ADMIRALTY INLET PILOT TIDAL PROJECT
FERC PROJECT NO. 12690

BENTHIC HABITAT MONITORING AND
MITIGATION PLAN

Submitted by:
Public Utility District No. 1 of Snohomish County

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TABLE OF CONTENTS

1.0 INTRODUCTION.............................................................................................................. 1
2.0 PROJECT DESCRIPTION .............................................................................................. 1
3.0 BACKGROUND INFORMATION ............................................................................... 3
   3.1 Existing Benthic Habitat .......................................................................................... 3
   3.2 Colonization of Hard Structure .............................................................................. 8
4.0 PLAN OBJECTIVES AND GOALS............................................................................... 9
5.0 POST-INSTALLATION MONITORING AND MITIGATION PLAN .................... 10
   5.1 Colonization of Structure ....................................................................................... 10
      5.1.1 Objective ......................................................................................................... 10
      5.1.2 Data Collection ................................................................................................ 10
      5.1.3 Data Analysis .................................................................................................. 12
      5.1.4 Reporting and Adaptive Management ............................................................ 12
   5.2 Changes to Seabed Benthic Habitat around Subsea Base ..................................... 13
      5.2.1 Objectives ....................................................................................................... 13
      5.2.2 Data Collection ................................................................................................ 13
      5.2.3 Data Analysis .................................................................................................. 13
      5.2.4 Reporting and Adaptive Management ............................................................ 13
   5.3 Colonization of Power Cables and Drill Hole Exit Point ...................................... 14
      5.3.1 Objectives ....................................................................................................... 14
      5.3.2 Data Collection ................................................................................................ 14
      5.3.3 Data Analysis .................................................................................................. 14
      5.3.4 Reporting and Adaptive Management ............................................................ 14
6.0 APPROACH TO ADAPTIVE MANAGEMENT AND MITIGATION .................... 15
7.0 REFERENCES............................................................................................................... 16


LIST OF FIGURES

Figure 1 – Conceptual instrumentation layout (fixed and recoverable). Instrumentation shown on a 4th Generation turbine (higher rotor solidity than 7th Generation turbine). The general dimensions of the subsea based and support structure are approximately constant between technology generations for the same rotor size................................................................. 2

Figure 2 – Turbine deployment location in northern Admiralty Inlet. Blue triangles denote turbines, each of which is connected back to shore via a separate power cable. Dashed red polygon to the east of Keystone Harbor is a marine protected area .............................................. 3

Figure 3 – Benthic community structure in the vicinity of the demonstration project (Source: Sound & Sea Technology). ............................................................................................................. 5

Figure 4 – ROV survey tracks from July, 2012 relative to turbine position and shore cable route (Source: Sound & Sea Technology). ............................................................................................................. 6

Figure 5 – Seabed composition in the vicinity of the proposed demonstration project (Source: Sound & Sea Technology). ............................................................................................................. 7

Figure 6 – Representative biofouling on Sea Spider instrumentation package (deployed May - August 2011) ............................................................................................................................ 9

Figure 7 – Focal observation points on subsea base for ROV survey ........................................... 12
1.0 INTRODUCTION

If tidal turbines are colonized by marine life, they are likely to provide artificial habitat for fish and invertebrates. Turbines may, therefore, attract structure-oriented species, such as rockfish. This artificial habitat may be beneficial if it enables population growth for species of concern or it may be deleterious if it draws species away from natural habitat, increases the frequency of interactions between fish and the operating turbine, or enables population growth for undesirable species (Polagye et al., 2011). There is also a small potential for the turbine foundations to cause scouring of the seafloor in the immediate vicinity of the contact points with the seabed. While the effect of a pilot project on benthic habitat is likely to be on a small scale, an improved understanding of the rate at which marine life colonizes tidal turbines and which species are involved in the colonization is desirable to understand the potential impacts or benefits of larger-scale projects. And although the potential for a short-duration pilot project to cause meaningful scour given the composition of the seabed at the turbine site is small, it is desirable to confirm the lack of scour. This information will be gathered through surveys of the turbine by a remotely operated vehicle (ROV). The ROV may also provide opportunistic information about how fish use the artificial reef around slack water. The Near-turbine Monitoring and Mitigation Plan includes provisions for observing artificial reef and fish aggregation device (FAD) effects during non-slack periods.

Data collected under this plan will be presented to the Admiralty Inlet Marine Aquatic Resource Committee (MARC) for evaluation of the degree and nature of Project effects on benthic habitats in the Project vicinity. This data will also be used to determine if any modifications to the project are necessary for mitigation purposes. Additional details regarding instrumentation on the turbines are presented in the Monitoring Plan Summary.

2.0 PROJECT DESCRIPTION

The proposed demonstration project consists of two turbines manufactured by OpenHydro, an Irish turbine developer. Each of these turbines has a 6 m diameter outer shroud, as shown in Figure 1. These will be deployed on a gravity tri-frame, with tubular cans contacting the seabed at the vertices. Turbine hub height will be 10 m above the seabed. The OpenHydro turbines are fixed-pitch, high-solidity rotors with an open center. The rotor cassette is the single moving part and is supported by water-lubricated bearings. A permanent magnet generator is contained in the shroud surrounding the blades. Anti-fouling coatings are applied to the interior surface of the shroud, hub, and rotor blades, but the gravity frame (steel, ballasted by concrete and aggregate) is left bare. The turbine shown in Figure 1 represents the 6 m version of 4th Generation technology. The turbines deployed in Puget Sound will be 6 m variants of 7th Generation technology – the principle differences being fewer blades and more streamlined central hub.

The turbines will be deployed in northern Admiralty Inlet, Puget Sound, Washington. Admiralty Inlet is a constricted sill separating the deep Main Basin of Puget Sound from the Straits of Juan de Fuca and Straits of Georgia. At the narrowest point, between Admiralty Head and Point Wilson, the channel is approximately 5 km wide and 70 m deep. Excepting a small exchange through Deception Pass, the entire tidal prism of Puget Sound passes through this constriction, giving rise to tidal currents that routinely exceed 3 m/s (6 knots) at mid-water. The project site is
approximately 1 km SE of Admiralty Head in 55 m of water (Figure 2). The project location was chosen on the basis of strong tidal currents (intensified by the proximity to the headland), negligible seabed slope (necessary to deploy the gravity foundation), separation from high vessel traffic areas (federal navigation lanes, ferry route), and ease of cable routing back to shore.

Each turbine will be connected to shore by a separate power cable. These cables will also provide power for monitoring instrumentation and fiber optic communication with the turbine and monitoring instrumentation. Turbine monitoring systems are grouped into two categories – instruments that will be deployed for the duration of the demonstration project (fixed) and instruments that will be periodically recovered for maintenance (recoverable). This will be enabled by an Adaptable Monitoring Package (AMP) consisting of a self-aligning frame with instrumentation and a wet-mate power and fiber connector.
3.0 BACKGROUND INFORMATION

3.1 Existing Benthic Habitat

In August, September, and October 2010, a remotely operated vehicle (ROV) was used to characterize the seabed and benthic communities in the proposed turbine deployment area using a transect survey pattern. Results are described in Greene (2011) and summarized in Figure 3. A second set of surveys was conducted in July 2012 along the cable route and in the turbine deployment area, as shown in Figure 4. The survey began at the exit point for shoreline directional drilling and proceeded along the cable route to the turbine deployment area. Figure 5 shows seabed composition over a broader area, inferred from multi-beam sonar data (Greene, 2011).

ROV surveys in 2010 and 2012 served to characterize the substrate and benthic communities. Substrate was classified as one or more of the following (in order of decreasing characteristic dimension): large boulder, medium boulder, small boulder, cobble, pebble, gravel, coarse sand, or clay. The characteristic dimension of the substrate was measured by a pair of ranging lasers. Organisms were classified as encrustations (e.g., sponges, tubeworms, barnacles, algae), sessile invertebrates (e.g., chiton, clams), mobile invertebrates (e.g., starfish, urchins), and fish (e.g., ratfish, sculpin). Video quality during the 2010 survey was superior to the survey in 2012 due,
Surveys demonstrated that the substrate in the turbine deployment area is dominated by a mix of cobble-pebble-small boulder or cobble-pebble (57% and 28%, respectively; Greene, 2011). Small boulders (< 0.4 m characteristic size) were observed in moderate number, but there were relatively few larger boulders. The tidal currents have removed most of the fine-grained sediments. Smaller clasts (e.g., pebbles) are relatively unencrusted, suggesting these are mobilized during periods of strong currents. This observation is consistent with acoustic data collected from this site, which indicates sound produced by bedload transport (Bassett et al., in prep). Larger clasts (cobbles and boulders) are stable enough to be moderately or heavily encrusted.

Greene (2011) describes the turbine deployment area as supporting a “diverse and robust ecological community”. In general, organisms are concentrated along transects with the most heterogeneous substrates. These are, conversely, the areas least suitable for the deployment of a gravity foundation turbine and the proposed turbine deployment locations do not overlap with the most ecologically active areas. Barnacles are prolific, occurring as individuals, clusters, and fields. Algae are similarly prolific, with approximately two-thirds being of a filamentous variety. Anemones are also common. Most were closed at slack water, opening to feed as currents increased during the survey. Clams were the most abundant sessile invertebrates observed, followed by chitin. Mobile invertebrates were also common, with green urchins accounting for 63% of all mobile invertebrates and five-legged, orange starfish accounting for 31%. Snails, shrimp, hermit crab, and crab were observed in small numbers (ten or less over the entire survey). One octopus was also observed during the 2010 and 2012 surveys. Approximately two hundred individual fish were counted during the 2010 survey. Of these, 49% were ratfish and 38% sculpin, with the remainder either lingcod, kelp greenling, pacific sand lance, or unidentified. The ecosystem composition observed during 2010 and 2012 were similar, but lower video quality during the 2012 survey precludes a quantitative comparison.

Figure 3 shows the representative benthic community structure in the vicinity of the turbines. The benthos is colonized in a relatively homogeneous manner, excepting fields of barnacles and anemones noted at the northwest and southeast corners of the survey area, respectively. While the July, 2012 survey data is insufficient to make such a spatially detailed representation of the benthic community (i.e., noting the locations of individual starfish), the survey data do not indicate any fields of barnacles or anemones at the proposed turbine sites. Conditions at the turbine sites are consistent with those in the eastern quadrant of the 2010 survey area – with colonization of the larger clasts by barnacles, sponges, and anemones.
Figure 3 – Benthic community structure in the vicinity of the demonstration project (Source: Sound & Sea Technology).
Figure 4 – ROV survey tracks from July, 2012 relative to turbine position and shore cable route (Source: Sound & Sea Technology).
Figure 5 – Seabed composition in the vicinity of the proposed demonstration project (Source: Sound & Sea Technology).
The July, 2012, survey also included the cable route to shore and horizontal directional drilling exit point. The cable route survey began in Keystone Harbor, near the Coupeville ferry landing, and proceeded southward to a depth of approximately 70 m due south of Admiralty Head, before rising to 55 m in the turbine deployment area.

Along this route, the substrate is initially soft, then, as depth increases, coarsens to “1) cobbles, pebbles and sand, with occasional piles of cobbles producing a rugged bottom, to 2) sand and gravel and 3) gravel and pebbles” (Greene, 2012). Scattered boulders were observed in water deeper than 30 m and one, small field of boulders was observed along the cable route, consisting of a half-dozen rocks approximately 1 m across. In shallow water, these clasts are heavily vegetated by algae (Greene, 2012). No geoduck clams were observed, but other types of clams were present, based on the shell fragments of butter and/or Manila clams (McCallister, 2012). No eelgrass was observed, nor was habitat suitable for eelgrass found in the survey (e.g., sandy bottom). As with the turbine deployment area, those clasts in deeper water “are heavily encrusted with sponges, barnacles, algae and bryozoans” (Greene, 2012). Along the cable route, one mud window was observed, indicating that the seabed along the cable route consists of a gravel/pebble/cobble pavement overlying mud.

There are several active and inactive power and communications cables on the seabed in the project area. Inactive cables include power and communications cables originally connecting military installations on Whidbey Island (Fort Casey), the Kitsap Peninsula (Fort Worden), and Marrowstone Island (Fort Flagler). These cables have been observed to be encrusted with marine life similar to the dominant cobble clast. Consequently, the colonization of the subsea cables for this project is not novel in this environment and only a limited number of survey points along the shore cable route will be monitored during the project.

### 3.2 Colonization of Hard Structure

While the turbines will be deployed beneath the photic zone, biofouling is to be expected, based on the colonization of cobbles and biofouling observed on Sea Spider instrumentation packages deployed by the University of Washington Northwest National Marine Renewable Energy Center. These packages have been recovered, cleaned, and redeployed every three months within the project area since mid-2009. Biofouling has seasonal variability, with the greatest biofouling generally observed in the May-August time frame and more limited fouling observed over other periods. Representative biofouling on an instrumentation package deployed in the project area from May-August 2011 is presented in Figure 6. Biofouling observed on the Sea Spider packages has included red algae, tubeworms, barnacles, and chitin. It is likely that unprotected surfaces on the turbine will be colonized in a similar manner (i.e., all surfaces on the subsea base, excluding the rotor and shroud, which will be protected by anti-fouling paint). Biofouling also shows a strong annual variability. From May 2009 – May 2010, very little biofouling was observed on any surfaces (e.g., instruments, floats, tripod frame). However, from May – August 2010, barnacles were recruited on virtually every surface on the instrumentation package. Conditions for the same period in 2011 bracketed these two extremes. In summary, colonization of the subsea base is expected to occur, even though the turbines will be deployed below the photic zone and the rate of colonization is expected to have both seasonal and annual variation.
4.0 PLAN OBJECTIVES AND GOALS

The goal of the Benthic Habitat Monitoring and Mitigation Plan is to describe the benthic habitat provided by the Project and changes to the existing benthic habitat where the Project directly contacts the seabed. To accomplish this goal, the Project will evaluate three hypotheses:

- **Hypothesis 1**: The turbine will be colonized and provide artificial habitat that supports different benthic communities than are currently present in the Project area.
- **Hypothesis 2**: The contact points between the turbines and the seabed will not result in deposition of fine sediments or scour.
- **Hypothesis 3**: The power cable and horizontal directional drill exit point will be colonized and are likely to return to pre-installation conditions over time.

To accomplish this goal, the District will 1) characterize colonization of the turbine structure, the subsea cable, and the horizontal directional drill exit point; 2) characterize scour and/or deposition where these structures contact the seabed; and 3) consult with the MARC to consider modification to this Plan in response to the results of benthic habitat monitoring efforts.
Characterization surveys will be conducted by remotely operate vehicle (ROV) during periods of weak currents.

The extent to which the turbine serves as an artificial reef or fish aggregating device (FAD) will be further informed by observations from the Near-turbine Monitoring and Mitigation Plan. This study will complement and be coordinated with the District’s use of an ROV to periodically inspect project components and monitor for derelict gear.

5.0 POST-INSTALLATION MONITORING AND MITIGATION PLAN

5.1 Colonization of Structure

5.1.1 Objective

Pre-installation surveys (Greene, 2011; Greene, 2012) have characterized the benthic habitat in the Project area as cobbles and boulders, colonized by barnacles, sponges, and algae. Smaller substrate (pebbles, gravel) are intermittently mobilized by strong currents and are generally free of encrustation. The turbine foundation will have considerably greater vertical relief (e.g., turbine shrouds will extend to 13 m above the seabed) and may support different benthic communities. Anecdotal reports from tidal energy projects in Europe indicate that turbine foundations are often colonized within a year of deployment. Information about how this project affects the local benthic community structure would provide information about how a larger array might affect the community and guidance for engineering refinements to foundations that promote desirable benthic communities (potential benefit) and minimize undesirable benthic communities (potential impact). The objective of this portion of the plan is to gather information about how the turbine structure is colonized (coverage, colonization rates, and species involved).

5.1.2 Data Collection

Equipment Description

Observations of the turbine structure will be conducted by a Remotely Operated Vehicle (ROV) with sufficient thrust capabilities to maneuver around the turbine during periods of relatively low currents (i.e., velocities < 1 m/s). Operation during stronger currents is not likely feasible given the capabilities of available ROVs in the region and the risks/challenges associated with umbilical management in strong currents.

“Slack” water in Admiralty Inlet is an ephemeral quantity. Often, the reversing of the currents from flood to ebb (or vice versa) are out of phase by nearly an hour between surface and seabed. Consequently, ROV operations will be scheduled around diurnal inequalities with protracted periods of weak currents. These will provide working windows of up to several hours a few times each year. This approach to ROV data collection was successfully demonstrated in July, 2012.

The ROV will be cabled back to the surface and video recorded using a standard digital format. The ROV will be equipped with high-resolution color and black & white cameras with sufficient lighting to illuminate the seabed. An example of a suitable ROV is the Seaeye Cougar-XT that
was used during 2010 benthic habitat surveys (Greene, 2011). Audio and written logs will be maintained during the survey.

Survey Procedure

Four ROV surveys will be conducted during the first year of turbine operation. Thereafter, there will be two surveys per year. During each survey, the ROV will perform a quick scan of both turbines, primarily to inspect for derelict gear (see Derelict Gear Removal Plan).

Focal observations of portions of one turbine will then be conducted. This subsampling approach is necessitated by limited bottom time for the ROV and justified given the close proximity of the two turbines (less than 100 m separation). Focal observation points are highlighted in Figure 7 and consist of:

- Subsea base member approximately perpendicular to the current direction (focal area #1)
- Subsea base member approximately parallel to the current direction (focal area #2)
- Junction of vertical supports for turbine with subsea base (focal area #3)
- Vertex of subsea base (focal area #4)

Each of these areas consists of the same substrate (mild steel) but will be subject to different hydrodynamic conditions that may preferentially support or inhibit colonization. During a focal inspection, the ROV operator will perform a slow pan of the area of interest, as constrained by tidal currents and umbilical management.

During each survey, the ROV will also inspect a comparison site on the seabed, roughly 5 m x 5 m in dimension at least 20 m away from the turbines. The purpose of characterizing this portion of the seabed is to observe any long-term changes to existing substrate and contrast this with colonization of the turbine foundation. The location of this survey area will be determined by consensus of the MARC following turbine installation.

During surveys, opportunistic sightings of fish, invertebrates, and marine mammals will be noted. However, because slack water is likely to be an incomplete description of site usage, artificial reef effects will be evaluated as part of the Near-turbine Monitoring and Mitigation Plan.
5.1.3 Data Analysis

A benthic ecologist will review video footage from each survey. The percentage of coverage by each type of benthic fauna (e.g., algae, barnacles) will be quantified for each of the four focal areas on the turbine foundation and for the comparison site. Qualitative notes regarding rates of growth or retreat will also be included. The purpose of this analysis is to quantify the rate of colonization through comparison of sequential surveys and qualify the species involved in this colonization.

Incidental observations of fish, marine mammals, and invertebrates during the survey (focal study areas and general scan) will be reported, but the effect of the ROV lighting and timing restrictions on the surveys (i.e., surveys only during weak tidal currents) will limit these to qualitative, rather than quantitative, observations.

5.1.4 Reporting and Adaptive Management

A preliminary, oral report will be made to the MARC within 30 days of each ROV survey describing observations and presenting survey imagery/video. Written and oral reports describing the colonization of the subsea base will be presented to the MARC within 90 days of the conclusion of each calendar year of operation. If the general inspections of the turbine structure indicate that areas of the turbine are being colonized at a different rate or by different species than those that are the subject of focal monitoring, then, with the concurrence of the MARC, the focal monitoring areas will be adjusted to include these areas.
5.2  Changes to Seabed Benthic Habitat around Subsea Base

5.2.1  Objectives

Pre-installation surveys indicate that the seabed in the project area is predominantly scoured of fine-grained sediments due to the strong tidal currents in the project area (Greene, 2011; Greene, 2012). Because turbidity is relatively low in Admiralty Inlet (Polagye and Thomson, 2010) and the currents reverse direction approximately every six hours no net accumulation of fine-grained sediments are expected in the turbine wake or around turbine structures. Further, the separation between the rotor and seabed (10 m hub height, 7 m from bottom of shroud to seabed) makes it likely that any sediment that begins to settle in the wake would be resuspended by currents before reaching the seabed. Accumulation of fine-grained sediments where none presently exist would, however, alter benthic communities and could be environmentally significant (i.e., rise to the level of an environmental change) for a large-scale installation. The most probable location for sediment accumulation or scour of existing bed material is at the contact points of the turbine foundations.

5.2.2  Data Collection

*Equipment Description*

The remotely operated vehicle (ROV) used for the colonization survey will also be used for this survey.

*Collection Procedure*

The ROV will inspect the three contact points between the seabed and the subsea base for each turbine. Observations will be recorded in a standard video format with associated audio and written logs for subsequent analysis. In addition to providing information about sediment deposition, this information is also necessary to evaluate turbine stability over time.

5.2.3  Data Analysis

Observations from sequential surveys will be reviewed to quantify scour, deposition, or other changes to the benthic environment at the inspection points. If scour or deposition is occurring, its spatial extent will be quantified.

5.2.4  Reporting and Adaptive Management

A preliminary, oral report will be made to the MARC within 30 days of each ROV survey describing observations and presenting survey imagery/video. Written and oral reports describing the colonization of the subsea base will be presented to the MARC within 90 days of the conclusion of each calendar year of operation.
5.3 Colonization of Power Cables and Drill Hole Exit Point

5.3.1 Objectives

As for the subsea base, the power and data cables to shore are likely to be colonized by marine life. Unlike the subsea base, these will not have significant vertical relief, so the creation of different benthic habitat is unlikely and the primary interest is in determining the rate at which these cables are colonized and whether, over time, any significant cable movement occurs. Similarly, the rate at which the horizontal directional drill exit point is colonized and returned to a pre-installation state is of interest.

5.3.2 Data Collection

Equipment Description

The remotely operated vehicle (ROV) used for the colonization survey will also be used for this survey.

Collection Procedure

During each survey, the ROV will inspect the horizontal directional drill exit point and 2-3 representative locations along the cable route. The specific locations will be determined in consultation with the MARC following turbine and cable installation. Locations might be chosen based on a stratification of cable depth, habitat, or cable feature (e.g., a suspended segment). Observations will be recorded in a standard video format with associated audio and written logs for subsequent analysis.

5.3.3 Data Analysis

A benthic ecologist will review video footage from each survey. The percentage of coverage by each type of benthic fauna (e.g., algae, barnacles) will be quantified for the drill exit point and focal locations along the cable route. Qualitative notes regarding rates of growth or retreat will also be included. The purpose of this analysis is to quantify the rate of colonization through comparison of sequential surveys and compare pre- and post-installation colonization. Cable movement would be indicated by changes in orientation or scour of marine life from the cable and adjacent seabed.

5.3.4 Reporting and Adaptive Management

A preliminary, oral report will be made to the MARC within 30 days of each ROV survey describing observations and presenting survey imagery/video. Written and oral reports describing the colonization of the subsea base will be presented to the MARC within 90 days of the conclusion of each calendar year of operation.

The focal locations along the cable route will be determined by the MARC following turbine and cable installation.
6.0 APPROACH TO ADAPTIVE MANAGEMENT AND MITIGATION

In implementing this Plan, the District will consult with the MARC as appropriate on the technical issues described above and data interpretation associated with the monitoring. Such consultation will include consideration of results from monitoring efforts and subsequent adjustments to monitoring methods. In particular, the District will adopt the triggers and subsequent actions described below.

The District will follow the procedures described in the Adaptive Management Framework when conferring with the MARC on implementation of the Acoustic Monitoring and Mitigation Plan and considering how to address the results of the monitoring.

**Adaptive Management and Mitigation Trigger 1:** If ROV scans of the turbine foundation indicate areas of colonization significantly different than those selected for focal study, the District, with the concurrence of the MARC, will modify focal study locations to include these areas.

**Adaptive Management and Mitigation Trigger 2:** If studies indicate that the species colonizing the turbines, the subsea cable, or the horizontal directional drill exit point are different from those on the seabed, the District will, after consultation with the MARC, take one or more of the following actions, as necessary:

- Modify the Monitoring and Mitigation Plan and/or sampling frequency to better understand colonization trends;
- Modify the Project to mitigate for effects if necessary; and/or
- Conduct additional sampling or studies.

Similar provisions apply if the species assemblage or density is markedly different from the pre-instillation survey conditions.

**Adaptive Management and Mitigation Trigger 3:** If surveys indicate significant erosion at the contact points between the subsea base and seabed, an evaluation of turbine stability will be undertaken, and the MARC consulted to determine if project modifications are necessary.

**Adaptive Management and Mitigation Trigger 4:** Following turbine installation, the MARC will select 2-3 focal survey locations along the cable route to evaluate the rate at which the cables are colonized by marine life.

By June 30 of each year, the District will develop and file an annual report to FERC fully describing its implementation of the Plan during the previous calendar year and a list of the proposed activities during the current calendar year. The MARC will have at least 30 days to review and comment on a draft report prior to the District finalizing and filing the report with FERC. The annual report will provide the following:

- A summary of the monitoring results.
- A summary of any issues or concerns identified by members of the MARC during the year regarding implementation of the Plan.
A list of any changes to the Plan or project proposed by consensus of the MARC during the year.
- A list of Plan activities planned for the current year.

### 7.0 REFERENCES


Attachment 1