ABSTRACT

Title of Thesis:	JAKARTA UNDERWATER: RISING SEAS AS OPPORTUNITY
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According to the UN, by 2100 nearly 5.25 billion people will live in coastal megacities in the global south where infrastructure, energy production, and water management has not kept pace with rapid urbanization. It is projected that this mass global migration will occur in Asian and African cities that also have the highest risk of vulnerability to climate change effects. The most concerning of these is sea level rise that could displace billions of people and submerge entire cities. This global transformation threatens massive humanitarian crises, ecological degradation, destruction of historical and cultural treasures, and the global economy. This thesis proposes a solution that integrates city development, coastal infrastructure, and public resources by merging architectural innovations and planning to create a protected megacity with a high quality of life and resiliency. These solutions will ease the effects of sea level rise and offer a promise of a better future for the planet -- ultimately creating a net positive solution for coastal megacities of the future.

JAKARTA UNDERWATER: RISING SEAS AS OPPORTUNITY

by

Lauren Gilmartin

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Chapter 1: Why Cities Matter – Climate Change and the Future of our Cities

Why Cities Matter

Cities are synonymous with the growth and prosperity of civilization. They are the foundation of human history, our greatest invention, and a symbol of hope and prosperity. They are the centers of culture, scientific discovery, technological advancement, economic power, and religion.

Cities represent the intersection of a system of interdependent flows that define and shape the human experience – flows of labor, industry, capital, trade, services and community. Asia and Africa represent the oldest and vastest of these flows, Europe some of its densest, and the Americas some of its most mysterious and intriguing.

As said by Jane Jacobs, cities are engines of innovation. From Athens, philosophers invented democracy; from Rome humans developed infrastructure; from Mesopotamia scholars created Algebra; from Ancient Egypt tradesmen created glass, from the Song Dynasty travelers invented the compass, from Florence artists cultivated human enlightenment, and from the settlements of the Holy Land grew the world's most dominant religions. Concentrations of people in small areas allows for the exchange of ideas. From these flows, more cities grew. These inventions spread to

other cities along trade routes, rivers, and ports. This is still evident today, as the world's most populated and important urban centers exist along these flows.

Our settlement patterns are not just a product of our geographic location. Cities are representative of cultures and ideas. Rational plans from the Greeks, astronomical alignment of buildings from the Aztecs, and the sprawling urban-suburbs representing the "American Dream" in the United States all speak to the fact that humans shape their cities based on culture, identity, and the power of an idea.

Cities are also constantly changing. They do not exist in a static state. Cities grow and shrink depending on economic factors, environmental disasters, cultural reasons, and conflict. On a global scale, while the world's total population is doubling, urban populations seems to be tripling. At the beginning of the 20th century, 14% of the world's population lived in cities. Today 60% of the population lives in cities. Still, cities facing deindustrialization or economic crisis, like Pittsburg and Detroit, have shrunk. Environmental disaster or human error, as seen in New Orleans or Chernobyl, respectively, can affect cities. Cultural and historic shifts in cities can also alter the trajectory of human history. The fall of the Roman Empire eventually threw Europe into the Middle Ages for hundreds of years.

Finally, cities can be resilient. Urban areas such as New York City and San Francisco have proven to rebound after economic and environmental disaster. Some bounce back better than before, taking on the opportunity to rebuild instead of retreat.

The complicated and interconnected history of our cities, ideas, and inventions manifested themselves in ancient cities and continue to shape the modern world. Today, cities still represent human progress and economic power. They are

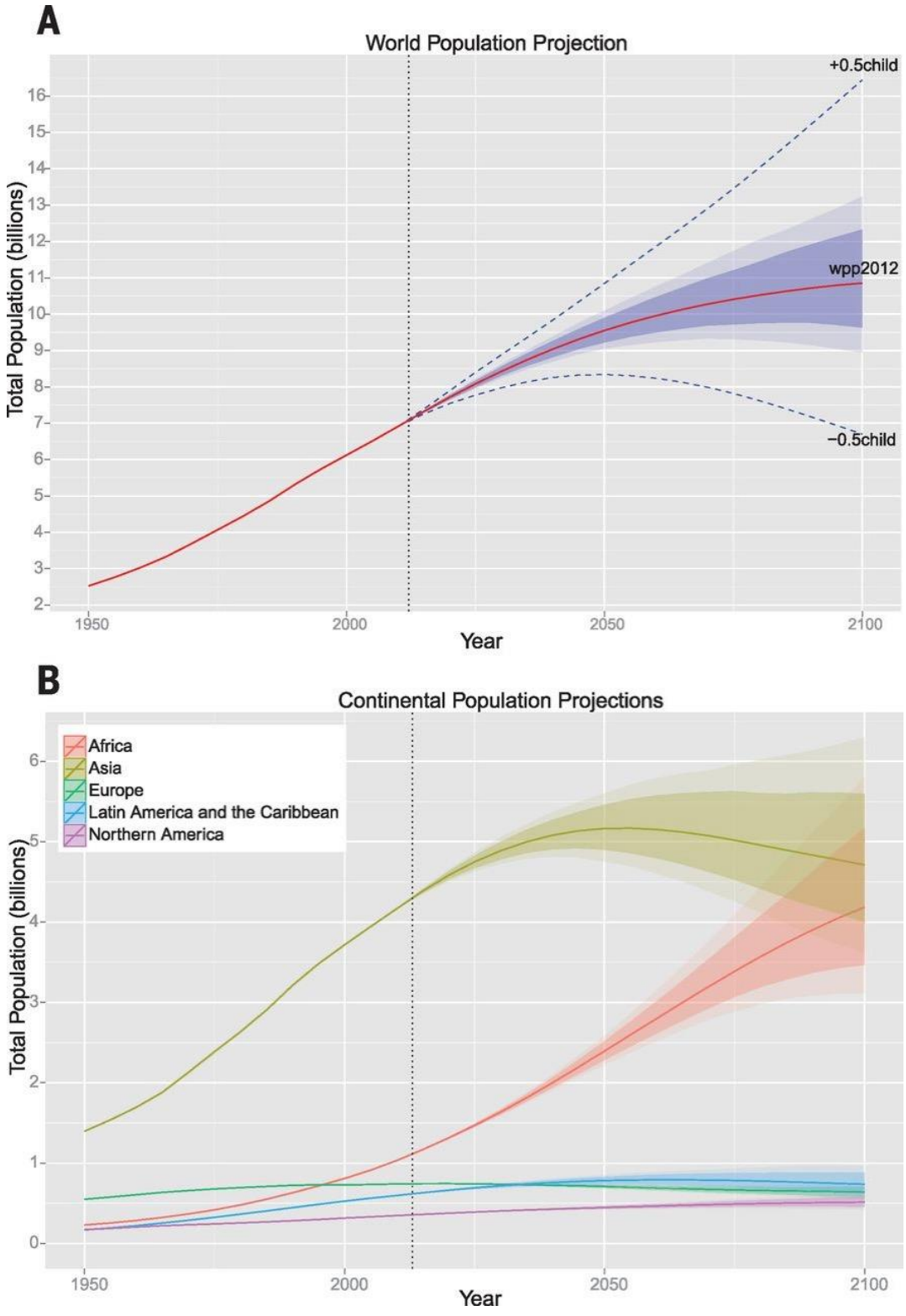
responsible for 80% of global gross domestic product and hold trillions of dollars in global assets. Furthermore, populations within cities consume 60%-80% of global energy consumption and 75% of natural resource consumption.[1] The way in which our cities are formed and how people live greatly impacts the planet, resources, and our relationship to one another. Our future advancement depends on the future of our cities. How we develop and grow our cities matters. How we approach transformations matters.

The Great Acceleration

Over the past one hundred years, the history of humanity and the state of the planet have once again experienced staggering transformations. Global population has sky-rocketed. In 1950, there were 2.6 billion people on the planet. Today, global population has stretched to a staggering 7.2 billion people and by 2050 it is projected to reach 9.7 billion people.[2] These projections give light to a global shift that our planet has already begun to experience. Data shows that of the 9.7 billion people projected to live on the planet in 2050, 7 billion of those people will live in cities. According to the UN, 90% of population growth will occur in the global south in Asian and African cities. The number of megacities – cities with 10 million residents or more – will reach 41. That is a staggering difference compared to the two megacities in 1950.[3] This suggests that this global migration will not result in the creation of new cities, but rather the expansion of existing ones. Evidence of this shift

[1] Gardner, Gary, et al. "World Cities at a Glance." *State of the World: Can a City Be Sustainable?*, Island Press, 2016.
[2] "The Worlds Cities in 2018 Data Booklet." *United Nations*, 2018.
[3] Gardner, Gary, et al. "World Cities at a Glance." *State of the World: Can a City Be Sustainable?*, Island Press, 2016.

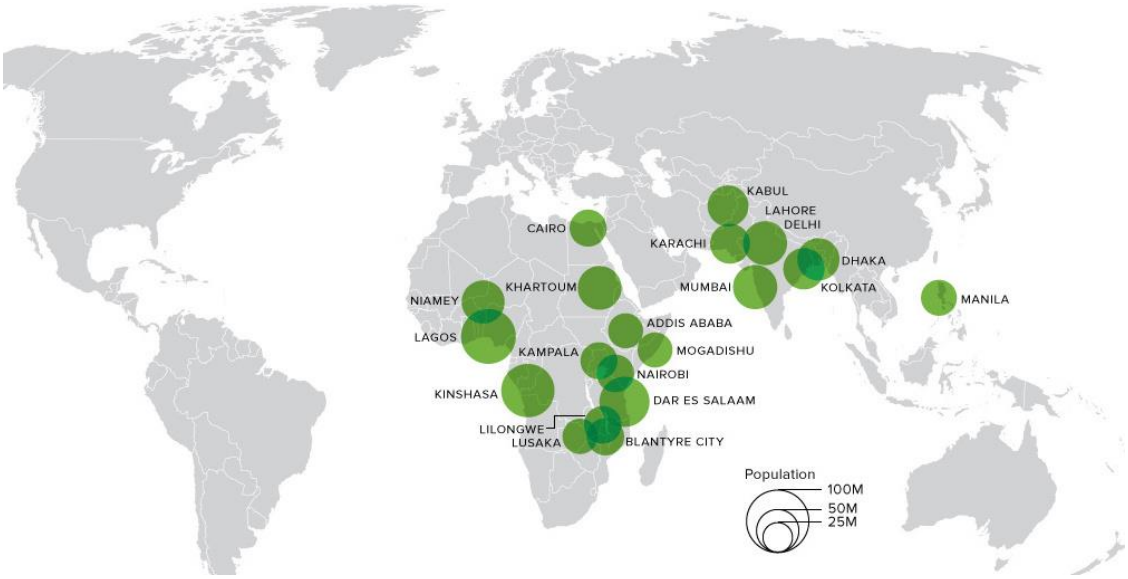
World Population vs Population by Continent



Source: United Nations. https://www.unfpa.org/data/world-population-dashboard

already exists in cities like Lagos, Dar es Salaam, Mumbai, and Dhaka – cities that will be the most populated cities in the world by 2050. Lagos alone is expected to grow from 18 million people today, to 88 million people by 2100.

The Most Populous Cities in the World in 2100 (placeholder)



Credit: World Cities Institute. https://www.visualcapitalist.com/animated-map-worlds-populous-cities-2100/

What is causing this recent acceleration? People move to escape the hardships of rural life, to seek economic opportunity, and to access basic needs like housing, water, healthcare, and access to reliable energy – especially in developing countries where these basic needs have historically not been met in rural areas of the country. As the populations of these cities grow, particularly in cities in Asia and Africa, more

people will be attracted to the city. It is estimated that 3 million people are moving to urban areas every single week.[4]

Positives and Negatives of this Transformation

Rapid urbanization can elevate a country in its global standing. Cities like Lagos and Jakarta have become the largest economic powers in Africa and Southeast Asia, respectively. Unfortunately, consequences of rapid urbanization have already materialized today as mass populations migrate from rural regions to cities that promise opportunity.[5] Population booms have quickly outpaced infrastructure, access to clean drinking water, adequate sanitation, and reliable access to electricity in developing cities. In 2009, the World Bank recorded that more than 33% of urban populations live in slums and 1 in 7 people in cities today live in poverty.[6] Less than 35% of cities today treat their waste water and over 170 million urban residents lack access to proper sanitation, including latrines. Around 1.5 billion people live among extreme air pollution, and 18% of urban populations use wood, dung, and charcoal for cooking which highlight poor access to energy sources and air pollution regulations.[7]

These circumstances become hazardous in over-populated cities and have very serious consequences when infrastructure cannot keep up with rapid urbanization. Poor access to sanitation, healthcare, and available fresh food and water can cause serious public health risks. Estimates suggest that 40% of the urban growth

[4] Boyd, Bret (2019). "Urbanization and the Mass Movement of People to Cities. *Grayline.* Retrieved 22 May 2019 from https://graylinegroup.com/urbanization-catalyst-overview/
[5] Desjardins, Jeff. "Animated Map: The 20 Most Populous Cities in the World by 2100." *Visual Capitalist*, 9 Mar. 2019, www.visualcapitalist.com/animated-map-worlds-populous-cities-2100/.
[6] "Urban Population." *World Bank*, Open Data, 2018, data.worldbank.org/indicator/SP.URB.TOTL.
[7] Gardner, Gary, et al. "World Cities at a Glance." *State of the World: Can a City Be Sustainable?*, Island Press, 2016.

in cities today is taking place in slums, further exacerbating socio-economic disparities and creating unsanitary conditions that facilitate the spread of disease. These public health hazards include preventable illnesses such as tuberculosis, respiratory infections from pollutants, diarrheal diseases from poor sanitation, and malnutrition.[8]

Unfortunately, the threats cities are facing today are expected to worsen as the danger of climate change becomes more apparent in the next twenty-five years.

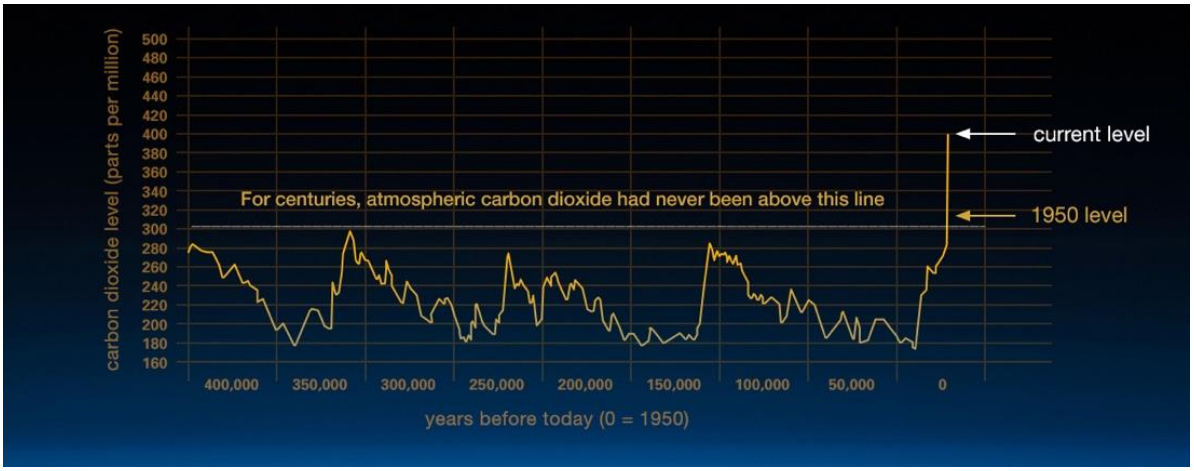
Climate Change and the Effects on Cities

In fifty years, average global temperatures have increased at the fastest rate in recorded human history. Experts agree that this trend is accelerating. Based on comparisons of atmospheric samples contained in ice cores, scientists are able to prove that for 400,000 years atmospheric carbon dioxide never exceeded 300 parts per million until 1950. Today, the atmospheric carbon has reached over 400 parts per million and is increasing. The Intergovernmental Panel on Climate Change (IPCC) estimates that carbon dioxide concentration in the atmosphere could rise to 1000 parts per million by 2100. This is significant due to the behavior of greenhouse gases in the Earth's atmosphere.

Earth's natural "greenhouse" effect is critical to supporting plants, organisms, and natural systems on the planet. The Earth receives energy from the sun in the form of radiation, which is then captured in the atmosphere, trapped within its ozone, and

[8] Stevens, Phillip (2004). "Diseases of poverty and the 10/90 gap." *International Policy Network.* Retrieved 22 May 2019 from https://www.who.int/intellectualproperty/submissions/InternationalPolicyNetwork.pdf

Concentration of CO2 in the Atmosphere over Time



Credit: Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record.

absorbed by land surface and the ocean.[9] This is a delicate system that is susceptible to any external forces. An increase in concentration of atmospheric gases such as methane, carbon dioxide, and ozone can disrupt this balance and increase the temperature of the planet because this heat cannot escape the Earth's atmosphere.[10]

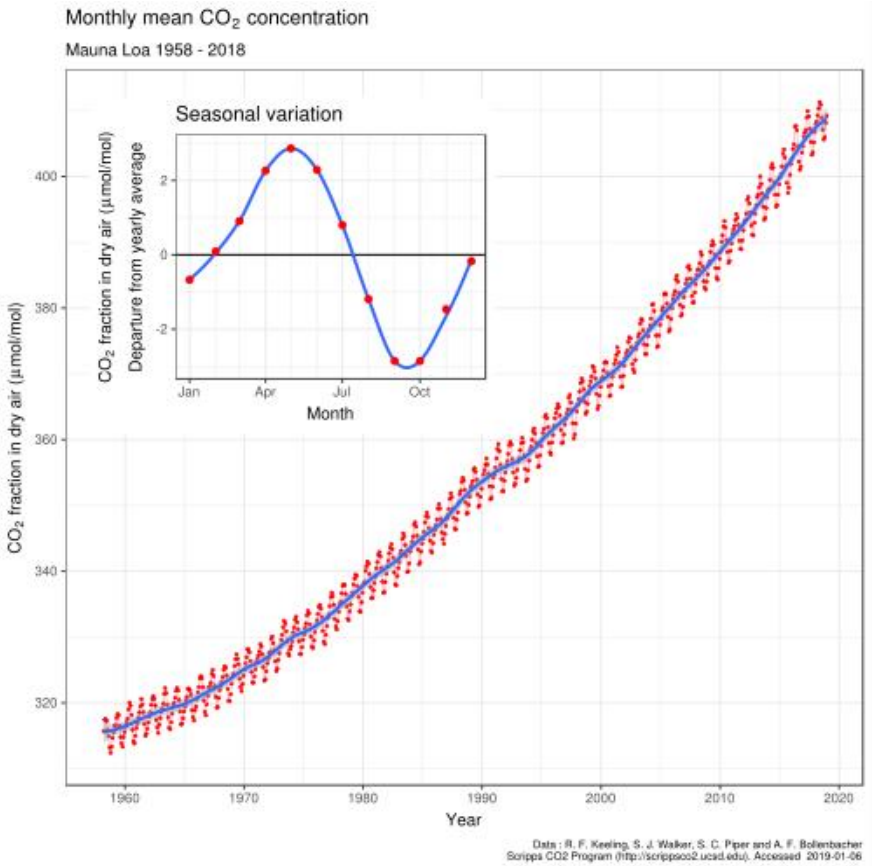
Charles David Keeling, a NOAA scientist working at the Mauna Loa Observatory in Hawaii, began tracking levels of carbon dioxide in the atmosphere starting in 1958. His observations discovered that concentrations of carbon dioxide in the atmosphere have been steadily rising for the last fifty years. When compared to recorded temperatures over the same time period, there is a positive correlation between concentration of carbon in the atmosphere and rising temperatures on the

[9] "The Causes of Climate Change." *Global Climate Change*, NASA. 23 May 2019, https://climate.nasa.gov/causes/

[10] "Climate Change Evidence: How Do We Know?" *NASA*, NASA, 26 Mar. 2019, climate.nasa.gov/evidence/.

planet.[11] This evidence strongly suggests human activity has accelerated the Earth's natural variation of global temperature, beginning with the Industrial Revolution in the 1800's. The Intergovernmental Panel on Climate Change (IPCC), a group of 1,300 independent scientific experts from various countries within the United Nations has concluded there's a more than 95 percent probability that human activity has been the primary cause for this global shift.

Keeling Curve Showing Increase in CO2 in the Atmosphere



Source: NOAA

[11] "The Early Keeling Curve." *Scripps CO2 Program,* Scripps Institute of Oceanography. 23 May 2014, http://scrippsco2.ucsd.edu/history_legacy/early_keeling_curve

Future Projections of Global Warming According to the IPCC

Since Keeling's discovery in 1958, the average global temperature has risen about 0.9 degrees Celsius.[12] According to the Intergovernmental Panel on Climate Change, the most conservative projections reveal a global increase of 2-degrees Celsius. In order to not surpass the threshold of 2-degrees Celsius, scientists suggest sweeping cuts in fossil fuel usage and consumption would have to cease immediately. Without any changes to global behavior, the most aggressive projections show 8-degrees Celsius in the next 75 years.[13] The IPCC predicts with high probability that the planet will experience between 3-degrees to 4-degrees of warming by 2100 with moderate changes to global consumption of fossil fuels.

All three scenarios present long-term effects that are serious and irreversible -- increased heat and heat wave intensity, more powerful, frequent storms, global water and food shortage, and species extinction, to name a few. Three degrees Celsius alone could radically alter the planet as we know it today.

Cities and Their Future

These projections give light to a global shift that our planet has already begun to experience. Are cities wholly to blame for this planetary shift? According to the International Biosphere Programme, we know that the urban population of our planet has exploded at an alarming rate and accounts for 70% of global consumption. This consumption -- increased water use, amplified product consumption, poor waste

[12] "Climate Change Evidence: How Do We Know?" *NASA*, NASA, 26 Mar. 2019, climate.nasa.gov/evidence/.
[13] "Special Report Global Warming of 1.5 Degrees Celsius." *Global Warming of 1.5 ºC*, Intergovernmental Panel on Climate Change, 2018, www.ipcc.ch/sr15/.

practices, burning of fossil fuels for vehicle use and electricity, and more -- have led to a shift in global temperatures. Because of this shift in global consumption, there appears to be a positive correlation between population increase in cities and the increase of atmospheric carbon dioxide, species extinction, woodland destruction, and ozone depletion. These factors all contribute to climate change.[14]

Similar to the effects of rapid urbanization, it is understood that global climate change effects the planet inequitably. Perhaps more concerning is that a majority of the top twenty most populated cities in 2050-2100 will lie in regions of the planet most vulnerable to climate change effects – the most concerning of these being sea level rise. These threats could exacerbate the negative impacts of rapid urbanization, especially in African and Asian cities that are expected to grow at an exponential rate over the next 75 years.

[14] "International Geosphere-Biosphere Programme the Earth as a System". *International Geosphere-Biosphere Programme*, 4 April 2019.

Chapter 2: Facing Sea Level Rise

The most concerning threats our cities are facing due to climate change is storm surges and sea level rise. According to the United Nations, of the 7 billion people projected to live in cities by 2050, two-thirds will live in coastal cities.[15] In addition to rising temperatures, floods, and increased risk of natural disasters, cities are facing the terrifying threat of sea level rise that could submerge entire cities and even countries. According to C40 Cities Institute, 800 million people – 2.25 times the population of the United States -- in 570 cities are vulnerable to just half of one meter rise in sea level. Furthermore, 13% of the world's population today lives less than 10 meters above sea level.[16]

Sea level rise and urban flood are detrimental to urban areas. These conditions could destroy homes, roads, bridges, power plants, sewage treatment facilities, and landfills that support urban and rural populations. They can contaminate water sources, displace animal species and wipe out valuable ecosystems that urban cities rely on for local economies and ecosystem services. Furthermore, sea level rise and sever flood damage could displace millions of people, resulting in a challenging global climate refugee crisis. With projections showing anywhere between three and six feet of sea level rise in a 2-degree Celsius world, sea level could be the single

[15] "World Urbanization Prospects The 2018 Revision." *United Nations*, 2018.
[16] "Staying Afloat: The Urban Response to Sea Level Rise." *C40 Cities*, C40 Cities Leadership Group. 23 May 2019, https://www.c40.org/other/the-future-we-don-t-want-staying-afloat-the-urban-response-to-sea-level-rise

most threatening crisis of all climate change affects. It is clear that we are facing a disaster that could submerge entire cities and countries. Looking toward the future, urban populations will need to prepare their cities for this inevitable threat.

The Causes of Sea Level Rise

Global sea levels have been rising over the past century and the rate of increase has grown every year since 1993. The two major causes of global sea level rise are thermal expansion and increased melting of land-based ice due to increased global temperature, specifically the Greenland and Arctic ice sheets.

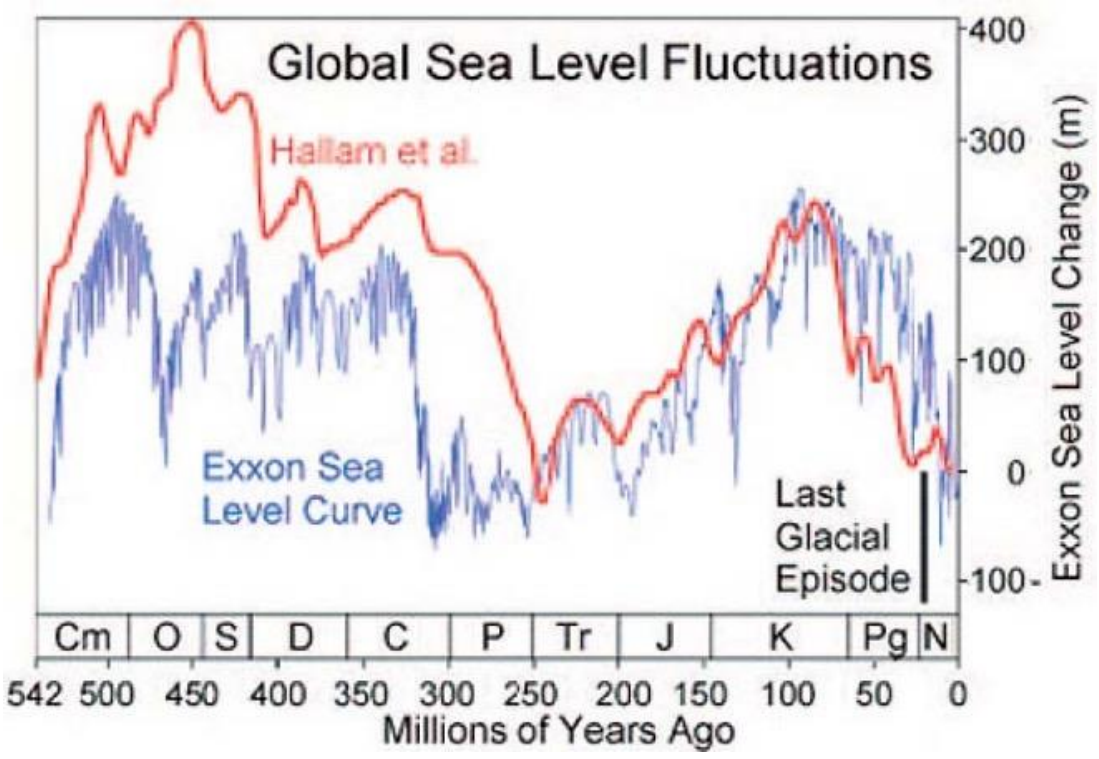
Thermal expansion can be defined as the "increase in volume of matter when it is exposed to an increase in temperature."[17] When put into the context of climate change, thermal expansion refers to the increase in volume that occurs when water becomes warmer. According to the National Oceanic and Atmospheric Administration, oceans have absorbed more than 97% of increased atmospheric heat associated with 90% of emissions from human activity. This had led to thermal expansion of ocean bodies across the globe. What is important to note is that water does not expand equally across large distances. Regions across the globe experience thermal expansion unequally. In short, tropical regions or hotspot areas experience more thermal expansion than other parts of the world, making the threat of sea level rise greater in these regions.

[17] Cousineau, Laurent. "Thermal Expansion Definition." *Climate Change Guide*, Climate Change Guide. 23 May 2019, https://www.climate-change-guide.com/thermal-expansion-definition.html

Compounding thermal expansion is the melting of ice in the polar regions of the planet. Greenland's ice sheets have already lost 286 billion tons of ice per year between 1993 and 2016, while Antarctica's ice sheets lost 127 billion tons of ice per year during the same time period. The combination of thermal expansion and melting ice has resulted in roughly eight inches of sea level rise in the last century. Should these patterns increase this could lead to sea levels that reach higher than any in this current century.

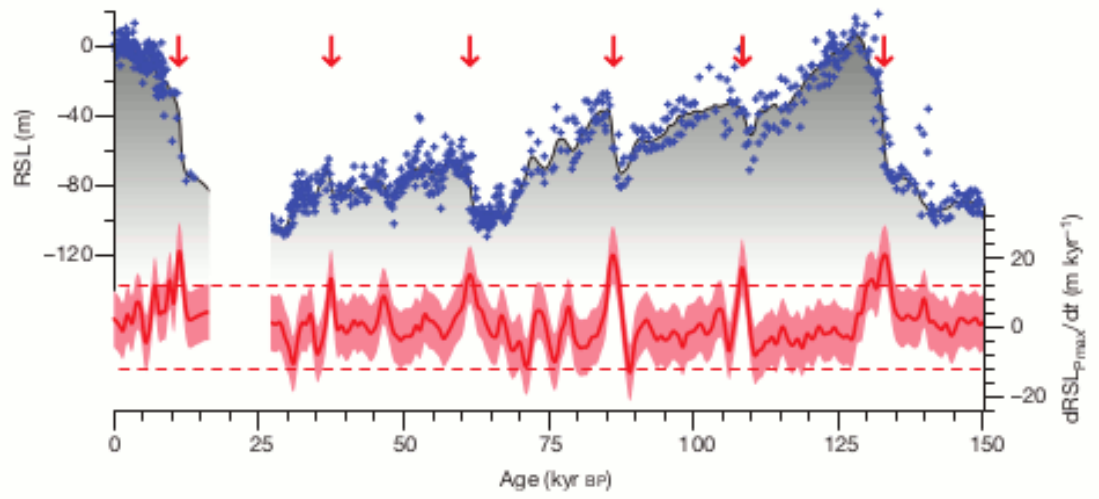
What are the historic patterns of sea level rise?

Historic Patterns of Sea Level Rise over 500 Million Years



Source: "Past 150,000 Years of Sea Level History Suggest High Rates of Future Sea Level Rise." Skeptical Science. https://skepticalscience.com/Past-150000-Years-of-Sea-Level-History-Suggests-High-Rates-of-Future-Sea-Level-Rise.html

Historic Patterns of Sea Level Rise over 150 Thousand Years



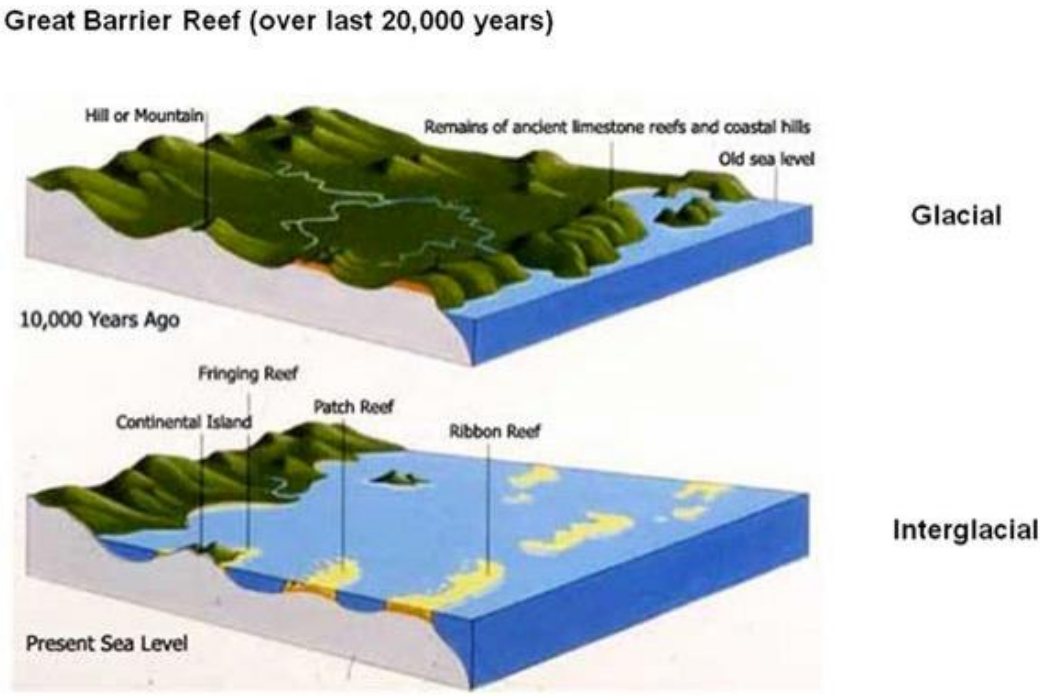
Source: "Past 150,000 Years of Sea Level History Suggest High Rates of Future Sea Level Rise." Skeptical Science. https://skepticalscience.com/Past-150000-Years-of-Sea-Level-History-Suggests-High-Rates-of-Future-Sea-Level-Rise.html

Despite recent attention to sea level rise in the last thirty years, it is important to note that for millions of years the planet has undergone constant transformations. These include fluctuations in mean global temperature and average sea level. In fact, in the last 550 million years, global sea level has fluctuated greatly. 400 million years ago, sea levels were 400 meters above today's existing sea elevation. In contrast, 250 million years ago, sea levels were about 25 meters below current sea levels.[18] In fact, just 20,000 years ago, average sea level was so low after the last Glacial Episode that

[18] Painting, Rob (2012). "Past 150,000 Years of Sea Level History Suggest High Rates of Future Sea Level Rise." *Skeptical Science,* Skeptical Science. 23 May 2019, https://skepticalscience.com/Past-150000-Years-of-Sea-Level-History-Suggests-High-Rates-of-Future-Sea-Level-Rise.html

the land now known as the Great Barrier Reef of the coast of Australia at one time existed above sea level.[19]

Great Barrier Reef: 20,000 years ago vs. the Present



Source: "The Decline of the Great Barrier Reef." https://skepticalscience.com/great-barrier-reef-decline.htm

Despite this fact, sea levels are the highest they have been in the last 150,000 years.[20] Comparing this with the fact that modern humans date back 300,000 years,

[19] Cook, John (2019). "The decline of the Great Barrier Reef." *Skeptical Science,* Skeptical Science. 23 May 2019, https://skepticalscience.com/great-barrier-reef-decline.htm

[20] Ayalon, A. Bar-Matthews, M. Grant, K. Rohling, E. Medina-Elizalde, M. Ramsey, C. Satow, C. Roberts, A (2012). "Rapid coupling between ice volute and polar temperature over the past 150,000 years." *Nature International Journal of Science* 491, 744-747. 23 May 2019, https://www.nature.com/articles/nature11593

humans have endured similar threats of sea level rise and climate change in the past. History is in fact repeating itself.

Furthermore, we now know that humans have endured similar threats of sea level rise and climate change not just 150,000 years ago, but many times over thousands of years. This is quite obvious when considering the multiple discoveries of ancient civilizations that now exist under water. Cities like Yonaguni-jima, Japan (10,000 BCE), Dwarka, India (7500 BCE), and Cleopatra's Palace (332 BCE – 619 CE) continue to offer researchers insight into planetary and oceanic transformations over time that were once considered geographical mythology. Historians now know that oceans have ebbed and flowed so much that entire civilizations were able to build and thrive before being submerged by water either over time or during disaster.

Future Projections and their Effects on Cities

Future projections of climate change and sea level rise are grim. Exact forecasts are challenging to predict due to variability of the planet's climate and human consumption patterns. However, it is clear that at minimum the global population can expect an average temperature increase of 2 - 3 degrees Celsius accompanied by 1 – 2 meters of sea level rise in 75 years. These projections are quite conservative and would take concerted internationally effort to reduce global consumption of fossil fuels to meet these goals.

Even the slightest increase in global temperature and sea levels could be disastrous. Higher sea levels can cause deadly storm surges, frequent nuisance flooding, contamination of fresh water, destruction of ecosystems, and loss of land along coastlines. This global transformation threatens massive humanitarian crises,

destruction of historic treasures and cultural landmarks, environmental degradation, threats to the global economy.

Environmental Impacts

When considering environmental impacts, even a small increase in sea level can devastate coastal habitats, fresh water resources, agricultural soil, and loss of habitats for fish, birds, and species. Already, according to the Organization for Economic Cooperation and Development (OECD), the loss of biodiversity and ecosystem functions due to rising sea levels have degraded 50% of salt marshes, 35% of mangroves, 30% of coral reefs and 29% of seagrass marshes. These delicate ecosystems are not only important of animal life, but for our cities. Coral reefs alone are estimated to protect over 100 million people from wave induced flooding. According to OECD's model, coral reefs save Cuba, Indonesia, Malaysia, Mexico, and the Philippines $400 million dollars in flood damage reduction annually. Our global economies rely on these natural resources and losing them could devastate not only the countries experiencing sea level rise, but other countries that rely on their exports.[21]

Humanitarian Impacts

The humanitarian impacts of this issue alone are daunting. When considering 800 million people are at risk to sea level rise, we are viewing this issue through the lens of climate justice. Increases in nuisance flooding can destroy homes and

[21] "Responding to Rising Seas OECD Country Approaches to Tackling Coastal Risks." Organization for Economic Co-Operation and Development, Mar. 2018, www.oecd.org/environment/cc/policy-highlights-responding-to-rising-seas.pdf.

infrastructure. Flash floods can be deadly. Sea level rise could displace millions of people at one time. Where will these people go?

This issue does not affect all regions equally. Sea level at specific locations could be more or less than the global average due to the nature of thermal expansion of the oceans, land subsidence from groundwater and fossil fuel extraction, and changes in sea currents. Some countries have already experienced land loss. Indonesia alone has estimated a loss of 2,000 of their 17,000 islands due to sea level rise.[22]

Further, it is recorded that the most vulnerable to sea level rise are poor populations in low-lying areas. As we have learned from the effects of disasters such as Hurricane Katrina and Hurricane Harvey, the most vulnerable to sea level rise are not only island nations, but poor populations in low-lying areas. The "low elevation coastal zone" – areas along the coastline less than 10 meters above sea level – holds 13% of global urban population. In Southeast Asia and Africa, these numbers climb to 33% and 18% respectively. These areas are historically made up of poor slums with an average density nearly twice that of inland urban density.[23] Populations living in these areas are extremely vulnerable to sea level rise and flood risk, especially those living in informal settlements that are not equipped to withstand yearly natural disasters.

[22] "Rising sea levels threaten 2,000 islands in Indonesia." *National News,* Jakarta Post. 23 May 2019, https://www.thejakartapost.com/news/2015/12/17/rising-sea-levels-threaten-2000-islands-indonesia.html

[23] "Cities at Risk from Rising Sea Levels." 23 May 2019, https://www.rrojasdatabank.info/statewc08093.3.pdf

The ability of these individuals to move or protect their own communities is extremely low. Internal and external climate migration is already occurring worldwide and has contributed to deepening the refugee crisis. In 2017 alone, 19 million new refugee displacements were recorded in 130 countries worldwide. These migrations have been mostly triggered by extreme weather events, floods, tropical cyclones, and sea level rise. To put this into context, there were more refugees displaced by climate change than armed conflict in 2017.[24] A study conducted by Cornell researcher in 2017 predicts this number could climb to 2 billion people by 2100.[25] Some countries have looked to buying land abroad to combat this threat. Kiribati, a nation of 100,000 people, has recently purchased land from Fiji in anticipation of moving its people when seas rise.[26]

Economic Impacts

The economic threat of sea level rise and urban flood is important to consider. A Global Investor Survey conducted in 2013 found that 81% of asset owners view climate change as a "material risk or opportunity across their entire portfolio." The same report predicts that private investors alone in 2013 were at risk of losing $4.2

[24] Freedman, Andrew (2018). "Climate change is already deepening the refugee crisis." Axios. 23 May 2019, https://www.axios.com/climate-change-refugees-are-already-on-the-move-d17b190c-122b-4e1f-9021-8ca666bf3880.html

[25] Freidlander, Blaine (2017). "Rising seas could result in 2 billion refugees by 2100."*Cornell Chronicle,* Cornell University. 23 May 2019, https://news.cornell.edu/stories/2017/06/rising-seas-could-result-2-billion-refugees-2100

[26] Doyle, Alister. "As Seas Rise, Pacific Island President Favors Buying Land Abroad." *Scientific American,* Reuters. 23 May 2019, https://www.scientificamerican.com/article/as-seas-rise-pacific-island-president-favors-buying-land-abroad/?redirect=1

trillion in assets between now and 2100.[27] According to the IPCC, the costs from damage due to climate change will only increase over time.

In the U.S. alone, the financial toll along the east coast and Gulf of Mexico is projected to increase from 11% to 27% in the next 15 years. The recent aftermath of Hurricane Sandy in New York City was an indicator of just how much it might cost to repair the damages of one intense storm in a developed megacity. Hurricane Sandy damaged 90,000 buildings, the subway system, and city infrastructure. This storm ultimately cost the city $19 billion dollars in damages. This is from a singular event. What will it cost when cities begin to feel the effects of climate change yearly? According to the C40 World Cities Institute economic costs to cities from rising seas and flooding could amount to $1 trillion every year by 2050. Some cities have taken steps to secure their coasts – but most have not. For example, within the United States, ocean-related industry accounts for $352 billion dollars in business profits a year. Annually the U.S. spends $150 million dollars a year to manage beaches. Despite the proven economic value of coastal cities and the annual cost to upkeep beaches, a study showed that only eight out of thirty-one U.S. states or territories are taking the minimal measures in protecting their coasts against temporary floods.[28]

The United States is not alone in this. The projections worldwide are even more staggering. Without climate action, the global community could experience a

[27] "The Investor's Guide to Climate Change." The Atlantic. 23 May 2019, https://www.theatlantic.com/sponsored/morgan-stanley/the-investors-guide-to-climate-change/696/
[28] Shukla, Priya. "Nearly 75% Of Coastal States Aren't Prepared For Sea Level Rise." *Forbes*, Forbes Magazine, 27 Dec. 2018, www.forbes.com/sites/priyashukla/2018/12/27/nearly-75-of-coastal-states-arent-prepared-for-sea-level-rise/#b6fca1f32057.

23% drop in global income by 2100.[29] In cities like Dhaka and Jakarta, monsoons cause devastating floods every three to five years. These disasters destroy communities and resources. But despite this, the governments in these two countries do little to implement serious measures to protect its capital cities. Low-income populations once again resettle along shorelines while temporary sea walls are replaced or created to hold back the next inevitable storm. Each time seawall infrastructure is replaced, the cost of installation rises twenty percent.[30]

Looking Ahead

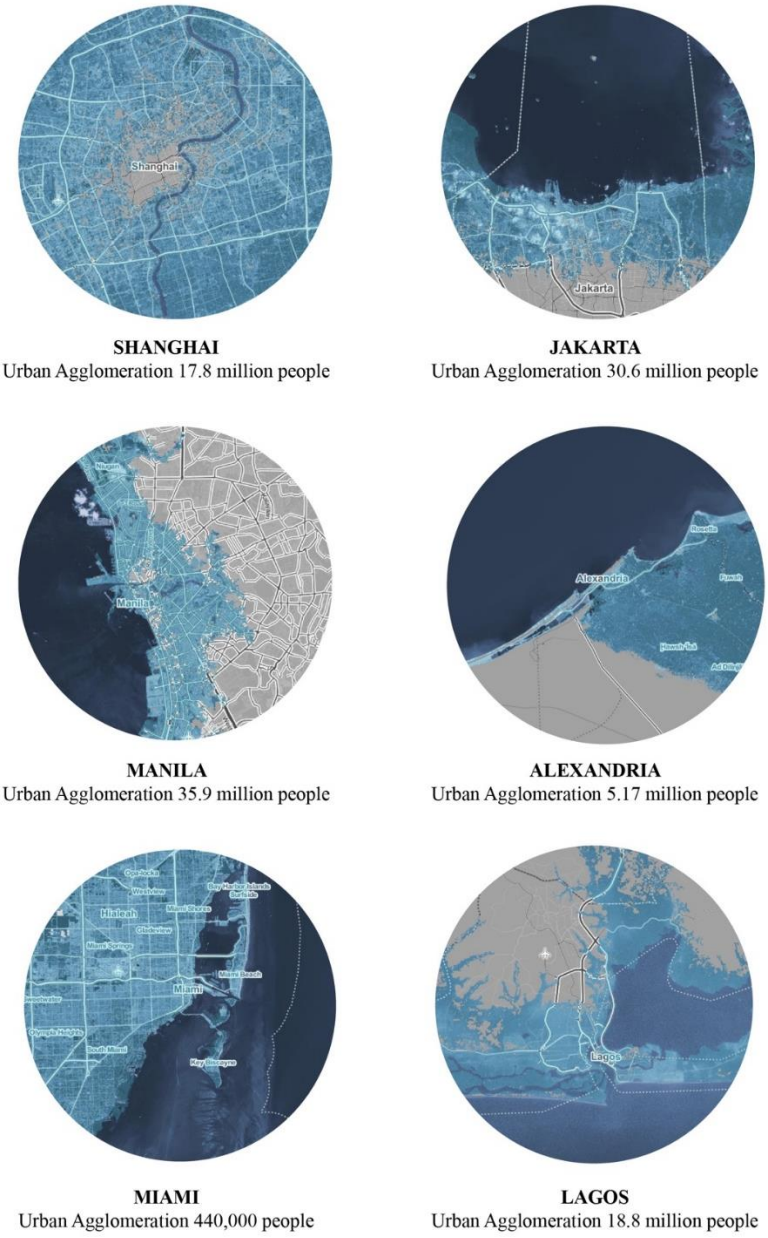
Megacities like Jakarta, Shanghai, Lagos, Dar es Salaam, Dhaka, Alexandria, Tokyo, Manilla, and Mumbai are expected to experience this sea level rise and its consequences sooner than other cities. These cities are home to millions of people, billions of dollars in assets, sacred historical landmarks, and important ecosystems in need of protection from this impending threat. Furthermore, these cities will not only need protection from rising seas, but will need to implement resiliency infrastructure that mitigates the effects of global warming and secures the safe, sustainable future of their cities.

What can be done to combat this crisis? What is getting in the way? Is it possible to frame this threat instead as an opportunity to protect cities as well as serve other needs? How can these proposals combine energy production and water security,

[29] "The Investor's Guide to Climate Change." The Atlantic. 23 May 2019, https://www.theatlantic.com/sponsored/morgan-stanley/the-investors-guide-to-climate-change/696/
[30] "The Costs of Shoreline Stabilization." *South Atlantic Alliance.* http://southatlanticalliance.org/wp-content/uploads/2016/04/17-Hoffman-The-Costs-of-Shoreline-Stabilization.pdf

while also engaging with the surrounding community in a collective effort to combat sea level rise in coastal cities?

Projected Sea Level Rise for Various Cities



SHANGHAI
Urban Agglomeration 17.8 million people

JAKARTA
Urban Agglomeration 30.6 million people

MANILA
Urban Agglomeration 35.9 million people

ALEXANDRIA
Urban Agglomeration 5.17 million people

MIAMI
Urban Agglomeration 440,000 people

LAGOS
Urban Agglomeration 18.8 million people

Source : Data provided by *Surging Seas.* https://sealevel.climatecentral.org/

Chapter 3: Response to the Threats of Urban Flood and Sea Level Rise

The interconnected threat of sea level rise, urban flood, and rapid urbanization in cities around the world are a proven reality. However, despite the insurmountable evidence supporting the need to prepare our cities for climate disaster, very few attempts to deal with the long-term threats of sea level rise exist around the world. Of the few attempts, only a handful have proved successful in creating infrastructure that stimulates economic profit in the city or improves the quality of life of its urban population. Most have relied on traditional methods of "gray" infrastructure to protect cities. The "pave, pipe, pump" approach that has governed flood response in urban design for over a century has proven to back fire in the face of climate change, sea level rise, and increased urban flood. The reality of these threats has exposed the weaknesses of this approach. From Bangladesh to Texas, urban flood and sea level rise have shown it is not just storms that cause disaster, it is also the nature of rapid urbanization.

The consequences of inaction pose human, environmental, and economic threats. So why are there not more examples of actions being taken to combat this issue? The answer lies in climate change denial, planning barriers, and inadequate architectural and engineering solutions.

Barriers to Development

In the last thirty years, there has been overwhelming investment in understanding the causes, issues, and consequences of sea level rise but there has been very little action from planning agencies.

It is easy to blame climate denial and "red tape" for this fact. Despite overwhelming evidence presented by 97% of scientists worldwide, climate denial is still a barrier to implementing planning strategies for combating this threat. Using the United States as an example, skepticism about climate projections still dominates politics. In 2012, North Carolina made it illegal to enact policies based on forecasts of climate change. If that isn't challenging enough, the United States Army Corps of Engineers holds jurisdiction over most coastline development, meaning that even if planning departments wanted to take action, it would require federal procedures to adopt adaptation strategies. These challenges usually halt policy measures from following through with sea level rise mitigation at a local or state level.

Another barrier to planning for disaster is the question of land rights, annexation, and the forced use of eminent domain that can often lead to corruption and mass eviction of low-income populations. This is especially a problem in cities like Lagos and Jakarta. In these cities capital improvements have been complicated by questions of land ownership, especially in areas of informal settlements. Capital improvement projects in these cities, such as Eko Atlantic in Lagos, have been primarily funded by third parties that have been shown to pay off the government to evict slum populations and hand over land rights in order to develop land with a promise of tacking on "sea level rise mitigation." In many cities, land ownership is

unclear and therefore relocation and development make implementation strategies challenging and fraught with corruption.

No strategy for reducing the impacts of sea level rise is complete without addressing the challenges of unchecked, rapid urbanization. Stemming from the issue of land rights, rapid urbanization makes it challenging to make decisions about mitigation strategies. This can be due to numerous reasons. The first possibility can be contributed to weak governments that lack control over the location and rate of development in areas most at risk. This is especially true in developing cities where there is not an existing land use approval process, risk management land use strategy, or a government that is able to enforce its restrictions. Rapid urbanization also halts governments and private developers from laying the groundwork for mitigation measures in the first place. In cities like Dhaka, Jakarta, and Lagos where millions of people are moving to the city every week, often infrastructure cannot keep up with the demand ultimately resulting in the establishment of informal settlements without access to infrastructure and no way for entities to construct needed infrastructure after settlement without displacing people.

While denial, bureaucracy, land rights, and rapid urbanization are easy to blame, the largest planning barrier to mitigation is the cost of implementation. When examining the costs of pre-disaster mitigation to post-disaster mitigation, the answer is clear. In March 2019, the OECD published a report that described policy approaches to attacking the issue of sea level rise. This report described that global adaptation to sea level rise prior to disaster could “reduce damage costs 2-3 orders of magnitude.” And while the report cites that a collective investment of $70 billion

worldwide by 2100 would have to be made in protecting our coasts, it also cites that the consequences of waiting post-disaster could reach $27 trillion to $50 trillion dollars a year globally with just 1.8 meters of sea level rise. This is a sobering statistic and can be quite convincing. However, the share of costs is not equal globally. The same study also cited that only 13% of the world's coastlines would need coastal protection to secure 90% of threatened populations and 96% of global assets. But what this study fails to mention is that the burden of constructing these developments falls on cities most vulnerable to sea level rise which has already been shown to be primarily in developing countries.[31]

Responses to the Threat: Methods and Case Studies

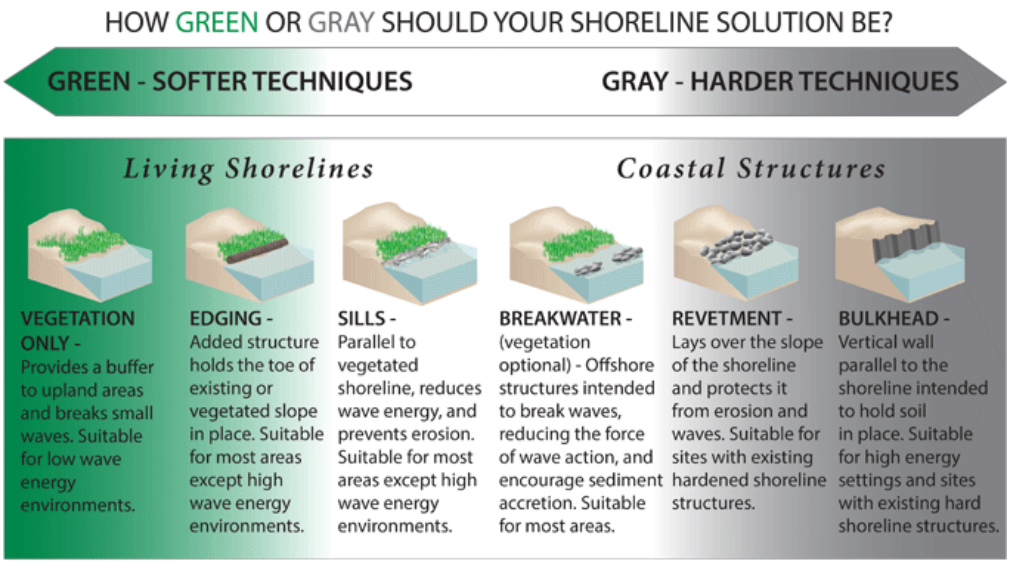
Despite lack of education surrounding sea level rise and rapid urbanization, land rights issues, and cost, there have been attempts to combat this threat. Many architectural and planning barriers exist to implementing mitigation strategies – leading to global inaction in protecting urban populations. A few projects that have made strides in this direction are the Maeslant Storm Barrier in the Netherlands, the Thames River Barrier in London, and the river dikes in Shanghai, China. However, few innovations have been made in coastal infrastructure that can satisfy the requirements to deal with the impending threat of permanent sea level rise and rapid urbanization.

[31] "Responding to Rising Seas OECD Country Approaches to Tackling Coastal Risks." Organization for Economic Co-Operation and Development, Mar. 2018, www.oecd.org/environment/cc/policy-highlights-responding-to-rising-seas.pdf.

Traditional Methods of Coastal Protection

While there has been little effort worldwide to fortify vulnerable coasts, some coastal infrastructure does exist. Traditional methods of coastal infrastructure have historically been sorted into two categories – "engineered" and "natural" infrastructure. Other names for these methods include "hard" and "soft" infrastructure, and "gray" and "green" infrastructure. Each method of traditional coastal protection has separate purposes, different costs associated with each approach, and have shown unintended consequences.

Shoreline Protection Methods



Source: NOAA. *"Understanding Living Shorelines."*

https://www.fisheries.noaa.gov/insight/understanding-living-shorelines

Engineered infrastructure, what is thought of as the traditional or conventional coastal defense, consists of sea walls, levees, dikes, bulkheads and jetties. In recent implementation, developers are combining levees and dikes with programed uses

such as running trails, viewing spots, pop-up stall areas, and more. These are known as “programmed levees.” They are often constructed of concrete or stone and permanently alter the existing natural coastline. “Gray” infrastructure is useful when space is limited or to protect important assets.

Hard methods of coastal infrastructure are extremely expensive, challenging to maintain, and most importantly, have proven to exacerbate flooding and storm surges in surrounding areas. Studies have shown that sea walls worsen the effects of flood in non-protected areas. These methods are also prone to failure – as the force of a wave hits a sea wall, its force amplifies, digging into the sand below and eventually destroying the foundation of the wall. Implementation of hard coastal infrastructure has also shown to degrade delicate ecosystems such as wetlands and marshes. Not only do these methods alter the existing coastline, but they also cut these ecosystems and organisms off from the surrounding bays, rivers, or oceans that replenish the marshes, mangroves, and coral reefs.

Issues with traditional methods of coastal mitigation infrastructure can be seen in Yamanda village in Japan. In 2011, a massive earthquake struck causing a thirty-foot-tall tsunami to hit the coast of Japan. This disaster killed 18,000 people and triggered a nuclear meltdown at Fukushima power plant. This event led Japan to construct a forty-foot-tall concrete sea wall along a 395 kilometer stretch of coastline where a 4-meter-tall breakwater once existed. All though construction of the wall was originally welcomed, and has since proven successful in mitigating floods in Japan, residents of Yamanda and other villages along the coastline have grown dissatisfied with the infrastructure project. Citing that they were never involved in the planning

process, local oyster fishermen have since lost access to the water, tourism has declined, and lack of water running from the land to the sea has damaged oyster populations. While the infrastructure has proven successful in holding back tides, it has failed the community it has served.[32]

Japan 40-foot Sea Wall (placeholder)

Source: Reuters. "Seven years after tsunami, Japanese live uneasily with seawalls." TRT World, 2018.

China is experiencing similar effects from its sea wall installations. In Shanghai alone, China has constructed over 520 kilometers of sea wall that has proven to be a bad investment. Sea wall construction has allowed the government to reclaim land for economic development and profit, but unfortunately has damaged

[32] Lim, Megumi. "Seven Years after Tsunami, Japanese Live Uneasily with Seawalls." *Reuters*, Thomson Reuters, 10 Mar. 2018, www.reuters.com/article/us-japan-disaster-seawalls/seven-years-after-tsunami-japanese-live-uneasily-with-seawalls-idUSKCN1GL0DK.

over half of its wetland coastlines that host nearly 230 different species of birds, plants, and aquatic life. According to the American Association for the Advancement of Science, this will cost China nearly $31 billion dollars in ecosystem services every year.[33]

"Natural" methods of coastal infrastructure, also called "living shorelines" can consist of vegetation-only barriers, edging shorelines, sill shorelines, or breakwaters. These have the ability to mitigate wave impact and keep local ecosystems intact. These methods also act like sponges during flood events while doubling as habitat areas for valuable ecosystems. Living shorelines are also easier to maintain and repair because they rely on natural processes of restoration. This makes natural methods of coastal protection more affordable over time. A study in North Carolina after Hurricane Irene found that living shorelines outperformed bulkheads mainly because 75% of the bulkheads surveyed were damaged by the storm. Engineered structures have to be replaced at full cost while living shorelines become more resilient over time.[34]

When comparing the two methods the cost difference for each is staggering. According to a pro-forma published for the "Big U" development in New York City in 2018, programmed levees cost approximately $42,000 per linear foot. Moreover, T-Walls can cost roughly $18,000 per linear meter. Compared to green infrastructure, living shorelines on average cost $100 per linear foot if there is minimal alteration to

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[33] Bryn, Brandon. "Science: China's Seawall Construction May Be a Bad Investment." *American Association for the Advancement of Science*, 20 Nov. 2014, www.aaas.org/news/science-chinas-seawall-construction-may-be-bad-investment

[34] Lightbody, Laura (2016). "Living Shorelines: A Key Line of Defense." The Pew Charitable Trusts. 23 May 22, 2019, https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2016/05/living-shorelines-a-key-line-of-defense

the coastline. Protection through green infrastructure is attractive when considering cost alone. However, while living shorelines are thought to be the preferred method for dealing with flood mitigation, they cannot handle the threats of sea level rise.[35] Unlike engineered methods of coastal infrastructure, living shorelines cannot stop inundation, they can only delay flood.

Both "hard" and "soft" methods of coastal infrastructure offer positives and negatives – but both are still categorized as conventional coastal protection acting as barriers. They are designed for resistance and are mostly static. They come at large economic costs, are designed for worst-case climate scenarios, and are not adaptable to changing conditions. Both hard and soft methods of coastal infrastructure are short term solutions and can only be engineered to accommodate certain storm sizes.

Is this the best that humans can engineer to protect coasts from the threat of sea level rise? Is it realistic to build coastal defenses along every meter of coast? Likely the answer is no. Instead, architectural and engineering solutions of the future need to be adaptable, creative, serve more than one function, and be forward thinking. Solutions should strive for resilience and be designed so that failure would not result in severe damages to buildings, ecosystems, and other infrastructure. Future implementation of coastal defenses should also be able to be implemented in succession so that their installation is based on the most current knowledge and forecasts. Finally, both gray and green infrastructure methods are short term solutions. What can be done on the long-term to protect cities by 2050?

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[35] Spiegel, Jan Ellen. "How to Protect Coasts from Sea-Level Rise » Yale Climate Connections." *Yale Climate Connections*, Yale School of Forestry and Environmental Studies, 12 July 2016, www.yaleclimateconnections.org/2016/07/as-sea-levels-rise-how-best-to-protect-our-coasts/.

Beyond Flood Defenses

Many planning and architectural barriers exist when considering mitigation strategies for sea level rise but one thing is certain – the water will come, and waiting for disaster can leave less time to implement long term solutions. Short term solutions to problems of this magnitude could result in reliance of "hard" infrastructure projects, local governments pursuing policies that may be rational for the local good but not a global good, and increasing costs for the tax base who will have to shoulder the burden of the construction of infrastructure.

The reality of building sea walls around all coastlines that could withstand the forces of the ocean is simply improbable. Coastal protections will soon need to consider complementing infrastructure with smart land-use planning policies that discourage growth in vulnerable areas and incentivize resilient construction. According to the World Bank, developing countries have a chance to implement urbanization in safe places. However, while this may be true, most developing cities still face the uphill battles of managing rapid urbanization with weak institutions, lack of land control, and the extension of informal settlements. The time has come to take an innovative approach to coastal adaptation. How can we frame this issue differently to come up with solutions that not only protect people and ecosystems, but create a net-positive solution to sea level rise?

Chapter 4: Making Room for Water

Human Resiliency and Living with Water

Humans are resilient beings. Modern humans have endured 200,000 years of environmental challenges and have thus grown resilient through evolution, circumstance, and modern technology. In the context of sea level rise and urban flood, humans have had a long history of living with water. From irrigation techniques in Egypt, to Chinese flood control practices, to living with daily tidal inundation in Indonesia, humans have proven able to adapt to the forces of water and have figured out ways to take advantage of these events.

Ancient Egyptians developed advanced farming and irrigation techniques that used the yearly flooding cycle of the Nile River Delta to their advantage. These civilizations built their cities around the knowledge of these floods and have come to regard this yearly cycle as a sacred gift to civilization rather than a disastrous event.[3637]

Ancient Xia Chinese also learned to live with water. Frequent seasonal flooding of the Yellow River was both a life giver and life taker – it supplied water to the fertile regions of China but was often a violent natural disaster. The Ancient Chinese, looking for a way to tame the effects of the yearly floods and distribute crop

[36] Tanner, Mark. " The Importance of the Annual Nile Flooding for the Nile River Valley Civilization." 23 May 2019, http://marktanner.com/niletrip/importance-of-nile-river-floods.html
[37] Driaux, Delphine. "Water Supply of ancient Egyptian settlements: the role of the state. Overview of a relatively equitable scheme form the Old to New Kingdom (ca. 2543-1077 BC." *Water History,* 2016; 8: 43-58. doi: 10.1007/s12685-015-0150-x.

throughout the region for internal trade, built the largest artificial canal in the world known as the "Grand Canal." This canal is an engineering marvel on the same scale as the Great Wall of China. It fostered communication, trade, and prosperity to inland China and connected its far-reaching cities together all while managing flood.[38]

Populations today have continued this approach to flood and sea level rise. Farmers in Indonesia, China, and India rely on flood for irrigation of their farms.[39] Homeowners in the Netherlands have started using amphibious structural techniques to allow homes to adjust to rising tides and flood through buoyancy. Conversations in Wales have started proposals to use artificial tidal lagoons to harness energy from flood and sea level rise.[40]

Change of Perspective

It is clear that over the course of human history, there have been populations that have chosen to take the resilient approach to inundation by understanding flood as a natural process to work with, rather than against. What if we look at sea level rise and urban flood as a resource, not a threat? Sea levels will rise, and countries like India, Bangladesh, and Indonesia will still continue to experience yearly monsoons. For a long time, urban design has overlooked the opportunity to design with water, not against it. What happens when we change this perspective?

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[38]"Grand Canal." *Grand Canal and other Water Projects in Ancient China.* Facts and Details. 23 May 2019, http://factsanddetails.com/china/cat2/4sub7/entry-4272.html

[39] "Irrigation Development in Indonesia." *International Executive Council,* The International Commission on Irrigation and Drainage. 23 May 2019, https://icid2019.com/irrigation-development-management-in-indonesia/

[40] "Swansea Council decides to build Swansea Bay Tidal Lagoon." Marine Energy.biz. 23 May 2019, https://marineenergy.biz/2018/10/23/swansea-council-decides-to-build-swansea-bay-tidal-lagoon/

United Nations Sustainable Development Goals

United Nations Sustainable Development Goals

Source: United Nations. https://sustainabledevelopment.un.org/sdgs

In 2015, the United Nations adopted what is known as 17 Sustainable Development Goals that provide a road map for prosperity and sustainability now and into the future. These 17 principles are urgent calls for actions for all countries both developed and developing.[41] The Division for Sustainable Development Goals provides substantive support and capacity building for cities and partnerships to apply the SDGs to issues such as water, energy, climate, urbanization, and poverty.

[41] "Sustainable Development Goals." United Nations. https://sustainabledevelopment.un.org/?menu=1300

Considering these goals will be important in developing strategies for development in coastal cities. The four most applicable Sustainable Development Goals are:

- Goal 1 / Goal 10 – No Poverty / Reduced Inequalities
    - End poverty in all its forms everywhere. Reduce inequality within and among countries. These two are lofty goal that will need effort from developers, policy makers, community members, and international organizations. However, the point is that development decisions should be made that do not inequitably impact poor populations. Strategies should be taken to lift people out of poverty when possible.
- Goal 6 – Clean Water and Sanitation
    - Ensure availability and sustainable management of water and sanitation for all. Many developing cities have clean water issues and do not handle waste. Poor drinking water and waste contamination are issues that reinforce each other and must be dealt with when considering strategies for tackling the consequences of rapid urbanization and fresh water contamination from rising seas.
- Goal 7 – Affordable and Clean Energy
    - Ensure access to affordable, reliable, sustainable and modern energy for all. Improved quality of life can be directly related to access to energy. So many cities including Lagos, Jakarta, Dhaka, and Manilla do not have ubiquitous access to energy resources. Rapid urbanization has made it challenging to install infrastructure that can reach communities that are growing quickly.

- Goal 9 – Industry, Innovation, and Infrastructure
    - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Infrastructure is the most important question in sea level rise mitigation. More importantly, do we build infrastructure everywhere, or only in specific locations? Who and what is most affected by infrastructure implementation?
- Goal 11 – Sustainable Cities and Communities
    - Make cities and human settlements inclusive, safe, resilient and sustainable. A sustainable future is not possible without these factors. Built strategies will need to incorporate the needs of all stakeholders and ensure a positive future for all people.
- Goal 14 / Goal 15 – Life Below Water / Life on Land
    - Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. As previously mentioned, traditional methods of coastal infrastructure and approaches to urban development have often resulted in the destruction of ecosystems that are valuable to people and the planet. Development strategies will need to incorporate environmental sustainability.

How should we approach the threat to sea level rise?

Coastal development in the future will need to be able to cast long-term, medium-term, and short-term solutions as cities reach a transition point in dealing with the issues of urban flood, sea level rise, and rapid urbanization. Furthermore, cities will need to look to strategies that fill other community needs and resources in order to meet the United Nation's Sustainable Development Goals. When designing a development approach, it will be important to frame the issue of sea level rise as an opportunity instead of a threat. Much like civilizations before our time, resiliency stems from adapting to conditions rather than working against them. How can we seed solutions for long term benefit? Designers, developers, government officials and community members must decide on a set of best values and goals in order to find the best solution. The goals should find solutions that solve multiple problems at once that also minimize the negative outcomes of the coming threats.

What are the current trends in innovative solutions?

Designers today are beginning to think in a new way about coastal development. Strategies such as floating developments, managed retreats, and floodable developments are starting to enter into the conversation about resiliency. Floating developments have become popular in residential communities in the Netherland and Dubai. The advantages of this method are that they are instantaneously adaptable to the current conditions. However, they provide no protection for surrounding development and they cannot withstand strong winds, rough waves, or tsunamis. Servicing these floating structures with drinking water and sanitation is also a challenge. It should be noted that this concept has not yet been

tested in dense environments and could encourage growth in water areas where jobs, transit, and other services are not in proximity.

Floating Multi-family Housing in the Netherlands

Source: Lauren Gilmartin

Floodable developments have also received some attention in recent years. Floodable parking garages in Rotterdam and contoured parks in Seattle, Portland, and London have started to appear in communities. However, this method has not been tested in sea-level rise conditions, only storm surges. Other disadvantages include the storage of contaminated, stagnant storm water runoff in ponds that may be slow to seep into groundwater or be pumped out by mechanical methods.

Finally, managed retreat zones have become another option for sea level rise mitigation. This strategy proposes removing settlement from encroaching shorelines –

including moving, demolishing, and relocating people and buildings, implementing strict setback laws, and implementing incentives for developing outside of dangerous zones. This may be the most controversial method because it involves relocation of people and community abandonment. Nevertheless, it is the single method that minimizes human suffering and is less expensive than armoring coastlines.[42]

Despite the options between tradition and non-conventional methods, designers should approach development that applies the "no-regret" strategy. This method refers to innovations that would have societal, economic, and environmental benefits even if the extent of climate change disaster turns out to be less than expected.[43]

[42] Tam, Laura. "Strategies for Managing Sea Level Rise." *SPUR*, The Urbanist, 9 Mar. 2016, www.spur.org/publications/urbanist-article/2009-11-01/strategies-managing-sea-level-rise.

[43] "Coping with Rising Sea Levels." *World Ocean Review*, 2017, worldoceanreview.com/en/wor-5/improving-coastal-protection/coping-with-rising-sea-levels/.

Chapter 5: Jakarta Part I -- City Underwater

Coastal megacities in Asia are facing serious impacts of climate change including flooding, sea level rise, intensified storms, large loss of life and infrastructure, as well as damage to the national and global economy. Of the many countries threatened by climate change disasters, Indonesia may be the most threatened by the effects of sea level rise. Jakarta, its capital city, is believed to be the most vulnerable coastal city in the world. Due to its low-lying topography, vulnerability to urban floods, and growing sinking issues, some believe the city has two to three years left to act before it is too late to save Jakarta. Despite global awareness of this issue, Indonesia has done little at a regional or city level to combat this threat. The great urgency surrounding this danger is very serious and waiting to act could have devastating impacts on the citizens of Jakarta, its local ecosystem, and the global economy.

History of Jakarta

Indonesia, the world's largest island country, consists of over 17,000 islands and has a long withstanding history of "living" with water through rice field farming and innovative irrigation techniques, fish farming, and maritime trade. With 261

million total people, it is the fourth most populated country in the world with hundreds of distinct ethnic and linguistic groups. [44] [45]

Fishing Boats Docked in Jakarta Bay

Source: Mike. “Sunda Kelapa: Sights around Jakarta, Indonesia's capital city.” 22 August 2016. *Flickr*.

Jakarta is Indonesia’s largest city and belongs to its own special administrative system of government. Located on an estuary of the Ciliwung River, Jakarta sits on the northern coast of northwest Java Island. Thirteen rivers flow through the 660-square kilometer city – home to nearly 30 million people in “Greater Jakarta.”[46]

[44] "Data Jumlah Penduduk DKI Jakarta". *Jakarta Open Data*. Pemerintah Provinsi DKI Jakarta, Dinas Kependudukan dan Catatan Sipil. 2014. Retrieved 5 December 2015.
[45] Waworoentoe, Willem Johan. "Jakarta." Encyclopædia Britannica. January 29, 2019. Accessed April 28, 2019. https://www.britannica.com/place/Jakarta.
[46] Indonesia: Java. "Regencies, Cities and Districts – Population Statistics, Charts and Map". *www.citypopulation.de*.

Jakarta has long sustained human settlement and dates back to the 4th century B.C.E. when it was primarily a Hindu settlement and port. Owing its existence to its geography and waterfront, Jakarta has been a subject of foreign influence for centuries. The city has been sequentially claimed by the Indianized Kingdom of Tarumanegara, the Hindu Kingdom of Sunda, and the Muslim Sultanate of Banten before Dutch settlers seized control and established the Batavia Dutch East India Company (VOC) trading post in Northern Jakarta as capital of the East Indies territories. It was briefly taken over by the Empire of Japan in World War II before Indonesia finally claimed its independence from the Dutch in 1945. Jakarta has existed as the capital city ever since. [47] [48]

Sketch of Jakarta Bay Prior to Colonial Rule

Source: "Jayakarta circa 1605-8." *Wikipedia*.

[47] Beranda. "Portal Resmi Pemerintah Provinsi DKI Jakarta." Accessed April 28, 2019. https://jakarta.go.di/.

[48] Drakeley S. *The History of Indonesia*. Greenwood, 2005. ISBN 9780313331145

Development in Jakarta Under the Colonization by the Dutch East India Company

Source: "Ville de Batavia c1780." *Wikipedia.*

Jakarta Skyline from Bund

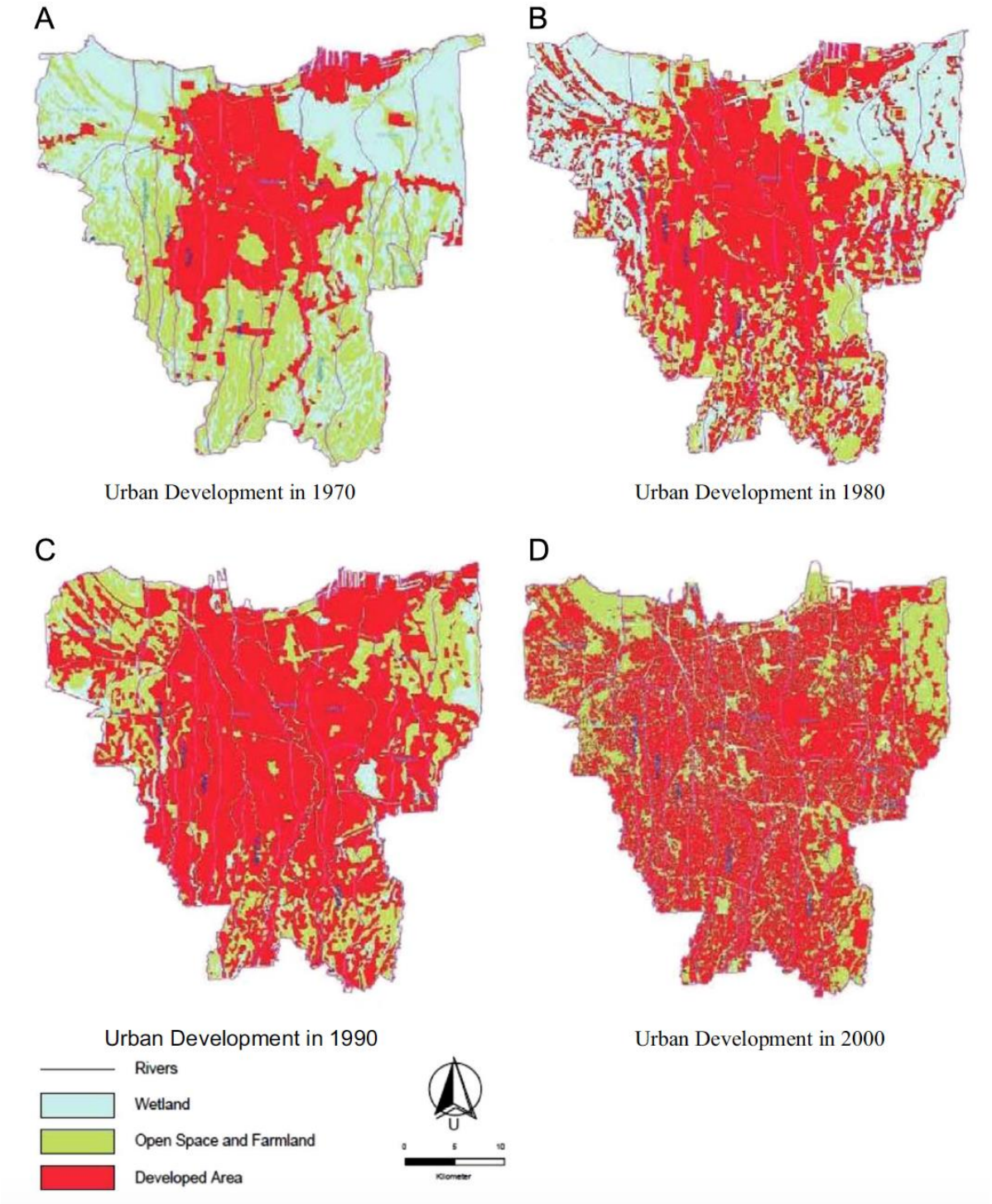
Source: Rizky Maharani. "Bahasa Indonesia." 24 September 2018. Google.

Because of its fluctuating influences over centuries, development within the city is an interesting patchwork of different foreign influences, socioeconomic classes, and urban development. As it exists today, Jakarta is split into different regions: North, South, East, West, and Central Jakarta. Prior to the takeover from the Dutch East India Company, Jakarta existed as a rural port city that traded valuable Sumatra spices, such as pepper. Since its colonization, Jakarta has gone through three major stages of development. Starting in 1595, the Dutch East India Company occupied Jakarta and developed what is known as the "Old City" in Northern Jakarta. The second development of Jakarta, known as the "new city" in the southern region, developed between 1809 and 1942 after the Netherlands took control over Batavia from the failed Dutch India Trading company. The third stage of development occurred post-colonialization after the Dutch left Jakarta. [49] Expulsion of the Dutch after 1950 caused tremendous social change in this city. In 1952, more than 90% of the city's population were Dutch. By the end of the 1960's most Dutch expatriates had evacuated Jakarta, leaving the opportunity for a massive migration of rural Indonesians to migrate to Jakarta with the promise of renewed economic opportunity.

Jakarta has enjoyed tremendous growth since its independence in 1945 and today is a bustling city with one of the highest urban densities in the world. It has undergone extremely rapid urban expansion in an impressive 74 years. In 1955 the city's population growth boomed at 35.8% and rapid urbanization has continued today. According to a study conducted by Waleed Alzamil, between 1970 and 2000,

[49] Merrillees, Scott (2015). *Jakarta: Portraits of a Capital 1950-1980*. Jakarta: Equinox Publishing. ISBN 9786028397308.

The Evolution of Development in Jakarta over a 30 Year Period



Source: Waleed Alzamil. "The Stages of Urban Development in Jakarta." 2017. *Data in Brief.*

the city's urban expansion stretched from roughly 25% to 90% in thirty years. However, rapid expansion comes with serious consequences. After liberation from Dutch rule, Jakarta's boom in population rapidly outpaced its capacity. The massive urbanization of Jakarta resulted in a shortage of land supply and high land prices which ultimately accounts for the loss of 25% of agricultural land uses being converted into commercial or residential uses to meet the population demand.[50] These valuable land areas acted as water absorption sinks and are now largely exist as impermeable surfaces.

National Museum of Indonesia in Jakarta: Recognizable Influences of Colonial Rule

Source: "7 Museum Bersejarah di Indonesia Yang Wajib Dikunjungi!." 3 August 2016. *Google.*

[50] Alzamil, Waleed. "The urban features of informal settlements in Jakarta, Indonesia." *Data in Brief* 15 (17 October 2017): 993-999. doi:10.1016.j.dib.2017.10.049.

Additionally, housing shortages, lack of community resources, and insufficient infrastructure to absorb the population boom at this time resulted in a high concentration of *kampungs,* or slums, in Jakarta and still make up about 25% of the city today.[51] Rapid urbanization has become a serious problem in Jakarta. Compounding this issue is Jakarta's susceptibility to natural disasters and climate change effects. Due to its geography, topography, and development patterns, Jakarta has become the most vulnerable city to sea level rise, urban flooding, and climate change in the developing world.

Overcrowded Kampungs Along Jakarta's Rivers

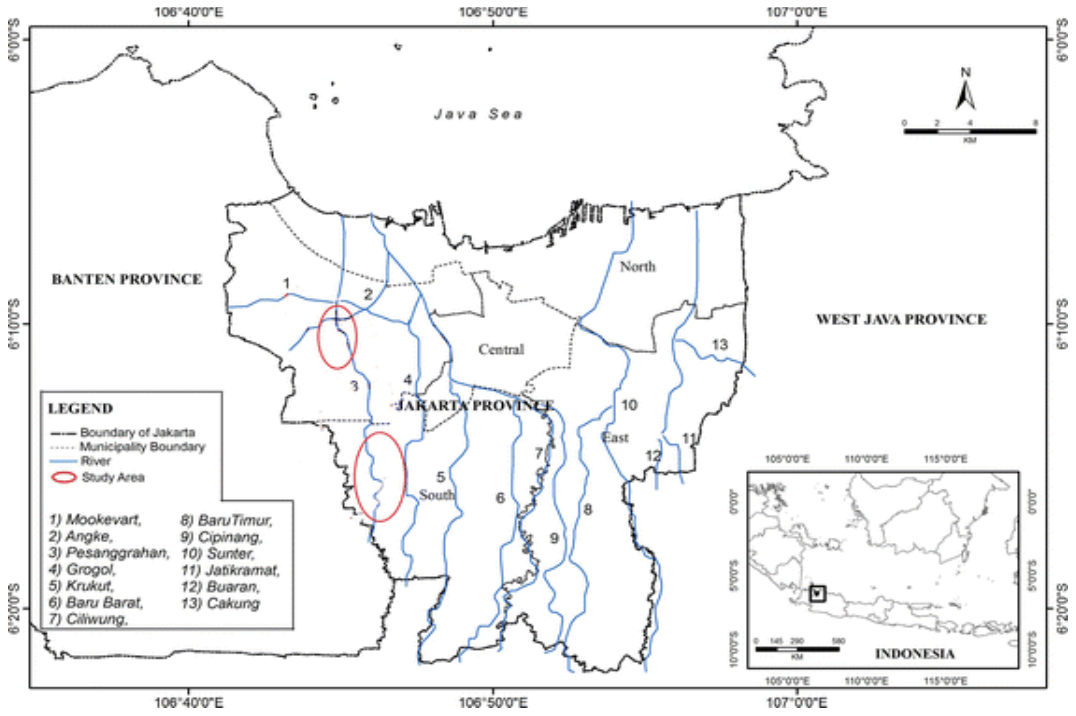
Source: World Bank Photo Collection. "Rehabilitating Jakarta's waterways to mitigate flood risk." 21 May 2013. *Flickr.*

[51] Simarmata, Hendricus Andy. Zhu, Jieming. "Formal land rights versus informal land rights: Governance for sustainable urbanization in the Jakarta metropolitan region, Indonesia." *Land Use Policy* 43 (2015) 63-73. Doi:10.1016/j.landusepol.2014.10016.

Future Projections in Jakarta

While Indonesians have "lived" with water for hundreds of years, Jakarta, and other similar coastal cities in the tropic region of the globe, is highly susceptible to natural disasters, flooding and intense storm events. Not only is the city low-lying, it also consists of 13 river beds and numerous canals making the inland areas of the city vulnerable to flood. These factors contribute to the three largest threats of climate change impacts in Jakarta – urban floods patterns, permanent sea level rise, and sinking land mass. Changes and increased severity of these conditions will threaten the local population and urban development within the city. [52]

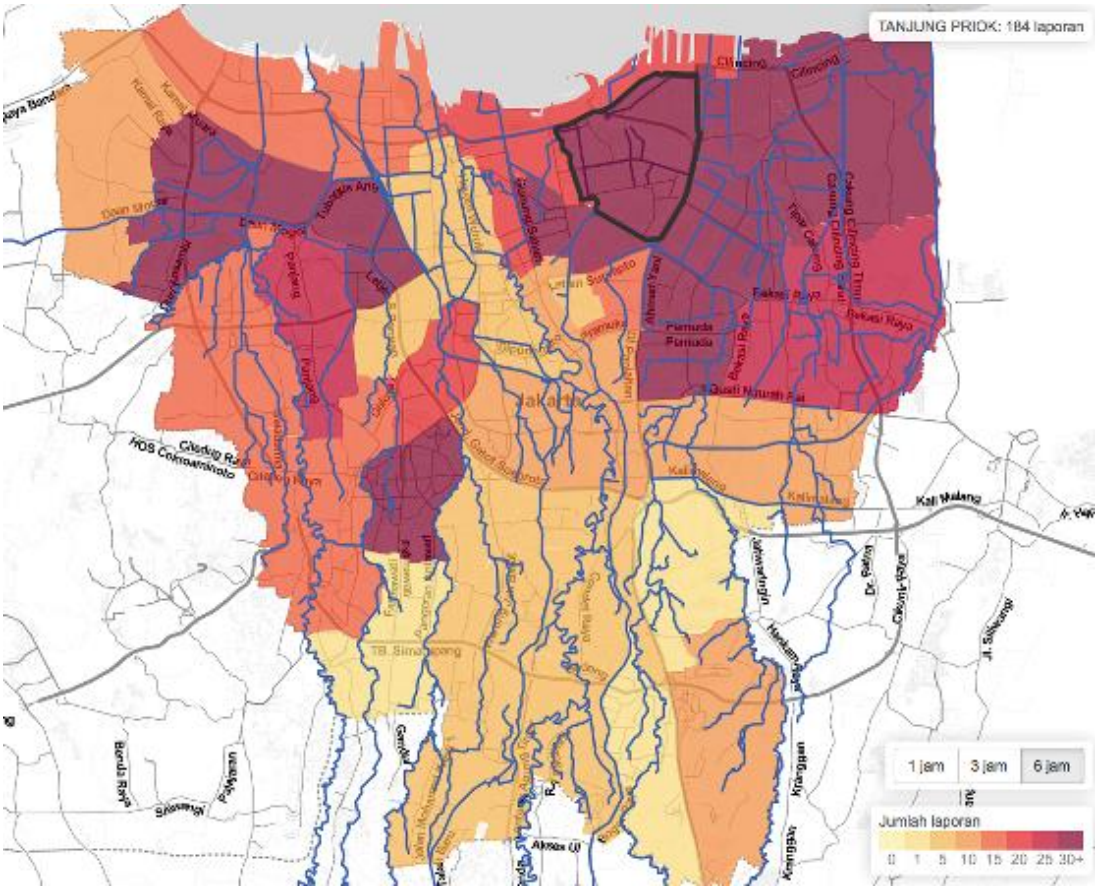
Hydrology Map Showing the Thirteen Rivers in Jakarta



Pini Wijayanti. Xuequn Zhu, Petra Hellegers, Yus Budiyono, Ekko C. van Ierland. "Estimation of river flood damages in Jakarta Indonesia." 20 December 2016. *Springer.*

[52] "Jakarta – Urban Challenges Overview – Human Cities Coalition". *www.humancities.co*. Retrieved 3 December 2017.

Map of Waterways and Vulnerabilities in Jakarta



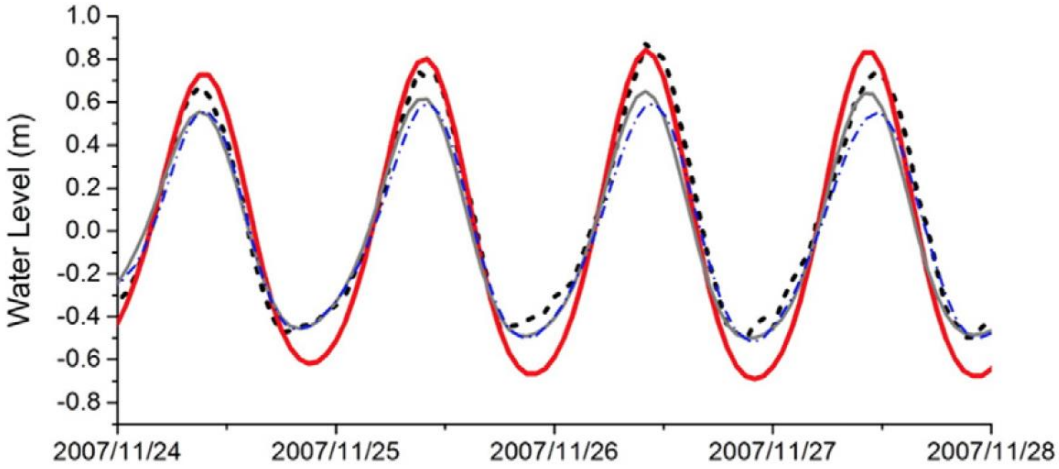
Source: Peta Jakarta. www.petajakarta.org

Urban Flood Patterns

Jakarta is a city that undergoes daily and yearly water "events" that are normal for the low-lying coastal city. When considering the effect of water inundation in the city, it is important to note that Jakarta's oceanic tides fluctuate on average 1.2 meters to 2 meters *daily.* While this may not seem severe, when considering that 40% of the city is at least 0.5 meters below sea level, these tidal fluctuations become more

alarming.[53] Tidal patterns have become a part of daily life in Jakarta. Daily flooding impacts traffic patterns, daily land use, and even work schedules of residents in Jakarta -- especially in North and Central Jakarta where specific land areas flood throughout the day on a regular basis.

Observed Tidal Fluctuations at a Point in North Jakarta



Source: Hiroshi Takagi, Miguel Estaban, Takahito Mikami, Daisuke Fujii. "Projection of coastal floods in 2050 Jakarta." 2016. *Urban Climate.*

This extremely populated city also experiences monsoons on a yearly basis and usually suffers severe storms ever five years during *El Nino* years that cause urban flooding in every district of Jakarta. Looking at the period between 2005 and 2008 alone, 178 instances of floods were recorded between North, South, East, West and Central Jakarta. Similar to cities like Rotterdam and Venice, Jakarta's 13 rivers

[53] Estaban, Miguel. Fujii, Daisuke. Mikami, Takahio.Takagi, Hiroshi. "Projection of coastal floods in 2050 Jakarta." *Urban Climate* 17 (2016) 135-145. Doi:10.1016/j.uclim.2016.05.003

and many canals make even the inland region of Jakarta vulnerable to urban floods with very few places for Jakarta's 30 million people to retreat.

In a medium-range forecast of urban flood patterns in Jakarta, flooding from monsoons and extreme weather events are expected to increase in number and severity as global average temperature rises. Effects of increasing severity due to monsoons have already been observed. The most significant damages to Jakarta have happened relatively recently in 2002, 2007, and 2014. In 2002, flood inundated roughly one fifth of the city. The same also happened in 2007 and displaced 500,000 people -- both rich and poor – from North and Central Jakarta.[54]

It is also important to note that Jakarta is also extremely vulnerable to the influence of the 18.6-year lunar nodal period that causes long-term fluctuations in ocean tides that could be large enough to swallow large areas of land along Jakarta's north shore and riverbeds. The next two occurrences of this cycle are expected to occur between 2025-2027 and 2044-2046.[55]

Threats of Sea Level Rise

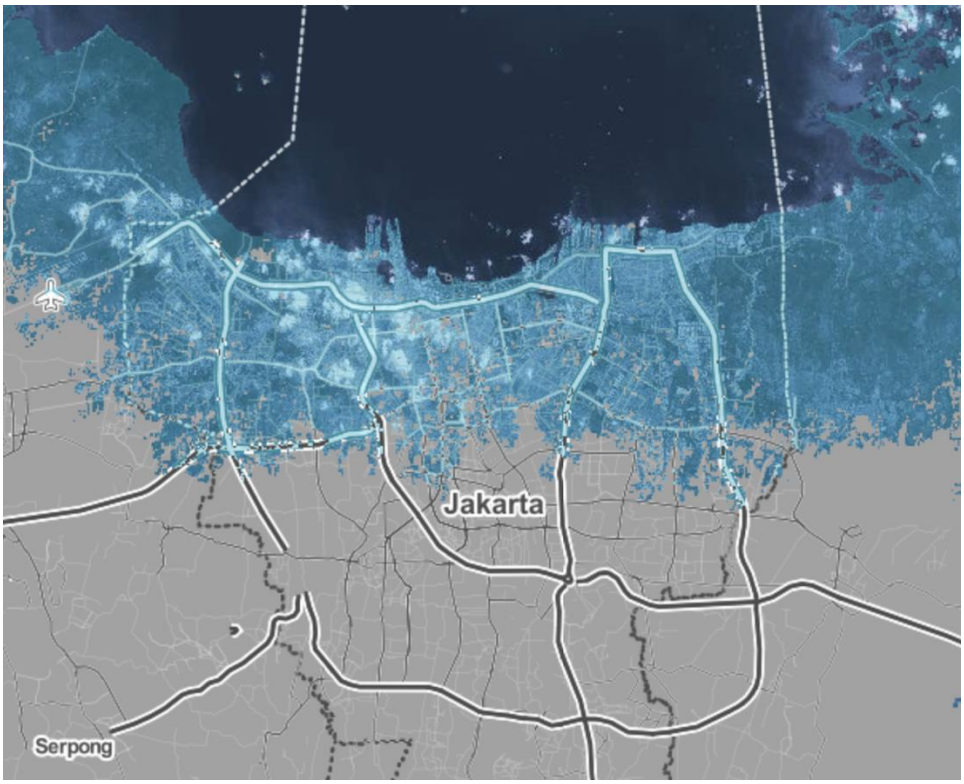
Even more distressing is Jakarta's fragility in the face of permanent sea level rise. Currently, sea level rise in Indonesia has been observed at a rate of 7 millimeters per year and is expected to reach at least 40 centimeters by 2050 if following a constant pattern of growth. This is large contrast to the global average 3.5 millimeters a year.

[54] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

[55] Estaban, Miguel. Fujii, Daisuke. Mikami, Takahio.Takagi, Hiroshi. "Projection of coastal floods in 2050 Jakarta." *Urban Climate* 17 (2016) 135-145. Doi:10.1016/j.uclim.2016.05.003

This highlights the effects of thermal expansion and further proving that climate change is experienced inequitably. *Projected Sea Level Rise in Jakarta with 4 Degree*

Projected Sea Level Rise in Jakarta



Source: Surging Seas. *"Mapping Choices." choices.climatecentral.org*

The Intergovernmental Panel on Climate Change has estimated a variety of future scenarios of temperature variability and projected effects for each setting. A two-degree Celsius change in global temperatures – a conservative estimate that could only be achieved by the most ambitious climate change action plans – could severely devastate North Jakarta and concentrated pockets of people inland by 2075. Consequences of sea level rise in Jakarta under this scenario could result in the displacement of nearly 10 million people. Even more alarming is a future global

average temperature four degrees Celsius higher than historic patterns. Estimates say one half of the total 660-square kilometers of Jakarta could be completely submerged under water along with the homes of more than 20 million people. Currently roughly 40% of the city already exists below sea level and is relying on short-term coastal infrastructure to hold back the tides. [56]

Sinking City

Just as alarming as intensified storms and the threats of sea level rise are the growing incidences of sinking land mass in Jakarta. This issue is the *most* urgent issue facing Jakarta. Nearly all of Jakarta is sinking – but not at a constant rate across the city. The average rate of land subsidence in Jakarta is 4 centimeters a year, whereas some parts of the city are sinking at 25 centimeters a year. To put it simply, Jakarta is sinking even faster than sea level is rising. Land subsidence in Jakarta will drastically exacerbate the issues of coastal sea level rise and severe weather events. Land subsidence is a problem faced by many other megacities throughout Asia. However, Jakarta appears to be the fastest sinking city in history in this region. [57] The consequences of uneven land subsidence are frightening. Besides the obvious threat of flooding, land subsidence will result in sinking structures that compromise the structural integrity of buildings, cause changes in river canal and drain flow systems, produce malfunctions in drainage systems, and increase inland sea water intrusion.

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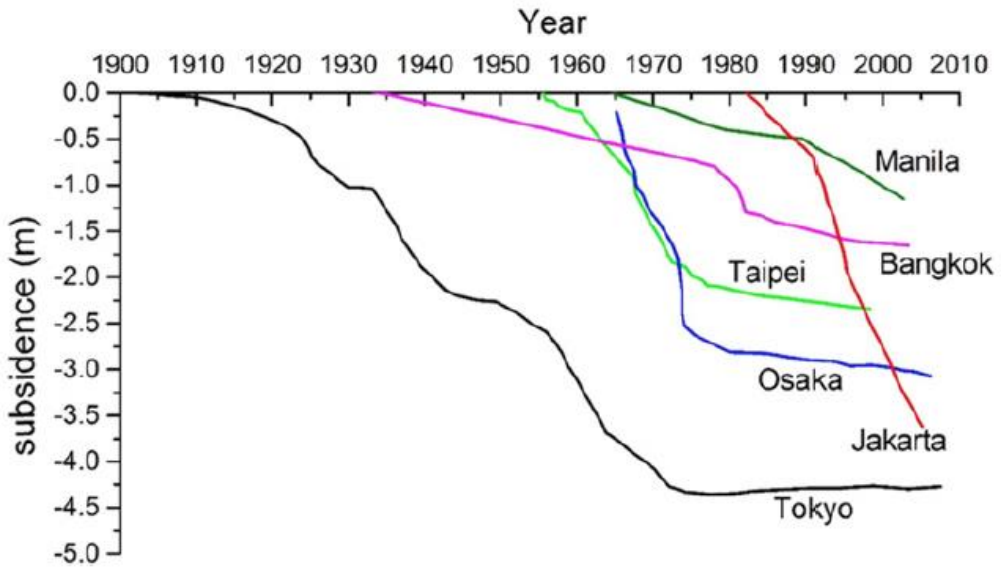
[56] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

[57] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

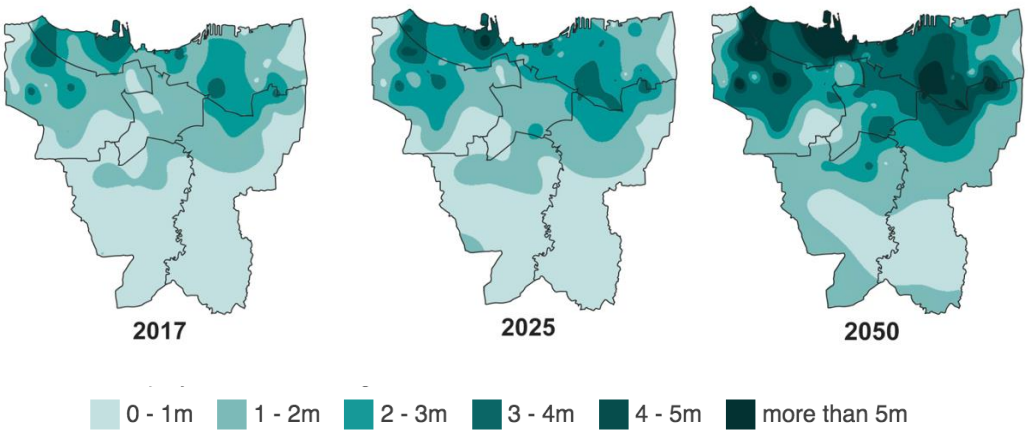
Land Subsidence in Asian Megacities Over Time



Hiroshi Takagi, Miguel Estaban, Takahito Mikami, Daisuke Fujii. "Projection of coastal floods in 2050 Jakarta." 2016. *Urban Climate.*

The evidence surrounding these three threats suggest that Jakarta is facing realistic threats to its city. In the short term, the most urgent threat to Jakarta is land subsidence. Sinking land masses are likely to exacerbate coastal and inland floods due to increased severity in storm surges over the next five to ten years. These physical shifts in the city would then be followed by the influence of sea level rise on a long-term basis. Despite these risks being highly temporal and dependent on human behavior, these three threats alone are enough to create crippling impacts on Jakarta and its people, environment, and economy.

Jakarta's Land Subsidence – Present and Projected



Source: Mayuri Mei Lin, Rafki Hidayat. "Jakarta, the fastest-sinking city in the world." *BBC Indonesian.*

Impacts from Inundation

Urban flooding in developing cities has very serious human, environmental, and economic consequences.

When considering the human impacts of these climate changes in Jakarta, there are clear public health concerns and obvious physical impacts due to increasing inundation, urban flooding, and sea level rise. Living in constantly wet environments and relentless water inundation creates a high probability of contracting water-related diseases such as acute respiratory infections, bronchial asthma, bronchitis, and eye and skin irritations.[58] Displacement of millions, damage to property and death due to

[58] [39] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

the inability to retreat from hazardous areas are important social factors of these three threats. The impacts of temporary flooding and sea level rise in the city have already

Children Play in Flood Waters after Torrential Rains in Kampung Melayu

Kate Lamb. "Children play in flood waters after torrential rains in Kampung Melayu, South Jakarta, Indonesia." 17 January 2013. *Voice of America: Monsoon Rains Flood Indonesian Capital.*

been observed and displaced hundreds of thousands of people. Damage to property and life will only multiply as time continues.

Irreversible damage to valuable ecosystems in Jakarta are also expected should sea levels rise. Delicate mangroves that support important ecosystem services for the city and local economies are threatened. Change in sea temperature and loss of habitats for the local fish populations will be destroyed. Loss of land, fresh water contamination, and sewage leaks are also expected.

This threat will also have lasting economic impacts, especially if immediate action is not taken and time and money is spent on post-disaster solutions. As an example, the city of Jakarta spent $872.12 million USD on clean up and recovery after the floods of 2007. Given that storms will intensify, land area affected will increase, and Jakarta will take a devastating hit to housing and economic prosperity, it is expected that it would cost $5.2 billion USD to resolve urban consequences of floods and sea level rise post-disaster.[59]

The impacts of climate change and flooding have already been revealed in the last 20 years. Despite the urgency surrounding this threat, Jakarta and the Indonesian government has done little to combat this urban danger. Reluctance or difficulty in implementing solutions reveals that there are likely specific barriers that are preventing sustainable development and long-lasting, effective solutions from being established.

[59] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

Chapter 6: Barriers to Development in Jakarta

Jakarta has very few years to implement solutions to urban flooding, sea level rise and land subsidence before it may be too late to save the city. So why is there little development so far? The answer lies in several factors that not only act as barriers for implementation, but also exacerbate Jakarta's vulnerability to disaster. These include complex, integrated issues surrounding government administration challenges, rapid urbanization, in-migration policies, land rights and use procedures, infrastructure needs, and socio-economic divisions in the city.

Capital Relocation

Perhaps the biggest barrier to development in Jakarta will be the relocation of the capital from Jakarta to another island in Indonesia. In April, the Government of Indonesia ruled that due to climate change effects and rapid urbanization, the capital will be moving out of Jakarta. An official date and location for this migration has not been announced, but the Government has declared it will be investing $36 billion dollars in developing a new capital city. The hope is that this move will attract development to other island in Jakarta, thus strengthening the economic stability of the country. However, this leaves an uncertain future for the city of Jakarta. Will out-migration occur? Will the city shrink in population? Will the government still invest in infrastructure to save the city? Answers to these questions are unknown. It is likely that Jakarta will experience a period of 5 – 10 years of transition while the capital moves, but what that transition will look like is unclear.

Governmental Barriers

A combination of lack of governing power, short governing cycles, and lack of attention to urban threats have poised as barriers to mitigation and resiliency development.

The city of Jakarta operates under its own special government with "special capital region" status. The provincial, autonomous government consists of five administrative cities and one administrative regency with the Jakarta Governor as the head of the governmental authority. Despite this, the government of Jakarta actually has very little governing and implementation power.[60] Added to this challenge is that officials may only serve five years which creates a challenge in making consistent, impactful change – especially if successive governors have competing political views.

There is also a lack of governmental institutions to handle development related to disaster management. While the City Government does have a Regional Development Planning Board, Disaster and Refugee Management Unit, and Board of Environmental Management, there is not an agency assigned to assess or oversee risk, manage data on climate and urban threats, or delegate information to the public or partnering committees. In recent years the government has created a subcommittee to establish flood zone maps and an emergency communication system but these efforts to combat urban flooding, sea level rise, and land subsidence have been mostly reactive rather than proactive. [61]

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[60] Simarmata, Hendricus Andy. Zhu, Jieming. "Formal land rights versus informal land rights: Governance for sustainable urbanization in the Jakarta metropolitan region, Indonesia." *Land Use Policy* 43 (2015) 63-73. Doi:10.1016/j.landusepol.2014.10016.q

[61] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

Land Use and Property Rights

Jakarta has a complex system of land use and property rights that also contribute to challenges in implementing meaningful infrastructure to protect the city.

Land Use

Land use regulation is important for controlling development in a city and internalizing externalities of certain land uses. Zoning regulation is relatively new in Jakarta. Modern development in the city boomed after the exit of the Dutch in 1945, and formal land use regulation did not begin until 2007, long after rapid urbanization had begun in the city. In the case of Jakarta, urbanization happened so quickly that without control over spatial planning, informality become the norm for development without regulation. Unfortunately, these occurrences compound the issues of poor governing over time because informal settlements and spatial mismatch seem to hamper the effectiveness of the state or local government to assert planning control. [62]Jakarta has since implemented a General Spatial Plan in 2007 that is updated every five to ten years. However, the Jakarta City Government has very little power or monetary means to enforce zoning regulations and has been explicitly absent from the implementation of township planning and management until 2017. [63]In this way, city planning in Jakarta has historically failed to perform its regulatory role over growth.

[62] Simarmata, Hendricus Andy. Zhu, Jieming. "Formal land rights versus informal land rights: Governance for sustainable urbanization in the Jakarta metropolitan region, Indonesia." *Land Use Policy* 43 (2015) 63-73. Doi:10.1016/j.landusepol.2014.10016.

[63] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

Jakarta's development is thus largely led by market and privatized land use planning which only serves the interests of wealthy land owners and not the whole.

Late-stage planning, lack of authority, and public endorsement of self-interest developers creates tough barriers to implementing any measures to comeback the crises of urban flooding, sea level rise and land subsidence. To its credit, in recent years the Jakarta City Planners have begun to collect, incorporate, and includes some data on flood, sinking, and inundation. However, it does not track climate vulnerability levels and does not detail information on public funding or commitment to climate change issues. As a result, Jakarta City Government tends to focus more on disaster management rather than managing integrated spatial development to deal with climate change.

Formal Property Rights vs. Informal Property Rights

There is also a complex issue of property rights in Jakarta that makes the process of spatial planning and development infinitely more complicated. Western colonization in Jakarta created a dual system of governance and property rights in the city. Only European quarters were serviced by infrastructure and property rights administration. The remaining lands owned and occupied by native Indonesians operated under *adat* law, or indigenous customary law. *Adat* law has two systems within it – *garapan,* or freehold use right, and *girik,* which operates similarly to a land lease. *Adat* law does not usually involve formal land titles or administration under a governing body. Subdivision is also easy to carry out with informal titles and can be sanctioned by a local village head. This makes proof of homeownership or

landownership problematic, and makes incessant land division uncontrollable, especially in a city with land scarcity and a high immigration rate.

Even 74 years after the end of colonial rule, this dual system is still intact and makes developing land complicated. 45% of all households in Jakarta claim land ownership under *adat* law. Of those 45%, only 31% have a registered land title. An added complication is that loans in Jakarta cannot be issued without a land title and lands operating under *adat* law are valued at only 80% of the land value of a property governed by Dutch law. [64] This makes it challenging for homeowners to make improvements on their property and discourages developers from improving these urban areas.[65]

The informal land rights that manage informal settlements are partly responsible for preventing municipal government from effective governance over urban land development. However, the governing body of Jakarta has failed to provide alternative affordable housing near places of employment for low-income citizens; therefore, *kampung* residents have no choice but to continue living in *kampungs* governed by *adat* law. Without an effective governing body in Jakarta's Planning Office, informal settlements will continue to multiply and spatial planning will be mostly handled by elite developers. Until Jakarta's Planning Office is able to solve the issue of dual land ownership systems and enforce its authority on planning,

[65] Simarmata, Hendricus Andy. Zhu, Jieming. "Formal land rights versus informal land rights: Governance for sustainable urbanization in the Jakarta metropolitan region, Indonesia." *Land Use Policy* 43 (2015) 63-73. Doi:10.1016/j.landusepol.2014.10016.

the city will be blocked from implementing widespread development that saves Jakarta from flood risk, sea level rise, and land subsidence.

Rapid Urbanization, Infrastructure, Migration Policies

Rapid Urbanization

Rapid in-migration of rural Indonesians seeking economic opportunity has led to a total population of more than 30 million people in the urban agglomeration of Jakarta. Due to the fast-paced growth rate, the city's population has quickly outpaced the capacity of its infrastructure.[66] Today only 30% of the city is serviced by municipal water and only 2.8% of waste is treated. Power distribution from nonrenewable resources is ubiquitous for luxury developments – but 60% of the city still lives in *kampungs* or low-income neighborhoods where these resources are not accessible.

Rapid urbanization and poor infrastructure have served as both barriers for development and worsened the negative effects that the city is experiencing throughout Jakarta. Poor waste management has greatly polluted the city. Not only is there not a formal trash service in Jakarta, but citizens are not properly educated about pollution and recycling. As a result, sewage, trash and toxic chemicals end up in the city's waterways. [67]

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[66] Kusumawijaya, Marco. "Jakarta at 30 million: my city is choking and sinkng – it need a new Plan B." *The Guardian* 21 November 2016.

[67] Simarmata, Hendricus Andy. Zhu, Jieming. "Formal land rights versus informal land rights: Governance for sustainable urbanization in the Jakarta metropolitan region, Indonesia." *Land Use Policy* 43 (2015) 63-73. Doi:10.1016/j.landusepol.2014.10016.

Infrastructure

Of the thirteen rivers running through Jakarta, only one is clean enough to drink. Lack of access to clean drinking water for all economic classes is considered to be the primary cause of severe land subsidence due to illegal groundwater pumping. It is estimated that more than 22.5 million cubic meters of water was extracted illegally from the ground in 2007 and the number has only increased. Due to land subsidence and uncontrolled extraction, North Jakarta has already observed contamination of its fresh water aquifers from salt water inundation. [68]

Informal Groundwater Pump

Source: Bay Ismoyo. "*Jakarta septic tank pumping businesses allegedly dumping waste into rivers*." Jakarta Post. 2019.

[68] Firman, Tommy. Idrose, Ichzar. Simarmata, Hendricus A. Surbakti, Indra M. "Potential climate-change related vulnerabilities in Jakarta: Challenges and current status." *Habitat International* 35 (2011) 372-378. Doi:10.1016.j.habitatint.2010.11.011

Housing

A troubling shortage in housing, poor land use regulation, and little governing power have forced rural-urban people to settle in informal settlements before the government has the ability to construct infrastructure especially in areas vulnerable to sea level rise and flooding. Due to lack of infrastructure these communities experience the effects of poor storm water management, and have poor access to water, sanitation management, and energy. Often, these settlements are built on top of riverbanks or in low-lying areas of the city that are not equipped with basic infrastructure and are not adequately equipped for a flood event or natural disaster.

Migration Policies

Mass urbanization in Jakarta has led to a strain on the city's capacity and infrastructure. Even under Dutch rule, governing bodies of Indonesia have sought to find solutions to Jakarta's overpopulation issue. Because the city has grown faster than the government has the power or money to keep up with problems related to rapid urbanization, Jakarta's City Government has enacted a dual policy "Transmigration Program" and "Return to Village" initiative to combat over population.

Started by the Dutch and continued today, Jakarta mostly relies on the Transmigration Program to manage the growth rate in Jakarta by making hopeful migrants apply to be a Jakarta resident. [69] Residents have to either own property or be employed in Jakarta to live there. Unfortunately, this program does not recognize

[69] Anata, Aris. "The Indonesian Crisis: A Human Development Perspective." *Institute of Southeast Asian Studies* 229-230.

adat law or employment in informal economies – meaning the law discriminates against mostly low-income people. This often results in forced eviction of people living in urban slums.

The "Return to Village" program is a secondary tool used by the government of Jakarta. In order to attract people to move out of the city, it subsidizes development and economic growth in other cities. The program is relatively new but has not shown much progress. Furthermore, it has been criticized for not investing that money in its own city.

Both of these policies address the problem of mass migration but they do not attack the underlying issue of poor infrastructure and access to resources. A disinvestment in urban infrastructure and development serves as a barrier to implementing solutions to climate disasters in Jakarta.

Planned Solutions and Failed Proposals

The government of Jakarta, private developers within the city, and urban residents agree that despite these barriers, something must be done to combat the threats of rapid urbanization and sea level rise. However there has been little progress make since 2007 to handle urban flood, land subsidence, and sea level rise thanks to a combination of financial restraints, a highly decentralized government, and lack of infrastructure. Two proposals – the National Capital Investment Project and the Socially Inclusive Climate Adaptation for Urban Revitalization Project have been put forward but both have made no progress towards implementation.

Its most ambitious plan, the National Capital Integrated Coastal Development Plan (NCICD), sought to solve the issues facing Jakarta today. In recent years, the city has

pushed for improvements under the Jakarta Spatial Plan 2030, Water Management Strategy 2030, and Climate Adaptation Road Map for 2030. These plans have strengths and weaknesses, but fail to gain input and perspective at the grassroots level of development, ultimately catering to the needs of the minority wealthy population rather than average Jakarta residents.

National Capital Integrated Coastal Development Plan

National Capital Integrated Coastal Development Plan Conceptual Design

Source: The National Capital Integrated Coastal Development Plan. Republik Indonesia.

The National Capital Integrated Coastal Development Plan is a $40 billion proposed master plan meant to rid the city of the threat of sea level rise in Jakarta. In

2013, the Jakarta government hired Dutch engineers from Witteveen+Bos to devise a master plan for development. The plan, a Public-Private Partnership backed by investment form countries like China and South Korea, proposed development for 650,000 people and employment for 350,000 people. This ambitious plan included reclamation of 1,080 hectares of land by dredging the ocean floor and finally installing a 32-kilometer sea wall around Jakarta. While the plan was proposed as a means to hold back sea level rise, the plan also proposed 52% of the development be for high-end housing and central business districts. Strangely, the engineers pointed out that this scheme would have "effects [that] will be negative as the current environmental system will change significantly." The sea wall proposed would also involve displacing kampung communities in North Jakarta and cutting off access to Jakarta Bay by construction of the sea wall which would impact local fishing and maritime economies.[70]

After approval of the master plan, residents of the city, especially North Jakarta residents, expressed their concerns with the NCICD proposal. An investigative Huffington Post article[71] published in 2016 incorporated interviews of residents and their insights about the proposed plan. Local fisherman were recorded as arguing that the dredging work had occupied traditional fishing grounds, destroyed the mangrove forests, and drove away the remaining fish in Jakarta bay. Community member in North Jakarta also complained about forced evictions, citing the Governor

[70] "Master Plan National Capital Integrated Coastal Development." Republik Indonesia. 23 May 2019.
[71] Sherwell, Philip (2016). "$40bn to save Jakarta: the story of the Great Garuda." Huffington Post. 23 May 2019. https://www.theguardian.com/cities/2016/nov/22/jakarta-great-garuda-seawall-sinking

as forcing North Jakarta kampung residents to leave the area without providing housing for them to go. One fisherman was quoted as saying:

"We're the ones who live and work here, but nobody is consulting us about our futures. The elite, the politicians and the rich, are making the decisions, but they don't care about us or understand us… If, instead, we can restore the bay and its polluted waters, that would mean something good for civilization in Indonesia. I believe that a new economy will come from that – in tourism, aquaculture and fisheries."

Implementation of the master plan was underway until 2017 when the government canceled the project due to backlash regarding the scheme's environmental consequences and negative impacts it would have on the existing community in North Jakarta. Today, two of the islands proposed have been constructed in Jakarta Bay but sit empty.

Socially Inclusive Climate Adaptation for Urban Revitalization

Since cancelation of the NCICD, Jakarta has proposed the Socially Inclusive Climate Adaptation for Urban Revitalization Project which includes creation of the Spatial Plan 2030, Jakarta Water Management Strategy 2030, and the Climate Adaptation Road Map for 2030. Key elements from these plans are protection from annual floods and construction of new apartment buildings for vulnerable communities in Jakarta. Since implementation the Government of Jakarta has constructed 14,201 new apartment units with an initial investment of $1.3 billion. However, so far this plan has been unsuccessful due to the management scheme of

the apartment complex and the displacement of residents more than a mile away from where they work.

Chapter 7: Rising Seas as Opportunity

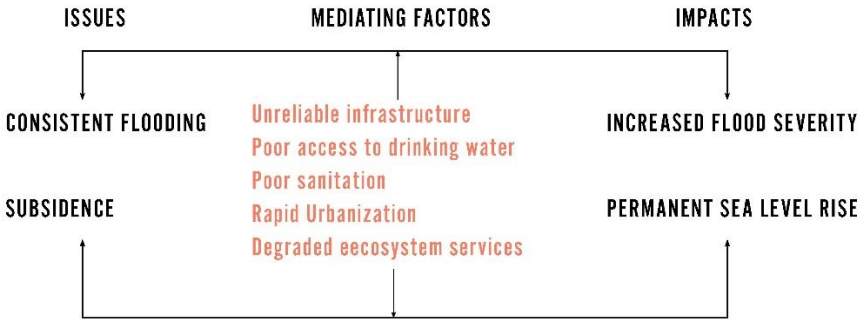
The consequences of climate change, sea level rise, and rapid urbanization are coming – especially in cities like Jakarta that are expected to feel the pain of these effects sooner than other cities globally. With flood predictions showing an increase in severity and frequency, certain inundation from sea level rise by 2050, and the capital moving, Jakarta is likely to experience a period of transition. The severity of the consequences of sea level rise require a combination of short-term, medium-term and long-term solutions. How can short-term solutions "seed" long term results? The answer is by proposing solutions that can serve multiple purposes simultaneously. In short, this thesis proposes planning and architectural solutions that can work together to halt subsidence, protect against flood and sea level rise, while also supplying water, sanitation services, and housing to communities in need. To demonstrate this repeatable solution, the proposal focuses specifically on the Sunda Kelapa community in North Jakarta.

Framing the Solution

The solutions to solving Jakarta's issues begin with understanding where and how it is possible to mitigate outcomes. Consistent flooding and rapid subsidence will ultimately lead to increased flood severity and permanent sea level rise. However, there are several mitigating factors that cause or could accelerate these impacts. These include unreliable infrastructure, poor access to drinking water, poor sanitation, rapid

urbanization, and degrading ecosystem services. Solutions that attack these factors can help to ease the effects of flood and halt the impacts of sea level rise.

Issues, Impacts, and Mediating Factors



Source: Lauren Gilmartin

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Opportunities

There are several opportunities available to Jakarta that not only solve the above mediating factors, but also allow for the opportunities to protect the city's historic core, improve access to people, goods and services, protect the city in a period of

transition, and ultimately limit suffering of those that could be displaced by flood and sea level rise. These opportunities include:

1. **The ability to implement infrastructure that protects important areas of the city, while also harnessing energy from flood and sea level rise by taking advantage of hydroelectric energy.** This renewable energy can be used to create fresh drinking water. Fresh drinking water halts subsidence by eliminating the need to pump from underground acquirers. Most importantly, the availability of fresh drinking water improves health and sanitation for the citizens of Jakarta. This infrastructure can be combined with "green" infrastructure methods that ease the effects of flood and perform further water purification through ecosystem services.
2. **Fresh water and energy resources, obtained sustainably, can be used to generate profit.** This opportunity improves the economic vitality of the city, and the money generated can be used to maintain the infrastructure. Using a profitable technology also opens the door for different opportunities in funding – both private investment and international loans. This incentive ensures the longevity of the proposed solutions.
3. **Making use of inundation from sea level rise by creating new waterways for transportation.** Allowing permanent inundation in areas that are unsafe for further development – such as flood plains or areas below future sea level – can open the opportunity for boat travel. Currently, canals and rivers in Jakarta are only used for stormwater drainage. Using these waterways as a

transportation asset can relieve traffic congestion, improve air pollution, and help to celebrate and bolster Jakarta's history as a maritime culture.

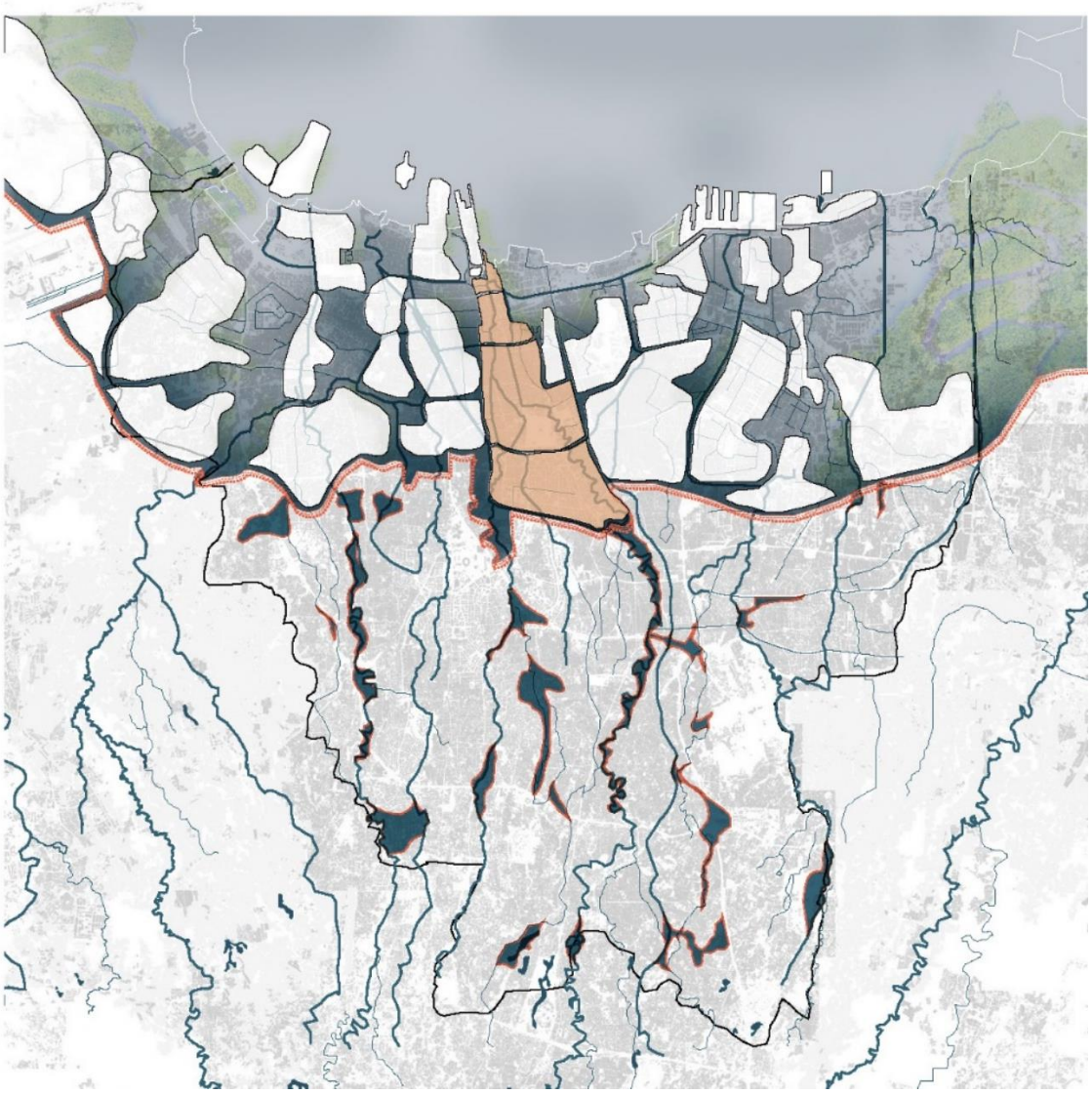
4. **Active retreat from flood plains and areas below sea level creates an opportunity to restore ecology.** North Jakarta was primarily a mangrove reserve before development in the 1970's. Restoring this landscape in strategic areas can naturally improve water quality, alleviate flood severity, and improves the local fishing economy of which most north Jakarta communities rely on for their livelihoods.

Possible Futures of Jakarta, 2075

To take advantage of these opportunities, it is important to plan the future of Jakarta's landscape in the long term. With the capital transitioning to Borneo island and Jakarta's residents left to respond to the threats of flood and sea level rise, it is likely that the city will need to actively retreat from some areas, and protect other areas using a combination of "gray" and "green" infrastructure. *Possible Future for Jakarta, 2075* demonstrates a possible future for Jakarta in which important zones are protected, such as the city's historic core (highlighted in orange), to create "islands" as water inundates the city over the next fifty years. Areas left for inundation would include zones that are frequently flooded, and the most severely subsided areas. Residents in these areas could be relocated to protected "islands" in nearby locations so that communities remain intact. These islands can adapt over time to adjust for changing circumstances. The "new edge" city creates the opportunity for restored mangroves and water transportation. Furthermore, these self-sufficient islands can double flood protection and sea level rise measures. If one area of infrastructure fails,

inundation will only affect the single island, rather than the entire city. These edge conditions, as seen in the map below, can be combined with community assets such as canal walks, boat docks, and shaded mangrove landscapes to not only protect these self-sufficient islands, but also create an amenity for the city.

Possible Future for Jakarta, 2075

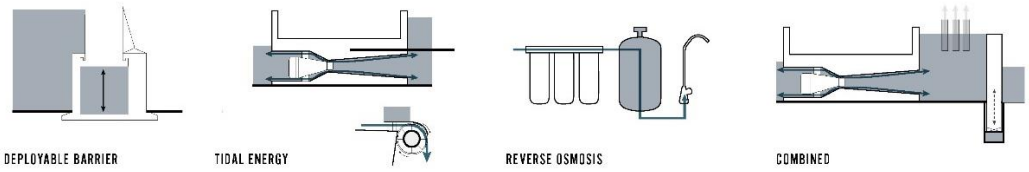


Source: Lauren Gilmartin

Threat to Opportunity

In order to reframe sea level rise as an opportunity, a combination of realized, technological solutions can be put into action to harness energy from flood and sea level rise, provide water to surrounding communities, and create protective barriers in time of emergency. These solutions include 1) a deployable flood barrier, 2) tidal energy using a turbine system, and 3) reverse osmosis water desalination.

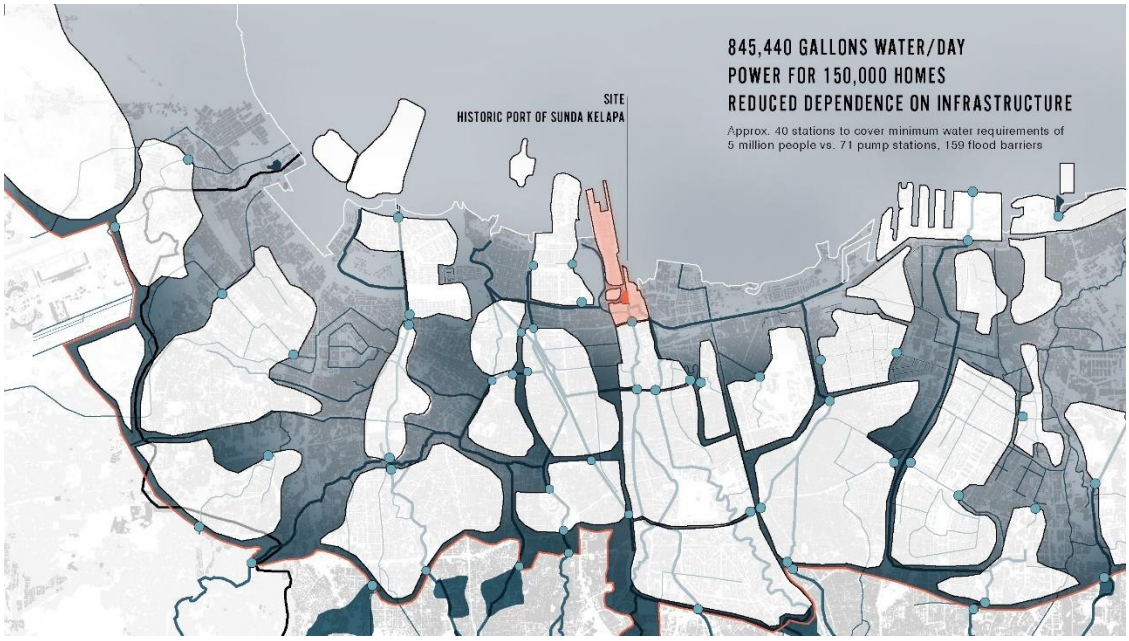
Technological Possibilities



Source: Lauren Gilmartin

The reverse osmosis system is a compact, “plug and play” system that can produce 105,680 gallons of water a day. Six of these systems can be used to produce enough water to serve 1.5 square miles of Northern Jakarta. These systems can be placed across the city using hydroelectric power from rivers and canals to produce enough energy to desalinate and disinfect river water. One site alone can provide 845,440 gallons of water per day and create enough power 150,000 homes. If these solutions are multiplied across the city, 40 “stations” can provide enough water for the 5 million residents in Jakarta who do not have access to water. Excess energy can be distributed to surrounding communities.

First Water Station Site and other Possible Locations



Source: Lauren Gilmartin

These solutions are easily deployable, proven to work in countries around the world, and can produce water cheaply with a four-year return on investment. To test this thesis, a historic site in Sunda Kelapa was used to demonstrate these technologies.

Sunda Kelapa

Sunda Kelapa, the historic port of Jakarta, was used for thousands of years for shipping and export of Jakarta's precious spices. It was used as the headquarters for the Dutch during the colonial era, and still today possesses the original spice warehouses. Presently, the port opens to direct access to Jakarta Bay, and connects south to the historic core of Jakarta.

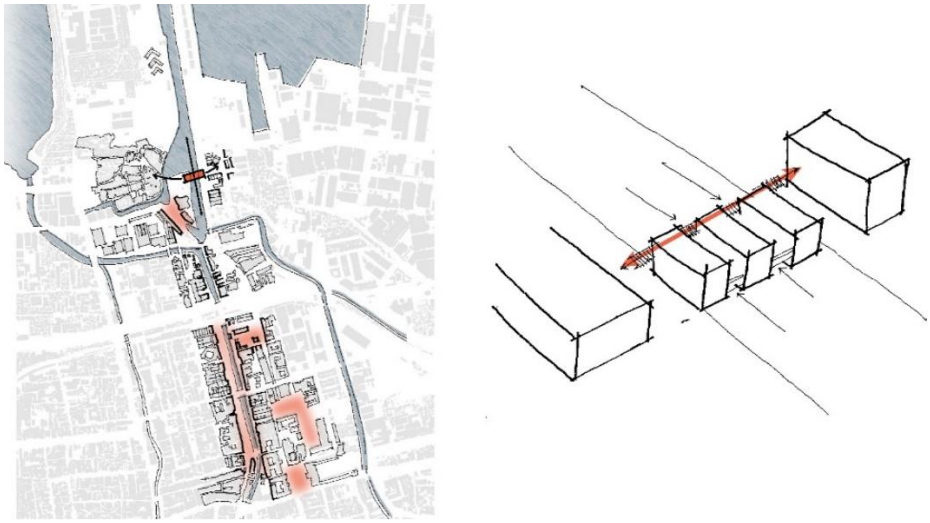
Historic Port of Jakarta and Thesis Site

Source: Undelay image from Google Earth

The community that exists to the west of the peninsula shown in *Historic Port of Jakarta and Thesis Site* works to the east of the peninsula in Sunda Kelapa's modern shipping port. Ease of access to their place of work is challenging and requires either a vehicle to reach the shipping port, or residents must climb an eight-foot sea wall, ride their boat across the harbor, and climb another sea wall to the other side of the port.

The conceptual design of the thesis acts as a "bridge" that spans the port to create better access to the peninsula and surrounding sites. The bridge creates a gateway condition that frames the historic core beyond. Massing for the building is made of four infrastructure bays that handle flood protection and house the reverse osmosis systems that supply water to surrounding residents. The flanking masses serve as a demonstration/teaching space, and a central distribution center for water and energy.

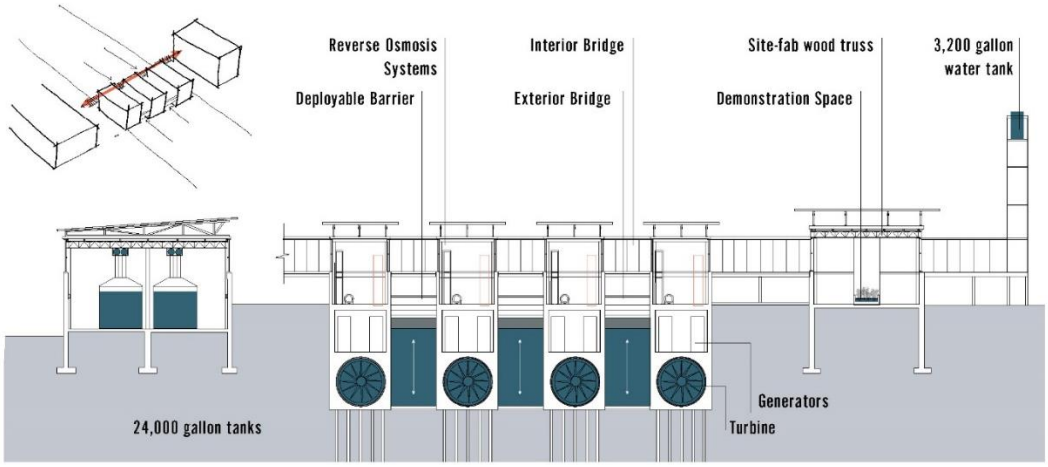
Conceptual Design



Source: Lauren Gilmartin

Detailed Conceptual Design below provides greater detail for the design. Each bay houses one turbine system, two reverse osmosis systems, and is connected to other bays by a deployable barrier that moves up and down with changing flood levels. The barriers can be lowered in low-risk events to allow small boats to pass through the "gateway." The bays are spanned by a pedestrian exterior bridge that can be used by local fisherman, and an upper service corridor that services the building. At the ends of the bridge exists the large distribution center that houses 24,000-gallon water tanks, meant to service trucks and boats for water distribution, and a symbolic water tower that services the community directly adjacent to it. This water tower creates the opportunity to make a public space outside of the water station for gathering.

Detailed Conceptual Design

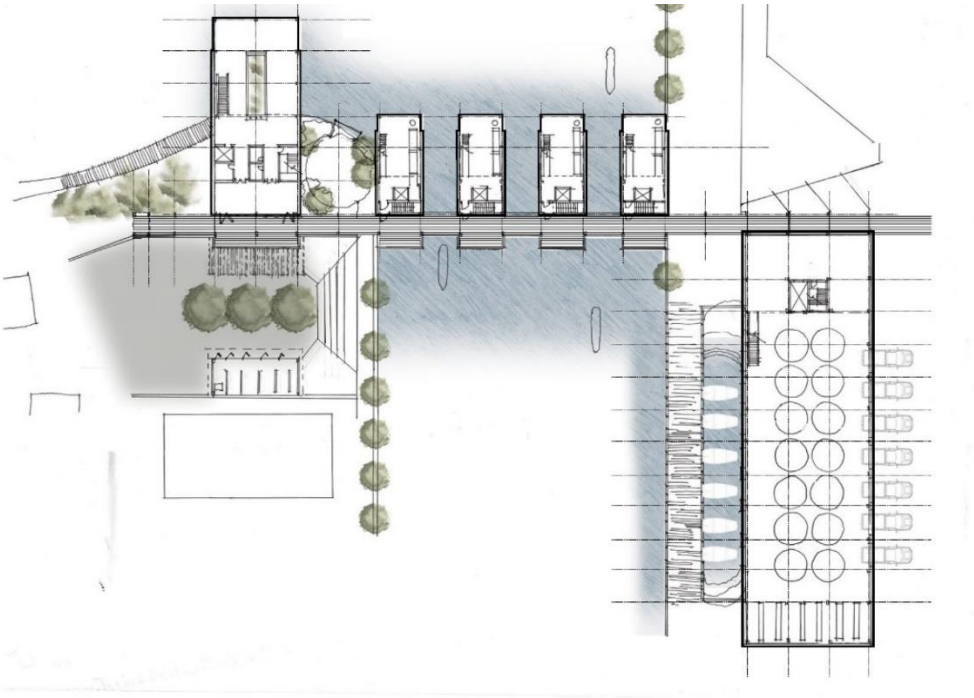


Source: Lauren Gilmartin

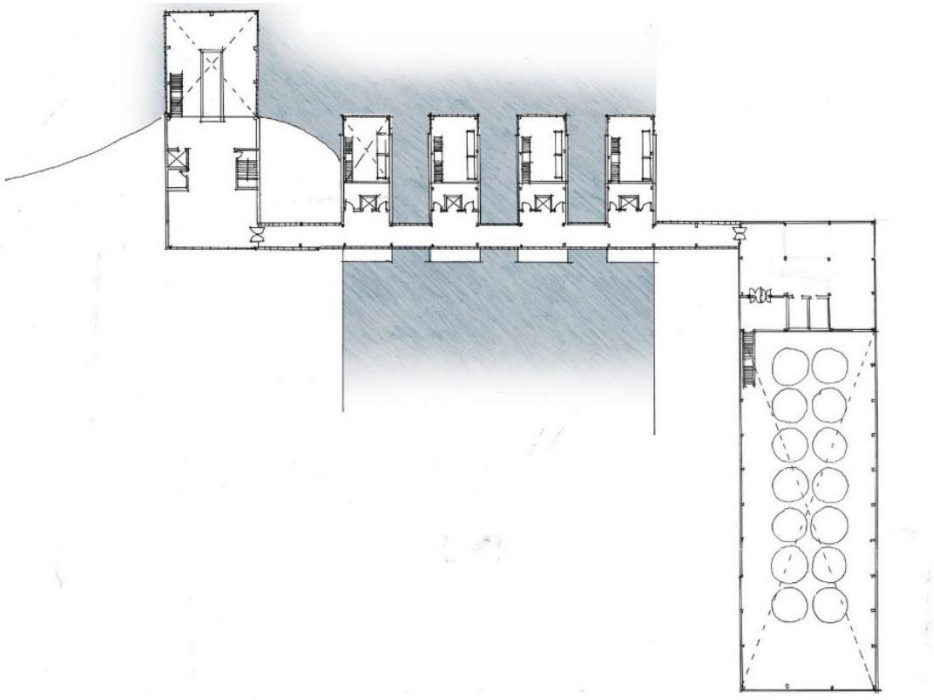
Gateway to the City

Source: Lauren Gilmartin

First Floor Plan



Second Floor Plan



Source: Lauren Gilmartin

Upon entering the building from the peninsula, one may transcend the amphitheater or ramp that opens to a large balcony overlooking a public space below. This public space serves as a water distribution pick-up point for daily deliveries. One can enter the building from the balcony and into a threshold space that can be opened for community events. This threshold space leads into a demonstration space where visitors can learn about the history of Sunda Kelapa, the challenges the city is facing, and the systems and technology that the building possesses to aide those challenges. Visitors can then transcend a staircase or take an elevator up to the second floor and walk along the service bridge that overlooks each water system "bay." Finally, visitors or service people may enter the main distribution center that houses 14 water storage tanks, mechanical and maintenance spaces, and main control room. From this space, boats and trucks can haul away daily water shipments. In the future, the building may be connected to water distribution infrastructure that can service surrounding communities.

Water Infrastructure, Bays, Systems, and Materiality

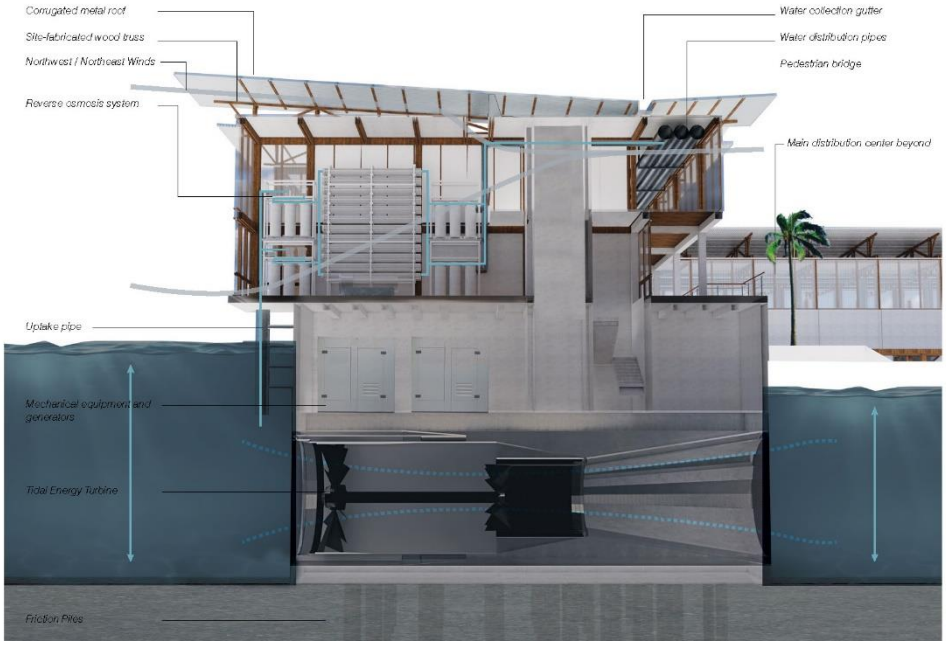
Infrastructure "Bay" below demonstrates a section through one of the four "infrastructure bays." Flood and sea level rise levels are managed by the turbine system that sits on the river floor and is anchored by friction piles. The housing for the generators and other mechanical equipment are placed in a concrete sealed floor directly above the turbine. These generators services the reverse osmosis systems above. Water is collected by rainwater collection or through an uptake pipe placed directly into the river. Water is fed into the reverse osmosis system and then distributed to central pipes that run along the ceiling of the service bridge. These

pipes lead to the large distribution space and to the single storage tank facing the adjacent community.

Demonstration Space

Source: Lauren Gilmartin

Infrastructure "Bay"

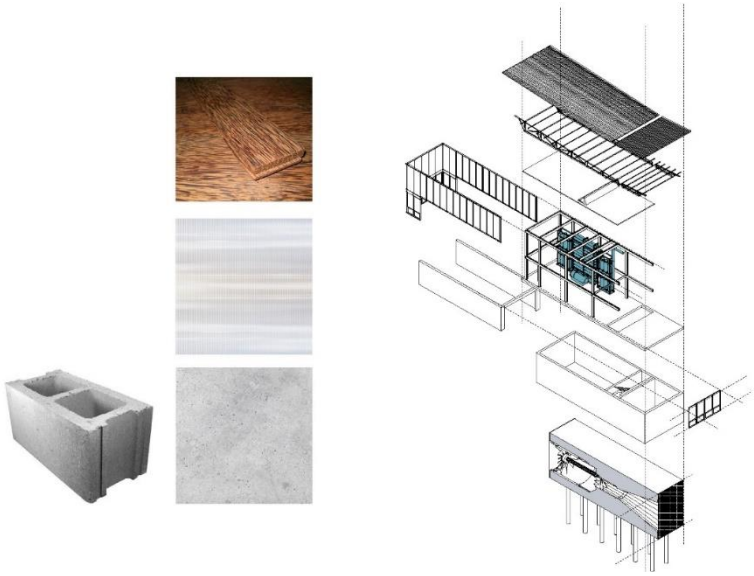


Source: Lauren Gilmartin

This space is naturally ventilated by taking advantage of strong northwest and northeast winds. The roofs on each bay are angled to the north and use fins to catch winds and direct them down into the space. The breeze is then captured and moves through the bay by opposite ventilation windows that move air through the bays and corridors.

The building is constructed of simple materials – Kayu Kelapa coconut wood, polycarbonate panels, and concrete and masonry CMU blocks. These materials are locally grown and produced and can be easily employed for construction. The bottom two levels housing the turbine and generators are constructed of concrete, and the remaining structure is comprised of post-and-beam structural system with a composite metal deck. Trusses are then used to support the north-facing corrugated metal roof. These materials and roof shape gesture to traditional forms of Indonesian architecture.

Materiality

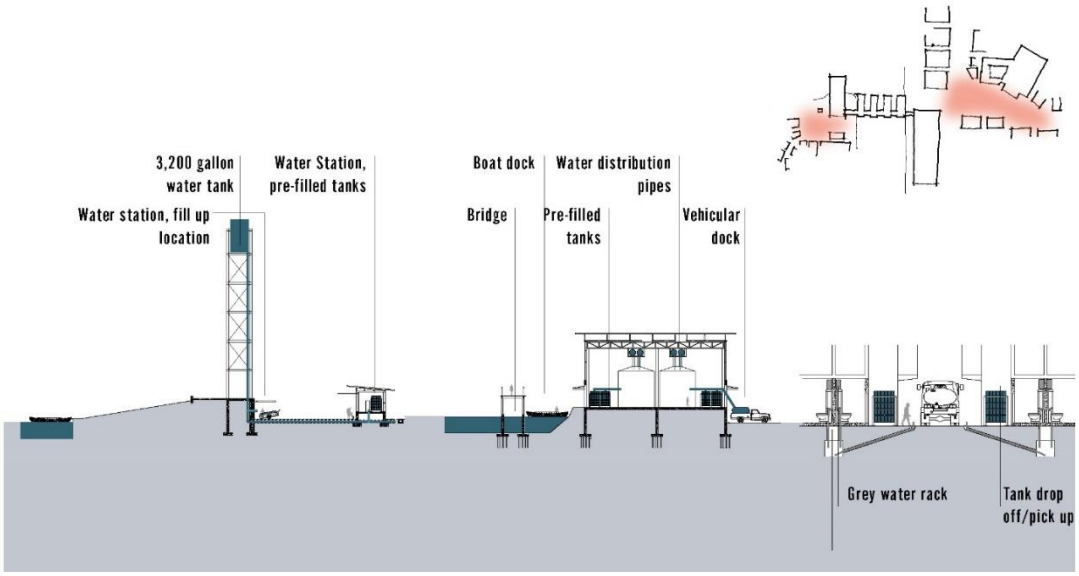


Source: Lauren Gilmartin

Making Place

This building can serve purposes beyond that of an infrastructure installation – it can also serve as a space for supporting community and making place. The design of this building creates the opportunity for two public spaces to open to the surrounding community.

Water Distribution



Source: Lauren Gilmartin

By creating this needed public space, daily water distribution from individuals with carts, boats, and small vehicles can happen smoothly in a shaded, comfortable space. People can sit and wait under shady trees or on the steps of the amphitheater looking over the courtyard activities. To the south of the water tower also exists a small pavilion for pre-filled tanks to speed up lines. This public space also allows for

other opportunities, such as pop-up markets for the sale of local goods, fish, and produce.

Public Space Outside of Water Station

Source: Lauren Gilmartin

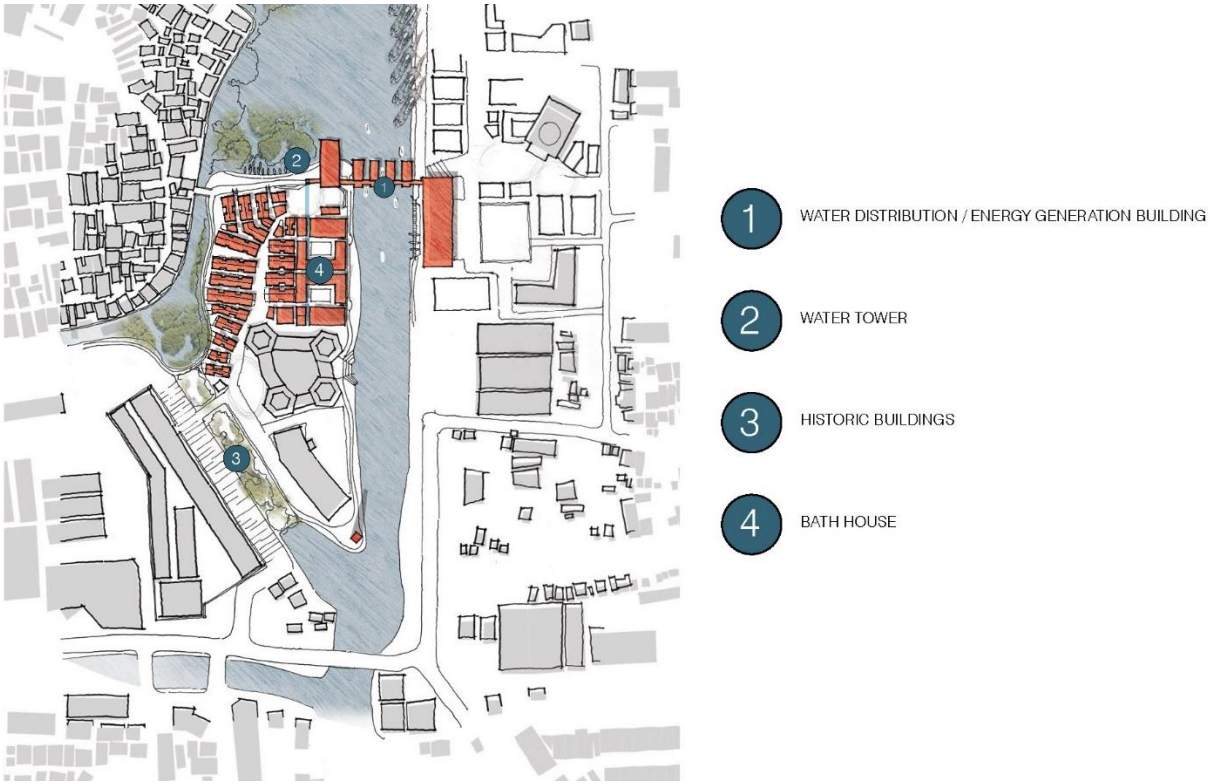
By "making place," this building goes beyond its purpose of flood mitigation, water production, and energy creation. It creates an opportunity for communities to engage with their neighbors, sell goods, and learn about the importance of the systems within this building.

Supporting Community

With the availability of fresh, drinkable water within the community emerges the opportunity for supporting other community needs. Lack of access to daily water makes everyday life in Jakarta for low-income residents extremely challenging – such

as cooking or bathing a child. Last year alone, the government of Indonesia spent $6.3 billion dollars dealing with the effects of poor health and sanitation. With this Water Station comes an opportunity to implement a community center and bath house to satisfy the daily needs of residents. This thesis proposes a bath house prototype that is serviced by the fresh water coming from the Water Station.

Sunda Kelapa Site Plan

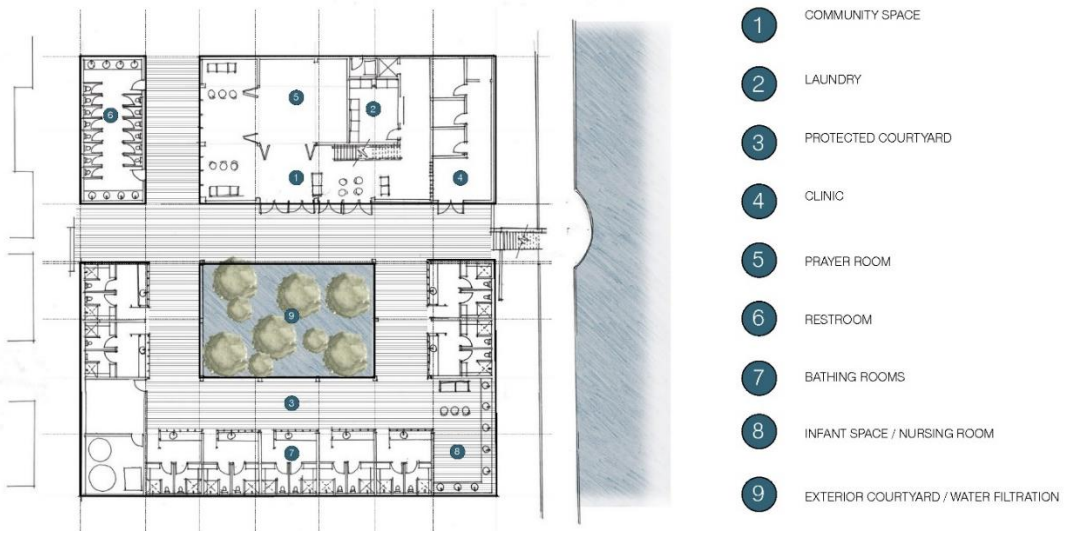


Source: Lauren Gilmartin

This thesis proposes the implementation of two bath houses – one male, one female, directly south of the Water Station at Sunda Kelapa. These bath houses provide enough facilities for 720 people daily. Each bath house is equipped with a community room that opens to a protected, shaded, courtyard space. Within the

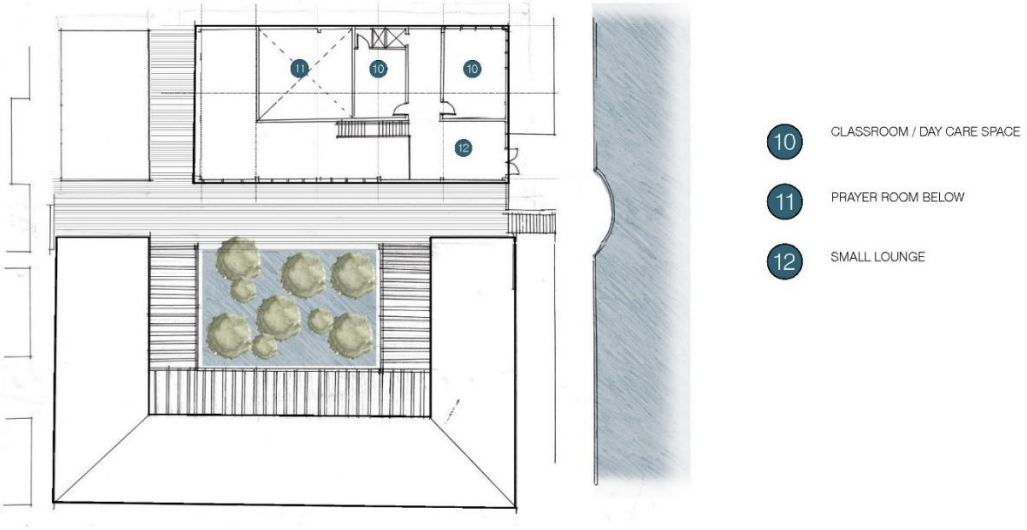
community building exists a prayer room, laundry facility, clinic, classrooms and daycare spaces upstairs. The exterior courtyard serves as a water filtration zone for treating rainwater. This water can then be returned to a gray water tank or released back into the river. Circumventing the courtyard is an addition restroom building and nine "family" bathing areas. Each bathing area consists of two large, enclosed rooms, each with a bench, changing area, shower and toilet. These coupled bathing rooms are superseded by a protected threshold space for temporarily holding personal belongings and providing a space for children and mothers to sit if needed. Finally, at the south east corner of the bath house complex is an infant area for nursing, washing, and changing infants and toddlers.

Sunda Kelapa Bath House First Floor



Source: Lauren Gilmartin

Sunda Kelapa Bath House Second Floor



Source: Lauren Gilmartin

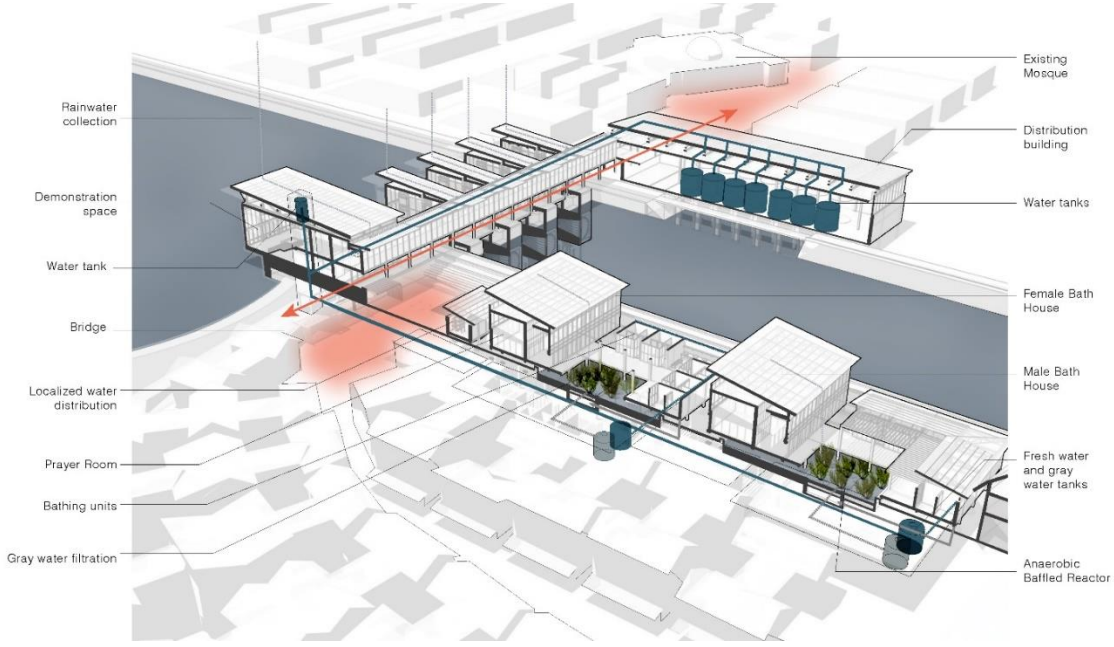
View from Bath House Courtyard

Source: Lauren Gilmartin

View from "Family Unit" Threshold

Source: Lauren Gilmartin

Water Systems at Sunda Kelapa



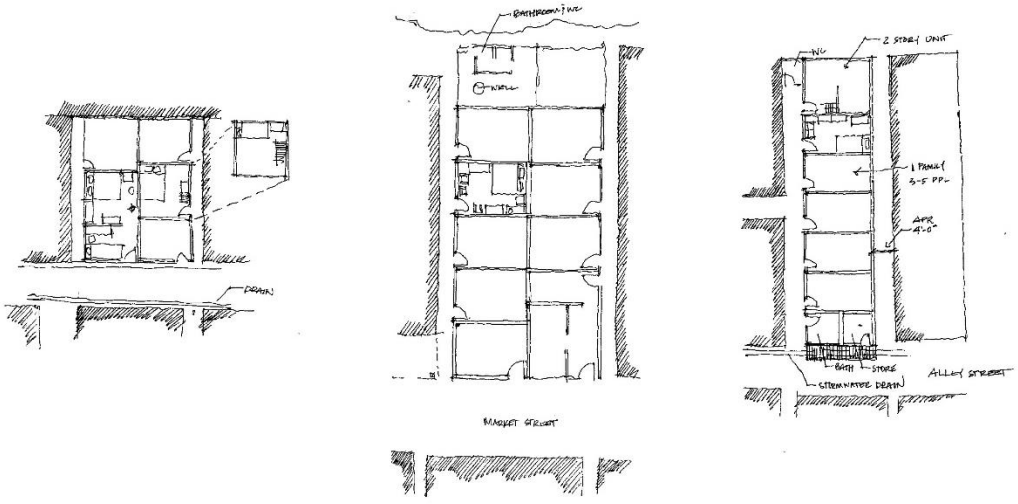
Source: Lauren Gilmartin

All toilets and gray water are flushed into an anaerobic baffled reactor septic tank that can treat waste and water. Excess water is pumped into the water treatment wetland and then returned to the gray water tank or river.

Housing Strategy

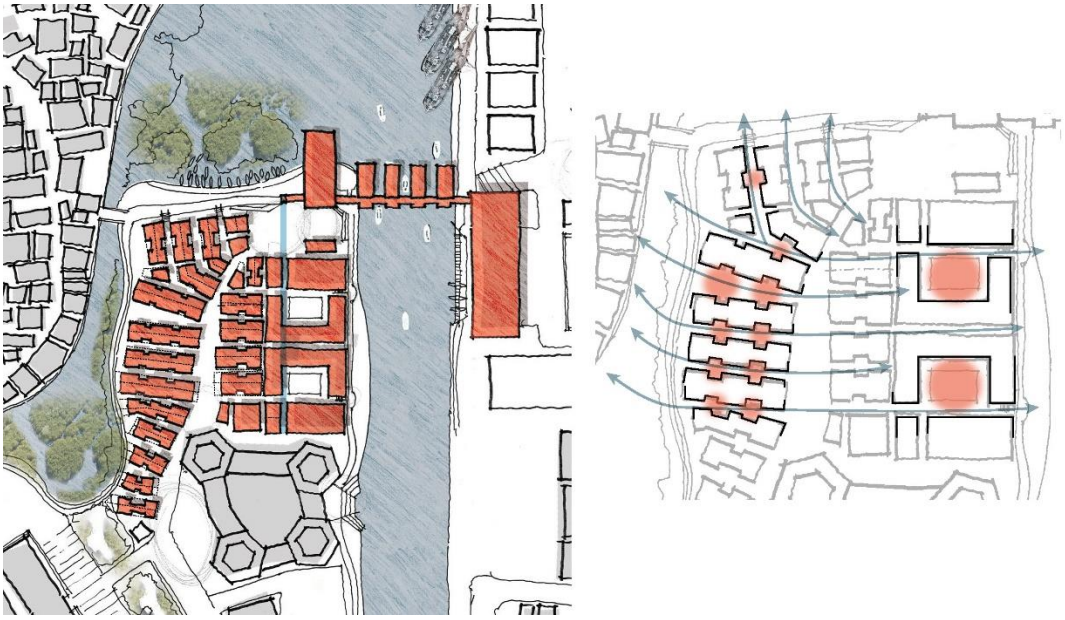
While fresh water and proper spaces for hygiene can drastically improve the quality of life of a community, resiliency cannot exist if housing conditions are still poor. The surrounding residents at Sunda Kelapa live in slum-like conditions where one room houses a family of four. Eating, cooking, changing, bathing, and sleeping all occur in one twelve-foot by ten-foot space. Blocks of homes share one toilet, which is usually a pit latrine that is rarely serviced. Houses are crammed together and access in eight-foot alleys where light and air are restricted from entering spaces.

Existing Housing Typology, North Jakarta



Source: Lauren Gilmartin

Community Site Plan Showing Courtyard Spaces



Source: Lauren Gilmartin

Modified Housing Typology

Source: Lauren Gilmartin

This thesis proposes a repeatable, adaptable adjustment to the typical Jakarta home typology by creating blocks of homes with courtyard spaces that allow light and air to penetrate the first-floor units. Each family begins with a two-room unit that

can grow over time to adapt to changing needs. Each block of homes also includes a toilet and shower room for times when it is inconvenient to use the local bath house. Finally, the party wall between the mirrored units can be built to be "plumbing wall ready" so as infrastructure is built over time, homes can be hooked up to water and sewage systems.

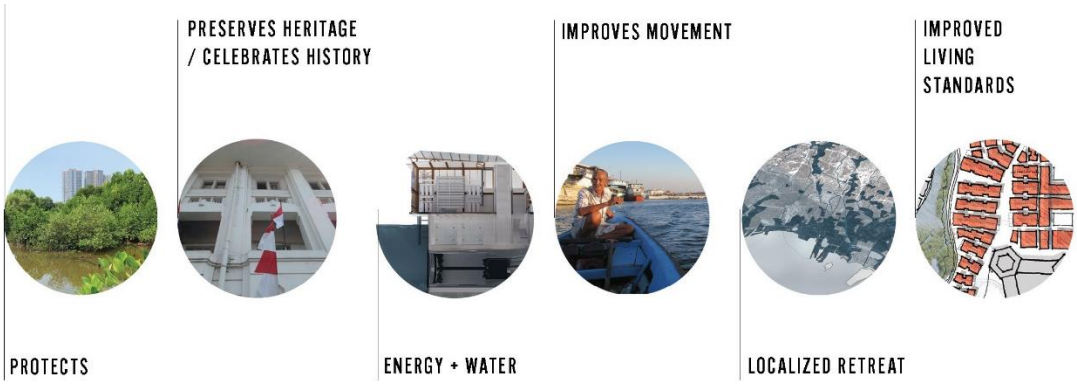
A mandated four-foot sidewalk on either side with a nine-foot alley down the middle ensures enough light and air can reach the courtyards, and a truck can drive through the site several times a year to service the showers and toilets. Outdoor stairs flank the sides to serve the upper units.

By multiplying these units across a community, residents can live in better housing conditions that can adapt and grow into the future. Furthermore, the courtyard spaces between each block provide more gathering zones and semi-private spaces.

Conclusion

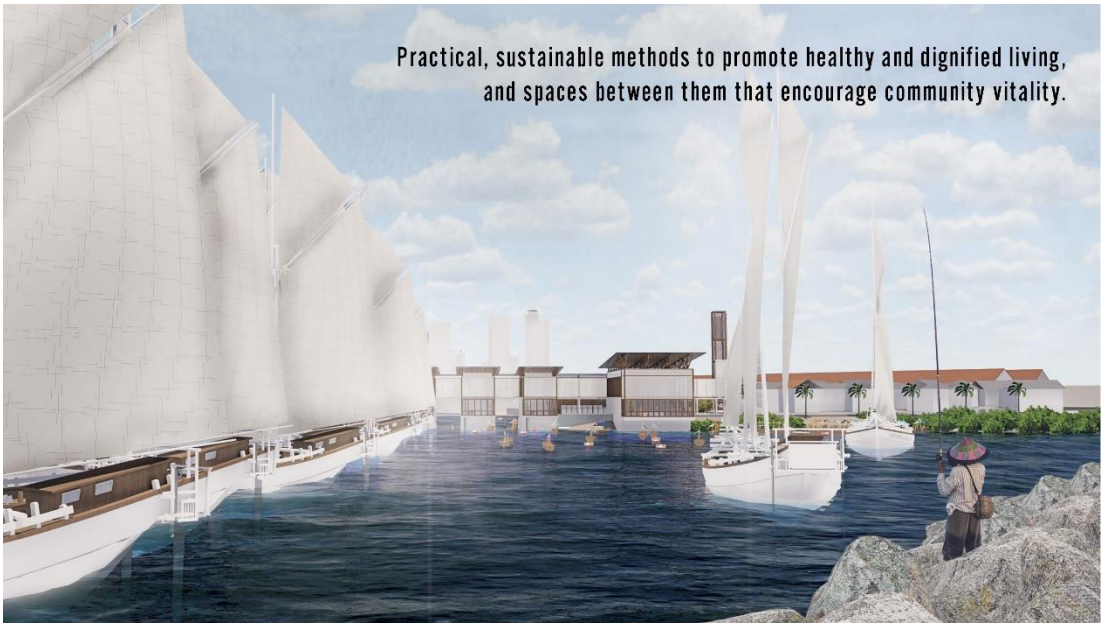
In conclusion, this proposal provides a realistic solution for protecting the city of Jakarta, preserving its cultural heritage, and celebrating its rich history, while also providing energy, water and improved living standards within a "localized" retreat strategy in which communities can remain intact. These solutions help to slow the projected outcomes of sea level rise and flood in Jakarta caused by water insecurity, poor sanitation, inadequate housing, and more. These practical, sustainable methods promote healthy and dignified living, with spaces between them that encourage community vitality.

Impacts of Suggested Strategies in Jakarta



Source: Lauren Gilmartin

View Looking from Sunda Kelapa Harbor Towards the Water Station



Source: Lauren Gilmartin

As the population of cities continues to explode and the threat of sea level rise grows, coastal megacities in the global south will be faced with serious challenges as water slowly inundates their land. This global transformation threatens massive

humanitarian crises, ecological degradation, destruction of historical and cultural treasures, and the global economy. Instead of viewing sea level rise as a threat, it is possible to change the position to one of opportunity by harnessing the inherent power of water to benefit a community, city, nation, and world.

This thesis proposes strategies for simple, profitable, deployable, systems and solutions that integrate city development, coastal infrastructure, and public resources by merging architectural innovations and planning to create a protected megacity with a high quality of life and resiliency. These solutions will ease the effects of sea level rise and offer a promise of a better future for the planet -- ultimately creating a net positive solution for coastal megacities of the future.

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