of some remnant drilling muds/cuttings from the historic drilling operations that took place on Gull Island. Overall, the average barium levels seen across all of the GULL stations were nearly twice as high as levels seen at the other three reuse sites with a mean of 76.1 mg/kg compared to mean range of 37.0 to 48.6 mg/kg at the other three sites, but barium concentrations at GULL were still low compared to Beaufort Sea background levels. Three separate exploration wells were drilled on Gull Island with drilling occurring in 1976, 1977, and 1992. The presence of mercury in drilling mud has been shown to be the result of trace contaminants in barite and has been shown to be highly variable, ranging from 0.13 to 28 mg/kg (Neff 1981 and Trefry 2004). Current federal regulations that have been in place since 1993 require that mercury concentrations in barite be less than 1 mg/kg for drilling mud discharges. It is unknown what the mercury levels might have been in the barite that was utilized during the Gull Island drilling.

The metals barium, chromium, lead, and zinc that are most often associated with oil exploration and development were generally found to be typical and in some cases low compared to Beaufort Sea background concentrations. However as noted earlier, barium levels did appear to be slightly higher at some of the GULL stations, but they were not at levels that would be a concern (i.e., levels were still low compared to Beaufort Sea regional data). Chromium, lead, and zinc were all found to be highly correlated with aluminum concentrations with regression (R^2) values of 0.95 for chromium, 0.92 for lead, and 0.92 for zinc with no obvious outliers for any of these parameters that could be attributed to contamination. Similarly, metals associated with refined petroleum products such as lead and vanadium were not found to be obviously elevated in any sample, with vanadium also being highly correlated with aluminum at an R^2 value of 0.96.

Based on this comparison, it would appear that the sediments at SBAY, WEST, and DOCK should be considered pristine in terms of metals concentrations, and that variability seen within and between sites can be explained by variations in % solids, sediment grain size distribution, TOC, and sediment source/mineralogy. Sediments at some of the GULL stations did appear to show some potential anthropogenic inputs from historic drilling activity based on slightly higher barium levels, though these mostly were still within the range of Beaufort Sea background levels. One mercury level at GULL was above that recorded for Beaufort Sea background levels, however, this concentration was below the SL and still less than half the PEL (where biological effects would become probable). All metals concentrations were below DMMP SLs as well as below PEL levels where a biological impact would be probable.

A comparison of metals concentrations at SBAY and WEST that were sampled during the 2014 MSP to those sampled during 2015 found very similar concentrations, with 2014 being slightly lower overall. Differences between years can be attributed to differences in grain size distribution and the percentage of alumino-silicates as a result of finer-grained sediments seen during 2015 (refer to Appendix B for 2014 MSP data).

4.1.1.3 Reuse Area – Petroleum Hydrocarbons

Sediments in the four potential reuse areas were analyzed for diesel range organics (DRO; C_{10}-C_{25}) and residual range organics (RRO; C_{25}-C_{36}). In 2014, these analyses indicated that some of the samples had concentrations of a non-petroleum signature as a result of high peat content. To address this problem in 2015, the sediments were also analyzed for DRO and RRO with the addition of a SGT procedure (DRO-SGT and RRO-SGT), which removes any polar non-petroleum-based hydrocarbons. Concentrations by these two methods (with and without silicate gel cleanup) can then be compared to get an indication of contribution from non-petrogenic sources such as peat.

Concentrations of DRO, DRO-SGT, RRO, and RRO-SGT in all samples and areas were found to be below ADEC-recommended soil cleanup levels for the Arctic. Concentrations of DRO-SGT ranged from not detected (ND) to 66 mg/kg at SBAY and were all ND at WEST, GULL, DOCK compared to the ADEC cleanup level of 200 mg/kg (note: the vast majority of concentrations were non-detect and/or below MRLs and were qualified with an "ND" or "J" flag as estimates; refer to Table 4-2 through Table 4-5. The few samples where concentrations were seen were correlated with high TOC levels in the same samples. Concentrations of RRO-SGT ranged from ND to 180 mg/kg at SBAY compared to the ADEC cleanup level of 2000 mg/kg, with all but that one value being reported as either below MRL (qualified with a "J") or as ND. RRO-SGT was all below MRLs at the three remaining sites and ranged from 7.1 to 50 mg/kg at WEST, from ND to 24 mg/kg at GULL, and from ND to 71 mg/kg at DOCK.

A number of samples appeared to have elevated levels of both DRO and RRO; however, on closer examination of the chromatographic fingerprints by the laboratory, the samples were flagged with a "Z" indicating that chromatograms did not resemble a petroleum product. All of these same samples also had higher TOC concentrations, which indicate high peat levels and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes. A comparison of the DRO to DRO-SGT and RRO to RRO-SGT in these samples also indicated that the majority of the hydrocarbon signal was from non-petroleum sources. Any sample that appeared to be slightly elevated in DRO or RRO was found to have substantially fewer hydrocarbons in the sample after the silicate gel treatment, which indicates that these samples were not contaminated with any petrogenic hydrocarbons. Overall, concentrations of petroleum hydrocarbons at the four reuse areas that were examined in 2015 are low and well within the range of natural background levels, are well below DMMP guidance and SQG levels, and show no evidence of anthropogenic inputs or contamination.

Similar results were seen by the laboratory during the 2014 MSP where the hydrocarbon concentrations were in general very low; in the samples where hydrocarbons were detected, the chromatogram indicated they were from a non-petrogenic source. Similar results were also seen in the ANIMIDA and cANIMIDA studies which examined hydrocarbons in detail across the entire Central Beaufort Sea coastal area, where the surficial sediments in the Prudhoe Bay region were found to exhibit a mixture of primarily terrestrial biogenic hydrocarbons with lower levels of petrogenic hydrocarbons (Exponent 2010 and Neff 2010). These researchers found that the petrogenic components of the PAH signatures included background concentrations of source rock (shale and coal) with lesser contributions from pyrogenic or combustion-related compounds.

4.1.2 Grain Size Compatibility – Dredge versus Reuse Areas

The preferred dredge disposal scenario is to beneficially reuse the dredged sediments from the dredge channel and turning basin locations at one of the four potential placement areas described previously. The shorelines adjacent to two of the reuse areas (SBAY and WEST) are undergoing gradual erosion and therefore could utilize material placed in the shallow areas alongshore to slow down erosional processes. Grain size characteristics of the dredge sediments are the dominating factor in determining how well these sediments respond to dredging and placement. Fine-grained material is more negatively impacted by the dredging process and is more likely to mobilize after placement.

The average fines content for the entire dredge area where samples were collected in 2011 and 2014 is 45.3% (AK LNG 2014). This is somewhat greater than the average fines content in the surface sediments of the four currently proposed reuse areas with concentrations of 19.3% at SBAY, 15.3% at WEST, 29.6% at GULL, and 33.5% at DOCK (Table 4-6). However, the sediments still contain enough coarse material to be beneficial even though much of the finer material may disperse from the immediate disposal area. It is expected that wave and current action will winnow the finer-grained particles, leaving the coarser-grained sediments to provide shore protection. The most common size fraction in the dredge area sediments was fine sand, which was also the most common size fraction in the majority of the samples from the SBAY, WEST, and GULL disposal sites, indicating a fair amount of compatibility. DOCK was found to have the greatest percentage in the silt size fractions.

In addition to the average sand and gravel content, another aspect that was evaluated to determine the suitability of reusing the dredge area sediments was how well the grain size gradations of the dredge sediments correspond to the grain size gradations of the surface sediments in the proposed reuse areas and adjacent offshore areas. Specifically, the gradation curves of the dredged material were examined to see if they fell within the compatibility envelopes of the reuse areas, including immediately offshore of the direct placement areas, as defined by the fine and coarse limits of each reuse area (Figure 4-2 through Figure 4-5). Each figure

Figure 4-2: Dredge Area Grain Size Gradations Compared to SBAY Grain Size

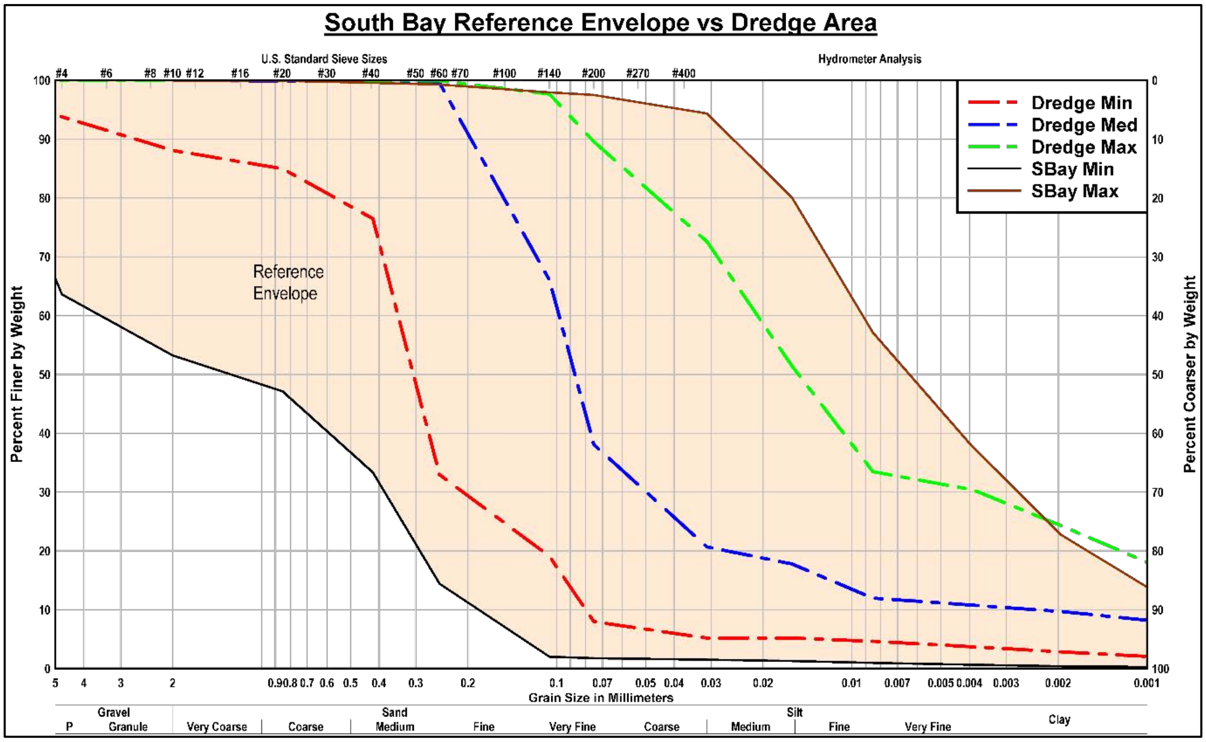


Figure 4-3: Dredge Area Grain Size Gradations Compared to WEST Grain Size

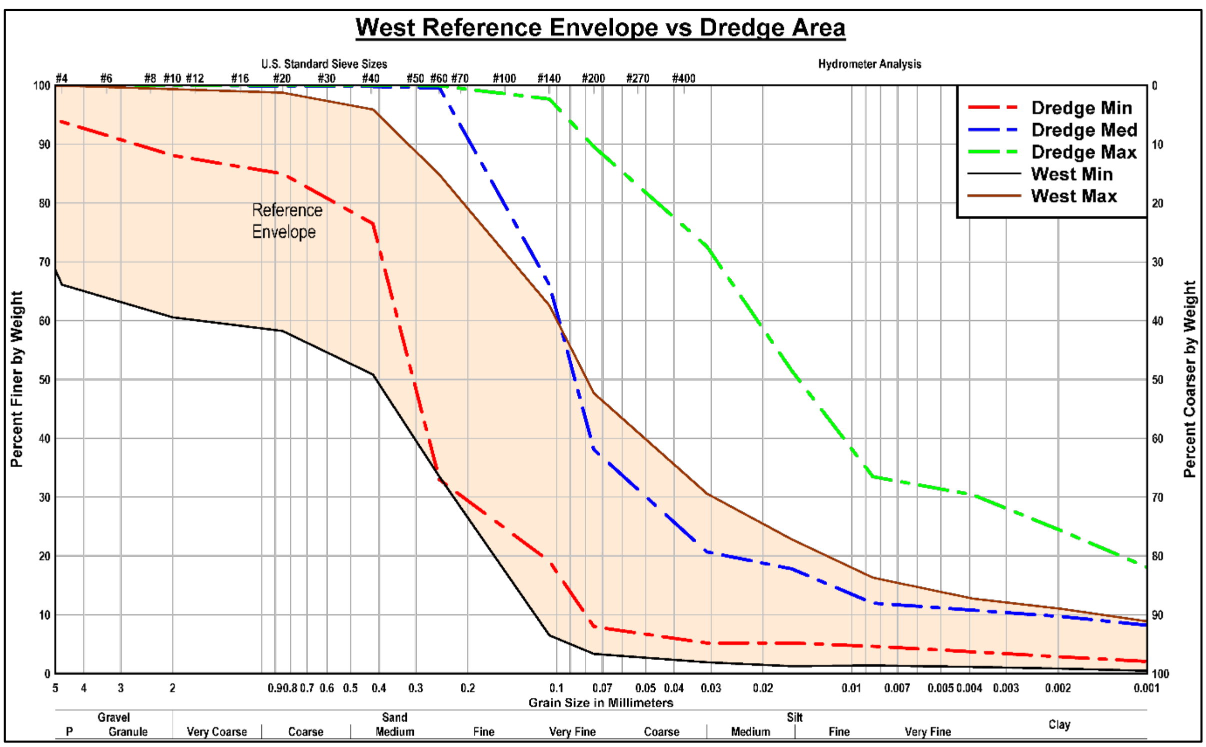


Figure 4-4: Dredge Area Grain Size Gradations Compared to GULL Grain Size

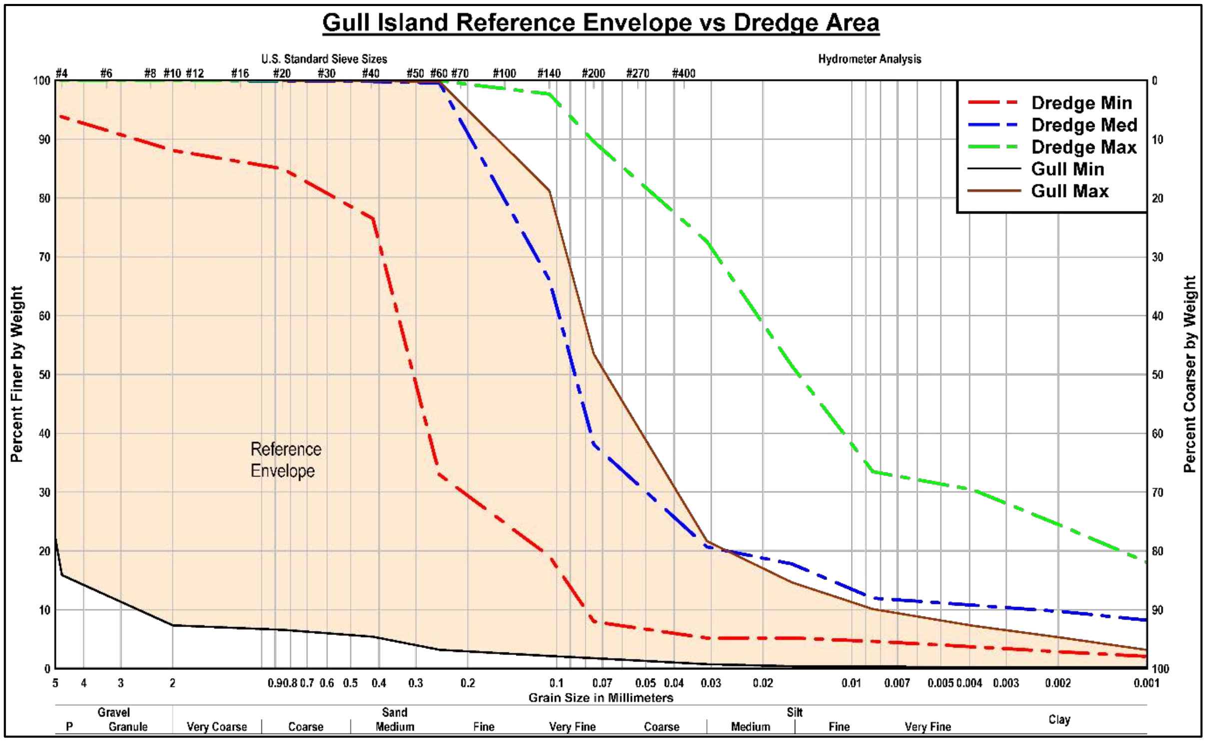
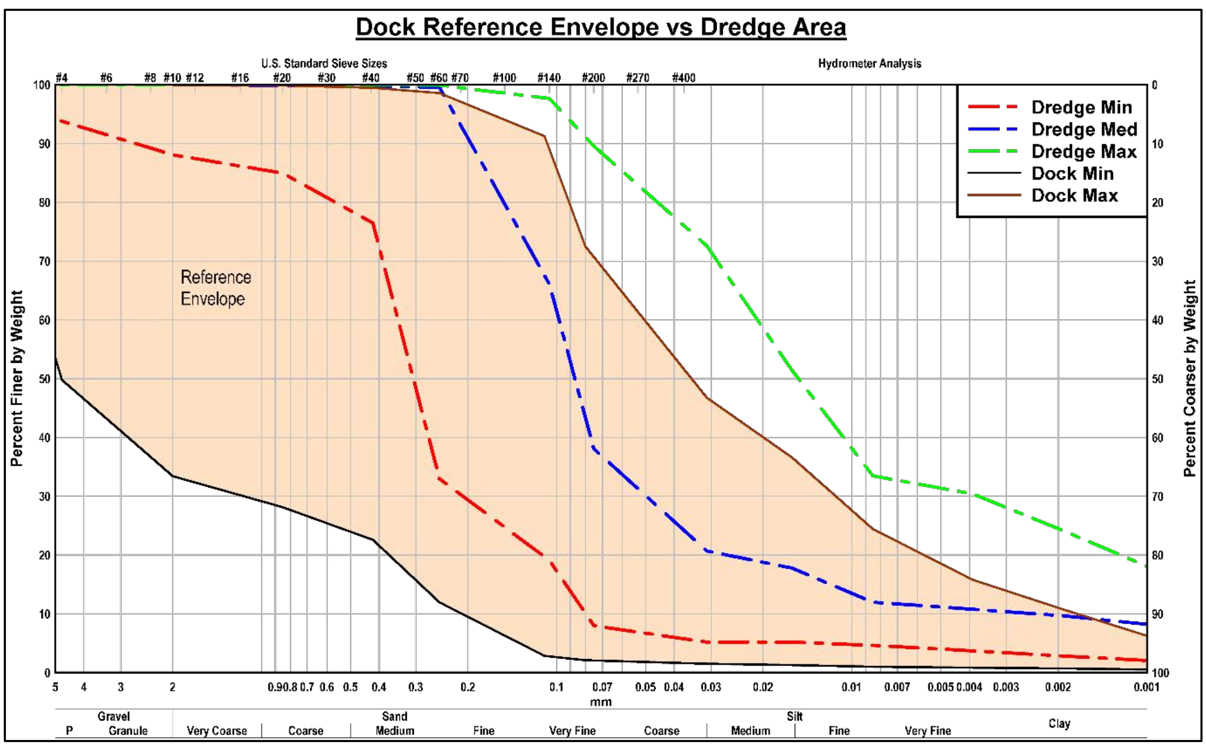


Figure 4-5: Dredge Area Grain Size Gradations Compared DOCK Grain Size



provides the minimum, maximum, and median gradation curves for the dredge area sediments (from 2011 and 2014) along with the fine and coarse grain limit gradation curves for each of the reuse areas (from both 2015 and 2014 for SBAY and WEST and from 2015 for GULL and DOCK), which is shown as the reference envelope into which the dredge area sediments would be placed.

In all four cases, the majority of the dredge area sediments were found to fit within the compatibility envelopes for each of the potential disposal areas. The "Dredge Max" as shown in the gradation figures represents the maximum percent finer material for each of the size class categories; this can be viewed as the outer limit of percent fines for the dredge area. This was outside of the compatibility envelope for WEST, GULL, and DOCK, indicating that a portion of the sediments from the dredge area was finer than that seen at each of these three disposal reuse areas. However, placement of material that does not fit well within a compatibility envelope of a reuse area may be appropriate if the fill material does not cause any issues with aesthetics issues, which are not anticipated for any of the reuse areas as these areas are remote and because most of the fine material is not expected to migrate onto any beach faces. At the SBAY site, the Dredge Max fell within the grain size envelope, indicating that even finer materials from the dredge site were compatible with the sediments at this reuse site. Also, as mentioned previously, the grain size is compatible in terms of fine sands being the most common size fraction for the dredge sediments and the SBAY, WEST, and GULL reuse areas. For DOCK, silt was the most common size fraction.

Sediment descriptions along with grain size data indicated that the fines content at the reuse areas was generally higher in the surface sediments collected farthest from shore, but this relationship was somewhat variable and did not always hold true. In some cases such as Transect T8 at SBAY, Transect T10 at WEST, and Transect T14 and T15 at GULL, the highest percent fines were found at the station closest to shore along each transect. These differences clearly indicate that sediment grain size distributions were highly variable. Although the reuse areas were generally still on the coarser side of the sediment distribution curves, the gradations are not that dissimilar to the dredge area sediments. Thus, over time it is expected that the coarser portion of the dredged material would remain near the beach and provide some continuing shoreline protection, while the finer portion of the material would migrate into deeper water where it would be deposited and also be compatible with the native materials in that area.

A number of photographs are presented below that clearly show the need for beach nourishment and shoreline protection at both SBAY (Figure 4-6) and WEST (Figure 4-7). At SBAY, the tundra is eroding creating a coastal bluff with exposed permafrost and an ice lens that can be seen in the photograph. At WEST, the AGI Pad is eroding on the southern end. Based on these photographs, it is clear that beach nourishment and shoreline protection would be beneficial. The shoreline at the third site, GULL, is largely protected by a steel seawall and not subject to erosion; however, there is a shoal to the south of Gull Island that is included in the potential dredge disposal area (Figure 4-8). Although Gull Island itself is not subject to erosion, the disposal of sediment in the nearshore area adjacent to GULL (in the vicinity of this shoal) may provide suitable nesting areas for shorebirds. The low relief tundra shoreline at DOCK is not undergoing active erosion as the site is somewhat sheltered by the West Dock Causeway on its eastern side and by Stump Island that is located directly north and offshore, both of which protect the area from waves and currents (Figure 4-9). Therefore, the need for beach nourishment and shoreline protection as a beneficial reuse of dredge sediments at DOCK would be harder to demonstrate.

Figure 4-6: Photograph of SBAY Showing Shoreline Erosion

Figure 4-7: Photograph of WEST Showing Erosion of AGI Pad

Figure 4-8: Photograph of GULL Looking North at Gull Island and Shoal

Figure 4-9: Photograph of DOCK and Low Relief Tundra Shoreline

4.2 BIOLOGICAL RESULTS

4.2.1 Benthic Infauna

Benthic infaunal data are presented here by site or station, taxonomic grouping or species, or benthic community parameter as appropriate. As noted in Section 3.2.4.1, it should be remembered that the separate megafaunal (1.0-mm) and macrofaunal (6.4-mm) fractions represent not only different sieve sizes, but also different surface areas of sediment collected due to the sampling methods used.

Abundance (number of individuals) and number of taxa seen at each site by station are presented in Table 4-7. Data for overall ranked taxa abundances, calculated density, and relative frequency by fraction are presented in Table 4-8. Raw sample data for the separate fractions by station and replicate are presented in Table 4-9 through Table 4-12 for SBAY, WEST, GULL, and DOCK, respectively. Density calculations are presented by site in Table 4-13, calculated indices that are useful for assessing general community diversity of the benthic fauna are presented in Table 4-14, and biomass for the major taxonomic groupings is provided in Table 4-15.

4.2.1.1 Overall Species Abundance

A total of 1,647 benthic organisms were enumerated at all 24 of the benthic infauna stations sampled during 2015 for both the macrofaunal and megafaunal fractions combined (Table 4-7). In terms of total counts, ~80% (*n*=1,321) of the benthic organisms for the combined fractions were annelids (worms). Crustaceans were the second most abundant group, accounting for ~13% (*n*=207) overall. The molluscs were the third most dominant taxonomic grouping, accounting for ~4% (*n*=63) of the overall specimens recorded, followed by the remaining taxa, a grouping commonly termed the “miscellaneous” taxa, which comprised ~3% (n =56) of the overall organism count.

Annelids in the macrofaunal fraction comprised ~86% (*n*=1,011) of the overall macrofaunal abundance (*n*=1,180). Both fractions combined were dominated by the slender tube-dwelling polychaete annelid *Pygospio elegans* (*n*=1,088), which accounted for ~66% of all individuals found and ~82% of the annelids recorded. In the macrofauna, *P. elegans* (*n*=868) accounted for ~74% of all organisms and ~86% of all annelids. In the megafaunal fraction, this species (*n*=220) made up ~47% of the total and ~71% of the annelids. This species occurred in ~78% of all macrofaunal fractions, ~47% of all megafaunal fractions, and ~64% of all the samples combined (Table 4-8), . *P. elegans* grows to a length of 10 to 15 mm and has a tube width of ~1 mm (Anger *et al*. 1986; Bolama and Fernandes 2003). The flexible tubes of this species can easily become entangled in the screen of either sieve mesh size making them difficult to accurately screen by size.

The next most abundant polychaete annelid was the tube-dwelling *Ampharete vega* of which 177 specimens were found comprising ~11% of the total organisms. The total abundance of *A. vega* (*n*=94) accounted for ~8% of the total macrofauna and comprised ~9% of all macrofaunal annelids. In the megafauna, *A. vega* (*n*=83) comprised ~17% of the total organisms and ~27% of the annelids. The frequency this species was found within samples was much lower than for *P. elegans*; *A. vega* occurred in only ~29% of all samples (19% in the macrofaunal fraction and 18% in the megafaunal fraction). In arctic environments, *A. vega* can reach a size of 50 mm (~2 inches) in length (Jirkov 1989). This species is more robust and much wider for its length than *P. elegans* and perhaps less likely to become entangled in the larger screen mesh, so its numbers may better reflect the sizing of the screens.

Table 4-7: Infauna Abundance and Number of Taxa by Site

Site / Fraction	SBAY		WEST		GULL		DOCK		1.0-mm Total	6.4-mm Total	All Total
	1.0-mm	6.4-mm	1.0-mm	6.4-mm	1.0-mm	6.4-mm	1.0-mm	6.4-mm			
Annelida											
Polychaeta											
Pygospio elegans	82	7	138	10	578	172	70	31	**868**	**220**	**1088**
Ampharete vega	11	71	65	7			18	5	**94**	**83**	**177**
Marenzelleria arctia	1	1	3				5		**9**	**1**	**10**
Chone sp. A	4								**4**		**4**
Eteone longa		1	1						**1**	**1**	**2**
Ampharetidae						1				**1**	**1**
Chaetozone ruffi		1								**1**	**1**
Terebellides stroemi	1								**1**		**1**
Oligochaeta											
Oligochaeta	23	2	10	1			1		**34**	**3**	**37**
Number of Individuals	**122**	**83**	**217**	**18**	**578**	**173**	**94**	**36**	**1011**	**310**	**1321**
Number of Taxa	**6**	**6**	**5**	**3**	**1**	**2**	**4**	**2**	**7**	**7**	**9**
Crustacea											
Isopoda											
Saduria entomon	18	39	4	39	5	3	4	13	**31**	**94**	**125**
Amphipoda - Gammaridea											
Monoporeia affinis	7		24		6		13		**50**		**50**
Monoculopsis longicornis			8		6		2		**16**		**16**
Gammarus setosus	3	6							**3**	**6**	**9**
Onisimus litoralis	3						1		**4**		**4**
Acanthostepheia incarinata					2				**2**		**2**
Mysidea											
Mysis relicta							1		**1**		**1**
Number of Individuals	**31**	**45**	**36**	**39**	**19**	**3**	**21**	**13**	**107**	**100**	**207**
Number of Taxa	**4**	**2**	**3**	**1**	**4**	**1**	**5**	**1**	**7**	**2**	**7**
Mollusca											
Bivalvia											
Cyrtodaria kurriana	39		4	5	2				**45**	**5**	**50**
Macoma balthica	6			2			3		**9**	**2**	**11**
Boreacola maltzani					1				**1**		**1**
Macoma spp.					1				**1**		**1**
Number of Individuals	**45**	**0**	**4**	**7**	**4**	**0**	**3**	**0**	**56**	**7**	**63**
Number of Taxa	**2**	**0**	**1**	**2**	**3**	**0**	**1**	**0**	**4**	**3**	**4**
Miscellaneous											
Priapulida											
Priapulus caudatus	1	2		1			2		**3**	**3**	**6**
Tunicata – Ascideacea											
Rhizomolgula globularis				6						**6**	**6**
Hydrozoa											
Tubularia indivisa	2	11	1	26		2		2	**3**	**41**	**44**
Bryozoa											
Alcyonidium spp.	P	P					P		**P**	**P**	**P**
Synnotum spp.	P								**P**		**P**
Number of Individuals	**3**	**13**	**1**	**33**	**0**	**2**	**2**	**2**	**6**	**50**	**56**
Number of Taxa	**4**	**3**	**1**	**3**	**0**	**1**	**2**	**1**	**4**	**4**	**5**
Total Number of Taxa (25)	**16**	**11**	**10**	**9**	**8**	**4**	**12**	**4**	**22**	**16**	**25**
Total Abundance	**201**	**141**	**258**	**97**	**601**	**178**	**120**	**51**	**1180**	**467**	**1647**

P Present (colonial; not enumerated)

Table 4-8: Overall Ranked Abundance, Density, and Relative Frequency

Taxon	Group	Total Abundance	Rank % Abundance	Mean Abundance (/0.009 m^2 or /0.091m^2)	Standard Deviation	Mean Density (/1.0 m^2)	Relative Frequency (%)
Macrofauna (1.0-mm Fraction)							
Pygospio elegans	Annelida	868	73.6	12.2	20.7	1340	78
Ampharete vega	Annelida	94	8.0	1.3	4.5	145	19
Monoporeia affinis	Crustacea	50	4.2	0.7	1.0	77	44
Cyrtodaria kurriana	Mollusca	45	3.8	0.6	2.1	69	17
Oligochaeta	Annelida	34	2.9	0.5	1.0	52	26
Saduria entomon	Crustacea	31	2.6	0.4	1.1	48	25
Monoculopsis longicornis	Crustacea	16	1.4	0.2	0.6	25	17
Macoma balthica	Mollusca	9	0.8	0.1	0.3	14	13
Marenzelleria arctia	Annelida	9	0.8	0.1	0.4	14	10
Chone sp. A	Annelida	4	0.3	0.1	0.3	6	3
Onisimus litoralis	Crustacea	4	0.3	0.1	0.2	6	6
Gammarus setosus	Crustacea	3	0.3	0.0	0.2	5	3
Priapulus caudatus	Misc.	3	0.3	0.0	0.2	5	4
Tubularia indivisa	Misc.	3	0.3	0.0	0.3	5	4
Acanthostepheia incarinata	Crustacea	2	0.2	0.0	0.2	3	3
Boreacola maltzani	Mollusca	1	0.1	0.0	0.1	2	1
Eteone longa	Annelida	1	0.1	0.0	0.1	2	1
Macoma spp.	Mollusca	1	0.1	0.0	0.1	2	1
Mysis relicta	Crustacea	1	0.1	0.0	0.1	2	1
Terebellides stroemi	Annelida	1	0.1	0.0	0.1	2	1
Alcyonidium spp.	Misc.	P	0.0	0.0	0.0	P	0
Synnotum spp.	Misc.	P	0.0	0.0	0.0	P	0
	Total	**1180**	**100.0**	**0.7**	**4.8**	**1821**	**99**
Megafauna (6.4-mm Fraction)							
Pygospio elegans	Annelida	220	47.1	3.1	6.3	35	47
Saduria entomon	Crustacea	94	20.1	1.3	2.0	15	50
Ampharete vega	Annelida	83	17.8	1.2	3.5	13	18
Tubularia indivisa	Misc.	41	8.8	0.6	1.7	6	22
Gammarus setosus	Crustacea	6	1.3	0.1	0.4	0.9	4
Rhizomolgula globularis	Misc.	6	1.3	0.1	0.5	0.9	3
Cyrtodaria kurriana	Mollusca	5	1.1	0.1	0.4	0.8	3
Oligochaeta	Annelida	3	0.6	0.0	0.2	0.5	4
Priapulus caudatus	Misc.	3	0.6	0.0	0.2	0.5	4
Macoma balthica	Mollusca	2	0.4	0.0	0.2	0.3	3
Ampharetidae	Annelida	1	0.2	0.0	0.1	0.2	1
Chaetozone ruffi	Annelida	1	0.2	0.0	0.1	0.2	1
Eteone longa	Annelida	1	0.2	0.0	0.1	0.2	1
Marenzelleria arctia	Annelida	1	0.2	0.0	0.1	0.2	1
Alcyonidium spp.	Misc.	P	0.0	0	0	P	0
	Total	**467**	**100.0**	**0.3**	**1.7**	**72.8**	**92**

Table 4-9: SBAY Infauna by Station and Replicate

Station (Depth in ft)	T7-3 (3.6)			T7-5 (7.5)			T8-3 (3.6)			T8-5 (6.1)			T9-3 (3.8)			T9-5 (4.5)			Total
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
Macrofauna (1.0-mm Fraction)																			
Annelida																			
Pygospio elegans				1		1	23	14	14	1	2		7	2	17				82
Oligochaeta	4		1	1			1		1	2	1	4			5	2	1		23
Ampharete vega										4		7							11
Chone sp. A				2		2													4
Marenzelleria arctia				1															1
Terebellides stroemi						1													1
Group Total	**4**	**0**	**1**	**5**	**0**	**4**	**24**	**14**	**15**	**7**	**3**	**11**	**7**	**2**	**22**	**2**	**1**	**0**	**122**
Crustacea																			
Saduria entomon			1	2	1	1			2	7	4								18
Monoporeia affinis													1		3	1	1	1	7
Gammarus setosus										1	1	1							3
Onisimus litoralis		1								1					1				3
Group Total	**0**	**1**	**1**	**2**	**1**	**1**	**0**	**0**	**2**	**9**	**5**	**1**	**1**	**0**	**4**	**1**	**1**	**1**	**31**
Mollusca																			
Cyrtodaria kurriana	1									3	3	2				11	9	10	39
Macoma balthica	1	1		1			1	1	1										6
Group Total	**2**	**1**	**0**	**1**	**0**	**0**	**1**	**1**	**1**	**3**	**3**	**2**	**0**	**0**	**0**	**11**	**9**	**10**	**45**
Miscellaneous																			
Tubularia indivisa				2															2
Priapulus caudatus							1												1
Alcyonidium spp.				P						P									P
Synnotum spp.				P															P
Group Total	**0**	**0**	**0**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**
TOTAL	**6**	**2**	**2**	**10**	**1**	**5**	**26**	**15**	**18**	**19**	**11**	**14**	**8**	**2**	**26**	**14**	**11**	**11**	**201**
Megafauna (6.4-mm Fraction)																			
Annelida																			
Ampharete vega				6	13	14				9	12	17							71
Pygospio elegans					1				4					1	1				7
Oligochaeta											1	1							2
Chaetozone ruffi											1								1
Eteone longa										1									1
Marenzelleria arctia						1													1
Group Total	**0**	**0**	**0**	**6**	**14**	**15**	**0**	**0**	**4**	**10**	**14**	**18**	**0**	**1**	**1**	**0**	**0**	**0**	**83**
Crustacea																			
Saduria entomon	1	1	3	1	1	4	5	1		6	8	2		1			2	3	39
Gammarus setosus										3	2	1							6
Group Total	**1**	**1**	**3**	**1**	**1**	**4**	**5**	**1**	**0**	**9**	**10**	**3**	**0**	**1**	**0**	**0**	**2**	**3**	**45**
Mollusca																			
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Miscellaneous																			
Tubularia indivisa				2						4	3	1			1				11
Priapulus caudatus				1								1							2
Group Total	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**4**	**3**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**13**
TOTAL	**1**	**1**	**3**	**10**	**15**	**19**	**5**	**1**	**4**	**23**	**27**	**23**	**0**	**2**	**2**	**0**	**2**	**3**	**141**
BOTH FRACTIONS	**7**	**3**	**5**	**20**	**16**	**24**	**31**	**16**	**22**	**42**	**38**	**37**	**8**	**4**	**28**	**14**	**13**	**14**	**342**

Table 4-10: WEST Infauna by Station and Replicate

Station (Depth in ft)	T10-3 (2.8)			T10-5 (3.9)			T11-3 (3.1)			T11-5 (3.8)			T12-3 (2.3)			T12-5 (3.6)			Total
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
Macrofauna (1.0-mm Fraction)																			
Annelida																			
Pygospio elegans	16	15	27	7	1	1	6	29	7	5	3	4	5	7	4		1		138
Ampharete vega				29	12	21				2		1							65
Oligochaeta				2	1	2	1	2	1							1			10
Marenzelleria arctia											2	1							3
Eteone longa								1											1
Group Total	**16**	**15**	**27**	**38**	**14**	**24**	**7**	**32**	**8**	**7**	**5**	**6**	**5**	**7**	**4**	**1**	**1**	**0**	**217**
Crustacea																			
Monoporeia affinis	4	2	3	1					1		2		3	1	3	3	1		24
Monoculopsis longicornis			1												1	3	1	2	8
Saduria entomon					1				1	1	1								4
Group Total	**4**	**2**	**4**	**1**	**1**	**0**	**0**	**0**	**2**	**1**	**3**	**0**	**3**	**1**	**4**	**6**	**2**	**2**	**36**
Mollusca																			
Cyrtodaria kurriana				1						1	2								4
Group Total	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**
Miscellaneous																			
Tubularia indivisa																	1		1
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**
TOTAL	**20**	**17**	**31**	**40**	**15**	**24**	**7**	**32**	**10**	**9**	**10**	**6**	**8**	**8**	**8**	**7**	**4**	**2**	**258**
Megafauna (6.4-mm Fraction)																			
Annelida																			
Pygospio elegans								1	1		1		1		4	1	1		10
Ampharete vega									1									6	7
Oligochaeta								1											1
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**0**	**1**	**0**	**1**	**0**	**4**	**1**	**1**	**6**	**18**
Crustacea																			
Saduria entomon	3	2	2	7	7	7	1		1	1	2				2		4		39
Group Total	**3**	**2**	**2**	**7**	**7**	**7**	**1**	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**2**	**0**	**4**	**0**	**39**
Mollusca																			
Cyrtodaria kurriana				3							2								5
Macoma balthica											1	1							2
Group Total	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**7**
Miscellaneous																			
Tubularia indivisa	1			1			4	2	13		2	2					1		26
Rhizomolgula globularis				4	2														6
Priapulus caudatus										1									1
Group Total	**1**	**0**	**0**	**5**	**2**	**0**	**4**	**2**	**13**	**1**	**2**	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**33**
TOTAL	**4**	**2**	**2**	**15**	**9**	**7**	**5**	**4**	**16**	**2**	**8**	**3**	**1**	**0**	**6**	**1**	**6**	**6**	**97**
BOTH FRACTIONS	**24**	**19**	**33**	**55**	**24**	**31**	**12**	**36**	**26**	**11**	**18**	**9**	**9**	**8**	**14**	**8**	**10**	**8**	**355**

Table 4-11: GULL Infauna by Station and Replicate

Station (Depth in ft)	T13-3 (2.8)			T13-5 (3.1)			T14-3 (3.0)			T14-5 (3.9)			T15-3 (3.9)			T15-5 (4.2)			Total
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
Macrofauna (1.0-mm Fraction)																			
Annelida																			
Pygospio elegans	21	19	32	104	77	45	69	64	78	5	17	12	15	8	8	1		3	578
Group Total	**21**	**19**	**32**	**104**	**77**	**45**	**69**	**64**	**78**	**5**	**17**	**12**	**15**	**8**	**8**	**1**	**0**	**3**	**578**
Crustacea																			
Monoculopsis longicornis			1			1					2	1	1						6
Monoporeia affinis				1	1							1		1	1	1			6
Saduria entomon							2	2		1									5
Acanthostepheia incarinata			1				1												2
Group Total	**0**	**0**	**2**	**1**	**1**	**1**	**3**	**2**	**0**	**1**	**2**	**2**	**1**	**1**	**1**	**1**	**0**	**0**	**19**
Mollusca																			
Cyrtodaria kurriana										1		1							2
Macoma spp.								1											1
Boreacola maltzani																1			1
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**4**
Miscellaneous																			
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL	**21**	**19**	**34**	**105**	**78**	**46**	**72**	**67**	**78**	**7**	**19**	**15**	**16**	**9**	**9**	**3**	**0**	**3**	**601**
Megafauna (6.4 mm Fraction)																			
Annelida																			
Pygospio elegans		2		27	12	33	13	16	5	8	19	14	4	9	5	3	1	1	172
Ampharetidae																	1		1
Group Total	**0**	**2**	**0**	**27**	**12**	**33**	**13**	**16**	**5**	**8**	**19**	**14**	**4**	**9**	**5**	**3**	**2**	**1**	**173**
Crustacea																			
Saduria entomon							1				1				1				3
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**3**
Mollusca																			
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Miscellaneous																			
Tubularia indivisa															2				2
Group Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**2**
TOTAL	**0**	**2**	**0**	**27**	**12**	**33**	**14**	**16**	**5**	**8**	**20**	**14**	**4**	**9**	**8**	**3**	**2**	**1**	**178**
BOTH FRACTIONS	**21**	**21**	**34**	**132**	**90**	**79**	**86**	**83**	**83**	**15**	**39**	**29**	**20**	**18**	**17**	**6**	**2**	**4**	**779**

Table 4-12: DOCK Infauna by Station and Replicate

Station (Depth in ft)	T16-3 (3.8)			T16-5 (4.4)			T17-3 (3.0)			T17-5 (4.6)			T18-3 (4.3)			T18-5 (3.9)			Total
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
Macrofauna (1.0-mm Fraction)																			
Annelida																			
Pygospio elegans	4		8	7		11	11	11	11	1		1	2	1		1	1		70
Ampharete vega				1		2				4	4	4			2		1		18
Marenzelleria arctia				1						2	1				1				5
Oligochaeta							1												1
Total	**4**	**0**	**8**	**9**	**0**	**13**	**12**	**11**	**11**	**7**	**5**	**5**	**2**	**1**	**3**	**1**	**2**	**0**	**94**
Crustacea																			
Monoporeia affinis							2	1	1	1	1	3	1		1	1		1	13
Saduria entomon		1			1	1				1									4
Monoculopsis longicornis									1			1							2
Onisimus litoralis						1													1
Mysis relicta										1									1
Total	**0**	**1**	**0**	**0**	**1**	**2**	**2**	**1**	**2**	**3**	**1**	**4**	**1**	**0**	**1**	**1**	**0**	**1**	**21**
Mollusca																			
Macoma balthica	1										1		1						3
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**3**
Miscellaneous																			
Priapulus caudatus				1						1									2
Alcyonidium spp.											P		P			P			P
Total	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**
TOTAL	**5**	**1**	**8**	**10**	**1**	**15**	**14**	**12**	**13**	**11**	**7**	**9**	**4**	**1**	**4**	**2**	**2**	**1**	**120**
Megafauna (6.4 mm Fraction)																			
Annelida																			
Pygospio elegans		5	7				5	11							1	1	1		31
Ampharete vega						1				1		1	1				1		5
Total	**0**	**5**	**7**	**0**	**0**	**1**	**5**	**11**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**2**	**0**	**36**
Crustacea																			
Saduria entomon	1		1	2	4	3			1		1								13
Total	**1**	**0**	**1**	**2**	**4**	**3**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13**
Mollusca																			
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Miscellaneous																			
Tubularia indivisa									1					1					2
Alcyonidium spp.																			0
Synnotum spp.																			0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**2**
TOTAL	**1**	**5**	**8**	**2**	**4**	**4**	**5**	**11**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**0**	**51**
BOTH FRACTIONS	**6**	**6**	**16**	**12**	**5**	**19**	**19**	**23**	**15**	**12**	**8**	**10**	**5**	**2**	**5**	**3**	**4**	**1**	**171**

Table 4-13: Mean Infauna Density/m² at each Site

Site	SBAY		WEST		GULL		DOCK		Total		All
Fraction (mm)	**1.0**	**6.4**	**1.0**	**6.4**	**1.0**	**6.4**	**1.0**	**6.4**	**1.0**	**6.4**	**Total**
Annelida											
Polychaeta											
Pygospio elegans	506	4	852	6	3568	105	432	19	1340	34	1373
Ampharete vega	68	43	401	4	0	0	111	3	145	13	158
Chone sp. A	25	0	0	0	0	0	0	0	6	0	6
Marenzelleria arctia	6	1	19	0	0	0	31	0	14	0	14
Terebellides stroemi	6	0	0	0	0	0	0	0	2	0	2
Ampharetidae	0	0	0	0	0	1	0	0	0	0	0
Chaetozone ruffi	0	1	0	0	0	0	0	0	0	0	0
Eteone longa	0	1	6	0	0	0	0	0	2	0	2
Oligochaeta											
Oligochaeta	142	1	62	1	0	0	6	0	52	0	53
Total Group	**753**	**51**	**1339**	**11**	**3568**	**106**	**580**	**22**	**1560**	**47**	**1607**
Crustacea											
Isopoda											
Saduria entomon	111	24	25	24	31	2	25	8	48	14	62
Amphipoda											
Monoporeia affinis	43	0	148	0	37	0	80	0	77	0	77
Gammarus setosus	19	4	0	0	0	0	0	0	5	1	6
Onisimus litoralis	19	0	0	0	0	0	6	0	6	0	6
Acanthostepheia incarinata	0	0	0	0	12	0	0	0	3	0	3
Monoculopsis longicornis	0	0	49	0	37	0	12	0	25	0	25
Mysidea											
Mysis relicta	0	0	0	0	0	0	0	0	2	0	2
Total Group	**191**	**28**	**222**	**24**	**117**	**2**	**130**	**8**	**165**	**15**	**180**
Mollusca											
Bivalvia											
Cyrtodaria kurriana	241	0	25	3	12	0	0	0	69	1	70
Macoma balthica	37	0	0	1	0	0	19	0	14	0	14
Boreacola maltzani	0	0	0	0	6	0	0	0	2	0	2
Macoma spp.	0	0	0	0	6	0	0	0	2	0	2
Total Group	**278**	**0**	**25**	**4**	**25**	**0**	**19**	**0**	**86**	**1**	**87**
Miscellaneous											
Priapulida											
Priapulus caudatus	6	1	0	1	0	0	12	0	5	0	5
Tunicata – Ascideacea											
Rhizomolgula globularis	0	0	0	4	0	0	0	0	0	1	1
Hydrozoa											
Tubularia indivisa	12	7	6	16	0	1	0	1	5	6	11
Total Group	**19**	**8**	**6**	**20**	**0**	**1**	**12**	**1**	**9**	**8**	**17**
TOTAL	**1241**	**87**	**1592**	**59**	**3710**	**109**	**741**	**31**	**1821**	**71**	**1892**

Table 4-14: Infaunal Community Indices by Station

Site	SBAY (Depth in ft)							WEST (Depth in ft)							
Station	T7-3 (3.6)	T7-5 (7.5)	T8-3 (3.6)	T8-5 (6.1)	T9-3 (3.8)	T9-5 (4.5)	Mean	T10-3 (2.8)	T10-5 (3.9)	T11-3 (3.1)	T11-5 (3.8)	T12-3 (2.3)	T12-5 (3.6)	Mean	
Macrofauna (1.0-mm Fraction)															
Number of Taxa (*S*)	2.3	4.0	3.3	5.3	2.3	2.7	**3.3**	2.3	4.0	3.0	4.0	2.3	2.7	**3.1**	
Number of Individuals (*n*)	3.3	5.3	19.7	14.7	12.0	12.0	**11.2**	22.7	26.3	16.3	8.3	8.0	4.3	**14.3**	
Diversity (Shannon *H*)	0.75	1.07	0.50	1.44	0.45	0.52	**0.79**	0.44	0.68	0.57	1.19	0.67	0.80	**0.73**	
Evenness (e^H/S)	0.93	0.96	0.53	0.82	0.80	0.64	**0.78**	0.69	0.51	0.63	0.84	0.86	0.97	**0.75**	
Dominance (*D*)	0.56	0.53	0.87	0.41	0.84	0.84	**0.67**	0.85	0.80	0.82	0.51	0.67	0.56	**0.70**	
Megafauna (6.4-mm Fraction)															
Number of Taxa (*S*)	1.0	3.3	1.0	5.7	1.3	0.7	**2.2**	1.3	2.3	3.0	3.0	1.0	1.7	**2.1**	
Number of Individuals (*n*)	1.7	14.7	3.3	24.3	2.0	2.5	**8.8**	2.7	10.3	8.3	4.3	3.5	4.3	**5.7**	
Diversity (Shannon *H*)	0.00	0.76	0.00	1.27	0.69	0.00	**0.47**	0.19	0.58	0.74	0.96	0.32	0.29	**0.53**	
Evenness (e^H/S)	1.00	0.65	1.00	0.65	1.00	1.00	**0.87**	0.96	0.90	0.76	0.97	0.97	0.93	**0.91**	
Dominance (*D*)	1.00	0.73	1.00	0.52	0.50	1.00	**0.80**	0.92	0.75	0.70	0.47	0.83	0.89	**0.76**	
Site	**GULL (Depth in ft)**							**DOCK (Depth in ft)**							
Station	**T13-3 (2.8)**	**T13-5 (3.1)**	**T14-3 (3.0)**	**T14-5 (3.9)**	**T15-3 (3.9)**	**T15-5 (4.2)**	**Mean**	**T16-3 (3.8)**	**T16-5 (4.4)**	**T17-3 (3.0)**	**T17-5 (4.6)**	**T18-3 (4.3)**	**T18-5 (3.9)**	**Mean**	**Grand Mean**
Macrofauna (1.0-mm Fraction)															
Number of Taxa (*S*)	1.7	2.0	2.3	3.0	2.0	1.3	**2.1**	1.3	3.0	2.7	5.0	2.3	1.7	**2.7**	**2.8**
Number of Individuals (*n*)	24.7	76.3	72.3	13.7	11.3	3.0	**35.4**	4.7	8.7	13.0	9.0	3.0	1.7	**6.7**	**16.9**
Diversity (Shannon *H*)	0.09	0.08	0.14	0.62	0.31	0.55	**0.28**	0.17	0.60	0.49	1.38	0.69	0.46	**0.63**	**0.61**
Evenness (e^H/S)	0.81	0.54	0.61	0.65	0.68	1.00	**0.70**	0.94	0.74	0.63	0.82	0.96	1.00	**0.85**	**0.77**
Dominance (*D*)	0.98	0.99	0.97	0.80	0.91	0.67	**0.90**	0.93	0.81	0.85	0.46	0.67	0.67	**0.73**	**0.75**
Megafauna (6.4-mm Fraction)															
Number of Taxa (*S*)	0.3	1.0	1.3	1.3	1.7	1.3	**1.2**	1.3	1.3	1.3	1.0	1.0	1.0	**1.2**	**1.6**
Number of Individuals (*n*)	2.0	24.0	11.7	14.0	7.0	2.0	**11.1**	4.7	3.3	6.0	1.0	1.0	1.5	**3.0**	**7.2**
Diversity (Shannon *H*)	0.00	0.00	0.09	0.07	0.30	0.23	**0.13**	0.13	0.19	0.23	0.00	0.00	0.35	**0.14**	**0.31**
Evenness (e^H/S)	1.00	1.00	0.88	0.87	0.94	1.00	**0.94**	0.91	0.96	1.00	1.00	1.00	1.00	**0.98**	**0.92**
Dominance (*D*)	1.00	1.00	0.98	0.98	0.88	0.83	**0.94**	0.96	0.92	0.83	1.00	1.00	0.75	**0.92**	**0.85**

Table 4-15: Infaunal Biomass by Station

Site	SBAY							WEST							
Station/(Depth in ft)	T7-3 (3.6)	T7-5 (7.5)	T8-3 (3.6)	T8-5 (6.1)	T9-3 (3.8)	T9-5 (4.5)	Total	T10-3 (2.8)	T10-5 (3.9)	T11-3 (3.1)	T11-5 (3.8)	T12-3 (2.3)	T12-5 (3.6)	Total	
Macrofaunal (1.0-mm Fraction) Biomass (Wet Weight in grams {g})															
Annelida	0.02	0.05	0.03	0.06	0.03	0.02	**0.21**	0.03	0.1	0.03	0.05	0.03	0.02	**0.26**	
Crustacea	0.02	0.12	0.11	0.81	0.03	0.03	**1.12**	0.03	0.07	4.7	0.16	0.03	0.04	**5.03**	
Mollusca	0.02	0.01	0.03	1.21	0	1.54	**2.81**	0	0.01	0.01	0.25	0	0	**0.27**	
Miscellaneous	0	0	0.01	0	0	0	**0.01**	0	0	0	0	0	0.01	**0.01**	
Total	**0.06**	**0.18**	**0.18**	**2.08**	**0.06**	**1.59**	**4.15**	**0.06**	**0.18**	**4.74**	**0.46**	**0.06**	**0.07**	**5.57**	
Megafaunal (6.4-mm Fraction) Biomass (Wet Weight in g)															
Annelida	0	0.31	0.01	0.48	0.03	0	**0.83**	0	0	0.02	0.01	0.02	0.14	**0.19**	
Crustacea	0.43	0.4	0.75	2.34	0.04	0.36	**4.32**	1.17	3.66	0.22	0.21	0.28	3.31	**8.85**	
Mollusca	1.17	0.76	0.2	3.82	0	3.61	**9.56**	0	2.7	0	2.21	0	0.75	**5.66**	
Miscellaneous	0	0.18	0	0.41	0.12	0	**0.71**	0	6.6	0.03	0.23	0	0.01	**6.87**	
Total	**1.6**	**1.65**	**0.96**	**7.05**	**0.19**	**3.97**	**15.42**	**1.17**	**12.96**	**0.27**	**2.66**	**0.3**	**4.21**	**21.57**	
Site	**GULL (Depth in ft)**							**DOCK (Depth in ft)**							
Station	**T13-3 (2.8)**	**T13-5 (3.1)**	**T14-3 (3.0)**	**T14-5 (3.9)**	**T15-3 (3.9)**	**T15-5 (4.2)**	**Total**	**T16-3 (3.8)**	**T16-5 (4.4)**	**T17-3 (3.0)**	**T17-5 (4.6)**	**T18-3 (4.3)**	**T18-5 (3.9)**	**Total**	**All Total**
Macrofaunal (1.0-mm Fraction) Biomass (Wet Weight in g)															
Annelida	0.04	0.23	0.14	0.03	0.03	0.02	**0.49**	0.02	0.02	0.04	0.03	0.03	0.02	**0.16**	**1.12**
Crustacea	0.01	0.03	0.02	0.03	0.03	0.01	**0.13**	1.74	0.25	0.03	0.03	0.02	0.02	**2.09**	**8.37**
Mollusca	0	0	0.01	0.02	0	0.01	**0.04**	0.28	0	0	0.99	0.01	0	**1.28**	**4.4**
Miscellaneous	0	0	0	0	0	0	**0**	0	0.04	0	0.01	0	0	**0.05**	**0.07**
Total	**0.05**	**0.26**	**0.17**	**0.08**	**0.06**	**0.04**	**0.66**	**2.04**	**0.31**	**0.07**	**1.06**	**0.06**	**0.04**	**3.58**	**14**
Megafaunal (6.4-mm Fraction) Biomass (Wet Weight in g)															
Annelida	0.01	0.04	0.03	0.04	0.03	0.03	**0.18**	0.02	0.01	0.02	0.02	0.02	0.02	**0.11**	**1.31**
Crustacea	0	0	0.05	0.06	0.11	0	**0.22**	0.17	3.38	0.29	0.09	0	0	**3.93**	**17.3**
Mollusca	0	0	0	0	0	0	**0**	1.22	0.3	0	0.49	0.65	0	**2.66**	**17.9**
Miscellaneous	0	0	0	0	0.01	0	**0.01**	0	0	0.01	0	0	0	**0.01**	**7.6**
Total	**0.01**	**0.04**	**0.08**	**0.1**	**0.15**	**0.03**	**0.41**	**1.41**	**3.69**	**0.32**	**0.6**	**0.67**	**0.02**	**6.71**	**44.1**

Crustaceans were the second most abundant group overall, accounting for ~13% (*n*=207) of all organisms. Crustacea accounted for ~9% of the macrofaunal individuals and ~21% of the megafaunal individuals. Within this group, the isopod *Saduria entomon* was by far the most abundant species with 125 individuals. It comprised ~29% of the macrofaunal crustacea and ~94% of the megafauna. The vast majority of individuals retained were probably juveniles, but due to their large size in general more individuals were captured on the larger screen. McCrimmon and Bray (1962) state that arctic males can reach 95 mm (3.74 inches) and females 79 mm (3.11 inches) and that the ratio of females to males is ~7:1. This species occurred in ~25% of all macrofaunal fractions and ~50% of all megafaunal fractions.

Within the crustacean group, the Gammarid amphipod *Monoporeia affinis* was the second most abundant crustacea found (*n*=50). This species only occurred in the macrofaunal fraction, which is most likely due to its small size even when mature (up to 10–12-mm, ~½ inch; Keast and Lawrence 1990). This species made up ~47% of the crustacea in the macrofaunal fraction, 4% of the total macrofaunal organisms, and occurred in ~44% of all macrofaunal samples.

All of the molluscs documented in the study were bivalve clams (*n*=63). The bivalves comprised ~5% of all macrofauna but less than 2% of all megafauna. The most abundant species in both fractions was *Cyrtodaria kurriana* (*n*=50) that made up ~80% (*n*=45) of the macrofaunal molluscs and ~71% (*n*=5) of the megafaunal molluscs. Many of the individuals of this species must have been juveniles because only five individuals were captured on the larger screen. This species can grow to a size of 30 to 40 mm (Bernard 1979). The second most common bivalve was *Macoma balthica* with just 11 individuals in total, nine in the macrofaunal fraction and two in the megafaunal fraction.

Finally, the miscellaneous taxa comprised ~3% (*n*=56) of the overall organisms recorded. Only six individuals were enumerated in the macrofauna while the megafaunal fraction had 50, comprising ~0.5% and 11%, respectively. The hydrozoan *Tubularia indivisa* was the most abundant of this group with 44 individuals enumerated in both fractions. They accounted for ~50% of this group in the macrofauna and ~82% in the megafauna. This species is a sessile stalked hydroid with individual polyps that are often found in colonies (on pebbles, shell fragments, etc.) and can be difficult to quantify, but these organisms were enumerated in the infaunal samples for this program as individual counts of specimens retained on the screens could be determined.

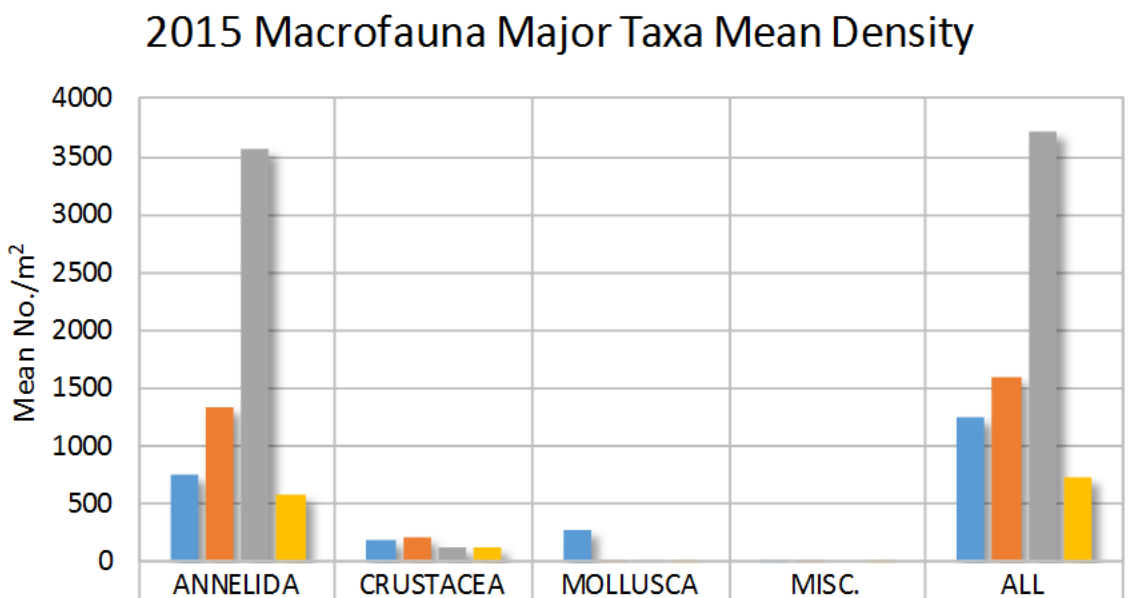
Other miscellaneous taxa included the sea grape *Rhizomolgula globularis* and the priapulid worm *Priapulus caudatus*, six specimens of each of which were recorded overall. Colonial bryozoans identified as *Alcyonidium spp.* and *Synnotum spp.* were also noted in the samples, though they could not be enumerated and are simply noted as present.

4.2.1.2 Species Abundance and Density by Site

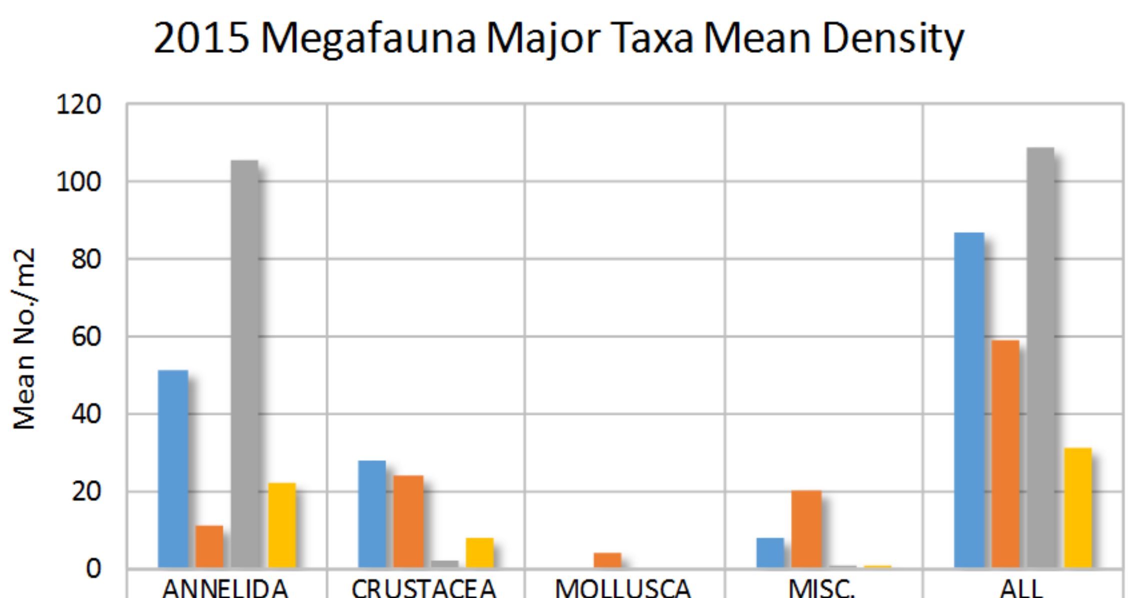
Individual site results are provided in Table 4-9 through Table 4-12. The greatest abundances overall were seen at the GULL, with a total of 779 organisms recorded in the combined megafaunal and macrofaunal fractions. The second most abundant site was WEST, with 355 organisms, closely followed by SBAY, with 342 organisms recorded. Finally, the DOCK site was the least populous overall, with only 171 organisms recorded.

Organisms were much more abundant in the macrofaunal fraction than in the megafaunal fraction, as expected, as can be seen in Table 4-9 through Table 4-12 and Figure 4-10. The number of organisms seen in the individual macrofaunal replicates ranged from 0 to 105, with the greatest numbers typically seen at GULL, followed by WEST. In the macrofaunal samples, organisms were reported for all replicates except for one sample at GULL (T15-5 Replicate {Rep.} 2). In the megafaunal fraction, the total number of organisms per replicate ranged from 0 to 33,

Figure 4-10: Mean Density of Major Taxa by Site



	ANNELIDA	CRUSTACEA	MOLLUSCA	MISC.	ALL
SBAY	753	191	278	19	1241
WEST	1339	222	25	6	1592
GULL	3568	117	25	0	3710
DOCK	580	130	19	12	741



	ANNELIDA	CRUSTACEA	MOLLUSCA	MISC.	ALL
SBAY	51	28	0	8	87
WEST	11	24	4	20	59
GULL	106	2	0	1	109
DOCK	22	8	0	1	31

with the highest numbers of organisms seen at GULL, followed by SBAY. There was, however, a high amount of variability between the megafaunal samples within a site, with all four sites having at least one replicate sample of megafauna with zero individuals recorded; 92% of the megafaunal samples had at least one organism. Six megafaunal replicates were recorded as having zero individuals: SBAY, T9-3 Rep. 1 and T9-5 Rep. 1; WEST: T12-3 Rep. 2; GULL: T13-3 Rep. 1 and Rep. 3; and DOCK: T18-5 Rep. 3.

Figure 4-10 and Table 4-13 compare the mean density of infauna by site for macrofauna and megafauna. Densities were calculated by converting the raw abundance estimates to a surface area of 1.0 m^2 based on a surface area of 0.009 m^2 for the macrofaunal fraction and 0.091 m^2 for the megafaunal fraction. Overall mean density of infauna for both fractions combined over all four sites was 1,892 organisms/m^2. The mean density of macrofauna was greatest at GULL (3,710 organisms/m^2), more than twice that seen at the WEST and SBAY sites and about five times higher than that at DOCK. The mean megafaunal density at highest at GULL (109 organisms/m^2), nearly 30% higher than SBAY, about twice as high as WEST, and more than three times higher than DOCK.

In terms of overall abundance within the macrofaunal fraction, the top five ranked species and taxa (*P. elegans, A. vega, M. affinis, C. kurriana*, and Oligochaeta) comprised 92% of the total individuals (Table 4-8). The top five ranked macrofauna comprised a total mean density ranging from 629/m^2 at DOCK to 3,617/m^2 at GULL (Figure 4-11). The spionid worm *P. elegans* accounted for 100% of the macrofaunal annelid group at GULL, as no other annelids were seen in that fraction at that site. The top five ranked megafaunal species (*P. elegans, S. entomon, A. vega, T. indivisa*, and the amphipod *Gammarus setosa*) made up 95% of the individuals found and comprised a total mean density ranging from 31/m^2 at DOCK to 108/m^2 at GULL. The relative frequency of occurrence for the top five macrofaunal taxa ranged from 17 to 78%, while in the megafauna, it ranged from just 4 to 50%.

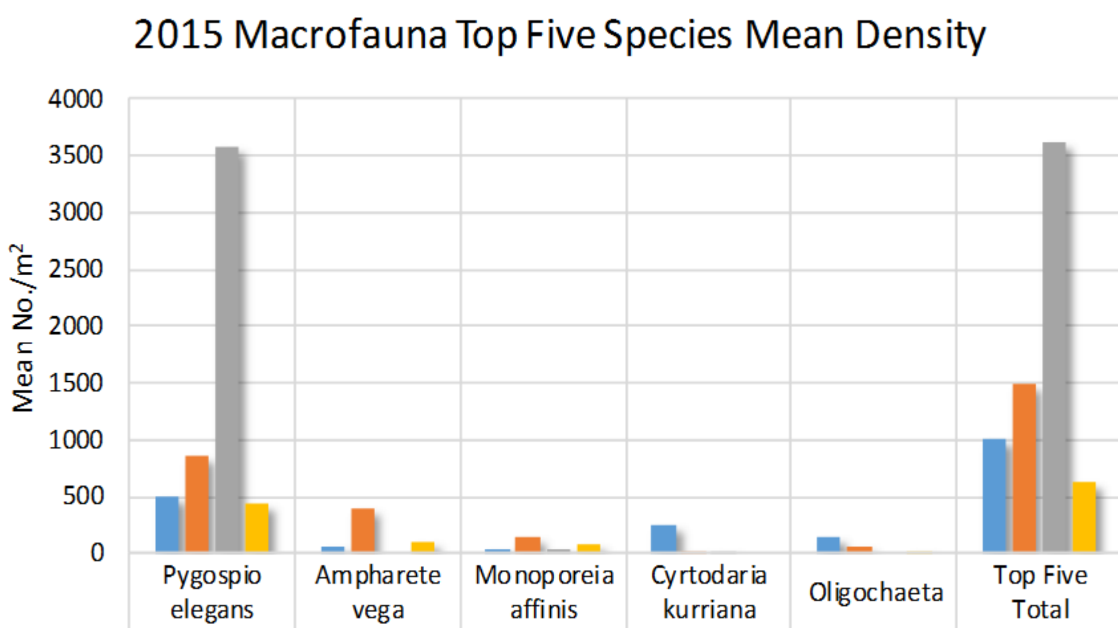
4.2.1.3 Number of Taxa

A total of 25 taxa were found in the 144 samples that were taken during 2015 (Table 4-7). Of these, 20 taxa were at the species level; others were at the lowest practicable taxon (Oligochaeta, Ampharetidae, *Macoma spp., Alcyonidium spp.,* and *Synnotum spp.).* The latter of these two groups, two colonial forms of bryozoan, were listed as “present” only, leaving 23 taxa being enumerated in both fractions. Twelve taxa and/or species occurred in both fractions, with ten taxa and species being exclusive to the macrofaunal fraction, while three were only found in the megafaunal fraction.

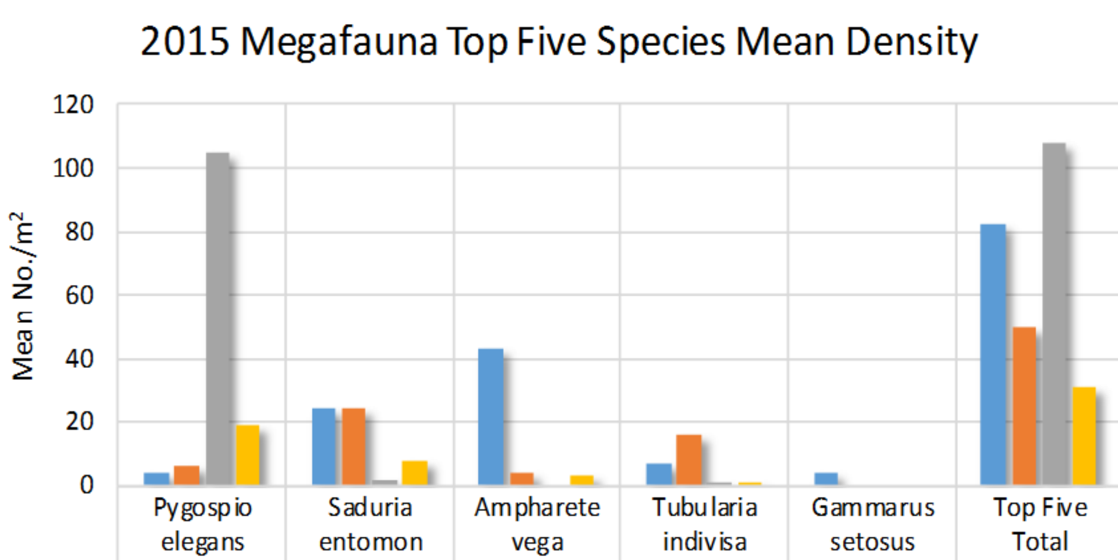
Twenty-two taxa were listed in the macrofaunal fraction, with 20 enumerated; 16 were recorded in the megafaunal fraction, with 15 enumerated. Overall, the annelids had the greatest number of taxa with nine; these were followed by the crustaceans with seven, the miscellaneous group with five, and the molluscs with four. In the macrofaunal fraction, the annelid and crustacea each had seven taxa, while the molluscs and miscellaneous each had four. In the megafauna, there were seven annelid, two crustacea, two mollusc, and four miscellaneous taxa recorded.

The number of macrofaunal annelid taxa or species richness (*S*) was highest at SBAY (*S*=6), followed by WEST, DOCK, and then GULL (*S*=5, 4, and 1, respectively; Table 4-7 and Figure 4-12). At GULL, only a single polychaete species (*P. elegans*) occurred, and that in high numbers (Table 4-11). Macrofauna crustacea richness was highest at DOCK (*S*=5) followed by both SBAY and GULL (each with *S*=4) and then by WEST (*S*=3). The molluscs were highest at GULL (*S*=3), then at SBAY (*S*=2), followed by both WEST and DOCK sites (*S*=1 each). The miscellaneous richness was highest at SBAY (*S*=4) followed by the DOCK and WEST sites (*S*=2 and 1, respectively); no members of the miscellaneous taxa were noted in the macrofauna at GULL. Overall, macrofaunal richness was highest at SBAY (*S*=16), followed by DOCK (*S*=12), WEST (*S*=10), and GULL (*S*=8; Figure 4-12).

Figure 4-11: Density of Top Five Taxa by Fraction, Site, and Overall



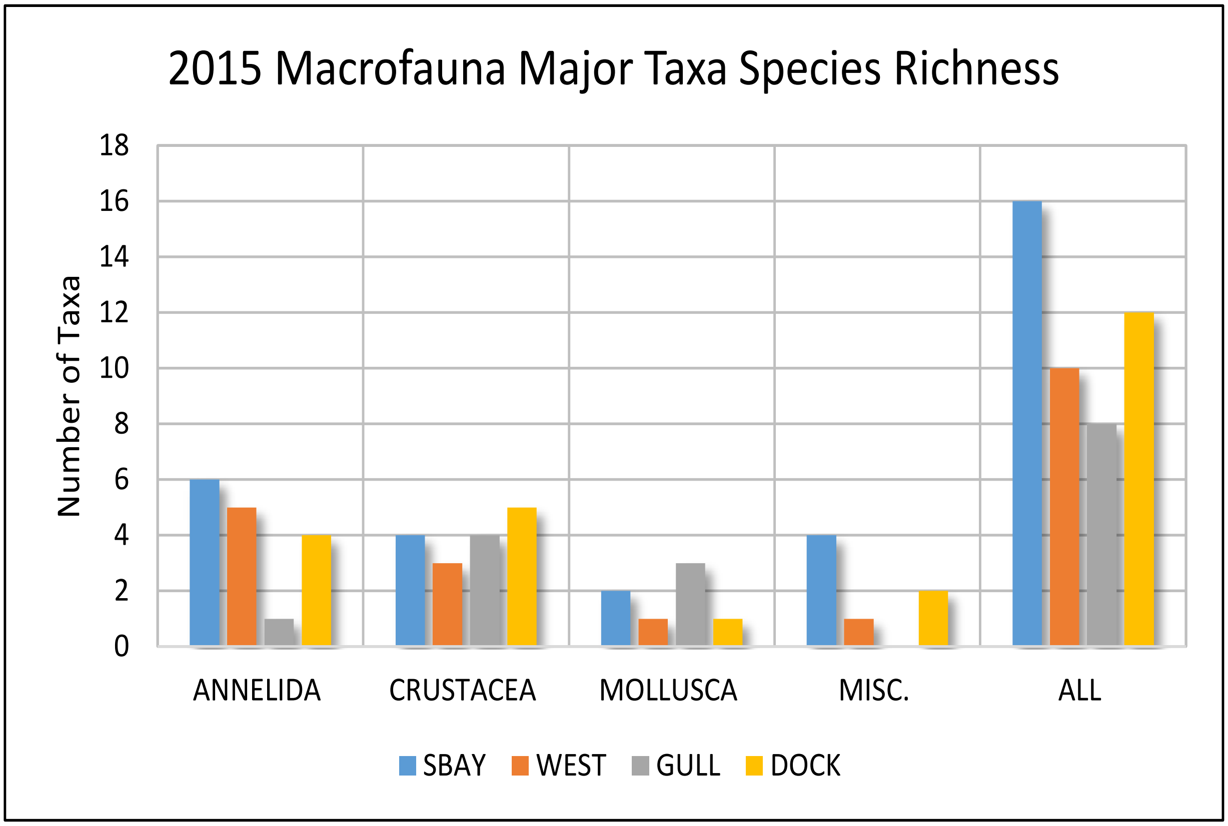
	Pygospio elegans	Ampharete vega	Monoporeia affinis	Cyrtodaria kurriana	Oligochaeta	Top Five Total
SBAY	506	68	43	241	142	1000
WEST	852	401	148	25	62	1487
GULL	3568	0	37	12	0	3617
DOCK	432	111	80	0	6	629

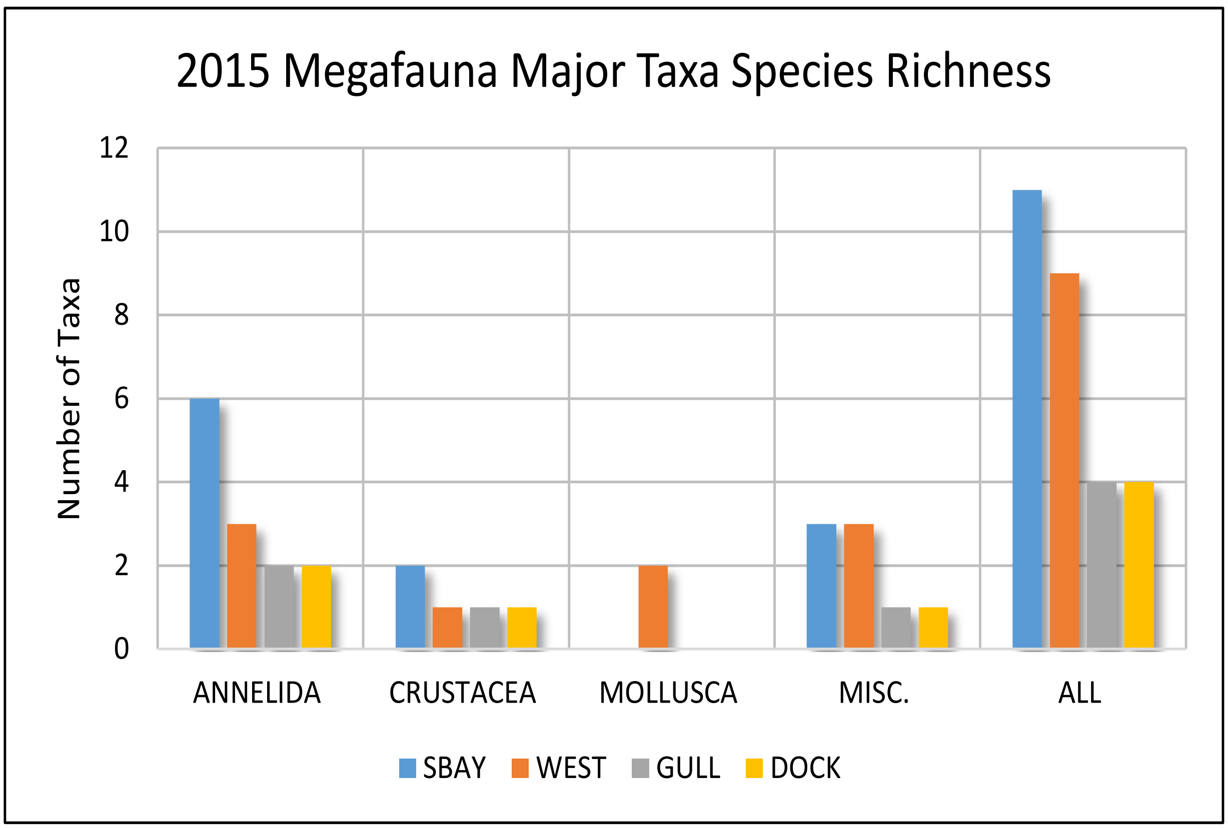


	Pygospio elegans	Saduria entomon	Ampharete vega	Tubularia indivisa	Gammarus setosus	Top Five Total
SBAY	4	24	43	7	4	82
WEST	6	24	4	16	0	50
GULL	105	2	0	1	0	108
DOCK	19	8	3	1	0	31

SBAY WEST GULL DOCK

Figure 4-12: Species Richness by Site





The species richness of the annelid megafauna was highest at SBAY (*S*=6) followed by WEST, GULL, and DOCK (*S*=3, 2, and 2, respectively; Table 4-7 and Figure 4-12). Richness for the crustacea was also highest at SBAY (*S*=2) with just one taxa at each of the remaining three sites. Only the WEST site had molluscs (*S*=2). Richness for the miscellaneous was highest at both the SBAY and WEST sites (*S*=3 each) and lowest at the GULL and DOCK sites (*S*=1 each). Overall, megafaunal richness was highest at SBAY (*S*=11), followed by the WEST (*S*=9), and then both GULL and DOCK (*S*=4 each).

4.2.1.4 Community Indices

Five diversity-related community-based indices were calculated for all samples and fractions and are presented as station mean values in Table 4-14). The five indices used include species richness (*S*), number of individuals or abundance (*n*), Shannon Diversity (*H;* Shannon and Weaver 1948), Evenness (e^H/S or *E*; Buzas and Gibson 1969), and Dominance (*D*; Berger and Parker 1970). While species richness (*S,* the number of taxa present) and abundance (*n*, total number of individuals) have already been discussed, the additional indices provide further information on the benthic community structure. Shannon *H* is a diversity index that takes into account the number of taxa as well as the number of individuals. It varies from zero for communities with only a single taxon to high values for communities with many taxa, each with few individuals. Evenness or *E* is Buzas and Gibson's evenness index (e^H/S, where *S* refers to number of species and *H* is calculated using natural logarithms). As used here, species evenness refers to how close in abundance each species is in a sample; it is scaled between 0 and 1. Diversity will increase as the number of species and evenness increase. *D* is Berger-Parker dominance and is the number of individuals in the dominant taxon relative to *n*; this is also scaled between 0 and 1. As used here, when *D* increases or decreases, *H* will inversely decrease or increase. All of the indices presented here were calculated using PAST Version 3.08 software for scientific data analysis.

The overall mean diversity or *H* of the macrofauna was 0.61, while *H* for the megafauna about half that with 0.31. Evenness or *E* for the macrofauna was 0.77, while that calculated for the megafauna was higher at 0.92. This reflects the presence of many low counts per species in the larger megafaunal fraction than that seen in the smaller macrofaunal fraction. Dominance or *D* was also lower for the macrofauna (0.75) than for the megafauna (0.85), reflecting the higher diversity in the macrofauna versus the megafauna.

Macrofauna diversity (*H*) was relatively similar at all sites but GULL (0.28), which was less than half that seen at the other sites, which reflects the fact that GULL was dominated by one annelid worm species (*P. elegans*). Evenness was not dramatically different among sites but was highest at the DOCK (0.85) and lowest at GULL (0.70). Dominance inversely mirrored diversity to some degree with GULL having a much higher value of 0.90 and SBAY having the lowest of the other three sites with 0.67. The indices at the GULL site reflect its low richness and high abundances. The annelid *P. elegans* accounted for ~96% of the individuals at the GULL site and was dramatically more abundant than the next most abundant taxa (578 *P. elegans* to 6 amphipod individuals, ~96 times higher). This scenario was not observed at the other three sites. Even though *P. elegans* was also the most abundant species at the other three sites, it never achieved the considerably larger proportions seen at GULL.

Megafaunal diversity was substantially higher at SBAY and WEST (0.47 and 0.53) than at either GULL or DOCK (0.13 and 0.14). Evenness was the opposite of diversity in this fraction with the GULL and DOCK sites having the highest values (0.94 and 0.98, respectively). The lowest evenness value occurred at SBAY with 0.87. Like evenness, dominance (*D*) was highest at both GULL and DOCK (0.94 and 0.92, respectively) and lowest at WEST (0.76). As in the macrofauna, very high abundances of *P. elegans* occurred in the megafaunal fraction at GULL, with this species accounting for ~97% of all the individuals in this fraction at this site.

Diversity of the megafaunal fraction was always lower than that seen for the macrofaunal fraction at the same site. Conversely, evenness and dominance were always higher at the same site for the megafauna. This not only reflects the lower overall number of taxa and number of individuals found in the larger megafaunal fraction but is a function of the lower frequency of occurrence for each taxa among samples.

4.2.1.5 Group Biomass

Biomass in raw grams (g) wet weight by fraction and site is presented in Table 4-15. Weights were recorded for each major taxonomic grouping by sample and not for individual taxa or organisms. Approximately 58 g of biomass was recorded in total for all fractions at all sites and stations. As would be expected, the megafaunal fraction accounted for the vast majority (~76%) of the total biomass with 44.1 g; the macrofaunal biomass totaled to only 14.0 g. The higher biomass in the megafauna is due mainly to the molluscs and crustacea which comprised 17.9 and 17.3 g, respectively, followed by the miscellaneous (7.6 g) and the annelids (1.3 g). In the macrofauna, crustacea and molluscs also comprised the bulk of the biomass with 8.4 and 4.4 g, respectively. In this fraction, the annelids comprised 1.1 g while the miscellaneous taxa accounted for <0.1 g of the total biomass.

Macrofauna biomass among sites was highest at WEST (5.6 g), followed by SBAY, DOCK, and GULL (4.2, 3.6, and 0.7 g, respectively). Megafaunal biomass followed a similar pattern with wet weights for WEST, SBAY, DOCK, and GULL at 21.6, 15.4, 6.7, and 0.4 g, respectively.

Major taxa biomass varied greatly among sites for both fractions. In the macrofauna, the annelids dominated the biomass only at GULL which was due to the overwhelming presence of *P. elegans* seen at this location. The crustaceans dominated the biomass at both the WEST and DOCK sites, while the molluscs only dominated biomass at SBAY. In the megafauna, annelid biomass was never more than ~0.9 g and was never a dominant component at any site. The crustacea megafaunal biomass was dominant at all sites except SBAY where the molluscs dominated. The biomass for the miscellaneous group was highest at WEST (6.9 g), followed by SBAY (0.7 g); it was ~0.01 g at the other two sites.

4.2.1.6 Historic Comparisons

The following discussion contrasts in general terms the SBAY and WEST disposal sites that were sampled in both 2014 and 2015 along with benthic data collected during the 2011 APP. Care should be taken in drawing too many conclusions from these comparisons since the areas examined during each program were different, even within the two sites sampled in both 2014 and 2015. In 2014, the areas sampled at SBAY and WEST for the Test Trench Program were much smaller and the stations much closer to shore than those sampled in 2015. The 2014 transects included one station nearly on the beach (in extremely shallow water), another in shallow water offshore but still within the bottom-fast ice zone, and a station farther out along each transect in deeper water; two transects were sampled at each of the sites. In 2015, the two benthic stations sampled along each of the three transects at each site were farther from shore and in deeper water to encompass the much larger potential dredge disposal zones currently under consideration for the Project. Benthic data collected during 2011 were from the proposed dredge area stations and a potential deepwater disposal site north of the channel.

Total abundance (of both the macrofauna and megafauna combined) compared between the two years and at both sites was always highest during 2015. Mean site total abundances (both fractions) were 822/m^2 at SBAY and 225/m^2 at WEST in 2014 compared to 1,326/m^2 at SBAY and 1,651/m^2 at WEST in 2015. These differences can be traced to the extremely low abundances seen in 2014 at the two shallow-most nearshore stations along each transect. Although higher than 2014, abundances seen in 2015 were lower than that seen in both 2011 and

2014 within the deeper dredge area where total abundances (of both fractions) were 1,543/m^2 and 1,925/m^2, respectively. The mean macrofaunal density measured at the offshore disposal site in 2011 was much greater at 7,165/m^2 based on analysis from nine sites in Stefansson Sound in ~20-25 ft of water.

Differences were seen in species richness between years with 2015 having more species and taxa than 2014 for both fractions. This was due mainly to differences in numbers between the annelids and crustacea. The 2015 dataset always had more annelid and crustacea species in the macrofaunal fraction. In the megafaunal fraction, only 2015 had any annelids, as none were recorded at either SBAY or WEST during 2014.

The dominant species during 2014 was the bivalve mollusc *C. kurriana* followed by the annelid *P. elegans* and the crustacean *S. entomon*. These species made up the vast majority of individuals overall. During 2015, *P. elegans* dominated, followed by the annelid *A. vega*, and then *C. kurriana*. At SBAY, *C. kurriana* dominated during 2014 but was not found during 2015 at all in the megafaunal fraction; in the macrofaunal fraction, this species was seen in lower numbers than in 2014. *P. elegans* were found in fairly even numbers at both SBAY and WEST when it occurred; it was not found at all in the 2014 megafauna nor were any other annelids. *S. entomon* was common at both sites and years except for the WEST macrofaunal fraction during 2014. Only a few *A. vega* were found during 2014 (at WEST), but this was another prevalent annelid species seen at both SBAY and WEST during 2015.

General comparisons of the benthic infauna stations at the SBAY and WEST disposal reuse areas can be made within each transect and with distance from shore for both 2014 and 2015. The abundance change with distance from shore (shallow to deeper) showed a variety of patterns depending on the fraction compared. The 2014 macrofauna increased more often in abundance with distance, while the 2015 macrofauna decreased more often with distance although depth was much less a factor in 2015. Both the 2014 and 2015 megafauna more often increased in abundance with distance. The differences noted for the megafaunal fraction are most likely the result of depth differences, where the T#-3 stations were within the bottom-fast ice zone and closer to shore in 2014, but these stations were much farther from shore and in deeper water in 2015 and were much more similar to the T#-5 depths sampled in 2014. There may also be seasonal differences in the data due to the timing of sampling during the open-water season. The 2015 samples were taken two months earlier in the season when salinity was lower and the departure of bottom-fast ice was more recent. The newly exposed “fresh” sediment made available by melting of the bottom-fast ice in early summer may allow for smaller colonizing species to quickly invade and populate the shallow waters near the shoreline, resulting in relatively greater abundance in the macrofaunal fractions at shallower depths. The differences noted for the megafaunal fraction with depth may simply be the result of larger individuals staying and surviving farther offshore in deeper water (potentially beyond the bottom-fast ice zone); these individuals were captured in higher numbers on the larger screen size.

4.2.2 Trawling

4.2.2.1 Fish

Overall fish catch in 2015 was low, with only 46 fish recorded over all 16 trawls performed at the four sites (SBAY, WEST, GULL, and DOCK; Table 4-16). Trawl catches are also presented by catch per 100 m^2 of bottom fished (Table 4-17); catches were normalized to a 100 m^2 area assuming a trawl width of 2.5 m and a straight trawl track between start and end GPS coordinates. Trawling at WEST yielded the most fish, accounting for ~46% of the total catch

Table 4-16: Trawl Catch Data by Site and Trawl

Site / Trawl Number / Average Depth in ft	SBAY				WEST				GULL				DOCK				Tot. Ind.
	12	13	14	15	9	10	11	16	5	6	7	8	1	2	3	4	
	5.9	4.8	4.0	6.8	4.9	4.9	3.6	3.1	4.0	3.9	2.7	4.7	4.2	4.1	4.4	4.5	
FISH																	
Boreogadus saida (Arctic cod)													1				1
Myoxocephalus quadricornis (fourhorn sculpin)		1	1			3	3	4	2		2		2	3			21
Osmerus mordax (Pacific rainbow smelt)	1																1
Pleuronectes glacialis (Arctic flounder)		1	7				3	8	1				1	1			22
Fish, unidentified larval				1													1
Group Total	1	2	8	1	0	3	6	12	3	0	2	0	4	4	0	0	46
CRUSTACEA																	
Amphipoda																	
Gammarida, unidentified							1	1		1							3
Gammaracanthus loricatus			1	1	1										1	2	6
Gammarus setosus				1	1										2		4
Monoporeia affinis			1														1
Weyprechtia heuglini					1								1				2
Mysidae (Mysid Shrimp)																	
Mysidae, unidentified					1		2	1				1		1	10	1	17
Mysis relicta			2									2	2		2		8
Neomysis rayii													1				1
Isopoda																	
Saduria spp.				4			1		31	2		2	1	2	5	2	50
Saduria entomon			2		3												5
Group Total	0	0	6	6	7	0	4	2	31	3	0	5	5	3	20	5	97
MOLLUSCA																	
Cyrtodaria kurriana				1													1
Group Total	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
HYDROZOA																	
Tubularia indivisa	P	P	P	P	P	P	P	P	P	P		P	P	P	P	P	P
Hydroid medusa, unidentified	14									1	3	2			5	2	27
BRYOZOA																	
?Synnotum spp.			P	P	P								P				P
?Alcyonidium spp.		P	P	P	P			P									P
TUNICATA (UROCHORDATA)																	
Rhizomolgula globularis (sea grape)	2	6	59	13	5		1	3							1		90
Group Total	16	6	59	13	5	P	1	3	P	1	3	2	P	P	6	2	117

Table 4-17: Total Catch per 100 m² of Bottom Area

Site / Trawl Number / Average Depth in ft	SBAY				WEST				GULL				DOCK				Total
	12	13	14	15	9	10	11	16	5	6	7	8	1	2	3	4	
	5.9	4.8	4.0	6.8	4.9	4.9	3.6	3.1	4.0	3.9	2.7	4.7	4.2	4.1	4.4	4.5	
FISH																	
Boreogadus saida (Arctic cod)													0.06				0.06
Myoxocephalus quadricornis (fourhorn sculpin)		0.06	0.06			0.16	0.17	0.23	0.11		0.11		0.12	0.16			1.17
Osmerus mordax (Pacific rainbow smelt)	0.05																0.05
Pleuronectes glacialis (Arctic flounder)		0.06	0.40				0.17	0.46	0.05				0.06	0.05			1.25
Fish, unidentified larval				0.05													0.05
Total Fish	**0.05**	**0.12**	**0.46**	**0.05**	**0**	**0.16**	**0.34**	**0.69**	**0.16**	**0**	**0.11**	**0**	**0.23**	**0.21**	**0**	**0**	**2.57**
Mean Fish Catch	**0.17**				**0.29**				**0.07**				**0.11**				
CRUSTACEA																	
Amphipoda																	
Gammarida, unidentified							0.06	0.06			0.06						0.17
Gammaracanthus loricatus			0.06	0.05	0.05										0.05	0.11	0.32
Gammarus setosus				0.05	0.05										0.11		0.21
Monoporeia affinis			0.06														0.06
Weyprechtia heuglini					0.05								0.06				0.11
Mysidae (Mysid Shrimp)																	
Mysidae, unidentified					0.05		0.11	0.06				0.05		0.05	0.55	0.05	0.93
Mysis relicta			0.11									0.09	0.12		0.11		0.43
Neomysis rayii													0.06				0.06
Isopoda																	
Saduria spp.				0.21			0.06		1.63	0.10		0.09	0.06	0.11	0.27	0.11	2.64
Saduria entomon			0.11		0.15												0.27
MOLLUSCA																	
Cyrtodaria kurriana				0.05													0.05
HYDROZOA																	
Hydroid medusa, unidentified	0.69									0.05	0.17	0.09			0.27	0.11	1.39
TUNICATA (UROCHORDATA)																	
Rhizomolgula globularis (sea grape)	0.10	0.35	3.38	0.68	0.26		0.06	0.17							0.05		5.06
Grand Total Catch	**0.83**	**0.47**	**4.19**	**1.10**	**0.62**	**0.16**	**0.62**	**0.97**	**1.79**	**0.16**	**0.34**	**0.33**	**0.52**	**0.37**	**1.43**	**0.38**	**14.27**

(*n*=21). The SBAY site was the second most abundant, accounting for ~27% of the overall fish catch (*n*=12), followed by DOCK at ~17% (*n*=8) and GULL with ~11% (*n*=5). Overall fish catch was lower in 2015 than it was during the 2014 MSP, when a total of 145 fish were recorded from the three nearshore reuse sites (WEST, SBAY, and EGG) during 12 trawls. Nearly 50% of those, however, were caught at the EGG site which was offshore and in deeper water than the two other reuse sites that were sampled in both 2014 and 2015 (SBAY and WEST).

Diversity of fish catch was also low with only five species of fish collected in total. Two species comprised 94% of the overall catch in nearly equal numbers with Arctic flounder (*Pleuronectes glacialis*) making up 48% and fourhorn sculpin (*Myoxocephalus quadricornis*) making up 46% of the total catch. In addition, one juvenile Arctic cod (*Boreogadus saida*) and one juvenile Pacific rainbow smelt (*Osmerus mordax*) were recorded. One unidentified larval fish was collected at SBAY that was ~30 mm in length and severely damaged, precluding identification. During the 2014 MSP, eight species of fish and one unidentified larval fish had been recorded at the three reuse sites. In 2014, the most dominant fish species was Arctic cod, of which only one was recorded this year; the majority of Arctic cod seen in 2014 were at the barrier island EGG site (which was not sampled in 2015). The other dominant species in 2014 was the fourhorn sculpin, which had comprised the bulk of the catch at SBAY and WEST. Arctic flounder were not recorded in any nearshore trawls in 2014 (although two were recorded at the deeper Prudhoe Bay optional disposal sites) but were quite prevalent in 2015, with the most nearshore trawls at both WEST (Trawls 16 and 11) and SBAY (Trawls 14 and 13) showing the highest abundances.

Distribution over all trawl samples was quite varied, with one trawl at WEST, two at GULL, and two at DOCK retaining no fish at all. Inshore trawls performed using a skiff at WEST (Trawl 16 between T10-3 and T11-3) and SBAY (Trawl 14 between T8-3 and T9-3) were the most abundant, with 12 and 8 fish caught, respectively. Nearly 70% of the Arctic flounder catch (*n*=15) was recorded from these two most abundant trawls, whereas only 24% of the fourhorn sculpin was seen there as the sculpin were more widely distributed over the trawl stations. In 2014, distribution was also quite variable between trawl stations.

The majority of the fish captured in the trawls were small and recorded as juveniles (i.e., less than {<} 150 mm in length), which is similar to the data recorded in 2014. Arctic flounder specimens ranged from ~72 to 181 mm in length, with a median of ~104 mm. About 82% of the Arctic flounder measured <130 mm in length, and only four were considered to be adult at lengths longer than 150 mm. Fourhorn sculpin observed in the trawls ranged from 60 to 279 mm in length, with a median of ~77 mm overall. About 48% of the fourhorn sculpin were <80 mm in length, and only three were considered adult. One of these was a very large specimen at 279 mm in length. In comparison, fourhorn sculpin lengths seen in 2014 ranged from 26 to 210 mm, with a median of ~90 mm. As noted above, no specimens of the Arctic flounder, the most dominant species collected in 2015, were recorded at SBAY, WEST, or EGG in 2014.

Another common way of examining catches is to normalize the trawl tows by unit surface area of the bottom covered to eliminate differences caused by varying tow speeds or length of tows. Overall, the normalized fish catches were very low with mean catches of 0.17/100 m^2 at SBAY, 0.29/100 m^2 at WEST, 0.07/100 m^2 at GULL, and 0.11/100 m^2 at DOCK (Table 4-17). These catches are similar to those seen during the 2011 APP, which ranged from a low of 0.11 to a high of 0.39/100 m^2 although there were differences in the makeup of the species since the 2011 effort was at the offshore disposal area. During the 2011 APP, only three species of fish were caught (identified as Arctic cod, Arctic staghorn sculpin, and kelp snailfish). The 2014 MSP trawling at SBAY, WEST, EGG, and three offshore areas in Prudhoe Bay (PRUD) showed catches that ranged from 0.28/100 m^2 in SBAY to 1.42/100 m^2 at EGG with catches of 0.51/100 m^2 at WEST and 0.94/100 m^2 at PRUD. Overall, both the abundance and diversity were much greater in 2014 than in either 2011 or 2015 with a total of ten species caught and a total abundance of 197, roughly four times as many as in 2015 with four fewer trawls performed in 2014 than in 2015.

One of the notable differences between 2014 and 2015 was the seasonal timing of the sampling effort: the 2014 sampling occurred in late September, while the 2015 sampling occurred in late July. This difference resulted in large differences in water mass properties with much higher salinity conditions observed during 2014 particularly at the EGG stations, which would help explain the large abundance of Arctic cod, a marine species prevalent at EGG. Also, the location of EGG was on the offshore side of the barrier islands where the prevalence of more marine species is expected. Oceanographic conditions seen during the 2015 sampling were much warmer and less saline with brackish estuarine conditions seen at all four sites.

4.2.2.2 Invertebrates

Invertebrates were more abundant in the trawls than fish during 2015, with an overall catch recorded of 215 specimens over all 16 trawls. For some taxa that were colonial in nature, only presence was noted. Due to the scarcity of the overall catch, as few specimens as possible were retained for laboratory identification.

Crustaceans comprised ~45% of the overall invertebrate catch. The benthic isopod *Saduria* spp. (commonly called “toe biter”) was the most abundant crustacean recorded (*n*=55), accounting for ~57% of the overall crustacean catch and ~26% of the overall invertebrate catch. The *Saduria* spp. were most likely to be *S. entomon* as indicated by the identification of the few specimens retained for laboratory identification, though *S. sabini* and *S. sibirica* have also been identified in samples during 2011 or 2014. During 2015, the distribution of *Saduria* was patchy, with five of the 16 trawls exhibiting no specimens at all. These organisms are generally ubiquitous in nearshore waters of the North Slope, as was seen during 2014, when they were recorded in 11 out of 12 trawls performed at the nearshore reuse sites with overall abundance being much greater (*n*=1,029).

The benthopelagic mysid shrimp (Mysidae, unidentified) accounted for an additional 27% of the overall crustacean catch across all sites, while amphipods accounted for the remaining 16%. Being semi-pelagic and smaller than the mesh size of the trawl net, the number of mysid shrimp and amphipods recorded at each site is likely an underestimate of the true number present at the time of sampling. Overall mysid and amphipod abundances were greatest at DOCK, where ~50% of both the mysids and amphipods were recorded. Both *Mysis relicta* and *Neomysis rayii* were identified in the laboratory voucher specimens; other mysid species (*Mysis littoralis),* typically found in deeper water, was documented during the 2011 APP sampling. Several species of amphipods (*Gammarus setosus*, *Gammaracanthus loricatus*, *Monoporeia affinis*, and *Weyprechtia heuglini*) were identified in the laboratory samples; three amphipods not retained for laboratory identification were of the infraorder Gammarida.

A solitary tunicate commonly referred to as a “sea grape” and tentatively identified as *Rhizomolgula globularis* was also a predominant species in the trawls. Ninety specimens were recorded, most of which were seen at the SBAY and WEST sites.

The presence of a stalked hydroid on small pebble substrates or pieces of drift algae was noted in all but one trawl (Trawl #7 at GULL) and was also noted in many of the sediment grabs collected during 2015. These hydroids have been tentatively identified from grab samples and trawl voucher specimen as *Tubularia indivisa*, as was noted in 2014. These organisms were not subject to enumeration in the trawls; though they have individual polyps, they tend to form sessile colonies and may be fused at the base, precluding enumeration. Specimens of up to ~13 centimeters in height were noted in the trawls and some grabs as well, indicating that bottom-fast ice was not present in all the sampling areas as these larger, more mature individuals were present.

Unidentified planktonic Hydrozoa medusoid forms (Hydroid medusa or “jellies”) were also noted in some of the trawl samples, particularly at SBAY where 14 specimens were recorded during one trawl. These pelagic and extremely fragile organisms are only opportunistically collected by the trawl, as many pass through the mesh while others are caught but typically severely damaged. Though expected to be extremely under-sampled by the trawl, these organisms are individual in nature and were subject to enumeration.

Colonial bryozoans, tentatively identified as *Alcyonidium* spp. and *Synnotum* spp., were seen on *T. indivisa* stalks and broken alga stipes, mostly in the SBAY and WEST trawls. These organisms were noted as present as they are colonial in nature and cannot be enumerated. Well-established colonial forms of bryozoans on larger *T. indivisa* stalks could also be indicative of the over-wintering of these organisms, indicating that, as expected, bottom-fast ice may not be present in all areas trawled.

4.2.2.3 Algae

General and qualitative general observations were made of macroalgae opportunistically collected during the trawling effort. Algae collected during the 2015 MSP were scarce compared to 2014, and no algal samples were retained for further identification. Algae that were noted consisted of small amounts of drift material that was free floating or, in some cases, attached to small pebbles. Trawls at some stations exhibited small pieces of detrital algae, unattached algae lacking their holdfasts, broken pieces of algal stipes or blades, or detached pieces of fine branched or filamentous algae entangled in the trawl net upon retrieval. In some cases, the algae pieces had bryozoans or *T. indivisa* attached, noted above. In no cases were larger pebbles or cobble with attached entire algal specimens with intact holdfasts retained in the trawl, nor was there any indication of the presence of an enriched boulder patch environment in the vicinity of any of the potential reuse areas.

4.3 OCEANOGRAPHY AND WATER QUALITY RESULTS

Water quality information was collected from each study site and included in situ measurements of conductivity, temperature, salinity, pH, DO, and optical backscatter measurements (OBS; a turbidity-type measurement) as well as discrete samples that were analyzed for TSS and turbidity. Study locations during 2015 included four potential disposal sites that are being considered for beneficial reuse (SBAY, WEST, GULL, and DOCK).

A summary of the water quality results from the study are summarized in Table 4-18 and Table 4-19. Because measurements within each site were performed on different days and are synoptic in nature, the results are a reflection of the prevailing oceanographic and meteorological conditions on the individual days that the measurements were made. Therefore, care should be taken in trying to compare measurements between study areas, since conditions at a specific site can change dramatically over the course of a short time-span due to the influence and proximity of local rivers and changing wind, wave, and current conditions.

Sampling activities during 2015 were initiated on 16 July 2015 during a period of light easterly wind conditions and extended through 25 July 2015. Winds during this period were light to moderate with wind speeds ranging from calm to 15 knots shifting between north-easterly and north-westerly in direction. As a result of shifting winds and tidal fluctuations, the corresponding water levels varied throughout the sampling as seen in Figure 4-13. Semidiurnal tidal fluctuations of ~0.5 ft can be seen superimposed on wind-induced storm surge fluctuations that ranged up to 1.5 ft. Easterly winds typically result in falling water levels, and westerly winds result in rising water levels. As noted above, water levels recorded in this report have been adjusted to the MSL datum established by the NOAA for the tide station located at the Prudhoe Bay STP.

Table 4-18: Summary of Hydrographic Data, All Stations

Site	Station	Date	Depth	Depth (ft)	Cond (S/m)	Temp (°C)	Salinity (psu)	OBS (NTU)	pH	DO (mg/L)
SBAY	T7-3	7/23/15	Surface	0.5	1.30	7.80	11.51	9.97	8.01	10.30
			Bottom	2.5	1.32	7.79	11.69	20.30	8.01	10.38
	T7-5	7/23/15	Surface	0.5	1.27	7.55	11.24	6.63	8.01	10.42
			Bottom	6.0	1.40	7.68	12.51	21.10	7.99	10.25
	T9-3	7/24/15	Surface	0.5	1.11	9.06	9.34	15.04	8.06	10.31
			Bottom	3.0	1.17	9.06	9.90	12.77	8.06	10.67
	T9-5	7/24/15	Surface	0.5	1.26	8.69	10.82	9.15	8.03	10.40
			Bottom	4.0	1.28	8.70	11.00	9.21	8.03	10.38
WEST	T10-3	7/19/15	Surface	0.5	1.62	7.96	14.65	2.06	7.95	10.45
			Bottom	3.5	2.23	6.86	21.14	2.10	7.96	11.12
	T10-5	7/16/15	Surface	0.5	1.84	8.78	16.30	10.31	7.97	9.21
			Bottom	4.0	1.85	8.77	16.36	20.68	7.97	10.09
	T11-5	7/16/15	Surface	0.5	1.79	8.68	15.81	7.12	7.99	9.12
			Bottom	4.0	1.84	8.67	16.28	12.07	7.99	10.20
	T12-3	7/17/15	Surface	0.5	1.90	7.75	17.35	9.16	8.01	10.08
			Bottom	2.5	1.90	7.82	17.27	9.36	8.01	10.06
	T12-5	7/17/15	Surface	0.5	1.89	7.31	17.48	9.36	8.02	9.94
			Bottom	3.5	1.89	7.31	17.48	10.18	8.02	10.22
GULL	T13-3	7/18/15	Surface	0.5	1.76	8.95	15.44	5.82	8.03	9.41
			Bottom	2.5	1.77	8.93	15.56	4.88	7.95	9.48
	T13-5	7/18/15	Surface	0.5	1.85	9.01	16.23	6.71	8.00	10.05
			Bottom	2.5	1.89	8.84	16.67	7.05	7.99	10.03
	T15-3	7/20/15	Surface	0.5	0.84	7.42	7.64	1.43	7.96	10.27
			Bottom	3.5	2.15	7.98	19.74	3.72	7.93	10.40
	T15-5	7/20/15	Surface	0.5	0.88	8.59	7.66	1.72	7.98	9.61
			Bottom	4.0	2.16	7.91	20.35	3.84	7.95	10.33
DOCK	T16-3	7/20/15	Surface	0.5	0.98	6.70	9.04	0.28	7.91	10.74
			Bottom	4.5	2.21	7.23	20.75	1.44	7.89	10.94
	T16-5	7/20/15	Surface	0.5	2.10	6.96	19.80	0.00	7.92	11.00
			Bottom	4.5	2.30	7.44	21.51	3.46	7.87	10.68
	T18-3	7/21/15	Surface	0.5	1.67	7.82	15.09	0.19	7.94	10.46
			Bottom	4.0	2.13	7.81	19.57	2.54	7.94	10.78
	T18-5	7/21/15	Surface	0.5	1.89	7.26	17.55	0.01	7.93	10.02
			Bottom	3.5	2.09	7.23	19.54	1.32	7.93	10.89

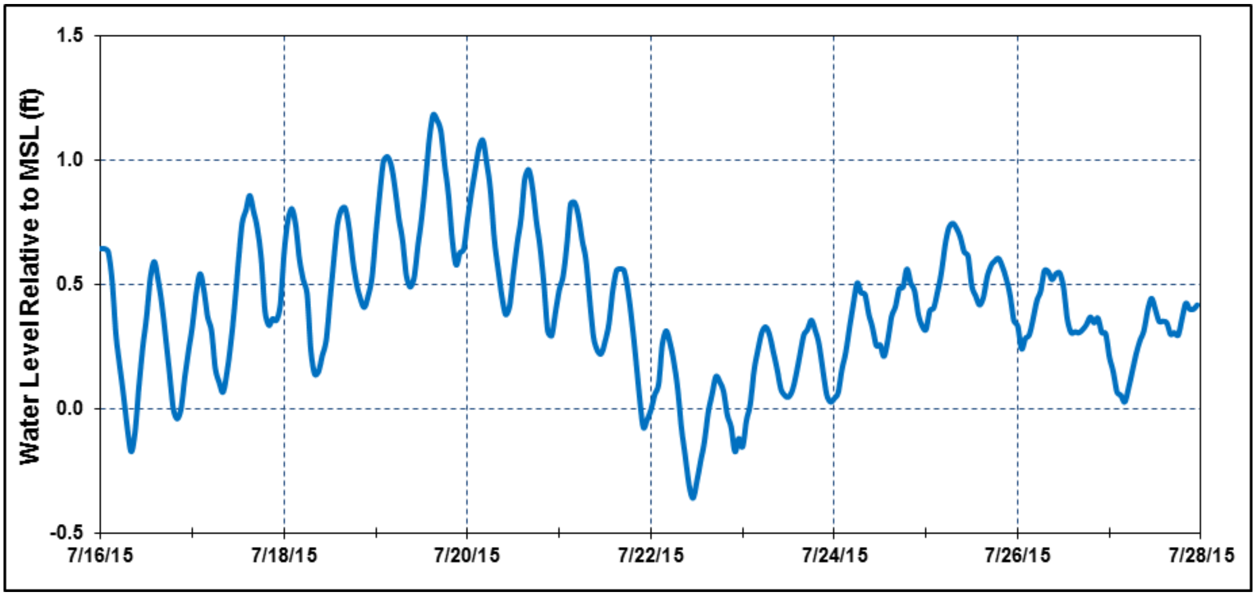
Table 4-19: TSS and Turbidity Water Analysis Results

Site	Station	Sample Date	TSS (mg/L)		Turbidity (NTU)	
			Surface	Bottom	Surface	Bottom
SBAY	T7-1	7/23/2015	71.6	NC	70.5	NC
	T7-3	7/23/2015	25.0	25.3	30.8	29.3
	T7-5	7/23/2015	24.5	26.0	22.4	22.0
	T9-1	7/24/2015	27.0	NC	26.5	NC
	T9-3	7/24/2015	11.5	17.5	16.5	17.5
	T9-5	7/24/2015	8.4	11.6	13.1	13.3
WEST	T10-1	7/18/2015	41.5	NC	24.8	NC
	T10-3	7/19/2015	15.5	16.0	6.47	5.83
	T10-5	7/16/2015	39.3	44.0	23.8	20.6
	T11-5*	7/16/2015	NC	NC	16.0*	16.1*
	T12-1	7/17/2015	34.7	NC	18.5	NC
	T12-3	7/17/2015	29.5	31.5	14.3	15.6
	T12-5	7/17/2015	26.7	27.5	16.6	15.4
GULL	T13-1	7/18/2015	20.0	NC	7.74	NC
	T13-3	7/18/2015	15.0	17.0	8.01	7.70
	T13-5	7/18/2015	15.0	13.5	12.1	9.99
	T15-1	7/20/2015	4.2	NC	2.44	NC
	T15-3	7/20/2015	12.2	7.4	5.92	5.21
	T15-5	7/20/2015	7.2	6.4	7.34	5.94
DOCK	T16-1	7/25/2015	12.4	NC	9.40	NC
	T16-3	7/20/2015	6.0	4.4	2.40	1.27
	T16-5	7/20/2015	8.2	9.2	3.38	4.98
	T18-1	7/25/2015	10.4	NC	8.72	NC
	T18-3	7/21/2015	7.4	7.0	5.05	3.92
	T18-5	7/21/2015	6.0	5.2	3.13	2.77

* Extra samples collected and analyzed in the field.

NC Not collected.

Figure 4-13: Observed Water Level Fluctuations Measured at the Prudhoe STP



An examination of the conductivity and salinity measurements revealed that the surface waters at a number of locations were influenced by the freshwater discharges from the Sagavanirktok River (SBAY, WEST, and GULL) and, to a lesser extent, the Putuligayuk River (WEST), as evidenced by the observation of a freshwater lens at these sites. DOCK was also influenced by freshwater inputs that most likely originated from the Kuparuk River. Since sampling within each area occurred over a two- to three-day period, a direct comparison between stations was not performed as conditions can change rapidly with shifts in wind speed and direction. Surface salinity levels measured across all sites and stations ranged from 7.64 to 19.80 practical salinity units (psu; Table 4-18). Bottom salinity measurements were found to be somewhat higher but still brackish, ranging from 9.90 to 21.51 psu.

Water temperatures were found to be fairly consistent with low variability across the entire study region. Overall, temperatures were found to have a narrow range with a low of 6.70°C and a high of 9.07°C for all sampling stations and depths. In general, the oceanographic conditions were typical of the early summer regime with relatively warm brackish water dominating the nearshore environment. DO levels were found to be high and either at or near saturation in all samples, ranging from a low of 9.12 mg/L to a high of 11.12 mg/L. The pH values recorded were typical for marine waters with a range of 7.87 to 8.06 pH units.

Measurements of suspended sediment and turbidity were examined by three different methods. Discrete TSS and Nephelometric turbidity samples were collected and analyzed at the analytical laboratory and in the field, respectively, and OBS turbidity measurements were obtained in situ with the SeaBird CTD. TSS measurements ranged from 4.2 to 71.6 mg/L at the surface and from 4.4 to 44 mg/L at the bottom. The highest measurement was seen at the SBAY T7-1 due to the elevated wave and surf activity during the sampling effort at this shallow near-beach location. A similar trend was seen for field-analyzed turbidity where levels ranged from 1.27 to 70.5 NTU, with the highest level also seen at the surface at SBAY T7-1. A regression of turbidity versus TSS indicated a high degree of correlation with an R^2 value of 0.77. OBS measurements from the CTD indicated that the water was relatively clear with little turbidity. Turbidity as measured by OBS ranged from a low of 0.0 NTU to a high of 21.2 NTU.

Sampling at WEST included a number of samples that were taken in the vicinity of the test trench disposal area that was utilized during the spring of 2015 for the Test Trench Program. The sampling team was able to visually establish the location of the dredge spoils as a portion of the dredge spoils rose above the water level. No evidence was seen that dredge disposal material was causing elevated TSS or turbidity levels, and no visual turbidity plumes were seen as the result of wind, wave, and current activity in this area. Based on this limited visual assessment, the dredge disposal sediments did not appear to be negatively impacting the water quality conditions in the immediate vicinity.

As has been seen in numerous other oceanographic studies that have been conducted in the nearshore Prudhoe Bay region over the past 40 years, the hydrographic and water quality conditions that were seen in 2011, 2014, and 2015 reflect current meteorological and oceanographic conditions at the actual time of sampling. Water quality conditions such as temperature and salinity are dependent on seasonal timing, riverine influences, air temperature, and recent and current wind activity since easterly winds tend to upwell cooler marine water on to the continental shelf where they mix with nearshore waters. For example, after the easterly storm that occurred during the middle of sampling in 2014, hydrographic conditions were found to be cooler and more marine following the storm event. Similarly, suspended sediment and turbidity are strongly influenced by wind and wave conditions, which result in the resuspension of bottom sediment. Also, riverine plumes that discharge into the nearshore environment tend to have higher turbidity levels as a result of storm events. Turbidity and TSS conditions seen during 2015 were generally much lower than those seen in 2014 as a result of more quiescent conditions, and the temperature and salinity conditions were generally warmer and fresher (less saline) due to seasonal timing of the sampling event in early summer versus later in the season.

4.4 QUALITY ASSURANCE/QUALITY CONTROL EVALUATION

All sediment and water analytical data for the program underwent QA/QC evaluation according to EPA National Functional Guidelines for inorganic and low concentration organic data review (EPA 2014). This evaluation is included as part of this interpretive report in Appendix A; the reader is also referred to the appendix for analytical laboratory reports and case narratives.

All sediment, water, and biological environmental samples and associated QC samples (i.e., field duplicates) were collected as required, resulting in a field completeness value of 100%. All sediment and water samples were received intact under proper chain of custody procedures at the analytical laboratory within the proper temperature ranges and were analyzed within acceptable EPA holding times. All biological samples were received intact under proper chain of custody at the biological facilities. In addition, no data were deemed invalid during the program. The analytical completeness was therefore assessed at 100%.

The overall quality of the 2015 program dataset was assessed and determined to be well within the data quality objectives as outlined in the program FEP and QAP. Overall evaluation of the analytical QA/QC data indicates that the chemical and physical data are for the most part within established performance criteria and can be used for characterization of sediments and waters as required by program objectives.

5.0 DISPOSAL EVALUATION AND FACTUAL DETERMINATIONS

Data collected from the 2011, 2014, and 2015 marine sampling events were intended to address the criteria for evaluation of dredge and disposal areas that fall under Section 404(b)(1) of the CWA, *Guidelines for Specification of Disposal Sites for Dredged or Fill Material.* Components required for the 40 CFR Section 230.11/Section 404(b)(1) factual determination, including the short-term or long-term effects of the proposed discharge of dredged material on the physical, chemical, and biological components of the aquatic environment, are included in this report. The 2015 MSP focused on evaluating four nearshore sediment reuse disposal areas, two of which were also examined in 2014, that are under consideration for the Project.

The 2015 MSP did not include any additional evaluation of the actual dredge area since the location of the dredge channel and marine offload facilities has not been finalized. Dredge area evaluations that were conducted during 2011 and 2014 determined that the dredge area sediments consist exclusively of clean marine sediments meeting available criteria for either inland disposal or reuse for beach nourishment. Thus, it is expected that effects of disposal will be largely related to the physical properties of the sediments and their direct and indirect effects on local habitat and associated ecosystem function. The size of the final dredge volume is currently estimated to be large (~1,000,000 yd^3); therefore, based on DMMP guidelines, it is expected that additional testing of the dredge area sediments will be required in the future to confirm that the dredge area sediments are "clean" and that contaminant levels are at or near regional background levels.

At this time, this section of the report is provided for informational purposes only and should be viewed as a preliminary evaluation based on available data since the actual dredge project has not yet been fully designed or proposed.

5.1 PHYSICAL SUBSTRATE DETERMINATIONS

The design of the sampling program at the four dredged material reuse sites utilized a transect approach where two to three locations along each transect were close to shore and within the probable sediment reuse placement areas, leaving two to three locations outside of the probable placement areas. This design allowed biological community analysis to be performed as a function of water depth and allowed some conclusions to be drawn on the effect of bottom fast-ice on those shallow-water areas. Also, it is expected that as the deposited dredged material winnows with the wave and current action, the finer-grained sediments will be deposited farther from the beach on the outer portions of each transect line. Thus, compatibility with those offshore areas was included in the analysis and evaluation for handling material from the entire channel dredge footprint.

Grain size analyses for the four reuse areas show differing grain size characteristics with coarser-grained sediments typically occurring closer to shore and finer-grained sediments farther from the beach face. Sediments from the DOCK and SBAY areas were on average the finest and therefore the most compatible with the dredge area sediments. Sediments were coarser at the WEST and GULL reuse areas but were still found to be compatible with the median and coarser-grained fractions from the dredge site. The majority of the disposal area sediments from all four sites were described as either fine sand or silty fine sand with occasional gravel.

Compatibility determinations were conducted for the dredge area sediments versus the four potential receiving area locations. Since final location of the dredge channel has not yet been determined, the dredge area evaluation utilized all of the available grain size data that were collected in both 2011 and 2014. The dredge area sediments were found to be relatively compatible with all four reuse areas examined in 2015, and it was determined that, based on grain size, dredged materials would be appropriate for beneficial reuse as shoreline protection. The final determination and selection of a disposal site will also need to take into account other considerations such as the overall need for erosion protection, engineering and cost issues such as length of ice road required, and biological resources that might be effected at each site.

5.2 WATER CIRCULATION, FLUCTUATIONS, AND SALINITY DETERMINATIONS

Current patterns will be initially altered in the immediate vicinity of material placement as a result of reduced water depths and the alteration in the geomorphology of the immediate coastline at the disposal site. Due to the estimated amount of dredged material, these changes are expected to last for a number of years after placement. Additionally, it is not expected that the discharge would have any effects on normal water level fluctuations or salinity gradients or would affect water quality parameters other than suspended sediment and turbidity in the immediate vicinity.

Given the open-coast location and high-energy environment on the north side of Gull Island, it is expected that the dredged material would provide less erosional protection at GULL as wave and current activity are expected to be much greater there than at the other three potential reuse areas. Although both the SBAY and WEST sites are located within Prudhoe Bay and are afforded some natural protection due to the natural geomorphology of the coastline, both sites are erosional as evidenced by the visually obvious shoreline erosion and retreat. The beach at the DOCK site appears to be less erosional and is protected by the West Dock Causeway to the east and by Stump Island located offshore of the site.

Because the dredged material will be spread in a long narrow band (~10,000 ft long by 900 ft wide) along the shoreline, currents will only be affected in the immediate vicinity of the dredge spoils, and the spoils will not be an impediment to fish passage and movements through the area during the open-water period. Additionally, since the distance between any of the four potential disposal areas and dredge channel is at least one mile, it is not expected that any significant amount of sediment from the disposal area would be re-deposited back into the dredge channel, although this will be further evaluated by the ongoing sedimentation studies being conducted by the Project.

5.3 SUSPENDED PARTICULATE/TURBIDITY DETERMINATIONS

5.3.1 Dredge Area Determinations

The dredging operations will take place during the winter months and will be conducted through the ice using trenchers and excavators, resulting in less impact to the water column at the dredge site than other potential dredging methods (such as the use of a cutter-head dredge).

Oceanographic conditions during the winter months are quiescent with very small currents that are typically less than 10 cm/s with average current speeds of <5 cm/s (Weingartner and Okkonen 2001). Under-ice concentrations of TSS are very low and typically less than 0.5 mg/L with turbidity values of less than 1 NTU (Trefry et al. 2009). It is expected that the dredging will generate suspended sediment in the water column and raise turbidity levels in the immediate vicinity of the dredging, but due to the relatively low currents and shallow under-ice water depths, any turbidity plumes that are generated will be short in duration and will not be expected to travel any significant distance from the dredge area.

State of Alaska Water Quality Standards (AWQS; 18 AAC 70) sediment criterion for marine water use for the “Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife” require that there must be:

- No measurable increase in concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method.

Applicable AWQS turbidity criteria for marine water uses state that the condition of marine waters:

- May not exceed 25 NTU, or
- May not reduce the depth of the compensation point for photosynthetic activity by more 10% and may not reduce the maximum secchi disk depth by more than 10%.

It is expected that both the sediment criteria for marine water uses and turbidity for marine water uses will be exceeded in the immediate vicinity of the dredge operation; however, effects will be short-lived, will be limited in size, and will not impact any unique biological community. Overall, the effects of the dredging operations on the water quality and oceanographic conditions are predicted to be minimal.

5.3.2 Disposal Reuse Area Determinations

It is expected that one of the four sediment reuse areas (SBAY, WEST, GULL, or DOCK) evaluated in 2015 will be utilized for the disposal of the dredged material, although it is possible that multiple sites will be selected for reuse. Based on the current plan, the dredged material will be transported to the selected reuse area via an ice road that will be constructed for that purpose. The dredge sediment will be placed directly on the sea ice in a band that runs parallel to and adjacent to shore, graded to a uniform depth, and spread over the designated reuse area. Since placement of dredged material will occur during the winter months, this will eliminate all issues with sediment and turbidity associated with initial placement of the dredged material.

During spring break-up, it is expected that the dredge spoils will sink to seafloor directly beneath the ice canopy as the ice melts. Because the sediment will present a dark surface compared to the surrounding white snow and ice, the area under and in the vicinity of the dredge spoils will absorb more solar radiation, hastening the melting process. The much greater weight of the overburden sediment will prevent the ice from lifting off the bottom and carrying any of the sediment from the reuse area. Placement of the dredged materials in the winter and subsequent melting in the spring will give the sediment time to consolidate prior to the open-water season, which will minimize resuspension from the nearshore area.

Since a greater portion of the dredged material is fine grained compared to any of the potential reuse areas, it is expected that wind and wave activity will begin to winnow and erode the deposited material and will transport that material with the prevailing alongshore currents to be eventually deposited into deeper water. The more coarsely grained portion of the dredged sediments is compatible with all of the reuse areas and will provide shoreline protection against erosion. Sediment plumes will be generated in the reuse areas as fine-grained sediments are resuspended into the water column, with resuspension events mainly taking place during storms when wave and currents are greater and when TSS and turbidity are naturally elevated throughout the entire region. It is expected that when sediment plumes are generated during storm activity, they will be masked by natural sediment resuspension processes that have been shown to increase as a function of wind and wave activity.

5.4 Contaminant Determinations

The evaluation and testing of the dredged material and surrounding area were performed during both the 2011 APP and 2014 MSP programs. These sampling programs followed EPA and USACE Seattle District Guidance for dredged material evaluations (USACE 2013 and 2014). In addition, other data from the immediate area and from the region were utilized for a comparison of both the physical and chemical properties of the sediment. Sediment chemistry data for the dredged material were extensively examined in 2014 and again in this report, and there is no evidence that there should be any concern with respect to disposal at any of the four sediment reuse areas.

Likewise, the sediment chemistry data collected for past maintenance dredging operations along West Dock (e.g., Oasis 2006 and 2008) did not indicate the presence of contamination from either metals or petroleum hydrocarbons. All petroleum hydrocarbon data collected between 2002 and 2009 along West Dock were reported as non-detect, and metals concentrations were within the natural variability of background values reported for Beaufort Sea coastal sediments.

Similar results were seen during both the 2011 APP and 2014 MSP efforts: sediments were generally found to be very clean in the proposed dredge area as well as at potential disposal sites that were examined. Metals concentrations were all found to be at or below regional background concentrations, all well below SLs established for the Seattle DMMP (USACE 2014), and mostly below ADEC's recommended SQGs consisting of marine TELs developed by MacDonald et al. (2000). In those instances where an exceedance occurred, the concentration level was within normal regional background levels. There was also no evidence of petroleum contamination. All GRO and volatile BTEX concentrations in the 2011 sediments were found to be below detection limits at all locations.

DRO and RRO concentrations were detected in several dredge and disposal area samples but at concentrations below ADEC's Arctic Zone Cleanup Levels (ADEC 2012). On close examination of the chromatographic fingerprints by the analytical laboratory, it was shown that chromatograms did not resemble a petroleum product or middle distillate pattern. Most of these same samples also had higher TOC concentrations, which indicate high peat levels and potential contribution to the hydrocarbon signature from terrestrial biogenic sources with the normal alkanes dominated by plant waxes. Similar results were seen in the ANIMIDA and cANIMIDA studies, which examined hydrocarbons in detail, where the surficial sediments in the Prudhoe Bay region were found to exhibit a mixture of primarily terrestrial biogenic hydrocarbons with lower levels of naturally occurring petrogenic hydrocarbons (Exponent 2010 and Neff 2010).

The dredge area was also examined for PAHs in both 2011 and 2014, both of which showed low levels of PAH compounds. Individual PAHs were found to be low in all samples analyzed, with all concentrations well below the DMMP SLs and ADEC's SQGs. Total PAH concentrations ranged from 7.6 to 75.4 µg/kg, with slightly higher levels seen at one site resulting from higher TOC and % fine contents in those samples. All of these concentrations are well within the natural background range for Beaufort Sea sediments.

In general, metals concentrations in the dredge area sediments were low and very similar to the four sediment reuse areas examined in 2015. All metals data were well below Seattle DMMP SLs, most metals were well below ADEC-recommended SQGs for TEL, and all metals were below the upper range of background concentrations for the Beaufort Sea coastal area. The only metals concentrations that exceeded any guidelines were arsenic and nickel in several samples and copper in a single sample. These metals slightly exceeded TELs (concentrations at which toxic effects can be rarely expected) but were well below PELs (concentrations where toxic effects can be expected). As noted earlier in this report, Beaufort Sea sediments are naturally high in these metals, and the suspended sediment naturally introduced by rivers in the region has similar concentrations.

Dredge area sediments were also examined to determine whether the metals were bioavailable and potentially toxic by examination of the molar ratios of SEM to AVS. One potential concern is that during the approximate six-month time period when the dredged disposal sediment is present on the ice, the surface layer of the sediment pile will be exposed to atmospheric oxygen and sunlight, which could potentially influence the speciation and bioavailability of metals at the surface of the pile. Upon exposure to atmospheric oxygen, a small fraction of the AVS present in the dredged material will oxidize, thereby increasing the overall ratio of SEM/AVS in the material. However, due to the low gas permeability of the frozen dredged material and the relatively slow rates of the oxidation reactions at subfreezing temperatures, the overall impacts of oxidation on the toxicity of the dredged material will be negligible. The dredged material is not expected to create any toxic conditions as it disperses in the nearshore waters of Prudhoe Bay.

Dredge site samples were further evaluated to assess whether the potentially bioavailable metals are reduced through binding to organic carbon. Using EPA guidance for deriving equilibrium partitioning sediment benchmarks for metal mixtures, each SEM value that exceeded the AVS concentration was normalized to the organic carbon concentration, which is also expected to bind with excess metals. Dredge area sediment indicated no risk to aquatic life with results ranging from less than zero (where AVS exceeds SEM) to 25.1 µMole/g_{oc}, where a value less than 130 µMole/g_{oc} indicates that there is little to no risk to aquatic life (EPA 2005).

Although no evidence of contamination of dredge area sediments was seen in any of the inorganic or organic testing that has been performed, additional testing will most likely be required given the large size of the dredge project and also due to the fact that no biological testing (e.g., toxicity or bioaccumulation studies) of the dredge sediments has been performed to date. As noted in Section 2.1.5, sediment "safety-net" toxicity testing would be necessary to confirm that there is no biological significant response to the dredged sediments and allow the dredged materials to meet the "low" ranking guideline as defined by the DMMP (USACE 2014).

5.5 Aquatic Ecosystem and Organism Determinations

The potential disposal areas that have been selected are in very shallow water adjacent to beaches. Biologically, these areas were shown to not be unique, and they were relatively depauperate as a result of winter freezing and bottom-fast ice mortality of most resident marine life on an annual basis. Because dredge sediment will be placed on top of the area that contains bottom-fast ice out to approximate 4-ft water depths, short-term effects on this area will be minimal since this soft-bottom area is essentially naturally denuded of most benthic life each winter. As a result, it is expected that placement of dredged material in these areas will have minimal short-term impact and no long-term impact on resident biological species. Other potential impacts to biological communities could result from suspended sediment and turbidity plumes that could in turn reduce light penetration and algae growth. However, no hard-bottom or algae communities that could be affected by turbidity were identified in the vicinity of the potential sediment reuse sites.

In terms of the dredge area, as with most any dredging, the biological communities within the designated dredge footprint will be eliminated. Because these areas contain typical soft-bottom biological communities, it is expected that the dredge area will recolonized over time. The length of time for this recolonization will depend somewhat on the rate of sediment infill to the dredge channel and turning basin as a result of natural sedimentation processes. Overall, the effect on this area would be limited in size and considered short term with no long-term impacts or loss to the aquatic ecosystem. Local turbidity of the nearby water column (where the ice is not bottom-fast) may increase during dredging operations, which are scheduled to occur in ice-covered winter conditions, but impacts are expected to be minimal in terms of the biota.

Data from the 2011 APP and the 2014 and 2015 MSPs all show the type of variability and patchiness among taxonomic group abundance that is expected in the Prudhoe Bay area. The marine environment in the Prudhoe Bay area is subject to many different physical forces that ultimately control the structure of the local benthic communities that exist there. These forces such as variable salinity and ice stressing influence the benthic community differentially from the shoreline environment out into deeper water in a gradient manner, dictating benthic abundance and diversity. This pattern is exhibited in the data that were collected during both the 2014 and 2015 MSPs where the harshest and most depauperate areas biologically are in the shallowest water in the nearshore environment, which is subjected to considerable variability in physical conditions. Soft-bottom benthic communities are typically more stable, diverse, and abundant in deeper waters offshore.

Since the dredging activities will take place during the winter, potential conflicts with fish, marine mammals, and migratory birds will be minimized. Because of the low densities of fish typically present during the winter period, only low numbers are expected to be affected by Project activities (see the Project's Essential Fish Habitat Assessment report). Polar bears and ringed seals may be also be in the area but are expected to occur in low numbers. One of the primary concerns for the disposal areas is the potential existence of polar bear maternal dens along the shoreline. Also, ringed seals build subnivian lairs in the offshore area and often take advantage of pressure ridges/cracks in the ice that provide natural cover for their lairs and breathing holes. These and other concerns with respect to marine mammals and threatened or endangered species are addressed in the Project's Wildlife Interaction Plan, which discusses avoidance and mitigation measures that will be followed to avoid or mitigate effects on wildlife from dredging and disposal activities. No migratory birds are expected to be in the area during the winter dredging activities.

During the summer open-water period, birds make extensive use of the marine ecosystem in the Prudhoe Bay area. An estimated 10 million individual birds of more than 120 species use the Beaufort Sea coastal area in Alaska (Johnson and Hertner 1989). Nearly all of the species are migratory, occurring from late May during spring break-up through September. Numerous studies have been conducted in the region over the past 40 years that list species likely to occur in the area. Although many of the species may migrate through, rest, and/or feed in the vicinity of the Project area, the loss of shallow-water habitat at the Project's disposal site locations is not expected to adversely affect bird populations based on the relative abundance of this habitat type in the general area.

The potential impact of the dredging and disposal activity on special aquatic sites is not an issue because no special aquatic sites exist in the vicinity of the planned operations. The only special aquatic site in the region that has been identified is the Boulder Patch, which is located 20 miles to the east of West Dock in Foggy Island Bay. This site is a unique hard-bottom biological community that has been the subject of numerous investigations over the past 30+ years including impacts of increased turbidity as a result of potential oil development in its immediate vicinity (i.e., the Liberty Project). Sampling that was performed as part of the 2011 APP, 2014 MSP, 2015 MSP, and other studies in the vicinity of both the proposed dredging and the potential disposal locations have not identified any other special aquatic site, hard-bottom area, or other unique biological communities in any area likely to be affected by the dredging and disposal operations. Other special aquatic sites that are identified in the regulations (40 CFR §230.40-45), including sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes, do not exist in the planned area of operations.

Alaska Native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Because the dredging will occur during the winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

5.6 PROPOSED DISPOSAL SITE DETERMINATIONS

Disposal sites SBAY and WEST were found to be very similar in terms of coastal geomorphology and exposure to wind and waves with currents being wind driven and parallel to shore. GULL is somewhat more exposed on the northern side but more protected to the south as evidenced by the wide range of grain size that was seen at the site. Overall, DOCK was found to be the most protected site with greatest amount of fine-grained sediments. All four disposal sites examined in

2015 are similar in terms of water depths within the deposit zone, with depths increasing from zero at the shoreline to ~4 ft depth at ~900 ft from shore.

Following dredge disposal, dispersion of very fine to silty fill material will occur outside the designated placement area during the subsequent open-water periods. This widespread dispersion would occur primarily during storm activity by natural means and would result in a thin layer of material that would be transported along and offshore adjacent to the disposal area and would result in no adverse environmental impacts. State of Alaska water quality criteria for sediment and turbidity will be exceeded in the immediate vicinity of the disposal activity. It is expected that ADEC's existing 401 Water Quality Certifications that will be issued for the dredging permit will address this issue and that no other exceedances would occur that would restrict the discharge of dredged materials. Moreover, it was determined that the material proposed for the dredging program will consist exclusively of clean marine sediments meeting regulatory criteria for either inland disposal or reuse for beach nourishment. Thus, the discharge of the dredge spoils at the disposal site would not be expected to cause or contribute to any applicable violation of State of Alaska water quality standards, violate any applicable toxic standard, jeopardize the existence of any species listed on the Endangered Species Act of 1973, or violate any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research and Sanctuaries Act of 1972.

A key point that is listed in the regulations (40 CFR §230.80) to shorten the permit processing time is advanced identification of the disposal area(s). Three potential disposal areas were examined in 2014, and four were examined during 2015 that included a re-examination of two sites from 2014. These areas have been characterized in terms of their physical, chemical, biological, and general oceanographic characteristics in sufficient detail to allow an evaluation of their appropriateness and suitability for the disposal of dredged material.

5.7 DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ECOSYSTEM

No cumulative effects on the aquatic ecosystem were identified in this evaluation.

In terms of the dredge area, as with most any dredging, the biological communities within the designated dredging footprint will be eliminated. Since these areas contain typical soft-bottom biological communities, it is expected that the dredge area will be recolonized over time, the length of which will be dependent upon the rate of natural sediment infill to the trenches. Overall, the effect on this area would be limited in size and would not result in long-term or cumulative impacts or loss to the aquatic ecosystem.

In terms of disposal operations, the winter disposal will ensure that no suspended sediment or turbidity plumes are generated during the actual placement of the dredged material. This will allow the sediment to settle and consolidate prior to being influenced by wave and current activity during the subsequent open-water period. The disposal areas have been selected that are in very shallow water adjacent to beaches. These areas are not biologically unique; they are relatively depauperate as a result of winter freezing and bottom-fast ice essentially resulting in the mortality of most resident life on an annual basis. As a result, it is expected that placement of dredged material in these areas will have minimal short-term effects, and there will be no long-term or cumulative impacts from the Project. In addition, the planned disposal of the dredged material will be for beneficial reuse as shoreline protection to mitigate erosion

5.8 DETERMINATION OF SECONDARY EFFECTS ON THE AQUATIC ECOSYSTEM

No secondary effects on the aquatic ecosystem were identified during this analysis and evaluation.

5.9 OTHER REGULATORY DETERMINATIONS

For the most part, potential effects on human use characteristics that are addressed in the 404(b)(1) guidance are not applicable to the proposed dredge activity. There are no municipal or private water supplies in the area; recreational and/or commercial fishing activities do not occur in the vicinity of the dredge or any of the disposal sites. Water-related recreation does not occur in the area and it is not expected that the activity would affect local aesthetics, nor are there any parks, historic monuments, national seashores, research sites, or similar preserves in the area. Aesthetics and visual impacts resulting from the placement of fill material in the nearshore area would be minor given the remote location and limited access to the area. Also, given the proposed locations of the disposal areas, no impacts to any navigational areas or channels are expected to occur. The winter construction timing will also aid in minimizing conflicts with other activities that occur at West Dock such as the tug, barge, and other oil industry support boat traffic prevalent in the summer months.

Alaska Native subsistence activities related to bowhead whaling do occur in the region during late August through mid-September. Because the dredging will occur during the winter, this will eliminate any potential conflict with whaling and other subsistence activities such as hunting, fishing, and gathering.

One of the primary means planned to minimize adverse impacts is to perform dredging and disposal operations during the ice-covered winter months. The winter construction timing ensures that the operations will occur during a period when biological activity in the area is minimal to nonexistent in terms of fish, marine mammals, and birds. Also, oceanographic conditions are quiescent and the ice canopy reduces the effective water depth; thus, suspended sediments generated by the dredge activities will only be transported a short distance before settling to the bottom. The winter construction will also avoid conflicts with vessel traffic that occurs near West Dock during summer.

6.0 ACRONYMS AND TERMS

Term	Definition
~	About or approximately
°C	Degrees Celsius
<	Less than
%	Percent
µg/kg	microgram per kilogram
µMole/g_{oc}	micro-Moles per gram of organic carbon
µSiemens	micro-Siemens unit (unit of electrical conductance)
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AK	Alaska
ANIMIDA	Arctic Nearshore Impact Monitoring in the Development Area Program
APP	Alaska Pipeline Project (2011)
APDES	Alaska Pollutant Discharge Elimination System
ASTM	American Society for Testing and Materials
AVS	Acid-volatile Sulfides
BOEM	Bureau of Ocean Energy Management
BP	BP Alaska LNG LLC
BSMP	Beaufort Sea Monitoring Program
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
cANIMIDA	Continuation of ANIMIDA Program
CFR	Code of Federal Regulations
cm	Centimeters
cm/s	Centimeters per second
CoC	Chemical of Concern
CTD	Conductivity, Temperature, and Depth Recorder
CWA	Clean Water Act
D	Dominance (benthic community index)
DDT	Dichlorodiphenyltrichloroethane
DEIS	Draft Environmental Impact Statement
DH	Dock Head
DMMP	Dredged Material Management Program
DMMU	Dredged Material Management Unit
DO	Dissolved Oxygen
DOCK	Disposal reuse site west of West Dock
DRO	Diesel Range Organics
DRO-SGT	Diesel Range Organics with Silicate Gel Treatment Cleanup
E	Evenness (benthic community index)
EGG	Egg Island disposal reuse site - Site 3, sampled during 2014 MSP
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
ERL	Effects Range Low
FEIS	Final Environmental Impact Statement
FEP	Field Execution Plan
ft	Feet or foot
ft^3	Cubic feet
ft^3/yr	Cubic feet per year
g	Grams
GRO	Gasoline Range Organics

Term	Definition
GTP	Gas Treatment Plant
GULL	Gull Island disposal reuse site
H	Shannon Diversity (benthic community index)
J	Data qualifier = estimated value for concentrations between the MDL and MRL.
KLI	Kinnetic Laboratories, Inc.
Km	Kilometer
Knot	Nautical miles per hour
L	Liter
lb/yr	Pounds per year
LCS/LCSD	Laboratory Control Spike/Laboratory Control Spike Duplicate
LNG	Liquefied Natural Gas
m	Meters
m^2	Square meters
MDL	Method Detection Limit
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MLLW	Mean Lower Low Water
mm	Millimeters
MMS	Minerals Management Service
MRL	Method Reporting Limit
MSL	Mean Sea Level
MSP	Marine Sampling Program (2014 or 2015)
MS/MSD	Matrix Spike/Matrix Spike Duplicate
n	Number of individuals
ND	Data qualifier = Not Detected or analyte was <5x the concentration seen in the associated method blank and below the MRL.
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPDES	National Pollutant Discharge Elimination System
NS&T	National Status and Trends
NTU	Nephelometric Turbidity Units
MSP	Marine Sampling Program
OBS	Optical Backscatter Measurement
OCSEAP	Outer Continental Shelf Environmental Assessment Program
PAHs	Polycyclic Aromatic Hydrocarbons
PBTL	PBU Gas Transmission Line
PBU	Prudhoe Bay Unit
PCBs	Polychlorinated Biphenyls
PEL	Probable Effects Level
POP	Persistent Organic Pollutant
ppm	Parts per million
ppt	Parts per thousand
PRUD	Prudhoe Bay Optional dredge disposal site (2014 MSP)
PSEP	Puget Sound Estuary Program
psu	Practical Salinity Units
PTTL	PTU Gas Transmission Line
PTU	Point Thomson Unit
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
R^2	Regression
Rep.	Replicate

Term	Definition
RRO	Residual Range Organics
RRO-SGT	Residual Range Organics with Silicate Gel Treatment Cleanup
S	Species richness (benthic community index)
SBAY	South Prudhoe Bay disposal reuse site
SEM	Simultaneously Extracted Metals
SGT	Silica Gel Treatment
SHC	Saturated Hydrocarbons
SL	Screening Level
SOP	Standard Operating Procedure
spp.	Species
STP	Seawater Treatment Plant
SQQ	Sediment Quality Guideline
TBTs	Tributyltins
TEL	Threshold Effects Level
TOC	Total Organic Carbon
TPHC	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
TVS	Total Volatile Solids
UCM	Unresolved Complex Mixture
US	United States
USACE	United States Army Corps of Engineers
WEST	West Prudhoe Bay disposal reuse site
yd^3	Cubic yards
Z	Data Qualifier = The chromatographic fingerprint does not resemble a petroleum product.

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APPENDIX R.4 2015 RESULTS OF TEST TRENCH FIELD STUDY TO SUPPORT WINTER NAVIGATION CHANNEL CONSTRUCTION (USAI-UR-SRZZZ-00-000052-000)

Alaska LNG

RESULTS OF TEST TRENCH FIELD STUDY TO SUPPORT WINTER NAVIGATION CHANNEL CONSTRUCTION

USAI-UR-SRZZZ-00-000052-000

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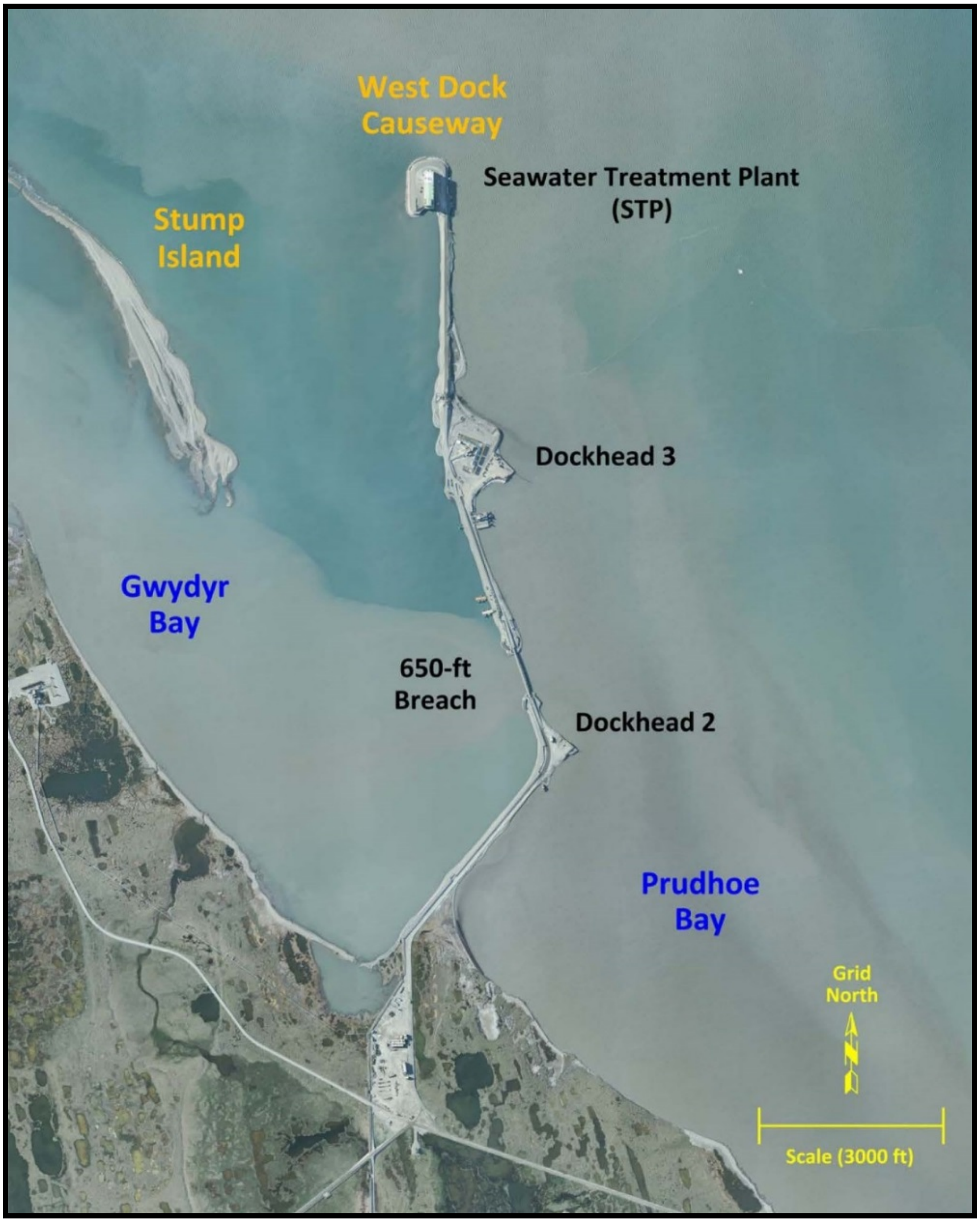
1.0 PURPOSE AND SCOPE

ExxonMobil is seeking to commercialize North Slope natural gas through construction of a gas treatment plant (GTP) in Prudhoe Bay with an export pipeline to Southcentral Alaska for the Alaska Liquefied Natural Gas (LNG) project. The current strategy is to transport the GTP modules via barge to West Dock Dockhead 2 over the course of three to four summer seasons beginning in 2021. The West Dock vicinity is shown in Figure 1-1.

Figure 1-1: Project Area



This strategy, investigated in detail as part of the Alaska Pipeline Project (APP) in 2012, requires construction and maintenance of an approximately 12,000 ft long dredged channel. As currently conceived, the navigation channel will be dredged to a depth of 16 ft below National Ocean Service (NOS) mean lower low water (MLLW). An 800 ft x 1,000 ft turning basin will be dredged to the same depth near the Dockhead to facilitate vessel maneuverability.

At the conclusion of the APP, it was recommended that the navigation channel be constructed during the winter months using on-ice construction techniques developed as part of prior subsea pipeline installation and offshore island construction efforts on the North Slope. To assess the feasibility of the proposed winter dredging techniques, a test trench construction program was conducted during February – April 2015. The program was conducted by Alaska Frontier Constructors (AFC) and Coastal Frontiers Corporation (CFC) on behalf of AECOM and ExxonMobil (Alaska LNG).

The purpose of this report is to document the findings of the test trench program and utilize those findings to evaluate the feasibility of constructing the proposed channel during a single winter season. The sections that follow provide pertinent background information, summarize test trench construction activities and results, and using these results, evaluate the feasibility of the proposed winter construction scenario.

2.0 HISTORICAL INFORMATION

In southern latitudes, a large ocean-going dredge would be used to construct the West Dock navigation channel. Such activities are commonly performed at large port complexes worldwide. Given the limited summer open-water season at Prudhoe Bay and environmental concerns related to Native subsistence whaling needs, large-scale summer dredging operations in this area may not be possible. Therefore, use of the winter ice-sheet to perform channel dredging is considered to be a promising alternative and is the focus of this study.

2.1 ANALOGUES THAT SUPPORT WINTER DREDGING

Since the advent of oil exploration and production operations at Prudhoe Bay, methods have been devised to effectively utilize the cold winter months for onshore and offshore construction (Agerton, 1983; Munday and Bricker; 1987; Gadd, et al., 2001; Leidersdorf, et al., 2008; Gadd, et al., 2012). Given limited marine construction resources during the summer open-water season, use of the winter sea ice as a work platform has been successfully performed since the early 1980s. Winter construction techniques can successfully support a dredging program conducted through the winter ice sheet. Previous offshore operations that have utilized techniques necessary for a winter dredge program include extensive ice road construction, gravel extraction and hauling to support island construction, and subsea pipeline installations.

2.1.1 Subsea Pipeline Installation

Subsea pipeline installations under Arctic conditions have utilized the winter ice sheet as the primary work platform. Relevant projects include buried pipeline installations for Northstar (BPXA - 2000), Oooguruk (Pioneer - 2007), Nikaitchuq (ENI - 2009), and Piltun Bay, Sakhalin (Exxon Neftegas - 2009). All of these projects included the early winter construction of an ice road/work platform over the pipeline right-of-way for pipe assembly, trench slotting and ice removal. The pipeline lengths varied from four to six miles. All of the projects have utilized similar methods that include the cutting of an eight foot wide ice slot, excavation of sea ice and the seabed by an excavator straddling the ice slot, placement of the pipeline (or bundle) into the trench using traditional side-boom techniques, and backfill with the excavated seabed soils. In Alaska, access to the ice road/platform has been available in early February with pipeline installation and backfill completed by late April.

2.1.2 Offshore Ice Road and Work Platform Construction

Ice roads are constructed on the sea ice by drilling a hole in the natural ice sheet and pumping seawater onto the ice surface. As the sea water (having a temperature of +29^{o}F) spreads over the sea ice, the cold winter air temperatures (-40^{o} to +10^{o}F range) cause rapid freezing. Successive flooding of the roadway will promote artificial thickening of the ice. The appropriate thickness for ice roads vary with road use, but ice thicknesses of six to ten feet can be produced. The flooding of the ice should begin as soon as possible in early winter, but certainly by early December to allow use of the completed ice road by early February. The ice road width can vary by project, but can be as wide as 300 feet if high traffic loads are expected. Such a wide road allows the alternating of traffic lanes so that periodic maintenance of the road surface can occur. While the bulk of the ice road is composed of frozen seawater, the top surface is often covered with fresh water as a more durable running surface. In shallow waters, ice roads can become grounded without pumping, as the natural freezing of the sea ice progresses. Ice chips can also be produced and spread on the ice road/pad to promote grounding on the seafloor.

As an example of offshore ice road construction, the leading contractor that performs such work at Prudhoe Bay (AFC) routinely constructs many miles of ice roads to access onshore and offshore sites during most winters. The ice road length needed for the proposed dredge channel project will be about 2.5 miles, with additional roads required to access the shallow water disposal site(s). The yet-to-be defined disposal site(s) would require ice road lengths of three to ten miles over very shallow water routes. Ice road construction of this magnitude will not be difficult and should yield an excavation start date in early February.

2.2 SCHEDULE OF WINTER ON-ICE WORK

Based on the historical use of offshore ice roads for island construction and pipeline installations, the following typical schedule will be followed:

- Survey ice road using snow machines, late November
- Begin flooding ice road, early-December
- Complete ice road construction, early February
- Begin channel excavation and heavy truck traffic on ice road, early February
- Complete offshore operations, April 26
- Demobilize and terminate all on-ice operations, May 1

3.0 PLANNED DREDGE EXCAVATION AREA

The following sections summarize the navigation channel and potential disposal sites used to develop the test trench program and to evaluate the feasibility of the winter dredging scenario.

3.1 NAVIGATION CHANNEL AND TURNING BASIN

The navigation channel alignment utilized as part of the 2015 Winter Test Trench Program and the feasibility evaluation presented herein is illustrated in Figure 3-1 and described below. The precise alignment coordinates are provided in Table 3-1. This alignment (30N) was originally recommended as part of the Alaska LNG Project 2014 Bathymetric Survey Program conducted by Coastal Frontiers (Doc No. USAI-EX-SRZZZ-00-000003-000). The primary design considerations that influenced the channel selection were minimization of the dredged volume and acceptable tug/barge navigability within the channel and turning basin.

Table 3-1. Proposed Navigation Channel Alignment

Desc.	Northing	Easting	Radius
[-]	[US-FT]	[US-FT]	[ft]
Start (14-ft Isobath)	6,004,594	1,826,432	-
PC-1	5,993,974	1,824,263	500-ft
PT-1	5,993,743	1,824,147	
End (Proposed Dock)	5,992,883	1,823,385	-

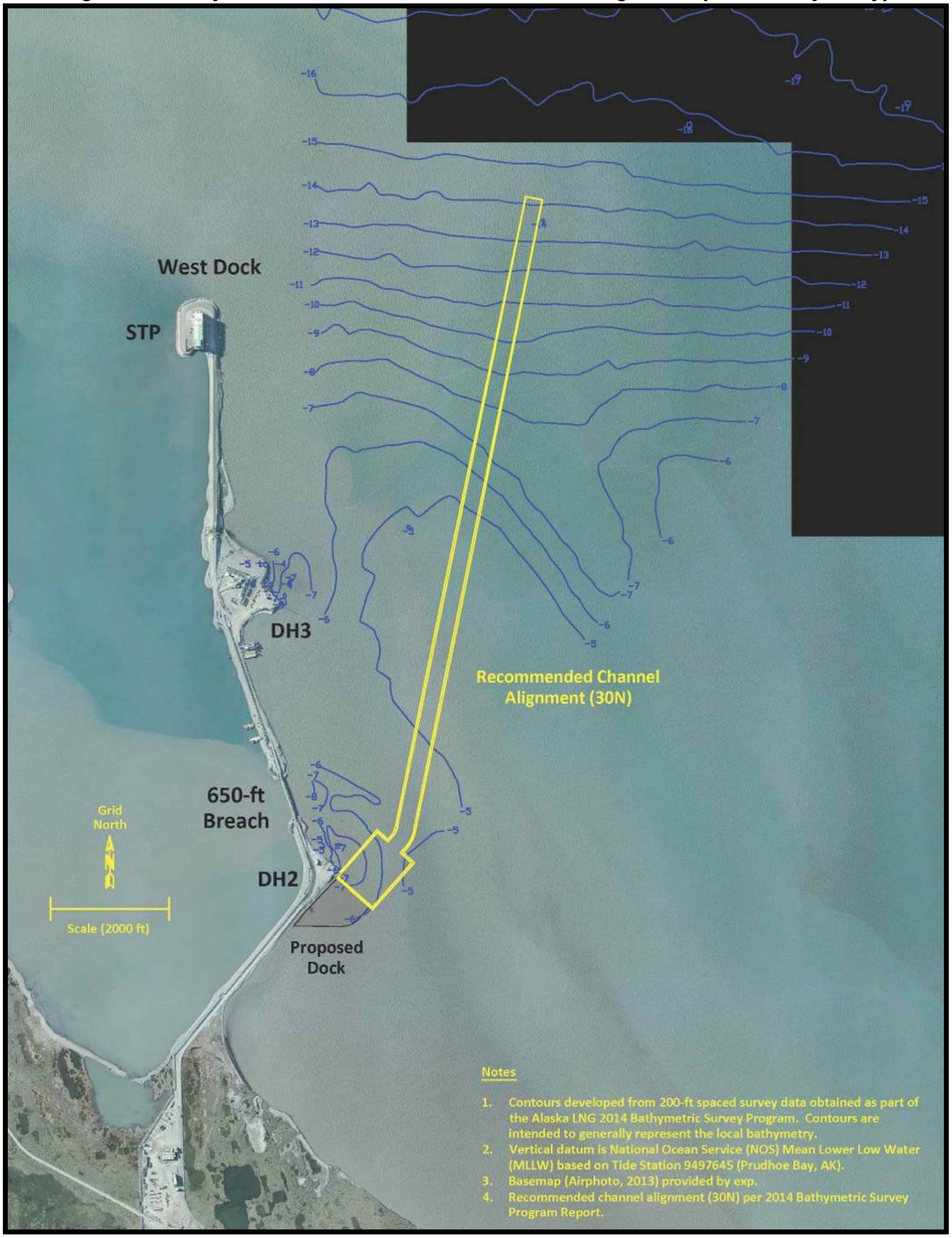
Notes:

1. Horizontal Datum is Alaska State Plane Zone 4, NAD83 (2007).
2. Alignment based on side-slope of 3:1 (H:V).

As currently conceived, the required bottom elevation of the channel is -14 ft below NOS MLLW. To accommodate an over-dredge contingency, the navigation channel will be dredged to -16 ft seaward to the -14 ft (MLLW) depth contour. An 800 ft x 1,000 ft turning basin will be dredged to the -16 ft elevation near the Dockhead to facilitate vessel maneuverability.

It should be noted that the channel proposed in the 2014 Bathymetric Survey Report extends to the 16 ft (MLLW) isobath. However, the alignment utilized herein terminates at the 14 ft (MLLW) isobath, which corresponds to the controlling depth for the Sealift.

Figure 3-1. Project Area with "BaseCase" Channel Alignment (2014 Bathymetry)



Navigation Channel

- Controlling depth (and start of channel alignment) = 14 ft (MLLW)
- Design depth (including 2 ft over-dredge allowance) = 16 ft (MLLW)
- Design width at bottom = 280 ft
- Side-slope (assumed) = 3:1 (H:V)
- Maximum turn along route = 30º

Turning Basin

- Controlling depth = 14 ft (MLLW)
- Design depth (including 2 ft over-dredge allowance) = 16 ft (MLLW)
- Design width = 775 ft
- Design length = 1,000 ft
- Side-slope (assumed) = 3:1 (H:V)

Estimated Dredge and Disposal Volumes

- Dredge Volume = 1,441,000 cy
- Disposal Volume (including 25% bulking factor) = 1,801,000 cy

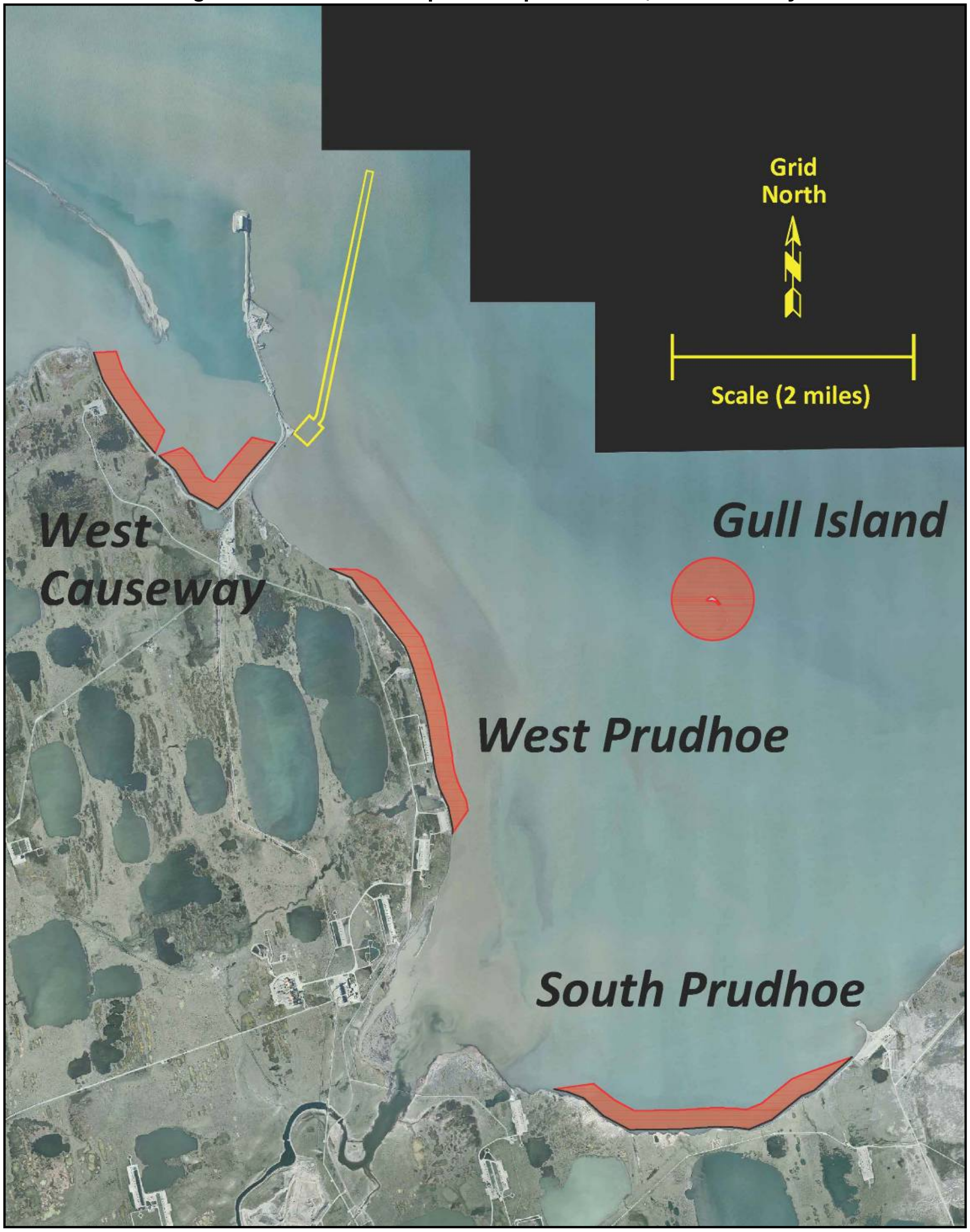
3.2 CANDIDATE SPOILS DISPOSAL AREAS

The disposal location for the dredged channel spoils has yet to be selected; however, four nearshore sites have been identified, as shown in Figure 3-2. Should the dredged channel volume be rounded up from the computed template volume to total 1.5 million cubic yards (cy) of spoils, a bulking factor of 25% (see Section 4.5.3) would yield a disposal volume of 1.875 million cy. To minimize traffic, haul units, fuel consumption, air pollution and cost, there is a benefit to minimizing the travel distance to the disposal site. All sites exist in shallow nearshore waters where winter ice roads can form naturally as the air temperatures decrease during the early winter. The spoils would be placed on the natural sea ice to an elevation no higher than five feet above the sea ice surface. At the coastal sites, the spoils would be placed over an alongshore distance of 2 nautical miles (2,160 ft). At Gull Island, the spoils would encircle the island. During the subsequent summer, the grounded sea ice would melt in-place thereby depositing the spoils pile onto the seabed. The spoils disposal site for the recent test trench program was immediately offshore from the AGI Pad, along the westerly shore of Prudhoe Bay.

3.2.1 West Shore of Prudhoe Bay

The west shore of Prudhoe Bay is situated in shallow water along an eroding coast. There are several oil production pads near the coastline in this area, as seen in Figure 3-2. Disposal of spoils in this nearshore area is considered beneficial in that the material would serve as an effective erosion buffer. The disposal area would be about 12,160 ft in length, 5 ft above the ice surface when the spoils are placed on the sea ice, and 916 ft wide. The disposal area would constitute about 256 acres. The round-trip haul distance between the dredge channel and disposal site varies from 2 to 10 miles.

Figure 3-2. Candidate Spoils Disposal Sites, Prudhoe Bay



3.2.2 Expansion of Gull Island

Gull Island is a former oil exploration island located in the shallow waters of central Prudhoe Bay. The island was constructed in the late 1970s and is surrounded by a steel sheet-pile wall. Birds nest on the island during the summer. Expanding the island with the dredged spoils would expand the potential bird nesting area thereby providing beneficial reuse of the material.

The dredged spoils would be trucked to the site over a grounded ice road. The initial spoils quantity (~1.875 million cy) would surround the island in a circle having a radius of about 1,889 ft and an area of 255 acres. As in the case above, the spoils height would be 5 ft above the sea ice when placed at the site. The haul distance (round-trip) between the dredge channel and disposal site is 8 – 9 miles.

3.2.3 West Side of Causeway

The west side of the base of the West Dock Causeway is considered another viable location for spoils disposal. The area is quite shallow and fronts the Pt. McIntyre PM-1 Production Pad. In addition, the area is adjacent to the south leg of the causeway which supports the elevated oil and seawater pipelines emanating from the Pt. McIntyre PM-2 Pad and the Seawater Treatment Plant. The west shore of the causeway has experienced erosion. Gravel bags have been placed along portions of the causeway to stabilize the eroding shore. Disposal of the dredged sediments in this area would be considered beneficial reuse due to the erosion control that would result. The round-trip haul distance between the dredge channel and disposal site is about 5 miles; less than all other alternatives.

The area envisioned for the disposal site would encompass a linear swath along the coast with dimensions comparable to that at West and South Prudhoe Disposal Sites. The length of the placement would be 12,160 ft with a width of 916 ft and a spoils height of 5 ft above the natural sea ice surface. The area of the disposal site would be 256 acres. The spoils placement may be segmented to accommodate local stream outflows in the area. Access to this site would be provided either around the north end of the causeway (requiring the construction of a floating ice road segment) or beneath the bridge at the 52 ft breach. This breach has been blocked with littoral sediments and no water exchange through the breach has occurred during the past 20 years. There is adequate vertical clearance beneath this bridge to accommodate the truck traffic, as shown in Figure 3-3. Traffic control near the bridge may be necessary at this route constriction during the haul activity. Truck travel beneath the 650 ft breach bridge is not considered feasible due to the height restrictions imposed by the underside of the bridge.

Figure 3-3. Possible Route of Spoils Disposal Trucks Beneath Bridge at 52 foot Breach

3.2.4 South Shore of Prudhoe Bay

This potential disposal area is in the nearshore shallow waters along the south side of Prudhoe Bay, extending about two nautical miles west from East Dock. This shore is eroding with oil pipelines located on the tundra several hundred feet south of the coastline. The trench spoils would reduce the natural erosion rate and thereby provide beneficial reuse of the sediments.

This location would result in the greatest haul distance from the dredged channel, with a round-trip haul distance ranging from 12 to 20 miles. The disposal site is envisioned to be 12,160 ft long, 916 feet wide and having a maximum spoils pile elevation of five feet above the natural sea ice. The area of the disposal site would be 256 acres.

3.2.5 Combination of Disposal Sites

To minimize the impacts of spoils disposal at a single site, several disposal sites could be used. This option will be discussed in Section 5.5.

4.0 WINTER TEST TRENCH FINDINGS (APRIL 2015)

4.1 OVERVIEW

In an effort to assess the feasibility of the proposed winter dredging techniques, a test trench construction program was conducted during the 2014-15 winter season. The objectives of the program were as follows:

1. Assess the feasibility of the proposed through-ice dredging techniques.
2. Assess the feasibility of the proposed dredge disposal techniques.
3. Assess the efficiency and functionality of the equipment proposed for channel construction.
4. Verify the effectiveness of the selected execution strategy with respect to minimizing safety risks on grounded and floating sea ice.

In addition to the objectives noted above, monitoring data obtained at the test trench sites over subsequent open-water seasons will be used to quantify site-specific sedimentation rates to aid in assessing the impact of sedimentation on navigation within the dredged channel. The sections that follow describe the test trench sites, activities undertaken at each site, and results of the construction monitoring program.

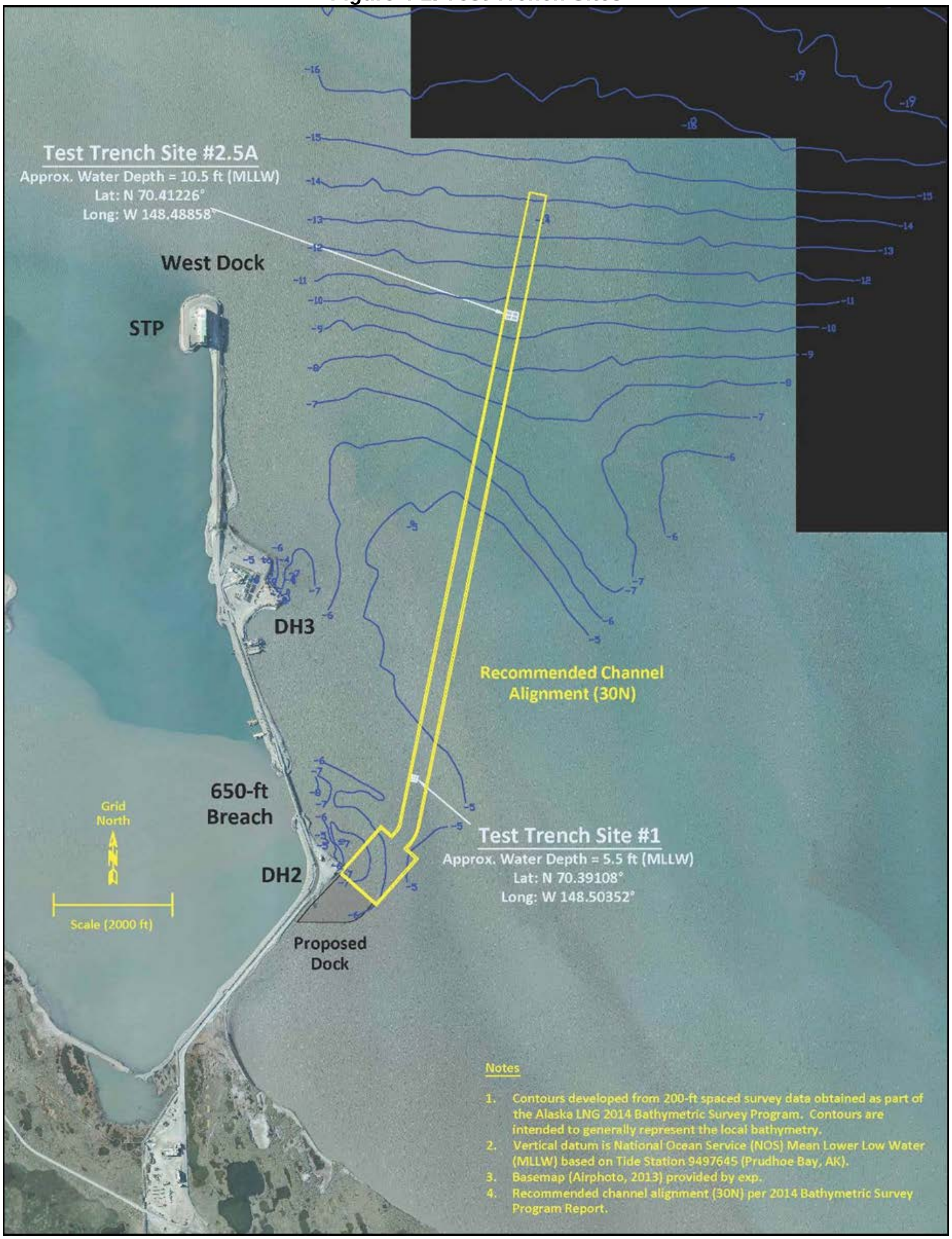
4.2 TEST TRENCH AND DISPOSAL SITES

Two test trench sites were constructed as part of the 2015 Winter Test Trench Program (Sites #1 and #2.5A), as illustrated in Figure 4-1. These sites were selected to encompass the range of conditions anticipated to impact construction and sedimentation during creation of the final navigation channel. The primary factors that influenced site selection included the local water depth, proximity to West Dock Causeway, anticipated ice conditions during construction, and permit stipulations. Additional detail is provided in the work plan developed for the program (Doc No. USAG-EX-SPZZZ-00-0003). It should be noted that Site #2.5A is also referred to as Site #2.5 herein for simplicity.

4.2.1 Test Trench Site #1

Test Trench Site #1 is located in the shallow waters adjacent to Dockhead 2 (Figure 4-1). This site was selected to evaluate the safety and feasibility of the proposed construction techniques on a grounded ice platform. In addition, the site represents that portion of the channel nearest to the causeway where sedimentation is expected to be influenced by the shallow water depth and proximity to the causeway and 650 ft breach. Site details are provided below. A conceptual illustration of the site is provided in Figure 4-2. Figure 4-3 is a photo that was taken at the site 6 days after the completion of the excavation activities.

Figure 4-1. Test Trench Sites



Test Trench Site #1

- Water Depth = 5.5 ft (MLLW)
- Target Dig Depth = 16.0 ft (MLLW)
- Depth of Dig = 10.5 ft
- Approximate Ice Thickness = 7.5 ft
- Horizontal Dimensions at Bottom of Test Trench = 100 ft x 100 ft (nominal)
- Estimated Excavation Volume = 3,500 cy (based on as-built survey)

The horizontal dimensions (100 x 100 ft at the bottom of the trench) were chosen such that the total volume of material excavated is less than 8,000 cy, as prescribed by the permit stipulations. These dimensions, while less than those utilized further offshore, allow the feasibility and rate of construction to be assessed near the maximum dig depth (10.5 ft below ambient seabed) within the channel.

Figure 4-2. Conceptual Illustration for Test Trench Site #1

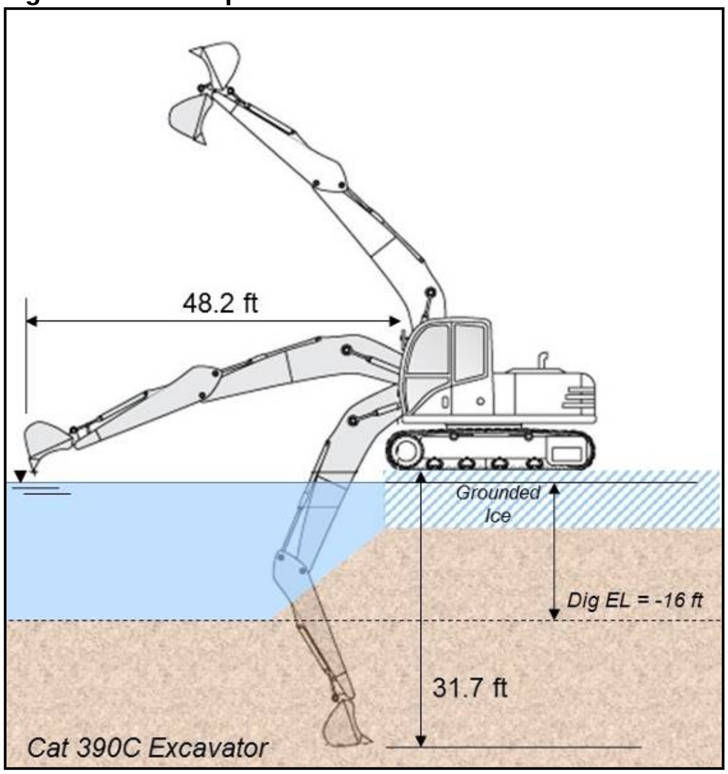


Figure 4-3. Test Trench Site #1 (April 9, six days after completion of excavation)

4.2.2 Test Trench Site #2.5

Test Trench Site #2.5 is located about 2,000 ft from the northern end of the proposed channel (Figure 4-1). The primary purpose of this site is to evaluate the safety and feasibility of the through-ice dredging techniques when conducted from a floating ice platform. In addition, the site represents the offshore portion of the channel where the influence of the causeway on sedimentation will likely be reduced. Site details are provided below, and a conceptual illustration is provided in Figure 4-4. Figure 4-5 illustrates Site #2.5 following the excavation activities.

Test Trench Site #2.5

- Water Depth = 10.5 ft (MLLW)
- Target Dig Depth = 16.0 ft (MLLW)
- Depth of Dig = 5.5 ft
- Approximate Ice Thickness = 8.6 ft
- Horizontal dimensions at bottom of Test Trench = 140 ft x 200 ft (nominal)
- Estimated Excavation Volume = 7,400 cy (based on as-built survey)

Given the modest excavation depth (5.5 ft below the ambient seabed), the horizontal dimensions (140 x 200 ft at the bottom of the trench) were chosen to be greater than Site #1 to more accurately estimate the sustained speed of long ice cuts, ice removal, and dredging along a channel width nearly as great as the full-scale channel (280 ft). The larger trench also provides additional capacity for sediment accumulation in subsequent seasons.

Figure 4-4. Conceptual Illustration for Test Trench Site # 2.5

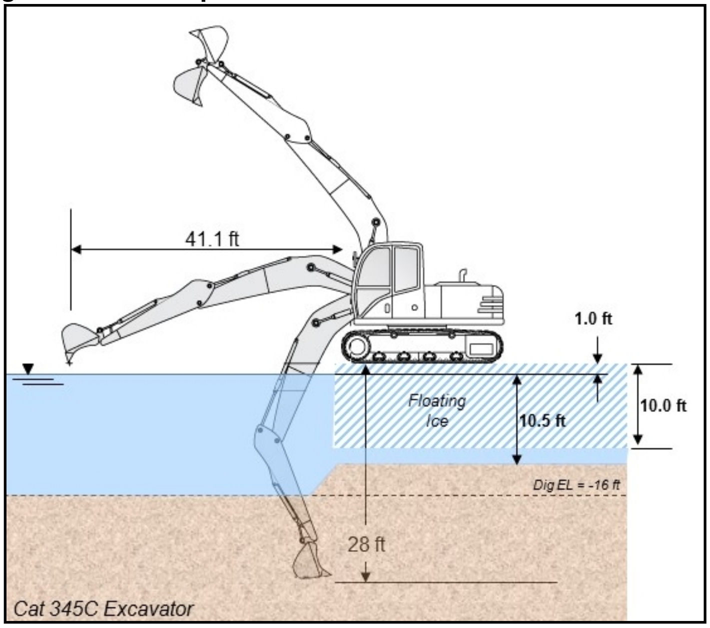


Figure 4-5. Test Trench Site #2.5 (April 9, 2015, one day after completion of excavation)

4.2.3 Disposal Site

The disposal site utilized for the test trench program is located on the bottom-fast sea ice adjacent to BPXA's AGI Pad, 3.5 miles south of Dockhead 2 on the west shoreline of Prudhoe Bay (Figure 4-6). The AGI pad extends approximately 1,700 ft alongshore and is located in close proximity to an actively eroding shoreline (based on 2013 imagery and ground inspection). Use of the excavated materials from the test trench to nourish the shoreline adjacent to the drill site is considered to be a beneficial use of these sediments. Figure 4-7 illustrates the condition of the pad in 2012, prior to gravel placement along approximately 450 ft of the pad edge nearest the waterline.

Figure 4-6. Test Trench Spoils Disposal Site

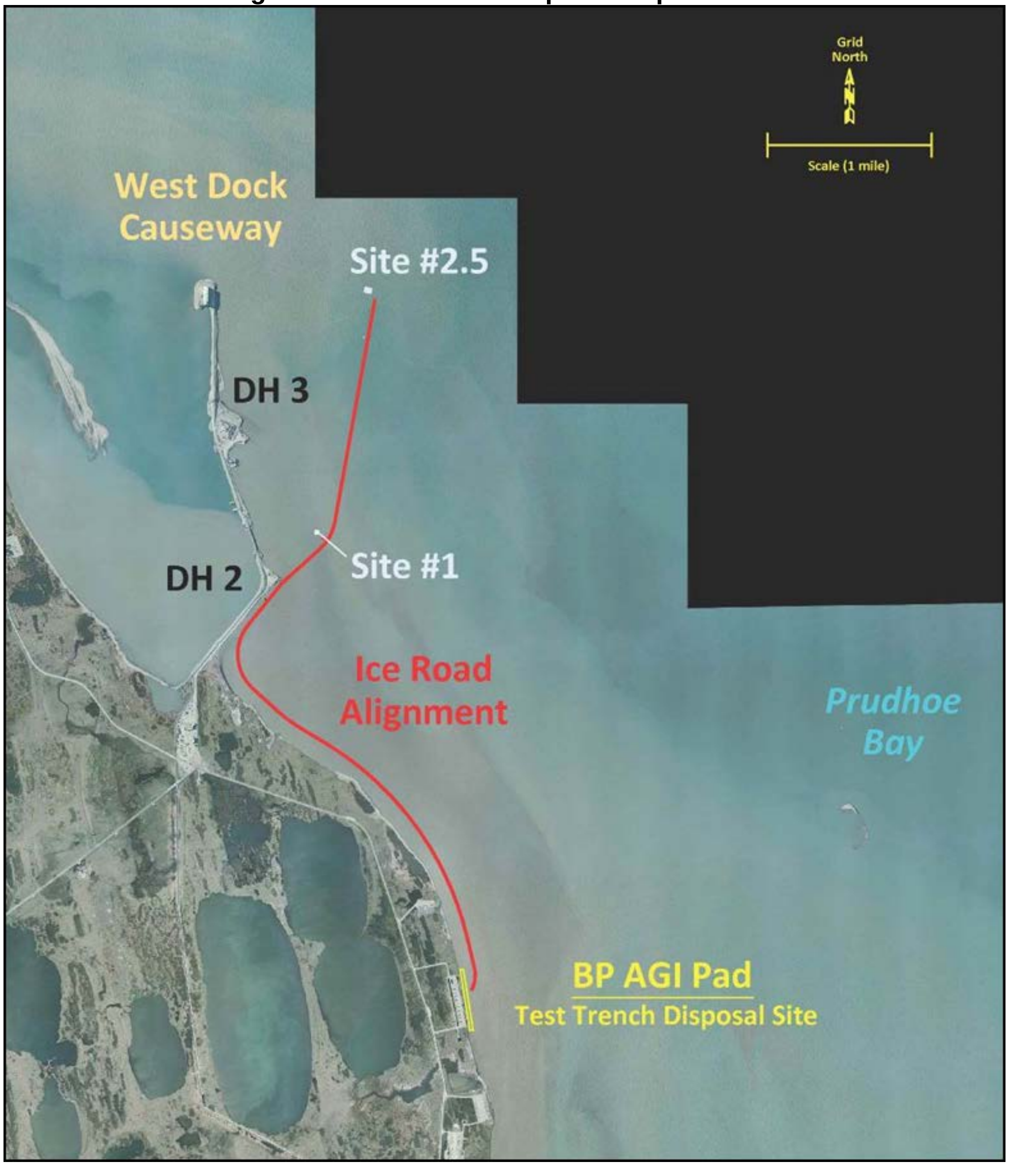


Figure 4-7. Coastal Conditions at AGI Pad, West Prudhoe Bay (2012, looking north)

4.3 CONSTRUCTION ACTIVITIES AND MONITORING DATA

This section describes the primary construction activities undertaken at each of the test trench sites. It should be noted that prior to the activities described below, ice roads and work pads were constructed by AFC and observed by others (AECOM / Alaska LNG). However, these work tasks are not presented herein.

At each site, the trench was constructed in segments (or swaths) approximately 10-13 ft wide and oriented with the long axis parallel to the northern border of the site. Accordingly, the width of each swath was 100 ft and 200 ft at Sites #1 and #2.5, respectively. At both sites, the work began on the north end of the trench and progressed to the south. At Site #1, nine swaths were excavated, and at Site #2.5 thirteen swaths were excavated.

For each swath, the sequence of construction began with slotting the sea ice to facilitate ice removal. Next, the ice along that swath was removed to expose the seabed. The ice was either pushed to the edges of the pad, or hauled by truck to a grounded ice location. Finally, the seabed material was excavated and hauled to the disposal site. The following sections describe each step in greater detail and provide the monitoring data obtained, which serve as the basis for the feasibility assessment presented herein.

Table 4-1 provides a summary of the daily activities undertaken during the program. The work was accomplished over the 13-day period spanning March 27 and April 8, with two days (March 31 and April 1) allocated to weather downtime due to high speed easterly winds. The air temperatures were typical for late March, fluctuating in the -5º to +5º F range. Water levels were monitored at the NOAA tide gage at West Dock and were found to be near the predicted tide levels, with the exception of the easterly storm period when the water level was lowered about one foot below the predicted level for about a day.

Table 4-1. Alaska LNG Test Trench Field Study Chronology

Day	Date	Activity
1	25-Mar	CFC field crew travels to Deadhorse, AK
2	26-Mar Noon 3 pm 4 - 7:30 pm	Mobilize field gear; Pick-up/unpack air freight; Safety Orientation, West Dock Office Safety Orientation w/ AFC Crew, AFC Safety Office Safety Orientation w/ Team, AFC Office
3	27-Mar	AFC mobilizes equipment to Test Trench 1; Ice cutting, removal, excavation begins
4	28-Mar	Excavation of Test Trench 1
5	29-Mar	Excavation of Test Trench 1; Check ice thickness at Test Trench 2.5; Mobilize equipment to Test Trench 2.5
6	30-Mar	Excavate Test Trench 2.5; Strong east winds suspend work at 4 pm
7	31-Mar	Strong east winds suspend work all day
8	1-Apr	Continued strong east winds suspend work until night shift
9	2-Apr	Move equipment back to Test Trench 1; John Deere 650 w/ grousers excavates Test Trench 1
10	3-Apr	Complete excavation at Test Trench 1; Move equipment to Test Trench 2.5 to continue excavation that was halted by weather on March 30th.
11	4-Apr	Excavate Test Trench 2.5
12	5-Apr	Excavate Test Trench 2.5
13	6-Apr	Excavate Test Trench 2.5; Team-wide debriefing meeting at end of day shift at AFC office to compare observations.
14	7-Apr	Excavate Test Trench 2.5; Collect turbidity data beneath floating ice
15	8-Apr	Complete excavation of Test Trench 2.5 by late afternoon; Collect turbidity data beneath floating ice.
16	9-Apr	Final measurements of side slope sloughing at both test trenches; Collect turbidity data at both trenches and at distances from Test Trench 2.5; Visit and photograph spoils disposal site off AGI Pad
17	10-Apr	Demobe field gear; Pack equipment and ship via air freight; CFC field crew departs Deadhorse on evening Alaska Air flight

Active Excavation = 11 days

4.3.1 Ice Slotting

To facilitate removal of the sea ice prior to dredging, a trencher was utilized to slot the sea ice. The slots were oriented parallel to the northern border of the site and were 100 and 200 ft long at Sites #1 and #2.5, respectively. Figure 4-8 shows an example of the trencher slotting the ice and the ice slot generated at Site #1.

During ice slotting activities, the length of the ice cut and duration of the slotting activities were recorded and used to estimate the cutting rate (ft/min). The nominal thickness of the ice (7.5 ft at Site #1 and 8.6 ft at Site #2.5) and equipment used was noted as well. The primary trencher utilized for the ice slotting activities was a Ditch Witch 8020 Turbo with a 10 ft blade. At Site #1 the first three slots were made using a smaller unit, the Ditch Witch RT115 with a 6 ft blade.

Figure 4-8. Trencher Slotting Ice (left) and Ice Slot (right)

The results of the ice slotting observations are summarized in Table 4-2. At the grounded ice location (Site #1), the average ice slotting rate was 5.5 ft/min using the Ditch Witch RT115, and 7.0 ft/min using the Ditch Witch 8020 Turbo. At the floating ice location (Site #2.5), the average slotting rate was slightly faster (8.1 ft/min); however, there was greater variability in the observed data (σ = 2.3 ft/min). ***For the purposes of evaluating the feasibility of the winter dredging techniques, it is recommended that a conservative cutting rate of 7.0 ft/min be used for both grounded and floating locations.***

Table 4-2. Rate of Ice Slotting, Sites #1 and #2.5

Equipment	Blade Length	Site	Ice Thickness	No. Slots Observed	Sea Ice Slotting Rate			
					Average	Max	Min	Std. Dev.
[-]	[ft]	[-]	[ft]	[-]	[ft/min]	[ft/min]	[ft/min]	[ft/min]
Ditch Witch RT115	6	1	7.5	3	**5.5**	7.3	3.6	1.8
Ditch Witch 8020 Turbo	10	1	7.5	3	**7.0**	7.2	6.7	0.3
		2.5	8.6	12	**8.1**	11.8	4.8	2.3

Notes:

1. Rate for 8020 Turbo at Site #1 excludes 3 slots with uneven work surface.
2. Rate for 8020 Turbo at Site #2.5 excludes 3 slots with ice cut to full depth (8.6 ft).

It should be noted that several observations were excluded from those summarized in Table 4-2. At Site #1, the work surface became very uneven following a three day hiatus in activities at the site between March 30 and April 1. This work suspension was caused by a temporary move to Site #2.5 (which required the placement of a security ice berm around the open trench that disturbed the otherwise flat ice surface) followed by two days of strong east winds which shut down construction activities. The uneven work surface caused the blade of the Ditch Witch 8020 Turbo to bind in the ice slot as it progressed from west to east, resulting in a much slower slotting rate (4.5 ft/min). However, this scenario should be avoided during the full-scale program with proper pad maintenance.

At Site #2.5, the majority of the ice slots were cut such that a small portion of the ice sheet remained connected to the work pad. This allowed the excavator operators to remove the ice in smaller sections, without the need to control and dig large floating ice beams. The three instances where the ice was cut to full depth were not included in the average rates shown in Table 4-2.

4.3.2 Ice Removal

Once the ice was slotted, an excavator working on the south side of the swath removed the sea ice, thereby exposing the seabed material. At Site #1, the ice was placed directly behind the excavator and pushed to the perimeter of the pad using a Cat 966 Loader (Figure 4-9). At Site #2.5, the ice was typically hauled to a grounded location (Site #1) using either Max Haul or Cat 730 haul units (Figure 4-10). For two of the 13 swaths at Site #2.5, the ice was pushed to the perimeter of the pad.

4.3.2.1 Site #1

At Site #1, where the ice was pushed to the perimeter of the pad, the measured parameters included the swath length, swath width, nominal ice thickness, and duration required to remove the ice. The ice removal rate for the swath (cy/min) was then computed as the volume of ice (length x width x thickness) divided by the excavation duration.

Figure 4-9. Ice Removal at Site #1

Figure 4-10. Ice Removal and Hauling at Site #2.5

The grounded ice and limited side-slope sloughing observed at Site #1 afforded the opportunity to safely evaluate the effectiveness of several excavator models and bucket sizes, which are summarized along with the computed ice removal rates in Table 4-3. As is shown in the table, the John Deere 650 (analogous to the Cat 365) was most effective at removing ice, with an average removal rate of 8.2 cy/min. While the Cat 390 is a more powerful machine with a larger bucket, the lack of ice grousers on the tracks caused the unit to be unstable when swinging the massive ice blocks, resulting in a lower removal rate (6.0 cy/min).

Table 4-3. Ice Removal Rates at Site #1

Equipment	Tracks	Ice Grousers	Nominal Bucket Size	No. Swaths Observed	Ice Removal Rate			
					Average	Max	Min	Std. Dev.
[-]	[-]	[-]	[cy]	[-]	[cy/min]	[cy/min]	[cy/min]	[cy/min]
Cat 345	Amphibious Undercarriage	No	3	3	**5.4**	6.6	4.6	1.0
Cat 345	Standard	Yes	3	1	**4.7**	-	-	-
Cat 390	Standard	No	8	1	**6.0**	-	-	-
John Deere 650	Standard	Yes	5	3	**8.2**	8.5	7.8	0.4

Notes:
1. Ice pushed to edges of pad at Site #1 (not hauled).

4.3.2.2 Site #2.5

As noted above, the ice at Site #2.5 was loaded into haul units for eleven of the swaths and pushed to the perimeter for the remaining two. The time and number of buckets required to load each haul unit were recorded and the cycle time (buckets/min) was computed. It should be noted that the loading time includes only that time when the haul units were actively being loaded, and does not include the time required for the haul units to back in (Figure 4-10). This was done based on the assumption that during the full-scale dredging operation, the haul units would approach to the rear of the excavator in a path that is parallel to the trench edge (eliminating the need for backing of the haul unit toward the trench). The truck would stop behind the excavator and the excavator bucket would then need to swing 180º from the trench to load the truck.

Due to the floating ice condition at Site #2.5, only the Amphibious Cat 345 was utilized. Table 4-4 summarizes the removal rates computed for those swaths where the ice removal activities were observed in their entirety. As is shown in the table, the ice removal rate achieved when the ice was hauled ranged between 9.4 and 6.3 cy/min, with an average rate of 8.0 cy/min. When the ice was pushed to the perimeter of the pad, the rate increased to an average of 10.6 cy/min; however, this method was only used for two swaths after cracks were observed on the perimeter of the ice pad where the ice was stockpiled. In addition, loading the ice directly onto the work surface required additional clearing of the site using a loader and grader, which is not reflected in the computed removal rate.

Table 4-4. Ice Removal Rates at Site #2.5

Equipment	Nominal Bucket Size	Ice Hauled or Pushed	No. Swaths Observed	Ice Removal Rate				Effective Bucket Vol.
				Average	Max	Min	Std. Dev.	
[-]	[cy]	[-]	[-]	[cy/min]	[cy/min]	[cy/min]	[cy/min]	[cy]
Cat 345 Amphib	3.0	Hauled	4	**8.0**	9.4	6.3	1.6	3.3
		Pushed	2	**10.6**	13.7	7.5	4.4	-

Notes:
1. Effective bucket volume only measured when ice was hauled.
2. Removal rate under the "pushed" scenario does not include time to clean work pad following ice removal.

As noted in Table 4-4, the effective bucket volume (= volume of ice per swath / total buckets) for the Amphibious Cat 345 was 3.3 cy, which is slightly larger than the nominal bucket size of 3.0 cy. This is to be expected, given that many of the heaped loads exceeded the bucket dimensions (Figure 4-10).

Cycle and ice loading times were recorded for a total of 233 trucks at Site #2.5, and the results are summarized in Table 4-5. The average cycle time among the 233 observations was 26 seconds, which corresponds to an ice removal rate of 7.6 cy/min when using the effective bucket volume noted above (3.3 cy). This further supports the 8.0 cy/min rate noted in Table 4-4. Loading times ranged between 0.8 and 4.8 minutes, with an average loading time of 2.6 min.

Table 4-5. Cycle and Loading Time for Ice Removal at Site #2.5

Equipment	Site	No. Trucks Observed	Parameter	Average	Max	Min	Std. Dev.	*Avg. + 1 σ*	*Avg. - 1 σ*
Cat 345 Amphib	2.5	233	Cycle Time (sec)	26	72	13	8	*34*	*18*
			Ice Removal Rate* (cy/min)	7.6	-	-	-	*5.8*	*10.7*
			Loading Time (min)	2.6	4.8	0.8	0.8	*3.3*	*1.8*

Notes:
1. Ice removal rate based on effective bucket volume of 3.3 cy.

For the purposes of evaluating the feasibility of the winter dredging techniques, it is recommended that a conservative ice removal rate of 7.0 cy/min be used for both grounded and floating locations. This rate is less than that observed using the John Deere 650 excavator at Site #1 (8.2 cy/min) and the Cat 345 Amphibious excavator at Site #2.5 (8.0 cy/min, hauled).

4.3.3 Seabed Excavation

Once the ice was removed, an excavator working on the south side of the trench dredged the seabed material to the desired grade (Figure 4-11). The material was loaded directly into the Max Haul and Cat 730 haul units and transported to the disposal site.

Figure 4-11. Seabed Excavation

The following parameters were recorded at each site: swath length, swath width, average excavation depth (estimated from as-built survey data), and duration required to complete the swath (when possible). The seabed excavation rate (cy/min) for those swaths observed in their entirety was computed as the volume of material (length x width x depth) divided by the duration. For swaths with only a portion of the excavation activities observed, the cycle and loading times were utilized, along with the effective bucket volume to compute the excavation rate.

As was the case for ice removal (Section 4.3.2.2), the loading time includes only that time when the haul units were actively being loaded, and does not include the time required for the haul units to back in.

4.3.3.1 Site #1

At Site #1, spoils excavation was performed by both the Amphibious Cat 345 and the John Deere (JD) 650 on standard tracks. Table 4-6 presents the excavation data based on the evaluation of entire excavated swaths. Two full swaths were noted for the Cat 345 and three full swaths were evaluated for the JD 650. The average excavation rates were higher for the JD 650 (7.0 cy/min) relative to the Cat 345 (4.3 cy/min). This difference is likely due to the more powerful JD 650 working with a larger bucket (5 cy). Both machines were highly stable on the grounded ice given the large track footprint of the Amphibious Cat 345 and the grousers affixed to the tracks of the JD 650.

To account for the excavation rates for portions of swaths, similar rates were computed based on cycle and loading time, as shown in Table 4-7. Cycle times were comparable for both the Cat 345 and the JD 650, averaging 38 – 40 seconds (despite the difference in bucket size). Loading times were faster with the JD 650 by virtue of the larger bucket size. The average excavation rates were comparable to the rates determined by the full swath analysis provided in Table 4-6. The Cat 345 averaged 4.2 cy/min while the JD 650 averaged 6.5 cy/min.

Table 4-6. Seabed Excavation Rate, Site #1

Equipment	Tracks	Ice Grousers	Nominal Bucket Size	No. Swaths Observed	Seabed Excavation Rate				Effective Bucket Vol.
					Average	Max	Min	Std. Dev.	
[-]	[-]	[-]	[cy]	[-]	[cy/min]	[cy/min]	[cy/min]	[cy/min]	[cy]
Cat 345	Amphibious Undercarriage	No	3	2	**4.3**	4.7	3.9	0.6	2.8
John Deere 650	Standard	Yes	5	3	**7.0**	7.7	6.2	0.7	4.1

Notes:
1. Excavation rate for Cat 345 adjusted to remove time required for trucks to back-in. Estimated average rate with back-in time (1-min) is 3.7 cy/min.

Table 4-7. Cycle and Loading Time for Seabed Excavation at Site #1

Equipment	Site	No. Observations	Parameter	Average	Max	Min	Std. Dev.	*Avg. + 1σ*	*Avg. - 1σ*
Cat 345 Amphib	1	88	Cycle Time (sec)	40	88	23	13	*53*	*27*
			Excavation Rate* (cy/min)	4.2	-	-	-	*3.2*	*6.3*
			Loading Time (min)	3.4	7.6	1.5	1.3	*4.6*	*2.1*
John Deere 650	1	109	Cycle Time (sec)	38	94	24	11	*49*	*26*
			Excavation Rate* (cy/min)	6.5	-	-	-	*5.0*	*9.3*
			Loading Time (min)	2.7	5.8	0.8	1.0	*3.7*	*1.7*

Notes:
1. Excavation rates based on effective bucket volumes of 2.8 cy (Cat 345) and 4.1 cy (JD 650).

4.3.3.2 Site #2.5

At Site #2.5, the spoils excavation rates were evaluated using the same methods as Site #1. Due to the floating ice condition, only the Amphibious Cat 345 was used. A total of three full swaths were evaluated and a substantially higher average rate of excavation was noted (7.6 cy/min) relative to the average rate determined at Site #1 (4.3 cy/min). The reason for this 77% increase in productivity is not obvious, but is believed to be due to the lack of sediment contact with the ice bottom at Site #2.5 and the general improvement in excavation technique as the test trench program progressed.

Table 4-8. Seabed Excavation Rate, Site #2.5

Equipment	Nominal Bucket Size	No. Swaths Observed	Seabed Excavation Rate				Effective Bucket Vol.
			Average	Max	Min	Std. Dev.	
[-]	[cy]	[-]	[cy/min]	[cy/min]	[cy/min]	[cy/min]	[cy]
Cat 345 Amphib	3.0	3	**7.6**	10.3	5.0	2.6	4.0

Using the cycle and loading time evaluation methods for 235 observations, a similar average production rate of 7.2 cy/min was calculated (Table 4-9). The average cycle time (34 seconds) was 15% less at Site #2.5 than at Site #1, suggesting a quicker digging process on floating ice.

In evaluating the feasibility of the winter dredging techniques, it is recommended that a spoils excavation rate of 7.0 cy/min be used for both grounded and floating locations. This rate was achieved by the JD 650 at Site #1 (grounded ice) where similar large, standard-tracked machines would be used. On floating ice, the Amphibious Cat 345 exceeded this excavation value, achieving average rates in the 7.2 – 7.6 cy/min range.

Table 4-9. Cycle and Loading Time for Seabed Excavation at Site #2.5

Equipment	Site	No. Observations	Parameter	Average	Max	Min	Std. Dev.	*Avg. + 1σ*	*Avg. - 1σ*
Cat 345 Amphib	2.5	235	Cycle Time (sec)	34	70	16	8	*42*	*25*
			Excavation Rate* (cy/min)	7.2	-	-	-	*5.7*	*9.5*
			Loading Time (min)	2.9	5.5	1.1	0.8	*3.7*	*2.1*

Notes:
1. Excavation rate based on effective bucket volume of 4.0 cy.

4.3.4 Spoils Hauling

Following excavation and loading into the Max Haul and Cat 730 haul units, the spoils were driven to the disposal site adjacent to the AGI Pad in West Prudhoe Bay along the route shown in Figure 4-6 (Figure 4-12). The round-trip travel distances to the dumpsite were 7 miles and 10 miles from Sites #1 and #2.5, respectively. The posted speed limit along most of the route was 35 mph, with the speed limit reduced to 25 mph over the floating ice road section (within about 2,000 ft of Site #2.5). The elapsed time from the conclusion of loading to the return of the truck to the excavation site was noted. This time interval included round-trip truck travel, dumping spoils at the dumpsite, and occasional clean-out of the truck beds of accumulated frozen spoils. Dividing the round-trip travel distance by the elapsed travel time yielded the average truck speed for each journey.

Figure 4-12. Spoils Hauling with Max Haul (left) and Cat 730 (right)

Table 4-10 presents the truck hauling speeds for both Sites #1 and #2.5. A total of 142 observations were collected. The computed average speeds varied between about 11 and 28 mph, with average values of 20 - 21 mph. The average speed was slightly higher at Site #2.5 (21.1 mph) relative to Site #1 (20.2 mph) perhaps due to the longer trip distance for Site #2.5 that would support longer travel at higher speeds.

Table 4-10. Spoils Hauling Rate at Sites #1 and #2.5

Site	No. Observations	Spoils Haul Rate			
		Average	Max	Min	Std. Dev.
[-]	[-]	[mph]	[mph]	[mph]	[mph]
1	76	**20.2**	28.1	11.4	2.6
2.5	66	**21.1**	26.2	14.7	2.5
Total	142	**20.6**	28.1	11.4	2.6

Notes:
1. Haul rate based on round-trip time (Includes time to dump and clean beds when needed).

The effective truck volumes were computed to be 17.3 cy/truck for spoils at Site #1 and 21.8 cy/truck for spoils at Site #2.5. These values are somewhat misleading as they reflect the in-situ volume of spoils carried and the use of two types of trucks with varying capacities. It is important to note, however, that the specified volume for the Max Haul trucks is 30 cy. If the excavated material within the truck is considered bulked, the 22 cy/truck that was calculated must be increased by 25% (bulking factor). Therefore, the volume of bulked spoils carried in each truck averaged 27.5 cy (= 22 cy/truck x 1.25) which agrees more closely with the Max Haul carrying capacity.

Based on these observations, an average truck speed of 21 mph is suggested for use in evaluating the feasibility of the winter dredging techniques. This presumes that the posted and observed speed limits along the ice road haul routes will be as high as 35 mph, as was the case in the test trench program.

4.4 SIDE SLOPE SLOUGHING

The sloughing of the side slopes of the test trenches was measured early in the test program at several locations. If the sloughing had been significant, loss of support of the grounded ice pad at

Site #1 could compromise the safety of the non-amphibious excavators. At both Sites #1 and #2.5, sloughing was found to be very modest initially and did not advance significantly with time.

The method of side slope measurement was by deploying a lead-line through holes augured in the ice sheet at known distances from the edge of the trench. At Site #1, the measurements were collected along the north edge of the trench at four transects. At each transect, the ice holes were augured at distances of 3, 5 and 9 ft back from the ice edge. At only one transect was sloughing initially noted 5 ft back from the ice edge. Six days following the conclusion of excavation at Site #1, a second surveyed transect indicated sloughing back 5 ft from the trench edge. No sloughing was noted at any of the holes located 9 ft back from the ice edge.

At Site #2.5, the slope profile was investigated along a single profile at the northern edge of the trench. Augured holes were located 3, 5, and 10 ft back from the ice edge. Similar to Site #1, side slope sloughing was very limited and only occurred at the 3 ft distance. No sloughing was detected at the 5 ft distance.

Because the augured holes were spaced several feet apart, it is not possible to know exactly where the sloughing ceased at either test trench site. However, it seems reasonable to estimate the as-built side slopes of both trenches to be on the order of 1:1 (H:V).

Additional qualitative assessments of side slope sloughing were possible during as-built survey activities that were conducted at the conclusion of each swath excavation at Site #2.5 A survey rodman would slide a long survey rod through the ice cover right at the excavated southern edge of the excavation. Within a foot or so from the ice edge, the trench bottom elevation was found to be close to the elevation dug by the excavator, based on the water mark on the excavator arm. If sloughing was extensive or ongoing, the trench bottom detected by the rodman would be noticeably higher than that previously dug.

4.5 SURVEY METHODS

The test trench excavations were surveyed using simple techniques that involved a surveyor operating an instrument at a known geodetic position and a rodman positioned at a desired site. The rodman could sample at the edge of the trench as shown in Figure 4-13. The rodman was anchored to the pickup truck by a rope to prevent him from walking or falling into the trench. To gather information within the interior of the test trench, a manlift was used that could move along the trench edge, as shown in Figure 4-14.

Figure 4-13. Surveying Near Test Edge by Tying off to Pickup Truck

Figure 4-14. Use of Man-lift to Survey Test Trench

While these simple survey methods were safe and adequate for the test trench application, they would be inappropriate to control the excavation of the full-scale dredged channel. These methods are too slow to allow efficient progress of the work and they gather data only at discrete points, rather than obtaining a comprehensive view of the trench bottom elevation.

Other survey methods that must be considered for both comprehensive and fast survey data collection in the dredged channel include the use of GPS technology that can provide “in cab” views of the digging operation to guide the excavator operator. Using these methods and radio telemetry, independent quality assurance checks in real-time by an analyst working in a nearby vehicle would be possible. These improved and necessary survey methods will be discussed in Section 5.2 of this report.

4.6 AS-BUILT SURVEYS – TEST TRENCHES AND DISPOSAL SITE

4.6.1 Test Trench Site #1

The as-built survey results at Test Trench Site #1 are shown in Figure 4-17. The dimensions of the excavation are approximately 100 ft x 100 ft. The original seabed elevation at the site was -5.5 ft (MLLW). The excavation was dug from the north to the south. The initial effort along the northern half of the trench resulted in a bottom elevation that averages about -15 ft (MLLW), indicating a dig depth below seabed of about 9.5 ft. Over the southern half of the trench, the digging depth was increased and an average bottom elevation of about -18 ft was achieved. The excavated volume of the trench was 3,500 cy.

4.6.2 Test Trench Site #2.5

Test Trench Site #2.5 was excavated from floating ice at an original seabed elevation of 10.5 ft. The volume of excavation is estimated to be 7,400 cy. The surface dimensions of the excavated trench were 100 ft x 140 ft, as shown in Figure 4-18. The northern half of the trench was dug to a uniform elevation of about -18 ft. Over the southern half of the trench, a 50 ft wide deeper portion (“sediment trap”) was dug to an average elevation of -22 ft. For the remainder of the trench located to the west of the sediment trap, an average elevation of 16 to -17 ft was achieved.

As discussed previously in Section 4.4, the side slopes of the test trenches did not slough readily. Observations over the duration of the test trench field work period indicated the side slopes adjusted quickly and remained at an inclination of about 1V:1H. Further adjustment of the side slopes may occur during the summer months and will be documented using the results of the forthcoming summer bathymetric survey operations.

4.6.3 Disposal Site

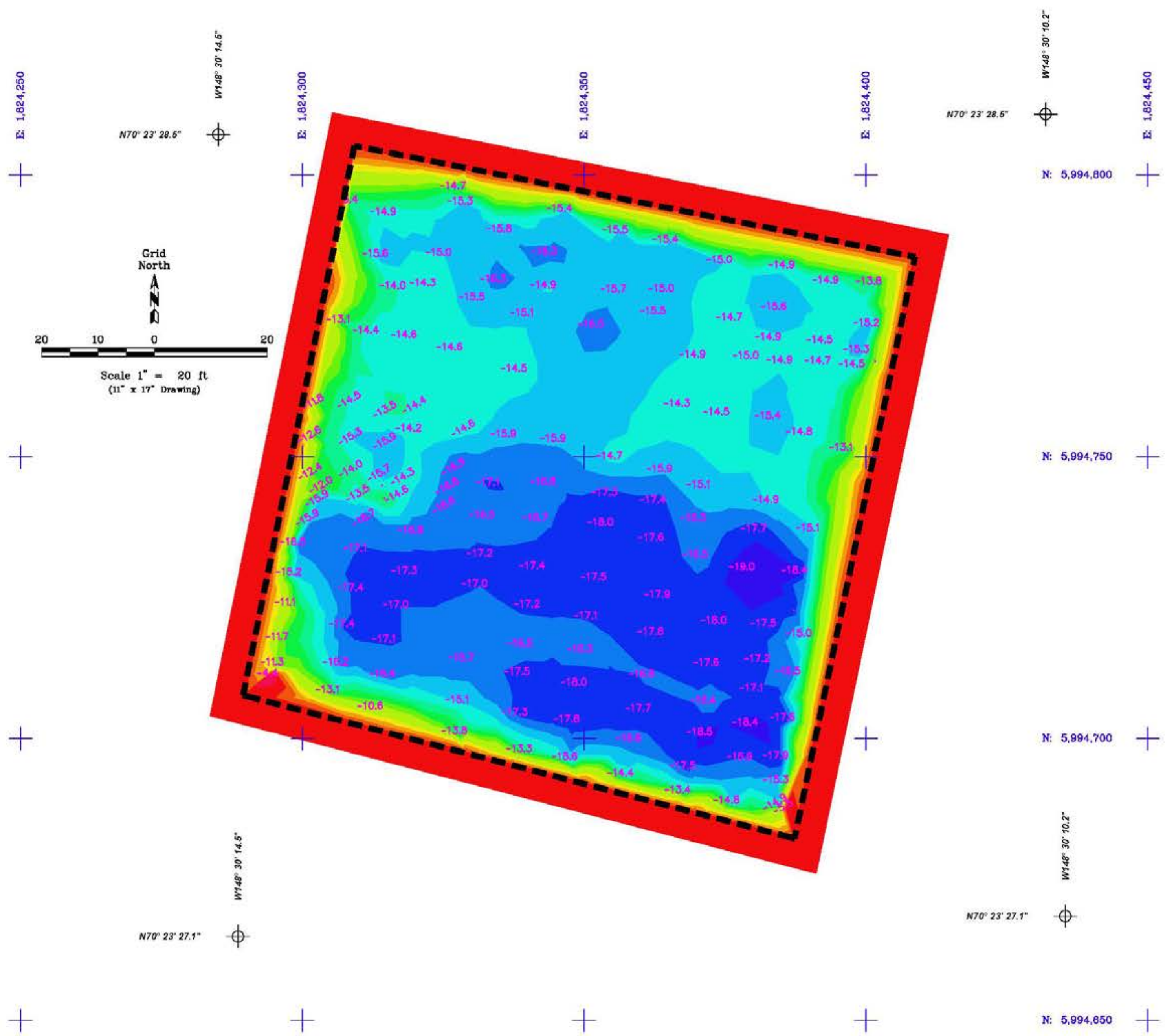
The as-built survey of the disposal site is shown in Figure 4-19. The spoils were delivered to the site by truck and a Cat D-7 dozer was used to consolidate and track-walk the spoils. The resulting spoils pile was compact, featureless, and uniform, as shown in Photos 12 and 13. The length of the disposal area is about 1,800 ft and the width is 50 - 80 ft. The spoils pile was placed approximately 50 ft offshore of the shoreline to minimize any negative impacts to nearby tundra. The height of the disposal pile was to be less than 5 ft above the sea ice surface. It is expected that the sediments will eventually lie on the seabed once the summer heat melts the sea ice. Initially, the disposal pile will be emergent; however, waves and currents will act to disperse the material alongshore, thereby lowering the pile height over time.

The elevations of the disposal pile are provided in feet above the MLLW datum. The elevation of the ice surface at the time of the survey was +0.8 ft (MLLW). The computed volume of the disposal pile is 13,500 cy. Given the computed test trench excavation volumes that totaled 10,900 cy (= 3,500 cy + 7,400 cy), the bulking factor of the disposed sediment was 23.9% (= (13,500-10,900)/10,900). For simplicity, the bulking factor has been assumed to be 25% for the disposal area computations provided in Section 3.2.

Figure 4-15. View of Spoils Disposal Site Seaward of AGI Pad

Figure 4-16. Top Surface of Spoils Disposal Site

Figure 4-17. As-Built Survey, Test Trench #1



Elevation (ft, MLLW)		
Min	Max	Color
−19	−18	
−18	−17	
−17	−16	
−16	−15	
−15	−14	
−14	−13	
−13	−12	
−12	−11	
−11	−10	
−10	−9	
−9	−8	
−8	−7	
−7	−6	
−6	−5	
−5	−4	

DEEP ↑ — SHALLOW ↓

NOTES

1. As-built survey performed between March 29 and April 3, 2015.
2. Horizontal datum is Alaska State Plane Zone 4, NAD 83, US Survey Feet. Geodetic coordinates are provided relative to NAD 83.
3. Vertical datum is National Ocean Service (NOS) Mean Lower Low Water (MLLW) based on Tide Station 9497645 (Prudhoe Bay, AK).
4. Horizontal and vertical survey control based off RTK GPS methods from Hydro 2 with the following coordinate values:

   Northing: 5,993,234.32 US ft
   Easting: 1,823,159.67 US ft
   Elevation: 10.60 ft, MLLW

5. Color-coded bathymetry developed from spot elevations shown on chart.
6. Full bottom coverage not attained as part of this survey.
7. Air photo (July 2013) provided by exp.
8. Horizontal position of test trench corners based on RTK GPS measurements of ice slot. Test trench boundary estimated based on corner locations and assigned an elevation of −5.5 ft (MLLW) for volume calculations.

LEGEND

-18.3 Elevation (ft, MLLW)

▬ ▬ Test Trench Excavation Boundary

Test Trench Site 1	
Ambient Seabed Elevation (August 2014)	−5.5 ft
Minimum Elevation	−19.0 ft
Excavated Volume (estimated)	3,500 cy

ALASKA LNG PROJECT WINTER 2015 TEST TRENCH PROGRAM SITE 1 AS-BUILT SURVEY		
Scale: 1" = 20'	Checked by: CPS	Drawn by: JBR
Date: 30 APRIL 2015	Sheet: 1 of 1	Revised:
Prepared for: AECOM/URS ALASKA & EXXONMOBIL DEVELOPMENT CORP.		
Prepared by: COASTAL FRONTIERS CORPORATION	Drawing No.: CFC-944-10-001	Rev.: 0

Figure 4-18. As-Built Survey, Test Trench #2.5

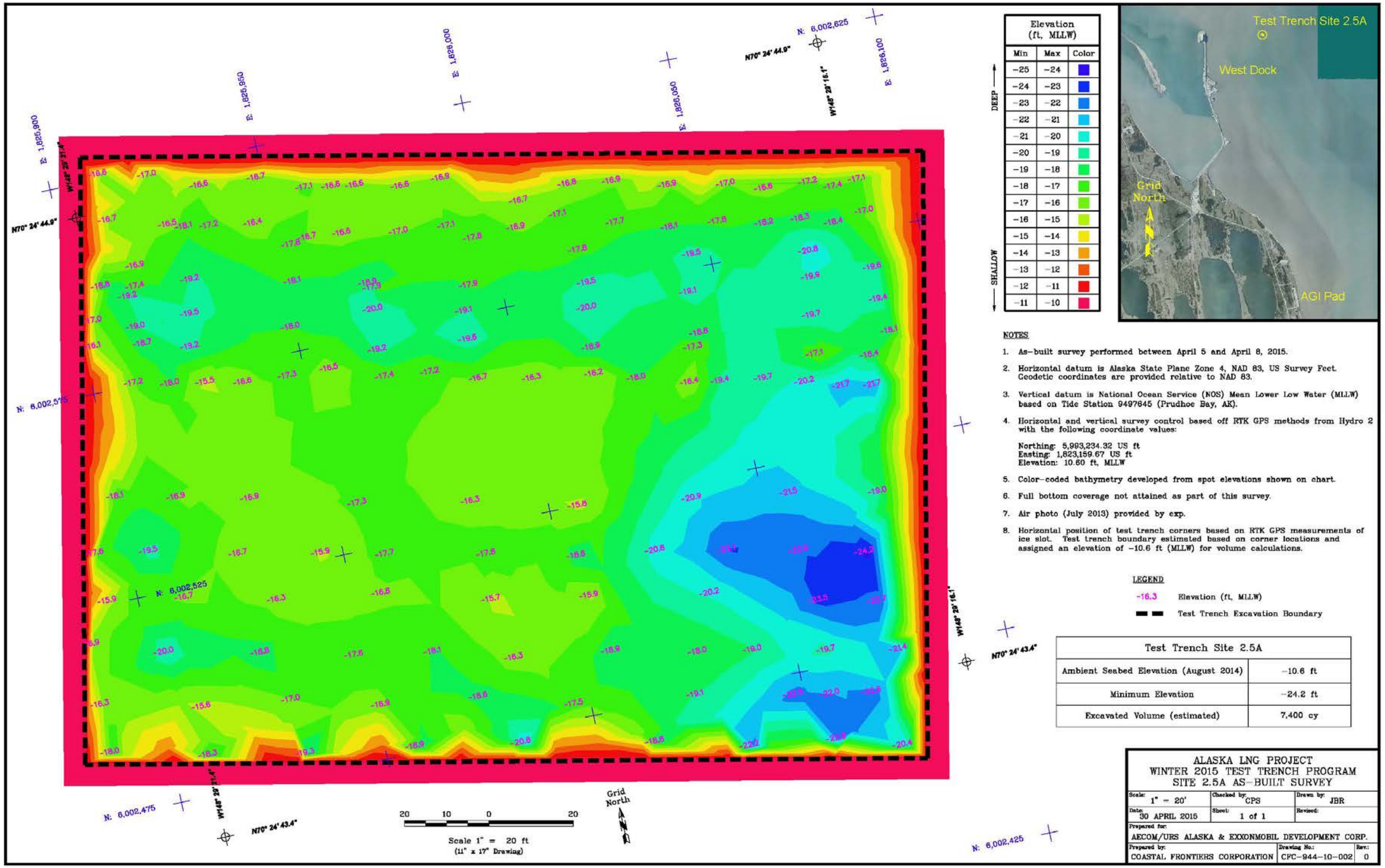
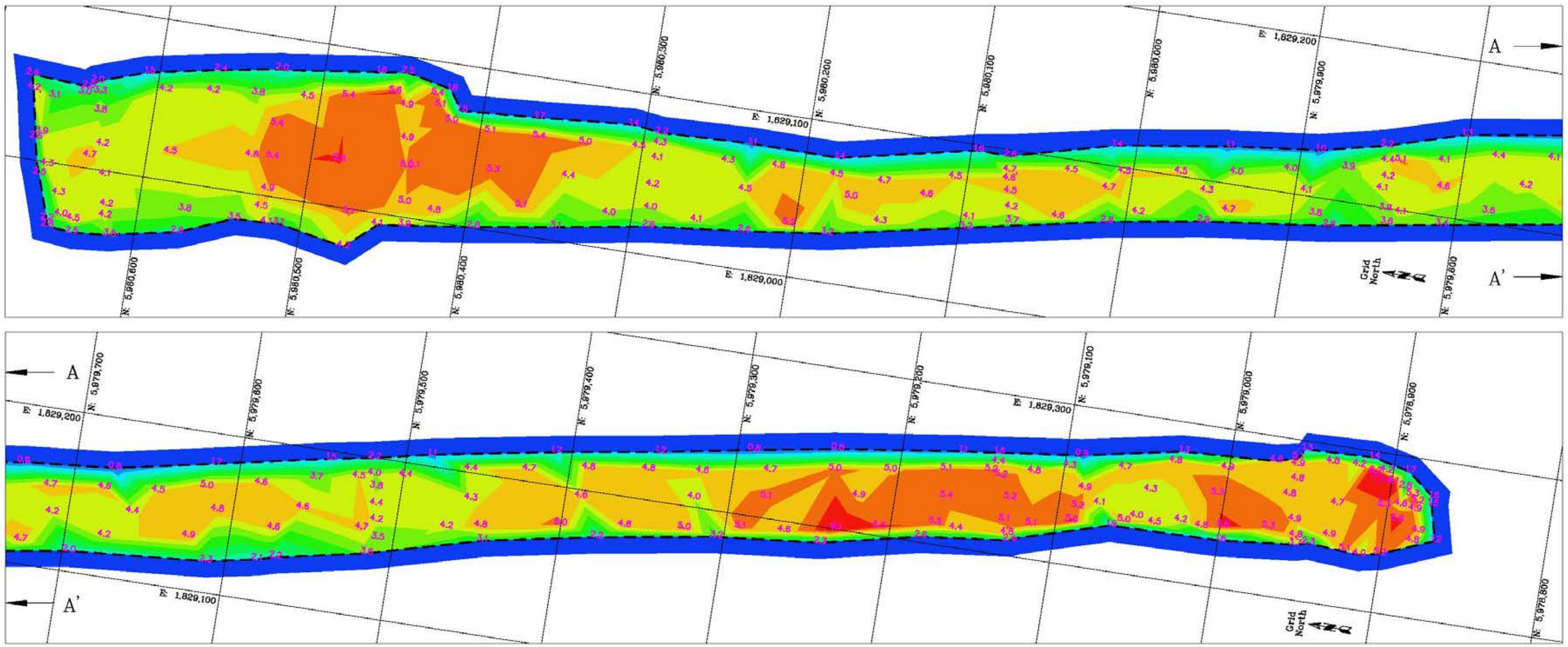


Figure 4-19. As-Built Survey, Spoils Disposal Site near AGI Pad



Elevation (ft, MLLW)		
Min	Max	Color
0.0	0.5	
0.5	1.0	
1.0	1.5	
1.5	2.0	
2.0	2.5	
2.5	3.0	
3.0	3.5	
3.5	4.0	
4.0	4.5	
4.5	5.0	
5.0	5.5	
5.5	6.0	
6.0	6.5	

LOW → HIGH

LEGEND

4.4 Elevation (ft, MLLW)

Test Trench Excavation Boundary

A Matchline

60 30 0 60

Scale 1" = 60 ft
(11" x 17" Drawing)

Excavation Disposal Site	
Top of Ice Elevation (idealized)	0.8 ft
Maximum Elevation	6.2 ft
Fill Volume (estimated)	13,500 cy

NOTES

1. As-built survey performed between April 9, 2015.
2. Horizontal datum is Alaska State Plane Zone 4, NAD 83, US Survey Feet.
3. Vertical datum is National Ocean Service (NOS) Mean Lower Low Water (MLLW) based on Tide Station 9497645 (Prudhoe Bay, AK).
4. Horizontal and vertical survey control based off RTK GPS methods from Hydro 2 with the following coordinate values:

   Northing: 5,993,234.32 US ft
   Easting: 1,823,159.67 US ft
   Elevation: 10.60 ft, MLLW
5. Color-coded elevations developed from spot elevations shown on chart.
6. Full coverage not attained as part of this survey.
7. Air photo (July 2013) provided by exp.
8. Boundary of excavation disposal pile based on RTK GPS measurements of the toe or field estimates when toe not discernable. Fill volume based on boundary extent and assigned an elevation of 0.8 ft (MLLW) for calculations.

ALASKA LNG PROJECT
WINTER 2015 TEST TRENCH PROGRAM
DISPOSAL SITE AS-BUILT SURVEY

Scale: 1" = 60'	Checked by: CPS	Drawn by: JBR
Date: 1 MAY 2015	Sheet: 1 of 1	Revised:
Prepared for: AECOM/URS ALASKA & EXXONMOBIL DEVELOPMENT CORP.		
Prepared by: COASTAL FRONTIERS CORPORATION	Drawing No.: CFC-944-10-003	Rev.: 0

4.7 TURBIDITY EFFECTS OF WINTER DREDGING

4.7.1 Test Trench Data Collection

During the later stages of the test trench excavation, a Hach Total Suspended Solid (TSS) Portable Nephelometer was used to measure turbidity within the excavated trench and beneath the floating ice near Test Trench #2.5. Deployment of the instrument sensor was accomplished through a 2 inch diameter auger hole that penetrated the ice. Turbidity measurement from the ice surface is shown in Figure 4-20. Measurements of turbidity were made just beneath the ice surface and at intervals below that elevation. Prior to the beginning of test trench excavation, the natural background turbidity was measured at several sites. The turbidity of the pristine Arctic water beneath the ice surface was noted on April 3 and 4 (prior to the commencement of excavation at Site #2.5) to be 0.3 – 0.5 Nephelometric Turbidity Units (NTUs), the standard of measure used in the United States. A correlation can be established between NTUs and TSS (mg/liter).

Figure 4-20. Deployment of Turbidity Sensor through Hole Augured in Sea Ice

4.7.2 Turbidity Results

The location of the turbidity measurements included within Test Trench #2.5 and at sites distant from the center of the trench along cardinal headings. The nearest turbidity sites were located 225 ft north, south, east and west of the trench center in order to avoid interference with haul truck traffic.

At locations where elevated turbidity was detected, additional sites were measured at distances of 500 ft and as much as 700 ft from the trench center. Observations were collected during the April 7 – 9 period. Excavation of the test trench was concluded on the afternoon of April 8th.

In Figure 4-21 the results of the turbidity data collection at a distance of 225 ft from the center of Test Trench #2.5 are provided in tabular form. The data collection began on April 7 during the digging process. As an example, the table at Station 2+25W (West) begins on the afternoon of April 7 with readings that are indicative of pristine Arctic water beneath the floating ice (0.3 NTUs). During trench excavation on April 8th, the turbidity measurements rose to 25 NTUs. The trench excavation was completed later that day. By the morning of the following day (April 9), the turbidity levels had returned to a pristine value of 0.3 NTUs.

The highest turbidity levels were noted south and east of the trench. At Station 2+25 S (South), a maximum reading of 75 NTUs was noted on the afternoon of April 7. The turbidity later fell to a value of 12 NTUs at this site and rose the following day as excavation continued to 63 NTUs. On the morning of April 9th (the day following the conclusion of excavation) the turbidity at this site fell to pristine levels (0.5 NTUs). The elevated values of turbidity noted south and east of the trench suggests a plume of turbid water being directed by tidal currents in those directions. Figure 4-22 provides a graphical view of this data showing peaks during excavation periods and a rapid reduction of turbidity following the completion of excavation.

All of the data is compiled in Figure 4-23, showing the rise and fall of turbidity at all four sites located 225 ft from the trench center and also in the trench. The maximum turbidity level measured within the trench was 75 NTUs, the same as the maximum noted at Station 2+25 S (South). The vertical pink regions indicate the periods of active excavation. The turbidity levels rise and fall in reaction to the periods when excavation occurred. On the morning following the completion of the excavation, the turbidity levels fell to pristine levels at all sites except for the test trench. Within the trench, the turbidity had fallen from 75 NTUs during the final excavation period to 30 NTUs the following morning.

Figure 4-24 shows the turbidity data in graphical form for locations 500 ft distant from the center of the test trench. The readings indicate pristine water at all sites except Station 2+25S (South), where a maximum turbidity value of 11 NTUs was noted. These findings indicate that the turbidity plume that was detected nearer the trench (at 225 ft distant) did not extend to the 500 ft distance from the trench center. Thus, the turbidity plume remained quite close to the excavation area.

Turbidity profiles were collected at the 500 ft distances from the trench, as shown in Figure 4-25. The profiles indicate very limited turbidity near the bottom of the ice (less than 2 NTUs), however, at Station 2+25S (South), turbidity increased over a one-foot interval near the seabed from 2 to 11 NTUs. This presence of more turbid bottom waters, termed a “nepheloid” layer, signifies higher concentrations of suspended sediments very near the seabed as the sediments settle in the water column.

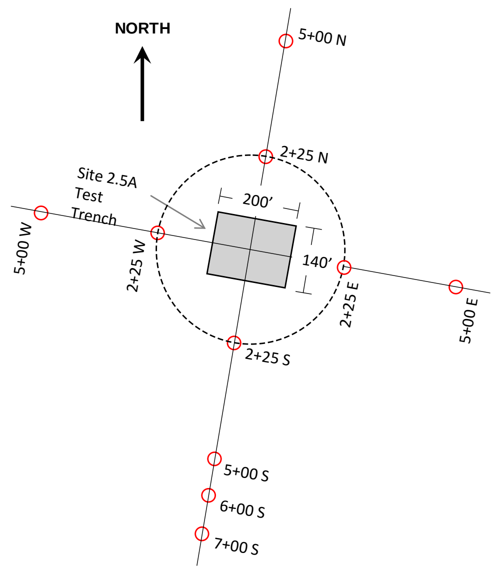
Figure 4-21. Tabular Turbidity Results at 225 feet from Trench Center

2+25 W

Date	Time (AKDT)	Turbidity (NTU)
4/7/2015	15:10	0.3
4/7/2015	16:17	0.3
4/8/2015	11:28	15.0
4/8/2015	12:54	25.0
4/8/2015	14:42	11.0
4/9/2015	7:57	0.3

2+25 N

Date	Time (AKDT)	Turbidity (NTU)
4/3/2015	16:35	0.3
4/4/2015	16:00	0.2
4/7/2015	14:38	0.2
4/8/2015	11:54	4.0
4/8/2015	13:08	4.0
4/8/2015	14:55	1.0
4/9/2015	8:02	0.7



Active seabed excavation

2+25 S

Date	Time (AKDT)	Turbidity (NTU)
4/7/2015	15:00	75.0
4/7/2015	15:40	50.0
4/8/2015	11:04	22.0
4/8/2015	12:35	12.0
4/8/2015	14:00	60.0
4/8/2015	16:27	63.0
4/9/2015	7:50	0.6
4/9/2015	9:05	0.5

2+25 E

Date	Time (AKDT)	Turbidity (NTU)
4/7/2015	14:50	0.6
4/8/2015	10:31	35.0
4/8/2015	12:24	27.0
4/8/2015	13:20	16.0
4/8/2015	16:13	3.6
4/9/2015	8:08	3.2
4/9/2015	9:28	1.0
4/9/2015	11:40	1.6

Figure 4-22. Graphical Turbidity Results Collected 225 feet from Trench Center

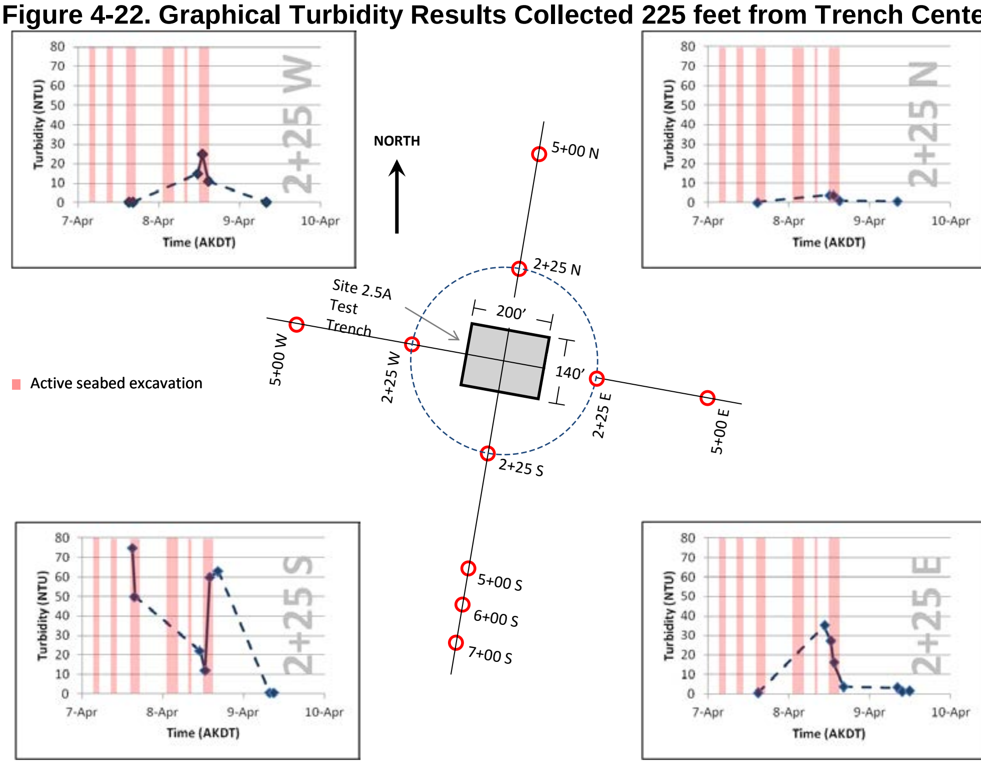


Figure 4-23. Compilation of Turbidity Results Collected 225 feet from Trench Center

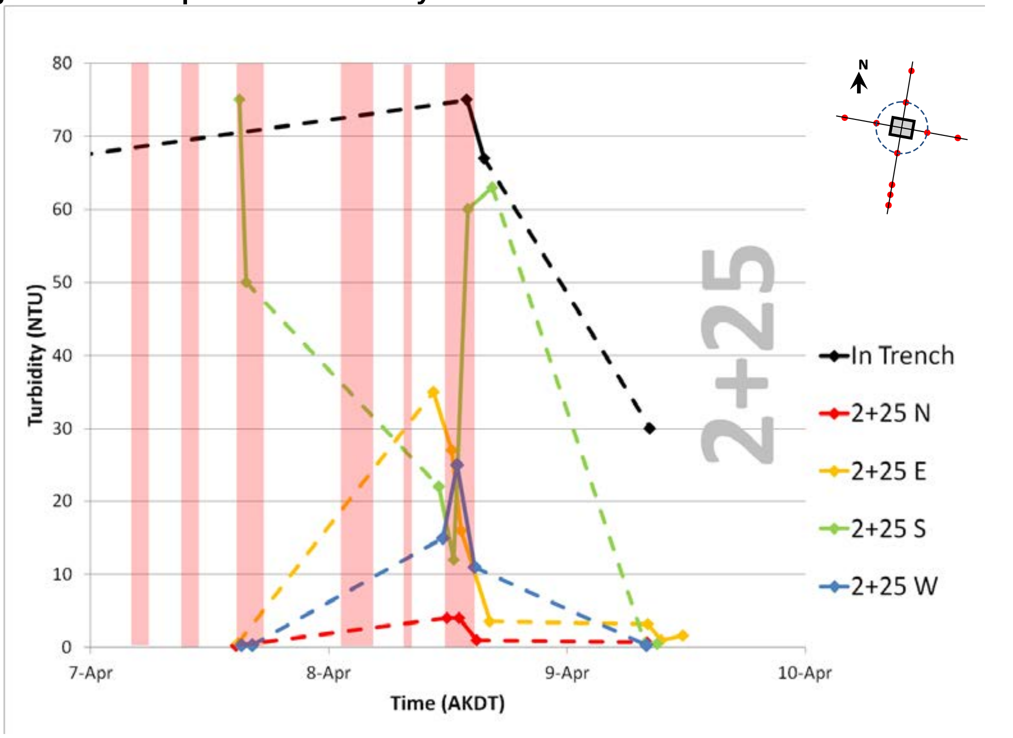


Figure 4-24. Graphical Turbidity Results Collected 500 feet from Trench Center

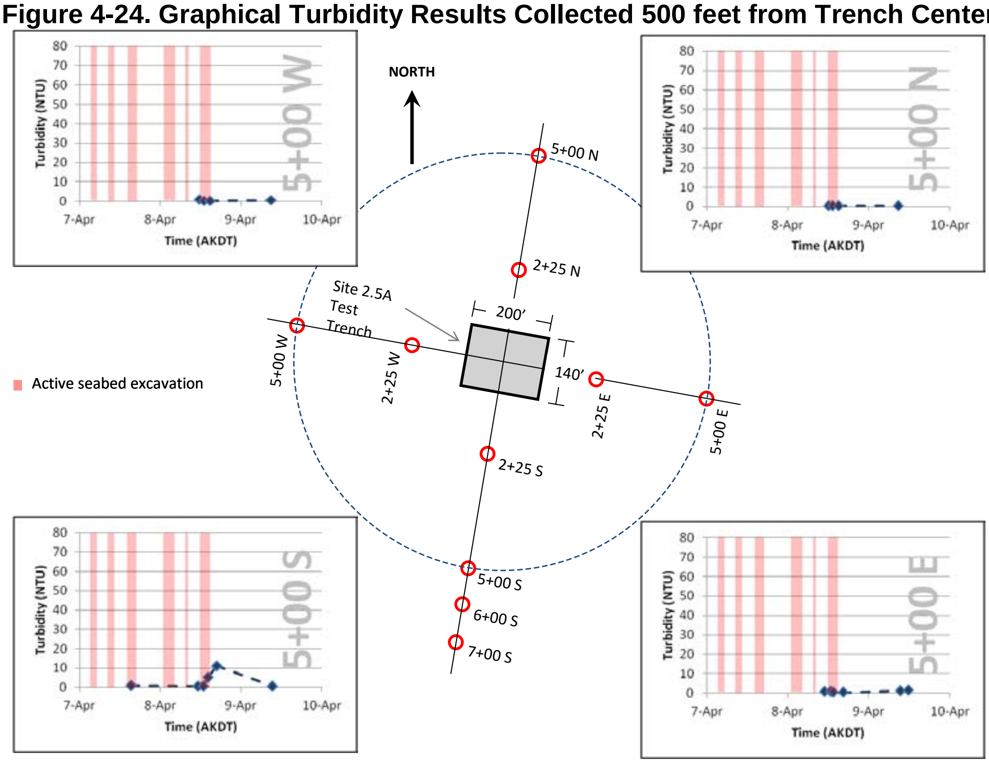
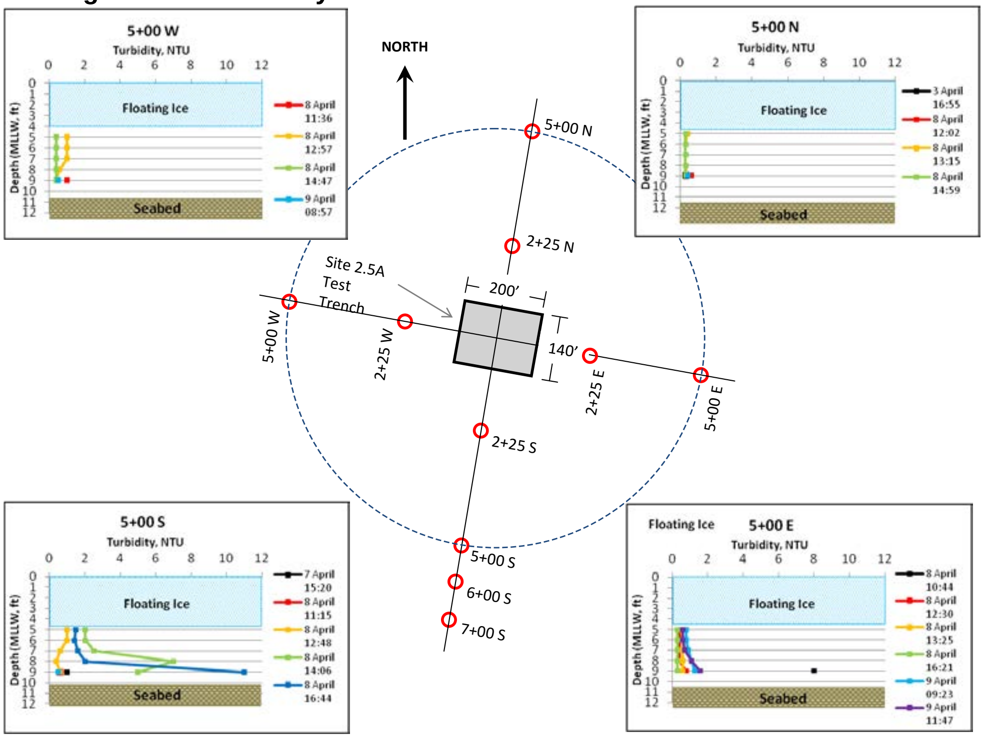


Figure 4-25. Turbidity Profiles Collected 500 feet from Trench Center



5.0 WINTER DREDGING PROGRAM

5.1 DESCRIPTION OF PROPOSED PROGRAM

Based on the accumulated experience of on-ice winter construction operations in Prudhoe Bay and the recent test trench construction, a feasible scenario for the winter dredging of the Alaska LNG navigation channel has been developed. The plan set forth is not intended to be the best or only way to accomplish the large-scale winter dredging effort, but is simply one possible plan to indicate the feasibility of this effort.

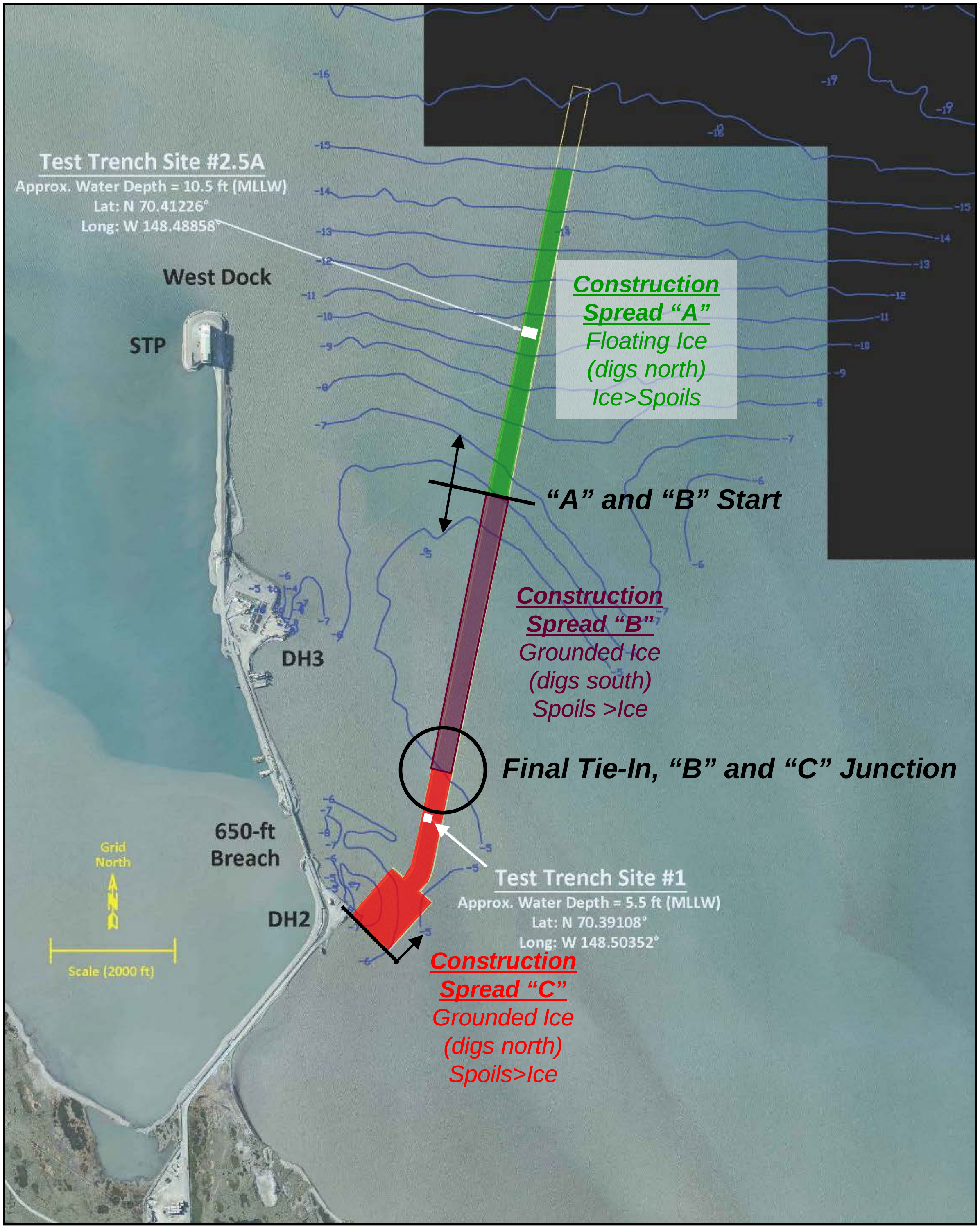
Three independent construction equipment spreads would be employed in order to divide the work effort into three efforts of equal magnitude. Each construction spread would include a trencher for ice cutting, two large excavators (one for ice removal and one for spoils excavation), and haul units to transport both ice and spoils to the designated disposal sites. The work would progress for each spread along the 280 ft channel width.

A plan view of the three-spread operational areas is shown in Figure 5-1. Construction Spread “A” would be located between the -6 ft and -14 ft seabed elevation contours. In this area, a portion of the work would be conducted on grounded ice (between the -6 and -9 ft contours) while the offshore segment would be performed on floating ice (between the -9 ft and -14 ft contours). Given the floating ice environment, the Spread “A” excavators are intended to be Cat 345s situated on amphibious pontoons. The maximum bucket size for this excavator is 4 cy, which is recommended in order to achieve maximum digging efficiencies.

Construction Spread “B” would span the grounded ice section in the central portion of the channel. The excavation would include the major shoal that exhibits seabed elevations in the -4 to -6 ft range. Within this shallow area, the excavation depths of the channel will be about 11 ft below the seabed. This grounded ice environment would utilize larger excavators, Cat 365s on standard (non-amphibious) tracks. The maximum bucket size for this excavator (6 cy) is recommended to achieve efficient digging rates. Spread “B” and Spread “C” would begin at a common location (near the -6 ft seabed elevation) and progress in opposite directions.

Construction Spread “C” would begin at Dockhead 2 and would proceed north. This work area includes the large (800 ft x 1,000 ft) turning basin. As the seabed elevations in the area average about -6 ft, the dig depths would be about 10 ft. As this area is situated on grounded ice, the Cat 365 excavators with standard tracks and 6 cy bucket would be used, similar to Construction Spread “B”. The areas of each construction spread have been selected to roughly equalize the excavation volumes.

Figure 5-1. Full Scale Winter Dredge Scenario

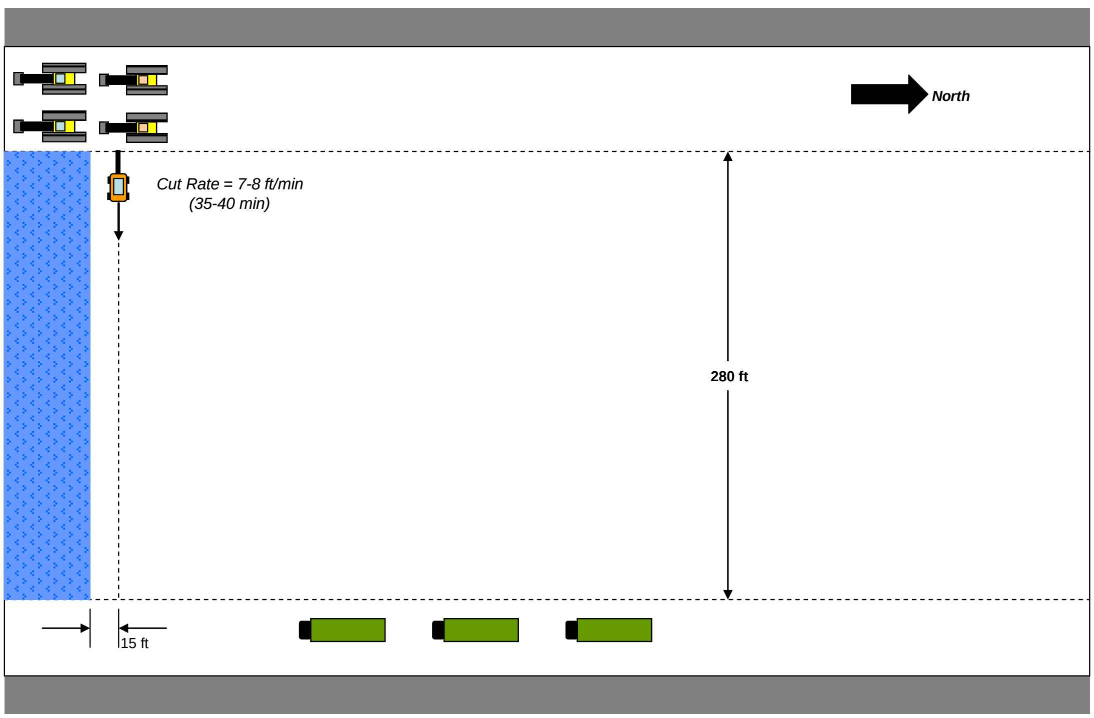


The sequence of actions to dredge the channel is the same for each construction spread. Initially, an 8 ft wide slot in the ice will be created by making two parallel cuts in the ice. An excavator will straddle this narrow trench in order to remove the sea ice and excavate the trench to the design grade. Once this initial trench is completed, ice cutting and removal and seabed excavation can progress on opposite sides of the trench. The general plan for channel excavation can be described, as follows:

Step 1. Slot Ice into 15 ft Swaths

This work is shown conceptually in Figure 5-2 in which a Ditch Witch DE8020 trencher with a 10 ft blade cuts the ice over the 280 ft channel width. Given the expected cut rate of 7-8 ft/min, this cut should require 35-40 minutes to complete.

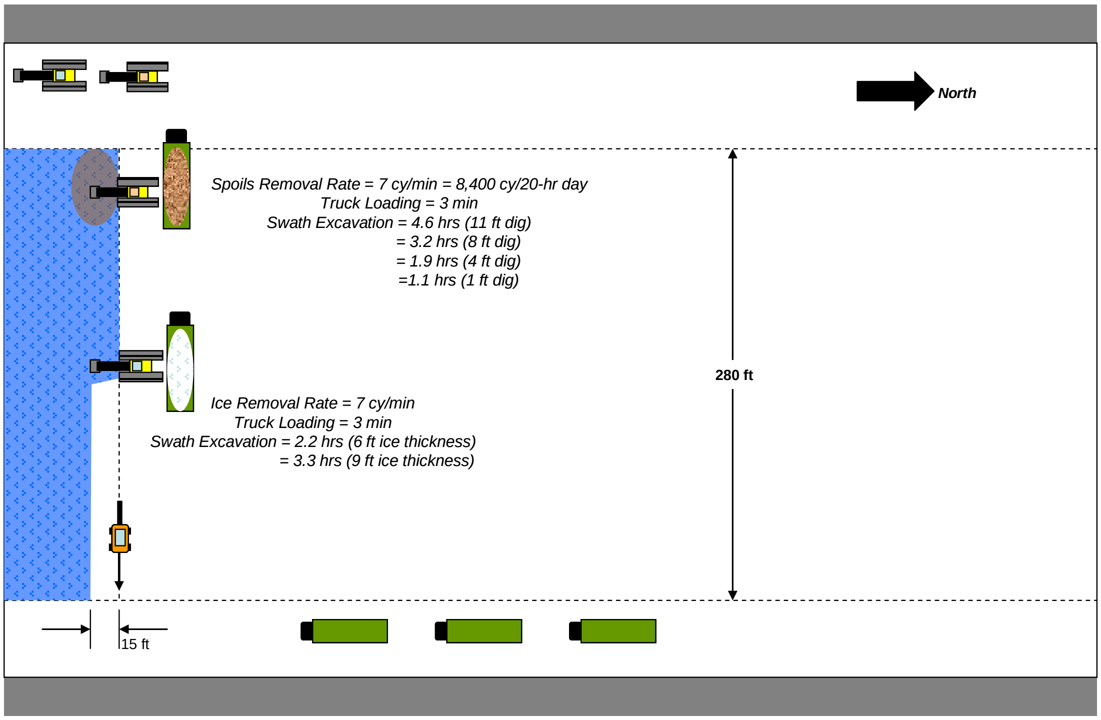
Figure 5-2. Slot Sea Ice



Step 2. Excavate and Remove Sea Ice

Once the trencher is perhaps 50 ft along the cut, the excavator can begin removing ice. The rate of ice excavation is 7 cy/min, based on a conservative assessment of the test trench progress achieved in the recent test trench program. The swath excavation time required will be 2.2 hrs in grounded ice (6 ft ice thickness) and 3.3 hrs for floating ice (9 ft ice thickness). The excavated ice will be loaded onto trucks for travel and disposal at the approved disposal location. On grounded ice, the ice disposal could occur along the periphery of the thickened ice pad. On floating ice, the ice disposal should occur on grounded ice initially. However, once the trench is large enough (several hundred feet along the longitudinal axis), the ice can be transported from the excavation site to the side of the completed trench where it can be pushed into the trench. The simultaneous actions of the ice cutting, ice removal and seabed excavation are shown in Figure 5-3.

Figure 5-3. Remove Sea Ice and Dredge Seabed

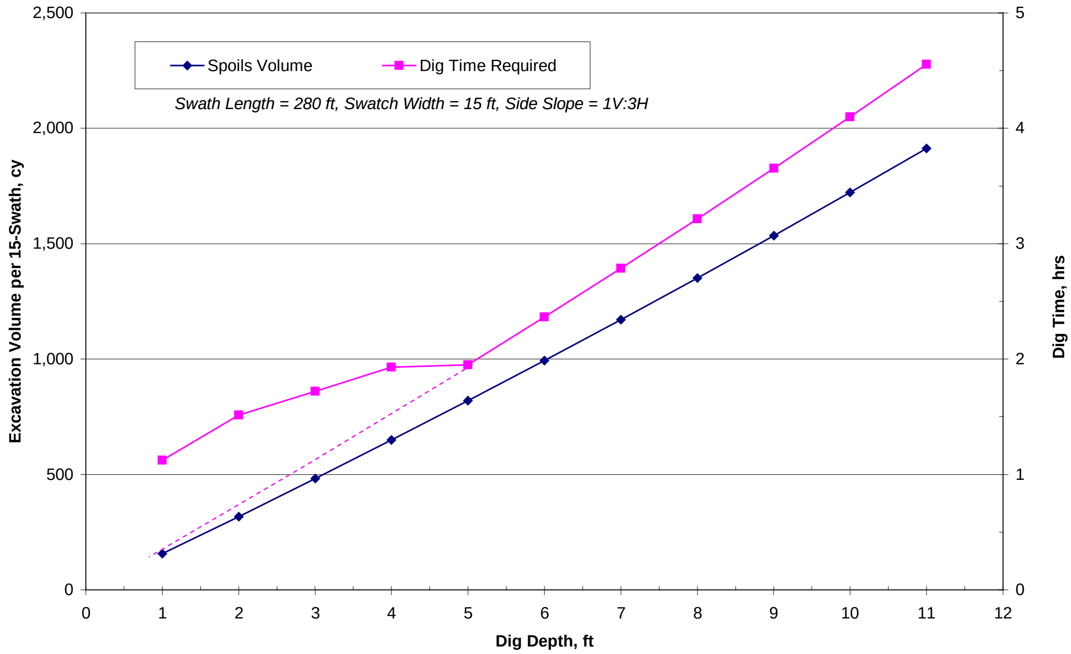


Step 3. Excavate, Haul and Dispose Seabed Spoils

Coincident with the ice cutting and ice excavation/removal, the seabed will be excavated at a rate of 7 cy/min, as shown in Figure 5-3. The excavator digging the spoils can progress immediately following the ice removal. The spoils will be loaded onto trucks for delivery to the designated disposal site. It is important to note that sufficient trucks need to be available to eliminate any delays in seabed excavation.

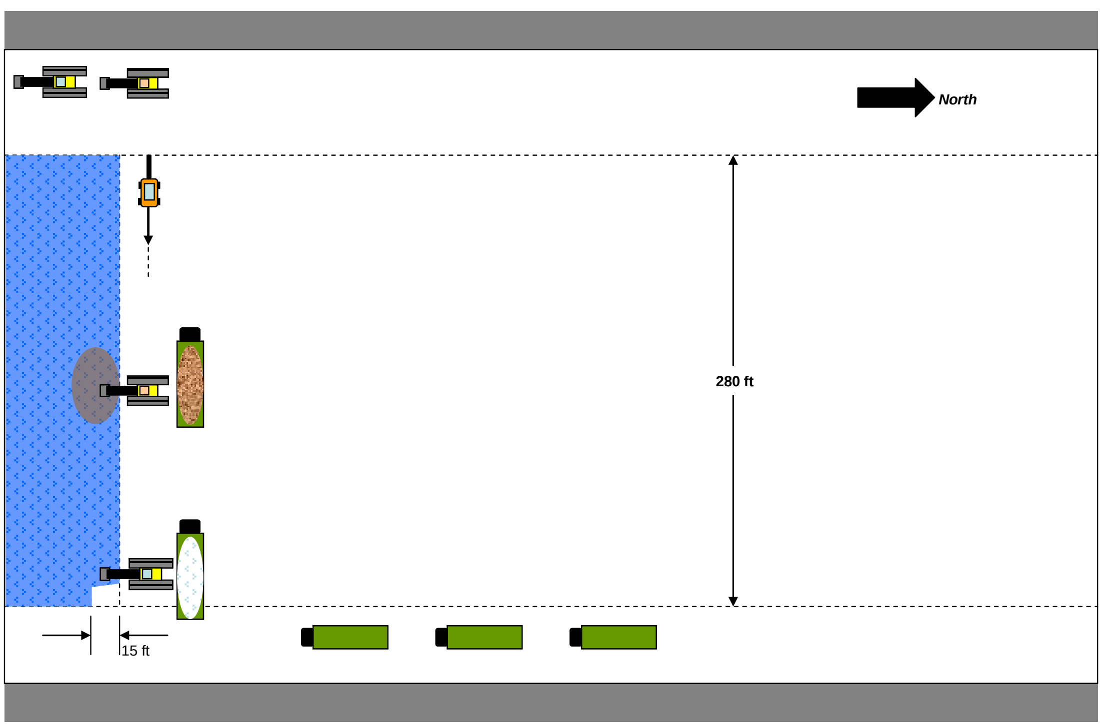
The speed with which the excavation progresses along the 280 ft width of the channel is dependent on the dig depth. The greater the volume of excavation, the longer the digging time required for each 15 ft swath. As an example shown in Figure 5-3, an 11 ft dig depth would require 4.6 hrs to complete the 280 ft swath while a 4 ft dig depth would require 1.9 hrs to complete. It is also noted that as the dig depth decreases to small values (e.g., 1 – 3 ft), the excavator will be digging partial bucket volumes accompanied by frequent excavator repositioning. Expected durations of digging for various dig depths are provided in Figure 5-4. Additional time is allocated when the dig depth becomes less than 4 ft. In the extreme case of a 1 ft dig depth, the partial bucket load and the frequent excavator repositioning is expected to require 1.1 hours for the 280 ft swath width—three times the time that would be required for full bucket excavation.

Figure 5-4. Time to Excavate Spoils Swath as a Function of Dig Depth



A later view of the ice cutting, ice and seabed excavation is shown in Figure 5-5. The work has progressed along the cut and a new cut has begun.

Figure 5-5. Remove Sea Ice and Dredge Seabed (cont.)



A view of the common starting location of Spreads “A” and “B” is shown in Figure 5-6. The work tasks would be accomplished at comparable rates on opposites ends of the trench. Local ice disposal requires loading trucks for short hauls to adjacent disposal areas – at the edge of the ice pad at grounded ice locations or, alternatively, to the side of the completed trench where the ice can be bulldozed into the ice slush of the trench. Independent haul truck fleets service the different construction spreads.

Ultimately, Construction Spreads “B” and “C” will meet. At this junction, the direction of movement of ice cutting and ice and spoils excavation must change. As shown in Figure 5-7, the remaining 300 ft wide ice sheet must be cut in a north-south direction along the west edge of the channel. This junction will occur in grounded ice, therefore, the Cat 365 (non-amphibious) excavators will be used. Later progress of the work at this junction is shown in Figures 23 and 24. Disposal truck movements within this restricted area will need to be regulated to ensure safe traffic patterns as the trucks will likely need to back towards the open trench.

Figure 5-6. Construction Spreads “A” and “B” Moving in Opposite Directions

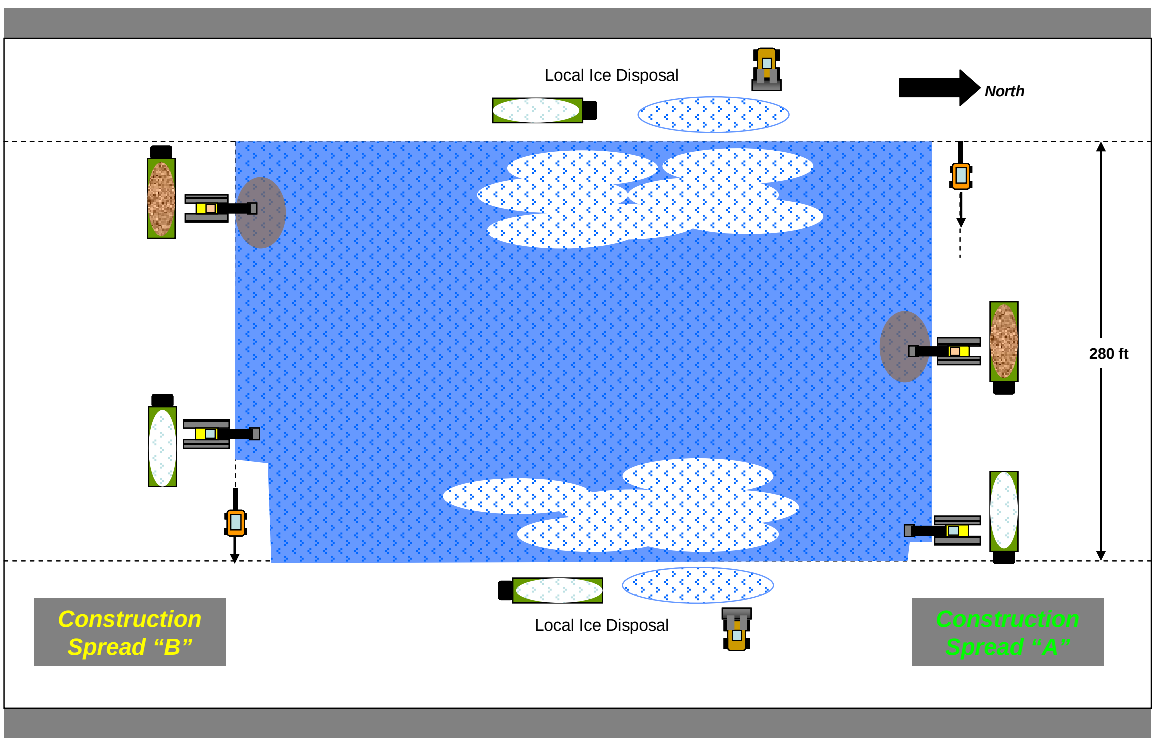


Figure 5-7. Final Tie-in at Spread "B" and "C" Junction (grounded ice)

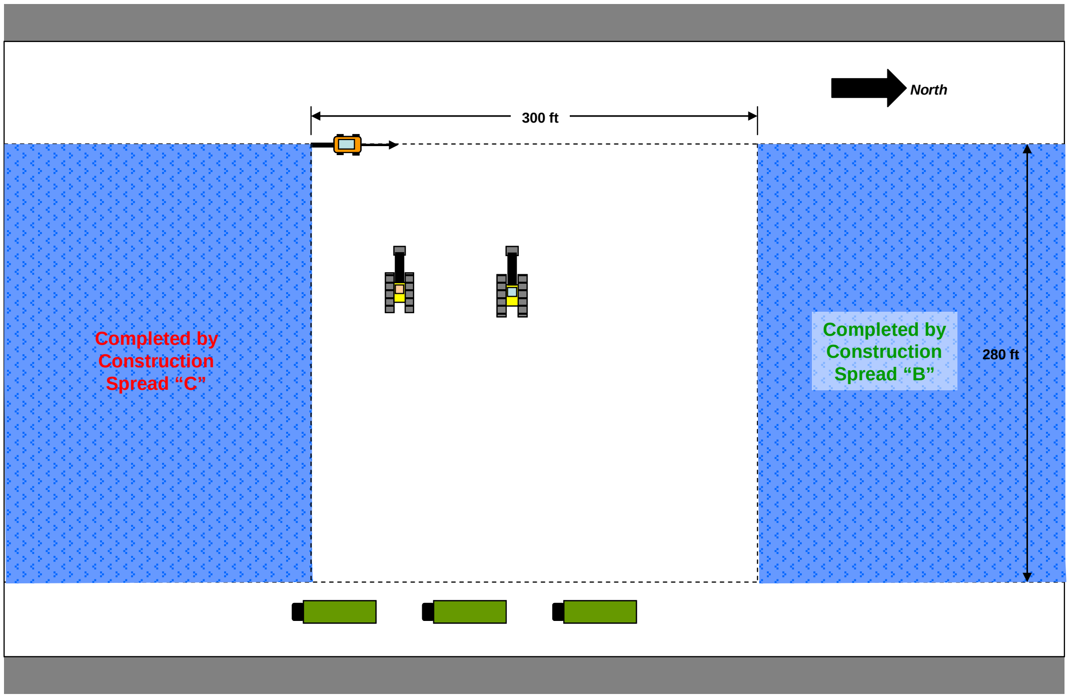


Figure 5-8. Final Tie-in at Spread "B" and "C" Junction (cont.)

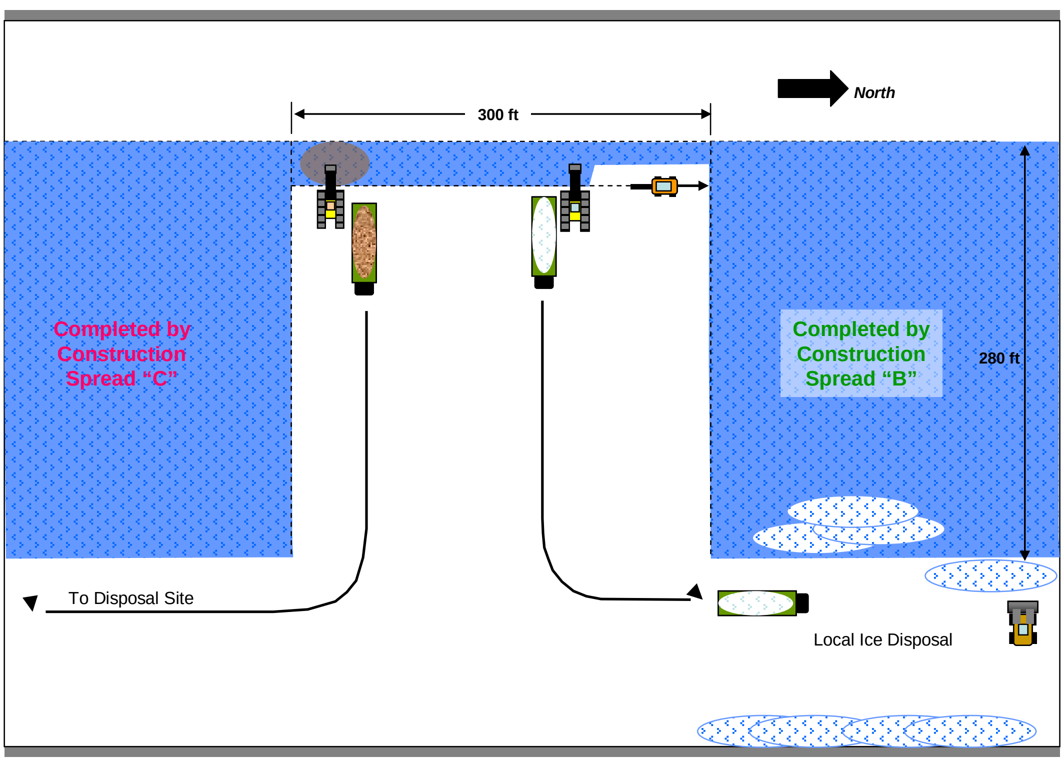
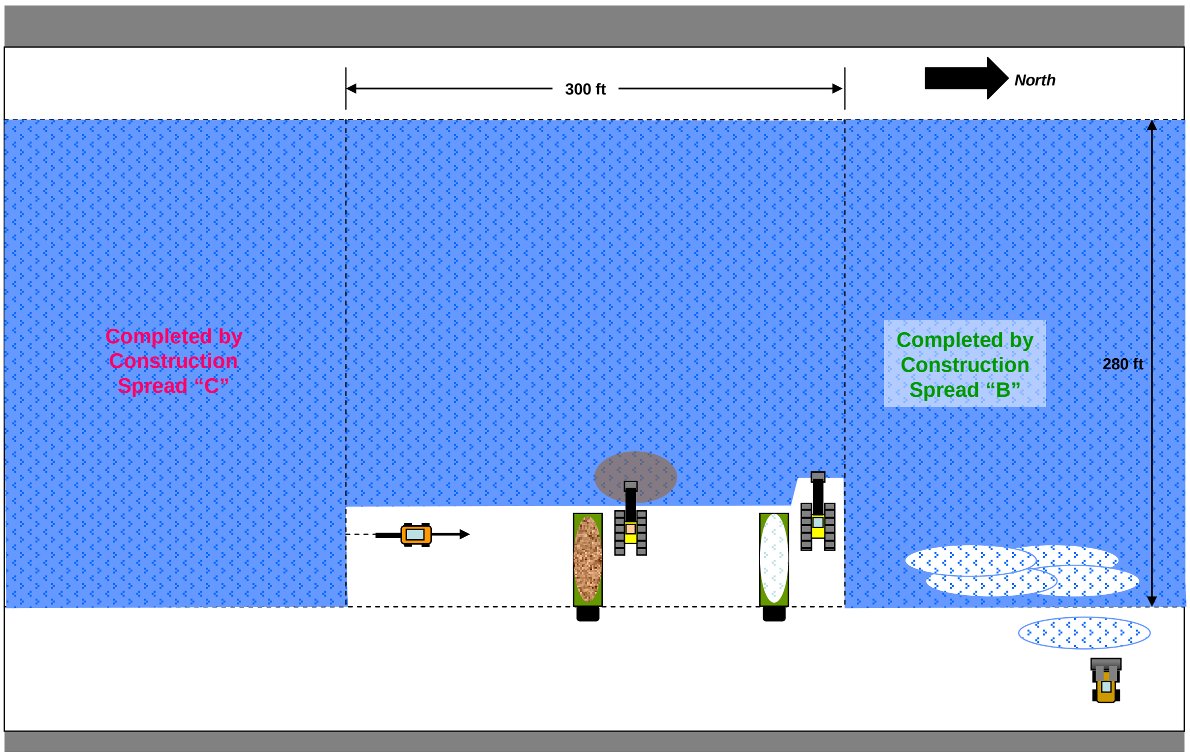
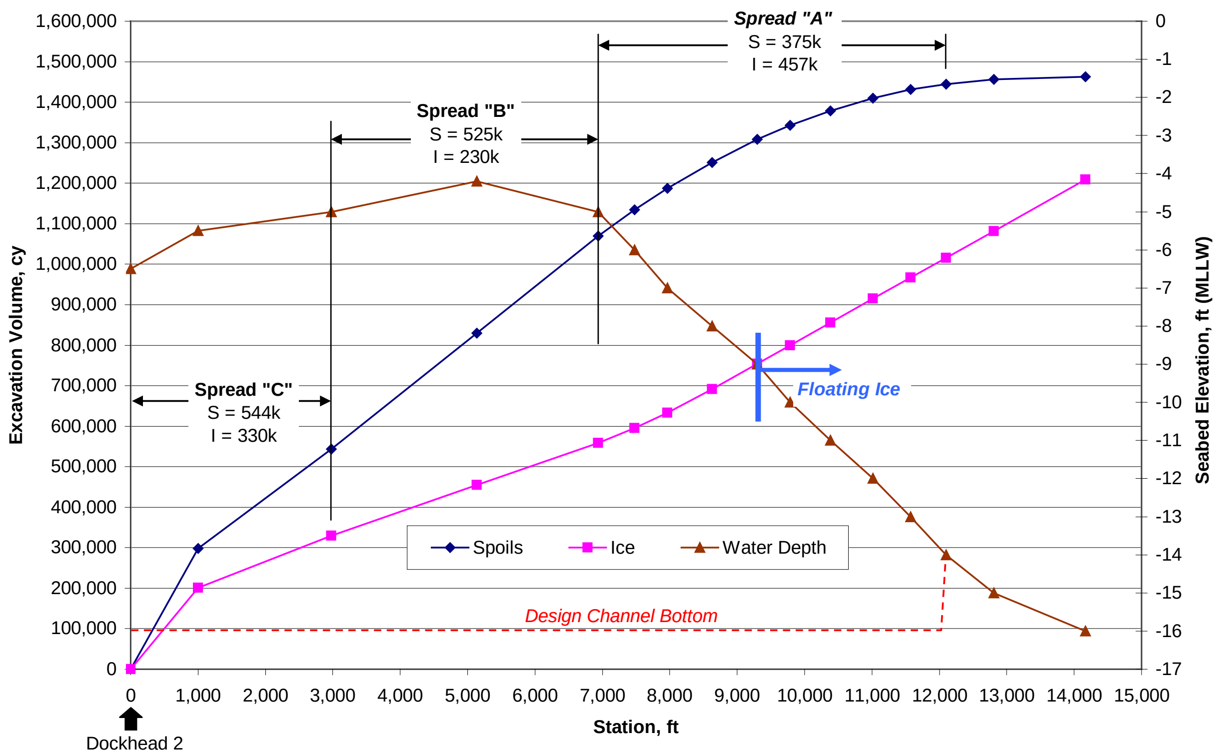


Figure 5-9. Final Tie-in at Spread "B" and "C" Junction (cont.)



The excavation requirements for the navigation channel and the three construction spreads are summarized in Figure 5-10. Along the horizontal axis, the distance from Dockhead 2 is shown. The cumulative volumes of both sea ice and spoils excavation are shown along the left-hand vertical axis. The vertical axis on the right side shows the seabed elevation. The areas of each construction spread have been selected to roughly equalize the excavation volumes. Floating ice is expected to begin at the -9 ft seabed elevation.

Figure 5-10. Cumulative Excavation Volumes, Full-Scale Winter Dredge Scenario



Construction Spread "A" begins at the -6 ft elevation contour located about 7,000 feet north of Dockhead 2. While it will begin on grounded ice, it will move onto floating ice when the water depth reaches about 9 ft, or about 2,500 feet north from its starting point. It will utilize Cat 345 excavators on amphibious pontoons. The excavation will extend to the -14 ft elevation contour, a total distance of about 5,000 ft. In this area, there is more ice to remove (I=457,000 cy) than spoils (S=376,000 cy). In the final stages of work, the modest dig depths of 1 – 3 ft will slow the excavation rate. The time required to excavate this area is dictated by the largest material volume to be excavated (sea ice). At the expected excavation rate of 7 cy/min (8,400 cy/20-hr day), the required time to complete this work is 55 days. This could allow a later start of this area if more time is needed to thicken the floating ice. However, since the work begins in a water depth of 6 ft (grounded ice), immediate start of the work is expected in early February. As the digging progresses north, continued flooding of the offshore floating ice section could occur in advance of the construction spread.

Both Construction Spreads "B" and "C" require deep excavations in shallow, grounded ice locations. Spread "B" will start at the start point of Spread "A" and will proceed south. Spread "C" will begin at Dockhead 2 and proceed north. Spreads "B" and "C" will eventually meet and the completion of the channel will occur using the methods shown in Figures 22 to 24.

Construction Spread "B" will be digging about 525,000 cy of spoils and, given the shallow water depth, 230,000 cy of ice. Spread "C" will dig 544,000 cy of spoils and 330,000 cy of ice. Given the comparable spoils excavation requirements, both spreads will require about 65 days to complete the work. A summary of the excavation areas and the volumes of ice and spoils to be removed is shown in Figure 5-11.

The expected duration of the excavation effort (65 days) yields some contingency time relative to the expected on-ice construction season length (February 2 – 26 April = 83 days). The contingency time totals 22% (= (83-65)/83). This extra time (18 days) will be consumed by start-up inefficiencies and weather downtime. The start-up difficulties are assumed to require 5 unproductive days while the weather down-time is estimated to be 10% of the total time (= 8 days). Thus, assuming 13 days of unproductive time during this construction season, the final contingency is 5 days, or 6% of the excavation work season. Should additional contingency be desired, the decision could be made to provide a fourth construction spread with the same equipment and personnel needs as required for the three spreads described. This would reduce the excavation requirement for each of the four spreads to about 375,000 cy, which could be completed in 45 days (= 375,000/8,400 cy per 20-hr day), leaving 38 days of contingency (46% of the on-ice construction season).

5.2 SURVEY REQUIREMENTS

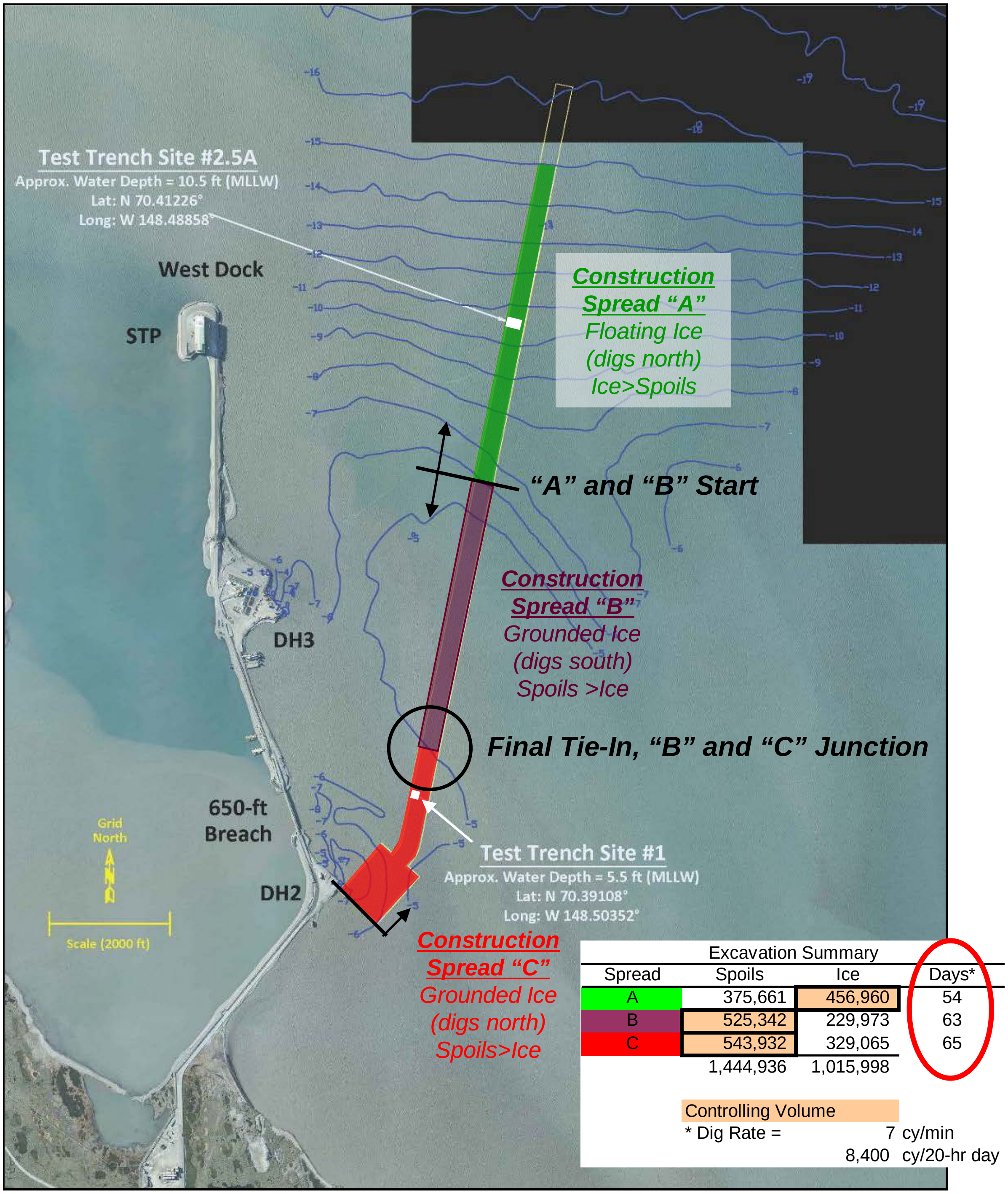
As noted previously in Section 4.5, the traditional survey methods used to perform as-built surveys of the test trench sites were time consuming and resulted in sparse data coverage of the excavation regions. At times, the excavator operators also were required to re-dig portions of the test trench that did not reach the design depths during the initial pass. The following sections discuss GPS-assisted machine control and improved survey methodologies which could minimize these inefficiencies during the large-scale winter dredging program.

5.2.1 GPS-Assisted Machine Grade Control

One essential component to improve the accuracy and speed of the dredge channel excavation is to provide real-time guidance to the excavator operators. Doing so would allow the operators to see, in both plan and profile views, where they have achieved the channel design elevation and where additional excavation is required. These visual displays would also aid in preventing over-digging of the seabed material, which would result in unnecessary excavation time.

Improvements in Real-time Kinematic Global Positioning System (RTK; GPS) and the integration of excavator-mounted sensors allows precise positions of the excavator bucket to be displayed on LCD monitors for each equipment operator. This technology is generally referred to as machine grade control and can be installed on both new and existing equipment dedicated to the project. The system works by utilizing a corrected GPS signal emitted from a static base receiver, which has a precisely known geodetic position and elevation. Each excavator is outfitted with a pair of RTK GPS antennas, mounted between the cab and counterweight of the machine. Using the corrected GPS signal from the base, the position and heading of the machine is calculated by an on-board computer system. A variety of sensors including tilt instruments, position-sensing cylinders, and boom/stick pin devices also are interfaced to the processing device. Based on the geometry of the sensors relative to the RTK GPS antennas, the real-time position of the excavator bucket is calculated during each removal cycle of seabed material.

Figure 5-11. Excavation Distribution, Full-Scale Winter Dredge Scenario



Excavation Summary

Spread	Spoils	Ice	Days*
A	375,661	456,960	54
B	525,342	229,973	63
C	543,932	329,065	65
	1,444,936	1,015,998	

Controlling Volume

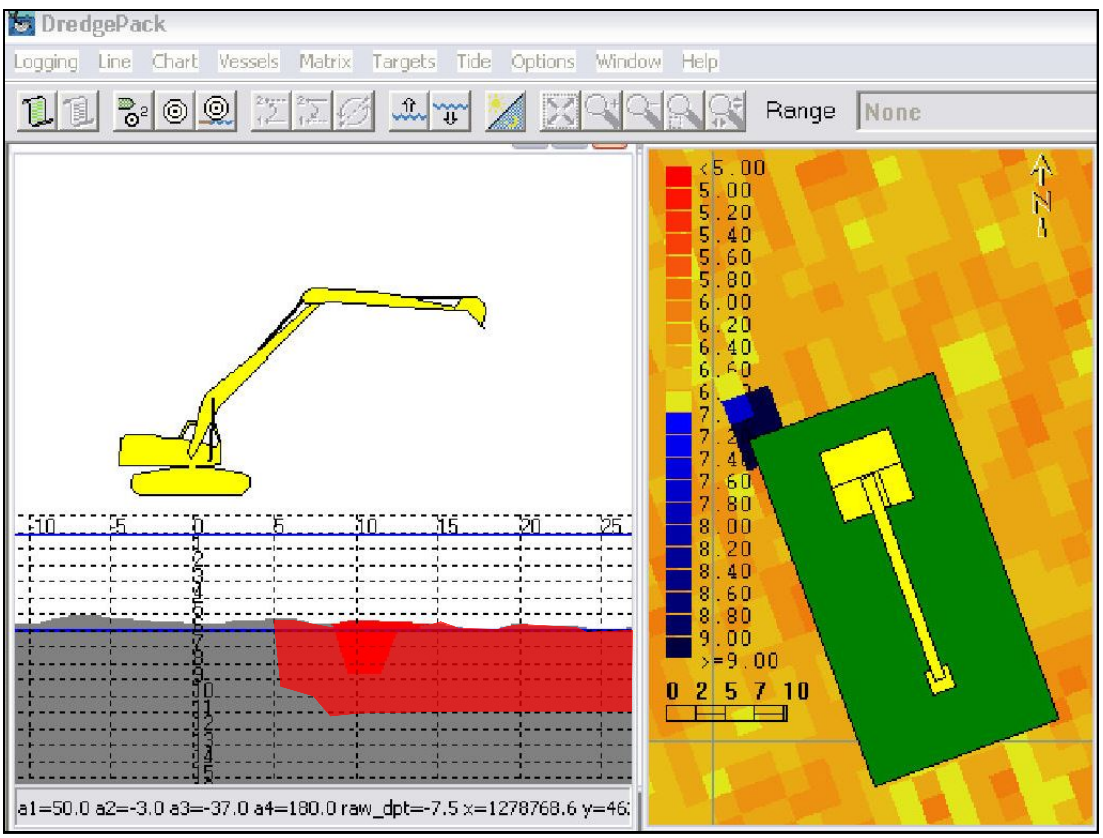
* Dig Rate = 7 cy/min
8,400 cy/20-hr day

Newer excavators can be purchased with grade control systems integrated into the machine at the factory, as is the case with Caterpillar's Attachment Ready Option© (ARO). The benefit of this includes internal wire routing, pre-installed sensors, and plug-and-play connections which allow system components to be quickly interchanged or replaced. Older machines would require retrofitting to accept the external boom and stick sensors. In such cases it will be imperative that all sensors and wired connections be protected appropriately to prevent damage from ice impacts during the winter dredging program.

5.2.2 As-Built Survey Methods

Several options should be considered to ensure that the as-built survey requirements of the project are satisfied during the winter construction. The method should be comprehensive and provide relatively dense data coverage over each swath of the dredge channel. Additionally, the survey method must be efficient, so as to not impede construction progress. One potential solution would be to integrate a dredging data collection program to the excavator machine control systems outlined above. Multiple vendors including Hypack Dredgepack© and QINSy Dredging© offer full data collection capabilities when interfaced with machine control components. These systems allow the same machine control guidance as above, in addition to the acquisition of user defined variables (e.g., max excavation depth, bucket cycles) during the excavation. The results are updated on the operators display as shown in Figure 5-12.

Figure 5-12. Display of Real-Time Excavation and Survey Data Acquisition



In addition to the in-cab display seen by the excavator operator, the dredging data could be broadcast over a local WiFi network to allow independent quality assurance (QA) inspection of the excavation by a qualified onsite engineer operating within a nearby vehicle. This QA check would put the onus of satisfying dredge channel requirements on personnel other than the operator, allowing them to focus solely on the excavation. This method is similar to that used by the US Army Corps of Engineers to fulfill Dredging Quality Management requirements (Hypack, 2015).

Should it be valuable to separate the as-built survey task from the excavator that is digging the seabed material, an additional excavator would be required to conduct the data acquisition. RTK GPS also would be installed on the equipment to provide precise positioning and elevation information during data collection. This QA excavator would utilize a screed bar, which would span the width of each trench swath and be lowered to the design trench elevation. Dredgepack© or a similar data collection system would be utilized for the as-built survey. Following excavation, the QA excavator would traverse the length of the dredge swath while data is acquired referencing the bottom-most elevation of the screed bar. Each successful pass of the screed bar would confirm that the seabed elevation is at or below the design grade. Areas that do not meet this condition will either be smoothed out by the passing screed bar to the desired elevation or in some cases may require additional excavation.

5.2.3 Future Research

Several alternatives have been presented to acquire as-built survey data in an efficient and comprehensive manner during the winter dredging program. While each method has the potential to satisfy the expeditious data collection requirements, future verification will be necessary to confirm that the methods will work in the harsh environment of a winter dredging program. The following items should be tested prior to selecting any one of the as-built survey methods:

Machine Control

- Confirm reliable use of systems in a marine environment with minimum temperatures of -40°F. This could be performed at Prudhoe Bay, or alternatively in a flooded gravel pit at Fairbanks or Anchorage, using local excavators that are equipped with GPS-assisted machine controls.
- Work with equipment and/or machine control suppliers to develop appropriately protected wiring systems if externally mounted to excavators.

Data Acquisition

- Test local WiFi streaming reliability of as-built survey data between data acquisition equipment (located on excavator) and independent quality assurance engineer (located in nearby vehicle).

5.3 WINTER DREDGING SCHEDULE

The project schedule will follow previous examples set for large-scale winter on-ice operations in the Prudhoe Bay area. It is important to stage the necessary ice-building equipment (hand pumps, snow machines for survey support and hand pump deployment, pumpers, water trucks, etc.) in early November so that the ice work can begin as soon as possible when air temperatures drop.

The important major tasks, recommended dates of start and completion, and the total days required for each task are provided in Table 5-1. Critical dates include the start of the ice road work (early- to mid-November), completion of the ice roads/pads in early February, and completion of the offshore excavation (late April). All on-ice work is expected to be forced off the ice by warming temperatures and weakening ice strength by May 1st.

Table 5-1. Alaska LNG Winter Dredging Schedule

Task	Description	Start	End	Days
1	Mobilize Equipment, Ready for Work	1-Nov	10-Nov	9
2	Survey Ice Roads and Platforms, Snow Removal	11-Nov	15-Dec	34
3	Construct Ice Roads/Platforms	30-Nov	1-Feb	63
4	Maintain Ice Roads/Platforms	30-Nov	20-Apr	142
5	Conduct Winter Dredge Program	2-Feb	26-Apr	83
	a. Cut Ice			
	b. Excavate/Remove Ice			
	c. Excavate/Remove Spoils			
6	*Demobilize Equipment*	27-Apr	30-Apr	3
7	*All Equipment/Facilities Off Ice*		1-May	

5.4 EQUIPMENT REQUIREMENTS AND ESTIMATED PROJECT COST

The estimated project costs for the initial dredging of the navigation channel are summarized in Table 5-2. The work tasks are identified as phases of construction – ice road/platform construction, ice road/platform maintenance, channel dredging and spoils hauling/disposal, and Deadhorse office support. Various support equipment (e.g., fuel trucks, mechanics trucks, light plants) have also been included. The duration of each activity is estimated allowing for the determination of project costs and labor force needs for each major task. The following elements of the cost basis have been assumed in the estimate:

- Equipment type and cost (w/ operator cost per 24-hr day)
- Fuel required for each equipment type (assumed fuel cost = $5.50/gal)
- Lodging cost per person-day (assumed lodging cost = $125/person-day)
- Round-trip spoils haul = 10 miles (e.g., West Prudhoe, West of Causeway, Gull Island)
- No contingencies for spare equipment have been included
- All costs in 2015 dollars.

No costs have been estimated for project oversight, construction management, safety monitoring, or project accounting provided by ExxonMobil or its designated representatives. The estimated equipment costs include normal maintenance and repair. Mobilization/demobilization cost has been included for expenses necessary to gather/disperse the equipment and personnel at the beginning and end of the project. General overhead (6%) and profit (7%) were identified through discussions with a leading North Slope contractor. No cost contingencies have been applied. The estimated cost for the capital dredge program is $47.3 million, representing a unit cost of $32.69/cy.

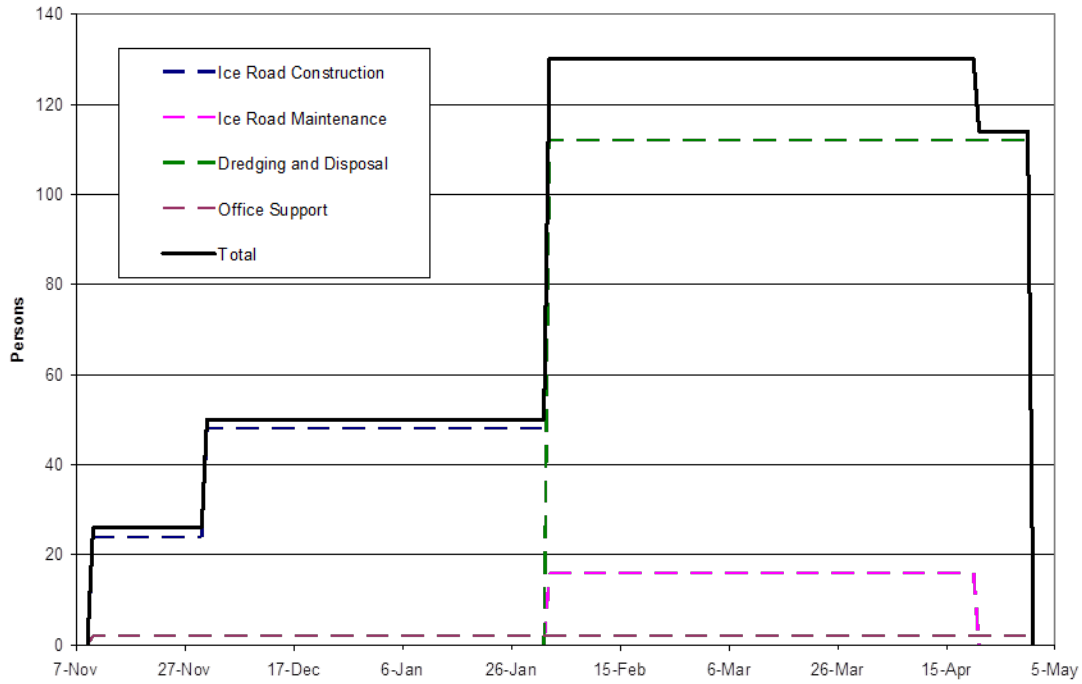
Table 5-2. Winter Dredge Cost Estimate

Activity/Equipment Type	Cost w/ Operator per 24-hr Day	Fuel per 24-hr Day, gals	Fuel Cost per 24-hr Day[1]	Units Required	Equipment + Fuel per 24-hr Day	Personnel Required per 24-hr Day	Lodging Cost per Day[2]	Number of Days	Cost
1. Mobilization/Demobilization									$500,000
2. Ice Roads/Platforms Construction (10 Nov - 1 Feb = 83 days)									
Hand Pumper	$1,250	24	$132	8	$11,056	0	$0	45	$497,520
Snow Machine for Hand Pumper Deployment	$1,250	24	$132	4	$5,528	8	$1,000	45	$293,760
Snow Blower	$3,300	96	$528	2	$7,656	4	$500	45	$367,020
Pumpers	$3,300	96	$528	6	$22,968	12	$1,500	83	$2,030,844
Water Trucks	$5,700	168	$924	2	$13,248	4	$500	45	$618,660
Cat 966 Loader w/ Ice Trimmer	$4,700	216	$1,188	2	$11,776	4	$500	30	$368,280
Haul Units, 30 cy End Dump (ice chip hauling)	$4,500	168	$924	4	$21,696	8	$1,000	30	$680,880
Fuel Truck	$2,700	96	$528	1	$3,228	2	$250	75	$260,850
Mechanics Truck	$2,900	96	$528	1	$3,428	2	$250	75	$275,850
Survey Crew w/ Van	$3,300	24	$132	1	$3,432	2	$250	83	$305,606
Foreman w/ Pickup	$2,400	24	$132	1	$2,532	2	$250	83	$230,906
Safety/Spill Tech w/ Pickup	$1,250	24	$132	1	$1,382	2	$250	83	$135,456
Heater	$600	96	$528	4	$4,512	0	$0	83	$374,496
Light Plant	$200	48	$264	9	$4,176	0	$0	83	$346,608
Crew Bus	$300	48	$264	2	$1,128	0	$0	83	$93,624
Office Trailer/Weather Shelter	$600	24	$132	1	$732	0	$0	83	$60,756
Envirovac	$600	24	$132	1	$732	0	$0	83	$60,756
						50			
3. On-going Ice Road/Platform Maintenance (2 Feb - 20 April = 78 days)									
Pumpers	$3,700	96	$528	4	$16,912	8	$1,000	40	$716,480
Snow Blower	$3,300	96	$528	2	$7,656	4	$500	40	$326,240
Water Trucks	$6,800	168	$924	2	$15,448	4	$500	70	$1,116,360
						16			
4. Channel Dredging and Spoils Disposal (2 Feb - 30 April = 87 days)									
Ditchwitch DE8020 Trencher, 10-ft blade	$3,500	96	$528	3	$12,084	6	$750	87	$1,116,558
Cat 345 Excavator, Amphib Tracks, 4 cy bucket	$4,900	216	$1,188	2	$12,176	4	$500	87	$1,102,812
Cat 365 Excavator, Std Tracks, 6 cy bucket	$6,000	264	$1,452	4	$29,808	8	$1,000	87	$2,680,296
Cat 988 Loader (local ice disposal)	$4,700	288	$1,584	6	$37,704	12	$1,500	87	$3,410,748
Cat D7 Dozer (spoils pile consolidation)	$3,300	120	$660	3	$11,880	6	$750	87	$1,098,810
Cat 330 Excavator (for clean-out of frozen soil in trucks)	$3,500	168	$924	3	$13,272	6	$750	87	$1,219,914
Haul Units, 30 cy End Dumps[3]	$4,500	168	$924	33	$178,992	66	$8,250	87	$16,290,054
Zoom Boom Man-Lift (grade checks)	$1,500	12	$66	3	$4,698	0	$0	87	$408,726
GPS Survey Support, QA at each trench	$4,440	24	$132	3	$13,716	6	$750	87	$1,258,542
Fuel Truck	$2,700	96	$528	2	$6,456	4	$500	87	$605,172
Mechanics Truck	$2,600	96	$528	2	$6,256	4	$500	87	$587,772
Survey Crew w/ Van	$3,300	24	$132	1	$3,432	2	$250	87	$320,334
Foreman w/ Pickup	$2,400	24	$132	2	$5,064	4	$500	87	$484,068
Safety/Spill Tech w/ Pickup	$1,250	24	$132	1	$1,382	2	$250	87	$141,984
Heater	$600	96	$528	4	$4,512	0	$0	87	$392,544
Light Plant	$200	48	$264	12	$5,568	0	$0	87	$484,416
Crew Bus	$300	48	$264	3	$1,692	0	$0	87	$147,204
Office Trailer/Weather Shelter	$600	24	$132	2	$1,464	0	$0	87	$127,368
Envirovac	$600	24	$132	2	$1,464	0	$0	87	$127,368
						130			
5. Office Support (Nov 1 - May 1 = 182 days)									
Personnel and Reporting	$1,400	0	$0	1	$1,400	2	$250	84	$138,600
								Subtotal =	$41,804,242
							General Overhead @	6%	$2,508,255
							Profit @	7%	$2,926,297
								Project Total =	**$47,238,793**
								Total Dredge Volume (cy) =	**1,445,000**
								Unit Cost ($/cy) =	**$32.69**

Assumptions:
1. Fuel cost, $/gal = $5.50
2. Lodging cost/man-day = $125.00
3. Travel Distance to Disposal Site, RT (miles) = 10
No equipment spares included.
Costs in 2015 dollars.

A manpower loading chart is shown in Figure 5-13 showing the labor needs for the various phases of the work. The field work crew will peak at 130 personnel during the channel excavation phase (early February to late April).

Figure 5-13. Labor Force Loading Chart



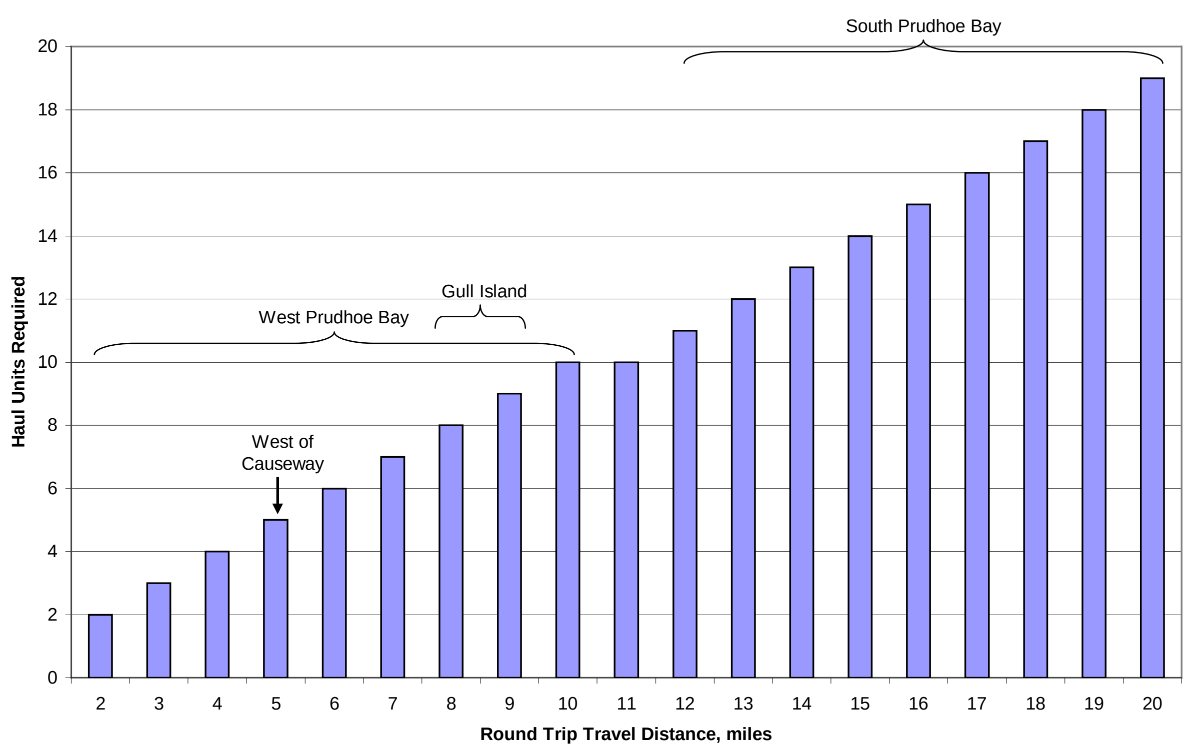
The project cost is significantly influenced by the location of the spoils dumpsite. A more distant dumpsite requires a larger number of haul units. In Table 5-3, the number of haul units required is determined based on the assumed bulk excavation rate (7 cy/min) and the round-trip haul distance to the disposal site. An average truck travel speed of 21 mph is assumed in conjunction with an average truck volume of 22 cy based the values determined from the recent test trench (Section 4.3.4). Figure 5-14 presents this information graphically. Use of the three closest disposal sites results in a truck fleet of no more than 10 trucks per construction spread. However, if the distant South Prudhoe disposal site is selected, the truck requirements double, to nearly 20 trucks per spread.

Table 5-3. Haul Units Required and Disposal Site Distances

Disposal Site	Round-Trip, miles	RT Travel Time @ 21 MPH, min	Each Truck, Trips/hour	Trucks Required
West Prudhoe Bay	2	5.7	10.5	2
	3	8.6	7.0	3
	4	11.4	5.3	4
West of Causeway →	5	14.3	4.2	5
	6	17.1	3.5	6
	7	20.0	3.0	7
Gull Island	8	22.9	2.6	8
	9	25.7	2.3	9
	10	28.6	2.1	10
	11	31.4	1.9	10
South Prudhoe Bay	12	34.3	1.8	11
	13	37.1	1.6	12
	14	40.0	1.5	13
	15	42.9	1.4	14
	16	45.7	1.3	15
	17	48.6	1.2	16
	18	51.4	1.2	17
	19	54.3	1.1	18
	20	57.1	1.1	19

Notes:
Dig/Haul Excavation Rate = 7 cy/min = 420 cy/hr
Average Truck Volume = 22 cy
Number of Trucks/hr = 19.1

Figure 5-14. Haul Units Required (per construction spread) for Various Disposal Sites



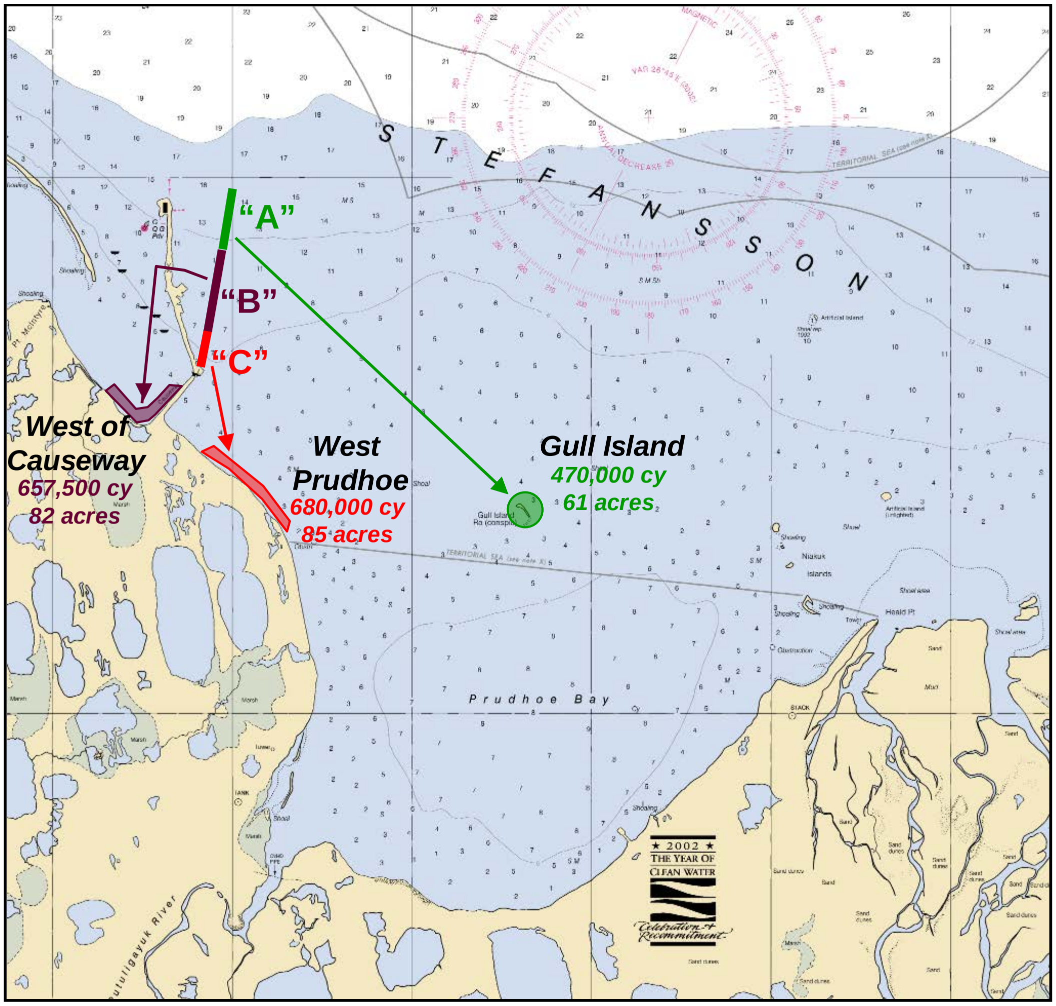
For the cost estimate provided in Table 5-2, the round-trip haul distance from the excavation location to the dumpsite is assumed to be 10 miles requiring a total of 33 haul units (10 active units for each of three construction spreads plus three contingency units to allow periodic truck bed cleanout of frozen spoils). This would be compatible with dumpsites located at West Prudhoe Bay, West of the Causeway, and at Gull Island. If the South Prudhoe Bay dumpsite is selected, the round trip travel distance would more than double to nearly 20 miles. In that case, a total of 60 haul units would be required (54 active haul units with six contingency units to allow for clean-out), resulting in a project cost of $60.8 million—an increase of $13.5 million (or 29%) relative to the options that utilize the closer dumpsites. Therefore, there are significant incentives to choose the closer dumpsites to minimize cost, fuel requirements, vehicle traffic, ice road construction and maintenance, and general intrusion on the environment.

5.5 COMBINED USE OF DISPOSAL SITES

In Section 3.2, various spoils disposal sites were described. Each site was assumed to accept the entire volume (1.5 million cy x 1.25 bulking factor = 1.875 million cy) produced by the winter dredge program thereby requiring a disposal site area of about 256 acres. An alternative disposal strategy that would reduce the impacts for any given site would be to share the spoils volume between several sites.

A conceptual view of this plan is shown in Figure 5-15. Each construction spread ("A", "B", or "C") would transport its spoils to a specific disposal site. In this example, the spoils of the offshore section of the dredged channel, Spread "A" (= 376,000 x 1.25 = 470,000 cy), would be transported to Gull Island. If piled five feet above the ice surface, the spoils would encircle the island to a radius of about 916 ft, encompassing an area of 61 acres. The spoils from Spread "B" (=526,000 x 1.25 = 657,500 cy) would be transported west through the 52 ft causeway breach to the West of Causeway disposal site. If spread along a one nautical mile length of shore (6,080 ft), the 5 ft tall pile would extend 584 ft offshore yielding an area of 82 acres. For the portion of the channel nearest Dockhead 2 (Spread "C"), the required spoils volume of 680,000 cy (= 544,000 cy x 1.25) would be transported south to the West Prudhoe Disposal Site. When piled 5 ft high, the disposal area would be 85 acres and extend about 604 ft offshore. The total area of the three disposal sites is 228 acres. By utilizing three disposal sites, the local environmental impacts at any given site are reduced and the haul unit traffic will be reduced along any given ice road route.

Figure 5-15. Potential Use of Several Spoils Disposal Sites



5.6 RISKS

5.6.1 Winter Weather

A productive offshore construction season requires cold weather. While there is much information in the media about Arctic warming trends, local weather data provided in Section 6 suggests a high probability of cold winter temperatures, suitable for traditional offshore construction similar to that successfully accomplished each winter since 1982. However, an early end to the winter season with warming temperatures early in April is possible and must be monitored. The ice strength degrades quickly when air temperatures warm.

Given sufficient ice thickness in deep waters and grounded ice over much of the dredged channel, the threat of ice fracturing is limited. In the shallow waters near Dockhead 2 where the water depth is less than 6 ft, the ice could fracture if it is not grounded. Care must be taken to ensure grounded ice in these shallow areas in order to support the loads imposed by the construction equipment. Initially, removal of ice within a grounded work area may produce a dry excavation. If this occurs, no excavation of the seabed should occur until seawater floods into the area as the ice sheet relies on its buoyancy to achieve stability.

5.6.2 Potential Conflicts/Competition with Other Offshore Projects

Competition for North Slope construction resources (personnel, equipment, camp space) is a reality that must be mitigated for large projects to be successfully performed. Mitigation would require an early commitment to the selected construction contractor(s). If the contractor is notified a year in advance of the dredge work, there would be an opportunity to receive assurances of dedicated personnel and equipment for the project.

It may be that given the magnitude of the dredge and disposal volume, some specialized equipment may be needed that does not presently exist on the North Slope. This will include excavators with amphibious undercarriages. Dedicated excavators with 6 cy buckets (Cat 365 or equivalent) could be purchased or leased by the selected contractor to ensure that this critical equipment is available. Sufficient spare parts would also be required, particularly the large excavator buckets (with spare teeth), and the chains and wear surfaces for the Ditch Witch trenchers. If augmentation of the existing Max Haul truck fleet is required, advance award of the contract would allow the selected contractor to procure these, or similar, haul units. Given advance notice of a year, a competent contractor would procure the necessary equipment fleet, spare units and parts on a timely basis and commit to gathering the proper workforce.

Very large projects in the Prudhoe Bay vicinity have always required extraordinary equipment and man-power support. The Endicott Project, constructed in 1985-1986, required a massive gravel haul of several million cubic yards to construct two large islands and an interconnecting gravel causeway. This was accomplished during the same winter season that two very large offshore islands (Sandpiper and Northstar Exploration Islands) were constructed, requiring an additional 600,000 to 800,000 cubic yards of gravel at each site. The timely commitments to these large projects allowed a single contractor to obtain the unique equipment, personnel, and materials to successfully complete these projects.

5.6.3 Wildlife Interactions

Offshore construction in winter can be impacted by wildlife. Continual early work tasks that include surveying and ice flooding with accompanying traffic, light plants and noise will induce polar bears to avoid the work area and establish their dens at more quiet and remote locations.

Seals may surface occasionally in open water created by ice removal in the offshore (floating ice) portions of the excavated channel. Being curious, the seals might be seen surfacing and looking briefly at the work activity and then submerging to move from the area. The presence of seals in previous pipeline excavation trenches has not been documented, but has been noted at deeper water sites where open-water is created during the late spring. Over the majority of the channel, the grounding of the sea ice and the rapid refreezing of the open trench will likely present a physical barrier to seal access.

6.0 ENVIRONMENTAL CONSIDERATIONS

6.1 WINTER WEATHER CONDITIONS

Sustained cold air temperatures are required for the successful completion of a winter construction program on the offshore ice. During December and January, cold temperatures solidify the nearshore ice sheet and promote the construction of ice roads and work pads. Adequate ice roads and pads must be constructed during this two month period in order to allow the beginning of offshore excavation in early February. Cold temperatures throughout the December – April period are necessary to maintain the integrity of the ice roads and pads in order to successfully complete the channel excavation. Air temperature data is available from the NOAA weather station located at West Dock dating back to 1994. Annual variations in winter air temperatures can be analyzed to assess the probability of experiencing sufficient cold weather to promote project success. In addition, weather records can be assessed to estimate the expected periods of high winds or extremely cold temperatures (less than -40°F) that could lead to suspension of on-ice work (weather downtime).

Analysis of historical air temperatures at Prudhoe Bay are summarized in Figure 6-1 for the 1 December – 15 April periods of 1995 – 2015. For these periods, maximum, mean and minimum temperatures are plotted. The data indicates a trend for colder winter temperatures during this 20-year period, although a recent warming trend is apparent over the past several years since the very cold winter of 2011-2012. The minimum temperature for the winter just past is -39°F, about average for the entire period. Likewise, the mean temperature this winter was -6°F, about three degrees warmer than the long-term average.

Figure 6-1. Historical Annual Air Temperature Averages, Prudhoe Bay 1995 – 2015

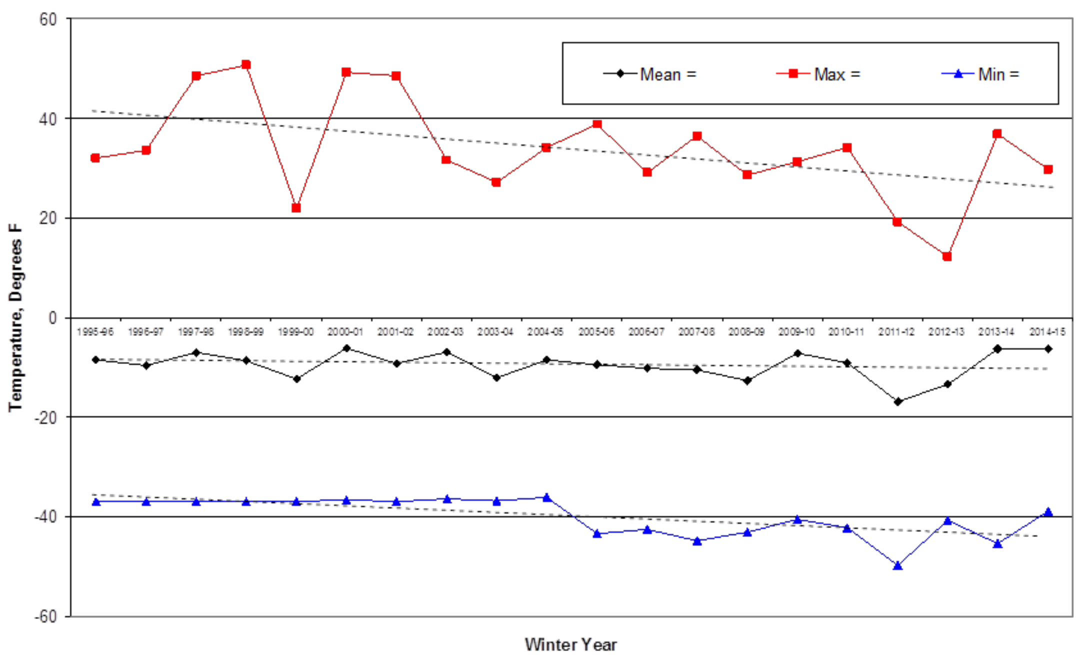
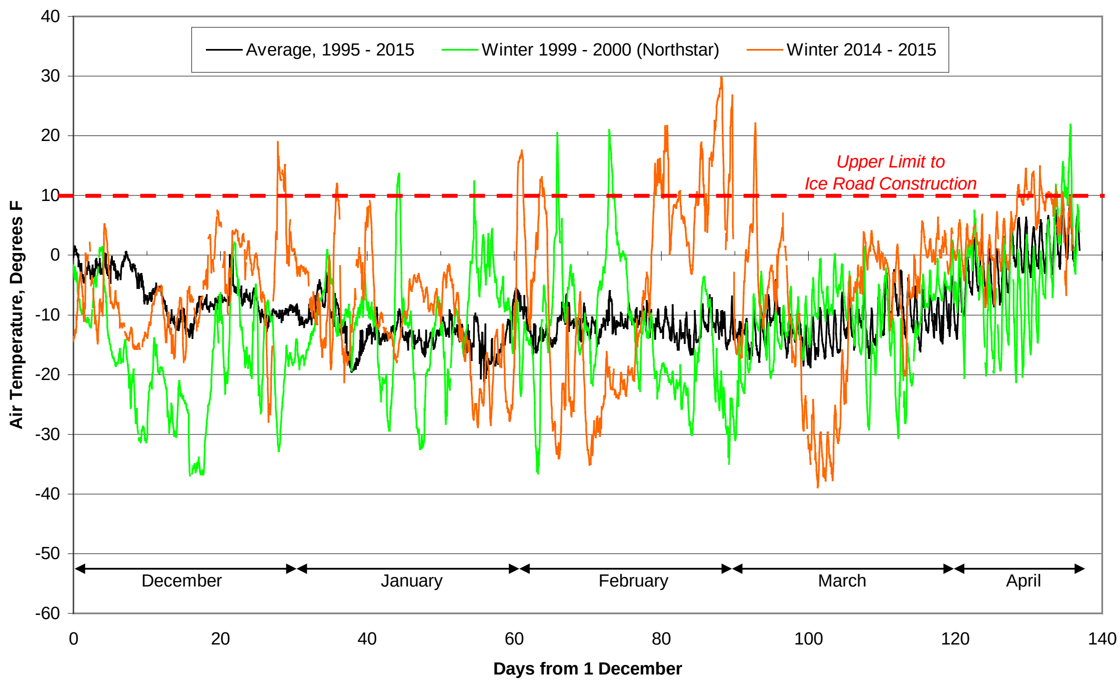


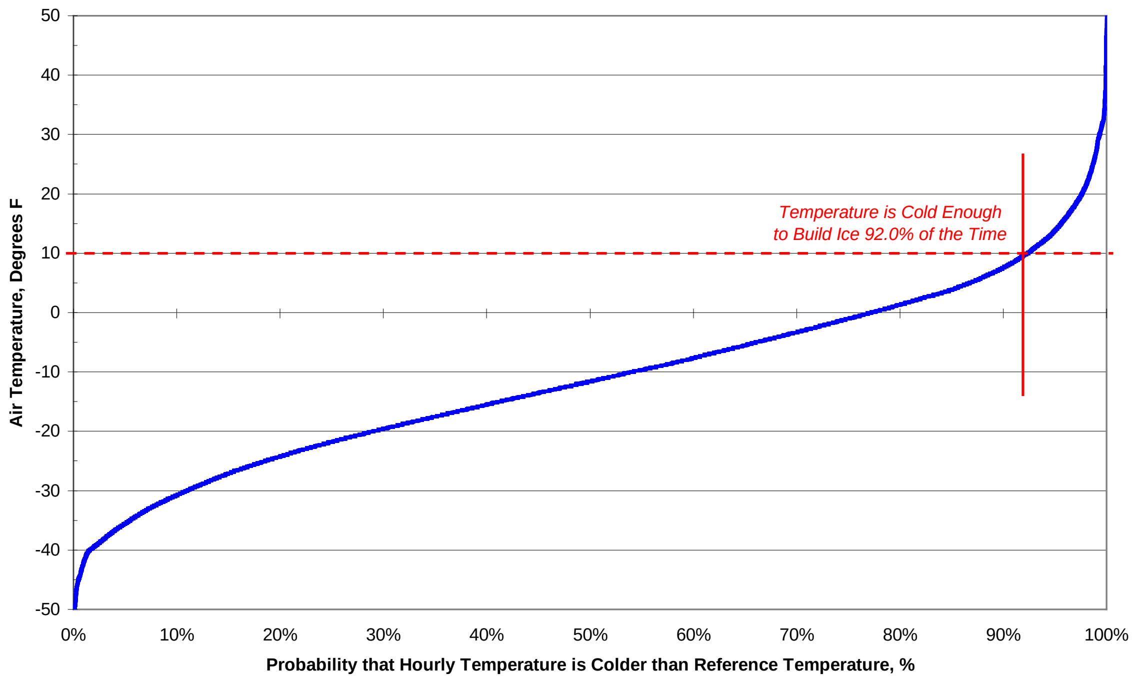
Figure 6-2 presents the hourly air temperatures measured at the NOAA weather station at West Dock for the recent winter (1 Dec 2014 – 15 April 2015) in comparison with the long-term average temperature of the 1995 – 2015 period. In addition, the temperature data for the very productive winter of 1999-2000 is displayed when the Northstar Production Island and subsea pipeline were installed. During that winter, two ice roads were constructed both having lengths of about six miles. The first road/pad served the installation of the subsea pipeline from the Pt. McIntyre shore crossing to the island including the fabrication of the two pipelines, excavation of the sea ice and the seabed trench, and installation/backfilling of the pipeline. The second ice road connected the gravel quarry in the Kuparuk River delta to the island and allowed the trucking of 600,000 cy of gravel and large volumes of materials (sheet pile, slope armor, and the related installation equipment) to the island. The success of this multi-faceted operation was supported by a winter that presented adequate cold weather, as shown in Figure 6-2.

Figure 6-2. Comparison of Winter Air Temperature, Winters of 1999 – 2000 and 2014 – 2015 versus Long Term Average (1995 – 2015)



For the 1995 – 2015 winter (1 Dec – 15 April) period, the percent exceedance of hourly air temperature has been computed. As shown in Figure 6-3, the winter air temperatures range from about +51º to -50ºF. Air temperatures are cold enough (+10ºF or below) to build and maintain ice roads about 92% of the time.

Figure 6-3. Exceedance Probability, Winter Air Temperatures, 1 December – 15 April, 1995 – 2015



Timely ice road construction should begin in mid- to late-November, as the cold winter air temperatures develop. In Figure 6-4, the variability of these early winter air temperatures is shown for the critically important December – January periods for the long-term average (1995 – 2015), the Northstar winter (1999 – 2000), the very cold recent winter of 2011 – 2012, and the most recent winter (2014 – 2015). The long-term temperatures during these two months average about -10ºF. The recent winter had an average air temperature during December and January (-7.8ºF) that was about two degrees warmer than the long-term average while the cold winters of 1999-2000 (Northstar) and 2011-2012 were markedly colder over these two month periods (-14.7º and -18.6º, respectively).

The probability of air temperatures during the critical 1 December – 31 January period is presented in Figure 6-5 for the long-term average (1995 – 2015) and for the most recent two winters (2013 – 2015). These two periods vary slightly in the percent probability of achieving an air temperature of 10oF (the upper limit of ice road construction/maintenance). This temperature was achieved 92.7% of the time over the long-term (1995 – 2015) while it was achieved 90.2% of the time over the most recent two winters when the mean temperatures have been warmer than average.

Figure 6-4. Hourly Air Temperatures, December and January (Ice Road Construction)

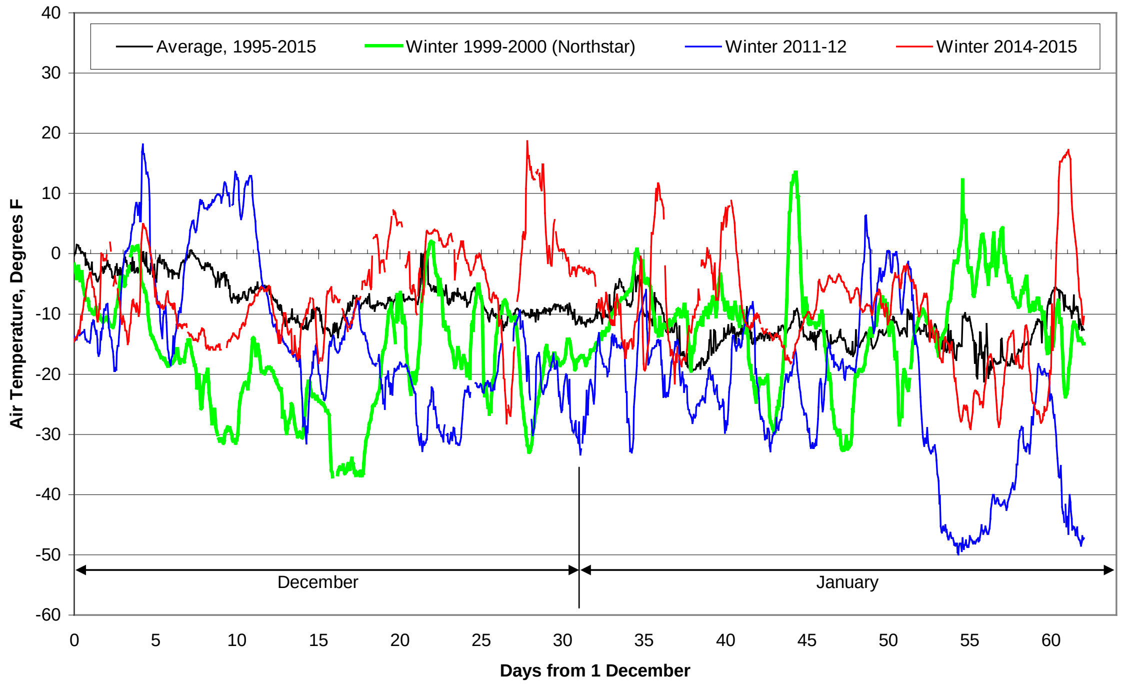
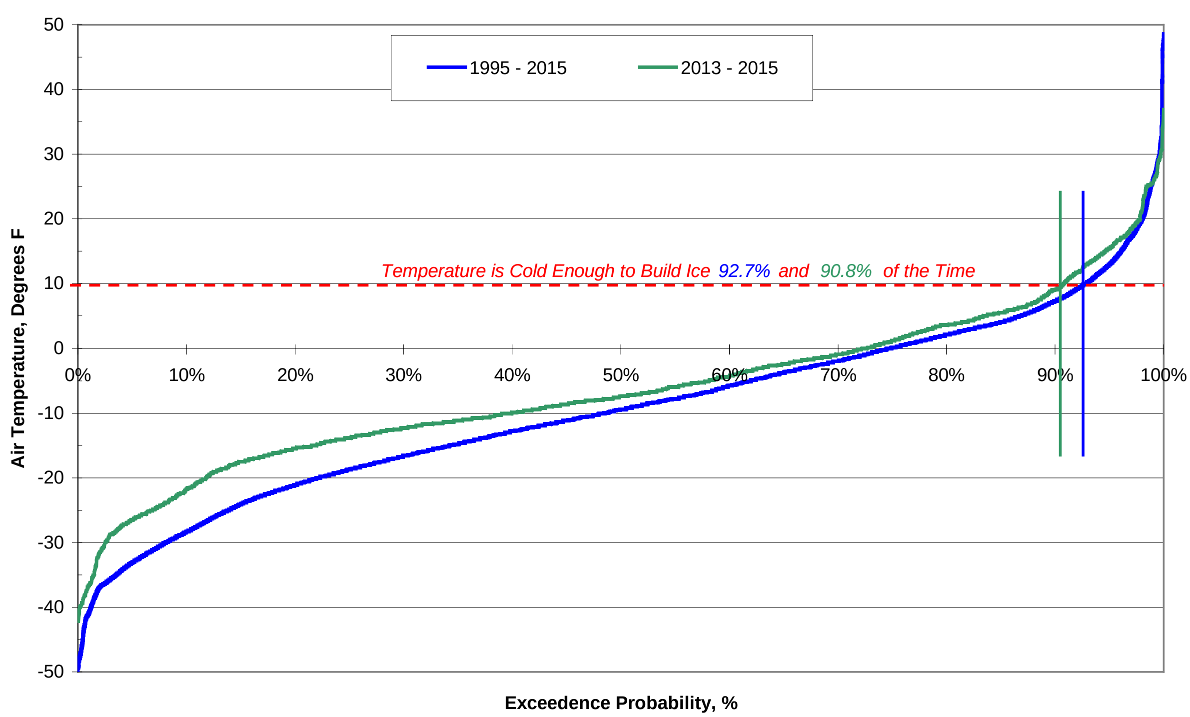
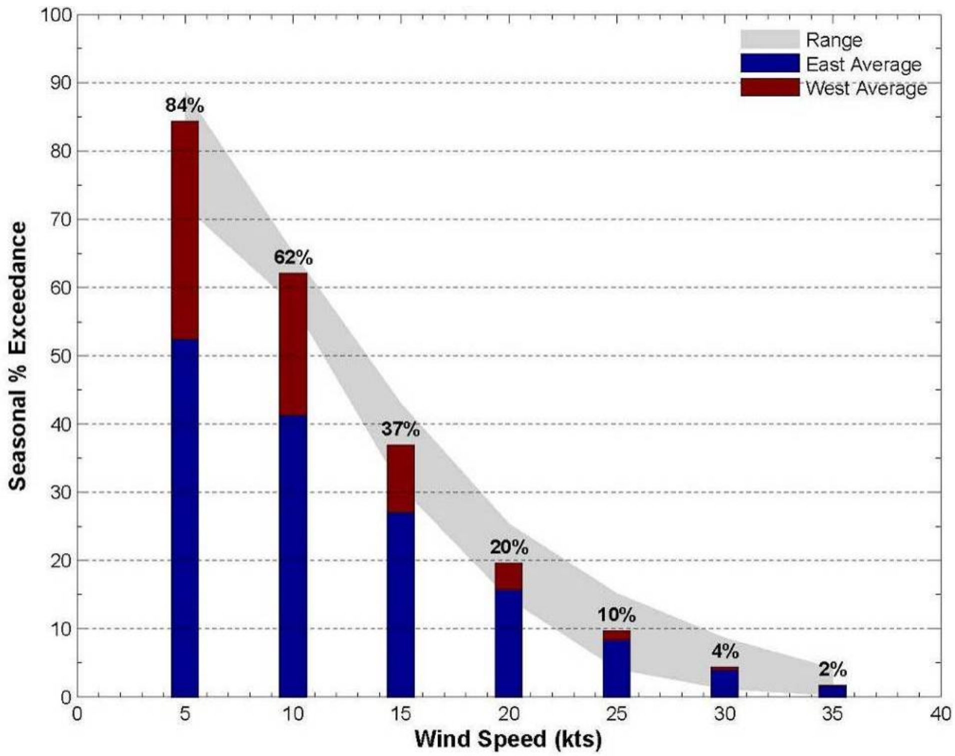


Figure 6-5. Exceedance Probability, Early Winter Air Temperatures 1 Dec – 31 Jan, 1995 – 2015 and 2013 – 2015



Work on the ice can be suspended during periods of extreme cold (< -40ºF) or during high winds of greater than 30-35 kts due to blowing snow that obscures visibility. High west winds can create storm surge in winter that can flood the nearshore ice for brief periods. This flooding condition will heal once the surface waters freeze under the cold winter air temperatures. Figure 6-6 shows the percent exceedance of wind speed at West Dock during the winter months for the 2001-2011 period. The percentages are shown for wind speed classes varying between 5 and 35 kts.

Figure 6-6. Winter Wind Speed Exceedance Probability, West Dock, 2001 – 2011



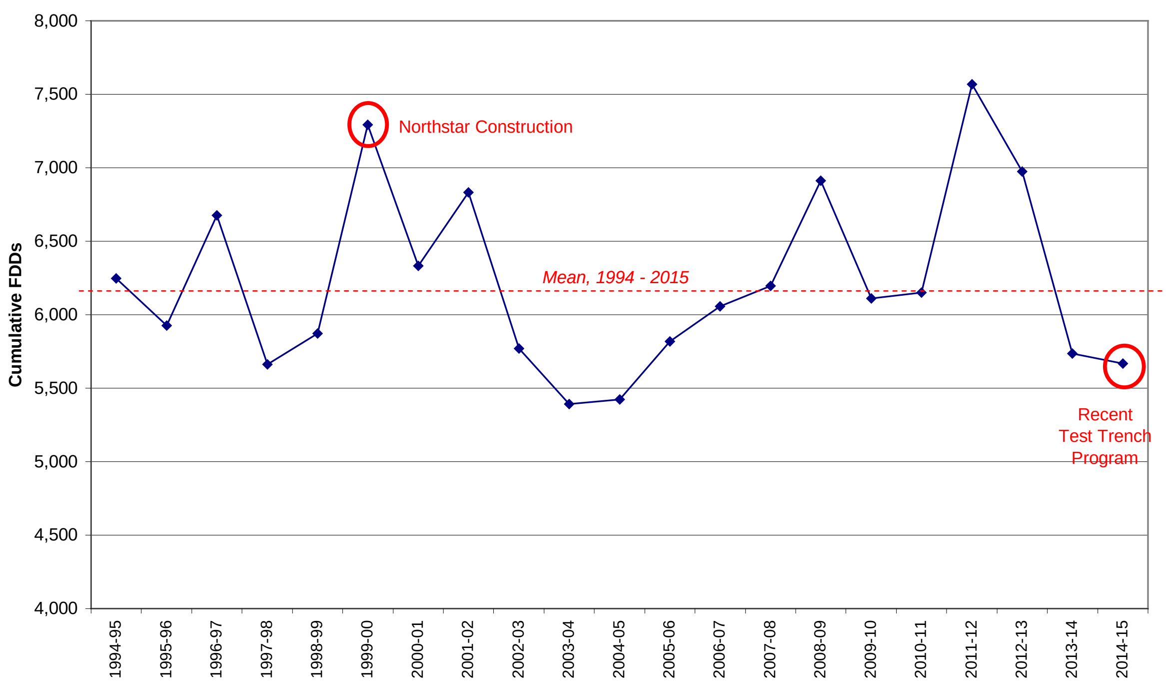
The wind speeds are divided by easterly and westerly approach. At lower speeds, both easterly and westerly winds occur, however, at higher wind speeds (30-35 kts), the winds are predominantly from the east.

High speed westerly winds that can create storm surge and promote flooding of the sea ice are rare. A more frequent occurrence is high speed winds from any direction that will create blowing snow leading to a potential for "white out" conditions thereby suspending offshore travel and construction. During periods of high winds, a Phase Condition is declared by Prudhoe Bay Security due to reduced visibility and traffic on the roads and offshore is restricted. Phase Alerts begin at wind speeds of 25-30 kts requiring special travel precautions. All but emergency traffic is stopped when winter winds reach 35-40 kts, although the precise conditions that dictate such restrictions can vary. For the purposes of this study, a downtime estimate of 10% should be assumed to account for restricted travel and subsequent clean-up (snow removal) when wind speeds exceed 30-35 kts.

6.2 CLIMATE FLUCTUATIONS AFFECTING WINTER ON-ICE WORK

A measure of the severity of a winter is the accumulated total of "Freezing Degree Days", or FDDs. Freezing-degree days are computed as the difference between the freezing point of seawater (29°F) and the mean daily air temperature, accumulated for each month. Any accumulated "negative" (>29°F) freezing-degree days are subtracted from the total. Air temperatures recorded at the NOAA weather station at the West Dock Seawater Treatment Plant provide local information adjacent to the proposed dredged channel. Figure 6-7 presents the annual FDD accumulation for the 21-year time period spanning 1994 and 2015. While the annual data fluctuates between 5,500 and 7,500 FDDs, no significant long-term trend is apparent in the data. Certain years are colder (e.g., 1999-2000 and 2011-2012) while other years are warmer (2003-2006 and 2013-2015). The annual average FDD accumulation over this period is 6,220.

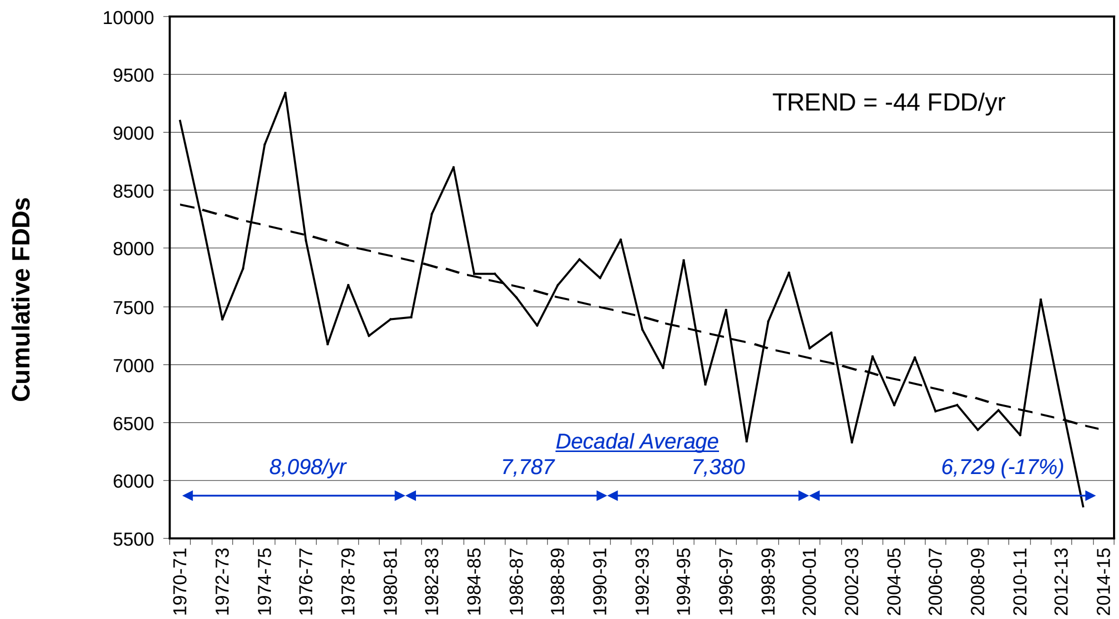
Figure 6-7. Cumulative FDDs, West Dock, 1994 – 2015



At Barrow, Alaska, there is a longer weather data record and FDDs can be compared over the 44-year period spanning 1970 and 2014. The annual cumulative freezing-degree days at Barrow for the 44-year database are plotted in Figure 6-8, showing a reduction of 44 freezing-degree days per year, a steady and increasing trend toward warmer winters. Based on decadal averages, there was a 4% decline in freezing-degree day accumulation from the 1970s to the 1980s, a 5% decline from the 1980s to the 1990s, and an 8% decline from 1990s to the 2000s (a 13-year period). The overall decline is 17% from the 1970s to the 2000s. In fact, six out of the last seven years rank in the top 10 warmest winters. Every year during the 1970s and 1980s had a colder winter than the average season in the 1990s and 2000s.

The expected reduction in ice thickness attributable to warmer temperatures may be exacerbated by an increase in the depth of the snow cover. To quantify the relative importance of these and other factors, Brown and Cote (1992) investigated the inter-annual variability in the maximum ice thickness at four sites in the Canadian High Arctic between 1950 and 1989 using a one-dimensional heat transfer model. The depth of the snow cover was found to be the most important factor, explaining 30% to 60% of the variability in the maximum first-year ice thickness due to its insulating effect. Density fluctuations in the snow cover were estimated to explain an additional 15% to 30%. In contrast, annual variations in air temperature accounted for less than 4%.

Figure 6-8. Cumulative FDDs, Barrow, Alaska, 1970 – 2014

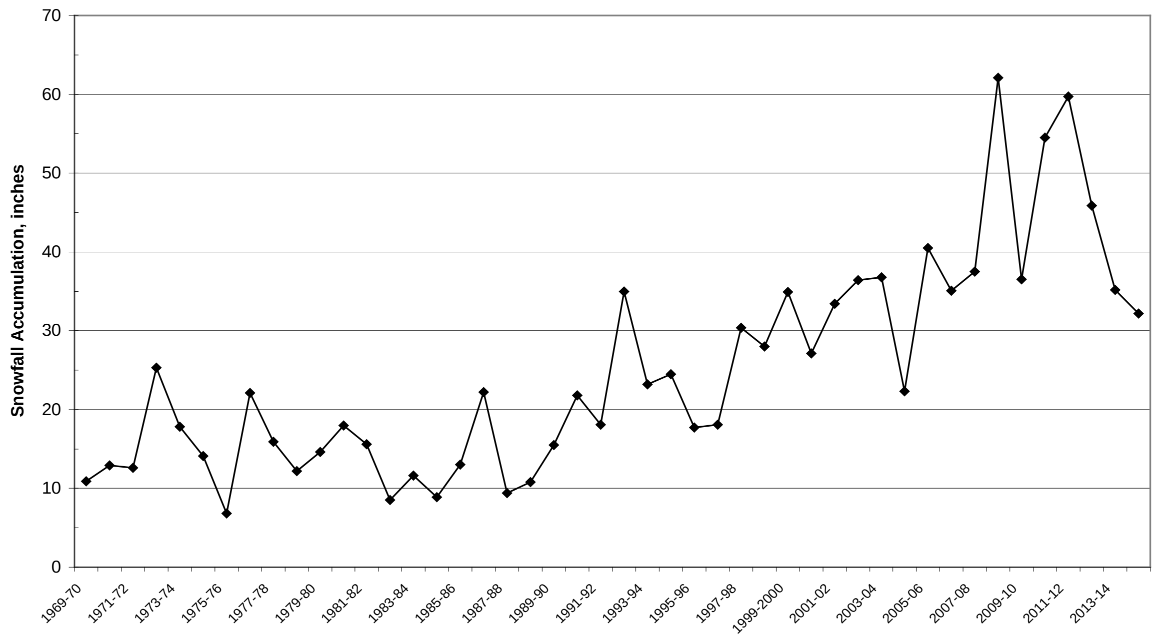


The average snowfall at Barrow during the six-month period from October through March has increased dramatically, from 14 inches in the 1970s and 1980s to 40 inches in the 2000s (Figure 6-9). Maximum average snowfall has achieved 60 inches in two recent winters. While the trend of increasing snowfall may reduce the thickness of natural sea ice, it should have no significant effect on the ability to construct ice roads and platforms assuming that snow clearance will be performed routinely on the roads and pads of the offshore work areas.

6.3 SUMMER WATER LEVELS AFFECTING CHANNEL DREDGE DEPTH

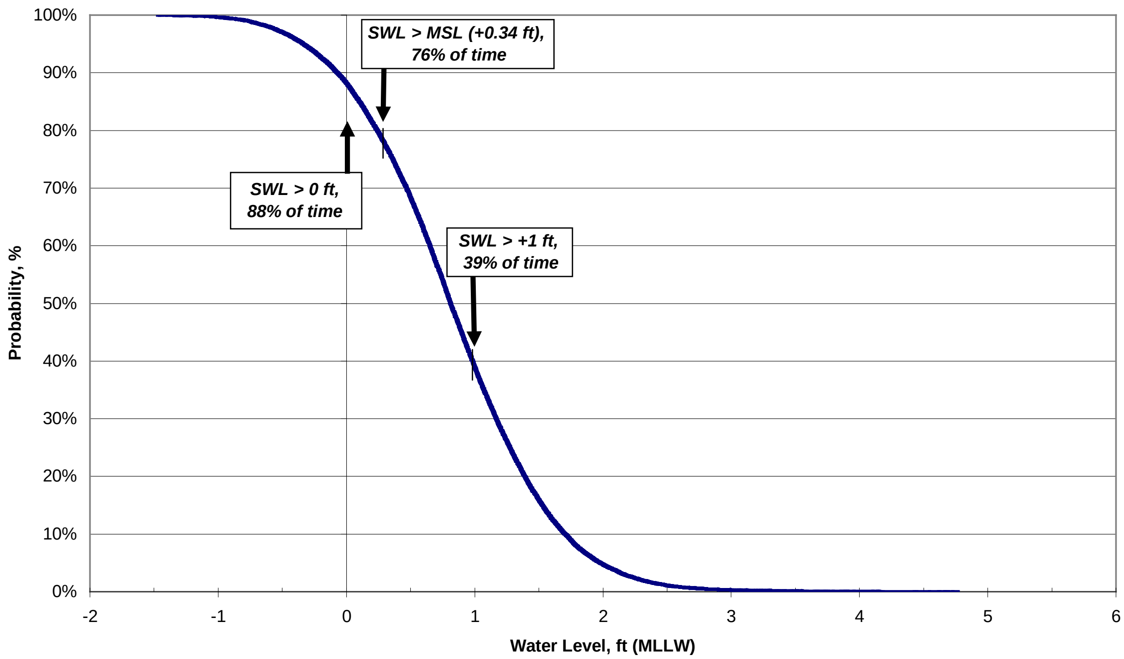
While the astronomical tidal range at Prudhoe Bay is quite modest (diurnal tide range = 0.7 ft), the sea level can span a total vertical range of about 8 ft during summer in response to storm wind events. During summer storms, the navigable water depths in the proposed navigation channel can vary significantly. Westerly winds typically raise the water level and easterly winds lower the water level.

Figure 6-9. Annual Snowfall Accumulation, Barrow, Alaska, 1969 – 2014



An analysis has been undertaken to determine the percent exceedance of water level elevations during the summer sealift period (August and September) that can help guide the design of the dredged channel depth. The water levels of August and September for the 20 year period spanning 1994 and 2014 have been ranked and a probability distribution of the data is shown in Figure 6-10. During these two months, the still water level (SWL) exceeds the 0 ft (MLLW) datum 88% of the time. Further, the SWL exceeds Mean Sea Level and the +1 ft (MLLW) elevation 76% and 39% of the time, respectively.

Figure 6-10. Exceedance Probability, Prudhoe Bay Water Level, August – September 1994 – 2014



6.4 ENVIRONMENTAL ADVANTAGES OF WINTER CONSTRUCTION

6.4.1 Regulatory Environment

A major hydraulic dredging program during early summer has only been performed once at Prudhoe Bay. That experience was in the spring of 1983 to create the flat landing bed on the seafloor for the Seawater Treatment Plant (STP) in a cove excavated at the north end of the West Dock Causeway. The work was performed by a small truckable Ellicott dredge that disposed its spoils on the ice surface to the west of the causeway. The more relaxed environmental regulations at the time allowed direct disposal of the sediment slurry onto the natural sea ice. At break-up, the sediments moved out of the area as the sea ice dispersed or dropped to the seabed west of the causeway. When the STP arrived as a floating barge from its Korean fabrication yard, it was floated onto the prepared seabed, ballasted down, and secured within the protective gravel of the causeway.

No other hydraulic dredge activities have been conducted during the summer on the Alaskan North Slope. Limited seabed smoothing (“screeding”) is performed near dockfaces to allow safe grounding of heavily laden barges. Dredging near the docks have been conducted during summer by backhoes working from barges, but the dredged volumes have been small and the disposal sites have been on the slopes of the causeway, above the high water line.

The understanding of the regulatory authorities is that disposal of the dredged sediments at a higher elevation on the causeway slopes allows those sediments to be eroded and dispersed into the sea only during times of significant storms. Therefore, the turbidity associated with the release of these sediments occurs during periods when natural turbidity levels are quite high due to wave-induced re-suspension of seabed sediments.

Since 1996, the preferred method of seabed excavation has been through the ice during the winter, as noted by the experiences of subsea pipeline installations. Heightened turbidity levels are more localized during the winter given the very low currents (driven by small tidal fluctuations) that exist beneath the ice. The height of the water column beneath the ice sheet is reduced relative to the summer open-water condition by the presence of the sea ice. This reduction leads to quicker settling times for the discharged sediments.

6.4.2 Marine Mammal and Subsistence Hunting Conflicts

River to the sea and then out to Cross Island—a traditional center of whaling activity located 15 miles northeast of West Dock. To avoid interference with Native whaling, major marine operations have been suspended in recent years beginning on August 25th. Non-whaling marine activities are not resumed for a period of 10-15 days; until either the whaling crews land their quota of whales or the whaling activity is otherwise terminated either due to adverse weather or the lack of whales in the offshore hunting area.

After the whaling activities cease, marine traffic and activities can resume, however, a good portion of the traditionally calm summer period has been lost. Fall storms are likely to occur from mid-September until the end of the open-water period at West Dock in early-October. Loss of 10 to 15 days of production in the middle of the calm summer period will greatly hamper summer dredge production.

Winter-time interactions with marine mammals must be avoided to the extent possible. Continual early surveying and ice road work on the young ice will divert polar bears from the work area. Seals may surface in open-water areas during the dredging activities, but such events are rare and of short duration. Further, the existence of open-water during winter will be short-lived given the rapid re-freezing within the excavated trench. In addition, the plan to ground the sea ice over much of the dredge channel and the limited seawater beneath the ice will create a physical barrier to seal movement into the work area.

7.0 OBSERVATIONS AND CONCLUSIONS

A number of observations were made during the conduct of the recent winter test trench program. Some systems and characteristics were found to work quite well and were highly supportive of a successful large-scale winter dredge program. Other systems were found to be lacking and not useful for further consideration without modification. Positive and negative influences on the on-ice dredging activities are noted in the following sections.

7.1 POSITIVE OUTCOMES

7.1.1 Rapid Ice Cutting

The rate of ice cutting approached 10 ft/min dependent on the depth of cut. A complete cut through floating ice caused the ice beam to float making it more difficult to excavate. Conversely, a floating ice beam could be beneficial in that it allows the excavator to pull the floating beam to it thereby minimizing or eliminating the need to move the excavator. With experience, the depth of the ice cut may be a personal preference of the excavator operator to allow or eliminate the possibility of a floating ice beam.

7.1.2 Ice Removal (no need to cross-cut)

The excavators were able to penetrate the ice pad without the need to perform time-consuming cross cutting of the ice swath. Cross-cutting is not necessary or desired.

7.1.3 Ice Roads and Pads

The ice roads and pads held up very well during the test trench work. There was concern regarding the overall strength and durability of the constructed ice, particularly as it related to the use of ice chips to thicken the ice. No loss of strength was apparent in those areas that were thickened by ice chips. However, maximum use of flooded ice should be the goal. Use of ice chips should be limited to those locations where the ice is nearly grounded and further flooding is not possible.

7.1.4 Ice Grousers on Excavator Tracks

Ice grousers are required for productive excavation. The test trench work utilized excavators (Cat 390 and Cat 345) without grousers and productivity and safety were compromised. Grousers were not needed for the amphibious undercarriages, presumably due to the large foot-print of the tracks.

To allow improved sea ice removal, the excavator operator suggested “grouser-like” ridges to be welded to the excavator arm near the bucket to prevent slippage of large ice chucks when picked up and pinned between the bucket and the arm. The suggestion seems worthy of consideration and is more likely to be helpful than the inclusion of a bucket “thumb.”

7.1.5 Large Bucket Sizes for Excavators

The bucket sizes used for the Cat 345 and the John Deere 650 were 3 and 5 cy, respectively. Commercial specifications indicate the maximum bucket sizes for these excavators are 4 and 6 cy. To maximize production, the larger buckets should be used for the full-scale dredge program.

7.1.6 Seabed Sediment Characteristics

The seabed spoils appeared to be similar at both test trench sites in that both were composed of cohesive, dense soils containing silt and clay. No significant areas of running sands were noted. These soils allowed for very large bucket volumes, typically 50% more than the struck bucket volume. For much of the excavation, limited water volumes were incorporated into the truck body given the dense nature of the spoils contained within most buckets.

7.1.7 Side Slope Sloughing

Due to the dense nature of the excavated seabed soils, the side slopes were quite steep and remained so for the entire survey period. The side slopes were approximately 1V:1H (45o from horizontal). The lack of foundation undercutting provides support for the excavators working on grounded ice and removes the need for amphibious undercarriages in these circumstances.

7.1.8 Spoils Pile Placement

The spoils were hauled to a nearshore area adjacent to the eroding coast at the AGI Pad. As the spoils were dumped from the haul units, they were consolidated and compacted by track-walking with a Cat D7 bulldozer. The resulting spoils disposal site was well consolidated and very neat yielding a uniformly placed and shaped sediment mass.

7.1.9 Ocean Turbidity Migration from Trench

Measurement of ocean turbidity related to the test trench excavation noted that the turbidity did not migrate far from the trench. Turbidity plumes were detected beneath the floating ice, however, the plumes did not extend as far as 500 ft from the trench. At a distance of 225 ft from the trench, the turbidity levels returned to pristine Arctic conditions less than a day following the conclusion of excavation.

7.1.10 Safety of Workers Approaching Trench

The only need for workers to approach the edge of the trench is to perform elevation checks of the excavation or to test for seawater turbidity. Given the rapid refreezing of the surface waters of the open trench, falling into water is not the risk. Regardless, when using a shore-side anchor (a pickup truck was used effectively) a worker can be tethered via a conventional climbing harness to provide a fall restraint. This prevents the worker from venturing into the trench. If such was to occur, the worker could use the rope to pull themselves out of the trench or the operator of the pickup truck to which the worker is physically attached can gently maneuver the truck to effectively and safely pull the worker out of the trench.

7.2 NEGATIVE OUTCOMES

7.2.1 Water Rescue Methods

During the planning of the test trench program, safety planners envisioned the presence of open-water in the excavated trench. The degree to which exposed water quickly froze to consolidated, solid, slush ice, was not appreciated. As a reaction to concern for workers falling into the trench and requiring rescue, a water rescue team was assembled despite the reality that a rescue operation in the ice clogged trench could not be performed by a swimmer. The need for or the design of a rescue team to assist a worker who falls into the trench needs to be reconsidered in advance of future channel dredging operations.

7.2.2 Primitive Trench Bottom Survey Methods

The simple survey methods used for the determination of the test trench bottom elevation is not suitable for the large-scale channel dredging program. Use of GPS technology is believed to promise more effective survey methods, as discussed in Section 5.2.

7.2.3 Spoils Freezing in Truck Beds

The cold air temperatures coupled with the water generated in the spoils excavation process promotes freezing of the spoils in the truck beds. This issue is well recognized from previous marine excavations conducted during the winter. Attempts to reduce (but not eliminate) this problem have traditionally included 1) the installation of durable bed liners (e.g., HDPE) that retard the adherence/freezing of the spoils, or 2) heating the truck beds to prevent freezing. Both methods may assist in reducing the accumulation of frozen material in the truck beds but neither method will eliminate the problem. A mitigation plan that was accomplished in the test trench program is to provide an excavator at each disposal site to scrape out the truck beds as they accumulate frozen soil. This also requires adding several more trucks to the haul spread to allow for the delays necessary to periodically clean the truck beds without negatively affecting the truck haul production.

7.2.4 Overbuild of Ice Pads in Shallow Water

Thickening the natural sea ice by flooding is not effective once the bottom of the ice approaches the seabed surface. At that time, ice thickening can only occur naturally through continued cold air temperatures or by building up the ice surface with ice chips and/or the application of water via water trucks from a fresh water source. Due to the time and cost associated with these non-flooding efforts, the thickening of the ice should be no more than one foot greater than the water depth. Thus, at a location where the water depth is 5 ft, a 6 ft thick ice pad should be constructed. Any additional ice thickness just requires more time to construct and excavate the ice and does not add to the ice stability.

7.2.5 Pushing vs. Hauling Excavated Ice

At Test Trench #1 where the ice pad was grounded, excavated sea ice was removed from the trench area by either truck hauling or pushing to the side with a Cat 966 loader. It seems that pushing is not effective in that 1) the ice debris on the ice pad hinders effective truck hauling of spoils that must leave the site, and 2) pushing ice with the loader creates ruts in the ice surface that can lead to binding of the cutting blade and thereby slow the subsequent ice cutting by the Ditch Witch Trencher. A reasonable plan seems to assume local trucking of the ice debris to the side of the ice pad at grounded locations, or placement of the ice by truck adjacent to the trench followed by pushing the ice into the completed trench via loader.

7.2.6 Haul Unit Traffic Patterns

The best traffic plan during excavation would require the trucks to drive in a straight line behind the excavators such that the excavators must swing its bucket 180º from the trench to load the truck. This eliminates the time required and the safety concerns of trucks backing towards the trench. Excavator choices (particularly for the large amphibious pontoons working on floating ice) should allow the 180º excavator swing to promote both digging efficiency and safety.

7.3 CONCLUSIONS

The large-scale dredging of the navigation channel in winter that may require as much as 1.5 million cubic yards of excavation is considered feasible, based on the following considerations:

The history of offshore operations in the Prudhoe Bay vicinity is dominated by projects that excavated and hauled large volumes of gravel and seabed soils. The production limitations of seemingly vast production requirements are typically overcome by advance planning and procurement of the proper equipment and workforce.

The recent test trench program has indicated production rates that, while generated during the initial “start-up” phase of activity, indicate feasibility over a typical winter season. Issues that support this feasibility include the following:

- Limited sloughing of excavated side slopes;
- Excellent performance of ice roads and pads despite the late (mid-February) start. No significant cracking or ice failures occurred in proximity to the excavators, haul units or in the vicinity of the trenches;
- Good excavation performance was noted at both test trench sites (heaped buckets, cohesive sediments, progressive improvement in efficiency);
- Excavator size, reach and bucket size can be further optimized to improve productivity;
- Well-organized, compact, and efficient nearshore spoils disposal was demonstrated;
- Turbidity created by the excavation process did not migrate far beneath the floating ice and suspended sediments settled quickly (within one day following the conclusion of excavation).
- The majority of the equipment fleet required is routinely available in Prudhoe Bay. Notable exceptions and enhancements are limited to the amphibious undercarriages to support the excavators on floating ice and the inclusion of GPS technology to ensure efficient, accurate, timely and comprehensive excavation.

Long-term sedimentation (and the annual variability of same) within the channel will dictate the magnitude and timing of future maintenance dredging requirements. While this issue is poorly understood presently, future field work and numerical modeling efforts will better define this concern.

Key issues for success to which the construction contractor must be committed include the provision of adequate haul units to ensure that excavators will not be idle waiting for trucks for any significant period of time and the use of real-time survey techniques to eliminate the need to halt excavation operations to obtain as-built survey results. This latter item is considered to be feasible given the use of state of the art GPS-assisted excavation control and recording.

Arctic winter weather appears to be experiencing a warming trend accompanied by reduced freezing degree days and increased snowfall. The long-term trends are more notable at Barrow given its greater data history and different geographic controls (i.e., on the Chukchi Sea coast) relative to Prudhoe Bay. Trends of winter climate warming are less obvious over the recent 20-year data history at Prudhoe Bay. Given relevant weather data analyses, winter weather will be supportive of winter dredging for the foreseeable future.

8.0 ACRONYMS AND TERMS

AFC	Alaska Frontier Constructors
APP	Alaska Pipeline Project
ARO	Attachment Ready Option
CFC	Coastal Frontiers Corporation
cy	cubic yards
ft	foot/feet
GPS	global positioning system
GTP	gas treatment plant
hr	hour(s)
kt	knot(s)
LNG	liquefied natural gas
mg	milligram(s)
min	minute(s)
MLLW	mean lower low water
NOS	National Ocean Service
NTU	Nephelometric Turbidity Unit
QA	quality assurance
STP	Seawater Treatment Plant
SWL	still water level
RTK	Real-time Kinematic
TSS	Total Suspended Solid

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APPENDIX R.5 2016 DATA REPORT – WEST DOCK SUMMER 2016 FIELD PROGRAM (USAG-EC-JRZZZ-00-000003-000)

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Alaska LNG™

AECOM

TITLE: DATA REPORT - WEST DOCK SUMMER 2016 FIELD PROGRAM

DOCUMENT NO. USAG-EC-JRZZZ-00-000003-000

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Revision	Section	Description
0	-	Incorporate comments from Jayce Locke and Tony Thomsen

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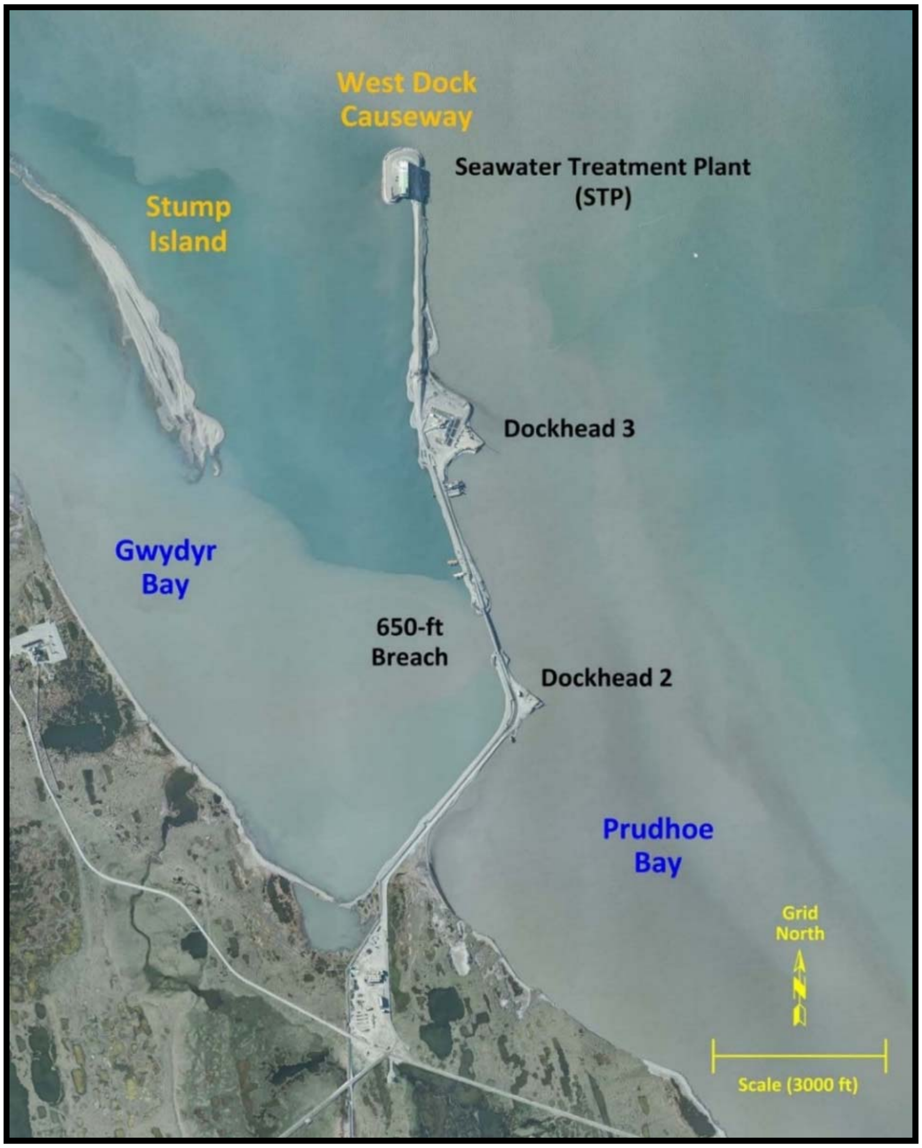
1.0 OVERVIEW

The Alaska LNG Project (AK LNG) is seeking to commercialize North Slope natural gas through the construction of a gas treatment plant (GTP) in Prudhoe Bay with an export pipeline to Southcentral Alaska. The current strategy is to transport the GTP modules via barge to the West Dock Causeway (Figure 1-1) over the course of approximately four summer seasons. Several offload strategies have been considered to accommodate the anticipated sealift draft. These include offload at Dockhead 2, Dockhead 3, and the STP, each of which would require construction of a dredged channel. The current project basis is to construct an extension to the causeway on the east side of the STP. This extension is herein referred to as Dockhead 4 (DH4).

Figure 1-1. Project Area



During the 2016 open-water season, Coastal Frontiers Corporation (CFC) conducted a field program designed to support a numerical assessment of potential sedimentation impacts on navigation, infrastructure design and execution planning. Similar programs were conducted on behalf of the project in 2014 (*Doc. No. USAG-EC-SRZZZ-00-000007-000*) and 2015 (*Doc. No. USAG-EC-JRZZZ-00-000002-000*). Please refer to the sedimentation assessment (*Doc. No. USAG-EC-JRZZZ-00-000001-000*) for additional analyses and interpretation of the data presented herein and recommendations for their use. The sections that follow provide an overview of the 2016 monitoring program, discuss the field activities and summarize the results.

1.1 2016 FIELD PROGRAM

The West Dock Summer 2016 Field Program was conducted between July 11 and September 25 in an attempt to capture the majority of the open-water season. Based on ice charts prepared by the U.S. National Ice Center (NIC, 2016), it is estimated that the 2016 open-water season near West Dock began on June 27 and ended on October 18.

The field program consisted of the data collection efforts described below. Detailed results and analyses are provided in the remaining sections of this report.

1.1.1 Bathymetric Survey Data

Bathymetric survey data were obtained to document the changes that have occurred at two test trench sites constructed in April 2015, supplement the bathymetric data sets obtained in the prior two open-water seasons, and provide supporting data to ongoing execution planning efforts.

Survey data were collected in two phases (early- and late-season). The early-season surveys were conducted from July 16 to 23 and the late-season work was conducted on September 19 and 20.

1.1.2 Oceanographic Data

Four oceanographic moorings were deployed near West Dock as part of the 2016 Field Program. Each mooring consisted of an Acoustic Doppler Current Profiler (ADCP) and an Optical Backscatter Sensor (OBS). The ADCP units were used to monitor current and wave conditions. The OBS units were used to monitor the local turbidity and suspended sediment concentration. All three parameters (current, wave, turbidity) are used to validate the sedimentation model noted above.

1.1.3 Meteorological Data

Two anemometers were installed north of the 52-ft Breach (same location used in 2015). The sensors were used to monitor the local wind conditions and provide a backup to the meteorological station operated by the National Oceanic and Atmospheric Administration (NOAA) at the STP.

1.1.4 Sediment Data

Qualitative and quantitative data characterizing the sediment within each test trench site, and in other areas of interest (STP, West Side), were obtained to support infill assessments and maintenance dredging feasibility studies. Quantitative data included surficial sediment samples and estimates of the mud thickness obtained via a rheological profiling system (Graviprobe). Qualitative data were obtained by estimating the thickness of the mud layer using a manual probe.

1.2 DATA DELIVERABLES

Data acquired as part of the Summer 2016 Field Program are provided along with the digital submittal of this report. These include the bathymetric survey data and time series of the wind, wave, current, and turbidity data. The data typically are provided as ASCII text files with headers describing the file contents. The survey datum and direction conventions are provided below.

1.2.1 Survey Datum

The horizontal and vertical datums used for the survey program are as follows:

- ***Horizontal Datum:*** Alaska State Plane Zone 4, NAD 83(2007) with units of U.S. Survey Feet.
- ***Vertical Datum:*** National Ocean Service (NOS) Mean Lower Low Water (MLLW) for the 1983-2001 Tidal Datum Epoch, with units of feet.

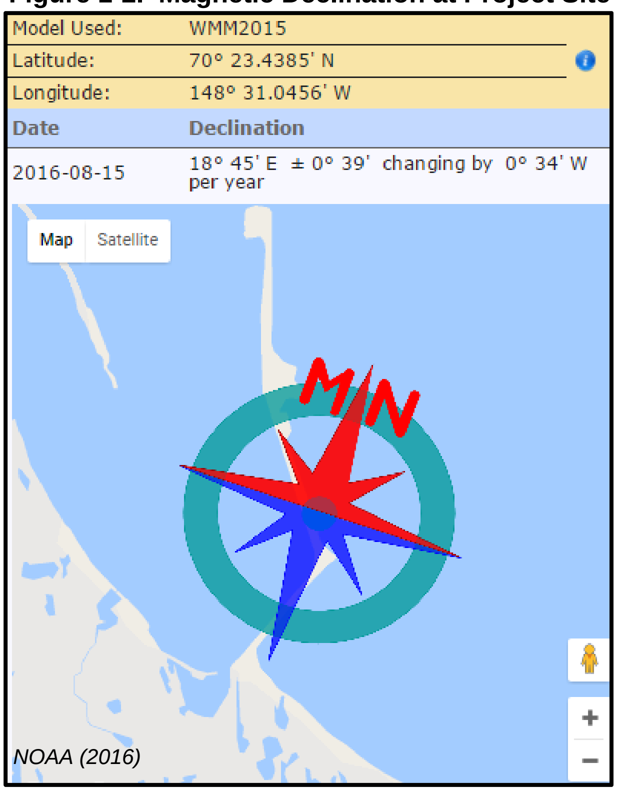
1.2.2 Direction Convention

All directions provided herein are relative to grid (true) north and increase clockwise. For reference, the magnetic declination at the site is 18.75° (Figure 1-2). Note that the magnetic declination changes with time. The value used herein corresponds to mid-season (August 15, 2016).

Standard conventions for wind, current, and wave directions were adopted and are as follows:

- ***Wind***: Wind direction is specified as the direction the wind blows ***from***. For example, 90° is wind blowing ***from*** east (90°) to west.
- ***Wave***: Wave direction is specified as the direction the wave travels ***from***. For example, 90° is a wave travelling ***from*** east (90°) to west.
- ***Current***: Current direction is specified as the direction the current flows ***to***. For example, 90° is current flowing from west ***to*** east (90°).

Figure 1-2. Magnetic Declination at Project Site



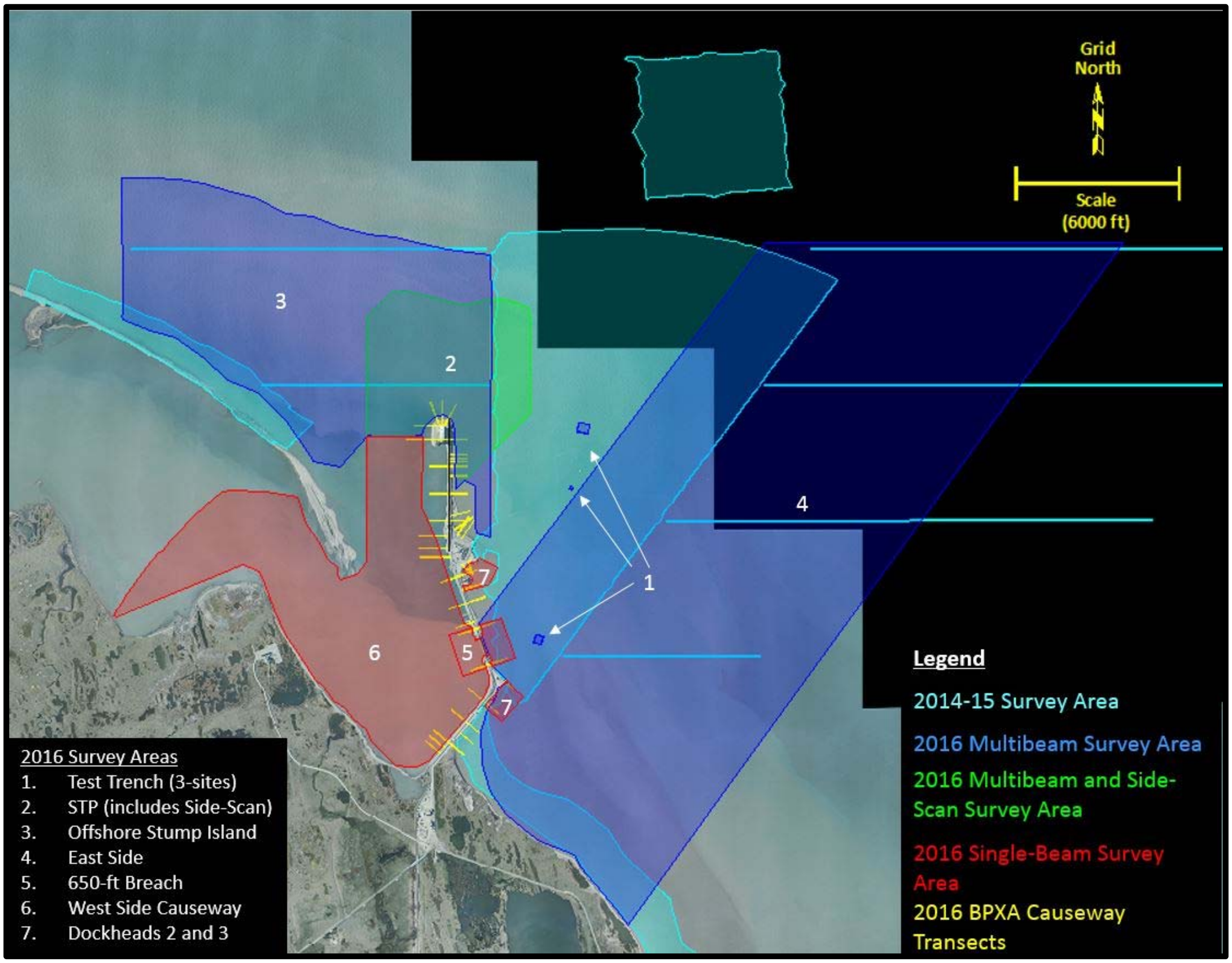
2.0 BATHYMETRIC SURVEYS

2.1 OVERVIEW

Bathymetric survey data were obtained to document the changes that have occurred at each of the two test trench sites, supplement the bathymetric data sets obtained in the prior two open-water seasons, and provide supporting data for hydrodynamic and sedimentation modeling, infrastructure design, and execution planning.

Seven survey areas were included as part of the 2016 program. Figure 2-1 illustrates each area, along with those included in the 2014 and 2015 field programs. The locations of the causeway transects surveyed by CFC on behalf of BP Exploration Alaska (BPXA) during the 2016 season also are noted, as these data were shared with the AK LNG project.

Figure 2-1. Survey Areas



Note: Single-beam sonar used in areas denoted "Multibeam" to the extent shallow water depths precluded safe operation of the research vessel.

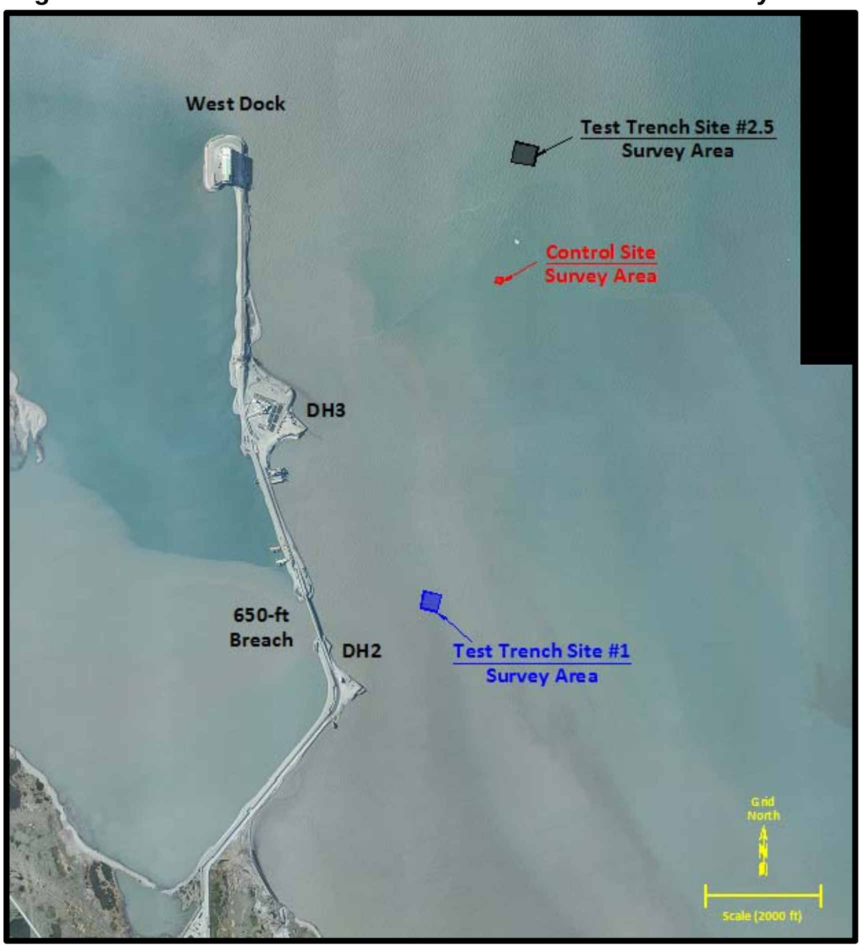
Survey data were collected in two phases. The first phase (early-season) was conducted between July 16 and 23 and included all seven survey areas noted in Figure 2-1. The second phase (late-season) was conducted on September 20 and 22. Only the Test Trench and 650-ft Breach areas were surveyed as part of the late-season effort. These areas were re-surveyed to assess the changes that occurred during the 2016 open-water season. The following sections describe the data obtained in each survey area and the objectives of the work.

2.2 SURVEY AREAS AND OBJECTIVES

2.2.1 Test Trench

As part of both the early- and late-season survey efforts, detailed bathymetric survey data were obtained at the two test trench sites and at one control site located between the two (Figure 2-2). The purpose of the surveys was to assess the bathymetric changes (both infill and erosion) that occurred at each site prior to and during the 2016 open-water season. The data are utilized by the numerical modeling team to validate the sedimentation model discussed in Section 1. For additional information regarding the test trench sites, refer to AK LNG Doc. No. USAI-UR-SRZZZ-00-000052-000.

Figure 2-2. Location of Test Trench and Control Site Survey Areas



Test Trench Site #1 was surveyed on July 17 and September 20. Site #2.5 and the Control Site were surveyed on July 20 and September 20. As noted above, it is estimated that break-up occurred near West Dock on June 27 (approximately three-weeks prior to the early-season survey) and freeze-up occurred on October 18 (approximately four-weeks after the late-season survey).

The survey scope was identical to that conducted in 2015. As a result, the data are directly comparable.

At each test trench site, bathymetric data were acquired on a 20-ft x 100-ft grid extending a minimum of 100 ft beyond the trench edge. In the deeper waters that prevail at Site #2.5, near-full bottom coverage was obtained. At the shallower Site #1, full-bottom coverage was not obtained, due to the limited swath width in shallow water. However, the survey grid was sufficiently dense to assess the bathymetric changes that occurred during the open-water season.

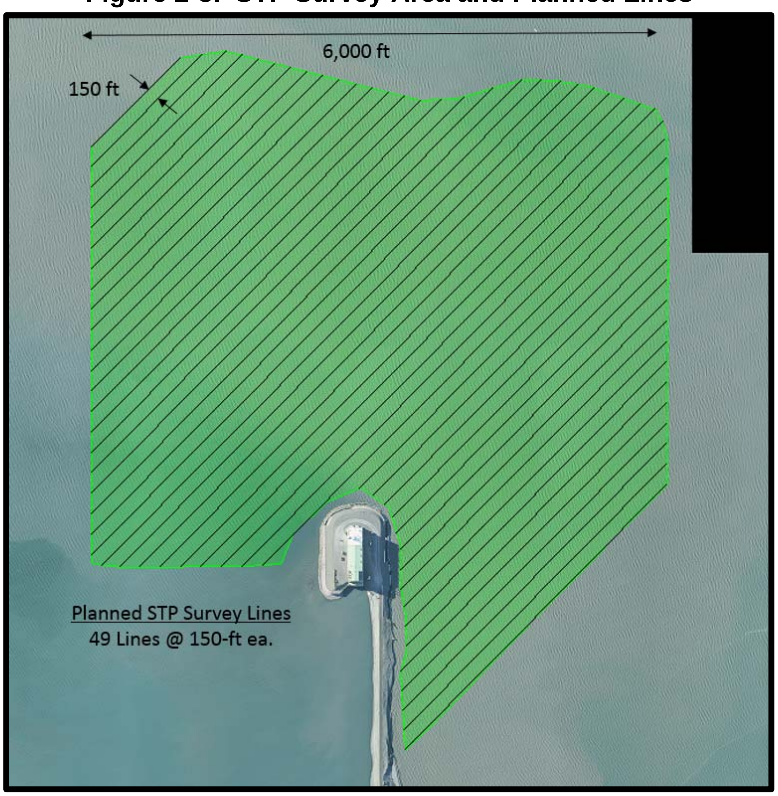
Bathymetric data also were obtained at the Control Site (first surveyed as part of the 2015 program) to provide an indication of natural changes that occurred in the area that were independent of the changes observed at the test trench sites. Data were obtained within the 100-ft x 100-ft area on a 15-ft x 25-ft grid using multibeam sonar.

2.2.2 Dockhead 4 and STP Area

As part of the early-season survey effort, multibeam and side-scan sonar data were obtained in the region surrounding the STP. The purpose of this task was to provide detailed bathymetric data near the potential STP and Dockhead 4 offload sites (dredged channel and causeway extension options). Side-scan sonar was included in this area to identify potential hazards to construction as well as any hard-bottom habitat. Survey data were obtained between July 20 and 23.

As illustrated in Figure 2-3, data were obtained within a region approximately 6,000 ft wide (east-west), centered on the causeway, and extending to the 16-ft isobath (MLLW). Forty-six survey lines nominally spaced 150 ft apart were included. Near full-bottom side-scan coverage was obtained. Full-bottom multibeam data coverage was not obtained (nor was it intended).

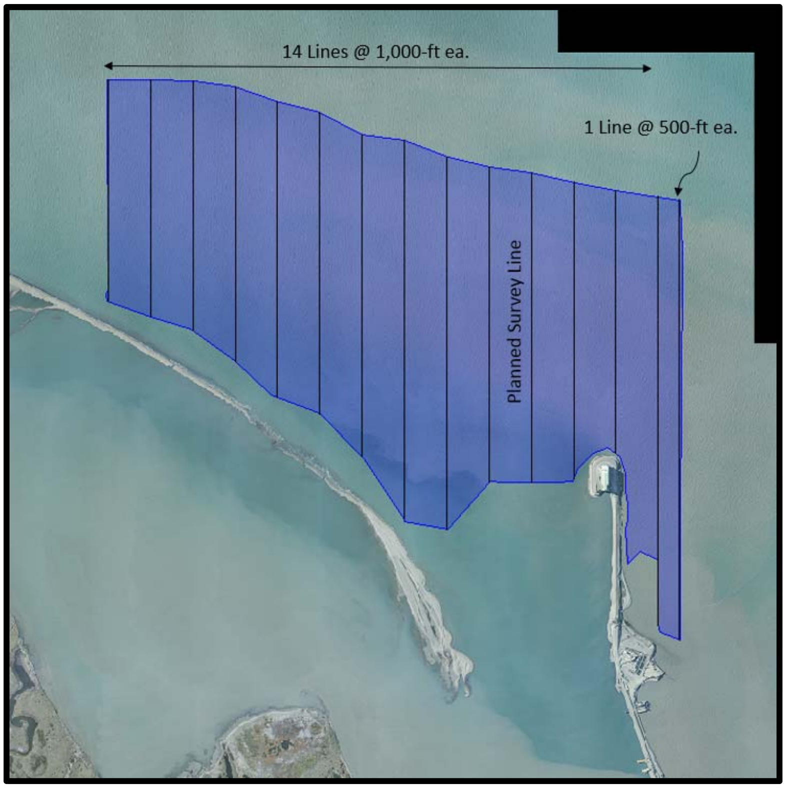
Figure 2-3. STP Survey Area and Planned Lines



2.2.3 Offshore Stump Island

Multibeam sonar data were acquired in the un-surveyed region west of the STP and north of Stump Island to support ongoing planning and modeling efforts. A total of 14 lines spaced 1,000 ft apart and oriented north-south were surveyed, along with one line located 500-ft east of the primary lines (Figure 2-4). The offshore terminus was the 18-ft isobath (MLLW). The survey was conducted on July 23 as part of the early-season survey effort.

Figure 2-4. Offshore Stump Island Survey Areas and Planned Lines



2.2.4 East Side Causeway

To support ongoing planning and modeling efforts, bathymetric data were acquired in the mostly un-surveyed region east of the 2014-15 survey area. A total of five lines were surveyed (Figure 2-5) on July 20 and 22. Four lines spaced 2,000 ft apart were located southeast of the 2014-15 survey area. The fifth line was coincident with one of the 2014 survey lines.

Both multibeam and single-beam sonar data were acquired. Multibeam sonar was utilized in the deeper offshore area, whereas single-beam sonar was utilized in shallow-water area near the coast.

2.2.5 650-Ft Breach

Bathymetric data were collected near the 650-ft Breach to support engineering analyses undertaken to evaluate module crossing strategies at the site. The survey grid (Figure 2-6) covered an area 2,000 ft wide (east-west) and 1,600 ft long (north-south). The survey line spacing ranged from 25 to 400 ft, with the tightest spacing in the central portion of the breach.

Figure 2-5. East Side Survey Area and Planned Lines

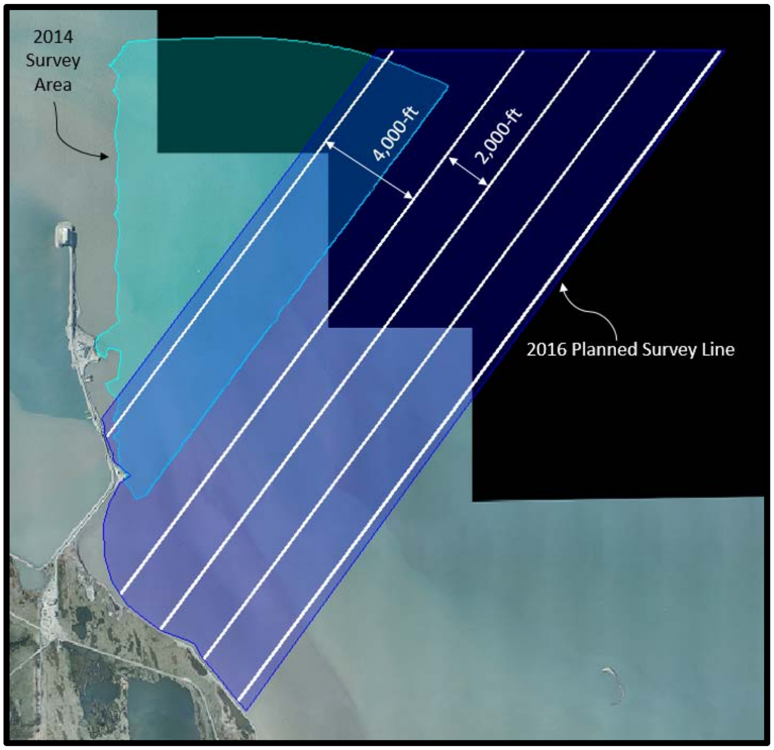
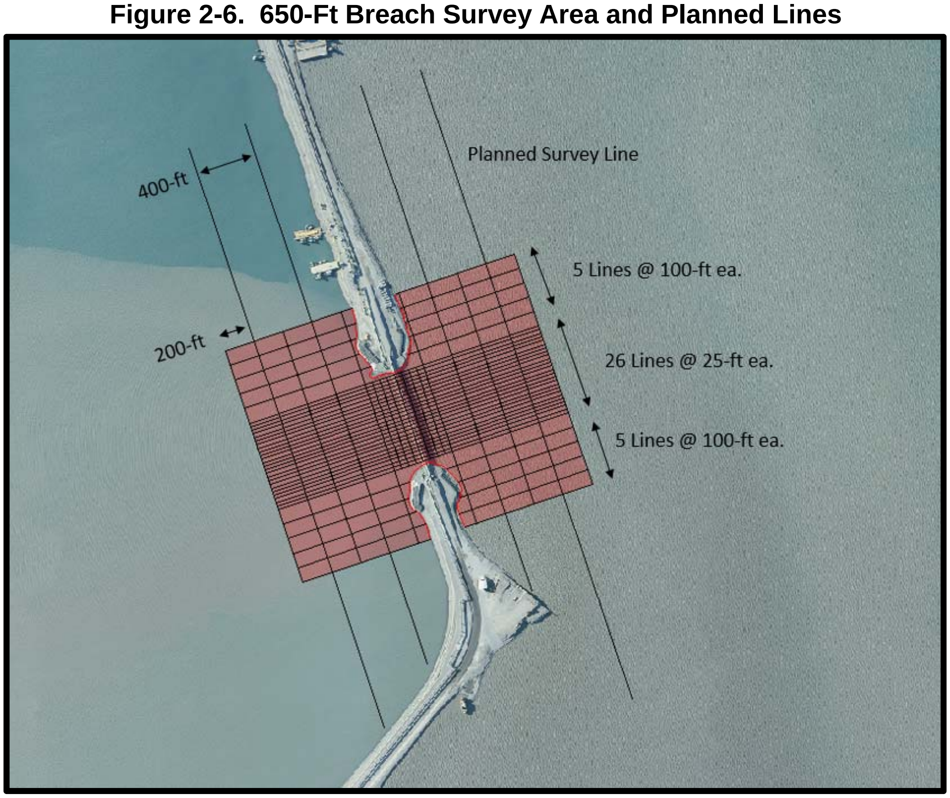


Figure 2-6. 650-Ft Breach Survey Area and Planned Lines



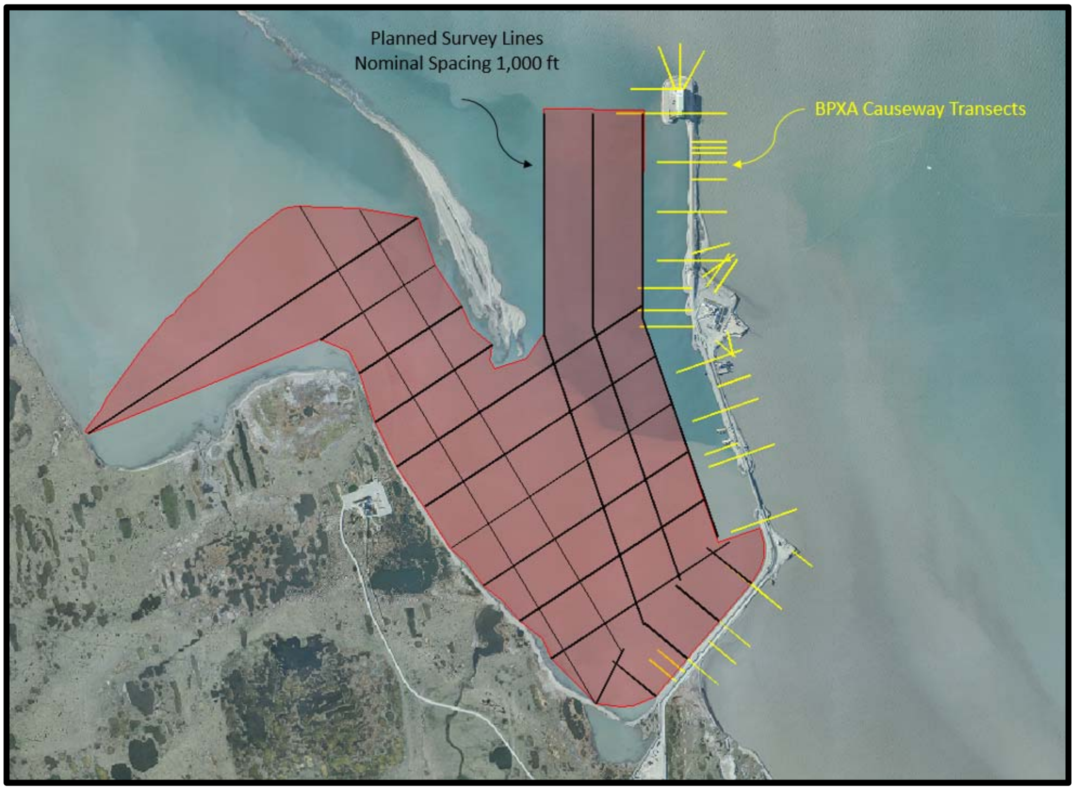
Data were acquired as part of both the early- and late-season survey efforts to assess the changes that can occur within a given open-water season. Data were acquired on July 21 and 22, then again on September 22. Single-beam sonar was utilized for both survey efforts.

2.2.6 West Side Causeway

Single-beam bathymetric survey data were obtained on the west side of the causeway in support of ongoing hydrodynamic and sedimentation numerical modeling efforts.

Data were acquired on July 22 along the survey lines illustrated in Figure 2-7. Additional data were obtained on July 23 along the shore-perpendicular transects illustrated in Figure 2-7 (yellow) on behalf of BPXA. These transects have been monitored historically and the data were provided to the AK LNG Project with BPXA's permission.

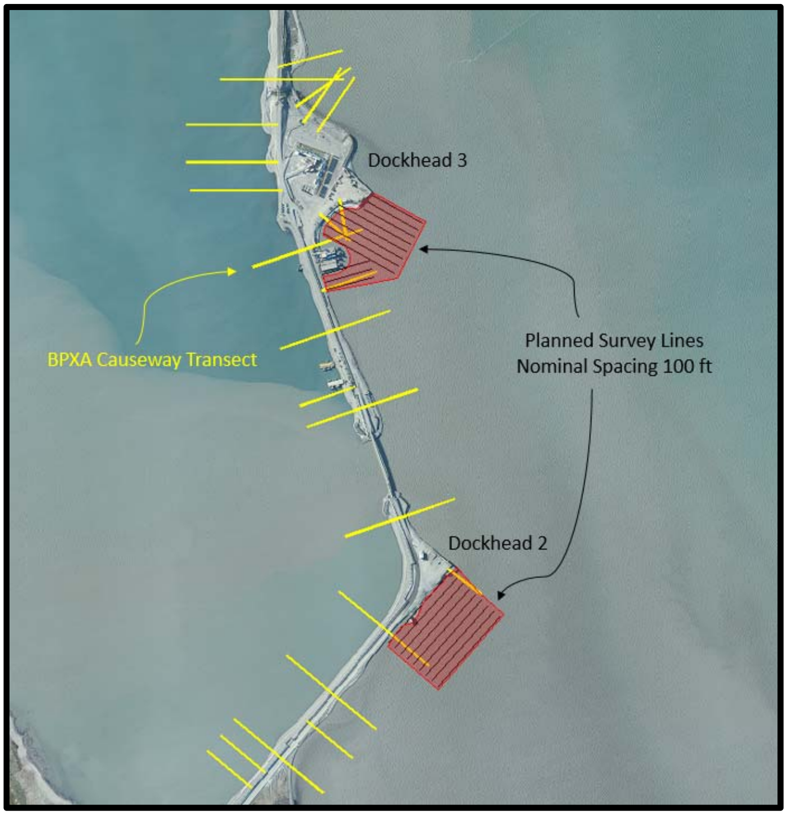
Figure 2-7. West Side Survey Area and Planned Lines



2.2.7 Dockheads 2 and 3

Twenty lines of varying lengths, nominally spaced 100 ft apart were surveyed within the footprint of the potential dock improvements located adjacent to Dockheads 2 and 3. The survey areas and planned lines are illustrated in Figure 2-8. Survey operations were conducted on July 16 and 18 at Dockheads 3 and 2, respectively.

Figure 2-8. Dockhead 2 and 3 Survey Areas and Planned Lines



2.3 DATA ACQUISITION

The *R/V Ukpik* (Figure 2-9) and *R/V Annika Marie* were used to conduct the early- and late-season field programs, respectively. These vessels were utilized in the deeper waters located near the STP, offshore of Stump Island, at the Test Trench Sites and the offshore half of the East-Side survey area. Multibeam sonar served as the primary survey tool onboard the research vessels, with side-scan sonar used near the STP, as noted above. The crew consisted of the vessel skipper, up to three CFC personnel, and a Protected Species Observer (PSO) provided by exp. Multibeam data were acquired in prevailing water depths greater than approximately 6 ft.

Figure 2-9. R/V Ukpik Underway near West Dock

CFC's shallow-draft inflatable survey vessel equipped with a single-beam sonar system was utilized in the shallow water areas on the west side of the causeway, at the 650-ft Breach, both Dockheads, and the onshore half of the East-Side survey area. Two CFC crew members operated the inflatable vessel. Single-beam data were acquired in prevailing water depths greater than approximately 3 ft.

2.3.1 Multibeam Sonar Data

The multibeam system installed onboard the research vessels acquires soundings in a swath on the seafloor, as opposed to a single point beneath the vessel, thereby increasing data coverage. Key components of the system included a Reson 7125 multibeam echosounder, Coda F-185 motion reference and heading sensor, Hemisphere A325 GPS receiver, Valeport MiniSVS velocimeter, and Seabird SBE-19 conductivity, temperature and depth (CTD) sensor. All systems were interfaced using the Hypack survey software package and synchronized using a 1PPS pulse output by the Hemisphere GPS receiver.

The Reson 7125 echosounder was operated at a nominal frequency of 200 kHz, with the return signal divided into 256 equally spaced sub-beams. A swath width of 140° was used during data acquisition and reduced during data processing based on the quality of the acquired data. A variable ping rate was utilized throughout the survey and typically was not less than 10 Hz.

The Hemisphere A325 GPS receiver served as the primary positioning device during the multibeam surveys. Real-time differential corrections obtained via the Wide Area Augmentation System (WAAS) were utilized to improve the accuracy of the GPS data. The attitude of the sonar head (pitch, roll, and yaw) was recorded in real-time using the Coda F-185 motion reference and heading sensor. Corrections for wave-induced heave also were recorded using the F-185.

Speed-of-sound measurements were obtained in real-time using a Valeport miniSVS velocimeter mounted near the sonar head. Additional speed-of-sound profiles were obtained at selected sites using a Seabird SBE-19 CTD, SonTek Castaway CTD, or Odom Hydrographic Digibar Pro.

2.3.2 Side-Scan Sonar Data

Side-scan sonar data were obtained in the STP survey area to identify potential areas of hard-bottom, dredging hazards, or archeological features that may be present on the seafloor. Side-scan sonar provides a two-dimensional, photo-like image that varies with the surface relief and acoustic reflectivity of the sea bottom (not measured depths). The system was installed on the research vessel as part of the early-season effort, and included an Edgetech 4125 towfish and topside computer. The towfish was positioned using the Hemisphere A325 GPS receiver.

The side-scan system was operated concurrently with the multibeam system described above. The side-scan system was operated at a frequency of 400 kHz and range of 50 m (164 ft to either side of the vessel track). Because the intended track lines included areas of shallow water, the side-scan fish was towed from the side of the vessel approximately 3 ft below the sea surface, rather than astern on a long tether.

2.3.3 Single-Beam Sonar Data

Single-beam sonar data were acquired in the shallow-water areas noted above (West-Side, 650-ft Breach, Dockheads 2&3, onshore half of the East-Side). The system consisted of an Odom Hydrographic Hydrotrac single-beam echosounder, TSS DMS-05 motion reference unit (MRU) and Hemisphere VS-110 GPS-heading unit. All systems were interfaced using the Hypack survey software package and synchronized using the VS-110 GPS-heading receiver.

The Hydrotrac was operated at a nominal frequency of 200 kHz and paired with a standard 9° transducer. A variable ping rate was utilized, and typically was not less than 10 Hz. The VS-110 GPS-heading unit was used to obtain both the position and heading of the survey vessel. To improve the accuracy of each position, differential corrections broadcast in real-time from WAAS were utilized.

2.3.4 Water Levels

Water level data relative to MLLW were obtained throughout the survey period from the NOS Prudhoe Bay Tide Station (#9497645) located in the West Dock STP (Figure 1-1). The local water level was obtained every six minutes and used to adjust the measured soundings to the survey datum.

2.3.5 Quality Assurance/Control

The following section summarizes the QA/QC procedures undertaken as part of the survey activities.

Multibeam Bathymetric Survey Data

As part of each survey day, the draft of the multibeam echosounder was measured and a patch test was conducted to estimate the angular roll offset between the sonar head and F-180 MRU. Determination of the yaw and pitch offsets relies on a combination of deep water and steep-sided bathymetric features not typically found in the survey area. Therefore, yaw and pitch offsets determined previously using the same vessel and sonar configuration were utilized and confirmed during post-processing. The horizontal and vertical offsets between each device were measured at the start of the survey program and utilized during post-processing.

Single-Beam Bathymetric Survey Data

As with the multibeam system, the horizontal and vertical offsets between each device were measured at the start of the survey program and utilized during post-processing. The calibration of the echo sounder was checked each day using a standard “rod check” procedure, whereby the water depth was physically measured in an area of calm water and used to verify the echosounder output.

Cross-Ties

As part of both the single-beam and multibeam surveys, overlapping survey lines, or “cross-ties”, were used to confirm the measured depths. During post-processing, the main-scheme and cross-tie lines were examined to ensure proper agreement. In addition, the 2016 data were compared to those obtained in 2014 and 2015 to ensure that any observed differences were consistent with those noted historically at the site.

Squat Test

A squat test was conducted onboard the *R/V Ukpik* near the West Dock STP on August 3, 2016 using an RTK GPS base-rover set. The RTK base unit was installed at a local survey monument, and the rover installed on the vessel. The average elevation of the vessel was recorded using the RTK rover at vessel speeds ranging from 0 to 7 kts.

On average, squat values were less than 0.1 ft at typical survey speeds (5 kts or less). Squat values increased at higher speeds (6 kts = 0.13 ft, 7 kts = 0.30 ft). Given that survey operations are typically conducted at vessel speeds between 4 and 5 kts, in addition to the fact that squat corrections yield a non-conservative (i.e. deeper) result, no squat correction was applied to the measured depths in post-processing. This is consistent with the methods followed historically using similar vessels and equipment.

Squat tests were performed as part of the 2015 survey program using the *R/V Annika Marie* and the inflatable survey vessel. Squat values were less than 0.1 ft at speeds less than 5 kts on both vessels.

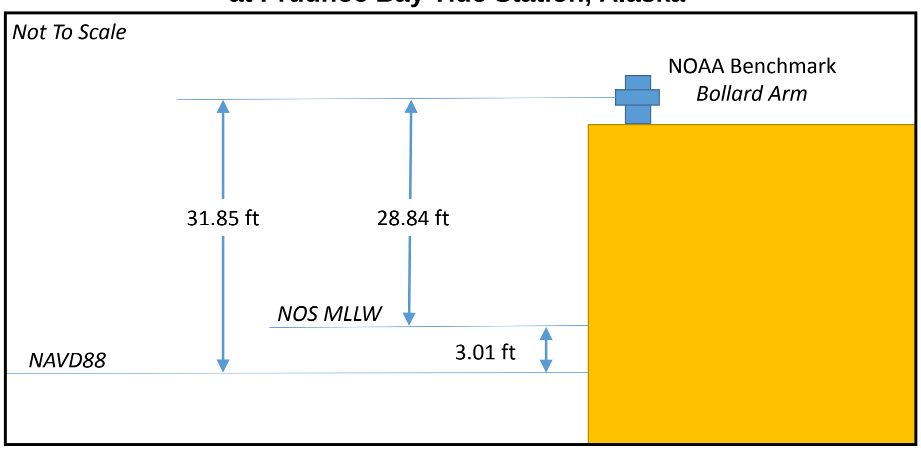
GPS Location Checks

Position checks were performed on July 17 and 19 at F. Robert Bell monument *Dickory* using the two GPS positioning devices described above. The position check conducted using the Hemisphere A325 GPS receiver (part of the multibeam system) yielded an RMS error of 1.6 ft between the measured GPS data and published monument location. The position check conducted using the VS-110 GPS receiver (part of the single-beam system) yielded an RMS error of 2.4 ft between the measured data and published monument location.

Static GPS Observation

A static GPS session was conducted at the tidal benchmark *Bollard Arm* established by NOAA at the West Dock STP as part of the 2014 AK LNG Bathymetric Survey Program. The relationship between the NOS MLLW (bathymetric survey vertical datum) and NAVD88 (Alaska LNG Project GIS vertical datum) vertical datums is provided in Figure 2-10 for reference.

Figure 2-10. Illustration of NOS MLLW (83-01 Tidal Datum Epoch) and NAVD88 (GEOID12A) Vertical Datums at Prudhoe Bay Tide Station, Alaska



2.4 DATA REDUCTION

The raw data from the multibeam portion of the survey consisted of Hypack files containing the sonar data along with data provided by each of the ancillary sensors. The Hysweep Editor was used to adjust these data based on the measured equipment offsets, patch test results, speed-of-sound casts and water levels recorded during the survey period. Preliminary depth and spike filters were applied to the adjusted soundings to remove outliers resulting from acoustic crosstalk, multiple returns, aeration in the water column and poor bottom-detection. In addition, the beam width of the sonar was reduced based on the quality of the outer beams. Drift in the heave record, typically caused by rapid course changes, was removed. Finally, the data were reviewed and outliers removed manually where appropriate.

Data obtained as part of the single-beam surveys were processed in a similar manner using Hypack's Single Beam Editor. The data were adjusted to account for the measured equipment offsets and water levels observed during the survey. Wave induced heave contamination was reduced and outliers caused by multiple returns or aeration in the water column were removed.

The horizontal positions obtained during the survey were adjusted from ITRF08 (GPS receiver datum) to NAD83(2007) using the NGS Horizontal Time-Dependent Positioning tool (HTDP, 2016). The processed soundings were thinned to an interval appropriate for chart preparation and exported as ASCII files containing easting, northing and elevation (x,y,z) triplets. No bias (e.g.

shoal, deep, etc.) was used in the thinning process. Data used to generate color-coded digital terrain maps (DTM) and sea-bottom profiles were thinned to nominal intervals ranging between 3 and 50 ft. Less dense thinnings were used to display spot soundings. Notes provided in each ASCII file specify the thinning used.

Trimble's Terramodel surface modeling software was used to evaluate agreement between overlapping data sets, including cross-ties and overlapping single-beam and multibeam data sets. Final charts illustrating the bathymetric data, as well as estimates of the volumetric changes, were generated using AutoCAD Civil 3D.

The digital side-scan sonar data were processed using software developed by CodaOctopus. The raw sonar and position data were imported into the software. Appropriate layback distances were applied and the vessel track was smoothed to create a reasonable image. Data from overlapping passes were evaluated to confirm that the correct layback values were used. The processed data then were combined to create digital mosaic images. Image resolutions of 3 pixels per meter (high-resolution) and 1 pixel per meter were generated.

Based on the position checks described above, the RMS accuracy of horizontal positions obtained during the survey is estimated to be at least 2.4 ft. The vertical accuracy of the processed soundings is estimated to be approximately ±0.5 ft. This value reflects the uncertainties associated with several factors, including both depth-dependent (sonar) and non-depth-dependent sources (motion reference unit, position and heading, speed-of-sound, and local water level). It is consistent with data obtained as part of similar work conducted on the North Slope.

2.5 RESULTS AND ANALYSIS

The results of the 2016 Bathymetric Survey Program are summarized in the following section and presented graphically in the drawing set attached as Appendix A (Table 2-1). These drawings illustrate the bathymetric data through the use of color coded DTMs, spot soundings, and sea bottom profiles.

The observations provided in the following section focus primarily on the changes observed at each of the test trench sites, as well as the 650-ft Breach. General observations regarding the bathymetric data obtained the remaining areas are provided as well.

Table 2-1. Summer 2016 Drawing Index (Appendix A)

Number	Title		Sheets	Final Rev. No.	Final Rev. Date
CFC-972-01-001	Drawing Index Map		1	0	21-Nov
CFC-972-01-002	West Dock Causeway Bathymetry Overview		1	0	21-Nov
CFC-972-10-001	Test Trench Site 1	July 2016 Survey	1	1	21-Nov
CFC-972-10-002	Test Trench Site 1	Net Change, September 2015 to July 2016	1	1	21-Nov
CFC-972-10-003	Test Trench Site 1	September 2016 Survey	1	1	21-Nov
CFC-972-10-004	Test Trench Site 1	Net Change, July 2016 to September 2016	1	1	21-Nov
CFC-972-10-005	Test Trench Site 1	Bathymetric Profiles	1	1	21-Nov
CFC-972-20-001	Test Trench Site 2.5	July 2016 Survey	1	1	21-Nov
CFC-972-20-002	Test Trench Site 2.5	Net Change, September 2015 to July 2016	1	1	21-Nov
CFC-972-20-003	Test Trench Site 2.5	September 2016 Survey	1	1	21-Nov
CFC-972-20-004	Test Trench Site 2.5	Net Change, July 2016 to September 2016	1	1	21-Nov
CFC-972-20-005	Test Trench Site 2.5	Bathymetric Profiles	1	1	21-Nov
CFC-972-30-001	650-Ft Breach	July 2016 Survey	1	0	21-Nov
CFC-972-30-002	650-Ft Breach	September 2016 Survey	1	0	21-Nov
CFC-972-30-003	650-Ft Breach	Net Change, July 2016 to September 2016	1	0	21-Nov
CFC-972-30-004	650-Ft Breach	Bathymetric Profiles	2	0	21-Nov
CFC-972-40-001	STP and Offshore Stump Island	July 2016 Survey	1	0	21-Nov
CFC-972-40-002	STP	Detailed Bathymetry	1	0	21-Nov
CFC-972-40-003	STP	Side-Scan Mosaic	1	0	21-Nov
CFC-972-50-001	West Side	July 2016 Survey	1	0	21-Nov
CFC-972-60-001	Dockhead 2	July 2016 Survey	1	0	21-Nov
CFC-972-60-002	Dockhead 3	July 2016 Survey	1	0	21-Nov
CFC-972-70-001	East Side	July 2016 Survey	1	0	21-Nov

2.5.1 Test Trench Site #1

Drawings CFC-972-10-001 and CFC-972-10-003 illustrate the bathymetric data obtained at Test Trench Site #1 in July and September, respectively. Bathymetric changes observed during the period between the September 2015 and July 2016 surveys are illustrated in Drawing CFC-972-10-002. Changes observed over the nine-week period between the July and September 2016 surveys are illustrated in Drawing CFC-972-10-004. Selected cross-sections illustrating all of the data obtained since construction of the trench (April 2015) are provided in Drawing CFC-972-10-005.

Table 2-2 summarizes the elevation and volumetric changes observed following each survey (changes observed in 2015 are included in the table for context). It should be noted that the average bottom elevation shown in the table was computed in the center of the trench (15 ft inside of the As-Built boundary) and does not include the side-slopes. Volumetric changes were computed within the boundary shown on Drawings CFC-972-10-002 and -004. The boundaries used in 2016 are identical to those used in 2015. The Cut, Fill, and Net Change quantities shown in Table 2-2 and 2-3 were computed directly from DTM surface comparisons and rounded to the nearest 100 cy. Summation differences between the (Fill – Cut) and Net Change quantities are due to rounding.

The remaining portion of the original (As-Built) trench capacity was computed at the time of each survey and is provided in the table. The capacity at the time of construction is estimated to be 3,600 cy. This value differs slightly from that shown on Drawing CFC-944-10-001 (3,500 cy) due to minor differences in the DTM used to model the edge of the trench.

Table 2-2. Elevation and Volumetric Changes at Test Trench Site #1

Survey Date	Site #1						
	Bottom Elevation		Elevation Change from Prior Survey	Estimated Volume Change from Prior Survey			As-Built Capacity Remaining
	Average	Std. Deviation		Cut	Fill	Net Change	
[-]	[MLLW, ft]	[ft]	[ft, + = Infill]	[cy]	[cy]	[cy]	[%]
April 3, 2015	-16.1	1.3	-	-	-	-	100%
July 17, 2015	-13.8	0.7	2.3	500	1,000	400	86%
September 13, 2015	-11.5	0.3	2.3	0	900	900	61%
July 17, 2016	-10.6	0.4	0.9	0	400	400	50%
September 20, 2016	-6.3	0.1	4.3	0	1,500	1,400	11%
April 3, 2015 to September 20, 2016		**Elev. Change**	**9.8**	**100**	**3,300**	**3,200**	

Notes:

1. Average bottom elevations exclude trench side-slopes. Computed based on data 15-ft inside of As-Built (April 2015) boundary.
2. Cut, Fill, and Net volumes computed within bound shown on Drawing CFC-972-10-002 and -004 and rounded to nearest 100 cy.
3. Summation differences in (Fill-Cut) and Net Change due to rounding.
4. "April 3, 2015 to September 20, 2016" taken from surface comparison, rather than table sum.
5. April survey included only spot elevations measured within the trench as construction progressed.
6. Summer (July and September) surveys conducted using single-beam and multibeam sonar and are more comprehensive and accurate than the April survey.
7. "As-Built Capacity Remaining" computed relative to April 3, 2015 survey. Volume at time of April 3, 2015 survey estimated to be 3,600 cy based on reference surface at elevation -5.5 ft (MLLW).

The condition of Test Trench Site #1 at the time of the early (July 17, 2016) and late-season (September 20, 2016) surveys is illustrated in Figure 2-11 (see Appendix A for more detail).

Early-Season Survey

At the time of the early-season survey, seabed elevations ranged from approximately -5.5 ft (MLLW) at the trench edge to -11.2 ft (MLLW) in the southwestern quadrant of the pit. The average sea bottom elevation within the trench (excluding the side-slopes) was -10.6 ft (MLLW), corresponding to 0.9 ft of infill relative to the September 2015 survey (Table 2-2).

It is estimated that approximately 400 cy of material entered the trench during the period between the September 2015 and July 2016 surveys. This period includes the portion of the 2015 open-water season from September 20 to October 6 (16-days) and the portion of the 2016 open-water season from June 27 to July 17 (20-days). Significant storms occurred during both periods.

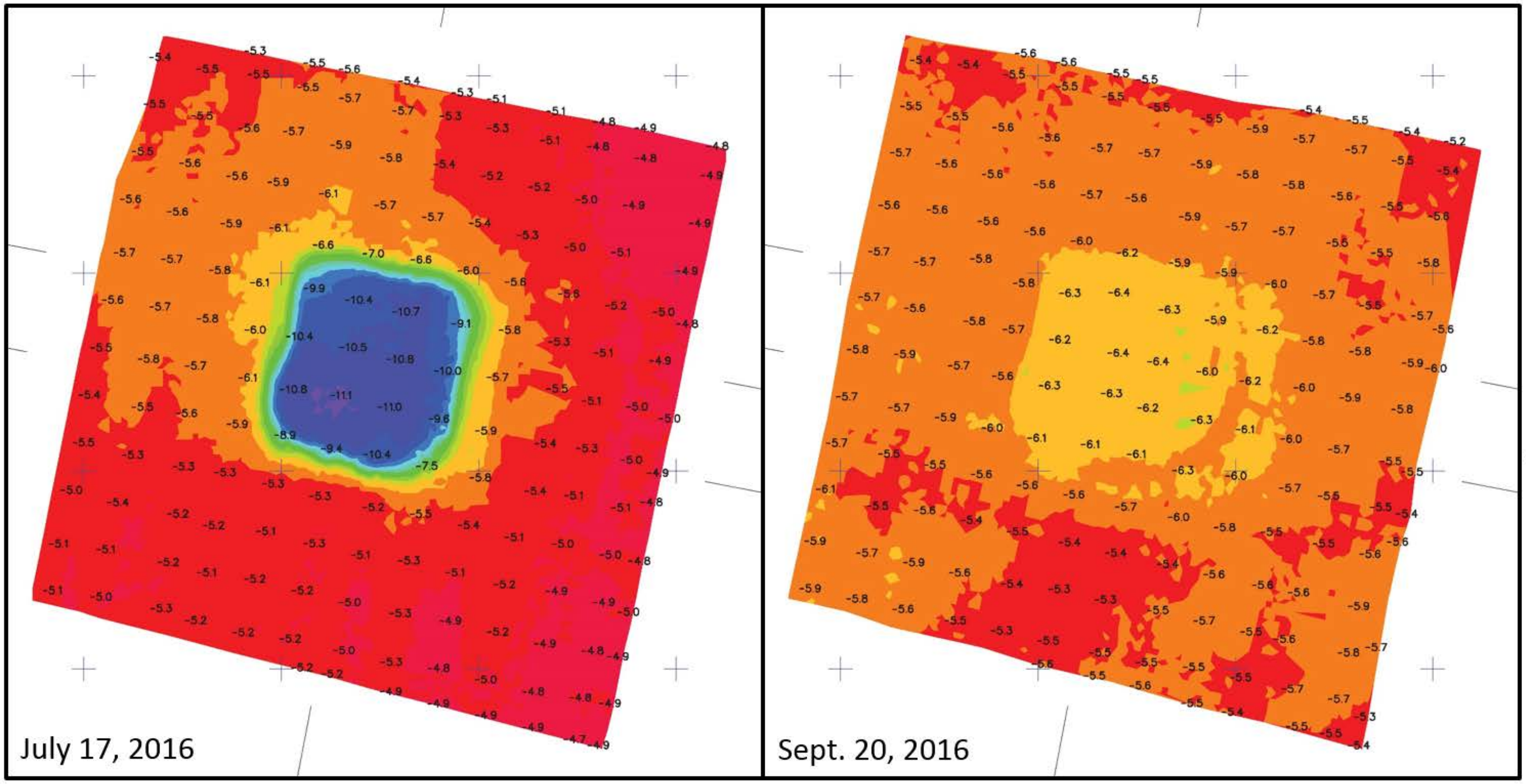
Late-Season Survey

During the roughly 9-week period between the early- and late-season surveys, significant infill occurred at the site, which resulted in the pit being essentially filled in (Figure 2-11). As noted in Table 2-2, the average elevation within the central portion of the trench increased by 4.3 ft, corresponding to a net increase of 1,400 cy at the site (the largest net increase observed since construction). At the time of the late-season survey, the average elevation in the trench (-6.3 ft, MLLW) was within 1 ft of the ambient seabed elevation measured prior to construction (-5.5 ft, MLLW).

The total infill from the time of construction (April 2015) to the late-season survey (September 2016) is estimated to be 3,200 cy (Table 2-2). The average elevation change was +9.8 ft. At the time of the late-season survey, only 11% of the original (As-Built) trench capacity remained.

Figure 2-12 illustrates the progressive infill of the trench along a selected cross-section through the center of the pit (Section C-C’, Drawing CFC-972-10-005). Both the significant infill during the 2016 open-water season and the nearly level seafloor at the time of the most recent survey are illustrated.

Figure 2-11. Test Trench Site #1, July and September 2016 Surveys



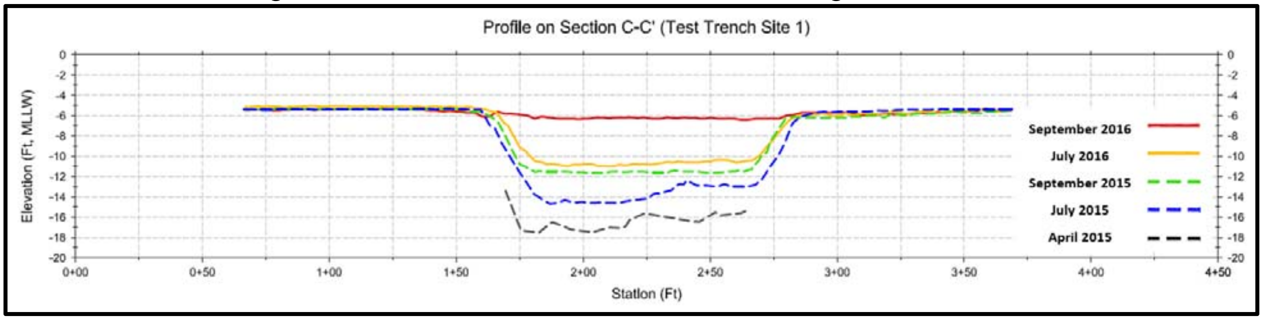
Elevation (ft, MLLW)		
Min	Max	Color
−11.5	−11.0	
−11.0	−10.5	
−10.5	−10.0	
−10.0	−9.5	
−9.5	−9.0	
−9.0	−8.5	
−8.5	−8.0	
−8.0	−7.5	
−7.5	−7.0	
−7.0	−6.5	
−6.5	−6.0	
−6.0	−5.5	
−5.5	−5.0	
−5.0	−4.5	

Approx. Scale

100 ft

Note: Taken from Appendix A (Drawings CFC-972-10-001 and CFC-972-10-003)

Figure 2-12. Test Trench Site #1, Profiles along Section C-C'



Note: Taken from Appendix A (Drawing CFC-972-10-005)

2.5.2 Test Trench Site #2.5

Drawings CFC-972-20-001 and CFC-972-20-003 illustrate the bathymetric data obtained at Test Trench Site #2.5 in July and September, respectively. Bathymetric changes observed during the period between the September 2015 and July 2016 surveys are illustrated in Drawing CFC-972-20-002. Changes observed over the roughly 9-week period between the July and September 2016 surveys are illustrated in Drawing CFC-972-20-004. Selected cross-sections illustrating all of the data obtained since construction of the trench (April 2015) are provided in Drawing CFC-972-20-005.

Table 2-3 summarizes the elevation and volumetric changes observed following each survey (changes observed in 2015 are included in the table for context). Similar to Site #1, the average bottom elevation shown in the table was computed in the center of the trench (20 ft inside of the As-Built boundary) and does not include the side-slopes. Volumetric changes were computed within the boundary shown on Drawings CFC-972-20-002 and -004. The boundaries are identical to those used in 2015.

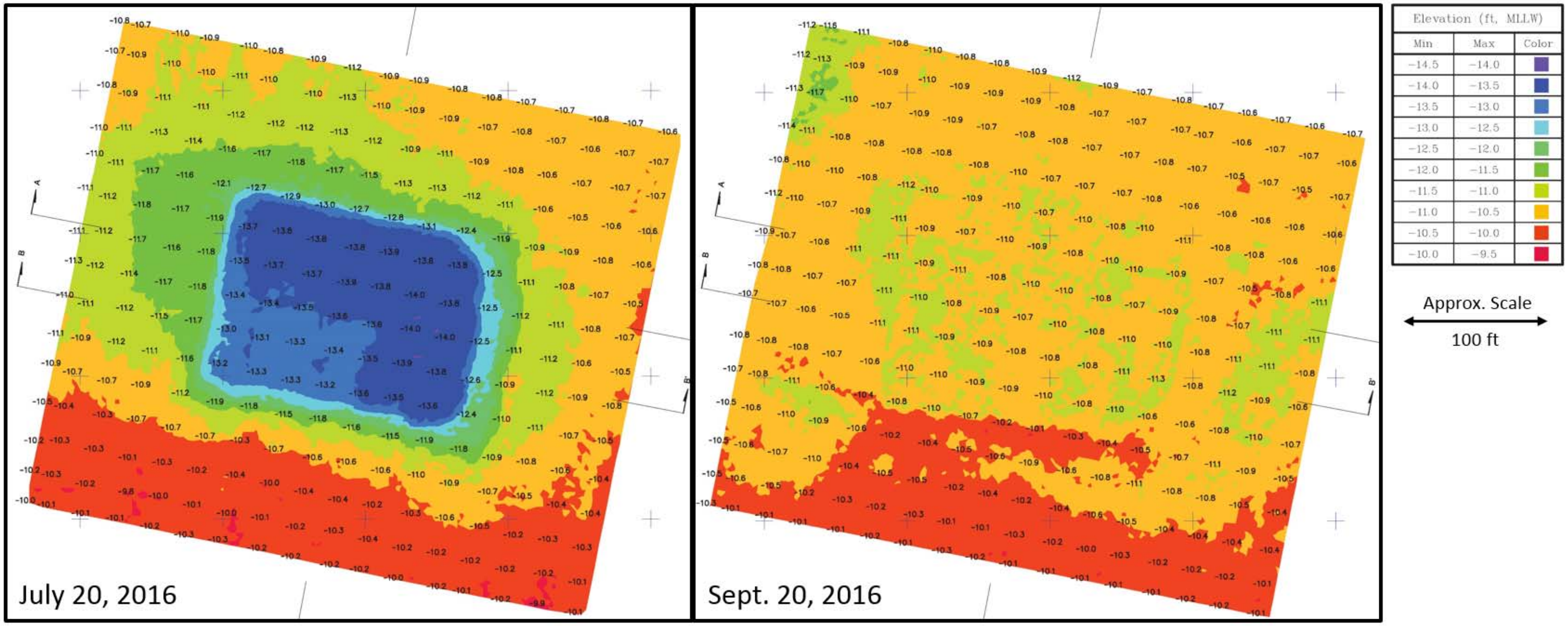
Table 2-3. Elevation and Volume Changes at Test Trench Site #2.5

Survey Date	Site #2.5						
	Bottom Elevation		Elevation Change from Prior Survey	Estimated Volume Change from Prior Survey			As-Built Capacity Remaining
	Average	Std. Deviation		Cut	Fill	Net Change	
[-]	[MLLW, ft]	[ft]	[ft, + = Infill]	[cy]	[cy]	[cy]	[%]
April 8, 2015	-18.3	1.8	-	-	-	-	100%
July 17, 2015	-16.5	0.6	1.8	600	1,800	1,200	84%
September 13, 2015	-13.5	0.1	3.0	200	3,200	3,000	45%
July 20, 2016	-13.7	0.2	-0.2	200	200	100	44%
September 20, 2016	-11.0	0.1	2.7	0	3,000	3,000	5%
April 8, 2015 to September 20, 2016		**Elev. Change**	**7.3**	**100**	**7,400**	**7,300**	

Notes:
1. Average bottom elevations exclude trench side-slopes. Computed based on data 20-ft inside of As-Built (April 2015) boundary.
2. Cut, Fill, and Net volumes computed within bound shown on Drawing CFC-972-10-002 and -004 and rounded to nearest 100 cy.
3. Summation differences in (Cut-Fill) and Net Change due to rounding.
4. "April 8, 2015 to September 20, 2016" taken from surface comparison, rather than table sum.
5. April survey included only spot elevations measured within the trench as construction progressed.
6. Summer (July and September) surveys conducted using single-beam and multibeam sonar and are more comprehensive and accurate than the April survey.
7. "As-Built Capacity Remaining" computed relative to April 8, 2015 survey. Volume at time of April 8, 2015 survey estimated to be 7,700 cy based on reference surface at elevation -10.6 ft (MLLW).

The condition of Test Trench Site #2.5 at the time of the early (July 20, 2016) and late-season (September 20, 2016) surveys is illustrated in Figure 2-13 (see Appendix A for more detail).

Figure 2-13. Test Trench Site #2.5, July and September 2016 Surveys



Note: Taken from Appendix A (Drawings CFC-972-20-001 and CFC-972-20-003)

The remaining portion of the original (As-Built) trench capacity was computed at the time of each survey and is provided in Table 2-3. The capacity at the time of construction is estimated to be 7,700 cy. This value differs slightly from that shown on Drawing CFC-944-10-002 (7,400 cy) due to minor differences in the DTM used to model the edge of the trench.

Early-Season Survey

As illustrated in Figure 2-13, seabed elevations at the time of the early-season survey ranged from approximately -11.0 ft (MLLW) at the edge of Site #2.5 to -14.1 ft (MLLW) along the east side of the pit. The average sea bottom elevation measured within the central portion of the trench (excluding the side-slopes) was -13.7 ft (MLLW). This value was 0.2 ft deeper than the average value observed in September 2015. It is likely that the apparent stability at Site #2.5 during this period is due to some combination of sedimentation during the period between the September 2015 and July 2016 surveys, settlement of the infilled material, and minor survey inaccuracies.

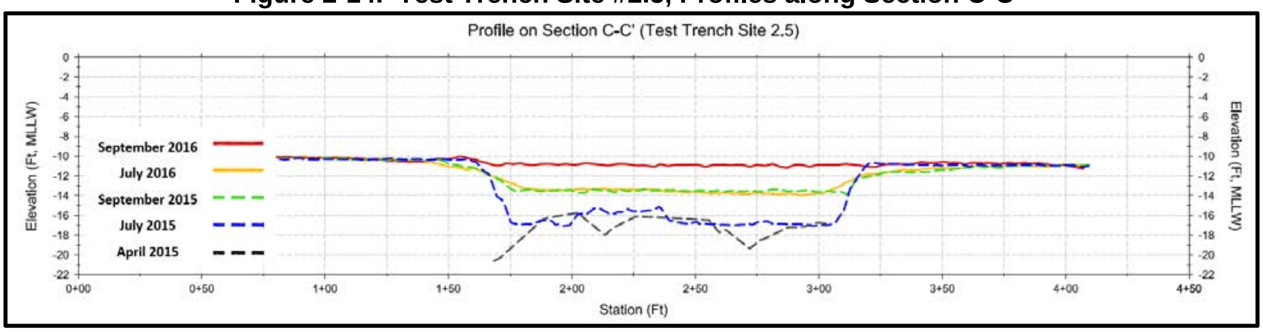
Late-Season Survey

As was the case at Site #1, significant infill occurred at Site #2.5 during the roughly 9-week period between the early- and late-season surveys, which resulted in the pit being essentially filled in (Figure 2-13). As noted in Table 2-3, the average elevation within the central portion of the trench increased by 2.7 ft during this period. This corresponded to a net increase of 3,000 cy at the site, which is equal to the magnitude observed between the early- and late-season surveys in 2015. At the time of the late-season survey, the average elevation in the trench (-11.0 ft, MLLW) was within 0.5 ft of the ambient seabed elevation measured prior to construction (-10.6 ft, MLLW).

The net change from the time of construction (April 2015) to the late-season survey (September 2016) is estimated to be 7,300 cy (Table 2-3). The average elevation change was +7.3 ft. At the time of the late-season survey, only 5% of the original (As-Built) trench capacity remained (based on an original trench capacity of 7,700 cy).

Figure 2-14 illustrates the progressive infill of the trench along a selected cross-section through the center of the pit (Section C-C', Drawing CFC-972-20-005). Both the significant infill during the 2016 open-water season and the nearly level seafloor at the time of the most recent survey are illustrated.

Figure 2-14. Test Trench Site #2.5, Profiles along Section C-C'



Note: Taken from Appendix A (Drawing CFC-972-20-005)

The fact that both sites filled near to capacity in less than two open-water seasons is significant and underscores the challenge that sedimentation poses to the construction and maintenance of dredged channels in this area.

2.5.3 Test Trench Control Site

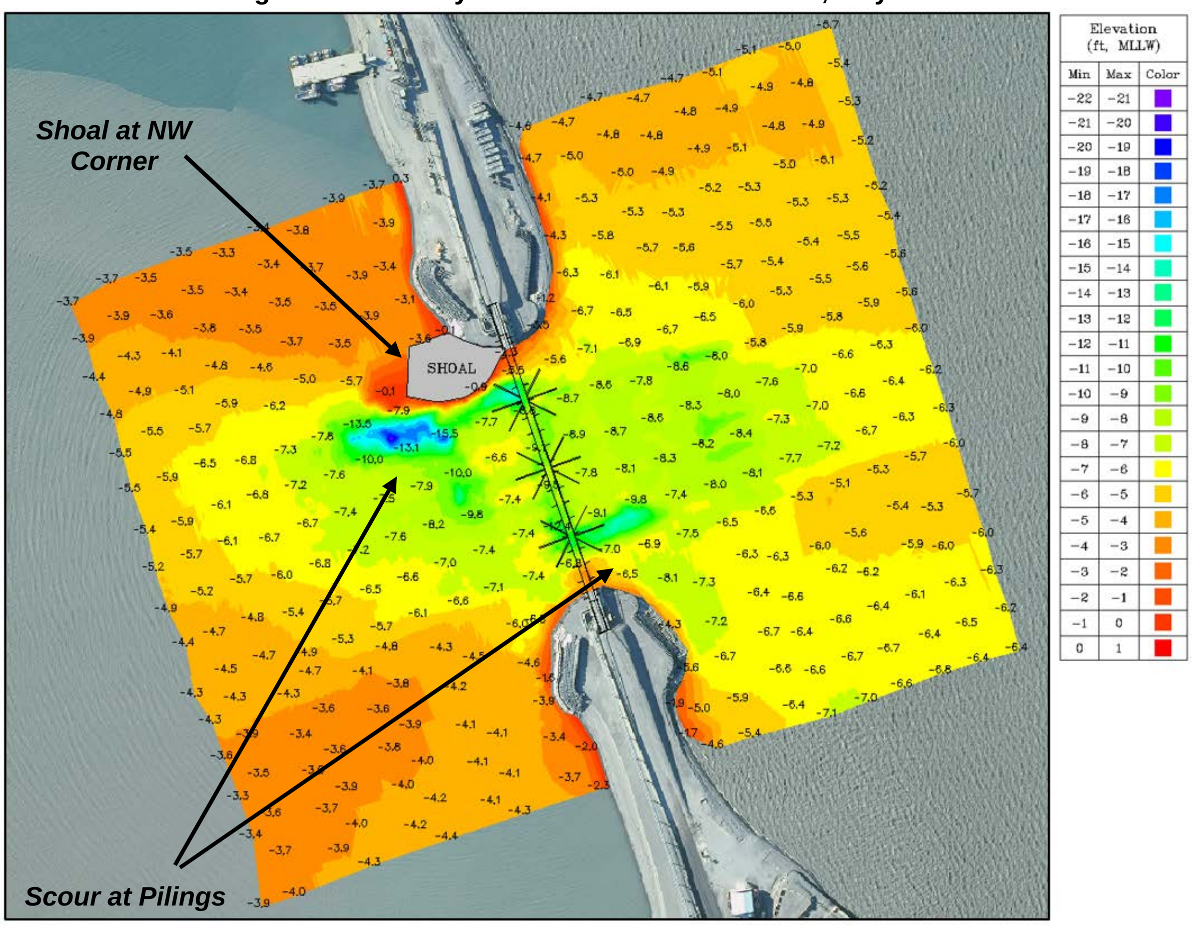
As noted above, a control site was surveyed at the time of the early- and late-season surveys. The average elevation change between the September 2015 and July 2016 surveys was 0.2 ft (standard deviation = 0.1 ft) within the 100-ft x 100-ft area. The average elevation change between the September 2015 and July 2016 surveys was 0.1 ft (standard deviation = 0.2 ft). Given that this is within the anticipated vertical accuracy of the survey (Section 2.4), it is likely that this change is comprised of some very small change in the seabed as well as inaccuracies in the survey technique.

2.5.4 650-Ft Breach

Data obtained at the 650-ft Breach as part of the early- and late-season survey efforts are illustrated in Drawings CFC-972-30-001 and CFC-972-30-002, respectively. Changes observed between the two surveys are provided in Drawings CFC-972-30-003 and CFC-972-30-004.

Figure 2-15 illustrates the bathymetric data obtained at the time of the July survey. Water depths within the breach are generally deeper than those to the north and south (adjacent to the causeway) as a result of accelerated currents which are generated through the breach. Smaller-scale depressions also are evident west of the north bridge piling and east of the south bridge piling. Depths reaching 21.6 ft (MLLW) were noted in the depression west of the north piling at the time of the July survey.

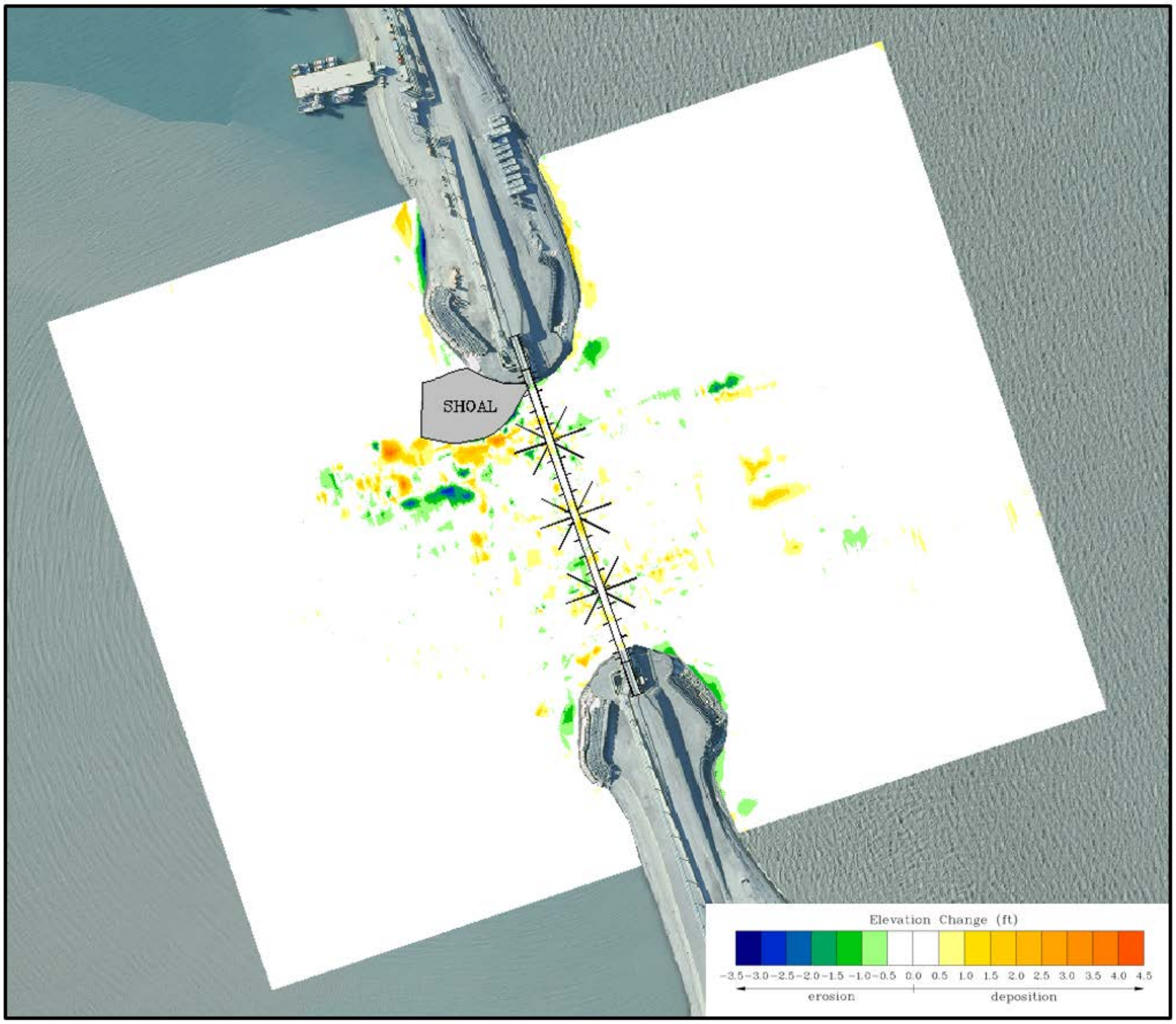
Figure 2-15. Bathymetric Data at 650-ft Breach, July 2016.



Note: Taken from Appendix A (Drawing CFC-972-30-001)

Figure 2-16 illustrates the changes noted during the 9-week period between the July and September Surveys. No large-scale changes were noted. Small-scale changes ranging from approximately -3.5 to +4.5 ft were noted near depressions in the seabed, particularly near the shoal on the northwest corner of the breach. It should be noted that inaccuracies in the survey data are amplified in steep regions where small errors in position can result in large changes in depth.

Figure 2-16. Elevation Changes at 650-Ft Breach, July to September



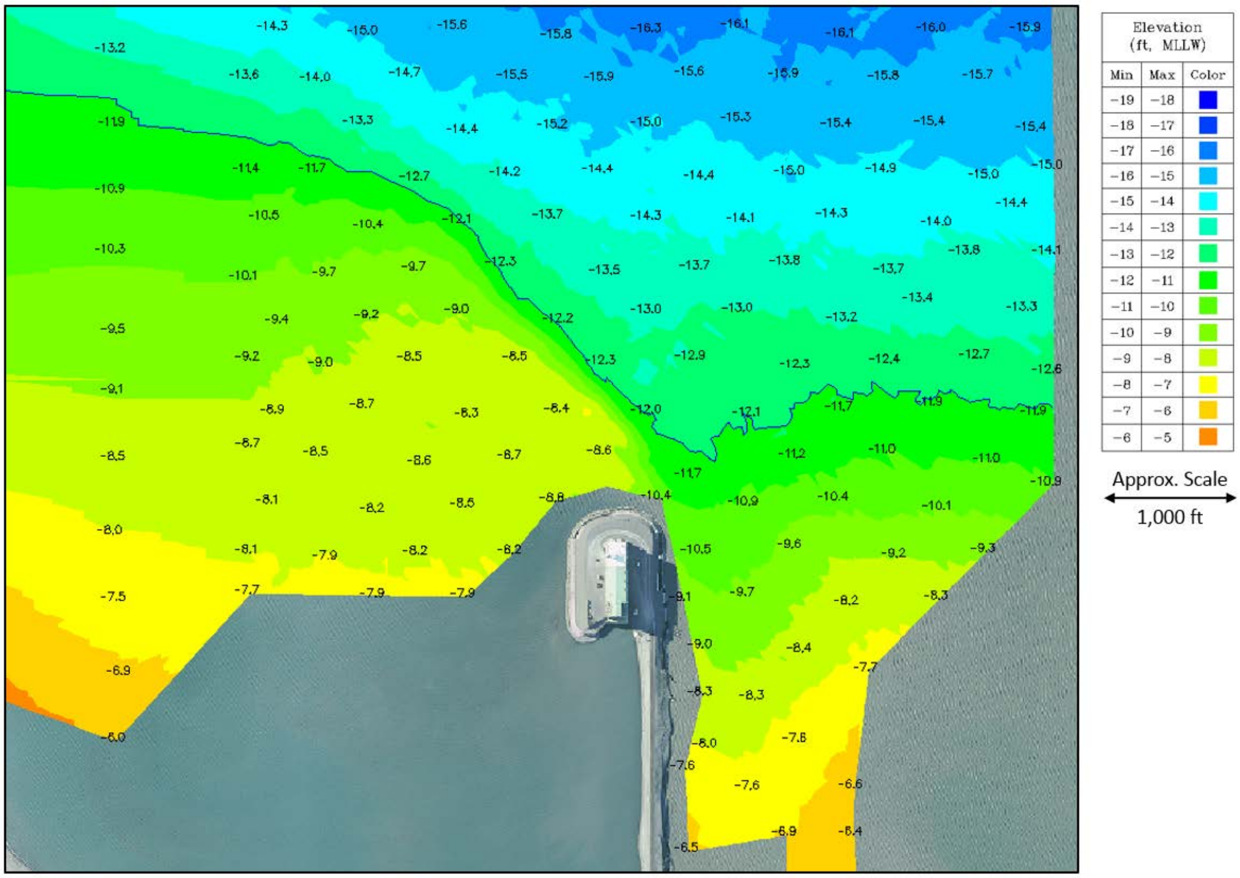
Note: Taken from Appendix A (Drawing CFC-972-30-003)

2.5.5 STP and Offshore Stump Island

The survey data obtained near the STP and offshore of Stump Island are illustrated in Drawings CFC-972-40-001 through CFC-972-40-003. These data were provided to the numerical modeling team (Resource Management Associates, RMA) for incorporation into the sedimentation model described in Section 1.

Of particular interest to the execution team is the STP area, where potential offload strategies have been proposed. This area is illustrated in Drawing CFC-972-40-002, an excerpt of which is provided in Figure 2-17. As shown in the figure, the seabed surrounding the STP is characterized by a deep region to the northeast and a shoal to the northwest. This feature, particularly, the shallow water located to the northwest of the STP should be noted when planning potential sealift approach routes.

Figure 2-17. Bathymetric Data near the STP



The results of the side-scan sonar survey are illustrated in Drawing CFC-972-40-003. The seabed appears to be relatively uniform, with ice gouges and wallows scattered throughout the area. Regions with varying sediment types (indicated by differing acoustic reflectivity) are evident, primarily to the north and east of the STP. Similar regions were identified during the 2014 survey program.

The side-scan sonar mosaic was inspected for potential areas of hard-bottom or hazards to navigation and construction. No large targets or areas of concern were identified; however, 22 small isolated targets were noted. The targets were most heavily concentrated near the STP and east of the causeway centerline. Table 2-4 summarizes the location of each target identified and provides a general description. A representative target is provided in Figure 2-18 for reference.

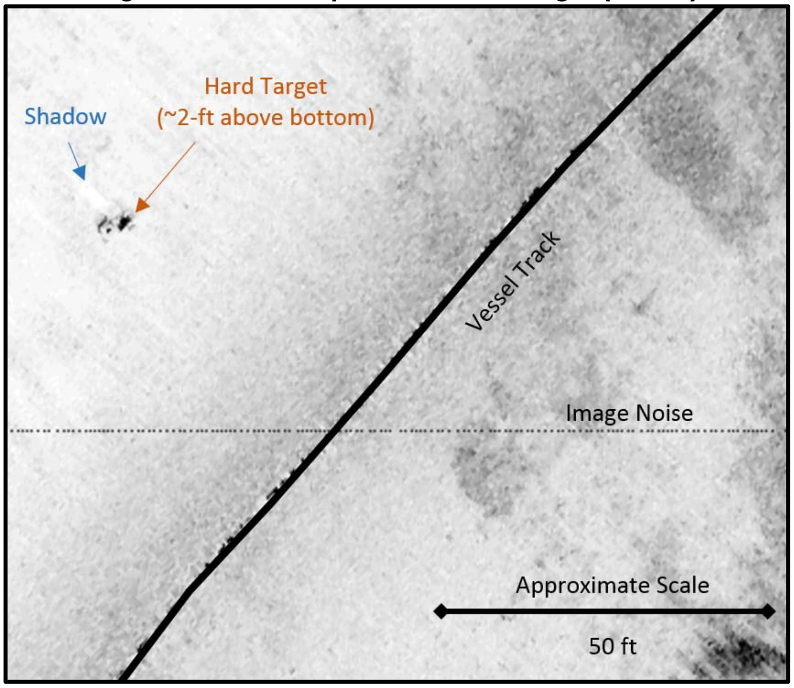
Table 2-4. Location of Side-Scan Targets in STP Survey Area

Target No.	Easting	Northing	General Description
[-]	[US-FT]	[US-FT]	[-]
1	1,817,761	6,005,012	Hard target. Does not penetrate above seabed.
2	1,819,559	6,003,728	Rocks on seabed.
3	1,819,564	6,005,468	Small target.
4	1,819,992	6,004,513	Area with harder seabed material.
5	1,820,097	6,002,861	Depression in front of hard target.
6	1,820,352	6,004,553	Rock (1-ft high).
7	1,820,441	6,005,293	Rock (less than 0.5-ft high).
8	1,820,933	6,005,110	Unknown.
9	1,821,287	6,005,303	Hard target (less than 0.5-ft high).
10	1,821,311	6,001,357	Hard target (1.2-ft high).
11	1,821,382	6,006,877	Hard target (1.5-ft high).
12	1,821,512	6,002,085	Small depression with hard substrate.
13	1,821,641	6,001,175	Hard target (2.0-ft high).
14	1,821,663	6,002,068	Holes around hard targets.
15	1,821,745	6,002,635	Scattered hard material. Does not penetrate above seabed.
16	1,821,859	6,006,183	Small hard target. Does not penetrate above seabed.
17	1,821,975	6,001,464	Hard target (1.0-ft high).
18	1,821,980	6,002,472	Hard target (0.5-ft high).
19	1,822,081	6,001,566	Hard target (less than 0.5-ft high).
20	1,823,075	6,004,967	Hard target. Does not penetrate above seabed.
21	1,823,245	6,002,853	Area with several hard targets (less than 0.5-ft high).
22	1,824,052	6,003,008	Hard substrate.

Notes:

1. Horizontal Datum is Alaska State Plane Zone 4, NAD83.

Figure 2-18. Example Side-Scan Target (No. 13)



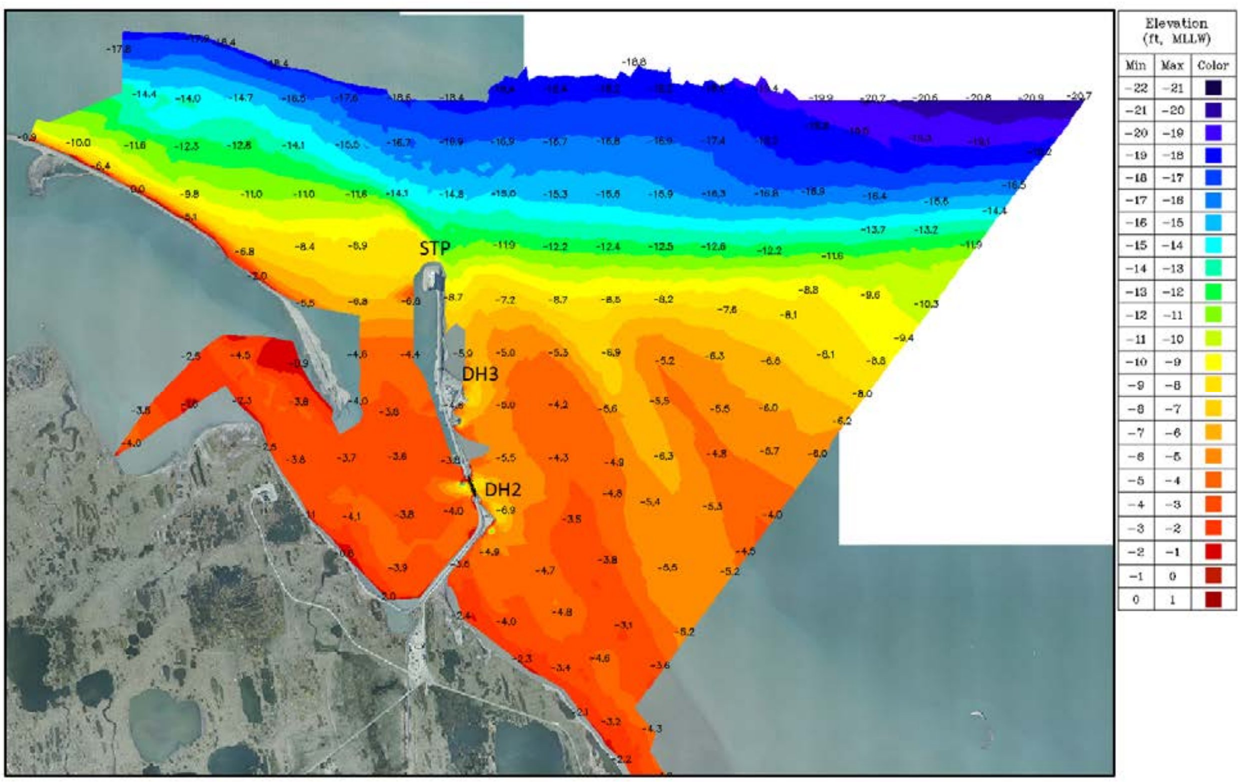
2.5.6 General Bathymetry

Bathymetric data obtained in the remaining two survey areas (east and west sides of causeway) were provided to the numerical modeling team for inclusion in the model simulations.

A composite data set developed from all of the survey data obtained on behalf of the project in 2014, 2015 and 2016 was developed and is illustrated in Drawing CFC-972-01-002 and Figure 2-19.

As is shown in the figure, water depths on the west side of the causeway are shallow and generally less than 5 ft (MLLW). On the east side of the causeway, two prominent shoals are evident. These shoals were first noted as part of the 2014 survey program and significantly limit the available approaches to Dockheads 2 and 3. As noted above, the bathymetric contours near the STP are characterized by a deep region to the northeast and a shoal to the northwest.

Figure 2-19. Composite AK LNG Bathymetric Data Set (2014-2016)



Note: Taken from Appendix A (Drawing CFC-972-01-002)

3.0 METEROLOGICAL DATA

NOAA (2016) has operated a meteorological station on the roof of the West Dock STP since 1993, providing a nearly complete record of wind speed and direction for the 24 open-water seasons between 1993 and 2016. As noted in the 2015 Field Data Report, one notable exception occurred between September 19, 2014 and August 3, 2015 (46-week gap).

Due to the critical nature of the wind data, which serve as a primary input to the sedimentation modeling effort, CFC installed two anemometers at the 52-ft Breach on West Dock Causeway as part of both the 2015 and 2016 field programs. These sensors were used primarily as a backup to the NOAA station, should it be taken off-line during the field season.

Figure 3-1 illustrates the location and type of sensor deployed. The installation was identical to that used in 2015 and consisted of an RM Young Wind Monitor and Onset Data Logger mounted to a 10-ft section of pipe secured to the supports on the north end of the 52-ft Breach. The wind speed and direction were sampled every three seconds. The average (sustained) values were recorded every six minutes, along with the gust speed (highest three-second wind speed during the six-minute interval). The sensors were installed on July 16 and removed on September 24, 2016.

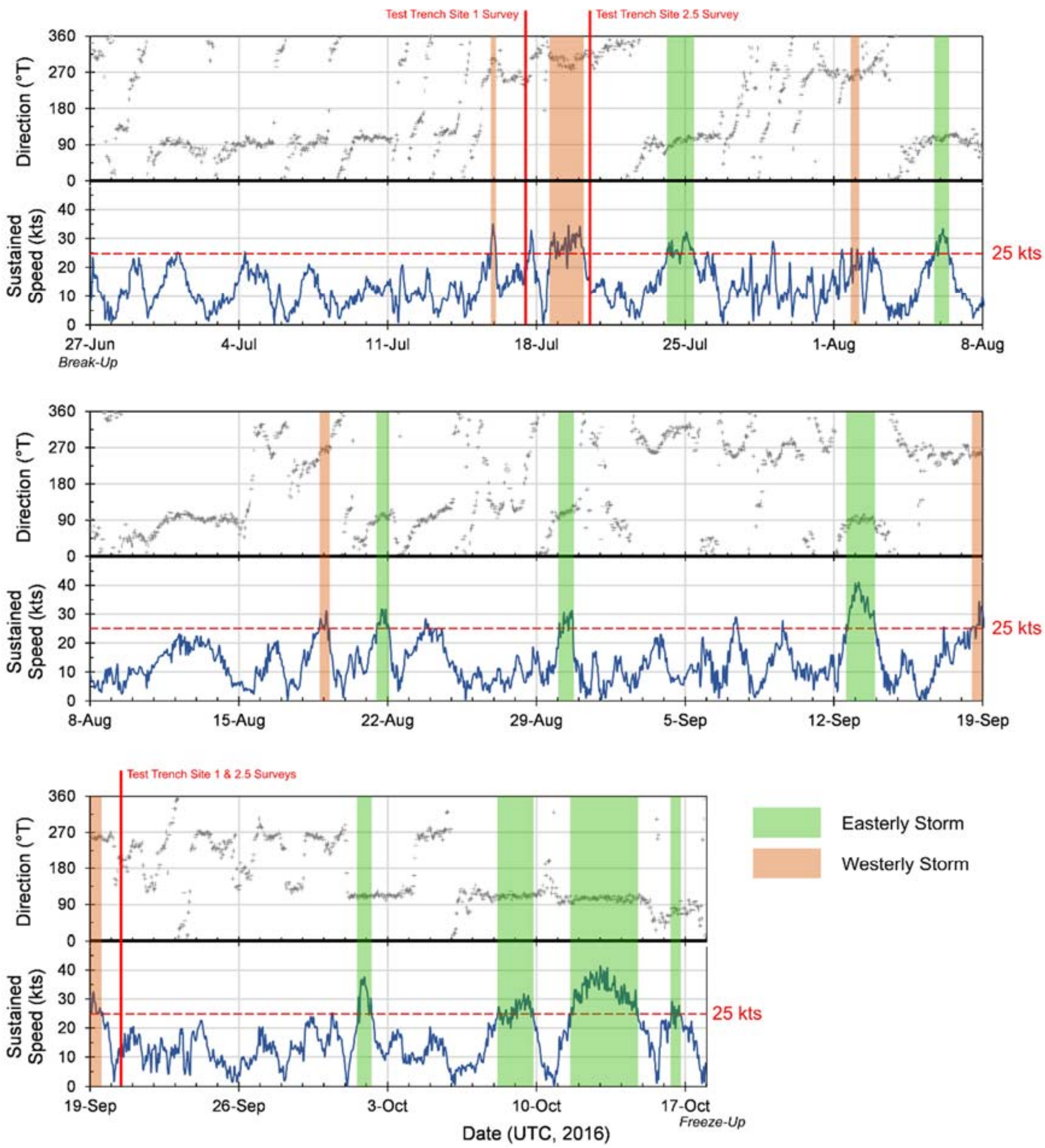
Figure 3-1. Anemometer Installation, West Dock Causeway 52-ft Breach (2016)

The NOAA STP station was operational for the duration of the CFC met station deployment. Following demobilization from the field, the CFC and NOAA data were compared. Given that the NOAA data are used for the long-term model predictions, these data were provided to the numerical modeling team for use in the 2016 model simulations. The CFC data were archived.

Figure 3-2 illustrates the sustained wind speed and direction measured at the NOAA station during the 2016 open-water season, along with the dates of the early- and late-season bathymetric surveys. Fourteen storms having sustained winds greater than 25 kts for at least six consecutive hours occurred during the open-water season. Five storms were westerlies and nine were easterlies. Using the same criterion, only eight storms occurred during the 2015 open-water season, and only one was westerly. The predominance of easterly conditions observed in 2015 is typical for the area.

It should be noted that four easterly storms occurred following the September 2016 survey effort, one of which was the largest storm of the open-water season (October 11-14). Had the late-season survey been conducted following these storm events, the infill noted in Section 2 would have almost certainly increased.

Figure 3-2. Sustained Wind Speed and Direction at STP, 2016 Open-Water Season



4.0 WAVE AND CURRENT DATA

4.1 OVERVIEW

As part of the of Summer 2016 Field Program, four Acoustic Doppler Current Profilers (ADCP) were deployed in the project area to monitor the wave and current conditions. The ADCP data are primarily used by the numerical modeling team to validate the wave, hydrodynamic and sedimentation models developed as part of the project.

4.2 DATA COLLECTION

4.2.1 Equipment and Sampling Scheme

Teledyne RD Instruments (TRDI) ADCPs were used as part of the program. Three of the sensors were Workhorse Sentinel models (same model used in 2015). Based on recommendations from TRDI, the fourth unit was a newer Sentinel V20 model.

Each ADCP was operated at a nominal frequency of 1200 kHz and was programmed to collect raw ensemble acoustic data for the first 20 minutes of each hour (the "burst" period). Data were acquired at 2 Hz, amounting to 2400 samples per burst. The sampling scheme was optimized to collect the largest amount of data during the anticipated 2-month deployment, given the storage and battery limitations of the sensor. Collection of raw ensemble data allowed for more flexibility in processing both the wave and current data following instrument recovery.

The ADCPs sample the current magnitude and direction along a profile in the water column. In all four cases, the face of the ADCP was located approximately 1.7 ft (20 inches) above the seafloor, with an initial sampling bin located 2.6 ft above the sensor face (4.3 ft above the seafloor). Successive bins were located at 0.8-ft intervals above the lower bin until reaching the water surface.

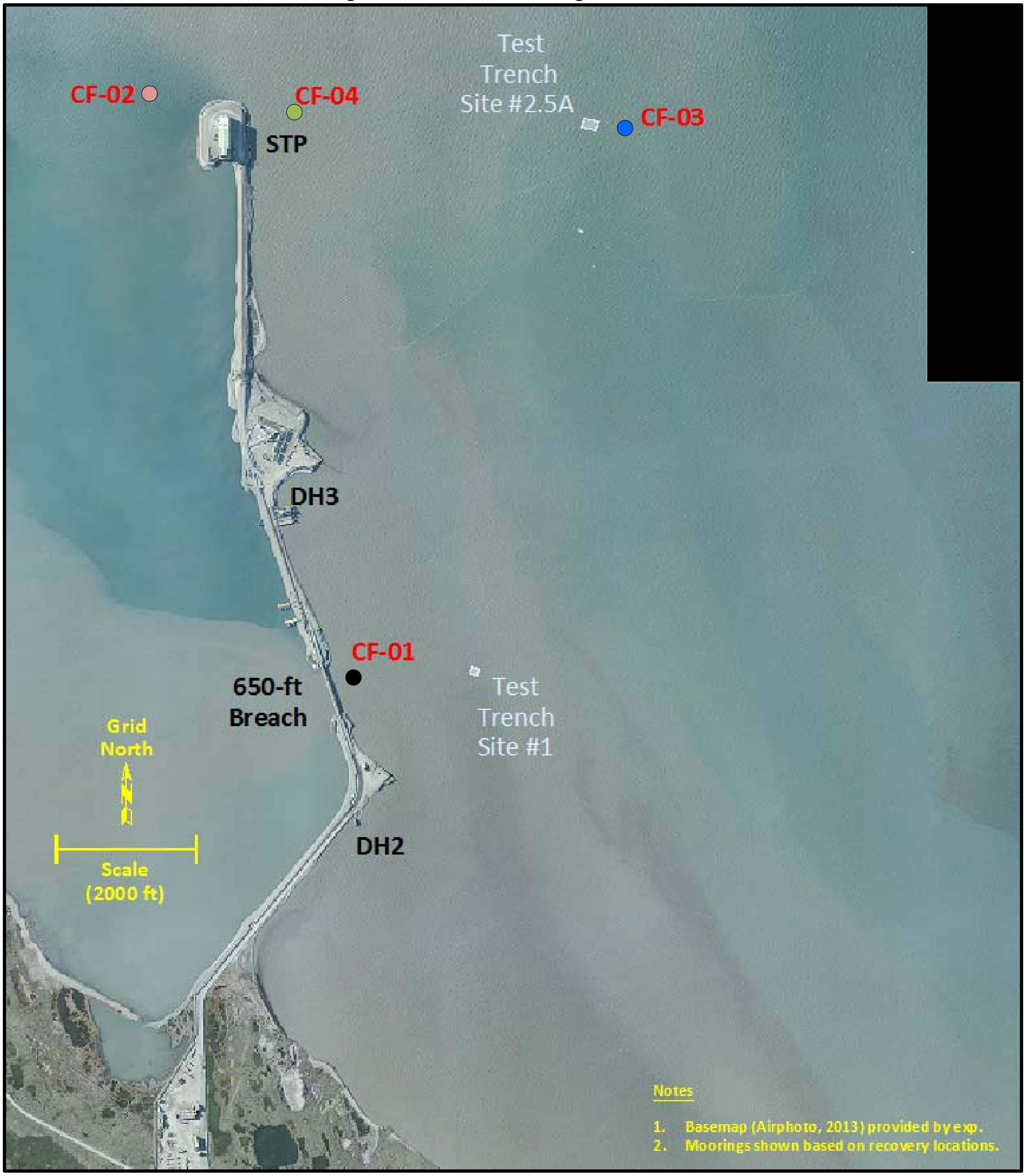
4.2.2 Mooring Locations

The mooring locations are provided in Table 4-1 and illustrated in Figure 4-1. The locations of the 650-ft Breach (CF-01) and Test Trench #2.5 (CF-03) moorings were similar to those used in 2015. The remaining two sites (CF-02 and CF-04) were new for 2016 and located on the west and east sides of the STP. It is important to note that the "CF" designation for the 650-ft Breach is different in 2015 (CF-04) and 2016 (CF-01). To avoid confusion, the site description (e.g. 650-ft Breach) is included along with the "CF" number when referenced herein.

Table 4-1. 2016 Mooring Deployment and Recovery Details

Mooring Number and Description	Sensor Type	NAD83, ASPZ4		NAD83				Approx. Water Depth	Deployment Date/Time	Recovery Date/Time
		Easting	Northing	Latitude (N)		Longitude (W)				
		[US-FT]	[US-FT]	Deg	Min	Deg	Min	[ft, MLLW]	[UTC]	[UTC]
CF-01 (650-ft Breach)	Sentinel V20	1,822,615	5,994,648	70	23.4556	148	31.0586	8.2	7/13/2016 22:05	9/21/2016 19:40
CF-02 (West-STP)	Workhorse	1,819,752	6,002,955	70	24.8283	148	32.3580	8.7	7/13/2016 21:29	9/21/2016 21:28
CF-03 (Test Trench #2.5)	Workhorse	1,826,509	6,002,470	70	24.7218	148	29.0633	10.5	7/13/2016 20:00	9/21/2016 20:07
CF-04 (East-STP)	Workhorse	1,821,778	6,002,706	70	24.7796	148	31.3714	10.4	7/13/2016 20:26	9/21/2016 22:27

Figure 4-1. 2016 Mooring Locations

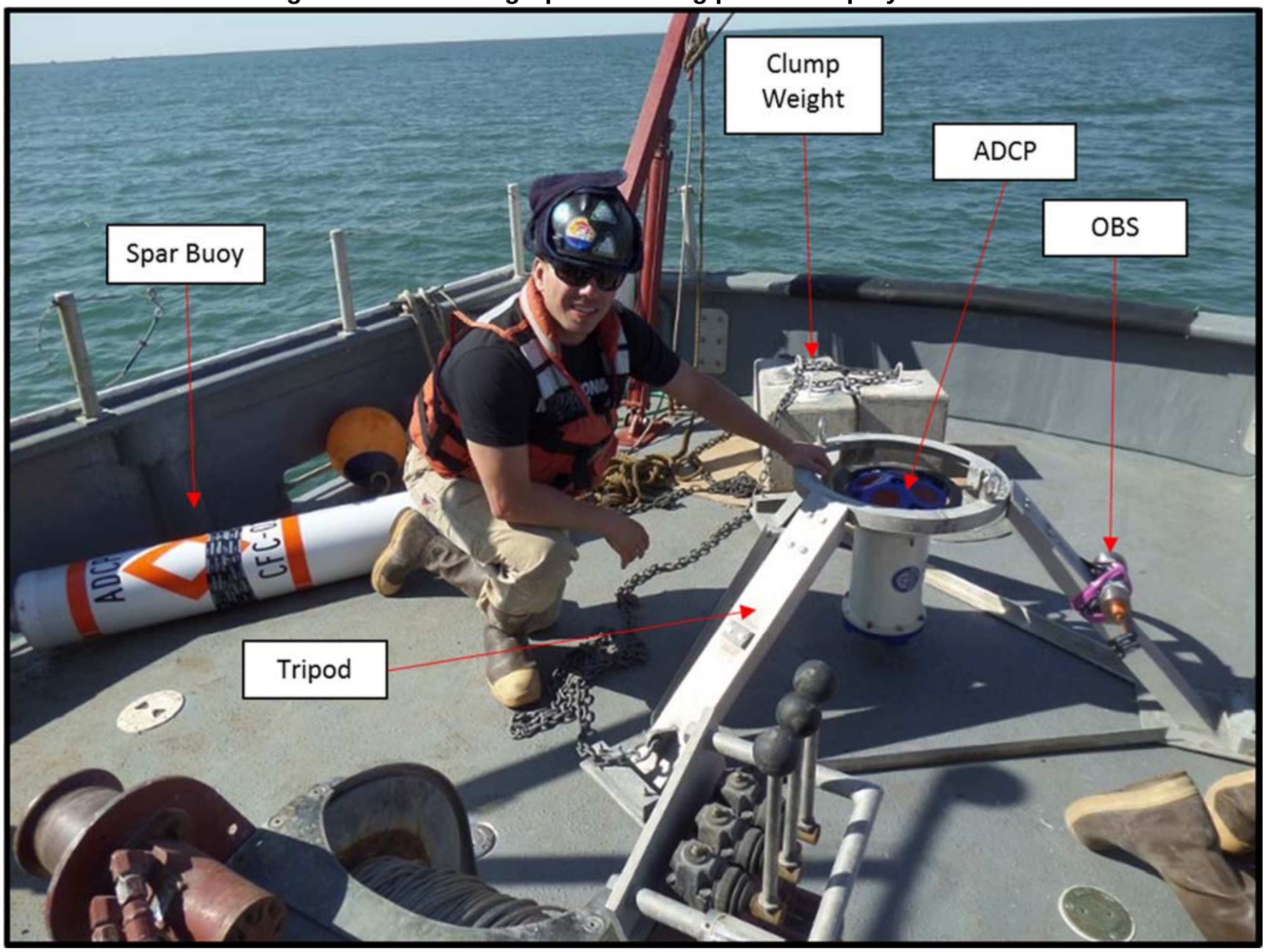


4.2.3 Instrument Deployment

The ADCPs were deployed on July 13 (prior to the early-season bathymetric survey effort) using methods identical to those employed as part of the 2015 program. Each ADCP was mounted to an aluminum tripod manufactured by Mooring Systems, Inc. (MSI). The tripod included a gimbaled connection to ensure that the instrument remained upward-facing during the deployment. In addition to the ADCP, an Optical Backscatter Sensor (OBS, Section 5) also was installed on each tripod.

To prevent the tripod from being displaced during storm events, a 450-lb clump weight consisting of three concrete cubes was attached to the frame with a 15-ft length of chain. A lighted spar buoy with a radar reflector was secured to the clump weight to identify the mooring and reduce the likelihood that vessels, particularly barges accessing Dockheads 2 and 3, would impact the instruments. The instrument frame and mooring components are shown in Figure 4-2.

Figure 4-2. Oceanographic Mooring prior to Deployment



Following calibration and initialization of the ADCP and OBS data acquisition systems, the tripods were loaded on to the research vessel and prepared for deployment. Refer to the 2015 Field Data Report for details regarding the deployment sequence.

Immediately following deployment of the moorings, strong westerly winds persisted for a period of approximately five days (July 16 – 20). During this period, large ice floes entered the project area, and floes with diameters of approximately 1,000 ft were observed just offshore of the STP. Sometime between approximately 11:00AM on July 18 and 08:30AM on July 19, the West-STP (CF-02) mooring was displaced approximately 1,400 ft east, presumably by the ice floes traversing the area.

On July 21 the displaced mooring was recovered and the instrumentation and mounting hardware inspected for damage. Following confirmation that no damage had been sustained, the mooring was re-deployed near its original location. It should be noted that during the recovery process, the East-STP (CF-04) mooring was displaced by the vessel approximately 225 ft south of its original location.

Additional ice incursions occurred on July 22 and 23, although no other significant movement of the moorings was noted. Figure 4-3 illustrates the West-STP (CF-02) site and nearby ice floes on July 22.

Figure 4-3. West-STP (CF-02) Spar Buoy and Nearshore Ice Floes (July 22, 2016)

4.2.4 Instrument Recovery

Recovery efforts were performed on September 21, immediately following completion of the late-season bathymetric survey described in Section 2. Table 4-1 (Section 4.2.2) delineates the time each tripod was recovered. Similar methods were used in both the deployment and recovery tasks. Refer to the 2015 Data Report for details regarding the recovery sequence.

While all four mooring frames, clump weights, spar buoys, and OBS sensors were recovered, the ADCP at the West-STP site (CF-02) was missing from the tripod at the time of recovery. Upon further inspection, damage to the tripod and gimbal were noted, indicating that the mooring had been struck at some point following re-deployment. It should be noted that CFC confirmed that this damage was not present at the time of the July 21 re-deployment described above. Efforts to locate and recover the missing ADCP were discussed; however, a feasible approach was not identified, primarily due to the following:

- The ADCP is a small cylindrical unit, which is not possible to locate and retrieve with a grapple.
- CFC is not approved to dive as part of the project.
- Visibility was minimal (less than 1 ft).

4.3 DATA PROCESSING

Following recovery, the raw ensemble data were retrieved from each ADCP. The raw data were processed using TRDI's WavesMon software package. Initial adjustments related to the deployment configuration (e.g., height of instrument above the seafloor) were made and the averaging interval for current measurements (6 minutes) was set.

As was the case in 2015, it was difficult to accurately resolve the high frequency, small amplitude waves that occurred during periods of calm weather. As these are not expected to drive substantial sediment transport, waves with significant wave heights (Hs) less than approximately 0.5 ft were purged from the wave data files at all but the 650-Ft Breach (CF-01) site. At this site, the newer model ADCP (Sentinel V20) was able to resolve the small amplitude waves without issue. It should be noted, however, that despite the sensor's ability to better resolve small waves, the compass used in the newer V20 model cannot be accurately calibrated at high latitudes. Following extensive discussions with the TRDI engineers and numerous calibration attempts, a method was developed to generate a "look-up" table of instrument and true headings. This was performed at West Dock following recovery of the sensor. The data were then used in post-processing to correct the original wave and current directions output by the sensor.

Following data processing in WavesMon, a separate Matlab routine provided further adjustments to the data files including the removal of spurious data and correction for magnetic declination at the project site. Time series of both wave characteristics and current parameters were output for analysis and provided to the numerical modeling team.

4.4 RESULTS

4.4.1 Wave Data

Wave data obtained as part of the 2016 Field Program are shown in Figure 4-4. Over the 9-week monitoring period, the average significant wave height (Hs) at the two offshore sites was approximately 1.6 ft (Test Trench #2.5 and East-STP). Relatively smaller waves prevailed at the more-sheltered 650-ft Breach (CF-01) location, with an average Hs value of approximately 0.6 ft.

As shown in the figure, the 2016 monitoring period was generally unsettled, with very few periods of calm conditions. The first storm with significant wave heights exceeding 3 ft occurred on August 22 (maximum Hs = 3.4 ft) at the East-STP (CF-04) site. Over the next month, energetic conditions persisted, intermixed with brief periods of calm, and culminated in the largest seas of the deployment period on September 19. Significant wave heights during this storm reached 4.2 ft at the Test Trench #2.5 (CF-03) site. Peak wave directions at each of the sites were generally bi-modal, following the wind direction. However some scatter was noted during periods when locally generated seas were present along with longer period (swell) waves generated from a prior (separate) storm event.

Details regarding storm events with significant wave heights exceeding 3 ft are provided in Table 4-2. At the Test Trench #2.5 (CF-03) site, all three of the events were out of the northwest (i.e. generated during westerly storm events). At the East-STP (CF-04) site, three of the events were out of the north (i.e. generated during westerly storm events) and one was out of the east (September 19, generated during easterly wind event). Wave periods were greater than 5 seconds in all cases.

Table 4-2. Wave Parameters for Storms with Significant Wave Heights of 3 ft or more

ADCP Designation	Date [UTC]	Hs [ft]	Tp [s]	Dp [degrees grid]
CF-01 (650-ft Breach)	See note 4	-	-	-
CF-02 (West STP)	See note 5	-	-	-
CF-03 (Test Trench #2.5)	8/22/16 20:00	3.0	5.1	338
	9/12/16 19:00	3.4	6.7	338
	9/19/16 16:00	4.2	9.8	331
CF-04 (East-STP)	8/22/16 20:00	3.4	5.6	11
	9/6/16 0:00	3.0	6.1	358
	9/13/16 0:00	3.8	5.6	55
	9/19/16 13:00	3.7	11.6	0

Notes:
1. Hs = Significant Wave Height
2. Tp = Peak Wave Period
3. Dp = Peak Wave Direction
4. Significant wave height did not exceed 3 ft at CF-01.
5. ADCP CF-02 not recovered.

As is illustrated in Figure 4-4, peak wave periods exceeding 6 seconds (swell) were common throughout the 2016 season. By contrast, wave periods rarely exceeded 4 seconds (local seas) during the 2015 monitoring period. This difference is likely due to the proximity of nearshore ice to the project area, which acts to limit fetch and the ability for waves with longer periods to enter the site. Weekly NIC ice charts selected for the 2015 and 2016 summer seasons are provided in Figures 4-5 and 4-6, respectively, and illustrate the difference in ice conditions. As is shown in Figure 4-5, a small band of ice (7-8 tenths concentration) persisted offshore of Prudhoe Bay late into the summer (through August 25). By contrast, ice concentrations near the site in 2016 were generally less than 1-3 tenths by August 2. This coincides with the arrival of waves with periods exceeding 4 seconds on around August 3, 2016, which persisted for the remainder of the 2016 monitoring period.

Wave periods at the 650-ft Breach (CF-01) were shorter (2 to 4 seconds) that the two offshore sites. This difference is likely due in part to wave reflection off the sheet pile structures, which also contributed to the considerable scatter noted in the wave directions at this site.

4.4.2 Current Data

Time series of depth-averaged current speed and mean current direction are provided in Figure 4-7. During the 2016 monitoring period, the average current speed at the two offshore sites (Test Trench 2.5 and East-STP) was similar (approximately 0.5 ft/s). At the 650-ft Breach (CF-01), the average speed was roughly twice that observed elsewhere (1.1 ft/s).

Similar to the wave directions, current directions at each of the sites were generally bi-modal, following the wind direction. At Test Trench #2.5 (CF-03) and the 650-ft Breach (CF-01), the directions were typically east-west. At the East-STP (CF-04) site, current directions were more heavily influenced by the presence of the causeway and contained a more north-south component.

As noted above, current speeds measured at the 650-ft Breach (CF-01) were higher than the other two sites, particularly during westerly wind events. This difference is presumably due in part to its proximity to the breach and to differential water levels during westerly events (water levels are higher on the west side of the causeway under strong westerly storms).

Table 4-3 provides a summary of the four highest current events measured at each site during the 2016 monitoring period. It's notable that all but one of the largest events at the 650-ft Breach (CF-01) and Test Trench #2.5 (CF-03) sites occurred during westerly wind events, while the largest events at the East-STP (CF-04) site occurred during easterly wind events. This is presumably due to shelter provided by the causeway at the East-STP (CF-04) site during westerlies.

Table 4-3. Four Largest Depth-Averaged Current Events

ADCP Designation	Date	Depth-Averaged Magnitude	Mean Direction	Wind Direction
	[UTC]	[ft/s]	[degrees grid]	[quadrant]
CF-01 (650-ft Breach)	7/15/16 23:00	4.9	36.4	W
	9/19/16 3:36	4.2	57.8	W
	7/19/16 14:36	3.7	64.3	W
	8/18/16 23:06	3.4	75.2	W
CF-02 (West STP)	See note 1	-	-	-
CF-03 (Test Trench #2.5)	9/19/16 6:06	2.6	107.8	W
	7/16/16 0:00	2.2	104.8	W
	9/13/16 2:06	2.2	284.8	E
	9/3/16 20:12	1.9	104.0	W
CF-04 (East-STP)	7/25/16 1:18	2.6	351.3	E
	8/6/16 8:06	2.6	349.4	E
	8/21/16 17:00	2.4	347.1	E
	9/13/16 2:12	3.3	345.5	E

Notes:

1. ADCP CF-02 not recovered.

Figure 4-4. 2016 Significant Wave Height (Hs), Peak Period (Tp) and Peak Direction (Dp)

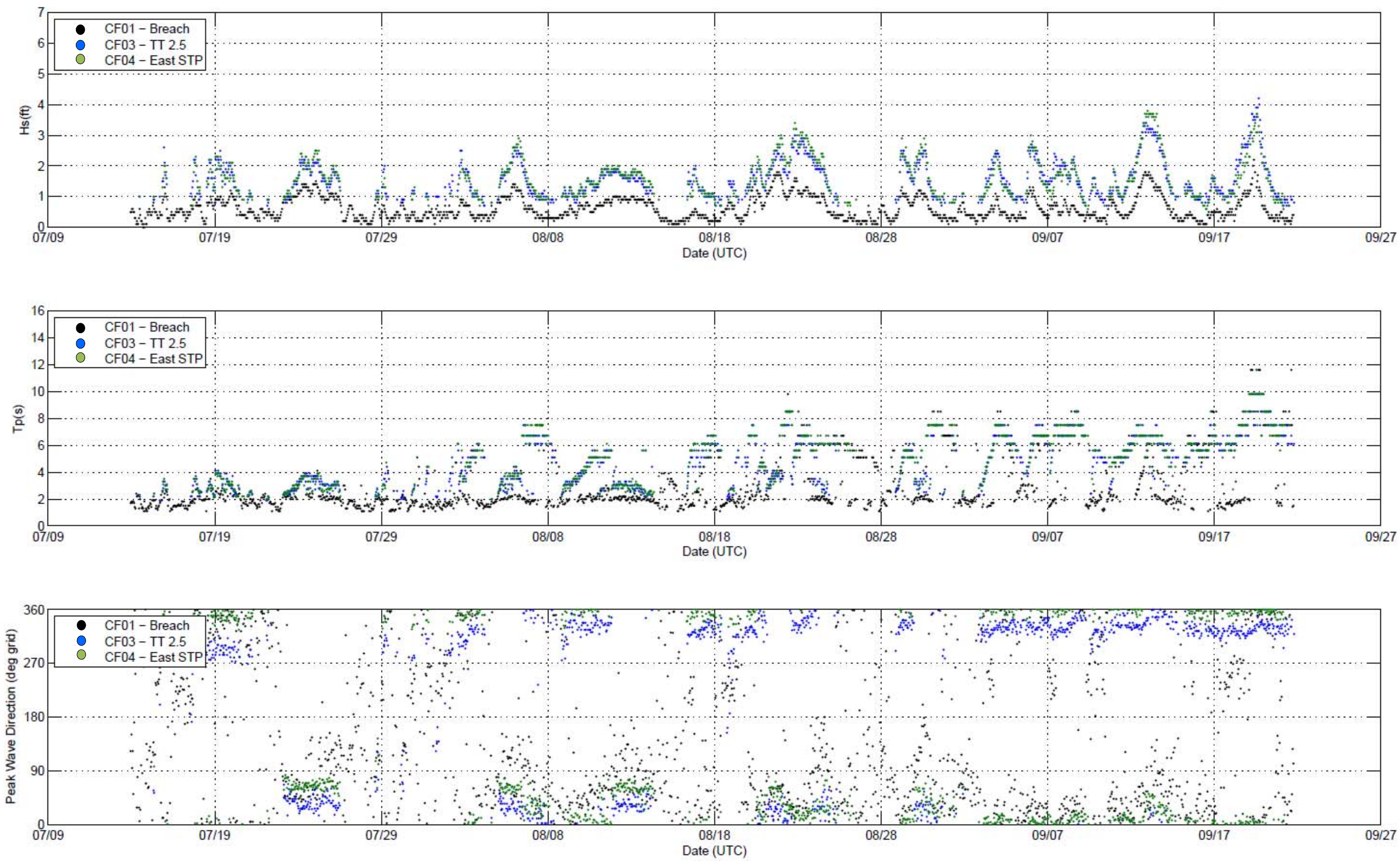


Figure 4-5. Selected NIC Weekly Ice Charts, Summer 2015

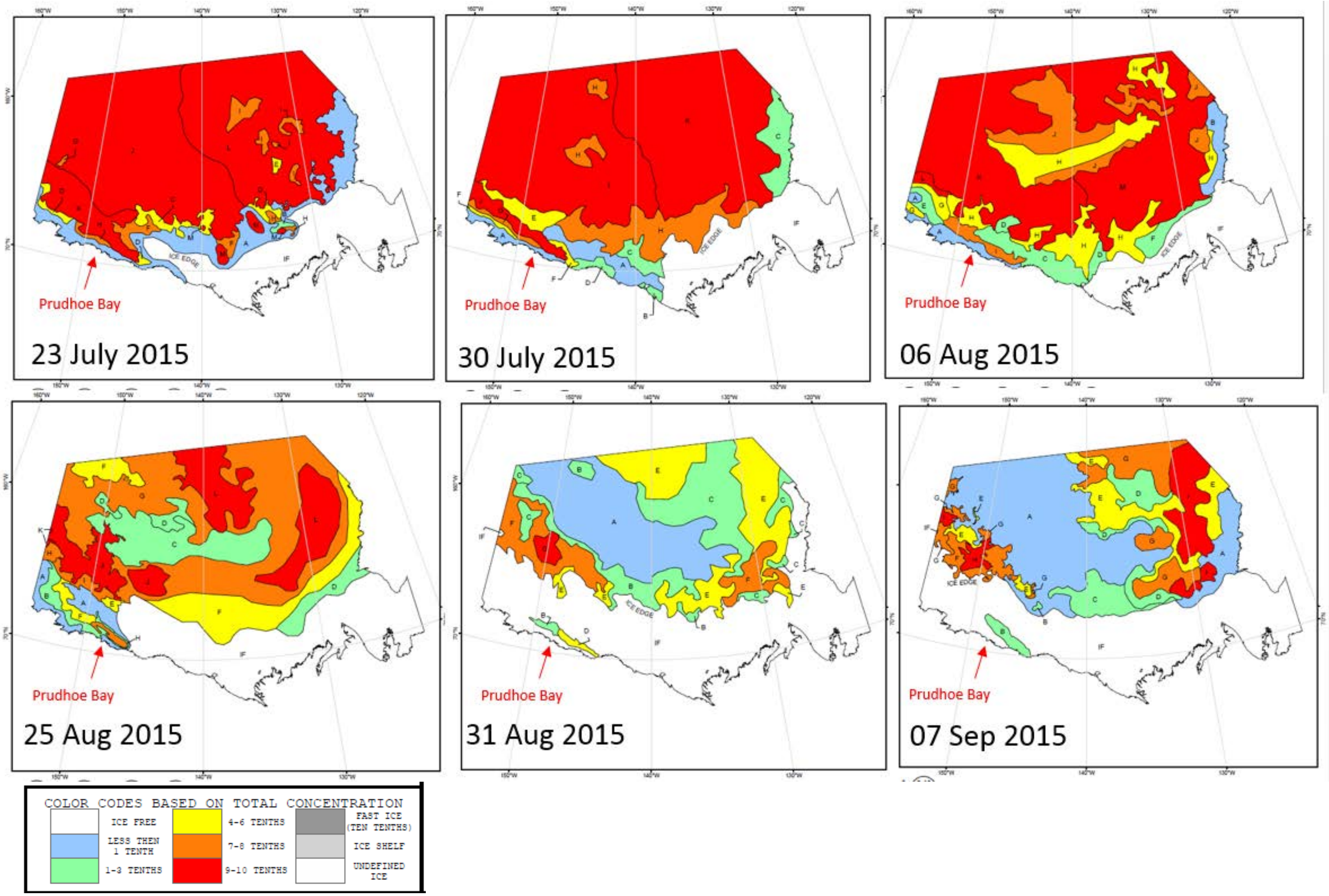


Figure 4-6. Selected NIC Weekly Ice Charts, Summer 2016

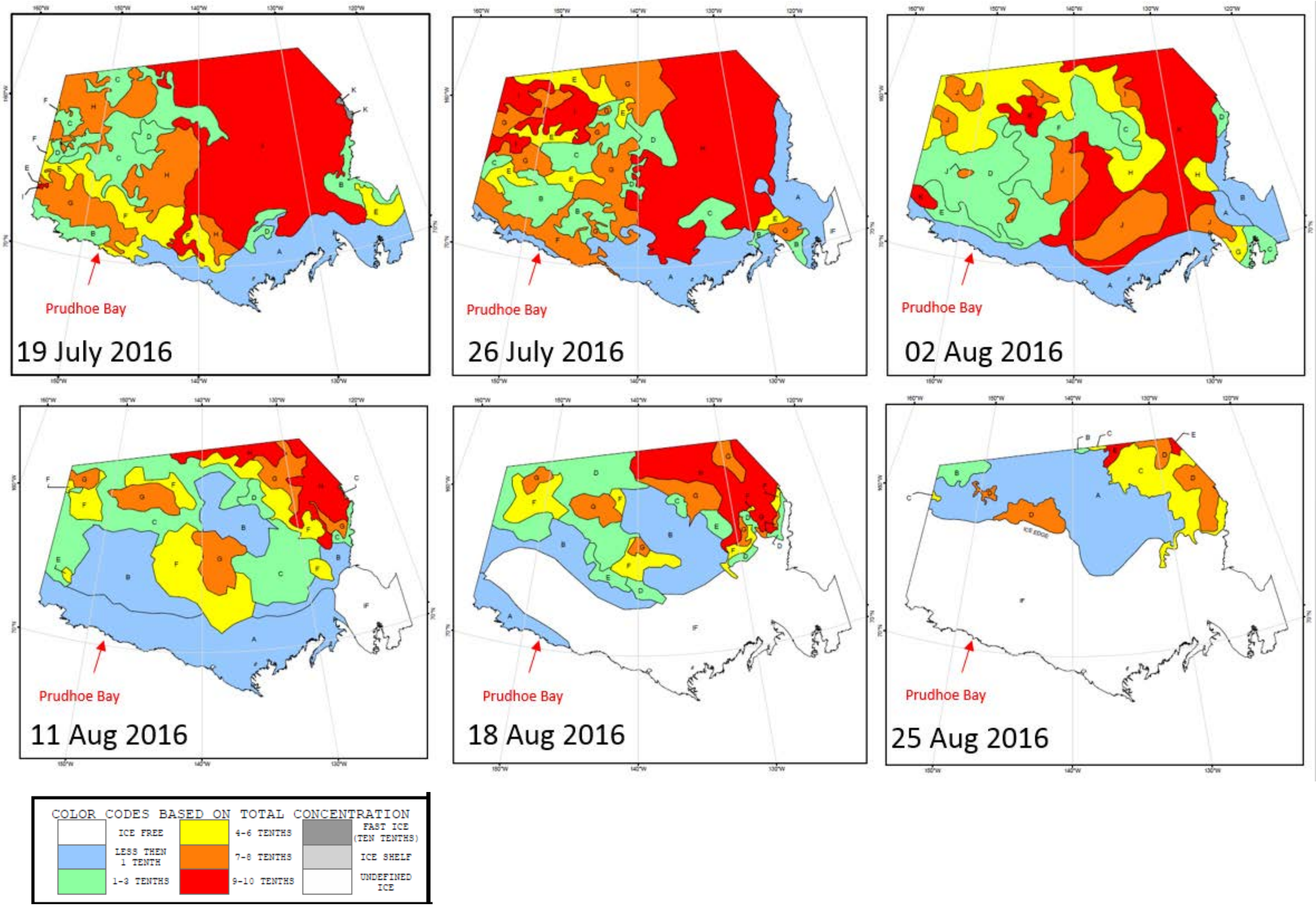
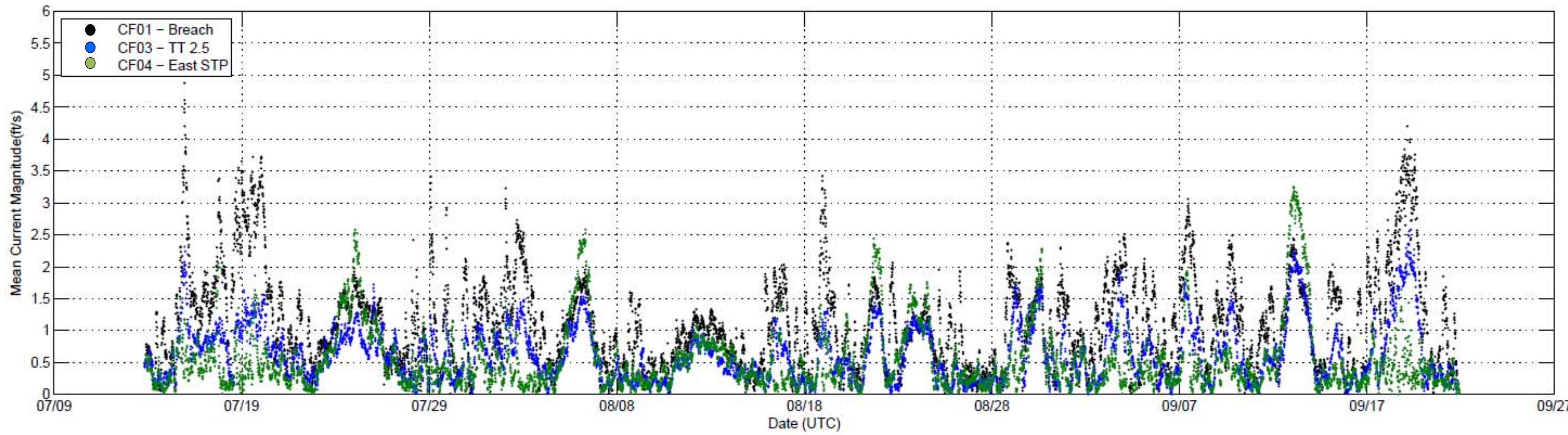
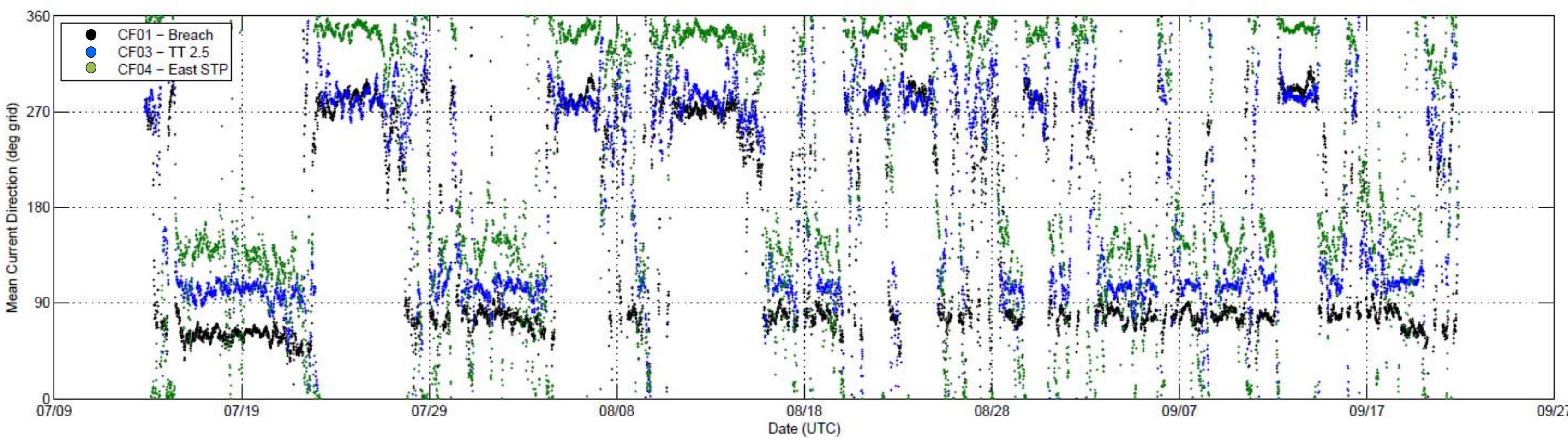


Figure 4-7. 2016 Depth-Averaged Current Speed and Direction





4.5 GPS DRIFTERS

In addition to the ADCP data described above, GPS drifter buys were deployed on two occasions to measure current speeds through the 650-ft Breach. These data are necessary to support numerical model validation efforts and design/feasibility assessments undertaken to evaluate module crossing strategies at the site.

Two Pacific Gyre Microstar drifters (Figure 4-8) were utilized. Each drifter included a buoy, strobe, internal differential GPS receiver and drogue. The drogue is calibrated by the manufacturer such that it allows the buoy to drift with the current speed approximately 1-m below the water surface. When deployed, the location of the buoy (latitude and longitude) is recorded every second, along with the time.

Figure 4-8. GPS Drifter with Drogue and Inflatable Vessel

Drifter data were obtained on September 20 and 23. In both cases, the units were deployed from an inflatable vessel, allowed to drift through the breach, then recovered and re-deployed. Sixteen deployments (8 each) were made on September 20. Thirty-six deployments (18 each) were made on September 23.

Figure 4-9 illustrates the drifter tracks obtained each day. As is illustrated in the figure, the current was flowing from east to west on September 20, and from west to east on September 23. Wind speeds were between 10 and 20 knots in both cases. As expected, the currents tend to diffuse once through the breach. This is particularly evident on September 23, when tracks spanning the entire breach were obtained.

Current speeds computed from the drifter positions are shown in Figure 4-10. Prior to computing the speeds shown in the figure, the data were down-sampled to values every 20 seconds (rather than 1-second data). This was necessary, given the resolution of the GPS data and slow drift speeds encountered. Drift speeds were highest on September 23, with average values of 1.2 and 1.8 ft/s for the two drifters, and a maximum speed of 3.0 ft/s (1.8 kts). Currents on September 20 were less swift, with average values of 0.7 and 0.8 ft/s. It should be noted that drifter tracks were not obtained during extreme storm events. Currents during such events are expected to be much higher than those noted herein.

Figure 4-9. GPS Drifter Tracks

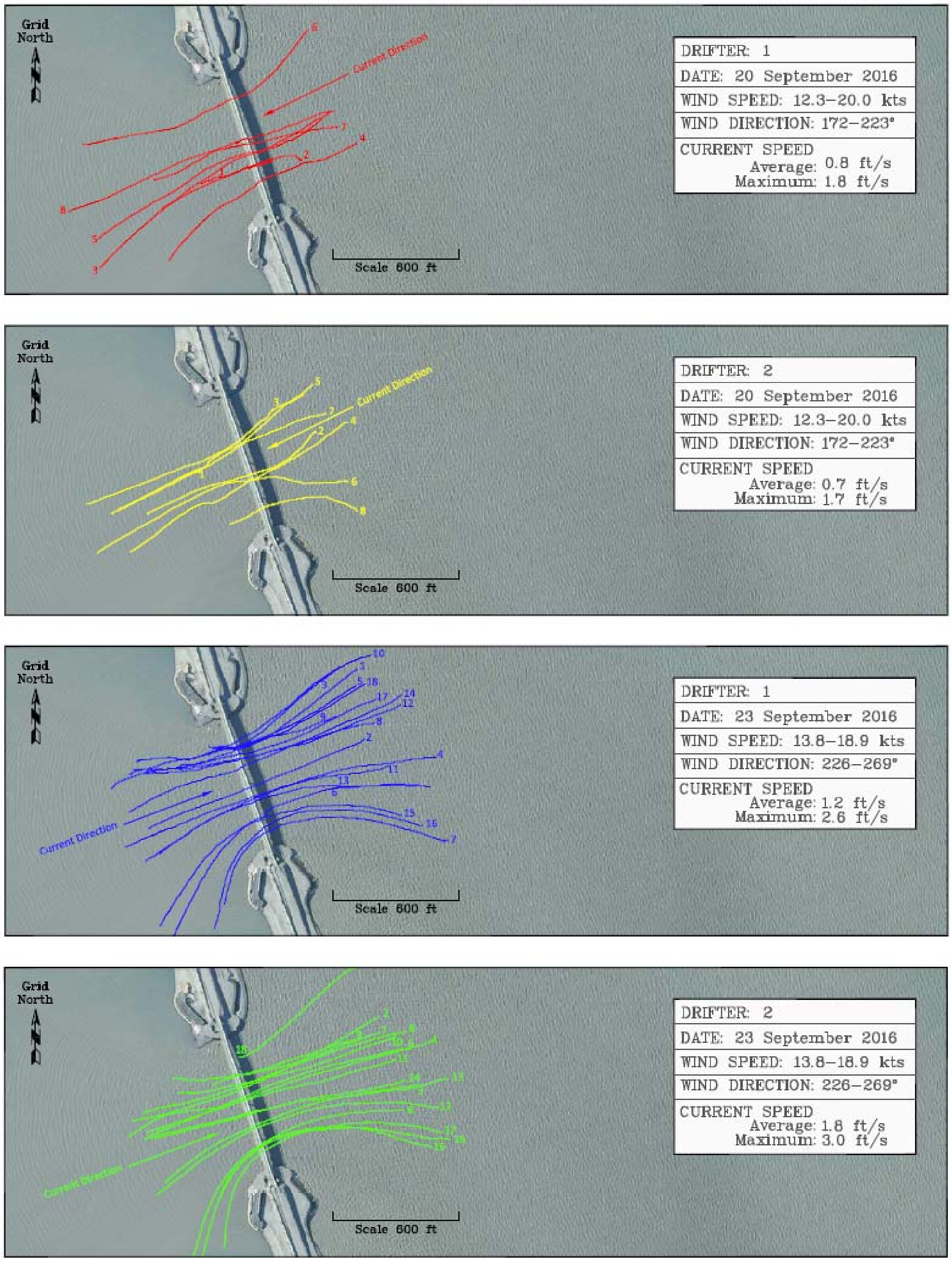
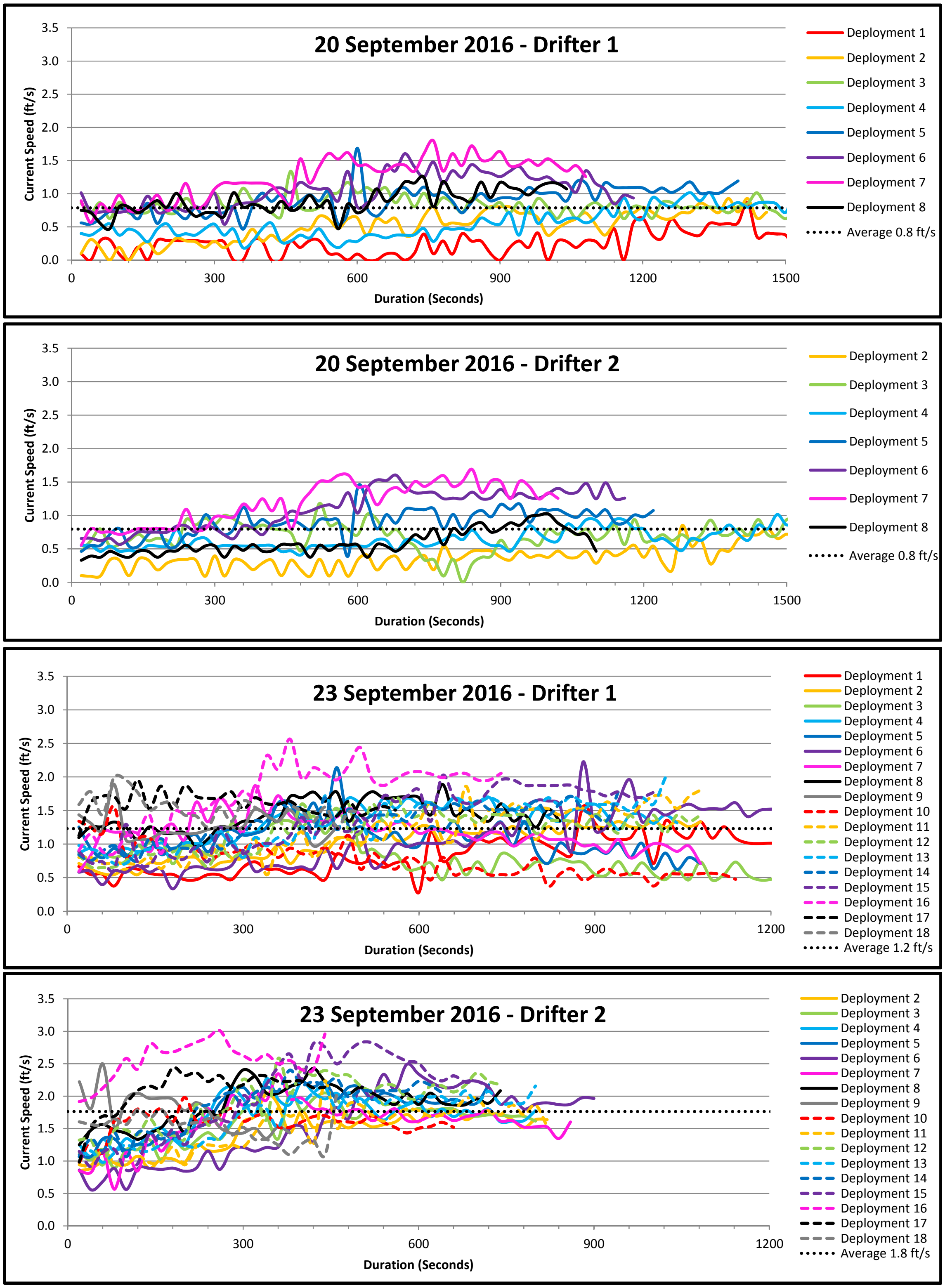


Figure 4-10. Estimated Drift Speeds



5.0 TURBIDITY DATA

Each of the moorings described in Section 4 was outfitted with a JFE Advantech Optical Backscatter Sensor (OBS). The OBS was used to measure the turbidity (in Formazin Turbidity Units, FTU) at a single point in the water column. The sensor was mounted approximately 12 inches above the seabed and horizontal-facing (Figure 4-2). One-minute average data were logged every 20 minutes for the duration of the deployment.

Figure 5-1 illustrates the turbidity data measured at each of the four moorings, along with the wind speed shown previously in Figure 3-2. The most turbid conditions occurred during the latter part of the summer, beginning around August 22. Turbidity levels at the 650-ft Breach (CF-01) site were generally lower than those measured at the three sites located further offshore. It should be noted that the OBS sensors at the Test Trench #2.5 (CF-03) and East-STP (CF-04) sites recorded turbidity values exceeding the reported limit of the instrument (1,000 FTU). These data, which accounted for only 0.4% of record, were purged as their validity was uncertain.

5.1 SUSPENDED SEDIMENT CONCENTRATION

Following recovery of the OBS sensors, the instruments were calibrated by CFC using sediment samples obtained near each site (Section 6.1.1). The methods used as part of the calibration were similar to those used as part of the 2015 calibration performed by Campbell Scientific. Each sensor was placed in water with known sediment concentration and the FTU value was recorded. Several concentrations were run and a curve was developed relating the FTU values and the suspended sediment concentration (SSC).

Figure 5-2 illustrates the SSC data measured at each of the four moorings, along with the wind speed. The data follow similar patterns to those identified in the turbidity data, with increases in SSC following significant wind events. The SSC values at the 650-ft Breach (CF-01) site are markedly lower than the other three locations. Relatively high levels of SSC persisted at the remaining three sites during the latter part of the 2016 summer wave season. This period coincides with the presence of swell events noted previously in Section 4.4.1.

Figure 5-1. Turbidity Time Series (FTU)

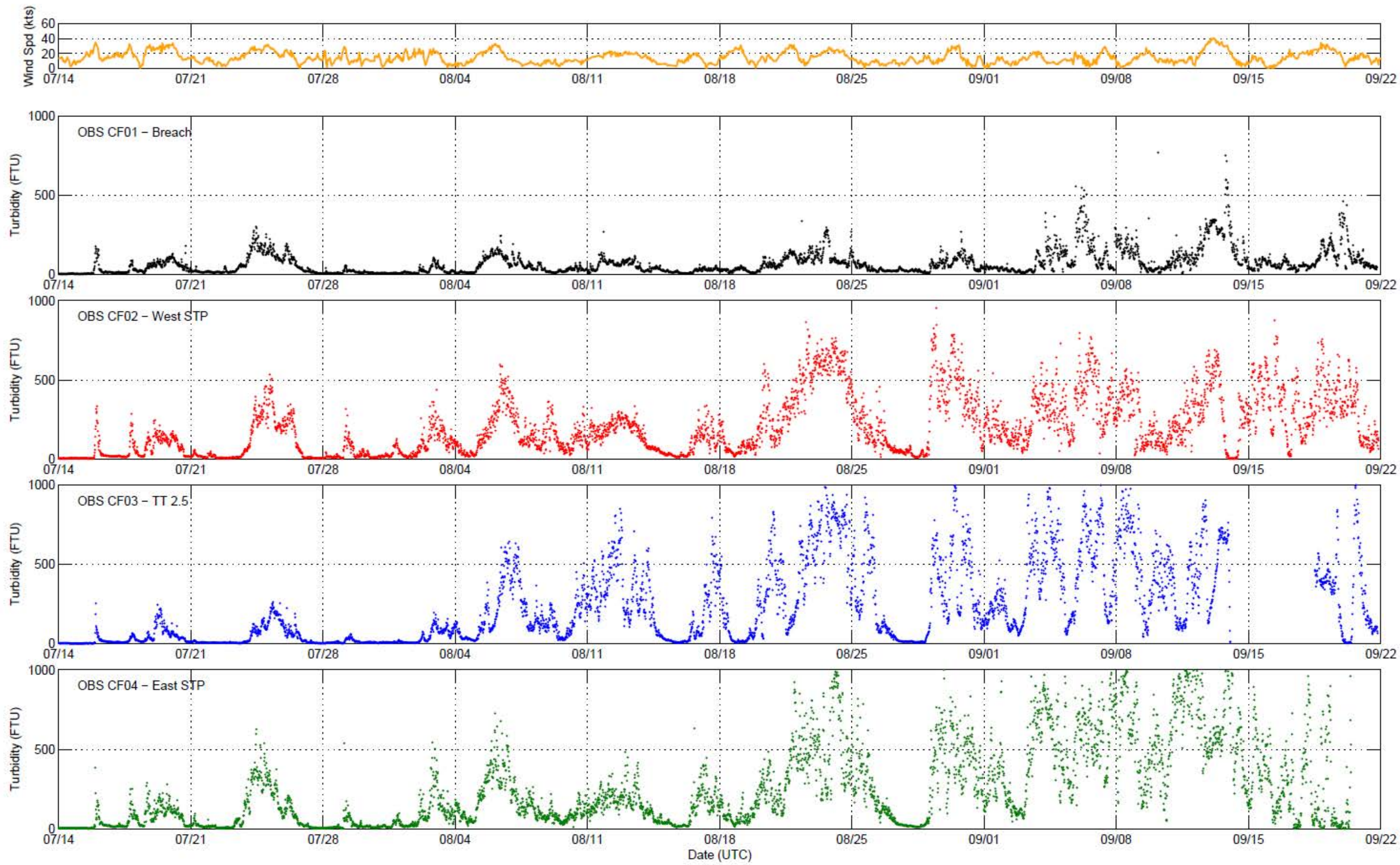
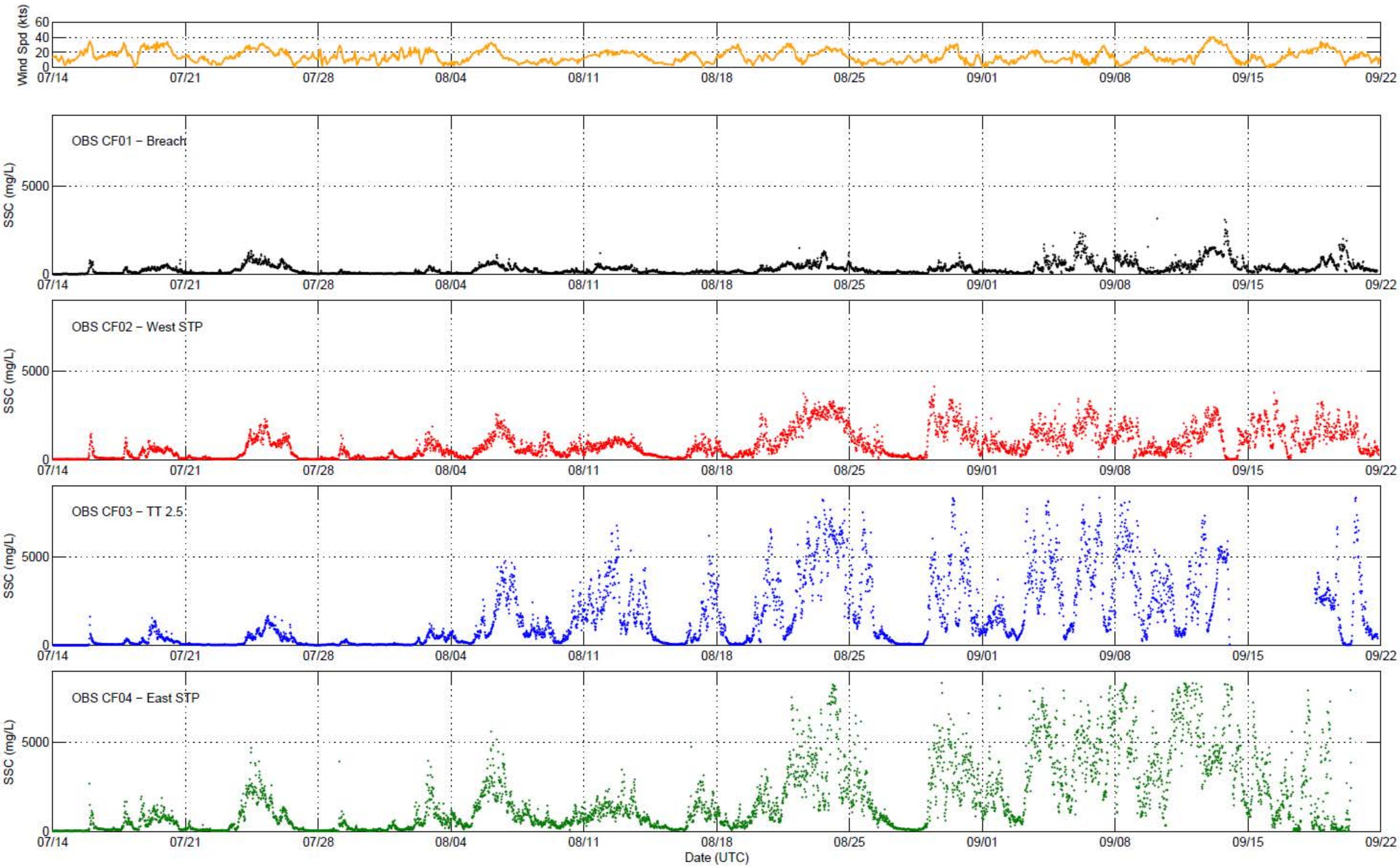


Figure 5-2. Suspended Sediment Concentration Time Series (mg/L)



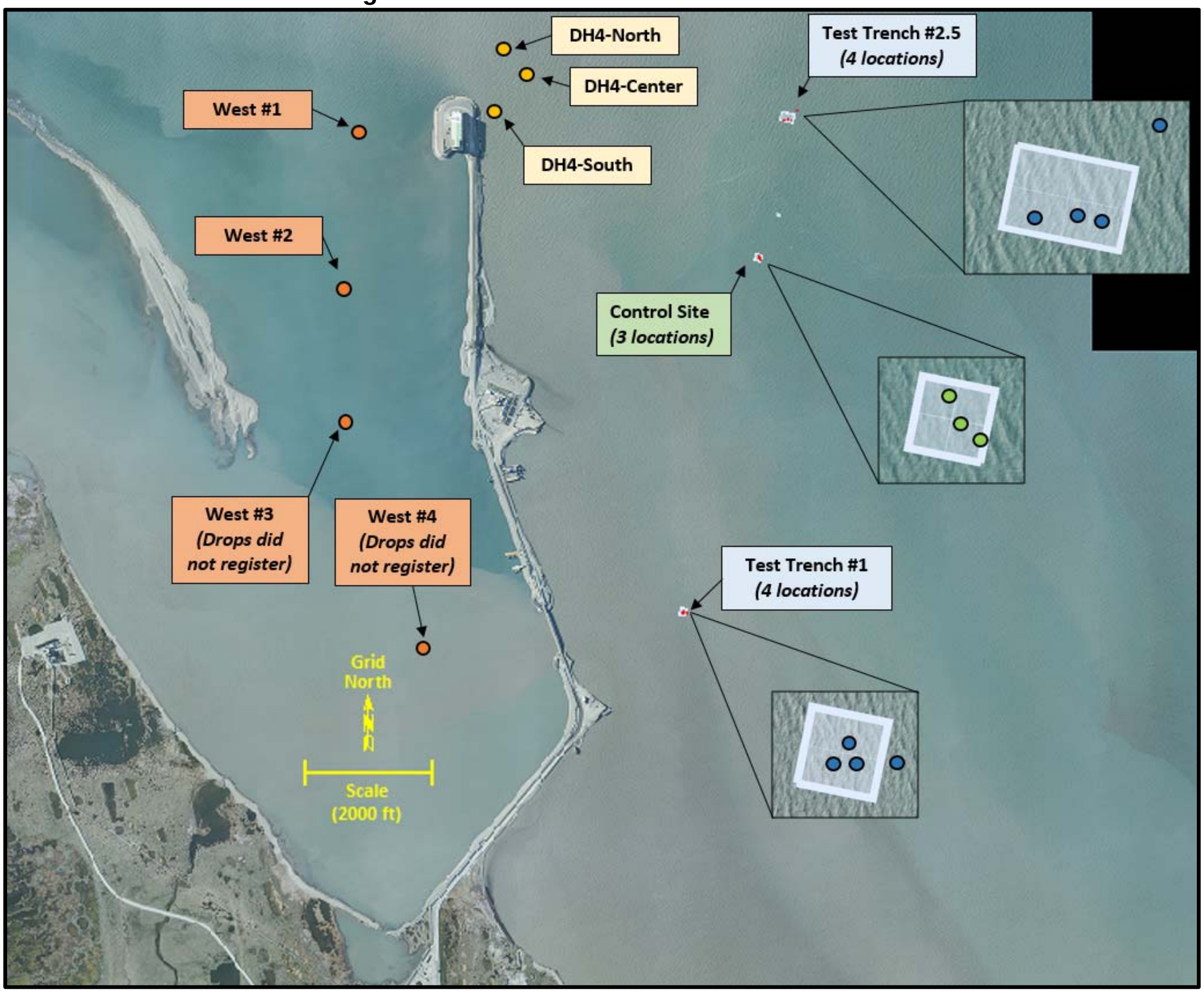
6.0 SEDIMENT DATA

The results of the 2015 Field Program suggest that a portion of the infilled material at each Test Trench Site contains a fluid-mud layer. As part of the 2016 Field Program, qualitative and quantitative data characterizing the sediment within each trench site, and at other locations of interest, were obtained to support infill assessments and maintenance dredging feasibility studies.

6.1 DATA COLLECTION

Data were obtained in five general areas, with multiple sampling locations in each area (total of 18 individual sampling locations). Each sampling location is illustrated in Figure 6-1 and is described below.

Figure 6-1. Sediment Data Collection Sites



- Test Trench Site #1
    - 4 sampling locations
    - Obtained to characterize infilled material properties
- Test Trench Site #2.5
    - 4 sampling locations
    - Obtained to characterize infilled material properties
- Test Trench Control Site
    - 3 sampling locations
    - Obtained to characterize seabed material on east side of causeway
- Dockhead 4 Site
    - 3 sampling locations
    - Obtained to characterize seabed material near STP
- West-Side of the Causeway
    - 4 sampling locations
    - Obtained to characterize seabed material on west side of causeway

As shown in Figure 6-1, four samples were obtained at each test trench site. Three of the samples were located within the trench, and one was located on the ambient seabed adjacent to the site. The intent was to provide some relative difference between the infilled material properties and those nearby the trench.

Both quantitative and qualitative data were obtained at each site. Quantitative data included a surficial sediment sample and estimates of the mud thickness obtained via a rheological profiling system (Graviprobe). Qualitative data were obtained by estimating the thickness of the mud layer via manual probe along with the relative stiffness of the seabed. Additional details regarding each data set are provided in the sections that follow.

The work was conducted from the *R/V Ukpik* on August 2 and 3. The crew included the vessel skipper, PSO (provided by exp), AK LNG GTP Field Lead (Jayce Locke), and two CFC personnel. At each site, the vessel was anchored to provide a stable work platform (2-point anchor required in most locations). The measurements described below were obtained from the stern of the vessel along with the location and prevailing water depth.

6.1.1 Sediment Samples

Surficial sediment samples were obtained at each of the 18 sites shown in Figure 6-1 using a Petite Ponar grab sampler (Figure 6-2). The number of drops required to collect each sample was recorded, as an indication of the relative stiffness of the seabed material. Photos of each sample (e.g. Figure 6-3) were obtained by the AK LNG GTP Field Lead and the samples were bagged and labeled for subsequent laboratory analyses (by others). All sample photos will be provided in a separate appendix.

Figure 6-2. Petite Ponar Grab Sampler

Figure 6-3. Representative Sediment Sample taken from Test Trench Site #2.5

6.1.2 Mud Thickness

Estimates of the mud thickness (fluid and consolidated) were obtained at each site using a dotOcean Graviprobe (Figure 6-4).

Figure 6-4. dotOcean Graviprobe

The Graviprobe is a free-fall device which is deployed by hand from the stern of the vessel. The unit contains high-precision accelerometers, inclinometers, and pressure sensors which are used to determine the dynamic cone penetration resistance and dynamic undrained shear strength of the mud layers as it penetrates the bottom. Three to five measurements, or "drops", were obtained at each sampling site. It should be noted that the Graviprobe data were discarded at the West #3 and West #4 sites due to the shallow water depths encountered.

6.1.3 Manual Probe

Qualitative estimates of the seabed stiffness and thickness of the mud layer were obtained using an aluminum rod, graduated in feet, with a 2-inch flange on the base. The rod was lowered until the approximate seabed surface was identified. Once this location was reached, the approximate depth was noted and the rod was pressed into the seabed until refusal. The depth of penetration was recorded along with qualitative comments regarding the stiffness of the seabed.

The same CFC Field Engineer conducted all 18 measurements so that the results can be directly compared. However, due to the subjective nature of the methods utilized, the data are intended only to provide relative comparisons at each site.

6.2 Data Reduction

Following demobilization from the field, the sample time, location, and prevailing water depth were tabulated along with the manual probe depth and applicable field notes.

Each of the 18 sediment samples was decanted and a subset sent to an outside laboratory for analysis. All 18 samples were tested for grain size (with hydrometer). Eight of the 18 samples also were tested for Atterberg Limits (ASTM D4318). All analyses were performed using applicable

ASTM, EPA, or API methodologies by PTS Laboratories on behalf of American Environmental Testing Laboratory (AETL).

The Graviprobe data were provided to dotOcean (equipment manufacturer) for post-processing. Processed data files returned to CFC included profiles of the dynamic undrained shear strength, cone penetration resistance and mud thickness for each sample. The term “mud thickness” is utilized herein, as the value can include some penetration into the consolidated mud layer, in addition to any fluid mud layer present at the site.

6.3 RESULTS

Summary data from each sample are provided in Table 6-1. Detailed results for each of the laboratory tests are provided in Appendix B. Salient observations are provided below.

6.3.1 Grain Size

As was noted in 2015, the material obtained at each of the test trench sites was very fine (silt), with an average median grain size of 0.015 mm and 0.009 mm in Sites #1 and #2.5, respectively. More than 90% of the sample passed the #200 Sieve at all but one of the six sites in the trenches. The material adjacent to each test trench site was coarser than that in the pit, but still quite fine (more than 50% pass 200 Sieve).

The material sampled near the STP (DH4 and West-1) and the 650-ft Breach (West-4) also was fine (silt), with median grain sizes ranging from 0.007 mm to 0.014 mm. The coarsest material sampled was located at the Control Site (median grain size = 0.088 mm, fine sand).

6.3.2 Manual Probe and Mud Thickness

As expected based on the sediment sample data obtained in 2015 and 2016, the material in each Test Trench was very soft. The average penetration distance (manual probe) at Sites #1 and #2.5 was 1.6 and 2.6 ft, respectively. By comparison, no penetration was observed on the ambient seabed immediately adjacent to the trenches.

Soft material, albeit not as soft as that observed in the Test Trenches, was identified on both the east and west sides of the STP. Penetration distances at these locations ranged between 0.3 and 0.8 ft. South of the STP on the west side of the causeway, the material was more firm (penetration distances of 0.1 ft or less). As expected, the most firm material was found at the Control Site on the east side of the causeway.

The Graviprobe data followed the trends identified above using the manual probe. The measured mud thickness at Test Trench Site #1 ranged between 2.1 and 2.6 ft. Similar values were observed at Site #2.5, ranging between 2.4 and 3.0 ft. At both sites the mud thickness on the ambient seabed next to the site was much lower (0.6 – 0.7 ft) and was similar to that observed at the Control Site (0.3 – 0.4 ft).

The fact that the values obtained using the manual probe are less than those obtained using the Graviprobe is not surprising, given the following:

1. The Graviprobe is able to more accurately identify the start of the fluid mud layer.
2. The Graviprobe typically penetrates some distance into the consolidated mud layer.

It is important to note that the relative difference between the values obtained in the Test Trenches and those obtained on the ambient seabed was similar for both systems (manual probe and Graviprobe). The average difference at Site #1 was 1.6 ft in both cases. At Site #2.5, the average difference was 2.2 ft using the Graviprobe and 2.6 ft using the manual probe.

Table 6-1. Sediment Data Summary

Site		Site Data[1]										Sediment Sample										Mud Thickness[3]				Manual Probe			
		Date	Time	Raw Depth	Tide	Corrected Depth	Easting	Northing	Conditions: Wind Spd.	Conditions: Wave Ht.	Time	Sample Designation	d50	Pass 200 Sieve	Classification[2]	Atterberg Limit: Liquid Lim.	Atterberg Limit: Plastic Lim.	Atterberg Limit: Plasticity Index	Atterberg Limit: Plasticity Symb.	No. Drops Req.	Time	No. Drops	Average	Notes	Time	Push Depth into Seabed	Material Type	Notes
		[GMT]	[GMT]	[ft, Amb.]	[ft, MLLW]	[ft, MLLW]	[US Ft]	[US Ft]	[kts]	[ft, est.]	[GMT]	[-]	[mm]	[%]	[-]	[-]	[-]	[-]	[-]	[-]	[GMT]	[-]	[ft]	[-]	[GMT]	[ft]	[-]	[-]
Test Trench Site #1	NW Quadrant	August 2, 2016	21:52	12.9	2.6	10.3	1,824,358	5,994,758	20-25 kts W	3 ft Chop	21:39	TT1-NW	0.017	90.8%	Silt	42.4	27.8	14.6	ML	1	21:52	3	2.6		21:43	1.5	Soft	
	SW Quadrant	August 3, 2016	0:14	12.7	2.2	10.5	1,824,338	5,994,732			0:03	TT1-SW	0.012	91.3%	Silt	-	-	-	-	1	0:14	3	2.1		0:10	1.8	Soft	Values from 1.5-2.0 ft
	SE Quadrant	August 2, 2016	23:08	12.5	2.4	10.1	1,824,364	5,994,731			22:58	TT1-SE	0.015	91.6%	Silt	-	-	-	-	1	23:08	3	2.3		23:06	1.5	Soft	
	Flat Portion Outside of Pit	August 2, 2016	22:26	8.3	2.5	5.8	1,824,418	5,994,734			22:09	TT1-Flat	0.070	51.8%	Silt	33.5	non plastic	non plastic	NP	4	22:26	3	0.7		22:24	0.0	Firm	
Test Trench Site #2.5	SW Quadrant	August 3, 2016	16:59	14.5	1.3	13.2	1,825,937	6,002,509	0-10 kts N	1-2 ft	16:48	TT2-SW	0.013	77.4%	Silt	-	-	-	-	1	16:59	3	2.4		16:57	2.5	Soft	Values from 2.0 - 3.0
	SE Quadrant	August 3, 2016	17:26	14.8	1.3	13.5	1,826,048	6,002,505			17:19	TT2-SE	0.007	92.1%	Silt	-	-	-	-	-	17:26	3	3.0		17:23	2.5	Soft	
	Center of Pit	August 3, 2016	18:00	14.9	1.4	13.5	1,826,010	6,002,513			17:49	TT2-Center	0.007	91.3%	Silt	53.6	26.0	27.6	CH	-	18:00	5	3.0		17:58	2.8	Soft	
	Flat Portion Outside of Pit	August 3, 2016	18:24	12.1	1.4	10.7	1,826,146	6,002,660			18:17	TT2-Flat	0.014	66.3%	Silt	34.4	20.9	13.5	CL	2	18:24	5	0.6		18:23	0.0	Firm	Values less than 0.1
Dockhead 4	South End of Proposed Site	August 3, 2016	19:00	12.1	1.5	10.6	1,821,364	6,002,642	0-10 kts N	1-2 ft	18:51	DH4-S	0.008	95.4%	Silt	-	-	-	-	2	19:00	5	1.3		18:58	0.4	Soft	Values from 0.3 - 0.5
	North End of Proposed Site	August 3, 2016	19:31	13.8	1.6	12.2	1,821,508	6,003,635			19:24	DH4-N	0.009	91.8%	Silt	-	-	-	-	3	19:31	5	1.5		19:30	0.8	Soft	
	Center of Proposed Site	August 3, 2016	19:57	13.0	1.6	11.4	1,821,865	6,003,234			19:50	DH4-Center	0.014	88.7%	Silt	43.4	25.8	17.6	CL	2	19:57	5	0.9		19:56	0.3	Soft	
West Side	Site 1, North End of Causeway	August 3, 2016	20:22	9.6	1.6	8.0	1,819,211	6,002,310	0-10 kts N	1 ft	20:17	West-1	0.007	93.0%	Silt	56.3	34.7	21.6	MH	1	20:22	3	1.1		20:26	0.4	Soft	Values from 0.3 - 0.5
	Site 2, Center of Offshore Leg	August 3, 2016	20:41	6.2	1.6	4.6	1,819,014	5,999,840			20:36	West-2	0.042	90.4%	Silt	-	-	-	-	4	20:41	2	0.4	1 Drop too Shallow	20:44	0.0	Firm	Values less than 0.1
	Site 3, Opposite PM2 Pad	August 3, 2016	20:59	5.6	1.6	4.0	1,819,011	5,997,743			20:55	West-3	0.029	83.4%	Silt	-	-	-	-	4	20:59	3	-	All Drops too Shallow	21:01	0.1	Firm	
	Site 4, Opposite Breach	August 3, 2016	21:20	5.3	1.6	3.7	1,820,252	5,994,144			21:16	West-4	0.013	81.4%	Silt	51.8	32.6	19.2	MH	1	21:20	3	-	All Drops too Shallow	21:19	0.1	Firm	
Control Site	SE Quadrant	August 3, 2016	22:37	8.8	1.6	7.2	1,825,575	6,000,310	0-10 kts N	1 -2 ft	22:30	Control-SE	0.090	28.2%	Fine Sand	-	-	-	-	5	22:37	4	0.3	1 Drop Eliminated as Outlier	22:35	0.0	Very Firm	Values less than 0.1
	NW Quadrant	August 3, 2016	22:59	8.7	1.5	7.2	1,825,535	6,000,370			22:52	Control-NW	0.092	24.2%	Fine Sand	-	-	-	-	5	22:59	5	0.4		22:58	0.0	Very Firm	Values less than 0.1
	Center	August 3, 2016	23:15	8.7	1.5	7.2	1,825,550	6,000,333			23:09	Control-Center	0.081	42.2%	Fine Sand	27.5	non plastic	non plastic	NP	4	23:15	5	0.4		23:14	0.0	Very Firm	Values less than 0.1

Notes:

1. "Site Data" taken from location of first GraviProbe Sample.
2. Classification based on ASTM-USCS Scale (task median).
3. "Mud Thickness" defined as the distance from the top of the fluid mud layer to the point at which the sensor met refusal. Value can include some distance into consolidated mud layers.
4. Atterberg Limits for Fine Fraction < No. 40 Sieve.
5. See PDF "AKLNG 2016 Sieve Analysis.pdf" for detailed sieve data.

7.0 REFERENCES

AK LNG Project, 2015, Results of Test Trench Field Study to Support Winter Navigation Channel Construction, Doc. No. USAI-UR-SRZZZ-00-000052-000.

AK LNG Project, 2016, Data Report, 2014 Summer Bathymetric Survey Program, Doc. No. USAG-EC-SRZZZ-00-000007-000.

AK LNG Project, 2016, Data Report, West Dock Summer 2015 Field Program, Doc. No. USAG-EC-JRZZZ-00-000002-000.

AK LNG Project, 2016, West Dock Sedimentation Modeling, Doc. No. USAG-EC-JRZZZ-00-000001-000

NGS, 2016, Horizontal Time-Dependent Positioning, *http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml*

NOAA, 2016, Meteorological Data at Prudhoe Bay Station ID 9497645, *https://tidesandcurrents.noaa.gov/*.

NOAA, 2016, Magnetic Declination Estimated Value, *http://www.ngdc.noaa.gov/geomag-web/#declination*

U.S. National Ice Center (NIC), 2016, *http://www.natice.noaa.gov.*

8.0 APPENDIX A – SUMMER 2016 BATHYMETRIC SURVEY DRAWINGS

The drawings listed below are provided in the attached PDF, *Alaska LNG 2016 Bathymetric Survey Drawings.pdf*.

				Final Rev.	
Number	Title		Sheets	No.	Date
CFC-972-01-001	Drawing Index Map		1	0	21-Nov
CFC-972-01-002	West Dock Causeway Bathymetry Overview		1	0	21-Nov
CFC-972-10-001	Test Trench Site 1	July 2016 Survey	1	1	21-Nov
CFC-972-10-002	Test Trench Site 1	Net Change, September 2015 to July 2016	1	1	21-Nov
CFC-972-10-003	Test Trench Site 1	September 2016 Survey	1	1	21-Nov
CFC-972-10-004	Test Trench Site 1	Net Change, July 2016 to September 2016	1	1	21-Nov
CFC-972-10-005	Test Trench Site 1	Bathymetric Profiles	1	1	21-Nov
CFC-972-20-001	Test Trench Site 2.5	July 2016 Survey	1	1	21-Nov
CFC-972-20-002	Test Trench Site 2.5	Net Change, September 2015 to July 2016	1	1	21-Nov
CFC-972-20-003	Test Trench Site 2.5	September 2016 Survey	1	1	21-Nov
CFC-972-20-004	Test Trench Site 2.5	Net Change, July 2016 to September 2016	1	1	21-Nov
CFC-972-20-005	Test Trench Site 2.5	Bathymetric Profiles	1	1	21-Nov
CFC-972-30-001	650-Ft Breach	July 2016 Survey	1	0	21-Nov
CFC-972-30-002	650-Ft Breach	September 2016 Survey	1	0	21-Nov
CFC-972-30-003	650-Ft Breach	Net Change, July 2016 to September 2016	1	0	21-Nov
CFC-972-30-004	650-Ft Breach	Bathymetric Profiles	2	0	21-Nov
CFC-972-40-001	STP and Offshore Stump Island	July 2016 Survey	1	0	21-Nov
CFC-972-40-002	STP	Detailed Bathymetry	1	0	21-Nov
CFC-972-40-003	STP	Side-Scan Mosaic	1	0	21-Nov
CFC-972-50-001	West Side	July 2016 Survey	1	0	21-Nov
CFC-972-60-001	Dockhead 2	July 2016 Survey	1	0	21-Nov
CFC-972-60-002	Dockhead 3	July 2016 Survey	1	0	21-Nov
CFC-972-70-001	East Side	July 2016 Survey	1	0	21-Nov

9.0 APPENDIX B – SEDIMENT SIEVE ANALYSIS

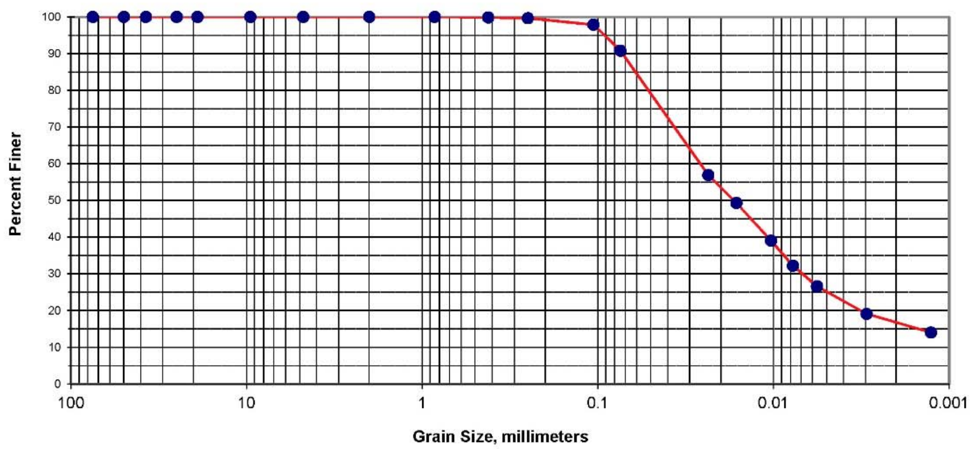
Sample TT1-NW

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client: American Environmental Testing Laboratory
Project: N/A
Project No: 84201
PTS File No: 46488
Sample ID: 84201.01A
Depth, ft: N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.2	99.7	0.3
0.0042	0.106	3.24	140	1.8	97.9	2.1
0.0029	0.074	3.75	200	7.1	90.8	9.2
0.0009	0.024	5.41	Hydrometer	33.9	56.9	43.1
0.00064	0.016	5.94	Hydrometer	7.6	49.3	50.7
0.00041	0.010	6.60	Hydrometer	10.2	39.1	60.9
0.00031	0.0078	7.01	Hydrometer	6.9	32.2	67.8
0.00022	0.0057	7.46	Hydrometer	5.5	26.6	73.4
0.00012	0.0029	8.41	Hydrometer	7.6	19.1	80.9
0.00005	0.0013	9.62	Hydrometer	5.0	14.0	86.0
			"PAN"	14.0		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.45	0.0036	0.092
10	3.79	0.0028	0.072
16	4.08	0.0023	0.059
25	4.52	0.0017	0.043
40	5.26	0.0010	0.026
50	5.90	0.0007	0.017
60	6.54	0.0004	0.011
75	7.67	0.0002	0.005
84	9.15	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	5.90	5.90	5.90
Median, in.	0.0007	0.0007	0.0007
Median, mm	0.017	0.017	0.017
Mean, phi	5.37	6.61	6.38
Mean, in.	0.0010	0.0004	0.0005
Mean, mm	0.024	0.010	0.012
Sorting	2.972	2.532	
Skewness	0.871	0.284	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	9.1
Silt/Clay	<200	90.8
	Total	100

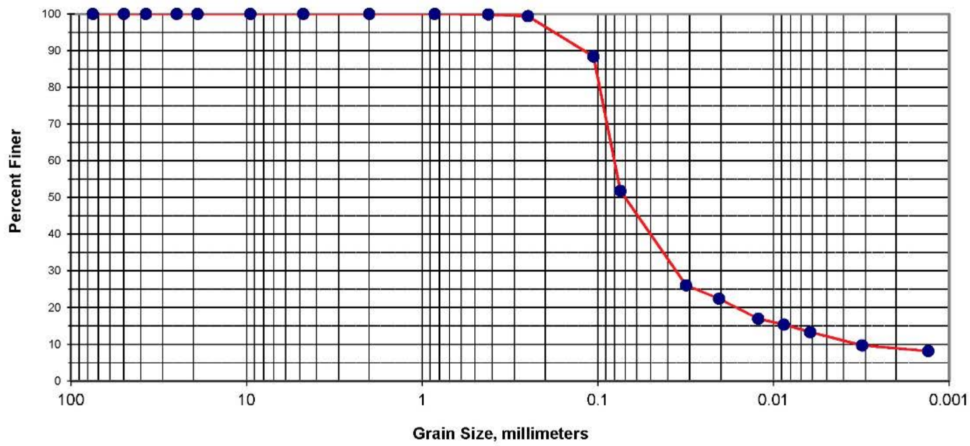
Phone: (562) 347-2500 Fax: (562) 907-3610

Sample TT1-Flat

PTS Laboratories, Inc. — **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.02A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.5	99.4	0.6
0.0042	0.106	3.24	140	11.0	88.4	11.6
0.0029	0.074	3.75	200	36.6	51.8	48.2
0.0012	0.032	4.99	Hydrometer	25.7	26.1	73.9
0.00080	0.020	5.61	Hydrometer	3.6	22.5	77.5
0.00048	0.012	6.35	Hydrometer	5.5	16.9	83.1
0.00034	0.0087	6.84	Hydrometer	1.5	15.4	84.6
0.00024	0.0062	7.33	Hydrometer	2.1	13.3	86.7
0.00012	0.0031	8.32	Hydrometer	3.6	9.7	90.3
0.00005	0.0013	9.57	Hydrometer	1.5	8.2	91.8
			"PAN"	8.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	2.50	0.0070	0.177
10	3.06	0.0047	0.120
16	3.30	0.0040	0.102
25	3.43	0.0037	0.093
40	3.64	0.0032	0.080
50	3.84	0.0028	0.070
60	4.32	0.0020	0.050
75	5.17	0.0011	0.028
84	6.65	0.0004	0.010
90	8.24	0.0001	0.003

Measure	Trask	Inman	Folk-Ward
Median, phi	3.84	3.84	3.84
Median, in.	0.0028	0.0028	0.0028
Median, mm	0.070	0.070	0.070
Mean, phi	4.05	4.97	4.59
Mean, in.	0.0024	0.0013	0.0016
Mean, mm	0.060	0.032	0.041
Sorting	1.832	1.673	
Skewness	0.726	0.679	
Kurtosis	0.280		

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	48.1
Silt/Clay	<200	51.8
	Total	100

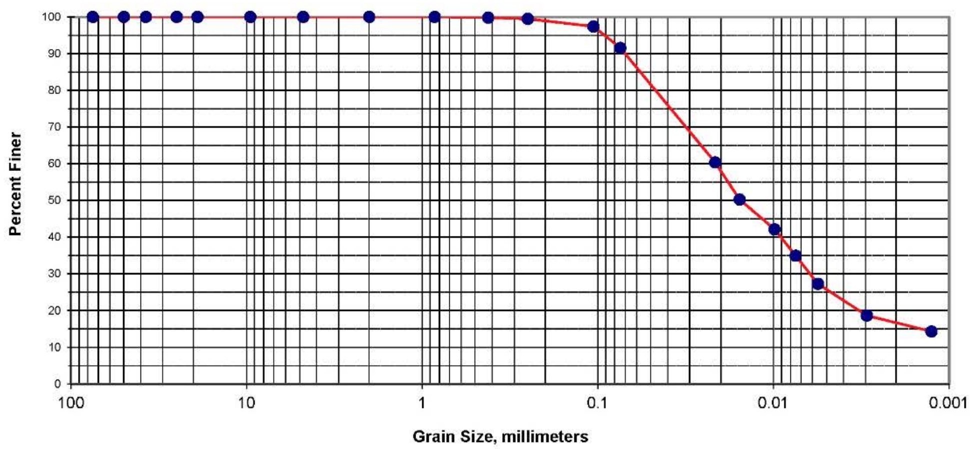
Phone: (562) 347-2500 Fax: (562) 907-3610

Sample TT1-SW

PTS Laboratories, Inc. — **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.03A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.2	99.8	0.2
0.0098	0.250	2.00	60	0.3	99.5	0.5
0.0042	0.106	3.24	140	2.1	97.5	2.5
0.0029	0.074	3.75	200	5.9	91.6	8.4
0.0008	0.021	5.54	Hydrometer	31.2	60.4	39.6
0.00062	0.016	6.00	Hydrometer	10.1	50.3	49.7
0.00039	0.010	6.66	Hydrometer	8.2	42.1	57.9
0.00029	0.0075	7.06	Hydrometer	7.2	34.9	65.1
0.00022	0.0056	7.48	Hydrometer	7.7	27.3	72.7
0.00012	0.0029	8.41	Hydrometer	8.6	18.6	81.4
0.00005	0.0013	9.63	Hydrometer	4.3	14.3	85.7
			"PAN"	14.3		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.45	0.0036	0.091
10	3.84	0.0027	0.070
16	4.19	0.0022	0.055
25	4.70	0.0015	0.038
40	5.56	0.0008	0.021
50	6.02	0.0006	0.015
60	6.78	0.0004	0.009
75	7.73	0.0002	0.005
84	9.15	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	6.02	6.02	6.02
Median, in.	0.0006	0.0006	0.0006
Median, mm	0.015	0.015	0.015
Mean, phi	5.53	6.67	6.45
Mean, in.	0.0008	0.0004	0.0004
Mean, mm	0.022	0.010	0.011
Sorting	2.853	2.483	
Skewness	0.876	0.260	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.2
Fine Sand	200	8.2
Silt/Clay	<200	91.6
	Total	100

Phone: (562) 347-2500 Fax: (562) 907-3610

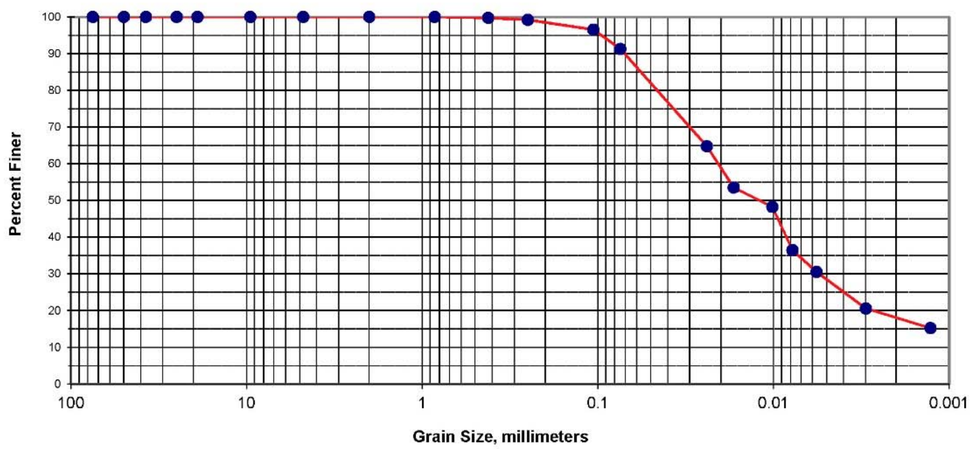
Sample TT1-SE

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.04A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.3	99.7	0.3
0.0098	0.250	2.00	60	0.5	99.2	0.8
0.0042	0.106	3.24	140	2.6	96.6	3.4
0.0029	0.074	3.75	200	5.3	91.3	8.7
0.0009	0.024	5.38	Hydrometer	26.5	64.8	35.2
0.00066	0.017	5.89	Hydrometer	11.2	53.6	46.4
0.00040	0.010	6.62	Hydrometer	5.3	48.2	51.8
0.00031	0.0078	7.00	Hydrometer	11.8	36.5	63.5
0.00022	0.0057	7.46	Hydrometer	5.9	30.6	69.4
0.00012	0.0030	8.39	Hydrometer	10.0	20.5	79.5
0.00005	0.0013	9.61	Hydrometer	5.3	15.2	84.8
			"PAN"	15.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.39	0.0038	0.095
10	3.83	0.0028	0.070
16	4.20	0.0021	0.054
25	4.75	0.0015	0.037
40	5.60	0.0008	0.021
50	6.38	0.0005	0.012
60	6.89	0.0003	0.008
75	7.98	0.0002	0.004
84	9.43	0.0001	0.001

Measure	Trask	Inman	Folk-Ward
Median, phi	6.38	6.38	6.38
Median, in.	0.0005	0.0005	0.0005
Median, mm	0.012	0.012	0.012
Mean, phi	5.61	6.82	6.67
Mean, in.	0.0008	0.0003	0.0004
Mean, mm	0.021	0.009	0.010
Sorting	3.055	2.618	
Skewness	1.012	0.167	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.3
Fine Sand	200	8.4
Silt/Clay	<200	91.3
	Total	100

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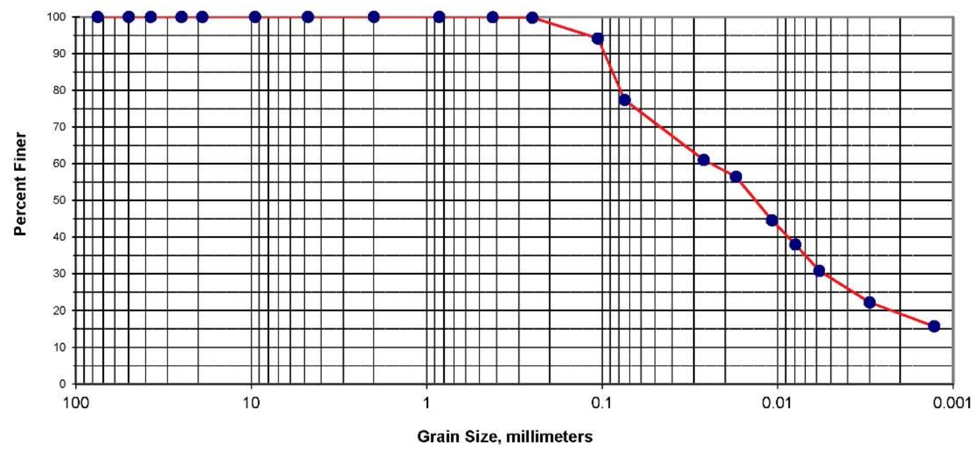
Sample TT2-SW

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.05A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.1	99.8	0.2
0.0042	0.106	3.24	140	5.6	94.2	5.8
0.0029	0.074	3.75	200	16.8	77.4	22.6
0.0010	0.026	5.24	Hydrometer	16.3	61.1	38.9
0.00068	0.017	5.86	Hydrometer	4.6	56.5	43.5
0.00042	0.011	6.53	Hydrometer	11.8	44.6	55.4
0.00031	0.0079	6.98	Hydrometer	6.6	38.0	62.0
0.00023	0.0058	7.43	Hydrometer	7.2	30.8	69.2
0.00012	0.0030	8.39	Hydrometer	8.6	22.2	77.8
0.00005	0.0013	9.61	Hydrometer	6.6	15.7	84.3
			"PAN"	15.7		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.06	0.0047	0.120
10	3.37	0.0038	0.097
16	3.55	0.0034	0.085
25	3.97	0.0025	0.064
40	5.39	0.0009	0.024
50	6.23	0.0005	0.013
60	6.85	0.0003	0.009
75	8.08	0.0001	0.004
84	9.54	0.0001	0.001

Measure	Trask	Inman	Folk-Ward
Median, phi	6.23	6.23	6.23
Median, in.	0.0005	0.0005	0.0005
Median, mm	0.013	0.013	0.013
Mean, phi	4.89	6.55	6.44
Mean, in.	0.0013	0.0004	0.0005
Mean, mm	0.034	0.011	0.012
Sorting	4.158	2.998	
Skewness	1.151	0.107	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	22.6
Silt/Clay	<200	77.4
	Total	100

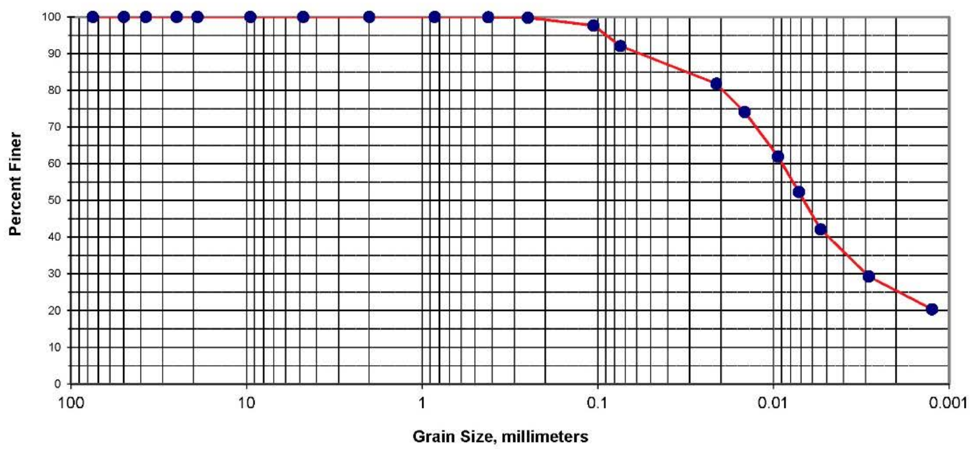
Phone: (562) 347-2500 Fax: (562) 907-3610

Sample TT2-SE

PTS Laboratories, Inc. — **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.06A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S.	Incremental		Cumulative
Inches	Millimeters	Screen	Sieve No.	Percent Finer	Percent Finer	Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.8	0.2
0.0042	0.106	3.24	140	2.2	97.7	2.3
0.0029	0.074	3.75	200	5.6	92.1	7.9
0.0008	0.021	5.56	Hydrometer	10.3	81.8	18.2
0.00057	0.015	6.10	Hydrometer	7.7	74.1	25.9
0.00037	0.009	6.73	Hydrometer	12.2	62.0	38.0
0.00028	0.0072	7.12	Hydrometer	9.6	52.4	47.6
0.00021	0.0054	7.53	Hydrometer	10.2	42.1	57.9
0.00011	0.0029	8.44	Hydrometer	12.8	29.3	70.7
0.00005	0.0013	9.64	Hydrometer	9.0	20.4	79.6
			"PAN"	20.4		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.48	0.0035	0.089
10	4.12	0.0023	0.058
16	5.18	0.0011	0.028
25	6.04	0.0006	0.015
40	6.81	0.0004	0.009
50	7.22	0.0003	0.007
60	7.69	0.0002	0.005
75	9.02	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	7.22	7.22	7.22
Median, in.	0.0003	0.0003	0.0003
Median, mm	0.007	0.007	0.007
Mean, phi	6.87		
Mean, in.	0.0003		
Mean, mm	0.009		
Sorting	2.812		
Skewness	0.805		
Kurtosis			
Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)		

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	7.9
Silt/Clay	<200	92.1
	Total	100

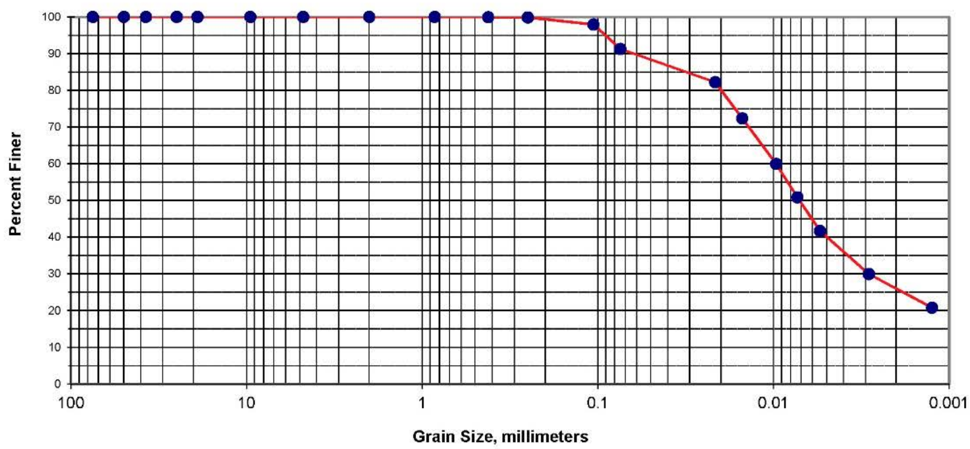
Phone: (562) 347-2500 Fax: (562) 907-3610

Sample TT2-Center

PTS Laboratories, Inc. — **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.07A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.9	0.1
0.0042	0.106	3.24	140	1.9	98.0	2.0
0.0029	0.074	3.75	200	6.7	91.3	8.7
0.0008	0.021	5.54	Hydrometer	9.1	82.2	17.8
0.00059	0.015	6.05	Hydrometer	9.8	72.4	27.6
0.00038	0.010	6.69	Hydrometer	12.4	60.0	40.0
0.00029	0.0073	7.10	Hydrometer	9.1	50.8	49.2
0.00021	0.0054	7.52	Hydrometer	9.1	41.7	58.3
0.00011	0.0029	8.44	Hydrometer	11.8	29.9	70.1
0.00005	0.0013	9.64	Hydrometer	9.1	20.8	79.2
			"PAN"	20.8		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	3.47	0.0036	0.090
10	4.01	0.0024	0.062
16	5.19	0.0011	0.027
25	5.92	0.0007	0.017
40	6.69	0.0004	0.010
50	7.13	0.0003	0.007
60	7.66	0.0002	0.005
75	9.09	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	7.13	7.13	7.13
Median, in.	0.0003	0.0003	0.0003
Median, mm	0.007	0.007	0.007
Mean, phi	6.77		
Mean, in.	0.0004		
Mean, mm	0.009		
Sorting	3.002		
Skewness	0.774		
Kurtosis			
Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)		

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	8.6
Silt/Clay	<200	91.3
	Total	100

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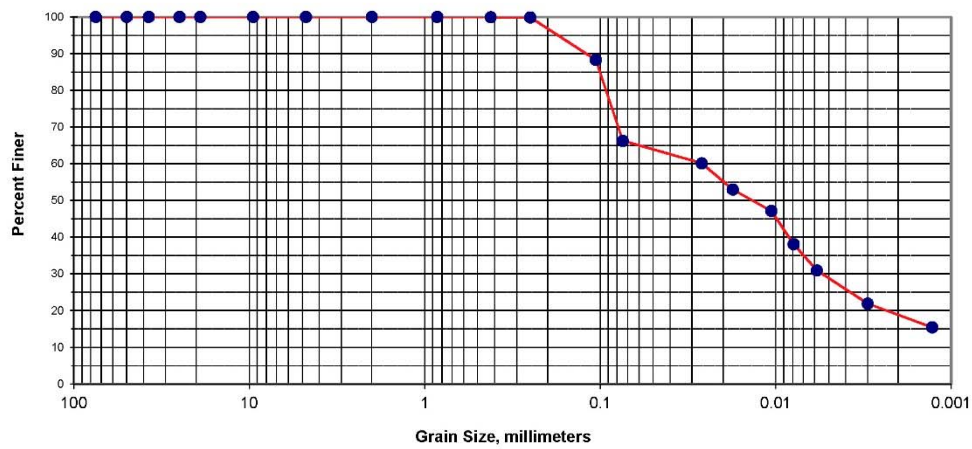
Sample TT2-Flat

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.08A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.9	0.1
0.0042	0.106	3.24	140	11.6	88.3	11.7
0.0029	0.074	3.75	200	22.0	66.3	33.7
0.0010	0.026	5.24	Hydrometer	6.2	60.1	39.9
0.00069	0.018	5.83	Hydrometer	7.1	53.0	47.0
0.00042	0.011	6.56	Hydrometer	5.8	47.1	52.9
0.00031	0.0079	6.98	Hydrometer	9.1	38.1	61.9
0.00023	0.0058	7.43	Hydrometer	7.1	31.0	69.0
0.00012	0.0030	8.39	Hydrometer	9.1	21.9	78.1
0.00005	0.0013	9.61	Hydrometer	6.5	15.4	84.6
			"PAN"	15.4		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	2.52	0.0069	0.174
10	3.06	0.0047	0.120
16	3.34	0.0039	0.099
25	3.55	0.0034	0.086
40	5.25	0.0010	0.026
50	6.20	0.0005	0.014
60	6.89	0.0003	0.008
75	8.06	0.0001	0.004
84	9.50	0.0001	0.001

Measure	Trask	Inman	Folk-Ward
Median, phi	6.20	6.20	6.20
Median, in.	0.0005	0.0005	0.0005
Median, mm	0.014	0.014	0.014
Mean, phi	4.48	6.42	6.35
Mean, in.	0.0018	0.0005	0.0005
Mean, mm	0.045	0.012	0.012
Sorting	4.774	3.079	
Skewness	1.322	0.069	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	33.7
Silt/Clay	<200	66.3
	Total	100

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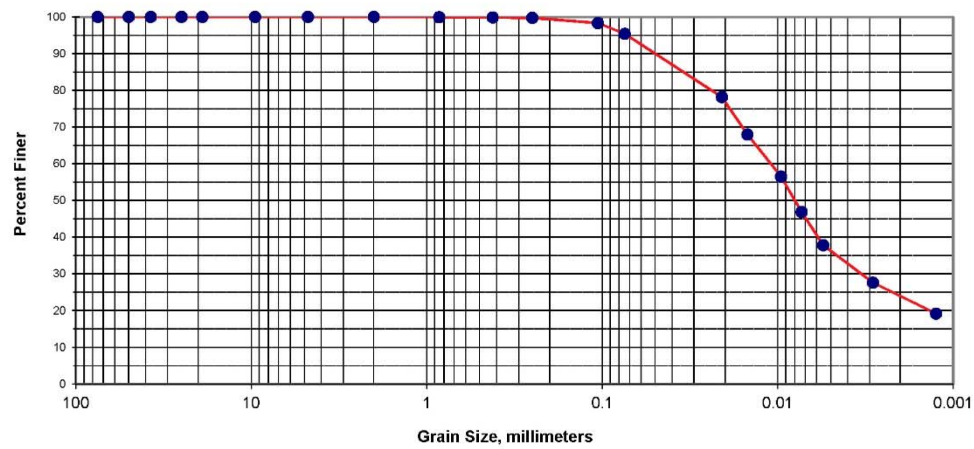
Sample DH4-S

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.09A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.1	99.8	0.2
0.0042	0.106	3.24	140	1.4	98.4	1.6
0.0029	0.074	3.75	200	3.0	95.4	4.6
0.0008	0.021	5.59	Hydrometer	17.2	78.2	21.8
0.00059	0.015	6.07	Hydrometer	10.2	68.0	32.0
0.00038	0.010	6.71	Hydrometer	11.4	56.5	43.5
0.00029	0.0073	7.10	Hydrometer	9.6	46.9	53.1
0.00022	0.0055	7.51	Hydrometer	9.0	37.8	62.2
0.00011	0.0029	8.44	Hydrometer	10.2	27.6	72.4
0.00005	0.0013	9.64	Hydrometer	8.4	19.2	80.8
			"PAN"	19.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.79	0.0028	0.072
10	4.33	0.0020	0.050
16	4.97	0.0013	0.032
25	5.74	0.0007	0.019
40	6.51	0.0004	0.011
50	6.97	0.0003	0.008
60	7.41	0.0002	0.006
75	8.81	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	6.97	6.97	6.97
Median, in.	0.0003	0.0003	0.0003
Median, mm	0.008	0.008	0.008
Mean, phi	6.58		
Mean, in.	0.0004		
Mean, mm	0.010		
Sorting	2.902		
Skewness	0.809		
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	4.5
Silt/Clay	<200	95.4
	Total	100

 Phone: (562) 347-2500 Fax: (562) 907-3610

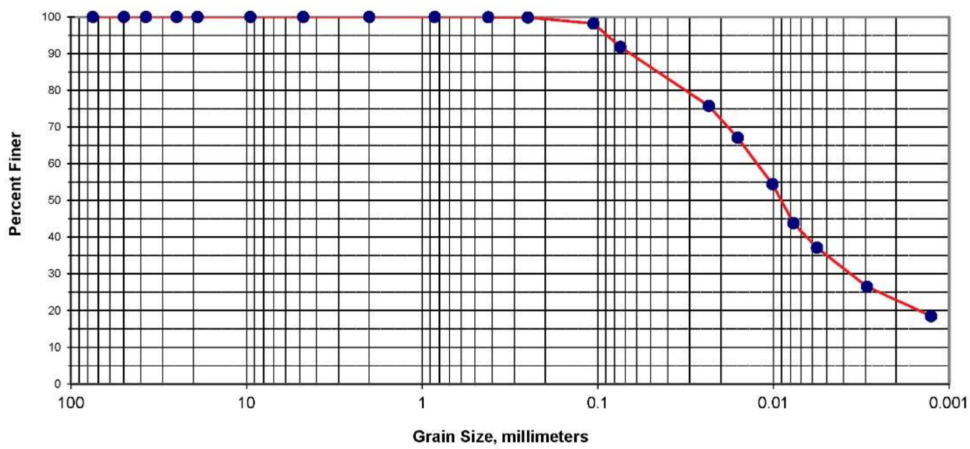
Sample DH4-N

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.10A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.9	0.1
0.0042	0.106	3.24	140	1.7	98.2	1.8
0.0029	0.074	3.75	200	6.4	91.8	8.2
0.0009	0.023	5.42	Hydrometer	16.1	75.8	24.2
0.00063	0.016	5.97	Hydrometer	8.7	67.1	32.9
0.00040	0.010	6.62	Hydrometer	12.7	54.5	45.5
0.00030	0.0077	7.02	Hydrometer	10.7	43.8	56.2
0.00022	0.0057	7.47	Hydrometer	6.7	37.2	62.8
0.00012	0.0029	8.42	Hydrometer	10.7	26.5	73.5
0.00005	0.0013	9.62	Hydrometer	8.0	18.5	81.5
			"PAN"	18.5		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	3.50	0.0035	0.089
10	3.94	0.0026	0.065
16	4.57	0.0017	0.042
25	5.47	0.0009	0.023
40	6.34	0.0005	0.012
50	6.79	0.0004	0.009
60	7.28	0.0003	0.006
75	8.64	0.0001	0.003

Measure	Trask	Inman	Folk-Ward
Median, phi	6.79	6.79	6.79
Median, in.	0.0004	0.0004	0.0004
Median, mm	0.009	0.009	0.009
Mean, phi	6.32		
Mean, in.	0.0005		
Mean, mm	0.013		
Sorting	3.004		
Skewness	0.831		
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	8.1
Silt/Clay	<200	91.8
	Total	100

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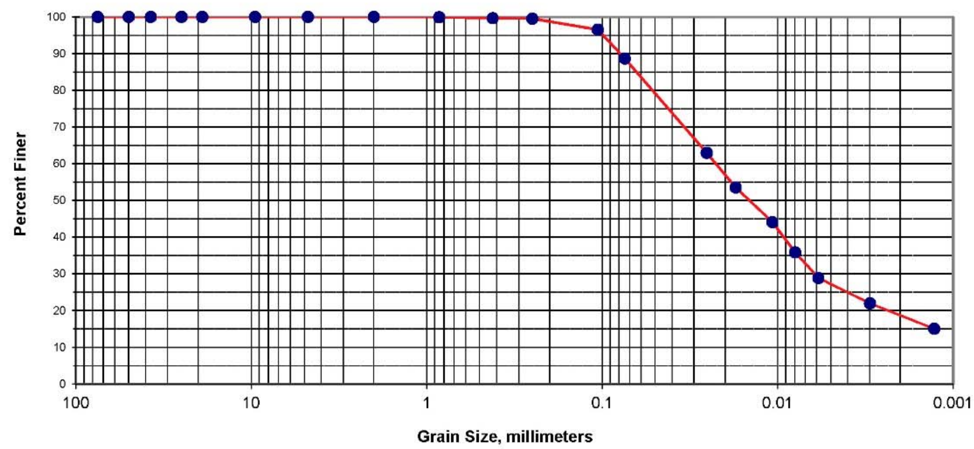
Sample DH4-Center

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.11A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.3	99.7	0.3
0.0098	0.250	2.00	60	0.1	99.5	0.5
0.0042	0.106	3.24	140	3.0	96.6	3.4
0.0029	0.074	3.75	200	7.9	88.7	11.3
0.0010	0.025	5.30	Hydrometer	25.7	63.0	37.0
0.00068	0.017	5.85	Hydrometer	9.5	53.5	46.5
0.00042	0.011	6.55	Hydrometer	9.5	44.1	55.9
0.00031	0.0080	6.97	Hydrometer	8.2	35.9	64.1
0.00023	0.0059	7.42	Hydrometer	6.9	28.9	71.1
0.00012	0.0030	8.39	Hydrometer	6.9	22.0	78.0
0.00005	0.0013	9.61	Hydrometer	6.9	15.0	85.0
			"PAN"	15.0		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.34	0.0039	0.099
10	3.67	0.0031	0.079
16	4.03	0.0024	0.061
25	4.58	0.0017	0.042
40	5.47	0.0009	0.023
50	6.11	0.0006	0.014
60	6.76	0.0004	0.009
75	7.97	0.0002	0.004
84	9.44	0.0001	0.001

Measure	Trask	Inman	Folk-Ward
Median, phi	6.11	6.11	6.11
Median, in.	0.0006	0.0006	0.0006
Median, mm	0.014	0.014	0.014
Mean, phi	5.44	6.73	6.53
Mean, in.	0.0009	0.0004	0.0004
Mean, mm	0.023	0.009	0.011
Sorting	3.238	2.701	
Skewness	0.894	0.231	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.3
Fine Sand	200	11.0
Silt/Clay	<200	88.7
	Total	100

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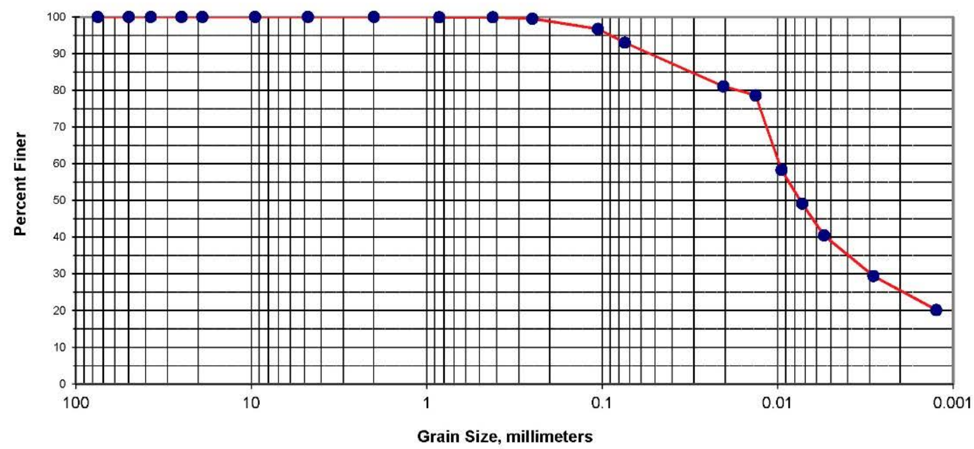
Sample West-1

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.12A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	99.9	0.1
0.0098	0.250	2.00	60	0.4	99.6	0.4
0.0042	0.106	3.24	140	2.8	96.7	3.3
0.0029	0.074	3.75	200	3.7	93.0	7.0
0.0008	0.020	5.61	Hydrometer	11.9	81.1	18.9
0.00053	0.013	6.22	Hydrometer	2.5	78.6	21.4
0.00038	0.010	6.71	Hydrometer	20.3	58.3	41.7
0.00029	0.0072	7.11	Hydrometer	9.2	49.1	50.9
0.00021	0.0054	7.52	Hydrometer	8.6	40.5	59.5
0.00011	0.0029	8.45	Hydrometer	11.1	29.4	70.6
0.00005	0.0012	9.65	Hydrometer	9.2	20.2	79.8
			"PAN"	20.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	3.48	0.0035	0.090
10	4.22	0.0021	0.054
16	5.16	0.0011	0.028
25	6.31	0.0005	0.013
40	6.67	0.0004	0.010
50	7.07	0.0003	0.007
60	7.56	0.0002	0.005
75	9.02	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	7.07	7.07	7.07
Median, in.	0.0003	0.0003	0.0003
Median, mm	0.007	0.007	0.007
Mean, phi	7.11		
Mean, in.	0.0003		
Mean, mm	0.007		
Sorting	2.560		
Skewness	0.660		
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	6.9
Silt/Clay	<200	93.0
	Total	100

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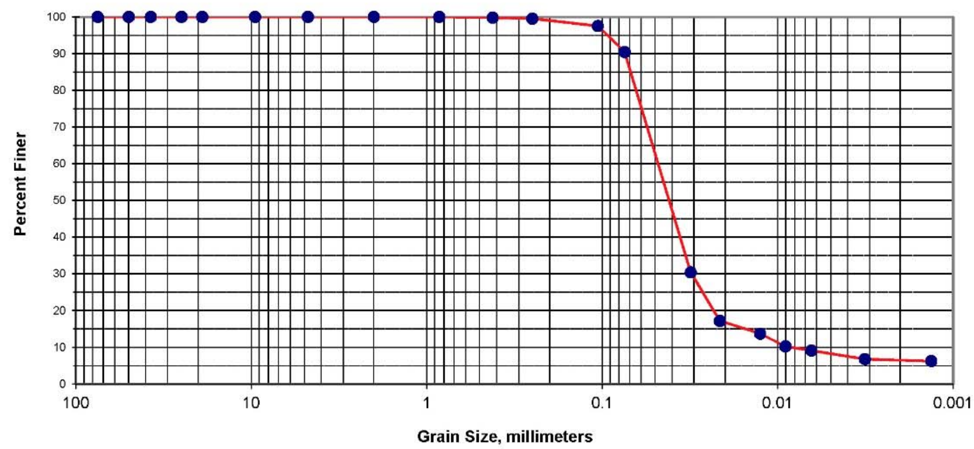
Sample West-2

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.13A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.3	99.6	0.4
0.0042	0.106	3.24	140	2.0	97.6	2.4
0.0029	0.074	3.75	200	7.1	90.4	9.6
0.0012	0.031	5.00	Hydrometer	60.0	30.4	69.6
0.00084	0.021	5.55	Hydrometer	13.2	17.2	82.8
0.00050	0.013	6.31	Hydrometer	3.5	13.7	86.3
0.00036	0.0091	6.79	Hydrometer	3.5	10.3	89.7
0.00025	0.0064	7.28	Hydrometer	1.2	9.1	90.9
0.00013	0.0032	8.29	Hydrometer	2.3	6.8	93.2
0.00005	0.0013	9.55	Hydrometer	0.6	6.2	93.8
			"PAN"	6.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	3.42	0.0037	0.093
10	3.76	0.0029	0.074
16	3.88	0.0027	0.068
25	4.07	0.0023	0.060
40	4.38	0.0019	0.048
50	4.59	0.0016	0.042
60	4.80	0.0014	0.036
75	5.22	0.0011	0.027
84	5.81	0.0007	0.018
90	6.90	0.0003	0.008

Measure	Trask	Inman	Folk-Ward
Median, phi	4.59	4.59	4.59
Median, in.	0.0016	0.0016	0.0016
Median, mm	0.042	0.042	0.042
Mean, phi	4.53	4.84	4.76
Mean, in.	0.0017	0.0014	0.0015
Mean, mm	0.043	0.035	0.037
Sorting	1.490	0.961	
Skewness	0.962	0.265	
Kurtosis	0.250		

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	9.4
Silt/Clay	<200	90.4
	Total	100

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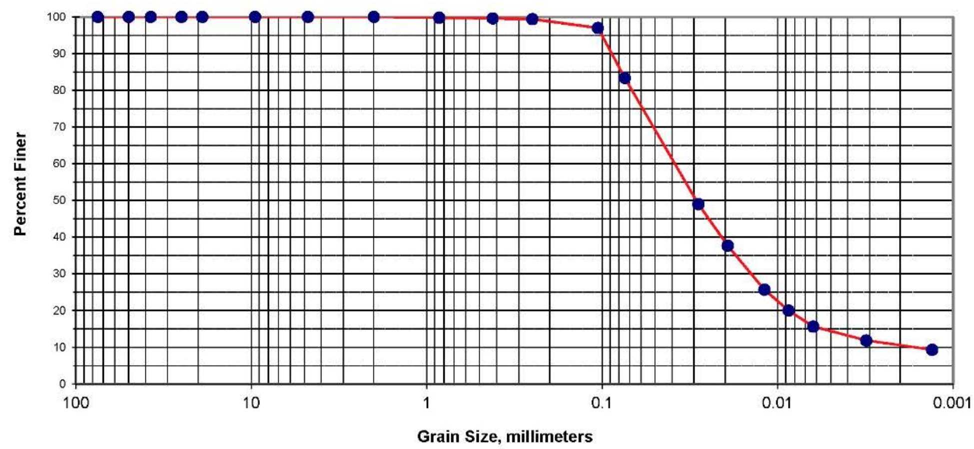
Sample West-3

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.14A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.2	99.8	0.2
0.0166	0.420	1.25	40	0.2	99.6	0.4
0.0098	0.250	2.00	60	0.2	99.4	0.6
0.0042	0.106	3.24	140	2.4	97.0	3.0
0.0029	0.074	3.75	200	13.7	83.4	16.6
0.0011	0.028	5.14	Hydrometer	34.3	49.0	51.0
0.00076	0.019	5.70	Hydrometer	11.3	37.7	62.3
0.00047	0.012	6.39	Hydrometer	12.0	25.7	74.3
0.00034	0.0087	6.85	Hydrometer	5.7	20.0	80.0
0.00025	0.0063	7.32	Hydrometer	4.4	15.6	84.4
0.00012	0.0031	8.32	Hydrometer	3.8	11.8	88.2
0.00005	0.0013	9.57	Hydrometer	2.5	9.3	90.7
			"PAN"	9.3		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	3.31	0.0040	0.101
10	3.50	0.0035	0.088
16	3.73	0.0030	0.076
25	4.09	0.0023	0.059
40	4.70	0.0015	0.039
50	5.10	0.0011	0.029
60	5.58	0.0008	0.021
75	6.45	0.0005	0.011
84	7.28	0.0003	0.006
90	9.23	0.0001	0.002

Measure	Trask	Inman	Folk-Ward
Median, phi	5.10	5.10	5.10
Median, in.	0.0011	0.0011	0.0011
Median, mm	0.029	0.029	0.029
Mean, phi	4.83	5.50	5.37
Mean, in.	0.0014	0.0009	0.0010
Mean, mm	0.035	0.022	0.024
Sorting	2.265	1.776	
Skewness	0.891	0.225	
Kurtosis	0.273		
Grain Size Description (ASTM-USCS Scale)		Silt (based on Trask Median)	

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.4
Fine Sand	200	16.3
Silt/Clay	<200	83.4
	Total	100

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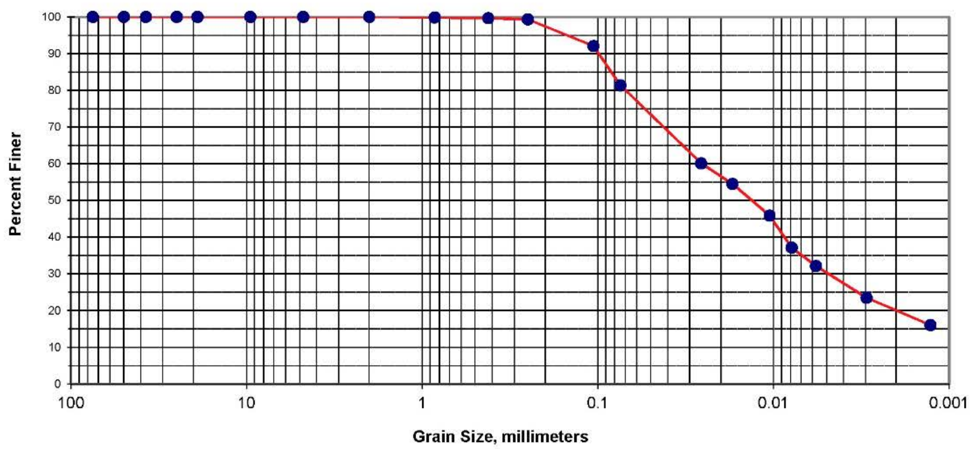
Sample West-4

PTS Laboratories, Inc.

Particle Size Distribution - ASTM D422: Sieve/Hydrometer

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.15A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.1	99.9	0.1
0.0166	0.420	1.25	40	0.2	99.7	0.3
0.0098	0.250	2.00	60	0.4	99.3	0.7
0.0042	0.106	3.24	140	7.3	92.1	7.9
0.0029	0.074	3.75	200	10.7	81.4	18.6
0.0010	0.026	5.27	Hydrometer	21.2	60.1	39.9
0.00067	0.017	5.87	Hydrometer	5.6	54.5	45.5
0.00041	0.011	6.57	Hydrometer	8.7	45.8	54.2
0.00031	0.0079	6.99	Hydrometer	8.7	37.1	62.9
0.00023	0.0057	7.45	Hydrometer	5.0	32.2	67.8
0.00012	0.0029	8.41	Hydrometer	8.7	23.5	76.5
0.00005	0.0013	9.61	Hydrometer	7.5	16.0	84.0
			"PAN"	16.0		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	2.74	0.0059	0.150
10	3.34	0.0039	0.099
16	3.62	0.0032	0.081
25	4.21	0.0021	0.054
40	5.29	0.0010	0.026
50	6.23	0.0005	0.013
60	6.85	0.0003	0.009
75	8.24	0.0001	0.003
84	9.60	0.0001	0.001

Measure	Trask	Inman	Folk-Ward
Median, phi	6.23	6.23	6.23
Median, in.	0.0005	0.0005	0.0005
Median, mm	0.013	0.013	0.013
Mean, phi	5.12	6.61	6.49
Mean, in.	0.0011	0.0004	0.0004
Mean, mm	0.029	0.010	0.011
Sorting	4.043	2.988	
Skewness	1.009	0.126	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Silt (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.3
Fine Sand	200	18.3
Silt/Clay	<200	81.4
	Total	100

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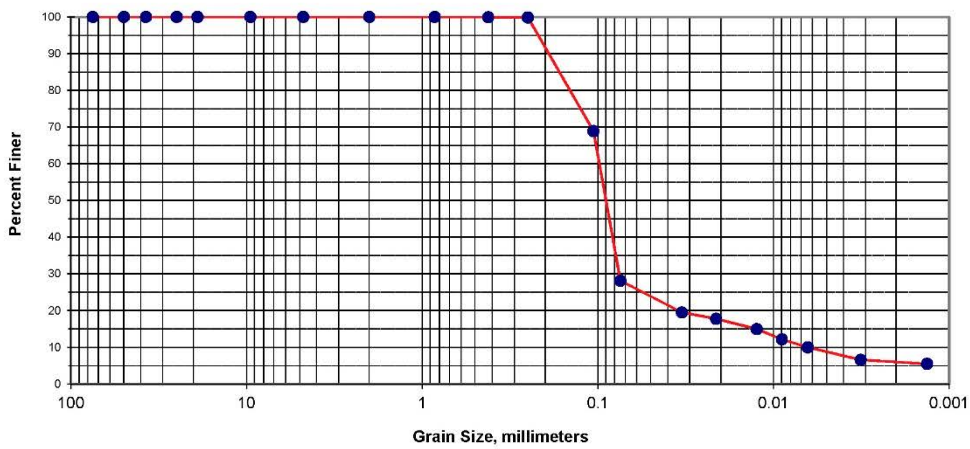
Sample Control-SE

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.16A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.9	0.1
0.0042	0.106	3.24	140	31.0	68.9	31.1
0.0029	0.074	3.75	200	40.8	28.2	71.8
0.0013	0.033	4.91	Hydrometer	8.7	19.5	80.5
0.00084	0.021	5.56	Hydrometer	1.7	17.8	82.2
0.00049	0.012	6.33	Hydrometer	2.8	15.0	85.0
0.00035	0.0089	6.80	Hydrometer	2.8	12.2	87.8
0.00025	0.0064	7.29	Hydrometer	2.2	10.0	90.0
0.00013	0.0032	8.29	Hydrometer	3.4	6.6	93.4
0.00005	0.0013	9.55	Hydrometer	1.1	5.5	94.5
			"PAN"	5.5		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained) Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	2.20	0.0086	0.218
10	2.40	0.0075	0.190
16	2.64	0.0063	0.161
25	2.99	0.0049	0.125
40	3.35	0.0039	0.098
50	3.48	0.0035	0.090
60	3.60	0.0032	0.082
75	4.17	0.0022	0.056
84	6.05	0.0006	0.015
90	7.28	0.0003	0.006

Measure	Trask	Inman	Folk-Ward
Median, phi	3.48	3.48	3.48
Median, in.	0.0035	0.0035	0.0035
Median, mm	0.090	0.090	0.090
Mean, phi	3.47	4.34	4.05
Mean, in.	0.0036	0.0019	0.0024
Mean, mm	0.090	0.049	0.060
Sorting	1.503	1.707	
Skewness	0.928	0.508	
Kurtosis	0.190		

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	71.8
Silt/Clay	<200	28.2
	Total	100

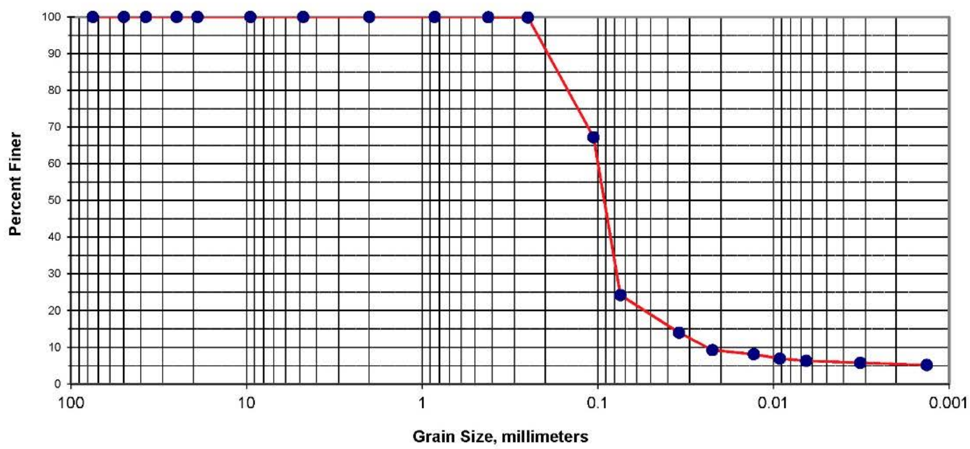
 Phone: (562) 347-2500 Fax: (562) 907-3610

Sample Control-NW

PTS Laboratories, Inc. — **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.17A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Incremental Percent Finer	Percent Finer	Cumulative Percent Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.0	100.0	0.0
0.0098	0.250	2.00	60	0.1	99.9	0.1
0.0042	0.106	3.24	140	32.6	67.3	32.7
0.0029	0.074	3.75	200	43.1	24.2	75.8
0.0014	0.034	4.86	Hydrometer	10.3	13.9	86.1
0.00088	0.022	5.49	Hydrometer	4.7	9.3	90.7
0.00051	0.013	6.27	Hydrometer	1.2	8.1	91.9
0.00036	0.0092	6.76	Hydrometer	1.2	6.9	93.1
0.00026	0.0065	7.26	Hydrometer	0.6	6.3	93.7
0.00013	0.0032	8.28	Hydrometer	0.6	5.7	94.3
0.00005	0.0013	9.54	Hydrometer	0.6	5.2	94.8
			"PAN"	5.2		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained) Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	2.19	0.0087	0.220
10	2.38	0.0076	0.193
16	2.60	0.0065	0.165
25	2.94	0.0051	0.130
40	3.32	0.0039	0.100
50	3.44	0.0036	0.092
60	3.56	0.0033	0.085
75	3.74	0.0029	0.075
84	4.64	0.0016	0.040
90	5.39	0.0009	0.024

Measure	Trask	Inman	Folk-Ward
Median, phi	3.44	3.44	3.44
Median, in.	0.0036	0.0036	0.0036
Median, mm	0.092	0.092	0.092
Mean, phi	3.29	3.62	3.56
Mean, in.	0.0040	0.0032	0.0033
Mean, mm	0.102	0.081	0.085
Sorting	1.318	1.017	
Skewness	1.072	0.174	
Kurtosis	0.163		

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Trask Median)

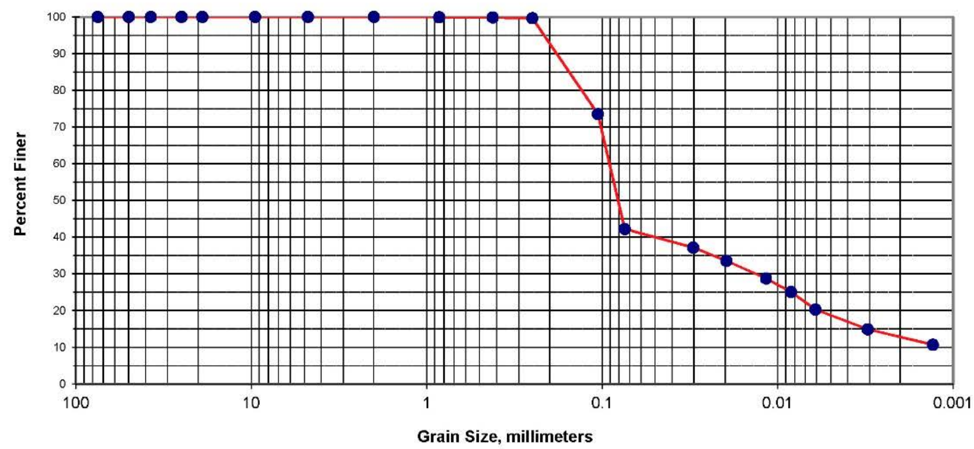
Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.0
Fine Sand	200	75.8
Silt/Clay	<200	24.2
	Total	100

Sample Control-Center

PTS Laboratories, Inc. **Particle Size Distribution - ASTM D422: Sieve/Hydrometer**

Client:	American Environmental Testing Laboratory	**PTS File No:**	46488
Project:	N/A	**Sample ID:**	84201.18A
Project No:	84201	**Depth, ft:**	N/A

SIEVE - HYDROMETER ANALYSIS



Opening		Phi of	U.S. Sieve	Incremental Percent	Percent	Cumulative Percent
Inches	Millimeters	Screen	No.	Finer	Finer	Retained
2.95	75.0	-6.23	3"	0.0	100.0	0.0
1.97	50.0	-5.64	2"	0.0	100.0	0.0
1.48	37.5	-5.23	1-1/2"	0.0	100.0	0.0
0.984	25.0	-4.64	1"	0.0	100.0	0.0
0.748	19.0	-4.25	3/4"	0.0	100.0	0.0
0.374	9.50	-3.25	3/8"	0.0	100.0	0.0
0.187	4.76	-2.25	4	0.0	100.0	0.0
0.0787	2.00	-1.00	10	0.0	100.0	0.0
0.0335	0.850	0.23	20	0.0	100.0	0.0
0.0166	0.420	1.25	40	0.1	99.9	0.1
0.0098	0.250	2.00	60	0.2	99.7	0.3
0.0042	0.106	3.24	140	26.1	73.6	26.4
0.0029	0.074	3.75	200	31.4	42.2	57.8
0.0012	0.030	5.05	Hydrometer	5.1	37.1	62.9
0.00077	0.020	5.67	Hydrometer	3.6	33.5	66.5
0.00046	0.012	6.43	Hydrometer	4.8	28.7	71.3
0.00033	0.0084	6.90	Hydrometer	3.6	25.1	74.9
0.00024	0.0061	7.36	Hydrometer	4.8	20.3	79.7
0.00012	0.0031	8.35	Hydrometer	5.4	14.9	85.1
0.00005	0.0013	9.58	Hydrometer	4.2	10.7	89.3
			"PAN"	10.7		100.0
TOTALS				100.0		100.0

Cumulative Percent greater than (retained)			
Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	2.22	0.0084	0.214
10	2.46	0.0072	0.182
16	2.74	0.0059	0.149
25	3.17	0.0044	0.111
40	3.46	0.0036	0.091
50	3.62	0.0032	0.081
60	4.32	0.0020	0.050
75	6.91	0.0003	0.008
84	8.15	0.0001	0.004

Measure	Trask	Inman	Folk-Ward
Median, phi	3.62	3.62	3.62
Median, in.	0.0032	0.0032	0.0032
Median, mm	0.081	0.081	0.081
Mean, phi	4.07	5.45	4.84
Mean, in.	0.0023	0.0009	0.0014
Mean, mm	0.060	0.023	0.035
Sorting	3.650	2.701	
Skewness	0.375	0.675	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Trask Median)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.0
Coarse Sand	10	0.0
Medium Sand	40	0.1
Fine Sand	200	57.7
Silt/Clay	<200	42.2
	Total	100

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