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DETAILED ISLAND RISK AND VULNERABILITY ASSESSMENT

HDh. Kulhudhuffushi



Prepared by:



for

Ministry of
Energy and
Environment



Detailed Island Risk and Vulnerability Assessment Hdh. Kulhudhuffushi

Integrating Climate Change Risk into Resilient Island
Planning in the Maldives (ICRRIP)

Prepared by



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Acronyms

DEM	Digital Elevation Model
DIRAM	Detailed Island Risk Assessment of Maldives
DNP	Department of National Planning
EIA	Environmental Impact Assessment
GIS	Geographic Information System
MEE	Ministry of Environment and Energy
MPND	Ministry of Planning and National Development
MWSC	Male' Water and Sewerage Company Pvt Ltd
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
ICCRRIP	Integration of Climate Change Risk Resilience in Island Planning
IPCC	International Panel on Climate Change
RF	Rufiyaa (Maldivian Currency)
SST	Sea Surface Temperature
STELCO	State Electric Company
SWOT	Strengths, Weaknesses, Opportunities and Threats
UNDP	United Nations Development Program

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Executive Summary

This report on Hdh. Kulhudhuffushi provides an update of the risk assessments conducted in 2008 to understand the vulnerability of the island towards natural hazards. It aims to provide a better understanding of the topography of the island and the physical changes that have occurred since the last assessment. These elements are mapped against the potential natural hazard risks; Tsunami, swell waves and rainfall flooding predicted for the island.

Since 2008, there have been major changes in the island through physical developments such as the development of harbor area, land reclamation of the west coast followed by more warehouses and business establishments near the port. The recent reclamation of the harbor area has shifted lot of infrastructures and housing near the shoreline inwards reducing its vulnerability to disasters in relation to storm surges, *udha*, Tsunami etc.

The vulnerability assessment showed that the natural setting of the island with high ridges (+2.5 m MSL) at the eastern end make the island resilient to the potential natural hazards. The hazard analysis revealed that the eastern area would be protected from the adverse effects of Tsunami and swell waves reducing the impact to the land uses located in that area. However, the study also notes that this important feature is under threat due to erosion, which the island has been experiencing for decades. If this erosion continues, there is a high possibility that the ridge would be severely undermined making the island more vulnerable to disasters. In addition to this, some areas of the island, especially the northern end is very vulnerable to rainwater flooding due to the low elevation compared to the rest of the island. The interface between the old island and the new reclamation is also susceptible to flooding. Due to lack of a proper drainage system the problem still persists and it has been impacting the people in many different ways. Nevertheless the rainfall patterns have changed over the past years and data shows that there has been a decline in mean annual rainfall between 2007 and 2011 while in 2012 it has increased. The future projection of rainfall by RIMES (2011), show both an enhanced variability and an increasing tendency, with the southern zones having a greater increasing in rainfall in the future. According to the findings of RIMES (2011), the increase in rainfall would be accompanied by extreme events such as maximum one-day rainfall and increased number of consecutive wet days.

Vulnerable groups in Kulhudhuffushi who are subjected to these conditions include elderly people, mentally and physically challenged individuals, at-risk children and youth, the families living near coastal areas, women etc. Approximately 16% of the population is above 65 years. According to the regional hospital, disabled people include the physically challenged and mentally ill patients. They are among the most vulnerable people as they will need full support

and assistance in moving from one place to another. Studies also show that women have a higher risk in case of a disaster than men. In Kulhudhuffushi, approximately 20 % of the households are located near the coast. However, since these 20% are mostly at the eastern side of the island where the island is protected by a high ridge, the impact predicted is lower than expected.

The potential social impacts the island would experience due to any potential natural disaster include loss of life, injury to members of household; destruction/damage of household properties; spread of diseases; damage to roads and infrastructure; disruption to economic activities; disruption to transport of goods; increased quantity of waste and water scarcity. All these impacts would mostly affect the vulnerable groups in the island. According to the current findings, factors that would exacerbate the impacts are; location of housing and infrastructure; improper waste management; increase in population and vulnerable groups; housing condition and condition of critical infrastructures; political imbalance; income saving practice. These factors were taken into consideration when proposing disaster risk reduction measures for the island.

Based on the natural hazard assessments the key economic establishments and infrastructures at risk include the power house, RO water plant and STP. The critical social infrastructures at risk are the hospital, police station, some of the schools and the main zone stadium (football field). With the reclamation, most of the business establishments are now located further away from the shorelines reducing their vulnerability to disasters. The economic losses are expected to be highest during a high magnitude Tsunami or a swell wave event. Impacts of other disasters such as rainfall flooding and strong wind are expected to be relatively low compared to Tsunami and swell waves.

The estimated loss from a severe tsunami event in Kulhudhuffushi ranges between Rf 100 Million and Rf 126 million. The estimated tangible loss from a severe swell wave or storm surge event in Kulhudhuffushi is Rf 29 million. The losses are small compared to a tsunami event as the intensity of the impact is low. The estimated tangible loss from a severe rainfall flooding event is Rf 2.3 million.

Measures to reduce the identified environmental vulnerabilities include; rehabilitation of the eastern coastal ridge; coastal protection in the southern and northern side; maintaining the Environmental Protection Zone; establishing a proper drainage system; maintaining the northern side wetlands; introduction of measures to reduce socioeconomic vulnerability to disasters.

In order to reduce the social vulnerability to risks, it is essential to integrate the Hyogo framework 2005-2015, the Millennium Development Goals (MDGs) and the Cairo principles in implementing the measures. The main measures are to promote disaster risk reduction and management; make the communities prepared to the disaster events and to strengthen the emergency response and recovery services.

A cost-benefit analysis was also conducted to realize the cost and benefits the proposed mitigation measures would cost in the different scenarios; 1) single Tsunami event, 2) a flooding event and 3) multiple disaster events.

Limitations of the current study and recommendations for further studies are also discussed to strengthen the present study and make it a comprehensive assessment. These include identification of the ways to incorporate climate smart planning into disaster risk reduction.


1. Introduction

Detailed Island Risk Assessment in the Maldives (DIRAM) is a set of reports based on studies conducted in 10 different islands of Maldives in 2008 to understand the past, present and future risks associated with different events including natural hazards, urbanization and other developments in the islands and its surroundings (UNDP, 2008). With the change in population and physical developments in the islands, these studies call for an update in order to understand how the risk profiles have varied over the years due to these changes. Under this line, the first climate adaptation project of Maldives, “Integrating Climate Change Risks into Resilient Island Planning in the Maldives” (ICRRIP) aims to review, update and strengthen the assessments that have been conducted for Hdh. Kulhudhuffushi and Gdh. Thinadhoo. The objective is to assist in developing policies, regulations and guidelines relevant to the islands to ensure risk resilience in the islands. The project also aims to contribute to the understanding of natural risks associated with climate change and other natural and human induced activities.

The DIRAM report prepared for HDh. Kulhudhuffushi (hereafter referred to as “*previous DIRAM study*”/ “*previous study*”) has been revised and assessed based on the current condition of the island. This update aims to provide a better understanding of the topography of the island and the physical changes that have occurred over the past 5 years. These elements are mapped against the potential natural hazard risks; Tsunami, swell waves and rainfall flooding predicted for the island. With time and data constraints the study has attempted to assess and analyse how the changes have affected the vulnerability of the island through developing a digital elevation model and by using a Geographic Information System (GIS). A similar methodology as used in the previous DIRAM study was adopted but with detailed surveying and modeling of the elevations (refer Annex I for the study approach/methodology adopted to conduct the review). The studies showed that while the increase of population and the rapid urbanization have increased the socioeconomic vulnerability, the geomorphology of the island and some of the physical developments have reduced the environmental and structural vulnerability of the island to some extent.

The analyses of the different vulnerabilities are discussed in the report in separate sections. Chapter 2 of the report gives the background of the island and describes the environmental and socioeconomic setting of Kulhudhuffushi. These data are then used to assess the environmental, social and economic vulnerability of Kulhudhuffushi to natural disasters in Chapters 3, 4 and 5 respectively. The findings are then summarized with a SWOT analysis in Chapter 6 and measures to reduce the vulnerabilities are proposed to conduct a cost benefit

analysis (Chapter 7). The report is concluded with recommendations for further studies, which are discussed in Chapter 9.

A photograph of a dirt road lined with palm trees leading to the ocean. The road is unpaved and appears to be made of sand and gravel. The palm trees are tall and lean, creating a natural archway over the road. The sky is clear and blue. The ocean is visible in the distance. The overall scene is tropical and serene.

2. Island context

A road heading to the shoreline of Kulhudhuffushi
Photo by: Shifna Saeed/ Riyan Pvt Ltd (2013)

2.1. Location

Kulhudhuffushi is located at the eastern periphery of South Thiladhummathi Atoll or Haa Dhaalu (HDh) Atoll at geographic coordinates of 73°04'10"E, 6°37'24"N (UNDP, 2008) (See figure 1). On the north of Kulhudhuffushi is Nolvaramu separated by the Nolvaramu Channel. On the south of Kulhudhuffushi is Kumundhoo separated by Kulhudhuffushi Channel. The island is located approximately 19km South of Hanimaadhoo (nearest Airport) and approximately 276km North of Male' City. Kulhudhuffushi is the administrative capital of HDh Atoll. As it is located at the northern rim, the island is exposed to the North-East monsoonal winds, waves and the occasional storms originated from the Indian Ocean cyclone belt (UNDP, 2006).

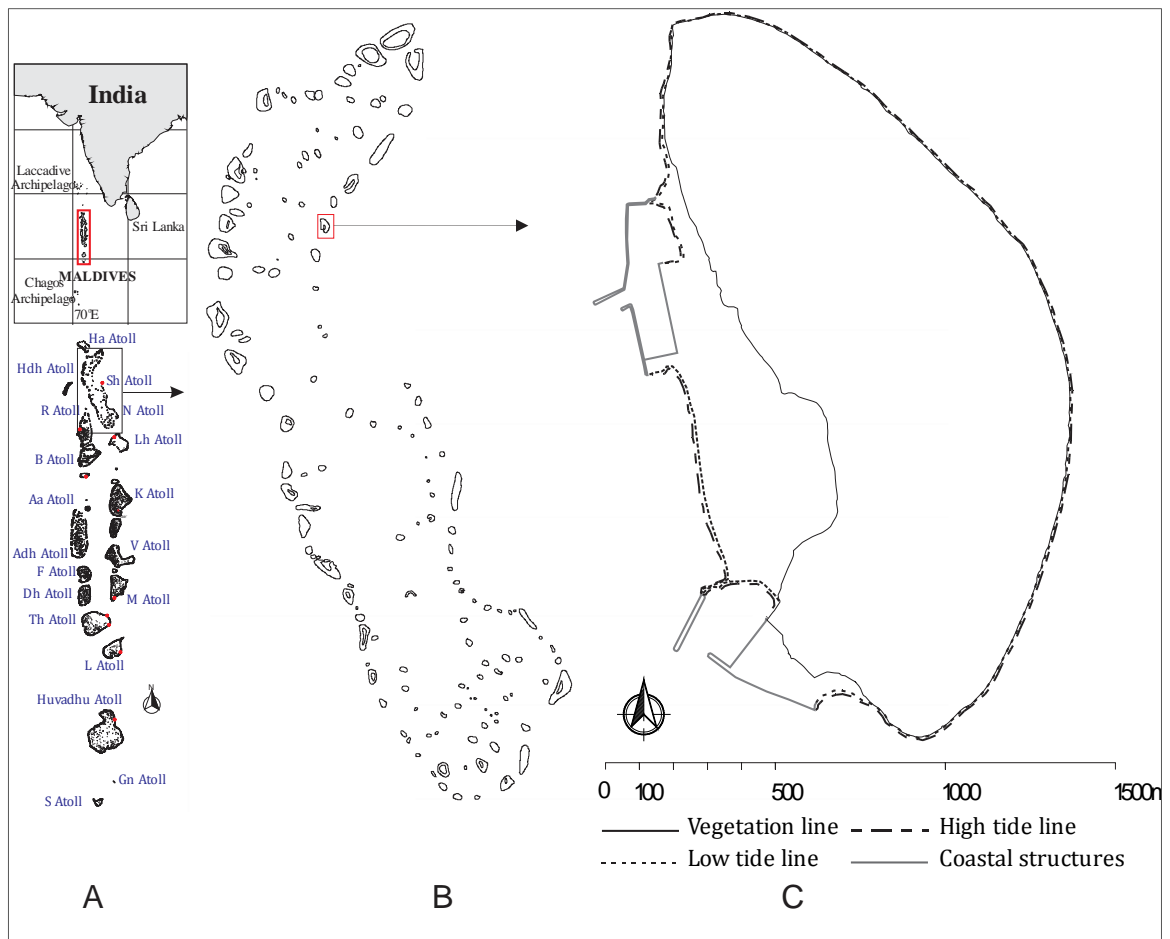


FIGURE 1 LOCATION MAP, HDH. KULHUDHUFFUSHI; A. GEOGRAPHIC LOCATION OF HDH. ATOLL IN THE MALDIVES ARCHIPELAGO, LOCATION OF KULHUDHUFFUSHI IN HDH. ATOLL, C. KULHUDHUFFUSHI

2.2. Physical Environment

i. Geomorphology

The island of Kulhudhuffushi is pea shaped and elongated on its north to south axis. The area of the island including the reclaimed areas is 236.85 hectares (ha) (2.37 km²) and it is the 11th largest island of Maldives, measuring 2,530m in length and 900m in width. The area of the island prior to reclamation of land was 199ha. In a whole, including the reef system it spreads over an area of 395.28 ha (3.95 km²) of which the island itself occupies 60.48%. The island lies nearer to the ocean ward reef edge than the lagoon ward reef edge with both having respective distances of 70m and 211m from the island. It has a very shallow reef flat averaging less than -1m MSL on the ocean ward side and slightly deeper on lagoon ward side. Since the island is oriented in a northwest-southeast direction, approximately 3.5km of the eastern coastline is exposed to wave activities generated from the East Indian Ocean. Table 1 below summarizes the physical attributes of the island.

TABLE 1 PHYSICAL ATTRIBUTES OF HDH. KULHUDHUFFUSHI

Physical attributes	Measurements
Length of the reef (visible extent)	2,870m
Width of the reef (visible extent)	1,780m
Length of the island	2,530m
Width of the island	900m
Wet land area (north and southern side wetlands)	33.46ha
Reclaimed land area (harbor area and west central area)	36.13ha
Total land area (average of HWL and LWL)	236.85ha

Thiladhummathi atoll is a relatively open atoll with a high number of atoll passes, mostly on the eastern rim. The depths within the atoll reach 70 m and have relatively few lagoonal reef systems. These features result in formation of waves within the atoll during South-West (SW) monsoon, causing negative impacts on the eastern shoreline of Kulhudhuffushi during the SW monsoon. Although the eastern rim is vulnerable to strong waves and the island is low in terms of elevation with an average of +1.4m MSL, in general Kulhudhuffushi can be considered as one of the secure islands in case of ocean induced natural hazards. This is mainly because of the strong natural defense system along the ocean ward coastline. The high ridges (+ 2.5 m MSL) and the coastal vegetation belt shield the area from such hazards to a greater extent. The

height of the ridge is highest along the central and southern shoreline and lowest on the northern shoreline.

ii. Water bodies

Kulhudhuffushi previously had two large areas of wetlands (0.5 km²) at the northern and southern end of the island. However, due to the issue of land shortage, some areas had to be reclaimed. While only a small area of wetland remains on the southern end, an area of 0.3km² of wetlands surrounded by mangrove vegetation can still be found at the northern end of the island.

iii. Vegetation

Even with the large population, vegetation cover on the island can be considered moderate. There is a strong vegetation zone at the central part of the eastern coastline. However this belt does not continue along the line, leaving some areas within the belt with less vegetation. However, not much vegetation is observed along western coastline of the island. This is mainly due to the new reclamation of the western side. It is expected that there will be greater vegetation cover once the area gets developed. In general, within the settlement the vegetation comprise of backyard trees such as breadfruit, mango and other tropical fruit trees.

iv. Settlement

The highly urbanized settlement with a registered population of 8,974 as of 2012 (DNP, 2012) is spread across the island leaving only the wetland areas and the newly reclaimed portion of land. The central area of the island, where people initially settled, houses are observed to be built in clusters and roads were not properly aligned. In comparison, in the areas where settlement came about later, a grid form settlement can be observed (see

The population density of the island (excluding the wetland area) is approximately 41 person per hectare. As Kulhudhuffushi is the regional hub and also the atoll capital, the island is growing at a faster pace. This rapid growth demands for changes that may be harmful to the environment resulting in the island becoming more vulnerable to the environmental and



FIGURE 2 WETLANDS AT THE NORTH END OF KULHUDHUFFUSHI



FIGURE 3 MANGROVES AT THE WETLANDS OF KULHUDHUFFUSHI

climate changes as well as natural hazards. Hence, the island thus becomes less safe for the residents.

2.3. Existing land use

Kulhudhuffushi can be considered as a highly urbanized island with a population density of 41 person/hectare. The settlement foot print of the island covers 43% of the total habitable land area. Within this settlement foot print the population density is 88 person/hectare. Since 2008, major changes have been brought to the island structure through physical developments such as development of the harbor area, land reclamation of the west coast followed by more warehouses and business establishments near the port.

Although the recently reclaimed area remains to be developed, other habitable areas are being used for the different types of land uses as illustrated in the land use map (Figure 4). The recent reclamation of the harbor area has shifted a large number of infrastructures and housing which used to be near the shoreline, inwards reducing its vulnerability to disasters in relation to storm surges, *udha*¹, Tsunami etc. All the infrastructures are at a close proximity to each other. Land was also reclaimed from the north and south wetlands to address the issue of land shortage with the increase in population. However, even with the increase in landmass, the island is still experiencing scarcity of land for housing and other urban services.

A number of projects are being carried out to address the issues related to land use. In 2010, under the national program of "10,000 Housing Units Programme" (7,000 Units in 7 Provinces), 25 row houses were proposed and construction was started last year (2012); however the project is now on hold. The road development project that was planned on 2009 has recently been started and is still ongoing. Other developments that have been planned include the construction of a youth center, an extension of the hospital for a maternal waiting area and extension of one of the preschools (IPS) located at the eastern side of the island.

Past land allocations were not done in a sustainable manner where large portions of land were given for residents. Furthermore, no zoning was done to separate the different types of land uses, which hence resulted in a mixed-use development with commercial and industrial activities located within the residential areas. While mixed-use developments are considered as a more sustainable way of planning, this was not well planned in Kulhudhuffushi, thus

¹ "Udha" is the local term used historically to describe a flooding event caused by elevated water levels coupled with swells and/or wind generated waves.

leading to the inappropriate location of some land use areas. This could cause difficulties with the rapid population growth and also in times of disasters.

2.3.1. Proposed land use plan

The proposed land use plan is undergoing revision. However the draft plan provides a general idea of the newly proposed land uses/ developments with a focus on developments in the newly reclaimed area (see Annex II). The plan has attempted to address the issue of land shortage by allocating more land for residential housing of different types, including public and commercial housing. A total of 25 row houses are located at the areas allocated for the commercial housing plots while flats will be built on the public housing plots. Separate areas are allocated for industrial and commercial uses, separating it from the residential areas. This arrangement will be safer for the residents as they will not be easily exposed to the different types of pollution caused by industrial activities such as boat building etc. The plan is being implemented to some extent and would be implemented in full once the plan gets approved after revision. Even now, the row houses that have been proposed are under construction, but are on hold due to budget constraints. In order to implement the plan, the most essential element is adequate funds and this has remained to be a constraint in Kulhudhuffushi and other parts of Maldives.



FIGURE 5 ROW HOUSES UNDER CONSTRUCTION AT THE NORTH SIDE WETLAND LAND AREA



FIGURE 6 ROW HOUSES UNDER CONSTRUCTION AT THE NEWLY RECLAIMED LAND (VELIGANDU)

2.4. Social Setting

2.4.1. Population and Migration characteristics

The population of Kulhudhuffushi highly depends on the migration of people from islands of Haa Dhaalu and the neighboring atolls of Haa Alif and Shaviyani. As per 2012 statistics, the total registered population is 8,974. Although this figure provides the total registered population, the most recent census was done in 2006 with an enumerated population of 6,983. With a growth rate of 1.0, the current registered population of the island is reported as 9,052 in 2013.

However, since there has been a delay in conducting the census which is now scheduled to be held in 2014, the most recent data that can be analyzed for this study is the 2006 census which was the baseline data used in the previous DIRAM reports as well. Thus, in order to provide the most updated information, some of the data are primarily collected from field surveys (See Table 2 below for the population figures).

TABLE 2 POPULATION OF HDH. KULHUDHUFFUSHI

	Maldives Census (Actual)					Registered
	1985	1990	1995	2000	2006	2012
Total	3,688	4,460	5,467	6,581	6,998	8,974
Male	1,695	2,033	2,571	3,131	3,299	4,602
Female	1,993	2,427	2,896	3,450	3,699	4,372

As illustrated in Table 2, Kulhudhuffushi has experienced a steady population growth. While the islands nearby have a negative growth rate, Kulhudhuffushi is growing with a rate of 1.0. As reported in DNP (2012) there were 4,602 males and 4,372 females registered in 2012. Since 2006, the population has increased by 28% and it can be seen that number of males have increased more than number of females. This difference is due to the difference in data reported, whereby, the 2006 census data shows the enumerated population while data from 2012 shows the registered population. From this difference, it is clear that men are usually out of the island for work whereas women stay in the island, making them more vulnerable to disaster risks.

The population density (excluding the wetlands) is 41 person per hectare. As discussed, one of the reasons for this increase in population would be due to the immigration of people from other neighboring islands who move to Kulhudhuffushi for its improved infrastructure and facilities. This growth and distribution has and would increase the population density of the island, thus increasing the demand for more infrastructure and facilities. Increase in urbanization and population density increases the vulnerability of the island to disasters to a great extent (ESCAP & UNISDR 2012).



i. Population Structure

The previous island assessment conducted in 2007 identified 42% of the population as dependent population based on the age groups. According to the study, children of age below 15 and elderly people with age of 65 and above are considered as dependent as they would require assistance and support for mobilization in case of a disaster event (UNDP 2008).

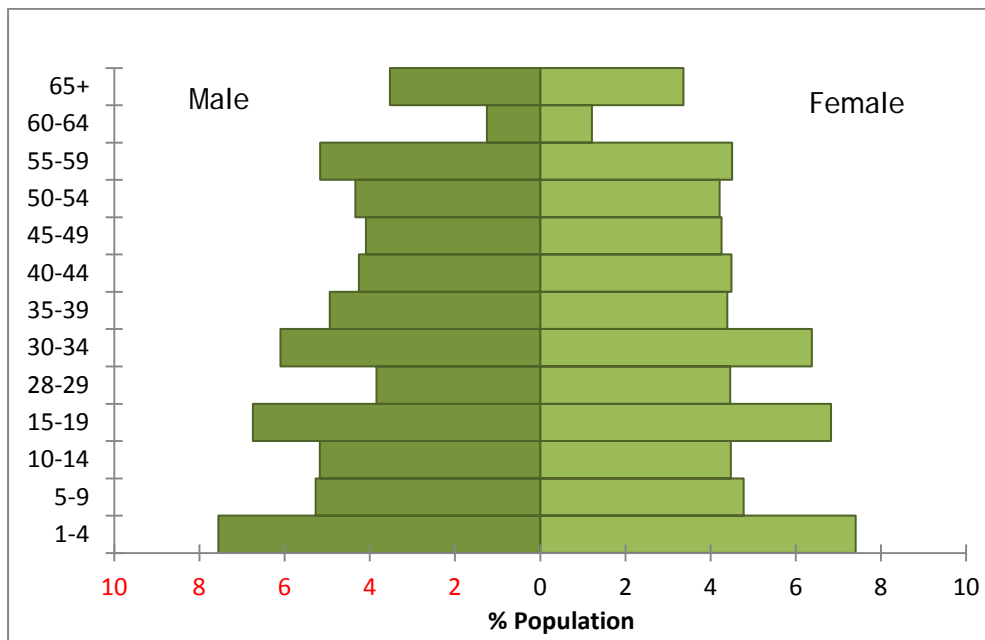


FIGURE 7 POPULATION DISTRIBUTION OF HDH, KULHUDHUFFUSHI BY AGE GROUPS (HDH, KULHUDHUFFUSHI ISLAND COUNCIL 2013)

As presented in Figure 7, compared to the previous study in 2008, the percentage of dependent population has decreased over the past 5 years. The current dependent population compose 34% of the total, with 28% of this being children under 15 and 6% being the elderly population. This indicates that the vulnerable population under this category has decreased reducing the risk to some extent (refer chapter 4 for details on vulnerability groups). Nevertheless, it can be seen that Kulhudhuffushi has a growing elderly population (6% of the total population), which could be an exacerbating factor in increasing the vulnerability of the population. In general, a fair distribution is observed in terms of male and females with a ratio of 1:0.95.

2.4.2. Households and Families

According to Census 2006, the average household size was 6.2 (MPND, 2007); however as observed during the field survey undertaken in 2013, with the increased population, this has now increased to 7 to 8 people per household. The plot size of the houses ranges from 1,430 square feet to 5000 square feet.

In the Maldives, households are mainly based on extended family systems; families living under one roof. However this trend is slowly changing as nuclear families choose to live separately. Nevertheless, in Kulhudhuffushi extended families are still found to be more than nuclear families, which explains the large household size. This may be due to land shortage and the emigration of men to work in Male' and tourist resorts. Another reason could be the respect for the elders of the family and the communal values which is relatively strong amongst Kulhudhuffushi families. This key feature of respect also shows a strong bond between family members and the support they provide at times of any difficulty.

2.4.3. Community Capacity and Resources

i. Natural Resources

Similar to any other island of Maldives, the largest natural resource for the island is its surrounding environment which constitutes the sea, beaches, vegetation and the land. The resources available within the island include the strong coastal vegetation, coconut palms, mangrove trees, fruit and vegetable trees, wetlands (*kulhi*), reef and ground water. However, these resources are under the threat of destruction with the change in climate and human interventions. The beaches are eroding; the land is becoming scarce; and the trees are being removed with every new development. Impacts caused by these changes are further discussed in section 3 of this report which focuses more on the environmental impacts.

ii. Physical Resources

The physical resources include the public infrastructure also considered as the critical infrastructures of the island. These include the power house, schools, mosques and hospitals. Parks and other open spaces allocated for recreational uses can also be considered as part of their physical resources from which they could gain benefit on a day-to-day basis.

iii. Financial Resources

As far as the island alone is concerned, they do not have many financial resources readily available. However, the Bank of Maldives branch situated on the island facilitates the loan

applications of investors and other residents. While they provide these facilities to a certain extent, investors mostly travel to the capital city Male' to seek loans. Also, people depend on interpersonal loans from large businesses and vessel owners to establish small businesses.

iv. Human Resources

Although employment has been noted as one of the main issues in the island, the level of education provided in the island and also the number of people with higher education is relatively high compared to most of the islands of the Maldives. However, there is no recent data available on employment, restricting the study to data from Census 2006. Figure 8 shows the level of education attainment in the island as identified in Census 2006 (MPND 2007).

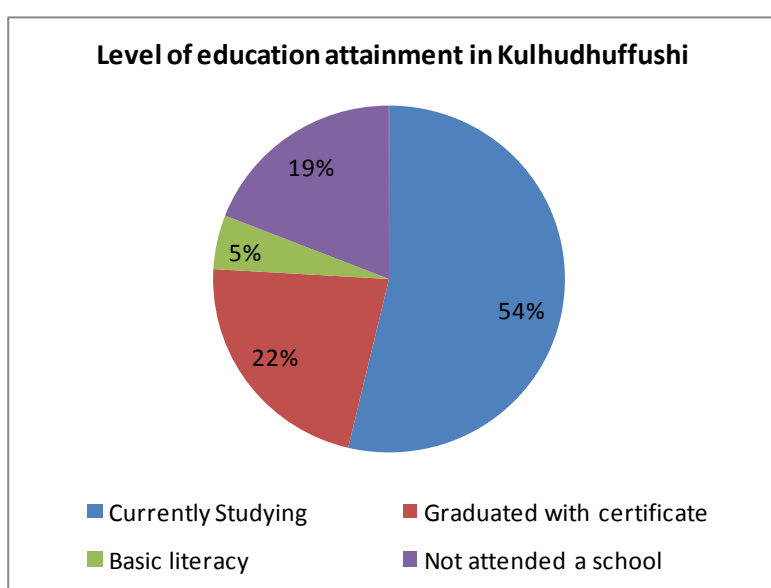


FIGURE 8 LEVEL OF EDUCATION ATTAINMENT IN HDH. KULHUDHUFFUSHI FROM CENSUS 2006 (MPND, 2007)

In addition to education, the number of skilled workers is also high. These include fishermen, people involved in fish processing, construction workers, engineers, health care providers, carpenters, boat builders, vessel operators, teachers and administrative staff. Skills involved in agricultural activities, rope weaving, food production and trading is also observed to be high in the island. The employment trends are further discussed in section 2.5.

v. Administrative and Institutional capacities

Health

The regional hospital for the region of Haa Alif, Haa Dhaalu and Shaviyani atolls is located in Kulhudhuffushi. The 50 bed hospital provides general medical services, specialist care, surgery (minor), emergency services, services of the intensive care unit and dental services. Although this hospital is supposed to cater for the whole region, it was evident from the stakeholder consultations that the people are not satisfied with the services provided. Main reason for the dissatisfaction was reported as the limited services and low capacity in terms of medical staff and equipment.

Education

Kulhudhuffushi caters for 2,474 students from Kulhudhuffushi and other islands in five public schools which consist of one preschool, two primary schools, one secondary and higher secondary school and a vocational training center. They also have a university campus offering few courses in the areas of teaching, nursing, business administration and management. However, the quality of education offered is low compared to Male' due to lack of professional teachers and sufficient budget. There are also private institutions, which offer tuition classes and Quran recitation classes.

Emergency services

Emergency services are provided by the hospital and police station. The regional hospital provides the service of ambulance and a speed boat in case of any medical emergency. Consequently the police offer the services of island security, firefighting and emergency services in events such as flooding. However, in case of a disaster or large scale emergency the existing facilities and equipment will not be able to cater to the whole island. Also, no institution has a disaster management plan and the community members are not aware of what should be done in case of such an emergency.

Municipal Services

With the decentralisation of the government, the island councils elected by the public are now responsible for providing the municipal services. They are also in charge of providing road

maintenance and waste management services. The utility companies manage such services in urban centers such as Kulhudhuffushi. Likewise, the waste site is managed by *Fenaka Corporation Limited*² and the sewerage system is managed by MWSC³ who also provides desalinated water to all residents of the island. However, services such as waste disposal and management of the waste site are not well provided. Waste collection is managed by some individuals. Although some households pay a fee to the individuals to take the waste to the disposal area this is not done in an organized way. While a certain area is designated for waste disposal, the distance of the site from the residential areas and the absence of dustbins within the island results in waste being disposed in different parts of the island. The island needs a better system with necessary equipment and staff to provide the regular municipal services.

2.4.4. Social trends

i. Youth

The youth of the island accounts for approximately 20% of the total population. With the provision of O'level and higher secondary education in the island, the youth are more educated and aware on the most pressing issues of the island. However, they are still not very familiar with the concept of climate change and its impacts on the environment. There is potential to advocate the youth on such issues and empower them to get actively involved in taking initiatives to protect the environment and raise awareness amongst others. More trainings and awareness campaigns are necessary for this to work.

ii. Drug abuse and antisocial behavior

Drug abuse has become one of the most concerning social issues amongst the island communities. All stakeholder groups consulted identified this as one of the major problems as more people are entering the drug circle. This has also led to other issues such as robberies, violence and arson. In addition, any income they earn is spent on purchasing drugs, hence affecting their career and future development of the island.

² *Fenaka Corporation Limited* is a government owned utility company with a mandate to provide island communities with electricity, water and sewerage. Also, the company aims to establish an environment friendly waste management system in the different parts of Maldives

³ Male' Water & Sewerage Company Pvt. Ltd. is a company partly owned by the government. Their mandate is also to provide safe water and sewerage services to the communities.

iii. Changes in governance

With the new Decentralisation Act in 2010, atoll and island councils were publicly elected. The aim of this Act is to make the councils accountable for the decisions made with regards to all matters relating to the island and to empower the people of the island to work together in a better environment, to improve their quality of life. Bringing what they need closer to island level is one of its objectives. This would allow transparency and is expected to speed up the procedural works.

The main responsibilities of the atoll/island councils are to work for the development of the atoll/island, provide all the municipal services by closely involving the community in planning, developing and providing the services to the atolls/ islands (*Decentralisation Act 2010*).

2.4.5. Poverty

The 2nd *vulnerability and poverty assessment* conducted in 2004 estimated that population with per capita income less than Rf10 falls under the poverty line (UNDP 2005). According to the assessment, 36% of the population has an income less than Rf15 per day while 23% has an income less than Rf10 per day. The percentage of people earning less than Rf15 per day is higher than the national average of 21% as well as the atoll average of 28% (UNDP & World Bank, 2005). However, this study was conducted in 2004 and the island has gone through a number of changes in terms of land use and population numbers over the past 9 years.

In comparison to other islands of Haa Dhaalu atoll, the people of Kulhudhuffushi are relatively well-off. Although there may be a small fraction of the population under the poverty line, the economic condition of the island has improved significantly with more economic activities being carried out in the island.

2.5. Island economic setting and baseline economic conditions

With the largest population in the northern region of Maldives, Kulhudhuffushi also has the largest economy among the islands in the north of Maldives. Being the capital of the atoll and the regional hub, the island is well equipped with all necessary facilities and infrastructures including the regional hospital, schools, power house, water and sewerage system, harbor etc. The economy of the island is mainly based on three basic sectors: wholesale and retail trade, manufacturing and fishing. Previously, fishing was the main economic activity, though this has now changed with the ban on shark fisheries and decreasing fish catch. With the changes and opportunities from operations of regional (International) port wholesale and retail business, transport sector (passenger and cargo) and employment in government, there has been a

significant increase in the number of public companies and private businesses. Unlike other atolls of Maldives, Haa Dhaalu atoll does not have any tourist resorts within the atoll. While this remains to be a problem that has been raised by the communities, few people from the island work in the tourism industry in other nearby atolls. Although two islands have been leased for tourist resorts none have been developed as yet.

Government incentive programs such as duty concession of 30% for goods discharged at Kulhudhuffushi port increased the whole sale and retail businesses. Furthermore, with the improved connectivity of the national transport system and reduced cost of transport, the well-established traders of Kulhudhuffushi earned the benefit. Boat building is also practiced to some extent in the island. They are mostly built for the purpose of transport of goods to and from Male' and also to and from other islands in Haa Alifu, Haa Dhaalu and Shaviynai Atoll.

Government (civil service) and public enterprises are the major employers on the island. Employment in whole sale and retail sector and transport sector shows a significant increase while there is a decrease in employment in fishing and related activities.

2.5.1. Employment and occupational structure

Since the previous DIRAM report, there have been no studies conducted to analyse the employment and occupation of the islands. According to Census 2006, a total of 2,544 people are economically active (MPND, 2007). However with the increase in population and economic activities in the island the figures stated in Table 3 below would be very different now. Unfortunately recent figures are not available and the analysis is based on the change of trends observed during field work surveys.

TABLE 3 EMPLOYMENT OF KULHUDHUFFUSHI COMMUNITY AS REPORTED IN POPULATION CENSUS 2006 (MPND 2007)

Economically active population	2,176
Economically inactive population	1,781
Labor force participation	57.6%
Rate of unemployment	14.5%

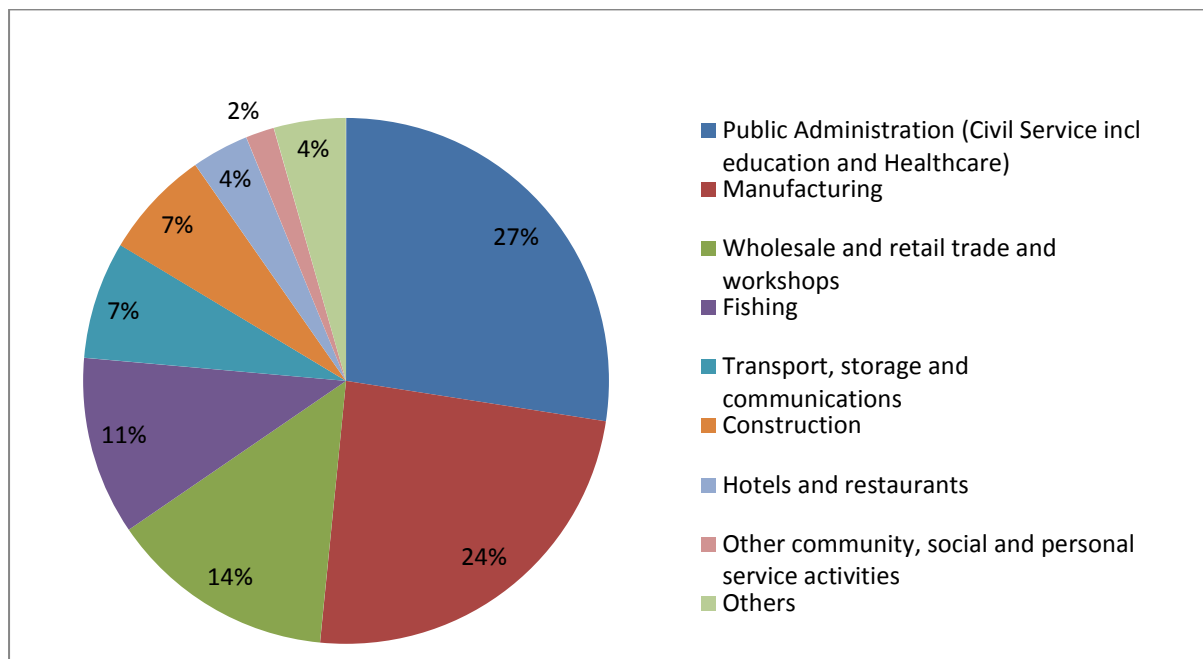


FIGURE 9 PROPORTION OF EMPLOYMENT BY ECONOMIC ACTIVITY FROM CENSUS 2006 (MPND 2007)

TABLE 4 EMPLOYMENTS BY SECTOR AND GENDER

Economic Activity	Female	Male	Total
Public Administration (Civil Service including education and Healthcare)	294	269	563
Manufacturing	375	120	495
Wholesale and retail trade and workshops	127	157	284
Fishing	19	206	225
Transport, storage and communications	10	138	148
Construction	2	135	137
Hotels and restaurants	40	32	72
Other community, social and personal service activities	7	29	36
Real Estate, renting and business activities	4	23	27
Mining and quarrying	0	23	23

Electricity, Gas and Water supply	1	19	20
Financial intermediation	6	6	12
Agriculture	2	7	9

As observed during the field work and based on data provided by the island office, the main employers are the government (civil service) and public enterprises. The current trends in employment are as follows:

- The increase in usage of International port and implementation of water and sewerage system has increased employment in Public enterprises.
- Employment in whole sale and retail trade is on the increase.
- Employment in the fisheries sector is decreasing due to the decreasing income level and other job opportunities.
- Number of females in employment has increased, especially in administrative and salesman positions in the whole sale and retail sector.

2.5.2. Economic structure by investment and income

The main economic activity in terms of income is employment in civil service and public enterprises. The development of water and sewerage services along with the functioning of international port has increased the employment and income from these sectors. The estimated values for the monthly income and estimated total investment by sector are presented in Table 5 below. Income from civil service and public enterprise accounts for 34% of total income earned while income from fisheries accounts for 23% and wholesale and retail trade is 12%.

Since 2008, major investments have been made in health and education infrastructures and capacity building. An additional investment of 391,919,856.16 Rufiyaa funded by the government, donations and loans have been made on the island in infrastructure, education, communication and health sector since 2008. Among the basic sectors, whole sale and retail trade have an estimated value of over 120 Million followed by fisheries sector with over 100 million. It should be noted that these figures are estimates based on averages and should be interpreted only as a guide rather than exact values.

TABLE 5 ESTIMATED VALUES OF INVESTMENT AND MONTHLY INCOME BY SECTOR

Sector	Estimated Monthly Income*	Estimated Investment
Fisheries	2,500,000.00	106,100,000.00
Public Administration (Civil Service incl. education and Healthcare)	4,411,303.90	243,083,869.08
Manufacturing	1,515,500.00	16,500,000.00
Wholesale and retail trade and workshops	1,658,000.00	120,000,000.00
Transport, storage and communications	766,666.00	371,229,267.81
Construction	440,000.00	25,000,000.00
Tourism	250,000.00	
Hotels and restaurants	197,950.00	3,300,000.00
Other community, social and personal service activities	116,095.00	31,519,493.98
Real Estate, renting and business activities	120,000.00	149,453,309.00
Electricity, Gas and Water supply	480,000.00	244,836,188.93
Mining and quarrying	250,000.00	4,000,000.00
Financial intermediation	90,000.00	3,000,000.00
Agriculture	25,000.00	100,000.00

* Estimated income is for salaried employees only and is based on average income multiplied by the number of employees

2.5.3. Key sectors

Fishing: Fishing was the dominant economic sector in Kulhudhuffushi but with the ban on shark fishing and the low fish catch experienced over the past years due to factors such as climate change and also the change in fishing practices, the estimated monthly income has decreased to 2.5 million Rufiyaa from 2.9 million Rufiyaa in 2008. A total of 30 mechanized fishing vessels

and 6 sailing vessels are involved in fishing activities. The main type of fishery now carried out is the Yellow fin tuna fishery. While the bigger vessels spend 1 to 2 weeks out at sea, the smaller vessels normally return daily with their catch. The main market is the collector vessels operating in the north region. They are also sold to the Felivaru fish canning factory located in Central Maldives. Although most of the catches are sold outside, a small proportion of tuna is processed on the island. This processed fish is directly exported overseas. The main investments are made on fishing vessels to buy engines and other equipment.

Agriculture: Agricultural activities are practiced on a very small scale in Kulhudhuffushi. Main crops grown include vegetables such as cucumbers, tomatoes, egg plants, chillies and green leaves which are mostly used for salads. They are mostly grown in the backyards of households and are sold to the island as well as being exported to Male'. Since it is being practiced on a small scale, investments made in the area are also small and comprise mainly of water pumps, fertilizers and seeds. In addition, large fruit trees are also present within the island but are sparsely distributed.

Trade: There are about 263 wholesale and retail trade businesses established in Kulhudhuffushi. The volume of trade is estimated to have increased from 5-8 million Rufiyaa per month in 2008 to 12 million Rufiyaa in 2013. Wholesalers have started utilizing the international port to import goods directly from India. With the aid of government incentive of 30% duty concessions, the wholesalers have started importing food and construction material such as sand, aggregate, cement, plywood and roofing sheets from neighboring countries. These goods are distributed to retailers in the island, wholesalers and retailers in Haa Dhaalu Atoll, Haa Alifu atoll and Shaviyani Atoll. These direct imports have also increased the storage and warehousing costs. There are about 6 major wholesalers on the island. The distribution network is supported by public transport network and private cargo boats.

Civil Service & Public Enterprises: This sector accounts for 33% of total income earned. Government is the largest single employer and employment in other public enterprises has increased employment economy. Employment is primarily in education, general island administration and health care sectors. These sectors provide the main source of income for most of the people of Kulhudhuffushi. Their dependence on government for income/finance reduces their vulnerability towards personal income losses from a disaster.

Construction: Although lots of construction works is ongoing on the island, the construction sector is not well developed and only a single company has the capacity to manage complex projects. Most construction projects are undertaken by foreigners who work in groups. They are more preferable among the community as their prices are lower compared to awarding to

a contractor for a lump sum fee. There is a high demand for construction sector especially in government housing projects. However apart from the construction of the 5 row house units, all other projects were awarded to companies out of Kulhudhuffushi. Investments in this sector are estimated to be around 25 million Rufiyaa and it accounts for 3% of total private investment. The foreign labor has become a concerning issue. Community members who are in construction work are jobless since they are being replaced by the foreign workers who offer cheaper rates.

Transport Sector: The transport sector is well-established with 02 cargo boats, 4 cargo plus passenger boats and 8 speed boats. Direct imports of goods from overseas to the island (regional port) have increased the demand for transport services. Kulhudhuffushi is the hub for distribution of goods to islands in Haa Alifu, Haa Dhaalu and Shaviynai Atoll. While the cargo plus passenger boats travel to and from Male', the speed boats cater for inter-island transport, particularly to and from the airport and for emergency medical transfers.

Other businesses: There are many small businesses in the service sector and also small-medium industries. However, exact numbers cannot be determined due to lack of data. Businesses involved in the service sector include the bank, tailors, saloons and guesthouses. Small-medium industries include rope making, weaving, cake baking and decorations etc. The available data on these establishments are presented in Table 6 below.

TABLE 6 LOCAL BUSINESS ESTABLISHMENT INVENTORY AS OBTAINED FROM FIELD SURVEYS

Economic Establishments	Number
Retail & Wholesale	263
Cafe's, Restaurants, <i>Hotaa</i> (tea shops)	13
Guest Houses	2
Warehouse	5
Fuel Supply	1
Personal Services (salon, tailors etc.)	10
Infrastructure	6
Field Office	1
Carpentry	4
Private Health Services	1
Pharmacies	5

Workshops	10
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2.5.4. Infrastructure and Services

i. Transport infrastructure

The key transport infrastructures in the island are the regional port and the local harbor. The port caters to large container vessels from overseas. The local harbor was completed in 2010 and 9 ha of land was reclaimed under the project with a total cost of 51 million Rufiyaa. The road development project which includes the provision of asphalt road surface and the necessary drainage for the selected main roads of the island is ongoing at a slow pace. This project involves upgrading of the main road (*Ameenee Magu*) of the island. In addition a total area of 36 ha of land has been reclaimed under the Kulhudhuffushi reclamation project with a cost of 124 Million Rufiyaa.

ii. Communications infrastructure

The *DHIRAAGU* and *Wataniya* site offices with the communication towers are the main communication infrastructures on the island. The site offices also house the necessary communication equipment to service a large part of the atoll. They also connect Haa Alif atoll to the main networks. The fiber optic submarine cable network system that has been implemented by DHIRAAGU with the aid of Japan's NEC Corporation runs through North to South of Maldives covering eight strategic locations. They include Kulhudhuffushi (starting point), Baa Eydhafushi, Hulhumale', Alif DhaalU Dhangethi, Laamu Gan, GaafuDhaalu Gahdhoo, Seenu Hithadhoo and Fuvahmulah. This system is expected to enhance the quality of the services and expand high-speed broadband internet service.

iii. Health care

Kulhudhuffushi has the regional hospital catering to Haa Alifu, Haa Dhaalu and Shaviyani atoll. The 50 bed hospital is currently equipped with 17 doctors and 68 nurses. The laboratory service provides blood and urine testing services. Lot of people from nearby islands and atolls move in and out every week mainly to attain health care services from the hospital. Approximately 19 million Rufiyaa has been invested since 2008 in the sector mostly in infrastructure development.

iv. Water supply

The main sources of water are desalinated water and rain water. Groundwater is also used for washing and bathing purposes. The water supply project was initiated in July 2010 and completed in 2011. It consists of a network of 43.3km which provides metered connection to

1600 households and all the government and private institutions. The project cost was approximately 22 million Rufiyaa.

v. Sanitation

The sanitation project including sewer reticulation system, sewer pumping system, sewer outfall, supply and installation of sewer outfall and construction of administrative building was initiated in July 2007 and completed in March 2010. The project cost was 96 million Rufiyaa

vi. Waste management

A waste management site has been established on the southeastern corner of the island and undertakes sorting and disposal activities for Kulhudhuffushi and surrounding islands. However they need a better system as at present the site and waste disposal is not managed properly.

vii. Power

Power supply for Kulhudhuffushi is provided and managed by State Electric Company (STELCO). The supply system comprises of 4 diesel generators. These generators are stationed at a higher elevation to protect them from disasters. The power grid is laid underground along the streets. A backup generator is stationed at the hospital which can be used in case of an electric emergency.

viii. Critical infrastructures

The regional hospital, pharmacies, power house and power grid, water supply system, sewerage system, island harbor, regional port and the communication infrastructures are all considered as critical infrastructures which are further analyzed under risk assessment (section 5.2).

3. Environmental Vulnerability Assessment

3.1. Natural Hazards

Natural hazards facing the Maldives can be classified into geological hazards (earthquakes, coastal erosion, landslides, reef slope failure), meteorological hazards (tropical cyclones, tropical storms, thunder storms, windstorms), hydrological hazards (tsunamis, storm surge, swells and other storm induced flooding (*Udha*), drought, saltwater intrusion) and climate change related hazards (sea level rise, changes in precipitation, sea surface temperature rise) (UNDP, 2008). For detailed background information of different types of natural hazards, the reader is directed to the previous DIRAM study (UNDP, 2008).

Out of these different types of natural hazards, the following major hazards were identified specifically for Kulhudhuffushi (UNDP, 2008):

- Windstorms
- Flooding due to heavy rainfall/storms
- Swell waves, storm surges and *udha*
- Tsunami
- Earthquake
- Climate change

3.1.1. Windstorms

The southwest monsoon generally brings heavy rain and strong winds. Apart from this annual monsoonal cycle, severe local storms (thunder storms) and tropical cyclone induced strong winds leads to extensive damage to trees and infrastructure. According to Maldives Disaster Risk Profile (UNDP, 2008) 11 cyclones crossed the Maldives during the last 128 years. Most of the cyclones passed over the north of the country. Since the destructive area of a cyclone can be very large, it can cause extensive damage to islands in the north of the country. According to UNDP (2008), Kulhudhuffushi lies in the region where the impact of cyclone related hazards would be felt the greatest.

Official records of historical storm events are not maintained. However UNDP (2008) list three storm events in July 1973, 17 June 1975 and 24 May 2005 that caused damage to few houses and uprooted trees. No such events that lead to any major damage due to high winds, have been recorded between 2008 and the present.

In order to understand the wind pattern since the 2008 DIRAM report, hourly wind data from Hanimaadhoo was analyzed and results are shown in table 7 and figure 10. From the analysis it was clear that between May 2008 and December 2012, the highest recorded wind speed at Hanimaadhoo was 30 knots which was well below gale force winds. Over this period, 99% of the time the recorded wind speed did not go above 4 in the Beaufort scale which is classified as moderate breeze. It was also evident that the highest wind speed and frequency was from the west quadrant, which corresponds to the southwest monsoon. According to the discussions and interviews held with the island community, there was no major damage to the island resulting from strong wind since 2008.

TABLE 7 HOURLY WIND DATA FROM KAADEDHOO STATION

Wind Direction	Freq	Cum. Freq.	Wind Speed (Knots)														
			>0 - 2	>2 - 4	>4 - 6	>6 - 8	>8 - 10	>10 - 12	>12 - 14	>14 - 16	>16 - 18	>18 - 20	>20 - 22	>22 - 24	>24 - 26	>26 - 28	>28 - 30
22.5 NNE	3.9%	3.9%	0.005%	2.784%	0.964%	0.119%	0.020%	0.005%	0.008%								
45 NE	3.8%	7.7%		0.961%	1.777%	0.821%	0.211%	0.033%	0.015%	0.005%	0.003%						
67.5 ENE	5.1%	12.8%		0.882%	2.339%	1.111%	0.486%	0.191%	0.074%	0.015%	0.005%						
90 E	5.1%	17.9%		1.154%	2.146%	0.905%	0.511%	0.211%	0.104%	0.018%	0.003%						
112.5 ESE	1.1%	19.0%		0.501%	0.534%	0.069%	0.013%										
135 SE	1.0%	20.0%		0.440%	0.422%	0.086%	0.036%		0.003%	0.003%							
157.5 SSE	0.8%	20.8%		0.285%	0.346%	0.114%	0.041%	0.020%	0.003%								
180 S	1.1%	21.9%		0.338%	0.460%	0.168%	0.066%	0.028%	0.005%					0.003%			
202.5 SSW	2.2%	24.1%		0.702%	0.913%	0.358%	0.163%	0.064%	0.013%	0.005%							
225 SW	4.1%	28.2%		0.519%	1.312%	0.994%	0.661%	0.297%	0.226%	0.051%	0.010%	0.005%					
247.5 WSW	10.9%	39.0%		1.147%	3.216%	2.278%	1.996%	1.200%	0.653%	0.264%	0.074%	0.036%	0.005%	0.005%			
270 W	25.2%	64.2%		2.464%	6.349%	5.133%	4.884%	3.165%	2.153%	0.572%	0.211%	0.117%	0.043%	0.041%	0.013%	0.008%	0.003%
292.5 WNW	15.3%	79.5%		2.087%	4.131%	3.351%	2.520%	1.599%	1.078%	0.249%	0.117%	0.066%	0.033%	0.025%	0.008%	0.008%	0.003%
315 NNW	9.2%	88.7%		2.174%	3.882%	1.775%	0.859%	0.305%	0.153%	0.046%	0.028%	0.008%	0.003%				
337.5 NNW	5.6%	94.3%		1.752%	2.771%	0.658%	0.287%	0.107%	0.043%	0.005%	0.013%						
360 N	5.7%	100.0%		2.303%	2.733%	0.481%	0.114%	0.023%	0.013%								
Cumulative %			0.005%	20.49%	34.30%	18.42%	12.87%	7.249%	4.543%	1.233%	0.463%	0.234%	0.084%	0.071%	0.020%	0.015%	0.005%

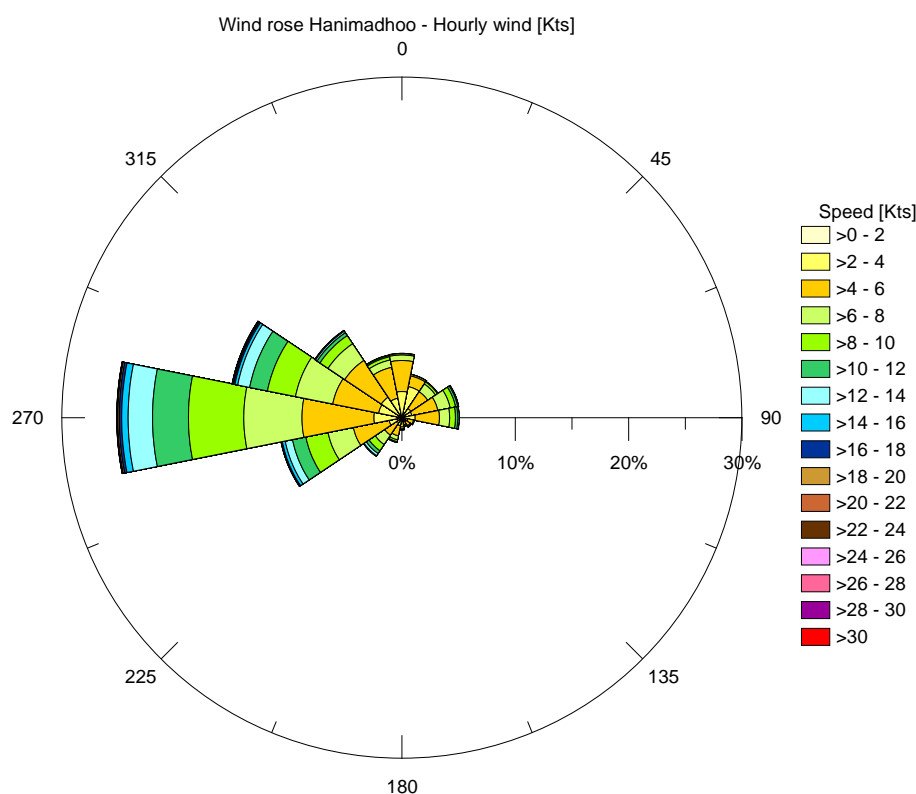


FIGURE 10 WIND ROSE DIAGRAM FOR RECORDED HOURLY WIND SPEED BETWEEN 2008 AND 2012

3.1.2. Flooding due to heavy rainfall

Flooding due to heavy rainfall is almost an annual event in Kulhudhuffushi. Due to the topography of the island, the north and south side of the island are most prone to flooding. The northern tip is mostly wetland or locally known as "*Kulhi*". The south end of the island used to have a similarly large wetland area which has since been reclaimed. However this reclaimed area is still generally lower than the rest of the island leading to periodic flooding during heavy rainfall.

Since the previous DIRAM study, Kulhudhuffushi has undergone major transformations. In 2010, 36 hectares of new land was reclaimed on the western side of the island. This new land was reclaimed to a height of 1.5m above mean sea level. The original western side of the island was much lower than this, resulting in a level difference of approximately 0.3-0.5m between the old and new island. Under the reclamation project, a natural ditch was provided to allow for natural drainage. But since this was not a properly engineered solution, water that would normally drain into the lagoon from the old eastern side of the island now gets accumulated in

this area. While the drain is reasonably effective in preventing major flooding of the roads and houses in the area, the island community reported minor flooding during heavy rain since the completion of the reclamation works.

For this study, daily rainfall data between 1998 and 2012 was obtained from the Hanimaadhoo weather station. According to the previous study the mean annual rainfall at Hanimaadhoo was 1818.7 mm and the mean monthly rainfall was 151.5mm. From the analysis of Hanimaadhoo data, it was found that the mean annual rainfall near Kulhudhufushi is 1761.6mm and the mean monthly rainfall is 146.8mm. Figure 11 shows the annual rainfall for the 15 year period between 1998 and 2012. The highest rainfall was measured at 2209.3 mm in the year 2004 with the lowest measured at 1346.5 in the year 2002.

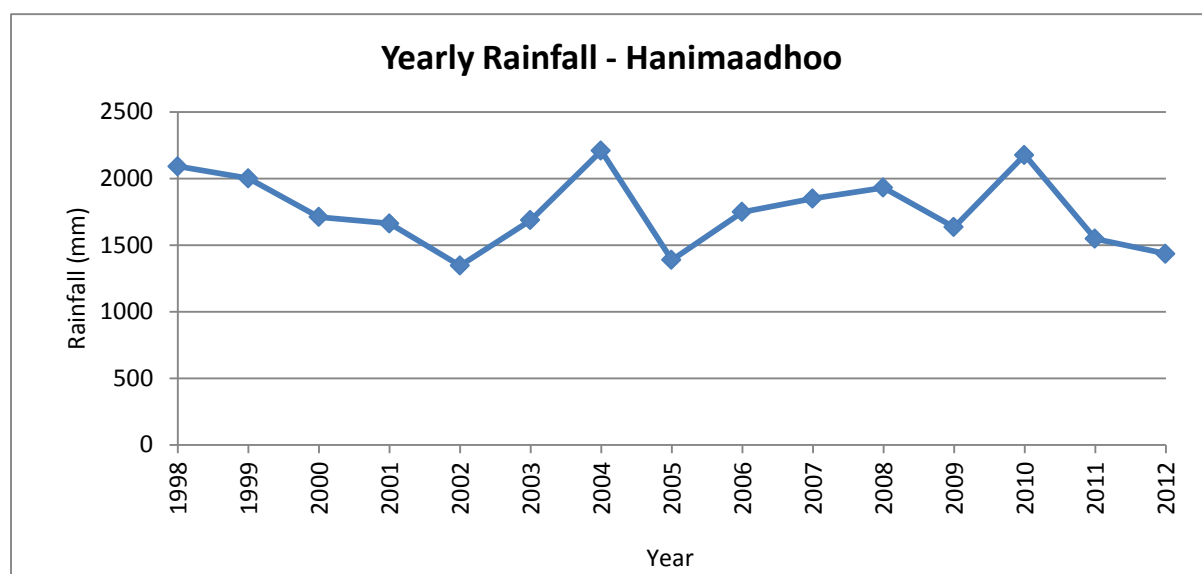


FIGURE 11 ANNUAL RAINFALL FOR THE 15-YEAR PERIOD BETWEEN 1998 AND 2012 (MMS , 2013)

For rainwater flooding, intensity of rain plays a major role, which can be determined by the rainfall per hour. However, the data that was available from Hanimaadhoo was daily measurements. Figure 12 shows the frequency of the daily rainfall measurements from the Hanimaadhoo data set.

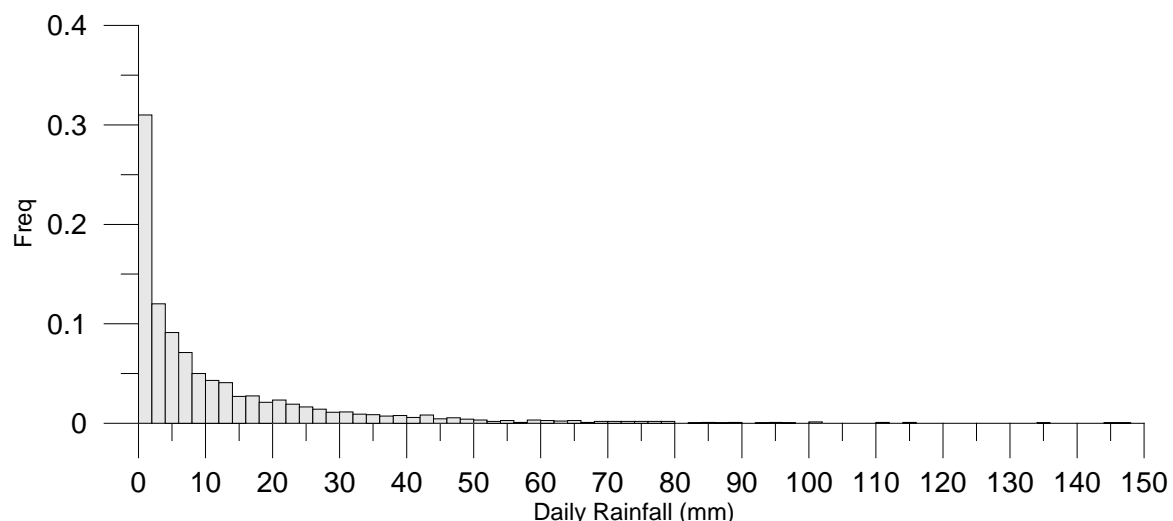


FIGURE 12 FREQUENCY OF THE DAILY RAINFALL

The highest daily rainfall was measured at 146.9 on 26th May 2008, which can be classified as Torrential Rain. From the results it was clear that for over 95% of the time, the daily rainfall limit was less than 50mm. If daily rainfall exceeds 50mm it is commonly referred to as Heavy rain. From these results it is evident that within a year, approximately 14 days would experience heavy rainfall, which can potentially cause flooding events in the island.

Future Predictions

UNDP (2006) predicted the probable maximum rainfall for different return periods using rainfall data from the Hanimaadhoo weather station (Table 8).

TABLE 8 PROBABLE MAXIMUM RAINFALL FOR DIFFERENT RETURN PERIODS

Return Period	50 Years	100 Years	200 Years	500 Years
Rainfall (mm)	141.5	151.8	162.1	175.6

More recently in 2011, Regional Integrated Multi-Hazard Early Warning System for Africa & Asia (RIMES) worked on the Development of High-Resolution Regional Climate Change Model for the Maldives through statistical and dynamic downscaling of global climate change models to provide future projects for rainfall, sea level rise and sea surface temperature. The future projection of rainfall by RIMES (2011), show both an enhanced variability and an increasing tendency, with the entire country having a greater increase in rainfall in the future.

According to the findings of RIMES (2011), the increase in rainfall would be accompanied by extreme events such as maximum one-day rainfall and increase number of consecutive wet days increasing over the Maldives. For example the baseline maximum daily rainfall of 55mm for the Maldives is projected to reach 100 mm in 2021-2050 and 112mm in 2082-2100. Similarly, consecutive five days rainfall 217mm would increase to 318mm in 2021-2050 and 382mm in 2082-2100.

3.1.3. Flooding due to swells, storm surge and *Udha*

“Udha” is the local term used historically to describe a flooding event caused by elevated water levels coupled with swells and/or wind generated waves. However in recent times “Udha” is commonly used to describe any flooding event caused by waves and high tides. This of course does not include flooding due to tsunamis. As described in the previous DIRAM study (UNDP, 2008) it is difficult to discern the difference between “Udha” and flooding due to swells and storm surge events. Hence for the purpose of this report, flooding due to swell and storm surge would also cover “Udha”.

Swells are long period waves generated from off-shore storm events. It has been established that swells predominantly approach the Maldives from a southerly direction (Young, 1999). Together with abnormal swell waves originating from storm events in the southern hemisphere, it leads to swells approaching the island from a south, south easterly direction and waves propagating through the atoll to approach from south westerly direction.

In addition to swell waves, Kulhudhuffushi is also exposed to storm surges generated due to low atmospheric pressure of severe storm events such as tropical cyclones. According to UNDP (2006) Kulhudhuffushi is located in a moderate storm surge zone that could see storm surges of a maximum of 0.6m. While this may seem small compared to storm surges reported in areas with continental shelf, the surge combined with high tides and large wind generated waves can cause serious overtopping and damage to the island.

Kulhudhuffushi coastline is also exposed to wind generated waves which are governed by the monsoonal winds. During the southwest monsoon and northeast monsoon, west and east coast would be impacted by wind generated waves respectively. The wind generated wave heights is a function of wind speed, duration and fetch length. Since to the east of Kulhudhuffushi is open ocean, wind generated waves from this direction are generally speed and duration limited, whereas waves during the southwest monsoon generated inside the atoll would probably be fetch limited. Wind generated waves are relatively small and in itself are not

likely to be a hazard. However wind generated waves combined with a severe storm surge could lead to wave overtopping causing widespread flooding.

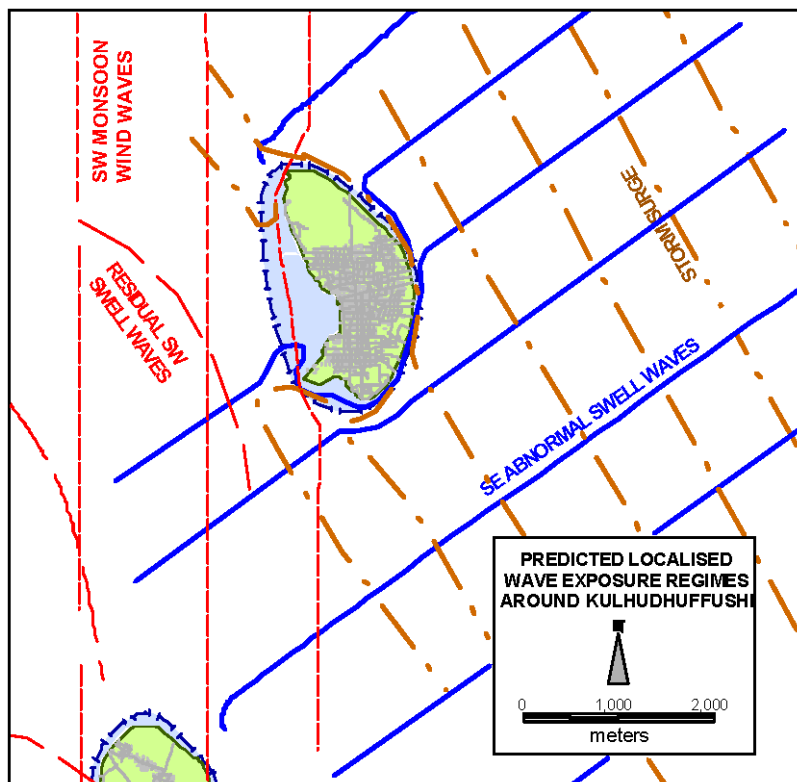


FIGURE 13 PROBABLE WAVE PROPAGATION PATTERN AROUND KULHUDHUFUSHI (SOURCE: DIRAM, 2008)

3.1.4. Tsunamis

Prior to the 2004 Indian Ocean Tsunami, there is no record of any tsunami events impacting the Maldives. This is in part due to the fact that tsunamis are relatively rare in the Indian Ocean. According to the National Geophysical Data Center of NOAA, only a total of 86 tsunami events are recorded in the Indian Ocean over the entire recorded history. Most of these events are of relatively low magnitude (NOAA 2005).

Tsunamis can be generated from various sources such as submarine earthquake, volcanic explosion, underwater landslides, underwater explosions and meteorite impact. Earthquake generated tsunamis are the most common and mostly likely to impact compared to other

generation sources. There are 3 earthquake zones in the Indian Ocean that could lead to the generation of a tsunami, which are The Sunda Trench, the Makran region and the Carlsberg Ridge (Figure 14).

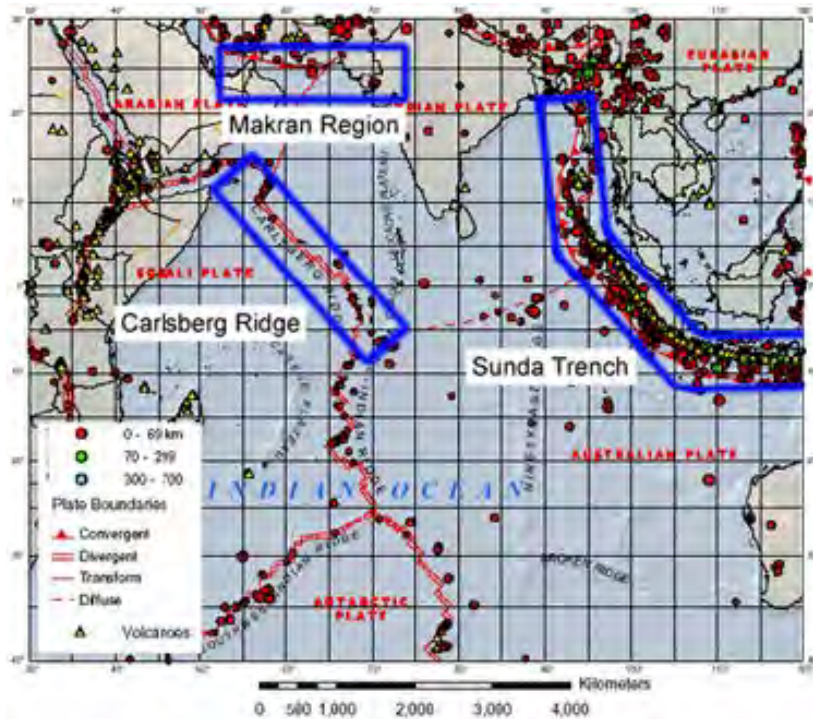


FIGURE 14 TSUNAMI SOURCE AND SIGNIFICANT EARTHQUAKE IN THE INDIAN OCEAN (USGS, 2003)

The NOAA tsunami catalog indicates that only three tsunamis were generated from the Makran region and a single tsunami was generated from the Carlsberg ridge in the entire recorded history. Most of the tsunamis generated in the Indian Ocean are the result of submarine earthquakes in the subduction zone known as the Sunda Trench.

Therefore tsunami hazard is the highest to east side of the country. Tsunami propagation and inundation in the islands is subject to a lot of parameters. Propagation is mainly governed by the offshore bathymetry. The Figure 15 below shows the offshore bathymetry and tsunami wave propagation model for a tsunami generated in the Sunda Trench.

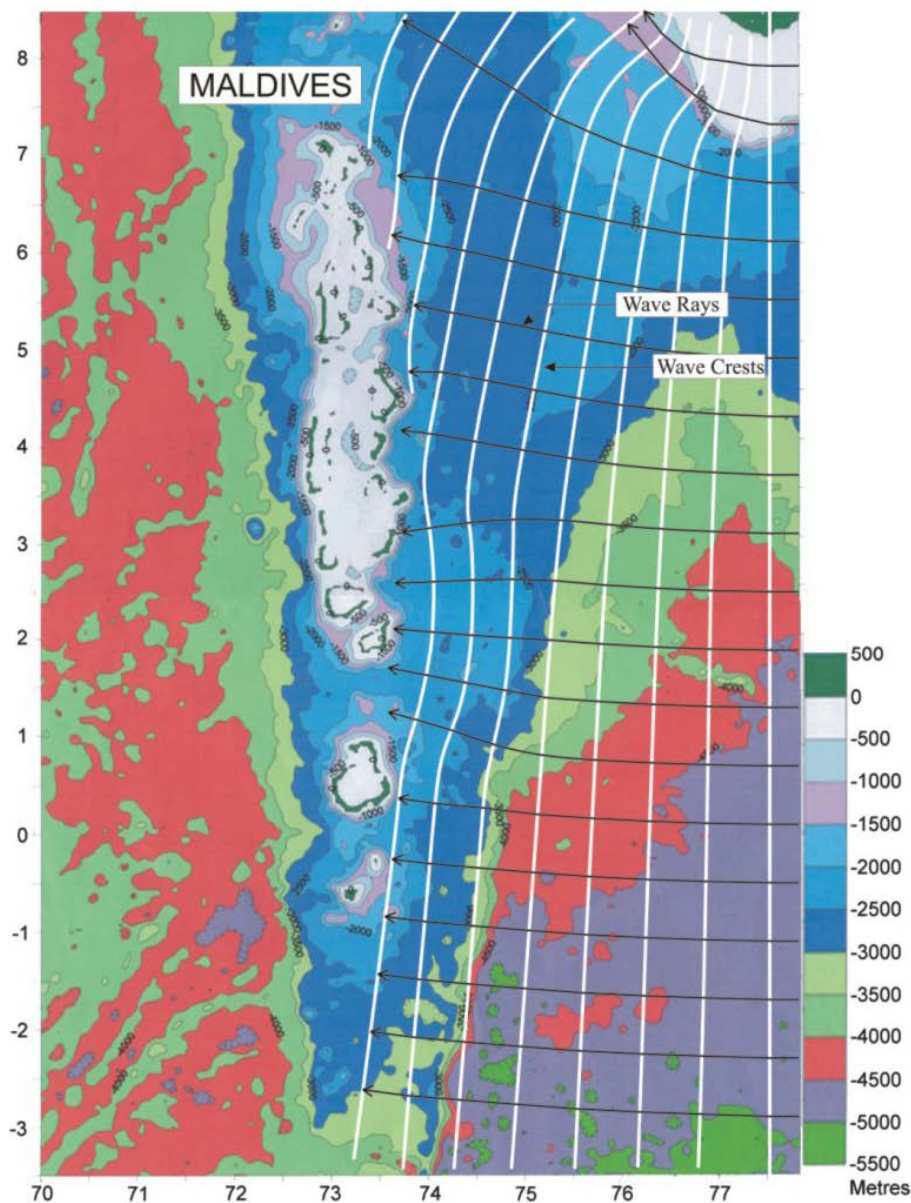


FIGURE 15 INDIAN OCEAN BATHYMETRY AND TSUNAMI PROPAGATION MODEL (ALI, 2005)

According to Ali (2005), due to the offshore bathymetry of the Maldives, tsunami wave convergence is always predicted for the central part of the country. This is true for any tsunami wave generated from the Sunda Trench. Therefore islands in Laamu, Thaa, Dhaalu and Vaavu are generally at the highest risk of tsunami impact compared to the rest of the country. However, Kulhudhuffushi being in the eastern rim of the Haa Dhaalu atoll, it is still at considerable risk from tsunami hazard. Figure 16 shows the tsunami hazard zones.

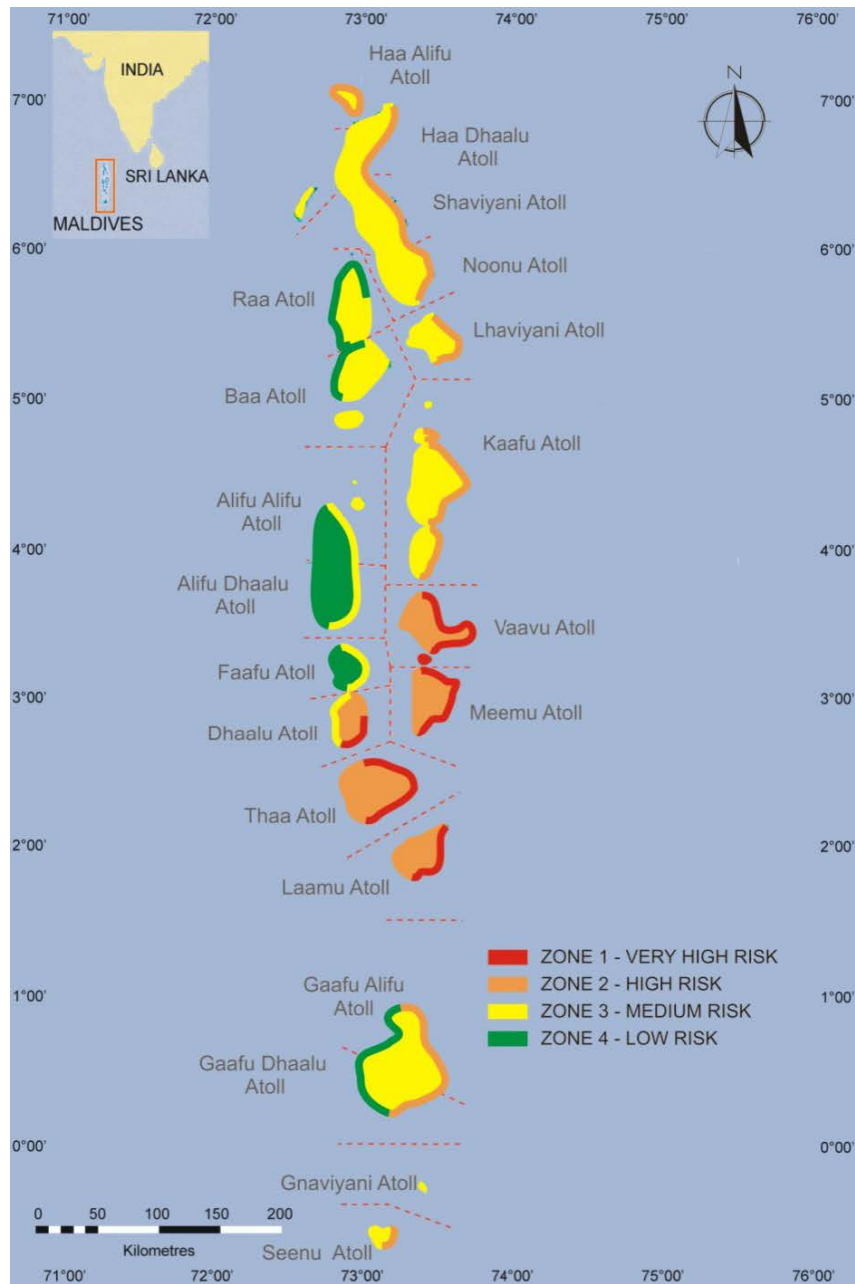


FIGURE 16 TSUNAMI RISK ZONE MAP (ALI, 2005)

3.1.5. Earthquakes

Maldives is not located in a seismically active zone and there are no records of any major earthquake activity in the Maldives. However tremors from distant earthquakes are felt in the country. The nearest source of earthquake activity is the mid-ocean ridge known as Carlsberg ridge located southeast of the country. Earthquakes generated at mid-ocean ridges are generally weak compared to subduction zone earthquakes. According to UNDP (2006) only southern atolls are at risk of any earthquake hazards, as shown in Figure 17.

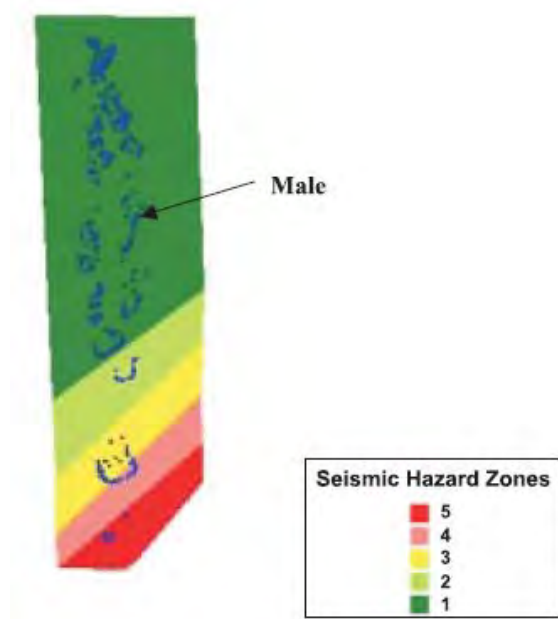


FIGURE 17 MALDIVES SEISMIC HAZARD ZONES (UNDP, 2006)

3.1.6. Climate change

Climate change has become one of the most critical issues facing the Maldives. Climate change induced Sea Level Rise (SLR) and Sea Surface Temperature (SST) rise would potentially have a devastating impact on the island ecology and geomorphology. The statistical downscaling carried by RIMES (2011) indicated that the sea surface temperature is projected to increase by 1.01°C to 1.93°C in the year 2050 and 1.27°C to 3.40°C in the year 2080. According to Khan et al. (2002) sea surface temperature around the Maldives could rise at a rate of 0.3°C per year.

The most comprehensive sea level rise study in the Maldives was carried out by Singh et al (2001) who concluded that the sea levels has risen between approximately 5.8 and 8.5 mm per

year around the Maldivian coast. This estimate is higher than the IPCC (2001) forecasted rate of 5mm per year. IPCC also forecasted that at the end of this century the sea level would rise to 0.88m above the current levels (IPCC, 2007). However it should be noted that the RIMES (2011) found that for the Haa Dhaalu atoll, the sea level is projected to rise by 0.89m in the year 2080.

The consequence of SLR and rise in SST is that the Maldives would be more vulnerable to hazards such as flooding of low-lying coastal areas, loss of land due to increase in coastal erosion, higher impact from future tsunami events, coral bleaching etc.

3.2. Existing environmental condition

3.2.1. Historical changes to Kulhudhuffushi shoreline and erosion

The shoreline of Kulhudhuffushi has been modified over the years both due to natural and man made changes. The 1969 and 1996 aerial image clearly shows that part of the north eastern shoreline and land is lost due to erosion (Figure 18). The enclosed mangrove pond at the northern side is now observed to be open while in comparison the 1969 image shows that it is closed and approximately 100m inside the shoreline. According to the image taken in 1996, a land area of approximately 300m length and 150m width has been lost.

Due to increased population and associated land requirement the southern side marsh land was reclaimed. The 1996 aerial image shows that almost 90% of the marsh land is filled with only a small area of south central pond and eastern side pond remaining. Currently the eastern pond area has been filled up and is used as a landfill. The two remaining small ponds are of 0.6ha and 0.2ha.

The western shoreline is observed to have undergone significant changes over the years due to development activities. The regional port facility at Kulhudhuffushi was completed in 2005, for which approximately 6.8ha of land was reclaimed. The domestic harbor facility at Kulhudhuffushi was completed in 2009. The dredged spoil generated from the basin excavations works was used to reclaim the land behind the harbor. Approximately 7.49 ha of land was reclaimed. The central western lagoon area was reclaimed in 2010 increasing the islands' area by approximately 28.6ha. These coastal modifications and reclamation projects have now straightened the previous concave shape of western shoreline.

The eastern shoreline of the island has not been modified over the years and remains relatively unchanged. Typical to exposed shorelines, Kulhudhuffushi eastern side shoreline is composed

of large rocks and rubble. The island ridge is most prominent at the east central and southern side of the island, while the north eastern ridge is less prominent compared to the central area. The only coastal structures on the eastern side are sea outfall pipe and Dhiraagu domestic submarine cable connecting Eydhafushi and Kulhudhuffushi. A trench is observed to be made at the central road across the island at the eastern side. This was possibly made during the construction works to lay the sewerage network.

Erosion around the island remains similar as discussed in the previous DIRAM study at the north, east and southern side of the island. Comparison of the satellite image and shoreline mapped during April 2013 (FIGURE 18) for this study showed that southern side of port area has gained land which is in contrast to the findings of the previous DIRAM study where this area was shown as area with lost land. The main reason for this accretion is constant movement of sediment from the eastern side due to erosion (swell wave induced). The coastal structures of the port (revetment and breakwater) stops the cyclic movement of the littoral sediment creating a net east to west flow. The revetment structure and the natural process at the southern end of the island creates a bay effect in this area.

Erosion is observed at the southern side of newly reclaimed land (close to the Regional Port's breakwater), while accretion is observed at the domestic harbor side. The coastal structures of the harbor and port acts as groynes in this area. The erosion and accretion is thought to be seasonal at this area. Since the final development of this area is a harbor facility protected by a breakwater, erosion issues at this area are not significant.

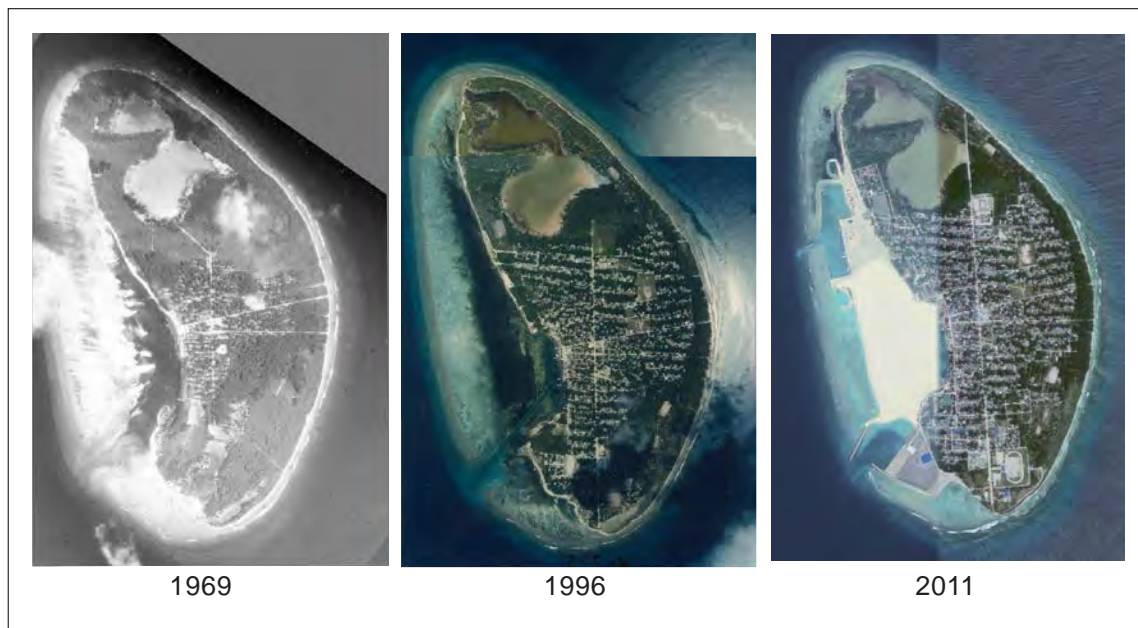


FIGURE 18 SATELLITE AND AERIAL IMAGES OF KULHUDHUFUSHI FROM 1969, 1996 AND 2011

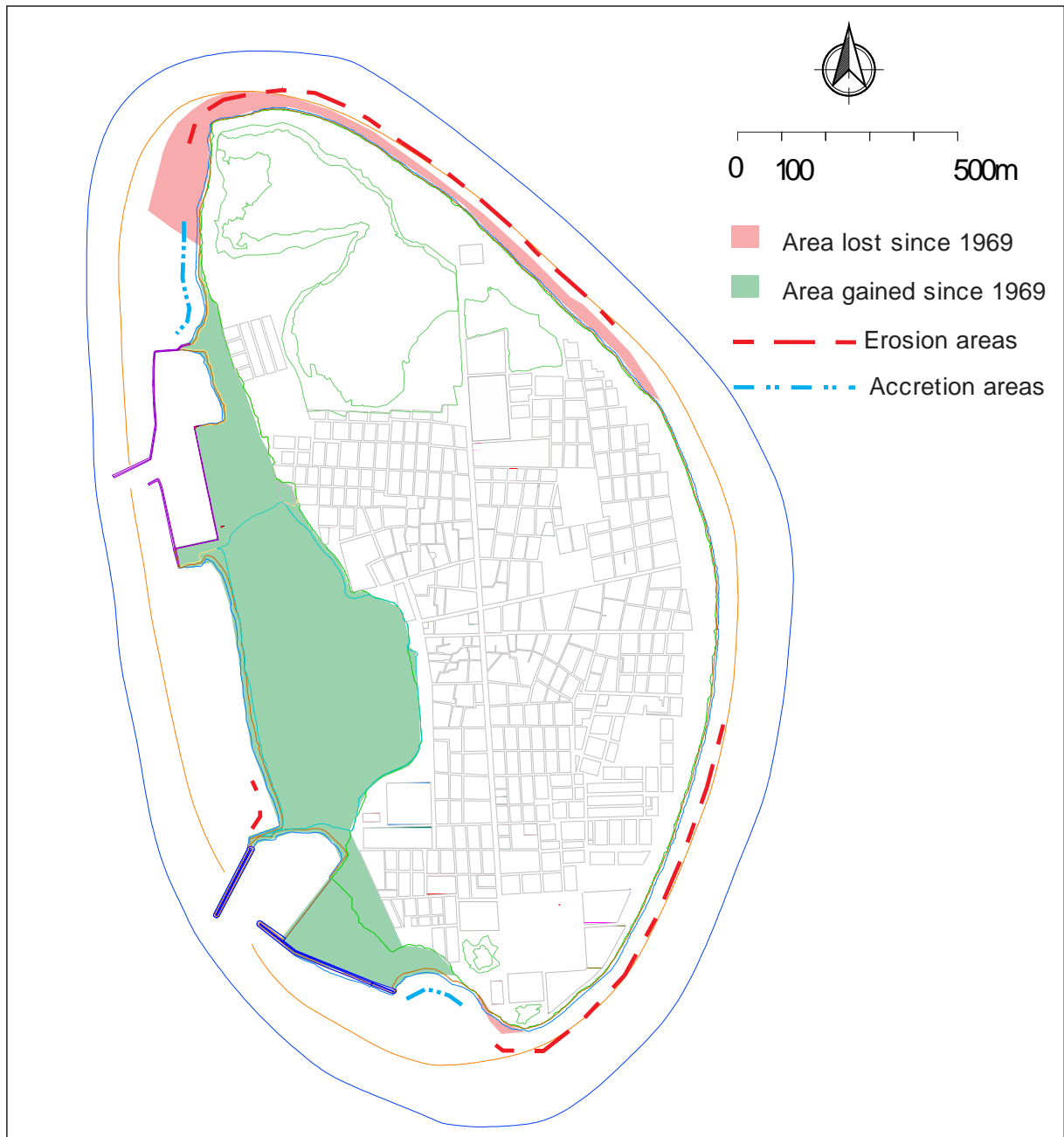


FIGURE 19 EROSION AND ACCRETION PATTERNS AT KULHUDHUFFUSHI [ADAPTED & MODIFIED FROM PREVIOUS DIRAM STUDY (UNDP 2008)]

3.2.2. Topography

Topographic assessment of Kulhudhuffushi in the previous study was assessed by using 3 profiles as shown in the figure below.

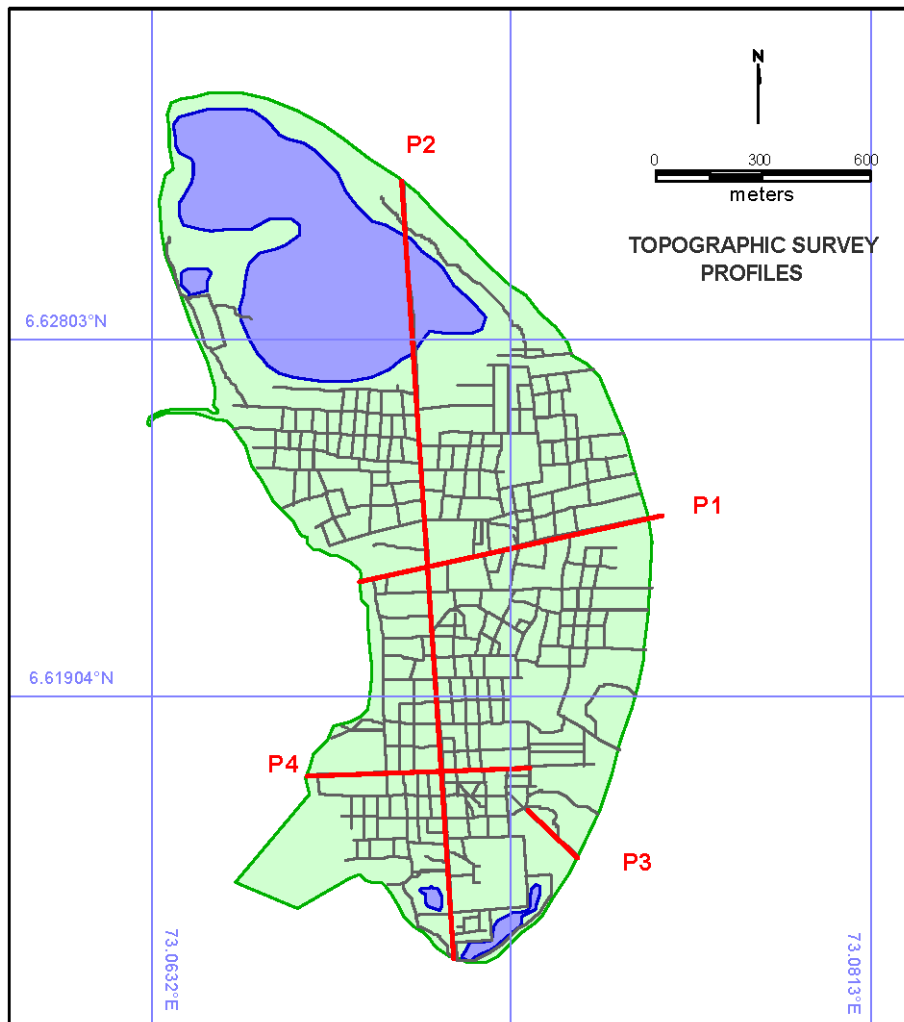


FIGURE 20 PROFILE LOCATION OF PREVIOUS DIRAM (UNDP 2008)

As part of this review process a Digital Elevation Model (DEM) was produced using elevation data collected from all roads, mangrove habitat and reclaimed land (see Figure 21). Two profiles were also derived from the DEM (see Figure 22) to assess changes to topography of the island (main road from south to north and road across the island from west to east). As part of DEM data collection process, 68 beach profiles were also taken. The beach profiles were taken from inside vegetation line to surf zone where possible. Selected profiles from this 68 are shown in this report for presentation purposes (Figure 25-Figure 32).

The DEM showed that the reclaimed lands (port, harbor and residential area reclaimed at the west central area) are significantly elevated compared to the rest of the island. The data also shows that the central area of the island is elevated compared to north and southern side. The maximum elevation (natural) at the eastern side of the island is 2.9m MSL (eastern side island ridge area). Similar to the findings in the previous study, the eastern side ridge is most prominent at the east central and south eastern side while north eastern and southern sides are less prominent.

The DEM shows that the finish height (the height after reclamation) of southern side marsh land is lower than the central area of the island, confirming the findings in the previous DIRAM study. Rainwater drainage is therefore diverted to these low elevated areas at the southern side of the island. Similar to the southern side, reclaimed marsh or wet land at the northern is also low elevated.

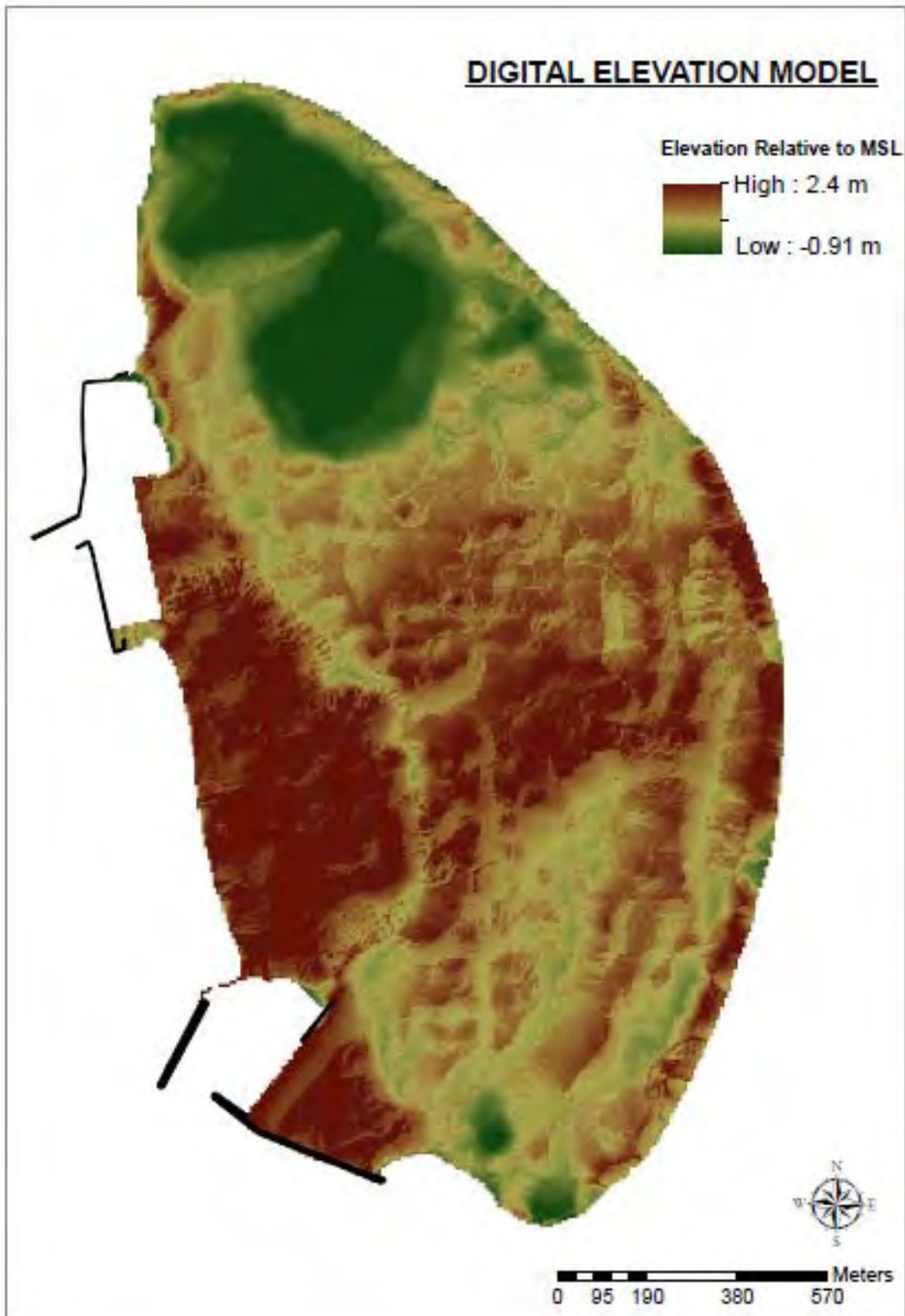


FIGURE 21 ELEVATION MODEL GENERATED USING ARCGIS SOFTWARE

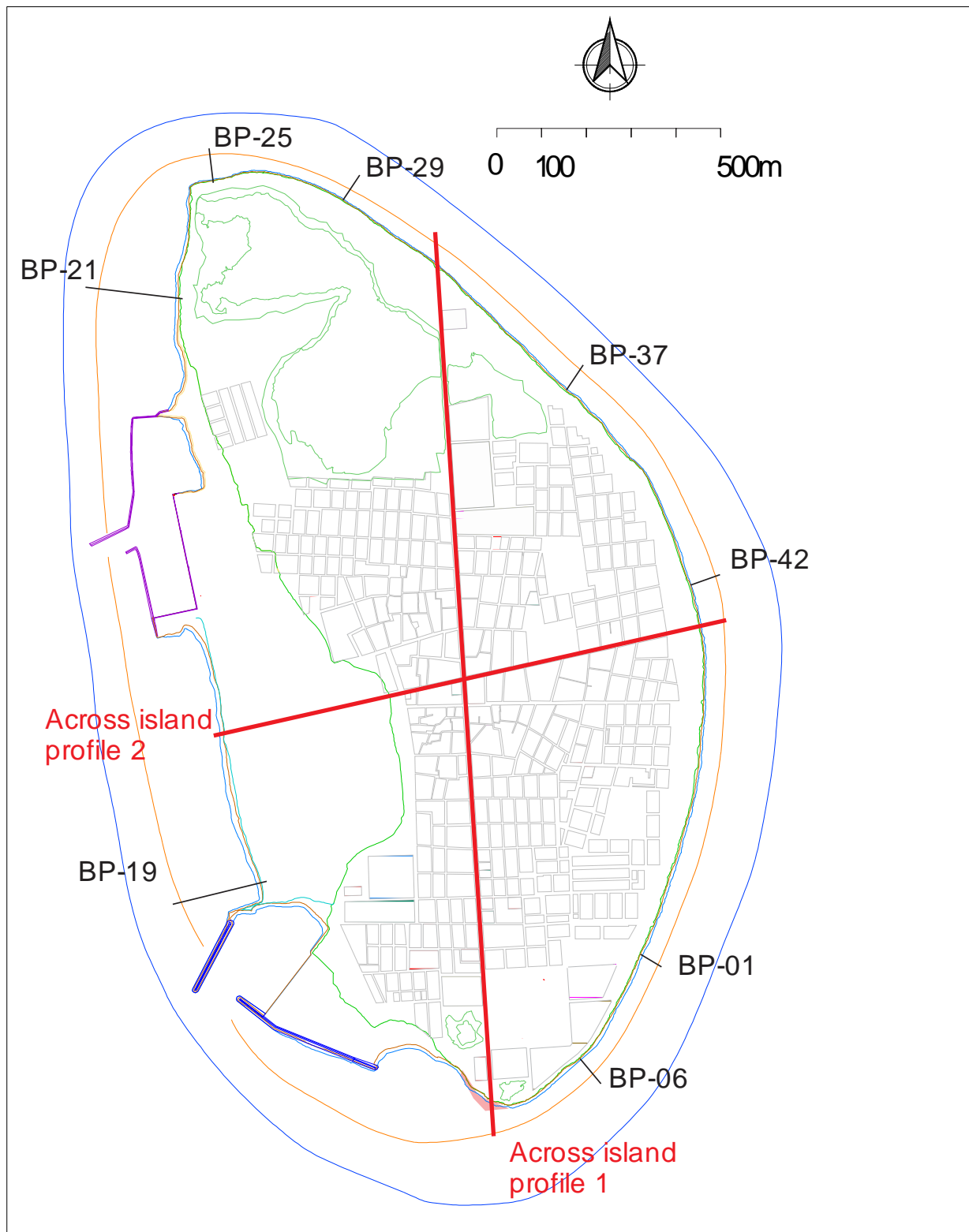


FIGURE 22 LOCATION OF ACROSS THE ISLAND PROFILES AND BEACH PROFILES

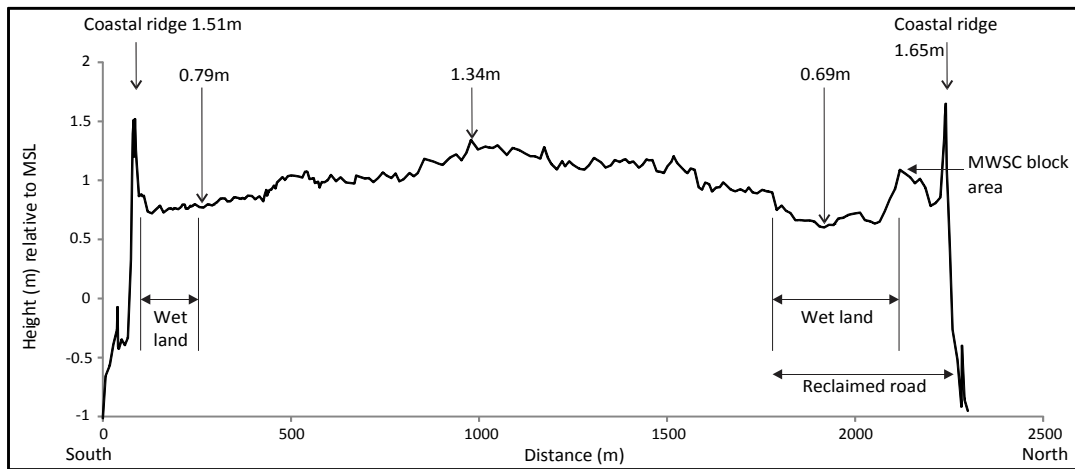


FIGURE 23 ACROSS THE ISLAND PROFILE 1

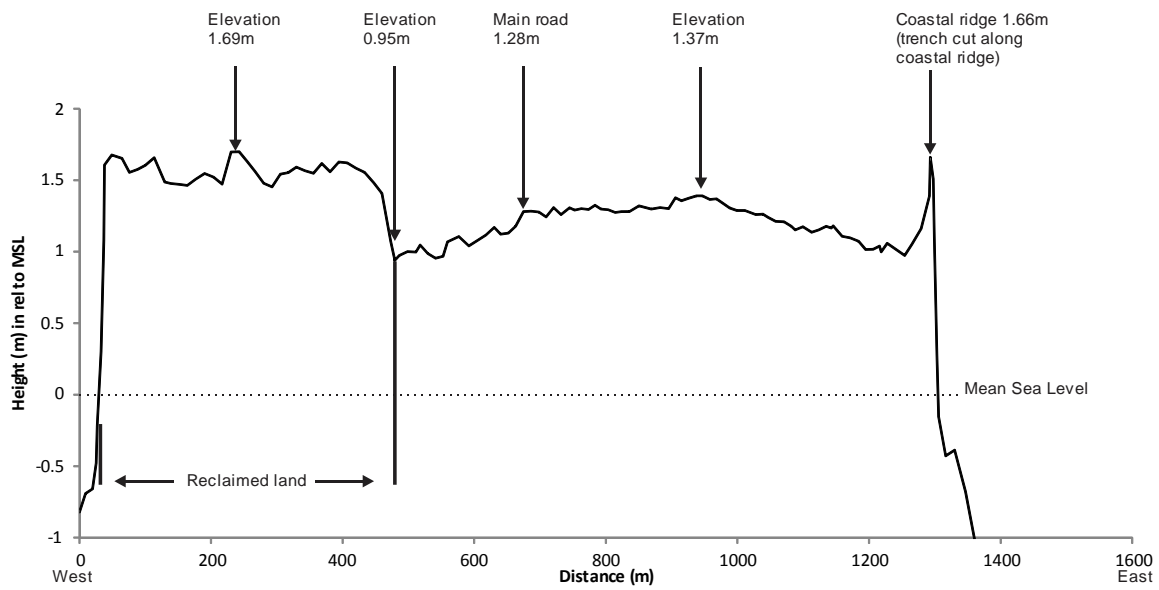


FIGURE 24 ACROSS THE ISLAND PROFILE 2

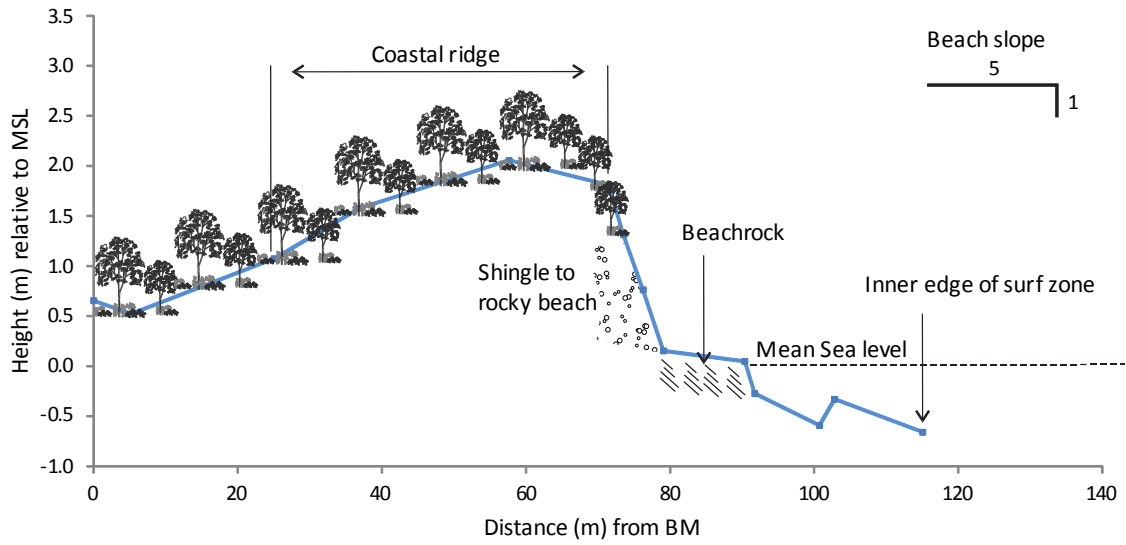


FIGURE 25 BEACH PROFILE 1

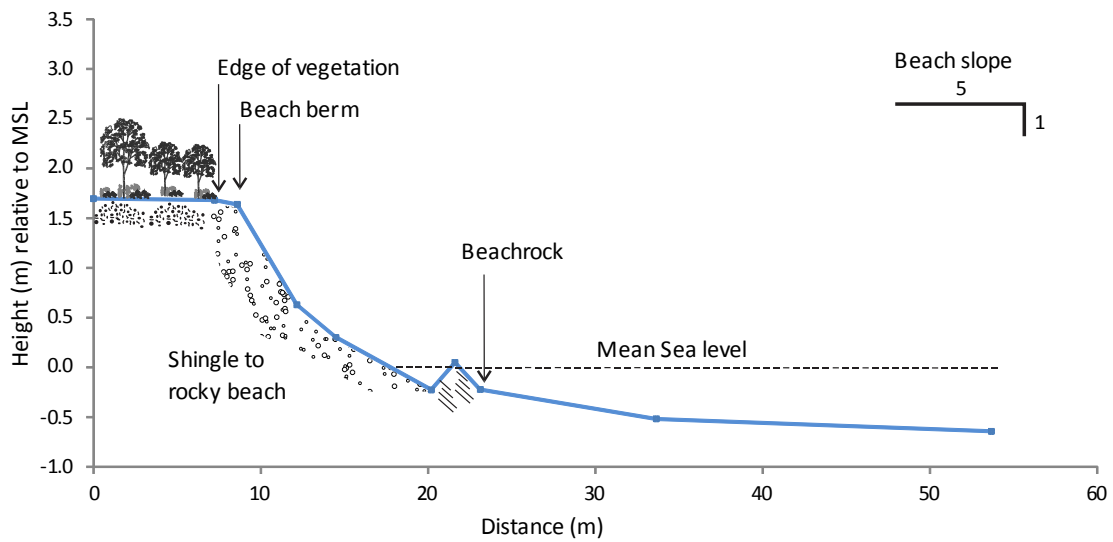


FIGURE 26 BEACH PROFILE 6

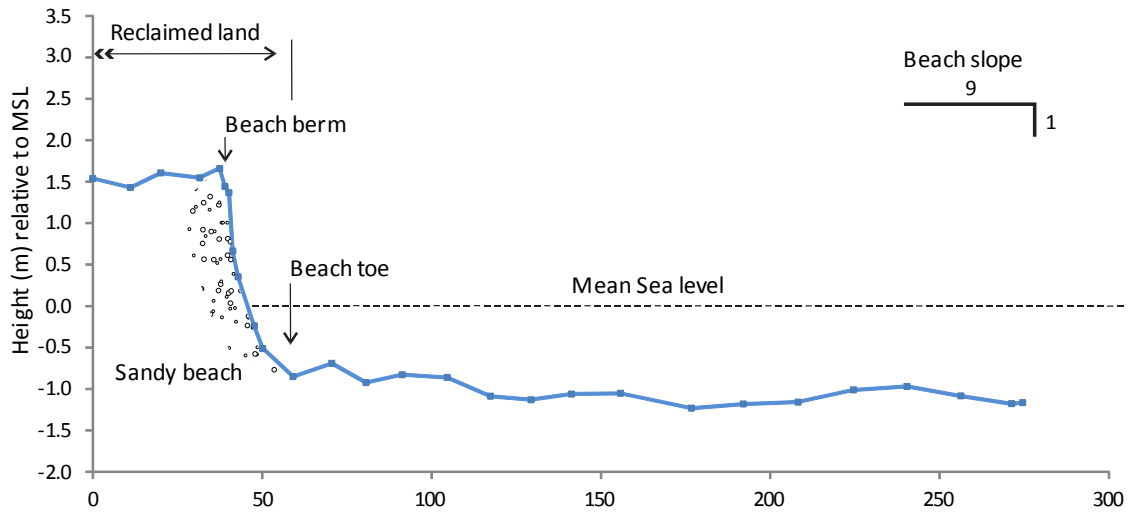


FIGURE 27 BEACH PROFILE 19

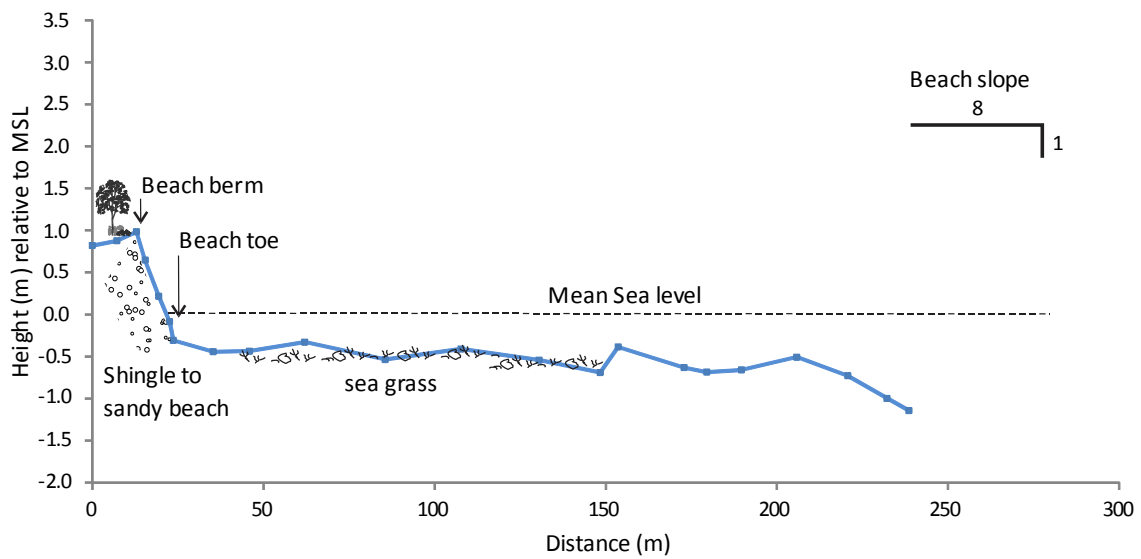


FIGURE 28 BEACH PROFILE 21

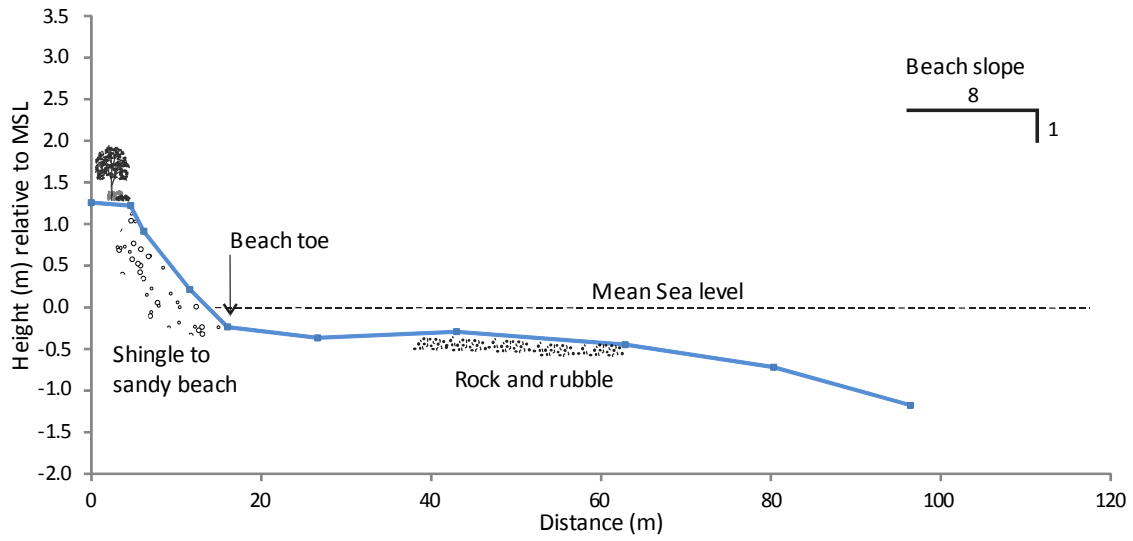


FIGURE 29 BEACH PROFILE 25

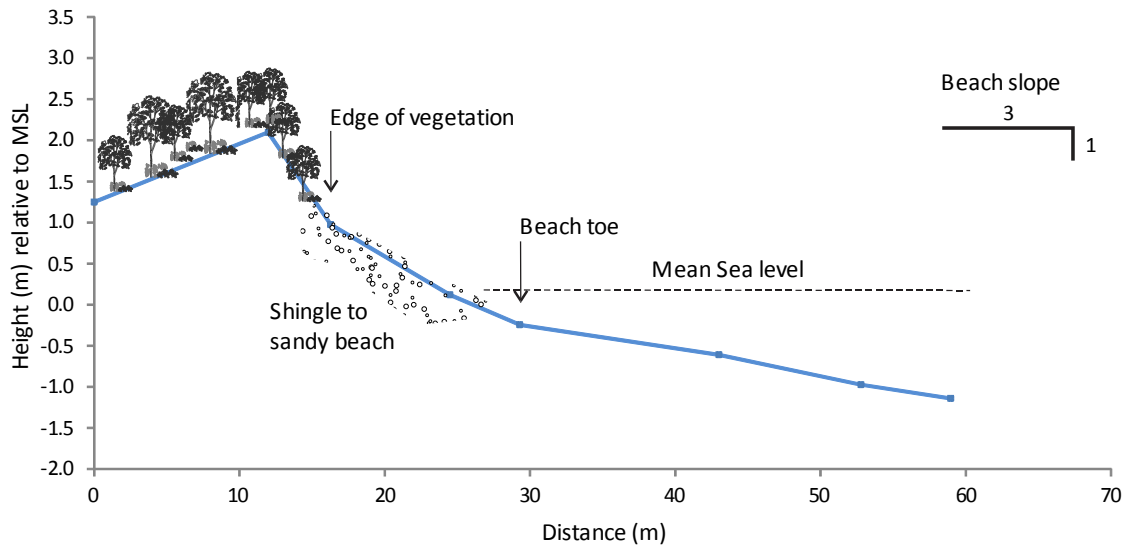


FIGURE 30 BEACH PROFILE 29

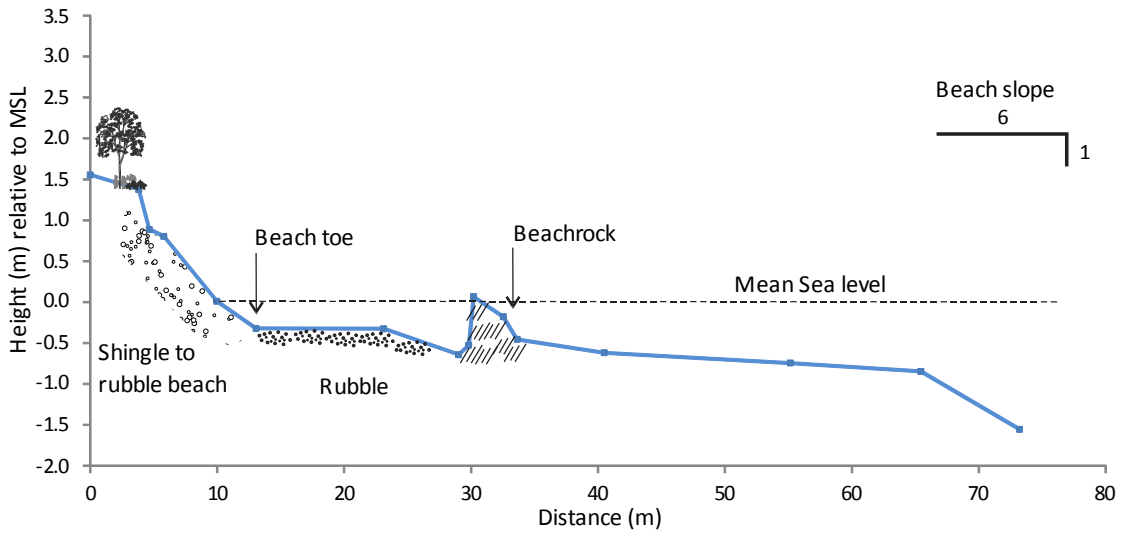


FIGURE 31 BEACH PROFILE 37

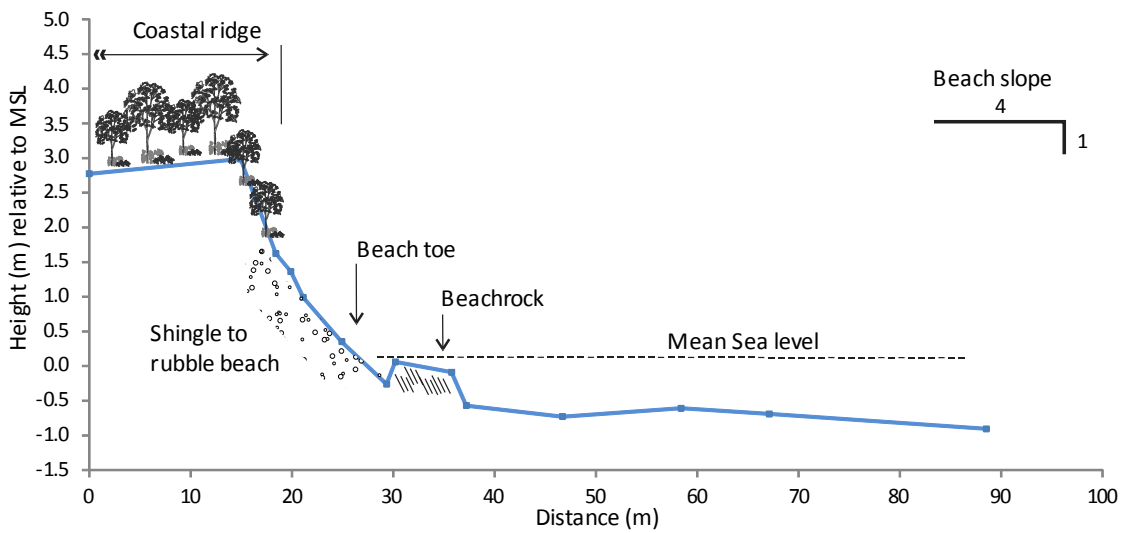


FIGURE 32 BEACH PROFILE 42

3.2.3. Vegetation

The vegetation cover at Kulhudhuffushi is sparse at the settlement area while dense vegetation is observed at the northern side wetland area and eastern side of the island (UNDP 2008). Vegetation at the settlement area are mostly fruit bearing trees or “shade trees”, which are observed at the back yards of residential plots.

Almost 90% of the southern wet land area has been lost, while remaining vegetation is observed on the eastern side of the wetland area. The northern side wetland vegetation is more or less intact. Part of the land east of the reclaimed land is being developed, therefore resulting in a loss of vegetation from these areas (MWSC plot and new housing areas).

The coastal vegetation on the eastern side is dense; this band of vegetation is denser at the east central and south eastern side of the island. The width of the coastal vegetation belt is 70m, confirming the findings in the previous study. Therefore the eastern side vegetation belt was largely untouched since the previous assessment. Although major part of the vegetation was untouched, part of this vegetation belt at the east central area was removed to construct a school. The width of vegetation belt at this area is now approximately 60m (see figure 33).

The eastern side coastal vegetation belt is a very important feature of the island in respect to coastal defense. The post tsunami assessment of Kulhudhuffushi also revealed that only minor inundation occurred at the east central area of the island (UNDP, 2008). The main reasons for this are the high coastal ridge and the thick strong coastal vegetation. Therefore it is essential to protect and restore this natural coastal defense features of the island through climate change adaptation and mitigation measures.

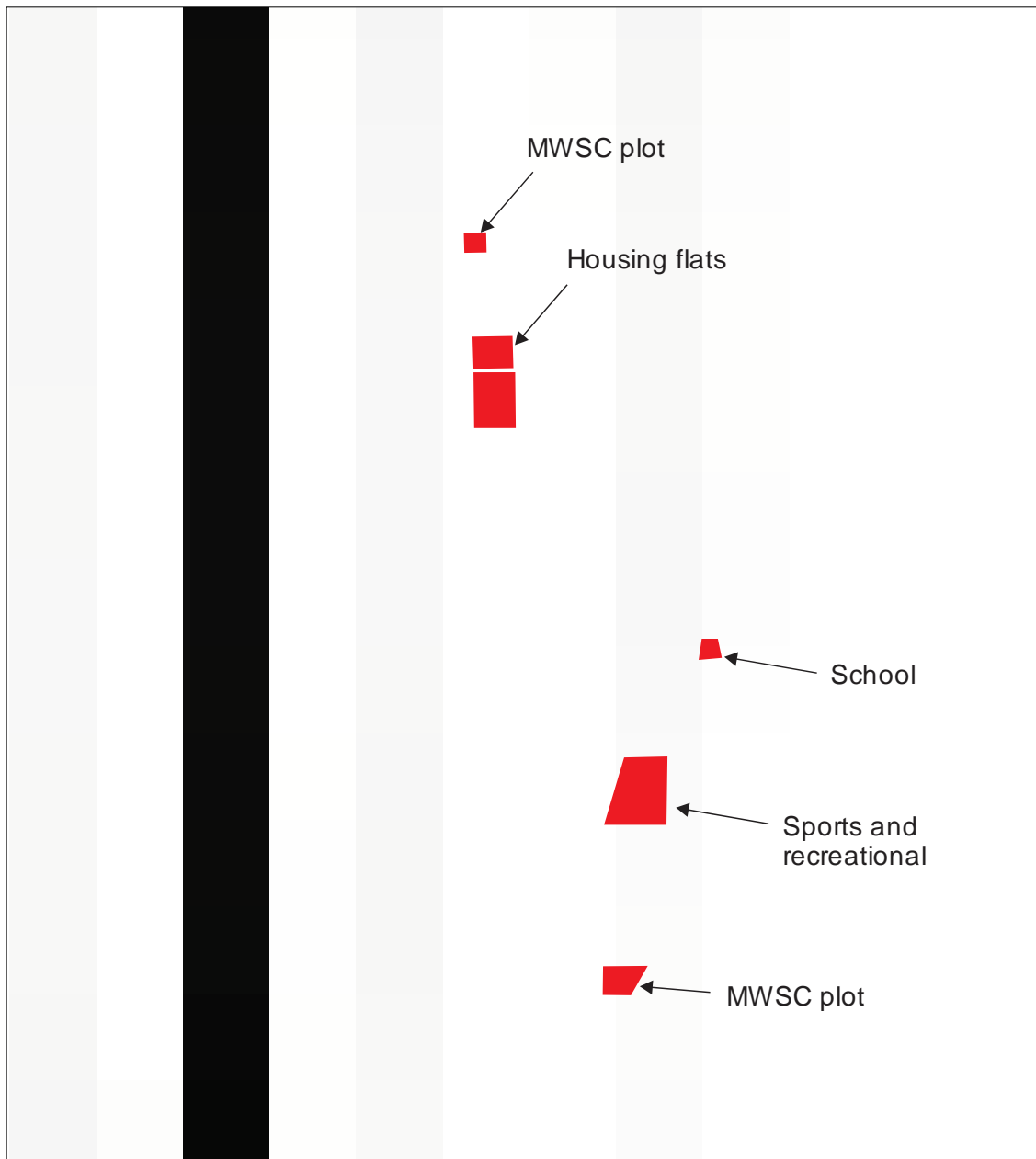


FIGURE 33 VEGETATION PATTERN CHANGES SINCE PREVIOUS STUDY (FIGURE ADAPTED & MODIFIED FROM PREVIOUS DIRAM)

3.2.4. Marine environment

The previous study noted that the quality of the surrounding reefs have declined over the past 50 years. With a low coral cover compared to the past, fisherman noted a decline in fish catch (UNDP 2008). Nevertheless the surveys did not show any sign of overgrowth of sea grass patches around the island. These findings were mostly based on anecdotal data.

Marine environment of Kulhudhuffushi is significantly impacted due to development activities. Consecutive reclamation and harbor development projects have been carried out at the western side of the island over the years. The EIA for the proposed reclamation project at HDh. Kulhudhuffushi stated that a manta tow survey showed live coral cover at the western side of the reef to be between 1-10% (Water Solutions, 2010).

However the EIA for the upgrading of Kulhudhuffushi Port (Water Solutions, 2011) stated that live coral cover at the northern side of port breakwater is 55% (which is approximately at the southern end of land reclaimed in 2010) and was dominated by tabulate acroporid forms. This report also states that live coral cover at southern side of port area is 2% (Water Solutions, 2011).

Although major coastal works have been undertaken at the western side of the reef, the eastern side remains largely untouched. Marine environment assessment done for Dhiraagu Domestic Submarine Cable Network Project- Kulhudhuffushi component under the EIA study for Dhiraagu Domestic Submarine Cable Network Project, under Dhiraagu Broadband Connectivity Project (LaMer, 2011) showed that live coral cover at eastern reef slope is approximately 40%. The dominant live coral forms observed at the reef slope area were tabulate and massive forms.

Almost 95% of the sea grass bed at the western side of the reef has been lost due to reclamation works. Prior to harbor development and reclamation works in the area the dominant substrate at the western side lagoon was sea grass (ADB, 2005). Currently, only sparse growth of sea grass is observed at the western side lagoon area near reclaimed land.

3.3. Vulnerability and risk assessment

To understand the vulnerability of the island it is important to have a detailed understanding of past hazard events. However apart from rainfall and wind data collected by the Hanimaadhoo weather station, records of past hazard events are not properly maintained. From the field interviews and review of existing data, it was established that since the previous DIRAM study in 2008, no hazard event of significance impacted the island. Table 9 is a list of known historic hazard events and their impacts on the island adopted from the previous DIRAM study (UNDP, 2008).

Table 9 List of historic hazard events of Kulhudhuffushi

Hazard	Dates of the recorded events	Impacts
Flooding due to heavy rain	Once in every few years	Flooding generally limited to the low lying areas where flooding was also occurred in the houses at these locations. The impacts are generally described as an inconvenience with no major structural or environmental damage.
Flooding caused by waves	1955 (<i>Bodu vissaara</i>) 18-20 June 2007	Very limited data exists for the incident in 1955. Elders talk about past "Udha" events, but no dates or impacts can be determined. The 2007 event destroyed parts of the old quay wall at the western side of the island and flooded houses within 40m of the coastline.
Windstorms	9 July 1973 17 June 1975 24 May 2005	According to the island council, one event caused severe damage to a few houses which included uplifting of the roofs and uprooting of trees. While the elders talk about numerous such events, no dates

		could be determined.
Droughts	No records of such an event	No records of such an event
Earthquake	No major event recorded	No major event recorded
Tsunami	26 th December 2004	The 2004 Indian Ocean Tsunami caused major flooding and some level of environmental and infrastructure damage to the island. As obtained from eyewitness accounts, some areas of the island were inundated to a depth of nearly 1m.

3.3.1. Environmental vulnerabilities to natural hazards

The previous DIRAM study identified the environmental vulnerabilities to natural hazards in Thinadhoo (UNDP 2008). The following table is adopted from previous DIRAM study highlighting the potential environmental vulnerabilities to natural hazards.

TABLE 10 POTENTIAL ENVIRONMENTAL VULNERABILITIES TO NATURAL HAZARDS

Hazard scenario	Probability of occurrence	Potential Major Environmental Impacts
Tsunami (Max. +4.5m MSL based on UNDP, 2005)	Very Low	<p>Short term impacts include major damage to coastal vegetation. Realignment of shoreline including major erosion.</p> <p>Long term impacts include damage to some inland vegetation and including common species such as mango and breadfruit. Saltwater intrusion into wetland areas and the freshwater lens.</p> <p>Contamination of ground water from potential damage</p>

			to sewerage
			Moderate damage to coral reefs
Storm surge	0.6m (1.53m storm tide)	Low	Minor damage to coastal vegetation
(based on UNDP,2005)			Minor damage to coastal structures.
			Minor geomorphologic changes to the island shoreline including increased erosion
Strong wind	28-33 Knots	Very High	Minor damage to vegetation
			Debris dispersion near waste yard
Strong wind	34-64 Knots	High	Moderate damage to vegetation including failing branches and occasional whole trees.
			Debris dispersion near waste yard
Strong wind	+65 Knots	High	Widespread damage to vegetation including failing branches and occasional whole trees.
			Minor damage to infrastructure including damage to roofs of buildings.
			Debris dispersion near waste yard
Heavy rainfall	187mm	Moderate	Minor flooding in low level areas including roads and houses
Heavy rainfall	240mm	Very Low	Widespread flooding in low level areas.
			Moderate to major damage to vegetation especially to backyard fruit and vegetable trees.
			Damage to individual septic tanks leading blockage and possible leakage.

Sea level rise (+0.88m in year 2100)	Moderate	<p>Permanent inundation of low lying areas in the island.</p> <p>Increased susceptibility to widespread flooding due to wave induced flooding</p> <p>Salt water intrusion and contamination of ground water.</p> <p>Loss of flora and fauna.</p>
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Based on these scenarios a hazard mapping analysis was conducted for the three major events, rainwater flooding swell waves and Tsunami.

3.3.2. Impacts of a Tsunami

The 2004 Indian Ocean Tsunami inundated a large area of the island. The following is the summary of inundation and damage extent at Kulhudhuffushi, gathered from post-tsunami surveys (Fujima et al, 2005) and from eyewitness accounts.

- The tsunami mainly inundated from the south and north of the island and to a lesser extent from the east. Even though Kulhudhuffushi is located in the eastern rim of the atoll, exposed to the incoming wave from the east, the relatively high crest of the eastern shoreline prevented the brunt of the wave from overtopping at this location.
- Few houses and some boundary walls in



FIGURE 34 1960 IMAGE OF KULHUDHUFFUSHI SHOWING THE WETLAND AREA

the north western side of the island collapsed. Maximum depth of inundation measured at this location was 0.78m

- Several boats were washed ashore from the old harbor area in the central part of the western shoreline
- From the eastern shoreline the tsunami wave that overtopped the high crest travelled down the downward slope and some houses in this area were flooded to a depth of about 6cm. Maximum flood depth measured at this location was 0.7m
- In the north coast, since there was no infrastructure at this side of the island, there was no major impact to be seen. Coral fragments transported by the tsunami wave to a considerable distance inland were observed. Since there was no reference point to measure inundation, there is no estimate for the inundation depth at this location.
- In the south coast the inundation caused the boundary wall of the work site of the former Ministry of Construction and Public Works to collapse. A large area was inundated in the south of the island with a maximum measured inundation depth of 0.6m.
- The maximum tsunami run-up with respect to MSL for Kulhudhuffushi was measured at 1.98m in the east coast. Even though the run-up was the highest at the east coast, inundation was less compared to the south and north due to the high elevation of the coastal ridge.

While these survey data and eyewitness reports give an excellent idea about the extent of tsunami impact on Kulhudhuffushi, the challenge is to determine the impact of future events. According to Dudley and Lee (1998, p.179-180) tsunamis from the same general geographic origin produce relatively similar patterns of wave run-up. Since run-up is generally used as a function of danger for tsunami events, it can be assumed that we would expect similar patterns of impact from possible future tsunami events from the Sunda Trench. Given that this is the only recorded tsunami event in the Maldives and is the largest event in the entire recorded history of the Indian Ocean, it is probably safe to assume that this tsunami event and the resulting impacts are on the high end of possible tsunami hazard to the island. According to the risk assessment carried out by Ali (2005), the 2004 event has a return period of 255 years with a probability of approximately 10 percent that a similar event might occur in the next 25 years. Taking all the available information into account, the elevation data with distance from shoreline was used in a weighted overlay to create the tsunami hazard intensity zone for Kulhudhuffushi (figure 35).

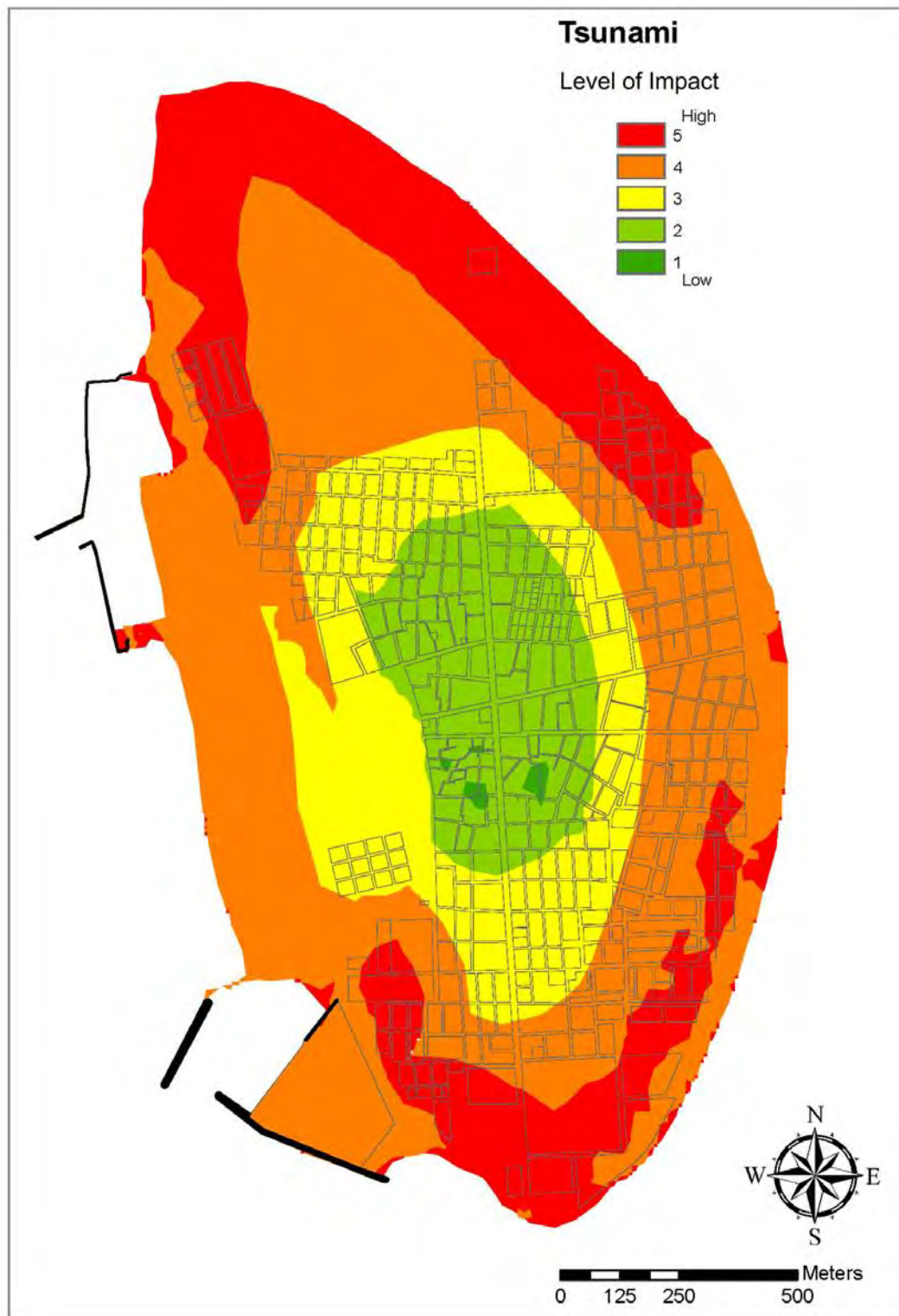


FIGURE 35 HAZARD ZONING MAP FOR TSUNAMI

The red color indicates the zone of highest intensity which coincides with the lowest area of the island matching the inundation of the 2004 event. The central part of the eastern coast is classified at a lesser risk compared to the south and north due to the higher elevation, but is still at considerable risk due to the proximity to the shoreline. Likewise the area near the shoreline of the newly reclaimed land is classified under the 2nd highest risk zone due to proximity to the shoreline. It should be noted that the zones indicate possible inundation zones and does not necessarily imply total infrastructure damage. The biggest change since the previous DIRAM study (UNDP, 2008) is that due to the reclamation projects, the main commercial zone and a large section of the residential area in the old western shoreline of the island is now relatively safe from tsunami hazard.

3.3.3. Flooding due to storm surge, swell waves

As predicted in the previous DIRAM study, the intensity of swell impact would be the highest in the southern, northern and the eastern shoreline. However due to the high ridge in the central part of the eastern shoreline, wave overtopping at this area would be relatively less compared to the southern and northern end of the island which is lower in elevation. From field surveys and interviews it can be concluded that while such events do occur occasionally the extent of impact is generally limited to the areas adjacent to the shoreline. As given in Table 9 only 2 major events of significance have been recorded. The 1955 event was a major storm event; however no date regarding inundation or level of damage is available. In the June 2007 event, the old quay wall in the western side was destroyed and houses within 40m from the edge in the eastern side were flooded. Since then the western side has been reclaimed to a higher elevation, however no measures have been taken in the eastern side to address the flooding issue.

Before the recent reclamation in the western side of the island, this area was susceptible to flooding due to the heavy southwest monsoon driven storm events. However due to the high elevation of the reclaimed land, the western side is now relatively safe from wave induced flooding. In order to estimate the impact zone of potential future wave induced flooding events, the elevation data of the island was used in conjunction with distance from shoreline buffer zones to undertake a weighted overlay in the GIS software. In the absence of inundation data of past events, apart from running numerical or physical models (which is not part of the scope of this project), this was determined to be the most practical approach to identifying potential hazard zones due to wave induced flooding (see figure 36).

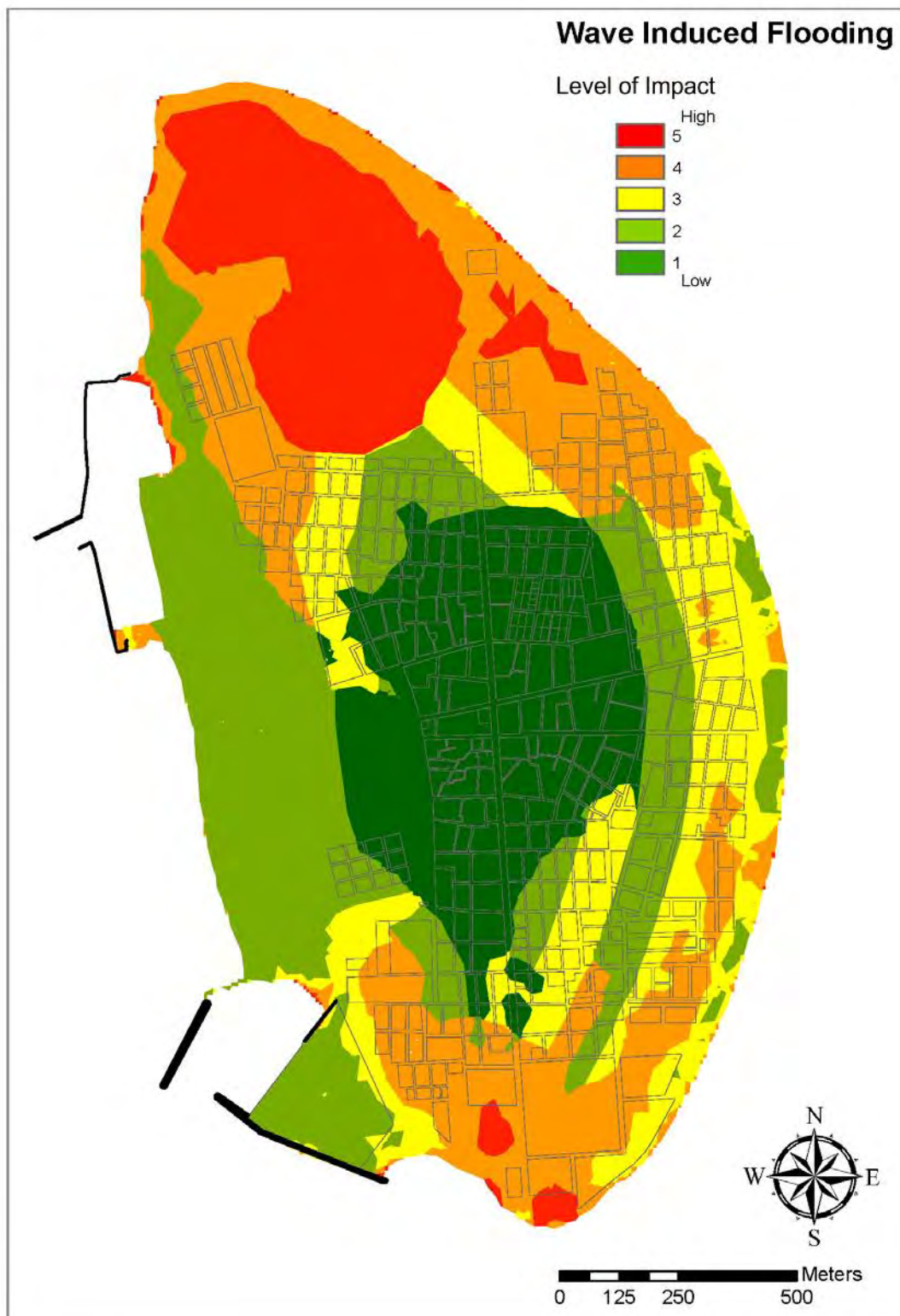


FIGURE 36 HAZARD ZONING MAP FOR SWELL WAVE INDUCED FLOODING

3.3.4. Flooding due to rainfall

The existing topography of the island makes it very susceptible for some areas to be flooded under heavy rainfall. The extent of flooding is generally governed by the topography and the drainage capacity of the island. Low areas with no means of drainage are the most vulnerable to flooding and flood related damage. Flooding due to rainfall is almost an annual occurrence in Kulhudhuffushi and to date no measures have been taken to specifically address the issue of flooding in the island. As discussed in section 3.1.2, the Statistical downscaling of global climate change models by RIMES (RIMES 2011) predicts 100% to 150% increase in rainfall in the year 2050. The highest recorded daily rainfall for Kulhudhuffushi area is 146.9mm. By using the results of RIMES (2011), it can be deduced that maximum daily rainfall could reach 370mm in the year 2050.

To understand the topography of the island a complete topographic survey of the island was conducted. This was carried out using Real Time Kinematic (RTK) surveying equipment with sub-15mm accuracy. This survey data was used to create a DEM of the island (Figure 14).

From the DEM results it was clear that the highest elevation in the island was found on the eastern ridge of the island which had an average maximum height of 2.4m. This eastern ridge was the highest at the center and gradually becomes lower towards the north of the island. From the eastern rim, the ground has a downward slope towards the center of the island. The lowest elevation at -0.94m was measured in the wetlands or “Kulhi” area in the north. The south side of the island is also generally lower than the island. Historically this area used to be a huge wetland (see Figure 34) and subsequent reclamation was done to a lower elevation. A small wetland area still remains in the south.

As explained in section 3.2 three major reclamation works were undertaken more recently on the island. Under the Regional Port Project about 10 hectares of land was reclaimed to a height of approximately 1.4m.

Later as part of the local harbor project a further 9 hectares was reclaimed to a height of 1.4m above MSL. The latest reclamation project saw 36 hectares of land being added to the island to an elevation of 1.5m above MSL. As result of these reclamation projects, almost the entire western side of the island is now relatively higher than parts of the original island. These level differences can be clearly seen in the DEM.

The natural drainage capacity of the island has been greatly reduced due to the reclamation projects undertaken over the years. From the early topography of the island, it is clear that storm water would flow into the north and south wetlands and to western lagoon. However

this natural drainage basin in the south and the capacity to drain water into the western lagoon has been lost due to the reclamation works. It should be noted that the most recent reclamation project has provided a temporary solution to the potential flooding issue in the area by providing a ditch between the old island and the new reclamation. The result of the DEM was used to map the most vulnerable areas to flooding (Figure 37).

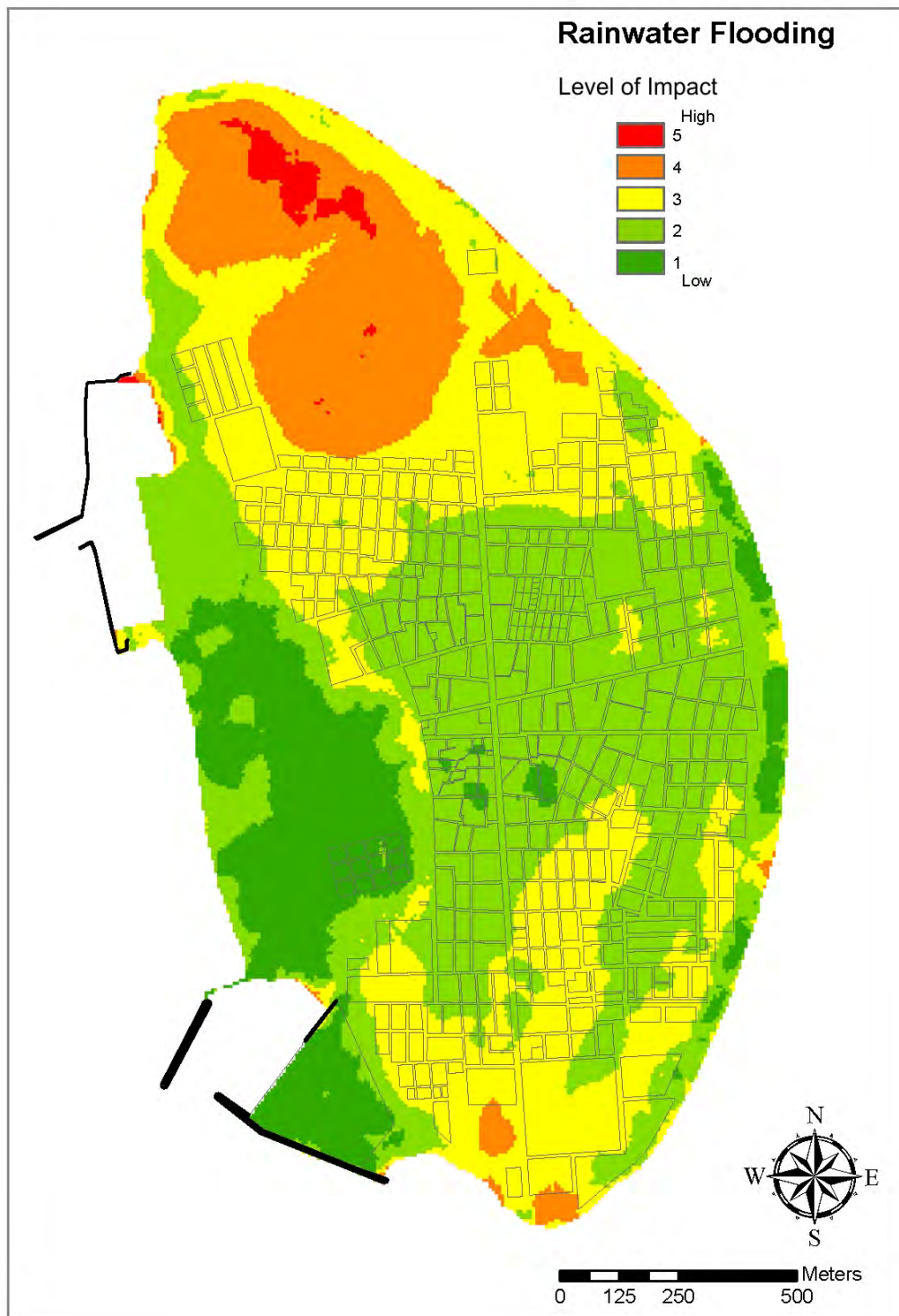


FIGURE 37 HAZARD ZONING MAP FOR RAINWATER FLOODING

3.4. Potential Impacts of climate change variability and sea level rise

As discussed in section 3.1.6, Sea Level Rise and rise in Sea Surface Temperature (SST) due to climate change could have severe impact on the islands' ecology and geomorphology. Apart from land-loss due to sea level rise, climate change would exacerbate other hazards such as wave induced flooding, rainwater flooding and tsunami hazard.

In order to identify potential land loss due to sea level rise the elevation data was used to map areas that would be inundated at the end of the century using IPCC (2001) forecasted sea level rise (Figure 38).

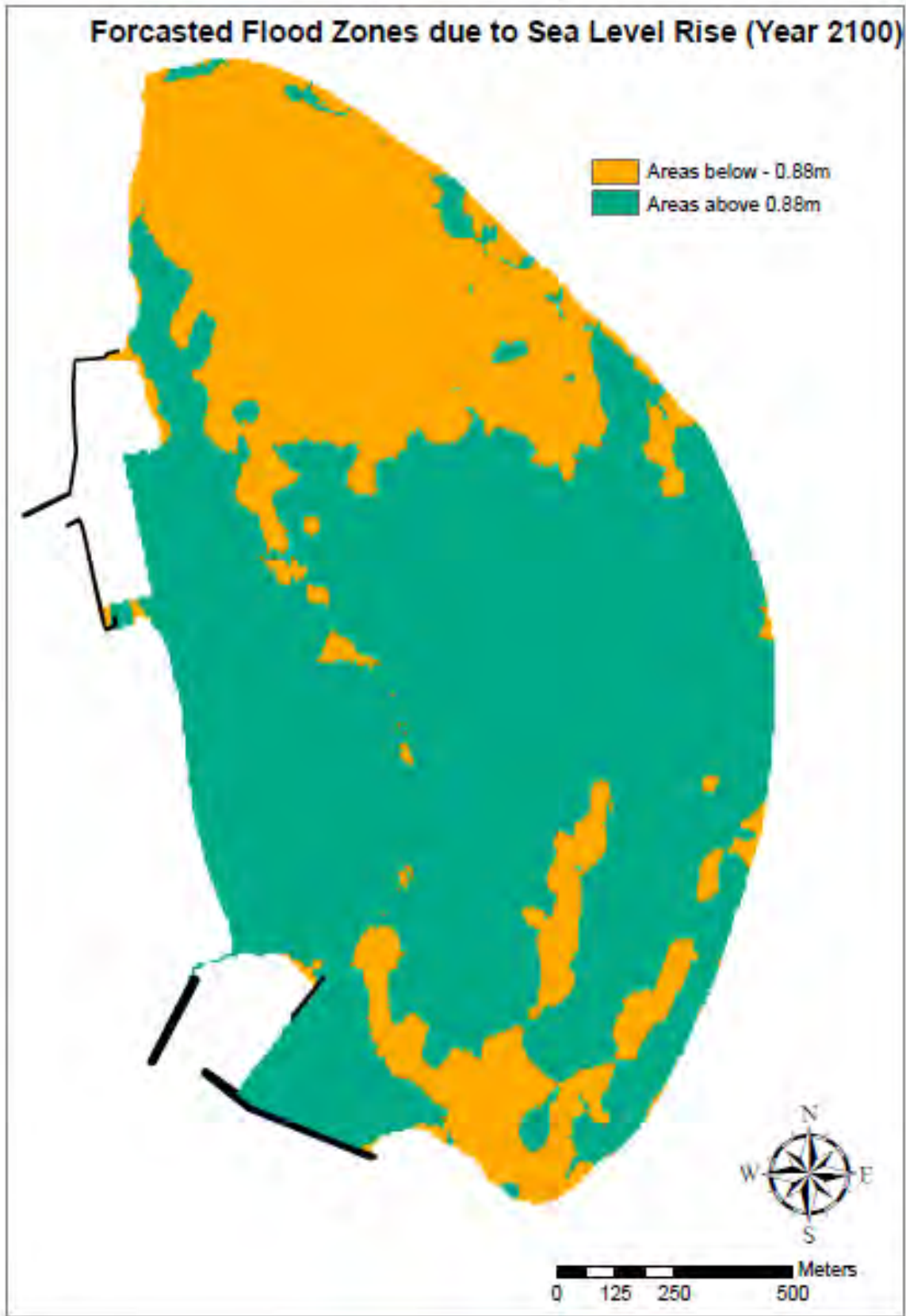


FIGURE 38 FORECASTED FLOOD ZONES DUE TO SEA LEVEL RISE (YEAR 2100)



People of Kulhudhuffushi gathered in the market place to buy local food produce of the island and neighboring islands
Photo by: Shifna Saeed/ Riyan Pte. Ltd (2013)

4. Social Vulnerability Assessment

In addition to hazard assessment, to evaluate hazard risks it is equally important to study and understand the social vulnerability (Wisner 2007).

4.1. Existing condition

The social island context has been derived and assessed from a number of studies including field survey data (focus group discussions, one-to-one interviews), previous studies including the previous DIRAM study, disaster risk profile of Maldives, statistical databases (Census 2006; Statistical year books),

“The vulnerability of communities and societies to disasters is closely and inversely related to the level of social and economic development” (Li 2012, p.1)

vulnerability assessments etc. Main methods used in collecting these data are through participatory approaches where stakeholders and community members were involved in collecting data, identifying issues and also the possible solutions. The following profile summarizes the key findings.

4.1.1. Accessibility to the basic services

i. Island Access

The major access point to the island is from the local island harbor. In addition the regional port and the hospital jetty can be used to access the island.

ii. Education

Kulhudhuffushi provides all levels of education. These include preschools, primary, secondary higher secondary and tertiary education. In addition they have a vocational training center which offers short courses for skill development. Students from nearby island migrate to Kulhudhuffushi in search of better education facilities. However, the students are not happy with the education services offered in the university campus. According to them, improving the quality of education and types of courses offered in this institution has remained as one of the challenges for the island.

iii. Health

The regional hospital for the upper northern region is located in Kulhudhuffushi. This is another reason for people to visit/migrate to the island. However, the islanders are not happy with the services provided by the hospital. There is a lack of essential facilities available at the hospital. Limited doctors, nurses and equipment has decreased the quality of services and also has limited the number of services that could be provided to the patients. Improving the quality of services provided by the hospital is one of the highest priorities amongst the people of the island.

iv. Drinking Water

A desalinated plant has been installed in late 2011. With the establishment of this system, people are able to access desalinated water from their houses. They use this water mainly for drinking, washing, bathing and other purposes. In contrary, use of rain water has significantly reduced. Rain water harvesting, one of the recommended ways to address the issue of water scarcity which had been extensively practiced is now decreasing. More awareness needs to be created amongst the people, to encourage them to use rain water as much as possible for the different activities.

Currently only 850 water tanks are available in 1975 households, whilst previously they used to have 2358 rainwater tanks in 1165 households. The community no longer has access to any community water tanks, although previously they had 4 tanks in the mosques.

v. Sewerage

Previously septic tank sewerage systems were used by most of the households. In 2011, a new sewerage system has been established in the island. Since the system is still new, no issues were raised regarding the functioning of the system.

vi. Waste management

The waste site is not well managed. Currently the utility (Fenaka) manages the waste site. But this does not include waste collection, which is managed by some individuals. Some households pay a fee to the individuals to take the waste to the site. But this is not done in an organized way. Although a certain area is designated for waste disposal, due to its distance from the residential areas and the unavailability of dustbins within the island, waste is disposed at any area which is convenient for the residents.

vii. Food Security

There is no major issue on food security within the island. Since Kulhudhuffushi is the regional hub that re-exports food supply to the neighboring islands, they normally have enough stock in the island. However, it was noted that in case of any interruption to the transport network, other islands that depend on Kulhudhuffushi for their food supply will have to face food security issues (shortage of food).

In Kulhudhuffushi, they do not have main food reserves for storage. Although there is no specific food storage or cold storage service, the food stocks are maintained by the major wholesalers and are stored in warehouses located within the island. As for local produce, agricultural activities within the island are minimal although people do home gardening where they grow chillies, cucumbers and different types of greens. While one third of local produce comes from the island, two-thirds of them are brought from the neighboring islands. A ferry which sells local products from neighbouring islands visits Kulhudhuffushi every Saturday.

viii. Safety and Security

With the large population residing in the island, stakeholders reported issues of violence, theft, robbery and break-ins. The regional police station is also located in the island and they are in charge of making the island a safe and secure place to live.

4.1.2. Organizations and networks

The main organisation at the highest hierarchy is the Island Council who is responsible to work for the development of the island through provision of all the municipal services (*Decentralisation Act 2010*). Previously there used to be government organisations such as the Island Development Committee and Women’s Development Committee. However, with the decentralisation of the government, the roles and responsibilities of these committees have been transferred to the island council.

As for non-governmental organizations, there are 10 small scale NGOs who work independently and as teams for the development of the island communities. In general, these NGOs promote recreational activities, awareness campaigns, sports events and work for the betterment of the community. Among these organisations, 5 are youth NGOs who mainly promote youth and sports development. Although there are number of NGOs with the aim of working towards the development of the island community, the participation has reduced significantly over the past years. There is one youth NGO where the active members are not youth but the people who were founders of the organisation long time ago. They have aged but unfortunately no youth is willing to take up their responsibility thus reducing the participation level and the activities.

4.2. Social Vulnerability to disasters

Vulnerability can be defined in many ways while for the purpose of this study vulnerability can be expressed as "the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Wisner et.al 2003, p.11 as cited in Desai & Potter 2013). In various vulnerability assessments disaster is illustrated by the formula: **Disaster = Hazard + Vulnerability**. This implies that disaster risk has a direct impact from the hazard and the vulnerability of hazard (Blaikie et.al 2004).

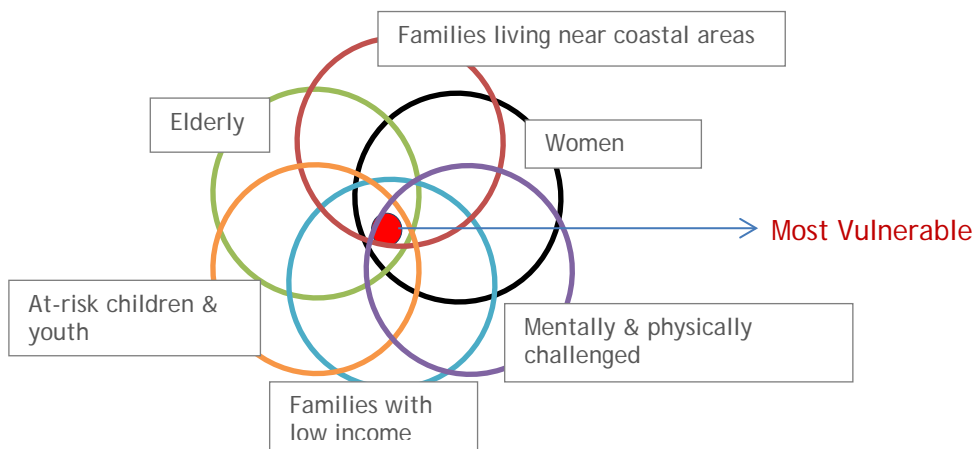


FIGURE 39 A REPRESENTATION OF VULNERABLE GROUPS

Vulnerability can be affected by physically unsafe conditions and socially unsafe conditions. Physically unsafe conditions include risky locations (near coastal area) and unprotected building, while socially unsafe conditions include the risks to local economies, lack of disaster preparedness measures, etc. Vulnerable groups who are subjected to these conditions include elderly people, mentally and physically challenged individuals, at-risk children and youth, the families living near coastal areas, women etc. Among these, the most vulnerable are the people who fall into the shaded area as shown in the diagram (figure 39).



i. Elderly people

Approximately 16% of the population is above 65 years and there were a number of people over the average age of life expectancy which is 75. This group of people are highly vulnerable in the community as they are mostly helpless in terms of fighting by themselves, for survival, in the instance of a disaster. Most of the elderly requires assistance and support to evacuate themselves from their homes in case of a disaster.

ii. At-risk children and youth

At-risk youth/children or high risk youth are referred to the ones who drop out from school or who do not have the opportunity to attain education at any level. The US code defines high risk youth as

“an individual who has not attained the age of 21 years, who is at high risk of becoming, or who has become, a drug abuser or an alcohol abuser, and who is identified as a child of a substance abuser; a victim of physical, sexual, or psychological abuse; has dropped out of school; has become pregnant; is economically disadvantaged; has committed a violent or delinquent act; has experienced mental health problems; has attempted suicide; has experienced long-term physical pain due to injury; or has experienced chronic failure in school” ([title 42](#), [chapter 6A](#), [subchapter III-A](#), [part B](#), [subpart 2](#), § 290bb-23).

This can be due to many reasons which include demographic, socioeconomic, and institutional characteristics of the island/family. The youth population of the island accounts for 20% of the total population. Although the number of children at risk cannot be determined because of lack of comprehensive data, it is evident that such individuals are highly vulnerable to disasters.

iii. Mentally & physically challenged individuals

The total number of disabled people in Kulhudhuffushi is not known. According to the regional hospital, disabled people include the physically challenged and mentally ill patients. They are among the most vulnerable people as they will need full support and assistance in moving from one place to another.

iv. Women

Women are considered to be more vulnerable to disasters than men due to many reasons including their nature, the patriarchal structure of the society and the low income level. Thus disasters make them more vulnerable to poverty, health implications, abuse of different kinds including rape and assault (APWLD, 2005). During the 2004 Tsunami, it was found that in India, Aceh and Sri Lanka where the impact of Tsunami was highest, 80% of the dead are women. From the above statistics it is evident that women have a higher risk in case of a disaster than

men. It is important to note that in Kulhudhuffushi, like most of the other inhabited islands, number of women residing in the island is more than men who are mostly out of the island for work related purposes.

v. People living near coastal areas

As highlighted section 3.3, the coastal areas especially at the north and south ends are at high risk in case of a disaster. This shows how vulnerable coastal communities would be in such a case. The heavier socio-economic costs that would be caused by climate related hazards and disasters are also greater in coastal zones (Smith, 2009). In Kulhudhuffushi, west coast area mostly comprises commercial and industrial zones. With the massive reclamation of the west coast of the island, the families who used to live near the coastal area are now shifted inwards. This would have definitely reduced their

“The pre-school (IPS) is located near the eastern shoreline of the island. The main environmental hazard we face is erosion. And during north-east monsoon rough periods/stormy events we experience water splashes which cause damage to the school walls and death of the plants due to salt intrusions”. (an interviewee; teacher)

vulnerability and made them safer to potential disasters such as Tsunami, storm surges and swell waves. However the commercial and industrial activities and people working in these zones are at risk. Also, the families at the east side are highly exposed to such disasters. In Kulhudhuffushi approximately 20% of the households are located near the coast making them the most vulnerable among all. However, since these 20% are mostly at the eastern side of the island where the island is protected by a high ridge, this may not be a very concerning issue.

The preschool (IPS) is also located at the hazard prone area and it is important to note here that a new block is being built even closer to the shoreline making the building and the people who will be living in the building more vulnerable to disaster events such as a Tsunami or storm surge.

vi. Families with low income

Low income groups are vulnerable to any shock that would force them to spend their earnings. Likewise, the low income families are more vulnerable to disasters than the middle and high income groups. The low income groups do not have the resources and capacity to act on disaster relief. In Kulhudhuffushi, the income levels of the households seem to be relatively good compared to previous years. The previous DIRAM study showed that there is a high percentage (30%) of people under the poverty line. However with the new developments which have brought a lot of changes to the size, land use and population of the island, this figure is

expected to be much lower, although exact number cannot be generated due to lack of updated data. According to the community discussions, they do not feel poor and they do not have much of a difficulty in terms of money. Nevertheless, even if it is small, there will be a fraction of people who are under the poverty line and a study like this should not neglect the minority in assessing the vulnerability. More data is required to identify the poverty index and to assess their vulnerability. Economic imbalance and disparity in power among social groups are among the several social factors Blaikie et.al (2004) highlighted as factors that can lead to vulnerability.

4.3. Community participation

From the field visits and the community consultations, it was evident that there is a strong community spirit among the people of the island. However, with the different political views, there also seems to have been segregation among groups and even within families. These issues were raised during the random individual interviews conducted within the island.

“Previously, we used to have strong cohesion between us, but now there is division among the community members due to the different political views/parties. When you are out about, people pass comments at you if you tend to be someone who does not share same political views as them. So it is difficult to come into a common understanding on any issue the island is facing” (an interviewee)

4.4. Perception of risks/disasters

During the focus group discussions, all the groups noted Tsunami, erosion, swell waves and strong wind storms as natural hazards. For some people of the island a hazard is something as huge as a tsunami, while for others erosion is a concerning issue. Thus it was difficult to get a general perception of hazards from the discussions. However, it was evident that the normal events that happen along with the seasonal changes are not considered as major hazards but huge events like Tsunami and after effects like erosion caused by swell surges are noted as high risks.

4.5. Potential social impacts due to disasters

Table 11 below summarizes the potential impacts which could be caused during a natural hazard event. Since Tsunami is considered as the most hazardous disaster, the impacts are predicted for such an event. Nevertheless the impacts caused by floods, swell surges, wind storms are also incorporated in assessing the impacts. Furthermore, the new developments are taken into consideration in predicting these impacts and their consequences.

TABLE 11 POTENTIAL IMPACTS DURING A NATURAL HAZARD EVENT

Major projected Impacts	Consequences	Groups Affected	Coping Strategy
<p>Event: Tsunami, heavy rain storm</p> <p>Loss of life/injury to members of household</p>	<ul style="list-style-type: none"> • Possible loss or injury of the head of household or ‘bread-winners’ • Disruption of economic and livelihood activities • The affected families and the whole island community would go through psychosocial health issues (injuries, fear, trauma, anxiety) thus impacting decision making 	<ul style="list-style-type: none"> • Vulnerable groups (See section 4.2) 	<ul style="list-style-type: none"> • Support from families, friends & community members
<p>Destruction/damage of household properties</p>	<ul style="list-style-type: none"> • Homelessness • Loss of valuables and personal belongings • Loss of productive assets (backyard agriculture, rope making, facilities & fishing vessels) causing unemployment, low productivity and loss of income • Scarcity of food • Psychosocial health issues (injuries, fear, trauma, anxiety) thus impacting decision making 	<ul style="list-style-type: none"> • Vulnerable groups identified in section 4.2 (Low income groups, women, children, families close to coastline), households not using bank services, key economic groups-fisherman, backyard, manufacturing & agriculture 	<ul style="list-style-type: none"> • Relocation of property • Move to temporary housing (provided by relatives, neighbors, other community members) • Support from relatives/neighbors/community members •
<p>Diseases</p>	<ul style="list-style-type: none"> • Possibility of epidemic of diseases • Overburdened health services due to lack of good health facilities. 	<ul style="list-style-type: none"> • Everyone 	<ul style="list-style-type: none"> • Emergency medical services provided by the government • Services from

			<ul style="list-style-type: none"> hospital Local medicines Home remedies Cleaning up the island Support from family, friends, the whole community
Damage to Roads	<ul style="list-style-type: none"> Disruption to movement of pedestrians Disruption to vehicle movement Inconvenience caused due to all disruptions of movement 	<ul style="list-style-type: none"> Pedestrians Drivers/passengers 	<ul style="list-style-type: none"> Sand filling of roads
Flooding of community buildings, houses & rooms	<ul style="list-style-type: none"> Loss and damage to properties Psychosocial health issues (injuries, fear, trauma, anxiety) 	<ul style="list-style-type: none"> People living in flood prone areas (section 3.3) 	<ul style="list-style-type: none"> Pumping out water from the places
Damage to infrastructure	<ul style="list-style-type: none"> Disruption to services provided by the critical infrastructures (power house, schools, mosques, health institutions) 	<ul style="list-style-type: none"> People living/using the infrastructures Vulnerable groups 	<ul style="list-style-type: none"> Services such as health services provided at temporary buildings Support from all community members, family & friends, NGOS, Aid groups
Disruption of economic activities	<ul style="list-style-type: none"> Damage to business establishments 	<ul style="list-style-type: none"> Businessmen, service providers, customers of the 	<ul style="list-style-type: none"> Support from the rich, well established

		<p>businesses</p> <ul style="list-style-type: none"> • Vulnerable groups who carry out small businesses 	<p>individuals</p> <ul style="list-style-type: none"> • Support from aid providers
<p>Disruption to transport goods</p>	<ul style="list-style-type: none"> • Damage to vessels • Decline in transferring goods from Male' to the island and from the island to other islands • Scarcity of food 	<ul style="list-style-type: none"> • Vulnerable groups • Fishermen, farmers, wholesalers, retailers • Other island communities • 	<ul style="list-style-type: none"> • Support from for the rich, well established individuals • Support from aid providers • Help from neighbors & all community members
<p>Increased quantity of waste</p>	<ul style="list-style-type: none"> • Waste spread all over the island • Spread of diseases 	<ul style="list-style-type: none"> • Vulnerable groups • (Elderly, children, women etc) 	<ul style="list-style-type: none"> • Cleaning the island by the community members (difficult to dispose the waste)
<p>Water scarcity</p>	<ul style="list-style-type: none"> • Damage to the water plant will cause disruption of water supply to the houses • Pollution of ground water 	<ul style="list-style-type: none"> • Everyone, especially households who do not have alternative ways of water supply such as rain water 	<ul style="list-style-type: none"> • Buy bottled water for drinking • Use ground water for other purposes

4.6. Social factors exacerbating the effects of a disaster

The diagram illustrates the key factors that would worsen the effects of a disaster in Kulhudhuffushi.

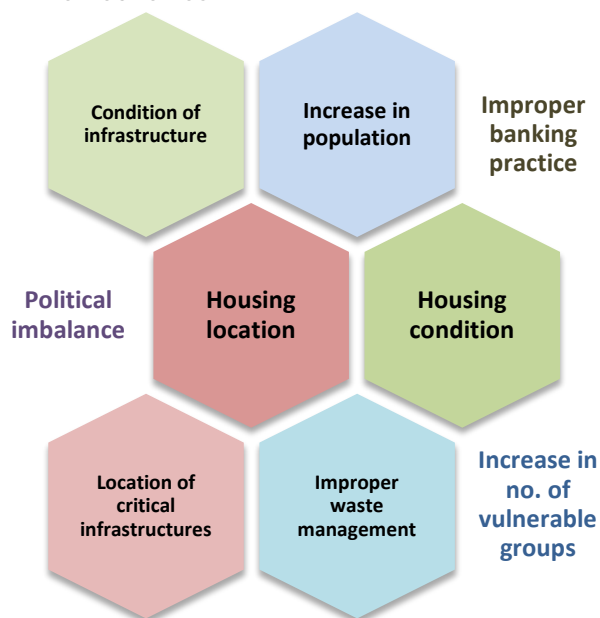


Figure 40 Social factors exacerbating the effects of a disaster

Location of housing and Infrastructure

As stated in section 4.2, houses located near severe hazard zones such as the coastal areas are more vulnerable to disasters. Also the houses built on swamp areas (reclaimed wetlands) pose higher risk of flooding making them more vulnerable than the houses located in safe zones.

Some of the critical infrastructures such as the schools & the water plant are located at areas prone to flooding and storm surges.

Improper waste management

The waste site is not well managed. Although a certain area is designated for waste disposal, waste is dumped at any area of convenience by the residents, due to the far proximity of the allocated disposal site.

At a time of disaster, issue of waste would worsen the problem as it will pollute the whole island and will cause spread of different types of diseases.

Increase in population and Vulnerable groups

When there is an increase in a population with a high population density the population density and urbanization further increases to cater for the growing population. This would in turn increase the vulnerable population and also would increase the vulnerability of the whole population to disasters (Donner & Rodríguez 2011).

Housing condition and Condition of critical infrastructures

The poor structural designs and construction methods practiced in the island make the buildings more vulnerable to extreme weather events and natural hazards. Houses and infrastructures with poor conditions located within hazard prone areas pose a higher risk of severe damage during an event of a disaster.

Political imbalance

Political differences are having a huge impact on peoples' perception towards helping and supporting people. Communities are being segregated because of their different political views. This could be the situation even in a case of a disaster.

It would also impact the decision making process even for environmental protection measures. Political views will influence the decision making and with many different views it becomes difficult to make the most optimum decision.

Income saving practice

The income and savings are normally stored in their houses. Valuable items and huge amount of money are kept at home without properly banking although banking services are provided on the island.

These practices expose the assets / money / valuables to disasters making the owners more vulnerable.

4.7. Factors that contribute to the relief of disaster effects

The positive social elements that have been identified as factors that would help in reducing the effects of disasters are illustrated in figure 41.

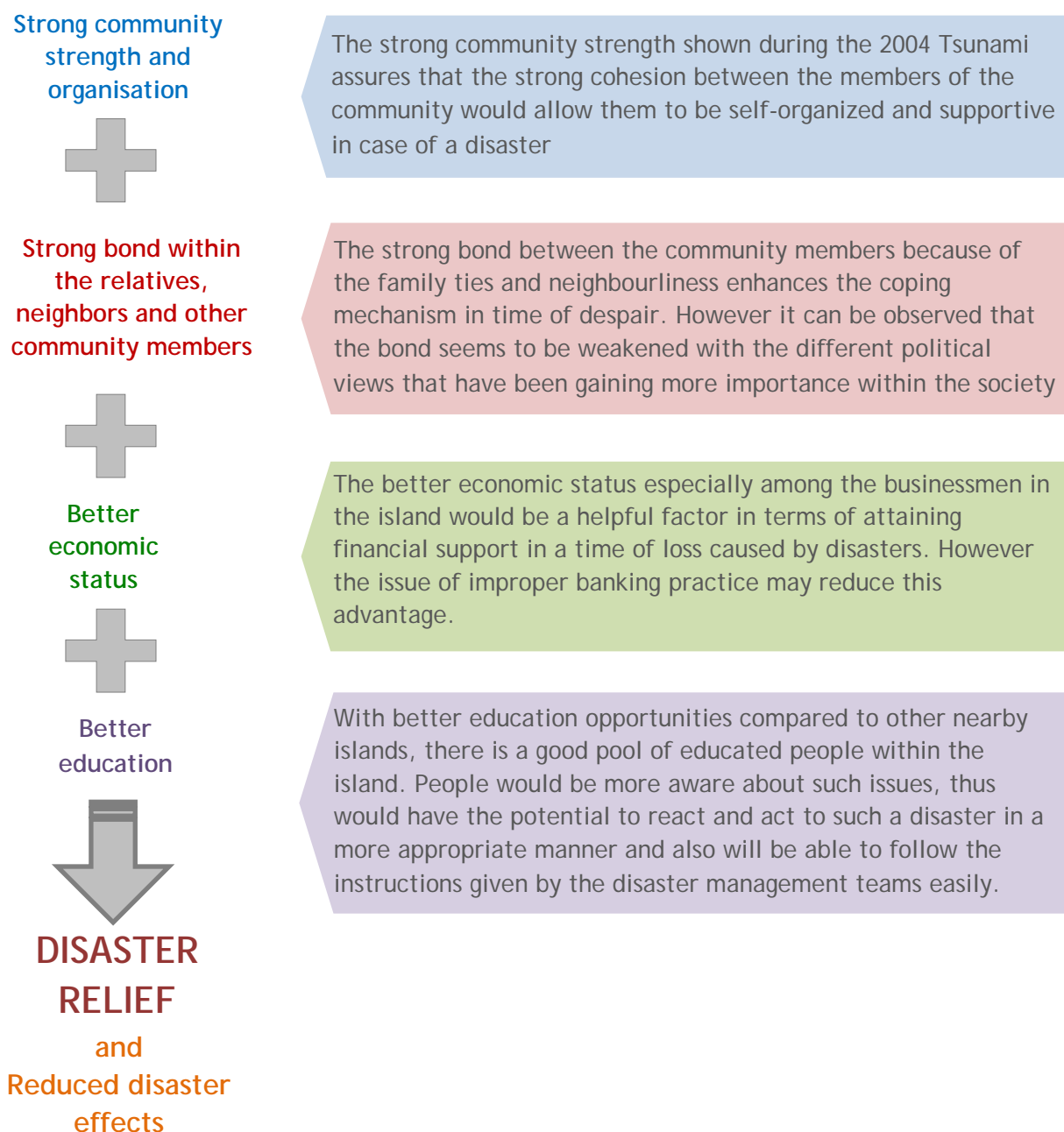


FIGURE 41 FACTORS THAT CONTRIBUTE TO THE RELIEF OF DISASTER EFFECTS

5. Economic Vulnerability Assessment



5.1. Value of economy

As discussed in the previous DIRAM study, unavailability of sufficient local economic data limits the study to generate an estimation of the value of an island economy. Normally economic data are aggregated at the national level thus it will be difficult to determine the local economy at individual island level. Nevertheless a rough estimate has been derived using the data from previous study and average values attained through field interviews and consultations.

Similar method as that used for previous DIRAM study was used to conduct the analysis. This includes:

- An inventory of the economic establishments and socio-economic infrastructures to determine the number and size of the establishments.
- Field interviews with random business establishments to attain some detailed information regarding employment income and investments/expenditure cost.
- Using the data, a rough estimate of the costs of public and private investments, their production values and expenditure were calculated and presented in table 12 below.

TABLE 12 ESTIMATED VALUE OF THE KULHUDHUFFUSHI ECONOMY

Sector	Public Investment	Private Investment	Production ⁴	Total
Fishing		106,100,000.00	25,000,000.00	136,100,000.00
Public Administration (Civil Service including education and Healthcare)	243,083,869.08		4,411,303.90	247,495,172.98
Manufacturing		16,500,000.00	2,273,250.00	18,773,250.00
Wholesale and retail trade and workshops		120,000,000.00	12,000,000.00	132,000,000.00
Transport, storage and communications	273,767,867.81	97,461,400.00	3,904,000.00	375,133,267.81
Construction		25,000,000.00	1,760,000.00	26,760,000.00
Hotels and restaurants		3,300,000.00	197,950.00	3,497,950.00
Other community, social and personal service activities	31,519,493.98		696,570.00	32,216,063.98
Real Estate, renting and business activities		149,453,309.00	100,000.00	149,553,309.00
Electricity, Gas and Water supply	244,836,188.93		3,964,000.00	248,800,188.93
Mining and quarrying		4,000,000.00	350,000.00	4,350,000.00
Financial intermediation		3,000,000.00	900,000.00	3,900,000.00
Agriculture		100,000.00	54,000.00	154,000.00
Households		336,900,000.00		336,900,000.00
Tourism			250,000.00	250,000.00
Total	793,207,419.80	861,814,709.00	55861,073.90	1,710,883,202.70

Note: The above values are based on data sourced during field work for current report

⁴ Production is calculated for a month using the number of business establishment and average income figures derived during field surveys

The total estimated value of the economy of Kulhudhuffushi is between 1.8 and 2.0 billion Rufiyaa. The major investment after 2008 is in housing and land reclamation (23 million Rufiyaa and 124 million Rufiyaa), Water and sewerage (118 million Rufiyaa), transport (51 million Rufiyaa) and communication (34 million Rufiyaa). Public infrastructure including health and education and others is 44 million Rufiyaa. Significant investments were observed in wholesale and retail trade but no major investments were observed in the fisheries sector. Nevertheless in terms of production, fisheries sector contributes the highest with 25 million Rufiyaa, followed by trade (12 million Rufiyaa) and transport, electricity, gas and water supply (3.9 million Rufiyaa).

The above values are indicative figures based on average numbers and should not be used as exact values of the economy. Nonetheless, these values are useful and sufficient in estimating the economic losses during a disaster in the absence of official statistical figures.

5.2. Key economic establishments and their physical distribution

5.2.1. Distribution of economic establishments

As noted in section 2.4, land was previously allocated for housing needs and agricultural purposes. No specific zoning was undertaken for business or industrial uses. Thus over 90% of the business establishments are located within the housing areas. Mostly the houses are transformed or parts of the houses are used for business activities similar to Male'. Nevertheless, a pattern can be observed in the distribution (figure 42).

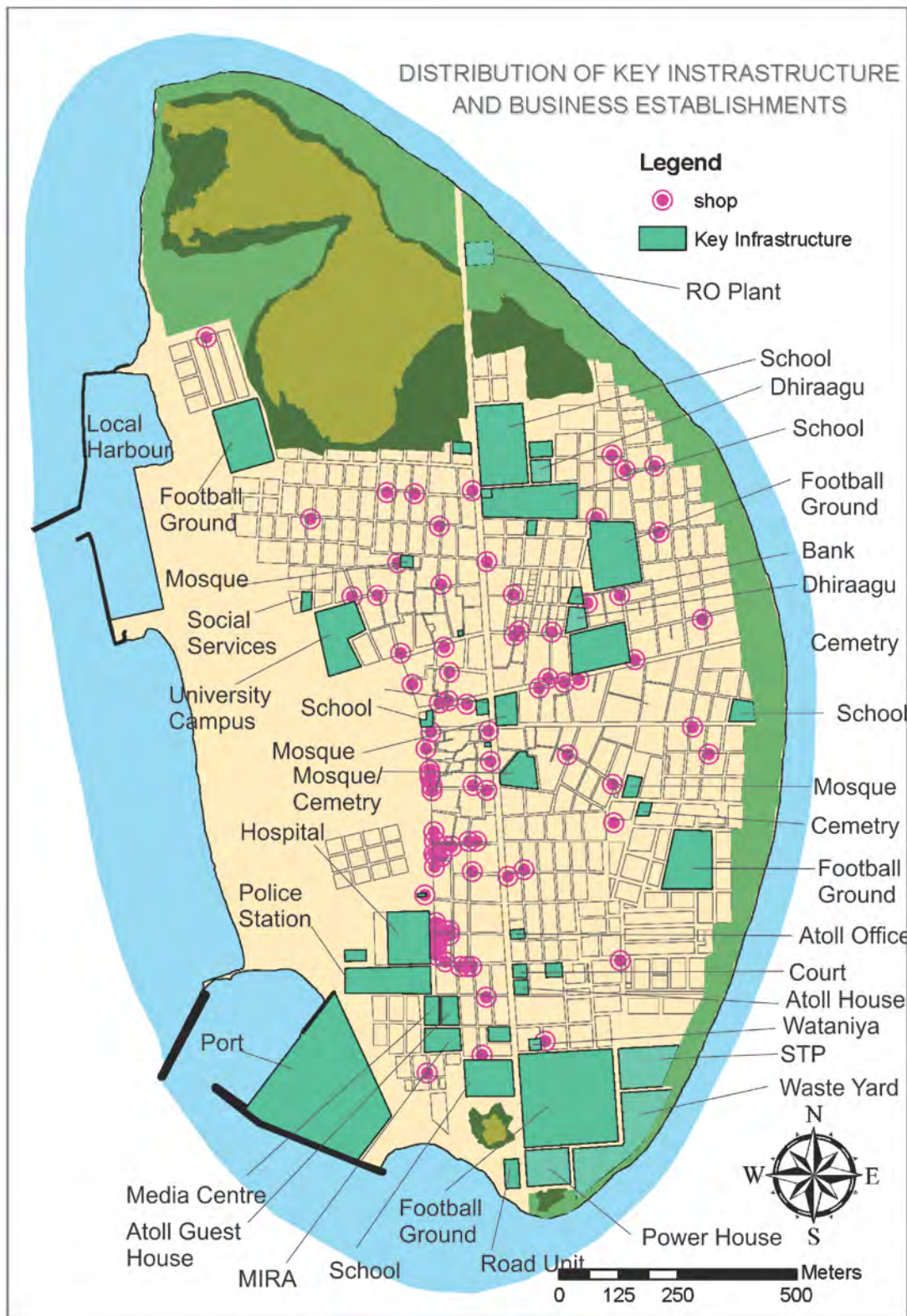


FIGURE 42 DISTRIBUTION OF ECONOMIC ESTABLISHMENTS AND KEY INFRASTRUCTURES

As it can be seen in the figure above, there is a high concentration of business activities along the old western shoreline, which now is the central part of the island. This area was previously the harbor area making it an ideal location to provide wholesale and retail activities especially for the visitors from other islands. However with the new reclaimed land, these areas are now shifted inwards. In near future it is highly likely that more establishments will be located near the existing harbor to cater to the visitors as proposed in the land use plan. There is also a high concentration of business activities on the main roads. This is mainly due to good accessibility to the roads making it easy for the customers and also for loading and unloading. While larger retail shops are located on the main roads, the small retail shops and personal service sectors such as workshops are randomly distributed across the island.

Boat building and repair activities are now located at the uninhabited northern part of the island.

5.2.1. Distribution of economic infrastructure

Economic infrastructures can be described as the facilities that drive the business activities which include communication, transportation and distributing networks, financial institutions and market and energy supply systems (Business Dictionary, 2013). In Kulhudhuffushi, the key economic infrastructures include the local harbor, communication infrastructures (Dhiraagu and Wataniya site), regional port, power house, roads and Bank of Maldives. In addition the public facilities and amenities and institutions can also be considered as contributors to the economy. Thus these elements are also mapped together with economic infrastructures. The figure 42 shows the location of the infrastructures.

5.3. Economic elements at risk and their vulnerability

This section presents the economic elements at risk to the major natural hazards identified in 3.1. The hazards are tsunami, swell wave, swell surge, rainfall flooding, strong wind and coastal erosion. A GIS was used to compute the hazard zones and these zones are compared against the business establishments and economic infrastructures.

The elements at risk of the existing land use at the different scenarios are described below:

i. Tsunami Hazard

The hazard analysis conducted for Kulhudhuffushi showed that a high magnitude Tsunami is most likely to approach from the eastern coastline. This wave would also wrap around the island and approach from the west causing floods around the island. However, with the newly reclaimed area the impact will be lower than predicted in the previous DIRAM study for the island. How a Tsunami would impact the infrastructures are summarized below and results of the hazard analysis are presented in figure 43.

Impacts of Tsunami to the key infrastructures

- The most critical infrastructures at risk are the power house, the RO plant and the sewerage treatment plant. Also, the waste site is highly exposed to risk of flooding. The power house is located in a highly vulnerable zone as it is very close to the southern coastline.
- The power house although located at the high risk zone, any damage to the systems is unlikely since the engines are located at elevated heights.. Additionally, after the 2004 tsunami, the distribution boards are all elevated making them resilient to impacts of flooding.
- The RO plant is located at the north east side of the island which is prone to flooding in any extreme weather event, tsunami or swell surge. Although the area has been raised to build the plant, the area is still vulnerable to flooding.
- The sewerage treatment plant is also located at the vulnerable south coastal area. Although no significant damage to the structure of the plant is expected some secondary impacts that could occur include over flow of pumping stations due to heavy flooding which may cause health implications to the public.

- The waste site would cause secondary pollution as the high pressure wave would disperse all the waste into the island polluting the island and thus leading to other types of risks including health hazards.
- The new island harbor is protected by a breakwater making the area less susceptible to floods. Also the area is high compared to other areas of the island reducing the impact of flooding. The harbor area noted in the previous DIRAM report has now been reclaimed at a higher elevation. Thus the impact of a tsunami or flood is expected to be relatively low
- The regional port is also protected with armor rocks and sheet piles. Nevertheless the rising tide may flood the area damaging the buildings, any vessels and goods present at the port area.
- From the communication infrastructures, *Wataniya* site is located at a moderate risk zone. However since the structure is elevated from the ground the impact is expected to be relatively low.
- The most critical public infrastructures at risk include the hospital, police station, schools and some office institutions.
- The hospital and police station is located at the high risk zone. These critical infrastructures are highly vulnerable to tsunami floods. However, the breakwater at the port area and the newly reclaimed area is expected to minimize the impact of the tsunami on the infrastructures.
- Four schools out of six and the university campus are at risk in terms of their location and building designs. The buildings are not elevated and are located at vulnerable areas. The primary school located at the southern end is the most vulnerable as it falls under the high risk zone.
- With the new reclaimed area the existing business establishments are now located within the low risk zones making them less vulnerable to a tsunami hazard. However, in case of an extreme flood caused by a tsunami, most of the wholesale and retail shops would be at risk as they are not well elevated and the goods are normally stocked at floor levels. Few shops are located at high risk areas although most falls under the low risk zone. Also it is important to note that the people have their own ways of adapting to such situations by having concrete bags ready to be used during such events.
- The boat building area located at the north west side of the island is also at a high risk zone and a tsunami would cause significant damage to the area. Moreover the fishing vessels and transport vessels which are not even insured are also susceptible to severe damage.
- The key employers at risk would be the utility companies, vessel owners, wholesale/retail traders and boat builders.

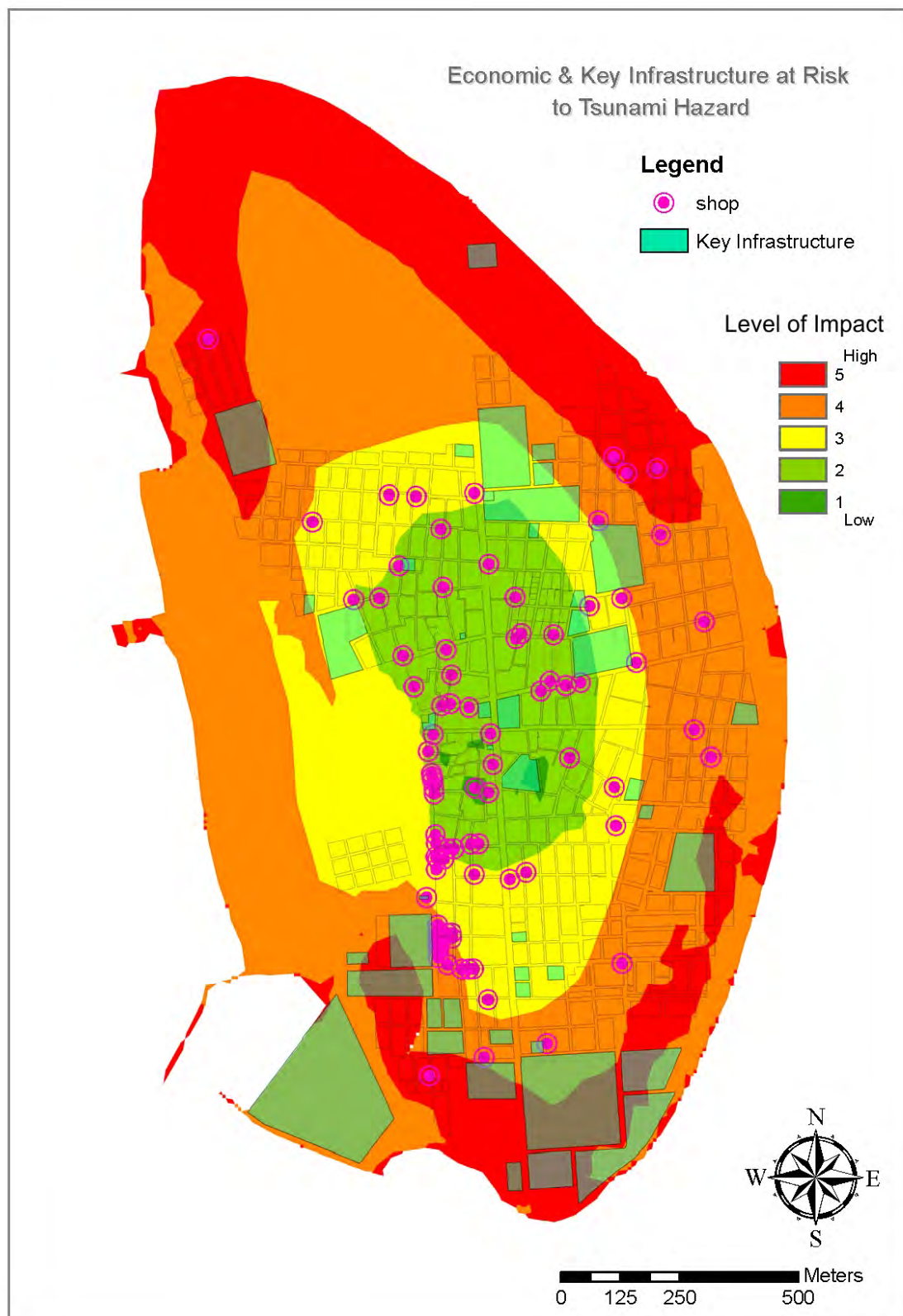


Figure 43 Economic elements and public infrastructures at risk to a Tsunami Hazard

Swell wave hazard

Swell waves and storm surges are expected to impact at a low intensity compared to Tsunami although the flooding patterns would be similar. Swell waves and surges are expected to approach the island from south, south east, south west, east and north east. Thus the coastal areas surrounding the island except the western coastline are vulnerable to the effects of swells. How a severe swell would impact the infrastructures are summarized below and results of the hazard analysis are presented in figure 44.

Impacts of a swell wave hazard to the key infrastructures

- The predicted impacts of a swell wave or surge are similar to the expected impacts of a tsunami. However the damage caused would be smaller as the wave height and its intensity are expected to be lower compared to tsunami waves. The damages are also calculated in section 5.4.

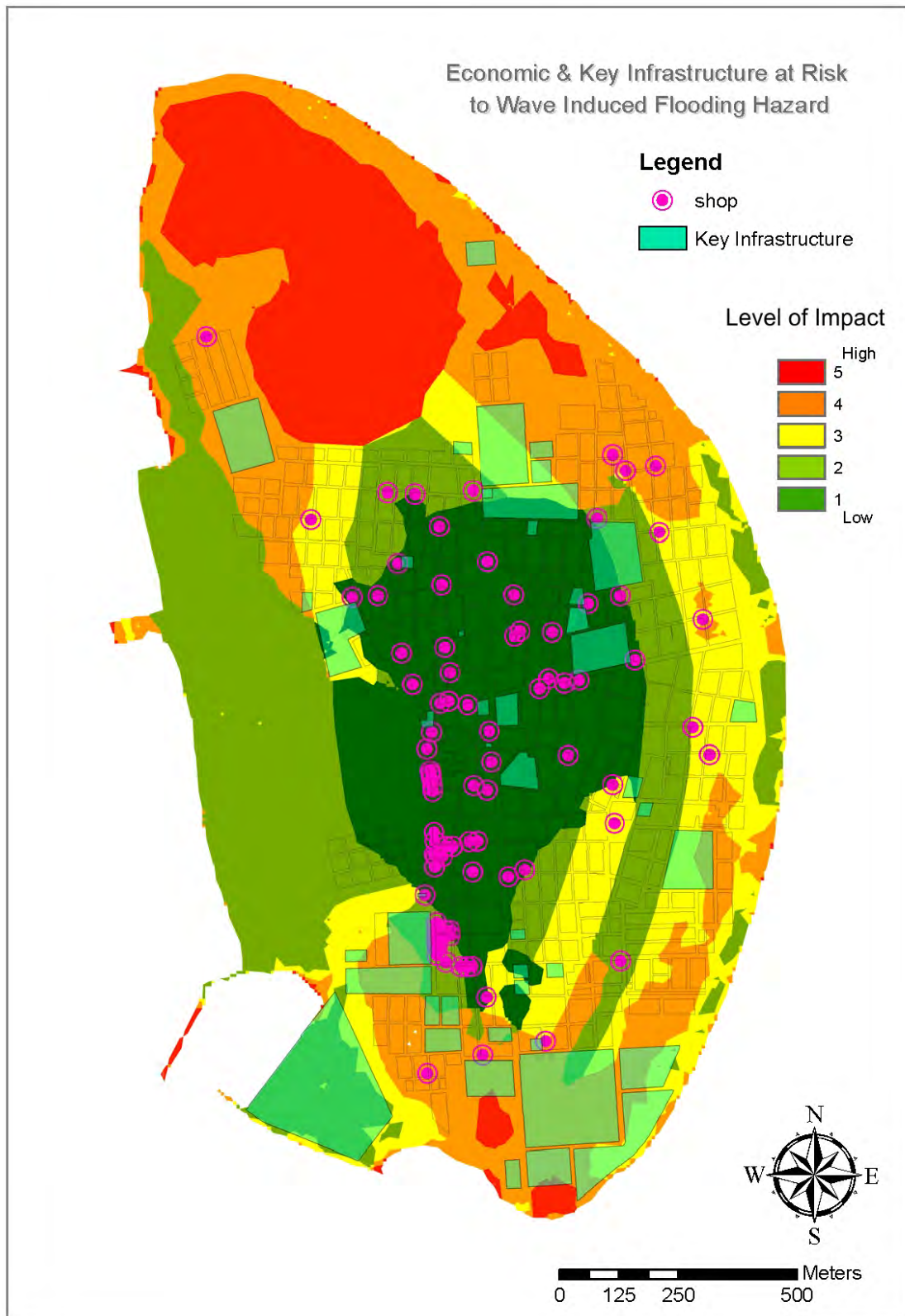


FIGURE 44 ECONOMIC ELEMENTS AT RISK TO A SWELL WAVE HAZARD

ii. Rainfall flooding hazard

The areas which are likely to be severely affected by a heavy rainfall event are the northern and southern ends of the island. As these two areas are the lowest areas of the islands the water flow is expected to run towards these areas causing severe floods. Even the reclaimed wetlands are prone to floods due its low level compared to the eastern, central and western parts of the island. How a severe rainfall event would impact the infrastructures are summarized below and results of the hazard analysis are presented in figure 45

Impacts of a heavy rainfall flood event to the key infrastructures:

- Although the two ends of the island is prone to flooding since they are located away from the settlement area it has not been a concerning issue for the people of Kulhudhuffushi as most of the households are located at the elevated areas
- According to the analysis, flooding due to a heavy rainfall event may impact the power house, Sewerage treatment plant (STP) and the RO water plant.
- Since the power house and the STP are located in the flood prone area, flood waters are likely to enter the buildings. However, the engines are located at an elevated height making them safe from the floods. It is also unlikely that the flood would damage any structure of the STP.
- The communication sites (Wataniya and Dhiraagu) maybe flooded although no damage is expected as the structures are elevated.
- The business establishments at risk of flooding are the retail shops located at the north east side and north west end and the few shops at southern end of the island. The goods sold at these shops maybe affected but measures currently adapted by the shops, such as putting concrete bags and elevating the entrance would minimize the impacts.

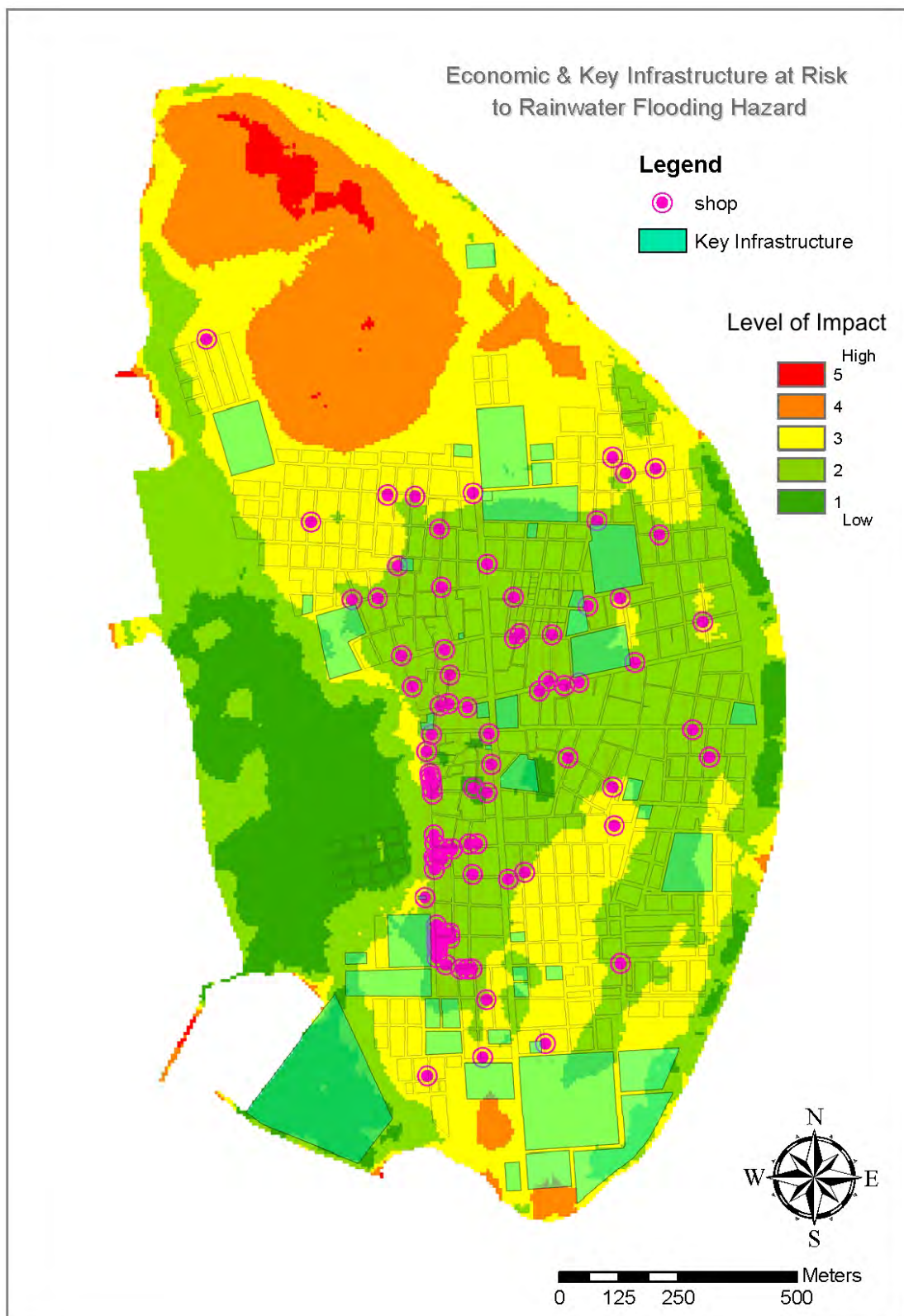


FIGURE 45 ECONOMIC ELEMENTS AT RISK TO A RAINFALL HAZARD

iii. Strong wind hazard

Geographically Kulhudhuffushi is located in a zone at risk from strong wind from localized storms. The strong wind generated from these storms would put the island at risk if it strikes the vegetation and the buildings. The expected impacts of a strong wind hazard include:

- Damage to the key infrastructures due to falling of trees and damage to roofs; Although the modern buildings constructed recently have stronger roofing system, old buildings are vulnerable to such events. Secondary impacts that arise from storms such as storm surges and rainfall would cause different impacts as described in sections ii and iii above.
- Damage to business establishments; damage maybe caused due to destruction of roofs due to strong wind or damage caused by falling of trees. These damages are not expected to cause any significant loss to the establishments. However secondary impacts such as rain followed by the storm may damage the stock if the roofs are damaged.

iv. Coastal Erosion

As noted in section 3.1, coastal erosion is a natural process exacerbated by hazard events and human induced events. Although erosion may not directly impact any infrastructure, it increases the vulnerability of the island to other natural hazards that would in turn affect the infrastructures as explained above.

The risk analyses of the infrastructures are based on the existing land use. Since the proposed land use plan is still under revision, no judgments can be made on the future developments. However, it is important that the vulnerabilities of the infrastructures and the hazard zones are taken into consideration in preparing the new land use plan.

5.4. Economic consequences of a disaster

5.4.1. General Findings

The economic outlook of Kulhudhuffushi economy has shifted from fisheries to other sectors mainly wholesale, retail and transport. There have been no major investments made in the fisheries sector but substantial private investment has been made in wholesale, retail and transport sector. The key contributor to the economy is income earned from government and other public enterprises. Kulhudhuffushi economy is also dependent on travel and supply of goods to neighboring islands especially from Haa Alifu, Haa Dhaalu and Shaviynai Atoll. The

impact on the economy would be highly affected if vessels for transport or harbor are damaged.

Based on the natural hazard assessments the study identified the key economic establishments and infrastructures at risk. According to the assessments, as explained in section 5.3 and calculations based on the figures gathered, economic losses are expected to be highest during a high magnitude tsunami or a swell wave event. Impacts of other disasters such as rainfall flooding and strong wind are expected to be relatively low compared to tsunami and swell waves.

The key economic infrastructures which are at high risk of being damaged during the disaster events described are the power house, RO water plant and STP. The critical social infrastructures at risk are the hospital, police station, some of the schools and the main zone stadium (football field). It is essential to understand the direct and indirect economic loss of the disasters as the functioning of the whole community depends on these infrastructure on a daily basis. It was found that a significant loss will be experienced by these infrastructures in the different disaster scenarios. These are further explained in the next section.

With the reclamation, most of the business establishments are now located further away from the shorelines reducing their vulnerability to disasters. However some of the wholesale and retail shops located at high risk areas and the boat building industry assets located at high risk zone are expected to cause significant losses in case of a severe disaster event. Also, rope making, the main activity in which women are involved in will also be at risk as the raw materials would be in short supply and the area where they carry out the activity will be at risk in a disaster event.

A temporary decline in the economy is highly expected and recovery may take a considerable amount of time depending on the intensity of the disaster and the damage caused. It is evident that if the expected losses of infrastructures, facilities and other assets are experienced, there will be a significant drop in the economic growth.

Although Kulhudhuffushi has been experiencing rapid development in terms of physical development, not much consideration has been given to disaster risk reduction or mitigation. The rapid urbanization increases the risk and vulnerability of the island to disasters.

5.4.2. Detailed Findings

The table 13 below shows estimated values of losses. The figures only represent losses for the tangible developments and do not consider developments proposed for the newly reclaimed area.

TABLE 13 ESTIMATED VALUES OF LOSSES

Sector	Tsunami losses	Swell waves and storm surge losses	Rainfall flooding losses
	(Rufiyaa)	(Rufiyaa)	(Rufiyaa)
Infrastructure	61,200,000	8,000,000	1,400,000
Households	8,800,000	3,200,000	400,000
Fisheries	9,500,000	4,700,000	-
Agriculture	75,000	15,000	10,000
Wholesale and retail trade	6,000,000	3,000,000	40,000
Manufacturing	495,000	100,000	10,000
Transport, storage and communications	4,300,000	1,500,000	120,000
Construction	1,250,000	350,000	90,000
Hotels and restaurants	495,000	250,000	50,000
Public Administration	25,000,000	6,500,000	200,000
Other community, social and personal service activities	1,200,000	600,000	20,000
Real Estate, renting and business activities	7,500,000	370,000	30,000
Tourism	-	-	-
Mining and quarrying	520,000	156,000	-
Financial intermediation	240,000	120,000	-
Total	126,575,000	28,861,000	2,370,000

The estimated loss from a severe tsunami event in Kulhudhuffushi ranges between Rf 100 million and Rf 126 million. The losses to infrastructures, particularly to the power house, RO plant, STP, hospital, police station, schools and the stadium form a significant proportion of the total losses. Damage to school and hospital contributes to public infrastructure and administration costs.

The estimated tangible loss from a severe swell wave or storm surge event in Kulhudhuffushi is Rf 29 million. The losses are small compared to a tsunami event as the intensity of the impact is low.

The estimated tangible loss from a severe rainfall flooding event is Rf 2.3 million. Compared to tsunami and swell wave events, a heavy rainfall event is expected to result in a smaller loss as flooding would mostly impact the low areas of the island which are mostly the areas at the two ends of the island. Also the intensity of the impact caused by flooding is much lower than that of a tsunami or swell wave.

6. Key island findings

The environmental, social and economic assessments have shown the extent of vulnerability of Kulhudhuffushi to a natural disaster. This section summarizes the findings as a SWOT analysis to provide an overall picture of the outcomes of the study.

Strengths	Opportunities
<p>Socio-economic</p> <ul style="list-style-type: none"> ▪ Strong community spirit ▪ Strong economy ▪ Educated and skillful people ▪ Locals enthusiastic to work at different level of jobs ▪ More land created for better facilities <p>Environmental</p> <ul style="list-style-type: none"> ▪ The high coastal ridges at the eastern coastline ▪ The green vegetation belt at the eastern rim ▪ High elevation of the new reclaimed area at the west side of the island ▪ Size of the island; relatively large compared to other islands 	<p>Socio-economic</p> <ul style="list-style-type: none"> ▪ Strong bonds between community members would help in creating resilience among the communities. ▪ Economically stable community will be able to cope better in a case of disaster crisis. ▪ Potential entrepreneurs willing to work in the island; strengthening the economy of the island. ▪ Climate-smart planning can be used to plan the newly reclaimed area hence increasing its resilience <p>Environmental</p> <ul style="list-style-type: none"> ▪ The island can be a safe island from natural disasters through proper mitigation measures such as rehabilitation of the coastal ridges and the vegetation belt.

Weaknesses

Socio-economic

- Population growth increases the vulnerability of the island
- Poor condition of housing and infrastructure
- Location of housing and infrastructure
- Buildings built at reclaimed areas are prone to damages
- Different political views slow down the decision making process

Environmental

- Reclamation of the wetlands disrupts the natural drainage system and creates more areas prone to flooding
- Relatively small reef flat compared to other islands restricting future expansions.

Threats

Socio-economic

- High population growth rate would increase the population density; more people are at risk in case of disaster- poverty may increase
- Location of some of the critical infrastructures/institutions/housing are subject to erosion, swell waves and flooding. Homelessness and loss of facilities
- Damage to critical infrastructures such water plant leading to water scarcity
- The different political views among the public decreases community spirit leading to segregation of the society

Environmental

- The fact that the original wetland areas were reclaimed, both ends are prone to flooding and may damage the existing and upcoming buildings in those areas
- Erosion of the eastern and northern side of the island may undermine the coastal ridge making the island more vulnerable to potential natural disasters

7. Reducing Vulnerability and exposure to disasters

7.1. Measures to reduce environmental vulnerability

i. Rehabilitation of the eastern coastal ridge

It was clear from the vulnerability assessment that the eastern coastal ridge of Kulhudhuffushi acts as a very important coastal defense. Even though the full impact of the tsunami and the highest run-up was from the eastern side, the high elevation of the ridge prevented major inundation of this area. Likewise it acts as a natural barrier to flooding from storm surge and wave induced flooding. Hence it is imperative that this ridge is maintained at all cost. Erosion continues to be a threat to the stability of the ridge, as it has the potential to fully undermine the ridge. Hence some form of coastal protection measure which will restore and maintain the ridge needs to be implemented.

ii. Coastal protection in the southern and northern side

The northern shoreline around the wetlands is eroding at an alarming rate. If left unchecked, the narrow land strip between the wetlands would be completely undermined, making this area more susceptible to flooding and tsunami hazards.

Coastal protection for the south side is also needed since the houses and other establishments in this area are constructed on lower ground, following the reclamation of the old wetland area. Apart from residential infrastructure, critical infrastructures like the power house and the waste disposal site is located very close to the shoreline.

iii. Maintaining the EPZ

The eastern side coastal vegetation stretches from the northwest corner to the southern tip of the island. This green zone acts as the 2nd line of defense after the high coastal ridge, in reducing the impact on the island from tsunami or wave induced flooding. It should be ensured that no development encroaches into this existing green zone and measures needs to be taken to strengthen the green zone especially in the southern and northern ends of the island.

iv. Establishing a proper drainage system

A functional drainage system is critical to prevent major damage due to flooding as well as from tsunami inundation. A large scale road development project has been recently announced by the government. The government should ensure that that the

newly constructed roads are implemented with a properly designed functional drainage system. Another critical area is the interface between the old and new reclamation. The existing ditch should be properly designed and it should be ensured that water flow into this area is safely channeled to the wetlands in the north.

v. **Maintaining the northern side wetlands**

The wetland in the north is a critical feature in reducing the impact of flooding in the island. The consequences of failure to maintain the wetlands is seen on the southern side of the island where flooding is frequent. The wetland also helps recharge the groundwater and would contribute to water security of the island.

7.2. **Measures to reduce socioeconomic vulnerability to disasters**

Socioeconomic vulnerability depends on many factors such as income, education, health, age and location of households as described in section 4. In order to reduce the risks, it is essential to integrate the Hyogo framework 2005-2015⁵, the Millennium Development Goals⁶ (MDGs) and the Cairo principles⁷ in implementing the measures. Following measures details out how this can be achieved and how the island community can be made resilient to natural disasters.

“Anticipating, educating and informing are the keys to reducing the deadly effect of natural disasters”
UNESCO Director-General
Koïchiro Matsuura, 3
January 2005

vi. **Promote disaster risk reduction and management:**

⁵ “The World Conference on Disaster Reduction ...adopted the present Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters...The Conference provided a unique opportunity to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazards. It underscored the need for, and identified ways of, building the resilience of nations and communities to disasters” UNISDR (2007)

⁶ “The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world’s countries and all the world’s leading development institutions”
(<http://www.un.org/millenniumgoals/bkgd.shtml>)

⁷ Guiding Principles for post-tsunami rehabilitation and reconstruction (UNEP-GPA 2005)

- Make disaster risk reduction a local priority through educating and creating awareness among the island community on natural disasters, the impacts they cause and the importance of risk reduction to ensure risk resilience (UNISDR 2007; Laukkonen 2009).
 - Empower the island council to act as the key facilitator to build awareness on disaster risks among the community.
 - Use knowledge and innovation to educate the people and create a culture that opts for safety and resilience of the island and the people (Latham n.d.)
 - Initiate capacity building programs in the public sector to increase their capabilities in addressing disaster risk reduction issues (Laukkonen 2009)
 - Adopt participatory approaches such as Participatory Rural Appraisal (Chambers 1997), to empower the vulnerable groups to be actively involved in risk reduction programs.
 - Identify ways to diversify the economy to improve the economic well-being of the community and eradicate poverty by adopting a sustainable approach as proposed in the UNDP's Millennium Development Goals (UNDP, 2010).
 - Develop financial plans to strategize the available resources and involve the community in the planning process to identify efficient ways to use the resources in a sustainable way. Equal opportunities can be provided to all, especially for youth and women by creating jobs and livelihoods through the diversification of the economy of the island , (UN 2013).
 - Identify the most vulnerable groups and provide them with social safety nets to reduce their vulnerability to disaster (ESCAP & UNISDR 2012).
 - Encourage the community to insure the high risk establishments and valuable assets at risk such as fishing vessels.
 - Incorporate hazard mapping and hazard zone analysis at policy level. Revise the land use planning regulation and building code to incorporate hazard analysis as part of the planning process as has been proposed in the *Integration of Climate Change Risks into Land Use Planning* (MHE, 2011).
- vii. **Prepare the communities for the possible disaster events**
- Use their local knowledge and incorporate scientific knowledge to anticipate, educate and inform on the disasters and ways to reduce the risks. It was evident from the consultations that the people are not very aware about the intensity of the risks and their impacts. Their perception towards risk shows that most of the people are not very concerned about natural hazards, but are rather concerned about other socio-economic factors. They need to be informed about how impacts on the natural environment

would affect the socioeconomic structure of the island and their social and economic well-being are factors that could make them more vulnerable to such events.

- Develop disaster management plans complemented with an early warning system at all levels; national, regional, atoll and island level. The plan for the island should cover ways to assist and support the vulnerable groups, evacuation plans and response procedures for the critical infrastructures.
- Train teams from the island for disaster response.
- Prepare a comprehensive registrar including permanent and temporary residents and expatriate population.
- Sufficient supply of food and water should be always kept in stock to avoid food and water shortage at a time of disaster.

viii. Strengthen the emergency response and recovery services

- Retrofit the hospital building to avoid flood impacts and equip the ambulance and emergency services with appropriate emergency response facilities.
- Revitalize the community spirit through interactive programs and awareness campaigns to strengthen their relationships and support especially during a time of a disaster and during time of recovery.

7.3. Costs and benefits of mitigation measures

This section presents a cost benefit analysis for the proposed measures to reduce socioeconomic and environmental vulnerability to disasters. The costs are calculated based on prices in 2013. Table 14 below provides a summary of the costs of mitigation measures and the responsible sector.

TABLE 14 SUMMARY OF MITIGATION ACTIVITIES FOR KULHUDHUFFUSHI AND THEIR COSTS

Measures	Cost (Rufiyaa)	Responsibility (Private/public)
Diversifying and strengthening the economic base	To be determined	public
Coastal protection measures (soft measures + revetments at Southern end)	21,000,000	public
Coastal protection measures (Soft measures + revetments at whole eastern coastline)	69,000,000	public
Construction of artificial drainage systems in low lying areas & main roads (especially at the boundary of the reclaimed land and old shoreline)	17,000,000	public
Making the hospital flood proof	600,000	Public
Protecting fuel storage	400,000	Private
Making the powerhouse flood proof	400,000	Public
Making all the communication infrastructures flood proof	200,000	Private
Making all the waste management sites flood proof	560,000	public
Relocate the pre-school located at the eastern coastline	5,000,000	public
Strictly establish the environmental protection zone (Assuming no relocation required)	300,000	public
Relocate petrol shed proposed at the eastern area	-	public
Review the proposed land use plan, taking into consideration the mitigation measures	150,000	public
Creating disaster risk awareness amongst business establishments	50,000	public

Creating awareness on importance of insuring high risk investments	50,000	Public
Creating awareness on storing cash through banking facilities	50,000	Public

The cost and benefit analysis has been carried out using the standard methods of the analysis. For the purpose of this study, the costs for the proposed measures are the direct expenditure estimated to implement the measures. The benefits comprises of two parts: a) the direct and indirect losses avoided from severe disaster event(s) and b) the value of life and injuries avoided.

The tables below summarizes the cost and benefits of the proposed mitigation measures for the different scenarios. In this analysis, all costs for making the island resilient to natural disasters are considered as costs. This assessment considers a 25-year time span due to the possibility of significant land use changes within such a timeframe.

The two scenarios evaluated in the previous DIRAM study; analysis for a single disaster (Tsunami) event (table 15) and analysis for possible multiple disaster events within a 25-year time span (Table 16), are re-evaluated using the current costs and benefits. In addition, given the frequent events of flooding, single rainfall flooding event per year for the 25-year time span (table 17) has also been evaluated. For the flooding event, the cost mitigation measures for coastal protection is deducted and measures relevant to flooding is considered.

TABLE 15 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION A SINGLE DISASTER EVENT IN 25 YEARS

Measures	Costs (Rufiyaa)	Benefits (Rufiyaa)	Net Benefits (Rufiyaa)
Benefits			
1. Damage to infrastructure, public investments avoided; production losses avoided.		126,575,000	
2. Lives saved and injuries prevented ⁸		25,870,250	
Costs			
1. Cost of Mitigation measures	114,760,000		
Net Benefits			37,685,250

TABLE 16 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION MULTIPLE DISASTER EVENTS⁹ IN 25 YEARS

Measures	Costs	Benefits	Net Benefits
Benefits			
1. Damage to infrastructure, public investments avoided; production losses avoided.		157,806,000	
2. Lives saved and injuries prevented		34,997,980	

⁸ Assumption: 0.001% lives may be lost; 0.5% may be injured; Statistical Value of Life = 1,927,500.00 using income-over-life method.

⁹ Assumes a disaster event of each type (tsunami, swell wave and rainfall flooding) in 25 years.

Costs			
1. Cost of Mitigation measures	114,760,000		
Net Benefits			78,043,981

TABLE 17 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION ONE RAINFALL FLOODING EVENT PER YEAR FOR 25 YEARS

Measures	Costs	Benefits	Net Benefits
Benefits			
3. Damage to infrastructure, public investments avoided; production losses avoided.		28,440,000	
4. Lives saved and injuries prevented		6,308,987	
Costs			
2. Cost of Mitigation measures	19,760,000		
Net Benefits			14,988,987

The calculations show a net benefit of 37 million Rufiyaa for the first scenario considered. Mitigation measures are often not designed for single disasters; it is designed for multiple hazards. The second scenario considers multiple hazards during the 25-year timeframe and it shows a net benefit of 78 million Rufiyaa. The third scenario considers a possible rainfall-

flooding event per year for the 25-year timeframe and it shows a net benefit of Rufiyaa 15 million.

The buildings and facilities proposed at the newly reclaimed area are not included in this analysis as the land use plan is under review and the developments are expected to change after the review. Hence, once the developments are complete or the plan gets approved it is recommended to revise the analysis as per the developments and their vulnerability.

7.5. Climate risk monitoring, assessment and data sharing

The above proposed mitigation measures would help the island to restore its defense mechanism to protect the island from the adverse impacts of climate change and natural hazards. However, in order to ensure that these measures are functioning and to identify how successful the measures are, it is essential to have a monitoring plan. The plan should be able to provide a way to monitor the predicted risks identified in this study in a continuous manner before and after implementation of the measures proposed.

Since the island community understands the nature of the island dynamics better than any outsider, this monitoring should ideally be conducted by the community members and reported to the relevant authorities so that the data can be shared among the relevant stakeholders for them to take any action regarding the findings. The following Table 18 plans out how the data can be collected for the monitoring. Annex III provides template sheets to collect the data followed by the methodology on how to collect them.

TABLE 188 RISK MONITORING PLAN

Monitoring parameter	Methodology	Sampling frequency	Training equipment requirement /
Shoreline mapping (high tide, low tide and vegetation line)	<p>Mapping of high and low tide using precision GPS (0.5m accuracy)</p> <p>Mapping of Vegetation line using precision GPS (0.5m accuracy)</p>	<p>Once every two months</p> <p>Once every 4 months</p>	<p>Surveyors at Kulhudhuffushi Island Council or HDh Atoll Council office can do these surveys without further training.</p> <p>GPS system that has an accuracy of 0.5m is required for these surveys.</p>
Beach profiles	<p>At least 10 beach profiles around the island need to be recorded. Initially permanent bench marks should be setup around 10 locations (spread around the perimeter of the island). MSL of these bench marks should be established by connecting the bench marks via level control survey.</p> <p>Features to be recorded are; inside island ridge, top of ridge, bottom of ridge, edge of vegetation, erosion scarp top, erosion scarp bottom, mid beach, beach toe, beach toe bottom, beach rock start, beach rock top, beach rock bottom and lagoon bottom</p>	Every four months	<p>Surveyors at atoll or island council does not need additional training</p> <p>Auto level with barcoded staff will be required to speed up the survey.</p>
Storm surge related flooding/ tsunami	<p>In the event of storm surge related flooding, extent of flooding should be recorded using GPS (0.5m accuracy). The can be recorded as points and later on during data processing a line feature should be generated from these points.</p> <p>Height of floodwater should be recorded using a staff. The height can be measured as water level above road level. The location of measurement should</p>	<p>N/A</p> <p>Should be carried out before water recedes.</p>	Graduated staff and GPS system (0.5m accuracy)

	be recorded using GPS. Measurement locations should be spread such that measurements are taken at near shore area, central area and at furthest extent of flooding		
Rainwater flooding	Baseline locations shall be established using GPS based on the rainwater flooding zonation map generated in this report. At least 10 locations shall be established (5 within worst flooding zones and 5 at moderate flooding zones). During SW monsoon extreme weather events (high precipitation periods), floodwater heights should be measured at the baseline locations. The height of floodwater should be taken from the center of the road using graduated staff.	N/A	Graduated staff and GPS system (0.5m accuracy)

As illustrated in the plan above, the parameters can be used to measure the changes that could be useful in analysing the impacts caused by climate change and natural hazards. These parameters are also considered in accordance with the recently developed coastal protection guidelines (MEE, 2013). However some parameters mentioned in this guideline are not covered in the list. These include a) the tide data, which cannot be taken at island level and can be attained from the Hanimaadhoo station, as they are more equipped in collecting such data; and b) Bathymetric data, where the guideline recommends to use LIDAR which is too costly that, it would not be feasible to be carried out at island level.

The monitoring plan provided here is mainly for data sharing purpose and is designed in a way that the island council can collect most data and share it with the relevant authorities.

8. Conclusion

In this review, the findings of the previous DIRAM study have been updated with the most recent data available. Although some of the data that could only be attained from a comprehensive census could not be updated as no census has been carried out after the previous study. With the substantial changes that have occurred over the past 5 years, the analysis of the impacts of natural hazards to the physical environment of the island and the community showed a significantly different scenario. The households, key infrastructures and business establishments which were under high risk zones are now in safer zones. This is mainly due to the large reclaimed areas. Also with a better elevation model the study was able to make predictions based on both elevations and width.

The studies showed that the natural setting of the island with high ridges (+2.5 m MSL) at the eastern end makes the island resilient to the potential natural hazards. The hazard analysis revealed that the eastern area would be protected from the adverse effects of tsunami and swell waves, reducing the impact to the various infrastructures and other land users located in that area. However, the study also noted that this important feature is under threat due to the problem of erosion which the island has been experiencing for decades. If this erosion continues, there is a high possibility that the ridge would be severely undermined making the island more vulnerable to disasters. Thus, soft and hard measures need to be adopted to protect the ridge in a sustainable manner so that the island remains to be protected.

Moreover the increase in population and the rapid urbanization has also increased the vulnerability of Kulhudhuffushi to disasters and impacts of climate change. Especially the vulnerable groups including elderly, women, low income households, at risk-children and youth etc. would be more susceptible to such events if proper risk reduction measures are not undertaken.

In case of a disaster event, the economy of the island would also be at risk. However, the damages caused would be less compared what was observed during the previous DIRAM study (UNDP, 2008). Main reasons for this are the coastal modifications and the reclamation of the island that have shifted the critical infrastructures inwards making them less vulnerable.

Certain measures that are required to reduce the vulnerability of the island to disasters and impacts of climate change are proposed. Measures to reduce the identified environmental vulnerabilities include; rehabilitation of the eastern coastal ridge; coastal protection in the southern and northern side; maintaining the Environmental Protection Zone; establishing a proper drainage system; maintaining the northern side wetlands; introduction of measures to

reduce socioeconomic vulnerability to disasters. Additionally, to reduce the socio economic vulnerability of the island, it is critical to: promote disaster risk reduction and management measures, prepare the communities for possible disaster events and strengthen the emergency response and recovery services. By doing so the community would be more informed and ready for such a disaster event. Also they would be more resilient with a strong economic base and a better environment. The cost benefit analysis conducted for the measures proposed for the scenarios of a single Tsunami event and multiple disaster events in 25 years period showed that there would be a net benefit of Rufiyaa 37 million and Rufiyaa 78 million respectively for the two scenarios. Also in case of a flood event the proposed measures are expected to give a net benefit of Rufiyaa 15 million. Thus it is evident that with proper implementation of the proposed measures, the island would be highly resilient to natural disasters and impacts of climate change.

9. Limitation of the study & recommendations for further studies

9.1. Limitations of the study

A number of limitations noted in the previous DIRAM study have been tackled in conducting this assessment, with the aid of detailed land surveys. The digital elevation model generated from these data helped in predicting the hazard event scenarios in a better form. However this study also had some major limitations that constrained the assessments at different levels. These include:

- Lack of recent socioeconomic data limited the socio-economic analysis as all the numbers had to be estimated based on the limited data gained from field surveys.
- Predicting impacts of tsunami/ swell waves requires complex data collected over a longer period of time as well as physical/numerical modeling for a comprehensive analysis. However this is out of scope of the project and is not possible within the short time frame of the project
- The limited time to complete the project and unexpected weather conditions caused significant delay in conducting the study. It also restricted the level of detailed work which was initially planned to be carried out.
- Uncertainties of climate change events especially regarding sea level rise and sea surface temperature restricts the predictions to assumptions which may or may not be realized.

9.2. Recommendations for further studies

Although this study has been successful in assessing the vulnerability of Kulhudhuffushi to the natural disasters to a detailed level there is always room for improvement. There is also room to expand the study in other directions to make it a more comprehensive assessment so as to ensure sustainable outputs which can be generated from the numerous studies. Following are some of the recommended activities that need to be carried out to make this study and the previous studies useful in making the island resilient.

- Identify ways to collect and analyse the available data on coastal process including sediment movement patterns, shoreline changes, currents and waves at different parts of Maldives. Create a database of these data that could be shared for such studies.
- Identify ways to incorporate climate smart planning and Climate Smart Disaster Risk Management Approach (CSDRM) in disaster risk reduction of the island. CSDRM offers ways to “tackle changing disaster risks and uncertainties, enhance adaptive capacity

and address poverty and vulnerability and their structural causes" (*Climate Smart Disaster Risk Management*, 2013)

- Evaluate the best possible ways to improve the livelihoods of the vulnerable groups to make them resilient to climate change and natural disasters.
- Prepare and implement management and monitoring plans for the mitigation and adaptation measures proposed in this study.

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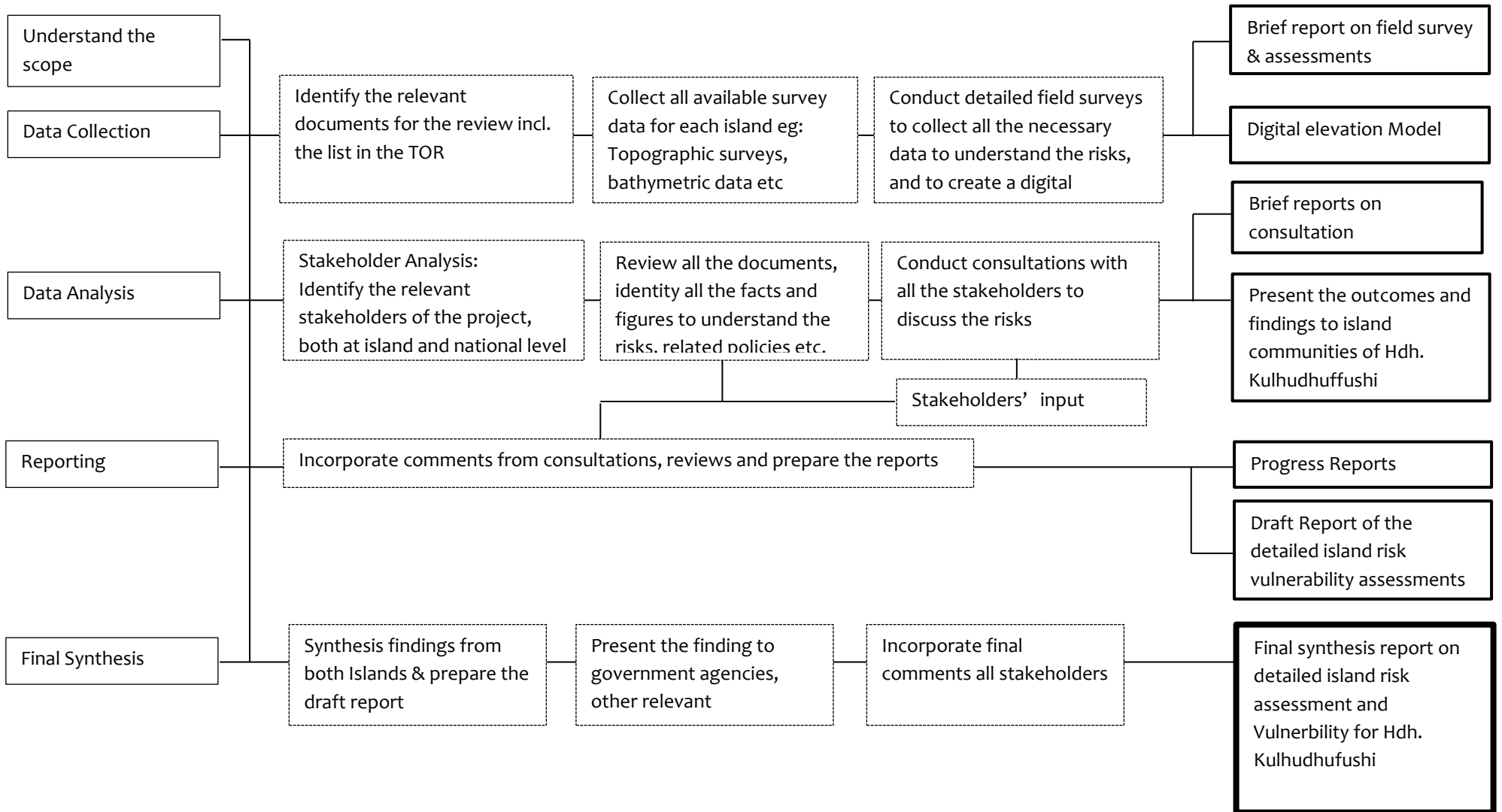
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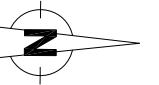
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Annexes

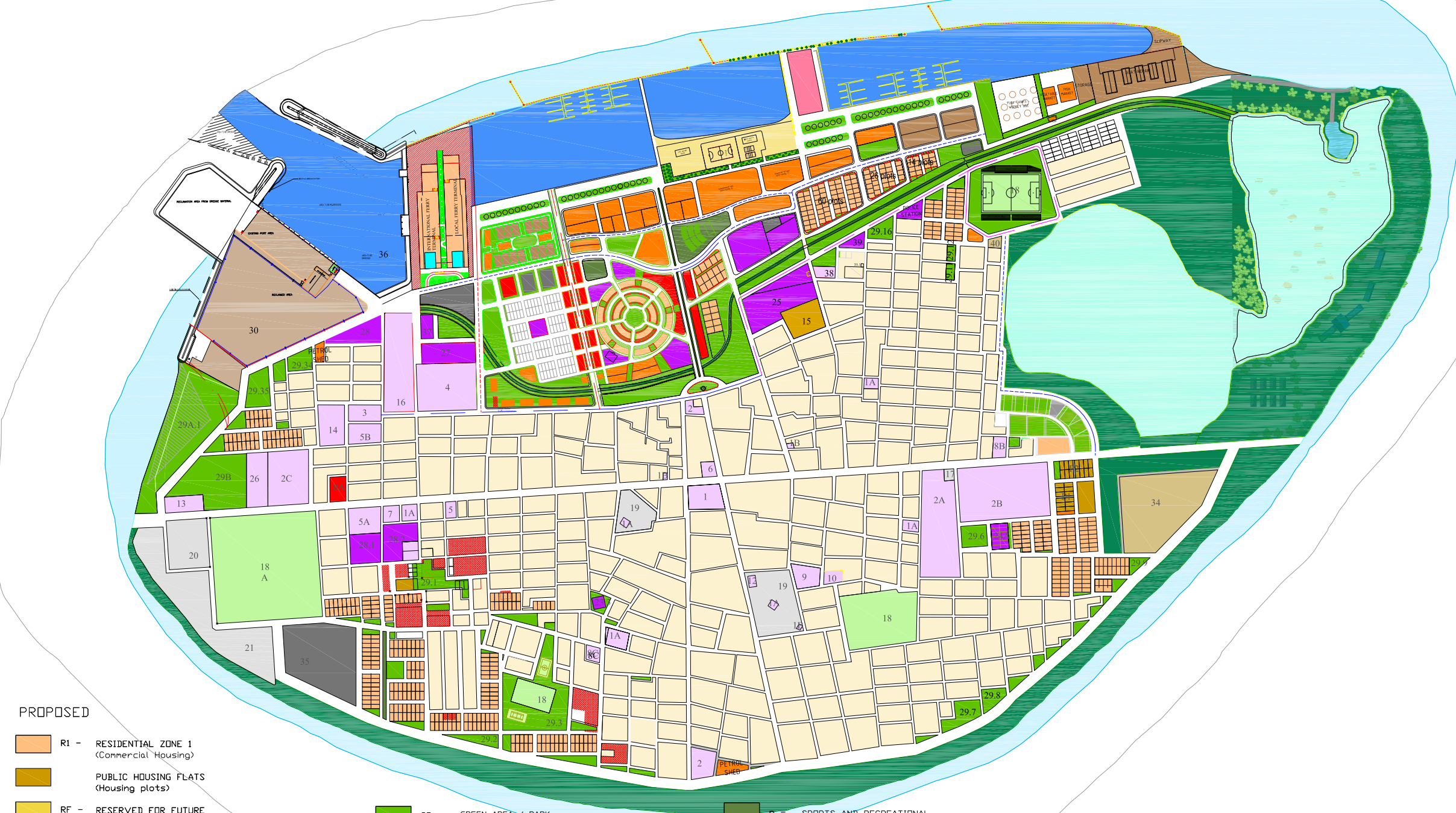
Annex I: Methodology Flow Diagram





LEGEND

- EXISTING**
- R - RESIDENTIAL ZONE
 - IC - INSTITUTIONAL & COMMUNITY FACILITIES ZONE
- 1 FRIDAY MOSQUE
 - 1A MOSQUE
 - 1B NAMAADHUGE
 - 2 SCHOOL
 - 2A ATOLL EDUCATION CENTER
 - 2B SECONDARY SCHOOL
 - 2C HIGHER SECONDARY SCHOOL
 - 3 ATOLL MEDIA CENTER
 - 4 REGIONAL HOSPITAL
 - 5 ATOLL OFFICE
 - 5A ATOLLHUGE
 - 5B ATOLL GUEST HOUSE
 - 6 ISLAND OFFICE
 - 7 ISLAND COURT
 - 8A DHEKUNU AVASHU GOATHI
 - 8B UTHURU AVASHU GOATHI
 - 8C IRUMATHI AVASHU GOATHI
 - 9 DHIRAAGU SITE
 - 10 BANK
 - STELCO OFFICE
 - POST OFFICE
 - 13 MCPW
 - 14 UPPER NORTH PROVINCE
 - 15 KULHUDHUFFUSHI CAMPUS(MITE)
 - 16 N.S.S
 - 38 SOCIAL SERVICES PROTECTION CENTRE
- PROPOSED**
- R1 - RESIDENTIAL ZONE 1 (Commercial Housing)
 - PUBLIC HOUSING FLATS (Housing plots)
 - RF - RESERVED FOR FUTURE NON-RESIDENTIAL USES
 - CD - COMMERCIAL ZONE
 - 22.11 COMMERCIAL RETAIL MIX PROPOSED FISH MARKET
 - RD - RETAIL & MIXED USE ZONE
 - MOSQUE
 - IC - INSTITUTIONAL & COMMUNITY FACILITIES ZONE
 - 23 - 23.3
 - 24A PRE SCHOOL
 - 24B PRIMARY SCHOOL
 - 25 COLLEGE CAMPUS
 - 26 COMMUNITY CENTRE
 - 27 HOSPITAL - EXTENSION
 - 28 RESERVED FOR FUTURE GOVERNMENT & INSTITUTIONAL USE
 - 36 COMMUNITY GUEST HOUSE
 - 37 REGIONAL FIRE SERVICES
 - 39 YOUTH CENTRE
 - 41 LAND FOR CUSTOMS
- SR - SPORTS & RECREATIONAL ZONE
 - 18 FOOTBALL FIELD
 - 18A ZONE STADIUM
 - M - UTILITY & MUNICIPAL SERVICES ZONE
 - 19 CEMETERY
 - 20 STELCO POWER HOUSE
 - 21 WASTE MANAGEMENT SITE
 - 17 SUB STATION
 - K - KULHI
 - L - LAGOON
 - ROADS
 - EDGE OF REEF FLAT
 - EXISTING SHORE LINE
 - REEF LINE



- SR - GREEN AREA / PARK
 - 29 - 29.38 GREEN AREA / PARK
 - 29A - 29A.1 PUBLIC BEACH
 - 29B COMMUNITY PARK
 - P - SPORTS AND RECREATIONAL
 - EPZ - ENVIRONMENT PROTECTION ZONE
 - C - CONSERVATION ZONE
 - LH - LOCAL HARBOUR BASIN
 - CH - REGIONAL HARBOUR BASIN
 - 36 - AREA REQUESTED BY MPA (to be left unreclaimed)
 - ROADS
 - QUAY WALL
 - SEA WALL
- RP-30 REGIONAL PORT AND HARBOUR
 - 30.1 LOADING/UNLOADING AREA (Local Harbour)
 - BR-31 BOAT REPAIR
 - ID1 - INDUSTRIAL ZONE 1
 - 32 - 32.1 GARAGE & WORKSHOP
 - 33 - 33.1 WAREHOUSE & STORAGE
 - ID2- INDUSTRIAL ZONE 2
 - 34 BONBI FAA
 - 40 COCONUT PROCESSING UNIT
 - M - UTILITY & MUNICIPAL SERVICES ZONE
 - 35 CEMETERY
 - 35.1 SUBSTATION
 - 35.2 RESERVED FOR FUTURE RESIDENTIAL USE

