PROJECT NAME

Minimum Required Tug

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References

1. Aleutian Islands Risk Assessment - Phase B Work Plan, November 2012.
2. Susan L. Bales, “Designing Ships to the Natural Environment”, April 1982.
3. OCIMF, “Prediction of Wind and Current Loads on VLCCs,” 2nd ed., 1994.
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5. Blendermann, W.; "Parameter Identification of Wind Loads on Ships," Journal of Wind Engineering & Industrial Aerodynamics, #51 (1994), pp. 339-351
6. Glosten, “SHIPMAN Maneuvering Simulator”
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Introduction

As part of the Aleutian Islands Risk Assessment Phase 2 work plan (Reference 1), it is required to identify the towing performance capacity required of a tug to handle existing vessels in the prevailing weather conditions. The work plan identified two vessels as being the largest typically found on routes passing close to the Aleutians; a 600,000 BBL crude oil tanker and a 68,000 DWT container ship.

Weather

The evaluation was run for a range of conditions that might be found in the Aleutians. Winds from 20 to 60 knots with sea states to match were examined. Reference 2, Table 7, shows a typical relationship between wind speed and sea state for the North Pacific and was used in this study. It is summarized in Table 1 below. Reference 8 requires an emergency towing vessel suitable for 40 knots. This wind speed and its associated sea state 6 are used in the conclusions for specifying the minimum required bollard pull.

Table 1 Wind and Sea State conditions.

	SS4	SS5	SS6	SS7	SS8
Mean Significant Wave Height (m)	1.88	3.25	5.00	7.50	11.50
Modal Wave Period (s)	8.8	9.7	13.8	13.8	18
Mean Wind Speed (kt)	20	25	40	50	60

Vessels

Actual vessels were selected to match the requirements in the work plan. The vessel particulars are summarized below in Table 2.

Table 2 Vessel Particulars.

	Tanker	Container Ship
Type	NASCO 675,930 BBL	HHI 5,060 TEU Class
Name	*Overseas Ohio*	*Maersk Djibouti*
Length Overall (m)	272(est.)	294
Length Between Perpendiculars (m)	261	238
Beam (m)	32.2	32.2
Deadweight(MT)	90,000	68,282
Design Draft (m)	15	12
Depth (m)	18(est.)	21.6
Block Coefficient	0.82	0.65(est.)

Analysis Methods

The tug force required to handle the vessels was computed for each vessel at each wind speed/sea state for a complete range of wind angles. Different components of the required force were computed for waves, wind, and current. No actual current was applied; the current loadings were used to represent smooth water towing resistance. One knot was used as a tow speed to allow hydrodynamic forces on the vessels to help with steering and control. Current, wave, and wind forces were calculated using the methods presented in References 3, 4, and 5 respectively. All forces were assumed to be aligned.

The towing force was calculated as the worst case of the straight ahead pull or the forward yawing force represented as the maximum turning force at approximately +/- 40 degrees. The towing force for the container ship was dominated by the yawing force due to the high windage while the towing force for the tanker was maximum in the straight ahead condition.

From the force components, the forces for holding the vessel in position, turning the vessel into the wind, and towing the vessel are computed.

Analysis Results

The figures below show the tug forces in MT required to handle the container ship and tanker for a range of wind speeds in knots. At higher wind speeds the wind forces dominate the solution which makes the container ship the limiting case for turning and arresting drift.

The three operations are:

- Arresting drift; the tug force required to prevent the vessel from drifting down wind when it is beam to the wind and waves
- Turning; the tug force required to turn a drifting vessel into the wind and waves without towing crosswind to develop forward speed
- Towing; the tug force required to tow the ship to windward at 1 knot.

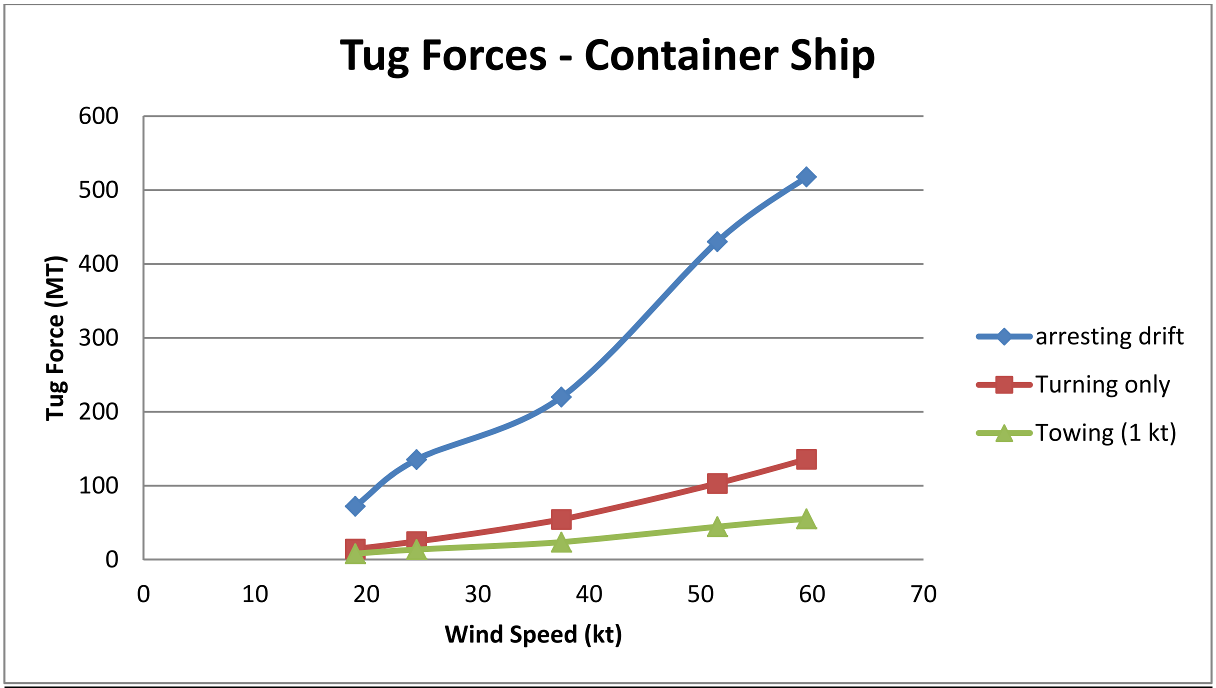

Figure 1 Tug forces on Container Ship.

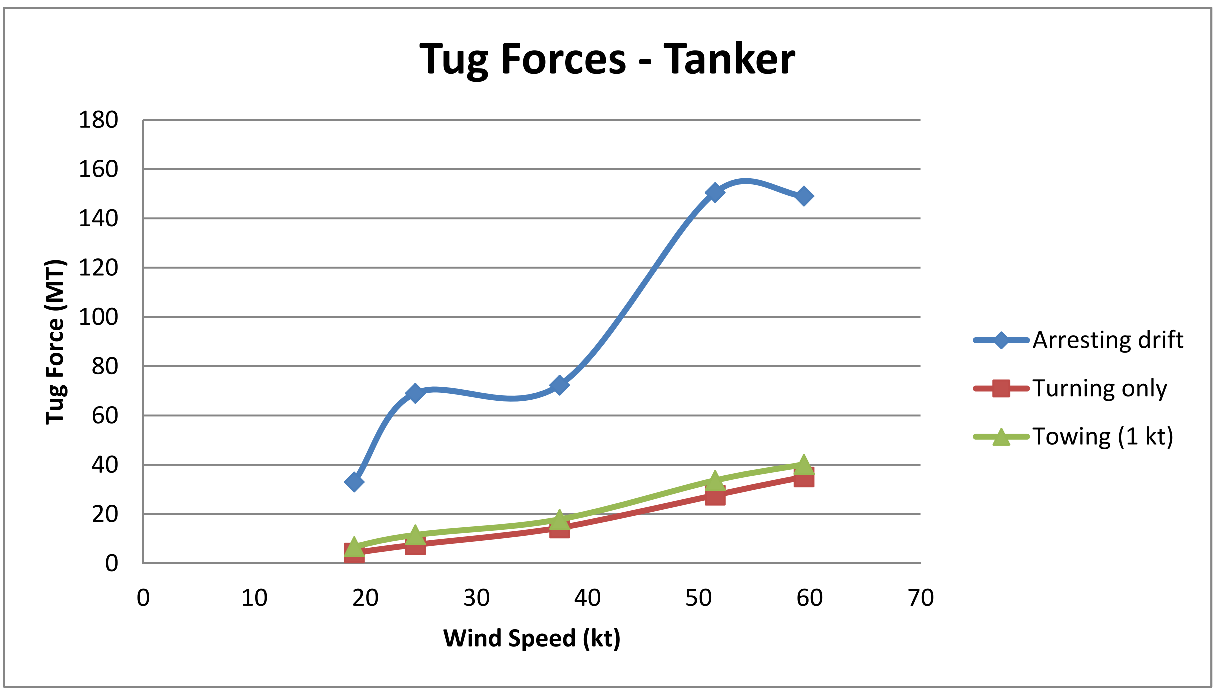

Figure 2 Tug forces on Tanker.

Simulations

As a check on the analysis a series of simulations were undertaken for comparison using Glosten's "SHIPMAN" maneuvering simulator, Reference 6. These simulations were run for the two vessels using 35 to 100 MT tugs with a wind speed of 40 knots. Two scenarios were studied. The first has the tug pulling into the weather until the ship is under control. The second has the tug aligned with the ship to start and gradually heading up wind as the simulation progresses. The second scenario is designed to get the ship moving to allow hydrodynamic forces to assist with the turning. The scenario was considered a success if when/if the vessel was moving forward into the wind. Table 3 shows the minimum tug force required for each vessel. Figures 3 and 4 show examples of the simulator output.

Table 3 Tug forces in Maneuvering Simulations

	Scenario 1 (Tow directly to windward)	Scenario 2 (Tow crosswind, then to windward)
Tanker	45 MT with 76% efficiency factor	35 MT with 76% efficiency factor
Container Ship	65 MT with 76% efficiency factor	55 MT with 76% efficiency factor

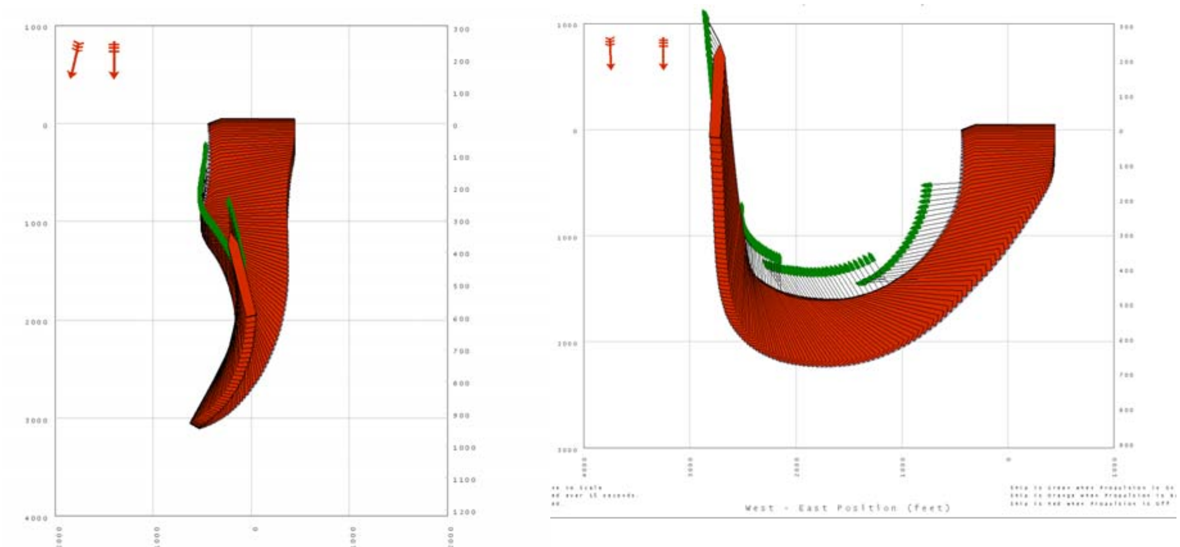

Figure 3: Drifting Simulation – 90,000 DWT tanker – 40 kts wind, 8ft waves
45 MT bollard tug Tow directly to windward (left), 35 MT bollard tug Crosswind tow (right)

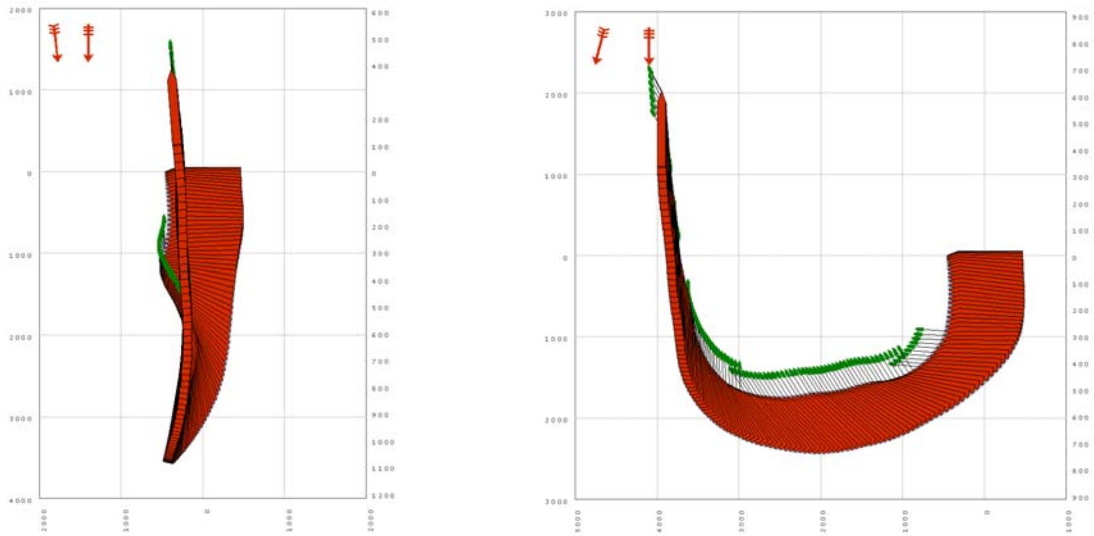

Figure 4: Drifting Simulation – 5060 TEU Containership – 40 kts wind, 8ft waves
65 MT bollard tug - Tow directly to windward (left), 55 MT bollard tug - Crosswind tow (right)

Discussion

Reference 8 requires a tug that can control the drifting vessel. It was not felt that immediate ship arrest would be necessary. The requirement is more important in a situation with extremely limited sea room and the required force for higher winds would be impossible to generate. In a narrow channel or near a rock a cross wind tow would be adequate in most situations to remove the drifting vessel from danger. Reference 8 also requires that the tug be able to tow a grounded vessel. This would greatly depend on the salvage method. If the vessel were floated off, the tug sized in this report would be perfectly adequate. If the tug needs to drag the vessel across the sea bed it would most likely not be adequate. This analysis only addresses towing a floating vessel.

Because the forces on the vessel are greatly reduced with the bow pointed into the weather, the strategy for this analysis is to turn the vessel while allowing drift to leeward. As such the required tug force would be the worst case of the turning or towing requirements. The simulations show less tug force required than the analysis. For scenario 1 this is due to using the worst case turning moments. These occur with the bow lying about 130-140 degrees off the wind. In the simulations the vessels start at about 100 degrees off the wind. The hydrodynamic hull forces due to the downwind drift are tending to turn the vessels more broadside than their worst case positions. The analysis shows that the turning moment is very sensitive to the precise drift angle. Because the actual vessel will be unknown and because both the analysis and the simulation depend on a few representative parameters it was felt that the precise drift angle was unknown and therefore the worst case tuning moments should be used for the tug requirements. Figure 5 shows the variation in turning force related to the drift angle to the wind. The bow is into the wind at zero degrees.

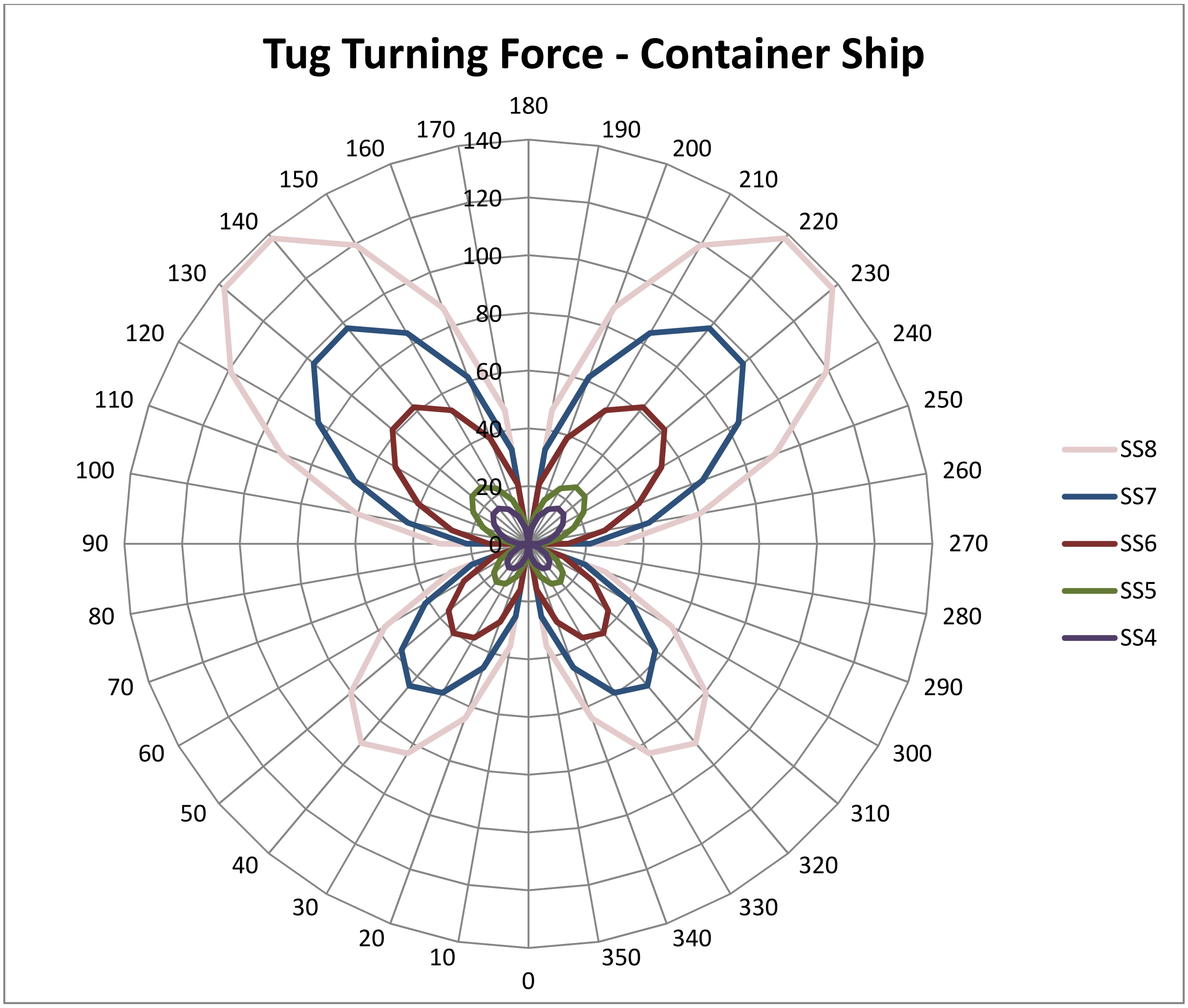

Figure 5 Container Ship Turning force

Similarly with scenario 2, the tug forces from simulation are even smaller than the analytic calculation. Starting the vessel moving allows its own hydrodynamic forces to generate a turning moment and is a good strategy for a smaller tug. It was felt, however that this was another area in which we did not want to be too optimistic. The smaller tug might not be able to operate safely beam on the weather in the worst conditions.

The downwind drift allowed by the smaller tugs in the simulations while gaining control of the vessels ranged from 700 to 1100 meters.

Tug Efficiency

The rated bollard pull of a tug is for ideal, calm, conditions. To equate a tug bollard pull to the tug force computed in this study tug efficiency is applied. This efficiency encompasses additional forces on the tug and decreases in performance due to the high sea states involved. The tug efficiency factors taken from Reference 7 include an allowance for the wave and wind drag on the tug, the drag on the tow line, propeller ventilation, and reductions in throttle settings to prevent over-speeding of the engines.

Conclusions

The tug force required for turning either of the representative vessels in 40 knots of wind and sea state 6 is approximately 62 MT. The tug force required for towing either of the representative vessels against 40 knots of wind and sea state 6 at 1 knot is about 40 MT. A tug with a rated bollard pull of 81MT will be able to handle either of the representative vessels in these conditions. The complete results are summarized in Tables 4 and 5 below.

Table 4 Container Ship.

Sea State	Wind (kt)	Towing Speed (kt)	Towing Force (MT)	Turning Force (MT)	Tug Efficiency	Tug Rated Bollard Pull (MT)
4	20	1	11	16	0.80	20
5	25	1	17	26	0.78	33
6	40	1	40	62	0.76	**81**
7	50	1	64	98	0.74	132
8	60	1	90	138	0.72	192

Table 5 Tanker.

Sea State	Wind (kt)	Towing Speed (kt)	Towing Force (MT)	Turning Force (MT)	Tug Efficiency	Tug Rated Bollard Pull (MT)
4	20	1	7	4	0.80	9
5	25	1	12	8	0.78	15
6	40	1	18	14	0.76	**24**
7	50	1	34	28	0.74	45
8	60	1	40	35	0.72	56