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DOCUMENT NO.:	REV:	DATE:
23056.02-001	-	28 February 2024

References

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2. PND CASCADE POINT FERRY TERMINAL, Metocean Review, Document 23056.01-001, Rev B, 6 September 2023.
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Introduction

Glosten was tasked with performing a statistical analysis to determine the operability of the exposed ferry mooring at Cascade Point. This statistical analysis was conducted to determine how many days during the summer season (April through September) the wind and waves at the exposed mooring location are within Alaska Marine Highway System's (AMHS) operational weather criterion. This task was done to support the design of the proposed Alaska Department of Transportation and Public Facilities (AKDOT&PF) ferry terminal site located at Cascade Point, Alaska, provided by PND Engineers, Inc (PND). The project site and the wind measurement station used in the study are presented in Figure 1.

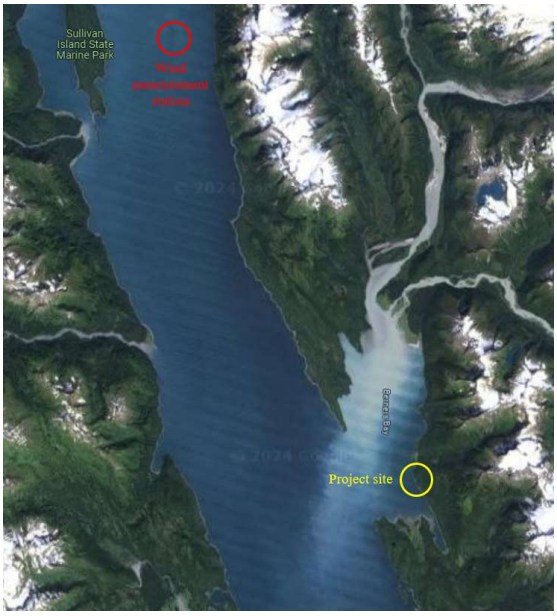

Figure 1 Project site and wind measurement station locations

Wind data

Wind data was taken from the National Data Buoy Center (NDBC) measuring station at Eldred Rock (Reference 1), located about 20 miles northwest of Cascade Point. The location of the wind measuring station, along with the project site, are indicated in Figure 1. The data used in the analysis were from 2006 to 2023 (18 years), presenting a good basis for the statistical analysis.

A previous review of the metocean data for the project site (Reference 2) indicated that the most dominant wind direction, corresponding to the longest fetch distances, are S, SW, W, and NW. Therefore, the current study only includes these directions in the analysis.

The data from the station were analyzed and a general wind rose, presented in Figure 2, as well as monthly wind direction percentages, presented in Figure 3, were computed. It is noticeable from this analysis that that majority of winds at the project site are from N and S, and with less frequency, from NW and SW. Figure 3 presents a noticeable change in the dominant wind direction, from N and NW in months 1-3, to more frequent S winds during the operational months of 4-9.

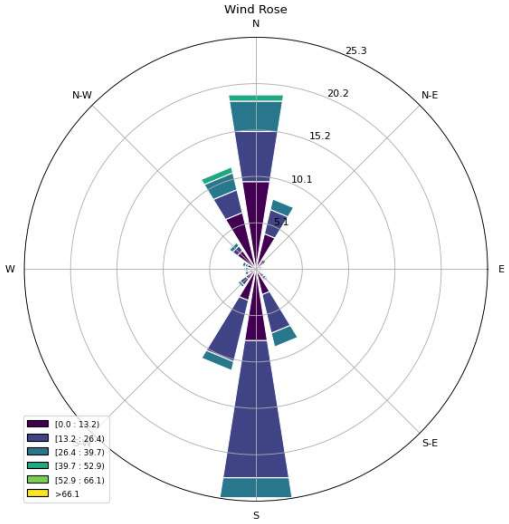

Figure 2 Wind rose for 2006-2023 at Eldered rock station (wind speeds in knots)

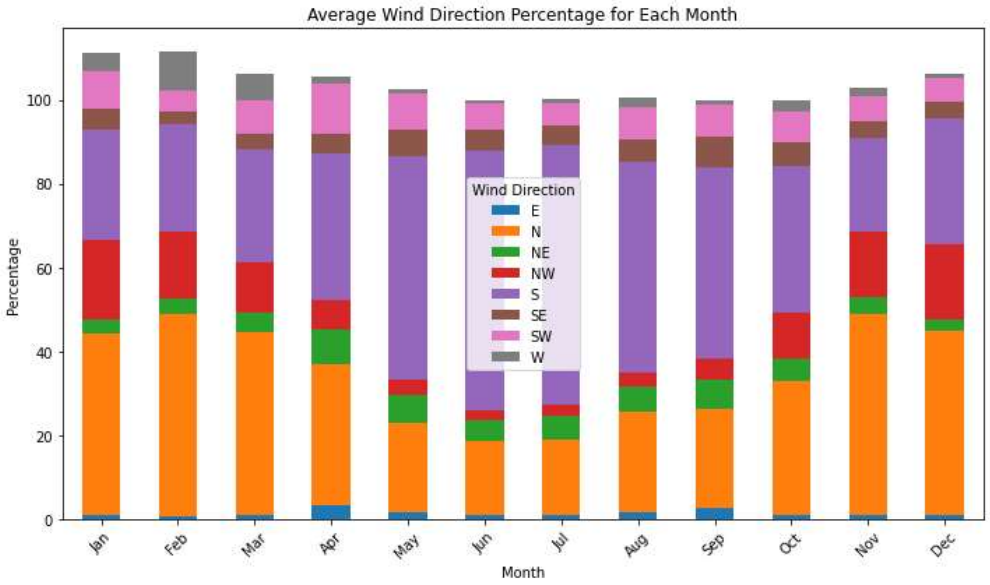

Figure 3 Monthly wind direction percentage at Eldered rock station

Limiting criteria

An operational criterion was provided by PND Engineers as a significant wave height (Hs) of 3 ft. The wave heights resulting from individual wind speeds and directions were computed using a model in both ACES (Reference 3) and SWAN (Reference 4). The same models were used to calculate the wind speeds needed to generate each target significant wave height. To determine wave height sensitivity, 4 wave heights were included in the study as 4, 3, 2, 1.65, and 1 ft, with the corresponding maximum wave heights of 7.25, 5.44, 3.63, 3, and 1.81 ft. The corresponding wind speeds from each direction are provided in Table 1. The more conservative values were found to be those produced by SWAN, including the local depth effects on the wind generated wave heights. An example of SWAN modeled results are presented in Figure 4. These wind speeds, specified for each direction, were used to perform the statistical analysis in the presented study.

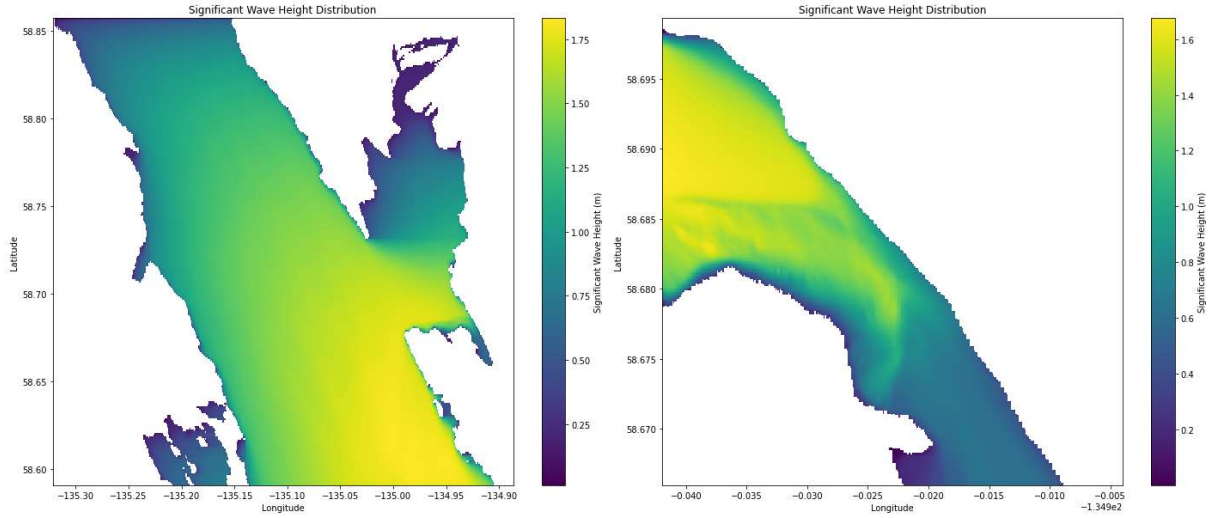

Figure 4 Example of wave heights generated using SWAN software for the whole region (left) and more local to the project site (right), with the project site located on the top left corner.

Table 1 Wind speeds for each target wave height

	H_S = 4.0 FT	H_S = 3.0 FT	H_S = 2.0 FT	H_S = 1.65 FT	H_S = 1.0 FT
DIRECTION	**Wind speed (knots)**	**Wind speed (knots)**	**Wind speed (knots)**	**Wind speed (knots)**	**Wind speed (knots)**
S	51.06	40.82	29.78	25.65	17.37
SW	38.27	30.37	21.91	18.77	12.55
W	34.34	27.38	19.89	17.10	11.52
NW	43.60	34.96	25.60	22.09	15.04
N	80.83	65.82	49.28	42.95	30.04

Statistical analysis and results

The wind data from Eldered rock station (for 18 years) was used to perform statistical analysis. Two exposure durations were included in the analysis, 12 hours (provided by PND Engineers) and an additional 24 hours (for sensitivity check). The results are presented in Table 2 to

Table 6 for each limiting significant wave height (and maximum wave height). Each table presents the following information:

- Minimum values: These values correspond to the minimum operability percent of each month observed during the 18 years of data.
- 10^{th} percentile: These values correspond to the operability percent that is smaller than 90% of times. In other words, 90% of the time operability would be bigger than the 10^{th}percentile value. In simpler terms, in 9 out of 10 instances, operability is higher than this value.
- The maximum wave height values provided for each table correspond to the significant wave height, with assumption of an average of about 720 wave cycles an hour (assuming average peak period of about 5 seconds in the region from Reference 2), using the following relation from Reference 5 (N is the number of waves) :

$$H_{max} = 0.707 H_s \sqrt{\ln N}$$

- The working days are number of total days in a month (30 days a month) based on the minimum observed criteria matching.

Table 2 The operational percentage of each month for significant wave height of 4 ft (Hmax = 7.25 ft)

	12 hrs exposure			24 hrs exposure		
Month	Minimum	90th Percentile	Working days	Minimum	90th Percentile	Working days
1	70.82	89.96	21.24	60.86	87.42	18.26
2	68.70	98.25	20.61	68.70	96.34	20.61
3	64.87	93.90	19.46	61.19	90.08	18.36
4	98.00	99.94	29.40	98.00	99.94	29.40
5	99.59	100.00	29.88	99.59	100.00	29.88
6	100.00	100.00	30.00	100.00	100.00	30.00
7	100.00	100.00	30.00	100.00	100.00	30.00
8	99.86	100.00	29.96	99.86	100.00	29.96
9	99.27	99.94	29.78	96.07	99.94	28.82
10	91.54	96.28	27.46	82.09	95.86	24.63
11	85.71	88.95	25.71	76.35	81.65	22.91
12	83.24	86.03	24.97	74.86	83.27	22.46

Table 3 The operational percentage of each month for significant wave height of 3 ft (Hmax = 5.44 ft)

	12 hrs exposure			24 hrs exposure		
Month	Minimum	90th Percentile	Working days	Minimum	90th Percentile	Working days
1	54.36	65.11	16.31	42.46	63.18	12.74
2	47.42	76.67	14.23	29.58	73.15	8.87
3	46.32	85.72	13.90	38.53	78.11	11.56
4	95.44	97.45	28.63	95.44	95.98	28.63
5	97.95	99.95	29.38	97.95	99.95	29.38
6	99.72	100.00	29.91	99.72	100.00	29.91
7	100.00	100.00	30.00	100.00	100.00	30.00
8	99.59	99.86	29.88	99.59	99.86	29.88
9	94.68	97.42	28.40	87.05	95.86	26.11
10	83.67	88.04	25.10	74.47	81.53	22.34
11	74.50	82.89	22.35	61.54	73.92	18.46
12	54.75	77.29	16.42	44.69	72.36	13.41

Table 4 The operational percentage of each month for significant wave height of 2 ft (Hmax = 3.63 ft)

	12 hrs exposure			24 hrs exposure		
Month	Minimum	90th Percentile	Working days	Minimum	90th Percentile	Working days
1	0.00	40.90	0.00	0.00	23.20	0.00
2	0.00	49.28	0.00	0.00	38.59	0.00
3	33.57	63.77	10.07	28.47	57.41	8.54
4	59.10	86.63	17.73	46.87	80.81	14.06
5	86.44	90.79	25.93	78.77	85.43	23.63
6	94.63	97.26	28.39	91.58	95.18	27.47
7	89.69	96.64	26.91	89.69	95.83	26.91
8	89.82	91.72	26.95	81.84	89.41	24.55
9	83.26	83.56	24.98	78.54	80.20	23.56
10	71.63	77.11	21.49	61.21	68.27	18.36
11	53.70	60.80	16.11	30.77	49.78	9.23
12	44.55	58.12	13.37	24.58	53.11	7.37

Table 5 The operational percentage of each month for significant wave height of 1.65 ft (Hmax = 3.0 ft)

	12 hrs exposure			24 hrs exposure		
Month	Minimum	90th Percentile	Working days	Minimum	90th Percentile	Working days
1	0.00	32.03	0.00	0.00	14.78	0.00
2	0.00	42.43	0.00	0.00	31.88	0.00
3	32.86	52.64	9.86	28.19	47.90	8.46
4	45.27	73.15	13.58	32.46	66.35	9.74
5	72.88	84.61	21.86	70.68	77.53	21.21
6	88.82	89.91	26.65	85.18	86.61	25.55
7	80.91	83.13	24.27	75.96	80.31	22.79

8	72.08	83.07	21.62	70.01	79.48	21.00
9	65.62	72.80	19.69	52.47	66.67	15.74
10	62.89	69.29	18.87	47.56	58.98	14.27
11	40.17	54.95	12.05	22.22	36.63	6.67
12	10.18	36.95	3.05	10.18	24.47	3.05

Table 6 The operational percentage of each month for significant wave height of 1 ft (Hmax = 1.81 ft)

	12 hrs exposure			24 hrs exposure		
Month	Minimum	90th Percentile	Working days	Minimum	90th Percentile	Working days
1	0.00	14.10	0.00	0.00	5.97	0.00
2	0.00	22.46	0.00	0.00	13.41	0.00
3	24.08	35.50	7.22	18.70	23.59	5.61
4	29.84	41.25	8.95	18.05	29.63	5.41
5	47.22	51.56	14.17	30.94	40.88	9.28
6	40.66	50.61	12.20	33.09	37.51	9.93
7	37.55	46.25	11.27	17.70	31.63	5.31
8	36.95	43.92	11.09	24.35	29.79	7.30
9	28.55	41.07	8.57	21.50	28.91	6.45
10	31.45	35.75	9.44	16.64	24.63	4.99
11	19.78	24.81	5.94	8.69	13.26	2.61
12	8.25	14.67	2.48	0.00	9.39	0.00

Concluding remarks

After conducting a comprehensive analysis of wind/wave conditions, we observed significant findings regarding operational efficiency. The study spanned the operational months from April through September. Key observations include:

- The percentage of operability, considering a maximum wave height of 3 feet for exposure periods of 12 (24) hours, ranged from 45.3% (32.5%) to 88.8% (85.2%). This translates to an operational capacity of approximately 14 (10) to 24 (23) days per month.
- A notable sensitivity was observed in the operational thresholds based on the limiting wave height. For instance, adjusting the limiting significant wave height from 4 feet to 1 foot altered the minimum operational percentage drastically, from approximately 98% to 28.5%. This sensitivity underscores the need for a tailored approach in determining the actual limiting values, which should ideally consider specific vessel characteristics.
- The analysis indicates that the implementation of wave mitigation structures, such as breakwaters, could significantly enhance operational periods at this location by reducing the impact of waves.

These findings suggest that a precise evaluation of wave height impacts, coupled with strategic implementation of mitigation measures, can substantially improve operational efficiencies at the project location. Further research into vessel-specific characteristics and their interaction with wave heights could provide more nuanced insights into optimizing operational thresholds.