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24 *The Open Hydrology Journal,* **2015,** *9,* **(Suppl-1 M4) 24-27**

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Mitigation and Adaptation Responses to Sea Level Rise

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Abstract: Owing to climate change, according to annual Intergovernmental Panel on Climate Change (IPCC) reports, sea level rise is inevitable. The sea level rise in different parts of the coastal areas in the world continents, may be calculated and thus predicted for ten years in the future, a hundred years out and beyond, with decreasing confidence. Amongst experts, the amount of sea level rise at different locations is a topic of heated debate. The objective of the current work is to review possible projects and undertakings that could be planned and carried out to face the challenges brought forth by rising seas. Some of these projects and actions are more suitable for rise of 1 to 3 feet, others are good for higher rises and still others are suitable for whatever the scenario. The innovative suggestion in the current work is to use municipal waste, in addition to rocks, gravel and sand, together with an impervious bottom lining, to uplift the low-lying areas. This sanitary landfill in the close-by coastal areas is recommended wherever the local community is agreeable to a master plan of action where landfilling is included as a desired tool. Municipal solid waste is more cost effective than trucking in or shipping in imported gravel and sand. In addition, it is a good way to use the community's solid waste. If the solid waste was previously making its way to the incinerators, it will also help to reduce carbon dioxide emissions to the atmosphere, which is one of the principal causes of climate change and the rising seas.

Keywords: Barrier, climate change, encroaching shorelines, landfill, solid wastes, solutions.

INTRODUCTION

The Netherlands is known throughout the world as one nation that has held back the sea successfully. Their knowledge and expertise of their engineers and urban as well as regional planners need to be respected. Certain countries like the Netherlands and Singapore are more advanced than others in taking steps because their citizens have witnessed the land slowly disappearing under water from their sight. Others like the USA, where climate change has been mired in politics, have been slow to react.

In one publication, it has been opined that if seas rise by 9 meters, as soon as 2100, and certainly by 2200 or 2300 [1], the glamorous cities of Dubai and Abu Dhabi, of the wealthy United Arab Emirates, will be underwater. In our modern times, the electrical infrastructure is at ground level or below. It will not be possible to inhabit or use a skyscraper which is flooded to the first or second story. Another such city with low areas and relatively new, tall skyscrapers is Shanghai, China.

The responses to sea level rise broadly fall into two categories, mitigation and adaptation. There are synergistic effects between some of these responses, even from two different categories, and their positive effects should be recognized and valued.

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LITERATURE ABOUT RISING SEAS

The Intergovernmental Panel on Climate Change (IPCC) reports [2-4], have in recent times repeatedly predicted substantial sea level rise owing to climate change. There is little, if any literature, repudiating the fact about rising seas. The IPCC was awarded with great honor the Nobel Peace Prize in 2007.

There is an unverified estimate that between 1991 and 2011, there were more than four thousand papers on climate change, with conclusions that were clear regarding whether climate change is taking place, and if humans were significantly responsible. Apparently, over 97% of the publications are in agreement that climate change is here, and that mankind is a significant contributor. The fact is that the literature is replete with publications about rising seas owing to climate change. In [5], Pielke *et al.* are calling for policy change and action to respond to this challenge. Nicholls and his group of researchers, have been studying rising seas for years [6-12]. According to Nicholls *et al.* [8], the areas threatened by coastal flooding are the southern Mediterranean, parts of Africa, and most definitely, South and Southeast Asia where there is a number of high-human population density deltas. The regions with the top-most flood-risk increment relative to others in the world, would be in the Caribbean, the islands of the Indian Ocean and the relatively tiny islands of the Pacific. Baker *et al.* [13] studied the vulnerability of the northwestern Hawaiian islands because of their value for natural resources, including endangered species.

Wanless of the University of Miami in the USA has been studying the geology, seas and oceans of the world and

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observed their characteristics with respect to time for several decades. Wanless *et al.* [14] wrote about this subject in 1994. A review has been performed by Yanez-Espinosa and Flores [15], about the consequences of rising seas on the mangrove forest.

In reference [16], Barnett et al. performed a review of the body of work related to water availability in areas which have a lot of snow throughout the year. This review confirms that there is a change in the season/months when the run-off from mountain glaciers is a maximum, owing to the warming climate. In many areas where water management has not been adjusted for this fact, the run-off goes directly to contribute to the rising waters in the immediate marine vicinity. Raper and Braithwaite [17] discussed the sea level rise from glaciers and polar caps due to global warming. This included the 'Three Poles' i.e. the Arctic, Antarctica and the Tibetan Plateau.

Other works include Rahmstorf [18] who predicted the sea-level rise in the future using a semi-empirical method. He connects the rising seas with the average temperature rise of the Earth's surface. Rahmstorf claimed a 0.5 to 1.4 meter range rise by 2100, relative to the 1990 sea levels across the globe. Fish *et al.* [19] studied the mitigation of sea turtle beach loss. Their work was mostly concentrated on eleven sea turtle beaches in the island nation of Barbados. Crooks *et al.* [20] produced a Vice Presidency (of Sustainable Development) paper for the World Bank in 2011. They focused on the course of actions to promote nature-based mitigating climate change by employing coastal wetlands and marine ecosystems.

MITIGATION RESPONSES

In areas near the mouth of small rivers, the Netherlands is showing a fascinating way of using hydrology to mitigate the effects of rising seas. The Dutch are creating a reservoir between the river, the river's mouth and the harbor to create a large fresh water containment area in their country, near Amsterdam. This strategic placement of the reservoir will help in flood control. This is an innovative approach, and a recognition that creative water management is essential to live in the era of climate change.

A practice that has been done for a long time is the building of sea walls or barriers, both below and above the sea level. The sea walls can be raised in height for the immediate future, and designed to accommodate future increases in height. The Singapore government stated that seventy to eighty percent of the island nation has some kind of coastal protection. A rise of two meters or more in the sea level would transform Singapore into some kind of a fortified island.

The level of the threatened coastal regions could be raised. This can be done by importing gravel and sand from the interior. Another option, recommended by the current work, is to use municipal solid waste from the community, as in a sanitary landfill. Of course, the lower layers will be imported rocks, gravel, sand and clay while the upper layers would be imported gravel and sand and clay. There will be no interaction between the municipal solid waste and the sea water, because the waste will be placed higher than the sea level. Moreover, an impervious plastic liner would be used, as in a sanitary landfill.

More resources and costs are involved in trucking in or shipping in imported gravel, sand and clay. Municipal solid waste destined for landfills elsewhere in the interior, can be routed to these coastal areas. A synergistic effect of this plan is that interior land could then be used for habitation, agriculture or other uses. That the community's solid waste is being used to help the community live with climate change is good philosophical thinking and strategizing.

On the other hand, if the municipal solid waste was previously being incinerated, the landfilling of sinking coastal areas will help to reduce carbon dioxide emissions. The synergistic effect is that one of the main causes of climate change, carbon dioxide, is being reduced instead of constantly being pumped into the air from burning. In mitigating the rising seas, this landfilling of solid waste will also help to cut down on one of the root causes of the rising seas.

The establishment of offshore barrier islands has been done by several countries, e.g. Singapore. Old barrier islands have to be made higher in elevation, and new high ones planned to strategically help protect the low-lying coastal areas. Traditionally, these islands have been made from imported rocks, gravel and sand. In addition, the shallow sea bed has been dredged and the dredged material used for these barrier islands. In addition, the current work suggests the use of municipal solid waste, with the accompanying environmental safety measures.

From [21], "the average air emission rates in the United States from municipal solid waste-fired generation are: 3685 lbs/MWh of carbon dioxide, (it is estimated that the fossil fuel-derived portion of carbon dioxide emissions represent approximately one-half of the total carbon emissions) 1.2 lbs/MWh of sulfur dioxide, and 6.7 lbs/MWh of nitrogen oxides". It is obvious that the usage of municipal solid wastes for building offshore barrier islands would help in reducing the production rate of carbon dioxide and the other two gases mentioned.

The dredging procedure presumably allows for a larger capacity for sea water to flow. It is the suggestion here that the design and engineering of the whole region needs to be taken into consideration. Not only should the flow through be considered, but the complex shape and size of the underwater volume should provide less opportunity for the sea water to collect and rise. In other words, the underwater mechanics have to be simulated correctly and planned right.

Model simulation and analysis, both physical and digital, should be employed to study the segment of the ocean basin adjacent to the threatened low-lying coastal area. The effect of the redesign of the ocean floor with barrier islands, should take into account the ocean currents and tides of the region. With the simulated results for a few, well-selected probable scenarios in hand, the hydrology of the near shore should be planned and designed to accommodate the potential increased volume of sea water flow. There should be an initial

mapping of the regional seabed with historical data regarding currents and tides. The ultimate objective is to design and engineer a hydrological system that would allow an increased volume of flow through the shallow water region, without a noticeable sea level rise on the low-lying coastal area. Oceanographers, marine scientists, engineers and regional planners should be involved in this significant task. Digital software packages for such simulation are readily available, some of them are open access.

The digital software should strive to be a complete simulation of fully 3-Dimensional (3D) flow which is time-dependent, with morphology and sediment transport, water quality, waves and ecology. It should be possible to simulate interactions between the processes mentioned, using parameters which are standard and not too difficult to measure for different parts of the world. Since domain experts and non-domain experts are expected to use the simulation software package, it should allow for collaborative use without too much difficulty. One successful structure of such a package comprises tested and validated programs which are linked to or dovetailed into one another. The interface for the user and the result processing portion of the package should, needless to say, be similarly user-friendly and compatible with established geographical information systems, etc. Having the facility to enable the user to visualize the 3D data as a time series and animations, is a much desired feature.

ADAPTATION RESPONSES

One of the first adaptation type responses to be suggested would be to use salt-resistant cultivars for sea water intruded areas. This is well and good if the area is originally for agricultural use. Since the worst damage and most expensive ones from sea water rise will occur in urban areas, responses that address urban issues will be discussed in greater detail.

In the realm of sea plants and sea weeds, some cultures in the world have consumed certain plants from the sea for centuries. The Japanese and Chinese people come to mind as examples. There are even some highly priced, special plant species in the gourmet menu. Use of flooded coastal areas for consumable sea plants would be put forward as a suggestion.

The cultivation of various sea plants as a source for biofuel can be studied and considered. This will certainly increase the number of plants that are suitable for biofuels. On the negative side, the increase use of biofuels from plants (whether land or sea plants) will not reduce the carbon dioxide in the atmosphere.

Newly flooded areas may be used for aquaculture. Sustainable aquaculture include that for different types of fishes and shell-fish. The upside is that the acreage for renewable bioresources could be increased with increased sea level rise.

The use of flooded coastal areas for desalination plants seems like a natural and ecologically friendly act. There is less pumping work required to be done to use the incoming sea water as the source. Most efficient and least energy-intensive methods of desalination should be used. The fresh water obtained would certainly help to mitigate the energy-nexus problems, arising in many places around the world.

In urban areas, flooded water-front areas with some of the most expensive homes should be replaced by multiple-story expensive homes with the first couple of stories used for purposes other than living. Transport to and from dry land should be done by boat, preferably the ones powered by solar power or human-powered.

In the same vein of living, luxury resorts can be built on stilts over the shallow water, as has been done in many touristy islands throughout the world. The ones in the Asia-Pacific region come to mind [22]. This would attract more tourists to the area. Cities threatened by rising seas e.g. Miami, will be nicely served with this adaptation to increase tourism and business.

In less affluent areas, the floating villages of Thailand and China have shown the way. Families that live off fishing and the sale of cultivated produce, could live in boats and/or floating houses.

Flooded areas can be adapted as extended wetlands. Mangroves, etc. can be planted to prevent further encroachment by the sea. These mangroves will also help to reduce erosion, and damage caused by hurricanes in areas that are prone to these natural phenomena e.g. New Orleans and the Mississippi delta region, Florida.

DISCUSSION AND CONCLUSION

A number of mitigation and adaptation responses have been discussed in the current work. Some of these responses have synergistic effects that would improve environmental quality and even help reverse the amount of carbon dioxide in the atmosphere.

A rather innovative recommendation here is the use of municipal solid wastes to augment the landfilling of low-lying coastal areas, barrier islands, etc., as long as sanitary environmental considerations are taken into account. This beneficial use of municipal solid wastes would certainly help to stop the growing size of wondering gyros of garbage in the oceans of the world. The flotsam and jetsam discarded by us humans worldwide were an inspiration for the current article.

The effectiveness of the response or responses selected will depend on the will and cooperation of regional authorities. In many places throughout the world, this might not be a problem. In island nations, forward-thinking governments would not be hindered by this at all because of their size, e.g. Singapore. However, where local authorities have autonomy, e.g. in the USA, it is important that the local authorities of affected neighboring areas be united in a concerted effort to meet this rising seas problem. There is much to be benefitted from mitigating rising seas and to live adaptively with the challenge. The only other option, not discussed here, is abandonment. This last choice should be viewed as unacceptable.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: March 25, 2015 Revised: April 23, 2015 Accepted: April 23, 2015