Impacts of Hurricane Protection Measures on Larval Fish Populations in Lake Pontchartrain using the Adaptive Hydraulics Code (AdH)

Background

The U.S. Army Engineer Hurricane Protection Office (HPO) requested a numerical modeling study for the purpose of analyzing the impacts of the proposed hurricane and storm damage risk reduction system (HSDRRS) measures to be placed in the Gulf Intracoastal Waterway (GIWW) and the Mississippi River Gulf Outlet (MRGO) on the larval fish transport in the area.

It is known that larval fish migrate from the Gulf of Mexico into Lake Pontchartrain. A particle tracking simulation is performed such that the particles are given basic larval fish transport behaviors and released at various locations in the area. The characteristic larval fish transport behaviors are provided by an interagency team composed of representatives from various state and federal regulatory agencies. The hydrodynamic processes move these particles within the system and the alterations to the transport due to the planned changes to the system are analyzed.

The MRGO Canal is a 66-mile-long deepwater channel that extends northwest from deep water in the Gulf of Mexico to New Orleans, LA. The MRGO merges with the GIWW and continues 5 miles further to the west where it joins the Inner Harbor Navigation Canal (IHNC). The IHNC proceeds another approximately 3 miles north from its intersection with the GIWW to connect with Lake Pontchartrain at Seabrook. To the East of the connection of the GIWW with the MRGO, the GIWW extends northeast approximately 6 miles to its first connection with Lake Borgne via Chef Menteur and 20 miles with its connection via the Rigolets.

Hydrodynamic Code

The hydrodynamic code used in this study AdH, which is a finite element code that can simulate three-dimensional groundwater, three-dimensional Navier-Stokes, and two- and three-dimensional shallow water equations. It can be used in a serial or multiprocessor mode on personal computers, UNIX, Silicon Graphics, and CRAY operating systems. The uniqueness of AdH is its ability to dynamically refine the domain mesh in areas where more resolution is needed at certain times due to changes in the flow conditions. AdH can simulate the transport of conservative constituents, such as dye clouds, as well as sediment transport that is coupled to bed and hydrodynamic changes. The ability of AdH to allow the domain to wet and dry within the marsh areas as the tide changes is suitable for the shallow marsh environment. This tool is a product of the System Wide Water Resources Program (SWWRP) at ERDC and has been used to model sediment transport in sections of the Mississippi River, tidal conditions in southern California, and vessel traffic in the Houston Ship Channel, among other sites. This study utilizes the 2-dimensional shallow water equations of AdH. The model is simulated on high performance computing machines in order to obtain quick results. Further details on the ADH model and its equations can be found at https://adh.usace.army.mil.

Larval Fish Characteristics

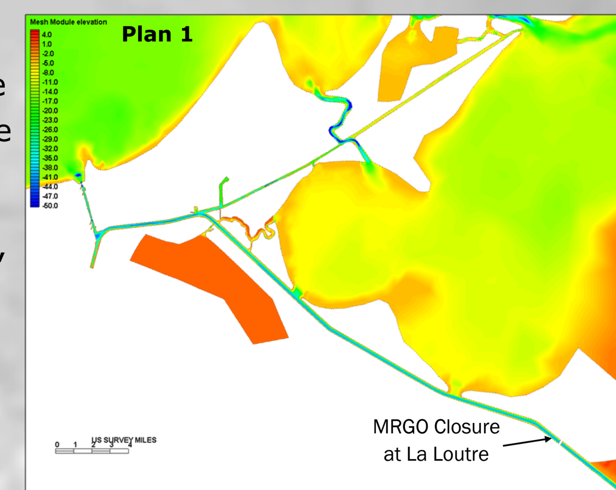
In order to model juvenile and fully grown fish, an equation must be available to define their swimming behavior. At this point, there has not been enough research to fully model the fish that inhabit this area. Larval fish behave in a much simpler manner and therefore can be modeled as particles with certain native tendencies. This type of modeling is being performed using the Particle Tracking Model (PTM). PTM is an ERDC-developed model designed specifically to track the fate of user defined particles (sediment, chemical, debris, biological particles, etc.) released from locations within complex hydrodynamic and wave environments. PTM is utilized to transport discrete passive particles which have been modified with characteristic larval fish transport behaviors through the hydrodynamic system. This effect will be approximate due to the limitation of the modeling tool to only transport larval fish with specified characteristics. This work will not address the effects on adult fish or behavior patterns that are not included. The interagency team noted eight dominant species with three general behavior characteristics.

- Tidal Lateral (move to the center during incoming tide)
- Tidal Vertical (move up during incoming tide)
- Passive or particles that move only with the water (as a default)
- Bottom Movers (25 cm from bottom)

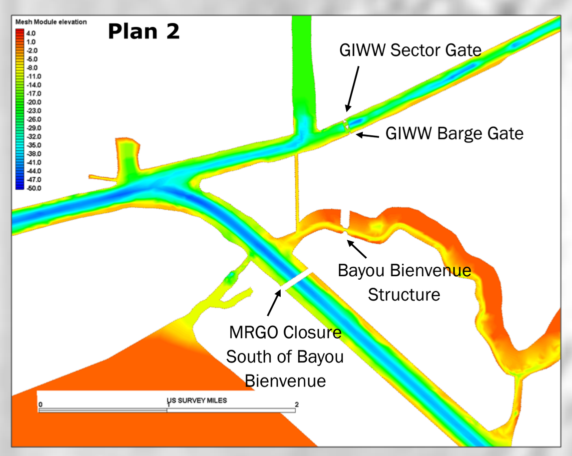
Plan Conditions

Base – includes the fully open MRGO, GIWW, and IHNC

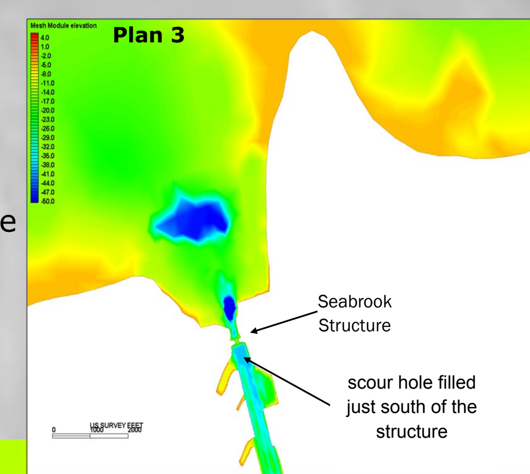
Plan 1 – close the MRGO at La Loutre



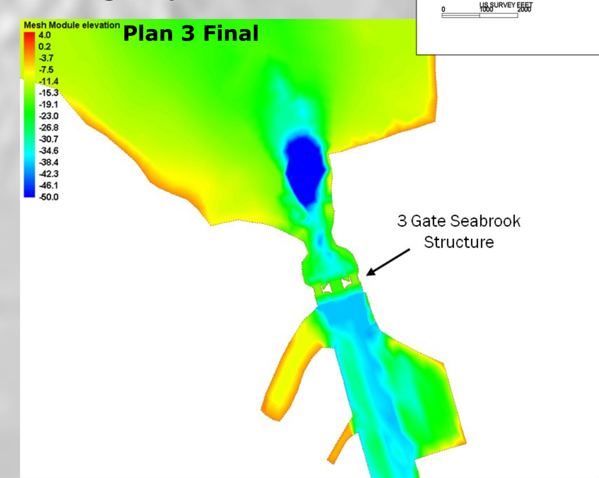
Plan 2 – close the MRGO at La Loutre, include the Borgne alignment (close the MRGO south of Bayou Bienvenue, 56 ft X 8 ft gate on Bayou Bienvenue, two 150 ft X 16 ft gates on GIWW)



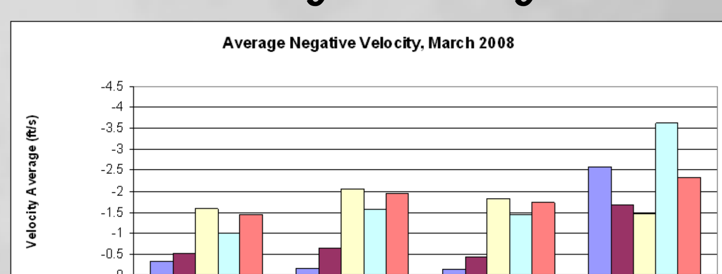
Plan 3 – close the MRGO at La Loutre, include the Borgne alignment, include the Seabrook structure with southern scour hole filled (95 ft X 16 ft gate)



Plan 3 Final - close the MRGO at La Loutre, include the Borgne alignment, include the 95 ft X 20 ft sector gate at Seabrook with two flanking 50 ft X 16 ft auxiliary gates with southern scour hole filled

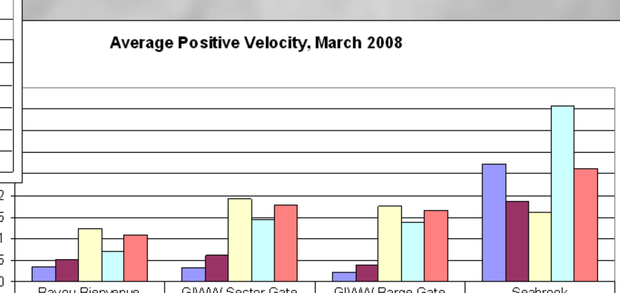


Hydrodynamic Results



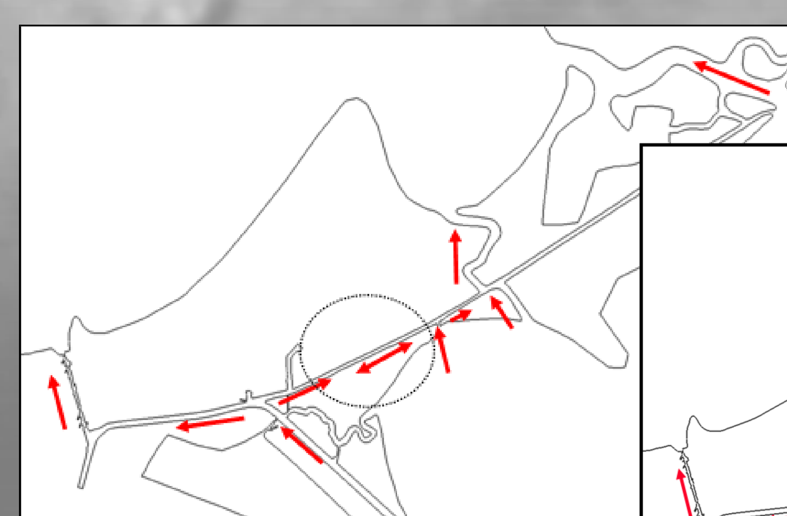
	Bayou Bienvenue	GIWW Sector Gate	GIWW Barge Gate	Seabrook
Base	-0.33	-0.18	-0.14	-2.59
Plan 1	-0.53	-0.65	-0.42	-1.68
Plan 2	-1.58	-2.06	-1.83	-1.46
Plan 3	-1.01	-1.56	-1.45	-3.63
Plan 3 Final	-1.43	-1.93	-1.73	-2.33

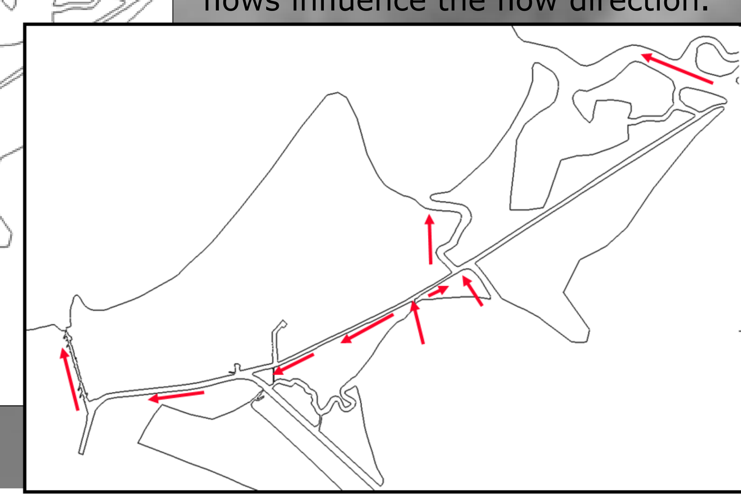
The AdH hydrodynamic simulations produce velocity and depth results throughout the model domain over the entire simulation period. These results will drive the PTM simulations.



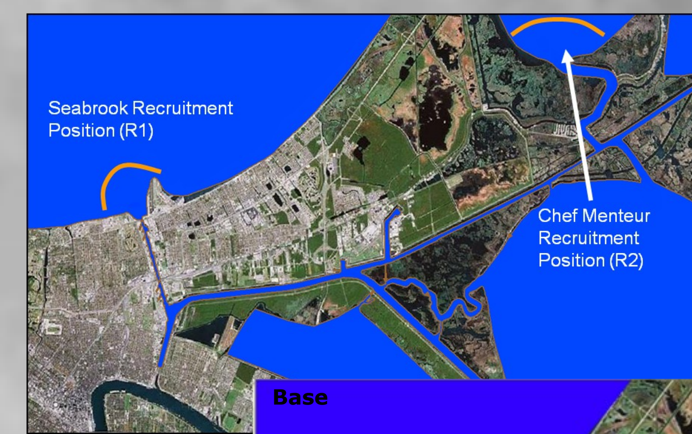
	Bayou Bienvenue	GIWW Sector Gate	GIWW Barge Gate	Seabrook
Base	0.36	0.32	0.21	2.73
Plan 1	0.51	0.61	0.39	1.87
Plan 2	1.23	1.92	1.76	1.62
Plan 3	0.70	1.46	1.38	4.07
Plan 3 Final	1.08	1.78	1.65	2.63

Each plan is analyzed for average and maximum velocity for flood and ebb at several locations near the planned structures. This is a means to determine safety for navigation and aquatic species. The intent is to have velocities at Seabrook that are similar to the Base condition. By cutting off the MRGO in Plan 1, the circulation in the GIWW changes such that the dominant flow direction in the GIWW between Lake Borgne and the MRGO (circled region) is toward the west as op posed to variable when the MRGO flows influence the flow direction.

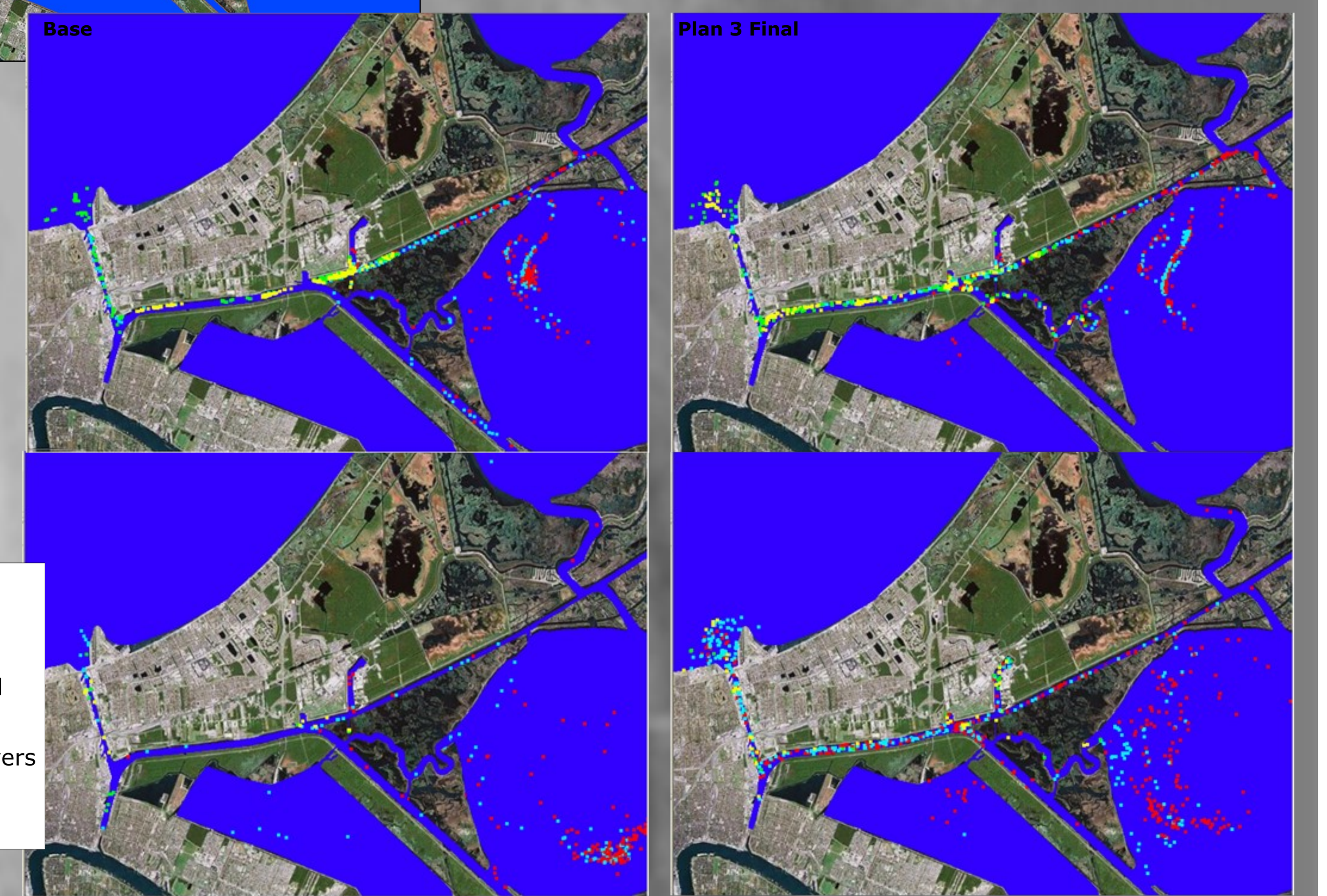




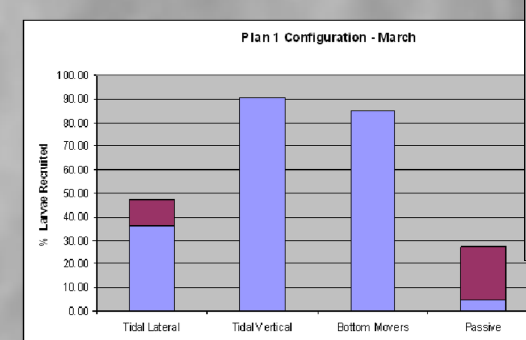
Larval Fish Transport Results

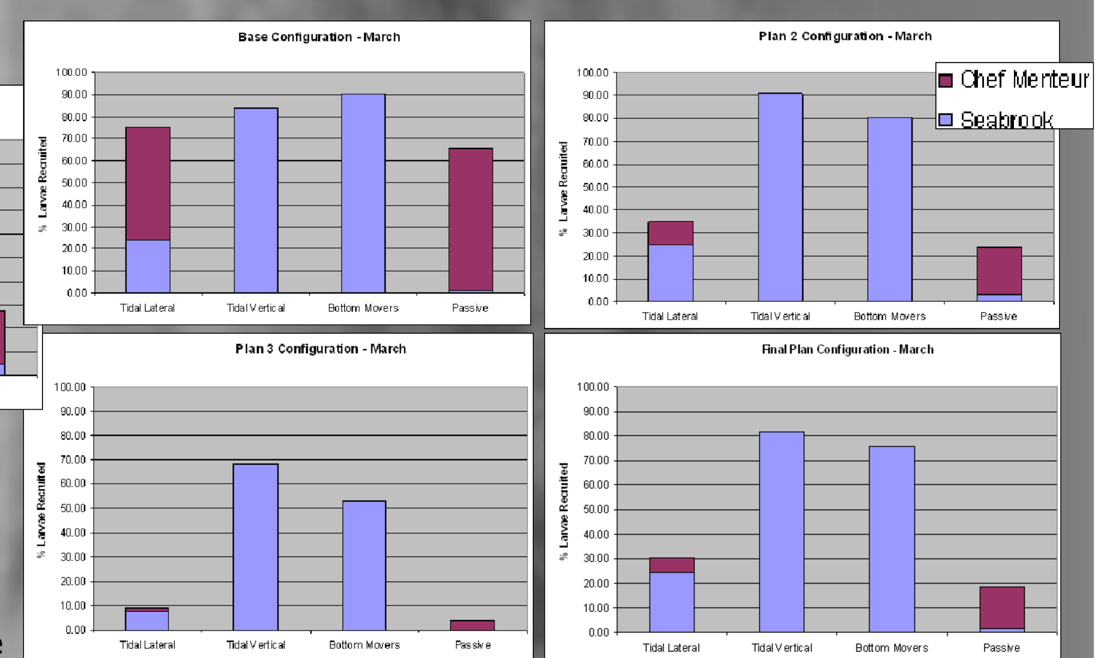


The PTM model requires the data and time of source release, the initial positions of the source, the rate at which the source is being introduced, and the AdH hydrodynamic results in order to perform the tracking analysis. Although AdH is a 2D model, a vertical velocity profile is assumed for the PTM analysis. The larvae are considered recruited, or having reached a successful habitat, when they enter Lake Pontchartrain at Seabrook and through Chef Menteur.

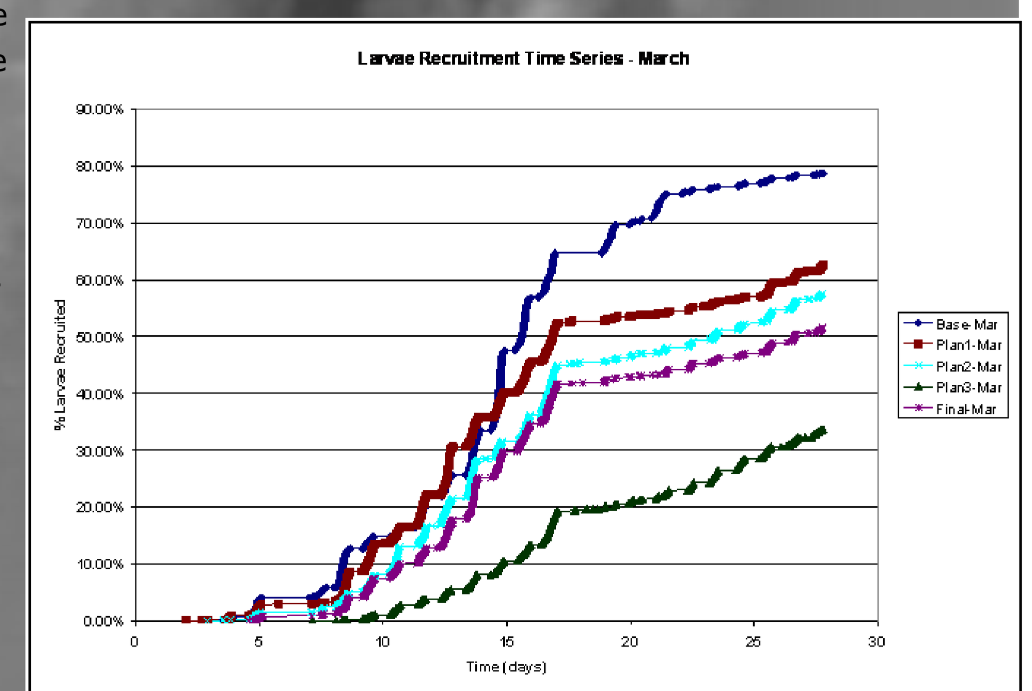


Blue— tidal lateral
Green— tidal vertical
Yellow— bottom movers
Red— passive





The larvae are tracked by behavior as well as by the recruitment location. During the four week simulation period, as many as 80% of the total released particles are recruited in the Base condition. However, the recruitment drops for all plans. The tidal vertical and bottom movers generally have the largest recruitment due to their behaviors capitalizing on the direction of flow. Although Plans 1 and 2 have higher total recruitment than Plan 3 and Plan 3 Final, the structure at Seabrook will be included in the HSDRRS, so the improvement of Plan 3 Final over Plan 3 for both velocity magnitude and larval recruitment makes the three gate structure a much more favorable construction alternative.



POC: Ms. Jennifer N. Tate jennifer.n.tate@usace.army.mil