Report to the Twenty-Fourth Legislature
Regular Session of 2008

Requesting the Department of Land and Natural Resources to Report to the Legislature on Certain Aquatic Surf Resources in the State Including the Cost of Funding a Study on the Feasibility of Constructing Artificial Reefs

Prepared by

Department of Land and Natural Resources
State of Hawaii

In response to House Concurrent Resolution 174
Regular Session of 2007

November 2007

Requesting the Department of Land and Natural Resources to Report to the Legislature on Certain Aquatic Surf Resources in the State Including the Cost of Funding a Study on the Feasibility of Constructing Artificial Reefs

EXECUTIVE SUMMARY

House Concurrent Resolution (HCR) No. 174 adopted by the Twenty-Fourth Legislature of the State of Hawaii, Regular Session 2007, requested the Department of Land and Natural Resources (DLNR) to: 1) Gather information and statistics on the character of aquatic surf resources in the State, 2) Estimate the cost of a study to identify potential locations for artificial reefs designed for surfing and the cost of constructing such reefs, and 3) To designate the Waianae Coast on the Island of Oahu as its initial location for an artificial reef study.

There are numerous references on surfing locations and beaches in Hawaii. There are between 10-24 known (there may be many more unnamed) surf sites on Kauai. Maui has between 27 and 49 known surfing sites. Molokai has nine known surfing sites and Lanai has 10. The Big Island has between 23 and 55 surfing locations. Oahu has between 81-94 surf sites.

The cost for an artificial reef designed for surfing has three major components: 1) Site selection, 2) Design costs, and 3) Construction costs. It is estimated that the cost for an artificial reef for surfing ranges between $3,330,000-5,420,000, not including annual maintenance costs.

Without a study as outlined in the second objective of the resolutions, DLNR cannot determine if Waianae has a suitable site for a surfing reef.

Any initiative to develop a surfing reef needs to consider the following: 1) The benefit of a new surf site, 2) Reduction in beach erosion, 3) An increase in fish populations, 4) The stimulation of local businesses, 5) The cost, 6) Any liability associated with a surf reef, 7) An increased use of area, 8) The effect of the surf reef on natural sand and water movements, and 9) An alteration of natural habitat.

PURPOSE

This report is submitted in compliance with HCR No. 174 adopted by the Twenty-Fourth Legislature of the State of Hawaii, Regular Session 2007. The concurrent resolution requests DLNR to report to the Legislature on certain aquatic surf resources in the State, including the cost of funding a study on the feasibility of constructing artificial reefs.

BACKGROUND

DLNR is responsible for the planning, creation, and management of artificial reefs, used to enhance fish populations. Beginning in the early1960's, DLNR established five artificial reef locations, four of them off Oahu (Maunalua Bay in 1961, Waianae in 1963, Kualoa in 1972, and Ewa in 1987), and one off Maui (Keawakapu in 1972). DLNR is researching potential locations to establish additional artificial reef sites around the Hawaiian Islands.

In 1950, the United States Congress created the Dingell-Johnson (DJ) Federal Aid in Sport Fish Restoration (SFR) Act. Funds for a SFR program are derived from a surcharge on fishing equipment and in 1984, from a tax on motorboat fuels (Wallop-Breaux Amendment). The purpose of the Act is to support fishing opportunities for recreational fishermen in the United States. DLNR uses DJ funds for its work on artificial reefs, which were created to increase fishing opportunities.

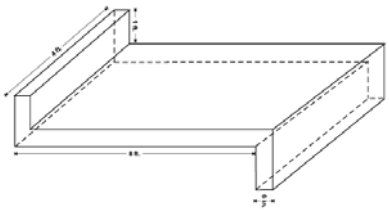
The artificial reef monitoring surveys, conducted by DLNR, have shown that the State's artificial reefs increase species diversity (up to 5 times compared to a barren area) and fish biomass (up to 20 times compared to a barren area) in the artificial reef location. DLNR believes this program has been successful in increasing the fishing opportunities for the residents of and visitors to our State.

DLNR is required to obtain State and Federal permits for its artificial reefs. It is assumed that the artificial reef designed for surfing would require the same permits. The permits for artificial reefs include: an Army Corps of Engineers (ACOE) permit, a State Department of Health (DOH) water quality certification, a State Coastal Zone Management Program (CZM) Federal consistency certification, and an DLNR-Office of Conservation and Coastal Lands (OCCL) Conservation District Use Permit. To make changes to an existing artificial reef program, amendment to these permits and certifications can take between 12-18 months. For a new artificial reef, it can take up to 5 years to obtain all of the necessary permits and certifications. This is because an Environmental Impact Statement (EIS) needs to be completed which can take up to 3 years to complete.

In accordance with the requirements of DLNR's permits and certifications, and prior to each reef structure deployment, DLNR must notify ACOE, DOH, and numerous other agencies, including but not limited to the Honolulu Police Department, the Honolulu Fire Department, the United States Coast Guard, and State Civil Defense giving each agency at least two weeks advance notice.

The main material that DLNR uses for fish habitat artificial reefs are reinforced concrete fish habitat modules called z-modules. They are 4 feet wide by 8 feet long and 6-8 inches thick with 12 inch "feet" on opposite sides that forms a z shape (see Figure 1).

Figure 1:



Each module weighs approximately 4,000 pounds and includes approximately 90 linear feet of rebar within the concrete. These modules were tested in 1997 by Robert A. Grace, an engineer, for stability during storms and hurricanes. Mr. Grace's findings showed that these modules were stable at a depth greater than 60 feet and should be able to stay in place during a high energy event. The modules were not tested in water shallower than 60 feet and further tests need to be conducted before using such modules as the material for an artificial reef in shallower depths.

RESPONSE TO HCR 174

HCR 174 asked DLNR to: 1) Gather information and statistics on the character of aquatic surf resources in the State, 2) Estimate a cost of a study to identify potential locations for artificial reefs designed for surfing and the cost of constructing such reefs, and 3) to designate the Waianae Coast on the Island of Oahu as its initial location for an artificial reef study. The following are a discussion of these three points.

Surf Site Characteristics & Statistics

There are numerous references on surfing locations and beaches in Hawaii (see bibliography). The "Beaches of ____" series by John R.K. Clark are good references for both beaches and surf locations around each island. References on surfing in Hawaii and Hawaii surf sites include "Surfing Hawaii-A Complete Guide to the Hawaiian Islands' Best Breaks" by Rod Sumpter, "Surfer's Guide to Hawaii-Revised Edition" by Greg Ambrose, "Surfing Hawaii-The Ultimate Guide to the World's Most Challenging Waves" by Leonard and Lorca Lueras, and "Surfing Hawaii-Oahu, Kauai, Maui, Hawaii" by Bank Wright.

These references provide information on the location of surf sites around the State and the character of these sites. For the purpose of this report, surfing is a general term for all of the following activities: bodysurfing; body boarding, knee boarding, wind surfing, and the board (traditional standup) surfing. The following is a summary of surf sites by island.

Kauai

According to the described references, there are between 10-24 known (there may be many more unnamed) surf sites on Kauai. Kauai has some of the best surfing locations in the State from the small beginners' breaks on the south shore to the high surf, for experts-only breaks on the north shore (Clark, 1990). Tunnels and Cannons are two of the more famous big wave spots on Kauai.

Maui

Maui has between 27 and 49 known surfing sites. Hookipa is probably the most famous wind surfing beach in Hawaii and perhaps the World. Two other world famous surf sites on Maui are Peahi, a.k.a. "Jaws", and Ma'alaea. Peahi is world famous for its giant

waves and tow-in surfing. Ma'alaea's "Freight Trains" is known as one of the fastest waves in the world. Other surf spots, such as Honolua Bay, host local and international surfing contests.

At Ma'alaea, the State and ACOE plan to expand the small boat harbor which would alter the existing surfing areas. As mitigation for this, ACOE had suggested creating an artificial surfing shoal. This idea was quickly discounted because of the liability associated with maintenance and use of an artificial surfing shoal. This liability issue is discussed later in this report.

Molokai and Lanai

Molokai has nine known surfing sites and Lanai has 10, none of them are considered world famous. Halawa Bay on Molokai and Manele Bay on Lanai are the best breaks for each island (Sumpter, 2005).

Hawaii

The Big Island has between 23 and 55 known surfing locations. Most of the surfing sites on the Big Island are appropriate for surfers of intermediate, advanced, or expert caliber, but there are a few breaks suitable for novice surfers (Clark, 1985).

Oahu

Published accounts of surf locations range between 81-94. In a 1983 Waianae Coast surfing site study final report, the authors claim that *"There are nearly 600 known surf sites around Oahu"* (VTN, February 1983). The reason for this may be that surfers have a different name for the same spot.

Oahu's North Shore sites are world famous for large surf during the winter months. Examples of such sites are Sunset Beach, Banzai Pipeline, and Waimea Bay. Other world famous locations on Oahu include Makaha, Ala Moana, and Waikiki. Local and international surfing events are held year-round, with the most famous occurring on the North shore during the winter months.

"In 1970, (John) Kelly reports there were 60,000 surfers on Oahu, mostly male (90%), with a median age of 18. The number of surfers on Oahu probably exceeds 100,000 today (1982)" (VTN, February 1983). We can assume that this number has increased since 1982 (25 years ago).

Estimated Costs

The second request was to estimate a cost for a site study and for the construction of an artificial reef designed for surfing. The budget for an artificial reef designed for surfing has three major components, 1) Site selection, 2) Design costs, and 3) Construction costs.

SITE SELECTION

According to a local marine engineering firm (Sea Engineering), the estimated cost for such a study to identify potential locations for artificial reefs designed for surfing would be about $80,000 and would involve bathymetric, geological, wave regime, and biological mapping followed by selected field surveys at the prime sites (Morgan, pers. comm.).

Another company, ASR Marine Consulting and Research of New Zealand, estimated $50,000 for a preliminary study. This study would include, but not be limited to, a site visit, data collection, regional and numerical modeling, the final report, and miscellaneous costs (Black, pers. comm.).

The location should have enough shoreline area for construction of, or improvements to the current, infrastructure. This would include a parking area, constructing or widening a road to the site, showers, restroom(s), and picnic area (VTN Pacific, Inc. February 1983).

If the proposed reef is in a location that is easily accessible and construction equipment can be driven right to the job site, this could actually reduce the cost of the reef. But if the proposed reef location is not easy accessible from land, such that a tug and barge must be used, the cost of the reef will increase. If the area is prone to high surf, heavy use by the community, etc. these could also delay the project and increase the cost significantly.

DESIGN COSTS

This includes designing the size and shape of the reef, permits, drawings, and physical modeling. The final design must minimize possible negative impacts to the area, as well as the surrounding areas and create a good surf break.

Size

The size of the artificial reef is very important. Pratte's Reef in El Segundo, California is considered a failure because it is too small. It involved using 1,350 cubic meters of artificial material and was cost $300,000. According to leading experts on surfing reefs, the minimum cost would be $1,000,000 for a successful reef. According to the 1983 VTN final report, *"An artificial shoal designed primarily for surf under 6 feet would cost an estimated $3 million and would be vulnerable to damage from tsunamis and extreme storm surf"* (VTN, February 1983). Today, that project would cost approximately $6.1 million.

Shape

The shape of the artificial reef is very important to maximize the total number of days that surfable waves are produced. The Waianae Coast has surfable waves during south

and northwest swells, so the design of the reef to produce surfable waves during these swells is important.

According to ASR Marine Consulting and Research, the shape of the artificial surfing reef may also help to minimize erosion occurring in the area by reducing the amount of wave energy that is reaching the beach (Black, pers. comm.).

Permits

The permitting process for an artificial reef designed for fishing is described in an earlier section of this report. It is assumed that the permitting process is the same for an artificial reef designed for surfing. Initially an EIS must be completed. An EIS cost approximately $150,000 and could take up to 5 years to complete (Morgan, pers. comm.).

With a finalized EIS, the Conservation District Use Permit for the use of state lands must be obtained from OCCL. During this process the public can attend a public hearing and provide testimony on the project.

The State DOH's Section 401 Water Quality Certification is also needed and may take from a few months to over a year to obtain. This certification is to ensure that artificial reef construction will not pollute nearshore waters during and after construction.

A coastal zone management federal consistency certification from CZM Program within the Office of Planning, Department of Business, Economic Development, and Tourism. This certification is to ensure that all projects in the coastal zone are consistent with the Federal plan for all coastal areas of the United States. This certification may take approximately three-six months to obtain.

Finally, with all three of the permit and certifications, ACOE permit application is required. The ACOE permit process may take between 9-12 months to complete. After the AOCE permit is issued, construction can begin.

Designs

Using the results from the preliminary study, a number of different designs of various reef sizes and shapes would need to be developed to determine the optimal arrangement for the area. These designs will show the necessary components that would be needed to create a reef that produces the desired surf break criteria.

There are many different types of surf breaks around the World and even in Hawaii, from a slow peeling wave of Waikiki to the hollow plunging wave of the Banzai Pipeline. The type of break that is desired will determine the overall design of the reef.

Physical modeling

In this process, the reef designer will take the information (bottom contour, amount and duration of wave energy, etc.) to create customized drawings and build scaled models of the proposed designs for the area. They will test each model in the lab to determine what type of break each customized design produces. The model that produces the desired wave break criteria will likely be advanced as the final design.

CONSTRUCTION COSTS

Construction costs include the type of material used for the reef, method of construction to be used, contractor selection, equipment used to build the reef, location preparation, fabrication, and deployment.

Material

Leading experts on the design and construction of a surfing reef believe that geotextile sandbags are the material of choice over rocks and concrete modules. An artificial reef designed for surfing that is constructed with rocks or concrete modules would be more costly than reefs made of geotextile sandbags. Even though rocks and concrete modules may be a cheaper material, it is the handling and placement of these materials that increases the cost of the reef. The precise placement of the rocks or concrete modules into the desired shape of the artificial reef leads to longer construction time and is more labor intensive, thus increasing costs (Black, pers. comm.).

Rocks

Rocks are not a favored construction material because they are very difficult to deploy into the desired shape of the artificial reef and may move during high wave energy events like winter storms or hurricanes.

Concrete Modules

Concrete modules are similar to rocks in that they are difficult to place into the desired shape of the artificial reef may also be displaced during high energy events.

Geotextile Sandbags

Geotextile is any permeable textile material used to increase soil stability, provide erosion control or aid in drainage. They are usually made from a synthetic polymer such as polypropylene, polyester, and polyethylene (see figure 2). They can be either woven, knitted or non-woven. Varying polymers and manufacturing processes result in an array of geotextiles suitable for a variety of applications.

Figure 2:

geotextile material

geotextile tubes

A woven geotextile is a flat textile structure produced by interlacing two or more sets of strands at right angles. There are two types of strands: slit films (flat) and monofilaments (round). Woven slit-film geotextiles are generally preferred for applications where high strength properties are needed and filtration requirements are less critical (artificial surfing reefs). Woven monofilament geotextiles are preferred for applications where both strength and filtration are needed.

Selection of a contractor

Local contractors would be contacted to determine if they are capable and have the proper equipment needed to build the reef as designed. Once the contractor is selected, the contracts need to be completed. Insurance costs for the contractor are also included in the contract. This could be worker's compensation insurance, insurance for the equipment, and insurance to the State that the contractor will not damage public property, natural resources, state equipment, etc. in constructing the artificial reef.

Equipment

The type of equipment used to build the artificial reef is also important. Tug and barges, tractors, excavators, and bulldozers are very expensive due to operator, maintenance, and/or rental costs. Additionally, any in-water component would require the use of certified commercial divers.

Location preparation

Once a location is selected, it must be prepared for the material used for creating the reef. If geotextile sandbags are being used as the material to construct the reef, screw-anchors would need to be deployed, and moorings need to be set up to keep a tug and barge or vessel in place. It may be necessary to remove any large boulders or other obstacles.

Fabrication

The geotextile sandbags are sewn together to conform to the selected design and is done onshore. The entire reef (empty sandbags sewn together) is then loaded onto a barge and readied for deployment.

Deployment

The deployment of rocks and concrete modules is very time consuming, tedious and if done incorrectly, could create negative impacts. If the rocks or modules are small (up to two tons), they are not stable enough in shallow water during high wave energy events (storms) and may move around, dismantling the artificial reef and possibly destroying natural habitat in the surrounding area. Larger rocks or modules (over two tons) are more difficult to handle during procurement, delivery, deployment, and increases costs.

For a geotextile sandbag reef, the sandbags are deployed off the barge and anchored to the ocean floor. Once this is completed, the filling of the sandbags takes place and the design of the reef is adjusted with the amount of sand that is placed into each bag.

ITEM	ESTIMATED COST
Study to identify potential location	**$50,000-80,000**
Construction:	
Design (size, shape, etc.)	70,000-100,000
Environmental Impact Statement	150,000
Permits (Application fees and labor)	10,000
Construction (materials, labor, equipment, etc.)	3,000,000-5,000,000
CONSTRUCTION	**$3,280,000-5,340,000**
GRAND TOTAL (Construction and Study)	**$3,330,000-5,420,000**
Annual Maintenance Costs	**Not determined**

Waianae Coast Designation

The concurrent resolutions' third request was to designate the Waianae Coast on the Island of Oahu as its initial location for an artificial reef study. A study, Final Report-Waianae Coast Surfing Site Study by VTN Pacific, Inc. was prepared for the Department of Parks and Recreation, City and County of Honolulu in February 1983. This study was funded with settlement money, approximately $250,000, which the City and County of Honolulu received from a civil litigation against the Hawaiian Electric Company.

This study's objectives were to 1) Review court records (and settlement) in which a group filed legal complaints against the Hawaiian Electric Company over the destruction of a small beginners surf spot with the extension of the Kahe Power Plant outfall; 2) Review public testimony and other records regarding past attempts to build an artificial surfing shoal at Kahe; 3) Documentation of the problems and hazards of existing and

potential surfing sites along the Waianae Coast, including which sites can be improved; and 4) With the assistance of the Waianae Ocean Recreation Advisory Council (WORAC), prepare two design schemes that could improve surfing sites along the Waianae Coast including preliminary oceanographic analysis, coastal engineering, conceptual design and environmental studies.

An artificial shoal for surfing was analyzed in the study, but not considered as an alternative for the community because of cost. The cost for the design and construction of the artificial shoal for surfing would exceed the $250,000 that the City and County received. The other two alternatives were 1) Safety improvements to existing surfing areas or 2) Conventional park improvements that benefit surfers.

The study identified nine potential surf sites (Yokohama Bay, Maili Point, Keaau, Lahilahi Point, Lualualei Beach Park, Green Lantern, Maili Beach, Tracks, and Ulehawa) that could use improvement due to safety concerns. In the end, only three (Yokohama, Maili Point and Maili) were identified as sites that could be made safer by removing coral outcroppings and coral heads in the surfing area. This alternative was not supported by the Community because they wanted to improve an area closer to the Kahe Power Plant outfall.

The Community's recommendation in the study was to use the settlement money for improvements (showers, restrooms, landscaping and a parking lot) at the surf site called "Tracks" (north of the Kahe Power Plant). Though some of the information in this study may not be applicable today, it demonstrates the importance of community involvement and communication with these types of projects.

This 1983 study also includes a list of six previous surf site development studies that may be useful for an updated study. These include: Surf Parameters- A General Surf Site Concept by James R. Walker and R. Palmer in September 1971 (U.H. Look Laboratory Technical Report #18); Recreational Surf Parameters by James R. Walker in February 1974 (U.H. Look Laboratory Technical Report #30); Surf Parameters, Part II-Social and Historical Dimensions by John Kelly in November 1973 (U.H. Look Laboratory Technical Report #33);Wave Transformations Over a Sloping Bottom and Over a Three-Dimensional Shoal by James R. Walker in May 1974 (U.H. Look Laboratory Miscellaneous Report #11); Preliminary Design Analysis Kahe Artificial Shoal and Amendments to Preliminary Design Analysis by Moffat & Nichol, Engineers in August and September 1976 (Unpublished reports prepared for Hawaiian Electric Company, Inc.); and Feasibility Study for an Artificial Surfing Site at Oceanside, San Diego County, California by Moffat & Nichol, Engineers in July 1981 (Prepared for the U.S. Army Corps of Engineers, Los Angeles District).

DLNR has not determined the Community's support or opposition to an artificial surfing reef.

RECOMMENDATIONS

In testimony provided during the session of the 2007 Regular Session of the Legislature on HCR174, DLNR supported the intent of the concurrent resolution but also stated that DLNR's existing artificial reef program is supported with federal funds, (described earlier in this report), and artificial reefs require careful attention to planning and situating. DLNR cited an example of a recent story about how Florida is now having to deal with thousands of tires that were used to build an artificial reef that broke apart and are now littering miles of white sand beaches. DLNR also provided an example of creating a surfing reef as mitigation for the proposed expansion of Maalaea Harbor on Maui, but that mitigation option has been withdrawn for liability concerns. DLNR was also concerned about the destruction of natural habitat with the installation of the artificial reef for surfing and for hastening beach erosion.

DLNR recommends that any study to identify potential locations for artificial reefs designed for surfing include information about the current infrastructure, infrastructure improvements that are needed, community concerns about such a project, community involvement, and with the possible increase in additional people, estimated additional revenue, and other issues that would affect the Waianae Coast.

Without a site selection study, DLNR cannot recommend designating the Waianae Coast as the initial site for an artificial reef designed for surfing.

DLNR recommends that the Legislature consider the following advantages and disadvantages before supporting an artificial reef designed for surfing.

ADVANTAGES

Creating a Surf Site

This is the primary reason for building an artificial reef in shallow water. A new surf site will be created where there once was none or a current surf site will be improved. Surfers will enjoy the new surf site and local businesses may see increased sales due to the increase in people coming to the area.

Reduce Beach Erosion

The artificial reef may reduce the amount of wave energy that impacts the shoreline, thus reducing the removal of sand and other material from the beach. This benefit can either be a primary or secondary reason for building an artificial reef for surfing.

Increase Fish Population

Another secondary benefit is that the new reef may increase the populations of fish and other organisms in the area due to the increase in three-dimensional reef structure. In general, a surfing reef is constructed in an area that lacks natural underwater structure

that causes a wave to break. It is this lack of structure that limits the amount of fish and other organisms present in the area.

Stimulate Local Businesses

The new surf site would attract people from not only from the Waianae Coast but from all over the island, including tourists. The increase in people may stimulate the local businesses (food, gas, beach gear rental) in the area due to this increase in the amount of people using or just curious about the new surf site.

DISADVANTAGES

Cost

ASR Marine Consulting and Research suggest that the minimum size for an artificial surfing reef should be 600 feet long by 600 feet wide and 10 feet high. The cost for such a reef would be between $3-5 million (Black, pers. comm.). Anything smaller might result in a repeat of Pratte's Reef in California (described earlier). An artificial reef designed for surfing may have additional recurrent, but undetermined, cost for maintenance. For example, the geotextile sandbags do not last forever and will eventually need to be replaced.

Liability

As seen in the Maalaea Harbor expansion project, both the State and ACOE were reluctant to support as a mitigation option, an artificial reef designed for surfing due to liability concerns. For DLNR artificial reefs, the liability is lower than for an artificial reef designed for surfing. This is because DLNR artificial reefs are in deeper water, subject to weaker wave action, and intended user groups (pole and line fishers) are conducting relatively safer activities. Unlike at the artificial reef designed for surfing, where the water is shallower, and subject to strong wave action, user groups (surfers) are conducting a more strenuous activity and could be subject to injury on a more frequent basis.

Because an artificial surfing reef needs to be located in shallow water, any material used for the artificial reef would be impacted by large storm swells. This may lead to additional damage to the surrounding natural habitat and have associated costs with removing the bags from the surrounding area and/or rebuilding the artificial reef.

Finally, an artificial reef for surfing is designed to making the area shallower, thus creating a swell to crest and break. This could potentially create navigational hazards for boaters, and if not properly planned, could increase the rate of shoreline erosion through the creation of waves nearer to shore. Dissipation of wave energy would therefore be focused onto the shoreline and may hasten its erosion.

Community Opposition

An artificial reef designed for surfing may attract people from other parts of the Island, including tourist, increasing use of the area and may lead to conflicts between the community and visitors. Some of the concerns for the community may include traffic, parking, trash, possible conflicts between the user groups (surfers, fishers, boaters, whale/dolphin tours operators), and an overcrowded surf spot. This occurs every winter when the northwest winter swells come to the North Shore of Oahu. The traffic jams and backs up for miles; parking is limited increasing tension between surfers, residents of the area, and residents and visitors that just want to view the large waves.

Impact on Natural Cycles

The artificial reef may influence the natural trends or "cycle" of sand and water movement. The artificial reef may reduce the wave energy in the area, and also lead to increased erosion of the surrounding shoreline areas due to the change in water movement, causing damage to important infrastructure (roads), beach parks (restrooms), and private property. Ecologically, larval dispersal and settlement of fish and other organisms in the area may be disturbed by the change in water movement.

Alteration of the Natural Habitat

The artificial reef may alter the natural habitat permanently. In most cases, artificial reefs that are designed for surfing are situated on sandy areas. Subtidal sand areas serve as habitat for important species of fish (goatfishes and bonefish) and invertebrates (Kona and white crab, cone shells, helmet shell, shrimps). Artificial structures could also cover harder substrates (limestone, live corals) which would permanently alter these types of habitats as well.

References

1. Ambrose, Greg. Surfer's Guide to Hawaii, revised edition. Bess Press Publishing Hawaii 2006

2. Black, Kerry. Amalgamates Solutions and Research, Ltd. August 2007 (Personal communication)

3. Clark, John R.K. Beaches of Oahu, revised edition. University of Hawaii Press Hawaii 2005

4. _____. Beaches of the Big Island University of Hawaii Press Hawaii 1985

5. _____. Beaches of Kauai and Niihau University of Hawaii Press Hawaii 1990

6. _____. The Beaches of Maui County, revised edition. University of Hawaii Press Hawaii 1989

7. Lueras, Leonard. Surfing Hawaii – The Ultimate Guide to the World's Most Challenging Waves. Tuttle Publishing Vermont 2000

8. Morgan, Charles. Planning Solutions, Inc. July 2007 (Personal communication)

9. Sumpter, Rod. Surfing Hawaii – A Complete Guide to the Hawaiian Islands' Best Breaks. Globe Pequot Press Connecticut 2005

10. VTN Pacific, Inc. Final Report – Waianae Coast Surfing Site Study (for the) C&C Honolulu, Parks and Recreation Department. February 1983

11. Wright, Bank. Surfing Hawaii – Oahu, Kauai, Maui, Hawaii. Mountain and Sea Publishing California 1972