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A REPORT ON THE TERRESTRIAL ASSESSMENT OF TSUNAMI IMPACTS

ON THE COASTAL ENVIRONMENT IN REKAWA, USSANGODA AND KALAMETIYA (RUK) AREA OF SOUTHERN SRI LANKA

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Research Team

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Executive Summary

The Rekawa, Ussangoda and Kalametiya (RUK) area constitute a section of the south-eastern coastline of Sri Lanka, located in the Hambanthota District. The area contains an array of coastal terrestrial and wetland habitats, including managed landscapes. IUCN Sri Lanka was involved in conducting an assessment and monitoring of inland and sub tidal biodiversity in the RUK area, as part of an on-going project implemented by the Coast Conservation Department, since October 2002. The survey enabled to gather baseline information on the biodiversity and environmental status of the RUK area, which in-turn provided an opportunity to document Tsunami-related environmental impacts to the coastal ecosystems in this area. Therefore, a rapid environmental assessment was designed and implemented in the 100m coastal stretch by a team of researchers from IUCN – The World Conservation Union in Sri Lanka, from 10th – 15th of January 2005. In addition to documenting the Tsunami-related impacts to the environment and biodiversity in the coastal zone, the survey was also intended to gather scientific evidence on whether coastal natural ecosystems have contributed to reduce the damage on inland landscapes, including human settlements and agricultural areas. The methodology included the study of qualitative ecological parameters and quantitative analysis on damage to trees and ground features. Comparisons were also made on the species composition and abundance of terrestrial fauna in relation to the baseline data gathered previously in the affected terrestrial environment. The findings of the survey would enable to prioritise post-tsunami environmental conservation actions for the RUK area and also integrate environmental concerns into the current redevelopment activities planned to be implemented in the affected coastal areas of Sri Lanka. The main findings of the survey are highlighted below:

General observations

- The damage to the coastal stretch in the RUK area was patchy in general. However, the RUK coastal area consist of four general bay segments, and the Tsunami had impacted mainly the western flanks of each bay, including Medilla to Tangalle, Oruwella fishery harbour area, Kalametiya fishery harbour area, and Pattiyawaraya to Ussangoda fishery harbour.
- Ecological impacts were severe where the beach was narrow and low in height.
- The Tsunami waves have entered inland with a higher force in narrow bay areas possibly with trenches in the sea bottom topography (e.g. Oruwella)
- Natural and man-made canals and lagoon outlets linked to the sea have transferred the impacts towards inland area, due to funnelling of sea water resulting in damage to life, ecosystem and property (e.g. Kapuhenwala, Walawe estuary)
- Qualitative observations and analysis of site-specific quantitative data revealed a clear relationship between damage to inland areas with human modifications in the seaward/beach front environment.
- The Tsunami waves have penetrated inland with a greater force in areas where natural sand-dunes have been exploited and/or converted into managed landscapes such as coconut plantations and home gardens (e.g. Kalametiya village)
- In general, the houses and tourist hotels constructed in sensitive areas declared as coastal reservation zones (i.e., bordering estuarine/lagoon outlet areas, immediate beach front) have been subjected to severe damage by the Tsunami waves (e.g. Wanduruppa - Modaragama village and Medilla area).

- Areas where coral reefs were subjected to previous destruction by mining and bottom set netting have resulted in more damage to inland areas by the Tsunami waves (e.g., Oruwella fishery harbour area).

Impact on coastal biodiversity (ecosystems and species)

- The gentle sea-shore vegetation consisting of creeping plants and Pandanus stands have been affected up to 75% of the original cover.
- Sandy beaches, including the seaward area of sand dunes have been eroded, resulting in reduction of beach width in certain locations.
- The natural edaphic conditions in salt marsh, coastal grasslands and mangrove ecosystems have been affected due to large volumes of sand and marine sludge being transported and deposited by the Tsunami waves, which in turn has destroyed the short vegetation (i.e., creepers and propagules) of these ecosystems.
- In mangrove stands, the tree line facing the Tsunami waves has been subjected to moderate to severeeee damage.
- The vegetation in home gardens affected by the Tsunami waves have been destroyed, either fallen off, or dieing due to high saline conditions in the soil.
- Low-lying coastal paddy fields have been destroyed by the saline water and marine sludge depositions.
- The invasive alien Prickly Pear Cactus (*Opuntia dillennii*) that occurred in the beachfront habitats have been removed and transported to distant inland areas by the Tsunami waves, and these propagules have now started to establish in new areas.
- The spread of another invasive alien plant – Mesquite (*Prosopis juliflora*), which is already prevalent in the RUK area, may increase rapidly over time, as it exhibits a competitive dominance under increased saline conditions.
- Freshwater invasive alien species such as Cattail reed (*Typha angustifolia*) and Water Hyacinth (*Eichhornia crassipes*) occurring in low-saline lagoons such as Kalametiya have been destroyed due to increased salinity.
- Many species of near-shore and estuarine fish populations have been subjected to mass mortality and washed off into inland areas.
- Freshwater fish species inhabiting low-saline lagoons have died due to increased salinity.
- According to information gathered from fishermen, species of marine fish that were not previously documented in lagoons are now occurring in some lagoons in the RUK area.
- Compared to the baseline information on faunal species gathered prior to the Tsunami, a clear reduction in species composition and abundance of fauna such as amphibians, reptiles, birds, butterflies and molluscs was observed in coastal habitats affected by the Tsunami (i.e., Kalametiya area).
- Apart from fish, other dead vertebrate animals observed in the RUK area include two specimens of Mouse Deer (*Tragulus meminna*), a Land monitor (*Varanus bengalenisis*) and a soft-shelled Terrapin (*Lissemys punctata*).
- Dead invertebrate animals observed in the affected habitats in the RUK area include several species of freshwater and terrestrial molluscs.
- A large number of turtle nests in the RUK area (i.e., in Rekawa) had been destroyed by the Tsunami waves. However, the Green Turtle (*Chelonia mydas*) and the OIive

Ridley (*Lepidochelys olivaceae*) were observed started to visit and lay eggs in the RUK beach areas subsequent to the Tsunami.

Defensive and protective role of natural coastal ecosystems

- Mature and intact sand dunes (i.e., old and broad dunes covered with scrubland vegetation) occurring in the RUK area have functioned as an effective barrier against the Tsunami waves, thereby protecting inland ecosystems and human settlements.
- Intact stands of broad mangrove and Pandanus vegetation have also served as a frontline defence by absorbing/decreasing the strength of the tsunami waves.
- Coastal wetlands, including mangrove swamps, salt marshes, broad estuaries and lagoons have contributed to absorb the sea-water and sediments brought in by the Tsunami waves, thereby protecting managed landscapes such as paddy fields and human settlements.
- Coral reefs, rocky beaches, sandstone reefs have also contributed to reduce the force and energy of the Tsunami waves.

Based on the observations made during the rapid assessment, a set of short, medium and long-term recommendations are made to facilitate post-tsunami environmental conservation activities in the RUK area.

1.0. INTRODUCTION

1.1. An overview of the coastal environment in the RUK area

The Rekawa, Ussangoda and Kalametiya (RUK) area constitute a section of the south-eastern coastline of Sri Lanka, located in the Hambanthota District, about 200 km away from Colombo (Figure 01). The area contains an array of coastal terrestrial and wetland habitats, including managed landscapes. The coastal wetlands in the area includes the Rekawa lagoon (250 ha), the interconnected Kalametiya (606 ha) and the Lunama (192 ha) lagoons, the narrowly branched Kahanda lagoon (<100ha) and the Walawe estuary.

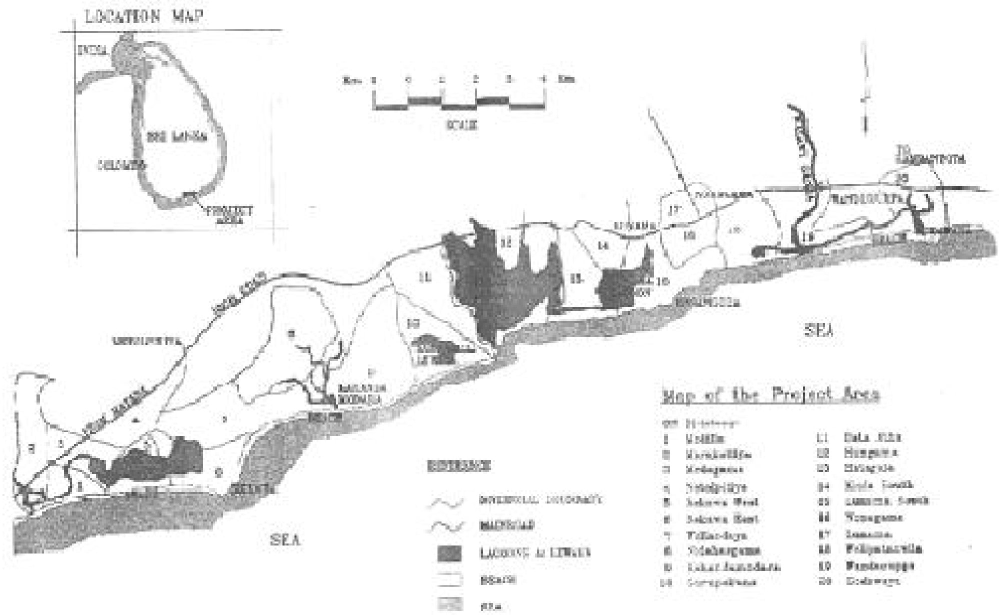

Figure 1: Location of the Rekawa, Ussangoda and Kalametiya coastal area

The area harbours a variety of natural and man-made vegetation/habitat types, including both terrestrial and wetland systems. The main natural coastal vegetation/habitat types include mangrove, scrubland, salt marshes, reed beds, and grasslands, while the managed landscapes include rice fields and home gardens. An assessment of biodiversity conducted by IUCN (IUCN Sri Lanka, 2004) enabled to document a total of 287 plant species belonging to 65 families from the above inland vegetation/habitat types of the RUK area. The fauna documented include a total of 328 species of vertebrates, of which 14 species (4%) are endemic, while 27 species (8%) are nationally threatened. The stretch of beach in this area is an important nesting site of five species of globally threatened marine turtles.

Based on floristic composition, the mangrove habitats in the area include *Lumnitzera* dominated stands (Rekawa), *Ceriops* dominated stands (Rekawa), *Avicennia* dominated stands (Rekawa), Mixed stands (Rekawa, Kahanda), *Excoecaria* dominated stands (between Lunama and Kalametiya) and *Sonneratia* dominated stands (Kalametiya, Malpeththawa).

The beaches of the RUK area is composed of a predominantly sandy coastline lying approximately in a "West South West - East-North Easterly" direction. The sandy beaches are interspersed by several rocky headlands often supporting coral reefs, river and lagoon estuaries and coastal sandstone beach-reefs. The beaches are steep, often rising 4-7m from the mean waterline, and are exposed to strong seas. There are significant dune formations as well.

1.2. Background of IUCN activities in the RUK area

In year 2002, the government of Sri Lanka secured financial assistance from the Global Environmental Facility (GEF) through United Nations Development Programme (UNDP) for implementation of a three-year project titled "*Conservation of Biodiversity through Integrated Collaborative Management in the Rekawa, Ussangoda and Kalametiya (RUK) Coastal Ecosystems*".

The main objective of the project was to ensure the conservation and sustainable use of the biodiversity of this globally significant site through the development of a collaborative management system, actively involving local communities, NGOs and governmental agencies. This project was implemented through the Ministry of Fisheries and Ocean Resources as the Executing Agency, while the Coastal Conservation Department (CCD) functioned as the Implementing Agency. IUCN – The World Conservation Union in Sri Lanka was identified as the facilitating agency of the project.

Under the above project a technical study was undertaken by IUCN for the assessment and monitoring of inland and sub tidal biodiversity in the RUK area, which contributed towards the preparation of a coastal environmental profile for the area. The overall objective of this study was to collect baseline data on biodiversity through a process of a detailed systematic scientific assessment documenting the status of inland and sub-tidal biodiversity in the RUK area and to use this data to design a biodiversity monitoring process that would contribute towards collaborative planning and management. The study on assessing the inland and sub-tidal biodiversity in the RUK area was conducted by IUCN during a period of six months, extending from October 1st 2002 – 31st March 2003, followed by the first phase of monitoring from December 2003 to March 2004. The second phase of biodiversity monitoring commenced in November 2004, and this work was ongoing at the time of the Tsunami disaster that affected this coastal stretch in the Hambanthota District. Since IUCN had gathered baseline information on the biodiversity and environmental status of the RUK area prior to the Tsunami, this provided an opportunity to document Tsunami-related environmental impacts to the coastal ecosystems in this area through a rapid scientific assessment. Therefore, a rapid environmental assessment was designed and implemented in the above coastal stretch by a team of researchers from IUCN, from 10th – 15th of January 2005.

1.3. Objectives of the present rapid environmental assessment survey

The main objectives of this rapid assessment was to document the impacts of the Tsunami on the coastal terrestrial environment in the RUK area and also gather scientific evidence on whether coastal natural ecosystems have contributed to reduce the Tsunami related impacts on managed landscapes, including human settlements and agricultural areas. The findings of the survey would also enable to propose recommendations towards the integration of environmental concerns into the current redevelopment plans for the coastal zone of Sri Lanka. The experiences gathered from this survey would also enable to plan out and implement similar rapid assessments to document the environmental impacts of the Tsunami in other parts of the island.

2.0. SURVEY METHODOLOGY

2.1. General sampling method

The rapid environmental assessment was based on the Quota sampling (Denscombe, 1999) approach, with certain modifications to suit the site-specific conditions. The RUK area, covering a coastal stretch of 27 km extending from Godawaya to Medilla was divided into four manageable survey segments, in the following manner:

Coastal segment 1: Medilla to Beliwinnegoda (Rekawa)
Coastal segment 2: Oruwella fishery harbour (Rekawa) to Kalametiya fishery harbour (Gurupokuna)
Coastal segment 3: Kalametiya & Lunama beach
Coastal segment 4: Ussangoda fishery harbour to Godawaya

The above stretches constitute four major bays found in the RUK area. Each segment was surveyed to document qualitative environmental features, while quantitative data on structural ecological damage of selected locations within these segments were also gathered.

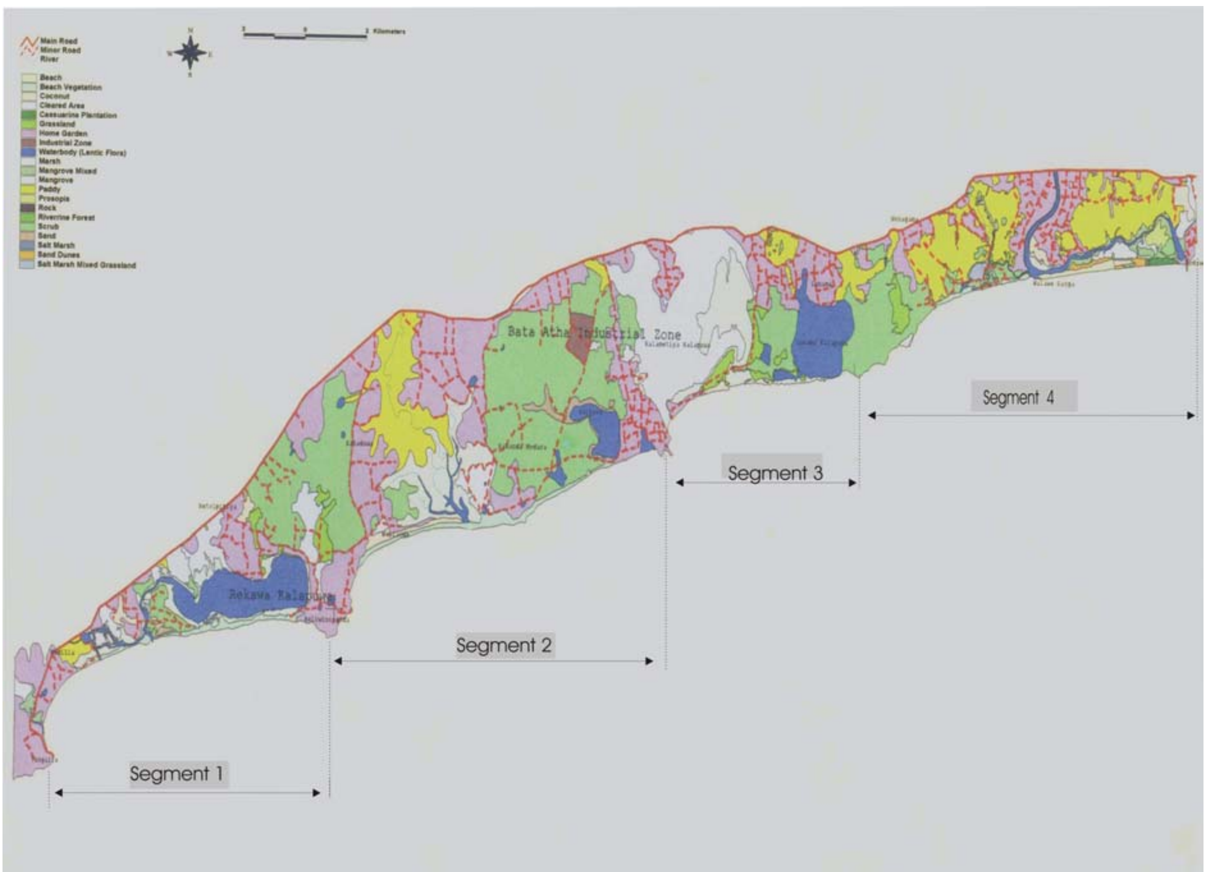

Figure 2: Map of RUK area showing the four coastal segments surveyed

2.2. Study of qualitative environmental parameters

General field observations were recorded in a qualitative manner for the entire beach stretch from Godawaya to Medilla, and the environmental parameters documented are highlighted below:

- Type of coastal land features and locations (plotted in a sketch map)
- Beach characteristics and beach profile
- Stability and condition of the beach and/or sand dune
- Type and condition of the beach vegetation
- Type and condition of the vegetation/land use type immediately bordering the beach
- Historical events and processes
- The density of human settlements and their proximity to coastline
- Pre-tsunami human interferences (coral mining, sand mining, beach front constructions, fisheries, tourism, etc.)
- Inland flooded areas (the distance to which sea water has penetrated inland and the distance to which the tsunami currents have caused major damage to vegetation and/or property).
- Structural damages caused by tsunami to coastal landscape and vegetation

2.3. Quantitative study of structural ecological damage

Detailed ecological investigations were made in selected locations that represent the beach characteristics within each of the four selected coastal segments, including the coastal habitats impacted by the Tsunami. The specific locations (within 100m of coastline) were selected in a manner that captures the diversity of beach/coastal features (including habitats and human modifications) in relation to the visual damage caused to inland areas (see Table 2.1 for the sites selected and their seaward environmental features). The structural ecological damage of 13 selected sampling plots was studied quantitatively, where a site-specific impact score was assigned for tree damage and alteration of ground features using a modified version of the rapid analytical techniques developed by FAO (1988).

Table 2.1: Locations selected for quantitative analysis of structural damage, and corresponding seaward/beachfront features (from south-west to south-east) and level of human modifications at the seaward environment

Location	Seaward/beach front features	Level of modifications
Segment 1 Medilla beach front	Artificial canal system and outlet, low stature sandy beach, beach front constructions (hotels etc), original beach scrub cleared	High
Segment 1 Medilla mangrove	Intact mangrove stands	Low
Segment 1 Rekawa coconut land	High stature sandy beach (>2m in height with a moderate slope) and coconut plantation	Moderate
Segment 1 Rekawa mangrove bordering the lagoon	>5m tall broad sand dune with a mature coconut plantation established without exploiting the dune. The dune borders the Rekawa lagoon & mangrove.	Low
Segment 2 Oruwella	Narrow bay and low stature narrow sandy beach, and severely exploited near-shore coral reef	High
Segment 2 Wellaodae	Low stature sandy beach (low in height, almost flat) with coconut plantation and	High

	constructions (hotels etc)	
Segment 2 Kahandamodara mangrove	Intact mangrove stands spread across lagoon branches	Low
Segment 2 Kunukalliya	>5m tall moderately mature sand dune with scrubland, bordering high saline lagoon	Low
Segment 3 Lunama sand dune	>5m tall moderately mature and broad sand dune with scrubland vegetation	Low
Segment 3 Lunama scrubland	Moderate stature sandy beach (1-2m tall, moderate slope) and immature sand dune	Low
Segment 4 Ussangoda fishery harbour	Low stature sandy beach degraded and cleared scrubland.	High
Segment 4 Wanduruppa	2-3m tall immature sand dune and beach, Walawe river, artificial canal	High
Segment 4 *Casuarina* plantation in Godawaya	Beach bordered by a 2-3m tall sand dune stabilized by a Casuarina plantation	Moderate

2.3.3. Structural damage to trees

The degree of structural damages to tree stems above 3cm diameter at breast height were recorded in a continuous 2m belt transect in the selected tree dominated habitat. Altogether 50 stems per plot were enumerated. The tree damage was estimated by assigning the following scores, based on leaning of stems, stem damage and canopy damage due to Tsunami waves:

Level of stem leaning:

Score-1: No leaning, stem is upright or showing natural leaning with or without tsunami influence.
Score-2: Leaning 60-45 degrees with clear evidence of damage due to tsunami waves.
Score-3: Leaning 45-30 degrees with clear evidence of damage due to tsunami waves.
Score-4: Fallen stem with clear evidence of damage due to tsunami waves.

Level of stem damage (stem below 50% of the total height of the tree)

Score-1: No damage with or without tsunami influence.
Score-2: Slightly damaged with clear evidence of damage due to tsunami waves.
Score-3: Severely damaged with clear evidence of damage due to tsunami waves, but the trees are not dead or separated from the main stem.
Score-4: Uprooted and fallen, dead stem or stump remains with clear evidence of damage due to tsunami waves.

Level of canopy damage (stem/branches above 50% of the total height of the tree)

Score-1: No damage with or without tsunami influence.
Score-2: Few branches damaged with clear evidence of damage due to tsunami waves.
Score-3: More branches damaged with clear evidence of damage due to tsunami waves.
Score-4: No canopy or dead canopy with clear evidence of damage due to tsunami waves.

General assessment of structural damage to mangrove stands (>1 ha) in the RUK area

The mangrove stands (> 1ha) located within 200m from the coastline were assessed to document structural damage caused to them, and identify areas for restoration. In each location, two parallel plots (50mX5m) located 50m apart were placed perpendicular to the water body (sea, lagoon, estuary, and river). Each plot was sub-divided into two equal sub-plots of 25mX5m, located in the distal and proximal areas facing the tsunami waves (either the sea or other water bodies). The structural damage to mangrove vegetation (uprooting, stem and canopy damage etc.), and the ground features (deposition of sand/silt, deposition of non-biodegradable material, soil erosion etc.) was estimated visually as a percentage, in relation to the size of the plot (25mX5m). Based on observations related natural regeneration capacity of mangrove (availability of propagules, level of coppicing of damaged trees, sand accumulation on the ground, disturbance to natural water flow/availability etc.), the potential for regeneration and the need for external interventions for restoration was determined for each site.

2.3.4. Alteration of ground features

The selected habitats were also traversed in a series of random walk transects, to document the alteration of ground features as a result of Tsunami waves. This was done by marking alternative points in the ground while walking along a transect of 50 paces (steps), and recording the ground cover type within the marked point. Each of the 13 sites was covered by ten transects of 50 paces having a total of 250 sampling points (25 points per transect). Ground cover types related to Tsunami event were emphasised to highlight the ground habitat alternation, as highlighted in Table 2.2. The proportion of different ground cover types in each site (in 250 sampling points) was used in interpretation of impacts. The total number of tsunami-related ground cover types within the total of 250 sampling points (ratio) was converted into a score that ranged within a scale of 1-4 (by multiplying with 4), and the level of alteration of ground features was expressed as follows:

Score 1 or <1: No or very low impact
Score 1+ to 2: Low Impact
Score 2+ to 3: High impact
Score 3+ to 4: Severe impact

Table 2.2: Examples of ground cover types, in relation to Tsunami impacts

Ground Cover Type	**Tsunami impacts (Yes/No)**
Transported organic debris	Yes
Transported sand/mud	Yes
Live natural vegetation	No
Exposed roots	Yes
Originally placed mud/sand	No
Transported building debris	Yes
Dead grass/herbs	Yes
Natural leaf-litter deposits	No
Eroded sand/mud	Yes
Fallen logs/tree branches	Yes
Mangrove roots (knee/aerial/surface)	No
Transported rock/coral/shells	Yes

2.4. Data analysis and interpretation of Tsunami related environmental impacts

Different kinds of scores tabulated for tree damage and ground cover features were translated to 1-4 scale. A score of 1 was assigned to no impact, while a score of 4 was assigned to the most intense impact. Mean composite plot scores were calculated from averaging the sum total of scores recorded for a particular site, and the level of damage was interpreted in the following manner:

Score 1 or <1: No or very low impact
Score 1+ to 2: Low Impact
Score 2+ to 3: High impact
Score 3+ to 4: Severe impact

In addition, the quantitative data (species richness and abundance documented along transect surveys) on inland faunal groups (amphibians, reptiles, birds, butterflies and land snails) gathered prior to the Tsunami were also used to compare post-tsunami changes in affected habitats.

2.5. Constraints and Limitations of the study

- Lack of access to pre and post-Tsunami satellite images and/or aerial photographs was a major constraint in analysing the impacts.

- Lack of data on coastal bathymetry, and physical information on the Tsunami waves (i.e., strength of waves, their direction etc.) that hit the RUK coastal zone posed a limitation in interpretation of impacts in relation to pre-tsunami human modifications to coastal habitats.

- Element of subjectivity associated with rapid environmental assessments.

3.0. FINDINGS OF THE RAPID ENVIRONMENTAL ASSESSMENT IN THE RUK AREA.

The damage to the coastal stretch in the RUK area was patchy in general. Considering the RUK coastal stretch consisting of four general bay segments, the Tsunami had impacted mainly the western flanks of each bay, including Medilla to Tangalle, Oruwella fishery harbour area, Kalametiya fishery harbour area, and Pattiyawaraya to Ussangoda fishery harbour area. The Tsunami waves have entered inland with a higher force in narrow bay areas possibly with trenches in the sea bottom topography (e.g. Oruwella), and a funnelling effect was evident in areas with narrow tidal inlets, river mouths and artificial canals, resulting in damage caused to inland areas. Maps indicating the general landscape of the four segments surveyed, and the limits of sea water incursion related to tsunami waves is presented in figure 3.1 – 3.4 (Part 2), while plates 1 - 6 (Part 3) shows the post-tsunami status of different locations in the RUK area. The following sections highlight the findings of qualitative observations and quantitative analysis of data gathered from selected locations in the RUK area.

3.1. Quantitative analysis of tsunami impacts on selected locations

Qualitative observations and analysis of site-specific quantitative data revealed a clear relationship between damage to inland areas with human modifications in the seaward/beach front environment. The level of impacts observed in different locations assessed quantitatively, in relation to beachfront features and a pre-tsunami human modification is presented in Table 3.1, while the analysis of raw data is given in annex 1-3.

Table 3.1: Level of environmental impacts in selected sites within the RUK area

Site	Level of Modifications (Pre-Tsunami)	Tsunami incursion of sea water (m)	Mean Ground Impact Score	Mean Tree Damage Score	Average Score and Level of Impact
1. Medilla beach front	High	700	3.9	3.4	3.6 (Severe Impact)
2. Medilla mangrove	Low	700	1.5	1.3	1.4 (Low Impact)
3. Rekawa coconut land	Moderate	60	2.4	1.0	1.7 (Low Impact)
4. Rekawa mangrove	Low	60	0.0	1.1	0.6 (No impact)
5. Oruwella	High	500	3.9	4.0	3.9 (Severe Impact)
6. Wella-ode	High	500	3.8	3.0	3.4 (Severe Impact)
7.Kahandamodara mangrove	Low	500	1.8	1.4	1.6 (Low Impact)
8. Kunukalliya	Low	60	3.0	1.1	2.0 (Low Impact)
9. Lunama sand dune	Low	75	2.6	1.1	1.8 (Low Impact)
10. Lunama scrubland	Low	250	3.9	3.6	3.7 (Severe Impact)
11. Ussangoda fishery harbour	High	600	3.8	3.4	3.6 (Severe Impact)
12. Wanduruppa	High	Up to 1km	3.5	3.7	3.6 (Severe Impact)
13. Casuarina plantation in Godawaya	Moderate	80	2.2	1.0	1.6 (Low Impact)

Evaluation of tsunami impacts in different locations within the RUK area provides a basic understanding of the benefits of maintaining natural coastal ecosystems for protection of the coastal zone. It is interesting to note that study locations shielded by sand rich broad beaches, tall mature sand dunes, thick stands of coastal scrubland, Casuarina plantations and broad intact mangrove patches have scored low or no habitat impact values, while they have functioned as effective barriers that have protected inland landscapes. Heavy ecosystem destructions were recorded from places where the natural beachfront features have been modified over time, including cutting of sand dunes, clearing of vegetation in beachfront, lagoon outlets and narrow bays and narrow artificial canals connected to the sea. Man-made infrastructure established in such modified beachfront areas such as tourist hotels in Medilla, the Moderagama Village at Wanduruppa in the lower part of the Walawe estuary, inadequately planned fisheries harbours in Ussangoda, Welipatanwila, Pattiyawaraya and Oruwella have been subjected to heavy damage. However, it should be noted that the level of damage couldn’t always be attributed to the site level modifications, as evident in the Lunama Scrubland area, indicating the need to consider other aspects such as coastal bathymetry, nature of currents, direction of currents and their force, to reach more accurate conclusions.

In Medilla (site 1), the impact on mangrove vegetation close to the estuary facing the sea showed severe damage to both ground habitat (score 3.9) and mangrove trees (score 3.4) with an average impact score of 3.6. This severe damage has resulted from the funnelling of sea water through the artificial canal. However, the strip of mangrove vegetation (site 2) located about 100m behind the site 1, and shielded by a thick and broad mangrove stand showed low damage, with an average damage score of 1.4. This highlights the buffering effect of front line mangroves , which has minimized the damage interior. The mangroves close to the estuary have trapped most of the rubble and debris.

In the Rekawa coconut land (site 3) located in an elevated sandy beach, the damage was low, with a ground impact score of 2.4 and tree damage score of 1. No damage was observed to the Rekawa mangrove (site 4), located behind the coconut land spread across the elevated beach.

The damage to habitats in the exposed Oruwella harbour area (site 5) was severe, as evident from the alterations caused to the ground (score 3.9) and damage to mangrove trees (score 4). A near-shore fringing coral reef is located about 50m away from the beach in this area, which is in a highly degraded status due to mining and bottom set netting.

The function of mangrove as a frontline buffer against Tsunami waves is evident in the damage analysis related to Wellaodae (site 6), and Kapuhenwala (site 7). Analysis of impact on mangrove vegetation immediately behind the beach at Kahanda estuary (wellaodae – site 6) showed severe damages to both ground habitat (score 3.8) and mangrove trees (score 3) with an average impact score of 3.4 on the habitat. However, the strip of mangrove vegetation (site 7) located about 50m behind the above plot shows low damage (average impact score 1.6), as a result of being shielded by the mangrove system close to the sea.

The woody vegetation located in the landward side of a moderately tall sand dune bordering the hyper-saline Kunukalliya lagoon (site 8) had negligible damage (score 1.1), but a significant impact was observed on the ground habitat (score 3) with an average habitat impact score of 2, indicating a low overall impact on the habitat.

Analysis of the impact on mangrove vegetation (site 9) immediately behind the Lunama sand dune showed little impact on both ground habitat (score 2.6) and mangrove trees (score 1.1), which highlights the sand dune as an effective barrier against the Tsunami waves.

In the Lunama scrubland (site 10), the frontline strip of vegetation close to the beach was severely damaged, showing an extremely high score in the both the ground habitat (score 3.9) as well as woody plants (score 3.6), with an average 3.7 impact on the habitat. The beach as narrow in this area and the beach crest was relatively lower compared to the adjoining stretches, which appears to have facilitated the tsunami incursions.

The scrubland vegetation (site 11) behind the Ussangoda fishery harbour beach showed an extremely high damage to both ground habitat (score 3.8) and woody plants (score 3.4) with an average 3.6 impact on the habitat. This is an area where the beach scrub vegetation was cleared and the sand dune was exploited prior to the tsunami.

The mixed mangrove system (site 12) located parallel and closer to the Walawe river and beach in Wanduruppa area showed a high impact to both trees (score 3.5) and ground habitat (score 3.7) with an average score of 3.6. Removal of large Kumbuk trees (*Terminalia arjuna*) of riverine vegetation and thinning of the mixed mangrove strip due to human encroachment in the recent past has probably enabled tsunami waves to cause heavy damage in this area.

The structural damage in the *Casuarina* plantation in Godawaya (site 13) was very low, which can be attributed to the high dune formation in the area. The sand dunes have been stabilized by the Cassuarine plantation, which has in turn enabled to withstand the impacts of the Tsunami waves.

3.2. Tsunami impacts on biodiversity of the RUK area

Impacts on habitats and ecosystems

The Tsunami-related impacts on the coastal biodiversity of the RUK area could be elaborated under damage caused to ecosystems and species. Among the affected ecosystems, the gentle sea-shore vegetation consisting of creeping plants such as *Spinifex* and *Ipomoea* and erect species such as *Pandanus* have been affected up to more than 50% of the original cover. However, these will recover naturally over time. The sandy beaches, including the seaward area of sand dunes (i.e., in Lunama) have been eroded, resulting in reduction of beach width in certain locations such as Oruwella (Rekawa). The natural conditions in salt marshes and maritime grasslands have been affected due to large volumes of sand and marine sludge being transported and deposited by the Tsunami waves, which in turn has destroyed the short vegetation of these ecosystems (i.e., in Rekawa and Welipatanwila). In mangrove stands, the tree line facing the Tsunami waves has been subjected to moderate to severe damage, while the mangrove in distal areas have been protected (see Table 3.2 for status of nine mangrove sites, each > 1ha in extent). The ground features of the exposed mangrove areas have also been changed, due to deposition of sand, mud and other debris. Among the mangrove sites surveyed, six sites (Medilla, Kapuhenwala, Wellaodae, Welipatanwila, Kiralakelle mangrove bordering the sea, and Moderagama) have been subjected to ecological damage that requires restoration actions. The vegetation in home gardens affected by the Tsunami waves have been destroyed (i.e., in Wanduruppa and Oruwella area), either being uprooted, or dieing off due to high saline conditions in the soil. Low-lying coastal paddy fields have been destroyed by the saline water and marine sludge depositions. The recovery of species in home gardens, and the suitability of affected rice fields for paddy cultivation will depend on the amount of rainfall that this area would receive in the future. Other wetland such as lagoons (ie., Kalametiya and Rekawa) and estuaries (Walawe, Kahanda) have undergone changes in relation to increase in salinity, and deposition of sand, mud and other debris, including non-biodegradable material.

Table 3.2. Damage to mangrove stands in the RUK area

Site	Mangrove Community	Damage to vegetation (%)	Damage to ground features (%)	Potential for Natural regeneration	Actions for restoration
Rekawa Lagoon	*Lumnitzera racemosa*	Prox. Plot: <5% Dist. Plot: 0% Average: 2.5%	Prox. Plot: 10% Dist. Plot: 0% Average: 5%	High	None

Medilla	*Ceriops tagal*	Prox. Plot: >75% Dist. Plot: <20% Average: 47.5%	Prox. Plot: 10% Dist. Plot: 0% Average: 5%	Low in the proximal area	Replanting of mangrove; removal of sand and debris
Kapuhenwala	*Avicennia officinalis*	Prox. Plot: >75% Dist. Plot: No mangrove	Prox. Plot: >50%	Low	Replanting of mangrove
Kalametiya lagoon	*Sonneratia caseolaris*	Prox. Plot: 25% Dist. Plot: <10% Average: 17.5%	Prox. Plot: 10% Dist. Plot: <10% Average: 10%	High	None
Kiralakelle (Malpettawa)	*Sonneratia caseolaris*	Prox. Plot: 40% Dist. Plot: No mangrove	Prox. Plot: 50%	Moderate	Replanting of mangrove; removal of sand; clearing of canal
Welipatanwila	Mixed	Prox. Plot: 75% Dist. Plot: <10% Average: 42.5%	Prox. Plot: 75% Dist. Plot: <10% Average: 42.5%	Low in the proximal area	Replanting of mangrove; removal of sand; clearing of canal
Wellaodae	*Mixed*	Prox. Plot: 75% Dist. Plot: <10% Average: 42.5%	Prox. Plot: 75% Dist. Plot: <25% Average: 50%%	Low in the proximal area	Replanting of mangrove; removal of sand; clearing of creeks
Lunama-Kalametiya canal	*Excoecaria agallocha*	Prox. Plot: <5% Dist. Plot: No mangrove	Prox. Plot: 25%	High	None
Wanduruppa (Moderagama)	*Sonneratia caseolaris, Terminalia arjuna*	Prox. Plot: 50% Dist. Plot: No mangrove	Prox. Plot: 50%	Low	Replanting of mangrove and *Terminalia*, removal of sand

Note: In Rekawa lagoon and Kapuhenwala, the plots were laid perpendicular to the lagoon and estuary respectively, while in the other locations, the plots were laid perpendicular to the sea

Impacts on species

Many species of near-shore and estuarine fish populations have been subjected to mass mortality and washed off into inland areas. Freshwater fish species inhabiting low-saline lagoons have died due to increased salinity. Dead specimens of freshwater fish species such as Snakeheads (*Channa* spp.) were observed in the Kalametiya lagoon. According to information gathered from fishermen, species of marine fish that were not previously documented in lagoon water are now found in lagoons such as Kalametiya and Rekawa in the RUK area. Apart from fish, other dead vertebrate animals observed in the RUK area includes two specimens of Mouse Deer (*Tragulus meminna*), a Land monitor (*Varanus bengalensis*) and a soft-shelled Terrapin (*Lissemys punctata*). Dead invertebrate animals observed in the affected habitats in the RUK area include several species of freshwater molluscs (ie., *Pila globosa. Lymnaea luteola*) and terrestrial molluscs (*Aulopoma* spp., and *Cryptozona bistralis*)

Compared to the baseline information on faunal species gathered prior to the Tsunami, a clear reduction in species composition and abundance of fauna such as amphibians, reptiles, birds, butterflies and molluscs was observed in coastal habitats affected by the Tsunami (e.g., Kalametiya area). Among the amphibian species recorded, a clear reduction is seen among the populations of *Bufo fergusoni.* Similarly, among reptiles, a distinct population reduction was observed in a skink that was commonly observed in home gardens (*Lankascincus fallax*) of the RUK area. A large number of turtle nests in the RUK area (ie., in Rekawa) had been destroyed by the Tsunami waves. However, the Green Turtle (*Chelonia mydas*) and the OIive Ridley (*Lepidochelys olivaceae*) have gradually started to visit and lay eggs in the RUK beach areas subsequent to the Tsunami, in small numbers. Among the birds recorded, a clear reduction of waders was observed in wetlands such as Kalametiya lagoon and Kunukalliya hyper saline lagoon, mainly due to the changes of habitats. A clear reduction of butterflies was observed especially in sand dune habitats.

Changes in the spread of invasive alien species

The invasive alien Prickly Pear Cactus (*Opuntia dillennii*) that occurred in the beachfront habitats have been removed and transported to distant inland areas by the Tsunami waves, and these propagules have now started to establish in new areas. The spread of another invasive alien plant – Mesquite (*Prosopis juliflora*), which is already prevalent in the RUK area, may increase rapidly over time, as it exhibits a competitive dominance under increased saline conditions. Freshwater invasive alien species such as Cattail reed (*Typha angustifolia*) and Water Hyacinth (*Eichhornia crassipes*) occurring in low-saline lagoons such as Kalametiya have been destroyed due to increased salinity. Many individuals of free-roaming domestic cats and dogs were observed in the RUK area subsequent to the Tsunami, and these may form feral populations in the future

3.3. The role of coastal ecosystems in mitigating Tsunami impacts

The survey clearly revealed that the intact coastal ecosystems have played a significant role in reducing the impacts of tsunami waves to inland landscapes that harbour homesteads, agricultural land and tourism infrastructure. Mature and intact sand dunes (i.e., old and broad dunes covered with scrubland vegetation) occurring in the RUK area have functioned as an effective barrier against the Tsunami waves, thereby protecting inland ecosystems and human settlements. Such intact sand dunes have protected a large area of the Lunama-Kalametiya Sanctuary. Sand dunes stabilized with Casuarina plantations have played a similar role, as seen in the Godawaya area. In areas where sand dunes have been exploited, the damage to inland areas was severe, as evident in the Kalametiya fisheries village and the Welipatanwila area.

Intact stands of broad mangrove and Pandanus vegetation have also served as a frontline defence by absorbing/buffering the force of tsunami waves. This is clearly evident in areas such as Medilla, Kalametiya lagoon and Kahandamodera, where the frontline stands of mangrove trees have been destroyed by the Tsunami waves, but back stands remain relatively intact. Coastal wetlands, including mangrove swamps with creeks, salt marshes, broad estuaries and lagoons have contributed to absorb the sea-water and sediments brought in by the Tsunami waves, thereby protecting managed landscapes such as paddy fields and human settlements. Examples of such sites in the RUK area include the Kiralakelle mangrove swamp, Kahandamodera mangrove swamp and creeks, Medilla mangrove swamp, Welipatanwila Salt marsh, Kalametiya and Rekawa lagoons, and the Walawe estuary. Intact coral reefs, rocky beaches, sand-stone reefs may also have contributed to reduce the force and energy of the Tsunami waves, since a severe damage to inland areas is visible in areas such as Oruwella, where the near-shore coral reefs has been severely destroyed by mining and bottom-set netting over the past decade.

4.0. RECOMMENDATIONS FOR FUTURE ACTIONS

4.1. Short-term recommendations

- The man-made infrastructure (tourist hotels, residences etc.) located in coastal reservations and other highly sensitive areas, which have been subjected to severe devastation by the Tsunami, should be translocated into safe inland areas. This includes the Modaragama village in the Wanduruppa area, which is located in the flood detention zone of the Walawe river, the Kalametiya Fishery village located at the beach front near Kalametiya lagoon outlet, houses near Wellaodae and Oruwella fishery harbour, and the tourism areas in Medilla and Kahanda modara.

- Reconstruction activities in sensitive coastal reservation areas in RUK (including low-lying beach front, borders of estuaries and lagoon outlets) should be prohibited.

- Propagules of the invasive alien Prickly-pear cactus (*Opuntia dillenni*) carried into interior areas by the Tsunami waves should be collected and burnt.

- The non-biodegradable material and concrete structures scattered in the beach and in other natural ecosystems (including protected areas such as the Lunama-Kalametiya Sanctuary and the Rekawa area) should be collected and dumped in suitable locations.

- Measures should be taken to strictly protect the intact sand dunes, mangrove stands and coral reefs in the RUK area.

- Measures should be taken to expedite declaration of the proposed Rekawa coastal sanctuary and turtle refuge area.

- A permanent station of the Department of Wildlife Conservation should be established in the Rekawa turtle refuge area, in order to continue the turtle in-situ conservation activities.

- Implement an awareness programme for local communities in the in the RUK area, highlighting the importance of maintaining coastal natural ecosystems for protection against natural disasters such as Tsunamis, cyclones and hurricanes.

- Identify suitable areas (outside the biodiversity rich habitats and at least 500m away from the existing protected areas in RUK) for relocation of affected villagers.

4.2. Medium and Long-term recommendations

- Areas that originally harboured sand dunes and mangrove stands, which were subsequently exploited should be considered for ecosystem restoration. *Casuarina* could be used as a nurse vegetation to stabilize immature and new sand dunes, which could gradually be removed in strips and replaced with native sand dune vegetation.

- Measures should be taken to restore certain mangrove patches that were severely affected by the Tsunami (ie., in Medilla, Kapuhenwala, Wellaodae, Welipatanwila, Kiralakelle seaward area and Moderagama area).

- The home gardens affected by the Tsunami should be restored with multipurpose multi-storyed vegetation, with measures taken to enhance the soil fertility as well. However, this should be done only during the rainy season, after the initial rains.

- The local community groups that were involved in tourism activities related to in-situ and ex-situ conservation of marine turtles that visit the RUK area should be supported to re-start their work, and best practice guidelines for hatchery management and in-situ conservation of turtles should be introduced.

- A monitoring programme should be implemented in the RUK area to document the following aspects

  - Regeneration of affected coastal habitats and ecosystems
  - Changes (if any) in the composition of fish species in lagoons, estuaries and near-shore marine areas, with the support of local fisheries societies.
  - Monitor the spread of invasive alien plant species such as Mesquite and Prickly pear cactus in areas affected by the Tsunami.
  - The population status of turtles visiting the beaches of the RUK area for nesting purposes
  - Monitor the inland shell mining, coral mining and destructive fishing practices that affect coral reefs.

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ANNEX 01

Mean composite tree damage scores for different impact variables of trees.

		Damage scores for different components of trees				
Site / plot	Plot No	Tree leaning	Stem damage	Canopy damage	Mean tree damage	Impact class
Medilla beach front	1	3.04	2.36	3.48	3.0	High impact
Medilla mangrove	2	1.34	1.24	1.64	1.4	Low impact
Rekawa coconut land	3	1.08	1.02	1.1	1.1	Low impact
Rekawa mangrove	4	3.22	3.2	3.76	3.4	Severe impact
Oruwella	5	1.16	1.02	1.12	1.1	Low impact
Wella-ode	6	1.12	1.12	1.16	1.1	Low impact
Kahandamodara mangrove	7	1	1	1	1.0	Low impact
Kunukalliya	8	3.98	4	4	4.0	Severe impact
Lunama sand dune	9	3.38	3.32	3.5	3.4	Severe impact
Lunama scrubland	10	1.32	1.24	1.22	1.3	Low impact
Ussangoda fishery harbour	11	3.18	3.64	3.94	3.6	Severe impact
Wanduruppa	12	3.6	3.66	3.92	3.7	Severe impact
Godawaya	13	1	1	1	1.0	Low impact

1-4 scale degree of damage

Impact classes

1	Score below one	No impact
2	Score from one plus to two	Low impact
3	Score from two plus to three	High impact
4	Score from three plus onwards	Severe impact

ANNEX 02

Abundance of different ground cover types encountered.

Location No	Ground cover types	Point counts per site	Percentage point counts	Tsunami outcomes (yes/No)
1	Transported coral debris	1	0.4	Yes
1	Transported sea shells	1	0.4	Yes
1	Exposed root	3	1.2	Yes
1	Transported wood	3	1.2	Yes
1	Transported roofing material (tiles, aluminium sheets, tar sheets)	4	1.6	Yes
1	Live plant	5	2	No
1	Transported non-biodegradable debris (Plastic, polyhthene, rubber)	8	3.2	Yes
1	Mangrove aerial / knee / surface root	9	3.6	No
1	Fallen stem	10	4	Yes
1	Building debris (concrete, brick, cement, glass, metal, wires)	19	7.6	Yes
1	Transported mud	25	10	Yes
1	Transported organic debris	26	10.4	Yes
1	Leaf litter- transported debris	49	19.6	Yes
1	Transported sand	87	34.8	Yes
2	Original sand	1	0.4	No
2	Transported clothes	2	0.8	Yes
2	Transported non-biodegradable debris (Plastic, polyhthene, rubber)	2	0.8	Yes
2	Exposed root	6	2.4	Yes
2	Transported sand	8	3.2	Yes
2	Fallen stem	10	4	Yes
2	Live grass	14	5.6	No
2	Mangrove aerial / knee / surface root	15	6	No
2	Original mud	25	10	No
2	Transported mud	27	10.8	Yes
2	Live plant	28	11.2	No
2	Leaf litter- natural	53	21.2	No
2	Transported organic debris	59	23.6	Yes
3	Original sand	1	0.4	No
3	Dead Opuntia dellini plant	1	0.4	Yes
3	Exposed root	3	1.2	Yes
3	Dead grass	5	2	Yes
3	Leaf litter- natural	5	2	No
3	Live grass	9	3.6	No
3	Live plant	10	4	No
3	Fallen stem	12	4.8	Yes
3	Dead herb	17	6.8	Yes
3	Eroded sand / soil	28	11.2	Yes
3	Live herb	37	14.8	No
3	Transported organic debris	47	18.8	Yes
3	Transported sand	75	30	Yes
4	Live Opuntia	1	0.4	No
4	Live plant	1	0.4	No
4	Dead Opuntia dellini plant	1	0.4	Yes
4	Transported fishing net debris (nylon, regifoam)	1	0.4	Yes
4	Transported wood	1	0.4	Yes
4	Dead herb	2	0.8	Yes

4	Transported rock	2	0.8	Yes
4	Exposed rock	3	1.2	Yes
4	Transported coral debris	3	1.2	Yes
4	Leaf litter- transported debris	5	2	Yes
4	Transported non-biodegradable debris (Plastic, polythene, rubber)	5	2	Yes
4	Building debris (concrete, brick, cement, glass, metal, wires)	6	2.4	Yes
4	Live grass	6	2.4	No
4	Live herb	6	2.4	No
4	Fallen stem	7	2.8	Yes
4	Transported sand	8	3.2	Yes
4	Dead plant	9	3.6	Yes
4	Transported sea shells	9	3.6	Yes
4	Dead grass	10	4	Yes
4	Transported mud	20	8	Yes
4	Transported organic debris	27	10.8	Yes
4	Exposed root	29	11.6	Yes
4	Eroded sand / soil	88	35.2	Yes
5	Transported fishing net debris (nylon, regifoam)	2	0.8	Yes
5	Dead plant	3	1.2	Yes
5	Fallen stem	5	2	Yes
5	Mangrove aerial / knee / surface root	6	2.4	No
5	Exposed root	6	2.4	Yes
5	Original mud	7	2.8	No
5	Live plant	10	4	No
5	Transported mud	13	5.2	Yes
5	Stagnant water-natural	15	6	No
5	Transported organic debris	37	14.8	Yes
5	Leaf litter- natural	52	20.8	No
5	Transported sand	94	37.6	Yes
6	Live plant	15	6	No
6	Seedlings	25	10	No
6	Mangrove aerial / knee / surface root	32	12.8	No
6	Original organic matter	81	32.4	No
6	Leaf litter- natural	97	38.8	No
7	Transported non-biodegradable debris (Plastic, polythene, rubber)	1	0.4	Yes
7	Live plant	2	0.8	No
7	Fallen stem	2	0.8	Yes
7	Transported fishing net debris (nylon, regifoam)	4	1.6	Yes
7	Eroded sand / soil	7	2.8	Yes
7	Dead grass	8	3.2	Yes
7	Transported sand	9	3.6	Yes
7	Leaf litter- natural	11	4.4	No
7	Live herb	18	7.2	No
7	Transported organic debris	60	24	Yes
7	Dead herb	62	24.8	Yes
7	Live grass	66	26.4	No
8	Transported rock	1	0.4	Yes
8	Transported wood	1	0.4	Yes
8	Transported coral debris	2	0.8	Yes
8	Transported fishing net debris (nylon, regifoam)	4	1.6	Yes
8	Transported sea shells	4	1.6	Yes
8	Seedlings	6	2.4	No
8	Dead grass	6	2.4	Yes
8	Transported non-biodegradable debris (Plastic, polythene, rubber)	6	2.4	Yes

8	Exposed root	9	3.6	Yes
8	Fallen stem	11	4.4	Yes
8	Transported roofing material (tiles, aluminium sheets, tar sheets)	11	4.4	Yes
8	Eroded sand / soil	12	4.8	Yes
8	Transported mud	13	5.2	Yes
8	Building debris (concrete, brick, cement, glass, metal, wires)	15	6	Yes
8	Dead herb	21	8.4	Yes
8	Transported organic debris	55	22	Yes
8	Transported sand	73	29.2	Yes
9	Live herb	1	0.4	No
9	Transported coral debris	1	0.4	Yes
9	Transported rock	1	0.4	Yes
9	Transported wood	1	0.4	Yes
9	Live plant	2	0.8	No
9	Transported fishing net debris (nylon, regifoam)	3	1.2	Yes
9	Transported sea shells	3	1.2	Yes
9	Eroded sand / soil	4	1.6	Yes
9	Live grass	5	2	No
9	Transported clothes	5	2	Yes
9	Dead herb	6	2.4	Yes
9	Dead plant	6	2.4	Yes
9	Transported non-biodegradable debris (Plastic, polythene, rubber)	9	3.6	Yes
9	Exposed root	13	5.2	Yes
9	Fallen stem	13	5.2	Yes
9	Dead grass	16	6.4	Yes
9	Building debris (concrete, brick, cement, glass, metal, wires)	19	7.6	Yes
9	Transported mud	27	10.8	Yes
9	Transported organic debris	44	17.6	Yes
9	Transported sand	71	28.4	Yes
10	Building debris (concrete, brick, cement, glass, metal, wires)	1	0.4	Yes
10	Dead grass	1	0.4	Yes
10	Dead herb	1	0.4	Yes
10	Stagnant water-natural	2	0.8	No
10	Transported wood	2	0.8	Yes
10	Exposed root	3	1.2	Yes
10	Live plant	4	1.6	No
10	Seedlings	4	1.6	No
10	Transported non-biodegradable debris (Plastic, polythene, rubber)	6	2.4	Yes
10	Fallen stem	7	2.8	Yes
10	Original mud	9	3.6	No
10	Transported organic debris	29	11.6	Yes
10	Transported sand	44	17.6	Yes
10	Leaf litter- natural	65	26	No
10	Mangrove aerial / knee / surface root	72	28.8	No
11	Dead grass	1	0.4	Yes
11	Transported fishing net debris (nylon, regifoam)	1	0.4	Yes
11	Transported wood	1	0.4	Yes
11	Live herb	2	0.8	No
11	Transported non-biodegradable debris (Plastic, polythene, rubber)	3	1.2	Yes
11	Live plant	5	2	No
11	Transported sea shells	9	3.6	Yes
11	Fallen stem	11	4.4	Yes
11	Leaf litter	12	4.8	Yes
11	Dead Opuntia dellini plant	16	6.4	Yes

11	Exposed root	17	6.8	Yes
11	Dead plant	37	14.8	Yes
11	Transported organic debris	63	25.2	Yes
11	Transported sand	72	28.8	Yes
12	Live plant	1	0.4	No
12	Transported wood	1	0.4	Yes
12	Live grass	2	0.8	No
12	Building debris (concrete, brick, cement, glass, metal, wires)	2	0.8	Yes
12	Live herb	3	1.2	No
12	Dead plant	3	1.2	Yes
12	Transported non-biodegradable debris (Plastic, polythene, rubber)	5	2	Yes
12	Dead herb	7	2.8	Yes
12	Dead grass	8	3.2	Yes
12	Fallen stem	9	3.6	Yes
12	Stagnant water-transported	15	6	Yes
12	Mangrove aerial / knee / surface root	23	9.2	No
12	Exposed root	24	9.6	Yes
12	Transported sand	24	9.6	Yes
12	Leaf litter	31	12.4	Yes
12	Transported organic debris	33	13.2	Yes
12	Transported mud	59	23.6	Yes
13	Seedlings	1	0.4	No
13	Exposed root	1	0.4	Yes
13	Transported log	2	0.8	Yes
13	Dead plant	4	1.6	Yes
13	Transported non-biodegradable debris (Plastic, polythene, rubber)	6	2.4	Yes
13	Transported fishing net debris (nylon, regifoam)	8	3.2	Yes
13	Eroded sand / soil	9	3.6	Yes
13	Dead Opuntia dellini plant	10	4	Yes
13	Original sand	20	8	No
13	Transported sand	25	10	Yes
13	Transported organic debris	72	28.8	Yes
13	Leaf litter	92	36.8	No

ANNEX 03

Abundance of ground cover types recorded as tsunami outcomes and ground impact score for different sites.

Plot no	Total point Counts per site recorded As tsunami outcomes	Percentage point counts	1-4 scale impact score per site	Impact class
1	236	94.4	3.8	Severe impact
2	114	45.6	1.8	Low impact
3	188	75.2	3.0	High impact
4	236	94.4	3.8	Severe impact
5	160	64	2.6	High impact
6	0	0	0.0	No impact
7	153	61.2	2.4	High impact
8	244	97.6	3.9	Severe impact
9	242	96.8	3.9	Severe impact
10	94	37.6	1.5	Low impact
11	243	97.2	3.9	Severe impact
12	219	87.6	3.5	Severe impact
13	137	54.8	2.2	High impact

<u>PART TWO</u> – SEGMENT MAPS OF THE STUDY AREA

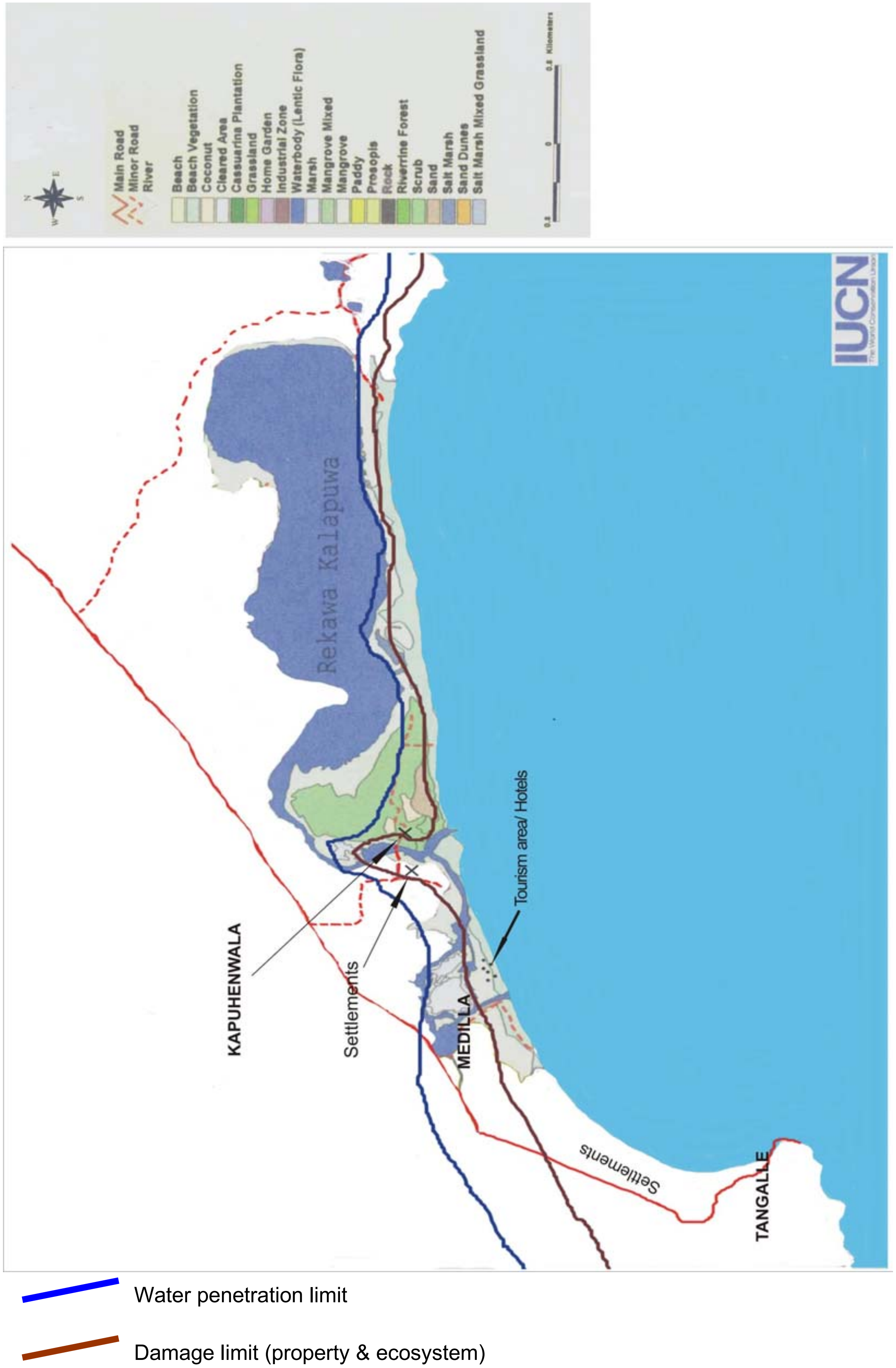


Figure 3.1: A sketch map of the segment 1 showing the pattern of damage

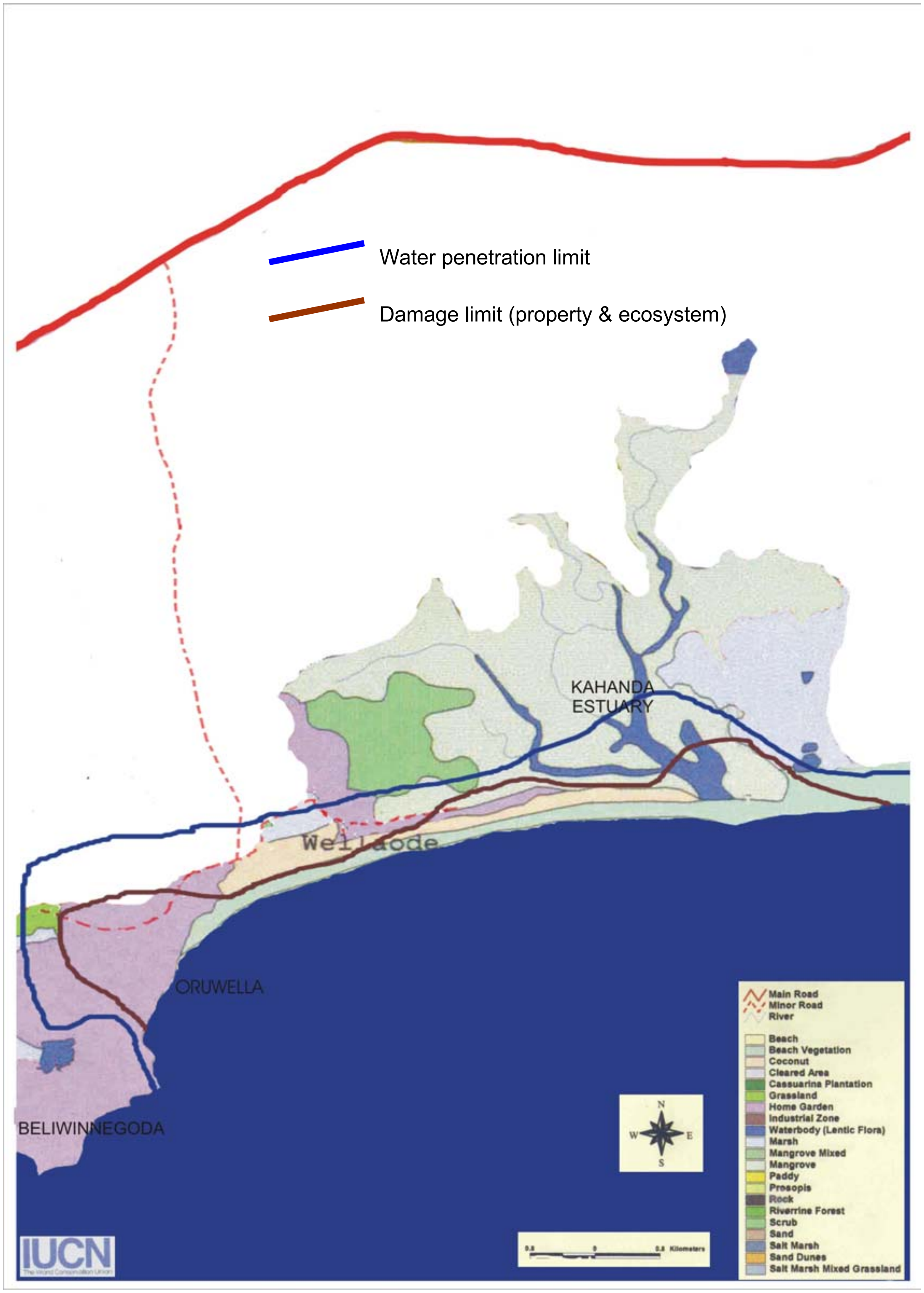


Figure 3.2-a: A sketch map of the western part of segment 2 showing the pattern of damage

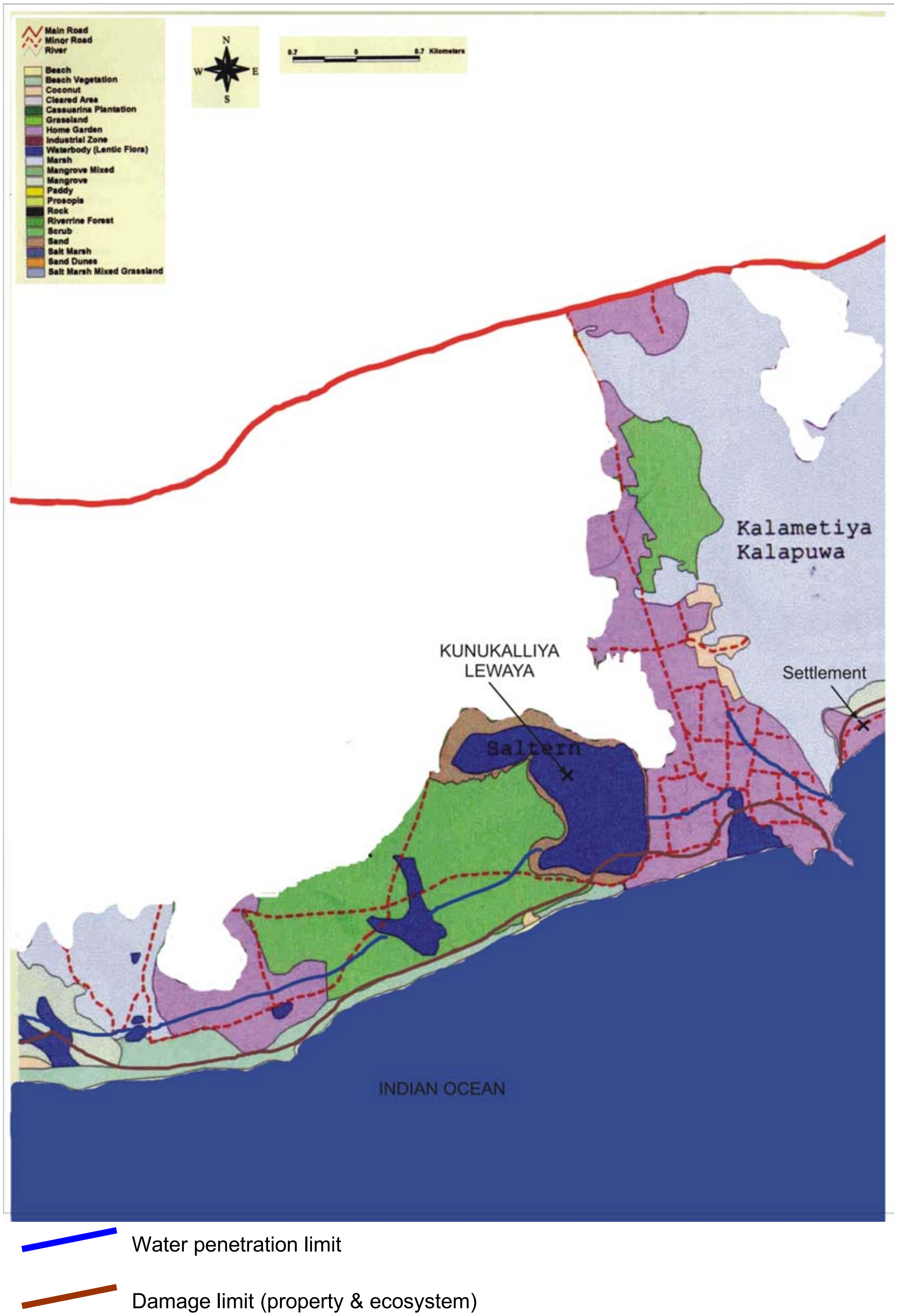


Figure 3.2-b: A sketch map of the eastern part of segment 2 showing the pattern of damage

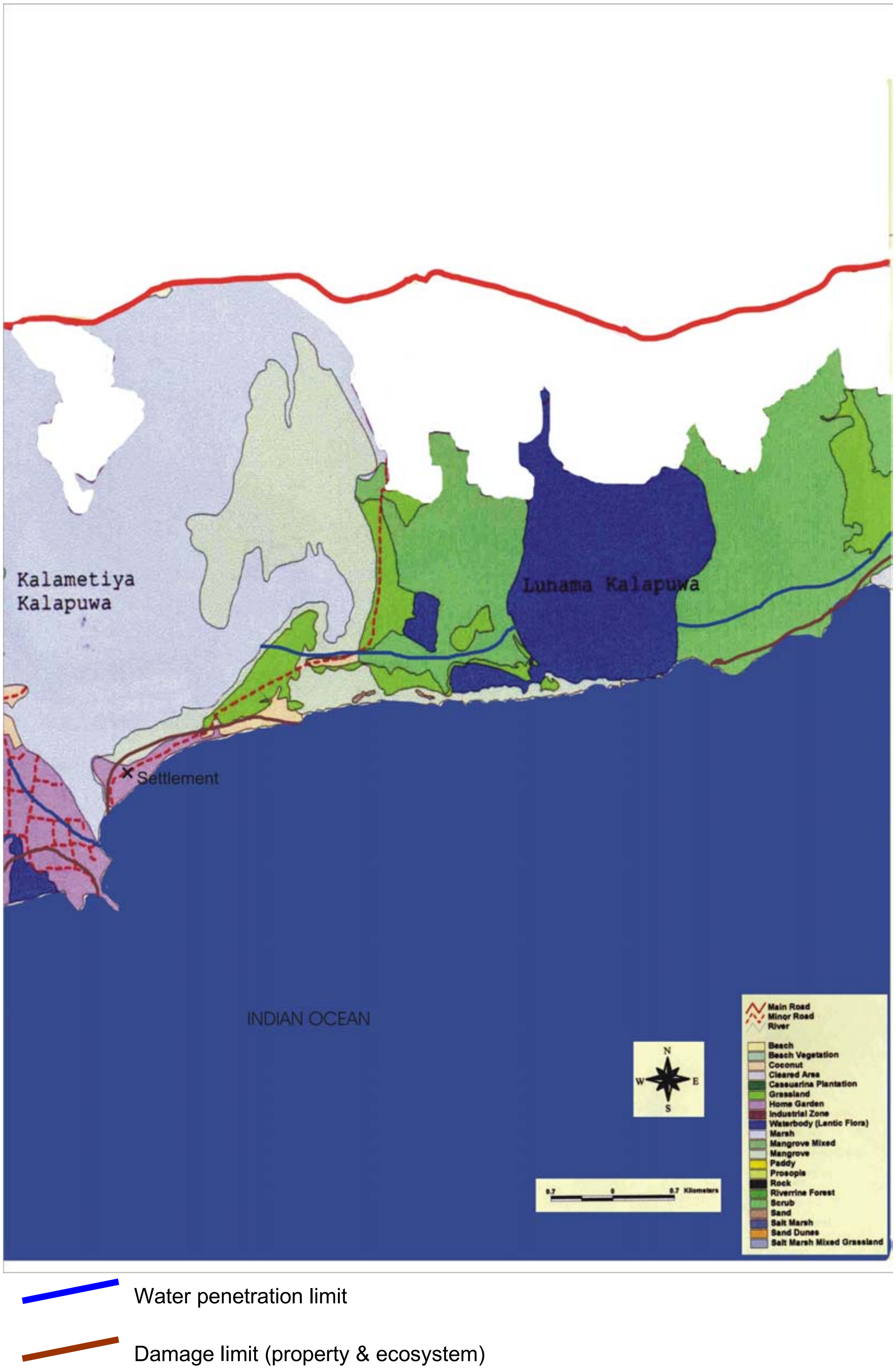
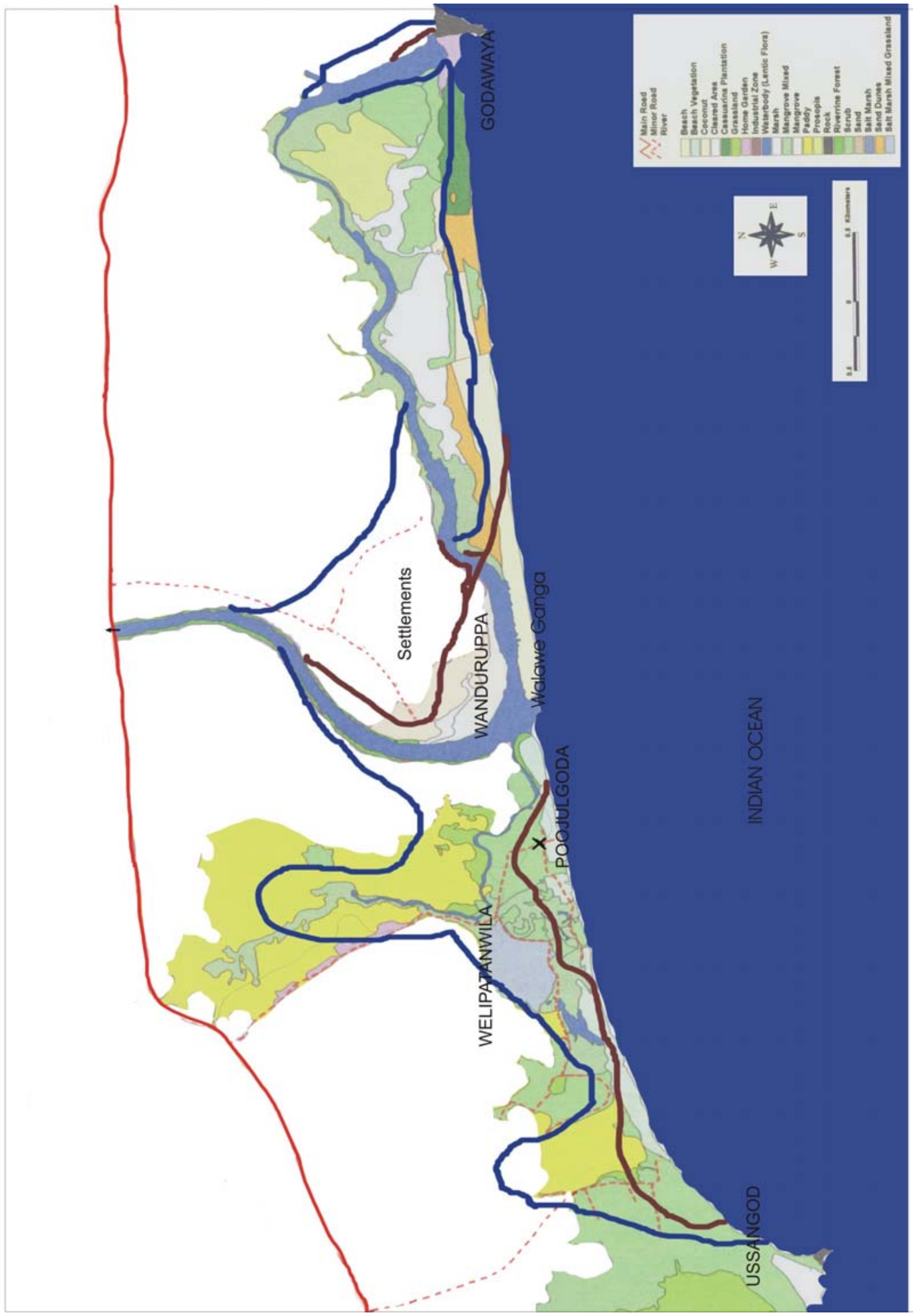


Figure 3.3: A sketch map of the segment 3 showing the pattern of damage



Water penetration limit

Damage limit (property & ecosystem)

Figure 3.4: A sketch map of the segment 4 showing the pattern of damage

PART THREE – COLOUR PLATES

PLATE 01

TSUNAMI IMPACTS ON THE RUK COASTAL SEGMENT 1

MEDILLA

Signs of severe erosion in beach front areas

Destroyed mangroves bordering beach front areas

KAPUHENWALA

A location subjected to funneling of sea water, and penetration through a thin mangrove stand

Damage in settled areas behind a thin mangrove strip

A damaged bridge across a lagoon outlet

PLATE 02

TSUNAMI IMPACTS ON THE RUK COASTAL SEGMENT 2

ORUWELLA

Destruction of scrubland and home gardens located behind an exposed beach area

Nipa dominant mangrove destroyed and sand deposited in estuary mouth

Severe erosion in coconut plantation at beach front

Completely destroyed house in the beach front

Structural damage to mangrove trees in the frontline

PLATE 03

TSUNAMI IMPACTS ON THE RUK COASTAL SEGMENT 3

KALAMETIYA

Damaged vegetation bordering a lagoon due to funneling of sea water

Invasive alien *Opuntia* transported inland by the tsunami water

LUNAMA

Broad and high sand dune stabilized with dune vegetation – very low tsunami impact

USSANGODA

Signs of erosion

Destroyed *Pandanus* stands, eroded beach and deposited coral debris on beach

PLATE 04

TSUNAMI IMPACTS ON THE RUK COASTAL SEGMENT 4

USSANGODA TO WELIPATANWILA

Avicennia tree clumps uprooted and transported 75m inland with the wave and deposited on the salt marsh

Mud deposition and salt water intrusion in to paddy land

WANDURUPPA

Structural damage in the mangrove stand at the frontline

Damaged human settlement at the Wanduruppa village behind the thin mangrove stand

GODAWAYA

Signs of severe erosion

PLATE 05

VISUAL COMPARISON OF SITES BEFORE AND AFTER THE TSUNAMI

ORUWELLA

PRE TSUNAMI
Narrow and steep beach with rocky shore

POST TSUNAMI
NOTE: Same location with wider angle

USSANGODA HEADLAND

PRE TSUNAMI

POST TSUNAMI
Signs of erosion in bank of the cliff
NOTE: The photograph was taken from a low angle than the pre-tsunami one

NEAR USSANGODA FISHERY HARBOUR

PRE TSUNAMI
Beach front scrubland cleared

POST TSUNAMI
Water have funneled inland through the cleared area in to low land

PLATE 06

VISUAL COMPARISON OF SITES BEFORE AND AFTER THE TSUNAMI

USSANGODA FISHERY HARBOUR AREA

PRE TSUNAMI

POST TSUNAMI

GODAWAYA BEACH

PRE TSUNAMI

POST TSUNAMI
With signs of erosion and damage to low lying vegetation at beach front

GODAWAYA

PRE TSUNAMI
Permanent sand dune separating sea ad the estuary, with dry fish processing shed on the dune

POST TSUNAMI
Dune is broken and the old river mouth re-opened