Asia Pacific Research Initiative for Sustainable Energy Systems 2011 (APRISES11)

Office of Naval Research
Grant Award Number N0014-12-1-0496

Preliminary Design and Analysis to Support Permitting, NEPA Process, and Device Modification Logistics Planning

Task 4.2

Prepared For

Hawaii Natural Energy Institute

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June 2016

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Preliminary Design and Analysis to Support Permitting, NEPA Process, and Device Modification Logistics Planning

2016

Final Report

Prepared for:

University of Hawai'i

Office of Research Services

Under Sub-award #MA160016

And Prime Award #N00014-12-1-0496

Prepared By:

Northwest Energy Innovations

6/8/2016

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1. INTRODUCTION

This document provides a summary of the information that was provided to the Naval Facilities Command ("NAVFAC") and Marine Corps Base Hawaii ("MCBH") to support the required approvals and permit modifications required to modify the Azura wave energy device ("Device") and extend testing at the Navy's Wave Energy Technology ("WET") site. This report satisfies the deliverable requirements of Exhibit B of the sub-award reference on the cover page.

2. PROJECT DESCRIPTION

The Device has been installed in the baseline configuration at WET test site since June 2015 ("Baseline Device"). The Baseline Device is described in CATEX #130520 dated 6 May 2013. The Baseline Device will be removed from its moorings and towed into Kaneohe Bay for modifications. The modifications will consist of the addition of a 1) heave plate, a 2) different float shape, and a 3) minor modification to the mooring system ("Modified Device"). The proposed modifications are designed to improve power output and to test design details that more closely resemble the full scale design that is currently being developed and is planned for testing at WETS in late 2017. Figure 1 shows the Baseline and Modified devices without the mooring system.

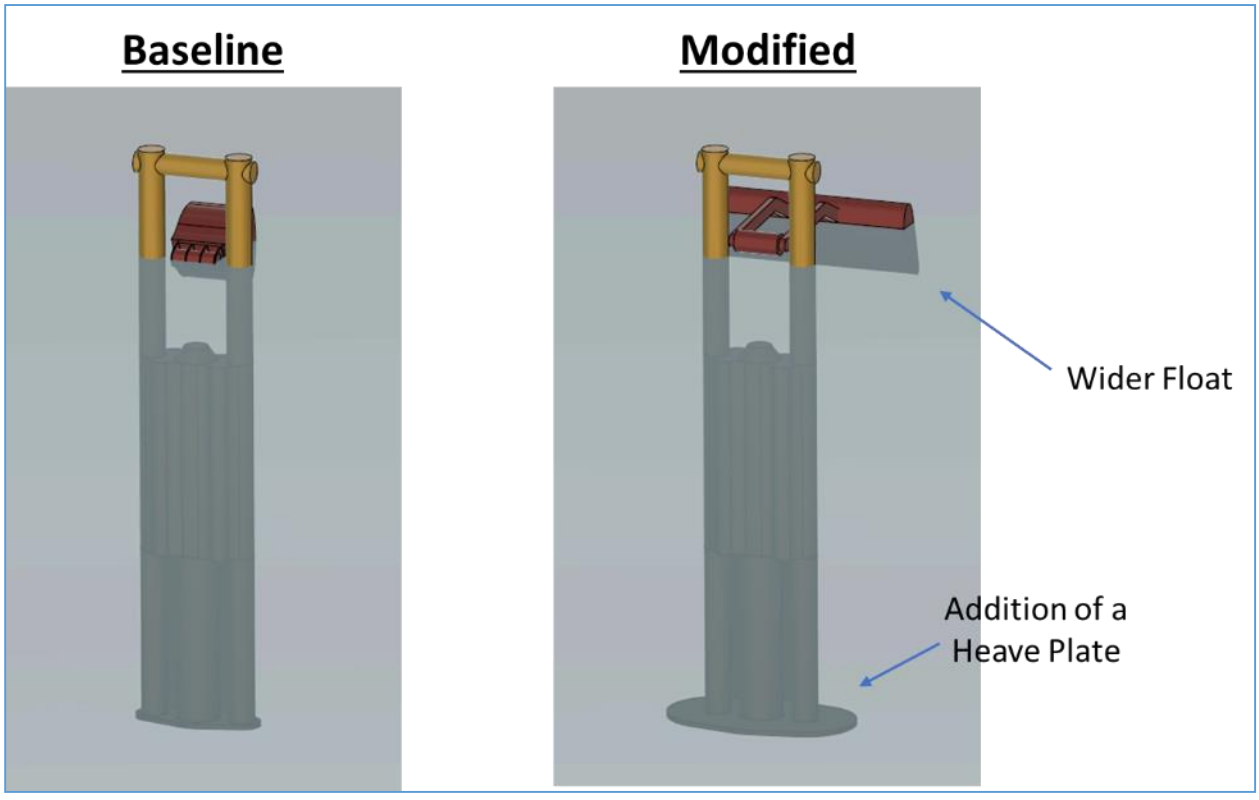


Figure 1 – Baseline and Modified Designs

2.1 Heave Plate

The Modified Device will include the addition of a flat plate attached to the bottom of the device ("Heave Plate"). The Heave Plate, as shown in Figure 2, is approximately 6.0 meters by 3.5 meters and will be fabricated from steel. The Heave Plate will be configured as a thin plate of steel with 3-inch by 3-inch stiffeners welded on the bottom side of the plate (not shown in picture). There will 2 stiffeners in the long direction and 4 in the short direction. The Heave Plate will be bolted to existing threads on the bottom of the existing Hull Structure. The foot print of the heave plate is approximately 16 square meters as shown in Figure 3. The overall displaced volume of the Heave Plate is 0.13 cubic meters or 4.6 cubic feet. The float will be coated with antifouling paint consistent with that used on the baseline Hull and Float.

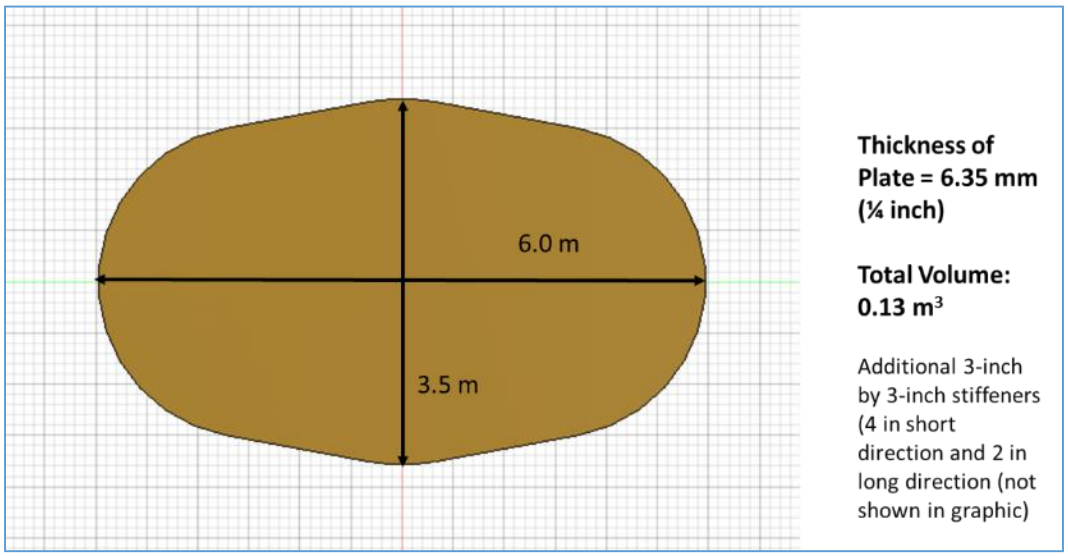


Figure 2 – Heave Plate Shape and Dimensions

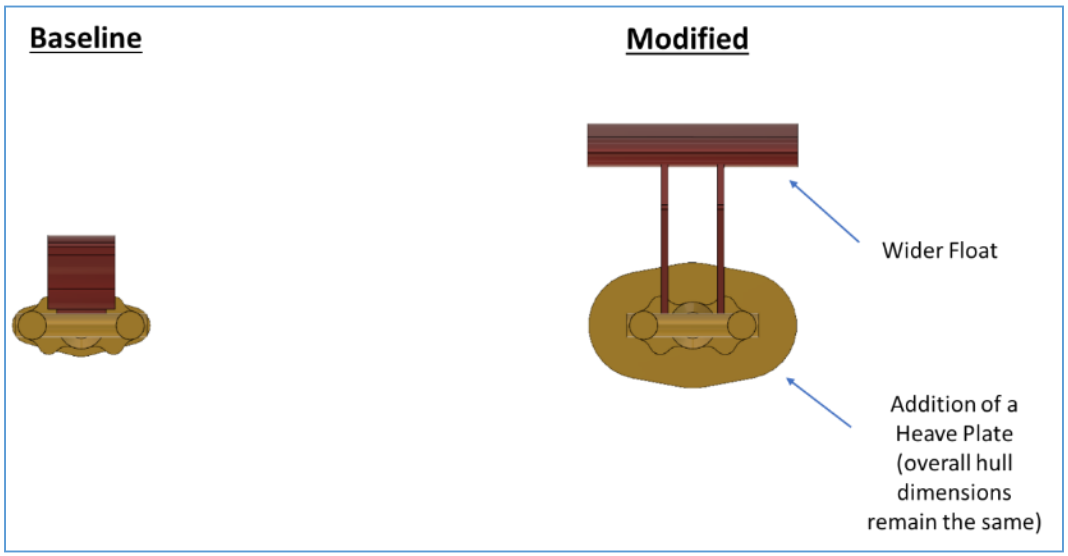


Figure 3 – Top View Showing Addition of Heave Plate

2.2 Float

The Modified Device will include a modified float which is small in cross section but wider to allow more energy capture. Figure 4 shows a front view showing of the modified float. The modified float is 6-meters wide compared to the baseline float which is 2-meters wide. Figure 5 shows a comparison of the cross section of the baseline and modified floats. The modified float has a chord (thickness) of approximately 0.8-meters, drafts 1.75-meters, and has a height above water of 0.7-meters. The modified float has a total displaced volume of about 9.9 cubic meters. The float will be either steel or fiberglass. The float will be coated with antifouling paint consistent with that used on the baseline Hull and Float.

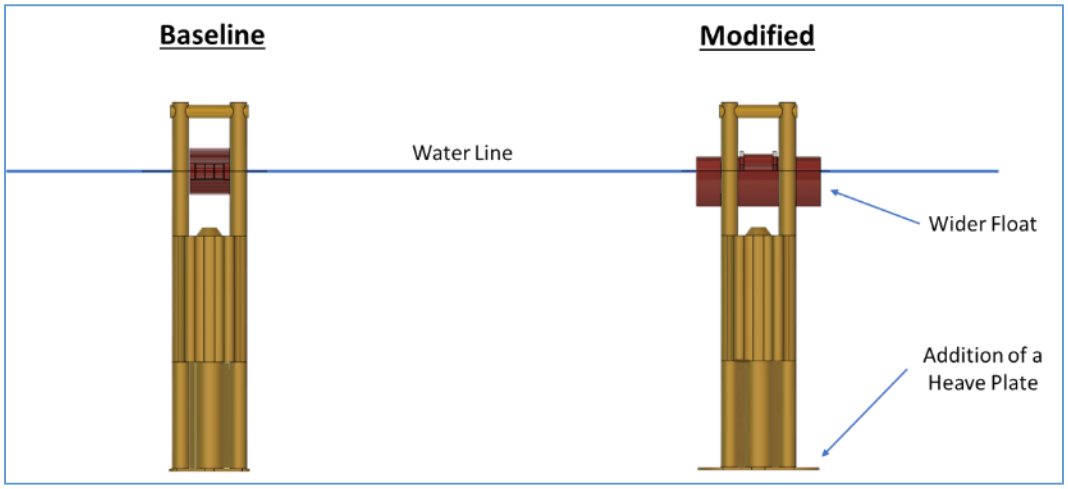


Figure 4 – Front View (looking from ocean toward land) of Baseline and Modified Floats

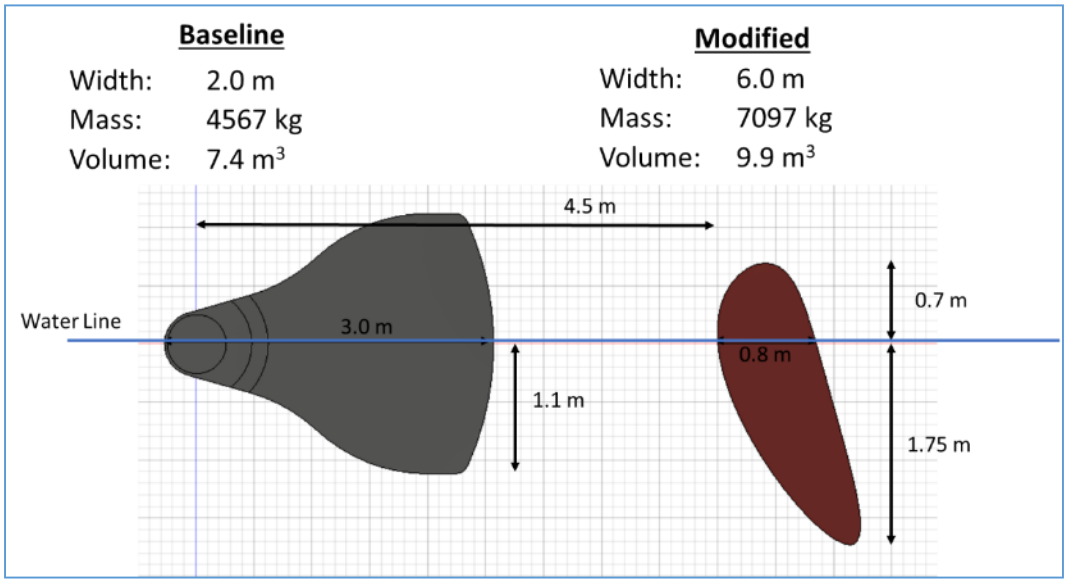


Figure 5 – Cross Section of Baseline and Modified Floats

2.3 Float Arms

Figure 6 shows a side view of the modified float. The float is attached to the PowerPod with two float arms as shown in Figures 6 and 7. Each float arm is approximately 4.1 meters long and has a volume of approximately 1 cubic meter. The float arms will be fabricated from steel and coated with antifouling paint consistent with that used on the baseline Hull and Float.

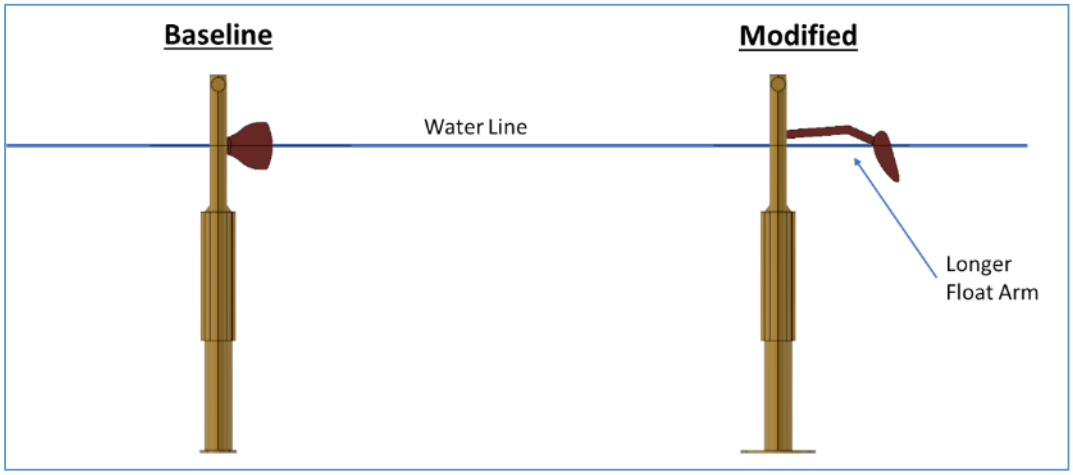


Figure 6 – Side View of Baseline and Modified Floats

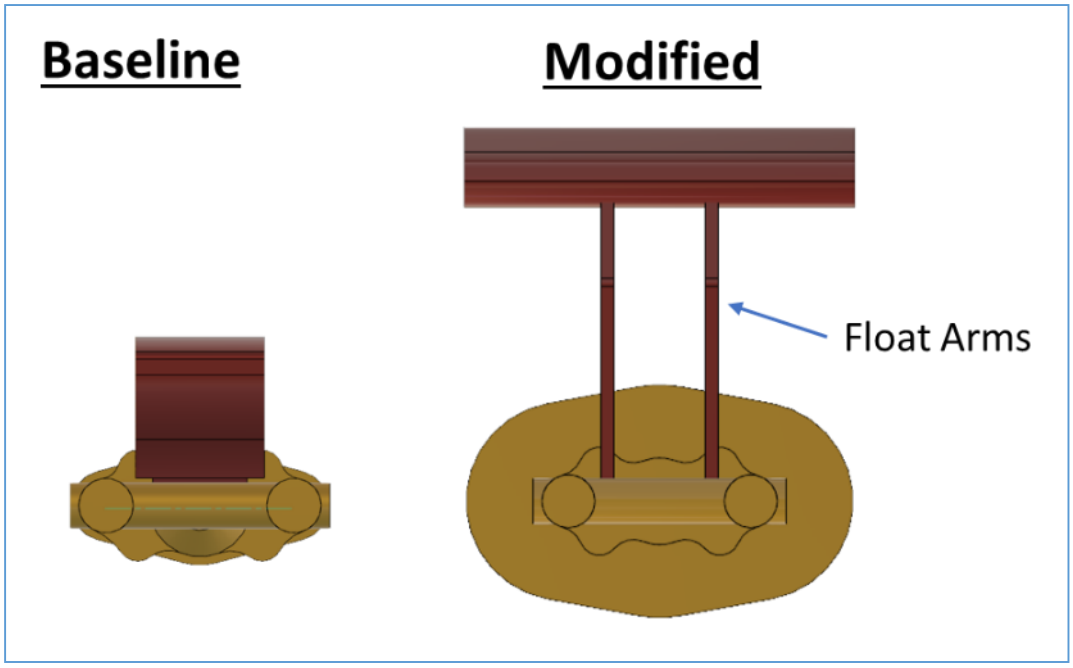


Figure 7 – Top View of Modified Float Showing Float Arms

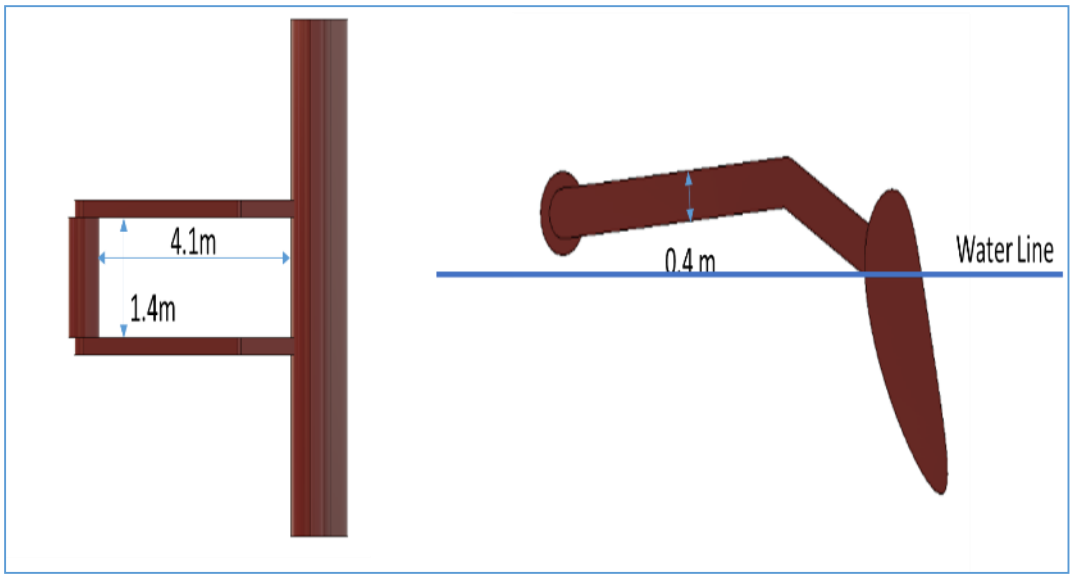


Figure 8 – Float Arm Dimensions

2.4 Mooring Modifications

A minor modification to the mooring is planned as part of the proposed project. Figure 9 shows an isometric view of the baseline mooring system. MC, MK, and AB refer to the position of the mooring legs. AB faces land and MC and MK are facing seaward. The riser connects the subsurface float to the anchor bases and the hawser connects the device to the subsurface float. Figures 10. 11 and 12 show the proposed modification to the mooring configuration. The proposed modification will include the addition of a bridle to the MC and MK legs identical to the AB mooring leg (green line). This is shown in more detail in Figure 11. As shown in Figure 12, the MC and MK hawsers will be shortened by about 4 meters each. A 10 meter long bridle will be used to connect the hawsers to the device. The net result is the addition of approximately 12 meters of mooring lines. All mooring lines will remain tensioned. All mooring lines are nylon and are 10 centimeters in diameter.

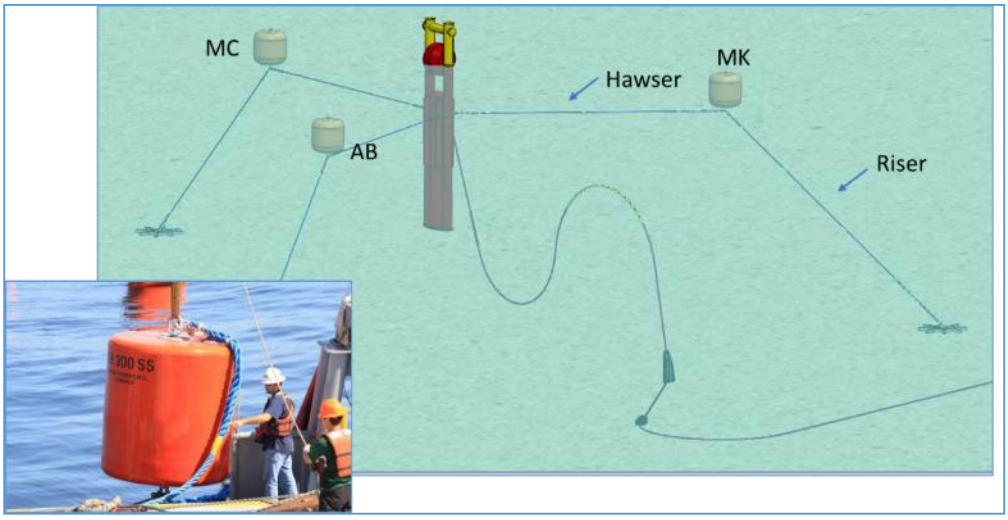


Figure 9 – Baseline Mooring Configuration

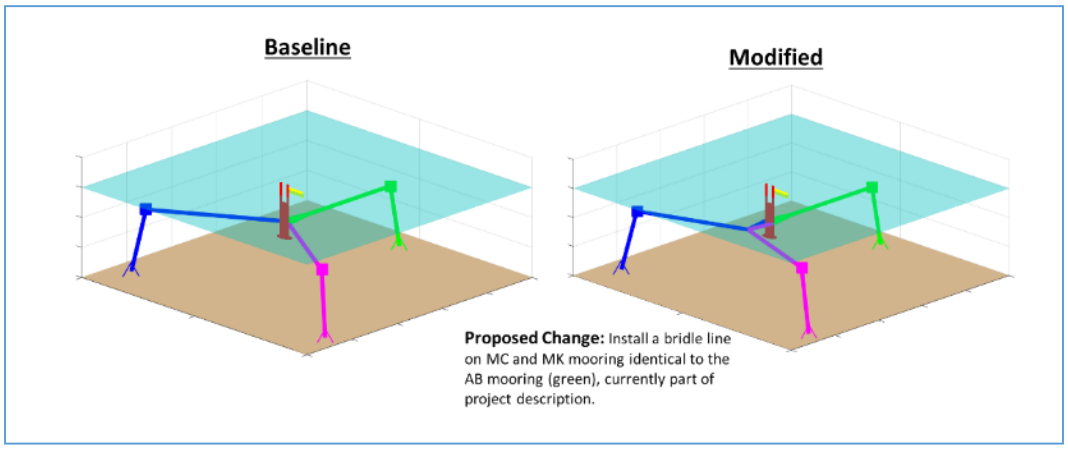


Figure 10 – Proposed Mooring Modification

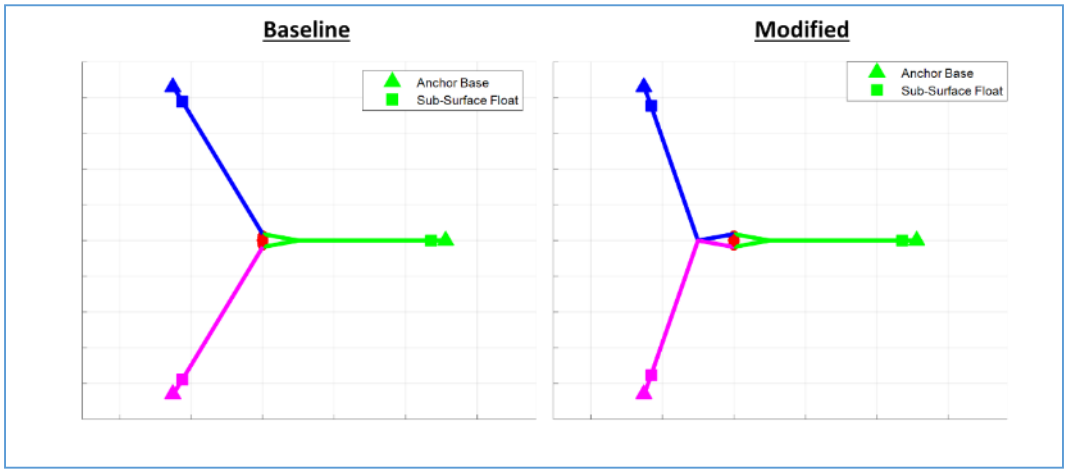


Figure 11 – Top View of Baseline and Modified Mooring Configurations

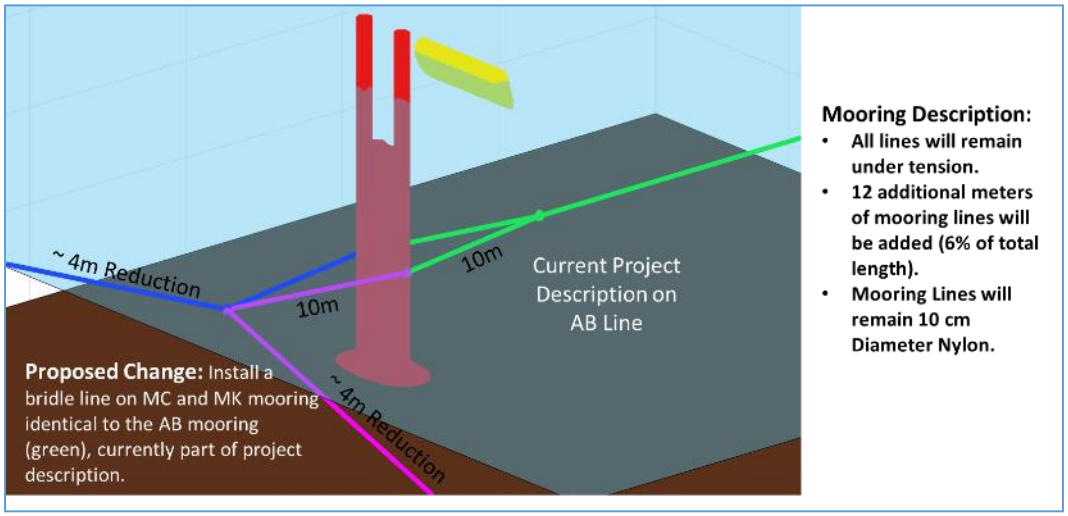


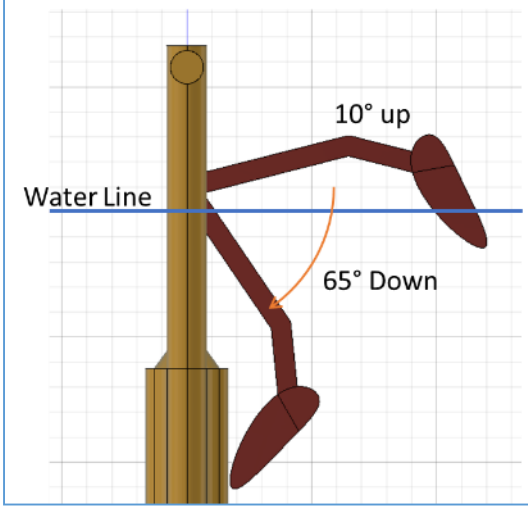
Figure 12 – Detail View of Modified Bridle

2.5 Device Motions

The WEC-Sim modelling software was used to calculate motions of the hull and float. Figure 13 shows the maximum float speed for a variety of wave conditions. The float speed increases by as much as 44%, however the movement is still relatively slow at a maximum of 3.2 meters per second in wave heights of 2.75 meters. Figure 14 shows the expected float angles as a function of sea state. The baseline float design can rotate 360 degrees, however the modified float requires end stops as the float width (6 meters) is wider than the vertical members of the PowerPod structure. The modified float is expected to occasionally contact the end stop in downward rotation direction at a wave height of approximately 3 meters. A simulation of the movement of the hull and float is shown on the following video: https://youtu.be/AL_QyoYF1EE. The simulation is for waves with a significant height of 2.75 meters and a period of 7.5 seconds. The waves are not perfectly synchronized between the baseline and modified simulations but are representative of similar wave climates.

Case	Wave Height (m)	Wave Period (sec)	Baseline max speed (m/s)	Proposed Max Speed (m/s)	Percent Increase
1	1.75	6.5	1.8	2.6	44%
2	1.75	9.5	1.5	2.1	40%
3	1.75	11.5	1.3	1.7	31%
4	2.75	7.5	2.7	3.0	11%
5	2.75	9.5	2.4	3.2	33%

Figure 13 – Device Motions as a Function of Sea State



Wave Height (meters)	Max Angle Up (deg)	Max Angle Down (deg)
1	4	5
2	10	35
2.5	10	55
3	10	65
4	10	65
5	10	65

Figure 14 – Float Angle as a Function of Sea State

2.6 Summary of Key Dimensions

Figure 15 shows a summary of the key dimensions. Note that the Baseline device does not have a true heave plate so the dimensions are shown for the footprint of the bottom of the hull structure.

Component/Key Dimension	Baseline	Modified
Heave Plate		
Width, m	4.0	6.0
Length, m	1.8	3.5
Thickness, mm	N/A	6.35
Footprint, sqm	5.1	16.0
Volume, m^3	N/A	0.13
Float		
Width, m	2.0	6.0
Cross Section, m	3.0 x 2.2	2.45 x 0.8
Volume, m^3	7.4	9.9
Displacement, m^3	4.6	7.1
Dry Mass, kg	4,567	7,097
Arm Length, m	N/A	4.5
Arm Spacing, m	N/A	1.4
Rotation, deg	360	10 up and 65 down

Figure 15 – Comparison of Key Dimensions

3. Project Phases and Work Plan

A summary of the project phases and schedule is shown below. Note that two different sites were evaluated to complete Phase 2 ('Work Site'), which are further detailed in Section 4.

Phase 1: Device Removal
Start: September 2016
Duration: 1-2 days

Phase 2: Modifications
Start: Immediately following removal
Location: 3 Options (see Section 13)
Option 1: LSV Ramp at MCBH
Option 2: He'eia Kea Marina
Option 3: SEI Mooring Ball
Duration: 2-4 days

Phase 3: Device Redeployment
Start: First available weather window late September to early October 2016
Duration: 2-3 days

Phase 4: Testing

Start: Following redeployment
Duration: through January 2017

3.1 Device Removal Plan

A summary of the work to be completed at the WET site to remove the device is shown below:

1. Wash device at test site.
2. Disconnect Umbilical Cable from device, attach waterproof cap and attach to a temporary float.
3. Connect a temporary mooring line from the bottom of the MC and MK Float to a existing hard point on the bottom. Objective is to keep tension in the MC and MK mooring legs.
4. Remove AB Float allowing device to move seaward and reduce tension in MC and MK.
5. Remove AB Hawser and Bridle.
6. Attach towline to device and position RIB landward of device.
7. De-ballast device (so it will lay flat) to allow float to be pinned.
8. Pin Float.
9. Remove MC and MK hawsers from both device and float ends.
10. Tow to Work Site.

3.2 Device Modification Plan

A summary of the work to be completed at the Work Site to modify the device is shown below:

1. Inspect entire device.
2. Remove Float using 10 to 20 ton crane
3. Replace shaft bearings using hand tools
4. Lift new float into position using 10 to 20 ton crane
5. Attach new float using mechanical fasteners (bolts) and hand tools
6. Install End Stops using mechanical fasteners (bolts) and hand tools
7. Weld pad eyes on ballast plates to facilitate removal.
8. Remove existing ballast plates (2) using 10 to 20 ton crane.
9. Position Heave Plate using 10 to 20 ton crane. Attach with mechanical fasteners (bolts) and hand tools.
10. Attach new mooring load cells and cables to MC and MK. Test.
11. Attach new MC and MK bridle and hawsers.

3.3 Device Reinstallation Plan

A summary of the work to be completed at the WET site to reinstall the device is shown below:

1. Tow device from Work Site to WET site with RIB.
2. Attach new MC and MK bridle and hawsers to MC and MK floats.
3. Ballast device to proper new waterline.
4. Attach AB bridle to device.
5. Reattach AB Float with lift bags.
6. Remove temporary mooring lines.
7. Reattach Umbilical Cable to Dry Box.

4. WORK SITE

Figure 16 shows an overview map of the WET site and the two Work Site options. NWEI proposes to use the LSV ramp area near the fuel pier to make modifications to the Azura wave energy device (Option 1). If NWEI is unable to secure MCBH permission to use this area then it is possible to make the modifications along side Sea Engineering's Huki Pau workboat at their mooring ball in Kaneohe Bay (Option 2). In both options it is expected that divers would be used to remove and install the required components. Some incidental welding or grinding may be required, however the majority of the work will involve hand and pneumatic tools driven by an air compressor.

Figure 16 – Map of Project Site and Work Site Options

4.1 Work Site Option 1 – LSV Ramp

Option 1 (Figure 17) is the LSV ramp area located on MCBH near the fuel pier. A mobile crane would be place on land to lift the heave plate and float. A 20-ton mobile crane will be required to complete the modifications. Work is planned for a 3-5 day period in September or October 2016. Once the modifications are complete, temporary storage (while waiting for suitable weather) is required prior to redeployment at WET. No work on the fuel pier is proposed. The plan is to moor the device at an angle to the wharf so that the crane can be located as close as possible to the float (Figure 18). The device would be moored in a manner that did not block the CONEX that houses the spill response equipment (labelled Boom Box in the figures). The device would be rotated 180-degrees to complete the mods to the heave plate. A work area for operating the crane and staging materials is shown in red. In order to provide access to the LSV ramp and full access to the CONEX the Azura device will be moored parallel to the Fuel Pier (Figure 19) at night during the 3 to 5 day modification period. The device will be moved to a mooring ball (owned by Sea Engineering) once modifications are complete and prior to reinstallation.

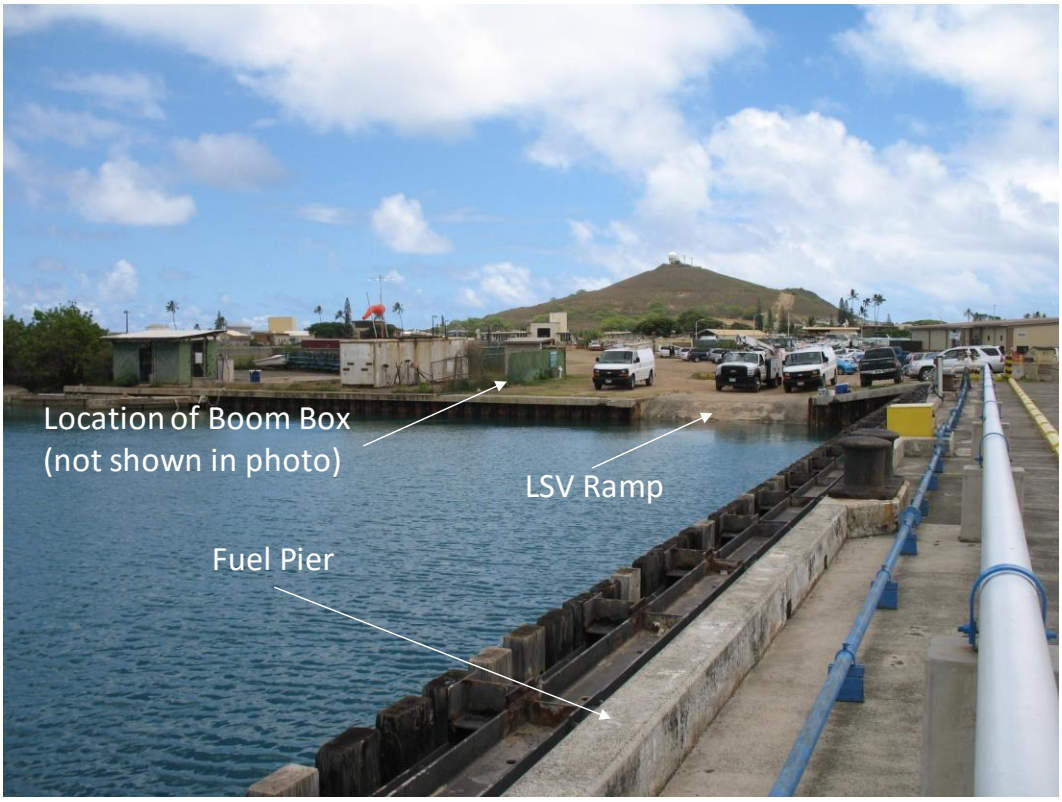


Figure 17 – Work Site Option 1: LSV Ramp at MCBH

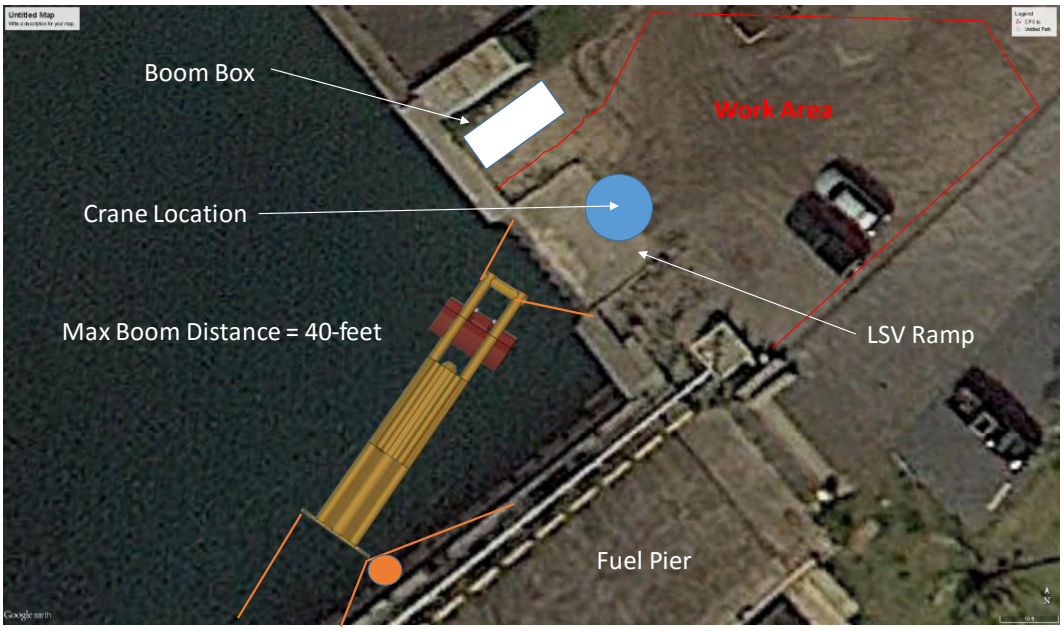


Figure 18 – Location of device during modifications

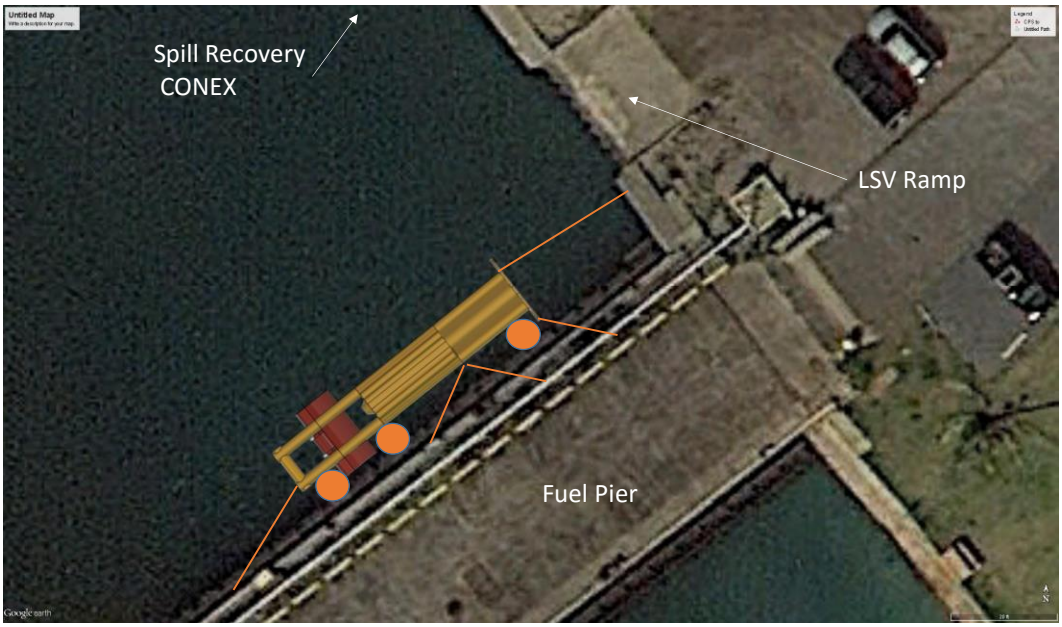


Figure 19 – Location of device during storage before and after modifications

4.2 Work Site Option 2 – SEI Mooring Ball

Option 2 (Figure 20) would utilize the SEI mooring location near He'eia Kea marina. SEI would moor their Huki Pau work boat and secure the Azura device alongside. The Huki Pau was used to install the baseline device (Figure 21) and will also be used to remove and reinstall the modified device. The deck crane on the Huki Pau (Figure 22) would be used to lift and position the heave plate and float.

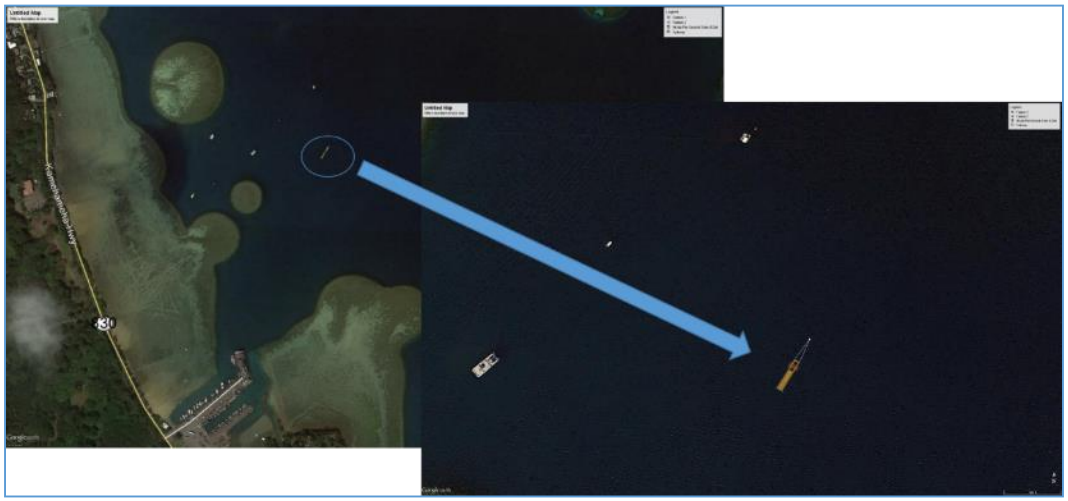


Figure 20 – Work Site Option 3: SEI Mooring Ball

Figure 21 – Huki Pau with Azura

Figure 22 – Deck Crane on Huki Pau