# Appendix E. Monitoring Plans

# List of Monitoring Plans

**NNMREC Ocean Test Facility (OTF) Short-term Acoustic Test**
(03/14/2012)

**Title**: Short-term acoustic assessment of wave energy conversion at OSU's OTF

**Principle Investigators**: Joe Haxel, Robert Dziak, and Haru Matsumoto – Oregon State University/ Cooperative Institute for Marine Resources Studies (CIMRS)

**Background:** Continuous long-term passive measurements of ambient sound levels (1 Hz – 2 kHz) have been collected from March 2010 – April 2011 at two sites within the MOTB providing a characterization of background acoustic levels (*Haxel et al., in press & in prep.*) over a range of sea states and environmental conditions. Ambient sound in the ocean is composed of a complexamalgam of sources. Despite prior knowledge of probablesound sources within an oceanic region, a distinguishingcharacteristic of marine ambient sound is that no individualsignal dominates or can be readily identified within thereceived field. Analogous to the background "hum"emanating from a large city, ambient sound in the ocean is thebackground sound resulting from remote and near-fieldcontributions of a multitude of anthropogenic and naturalsources. At the MOTB site, theambient noise field consists primarily of sounds emanatingfrom breaking waves, winds, vessel traffic, marine mammals, and fish.

Root mean square (rms) maximum and minimum total sound pressure levels ($SPL_{rms}$) from the 1Hz-2kHz band calculated over 1 minute intervals during the experiment reached 136 dB re 1 μPa and 95dB re 1 μPa respectively. Meanwhile, the time averaged $SPL_{rms}$ value for the year-long deployment was 113 dB re1μPa.

$$SPL_{rms}\ (\text{dB re } 1\mu\text{Pa}) = 20 \log_{10}(p_{rms}/p_{ref})$$

Peak $SPL_{rms}$ values were encountered during heavy surf conditions recorded at a nearby offshore NOAA NDBC buoy (http://www.ndbc.noaa.gov/station_page.php?station=46050).

Underwater sounds generated by the operations of the mobile ocean test berth (MOTB)instrumentation buoy (Ocean Sentinel) and wave energy converter (WEC)this summer (2012) are expected to contribute to the local noise budget. The purpose of this study is to provide a rapid measurement of the maximum, root mean square (rms), and minimum absolute sound pressure levels (SPL) received at a range of 10 m – 200 m distance from the WEC device. These observations will provide the necessary information to evaluate the acoustic impact of the operational WEC on marine mammals based on NMFS criteria for harassment (120 dB) and injury (180 dB).

**Project Objectives:** Little information is knows about the sound impact of WECs. The objective of the acoustic monitoring is to determine if the device under test transmits acoustic energy above mammal harassment thresholds.

**Project Description:** The methods and instrumentation will be similar with techniques used by Bassett et al. (*in press*) to perform a similar evaluation of a WEC in Puget Sound operated by Columbia Power Technologies. Unlike the drifter used in the Bassett et al. (*in press*) study, we propose to deploy a calibrated cabled hydrophonefrom a vessel. Each recording will begin and end ~200 m up and down drift of the WEC device. The hydrophone will be dropped to ~10 m below the sea surface and the vessel's engines will be shut down in order to eliminate noise contamination. The calibrated hydrophone system will record continuously at a sample rate of 50 kHz, providing reliable power spectral density estimates up to 20 kHz. A series of 4 drifts will be made past the WEC device during each recording cruise session.

Initial baseline near surface acoustic recordings using the protocol outlined above will be performed in May prior to any MOTB mooring installations in the area designated by Oregon State University for the WEC test. These baseline measurements will provide background for comparison of operational acoustic transmissions from the WEC, as well a test of our recording procedure prior to WEC installation and operation. Additionally, these initial recordings may indicate pre-existing ambient sound conditions above NMFS threshold criteria prior to MOTB activity. A subsequent recording cruise mission will be carried out after the WEC device has been deployed and is in operation.

**Reporting:** Data from each recording session will be processed and analyzed in a timely manner to provide NMFS and ODFW regulatory personnel with the necessary received SPL measurement information in order to assess acoustic levels produced by the WEC test.

**Adaptive Management:** Upon review of the initial results, and in coordination with NMFS and ODFW, NNMREC scientists may recommend further recording or no further recording upon satisfactory completion of the acoustic monitoring required by the WEC test permit.

If confirmed testing indicates that sound levels are above Level A (180dB SPL for cetaceans and 190dB for pinnipeds) or Level B (120dB SPL) harassment threshold criteria, and that the sound levels are attributable to the WEC test, NNMREC scientists and Ocean Test Facility Manager, in coordination with NMFS and ODFW, will determine the appropriate action. Action may include:

- Further recording to confirm acoustic pressure levels;
- Modifying the operation of the WEC or Ocean Sentinel;
- Ceasing operation and performing necessary modifications to minimize noise levels. Testing would be conducted to verify that the noise associated with the test has been abated; and/or
- Applying for an Incidental Harassment Authorization.

**<u>Schedule:</u>**

May 2012–baseline recording

July 2012 – initial recording of WEC (within 2 weeks of installation, weather permitting)
(initial results provided within 1 week)

August 2012 – continued recording of WEC (if necessary)

## NNMREC OTF Benthic Monitoring Studies

**Title:** Monitoring of benthic habitat, invertebrates, and fishes at OSU's ocean test facility

**Principle Investigator:** Sarah Henkel – Oregon State University, Northwest National Marine Renewable Energy Center and Hatfield Marine Science Center

**Background:** Pre-installation baseline sampling of benthic habitats and species was conducted at and around the future ocean test facility location from May 2010 to December 2011. After exploratory video sled surveys in May 2010, sample stations were established on a regular grid. Twelve stations were established: two transects north of Yaquina Head, two transects south of the Head, and stations at approximately 30, 40, and 50 m on each of the transects. These transects are designated as (north to south): BB (Beverly Beach), MB (Moolack Beach), NH (Newport Hydrographic Line), and NS (Newport-South). All 12 stations were sampled ~bi-monthly for sediment and infaunal organisms using a box corer. For beam trawl surveys, only 9 stations were sampled on each visit. Those stations along the southern-most transect lie at the edge of a reef, and it is too risky for the net and the reef organisms to sample those stations. Video footage from the beam trawl was effectively captured in summer months; winter videography (attempted in February 2011) did not yield useful footage. Although not a primary objective of the videography, evidence of derelict gear did not show up on any of the transects. Wayward crab pots and research gear are anticipated to be the predominate type of derelict gear in the test area.

**Project Objectives:**

1. The presence of anchors and the potential for changes in benthic habitat may affect the distributions of benthic fishes and invertebrates. To investigate this hypothesis, benthic species and habitat monitoring will be conducted in to determine how benthic organisms will respond to WEC-induced changes to the habitat.

2. The introduction of hard surfaces may encourage colonization by marine invertebrates and fish attraction. To investigate this hypothesis, visual observations of the introduced surfaces to assess colonization will be conducted. Additionally, the ongoing benthic sampling conducted under objective (1) will investigate whether resident species are being affected by those attracted to the structures.

3. Marine mammals could become entangled or entrapped by derelict gear that has been ensnared on any Project structure. To investigate this hypothesis, derelict gear monitoring will be conducted to determine if gear is being ensnared by the anchors and mooring lines.

**Project Description:** The OTF is planned to be located approximately on the MB sampling transect in 45 m of water, so it will be in between the 40 and 50 m sampling stations on that line. Post installation monitoring of the NNMREC Ocean Test Facility (OTF) for assessing interactions with benthic habitats and species will be carried out in much the same manner as pre-installation baseline sampling. Table 1 indicates the pre-installation sampling already conducted (black text) and planned future monitoring, generally at the permitted site and for the 2012 test (blue text).

**Table 1: Sampling visits and gear types.**

| | Box Core | Trawl | Trawl Video | Lander Video |
|---|---|---|---|---|
| June 2010 | ✔ | ✔ | | |
| August 2010 | ✔ | ✔ | ✔ | |
| October 2010 | ✔ | ✔ | | |
| February 2011 | | ✔ | ✔ | |
| April/May 2011 | ✔ | ✔ | ✔ | |
| June 2011 | ✔ | ✔ | ✔ | |
| August 2011 | ✔ | ✔ | | |
| October 2011 | ✔ | ✔ | ✔ | |
| December 2011 | ✔ | ✔ | | |
| June 2012 | ✔ | ✔ | ✔ | ✔ |
| August 2012 | ✔ | ✔ | ✔ | ✔ |
| October 2012 | ✔ | ✔ | ✔ | ✔ |

We will visit the site in June 2012, once more prior to deployment since it will have been 6 months since our last visit. After the Sentinel Buoy and associated WEC device under test are deployed in July, we will visit the site again in August 2012 for an assessment while the devices are operational. Weather permitting, we will again visit the site after the Sentinel Buoy and WEC device are removed to assess if there are 'decommissioning' effects or if site characteristics are similar to pre-test conditions and/or baseline observations. Sample collection and data analysis methods are described in detail below.

### *Sample Collection Methods*

i. Box core. One box core will be taken at each beam trawl station. The box core is a 0.1 $m^2$ modified Gray-O'Hare box corer. Upon landing the corer, a subsample of sediment from the undisturbed surface will be collected and preserved for grain size and total organic carbon analysis. The sample will then be sieved onboard through a 1 mm mesh screen; samples will be stained and preserved for later identification and enumeration. Samples will be sorted into major taxonomic groups by lower level staff; these major taxonomic groups will be weighed for biomass determination. The laboratory manager will identify the echinoderms and molluscs to species and crustaceans and polychaetes to family (lower if possible).

ii. Beam trawl with mounted video camera. The beam trawl is 2 m wide by 0.5 m high with 20 mm wall netting and 3 mm cod end netting. The duration of beam trawls will be kept to 10 min from contact with bottom to retrieval. We will collect and preserve (freeze with dry ice and store at -20 $^{o}$C) fish and invertebrates from the net catches for later taxonomic identification. In the laboratory, all fish will be analyzed for size and morphometric body condition as well as their gut contents identified. This will enable us to investigate if the condition of the fish or their feeding habits has changed from what we observed in our 18 months of pre-installation baseline monitoring. Invertebrates will be sorted to species and each species' biomass determined. Videos will be viewed to determine the densities of sessile and mobile invertebrates (e.g. sea pens, crabs, sea stars) that are not well captured with the net.

iii. Video lander (drop-video camera). This is a sampling tool that was not used for baseline monitoring but will be valuable for assessing potential fish aggregating effects of anchors. The video lander is an aluminum frame with two sets of video cameras with lights mounted on the frame. The two cameras are oriented 180° from each other so that they are facing opposite directions. The lander will be deployed at the 40 and 50 m stations on the BB and MB lines as reference locations as well as dropped near each anchor of the Ocean Sentinel (n = 3; ~45 m depth) and at each anchor of the WEC under test (as appropriate for each device type). The lander will be left on the bottom for a total of 15 minutes at each drop station. The number of each species or taxa of fish observed over time by each camera will be counted and the primary (mostly sand) and secondary (potentially anchor) substrate observed will be recorded. Counts will be compared to determine if more fish are observed at anchor locations than at reference locations and if more fish are observed by the camera facing the anchor than facing away. Since the anchors for the Ocean Sentinel are planned to be left in the water, video lander sampling of Ocean Sentinel anchors and reference locations will continue for the duration of the project, regardless if whether there is a WEC device under test. This sample method will also provide for monitoring of derelict gear that may become tangled on the anchors and animal entanglement. For derelict gear, the location (lat/lon in decimal degrees), type of gear, and condition (approximate size, line color, number and color of floats, if attached, presence or absence of pots or webbing) will be recorded. For entanglement, the species, its condition of entanglement and location will be recorded.

iv. CTD-DO with chl a, and alkalinity. We will sample properties of the full water column with a SeaBird CTD profiler (SBE 25) with DO (SBE 43), pH, transmissivity and chlorophyll a sensors at every sampling station on each visit.

### *Data Analysis*

For species assemblage analyses (conducted separately for box core invertebrates, trawl invertebrates, trawl fishes, and video lander fishes), taxa for which there is just one individual collected/observed for the entire dataset will be removed so as not to skew the data based on rare species. Cluster analysis will be conducted on transformed density datasets for each assemblage in order to produce groups of similar stations based on species abundances. The SIMPROF routine will be run in Primer 6. This routine conducts a series of permutation tests to determine if clusters in a dendrogram have statistically significant structure. Samples within a cluster that cannot be significantly differentiated are considered to be a genuine group. The SIMPER procedure in Primer then will be used to identify species contributing most to similarities within clusters and differences between clusters. This analysis will be used to determine if there are unique communities within each assemblage found across the site. Analysis of the pre-installation collections indicated that there was strong spatial heterogeneity in the invertebrate collections that were stable over time. The spatial distributions of significantly different species groups from the post-installation surveys will be compared to the pre-installation surveys. Analysis of the fish data from pre-installations collections did not elucidate any spatial patterns of species presence or abundance; thus it will be interesting to see if we observe spatial differences in fish distributions post-installation. There was however, strong temporal variability in species present across seasons. We will determine if those patterns are consistent post-installation.

Multivariate analysis of the combined pre- and post-installation datasets will be conducted in Primer. Multidimensional Scaling (MDS) will be used to analyze the transformed density data to examine species composition and proportions across stations. MDS is an ordination technique where a small number of axes are selected prior to analysis and data are fitted to those dimensions, Data will be displayed in MDS plots such that samples that form a genuine cluster, as determined using the SIMPROF routine, have the same symbol on the plot. Thus, we will be able to visually determine if samples from the same season before and after installation cluster together or if post-installation samples are significantly different from pre-installation. Following MDS analysis of the organism data, the BEST function in Primer will be used. The BEST function is based on the BIO-ENV procedure, which uses all the available potential ‘explanatory’ (usually environmental) variables to find the combination that corresponds best to the patterns in the biological data. A correlation value is given for each comparison of the biological assemblage patterns and every combination of environmental variables. We will include a binary factor indicating pre- or post-installation in the environmental matrix in order to determine if that factor contributes to observed distinctions among collections.

In addition to multivariate analyses at the species level, we will compare our observations of infaunal invertebrates and fishes to longer time series by comparing summary statistics. The US Army Corps of Engineers samples the dredge spoils from Yaquina Bay for infaunal invertebrates and occasionally fishes. The location of the North Disposal Site and sampling area falls within the NNMREC sampling area (Figure 1); thus we are able to compare densities of major taxonomic groups (Polychaetes, Molluscs, Crustaceans, Echinoderms) to the USACE to expand our reference dataset, enabling us to put post-installation observations in the context of longer term, inter-annual trends and variability. Various Oregon State University researchers have been sampling flatfish along the MB and NH transects at various time since the mid-1970s. While direct density comparisons may not be possible due to differences in gear types, we will compare the relative abundances of different flatfish species in our pre- and post-installation observations to those observed over the past few decades.

Drop camera footage will be viewed to determine if more fish are observed at anchor locations than at reference locations and if more fish are observed by the camera facing the anchor than facing away. Derelict gear and incidents of entanglement will also be recorded if found on the footage.

### *Reporting*

Following each WEC test, a summary report of the pre-, during-, and post-test surveys will be prepared and submitted to NMFS and ODFW for review of both sampling procedures and findings. The report will include findings related to derelict gear and animal entanglement. This reporting will be in compliance with NNMRECs Mobile Ocean Test Berth Operations and Maintenance Plan, Section 9: Marine Mammal Consideration, Reporting Protocol for Injured or Stranded Marine Mammals. The presence of derelict gear itself will be reported to the Oregon Department of Fish and Wildlife. If marine mammal entanglement is observed the Oregon Marine Mammal Stranding Network, which is based at the Hatfield Marine Science Center, will be contacted as well.

The approach described above is that which will be used for the NNMREC Ocean Test Facility site, generally, as well as what is proposed for the 2012 test, which will commence in July 2012. Changes to the timing of deployment for future tests may necessitate slight changes to the sampling schedule. Study plans for the following year and subsequent tests will be submitted to NMFS and ODFW, particularly in the event that any changes from the previous sampling are proposed. If adaptive measures are planned (see below), they will be reflected in the report.

### *Adaptive Management*

We believe it will be difficult to detect measureable changes in most of the sampled populations due to project effects of the Ocean Sentinel and a single WEC device under test. The ‘baseline’ sampling for the Ocean Power Technologies project off Reedsport, OR, is scheduled to commence when they have the first buoy in the water, as this is still considered ‘pre-installation’, and no measureable changes are expected with the deployment of the single buoy. Thus, for benthic monitoring at the NNMREC Ocean Test Facility site, there are few scenarios we can anticipate that would trigger a change in sampling strategy or test operations based on benthic changes.

If monitoring shows that derelict gear has become ensnared or collected on any Project structure, the NNMREC Ocean Test Facility Manager will be notified by the NNMREC scientist to review the footage and evaluate whether the gear has the potential to endanger the safety of species and/or the devices in the area. This may include taking additional photos or footage to characterize the gear more, if necessary. Action will depend on the severity of the derelict gear entanglement and the risk the gear poses to the safety of the test or entanglement of animals. If the gear poses no threat to safety or animals, it will be removed during removal of the project. Gear removal planning and coordination will be initiated by the Ocean Test Facility Manager if deemed appropriate.


**Figure 1: Map of project area. Repeat sampling locations are indicated with blue pins. The Ocean Test Facility project area is indicated by the light blue box. The planned location for the first test is indicated with the red star. US ACE dredge spoils sampling area is indicated by the white outline.**

**PROPOSED STUDY**

# Electric and Magnetic Field (EMF) Monitoring of WET-NZ 1/2 scale Wave Energy Generator at NNMREC Ocean Test Facility

PI: Dr. Adam Schultz, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis OR 97331-5503

Proposed Project Start Date: 1-April-2012
Proposed Project Duration: 24 months

## Background

The proposed project involves deploying the WET-NZ ½ scale wave energy converter (WEC) with the Ocean Sentinel instrumentation buoy at the Northwest National Marine Renewable Energy Center (NNMREC) Newport test site offshore Yaquina Head, Oregon. Deployment of the Ocean Sentinel and the WEC unit is planned for July, 2012. We propose to carry out measurements of electric and magnetic fields on the seafloor within and adjacent to the test site during periods when the Ocean Sentinel and WEC are installed and energized. To characterize background, baseline EMF levels, we propose to carry out measurements of EMF during periods when the devices have been removed.

EMF monitoring is not a yet a fully defined science for marine renewable energy applications, and mission-specific instrumentation is needed for the industry. OSU is in the process of developing this instrumentation and will be applying it for the first time to this project in an experimental mode. The National Science Foundation (NSF)-supported National Geoelectromagnetic Facility (NGF) at Oregon State University, led by the PI of this proposal, operates the US national academic instrument pool for terrestrial geoelectromagnetic instruments. The NGF pool currently consists of 46 transportable long-period magnetotelluric (magnetic and electric field) geophysical measuring instruments, as well as 7 such instruments that are permanently deployed at sites across the continental US. The NGF is also currently constructing the first 10 geoelectromagnetic instruments of a new type – termed "ultra-wideband". This collection of instruments is used extensively in geophysical investigations on land, both to image the electrical resistivity structure of the Earth's shallow near surface, crust and mantle, and to characterize both natural and anthropogenic electric and magnetic fields (EMFs).

Under Oregon Wave Energy Trust support, the PI of this proposal collaborated with M. Slater of SAIC in construction of a first generation marine EMF sensing platform that was a marine adapted direct offshoot and functional copy of the NGF ultra-wideband instruments that the PI developed under separate NSF support, in collaboration with Zonge, International, Inc. In July 2010, this instrument was successfully used by the PI, NGF technician A.T. Peery and M. Slater, to detect EMFs on the bottom of Yaquina Bay Oregon. The NGF team induced an artificial EMF in a buried, submerged pipeline under the bay by using a Zonge International, Inc., controlled source electromagnetic generator connected to the pipeline. In addition to detecting the location of the buried pipeline, this team also characterized the background natural and anthropomorphic EMFs at the waterline and on the seafloor in Yaquina Bay.

In 2011, under Oregon State University support, and with contributions from Zonge International, Inc. (and more recently through additional NNMREC/DOE support), the PI began the development and construction of a more advanced, 2nd generation "multi-physics bottom lander" (MPBL) system that incorporates a significantly improved EMF sensor package, a wideband ocean bottom seismometer, auxiliary sensors including pressure, accelerometers, etc., capabilities for acoustic telemetry of sensor data from the seafloor to a surface vessel, a trawl resistant cowling to protect the instrument from damage due to fishing activity, and the capability for autonomous deployment of the sensor platform from the deck of a ship and buoyant return of the platform to the surface, by acoustic command.

The MPBL has been carefully designed to characterize EMFs associated with Ocean Sentinel and WEC installations (and, with the addition of its ground motion sensors/seismometers/accelerometers, it is also well suited to environmental monitoring of offshore wind energy installations, as well as to a variety of marine geophysical investigations). The sensors have been designed following guidance found in Slater, Schultz, Jones and Fischer, *Electromagnetic Field Study* (2010), Oregon Wave Energy Trust (346 pages).

The MPBL system consists of an EMF sensor package in a trawl-resistant conical capsule approximately 2m in diameter and 1.5m tall. The lander is hoisted overboard using a vessel-mounted winch at the locations indicated in the survey lines. After approximately 10-20 minutes of recording, it is winched back on to the vessel to be deployed at the next location. Operating in this deployment mode, a single MPBL can be used to characterize the EMF signature of a WEC/Ocean Sentinel installation. In future, the MPBL will also be configurable for an autonomous long-term monitoring mode, where it is deployed at a fixed position on the seabed to monitor EMFs and other environmental parameters over periods of days-to-weeks or longer.

The magnetic field sensors have been custom developed for the MPBL, with a noise floor of approximately 0.05 pT/√Hz at 1 Hz and 0.002 pT/√Hz at 50 Hz (where 1 pT = $10^{-12}$ Tesla). The Earth's magnetic field intensity as measured by a compass is about 50,000 nT (1 nT = $10^{-9}$ Tesla). In addition to their extraordinary sensitivity, the MPBL's magnetic field sensors have a flat frequency response from 0.1 Hz to 1 kHz, which makes them ideally suited to detecting even extremely small levels of 50/60 Hz power line noise at the fundamental frequency and its significant harmonics.

We have also developed a custom marine electric field detection system that is matched to the sensitivity of the magnetic field sensors, and both electric and magnetic field sensors detect both the amplitude and the direction of the EMFs, which is critically important during a survey in discriminating between several geographically disparate sources of EMFs (i.e. to determine which cable/installation is the origin of a given signal at a given location). These sensors have been coupled to the first portable, low power geophysical data acquisition system employing a digitizer with 32 bits of precision, providing the ability to digitize the MPBL's sensor signals with extraordinary fidelity (e.g. with a signal-to-noise ratio of 3.2 million:1 for signals at 250 Hz). This extended fidelity is important in efforts to detect the sometimes-subtle EMFs of interest that may be otherwise overwhelmed by signals (natural and anthropogenic) that may come from other sources such as the shore-side power grid.

Such a degree of sensitivity to, and ability to distinguish the sources of, EMFs is required if we are to match the known and postulated electro- and magneto-sensitivity of indicated species, some of which are endangered within this range, as detailed in Slater, et al (2010). That report also indicates that with appropriate conditions (bathymetry, seafloor rock type), it is possible for electrically resistive sub-seafloor geologic formations to act as a type of waveguide, extending the distance range over which potentially biologically significant EMFs may propagate, relative to the more rapid attenuation of such fields in electrically conductive seawater. It is therefore necessary to carry out a program of EMF monitoring of WEC sites in order to characterize background and induced EMFs from such installations. Ideally such monitoring efforts will be coupled with numerical modeling of EMF propagation using a realistic 3D model of the electrical resistivity structure of the seafloor, water column and coastline.

Our current development plan calls for completion of the data acquisition, power supply, magnetic and electric field sections of the MBL, and fabrication of a survey frame to mount these components to so they are field deployable for pre-deployment acceptance testing in Yaquina Bay Oregon, by early August 2012.

**Monitoring Objectives:**

1. Marine EMF monitoring for marine renewable energy is a newly emerging application of this method, and mission-specific instrumentation is needed for the industry. To increase our understanding of EMF monitoring, OSU has designed and will carry out the first deployment of an advanced 2nd generation EMF monitoring instrument.
2. It is hypothesized that the proposed project is highly unlikely to generate EMF at levels that would adversely impact endangered species. To investigate this hypothesis EMF monitoring will be conducted to characterize EMF during an energized WEC test.

**Proposed EMF Monitoring**

We propose to carry out two EMF surveys within and immediately surrounding the NNMREC ocean test site. It will be necessary to map the seafloor EMFs surrounding the Ocean Sentinel/WEC installation when that system is operational and energized, and also to repeat the survey after the Ocean Sentinel/WEC system has been removed or powered down. Given the MPBL's acceptance testing schedule, we propose to begin monitoring operations in August 2012, while the Ocean Sentinel/WEC is in its energized configuration. Following its removal and before any new deployments of the Ocean Sentinel take place during the spring/summer of 2013, we will return to ocean test site and repeat the survey to obtain baseline EMF measurements.

During each survey, we plan to acquire data using a 4 kHz sampling rate, so we may resolve power line frequencies up to the 16$^{th}$ harmonic (960 Hz) of the 60 Hz fundamental frequency and beyond. The survey will be capable of detecting both AC EMFs originating at the WEC generator (at ocean swell frequencies of ~0.07 Hz and harmonics, as well as at 60 Hz power line frequencies and harmonics) as well as DC power line transmission related electric fields that might arise in the event of faulty/damaged/cut cable insulation or connector failures..

## Survey Configuration

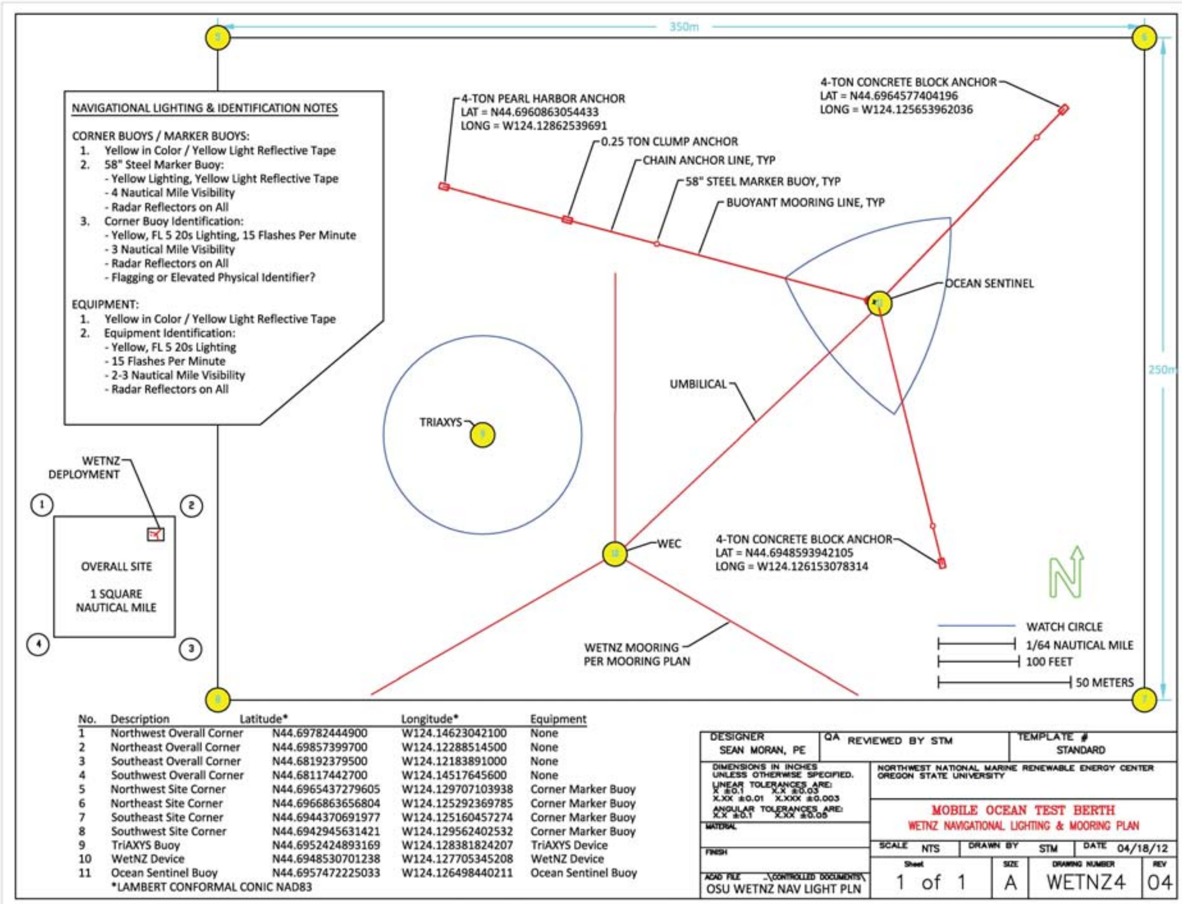
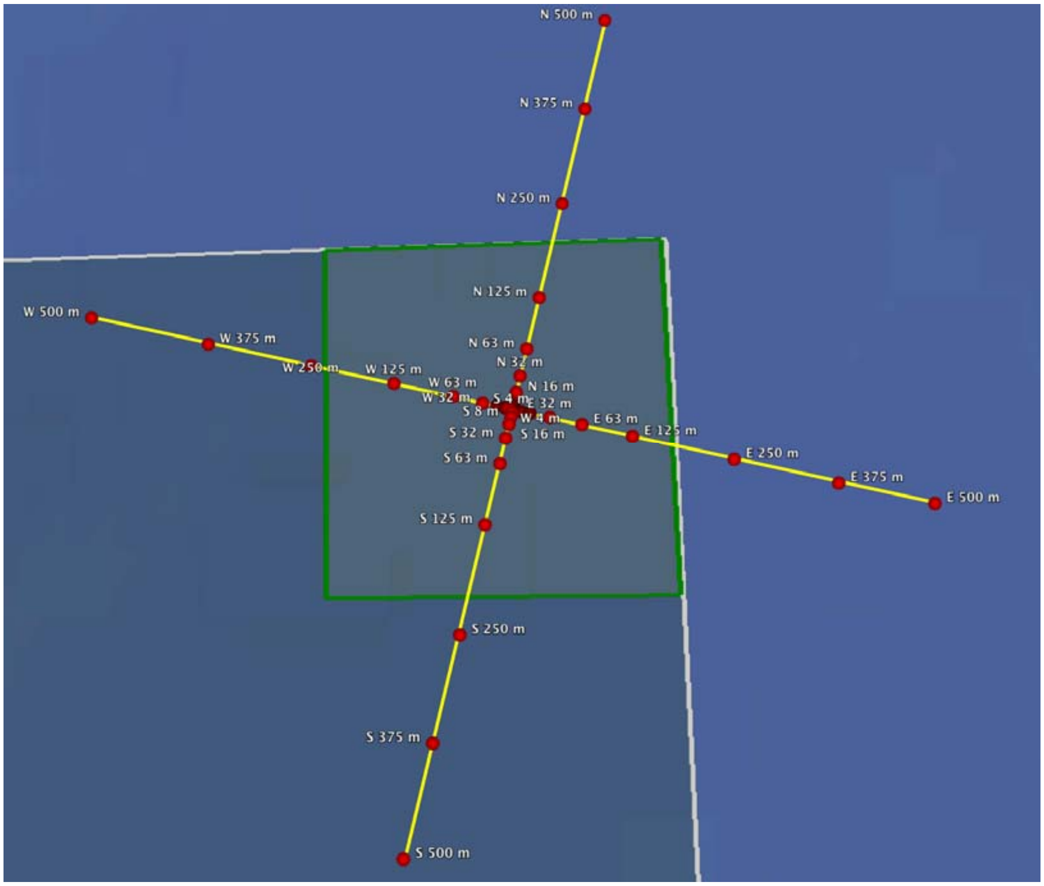



**Figure 1**. Map view of the Ocean Sentinel/WEC installation mooring lines and watch circle. The distance scale is marked in feet.

Our survey configuration is shown in Figure 2. This survey configuration will be repeated twice; first in August 2012 while the Ocean Sentinel/WEC system is positioned and energized, and again in the spring/summer of 2013 when it has been removed and prior to the reinstallation of the Ocean Sentinel. In the event of delays on the part of the WEC or Ocean Sentinel operators in deploying the system, we will adapt our schedule accordingly, reserving the ability to carry out all survey in 2013 if required. During each of these surveys the ship (the 53' Oregon State University coastal research vessel R/V Elakha) will deploy the EMF sensor platform on the seafloor at the positions indicated in Figure 2 (the red dots), using the vessel's winch. The positions will be navigated with reference to GPS.

36 separate survey stations are identified in Figure 2. Two 1-km long survey lines are shown. All directions are with reference to Magnetic North, a direction that in this location is close to parallel to the coastline and to lines of constant bathymetry. The first survey line is oriented to magnetic north-south and the second orthogonal line is oriented to magnetic east-west. The two lines cross near the center of the Ocean Sentinel/WEC installation midway along the umbilical between the Ocean Sentinel and WEC that is shown in Figure 1.

**Figure 2**. Each seafloor EMF measurement station is shown as a red dot lying along either a N-S or E-W (magnetic coordinates) survey line. Survey locations are found 4m, 8m, 16m, 32m, 63m, 125m, 250m, 375m and 500 m radially outward from the array center, in each of the four cardinal magnetic directions.




The EMF surface array is designed to tighten spacing between stations geometrically as the center of the array, i.e. the Ocean Sentinel/WEC installation is approached. Field intensity will increase geometrically with proximity to the signal source, so tighter station spacing is required closer in, while sparser EMF sampling is appropriate at greater distances. In addition to stations obtained along the cardinal directions (an approach that also increases ease of survey navigation and operational efficiency), as time allows additional EMF stations will be acquired within each of the quadrants bounded by the survey lines.

It is appropriate to monitor EMFs using such an array configuration to account for bathymetric effects on EMF propagation, and for the possibility that shallow sub-seafloor geology structure may vary in three dimensions, leading to non-uniform EMF propagation with distance from the Ocean Sentinel/WEC installation. The 500 m radius of the survey footprint allows for capture of EMFs that may have propagated along buried geologic waveguides. Experience from studies of induced EMF propagation along such waveguides, a phenomenon used in the oil industry to characterize marine oil/gas reservoirs, provides a rule of thumb: the propagation of induced EMFs due to an “electric dipole” source of a given length can be detected approximately ten dipole lengths distant, if a geologic waveguide is present. The length of the power transmission line between the Ocean Sentinel and the WEC is approximately 50 m, thus the EMF rule of thumb suggests we should monitor EMFs to distances of up to 500 m radially from that cable. In the absence of such a waveguide, we would expect much more rapid attenuation of EMFs with distance from the center, thus the denser station spacing closer in, with stations as close as practical to the center point of the cable (minimum distance to be determined by the Ocean Sentinel manager and the Elakha's captain given prevailing winds and currents. The closest stand-off distances illustrated in Figure 5 are subject to change).

EMFs are best measured from a stable platform of the seafloor. The motion of the sensor platform dragged through the water column leads to a series of technical complications. Such a scenario would move the sensor package through the Earth's magnetic field lines, inducing an electric field that is an artifact of that motion. The platform would also pitch and yaw, changing the orientation of the sensors with respect to the EMFs being measured. Such motion would need to be carefully logged so the measured EMFs could be numerically rotated into constant orientation coordinates. Finally the motion of seawater across the electric field sensor electrodes would create "streaming potentials" that lead to spurious electric field measurements. Given these complications, it is preferable to execute the survey as described above, i.e. as a series of stable bottom station measurements.

**Reporting**

Post monitoring data analysis will take on the order of 90 days. The results will be written up in a short monitoring summary and transmitted to NMFS and ODFW for review.

**Adaptive Management**

The EMF results will be compared with known values for impact on endangered species known or likely to be present in the area. If the results indicate that WEC-related EMF levels are within the documented magnetic or electric field sensitivity range of such species, NMFS, ODFW, OSU scientists and the Ocean Facilities Manager will work together on an approach to reduce EMF levels during a test. In the event that the monitoring shows EMF signatures at levels below concern, and after consulting with NMFS and ODFW, the EMF monitoring program will be modified accordingly.