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LETTER OF TRANSMITTAL

Document No. TTT-0045

To: **Alabama Department of Transportation**

Date: 8/9/16 Job No. 15-1101-0300
Attention: Edwin L. Perry, III, PE
Re: Mobile River Bridge Vessel Collision Report

WE ARE SENDING YOU: ☒ Attached ☐ Under separate cover via _____ the following items:
☐ Change Order ☐ Prints ☐ RFI ☐ Drawings ☐ Specifications ☐ Copy of letter ☐ Contract
☐ Work Authorization Order

Copies	Date	No.	Description
1	8/9/16	TTA-0045	Vessel Collision Report

THESE ARE TRANSMITTED as checked below:
☒ For approval ☐ Approved as submitted ☐ Resubmit _____ copies for approval ☐ Approved as noted
☐ For your use ☐ Returned for corrections ☐ Submit _____ copies for distribution ☒ For review and comment
☐ As requested ☐ For bids due ☐ Return _____ corrected prints ☐ Prints returned after loan to us

Remarks: Please find attached for your review and comment the vessel collision report for the Mobile River Bridge.

Let us know if you have any questions or comments.

FROM: Patrick Hickox, PE

COPY TO: File…/contracts/HDR
Steve Flukinger, PE
Manuel Carballo, PE, SE
Michael Lamont, PE

If enclosures are not as noted above, please notify sender immediately

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I-10 Mobile River Bridge and Bayway Widening

Proposed Bridge Vessel Impact Recommendations for the I-10 Mobile River Bridge

Mobile, Alabama
August 8, 2016

1 Introduction

The purpose of this memorandum is to provide a summary of our initial findings and recommendations for the magnitude and application of vessel collision loads for the proposed main span over the Mobile River as presented to ALDOT on June 24, 2016 (Refer to Attachment A for a copy of the presentation). In accordance with the requirements of *AASHTO LRFD Bridge Design Specifications, provisions of Section 3.14* apply to all bridge components in a navigable waterway crossing with water depths over two feet, and requires such structures to be assessed and designed for vessel impacts. The design shall account for the recommended loads by either resisting the demand, or adequately protecting the structure.

The primary requirement of *AASHTO 3.14* is for a site-specific vessel collision study to be conducted; in order to ascertain the parameters necessary for a probabilistic assessment, considering site geometry and vessel traffic, and to determine a risk-based loading requirement for design. In accordance with 3.14.2, it shall remain the responsibility of the owner to establish and/or approve;

- The bridge's operational classification (I.e. Critical/Essential or Typical) – Recommendation provided in this Technical Memorandum
- The vessel traffic density in the waterway – Recommendation provided in this Technical Memorandum
- The design velocity of vessels for the bridge – Recommendation provided in this Technical Memorandum
- The degree of damage that the bridge components, including protective systems, are allowed to sustain. – Analysis is currently under way, recommendations will be provided under separate cover.

2 Vessel Collision Assessment (VCA) Approach

The proposed main span crossing of the Mobile River Bridge is the focus of this vessel collision study, which has been conducted to establish the appropriate vessel collision loading at the site. The assessment evaluated available historical commercial vessel traffic data between 2009 and 2014 and considered future growth rates in order to establish a *future fleet* that would be utilized for design and analysis. Air draft impacts were not assessed as this has previously been addressed in previous reports[1].

The AASHTO approach utilizes various factors that rely upon site-specific information and vessel traffic that is computed to calculate an Acceptance Criteria (AF) which is required to meet the minimum stipulation for the bridge type. The inverse of the AF is the return period.

For the assessment of the proposed Mobile River Bridge, our recommendation is to use a classification of "Critical" or "Essential". AASHTO defines a "Critical" or "Essential" bridge as a bridge that may be damaged to an extent acceptable to the Owner;

- **"*Critical*" or "*Essential*", having a minimum return period of 10,000 years**
    - **This corresponds to a 1% in 100 years exceedance rate, or an AF of 0.001.**

[1] Draft Environmental Impact Statement,
Appendix C, Air Draft Clearance Report, December 2012

The AF is computed for all bridge components located within a stipulated range and includes both primary piers of the proposed Mobile River Bridge. The analysis evaluates the input parameters and outputs a minimum design loading (demand) that meets an anticipated future fleet and the minimum return period.

Key assumptions:

- The siting of the proposed main span bridge and location of the main span piers is such that some bank/channel protection is available to reduce vessel impact vulnerability. The West pier has some bank protection in both directions of vessel traffic; while the East pier has bank protection in the inbound direction, and is somewhat protected in the outbound direction by a shallow channel region to the North.
- Passenger/ Cruise Vessels have been incorporated into the commercial vessel by adjusting their weight ratios to match the impact loading of similarly-sized tanker and bulk container vessels.

3 Mobile River Site Vessel Traffic

The Mobile Bay is a high-density vessel traffic region servicing major public and private cargo and tanker facilities. Using publically available real time AIS data from NOAA (marinecadastre.org), actual vessel traffic for the available years (2009 to 2014) for the bridge site was analyzed and reduced to produce a vessel traffic distribution list for use in the vessel collision analysis.

The site vessel traffic data shows a steady level of large vessel traffic, with 2009 having the most vessels and largest distribution of passenger (cruise) ships.

As a result, it is our recommendation to use 2009 as the base year for the current vessel data traffic (density) and velocities, and also as the base for the future condition.

Figure 1 Mobile River Vessel Traffic (2009)

Considering the 2009 base year, approximately 750 tankers and cargo ships (of the over 4000 recorded vessels) directly influence the vessel collision results due to their large size. Smaller vessels including barge and tow traffic are included in the overall traffic data, but due to their relative size are not included in the vessel fleet classes.

Each vessel's data was captured, including the vessel name, length (LOA), beam (Width), transiting draft (depth), and velocity. All of these properties were carried through the data analysis to assist with fleet classification and associated speeds that represent this bridge site.

The following tables present the fleet class, characteristics and vessel class speeds for each direction utilized in the AASHTO analysis for 2009 (considered the base year).

2009 Vessel Fleet ***Vessel Class Speed, Knots***

Class	*DWT Class, tonnes*	*Inbound*	*Outbound*	*Average*
V-1	160,000-180,000	4.3	4.1	4.2
V-2	140,000-159,999	4.2	4.8	4.5
V-3	120,000-139,999	4.0	5.0	4.5
V-4	100,000-119,999	4.5	5.1	4.8
V-5	80,000-99,999	4.4	4.8	4.6
V-6	60,000-79,999	4.7	5.0	4.9
V-7	40,000-59,999	4.7	5.3	5.0
V-8	20,000-39,999	5.1	4.9	5.0
V-9	10,000-19,999	5.4	6.1	5.8
V-10	1,000-9,999	5.6	6.5	6.0

Table 1 Fleet Class Characteristics

4 Future Growth Rates

In order to assess the bridge's vulnerability to vessel collision over the 75 year life of the bridge, a future fleet definition is necessary in order to determine the demand. Although the past data analyzed was finite and highly accurate, the future data is less certain and necessitates an estimation based upon growth rates in order to present a future vessel fleet for evaluation. After considering a range of growth models in order to evaluate the sensitivity of the results, including research produced by Florida DOT and predictions generated from a nearby Gulf port, we are recommending a compound growth rate of 2% across the fleet. The resulting future vessel traffic numbers are considered to be conservative, upper-bound values given the current traffic trends. The following chart presents the 2009 and future (+75-year) projection for each class of vessel DWT

The application of the future fleet compound growth rates produces a fleet distribution illustrated in the figure below.

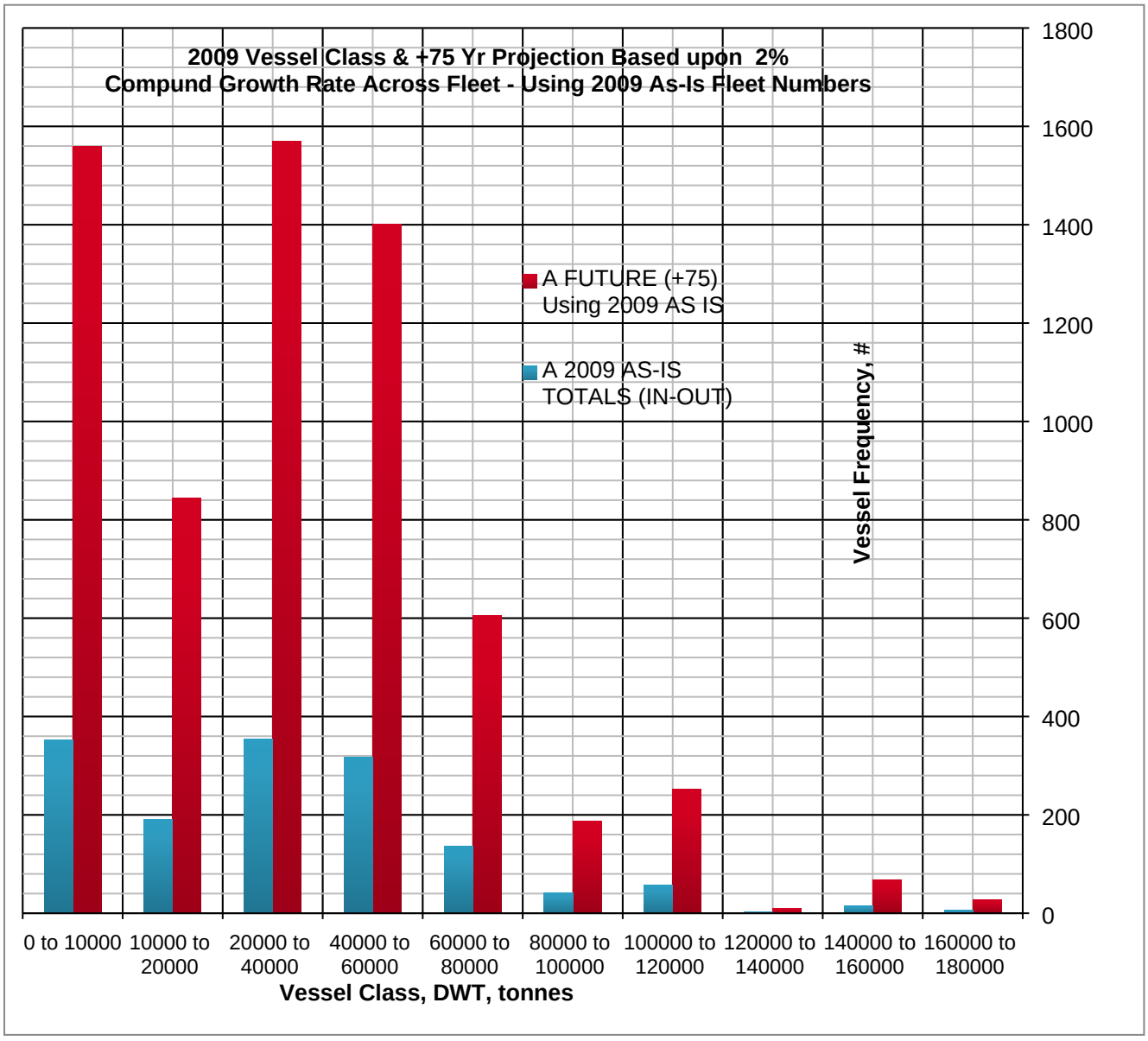


Figure 2 2009 Vessel Class and 75Year Projections

5 Analysis Results and Force Recommendations

The following table summarizes the AASHTO vessel collision analysis results, indicating the lateral pier design force for both the current traffic data and the future fleet condition based upon the aforementioned growth factors. **The recommended design vessel collision force, using the traffic values for the future fleet, and the vessel speeds from the 2009 fleet, is 17,000 kips.**

	2009 ACTUAL AS-IS (CASE A)			FUTURE with AS-IS (CASE A2)		
	No Rate Increase, AS-IS			2% Across the Fleet Increase		
DWT Class	IN	OUT		IN	OUT	
160000-180000	**3**	**3**		**14**	**14**	
140000-159999	**8**	**7**		**36**	**31**	
120000-139999	**0**	**0**		**5**	**5**	
100000-119999	**28**	**29**		**124**	**129**	
80000-99999	**22**	**20**		**98**	**89**	
60000-79999	**69**	**68**		**305**	**301**	
40000-59999	**157**	**160**		**694**	**707**	
20000-39999	**179**	**176**		**791**	**778**	
10000-19999	**97**	**94**		**429**	**416**	
1000-9999	**178**	**175**		**787**	**773**	
Pier Location	Pier #					
		Design Vessel/Ps			***Design Vessel/Ps***	
1E-DN	P6	50,000	*DWT*		70,000	
		14,601	*Ps, kips*		16,661	
1W-DN	P5	50,000	*DWT*		70,000	
		15,022	*Ps, kips*		17,046	
1E-UP	P2	70,000	*DWT*		110,000	
		15,731	*Ps, kips*		18,662	
1W-UP	P1	50,000	*DWT*		92,754	
		13,342	*DWT*		16,991	
Hp to meet AF	**H_p**	13,000			**17,000**	
(AF>10,000 = OK)	**AF**	10,530			10,386	

Table 2 Vessel Collision Analysis Results

6 Degree of Damaged and Protective Measures

Once the vessel collision force is calculated it will be applied to the bridge structural model to assess the level of damage and to identify potential mitigation strategies such as reinforcing of key structural elements and/or provide supplementary protective measures. Table 3 below uses five cable-stayed bridges over a major navigation channel to illustrate the various protection strategies that have been used previously on similar bridges.

This analysis is underway way and the result will be presented to ALDOT under separate cover.

Vessel Collision Design Similar Projects							
Project Name	***Project Photo***	***Project Location***	***Project Description***	***Design Load (main pier) (kips)***	***Vessel Speed***	***Protection System***	***Notes***
Tappan Zee Bridge Replacement		New York	Cable-Stay – 1,200 ft. Main Span (Under Construction)	23,000	10 knots	No Protection	Capacity of bridge with one pile removed at service level is evaluated
Port Mann Bridge		Vancouver, B.C.	Cable-Stay – 1,542ft. Main Span (Completed 2012)	16,900	Not Readily Available	No Protection	Designed for Ultimate Capacity
CCHB (Proposal)		Corpus Christi, Texas	Cable-Stay – 1,520ft. Main Span	18,700	7 knots	Grounding considered, Permanent Cofferdam to protect slender piles	Designed for Ultimate Capacity
Veterans' Glass City Skyway		Toledo, Ohio	Cable-Stay - 612.5ft. Main Span (Completed 2007)	23,000	Not Readily Available	No Protection	Designed for Essentially Elastic criteria
Sunshine Skyway		Tampa, Florida	Cable-Stay - 1,200ft. Main Span (Completed 1987)	12,000	Not Readily Available	Dolphin and Rock Islands	Designed for Ultimate Capacity

Table 3 Vessel Collision Design of Similar Projects

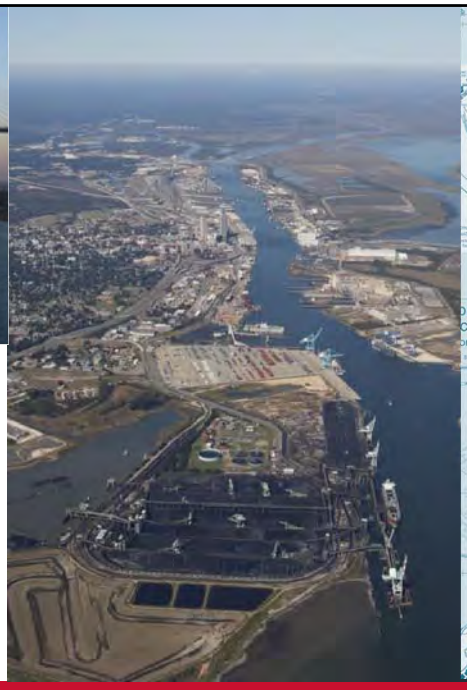
Appendix A – June 24, 2016 Presentation

Mobile River Bridge

Vessel Collision Analysis

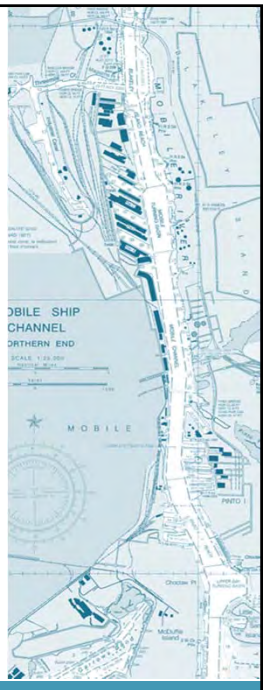
June 24, 2016

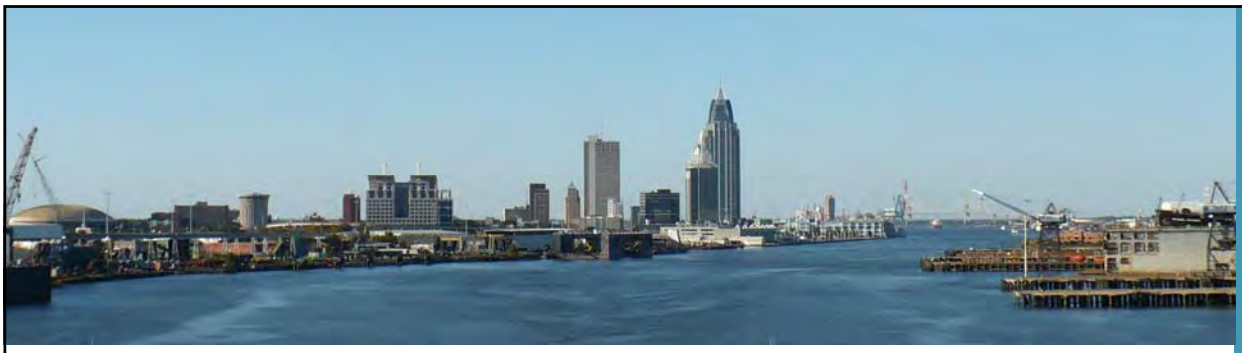
HDR



General Presentation Outline

1. Purpose of Analysis
2. Studies to Date
3. AASHTO Vessel Collision Analysis Approach/Methodology
4. Mobile River Bridge Site Vessel traffic
5. Application of Loads to Structure
6. Considerations for Loading
7. Acceptance Frequency (AF) Analysis for Site
8. Future Fleet Considerations
9. Summary and Recommendations
10. Comments/Input



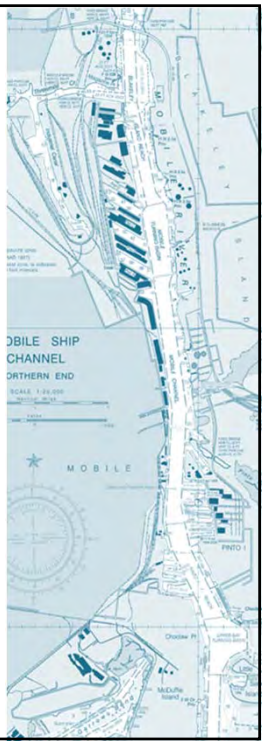


01 Purpose of Analysis

- Purpose of Analysis
  - AASHTO requirement;
    - *3.14.1All bridge components in a navigable waterway crossing, located in design water depths over 2.0 ft shall be designed for vessel impact*
    - Design to resist vessel collision forces AND/OR adequately protect

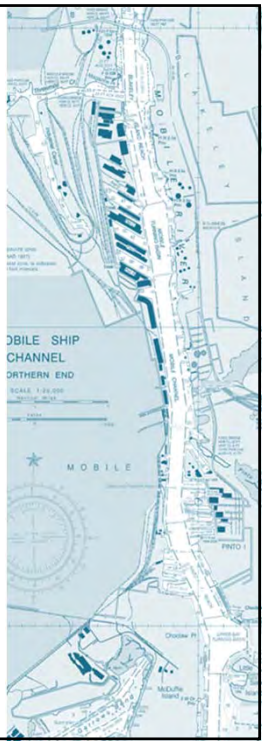
3.14.2—Owner's Responsibility

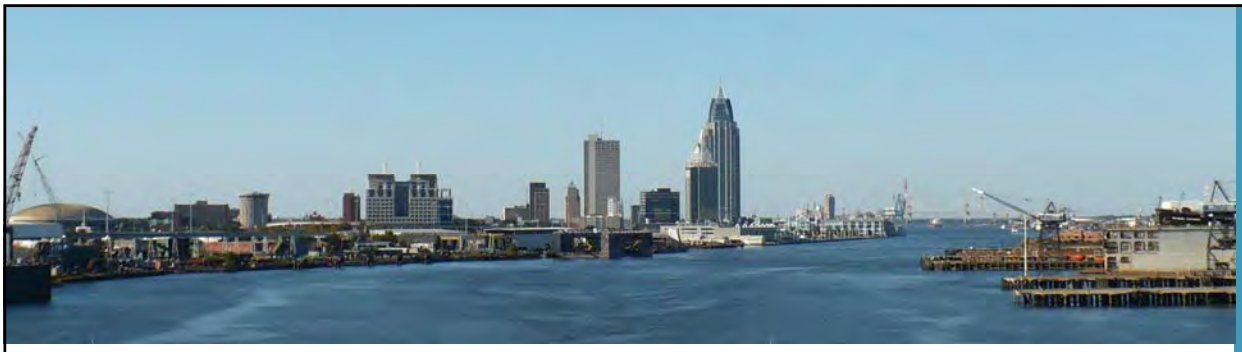
The Owner shall establish and/or approve the bridge operational classification, the vessel traffic density in the waterway, and the design velocity of vessels for the bridge. The Owner shall specify or approve the degree of damage that the bridge components, including protective systems, are allowed to sustain.



Scope:

- Main Span Focus
  - Assess Current snapshot of Commercial Vessel Traffic the operational classification (critical or typical)
  - The vessel traffic density
  - Understand Future Commercial Vessel Traffic Scenario
  - Foundation and Pier Vulnerability
  - The design velocity of vessels for the bridge
    - Tankers
    - Bulk Containers
    - Passenger vessels
    - Barges and tows
  - Vessels not Included in Analysis:
    - Naval Vessels
    - Recreational vessels
    - < 1,000 DWT
    - Security Considerations
  - Impacts due to Air Draft Not Included
    - Assumed addressed

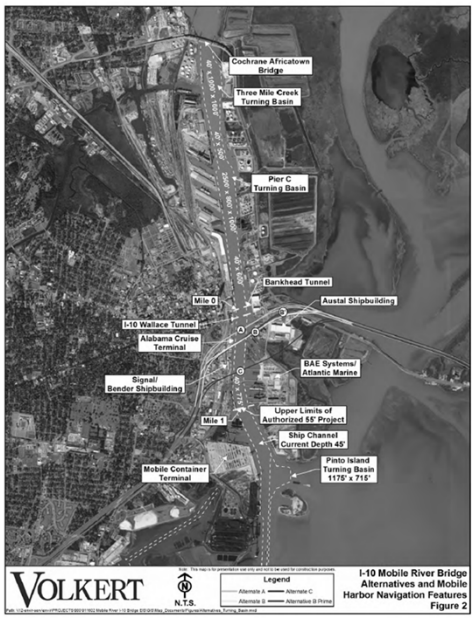


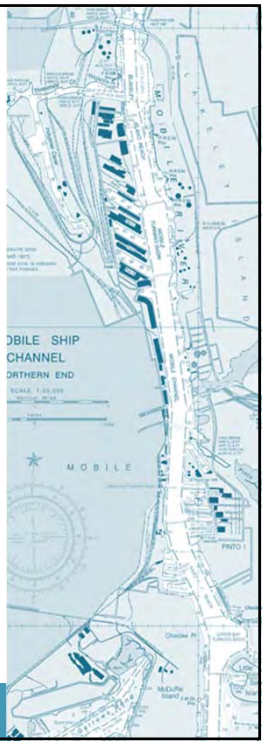


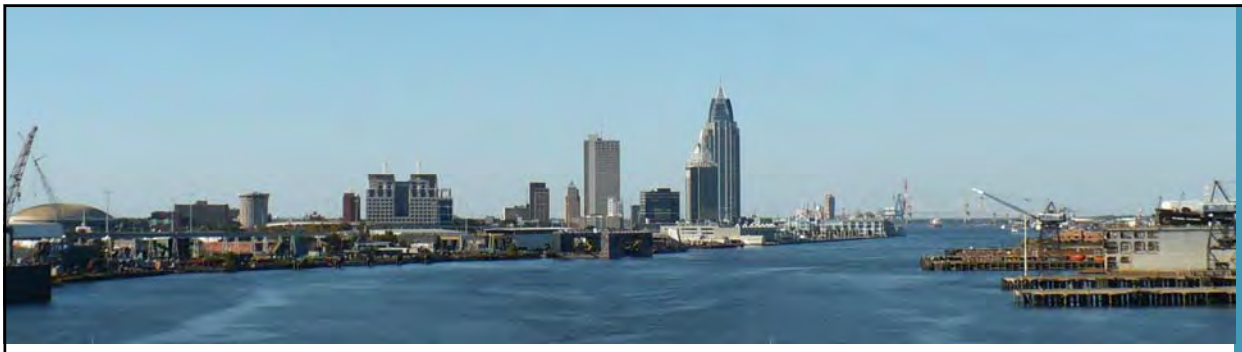
02 Studies to Date

Studies to Date

- Draft Environmental Impact Statement
  - FHWA-AL-EIS-14-01-D
  - July 2014
- Appendix C:
  - » Air Draft Clearance Report (December 2012) : 215 ft.





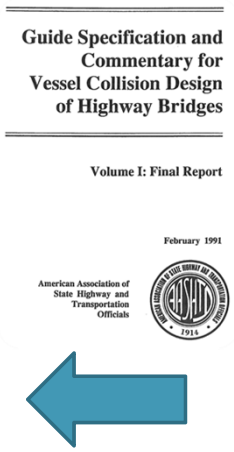


03 AASHTO Vessel Collision Analysis Approach/Methodology

Guide Specifications for Vessel Collision

3 Original Methods:

- MI – Simplified, conservative approach, good when barges are predominant and only in certain prescriptive cases can it be used.
- MII – Probabilistic (expected approach) uses actual traffic data, vessel characteristics and details with the site geometry to assess the probable "design vessel" which meets an "acceptance criteria".
- MIII – Risk + Economic approach to better determine the costs of disruption to the bridge, and other potential factors as a means to understand the protection needs.



Current AASHTO 3.14 Requires Method II

Loading Combinations

Extreme Event II

- CV – Vessel Collision

3-14 AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, SEVENTH EDITION, 2014

Table 3.4.1-1—Load Combinations and Load Factors

Load Combination Limit State	DC DD DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	WL	FR	TU	TG	SE	Use One of These at a Time: EQ	BL	IC	CT	CV
Strength I (unless noted)	γ_p	1.75	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength II	γ_p	1.35	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength III	γ_p	—	1.00	1.40	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength IV	γ_p	—	1.00	—	—	1.00	0.50/1.20	—	—	—	—	—	—	—
Strength V	γ_p	1.35	1.00	0.40	1.0	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Extreme Event I	γ_p	γEQ	1.00	—	—	1.00	—	—	—	1.00	—	—	—	—
Extreme Event II	γ_p	0.50	1.00	—	—	1.00	—	—	—	—	1.00	1.00	1.00	1.00
Service I	1.00	1.00	1.00	0.30	1.0	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service II	1.00	1.30	1.00	—	—	1.00	1.00/1.20	—	—	—	—	—	—	—
Service III	1.00	0.80	1.00	—	—	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service IV	1.00	—	1.00	0.70	—	1.00	1.00/1.20	—	1.0	—	—	—	—	—
Fatigue I—*LL, IM & CE* only	—	1.50	—	—	—	—	—	—	—	—	—	—	—	—
Fatigue II—*LL, IM & CE* only	—	0.75	—	—	—	—	—	—	—	—	—	—	—	—

Acceptance Criteria (AF)

- "Critical" or "Essential" is Assumed
  - 10,000 year Return Period (1/AF)
  - 0.01 in 100 years (1% in 100 years)
  - AF = 0.0001
- Calculated for the entire bridge within 6 x LOA
- Statistics and probabilities managed with site specific conditions

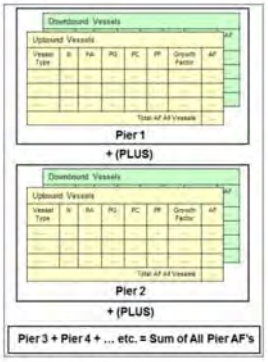


Figure 4 – Computation of Annual Frequency of Collapse (AF)

4.8.2 Design Vessel Acceptance Criteria

The design vessels shall be selected based on the bridge operational classification, vessel, bridge, and waterway characteristics in accordance with the following acceptance criteria for the total bridge:

- *Critical/Essential Bridges*. The acceptable annual frequency of collapse, *AF*, of critical/essential bridges shall be equal to, or less than, 0.01 in 100 years (*AF* = 0.0001).
- *Typical Bridges*. The acceptable annual frequency of collapse, *AF*, of typical bridges shall be equal to, or less than, 0.1 in 100 years (*AF* = 0.001).

The acceptable annual frequency of bridge collapse for the total bridge as determined above shall be distributed over the number of pier and span elements located within the waterway, or within the distance

4.8.3 Annual Frequency of Collapse

The annual frequency of bridge element collapse shall be computed by:

$$AF = (N)(PA)(PG)(PC)(PF) \qquad (4.8.3\text{-}1)$$

where:

AF = annual frequency of bridge element collapse due to vessel collision;

N = annual number of vessels classified by type, size, and loading condition which can strike the bridge element;

PA = probability of vessel aberrancy;

PG = geometric probability of a collision between an aberrant vessel and a bridge pier or span;

PC = probability of bridge collapse due to a collision with an aberrant vessel; and

PF = adjustment factor to account for potential protection of the piers from vessel collision due to upstream or down stream land masses, or other structures, that block the vessel.

AF shall be computed for each bridge element and vessel classification. The summation of all element *AF*s equals the annual frequency of collapse for the entire bridge structure.

Probability of Aberrancy (PA)

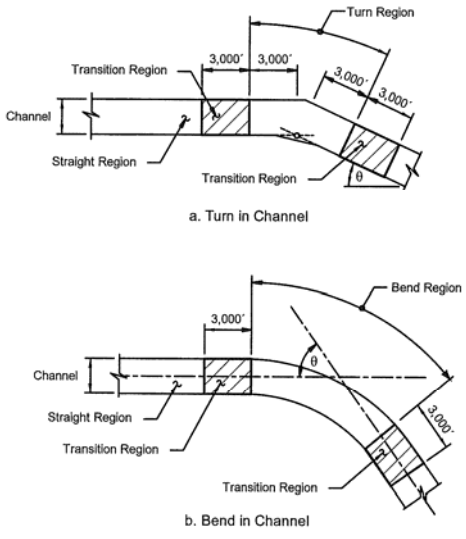


Figure 4.8.3.2-1—Waterway Regions for Bridge Location

$$PA = BR(R_B)(R_C)(R_{XC})(R_D) \qquad (4.8.3.2\text{-}1)$$

BR = A historical accident data value specific to bridges or barges.

R_b= Factor for Channel Characteristics, Straight, transition, or a bend/turn region

Others to account for currents and traffic density.

Geometric Probability (PG)

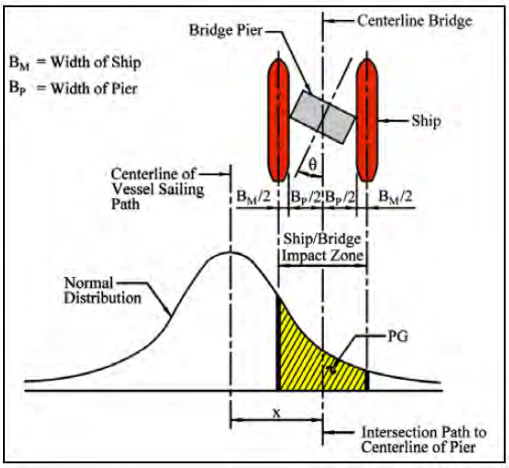


Figure 5 – Geometric Probability of Pier Collision

PG → A geometric probability associated with the possibility that an aberrant vessel (losing control) could hit a pier or bridge element.

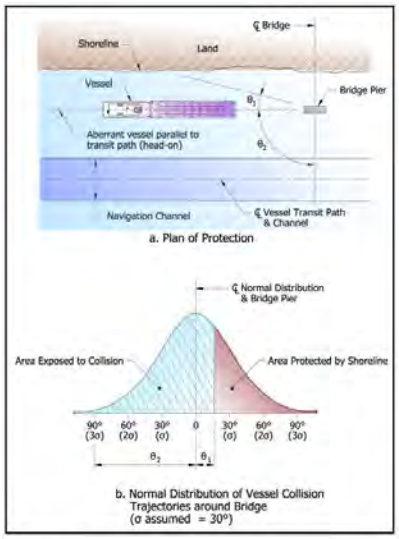
Based upon a normal distribution using the mean as the CL transit path, the std Dev is equal to the LOA of the vessel design fleet, and extends 3 x LOA either side of the CL transit path.

Protection Factor (PF)

This Adjusts the AF for full or partial protection such as that provided by artificial islands, dolphins, piling systems or other, including the river banks.

In some cases and for particular directions, a wharf , waterway feature, or parallel bridge may protect the bridge element in question, affecting the AF.

Full protection means PF= 0.0, and none is 1.0



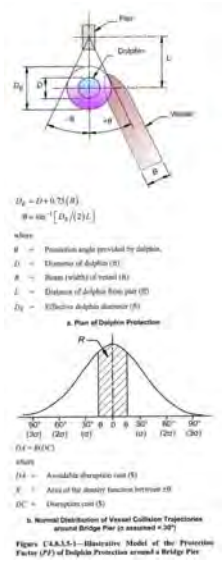


Figure 6 – Protection Factor Illustration

Vessel Frequency (N)

- The number of vessels for that class, adjusted for the physical and geometric possibility that each vessel could collide with that particular bridge element:
- Depth at location may reduce fully loaded vessels for that direction
- Airspace clearance (Vertical Nav Envelope) effects to that class (Perhaps large low vessels won't hit the superstructure).

Example NOAA Real Time Data

Probability of Collapse (PC)

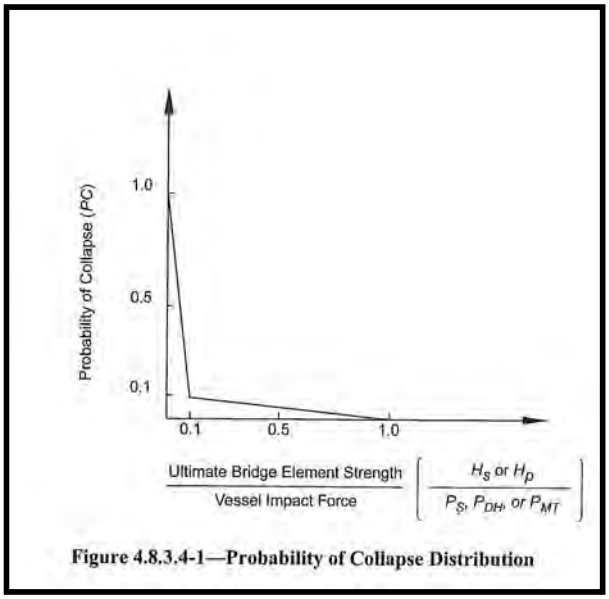


Figure 4.8.3.4-1—Probability of Collapse Distribution

PC includes a combination of effects based upon impact speed, vessel size and mass:

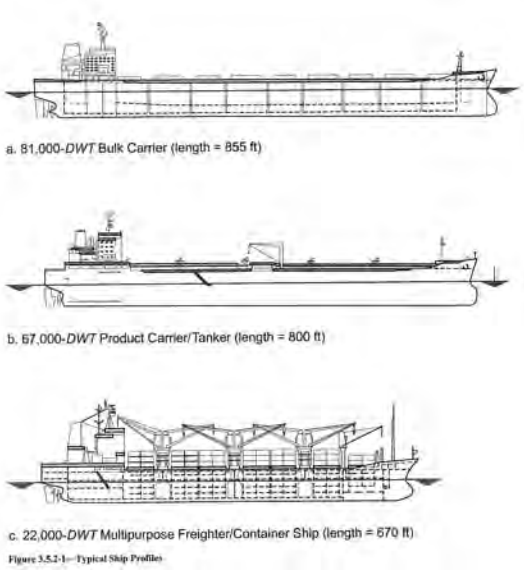
- Hp
- Ps

Computed based upon analysis of Ps (Vessel impact loading) with the Ultimate Pier Resistance (to be determined).

Iterative Process:
The Ultimate pier lateral resistance (Hp) required so that the AF is met for the bridge: Iterated until met.

Probability of Collapse (PC) (cont'd)

Sample Ship Impact Forces (P_s)

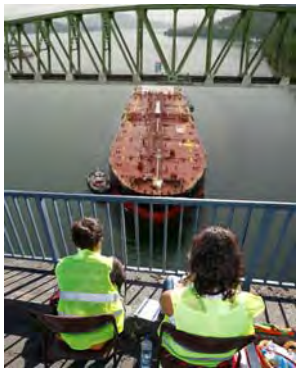


AASHTO Guide Specification C3.9.1-1

Vessel Type	Displacement Tonnage (Carrying Capacity), Tons	Typical AASHTO Impact Forces, Kips (10 knots Assumed)
Barges	3,000 to 6,000	2,000
Ships:		
Small Ship	3,000	6,900
Medium	10,000	12,300
Large	40,000	25,800
Extra Large	100,000	41,300

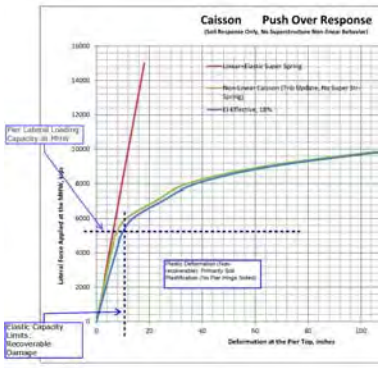
Where to Obtain "N" – Number of Vessels?

- NOAA – Real Historical Data from 2009 to 2014
  - Vessel rich (I.e. tankers, cruise, cargo)
  - Key to information for Mobile, AL.
- WSCS/USAC – Passed the Point historical data
  - Barge Information rich
  - Less critical information (Large Vessels Govern)
- Movable Bridge Logs
- Interviews with Barge Operators
- Lock Gate Records
- The *Tired* and True Approach

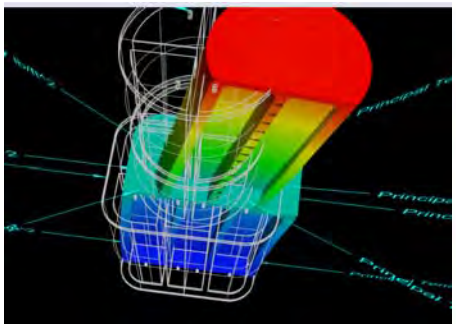


Ultimate Pier Capacity (Hp):

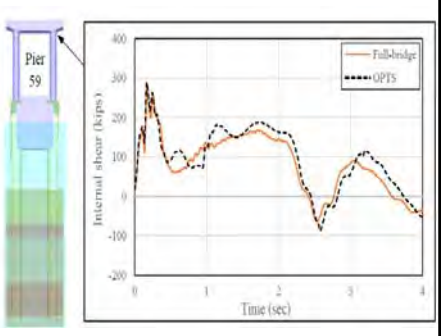
- The AASHTO analysis iterates to the required demand that the bridge is then designed for.
- The new bridge can be allowed to plastify to absorb damage:
  - AASHTO 3.14.13 allows for inelastic behaviour and redistribution of force effects as long a “no collapse” criteria is met
  - Owner approval for damage state required (By AASHTO 3.14.2)
    - Fully Elastic – All damage to vessel, bridge has minor non-structural damage, remains in full serviceability
    - Partial damage – Damage to vessel and structure



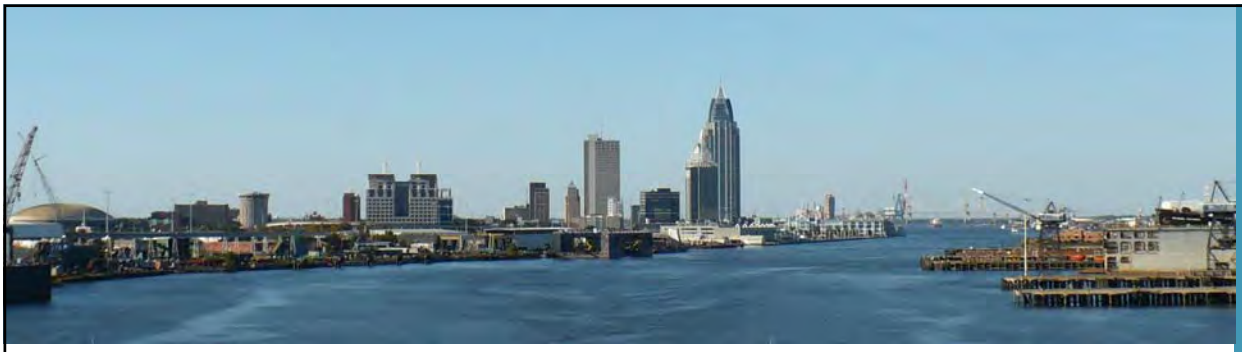
Push Over Response of a bridge Foundation



Stress Analysis and Response of a bridge Support (Pier)



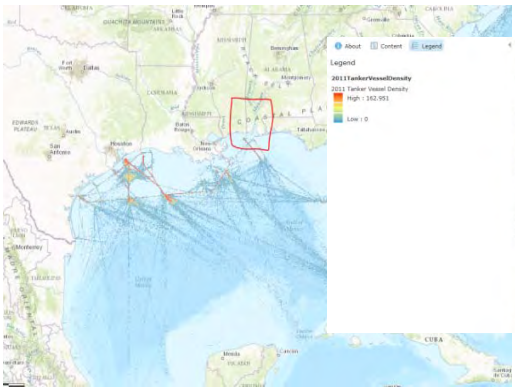
Time-history Response of a bridge Foundation to dynamic/impact loading

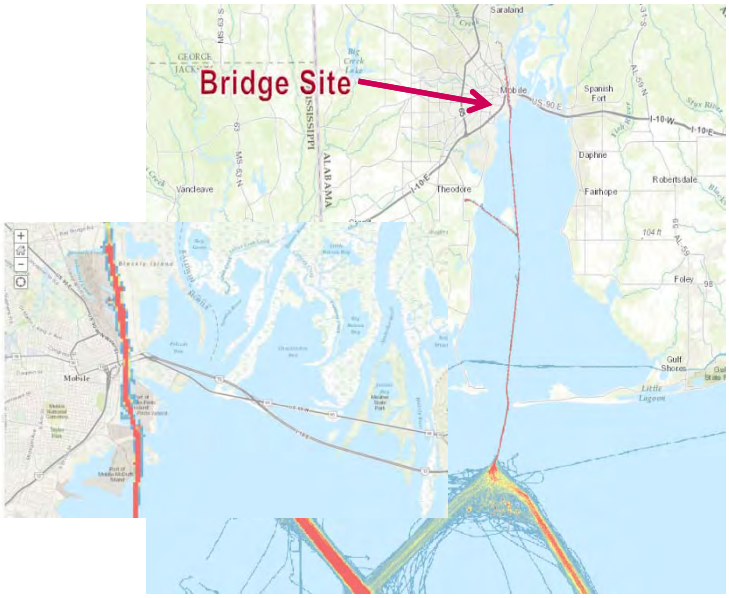


04 Mobile River Bridge Site Vessel Traffic

Mobile Bay: High Density, Large Vessels

- Major link for ASPA and other maritime facilities
- Future Cruise Terminal
- Maritime Industry
- Public and private cargo terminals
- 25.1 Million tons of Cargo (2011)*
- Long term ship building - Austal USA

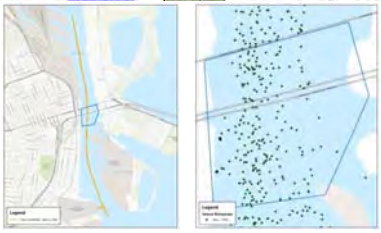




NOAA Data: heat maps

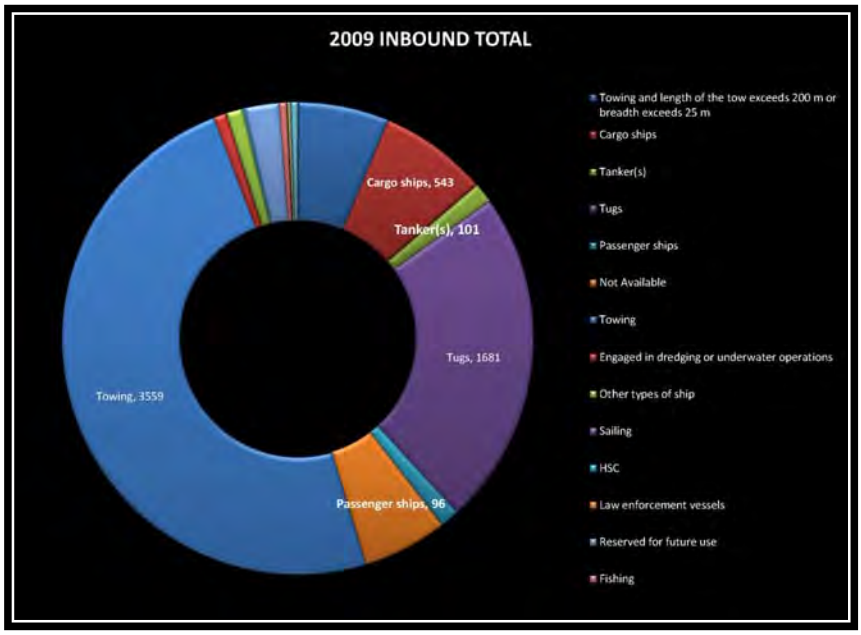
Mobile Bay: High Density, Large Vessels

Unique MMSI	In # mo	Vessel Name	VesselType	Length	Length	Width	Width	dwt
235058591	5	CMA CGM SWORDFISH	Cargo ships	294	964.32	32	104.96	nessind
235059982	3	CMA CGM TARPON	Cargo ships	294	964.32	32	104.96	
235052093	2	CMA CGM WHITE SHARK	Cargo ships	294	964.32	32	104.96	
235012140	2	CMA CGM ORCA	Cargo ships	294	964.32	32	104.96	
235012310	9	CMA CGM BLUE WHALE	Cargo ships	293	961.04	32	104.96	
235012300	5	CMA CGM DOLPHIN	Cargo ships	293	961.04	32	104.96	
235054096	2	CMA CGM MARLIN	Cargo ships	293	961.04	32	104.96	
235054102	2	CMA CGM KINGFISH	Cargo ships	293	961.04	32	104.96	
367685000	1	MAERSK UTAH	Cargo ships	292	957.76	32	104.96	
303548000	8	SEALAND RACER	Cargo ships	292	957.76	32	104.96	
368348000	4	SEALAND EAGLE	Cargo ships	292	957.76	32	104.96	
338401000	6	SEALAND METEOR	Cargo ships	292	957.76	32	104.96	
366196000	7	SEALAND CHAMPION	Cargo ships	291	954.48	32	104.96	
368991000	4	REGULUS X	Cargo ships	289	944.84	32	104.96	
235005690	1	CAPE OSPREY	Cargo ships	280	918.4	45	147.6	
538003322	1	OVERSEAS YELLOWSTONE	Tanker(s)	280	918.4	40	131.2	
259975000	1	CATHERINE KNUTSEN	Tanker(s)	277	908.56	44	144.32	
538001641	2	GENMAR ORION	Tanker(s)	274	898.72	48	157.44	
538090158	1	SKS MENINE	Tanker(s)	274	898.72	48	157.44	
538003210	1	NORDIC JUPITER	Tanker(s)	274	898.72	48	157.44	
259833000	1	SKS SINNI	Tanker(s)	274	898.71	48	157.44	
636014185	1	ARIADNE	Tanker(s)	274	898.72	50	164	
538029000	1	ZENITH SPIRIT	Tanker(s)	272	892.16	48	157.44	
259820000	1	WILMA	Tanker(s)	271	888.88	44	144.32	
538090184	1	HELLESPONT TRINITY	Tanker(s)	270	885.6	46	150.88	
235010440	1	ZIM KIAMEN	Cargo ships	260	852.8	32	104.96	
247165700	4	DRUMMOND VOYAGER	Cargo ships	258	846.24	42	137.76	
636091513	9	ZIM JAMAICA	Cargo ships	254	833.12	32	104.96	
636091515	2	ZIM IBERIA	Cargo ships	254	833.12	32	104.96	
240773000	5	CMA CGM LOTUS	Cargo ships	253	829.84	32	104.96	
366204000	3	PLESS	Cargo ships	250	820	32	104.96	
538003233	2	OVERSEAS ACADIA	Tanker(s)	250	820	45	147.6	



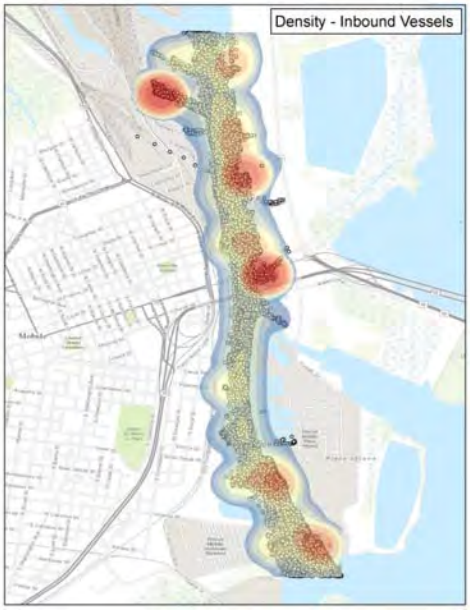
NOAA Site Specific Data Shown

Mobile Bay: High Density, Large Vessels



NOAA Reduced Data Source at Bridge Site

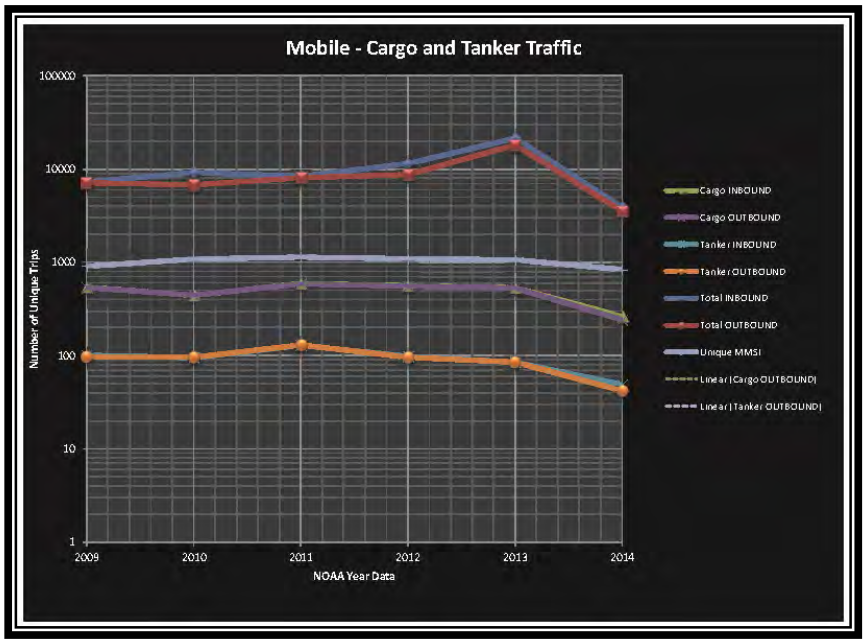
Mobile Bay: High Density, Large Vessels



NOAA Data Source at Bridge Site: All Vessels

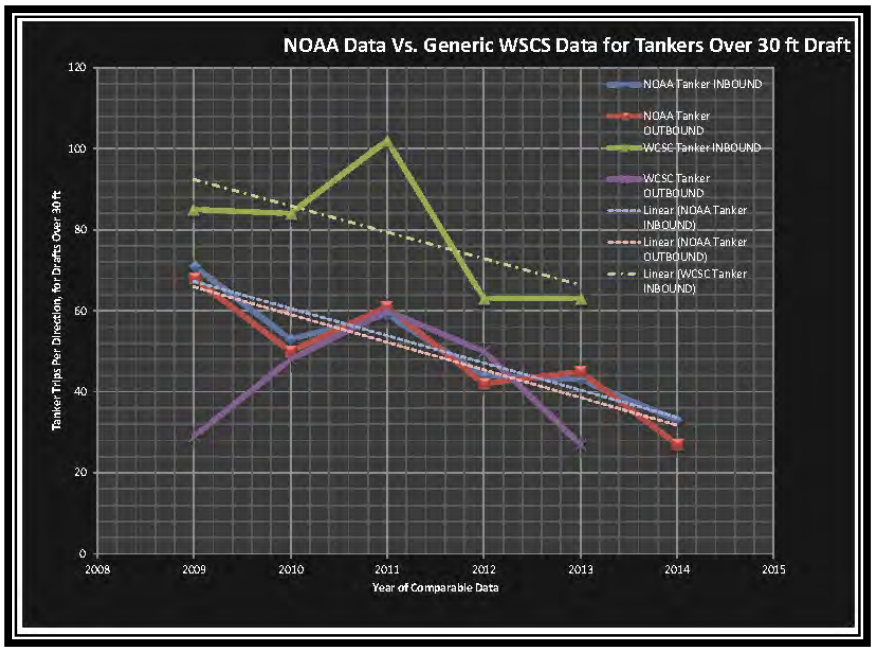
NOAA Reduced Data Source at Bridge Site:
> 656 ft . & >3.5 knots

Mobile Bay: High Density, Large Vessels



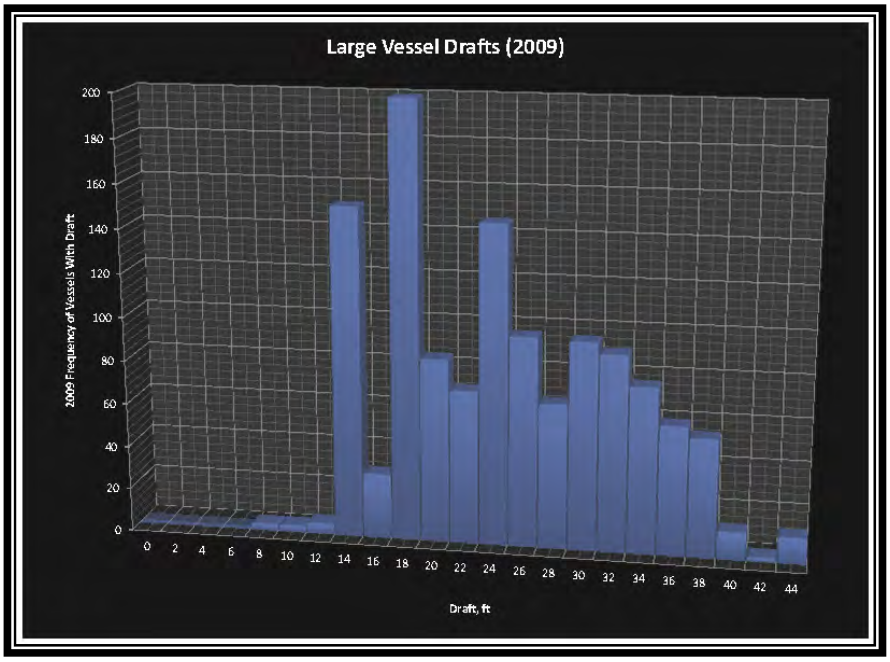
NOAA Reduced Data Source at Bridge Site

Mobile Bay: High Density, Large Vessels



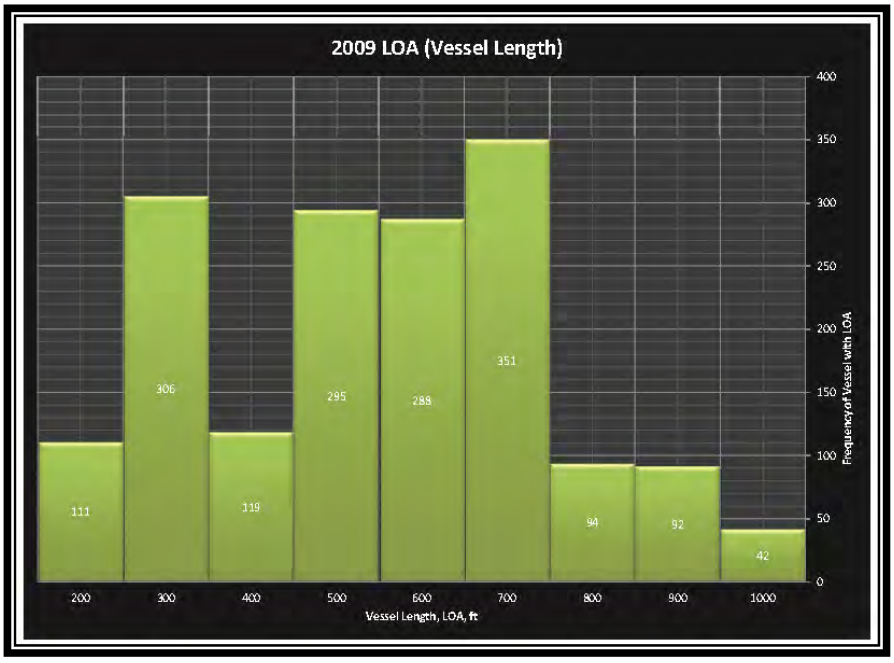
NOAA Reduced Data Source at Bridge Site

Mobile Bay: High Density, Large Vessels



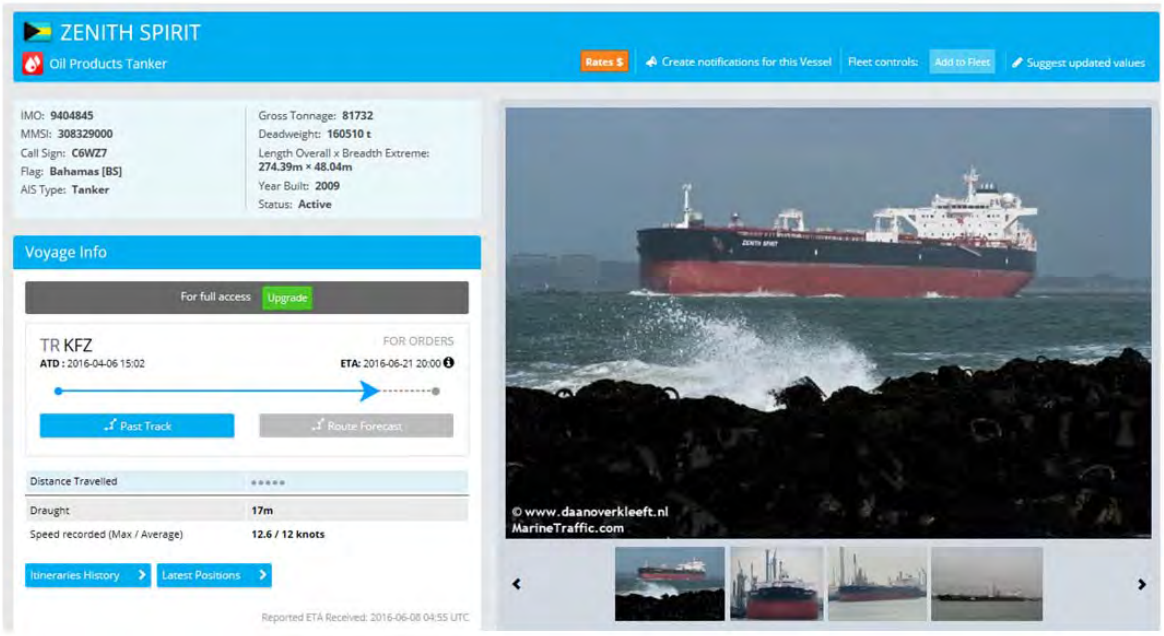
NOAA Reduced Data Source at Bridge Site

Mobile Bay: High Density, Large Vessels



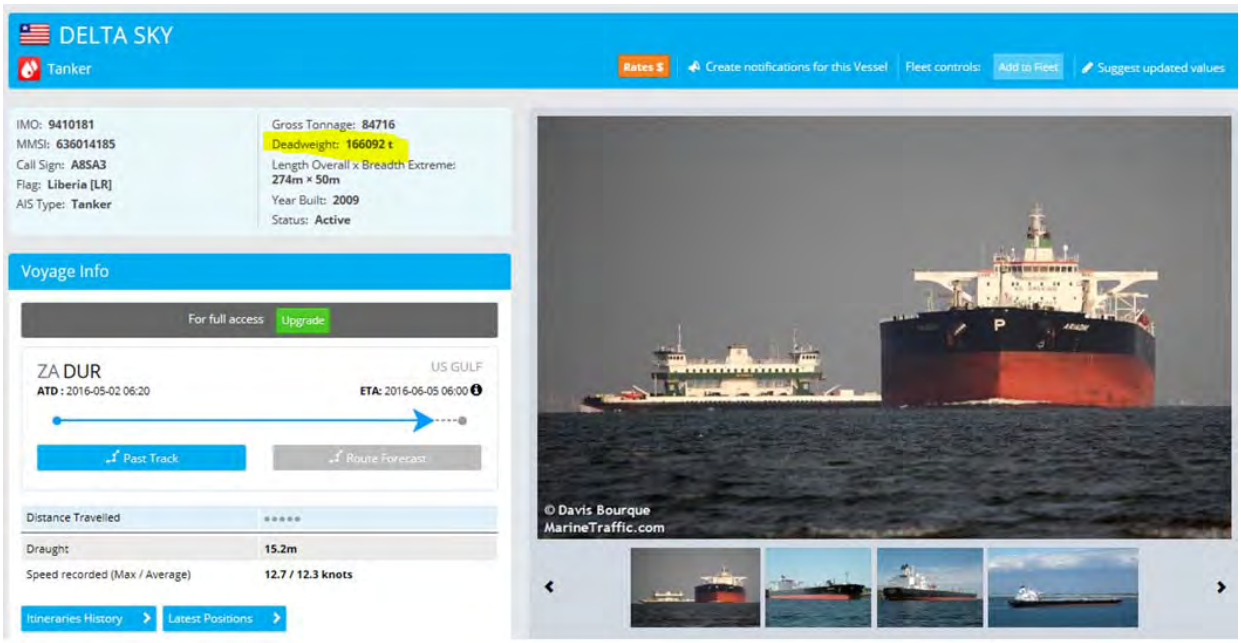
NOAA Reduced Data Source at Bridge Site

Mobile Bay: High Density, Large Vessels



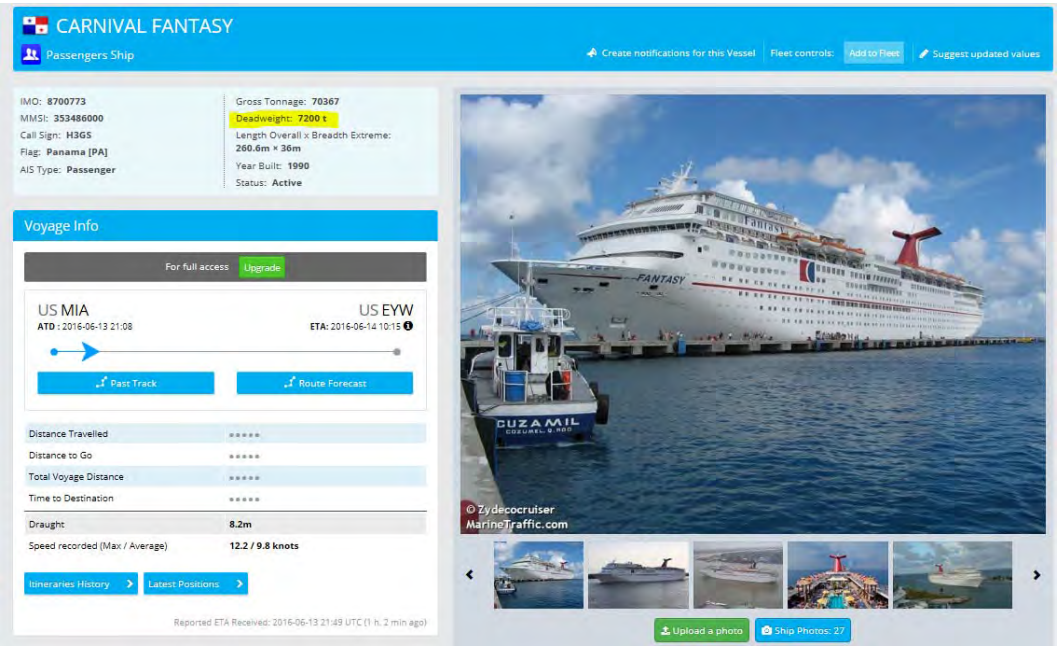
Source: Marinetraffic.com

Mobile Bay: High Density, Large Vessels



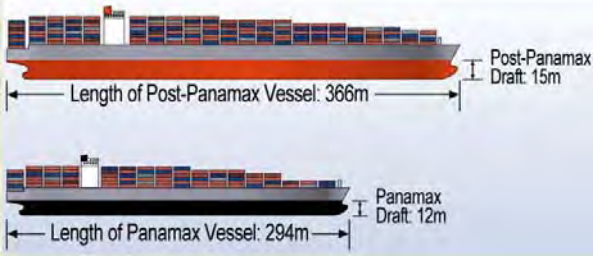
Source: Marinetraffic.com

Mobile Bay: High Density, Large Vessels



Source: Marinetraffic.com

Mobile Bay: High Density, Large Vessels



Panamax:

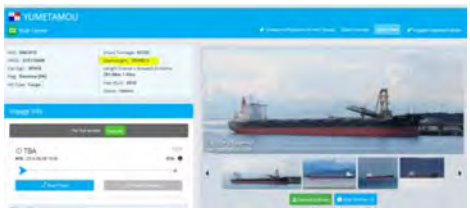
- 52,000 DWT
  - 30,000 kip @10 kt
  - LOA = 980 ft
  - Beam = 106 ft
  - Draft = 40ft

Post Panamax:

- 120,000 DWT
  - 45,000 kip @ 10 kt
  - LOA = 1,400ft***
  - Beam = 180ft
  - Draft = 50 ft

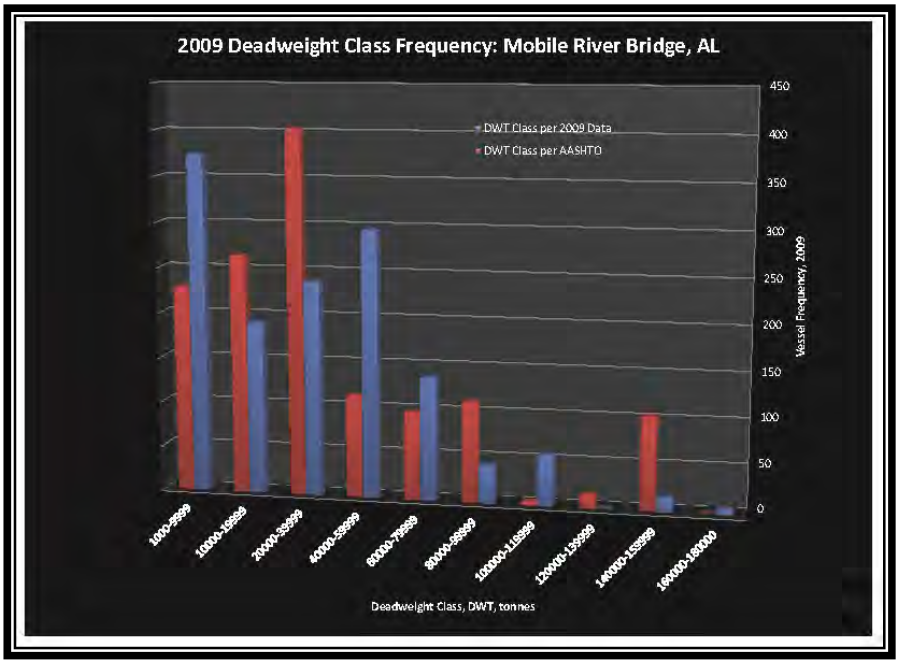
<u>Mobile River:</u>

- Largest Vessels (Oil Tankers)
  - 182,000 DWT (2013) – 55,000 kip @10 kt
  - 167,000 DWT (2009) – 53,000 kip @ 10 kt

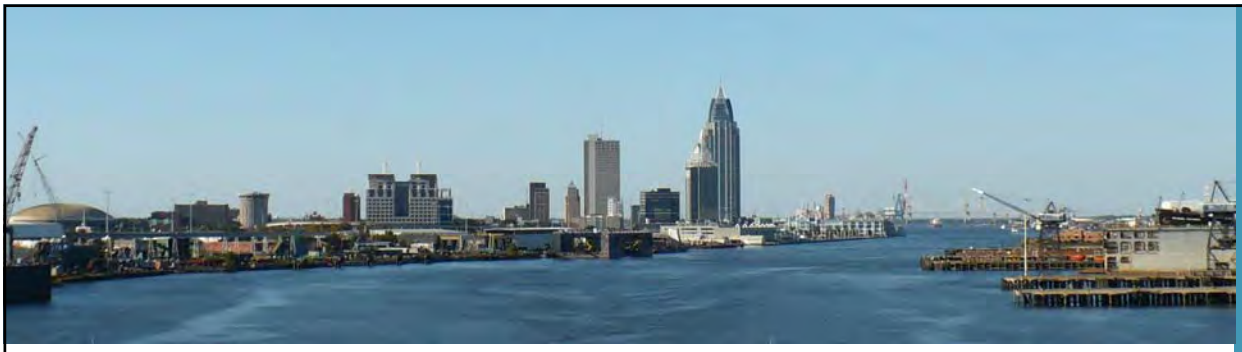


Source: Marinetraffic.com

Mobile Bay: High Density, Large Vessels



NOAA Reduced Data Source at Bridge Site



05 Application of Loads to Structure

Applying the Design Load to Structure

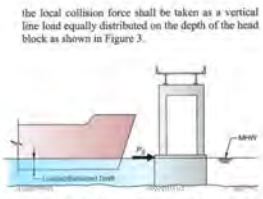


Figure 3.15.1-1—Ship Impact Concentrated Force on Pier (for Foundation Design and Overall Stability)

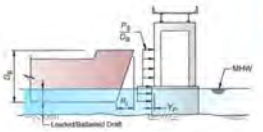


Figure 3.15.1-2—Ship Impact Line Load for Local Collision Force on Pier (for Structure Check and Design)

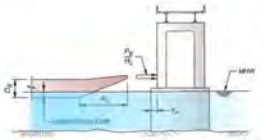


Figure 3.15.1-3—Barge Impact Line Load for Local Collision Force on Pier (for Structure Check and Design)

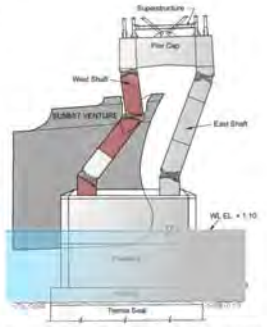


Figure C3.15.1-1—Collapse of Pier 25 of the Sunshine Skyway Bridge Subsequent to Impact by the Bow Overhang of the M/V Summit Venture

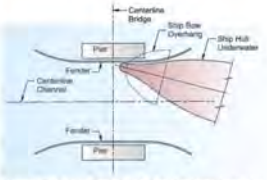
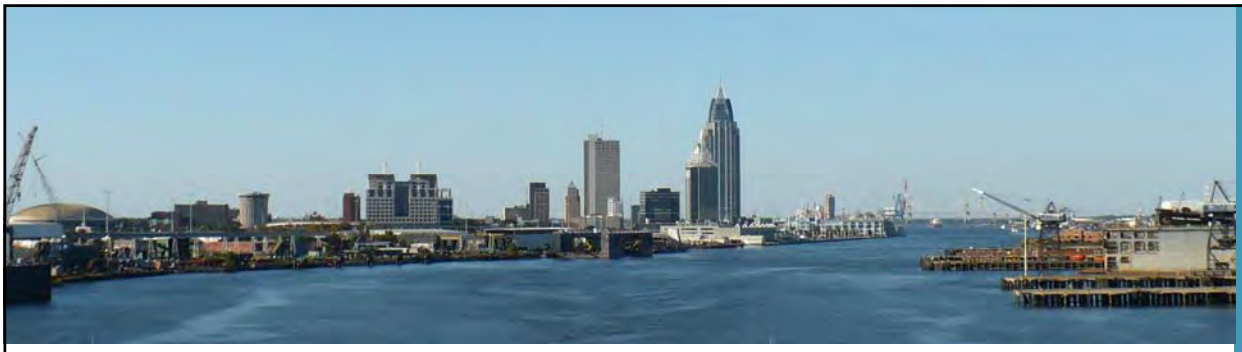


Figure C3.15.1-2—Plan of Ship Bow Overhang Impacting Pier Behind Fender

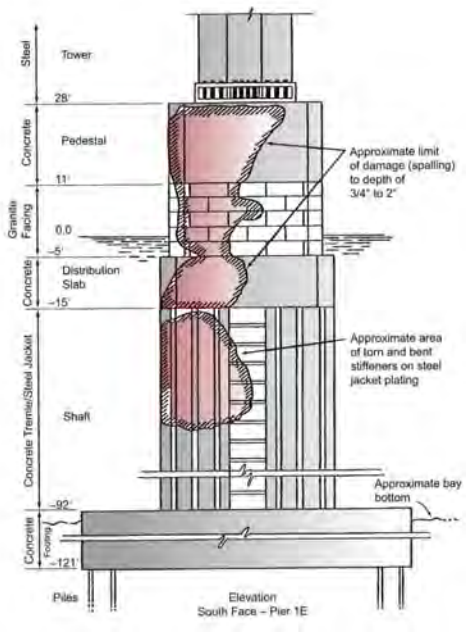
- Once Design Vessel Is determined at each location (Could differ for each pier, superstructure), how applied:
- Extreme Event II Loading Combination
- For Substructure:
  - Equivalent Static Force applied as:
  - 100% at MHW in Transverse Direction
  - 50% at MHW, Longitudinal Direction
  - Not Concurrent.



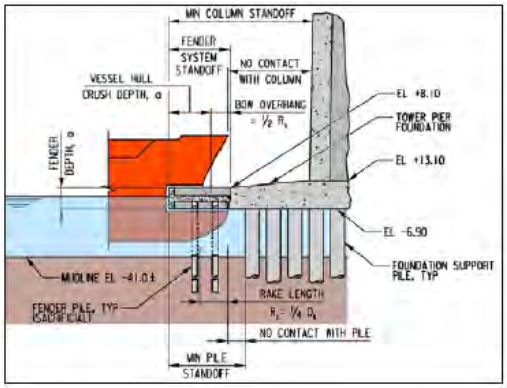
06 Considerations for Loading

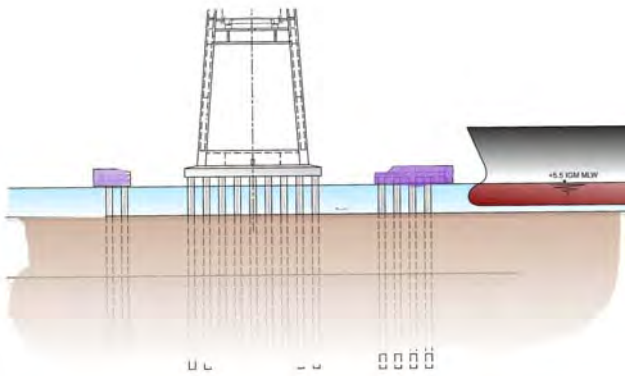
Considerations: Vessel Geometry and Impact Exposure

1. Direct Application to Structure



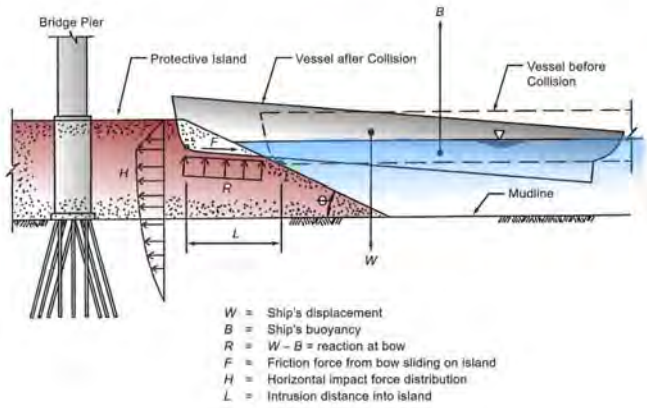
Considerations:



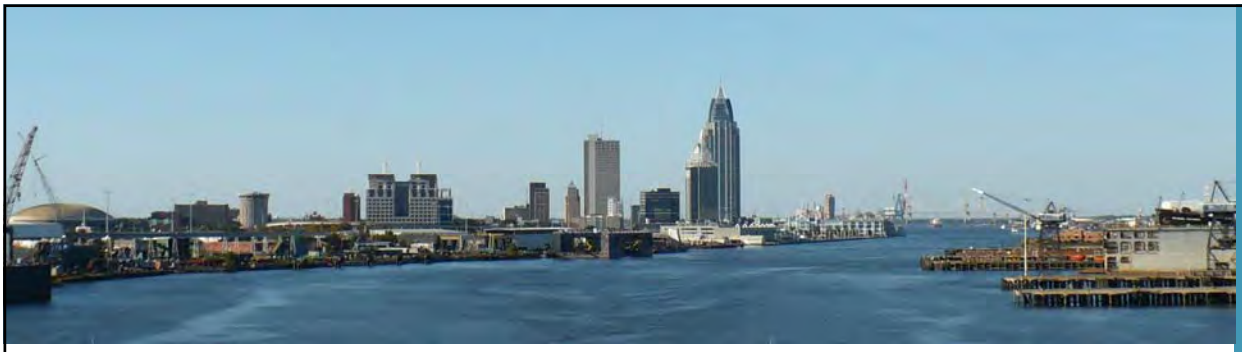


2. Permanent Protection to Structure
- Artificial Islands
- Dolphins
- Other Structure

Considerations:

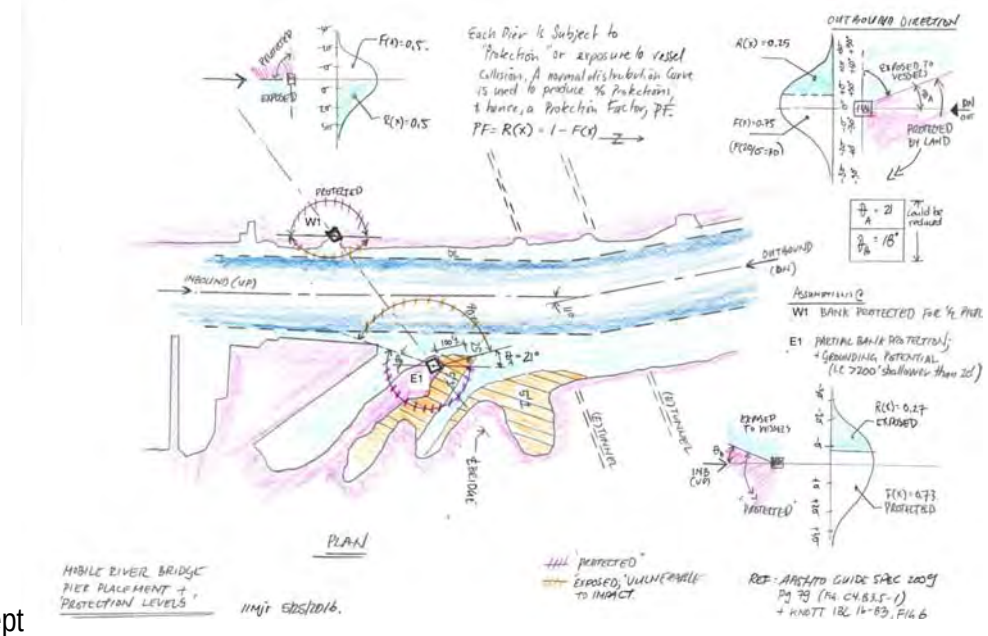


3. Grounding Study As Permanent Protection
   - Artificial Islands
   - Reef
   - Bank Protection



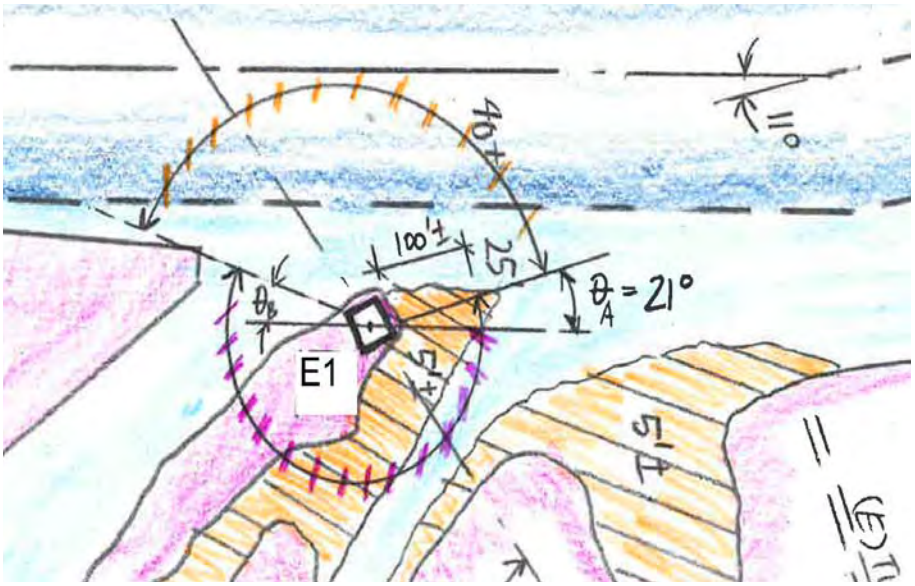
07 Acceptance Frequency (AF) Analysis for Site

AF Analysis for Mobile, AL



Pier Protection Concept

AF Analysis for Mobile, AL



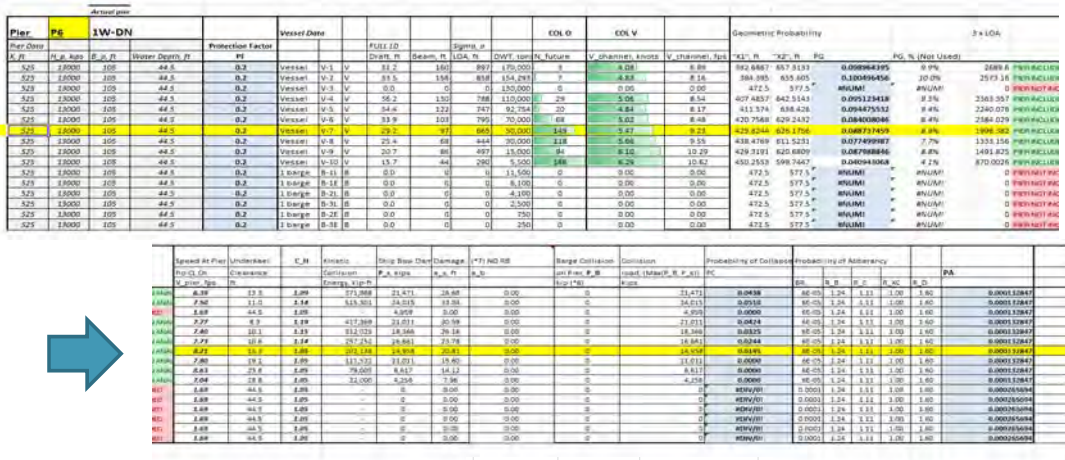
Pier Protection Concept Detail at Eat Pier

AF Analysis (2009 With Bank Protection Shown): Input

Critical or Typical ?	Critical	AF Limit	0.0001
			Variables
BR	Ship	*0.00006*	*BR_ship*
	Barge	*0.00012*	*BR_barge*
Cross Current, knots	0	*1*	*R_XC*
Current, Parallel, knots	1.12	*1.112*	*R_C*
Channel Tur/Bendn Angle	degrees	11	*THETA*
Region	TURN/BEND	1.24	*R_B*
Channel Density	HIGH	1.60	*R_D*
Protection Factor, %	0%	1.0	*PF*
Design Life	75		
Mean High Water, ft	1.5	MHW=1.5 ft, MHHW=1.6 ft, MLW = 0.1 ft (CHART)	
Growth Factor, %	0%		
Channel Width, ft	**589**		*C*
Mean statistics	**0**		
Minimum Channel Speed, knot	1	1.688	*V_min , fps*
Mud Dpeth Assumption	3	ft	

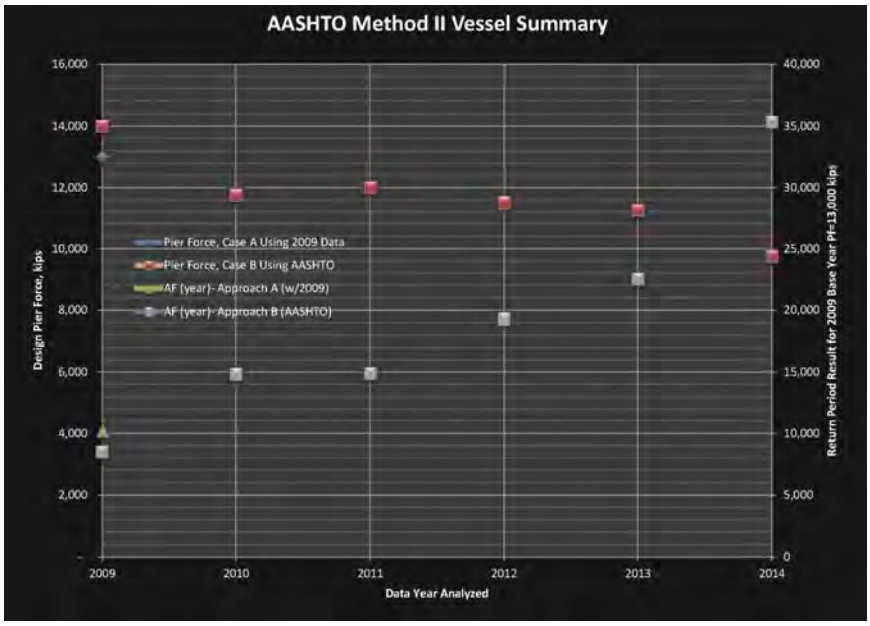
	Pier Protection			
	Pier Protection Angles			
	Enter θ_1, deg	Enter θ_2, deg		PF
1E-DN	0	90	50.0%	0.5000
1W-DN	90	18	72.6%	0.2743
2E-DN	90	90	99.9%	0.0000
2W-DN	90	90	99.9%	0.0000
1E-UP	0	90	50.0%	0.5000
1W-UP	21	90	75.8%	0.2420
2E-UP	90	90	99.9%	0.0000
2W-UP	90	90	99.9%	0.0000

AF Analysis for Mobile, AL

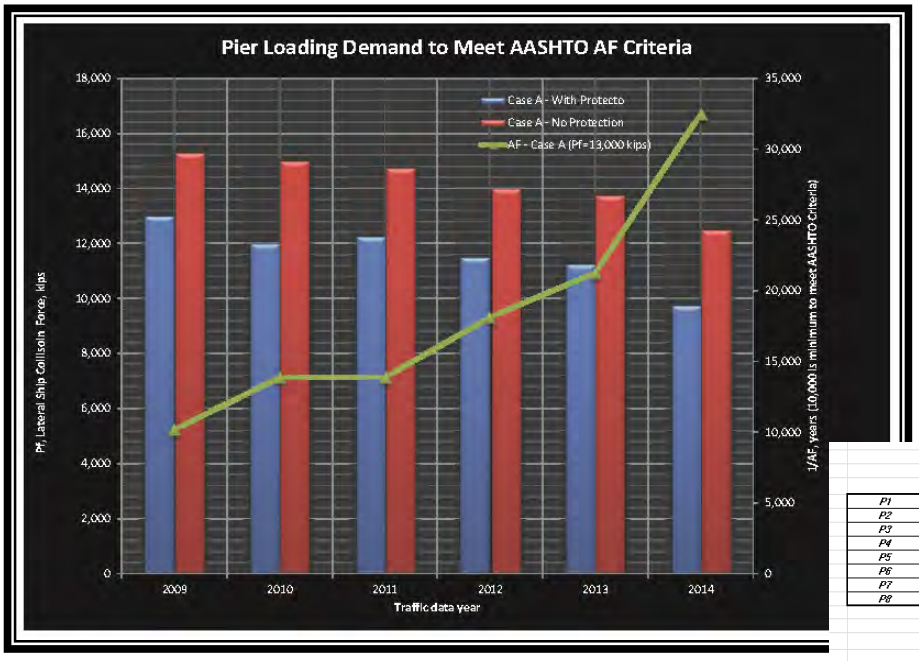


AF Limit	*0.0001*	
Pier	*ΣAF*	*% Risk to Pier/year*
1E-UP	0.000026	26%
1W-UP	0.000011	12%
2E-UP	0.000000	0%
2W-UP	0.000000	0%
1E-DN	0.000043	44%
1W-DN	0.000018	18%
2E-DN	0.000000	0%
2W-DN	0.000000	0%
Bridge Total	0.000098	100%
Return Period	***10,176***	***yrs***

AF Analysis for Mobile, AL



AF Analysis for Mobile, AL

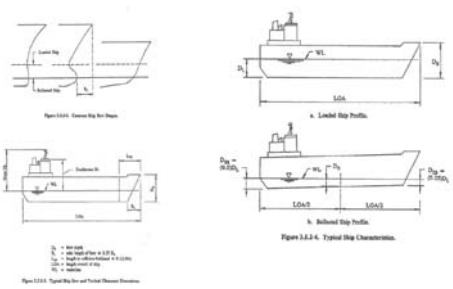


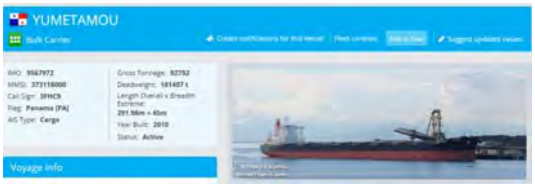
	AF Limit	0.0001	
	Pier	ΣAF	% Risk to Pier/year
P1	1E-UP	0.000026	26%
P2	1W-UP	0.000011	12%
P3	2E-UP	0.000000	0%
P4	2W-UP	0.000000	0%
P5	1E-DN	0.000043	44%
P6	1W-DN	0.000018	18%
P7	2E-DN	0.000000	0%
P8	2W-DN	0.000000	0%
	Bridge Total	0.000098	100%
	Return Period	10,176	yrs

AF Analysis for Mobile, AL

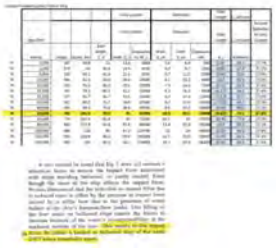
Preliminary Design Summary:

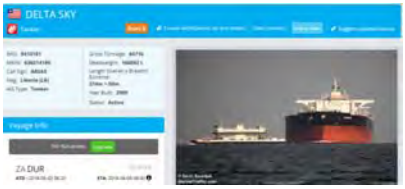
- Largest Vessel
  - 182,000 DWT (2013)
  - 167,000 DWT (2009)
- Design Vessel (No Future Fleet)
  - 50,000 DWT
  - LOA = 665 ft
  - Beam = 97 ft
  - Draft = 30 ft
  - 9.23 fps (5.5 knots)
  - Ps= 15,400 kips





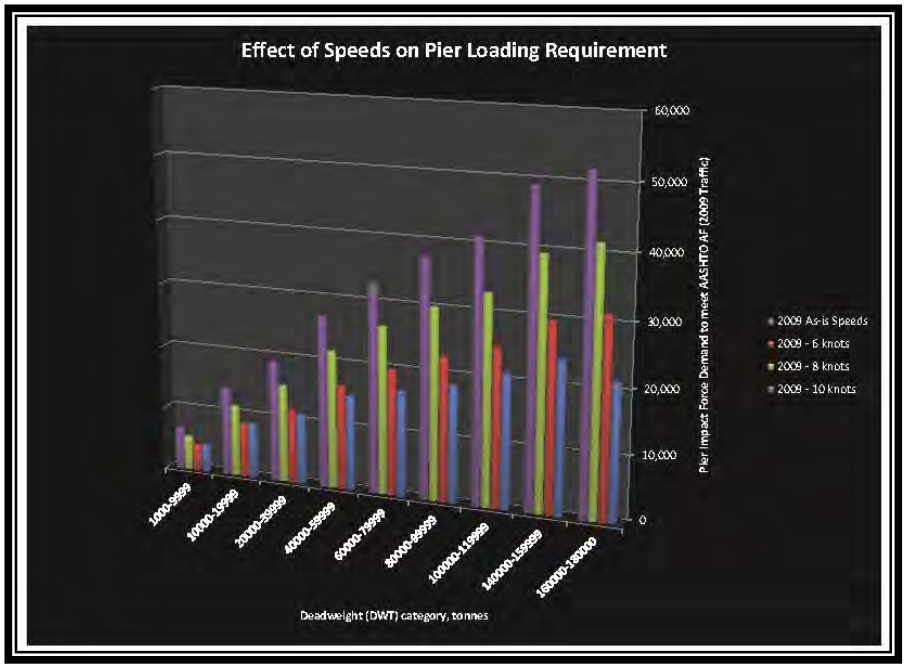
2013 MAX

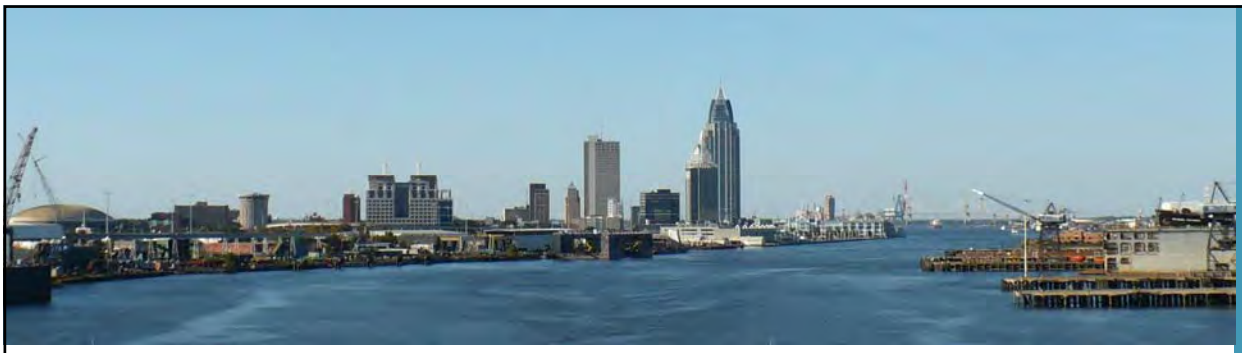




2009 MAX

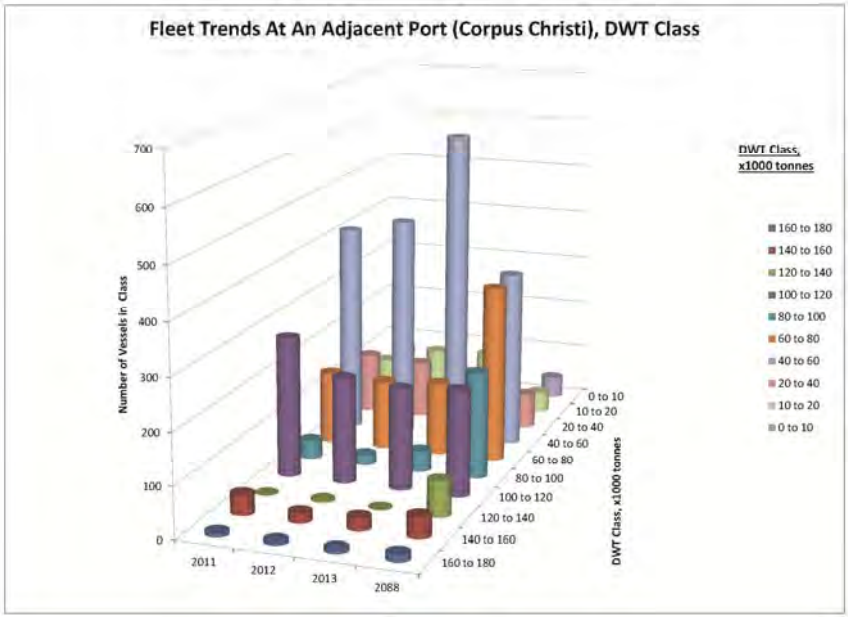
AF Analysis for Mobile, AL



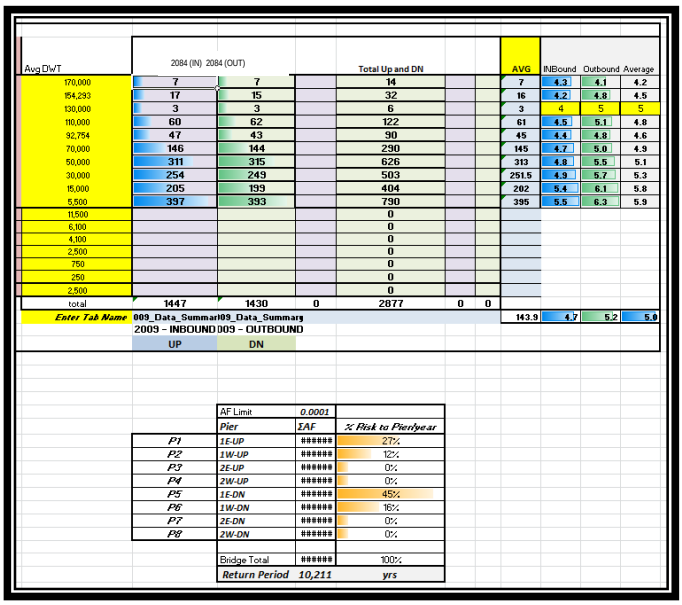


08 Future Fleet Considerations

AF Analysis for Mobile, AL – Future Fleet



AF Analysis for Mobile, AL – Future Fleet



Avg DWT	2084 (IN)	2084 (OUT)		Total Up and DN			AVG	INBound	Outbound	Average
170,000	7	7		14			7	4.3	4.1	4.2
154,293	17	15		32			16	4.2	4.8	4.5
130,000	3	3		6			3	4	5	5
110,000	60	62		122			61	4.5	5.1	4.8
92,754	47	43		90			45	4.4	4.8	4.6
70,000	146	144		290			145	4.7	5.0	4.9
50,000	311	315		626			313	4.8	5.5	5.1
30,000	254	249		503			251.5	4.9	5.7	5.3
15,000	205	199		404			202	5.4	6.1	5.8
5,500	397	393		790			395	5.5	6.3	5.9
11,500				0						
6,100				0						
4,100				0						
2,500				0						
750				0						
250				0						
2,500				0						
total	1447	1430	0	2877	0	0				
Enter Tab Name	009_Data_Summar	009_Data_Summary					143.9	4.7	5.2	5.0
	2009 – INBOUND	009 – OUTBOUND								
	UP	DN								

	AF Limit	0.0001	
	Pier	IAF	% Risk to Pier/year
P1	1E-UP	######	27%
P2	1W-UP	######	12%
P3	2E-UP	######	0%
P4	2W-UP	######	0%
P5	1E-DN	######	45%
P6	1W-DN	######	16%
P7	2E-DN	######	0%
P8	2W-DN	######	0%
	Bridge Total	######	100%
	Return Period	10,211	yrs

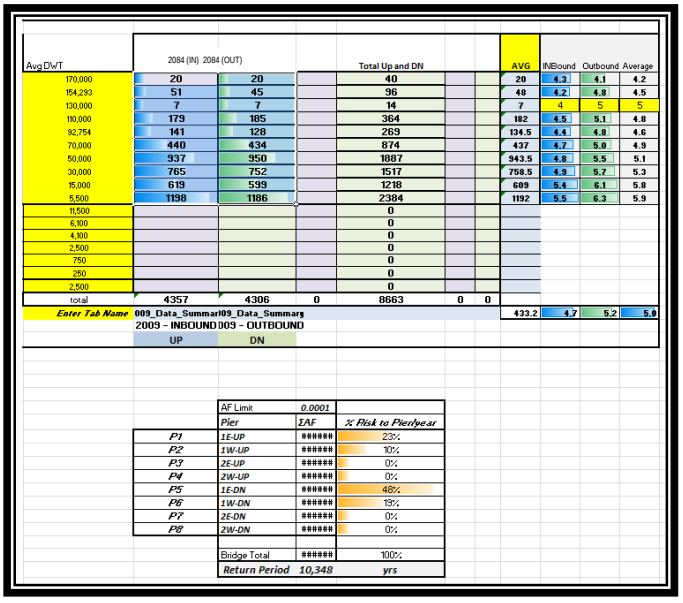
1% Growth Rate On All Fleet Classes

=(N_2009)*(1+1%)^75

<u>Apply a 1% growth rate to Mobile 2009 Fleet</u>

- Ps=15,000 kips
- Design Vessel: 70,000 DWT (16,661 kips)

AF Analysis for Mobile, AL – Future Fleet



Avg DWT	2084 (IN)	2084 (OUT)		Total Up and DN			AVG	INBound	Outbound	Average
170,000	20	20		40			20	4.3	4.1	4.2
154,293	51	45		96			48	4.2	4.8	4.5
130,000	7	7		14			7	4	5	5
110,000	179	185		364			182	4.5	5.1	4.8
92,754	141	128		269			134.5	4.4	4.8	4.6
70,000	440	434		874			437	4.7	5.0	4.9
50,000	937	950		1887			943.5	4.8	5.5	5.1
30,000	765	752		1517			758.5	4.9	5.7	5.3
15,000	619	599		1218			609	5.4	6.1	5.8
5,500	1198	1186		2384			1192	5.5	6.3	5.9
11,500				0						
6,100				0						
4,100				0						
2,500				0						
750				0						
250				0						
2,500				0						
total	4357	4306	0	8663	0	0				
Enter Tab Name	009_Data_Summar	009_Data_Summary					433.2	4.7	5.2	5.0
	2009 – INBOUND	009 – OUTBOUND								
	UP	DN								

	AF Limit	0.0001	
	Pier	IAF	% Risk to Pier/year
P1	1E-UP	######	23%
P2	1W-UP	######	10%
P3	2E-UP	######	0%
P4	2W-UP	######	0%
P5	1E-DN	######	48%
P6	1W-DN	######	19%
P7	2E-DN	######	0%
P8	2W-DN	######	0%
	Bridge Total	######	100%
	Return Period	10,348	yrs

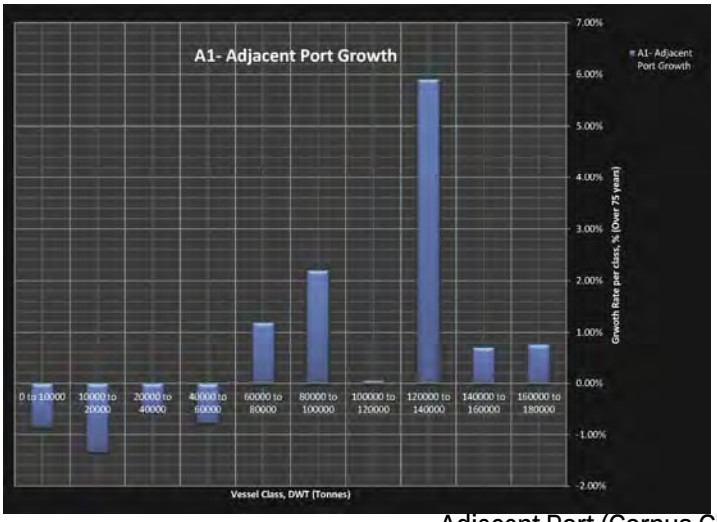
2.5% Growth Rate On All Fleet Classes

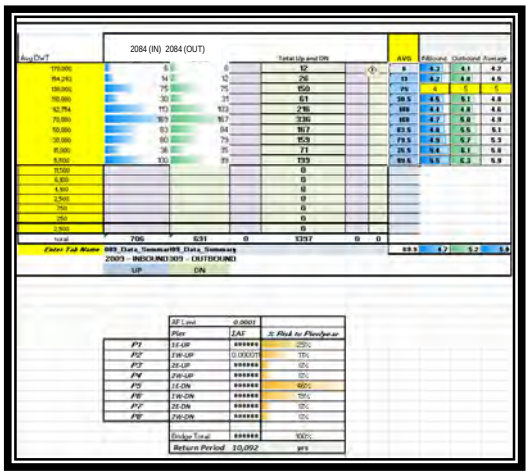
=(N_2009)*(1+1%)^75

<u>Apply a 2.5% growth rate to Mobile 2009 Fleet</u>

- Ps=17,500 kips
- Design Vessel: 90,000 DWT (18,500 kips)

AF Analysis for Mobile, AL – Future Fleet

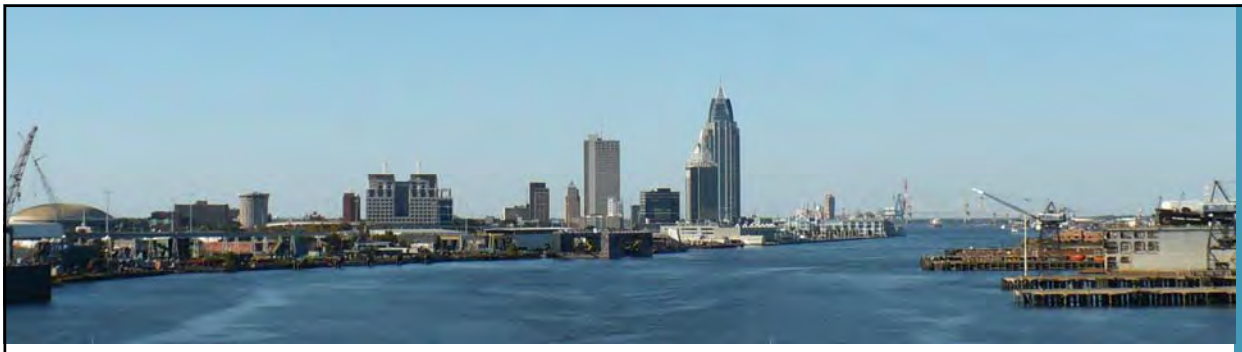




Variable% Growth Rate On Fleet Classes

Adjacent Port (Corpus Christi) Growth Rates Result Applied to Mobile

- Ps=16,000 kips
- Design Vessel: 70,000 DWT (16,661 kips)



09 Summary and Recommendations

Summary, Recommendations

1. Summary
   - A very busy Port, high density of large vessels
   - Significant amount of site-specific data analyzed to produce a customized solution meeting AASHTO and cost-effectiveness
2. Recommendations
   - Design Vessel for Analyzed Data (50,000 DWT), P_s= 13,000 kips
   - Design Vessel for 1% Growth Data (70,000 DWT), P_s= 15,000 kips
   - Design Vessel for 2.5% Growth Data (90,000 DWT), P_s= 18,500 kips
   - Design Vessel for Global Growth Trend (70,000 DWT), P_s= 16,000 kips

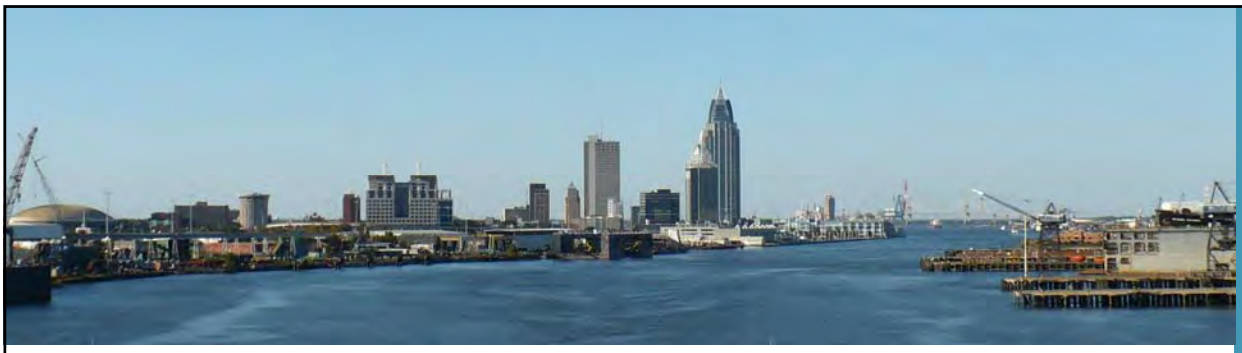
   (Based upon Similar Port Region Growth Rates, Conservative for Pier Protection and Speed Assumptions)

ALDOT Input & Next Steps

1. ALDOT Input

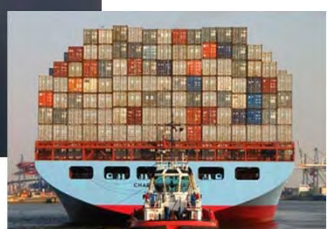
   3.14.2 Owner's Responsibility: To establish/approve

   The operational classification (critical or typical)
   The vessel traffic density
   The design velocity of vessels for the bridge
   The ***degree of damage*** that the bridge components, including protective systems, are allowed to sustain.
   Fleet Growth Level
2. Next Steps
   - Application of design loading into Structural design or super and sub structure approach
   - Bathymetry Verification for Protection and Grounding Levels
   - USACE "passed-the-point" Data to cross check trends over more years
   - Determination of structure type to resist the demand, protection etc.
   - Loading and protection level refinement



10 Comments/Input

Mobile River Bridge: Vessel Collision Analysis



Questions/Input/Comments?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