Recommended Decision-Making Strategies for San Francisco's Oceanside Wave Energy Project

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Abstract

As pressure to develop renewable energy increases, wave energy emerges as one of the potential solutions to the nation's energy crisis. To displace fossil fuel generation, the City and County of San Francisco (CCSF) is pursuing wave energy as a portion of its energy portfolio. In pursuing this project, CCSF will face several challenges, including the need to understand the regulatory landscape, to move stakeholders from having conversations into a process where feedback is used to form agreements, and analyze different data layers to find preferred wave energy sites.

To assist CCSF in moving the Oceanside Wave Energy Project forward, I have: 1) outlined the basic federal and California regulations governing hydrokinetic projects and actions CCSF can take to overcome regulatory challenges , 2) identified existing decision support tools that will formalize the stakeholder process and feedback, and 3) developed the framework of an interactive GIS tool that will allow users to understand the impact of a wave energy project on different environmental and socioeconomic criteria. Together, these products help stakeholders understand the impact of a wave energy project on different regulatory, environmental, and socioeconomic criteria in San Francisco, CA.

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Introduction

As pressure to develop and harvest renewable energy resources increases, wave energy emerges as one of the potential solutions to the nation's energy crisis. Wave energy is the surface waves and pressure variations below the ocean's surface that may be used to generate intermittent power. Harnessing wave energy is a type of hydrokinetic project, which is a general term that refers to the generation of electricity from waves, tides and ocean currents, or inland waterways. Unlike more conventional renewable energy such as wind and solar power, wave energy is always available (Von Jouanne 2006). Even during seasonal periods when the ocean appears calm, swells are moving water up and down to sufficiently generate electricity. The wave's constancy and predictability enables a more straightforward and reliable integration into the electric utility grid (Von Jouanne 2006). Since water is dense, the energy it imparts is concentrated. This allows for a device to generate kilowatts of power from a wave to be much smaller than what's required to harness kilowatts from wind or solar (Venugopal and Smith 2007).

Despite wave energy's potential, a myriad of complications exists, especially in the construction of a device that can withstand intensive waves and winds, corrosion by saltwater, floating debris, growth of marine organisms, and curious marine mammals (Pelc and Fujita 2002). Today, floating buoys, platforms, and submerged devices placed in deep water can generate electricity using the ocean's waves. However, these diverse technologies require further refinement and new wave energy conversion (WEC) devices are being developed for this emerging industry.

Hope in meeting these challenges prevails; the vision of an apparatus that can harness an inexhaustible, comparatively nonpolluting energy source and be deployed economically to generate significant amounts of electricity compels this field to move forward. According to the Electric Power Research Institute, an electric energy think tank, waves could fuel approximately 6.5% of today's electricity needs. This is equivalent to the energy in 150 million barrels of oil, enough to power 23 million typical American homes (EPRI 2004). With the most powerful waves occurring on western coasts due to strong west-to-east global winds, the West Coast of the United States is a prime location for the development of wave energy. As of fall 2009, no commercial WEC farms exist in the world, but three are under development in Portugal, Spain, and Scotland (Palha, Mendes et al. 2010).

In the United States, a handful of small pilot wave energy projects are running. As of February 2010, construction began off Oregon's coast on the first commercial U.S. wave-energy farm, which will supply power to approximately 400 homes (Loew 2010). Currently, no operational commercial wave energy facility exists in the States. San Francisco, California displays potential to support a wave energy farm. In May 2007, the California Energy Commission released a wave energy assessment for the state, showing a wave power density of 30.3 kW/m along a 104 km section of the coast centered on San Francisco (Kane 2008).

Currently, the City and County of San Francisco (CCSF) employs a number of different renewable energy technologies such as solar power and cogeneration, a combined heat and power system, to achieve a series of ambitious goals: 1) generate 50 MW of in-city renewable energy, 2) reduce greenhouse gas emissions to 20% below 1990

levels by 2012, and 3) become completely carbon neutral by 2030 (Climate Change Goals and Action Plan). Guided by the goal to gradually displace existing fossil fuel generation with renewable energy technologies, CCSF is pursuing wave energy as a substantial portion of its energy portfolio and to prove whether wave energy is a viable option for an urban environment.

Aware of the technical challenges and also the ocean's energy potential, the San Francisco Public Utilities Commission (SFPUC) and San Francisco Department of the Environment (SFDOE) are leading the San Francisco Oceanside Wave Energy Project. This project demonstrates the feasibility of generating electricity from waves in a zone 8 miles off the west coast of San Francisco and 10.5 miles in the alongshore direction (Appendix 1). This exclusion zone lies outside the nearby Gulf of Farallones and Monterey Bay National Marine Sanctuary (Appendix 1) due to the presence of a 4.5 mile long pipeline, Southwest Ocean Outfall, from the City's Oceanside Wastewater Treatment Plant (3500 Great Highway, San Francisco 94132). Furthermore on February 12, 2009, the Gulf of the Farallones and Monterey Bay National Marine Sanctuary Advisory Councils passed a joint resolution stating the sanctuaries were not appropriate locations for wave energy devices and development (Brown and Michel).

As of October 22, 2009, CCSF and BioPower Systems, an Australian ocean energy company, entered into a collaborative agreement to further investigate the feasibility of developing a wave farm in the study area (Prill 2009). Contingent on the feasibility study's results, both parties will work towards the goal of developing the project to supply clean renewable electricity into the City's power grid by 2012.

Master Project's Objective

Currently, federal regulations concerning hydrokinetic projects are being refined. Developers will need to understand these regulations in order to successfully navigate through them. Furthermore, CCSF has started conversing with different stakeholder groups about their perceptions, interests, and concerns regarding a wave energy project. However, CCSF is unsure how to move these conservations into a structured stakeholder process, where the exchange of information is used to reach decisions. Many decision support tool are available to structure the stakeholder process and whether one of them will fit CCSF's project needs has yet to be determined. This also means it is unknown whether a tool needs to be developed to specifically address the project needs. To move Oceanside Wave Energy Project forward, CCSF will need to address several obstacles, which include understanding the regulatory landscape, transforming stakeholder conversations into a formal process where feedback will be used to develop agreements, and analyzing environmental, social, and economic data to find preferred project locations. To address these obstacles, I will:

1) outline the basic federal and California regulations governing hydrokinetic projects and actions CCSF can take to overcome regulatory challenges,
2) identify existing available decision support tools that will formalize the stakeholder process and feedback, and
3) develop the framework of an interactive GIS tool that will allow users to understand the impact of a wave energy project on different environmental and socioeconomic criteria in San Francisco, CA.

Total Ecology

I will examine the total ecology of how CCSF can better prepare itself to obtain the necessary documentation for their wave energy project and overcome regulatory challenges linked to hydrokinetic projects. An understanding of the total ecology will be achieved by outlining 1) the study area's biology, 2) the regulatory structure of the following four key agencies: Minerals Management Service (MMS) within the Department of the Interior, Federal Energy Regulatory Commission (FERC) housed in the Department of Energy, and the state agencies, California Coastal Commission (CCC) and California State Lands Commission (CSLC), and 3) discussing the stakeholders involved in implementing the wave energy project. In addition, this paper identifies potential conflicts and proposes possible solutions. By bringing attention to these potential conflicts, CCSF will be able to better develop equitable solutions, and maintain public support of the wave energy project.

Study Area's Biology

Within the exclusion zone, a study area, approximately 5.5 nautical miles parallel to shore and 3.5 nautical miles offshore, will host a variety of studies, including gray whale migration tracking, wave energy reduction and coastal sediment transport, and crab fishery study. From these studies, a better understanding of how the proposed wave energy farm will impact the surrounding marine environment. The implementation of these studies is contingent on federal funding, which has not been approved as of November 2009. Paired with these proposed studies are long-term wave buoy data and

site-specific wave studies performed by SFPUC in 2008-2009, confirming the waves within the exclusion zone are suitable for wave energy extraction. This study area will potentially contain a targeted capacity range of 10MW to 30 MW wave energy farm, operating in water depths of approximately 110 feet using fully submerged wave energy conversion (WEC) devices such as bioWave , WaveRoller, or bioWAVET (Prill 2009; Smith 2009).

Regulatory Framework

Overview

A myriad of agencies and legislation have an impact on the development of the hydrokinetic industry at the federal, state, and municipal level. The goal of this paper is not to discuss every piece of legislation impacting wave energy projects, but to give insight into the most influential governing bodies and regulations concerning wave energy development. Like the hydrokinetic industry itself, the regulatory process for these projects is still evolving, as shown by recent changes in law aimed at clarifying the federal role in ocean energy. To bring this project to a commercial scale, CCSF needs a MMS lease, FERC preliminary permit or lease, CCC coastal development permit, and CSLC submerged lands lease.

However, regulatory challenges exist at the federal and state level. In federal waters, CCSF will run into obstacles such as 1) the inconsistent treatment of municipalities between FERC and MMS, 2) conflicting agency goals regarding regulatory barriers for hydrokinetic projects, 3) the disadvantage of not being issued a preliminary permit in the Outer Continental Shelf (OCS), ocean territory between three

and 200 miles from the coast of the United States, and 4) difficulties in collaborating with MMS. In state waters, CCSF will have to ensure compliance with state conservation acts such as the Coastal Act. In both situations, CCSF will have to understand the regulatory structure and find solutions in moving their project forward.

Federal Regulations

The two major federal regulatory agencies for ocean energy projects are FERC and MMS. FERC is responsible for regulating all hydrokinetic projects and interstate electricity transmission (Federal Power Act). While MMS's role is to manage activities on the OCS such as oil and gas, offshore renewable energy projects such as wind and solar and leasing, rights-of-way, and easements of OCS lands (Outer Continential Shelf Lands Act, Energy Policy Act of 2005). As hydrokinetic projects were proposed on the OCS, the jurisdiction of MMS and FERC became unclear. For instance, what type of authority would each agency possess? Furthermore, what would the regulatory structure be like for hydrokinetic projects on the OCS?

On April 9, 2009, FERC and MMS signed the Memorandum of Understanding (MOU) to clarify their roles regarding hydrokinetic projects on the OCS. Under the MOU, FERC maintains authority in issuing a standard license to construct and operate a hydrokinetic electric generation facility including the primary transmission line for up to 30-50 years in the OCS. FERC also retains jurisdiction over the sale of power from facilities located on the OCS. However, FERC is not allowed to issue preliminary permits for projects located in the OCS, marking a major change in FERC's current practices. FERC's preliminary permits do not authorize construction, but they give the

developer priority to study a project at a specific site for the duration of the permit and priority to later seek a standard license at the permit site. Without preliminary permits for projects in the OCS, developers are left with a sense of uncertainty. Secondly under the MOU, MMS remains the lead federal agency for offshore renewable energy projects on the OCS and is responsible for leasing, rights-of-way, and easements for all renewable energy sources on the OCS (Energy Policy Act of 2005). This means MMS possesses no jurisdiction regarding the production, transportation or transmission of energy from hydrokinetic projects on the OCS. Lastly, developers of hydrokinetic projects must obtain a MMS lease, allowing use of lands in the OCS, before applying for a license from FERC.

While the MOU clarifies the jurisdictional roles of FERC and MMS on the OCS, it also leaves other issues unresolved such as an agency's treatment of municipalities, conflicting agency goals, impacts of not having a preliminary permit in the OCS, and challenges in working with MMS. All four issues impact CCSF's ability to obtain the necessary federal documentation to move its wave energy project forward.

Inconsistencies in the MOU exist for municipalities with projects spanning state and federal waters. In FERC's permit process, the Commission gives preference to the municipal applicant when two or more applicants vie for the same site in state waters. This preference is not reflected by MMS when issuing leases in the OCS, rendering this advantage useless. For a municipal candidate, MMS may incorporate considerations such as "public benefit" or "state and local needs" into the auction format, but this does not guarantee a lease. Furthermore, if MMS holds a competitive lease sale, based on applicants' bids, this selling method might create preference towards the private sector,

who tend to have more capital available than municipalities. To address this issue of inconsistency and bias, criteria should be developed (if not done so already) to clearly define when a municipality will and will not be granted preference by MMS. This information should be made available to the public, which would assist in creating transparency between MMS and applicants.

In 2007, Commissioner Philip Moeller stated, "FERC wants to harness this enthusiasm [surrounding the development of hydrokinetic technologies] by exploring ways to reduce the regulatory barriers to realize the amazing potential of this domestic renewable power source." To encourage innovative hydrokinetic projects and reduce regulatory barriers, FERC created the pilot project license in 2007. This allowed the testing of experimental pilot projects including interconnection to the grid, over the short-term, without the need for the full licensing process required by the Commission's regulations under Part I of the Federal Power Act. This license also minimized environmental impacts by confining projects to low-sensitivity sites and requiring shut-down or removal if significant adverse environmental problems occur. However, FERC's desire to reduce regulatory barriers for this industry is not reflected by MMS. In this case, the MOU intensifies regulations in federal waters and does not resolve the conflict between the two agencies' stance on the amount of regulations for hydrokinetic projects.

Additionally, since FERC will no longer issue preliminary permits for OCS projects, the MOU could serve to impede hydrokinetic development. Developers, such as CCSF, no longer have the ability to obtain the priority of application provided by these permits for the very purpose of promoting investigation and assessment of a potential

project site in the OCS. This might reduce certainty for developers and create hesitation in investing money and technology into hydrokinetic projects.

The complex process of dealing with MMS might act to deter developers from further pursuing projects or encourage project downsizing to a scale that might not be commercially viable, essentially countering the goals of FERC to reduce regulatory barriers. While the regulatory structure of each agency regarding hydrokinetic projects is in flux, the final configuration of each agency's regulatory framework could have a major impact on project-siting decisions. Developers may decide to site projects completely on one side of the OCS boundary, depending on which regulatory process they view as being more favorable (Whieldon 2009). This type of approach could distort the industry's development or leave promising sites undeveloped. Furthermore by giving both agencies a major role in the authorization of hydrokinetic projects, it is not clear whether the MOU will support the development of ocean energy as a viable renewable resource. CCSF could decide to reduce their project proposal to only occupy state waters. Although this would make the regulatory process easier, CCSF's wave project might not produce enough energy to make the project economically feasible.

California Regulations

In addition to the federal permits required to develop this project, CCSF needs a California Coastal Commission (CCC) coastal development permit, and California State Lands Commission (CSLC) submerged lands lease. Under California Coastal Act of 1976, CCC is responsible for development and securing public access to the coastal zone, generally extending 1,000 yards inland from the mean high tide line. The Coastal

Commission's activities include helping local communities develop local coastal plans that address water quality, cumulative and secondary impacts, coastal habitat, and other issues to developing regional public access guides. CCC is one of three California agencies, the other two being San Francisco Bay Conservation and Development Commission (BCDC) and California Coastal Conservancy, in the California Coastal Program approved by NOAA in 1978 under the Coastal Zone Management Act (CZMA). With respect to CCSF's hydrokinetic project, the City will need to apply for a coastal development permit from CCC since new development is proposed on submerged lands, a public trust land.

One of the major issues between wave energy projects and CCC is whether projects will comply with the Coastal Act. The overarching goal of the act is to protect California's coast through state and local government implementation of policies that safeguard state interests in coastal resources, including the provision of maximum public access and recreational opportunities to and along the shoreline. This means CCC will have questions regarding the proposal's impacts on marine biological resources and water quality, public access and recreation, and other coastal-dependent uses –fishing, use of the shoreline, etc. They will also be interested in alternative designs and locations, or mitigation measures that would make the project less environmentally damaging. These concerns from CCC make FERC's preliminary permit vital to project development since the permit allows for a period of secure project research that will provide answers to the above state concerns.

Under Division 6 of the California Public Resources Code and the federal Submerged Lands Act, the California State Lands Commission (CSLC) was established

and given responsibility over submerged lands in state waters. CSLC possesses authority to manage and protect the important natural and cultural resources on certain public lands and the public's right to access these lands. The public lands under CSLC's jurisdiction are sovereign and school lands. Sovereign lands encompass the beds of California's naturally navigable rivers, lakes, and streams, including the state's tide and submerged lands along the coastline in state waters. Furthermore, CSLC "maintains a multiple use management policy to assure the greatest possible public benefit is derived form" its public lands under the Public Trust.

CCSF will need to apply for a submerged lands lease from CSLC since the hydrokinetic project will be located on sovereign lands. CSLC considers a number of competing factors in issuing a lease, including whether the project is consistent with the goals of the Public Trust. This could prove to be a challenge in securing a lease from CSLC. To make this leasing process less vague, CCSF should establish early and straightforward conversations with CSLC. Also to obtain a submerged lands lease, CCSF should ensure that minimizing environmental impacts and allowing the greatest degree of public access are major priorities in the project development.

Other non-permitting yet important state agencies are the California Energy Commission (CEC) and California Public Utilities Commission (CPUC); both agencies will have prominent roles in determining the pace of hydrokinetic development in California. CEC is the state's primary energy policy and planning agency. Their responsibilities include supporting renewable energy by providing market support to existing, new, and emerging renewable technologies. With enough public interest in

wave energy, CEC could potentially support this industry by providing subsidies to lower the cost of energy and develop a steady set of consumers.

CPUC regulates privately owned electric, natural gas, and a variety of other companies. Also, CPUC administers California's Renewables Portfolio Standard (RPS), which requires that publicly owned utilities generate 20% of their electricity from renewable energy sources, which includes hydrokinetic projects, by 2010. On average, 12% of the utilities' energy is currently from renewable energy sources. The RPS favors the creation of customers for renewable energy, which is promising for the hydrokinetic industry and its investors. More importantly, CPUC has the ability to reject power purchase agreements between private electric companies and wave energy development companies due to unreliable technology and high power purchase agreement prices. Without CEC's financial support and CPUC's approval for power purchase agreements, wave energy projects, such as CCSF's, might not reach its commercial potential.

Stakeholders

General relevant stakeholders for SF's wave energy project include:

- Federal, state, and municipal agencies
- Scientific community (e.g.) academia for a possible advisory group
- Non-government organizations (NGOs) (e.g.) environmental, fishing, recreational users, and other special interest groups
- Local residents

The stakeholders that SFPUC and SFE have contacted regarding their opinion on the proposed wave energy project are listed in Table 1.

Table 1 - Stakeholders consulted as of February 2009

Federal Agencies
US Department of Commerce
National Oceanographic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
National Marine Sanctuaries (NMS)
Gulf of Farallones NMS
US Department of Interior
Minerals Management Service
Fish & Wildlife Service
National Park Service
Golden Gate National Recreation Area
US Coast Guard

State Agencies
California Coastal Commission
California Department of Fish & Game
California Energy Commission
California State Coastal Conservancy
California State Lands Commission

Municipal Agencies
Marin County Community Development Agency
City of Pacifica
San Francisco Ocean Beach Vision Council

NGOs
Environmental Action Committee of W. Marin
Farallones Marine Sanctuary Foundation
Natural Resources Defense Council
Ocean Conservancy
Save the Waves Coalition
Sierra Club
Surfrider Foundation
Golden Gate Fishermen's Association
Pacific Coast Federation of Fishermen Association
Recreational Fishing Alliance
Boat Owners Association of San Francisco

By asking stakeholders (Table 1) for their concerns and opinions regarding the wave energy project (Smith 2009), the following concerns were identified:

- The presence of marine mammals in particular grey whales
- Dredging operation for the Ocean Beach and Great Highway sediment transport and restoration program, and possible impacts on the regional littoral sediment transport mechanism due to changes in the wave climate
- Impact on commercial fishing activities, particularly Dungeness crab fishing grounds, in the site area
- Recreational flat fish and salmon sport fishing

- The presence of commercial vessel traffic lanes entering and exiting San Francisco Bay
- Surfing, and other recreational activities
- The impacts of electromagnet fields surrounding power generation and submarine cables on habitat and species
- Underwater noise that may be generated from device motion

Of particular concern to stakeholders were gray whale migration tracking, wave energy reduction and coastal sediment transport, and crab fishery study. In response, SFPUC is overseeing the below site-specific studies with funding from the Department of Energy:

- Gray Whale Tracking: the objective of understanding northward and southward whale migration pathways in the zone 3 to 15 kilometers offshore, and 19 filling a site-specific data gap in knowledge of whale movement patterns in the San Francisco Bight area.
- Wave Energy Reduction and Coastal Sediment Transport: the objective of predicting the near-field and far-field wave patterns resulting from energy removal and the consequences for sediment transport in the Ocean Beach area.
- Crab Fishery Study: the objective of documenting historical catch patterns, annual variability, and the likely economic loss if a zone approximately 1 kilometer long by 0.5 kilometer wide was excluded from the fishing grounds.

As SFPUC and SFDOE continue developing this project, the above stakeholder list might need to be expanded. Based on the above listing, I recommend the inclusion of San Francisco Baykeeper, who will offer a public's perspective on water quality issues especially in the Oceanside Wastewater Treatment Plant area. CCSF should consider including the Ocean Beach Foundation and Sunset Residents Association to expand residents' input on this project, but reaching the latter organization might be difficult since it seems to be one of the less active neighborhood associations. Residential outreach and representation in the stakeholder group, especially in the Outer Sunset District, are vital in order to achieve public support and successful project implementation. With SFDOE's established relationships with residents throughout the City, this can be easily achieved.

In addition, I urge SFPUC and SFDOE to include scientific experts from academia, research institutions, etc. on wave energy, marine ecology, and other disciplines to be a part of the project discussions with other stakeholders; these experts could act as an advisory board by offering scientific advice to guide decision-making. Furthermore, FERC should be considered a stakeholder early on to establish a relationship of project transparency and to facilitate the City's preliminary permit application to connect the wave project to the grid in the future. While the stakeholder list and formation of possible boards expands, CCSF should keep in mind that including too many people might create a less effective decision-making process. Therefore, CCSF should limit the number of people to those who actively contribute and participate in the project development.

Summary of the Major Challenges

CSSF will face a number of challenges in moving the wave energy project forward. Below is a summary of the major federal and state regulatory and increasing public support obstacles.

1) At the federal level, the major issues are FERC's and MMS's inconsistent treatment of municipalities, conflicting agency goals regarding the reduction of regulatory barriers for hydrokinetic projects, impacts of not having a preliminary permit in the OCS, and challenges developers face when working with MMS. All four issues affect CCSF's ability to obtain the necessary federal documentation to move its wave energy project forward.
2) In working with state agencies, CCSF will need to comply with the Coastal Act to minimize impacts on the marine environment, public access, and other coastal-dependent uses. CCSF will also need to be consistent with the goals of the Public Trust under Division 6 of the California Public Resources Code and the federal Submerged Lands Act.
3) To firmly establish hydrokinetic projects as a viable renewable energy source, developers will need CEC's financial support and CPUC's approval for power purchase agreements. Otherwise, wave energy projects, such as CCSF's, might not reach its commercial potential.
4) Currently, CCSF needs to increase residential representation and ensure the integration of input from scientific experts into its project development. Without

these two components, CCSF might encounter strong opposition from the community and develop a project with large, unforeseen environmental impacts.

Possible Solutions and Their Impact

To better prepare CCSF for the regulatory challenges of a wave energy project and suggest possible ways in which CCSF can obtain the required documentation for the project, the following short- and long-term solutions were made:

Short-Term Solutions

1) To avoid unseen regulatory road blocks, work through inconsistencies in federal regulations, and promote transparency during the application review process, CCSF should establish early and frequent communication with MMS, FERC, CCC, and CSLC.
2) Since the regulatory process at the moment contains many unknown impacts, CCSF should continue in applying for a FERC permit in case they reduce their project to be only in state waters, and a MMS lease if they decide to maintain their current project size. This will allow for all possible options for developing in both state and federal waters until CCSF receives further feedback from the agencies involved.
3) Since funding for scientific studies such as sediment transport is a limiting factor for CCSF, the City should consider private-public partnerships similar to the ones employed in the Marine Life Protection Act (MLPA) or require BioPower Systems fund scientific studies as part of their feasibility study.

4) To secure public support, CCSF must establish better residential and scientific representation during the project development phase. Some organizations to consider would be the Sunset Residents Association, Ocean Beach Foundation, and San Francisco Baykeeper. To avoid a scenario with too many stakeholders that results in an ineffective planning process, CCSF should limit the participants to those who actively contribute to the project development.

Long-Term Solutions

1) CCSF should be vocal in urging for consistency of municipality treatment between FERC and MMS. Perhaps instead of giving preference based on applicant type, agencies should establish weighted criteria to evaluate the public benefits and impacts of a proposed project. This would also prevent preferential treatment of a specific applicant type.
2) Like other developers, CCSF experiences uncertainty and feels a lack of transparency in decision-making from MMS. By teaming up with other applicants, developers, and politicians, CCSF can apply pressure in encouraging MMS to provide further instructions on the regulatory process regarding hydrokinetic projects.
3) CCSF should take an active role in creating political will by uniting with hydrokinetic industry leaders, politician support, and more establish renewable energy sectors such as wind and solar to support streamlining of the current regulatory structure concerning renewable energy and increase federal funding.

4) Although RPS begins to create customer support for renewable energy, more policies that favor creation of customers and provide financial incentives to hydrokinetic projects will be needed. By creating these policies, project financing will increase. Therefore, CCSF should also take an active role at the state level, especially in working with CEC and CPUC to create future plans and policies to integrate wave energy into their agency plans. Without favorable policies, CEC's financial support, and CPUC's approval for power purchase agreements, wave energy projects will continue to struggle in reaching its commercial potential.

Although many barriers exist for CCSF's proposed hydrokinetic project, their commitment to proceed forward offers hope to the emerging industry and displays an understanding of the ocean's potential as a renewable resource. This project could provide the breakthrough necessary to transform the wave energy industry from a struggling sector to an established enterprise.

Identifying Decision Support Tools

Introduction

As marine environments become degraded, stakeholder conflicts for ocean space increases, and new industries such as wave and offshore wind energy emerge, marine spatial planning (MSP) becomes one of the possible tools to address these complex problems. MSP is a public process for analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives (Marine Spatial Planning Initiative). MSP possesses the potential to:

- Reduce conflicts between users and increase regulatory efficiency
- Facilitate the development of emerging industries such as wind and wave energy and aquaculture
- Help maintain ecological processes and the ecosystem services they support such as fishing, marine tourism and recreation, and cultural uses of the ocean (Tools for Marine Spatial Planning).

To reach MSP's potential, implementers must keep in mind three important attributes of MSP, which are:

- Multi-objective. MSP balances ecological, social, economic, and governance objectives.
- Spatially focused. The ocean area to be managed must be clearly defined and large enough to incorporate relevant ecosystem processes.

- Integrated. The planning process should address the interrelationships of each use within the defined management area, including natural processes, activities, and authorities (Basic Concepts – Marine Spatial Planning).

By using the multi-objective, area-based, and integrated concepts of MSP, CCSF and its stakeholders will be able to strategically decide where to place a wave energy project while meeting its environmental, social, and economic objectives. These objectives should be decided and refined as a group while undergoing public review. By establishing the project objectives as a group, stakeholders will feel more involved and in turn, might provide more support in ensuring project completion.

In addition to being guided by the concepts of MSP, stakeholders need to understand the different layers of information in the project, ranging from whale migration to sediment transport data. To comprehend all the different data, stakeholders will need to select appropriate decision support tools, which will provide guidance in choosing a suitable project location. In this context, decision support tools are interactive, online-based programs intended to assist decision makers in compiling useful information such as scientific data, personal knowledge, etc. to offer several solutions or courses of action for a specific problem. By using existing tools, stakeholders will enable CCSF's wave energy project to develop while preserving other neighboring ocean uses such as whale migrations, crabbing, and ecosystem functions.

Before discussing the available tools, an understanding of the stakeholders' objectives and contentions and an understanding on how to maximize the benefits and minimize the shortcomings of decision support tools should be established. In the below

sections, I provide suggestions on how CCSF should proceed in mapping the stakeholder situation, and create a list of disclaimers about the capabilities of decision support tools. Lastly, I highlight three current decision support tools that would be most beneficial to the development of the wave energy project.

Mapping the Stakeholder Situation

Before selecting decision support tools, CCSF should map the stakeholder situation by listing the stakeholder's 1) organizational goal or core interest, 2) prioritization of issues, 3) potential topics of conflict in relation to the proposed energy project, and 4) possible synergies and opposition with other stakeholders. For example, the organizational goal of the Golden Gate Fishermen's Association is to preserve and enhance California's fisheries while also providing a voice to recreational anglers, fishing related businesses, and passenger fishing boat operators. This means the association would prioritize maintaining current fishing areas above other issues. A source of conflict for this organization would be activities which limit their constituent's fishing capacity. Furthermore, there is a potential for alliance formation with environmental NGOs such as the Natural Resources Defense Council to preserve ocean space and conflict with regulatory agencies supporting the development of wave energy.

By mapping the stakeholder situation, this end product offers a rough estimation of where stakeholder tensions and alliances might form. By understanding and anticipating the stakeholder dynamics, CCSF will be empowered and prepared to foster collaboration among the different players. Also with this understanding, CCSF will be able to assist stakeholders in moving forward into the decision making process at a

quicker pace. The stakeholder chart should be verified with each group on whether the listed organizational goals and topics of conflict are accurate.

Disclaimer on Decision Support Tools

As CCSF proceeds in its wave energy project, it is important to understand the general capabilities and shortcomings of decision support tools. The online resource, EBM Tools, provides a comprehensive look at the limitations of tool use (Ecosystem-Based Management (EBM) Tools Network). The below list highlights four major points that CCSF and its stakeholders should keep in mind when using the selected tool:

1) As stakeholders proceed in the decision-making process, it is important to remember that tools do not provide answers or decisions, but rather provide quantitative results and visualizations to help make decisions. While using a tool, users should be aware of missing data and discuss whether the tools should be used without all the data inputs.

2) Tools do not eliminate the need for stakeholders to make tradeoffs between competing objectives. However, they enable stakeholders to identify solutions that reduce negative impacts (Getting Started).

3) Although some stakeholders might not be technically savvy, at a minimum, stakeholders should know what tools will be used, why the tools were selected, the end product the tool provides, the level of uncertainty of the tool results, and how the tool results will be incorporated into the decision making process (Best Practices for Using EBM Tools).

4) Lastly, tool results should be paired with a technical advisory committee. This peer review of tool use will ensure credible results. Subject matter experts can provide expertise when no data sets are available and validate tools results once generated. The committee can review data, identify tool analyses flaws and offer possible insight to unexpected data trends. By checking tool results with experts, stakeholders will be able to make more informed decisions (Best Practices for Using EBM Tools).

Suggested Best Available Decision Support Tools

Prior to selecting a tool, all relevant stakeholders should take part in discussions about what they want to get out of the tool use, what resources and information they have available to use tools, and how they will use the tools within their decision making process (Getting Started). These discussions will help stakeholders decide which tools should be selected for CCSF's wave energy project and how they will use the tools.

To guide stakeholders in determining the specific goals of using a tool, they should consider the following questions (Getting Started):

- What are specific environmental features in the project is interested in protecting?
- What are the specific social and economic features that the project is interested in protecting?
- Lastly, why did you select these environmental, social, and economic features?

Some examples of environmental features include habitats, marine species, ecosystems, etc. Examples of social and economic features are recreational and commercial land or marine opportunities, possess cultural or community importance, etc.

In answering the above questions using information from CCSF internal documents and past conversations with stakeholders, the three most important environmental, social, and economical features that should be protected are gray whale migration, wave energy reduction and coastal sediment transport, and the crab fishery. Under these assumptions, I highlighted the Multipurpose Marine Cadastre paired with the California Legislative Atlas, MarineMap, and California Ocean Uses Atlas tools to understand the ocean governance framework and to address the topic of preserving the above listed features. The goal of this section is not to name every available decision support tool, but to bring attention to a select few that would be most beneficial to CCSF.

Multipurpose Marine Cadastre & California Legislative Atlas

The Multipurpose Marine Cadastre (MMC) is a web-based tool that provides information about the national ocean regulatory framework for the outer continental shelf and state waters (Tools: Multipurpose Marine Cadastre). In MMC, users can view jurisdictional boundaries, ocean laws, critical habitat locations, and restricted areas (Tools: Multipurpose Marine Cadastre). From a permit review standpoint, this tool provides users guidance in selecting the best sites for renewable energy projects by avoiding conflict with other regulatory institutions. To specifically understand the ocean governance framework for California, the California Legislative Atlas would be a key tool to utilize (Digital Coast: Legislative Atlas) in combination with the national

regulatory tool, MMC. The California Legislative Atlas allows the user to visualize where selected ocean and coastal laws apply to a region of interest.

Currently, MMC is being used as a valuable decision support tool by state agencies to address alternative energy development demands. For example with the guidance of the NOAA Coastal Services Center and data from MMC, the California Coastal Conservancy and the California Ocean Protection Council produced a series of maps to inform appropriate locations for potential energy infrastructure by mapping the existing structures or uses such as shipping lanes and marine protected areas (Supporting Wave Energy Development in California). These maps show the potential impacts of wave energy development to other sectors. It might be beneficial for CCSF to contact the respective California regulatory agencies about the wave energy maps and investigate whether these maps would be useful for CCSF's project.

MMC paired with the California Legislative Atlas offers CCSF and its stakeholders the opportunity to understand the larger regulatory context, which would enable the project to avoid regulatory conflicts and better navigate through the permit review process. Furthermore by understanding the regulations and management agencies, CCSF could better embark on regional collaborations with key agencies to move the energy project forward. Lastly by using geographic information system (GIS), CCSF and its stakeholders can download spatial data from MMC and use the information for its own analysis purposes. MMC offers an understanding of the ocean governance framework and data to be integrated into the analysis of a suitable project location.

In addition to the tool's potentials, stakeholders should be aware of the tool's constraints, which are MMC's lack of environmental data sets and large scale data

resolution. MMC lacks comprehensive national data sets concerning habitat and biodiversity, marine geology, biological characteristics such as wave height, and human uses. Other decision support tools will be needed to compensate for this missing information. Also, the scale of the data within this tool will often be too large for CCSF. However, this large scale dataset provides context in how CCSF can proceed with its project. For example, knowing the existing regulations and marine infrastructure beyond the project's exclusion zone would enable CCSF to make a better case in proposing the wave energy project.

MarineMap

MarineMap Decision Support Tool is an interactive web-based tool that permits users to draw and edit prospective Marine Protected Areas (MPAs), and receive results regarding the protections and impacts of the proposed MPAs (MarineMap). Users are also allowed to share the drawn MPAs with other stakeholders. MarineMap contains a variety of environmental and human use data such as marine mammals, fishing, nearshore habitats, etc. (MarineMap). MarineMap has been heavily tested and used in real-life scenarios. Under the Marine Life Protection Act (MLPA), California stakeholders relied on this tool to assist in creating a series of interconnected MPAs in state waters.

MarineMap would be useful to CCSF's stakeholders in incorporating biological information into decision making and fostering collaboration. In MarineMap, stakeholders have the opportunity to understand the benefits and trade-offs of protecting biological features such as gray whale migrations and areas susceptible to wave energy

reduction and coastal sediment transport. Furthermore, this tool allows stakeholders to see how protecting certain areas within the exclusion zone will link up to the larger surrounding MPA network. Since MarineMap enables data sharing among users, it encourages collaboration among stakeholders. Also, this program allows users to test various ideas and "what if" scenarios, making it suitable in a group setting.

Two problems in using MarineMap is the availability of the tool for the North Central Coast Study Region and the ability of stakeholders to remember they are employing this tool to explore preserving marine space rather than creating MPAs. Before CCSF can use MarineMap, the organization will need to request access to MarineMap for the North Central Coast Study Region, because this region is not currently available online. One of the difficulties about this tool is that stakeholders will need to remember they are not actually creating MPAs. Rather, CCSF stakeholders are exploring and suggesting areas that should be restricted from the wave energy development. Although this tool's purpose is to create MPAs, this tool will help stakeholders visualize the benefits and impacts of preserving areas of biological interest.

California Ocean Uses Atlas

The California Ocean Uses Atlas (Atlas) contains the most comprehensive range of significant human uses of state and federal marine waters of California (The California Ocean Uses Atlas). The Atlas targeted mapping three broad use sectors, which were non-consumptive, fishing, and industrial and military activities. These broad uses were broken down into 26 specific ocean uses, including tidepooling, commercial fishing with benthic mobile gear, cruise ships, and others (The California Ocean Uses Atlas). In

addition, the Atlas resulted in three distinct layers of spatial information for all ocean uses targeted in the study: the general use footprint, dominant use areas, and potential future use areas (The California Ocean Uses Atlas). Regional experts in ocean use and management throughout the state worked together to create the ocean use maps. These experts included marine scientists, lifeguards, park managers, harbor masters, Coast Guard and Navy representatives, recreational and commercial fishermen, environmental organizations, etc. (The California Ocean Uses Atlas).

An interactive map for the California Ocean Uses Atlas is not yet available. However, GIS data for all the ocean uses is available and could provide CCSF with a baseline for current human use patterns in the project area. Also, this Atlas could serve as a model for how CCSF could map specific uses such as the crab fishery in the exclusion zone. With proper technical support and participation from ocean use experts, uses for the project area could be mapped out and reveal relevant trends that guide the siting of the wave energy project. By gaining a clear understanding of human uses, stakeholders could make an informed decision about the project location.

Discussion

To understand the stakeholder dynamics, CCSF will need to understand each stakeholder's organizational goal, method of prioritizing issues, sources of conflict, and possible alliance formations. Equally important to understanding the stakeholder situation is for CCSF and its stakeholders to be aware of the capabilities and limitations of decision support tools. From understanding the stakeholder relationships and the abilities of decision support tools, CCSF and its stakeholders will be better able to reach

consensus and to evaluate the usefulness of specific decision support tools. Furthermore, this will enable CCSF to guide its stakeholders in selecting appropriate decision support tools that will identify suitable locations for wave energy development.

In examining the suite of current decision support tools, the Multipurpose Marine Cadastre paired with the California Legislative Atlas, MarineMap, and California Ocean Uses Atlas tools appear to be most beneficial in selecting an appropriate wave energy project location. The Cadastre and California Legislative Atlas will provide information regarding the national and state ocean regulations and governance. These two tools will help CCSF to avoid regulatory conflicts, better navigate through the permit review process, collaborate with key management agencies, and analyze spatial data to identify suitable project locations. MarineMap will enable CCSF to incorporate biological data, such as gray whale migrations and areas impacted by wave energy reduction and coastal sediment transport, into the decision making process and foster collaboration among stakeholders. The California Ocean Uses Atlas could be a model for CCSF in mapping specific human and economic uses such as crabbing in the exclusion zone. In addition to using these tools, CCSF project managers will need to allocate appropriate staff time, technical expertise, and financial resources to properly use the tools and provide general training to stakeholders if needed. By combining the use of these tools paired with the proper financial and technical support, CCSF and its stakeholders will be able to support wave energy development while understanding the ocean governance framework and preserving key environmental and socioeconomic features.

Interactive GIS Tool

Introduction

While reviewing available decision support tools, I identified tools that assist in developing an understanding of the stakeholders' objectives and contentions, and secondly, assist stakeholders in compiling useful information such as scientific data, regulatory boundaries, and personal knowledge to identify appropriate wave energy project locations. Each of the previously identified tools would be useful to CCSF. However, the decision support tools examined large ocean areas such as all of the west coast or the coast of Northern California. This resulted in outputs with large resolutions. Since CCSF is focused on examining a specific, small area, the project resolution is much smaller than the recommended decision support tools' resolution. Due to this resolution incompatibility, CCSF might need to develop a tool to analyze their datasets. By using a developed tool in combination with the suggested tools such as the Multipurpose Marine Cadastre paired with the California Legislative Atlas, MarineMap, and California Ocean Uses Atlas, CCSF would have a more robust project analysis.

In response to the resolution incompatibility, I developed the framework of an interactive GIS tool that will allow stakeholders to understand the impact of a wave energy project on different environmental and socioeconomic criteria in San Francisco, CA. I intended this tool to be used by stakeholders and have stakeholders add additional data layers to increase the comprehensiveness of the analysis. The goal is to create a geoprocessing model that displays how user-defined and user-weighted criteria can identify the most suitable location(s) for a potential wave energy project in an exclusion

zone off of San Francisco, CA. Furthermore, users are able to create polygons representing project sites to see the location impact on different criteria.

Methods

Project Criteria

The created tool allows stakeholders to rank characteristics within a criterion and rank between the following project criteria:

- Wave characteristics such as average height, period, and power at random sampled locations. The most preference is given to areas with significant average wave height since it is the more influential variable in the wave power formula (Figure 1).
- Distance from wastewater pipeline. Since CCSF plans to place the wave energy project's transmission lines along the wastewater pipeline, areas near the water pipes have higher ranking.
- Gray whale (*Eschrichtius robustus*) southward and northward migration. The City would like to avoid project overlap with the migration paths.
- Distance from coastline. A project closer to shore would allow better access for maintenance. Therefore, a project situated closer to shore is preferred.

The ideal project location would be located in areas of large wave power, be close to the wastewater pipeline and shore, and minimize overlap with whale migration paths.

Figure 1 – Wave Power Formula. P means the approximate wave energy flux per unit wave crest length (kW/m). H represents significant wave height (m) and T equals the wave period (sec).

$$P \approx \left(0.5 \frac{\mathrm{kW}}{\mathrm{m}^3 \cdot \mathrm{s}}\right) H_{m0}^2 \, T_e$$

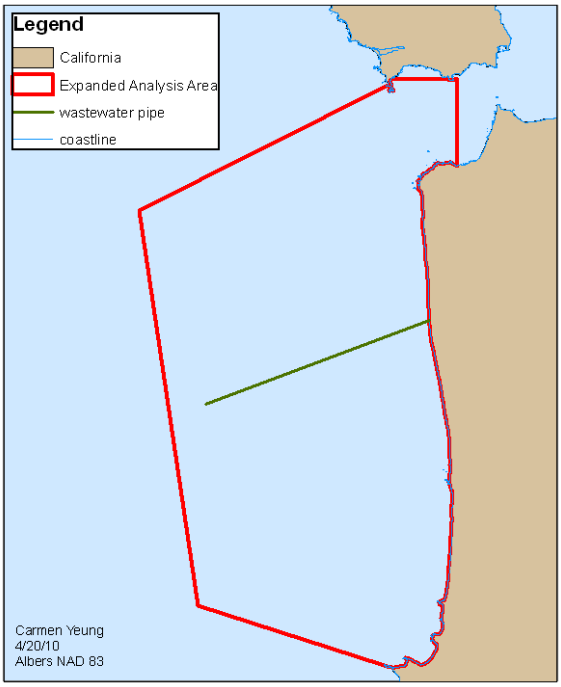
Gathering Data

The following files were retrieved from the Sanctuary Integrated Monitoring Network (SIMoN) Central California Marine Habitat Viewer: California State (California shapefile), Central California National Marine Sanctuaries (NMS) boundaries (cen_ca_nms shapefile), California coastline (coastline shapefile), and environmental sensitivity index (ESI) shoreline classification (esi_pline). The Monterey Bay GIS extent (kb_boundary) was found from the Coastal and Marine Geology Program Internet Map Server: Monterey Bay Region.

In creating this tool, I quickly discovered that since my area of interest was such a small location, finding substantial data to use in my analysis was nearly impossible. Also, CCSF had not yet begun collecting data in their study area. Furthermore by focusing on such a small area, I was encountering prolonged analysis time due to the small cell size setting. In order to bypass missing data problems and avoid prolonged analysis time for extremely small cell sizes, I had to expand my analysis area from the previously shown small study area to the ocean side of San Francisco, which is still a smaller resolution than the ones found on the decision support tools, (Figure 2) and created the following mock datasets based on real world parameters:

- Wave height, period, and power – I used the 2008 data from NOAA's buoy station 46237 (Station 46237 - San Francisco Bar, CA (142)), located in San Francisco, to create the mean wave height and mean wave period for randomly selected coordinates. The wave height and period were used to calculate wave power using the above formula.
- Wastewater pipeline – Since I couldn't find coordinates for this pipeline, I drew in the pipeline as best I could to represent the actual pipe placement.
- Southward and northward gray whale migration – During the southward migration in winter months, the whales are within 5 km (approximately 3 mi) of the shoreline. During the northward migration, the whales are found closer to the coast in the spring months. I created a dataset for 1 whale in each migration direction.

Figure 2 – Map of expanded analysis area in the ocean side of San Francisco, CA



Data Prep

I created the expanded analysis area mask using the NMS boundaries and California shapefiles with the Erase tool (Appendix 2); this mask was set as my model extent. I projected the wave data and whale migration paths to Albers NAD 83 (Appendix 3). Also, I created point files from the migration data and turned the points into a migration path using Hawth's Tool: Animal movements – Convert locations to path (points to lines).

Analysis

For the coastline, wastewater pipe, and whale migration paths files, I used the Euclidean Distance tool to calculate the distance moving away from the object of interest (Appendix 4). I employed the tool since it allowed me to rank the preferred distance within each criterion; the preferred distance had a higher numerical ranking (Nobre et al. 2009). I used the Inverse Distance Weighted (IDW) tool to interpolate the wave height, period, and power (Nobre et al. 2009). IDW estimates cell values by averaging the values of the sample data points in a neighborhood. The Reclassify tool was used to assign ranking to preferred characteristics of each criterion (Appendix 4). I attempted to create a reclassification parameter for the Reclassify tool to allow users to specify the ranking within a criterion. However, the outcome appeared to be a process that might be too burdensome for the user. I decided to only designate two criteria, wave height and northward whale migration, with the reclassification parameter (Appendix 5).

I applied the Weighted Overlay tool to assign a percentage of influence for each criterion, which allows ranking among the different criteria (Appendix 5). This

combined all weighted project criteria into one raster output, which displays preferred locations for the wave energy project. The distribution of percent influence used in the Weighted Overlay tool (Figure 3) is one possible scenario for the percentages, changing the percent influence would change your resulting raster output of preferred locations.

Figure 3 – Distribution of percent influence used in the Weighted Overlay tool

Criteria	% Influence
Distance from Coastline	4
Wave Period	5
Gray Whale Paths - Northward	8
Gray Whale Paths - Southward	8
Wave Power	20
Distance from Pipeline	25
Wave Height	30
Total Percentage:	100

For users to understand the impact of their criteria preferences, I created the Selecting Project Sites model (Appendix 6). This allows a user to create a polygon, which represents a project location, and view how it overlaps different ranked criteria and the final Weighted Overlay raster. However, there is currently no mathematical summery of how the created polygon overlaps with other data layers.

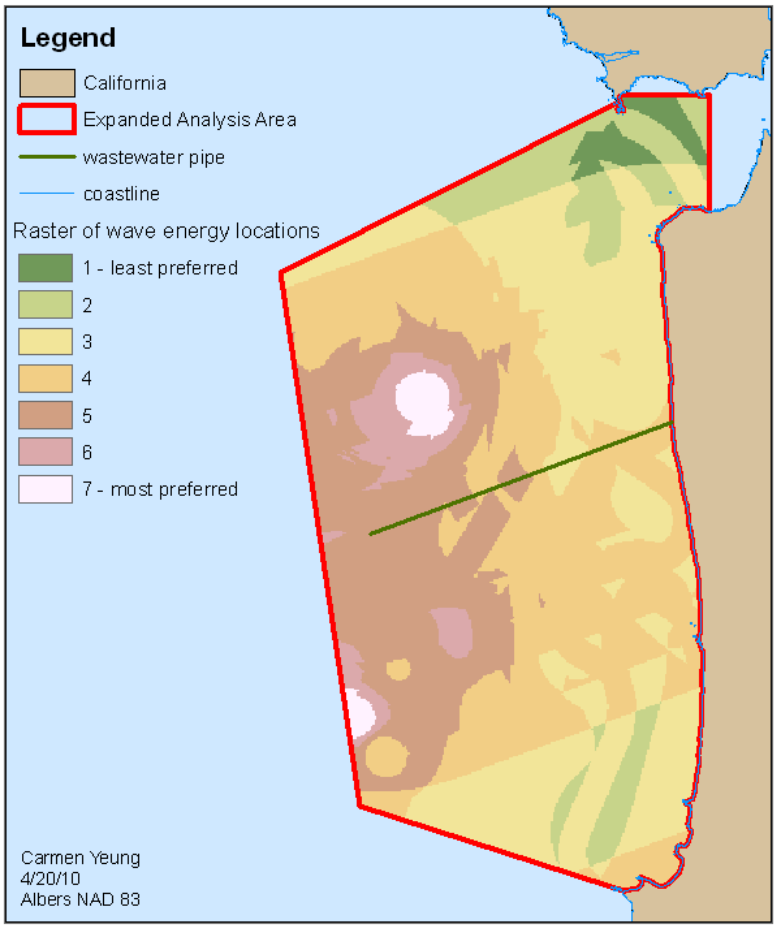
Discussion

In Figure 4, the red areas are the preferred locations for a wave energy project given the reclassification within each criterion and the percentage setting of the Weighted Overlay. In my weights, I placed a strong emphasis on wave height, which is reflected in this output since the deep red spots are locations with the largest wave heights.

The goal of this tool is to allow stakeholders to visualize tradeoffs based on the decisions they make. In this tool, stakeholders have two ways to influence the resulting raster. First, stakeholder can completely change the binning of their data within a criterion and reclassify it. Secondly by changing the distribution of percent influence among the different criteria in the Weighted Overlay tool, stakeholders could rank the importance of each factor. This allows stakeholders to visually understand the tradeoffs associated with ranking one factor over another. The resulting output is a raster of the preferred locations for a wave energy project.

To strengthen the visualization of tradeoffs, the Selecting Project Sites model allows users to see the impacts or benefits of a specific site selected to be a wave energy location. I hope this tool will provide guidance for stakeholders to make informed planning decisions that balance conservation goals with project logistics.

Figure 4 – Resulting raster layer from the Weighted Overlay tool, where the deep red areas indicated preferred locations for a wave energy project.



Shortcomings and solutions

From creating this tool, I have encountered several shortcomings, which include the need for real data, creating more accurate mock data, fashioning a user-friendly classification parameter, and limiting the shape of the Selecting Project Sites model. Below is a listing of my limitations and solutions:

1) Certainly, real data is needed. By using actual data, CCSF will be able to test the applicability of this tool and make modifications to enhance its usability. Additional data that should be incorporated include underwater cables locations and shipping lanes.
2) In creating the mock data, I believe by incorporating absence data within my analysis I would create a more accurate mock habitat modeling scenario for whale migrations and other environmental data sets. Absence data refers to recording an object of interest not being found at a specific location. As CCSF moves forward with their data collection, they should consider collecting absence data since this provides a comprehensive picture of where objects of interest might be and not be located.
3) From creating the classification parameter, I realized how tedious it would be to rank all the characteristics within a criterion. This is why I decided not to proceed in creating parameters for all the criteria. I want to modify the ranking interface to create a more user-friendly one.
4) In creating a polygon within the tool, it would be helpful to limit the polygon shape to be squares and rectangles and confine them to the mask area. Actual projects in the marine environment, such as marine protected areas (MPAs) to oil development facilities, are typically rectangular shaped, which enables easier management. By limiting polygon creation to squares and rectangles in the tool, this would better reflect the real-world limitations on the wave energy project site selection.

Next steps

Several key points to keep in mind about the interactive GIS tool are being aware of the composition of stakeholders and using this tool in conjunction with other available decision support tools and expert opinion. The interactive GIS tool is reliant on the make-up of stakeholders as many tools are. Therefore, it is important to incorporate a diverse range of stakeholders to avoid overrepresentation or underrepresentation from any one interest group. Equally important, this tool should not be used in isolation. The interactive GIS tool should be paired with other decision support tools and incorporate input and data verification from leading experts. Possible decision support tools of interest would be the Multipurpose Marine Cadastre paired with the California Legislative Atlas, MarineMap, and California Ocean Uses Atlas.

Further Improvements should be made to the tool in order to increase its usability such as calculating summaries of the area and percentage of overlap between the created wave energy site polygon and data layers, and further examining the connectivity between the proposed energy sites with the larger marine environment. Currently, the created tool does not contain a mathematical aspect since real data is not yet available. To plan for the incorporation and analysis of real data in the interactive GIS tool, a next step would be to create a percentage and area summary of how the created wave energy site polygon overlaps with other data layers. For example, what is the total crabbing area that a proposed wave energy facility will cover? How many grey whale sighting might be within the wave energy project? Another analysis component that could be added to the tool would be to examine the ecological importance of the selected project area in terms of connectivity with the large marine environment. For example, is this area an

important spawning ground for marine invertebrate and vertebrate species? Is this an ecologically important area that should be preserved? These mathematical components would create a more robust tool and allow users to have a more in-depth understanding of their decisions on the environmental and socioeconomic factors.

In moving forward with this GIS tool, I hope that CCSF will built off this initial tool by adding more data layers to it such as areas with economically valuable crabbing grounds and adding mathematical components to the tool to meet their needs.

Conclusion

The goal of my Master's Project is to assist CCSF in moving the Oceanside Wave Energy Project forward by gaining a better understanding of the regulatory framework, identifying decision support tools that account for stakeholder input in the site evaluation, and creating an interactive GIS tool to analyze data for the specific, small resolution project area. Together, these products help stakeholders understand the impact of a wave energy project on different regulatory, environmental, and socioeconomic criteria in San Francisco, CA.

In reviewing the federal and state regulations concerning hydrokinetic projects, CCSF can take several short- and long-term actions to overcome the regulatory challenges. The short-term actions include: establishing early and frequent communication with federal and state managing agencies, continuing to apply for the MMS lease and FERC permit to maintain project size flexibility, pursuing private-public partnerships for project funding, and establishing better residential and scientific representation to secure public support. CCSF can implement the following long-term actions: urge for consist treatment of municipalities by FERC and MMS, encourage MMS to provide transparent decision-making, unit with other hydrokinetic industry leaders, politicians, and renewable energy sectors to push for a streamlined regulatory structure and increased federal funding, and support policies that provide financial incentives and create customers for hydrokinetic projects.

In evaluating decision support tools, CCSF should use the Multipurpose Marine Cadastre paired with the California Legislative Atlas, MarineMap, and California Ocean

Uses Atlas tools. Each tool meets a different purpose; these tools will provide background on national ocean governance, incorporate biological data into determining the best project site, and serve as a model for mapping specific human and economic uses. With these tools and proper financial and technical support, CCSF will be able to make informed wave energy project decisions while meeting their environmental and socioeconomic objectives.

The goal of the interactive GIS tool is to provide stakeholders with the ability to visualize tradeoffs in the marine environment near San Francisco. This tool allows stakeholders to change the classification within a criterion and among criteria. As a result, the preferred locations for a wave energy project would change due to stakeholder preference. This tool framework requires further improvements to increase its applicability. Some improvements include calculating summaries of the area and percentage of overlap between the created wave energy project polygon and data layers, and calculating connectivity between the energy sites with the surrounding marine environment. With these mathematical additions and incorporation of other data layers, the tool would be more robust in enabling stakeholders to understand the impact of the energy project on different criteria.

Even with the regulatory understanding, decision support tools, and interactive GIS tool, CCSF will continue to face many challenges, ranging from regulatory barriers to technological uncertainty, in transforming the wave energy project into a reality. Despite these obstacles, I believe that CCSF can make wave energy a substantial portion of its energy portfolio and prove that wave energy is a viable option for the urban environment. The hope for an apparatus that can harness comparatively nonpolluting

energy from waves and generate significant amounts of electricity drives many researchers and developers in supporting the hydrokinetic sector. CCSF's wave energy project will add to the momentum of transforming the emerging hydrokinetic sector into an established, renewable energy source.

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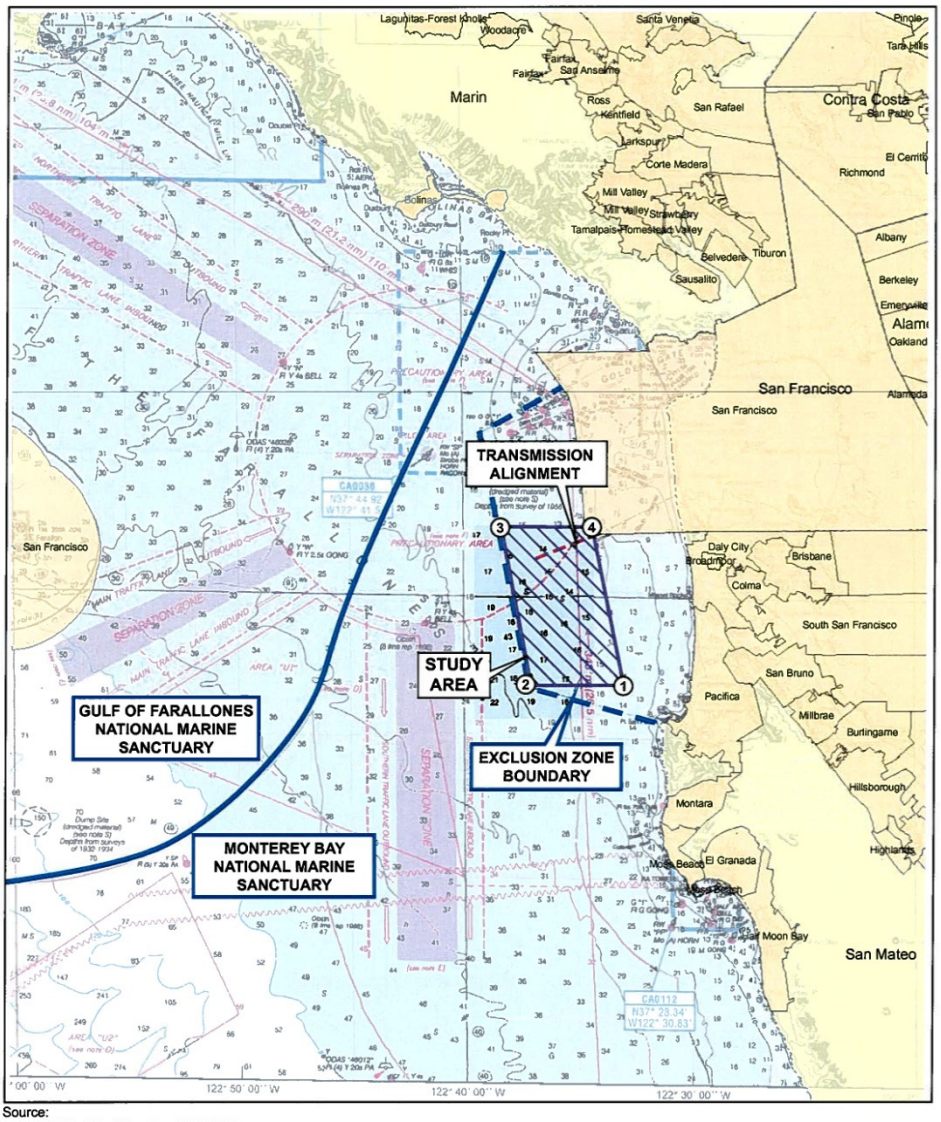
Appendices

Appendix 1 – Proposed Boundaries of SFPUC's Oceanside Wave Energy Project as submitted as part of the FERC PERMIT application



Source:
NOAA, 2001; Chart Number 1210PG02

Counties
City areas

2/9/09 vsa/hk ..T:\SFPUC Wave Energy\Fig 2_jurisd boundaries.ai

N

0 5
Scale in Miles

JURISDICTIONAL BOUNDARIES
Oceanside Wave Energy Project
February 2009 SFPUC
28067524 San Francisco, California
URS **FIGURE 2**

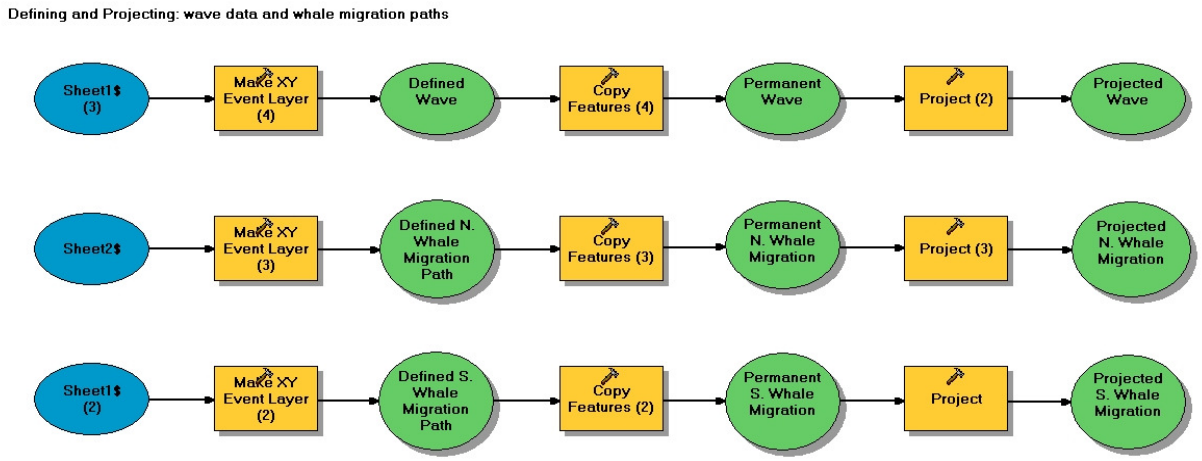
Appendix 2 – Graphic of creating wastewater pipeline and mask model

Script of creating wastewater pipeline and mask model

```
# ---------------------------------------------------------------------------
------
# data_prep.py
# Created on: Sat Apr 24 2010 09:09:57 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------
------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "S:\\Project\\Scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
```

```
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "S:\\Project\\Scratch"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
kb_boundary = "kb_boundary"
mask = "mask"
california = "california"
Mask_w_o_NMS = "S:\\Project\\Scratch\\mask_erase.shp"
Final_Mask = "S:\\Project\\Scratch\\mask_erase2.shp"
mask_final = "mask_final"
Wasterwater_Pipeline = "S:\\Project\\Scratch\\wastewater_pipe1.shp"
pipe_rough_shp = "S:\\Project\\Scratch\\pipe_rough.shp"

# Process: Erase...
gp.Erase_analysis(mask, kb_boundary, Mask_w_o_NMS, "")

# Process: Erase (2)...
gp.Erase_analysis(Mask_w_o_NMS, california, Final_Mask, "")

# Process: Clip (3)...
gp.Clip_analysis(pipe_rough_shp, mask_final, Wasterwater_Pipeline, "")
```

Appendix 3 - Graphic of projecting wave data and whale migration paths to Albers NAD 83 model



Script of projecting wave data and whale migration paths to Albers NAD 83 model

```
# ---------------------------------------------------------------------
------
# project.py
# Created on: Sat Apr 24 2010 09:18:21 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------
------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data
Management Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "S:\\Project\\Scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "S:\\Project\\Scratch"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
Defined_S__Whale_Migration_Path = "south_Layer2"
Permanent_S__Whale_Migration_Path =
"S:\\Project\\ToolData\\south_graywhale.shp"
Sheet1___2_ = "S:\\Project\\ToolData\\graywhale.xls\\Sheet1$"
Defined_N__Whale_Migration_Path = "north_Layer"
Permanent_N__Whale_Migration_Path =
"S:\\Project\\ToolData\\north_graywhale.shp"
Sheet2_ = "S:\\Project\\ToolData\\graywhale.xls\\Sheet2$"
Defined_Wave_Data = "wave_def"
Permanent_Wave_Data = "S:\\Project\\Scratch\\wave_data.shp"
Sheet1___3_ = "S:\\Project\\ToolData\\wdata.xls\\Sheet1$"
Projected_S__Whale_Migration_Path =
"S:\\Project\\Scratch\\swhale_project.shp"
```

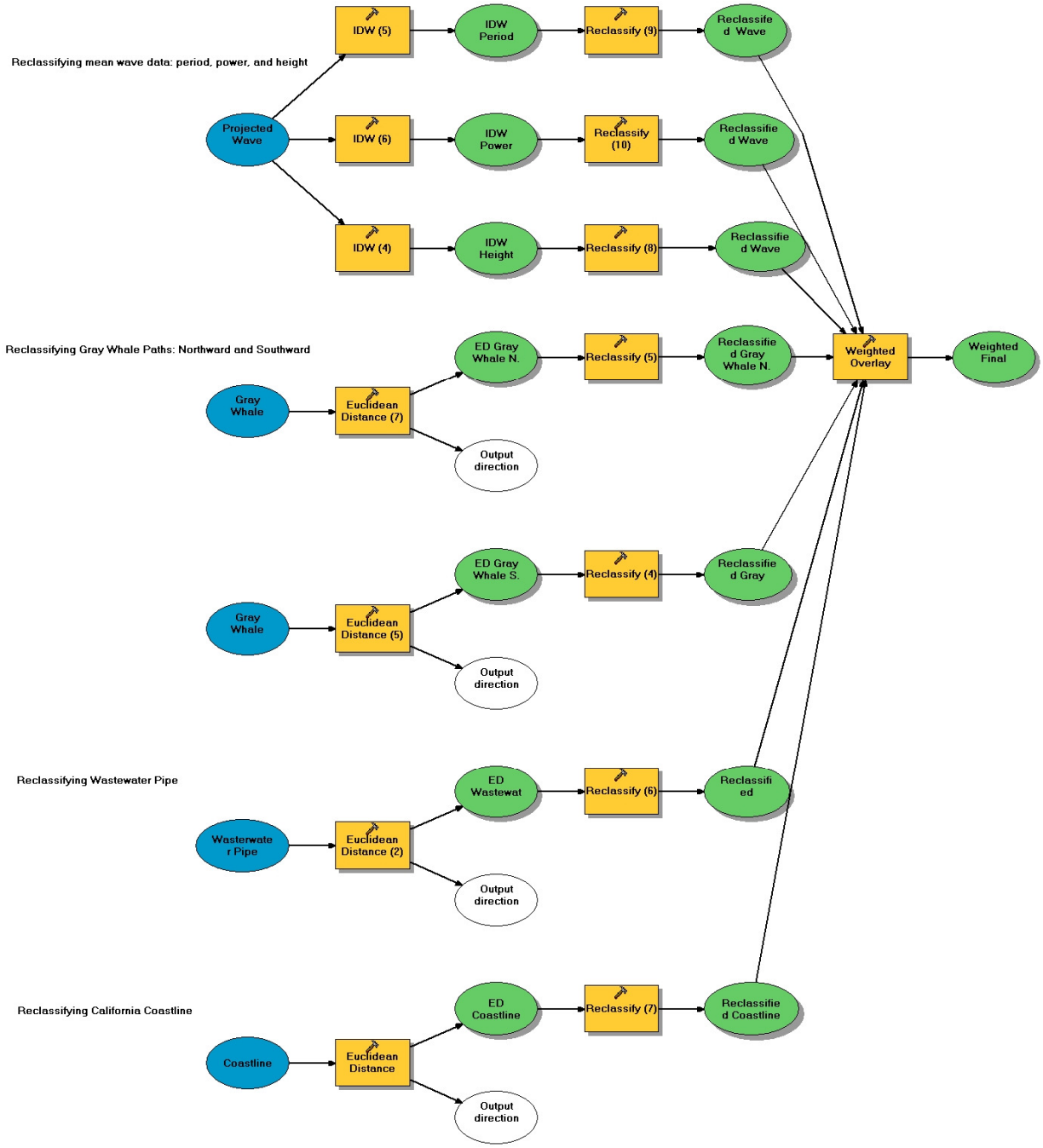
```
Projected_Wave_Data = "S:\\Project\\Scratch\\wave_data_Project.shp"
Projected_N__Whale_Migration_Path =
"S:\\Project\\Scratch\\north_graywhale_Project.shp"

# Process: Make XY Event Layer (2)...
gp.MakeXYEventLayer_management(Sheet1___2_, "X", "Y",
Defined_S__Whale_Migration_Path,
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]];IsHighPrecision")

# Process: Copy Features (2)...
tempEnvironment0 = gp.XYResolution
gp.XYResolution = ""
tempEnvironment1 = gp.scratchWorkspace
gp.scratchWorkspace = "S:\\Project\\Scratch"
tempEnvironment2 = gp.MTolerance
gp.MTolerance = ""
tempEnvironment3 = gp.randomGenerator
gp.randomGenerator = "0 ACM599"
tempEnvironment4 = gp.outputCoordinateSystem
gp.outputCoordinateSystem = ""
tempEnvironment5 = gp.snapRaster
gp.snapRaster = ""
tempEnvironment6 = gp.outputZFlag
gp.outputZFlag = "Same As Input"
tempEnvironment7 = gp.qualifiedFieldNames
gp.qualifiedFieldNames = "true"
tempEnvironment8 = gp.extent
gp.extent = "-233006.877772628 3956021.81654208 -219513.514449276
3981053.37118484"
tempEnvironment9 = gp.XYTolerance
gp.XYTolerance = ""
tempEnvironment10 = gp.cellSize
gp.cellSize = "MAXOF"
tempEnvironment11 = gp.outputZValue
gp.outputZValue = ""
tempEnvironment12 = gp.outputMFlag
gp.outputMFlag = "Same As Input"
tempEnvironment13 = gp.geographicTransformations
gp.geographicTransformations = ""
tempEnvironment14 = gp.ZResolution
gp.ZResolution = ""
tempEnvironment15 = gp.mask
gp.mask = "S:\\Project\\Scratch\\mask_final.shp"
tempEnvironment16 = gp.workspace
gp.workspace = "S:\\Project\\Scratch"
tempEnvironment17 = gp.MResolution
gp.MResolution = ""
tempEnvironment18 = gp.ZTolerance
gp.ZTolerance = ""
gp.CopyFeatures_management(Defined_S__Whale_Migration_Path,
Permanent_S__Whale_Migration_Path, "", "0", "0", "0")
gp.XYResolution = tempEnvironment0
gp.scratchWorkspace = tempEnvironment1
```

```
gp.MTolerance = tempEnvironment2
gp.randomGenerator = tempEnvironment3
gp.outputCoordinateSystem = tempEnvironment4
gp.snapRaster = tempEnvironment5
gp.outputZFlag = tempEnvironment6
gp.qualifiedFieldNames = tempEnvironment7
gp.extent = tempEnvironment8
gp.XYTolerance = tempEnvironment9
gp.cellSize = tempEnvironment10
gp.outputZValue = tempEnvironment11
gp.outputMFlag = tempEnvironment12
gp.geographicTransformations = tempEnvironment13
gp.ZResolution = tempEnvironment14
gp.mask = tempEnvironment15
gp.workspace = tempEnvironment16
gp.MResolution = tempEnvironment17
gp.ZTolerance = tempEnvironment18

# Process: Project...
gp.Project_management(Permanent_S__Whale_Migration_Path,
Projected_S__Whale_Migration_Path,
"PROJCS['Albers_NAD_83',GEOGCS['GCS_North_American_1983',DATUM['D_North
_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['G
reenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Albers'],
PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',-
40.0],PARAMETER['Central_Meridian',-
120.0],PARAMETER['Standard_Parallel_1',34.0],PARAMETER['Standard_Parall
el_2',40.5],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]",
"",
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]]")

# Process: Make XY Event Layer (4)...
gp.MakeXYEventLayer_management(Sheet1___3_, "x", "y",
Defined_Wave_Data,
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]];IsHighPrecision")

# Process: Copy Features (4)...
gp.CopyFeatures_management(Defined_Wave_Data, Permanent_Wave_Data, "",
"0", "0", "0")

# Process: Project (2)...
gp.Project_management(Permanent_Wave_Data, Projected_Wave_Data,
"PROJCS['Albers_NAD_83',GEOGCS['GCS_North_American_1983',DATUM['D_North
_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['G
reenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Albers'],
PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',-
40.0],PARAMETER['Central_Meridian',-
120.0],PARAMETER['Standard_Parallel_1',34.0],PARAMETER['Standard_Parall
el_2',40.5],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]",
"",
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
```

```
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]]")

# Process: Make XY Event Layer (3)...
gp.MakeXYEventLayer_management(Sheet2_, "X", "Y",
Defined_N__Whale_Migration_Path,
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]];IsHighPrecision")

# Process: Copy Features (3)...
tempEnvironment0 = gp.XYResolution
gp.XYResolution = ""
tempEnvironment1 = gp.scratchWorkspace
gp.scratchWorkspace = "S:\\Project\\Scratch"
tempEnvironment2 = gp.MTolerance
gp.MTolerance = ""
tempEnvironment3 = gp.randomGenerator
gp.randomGenerator = "0 ACM599"
tempEnvironment4 = gp.outputCoordinateSystem
gp.outputCoordinateSystem = ""
tempEnvironment5 = gp.snapRaster
gp.snapRaster = ""
tempEnvironment6 = gp.outputZFlag
gp.outputZFlag = "Same As Input"
tempEnvironment7 = gp.qualifiedFieldNames
gp.qualifiedFieldNames = "true"
tempEnvironment8 = gp.extent
gp.extent = "-233006.877772628 3956021.81654208 -219513.514449276
3981053.37118484"
tempEnvironment9 = gp.XYTolerance
gp.XYTolerance = ""
tempEnvironment10 = gp.cellSize
gp.cellSize = "MAXOF"
tempEnvironment11 = gp.outputZValue
gp.outputZValue = ""
tempEnvironment12 = gp.outputMFlag
gp.outputMFlag = "Same As Input"
tempEnvironment13 = gp.geographicTransformations
gp.geographicTransformations = ""
tempEnvironment14 = gp.ZResolution
gp.ZResolution = ""
tempEnvironment15 = gp.mask
gp.mask = "S:\\Project\\Scratch\\mask_final.shp"
tempEnvironment16 = gp.workspace
gp.workspace = "S:\\Project\\Scratch"
tempEnvironment17 = gp.MResolution
gp.MResolution = ""
tempEnvironment18 = gp.ZTolerance
gp.ZTolerance = ""
gp.CopyFeatures_management(Defined_N__Whale_Migration_Path,
Permanent_N__Whale_Migration_Path, "", "0", "0", "0")
gp.XYResolution = tempEnvironment0
gp.scratchWorkspace = tempEnvironment1
gp.MTolerance = tempEnvironment2
```

```
gp.randomGenerator = tempEnvironment3
gp.outputCoordinateSystem = tempEnvironment4
gp.snapRaster = tempEnvironment5
gp.outputZFlag = tempEnvironment6
gp.qualifiedFieldNames = tempEnvironment7
gp.extent = tempEnvironment8
gp.XYTolerance = tempEnvironment9
gp.cellSize = tempEnvironment10
gp.outputZValue = tempEnvironment11
gp.outputMFlag = tempEnvironment12
gp.geographicTransformations = tempEnvironment13
gp.ZResolution = tempEnvironment14
gp.mask = tempEnvironment15
gp.workspace = tempEnvironment16
gp.MResolution = tempEnvironment17
gp.ZTolerance = tempEnvironment18

# Process: Project (3)...
gp.Project_management(Permanent_N__Whale_Migration_Path,
Projected_N__Whale_Migration_Path,
"PROJCS['Albers_NAD_83',GEOGCS['GCS_North_American_1983',DATUM['D_North
_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['G
reenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Albers'],
PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',-
40.0],PARAMETER['Central_Meridian',-
120.0],PARAMETER['Standard_Parallel_1',34.0],PARAMETER['Standard_Parall
el_2',40.5],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]",
"",
"GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROI
D['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['De
gree',0.0174532925199433]]")
```

Appendix 4 - Graphic of employing IDW on wave data and Eculidean Distance on coastline, wastewater pipe, and whale migration paths, followed by reclassification of the outputs



Script of employing IDW on wave data and Eculidean Distance on coastline, wastewater pipe, and whale migration paths, followed by reclassification of the outputs

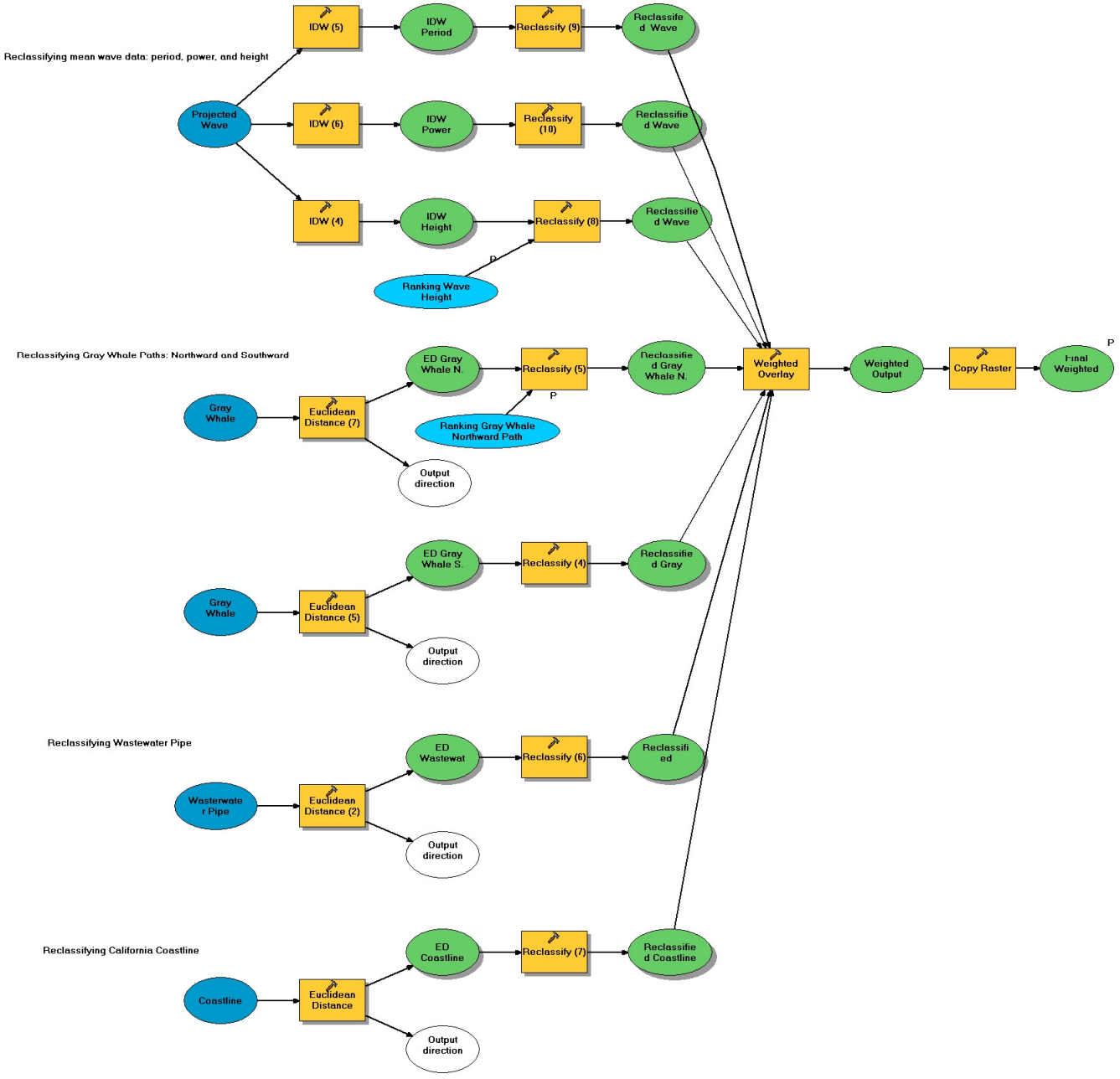
```
# ---------------------------------------------------------------------
------
# Analysis_model.py
# Created on: Sat Apr 24 2010 09:03:29 PM
#   (generated by ArcGIS/ModelBuilder)
# Description:
# This model ranks the characteristics within each of the different
logistical and conservation criteria of the wave energy project using
the Euclidean Distance and IDW tools.  This allows for comparison
within a specific criterion.  The weighted overlay tool assigns weights
to each of the different criteria, allowing for comparison between
different types of data.  The output is a single weighted raster of the
different criteria: wave data, whale migration, wastewater pipeline and
coastline.
# ---------------------------------------------------------------------
------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial
Analyst Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "S:\\Project\\Scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "-233006.877772628 3956021.81654208 -219513.514449276
3981053.37118484"
gp.XYTolerance = ""
gp.cellSize = "MAXOF"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = "S:\\Project\\Scratch\\mask_final.shp"
gp.workspace = "S:\\Project\\Scratch"
```

```
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
ED_Wastewater_Pipe = "S:\\Project\\Scratch\\eudist_pipe2"
Output_direction_raster__2_ = ""
Coastline = "coastline"
Wasterwater_Pipe = "wastewater_pipe"
ED_Gray_Whale_S__Path = "S:\\Project\\Scratch\\EucDist_sgra2"
Output_direction_raster__5_ = ""
Reclassified_Wastewater_Pipe = "S:\\Project\\Scratch\\pipe_recl2"
Reclassified_Coastline = "S:\\Project\\Scratch\\coast_recl2"
ED_Coastline = "S:\\Project\\Scratch\\eudist_coast2"
Output_direction_raster = ""
ED_Gray_Whale_N__Path = "S:\\Project\\Scratch\\EucDist_ngra2"
Output_direction_raster__7_ = ""
Gray_Whale_Southward_Path = "gray_southpath2"
Reclassified_Gray_Whale_S__Path = "S:\\Project\\Scratch\\sgray_recl2"
Gray_Whale_Northward_Path = "gray_northpath2"
Reclassified_Gray_Whale_N__Path = "S:\\Project\\Scratch\\ngray_recl2"
Projected_Wave_Data = "wave_data_Project"
Reclassified_Wave_Height = "S:\\Project\\Scratch\\height_recl"
Reclassifed__Wave_Period = "S:\\Project\\Scratch\\period_recl"
Reclassified_Wave_Power = "S:\\Project\\Scratch\\power_recl3"
IDW_Height = "S:\\Project\\Scratch\\Idw_height"
IDW_Period = "S:\\Project\\Scratch\\Idw_period"
IDW_Power = "S:\\Project\\Scratch\\Idw_power"
Weighted_Final_Output = "S:\\Project\\Scratch\\overlay2"

# Process: Euclidean Distance (2)...
gp.EucDistance_sa(Wasterwater_Pipe, ED_Wastewater_Pipe, "", "55",
Output_direction_raster__2_)

# Process: Euclidean Distance (5)...
gp.EucDistance_sa(Gray_Whale_Southward_Path, ED_Gray_Whale_S__Path, "",
"55", Output_direction_raster__5_)

# Process: Euclidean Distance...
gp.EucDistance_sa(Coastline, ED_Coastline, "", "55",
Output_direction_raster)

# Process: Euclidean Distance (7)...
gp.EucDistance_sa(Gray_Whale_Northward_Path, ED_Gray_Whale_N__Path, "",
"55", Output_direction_raster__7_)

# Process: IDW (4)...
gp.Idw_sa(Projected_Wave_Data, "w_mean_hei", IDW_Height, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (8)...
gp.Reclassify_sa(IDW_Height, "Value", "0.54031854867935181
1.0874698920683428 5;1.0874698920683428 1.6346212354573337
10;1.6346212354573337 2.1817725788463247 20;2.1817725788463247
2.7289239222353157 30;2.7289239222353157 3.2760752656243066
```

```
40;3.2760752656243066 3.8232266090132976 50;3.8232266090132976
4.3703779524022881 60;4.3703779524022881 4.9175292957912795
70;4.9175292957912795 5.4646806391802709 80;5.4646806391802709
6.0118319825692623 90;6.0118319825692623 6.558983325958252 100",
Reclassified_Wave_Height, "DATA")

# Process: IDW (5)...
gp.Idw_sa(Projected_Wave_Data, "w_mean_per", IDW_Period, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (9)...
gp.Reclassify_sa(IDW_Period, "Value", "4.2006115913391113
5.3185447216033932 5;5.3185447216033932 6.4364778518676751
10;6.4364778518676751 7.5544109821319569 15;7.5544109821319569
8.6723441123962388 20;8.6723441123962388 9.7902772426605207
25;9.7902772426605207 10.908210372924803 30;10.908210372924803
12.026143503189084 35;12.026143503189084 13.144076633453366
40;13.144076633453366 14.262009763717648 50;14.262009763717648
15.379942893981934 60", Reclassifed__Wave_Period, "DATA")

# Process: IDW (6)...
gp.Idw_sa(Projected_Wave_Data, "wave_mean_", IDW_Power, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (10)...
gp.Reclassify_sa(IDW_Power, "Value", "1.0692613124847412
21.83857185190374 1;21.83857185190374 42.60788239132274
5;42.60788239132274 63.377192930741742 20;63.377192930741742
84.146503470160738 30;84.146503470160738 104.91581400957973
40;104.91581400957973 125.68512454899873 50;125.68512454899873
146.45443508841774 60;146.45443508841774 167.22374562783673
70;167.22374562783673 187.99305616725573 80;187.99305616725573
208.76236670667473 90;208.76236670667473 230 100",
Reclassified_Wave_Power, "DATA")

# Process: Reclassify (4)...
gp.Reclassify_sa(ED_Gray_Whale_S__Path, "Value", "0 1025.53984375
0;1025.53984375 2051.0796875000001 5;2051.0796875000001
3076.6195312500004 10;3076.6195312500004 4102.1593750000002
15;4102.1593750000002 5127.69921875 30;5127.69921875 6153.2390624999998
40;6153.2390624999998 7178.7789062499996 50;7178.7789062499996
8204.3187500000004 60;8204.3187500000004 9229.8585937500011
70;9229.8585937500011 10255.3984375 80",
Reclassified_Gray_Whale_S__Path, "DATA")

# Process: Reclassify (5)...
gp.Reclassify_sa(ED_Gray_Whale_N__Path, "Value", "0 889.04570312500005
0;889.04570312500005 1778.0914062500001 5;1778.0914062500001
2667.1371093750004 10;2667.1371093750004 3556.1828125000002
15;3556.1828125000002 4445.228515625 30;4445.228515625
5334.2742187499998 40;5334.2742187499998 6223.3199218749996
50;6223.3199218749996 7112.3656249999995 60;7112.3656249999995
8001.4113281249993 70;8001.4113281249993 8890.45703125 80",
Reclassified_Gray_Whale_N__Path, "DATA")
```

```
# Process: Reclassify (6)...
gp.Reclassify_sa(ED_Wastewater_Pipe, "Value", "0 1355.20048828125
100;1355.20048828125 2710.4009765625001 90;2710.4009765625001
4065.6014648437504 80;4065.6014648437504 5420.8019531250002
70;5420.8019531250002 6776.00244140625 60;6776.00244140625
8131.2029296874998 40;8131.2029296874998 9486.4034179687496
30;9486.4034179687496 10841.60390625 20;10841.60390625
12196.804394531251 10;12196.804394531251 13552.0048828125 5",
Reclassified_Wastewater_Pipe, "DATA")

# Process: Reclassify (7)...
gp.Reclassify_sa(ED_Coastline, "Value", "0 2349.6009765624999
50;2349.6009765624999 4699.2019531249998 40;4699.2019531249998
7048.8029296874993 30;7048.8029296874993 9398.4039062499996
20;9398.4039062499996 11748.0048828125 10", Reclassified_Coastline,
"DATA")

# Process: Weighted Overlay...
gp.WeightedOverlay_sa("('S:\\Project\\Scratch\\height_recl' 30 'VALUE'
(5 1; 10 1; 20 2; 30 3; 40 4; 50 5; 60 6; 70 7; 80 8; 90 9; 100
9;NODATA NODATA); 'S:\\Project\\Scratch\\period_recl' 5 'VALUE' (5 1;
10 2; 15 3; 20 4; 25 5; 30 6; 35 7; 40 8; 50 9; 60 9;NODATA NODATA);
'S:\\Project\\Scratch\\power_recl3' 20 'VALUE' (1 1; 5 2; 20 3; 30 4;
40 5; 50 6; 60 7; 70 8; 80 9; 90 9; 100 9;NODATA 1);
'S:\\Project\\Scratch\\sgray_recl2' 8 'VALUE' (0 1; 5 5; 10 1; 15 3; 30
4; 40 5; 50 6; 60 7; 70 8; 80 9;NODATA 2);
'S:\\Project\\Scratch\\ngray_recl2' 8 'VALUE' (0 1; 5 5; 10 1; 15 3; 30
1; 40 1; 50 1; 60 1; 70 1; 80 1;NODATA 4);
'S:\\Project\\Scratch\\pipe_recl2' 25 'VALUE' (5 5; 10 1; 20 1; 30 1;
40 5; 60 6; 70 7; 80 8; 90 9; 100 9;NODATA NODATA);
'S:\\Project\\Scratch\\coast_recl2' 4 'VALUE' (10 1; 20 1; 30 1; 40 1;
50 1;NODATA NODATA));1 9 1", Weighted_Final_Output)
```

Appendix 5 - Graphic of employing IDW on wave data and Eculidean Distance on coastline, wastewater pipe, and whale migration paths, followed by reclassification parameter of the wave height and northward whale migration outputs



Script of employing IDW on wave data and Eculidean Distance on coastline, wastewater pipe, and whale migration paths, followed by reclassification parameter of the wave height and northward whale migration outputs

```
# ---------------------------------------------------------------------------
------
# Analysis_model with parameters.py
# Created on: Sat Apr 24 2010 09:08:32 PM
#   (generated by ArcGIS/ModelBuilder)
# Usage: Analysis_model with parameters <Ranking_Wave_Height>
<Ranking_Gray_Whale_Northward_Path> <Final_Weighted_Output>
# Description:
# This model gives the same results as the Analysis model (see general
description).  In order to allow users to determine the ranking scheme
for the criteria, two parameters were added.  The added parameters were
wave height and northward whale migration.  This also shows how ranking
can change how conservation-oriented a project can be.

***WARNING***
Running this model will cause many of the data on the map to become
invalid due to the file replacement that occurs.  Please run this model
last when exploring the different models/functions of this project.



# ---------------------------------------------------------------------------
------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial
Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data
Management Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "S:\\Project\\Scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "-233006.877772628 3956021.81654208 -219513.514449276
3981053.37118484"
```

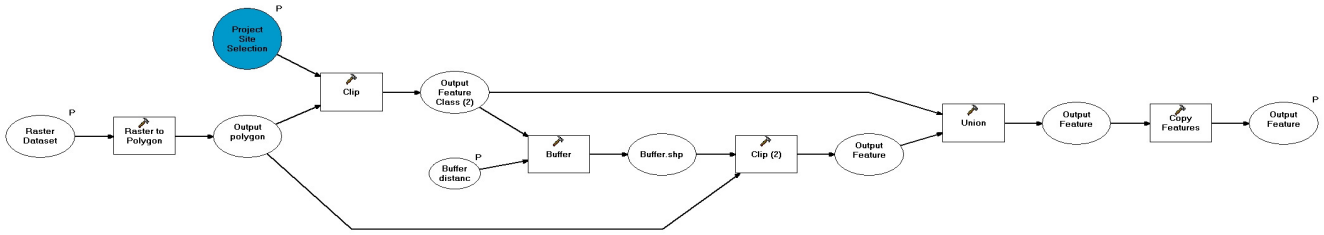
```
gp.XYTolerance = ""
gp.cellSize = "MAXOF"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = "S:\\Project\\Scratch\\mask_final.shp"
gp.workspace = "S:\\Project\\Scratch"
gp.MResolution = ""
gp.ZTolerance = ""

# Script arguments...
Ranking_Wave_Height = sys.argv[1]
if Ranking_Wave_Height == '#':
 Ranking_Wave_Height = "0.54031854867935181 1.0874698920683428
5;1.0874698920683428 1.6346212354573337 10;1.6346212354573337
2.1817725788463247 20;2.1817725788463247 2.7289239222353157
30;2.7289239222353157 3.2760752656243066 40;3.2760752656243066
3.8232266090132976 50;3.8232266090132976 4.3703779524022881
60;4.3703779524022881 4.9175292957912795 70;4.9175292957912795
5.4646806391802709 80;5.4646806391802709 6.0118319825692623
90;6.0118319825692623 6.558983325958252 100" # provide a default value
if unspecified

Ranking_Gray_Whale_Northward_Path = sys.argv[2]
if Ranking_Gray_Whale_Northward_Path == '#':
 Ranking_Gray_Whale_Northward_Path = "0 889.04570312500005
0;889.04570312500005 1778.0914062500001 5;1778.0914062500001
2667.1371093750004 10;2667.1371093750004 3556.1828125000002
15;3556.1828125000002 4445.228515625 30;4445.228515625
5334.2742187499998 40;5334.2742187499998 6223.3199218749996
50;6223.3199218749996 7112.3656249999995 60;7112.3656249999995
8001.4113281249993 70;8001.4113281249993 8890.45703125 80" # provide a
default value if unspecified

Final_Weighted_Output = sys.argv[3]
if Final_Weighted_Output == '#':
 Final_Weighted_Output =
"S:\\Project\\Scratch\\overlay2_CopyRaster.img" # provide a default
value if unspecified

# Local variables...
ED_Wastewater_Pipe = "S:\\Project\\Scratch\\eudist_pipe2"
Output_direction_raster__2_ = ""
Coastline = "coastline"
Wasterwater_Pipe = "wastewater_pipe"
ED_Gray_Whale_S__Path = "S:\\Project\\Scratch\\EucDist_sgra2"
Output_direction_raster__5_ = ""
Reclassified_Wastewater_Pipe = "S:\\Project\\Scratch\\pipe_recl2"
Reclassified_Coastline = "S:\\Project\\Scratch\\coast_recl2"
ED_Coastline = "S:\\Project\\Scratch\\eudist_coast2"
Output_direction_raster = ""
ED_Gray_Whale_N__Path = "S:\\Project\\Scratch\\EucDist_ngra2"
Output_direction_raster__7_ = ""
Gray_Whale_Southward_Path = "gray_southpath2"
```

```
Reclassified_Gray_Whale_S__Path = "S:\\Project\\Scratch\\sgray_recl2"
Gray_Whale_Northward_Path = "gray_northpath2"
Reclassified_Gray_Whale_N__Path = "S:\\Project\\Scratch\\ngray_recl2"
Projected_Wave_Data = "wave_data_Project"
Reclassified_Wave_Height = "S:\\Project\\Scratch\\height_recl"
Reclassifed__Wave_Period = "S:\\Project\\Scratch\\period_recl"
Reclassified_Wave_Power = "S:\\Project\\Scratch\\power_recl3"
IDW_Height = "S:\\Project\\Scratch\\Idw_height"
IDW_Period = "S:\\Project\\Scratch\\Idw_period"
IDW_Power = "S:\\Project\\Scratch\\Idw_power"
Weighted_Output = "S:\\Project\\Scratch\\overlay2"

# Process: Euclidean Distance (2)...
gp.EucDistance_sa(Wasterwater_Pipe, ED_Wastewater_Pipe, "", "55",
Output_direction_raster__2_)

# Process: Euclidean Distance (5)...
gp.EucDistance_sa(Gray_Whale_Southward_Path, ED_Gray_Whale_S__Path, "",
"55", Output_direction_raster__5_)

# Process: Euclidean Distance...
gp.EucDistance_sa(Coastline, ED_Coastline, "", "55",
Output_direction_raster)

# Process: Euclidean Distance (7)...
gp.EucDistance_sa(Gray_Whale_Northward_Path, ED_Gray_Whale_N__Path, "",
"55", Output_direction_raster__7_)

# Process: IDW (4)...
gp.Idw_sa(Projected_Wave_Data, "w_mean_hei", IDW_Height, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (8)...
gp.Reclassify_sa(IDW_Height, "Value", Ranking_Wave_Height,
Reclassified_Wave_Height, "DATA")

# Process: IDW (5)...
gp.Idw_sa(Projected_Wave_Data, "w_mean_per", IDW_Period, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (9)...
gp.Reclassify_sa(IDW_Period, "Value", "4.2006115913391113
5.3185447216033932 5;5.3185447216033932 6.4364778518676751
10;6.4364778518676751 7.5544109821319569 15;7.5544109821319569
8.6723441123962388 20;8.6723441123962388 9.7902772426605207
25;9.7902772426605207 10.908210372924803 30;10.908210372924803
12.026143503189084 35;12.026143503189084 13.144076633453366
40;13.144076633453366 14.262009763717648 50;14.262009763717648
15.379942893981934 60", Reclassifed__Wave_Period, "DATA")

# Process: IDW (6)...
gp.Idw_sa(Projected_Wave_Data, "wave_mean_", IDW_Power, "55", "2",
"VARIABLE 12", "")

# Process: Reclassify (10)...
```

```
gp.Reclassify_sa(IDW_Power, "Value", "1.0692613124847412
21.83857185190374 1;21.83857185190374 42.60788239132274
5;42.60788239132274 63.377192930741742 20;63.377192930741742
84.146503470160738 30;84.146503470160738 104.91581400957973
40;104.91581400957973 125.68512454899873 50;125.68512454899873
146.45443508841774 60;146.45443508841774 167.22374562783673
70;167.22374562783673 187.99305616725573 80;187.99305616725573
208.76236670667473 90;208.76236670667473 230 100",
Reclassified_Wave_Power, "DATA")

# Process: Reclassify (4)...
gp.Reclassify_sa(ED_Gray_Whale_S__Path, "Value", "0 1025.53984375
0;1025.53984375 2051.0796875000001 5;2051.0796875000001
3076.6195312500004 10;3076.6195312500004 4102.1593750000002
15;4102.1593750000002 5127.69921875 30;5127.69921875 6153.2390624999998
40;6153.2390624999998 7178.7789062499996 50;7178.7789062499996
8204.3187500000004 60;8204.3187500000004 9229.8585937500011
70;9229.8585937500011 10255.3984375 80",
Reclassified_Gray_Whale_S__Path, "DATA")

# Process: Reclassify (5)...
gp.Reclassify_sa(ED_Gray_Whale_N__Path, "Value",
Ranking_Gray_Whale_Northward_Path, Reclassified_Gray_Whale_N__Path,
"DATA")

# Process: Reclassify (6)...
gp.Reclassify_sa(ED_Wastewater_Pipe, "Value", "0 1355.20048828125
100;1355.20048828125 2710.4009765625001 90;2710.4009765625001
4065.6014648437504 80;4065.6014648437504 5420.8019531250002
70;5420.8019531250002 6776.00244140625 60;6776.00244140625
8131.2029296874998 40;8131.2029296874998 9486.4034179687496
30;9486.4034179687496 10841.60390625 20;10841.60390625
12196.804394531251 10;12196.804394531251 13552.0048828125 5",
Reclassified_Wastewater_Pipe, "DATA")

# Process: Reclassify (7)...
gp.Reclassify_sa(ED_Coastline, "Value", "0 2349.6009765624999
50;2349.6009765624999 4699.2019531249998 40;4699.2019531249998
7048.8029296874993 30;7048.8029296874993 9398.4039062499996
20;9398.4039062499996 11748.0048828125 10", Reclassified_Coastline,
"DATA")

# Process: Weighted Overlay...
gp.WeightedOverlay_sa("('S:\\Project\\Scratch\\height_recl' 30 'VALUE'
(5 1; 10 1; 20 2; 30 3; 40 4; 50 5; 60 6; 70 7; 80 8; 90 9; 100
9;NODATA NODATA); 'S:\\Project\\Scratch\\period_recl' 5 'VALUE' (5 1;
10 2; 15 3; 20 4; 25 5; 30 6; 35 7; 40 8; 50 9; 60 9;NODATA NODATA);
'S:\\Project\\Scratch\\power_recl3' 20 'VALUE' (1 1; 5 2; 20 3; 30 4;
40 5; 50 6; 60 7; 70 8; 80 9; 90 9; 100 9;NODATA 1);
'S:\\Project\\Scratch\\sgray_recl2' 8 'VALUE' (0 1; 5 5; 10 1; 15 3; 30
4; 40 5; 50 6; 60 7; 70 8; 80 9;NODATA 2);
'S:\\Project\\Scratch\\ngray_recl2' 8 'VALUE' (0 1; 5 5; 10 1; 15 3; 30
1; 40 1; 50 1; 60 1; 70 1; 80 1;NODATA 4);
'S:\\Project\\Scratch\\pipe_recl2' 25 'VALUE' (5 5; 10 1; 20 1; 30 1;
40 5; 60 6; 70 7; 80 8; 90 9; 100 9;NODATA NODATA);
```

```
'S:\\Project\\Scratch\\coast_recl2' 4 'VALUE' (10 1; 20 1; 30 1; 40 1;
50 1;NODATA NODATA));1 9 1", Weighted_Output)

# Process: Copy Raster...
gp.CopyRaster_management(Weighted_Output, Final_Weighted_Output, "",
"", "", "NONE", "NONE", "")
```

Appendix 6 – Graphic of Selecting Project Sites model, where user can create a polygon, representing the project location, to view how it overlaps with other data layers



Script of Selecting Project Sites model, where user can create a polygon, representing the project location, to view how it overlaps with other data layers

```
# ---------------------------------------------------------------------
------
# selecting project site.py
# Created on: Sat Apr 24 2010 09:19:14 PM
#   (generated by ArcGIS/ModelBuilder)
# Usage: selecting project site <Raster_Dataset> <Output_Feature_Class>
<Project_Site_Selection> <Buffer_distance>
# Description:
# This model allows a user to create a polygon, which represents a mock
project site.  From this polygon, users are able to see how a site
selection will impact different weighted criteria (in raster format).
A user can also create a buffer for the polygon.  The selected polygon
and buffer are clipped from the user-designated raster layer.
# ---------------------------------------------------------------------
------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data
Management Tools.tbx")
```

```
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "S:\\Project\\Scratch"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.snapRaster = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.cellSize = "MAXOF"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "S:\\Project\\Scratch"
gp.MResolution = ""
gp.ZTolerance = ""

# Script arguments...
Raster_Dataset = sys.argv[1]

Output_Feature_Class = sys.argv[2]
if Output_Feature_Class == '#':c
 Output_Feature_Class = "S:\\Project\\Scratch\\Union_CopyFeatures.shp"
# provide a default value if unspecified

Project_Site_Selection = sys.argv[3]
if Project_Site_Selection == '#':
 Project_Site_Selection = "in_memory\\{A0B3550D-396D-4021-A06E-
1DCE63B1BB98}" # provide a default value if unspecified

Buffer_distance = sys.argv[4]

# Local variables...
Output_polygon_features = ""
Output_Feature_Class__2_ = ""
Buffer_shp = ""
Output_Feature_Class__3_ = ""
Output_Feature_Class__4_ = "S:\\Project\\Scratch\\Union.shp"

# Process: Raster to Polygon...
gp.RasterToPolygon_conversion(Raster_Dataset, Output_polygon_features,
"SIMPLIFY", "")

# Process: Clip...
gp.Clip_analysis(Output_polygon_features, Project_Site_Selection,
Output_Feature_Class__2_, "")

# Process: Buffer...
```

```
gp.Buffer_analysis(Output_Feature_Class__2_, Buffer_shp,
Buffer_distance, "FULL", "ROUND", "ALL", "")

# Process: Clip (2)...
gp.Clip_analysis(Output_polygon_features, Buffer_shp,
Output_Feature_Class__3_, "")

# Process: Union...
gp.Union_analysis("# #;# #", Output_Feature_Class__4_, "ALL", "",
"GAPS")

# Process: Copy Features...
gp.CopyFeatures_management(Output_Feature_Class__4_,
Output_Feature_Class, "", "0", "0", "0")
```