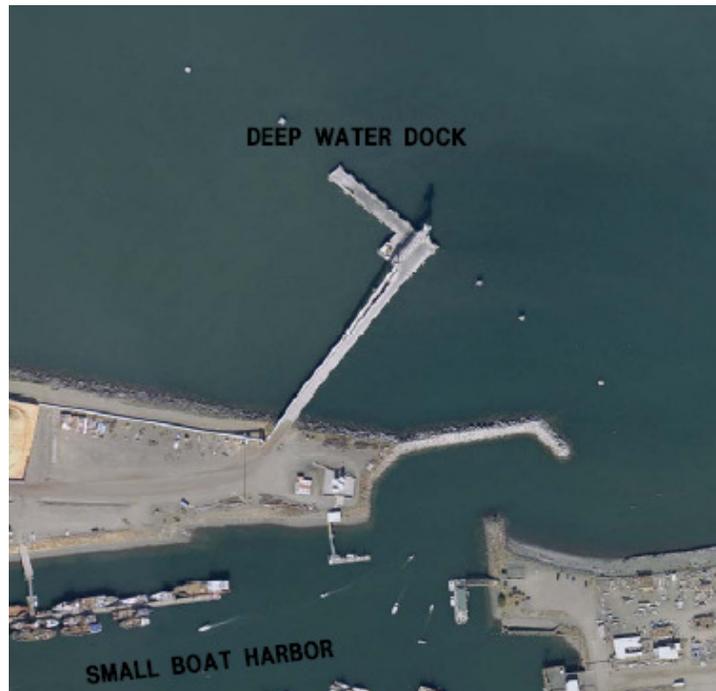


Homer Tidal Power and Marine Instrument Test Station

Interim Report



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Abstract

The Homer Tidal Incubator project began in 2012 as a group of Homer proponents, agency representatives, and industry professionals started meeting to discuss the potential of utilizing the Homer Deep Water Dock as a tidal generator testing station. The City of Homer is sponsoring a project with the University of Alaska Anchorage (UAA) School of Engineering as part of the working group, offering advice and directing resources from an engineering capstone class to further the feasibility investigation. The UAA capstone engineering class examined various potential solutions and selected two test station alternatives for research and discussion. The two alternatives, which include a facility fixed on the Homer Deep Water Dock and a floating system based at the dock, appear viable and are undergoing further investigation. Through exploring the advantages and disadvantages of implementation for each alternative reported by the engineering students, The City of Homer and the Homer Tidal Incubator working group are enabled to select the preferred option for the UAA engineering capstone class to complete the design to 35%.

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Introduction

Project Context

The location of the proposed tidal generator and marine instrumentation test station is located on the deep water dock in Homer, Alaska. The deep water dock is located near the end of a spit and borders the small-boat harbor (Figure 1). This location poses as an attractive outlet to vendors seeking to test experimental tidal generators and marine instruments due to its easy access and ideal marine conditions.

The City of Homer is the sponsor of the project and is considering the feasibility of using the Homer Deep Water Dock as a test station for tidal generators. The University of Alaska Anchorage (UAA) is part of the working group, offering advice and directing resources from an engineering capstone class to further the feasibility investigation. The UAA group will complete a 35% design for the Homer Tidal Incubator project in addition to developing alternatives, delivering engineering documents, and offering recommendations. The deadline for this work is April 26, 2013; at the end of the UAA Spring 2013 Semester.

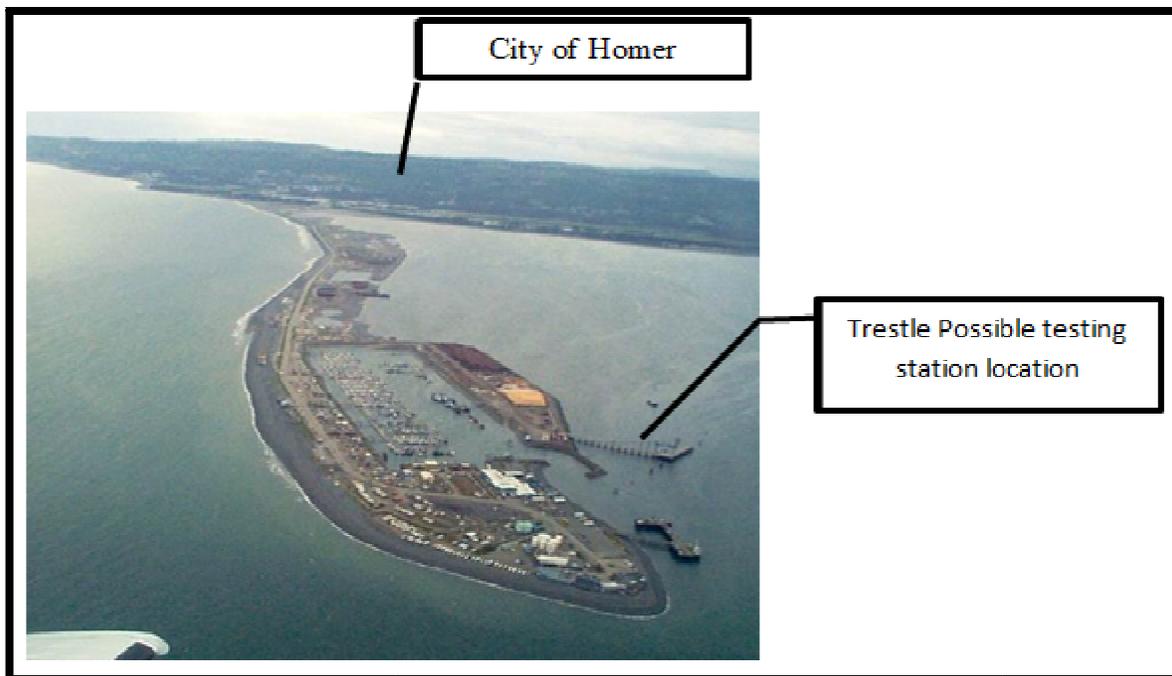


Figure 1: Aerial view of Homer Spit.

Scope and Schedule

See Figure 2 for the Project Schedule and Appendix D for the full page version of the Project Schedule. The scope of the project includes the following items:

- 1 Define opportunities
- 2 Develop design and evaluation criteria
 - a Functional performance
 - b Structural integrity
 - c Marketability, funding, and economic constraints
 - d Environmental constraints
- 3 Determine site conditions
 - a Discover facts on file
 - b Site visit (early February)
- 4 Formulate alternative concepts
- 5 Evaluate and compare alternatives
- 6 Refine best options and estimate costs
- 7 Submit interim progress report, identifying the most viable alternatives (8 March)
- 8 Choose preferred plan
- 9 Complete design to ~35%
- 10 Submit draft final report (17 April)
- 11 Present report (26 April)

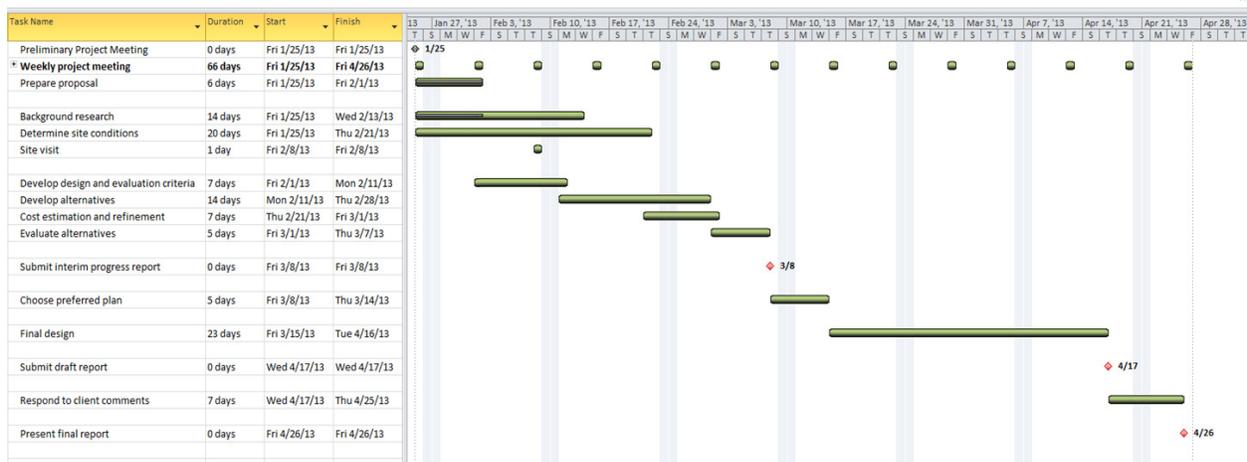


Figure 2: Project Schedule

Organization

The project organization includes the client, faculty advisor, course instructors, project manager, Civil/Structural technical team, Cradle Mechanism technical team, Instrumentation technical team, and Power technical team. See Figure 3 for Project Management Organization.

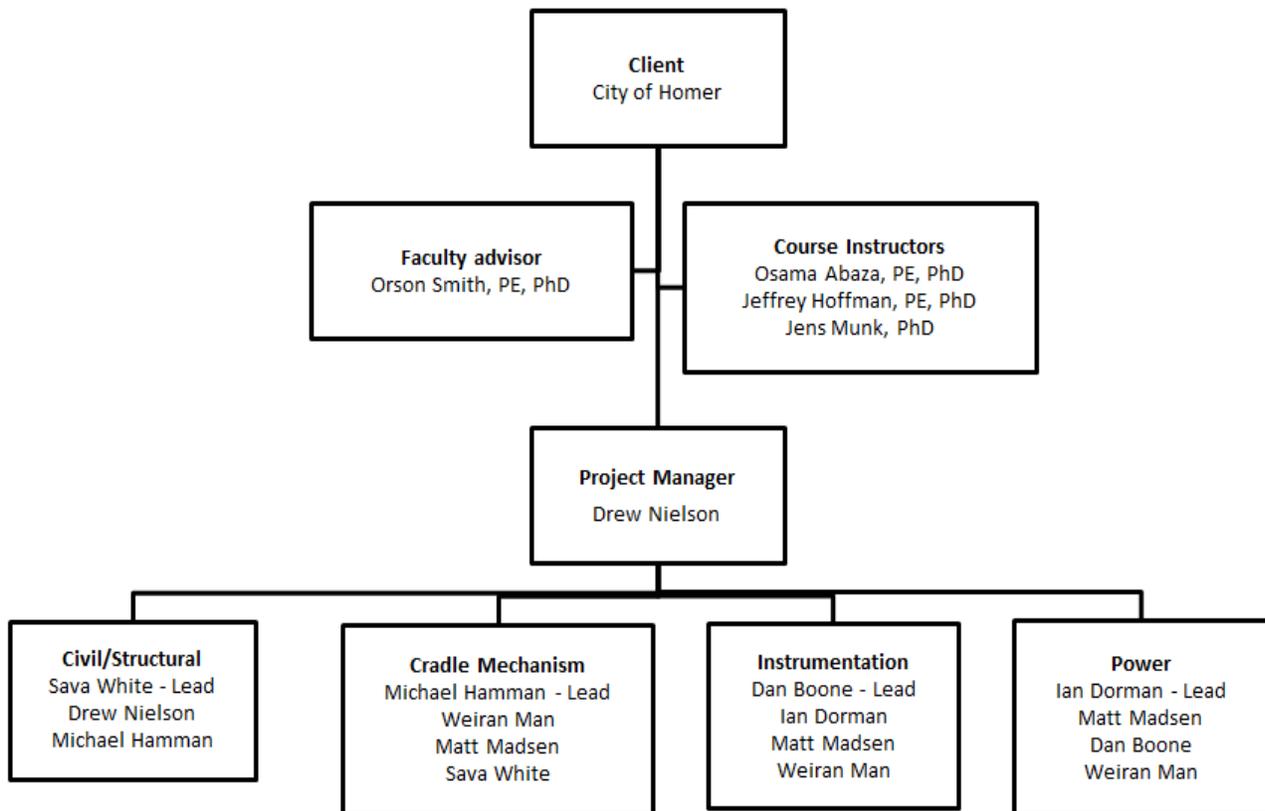


Figure 3: Project Management Organization

Civil/ Structural

The purpose of the civil/structural engineering team is to provide expertise in all civil engineering aspects of the project. The team will be analyzing the structural capabilities of the existing dock, designing excess reinforcement for an additional deck to support the cradle mechanism mount, and designing the shelter. In the case of a barge or pontoon, the team will assume the responsibility of performing the stability analysis, determining the size and ballast requirements, corrosion engineering, environmental evaluation, and developing the overall system interconnections.

Cradle Mechanism

Since tidal generators capture kinetic energy from the current, the energy dissipated over the device is proportional to the cube of the velocity change over the device. By measuring the velocity differential and the mechanical output of the device researchers can develop empirical equations for the efficiency of their device. To accomplish this goal, the hydrokinetic device

must conveniently be placed and retracted from the flow for monitoring and maintenance procedures. This not only implies the design of adequate mechanical devices for vertical mobility, but also the structural stability of the mounting system in order to withstand drag loads on the system.

Instrumentation

When testing a prototype tidal generator at any location, three primary areas of operation should be monitored. First, the performance of the tidal generator, including power output and efficiency, is monitored in order to determine the electrical power generation viability of the tidal generator. Second, measurements are made of how well the tidal generator endures within the testing environment. Lastly, the effect of the tidal generator on the surrounding environment is also observed. The above measurements are made using a system of instrumentation consisting of a series of strategically placed instruments, a data collection and storage device, a user interface computer with software able to display and control the various instruments, and a data transmission system. Additionally, some aspects of generator durability may be made using direct visual observation of the tidal generator itself. For further discussion of tidal generator and site monitoring, refer to Appendix C.

Power

The power generated by the tidal generators will need to be safely dissipated or be stored. This will be accomplished by the use of a load bank with a possibility of an electrical interconnection to the HEA utility grid.

All options detailed within this report will require the use of a load bank. The load bank not only dissipates the energy but can simulate different load conditions. Thus the customer will be able to subject their prototype design to numerous simulated conditions.

An electrical interconnection is not necessary for the overall success of the project but can offer a novel amenity to the proposed facility.

Of the alternatives listed in this report the dock mounted option will accommodate the largest range of tidal generators and is the only alternative that will accommodate an interconnection with the utility. However these advantages may not be important to the market, especially when one considers that the floating option can accommodate small scale prototypes just as well if not better than the dock mounting alternatives.

The interconnection and wiring methods are governed by various standards and guides. An overview of these publications can be found in Appendix B.

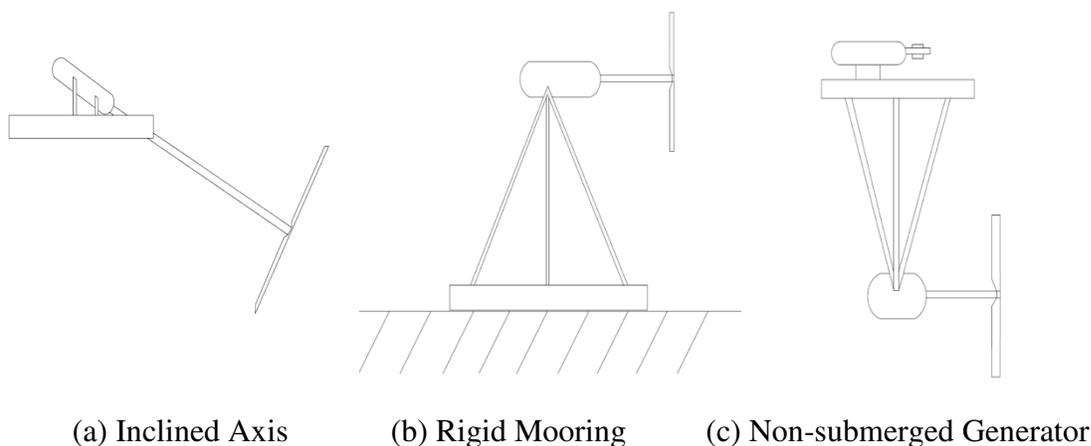
Hydrokinetic Overview

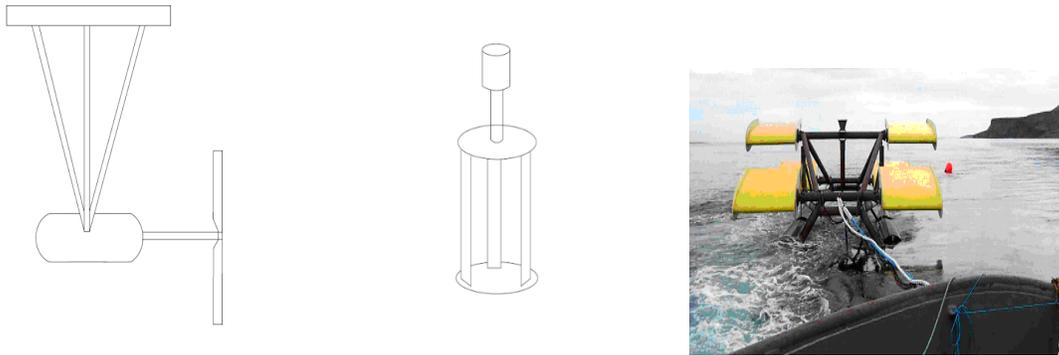
Hydrokinetic devices have long been employed to improve the quality of life. In modern times we have gone from the simple watermill for rude industrial purposes to the great dames of the past century. Today with high energy prices interest has grown in the development and utilization of small scale hydrokinetic devices to offset the reliance on high price oil or natural gas. These devices are characterized by low power generation, which is due to low hydraulic head and current technology. These devices are referred to as unconventional systems (Khan, Bhuyan, Iqbal & Quaicoe, 2009). The demand for alternate sources of electric power generation and available hydro resource has drawn researcher and developers (R/D) to pursue further hydrokinetic development.

On the numbers of R/Ds currently working on the development of hydrokinetic devices one research group reported 76 R/Ds surveyed (Khan, Bhuyan, Iqbal & Quaicoe, 2009). This is in no case on exhaustive list; however, it does show the current efforts being placed into bringing this technology forward. This interest is important since technological advancement is needed in some areas to make unconventional generation possible (Johnson, 2010).

The positioning of Alaska is promising in reference to hydrokinetic energy potential. Alaska has 40% and 90% of U.S. river energy and tidal energy resources (Johnson, 2010). To put this in perspective, this amounts to 1,250 TWh/yr for southern Alaska.

Currently there are multiple hydrokinetic device designs under R/D, Figure 4 shows several turbine variations and one non turbine (f) of the Sea-snail design. The turbine types (a)-(e) employ drag or lift forces on their blades for power generation and Sea-snail (f) employs drag forces on the hydrofoils (Khan, Bhuyan, Iqbal & Quaicoe, 2009). Other designs exist however for brevities' sake only designs specific to Figure 4 represented. This is not to say that other designs would not be compatible with testing station this project and report is exploring. The orientations of many designs can be accommodated and accurately tested in a slightly different geometric orientation. For example the rigid mooring can be tested upside down from its design orientation.





(d) Submerged Generator

(e) Squirrel Cage

(f) Sea-snail

Figure 4: Assorted hydrokinetic device types. (f) Non turbine taken from, <http://www4.rgu.ac.uk/cree/general/page.cfm?pge=10769>

Opportunities

The purpose of initiating the tidal power incubator project is to provide manufacturers with a venue for testing tidal generators and marine instruments. This project presents an opportunity for the City of Homer to be the premier provider of tidal generator testing services to tidal generator manufacturers from around the world. The test station will provide the Port of Homer, and City of Homer, with increased revenue stemming from the provision of the incubator to tidal manufacturers. A secondary purpose of the tidal incubator is to provide the City of Homer preliminary data of the effectiveness and practicality of implementing tidal power in the Kachemak Bay to provide renewable energy to the City of Homer. Providing the incubator will enable the City of Homer to establish relationships with tidal generator manufacturers and tidal power organizations.

Design and Evaluation Criteria

The following criteria were developed by the team in order to rank and determine the best options while designing and engineering.

1 Functional Performance:

- System must accommodate multiple R/D designs and sizes.
- Lifting system must easily deploy testing devices.
- Must simulate most field conditions and constraints.
- Have compatibility for several tidal generator models and configurations.

- Safely dissipate generated energy.
 - Must be able to monitor tidal generator performance.
- 2 Structural Stability:
- Must withstand vertical and horizontal dynamic and static loading in conjunction with corrosion, fatigue, and fracture fail modes.
 - Must provide for protection of instrumentation and data collection devices.
- 3 Economical Profitability:
- Operation and Installation costs must be minimized as not to exceed R/D revenue constraints.
- 4 Environmentally Safe:
- Power Generation fuel and mechanical system hydraulic fluid must be able to be reasonably contained against possible pollution.
 - Hydrokinetic devices must not adversely affect the marine life surrounding the teststation.
 - Must be able to monitor environmental conditions at the site.

Site Conditions

On February 22, 2013, the UAA Tidal Energy Incubator Project design team accompanied by Dr. Orson Smith traveled to Homer, Alaska to perform a site visit and discuss various issues and ideas with members of the Homer community. Upon arrival in Homer, the design team met with Community and Economic Development Coordinator, Katie Koester, Port Director/Harbormaster, Bryan Hawkins and Public Works Director, Carey Meyer. At this meeting, Mr. Hawkins provided the team with a brief history of the harbor and its current mission in serving the City of Homer. Mr. Hawkins reiterated that both sides of the Homer Deep Water Dock would be unavailable for use as potential locations for the tidal generator incubator project as these areas are used to moor vessels. Mr. Hawkins indicated that two large beams left over from the wood chip conveyor system currently extend from the dock roadway adjacent to, but not attached to the deep water dock. These two beams would be in a prime location to site the tidal generator project as they are located along the dock roadway furthest from the shore and above the deepest available water, as well as on the correct side of the roadway to receive the incoming tidal stream with little interference from the roadway piles. Mr. Hawkins also told the team that the tide at the deep water dock flowed in the same direction - roughly southeast - for both incoming and outgoing tides. Mr. Hawkins also provided the team with the available as-built structural and electrical documents for the deep water dock and dock roadway. These documents were photographed by team members as necessary.

Following this discussion, the design team split into two groups to view the deep water dock and roadway from above and below. Mr. Hawkins and Mr. Meyer escorted one of the groups onto the dock roadway to give team members a top side view of potential project site locations. Team members observed the two beams previously described by Mr. Hawkins as well as the availability of utility services along the dock roadway. Team members also took pictures of the deep water dock and roadway in order to maintain an accurate picture of the site details as the design process moves forward. The second group was taken by Port Maintenance Supervisor, Aaron Glidden in the harbormaster patrol vessel to observe the underside of the dock roadway from sea level. During this aspect of the site visit, the dock piles were closely examined, the undersides of the two beams were observed, and the northwest face of the dock roadway was looked over for potential advantages and disadvantages related to designing the tidal generator project. Additional pictures were also taken. The groups then switched places to allow each group a complete view of the site potential.

Upon returning from the visit to the deep water dock, the team met with Homer Electric Association (HEA) Engineer, Mike Tracy. Mr. Tracy indicated that connecting the prototype tidal generators to the HEA electrical grid through an intertie would likely not pose any problems for HEA.

At 1:00 p.m., the UAA design team met with the Homer Tidal Energy Incubator Working Group and other community members at Homer City Hall. The design team gave a brief presentation to the working group outlining the project in its current state. The presentation consisted of the organizational structure of the design team, a timeline of how the team planned to move forward with the project including a list of deliverables for the working group, and various design possibilities for the tidal energy incubator project. Following the presentation, a general discussion of the project took place between the working group and team members. At this time, Kachemak Bay Research Reserve Manager, Terry Thompson offered to provide the team with any data his organization had available concerning the conditions at the potential project site. Additionally, Public Works Director, Carey Meyer offered to provide structural and loading information about the deep water dock and dock roadway.

During the site visit, the team assessed the existing electrical equipment. The current electrical service to the dock is fed by a 24.9Y/14.4 kV primary to 480Y/277V secondary 150VA rated padmount transformer feeding a 600A rated switchboard NEMA 4X/3R type. This switchboard is the main distribution panel and named 'MDS'. Both the transformer and MDS are located at shore. The MDS provides power to the dock via a 225A rated circuit breaker feeding a two inch rigid metal conduit with four #4/0 AWG XHHW conductors. This conduit is routed on the north side of the trestle. These conductors land on the line side terminals of another switchboard rated for 400A named 'DS'. This switchboard is located on the dock itself and provides the power for all loads on the dock and the heat trace for the main water pipe serving the dock.

Alternative Concepts

The design team held several meetings where alternative concepts were formulated. The initial concept was a facility placed somewhere on the deep water dock. Much of the space along the dock was eliminated in consultation with the Harbormaster and Public Works Director. The end of the dock was eliminated because it is still in use for mooring large vessels, and the shallower end of the trestle was eliminated because the water needs to be deep enough to accommodate the prototype tidal generator. During the team's site visit, two beams that protrude out near the end of the trestle were pointed out by the Harbormaster (Figure 5), and have been selected as the most practical location for the testing facility on the dock.

The design team also formulated the concept of having a floating facility that could be moored at the dock so testing could take place either at the dock or at some other location. The team formulated two alternatives for this concept. Either the facility could be built on a large barge that would be more seaworthy, or it could be built on a smaller pontoon barge that would be more mobile.

The alternative concepts are summarized below:

- A permanent facility built at the deep water dock on the two beams protruding out near the end of the trestle.
- A floating facility built on a large barge
- A floating facility build on a smaller, more mobile pontoon barge

Alternatives Analysis

The following section discusses the remaining alternatives that were deemed practical by the constraints of the project.

Alternative 1 - Dock Mounted

The structural support for the trestle mounted cradle system and the instrumentation and system auxiliary equipment housing would be placed on the empty beam sections presented in Figure 5 below. These beams are left over from the wood chip exportation project where the conveyor belt loading system rested.

A setupsuch as a rack and pinion system as depicted in Figure A1 (see Appendix A) could be used to deploy the testing devices. The system would be equipped with instrumentation and sensors to sense the changing tides. This will allow the system to automatically raise and lower the cradle system in sequence with the tide. The option of deploying the system at a set distance above the bay floor would also be included.



Figure 5: Dock extension from the sawdust operation. These unused beams would ideal for the location of a Hydro Test Station to be mounted on the trestle.

Advantages

Revenue: An advantage of attaching the cradle mechanism to the dock is that the revenue generated will be confined to the City of Homer. Researchers who desire to test their devices in the unique conditions of Kachemak Bay can be charged for the time they take to complete their experiments and for the use of the site location that is within Homer's jurisdiction. By attaching the cradle to the dock, the city of Homer could potentially add new employment options for its citizens. The mechanism itself will require maintenance and repairs, both of which can be done by Homer businesses or by the City of Homer.

Interconnection compatibility: A dock mounted system allows for interconnection of the tidal generator output to the city of Homer's electrical grid system. The customer's prototypes could be allowed to run for a period of several months. This free electrical energy is a minor benefit to HEA. The real appeal of a grid interconnection to the project is that it gives the customer a proof of design capability. If a tidal generator was left in place for an extended duration, the power generated could potentially be used for supplementing power to the ice plant.

Wider range of generators could be tested: The Dock Mounted option could be designed in such a way to allow for larger kW rated tidal generators than the floating options. This is in part due to the fact the dock has a much larger weight limits than the other alternatives. This allows for the installation of a larger load bank. The only variable limiting the type of tidal generator to be

installed is that tidal generator's physical dimensions. Hypothetically, the dock option's electrical system could accommodate a 1-MW tidal generator.

Reuse of existing electrical components: The transformer for the dock is serving no other loads and can therefore be utilized as an isolation transformer for the site. This means that the dock mounted option can accommodate a tidal generator with a peak output of around 150 KW without the need for installation of a new transformer. In addition, the main distribution panel is rated for 600A which can accommodate a wide range of possible designs.

Enclosure options: The physical elements of the coastal and ocean environment dictate the protection of instrumentation, data collection system, and the cradle mechanism system. The unused beams of the dock offer simple accommodation by either employing a connex or a simple frame structure. The enclosure would be similar to the existing building located on the trestle.

Secondary use as an ocean sensor test facility: Long-term monitoring of oceanographic conditions is a mission of the Kachemak Bay Research Reserve, based in Homer. This NOAA-funded monitoring would be an advantage to vendors of oceanographic instrumentation who want to test new sensor systems in comparison to well-maintained systems operated by the Reserve. The features that would accommodate monitoring of conditions and performance of tidal generators are compatible with this secondary use of a test station fixed at the Deep Water Dock.

Available structure for mounting instruments: The in-place dock structure provides additional options when deciding upon instrument placement and orientation. These additional placement options may allow for better monitoring of site conditions, environmental impact, and generator performance than would be reasonably available with the mobile floating test site option.

Available electrical power: Reliable power is accessible from the Homer Electric Association grid to provide electricity for the facility and instrumentation system.

Long term monitoring of site conditions: Instruments can be put in place on a permanent or semi-permanent basis, allowing for long term monitoring of the site conditions. This monitoring will take place during tidal generator testing, but can also be performed separate from a tidal generator test in order to increase the baseline data available for the test site. This additional baseline data may be a positive marketing characteristic for potential clients.

Protected location with known site conditions: The project site next to the deep water dock is in a protected location with known environmental conditions. Thus, choosing appropriate instruments and calibrating them for these conditions will be easier than doing the same for the changing environmental conditions found with the floating test site option.

Adding further instruments: If a client or the City of Homer deems it necessary to enhance the existing instrumentation system, placing additional instruments at the test site would be

relatively straightforward. Additional power would be readily available, and the existing dock structure along with the deployed instrumentation system would allow for an uncomplicated deployment of further instruments.

Data collection, storage, and transmission: The permanent and land based nature of the project location at the dock allows data generated by the instrumentation system to be collected, stored and analyzed in a protected and in an easily accessible environment. A client would have the ability to observe the testing data in real time as it is being collected and analyzed by the instrumentation computer in the sheltered laboratory. The client could also extract data for further transmission or analysis at any time. Additionally, if further transmission of data is required by a client, internet access at the dock site is readily available.

Site conditions: One of the benefits for researchers in testing their designs in application type conditions is for design flaws and weaknesses to be analyzed. This permits the researcher to alter the design until satisfactory test results are obtained; saving capital that would have been lost if the flawed design had been marketed. In order for testing facilities to attract researchers they must simulate actual operating conditions. In tidal power generation the velocity, direction, and sediment content of tidal currents is of crucial importance. Since Kachemak Bay has a significant silt content and seasonal presence of frazil and brash ice it is not a mitigating decision factor in the stationary and mobile test station options. The above variable conditions are ideal for testing devices in a real world environment.

Disadvantages

Moderate and unidirectional current: The location of the Deep Water Dock produces a unidirectional flow with a peak mid-tide velocity of around two knots. Two knots (one meter per second) is generally considered the minimum current velocity necessary for testing hydrokinetic devices (Johnson, 2010). The low velocity current with the dock mounted option leaves uncertainty as to whether or not significant interest in testing devices at the dock is realistic. On the other hand, rural coastal communities that install micro-hydropower systems of 100kW or less to supplement other power generation mechanisms may be well-represented by the conditions at the Deep Water Dock.

Higher freeboard: Kachemak Bay has a tidal range of approximately 18 ft. This relatively large tide range makes the Bay an attractive place to test tidal power turbines and also presents additional difficulties in the design of the mounting system for testing devices. The testing devices must be kept beneath the trough of the waves, and preferably at a consistent relative position to either the water surface (floating systems) or the seabed (bottom-mounted systems). Testing floating systems requires that the mounting system be capable of fluctuating with the tide change. In addition to this challenge, the full extension of the cradle mechanism for yearly low tides requires a larger system to accommodate the reach. Also, it requires systems to be significantly stronger to withstand the high stresses created by the large tidal moment on the system.

Instrumentation maintenance: Permanently deployed instruments would require significant effort to calibrate and replace. Some instruments may be placed underwater either at the dock or some distance away. These instruments would be less accessible for maintenance than the equivalent instruments in a floating test site system.

Alternative 2 - Floating

This is a major alternative with two variations: flat-deck barge and pontoon barge. Both could be kept afloat and be moored at the Dock for testing there or moved to a location with stronger tidal currents or other conditions different from those at the Dock. The pontoon variation might even be designed for disassembly and transport by truck for use at a river site.

A floating system based at the dock would have a cradle mechanism and instrumentation housing implemented on a watercraft that could be towed to other locations. The cradle mechanism on the floating option would keep the test tidal generators at a consistent depth below the waterline as the craft's vertical position relative to the water would not change.

Advantages

Use of trestle electrical interconnection system at Homer only: By implementing a marine electrical connection system the floating option could utilize the interconnection to the Homer power grid allowing for the respective inherent benefits of the dock mounted option. However, this benefit would be restricted to the vicinity of the deep water dock, and limited by the length of the marine electrical connection system.

Transportation: To accommodate additional research conditions and locations, the floating designs would be capable of sea transportation.

Instrumentation access: Periodically instrumentation needs to be calibrated and repaired or replaced. Because the floating design options will require a method of readily deploying and retrieving the in-water instrumentation, required maintenance will be easier to perform.

Disadvantages

Generator system required: Due to the remote nature of the floating options, portable electrical generation will be required. Most likely this will be accomplished with a fuel powered generator. Electrical power is necessary to run the monitoring devices for the testing system and testing equipment for the proposed testing facility. Both floating options would only be able to utilize HEA power at the Deep Water Dock, and would require an onboard power generation system. For the addition of the generator system, fuel transportation and explosion prevention design considerations must be made.

Anchoring system: To properly and safely anchor a barge so that operations and testing of equipment may begin, the barge must be both stable and able to retain a specific position and orientation as determined by the needs of the tester. Anchoring systems for barges vary only

slightly from well-established anchoring systems for small boats. If a barge were to be anchored in the traditional single anchor method, the position and direction would be set by the currents and wind. With the layout and orientation restraints of the cradle mechanism, the preferred method of anchoring would be to either use a two-anchor method or four-anchor method.

Unknown site conditions: Whenever the floating option is taken to perform testing at a new location the site conditions will only be known to a small extent. Repeated testing at one site, such as the deep water dock, will build up a collection of site condition data. This data would enable the clients to know exactly what conditions their prototype tidal generator will encounter. Of course the floating option could be taken to the same locations repeatedly, but site condition data taken at a few sites will be less accurate than repeated testing at just one site.

Deploying/retrieving instruments: Just as the floating option has an advantage in being able to readily deploy and retrieve instruments, it also has some disadvantages. Every time the floating facility is moved, the instruments will need to be retrieved, stored, and then deployed at the new site. The instruments could remain in place at a permanent facility, only needing to be moved when necessary. Retrieving and deploying instruments also entails attaching some mechanism to the floating facility to do the work, which adds complexity to the design.

Data storage/collection: Data collected by the instrumentation will need to be stored and retrieved by the clients. This system is a challenge because the data will either need to be stored while the test is taking place and later retrieved or transmitted from the floating facility to an on-shore computer. If the data is to be retrieved it would entail either the client visiting the floating facility at regular intervals to download the data, or downloading it after the test is complete. There may be issues with this method because while the facility is out at sea, a problem could occur with the test that would render the data unusable. Transmitting the data from the facility presents a large design challenge, and would require access to a network of some type that may not be available throughout the Cook Inlet.

Long term testing: The client may want to test their prototype tidal generator over an entire lunar cycle to expose it to a variety of tidal conditions. This presents a challenge for the floating option because it will need to remain at sea and anchored in place through a large range of weather and sea conditions. If the conditions get too bad a long term test may need to be aborted in order to protect the vessel and tidal generator from being damaged.

Barge

A typical flat deck ocean barge would be retrofitted to secure an excavator for deploying hydrokinetic devices and marine instrumentation. A connex retrofitted for housing instrumentation and data collection and a marine grade generator with a fuel tank would be placed on the barge opposite from the excavator. The dredge barge in Figure 6 represents the barge testing station with the placement of the instrumentation housing and power generation system substituting the rock collection.

A bracket system would be attached to the excavator arm in the place of the bucket. The testing devices would be deployed using the existing excavator controls. The instrumentation and power feeds would be secured along the excavator's arm from the devices to the onboard processing center.



Figure 6: Dredge Barge with Excavator for cleaning Channel; similar to the cradle mechanism the for barge option. Borrowed (with permission?) from www.hcmm.com.my.

Advantages

Stability: Though most barges are used in river and lake environments, coastal barges also see some degree of success. When anchored near the shore, the flat-bottomed design of the barge provides enough stability to prevent it from capsizing. Likewise, due to the large size of the hull, the barge offers more carrying capacity in comparison to the pontoon, whose design decreases storage space while also increasing its chance of capsizing in rough waters. Also, most barges were designed to ride the waves instead of crashing into them, which when added to their already structurally sound design, provide stable platforms upon which research can be completed.

Excavator utilization: The flat deck barge option allows for the simplification of the cradle mechanism design by utilizing an excavator to deploy the hydrokinetic device and instrumentation as depicted in Figure 6. This is done simply by positioning the excavator on the end of the barge to lower the testing device into the tidal current with the excavator arm.

Use of trestle electrical interconnection system at Homer only: By implementing a marine electrical cabling system the flat deck barge option could utilize the interconnected to HEA's grid allowing for all the benefits inherent to the dock mounting option. However, this benefit

would be restricted to the vicinity near the deep water dock and limited by the length of the marine electrical cabling scheme.

Barge application flexibility: A barge outfitted with a cradle mechanism may serve a larger purpose than just testing tidal generators. In the event that tidal generator manufacturers find the incubator less popular than expected, the barge may be used for alternative purposes in areas of academic research. Also, the flexibility of a barge to be used for various purposes allows purchased used barges to be refitted for the purpose of the project.

Disadvantages

Barge availability: Though barges are common, it may be difficult to find the correct size and type of barge for the project in Alaska. A seller for this type of barge could eventually be found if a used barge is preferred. Transportation from another part of the world may be necessary to obtain a barge, which would add a significant cost to the project in time and fuel. A larger barge found locally would also be an extra expense and would also take up precious dock space as large barges are usually not capable of effective grounding for storage purposes. Depending on the size and availability of barges available for sale, a custom barge may have to be commissioned. A custom barge would enable the team to design specific requirements for the size and function. In any case, an existing barge can also be modified to meet the requirements of the design.

Pontoon

The pontoon option would resemble a catamaran style flat deck barge with the center open to allow for the deployment of the cradle system as depicted below in Figure 7. This pontoon would be custom to meet the design constraints and objectives. The cradle system would be mounted directly over the void in deck and could resemble the rack and pinion system in Figure A1, see Appendix A.



Figure 7: Model of pontoon testing setup.

Advantages

Symmetric loading: The separation of the pontoons in the catamaran design is convenient for the implementation of the cradle mechanism for mounting the testing devices. The position of the cradle mechanism and attached device in conjunction with the identical pontoons yields symmetric loading. This system provides excellent stability and requires fewer complicated design calculations.

Land transportation: In addition to being transported by sea, the pontoon could be designed to be disassembled and trucked to river locations throughout the state on the road system for testing.

Disadvantages

Custom fabrication: Due to the uniqueness of the cradle mechanism application and the weakness of aluminum, which pontoons are usually made out of, to galvanic corrosion in seawater, a custom made pontoon would have to be ordered. The custom pontoon would be made out of a strong, corrosion resistant material and would add to the capital expenditure.

Seaworthiness: In rough seas, pontoons are generally known to plow into the waves instead of riding them due to their design. This instability could prove to be problematic, as the increasing frequency of rough waves could damage the pontoon.

Spatial weight challenges: The placement of fuel and the generator creates potential spatial weight challenges with meeting the size limitations of a river testing operation. These spatial weight challenges may also be detrimental to the general stability of the craft.

Conclusion

This report shows that the vision of developing a Tidal Generator and Marine Testing Station can be realized through either a dock mounted system or two alternative floating mounted systems.

For the dock mounted option, the cradle system would be deployed from the trestle of the Deep Water Dock and into the tidal flow. The cradle system would mechanically raise and lower to counter the fluctuation of the tides. An instrumentation system for monitoring the performance of the tidal generator and the marine environment conditions would be deployed with the cradle system and in the surrounding environment.

The barge and pontoon designs' cradle system would be less complicated since there is no need to counter the tidal fluctuation. However, factors such as the vessel design and material used must be considered to prevent capsizing or structural fail. A method for deploying the instruments and retrieving collected data would also have to be developed.

Considerations must also be made to the economic factors that surround the project. For the barge or pontoon option, factors like transportation fees and the cost to build could sway the project towards being unprofitable. Likewise, the close proximity of the dock mounted option to Homer's port and with no need to buy or construct a floating platform when an existing one can be used could be an economically viable method moving forward.

Based on the advantages and disadvantages of each option presented in this report, the Homer Tidal Energy Incubator Group will need to select one alternative for further development in the next phase of the project.

Appendix A - Cradle System

The mechanism for deploying the testing devices as depicted below in Figure A1 would utilize a rack and pinion system as the raising and lower mechanism. The structural stability comes from sandwich beams incorporating the rack. The system would be run by either hydraulic or electric motors that would provide the raising and lowering capacity. Instrumentation for automatic or manual operation would be integrated into the system.

The hydro turbine below depicts the mounting orientation for typical testing devices. It should be understood that some devices would have to have custom adaptors in order to attach to the cradle system.

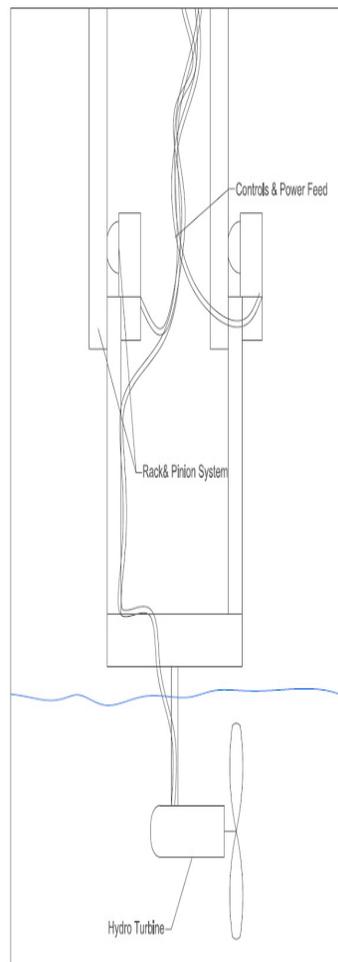


Figure A1: Schematic side view of perspective cradle system.

Appendix B - Literature Review

The most important literature governing interconnection to utility power for this project is Homer Electric Association's (HEA) "Electric Service Requirements (Service Assembly Guide) 2009" (HEA, 2009) and "Requirements For The Interconnection of Member-Owned Alternative Power Installations" (HEA, n.d.). The latter is a summation of the applicable standards found in the former and in HEA's Current Tariff (HEA, n.d.). These standards are in turn derivative of Institute of Electrical and Electronics Engineers standards 1547. This standard lays out the "...*minimum functional technical requirements...*" (IEEE, 2003, p. iv) rather than a design guide. The standard seeks to be technology neutral in its requirements. The IEEE does provide a guide to the IEEE 1547, the IEEE 1547.2, which provides clarification, explanation and justification for the standards described in IEEE 1547 (IEEE, 2008). Also, its appendix contains some example designs that meet the requirements.

The IEEE publishes two more additional design guides for interconnections. IEEE 1547.3 is meant to "...*help implement optional approaches for monitoring information exchange, and control*" (IEEE, 2007, p. iv) between the alternative energy source and the utility grid. IEEE 1547.4 covers good design, operation and integration practices connecting and or disconnecting the alternative energy source for the local utility without disturbing the local grid or power on the facility site (IEEE, 2011).

If and when the interconnection is installed, it is required by HEA to be tested, prior to being energized, in accordance with IEEE 1547.1 (IEEE, 2005). The IEEE 1547.1 "... *provides conformance test procedures to establish and verify compliance with the requirements of IEEE 1547*" (IEEE, 2005, p. iii) but does not define specific measurement techniques, those are outlined in other technical publications.

In addition HEA requires that converter/inverter required for the interconnection meet the minimum requirements described in Underwriters' Laboratory Standard 1741 (UL, 1999) and the recommendations in IEEE 519 (IEEE, 1992).

IEEE 1159 (IEEE, 2009) presents useful guidelines and recommendations for power quality monitoring and it "...*discusses the selection of appropriate measuring instruments, limitations of these instruments, application techniques, and the interpretation of monitoring results.*" (p. iv). The IEEE has also published recommendations for transferring that data in IEEE standard 1159.3, and outlines useful tips for the encoding and decode of software files containing power quality data (IEEE, 1992).

Any land based alternative's electrical installations by Alaska Statutes 18.60.580 shall adhere to the National Electrical Code 2011 (NFPA, 2011) on the secondary side of the site transformer and the National Electrical Safety Code 2012 (NFPA, 2012) on the primary side of the site transformer.

Wiring methods implemented for the installation of electrical components will be appropriate for corrosive and wet conditions as illustrated in UL standards 1309 (UL, 2011).

Appendix C - Instrumentation and Environmental Monitoring

The strategy for monitoring the effects of the tidal generator on the surrounding environment consists of measuring several ocean properties both before and after interaction with the tidal generator. Measuring the effect of the tidal generator on the surrounding environment is necessary for environmental permitting purposes as well as fully understanding the performance and efficiency of the tidal generator.

The environmental properties that should be monitored are:

- Water velocity – the overall movement of the water
- Water turbulence – small variations in the overall movement of the water
- Water depth at the test site
- Water temperature
- Water conductivity - used to determine water salinity
- Water turbidity – the cloudiness of the water
- Size of particulates suspended in the water
- Scouring of the seafloor beneath the hydrokinetic device
- Noise produced by the hydrokinetic device
- Cetacean activity near the test site
- Other wildlife activity near the test site
- Capability to extract water samples for further laboratory testing

“The energy flux contained in a fluid stream is directly dependent on the density of the fluid, cross-sectional area, and fluid velocity cubed” (Khan, 1824). Thus, the water velocity contains the majority of the energy in a tidal stream. Measuring the water velocity over the entirety of the affected water column both upstream and downstream of the generator is of high importance. “Acoustic Doppler Current Profiler (ADCP) instruments are used to measure the speed of water across an entire water column” (Hydro International, 1).

Water turbulence is important to measure in order to understand the small variations in water movement that occur at the test site naturally as well as those resulting from tidal generator activity. Water turbulence can adversely affect a tidal generator as inconsistent water flow can reduce power output efficiency and increase generator deterioration. An instrument commonly used to monitor water turbulence is called the Acoustic Doppler Velocimeter (ADV).

“Velocimeters belong to a special class of high-resolution 3D instruments used to study rapid velocity fluctuations in the laboratory or in the ocean. These instruments have three or more focused beams to measure with high sampling rates in a small point” (Nortek AS, 2013). Use of multiple ADV devices will likely be necessary for accurate monitoring of the test site.

Water conductivity, temperature and depth are typically monitored using a device called a CTD. “The device’s primary function is to detect how the conductivity and temperature of the water column changes relative to depth. Conductivity and temperature information is valuable because

the salinity (the concentration of salt) of the seawater can be derived from these two variables” (Ocean Explorer, 1). The salinity of the seawater contributes to its overall density. As stated above, the energy present in a tidal stream is dependent on the water density (Khan, 1824), thus measuring this quantity is important for determining the efficiency of the tidal generator.

The measurement of turbidity, or the amount of sediment suspended within the water, is crucial when monitoring a tidal generator test site. High sediment levels may cause significant wear on a tidal generator. Test site clients will want accurate turbidity data to compare with the deterioration observed on the tested tidal generator. Optical backscatter sensors (OBS) “measure the amount of light transmission of water to give a measurement of the suspended solids in that water” (Campbell Scientific, 2013). An optical backscatter sensor coupled with water sampling will provide sufficient suspended sediment data for the test site.

A tidal generator that causes significant changes to water flow can cause scouring of the seafloor in a shallow ocean environment. This seafloor scouring can affect sea life present on the ocean floor beneath the tidal generator, and over the long term, change the floor contour. A simple underwater camera with appropriate lighting appears to be the most reasonable and cost effective method for observing seafloor scouring.

A tidal generator consists of moving parts which may generate sounds audible to local cetaceans - primarily beluga whales. Due to the protected status of Cook Inlet beluga whales, environmental permitting will not allow any significant disruption to the whale’s behavior. Thus, any tidal generator tested in Cook Inlet cannot produce noise which is disturbing to beluga whales. The use of a hydrophone (underwater microphone) tuned to appropriate frequency range can monitor the tidal generator’s audible noise output. This hydrophone can also be used observe the behavior of beluga whales as they travel near the tidal generator site.

Surveillance of other sea life at the tidal generator site may also be desirable. Salmon returning to the Homer Spit ‘Fishing Hole’ pass near the tidal generator site each spring and summer. Observing these salmon as they pass near and interact with the test tidal generator is most effectively accomplished with the underwater camera which is already in place to view the behavior of the tidal generator itself.

Tidal generator incubator clients may want the ability to perform further testing on the seawater at the test location. Having the means to extract water samples at the tidal generator site, as well as upstream and downstream of the tidal generator will allow clients to collect water samples to be analyzed by an outside laboratory.

Generator monitoring instrumentation

For monitoring the electrical generation capabilities and the environments effect on the tidal generator the team has identified the following measurements:

- 1 Rotation speed
- 2 Tidal generator vibrations
- 3 Strain on tidal generator components
- 4 Electrical Characteristics (voltage, current, power)
- 5 Power quality monitoring
- 6 Tidal generator loading
- 7 Visual inspection of the tidal generator

A measure of the tidal generators rotation speed is necessary so the tidal generators response to the water velocity under a variety of loading conditions can be characterized. The client will also need to know how much power the tidal generator is outputting based on its rotation speed.

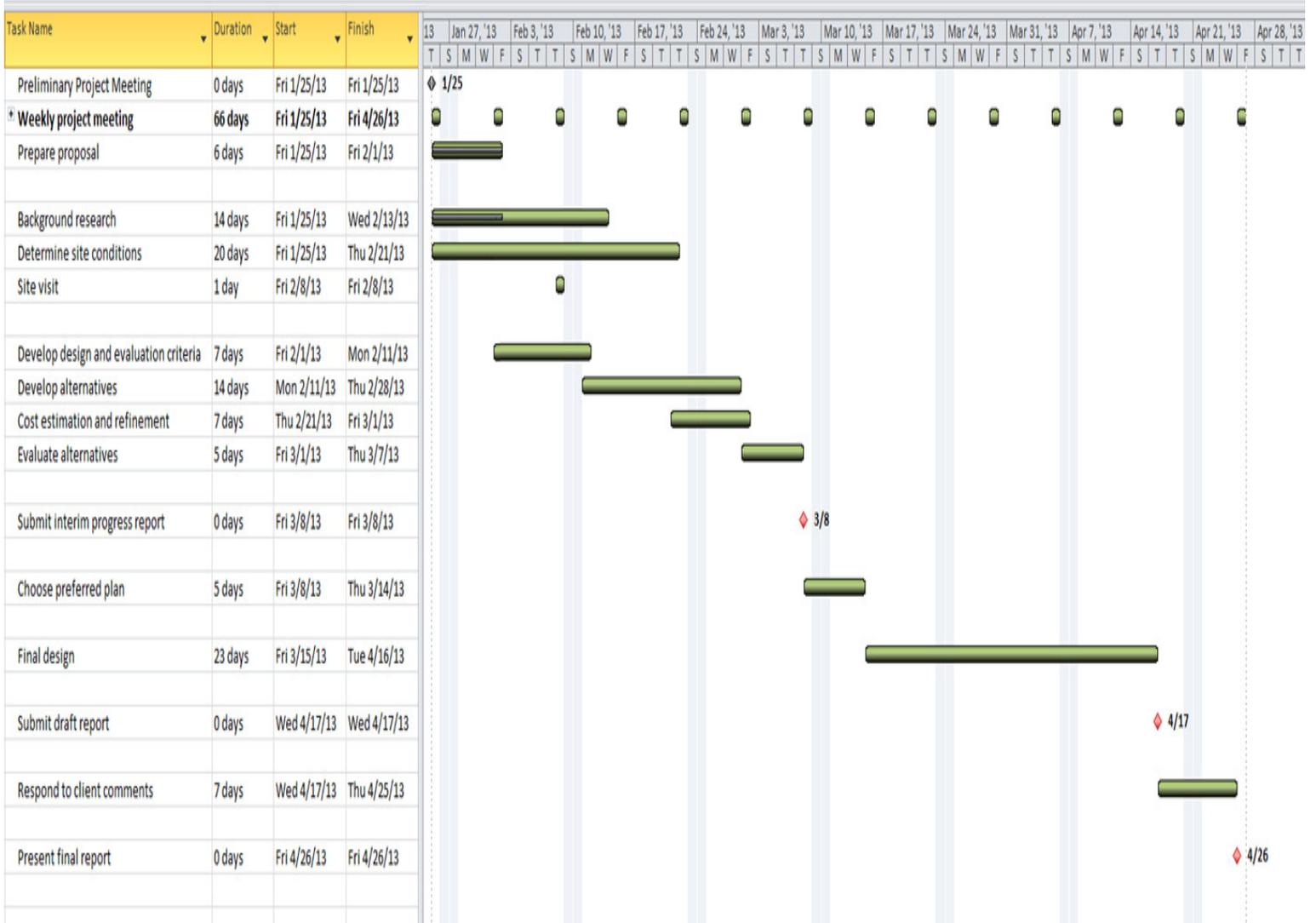
As the prototype tidal generator operates under a variety of environmental conditions it will experience strain on its components and vibrations. Over time the strain and vibrations will cause wear on the prototype tidal generator. The capacity to monitor the strain and vibrations, along with the conditions that caused them, will allow the client to gain a better understanding of what will be required to limit them. The client may or may not have an instrument for measuring strain and vibration installed on their tidal generator, so providing them for use is necessary. Typical instruments for measuring strain are strain gauges, and accelerometers are used to measure vibration.

Monitoring the electrical characteristics of the prototype tidal generator is essential for this project. The clients who are performing the testing will need to know what voltage their tidal generator is producing, what current it is producing, and what the power output is, all under a variety of site conditions and electric loads. Providing the means to monitor the electrical characteristics of the prototype tidal generator will allow the client to determine the overall power quality produced by the device. These measurements are all importing for the clients in determining their tidal generators performance. There are a large variety of instruments that can be used to monitor the electrical characteristics of a tidal generator, such as the digital multimeter and oscilloscope. Power quality monitoring will be implemented in accord with the IEEE Recommended Practices for Power Quality Monitoring standard.

In order to adequately test the prototype tidal generator, the client will need to be able to control the tidal generators loading. The client will need to be able to simulate a wide variety of loads in order to thoroughly test the prototype tidal generator. The instrument required for controlled loading is a load bank.

The client will need to be able to view the tidal generator operating while it is deployed. Being able to see the prototype tidal generator as it operates will allow the client to understand what may be causing any problems the tidal generator is facing. An underwater camera will need to be deployed alongside the tidal generator so that it can be viewed while operational.

Appendix D - Schedule



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