# Impact Of Climate Change Due To Sea Level Rise In Malaysia- Preliminary Development Of Coastal Vulnerability Index (CVI)

## CASE SUDY OF LANGKAWI ISLAND, KEDAH

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# INTRODUCTION

- The coastal zones are highly resourceful and dynamic. The coastal zones are facing many natural hazards such as coastal erosion, Storm surge, Tsunami, coastal flooding and sea level rise.

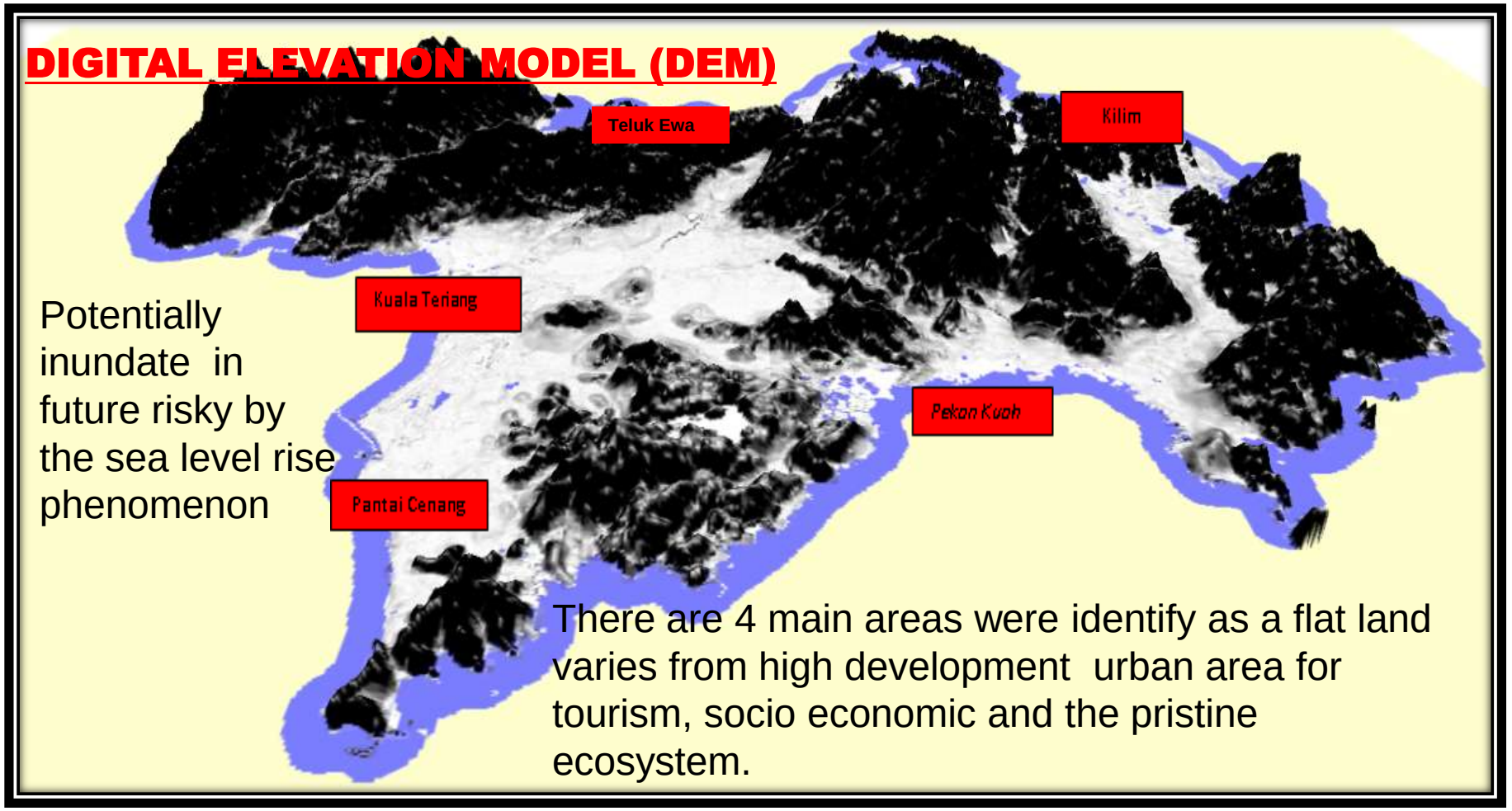
- The Intergovernmental Panel on Climate Change (IPCC-CZMS, 1992) defines vulnerability of coastal zones by their degree of incapability to cope with the impacts of climate change and accelerated sea-level rise.

- vulnerability assessment includes a combination of factors that determine the degree to which someone‟s life, livelihood, property and other assets are put at risk by a discrete and identifiable event in nature and in society.

# OBJECTIVE

i) To investigate the degree of shoreline vulnerability due to projected sea level rise (SLR) in the year 2040, and 2100.
ii) To investigate the impacts of SLR at the most vulnerable shoreline areas

# STUDY AREA




## LANGKAWI ISLAND, KEDAH

# Methodology For the Study

**Review existing data and information on coastal features (if available) of Langkawi Island.**

**Sub divide the shoreline areas into Management Unit(Mu) and carry out general assessment of coastal features for the entire coast of Langkawi Island.**

**Determine the physical, socio economic, ecology and total vulnerability index for each Management Unit.**


**The entire island and along the coast. Coastal sites are segregate into 13 Sub-reach (SR) with 82 Management Unit (MU)**

# Langkawi Coastal Area

- More than half of the island is hilly terrain.
- The eastern, western and northern part of Langkawi
  - forests with minimum economic activities.
- Economic activities are concentrated along the southern part of Langkawi, from SR2 to SR7.
- The business and administration centre is located at Kuah.
- Most of the beaches are public beaches. However, some beaches are privately owned or resort operated.
- Small river outlets can also be found along SR2 to SR7 with wide mudflats spreading the river mouth area.
- Patches of mangrove can be seen sparsely on the southern side of Langkawi while a reserved mangrove area can be found on the northeastern part of Langkawi known as the Kilim Forest

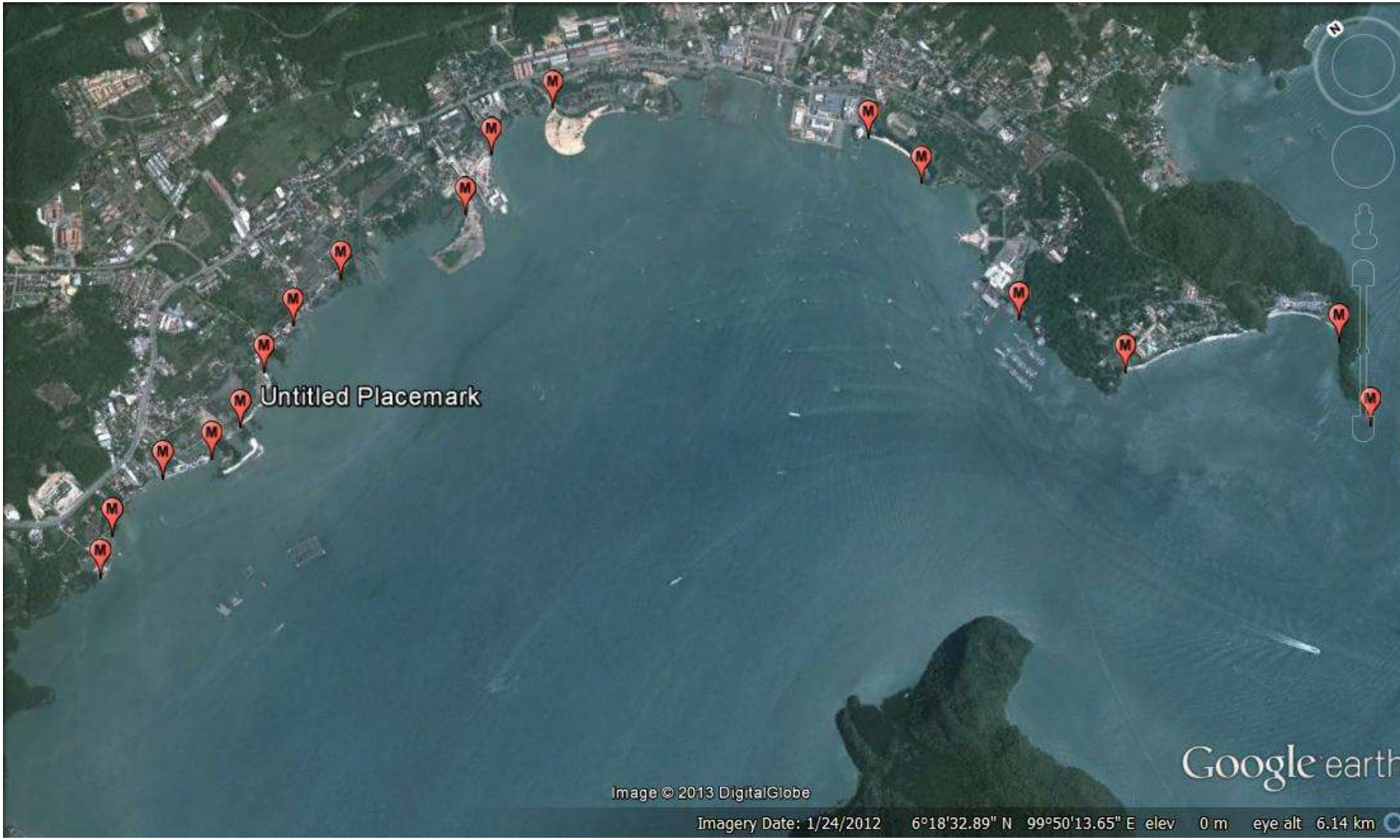
# Sub Reach 3 (SR3)

# Sub Reach 3 (SR 3) – Management Unit (MU:1-9)






# Sub Reach 6 (SR6)



# Sub Reach 6 (SR 6) – Management Unit (MU:1-16)




# Vulnerability Assessment

1. 5 vulnerability indicators are used to map the vulnerability

- Socio-economic index
- Public infrastructure and facilities,
- Population
- Tourism
- Ecology index
- Physical index.

**(The landward coverage -500 meters from the water edge. )**

2. MUs are categorized as units with "No Evaluation Required" (NER), and thus not considered for vulnerability assessment.

3. "Further Evaluation is Required"(FER)-possible adaptation measures and determination

# Physical Vulnerability Index

1. The physical vulnerability index - the existence of natural or man-made coastal protection measures that may afford protection against sea level increase.
2. Developed area -southern coast of Langkawi-the platform level of the coastal development is important in determining the severity of impacts due to sea level rise.
3. The higher the platform level, the less severe will be the impacts.
4. If the platform level is lower than the sea level rise, then this could give risk to several problems such as permanent loss of land area (for very high sea level rise), occasional coastal flooding (for moderate sea level rise), backwater effects and drainage problems.

# Physical Vulnerability Index

1. This vulnerability scaling -concrete sea walls and revetments at the southern coast of Langkawi.
2. Several shore profile surveys have been carried -survey profile levels are then viewed with respect to estimated SLR in year 2040, 2060, 2080, 2100 and also with HAT tide levels obtains from numerical modelling simulations.

3. The surveys are carried out in two methods,
   -Digital elevation map (DEM) and
   -Normal land survey (LS).

Vulnerability Scaling for Coastal Protection Platform Level

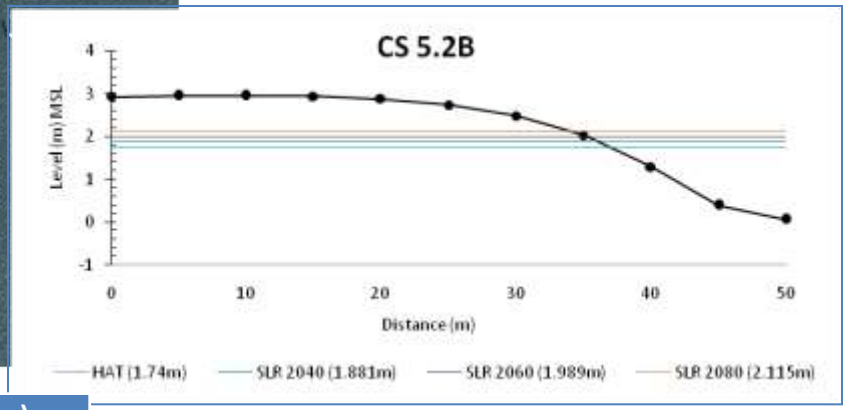
| Description | Very Low (1) | Low (2) | Medium (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| Platform level (m MSL) | > 2.5 | 2.0-2.5 | 1.5-2.0 | 0.5-1.5 | < 0.5 |

# Physical Vulnerability Index


**Digital Elevation Map (DEM) Survey**

The survey results using DEM methods mostly cover the shoreline that is inaccessible either due to its location or the shoreline conditions.

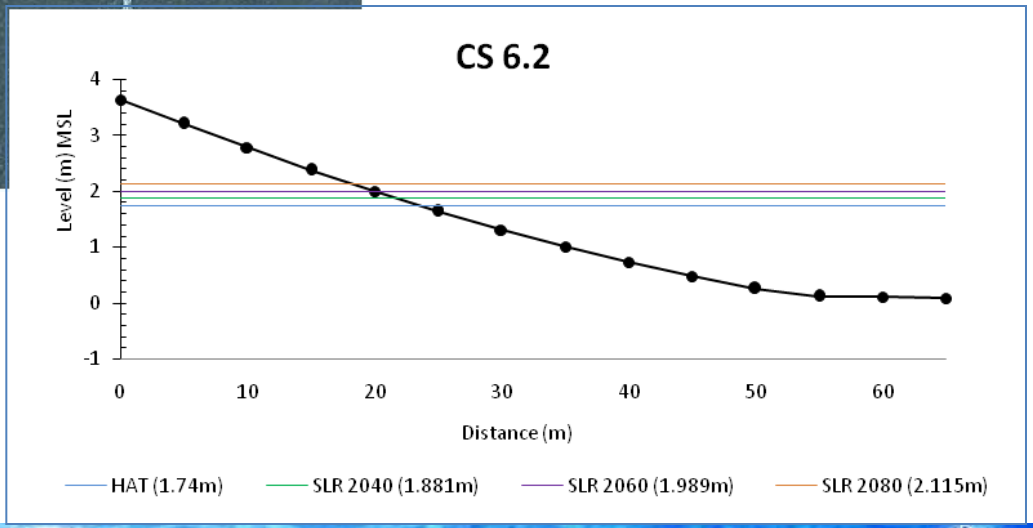
# Coastal Profile Surveys




| Distance (m) | Latitude (°N) | Longitude (°E) | MSL Height (m) |
|---|---|---|---|
| 50 | 99.73589 | 6.266069 | 0.062 |
| 45 | 99.73586 | 6.266108 | 0.394 |
| 40 | 99.73581 | 6.266146 | 1.295 |
| 35 | 99.73577 | 6.266191 | 2.030 |
| 30 | 99.73572 | 6.266236 | 2.476 |
| 25 | 99.73568 | 6.266281 | 2.740 |
| 20 | 99.73563 | 6.266325 | 2.878 |
| 15 | 99.73559 | 6.266370 | 2.933 |
| 10 | 99.73554 | 6.266415 | 2.951 |
| 5 | 99.73550 | 6.266460 | 2.947 |
| 0 | 99.73545 | 6.266505 | 2.929 |

# Coastal Profile Surveys

| Distance (m) | Latitude (°N) | Longitude (°E) | MSL Height (m) |
|---|---|---|---|
| 65 | 99.80178 | 6.314704 | 0.080 |
| 60 | 99.80174 | 6.314749 | 0.104 |
| 55 | 99.80169 | 6.314794 | 0.108 |
| 50 | 99.80165 | 6.314839 | 0.246 |
| 45 | 99.80160 | 6.314884 | 0.467 |
| 40 | 99.80156 | 6.314928 | 0.721 |
| 35 | 99.80151 | 6.314973 | 1.001 |
| 30 | 99.80142 | 6.315063 | 1.304 |
| 25 | 99.80137 | 6.315108 | 1.634 |
| 20 | 99.80128 | 6.315198 | 1.992 |
| 15 | 99.80124 | 6.315243 | 2.376 |
| 10 | 99.80119 | 6.315288 | 2.779 |
| 5 | 99.80115 | 6.315333 | 3.199 |
| 0 | 99.80110 | 6.315378 | 3.635 |



The only vulnerability factor used to compute Physical Vulnerability Index (PVI) would be the platform level.

$$PVI = \frac{A1 \times W1}{1}$$

Where,

A1 = Platform level

W1= weighting factor

Since there is only one indicator being considered, the weighting factor will be the value of 1. Hence,

$$PVI = \frac{A1 \times 1}{1}$$

The value of PVI is obtained directly without the requirement of weighting factor.

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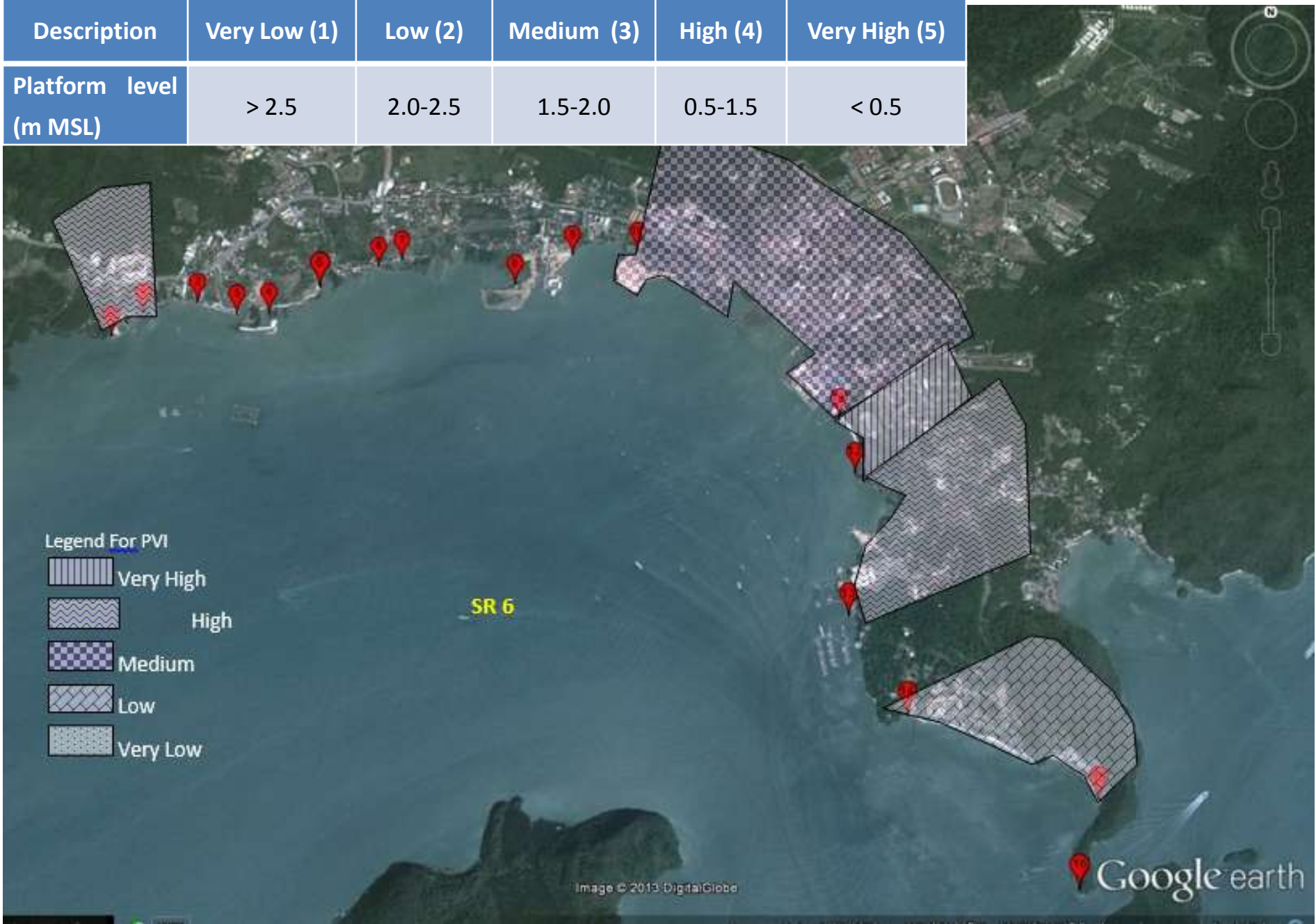
| Description | Very Low (1) | Low (2) | Medium (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| Platform level (m MSL) | > 2.5 | 2.0-2.5 | 1.5-2.0 | 0.5-1.5 | < 0.5 |



# Ecological Vulnerability Index

1. Ecological vulnerability -existence of coastal vegetation or mangrove forest that may be impacted by sea level increase.
2. The coast of Langkawi is partially represented by steep hilly terrain constituting tropical forest. Such areas are not covered in the VI evaluation as there seems to be no impact due to the steepness of the terrain.
3. Of 82 management units in 13 sub-reaches being studied, 35 are considered not significantly impacted by the sea level rise phenomena.
4. Henceforth, only affected MUs are taken into account for EVI assessment.

- As indicated earlier, the only vulnerability factor used to compute ecological vulnerability index would be the percentage of area occupied by coastal vegetation.

$$EVI = \frac{A1 \times W1}{1}$$

- Where,

  A1 = % area occupied by coastal vegetation

  W1= weighting factor

- Since there is only one indicator being considered, the weighting factor will be the value of 1.Hence,

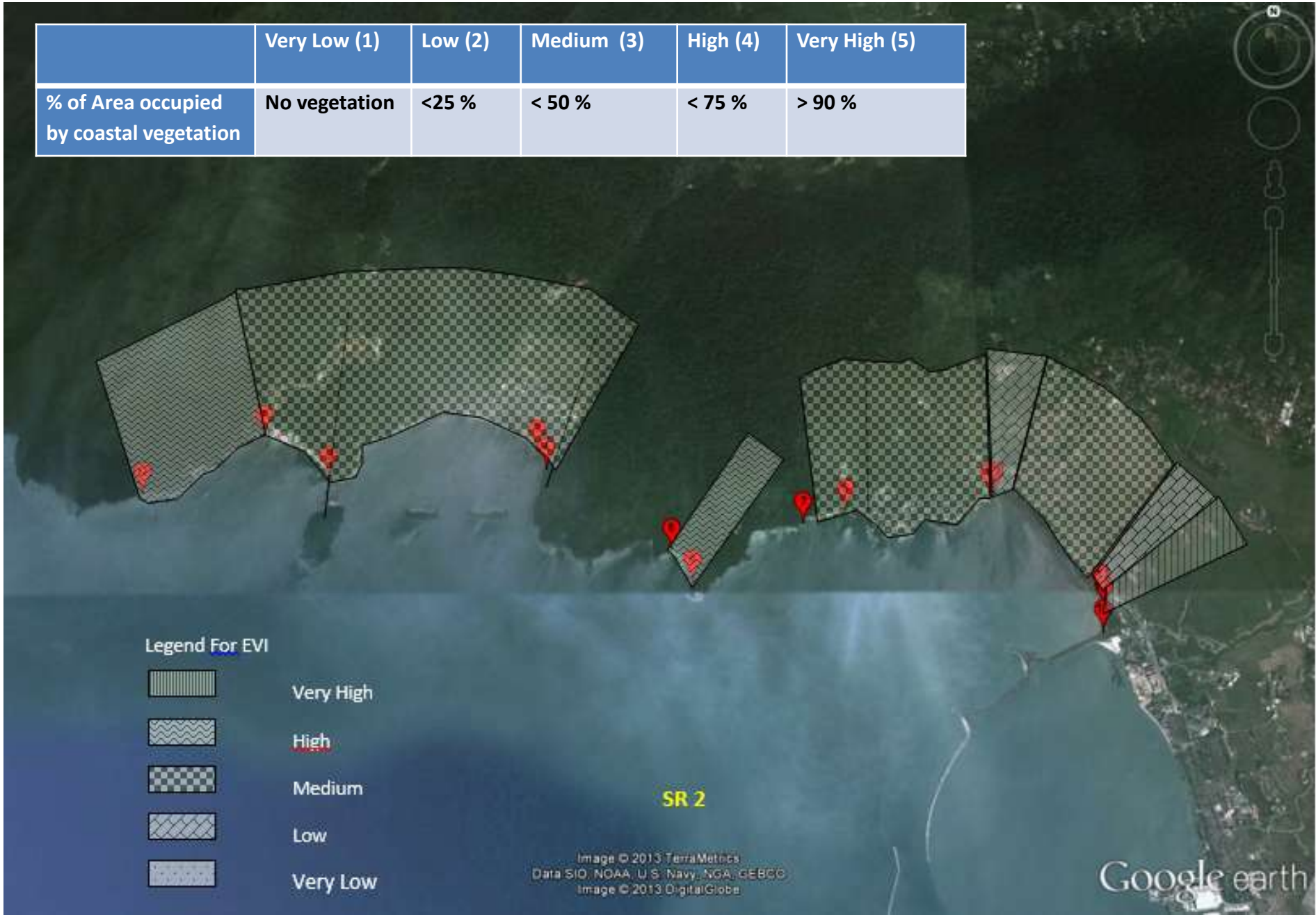
$$EVI = \frac{A1 \times 1}{1}$$

- In this case, the value of EVI is obtained directly without the requirement of weighting factor .

| | Very Low (1) | Low (2) | Medium (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| % of Area occupied by coastal vegetation | No vegetation | <25 % | < 50 % | < 75 % | > 90 % |

| MU | Area | Area Occupied by Coastal Vegetation | EVI Score |
|---|---|---|---|
| 2-1 | Steep coastal forest with water resort near shoreline | 4 | 4 |
| 2-2 | Beach resort | 3 | 3 |
| 2-3 | Public beach | 3 | 3 |
| 2-4 | Telaga Harbour | 3 | 3 |
| 2-6 | Rocky headland with near-beach resort | 4 | 4 |
| 2-8 | Beach resort | 3 | 3 |
| 2-9 | Beach resort | 3 | 3 |
| 6-3 | Factories, buildings and jetties | 3 | 3 |
| 6-5 | Beach with scarce coastal vegetation | 3 | 3 |
| 6-6 | Coastal vegetation & coastal settlement | 3 | 3 |
| 6-7 | Coastal vegetation & coastal settlement | 3 | 3 |
| 6-8 | Coastal vegetation, coastal settlement, river training bund, reclamation area and jetty | 3 | 3 |
| 6-10 | Shopping mall, parking lot and reclaimed area | 2 | 2 |
| 6-11 | Resorts, shop lots, parking area, jetty, bridge, coastal road and undeveloped reclaim land | 2 | 2 |

| | Very Low (1) | Low (2) | Medium (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| % of Area occupied by coastal vegetation | No vegetation | <25 % | < 50 % | < 75 % | > 90 % |



## Socio Economic Vulnerability Index

1. The Socio Economic Vulnerability -The main indices that need to be addressed are as follows:-
   - Public infrastructure and facilities
   - Population
   - Tourism
2. The Socio Economic Vulnerability Index is then computed based on the average of these indicators and adjusted based on a certain weightage.
   -Population – 40 %
   -Tourism – 30 %
   -Public infrastructure – 30 %

3. Greater weightage towards population as compared to the other two indicators reflect greater concern on the impact of the livelihood of the people affected.
4. This approach of giving more emphasis on the population is in line with other studies of a similar nature such as the 'Tsunami Modelling Impact Studies For The East Coast Of Sabah, Malaysia' by JPS.
5. The sub-indices selected for the socio-economic index which are population, tourism and public infrastructure are further discussed below.

# Population

- Indicator of population refers to population density at specific location.
- This only refers to residential areas.
- The population along the coastline comprises mainly of fishing community, apart from rural villages. There are also isolated modern bungalows along the coast line.

| Population | Very Low (1) | Low (2) | Moderate (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| Population Density (individual/km$^2$) | < 5 | 5 - 10 | 10 – 50 | 50 – 100 | > 100 |

**Scaling of population density indicator**

# Tourism

- Langkawi is very prominent in tourism, providing major revenue for the island.
- Significant attention needs to be given to the tourism sector in the vulnerability analysis.
- The impact on tourism due to sea level rise is estimated based on estimated number of beds in the hotels, resort etc for each MU.

| Tourist Population | Very Low (1) | Low (2) | Moderate (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| No. of Tourists (no. of beds) | < 100 | 100 - 300 | 300 - 500 | 500 – 700 | > 700 |

**Scaling of tourist population indicator**

# Public Infrastructure and Facilities

- Infrastructures are important in the event of rescue and necessary upon mishap, such as sea level rise. Vulnerability of these facilities is determined based on the number of critical facilities available in each MU.
- It is expected that the number of critical facilities are greater in urban areas.

| Critical Facilities | Very Low (1) | Low (2) | Moderate (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| **Presence of critical infrastructure e.g. school, clinic, hospital, police station, airport, port, jetties, power station, water treatment plant, telecommunication tower (no. of infrastructure)** | None | 2 | 3 | 4 | > 4 |

**Scaling of critical facilities indicator**

## Combined Socio-Economic Vulnerability index (SVI)

The combined SVI is then computed as follows according to the weightages that have been described earlier.

$$SVI = \frac{(B_1 \times W_1) + (B_2 \times W_2) + (B_3 \times W_3)}{3}$$

Where,

$B_1$ = population

$B_2$ = tourism

$B_3$ = public infrastructure

Hence,

$$SVI = \frac{(B_1 \times 0.4) + (B_2 \times 0.3) + (B_3 \times 0.3)}{3}$$

The Socio Economic Vulnerability Index (SVI) is scored based on quantile range (20th percentile, 40th percentile, 60th percentile and 80th percentile)

| 20th percentile | 40th percentile | 60th percentile | 80th percentile |
|---|---|---|---|
| 0.48 | 0.67 | 0.85 | 0.95 |

**Quantile Range of Socio-Economic Vulnerability Indicators**

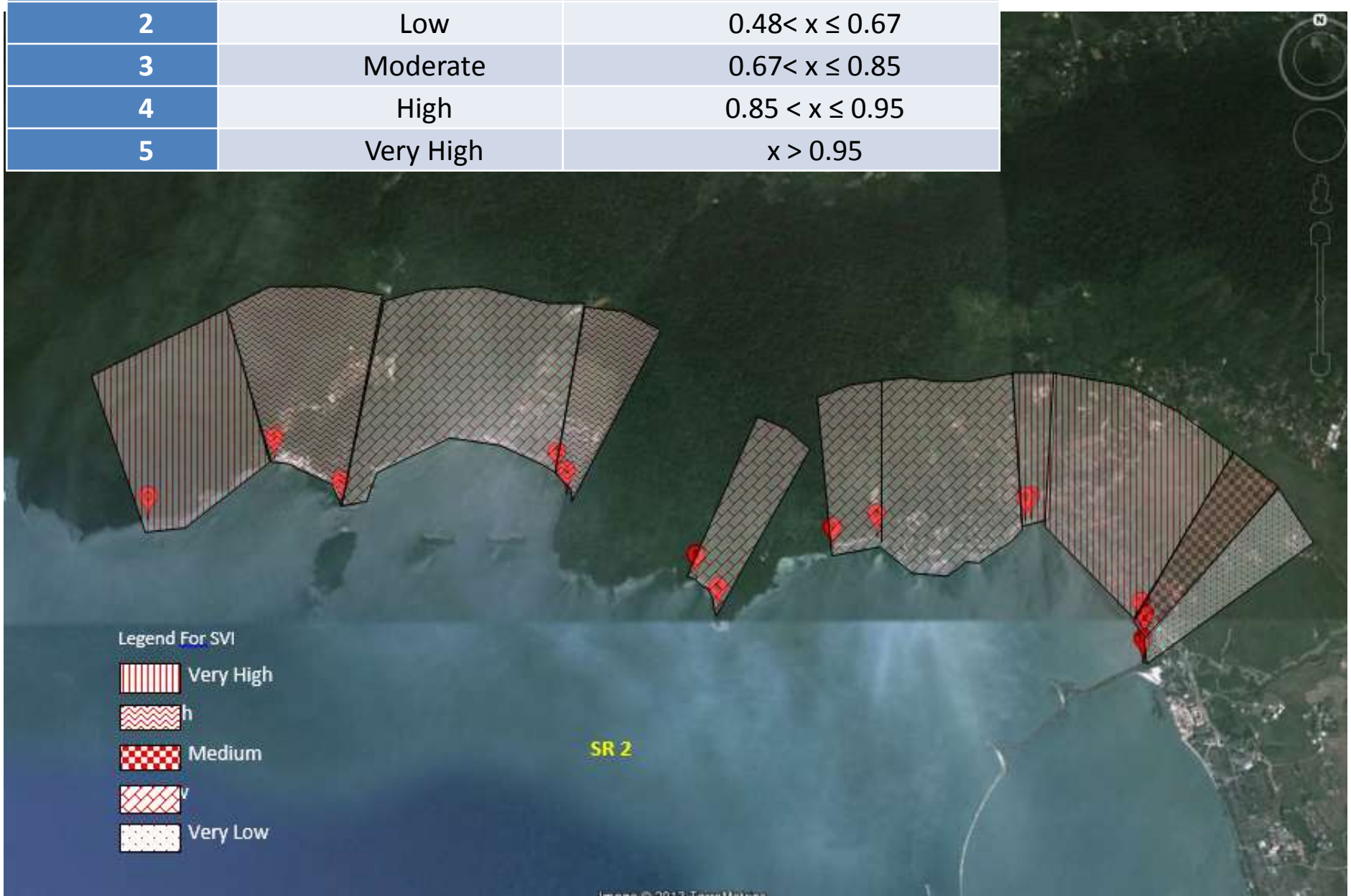
| Rank | Vulnerability | Range |
|---|---|---|
| 1 | Very Low | $X \leq 0.48$ |
| 2 | Low | $0.48 < x \leq 0.67$ |
| 3 | Moderate | $0.67 < x \leq 0.85$ |
| 4 | High | $0.85 < x \leq 0.95$ |
| 5 | Very High | $x > 0.95$ |

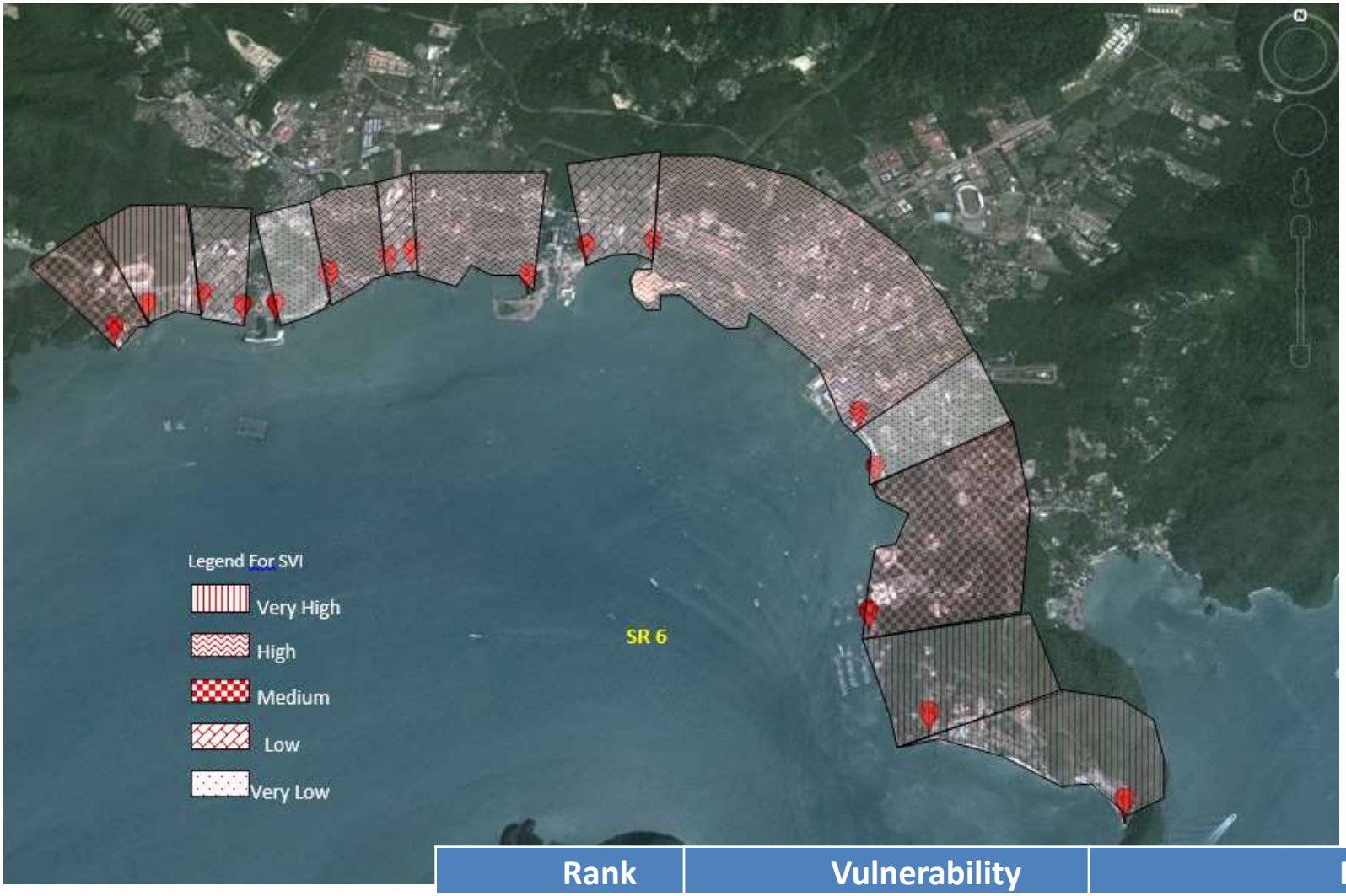
**The SVI Score for the Study Area**

# Socio-Economic Vulnerability index

| MU | Area | Population | Tourism | Public Infrastructure | Relative SVI | SVI Score |
|---|---|---|---|---|---|---|
| 2-1 | Steep coastal forest with water resort near shoreline | 2 | 4 | 3 | 0.97 | 5 |
| 2-2 | Beach resort | 2 | 4 | 2 | 0.87 | 4 |
| 2-3 | Public beach | 2 | 2 | 2 | 0.67 | 2 |
| 2-4 | Telaga Harbour | 2 | 3 | 3 | 0.87 | 4 |
| 2-6 | Rocky headland with near-beach resort | 1 | 3 | 2 | 0.63 | 2 |
| 2-8 | Beach resort | 1 | 3 | 2 | 0.63 | 2 |
| 2-9 | Beach resort | 1 | 3 | 2 | 0.63 | 2 |
| 2-10 | River channel | 5 | 1 | 3 | 1.07 | 5 |
| 2-11 | Fishermen village | 5 | 1 | 2 | 0.97 | 5 |
| 2-12 | Sg. Melaka river mouth | 3 | 1 | 3 | 0.80 | 3 |

| Rank | Vulnerability | Range |
|---|---|---|
| 1 | Very Low | X ≤ 0.48 |
| 2 | Low | 0.48< x ≤ 0.67 |
| 3 | Moderate | 0.67< x ≤ 0.85 |
| 4 | High | 0.85 < x ≤ 0.95 |
| 5 | Very High | x > 0.95 |






| Rank | Vulnerability | Range |
|---|---|---|
| 1 | Very Low | X ≤ 0.48 |
| 2 | Low | 0.48< x ≤ 0.67 |
| 3 | Moderate | 0.67< x ≤ 0.85 |
| 4 | High | 0.85 < x ≤ 0.95 |
| 5 | Very High | x > 0.95 |

# Total Vulnerability Index

1. The Total Vulnerability Index is estimated by computing the weighted mean of all the individual vulnerability that has been assessed.

2. The evaluation approach attempts to factor in all relevant indicators in order to achieve a comprehensive assessment. The proposed weightage for the MUs in the Langkawi Island are as follows:-

| | | |
|---|---|---|
| Socio economic | - | 45 % |
| Ecology | - | 30 % |
| Physical | - | 25 % |

In the event that physical impact is insignificant, only socio-economy and ecology factors are considered.

| | | |
|---|---|---|
| Socio economic | - | 60 % |
| Ecology | - | 40 % |

The main reason for adopting this weightage -importance to the livelihood of the population as compared to other vulnerabilities.

It is followed by ecology, -globally known for eco-tourism noted for the UNESCO's sanctioned geopark as well as various nature attractions

The TVI is scored based on quantile range (20th percentile, 40th percentile, 60th percentile and 80th percentile). The TVI scores computed for each MU.

$$TVI = \frac{(SVI \times Wx) + (EVI \times Wy) + (PVI \times Wz)}{3}$$

Where,

| | |
|---|---|
| SVI | = Socio-economic Vulnerability Index |
| PVI | = Physical Vulnerability Index |
| Wx,Wy, Wz | = weighting factor |

Hence,

$$TVI = \frac{(SVI \times 0.45) + (EVI \times 0.30) + (PVI \times 0.25)}{3}$$

| 20th percentile | 40th percentile | 60th percentile | 80th percentile |
|---|---|---|---|
| 0.73 | 0.92 | 1.05 | 1.23 |

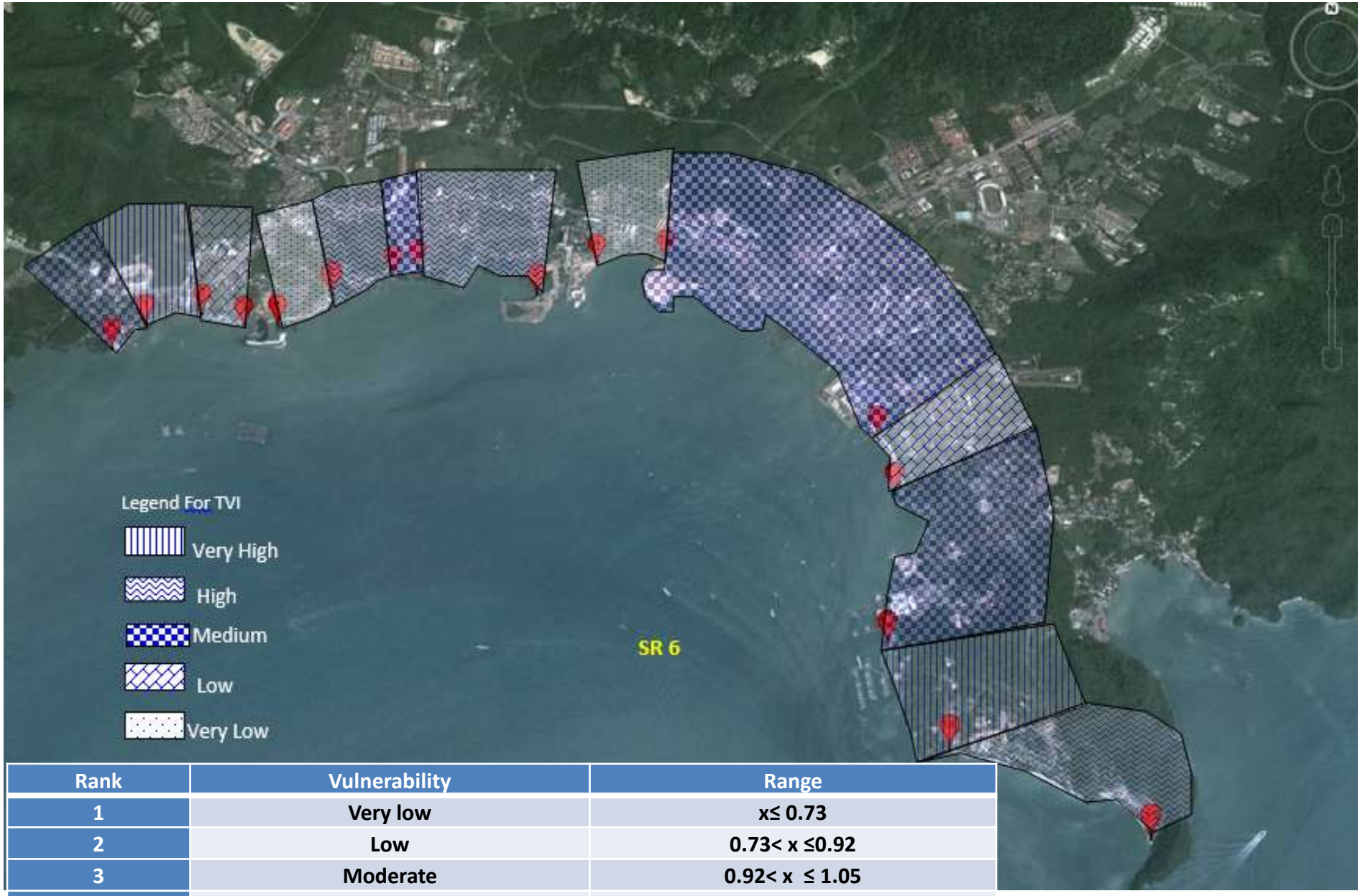
**Quartile Ranges of the Total Vulnerability Index**

| Rank | Vulnerability | Range |
|---|---|---|
| 1 | Very low | $x \leq 0.73$ |
| 2 | Low | $0.73 < x \leq 0.92$ |
| 3 | Moderate | $0.92 < x \leq 1.05$ |
| 4 | High | $1.05 < x \leq 1.23$ |
| 5 | Very high | $x > 1.23$ |

**TVI Scores for the Study Area**

# Total Vulnerability Index (TVI) for the Study Area

| MU | Area | SVI Score | EVI Score | PVI Score | Relative TVI | TVI Score |
|---|---|---|---|---|---|---|
| 2-1 | Steep coastal forest with water resort near shoreline | 5 | 4 | 1 | 1.23 | 4 |
| 2-2 | Beach resort | 4 | 3 | 2 | 1.07 | 4 |
| 2-3 | Public beach | 2 | 3 | 2 | 0.77 | 2 |
| 2-4 | Telaga Harbour | 4 | 3 | 1 | 0.98 | 3 |
| 2-6 | Rocky headland with near-beach resort | 2 | 4 | 2 | 0.87 | 2 |
| 2-8B | Beach resort | 2 | 3 | 3 | 0.85 | 2 |
| 2-9A | Beach resort | 2 | 3 | 2 | 0.77 | 2 |
| 2-10 | River channel | 5 | 2 | 4 | 1.28 | 5 |




| Rank | Vulnerability | Range |
|---|---|---|
| 1 | Very low | x≤ 0.73 |
| 2 | Low | 0.73< x ≤0.92 |
| 3 | Moderate | 0.92< x ≤ 1.05 |
| 4 | High | 1.05< x ≤1.23 |
| 5 | Very high | x > 1.23 |

# INUNDATED AREAS ALONG THE SHORELINE – 2100 SLR

# Affected Land

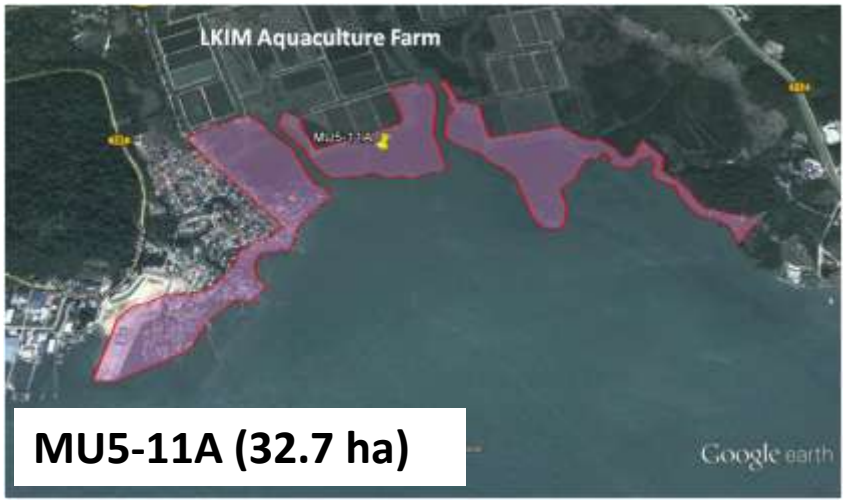

MU2-2 (2.69 ha)


MU4-1 (0.1 ha)

MU4-3A (4.39 ha) & 4-3B (1.73 ha)

# Affected Land

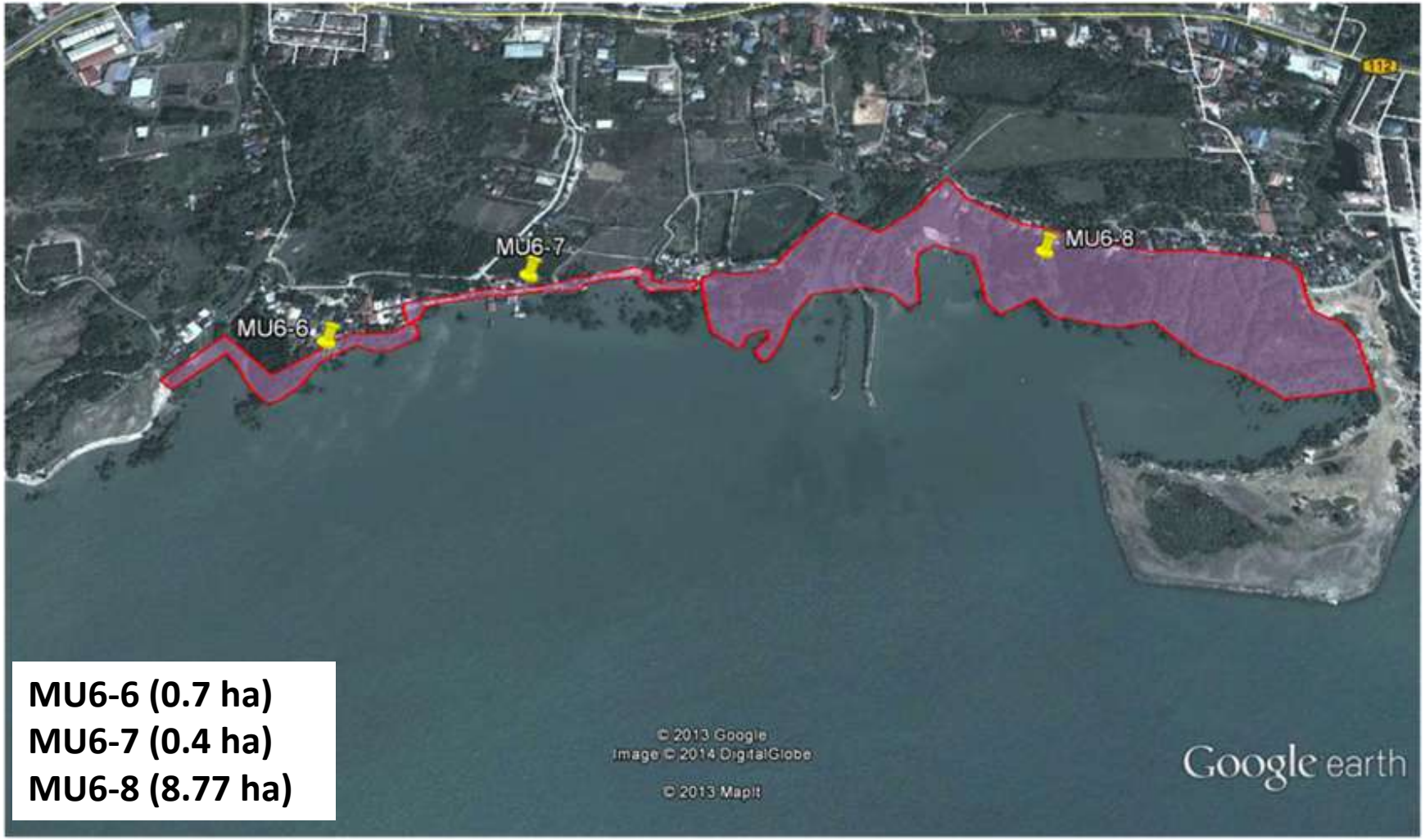

MU5-5 (5.71 ha) & 5-6 (2.5 ha)




MU5-11A (32.7 ha)

MU6-2 (4.9 ha)

# Affected Land

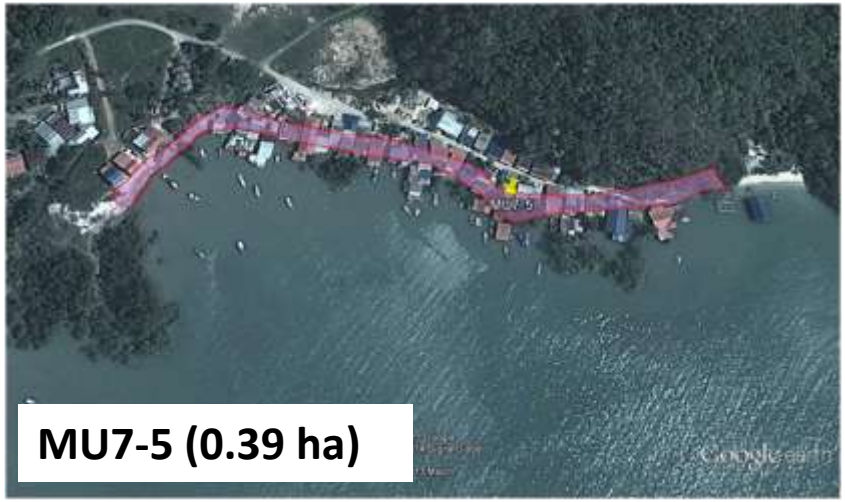



**MU6-6 (0.7 ha)**
**MU6-7 (0.4 ha)**
**MU6-8 (8.77 ha)**

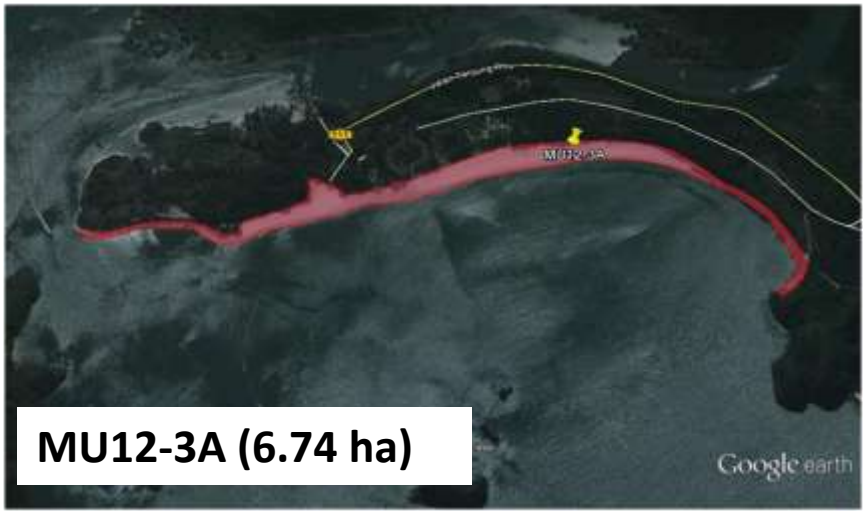
# Affected Land

MU6-12 (0.7 ha)

MU7-2 (0.3 ha)



MU7-5 (0.39 ha)



MU12-3A (6.74 ha)

# Affected Land


**MU12-4 (11.3 ha)**
**MU12-5 (2.1 ha)**

# Affected Land


**MU13-1 (2.65 ha)**


**MU13-6B (1.99 ha)**

| Rank | Coastal Vulnerability Index (CVI) | Area |
|---|---|---|
| 1 | Very Low | 1 Area (Temoyang River Mouth) |
| 2 | Low | 4 Area (Langkawi Sheraton Beach Resort, Kuala Teriang; Chenang River Mouth; Temoyang River Mouth; and Bella Vista Beach) |
| 3 | Moderate | 6 area (area beside Chenang River; Meritus Pelangi Beach & Spa Resort, Chenang; Kuah Town; Kuah area; Bella Vista Resort; and Teluk Yu Public Park) |
| 4 | High | 9 area (Teriang River Mouth until Melaka River Mouth ; Melaka River Mouth; Meritus Pelangi Beach & Spa Resort; Kuah Town; Dataran Lang;Kuah Jetty & Marina; TNB Power Station Apau Village; dan Pasir Tengkorak Beach). |
| 5 | Very High | 6 area (Teriang River Mouth; LKIM Aquaculture Farm; Kuah Town; Beringin Viilage until Penarak Village; Kilim River Mouth; dan Tg. Rhu Beach). |

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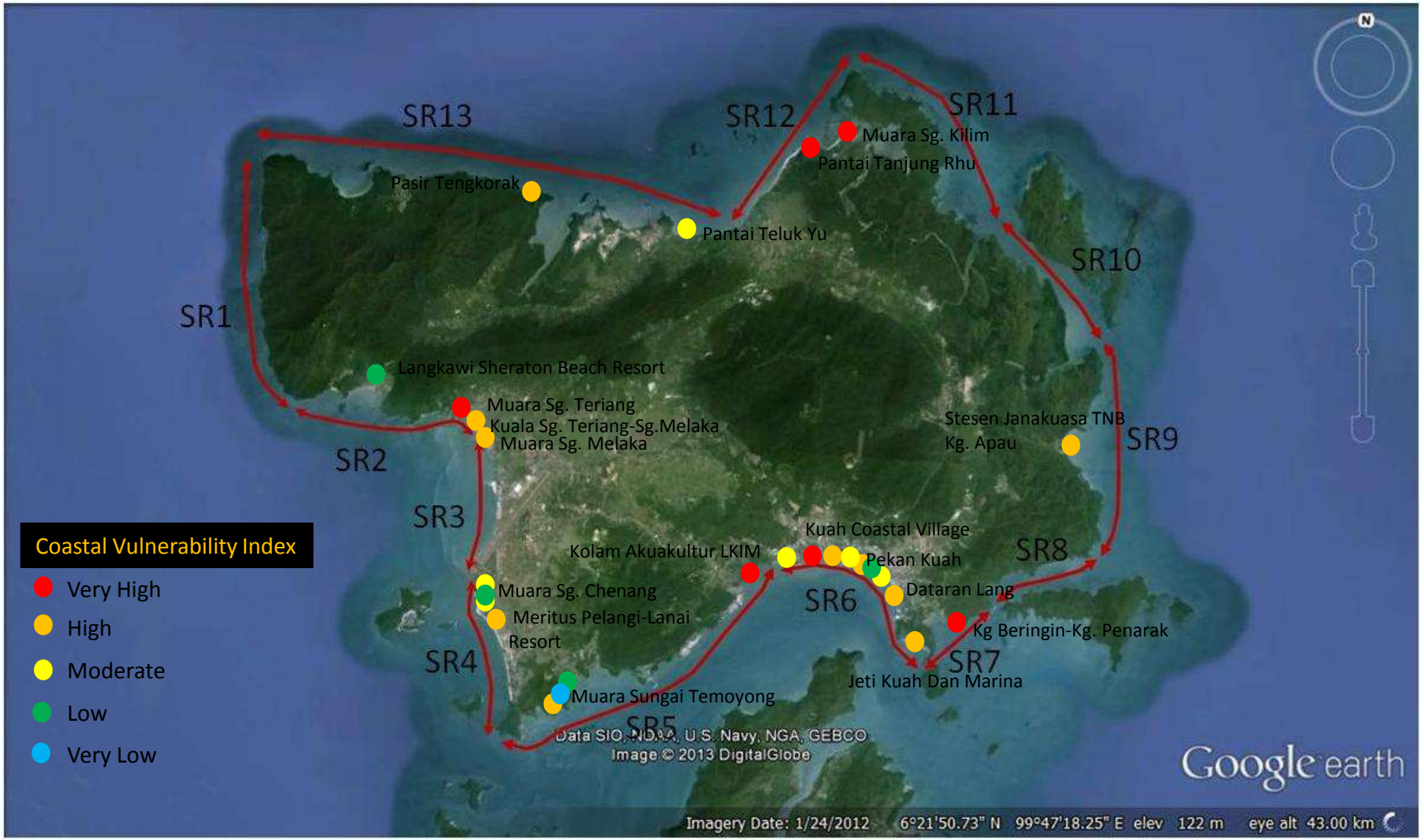

| No: | MU | CVI | Adaptation Measures | Cost / m (RM) | Length (m) | Estimated Cost (RM) 2040 | Estimated Cost (RM) 2100 |
|---|---|---|---|---|---|---|---|
| 1 | 2-8B | Low | Increased rock revetment crest height | 1000.00 | 200 | - | 200,000.00 |
| 2 | 2-10 | Very High | Maintenance dredging – Sg. Teriang<br>Rock groyne for river training | 200.00<br>5,000.00 | 300<br>200 | - | 60,000.00<br>1,000,000.00 |
| 3 | 2-11 | High | Construct geotube to protect mangrove as wave buffer to water village | 30,000.00 | 900 | - | 27,000,000.00 |
| 4 | 2-12 | High | Maintenance dredging – Sg. Melaka | 200.00 | 250 | - | 50,000.00 |
| 5 | 4-1 | Moderate | Rock revetment with suitable toe at shoreline | 5,000.00 | 100 | 500,000.00 | - |
| 6 | 4-2 | Low | Periodic dredging<br>Rock groyne for river training and prevent sand bypassing | 200.00<br>5,000.00 | 250<br>200 | 50,000.00<br>1,000,000.00 | 50,000.00<br>- |
| 7 | 4-3A | Moderate | Periodic Beach replenishment | 3000.00 | 350 | 1,050,000.00 | 1,050,000.00 |
| 8 | 4-3B | High | Periodic beach replenishment | 3000.00 | 450 | 1,350,000.00 | 1,350.000.00 |


There are three generic categories of adaptation options that can be used in areas affected by sea level rise, storm surge activity, and/or coastal erosion: planned retreat, accommodation, and protection.

| Item | MU No | Brief description | Probable Impacts due to SLR | Possible Adaptation Measures | Remarks |
|---|---|---|---|---|---|
| 1 | 1 | Steep coastal forest | None | None | NER |
| 2 | 2-1 | Steep coastal forest with water resort near shoreline | Impact to Berjaya Resort, a prominent resort. Insufficient platform level of water resort and walkways | Increase platform level | FER |
| 3 | 2-2 | Beach resort | Impact to Berjaya's beach. Beach erosion threaten near-beach structures | Relocate further inland (higher ground) | FER |
| 4 | 2-3 | Public beach | Beach erosion. Beach also serve as landing points for fishermen's boats | Man-made islands fronting the beach may reduce the impact | FER |

**"No Evaluation Required" (NER)**
**"Further Evaluation Required" (FER)**

# CONCLUSIONS

1. The coastal vulnerability index will indicate the high vulnerability area along the shore line for the impact of sea level rise.
2. This output would help the implementation agencies in preparedness the impact of SLR. Furthermore, in early planning stage the prevention in developing the high risk to SLR impact.
3. Any loss consequence of the phenomenon can be minimize to safeguard the live of the coastal population in study area.
4. Decision Support System(DSS)-Assessment of sea level rise at risky area also suggesting the best practice in adaptation and mitigating the SLR impact for the implementing agencies.
5. Assessing the impacts of sea level rise remains challenge from the fact that sea level rise is a long term phenomenon, slowly varying process and the consequences is not immediately destructive.

# THANK YOU