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# 1 INTRODUCTION

In support of ongoing Department of Energy research, Columbia Power Technologies (C·Power) will install the SeaRAY Wave Energy Converter (WEC) at the U.S. Navy's Wave Energy Testing Site (WETS), located off Marine Corps Base Hawai'i, at Kaneohe, Hawai'i (Figure 1). WETS is located approximately two kilometers due north of Pyramid Rock lighthouse, with the SeaRAY deployed in about 80 meters (m) of water. The SeaRAY is a deployable power system for maritime sensors, monitoring equipment, communications, unmanned underwater vehicles, and other similar payloads. This Project is to design, deliver, and test a prototype low-power Wave-Energy-Converter (WEC) that lowers the total cost of ownership and provides robust, new capabilities for customers in the maritime environment. This report includes a preliminary plan for the installation, operation, and maintenance (IO&M) of SeaRAY. This document serves as a Preliminary IO&M Plan for Budget Period 1 (BP1) and is Deliverable 6.7 of the DOE contract for project DE-EE0008627.

# 2 INSTALLATION PROCEDURES AND BEST MANAGEMENT PRACTICES

## 2.1 Installation Procedures

The SeaRAY system will be shipped to Hawai'i in two shipping containers. The first container housing the WEC; the second housing the seafloor garage, heave plate, and mooring EOM/cable.

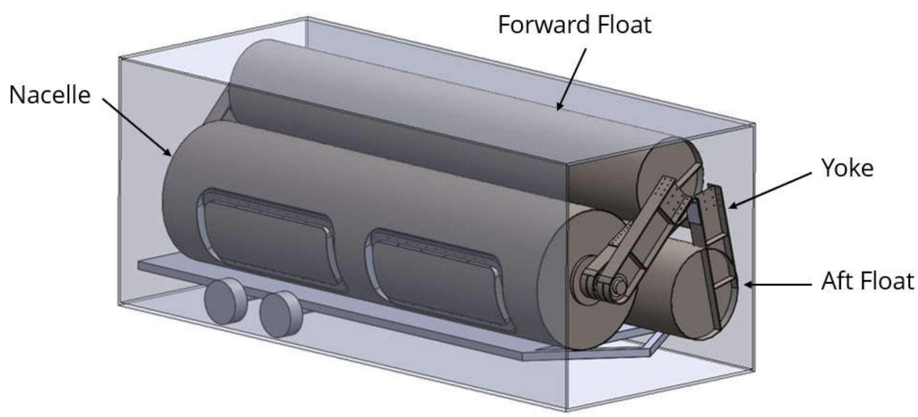


*Figure 1 - WEC in 20' shipping container*

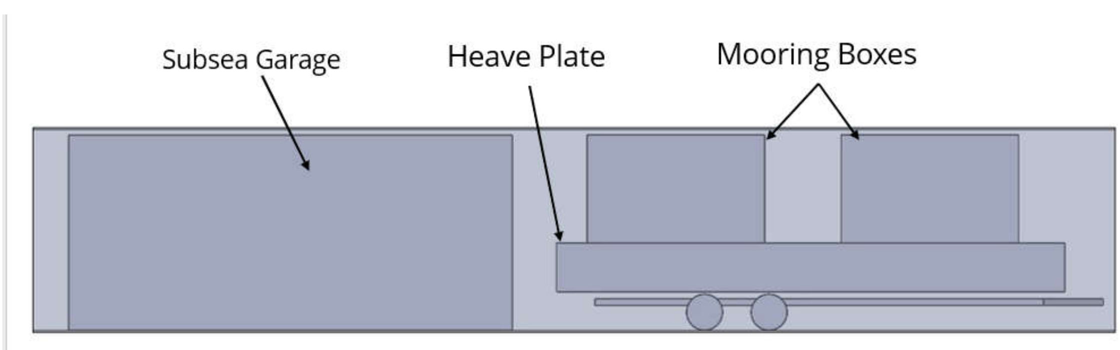


*Figure 2 - Subsea garage, heave plate, and mooring in 40' shipping container*

Once in Honolulu, the garage, heave plate and mooring will be staged at Sea Engineering's facility at Honolulu Harbor. The Kupa'a, an 84-foot vessel set up to support diving, marine construction, and engineering operations at WETS, in will be used for this Project. The heave plate will be positioned on the Kupa’a next to the knuckle crane and the garage will be positioned under the A-frame. The mooring/umbilical lines will then be connected to the WEC, heave plate and garage. The WEC will be placed into the water and towed to the test site.

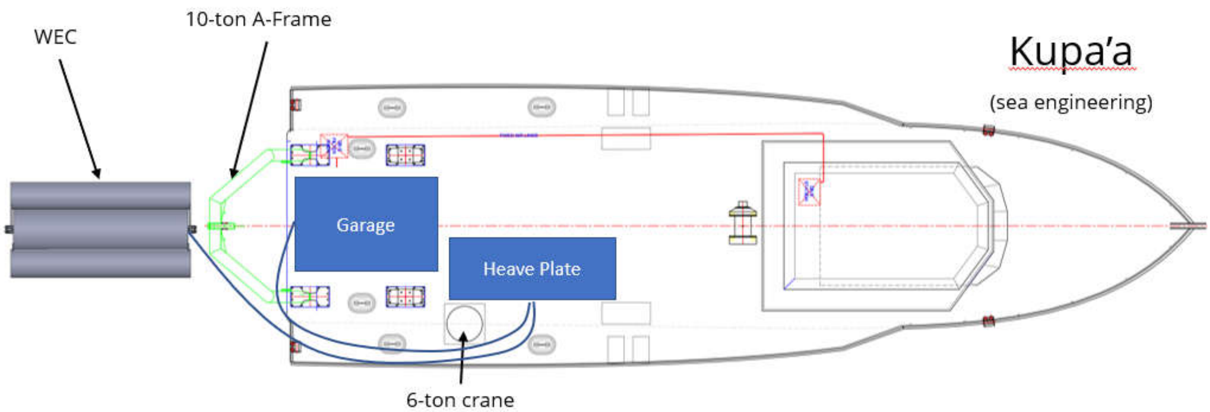


*Figure 3 - Deployment configuration on the Kupa'a*

Upon reaching the designated deployment location at WETS, an initial survey will commence to ensure there are no species present listed in the Endangered Species Act (ESA, see Section 2.2). When the installation area is determined to be clear of ESA species, the WEC will be untethered from the Kupa’a and tended by a small vessel. The heave plate will then be lowered onto the surface of the water with a knuckle crane. The heave plate will be positively buoyant for this operation.

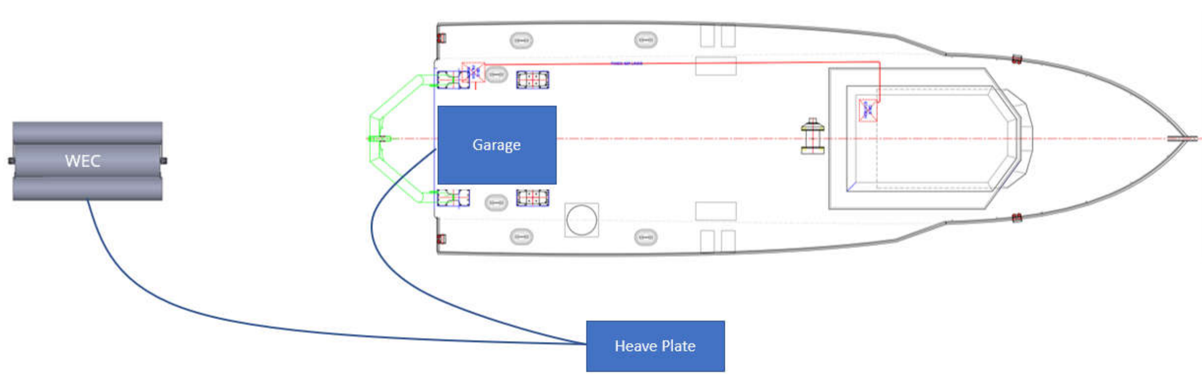


*Figure 4 - Heave plate lowered onto water surface*

The garage will then be lowered to the seafloor using the A-frame crane at the stern of Kupa’a. The mooring/umbilical line connecting the heave plate to the garage is a flexible member and can stretch from its deployment configuration length of 60 meters to the full water depth of 80 meters with under 200 pounds of force.

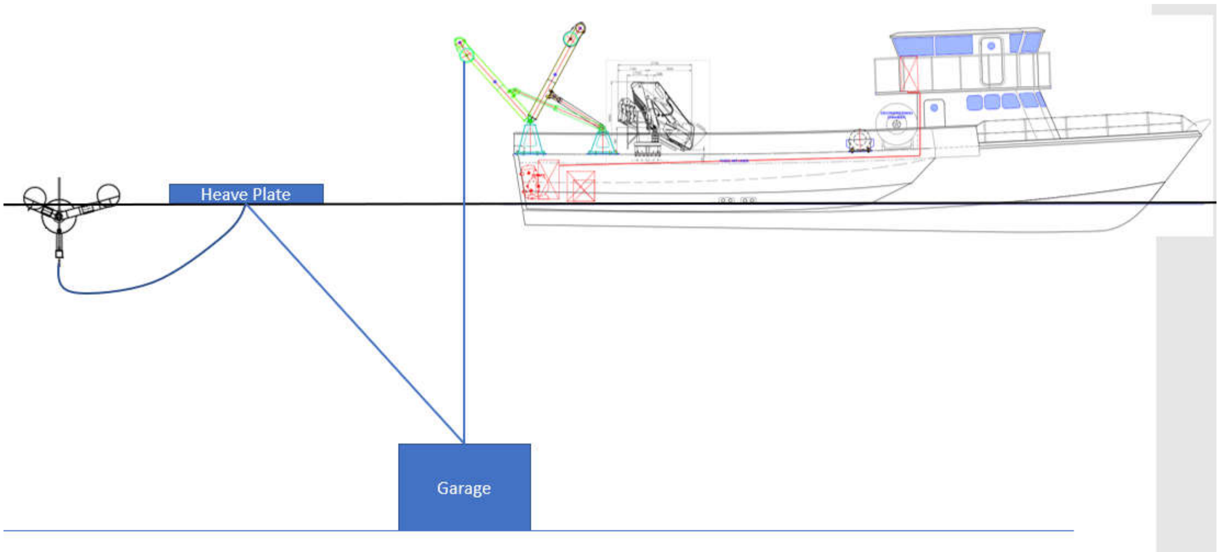


*Figure 5 - Garage lowered to seafloor*

The heave plate will then be flooded with seawater and will sink to its operational position at an approximate depth of 25 meters. Following installation, the onboard global positioning system will be used to monitor the SeaRAY system for the unlikely occurrence of anchor drag.

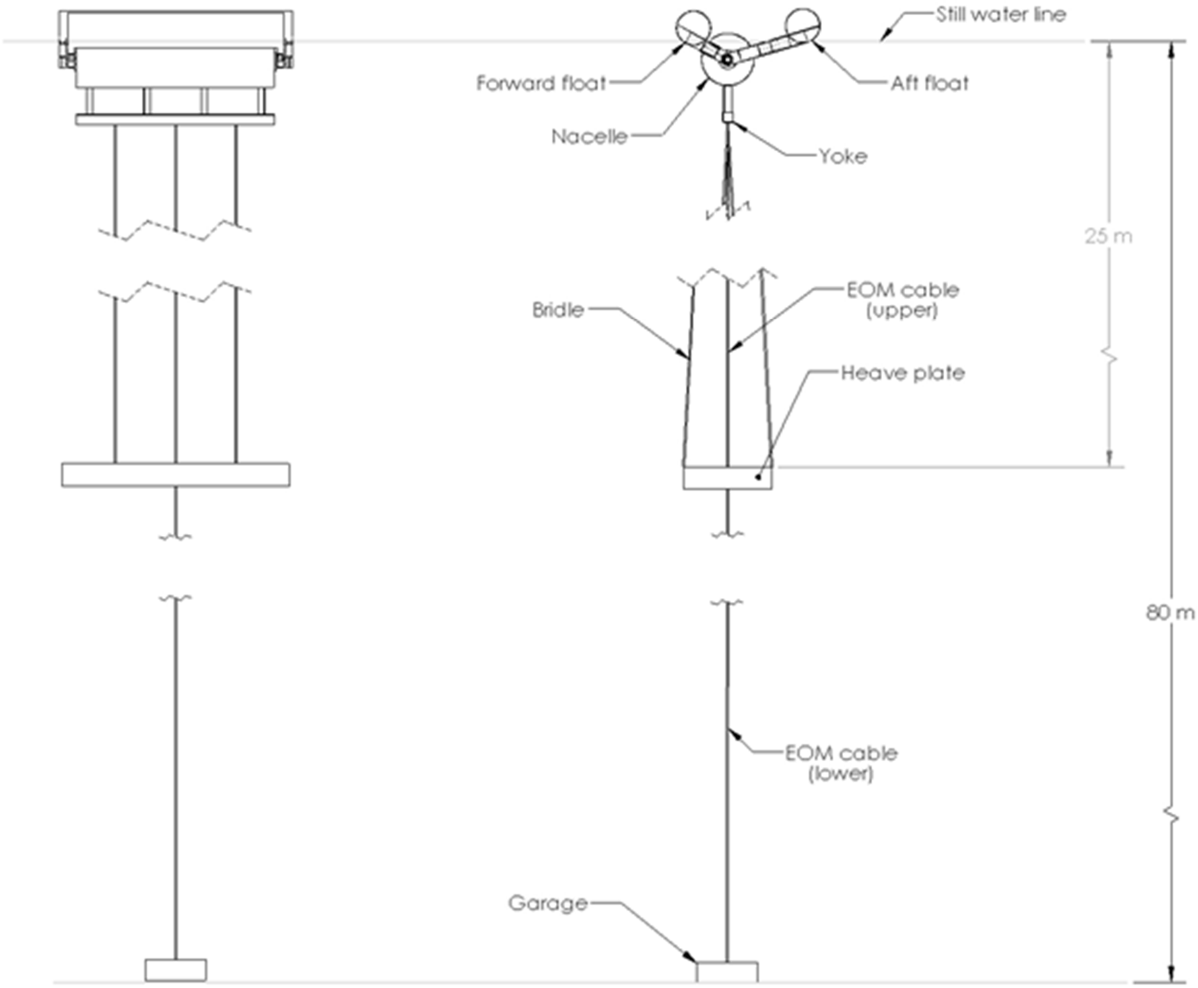


*Figure 6 - Operational configuration of WEC*

## 2.2 Best Management Practices

A series of best management practices (BMP) will be applied during the installation and operation of the proposed action. These BMPs are divided into two parts (A and B). Part A is specific BMPs directed at minimizing effects from the project on protected ESA species. Part B is a series of BMPs that minimize effects from the project on the environment. Prior to deployment of the WEC, all workers associated with this project, irrespective of their employment arrangement or affiliation (e.g. employee, contractor, etc.) shall be fully briefed on these BMPs and required to adhere to them for the duration of their involvement in this project.

**Part A: Constant vigilance shall be kept for the presence of ESA-listed marine species during all aspects of the proposed action, particularly with respect to in-water activities such as boat operations, diving, and deployment of anchors and mooring lines.**

1. The Hawaii Natural Energy Institute (NHEI) in support of the Applied Research Laboratory (ARL) at the University of Hawaii (UH) will provide observers at sea during deployment to monitor for marine mammals, sea turtles, vessel activity, or other relevant events related to

operations at WETS. This observer shall be in constant communication with the project manager that is running the operations.

2. Surveys shall be made prior to the start of work each day and prior to resumption of work following any break of more than one half-hour. Periodic additional surveys throughout the workday are strongly recommended.

3. Personnel shall remain alert for marine mammals and ESA-listed species before and during installation. Do not commence deployment of equipment if an ESA-listed species is observed within 500 m of operation. Wait 30 minutes after the last sighting of the ESA-listed species before starting deployment. If installation is already started and a protected species is sighted within 500 m after deployment has commenced, installation can continue unless the animal comes within 250 m during deployment; operations should then cease until the protected species is seen to leave the area of its own volition or after 30 minutes have passed since the last sighting.

4. Marine wildlife monitoring devices may also be used; active outputs within marine mammal hearing range that are an intensity of 160 decibel (dB) re 1 µPa and above (impulsive sound) or 120 dB re 1 µPa and above (continuous sound) would require observers to monitor the area influenced by that sound level for half an hour prior to activating the active audible output, if the device does not have a validated automated mechanism to detect marine mammals within that range. Observers would continue to monitor the impacted area, requiring daylight and suitable monitoring conditions, and would call for a shutdown of the equipment in the event that a marine mammal or sea turtle enters the zone in which disturbance due to an audible sound intensity of 160 dB re 1 µPa and above (impulsive sound) or 120 dB re 1 µPa and above (continuous sound) could occur. Light sources used in wildlife monitoring devices must be "eye-safe" for wildlife.

5. All work shall be postponed or halted when ESA-listed marine species are within 46 m of the proposed work and shall only begin/resume after the animals have voluntarily departed the area. If ESA-listed marine species (other than monk seals on land) are noticed within 46 m after work already has begun, that work may continue only if, in the best judgment of the marine species observers, the activity would not affect the animal(s). For example; divers performing surveys or underwater work would likely be permissible, whereas operation of heavy equipment is likely not.

6. Special attention will be given to verify that no ESA-listed marine animals are in the area where equipment or material is expected to contact the animal before that equipment /material may enter the water.

7. All objects will be lowered to the bottom (or installed) in a controlled manner. This can include the use of buoyancy controls such as the use of cranes, winches, or other equipment that affect positive control over the rate of descent.

8. In-water tethers, as well as mooring lines for vessel(s) and marker buoys, shall be kept to the minimum lengths necessary and shall remain deployed only as long as needed to accomplish the required task properly.

9. When piloting vessels, vessel operators shall alter course to remain at least 91 m from whales, and at least 46 m from other marine mammals and sea turtles.

10. Reduce vessel speed to 10 knots or less when piloting vessels at or within the distance ranges described above from marine mammals and sea turtles. Operators shall be particularly vigilant to watch for turtles at or near the surface in areas of known or suspected turtle activity, and if practicable, reduce vessel speed to 5 knots or less.

11. If despite efforts to maintain the distances and speeds described above, a marine mammal approaches the vessel, put the engine in neutral, as safety permits, until the animal is at least 15 m away, and then slowly move away to the prescribed distance.

12. Marine mammals and sea turtles shall not be encircled or trapped between multiple vessels or between vessels and the shore.

13. Do not attempt to feed, touch, ride, or otherwise intentionally interact with any ESA-listed marine species.

**Part B: Minimizing effects to the marine environment from project-related activities.**

14. A contingency plan to control toxic materials is required.

15. Appropriate materials to contain and clean potential spills shall be stored at the work site (including aboard project-related vessels) and be readily available.

16. All project-related materials and equipment placed in the water shall be free of pollutants.

17. The project manager and heavy equipment operators shall perform daily pre-work equipment inspections for cleanliness and leaks. All heavy equipment operations shall be postponed or halted should a leak be detected and shall not proceed until the leak is repaired and equipment cleaned.

18. Fueling of land-based vehicles and equipment shall take place at least 46 m away from the water, preferably over an impervious surface. Fueling of vessels shall be done at approved fueling facilities.

19. Turbidity and siltation from project-related work shall be minimized and contained through the appropriate use of erosion control practices, effective silt containment devices, and the curtailment of work during adverse weather and tidal/flow conditions.

20. A plan shall be developed to prevent debris and other wastes from entering or remaining in the marine environment during the project.

# 3 OPERATION & MAINTENANCE

Once installed the SeaRAY system will remain on location under continuous operation for 6 months. SeaRAY systems will be continuously monitoring remotely throughout the deployment period.

## 3.1 Operation Modes

This section details the distinct modes in which the WEC operates. The modes of operation are listed in Table 1, along with distinguishing characteristics of each mode. Broadly defined modes are further broken into sub-modes, which is indicated in Table 1 by the level of indenture.

Normal modes of operation encompass all those conditions in which the WEC is floating in its operational orientation, held on-station by its mooring, and no emergencies have occurred. In the power production mode, the PTO is operational and the WEC is intended to effectively convert wave energy to electrical energy, while staying on station and oriented into the incident waves, and keeping PTO and electric plant systems within operating limits. Normal includes modes that are expected to occur as a part of normal operations such as standby (where the PTO is freewheeling and not producing power), and also transitory modes such as startup (where the generators and power electronics are brought online).

Emergency modes of operation occur as the results of the occurrence of a serious, unexpected event that increases the risk to personnel, equipment, or the environment. Typically, the WEC would be in normal mode of operation when the event occurs. Some events that would induce an emergency mode include a flooded compartment, a mooring failure, or a fire. Emergency power mode occurs when the PTO is offline; in this mode batteries provide power to critical loads. Emergency shutdown is included as a transitory emergency mode of operation.

Transit modes of operation encompass local transit from Honolulu Harbor to WETS berth when the WEC is towed behind the Kupa'a. For long distance transit from the West coast of the US to Honolulu Harbor the components will be loaded into shipping containers and shipped via standard routes.

The commissioning mode of operation encompasses the WEC configuration as various systems are taken online and offline as tests are preformed to confirm seaworthiness and readiness to test.

*Table 1 - Modes of Operation*

| Modes of Operation | Characteristics |
|---|---|
| **Normal** | • Operational configuration, floating, moored |
| Power production | • PTO controlled for power production<br>• PTO is functioning properly |
| Fore-in-aft | • Fore float is flipped over and nested in the aft float due to large wave(s) |
| Standby | • PTOs freewheeling (no power to or from PTOs)<br>• WEC Battery provides power for station power loads |
| Reduced power production | • Normal ops but with reduced power production<br>o Due to fault(s) or elective test |

| Modes of Operation | Characteristics |
|---|---|
| Startup | • Transitory mode in which generators and power electronics are brought online in a controlled manner |
| Shutdown | • Transitory mode in which generators and or power electronics are taken offline in a controlled manner |
| **Emergency** | • WEC emergency modes |
| Flooded compartment | • Flooded compartment<br>• Equipment de-energized in affected compartment |
| Mooring failure | • Mooring line failure<br>• Connection to subsea garage severed |
| Emergency power | • WEC battery failure resulting in power draw from subsurface battery |
| Fire emergency | • Reduced or shutdown PTOs and power electronics as needed |
| Emergency shutdown | • Transitory mode in which generators and power electronics are taken offline in an emergency manner |
| **Transit** | • Condition for shipment, vessel deck transport and in-water towing |
| Shipping Container | • Batteries disconnected<br>• Freewheeling<br>• All systems unpowered |
| Deployment | • WEC towed behind Kupa'a<br>• Freewheeling<br>• Batteries turned off<br>• Power provided by service vessel as needed<br>• Systems offline (SCADA, bilge, emergency systems) |
| **Installation & Removal** | • Lifting and placement of seafloor garage<br>• Lifting and placement of heave plate<br>• Floating while attached to vessel<br>• Vessel tended |
| Installation | • Battery connected<br>• Necessary systems online (SCADA, bilge, emergency systems?)<br>• Umbilical cable de-energized |
| Removal | • Battery connected<br>• Necessary systems online (SCADA, bilge, emergency systems?)<br>• Umbilical cable de-energized |
| **Commissioning** | • Various systems online for commissioning activities<br>• Floating, and vessel tended / mooring set |

## 3.2 Scheduled Maintenance

This maintenance category comprises any task which is pre-planned at the design stage and normally requires the SeaRAY to be temporarily stopped for maintenance work to be undertaken (see Table 2). These maintenance tasks are performed by trained Sea Engineering technicians who are transported to

WETS via marine vessels, originating from Honolulu, and who then perform the maintenance services equipped with basic tools and consumables. Such scheduled work may need to be conducted on a seasonal basis (i.e., during ideal weather conditions). Table 2 outlines the required maintenance during the 6-month deployment window

When approaching the WEC, the maintenance boat will typically be oriented to provide the greatest likelihood of suitable weather conditions for a safe operation. Normally this will result in the vessel bow or stern facing into the predominant wave and current directions, such that waves or strong current across the vessel are less likely.

*Table 2 - Scheduled maintenance tasks*

| System # | Component | Maintenance Cycle | Description |
| --- | --- | --- | --- |
| 0100 | Hull components | 3 months | Visual external inspection. Clean via divers is necessary |
| 0200 | PTO | N/A | N/A |
| 0300 | Electric Plant | N/A | N/A |
| 0400 | SCADA | N/A | N/A |
| 0500 | Auxiliary Systems | N/A | N/A |
| 0600 | Outfit and Furnishings | 3 months | Visual inspection of cable penetrations |
| 0700 | Mooring & Umbilical Stretch Hose (Top Section) | 3 months | Visual inspection with ROV |
| 0700 | Mooring & Umbilical Stretch Hose (Bottom Section) | 3 months | Visual inspection with ROV |
| 0750 | Garage | 3 months | Visual inspection with ROV |

### 3.3 Unscheduled Maintenance

Any unplanned maintenance activities resulting from a failure of any SeaRAY system will be diagnosed by onboard SCADA sensors and internal and external surveillance cameras if possible. The level of corrective action, and the impact of the unscheduled maintenance depends on the severity of the failure and will be addressed at the time of occurrence.

## 4 RECOVERY PROCEDURES

Upon completion of the 6-month deployment of the SeaRAY, the WEC will be recovered from the deployment location. The first step is to acoustically release the mooring/umbilical connection to the garage. An acoustic release is standard industry practice for the recovery of instrumentation from the sea floor. A secure acoustic command is sent from a topside unit to the subsea unit. The WEC will then be tended by a small vessel. The heave plate will be filled with air and will return to the surface where it can be picked and set on the vessel’s deck. Then a recovery line will be released from the garage which the Kupa’a will use to raise the garage via the A-frame onto its deck. Next, the WEC will be secured via tow lines to the vessel and be towed back to Honolulu Harbor. The components will be loaded into shipping containers and shipped to C·Power's facilities in Oregon.

# 5 GLOSSARY

| | |
|---|---|
| ARL | Applied Research Laboratory |
| BMP | Best Management Practices |
| BP | Budget Period |
| C·Power | Columbia Power Technologies Inc. |
| DOE | Department of Energy |
| ESA | Endangered Species Act |
| IO&M | Installation Operations and Maintenance |
| NHEI | Hawaii Natural Energy Institute |
| PTO | Power Take Off |
| SCADA | Supervisory Control and Data Acquisition |
| UH | University of Hawaii |
| WEC | Wave Energy Converter |
| WETS | Wave Energy Test Site |