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New York State Energy Research and Development Authority

Proposed Broadwater Liquefied Natural Gas Project in Long Island Sound

Task 6: Review of Ocean Conditions Data and their Impact on Project Feasibility

NYSERDA Contract No. 9562

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This report summarizes Battelle's independent assessment of USACE and NOAA data in conjunction with information provided in Broadwater's supporting documents to the Draft EIS and statements by Applied Production and Loading, Inc. in regards to operating conditions for a Floating Storage and Regasification Unit and Shuttle Regasification Vessel. This document may not reflect the opinions of NYSERDA or NYSDOS.

Task 6 Final Report

Background

This report provides an analysis of the suitability of operating a liquefied natural gas (LNG) receiving terminal facility at three locations in the Atlantic Ocean, south of Long Island in the New York Bight, as proposed by the New York State Department of State (DOS). The analysis is based on an investigation of the ocean wave climate at the proposed locations and the subsequent comparison of those results to the operating limits of the proposed LNG Floating Storage and Regasification Unit (FSRU).

Data Source

The primary source of data for this study was the wave hindcast performed by the U.S. Army Corps of Engineers as part of the Wave Information Studies (WIS) program.[1] The WIS data set was created by the Corps of Engineers in an effort to produce wave climate information for U.S. coastal waters. Wave data are measured at a number of offshore National Oceanic and Atmospheric Administration (NOAA) weather buoys and nearshore stations scattered throughout the continental waters of the United States. However, these measurement stations are separated by a considerable distance in most areas and the WIS program was undertaken to develop spatially more highly resolved wave climatology for the U.S. coastal waters.

The WIS data set is generated by numerical simulation of past wind and wave conditions (hindcasts) using historical weather records. The hindcasts were performed for the Atlantic using an advanced version of the wave hindcast model WISWAVE, which incorporated accurate and highly resolved input winds, and an accurate representation of shallow water topographic effects, and sheltering by landforms. The model takes advantage of all available measured wind data (from buoys and satellites) and methods for integrating measured data with model-generated wind fields. The Atlantic Ocean hindcasts performed as part of the WIS program include simulations for the period from 1980 through 1999. For this study, the ten-year period from 1990 through 1999 was examined.

The WIS data set includes multi-year time series of bulk wave parameters, significant wave height, period, direction, as well as wind speed and direction at 1-hour intervals. Time series are available for a densely spaced series of nearshore points along the U.S. coastline (in water depths of 15 to 20 meters) and a less-dense series of points in deep water (water depths of 100 meters or more). The WIS stations coverage for the New York Bight is shown in Figure 1.

[1] USACE WIS Hindcast Website for the Atlantic is located at http://frf.usace.army.mil/cgi-bin/wis/atl/atl_main.html

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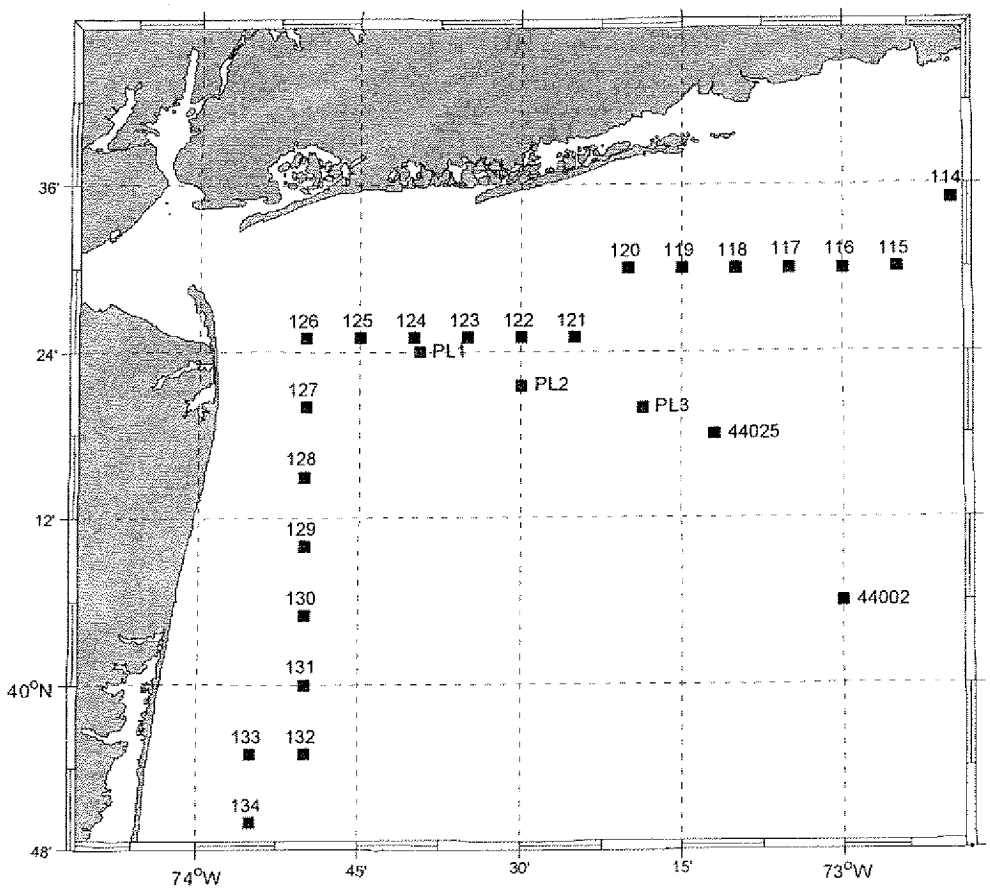

Figure 1. Location of WIS Station Array (Blue Numbered Boxes), Proposed LNG Facilities (Red PL Numbered Boxes), and NOAA NDBC Buoys (Black Numbered Boxes) in the New York Bight.

The three sites proposed for location of a LNG facility are:

- Potential Location 1 (PL1) - a potential FSRU location, 11 nautical miles due south of Long Beach, Long Island (at point of Transco landfall);
- PL2 - a potential Shuttle Regasification Vessel (SRV) or FSRU location, 14.5 nautical miles south southeast of Long Beach, Long Island (at point of Transco landfall); and,
- PL3 - a potential SRV or FSRU location, 17.3 nautical miles south of Democrat Point (western terminus of Fire Island).

The coordinates of these locations and their nearest WIS station(s) are presented in Table 1 and shown in Figure 1.

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Table 1. Coordinates of Proposed LNG Facility Locations and Nearest WIS Station or Stations.

Location	Latitude	Longitude	Nearest WIS Station(s)	Distance Between the WIS and PL Station (km)
PL1	40° 24.0′	73° 39.5′	WIS124	2.0
PL2	40° 21.5′	73° 30.0′	WIS122	6.5
PL3	40° 20.0′	73° 18.7′	WIS119, WIS121	12.8, 19.2

The operational limits for safely operating a LNG Tanker along side a FSRU were assessed by Broadwater in their reports (Broadwater submittal to FERC numbered Resource Report 10) as being controlled by a combination of wind, wave, and current conditions. Only the wave height operational limits presented in Table 2 were considered in this analysis (U.S. Coast Guard [USCG] Waterways Suitability Report [WSR], 2006).

Table 2. Summary of Approach, Side-by-Side Mooring, and Departure Operational Limits for a FSRU. *

Operational Limits	Significant Wave Height (meters)
Approach Limits	2
Side-by-side Mooring Limits	3
Departure Limits	2

*Data is from page 57 of the USCG WSR,

Data Quality

The high quality of WIS wave hindcast data is generally accepted by the oceanographic community.[2] The Corps has performed extensive comparisons between hindcasted and measured wave parameters at locations where WIS stations are in close proximity to NOAA's National Data Buoy Center (NDBC) buoys, with excellent results. In previous studies performed by Battelle using WIS data, comparisons have been made between NDBC buoy measurements of waves and nearby WIS stations. Typically, wave climatology statistics derived from the WIS data differ only by a small percentage from those derived from the NDBC buoys.

The WIS stations in the New York Bight are not located within close proximity of any NDBC Buoy. However, to demonstrate the accuracy of WIS hindcasted wave data, a nearby location was selected where a WIS station is located in close proximity to a

[2] This is base on Battelle's professional experience including personal discussions with other coastal engineers from respected environmental consulting companies. The USACE WIS data is commonly used to model conditions for other marine projects as was done in this report.

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NDBC Buoy. The stations chosen were WIS station 51 and NDBC Buoy 44013, located within 2 kilometers of each other in Massachusetts Bay. A review of wave climatology statistics for the period 1984 to 1999 from both locations shows very close correspondence between the WIS hindcast and the NDBC buoy measurements (Table 3).

Table 3. Annual Percent Frequency of Occurrence of Wave Heights from WIS Station 51 and NDBC Buoy 44013 in Massachusetts Bay for the Period 1984 to 1999.

Wave Height (meters)	0-0.49	0.5-1.49	1.5-2.49	2.5-3.49	3.5-4.49
Stations	Annual Percent Frequency (%)				
WIS Station 51	37.9%	52.3%	7.7%	1.5%	0.5%
NDBC Buoy 44013	35.9%	52.3%	8.5%	2.2%	0.7%

Wave Climate

Monthly distributions of significant wave height are presented in Table 4 for the four WIS stations under consideration. The frequency of occurrence of large waves decreases from east to west, reflecting the transition to the more protected waters in the apex of the Bight. For example, 2-meter (m) waves occurred between 12% and 24% of the time at WIS station WIS124 and WIS119, respectively, during January for the 10-year period analyzed. This finding is further supported by observations at the NDBC buoys in the New York Bight used in the analyses conducted under Task 3 of this Contract, where 2 meter waves occurred 22% and 24.4% of the time during January at Stations 44025 (southeast of WIS119) and 44017 (south of Montauk, NY on the eastern end of Long Island), respectively.

Table 4. Monthly Percent Frequency of Occurrence of Wave Heights Greater Than 1, 2, 3, 4, and 5 meters at Four WIS Stations for 1990-1999.

Station WIS119 associated with PL3					
	>1m	>2m	>3m	>4m	>5m
Jan	65.4	23.7	5.5	1.1	0.1
Feb	61.4	14.2	1.5	0.0	0.0
Mar	54.4	14.1	3.1	0.8	0.3
Apr	44.1	5.0	0.4	0.0	0.0
May	38.3	2.9	0.2	0.0	0.0
Jun	29.0	1.6	0.1	0.0	0.0
Jul	24.4	2.0	0.2	0.1	0.0
Aug	29.8	4.3	0.8	0.0	0.0
Sep	50.5	6.4	1.3	0.3	0.0
Oct	46.0	10.3	1.4	0.2	0.0
Nov	59.0	16.4	4.4	0.5	0.1
Dec	61.0	17.3	2.9	0.7	0.4

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Table 4. Monthly Percent Frequency of Occurrence of Wave Heights Greater Than 1, 2, 3, 4, and 5 meters at Four WIS Stations for 1990-1999 (continued).

Station WIS121 associated with PL3					
	>1m	>2m	>3m	>4m	>5m
Jan	65.9	21.5	5.3	1.3	0.1
Feb	63.2	13.4	1.7	0.0	0.0
Mar	55.7	13.7	2.7	0.8	0.2
Apr	45.4	5.0	0.4	0.0	0.0
May	38.7	3.3	0.2	0.0	0.0
Jun	29.6	1.4	0.1	0.0	0.0
Jul	23.1	1.9	0.1	0.1	0.0
Aug	29.9	4.3	0.8	0.0	0.0
Sep	51.2	6.6	1.2	0.2	0.0
Oct	47.1	10.0	1.3	0.2	0.0
Nov	60.3	15.3	3.9	0.4	0.1
Dec	62.7	16.4	2.7	0.6	0.4
Station WIS122 associated with PL2					
	>1m	>2m	>3m	>4m	>5m
Jan	63.8	18.8	4.0	1.1	0.0
Feb	60.3	10.6	1.4	0.0	0.0
Mar	53.6	12.4	2.4	0.8	0.2
Apr	43.3	3.9	0.3	0.0	0.0
May	36.7	2.6	0.1	0.0	0.0
Jun	27.2	1.2	0.1	0.0	0.0
Jul	21.2	1.6	0.1	0.1	0.0
Aug	28.1	4.1	0.5	0.0	0.0
Sep	48.0	5.8	1.0	0.1	0.0
Oct	44.4	8.6	1.0	0.2	0.0
Nov	57.4	13.4	3.3	0.3	0.1
Dec	59.8	13.9	2.3	0.5	0.4
Station WIS124 associated with PL1					
	>1m	>2m	>3m	>4m	>5m
Jan	55.4	11.6	2.4	0.3	0.0
Feb	51.2	4.9	0.4	0.0	0.0
Mar	46.5	8.0	1.2	0.4	0.1
Apr	34.4	2.1	0.2	0.0	0.0
May	28.8	0.9	0.0	0.0	0.0
Jun	19.2	0.6	0.0	0.0	0.0
Jul	15.6	0.9	0.1	0.0	0.0
Aug	22.2	2.5	0.0	0.0	0.0
Sep	37.7	2.9	0.4	0.0	0.0
Oct	37.2	5.4	0.4	0.0	0.0
Nov	48.1	8.6	1.4	0.2	0.1
Dec	50.0	7.5	1.3	0.4	0.2

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Effect of Wave Climate on LNG Operations

Battelle concludes from the climatology presented in the previous section that if the FSRU's berthing and deberthing operational limits are set at 2 m waves, then an LNG tanker would be unable to berth or deberth from the FRSU between December and February as follows:

- 8 % of the time (2.4 days out of 30) at PL1 (based on data from WIS124)
- 14 % of the time (4.2 days out of 30) at PL2 (based on data from WIS122)
- 18 % of the time (5.4 days out of 30) at PL3 (based on data from WIS119 and 121)

During the shoulder heating months of November and March, an LNG tanker would be unable to berth or deberth from the FRSU:

- 8 % of the time (2.4 days out of 30) at PL1
- 13 % of the time (3.9 days out of 30) at PL2
- 15 % of the time (4.5 days out of 30) at PL3

These are averages, however, and do not provide any indication of how often shutdown intervals would be required and how long they would last. To understand this, temporal trends in the estimated significant wave heights over the 10-year record were analyzed to determine the duration of periods of large waves, and thereby the frequency of intervals during which LNG operation along side of the FSRU would need to be suspended. Table 5 presents these results for 1, 2, 4, and 8 day durations of waves greater than the operational limits of 2 and 3 meters during the winter months (December - February).

Table 5. Frequency of Occurrence During Winter, 1990 – 1999.

		1-Day Average Wave Height Greater Than		2-Day Average Wave Height Greater Than		4-Day Average Wave Height Greater Than		8-Day Average Wave Height Greater Than	
PL	Station	2 m	3 m	2 m	3 m	2 m	3 m	2 m	3 m
3	WIS119	16.8%	3.2%	15.3%	1.5%	8.7%	0.5%	4.0%	0.0%
3	WIS121	15.7%	3.0%	12.3%	1.6%	8.7%	0.5%	3.8%	0.0%
2	WIS122	13.5%	2.3%	10.1%	1.0%	6.5%	0.5%	3.1%	0.0%
1	WIS124	7.4%	1.0%	5.6%	0.4%	2.2%	0.1%	0.3%	0.0%

The range of results varies significantly with location. Battelle concludes that the FSRU could be expected to be unable to conduct berthing and deberthing operations for at least one day:

- 7% of the time at PL1
- 14% of the time at PL2
- 16-17% of the time at PL3

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Battelle concludes that the FSRU could be expected to be unable to conduct berthing and deberthing operations for at least eight days:

- <1% of the time at PL1
- 3% of the time at PL2
- 4% of the time at PL3

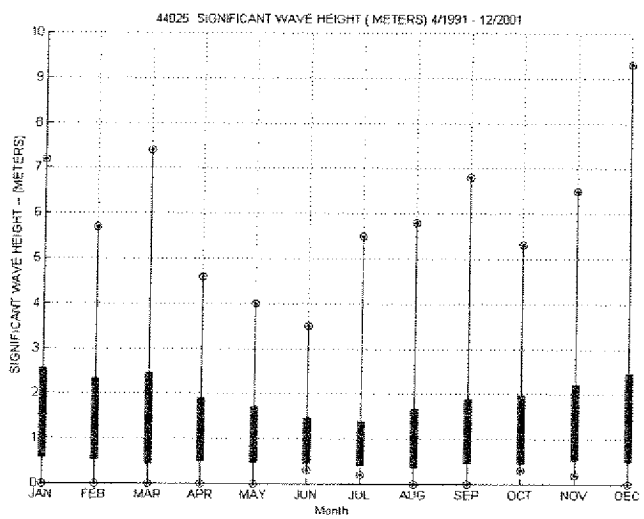
Battelle concludes that a FSRU LNG terminal with an 8-day reserve storage capacity will be completely depleted of the reserve 4% of the time in winter (December through February) at PL3 and less than 1% of the time at PL1.[3] During November and March, there are additional possibilities of the FSRU being completely depleted of the reserve approximately 3% of the time at PL3. However, at PL1, depending on the storms that come through, a complete depletion may or may not occur during November and March.

Battelle Findings

FSRU Operation South of Long Island

Based on the data above and Broadwater's operating parameters noted above, PL1 is likely the best location that could be considered as a viable FSRU location from the three locations considered. Battelle understands that the FSRU is presently being designed to withstand a maximum wave height of 7 meters (23 feet). NOAA buoy 44025 data indicates a wave height of 9.3 meters (30.5 feet) has been experienced off the southern coast of Long Island within the past 10 years, which would exceed the present design (see Figure 2).

Figure 2. Wave Heights of 44025 (located south of Long Island)



According to the data in Table 6 (excerpted from NOAA's NDBC Station 44025 Summary Data Tables for all Historical Data), there has only been one occurrence of a

[3] Assuming the 8-day average wave height is greater than 2 meters and the FSRU's average output is 1 bcfd

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wave greater than 9 meters in 10 years of monitoring approximately 33 nautical miles south of Islip (Station 44025 is between 15.5 and 22 miles south of the PL locations). Beyond that occurrence, there are 23 additional occurrences of a wave 7-meters or greater in the same data set. Using the historical data, there appears to a 0.03% occurrence of a 7-meter or higher significant wave height based on approximately 10 years of data. Therefore, based on the present design of the FSRU, Battelle's opinion is that the FSRU mooring system can withstand waves that occur south of Long Island more than 99 percent of the time. However, waves occurring less than 1 percent of the time are strong enough to potentially damage the yoke mooring system. What is not available to Battelle staff is whether a FSRU could be designed to withstand wave heights of 9.5 meters, which would presumably allow Broadwater to operate south of Long Island without damage.

Table 6. Monthly and Annual Frequency and Cumulative Percent Frequency of Significant Wave Height Measured at Station 44025 between 4/1991 and 12/2001

STATION: 44025

1 - MONTHLY AND ANNUAL FREQUENCY AND CUMULATIVE PERCENT FREQUENCY (LOTTS)

ELEMENT: SIGNIFICANT WAVE HEIGHT (METERS) --- FOR: 4/1991 - 12/2001 (55617 RECORDS, 69.0% HAVE ELEMENT)

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANN	
	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF
10.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	#
9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#	1	#
9.0		-			-	-	-	-	-	-				-	-										0	999
8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	999	1	999
8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	999	4	999
7.5		-			5	#		-					-	-	-							-	1	999	4	999
7.0	1	#	-	-	6	999	-	-	-	-	-	-	-	-	-	-	1	#	-	-	-	-	6	999	14	999
6.5	4	999			10	999		-		-							2	999			1	#	2	999	23	999
6.0	5	998	-	-	9	997	-	-	-	-	-	-	-	-	1	#	-	-	-	-	-	-	12	999	37	999
5.5	10	995	10	#	16	996	-	-	-	-	-	-	1	#	1	999	-	-	1	#	3	998	15	999	59	999
5.0	20	993	13	998	21	993	-			-			2	999			4	998	4	998	5	998	15	999	97	998
4.5	31	991	19	996	62	996	4	#	-	-	-	-	2	999	1	999	10	999	20	997	10	997	24	997	217	997
4.0	76	985	65	995	70	992	14	999	3	#			4	999	4	999	28	998	19	997	44	996	55	997	409	996
3.5	152	972	87	984	148	972	49	997	23	999	1	#	1	999	31	999	81	994	65	992	136	985	127	979	902	989
3.0	275	944	183	969	250	950	92	986	50	997	46	999	10	999	139	998	170	986	155	983	199	964	302	959	1355	993
2.5	506	892	502	938	494	915	342	975	201	986	160	994	79	997	229	974	247	970	328	964	369	935	559	914	3068	976
2.0	829	810	868	851	851	844	606	926	540	941	365	981	234	988	431	945	630	933	725	921	749	890	896	864	7591	911
1.5	1299	668	1138	761	1487	722	1563	839	1586	891	1134	946	957	963	927	892	1617	856	1540	829	1617	768	1540	706	14416	823
1.0	1570	438	1515	470	2003	509	2508	611	2259	686	3454	800	1509	859	2864	767	2966	746	2948	632	2302	527	2084	485	31744	628
0.5	404	144	1195	208	1433	293	1445	250	2071	279	2640	344	1111	394	2484	369	1972	263	2855	252	1239	184	1367	189	23140	305
0.0	34	6	96	37	127	18	71	10	62	6		-	35	4	56	4	32	3	-	-	6	1	29	4	550	6
MEAN		1.6		1.4		1.4		1.3		1.1		1.0		0.9		1.0		1.3		1.2		1.4		1.5		1.2
S.D.		0.9		0.8		0.9		0.6		0.5		0.4		0.4		0.4		0.6		0.7		0.8		0.9		0.7

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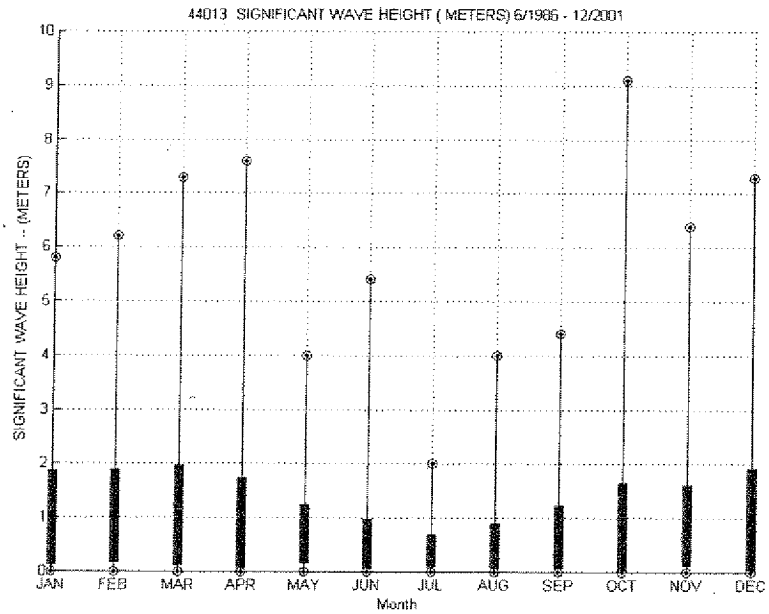
SRV Operation South of Long Island

In regard to operating a SRV at PL 1 through PL3, it is Battelle's opinion that the SRV could operate in the wave conditions found south of Long Island. According to Advanced Production and Loading, Inc.[4], a SRV can connect to the submerged turret loading system in 3.5-meter (11.5 foot) waves. As noted in Table 5 and Figure 2 above, seas less than 3 meters occur approximately 99 percent of the time during the winter, with most seas averaging less than 3 meters year round. SRV's can also withstand maintaining that connection in seas greater than 10 meters, which is greater than the largest wave experienced in the last 10 years.

Beyond the WIS and Station 44025 data, Battelle reviewed data from the NOAA NDBC Buoy 44013, which is closest to the future location of the Northeast Gateway LNG project in Massachusetts Bay. The Northeast Gateway project will use the SRV system to deliver gas to Massachusetts. Based on comparing the data provided in Figures 2 and 3 for wave heights and Figures 4 and 5 for Dominant Wave Period, and the information provided from the WIS data analysis, Battelle has concluded that operation of a SRV system south of Long Island is possible. The data from Stations 44025 and 44013 were quite similar in wave conditions and dominant wave periods.

Figure 3. Wave Heights of 44013 (in Massachusetts Bay, near Northeast Gateway)



[4] Advanced Production and Loading, Inc. (APL) is a market leader in the development, fabrication, and sale of advanced systems for offshore production and loading of oil and gas by ships. They were founded in 1993 to develop and commercialize the Submerged Turret Loading (STL) and the Submerged Turret Production Systems. Currently, APL has 10 STL systems in operation worldwide including the North Sea, Norwegian Sea, Gulf of Mexico, and Timor Sea (Australia).

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Figure 4. Dominant Wave Periods of 44025 (off Long Island)

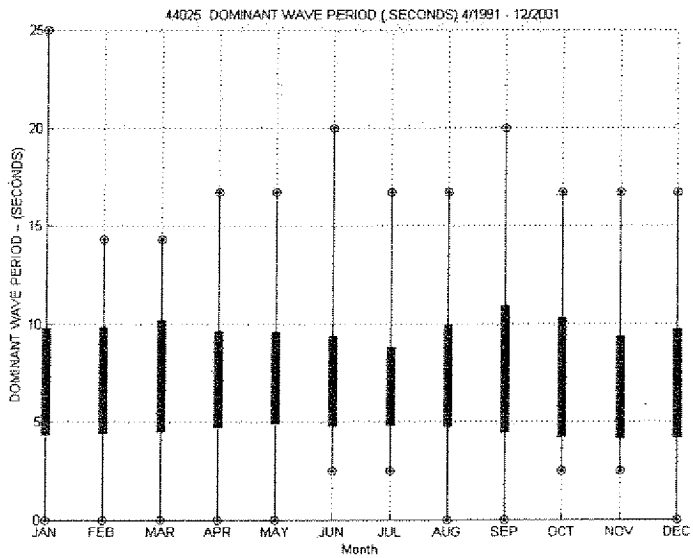
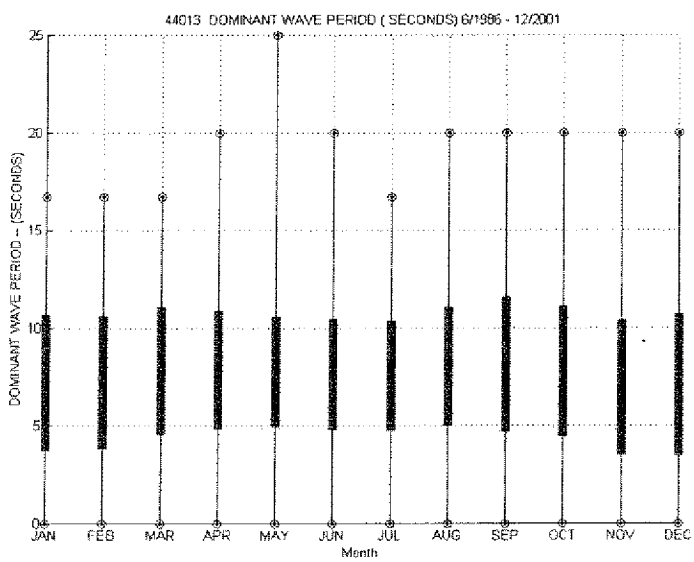


Figure 5. Dominant Wave Periods of 44013 (in Massachusetts Bay, near Northeast Gateway)



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NEW YORK STATE
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

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DEC Permit Application Detail

Application ID:	8-5442-00338/00001
Facility:	Sodus Center Rd Bridge
Location:	Sodus Center Rd Over Salmon CREEK|E of Barclay Rd & W of Geneva Rd, Sodus , NY
Town or City:	Sodus
Applicant:	Wayne County
Permit Type:	Freshwater Wetlands
Application Type:	New
Date Received:	12/14/2007
Status:	Incomplete as of
Complete Status:	Incomplete as of 12/19/2007
UPA Class:	Minor
Short Description:	replace bridge over Salmon Creek
ENB Publication Date:	
Written Comments Due:	
SEQR Class:	Type II Action
SEQR Determination:	Not Applicable
Lead Agency:	Nd
Environmental Justice:	The application is not subject to the Department's Environmental Justice policy (CP-29). Either the permits needed for the project are not subject to the policy or it has been determined that the project would not affect a Potential Environmental Justice Area.
SHPA Status:	The proposed activity is not subject to review in accordance with SHPA. The permit type is exempt or the activity is being reviewed in accordance with federal historic preservation regulations.
Coastal Zone Status:	This project is not located in a Coastal Management area and is not subject to the Waterfront Revitalization and Coastal Resources Act.
Final Disposition:	
Permit Effective Date:	
Permit Expiration Date:	
DEC Contact:	Christine Setari 6274 East Avon Lima Rd, Avon, NY 14414 Tel:(585)226-2466

Please email the Regional Office for additional information or questions regarding this application.

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New York State Energy Research and Development Authority

Proposed Broadwater Liquefied Natural Gas Project in Long Island Sound

Task 6: Review of Ocean Conditions Data and their Impact on Project Feasibility

NYSERDA Contract No. 9562

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This report summarizes Battelle's independent assessment of USACE and NOAA data in conjunction with information provided in Broadwater's supporting documents to the Draft EIS and statements by Applied Production and Loading, Inc. in regards to operating conditions for a Floating Storage and Regasification Unit and Shuttle Regasification Vessel. This document may not reflect the opinions of NYSERDA or NYSDOS.

Task 6 Final Report

Background

This report provides an analysis of the suitability of operating a liquefied natural gas (LNG) receiving terminal facility at three locations in the Atlantic Ocean, south of Long Island in the New York Bight, as proposed by the New York State Department of State (DOS). The analysis is based on an investigation of the ocean wave climate at the proposed locations and the subsequent comparison of those results to the operating limits of the proposed LNG Floating Storage and Regasification Unit (FSRU).

Data Source

The primary source of data for this study was the wave hindcast performed by the U.S. Army Corps of Engineers as part of the Wave Information Studies (WIS) program.[1] The WIS data set was created by the Corps of Engineers in an effort to produce wave climate information for U.S. coastal waters. Wave data are measured at a number of offshore National Oceanic and Atmospheric Administration (NOAA) weather buoys and nearshore stations scattered throughout the continental waters of the United States. However, these measurement stations are separated by a considerable distance in most areas and the WIS program was undertaken to develop spatially more highly resolved wave climatology for the U.S. coastal waters.

The WIS data set is generated by numerical simulation of past wind and wave conditions (hindcasts) using historical weather records. The hindcasts were performed for the Atlantic using an advanced version of the wave hindcast model WISWAVE, which incorporated accurate and highly resolved input winds, and an accurate representation of shallow water topographic effects, and sheltering by landforms. The model takes advantage of all available measured wind data (from buoys and satellites) and methods for integrating measured data with model-generated wind fields. The Atlantic Ocean hindcasts performed as part of the WIS program include simulations for the period from 1980 through 1999. For this study, the ten-year period from 1990 through 1999 was examined.

The WIS data set includes multi-year time series of bulk wave parameters, significant wave height, period, direction, as well as wind speed and direction at 1-hour intervals. Time series are available for a densely spaced series of nearshore points along the U.S. coastline (in water depths of 15 to 20 meters) and a less-dense series of points in deep water (water depths of 100 meters or more). The WIS stations coverage for the New York Bight is shown in Figure 1.

[1] USACE WIS Hindcast Website for the Atlantic is located at http://frf.usace.army.mil/cgi-bin/wis/atl/atl_main.html

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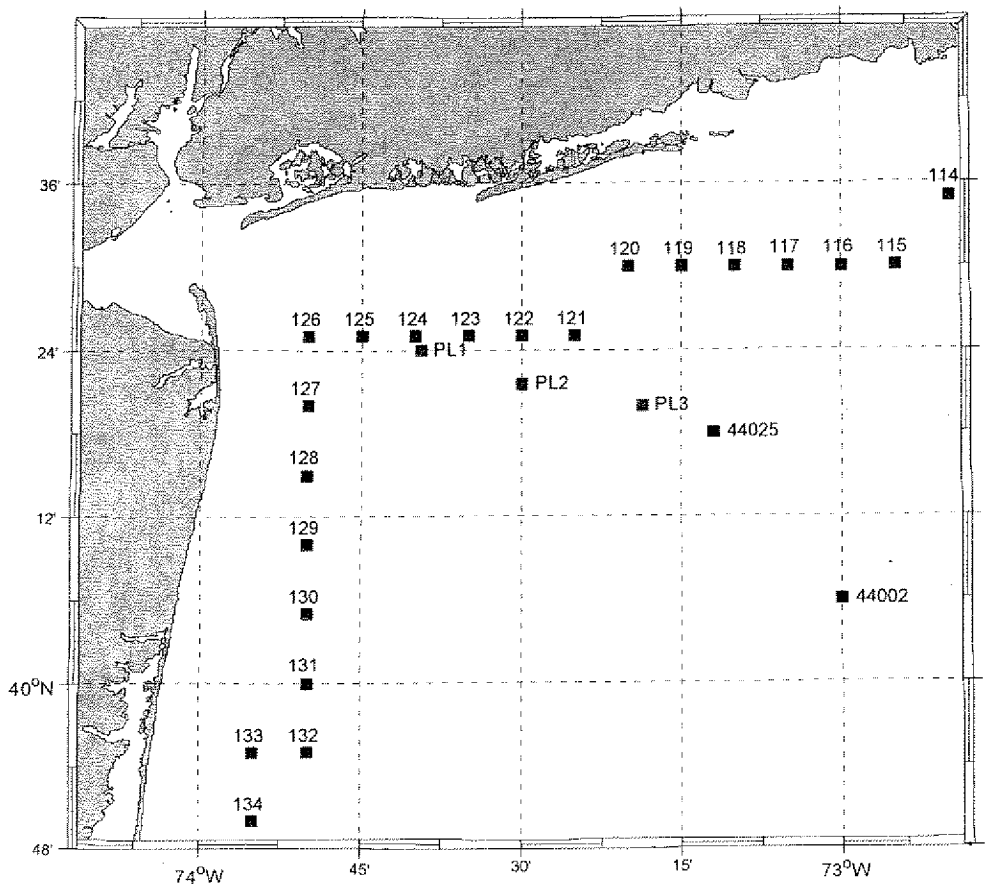

Figure 1. Location of WIS Station Array (Blue Numbered Boxes), Proposed LNG Facilities (Red PL Numbered Boxes), and NOAA NDBC Buoys (Black Numbered Boxes) in the New York Bight.

The three sites proposed for location of a LNG facility are:

- Potential Location 1 (PL1) - a potential FSRU location, 11 nautical miles due south of Long Beach, Long Island (at point of Transco landfall);
- PL2 - a potential Shuttle Regasification Vessel (SRV) or FSRU location, 14.5 nautical miles south southeast of Long Beach, Long Island (at point of Transco landfall); and,
- PL3 - a potential SRV or FSRU location, 17.3 nautical miles south of Democrat Point (western terminus of Fire Island).

The coordinates of these locations and their nearest WIS station(s) are presented in Table 1 and shown in Figure 1.

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Table 1. Coordinates of Proposed LNG Facility Locations and Nearest WIS Station or Stations.

Location	Latitude	Longitude	Nearest WIS Station(s)	Distance Between the WIS and PL Station (km)
PL1	40° 24.0′	73° 39.5′	WIS124	2.0
PL2	40° 21.5′	73° 30.0′	WIS122	6.5
PL3	40° 20.0′	73° 18.7′	WIS119, WIS121	12.8, 19.2

The operational limits for safely operating a LNG Tanker along side a FSRU were assessed by Broadwater in their reports (Broadwater submittal to FERC numbered Resource Report 10) as being controlled by a combination of wind, wave, and current conditions. Only the wave height operational limits presented in Table 2 were considered in this analysis (U.S. Coast Guard [USCG] Waterways Suitability Report [WSR], 2006).

Table 2. Summary of Approach, Side-by-Side Mooring, and Departure Operational Limits for a FSRU. *

Operational Limits	Significant Wave Height (meters)
Approach Limits	2
Side-by-side Mooring Limits	3
Departure Limits	2

*Data is from page 57 of the USCG WSR,

Data Quality

The high quality of WIS wave hindcast data is generally accepted by the oceanographic community.[2] The Corps has performed extensive comparisons between hindcasted and measured wave parameters at locations where WIS stations are in close proximity to NOAA's National Data Buoy Center (NDBC) buoys, with excellent results. In previous studies performed by Battelle using WIS data, comparisons have been made between NDBC buoy measurements of waves and nearby WIS stations. Typically, wave climatology statistics derived from the WIS data differ only by a small percentage from those derived from the NDBC buoys.

The WIS stations in the New York Bight are not located within close proximity of any NDBC Buoy. However, to demonstrate the accuracy of WIS hindcasted wave data, a nearby location was selected where a WIS station is located in close proximity to a

[2] This is base on Battelle's professional experience including personal discussions with other coastal engineers from respected environmental consulting companies. The USACE WIS data is commonly used to model conditions for other marine projects as was done in this report.

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NDBC Buoy. The stations chosen were WIS station 51 and NDBC Buoy 44013, located within 2 kilometers of each other in Massachusetts Bay. A review of wave climatology statistics for the period 1984 to 1999 from both locations shows very close correspondence between the WIS hindcast and the NDBC buoy measurements (Table 3).

Table 3. Annual Percent Frequency of Occurrence of Wave Heights from WIS Station 51 and NDBC Buoy 44013 in Massachusetts Bay for the Period 1984 to 1999.

Wave Height (meters)	0-0.49	0.5-1.49	1.5-2.49	2.5-3.49	3.5-4.49
Stations	Annual Percent Frequency (%)				
WIS Station 51	37.9%	52.3%	7.7%	1.5%	0.5%
NDBC Buoy 44013	35.9%	52.3%	8.5%	2.2%	0.7%

Wave Climate

Monthly distributions of significant wave height are presented in Table 4 for the four WIS stations under consideration. The frequency of occurrence of large waves decreases from east to west, reflecting the transition to the more protected waters in the apex of the Bight. For example, 2-meter (m) waves occurred between 12% and 24% of the time at WIS station WIS124 and WIS119, respectively, during January for the 10-year period analyzed. This finding is further supported by observations at the NDBC buoys in the New York Bight used in the analyses conducted under Task 3 of this Contract, where 2 meter waves occurred 22% and 24.4% of the time during January at Stations 44025 (southeast of WIS119) and 44017 (south of Montauk, NY on the eastern end of Long Island), respectively.

Table 4. Monthly Percent Frequency of Occurrence of Wave Heights Greater Than 1, 2, 3, 4, and 5 meters at Four WIS Stations for 1990-1999.

Station WIS119 associated with PL3					
	>1m	>2m	>3m	>4m	>5m
Jan	65.4	23.7	5.5	1.1	0.1
Feb	61.4	14.2	1.5	0.0	0.0
Mar	54.4	14.1	3.1	0.8	0.3
Apr	44.1	5.0	0.4	0.0	0.0
May	38.3	2.9	0.2	0.0	0.0
Jun	29.0	1.6	0.1	0.0	0.0
Jul	24.4	2.0	0.2	0.1	0.0
Aug	29.8	4.3	0.8	0.0	0.0
Sep	50.5	6.4	1.3	0.3	0.0
Oct	46.0	10.3	1.4	0.2	0.0
Nov	59.0	16.4	4.4	0.5	0.1
Dec	61.0	17.3	2.9	0.7	0.4

BW041979

Table 4. Monthly Percent Frequency of Occurrence of Wave Heights Greater Than 1, 2, 3, 4, and 5 meters at Four WIS Stations for 1990-1999 (continued).

Station WIS121 associated with PL3					
	>1m	>2m	>3m	>4m	>5m
Jan	65.9	21.5	5.3	1.3	0.1
Feb	63.2	13.4	1.7	0.0	0.0
Mar	55.7	13.7	2.7	0.8	0.2
Apr	45.4	5.0	0.4	0.0	0.0
May	38.7	3.3	0.2	0.0	0.0
Jun	29.6	1.4	0.1	0.0	0.0
Jul	23.1	1.9	0.1	0.1	0.0
Aug	29.9	4.3	0.8	0.0	0.0
Sep	51.2	6.6	1.2	0.2	0.0
Oct	47.1	10.0	1.3	0.2	0.0
Nov	60.3	15.3	3.9	0.4	0.1
Dec	62.7	16.4	2.7	0.6	0.4
Station WIS122 associated with PL2					
	>1m	>2m	>3m	>4m	>5m
Jan	63.8	18.8	4.0	1.1	0.0
Feb	60.3	10.6	1.4	0.0	0.0
Mar	53.6	12.4	2.4	0.8	0.2
Apr	43.3	3.9	0.3	0.0	0.0
May	36.7	2.6	0.1	0.0	0.0
Jun	27.2	1.2	0.1	0.0	0.0
Jul	21.2	1.6	0.1	0.1	0.0
Aug	28.1	4.1	0.5	0.0	0.0
Sep	48.0	5.8	1.0	0.1	0.0
Oct	44.4	8.6	1.0	0.2	0.0
Nov	57.4	13.4	3.3	0.3	0.1
Dec	59.8	13.9	2.3	0.5	0.4
Station WIS124 associated with PL1					
	>1m	>2m	>3m	>4m	>5m
Jan	55.4	11.6	2.4	0.3	0.0
Feb	51.2	4.9	0.4	0.0	0.0
Mar	46.5	8.0	1.2	0.4	0.1
Apr	34.4	2.1	0.2	0.0	0.0
May	28.8	0.9	0.0	0.0	0.0
Jun	19.2	0.6	0.0	0.0	0.0
Jul	15.6	0.9	0.1	0.0	0.0
Aug	22.2	2.5	0.0	0.0	0.0
Sep	37.7	2.9	0.4	0.0	0.0
Oct	37.2	5.4	0.4	0.0	0.0
Nov	48.1	8.6	1.4	0.2	0.1
Dec	50.0	7.5	1.3	0.4	0.2

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Effect of Wave Climate on LNG Operations

Battelle concludes from the climatology presented in the previous section that if the FSRU's berthing and deberthing operational limits are set at 2 m waves, then an LNG tanker would be unable to berth or deberth from the FRSU between December and February as follows:

- 8 % of the time (2.4 days out of 30) at PL1 (based on data from WIS124)
- 14 % of the time (4.2 days out of 30) at PL2 (based on data from WIS122)
- 18 % of the time (5.4 days out of 30) at PL3 (based on data from WIS119 and 121)

During the shoulder heating months of November and March, an LNG tanker would be unable to berth or deberth from the FRSU:

- 8 % of the time (2.4 days out of 30) at PL1
- 13 % of the time (3.9 days out of 30) at PL2
- 15 % of the time (4.5 days out of 30) at PL3

These are averages, however, and do not provide any indication of how often shutdown intervals would be required and how long they would last. To understand this, temporal trends in the estimated significant wave heights over the 10-year record were analyzed to determine the duration of periods of large waves, and thereby the frequency of intervals during which LNG operation along side of the FSRU would need to be suspended. Table 5 presents these results for 1, 2, 4, and 8 day durations of waves greater than the operational limits of 2 and 3 meters during the winter months (December - February).

Table 5. Frequency of Occurrence During Winter, 1990 – 1999.

		1-Day Average Wave Height Greater Than		2-Day Average Wave Height Greater Than		4-Day Average Wave Height Greater Than		8-Day Average Wave Height Greater Than	
PL	Station	2 m	3 m	2 m	3 m	2 m	3 m	2 m	3 m
3	WIS119	16.8%	3.2%	15.3%	1.5%	8.7%	0.5%	4.0%	0.0%
3	WIS121	15.7%	3.0%	12.3%	1.6%	8.7%	0.5%	3.8%	0.0%
2	WIS122	13.5%	2.3%	10.1%	1.0%	6.5%	0.5%	3.1%	0.0%
1	WIS124	7.4%	1.0%	5.6%	0.4%	2.2%	0.1%	0.3%	0.0%

The range of results varies significantly with location. Battelle concludes that the FSRU could be expected to be unable to conduct berthing and deberthing operations for at least one day:

- 7% of the time at PL1
- 14% of the time at PL2
- 16-17% of the time at PL3

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Battelle concludes that the FSRU could be expected to be unable to conduct berthing and deberthing operations for at least eight days:

- <1% of the time at PL1
- 3% of the time at PL2
- 4% of the time at PL3

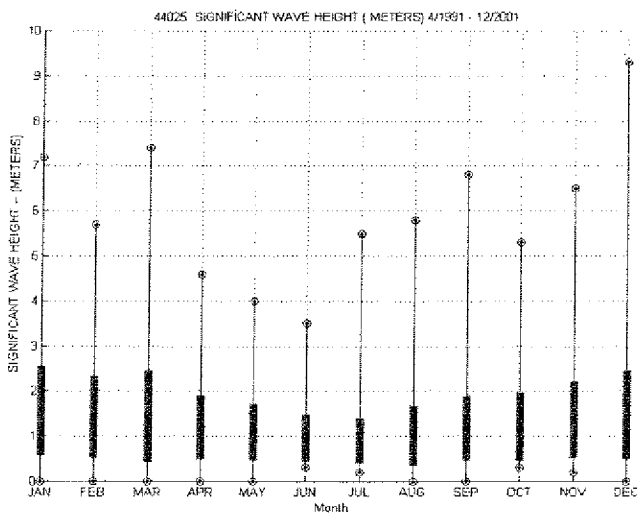
Battelle concludes that a FSRU LNG terminal with an 8-day reserve storage capacity will be completely depleted of the reserve 4% of the time in winter (December through February) at PL3 and less than 1% of the time at PL1.[3] During November and March, there are additional possibilities of the FSRU being completely depleted of the reserve approximately 3% of the time at PL3. However, at PL1, depending on the storms that come through, a complete depletion may or may not occur during November and March.

Battelle Findings

FSRU Operation South of Long Island

Based on the data above and Broadwater's operating parameters noted above, PL1 is likely the best location that could be considered as a viable FSRU location from the three locations considered. Battelle understands that the FSRU is presently being designed to withstand a maximum wave height of 7 meters (23 feet). NOAA buoy 44025 data indicates a wave height of 9.3 meters (30.5 feet) has been experienced off the southern coast of Long Island within the past 10 years, which would exceed the present design (see Figure 2).

Figure 2. Wave Heights of 44025 (located south of Long Island)



According to the data in Table 6 (excerpted from NOAA's NDBC Station 44025 Summary Data Tables for all Historical Data), there has only been one occurrence of a

[3] Assuming the 8-day average wave height is greater than 2 meters and the FSRU's average output is 1 bcfd

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wave greater than 9 meters in 10 years of monitoring approximately 33 nautical miles south of Islip (Station 44025 is between 15.5 and 22 miles south of the PL locations). Beyond that occurrence, there are 23 additional occurrences of a wave 7-meters or greater in the same data set. Using the historical data, there appears to a 0.03% occurrence of a 7-meter or higher significant wave height based on approximately 10 years of data. Therefore, based on the present design of the FSRU, Battelle's opinion is that the FSRU mooring system can withstand waves that occur south of Long Island more than 99 percent of the time. However, waves occurring less than 1 percent of the time are strong enough to potentially damage the yoke mooring system. What is not available to Battelle staff is whether a FSRU could be designed to withstand wave heights of 9.5 meters, which would presumably allow Broadwater to operate south of Long Island without damage.

Table 6. Monthly and Annual Frequency and Cumulative Percent Frequency of Significant Wave Height Measured at Station 44025 between 4/1991 and 12/2001

STATION: 44025

1 - MONTHLY AND ANNUAL FREQUENCY AND CUMULATIVE PERCENT FREQUENCY (10TH)

ELEMENT: SIGNIFICANT WAVE HEIGHT (METERS) -- FOR: 04/1991 - 12/2001 (9510 RECORDS, 99.0% WAVE ELEMENT)

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANN	
	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF
10.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	#
9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#	1	#
9.0		-	-			-											-	-	-	-		-			0	999
8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	999	1	999
8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	999	4	999
7.5		-	-		1	#	-	-									-	-	-	-	-	-	1	999	4	999
7.0	1	#	-	-	6	999	-	-	-	-	-	-	-	-	-	-	1	#	-	-	-	-	8	999	14	999
6.5	8	999			12	999								-			2	999			1	#	3	999	25	999
6.0	7	999	-	-	9	997	-	-	-	-	-	-	-	-	1	#	-	-	-	-	-	-	12	999	37	999
5.5	12	999	10	#	13	996	-	-	-	-	-	-	1	#	1	999	-	-	1	#	1	999	15	999	59	999
5.0	24	996	15	998	21	993							2	999			6	999	6	999	5	999	15	998	97	998
4.5	31	993	19	996	47	990	4	#	-	-	-	-	7	997	1	999	10	999	20	999	30	999	34	997	217	997
4.0	74	985	40	990	70	982	16	999	1	#			1	999	4	999	18	998	34	997	43	998	55	997	394	997
3.5	152	972	67	984	148	972	49	997	23	999	1	#	1	999	31	999	41	994	65	995	126	995	157	979	901	993
3.0	272	940	165	969	340	950	95	990	85	997	42	999	14	999	119	998	129	990	155	993	198	994	302	989	1955	993
2.5	536	892	502	928	496	915	242	975	261	988	150	994	45	997	229	994	247	978	358	984	365	975	565	974	3948	986
2.0	806	817	844	851	951	844	605	924	548	901	265	961	234	988	401	948	520	938	725	921	749	887	886	834	7591	911
1.5	1299	648	1033	700	1487	722	1556	689	1566	698	1174	846	867	945	927	902	1612	856	1548	829	1417	764	1550	708	14824	904
1.0	1570	438	1515	470	2003	509	2509	611	2259	688	3454	850	3599	839	2954	747	2944	646	2948	632	2302	527	2054	485	31041	818
0.5	904	164	1109	208	1431	221	1465	250	2071	273	2640	346	3121	396	2484	348	1972	240	2055	259	1279	154	1207	188	22140	245
0.0	94	6	96	17	127	24	71	19	62	6			33	4	56	9	22	3			6	1	39	5	6[illegible]	5
MEAN		1.4		1.4		1.4		1.1		1.1		1.0		0.9		1.0		1.2		1.2		1.4		1.5		1.2
S.D.		0.9		0.8		0.9		0.6		0.6		0.4		0.4		0.6		0.6		0.7		0.8		0.9		0.7

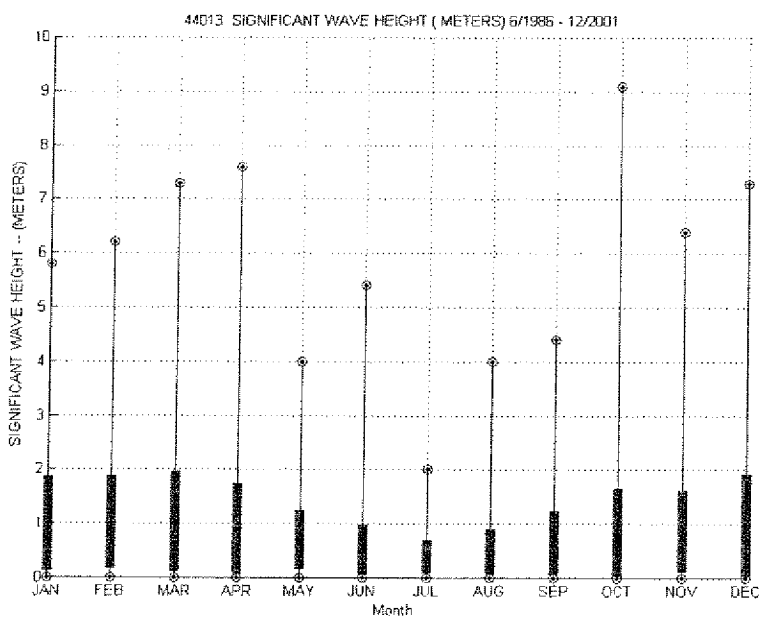
BW041983

SRV Operation South of Long Island

In regard to operating a SRV at PL 1 through PL3, it is Battelle's opinion that the SRV could operate in the wave conditions found south of Long Island. According to Advanced Production and Loading, Inc.[4], a SRV can connect to the submerged turret loading system in 3.5-meter (11.5 foot) waves. As noted in Table 5 and Figure 2 above, seas less than 3 meters occur approximately 99 percent of the time during the winter, with most seas averaging less than 3 meters year round. SRV's can also withstand maintaining that connection in seas greater than 10 meters, which is greater than the largest wave experienced in the last 10 years.

Beyond the WIS and Station 44025 data, Battelle reviewed data from the NOAA NDBC Buoy 44013, which is closest to the future location of the Northeast Gateway LNG project in Massachusetts Bay. The Northeast Gateway project will use the SRV system to deliver gas to Massachusetts. Based on comparing the data provided in Figures 2 and 3 for wave heights and Figures 4 and 5 for Dominant Wave Period, and the information provided from the WIS data analysis, Battelle has concluded that operation of a SRV system south of Long Island is possible. The data from Stations 44025 and 44013 were quite similar in wave conditions and dominant wave periods.

Figure 3. Wave Heights of 44013 (in Massachusetts Bay, near Northeast Gateway)



[4] Advanced Production and Loading, Inc. (APL) is a market leader in the development, fabrication, and sale of advanced systems for offshore production and loading of oil and gas by ships. They were founded in 1993 to develop and commercialize the Submerged Turret Loading (STL) and the Submerged Turret Production Systems. Currently, APL has 10 STL systems in operation worldwide including the North Sea, Norwegian Sea, Gulf of Mexico, and Timor Sea (Australia).

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Figure 4. Dominant Wave Periods of 44025 (off Long Island)

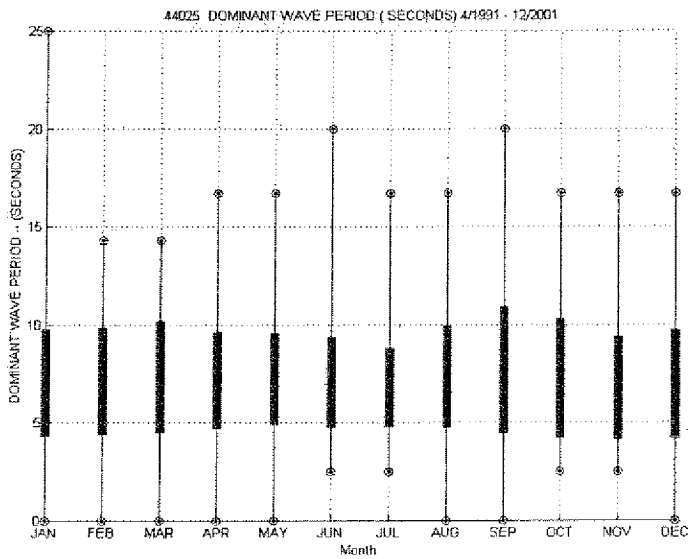
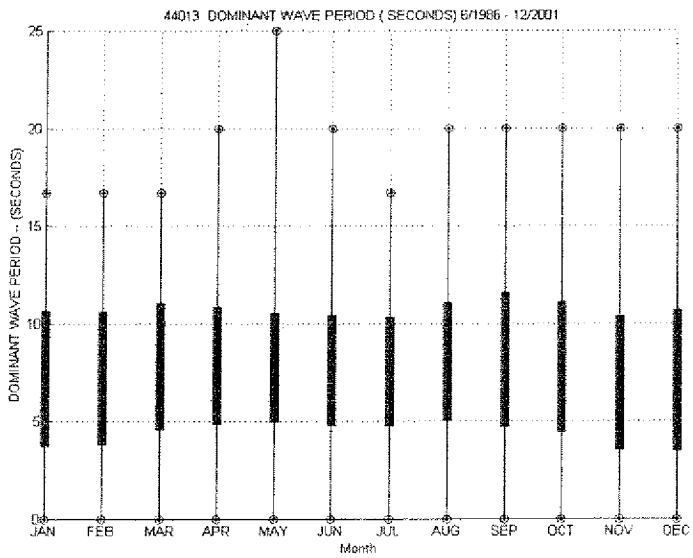


Figure 5. Dominant Wave Periods of 44013 (in Massachusetts Bay, near Northeast Gateway)



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