Alaska Department of Transportation & Public Facilities

Research & Technology Transfer

Analysis of AMHS Fast Vehicle Ferry Wake Wash Predictions Phase 1 Report

Comparison of the AMHS FVF Expected Wash Characteristics Against Measured Vessels and Past Studies

Prepared by: Stumbo Associates
15985 Euclid Avenue
Bainbridge Island, WA 98110

June 2002

Prepared for:
Alaska Department of Transportation and Public Facilities
Statewide Research Office
3131 Channel Drive
Juneau, AK 99801-7898

Publication Number:
FHWA-AK-RD-02-04

Form Approved OMB No. 0704-0188

REPORT DOCUMENTATION PAGE

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
JUNE 27, 2002

3. REPORT TYPE & DATES COVERED

4. TITLE AND SUBTITLE
Analysis of AMHS Fast Vehicle Ferry (FVF) Wake Wash Predictions-Phase 1 Report
Comparison of the AMHS FVF Expected Wash Characteristics Against Measured Vessels and Past Studies

5. FUNDING NUMBERS

6. AUTHOR(S)
Stan Stumbo

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Stumbo Associates
15985 Euclid Ave
Bainbridge Island, WA 98110

8. PERFORMING ORGANIZATION REPORT NUMBER
FHWA-RD-AK-02-04

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Alaska Department of Transportation and Public Facilities
Statewide Research Office
3131 Channel Drive
Juneau, AK 99801-7898

10. SPONSORING OR MONITORING AGENCY REPORT NUMBER
FHWA-RD-AK-02-04

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This study reviewed the predicted wake wash of the Fast Vehicle Ferry and compared it to wake wash of other vessels. Model tests were conducted in a tow tank to predict the ship's wake wash. Predictions were difficult to obtain and tended to be high. Wake wash as reported by Washington State Ferries was compared to the FVF and corroborated that predictions for wake wash on the FVF were probably high. Conclusions and recommendations are presented.

14. SUBJECT TERMS
Ferry, Fast Vehicle Ferry, Predictions, Wake Wash, Wake Energy, Environmental Impacts, Scour, Water, Water Transportation, Marine Transportation, Maritime Transportation, Water Waves, Hydrologic Phenomena

15. NUMBER OF PAGES
28

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	17. SECURITY CLASSIFICATION OF THIS PAGE	18. SECURITY CLASSIFICATION OF ABSTRACT	19. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Table of Contents

List of Figures

List of Tables

Stumbo Associates
email: stumbo@speakeasy.org

ANALYSIS OF AMHS FAST VEHICLE FERRY (FVF) WAKE WASH PREDICTIONS - PHASE 1 REPORT

EXECUTIVE SUMMARY

PURPOSE
This study reviewed the predicted wake wash of the FVF, and compared that with wake wash of other vessels.

DEFINITION OF TERMS
Wake Wash Height: The height, from peak to trough, of the highest wave in the series.
Wake Wash Period: The time, in seconds, for the highest complete wave cycle to pass a point.
Wash Energy: Wake wash energy measures the impact a wave train can have on a beach, structure, or vessel.

DESIGNER'S WAKE WASH PREDICTION
The designer of the FVF, Nigel Gee & Associates conducted model tests in a tow tank to get predictions of the ship's wake wash. At a service speed of 32 knots, the predictions are:

- Wash Height = 74.2 centimeters (29.2 inches)
- Wave Period = 6.3 seconds
- Wash Energy = 42,960 joules/meter

It is difficult to get good predictions of wake wash with model tests because of the narrowness of the tow tank. Wash predictions are historically on the high side of full scale measurements.

WASHINGTON STATE FERRIES' FVF FEASIBILITY STUDY
In 1996 Washington State Ferries (WSF) conducted a study of six different designs of FVF's to predict their wake wash. Later, data from actual full sized vessels was added to the study, notably the Canadian Pacificat ferries. For the AMHS FVF to compare on the same basis to the others in this study, the wake wash would be:

- Wash Height = 47 centimeters (18.5 inches)
- Wave Period = 6.3 seconds
- Wash Energy = 27,600 joules/meter

This is much less than the tow tank test results and further indicates that predictions may be high.

COMPARISON WITH OTHER VESSELS
FVF wake predictions are compared to actual measurements of other ships as follows:

VESSEL	WASH HEIGHT	WASH ENERGY
QUEEN OF COQUITLAM	23 inches	24,920 j/m
AMHS FVF (range)	18.5 - 29 inches	27,600 - 42,960 j/m
PACIFICAT	44.5 inches	180,000 j/m

CONCLUSIONS

1. The actual FVF may prove to have lower wash characteristics than predicted.
2. If the actual vessel wash characteristics prove to be lower than predicted, they may be comparable to existing ferries that successfully operate in a region with waters of similar depth and shorelines to Alaskan waters.
3. Depending on a comparison with wake wash measurements from AMHS vessels and cruise ships, there is a strong probability that the size and energy of the FVF wash will not exceed that of these present vessels.

RECOMMENDATIONS

1. Obtain wake wash measurements of AMHS vessels and cruise ships that ply Alaskan waters for further comparison with the predicted and actual FVF wake wash. This is Phase 2 of this Study and is expected to be complete in July 2002.
2. FVF operational guidelines and route planning decisions should be based on the comparisons with other vessels that are operating successfully on the same route, along with thorough review of the route and associated shorelines.
3. Even though the actual FVF wash may prove to be less than predicted and similar to other vessels in the region, public perceptions of fast ferry wash make it prudent to thoroughly document the shoreline conditions of sensitive locations along proposed routes.

Stumbo Associates
email: stumbo@speakeasy.org

June 27, 2002

ANALYSIS OF AMHS FAST VEHICLE FERRY WAKE WASH PREDICTIONS for ALASKA MARINE HIGHWAY SYSTEM FAST VEHICLE FERRY (FVF)

PHASE 1 REPORT

COMPARISON OF THE AMHS FVF EXPECTED WASH CHARACTERISTICS AGAINST MEASURED VESSELS AND PAST STUDIES

Purpose

To compare the predicted wash characteristics of the AMHS FVF with other vessels measured and to make an initial assessment of the impact and acceptability of the wake wash on the proposed route of the new ferry in Southeast Alaska.

DEFINITION OF TERMS USED IN ANALYSIS

Wake Wash Height: the height, measured in centimeters, from peak to trough, of the highest wave in the series of waves produced by the passing of the measured vessel. Wake wash height is measured or mathematically normalized to a distance of 300 meters perpendicular to the centerline of travel of the vessel. 300 meters is chosen to provide a basis for comparison between various vessels measured under similar circumstances by the investigators.

Wake Wash Period: the time, in seconds, for one complete wave cycle to pass a fixed point. The period of the highest wave in the series of waves produced by the passing of the measured vessel is determined by the time difference between the zero crossing of the start of the highest wave and the zero crossing of the start of the next wave in the series.

Wash Energy : Wash energy is calculated from the standard formula in numerous texts (the U.S. Army Corp of Engineers' Shore Protection Manual, Reference 1, for one) of:

$$E = \frac{\gamma g\ H^2 L}{8}$$

where γ is the density of water, g is the acceleration due to gravity, H is the wash height, and L is the wash wavelength. The term for wavelength in this formula is to be replaced by a function of wash period from the relationship given below:

$$L = \frac{gT^2}{2\pi}$$

resulting in the following equation:

$$E = \frac{\gamma g^2 H^2 T^2}{16\pi}$$

In metric units, with H in meters and T in seconds, this formula reduces to:

$$E = 1961 H^2 T^2$$

with the output expressed in joules per meter of wave front.

Length Froude Number: a convenient non-dimensional ratio for use in comparisons is given by:

$$F_{nl} = \frac{V}{\sqrt{g(LWL)}}$$

where V is vessel speed, g is the gravitational constant, and LWL is the vessel waterline length.

FVF WAKE WASH PREDICTIONS

Reference 2 provided data from the Nigel Gee and Associates (NGA) tow tank tests of a 70 meter FVF which predicted wake wash characteristics of the proposed hull form for the AMHS FVF. It has been the investigators' practice to measure wake wash at 300 meters from the sailing line or convert the measurements to that distance in order to have a convenient common basis of comparison for all vessels. NGA provided data at 304.8 meters (1000 feet) and the data at that distance is not discernibly different than for 300 meters. This data has been graphed and is presented in Figures 1 and 2 below with the data points for the service speed of 32 knots noted.

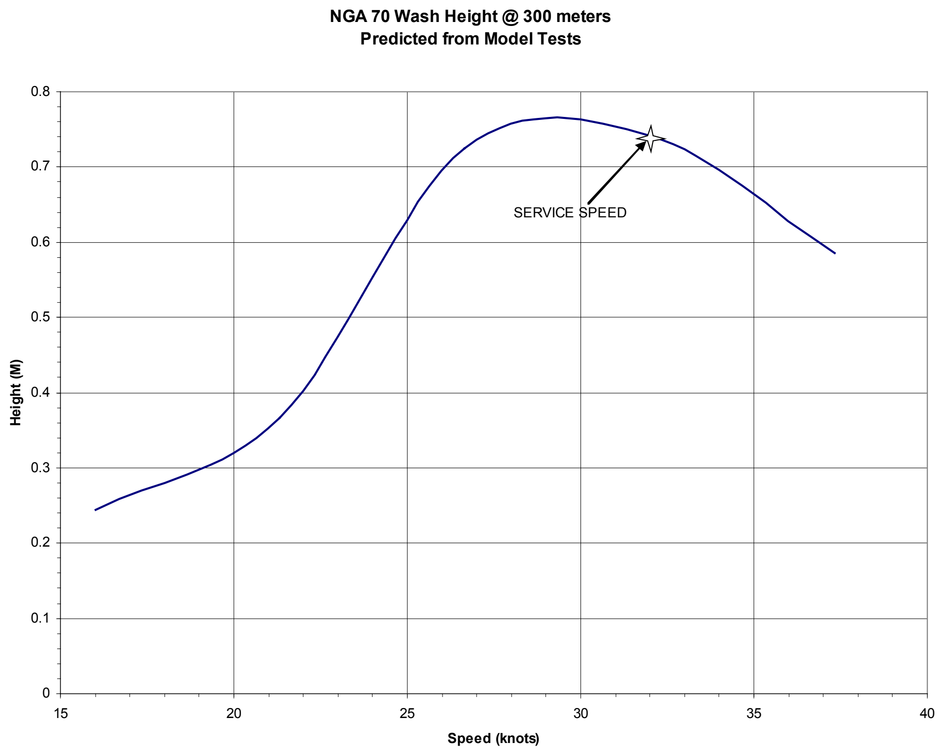

Figure 1. NGA 70 Predicted Wash Height

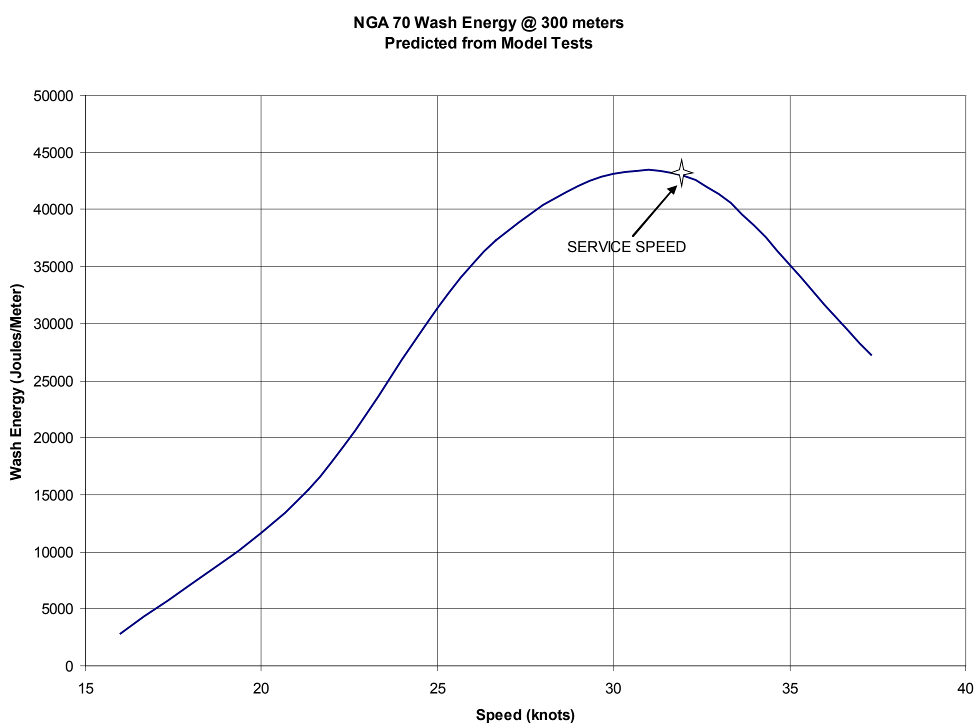

Figure 2. NGA 70 Predicted Wash Energy

At the service speed of 32 knots, the wash characteristics are predicted to be:

- H = 74.2 cm
- E = 42, 960 joules/meter

The hump, or maximum, for height is at 29 knots (F_{nl} = .608) and for energy, the hump occurs at 31 knots (F_{nl} = 0.65). These hump speeds are slightly high as most vessels in the investigators' data base experience the height and energy humps at F_{nl} of 0.55 to 0.60. This means that if the prediction curves are in error, the actual wake wash of the full size vessel will be lower than predicted at service speed.

The tow tank tests were conducted on a model of a 70 meter FVF whereas the AMHS FVF being constructed is a 73 meter vessel, 3 meters longer than the hull form tested. If the parent hull form remains the same and is just "stretched" to 73 meters, it can be expected that the predicted wash from the stretched vessel will change. The 73 meter FVF wash height will likely be slightly less and the period will be slightly more than for the 70 meter vessel. The hump speeds for height and energy will also increase slightly.

Some comments need to be made about wake wash predictions based on hull model tow tank tests. Almost all tow tanks in the world are too narrow to accurately assess wake wash characteristics of vessels tested. The distance between the centerline of travel and the tow tank walls is too short to allow, first, the 'forced' waves from the vessel to settle into gravity waves and, second, for the divergent bow wave to interact with the transverse Kelvin wake before the waves are measured. Moreover, there are usually reflected waves from the side walls which influence the measurements. The usual result is that predictions based on tow tank tests tend to be higher in height and energy than the actual full size vessel on its route.

WASHINGTON STATE FERRIES' PASSENGER/VEHICLE FAST FERRY (PVFF) CONCEPTUAL FEASIBILITY STUDY

There are not many vessels afloat that fall in the range of characteristics of the FVF for comparison purposes, and of those that exist, there is no record of wake wash measurements having been made. However, in 1996, Washington State Ferries (WSF) conducted a Passenger/Vehicle Fast Ferry (PVFF) Conceptual Feasibility Study for a vessel of similar characteristics.. This study used computational fluid dynamics to predict the wash characteristics of six PVFF concept design catamaran hull forms and related the data to actual vessels wherever possible.

Six design firms submitted independent concept design hull forms for this study, some submitting multiple designs (variations on the same parent hull form). The firms were:

- Art Anderson Associates, Bremerton, WA
- The Glosten Associates, Seattle, WA
- Advanced Multihull Designs, Sydney, Australia
- INCAT, Hobart, Tasmania
- Appolonio Associates, Bellingham, WA

WSF found there is an apparent consistency in the variation of wake wash characteristics (height, period and energy) with vessel displacement for catamarans of roughly the same service speed. This consistency held true when actual vessel data was included. Actual vessels were WSF's CHINOOK and B.C. Ferries' PACIFICAT.

The following graphs depict this relationship overlaid with trend lines and their formulae. The NGA predictions from Reference 2 are also shown and are further indication (not evidence or proof) that the NGA predictions may be high.

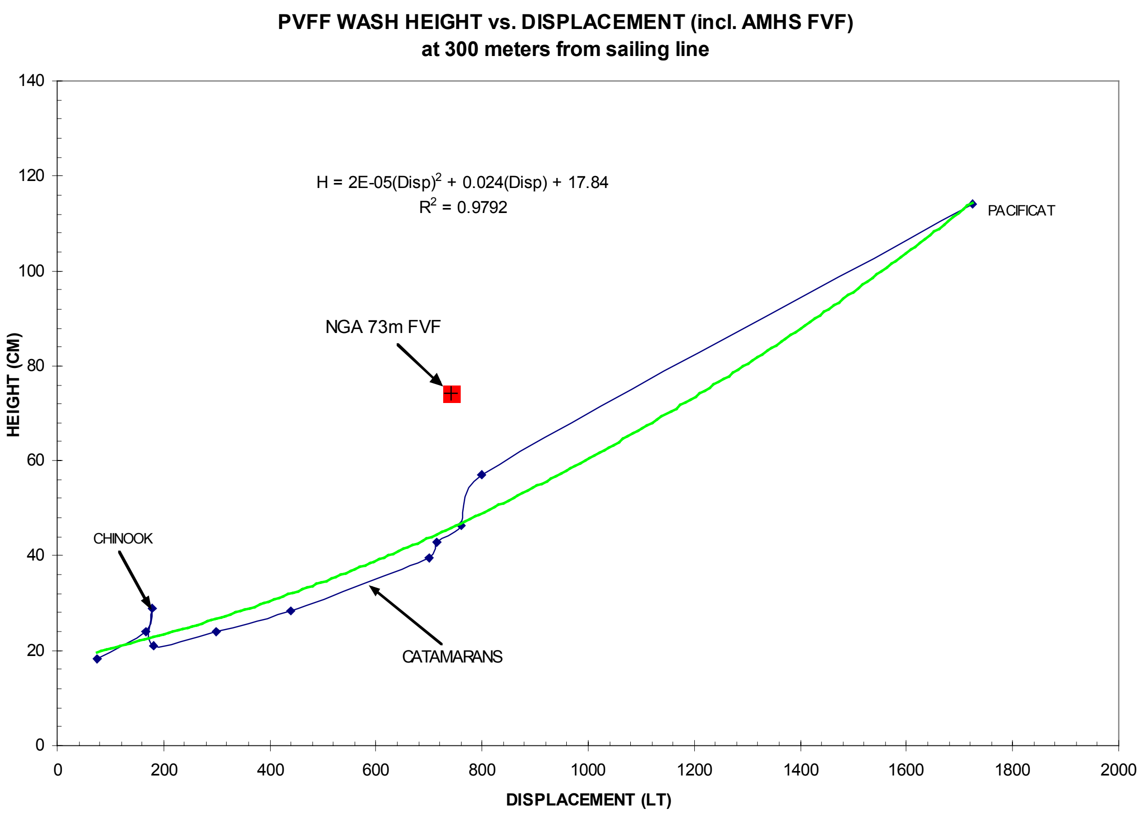

Figure 3. PVFF Wash Height vs. Displacement (incl. AMHS FVF)

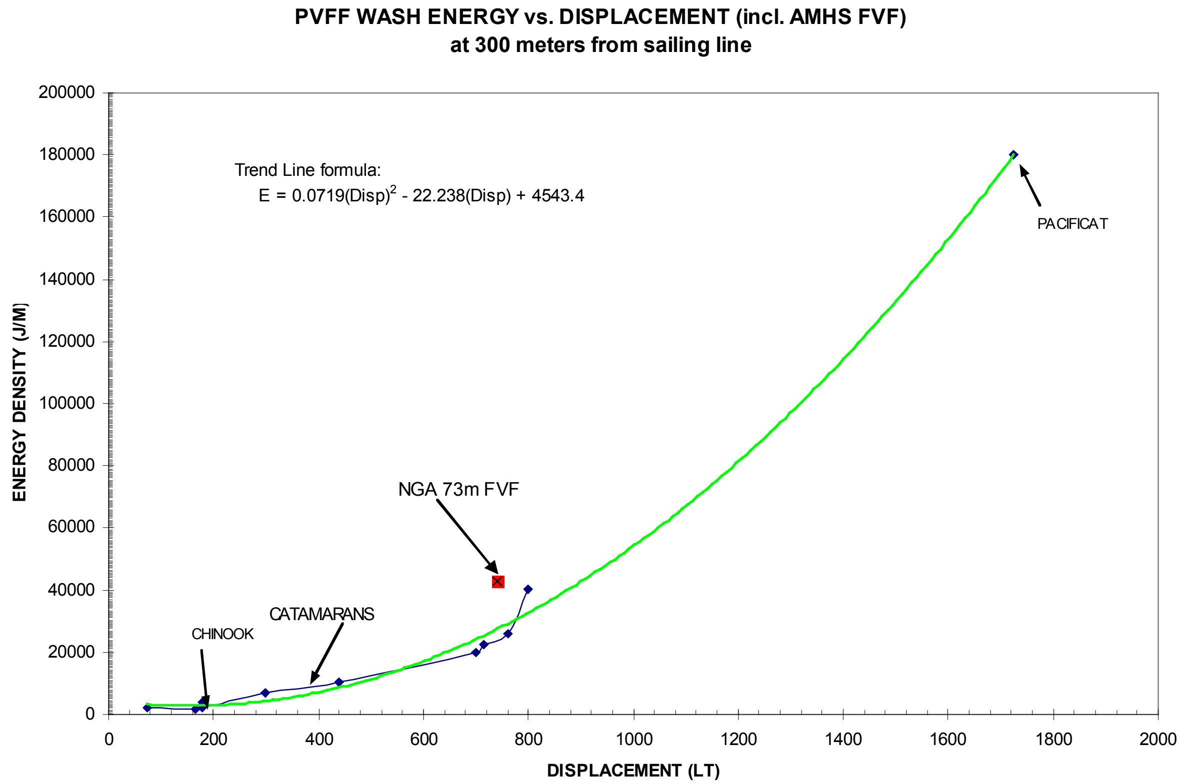

Figure 4. PVFF Wash Energy vs. Displacement (incl. AMHS FVF)

Using the trend line formulas to compute a possible "lower bound" on the FVF wash predictions results in the following

- H = 47 cm
- E = 27,600 joules/meter

Using the NGA tow tank predictions as an upper bound, the expected range of wash characteristics is then:

- H = 47 – 74 cm
- E = 27,600 – 42,960 joules/meter

If the hull form of the AMHS FVF is a development of the FLYING CLOUD and FINEST designs by NGA, as we understand it to be, we have more reason for an optimistic prediction that the wash of the AMHS FVF will be closer to the bottom of the range than the top.

COMPARISON WITH OTHER VESSELS

From their data base of wash measurements of over 50 vessels, the investigators extracted wash characteristics of a broad range of vessels. These characteristics are presented in Table 2 below, which includes the NGA FVF predictions. The vessels are presented in order of increasing wash energy. The New York Fast Ferry M/V BRAVEST has been included because we understand it is the parent hull form for the larger FVF.

VESSEL NAME	VESSEL TYPE	CAPACITY (CARS/PAX)	SERVICE SPEED (KTS)	DISPLACEMENT (LT)	WASH HEIGHT (CM @ 300 M)	WASH ENERGY (JOULES/M @ 300 M)
ST. NICHOLAS	Medium Speed Aluminum Catamaran	0/149	27.7	55	16.2	973
BRAVEST	High Speed Aluminum Catamaran	0/350	31.5	150 ?	20.6	1677
CHINOOK/ SNOHOMISH	High Speed Aluminum Catamaran	0/350	34	190	22	2100
SKAGIT/ KALAMA	Medium Speed Aluminum Monohull	0/250	25	98	38	5613
Jumbo Mark II Class	Steel Double-Ended Monohull	218/2500	18	4660	55	9530
Spaulding Class Golden Gate Monohulls	Medium Speed Aluminum Monohull	0/750	20	220	51	14,100
QUEEN OF COQUITLAM	Steel Double-Ended Monohull	362/1466	21	6551	59	24,920
AMHS FVF (predicted)	High Speed Aluminum Catamaran	35/250	32	741.88	74	42,960
PACIFICAT	High Speed Aluminum Catamaran	235/1000	34	1900	113	180,000

Table 2. Wake Wash Characteristics of Selected Ferries

COMPARISON OF FVF WAKE WASH WITH QUEEN OF COQUITLAM CLASS AND PACIFICAT

Because the predicted AMHS FVF wash characteristics fall between the QUEEN OF COQUITLAM Class[1] and PACIFICAT Class ferries, it is appropriate to examine these characteristics more closely. Figures 5 and 6 plot the full range of wash height and energy characteristics of these vessels:

[1] Queen of Coquitlam is a conventional monhull operating below hump speed. PACIFICAT is a high speed catamaran, also operating below hump speed.

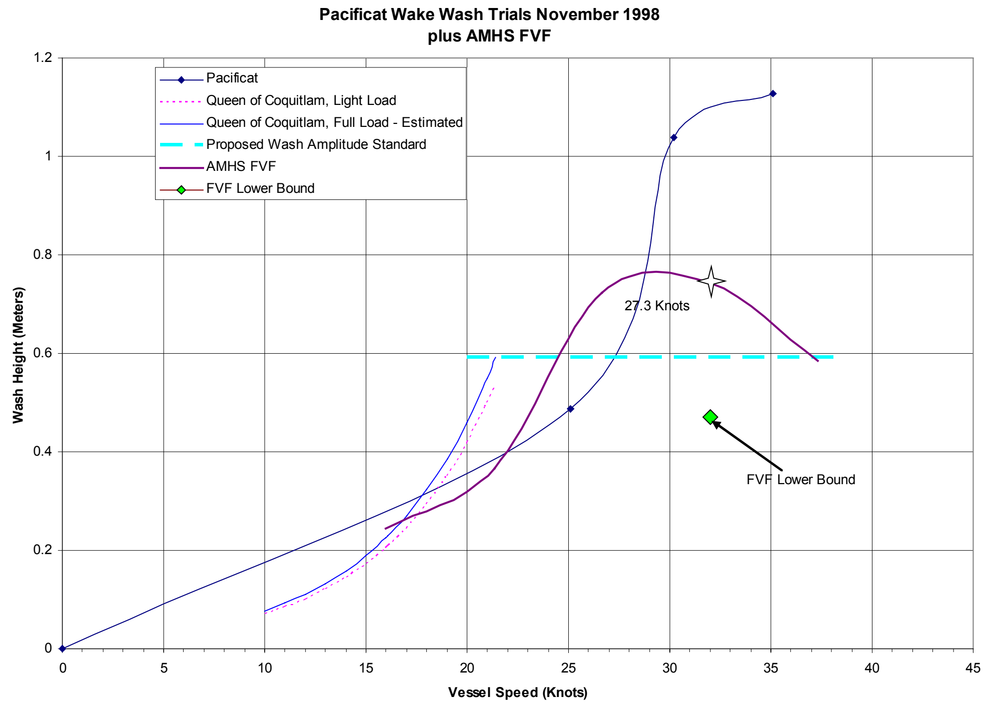

Figure 5. Pacificat Wake Wash Trials with AMHS FVF Predictions (Height)

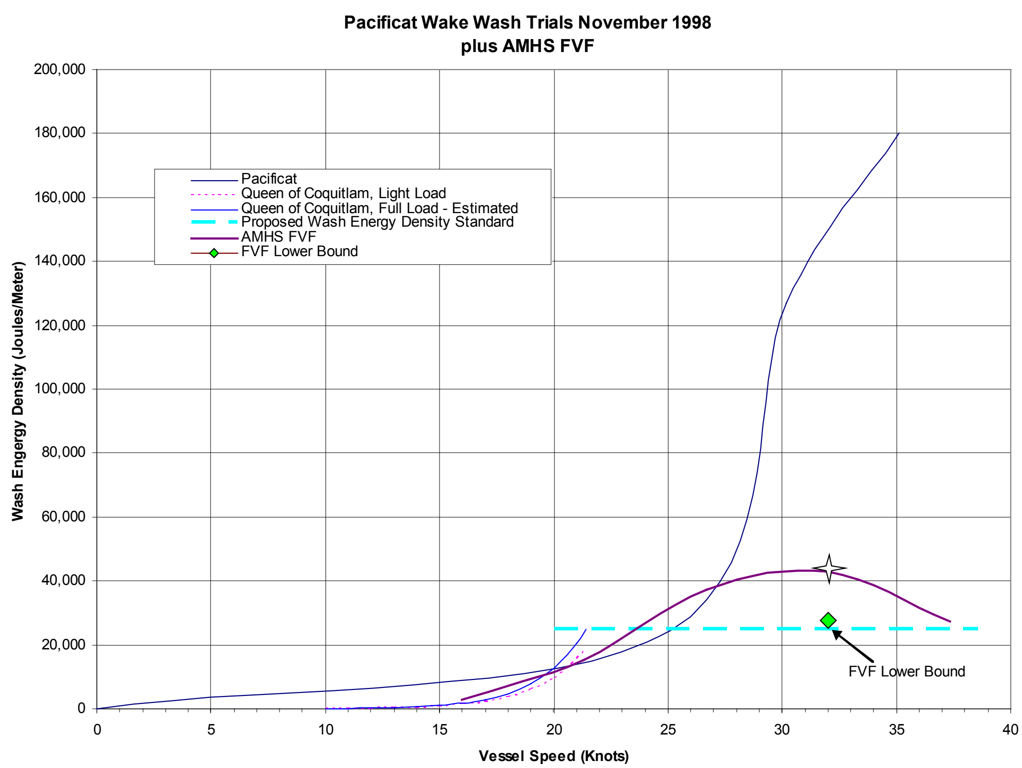

Figure 6. Pacificat Wake Wash Trials with AMHS FVF Predictions (Energy)

The range of wash heights and energies of the AMHS FVF are predicted to be significantly less than the PACIFICAT and, if actual measurements are lower than predicted, could approach the characteristics of the QUEEN OF COQUITLAM Class, vessels that have successfully operated without adverse wake wash impact on Howe Sound and the Georgia Strait for decades. The waters of Howe Sound and the Georgia Strait are similar to Peril Strait and Chatham Strait with the exceptions that those in Alaskan waters have several narrow passages but do not have the human shoreline habitation and construction of those in Canadian waters.

CONCLUSIONS

1. The nature of the data provided in Reference 2 indicates that the actual vessel may prove to have lower wash characteristics than predicted.
2. If the actual vessel wash characteristics prove to be lower than predicted, they may be comparable to an existing monohull ferry that successfully operates in more populated waters of similar depth and shoreline characteristics, compared to the proposed AMHS route.
3. Depending on a comparison with data from AMHS vessels and cruise ships that ply the Sitka – Juneau route, there is good probability that the FVF wash characteristics will not exceed that of these present vessels.

RECOMMENDATIONS

1. Obtain wake wash measurements of AMHS vessels and cruise ships that ply the Sitka – Juneau route for comparison with the predicted and actual FVF wash characteristics.
2. Base route planning decisions on the comparisons with other vessels that are operating successfully on the same route.
3. Even though the actual FVF wash may prove to be less than predicted and similar to other vessels in the region, public perceptions of fast ferry wash make it prudent to thoroughly document the shoreline conditions of sensitive locations along proposed routes.

REFERENCES:

1. **"Shore Protection Manual",** Coastal Engineering Research Center, Dept. of the Army, Waterways Experiment Station, Corps of Engineers, 1984.
2. **"Alaska Marine Highways 70 m Car Passenger Ferry, Wave Signature"**; Nigel Gee and Associates; undated.

Stumbo Associates
Email: stumbo@speakeasy.org

ROUTE FAMILIARIZATION VOYAGE NOTES

Introduction

On April 19, 2002, the investigators made a familiarization voyage from Sitka to Juneau aboard the M/V KENNICOTT accompanied by Mr. Gary Smith of AMHS and operations consultant, Captain Trafford Taylor. Winds were light and the opportunity for observation was good. Most of the 133 nautical mile route is in deep water with sufficient channel width to attenuate the wash waves before they reach steep, rocky, uninhabited shorelines where concern for wash is minimal. Based on the anticipated wash characteristics of the FVF, the following locations outside harbor vicinities were identified where wash concerns must be resolved:

- A float house in a cove 600 meters south of Dog Point on the Lisianski Peninsula.
- Olga Strait
- Neva Strait
- Sergius Narrows
- Cabins at the southwest corner of Shelter Island west of Auke Bay

Discussion

Dog Point Float House. The ferry passes 600 meters from the cove shoreline. Deep draft vessels currently slow when passing this area. The FVF should also briefly slow in this area to a speed of 12 to 15 knots. See Figure 7.

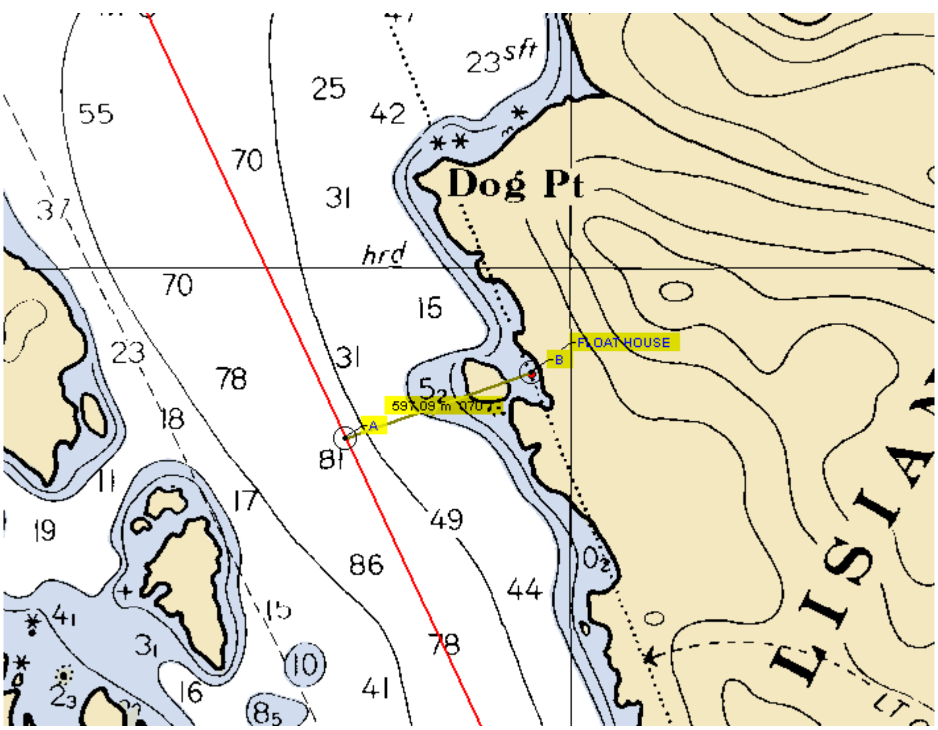

Figure 7. Location of float house near Dog Point

Figure 8. Float house near Dog Point

Olga Strait

Olga Strait is a 4 nautical mile long strait that has an average width of 400 meters and a depth that varies from 150 feet to 30feet.

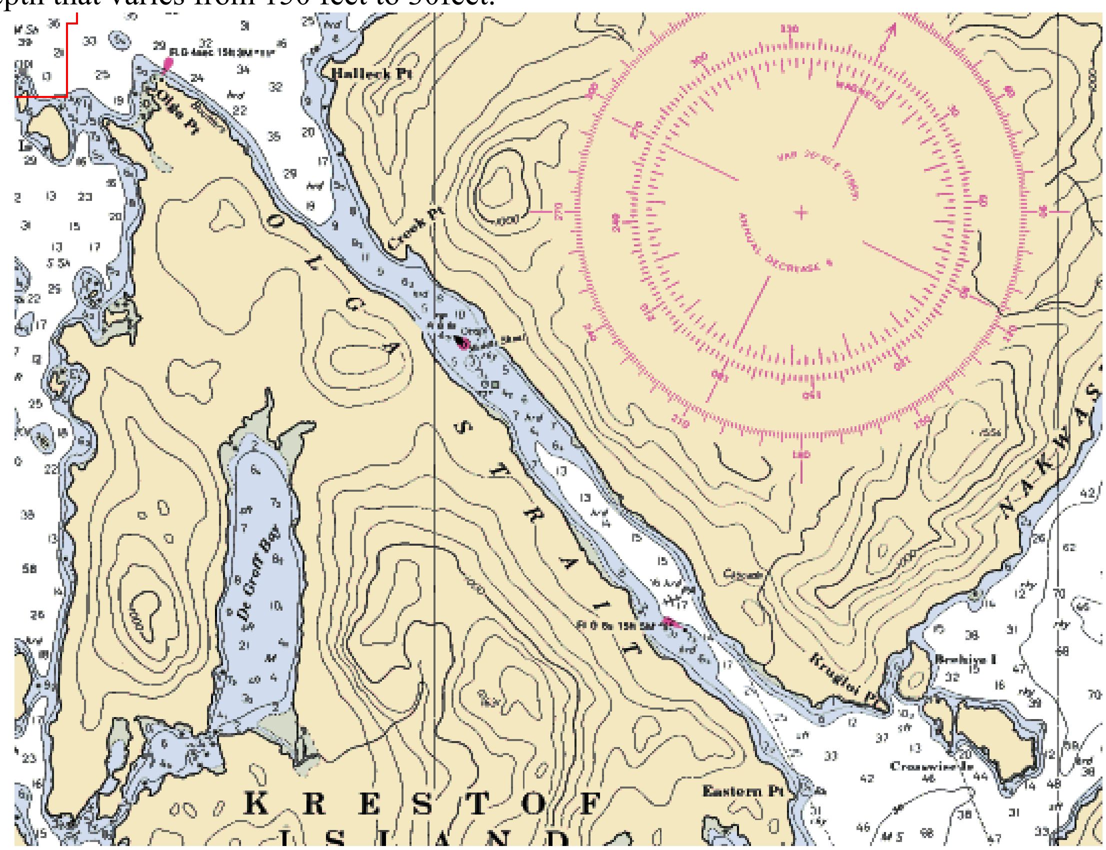

Figure 9. Olga Strait

It may be possible to transit Olga Strait at service speed but there are factors that will need operational trials before making that decision. The lower portion of the strait has depths for about 1 mile that, depending on the tide level, will be close to or equal to the critical depth for the FVF at 32 knots. The critical depth is 18 fathoms or 108 feet. The area of concern is crosshatched in the chart excerpt in Figure 10. It requires a finite period of time at critical depth for the critical wave to develop. The longest sailing line at or near critical depth occurs at tide levels between +6 feet and +12 feet.

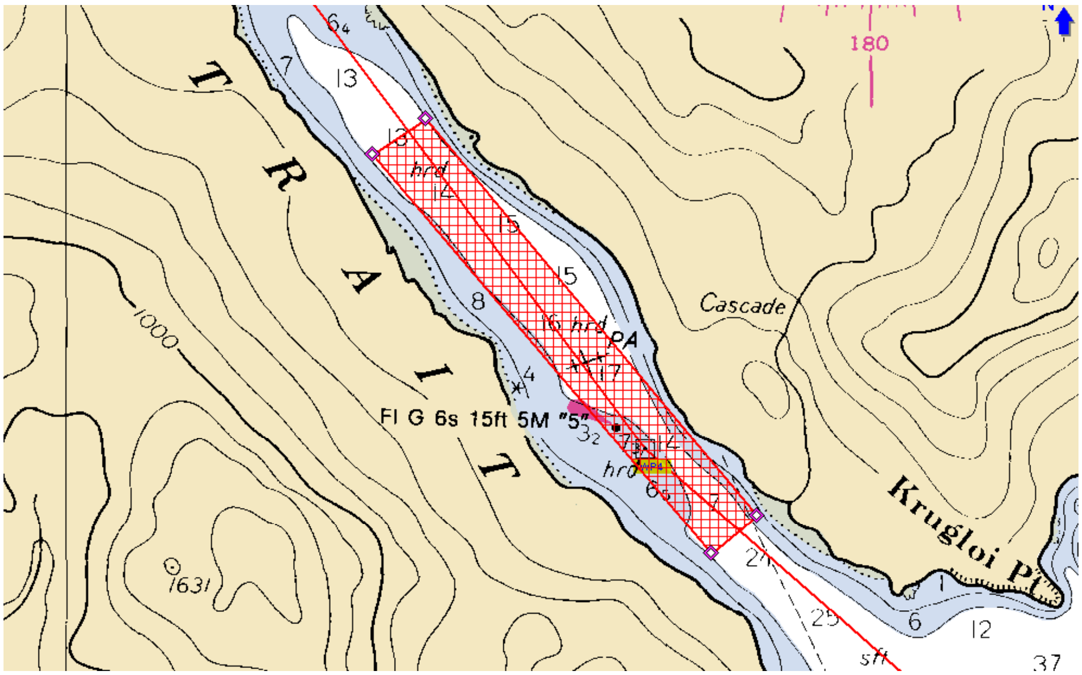

Figure 10. Possible critical wave area in Olga Strait

If critical waves develop in this area, the divergence angle of the bow and stern waves will increase and may approach 90 degrees. At the same time, the wash height will increase and could double. The resulting wash pattern resembles Figure 11 below:

Email: stumbo@speakeasy.org

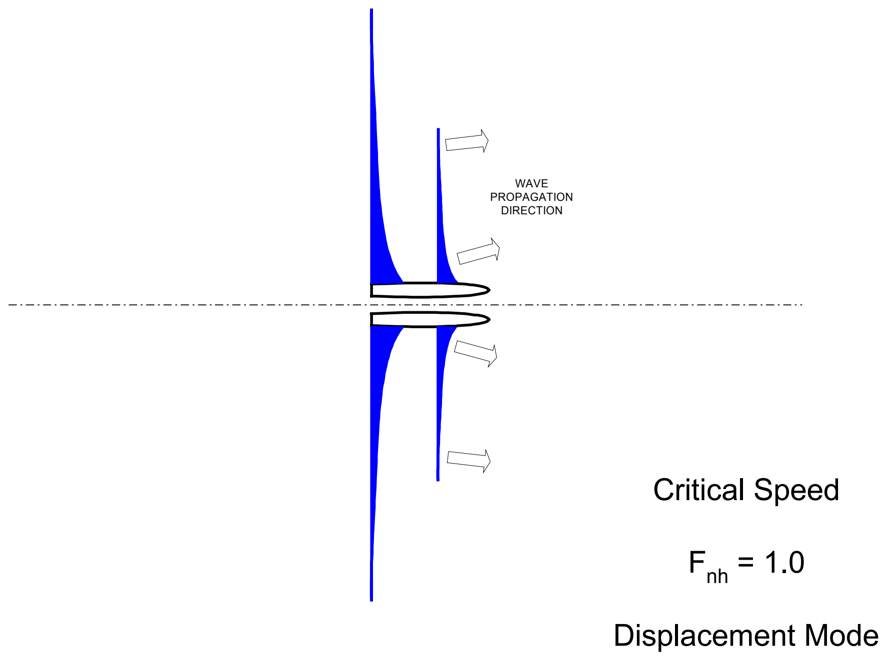

Figure 11. Critical wave pattern, catamaran hull

If there is any concern about a wake wash problem developing in this area, this could be a situation requiring speed and or course adjustment at certain tidal conditions. Once past the critical depth area, the remainder of Olga Strait is shallow, averaging 5 to 7 fathoms. At service speed, the FVF will create a supercritical wave pattern that is depicted in Figure 12.

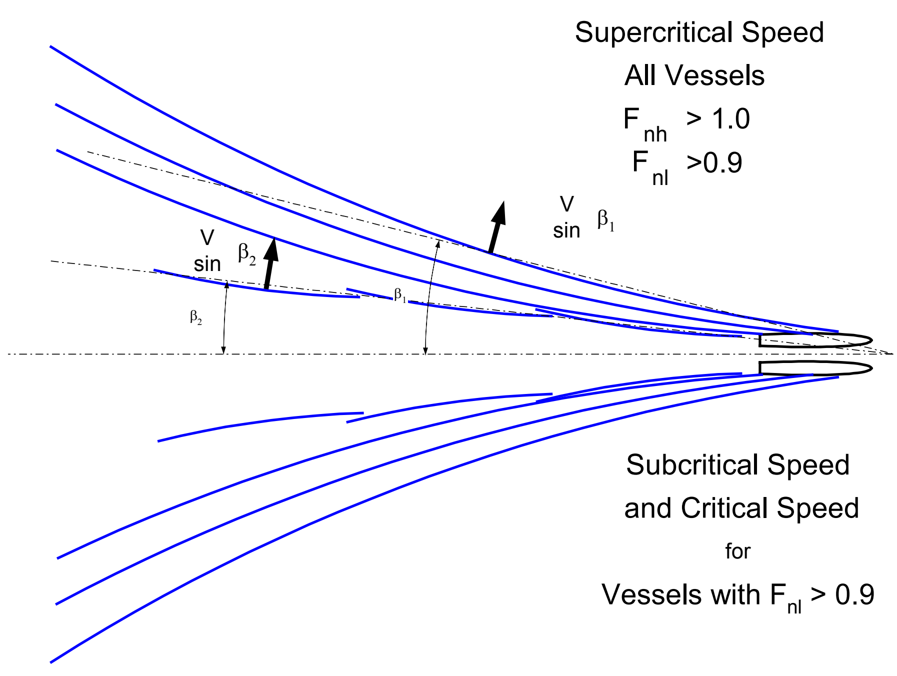

Figure 12. Supercritical wave pattern, catamaran hull

Note the fan-shaped pattern of continuous waves that will arrive at a parallel beach at a shallower angle than the typical deep water wave pattern shown below for this vessel in Figure 13.

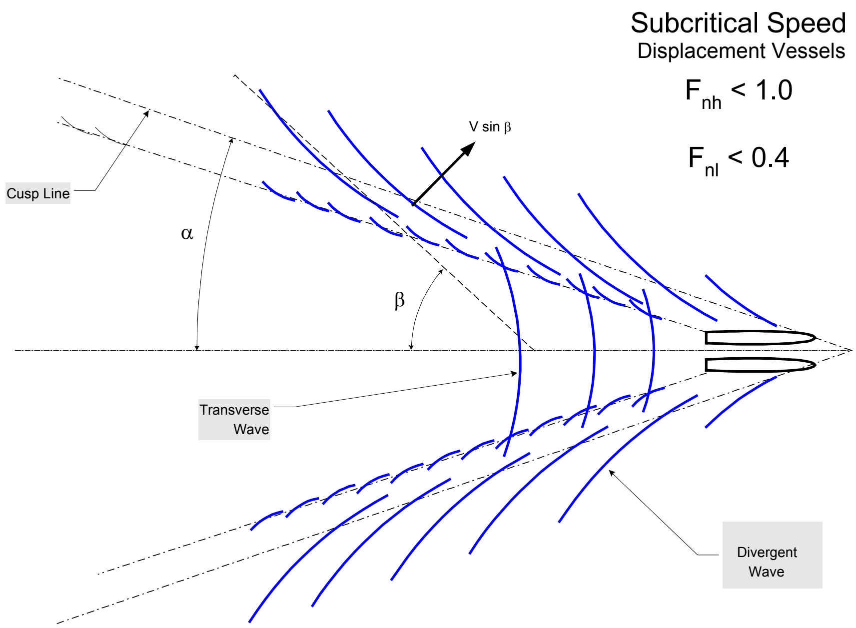

Figure 13. Subcritical wave pattern

The existence and impact of this phenomenon will have to be assessed before a decision can be made to transit this strait at service speed.

<u>Neva Strait</u>

Neva Strait, like Olga Strait, is about 4 nautical miles long and 400 meters in average width. The depth varies from about 190 feet at the entrances to a minimum of 24 feet in mid-channel. There is a recreational clam harvesting site on the east side of Neva Strait, south of Highwater Island, approximately 340 m. from the mid-channel line.

Stumbo Associates
Email: stumbo@speakeasy.org

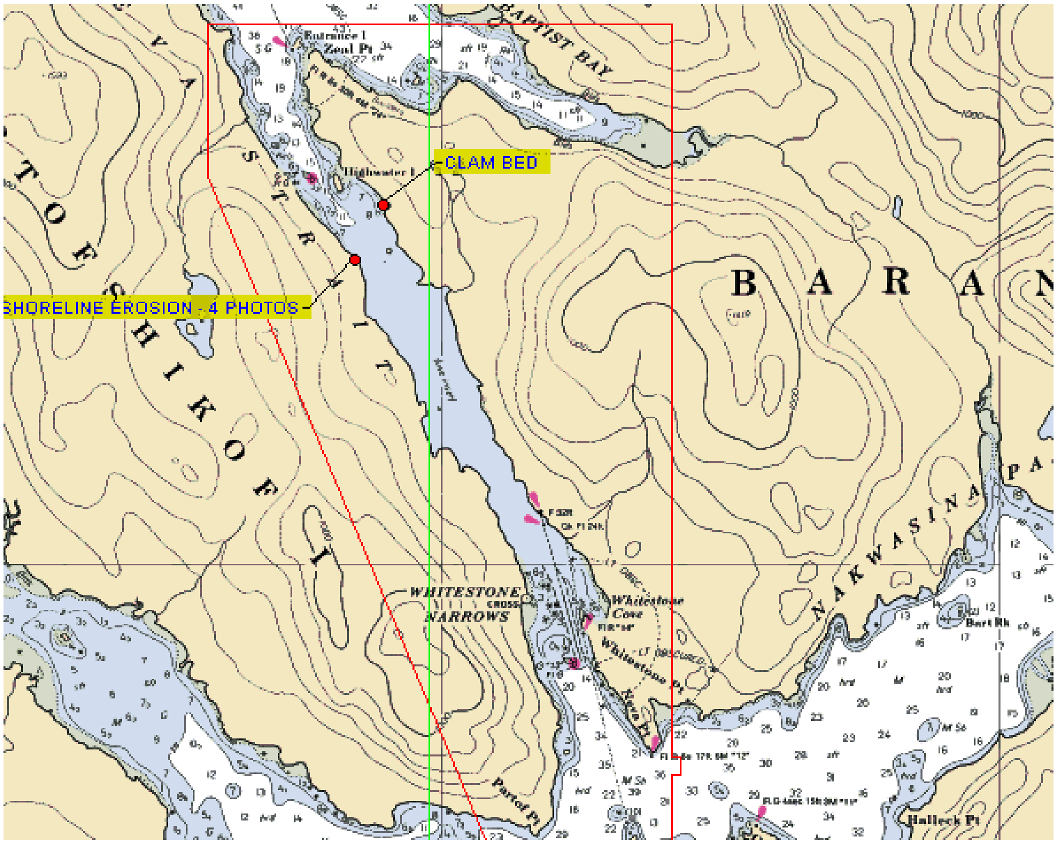

Figure 14. Neva Strait

The transition from deep to shallow water is very abrupt at the south end of Neva Strait without a significant length where the depth beneath the track can cause critical waves. There is a portion of the north end of the strait shown in Figure 15 where it may be possible to develop critical wave patterns at extreme high (+12) tide levels. Also, like Olga Strait, the water is shallow enough in the central part of the strait that the wash pattern will change from the subcritical pattern of Figure 13 to the supercritical pattern of Figure 12.

Email: stumbo@speakeasy.org

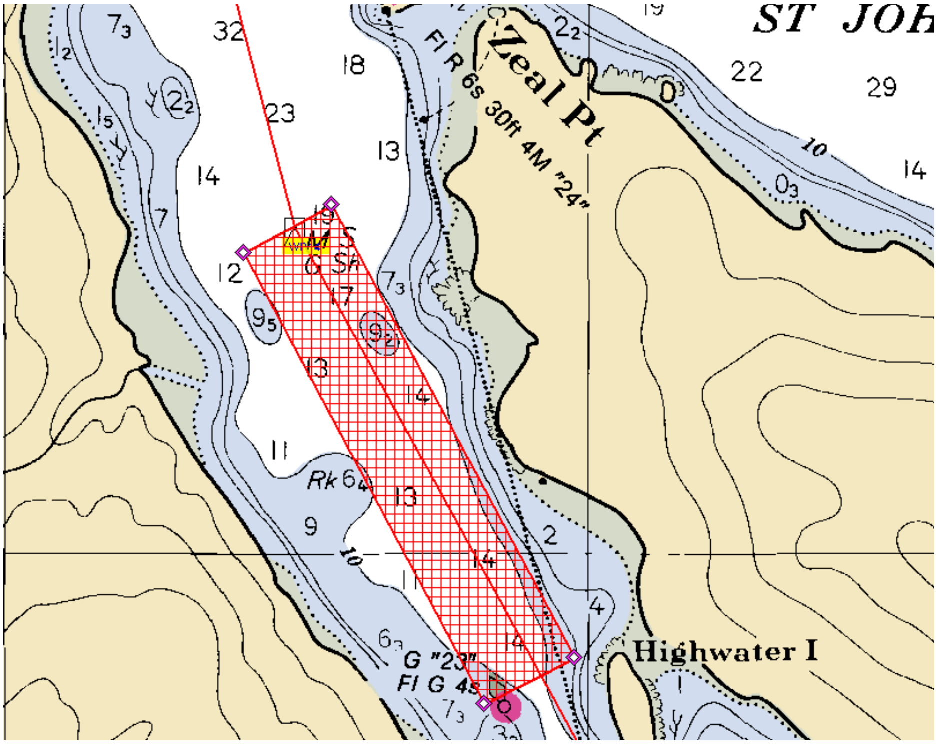

Figure 15. Possible critical wave area, north end, Neva Strait

On the western shore of the strait, as marked on the chart in Figure 15, there is an area of obvious on-going erosion on the shoreline. The distance from the channel centerline to this shore is only 140 m. and KENNICOTT, traversing at 13 knots, did not appear to significantly impact this condition. The erosion may be due to wind waves and current, present vessel traffic or both. Before a decision to transit the strait at service speed is made, we recommend AMHS document the shoreline conditions and determine the impact of the FVF. This area is shown in Figures 16 and 17 below.

Figure 16. Eroding foreshore on the western side of Neva Strait

Figure 17. Another view of the eroding foreshore on the western side of Neva Strait

Kakul Narrows
There is an ocean swell from Salisbury Sound coming into the entrance to Kakul Narrows, resulting in wave action at Kakul Point. There is a forestry cabin to the northwest on the beach in Bradshaw Cove.

Sergius Narrows

Sergius Narrows is a very narrow (140 meters wide) channel with high turbulence currents of up to 8 knots. The channel is dredged to a depth of 21 feet in the narrowest portion. The necessity to slow in Sergius Narrows would be a navigation safety issue and not a wake wash issue. The shoreline is steep an rocky (Figure 20) and there is no nearby human habitation.

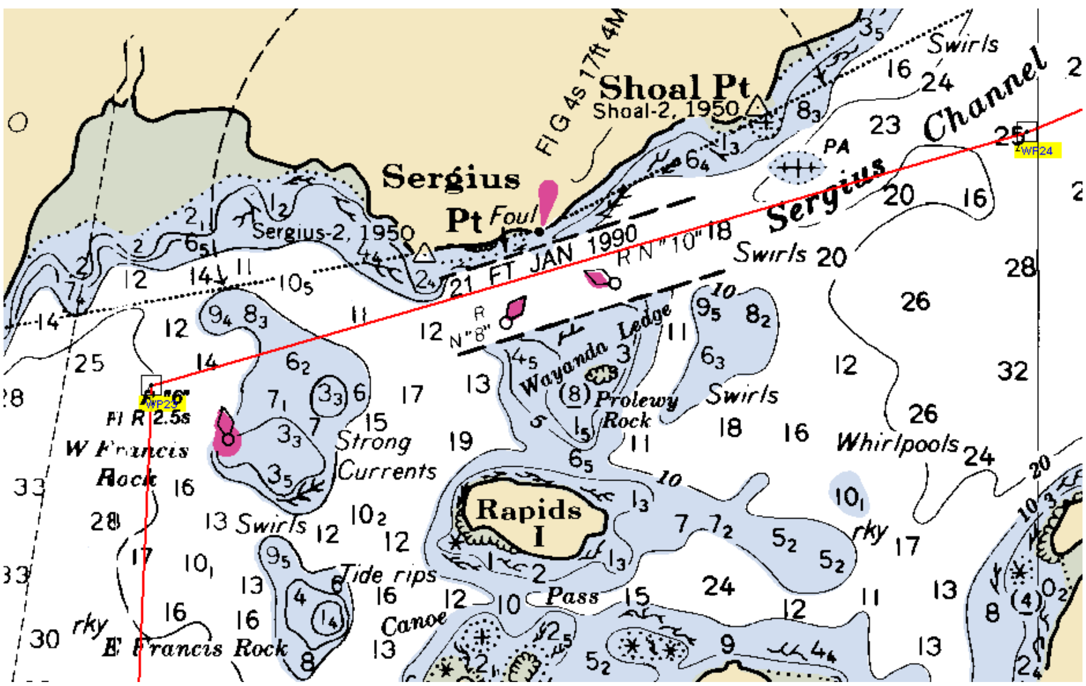

Figure 18. Sergius Narrows

Figure 19. Sergius Narrows, looking northeast

Figure 20. Sergius Narrows' steep, rocky shoreline

Just northeast of Sergius Narrows, however is Sergius Channel where the depths involve the possibility (at various tide levels) of critical pattern waves at 32 knots (See Figure 21). AMHS should make test runs at various tide levels or closely observe the wake wash in this area for a period of time after start of operations. It may be that critical depths will not exist for sufficient distance to develop a critical wave pattern and no operational slowing would be required.

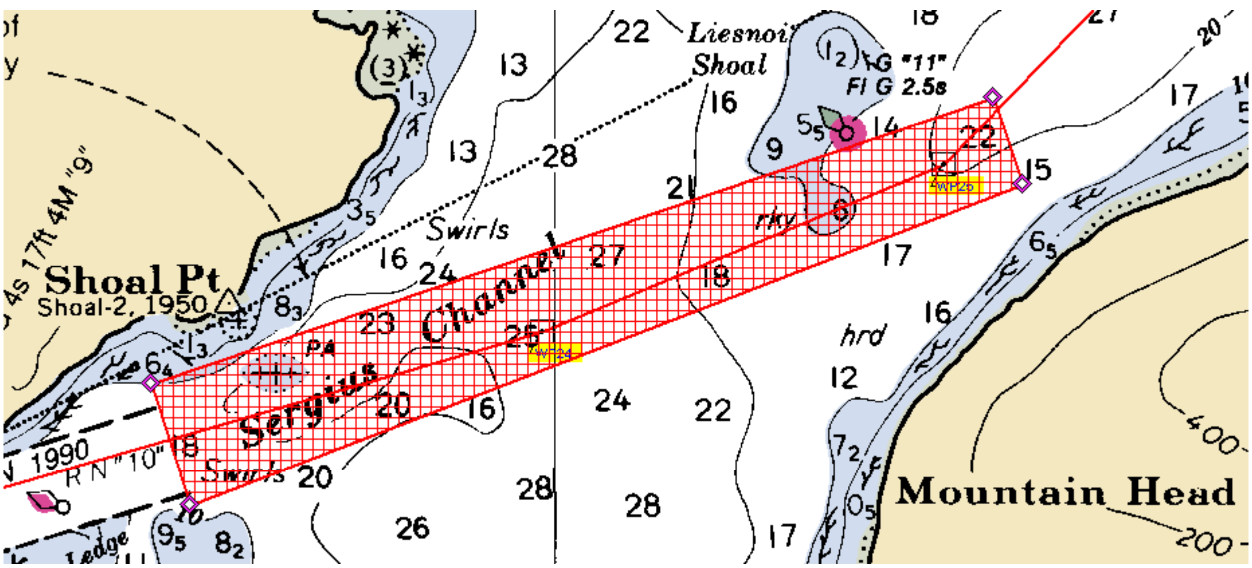

Figure 21. Possible critical wave area in Sergius Channel

Shelter Island Cabins. On the southeast corner of Shelter Island are a number of homes and cabins, many of which have boat ramps on the foreshore which use boat trailers and winches to launch skiffs. The transit line passes these dwellings at a distance of approximately 1500 meters. Two offshore reefs provide some protection to this shoreline.

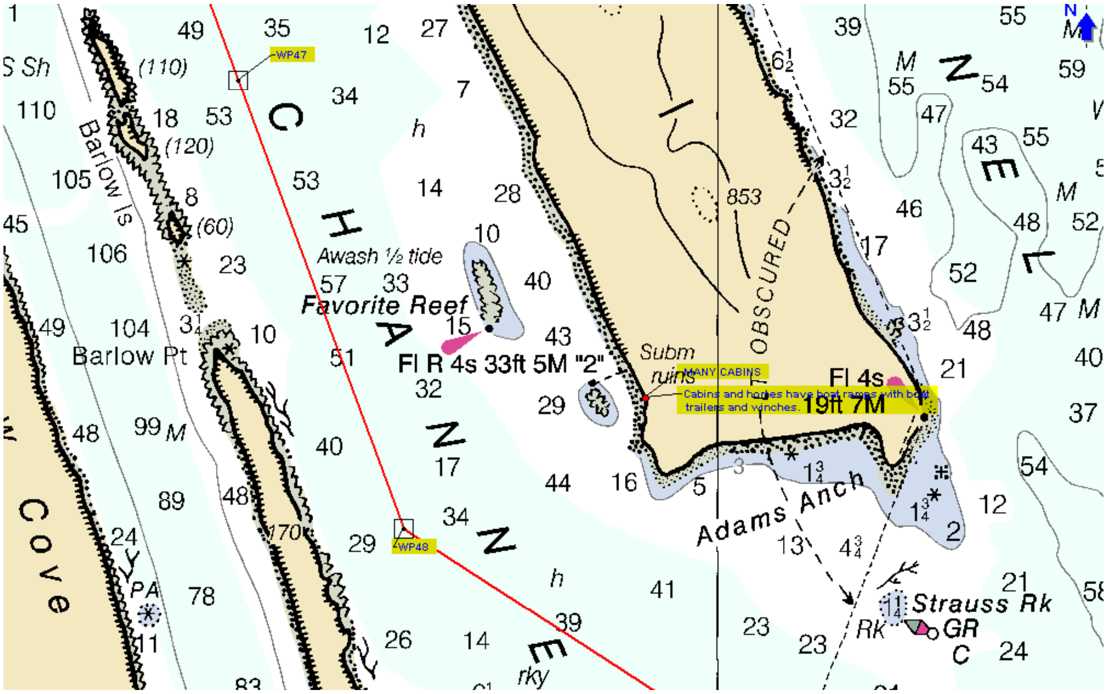

Figure 22. Southern end of Shelter Island showing protective reefs offshore of the western side.

Figure 23. Homes on Shelter Island. Note boat ramps.

There are no structures such as piers or floats on this shoreline that would be at risk from wake wash. Also, there is sea room to modify the FVF route to stay 2200 meters from the shore if necessary. At that distance the wash height, if unattenuated by wind waves, would be 38 centimeters (about 15 inches), certainly less than wind generated waves that strike the same shore at times.

Auke Bay

As the northbound ferry route approaches Coughlan Island, there is a natural breakwater formed by Coughlin to the north and Spuhn Island to the south, where the wake energy from slowing down through the "hump" could be absorbed on empty shallow beaches if the vessel slowed to maneuvering speed at this point.

RECOMMENDATIONS:

- Conduct trial runs in the areas identified in these notes to aid in route planning decisions.
- For a period of perhaps one month after initiating service, observe the wash patterns at various tide levels in the areas identified and modify route planning decisions accordingly.
- Thoroughly document the condition of shorelines and structures in the areas identified in these notes **before** initiating service. The documentation should consist of detailed photographs, measurements and a history of erosion patterns as far back as is feasible. The survey should be conducted by coastal engineers, geomorphologists and marine biologists and should be held in readiness to counter future claims of erosion, damage and environmental harm[1]

- [1]. This same recommendation was made to B.C. Ferries prior to initiating service with the PACIFICAT catamarans and was not taken. Other clients, as well, have felt this recommendation was excessive and only realized too late that the survey would have been invaluable. Since the investigators in this study would have little or no participation in the survey, the recommendation is not made in anticipation of future contracts.