FLOATING ARCHITECTURE:
HAWAI‘I’S RESPONSE TO SEA LEVEL RISE

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI‘I AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Dedication Page

I dedicate this to those who will come after, especially to the residents of Hawaiʻi in the year 2100. Ten thousand mea culpas for the world we left you. Although you might not think very highly of us, you might be surprised to know that most of us care very much about what happens to you.

Phap Vu
May, 2016

Abstract

This research document briefly reviews existing knowledge of global warming and climate change, along with the consequences. It examines sea level rise, and briefly discusses the controversy that still lingers, allegedly because of what oil companies have done. It goes through strategies for mitigating sea level rise, with a final focus on floating development, not as a solution, but as one of a number of suggested ways to mitigate the problem of sea level rise. From there the topic moves to the predicted impact of sea level rise on cities, landmarks, and finally Hawai‘i, and how Hawai‘i is dealing with it. A brief summary of what the international community has done so far in an attempt to hold down temperatures is presented, as well as President Obama’s comments about global warming that he made during his final State-of-the-Union Address. Research extends to the Netherlands, where the Dutch are considered world leaders in water management and examines how their water-based architecture is helping them to adjust to sea level rise. Koen Olthuis, a leading Dutch architect, is featured, along with some of his current projects in the Maldives, which, like Hawai‘i, has a tourism-based economy. Following that, examples of future floating development that could be used in Hawai‘i are studied. Including examples of floating residences, floating tourist destinations, and floating support structures for energy, food, and fresh water. Since the writer is doing a design project at Ke‘ehi Lagoon, a historically rich site near the Honolulu International Airport, much discussion is given over to Ke‘ehi Lagoon and conditions in and around the lagoon. Following that a wide range of topics, some practical, and some peripheral, all directly related to the design project itself, were investigated. Practical questions like how the development floats and how are utilities provided, are raised and researched. The name of the project is HydroVillage & Research Farms at Ke`ehi Lagoon and residents work as sea farmers or researchers and live and work on site. HydroVillage is a dynamic community floating around a central hub where residents live, work, and play in meaningful and productive ways.

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Chapter 1

Introduction: General Overview

"Water is the driving force of all nature."
— Leonardo Da Vinci —

1.1 Living in the Best / Worst of Times

Would you agree with the following statement? Thanks to advances in science and technology, we are living in the greatest period in world history. Or would you agree with this? We are living in the worst period in world history, and that's because we have so many serious problems now and ahead of us!

Here are five reasons to help you agree with the first statement. The first: In 1800, life expectancy was 39 years at birth. In 1900 it was 49 years, in 1950, 68 years, and today it is 70 years. A newborn today can look forward to living an entire generation longer than his great-grandparents could. The second: The average U.S. citizen currently retires at the age of 62, whereas a hundred years ago, the average citizen died at the age of 51. Savor your golden years. Your forefathers (and mothers) just didn't have them. The third: In 1900, only two percent of homes in the U.S. had electricity. In 1950 thirty percent. Virtually all homes only had electricity in the 1970s. Electricity cost more than ten times as much in 1900 than today. The fourth: In 1850 the average work week in the U.S. was 66 hours. In 1909 it was 51 hours. Today it is 34.8 hours. Enjoy the weekend. The last reason for saying we live in the greatest period in world history is this: Considering the worldwide population, only 4% are lucky enough to live in the U.S. You are most certainly one of them. Be appreciative.[1]

Here are five reasons that might make you agree that we are living in the absolute worst period of human history. The first: The current global economy is fragile and could tip developed countries into an economic collapse. The second: Though petroleum has powered the world for almost a century, we may soon reach a peak in oil production and run out. The third: We are facing a global water crisis, since during the last 50 years the population has almost tripled, while unsustainable agriculture, industrial pollution, and bad civic planning have diminished the overall supply of water. The fourth: A number of species that people rely on for food are going extinct (tuna, for example), and if that happens, humans may face extinction themselves.

1 Housel, Morgan. Motley Fool.com, "50 Reasons We're Living Through the Greatest Period in World History." Last modified January 29, 2014. http://www.fool.com/investing/general/2014/01/29/50-reasons-were-living-through-the-greatest-period.aspx. (Accessed June 27, 2015.)

The last reason for saying we live in the worst period in history: Climate change and global warming is an undisputable fact, and if we and our international neighbors can't accept that and begin to seriously deal with it, we face consequences that could be catastrophic.[2]

1.2 Problems Now and in the Future

Like many other people of my generation (I'm 26), I mostly agree that we are living in the greatest period of human history, and firmly believe it is a wonderful time to be alive. I am, however, seriously concerned with what we have done to the environment and, now, in light of global warming and climate change, I wonder what kind of future we are likely to have. NOAA (National Oceanic and Atmospheric Administration) is predicting that, by 2050, most coastal cities in the U.S. likely will be threatened by at least 30 days of flooding each year.[3] That is for coastal cities on the Mainland. Islands in the Pacific (including Hawai'i) will likely have it much worse.[4] Moreover, reputable scientists are saying that, by 2100, the oceans will rise between 2.5 and 6.5 feet feet (0.8 and 2 meters), which is more than enough to flood many U.S. coastal cities.[5] That is enough for a lot of concern and worry.

2050 is 34 years from now, and assuming I am still alive at that time, I will be 60 years old. That will make me a member of the "transition generation," having lived through and witnessed the first, serious effects of global warming, climate change, and sea level rise, especially if I stay in Hawai'i. I want to understand what got us in this situation.

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2 Petersen, John L. Arlington Institute.org, "The World's Biggest Problems." Last modified January 1, 2012. http://www.arlingtoninstitute.org/wbp/portal/home. (Accessed June 27, 2015.)

3 NOAA News.noaa.gov, "NOAA Establishes 'Tipping Points' for Sea Level Rise Related Flooding." Last modified December 18, 2014. http://www.noaanews.noaa.gov/stories2014/20141218_sealevelrise.html. (Accessed February 10, 2015.)

4 Roach, John. "Hawaii to Suffer Most as Global Sea Levels Rise, Study Says." NBC News.com. February 21, 2013. Accessed March 30, 2014. http://science.nbcnews.com/_news/2013/02/21/17044546-hawaii-to-suffer-most-as-global-sea-levels-rise-study-says?lite.

5 Mellino, Cole. EcoWatch.com. "Which Country Will Be First to Go Completely Underwater Due to Climate Change?" May 22, 2015. http://ecowatch.com/2015/05/22/maldives-underwater-climate-change/. (Accessed July 18, 2015.)

Small waves thrash the beach and sand in Waikiki.
(Courtesy of Civil Beat)

Sandbags are piled up in front of properties damaged by severe beach erosion in Oahu's North Shore.
(Courtesy of Civil Beat)

I want to understand why we are in this situation. I want to understand what is happening and what will happen in the future. And, as an architect, I seriously want to be a part of humanity's reaction to this crisis. Before starting research for this project, I had a lot of questions in my mind about global warming and climate change. The most important question, of course, was whether it is real or not. The second question for me was what I could personally do, if it was real.

1.3 My Contribution as an Architect

Living and working on the Mekong River
(Courtesy of Blue Ocean Travel)

I am from Vietnam and have seen people spending their entire lives living on the water. In surprisingly strong floating structures, they do water-based agriculture and water-based commerce, while going about their lives as naturally as people on the land do. After hearing so much about rising sea levels, and reading about such dire predictions about what would happen, I decided to research floating architecture. I had a lot of questions in my mind about floating architecture.

This time, the most important question in my mind was whether floating architecture is a viable and helpful response to rising sea levels, and if it is, I decided that the thesis would contain a design project for a some kind of floating village.

I realized that there are a lot of resources available, meaning there is plenty of available literature about floating architecture, almost all from a Mainland or European viewpoint. I will add to the literature by writing about these issues from a Hawaiʻi resident's point of view, and maybe, in doing so, answer questions for other local residents who are asking some of the same questions that I am.

Additionally, anyone who has lived in Hawaiʻi for any given period of time knows that we pay a steep price indeed for living in paradise. Forbes magazine says that Honolulu tops its list of "America's Most Overpriced Cities" and rates it right alongside New York City as the two most expensive places to live in the U.S.[6] One major factor in the high cost of living here is the exorbitant cost of housing, and the unavailability of low-cost housing. As an architect, I want to work on housing units that, even if not initially affordable, could, after some time, turn into something that approaches affordability for their residents.

1.4 The Main Looming Problem: Global Warming and Climate Change.

This research will review existing knowledge on global warming and climate change, particularly in terms of sea level rise. It will examine how much of a threat global warming really is, and suggest that it is, in fact, serious enough that major preparations should begin now. It will look at the causes of global warming and consider the reasons for the controversy that has surrounded it. The research will report on what might happen in the future and take a look at what has already started happening around the world, and here in Hawaiʻi, as a result of global warming and climate change. It will present what the international community has recommended be done to slow down the process of climate change, and look at comments made by the president of the U.S. as he speculates on what might be coming up in the future.

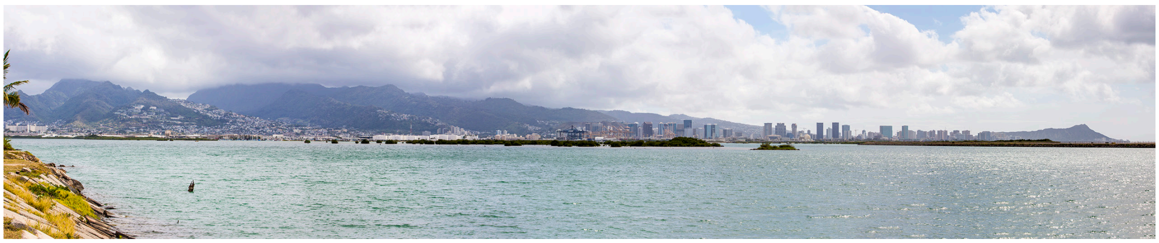
6 Carlyle, Erin. Forbes.com, "America's Most Overpriced Cities." Last modified February 25, 2014. http://www.forbes.com/sites/erincarlyle/2014/02/26/americas-most-overpriced-cities/. (Accessed October 21, 2015.)

1.5 Actions to Manage and/or Mitigate the Problem.

Unfortunately, short of eliminating all greenhouse gasses from the atmosphere, the literature tells us that there are no permanent solutions to the problem of climate change and sea level rise. There are, however, various recommended strategies to manage or mitigate global warming, and they will be examined here, culminating in a focus on floating development, not as a solution to the problem, but as one strategy among a number of strategies to mitigate the problem. The underlying research question that has driven this research since the writer began this investigation in 2014 is this: Is floating architecture one viable response to sea level rise in Hawaiʻi?

1.6 Additional Content in this research thesis.

Furthermore, this research paper will include information about the Netherlands as world leaders in water management, and present one Dutch architect, known as the "Floating Dutchman," as an international figure in the field of floating architecture, and show that ideas behind many of his projects could be of benefit to Hawaiʻi. Acknowledging the fact that tourism and the economy in Hawaiʻi are likely to be hit hard, alternative tourist destinations will be explored. In addition, this research paper will give an overview of everything from floating residences to floating power plants, and numerous other types of floating structures that could be of great value to Hawaiʻi in the future while demonstrating that floating architecture in general has a great many benefits.



With his design project, the author envisions a rebirth of life and activity at Ke`ehi Lagoon.
(Photographs by Author)

1.7 The Location of The Design Project.

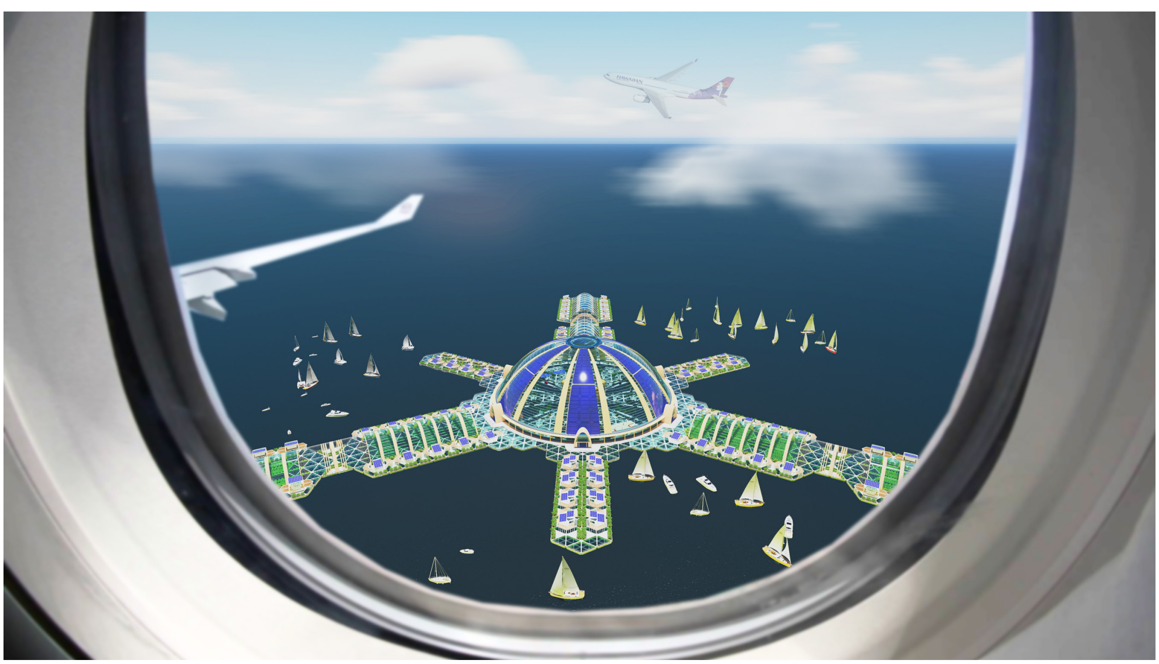
In additional to the research thesis itself, this writer optioned to culminate the research with a design project that would incorporate what had been learned from the research with the writer's own vision of what floating development might mean to Hawaiʻi. After considering various locations, he chose Ke`ehi Lagoon, on O`ahu, which is immersed in history from ancient Hawai`i through WW II, when the government dug landing strips for seaplanes, and, in doing so, forever and irrevocably altered the natural environment that had existed for millennia throughout the area. In the 1950s the seaplane runways were further used by the "flying boats" made famous by Pan Am.

1.8 Issues and Concerns for the Design Project

After acknowledging the significance of designing with a Hawaiian sense of place, and the importance of using abundant greenery throughout the design project, this section of the research turns to the specifics of designing floating structures in Ke`ehi Lagoon. Questions like, "How does it float," "How about utilities," and, since Ke`ehi Lagoon is a saltwater estuary for several mountain streams, "Where will freshwater come from," will be discussed here. Also to be researched and included will be the question of power, as in, “How are you going to get electricity?” Moreover, since Hawai‘i residents know that despite being billed as a paradise, living in Hawai‘i does involve living with a few risks (hurricanes, flash floods, tsunami, and earthquakes immediately come to mind) the question of safety requires further fact-finding. Finally, management, housing, employment, and even a ferry service will close out the chapter on issues and concerns for the design project at Ke`ehi Lagoon. Incidentally, it isn’t by accident that the topic of employment will bring our modern world, in full circle, back to the world of ancient Hawaiians, as we examine new research on sea farming in Ke`ehi Lagoon.

1.9 Design Project: HydroVillage & Research Farms at Ke`ehi Lagoon.

The design project is called HydroVillage & Research Farms at Ke`ehi Lagoon, and is to be located in Ke`ehi Lagoon on the south shore of O‘ahu, near the Hawai‘i International Airport. It will eventually be a large, self-supporting, floating community. It combines housing with aquatic farming and research. All structures in HydroVillage float on large floating, hexagonal, interconnected slabs that provide about 3,000 square feet of floor space each.



HydroVillage & Research Farms at Ke`ehi Lagoon
(Graphic by author)

Structures at HydroVillage include housing units, in two styles and sizes and research labs (sometimes referred to as science labs) where experimentation and study of various aspects of sea farming would be done. The housing units are mounted on an interconnected framework of floating foundations that have a long section of open water stretching along the center in which sea farms will be located. Finally, there is a large domed area in the center of HydroVillage which is the hub of all activity and which serves as a multipurpose community center. All power in HydroVillage comes from solar panels, fresh water is harvested, and human waste is eliminated with specialized toilets. The waters around HydroVillage will host additional floating energy farms, water catchment systems, and floating constructed wetlands.

Summing Up

In the introduction we considered good and bad points about living today, and conceded that this is actually a good time to be alive, even though we have to face and deal with numerous problems, including the serious issue of sea level rise that has resulted from world-wide climate change. Being an architectural student who came from Vietnam, and who has seen floating communities first hand, the writer says he will focus on floating architecture as one of a number of ways to mitigate sea level rise, and "mitigate" is stressed here, since currently there are no real and permanent solutions, at least none found in the current literature. A brief sketch of the entire research thesis includes a look at a Dutch architectect, a leader in the field of floating architecture, who will be quoted and whose projects in the Maldives will examined as possible models for Hawai'i. An overview of floating architecture is to later be presented showing the almost infinite range of what can be done now and in the future with floating architecture. Lastly this research paper will conclude with an original design project which is preceded by a discussion of its location and of specific, related issues to address.

Coming Up

In Chapter 2, we will specifically research global warming, how global warming is related to climate change, how climate change is causing sea level rise, and what the consequences of sea level rise are. We will see that sea level rise is likely to affect the thousands of people living in cities along the coasts. We will try to understand why climate change and sea level rise have become such divisive issues, and find out if opinions are changing. The destructive consequences of sea level rise will be researched, A number of specific recommendations for mitigating sea level rise will be presented, along with advantages and disadvantages that are associated with each.. Also we will consider how long, in the future, climate change and sea level rise are likely to continue, and how that might affect our choices for mitigation.

Chapter 2

Global Warming and Climate Change: Important Considerations

"How inappropriate to call this planet Earth when it is quite clearly Ocean."
— Arthur C. Clark —

2.1 What Is Global Warming?

"Global warming" refers to the rise in temperature as greenhouse gasses are added to the Earth's atmosphere. Some of the energy that the Earth gets from the sun is held in the Earth's atmosphere, and some is sent back out. That process is controlled by greenhouse gasses, which act like a blanket keeping the Earth warm. Too much greenhouse gas, though, coming from burning fossil fuels, is similar to using a thicker blanket, and that warms the Earth up too much, resulting in "global warming." "Climate change" is a result of global warming. As Earth's temperatures go up, seasonal patterns are changed, or destabilized. That affects the seasons, the weather, the ice at the north and south poles, the amount of rainfall, sea level rise, and so on. The term "global warming" was used for the first time in a science article in 1975 by Wallace Broecker of Columbia University. The article was called, "Climatic Change: Are We on the Brink of a Pronounced Global Warming.[7]

2.2 Some Consequences of Climate Change

According to the "Third National Climate Assessment Report," long term effects of global climate change in the U.S. will include some of the following. Climate change will extend beyond this century, and temperatures will continue to rise. The length of the frost-free growing season will be extended, and there will be changes in precipitation patterns. There will be more droughts and heat waves, as well as stronger and more intense hurricanes. Sea level rise will be one to four feet by 2100, and the Arctic is likely to become ice free in summer.[8]

2.3 Background for Sea Level Rise

As we saw in Chapter 1, sea level rise is only one consequence of climate change, but it is one aspect of climate change that will have major, irreversible ramifications for life later in this century. Looking briefly back in time at rising sea levels stresses the importance of beginning preparations now for dealing with this increasingly important phenomenon.

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7 "ThinkProgress.org, "Wallace Broecker's Remarkable 1975 Global Warming Prediction." Last modified August 24, 2011. http://thinkprogress.org/climate/2011/08/12/286706/wallace-broecwallace-broecker-1975-global-warming-prediction/. (Accessed December 5, 2014.)

8 NASA Global Climate Change, "The Consequences of Climate Change." Last modified January 6, 2016. http://climate.nasa.gov/effects/. (Accessed January 8, 2016.)

In the late 1800s, after two or three thousand years of stability, sea levels began to rise at a steady rate of about 0.07 inches per year. Then, from 1993 to 2007, the rate of sea-level rise increased to about 0.12 inches per year. For at least the next few centuries sea levels are expected to continue to rise due to climate change and processes already set in motion.

Storm surge on a Louisiana highway shows the effects of rising sea levels.
(Courtesy of National Oceanic and Atmospheric Administration)

Flooding on the New Jersey shoreline caused by Superstorm Sandy.
(Courtesy of U.S. Air Force, Master Sgt. Mark C. Olsen)

For example, most predictions say that by the year 2050, sea levels will have risen by one to two feet, and by 2100, three to six feet. Some predictions are slightly under that figure, and some are slightly over. How much higher the levels will rise depends on whether people can reduce their greenhouse gas emissions, and how much of the West Antarctic and Greenland ice sheets melt.[9]

The National Oceanic and Atmospheric Administration (NOAA) is a federal agency that focuses on the state of the oceans and the atmosphere. According to NOAA, there is proven evidence that sea levels around the world progressively rose in the 20th century and at the present time are rising at an ever-increasing rate. Also sea levels are expected to rise at an even greater rate in the 21st century. Two main reasons are said to be thermal expansion of the seas (as it warms, water expands) and the melting of land-based ice because of climate warming. Moreover, NOAA points out that sea levels are not rising the same around the globe. This variation results from the fact that changes in temperature are not the same around the world and also from changes taking place in the circulation of waters of the ocean.[10]

2.4 What is Known About Climate Change

Scientific research shows that climate change is real. An intergovernmental panel on climate change has said that scientific evidence for warming of the climate system is unequivocal. Numerous studies published in scientific journals show that 97 percent of climate scientists agree that the general warming of the climate during the last hundred years was very likely because of human activities. Furthermore, almost all leading scientific organizations around the world have issued public statements supporting that position. These organizations include the American Association for the Advancement of Science, the American Chemical Society, and the American Meteorological Society.[11]

2.5 Other Consequences of Sea Level Rise

Human activity has resulted in global warming and global warming has resulted in climate change. As the climate changes the world gets warmer and sea levels rise. Much of what we hear about on the topic of climate change has to do with sea level rise and we think of flooding of coastal areas around the world.

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9 United States Environmental Protection Agency, "Climate Change: Basic Information." Last modified March 18, 2014. http://www.epa.gov/climatechange/basics . (Accessed December 10, 2014.)

10 National Oceanic and Atmospheric Administration, "Is sea level the same all across the ocean?." Last modified February 6, 2015. http://oceanservice.noaa.gov/facts/globalsl.html. (Accessed March 9, 2015.)

11 NASA: Global Climate Change, "Scientific Consensus: Earth's Climate Is Warming." Last modified January 6, 2016. http://climate.nasa.gov/scientific-consensus/. (Accessed January 8, 2016.)

There are at least five other effects that we don't hear so much about.

One consequence of sea level rise is that it will contaminate our fresh water supplies. Many coastal communities rely on underground freshwater sources for drinking water and, in fact, groundwater provides most of our freshwater. It is possible to take the salt from water, but it is expensive and complicated. San Diego County in California, for example, is in the process of building a large seawater desalination plant that is expected to cost about $1 billion. Secondly, rising sea levels will disrupt agriculture. The very same freshwater sources that give us drinking water also supply water for agriculture. Saltwater can stunt and kill crops, but, as just mentioned, creating freshwater from saltwater is expensive. The third consequence of sea level rise is that it will alter coastal plant life. Plants are especially affected by their environments, particularly trees. The fourth is that wildlife populations will be threatened. Numerous kinds of wildlife live on the beach. As the areas that support wildlife flood, animals like shorebirds and sea turtles will be affected. The fifth consequence of sea level rise is that it will damage the economy. Tourism and real-estate are likely to be seriously impacted by rising water.[12]

2.6 Doubts About Global Warming and Sea Level Rise

Why is climate change such an issue? Part of this disbelief might be blamed on the media. Journalist Charles Blow in an editorial in The New York Times says that people should be outraged that we are in a downward spiral toward an irreparable change in climate, and that few people seem interested in it or making much effort to avert it. He says it is given little coverage by the news media, and when it is covered, the information isn't always accurate.[13]

12 Harvey, Chelsea. Business Insider.co, "Sea-level Rise Will Cause More than Flooding — These 5 Other Impacts of Rising Oceans Are Just as Bad." February 17, 2015. http://www.businessinsider.com/5-terrifying-impacts-of-rising-sea-levels-2015-2. (Accessed December 12, 2015.)

13 Blow, Charles. The New York Times, "We Should Be in a Rage." Last modified April 09, 2014. http://www.nytimes.com/2014/04/10/opinion/blow-we-should-be-in-a-rage.html. (Accessed March 5, 2015)

Mr. Blow is backed up by the Pew Research Center which reports that the American public always rates managing global warming far down on its list of concerns for the president and the U.S. Congress. It reports that for the year 2014, global warming ranks next to last in a list of twenty current issues.[14]

He is further supported by the organization called the Union of Concerned Scientists. That group says that in 2013, news reports related to science from CNN, Fox, and MSNBC were filled with errors. They report that Fox News had the highest number of inaccuracies, with 72% of its science-related news segments contained wrong information. CNN came next with around a third of its news segments containing incorrect information. MSNBC had fewer inaccuracies, with only eight percent of its news segments giving inaccurate information.[15]

2.7 Oil Companies Contributing to Doubts

InsideClimate News, is a Pulitzer Prize-winning, online news organization that covers clean energy, carbon energy nuclear energy, and environmental science. Following months of investigation, InsideClimate News began, in the fall of 2015, to release a series of reports titled “Exxon: The Road Not Taken; Exxon’s Own Research Confirmed Fossil Fuels’ Role in Global Warming Decades Ago.” It presents a history of how Exxon involved itself with the science of climate change. It covers forty years, and is based on internal company files that go back to the late 1970s, interviews with former company employees, and other evidence. It tells how Exxon did cutting-edge research on the climate decades ago, and then, while not revealing what it had learned, was a leader in climate denial, and manufactured doubt about the scientific facts that its own scientists had proven.[16]

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14 Pew Research Center, “Climate Change: Key Data Points from Pew Research.” Last modified January 27, 2014. http://www.pewresearch.org/key-data-points/climate-change-key-data-points-from-pew-research/. (Accessed April 11, 2014.)

15 Union of Concerned Scientists, “Science or Spin?: Assessing the Accuracy of Cable News Coverage of Climate Science.” Last modified April 04, 2014. http://www.ucsusa.org/global_warming/solutions/fight-misinformation/cable-news-coverage-climate-change-science.html#.VpB9ajaZPt4. (Accessed April 11, 2014.)

16 Banerjee, Nella, Lisa Song, and David Hasemyer. InsideClimate News, “Exxon: The Road Not Taken; Exxon’s Own Research Confirmed Fossil Fuels’ Role in Global Warming Decades Ago.” Last modified September 16, 2015. http://insideclimatenews.org/news/15092015/Exxons-own-research-confirmed-fossil-fuels-role-in-global-warming. (Accessed December 23, 2015.)

Honolulu Traffic Jam
(Courtesy of Civil Beat)

Exxon wasn't alone. The American Petroleum Institute, the most powerful lobbyist in the country, set up a task force to monitor and share climate research from 1979 to 1983, suggesting that the entire oil industry, not just Exxon, knew of the possible impact on the climate much earlier than thought. According to internal documents obtained by InsideClimate News, and interviews with a former director of the task force, members included scientists and engineers from almost every major U.S. and multinational oil and gas company.[17]

The good news is that Americans are changing their minds about climate change. According to a new poll (fall of 2015) done by National Surveys on Energy and the Environment, 70 percent of Americans currently believe that global warming during the last four decades is real and that it is supported by solid evidence. Surprisingly, among the numbers of Republicans doubting the truth of climate change, the survey found a drop from 41 percent one year ago to 26 percent today.[18]

17 Banerjee, Neela. InsideClimate News.com, "Exxon's Oil Industry Peers Knew About Climate Dangers in the 1970s, Too." December 22, 2015. http://insideclimatenews.org/news/22122015/exxon-mobil-oil-industry-peers-knew-about-climate-change-dangers-1970s-american-petroleum-institute-api-shell-chevron-texaco. (Accessed December 23, 2015.)

18 Cimons, Marlene. ThinkProgress.org, "Poll Finds Fewer Americans Than Ever Doubt Climate Change Is

2.8 Mitigating / Managing Sea Level Rise

Maeslant Barrier on the Rhine River in the Netherlands. It stop a surge of more than three meters (Courtesy of Rotterdam Marketing)

Rebuilding the seawall along The Embarcadero would cost an estimated $5 billion dollars, but without a fix, water could rise up to BART and Muni tunnels (Courtesy of San Francisco Examiner)

SPUR, previously known as San Francisco Planning and Urban Research Association, is a non-profit research, education, and advocacy organization that focuses on planning and governance. (SPUR goes back to 1910, when a group of city leaders met to improve housing in San Francisco just after the great earthquake and fire in San Francisco in 1906.)

Happening." Last Modified October 16, 2015. http://thinkprogress.org/climate/2015/10/16/3713267/climate-change-poll/. (Accessed November 3, 2015.)

Listed in their online newsletter are seven strategies for managing sea level rise, and examples of each are given. Additionally, both advantages and disadvantages of each strategy are pointed out. Those seven strategies consist of barriers, coastal armoring, elevated development, floating development, floodable development, living shorelines, and managed retreat.[19] Let's briefly examine each of these seven strategies and look at the pros and cons of each.

The first strategy is based on barriers, which are large dams, gates, or locks, of a series of them, that manage tidal flows and/or prevents storm surges. One example is the Maeslant Barrier on the Rhine River at the Port of Rotterdam, in the Netherlands. It can hold off a surge of more than three meters. Another example is the Thames Barrier, which is a series of river gates that were built in the 1970s to protect London from storm surges. One advantage to barriers is that they can protect a large area of land in a single sweep. A disadvantage is that they are expensive to build. The Maeslant Barrier, for example, cost around $4 billion. Another drawback is that they can damage the local ecology.[20]

The second strategy has to do with coastal armoring, which is protection that is linear, such as levees, and seawalls, that secure the shoreline in its present position. The kind of armoring depends on the kind of coastline. Engineered concrete seawalls and bulkheads, the most hardened form of armoring, protect shores from strong wave action. Different kinds of levees of earth protect low-lying lands, often from river floods. In emergencies, they can be made from sandbags. For protection of non-hardened shorelines, a softer approach is called for, that is, beach nourishment, which is bringing in sand to maintain or restore eroding beaches. Other strategies to protect beaches include offshore breakwaters, which are barriers to reduce the force of waves and groins, low walls that reduce erosion. An example of coastal armoring is San Francisco's Embarcadero, which rests on the top of a seawall that was completed in the 1920s. Other examples are the numerous levees that are used in areas throughout the Mississippi Delta. Advantages of coastal armoring include the fact that it can be used together with other strategies, and used as protection from storm surge and sea level rise. Disadvantages include the fact that armoring is a short-term solution since all

19 SPUR.org, "Strategies for Managing Sea Level Rise." Last modified November 1, 2009. http://www.spur.org/publications/article/2009-11-01/strategies-managing-sea-level-rise. (Accessed May 23, 2015.)

20 Ibid.

coastal armoring is engineered to deal with storms of a certain size, or a particular rise in sea level.[21]

The third strategy is elevated development, which means to raise the height of land, or existing development, and then protecting it with coastal armoring. It can also be used to protect airports, roads, or railways. Examples of elevated development can be seen in elevated houses in New Orleans in the wake of Hurricane Katrina. That city now requires that new housing in areas that are protected by levees to be elevated either three feet, or to flood elevation levels predicted by the Federal Emergency Management Agency, depending on which is higher. An advantage of elevated development is that it allows buildings to be built on an endangered shoreline or in an area that is vulnerable to flooding. A shortcoming is that it is short term since it provides protection only for a given period of time.[22]

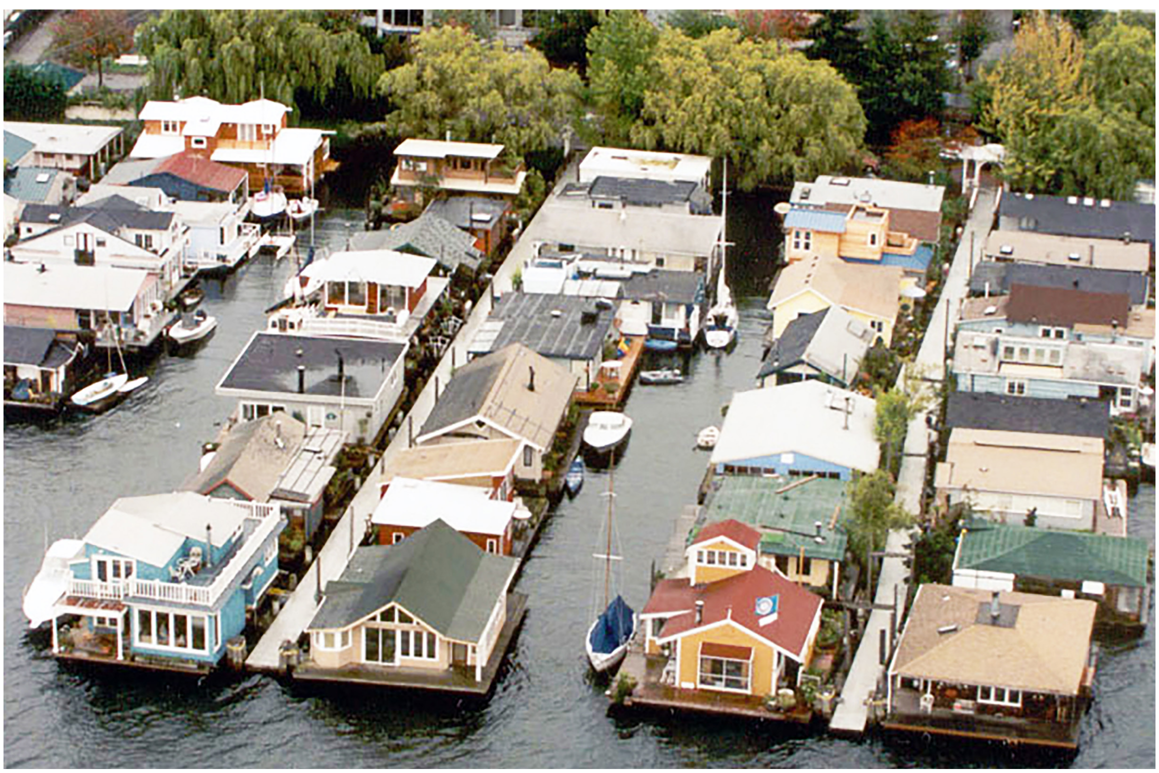
The fourth strategy, floating development, consists of structures that either permanently float on the surface of water, or only float during a flood, both of which make them safe from changing tides. Floating houses can be either secured to the shore or the seafloor. Floating homes differ from houseboats in that they don't have propulsion systems. The advent of sea level rise has prompted designs for floating structures that are much larger than single-family homes, for example, an offshore airport in the North Sea, and floating hotels and restaurants offshore in Dubai.

If alternative energy sources aren't used, electricity, water, and sewage infrastructure is supplied to floating structures through flexible pipes. Some already existing examples of floating communities can be found in Sausalito, and other waterfront cities with fairly protected waterfronts, like Seattle and Amsterdam. Advantages of floating development include the fact that floating structures deal with the uncertainty of high tides and earthquakes. Floating structures can be viable despite the uncertainties associated with the timing and nature of sea level rise.

21 Ibid.

22 Ibid.

In New Orleans the FLOAT House can rise vertically on guide posts, floating up to twelve feet as water levels rise (Courtesy of Architectenbureau Marlies Rohmer)



Floating Community in Seattle.
(Courtesy of www.inspirationgreen.com)

Disadvantages are that currently floating structures work only in protected areas, and aren't suited for places that are subject to heavy wind and wave action generated by storms.[23] (That could change in the future. See 5.14 for a discussion on "Petropolis," a prototype floating community in the ocean that oil companies are now considering to accompany oil rigs that are far out to sea.)

The fifth strategy is related to floodable development, which is one of two things. One is designing buildings and infrastructure that resist occasional or periodic flooding, and that can be backup strategy in case shoreline armoring fails. The other is creating areas for retention of stormwater, water from heavy rainfall or water from ocean surges, where water could be held until the flood water recedes. Floodable development is a form of "low impact development," (LID) that infiltrates stormwater into the ground, creating green spaces, and, at the same time, reducing the load on urban wastewater treatment systems. One example is a large underground parking garage in Rotterdam, the Netherlands, which holds water instead of cars during floods. Another example is in the U.K. where several towns with river flood problems are considering something called a "village blue." The idea there is to create a central area for recreation that can become an expandable lake in flood conditions. This strategy is already in wide use in Seattle and Portland. They include contoured ground, permeable pavement, and even large cisterns for storing water for use in the future. Floodable development's advantage is that it may be a step up in small-scale development since the actual strategy selected is based on which would work best for a particular site. The main disadvantage is that it could be dangerous. Stormwater is most often seriously polluted, and large bodies of stormwater, either on the surface or underground, could be a health hazard both during flooding or afterwards when contamination is left behind. Also it isn't known if buildings and infrastructure can be designed or retrofitted to deal with occasional flooding in a way that is cost-effective.[24]

Strategy number six is the use of living shorelines, which are wetlands. Wetlands are nature's way to absorb floodwaters, curb erosion, and provide a natural environment for both plants and animals. Water in wetlands is either, fresh, brackish, saltwater, and different types of wetlands include swamps, marshes,

23 Ibid.

24 Ibid.

bogs, and fens. An example of wetland in the San Francisco Bay shoreline is the South Bay Salt Pond Restoration Project, which is the largest tidal wetland restoration project anywhere on the West Coast. Major wetlands and restoration projects in the South and East Bay include the Don Edwards Wildlife Refuge in Redwood City and the South Bay Salt Pond Restoration Project, the largest tidal wetland restoration project on the West Coast. There are many advantages to Wetlands. They benefit society, since they filter pollutants out of water, and remove carbon. They provide recreational space and provide habitat for fish, wildlife and numerous organisms that live in tidal mud and serve as the basis for aquatic food chains. There are disadvantages in that they are usually "thicker" than linear armoring strategies, like levees, so they require more land. Additionally, they need management, monitoring, and time to become established.[25]

The seventh and last strategy for dealing with rising sea levels is managed retreat. Managed retreat is defined here as "the planned abandonment of threatened areas near the shoreline." It removes human activity from receding shorelines, and allows the water to advance unrestricted. It includes leaving, dismantling, or relocating buildings that exist in the area to higher ground. Managed retreat additionally includes the banning of new development in areas that are expected to be flooded, and is used when other shoreline protection efforts are too expensive or not successful. Managed retreat also involves the establishment of "thresholds" that would lead to certain activities, such as tearing down buildings or stopping efforts to control erosion. Thresholds can be part of buyback programs that compensate property owners for loss, and can be tied to strict building codes that permit only certain types of structures. An example of this is the current setback rules for construction in most coastal and Great Lakes states. They allow development only outside a specified distance from the water's edge.[26]

An advantage of managed retreat is that it is usually not as expensive as armoring, especially when those measures are not permanent. Another good thing is that it can allow the restoration of wetlands and natural shoreline habitat. A disadvantage is that it can be very costly for areas that are highly developed and will result in a loss of property values if setback lines are moved. It is also said to

25 Ibid.

26 Ibid.

be a “political quagmire,” because not all property owners are willing to sell, and that brings in issues of legality and equity. Moreover, shoreline communities in many places are already disadvantaged and don’t have the ability to relocate.[27]

2.9 Floating Architecture - “Last Man Standing”

As can be seen in the last few paragraphs, there are a number of strategies to manage (notice the choice of words: manage) sea level rise. Floating development, i.e., floating architecture, is only one of a number of suggestions for dealing with sea level rise, but, in the end, could be the “last man standing” if sea level rise continues indefinitely into the unforeseeable future. Unfortunately, there is nothing the writer has seen in the literature that suggests a specific time for sea level rise to stop.

There are, however, now chilling predictions for how long sea level rise might continue, or at least for how long they might stay elevated. The Nature Climate Change published an online report in February, 2016, saying that even if there is only a 2C rise in temperature, as agreed on by the international community in a Paris conference earlier in 2016, (an agreement discussed in the next chapter of this thesis), sea level rise, over the next 2,000 years, would still be 25 meters, and stay at that height for, at the very least, 10,000 years, which turns out to be two times as long as human history. Furthermore, it says that If there is only a 2°C rise in temperature, 20% of the world’s population, residents of coastal cities, will still be forced to migrate inland. It goes on to say that if today’s use of coal, oil, and gas is not reduced, the amount of sea level rise, over the next 2,000 years, would be 50m, altering completely the world as we know it today. The reason for this, according to the report, is because most of today’s research considers the consequences of global warming by 2100, and doesn’t take into account the melting of polar ice caps, as it affects sea level rise, over the long term. Professor Peter Clark, of Oregon State University, led the new research, and had this to say: “People need to understand that the effects of climate change won’t go away, at least not for thousands of generations.” He also said, “We can’t keep building seawalls that are 25m high.”[28]

27 Ibid.

28 Carrington, Damian. “Sea-level rise ‘could last twice as long as human history’” Guardian.com. Last Modified February 8, 2016. http://www.theguardian.com/profile/damiancarrington. (Accessed February 22, 2016.)

Moreover, we can't continue building barriers indefinitely, and we can't endlessly continue elevating property. That, unfortunately, means that unless someone comes up with some new technology that will miraculously suck excess carbon dioxide out of the atmosphere (and how likely is that), we are facing a very, very serious problem, which gives the idea of floating architecture a lot more credibility when it is described as being the "last man standing?" After taking everything into consideration, one obvious fact remains: no matter high high sea level rise goes, it will still have a surface, and certain things will still float.

This is not to say that floating development is a panacea, nor is it "the solution to the problem." This is not saying that floating development is the best thing (or the only thing) people can do as a reaction to sea level rise. Floating architecture is one of a number of suggested ways to mitigate, i.e., deal with, sea level rise. It certainly doesn't mean we should start immediately replacing shoreline structures with floating structures. Moreover, no one is saying that waters everywhere are the same, nor is anyone saying and that the same designs can be transported everywhere, and it certainly isn't saying that we can start development in the open ocean. On the other hand, however, based on literature that is available to anyone, research clearly shows that floating architecture is one, good viable option for living with rising water, and that is one reason floating architecture is now appearing in cities around the world. Fortunately, not only can floating architecture help in mitigating sea level rise, it has a number of other advantages and benefits for people and the environment, which will be discussed later.

Summing Up

In this chapter we examined global warming, climate change, and some of the consequences of those changes, homing in on sea level rise. We discussed doubts about global warming and climate change and it was sadly reported that not only have oil companies allegedly known for years what was happening, they hired groups to convince the public that climate change was all a fantasy. Despite what they have supposedly done, however, more Americans agree now, than at any other time in the past, that climate change is real. After that, from San Francisco we examined seven strategies for managing sea level rise and pointed out reasons that floating architecture might be considered the last man standing when attempting to mitigate sea level rise.

Coming Up

In Chapter 3, we will look specifically at impacts of sea level rise on cities, landmarks, island nations, and here in Hawai‘i. We will investigate what is coming up and how sea level rise is making itself known today, We will try to see what the state of Hawai‘i has in mind in terms of preparation for climate change, and what the international community has done in an attempt to slow climate change. Finally, we will hear President Obama weigh in on the topic when giving his last State of the Union address.

Chapter 3

Results of Climate Change and Sea Level Rise

"Even castles made from sand fall to the ocean."
— Jimi Hendrix —

3.1 Sea Level Rise will Impact the World's Largest Cities

According to an online report by MSNBC more than two-thirds of the world's largest cities are located in areas that will be impacted by current sea level rise and millions of people will be in danger of floods and storms. Over 634 million people live in endangered coastal areas (areas that are less than thirty-three feet above sea level), and that number is increasing. Also there are over 180 countries that have people in those areas, and two-thirds of those countries have areas where five million people live, including Tokyo and New York. Solutions will be expensive and will likely involve the relocation of many people, along with the construction of protective barriers. It is strongly suggested that countries stop or reduce the growth of populations in areas along their coasts.

Tidal flooding to be more frequent in Miami as seas rise
(Courtesy of Miami Herald)

3.2 Top 5 American Cities to be Impacted by Sea Level Rise

By the middle of this century, what will American cities be losing annually for flood losses due to rising sea levels? Nature Climate Change did a study to find the 20 cities around the world with the most to lose and it turned out that five of those are American cities. They are #5) Boston, #4) the Tampa-St. Petersburg area, #3) New Orleans, #2) the New York City and Newark, New Jersey area, and #1) Miami.[29]

On that list, Boston, with a population of about 4.5 million people, will be paying the fifth highest amount. It is expected to lose $741 million from annual flood losses. Number four on the list is the Tampa-St. Petersburg metro area. By 2050, they are expected to deal with flood losses that could reach $859 million every year, according to the study. Number three is New Orleans, which is already sinking up to an inch every year. That city is expected to be paying more than $1.8 billion by 2050 to deal with impacts of flooding. Number two is the New York City and Newark, New Jersey area, with a shared population of more than 18 million people. By 2050, they are expected to spend just over $2 billion every year for flood protection and damage repair. Topping the list is Miami, which is home to 5 million people. Miami ranks at or near the top of many lists of the world's most susceptible cities to damage from sea level rise. The Nature Climate Change study says that Miami will have to spend more than $2.5 billion every year on flood protection and damage repair. It has been said that if global sea level rise is as much as has been predicted in a worst-case chain of events, the Miami that we know today will no longer exist.[30]

3.3 National Landmarks to be Impacted by Sea Level Rise

Rising sea levels are not only threatening things like housing and the economy. They are threatening to take away irreplaceable pieces of history, places that have made the U.S. what it is. If this is permitted to happen, the loss will be great. It will be like losing a much-loved family member who can never be replaced. An architect from the Netherlands told this writer that Hawaii should protect the things it loves from sea level rise. These are surely the places that illustrate what that architect had in mind.

According to the Union of Concerned Scientists (UCS), numerous national parks and landmarks are being seriously threatened from climate change, and the danger is so great that they will likely either be irreparably damaged or will

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29 Johnson, Terrell. Weather.com, "Climate Change Warning: 20 Cities With The Most To Lose From Rising Seas." Last modified April 2, 2014. http://www.weather.com/science/environment/news/20-cities-most-lose-rising-sea-levels-20130822#/1. (Accessed August 8, 2015.)

30 Ibid.

disappear completely. They chose thirty different places in the United States to feature in a report. Five of those places are featured here. The first is the Statue of Liberty and Ellis Island, which welcomed twelve million immigrants. The second is the Harriet Tubman Underground Railroad National Monument, which recognizes one of the many who put their lives at risk in the antislavery movement. The third and fourth are the Kaloko-Honokōhau and Pu'uhonua o Hōnaunau National Historic Parks on the west coast of Hawaii's Big Island.

Threatened by Sea Level Rise: Kaloko Fishpond Wall
(Courtesy of PacificIslandParks.com)

At Kaloko-Honokōhau, there are ancient structures that were used for catching fish, and also the Aimakapā fishpond, a possibly 600-year-old site, which was used to raise fish for royal chiefs. Pu'uhonua o Hōnaunau was a place of refuge during wartime, where anyone could find sanctuary, and also the place where one of the earliest contacts between Native Hawaiians and Europeans took place. It is also the place, where, in 1779, Captain James Cook was killed.[31]

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31 Brones, Anna. Care 2.com, "10 National Parks, Monuments and Landmarks Threatened By Climate Change." Last modified June 3, 2004. http://www.care2.com/causes/10-national-parks-monuments-and-landmarks-threatened-by-climate-change.html. (Accessed January 30, 2015.)

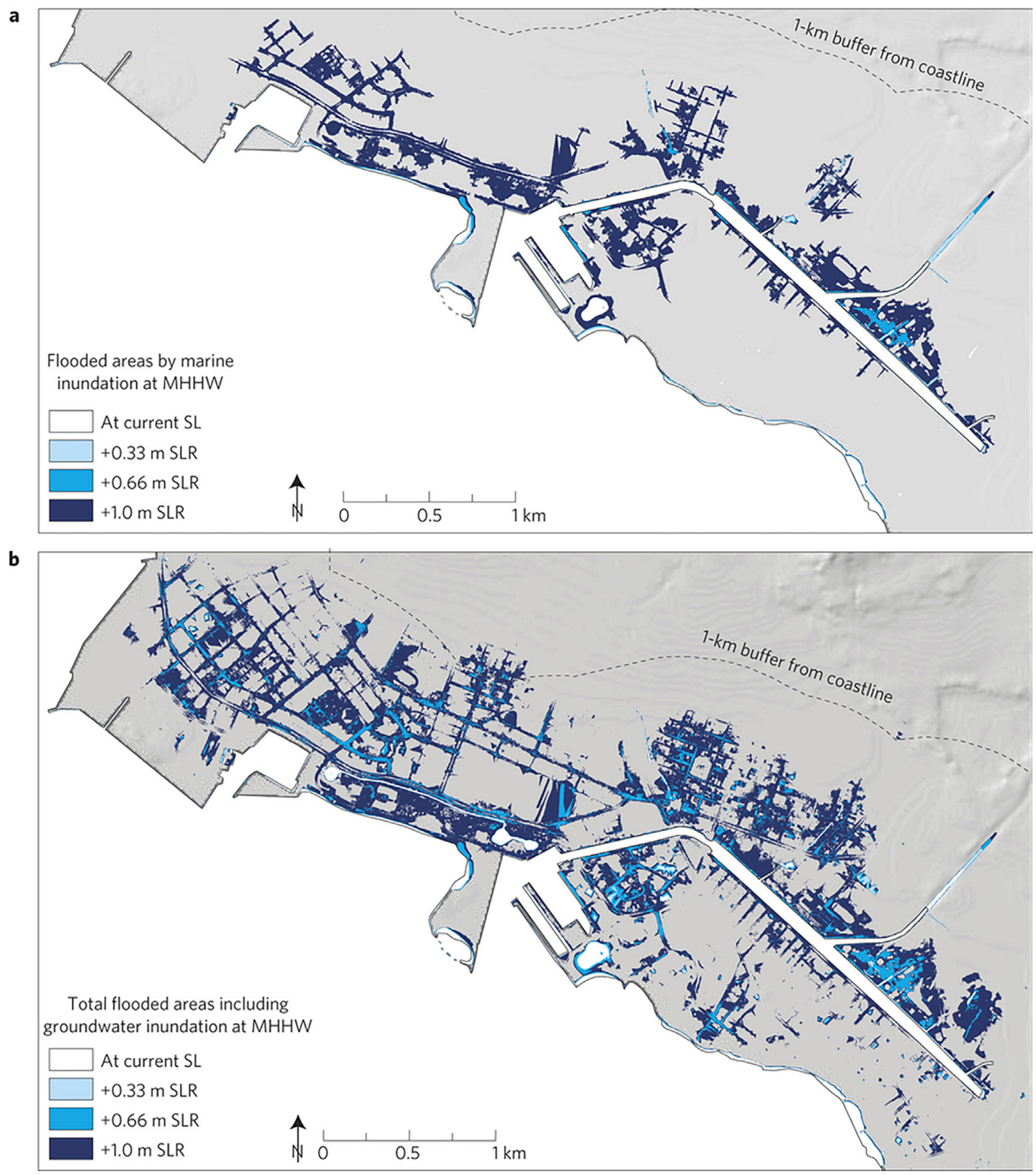
Threatened by Sea Level Rise: Pu’uhonua o Hōnaunau
(Courtesy of TravelObservers.com)

Planners everywhere need to keep in mind that losing irreplaceable landmarks like any of those just mentioned could profoundly affect the way people feel about themselves and the world around them, whereas the act of somehow saving them could only result in positive feelings and strengthen the belief that we can and will overcome, or at least outlast, the devastation brought on by climate change.

3.4 Climate Change and Sea Level Rise in Hawaiʻi

Unfortunately some predictions say that Hawaiʻi will especially suffer more than other places due to sea level rise. One study says that the seas around the world are being pushed up unevenly as ice melts in Antarctica and elsewhere and that Honolulu will be inundated by the highest waters. This is due, in part, to the fact that at both poles there will be an actual fall in sea levels because of the interaction of sea, land, and ice.

On the other hand, oceans on the equator might experience as much as two feet of rise, taking into account the fact that water expands as it warms. That could mean that the rate of sea-level change in Honolulu will be more than 0.3 inches a year after the first half of this century.[32]



Waikiki Coastal
Map a: Inundation at MHHW under sea-level rise in the Honolulu caprock aquifer, Oahu, Hawaii.
Map b: Total inundated areas including groundwater inundation.
Click on the link for Coastal Flythrough http://www.soest.hawaii.edu/coasts/sealevel/3ftHonoluluTour.html
(Courtesy of UH School of Ocean and Earth Science and Technology)

32 NBC News Science, "Hawaii to suffer most as global sea levels rise, study says." Last modified February 21, 2013. http://science.nbcnews.com/_news/2013/02/21/17044546-hawaii-to-suffer-most-as-global-sea-levels-rise-study-says?lite. (Accessed August 2, 2014.)

The School of Ocean and Earth Science and Technology at UH Manoa is predicting that the mean sea level in Hawaii may be one foot higher by the middle of this century and two to six feet by the end of the century. They say that planners in Hawaii should consider a worst case scenario of an increase of six feet by the end of the century and what that impact will be on the state. This group says these facts should now be considered in designs for all projects in Hawaii where public health and safety are in danger, such as hospitals, schools, and coastal highways. Additionally, according to that report, it would be wise to expect three serious hurricanes in Hawaii to make direct landfall after sea levels are higher.[33]

Climate change in Hawaiʻi is very much in line with what scientists have been predicting in terms of general global warming. These changes include a rise in air temperature, a decrease in overall rainfall, an increase in the intensity of the rain, both surface temperatures and sea levels have increased, and the seas are becoming more acidic.[34]

Some specific predictions for local areas on Oahu have been made. For example, submersion of Hickam Air Force Base would begin with a three-foot rise in sea level, and, at six feet, be totally submerged. Costo at Iwilei would be inundated with a four-foot sea level rise. The Kakaʻako Waterfront Park would become an island somewhere between a five-foot and six-foot rise in sea levels. Kapiolani Blvd. and Ala Moana Blvd. between Chinatown and Waikiki would be flooded at a six-foot sea level rise. Also at six feet, the Old Stadium Park in Mō`ili`ili would be transformed into oceanfront property and Kailua would become an island.[35]

3.5 How Hawaiʻi is Dealing With Climate Change

Some reassurance can come from the fact that the state government is making an effort to prepare for climate change. Until fairly recently, Jacqueline Kozak Thiel was Hawaii's State Sustainability Coordinator (leaving Hawaiʻi in 2015 for a job as chief sustainability officer for the city of Fort Collins, Colorado). In an interview in 2014, for the National Oceanic and Atmospheric Administration, she

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33 University of Hawaii at Manoa: Coastal Geology Group , "Sea Level Rise Hawaiʻi; Hawaiʻi's Changing Climate." Last modified March 9, 2012. http://www.soest.hawaii.edu/coasts/sealevel/index.html. (Accessed February 2, 2015.)

34 Ibid.

35 Ibid.

answered questions about climate change in Hawai‘i, opening a window on the position of the state government on the topic.[36]

When asked if there was any one issue related to climate change she was most concerned with for Hawai‘i, Ms. Thiel responded that she was concerned that certain climate-sensitive diseases would proliferate and affect community health, adding that that would impact the tourism-based economy. She also said that she was worried that climate change would affect food and energy security in Hawai‘i, since we will be faced with the possibility of drought, and worried about how to protect critical infrastructure along the coastlines from erosion and sea level rise. She voiced concern about preserving biodiversity and said that there wasn't one thing, but the interaction of those things.[37]

When talking about tourism and the economy she pointed out that 70 percent of the beaches are eroding, and that the impact on Waikiki Beach would cost more than $2 billion. She said that people visit Hawai‘i for authentic natural experiences but that places to have those experiences will be disappearing. She said that changes in the environment will not only change the visitor experience, they will change the lives of people who live in Hawai‘i and added that as an island state, it is a microcosm of climate change elsewhere, and can be a model for dealing with the challenges of climate change.[38]

On the subject of specific state preparations for climate change, she discussed an initiative called the "Rain Follows the Forest Watershed Initiative." Dealing with watershed management first, insures that ecosystems are resilient and that everything is being done to deliver pure water through those ecosystems. That is being done since climate change will have a very serious impact on the amount of available fresh water. She also said that the state government had signed into law the "Hawai‘i Climate Adaptation Initiative," which puts into place an interagency climate committee, bringing in a multitude of agencies to work on related issues.

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36 Greenhalgh, Emily. "Jacqueline Kozak Thiel Talks about Hawaii's Sustainability Efforts and Preparing the Island Chain for Climate Change." Last Modified July 1, 2014. https://www.climate.gov/news-features/decision-makers-take-5/jacquel. (Accessed September 19, 2015.) .

37 Ibid.

38 Ibid.

She said that it was starting with sea level rise as the foundational framework, and that by 2017, they hoped to have a sea level rise strategy so the counties and the state can start to deal with infrastructure and natural resources along the coastlines.[39]

3.6 Current Impacts of Sea Level Rise

Current rises in sea levels are already being felt in low-lying areas around the world. Rising sea levels are causing flooding of coastal land resulting in damage or destruction to buildings, roads, power stations, and so on. Rising sea levels are bringing saltwater into important underground sources of freshwater. They are increasingly eroding the land and contaminating ground water with salt water. They are already responsible for the decline of coastal wetlands, and marshes. Additionally, the physical impacts of sea level rises are already having negative socioeconomic impacts, in housing, businesses, property values, and so on.[40]

3.7 Current Impacts of Sea Level Rise in Some Island Nations

Climate change is already being felt all over the Pacific, and things are going to get a lot worse between now and the end of this century. Sadly, many islands in the Pacific will have disappeared entirely, by that time, while others will no longer be habitable. People will be uprooted and the era of climate refugees will have begun. Following are four sets of islands that are already facing, and dealing with, rising sea levels.[41]

Kiribati, which is midway between Hawaii and Australia, consists of 32 low-lying atolls and one raised island. Most people there have already moved to the one island, Tarawa, since the rest of their land has become inundated with seawater. The president of Kiribati is currently negotiating with the government of Fiji to purchase 5,000 acres of land, where the entire population will be relocated.[42]

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39 Ibid.

40 Union of Concerned Scientists, “Encroaching Tides.” Last modified January 1, 2014. http://www.ucsusa.org/global_warming/impacts/effects-of-tidal-flooding-and-sea-level-rise-east-coast-gulf-of-mexico. (Accessed October 21, 2014.)

41 Astaiza, Randy. Business Insider.com, “11 Islands That Will Vanish When Sea Levels Rise.” Last modified October 12, 2012. http://www.businessinsider.com/islands-threatened-by-climate-change-2012-10?op=1. (Accessed January 31, 2015.)

42 Ibid.

Flooding of graveyard during high tide in Marshall Islands.
(Courtesy of Drowning Islands)

The Maldives, made up of over 1,100 islands just west of India, has a population of 325,000, and is the lowest-lying nation in the world. The islands are, on average, just a little more than four feet above sea level. If the sea level rises three feet, the Maldives would be uninhabitable.[43] (The Maldives will be discussed later in this research paper [see 4.14], since it has hired an architectural firm from the Netherlands to build floating houses, hotels, and tourist destinations.)

Micronesia comprises 607 mountainous islands and low-lying coral atolls, has a population of 102,624, and is located in the western Pacific. At the present time, rising sea levels are killing off food crops. In a widely circulated picture, a man is standing in about two feet of water where a cemetery was. In an interview with ABC News, the Micronesian Ambassador to the U.N. said, "Even the dead are no longer safe in my country." A three-foot rise in sea levels would make Micronesia uninhabitable.[44]

43 Ibid.

44 Ibid.

Palau is composed of eight main islands and more than 250 smaller islands. It is also located in the western Pacific and has a population of 20,000. Rising sea levels are currently eroding Palau's coasts, and polluting its farmlands with saltwater. Palau's president has described the damage they are currently experiencing as "a slow-moving tsunami."[45]

High Tide in Palau Causes Significant Flooding
(Courtesy of Pacific Climate Change Science)

The sea level rise taking place in the Pacific islands is irony at an epic level. Charles Fletcher, a geologist at UH Manoa, told NBC News that the Pacific islanders are not the ones who contributed to the problem, and yet they are the ones now being adversely affected.[46]

Some of these islands and populations are neighbors to the people of Hawaii, and share lifestyles and customs, and at least some of the people mentioned above will come to Hawaii as climate refugees, unfortunately, at a time when Hawai'i itself could be facing its own set of problems related to climate change. This, of course, would add a whole new level of difficulties that Hawai'i would have to deal with, especially in term of additional housing, food, and fresh water.

45 Ibid.

46 NBC News Science, "Hawaii to suffer most as global sea levels rise, study says."

3.8 Current Impacts of Sea Level Rise in Hawai‘i

The Climate Reality Project was established in 2011 after two non-profit environmental advocacy groups, both founded by Al Gore, joined together. Here is what they have reported has having already happened in Hawai‘i as a result of climate change.

In Hawai‘i, air temperatures at high elevations have warmed at about 0.5 degrees fahrenheit per decade for the last three decades, which is faster than the rate of rise anywhere in the world. This rise in temperature is a threat to both society and the environment as the amount of fresh water declines and various diseases spread. The temperature of the surface of the sea has warmed 0.2 degrees fahrenheit per decade.[47]

There has been a steady 15 percent drop in rainfall since 1990. Between 1958 and 2007, the strength of the rainfall went up about 12 percent resulting in a number of flash floods, mudslides, and flooding with dangerous debris and sediment, called debris-flow events.[48]

Kamehameha Highway, on the North Shore of O‘ahu near Sunset Beach, being cleared of sand in February, 2016 after being hit by high wind and waves. (Courtesy of Civil Beat)

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47 Climate Reality Project, “What Does Climate Change Mean for Hawaii.” Last Modified March 28, 2014. http://www.usclimatenetwork.org/resource-database/what-does-climate-change-mean-for-hawaii. (Accessed December 23, 2015.)

48 Ibid.

In waters around Hawai‘i, sea levels went up about 0.6 inches per decade during the last ten decades, resulting in continuing problems with flooding in coastal areas, salt contamination, and problems with drainage.[49]

Beaches throughout Hawai‘i are rapidly eroding as sea levels rise. Maui experienced 78 percent of all its beaches eroding at an average rate of 5.1 inches per year during the last century. O‘ahu experienced 52 percent of its beaches eroding at 1.2 inches per year.[50]

3.9 What the International Community Has Done to Slow Down Global Warming

In December, 2015, representatives from almost 200 countries gathered in Paris reached the world's most important agreement to tackle climate change since concerns first arose about climate change decades ago. The Paris Agreement is intended to show the beginning of the end to the use of fossil fuels and that governments everywhere, both developed and developing, are taking climate change seriously. The agreement requires that each country that accepts the agreement take steps to act to reduce its greenhouse emissions and continue reductions throughout the century. Each country will aim to keep global temperatures from rising more than 3.6°F (2°C) by 2100.[51]

3.10 The President's Remarks on Climate Change and Sea Level Rise

In his final State of the Union address, in January, 2116, President Obama linked climate change to rising economic hope instead of to crippling catastrophes, framing climate change as a challenge for younger generations. He said that if anyone still wanted to dispute the science around climate change, they could do it, but that they would be lonely, because they would be debating the military, most business leaders, most Americans in general, almost all of the scientific community, and 200 nations around the world who are in agreement that it is a problem which they plan to solve. He added that this is a great chance for American businesses to produce and market energy of the future. These statements build on his ideas to leave fossil fuel deposits alone, thereby avoiding

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49 Ibid.

50 Ibid

51 Worland, Justin. Time.com, "What to Know About the Historic 'Paris Agreement' on Climate Change." Last modified December 12, 2015. http://time.com/4146764/paris-agreement-climate-cop-21/. (Accessed January 5, 2016.)

the release of emissions, while advancing alternative sources of energy. In his address, he said that we have to accelerate the transition away from dirty energy and instead of subsidizing the past, we need to invest in the future, particularly in communities that depend on fossil fuels. He said that he wanted to change the way oil and coal resources are managed, so they are more in line with what they really cost taxpayers and the planet.[52]

Public interest in climate change is now growing, as more and more people wake up to what is happening, more and more people are concerned with what can be done to slow down climate change. Simply put, slowing down climate change means trying to reduce the amount of greenhouse gasses that are being released into the atmosphere. Carbon dioxide, as a main greenhouse gas is released routinely as fossil fuels are burned to produce electricity, provide transportation, and power industry. Clearly reducing carbon dioxide means reducing the amount of fossil fuels being burned.[53]

Whether or not societies around the world can reduce greenhouse gasses remains to be seen. Of course reducing greenhouse gasses, especially reducing the amount of carbon dioxide that is released, presents a very difficult dilemma to solve. The fact of the Paris Climate Agreement demonstrates that governments are working on the problem, but in the end it will be difficult since all modern societies are driven by electricity, transportation and industry. Average people can help by driving less, using less electricity, and producing less waste, and doing that has begun to enter the national consciousness. It is important to remember, though, that even if the amount of greenhouse gasses were suddenly reduced, the effects of climate change would not suddenly disappear. It has taken humanity a while to reach this point, and it would take a while for nature to repair itself.

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52 Lehmann, Evan. Scientific American.com, "Obama Forecasts Economic Opportunity in Fighting Global Warming." January 13, 2016. http://www.scientificamerican.com/article/obama-forecasts-economic-opportunity-in-fighting-global-warming/. (Accessed January 13, 2016.)

53 United States Environmental Protection Agency, "Overview of Greenhouse Gasses. "Last modified July 2, 2014. http://www.epa.gov/climtechange/ghgemissions/gases/co2.html. (Accessed January 20, 2015.)

Summing Up

In this chapter we explored various ramifications of sea level rise including impacts on coastal cities, historical landmarks, and in the state of Hawai‘i itself. Additionally, considerations for preparations by the state of Hawai‘i were mentioned, as was the international Paris agreement. Finally, we saw President Obama’s positive assessment of dealing with climate change by saying this is a great chance for American businesses to produce and market the energy of the future.

Coming Up

In the next chapter we will take a close look at the Netherlands and research how they have become world leaders in water management. We will see how Dutch society has made a fundamental change in their attitudes towards the sea and their relationship with it, which was originally to fight to keep the water out, but now is to invite it in. We will explore how Dutch architects, in terms of floating architecture, have now become advisors to the world. We will hear from the floating Dutchman who has a lot to say about floating development. We will also see that he and a project of his in the Maldives could be important to Hawai‘i.

Chapter 4

The Netherlands As World Leaders In Water Management And Some Words From The Floating Dutchman

"Smooth seas do not make skillful sailors."
— African Proverb —

4.1 Early Efforts in the Netherlands to Deal With the Sea

A Dutch terp; protection from floods when the polder below the terp was flooded.
(Courtesy of Nederland Fietsland 2016)

The first coastal dikes in the Netherlands were built around 500 B.C., and since then, the Dutch people have continuously been fighting against the power of the sea. After completion of the early dikes, which are long walls to keep out the sea and rising rivers, the Dutch embarked on huge land reclamation projects. The final dike was built in 1932. Today about twenty-five percent of the land in the Netherlands is below sea level. Since water levels along some coasts make them subject to flooding, the Dutch began constructing artificial hills, called terps, and putting villages and towns on top of them. Later they began to use dikes to connect the terps together, keeping the water out of land to use for farming. Finally, they began to look at marshes, lakes and flood zones, and began building dikes around them, calling those areas polders. Windmills were connected to pumps to make, and keep, the polders dry enough for farming or building.[54]

4.2 A Change in Approach

After fighting against the water for centuries, the Dutch are now taking a different approach. Koen Olthuis, a well-known Dutch architect, explains that they are now moving away from fighting against the water. Instead, he says, they are beginning to let the water in and "make friends with it," meaning they are beginning to flood some of the previously dry polders with water. He says they have to do that because of climate change and rising sea levels, and as the seas continue to rise, the present dikes around the two major rivers in the Netherlands won't be able to deal with the rising water, which could lead to massive flooding.[55]

54 Lee, Krystek. Museum of Unnatural Mystery , "The Zuiderzee and Delta Works of the Netherlands." Last modified January 1, 2011. http://www.unmuseum.org/7wonders/zunderzee.htm. (Accessed February 6, 2015.)

55 Fehrenbacher, Jill. Inhabitat.com, "Inhabitat Interview: Koen Olthuis of WaterStudio.nl Talks About Design for a Water World." Last modified July 8, 2014. http://inhabitat.com/interview-koen-olthius-of-waterstudionl/. (Accessed February 4, 2015.)

A polder, a diked in and drained low-lying piece of land, with old wind-powered polder mill that pumped water out and kept the polders dry. (Courtesy of Travel Center.com)

Hans Brouwer, a Dutch river specialist, explained to ABC News that the present dikes will continue to function on daily basis, but when the rivers are expected to flood as the sea levels rise continue to rise, they have decided it is better to let the water into some of the previously dry polders.[56]

4.3 Making Room for the River and Using Amphibious and Floating Houses

Making room for the river became “Room For the River,” a $3.5 billion government project that started in the Netherlands in 2006 and was expected to be completed by the end of 2015. Hans Brouwer explains that river beds are being deepened at more than 30 locations, overflow areas have been designated, new channels were being constructed, and dikes were moved. He points out that in the past, many Dutch lived behind the dikes, whereas now some are venturing onto the other side of the dikes, into a more flexible kind of house. Many homes along the river are amphibious.

56 Miller , Barbara. ABC.net, “New Dutch solution to floods.” Last modified May 5, 2014. http://www.abc.net.au/lateline/content/2014/s3999293.htm. (Accessed February 6, 2015.)

When these new polders near the river are dry, or have low levels of water, amphibious houses rest on a concrete base. When the polders are filled with overflow water, these houses rise up on floats, staying on the surface, but fixed in place by pylons that are embedded in the concrete foundation. Utilities and sewage are encased in flexible and stretchable pipes that can rise up to six meters, more than nineteen feet.[57]

Amphibious houses on the Maas River with cellars that act as floatation devices.
When water level rises, the building rises with it, sliding up two steel posts. (Courtesy of Dura Vermeer)

Floating homes at Ijburg,Amsterdam.
(Courtesy of Bowcrest.com)

57 Ibid.

The amphibious house is considered to be more of a new type of construction than it is to be a new type of house, and can be solar-powered. Another option that Dutch homeowners have for living on water in polders and canals is coming from a number of Dutch architectural firms, especially from WaterStudio, and those are free-floating houses, which are the next level up from houseboats, a common sight in the Netherlands for many years.[58]

Because of the length of time the Dutch have been working to deal with the sea, and because of what they have been able to do, the Netherlands is now considered a world leader "for how to tame rivers and seas."[59]

4.4 Advising the World

Since scientists have been predicting climate change and rising sea levels, the Dutch have become one big consulting company, traveling everywhere in the world to talk about dealing with water. From the Mississippi to the Mekong, they are working on water-related projects and some of their thinking was incorporated into New York's $20 billion post–Hurricane Sandy protection plan.[60]

4.5 Koen Olthuis: Background and Education

There are numerous architects and firms in the Netherlands (and throughout Europe) who are working locally and internationally with water-based structures. One Dutch architect, Koen Olthuis, however, stands out as being a visionary in the truest sense of the word.

58 Basulto, Dominic. Washington Post.com, "It's time to get serious about flood-resistant and amphibious houses." Last modified October 31, 2013. http://www.washingtonpost.com/blogs/innovations/wp/2013/10/31/its-time-to-get-serious-about-flood-resistant-and-amphibious-houses/. (Accessed February 6, 2015.)

59 Ibid.

60 Chu, Jeff. Fast Company Magazine , "Against the Tide; For Centuries, the Netherlands has Suffered from Catastrophic Floods. As the Rest of the World Now Reckons with the Same Fate, the Dutch are Sharing--and Selling--What They've Learned ." Last modified October 14, 2013. http://www.fastcompany.com/3018621/against-the-tide. (Accessed February 6, 2015.)

Koen Olthuis after speaking to author.
(Photograph by Author)

Koen Olthuis, born in 1971, studied architecture and industrial design at the Delft Technology University in the Netherlands. He is the founder of Waterstudio, an architectural firm that specializes in designing floating structures to help deal with rising sea levels. He is also the co-founder of Dutch Docklands, a company that specializes in the development of floating structures.[61] He was ranked by Time as number 122 on their list of the most influential people in the world in 2007.[62] A BBC journalist once referred to him as the "Floating Dutchman," and the name stuck.[63]

At his first job after graduating, Olthuis' firm assigned him to work on designs for traditional Dutch houseboats. He comes from a family with a long history of boat building and architecture, which may explain why he was among the first to see a connection between houseboats, rising sea levels, and the creation of something entirely new. A house can float, he thought, so why can't something

61 Archi-Europe, "Architecture Water." Last modified November 1, 2014. http://www.archi-europe.com/archinews/2014/112014/opmaken/newsletter_en.html. (Accessed February 3, 2015.).

62 Architizer.com, "Koen Olthuis." Last modified Februrary 1, 2015. https://architizer.com/users/koen-olthuis/. (Accessed February 4, 2015.)

63 Mapolis Architectural Magazine, "Waterstudio.NL." Last modified July 28, 2011. http://architecture.mapolismagazin.com/content/waterstudionl. (Accessed February 10, 2015.)

larger, something large enough to hold a city?[64]

Olthuis, along with newly-formed Dutch Docklands, was invited to design a section of floating islands for Dubai. (Not to be confused with Dubai's artificial islands that are on top of artificial sandbars.) At that time he patented a technology for floating foundations, based on traditional houseboats, that was strong enough to support large floating structures like office buildings or even roads and cars.[65]

4.6 Olthuis: Building on the Water

In an interview with Reuters, Olthuis said that building on water involves a change of mindset, adding that floating foundations allow water to provide viable new building space and a whole new world of possibilities. He pointed out that all big cities have space limitations because of urbanization and climate change, but creating new building space on water helps solve the space limitations. He said that his designs for floating foundations made of concrete and foam are quite heavy, stable and that they allow the structure to move up and down with the sea level.[66]

4.7 Olthuis: Traditional Cities

For centuries, the climate and sea levels were relatively stable, and cities have been built to be permanent and static, though, in reality, most urban elements become obsolete after about fifty years. Now, because of climate change and rising sea levels, people have to change the way they think about coastal cities. Cities need to be more dynamic, flexible, environmentally friendly, and able to reinvent themselves. They need to be more adaptable to changing needs, which are often difficult to predict.[67]

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64 Cowan, Roberta. Reuters.com, "Dutch architect dreams of future floating cities." Last modified October 9, 2012. http://www.reuters.com/article/2012/10/09/uk-dutch-architect-water-idUSLNE89801Z20121009. (Accessed February 3, 2015.)

65 Ibid.

66 Ibid.

67 Archi-Europe, "Architecture Water." Last modified November 1, 2014. http://www.archi-europe.com/archinews/2014/112014/opmaken/newsletter_en.html. (Accessed February 3, 2015.)

Olthuis compares his techniques for building floating structures with the creation of the elevator, by saying if the elevator had never been invented, buildings in cities would be limited to three or four floors, but the elevator opened up vertical space that had never been available in the past. According to Olthuis, future designs for floating structures will not only open up large amounts of new space in a city, but will also allow the structures to be detached and moved to new locations, or even to different cities.[68]

He says that plans right now, however, do not call for putting entire cities on the water. He proposes that cities combine floating structures with land-based architecture, along with flotation devices, raised platforms, and so on, as protection from the sea. An integrated, flexible approach is crucial, he says. Instead of having cities with buildings that can't cope with the changing needs of the city, urban planners will be creating floating developments that are dynamic and can react to new and unpredictable needs.[69]

4.8 Olthuis: What Coastal Cities Can Do to Prepare for Rising Sea Levels

Coastal cities must design with flexibility, and that means to design not solely for today's conditions, but make plans that are open-ended. It would be to the advantage of the city if planners embrace the upcoming increase in water, and, instead of fighting it, viewing it as a chance to upgrade the cities. He believes a resilient city isn't one that simply prepares for the water to come, but a city that allows the water to expand. By making the water a part of the city, he says, it means working with more water, but avoiding the great shock that will suddenly come when the situation goes from dry conditions to flooding. Also in terms of planning, coastal cities need to focus on which areas should be kept absolutely dry and which can be changed from dry to wet, and which existing waters are suitable for expansion. He is firm in his belief that the future of resilient coastal cities is on the water, and says that large cities like Jakarta, London, Miami, and Tokyo will each expand its territory by five to ten percent on urban waters within the next 25 years.[70]

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68 Cowan, Roberta. Reuters.com, "Dutch architect dreams of future floating cities."

69 De Melker, Saskia. PBS.org, "Floating Architecture: Finding Ways to Live With Rising Water." Last modified May 29, 2012. http://www.pbs.org/newshour/rundown/preparing-for-a-life-on-water-with-floating-architecture/. (Accessed February 3, 2015.)

70 Meinhold, Bridgette. Inhabitat.com, "Inhabitat Interview: Water Architect Koen Olthuis on How to Embrace Rising Sea Levels." Accessed February 6, 2015. http://www.waterstudio.nl/archive/863. (Last modified July 1, 2014.)

4.9 Olthuis: Floating Cities - Start With Hybrids

Next City is a nonprofit online news organization whose mission is to inspire cities to become better. In a 2014 interview with Next City, Koen Olthuis was asked if the time has actually come for floating cities. Olthuis said that it depends on the definition of "floating city." He said if it means a community of 100,000 people living in the middle of the sea, it is probably fifty years away. If that city is to be completely self-supporting, it is probably 70 years away. Hybrid cities, he says, are the next step toward floating cities. Developments built on the edge of an existing city could easily be connected to electrical and sanitation facilities. He adds that as far as technology is concerned, we are already there for hybrid cities, and building developments of this kind are relatively easy to engineer. He finishes by saying since we have all the necessary technology, floating expansions to land-based coastal cities would be straightforward to regulate and, from the point of investors, much less risky.[71]

4.10 Olthuis: Safety of Floating Structures

If an area is threatened by the water. people are safer on the water than they are on land. Effects of an average tsunami are much less powerful in open water than being on or close to the shore, because a tsunami wave gains height when it hits the shore. When designing a floating structure for a specific location, engineering for Waterstudio is done by the best maritime companies who take into consideration the existing and expected extreme weather conditions, in addition to local wave conditions. To find a balance between feasibility and safety, they use maritime safety regulations and work with insurance companies. The large shockwave, caused by an earthquake like the one in Japan a few years ago, are absorbed by the water and don't affect floating developments. Flash-floods that make land-based houses float can affect floating developments in urban waters and near shorelines, but the amount of damage from the impact is not as strong because they are already floating and just move along with the waves.[72]

71 Keeton, Rachel. Next City.org, "Has Floating Architecture's Moment Finally Arrived?." Last modified October 1, 2014. http://nextcity.org/daily/entry/floating-architecture-cities-build-on-water. (Accessed February 3, 2015.)

72 Pham, Diane. Inhabitat.com, "Inhabitat Interview: Water Architect Koen Olthuis on Floating Buildings & Hydro-Cities." Last modified September 29, 2014. http://inhabitat.com/inhabitat-interview-water-architect-koen-olthuis-on-floating-buildings-hydro-cities/. (Accessed February 4, 2015.)

4.11 Olthuis: Floating Architecture and Sustainable Design

Koen Olthuis says that the number one goal in all of their floating designs is to create scarless developments, and that during the lifespan of the structure, and after, there is little or no physical or carbon footprint. (For example, greenhouse gasses are emitted through land clearance, whereas there is no land clearance for water-based structures. When water-based structures are built to be off-the-grid, fossil fuels are not used.) He says that additionally, in contrast to building on land, water offers several options for a more sustainable approach, and that water can be used for both cooling and heating. Water based designs can use wind for cooling, floating solar panels for energy, and with flexibility that has never been seen before, it is possible to reuse structures at different locations. Even the building process can be far more efficient by centralizing construction in a place other than the actual site.[73]

4.12 Olthuis: Reasons for World-Wide Interest in Floating Architecture

It has only been in the last decade or so that floating architectural projects (both on computer screens, and in the real world) are suddenly starting to appear worldwide. These projects have a new urgency based on rising sea levels and also on the massive rural-to-urban migration that has gone on. Within the last year, Business Insider, Bloomberg and The Guardian have all run stories about floating architecture.[74] In an interview with Inhabit, Koen Olthuis discusses how population growth itself has helped to drive this surge of interest in water-based architecture. He says that the world's population has been estimated to reach about ten billion people by the end of this century. (Whereas, today's population is about seven billion, three hundred thousand.) The result, he says, is that large cities are looking desperately for space, and that planners will have to use the existing water in and around cities, to create new space. He is not saying leave the land, but he is saying that the solution to the problem of a sustainable future is finding a healthy balance between the use of land and water for the production of shelter, food, energy, and clean water. (Later in this paper, in Chapter 5, in a section on the kinds of floating structures that need to be considered for future use in Hawai‘i, these necessities will be discussed.) Olthuis concludes that discussion

73 Ibid.

74 Keeton, Rachel. Next City.org, "Has Floating Architecture's Moment Finally Arrived?." Last modified October 1, 2014. http://nextcity.org/daily/entry/floating-architecture-cities-build-on-water. (Accessed February 3, 2015.)

by saying that moving out onto the water is a viable and compelling way to bring new space to our cities.[75]

4.13 A Project by Koen Olthuis in the Netherlands

Looking at a few of Koen Olthuis' projects will help to understand how creative he is as an architect and designer. One truly innovative project is the first entire floating neighborhood which he designed with Waterstudio. It is located between The Hague and Rotterdam, in a large polder. It is called "The Citadel," and is an urban development that will eventually consist of individual residences, apartments, and villas with boathouses and swimming pools.[76]

Caption: The Citadel, secured to the bottom with expandable tethers, will rise and fall with the changing water levels, making it impervious to flooding, tides, and sea level rise.
(Courtesy of WaterStudio)

The floating apartment complex in New Water, a flooded polder, is called "The Citadel," and will consist of sixty luxury apartments, built from prefabricated modules, each of which has its own garden terrace. There is a parking garage, and a floating road to access the structure. To avoid corrosion, aluminum is used for the facade of The Citadel. The Citadel uses 25 percent less energy than its land-based equivalent, due to the use of water cooling techniques.[77]

75 Ibid.

76 Archi-Europe, "Architecture Water."

77 Inhabitat.com, "The Citadel: Europe's First Floating Apartment Complex." Last modified July 30, 2009. http://inhabitat.com/the-citadel-europes-first-floating-apartment-complex/2009-07-14-010-citadel/. (Accessed February 8,

There are plans for a number of new neighborhoods to be built on flooded polders in the Netherlands. As mentioned earlier, polders are reclaimed, low-lying land areas that are surrounded by dikes. In the past, they were mostly kept dry and used for land projects. Recently, however, because of sea level rise, polders are being flooded to accommodate the additional water. Polders are calm and smooth and look like artificial lakes. (The surface of a polder is similar to the surface of Ke'ehi Lagoon, the proposed location for this writer's design project. Except for the rare hurricane or tsunami, the surface of Ke'ehi Lagoon is also calm and smooth, and only disturbed by passing boats, the wind, and the slow rising and falling of the tides.)

4.14 A Project by Koen Olthuis in the Maldives

The Republic of the Maldives is an island nation in the Indian Ocean that is located about 370 miles off the coast of south-west India. Since the highest point in the country is just over six feet, the islands are extremely vulnerable to flooding. The worst-case prediction for sea level rise by the end of this century is around six feet. If that happens the Maldives will simply disappear.

The Maldives, like Hawai'i, is a tropical tourist destination, and also like Hawaii, the economy, for the most part, depends on tourism. (In both places, tourism amounts to about 30% of the overall economy.) To prevent the Republic of the Maldives from disappearing, and to insure that that source of income continues well into the next century, the government of the Maldives has an impressive joint plan with Dutch Docklands (the development side of Koen Olthuis' Waterstudio) to save their tourist industry by creating, among other things, an unbelievable golf course, along with a hotel, build some additional living space, and, at the same time, create a new high-end real estate business, all being projects by Koen Olthuis.[78]

Dutch Docklands CEO Paul van de Camp has said that they told the president of the Maldives that they could transform them from climate refugees to climate innovators, and that they could do it in a very environmentally friendly

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78 Fast Company.com, "Floating Housing (And Golf Courses) For Post-Climate-Change Island Paradises." Last modified August 24, 2012. http://www.fastcoexist.com/1680382/floating-housing-and-golf-courses-for-post-climate-change-island-paradises. (Accessed February 10, 2015.)

way.[79]

The plan includes private floating islands and opulent floating villas, both designed to survive whatever comes their way as a result of climate change and rising sea levels. The plan calls for a floating 18-hole golf course that is equipped with underwater, see-through tunnels that connect the holes, a combined floating hotel and convention center, a housing development called the "Ocean Flower" that is comprised of 185 villas, and finally the White Lagoon, which features four ringed islands made up of 72 houses.[80]

The 5 Lagoons Project will feature 185 $1-million waterfront homes connected along a flower-shaped pier. (Courtesy of Dutch Docklands.)

The floating islands will be anchored to the seafloor using cables, or telescopic mooring piles, making floating landforms that are stable even in storms. This approach limits damage to the seabed. Overhead photos show that the islands are built inside a large, protected ring-shaped reef that would offer protection from large waves and swells. Also they will build many small islands to reduce the shadow on the seafloor, which could affect wildlife. To help keep costs down, the islands will be constructed in India or the Middle East, and then towed to their final destination in the Maldives.[81]

79 Daily Mail, "The Floating future of the Maldives." Last modified January 1, 2014. http://www.dutchdocklands-maldives.com/About/In-the-media/The-Floating-future-of-the-Maldves. (Accessed February 10, 2015.)

80 Fast Company.com, "Floating Housing (And Golf Courses) For Post-Climate-Change Island Paradises." Last modified August 24, 2012. http://www.fastcoexist.com/1680382/floating-housing-and-golf-courses-for-post-climate-change-island-paradises. (Accessed February 10, 2015)

81 Ibid.

The islands can be moved to other locations in the Maldives, if necessary, and according to both Waterstudio and Dutch Docklands, they will barely leave a trace if moved. Dutch Docklands' CEO, Paul van de Camp says these projects are good for the Maldives, not only as a way to deal with rising sea levels, but also as a way to add much-needed space to the country. Both co-CEOs Paul van de Camp and Koen Olthuis see the projects in the Maldives as a testing ground for floating island technology.[82]

4.15 The Maldives as a Model for Hawai'i

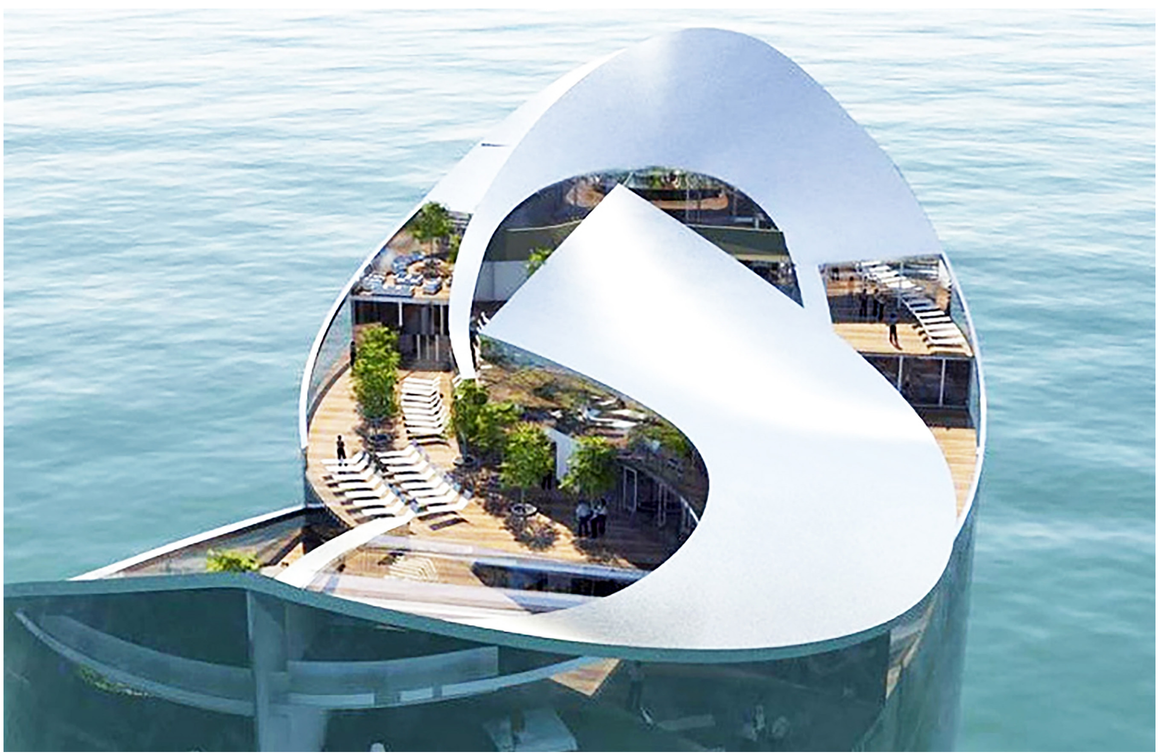
The projects in the Maldives are of special interest to Hawai'i, since both the Maldives and Hawai'i are made up of strikingly beautiful tropical islands and both have economies that are heavily based on tourism. As mentioned earlier, the Maldives is rapidly experiencing the worst possible effects of rising sea levels since the highest points of most islands in the Maldives sit only a few feet above sea level. The government of the Maldives has been forced to make momentous decisions relatively quickly in order to hold onto some semblance of their national identity and to rescue their economy. (While, incidentally, providing an extremely fortuitous testing ground for cutting edge technology related to floating architecture.) At this point, it would appear that their decisions have paid off, as evidenced by the free online publicity they have gotten. Completion dates for a number of projects there are scheduled for were scheduled for 2015 and 2016.

There is certainly no chance that Hawai'i will disappear beneath the waves within this century, but there is a good chance that many of the most famous tourist destinations in Hawai'i, i.e., its beaches, along with their attendant hotels, will be dramatically altered, or possibly gone, by 2100. Of course any degeneration of the beaches would dramatically affect the number of tourists coming to Hawai'i, and lead to a profound decline in the local economy. (First Hawaiian Bank in a 2009 report, estimated that about a quarter of the local Hawai'i Gross Domestic Product (GDP) comes from tourism as do about a third of local jobs. The report went on to say if a large part of the economy were removed, the remaining parts would be seriously affected because of massive unemployment and fewer government services.[83]

82 Ibid.

83 Laney, Leroy O. First Hawaiian Bank, "Economic Forecast: Special Report." Last modified Jaunary 1, 2009. https://www.fhb.com/en/assets/File/Marketing/FHB_Tourism_Study_09325.pdf. (Accessed March 6, 2015.)

Concern for Hawai‘i’s economy later this century should seriously motivate planners to consider what is being done in the Maldives in terms of floating architecture as tourist destinations and use that as inspiration for what could be done in Hawai‘i. For example, what possibilities does the idea of a floating golf course bring to mind? How about a floating volleyball court? Or two or more volleyball courts and/or tennis courts riding on one floating foundation, complete with sand, tropical vegetation, and landscaping? How about a landscaped jogging park (or hiking trail) that would include Plexiglas areas extending under the surface of the water to provide a unique jogging (or hiking) experience for locals and tourists alike? Floating hotels and restaurants certainly would be in order, and, since golfing is extremely popular in Hawai‘i, how about a Hawaiian version of a floating golf course? Moreover, Hawai‘i can look past the Maldives for additional inspiration. Floating hotels are being considered in a number of places around the world right now. One example is Oryx Island, a collection of private rental islands in Qatar which is being proposed as housing during the 2022 World Cup.[84]



A number of floating hotels and apartments have been proposed for the 2022 World Cup in Qatar (Courtesy of Inhabitat.com)

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84 Goodwin, Andrew. Inhabitat.com, “Qatar Unveils Luxurious Off-Grid Floating Hotels for 2022 World Cup.” Last modified May 7, 2014. http://inhabitat.com/qatar-unveils-luxurious-off-grid-floating-hotels-for-2022-world-cup/. (Accessed September 20, 2014.)

Another example is the AquaDomi Floating Hotels proposed for Dubai's high-end tourist industry.[85] A final example, scheduled to open in 2016, is the floating Snowflake Hotel in Norway which is designed for visitors to view the northern lights.[86]

The AquaDomi Hotels are being designed and developed for Dubai investors.
(Courtesy of Inhabitat.com)

4.16 Why Hawai'i is Lucky

Even though Hawai'i is facing serious changes between now through the end of the century, Hawai'i is incredibly lucky for at least two reasons. One is the fact that major changes related to sea level rise are relatively slow, thereby giving planners lots of time to make necessary decisions to be prepared for whatever comes. The other is that Hawai'i is not the first place to have to deal with possibly serious consequences of climate change and rising sea levels; already there are models.

85 e-architect.com.uk, "AquaDomi Floating Hotels." Last modified January 8, 2015. http://www.e-architect.co.uk/dubai/aquadomi-floating-hotels. (Accessed February 2, 2015.)

86 Strutner, Suzy. HuffingtonPost.com, "Norway's Floating Snowflake Hotel Is A Five-Star Fjord Paradise." Last modified April 8, 2014. http://www.huffingtonpost.com/travel/. (Accessed September 26, 2014.)

4.17 The Sustainability Advantage

One additional basic advantage that water-based architecture has over land-based architecture is that it can be far less destructive of the environment. Traditionally, when land is "developed" for whatever use, residences, businesses, whatever, what is the first thing that is done? The land is bulldozed and stripped of every single living thing that ever grew on it. That stripping process is just the first step in preparing the area for actual construction. Much of it has to do with digging and moving the earth around. Finally, after everything is prepared, the actual structure can be built. If a structure is later removed for some reason, how long would it take for the land to heal itself? Could it ever again return to its previous state? If the structure were a large modern office or highrise building, the answer, of course, is no, the land could never return to its original state, not without the intervention of people who want to restore it. Even then it is unlikely the land would ever be the same again. Contrast that with the floating architecture in this research paper which virtually leaves no footprint when removed. Koen Olthuis' Waterstudio calls its projects "scarless."

Summing Up

In this chapter, we investigated the Netherlands, first looking briefly at its history, to understand where they are today. We learned that today about twenty-five percent of its land is below sea level making the country very vulnerable to sea level rise, and to prepare, they are planning to allow some of the seawater to come into parts of the country. Dutch architects and designers are now being sought out around the world as more places try to plan for the future. We heard from Koen Olthuis, and found that his designs could, in fact, be important for Hawaiʻi

Coming Up

In Chapter 5, we will explore numerous kinds of floating development that could be useful to Hawaiʻi in the future, including residences, tourist destinations, and structures that can provide energy, food, and even fresh water.

Chapter 5

Ideas For Future Floating Structures In Hawai‘i

“Where water is the boss, there must the land obey.”
— African Proverb —

Olthuis is quoted earlier in Chapter 4 as saying that the solution to the problem of a sustainable future is finding a healthy balance between the use of land and water for the production of shelter, food, energy, and clean water. Those issues are to be the focus of this chapter; research will indicate whether water-based structures could deal with all of them.

This section of this research paper, a kind of overview, will look at 1) floating individual and communal residences as alternative housing, and as a way to provide additional space for a city or an area to grow, 2) a further look at floating hotels and tourist destinations as a way to keep the economy from totally sinking, and 3) floating support structures to supply energy, food, and fresh water. The point of view will be function, not design, since function is the main concern here.

5.1 Floating Residences

Before we look at a few new floating residences around the world, let's get started in the U.S. and look at the legal definition of "floating residence." Here, states define floating homes slightly differently, but generally they are defined as being:

1. Built on a float
2. Planned and built to be used as a residential dwelling
3. Moored or anchored in one specific place, and not intended for navigation
4. Constructed with no means of self-propulsion
5. Powered by utilities hooked up to the shore
6. Connected to a sewage system on shore.[87]

87 Gromicko, Nick and Kenton Shepard. International Association of Certified Home Inspections, "Inspecting Floating Homes." Last modified January 21, 2016. https://www.nachi.org/inspecting-floating-homes.htm. (Accessed January 25, 2016.)

Fennell Residence designed by well-known architect, Robert Oshatz. (Courtesy of Ihnabitat.com.)

Floating homes are built on foundations that float, and there are numerous types of floating foundations, including, but not limited to, concrete barges, logs, foam, or foam-filled steel.[88]

As an outstanding example of a floating residence in the U.S., consider a structure by architect Robert Oshatz. Called "Fennell Residence," it floats on the Willamette River in Portland, Oregon. A 2,364 square foot, low energy house, it is made of Glulam wood beams (glued laminated beams that are stronger than steel) that are stacked and connected to produce this swirling and curved design. The huge window wall allows the sun to light the interior during the day while providing natural ventilation. The second level of the home provides space for a master bed and bathroom. The first level includes a common area to enjoy the waterside.[89]

88 Ibid.

89 Molly Cotter. Inhabit.com, "Robert Oshatz's Floating Fennell House Is a Passive Riverside Dream Home." Last Modified November 7, 2012. http://inhabitat.com/robert-oshatzs-floating-fennell-house-is-a-passive-riverside-dream-home/?newgallery=true. (Accessed November 15, 2014.)

Floating houses in Amsterdam, the Netherlands, by architect Marlies Romer (Courtesy of Archdaily)

To look at examples of residences that can or have been constructed to float on water, we will return to the Netherlands. Houseboats are common in canals in Dutch cities, but houseboats are individual units that are closer to boats than houses. Recently, as has been discussed, there has been an increase in the number of water-based housing developments that are more like land-based housing. These floating homes make up part of an urban design. Financially, they are classified as immovable properties, and they compete with land-based residences in terms of size and comfort. The Ijburg district of Amsterdam, for example, as mentioned before, is complete with floating neighbourhoods, and city plazas, with jetties instead of sidewalks.[90]

90 Singhal, Sumit. AEC Cafe.com, "Water Houses/ Floating Houses in Steigereiland IJburg, Amsterdam, Netherlands by Architectenbureau Marlies Rohmer." Last modified March 26, 2011. http://www10.aeccafe.com/blogs/arch-showcase/2011/03/26/water-houses-floating-houses-in-steigereiland-ijburg-amsterdam-netherlands-by-architectenbureau-marlies-rohmer/. (Accessed January 10, 2015.)

The concept of floating residences is innovative, but how are traditional houseboats and these new floating houses different? Marlies Rohmer, another well-known Dutch architect, answers by saying that the new floating houses all have pipes, wires, and services connected, but houseboats don't always have these amenities. The developer of one project in IJburg, called the Water Neighborhood, is Ton van Namen. He explains that the dimensions of floating houses are more like normal, land-based houses than houseboats are. Floating houses often has three floors, and don't have the long, narrow shapes that most houseboats have. To further differentiate between them, he says that their floating houses are just about the same as land-based houses, and houseboats can't make that claim at all. Also he says that their floating houses meet all the requirements of the local building codes, that they will last just as long as land-based houses, and that their value increases over time.[91]

This sailboat inspired German home would look right at home sitting on the side of the Ala Wai Canal.
Not only is it modular and energy efficient, land based versions will also to be sold. (Courtesy of inhabitat.com)

91 Ibid.

Places other than the Netherlands are beginning to design and produce single floating homes. For instance, German architects Steeltec37 have designed a floating home they call the Aqua Floathome, which they say is inspired by sailboat silhouettes and life on the water. It is made of glass and steel and has a curved vaulted roof up to the rooftop deck. The interiors are modern and compact. There is floor-to-ceiling glass that frames the views of the water, and provides a lot of natural light.[92]

Easily imagined floating somewhere in Kāneʻohe Bay, with enough rooms for a small family.
It's open style and large terraces would make it perfect for a Hawaiian climate. (Courtesy of Dymitr Malcew)

Another example of a modern, floating home comes from architect Myitr Malcew for H2ORIZON, a French developer that specializes in floating architecture. It is built on top of a flat, floating foundation, and features two bedrooms, two bathrooms, a living room and a kitchen with a bar, and entirely encircled by large terraces. The house also features a system of columns and glass curtain walls, so that the roof appears to float on top of the structure and its residents have wide, panoramic views of the harbor.[93]

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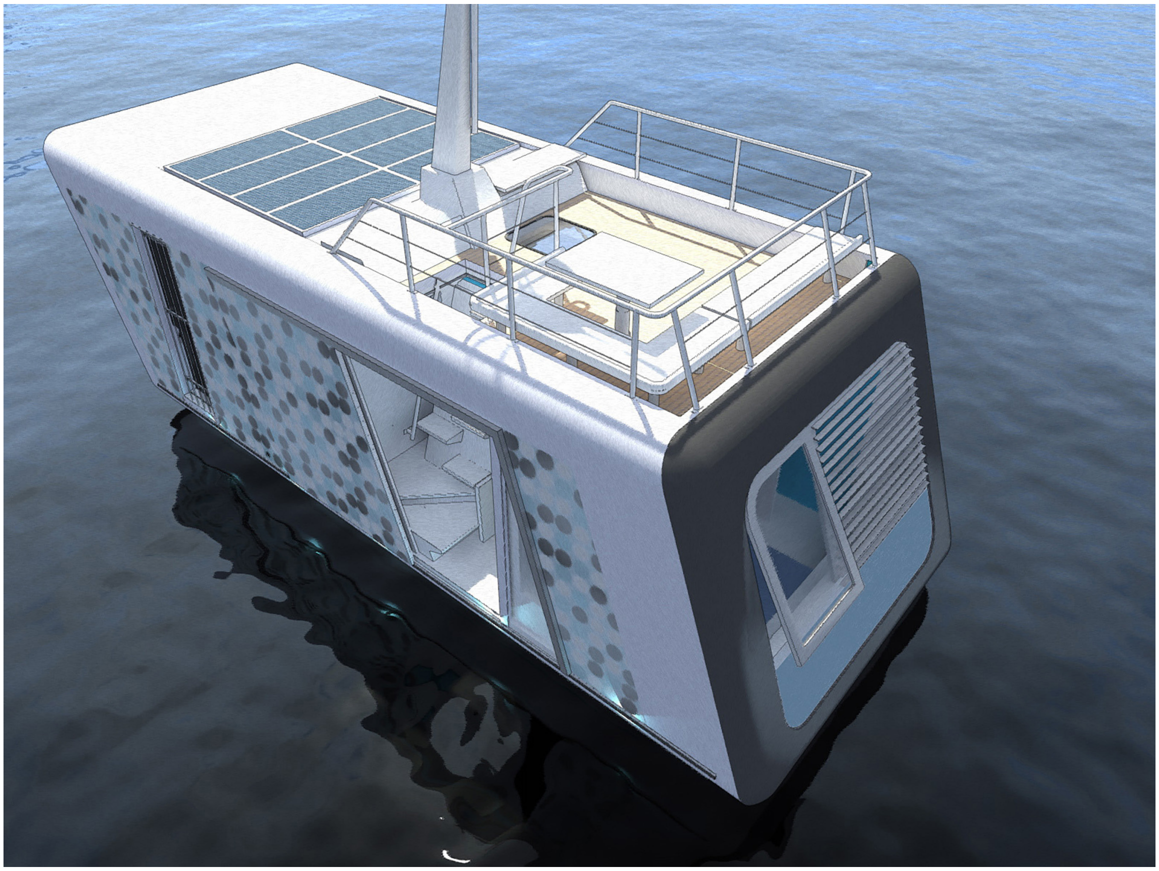
92 Trendir: Modern House Design and Decorating, "Floating Lake House Inspired by Sailboats." Last modified January 2, 2012. http://www.trendir.com/house-design/floating-lake-house-inspired-by-sailboats.html. (Accessed February 12, 2015.)

93 Gayle, Damien. Daily Mail.com, "Property with panoramic sea views for sail." Last modified December 7, 2013.
69 Gayle, Damien. Daily Mail.com, "Property with panoramic sea views for sail." Last modified December 7, 2013. http://www.dailymail.co.uk/news/article-2519780/Property-panoramic-sea-views-sail-Architect-designs-incredible-floating-home--want-decamp-dry-land-storm.html. (Accessed September 23, 2014.)

Polish architect Monika Wierzba has given us Eco House which is a floating house with little environmental impact. Based on a modular structure, it features low-energy solutions and environmentally friendly construction materials. The way it is constructed even allows its owner to modify the way it looks and size at any time. The best thing about this house is that it can function independently of any urban technical infrastructure since it uses off-grid technology.[94]

This low-impact, modular building recycles rainwater, features recyclable and recycled materials, and uses solar panels to generate electricity. The structure can be rearranged for different environments, and has a wastewater collection tank at the lowest level where about 80% of is converted into gray water. It would work well in a Hawaii community setting. (Courtesy of inhabitat.com)

94 Baker, Lisa. Built on Water; Floating Architecture Design. Salenstein, Switzerland: Braun Publishing, 2015. pp. 121-123.



Reminiscent of an O‘ahu Accessory Dwelling Unit (except that it floats), it has all the amenities of a real home. Comes with optional wind turbine and solar panels, and versatile floor plans. (Courtesy of WaterSpace.)

UK-based WaterSpace, also wants to build small stand-alone (float-alone?) units that function independently. It‘s called Floating Studio Flat, and each unit consists of a bedroom, kitchen, wet room (a bathroom with an open shower and a floor that is flush with the rest of the room), and even an upper sundeck on top. A wind turbine and integrated solar panels are optional at purchase, as is the floor plan. Its number one selling point is that its wind turbine and solar panels make it nearly self-sufficient.[95]

95 Lie, Eunju. Business Insider, “Million-Dollar Idea: Floating Apartments That Could Be NYC’s Next Real-Estate Expansion Plan.” Last modified November 9, 2010. http://www.sfgate.com/news/article/MILLION-DOLLAR-IDEA-Floating-Apartments-That-2473799.php. (Accessed October 13, 2014.)

Modular design, intended to be assembled on-site. Ample garden space making it work well in Hawai‘i. If more than one house in use, floating gardens can be spread among them and walkways can connect them. Without base, can be land-based structure. (Courtesy of Carl Turner Architects.)

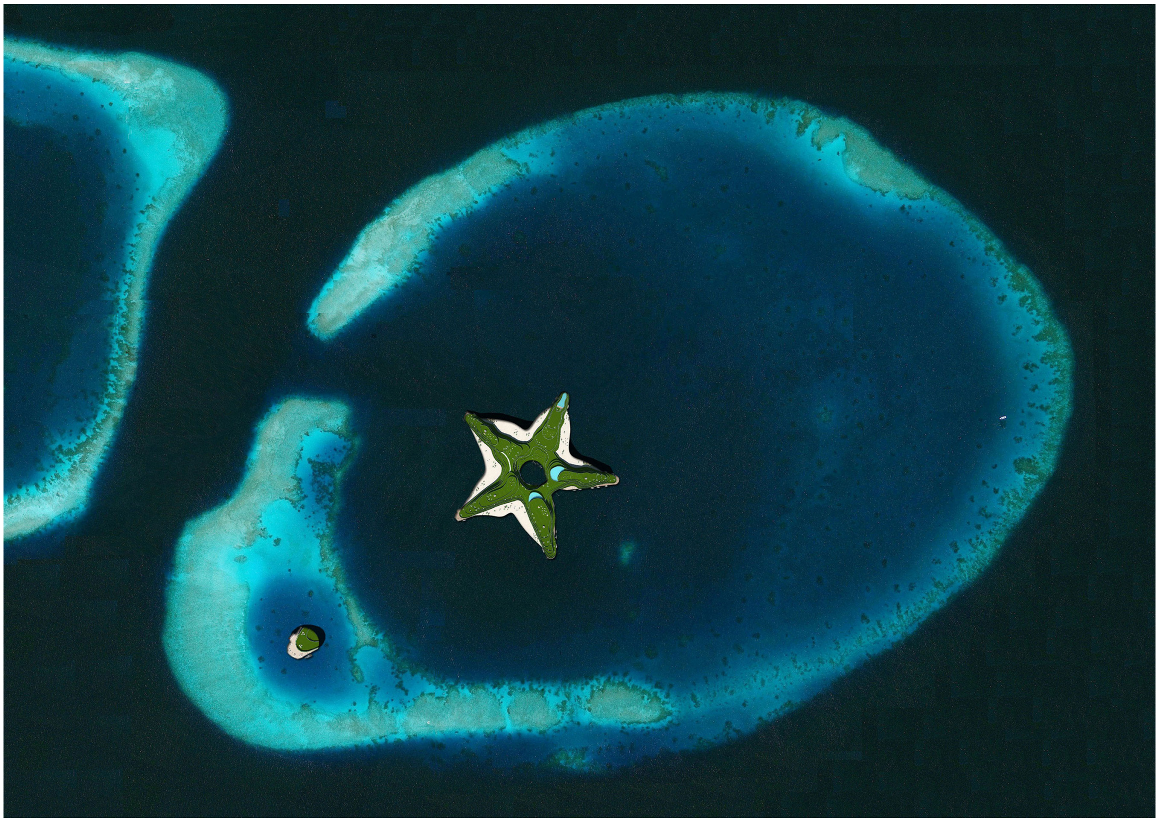
A final example of a single floating home is also from the UK, but this one has an extra twist. The plans for this home are open source, which means anyone is free to copy it, use it, and even modify it in the future. It was designed by Carl Turner Architects and can be soon downloaded from <www.paperhouses.co>. This floating residence wasn't intended for any specific site, and the company says its design is a solution for the problem of flooding that now hits many parts of the UK. The design consists of one lightweight structure which can be built on a traditional pile foundation or over a concrete "tray" that gives it buoyancy and allows it to float. The design is carbon-neutral and self-sufficient, and features windows that are triple-glazed, a wall of photovoltaic panels, and plenty of space for planting vegetables or greenery. It also has a terrace on the rooftop and a crow's nest that integrate harvesting rainwater.[96]

96 Frearson, Amy. DeZeen Magazine, "Carl Turner design open-source house that floats of floodwater." Last modified January 23, 2015. http://www.dezeen.com/2015/01/23/carl-turner-prefabricated-open-source-floating-house-floodwater/. (Accessed February 12, 2015.)

5.2 Floating Tourist Destinations

As was mentioned earlier, in tourism-based economies like Hawai‘i and the Maldives, alternatives to shoreline tourist destinations have to be created in order to prevent the local economy from a possible collapse, and that is why Hawai‘i should pay attention to the the building boom in floating architecture that is currently underway in the Maldives. They have started doing something, specifically with that situation in mind, and this writer has seen nothing in the literature to suggest that Hawai‘i has. To further convince the reader that large floating structures are real and here today, and, in truth, to dispel any lingering ideas that floating architecture is fantasy and/or science fiction, this writer researched real life examples of floating hotels. Here are two real-world examples of floating hotels, and further information about the floating golf course and other attractions being built in the Maldives.

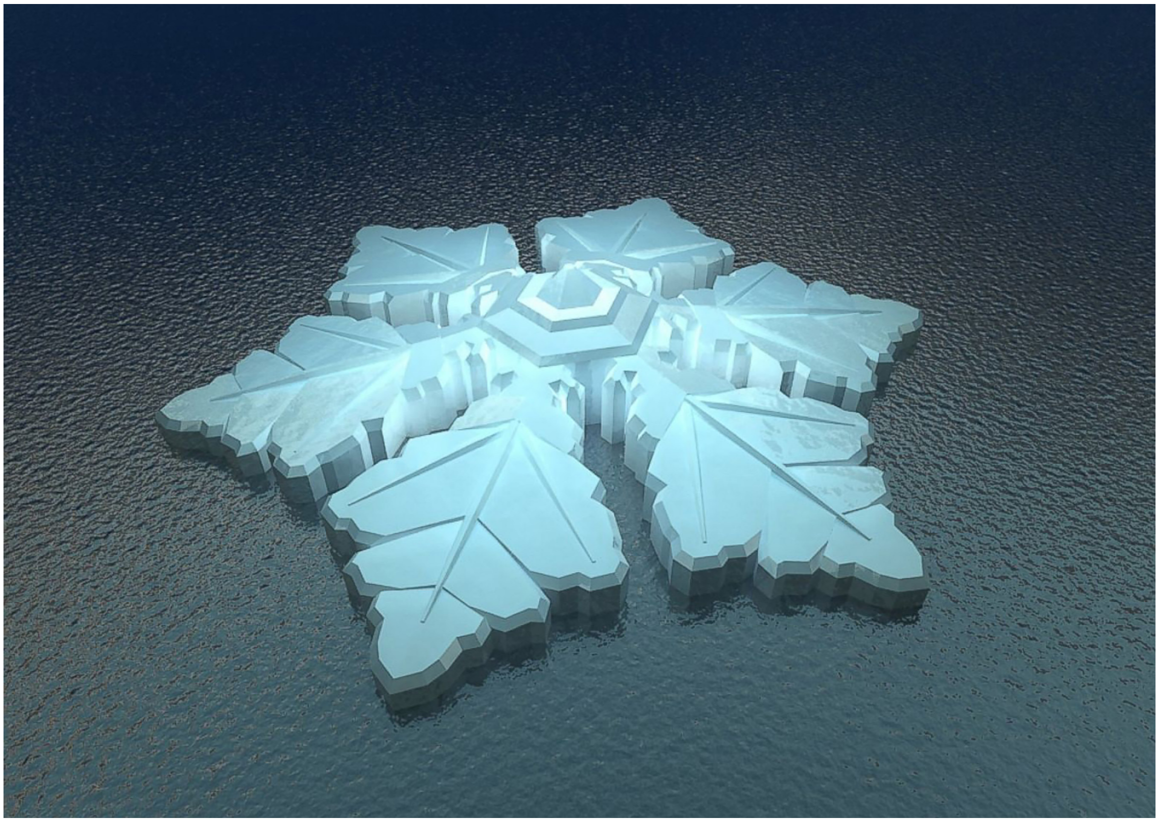
The point here is not that these projects are specifically applicable to Hawai‘i in general, nor is it that they are applicable to specific places in Hawai‘i. These or similar projects should be considered by any coastal areas that will experience sea level rise and which are currently dependent on tourism. To come up with new ideas and approaches to deal with a situation, one technique is to take a look at what others are doing to deal with it. Hence these examples are presented.



The Greenstar is a star shaped floating convention hotel. It is expected to ensure that tourism will continue despite sea level rise. (Courtesy of Dutch Docklands.)

One example of a floating hotel is a massive new hotel, called the Greenstar, which is currently under construction in the Maldives. It will feature 800 rooms plus a conference center accommodating up to 2000 participants. The Greenstar is predicted to become the worldwide hotel of choice for global conferences on climate change, water management, and sustainability. It was designed by Koen Olthuis of Waterstudio. The Greenstar is planted with multiple levels of greenery, and designed to naturally blend in with its surrounding islands. The star shape of the structure was selected to represent the Maldivian government's innovative way of dealing with climate change. There is a floating restaurant near the hotel, and together they are expected to bring more tourists than ever to this island nation that is already suffering from climate change.[97]

97 Defreitas, Susan. EarthTechling.com, "Architecture for a Hot Planet: The Maldives' Floating Hotel." Last modified June 11, 2012. http://earthtechling.com/2012/06/architecture-for-a-hot-planet-the-maldives-floating-hotel/. (Accessed February 13, 2015.)



Located within the Arctic Circle and floating offshore from the city of Tromsco, the Krystall is designed to be self-supporting and self-sustainable. (Courtesy of Dutch Docklands.)

Another new floating hotel that is scheduled for completion by the end of 2016, is the Krystal hotel. It is under construction near the Norwegian city of Tromso in a fairly protected area of the Norwegian Sea. Also the work of Waterstudio and Dutch Docklands, it is an 86-room luxury hotel that it meant to attract wealthy visitors from Russia, Japan, and other parts of Europe. The Krystal will serve as a truly unique tourist destination. What it will serve up to its guests is an incomparable view of the northern lights through its glass roofs, and windows that look out on the snowy tree-lined coast of Norway. Architect Koen Olthuis says that the Krystall was inspired by the floating architecture found in the Netherlands but that it will be on a much grander scale. He told CNN that the hotel is only accessible by boat since it is out at sea and not moored to the land. He said that the hotel would not be affected by high winds and waves thanks to “dampers, springs, and cables.” He ended by saying that the Krystal is an example of scarless development, and that if it was taken away in a hundred years, it would leave little or no footprint on the environment.[98]

98 DeFreitas, Susan. Dutch Docklands, “The Krystall, a floating 5-star hotel for Norway.” http://www.dutchdocklands.com/News/The-Krystall,-a-floating-5-star-hotel-for-Norway. (Accessed February 13, 2015.)

In addition to floating hotels, what else is likely to get the attention of the travel industry and the public? How about the most expensive twenty-seven-hole golf course in the world, one that is coming in at $500 million? How about a twenty-seven-hole golf course that is floating on the Indian Ocean, and also just happens to be near a huge floating hotel? How about an underwater tunnel that leads to the clubhouse, where a glass elevator drops down to a main bar?[99]

The Royal Indian Ocean Club features holes that are interconnected by an underwater tunnel.
(Courtesy of Dutch Docklands.)

This new golf course, called the Royal Indian Ocean Club, is both spectacular, and environmentally friendly and was also designed by Dutch Docklands' Koen Olthuis. It is set upon three interlinked islands and is situated a five-minute speedboat ride from Male, the capital city of the Maldives. Mark Spalding, senior marine scientist at the Nature Conservancy, says that its construction puts the Maldivian government on the front lines in the battle against climate change, and that if this project is done right, it could be a sign of things to come. Managing director of the project, Bruce Glasco, says they expect it to bring in a bonanza of additional tourism and investment to the Maldives.[100]

99 Tidey, Will. CNN.com, "Water hazard! $500 million floating golf course planned for Maldives." Last modified May 17, 2011. http://edition.cnn.com/2011/SPORT/golf/04/27/floating.golf.course/. (Accessed February 14, 2015.)

100 Ibid.

Dutch Docklands says that, as an extra attraction, homes and townhouses with a venetian style are being built in a nearby floating hidden village where residents and visitors can stroll through the streets lined with boutiques, and little restaurants and bars. They are predicting that this will be the place where every golfer in the world will dream about.[101]

5.3 Floating Support Structures: Energy

According to the U.S. Energy Information Administration, because of its geographic location, Hawai‘i's energy infrastructure is unique in the U.S. The state spends one-tenth of its gross domestic product on energy, mostly for imported crude oil and petroleum products. Hawai‘i is the most petroleum-depend state in the nation, since four-fifths of its energy comes from petroleum. In 2008, the state of Hawai‘i and the U.S. Department of Energy agreed to a partnership called the Hawai‘i Clean Energy Initiative which has as its goal the reduction of the state's dependence on petroleum and an increase in the use of sustainable local energy sources.[102] At the end of 2015, Hawai‘i's State Energy Office said that the goals of the Hawai‘i Clean Energy Initiative to meet 100% renewable energy by 2045 had been surpassed. In 2013, a previous target of 15% was reached, and in 2014, it reached 21%, over a fifth of the way to the latest goal of 100% by 2045.[103]

Hawai‘i and most modern societies require a staggering amount of energy to function. Currently most of this energy comes from the use of fossil fuel, which, as everyone knows by now, has two serious disadvantages. One is that fossil fuels will eventually run out. (Scientists now predict, for example, oil will disappear by 2070.)[104] The other, as mentioned earlier in this paper, is that using fossil fuels has polluted the environment.[105] Which, in turn, has resulted in climate change.[106]

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101 Dutch Docklands, "The Royal Indian Ocean Club." http://www.dutchdocklands.com/Development/The-Royal-Indian-Ocean-Club. (Accessed January 13, 2015.)

102 U.S. Energy Information Administration, "Hawaii: State Profile and Energy Estimates." Last modified June 19, 2014. http://www.eia.gov/state/analysis.cfm?sid=HI. (Accessed October 3, 2014.)

103 "Hawaii Releases Renewable Energy Progress Report." Hawaii Clean Energy Initiative. December 15, 2015. http://www.hawaiicleanenergyinitiative.org/hawaii-releases-renewable-energy-progress-report/. (Accessed January 2, 2016.)

104 Senior, Kathryn. Carbon Counted.co.UK, "When Will Fossil Fuels Run Out?." Last modified January 29, 2015). http://www.carboncounted.co.uk/when-will-fossil-fuels-run-out.html. (Accessed February 16, 2015.)

105 Kukreja, Rinkesh. Conserve Energy Future, "Fossil Fuels." Last modified January 1, 2015. http://www.conserve-energy-future.com/Disadvantages_FossilFuels.php. (Accessed February 16, 2015.)

106 BioMass Energy Centre, "The Problem With Fossil Fuels and Climate Change." Last modified January 1, 2011. http://www.biomassenergycentre.org.uk/portal/page?_pageid=76,539186&_dad=portal&_schema=PORTAL. (Accessed February 16, 2015.)

The magnitude, of course, of those two disadvantages is behind the search for alternative energy sources. What is "alternative" energy and where does it come from?

Alternative energy sources are defined here as energy sources that are not related to fossil fuels, i.e., they are possible alternatives that can replace fossil fuels in the future. Alternative energy sources have a number of attractive features. One is that they are often renewable, and the two best-known are solar power and wind power. The sun will be around for millions of years, and wind is a constant factor in the Earth's atmosphere. Neither will, for all practical purposes, ever be exhausted.[107]

The other attractive feature of alternative energy is that it is clean, i.e. using it will not pollute the environment. (That's the reason people don't consider nuclear power as an alternative; it produces highly toxic radioactive materials.) Hydroelectric power is considered a clean alternative because water is the only source of power.[108]

Society's demand for energy will only increase in the future, and fortunately for humanity, and of course Hawai'i, the oceans of the world provide a virtual treasure trove of untapped floating options for the production of alternative energy from the sun, from the wind, and from the water of the ocean.

5.4 Floating Solar Panels

A solar panel produces a flow of electricity by allowing photons, particles of light, to knock electrons loose from atoms. They are made up of many smaller units that are called photovoltaic cells. Photovoltaic cells mean the cells transform light into electricity. Linking many of those cells together produces a solar panel. Actually there are other types of technology for using solar power, one being solar thermal and another being concentrated solar power. They operate differently from a solar panel, but in the end they all use sunlight to create electricity or to heat water.[109]

107 Jessa, Tega. Universe Today.com, "What is Alternative Energy." Last modified September 29, 2010. (Accessed February 16, 2015.) http://www.universetoday.com/74599/what-is-alternative-energy/. (Accessed February 17, 2015.)

108 Ibid.

109 Dhar, Michael. Live Science.com, "How Do Solar Panels Work?." Last modified December 16, 2013. http://www.livescience.com/41995-how-do-solar-panels-work.html. (Accessed January 30, 2015.)

In Hawai‘i, solar panels are a common sight, from rooftops to backpacks. Up to now, however, their use has been limited to the land. In contrast, solar power plants that float on the water are already being used in a number of places around the world. They are either in use or currently being installed in, among other places, Australia, Italy, Japan, India, and the United Kingdom.[110]

In Japan, they have been in use for some time, including a large installation in Kagoshima. During that time, they have proven themselves to be both reliable and productive. In India floating solar panels have been used for dual purposes. Installed on the surface of a canal in the state of Gujarat, they serve not only to generate power, but also to prevent water from evaporating from the canal.[111] In terms of output, the biggest floating solar power plant so far is to soon be built on top of a reservoir of Japan’s Yamakura Dam, in Chiba prefecture, which is just east of Tokyo. In March 2016, when construction is scheduled to be completed, it will cover 180,000 square meters, and consist of 50,000 photovoltaic solar panels. It will power nearly 5,000 households.[112]

The use of floating solar panels is especially useful in areas where the land is overcrowded, as in Japan. Often in situations like that, the nearby seas (or waters) are largely unused, so it makes sense to use the space on the water for power. Additionally, even though people are taught to believe that having water and electricity in close proximity is to be avoided, solar panels are totally waterproof, so there is little danger in using them over the surface of water.[113]

As they are used more extensively, it has been observed that there are unexpected advantages in using floating solar panels, rather than basing them on land. One is that they actually work much better when they are cooler, so positioning them over water helps their performance considerably. Another advantage is their relative ease of installation and use.

110 Lufkin, Bryan. News National Geographic.com, “Solar Panels Floating on Water Will Power Japan’s Homes.” Last modified January 16, 2015. http://news.nationalgeographic.com/news/energy/2015/01/150116-floating-solar-power-japan-yamakura/. (Accessed February 1, 2015.)

111 Major, Jon. The Week.com, “Why Japan is turning to high-tech floating islands to solve its energy needs.” Last modified September 18, 2014. http://theweek.com/articles/443781/japan-turning-hightech-floating-islands-solve-energy-needs. (Accessed January 8, 2015.)

112 Lufkin, Bryan. News National Geographic.com, “Solar Panels Floating on Water Will Power Japan’s Homes.”

113 Major, Jon. The Week.com, “Why Japan is turning to high-tech floating islands to solve its energy needs.”

World's largest floating solar power plant being placed on top of reservoir in Chiba prefecture.
(Courtesy of Post Online Media.)

Photovoltaic panels can be bought over the counter, and installing them is just a matter of plugging them in. Basically the engineering for offshore solar farming is not much more than building a floating pier and covering it with solar panels.[114]

In both Japan and India, the motive for the installation of floating solar panels mostly came from government. In Britain private enterprise has stepped in. Farm owner, Mark Bennett, hoping to save on his farm's power bills, has set up an 800-panel floating project that covers about an acre of surface water. It is situated on a reservoir at Bennett's 300-acre fruit farm. He says it will be a model for new solar panel installations across the UK. He also says that floating solar panels are more profitable than those placed on land, because no agricultural land has to be given up to make space for them.[115]

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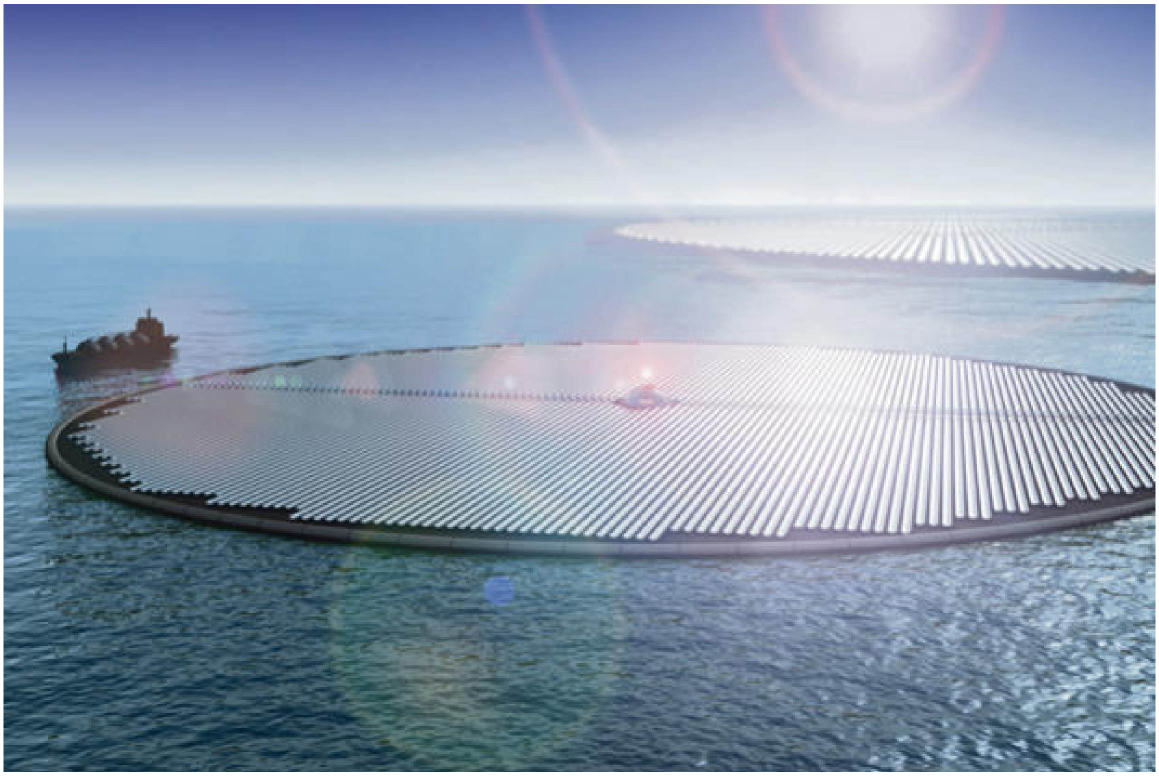
114 Ibid.

115 Gosden, Emily. Telegraph.co.UK, "Britain's first floating solar panel project installed." Last modified September 29, 2014. http://www.telegraph.co.uk/news/earth/energy/solarpower/11110547/Britains-first-floating-solar-panel-project-installed.html. (Accessed October 26, 2015.)



There are stories of companies that have begun to tackle the challenge of placing solar power systems an the open ocean (Courtesy of Solarfeeds.com)

Floating solar panels can be mounted on fairly simple floating platforms. Obviously early models would need to be in fairly calm waters, as would any other kind of floating development. As mentioned in the last few paragraphs, canals, protected bays, and canals are some of the earliest choices.

5.5 Floating Wind Turbines

Stronger wind speeds are available offshore compared to those on the land, and offshore wind power comes from construction of wind farms in bodies of water to produce electricity from wind. (Courtesy of Bluebird-Electric.net.)

The principle underlying how turbines operate is simple. Wind energy turns two or three blades like propellers, and that activates a rotating assembly. That rotor is connected to a shaft which rotates a generator, thus creating electricity. There are two basic groups of wind turbines. One has a horizontal-axis, like an airplane propeller, and one has a vertical-axes design, like an eggbeater. Energy that is produced by wind turbines can range from 100 kilowatts to several megawatts, and large wind turbines are grouped together into wind farms. Within the last few years, the number of offshore wind farms has increased so as to take advantage of the huge potential of wind energy off the coasts of the U.S. and other countries.[116]

Various types of foundations for wind turbines are used in offshore wind farms, and the type used largely depends on the depth of the water. Additionally, wind turbines are sometimes being installed on floating foundations in depths over 60 meters.

116 Energy.Gov: Office of Energy Efficiency & Renewable Energy, "How Do Wind Turbines WorK?." Last modified March 11, 2015. http://energy.gov/eere/wind/how-do-wind-turbines-work? (Accessed March 12, 2015.)

Some recent studies have showed that offshore winds blow 40 percent more often offshore than on land (Courtesy of Wikipedia.)

Several alternative designs for floating turbine foundations exist, all of which have come from the oil and gas industry.[117]

Offshore wind turbines really got started in the U.S. in 2010 when a multi-state east coast effort to coordinate efforts to utilize offshore wind power in shallow water got underway. Recently a milestone occurred when the Energy Department conditionally agreed to a $150 million loan guarantee for the huge Cape Wind offshore wind farm in Massachusetts. Also an offshore wind farm is set for completion in Rhode Island in 2016. The situation on the west coast is different. The Continental Shelf suddenly drops steeply and doesn't allow for offshore wind turbines in shallow water. The solution is to use floating platforms and tether them in place, and, as was pointed out in the previous paragraph, much of the knowledge and related technology to do this has come from deep water oil drilling operations. Coos Bay, Oregon, will have the west coast's first

117 COast to COast NETworks, "Wind Turbine." Last modified January 1, 2012. http://coconet-fp7.eu/children/TeachersWindE.html. (Accessed February 12, 2015.)

offshore wind farm, called WindFarm Pacific, and it will be a floating wind farm.[118]

5.6 Floating Wind Farms in Hawaiʻi

First announced last year, plans are in effect for a $1.6 billion offshore wind development project by Denmark-based Alpha Wind Energy. It is planned off Oahu waters, 17 miles southeast of Diamond Head and 12 miles northwest of Kaena Point. It is to be a 408-megawatt project, including more than a hundred turbines at two separate sites. Now comes the announcement that Ted Peck, who once let Hawaiʻi's Energy Office, along with one other person, plans to develop a $1.6 billion offshore wind energy farm for waters located 10 southeast of Barbers Point in West Oʻahu. Progressio Energy, a Portland, Oregon-based along with investors have formed Progression Hawaiʻi offshore to develop the 400-megawatt project.[119]

5.7 Energy from the Ocean

The oceans are a huge potential source of energy. Scientists have judged that just 0.1% of the energy in ocean waves is enough to supply the entire world's energy requirements times five. There are currently a number of technologies being studied with the aim of making use of this potential and they are at different levels of development. These include tidal and marine energy, wave energy, difference of temperature and salinity energy. Converting tidal energy into electricity has been studied widely and is comparable to hydroelectric power plants. The generation of electricity is a result of water flowing in and out of gates and turbines that are installed along a dam or barrier built across a tidal bay or estuary. More recently, scientists are studying the use of waves and currents for energy. Finally, even more recently, studies connected to the difference of temperature and of salinity as energy sources are also being done.[120]

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118 Casey, Tina. Clean Technica.com, "Floating Wind Turbines Float Into US Waters (Finally!)." Last modified July 7, 2014. http://cleantechnica.com/2014/07/07/floating-wind-turbines-float-into-us-waters-finally/. (Accessed September 16, 2014.)

119 Shimogawa, Duane. "Another $1.6B Offshore Wind Energy Project Planned off Hawaii's Waters." Pacific Business News. October 6, 2015. http://www.bizjournals.com/pacific/news/2015/10/06/another-1-6b-offshore-wind-energy-project-planned.html. (Accessed January 4, 2016.)

120 European Commission Research & Innovation, "Ocean Energy." Last modified August 19, 2013. http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-oceanhttp://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-ocean. (Accessed March 13, 2015.)

Wave power, however, still lags behind. There has been progress, but most experts agree that it is decades behind other forms of renewable energy, requiring large amounts of money and research to catch up. There are no commercial wave power operations in existence right now, though a small-scale version operated near Portugal in 2008 and 2009. Locheed Martin has announced a project off the coast of Australia, and the government of Scotland has approved a wave energy project in the Shetland Islands. There are a number of ideas right now to convert wave power into energy but which will emerge as a winner is not yet clear.[121]

5.8 Ocean Energy in Hawai‘i

In Hawai‘i, there are two types of ocean energy that are being explored. One is thermal energy and the other is marine hydrokinetic energy. Thermal energy, has to do with seawater air conditioning and ocean thermal energy conversion. Marine hydrokinetic energy has to do with energy carried by moving water. The motion is converted to energy by a device that spins as the water goes past or it bobs up and down.[122]

5.9 Alternative Energy in Hawai‘i

A study by Hawai‘i's Natural Energy Institute at the University of Hawaii at Mānoa, General Electric Company, and the Hawaiian Electric Company, in this older study, showed that O‘ahu could meet 25% of it energy needs by utilizing 500 MW of wind power and 100 MW of solar power. The study, the O‘ahu Wind Integration Study (OWIS) indicated that having 600 MW of renewable energy would take the place of 2.8 million barrels of oil and 132,000 tons of coal each year. Rick Rocheleau, director of the Hawai‘i Natural Energy Institute, says that in Hawai‘i the results of this study show two important things: one is that integrating large-scale wind and solar energy projects are entirely viable, and the other is that this study is valuable outside Hawai‘i to any groups wanting to integrate large amounts of renewable energy while providing reliable energy to their customers.

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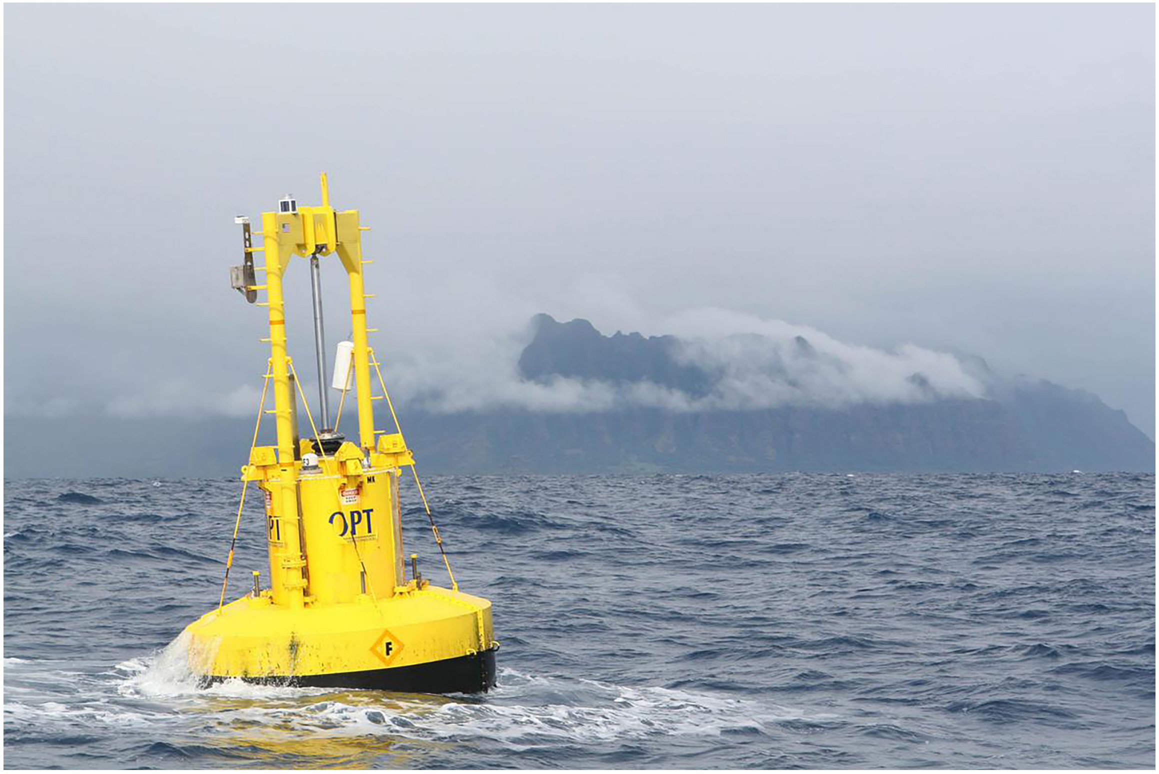
121 Levitan, Dave. Yale: Environment 360, "Why Wave Power Has Lagged Far Behind as Energy Source." Last modified April 28, 2014. http://e360.yale.edu/feature/why_wave_power_has_lagged_far_behind_as_energy_source/2760/. (Accessed November 13, 2014.)

122 "Ocean Energy." Hawaii State Energy Office. http://energy.hawaii.gov/renewable-energy/ocean. (Accessed December 20, 2015.)



This Power buoy system is based on modular, ocean-going buoys that capture and convert wave energy into electricity. (Courtesy of U.S. Marine Corps and Cpl. Jody Lee.)

Robbie Alm, Hawaiian Electric executive vice president added, though, in spite of these results, on-island resources are still not enough to meet Oʻahu's power needs.[123]

Considering the important decisions that will have to made this century, it is critical that citizens of Hawaiʻi have some basic knowledge about alternative energy sources that are available in Hawaiʻi and it is even more important for professional people and leaders in the state to understand even more, because, even though we are living in a wonderful, challenging period of time, we are living in a critical period of time, and decisions we make today can change the world of tomorrow. (Steve Jobs was right, as is President Obama.) If one is dreaming of becoming an architect, as this writer is, one needs to understand as much as possible about alternative sources of energy in the state because 1) as mentioned earlier, the state is in a race to switch to 100% alternative energy sources as soon as possible since fossil fuels are undeniably destroying the planet, and 2) that makes the use of alternative energy critical in any kind of architectural project.

123 Singh, Timon. Inhabitat.com, "Hawaii's Oahu Island Could Receive 25% of its Electricity from Wind and Solar." Last modified March 25, 2011. http://inhabitat.com/hawaiis-oahu-island-could-receive-25-of-its-electricity-from-wind-and-solar/. (Accessed December 14, 2014.)

5.10 Hawaii's Need for Food Sovereignty

The need for food is even more basic than the need for energy. Before looking at examples of how farming might take place on water, a discussion on food in Hawai‘i is appropriate. People in Hawai‘i say that without shipments of food and other goods coming in, they could only survive a couple of weeks. Thus a major crisis, the events of 9/11, for example, or a prediction for a possible tsunami, often results in stampedes in food stores and the stripping of food and household products, most notably, toilet tissue, from store shelves.

In actuality, the need for food security in Hawai‘i at the present time is quite alarming. According to an article in Civil Beat, “captive populations” are societies that depend on others for their food, and modern Hawaiian society fits that description perfectly. In 2010, 13 percent of crop production in Hawai‘i was edible, and that includes crops that were exported like macadamia nut, pineapple, guava and lilikoi. Only about eight percent of crops grown in Hawai‘i were eaten in Hawai‘i. 92 percent of Hawai‘i's agricultural production was exported that year, and 92 percent of the food that was consumed in Hawai‘i was imported. One final alarming fact: between 1960 and 2005, farmland shrank in Hawai‘i from 2.6 to 1.3 million acres. The article ends by suggesting that citizens in Hawai‘i need to advocate for sustainable and renewable agriculture to the legislature, because, for now, “It's the most effective means for positive change we have.”[124]

If this is the situation today with food security in Hawai‘i, what will it be like in thirty-five years if sea levels have increased by a foot? What will it be like by the end of the century when sea levels have increased six feet? With this in mind, it becomes important to examine ways that farms can be transitioned to water, through various means and on various scales.

5.11 Floating Agriculture

First consider floating farms on a grassroots level. In Bangladesh, the Gumani river swells during the summer monsoon, inundating the nearby fields and the village of Charbhangura, where 2,300 people live. Between July and October

124 Russell, Simon. Civil Beat.com, “Hawai‘i Needs Food Sovereignty Now.” Last modified February 12, 2013. http://www.civilbeat.com/2013/02/18309-hawaii-needs-food-sovereignty-now/. (Accessed January 17, 2015.)

each year the water can rise ten feet, and when the fields flood, the farmers can do no work. Three years ago, a nonprofit organization in Bangladesh started training women in villages in how to tend a new source of food and income, a floating farm. The covered farm includes a duck pen, enclosures for fish, and a vegetable garden, all of which are connected to the riverbank by rope. Up to ten women can share the structure, sharing a profit of about $1,700 a year. The nonprofit organization, called Shidhulai, supplies seeds, fish and duck food, and other basic necessities. Up to now, Shidhulai has produced forty floating farms that are tended by about 300 women. Shidhulai has plans to create 400 more in the next few years to serve 3,000 women and their families, as climate change is expected to worsen river flooding in Bangladesh.[125]

Floating farm in Bangladesh being tended by villagers. (Courtesy of New York Times)

One floating farm is about 56 feet long and 16 feet wide. The duck pen has space for a hundred ducks and has a solar panel to power lights inside. The farm floats on oil drums, plastic containers and a bamboo platform. The duck pen is fastened to bamboo poles that make up two rows of fish enclosures where tilapia are raised. The outer rows of bamboo support the garden, which holds old plastic jugs that are cut in half where cucumbers, beans, and gourds are grown in soil and natural fertilizer. People in the village can now construct the entire farm

125 Yee, Amy. New York Times.com, "The Floating Gardens of Bangladesh: Farming on Water to Prevent the Effects of Climate Change." Last modified November 18, 2014. http://www.nytimes.com/2014/11/19/business/energy-environment/bangladesh-farming-on-water-to-prevent-effect-of-rising-waters.html?_r=0. (Accessed February 1, 2015.)

for about $260, which Shidhulai now covers. The organization says these simple floating farms can be copied almost anywhere in the world.[126]

For something more sophisticated, something called “Jellyfish Barge” merits examination, since it is a good example of simple, small-scale farming in a higher-tech environment than the floating farms in Bangladesh. For those looking to do alternative farming, i.e., farming that is not land-based, it is rather an attractive alternative. Making use of recycled materials, designers Antonio Girardi and Cristiana Favretto of Studiomobile came up with this floating modular greenhouse that rides on top of a foundation of ninety-six repurposed plastic drums. The purpose of this octagonal design is to allow families and communities living in coastal areas, or even near a body of water, to grow their own food without being dependant on having any land.[127]

Jellyfish Barge from Studiomobile on Vimeo. (Courtesy of Studiomobile.)

126 Ibid.

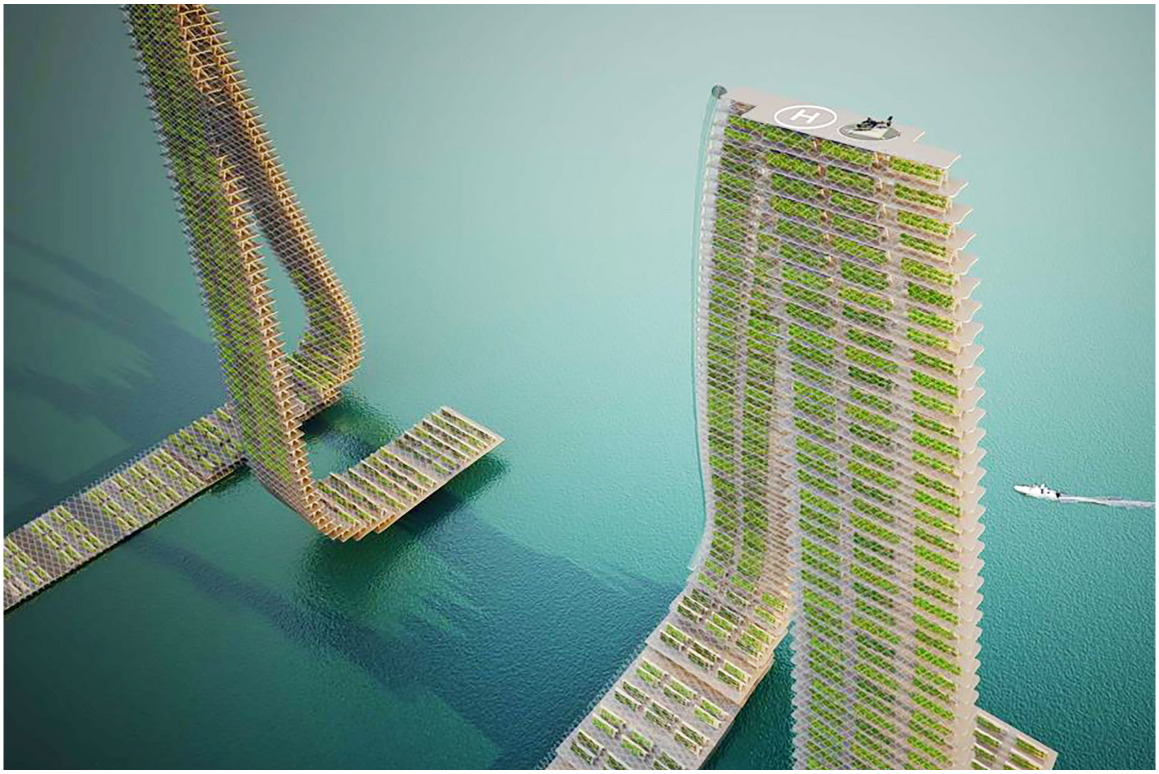
127 Mok, Kimberley. Tree Hugger.com, “Brilliant floating greenhouse sustains itself with sun & harvested rainwater.” Last modified November 25, 2014. http://www.treehugger.com/green-architecture/jellyfish-barge-solar-powered-floating-greenhouse-studiomobile.html. (Accessed February 26, 14, 2015.)

Jellyfish Barge from Studiomobile. (Courtesy of Studiomobile.)

In this 750-square-foot space, food crops are hydroponically grown. Rainwater is captured and distilled through seven stills in a solar-powered, self-sustaining system. With either seawater or rainwater, it can catch and process up to thirty-nine gallons of clean, purified water daily that is suitable for crops.

The modular design of the barge allows it to be scaled up or down, or even customized for various applications, such as floating farm-to-table homes and restaurants, floating farmer's markets, or even as floating gardens shared by a community. This crop-growing barge that is powered by renewable energy provides a possible solution to food production when land is scarce, and additionally, is able to float to wherever it is needed.[128]

128 Ibid.



Floating farms to be built in Singapore by Forward Thinking Architecture. (Courtesy of JAPA.)

A look at truly high-tech farming is an appropriate final example of floating agriculture. In this vision of floating agriculture for the shores of Singapore, food is to be grown in tall towers floating on the sea. Barcelona-based architectural firm JAPA has drafted a network of looping towers that float on the shoreline to produce crops for this small nation that is increasingly losing its land. Javier Ponce of JAPA says all crops will be grown inside vertical structures that will be situated near cities and dense areas of population. Growing areas are stacked in towers that look like looped ribbon and float upright on the coastlines.[129]

Although prototypes will begin much smaller, the towers are designed to eventually reach 150 meters (492 feet). Ponce says the sun drove the design, and the loop shape allows the vertical structure to get more sunlight with fewer shadows. He believes this design could be the solution to concerns about food security for small densely populated nations that are in the position to lose more farmland to climate change, sea level rise, and population growth.[130]

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129 Tencic, Natalie. ABC.net.au, "Floating farms in the sky: Singapore concept design shows possible future of sustainable farming." Last modified September 29, 2014. http://www.abc.net.au/news/2014-09-30/floating-farms-pilot-for-singapore/5776134. (Accessed October 21, 2015.)

130 Ibid.

5.12 Floating Agriculture in Hawai‘i

Ancient Hawaiian made use of ponds and fish farming, though, of course it wasn’t “floating.” They used aquaculture to supplement their other fishing activities since permanent fishponds insured a food supply for the population when food was scarce and it added to the wealth of the chief. Ponds provided fish without requiring knowledge of fishing and didn’t depend on the weather.[131] Except for a few businesses that do some fish farming, there is little information about other farming in the sea at the present time, which is regrettable since food remains an issue in Hawai‘i.

5.13 Floating Structures to Desalinate Seawater

What about the problem of freshwater as sea level rise reaches underground aquifers? What happens if many sources of freshwater are contaminated by saltwater? Are there solutions?

It turns out seawater can be made safe to drink through a process called desalination, which removes dissolved minerals, including salt, from seawater, brackish water, or even treated wastewater. There are a number of ways to do that, including reverse osmosis, distillation, electro dialysis, and vacuum freezing. (Reverse osmosis uses a membrane to remove particles from water, distillation, the oldest and most common method, purifies water by heating and cooling, electro dialysis uses an electric field to move salt ions through a membrane, and vacuum freezing uses a process of instant freezing in a vacuum to remove salt.)

Seawater is an attractive water resource because it provides an unlimited reliable water supply for coastal populations worldwide. 97 percent of all of the Earth’s water is salt water, and only one percent is fresh water for people to drink.[132]

Floating desalination plants are now becoming a reality. Land based desalination plants are common but are limited to towns and cities within reach

131 “Fishponds.” Hawaii History.org. http://www.hawaiihistory.org/index.cfm?fuseaction=ig.page&CategoryID=306. (Accessed December 17, 2015.)

132 APEC: Free Drinking Water.com, “Can You Make Seawater Drinkable?.” Last modified November 21, 2014. http://www.freedrinkingwater.com/water_quality/quality1/1-make-seawater-drinkable-page2.htm. (Accessed October 15, 2014.)

of pipelines, and are notorious for environmental problems. Mobile, floating desalination can travel to different places to serve people water as they need it. The Saudis, for example, have been using desalination plants that are mounted on barges since 2008. Now, however, Israel's IDE Technologies Ltd. and Japanese shipbuilders are planning to do much more. The former recently announced that, within the next three years, it is planning to have a fleet of offshore floating desalination plants with each ship producing up to 120,000 cubic meters of fresh water a day, or enough water for a city of 850,000 people and Japan shipbuilders are a strong potential partner.[133]

The idea of converting old ships to floating desalination plants has been around a while. With some alterations, many naval military ships could be retrofitted as desalination plants and supply very large amounts of fresh water (and power) for long periods of time to cities in need. They could do that with minimal damage to the environment. A number of things are coming together to make this happen. Desalination is now more efficient and less expensive than before, and also, at sea, increasingly more environmentally friendly, since ships can take advantage of a number of alternative energy sources.[134]

Some form of mobile desalination are already in the works in many countries. For example, Australia's Queensland government has proposed mobile desalination barges on the Brisbane River to ensure future water supplies. Also the Cyprus Ministry of Agriculture recently unveiled plans to build a floating desalination plant near Limassol, the second largest city in the country, as a way of dealing with intense drought. About 27 percent of the water supply in Cyprus already comes from land-based desalination plants.[135]

Finally, it isn't necessary to build new ships as desalination and power plants. U.S. armed forces around the world are home to fleets of aging or mothballed ships that could be retrofitted as desalination and power-generating vehicles. Also allocating money to refurbish those ships goes along with the U.S.

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133 Laylin, Tafline. Green Prophet, "IDE Technologies aims for a fleet of floating water desalination plants in three years." Last modified April 21, 2014. http://www.greenprophet.com/2014/04/ide-technologies-aims-for-a-fleet-of-floating-water-desalination-plants-in-three-years/. (Accessed November 20, 2015.)

134 Kreamer, David. Earth: The Science Behind the Headlines, "Dry dock to wet tap: Old ships become floating desalination plants." Last modified May 14, 2009. http://www.earthmagazine.org/article/dry-dock-wet-tap-old-ships-become-floating-desalination-plants. (Accessed December 8, 2014.)

135 Ibid.

military's mission to do humanitarian work to deal with the root causes of conflict.[136]

The technology for converting seawater to freshwater will continue to improve, as will the ability to do that from mobile, floating structures. That means that even if sea level rise produces a critical need in the future for fresh water in Hawai'i, there will be the means to acquire it, though it is currently expensive.

Interestingly, according to the Nature Conservancy, 75% of Americans, people the organization recently polled, did not know where their drinking water came from. They also didn't know where it came from before it came out of the tap. In actuality, 80% of drinking water on the mainland comes from lakes and rivers, whereas in Hawai'i, it is pumped up from underground aquifers (now in danger of sea level rise) or taken from mountain streams. Also people don't pay for water. Instead they pay for treatment and delivery through a public water system.[137] Moreover, although people complain about their water bills today, if fresh water today had to depend on desalination plants, most people would pretty much stop drinking water. Hopefully when the time comes and freshwater supplies are drying up, the cost of desalination will have gone down (as it already has in some places).

5.14 Living on the Open Ocean - Petropolis

Oil rigs are the ultimate very large floating structures (VLFS) in terms of level of development. The technology for drilling and storing oil far out in the sea is truly cutting edge. One country that is currently emerging as a world leader in oil production is Brazil, and all of their drilling is done far offshore. Recent drilling is being done in an area called the Libra oil field, in which is 230 kilometers (140 miles) off the coast of Rio de Janeiro, Brazil. Helicopters are regularly used to ferry 45,000 workers from the shore to the rigs and back, and that results in 70,000 helicopter trips every month, and as new oil discoveries move further and further offshore, helicopters are barely able to cope with the flying distance. That means getting workers to and from work is difficult and expensive. Petrobras, a large Brazilian oil company is trying something different, and other oil companies are becoming interested.

136 Ibid.

137 Case, Suzanne. "Water for Life." http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/hawaii/explore/where-does-your-water-come-from-1.xml. (Accessed December 20, 2015.)

Petrobras is developing a series of “floating frontier towns,” actually floating islands, on which 25,000 workers along with their families could live for long periods of time, and is considering designs from students at Rice University in Houston. Underneath each hub is designed a mountain of submerged steel, including massive ballast tanks. “With the ballasting techniques, not only can you raise and lower the island by the ratio of water to water, they also have techniques now for digitally sensing wave levels and these things are constantly being calibrated,” Bhatia says. “So the technique of using digital stabilizers that are constantly re-ballasting the tanks would be what was employed.”[138]

What the Petropolis project means is that oil companies that do offshore drilling are very seriously looking at the construction of floating communities far offshore--at least 140 miles--in the open ocean, as a way of housing their workers and their families. It means predictions made that independent floating communities in the open ocean were very, very far away could be wrong. If anyone has the money and resources to make that a reality, surely it would be oil companies.

As floating architecture becomes more and more common, more and more innovative and unique designs will emerge, many unlike anything imaginable today. Climate change and sea level rise are generally not considered positive events, but one positive result is the motivation to create new ways to live and work. Along with radical new designs, radical new functions will come into play. Human beings are endlessly creative and adaptable, and eventually life on water will seem no more unusual than life on land, and humanity will keep moving forward.

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138 Goodwyn, Wade. NPR.org, “A College Project That Imagines A Floating City For Oil Workers.” Last modified February 25, 2014. http://www.npr.org/2014/02/25/280671831/a-college-project-that-imagines-a-floating-city-for-oil-workers. (Accessed March 23, 2015.)

Summing Up

As examples of future floating development that could be used in Hawai‘i, we examined examples of floating residences, floating tourist destinations, and floating support structures for energy, food, and fresh water

Coming Up

In Chapter 6, we will consider what features of a site on the water might be most important when looking for a site. We will then take a look at Ke`ehi Lagoon and see how it matches up. We will learn of its historical importance and see why it is clearly environmentally stressed today, especially as a result of governmental activity during WW II. We will see some of the wildlife that lives there today and try to find out about weather and sea patterns. Additionally, we will learn something about Resilient Coastal Land Use.

Chapter 6

Design Project Location: Ke`ehi Lagoon

"You can't cross the sea merely by standing and staring at the water."
— Rabindranath Tagore —

6.1 Considerations in Choosing a Site

This writer believes that the main considerations in choosing an ideal site for floating residences are weather, location, and conditions and characteristics of the water.

Ideally (for this writer) the weather would be mild with few extremes in temperature, with some occurring moderate wind. This means a place with a climate like Hawai‘i, for example. (Not everyone would agree to that. A resident of a floating neighborhood in the Netherlands said that, for her, the best thing about living on water was having the option to ice skate from her front door to her train station during winter.)

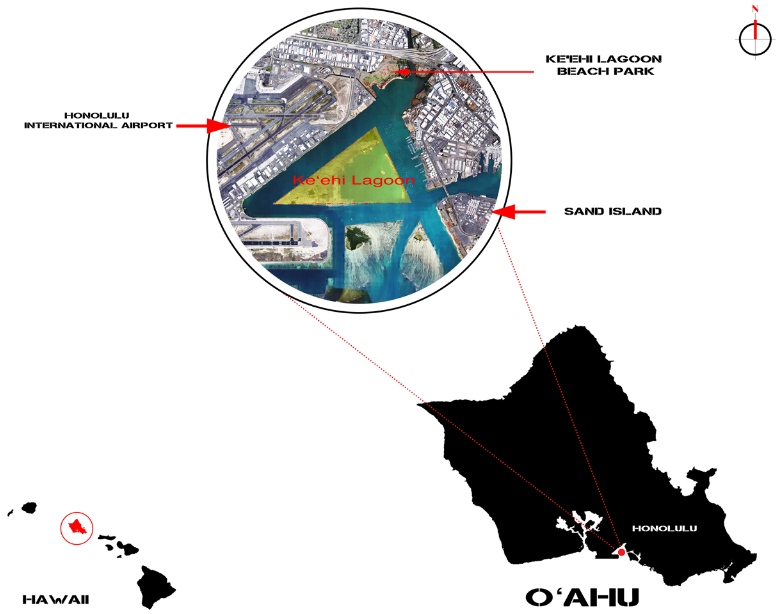
As for the location, the site should have easy access to the shore, and nearby road or highway. It should be in a calm and protected body of water. If it is an ocean location, it should be at least partly protected from the open sea.

As for the water, ideally the water would be clean with minimal amounts of pollution (the water should be relatively free of sewage, crop runoffs, trash, plastics, and so on.) There would be little variation in wave frequency, height, or strength, and currents would be mild. It should be deep enough to allow space between the underside of the floating foundation and floor of the body of water. Minimum depth levels will vary with the design of the structure and type of floating foundation.[139] On the other hand, the Self Sustaining Floating Home, discussed earlier, requires a depth of ten feet.[140]

139 BUILD LLC, "Floating Homes: Interview With Dan Wittenberg." Last modified July 4, 2008. http://blog.buildllc.com/2008/07/floating-houses/. (Accessed February 5, 2015.)

140 Architecture for Humanity, "Sustainable Floating Home." Last modified January 1, 2012.

6.2 Proposed Design Project Site Location: Ke‘ehi Lagoon



Regional Map (Graphic by author)

This writer believes that Ke‘ehi Lagoon meets his main considerations as an ideal site for creating a floating neighborhood in terms of weather, location, and conditions and characteristics of the water. Additionally, the area has ample space for construction plants in which to manufacture prefabricated modules for floating structures, assemble them and, finally, to float them to the final location where they will be moored. It is easily accessible by private car and TheBus goes right past it, on 19 Waikiki and 19 Alapai Transit.

This is not the first time the Ke‘ehi Lagoon area has been considered for a large developmental project. According to a 2008 article in the Star Bulletin, there have been a number of development plans for the Ke‘ehi Lagoon area, the two most recent being a proposal in the 1980s by Gov. John Waihe‘e which was part of a plan to attract the America’s Cup yacht race to Hawai‘i in 1991. He wanted to build an ocean recreation complex within the Ke‘ehi Lagoon and Sand Island area, and the proposal called for a large dredging of the lagoon and the use of almost 3.8 million cubic yards of landfill in order to build a 250-acre island.

KE'EHI LAGOON

VIEWS / OCEAN ACTIVITIES

Point of View

Keehi Lagoon:
Functions as a large, mixed-use commercial and recreational area. Access to the ocean is mostly through the Kalihi Channel and to a lesser extent, through the WCC adjacent to the RRBP. One of the islands.

Mokauea Island, in the eastern portion of the lagoon and roughly opposite the State boat ramp; the location of several permitted houses.

EASTERN

The eastern portion of the lagoon bordered by numerous small businesses, many of which require access to the ocean, for example, ship repair, ocean tourism, commercial dockage, several shoreline parks, extensive mooring areas for power and sail boats, and launching ramps for trailered boats.

Point of View

Designated areas within the lagoon are for competitive canoe racing, water skiing, and jet skiing.

WESTERN

Western part of the lagoon; several designated seaplane runways, with one commercial seaplane charter business based on Lagoon Drive currently operating.

Point of View

Ocean activities within the BP and on the inner and outer reef flats that border the dredged area: fishing, from boat and shore; SCUBA diving and snorkeling from boats; kayaking; tropical fish collecting from boats; and thrill craft riding.

Ke'ehi Lagoon point of interest
(Graphic by author)

In 2008, Gov. Linda Lingle proposed building a triangle-shaped island twice the size of Ala Moana Beach Park in the center of Ke'ehi Lagoon, along with up to a thousand new boat slips along Lagoon Drive, a number of moorings for ultra-expensive yachts, and a light industrial park.[141]

The Keʻehi Lagoon area is clearly environmentally stressed, and is similar to other stressed sites that have been used, polluted, and abandoned. It can never be returned to its original state. In addition to showcasing the first floating community in Hawaiʻi, parts of the Keʻehi Lagoon area could be landscaped and made into a living, growing, changing environment that would be of benefit to everyone, local people and tourists alike

6.2.1 Estuaries and Lagoons

Ke`ehi Lagoon joins the sea. Why isn't it considered an estuary? Estuaries and lagoons are different. One difference is in the flow of water. In estuaries, the water is likely to be from a river and usually flows fast and strong, whereas, In lagoons, the water, often from streams, is more shallow and flows in a slower way.[142] That is the case with Keʻehi Lagoon. Both have brackish. or slightly salty, water. In the case of Keʻehi Lagoon, it is fed fresh water from the north by a number of Oʻahu's mountain streams. From the south, ocean water is pushed in with the tides. After a heavy rain, the lagoon has a layer of freshwater from the streams and from runoff that often isn't very clean. In the lagoon, that freshwater then sits on top of the salt water, which is heavier.[143]

Another difference is that generally estuaries are open to the ocean while lagoons are separated from the ocean, as Keʻehi Lagoon is separated from the ocean by a large reef system. Still another difference is that estuaries are often deeper than lagoons, where sunlight reaches the floor and encourages life to flourish.[144] "What Are Lagoons and Estuaries." Keʻehi Lagoon is not a typical

141 *Honolulu Star Bulletin*, "Keehi Lagoon future could include adding an industrial island." Last modified September 3, 2008. http://www.urbanplanet.org/forums/index.php/topic/47612-keehi-lagoon-future-could-include-adding-an-industrial-island/. (Accessed April 16, 2015.)

142 Royal, Rita. "What Are Lagoons and Estuaries." Merit Nation. Last Modified July 16, 2013. http://www.meritnation.com/ask-answer/question/what-are-estuaries-and-lagoons/improvement-in-food-resources/4796361. (Accessed February 25, 2016.)

143 Heatherly, Mark. "Oahu Water Ski Club: Contact and Location." Oahu Water Ski Club. Last Modified January 1, 2006. http://www.oahuwaterskiclub.com/6.html. (Accessed February 25, 2016.)

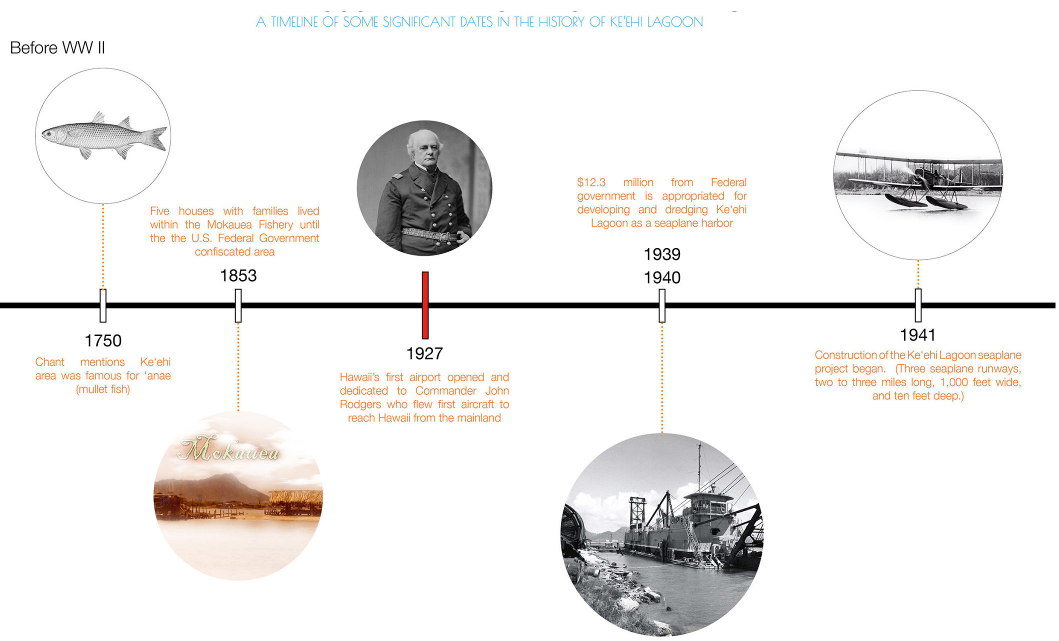
144 Royal, Rita.

lagoon, however, because of dredging that went on there for years. At present, its water depth is from eight to ten feet with a tidal variation of about two and a half feet.[145] Dredging and other human activities have clearly left the entire area of Keʻehi Lagoon seriously environmentally stressed.

6.3 Brief History of Keʻehi Lagoon and Surrounding Area Before, During, and After WW II

6.3.1 Before WWW II

Before any dredging or landfills, there were three islands on the west side of Kalihi Channel, Mokuʻeo, Mojupilo, and Mokumoa islands. On the east side of the channel, there were two tidal islands, the Mokauea Islands. The northern one was a tidal island dredged out in 1941. The southern one enlarged by channel dredging is the modern-day Mokauea Island, and was surveyed by Hawaiʻi state archaeologists in 1976. It was concluded that, even though the islands had no archaeological sites, "the cultural value of Mokauea lies not in tangible structures but in its existence as a more or less traditional fishing community." According to one informant, Dorothy Barrere, the nearby area of Moanalua was possibly originally settled between 766-1126 A.D.



Ke'ehi Lagoon Before WW II Timeline
(Graphic by author)

145 Heatherly, Mark. "Oahu Water Ski Club: Contact and Location."

One chant from the 1900s that was found in the Gertrude Damon Notebooks names the ancestors of the people of Moanalua, Kamawaelualani, a man and Kahikilaulani, a woman. Another account says that human settlement in that area started with a settler named Newalani. One of the chants, a chant to Makalii, the Guardian Shark of Moanalua, mentions many geographical landmarks, including Moku Onini, an island that existed in the 1900s where Ke‘ehi Lagoon park is now. Today a small section of this island is still there.[146]

Another chant from the 1750s notes that the seas around the Ke‘ehi area were famous for ‘anae (mullet fish). The ‘anae fish was a popular source of food, and this area was important for early fishing. In a code of laws issued in 1839, Kamehameha III assigned Ke‘ehi to be royal fishing grounds placed under taboo by the tax officers of the crown. The King, in 1845, set the tax on fish from this area to be an equal division of fish between the fishermen and the King.[147]

A map drawn in 1853 is the earliest documentation of people living within the Mokauea fishery. A sketch shows five major house sites there. Also, an Advertiser article from 1907 notes, “There were many fishing families there at the time and their ancestors had lived there for many generations.” Since 1853 people continuously lived there right up until WW II when the entire area was confiscated by the U.S. Federal Government and dredging began.[148]

6.3.2 During WW II

In 1940, because of increasing flights between Hawai‘i and the U.S. Mainland, the U.S. Congress authorized $3.3 million for the dredging of a brand-new seaplane project at Ke‘ehi Lagoon, and in 1941 an additional $1.9 million was authorized for the further development of John Rodgers Airport (today, Honolulu International Airport). Construction of the Ke‘ehi Lagoon seaplane project began in October, 1941. Plans called for three seaplane runways at Ke‘ehi Lagoon, which were to be two to three miles long, 1,000 feet wide, and ten feet deep.[149]

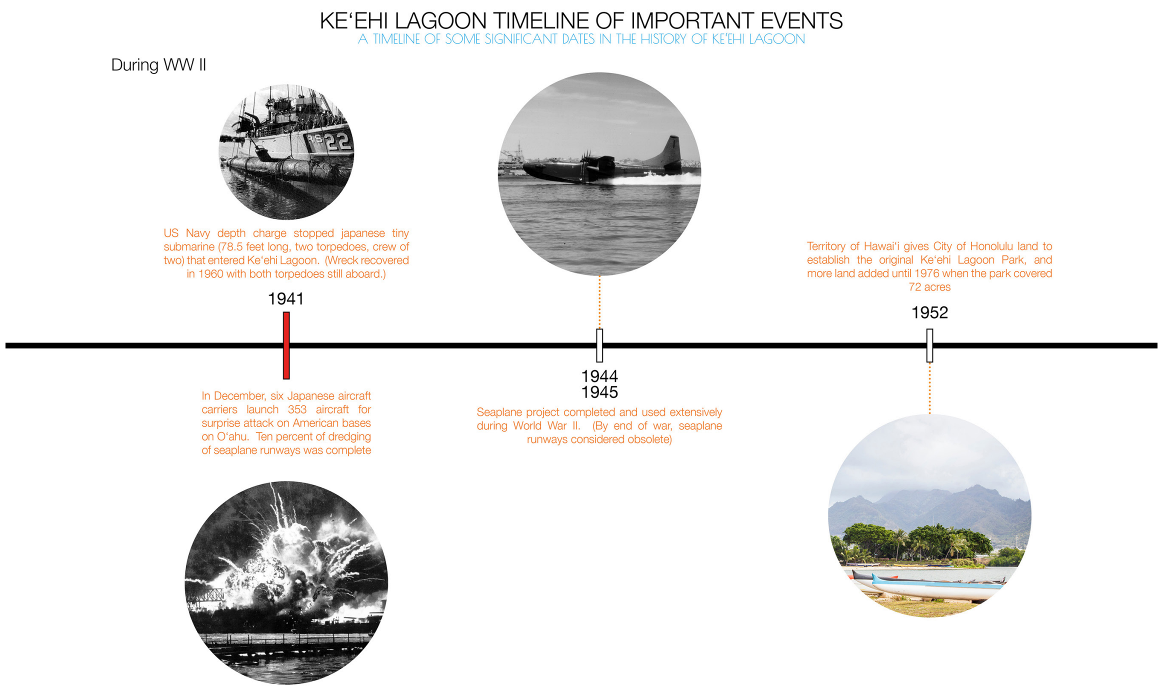
146 Napoka, Nathan. Hawaii Department of Land and Natural Resources, “Mokauea Island.” Last modified December 1, 1976. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CCsQFjAC&url=http://www.ahamoku.org/docs/Doc%20Napoka.pdf&ei=R4okVczILonuoAT8x4GgCg&usg=AFQjCNF7hHgZSsJvHlnmsAquu1MhZ-BoRQ&sig2=EhV9dzLLzUjCqcOaoc-G5Q&bvm=bv.90237346,d.cGU. (Accessed Marchl 9, 2015.)

147 Ibid.

148 Ibid.

149 Hawai‘i.gov, “Honolulu International Airport: HNL 1940-1949.” http://hawaii.gov/hnl/airport-information/hnl-1940-1949. (Accessed February 25, 2015.)

Additionally a Seadrome project was started, but never completed. (A seadrome was to be a floating steel landing strip, which was the size of an aircraft carrier, anchored to the ocean floor by steel cables.)[150] A little less than two months later, on the morning of December 7, 1941, 353 aircraft from six Japanese aircraft carriers made a surprise attack of American military facilities on O‘ahu. At that time, the Army Corps of Engineers had finished about ten percent of the dredging of the three seaplane runways at Ke‘ehi Lagoon. The work was intensified, and, though not finished, the military began to use the seaplane runways in late 1943. The project was completed in September, 1944.[151]



Ke’ehi Lagoon During WW II Timeline
(Graphic by author)

By the time the project was finished, more than ten million cubic yards of coral had been placed between John Rodgers Airport and Hickam Field, in Fort Shafter, in Mapunapuna and other places in that area. The three seaplane runways at Ke‘ehi Lagoon were put to use during World War II, but by the time the war had ended, the three seaplane runways were considered obsolete, and the project was officially abandoned in 1965.[152]

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150 *Modern Mechanic*, “Seadromes to Dot the Atlantic Ocean.” Last modified February 1, 1930. http://blog.modernmechanix.com/tag/seadromes/. (Accessed February 25, 2015.)

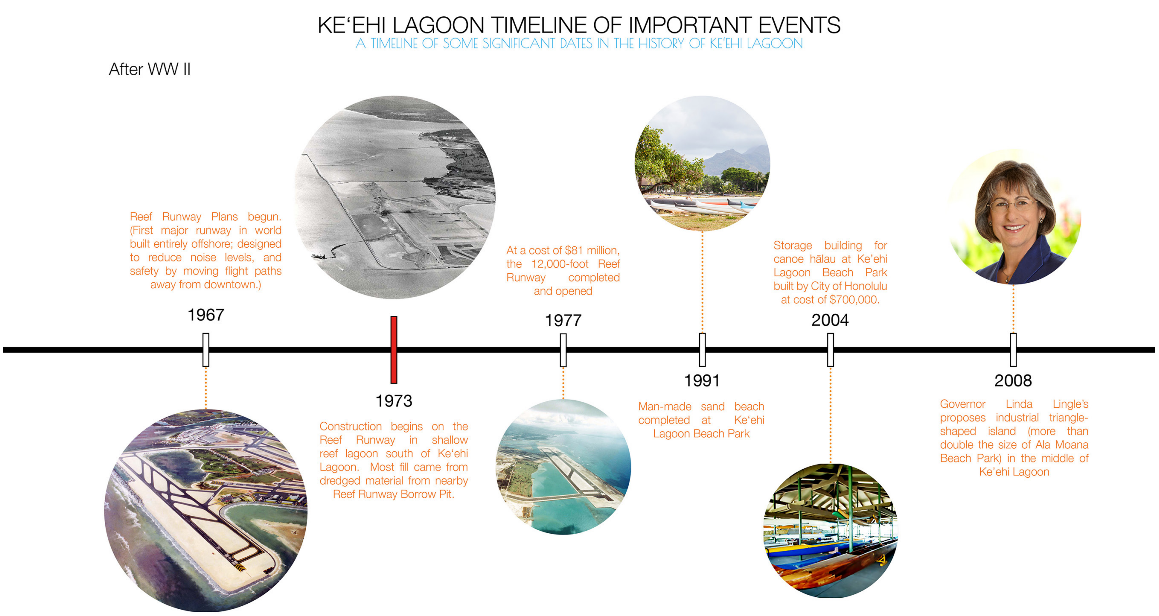
151 “HNL 1940-1949.” Honolulu International Airport. http://hawaii.gov/hnl/airport-information/hnl-1940-1949. (Accessed February 19, 2015.)

152 Ibid.

6.3.3 After WW II

The Honolulu International Airport's Reef Runway, located in the Ke‘ehi lagoon area, was the first major airport runway in the world that was built completely offshore on an underwater fringing coral reef. The runway was constructed as a way to mitigate noise during takeoff of large aircraft, and planning started in 1967. It was placed offshore in order to reduce noise levels, and to increase safety by moving flight paths away from downtown Honolulu.[153]

The runway was built on coral fill. It required more than 19 million cubic yards of dredged material, some of which came from the nearby Reef Runway Borrow Pit. Additionally, 800,000 tons of quarried stone and 18,100 four and six-ton concrete blocks were used for a protective structure that separates the runway from the ocean. The runway itself is 12,000 by 200 feet, and the entire structure is 16,100 feet by 2,050 feet. 1,000 acres of new land was created by dredging 19 million cubic yards of material. It was completed for use in 1977, at a total cost of $81 million.[154]



Ke'ehi Lagoon After WW II Timeline
(Graphic by author)

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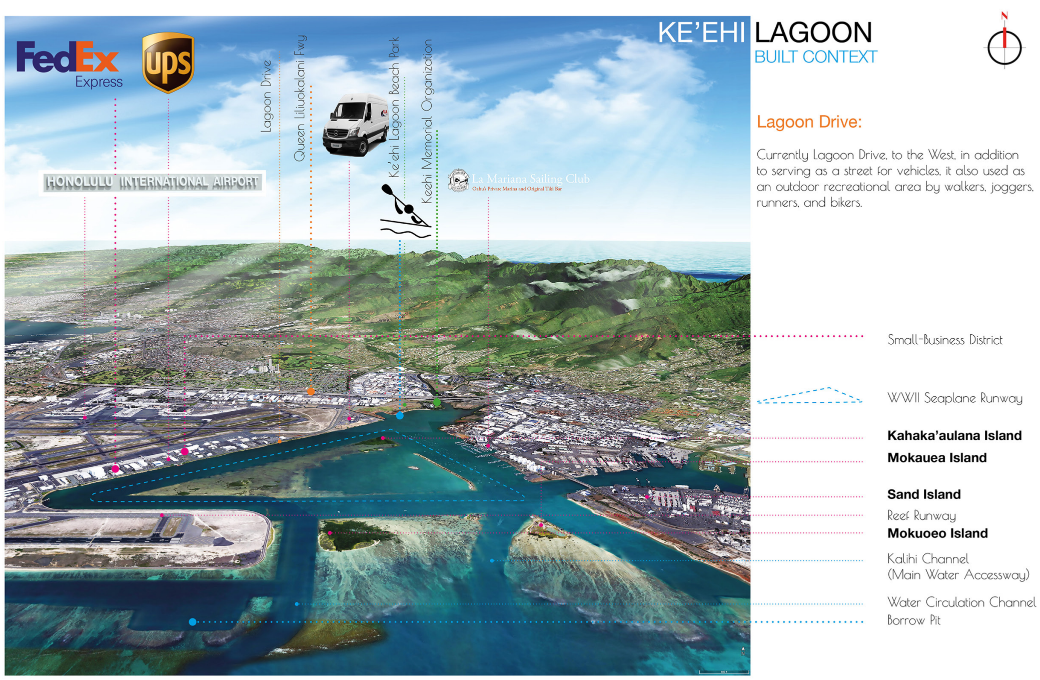
153 Honolulu International Airport, "Reef Runway." Last modified January 1, 2007. http://hawaii.gov/hnl/airport-information/reef-runway. (Accessed April 9, 2015.)

154 Ibid.

6.4 The Setting

Getting in and out of Ke'ehi Lagoon (Graphic by author)



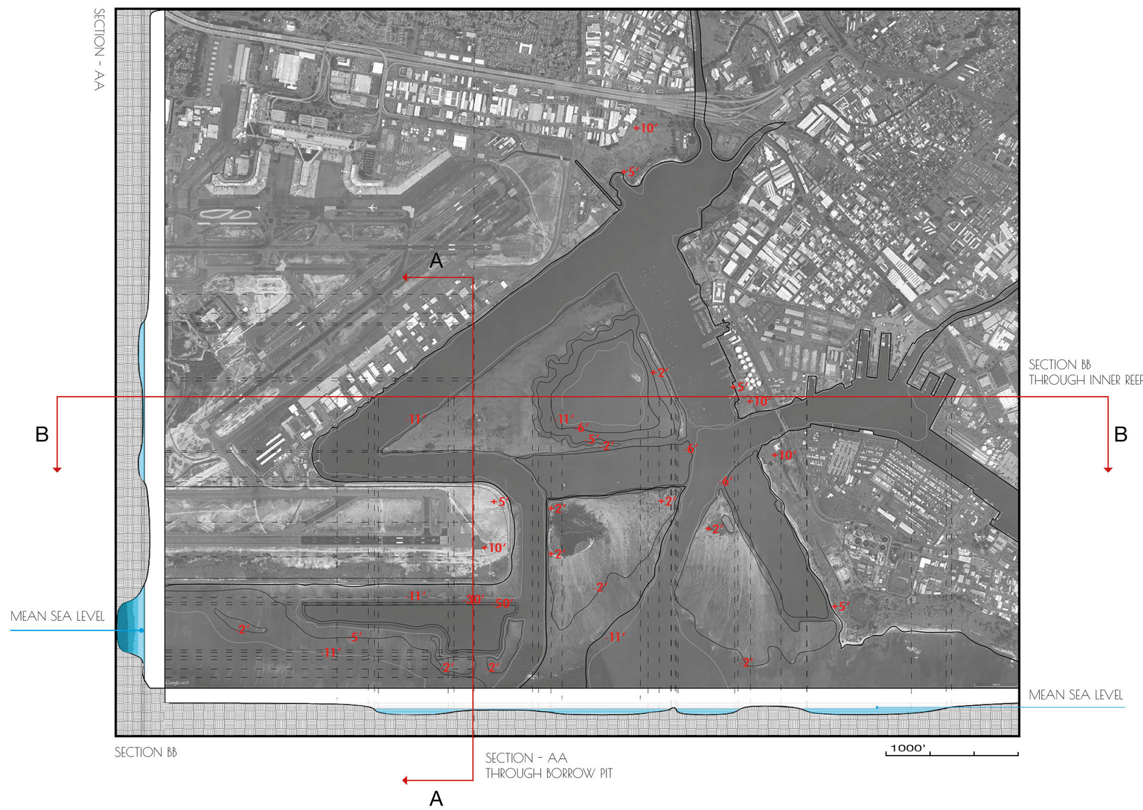
Ke'ehi Lagoon Site Neighbor
(Graphic by author)

Ke'ehi Lagoon area and important locations. Key: a) Reef Runway; b) Borrow Pit; c) Sea Plane Runway; d) canoe racing area; e) water skiing area; f) Water Circulation Channel; and, g) Kalihi Channel. (Graphic by author)

The Ke'ehi Lagoon area is bordered on its landward side by a small inner reef directly adjacent to the HIA Reef Runway. On the seaward side, it is bordered by a much larger outer reef flat that is exposed to open ocean conditions. The western extent of the borrow pit (BP) ends in a continuation of the fringing reef. (In photo: "b.") The eastern end of the BP opens to the Ke'ehi Lagoon Drainage Channel, also called the Water Circulation Channel (WCC), which opens to the ocean.

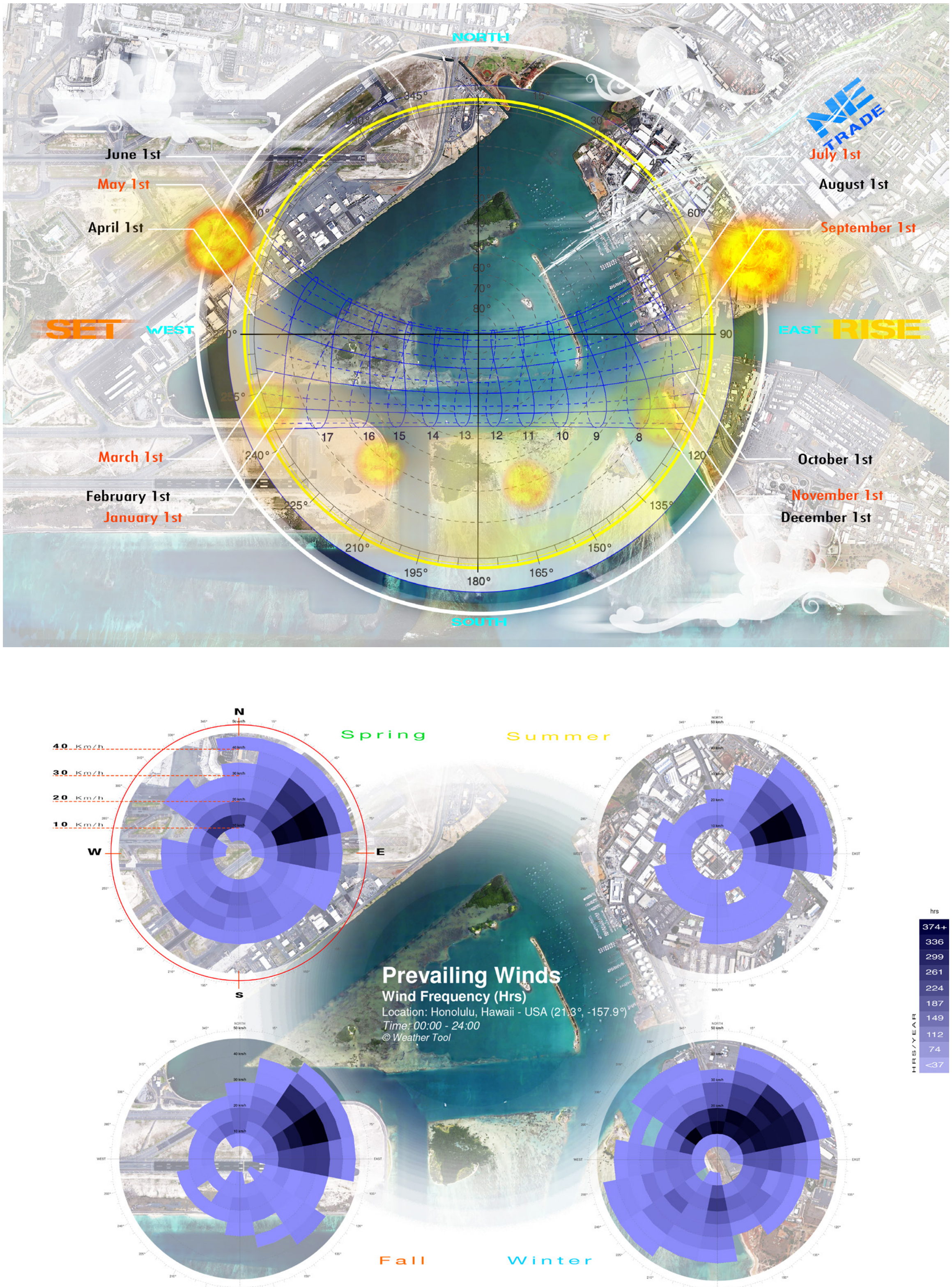
The WCC was constructed specifically to improve circulation and water exchange in the lagoon. The eastern shore of Ke'ehi Lagoon is bordered by a variety of light industry and marine-related recreational and commercial uses, e.g., Ke'ehi Lagoon Park, Ke'ehi Harbor, and Offshore Mooring Area, La Mariana Sailing Club, Sand Island Regional Park, Hawaiian Marine Educational and Training Center, and various other small businesses on Sand Island and along Lagoon Drive. (In photo: "c.") Seaward, within the eastern lagoon, there are two occasionally used seaplane runways, a Canoe Racing Zone and a competitive Water Ski Zone. (In photo: "d.") The entire RRBP site is a designated Recreational Thrill Craft Zone for Jet Ski riding. (In photo: "b.") Well offshore of the RRBP, there are three designated anchorages for large ships as they wait to enter Honolulu Harbor. The eastern border of the RRBP is part of a large Security Zone that extends toward the ocean and encompassing the entrance to Pearl Harbor.[155]

SITE SECTION



Site Section
(Graphic by author)

155 Royal, Rita. "What Are Lagoons and Estuaries." Merit Nation. Last Modified July 16, 2013. http://www.meritnation.com/ask-answer/question/what-are-estuaries-and-lagoons/improvement-in-food-resources/4796361. (Accessed February 25, 2016.)



Wind and Sun Patterns (Graphic by Author)

6.4.1 Environmental Study: Ke`ehi Lagoon and Reef Runway Borrow Pit

This environmental information comes from a proposal for "A Commercial Sea Cage Facility for Moi Aquaculture in the Reef Runway Borrow Pit in Keehi Lagoon," and was prepared in October of 2014 for the Office of Conservation and Coastal Lands Department of Land and Natural Resources. The site for the facility was located in the western portion of Ke`ehi Lagoon, an area that was previously dredged extensively to provide fill for the Honolulu International Airport Reef Runway. (Although this environmental study was conducted as part of the process to allow a fish farm to be built in the Reef Runway Borrow Pit, the entire Ke'ehi Lagoon area was included in the study.) Ke`ehi Lagoon is made up of a large fringing coral reef that is situated seaward of urban Honolulu's Moanalua District. It has been significantly altered by dredging and filling since the 1930s. Three permanent streams feed fresh water into the lagoon, the Moanalua, Kalihi, and Nu'uanu streams.[156]

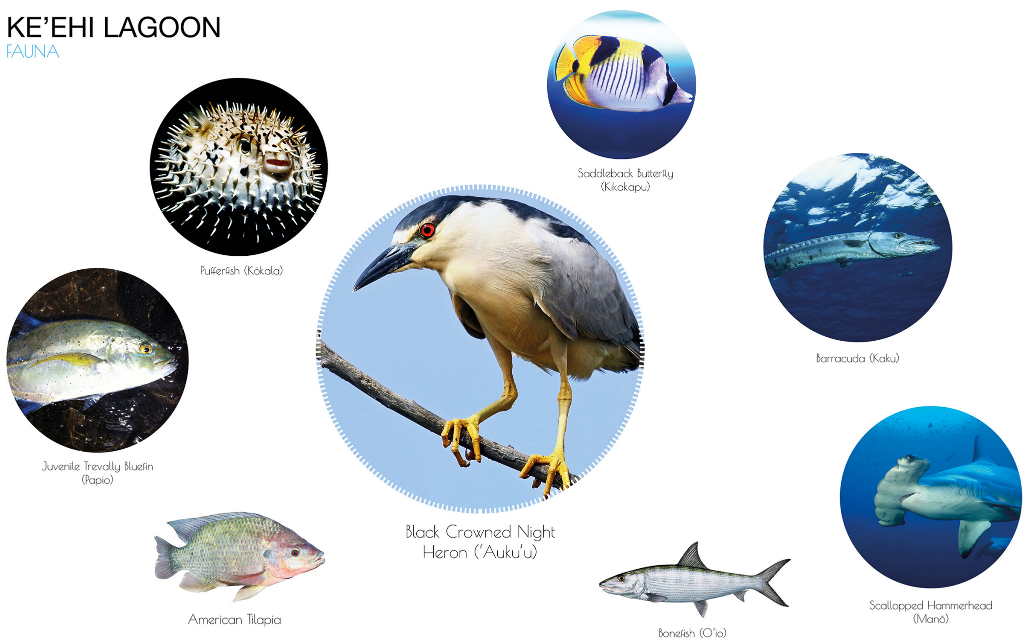
6.4.2 Environmental Studies: Fauna and Flora

The Ke'ehi Lagoon area has been subject to major developments and ecological disturbances since the 1930s, during which time, the native terrestrial fauna and flora have been degraded and displaced. The dredging of the three seaplane runways during WW II further degraded the environment.

There are approximately seventeen species of non-native birds that use HIA and the surrounding area as habitat. The lagoon area is habitat for several common migratory shore birds. The Ke'ehi Lagoon marine ecosystem has been studied over the past forty years and almost all have concluded that the inner lagoon is poorly populated by marine species that are characteristic of disturbed habitats.[157]

156 Aquaculture Planning & Advocacy, LLC, "Final Environmental Assessment: A Commercial Sea Cage Facility for Moi Aquaculture in the Reef Runway Borrow Pit in Keehi Lagoon, Honolulu, Oahu, Hawaii ." Last modified October 15, 2014. http://dlnr.hawaii.gov/occl/files/2013/08/3719-Mamala-Bay-Mariculture-FEA.pdf. (Accessed March 16, 2015.)

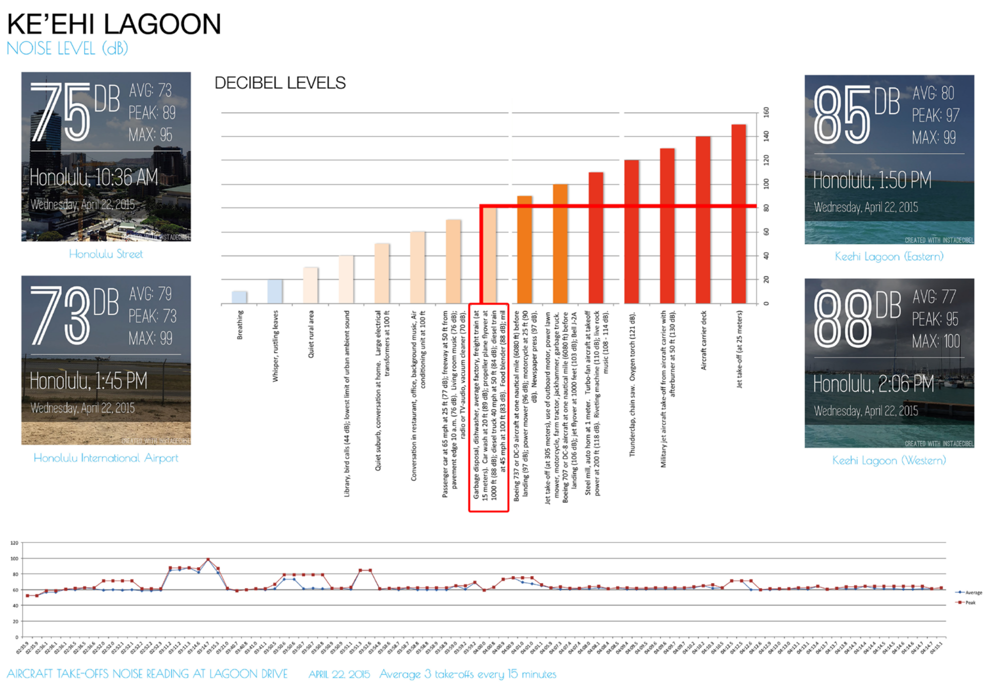
157 Ibid.



Ke'ehi Lagoon wildlife
(Graphic by author / Images courtesy of Google Images)

6.4.3 Noise

On the topic of noise from the Honolulu International Airport, this writer went to Ke`ehi Lagoon on April 2, 2015 at 2:00 p.m. with a sound meter. Measurements were taken at three spots around the lagoon, with five measurements taken at each location. One was near the reef runway, one was on Lagoon Drive, approximately 60 feet away from the reef runway, and the other was on Sand Island Access Road. The 15 samples averaged to a decibel level of 80. According to the above chart, 80 is the level of a kitchen garbage disposal or a household washing machine. It was not particularly uncomfortable.



Noise Reading at Ke'ehi Lagoon Area (Graphic by Author)

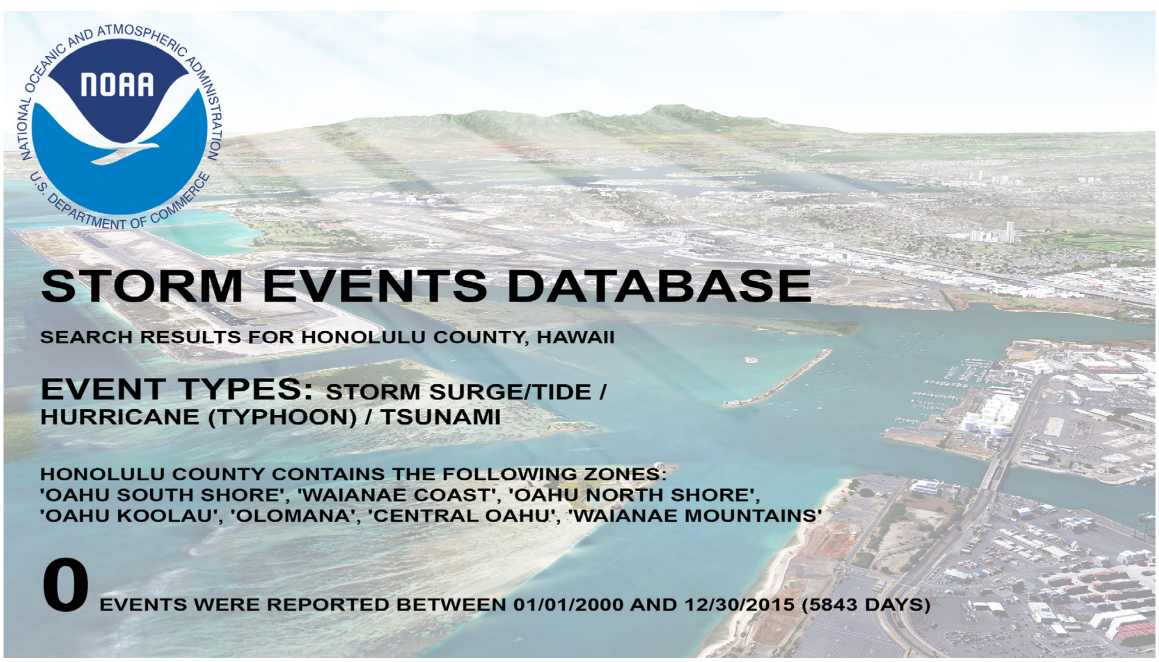
6.5 Waves and Currents

In this area, waves are generated by two types of winds: one is the type of wave that is produced by the pervasiveness and intensity of wind that is generated in this area, and the other is the type of wave that is generated by distant storms. The size of the resulting surf is in direct relation to the size of the wave and the depth of the rising sea bottom. The ocean currents around Hawai'i are thought to depend on the velocity and direction of the wind. The waters offshore along O'ahu's south facing shore generally have a flow of 0.5 to 2 knots per hour. The C area is protected from high surf generated from North Pacific winter storms. South swells that can impact the area are from storms in the Southern hemisphere, but energy from those storm waves is mostly dissipated by the extensive outer reef.[158] This area is well protected from both the north and from the south, and, except during times of extreme weather or disturbance, one wouldn't expect much wave action on the lagoon itself.

Wind Directions (Graphic by author)

158 Ibid.

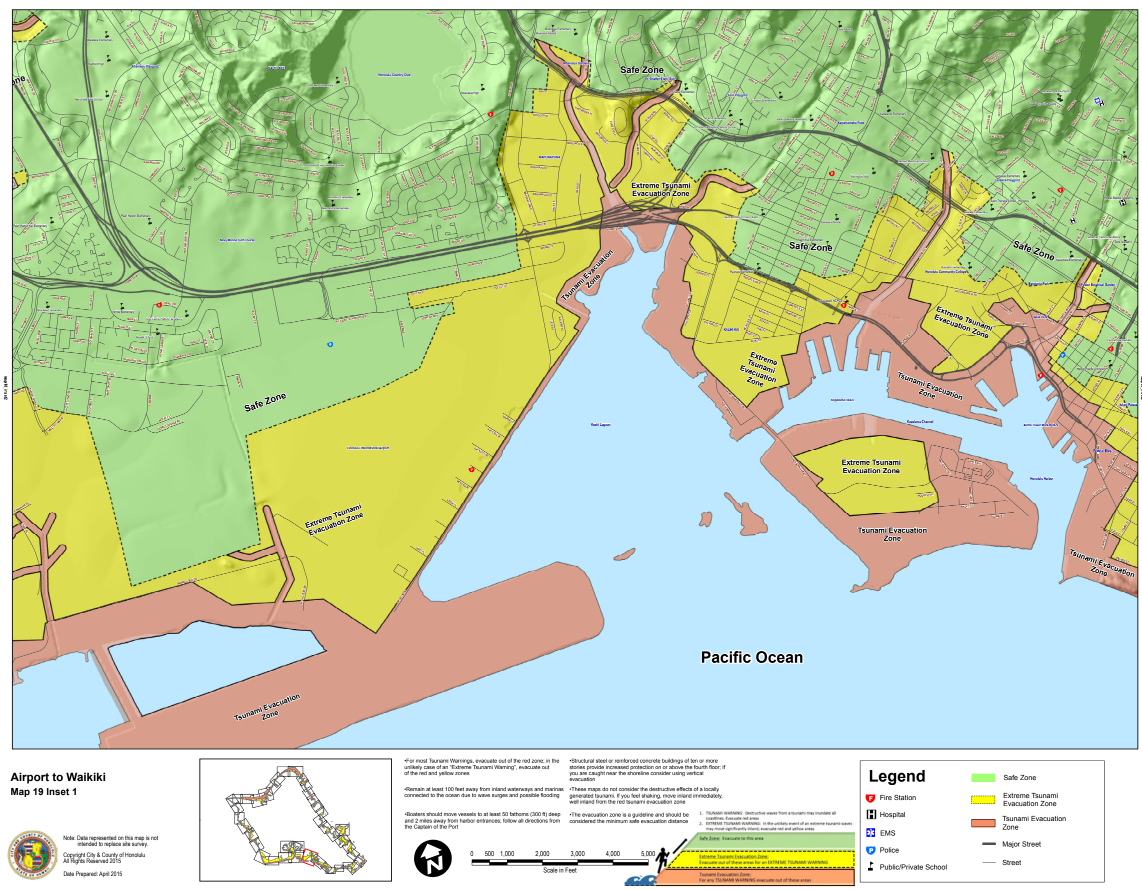
Wave direction (Graphic by author)



Search Result for Storm Events (Graphic by Author)

6.6 Tsunami Risk

On March 11, 2011, the Tohoku earthquake, measuring 9.0 on the moment magnitude scale (said to be more accurate than the Richter scale), hit offshore of northeastern Honshu, Japan. It generated a disastrous, near-field tsunami of 39.75 meters and triggered warnings throughout the Pacific. 1.75-meter waves reached Hawaiʻi, seven hours later, at 3:00 a.m. local time, and resulted in localized damage across the state. A tsunami warning was maintained for Hawaiʻi until 7:31 a.m. when the waves had reduced to less than 1 meter at tide gauges throughout Hawaiʻi. The advisory was removed at 11:26 a.m. when the waves fell below 0.5 meters. Honolulu Harbor and nearby marinas, despite being located in sheltered basins, experienced strong currents and fluctuations, and around 200 small boats in Keʻehi Lagoon were destroyed.[159]



Tsunami Evacuation Zones
(Courtesy of City and County of Honolulu)

159 Yamazaki, Yoshiki, Kwok Fai Cheung, Geno Pawlak, and Thorne Lay. Online Library Wiley.com, "Surges along the Honolulu coast from the 2011 Tohoku tsunami." Last modified March 7, 2012. wileyonlinelibrary.com. (Accessed April 27, 2015.)

The Tohoku earthquake and its resulting tsunami, cause one to wonder how often Hawai‘i has been affected by tsunamis. People who live in Hawai‘i might have trouble remembering the last time a tsunami hit the islands, but history shows that Hawai‘i has actually been hit by its share of damaging waves. The first reported tsunami in Hawai‘i was in 1833 and the worst ever happened in 1946, when 173 people were killed in Hilo, and the most recent deaths resulting from tsunamis happened in 1975 when an earthquake on the Big Island triggered a tsunami that killed two people.[160]

In a statewide hazard profile, the Department of Civil Defense for the state of Hawai‘i identifies the top four threats to Hawai‘i residents. At the top is the threat of hurricanes, followed by flash floods, followed by the threat of tsunami, which, in turn, is followed by the threat of earthquakes. All are rated at high risk, except for flash floods, which are rated as frequent seasonal risk.[161] Natural disasters happen everywhere in the world, and sometimes people are warned in advance and sometimes they are not. Some places are at greater risk than others, but every place is at risk for something. The best advice if one is planning to move into a new area is to make it a point to know about and understand the history and risks that are related to the area under consideration. Based on all research and reading this writer has done on Ke‘ehi Lagoon, there is little danger and few risks associated with building or residing in the area, as long as emergency warnings in Hawai‘i continue to be broadcast as they are now.

It has already been shown that the lagoon area is relatively safe on a daily basis when it comes to waves and currents. How about protection from storm surges resulting from something as severe as a Category 3 hurricane? Starting with downtown Honolulu, the effects of a Category 3 hurricane would not lead to major flooding, according to John Cummings III, O’ahu Civil Defense Agency spokesperson, though that area would still be susceptible to wind damage. That is because the downtown area is protected by a buffer zone to the east that is formed by Sand Island and Honolulu Harbor.

However, areas still further to the east, including the reef runway at Honolulu

160 Lin, Sara. Civil Beat, “A History of Tsunamis in Hawaii.” Last modified March 11, 2011. http://www.civilbeat.com/2011/03/9558-a-history-of-tsunamis-in-hawaii/. (Accessed April 27, 2015.)

161 “State of Hawai‘i Multi-Hazard Mitigation Plan 2013 Update.” State of Hawaii, Department of Defense, Civil Defense Division. Last modified August 19, 2013. http://scd.hawaii.gov/docs/2013HawaiiStateMitigationPlan.pdf. (Accessed January 2, 2016.)

International Airport, Sand Island, and Ke`ehi Lagoon would likely be flooded during a natural disaster. Residents and business people in those areas would be required to evacuate with the approach of a Category 3 hurricane. Cummings went on to say the chances for a Category 4 or 5 hurricane, would be very rare.[162]

On the topic of noise from the Honolulu International Airport, this writer went to Ke`ehi Lagoon on April 2, 2015 at 2:00 p.m. armed with a sound meter for measuring the volume of sound. Over a period of 30 minutes an average decibel level 80 was recorded.

6.7 Site and Design Project: Resilient Coastal Land Use

In his book, Planning for Coastal Resilience; Best Practices for Calamitous Times, writer Timothy Beatley lists a number of things that he says are the key elements of Resilient Coastal Land Use.[163] Here are some of those key elements and, though his are written for land-based development, how they are related to the Ke`ehi Lagoon HydroVillage project.

1. Development should be located, as much as possible, a considerable distance from coastal hazard zones.[164] Most of the south shoreline of O‘ahu is included in a list of tsunami evacuation areas. That list includes the most densely populated and developed areas on the island, such as Waikiki, Ala Moana, Kaka‘ako, downtown, all the way through Ke‘ehi Lagoon. No one is calling for a moratorium of building or development in any of those areas because of coastal hazards, including tsunamis. The actual risk for tsunamis is small and as long as the Civil Defense system is working, it is safe to live and work in any of those areas. There is some risk to living and working anywhere in the world, and those risk factors are usually taken into consideration by people who are thinking of moving into those areas.

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162 Gonser, James. Honolulu Advertiser.com, “Downtown expected to hold up well in storm.” Last modified September 23, 2005. http://the.honoluluadvertiser.com/article/2005/Sep/23/ln/FP509230376.html. (Accessed May 4, 2015.)

163 Beatley, Timothy. Planning for Coastal Resilience. Washington, DC: Island Press, 2009. pp 73-75.

164 Ibid.

2. Patterns for new coastal growth should be based historically on typical towns and villages that already exist along the coasts.[165] HydroVillage is not being designed to exist along a coast. However, design elements for HydroVillage could come from settlements and villages that appear all along the shores of present-day O‘ahu. That could include anything from old wooden storefronts in Haleiwa to petroglyphs that are hidden under the sand along the North Shore beaches.

3. Structures that are being developed on coastal lands should be closely and neatly packed together and walkable. They should conserve land (space). They should decrease residents’ dependence on cars and also their use of energy. They should also present the possibility of healthier lifestyles.[166] The entire HydroVillage has been designed so that everything, even work and recreation, are all within walking distance of the residences.

4. Policies should be in place to protect, preserve, and restore ecological systems and natural features of the area.[167] Floating treatment wetlands are part of the HydroVillage design project. Additionally, this writer is suggesting that Ke`ehi Lagoon and its surrounding land areas be restored, landscaped, and converted to parklands in the future.

5. The way the land is used and the design of the community should include “direct access to nature and natural systems.”[168] The entire HydroVillage is designed to be immersed in nature, i.e., on the water itself. Also greenery on the floating treatment wetlands will, as much as possible, consist of plants that are native to that area and to this island.

6. The way the land is used and the design of the community should “promote social and community interaction” through the use of streets that are friendly to pedestrians, sidewalks, and places to gather.[169] That could be part of the official description of HydroVillage, though it has no “streets.”

165 Ibid.
166 Ibid.
167 Ibid.
168 Ibid.
169 Ibid.

7. Essential services and facilities, like hospitals, and police and fire stations, should be located outside of high-risk areas, in places where they can continue to function after a major community disruption. The same is true for water and sewage treatment plants.[170] There is a sewage treatment plant that is nearby Ke`ehi Lagoon on Sand Island. The nearest police station is downtown, as is a fire station.

8. The way the land is used and the design of the community should emphasize the benefits that come from a green infrastructure, which might include green rooftops, living walls and trees.[171] At least one study has shown that, in terms of mental health, people who live in green areas are greatly benefitted. (See Section 7.2 in Chapter 7.) That is one of a number of reasons that there will be virtually no spot in HydroVillage that doesn't have a view of the water combined with greenery, and in most cases that is combined with a view of the land along the shoreline.

170 Ibid...

171 Ibid.

Summing Up

In Chapter 6 we examined Ke`ehi Lagoon, a place that is historically rich and currently environmentally stressed, which are two very good reasons for considering trying to restore it in such a way that people are encouraged to be there and to enjoy the environment. In ancient Hawai‘i, it was used for royal fishing ponds. In WW II it was used to accommodate seaplanes. At present it's used by a canoe club, and as a park, and for numerous water sports. Despite that, there is something eerily silent about some of the area. One knows something unusual must have happened there, but few people know that the government, in the past, dredged three seaplane runways up to three miles long. It is time to start bringing Ke`ehi Lagoon and the surrounding areas back to life.

Coming Up

In Chapter 7, we will discuss other considerations for the floating design project, for example, making sure it has a Hawaiian sense of place through the use of abundant greenery. We will take a serious look at floating foundations (sometimes, in the literature, referred to as just "floats"). An examination of utilities, including sewage systems will follow. We will consider how it might be managed, and finally do some research on ocean farming.

Chapter 7

Some Issues and Concerns for the Floating Design Project

"Don't build a new ship out of old wood."
— Chinese Proverb —

7.1 Design: Importance of Hawaiian Sense of Place

People may not agree on the meaning of sense of place. For our purposes here, the writer offers a definition: a sense of place refers to a unique, positive feeling that people get from seeing (or even thinking about) a certain place. Modern urban developments on the mainland are often criticized for having no sense of place. Everywhere you go seems to look like every other place and shopping malls often mirror each other with the same look and the same shops. Hawai‘i is different. Step out almost any door anywhere, and you are instantly reminded of where you are, and of the beauty and the uniqueness of Hawai‘i. This is especially important for designers and architects and developers here to remember. (And sadly, that doesn’t always happen.) A good rule of thumb is this: when designing in Hawai‘i, design *for* Hawai’i.

7.2 Design: Importance of Greenery

Everyone would agree that one thing that contributes to a strong sense of place in Hawai‘i is greenery. Moreover, there are other reasons to include lots of greenery in any design project. Researchers from the University of Exeter Medical School have shown that green spaces can affect mental health. The lead author of a new report says the results of the study suggest that immediate and lasting benefits come from parks and greenery. He said in a press release that they have shown that individuals who move to greener areas have significant and long-lasting improvements in mental health.[172]

172 Ericson, John. Medical Daily.com, “Parks And Greenery Tied To Improved Mental Health In City-Dwellers.” Last modified January 6, 2014. http://www.scoop.it/t/foodhub-las-vegas/p/4013929246/2014/01/09/parks-and-greenery-tied-to-improved-mental-health-in-city-dwellers. (Accessed March 29, 2015.)

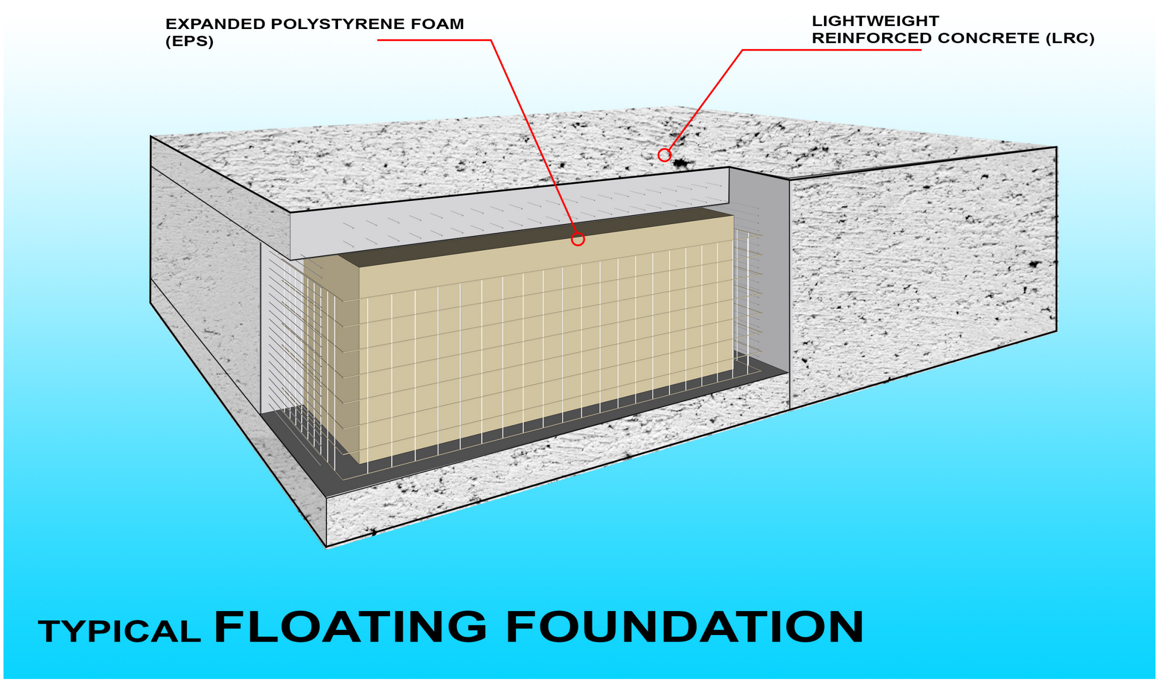
Dutch city to get a floating forest in its harbor.
(Courtesy of Mothership.)

Koen Olthuis has something to say about greenery, too. In a book that he co-authored, he says that at the present time, cities are generally made up of buildings, asphalted open spaces, green spaces, and water. He says that parks and greenery are important not for just the way they look, but also because they contribute to better air quality, to the ecological structure, and to social coherence. He says that cities can add more parks and greenery on the water, and thereby improve the quality of the city. Floating gardens and parks are living and flexible and can be moved into to a neighborhood giving it instant character. He says if floating neighborhoods are to be constructed; green spaces have to be integrated. Rather than being just decoration, he says they are vital to the community.[173]

173 Olthuis, Koen, and David Keuning. FLOAT! Building on Water to Combat Urban Congestion and Climate Change. Amsterdam: Frame Publishers, 2010. pp.198.

7.3 Practical Matters: How does it float?

First, a little history of flotation devices is in order. Expanded polystyrene (EPS), a cousin of the packing material Styrofoam, started out as the basis for a variety of floatation devices like rafts, docks, and billets (floating slabs). They are usually produced in standard sizes but can easily customized. They can be used in both fresh and salt water and are not affected by cold temperatures. EPS billets can support 55 pounds per cubic foot, which is quite a bit more than the usual wood flotation devices. As EPS floatation devices became more and more popular, new uses and designs appeared.[174]



Typical Floating Foundation
(Graphic by author)

At the present time, entire floating neighborhoods dot the west coast of the U.S. and Canada, and many depend on EPS floatation foundations to remain above the waves. Homes cannot float on the same polyurethane floats that used under docks. Because of the extreme weight of the structure, EPS is used as the core of a reinforced lightweight concrete platform.

174 ESP Industry Alliance. “Flotation Billets.” Last Modified January 1, 2012. http://epsindustry.org/other-applications/floatation-billets. (Accessed October 20, 2015.)

One design consists of blocks of EPS steel reinforced concrete walls at 10 to 15 feet on centers and a top slab. Under slab items, plumbing, for example, are encased by the EPS before casting the concrete. Some of the platforms exceed six feet in height. All voids under floor are filled with EPS to make sure the home is unsinkable. These homes are constructed to meet and sometimes exceed local and regional building code standards and are fireproof. The same foundation design is also used for larger structures, including floating restaurants, office buildings, and pubic restrooms. By connecting the platforms, floating walkways and roads are created.[175] The main difference is that instead of one platform of varying sizes, the foundation of HydroVillage is built in the form of hexagons that can be attached to form various sizes for floating foundations.

The floating foundation for the HydroVillage is also constructed of EPS and fiber reinforced lightweight concrete. The main difference is that instead of one platform of varying sizes, the foundation of HydroVillage is built in the form of hexagons that are attached to form a larger floating foundation.

7.4 Practical Matters: A Word About Utilities in Floating Homes

A discussion on floating development wouldn't be complete without some discussion about utilities. Power can come from solar panels (which are being used on the design project that's coming up). But what about human waste? Both power and sewerage are relatively simple in cities that have floating communities that have been in existence for a while, like in American cities on the west coast.. In Chapter 5, we read that most states on the mainland include in the definition of "floating residences" the fact that they are hooked up to the shore for electricity, water, and sewage.[176] On the other hand, starting a floating community in a place like Ke`ehi Lagoon, the proposed site for HydroVillage, would mean basically starting from scratch when dealing with utilities and sewage since currently there are no connections from out in the center of the lagoon to the shore. That doesn't mean it couldn't be done. It would requires a lot of time and effort on the part of the City and County of Honolulu to get something like that started. In the meantime, there are numerous ways to deal with those issues from individual homes. Let's first see what it is like to live in a floating home that

175 Ibid.

176 Gromicko, Nick and Kenton Shepard. International Association of Certified Home Inspections, "Inspecting Floating Homes."

is connected to the shore. After that we will look at options for individual floating homes that are not connected to utilities on the shore.

On a blog page for marketing, the owner of a floating home that sits on the Columbia River, in Portland, Oregon, shared information about utilities in his family's floating home. He said that their floating home had everything that a usual home would have, including cable, internet, electricity, gas, water, and sewer. He said that with the exception of the sewer line, everything worked the same as a land-based home. He said the only difference was in the wire, pipe, and hose connections from utility sources on land. He explained that they were longer and more flexible which allowed them to rise and fall with the level of the river, which could vary up to ten feet.[177]

He further explained that most of those connections ran under the docks that connect the eleven floating homes in that area together. The exception was electricity and phone service whose connections came from wires from a telephone pole mounted a nearby dike. Those wires were slung from additional poles and then directly connected to the houses. He said that like the sewer pipes, the wires had enough slack to allow for fluctuations in the water level. He added that all of the homes had their own electric and gas meters.[178]

He went on to explain the one thing that is unique about their floating home, the one thing that makes them different from land-based homes. He said that each home has a tank, called a "honey pot." that contains a macerator (a device that softens solids) and a pump. When a toilet is flushed, the contents are sent to the honey pot where the macerator grinds the contents into a slurry, a semi-liquid mixture, called, which is a bit like thin mud. The slurry is pumped through a flexible hose under the docks and connects to the city sewer system.[179]

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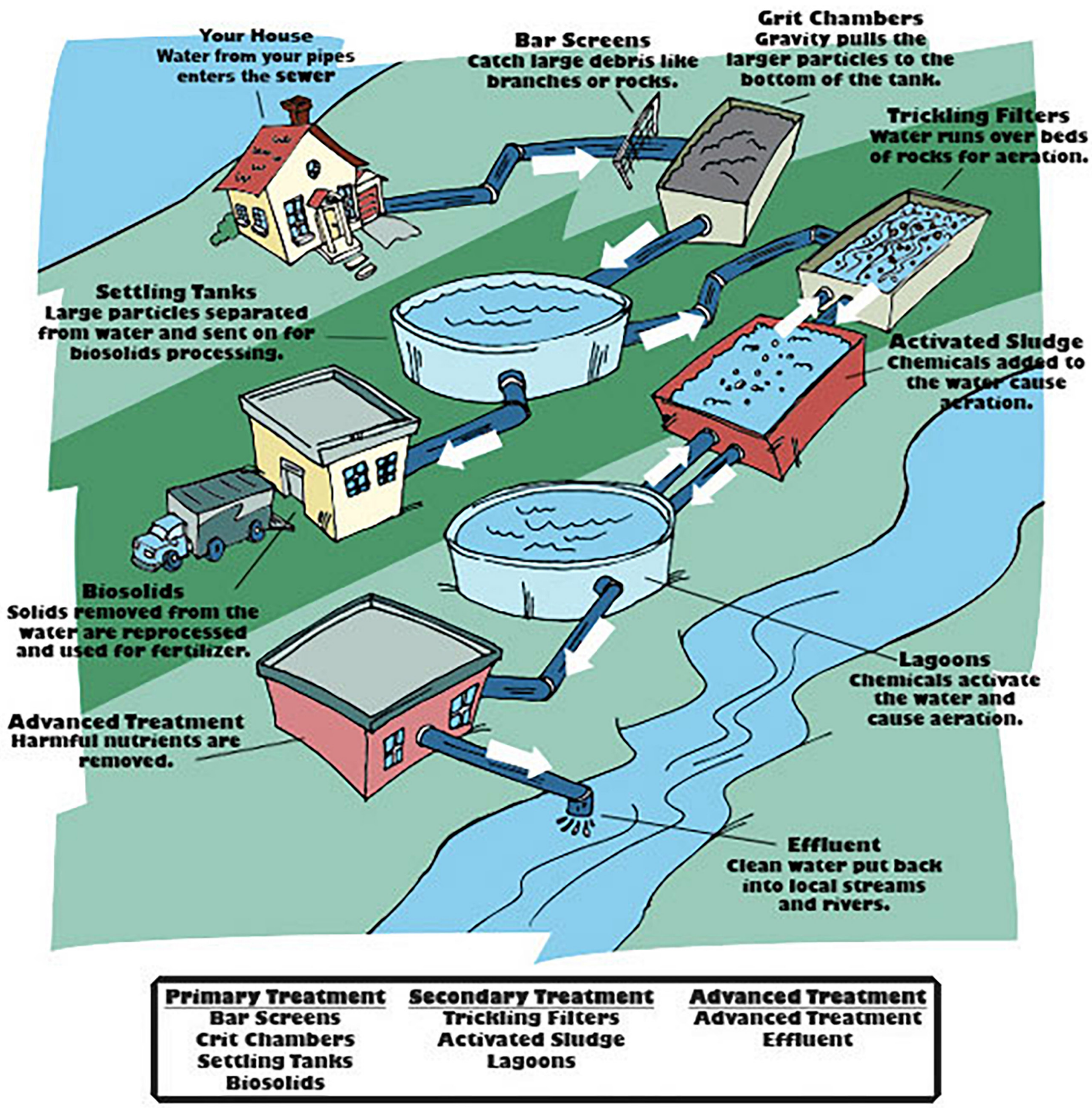
177 Knight, M. Living on the Columbia: Life in a Floating Home, "Summer Sings on the Columbia River." Last Modified September 3, 2011. https://michellesfloatinghome.wordpress.com/2011/09/03/summer-sings-on-the-columbia-river/. (Accessed March 10, 2015.)

178 Ibid.

179 Ibid.



There are a number of steps to make wastewater pure again. (Courtesy of Western Carolina Regional Sewer Authority)

7.5 Practical Matters: How Do Sewer Systems Work?

In urban areas where many people are living packed together, and there is a lot of waste water to treat, the community constructs a sewer system that collects wastewater and sends it to a facility for wastewater treatment.[180]

In the best possible situation, a sewer system is entirely powered by gravity. Pipes from each house flow to a sewer main that might run down the middle of the street. This pipe is generally three to five feet in diameter. Occasionally, a

180 Marshall Brain. How Stuff Works: Home and Garden, "How Sewer and Septic Systems Work." April 1, 2000. http://home.howstuffworks.com/home-improvement/plumbing/sewer3.htm. (Accessed January 24, 2016.)

vertical pipe goes up from the main pipe to the surface to be covered by a manhole cover. Manholes provide access to the main for maintenance. The sewer mains flow into larger pipes until they reach the wastewater treatment plant. In order to help gravity do its job, the plant is located in a low-lying area. If gravity can't do all the work, the sewer system will include a grinder-pump or a lift station to move the wastewater up over a rise.[181]

After the water reaches the wastewater treatment plant, it goes through one to three stages of treatment. The first, known as primary treatment allows the solids to settle out of the water and the scum to rise. It then collects the solids for disposal (in an incinerator or a landfill). The second stage is the secondary treatment in which organic materials and nutrients are removed. This is done through the use of bacteria; the water goes into large aerated tanks where bacteria consume almost everything. The water then goes into settling tanks where the bacteria settle out. The third stage, tertiary treatment, usually uses chemicals to remove phosphorous and nitrogen, but may also include filters and other types of treatment. Chlorine is added to kill any remaining bacteria, and the water is finally discharged.[182]

7.6 Practical Matters: A Sewer System for Ke`ehi Lagoon?

We have read earlier that floating homes on the mainland are connected to municipal sewage systems on shore, and as to whether or not that should be the eventual goal at HydroVillage is still open for discussion. The nearest sewage system to Ke`ehi Lagoon is on Sand Island. Sewage from HydroVillage could conceivably be connected by underwater pipes, but because of the distance, the suggestion here is that all sewage from homes and labs be taken care of by residents themselves by using special toilets, either composting or incinerating (soon to be discussed). If it were decided that the best arrangement for the dome and community center would be to use regular flush toilets, the sewage from there could be pumped into storage areas inside the floating hexagonal foundations. Special maintenance workers hired by HydroVillage would regularly pump it out, and transport it (by boat and by truck) to the sewage disposal facility on Sand Island.

181 Ibid.

182 Ibid.

Fortunately, for residents of HydroVillage, there are a number of options for individual waste disposal systems. The two most common are composting the waste for reuse on land, and incinerating the waste to ash that can be put in the ground or in water.

Composting toilets work basically the same as a compost bin in the garden. Waste is collected in a composting chamber, and there is no smell. (Courtesy of RealEstate.com)

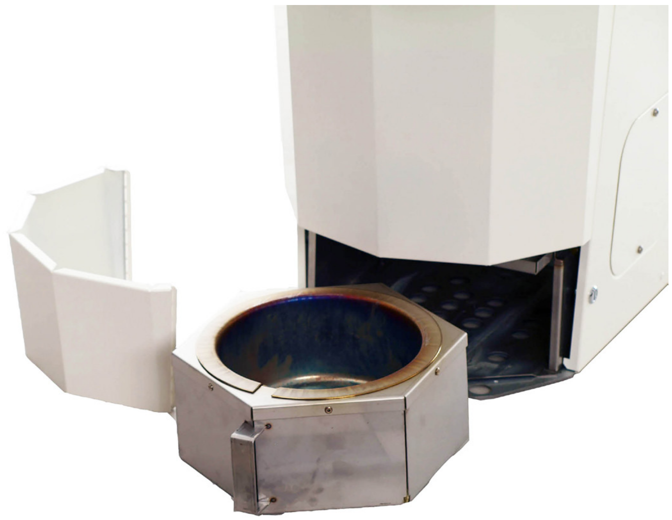
A standard composting toilet is waterless, and the waste is processed on site. For some homeowners, the downside is that the waste collection chamber must be periodically emptied, but others find that the extra care involved is worth it because it saves water and produces useful compost material. [183]

Again, a standard incinerating toilet is waterless, and the waste is processed on site. it works exactly as the name implies. Electric heating elements in the base of the toilet heat up to 1,200 degrees Fahrenheit, eliminating human waste that has been deposited into the chamber (using something like a coffee filter) to ash in about an hour. It runs on electricity or gas.[184]

183 "Composting Toilets." Last modified January 2, 2013. https://www.go-gba.org/resources/green-building-methods/composting-toilets/. (Accessed November 11, 2015.)

184 Matt, Goering. "Incinerating Toilets." HomeAdvisor. Accessed http://www.homeadvisor.com/article.show.Incinerating-Toilets.14709.html. (November 11, 2015.)

In terms of cost, composting toilets are the most appealing choice. They range from about $875 to $3,000, and cost less than incinerating toilets, which range from $1,200 to $4,000. Composting toilets use peat moss which is $5 to $10 for a small bale, and incinerating toilets use bowl liners which cost $18 for 200 liners.[185]



Incinerating toilets incinerate all waste at 550 degrees, leaving a small quality of dry ash for disposal, preferably in a garden where it makes an excellent fertiliser. (Courtesy of Eco-Toilets.)

It is common knowledge that older toilets can use up from three to seven gallons of water with each flush, and that doesn't support today's ideas about sustainability. With that in mind, and also the fact that composting toilets require that the waste collection chamber be emptied periodically (an activity that some find distasteful) , it is being recommended here that residents of HydroVillage use incinerating toilets because they require no water, plus the fact they require less attention from users.

185 Cabin Living Mag.com, "Composting vs. Incinerating Toilets." Last Modified March 31, 2015. http://www.cabinlivingmag.com/diy-advice/green-ideas/composting-vs-incinerating-toilets/. (Accessed January 3, 2016.)

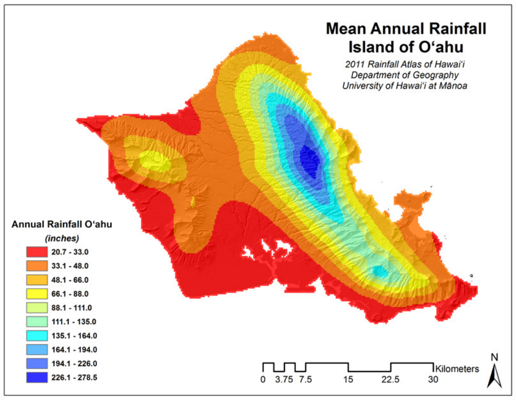
7.7 Practical Matters: Freshwater: Home Catchment Systems

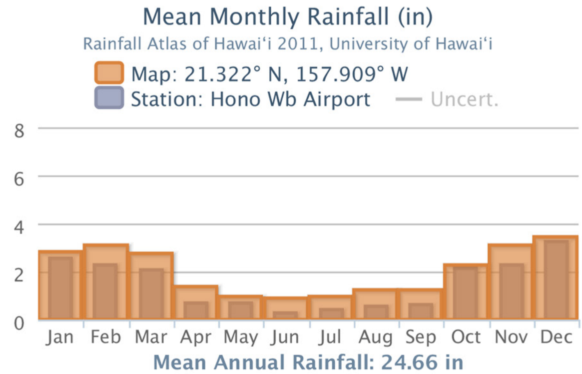
Ideally HydroVillage, like floating homes on the mainland, would be connected to the city water system. If that turns out to be an impossible task, what are the alternatives? One particular system has worked well for the many modern homes that, for whatever reason, can't connect to a city water system.

They all have water catchment systems, which could all work basically the same way, whether on a land-based home or one that is floating. Rainwater that hits the roof is stored and then reused.

Collecting and storing rain for later use, rainwater harvesting, has been in use since ancient times, and is still in use in many rural areas throughout the world. (Courtesy of Houzz.com.)

Rainwater that falls onto a roof is channeled into a storage tank through a system of gutters and pipes, and then through filters, and the tank is sized to store up to 18 months of water for the land-based household. They are covered to prevent mosquito breeding and to reduce evaporation, contamination, and algal growth. Everything could be the same with our floating rainwater catchment systems except that the water would be stored in tanks in the floating hexagonal foundation. The water is then piped to the house for domestic use through a series of filters and ultraviolet light. All of the housing units and science labs In HydroVillage will have rain catchment systems. There will be additional small free-floating water catchment systems mounted on one or more floating hexagonal slabs that float in waters around the village to provide extra fresh water. Again the fresh water is stored in tanks inside the floating foundation slabs.





Mean Annual Rainfall Island of O'ahu and Honolulu Airport (Courtesy of University of Hawai'i)

$$\text{Harvested water (gal)} = \text{catchment area (ft}^2\text{)} \times \text{rainfall depth (in.)} \times \text{0.623 conversion factor}$$

Rainwater Harvesting Calculation (Courtesy of Texas A&M University)

The above formular was used for this sample calculation of the lab roof. 2.05 is the amount of annual rainfall in feet at Ke'ehi Lagoon. To convert the amount of harvested rainfall in cubic feet to gallon, a factor of 7.48 was used.

Lab roof area footprint: 1074 sq. ft.

1074 ft^2 X 2.05 ft X 0.623 = 1,372 ft^3 = 10,263 gallons

After calculating the amount of rainwater that can be collected on site, we see that one lab can produce up to 10,263 gallons of fresh water per year. Therefore, 24 labs can provide up to 246,312 gallons per year. The harvested rainwater will flow directly to storage compartments, which are located within the floating foundation. The water would then be pumped out when needed. For additional freshwater, water catchment systems can be mounted on individual floating foundations along with roofs to collect rainwater, which is stored in tanks in the floating hexagonal foundation.

Rainwater is naturally pure and doesn't require any water softening systems. Rainwater harvesting systems call for regular maintenance, cleaning and testing, to keep the system clean and in good working order.[186] If rainwater catchment systems were to be the standard source of freshwater for HydroVillage residents, HydroVillage could hire maintainance people from outside to visit regularly for the required maintainance of the catchment systems.

7.8 Practical Matters: Solar Energy

For the design project, HydroVillage, we need to get an estimate on how many solar panels would be needed to power the housing units and the science labs. On a website called "GoGreenSolar.com," the following advice for calculation is given, saying the totals will be a rough estimate of what is needed, and right now a ballpark figure is perfectly adequate for HydroVillage.[187]

This is their suggested procedure:

1. First calculate your average energy consumption in kWh. (A kilowatt-hour is a unit on energy equivalent to one kilowatt [1 kW] of power sustained for one hour.)[188]

2. Get a monthly average of your kWh usage.[189] (HECO gives us that number by saying the average Hawaii customer uses 500 kilowatt-hours per month.[190]

3. Next divide your average monthly use by 30 giving your average daily kWh consumption. In this case it would be about 17 kWh per day.[191]

4. In an attempt to keep things simple for a rough estimate, we are assuming that a 250W solar panel produces about 1kWh per day.[192] Keeping in mind that this is a rough estimate, based on a site location getting about 5 hours

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186 Builtsmart Resources, "How Water Catchment Works." https://www.builtsmartresources.com/how-water-catchment-works.html. (Accessed November 11, 2015.)

187 Go Green Solar.com, "How to Calculate a Quick, Easy GUESStimate for Sizing a PV System." Last Modified April 12, 2013. http://blog.gogreensolar.com/2013/04/how-many-solar-panels-do-i-need.html. (Accessed January 20, 2015.)

188 Ibid..

189 Ibid.

190 Sillaman, Joe. Hawai'i Life.com, "How Much Does Electricity Cost in Hawaii?" Last Modified August 11, 2015. http://www.hawaiilife.com/articles/2015/08/how-much-does-electricity-cost/ (Accessed January 5, 2016.) .)

191 Go GreenSolar.com, "How to Calculate a Quick, Easy GUESStimate for Sizing a PV System."

192 Ibid.

of sunlight per day.[193]

5. Assuming that you need about 17kWh per day, you would need a maximum of 17 solar panels (or a little less) to power one household and meet 100% of your average energy needs.[194]

For our houses and labs, that means that, for power, we need at least 17 solar panels on all housing units and labs to operate at maximum efficiency. Right now, both the one-bedroom and two-bedroom housing units have 36 solar panels. The science labs have, in their present design, 42 solar panels. That is more energy than needed to allow day-today functioning. For extra energy, or even to produce more energy for the state of Hawai‘i, as with water catchment systems, solar panels will be mounted on floating hexagonal foundation slabs, possibly combined with water catchment systems to be floated in the waters nearby HydroVillage.

Right now there is space for up to 9,000 solar panels on the dome roof, but that seems to be more than needed. The actual number of solar panels on the dome will be worked out later. Because of the sophisticated construction of the roof, traditional PV panels don’t seem appropriate. A next generation of solar cell called “thin film solar cells” will be investigated for possible use on the roof of the dome. For more information on thin film solar cells, go to: http://science.howstuffworks.com/environmental/green-science/thin-film-solar-cell.htm

Although the writer advocates that all forms of alternate energy be used in Hawai‘i, only solar energy is being suggested for HydroVillage at this time. There are a number of reasons for that, including the fact that solar panels are silent, have no moving parts, and are virtually maintenance-free. They can be installed in places that aren’t generally used, i.e., the roof.

Wind turbines, on the other hand, are often noisy, and can require a lot of space, making them better suited for rural or offshore locations instead of urban sites. Not surprisingly, wind turbines work best in windy places (and Ke‘ehi

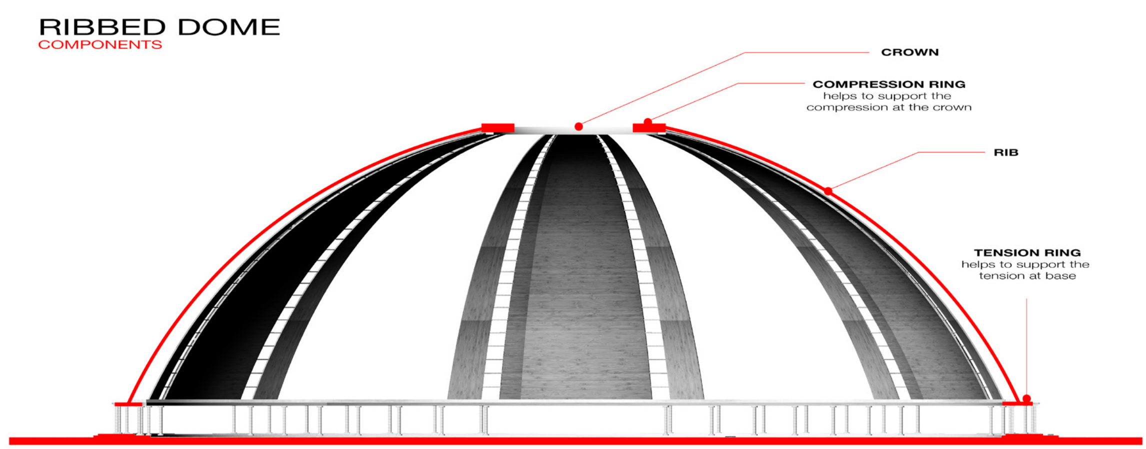
193 “Dynamic Maps, GIS Data,& Analysis Tools.” National Renewable Energy Laboratory. Last Modified February 2, 2015. http://www.nrel.gov/gis/solar.html. (Accessed February 3, 2016.)

194 Go Green Solar.com, “How to Calculate a Quick, Easy GUESStimate for Sizing a PV System.”

Lagoon is not particularly windy). Finally wind turbines need maintenance.[195] As for wave energy, again, not surprisingly, they work best in places that generate consistent waves. (Again not particularly true in Ke‘ehi Lagoon.)

7.9 Basis for Dome Construction and Recommended Materials

At the core of the design project, HydroVillage, is a community center in the form of a large dome. What, you may wonder, is a dome? In Building Structures Illustrated; Patterns, Systems, and Designs, under "Shell Structures," the salient points that are the basis for dome design are presented, and this information was basic to the design of the dome used in HydroVillage. The writers define a dome as a structure that has a circular plan with a round surface. It is made from a rigid material, reinforced concrete, for example, and is, seemingly, without a break. It is much the same as a rotated arch. A very simple explanation of how domes work is that there are two main forces in the dome, compression (near the crown) and tension (in the lower portions). Meridians are vertical lines of the dome that go from the top to the bottom. At the top, meridians push together creating compression forces. Towards the bottom, meridians push out with horizontal tension forces.[196]



Basic Dome Construction
(Graphic by author)

195 Wheeland, Matthew. Pure Energies.com, "The Advantages of Solar Energy vs Other Renewable Energy Sources." Last Modified July 22, 2010. http://pureenergies.com/us/blog/the-advantages-of-solar-power-vs-other-renewable-energy-sources/. (Accessed January 14, 2016.)

196 Ching, Francis D.K., Barry S. Onouye, and Douglas Zuberbuhler, Building Structures Illustrated; Patterns, Systems, and Designs. Hoboken, NJ: John Wiley & Sons, 2009, 247.

In The Architect's Studio Companion: Rules of Thumb for Preliminary Design, suggestions are given for the selection of structural systems. If one wants to limit the amount of time to construct the structure on site, for example, it is suggested that systems that use highly preprocessed, prefabricated, and/or modular components be considered. Four examples of those systems are: rigid steel frames that are one story, standard steel frames, especially those with hinge connections, a concrete system that is precast, and a heavy timber frame. Also, if one wants to limit the amount of time to construct one or two-story buildings, it is suggested that systems that are light and easy to form, or prefabricated and therefore easy to assemble be considered. An example of that would be heavy timber frames.[197]

Also in The Architect's Studio Companion, information about practical span ranges for various structural systems are given. Under "Wood" as a structural system, four variations are given. For Glue Laminated Beams, a possible span range of 10 to 100 feet are shown. For Heavy Trusses, there is a possible span range of 30 to 200 feet. For Glue Laminated Arches, there is a possible span range of 30 to 250 feet are. Finally, for domes, the possible span range is 50 to 500 feet.[198]

Additionally, two wood structural systems are described. Our focus here is on heavy timber construction, which is described as being highly resistant to fire, having a capacity to support high loads, and being uniquely, aesthetic pleasing, due to the exposed wood. Heavy Timber construction can either be through the use of solid wood or glue laminated. On-site erection speed can be very fast, because they are often prefabricated.[199]

As will be seen in the next chapter, all of the information above went into the planning and actual final design of the dome in HydroVillage. Without having this information to draw on, HydroVillage would not have a community center.

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197 Allen, Edward and Joseph Lano, The Architect's Studio Companion: Rules of Thumb for Preliminary Design. NewYork: John Wiley & Sons, 2002. 21.

198 Ibid.

199 Ibid.

7.10 Floating Treatment Wetlands

The federal Clean Water Act (CWA) calls for each state to identify and list surface water bodies that are polluted. These bodies of water, called by the law "water quality limited segments," do not meet national standards of water quality.[200] In one such report by the state of Hawaii, Ke'ehi Lagoon is listed with this comment: "The assessment of new data documents indicate that applicable Water Quality Standards are not being attained.[201] Despite this assessment, water sports at the lagoon, fishing, canoe paddling, jet skiing, parasailing and so on, are popular. Since this is to be the location of HydroVillage, this writer's design project, what can be done to clean the water?

That is where wetlands come in. They are sometimes referred to as nature's water purifiers because, as unclean water moves through a marsh, bacteria that live on plants, wood, and rocks ingest the common water pollutants. Other pollutants are trapped in the mud and sludge. Because of that, water flowing out of a wetland is cleaner than it was flowing in.[202]

Researchers are now attempting to do the same thing with bodies of water that don't connect with natural marshlands. Bruce Kania, founder of Floating Island International, a company that builds floating treatment wetlands called BioHaven floating islands, says that their floating islands are "concentrated wetland systems" that copy "nature's wetland effect."[203]

To make a BioHaven island, they start with layered mesh that comes from recycled plastic. Using the mesh, they make a floating raft that can vary from the size of a home aquarium to the size of a large football field. They put soil and plants on top of the raft and put it in a pond, stream, lagoon, or lake. Finally it is anchored in place. As time passes, roots of the plants grow into and through the raft, reaching into the water below. As that is happening, bacteria colonise the raft

200 California Environmental Protection Agency, "San Diego Region - Clean Water Act Section 305(b) Surface Water Quality Assessment and Section 303(d) List of Water Quality Limited Segments." Last Modified November 21, 2011. http://www.swrcb.ca.gov/sandiego/water_issues/programs/303d_list/index.shtml. (Accessed February 24, 2016.)

201 "2012 State of Hawaii Water Quality Monitoring and Assessment Report." Health. Hawaii.gov. Last Modified December 2012. http://health.hawaii.gov/cwb/files/2013/04/IntegragedReport.pdf. (Accessed February 24, 2016.)

202 Anthes, Emily. BBC.com, "Nature's Water Purifiers Help Clean up Lakes." Last Modified September 26, 2012. http://www.bbc.com/future/story/20120925-natures-water-purifiers?goback=.gde_94811_member_169923730. (Accessed February 24, 2016.)

203 Ibid.

as a slimy covering called biofilm and cover the floating island and the roots of the plants that are hanging in the water.[204]

The secret to a floating island's ability to clean the water is the bacterial biofilm. Nitrogen and phosphorus that often drain into bodies of water result in an overgrowth of algae, which blocks sunlight from reaching plants in the water, and starves the water of the oxygen that is necessary for fish and other animal life. As polluted water flows through a floating island, the bacteria absorbs contaminants and converts them into less harmful material. Additionally the roots of the plants hanging from the floating island absorb nitrogen and phosphorus through their roots. A floating island also automatically filters out other contaminants, like metals, says Kania, because all of the suspended solids tend to bond to the sticky biofilm.[205]

Floating treatment islands are being used more and more to clean bodies of water.
(Courtesy of American Nurseryman)

204 Ibid.

205 Ibid.

Removing contaminants from the water does more than improve the water itself. It also helps to support a healthier ecosystem. Water that is clear allows light go deeper, and that stimulates the growth of aquatic plants, which provide oxygen. The plants become part of the food chain and, in turn support larger numbers of fish and other animals. Moreover, the substances that attach to the underside of a floating island become food for fish and the entire island can become a new habitat for birds.[206]

Floating treatment wetlands at HydroVillage could utilize the same hexagonal floating foundations as are generally used for everything else. Those floating foundations could be constructed in a variety of ways and placed in an around the village in waters that had been tested and found to have the highest levels of pollution. Since they are covered with greenery they will add to the beauty of the environment. Solar panels could be added, allowing lights to illuminate the green islands at night, further enhancing the attractiveness of the environment around HydroVillage.

Because of runoff, floating treatment wetlands should seriously be considered for use in and around HydroVillage. If that were to happen, specifically, what plants would be best to use? Even though the water at Ke`ehi Lagoon is brackish, a variety of Hawaiian wetland plants could be considered. Various wetland plants could be tested by researchers working at HydroVillage, along with the levels of salinity in the lagoon to find the best plants for the floating treatment wetlands.

With that possibility in mind, let's consider some wetland plants in Hawai'i, although at least one common wetland plant today is actually not native to Hawai'i. Some freshwater ponds in lowlands consist of water surrounded by vegetation with roots in the wet soil around the ponds. Much of the vegetation in the shallow water around the ponds consists of native grass-like plants, which are called sedges. Tall bulrushes such as makai and 'aka'akai, and the shorter makaloa are members of the sedge family. The larger California bulrush, likely not native to Hawai'i, can be found growing In some ponds and wetlands,mixed in with native bulrushes.[207]

206 Ibid.

207 Stone, Charles. "Hawai'i's Wetlands, Streams, Fishponds, and Pools." Manoa.Hawaii.edu. Last Modified 1987. http://manoa.hawaii.edu/hpicesu/book/1988_chap/29.pdf. (Accessed February 25, 2016.)

Additional native plants that are often found growing in the muddy edges of ponds are water hyssop, beach dropseed grass, and ʻakulikuli. Where water is brackish, the introduced pickleweed now dominates.

Indigenous to Oʻahu, ancient Hawaiians used this wetland plant to make plaited mats and also for medicinal purposes. ((Courtesy of David Eickhoff))

Another type of wetland that is today only found in a few places on Oʻahu is the vernal (spring) pool, where the natural vegetation is the rare water fern ʻihiʻihilauakea, an endangered species.[208]

These pools are found only in leeward lowlands. Standing water (pools of water that don't flow) is only there during seasons of heavy rainfall. The soil is dry for the rest of the year, and at that time the water fern shrinks, as a ground cover, and becomes brown.[209]

208 Ibib.

209 Ibid.

The pickleweed which is eaten in Mexico and in England (as pickles).
(Courtesy of Santa Monica Mountains Recreation Area)

Thought it looks like a four-leaf clover, ‘ihi‘ihilauakea is not a flowering plant at all, but instead a tiny fern.
(Courtesy of Hui Kū Maoli Ola.)

There are few native plants In Hawai‘i that are associated with wetlands. Those that are here are also found on other Pacific islands and on continents in tropical regions. Despite the fact that Hawaiian wetlands are not known for having a wide variety of hard-to-find-species, their limited distribution, their small sizes, their impact on native animals, and the threat of destruction by development are strong reasons to try to save those that remain.[210] Using these plants on floating treatment wetlands at HydroVillage could serve two purposes. One would be to help clean the water, and the other would be to help keep these plants from extinction.

Floating treatment wetlands (sometimes called floating treatment islands) at HydroVillage could be combined with individual floating solar panels, and/or water catchment systems to produce original and unique designs that serve both practical and aesthetic functions. Scattered in the water around HydroVillage, these small floating islands could help to clean the water of the lagoon while providing additional power and fresh water, and, at the same time, add a park-like atmosphere to the surface of the water during both daytime and illuminated at night.

7.11 HydroVillage: Mighty Oaks from Little Acorns Grow: Start Small

Obviously this is a huge project that would require a lot of investors and a huge amount of work to be realized. However, there is no problem with starting it on a very small scale. One section of a wing, containing eight or ten housing units, and their accompanying farms, could be the beginning. Later a section for science labs could be added. It could grow naturally as more and more people became interested until it finally reached full development with the dome being built to serve as a community center. This could also be done in planned phases, that would culminate in the complete HydroVillage.

7.12 HydroVillage: Managing

HydroVillage, with minor changes, could be managed in the same way that condominiums are managed today. A condominium development can be apartment-style complexes, townhouses, or converted multi-family

210 Ibid.

dwellings. What makes it different from other multi-tenant buildings is that the developer has legally filed it as a condominium, and people can buy units in the complex. This means that, in most states, the development is done under specifically designed laws and regulations that are applied to condominiums.[211]

When buying a condo, the buyer buys the title to his or her individual unit, up to the walls, but not including them, hence the description of a condo as a "box in the air."[212] In the case of HydroVillage, a buyer would buy the complete housing unit, since units are not attached to each other.

For areas of the development in a condo, such as stairwells, walls, and gardens ownership is shared, and each unit owner holds an interest in those areas. Every condo development has a condominium association, also known as a unit-owners association, in order to manage maintenance and repair of the shared areas.[213] This would work the same in HydroVillage. Common areas such as the wings and wing sections, farms, science labs, and the main dome housing the community center would be owned by everyone. Governance of the entire structure would be done by a unit-owners association. Management of the ocean farms, including research, implementing the research, and even marketing the produce could be done by a hired outside third party.

7.13 HydroVillage: Ocean Farming

Life among residents of HydroVillage will be centered around sea farming and research. That calls for a brief look at sea farming in general and find out how modern approaches have changed very much within the last few years. Ocean farming is not a modern idea. Cultures such as the ancient Egyptians, Romans, Aztecs, and Chinese have farmed finfish, shellfish, and aquatic plants. Scotland farmers have been raising Atlantic salmon since the early 1600s. Seaweed was a food staple for American settlers. Regrettably, what started as a sustainable fishery was modernized into large-scale, industrial farming, after being modeled on land-based, factory livestock farms. Today nearly 90 percent of large fish stocks are threatened by over-fishing, and a growing network of scientists, ocean

211 Lending Tree, "A Beginner's Guide to Condominiums." August 6, 2007. https://www.lendingtree.com/mortgage/beginners-guide-to-condominiums-article. (Accessed January 29, 2016.)

212 Ibid.

213 Ibid.

farmers, and environmentalists around the world no longer see the oceans as home for monolithic factory farms. Instead, they view the oceans as the home of small-scale farms where complementary species are cultivated to provide food and fuel, while helping to clean up the environment and fight climate change.[214]

Instead of finfish, the mainstay crops of the emerging green ocean farms are seaweed and shellfish, two special products of the sea that could well be mother nature's very own way to fight climate change. Seaweed, long considered the "tree" of coastal ecosystems, uses photosynthesis to remove huge amounts of carbon from the atmosphere. Some varieties of seaweed are capable of absorbing five times more carbon dioxide than land-based plants. Additionally, seaweed is known to be one of the fastest growing plants in the world. For example, kelp grows nine to twelve feet in three months. Oysters, as well, absorb carbon, but their real gift is filtering nitrogen out of the water.

Nitrogen happens to be nearly 300 times as strong as carbon dioxide, and the number one nitrogen polluter is agricultural fertilizer runoff, which ends up in the oceans. Nitrogen is now 50 percent above normal levels in oceans worldwide. That's where oysters come in. One oyster can filter 30-50 gallons of water a day, and, in doing do, filters nitrogen out of the water. A healthy oyster habitat can remove 20 percent of the total added nitrogen.[215]

A variety of projects are appearing that use a mix of seaweed and shellfish to clean up polluted urban waterways and help communities prepare for the effect of climate change. One, for example, at the university of Connecticut, is growing kelp and shellfish on floating lines in the Bronx River in New York to filter nitrogen, mercury, and other pollutants from the city's dirty waterways. Another, from the design firm SCAPE is developing urban aquaculture parks that use floating rafts and hanging shellfish on long lines to build more urban green space while improving the environment. SCAPE sees the new urban ocean farmer as part shell fisherman tending oyster reefs and part landscaper, tending the above-surface floating parks. Finally, finding a clean substitute for existing biofuels is becoming more and more critical, and seaweed and other algae are turning out

214 Brendan Smith. Atlantic, The, "The Coming Green Wave: Ocean Farming to Fight Climate Change." Last Modified November 23, 2011. http://www.theatlantic.com/international/archive/2011/11/the-coming-green-wave-ocean-farming-to-fight-climate-change/248750/. (Accessed December 27, 2015.)

215 Ibid.

to be viable substitutes. About 50 percent of the weight of seaweed is oil, which can be used to make biodiesel for trucks, cars, and airplanes. Scientists at the University of Indiana recently discovered how to turn seaweed into biodiesel fuel four times faster than other biofuels, and scientists at the Georgia Institute of Technology have found a way to use alginate extracted from kelp to increase, by ten times, the storage power of lithium-ion batteries. An added advantage is that seaweed farming, unlike land-based biofuel crops, does not require fertilizers, forest clearing, water, or heavy use of fuel-burning machinery, and, according to the World Bank, has a negative carbon footprint, i.e., It removes carbon dioxide rather than adding it.[216]

What does all of this mean? It means that instead of building huge ocean factories, we need to build sea farms on a much smaller scale, sea farms that could even serve as alternate fuel farms. These new small farms would grow food, alternate fuel, and, in doing that, create jobs. Though sea farming, is not a cure for everything, it could be a crucial part of a new ecologically friendlier future.[217] It is in this direction in which HydroVillage & Research Farms at Ke`ehi Lagoon has been conceived.

Along similar lines, Monterey Bay Aquarium Seafood Watch reports that most fish that we eat in the next decade won't be wild fish; it will be raised on a fish farm. Over 100 species of fish are now farmed worldwide in a variety of ways from traditional earthen ponds to high-tech tank systems. Each farming method has its own specific environmental footprint. Here are a few examples of those methods..[218]

There are a number of ways to grow shellfish, including oysters, and bag-and-rack culture is one that is environmentally responsible. Young shellfish are cultivated on racks that sit within the tidal zone and are periodically covered with water. The young ones come from hatcheries, so wild populations aren't disturbed. In the AquaVillage fish farms, perhaps shellfish could be raised this way in racks that are suspended underneath the foundations.[219]

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216 Ibid.

217 Ibid.

218 Monterey Bay Aquarium Seafood Watch, "Fish Farming (Aquaculture)." http://www.seafoodwatch.org/ocean-issues/fishing-and-farming-methods. (Accessed January 29, 2016.)

219 Ibid.

Kelp is one of the most nutrient-rich plants on earth.
(Courtesy of The Nautical Dog)

Not only are shellfish nutritious, they clean the water by filtering it.
(Image Courtesy of Village Culture)

Hatchery fish are bred and grown in nurseries. Environmentalists are concerned that fish raised this way could be released and interbreed with wild species. In the AquaVillage fish farms, tanks or pens could be suspended underneath the surface of the water, and special care would be taken to be sure none were released into the wild.[220]

Suspended shellfish culture can be quite sustainable. Oysters, mussels and clams are filter feeders that don't need additional food, and thereby don't impact wild fish stocks. (Filter feeders are animals that feed by straining suspended food particles from water.) They can be suspended in water by ropes, nets, trays, or mesh bags. Environmental damage and impact from effluent are usually minimal. This seems especially suitable for HydroVillage.[221]

A lot of research would have to be done to find out which kinds of finfish and shellfish could best be raised in the HydroVillage area, and what kinds of seaweed would be suitable. Also research would have to be done to find the very best ways to do that while being socially responsible, especially in terms of the environment. That is why the researchers would be hired to work on the site along with (experienced) fish farmers, and those are also the reasons the facilities in which to do the research, the science laboratories, are crucial.

7.14 The Farms: What They Will Grow and How They Will Look

According to Paul Greenberg, an expert in the fishing industry, the demand for seafood in going up while ocean resources, as a result of climate change, pollution, and overfishing, are diminishing. That means Americans need to change two things: which fish we are eating and how we manage both natural food that is being harvested from the sea and foods that are farmed from the sea. He says we have to change our "seafood pyramid" and start to elevate seaweed and shellfish, since they are easy to harvest, they grow quickly, and they clean the oceans by absorbing dangerous pollutants.[222]

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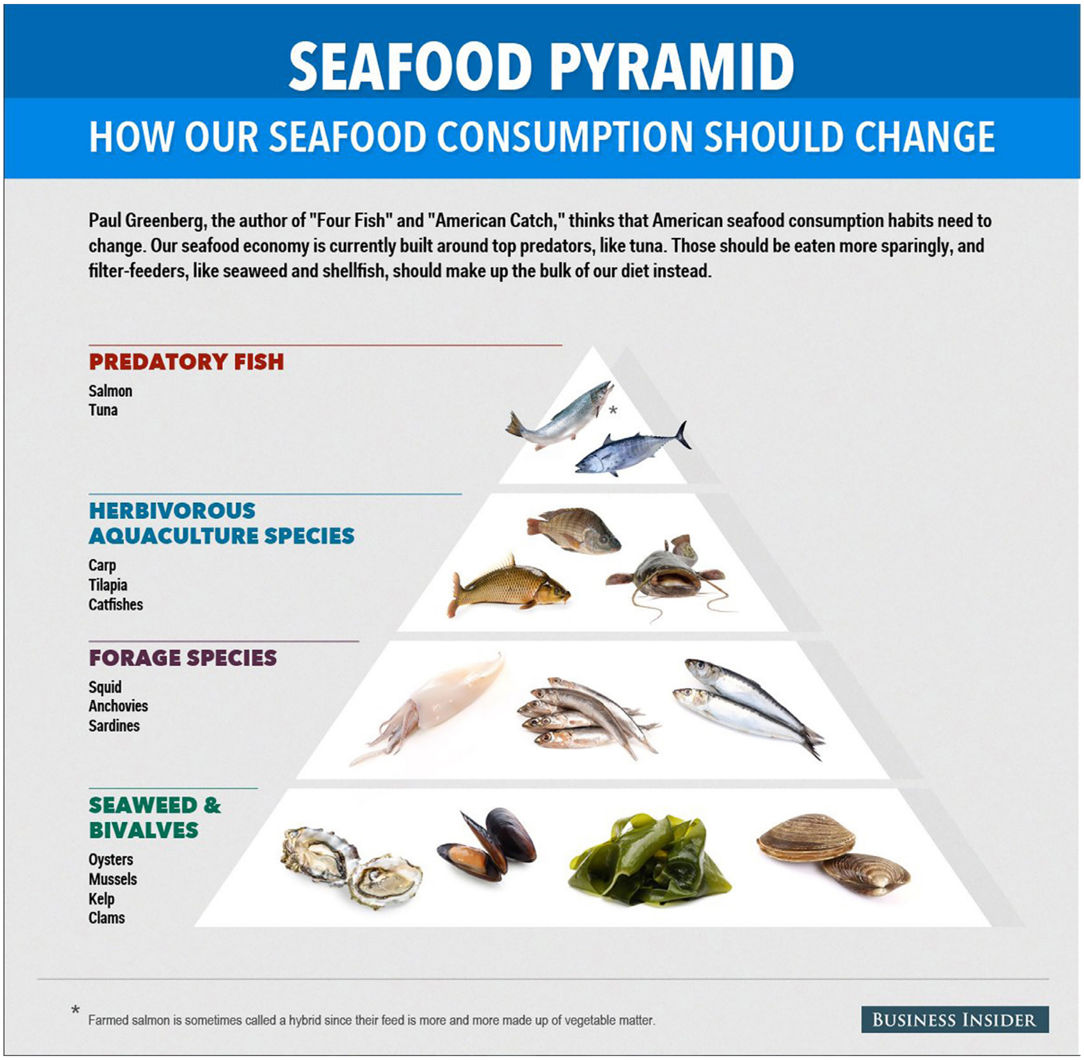
220 Ibid.

221 Ibid.

222 Spector, Dina. Business Insider.com, "Forget Tuna: These Are The Seafoods We'll Be Eating In The Future." Last Modified July 8, 2014. http://www.businessinsider.com.au/seafood-well-be-eating-in-the-future-2014-6. (Accessed February 13, 2016.)



Seaweed and Bivalves should be at the top of the pyramid.
(Courtesy of Business Insider.)

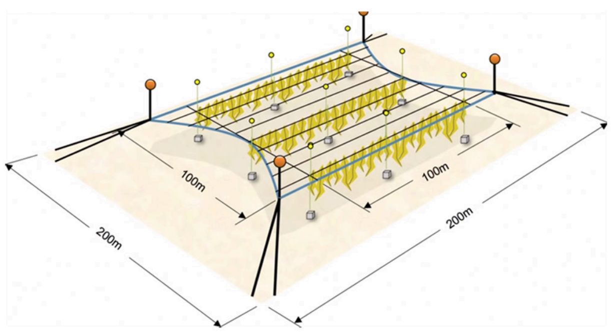
Greenberg anticipates that in two decades that a seaweed known as kelp will be one of the top most eaten seafood in America. He says that if kelp futures were being sold, he would buy them. He further says that, for environmental reasons, aquaculture has gotten a bad reputation, but that aquaculture is fine if it is done correctly. "Done correctly" means stopping the large-scale systems that damage the ocean, and, in its place, start farming plants and animals that thrive in small plots of seawater, i.e., clams, mussels, and oysters, and seaweeds that are edible, like kelp.[223]

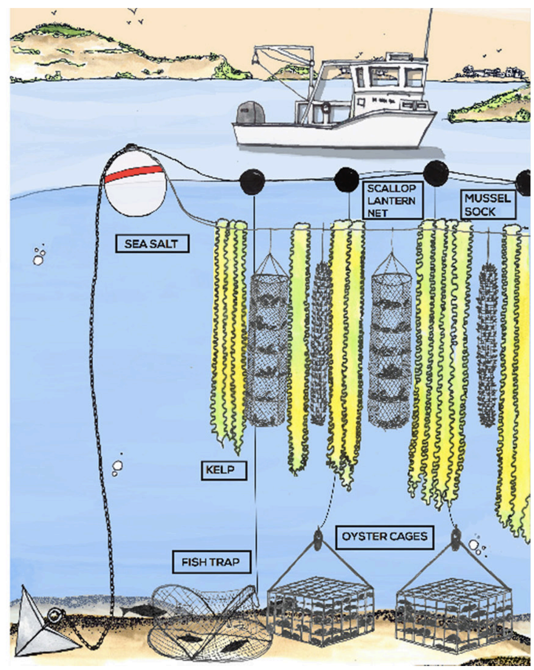
223 Ibid.

Bren Smith, owner of one of the largest kelp farms in the U.S., refers to this type of ocean farming as aquaculture 2.0. Smith has developed a system that he says, "restores rather than depletes the ocean." Mussels and kelp are grown on floating lines that are anchored to the sea floor. Below those lines are cages of oysters and clams.[224]

Videos of Bren Smith, modern sea farmer, discussing his work can be seen at: https://www.youtube.com/watch?v=nHtx5bNxORw and https://www.youtube.com/watch?v=j8ViaskDSeI)

https://www.youtube.com/watch?v=j8ViaskDSeI





Bren Smith 3D Ocean Farms (Courtesy of Futureoffish.org)

Smith's farms need very little equipment, so they are environmentally friendly, and since the kelp and shellfish feed themselves by taking food particles out of the water, they are self-sustaining. An additional plus is that they help the ocean by taking nitrogen from the water. A problem with the farming of kelp is that although more and more Asian foods are becoming popular, and it is being served in salads and in soups and sold in American food stores as a dried snack, it still isn't considered that tasty by that many Americans. Smith is trying to change

224 Ibid.

that by working with restaurants to put kelp into foods that are already considered tasty, such as kelp butter and kelp fettuccine.[225]

Paul Greenberg believes that whatever seafood is eaten in the future will be based on whatever is left in the ocean and the decisions we make about what is helpful to the environment, and says that people will probably choose seafood that is cheaper and more efficient.[226]

Through research, the sea farms at HydroVillage, have emerged as first choice for providing jobs to the residents of HydroVillage. Moreover, due to climate change and rising sea levels, it is critical that providing more locally grown food be given top priority.

7.15 Edible Seaweed and Shellfish in Hawai'i

Some historical background on Limu (Seaweed) as a Food Staple in Hawai'i

It turns out that Hawai'i has a long history of eating and using seaweed. Limu is a Hawaiian word that actually means any plants that live underwater. However, for most people in Hawai'i, today it means "edible seaweed."[227]

What are Seaweeds Anyway?

Seaweeds are algae, which means that they are aquatic, nonvascular plants, that is, plants without a vascular system. (Land plants have a vascular, circulatory, system which carries water and nutrients throughout the plant.) Algae absorb everything they need directly through the "stems and leaves" that make up the plant. There are an estimated 420 species of algae that currently live in the oceans around Hawai'i, and only about 13 of those are native to Hawai'i. Scientists divide seaweed into four main groups, which are green, blue-green, red, and brown, although the visible color isn't always a dependable way to identify them. For example, nori, the seaweed used in sushi, is actually red algae, but it looks green.[228]

225 Ibid.

226 Ibid.

227 Scott, Susan. Plants and Animals of Hawaii. Honolulu: Bess Press, 1997. p. 35-36.

228 Ibid.

Limu has always been a stand part of traditional Hawaiian food, and still popular today. They are sold in grocery stores and supermarkets, and are still prepared in the original Hawaiian way. Here are four examples of ordinary,

#1 LIMU WAWAE'IOLE (CODIUM EDULE)

#2 LIMU MANAUEA (GRACILARIA CORONOPIFOLIA)

#3 LIMU 'ELE'ELE (ENTEROMORPHA PROLIFERA)

#4 LIMU KOHU (ASPARAGOPSIS TAXIFORMIS)

Edible Limu (Courtesy of University of Hawaii: Botany Department)

common limu:

(#1) These are dark green with a surface that feels like felt. It is found throughout Hawai‘i in shallow water and beach areas that are covered by high tides. Must be carefully cleaned since they attach themselves to rubble and dead coral. (#2) There are two species of Gracilaria (limu manauea and ogo). Limu manauea is four to six inches tall, and has cylindrical branches that are dark rose to light pink. Ogo is ten to 12 inches tall and with branches that look slightly flattened. (#3) Limu ‘ele‘ele is dark green and grows in clumps on rocks in powdery sand. To harvest, cut it about a half-inch above the base and clean it carefully to wash off all the sand. (#4) Limu kohu has a creeping base that produces soft and fuzzy upright “arms.” They are found on the edges of reefs in water that is in constant motion. Only the upright “arms” are collected.[229]

229 University of Hawaii: Botany Department, “Limu: Our Hawaiian Tradition.” Last Modified January 1, 2002. http://www.hawaii.edu/reefalgae/publications/ediblelimu/. (Accessed February 17, 2016.)

A Balanced Diet for Ancient Hawaiians

Limu was the third component of a balanced diet for ancient Hawaiians, which was fish, poi, and limu. These three components provided all the nutrients that those ancient people required to stay healthy. As well as vitamins and minerals that the other two components didn't have, limu made the Hawaiian diet more interesting and tasty. Ancient Hawaiian women, however, had little variety in their diets, because of the kapu system that didn't allow women to eat among other things, pork, and several species of fish. King Kamehameha's favorite wife, Queen Ka'ahumanu, finally stopped that discrimination in 1819. By that time, limu was already a favorite for men and women both. Culturally very important to Hawaiians, in addition to being an important food, it was also used for medicinal purposes, leis, and various ceremonies.[230]

Additional Fans of Limu: Descendants of Asian Immigrants

In addition to being used by Hawaiians today, Filipino, Korean, and Japanese also eat various kinds of limu. Seaweed in Hawai'i is so popular that some species have become quite scarce, since limu pickers harvest so much of the plant, that it is unable to grow again or to reproduce itself.[231]

Kelp, the Miracle Plant

Kelp, a seaweed discussed earlier, when describing the new ocean farms, has many uses, and many products are made from kelp, including toothpaste, shampoo, salad dressings, cakes, and various pharmaceutical drugs. As already pointed out, it grows quickly and can produce methane and ethanol, valuable sources of renewable energy. There are over 30 different varieties of kelp, and some can grow to lengths of 80 meters (about 262 feet). Many live in cooler water, but luckily there are varieties of kelp species that are native to the oceans around Hawai'i.[232]

230 Ibid.

231 Ibid.

232 Gardens and Flowers.com, "Hawaiian Ocean Plants." Last Modified August 26, 2015. http://www.gardenandflowers.com/list_7649241_hawaiian-ocean-plants.html. (Accessed February 15, 2016.)

Cultivating Seaweed in Ocean Farms at HydoVillage

It is clear that ocean farming of seaweed in Hawai‘i has much potential. Not only does it have a long history here, its popularity is growing due to the influx of many Asian dishes to Hawai‘i and the mainland. Moreover, in addition to serving as a valuable food source, kelp, brings the advantage of being used as a source of renewable energy. This makes ocean farming at AquaVillage an exciting and possibly lucrative venture..

How about shellfish? How do they stack up in Hawai‘i? If we use the model for new ocean farming, small farms of seaweed and shellfish, are shellfish likely to be as suitable for HydroVillage ocean farming as seaweed is?

Some Historical Background on Shellfish in Hawai‘i

The diet of ancient Hawaiians included a number of shellfish, including ‘opihi, leho, pipipi, puho‘okani, and ‘olepe. ‘Opihi are limpets, which are mollusks with a shallow, conical shell and a broad muscular foot, famous for its ability to cling tightly to rocks. They were extremely popular, and likely, in ancient times, to have been the shellfish that was most commonly eaten. Clinging to shoreline rocks, they were knocked loose with stones. As we know from headlines today, harvesting ‘opihi in areas with rough seas was dangerous, giving birth to the ancient belief that it was forbidden to eat ‘opihi while someone was gathering it, because the gatherer could be dragged out to sea by rough waves.[233]

Pipipi are small mollusks, and grow on rocks in tidal pools. Ancient Hawaiians collected them both during the day and the night. A needle was used to remove the meat from the shell so they could be eaten.[234] The Hawaiian word for cowry is leho, which usually referred to the larger ones, and smaller cowries were called poleholeho. Not only were cowries eaten, their shells were used for making a number of tools, like scrapers and fishing lures.[235]

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233 Hawaii History. Org, “Other Seafood.” http://www.hawaiihistory.org/index.cfm?fuseaction=ig.page&PageID=512. (Accessed February 15, 2016.)

234 Ibid.

235 Ibid.

Hawaiians also gathered puhoʻokani, conches, for the meat and for their shells. They made shell trumpets, or pu, from two types of large shells, which were the conch, the triton, and the cassis cornuta. The long pointed parts of the triton shells were removed to make mouth holes. They were four inches wide and from eight to eleven inches long. The larger casis shells were made into trumpets by drilling a hole in the flattened top. The trumpets, called pu, can produce a sound that can be heard two miles away. It was used to call people together for a special event.[236]

Bivalves, known as ʻolepe, were not an especially favorite food for ancient Hawaiians but their shells were used for making shell hooks.[237]

7.16 Shellfish Brought Into Hawaiʻi

Several species of oysters and clams were brought into Hawaiʻian waters from Japan and North America as a food source in the 1920s. These included the Japanese littleneck clam, which is also called the Manila clam.[238]

Those clams did well here, and gathering them from the mud flats of Kaneohe Bay was a favorite thing to do. Unfortunately, however, in 1969, silt and over-harvesting generally wiped them out. Some of those edible species, however, still live in shallow, sheltered areas, in Kaneohe Bay, Maunalua Bay and Pearl Harbor.[239] If they lived in the wild successfully, there is no reason they couldn't be cultivated in the farms at HydroVillage.

7.17 Shellfish Farming on the Big Island

The Big Island is in a position to play a major part in the U.S. oyster industry, while growers on the mainland try to deal with the effects of climate change. Oyster farms on the West Coast began experiencing a disturbing trend around 2007. Dave Nisbet, owner of Goose Point Oysters of Washington state's Willapa Bay explains that oceanographers observed increased acidification of

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236 Ibid.

237 Ibid.

238 Scott, Susan. Ocean Watch, "Check the Water Before Digging Clams." Last Modified May 9, 2003. http://susanscott.net/OceanWatch2003/may09-03.html. (Accessed February 15, 2016.)

239 Ibid.

the West Coast's ocean water during the spring and summer, and the change was just enough to kill the oyster larvae. He says the acidification was due to climate change. Maria Haws, director of the University of Hawaii at Hilo Pacific Aquaculture and Coastal Resources Center in Keaukaha says the same thing is happening around the world, but to a lesser degree here. She says that the acidification process is stronger on the West Coast because it experiences more acidified water coming up onto the continental shelf during the spring and summer months.[240]

In 2009, Nisbet formed a partnership with Haws to examine the possibility of growing oyster seed in Hawai'i. Things were so successful that he started Hawaiian Shellfish LLC and produced enough seed for his business and other growers in Washington. Today he employs six people, three with degrees from UH in aquaculture. They pump 60,000 gallons of water from a deepwater, saltwater well, into 12 big tanks that provide an ideal environment for the oysters. Finally it is reasonably inexpensive to ship the oyster larvae to the mainland where they finish their growth cycle, since the oyster seed is quite small and easily shipped.[241]

Maria Haws, director of the Pacific Aquaculture and Coastal Resources Center is responsible for supervising research that will lead to farmers building a shellfish industry here in Hawai"i so she is pleased with Nisbet's success story. Located on Kalanianaole Avenue, the center uses large tanks that test experimental cultures of various kinds of fish. UH students and faculty work at maintaining, feeding, and breeding colonies of different kinds of fish.[242]

Haws says that the next thing to do is for aqua farmers to raise bivalves, such as oysters and clams, to adulthood in Hawai'i. For that to happen, the Department of Health has to do a study of the water quality in areas that farmers want to use for oyster cultivation, to make sure the oysters would be safe to eat. If things go well, that would allow sellers to offer Hawai'i grown oysters to consumers here. Additional permits would allow shellfish from Hawai'i to be exported to the mainland. Hawai'i, however, has far to go to even satisfy its present-day demand for oysters. Haws says that currently 400,000 oysters are

240 Stewart, Colin M. West Hawaii Today.com, "Oyster Industry Growing Here" Last Modified July 3, 2013. http://westhawaiitoday.com/sections/news/local-features/oyster-industry-growing-here.html. (Accessed July 8, 2013.)

241 Ibid.

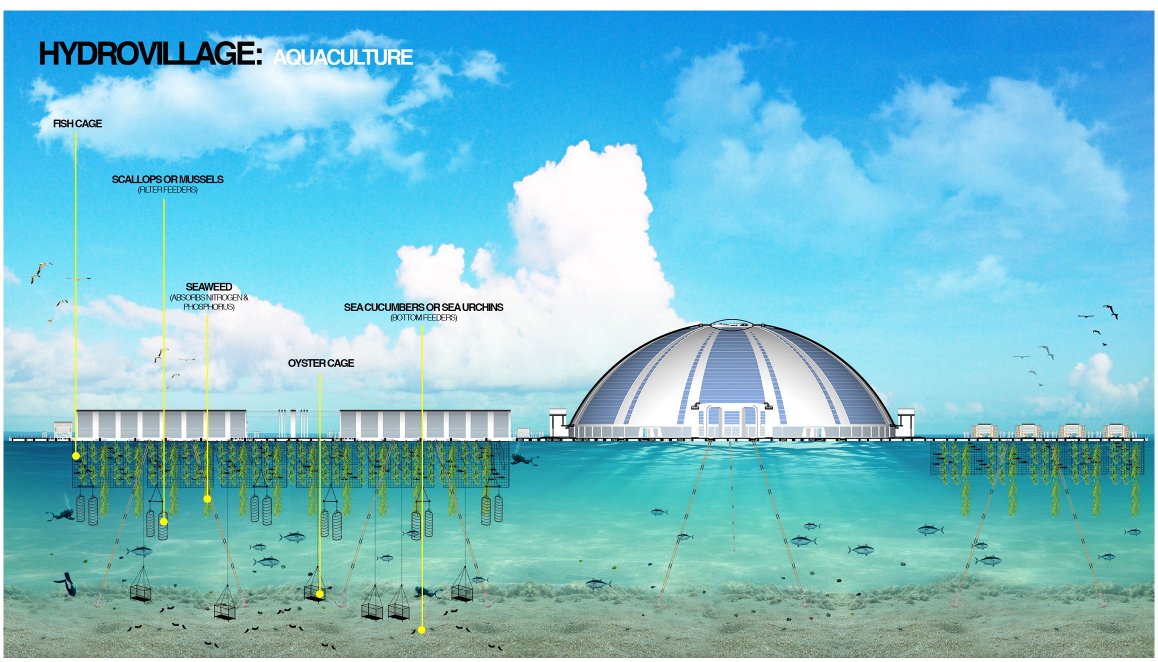
242 Ibid.

imported to Hawai‘i each month. She adds that, in the near future, Hawai‘i will be like restaurants in the Northwest offering a variety of choices to their customers. She adds that local people in Hawai‘i want to buy local products, and she predicts that the growth of the shellfish industry here will be huge. She ends on a positive note saying that the industry here is “right on the cusp.”[243]

7.18 Seaweed and Shellfish at HydroVillage Ocean Farms

Both seaweed and shellfish have a long history in Hawai‘i, and are very popular in modern Hawai‘i’s multicultural environment. They definitely should be included in any discussion about producing local food and about not being dependent on imported food. This makes them perfect candidates for food crops in the ocean farms at HydroVillage. Moreover, the experiments on the Big Island’s Pacific Aquaculture and Coastal Resources Center provide a model for the use of the science labs at HydroVillage where researchers can experiment with breeding, feeding, and maintaining colonies of different kinds of seaweed and shellfish (and possibly different species of ocean fish in the future).

7.19 What It Means to Be an Aquaculture Farmer



HydroVillage Aquaculture (Graphic by author)

243 Ibid.

There are basically three ways to learn about being an aquaculture farmer. One way is to work on an aquaculture farm and learn from experience. The second is to use the many educational resources available, many from the National Aquaculture Association. The third is to attend college and get a degree. Degree programs in aquaculture can be part of an agriculture or biology departments. Part of the graduation requirements usually includes an internship. Outstanding schools with degree programs in aquaculture include the University of Arkansas, Unity College (in Maine), and Sheridan College in Wyoming.[244]

Whether the farm is for breeding, raising, processing, selling, or releasing in the wild, it will require starting stock or plants. It will also need supplies, like feed, water purification products, and equipment, that are specific to whatever species is being raised. Organizations like the American Tilapia Association can help find reputable and quality suppliers.[245]

Buyers to purchase the species being raised should be found before beginning production. This might be local retailers or restaurants who buy fresh fish or produce for food. Aquaculture organizations that are related to the species being raised can often put buyers and sellers in touch with each other. After potential buyers are found, the farming operations can be started without worrying about how the products are going to be sold.[246] As global demand increases for more sustainable and manageable food sources, aquaculture is becoming a high-priority industry. There are a number of optional career advancement options for aquaculture farmers who are involved in continuing education and who gain experience. These include jobs with government agencies, large-scale operations, and industry sales.[247]

Aquaculture (ocean farming or sea farming) seems particularly suited to a warm, humid climate like that of Hawai‘i, and especially so in a fairly quiet and calm place like Ke‘ehi Lagoon. Hawai‘i desperately needs more locally produced foods and, as lands for agriculture gradually shrink away, more and more attention is being given to sea farming.

244 Study.com, "How to Become an Aquaculture Farmer: Education and Career Roadmap." Last Modified January 1, 2016. http://study.com/articles/How_to_Become_an_Aquaculture_Farmer_Education_and_Career_Roadmap.html. (Accessed February 3, 2016.)

245 Ibid.

246 Ibid.

247 Ibid.

7.20 HydroVillage: Ferry Service

A ferry service linking HydroVillage to the shore line of Ke‘ehi Lagoon would be necessary. It could be managed and run by the same HydroVillage governing board that is responsible for managing the entire Village. There are two possible locations for where the floating docks for the HydroVillage ferry could be built on the shore. One is at the Ke’ehi Small Boat Harbor and the other one is at the existing car rental area. At HydroVillage, there are also two possible sites for docking, both on the eastern side.

Ferry Docks (Graphic by author)

The fares and schedules would be set by the governing board of Hydro Village. An additional emergency "taxi-ferry" would be available twenty-four hours a day, seven days a week. Two groups of people would be using the ferry. One group that would need to use it on a daily basis is the maintenance people who work for HydroVillage, plus the owners and/or their employees who run shops in the community center. Goods and products to be served or sold in the shops would also be transported by ferry.

7.21 How Well Does HydroVillage & Research Farms at Ke`ehi Lagoon Follow Koen Olthuis' Comments About Living on Water?

Earlier "(See 4.6 through 4.12), we read general comments about floating architecture made by Koen Olthuis in various interviews. How does HydroVillage compare to some of the things he said? For example, he said that floating foundations allow water to provide viable new building space. Since the HydroVillage project is all built on floating foundations, it is providing new building space. Also relating to floating structures, Olthuis says they leave little or no physical or carbon footprint, and that is certainly one goal for the HydroVillage project. Additionally, floating structures can be reused at different locations, he says, and that even the building process can be more efficient by centralizing construction in a place other than the actual site. This is absolutely true for HydroVillage.

He said that cities need to be more dynamic, flexible, environmentally friendly, and able to reinvent themselves. They need to be more adaptable to changing needs, which are often difficult to predict. The HydroVillage is extremely flexible since all of the elements can be separated to float individually. In terms of reinventing itself, the sea farming aspect could change as needs change.

When designing a floating structure for a specific location, engineering for Waterstudio is done by the best maritime companies who take into consideration the existing and expected extreme weather conditions, in addition to local wave conditions. That is what should be done with the HydroVillage project. In fact, virtually everything Koen Olthuis has said in regard to floating development applies to this project, and his ideas have had considerable influence in the development of the project.

Summing Up

In Chapter 7, we looked at various other considerations for the floating design project, like the importance of including a Hawaiian sense of place, and the importance of greenery. We considered floating foundations and saw that the foundations in use at HydroVillage are are similar to those already in use on the mainland. A look at utilities, sewage systems, and catchment systems followed. We saw that even though HydroVillage is a huge project, it can start small. We talked about the management of HydroVillage, and saw what modern ocean farming really means. Finally, we compared HydroVillage to the comments by the Floating Dutchman to see how it fared.

Coming Up

In Chapter 8, we will look at a plan to deal directly with three current issues in Hawaii, which are housing, jobs, and locally produced food. HydroVillage at Ke`ehi Lagoon will consist of floating farms, where farmers and researchers will tend food crops, and where they all will live in housing that is within walking distance to their places of work. Also within walking distance, and placed in a central dome, there will be a community center which will have enough space to market the produce or to open other small businesses to serve the HydroVillage community. The community center would serve as a hub for whatever activity people might consider appropriate, even entertainment and nightlife. Potentially it could become an icon and a tourist destination representing a new Hawaiʻi. Welcome to HydroVillage.

Chapter 8

Design Project: HydroVillage & Research Farms at Ke`ehi Lagoon

"No water, no life. No blue, no green."
– Sylvia Earle –

8.1 Vision

The vision of the Hydro Village at Ke`ehi Lagoon is broad, and is basically intended to introduce the idea of floating architecture to Hawai‘i for a number of reasons, including these:

1. It is one of a number of viable responses to the problem of rising sea levels.

2. Floating architecture can provides much-needed space to an area that is seriously lacking land for agriculture, for housing, and for commercial growth.

3. Floating architecture will allow for the creation of new and innovative tourist destinations at a time when many of Hawai‘i's best-known sites are under attack by rising seas.

4. Floating structures leave a much smaller footprint than land-based designs. During construction and use of the structure, there is far less stress placed on the environment. After the building has served its purpose and needs to be taken down, a floating structure can simply be towed away. The environment can recover much easier from whatever stress had been placed on it, than the environment supporting a land-based structure. In the latter situation the immediate environment will never recover on its own.

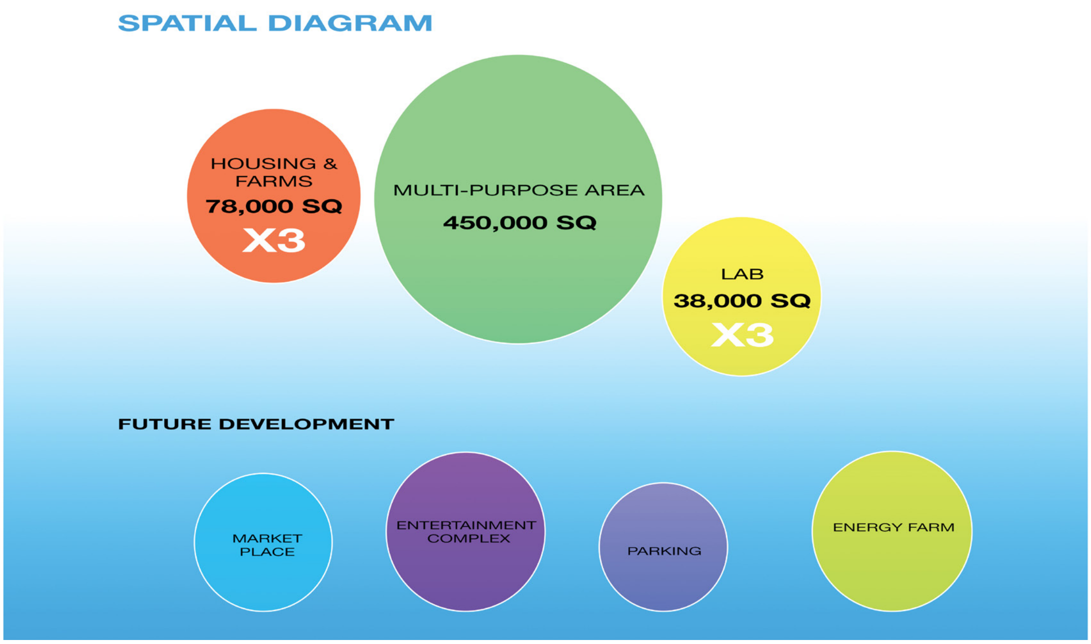
5. It is almost always designed to take advantage of numerous sources of renewable energy.

This plan could be used as a prototype model floating community for other locations in Hawai‘i and also for other places with protected coastal areas, fairly calm lakes, canals, and so on, anywhere in the world.

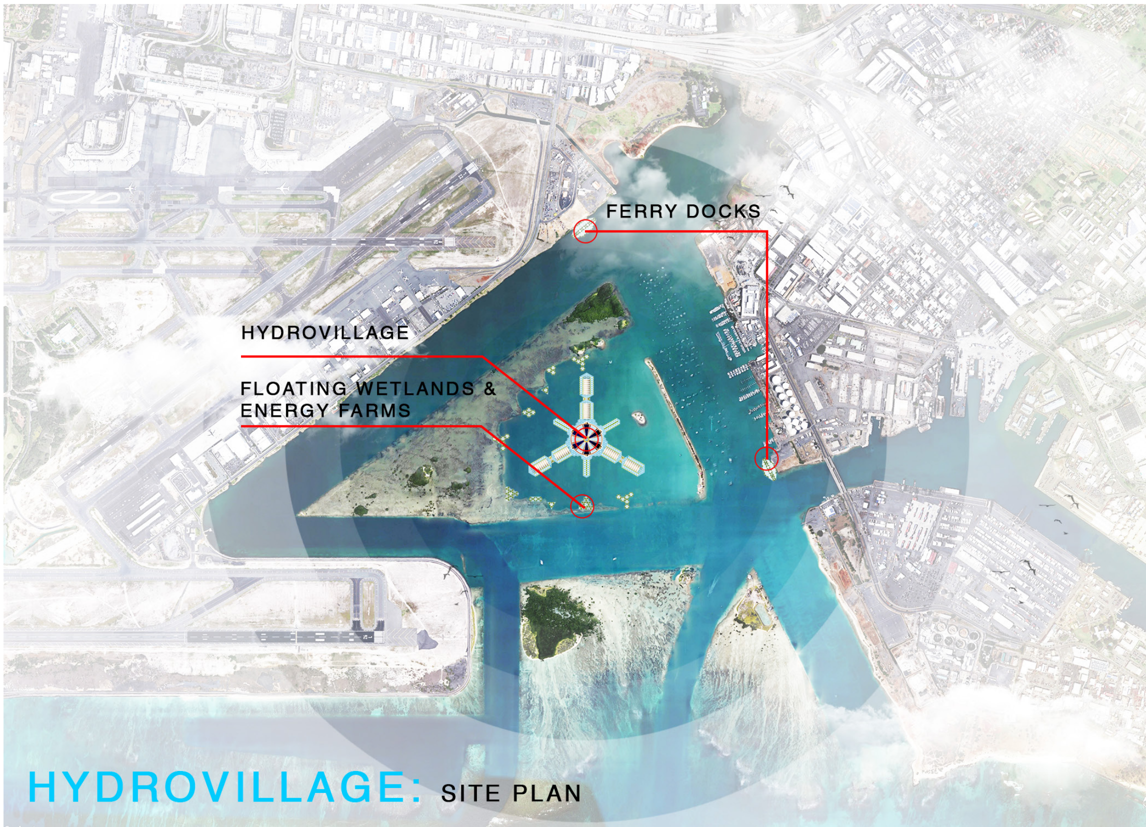
8.2 Design Project Proposal: HydroVillage at Ke`ehi Lagoon

This design project is a culmination of two years of research that I have been doing (mostly on floating architecture, and some on climate change). It combines ideas from floating projects that have already been done with my own original ideas for a floating farming community that have gradually come to my mind during the time of research.

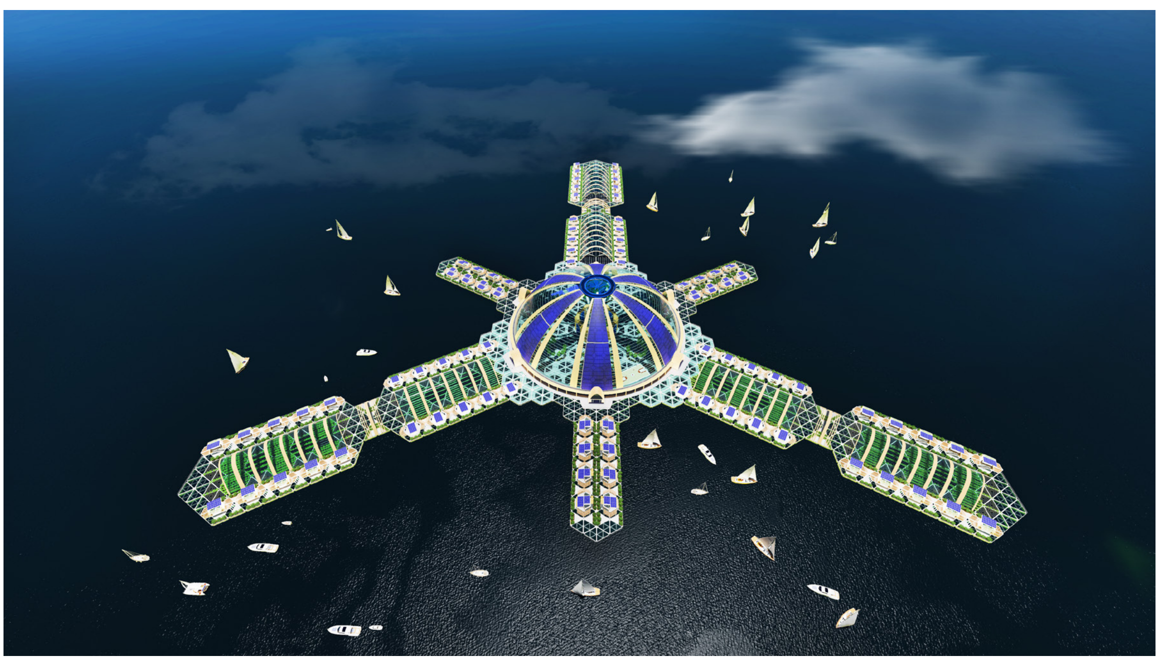
In addition to being a reaction to climate change and sea level rise, the vision behind this project is to begin to deal with some of local issues in Hawai‘i that are either problems now or likely to be in the future, especially in light of sea level rise. These issues include housing, jobs, more food that is produced locally, and alternative energy sources. HydroVillage will be a collection of working farms, that will be maintained by farmers who will (initially, at least) raise seaweed and shellfish in the lagoon, and by researchers who will work there with the farmers to keep the farms healthy and thriving.



Both farmers and researchers will live on site. Additional people, hired by HydroVillage and working in maintenance, for example, would not live on site, nor would people working in the shops in the community center. (Outside people living on the site would be one of a number of details to be worked out later by the managing board of directors at HydroVillage.)



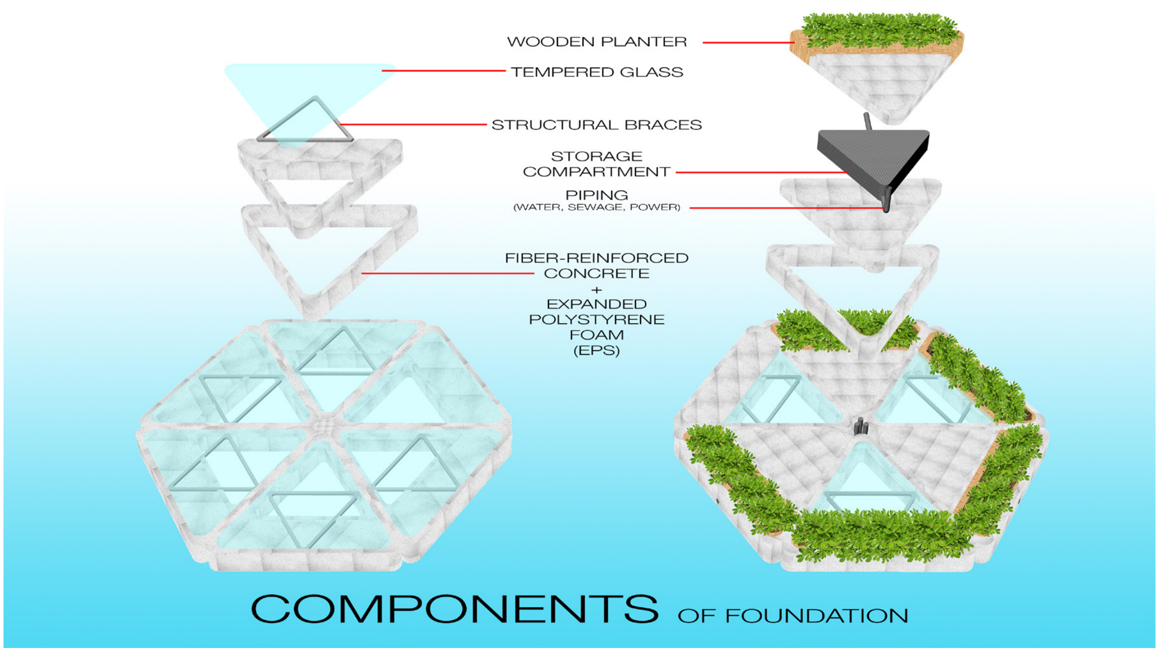
The overall site plan above illustrates Hydrovillage itself, floating treatment wetlands, floating energy farms, and two ferry docks. (All Graphics In This Chapter Done by author)

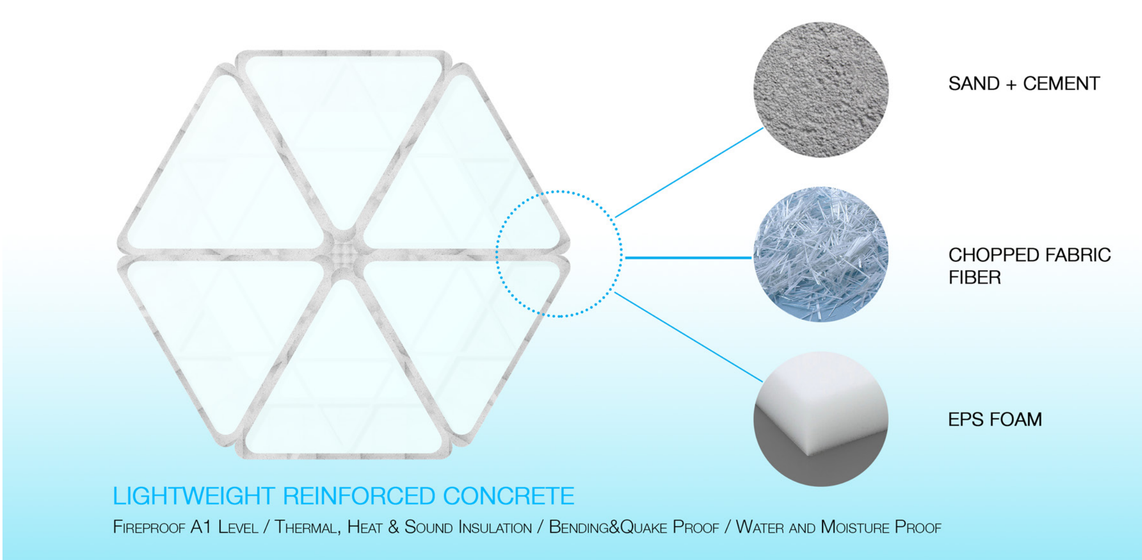


HydroVillage Aerial View

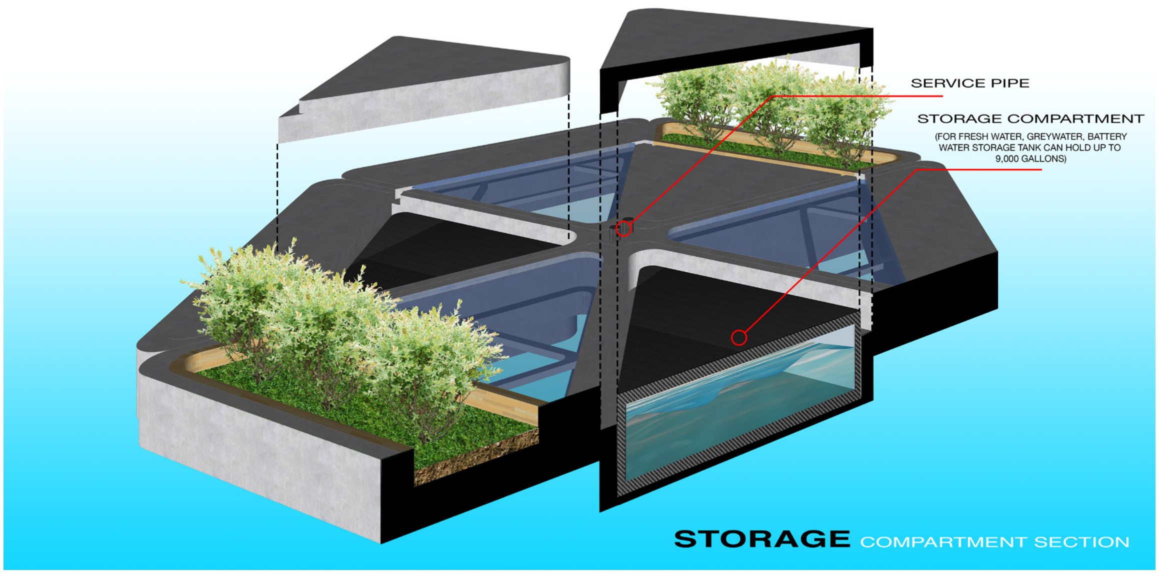
8.3 Basis of Floating Foundation and How It Is to Be Used

All structures in HydroVillage float on huge floating, hexagonal slabs. The main material for these slabs is fiber-reinforced lightweight concrete, which is made of sand, chopped fiber and EPS foam. The aggregate component for making typical concrete is left out to reduce overall weight. Since it is fiber reinforced, the base is light and yet still strong.



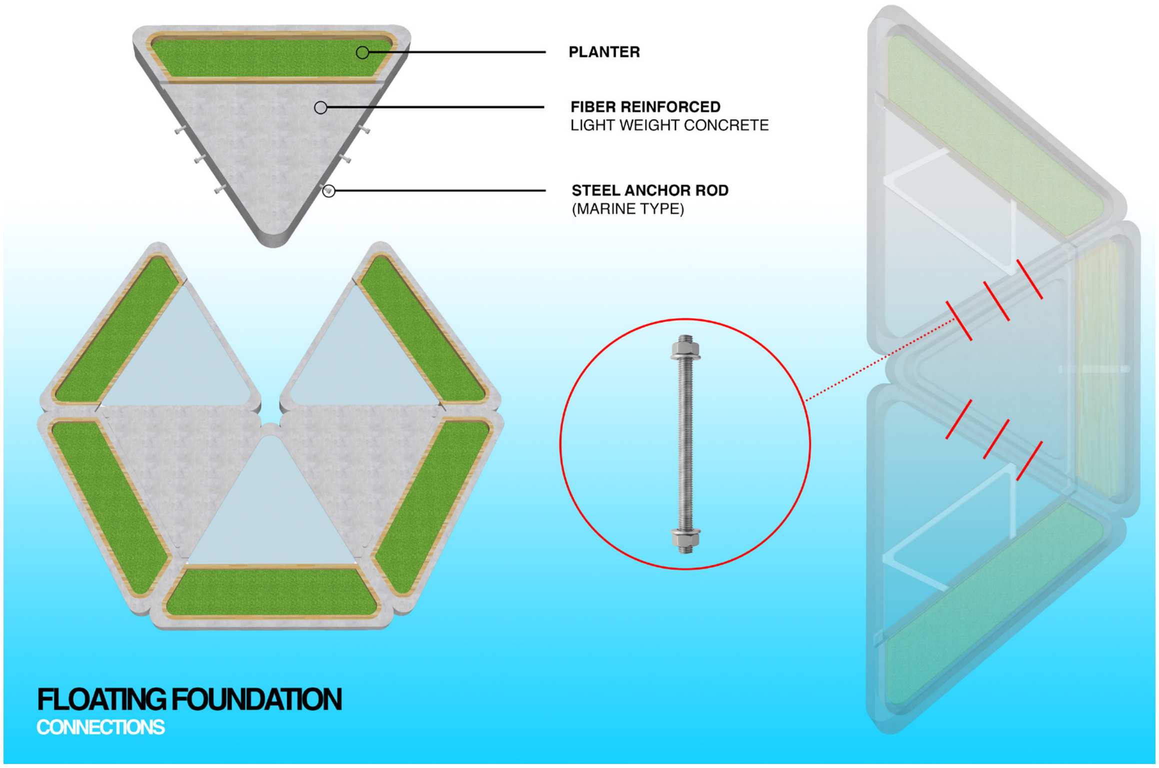


There are three triangular storage areas in the floating slabs. In addition to providing buoyancy, the triangular tanks can also serve other purposes. They can store greywater, fresh water, and energy stored in batteries. These three compartments are approximately eight feet deep. Three other sections in the slabs are made with translucent materials to allow light to penetrate into the lagoon itself. These floating slabs are designed to tie all the components of HydroVillage together into one large "structure."

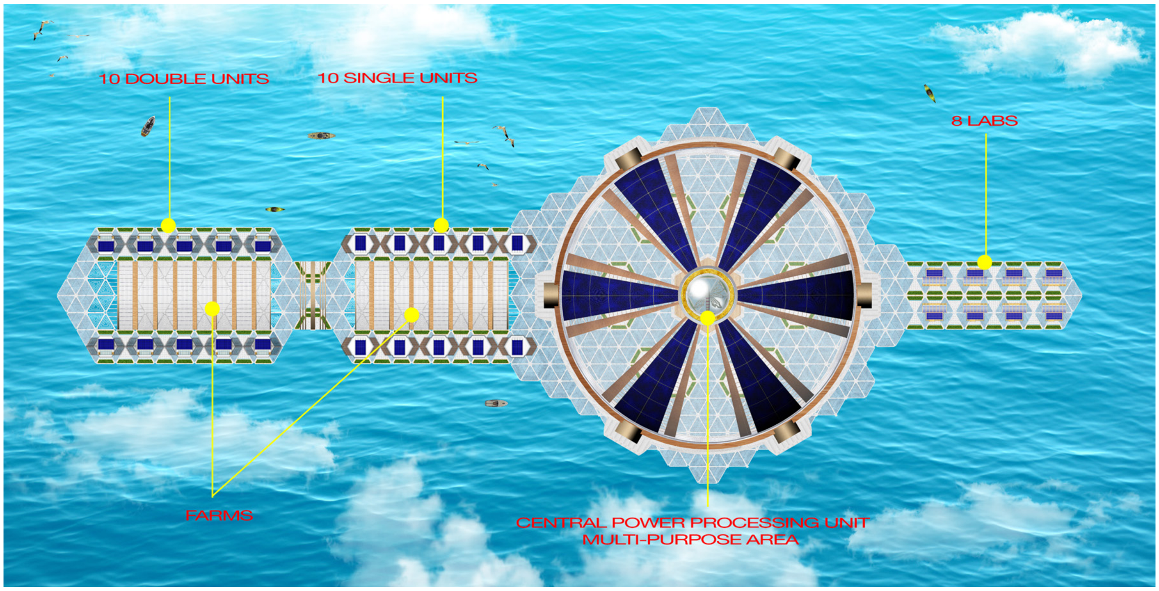


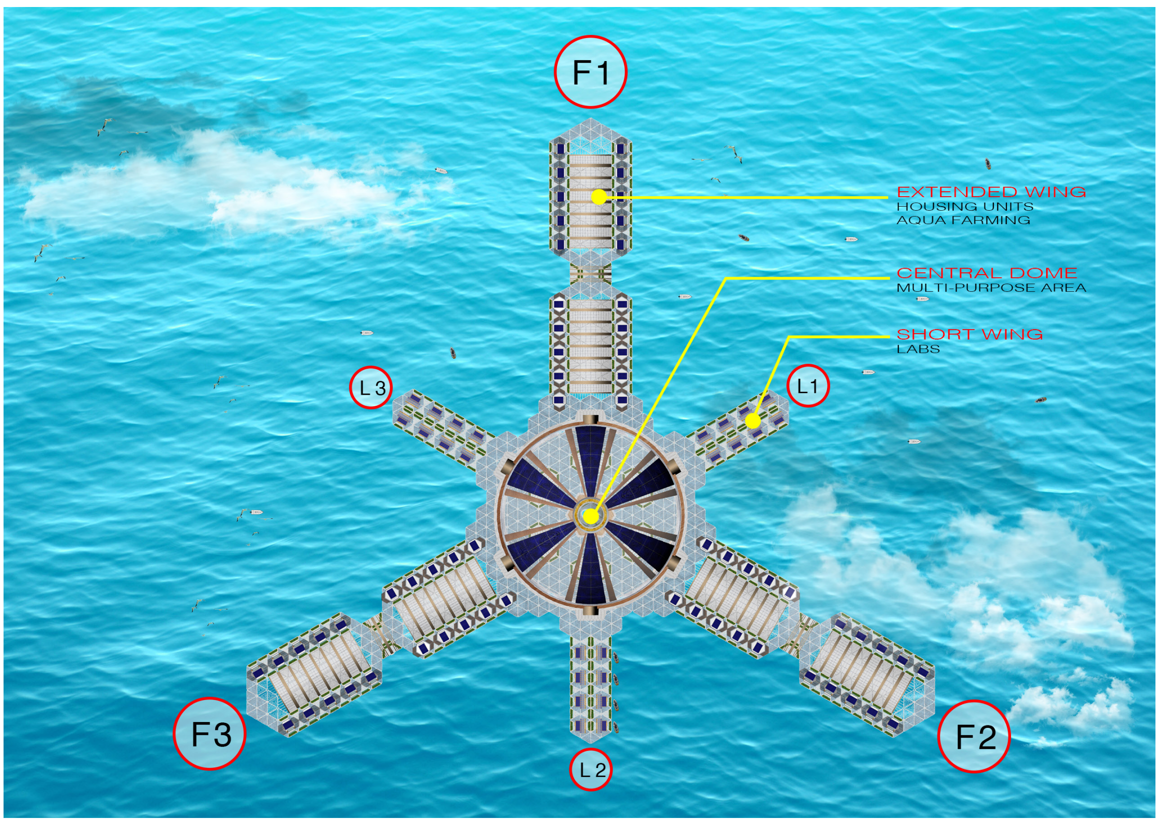
To provide horizontal stability and prevent drift, the floating hexagon foundations can be attached (or weighted) to the bottom of the lagoon, which is about ten feet down, with telescoping tethers (vertical steel tubes) similar to those that eliminate vertical movement in floating oil rigs.[248] A short wing could be attached with possibly two tethers, an extended wing, with three, and the dome itself with four to six tethers strategically located underneath. Attaching the hexagons to each other will provide vertical stability to the overall structure.

248 "Offshore: Oil and Gas under the Bottom of the Sea." Wintershall.com. Last Modified January 1, 2016. http://www.wintershall.com/en/technology/production-technology/offshore.html. (Accessed February 16, 2016.)



These floating hexagonal slabs serve as foundations for all structures, and can be bound together for different purposes. For example, a large configuration of floating slabs support the central dome. The central dome has six connected floating wings which are also made up of the floating slabs. Three of the wings are "extended," and are made up of two sections. Each extended wing supports 20 housing units for the farmers and researchers. Ten one-floor housing units are on the inner section, and ten two-floor units are on the outer section. The housing units are set alongside the ocean farms that run the entire length of the extended wings. The remaining three wings are shorter and they provide support for the eight science labs per wing. The six wings can be detached from the dome, and the housing units can also be detached from the wing and float independently. The floating HydroVillage project could start very small with a few houses and farms and gradually become a complete village as more people became interested in living there and doing ocean farming.

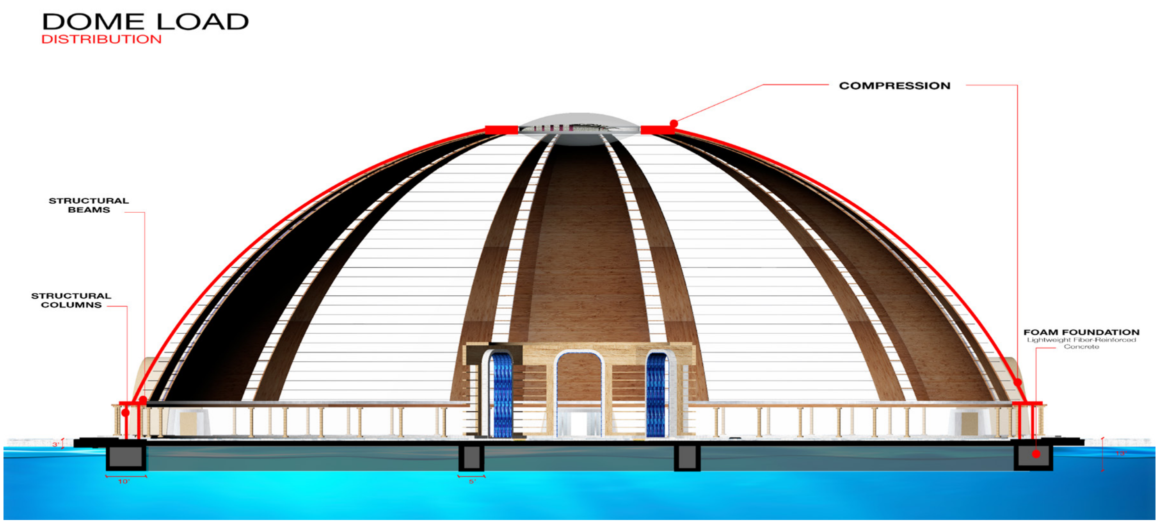


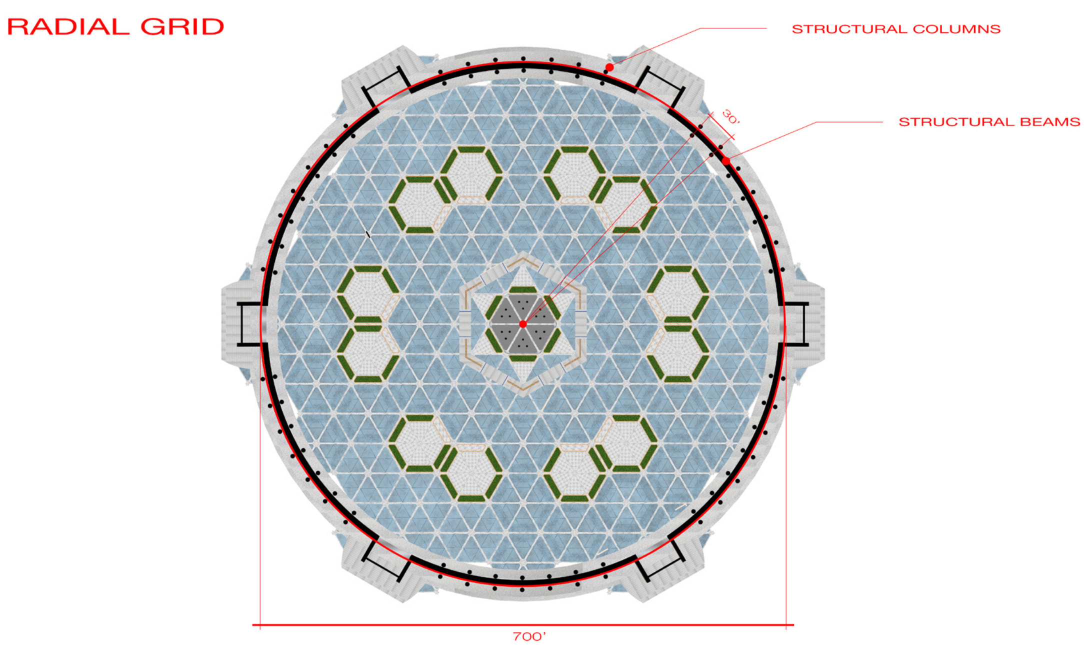


HydroVillage Programs

8.4 Calculations for Dome Foundation

After consulting with a structural engineer, I was able to show that the hexagonal floating foundation slabs that support everything in HydroVillage are adequate for the job, including being buoyant enough to support everything, including the central dome in HydroVillage. Here are the calculations, along with the results. Since the project is huge, calculations were only done for the dome.

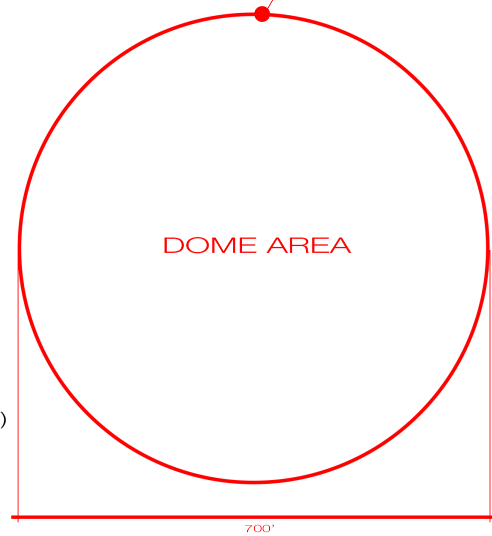




GIVEN

DIAMETER = 700 FT
DEAD LOAD (DL) = 12 PSF
PV PANELS = 3 PSF
LIVE LOAD (LL) = 20 PSF
OCEAN WATER DENSITY = 60 #/FT^3

PERIMETER $= \pi \times D$
$= \pi \times 700$ FT
= **2,199 LF**



① ROOF AREA

$= \pi r^2$
$= (350 \times 350) \times \pi$
= **384, 846 FT^2**

② ROOF GRAVITY LOAD

= AREA X (DL + LL)
= 384, 846 FT^2 X (35 PSF)
= **13,469,610 LBS**

③ GRAVITY LOAD/LINEAR FOOT @ PERIMETER

W/LF

$$= \frac{13{,}469{,}610\ \#}{2{,}199\ \text{FT}}$$

= **6,125 #/LF**

④ FOAM VOLUME

$$V_{\text{FOAM}} = \frac{6{,}125\ \#/\text{LF}}{60\ \#/\text{FT}^3}$$

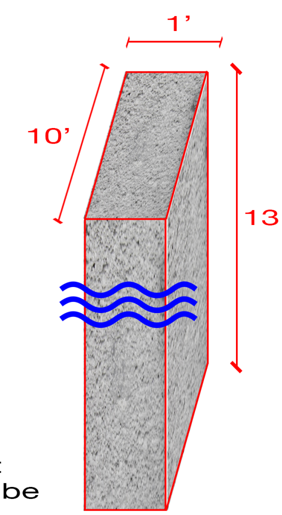
= **102 FT^3/LF**

CONCLUSION

For every pound of foam pressing down, sixty pounds of buoyancy is pushing it up.

FOAM VOLUME MINIMUM REQUIREMENT/CUBIC FOOT

V_{FOAM} = **102 FT^3/LF**



DOME FOUNDATION OF HYDROVILLAGE

In order to support the large dome, the volume of the foundation should be increased. In this case, we want 3' to rise above water surface, the final number would be a section that is 10' wide by 13' deep per linear foot.

FIND WHETHER THE FOUNDATION FLOATS OR NOT
BY COMPARING THE FORCE OF GRAVITY & THE FORCE OF BUOYANCY.

Archimedes's Principle stated that if the force of buoyancy is greater than the force of gravity, the object will float. On the other hand, if the force of gravity is greater, it will sink.

FIND THE FORCE OF BUOYANCY

$$F_b = F_g \times \rho \times V$$

$= (1027\ kg/m^3) \times (9.8\ m/s^2) \times (2.8\ m^3)$
$= 26{,}168\ kg.\ m/s^2$
$= \mathbf{28{,}181\ N}$

FIND THE FORCE OF GRAVITY ACTING ON THE OBJECT

$$G = (\text{Mass of Object})(9.8\ m/s^2)$$

$= (2{,}778\ kg) \times (9.8\ m/s^2)$
$= 27{,}224\ kg.\ m/s^2$
$= \mathbf{27{,}\ 224\ N}$

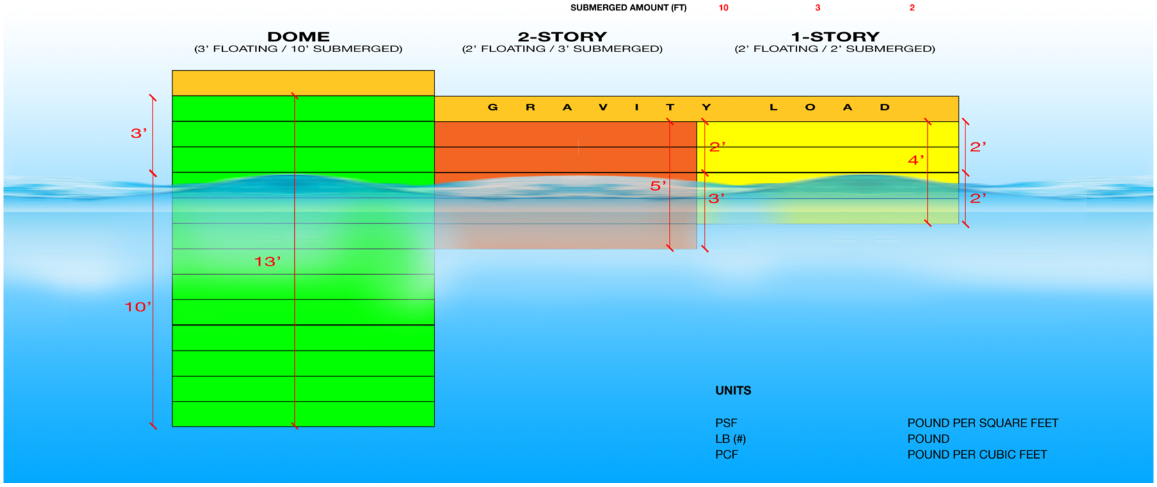
SUBMERGENCE DIAGRAM

TYPICAL HOUSE	ROOF (PSF)	FLOOR (PSF)
Live Load (LL)	12	25
Dead Load (DL)	20	40
PV PANEL	3	

GRAVITY LOAD

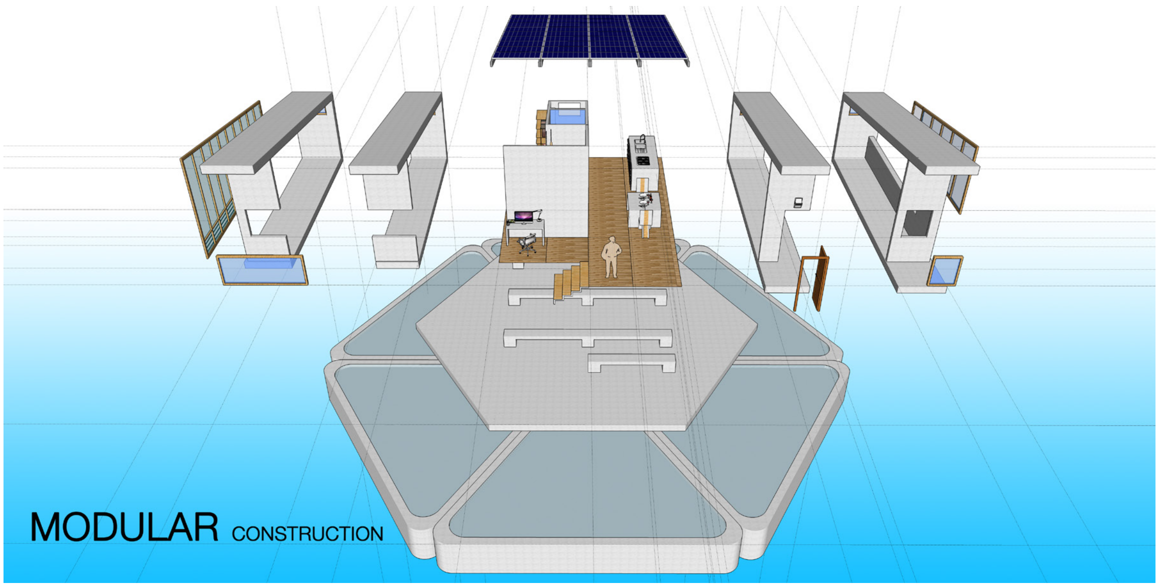
The total dead load plus the total live load make up the "gravity load" for any given structure.

	4-STORY DOME	2-STORY DOUBLE UNIT /LAB	1-STORY SINGLE UNIT
ROOF	1	1	1
FLOOR	4	2	1
	12	12	12
	20	20	20
	3	50	25
	100	80	40
	160	3	3
TOTAL (PSF)	295	165	100
SUBMERGED AMOUNT (FT)	10	3	2



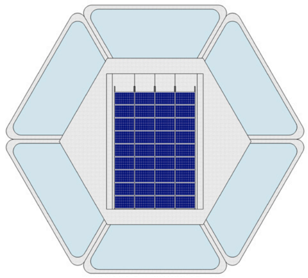
8.5 Housing Units, One (Single) and Two (Double) Bedrooms

The housing units would be available in two styles and sizes. One is a one story unit, and one is two stories. The one-story unit provides about 800 sq. ft. of living space, while the two-story version provides about 2000 sq. ft. Features of the housing units include full bath, kitchen, dining, sleeping area, storage, and so on. Roofs are covered with solar panels. The housing units are all modular and would be constructed off site. The modular construction contains built-in furniture, bathroom fixtures, and everything needed to walk in and be at home. Housing is located along the sea farm areas so that the farmers and researchers basically live and work in the same place.



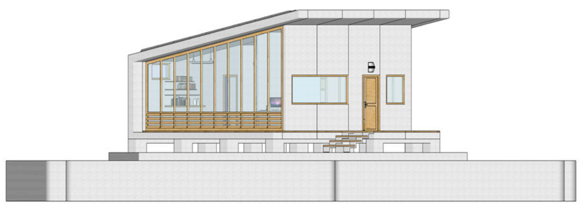
On the east and west sides of the housing units and labs, there are large windows with a minimal amount of shading in order to maximize the view of the outdoors. To do this, a new kind of glass that is part of the Curtainwalls System called View Dynamic Glass will be used at HydroVillage. This "intelligent" glass adjusts to the sunlight throughout the day to provide the best lighting for residents without restricting the views of surrounding nature. It has four levels of setting which can be set to automatically adjust or the settings can be controlled by an app from a smartphone. To watch a video about View Dynamic Glass go to: http://viewglass.com.[249]

249 View Dynamic Glass, "A More Intelligent Window." Last Modified December 10, 2015. http://viewglass.com. (Accessed February 17, 2016.)



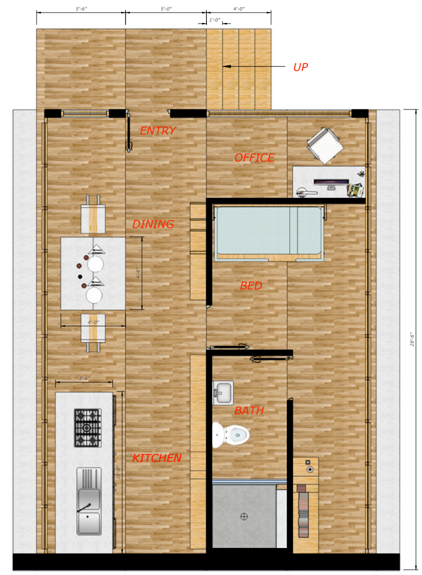
ROOF PLAN

SCALE: 1/8" = 1' - 0"



PERSPECTIVE

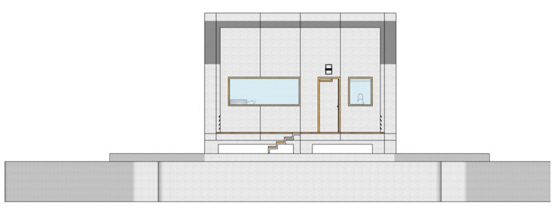
SCALE: 1/4" = 1' - 0"



FLOOR PLAN

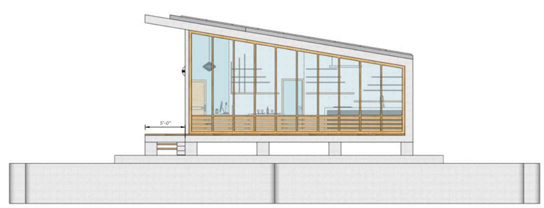
SCALE: 1/2" = 1' - 0"

SINGLE UNIT ROOF PLAN/FLOOR PLAN/ PERSPECTIVE



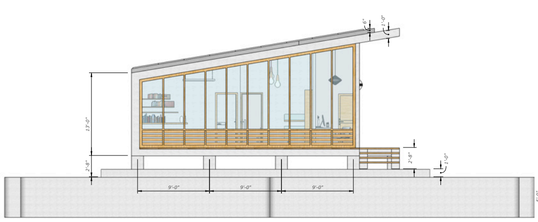
NORTH ELEVATION

SCALE: 1/4" = 1' - 0"



EAST ELEVATION

SCALE: 1/4" = 1' - 0"



WEST ELEVATION

SCALE: 1/4" = 1' - 0"

SOUTH ELEVATION

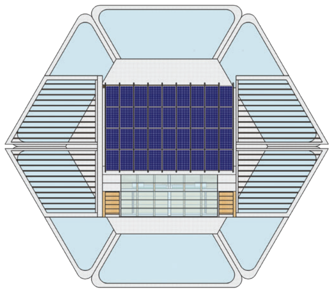
SCALE: 1/4" = 1' - 0"

SINGLE UNIT ELEVATIONS

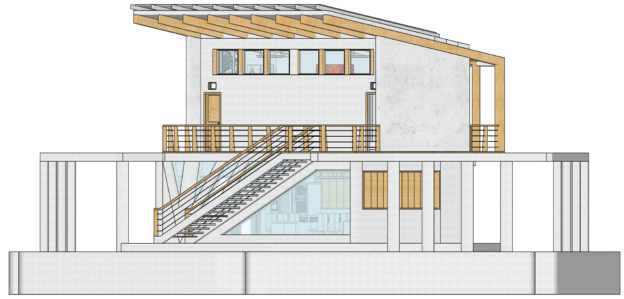
Architectural Drawings: Single Unit

Single Unit Interior Rendering.

Single Unit Exterior Rendering.

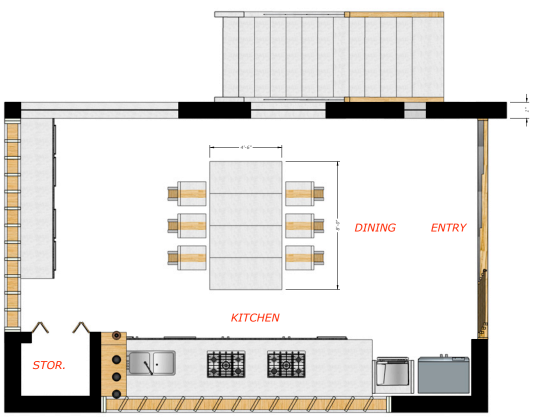


ROOF PLAN
SCALE: 1/8" = 1' - 0"



PERSPECTIVE
SCALE: 1/4" = 1' - 0"

DOUBLE UNIT ROOF/PERSPECTIVE



1ST FLOOR
SCALE: 1/2" = 1' - 0"

2ND FLOOR
SCALE: 1/2" = 1' - 0"

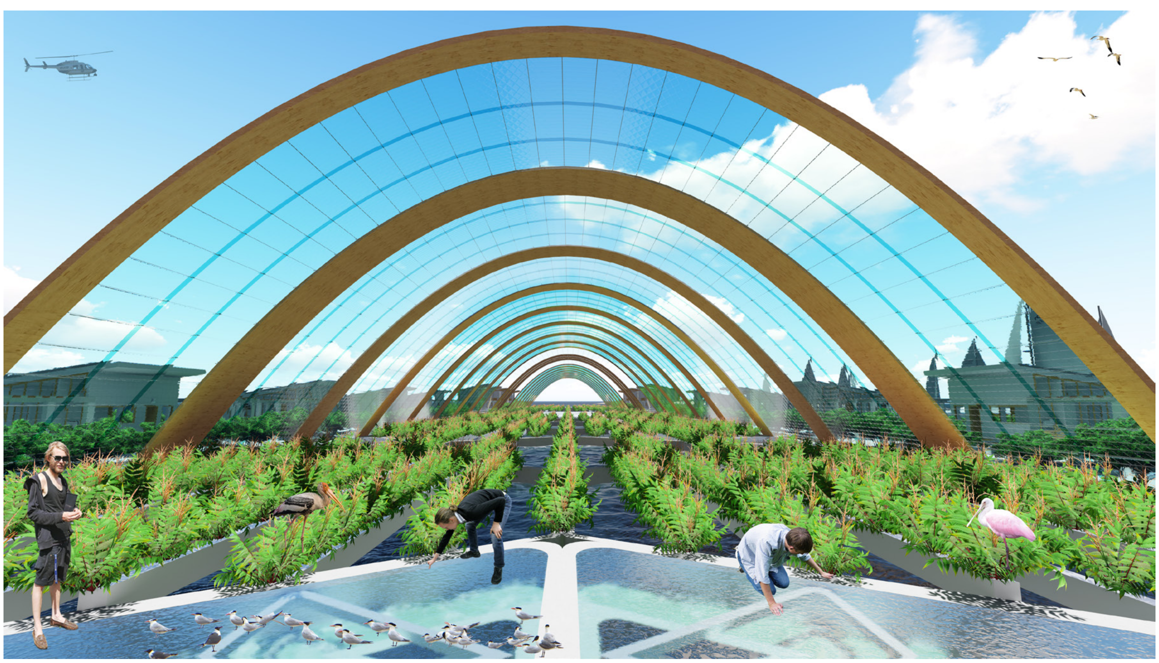
DOUBLE UNIT FLOOR PLANS

Architectural Drawings: Double Unit

Double Unit Interior Rendering.

Double Unit Exterior Rendering.

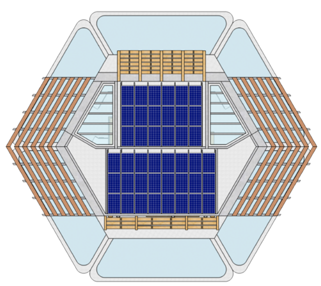
Initially the focus of the farms would be on shellfish and a few kinds of seaweed to determine which are most suited for life in the lagoon. Later different varieties could be studied so that a variety of products would eventually be produced. If chosen wisely, the food crops could even help remove pollution from the water of the lagoon.



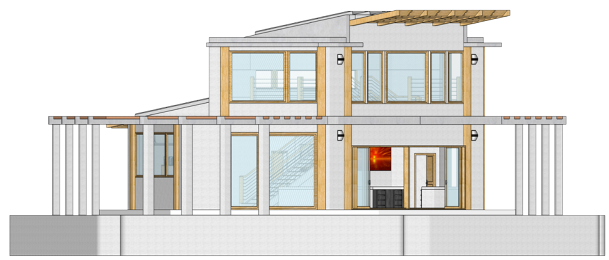
Farm Area

8.6 Science Labs

The science labs would be available in one style of versatile, two-story units. Each unit would provide about 1500 sq. ft. of workspace. Modern, sustainable ocean farming requires careful research, a lot of trial and error, and finally the effort of actually producing products. The science labs are designed to support the HydroVillage ocean farms. Researchers from the University of Hawai‘i could be involved in the research and work of ocean farming.

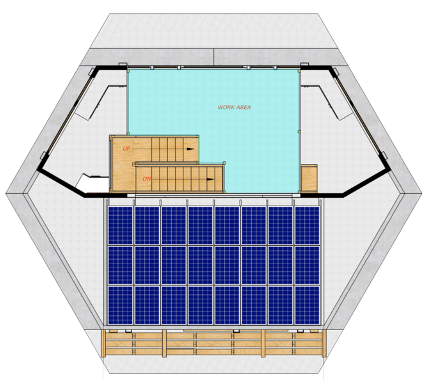


ROOF PLAN
SCALE: 1/8" = 1' - 0"

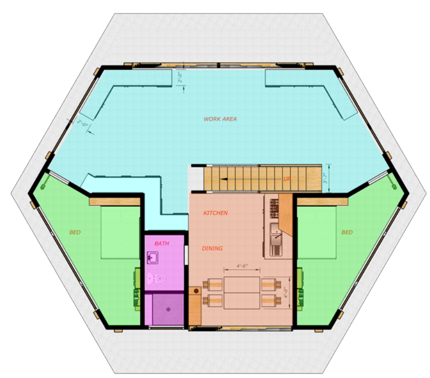


PERSPECTIVE
SCALE: 1/4" = 1' - 0"

SCIENCE LAB ROOF PLAN/PERSPECTIVE



LOFT FLAN
SCALE: 1/4" = 1' - 0"



1ST FLOOR PLAN
SCALE: 1/4" = 1' - 0"

SCIENCE LAB FLOOR PLANS

NORTH ELEVATION
SCALE: 1/4" = 1' - 0"

SCALE: 1/4" = 1' - 0"

WEST ELEVATION
SCALE: 1/4" = 1' - 0"

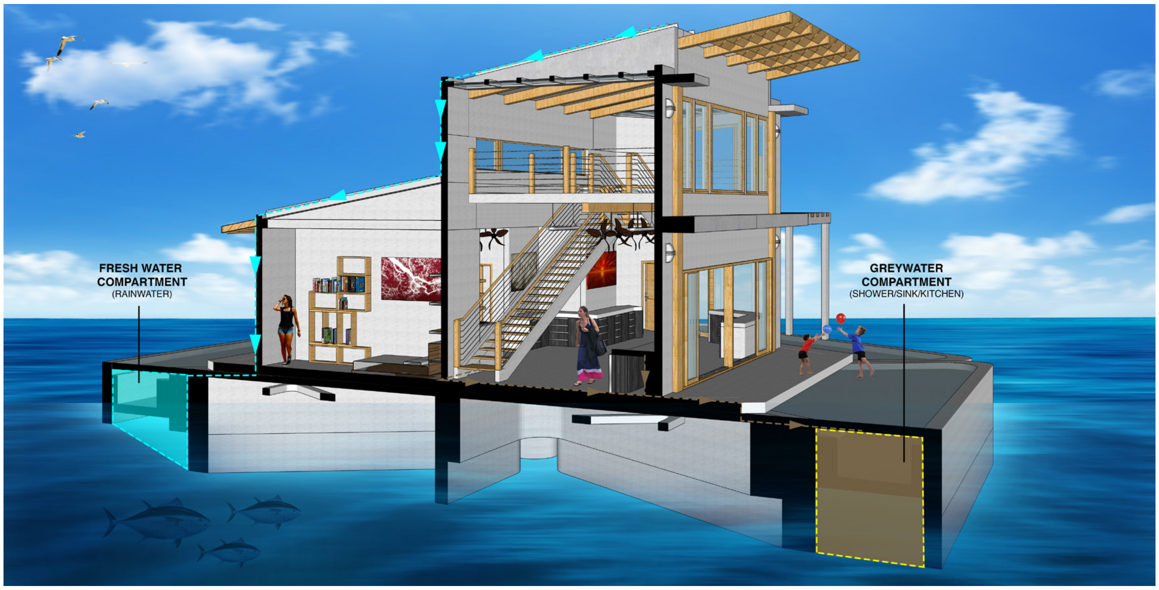
SOUTH ELEVATION
SCALE: 1/4" = 1' - 0"

SCIENCE LAB ELEVATIONS

Architectural Drawings: Science Lab

Science Lab Interior Rendering.

Science Lab Exterior Rendering.



Perspective section cut of lab unit.

The picture above shows a lab and its water catchment system. The water is caught on the roof and moves down to a storage tank where the water is kept until it is needed. At that time, it will be pumped, through a system of filters, back into the lab. Another storage tank is used to store greywater from the kitchen, showers, and sinks for future irrigation. (There is no sewage since the decision has been to use, at least for now, incinerating toilets for labs and residences.) A third tank holds a battery to store excess power. It is, of course, waterproof, and can be accessed only from the top. Another advantage of having a storage battery inside the floating foundations is that being submerged, will help keep the temperature of the battery down.

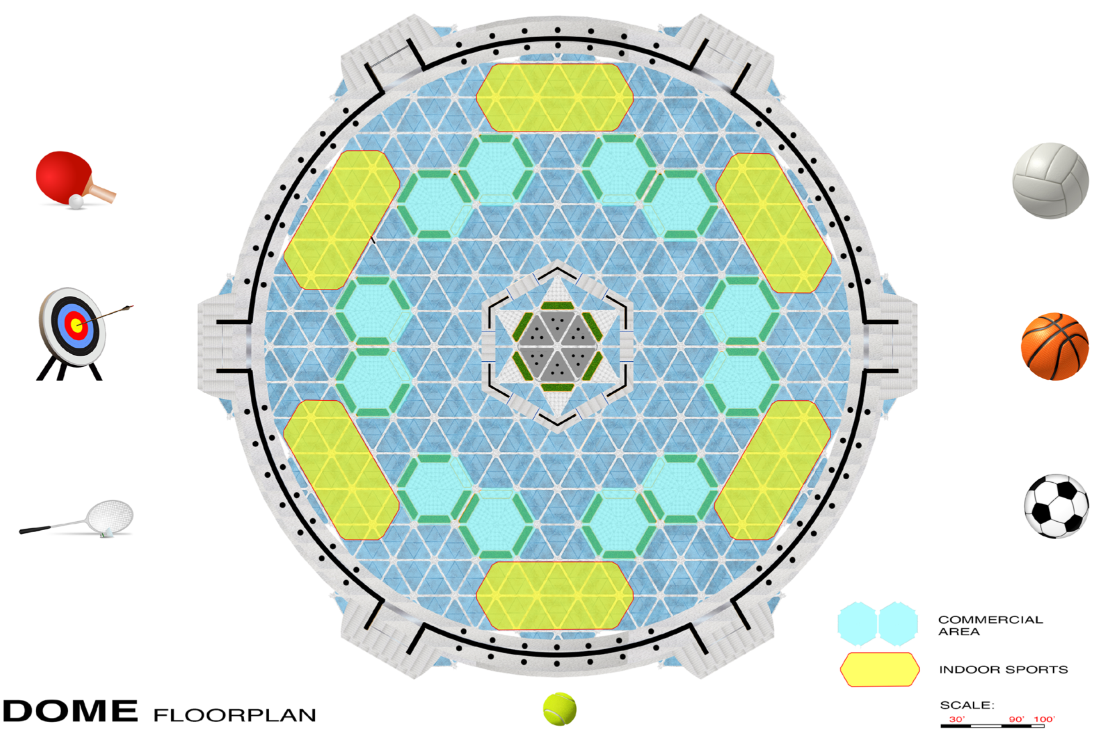
In addition to studying which sea species would grow best in the HydroVillage farms, researchers could study which land-based vegetables can grow in saltwater. Dutch farmers, for example, have discovered that some varieties of potatoes thrive when grown in salt water, as do carrots, cabbage, onions, and beet roots.[250] Finally other people (business specialists) would focus on marketing strategies to insure the products produced were products people would really want to buy.

250 Putic, Georg. "Dutch Experiment Shows Farming With Salty Water Possible." Voice of America. Last Modified November 5, 2014. http://www.voanews.com/content/farming-with-salty-water-is-possible/2510044.html. (Accessed February 17, 2016.)

8.7 A community center

At the center of HydroVillage there is a large domed area, that serves as a multipurpose community center. The size of the dome is roughly the size of the Neal Blaisdell Center. It's a large area because it is the center for everything that takes place in HydroVillage. It is divided into sections by movable walls to accommodate a wide variety of activities and programs. It could, for example, house office space for the board that governs HydroVillage.

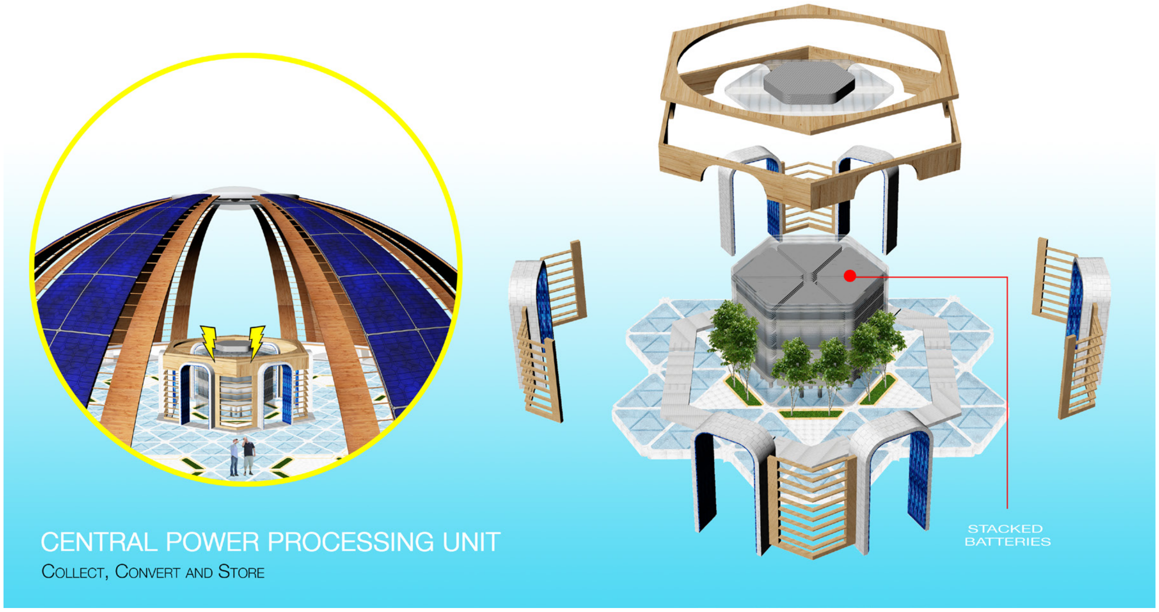
It could provide an "open-market" area to sell products from the farms. It could provide a shopping area with third party small businesses from clothing to sports equipment. It could provide an area for restaurants, another for movies, and some areas can be given over to indoor sports, including tennis, basketball, ping pong, and so on. Small garden areas and parts areas could be scattered throughout, so that one is never out of sight of greenery.

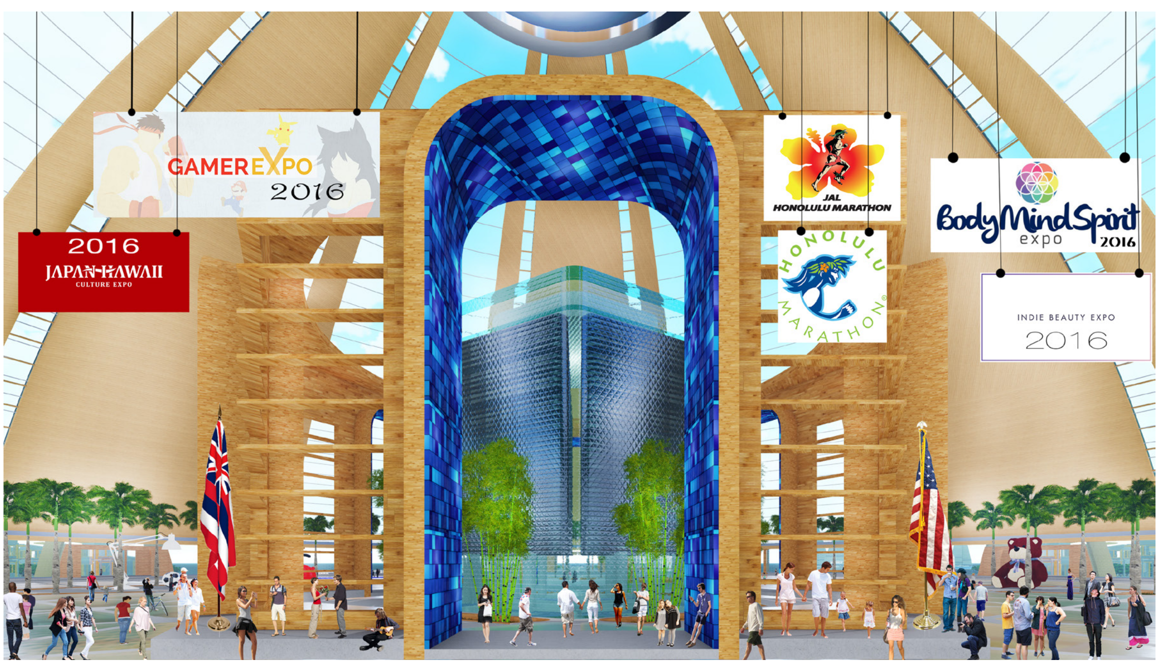


Dome Entrance

Dome Indoor Sports Area

On the dome roof, there is a huge array of thin-film PV modules to take advantage of the sun's power to provide energy for all activities inside the dome. In the center of the dome, there is a central power processing unit, which collects, converts, and stores energy for later use. Excess energy from the dome will also provide power to the farm areas.

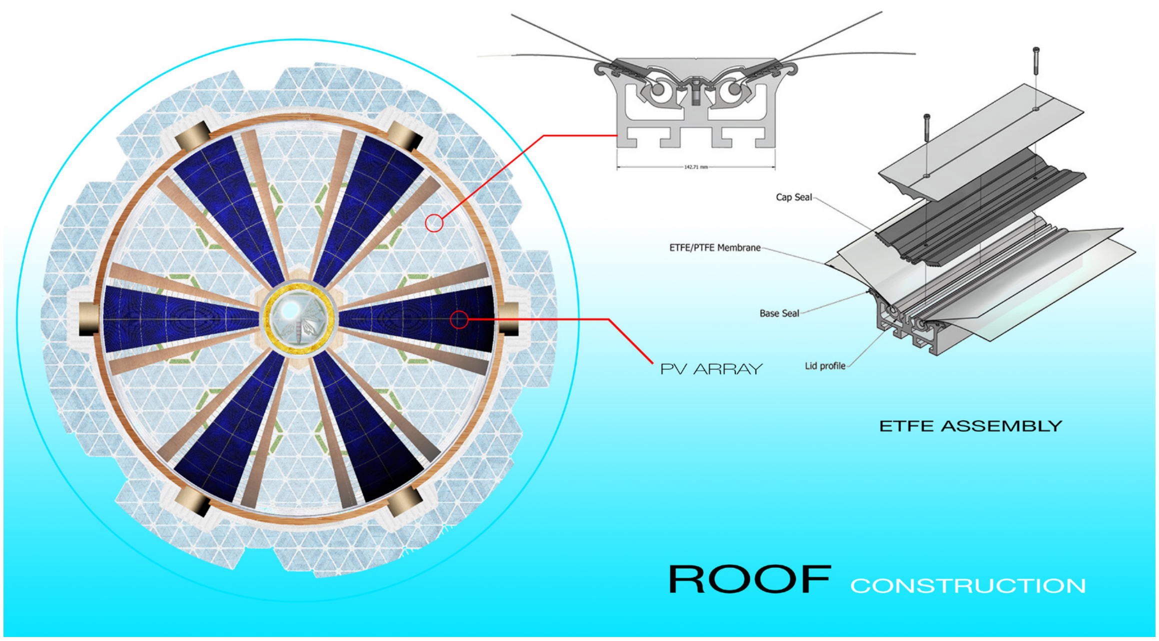




Dome Central Process Unit

8.8 Roof Construction for the Dome and Farm Areas

The dome itself is covered with alternating panels, one of which is a PV array to take advantage of the sun. The other panel is made of ETFE film which is a new material used for covering overhead areas in building construction. It looks like plastic film, but instead is thick, strong, and extremely lightweight, making it, according to the company that makes it, require less structural steel for support. It is unlike glass in that it is shatterproof so if it is broken there are no sharp shards. Like curved glass, this film produces a bright and open space producing a feeling of being outdoors. It has self-cleaning capabilities, and will last a minimum of 20 years. When the two or three-layer model is used, it is a great source of insulation. Finally it is highly recyclable.[251]

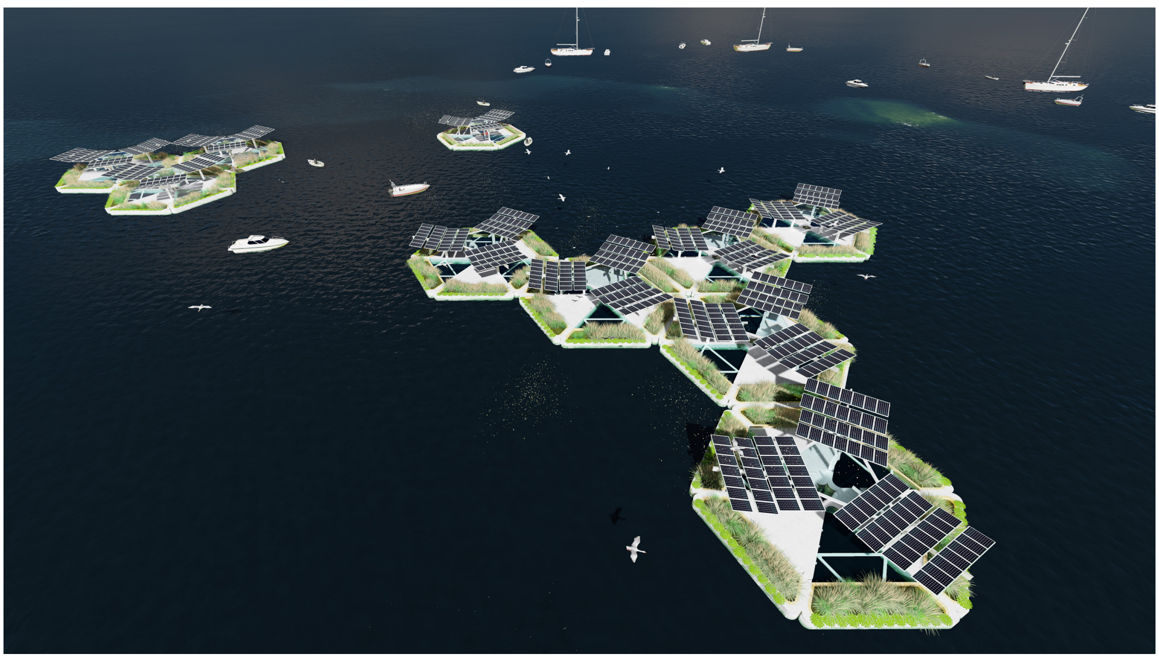


Roof Assembly

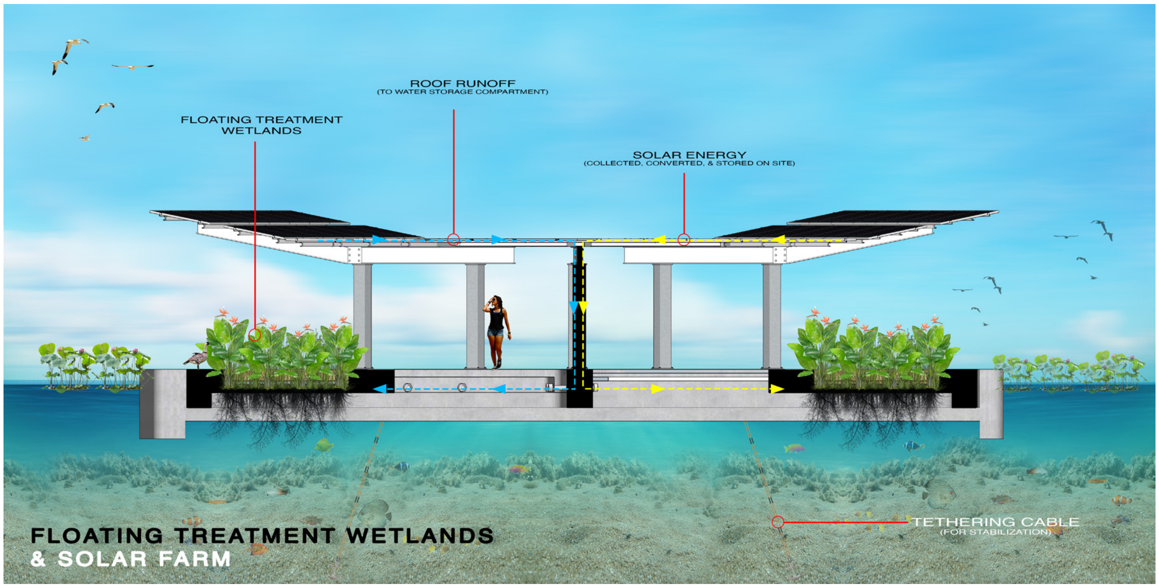
251 Birder.com, "What Is ETFE Film?" Last Modified December 2, 2015. http://www.birdair.com. (Accessed November 23, 2015.)

8.9 Floating Power Farms, Rainwater Catchment Pavilions, and Floating Constructed Wetlands

As discussed in the last chapter, small floating islands can be created by combining a limited number of floating slabs. In addition to cleaning pollution from the lagoon, they can be used to generate additional power and produce additional fresh water. These floating islands can be designed as pavilions, and can add a touch of landscaping to the village and provide park-like green areas to encourage residents to enjoy the outdoors. Illuminated at night, and reflecting in the water, they would very much enhance the overall natural beauty of the site.



Floating Treatment Wetlands with Solar Panels



Floating Treatment Wetlands with Solar Panels Section

Floating Treatment Wetlands with Solar Panels Perspective Rendering

8.10 The Potential of HydroVillage

HydroVillage has the potential to provide a satisfying lifestyle for a number of people. Not only will living on the water make residents feel closer to nature, they will live within walking distance of their places of work. The work itself will be satisfying because it will be providing more local food for Hawai‘i residents plus its research and development will be coming up with new and useful ways to produce food from the ocean in an ecologically sound way. Of course, recreation and entertainment will always be available to its residents.

Hopefully the design of HydroVillage itself will inspire others to do similar or wildly different things in the future. All of our creative energies will be needed in the coming years to deal with climate change and all of the things it is bringing.

8.11 HydroVillage as an Example of Innovation in Design

There are number of ways to define “innovation.” One definition (from this writer) is “Innovation is the process of combining old ideas into something entirely new.” From that we can say, “The combination of ideas here is very innovative.” We can also say, “This is a very innovative product.” With that definition in mind, let’s take a look at what might be considered innovative in HydroVillage, considering both the place itself and things that could go on there.

8.11.1 The Foundation

The floating foundation for HydroVillage is innovative. Floating structures have to have floating foundations, and, as mentioned in this research paper, there are a number of different kinds of floating foundations that are currently being used.

One is a combination of lightweight fiber and reinforced concrete that is shaped like a bathtub with the inside of the “tub” being submerged under the surface of the water, like a basement of a land-based structure.

Another is a combination of lightweight fiber and reinforced concrete that is put together in flat layers like a cake. These are made in various sizes to accommodate whatever the size of the structure above might be, and can be joined to similar foundations to support larger structures.

The difference in the HydroVillage design, however, is that the foundation is considerably thicker (up to eight feet thick) and the hexagon itself is divided into six sections. Three of the sections carry tanks that can be used to store fresh water, grey water, and energy stored in batteries. Three of the sections are covered with translucent material to allow light to penetrate into the lagoon itself.

After two years of combing through the literature, the writer has, so far, found nothing similar to the floating foundation of HydroVillage with its embedded storage tanks, and that makes this type of floating foundation truly innovative in that it provides for storage in a way that doesn't spoil the aesthetics of the surroundings and doesn't take up valuable surface space.

8.11.2 Floating Islands

Due to the flexibility of design that the hexagonal floating slabs provide, the designs for the small floating islands that produce additional energy, harvest extra water, and provide wetland treatment are all totally innovative. Small islands that are covered with plants for wetland treatment can be designed as small attractive parks that just happen to produce additional energy and/or to harvest fresh water while, at the same time, providing places for residents to stroll around and enjoy the outdoors or provide lookout points for attractive views of HydroVillage and its surroundings. Illuminated at night, and reflected in the water, these small islands would provide residents with breath-taking views of the Ke‘ehi Lagoon.

8.11.3 Floating Community with Housing and Aquaculture

The literature has a lot of available information and resources related to floating communities, floating houses, and sea farming but this writer has seen nothing that combines them or connects any of them together. In that sense, HydroVillage is a truly unique and innovative design. It perfectly illustrates the writer's definition of innovation as "the process of combining old ideas into something entirely new."

8.12 Concluding Remarks

I tend to agree with President Obama that sea level rise will open up a lot of new economic opportunities, especially in the area of alternative energy sources. I also think that no matter how bad the situation actually gets, there will also be much good that will come out of the changes we face this century. I think it is important for people to educate themselves about what is going on, and what is likely to happen in the future. It is absolutely true that each bit of knowledge we can gain makes us stronger and encourages us to participate in positive change.

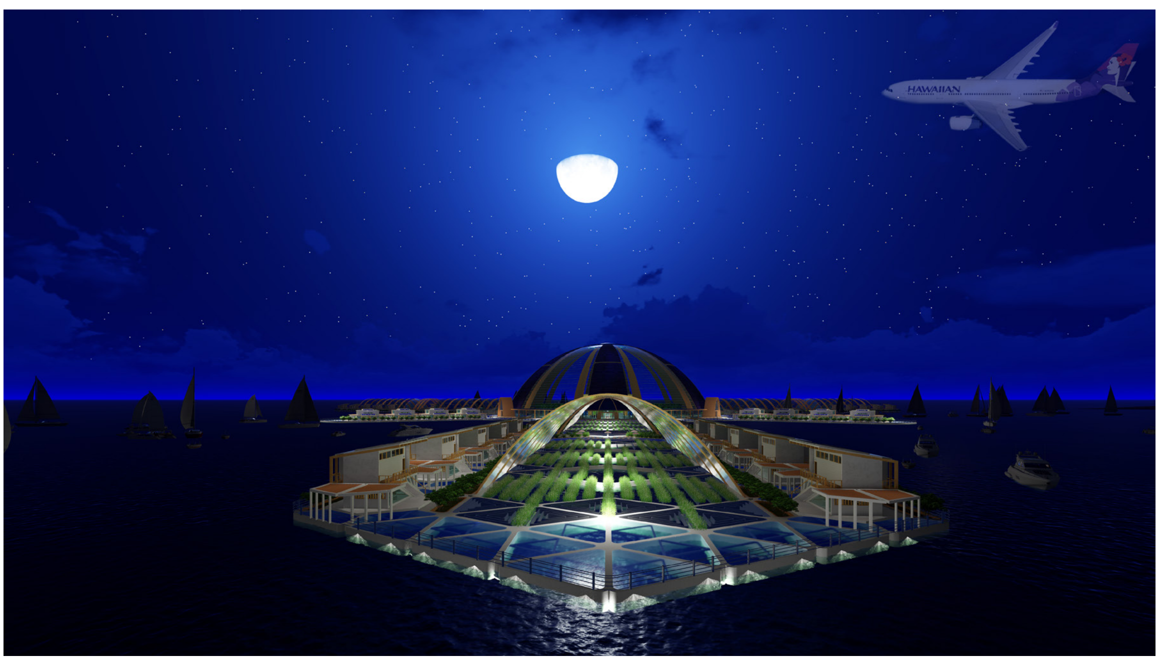
When I first became interested in sea level rise and floating architecture, in the spring of 2014, the available information was limited and not always reliable. Now, exactly two years later, there is a wealth of information at everyone's fingertips that is constantly developing and evolving. Anyone can learn absolutely cutting-edge information about this subject by just simply going online. Granted, the information still isn't 100 percent reliable all the time, but through using the Internet, one soon learns to distinguish between what is a reliable site and what isn't.

The thing that sets the Internet apart from printed materials is that when something happens, or when something new has been discovered, it can be shared instantly with the world. We have more reliable, solid knowledge available at our fingertips today than anyone in the past ever dreamed possible.

I want readers of this thesis to be keenly aware of this because the subject of rising sea levels and dealing with that fact is just getting started, and will continue to develop this century at an ever-increasing pace. The topic of climate change is so extremely important, it is absolutely critical that the public makes an effort to keep up with whatever is actually going on and avoid being deceived again by the oil companies, as has been alleged.

I also hope that I will have convinced at least some readers of this thesis that floating architecture can and should, in fact, be one mitigating factor in dealing with sea level rise in Hawai‘i. Anyone who has read this thesis is most likely connected to architecture and architecture is what we can use to help to keep the world livable and perhaps keep Hawai‘i the unique and beautiful place that it is today.

During these two years, through my own efforts, I have learned enough to be able to design the basic elements of a viable, workable, (almost) self-supporting community. Almost none of the subjects discussed in this thesis ever appeared in any of my design classes, and though I am still learning, I now have a lot to say when the subject of sea level rise comes up, and what positive things can be done to mitigate the situation from an architectural point of view. I said earlier, in the introduction, that the underlying research question that has driven this research since I began in 2014 is this: Is floating architecture one viable response to sea level rise in Hawai‘i? Two years after asking myself that question, I am, without a doubt, convinced that it is.



HydroVillage at Nighttime

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