THE SEASTEADING INSTITUTE

The Floating City Project

Research Conducted between March 2013 and March 2014

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The first floating city
with significant political autonomy
could be established by 2020.

Key Findings

1. A market for a residential seastead exists.
2. A practical design can be built to match the market's price point.
3. It is likely that the Seasteading Institute can reach a deal with a host nation willing to grant a floating city substantial political independence.

Executive Summary

- The Floating City Project presents a practical path to establishing the first floating city with considerable political autonomy.
- We have concluded that it would be possible to station a floating city in the calm territorial waters of a host nation in order to reduce the costs of the structure compared to constructing for the open ocean.
- A coastal nation may be interested in offering to host a floating community in their territorial waters and allow substantial political independence in exchange for economic, social, and environmental benefits.
- At the time of publication of this report, we are engaged in high level talks with a potential host nation, and entry level talks with others. When we close a deal with a host nation we will make an announcement.
- We commissioned the Dutch aquatic engineering firm DeltaSync to produce a design and preliminary feasibility study for the Floating City Project, wherein they project that 50-meter-sided square and pentagon platforms with three-story buildings could be constructed for approximately $500/square foot of usable space. A square platform could house 20-30 residents; and cost approximately $15 million. A sea-village in a tropical location could feasibly power itself almost entirely with renewable energy.
- Potential residents from 67 countries and many income levels provided extensive feedback on what they desire from a floating city with political autonomy, and their requests are remarkably consistent.
- The market demand for the first floating city with some level of political independence is vigorous and growing.
- The Floating City Project will serve as test-case for a floating experiment in governance. If it prospers, the incentive to solve more ambitious engineering challenges on the high seas will be engaged.

Introduction

The Seasteading Institute was founded as a think tank in 2008 to enable the establishment of permanent, floating communities – "seasteads" – to experiment with innovative, alternative forms of government. After five years of foundational research supported by the social and intellectual capital of our large network of supporters, we are working to launch the world's first floating city. Our conviction is that by developing seasteads which will utilize the broad parameters of law offered by the freedom of international waters, the world's greatest moral imperatives can be addressed through experimentation with innovative, new forms of government.

Goal of the Floating City Project

The primary objective of the Floating City Project was to identify a method to start seasteading that is desirable and affordable to the market base of potential full- and part-time residents.

Rationale

The idea of ocean colonization is no longer the domain of science fiction writers, utopian dreamers, and scheming free-wheelers.[1] The cruise ship and offshore drilling industries demonstrate that temporary living on the sea can be profitable, peaceful, and even luxurious.

The Seasteading Institute has taken up the challenge to enable more businesses to be commercially viable on the open seas, either on ships, platforms, or other novel designs. We promote aqua farming, mariculture, floating hospitals, medical research, “bluegreen energy” technologies, political asylums, or any other peaceful enterprise. If these ventures succeed and create jobs and thriving communities, seasteads will provide prosperity to a new wave of immigrants.

If ocean pioneers develop superior models of governance, governments on land may take notice. The precedents of the Cayman Islands, Hong Kong, Singapore, and the African island of Mauritius demonstrate that small islands nations can compel larger governments to alter their policies. If seasteads demonstrate superior governance practices, all governments may be compelled to experiment, iterate on basic functions, and innovate with new policies to keep up with seastead competition for businesses and talent.

Our supporters tend to view government as an industry, lacking competition due to high “barriers to entry.” In other words, it’s exceedingly difficult to enter the government industry and offer a government startup.

Seasteads, by their very nature, would provide citizens with the technology to move fluidly among governments. In the seasteading model, citizens would take on the role of customers,

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[1] A rich history of past seasteading and other attempts to create new nations is available in Erwin Strauss’ classic, “How to Start Your Own Country.”

choosing their government according to their unique preferences. If modular ocean homes and offices are mobile and can be reassembled according to individual preferences, small groups of entrepreneurs and investors can feasibly build “startup” societies on earth’s last unclaimed frontier. Thus seasteading attempts to transform a political problem into an engineering challenge. Whereas solutions in politics continue to elude even the most competent technocratic managers, relatively small groups of people have proven highly adept at solving complex engineering problems.

The strategy of The Seasteading Institute has always been to start small, grow incrementally, and employ reliable technologies that currently serve ocean industries. Through this project and previous research by the Institute it became evident that the jump to an autonomous man-made island on the high seas was itself a formidable barrier to entry. It is difficult to overcome the high cost of engineering structures that are capable of withstanding the ocean's elements - waves, wind and corrosive seawater - while remaining comfortable enough to live on for extended periods of time.

At the same time, our movement has grown steadily and thousands of people around the world are looking to the Institute to lead the way to colonizing the ocean.

With the long-term vision always in mind, we have investigated practical, incremental, and politically-inspired seasteading approaches. The challenge for the Institute has been to render seasteading affordable while seeking unprecedented political independence. The Floating City Project has made progress on both these fronts.

Reducing the Barriers to Startup Nations-- Before the Stride, Take the Step.

Near the beginning of this project we had an "aha moment", where we concluded that one path to reducing the barriers to seasteading would be to establish a floating city in the calm territorial waters of a host nation, in essence marrying the seasteading concept with the startup cities concept[2]. We posited that a host could welcome a seastead with substantial political autonomy in their waters in exchange for the economic, social, and environmental benefits of having the seastead as a neighbor. The host would reap these benefits without displacing any of its citizens, and the residents of the seastead could more easily travel and engage in commerce by being closer to shore and the accompanying commercial entities.

A Corporate Entity to Develop a Floating City

As we move to the next stage of this project our key priority is to encourage the formation of a corporate entity to develop and manage a floating city capable of starting small and growing to accommodate the market demand of residents. The reasons for this are fourfold:

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[2] "Startup Cities are opt-in, competing communities for political and legal reform." see www.startupcities.org.

1. An increasing number of people wish to pioneer a new floating society;
2. When interviewed in the preliminary phase of this project, many potential seasteading pioneers and entrepreneurs expressed a strong desire to lease or purchase real estate for their residence or businesses on a seastead owned by a separate corporation, which would be responsible for construction, management and basic operation of the structure;
3. Despite significant environmental, geographical or jurisdictional advantages, the barriers to entry of operating a single-purpose business at sea are high when compared to land-based businesses. If one entity developed and managed the platforms, individuals could more easily bring their businesses and residents to the city ;
4. Many in our community expressed an interest in participating in the development of a floating *city*, rather than working or living on a repurposed ship (an idea the institute floated as an early step to seasteading).

Furthermore, pragmatism dictates that the seastead must be designed such that it can be built and operated within the financial constraints of the market. In order to substantially reduce costs associated with constructing and operating in the open ocean, we concluded that it will be more affordable to initially design for calmer, shallower waters found within territorial seas. We reached this conclusion after investigating costs and operating expenses of a semi-submersible platform designed to house residents on the open ocean (details of this investigation are included in this paper).

In order to move forward with this vision, we will need a coastal nation to cooperate by agreeing to host a floating city with substantial political independence within their territorial waters. Negotiations for such an agreement are underway at the time of the publishing of this report.

Objectives of The Floating City Project

The three primary objectives of this project are the following:

1. Establish evidence of market demand for a realistic and alternatively-governed seastead;
2. Produce designs and conduct feasibility studies for the structure itself;
3. Find host nations to harbor and offer substantial political autonomy to the seastead within their protected, territorial waters.

In the pages to come, we aim to establish the following:

1. There is reasonable evidence of a market for real estate aboard a floating city;
2. A seastead can be designed to meet the price point of the market;
3. A host nation may be interested in an agreement that offers a seastead substantial autonomy.

We believe that if these three statements can be reasonably well-established, our report will be used to prompt the formation of a corporation that will take the next steps to actualizing the floating city.

The Floating City Project Process

In order to achieve the objectives above this investigation including the following activities:

1. Investigated the costs of developing and maintaining a semi-submersible structure suitable for living safely on the open ocean outside of territorial waters.
2. Surveyed other attempts to develop ocean or similar residences to inform our prospects for developing a floating city.
3. Gathered market data.
    a. First we conducted extensive interviews with 12 people who expressed interest in living on a seastead and who had the financial means to contribute to the development of the seastead.
    b. We used the answers from the qualitative interviews to inform the creation of a quantitative survey
4. Investigated a modular design suitable for calm protected waters, which could expand over time.

Note that the remainder of this report is not produced in the chronological order of our work, rather we chose to present the data in a manner that emphasized the most important aspects first.

Conclusions

This Floating City Project set out to establish the feasibility of developing a floating city before the end of the decade. We affirm, based on findings in the main sub-sections of the report, that:

1. a market for a residential seastead exists,
2. a practical design can be built to match the market's price point, and
3. it is likely that the Seasteading Institute can reach a deal with a host nation.

Our conclusions on market demand were reached through a mix of qualitative interviews and quantitative survey data on the prospective customers, mostly comprising members of our extended community. While not all respondents claimed to be able to afford the price point determined through the modular floating city design, the shift in strategy towards locating in protected waters opened up the possibility of living on a seastead for a sizable segment of our audience. Further study will be needed to determine whether the modular concept would be suitable for a particular location, and this can only be confirmed after extensive oceanographic and environmental studies are undertaken. However, diplomatic results look promising in the regions most likely to serve as a host for The Floating City Project.

The next steps of this project appear to be twofold. First, it will be necessary to secure a letter of intent from at least one potential host nation, as a signal to investors and developers that the opportunity for an autonomous seastead is indeed available. Second, the results revealed in this report will be used to entice developers and investors (including the most dedicated prospective residents and businesses) in order to fund a detailed engineering report, specific to the chosen location, and an expanded marketing effort.

This report can be viewed as the first mile of the marathon. Each successive step will require additional commitments and resources from the primary stakeholders, namely potential pioneers, investors, developers, and the host nation. As the Institute has sought to be “cheerleaders” for this cause, we can now be said to be picking up the baton and starting the first leg of the race. The research and data below are our best effort to give a head start to the most dedicated members of community and network, and catalyze what we hope will be the world’s first seastead before the end of this decade.

Quantitative Survey Results

Qualitative data from in-depth interviews proceeded our quantitative data collection to gauge motivations of our most dedicated financially independent supporters, we also needed to demonstrate broader demand for our vision with a cross-sectional study of our community and wider online audience. Our aim was to collect data from people with the ability to afford a unit of a particular size, whose needs and desires align with one another and with those expressed in our qualitative interviews.

We offered a roughly 30-question survey with our Floating City Project, obtaining data from 1235 people interested in living on a floating city between May 17, 2013 and March 12, 2014. We cleaned our dataset by eliminating the small handful of answers from underaged or prank respondents. Our survey questions were written to elicit mainly quantitative metrics, with a few qualitative responses to gauge additional needs we may have overlooked in our survey design. We sought to first determine whether market demand exists for the floating city experience, at realistic prices to buyers. Second, we sought to find common denominators among those customers who expressed an ability to afford a unit that fits their needs. Not all questions were answered by all 1235 respondents.

Willingness to Pay

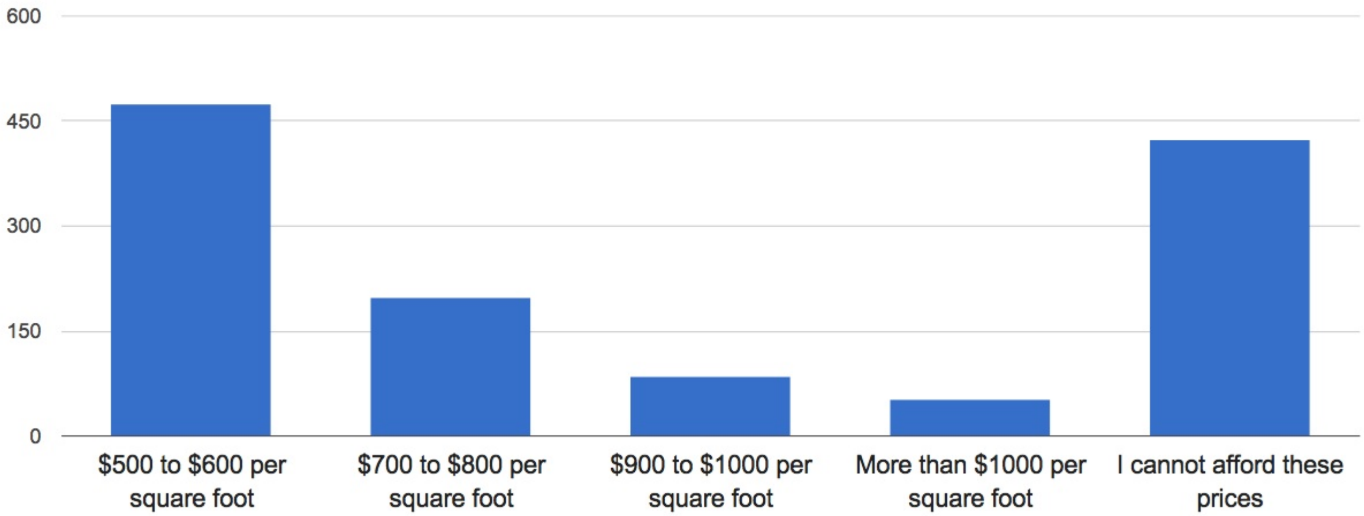
To determine the existence of a viable market, we asked our respondents the following:

"What is the MOST you would spend for a unit?"[3]

- ❑ *$500 to $600 per square foot*
- ❑ *$700 to $800 per square foot*
- ❑ *$900 to $1000 per square foot*
- ❑ *More than $1000 per square foot*

[3] Gaps between each bracket were intended to clearly distinguish the range of options.

The distribution of responses was as follows:



Desired Square Footage

Willingness to pay their maximum will depend on the size of their unit, and other features of the seastead. Accordingly, we then asked the following:

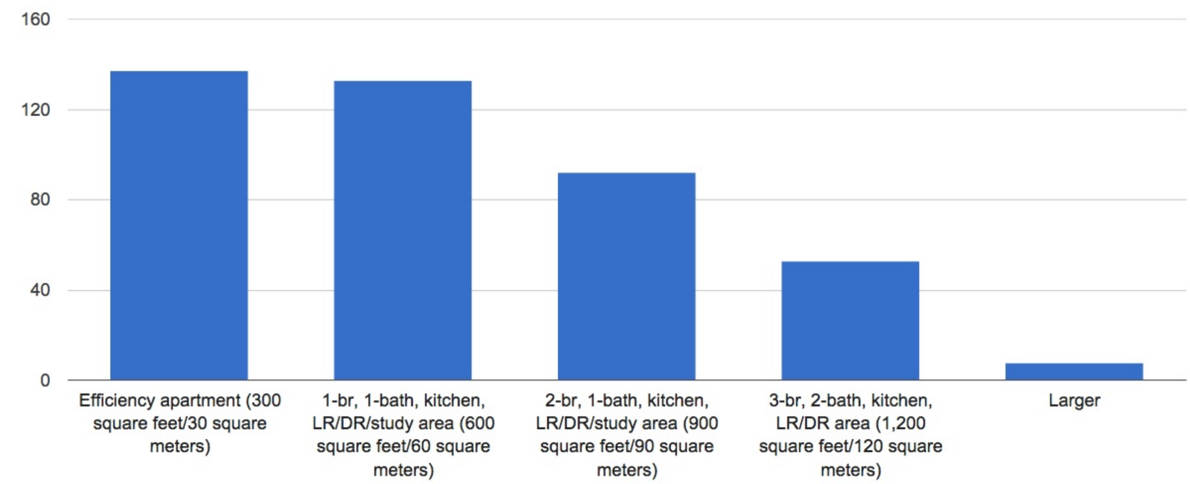
*"What is the minimum square footage you would want for your unit? *"*

- ❏ *Efficiency apartment (300 square feet/30 square meters)*
- ❏ *1-br, 1-bath, kitchen, LR/DR/study area (600 square feet/60 square meters)*
- ❏ *2-br, 1-bath, kitchen, LR/DR/study area (900 square feet/90 square meters)*
- ❏ *3-br, 2-bath, kitchen, LR/DR area (1,200 square feet/120 square meters)*
- ❏ *Larger*

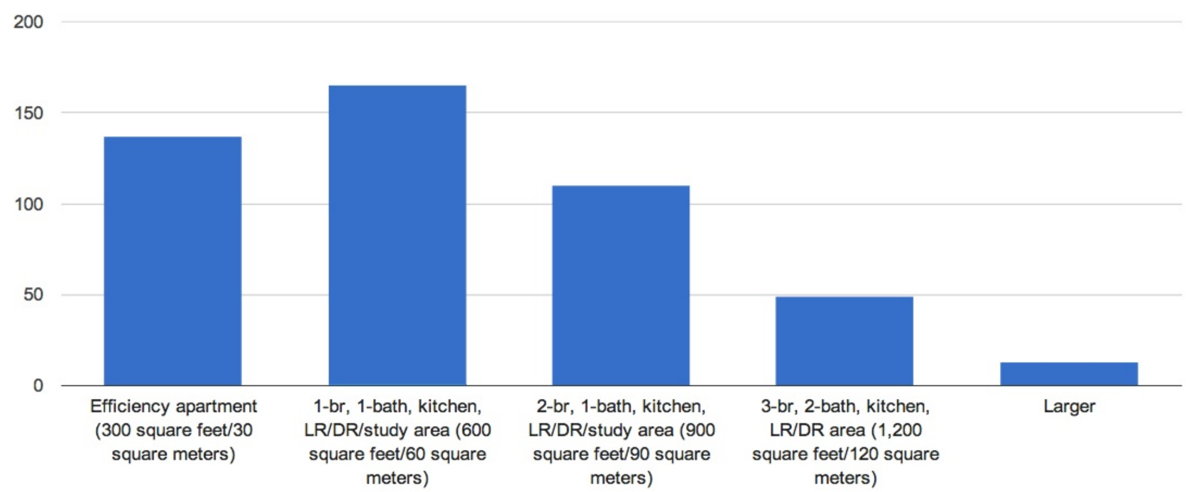
The distribution of all responses was as adjust follows:

The aggregate data is telling, and shows an overall acceptance of reduced living space. The most popular offering by far was a 60 square meter apartment with one bedroom, one bathroom, kitchen, living room, dining room and study area. However, to ensure that this result was not slanted by those on the lower end of the willingness-to-pay scale, we ran a filter on each range and found similar results for each bracket:

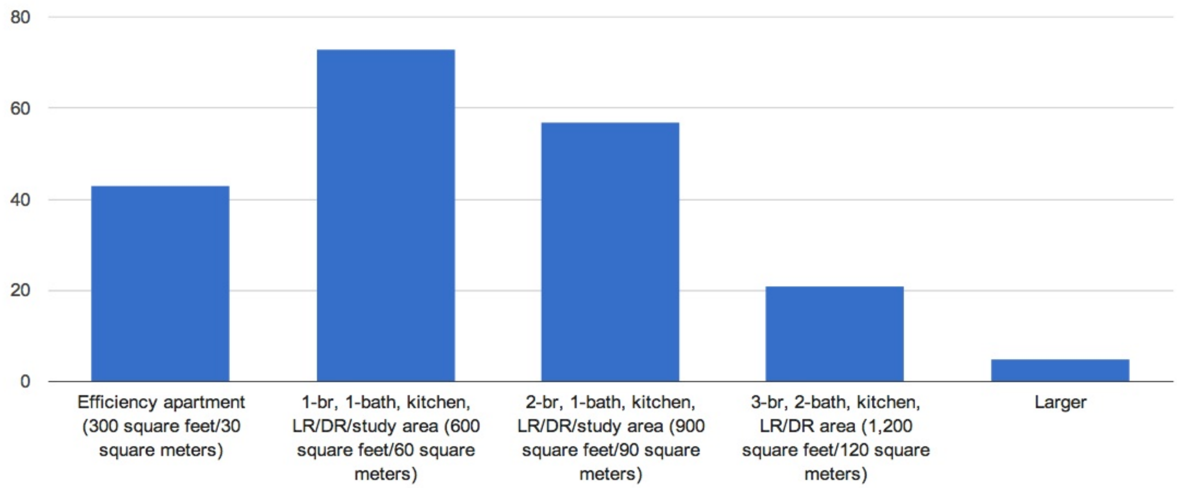
Cannot afford at least $500/sq foot



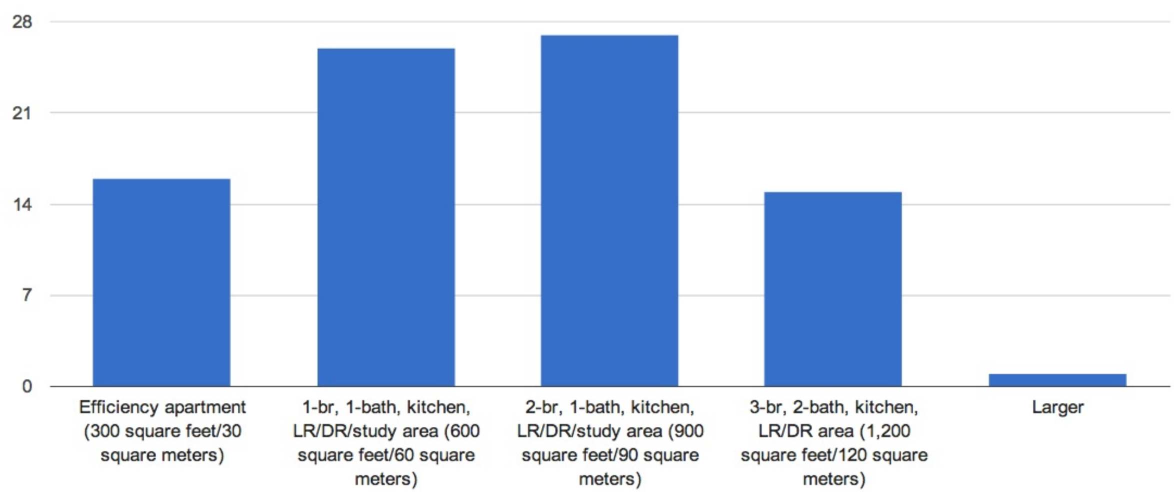
$500 - $600 / Sq.ft.



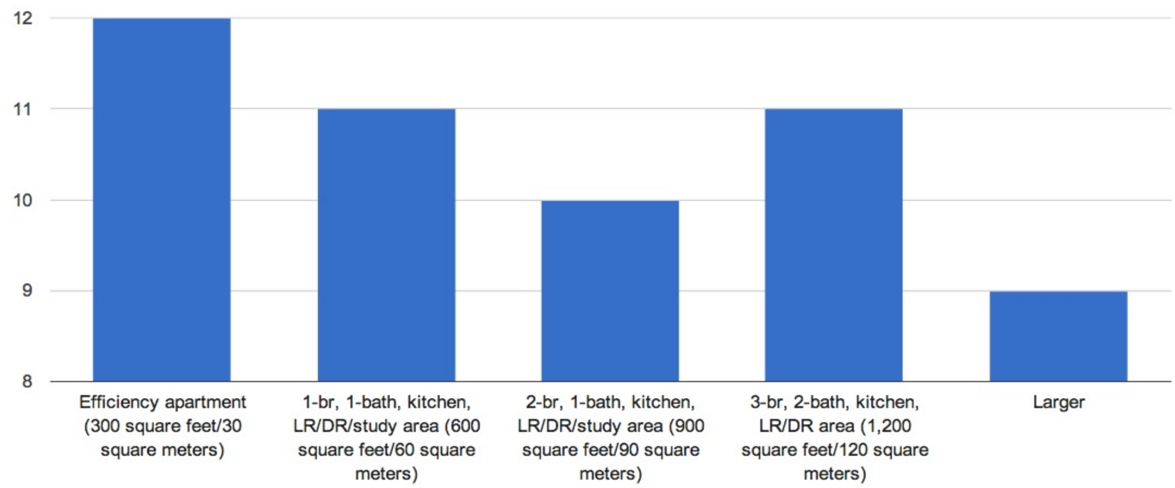
$700 - $800 / Sq.ft.



$900 - $1,000 / Sq.ft.



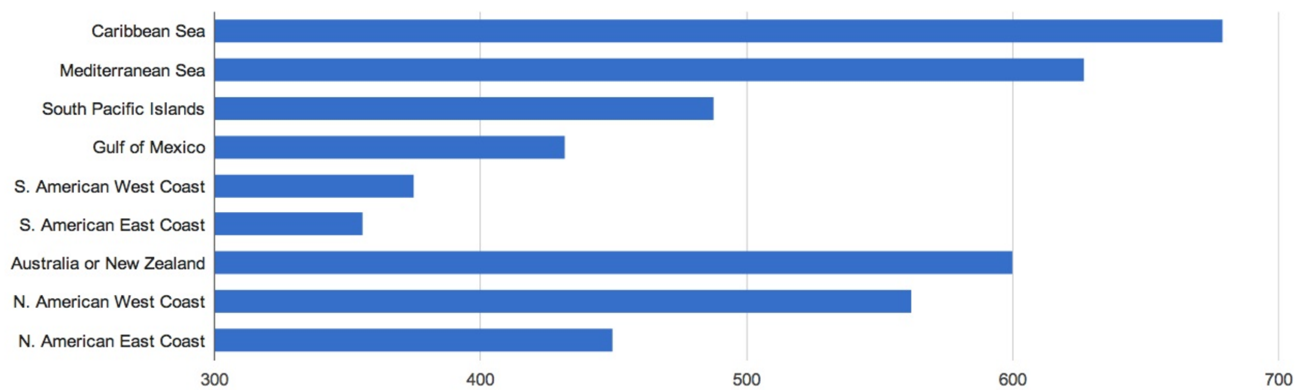
<u>Greater than $1,000 / Sq.ft.</u>



We can see that respondents willing to pay more have a slight preference for larger sized units, and vice versa, but the result remains surprisingly consistent, suggesting space is not a primary concern, so long as a minimum living area remains affordable.

Desired Location

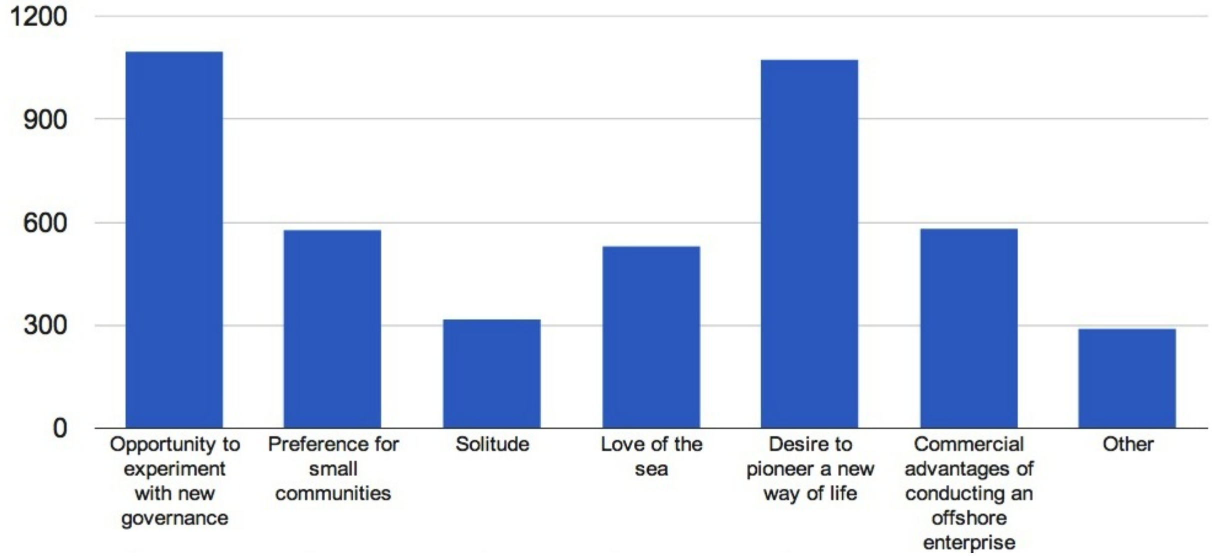
- The breakdown of preferred locations was as follows:



This criteria was used for the diplomacy component, in which we gave greater positive consideration to potential host nations within preferred regions. Respondents were allowed to pick as many locations as they liked. Warm climates like the Mediterranean and the Caribbean stand out as most popular, with a surprising number of respondents favoring "Australia or New Zealand," possibly owing to these countries' increasing rankings on major indexes of economic freedom.

Reasons to Live on a Seastead

- ❏ Why would you choose to live on a seastead? (check all that apply)



Demographics

While we did not ask for any truly sensitive information, two months into the survey we added the following questions to give investors and developers a better portrait of our potential customers, and their ability to afford space on a seastead[4]:

Basic personal information was required of respondents, allowing us to zoom in on our current audience and to verify the authenticity of the responses, especially with respect to willingness to pay. All respondents were asked their name, age and email contact info, along with their reasons for wanting to live on a floating city, and preferred locations.

- ❏ Age breakdown:[5]

Age	# of respondents	Percentage of sample
18 - 23	268	29.26%
24 - 29	272	29.69%
30 - 39	185	20.20%
40 - 49	113	12.34%
50 - 65	67	7.31%
65 +	11	1.20%

[4] To view the specific wording of our survey questions see the appendix.
[5] Not all respondents provided their age.

Nearly 30% of our respondents are between 18-23, which corresponds to the significant amount of respondents who indicated that they are students[6]. While it's unlikely that students will be early investors in the development of a floating city, it is heartening to know that the vision of the Floating City Project resonates with college-aged people.

- ❏ *Current Country of Residence*

Here we found a remarkable diversity in respondents' home countries – more than 67 total:

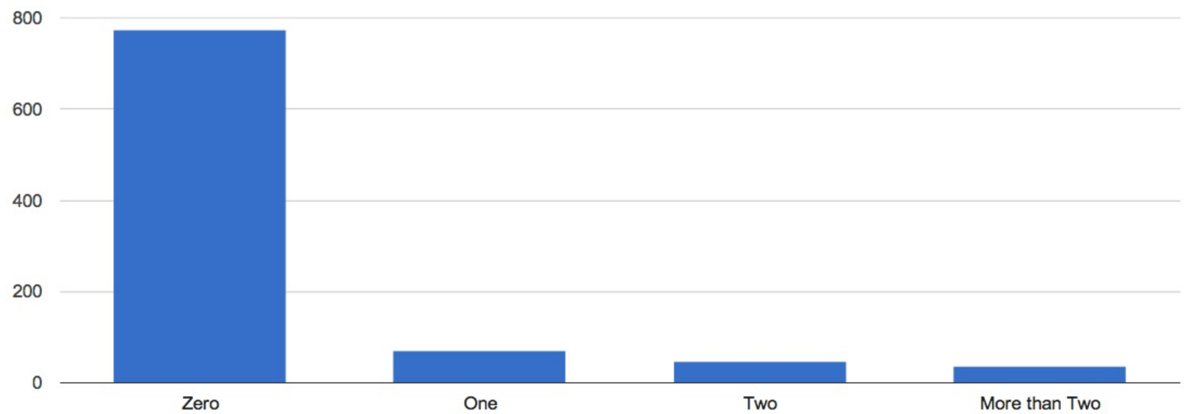
Afghanistan	Czech Republic	Japan	Panama	South Korea
U.S.A	Denmark	Jordan	Philippines	Spain
Argentina	England	Kazakhstan	Poland	Sweden
Australia	Estonia	Kuwait	Portugal	Switzerland
Austria	Finland	Latvia	Puerto Rico	Taiwan
Belgium	France	Malaysia	Romania	Thailand
Brazil	Germany	Maldives	Russia	Trinidad and Tobago
Bulgaria	Ghana	Malta	Saudi Arabia	Turkey
Cambodia	Greece	Marshall Islands	Scotland	Ukraine
Canada	Hungary	Mexico	Serbia	UAE
China	India	Netherlands	Singapore	Venezuela
Colombia	Ireland	New Zealand	Slovakia	
Croatia	Israel	Nigeria	Slovenia	
Cyprus	Italy	Norway	South Africa	

Approximately 55% (396 out of 719) of respondents who listed their current country of residence were from the United States.

[6] Profession data was collected as an open variable in the survey but the data was not analyzed for this report, except as world cloud in the appendix.

❑ *Number of Children Under the Age of 18*

775 people, or 83.2% of respondents, said they had no children under the age of 18. Of those with children, 72 had one child, 48 had two children, and 36 had more than two children.



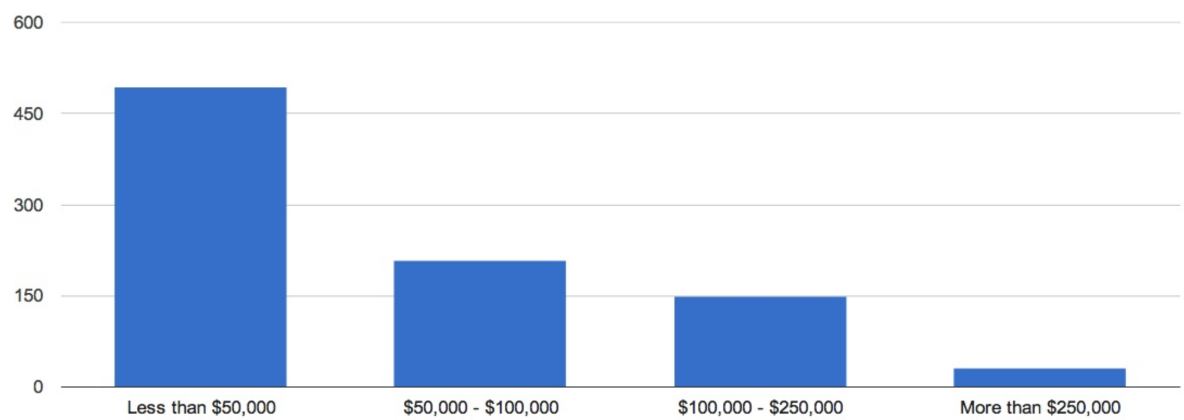
❑ *Are you Married or Single?*

Married	*272*
Single	*709*

Income Level and Net Worth

- *Total Annual income*

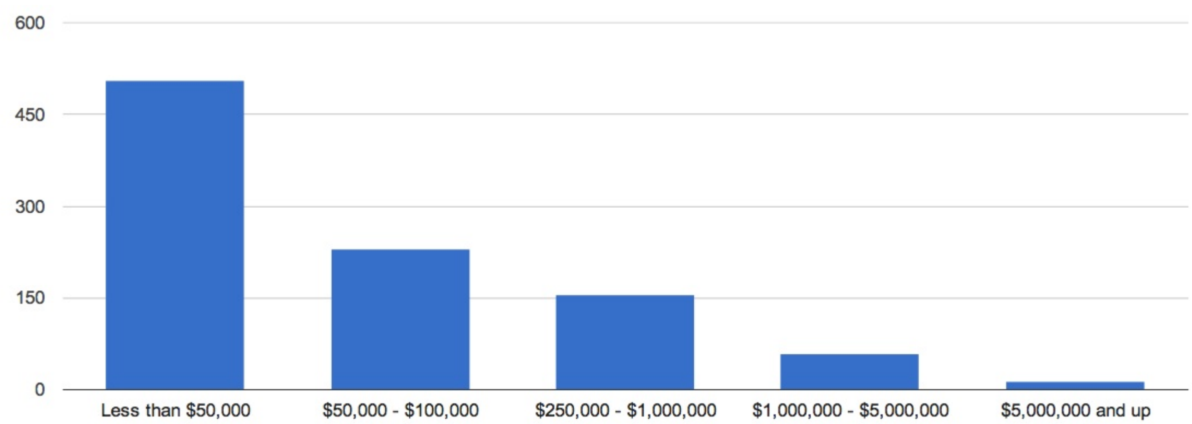
Range	*Number of people*	*Percentage of total*
< $50,000	*494*	*56.01%*
$50,000 - $99,000	*208*	*23.58%*
$100,000 - $249,000	*149*	*16.89%*
More than $250,000	*31*	*3.51%*



A significant portion of survey respondents were students, which presumably accounts for a significant portion of those who make less than $50,000/year.

- *Net Worth*

Range	*Number*	*Percentage*
< $100,000	*506*	*53.15%*
$100,000 - $249,000	*231*	*24.26%*
$250,000 - $1mm	*155*	*16.28%*
$1mm - $5mm	*60*	*6.30%*
$5m+	*13*	*1.37%*



- *Monthly Housing Payment*

Range	*Number*	*Percentage*
<$500	*418*	*42.96%*
$500 - $999	*258*	*26.52%*
$1,000 - $1,999	*208*	*21.38%*
$2,000 - $4,999	*83*	*8.53%*
$5000 +	*6*	*0.62%*

❏ *Value of Real Estate Assets*

Range	***Number***	***Percentage***
<$50,000	*661*	*70.02%*
$50,000 - $99,000	*37*	*3.92%*
$100,000 - $249,000	*83*	*8.79%*
$250,000 - $499,000	*82*	*8.69%*
$500,000 - $999,000	*43*	*4.56%*
$1,000,000 - $5,000,000	*35*	*3.71%*
$5,000,000 +	*3*	*0.32%*

We asked this question as a means of gauging our market's real value, and to show potential developers that the market exists. It is also a correlated metric for one's net worth, which we used to determine the validity of the respondents' separately reported net worth.

❏ *Do You Own a Timeshare?*

Yes	*30*
No	*951*

❏ *Do You Own or Rent Your Primary Residence?*

Other	*219*
Own	*297*
Rent	*465*

We assume the high number of respondents who selected "other" is due to a high number of student respondents who likely have their living units paid by parents or institutions.

- *Would this be:*[7]

Vacation	674
Full-time	1096
Retirement residence	110

- *How Much Do You Spend on Vacation Annually?*

Range	***Number***
Less than $1000	223
$1,000 - $2,499	161
$2,500 - $4,999	124
$5,000 - $9,999	95
$10,000 - $24,999	95
$25,000 - $99,999	17
More than $100,000	3

[7] Respondents could choose multiple answers.

DeltaSync Protected Waters Design Concept

See the full DeltaSync report accompanying this paper in the appendix.

After receiving cost estimates for a semi-submersible design (see semi-submersible design and feasibility section), we commissioned an alternative design and feasibility study from the Dutch aquatic architecture firm, DeltaSync, based on the evolving priorities for this project, namely the following:

- Future inhabitants' desires and requirements;
- Location (protected waters, pleasant climate, and non-remote);
- Growth and development process (scalable);
- Images of the first Seastead (concept design);
- Costs (financial estimate of the concept design).

DeltaSync in turn identified six important objectives: *movability, dynamic geography, growth, seakeeping, safety,* and *water experience*. Confirming The Seasteading Institute Engineer George Petrie's work (see semi-submersible design and feasibility section), DeltaSync found that that semi-submersibles and breakwaters are the options most suitable for the open ocean. However, since the costs of a breakwater are prohibitively expensive, we instructed them to design something for within nature's breakwaters, i.e., the land surrounding a body of protected territorial waters, more commonly referred to as a bay.

After reviewing the practical cost constraints and considerations each of these objectives entail, they settled on a design for a standard platform: a hollow box or "caisson" made from steel reinforced concrete, measuring 50 meters per side. The total cost of a single 50 x 50 meter platform, including moorings and building structures, comes to $15,226,378, or roughly $504 per square foot of useable space ($393 gross space). A secondary, pentagon-shaped platform, with sides equalling 50 meters, was also designed for the purpose of generating novel shapes and configurations in conjunction with the standard square modules.

Construction Material and Components

Concrete was selected as the material to build the floating platforms for its balance of stability, cost and maintenance. In determining the optimal size of a single module, DeltaSync had to balance stability and dynamism with the costs of building, disconnecting and towing. Larger platforms are more stable, but must be braced by a taller, more expensive internal structure in order to endure the stress of "hog" and "sag" motions, which describe the bending of a vessel under the stress of loading and unloading. On the other hand, having a segmented city of smaller platforms provides less stability in harsher waters, and introduces additional engineering requirements for connections and moorings, which have not been studied in detail. The size selected provides enough space for one or two rows of 3-story buildings, with the rest of the space reserved for terraces, walkways, and ground-level gardens. Buildings can be used as residences, offices, or hotel accommodations.

Movability

The movability of such platforms appears feasible with either tugboats or semi-submersible ships. In our vision, the moving of platforms would be rare but necessary in the event of a storm or for political reasons. Some situations may require the platforms to be towed onto the open ocean, which may only be feasible for larger platforms than the standard size. More research is needed to determine whether the optimal size (in terms a comfort) and number of connections (fewer) can be moved at a reasonable cost. Integrated propulsion is probably too expensive, so we would need to have tugboats ready at a moment’s notice to mobilize the whole city.

Environmental Analysis

The report contains an environmental analysis of characteristics of the ocean which are to be avoided because they add expense (i.e., waves, tide, depth, wind), along with positive characteristics, such as precipitation (for water collection), sunlight (for solar panels) and wind (for wind turbines). Other beneficial features of the ocean that are less proven are also explored, such as nutrient recycling and ocean thermal energy conversion (OTEC).

Location of study

Since the results and feasibility of this analysis depend on location, we instructed DeltaSync to focus on one specific region representative of our potential host nations, and ideal in terms of weather, protection, sun and rainwater resources. We arbitrarily chose the Gulf of Fonseca, which borders three potential hosts: Honduras, Nicaragua and El Salvador. Since data was not readily available within the Gulf of Fonseca, DeltaSync summarized the data for two locations on the open ocean immediately outside the gulf.

Environmental Remediation

The concept also includes an adaptation strategy that works in concert with the surrounding environment. “The Blue Revolution” is a term that has been independently coined by several seastead enthusiasts, including Patrick Takahashi, the biochemical engineer seeking to create OTEC plants, the team at DeltaSync, and some of the authors of this report. We seek to evoke The Green Revolution of Norman Borlaug, a plant geneticist who is credited with saving over a billion lives. The sustainability potential of the Blue Revolution should make it more appealing to potential host nations, since it creates possibilities for remediating the environment with innovative reuse of nutrients to foster next-generation algal biofuels, as well as high-technology food production methods such as integrated multi-trophic aquaculture.

DeltaSync used data from our location reference point to determine whether water and energy needs could be met primarily or entirely through natural resources. Based on platform size and population density, they found that enough water could be collected to meet typical needs of an average American. Similarly, based on insolation data, and the amount of available rooftop space, they found that solar panels could meet electricity needs more cheaply than a diesel generator, even after adding the costs of a microgrid.

Growth

The Blue Revolution concept also emphasizes dynamic growth, finding inspiration in the animal kingdom. Salmon start their lives in rivers, before moving to protected waters, and then finally to the high seas. Analogously, a floating city can begin with just a few connected platforms, before outgrowing its protected niche and constructing a partial breakwater that enables it to move into a less protected bay. Eventually, when there are enough citizens to finance the construction of a full circular breakwater, the city could move out to the open ocean and expand indefinitely. Each step of the way, 50 x 50 meter platforms would retain the ability to disconnect from their neighborhoods and experiment with dynamic geography, allowing citizens to peacefully resolve disagreements and put competitive pressure on their local governing units to keep the quality of government high.

Host Nation Identification & Diplomacy

Overview

Depending on the source consulted, there are somewhere between 190 and 210 countries worldwide. The United Nations recognizes 193 nations, of which approximately 150 have territorial waters and a coastline to potentially host a floating city. Narrowing down this list to a manageable number of host states required us to enlist the help of geopolitical scholars, who could help us identify the most important criteria for our purposes. A promising candidate host nation would exhibit the following broad qualities:

1. Located in a desirable and strategic location from the perspective of our intended residents.
2. Ability of the government and relevant authorities to act nimbly, granting substantial autonomy for the residents and businesses in exchange for the economic, environmental and societal benefits to the host nation.

Elimination Criteria

Our process of elimination began with simple rules-of-thumb, removing any nations exhibiting strictly negative “dealbreaker” qualities in either of two major criteria.

First, we eliminated countries entirely within hurricane/cyclone zones, or in the polar extremes. This follows from the overall strategy behind The Floating City Project to increase feasibility of establishing safe, comfortable platforms at a reduced engineering cost. Our earlier location study (Petrie, Hogan, Stopnisky, et al.)[8] provided a foundation for this investigation. As intended, the location study served as a framework for thinking clearly about critical environmental factors, while allowing us to de-emphasize certain other factors which would be important for an open-ocean seastead.

Our next elimination criteria assessed human risk factors, including the presence of obviously negative factors such as pirate-infested waters, strong authoritarian tendencies in the nation’s government, or the existence of severe political unrest. A handful of Middle Eastern, South East Asian and African countries, for example, were eliminated based on precarious political situations that would severely dampen investor confidence and the prospects for fruitful negotiation.

A more subtle concern relates to certain countries’ legally binding relations with major world powers, such as the European Union, or any permanent members on the United Nations Security Council (the U.S., France, the United Kingdom, Russian Federation, and China). This reasoning warrants an additional explanation as to the nature of national sovereignty. It will be necessary for our purposes to define and explore the implications of sovereignty as distinct from

[8] http://www.seasteading.org/wp-content/uploads/2014/02/Seasteading_Location_Study.pdf

the autonomy we are seeking for the seastead. “Sovereign” means that a political entity has a seat in the United Nations, is recognized by other states, issues passports which are recognized by other nation’s border controllers, and has its own stamp and internet domain. Autonomy, on the other hand, we will define as the degree to which a nation or group of people are free to create whatever legal system they want without interference from the outside world. Sovereignty is the external manifestation of political independence, while autonomy is the actuality.

We excluded nations whose sovereignty is not unanimously recognized by other UN nations.

Positive Criteria

While basic stability, environmental safety, and bona fide sovereignty are a necessary conditions for our host nation, they are not sufficient conditions, since it would be impractical to negotiate with the full list of countries matching this description. We viewed the presence of calm, shallow coastal waters, atolls, or inlets as adding to the practicality of our proposal, especially for designs like DeltaSync’s which are optimized for lower wave profiles and capable of interacting with coastal cities in a unique symbiosis (more on this in the engineering section above).

We also looked at the potential for a floating city’s physical proximity to many other countries. For instance, the difference between being located on the Pacific versus the Caribbean coast of Nicaragua is the difference between having 5 to 10 nearby nations and having 25 or more. More neighboring nations increases opportunities for jurisdictional switching and international trade.

A related criteria was the proximity to major cities and transit hubs, both in the coastal nation and in the global scheme. This led us to strongly favor countries with non-hurricane-exposed Central American coastline with protected waters, and Pacific Island atolls near larger hubs like Singapore, Taiwan, and Australia.

Ambiguous Criteria

After applying our hard elimination criteria and tentatively favoring remaining countries with more positive traits (protected waters and proximity), we were left with a trimmed list, but it was still too long to pursue diplomacy with each one individually. Accordingly, we turned our attention to more ambiguous criteria which could indicate either a promising opportunity or a locale to be avoided. These “sweet-spot” criteria required a heavier degree of intuition, which created a risk that our methodology would exhibit group-think, resulting in an unjustified acceptance or rejection of a given country.

Recognizing our potential bias, we separated ourselves from our two scholars, and each came up with independent rankings based on quantitative rankings across a variety of criteria. Each researcher was instructed to select whatever factors or criteria they deemed most important, find existing databases and reputable rankings, and apply their subjective weighting to the factors to produce an overall ranking based on a “meta-score.” A low ranking on any of these axes was thought to be too weak to warrant elimination, but important enough to warrant consideration. For example, a lower ranking was given to wealthy, developed, non-EU, non-Security Council countries, as well as those with very large Gross Domestic Product. Our intuition suggests that economic powerhouses would be less welcoming of our proposal, given a seastead's relatively small size relative to GDP, yet we still included a few countries like Singapore and the Seychelles on our list in spite of their high GDP. Conversely, we believe Special Economic Zones and an open flag registry for maritime matters are positive indicators, but did not include every country which matched these criteria on our list. The sub-rankings and criteria used for the majority of decisions were the following:

- 2012 Fund for Peace Index (Stability)
- 2012 Heritage Foundation/Wall Street Journal Index of Economic Freedom (Freedom and rule of law)
- The Existence of an Open Flag Registry, Free Trade Zone, or Special Economic Zone (Willingness to "franchise sovereignty" or bargain laws for foreign investment)
- Overall GDP, GDP per Capita (Willingness to negotiate, consider economic benefits non-negligible)
- 2013 Freedom House Freedom of the Press Ranking (Overall political freedom)
- The Worldwide Governance Indicators (WGI) Project (Stability, rule of law, control of corruption)

The ideal country would be stable, non-corrupt, small, and relatively poor by first world standards. It would also have to be open to foreign investment, the values of freedom, and the leveraging of its sovereignty. Of course no country was ideal, but our rankings yielded a consistent pattern, and allowed us to examine borderline countries in depth while ignoring those nations that would most likely be a waste of diplomatic effort. The following countries were selected for their overall balance of the criteria listed above:

- [ ] Colombia
- [ ] Costa Rica
- [ ] El Salvador
- [ ] Ghana
- [ ] Guatemala
- [ ] Guyana
- [ ] Honduras
- [ ] Hong Kong
- [ ] Maldives
- [ ] Montenegro
- [ ] Mozambique
- [ ] Nicaragua
- [ ] Norfolk Islands
- [ ] Palau
- [ ] Panama
- [ ] Senegal
- [ ] Sierre Leone

- ❏ Singapore
- ❏ Suriname
- ❏ Vanuatu

At the time of the publishing of this report we are pursuing diplomacy, and have made contact with influential people in government and business in several of the nations listed above. However, due to ongoing diplomatic efforts, we are not at liberty to publicly comment on our engagements.

Our primary diplomatic technique has been to leverage connections via the seasteading community to make contact with influential people and government agents. We have then sent an introductory letter, summarizing our motivations and objectives, and requesting meetings to our target audiences. A generic template of the letter we adapt for different countries has been attached in the Appendices to this report.

Qualitative Interviews

We conducted 12 qualitative interviews to inform our strategy for moving this project forward, to better understand why potential residents want to live on a seastead, and to find out what they would want the seastead to be like. Interviewees were selected based on their previous expression of serious interest in seasteading and their ability to afford the predicted costs associated with being a resident. The interviews were conducted by Randolph Hencken and took between 30 minutes to an hour each.

The following section showcases a few of our questions and some of the more informative answers we received:

Reasons to Live on a Seastead

Q: What are the problems that a seastead would solve for you (as an individual, business, or both)? Or, why would you choose to live on a seastead?

Interviewees tended to express an interest in pioneering something new, living with a community of like-minded people, having security and stability, having business opportunities that aren't overly restricted by arbitrary regulations or regime uncertainty, while still having regulatory stability and personal liberty.

Examples:

> *"...A small community of people with autonomy might be able to protect each other and that is the main thing I want, really I think some kind of security, stability over time. Even if I don't get the rules that I want necessarily I still want to have the certainty that the rules are not going to change on me that easily. This is the one main thing that would attract me on a seastead stability, rule-making stability."*

> *"As an individual I think the sense of adventure is one. A new way of living. Also an opportunity to build a real community would be exciting."*

Deal Breakers

Q: Can you foresee what kind of "deal breakers" would prevent you from purchasing/leasing units on a seastead?

Subjects shared they would be reluctant to participate in a seastead if the group putting it together lacked credibility, or if there was a lack of quality high-speed internet, safety or medical care.

Examples:

"The credibility of whoever put the seastead together, if it looked like it was going to financially fail, I wouldn't be interested."

"Well, obviously, history of security problems like attacks on the seastead, crashes, or accidents, things that basically endangered life."

"Yeah. Definitely, it has to do with connectivity because my business is pretty much online and if I don't have good connection, I definitely can't do anything. I can't run my business which means that basically I have to go back to land, so that would be a deal breaker for sure."

"It would be, I think if there was no way to get internet access, in this modern age it's like being stranded on an island with no connection to the rest of the world."

"Certainly to know that if one got sick, I could get to a decent hospital quickly. That's important. Again, you are talking to an older generation, we know we need medical care."

Ideal Seastead

Q: Could you describe your ideal seastead?

Responses indicated an interest in at least a minimum standard of living, if not a high standard of comforts, reasonable conveniences for traveling, and substantial political autonomy in order to have a minimal government structure.

Examples:

"Ideal would be something that was a floating city … like a cruise ship you can to some extent forget that you are on a boat because it's so controlled and climate-optimized. It's like a floating hotel, but taking that one step further and getting to a floating city would be the ideal."

"It will be the equivalent of a very high-end country club, but floating. With the added security that there's no political uncertainty."

"If a seastead offered a very practical degree of independence from any of the current powers, that would be very attractive. It would make up for a lot of other shortcomings.

In terms of a seastead's own governance, I'm kind of pragmatic … I am not anywhere close to desiring to live in an anarchistic society. I do mean that in the positive sense of the term. I would be happiest to see a … ideally, in a very idealistic sense, a wise use of the police power. I'd expect that there would be some governance where there was police power. There would be somebody with arms, who could stop criminals."

"I think I am seeing it a little bit more in the lifestyle. A little bit of luxury would be kind of nice. Sort of like the first thing that swings to mind is a little bit like a vacation home to be honest with you. Somewhere where I can go and get away from society. From ordinary default reality."

Income Generation

Q: Would you attempt to operate a business from the seastead? If so, what kind?

The subjects in our focus group are predominantly knowledge workers. Accordingly respondents showed interest in business related to consulting, bitcoin, finance, and software. However, we also received answers indicating interest in service sector industries such as running a fitness center, a cafe, and assorted tourism ventures.

Examples:

"I might actually start not with the biotech thing but with something that's pure software just because of the nimbleness that pure software offers."

"I could see getting involved in some kind of tourism or hospitality thing there come to think of it. That would probably be a natural place for me to be."

Q: How much more likely are you to bring a business to a seastead if there was a company that managed the seastead and allowed you to focus on your business by mostly renting /owning space (as opposed to you having your business own and operate the seastead)?

"Yeah, that's an attractive option. It's like a landlord for the seastead. I think that would be good training wheels kind of option at first, and then maybe eventually, one might buy one of his own."

Climate

Q: Do you have a strong preference about the climate of the seasteads location?

The majority (n=8) of the interviewees prefered warmer climates closer to the US for ease of travel (albeit, this focus group was US centric, with only 3 people residing more than half time outside of the US). A small minority (n=2) indicated a preference for cooler climates, or no preference at all (n=2).

Proximity to airport/port

Q: How important is proximity to a nearby international airport? What amount of time would be reasonable for you be transported to a nearby port/airport?

Answers to this question varied from "Little enough to get emergency medical care" to "3-4 days." Most wanted to be able to get to an airport within a couple of hours and fly to the United States within a day.

Willingness to Pay

Q: Can you state how much you would pay to live/operate a business on a seastead (down payment, monthly payment, total payment)? What would you expect for that rate in terms of square footage and quality of space?

Answers to this question varied from as little as $1,500/month to tens of millions up front for a residence. Most respondents, even those discussing paying higher prices, appeared content with residential units in the 1,000 - 2,000 square foot range.

> *"I understand this thing is a new undertaking and I wouldn't expect to have luxury and expansive areas. I'm sure it would be similar to a cabin on a ship, but I would expect to at least have privacy and have my own room bathroom facilities."*

> *"I guess in my mind I was picturing that I'm going to need to put in 10 million or something like that or more. It's going to have to be relatively comfortable. It's going to have to be nice-ish. It can be functional. It doesn't have to be a luxury resort. It could be functional."*

> *"If I have to build it, it's maybe 100 meters square and would cost me $10 million. I'm not looking for a 10 by 10 room though. If I can't get at least a couple thousand square feet of space for a few million dollars, then I probably would be inclined to make my own as opposed to buy somebody else's. Let's say given the likely costs, something in the range of $1,000 a square foot, maybe $2,000 a square foot. Got a friend that bought some apartments in Singapore. He paid $2,700 a square foot. Of course, he's got infrastructure, a modern, safe city and the tenants who will pay him rent. On a seastead, we won't have much of that. I am accustomed to holding higher standards than a lot of people. My calibration on the amount that I would pay is not a very good guide for what other people might pay."*

Community Size

Q: Is there a minimum-sized community (population) you would want to have on the seastead? Is there a maximum-sized community you would want to have?

For this question answers ranged from a few people (n=4) to a medium-sized town (n=1), in between subjects anticipated starting with 50 to 500 people:

Subject 1: Not of concern, likes solitude
Subject 2: As little as 3
Subject 3: As little as 10
Subject 4: At least 10
Subject 5: at least 50
Subject 6: at least 100
Subject 7: 200 or more people
Subject 8: 300 - 500
Subject 9: 300 - 1,000 (concerned that wife would be unhappy with as little as 300)
Subject 10: at least 500
Subject 11: at least 500, would prefer 2,000-5,000
Subject 12: "medium-sized town", larger is important

Architecture

Q: What kinds of architecture would make you want to live there?

Most subjects expressed a desire for modern, appealing, attractive architecture, while just a few were comfortable with industrial, bare minimum designs. Open space, sunlight, and access to the water were important to most subjects.

> *"I would be okay with kind of an office building, modern style. I don't want any industrial smoke and definitely not noisy, that would be a deal breaker for me. I would live in an office building, like a high-rise, high-end New York or Chicago high-rise that's metal and glass and cement. That's fine. Greenery would be nice, but it's more the modern clean lines."*

> *"I do think that the architecture would have to be kind of pleasing. I'm particularly thinking of my wife. She just, even more than I, would be looking at it. For me personally, it could be artificial, manmade, but I would like to see a pleasant architecture. I think that I would get kind of claustrophobic in an all interior environment. Having windows out into the world, even if it's just the ocean world, would matter. I think having a garden, even if it was like a shared common central garden or interior area, it would be pretty important. I'm probably in the camp where it would need to be a reasonably pleasing architecture and more than interior."*

> *"My mental picture of a seastead is a pretty large entity. It has a section that might look kind of like a modern version of Venice with canals and buildings and plazas. Maybe has a section*

that looks kind of like Singapore, downtown Singapore with high-rise buildings and has ultimately enough scale that it can have an international airport once it gets up and going to the size that becomes interesting. It would be nice for my seastead to have a lagoon where I wanted to go scuba diving ... Basically, I'm looking for some place that is livable, that doesn't feel totally crowded and cramped. I need more space than one would get in a cabin of a cruise ship for example. I think a mix of Venice and Singapore probably defines what I would find perfect."

"The idea would be something where everyone, like this just one big flat deck and like an aircraft carrier or maybe an oil platform or something like this and everyone has individual houses, but of course it is not going to be like that so apartments would be fine, but we still have to have open spaces outside and also private spaces outside. That would definitely be something that would turn me off if we didn't have this."

"I think the all-industrial approach tends to appeal to me because that way we could probably get to market sooner, less cost in design and material. As an engineer I guess it sort of appeals to me, but the slick, modern look would definitely help attract some of the more comfortable people from terrestrial jobs. So somewhere in between. Not entirely industrial, and comfortable enough to make it feel like you could spend some time there."

The range of responses offered in our interviews suggests a diversified and open-ended strategy in the early stages. It would be much more feasible to develop an attractive product for a portion of respondents who are most in agreement and have the fewest specific "deal breakers" that do not align with others, than to try to satisfy everyone's desires with an offering that truly suits no one.

With that said, a portrait begins to emerge of a relatively common vision for a small village, with certain physical and legal features which seem to be achievable. Our interviewees expressed a general preference for a managed experience, which would leave them free to manage their own lives or businesses, and conduct pioneering experiments in a stable regulatory environment.

Semi-submersible Design Design and Feasibility

Surveying existing technology for comfortably inhabiting the high seas, the semi-submersible stands out above all other options.[9] Primarily used in the offshore drilling industry, semi-submersibles offer a stable floating platform where waters are too deep for “jack-up” rigs, which utilize stilts touching the sea floor. To minimize fluctuations with the waves, semi-submersibles are designed with small amounts of surface area exposed to the waterline. The platform sits atop an array of tall columns, resting on a hollow ring or set of pontoons located meters below the surface wave action. The massive water displacement from the inflated submerged base provides enough buoyancy for heavy drilling equipment and worker accommodations.

Our engineering team, led by former Director of Engineering George Petrie, set out to determine the feasibility of this design for an early seastead platform in terms of costs and logistics, while factoring in the necessary amenities to sustain a small residential and commercial community.

In order to produce realistic estimates for the semi-submersible seastead, Petrie rendered a design for a hull and deck structure based on industry standards, and submitted it for bidding to several shipyards. As of May 2013, only one shipyard – located in Texas – returned a bid. This quote for the hull and deck structure represented the single largest expense for a semi-submersible seastead but did not include numerous other costs, which needed to be calculated based on educated estimates, previous research, and quotes from maritime professionals in our network.

We based our estimates for the structure and basic systems on existing products and technologies, at current market rates, employing standard installation protocols used in offshore industries. The structure was designed to support a five-story structure with 180 units, meant to accommodate a total of approximately 360 people. Each unit was based on the size of two standard shipping container units, roughly 640 square feet. Lina Suarez, a student of naval architecture, conducted a month-long internship with Petrie, during which she conceptualized the top-side design: a modular, adaptable seastead, complete with top-side crane mechanism for rearranging “modules” or residential units. The ability to easily enter or exit such a seastead configuration (i.e., voting with your house) is expected to enable greater freedom of choice and amplify the competitive pressures needed to spur governmental innovation.

In addition to 105,600 square feet of residential space, the corners of the platform were allocated

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[9] Our semi-submersible investigation began before we honed in on the strategy of situating the floating city in territorial seas.

to commercial real estate totalling 125,200 square feet. Finally, the roof top area would add 22,040 square feet of common space, and a floating pier below the structure would add 17,500 square feet for docking and recreation.

Capital Costs

The figures below show the upfront **Total Capital Cost** of the platform:

Component	Cost
Hull and Deck Structure	$115,492,000
Transport to Caribbean site from Orange, Texas	$2,000,000
Anchor handling tugs (two tugs from Trinidad for seven days at $40,000 per day per tug)	$560,000
Fuel for anchor handling tugs ($10,000 per day per tug)	$140,000
Mooring system	$15,000,000
Fuel System	$1,000,000
Ballast System	$1,000,000
Fresh Water System	$1,000,000
Waste Treatment System	$1,000,000
Navigation & Communication	$1,000,000
Lifeboats & Life-Saving Equipment (Eight 120-person enclosed lifeboats at $125,000 each, from Alibaba)	$1,000,000
Safety & Firefighting Systems	$1,000,000
HVAC System	$1,000,000
Residential modules (180 duplex models at $96,000 each)	$17,280,000
Deckhouse structure (estimated 1,000 tons at $15,000 per ton)	$15,000,000
Wind turbine (2-mW)	$4,000,000
Genset Generators (two at 1000-kW each)	$1,000,000

Cooling System (FW & SW)	$1,000,000
Batteries	$1,000,000
Power Distribution and Control	$1,000,000
Corner towers, common areas	$1,250,000
Rooftop areas	$2,750,000
Helideck	$1,000,000
Floating Pier	$2,625,000
Revolving cranes	$1,500,000
Sub-Total	$190,597,000
Engineering	
pre-FEED (pre-Front End Engineering Design)	$571,791
FEED (Front End Engineering Design)	$1,905,970
Construction Support	$5,717,910
Project Management	$7,623,880
Contingency	$19,059,700
Total Capital Cost:	$225,476,251

From these figures we can calculate the capital cost per square foot of residential and commercial space, which comes out to $978.

Operating Expenses

Item	Capital Cost	Annual % Maintenance Cost	Annual $ Maintenance Cost	Service Life (years)	Sinking Fund	Interest Rate	Override Default Rate	Annualized Total Cost
Maintenance & Inspection								
Hull and Deck Structure	$100,000,000.00	0.01	$1,000,000.00	40	$386,016.00	0.08	0.08	$1,386,016.00
Mooring system	$15,000,000.00	0.01	$150,000.00	20	$453,639.00	0.05		$603,639.00
Fuel System	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
Ballast System	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
Fresh Water System	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
Waste Treatment System	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
Navigation & Communication	$1,000,000.00	0.01	$10,000.00	20	$30,243.00	0.05		$40,243.00
Lifeboats & Lifesaving eqpt	$1,000,000.00	0.01	$10,000.00	20	$30,243.00	0.05		$40,243.00
Safety & Firefighting Systems	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
HVAC System	$1,000,000.00	0.03	$30,000.00	20	$30,243.00	0.05		$60,243.00
Residential modules	$17,280,000.00	0.03	$518,400.00	40	$143,047.00	0.05		$661,447.00
Deckhouse structure	$15,000,000.00	0.01	$150,000.00	40	$124,172.00	0.05		$274,172.00
Gensets (two @ 1000-kW each)	$1,000,000.00	0.05	$50,000.00	20	$30,243.00	0.05		$80,243.00
Cooling System (FW & SW)	$1,000,000.00	0.03	$30,000.00	40	$8,278.00	0.05		$38,278.00
Batteries	$1,000,000.00	0.05	$50,000.00	10	$79,505.00	0.05		$129,505.00
Power Distribution and Control	$1,000,000.00	0.01	$10,000.00	40	$8,278.00	0.05		$18,278.00
Corner towers, common areas	$1,250,000.00	0.01	$12,500.00	40	$10,348.00	0.05		$22,848.00
Roof top areas	$2,750,000.00	0.01	$27,500.00	40	$22,765.00	0.05		$50,265.00
Helideck	$1,000,000.00	0.01	$10,000.00	40	$8,278.00	0.05		$18,278.00
Floating Pier	$2,625,000.00	0.05	$131,250.00	20	$79,387.00	0.05		$210,637.00
Revolving cranes	$1,500,000.00	0.01	$15,000.00	40	$12,417.00	0.05		$27,417.00
Supply/Transport Boat (optional)	$5,000,000.00	0.05	$250,000.00	20	$151,213.00	0.05		$401,213.00
Recurring Costs								
Insurance	1% of total construction cost							$1,865,970.00
Licensed officers - 1st Officer	2	$48,000.00 salary						$96,000.00
Non-licensed crew - Bosun	2	$24,000.00 salary						$48,000.00
Non-licensed crew - Seaman	4	$18,000.00 salary						$72,000.00
Supply Boat - Charter -Trips per year =>	26	$6,000.00 cost/day		1 day/trip				$156,000.00
Fuel Costs								
Diesel Generators - Avg power, kW =>	500	0.072 gal/kW-hr		8760 hours/year		$4.00 per gallon		$1,261,440.00
Supply Boat - Charter -Trips per year =>	26	3000 gal/day		1 day/trip		$3.00 per gallon		$234,000.00
Supply/Transport Boat (optional)	104	120 gal/hour		6 hours/trip		$3.50 per gallon		$262,080.00
								$8,359,670.00

Survey of Current and Planned Semi-permanent Ocean Living Options

One of the initial tasks of this investigation was to survey the current commercial availability of permanent or semi-permanent ocean inhabitations. The successes and failures of previous companies serve as indicators of the existing market for ocean dwellings, which closely albeit imperfectly parallel our vision of seasteading. Cruisers – people who live on small private yachts suitable for a single family – were not included in this investigation. With the prospect of inspiring the creation a corporate entity, we looked at large seafaring vessels capable of housing hundreds of people and offering residential units for sale. Accordingly, we also did not investigate "flotel" accommodations used solely in the offshore industry to temporarily house workers.

We identified six business models based around sales of permanent or semi-permanent residential units. One of these businesses is actively operating a vessel, two are still being planned and marketed, and three appear defunct.

The World: The Sole Operating Condominium Cruiseship

The World is the only operating condominium cruiseship. It has been in operation since 2002.

According to their website (www.aboardtheworld.com), The World is a five-star luxury cruise ship that is owned by its residents and managed by ResidenSea, an independent company located in Miramar, Florida. The following are the most salient facts relating to The World from our perspective:

- The project is the brainchild of Norwegian shipping magnate Knut Kloster Jr, and started in 1997, and the ship was completed in March 2002, at the cost of $280M.
- In October 2003, the residents purchased the ship for $71M, which means the original owners lost at least $209M investing in the ship.
- In 2006 the original inventory of residences was sold out. Units are occasionally, but rarely, offered for resale.
- There are a total of 165 residential units aboard The World, including 106 two- and three-bedroom apartments, 19 one- and two-bedroom studio apartments, and 40 studios.
- Prices began at $825,000 for studio units (329-sq ft), or about $2,500 per sq ft.
- One-bedroom apartment (1,106-sq ft): $1,450,000, or about $1,310 per sq ft.
- Two-bedroom apartment (size unknown): $2,325,000.
- Three-bedroom apartment (size unknown): $3,575,000.
- Maintenance costs are reported to start at $20,000 per month for apartments, increasing depending on size of the unit.

- Note: These are prices as shown on The World website, but most likely reflect prices for the (now sold-out) original inventory. Resale prices would be set by supply and demand.
- Rental prices start at $1,300 per night for studios and $2,500 per night for apartments
    - One article[10] states that the rental policy has recently changed; The World now requires that renters have "minimum assets of $10 million and a clear intention of interest to purchase" before an application to sail as a guest would be approved.

The ship offers four restaurants, a 7,000-sq.ft. spa and a host of other amenities while maintaining an active round-the-world cruising itinerary. To support this level of service, The World employs some 320 crew and staff. Other information obtained online suggests that the prices originally sought by the project's developers were substantially higher, but that the occupancy rates were sparse. In order to generate cash flow, the developers undertook an aggressive rental campaign, which precipitated an owner rebellion in protest of circumstances caused by unruly renters. Hoping to protect their investments, the owners purchased the ship in 2003, although the original inventory of residences was not sold out until 2006.

Purchase prices (as reported on the website) reflect the high-end accommodations provided on board the ship. However, ongoing maintenance costs of $20,000 per month and more would be daunting for all but the very wealthy. This cost is mainly driven by two factors; cruising costs (crew, fuel, maintenance, port charges, etc.) and service costs (chefs and staff for four restaurants, spas and other onboard services). Part of the monthly maintenance charge includes a meal allowance for residents, which we suspect ensures that there is sufficient cash flow to support full-time staff even though the ship typically sails with about 50% occupancy.

Lessons from The World

- Investors should be prepared for the long haul: five years from conception to delivery, and another four years for units to fully sell out.
- Good management is essential for marketing and for operations; investors and owners must feel that their interests are being protected.
- There has been a market for pricing at or greater than $1,000.-sq. ft., which comes with the expectations of first-rate amenities. However later attempts to replicate The World's business model have to come to fruition, which likely means this niche market is already satisfied.
- Because a seastead will not be cruising, monthly maintenance costs will be substantially lower; crew, fuel, port costs, etc. will be reduced or eliminated if possible.

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[10] http://www.travelweekly.com/Richard-Turen/A-tale-of-two-ships/

Projects Still Planned

Marquette

The Marquette[11] is a Mississippi River barge cruise, planned to travel the internal waterways of the US. We spoke with the project's developer David Nelson, and inferred that he had taken deposits on a few units since launching the idea in 2008. However, they are still a long way from collecting earnest money for the 90% of units they require to begin construction. David attributes his lack of success to two factors: 1) economic uncertainty in the US market since his launch, and 2) insufficient marketing. David reported that they planned a renewed marketing push in the coming year and are optimistic that the project will launch soon.

The information on their website displays floor plans, pricing options, a pre-construction reservation form, and a disclaimer that the project is in its early stages, pending investment.

Ownership can be full time or structured as a timeshare in six month or two month increments.

Unit Size	Full Time	Six Months	Two Months	HOA/mo
528 sqft	$299k ($566/sqft)	$161k	$54.6k	$1,166
660 sqft	$362k ($548/sqft)	$193k	$63.6k	$1,458
748 sqft	$404k ($540/sqft)	$215k	$69.9k	$1,652
924 sqft	$499k ($540/sqft)	$264k	$84.9k	$2,040

Lessons from Marquette

- Extensive funds must be allocated to marketing.
- A sufficient number of units need to be claimed by potential residents in the early marketing push in order to maintain momentum and to not lose interest of the initial claimants.
- Even a price point affordable for middle income individuals isn't an easy sale, presumably because the niche market is small and difficult to reach and convince to buy in.

[11] www.rivercitiescondos.com

Utopia

Utopia has a letter of intent to commence construction with Samsung, but the project is awaiting additional financing before a final contract is signed and construction begins. Publicly, the promoters claim Utopia is scheduled to set sail in 2016, but this seems unrealistic since construction hasn't begun yet. There is a showroom in Beverly Hills, California. If built, the ship is projected to cost $1.1 billion. It would house 199 residences ranging in price from $3.9 million to $30 million.

Projects Cancelled

The following three projects appear to be defunct:

Orphalese - This project appears to have actually transformed into *Utopia,* after changes in the executive team and associated lawsuits.

Four Seasons Magellan - This project was expected to cost $650 million, house 200 residential units costing between $1.8 million and $8 million each. No information on why the project halted is publicly available.

Murano - There is very little information available about this project, except that it was planned to be converted from a retiring cruiseliner rather than built from scratch.

Lessons from Cancelled Projects

- Several groups have promoted big ideas for semi-permanent ocean residences, some of which appear to have had the backing of major companies. However, actualizing such large ventures is a daunting task.
- For a large vessel, it is difficult to sell the majority of the units before construction. Our research indicates that an ocean-residential structure with the ability to incrementally grow would be easier to finance and construct.
- The World shows that the market for expensive condos on a cruise ship that travels the world is extremely small. To succeed, we must find a new market through cost reductions, innovative governance, better infrastructure due to a fixed location, and other amenities that would appeal to the seasteading audience.

Appendix

Template Letter for Contacting Potential Host Nations

Dear <>,

Several high-profile technology billionaires in the United States have advocated for the formation of legally independent territories, to promote new economic and social opportunities. These include Peter Thiel, co-founder of our nonprofit think tank, The Seasteading Institute, which promotes the creation of independently-governed floating cities – seasteads – to experiment with policies and technologies that could spur economic development around the world. I would like to set up a meeting with you as an early step to working with <nation> on developing an alternatively-governed floating development within <nation's> territorial waters as a way to bring new wealth and opportunities to your country.

Our proposal begins with a floating platform, which could lure hundreds of millions of dollars of residential, technological and tourism investment to the region over the next decade. We also envision a flood of novel ocean-based businesses, which would establish <nation> as the capital of the emerging blue economy.

The Floating City Project

Our Institute has spent the past five years conducting in-depth research into the challenges associated with establishing permanent, autonomous cities at sea. Based on the increasing level of interest from entrepreneurs, individuals, and the media, we believe the first floating city will be developed by the end of this decade. The Floating City Project, in its initial phase, has sought to lay the foundation of the first seastead through these three key areas of focus:

1. *Determine the market for businesses and residents* - We have collected survey data from nearly 1,000 members in our global network, including entrepreneurs and investors, who say they want to be pioneers of such a city.
2. *Design a structure* - DeltaSync, a Dutch water architecture firm, is currently assessing the feasibility of various floating platform designs that would meet the needs of residents and business.
3. *Identify a willing host nation* - We are seeking a country to grant the floating city substantial legal independence within its calm, shallow territorial waters in exchange for the benefits listed below. While we are expressing our intent to several nations, we will ultimately select just one nation to host the first seastead.

Benefits for <nation>

We believe <nation> would be an ideal host nation for our proposed city. In offering the opportunity to sign onto such an arrangement, we expect the following benefits for <nation> and its people:

- **Economic Activity -** Permanent construction and maintenance jobs would be required for the continuous scaling up of a floating city, as would upfront investments in transportation, communications and other infrastructure.
- **Increased Revenues -** Brand-new aquatic real estate – both commercial and residential space – can can generate new revenue streams that will directly and indirectly increase the wealth of <nation>.
- **Global Recognition** - Hosting the world's first seastead would attract world-wide attention among innovative companies and prominent individuals, like Larry Page (Google CEO and 13th richest person), who has publicly promoted the concept of small-scale laboratories of economic and regulatory policy.
- **Sustainability and Security -** The floating city would develop technologies to relieve the growing threats of climate change and resource scarcity, including renewable ocean energy, resilient architecture, and sustainable aquaculture that improves coastal water quality.

Our initial goal is acquire a letter of intent indicating your nation's welcoming of a full proposal and willingness to enter into serious conversations about being a host nation. It is only a matter of time before humanity begins to capitalize on seasteading-related opportunities. We hope <nation> will consider collaborating with The Seasteading Institute in this endeavor.

I look forward to hearing from you.

On behalf of The Seasteading Institute,
Randolph Hencken, Executive Director

Full Survey Questions

Introductory text to survey

"Survey data will be used to help us develop our plans for the world's first city at sea. While the information we are requesting is personal, we are not looking for any sensitive information such as social security numbers or bank statements. We assure you that everything we gather will be kept confidential, and will not be shared outside of those directly affiliated with the project. We may contact you with more questions or information as we proceed with this development."

Questions

1. Name
2. Phone
3. Email Address
4. Physical Address
5. Why would you choose to live in a seastead? (Check all that apply)
    a. Opportunity to experiment with new governance
    b. Preference for small communities
    c. Solitude
    d. Love of the sea
    e. Desire to pioneer a new way of life
    f. Commercial advantages of conducting an offshore enterprise
    g. Other
    h. If you checked other above please explain
6. Would this be:
    a. A vacation/part-time residence
    b. A full-time residence
    c. A retirement residence
7. If it would be a part-time or vacation residence how many weeks a year would you like to live there?
8. What is the minimum square footage you would want for your unit?
    a. Efficiency apartment (300 square feet/30 square meters)
    b. 1-br, 1-bath, kitchen, LR/DR/study area (600 square feet/60 square meters)
    c. 2-br, 1-bath, kitchen, LR/DR/study area (900 square feet/90 square meters)
    d. 3-br, 2-bath, kitchen, LR/DR area (1,200 square feet/120 square meters)
    e. Larger
9. What is the MOST you would spend for a unit?
    a. $500 to $600 per square foot
    b. $700 to $800 per square foot
    c. $900 to $1000 per square foot
    d. More than $1000 per square foot
    e. I cannot afford these prices

10. Would you want to operate a business from the seastead?(businesses could be community-oriented, like a restaurant, or non-community-oriented, like an internet based business that serves customers outside the community)
11. If you answered yes to the above what kind of business would you like to operate?
12. What other considerations should we take into account when developing a floating city to meet your desires?
13. Do you agree with the following statement? I would live in the first floating community if I could afford a unit, and if it met my needs as well as important desires.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
14. Would you like us to contact you in the near future to gain more insight from you about what we should consider when designing the community?

PERSONAL INFORMATION

15. Marital Status
    a. Married
    b. Single
16. Age
17. Gender
    a. Male
    b. Female
18. Number of children under the age of 18
19. Total Annual Income (In USD)
    a. Less then $50,000
    b. $50,000 - $100,000
    c. $100,00 - $250,000
    d. $250,000 - $1,000,000
    e. More than $1,000,000
20. Current Net Worth (In USD)
    a. Less than $100,000
    b. $100,000 - $250,000
    c. $250,000 - $1,000,000
    d. $1,000,000 - $5,000,000
    e. $5,000,000 and up
21. Current Profession
22. Housing Status
    a. Own
    b. Rent
    c. Other
23. Monthly housing payment
24. Do you own more than one home?

    a. Yes
    b. No

25. What is the total value of your real estate assets?
26. How many days a year do you spend on vacation?
27. Do you own a timeshare?
28. If so, how much do you pay for it annually?
29. Estimate how much you spent on vacations in the last year

Survey Respondents' Profession Word

Seasteading implementation plan

Final report

Seasteading implementation plan

Final report

Date:	16 December 2013
Status:	Final report

Submitted to:	Randolph Hencken
	The Seasteading Institute

Project team:

Ir. Karina Czapiewska	Project leader and principal investigator
Ir. Bart Roeffen	Architect and researcher
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Contents

1. Introduction

Floating cities have been proposed by designers, researchers and organizations all over the world as a solution to the expected effects of climate change and land scarcity, or as a way to create opportunities for societal and political change. While the number of visions and designs for floating cities is impressive, the actual implementation to date remains limited to small-scale demonstration projects.

The Seasteading Institute is now working on the first part of the implementation phase, by preparing a business case for development of the first seastead. For this process, five important subjects have been identified as current priorities:

- future inhabitants' desires and requirements;
- location (suitability);
- growth and development process;
- images of the first seastead (concept design);
- costs (financial estimate of the concept design);

DeltaSync was invited to join this process and to think about the development strategy, to make a contemporary concept design and a rough cost calculation of this first seastead. The report will serve as the starting point for the development of the first seastead. It also gives an overview on which research needs to be addressed before this development can start.

This report is focused on the feasibility of the first step of the seastead, which can serve as a concept for the end goals of a seaworthy floating city. To be able to offer this, a design concept and development strategy is needed that on one hand is financially feasible and on the other hand is able to change locations in the event that the initial location is no longer suitable. To increase the feasibility, the focus for the first step will be on a design concept situated in protected waters. Because of this, the dimensions of the floating platform will be smaller than a design for the high seas. The ideal situation would be that platforms can exist without a breakwater. When moved to the high seas, the platforms should be able to survive, but be less attractive to live on from a comfort point of view. For example, moving to the high seas could be a short-term solution during a hurricane, after which the platform would be moved back into protected waters. In the best case, the floating structures could be enclosed within a breakwater to make them suitable for the high seas.

In chapter 2, the (internal) objectives are analyzed and the options not interesting for this case are eliminated. Chapter 3 describes the (external) influences from the environment, like climate and waves. Chapter 4 discusses how these objectives and characteristics shaped the design. Here, a first-draft design proposal is also given. Chapter 5 details ecological opportunities and how these could serve the implementation of a seastead. In chapter 6, the feasibility of the design proposition is described, followed by chapter 7 on growth strategy, chapter 8 on future possibilities of growth dynamics, and finally the conclusions and recommendations.

2. Design objectives

This chapter elaborates the design objectives. The six most important objectives are: movability, dynamic geography, growth, seakeeping, safety, and water experience. For each objective, the pros and cons will be discussed, including how the objective will influence the design of the floating city. After the discussion of objectives, a prioritization of the six objectives is made, and the options that are feasible will be eliminated.

2.1. Movability

The most important ambition of The Seasteading Institute is to guarantee political freedom. This aspect is directly linked to the ability to move a floating community when a specific location is no longer suitable because of political interference. The most important design qualities in terms of movability are the speed, safety, and convenience of the movement. The different possibilities to move a floating structure are directly linked to the size. A large structure has a relatively simple mooring system and can be moved quickly. Smaller scale floating structures have more connections between the city elements and with the ocean floor. The expected frequency of movements is infrequent, if at all. However, in some regions it would be a large benefit to be able to move away from hurricanes or cyclones.

Table 1.1 provides an overview of methods that can be applied for moving a floating city. If the structures are only moved occasionally (e.g. once in ten years or less) the self-propelled option would not be cost effective. To achieve the ability to move away from a hurricane, the option of disassembly is also not viable because it would cost too much time to disassemble. The two most suitable options are towing the floating district away and moving the floating district by semi-submersible ships. Both methods can be used to transport large and small structures, but the semi-submersible ship can also transport smaller structures over high seas. The Blue Marlin, for example, has a deck space of 63 m × 178.2 m (207 ft × 584.6 ft) and a deck area of 11,227 m2 (120,850 sq ft).[1] The largest semi-submersible ship is the Dockwise Vanguard (Boskalis) which is 70 x 275 m and suitable for extremely heavy loads.

Table 2.1 Options for Movability

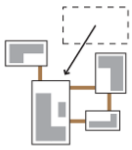
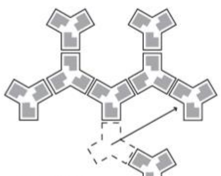
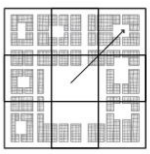
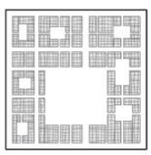
TYPE	DESCRIPTION	PROS	CONS
 SELF-PROPELLED	Ultimate movability is gained by integrating a seastead with or building it on a ship – the most suitable option if city is often relocated.	– Easy to move – Can be moved quickly – With large structures, a simple mooring system	– Large propulsion system – needed for occasional transport – High maintenance costs.
 TOWED	Seastead platform(s) are designed in such a way that they are easy to move using a tugboat or other external device that can generate propulsion.	– Easy to move – Can be moved quickly	– External device needed for transport. – Design should be suitable for towing. – For travelling high seas, only large structures possible.
 SEMI-SUBMERSIBLE SHIP	Seastead is transported by a semi-submersible ship.	– Can be moved quickly – Least design restrictions. – Freeboard can be lower, allowing better water experience – A large variety of platform sizes can be transported. – Allows smaller scale structures to be transported over high seas. – The total structure stays intact.	– External device needed for transport – Large number of ships needed when there is a large number of small platforms. – Mainly suitable for large structures. – Size of floating platforms is restricted to the size of the ship (but ship size is very large) –Structure must be strong enough to be lifted out of the water.
 DISASSEMBLED	Seastead is designed in such a way that it can be disassembled and transported using containers.	– Transport can be fast. – Transport can be to any given location.	– Preparation for transport takes a long time. – Inhabitants must be transported separately.

2.2. Dynamic geography

In addition to granting maximum freedom for its inhabitants from the political point of view, a seastead can enable greater freedom at a city level, on the community level, or individual level. This can be achieved by possibilities for moving inside the seastead with one's own house as an individual, or even moving away from the community with a group of inhabitants. The Seasteading Institute refers to this as 'dynamic geography'. Preferably, this would be enabled on as fine-grained a scale as possible, allowing movability all the way down to the size of a single autonomous house.

Table 2.2 shows different spatial configurations of floating cities that are evaluated for their ability to achieve dynamic geography. The two most suitable options are the islands and the branch. Both structures consist of a small amount of houses. Where the islands are connected by bridges or jetties, the branches are connected using a hinged connection. Because of this, both structures can be disconnected easily. The islands can be used by only one person, a family, and in the case of the branches structure, a small number of families. This gives people the ability to move to another location.

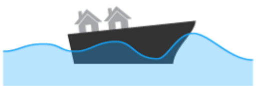
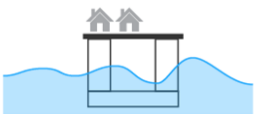
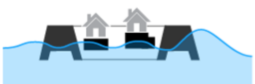
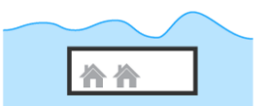
Table 2.2 Options for Dynamic Geography

TYPE	DESCRIPTION	PROS	CONS
 ISLANDS	Every building is located on its own platform (or hull). This enables maximum freedom of movement. Structures are connected with hinged joints.	- Optimal dynamic geography.	- Large number of connections. - Large number of moorings is needed. - Large swell.
 BRANCH	The floating structures consist of several houses or other buildings. The structures can be connected with hinged or rigid joints.	- Easy to move away. - Less swell than 'islands'.	- No possibility to move a single house - Structures need to be uniform to be able to fit together. - Large number of mooring constructions are needed
 COMPOSITE STRUCTURE	Semi large structures are connected to each other until they form one larger structure. Connections are rigid.	- Fewer moorings needed. - Little swell.	- Not easy to disconnect - When rearranging, adjacent structures also need to be moved.
 SINGLE LARGE STRUCTURE	Using a large structure such as a (cruise)ship or oil platform as one unit.	- Fewer moorings needed. - Little swell.	- Rearrangement not possible.

2.3. Seakeeping

Seakeeping consists of two levels: the ability to survive severe sea conditions in a protected bay and to be able to adapt for survival on the high seas. Major issues on the high seas are the depth, the large (rogue) waves and (tropical) storms. These factors present challenges for mooring, wave breaking and comfort. Table 2.3 presents the options that are available for seakeeping. The cruise ship and the submerged option are not suitable for achieving a high level of comfort for the citizens. The ship experiences too much swell, whereas the submerged has no direct fresh air or sunlight. Therefore the most suitable options are the oilrig and the breakwater structure.

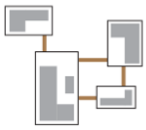
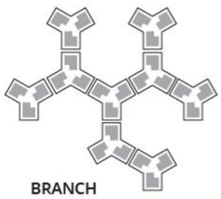
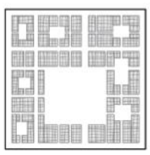
Table 2.3 Options for seakeeping

TYPE	DESCRIPTION	PROS	CONS
 SHIP	Ships are a proven concept and large vessels are especially suitable for the high seas because of their shape and size. Wave attenuation is integrated into the ship itself. The structures are very responsive to waves and can experience a large amount of swell.	- Integrated wave protection.	- Wave attenuation only functions when ship is in motion. - Not optimal shape to create a city with public space, connections etc.
 RAISED PLATFORM	A raised platform like an oilrig or an air container type of structure minimizes the surface that is in contact with the water's surface and thus minimizes the force of the waves.	- Integrated breakwater. - Minimum contact with water surface reduces wave impact and wave influence.	- Only suitable for large structures
 BREAKWATER	An external structure is constructed to serve as a breakwater, and behind this the city can take any shape.	- Large design freedom. - Breakwater could be integrated with other systems or functions. - Creates calm water behind structure that could be used for aquaculture, recreation etc.	- External structure needs additional mooring solutions. - Is not able to withstand every wave type, which would result in swell behind it under some circumstances.
 SUBMERGED	When the structure is submerged, the impact of waves is minimized. The force of waves decreased exponentially with the depth.	-Suitable for almost every location.	- Providing enough daylight would be a challenge. - Inhabitants need oxygen. - No contact with outside climate could also cause mental discomfort.

2.4. Water experience

Water experience in the seastead can be subdivided into visual experience and physical experience. The first experience is primarily concerned with residents' ability to see the water. The second experience includes swimming, sailing, diving, aquaculture, and perhaps even surfing. Living in a neighborhood close to the water would be preferable to an oilrig or a cruise ship where the connection to the water is only visual, from a large distance. Table 2.4 presents various options to create a water experience.
Only the large platform is not suitable. In all other options, the smaller the platform the better the water experience. The island and branch options have the best water experience because the distance to the water is the smallest and all houses have a direct relation with the water.

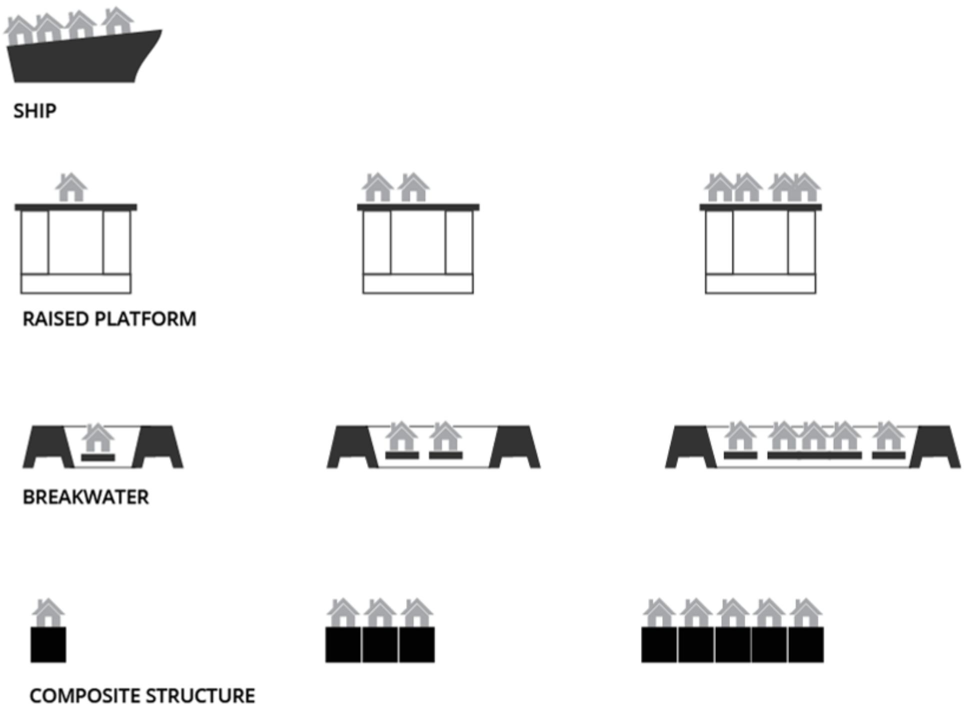
Table 2.4 Options water experience

TYPE	DESCRIPTION	PROS	CONS
 ISLANDS	Every building is located on its own platform (or hull). This enables maximum freedom of movement. Structures are connected with hinged joints.	- Maximum water experience.	- Less stability. - Needs protection by breakwater, which may obstruct ocean view.
 BRANCH	The floating structures exist from several houses or other buildings. The structures can be connected with hinged or rigid joints.	- Very good water experience. - Intermediate stability.	- Needs protection by breakwater, which may obstruct ocean view.
 BAY	Semi-large structures are connected to each other until they form one larger structure. Connections are rigid.	- Nice bay-like experience. - Very stable.	- Many different platform types - Many rigid connections needed
 PLATFORM	Using a large structure as a (cruise)ship or oil platform as one unit.	-Building shapes not limited by platform -Very stable	-Little water experience, except from the edges. -Even the edge has less optimal water experience, because exposed to waves.

2.5. Growth development

Looking at the previous sections, roughly two types of structures can be distinguished: large structures developed at once and modular structures that grow gradually. Table 2.5 provides an overview of the options. The 'ship' or 'raised platform' structures need to be constructed and financed at once and are difficult to expand. Smaller structures, which may be protected by a breakwater or combined to one large structure, allow for much more gradual growth. For a gradual strategy, a modular system consisting of smaller parts is more suitable than large structures that are constructed at once.

Table 2.5 Growht development



2.6. Safety

A major requirement that is connected to all objectives discussed in this chapter is securing the safety of the inhabitants. This aspect will have a strong influence on the design decisions. Safety is on one hand providing a reliable floating structure and a living environment where people can safely move around and enjoy their life. It is equally important to protect the floating city from environmental hazards like large waves, storms, and even hurricanes. Therefore it is important to move away fast enough to avoid a hurricane. More information about this can be found in chapter 3.5 Climate.

2.7. Prioritization of objectives and influence on the design

Conclusions on the relative importance of the aforementioned objectives were determined during the design and research process of this study. The most important objectives were identified as movability and seakeeping, especially in terms of safety. The dynamic geography, water experience and growth development are less important. How dynamic geography could work in future situations is discussed in chapter 8. Because the size of the platform has to be estimated in order to make the design and calculate the feasibility, a first selection on size is made using the objectives. For movability in normal conditions, any size can be towed, whereas transporting in rough waters can only be achieved with larger platforms. The semi-submersible ships can move very large-scale oil platforms, but the maximum size is limited to that the size of the semi-submersible.

The dynamic geography is mainly influenced by number of people living on the platform and agreeing on moving. A smaller size platform is easier to move around in a city than a large one. From the point of view of seakeeping the size greatly depends on the significant wave characteristics a region. The smaller the platform size, the more swell. On the other hand, if the platform is too large, hog and sag can occur, which will lead to extra investments in order to strengthen the construction. The water experience will be maximized if the platforms are small in size and low in height. Small platforms are also more favorable for growth development; smaller platforms require smaller investments than larger ones. From the point of view of movability the next location is important to take into consideration. While future seasteading communities are envisioned to withstand the high seas, the first communities in The Floating City Project will start out in more protected waters, and will only be in higher seas occasionally and for short periods of time, such as when moving or fleeing hurricanes (figure 2.1).

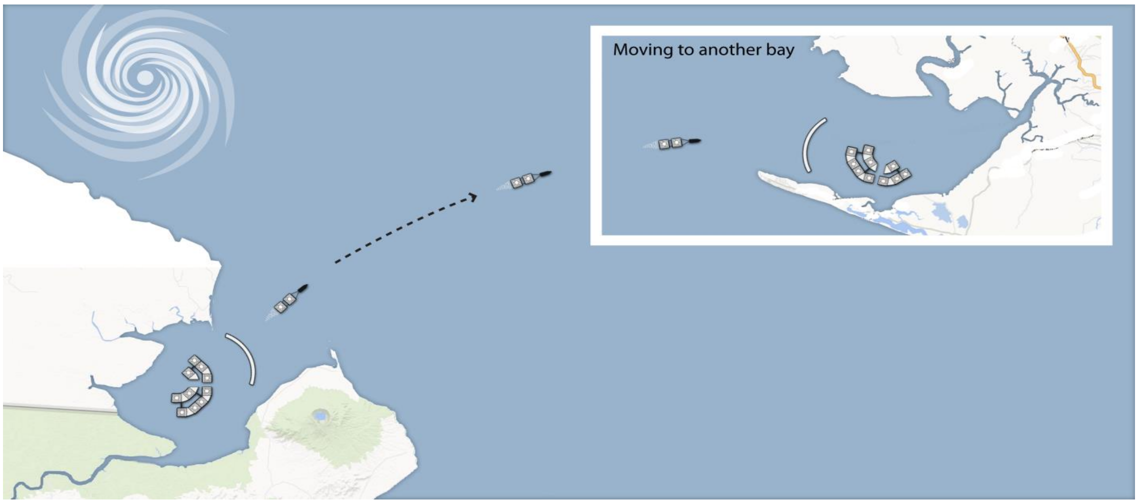


Figure 2.1 Moving from one bay to another

From the analysis in this chapter, a first selection of possibilities is made (figure 2.2). For occasional movability, the options of semi-submersibles and towed platforms remain interesting options. Because the large structures like a ship or oilrig are not interesting from the point of view of water experience, comfort, dynamic geography and growth strategy, these options are excluded. Because of this, only the breakwater option remains for the seakeeping. The small islands are also not suitable for seakeeping, because even with a breakwater comfort would be compromised. The remaining options can be summarized as a branch-like structure that can be composed into one larger structure or can be placed behind a breakwater. Modular components of a branch like city could be towed or moved with a semi-submersible ship.

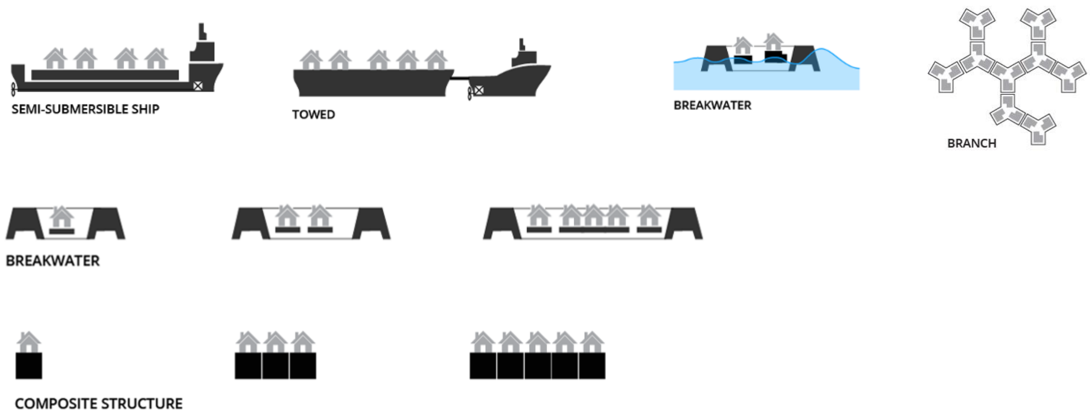


Figure 2.2 First selection of possibilities based on the objectives

3. Local conditions

It is unavoidable that the design of a seastead will be affected by local conditions. For example the wave conditions will determine the dimensions of the floating structure and breakwaters. The depth of the ocean floor (bathymetry) will affect the dimensions and costs of mooring systems and whether such systems are more cost effective than station keeping facilities. At the same time, the local characteristics that the seastead has to deal with should not be regarded as fixed values. The seastead should be able to relocate and deal with many possible scenarios. It should at least be able to be moved to another bay with approximately the same conditions. It should be able to survive less attractive wave conditions during storms and temporary relocation in case of hurricanes. In the ideal situation it should be able to handle the high seas with or without additional protection (figure 3.1).

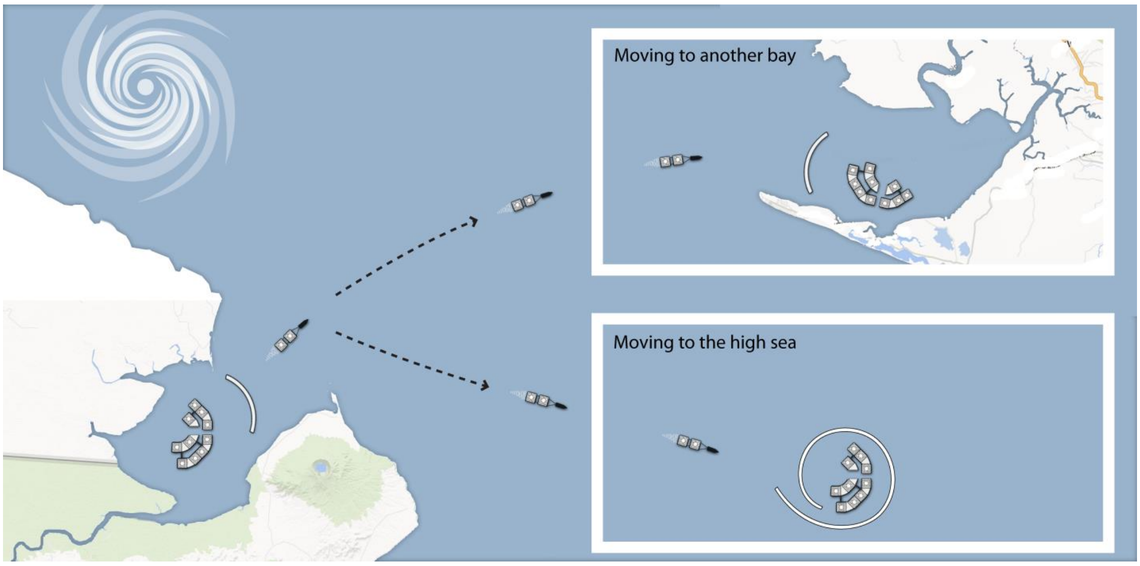


Figure 3.1 Scenarios of relocation

In order to successfully develop a growth strategy for The Seasteading Institute, an inventory of local conditions and their effects on the design have been drawn up. The conditions were subdivided into those that are of structural influence and those that affect the design in terms of energy and resource, as illustrated in figures 3.2 and 3.3.

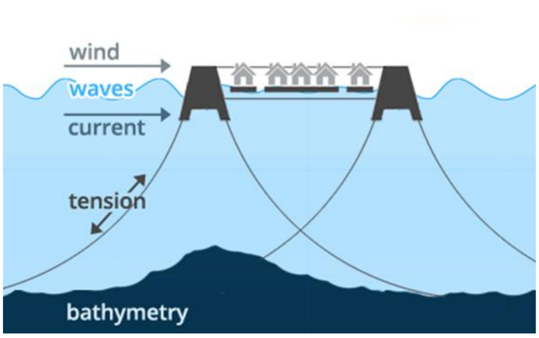


Figure 3.2 Structural aspects

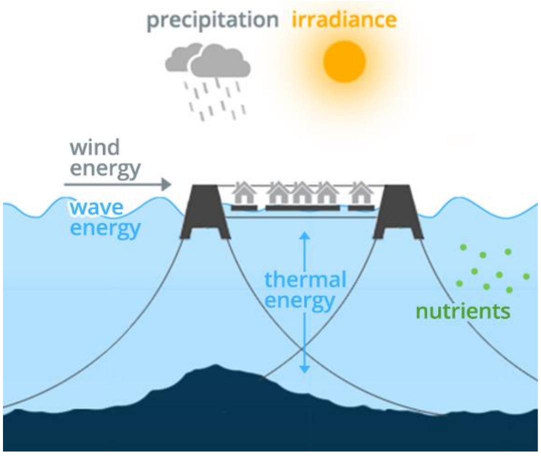


Figure 3.3 Energy and resources

3.1. Bathymetry

The depth of the ocean floor will affect the dimensions, type of material and costs of the mooring systems. Chains attached to anchors are the most common choice for shallow water up to 100 m.

Different material compositions are applied depending on soil properties, strength due to currents, differences in tides, how often the structure will need to be moved and so on. Seamounts and ridges may provide good locations for the seastead because they decrease the depth and for this the length of the anchoring system. In relatively shallow water, bathymetry also affects waves. Typically the depth of a wave is equal to half the wavelength, which means that a 200m long wave will tend to get shorter and higher if the depth is smaller than 100 meters. When the wave approaches to the coast, more and more energy is pushed upward and the wave becomes steeper and less stable until it breaks, at wave height greater than 80 percent of the water depth.[2]

3.2. Tides and currents

The local currents and tides determine the water forces on the submerged part of the Seastead. A counterforce needs to be present in order to keep the Seastead at the same position, either by mooring it or by propelling it. This means that the mooring system will also have to deal with these forces. The equation used to calculate this is shown in appendix 1.
In some locations ocean currents can get quite high. For example the Gulf Stream can reach ocean current surface speeds of 2.5 meter per second. At an ocean current speed of 2.0 m/s the pressure on the structure amounts to 2.0 kPa (kN/m^2).[3] This amount of pressure compares to a category 3 hurricane with wind speeds of around 60 m/s (107 knots). Ocean current speeds of 1.0 m/s compare to wind speeds of 30 m/s (58 knots): a wind force of 11 on the Beaufort scale. Such speeds may even be encountered close to continents, as is illustrated in figure 2.3. In storm conditions it is likely that the structure will deal with currents and wind that have the same direction. This means that high water pressure and wind pressure can occur simultaneously.

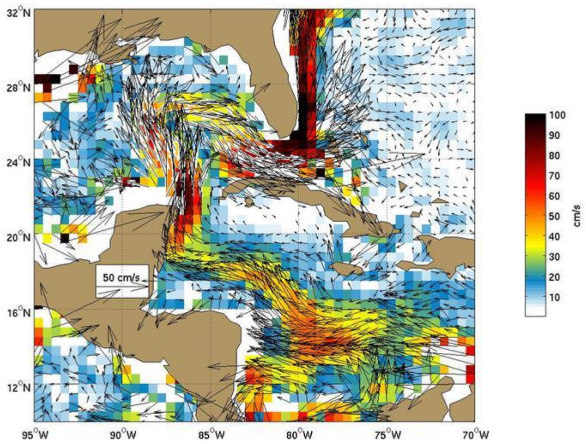


Figure 3.4 Ocean Currents[4]

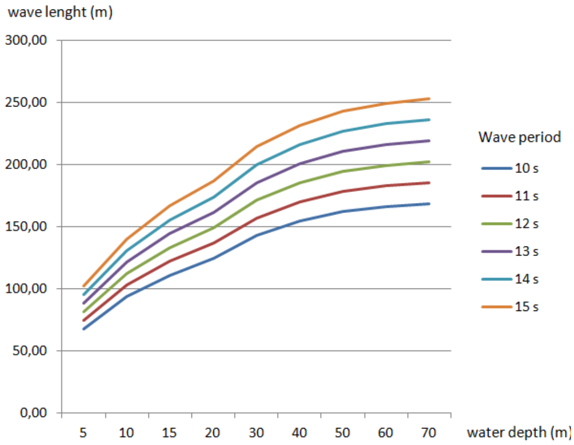


Figure 3.5 Variation in wavelength of wave with period 15s.

3.3. Waves

The main characteristics of a wave are the period, the wave height, and the wavelength. Wave period is the time it takes for successive waves to pass the same point in seconds. Long period waves (T>14 s) have more energy, a flatter profile in deep water and they create taller waves when entering shallower water but decrease in length (fig. 2.5 and 2.6). Wavelengths can be classified in short (λ<100 m), average (100< λ<200 m) and long waves (λ>200m); wave heights are classified in low (H<2 m), moderate (2<H< 4 m) and high waves (H>4 m). Wavelength and height are related to the wave period. The wavelength was calculated using Hunt's method. This allows calculating the wavelength of known period waves in any water depth, with an accuracy of 0.1 percent. The equation for wavelength can be found in appendix 1.

Wave characteristics are important to know, because they affect the size of the platform, as explained in chapter 4. The wave characteristics for the selected locations will likely be a lot more favourable than the high seas conditions, since preferable areas for the first phase of the seastead will be bays or gulfs.

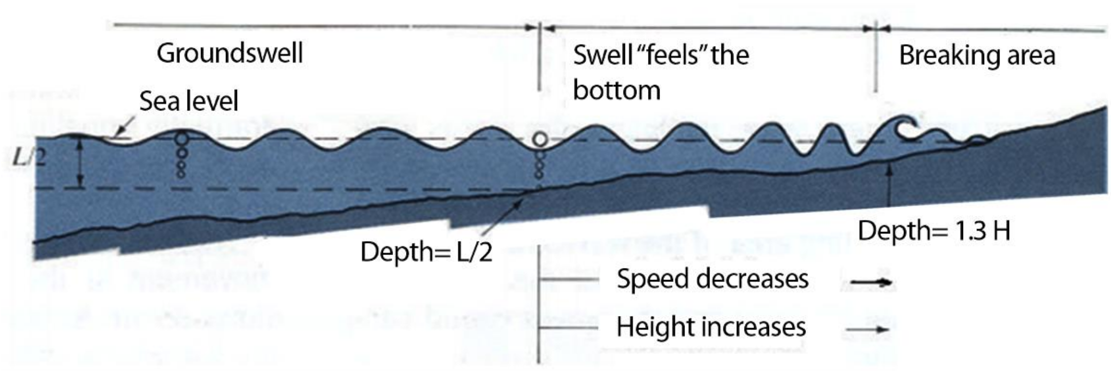


Figure 3.6 Behavior of a wave that approaches the coast[5]

3.4. Wind

Wind blowing on the water is responsible for wave formation. The size of the wave depends on the strength and duration of the wind, in conjunction with water depth. Large waves formed in open seas will continue travelling for long distances after winds have already stopped. During their travel those waves will be influenced by tides and wind from other directions, but also from the shape of shorelines. For this reason it is important to know data on wind speed and directions for the specific locations. In a bay, for example, wind waves (surface waves that occur on the free surface of sea, as result from the wind blowing over a vast stretch of fluid surface) could be predicted knowing the fetch and the wind speed. This will allow wave protection to be applied specifically in the areas where they are needed.

3.5. Climate

The general climate conditions, such as precipitation, humidity, wind and solar radiation are relevant for the construction and detailing of the buildings. High humidity will be inherent to water surface locations. This means that the structures are to be built with consideration for moisture.

In addition, particular climate zones may see more heavy storms such as cyclones and hurricanes. Cyclones are smaller and less intense than hurricanes and therefore less of an issue. Some of the potential areas for future seasteads are in hurricane prone zones (figure 3.7). "Globally, about 80 tropical cyclones occur annually, one-third of which achieve hurricane status. The most active area is the western Pacific Ocean, which contains a wide expanse of warm ocean water. In contrast, the Atlantic Ocean averages about ten storms annually, of which six reach hurricane status"[6].
The intensity of a hurricane can be measured using the Saffir-Simpson hurricane scale (appendix 2). A hurricane's destructive winds and rains can extend outward from 40 km to more than 240 km. The force of a tropical storm can extend up to 500 km from the eye of the hurricane.[7] Once a hurricane has formed is can be tracked and its path predicted for 3-5 days in advance.[8] Using a bad case scenario of a hurricane scale five and a prediction of 24 hours in advance. In this time all platforms should be disconnected, one or more tugboats should arrive on short notice and the platforms should be placed in formation to be tugged away. A tugboat can reach a speed up to 12 knots, but in case of heavy currents 6 knots (11 km / hour) is used. This would mean that getting away from hurricane destructive winds would take 21 hours and 3 hours would be left for all the other tasks. To get away from the tropical storm force zone requires another 24 hours.

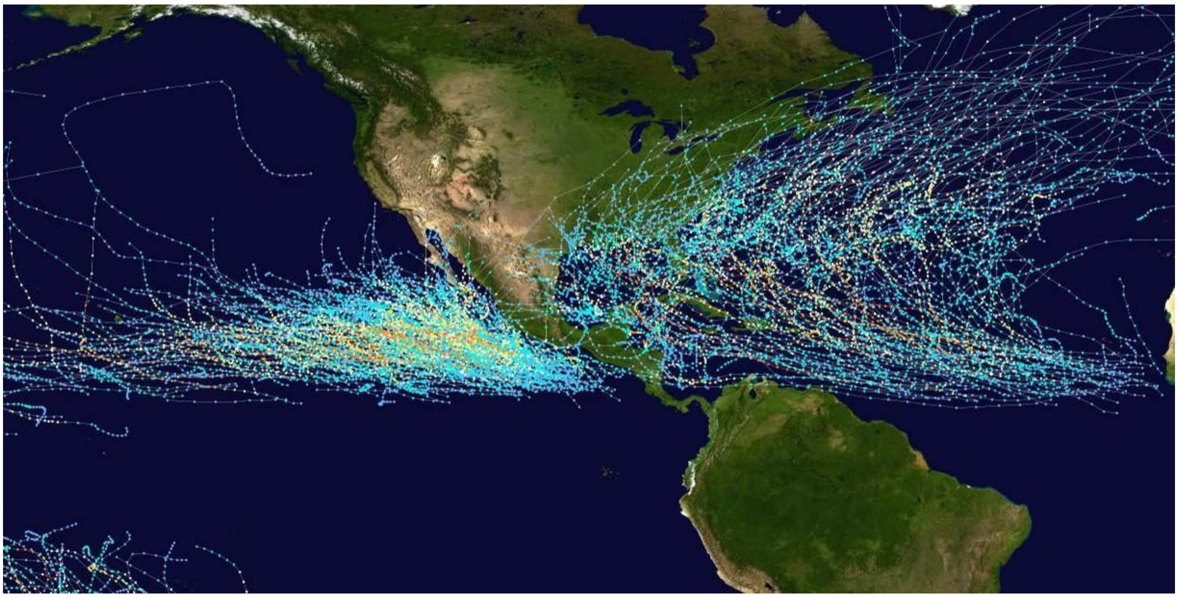


Figure 3.7 Tropical cyclone tracks, from 1985 - 2005 color is linked to the Saffir-Simpson hurricane scale.

3.6. Precipitation

Fresh water is a necessity for human survival and needs to be available at all times. Being dependent on supply from imports has risks. At the start of the development dependency is unavoidable, but as soon as the seastead reaches a certain size, it becomes an interesting option to locally produce fresh water. There are two options: water desalination and rainwater harvesting, both of which may contribute to sufficient and commercially feasible water supply. The calculation model determined that rainwater is likely to be sufficient for most applications in the site selected for this feasibility study.

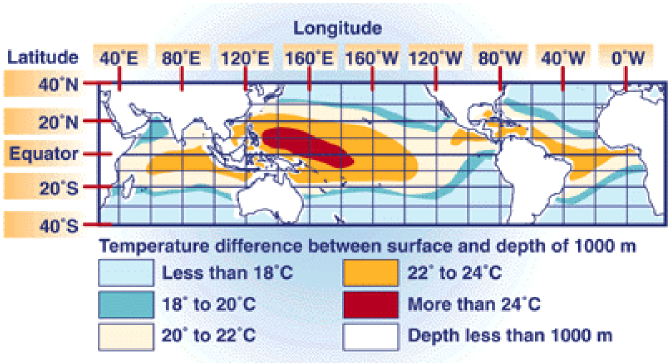


Figure 3.8 Interesting zones for OTEC: wikimedia.org/wikipedia/commons/e/e7/Temperaturunterschiede_Ozeane.png

3.7. Ocean energy production

Depending on the local conditions, a combination of renewable energy systems may be chosen. Currently, several small-scale commercial floating wind farms have been realized. Most of the designs use offshore platform technology, for example the Hywind system that features a turbine mounted on a floating pole with a 100-metre deep draft similar to a spar.[9] Costs of offshore wind facilities are substantially higher than their on-shore counterpart and will depend on the water depth and wave conditions. However, in the seasteading project there may be ample opportunities to combine wind turbines with other functions, such as breakwaters. This may bring prices down to the level of on-shore wind energy and could prove to be one of the most cost-effective renewable energy sources.

Ocean Thermal Energy Conversion (OTEC) uses the temperature difference between deep and shallow ocean water to produce electricity and, as a by-product, desalinated fresh water. The feasibility depends on the temperature difference, which is relatively high in tropical areas (as illustrated in figure 2.8). No commercial facilities have yet been realized. Other energy producing options could be solar cells, algae biofuel and osmotic power.

3.8. Nutrients

Worldwide, a vast amount of nutrients are discharged into the oceans. These nutrients can be used to produce food or algae. Part of the supply may be recycled from human waste, which at the same time would prevent pollution of the environment. Figure 2.9 shows the level of chlorophyll, which is an indicator for the nutrient concentration. The largest concentrations occur at the edge of continental shelves where the currents cause upwelling.

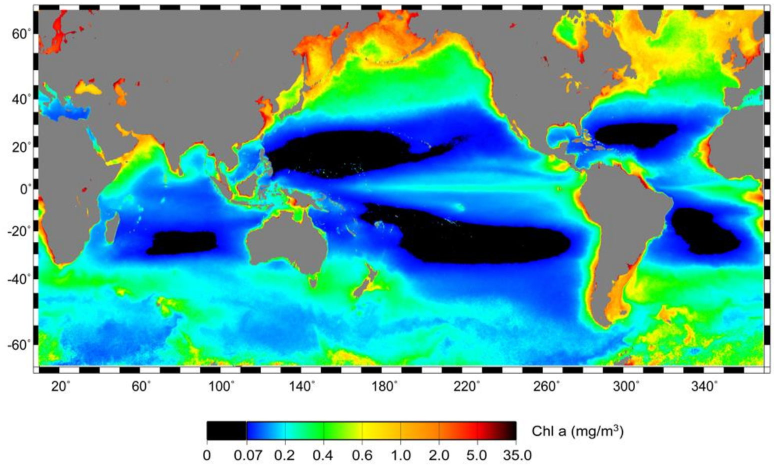


Figure 3.9 Level of chlorophyll Source: http://www.vos.noaa.gov/MWL/apr_08/Images/globe1big.jpg

3.9. Conclusions

Each of the aspects discussed in this chapter are listed in table 3.1, with corresponding influence on design. Bathymetry, waves, tides and winds were found to be the most important aspects that influence the most critical elements of the seastead. Consequently, the mooring system and the platforms will be the major focus for the design. The energy and resources overview will be mainly used for the calculation model.

Table 3.1 Overview conditions

	Local conditions	Influence on design
1) Structural	Local bathymetry	mooring system dimensions
	Tides and currents	structure and mooring system dimensions
	Waves	platform dimensions
		breakwater dimensions
		mooring system
	Wind and tropical storms	structures and mooring system dimensions
		time needed to escape, 240 km max from destructive hurricane force, 500 max from tropical storm force
	Climate	building design and construction (sun/rain control)
2) Energy & Resources	Precipitation	water treatment & storage facilities
	Nutrient upwelling	food production opportunities
	Solar radiance	energy production opportunities
	Wave energy	energy production opportunities
	Ocean thermal energy	energy production opportunities
	Wind energy	energy production opportunities

3.10. Characteristics of a specific location

To be able to provide a more realistic design, the location characteristics described in chapter 3 have been examined for one specific location. The Seasteading Institute conducted a large-scale selection process for suitable countries. Locations were analyzed on criteria ranging from the political situation in nearby nations, piracy, climate, the presence of protected waters, among others. The Institute instructed us to focus on the Pacific coast of Honduras for this investigation.

The first location that has been selected for study for the design and cost estimation is the Gulf of Fonseca situated in Honduras. The location is situated on the Pacific coast and covers a coastline of 115 km belonging to Honduras. Most of the coastline is Exclusive Economic Zone (EEZ) and Honduras owns the North East part of the gulf, including the Bays of S. Lorenzo, Chismuyo, Choluteca delta and part of the Bay De La Union. Large parts of the coastal area consist of wetlands (light green zones), including swamps and areas with mangroves vegetation (figure 3.10).

Figure 3.10 Location of the Gulf of Fonseca and map including EEZ.

Input for the design

The proposed location in Honduras is marked with a star in figure 3.10. This location could be an interesting option because of protected bay area and the proximity of the Choluteca airport, which could be reached by car in less than an hour (45 km). The existence of effluents from shrimp farms (currently a cause of eutrophication and hypoxic conditions), could provide nutrients for algae farming. In table 3.2 the local conditions have been summarized and linked to the design. Because no data on waves was available, two buoy points (figure 3.11) close to the bay have been used as input. In appendix 3 a full description of the analyzed input data is given.

Table 3.2 Local conditions structural influence

	Characteristics	Influence on the design
Local bathymetry	0 to 10 m depth within 10 km from the coastline.	Mooring system dimensioning will take into account an average depth 5 m.
Tides and currents	Cycle of tides is on average 2.5m/day (2 cycles per day). Current speed 0 to 20cm/second.	The variation is height considers a mean tide of 2.5m +4m (highest wave). Total = 7m circa

Waves	Significant height: 0.5–2m*. 1 out of 100: 3.3m and in storm 4m10. Yearly average: Wave period** Data based on wave forecast Average wave period 12–14s. Wave length*** at 10m depth 115m**** Swell direction SSW
Wind and tropical storms	Within 100 km radius a few severe storm tracks were registered, which occurred every 10 years. In 2005 tropical storm Adrian passed through the Gulf.

*Based on NWW3 model predictions since 2006 (values every 3 hours). The wave model does not forecast surf and wind right at the shore so we have chosen the optimum grid node based on what we know about Punta Mango. Here the best grid node is 23 km away (14 miles). Swell heights are open water values from NWW3. Coastal wave heights will generally be less. No swell: 1.3%, 0.5-1.3m waves: 71%, 1.3-2m waves: 26%, 2-3m waves: 1.5%, >3m waves: 0.1%.
**Historic data on wave period was not found. Weather data forecast from October 9 - 20 at Punta Mango show an average wave period of 16s (varying from 13s to 19s). Green alert by Honduran authorities predicted a tropical storm with wave period of 12-14s in October 2011.
*** Historic data on wavelength were not found. If period values between 12-14 seconds are chosen, waves length will vary between 190-240m at the inlet of the Gulf (sea floor depth of 40m) and 100-130m at 10 km circa from the coast (sea floor depth of 10m)
***Based on NWW3 model predictions since 2007 (values every 3 hours). The wave model does not forecast wind or surf waves right at the coastline so we have chosen the best grid node based on what we know about Corinto. The best grid node is 21 km away (13 miles). Swell heights are open water values from NWW3. Coastal wave heights will generally be less, especially if the break does not have unobstructed exposure to the open ocean.

Figure 3.11 Buoy points

4. Design

In this chapter the objectives discussed in chapter 2 and the characteristics of a specific location of chapter 3 are applied to the design of the floating structure and real estate. First of all, an estimation of the most optimal platform size is made. Then, considerations on the most suitable materials will be made and finally, a structural concept and the design of the real estate will be outlined.

4.1. Estimation of platform size

The ideal size of individual platforms will depend on many factors, some of which can be precisely determined while others remain speculative. The relevant factors that have been included in this study are illustrated in figure 4.1:

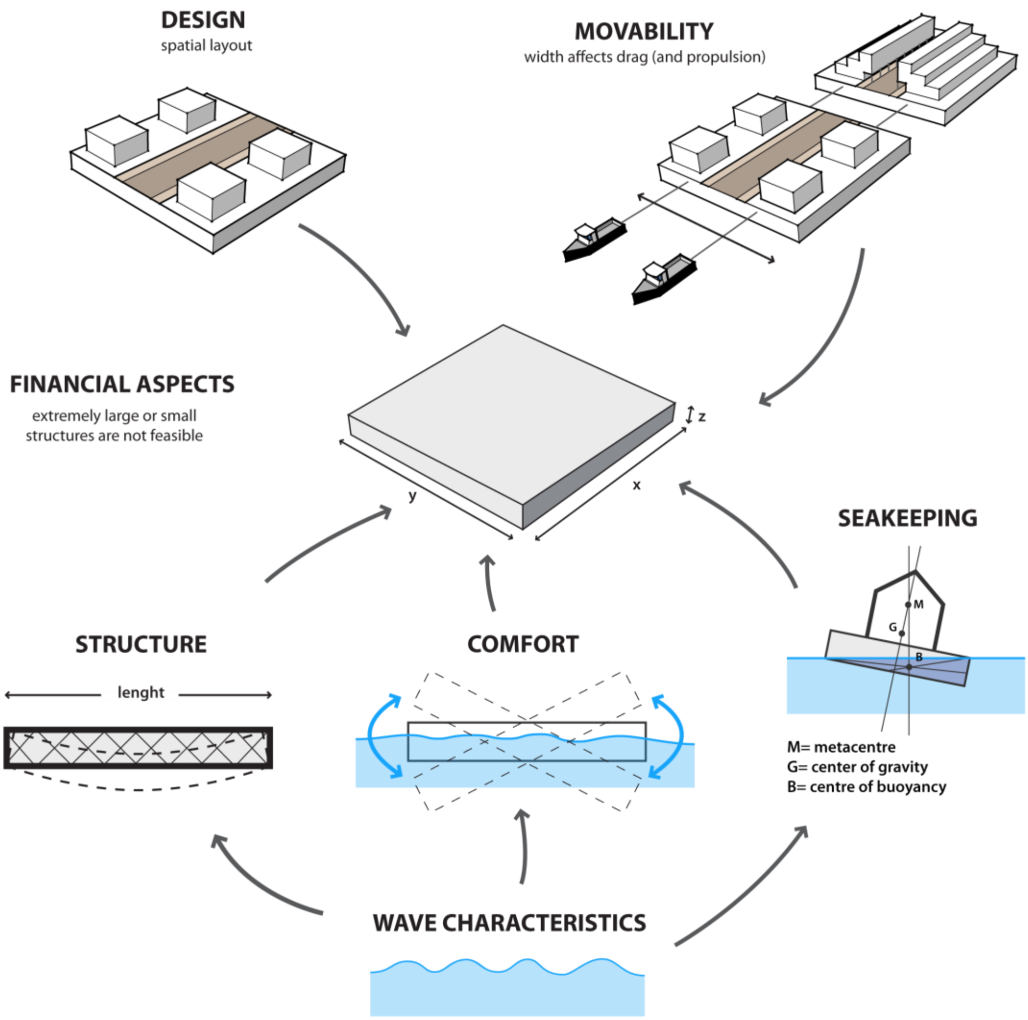


Figure 4.1. Factors that influence the optimal size of a floating platform

Movability

It is important to be able to relocate the seastead, in case of emergency or if a new location is required. Whether this is a feasible option will depend on several factors: **Connections**: the type and number of mooring connections and interconnections between platforms; **Resistance**: The hull resistance to water during transportation; **Type of transportation**: e.g. semi-submersible, tugboat, etc.

Connections, both to the ocean floor and in between different platforms are vital to the feasibility of a seasteading community. Mooring connections will keep the community stationary. In between the platforms there will be several types of connections: structural connections, utility connections and bridges. In order to enable emergency relocation, these connections not only need to be strong and flexible, but also easily disconnected. These parameters will affect the costs. Opting for smaller platforms means that an exponentially greater number of platforms are required for the same amount of space, which will increase the number of connections. This is illustrated in figure 4.2, which assumes a population of 225 people and 100 m^2 platform space per person. It follows that for a platform size of 50 by 50 meters, a total of 9 platforms are required. At least 8 connections are required to connect all 9 platforms (but additional connections may improve the strength and dimensional stability of the cluster).

When the platform size becomes smaller than about 25 x 25 m the number of connections grows rapidly. Connections between floating structures are often complex and at smaller sizes may become a substantial part of the overall costs. Additionally, a large number of connections may adversely affect the ability to relocate the seasteading community in case of emergency.

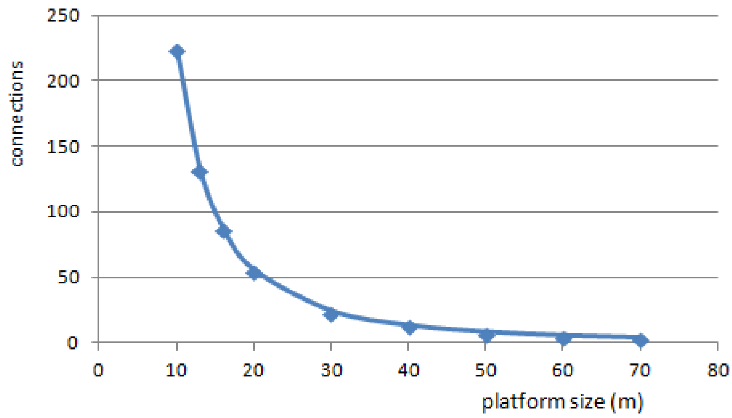


Figure 4.2 Relation between the amount of connections and platform size.

Whether movability is feasible will also depend on the amount of resistance in the water. When platforms are towed during relocation, the shape of the hull will affect the amount of resistance and thus the amount of power that is required for propulsion. A larger platform requires greater structural height and a larger part of this height will be submerged, resulting in increased draft. This means that increasing the size of the platform will exponentially increase the resistance (and the required propulsion power). Propulsion is one of the main challenges for larger vessels[11].

While the seastead under transportation is likely to travel at a lower velocity, will have a different shape and will be propelled by smaller engines (of tugboats), this comparison does indicate that the width of the platform will have a large impact on movability. A more detailed calculation is required in order to determine the maximum platform size for a given towing speed and tugboat engine capacity.

The last factor that influences movability is the required type of transportation. The ability to move away during a hurricane is one of the issues that is considered, as discussed in chapter 2. It is for this reason that the floating structure should be able to move away quickly and the mode of transportation should be one that is available at any given time. The option of the semi-submersible ship is not feasible, because the risk that it will not arrive on time is quite large. An integrated propulsion system is expensive, especially if it is only used as an emergency system. This limits the options to a towed form of transportation, such as local (tug-)boats. These boats can also be used for the transportation of people and supplies.

Seakeeping, comfort and structural aspects

The definition of 'seakeeping' is somewhat ambiguous. It can be used either to denote dynamic response of a vessel to wind and wave conditions or a measurement of a vessel's performance in the environment (sea state) it operates in. In this study a distinction is made between 1) safety, which includes adequate strength, stability and buoyancy for given design conditions, and 2) comfort, which focuses on deformations, motion and acceleration arising from interaction with waves and wind. Both objectives are influenced by the size of the platform. Generally, larger and heavier platforms will have lower motions compared to small or light platforms, because the relative size and energy of the waves will be lower.

Stability is a measure of the platform's resistance to tilting. When waves or other forces tilt the platform, the center of buoyancy moves to the direction of the tilt, because this side now displaces more water. The upward buoyant force will counteract the tilting motion and in combination with the downward weight of the platform, it rotates back to its equilibrium. The distance between the forces of buoyancy and gravity is referred to as the *righting arm*. A larger platform has more resistance to tilting, because more water needs to be displaced in order to tilt the platform. Very small platforms with a high center of gravity are not an option because of the high risk of negative stability. Large platforms with a low center of gravity, on the other hand, also have some points of attention. In this situation the righting arm will be very large, which means that the platform will rapidly return to the upright position. This is referred to as a 'stiff' vessel. While this condition reduces the risk of deck immersion, it will result in larger forces in the structure and higher accelerations that may cause motion sickness.

As described in the Seasteading Engineering Report (Hoogendoorn, 2011), a structure that is less than half a wavelength in size will tend to mostly follow that wave; if the structure is more than twice the wavelength, its response will tend toward zero. This is illustrated in figure 4.3. It is also indicated in the report that where waves with length of over 100 m are concerned, a huge platform would be needed in order to minimize wave-induced motion for all types of waves. Furthermore, such a structure will be exposed to extreme forces due to sagging and hogging. In order to deal with such forces, the structural height may need to be increased, which will have dramatic effects on financial feasibility and practical usability.

Whether a size of half the wavelength results in acceptable levels of acceleration (the main cause of motion sickness),will depend on many factors. As described above, the wave response time of the structure will depend on the total mass and distribution of mass in the structure. Secondly, research indicates that altering the shape of the platform may reduce acceleration considerably.[12] Finally, several platforms will need to be connected. This may further reduce negative effects of waves. More research and detailed simulations are needed to further investigate the optimal size, shape and connections.

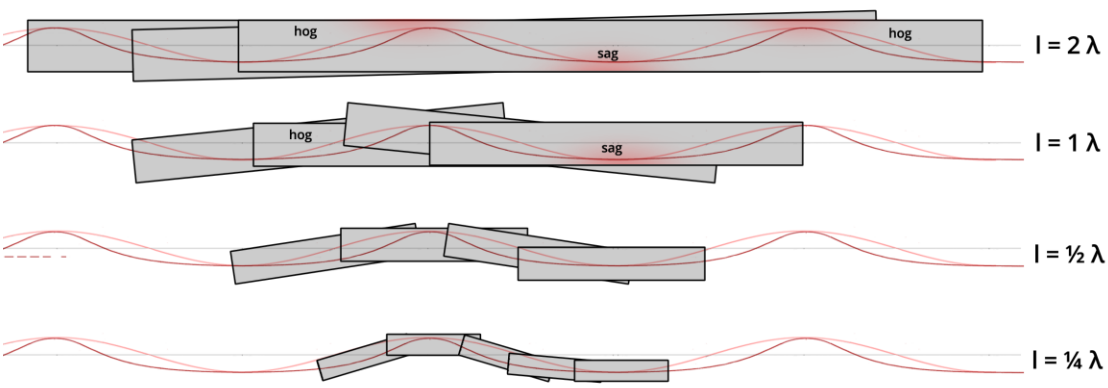


Figure 4.3. Wave-induced motion of a platform at different sizes and resulting stresses in the structure.

Ideal size from a design perspective

The platform is likely to be the most expensive part of the seastead. In order to keep the costs down, the amount of sellable floor space needs to be optimized. A platform width between 40 and 60 m is ideal to fit two rows of houses and leave enough space for roads or access/escape routes. Smaller platforms with a single row of houses would still need a road in order to access the house or provide emergency escape routes. This would make the design less efficient in terms of sellable floor space. This will be further elaborated in section 4.3.

Conclusion

One of the objectives of this project was to come up with a more feasible alternative to large scale floating developments such as cruise ships or semi-submersibles. It was found that from a design perspective 40-60 m platforms, with a mean size of 50 by 50 m, would be ideal. This is also a good size to ensure movability by tugboats. Larger wavelengths may present problems in terms of comfort, but as discussed, it is not structurally feasible to try and deal with this by making extremely large platforms. In order to solve comfort requirements it is advised to do a more detailed study on how interconnected platforms with semi-flexible connections behave under different wave conditions. Although the data on the ideal dimensions of the platform is not yet conclusive, for this design the size of 50 x 50 meter has been chosen as a basic size. More detailed data on local wave characteristics and further research on the structural design is needed to evaluate this assumption. For comparison of the chosen size, the platforms have been compared to other sea vessels in figure 4.4.

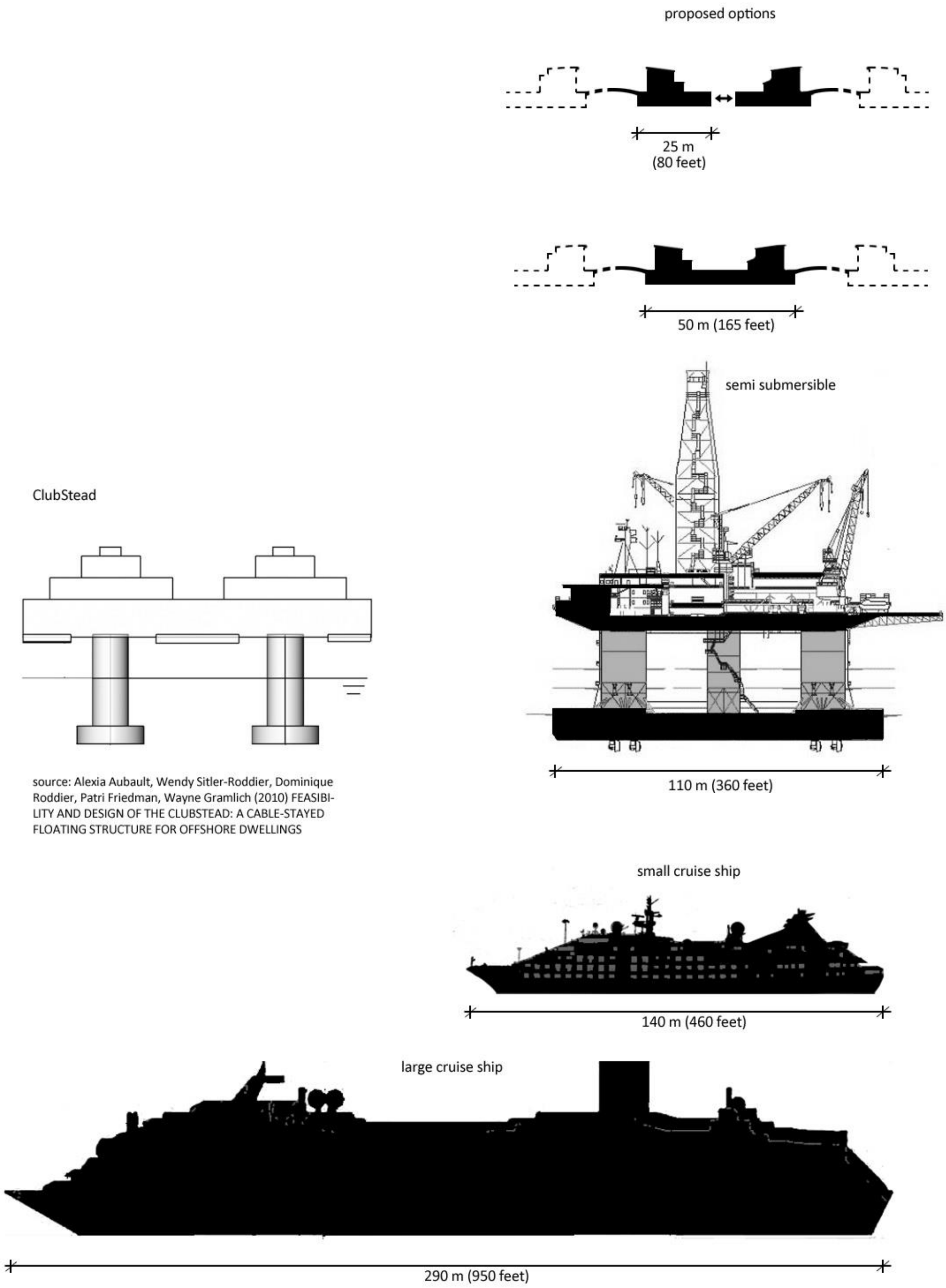


Figure 4.4 Size comparison of floating platform with alternative strategies.

4.2. Platform structure and material

There are three main material options for the platform structure: steel, composites, and concrete. Steel is the most frequently used material in the ship building industry, because it can be easily shaped and curved, has a high tensile strength and is easy to repair or modify. The drawbacks of steel are the high price and high maintenance costs (needs to be repainted on a regular basis in order to prevent corrosion).

Composites materials combine fibers (carbon-, glass-, cellulose, Kevlar, etc.) and a hardened resin (epoxy, polyester, vinyl ester, etc.). Despite their generally high costs, they are increasingly used in high-performance products, such as racing cars, airplanes, tennis rackets and fishing rods. The material is also commonly used in the construction of yachts, sailboats and surfboards, and the use of the material is currently expanding to many other industries. The material does not corrode, is durable, requires hardly any maintenance, is lightweight and can be stronger than steel. The main drawback is the price, which ranges from high to very high, depending on the type of resin and fibers that are used.

Concrete is also frequently used in water-related projects, such as submerged tunnels or offshore facilities. There are examples of submerged concrete that have remained structurally sound for over 50 years. Concrete has high-pressure strength but a rather low tensile strength. The main vulnerability of concrete is the reinforcement steel that is embedded in the concrete to provide tensile strength. This material may corrode. Therefore, a sufficiently thick layer of concrete needs to be applied to make sure the steel is not affected. This has large implications for the weight of concrete structures, and the amount of material that is used. Recently, other types of reinforcements have been used such as fibers (e.g. Fiber-reinforced concrete (FRC) and Engineered Cementitious Composite (ECC)). For floating platforms, using non-corrosive reinforcements would bring great improvements of durability, weight and material use.

The three basic materials described above are all technically viable for water constructions. In table 4.1 the pros and cons of each material are listed. Concrete is preferred, because it hardly needs maintenance and is the cheapest option, in particular when there is a lot of repetition in the construction. A heavy concrete base will also be very stable, because it has a low center of gravity. Lighter platforms on the other hand have higher center of gravity and therefore they are less stable, especially if real estate structures are added. Except for the price, composites would also be an interesting option, and is a lighter construction that could be used for the real estate as well. Currently, several new systems are being developed and tested. Because not all of the information on these new techniques are yet available, the conventional concrete is chosen for this design and cost estimate.

Table 4.1 Comparison of materials for the platform

	Maintenance	Costs	Weight*	Stability
Concrete	20-50 years	$	600 kg/m²	very stable
Steel	2-5 years	$$	200 kg/m²	stable
Composites	20-50 years	$$$($)	70 kg/m²	less stable

* weight calculations: Hull weight (kg/m2) = Hull thickness (m) * material density (kg/m3). Concrete: 0.25 m * 2400 kg/m3 = 600 kg/m2 ; Steel 0.025 m * 8000 kg/m3 = 200 kg/m2; Composites 0.04 m * 1500 kg/m3 + 0.04 m * 250 kg/m3 core = 70 kg/m2.

The floating platform will be designed as a hollow box (*caisson)*. Usually, large concrete caissons are compartmentalized with walls, in order to reinforce the structure. Instead of using walls everywhere, a series of ribs can be placed on the floor of the caisson. The ribs will carry the load of the water pressure to the columns, similar to beams that carry the load of a floor. The voids, in between the ribs, may be used for cables and wiring and fitted with insulation material. The main elements of the concrete floating platform are shown in figure 4.5. The dimensioning is based on expert judgement from a specialist on large scale floating structures. Part of the hull thickness provides concrete cover, which is needed to protect of the steel reinforcement in the concrete structure from the saline waters. The sizes shown in the figure are estimations; a thorough calculation would be needed in the next phase, including maritime conditions on selected locations.

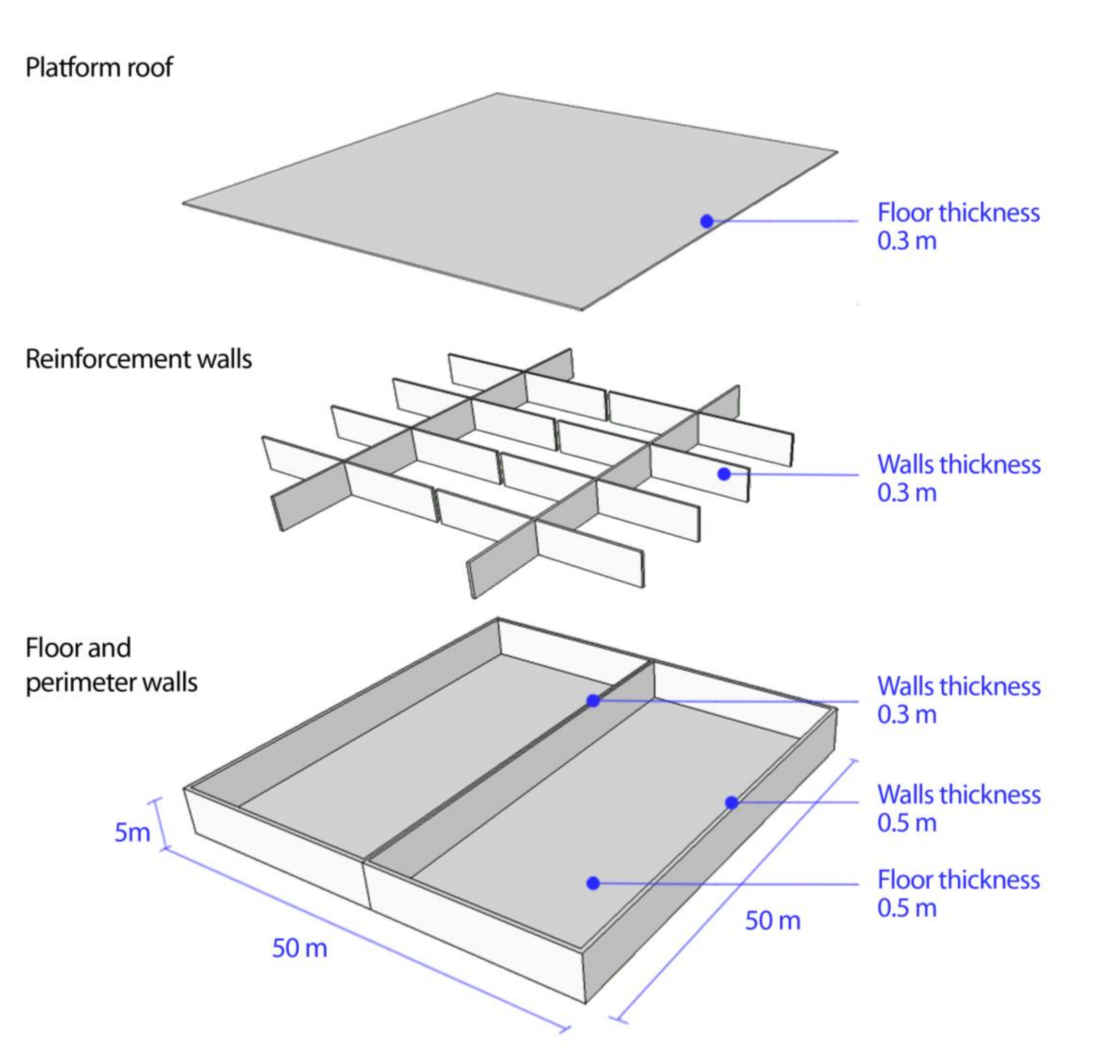


Figure 4.5. Exploded axonometric of the structural elements of the platform and assumptions of dimensions.

4.3. Buildings on the platform

In this section the platform size is evaluated from the point of view of the real estate. This is done to understand how different functions and building typologies can be accommodated on it. The functions include:

- buildings for housing, offices and hotel
- streets
- green and public space
- private open space

Buildings and open space need to be integrated in 50 m x 50 m platforms. Sections combining multiple functions on the basic platform were made, showing design options for housing, offices and hotels. The street width varies between 7 to 10 meters in order to keep enough distance between two facing households. The building depth is usually not larger than 12 meters in order to facilitate natural ventilation, fundamental for the comfort in hot-humid climates.

Housing

Three different housing typologies were studied for the square platform. The first typology includes 3-floor apartment blocks with large terraces oriented towards the water. On the platform, two of those buildings are constructed and the space between them (7m to 10m circa) is used for the street and the public green space. The edges of the platform include private open spaces owned by apartments on the ground floor. Facades on the street can include arcades that provide covered public space and protect inhabitants during rains. Ground floor space can be used for apartments, small offices and shops. Such buildings on one platform are suitable for approximately 30 inhabitants.

The second housing typology includes detached houses (villas) with private gardens. This typology has a very low density, from one to six houses. When two or more houses are built on one platform a street to access them is necessary.

A solution that allows achieving higher density with houses is to build two blocks with 3-floor terraced houses or 2-floor houses on top of shops/offices. The section for those building typologies includes a street in the middle and two rows of houses with private gardens facing the water. The density is equal to roughly 30 inhabitants per platform.

Offices

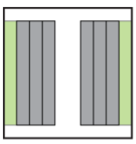
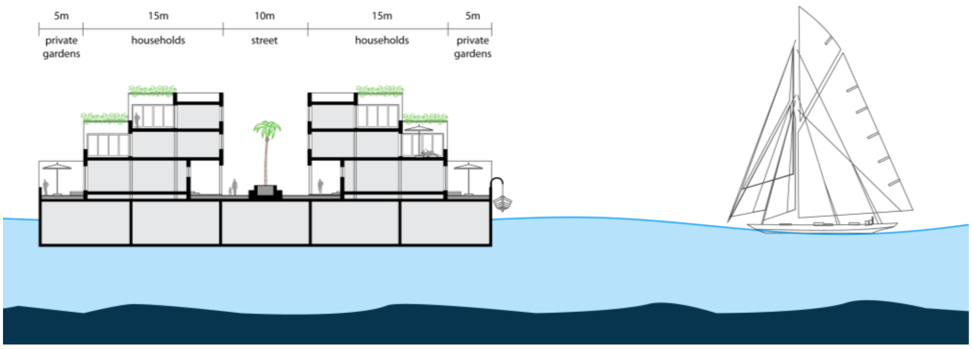
An option for a large office building is also included in the design exploration. The footprint of the building includes a covered courtyard in the center. Streets and green spaces are built around the office building, which can be used by a large company or shared among more offices.

Hotel

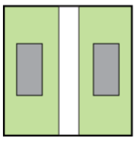
The building, dimensioned for 50 guests, has a gross floor area of about 2000 m^2. If the hotel is designed on multiple floors, space on the platform is available for a large swimming pool and/or other facilities. Attention should be given to the balance of all those elements that share the platform.

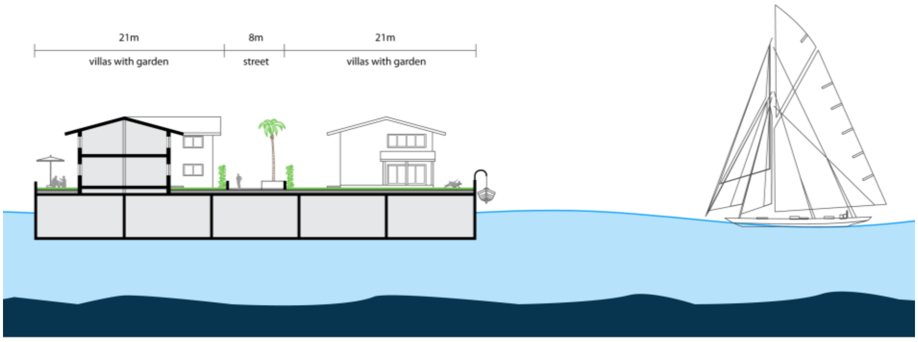
Preliminary designs for all of these functions are included in table 4.2.

Table 4.2: Overview of possible building typologies that can be constructed on a 50x50m platform.

FUNCTION	
Apartments block  Building footprint:1,200m^2 Street/public space: 900m^2 Private open space: 400m^2	

Villas



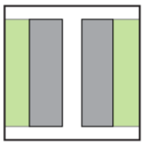


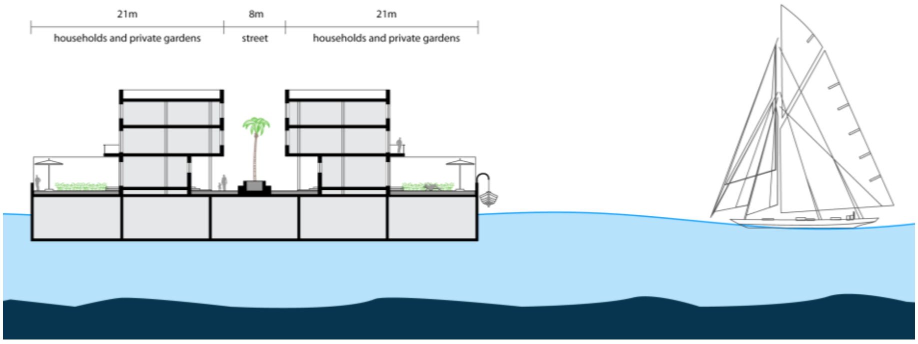
Building footprint: 400m²

Street/public space: 400m²

Private open space: 1,700m²

Terraced houses block



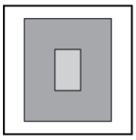


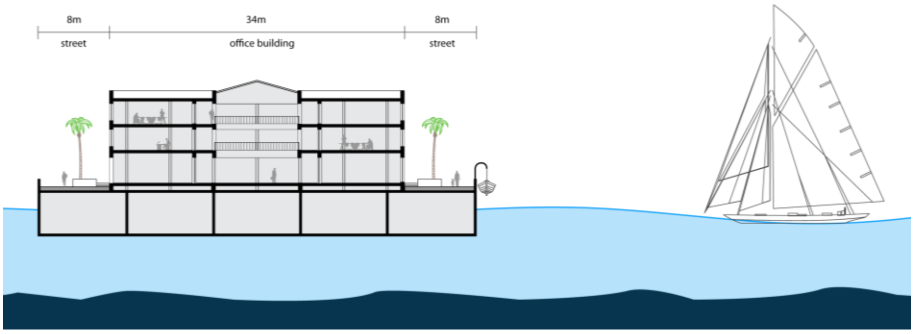
Building footprint: 880m²

Street/public space: 820m²

Private open space: 800m²

Offices

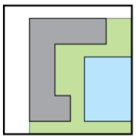


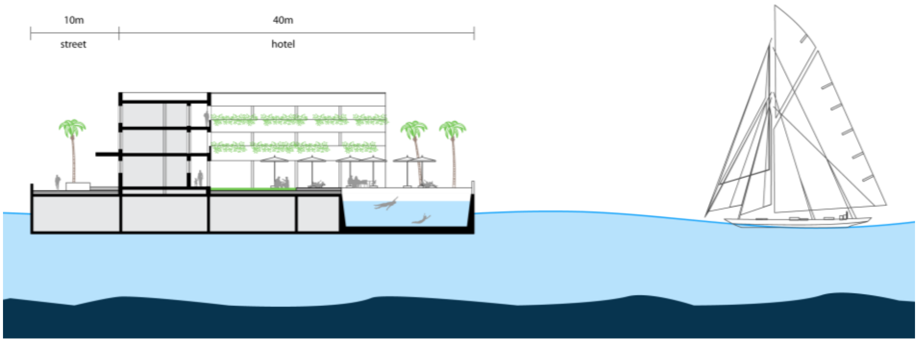


Building footprint: 1,360m²

Street/public space: 1,140m²

Hotel





Building footprint: 660m²

Street/public space: 700m²

Private open space: 1,140m²

Ground floor

When buildings, roads and green areas are constructed together on one platform, it is important to keep the ground floor of the buildings higher than the space outside, in order to prevent rainwater and dirt from streets and gardens to flow inside. Extensive green on the platform roof for example, can have a total height of 30-40cm, including soil, drainage layer, membranes and floor gradient. This means that building floors need to be raised some tens of centimetres in order to be higher than the exterior space.

For the floating platform, two options are available. The first option is to raise the areas of the platform roof where the buildings are going to be constructed. The second option is to build one flat platform roof and raise the ground floor of the buildings enough to keep water and dirt away. The main pros and cons of each option are summarized in Table 4.4. Option "a" includes different levels on the platform roof, whereas option "b" proposes a standard platform that doesn't need to plan in advance the exact location of the buildings. From the comparison, option "b" appears more optimal from the point of view of construction standardization, flexibility and waterproofing of the floating platform. However, this option requires an additional floor to be built on top of platform. An option to realize it is to use plastic formwork for concrete foundations (Figure 4.6). Those modular elements allow creating a self-load platform where a concrete floor can be poured on. The system is simple to construct, flexible and economic (30-40 euro/m^2). The advantages are rapid construction times, availability of space for pipes under the floor and possibility to keep the area ventilated against humidity. For the feasibility calculation option "b" is chosen.

Figure 4.6 Plastic formwork elements for ventilated foundations and raised floors. www.infobuild.it

Table 4.4: Overview of pros and cons of the two options for the platform roof.

Option "a": multiple-heights platform roof	Option "b": single-height platform roof
	
Pros: • Flooring can be constructed directly on the platform: no need for an extra floor	**Pros:** • Standard platforms with a defined roof height are built for every typology of buildings • Since the platform roof is one flat surface, waterproofing and drainage are easier • Standard columns with the same height can be used in the platform
Cons: • Buildings' type and placement have to be decided in advance before manufacturing each platform • Since the platform roof is made of higher parts (buildings' floors) and lower parts (roads and gardens floors) waterproofing and drainage might present issues • Columns in the platform have different heights • Higher platform costs compared to platform in option "b"	**Cons:** • An extra floor is built to raise the ground floor • Additional costs for the raised floor (~30-40euro/m^2).

4.4. Urban configuration and preliminary design

The conclusions of the previous chapters form the basis of the preliminary design for the first seasteading community. Chapter 2 concluded that smaller interconnected structures would be a promising option. This allows relocation with ordinary tugboats. Floating breakwaters can provide additional protection against waves. In chapter 3 the influence of local conditions were established and in this chapter (chapter 4) it was concluded that medium sized platforms of around 50 m would provide an optimal balance between safety, comfort and feasibility. A strategy for growth, which allows the seastead to start out as a small settlement and gradually grow bigger, has also been taken into consideration. This strategy will be discussed in detail in chapter 7.

Aside from the objectives discussed in previous chapters, the system to be developed needs to address several other considerations:

1. The system should consist of a small number of basic elements in order to keep down costs and allow uniform standardized connections. This will simplify the configuration and later reconfiguration of the urban layout.
2. The system should enable many different variations to keep open future possibilities for the floating community.
3. The system should enable circular layouts in order to efficiently fit a floating breakwater that is as short as possible (a circle has the shortest perimeter for a given area).
4. The platforms should be connected in such a way that they create a dimensionally stable cluster. This means that several platforms will need to connect with more than two other platforms.

A system was developed that meets the above criteria, based on two basic shapes: a square and a pentagonal shape. The results and considerations are illustrated in figure 4.7. A pentagon allows the creation of circular clusters, because two opposing edges are oriented at an angle of 36 degrees. This means that 10 pentagons are required to create a full circle. One or more rectangles can be placed in between the pentagons to change the radius of the circle, or to create a different amount of curvature. The system was further developed into a preliminary design for the initial seastead and a perspective for possible future stages of the seastead (as shown in figure 4.8).

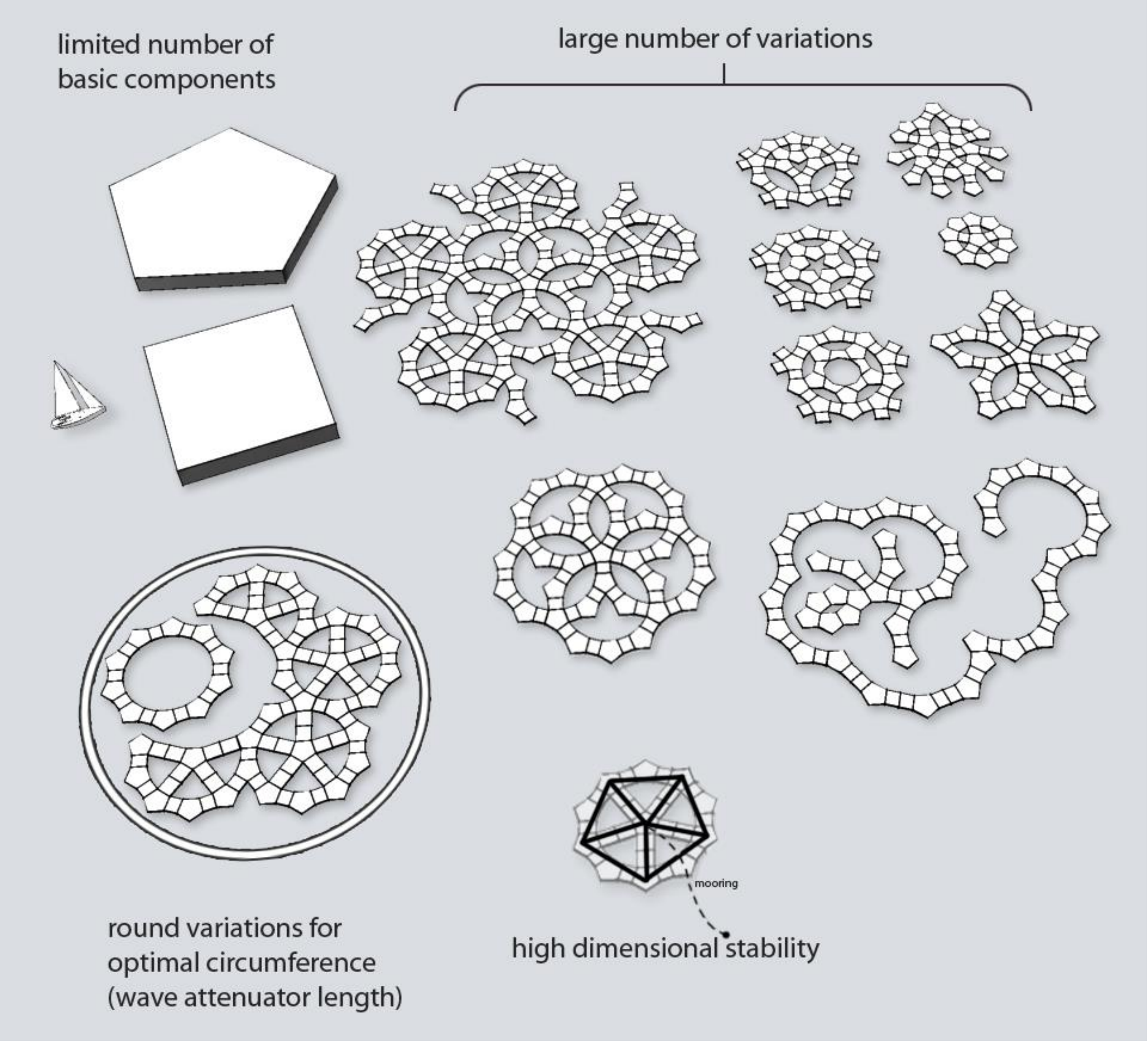


Figure 4.7 System for urban configuration

Figure 4.8 Preliminary design for initial and long-term seasteading community.

5. Sustainability and ecology

After the concept design is finished, the next challenge is to find the appropriate adaptation strategy – a strategy that creates a safe and livable urban environment on the sea, while minimizing impact on the ecosystems and making efficient use of the available resources. In this section, we explain the Blue Revolution concept and apply it to the seasteading concept, in order to find out how it may contribute to providing three necessities: food, water and energy.

5.1. Blue Revolution concept

For centuries, cities have been depending on surrounding areas for land, water, energy, food and materials. In the last decades, raising awareness on the limited amount of natural resources available for a constantly growing population pointed out the necessity of changing the way cities manage those resources to fulfill their needs.

In their process of growing and developing, "Cities transform raw materials, fuel, and water into the built environment, human biomass and waste". [13] The flow of energy and material through cities is called Urban Metabolism. As cities grow, this flow increases, using more resources and producing large quantities of waste, which is often dumped in the environment. This so-called "linear metabolism" leads to a rapid depletion of resources at the beginning of the resource flow and accumulation of waste at the end. In order to make a more efficient use of the finite resources of the planet, the concept of waste needs to be eliminated (figure 5.1).

If the output of one system becomes an input for another, the metabolism of cities will increase its efficiency. Closing the linear resources flow of cities and transforming it into a cycle is fundamental for current and future cities. Those principles are at the basis of the Blue Revolution, which propose floating cities as a solution to reuse the waste (nutrients and CO_2) from existing delta cities, producing food and biofuel on the water, in an efficient way. The following paragraphs will explain which parts of the Blue Revolution concept can be applied to the seasteading design.

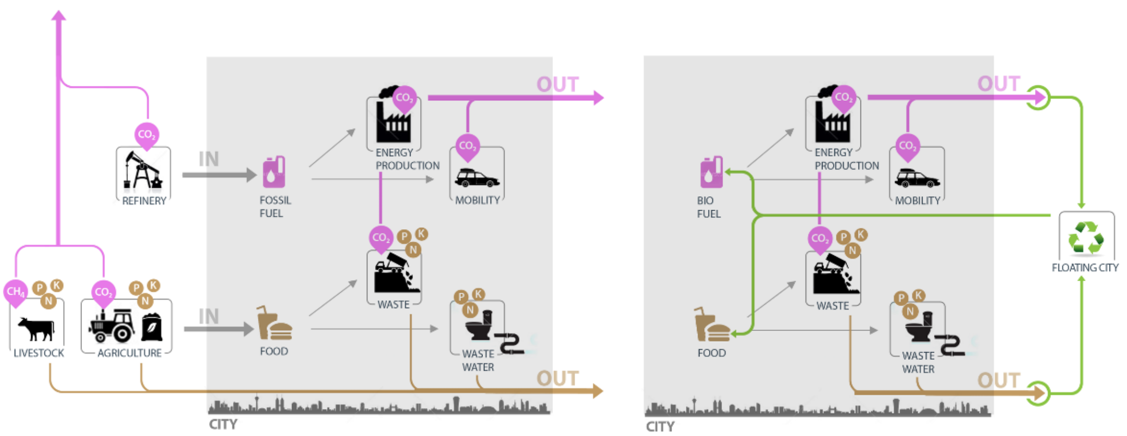


Figure 5.1 Comparison between linear metabolism of current cities and the closed loop of nutrients created by introducing a floating city that uses the Blue Revolution concept (DeltaSync, 2012).

5.2. The reuse of nutrients

A vast amount of energy is required for industrial ammonia synthesis, necessary to sustain the current size of human population. However, at the same time, nutrients introduced in agro-ecosystems are often lost in the environment, polluting water bodies and destroying aquatic life in affected areas. Depletion of nutrients is a serious risk for the food security of cities.

Algae production

Those nutrients now wasted could be used as inputs by floating cities to grow algae and produce food and biofuels (Blue Revolution). Biofuel can be produced on the water, 10 to 20 times more efficiently than crops and without competing for scarce agricultural land. Biofuel production from microalgae has a lipid content of around 40%, giving biodiesel yields of 40 to 50 tons per ha per year.[14] This means that a floating city could be able to produce energy through the reuse of waste products as wastewater and CO_2. Another benefit is the positive impact that floating cities will have on the ecosystems. By extracting nutrients and CO_2, water quality of aquatic ecosystems can be significantly improved.

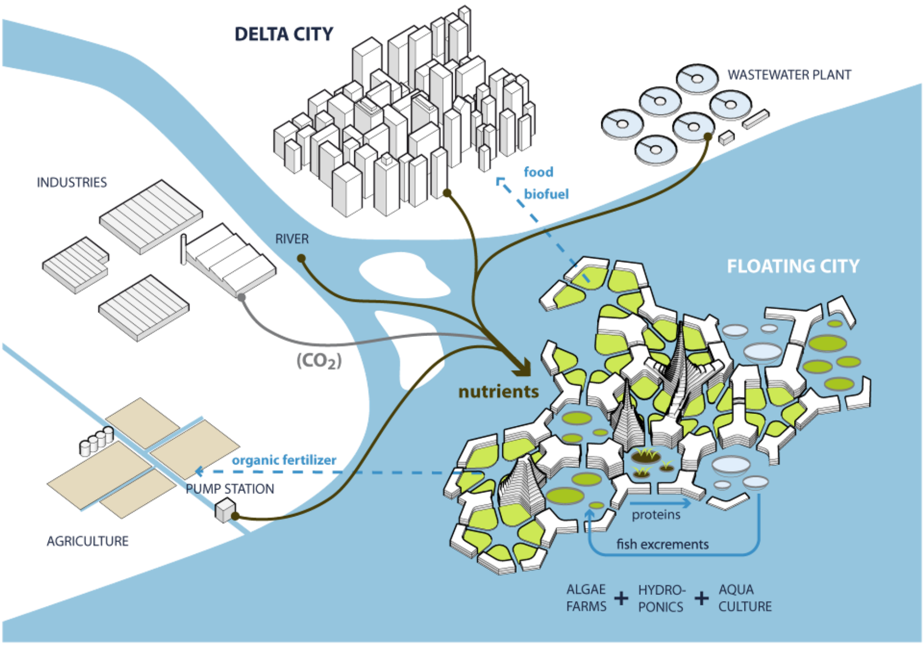


Figure 5.2 Scheme of nutrients and CO_2 flows within the floating city-delta city system. Waste from delta areas is used for energy and food production, creating a symbiotic relation between the land-based city and the floating city (Deltasync, 2012).

Floating algae and seaweed farms could be constructed within the seastead. An innovative system to grow algae on the sea is the OMEGA (Offshore Membrane Enclosure for Growing Algae), developed at NASA by Jonathan Trent. OMEGA is a collection of closed photo-bioreactors constructed of flexible plastic that can be filled with treated municipal or agricultural wastewater that would normally be discharged into the ocean. The modules float on the sea surface, maintaining the algae in ample sunlight. Forward osmosis membranes allow clean water to diffuse out of the bioreactors, leaving inside an algal paste, which can be easily harvested and processed into biofuels, animal feed, fertilizer, and other bio-products (NASA, 2012).

Food production

In combination with algae culture, food production can be realized in floating cities. There are multiple concepts and technologies available for water-based food production. The concepts of aquaponics and multi-trophic aquaculture could be applied within the seastead, producing local fresh food that can be directly consumed by the city or exported. Local food production is fundamental for some products, fresh vegetables in particular, which would be more difficult to keep fresh while being shipped from the continent to the floating city.

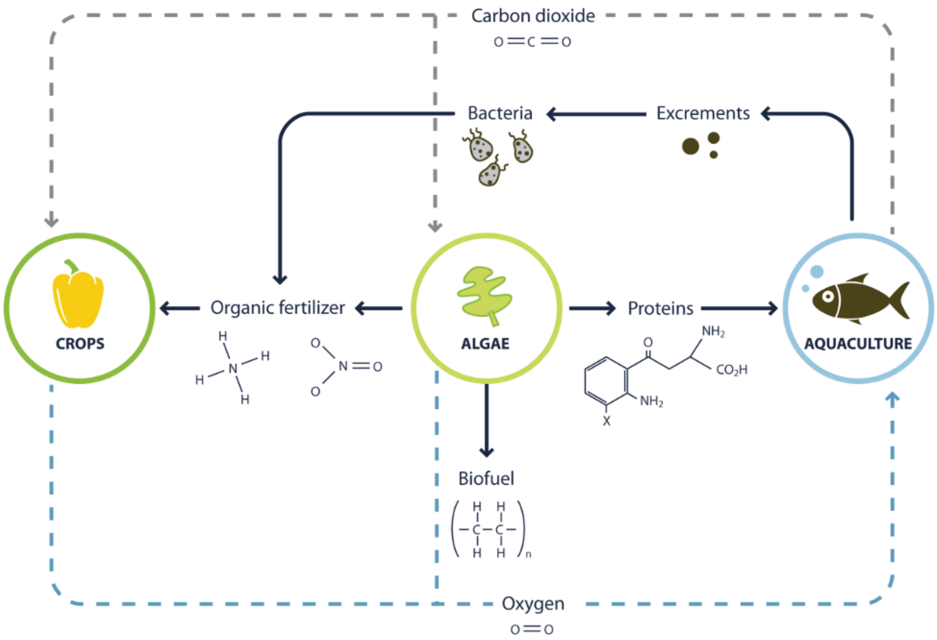


Figure 5.3 Combination of algae culture, aquaculture and crops production in the floating city (Deltasync, 2012).

Fresh vegetables could be grown on the seastead through aquaponics, a food production system that combines aquaculture and hydroponics in a self-contained ecosystem. Hydroponics is a method to grow plants in a liquid solution consisting of water and the required nutrients for a particular plant.[15] Plants and bacteria purify the water using the nutrients that fish create. The water use for crops can be reduced up to one tenth of regular vegetable growing and reduces the water needed for single usage fish farming by 95% or greater. The system can be applied in fresh water growing tomatoes, bell peppers, cucumbers, herbs, lettuce, spinach, chives, watercress and other plants in combination with tilapia, trout, perch, arctic char and bass.[16]

For saltwater fish, another type of aquaculture that can be framed into the idea of circular metabolism is integrated multi-trophic aquaculture (IMTA). In this system, leftover feed, waste, nutrients and by-products of one species are recaptured and converted into fertilizer, feed and energy for the growth of the other species. IMTA combine fish, with “extractive” species that are fed by organic and inorganic nutrients available in the environment. Organic extractors, such as shellfish, absorb small particulate matter like uneaten fish feed and fish feces. Inorganic extractors such as seaweed use the inorganic dissolved nutrients, such as nitrogen and phosphorus, that are produced by the other farmed species. The natural ability of these species to recycle the nutrients, provides a food production system that does not have negative impacts on the ecosystems. The IMTA concept is very flexible and allows the integration of different types of fish/shrimp with vegetables, microalgae, shellfish (bivalves, abalone) and/or seaweed (Neori et al., 2003).[17]

On the seastead, aquaponics and IMTA systems could be used to produce food for the city in an efficient and environmentally-friendly way. Compared to conventional farming and agriculture systems, aquaponics allows growing vegetables and fish in a closed system at the same time, while re-circulating freshwater and minimizing water losses. As shown in figure 5.5, about one kilo of fish and seven kilos of vegetables can be grown for every 22 liters of water.[18]

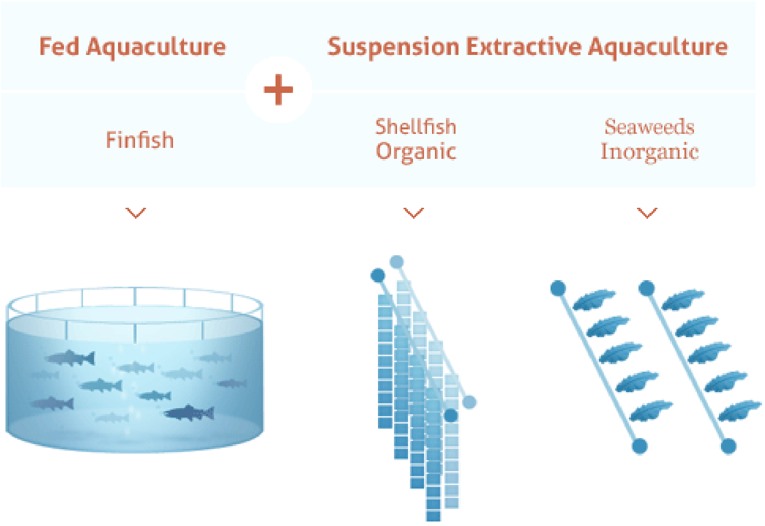


Figure 5.4 Integrated multi-trophic aquaculture (IMTA) operation scheme showing how a combination of varying levels of the food chain in the same environment take advantage of organic and inorganic nutrients made available by the various organisms (www.oceansfortomorrow.ca).

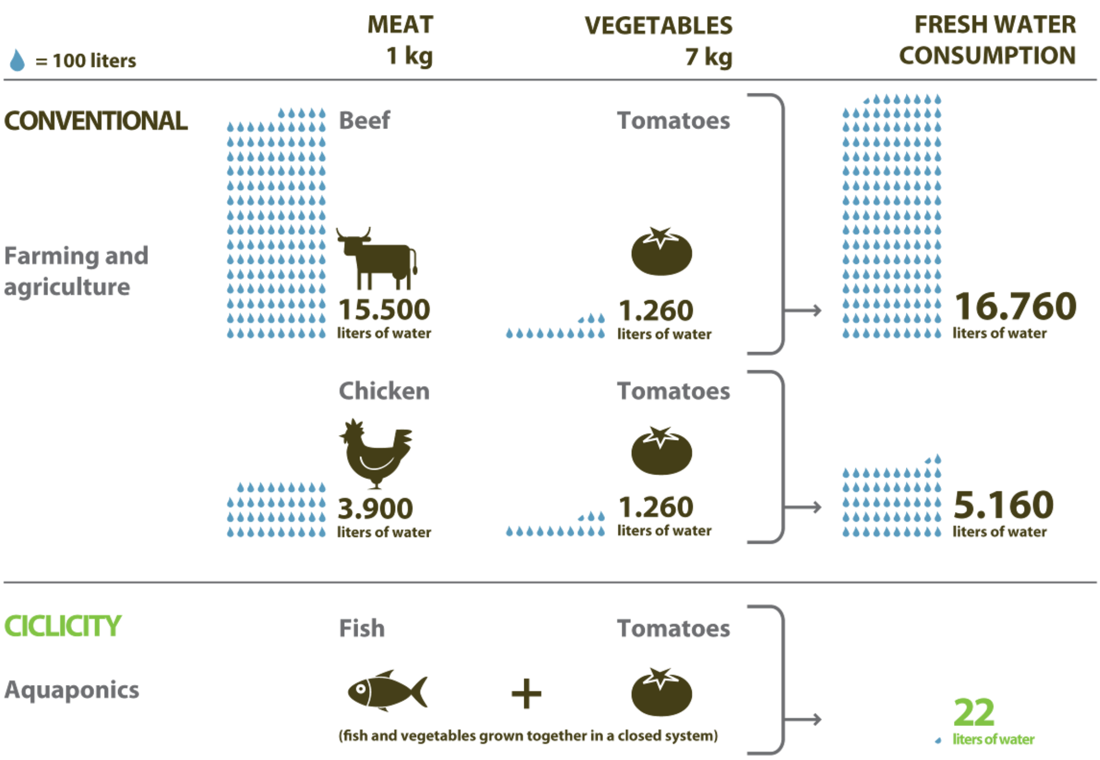


Figure 5.5 Water consumption of food production: comparison between conventional farming / agriculture and aquaponics systems (Deltasync, 2013)

5.3. Sustainable water system

The efficient management strategy for water can be expanded to the water use of the floating city's inhabitants. Cities use clean water as an input and produce wastewater as an output. Rainwater is a resource that is not often utilized – instead it is mainly converted into wastewater in combined sewer systems. However, rainwater can be applied for many purposes. On a seastead in particular, rainwater could be an important resource of freshwater. If rainwater will not be collected, fresh water would need to be imported or produced locally from desalination of seawater.

For these reasons, rainwater collection and storage should be provided on the seastead. In warm-humid climates, dry and rainy periods usually alternate. To ensure the use of rainwater during dry months, adequate rainwater storage needs to be provided. On the seastead, precipitation can be collected using buildings' roofs and the floating platforms, and stored in flexible tanks. Rainwater can be treated and used for cooking, drinking, showering and bathing. After use, water could be collected in another tank for grey water. Grey water is not suitable for drinking use but, with adequate treatment, can be used for washing machines and toilets. While water used for the washing machine goes back to the grey water tank, wastewater from toilets could be used as a free source of nutrients for algae (figure 5.6). When wastewater is pumped in OMEGA floating bioreactors, algae extract nutrients and clean water is slowly released in the sea.

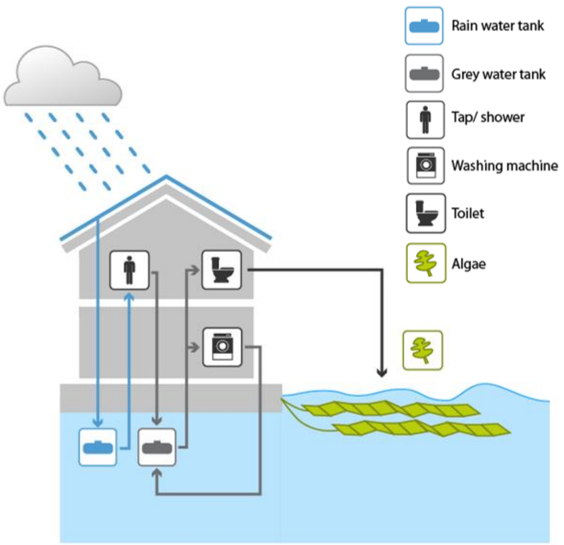


Figure 5.6 Sustainable water reuse system (DeltaSync, 2013).

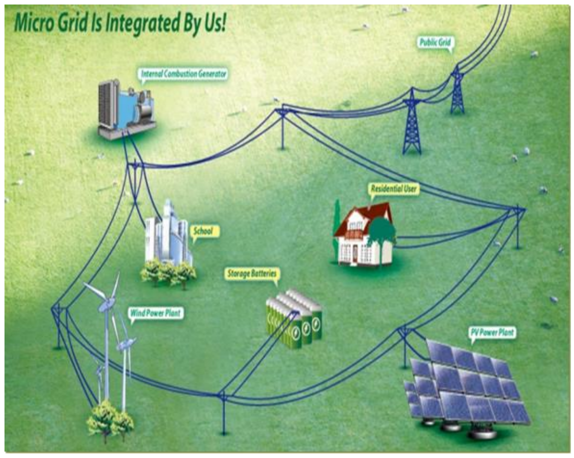


Figure 5.7 Example of a micro grid, source: Phono Solar

5.4. Sustainable energy

One of the anticipations of The Seasteading Institute is to settle in tropical climate zones. One of the benefits of these regions is the availability of a vast amount of solar power. Solar panels generate electrical power by converting solar radiation into direct current electricity with semiconductors. The amount of electricity solar panels can produce depends on the local solar radiation, or 'insolation'. In the case of Honduras, this is around 6 $kWh/m^2/day$ or 2190 kWh/m^2 annually (average).[19] The efficiency of the panels is currently around 15% but increasing rapidly. Expectations are that by 2015 solar panels will be competing with regular electricity prices.

The downside of solar panels is that storage is needed for the time that the sun is not shining. This can be accomplished by connecting the system to the electrical grid, but given that a seastead must be detached and movable from land, this is a less practical option. Alternatively, a micro grid system is proposed, where solar panels would be combined with batteries, and diesel generators would be on hand as an emergency system backup.

6. Cost estimate and feasibility

In this chapter, the cost estimate that is made in the excel model is elaborated, see appendix 6. Along with the cost considerations, the location and the future inhabitants have an important influence on the feasibility. Especially for the first seastead it is important to have reasonable access to the main land for the transport of goods and people and the continuity of economic processes. Furthermore, the number of inhabitants should be able to serve the initial purpose of the seasteading community.

6.1. Connection to coastal city

The combination of the initial small scale of the seastead and the continuity of the economic processes would be easier with a large coastal city nearby. In the past, settlements that developed into cities were usually built as trading centers or as fortifications to defend strategic locations. For this reason, most major cities are located along rivers or harbors, or at the junction of important overland trade routes. This new city should take this into account. The general observation from studying the growth of cities is that three major influences are responsible: economic growth, natural increase and rural-urban migration. The most significant reason to move into a city is economic opportunity. Important pull factors are expectations of jobs and comfort, while the main push factors are adverse circumstances in the countryside.

While experimentation with rules and new forms of government is the highest priority for the seastead, economic influences cannot be ignored. This means the city should be attractive for a diverse array of manufacturing and service-based companies. Also sufficient incentives should be developed for companies and entrepreneurs to move to the seastead. Such incentives should include: clear and simple legislation, low taxes, lower office rents than in the city center, a diverse and well-educated work-force, access to knowledge, technology and innovation, good (public) transport connections to the wider metropolitan area, especially when the city is small at the beginning. Another important asset is the access to global markets by connections to an airport and seaport. The marketing to attract these businesses to the floating city should be very good. The first floating city in the world will also attract a large number of tourists, in order to create opportunities for recreational businesses like hotels and restaurants.

6.2. Cost estimate

To estimate the costs of the first floating structure an excel model has been designed consisting of the following components:

- Housing
- Office space
- Hotel
- Water supply
- Energy supply

Functions that will influence the visuals but are not directly incorporated in the excel model are:

- Port
- A quick connection to a hospital resulting in a helipad
- School annex community center

Model

The initial conditions for this calculation are a platform size of 50 x 50 m, that is divided into 10% green space, 10% sidewalks and 80% ground that can be developed for rent or sale (issuable ground) see table 6.1. The average building consists of three floors and has a gross/net space ratio of 0.78, which results in an average gross space of 3,000 m² and useable floor area of 2,340 m² per platform. We calculated a per person residential area of 75 m² and 25 m² of commercial area. This results in an average of 30 inhabitants per platform, combining this with commercial space and hotel space will accommodate more people which will lead to a rich and diverse environment.

Table 6.1

Distribution of ground space		
Platform	100%	2500 m²
Sidewalks	10%	250 m²
Green	10%	250 m²
Issuable Ground	80%	2000 m²
*Built-up Area**	50%	1000 m²

We then estimated the per platform costs. This was done using the concept design from the section 4 design platform structure and a price per cubic meter of concrete derived from FDN information on an average price for concrete of €1,000, we used €1,400 for our estimates. This should be calculated more thoroughly in the next phase, when the design for the floating structure is also calculated on the specific wave data. This also accounts for the connections in between the platforms and the mooring system, which will need to be fully designed for more detailed cost information. The concrete structure of the platform with the cables and sewer system will cost about €2,8 million or € 1100/m² (ex.).

During the design process, the designers decided that the flexibility for the configuration of the floating city would benefit form a combination of square platforms and pentagon shaped platforms. The 4,300 m² pentagon platform (using the per square meter costs of the square platform) would cost €4,8 million assuming that all the other cost aspects of the platform stay the same. In the design 4 pentagons are used and 7 square platforms. The pentagons are larger, although about 10% less efficient in space use, these 4 new structures would increase the sellable space by 15,000 m² when also calculating with three floors per platform. This space is not accounted for in the water and energy use calculation and is called vacant space in the model.

For the calculation of the real estate €1100/m² is used as a rule of thumb. In total, including Honduras' Value Added Tax (assuming the seastead would also be constructed there), the cost estimate equals about €130 million for all 11 platforms, including the pentagon considered in this concept.

In addition for cost calculation, our model also allows us to assess the feasibility of sustainable water and energy supply. On both counts, we find the platform could be fully supplied using rainwater and solar power. In this calculation, the additional space created by the pentagons (5,100) is not yet calculated.

Water supply

To calculate the feasibility of a self-supporting water system, we first had to calculate the availability of (rain) water. The numbers we used were based on the monthly precipitation data from the department Valle, Honduras.[20] Next the amount of available water was compared to the water use for the domestic situation (per person per day), for the offices (per square meter per day) and the hotel (per room per day). For each of the three functions, we evaluated a low-water-use (that could be compared to the water use in the Netherlands) and a high-water-use scenario (that can be compared to the water use in the USA). From our calculations it can be concluded that for both the low-use scenario and the high-use scenario, enough rainwater can be collected for all needs.

Water collection is divided per platform and per function, meaning every platform has its own water collection and purification systems. The high-use scenario for a hotel platform was the only one for which the amount of water collected is not sufficient, and would require additional supplies from another platform, such as an office platform, which does not use as much as it collects. The cost estimate for the rainwater and water purification systems are around half a million euros. This figure represents the costs for one year. Every additional year would entail additional costs for new filters, management, maintenance, etc.

Figure 6.1 Example of drinking water transport using a plastic bag[21]

Energy

For the calculations related to solar power, we examined climate data on solar radiation for the location within Honduras. This location features some of the most favorable conditions for solar in the world. Solar radiation data was converted into kilowatt-hours so we could compare it with the electricity demand. We constructed two scenarios, for low and high use, and again split these up into three functional categories; residential, commercial (offices) and hotel. The demand numbers were compared with the yield from the panels, based on the amount of space available on the rooftops. Both scenarios were found to be feasible, i.e., energy supply was at least as great as demand.

Subsequently, the costs of a micro grid system were compared to a diesel generator system and the micro grid appeared to be the most cost effective. This is for one year; every additional year would have exploitation costs for new diesel needed in the power backup, replacement of the batteries, management and maintenance, etc.

7. Growth strategy

The animal kingdom is a source of inspiration for growth strategies. Several species, like salmon, spend their infancy in calm and protected waters and migrate towards the seas as they grow stronger. Analogously, a seastead is most likely to start in protected waters. After acquiring sufficient size and strength, the seastead will make its way to deeper waters, and finally the open ocean. During the seastead's development a breakwater should be part of the strategy and can grow at incremental stages. By the time it reaches the high seas, it should be ready to defend itself against the waves it may encounter. Just like the fish, the seastead should be part of the aquatic ecosystem. Because it is manmade it can even help reverse the damage that is done to the ecosystems by remediating surrounding waters.

During the seastead's early years, only a small number of urban functions can be sustained. However, as it grows, additional functions will be added, such as a hospital, a school and perhaps a landing strip. This development will also help the community become more independent of the mainland (and host country). In the end, when the seastead has become completely independent in terms of water and energy, as well as politics and economics, it is ready for its final stage: to take on the high seas.

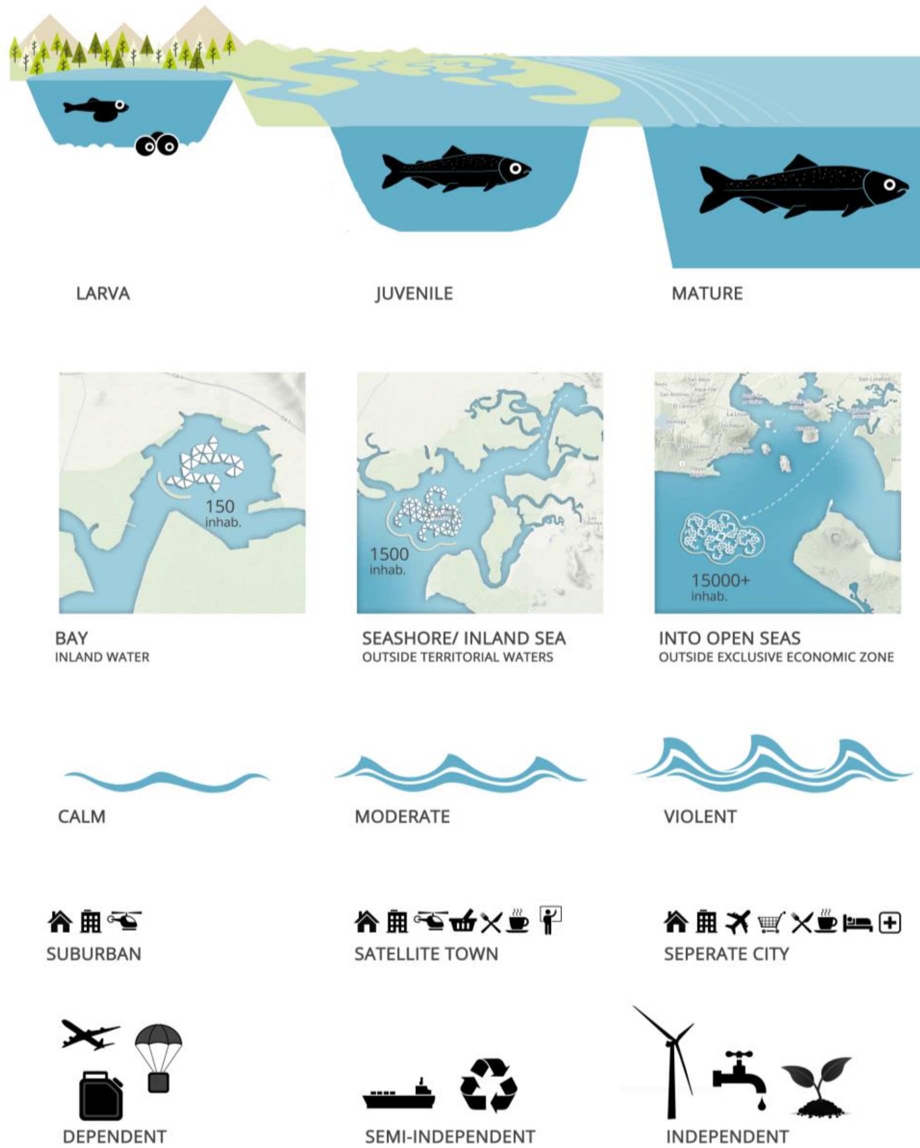


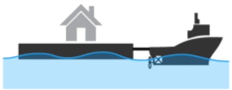
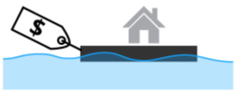
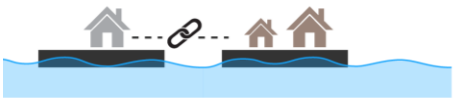
Figure 7.1 Development floating cities

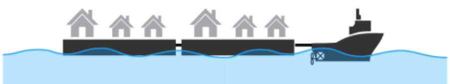
8. Growth dynamics

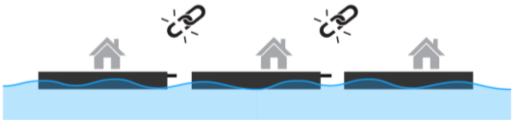
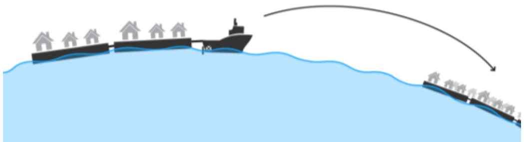
This draft document provides a vision of the different growth dynamics of the floating city. Several levels are distinguished:

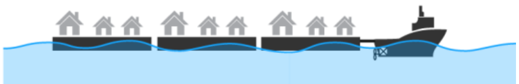
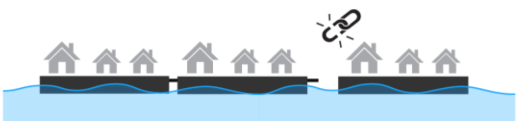
- House
- Neighborhood (500-5000 houses)
- District (5,000-20,000)
- City (20,000- larger)

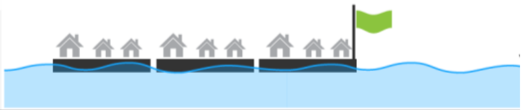
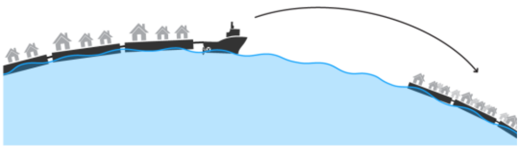
The dynamics that are distinguished on these levels are listed in table 8.1.

HOUSE LEVEL		
Dynamic	Description	Possible drivers
Move with house 	Move to another location within the city with your floating house	Unhappy with neighborhood Living closer to work, family or friends
Sell and move 	Similar to land-based city. Sell your house and move to another place within the city or in another city	Unhappy with your house Desire to live on more attractive location
Stay and upgrade 	Stay at the same location. Sell your house on web-based platform. Buy a larger house for your location	Happy with neighborhood but unhappy with house
Unite 	Find other people with the same interests, values and vision and create your own new neighborhood within the city or in another city	Desire to create a great community

NEIGHBORHOOD LEVEL		
Dynamic	Description	Possible drivers
Move 	Move your neighborhood to another location within the city	Better opportunities for economic growth Move needed for overall growth strategy of city
Merge 	Merge with another neighborhood to create district or larger neighborhood	Become more attractive for companies and inhabitants Increase lobby power with district or city government Improve ability to create

		good facilities
Split 	Split your neighborhood to create to smaller neighborhoods	Improve human scale Unhappy with neighborhood board
Dissolve 	Split neighborhood into individual houses that are free to go wherever they like in the city	Lack of social cohesion Conflicts
Spinout 	Leave the city to start a new floating city in a protected bay near shore with your neighborhood	Unhappy with city government Attractive opportunities to locate near coastal city
Transfer 	Move with your neighborhood to another city	Unhappy with city government Attractive offer of another city

DISTRICT LEVEL		
Dynamic	**Description**	**Possible drivers**
Move 	Move your district to another location within the city	Better opportunities for economic growth Move needed for overall growth strategy of city
Merge 	Merge with other districts to create larger district	Become more attractive for companies and inhabitants Increase lobby power with city government Improve ability to create good facilities
Settle 	Merge with other districts from same city or other cities to create a new city	Better opportunities elsewhere Economic synergy of districts
Split 	Split your district to create to smaller districts	Improve human scale Unhappy with district board
Dissolve 	Split districts in separate neighborhoods that are free to go wherever they like in the city	Lack of social cohesion Conflicts Incapable district board

Spinout 	Leave the city to start a new floating city with your district on the high seas	Unhappy with city government Attractive opportunities elsewhere
Transfer 	Move with your district to another city	Unhappy with city government Attractive offer of another city

These urban growth dynamics would create the necessary conditions for competitive governance. Neighborhoods will have to provide a good value for the cost of living there, or else people leave. There will be a large reward for cost-effective operations, since these will attract a greater number of new citizens and businesses. City governments with taxes that are too high and who do not deliver good services will find their best districts being lured away by other floating cities. With a very incapable city government, the city might even dissolve. These growth dynamics create therefore a great incentive to provide value for money on all levels of government. Additionally they create almost unlimited possibilities for individual and collective freedom.

9. Conclusions and recommendations

One of the important topics in this report has been the question of which platform size would be suitable for the future seastead in terms of the objectives, location characteristic and other factors like financial and construction limitations. The ideal size of individual platforms depends on many factors, some of which can be precisely determined while others remain speculative. The most relevant ones that have been included in this study can be seen in figure 9.1. It can be concluded that the size of the platform would ideally range between 45 and 75 meters. For this design the size of 50 x 50 meter has been chosen as the standard. More detailed data on local wave characteristics and further research on the structural design are needed to evaluate these assumptions.

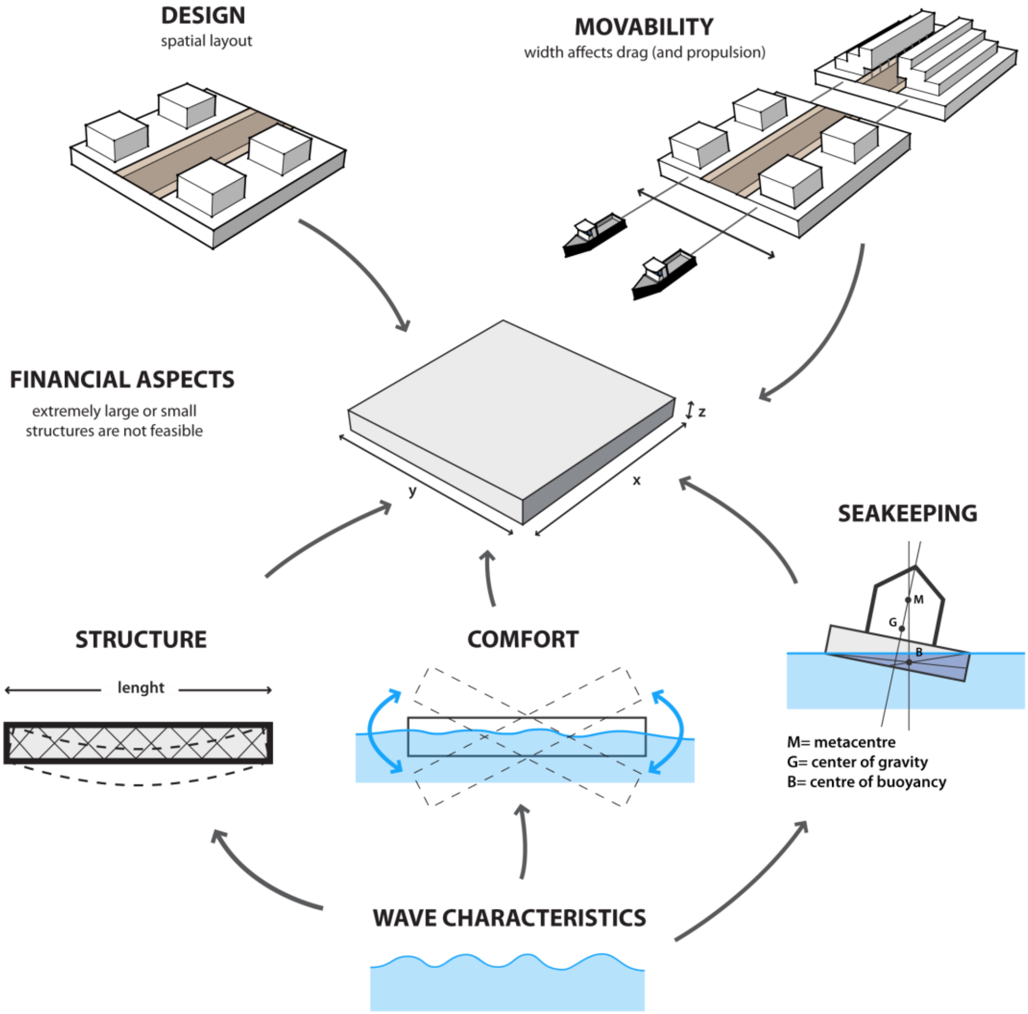


Figure 9.1 Factors that influence the optimal size of a floating platform

The most challenging objective was seakeeping. First, it had to be decided for which location the structure should be suitable. During the concept design phase the initial location – a protected bay – and the future location - the high seas - clashed frequently. Eventually an important decision was made that while future seasteading communities are envisioned to withstand the high seas, the first communities in The Floating City Project will start out in more protected waters, and will only be in higher seas occasionally and for short periods of time, such as when moving or fleeing hurricanes.

Movability

During the research it has been concluded that the seastead should be able to move away in the event of a hurricane. It would be important to conduct simulations of this situation to see if the estimated time to escape the path of the hurricane is feasible. The main research questions for this future investigation would be which type of tugboat and which configuration of the platforms would be most suitable for this transport. It may be an option to transport several interconnected platforms at once in a train configuration, quite similar to barge tows. This combination creates a longer vessel, which is more favorable in terms of water resistance. Therefore, it is important to research what hull shape could be the most suitable in terms of costs and manufacturability, and if this would be only necessary for the front platform or if all of the should be designed this way. Furthermore it should be tested how these platforms and how the interior of the real estate would behave during this transport.

Connections

An aspect that is directly linked to this transport is the connections between the platforms, which should be easy to disconnect at some places. These connections should be dimensioned differently when the platforms are towed separately or towed in a row. For the current cost estimation the data for the interconnection is based on existing structures, for this unique purpose, this would have to be designed and recalculated.

The mooring systems should also be easy to disconnect, and the specific engineering must be further developed and the cost calculated. Subsequently the question arises of what will happen with the seastead during its temporary residence when fleeing from a hurricane, and how it will be kept in position in the temporary location. Depending on the connections between the platforms and the expected forces in the bay, the system must be optimized, which will probably favor fewer connections and larger anchors.

Location

The simulation would also have to include the seakeeping performance given the expected wave characteristics. When there is more certainty about the first location for the seastead, the characteristics of that specific location should be further examined. More detailed information is needed on the waves, bathymetry and other local conditions like nature and pollution. The current estimate is made on basic principles and assumptions. For the wave characteristics, data from two nearby buoy points have been used as input. Since information is probably not currently available in the actual location, a buoy could be placed to measure the wave characteristics. This could be done right away in one or more potential future locations.

Water and energy supply

The analysis of available solar energy and other climate factors like precipitation demonstrate the feasibility of a floating city harvesting enough of these gifts of nature to support itself. This depends on specific climate characteristics of a location, and further research would need to be done for a other locations.

Platform

The platform is now sketched and not designed. Very rough estimations have been made to be able to see if the platform to assess its suitability for sea conditions. The risk of under- or over sizing the platform exists, and a more detailed design and calculation is needed in the next phase. Furthermore a conservative concrete structure is now used for the calculation. More innovative systems based on composites and plastics may possibly be much more appropriate for this environment. Some of these systems are currently in development and if more accurate data is available they could substitute the concrete structures in the cost calculation model.

For the next design phase, rules and regulations for the buildings and platforms on fire hazards and collision risks should be taken into account. Furthermore the use of the space in the platform should be determined, for example for food storage, water storage, and commercial applications.

In the current design, two shapes have been used for the platform: a square and a pentagon. The pentagon configuration can be connected to the square platforms and, in large enough configurations, can create a circular cluster, since the two opposing edges are oriented at an angle of 36 degrees. The structure of the pentagon and the distribution of the real estate on the pentagon should be taken into account during the next phase.

The current status of the cost calculation is shown in table 9.1.

Table 9.1 Costs

General		
Average costs per platform	€	11.055.386
Costs gross space	€/m²	3.152
Costs usable space	€/m²	4.042

Appendix 1 Formulas

Ocean surface current speed

The following two formulas were used to roughly determine the amount of force that a seastead may deal with at a given ocean surface current speed. Drag is not yet taken into account.

$p_d = 1/2\ \rho\ v^2$

where

pd = dynamic pressure (Pa)
ρ = density of fluid (kg/m^3),
1025 kg/m^3 for surface sea water;
1.225 kg/m^3 for air (15°C).
v = velocity (m/s)

$F = A\ P\ C_d$

where

F = force
A = area
P = pressure
C_d = drag coefficient (1)

Formulas for wavelength

$$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$$

Where "g" is the gravitational acceleration, "T" is the period and "d" the depth. To solve this equation Hunt (1979)[22] used an approximation that gives:

$$\frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right) \approx \sqrt{\frac{gd}{F}}$$

where $\sqrt{\frac{gd}{F}}$ is an approximation for the wave celerity and

$$F = G + \frac{1}{1.0 + 0.6522G + 0.422G^2 + 0.0864G^4 + 0.0675G^5}$$

and $G = 2\pi\left(\frac{d}{L_0}\right) = \left(\frac{2\pi}{T}\right)^2 \frac{d}{g}$

The wavelength then is given as:

$$L = T\sqrt{\frac{gd}{F}}$$

Appendix 2 Saffir-Simpson Hurricane Scale

Saffir-Simpson Hurricane Scale[23]

Saffir-Simpson Hurricane Scale

Category	Wind speed mph (km/h)	Storm surge ft (m)
5	≥156 (≥ 250)	>18 (> 5.5)
4	131 – 155 (210 – 249)	13 – 18 (4.0 – 5.5)
3	111 – 130 (178 – 209)	9 – 12 (2.7 – 3.7)
2	96 – 110 (154 – 177)	6 – 8 (1.8 – 2.4)
1	74 – 95 (119 – 153)	4 – 5 (1.2 – 1.5)
Additional classifications		
Tropical storm	39 – 73 (63 – 117)	0 – 3 (0 – 0.9)
Tropical depression	0 – 38 (0 – 62)	0 (0)

Appendix 3 Location analysis

Inside the gulf, there are small islands that are part of Honduras and El Salvador. The larger islands are El Tigre (Honduras), Conchaguita and Meanguera (El Salvador). According to nautical maps, the bathymetry of the gulf varies from 0 to 10 m within 10 km from the coastline, in the Chismuyo bay (Nicaragua) and in the islands' area (figure A3.1&A3.2). At the inlet of the gulf, water depth increases from 10m to about 40m between Cape Cosiguina and Cape Amapala. Several rivers flow into the Gulf of Fonseca: Goascoran River, which defines the border between El Salvador and Honduras, Negro River and Choluteca, flowing in Honduras, and Estero Real River, which is part of Nicaragua.

Figure 1 and 2. Gulf of Fonseca map and satellite image. http://www.worldatlas.com/aatlas/infopage/fonsecag.gif, Google Maps

According to the Koppen classification, the climate in the Gulf is humid equatorial, with two distinct seasons, the rainy (May - November) and the dry (December - April). From May until November thunderstorms are quite common (over 70% of the precipitation happens during thunderstorms), and hurricanes might occur in the area (See appendix 3). The Gulf receives nearly 80% of its total yearly rainfall of 1400–1600 millimetres during the rainy season[24]. The dry season contributes to an annual evaporation rate of 2800 millimetres. As a result of less water in the Gulf, the currents tend to flow inward from the Pacific Ocean, the levels of salinity in the estuaries increase and seasonal drought occurs[25].

The tidal difference (predominantly semidiurnal) is on average 2.5 metres per day[26]. During low tides the soils are inhabited by crabs, conch, and other species. During the high tide the mangrove forests serve as a feeding ground, habitat and refuge for fish, shrimp, and other species[27].

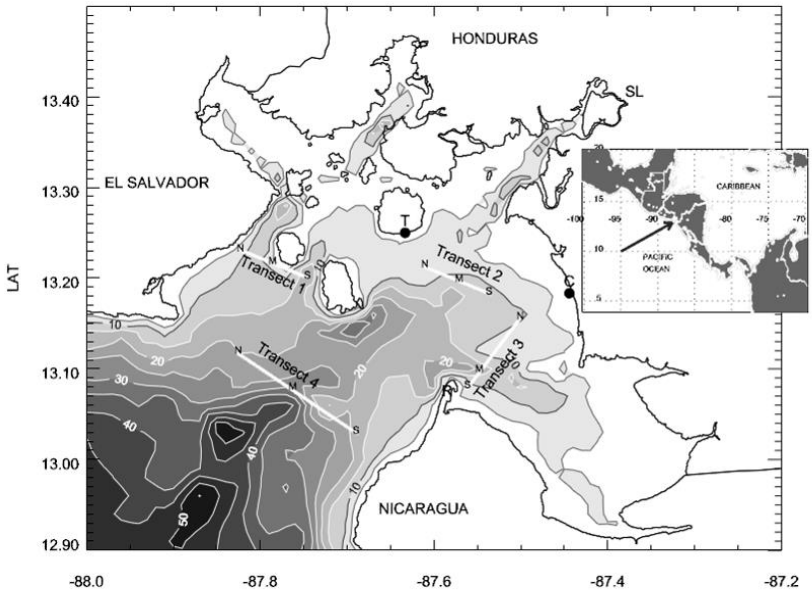


Figure 3. Gulf of Fonseca, nautical map. Areas in blue represent salt marshes, areas in light blue include sea floor depth between 0 to 10m, and areas in white represent sea floor depths deeper than 10 m (http://marine.geogarage.com/routes)

Currents in the dry season exhibit different behavior compared to those in rainy season: in dry months the water enters from the surface and exits at the bottom (reverse estuary type), whereas in rainy months the opposite happens and water that comes in from the bottom exits from the surface (estuary type).

The Cosiguina Peninsula and several extinct or dormant volcanic islands protect most of the Gulf of Fonseca from ocean waves. The significant wave height is between 0.5 and 2 m in more than 95% of the cases. High waves occur mostly in autumn (October - November) and in Spring (May - June), as consequence of tropical storms. High wind waves in combination with high tide can generate waves up to 3 meter or even higher in rare cases. According to an alert emitted by Copeco authorities (Comisión Permanente de Contingencias of Honduras) at the beginning of October 2011, during a tropical storm, waves could have reached up to 10 feet height (about 3 m), with periods between 12-14 seconds[28]. In November 2011, Honduran authorities declared a green alert in the coastal zone of the Gulf of Fonseca, Pacific, after the tsunami occurred in Japan. After this phenomenon, generated by an earthquake of 8.9 on the Richter scale, Copeco emitted preventive measures in case the tsunami could have generated high waves that would have been introduced to the mainland[29]. Another source reports data on a storm in June 2012 that was expected to cause waves height of 7 to 9 feet (2 to 2.7 m)[30]. Data on the average wavelength was not found. If period values between 12-14 seconds are chosen, waves length will vary between 190-240 m at the inlet of the Gulf (sea floor depth of 40m) and 100-130m at 10 km circa from the coast (sea floor depth of 10m).

Temperatures in the Gulf are between 24 and 34 °C. March and April are the warmest months; October and November the coolest. Relative humidity varies between 45%-80% in dry months, and 68%-90% in the rain season. Average water temperature in the Gulf of Fonseca is usually around 26°C. In the open sea, at a few hundred km distance from the Gulf, high water temperature might further increase.

Water pollution, habitat loss, excess sedimentation and over-exploitation of fisheries affect the Gulf's environment. In the last 40 years, pollution, deforestation, and inappropriate land use put enormous pressures on the coastal ecosystem and have contributed to loss and degradation. The mangrove ecosystem has been diminished to provide space for shrimp aquaculture. Satellite images from 1973 and 2006 show the significant loss of mangrove swamps as a result of the expansion of shrimp farming in the region of Estero La Jagua. Effluents from shrimp farms, rich in nutrients and organics, flow into the Chismuyo Bay and contribute to eutrophication and hypoxia in the gulf. Hypoxia has caused fish mortality and decline in artisan fishery of all species. Actions to restore the environment in the area are important also for the productivity of shrimp aquaculture, which is now the third largest export of Honduras, after bananas and coffee[31].
Moreover, the livelihoods of many species are connected to the health of the mangrove ecosystem. *"The indigenous plant and animal life in the mangroves depend on the delicate balance of fresh and tidal waters. Mangroves provide drainage and filtration, stabilize shorelines that protect the coastline and the surrounding farmland, and offer natural windbreaks as well as fresh water conduits (Martínez 1991; Hamilton and Snedaker 1984). They also serve as a prime source of fish, shrimp and other crustaceans, fuelwood, and timber for surrounding communities and the broader population"*[32].

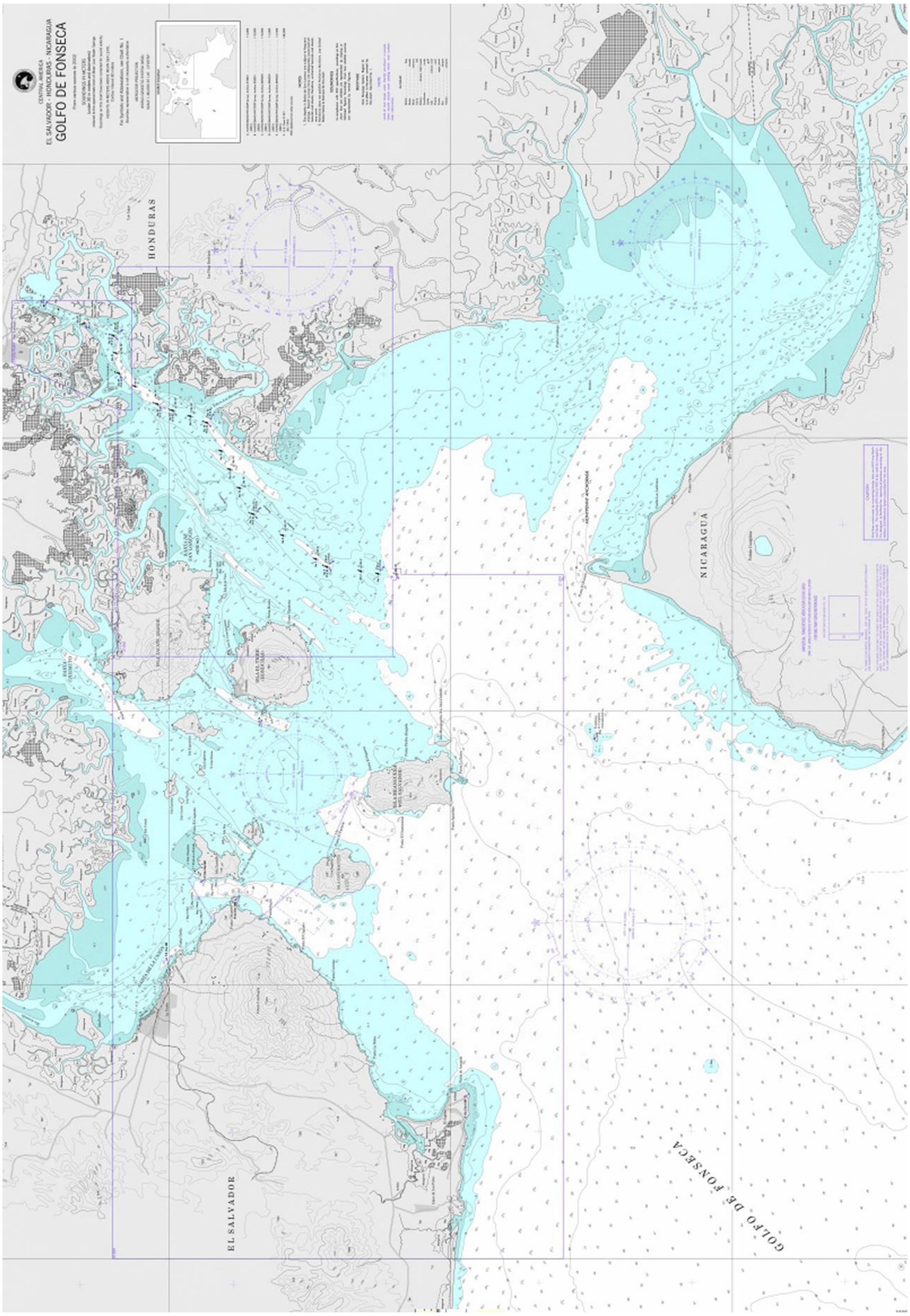


Figure 4. Climate map of Central America (http://www.boqueteweather.com/images/world_climate_map.jpg)

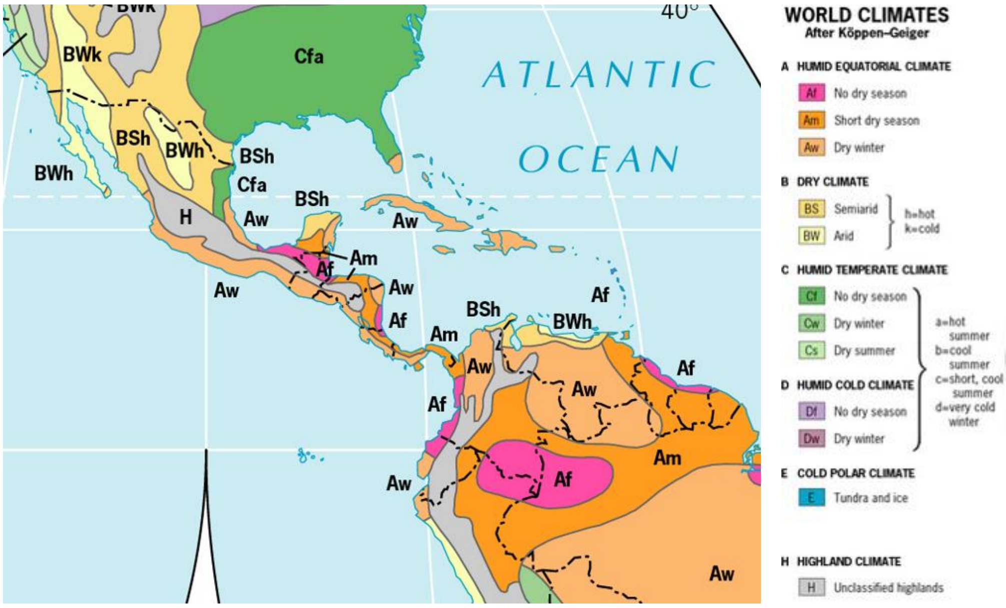
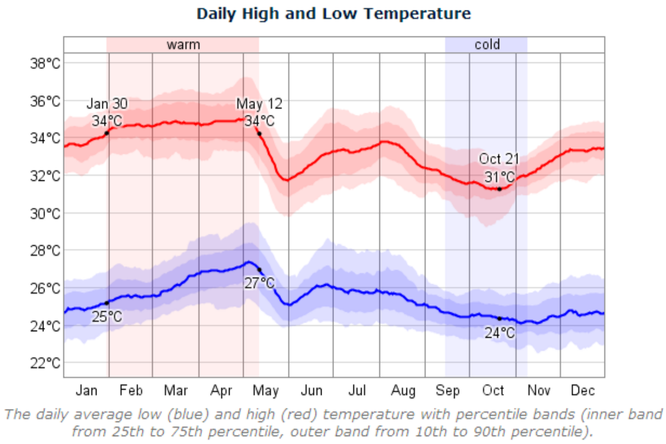


Figure 5. Monthly data on average temperature and humidity in the Gulf of Fonseca (Ampala, Honduras) (http://weatherspark.com/averages/32506/Amapala-Valle-Honduras).



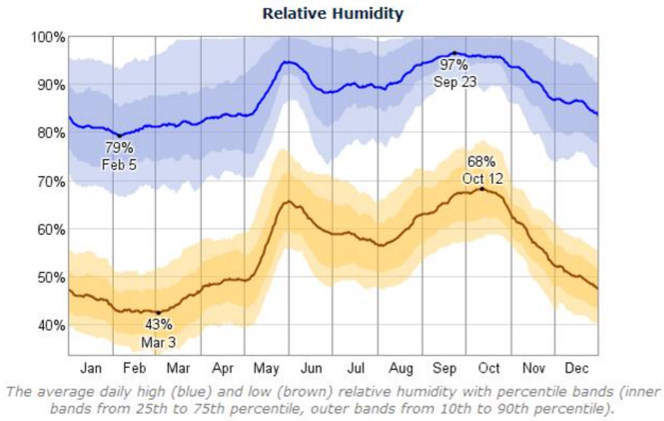
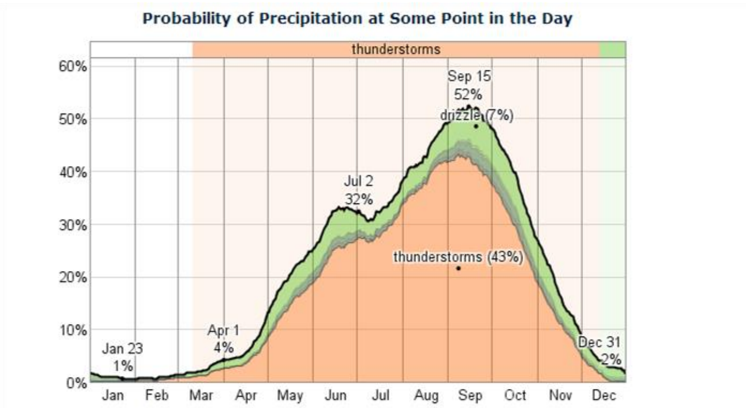
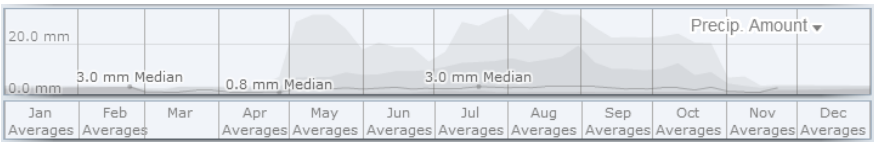
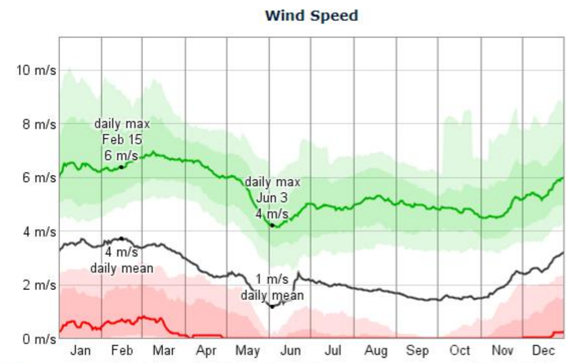


Figure 6. Monthly data on precipitation in the Gulf of Fonseca (Ampala, Honduras) (Source: http://weatherspark.com/averages/32506/Amapala-Valle-Honduras).



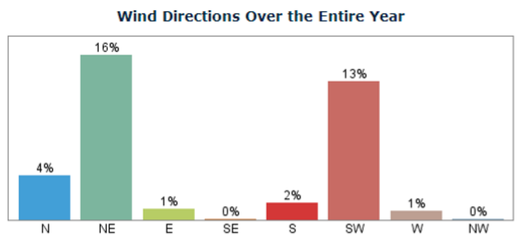
The fraction of days in which various types of precipitation are observed. If more than one type of precipitation is reported in a given day, the more severe precipitation is counted. For example, if light rain is observed in the same day as a thunderstorm, that day counts towards the thunderstorm totals. The order of severity is from the top down in this graph, with the most severe at the bottom.





The average daily minimum (red), maximum (green), and average (black) wind speed with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

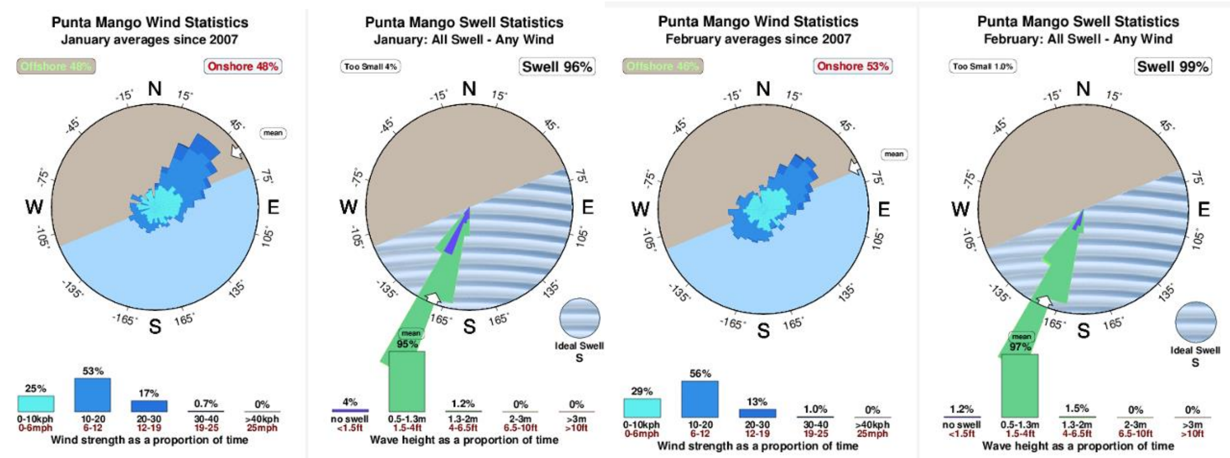
The wind is most often out of the *north east* (16% of the time) and *south west* (13% of the time). The wind is least often out of the south east (0% of the time), north west (0% of the time), west (1% of the time), east (1% of the time), south (2% of the time), and north (4% of the time).



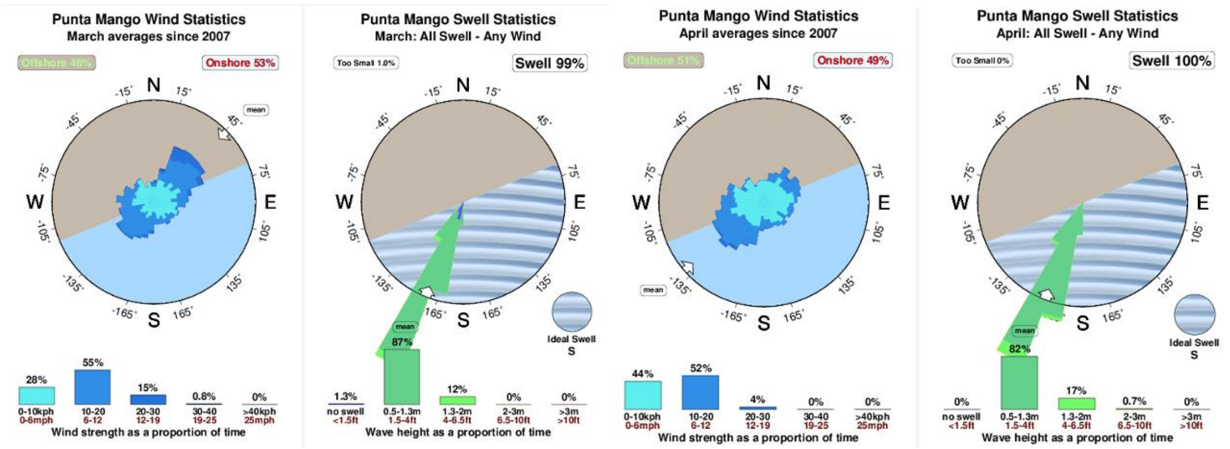
The fraction of time spent with the wind blowing from the various directions over the entire year. Values do not sum to 100% because the wind direction is undefined when the wind speed is zero.

Figure 7. Monthly data on wind in the Gulf of Fonseca (Ampala, Honduras) (http://weatherspark.com/averages/32506/Amapala-Valle-Honduras).

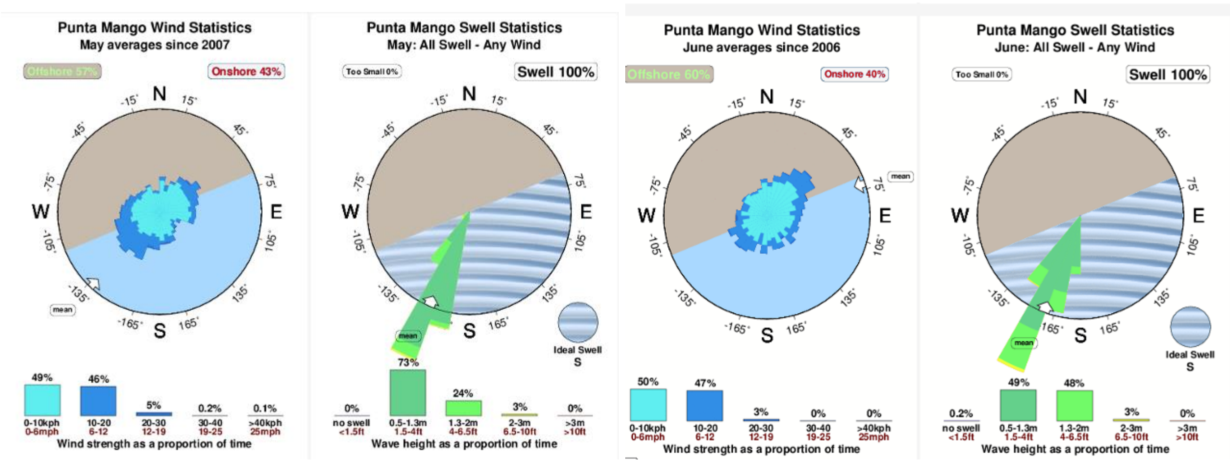
January and February



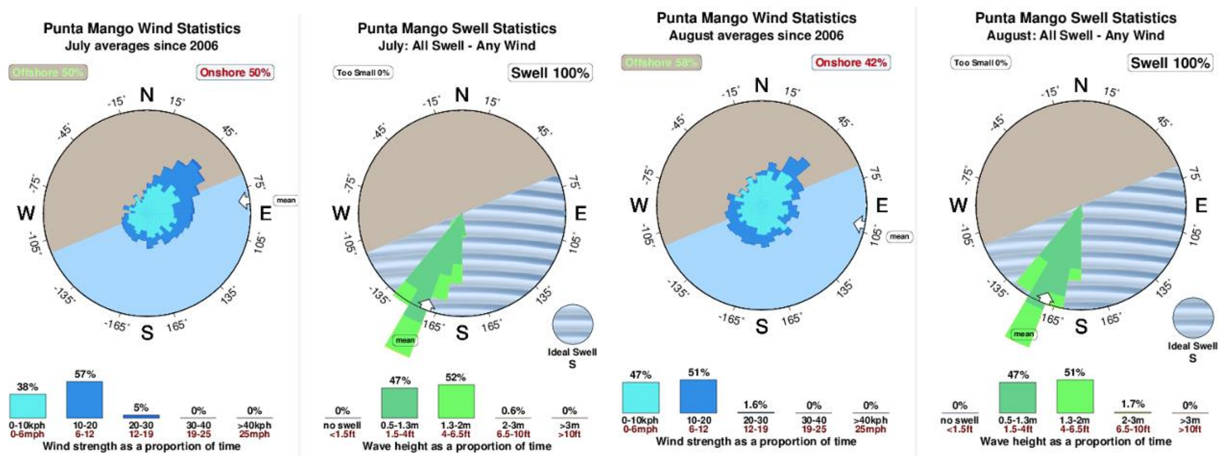
March and April



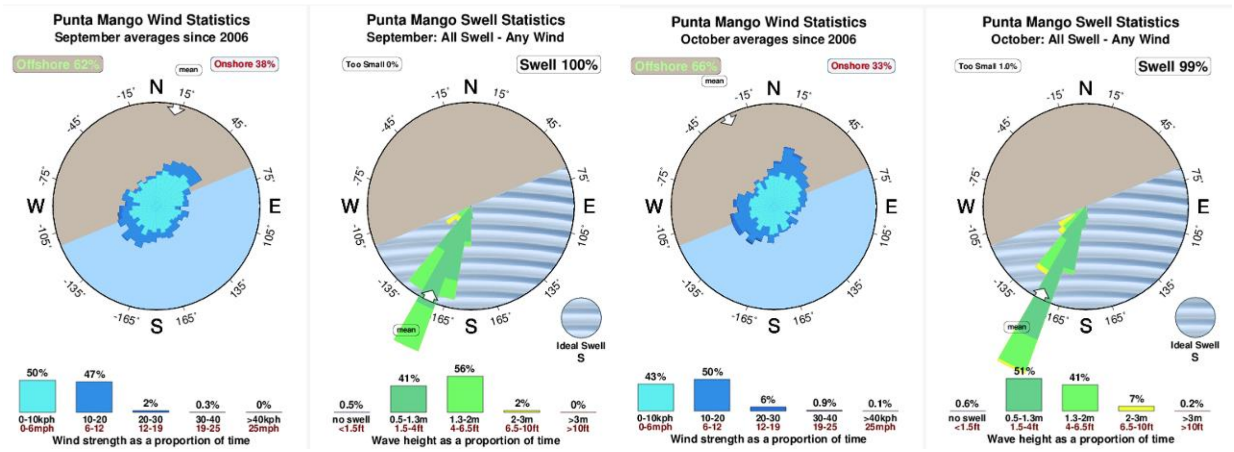
May and June



July and August



September and October



November and December

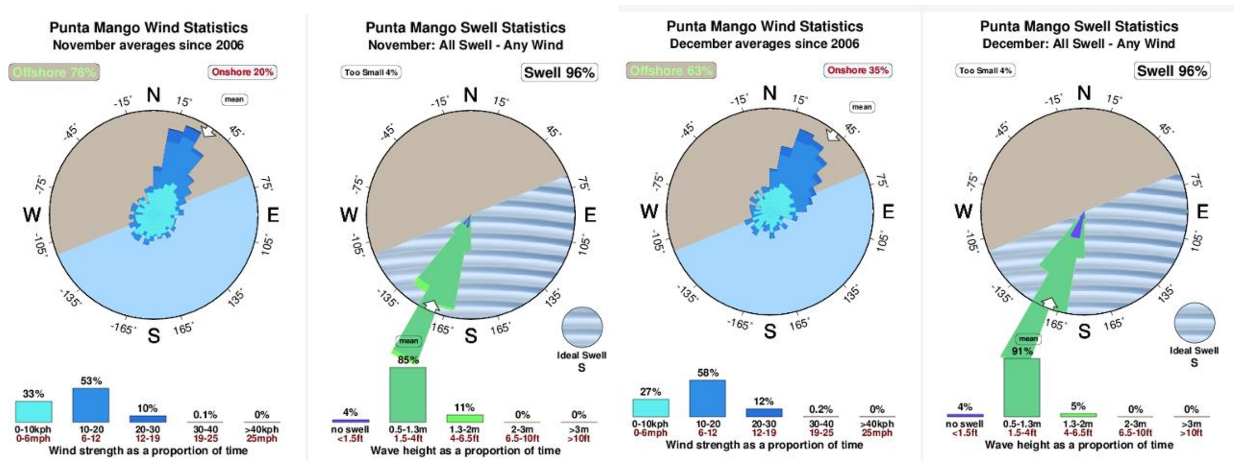


Figure 8. Monthly data on swell and wind in Punta Mango, 50 km from the Gulf of Fonseca, for near shore open water (http://www.surf-forecast.com/breaks/Punta-Mango).

	no swell	0.5 - 1.3 m	1.3 – 2 m	2 – 3 m	> 3 m
Summer (%)	0	48	50	1.9	0.1
Autumn (%)	1.8	63	32	3	0,2
Winter (%)	3	94	3	0	0
Spring (%)	0.4	80.5	18	1,1	0
Yearly average (%)	**1.3**	**71.4**	**25.8**	**1.5**	**0.1**

Figure 9. Graph of the tidal movements in the Gulf of Fonseca, 11th October 2013 (Source: http://www.fisica.uniud.it:8080/locations/3297.html).

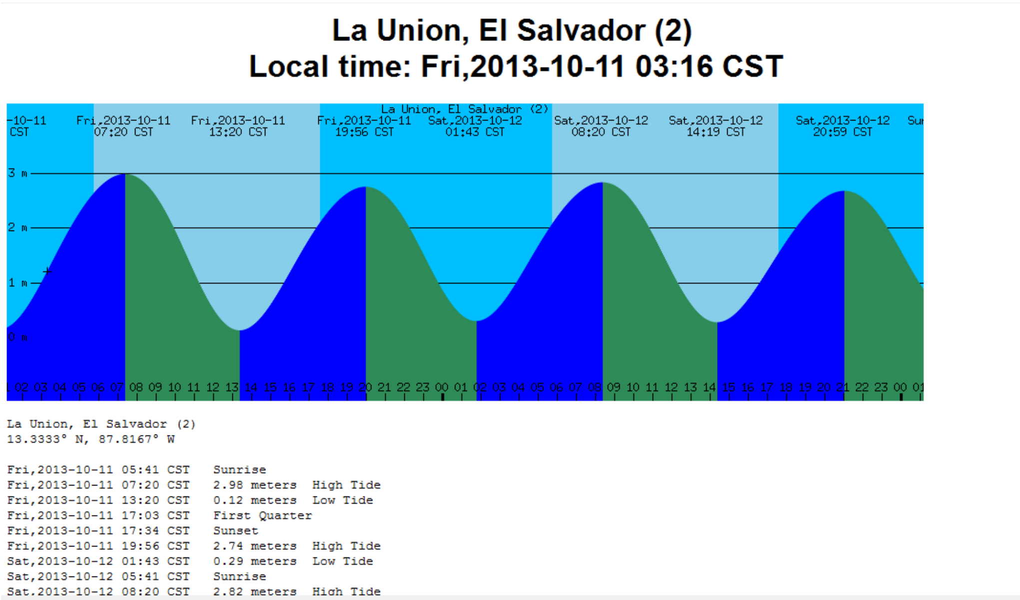


Figure 10. Average surface streams March 9- April 13, 2001 (www.marn.gob.sv/phocadownload/pp_nn_13.pdf from Valle-Levinson, A., and K. T. Bosley, Reversing circulation patterns in a tropical estuary, J. Geophys. Res., 108(C10), 3331, doi:10.1029/2003JC001786, 2003).

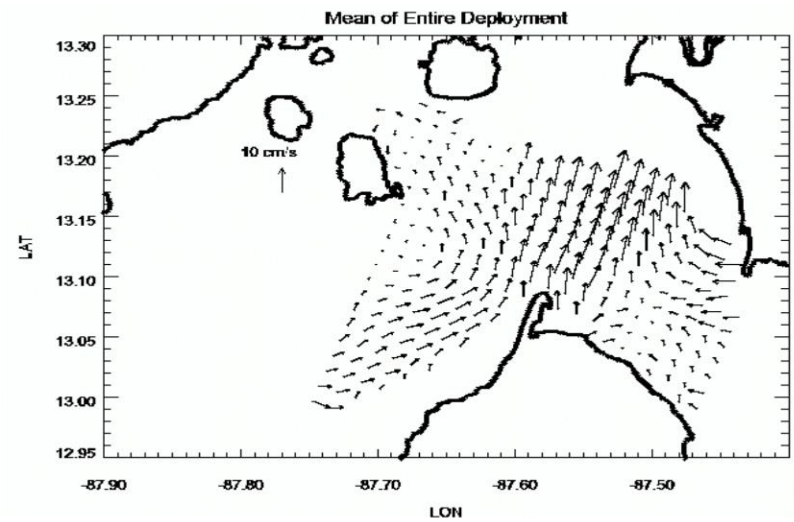
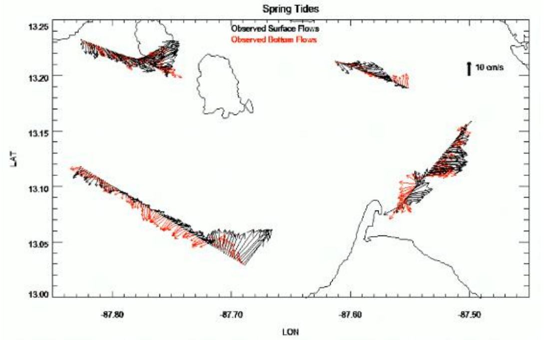


Figure 11. Circulation patterns in the Gulf of Fonseca, dry and rainy season (www.marn.gob.sv/phocadownload/pp_nn_13.pdf from Valle-Levinson, A., and K. T. Bosley, Reversing circulation patterns in a tropical estuary, J. Geophys. Res., 108(C10), 3331, doi:10.1029/2003JC001786, 2003).

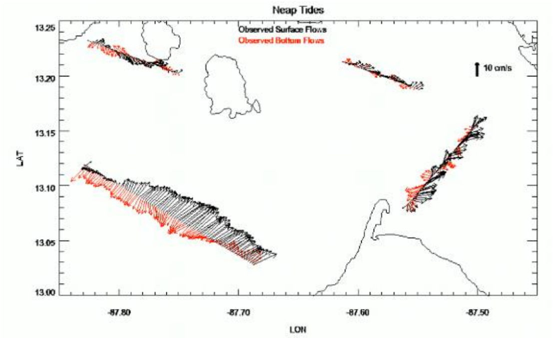
Circulation in dry season

Reverse estuary type: water entering from the surface (black arrows) and exiting at the bottom (red arrows).

Spring tide



Neap tide

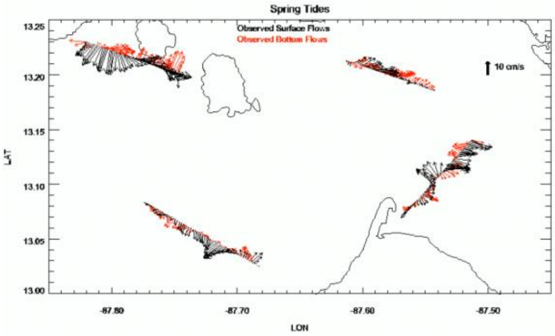


Observed surface flows: black
Observed bottom flows: red

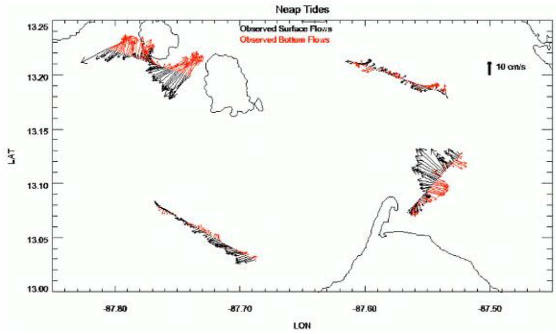
Circulation in rainy season

Estuary type: water exiting from the surface (black arrows) and entering from the bottom (red arrows).

Spring tide



Neap tide



Observed surface flows: black
Observed bottom flows: red

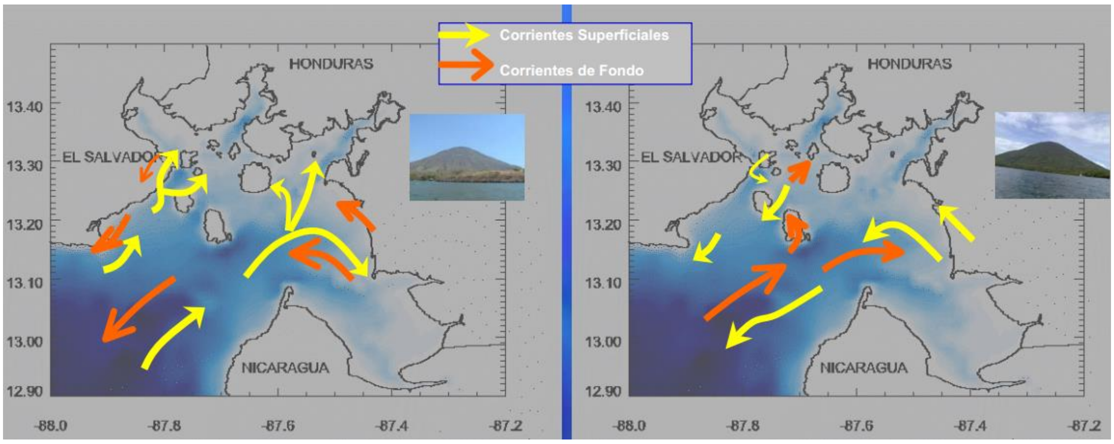


Figure 12. Significant wave height in meters on 11th October 2013 (http://www.surf-forecast.com/maps/Honduras/significant-wave-height/6).

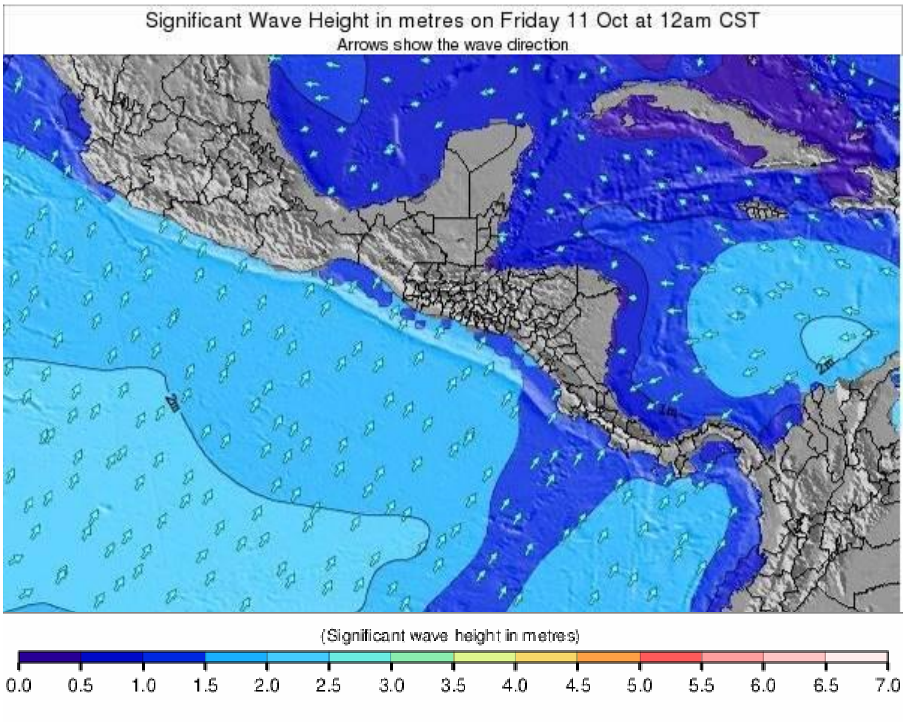
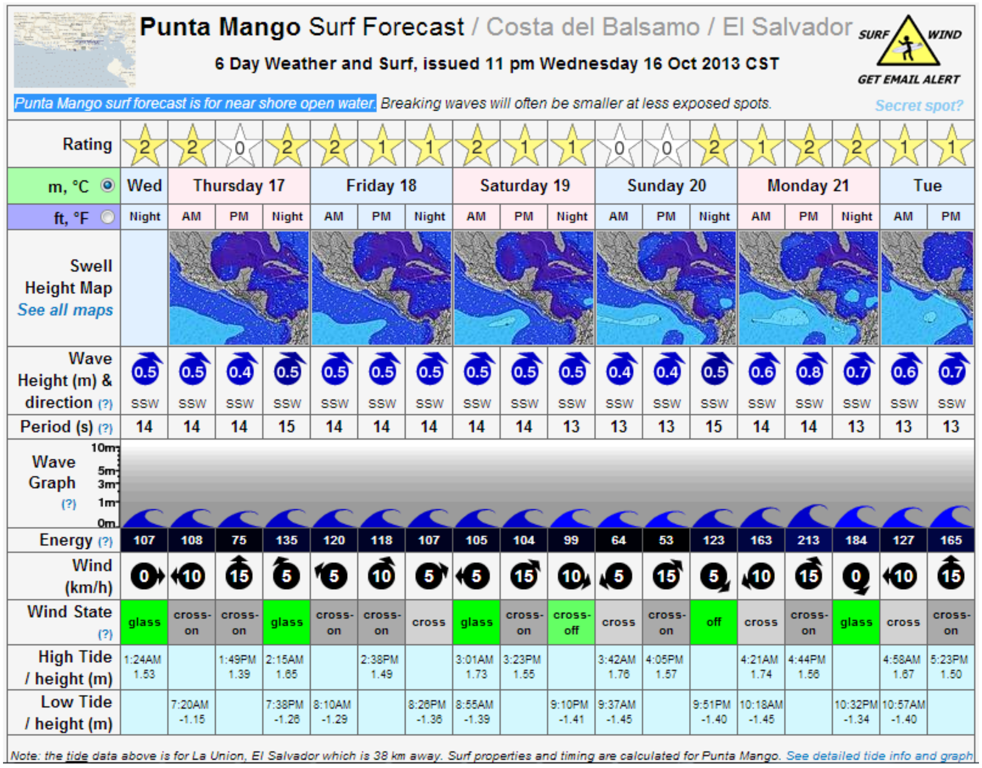


Figure 13. Surf forecast for Punta Mango (El Salvador) (http://www.surf-forecast.com/breaks/Punta-Mango/forecasts/latest/six_day#)



Punta Mango Surf Forecast / Costa del Balsamo / El Salvador

SURF WIND GET EMAIL ALERT

6 Day Weather and Surf, issued 11 pm Wednesday 16 Oct 2013 CST

Punta Mango surf forecast is for near shore open water. Breaking waves will often be smaller at less exposed spots. Secret spot?

Rating	2	2	0	2	2	1	1	2	1	1	0	0	2	1	2	2	1	1
m, °C	Wed	Thursday 17			Friday 18			Saturday 19			Sunday 20			Monday 21			Tue	
ft, °F	Night	AM	PM	Night	AM	PM	Night	AM	PM	Night	AM	PM	Night	AM	PM	Night	AM	PM
Swell Height Map See all maps																		
Wave Height (m) & direction (?)	0.5 SSW	0.5 SSW	0.4 SSW	0.5 SSW	0.5 SSW	0.5 SSW	0.5 SSW	0.5 SSW	0.5 SSW	0.5 SSW	0.4 SSW	0.4 SSW	0.5 SSW	0.6 SSW	0.8 SSW	0.7 SSW	0.6 SSW	0.7 SSW
Period (s) (?)	14	14	14	15	14	14	14	14	14	13	13	13	15	14	14	13	13	13
Wave Graph (?) 10m 5m 3m 1m 0m																		
Energy (?)	107	108	75	135	120	118	107	105	104	99	64	53	123	163	213	184	127	165
Wind (km/h)	0	10	15	5	5	10	5	5	15	10	5	15	5	10	15	0	10	15
Wind State (?)	glass	cross-on	cross-on	glass	cross-on	cross-on	cross	glass	cross-on	cross-off	cross	cross-on	off	cross	cross-on	glass	cross	cross-on
High Tide / height (m)	1:24AM 1.53		1:49PM 1.39	2:15AM 1.65		2:38PM 1.49		3:01AM 1.73	3:23PM 1.55		3:42AM 1.76	4:05PM 1.57		4:21AM 1.74	4:44PM 1.56		4:58AM 1.67	5:23PM 1.50
Low Tide / height (m)		7:20AM -1.15		7:38PM -1.26	8:10AM -1.29		8:26PM -1.36	8:55AM -1.39		9:10PM -1.41	9:37AM -1.45		9:51PM -1.40	10:18AM -1.45		10:32PM -1.34	10:57AM -1.40	

Note: the tide data above is for La Union, El Salvador which is 38 km away. Surf properties and timing are calculated for Punta Mango. See detailed tide info and graph

Figure 14. Severe storm tracks (Google Earth, http://upload.wikimedia.org/wikipedia/commons/2/23/Global_tropical_cyclone_tracks-edit2.jpg)

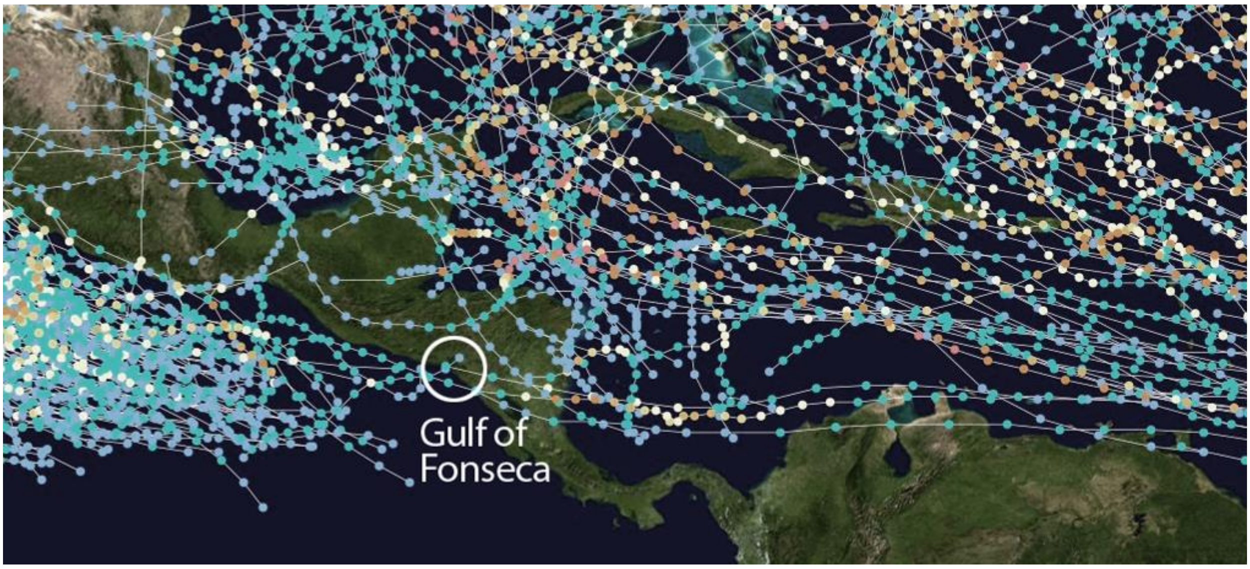


Figure 15. Sea Surface Temperature in °C (9-14/03/2001 (www.marn.gob.sv/phocadownload/pp_nn_13.pdf)

In the gulf: Tropical storm Adrian, 5/20/2005

Within 100 km radius: Tropical storm Alma 5/30/2008, Tropical storm Andres 6/7/1997, Tropical storm Miriam 10/23/1988, Tropical storm Olivia 9/21/71.

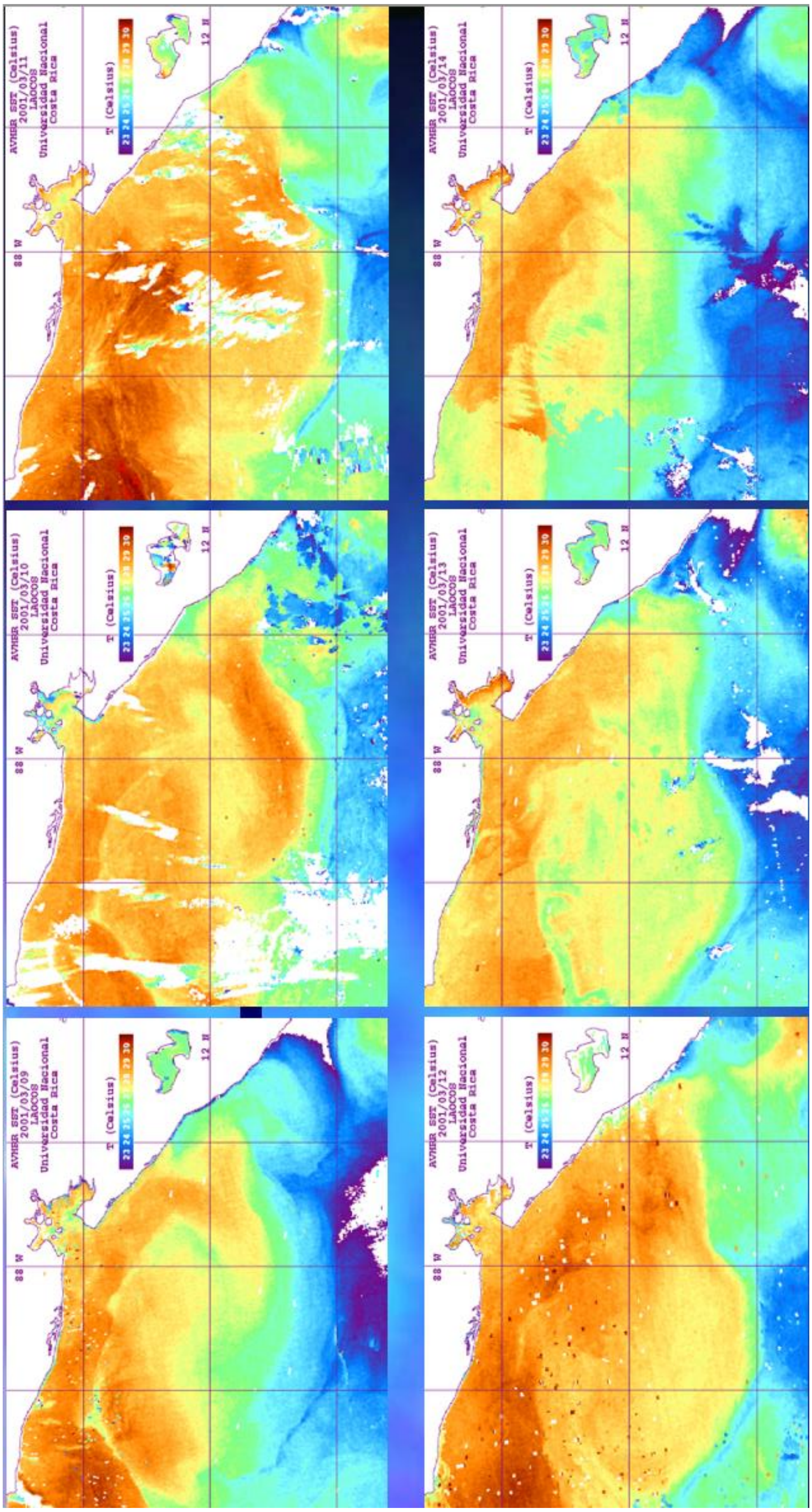
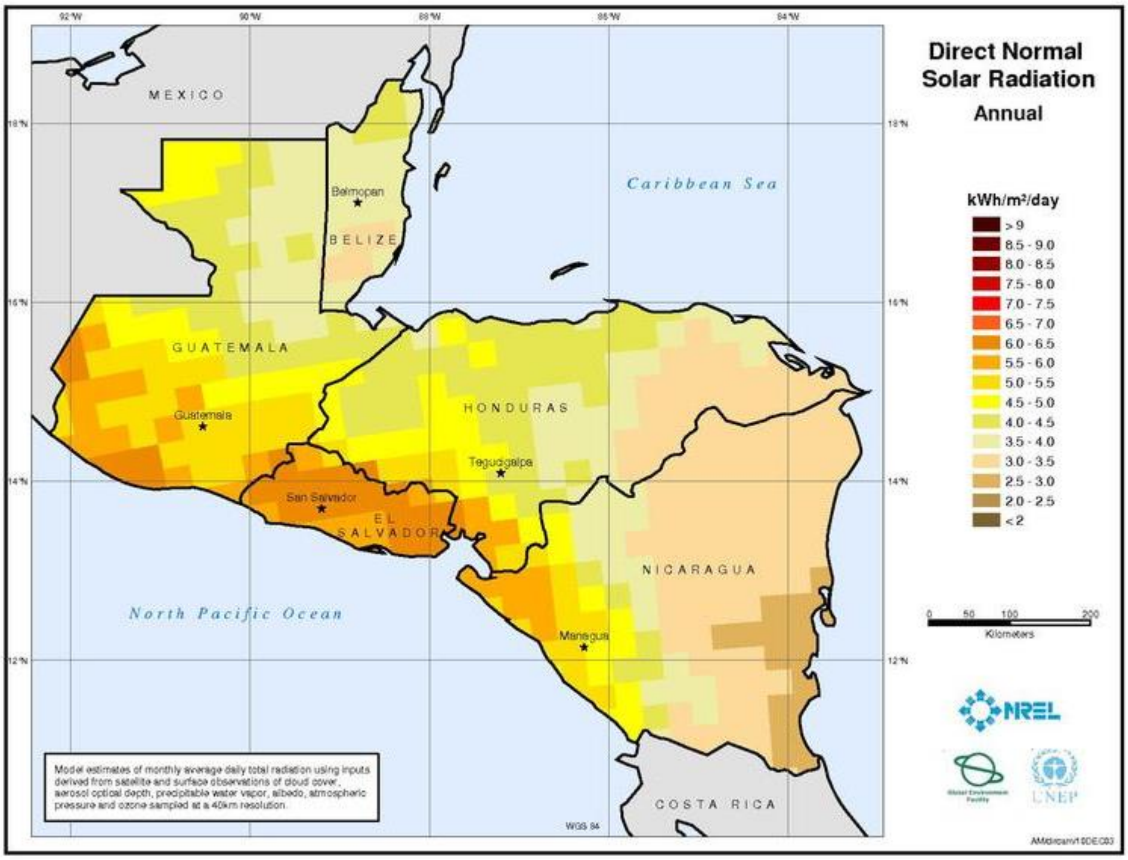


Figure 16. Satellite images of the Chismuyo Bay showing the large sediment plume flowing from the shrimp farms to the Gulf's water (Source: NASA).

Figure 17. Satellite images of Estero la Jagua and Chismuyo Bay in 1973 and 2006, after the conversion of the wetland areas into industrial shrimp production. (http://www.cathalac.org/lac_atlas/index.php?option=com_content&view=article&id=44:gulf-of-fonseca-honduras&catid=1:casos&Itemid=5).

January 1973 April 2006

Figure 18. Annual direct normal solar radiation in Honduras (http://en.openei.org/w/index.php?title=File:NREL-camdirann.pdf&page=1).



Douglas scale with the estimate of the state of the sea. The "wind sea" is the motion of the waves generated by the wind blowing directly on the observed sea area or in its immediate vicinity.
http://www.eurometeo.com/english/read/doc_douglas

DOUGLAS SCALE

WIND SEA

DESCRIPTION TERM State of the sea	WAVES AVERAGE HEIGHT
0 Calm (glassy)	-
1 Calm (rippled)	0 - 0,10 metres
2 Smooth	0,10 - 0,50 metres
3 Slight	0,50 - 1,25 metres
4 Moderate	1,25 - 2,50 metres
5 Rough	2,50 - 4 metres
6 Very rough	4 - 6 metres
7 High	6 - 9 metres
8 Very high	9 - 14 metres
9 Phenomenal	over 14 metres

SWELL

	WAVE LENGTH AND HEIGHT
0	**No swell**
1	**Very low** (short or low wave)
2	**Low** (long and low wave)
3	**Light** (short and moderate wave)
4	**Moderate** (average and moderate wave)
5	**Moderate rough** (long and moderate wave)
6	**Rough** (short and heavy wave)
7	**High** (average and heavy wave)
8	**Very high** (long and heavy wave)
9	**Confused** (wave length and height indefinable)

SPECIFICATION	Metres
Short wave	< 100
Average wave	100 - 200
Long wave	> 200
Low wave	< 2
Moderate wave	2 - 4
Heavy wave	> 4

NOTE
The swell reports also comprise the wave direction according to the eight main directions of the wind rose expressed in the english notation (N, NE, E, SE, S, SW, W, NW). For instance: Swell 2 from SW or Low swell from NW.

The "Swell" waves are generated by winds blowing over a distant sea area which travel rapidly over the surface with a regular period and flat crests

Appendix 4 Ship sizes

Type	Name [33], [34], [35], [36]	Length (m)	Length (ft)	Beam (m)	Beam (ft)
Cruise ship	Royal Caribbean – Allure & Oasis of the Seas	360	1,181	63	208
Cruise ship	Royal Caribbean – Freedom, Liberty & Independence of the Seas	339	1,112	56	184
Cruise ship	Royal Caribbean – Navigator & Mariner of the Seas	311	1,020	49	161
Oil Tanker	TI-Class Supertanker	380	1,247	69	226
Bulk Carrier	MS Vale Brasil	362	1,187	65	213
Container ship	Mærsk - Mary, Majestic & Mc-Kinney Møller	398	1,306	58	190
Container ship	CMA CGM - Marco Polo, Alexander von Humboldt & Jules Verne	396	1,299	54	177
Container ship	Mærsk - Emma, Estelle, Eleonora, Evelyn, Ebba, Elly, Edith & Eugen	398	1,305	56	185
Aircraft Carrier	**USS Theodore Roosevelt, John C. Stennis**	333	1,092	77 (deck)	252
Barge	Heerema H-851	260		63	

Appendix 5 Floating breakwaters: opportunities and challenges

A seastead protected by floating breakwaters presents an alternative to large ship-like or semi-submersible structures and may be worth investigating. The main benefit of applying a breakwater structure is that it provides a shelter for the seastead by breaking or reflecting large waves. Behind the breakwater, floating structures would not have to deal with huge waves. This allows smaller structures to be constructed that have a better water experience and allow for a more dynamic urban structure.

While the concept of a breakwater seems simple, it is quite a challenge to neutralize the enormous power of ocean waves. Most other strategies for dealing with enormous waves are actually based on evading wave energy. For example, ships are designed to either cut through water or plane on the water (lifting it on top of the water) and semi-subs and spars are designed with rounded or slender structures to minimize the effects of waves and water forces. Instead of evading waves, breakwaters have a brute force approach, facing the waves head-on. This means that both the structure and the mooring system need to be able to deal with enormous forces. Another complicating factor is that floating breakwaters are difficult to design, because the buoyant structure responds to waves, while it alters the waves at the same time.

Floating breakwaters that are anchored, instead of tautly moored, are only effective against relatively small wavelengths: According to Mani[37] this type of breakwater needs to be at least as wide as 0.3 times the wavelength in order to halve the height of incoming waves (K_t<0.5). This is because at longer wavelengths the breakwater will tend to move along with the wave instead of breaking it. This property of floating breakwaters is not a real issue, because as explained in the Seasteading Engineering Report[38] the most harmful waves are typically not the long wavelengths but the shorter and higher waves.

When 100-meter waves are considered, it can be assumed that they will be lower than 20 meters (waves that are higher than 1/5th the length are not able to support themselves). In order to break such a wave and bring it down to 10 meters, we would need a breakwater of at least 30 meters wide. Theoretically, a second breakwater of the same length (for a total of 60m) would bring it down to 5 meters, which at a wavelength of 100 meters should present no threat.

However, if the breakwater is somehow fixed it becomes more effective, reaching K_t<0.5 at a width of around 0.15 times the wavelength[39]. It becomes more effective because rolling and swaying of the structure are prevented. In this case, the width of the breakwater discussed above could be halved. While this is an interesting option for relative shallow waters, where piles may be used to secure the breakwater, it seems an unlikely solution for a structure that is to be placed in the high seas. 'Fixing' a breakwater in the middle of the ocean would require extremely taut mooring and a high amount of buoyancy to compensate the downward force. At the same time the structure and mooring system will be under additional stress from the waves and tidal influences. Such a system, which requires the elements to be fixed to one spot, is also very inflexible and would present many challenges when the seastead is to be relocated.

Perhaps there are alternative strategies to create downward force, other than using taut mooring systems. One possibility is to use the water mass itself to push down the breakwater, by creating a ramp-like structure. This structure may act as an artificial shore. Waves that approach it will 'feel bottom', slow down as they climb the ramp, build up until they become too steep and eventually break. At the same time the water creates a downward force that prevents the structure from rolling or drifting up. In this scenario the breakwater will not be exposed to the full strength of the waves.

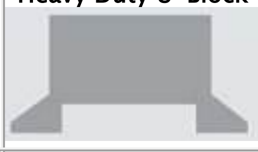
Inclined plate breakwaters have been researched extensively with positive results at widths between 0.25 and 0.75 times the wavelength[40]. Considering that this data is based on flume testing, rather than real-life situations, additional research will be necessary.

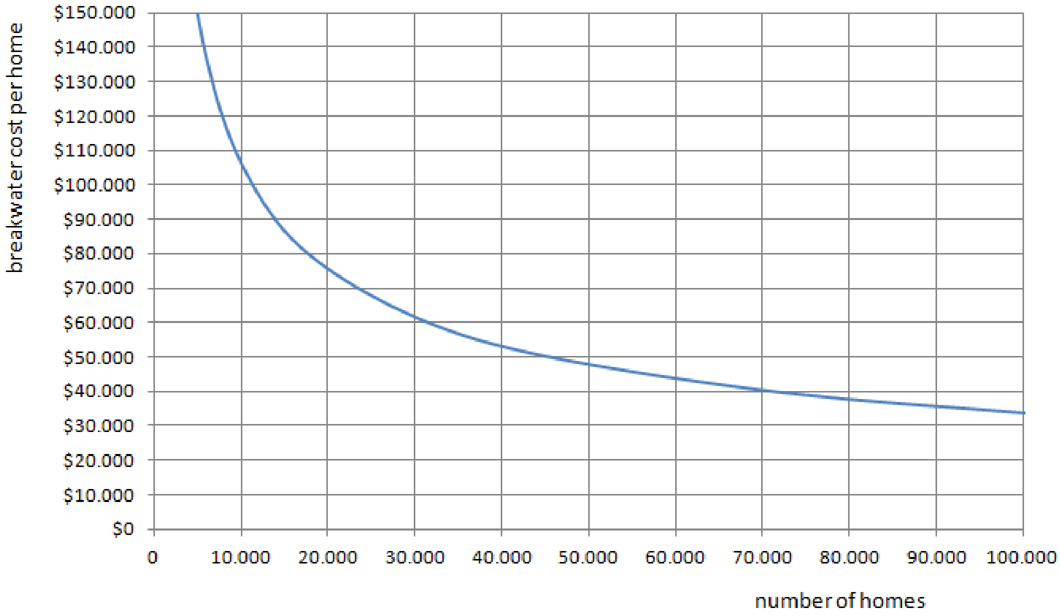
If a breakwater were designed for the most destructive wavelength reported in the ClubStead paper, which has a steepness of 0.12 and a length of 86 meter, the breakwater would need to be up to 65 m wide. The costs for the breakwater can be based on taking the volumetric costs of reference projects, for example FDN's estimates, which are between $125 and $320 per m^3.

Assuming a thickness of 5 meters and cost of €330 per m3, the breakwater would cost €108,000 per meter. If 80% of the structure were submerged, it would weigh 260t/m and the cost per ton per meter would be about €415. These costs include a mooring system for shallow water. For deep water additional costs will be made to secure the breakwater. These costs are directly proportional to the depth of the water and the amount of force the lines need to be able to withstand[41]. The Seasteading Engineering Report assumes that for a water depth of 2,000 meters mooring facilities amount to roughly 1/4th of the estimated costs for hull construction. If the same relation holds true for breakwaters, it implies a total cost of €135,000 per meter.

In order to judge these costs, they must be considered in relation to the size of the Seastead. When the breakwater is conceived of as a perfect circle drawn around a community of homes, the length of the breakwater is equal to the radius times twoπ. Because the size of the community will increase exponentially as the radius increases, the per capita costs for the breakwater will decrease rapidly as the community grows. Figure XX illustrates this; it is based on 20 homes per hectare and breakwater construction costs of $ 35,000 per meter. A 5,000-home seastead would require about $150,000 per home, whereas a 100,000-home Seastead would require only about $34,000 per home.

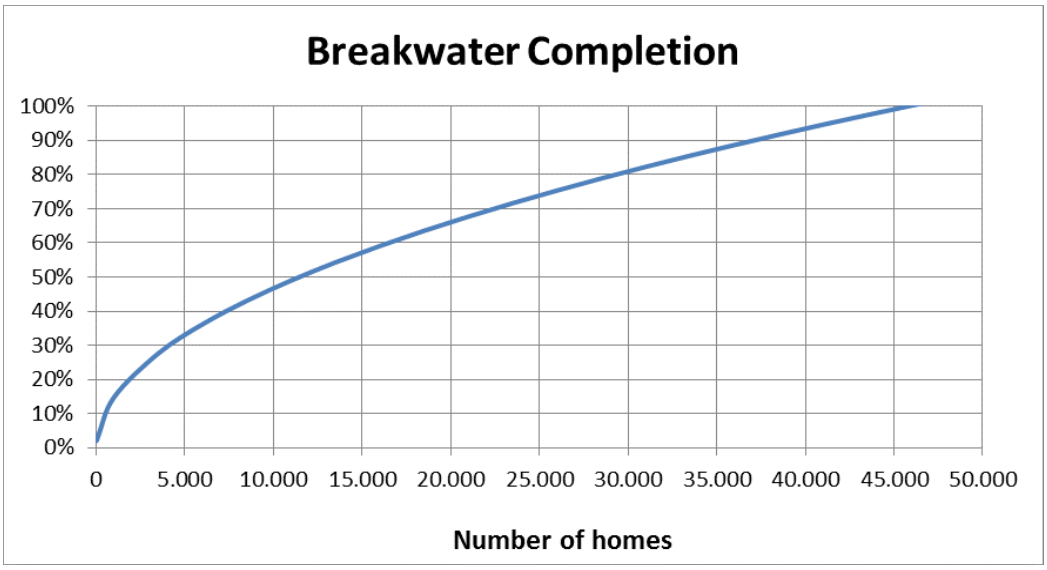
Table X Cost reference data FDN[42]

	T-Block 	U-Block 	Heavy Duty U-Block 	Monaco 
Length	up to 20 m	up to 30 m	50+ m	352 m
Width	3 - 4 m	4 - 7 m	7 - 18 m	30 m
Height (total)	3 - 4 m	4 - 7 m	7 - 18 m	30 m
Section area (est)	10 m^2	20 m^2	80 m^2	900 m^2
Water depths	up to 6 m	6 - 12 m	> 12 m	175 thousand tons
Wave heights	up to 1.1 m	1.1 - 2.5 m	> 2.5 m	
Cost estimate	€ 3,000 / meter	€ 5,000 / meter	€ 10,000 / meter	€ 150 million
Cost / m3 construction	€ 300	€ 250	€ 125	€ 320



Breakwaters are also an interesting option because they don't have to be applied right from the start. When a seastead starts at a bay or other sheltered water surface and is not yet exposed to large waves, there is no need for wave protection. As it grows larger, at a certain point it may be able to finance a breakwater, especially if there is future growth potential. For many alternative options, such as seaworthy ships or semi-submersible rigs, their seakeeping measures are an integral part of the structure and cannot be applied later on.

Figure below illustrates the process of completing the breakwater if every home finances $50,000 or 37 cm of breakwater. At 10,000 homes, half of the breakwater will already be financed. At 47,000 homes it will be finished.



Appendix 6

COST ESTIMATION TOTAL OVERVIEW

General input			total
Amount of inhabitants			225
Gross space		m²	39.576
Residential space	75%	m²	28.182
Office space	25%	m²	9.394
Hotel		m²	2.000
Vacant space (pentagon addition)	GFA	m²	15.076
Total amount of platforms			11

Development costs	per unit		total
Platform costs	3.242.495	costs	38.909.940
Mooring system	37.500	costs / platform	3.300.000
Connections between islands	70.000	costs	770.000
Bridges between islands	330.000	costs	3.630.000
Real estate	1.100	costs/m² gross	43.533.600
Water and energy			2.450.654
TOTAL COSTS ex			**92.594.194**
Total + development costs (fees, financing etc.)	25%		115.742.743
Tax (Honduras)[1]	12%		129.631.872

General		
Average costs per platform		11.784.716
Costs gross space	costs/m²	3.276
Costs gross space	costs/ft²	304
Costs usable space	costs/m²	4.199
Costs usable space	costs/ft²	390

Systems		high
Energy - micro grid	costs	2.035.404
Energy - generator	costs	1.788.524
Water	costs	415.250
Total costs	costs	2.450.654

In the first block the total space is larger than the space distributed among the functions; residential, offices and hotel. This is because this space is not jet been assigned to a function (vacant space). The platform for this space, as also the square meter costs are already calculated the systems for energy and water are not.

Background calculations

Floating platform cost estimate

Sewerage, drainage, cables and wires				
sewer/drainage pipes	100	m^1	375,00	37.500
cables and wires	2500	m^2	0,75	1.875
sidewalks top layers	250	m^2	30,00	7.500
additional floor	780	m^2	35,00	27.300
TOTAL SEWERAGE				**74.175**

Basement structure				
ground floor (hollow-core)	735	m^3	50	36.750
basement floor [2]	1210	m^3	1.400	1.694.000
outer walls	349	m^3	1.400	488.236
inner walls	364	m^3	1.400	510.149
TOTAL BASEMENT				**2.729.135**
TOTAL PLATFORM				**2.803.310**

Pentagon platforms	4.821.693	4	19.286.771
Square platfroms	2.803.310	7	19.623.169
		3.242.495	**38.909.940**

Maritime constructions

mooring system	37.500	/piece	8		3.300.000
connections between islands	70.000				770.000
bridges between islands	2000	costs/m^2	3,00	5,00	330.000
TOTAL MARITIME CONSTRUCTIONS					**4.400.000**

Systems

Energy low scenario			Demand		
Micro grid[4]	0,71	€/kWh	996.943	kWh	709.695,4
	0,33	l/kWh	64.000	kWh	24.288
yearly use price based on 2012[3]	1,15	€/litre			
TOTAL SUSTAINABLE LOW SCENARIO					**733.983**
Diesel generator[3]					
	32.000		8	units	256.000
	0,33	l/kWh	1.060.943	kWh	402.628
yearly use price based on 2012[3]	1,15	€/litre			
TOTAL CONVENTIONAL LOW SCENARIO					**658.628**

Energy high scenario			Demand		
Micro grid[4]	0,71	€/kWh	2.764.615	kWh	1.968.051,5
	0,33	l/kWh	177.478	kWh	67.353
yearly use price based on 2012[3]	1,15	€/litre			
TOTAL SUSTAINABLE HIGH SCENARIO					**2.035.404**
Diesel generator[3]					
	32.000		21	units	672.000
	0,33	l/kWh	2.942.093	kWh	1.116.524
yearly use price based on 2012[3]	1,15	€/litre			
TOTAL CONVENTIONAL HIGH SCENARIO					**1.788.524**

(1) http://www.doingbusiness.org/data/exploreeconomies/honduras/paying-taxes/
(2) http://www.gwwmaterialen.nl/soortelijk-gewicht-materialen/
(3) http://knoema.com/atlas/Honduras/Pump-price-for-diesel-fuel-USdollar-per-liter, 2012
Generators 0,28 - 0,4 litre per kWh 400 kw : 40k - 47k pp
(4) based on data from Phono Solar, the price of a micro grid per kWh for a solar system with a diesel engine backup is 1 per kWh 0,71187196
The price per kWh is higher than de average price on the main land. This is mainly due to the independent micro grid system. In this case the seastead can leave the location without having to 'plug out' of the energy grid of the current county it's residing.

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