Analysis of AMHS Fast Vehicle Ferry Wake Wash Predictions-Phase 2 Report; Comparison of the AMHS FVF Expected Wash Characteristics to Existing AMHS Vessels and Cruise Ships

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

Date  September 2002

Prepared for:
Alaska Department of Transportation
Statewide Research Office
3132 Channel Drive
Juneau, AK 99801-7898

FHWA-AK-RD-02-09
This study reviewed the predicted wake wash of the Fast Vehicle Ferry and compared it to wake wash characteristics of existing AMHS vessels and cruise ships operating in Southeast Alaska. Investigators conducted on-scene wake wash measurements of AMHS vessels and cruise ships in the vicinity of Ketchikan, Alaska. Data, conclusions and recommendations are presented.
ANALYSIS OF AMHS FAST VEHICLE FERRY WAKE WASH PREDICTIONS

PHASE 2 REPORT

COMPARISON OF THE AMHS FVF EXPECTED WASH CHARACTERISTICS TO EXISTING AMHS VESSELS AND CRUISE SHIPS

Conducted for
ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES

ALASKA MARINE HIGHWAY SYSTEM

By
Stumbo Associates
Marine Transportation Consultants
September 2002
Table of Contents

Table of Contents........................................................................................................................................ ii
List of Figures .................................................................................................................................................. iii
List of Tables ................................................................................................................................................ iv
Executive Summary .......................................................................................................................................... v
  Purpose......................................................................................................................................................... v
  FVF Wake Wash Predictions.......................................................................................................................... v
  Wake Wash Measurement of AMHS Vessels and Cruise Ships................................................................. v
  Conclusions................................................................................................................................................... vii
  Recommendations ........................................................................................................................................ vii
Report............................................................................................................................................................ 1
  Purpose......................................................................................................................................................... 1
  Definitions .................................................................................................................................................... 1
    Wake Wash Height ...................................................................................................................................... 1
    Wake Wash Period...................................................................................................................................... 1
    Wash Energy............................................................................................................................................... 1
    Length Froude Number............................................................................................................................... 2
  FVF Wake Wash Predictions.......................................................................................................................... 2
  Wake Wash Measurement of AMHS Vessels and Cruise Ships................................................................. 4
    Procedure .................................................................................................................................................... 7
    Vessels Measured ....................................................................................................................................... 7
    Results......................................................................................................................................................... 13
  Comparisons of Present Vessels with AMHS FVF Predicted Wash............................................................ 17
    Discussion of Results.................................................................................................................................. 20
    Conclusions................................................................................................................................................ 20
    Recommendations...................................................................................................................................... 20
References....................................................................................................................................................... 21
Appendix.......................................................................................................................................................... 22
List of Figures

Figure I  Wash Height Regions by Ship Type ................................................................. 1
Figure II Wash Energy Regions by Ship Type ................................................................. 1
Figure 1. NGA 70 Predicted Wash Height ........................................................................ 3
Figure 2. NGA 70 Predicted Wash Energy ........................................................................ 3
Figure 3. Wash Measurement Sites in Northern Tongass Narrows .................................... 4
Figure 4. Wash Measurement Sites South of Tongass Narrows ......................................... 5
Figure 5. Wake Wash Instrumentation Setup ..................................................................... 6
Figure 6. M/V Columbia.................................................................................................... 7
Figure 7. M/V Matanuska ................................................................................................. 8
Figure 8. M/V Taku .......................................................................................................... 8
Figure 9. M/V Prince of Wales ......................................................................................... 9
Figure 10. MS Summit ....................................................................................................... 10
Figure 11. MS Vision of the Seas ..................................................................................... 10
Figure 12. MS Sun Princess ............................................................................................. 11
Figure 13. MS Volendam .................................................................................................. 11
Figure 14. MS Norwegian Wind ...................................................................................... 12
Figure 15. MS Statendam ............................................................................................... 12
Figure 16. MS Universe Explorer ..................................................................................... 13
Figure 17. AMHS Wake Wash Trials 6/23/02 Columbia .................................................... 14
Figure 18. AMHS Wake Wash Trials 6/23/02 Summit ....................................................... 14
Figure 19. Height vs Speed of Measured Vessels ............................................................... 16
Figure 20. Energy vs Speed of Measured Vessels ............................................................. 16
Figure 21. Comparison of Ferries and Cruise Ships to AMHS FVF (height vs speed) ....... 17
Figure 22. Comparison of Ferries and Cruise Ships to AMHS FVF(energy vs speed) ......... 18
Figure 23. Wash Regions by Ship Type (height vs speed) .................................................. 19
Figure 24. Wash Regions by Ship Type (energy vs speed) .................................................. 19

Wake Wash Trials
Figure A-1. AMHS Columbia 6/23/02 .............................................................................. A1
Figure A-2. AMHS Columbia 6/23/02 .............................................................................. A2
Figure A-3. AMHS Matanuska 6/23/02 ............................................................................ A3
Figure A-4. Norwegian Wind 6/22/02 .............................................................................. A4
Figure A-5. Norwegian Wind 6/22/02 ............................................................................ A5
Figure A-6. Prince of Wales 6/21/02 ............................................................................... A6
Figure A-7. Prince of Wales 6/23/02 ............................................................................... A7
Figure A-8. Prince of Wales 6/23/02 ............................................................................... A9
Figure A-9. Prince of Wales 6/23/02 ............................................................................... A9
Figure A-10. Statendam 6/21/02 .................................................................................... A10
Figure A-11. Summit 6/23/02 ......................................................................................... A11
Figure A-12. Summit 6/23/02 ......................................................................................... A12
Figure A-13. Sun Princess 6/22/02 ................................................................................ A13
Figure A-14. Taku 6/23/02 ............................................................................................... A14
Figure A-15. Universe Explorer 6/22/02 ........................................................................ A15
Figure A-16. Vision of the Seas 6/21/02 .......................................................................... A16
Figure A-17. Volendam 6/22/02 ..................................................................................... A17
Figure A-18. Volendam 6/22/02 ..................................................................................... A18
List of Tables

Table I. Ketchikan Data Analysis Summary................................................................. 1
Table 1  Alaska Marine Highways System Ships (and Prince of Wales)................... 7
Table 2. Cruise Ships .................................................................................................. 9
Table 3. Ketchikan Data 6/21-6/23/02-Analysis Summary........................................ 15
Table A1. Sample Numerical Data Run 19b .............................................................. A8
ANALYSIS OF AMHS FAST VEHICLE FERRY (FVF) WAKE WASH PREDICTIONS -- PHASE 2 REPORT

EXECUTIVE SUMMARY

PURPOSE

This study compared the predicted wash characteristics of the AMHS FVF to the wash characteristics of existing AMHS vessels and cruise ships operating in Southeast Alaska.

FVF WAKE WASH PREDICTIONS

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

- Height = 47 - 74.2 cm
- Energy = 27,600 - 42,960 joules/meter

WAKE WASH MEASUREMENT OF AMHS VESSELS AND CRUISE SHIPS

From June 21 through June 23, 2002, the investigators conducted on-scene wake wash measurements of AMHS vessels and cruise ships in the vicinity of Ketchikan, Alaska. The measured wash characteristics of these vessels are shown in the table below, first as measured and then adjusted to a common distance of 300 meters.


<table>
<thead>
<tr>
<th>Run Number</th>
<th>VESSEL</th>
<th>Speed</th>
<th>Distance (Meters)</th>
<th>Period (Seconds)</th>
<th>Height (meters)</th>
<th>Energy (Joules/meter)</th>
<th>Period (Seconds)</th>
<th>Height (meters)</th>
<th>Energy (Joules/meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>COLUMBIA</td>
<td>16.5</td>
<td>960</td>
<td>3.27</td>
<td>0.346</td>
<td>2,907</td>
<td>3.27</td>
<td>0.510</td>
<td>5,443</td>
</tr>
<tr>
<td>18</td>
<td>COLUMBIA</td>
<td>18.6</td>
<td>764</td>
<td>4.34</td>
<td>0.523</td>
<td>10,112</td>
<td>4.34</td>
<td>0.715</td>
<td>18,957</td>
</tr>
<tr>
<td>17</td>
<td>MATANUSKA</td>
<td>15.5</td>
<td>650</td>
<td>3.64</td>
<td>0.609</td>
<td>9,612</td>
<td>3.64</td>
<td>0.788</td>
<td>16,095</td>
</tr>
<tr>
<td>8</td>
<td>NORWEGIAN WIND</td>
<td>12.0</td>
<td>660</td>
<td>4.37</td>
<td>0.496</td>
<td>9,228</td>
<td>4.37</td>
<td>0.646</td>
<td>15,609</td>
</tr>
<tr>
<td>12</td>
<td>NORWEGIAN WIND</td>
<td>17.3</td>
<td>607</td>
<td>5.19</td>
<td>0.571</td>
<td>17,218</td>
<td>5.19</td>
<td>0.722</td>
<td>27,545</td>
</tr>
<tr>
<td>2a</td>
<td>PRINCE OF WALES</td>
<td>13.0</td>
<td>600</td>
<td>4.14</td>
<td>0.380</td>
<td>4,636</td>
<td>4.14</td>
<td>0.478</td>
<td>7,677</td>
</tr>
<tr>
<td>16a</td>
<td>PRINCE OF WALES</td>
<td>15.0</td>
<td>494</td>
<td>3.62</td>
<td>0.551</td>
<td>7,820</td>
<td>3.62</td>
<td>0.651</td>
<td>10,905</td>
</tr>
<tr>
<td>16b</td>
<td>PRINCE OF WALES</td>
<td>15.3</td>
<td>147</td>
<td>3.67</td>
<td>0.806</td>
<td>17,247</td>
<td>3.67</td>
<td>0.637</td>
<td>10,720</td>
</tr>
<tr>
<td>1a</td>
<td>PRINCE OF WALES</td>
<td>15.0</td>
<td>240</td>
<td>3.90</td>
<td>0.464</td>
<td>6,426</td>
<td>3.90</td>
<td>0.431</td>
<td>5,538</td>
</tr>
<tr>
<td>2</td>
<td>STATENDAM</td>
<td>9.0</td>
<td>566</td>
<td>2.94</td>
<td>0.324</td>
<td>1,778</td>
<td>2.94</td>
<td>0.401</td>
<td>2,721</td>
</tr>
<tr>
<td>16</td>
<td>SUMMIT</td>
<td>21.7</td>
<td>780</td>
<td>4.36</td>
<td>0.939</td>
<td>32,880</td>
<td>4.36</td>
<td>1.291</td>
<td>62,171</td>
</tr>
<tr>
<td>19</td>
<td>SUMMIT</td>
<td>23.0</td>
<td>732</td>
<td>5.32</td>
<td>1.031</td>
<td>58,998</td>
<td>5.32</td>
<td>1.388</td>
<td>106,929</td>
</tr>
<tr>
<td>7</td>
<td>SUN PRINCESS</td>
<td>11.0</td>
<td>670</td>
<td>2.80</td>
<td>0.998</td>
<td>15,346</td>
<td>2.80</td>
<td>1.304</td>
<td>26,220</td>
</tr>
<tr>
<td>20</td>
<td>TAKU</td>
<td>17.4</td>
<td>536</td>
<td>3.36</td>
<td>0.574</td>
<td>7,312</td>
<td>3.36</td>
<td>0.605</td>
<td>10,685</td>
</tr>
<tr>
<td>10</td>
<td>UNIVERSITY EXPLORER</td>
<td>9.7</td>
<td>656</td>
<td>2.82</td>
<td>0.119</td>
<td>222</td>
<td>2.82</td>
<td>0.150</td>
<td>361</td>
</tr>
<tr>
<td>1</td>
<td>VISION OF THE SEAS</td>
<td>10.5</td>
<td>492</td>
<td>2.55</td>
<td>0.452</td>
<td>2,813</td>
<td>2.55</td>
<td>0.500</td>
<td>5,197</td>
</tr>
<tr>
<td>9</td>
<td>VOLENDAM</td>
<td>8.0</td>
<td>380</td>
<td>3.66</td>
<td>0.125</td>
<td>413</td>
<td>3.66</td>
<td>0.137</td>
<td>462</td>
</tr>
<tr>
<td>13</td>
<td>VOLENDAM</td>
<td>16.7</td>
<td>746</td>
<td>5.09</td>
<td>0.448</td>
<td>10,000</td>
<td>5.09</td>
<td>0.607</td>
<td>18,519</td>
</tr>
</tbody>
</table>
All of the data was then plotted in two graphs – wash height vs. speed and wash energy vs. speed. These plots are shown below with the AMHS ships’ plots shown with heavier lines. The regions on the charts representing the various ship types are highlighted.
CONCLUSIONS

1. The wake wash from the AMHS Fast Vehicle Ferry will, in all likelihood, be less both in height and energy than cruise ships at service speeds greater than 20 knots.
2. The wake wash height of the AMHS Fast Vehicle Ferry will likely be less than that produced by the largest, fastest conventional AMHS ships.
3. The wake wash energy of the AMHS Fast Vehicle Ferry may be more than that produced by the largest, fastest conventional AMHS ships.
4. If there will be a perceived wake wash problem with the FVF, it will probably be due to the longer period bow waves produced by the FVF at 32 knots which may persist for longer distances and have a longer run-up on beaches than the shorter period waves of other vessels.

RECOMMENDATIONS

1. Measure the wake wash of the completed FVF during builder’s trials with the vessel in a fully loaded condition. Re-examine the comparison with other ship types with the resulting full scale data.
2. Route planning decisions in narrow portions of the Juneau – Sitka route (Olga and Neva Straits, Sergius Narrows) should be made as a result of careful observations of the FVF on the 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 possible sensitive locations along proposed routes.
4. Observe the effect of the FVF wake wash on any floating docks and other structures along the route of the FVF at an early opportunity and determine if undue motions develop.
5. The wash measurements made during builder’s or acceptance trials of the first AMHS FVF should include measurements designed to validate the attenuation rate of the longest period waves produced by the vessel.
ANALYSIS OF AMHS FAST VEHICLE FERRY (FVF) WAKE WASH PREDICTIONS

for

ALASKA MARINE HIGHWAY SYSTEM

PHASE 2 REPORT

COMPARISON OF THE AMHS FVF EXPECTED WASH CHARACTERISTICS TO EXISTING AMHS VESSELS AND CRUISE SHIPS

PURPOSE

To compare the predicted wash characteristics of the AMHS FVF to the wash characteristics of existing AMHS vessels and cruise ships operating 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:

\[ E = \frac{\gamma \cdot g \cdot H^2 \cdot L}{8} \]

where \( \gamma \) 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:

\[ L = \frac{g \cdot T^2}{2 \cdot \pi} \]
resulting in the following equation:

\[ E = \frac{\gamma \cdot g^2 \cdot H^2 \cdot T^2}{16 \cdot \pi} \]

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

\[ E = 1961 \cdot H^2 \cdot T^2 \]

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:

\[ F_{nl} = \frac{V}{\sqrt{g \cdot (LWL)}} \]

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 was presented in the Phase 1 report of this investigation (Reference 3). Also, in Phase 1, lower bounds for predicted wave height and energy were established based on data from other investigations and measurements. Figures 1 and 2 from that report are repeated 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 range of wash characteristics are predicted to be:

- \( H = 47 - 74.2 \) cm
- \( E = 27,600 - 42,960 \) joules/meter

**WAKE WASH MEASUREMENT OF AMHS VESSELS AND CRUISE SHIPS**

From June 21 through June 23, 2002, the investigators conducted on-scene wake wash measurements of AMHS vessels and cruise ships in the vicinity of Ketchikan, Alaska. Locations were chosen in deep water (> 200 feet) both north and south of (or in) Tongass Narrows in order to measure the maximum number of vessels in the time permitted, and also to measure each vessel at two or more speeds if possible. These locations are shown on the charts below (Figures 3 and 4). Each site is marked by a point “A” at one end of a line approximately 1000 meters long.

![Figure 3. Wash Measurement Sites in Northern Tongass Narrows](image)
Wave heights and periods of vessel wash were measured using a submerged instrument package that measures pressure 4 times per second and records data to a HEX file in computer memory in the package. Speeds were obtained by radio communication with each vessel at the time the vessel passed the wave buoy marker. The instrument package is anchored to the bottom, typically in 200 feet of water, and suspended from a buoy that is held 6 to 10 feet below the surface of the water by a taut line to the anchor. A marker buoy on the surface is used for location and recovery. This test setup is depicted in the Figure 5:
After data download, custom software converts the pressure readings to wave heights as a function of time, enabling measurements and plots to be made of wave patterns passing over the buoy.
PROCEDURE

To gather data, the vessels passed the deployed instruments on their normal course through the area. The instrument deployment sites were chosen so that vessels would pass within 1000 meters. The actual distance was measured using a laser rangefinder. Speeds were determined by hailing each vessel on VHF radio and getting a reply of the vessel’s speed at the time of passing the instruments. Each passage’s data was normalized to a distance off centerline of travel of 300 meters (~1000 feet) to enable valid comparisons. Plots were then developed of wash height vs. speed and wash energy vs. speed.

VESSELS MEASURED

Table 1. Alaska Marine Highway System Ships (and PRINCE OF WALES)

<table>
<thead>
<tr>
<th>NAME</th>
<th>LENGTH (meters)</th>
<th>Est. LWL (meters)</th>
<th>PAX</th>
<th>VEHICLES (std. autos)</th>
<th>SERVICE SPEED (knots)</th>
<th>SPEED Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLUMBIA</td>
<td>127.4</td>
<td>121</td>
<td>625</td>
<td>134</td>
<td>17.3</td>
<td>16.5, 18.6</td>
</tr>
<tr>
<td>MATANUSKA</td>
<td>124.4</td>
<td>118.1</td>
<td>500</td>
<td>88</td>
<td>16.5</td>
<td>15.5</td>
</tr>
<tr>
<td>TAKU</td>
<td>107.3</td>
<td>102</td>
<td>450</td>
<td>69</td>
<td>16.5</td>
<td>17.4</td>
</tr>
<tr>
<td>PRINCE OF WALES</td>
<td>60</td>
<td>53.5</td>
<td>150</td>
<td>30</td>
<td>15</td>
<td>13, 15, 15.3</td>
</tr>
</tbody>
</table>

Figure 6. M/V COLUMBIA
Table 2. Cruise Ships

<table>
<thead>
<tr>
<th>NAME</th>
<th>LENGTH (meters)</th>
<th>Est. LWL (meters)</th>
<th>PAX</th>
<th>CREW</th>
<th>SERVICE SPEED (knots)</th>
<th>SPEED MEASURED</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMIT</td>
<td>294.1</td>
<td>279.4</td>
<td>1950</td>
<td>24</td>
<td>21.7, 23</td>
<td></td>
</tr>
<tr>
<td>VISION OF THE SEAS</td>
<td>278.9</td>
<td>265</td>
<td>2435</td>
<td>22</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>SUN PRINCESS</td>
<td>260.9</td>
<td>247.9</td>
<td>1950</td>
<td>830</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>VOLENDAM</td>
<td>238</td>
<td>226</td>
<td>1440</td>
<td>23</td>
<td>8, 16.7</td>
<td></td>
</tr>
<tr>
<td>NORWEGIAN WIND</td>
<td>229.8</td>
<td>218.3</td>
<td>1748</td>
<td>689</td>
<td>18</td>
<td>12, 17</td>
</tr>
<tr>
<td>STATENDAM</td>
<td>219.4</td>
<td>208.5</td>
<td>1266</td>
<td>602</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>UNIVERSE EXPLORER</td>
<td>188</td>
<td>178.7</td>
<td>737</td>
<td>18</td>
<td>9.7</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** It was not possible to obtain measurements of the wake wash of all of the cruise ships at service speed. Several were slowing to time their entrance into Ketchikan or had set a slower speed for their next destination because their scheduled arrival did not require full service speed. Sufficient data was gathered at service speeds, however, to be representative of the ship type.
Figure 10. MS SUMMIT

Figure 11. MS VISION OF THE SEAS
Figure 12. MS SUN PRINCESS

Figure 13. MS VOLENDAM
Figure 14. MS NORWEGIAN WIND

Figure 15. MS STATENDAM
RESULTS

In the analysis, the height, period and energy of each wave in the wave train of each vessel tested was calculated and a graph produced for all runs. These graphs are included in this report in the ‘Individual Runs’ tab. The summary data for Run 19b is also included as a sample of more detailed numerical data. If needed, such data can be produced for each run as well as detailed data points that are summarized in the graphs. Representative graphs of wave trains are shown below for the M/V COLUMBIA and the MS SUMMIT. In these representative graphs, the tallest wave in the train has been highlighted in yellow and the graphs are presented for the actual distance off centerline of travel, i.e., the height and energy has not yet been adjusted to a common 300 meters.
Figure 17. Run No. 18, M/V COLUMBIA

Alaska Marine Highway System Wake Wash Trials June 23, 2002
COLUMBIA

Run Nº 18 Data
Speed 18.6 Knots, Distance 764 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 52.3 cm
Period of Tallest Wash Wave 4.34 Seconds
Energy of Tallest Wash Wave 10,096 Joules/Meter

Figure 17. Run No. 18, M/V COLUMBIA

Alaska Marine Highway System Wake Wash Trials June 23, 2002
SUMMIT

Run Nº 16 Data
Speed 21.6 Knots, Distance 780 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 93.9 cm
Period of Tallest Wash Wave 4.36 Seconds
Energy of Tallest Wash Wave 32,880 Joules/Meter
The measured wash characteristics of the vessels measured in June 2002 are shown in Table 1 below, first as measured and then adjusted by the inverse cube root rule to a common distance of 300 meters.

### Table 3. Analysis Summary

The data was then plotted in two graphs – wash height vs. speed and wash energy vs. speed. These plots are shown in Figures 19 and 20 below with the AMHS ships’ plots shown with heavier lines. Where the height or energy curve is represented as a straight line, it is only because a single speed was measured for that vessel. Measurement at multiple speeds would have resulted in defining a curve for the characteristics.
Figure 19. Height vs. Speed of Measured Vessels

Figure 20. Energy vs. Speed of Measured Vessels
COMPARISONS OF PRESENT VESSELS WITH AMHS FVF PREDICTED WASH

The AMHS FVF wake wash prediction curves from Figures 1 and 2 were added to the charts to plot all characteristics on the same chart:

![Graph showing comparisons of present vessels with AMHS FVF predicted wash](image_url)

Figure 21. Comparison of Ferries and Cruise Ships to AMHS FVF (Height vs. Speed)
Several observations can be made in these last two graphs:

- The maximum wave height for any measured existing AMHS vessel is 0.715 meters (~ 28 inches). This observation includes the PRINCE OF WALES.
- The maximum wave height for cruise ships is 1.388 meters (~ 55 inches). The data from cruise ships measured at slower speed trends toward the same heights for those capable of service speeds in excess of 20 knots. This is true with the exception of VOLENDAM.
- Based on the FVF predictions, the FVF may have a lower wash height than existing AMHS ferries but will probably exceed existing AMHS ferries in wash energy due to the longer wave period of the FVF.
- The FVF’s predicted wash height and energy is substantially lower than that of cruise ships with service speeds above 20 knots.

These observations are perhaps clearer if the regions on the charts representing the various ship types are highlighted. In the charts below, Figures 23 and 24 are repeated but with these regions highlighted.
Figure 23. Wash Regions by Ship Type (Height vs. Speed)

Figure 24. Wash Regions by Ship Type (Energy vs. Speed)
DISCUSSION OF RESULTS

In analyzing the data from measured vessels, the investigators have consistently used the inverse cube root rule (References 4, 5 and 6) to account for wave attenuation with distance. All measurements were adjusted to a common distance off centerline of travel of 300 meters (~ 1000 feet). The formula for this adjustment is:

\[
\frac{H_2}{H_1} = \left( \frac{d_1}{d_2} \right)^{1/3}
\]

In discussions with other investigators of wake wash (mostly international) and review of the current literature, we find that theories have been presented that the attenuation rate for the longer period waves produced by large fast ferries may be less than that calculated by the inverse cube root rule. No definitive proof or disproof of this possibility has yet been published. If a lesser rate of attenuation proves to be true:

- The FVF wake wash predictions of Reference 2 may be lower than the wake wash of the actual vessel.
- The wash of the FVF (and some large cruise ships) may affect shorelines and structures at greater distances than anticipated due to higher “persistence” of longer period waves.

Consequently, it is recommended that the wash measurements made during builder’s or acceptance trials of the first AMHS FVF include measurements designed to validate the attenuation rate of the longest period waves produced by the vessel.

CONCLUSIONS

5. The wake wash from the AMHS Fast Vehicle Ferry will, in all likelihood, be less both in height and energy than cruise ships at service speeds greater than 20 knots.
6. The wake wash height of the AMHS Fast Vehicle Ferry will likely be less than that produced by the largest, fastest conventional AMHS ships.
7. The wake wash energy of the AMHS Fast Vehicle Ferry may be more than that produced by the largest, fastest conventional AMHS ships.
8. If there will be a perceived wake wash problem with the FVF, it will probably be due to the longer period bow waves produced by the FVF at 32 knots which may persist for longer distances and have a longer run-up on beaches than the shorter period waves of other vessels.

RECOMMENDATIONS

6. Measure the wake wash of the completed FVF during builder’s trials with the vessel in a fully loaded condition. Re-examine the comparison with other ship types with the resulting full scale data.
7. Route planning decisions in narrow portions of the Juneau – Sitka route (Olga and Neva Straits, Sergius Narrows) should be made as a result of careful observations of the FVF on the route.

8. 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 possible sensitive locations along proposed routes.

9. Observe the effect of the FVF wake wash on any floating docks and other structures along the route of the FVF at an early opportunity and determine if undue motions develop.

10. The wash measurements made during builder’s or acceptance trials of the first AMHS FVF should include measurements designed to validate the attenuation rate of the longest period waves produced by the vessel.

REFERENCES:


2. “Alaska Marine Highways 70 m Car Passenger Ferry, Wave Signature”; Nigel Gee and Associates; undated.


Appendix A
Alaska Marine Highway System Wake Wash Trials June 23, 2002
COLUMBIA

Run Nº 15 Data
Speed 16.5 Knots, Distance 960 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 34.6 cm
Period of Tallest Wash Wave 3.27 Seconds
Energy of Tallest Wash Wave 2,507 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
COLUMBIA

Run Nº 18 Data
Speed 18.6 Knots, Distance 764 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 52.3 cm
Period of Tallest Wash Wave 4.34 Seconds
Energy of Tallest Wash Wave 10,096 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
MATANUSKA

Run Nº 17 Data
Speed 15.5 Knots, Distance 650 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 60.9 cm
Period of Tallest Wash Wave 3.64 Seconds
Energy of Tallest Wash Wave 9,612 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 22, 2002

NORWEGIAN WIND

Run N° 8 Data
Speed 12 Knots, Distance 660 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 49.6 cm
Period of Tallest Wash Wave 4.37 Seconds
Energy of Tallest Wash Wave 9,228 Joules/Meter
Run Nº 12 Data
Speed 17 Knots, Distance 607 Meters
2.25 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 57.1 cm
Period of Tallest Wash Wave 5.19 Seconds
Energy of Tallest Wash Wave 17,218 Joules/Meter

Alaska Marine Highway System Wake Wash Trials June 22, 2002
NORWEGIAN WIND
Alaska Marine Highway System Wake Wash Trials June 21, 2002

PRINCE OF WALES

Run Nº 2a Data
Speed 10 Knots, Distance 600 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 38 cm
Period of Tallest Wash Wave 4.14 Seconds
Energy of Tallest Wash Wave 4,836 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
PRINCE OF WALES

Run Nº 16a Data
Speed 15 Knots, Distance 494 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 55.1 cm
Period of Tallest Wash Wave 3.62 Seconds
Energy of Tallest Wash Wave 7,820 Joules/Meter
## SAMPLE NUMERICAL DATA -- RUN 19b

<table>
<thead>
<tr>
<th>Wave N°</th>
<th>Time</th>
<th>Period (Seconds)</th>
<th>Height (Meters)</th>
<th>Energy (Joules/M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19:21:26.26</td>
<td>4.006</td>
<td>0.178</td>
<td>1,000</td>
</tr>
<tr>
<td>2</td>
<td>19:21:30.26</td>
<td>3.608</td>
<td>0.550</td>
<td>7,730</td>
</tr>
<tr>
<td>3</td>
<td>19:21:33.87</td>
<td>3.671</td>
<td>0.808</td>
<td>17,247</td>
</tr>
<tr>
<td>4</td>
<td>19:21:37.54</td>
<td>3.824</td>
<td>0.673</td>
<td>12,998</td>
</tr>
<tr>
<td>5</td>
<td>19:21:41.37</td>
<td>4.211</td>
<td>0.427</td>
<td>6,340</td>
</tr>
<tr>
<td>6</td>
<td>19:21:45.58</td>
<td>2.861</td>
<td>0.276</td>
<td>1,226</td>
</tr>
<tr>
<td>7</td>
<td>19:21:48.44</td>
<td>2.127</td>
<td>0.221</td>
<td>433</td>
</tr>
<tr>
<td>8</td>
<td>19:21:50.57</td>
<td>3.052</td>
<td>0.658</td>
<td>7,923</td>
</tr>
<tr>
<td>9</td>
<td>19:21:53.62</td>
<td>1.902</td>
<td>0.222</td>
<td>349</td>
</tr>
<tr>
<td>10</td>
<td>19:21:55.52</td>
<td>2.920</td>
<td>0.459</td>
<td>3,530</td>
</tr>
<tr>
<td>11</td>
<td>19:21:58.44</td>
<td>1.927</td>
<td>0.263</td>
<td>506</td>
</tr>
<tr>
<td>12</td>
<td>19:22:00.37</td>
<td>2.855</td>
<td>0.280</td>
<td>1,251</td>
</tr>
<tr>
<td>13</td>
<td>19:22:03.22</td>
<td>4.734</td>
<td>0.260</td>
<td>2,963</td>
</tr>
<tr>
<td>14</td>
<td>19:22:07.96</td>
<td>3.876</td>
<td>0.235</td>
<td>1,623</td>
</tr>
<tr>
<td>15</td>
<td>19:22:11.83</td>
<td>4.684</td>
<td>0.177</td>
<td>1,355</td>
</tr>
<tr>
<td>16</td>
<td>19:22:16.52</td>
<td>5.247</td>
<td>0.175</td>
<td>1,660</td>
</tr>
<tr>
<td>17</td>
<td>19:22:21.76</td>
<td>4.721</td>
<td>0.209</td>
<td>1,906</td>
</tr>
<tr>
<td>18</td>
<td>19:22:26.48</td>
<td>4.672</td>
<td>0.187</td>
<td>1,491</td>
</tr>
<tr>
<td>19</td>
<td>19:22:31.16</td>
<td>4.972</td>
<td>0.172</td>
<td>1,436</td>
</tr>
<tr>
<td>20</td>
<td>19:22:36.13</td>
<td>4.653</td>
<td>0.154</td>
<td>1,002</td>
</tr>
<tr>
<td>21</td>
<td>19:22:40.78</td>
<td>4.874</td>
<td>0.168</td>
<td>1,321</td>
</tr>
<tr>
<td>22</td>
<td>19:22:45.66</td>
<td>4.888</td>
<td>0.156</td>
<td>1,146</td>
</tr>
<tr>
<td>23</td>
<td>19:22:50.54</td>
<td>4.728</td>
<td>0.100</td>
<td>440</td>
</tr>
<tr>
<td>24</td>
<td>19:22:55.27</td>
<td>4.538</td>
<td>0.144</td>
<td>838</td>
</tr>
<tr>
<td>25</td>
<td>19:22:59.81</td>
<td>4.562</td>
<td>0.096</td>
<td>374</td>
</tr>
<tr>
<td>26</td>
<td>19:23:04.37</td>
<td>4.839</td>
<td>0.098</td>
<td>442</td>
</tr>
<tr>
<td>27</td>
<td>19:23:09.21</td>
<td>4.858</td>
<td>0.149</td>
<td>1,030</td>
</tr>
<tr>
<td>28</td>
<td>19:23:14.07</td>
<td>4.720</td>
<td>0.136</td>
<td>806</td>
</tr>
<tr>
<td>29</td>
<td>19:23:18.79</td>
<td>4.767</td>
<td>0.173</td>
<td>1,340</td>
</tr>
<tr>
<td>30</td>
<td>19:23:23.56</td>
<td>4.643</td>
<td>0.140</td>
<td>827</td>
</tr>
<tr>
<td>31</td>
<td>19:23:28.20</td>
<td>4.770</td>
<td>0.134</td>
<td>805</td>
</tr>
<tr>
<td>32</td>
<td>19:23:32.97</td>
<td>4.382</td>
<td>0.121</td>
<td>553</td>
</tr>
<tr>
<td>33</td>
<td>19:23:37.35</td>
<td>4.491</td>
<td>0.122</td>
<td>590</td>
</tr>
<tr>
<td>34</td>
<td>19:23:41.84</td>
<td>5.980</td>
<td>0.090</td>
<td>565</td>
</tr>
<tr>
<td>35</td>
<td>19:23:47.82</td>
<td>4.604</td>
<td>0.100</td>
<td>417</td>
</tr>
<tr>
<td>36</td>
<td>19:23:52.43</td>
<td>4.610</td>
<td>0.130</td>
<td>709</td>
</tr>
<tr>
<td>37</td>
<td>19:23:57.04</td>
<td>4.965</td>
<td>0.136</td>
<td>899</td>
</tr>
<tr>
<td>38</td>
<td>19:24:02.00</td>
<td>4.743</td>
<td>0.126</td>
<td>703</td>
</tr>
<tr>
<td>39</td>
<td>19:24:06.74</td>
<td>4.768</td>
<td>0.136</td>
<td>820</td>
</tr>
<tr>
<td>40</td>
<td>19:24:11.51</td>
<td>5.100</td>
<td>0.123</td>
<td>777</td>
</tr>
</tbody>
</table>
Alaska Marine Highway System Wake Wash Trials June 23, 2002

PRINCE OF WALES

Run Nº 19b Data
Speed 15.3 Knots, Distance 147 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 80.8 cm
Period of Tallest Wash Wave 3.67 Seconds
Energy of Tallest Wash Wave 17,247 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002

PRINCE OF WALES

Run Nº 19a Data
Speed 15 Knots, Distance 240 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 46.4 cm
Period of Tallest Wash Wave 3.9 Seconds
Energy of Tallest Wash Wave 6,426 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 21, 2002

STATENDAM

Running Nº 2 Data
Speed 9 Knots, Distance 568 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 32.4 cm
Period of Tallest Wash Wave 2.94 Seconds
Energy of Tallest Wash Wave 1,778 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
SUMMIT

Run Nº 16 Data
Speed 21.6 Knots, Distance 780 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 93.9 cm
Period of Tallest Wash Wave 4.36 Seconds
Energy of Tallest Wash Wave 32,880 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
SUMMIT

Run Nº 19 Data
Speed 23 Knots, Distance 732 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 52.3 cm
Period of Tallest Wash Wave 4.34 Seconds
Energy of Tallest Wash Wave 10,096 Joules/Meter
Run Nº 7 Data
Speed 11 Knots, Distance 670 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 99.8 cm
Period of Tallest Wash Wave 2.8 Seconds
Energy of Tallest Wash Wave 15,346 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 23, 2002
TAKU

Run Nº 20 Data
Speed 7.4 Knots, Distance 530 Meters
2.25 Seconds Low Filter
16 Seconds High Filter

Height of Tallest Wash Wave 57.4 cm
Period of Tallest Wash Wave 3.36 Seconds
Energy of Tallest Wash Wave 7,312 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 22, 2002
UNIVERSE EXPLORER

Run Nº 10 Data
Speed 9.7 Knots, Distance 595 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 11.9 cm
Period of Tallest Wash Wave 2.82 Seconds
Energy of Tallest Wash Wave 222 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 21, 2002
VISION OF THE SEAS

Run Nº 1 Data
Speed 10.9 Knots, Distance 406 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 45.2 cm
Period of Tallest Wash Wave 2.55 Seconds
Energy of Tallest Wash Wave 2,613 Joules/Meter
Alaska Marine Highway System Wake Wash Trials June 22, 2002
VOLENDAM

Run Nº 9 Data
Speed 8 Knots, Distance 390 Meters
1.75 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 12.5 cm
Period of Tallest Wash Wave 3.66 Seconds
Energy of Tallest Wash Wave 413 Joules/Meter
Run Nº 13 Data
Speed 16.7 Knots, Distance 746 Meters
2.25 Seconds Low Filter
No High Filter

Height of Tallest Wash Wave 44.8 cm
Period of Tallest Wash Wave 5.06 Seconds
Energy of Tallest Wash Wave 10,090 Joules/Meter