STANDARD INDUSTRI PEMBINAAN

(CONSTRUCTION INDUSTRY STANDARD)

CIS # :

FLOOD RISK ASSESSMENT IN MALAYSIA

Description Flood, Risk assessment, Vulnerability index, Map

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CONSTRUCTION INDUSTRY DEVELOPMENT BOARD

Construction Industry Development Board Malaysia

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FLOOD RISK ASSESSMENT IN MALAYSIA

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TABLE OF CONTENTS

COMMITTEE REPRESENTATION

This Construction Industry Standard Industry (CIS) was managed and developed by the Construction Industry Development Board Malaysia with the assistance of the Technical Committee of CIS for Flood Risk Assessment which comprises representative from the following organizations;-

Agensi Pengurusan Bencana Negara (NADMA)
Board of Engineers Malaysia (BEM)
Creative Variety Sdn Bhd
Dewan Bandaraya Kuala Lumpur (DBKL)
Dr Nik & Associates Sdn Bhd
Environmental Resources Management (ERM)
Institut Penyelidikan Air Kebangsaan Malaysia (NAHRIM)
Jabatan Pengairan & Saliran Malaysia (JPS)
Kementerian Kerja Raya
Master Builders Association Malaysia (MBAM)
RBM Engineering Sdn Bhd
The Association of Consulting Engineers Malaysia (ACEM)
Universiti Teknologi Malaysia (UTM)
Universiti Teknologi Mara (UiTM)
Veritas Architects Sdn Bhd

PREFACE

This Construction Industry Standard (CIS) hereby referred as CIS ##: #### was developed as Construction Industry Standard for Flood Risk Assessment by the Construction Industry Development Board (CIDB) Malaysia which acted as a moderator and facilitator for the technical committee throughout the development process of this standard.

Compliance with this Construction Industry Standard does not of itself confer immunity from legal obligations.

In the event of a dispute in the computation methods/formulas/parameters/assumptions, criteria published and used by the Department of Irrigation and Drainage will have an upper hand or superceed this document.

Any feedback or questions on this document should be directed to CIDB at www.cidb.gov.my.

FLOOD RISK ASSESSMENT IN MALAYSIA

SECTION 1 GENERAL

1.1 Scope

This standard complements the Guideline and Manual for Flood Risk Assessment (FRA) published by Construction Industry Development Board (CIDB), (2019) Malaysia as well as any existing acts,, guidelines,standards, and regulations in force. It is structured to facilitate the Principal Submitting Person (PSP), or any other involved parties, in conducting assessment of potential flood impacts associated with proposed new developments.

This document sets outthe standard methodology forconducting a Flood Risk Assessment (FRA) and Flood Vulnerability Index (FVI) in Malaysia and enhanced the needs for the local authorities to utilise flood hazard map provided by the Department of Irrigation and Drainage (DID) in producing flood risk maps.

1.1.1 Consideration of Flood Risk Assessment

Consideration of flood risk assessment and flood vulnerability index into existing local acts and guidelines are as follows:

(I) The proposed development area falls into the flood risk area as in the enforced development plan (rancangan pemajuan yang berkuatkuasa) or identified by the local authorities

(II) Land development area of 50 ha and above.

(III) Land development of less than 50 ha in flood prone areas.

(IV) DID is entrusted to produce flood hazard maps for all major river basins. At the same time, DID has also developedflood risk maps atselected river basins.

(V) In the event, flood risk map is inavailable, developer shall conduct flood risk map of the development project as well as a more detailed analysis and assessment.

1.1.2 Application of Flood Risk Assessment

The process of integrating flood risk assessments and the creation of flood risk or vulnerability maps into new development can be executed by the following parties:

a. **Federal**:
Incorporate flood risk assessment and vulnerability maps into national planning coordinated by PLAN Malaysia and overseeing by DID.

b. **State/Local Authority**:
Incorporate flood risk assessment and vulnerability maps into state or local authority's structure plan, local plan, or special area plan (Rancangan Kawasan Khas) coordinated by the State PLAN Malaysia and overseeing by the State DID. While for Federal Territories, they should align with their respective requirements. Integration into any comprehensive river basin management plan is recommended.

c. **Developer**:
Developers should undertake a flood risk assessment for the proposed site, its surroundings and downstream areas; ensuring control at source. Additional flood risk assessments might be needed during the planning permission phase.

1.2 Normative References *(mandatory)*

There are no normative references in this document.

1.3 Terms and Definitions

The definition provided are sourced from the United Nations Office for Disaster Risk Reduction (UNDRR, 2016) and Chow (1964).

1. Average Recurrence Interval (ARI)

Average Recurrence Interval is the average length of time between rain events that exceeds the same magnitude, volume, or duration..

2. Capacity

The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience

3. Climate change

(a)The Inter-governmental Panel on Climate Change (IPCC) defines climate change as:

"a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

(b)The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

4. Critical Infrastructure

The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society

5. Disaster

A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

6. Disaster risk

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

7. Disaster risk assessment

A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

8. Disaster risk management

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

9. Exposure

The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard prone areas.

10. Hazard

A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

11. Mitigation

The lessening or minimizing of the adverse impacts of a hazardous event.

12. Natural hazard

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

13. Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

14. Response

Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

15. Structural and non structural measures

Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

16. Vulnerability

The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

SECTION 2: CONCEPT AND FRAMEWORK

2.1 Flood Risk Components

Risk assessments canbe conducted using one of the three methods;probabilistic analysis, or risk matrix, or index based as illustrated in Figure 1.

For probabilistic analysis in risk assessment, flood damage assessment method is recommended. This method takes into account two main components; hazard probability and the potential damage cost.

$$\text{Risk} = f(\text{Hazard probability, damage cost}) \qquad \text{(Equation 1)}$$

For the risk matrix and index based method may include the components of the following;

- Hazard: The potential flooding event.
- Exposure: The presence of people, assets, or systems that could be adversely affected.
- Element at Risk: Specific entities that are exposed to the hazard.

- Vulnerability: Assessment of the degree to which the community or asset might be affected
- Capacity: The ability to cope with or adapt to potential flood events.

Risk = f (Hazard, Exposure, Vulnerability, Capacity) (Equation 2)

For minimal analysis of flood risk, the component shall include hazard and vulnerability.
The approaches to measure risk should be practical, understandable and relevant to local condition for decision-making processes for disaster risk reduction and emergency planning.

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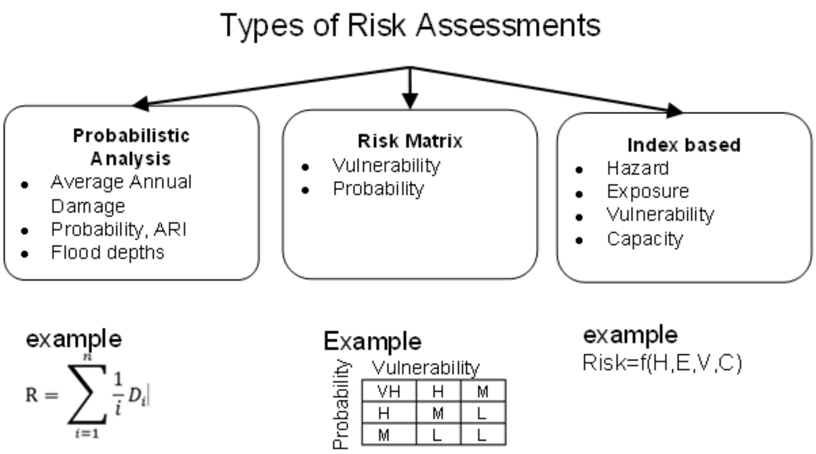

Figure 1: Types of Risk Assessments

2.2 Data Collection and Management

The data associated to flood risk and flood vulnerability assessment are suggested in this section. Table 1 presents the recommended sources of data from authorized agencies in Malaysia. All data should be obtained from trusted and recognized sources accepted by the authorities. Requirements for standardization of the data is presented.

Table 1: Recommended data sources

Data	Associated Data	Sources	Standard Requirement
Hydrological data	Calibration and validation: • Rainfall Data • Water Level Data • Streamflow Data	• DID • METMalaysia	• Small catchment < 35 ha • Large catchment > 35 ha • 20 years minimum duration record (for ARI 40 year to 50 year design) • 50 years minimum duration record (for more than ARI 50 year to 100 year design)
	• Design rainfall scenario	• DID	• Refer to HP 1 (Peninsular Malaysia) (DID, 2021) or HP 26 (Sabah & Sarawak) (DID, 2018) or any latestrelevant HPs produced by DID. • Inclusion of climate change factor published by NAHRIM.

Digital Elevation Data (DEM)	• IFSAR • LiDAR	• JUPEM	• Minimum 5-meter spatial resolution data
Data	Associated Data	Sources	Standard Requirement
Basemap Imagery	• Satellite image • Drone image	• MySA • Free/open source map service	• Latest (for current) • Relevant (for validation) available image
Landuse Data	• Residential area • Institutions and public facilities • Infrastructure and utilities • Transportation • Commercial area • Open space and recreational • Industrial area • Waterbodies • Agricultural area cash crop • Agricultural area perennial crop • Forest area	• Local authority • PLAN Malaysia • Jabatan Galian (Sabah) • Jabatan Tanah dan Survei (Sarawak)	• Latest • Relevant available data
River Cross Section	• River cross section and alignment • River network	• Primary data	• Latest • Relevant available data • Maximum interval 50-meter for small catchment
Tidal Data	• Tide Table	• NHC • JUPEM	• Highest astronomical tide (HAT)
Risk indicator: Hazard	• Flood depth • Average Recurrence Interval	• DID	• Refer Section 3.3, Table 2 • Refer to HP 1 (Peninsular Malaysia) (DID, 2021) or HP 26 (Sabah & Sarawak) (DID, 2018) or latestHPs produced by DID.
Risk Indicator: Damage Cost	• Damage rate	• DID	• Refer to Guideline on flood damage rate published by DID (DID, 2012) or any latest publications produced by DID.
Risk Indicator: Vulnerability	• Physical e.g.Traffic Volume	• Public Work Department (PWD)	• Refer to Latest Road traffic volume and any other recent relevant publication/report produced by PWD and Ministry of Work
	• Social e.g. Projected population density within the proposed new development	• Local authority	• Refer to Latest planning guideline by local authority
	• Economy e.g.Household Income	• DOSM	• Based on income classification

2.2.1 Hazard

The data required for quantifying flood hazards for risk assessment must include measurements of flood probability and depth. Flood depth information from DID's Hazard maps should be used if available. In the absence of such hazard maps, hydrological, topographical, and hydraulic data must be used to generate hazard maps.

2.2.2 Exposure or Element at Risk
The exposure or element at risk may include, but is not limited to, infrastructure and utilities, transportation, institutions and public facilities, residential areas, commercial and industrial areas, and plantations.

2.2.3 Vulnerability
The element at risk can be ranked or quantified based on its vulnerability (susceptibility to the harmful effects of a hazard and its importance). Depending on the asset at risk, the indicators for quantifying vulnerability must incorporate at least one of the social, economic, cultural, institutional, physical, and environmental dimensions.

SECTION 3: CALCULATING FLOOD HAZARD

3.1 Land Development less than 50 ha in Flood Prone Areas.

Utilise flood depth from the DID's available flood hazard map. Otherwise, historical flood map or report data shall be used.

3.2 Land Development Area 50 ha and Above.

Flood depth extracted from the available hazard map produced by DID shall be used. Alternatively, a flood hazard map can be generated by utilizing hydrological and hydrodynamic models.

3.2.1 Type of Hydrological and Hydrodynamic Models

Any hydrological and hydrodynamic models may be used but are subject to clarification of their methodology, and must undergo a successful calibration, and validation process.

The calibration and validation must include a comparison of observed and simulated data. Qualitative and quantitative model performance shall be used.

3.2.2 Hydrological Analysis

Hydrological analysis should be conducted to provide input to the hydrodynamic model. The hydrological analysis shall provide information on the hydrological characteristics and simulation of the surface hydrological processes. The hydrological analysis comprises of 3 major components of; hydrological data description and analysis, derivation of design storms, characterization of sub-catchments and hydrological characterization.

3.2.2.1 Hydrological Data and Analysis

Hydrological data consisting of rainfall, water level and streamflow discharge data should be obtained from relevant authorities. The water level and streamflow data available should be located within the study area catchment, while the rainfall data should be within and surrounding the study area catchment. Available historical flood water mark should be obtained when available. All hydrological data needs to be thoroughly processed to remove data inconsistency, conduct quality checking, and error corrections.

3.2.2.2 Derivation of Design Storm

The design storm should be calculated from methodology published by relevant authorities or methodology recognized from academic literatures. Example of methodology established by the authorities are the use of the Intensity-Duration-Frequency (IDF) Curve presented in the Hydrological Procedure, and Malaysia storm water manual (MSMA) published by the Department of Irrigation and Drainage Malaysia. The design storm may also be calculated using methodology recognized in academic literatures such as frequency analysis.

Design storms of various Average Recurrence Interval (ARI) should be included in the flood model simulation. The ARIs of 5, 10, 20, 50, 100 and 200-year ARI is recommended by the Department of Irrigation and Drainage (DID).

3.2.2.3 Hydrological Characterization

Hydrological characterization should be conducted. The hydrological characterization process comprises identification of the sub-catchments' characteristics such as its area, slope, and landuse types. The usage of Geographical Information System software (e.g., ArcGIS) may be used to analyze various type of the spatial and non-spatial data.

Output from hydrological characterization includes but not limited to delineated sub-catchments and its characteristics, time of concentration, and the infiltration capacity. These are the important parameters required during the hydrodynamic modelling processes. It will be a major input during the execution of the respective modelling process.

3.2.3 Hydrodynamic Modeling

Hydrodynamic or hydraulic modelling should be conducted to model the flood depths and flood inundation extent. It consist of river and drainage survey, model set-up, critical storm duration analysis and model calibration and validation.

3.2.3.1 River and Drainage Survey Data

River and drainage survey data consists of the dimensions of the river and drainage cross section data and its alignment. The river and drainage survey shall include all the river and drainage within the study catchment area.

3.2.3.2 Model Set-up

The model set-up shall consider the existing drainage condition of both current and future land use. The model shall comprise all but not limited to the component including river cross sections, river alignments, time series data as boundary condition, initial water level, characterised sub catchment with hydrological parameters i.e., Rainfall Runoff, Curve Number, time of concentrations (Tc) and Manning's roughness.

3.2.3.3 Critical Storm Duration Analysis

It is recommended to conduct sensitivity analysis to identify the most significant storm duration. Simulations of various storm durations and ARIs should be conducted to estimate the critical storm duration.

3.2.3.4 Model Calibration

Model calibration should be conducted from model predictions and actual measurements. Estimating a unique set of model parameters that provide a good description of the simulated flood event is necessary.

After calibration, model validation should be conducted. Model validation is the set of processes and activities intended to verify that models are performing as expected. The period of the event chosen for conducting calibration and validation needs to be carefully selected. Available rainfall and river water level or streamflow is crucial to test the model performance. The performance of the model should also be tested using any error analysis method.

3.3 Flood Hazard Map

Flood hazard maps shall be produced based on 2, 5, 10, 20, 50 ,100 and 200-year ARIs at the scale of 1:25,000 for present and future land use conditions. The flood hazard maps for the specified ARIs must clearly indicate flood depth and flood extent. The flood depth shall be denoted by the colour scheme as showed in Table 2 with the description of flood hazard degree as in Table 3.

Table 2: Flood Hazard Map Colour Scheme

Colour	Degree of Flood Hazard	Flood Depth	R	G	B
	Low	0–0.5m	190	232	255
	Moderate	0.5–1.2m	0	197	255
	High	1.2m-2.5m	0	92	230
	Very High	> 2.5m	0	77	168

Table 3: Description of Flood Hazard Degree

Degree of Flood Hazard	Flood Depth (m)	Description
Low	**<0.5**	**Caution (Level 1)** "Caution: Flood zone with shallow flowing water or deep standing water" Note: It is still possible to walk through the water
Moderate	**0.5-1.2**	**Dangerous for some (example: children) (Level 2)** "Danger: Flood zone with deep or fast flowing water" Note: The ground floor of the buildings will be flooded, and inhabitants have either to move to the first floor or evacuate.
High	**1.2 – 2.5**	**Dangerous for all (Level 3)** "Extreme Danger: Flood zone with deep fast flowing water" Note: The ground floor and possible also the roof will be covered by water. Evacuation is a compulsory action.
Very High	**> 2.5**	**Dangerous for all (Level 4)** "Extreme Danger: Flood zone with deep fast flowing water" Note: The ground floor and possible also the roof will be covered by water. Evacuation is a compulsory action.

Note: The choice of those depth classes is based on 'human characteristics' (Source: DID)

SECTION 4: FLOOD RISK DEVELOPMENT AND ASSESSMENT

4.1 Flood Risk Analysis Calculations

Flood risk assessment enables decision-makers to understand and prioritize potential risk associated with flooding.There are three commonly used method for conducting risk assessments; Probabilistic Analysis, Risk Matrix or Multi-criteria Likelihood Scenario Analysis, and the Index-based method.

Any methodology may be used for flood risk analysis computation. However, if critical infrastructure is present, the probabilistic analysis method as described in section 4.2 is recommended.

However when the socio-economic aspects is considered, the index-based method as described in *Section 2.1* is recommended as it provides more information on it. The index-based method also considers structured vulnerability dimension indicators into the risk model as presented in *Section 5.1.1*.

4.2 Flood Damage Assessment

Flood events may damage various assets in urban, residential, industrial, agricultural, and low-lying areas. The benefits of flood control is measured according to the expected reduction in flood damages before and after flood mitigation measures are implimented.The Flood Damage Risk analysis as described in section 2.1 is recommended for critical infrastructures with the procedures as the following:

i. Preparation of the flood inundation map of the worst flood event represented by various ARIs.
ii. Overlaying of the flood inundation map to recent available land-use map
iii. Estimation of the monetary flood damage according to land-use type and flood depth information
iv. Computation of the flood damage

The land-use categories recommended but not limited to are:

i. Residential
ii. Commercial
iii. Industrial
iv. Institutional
v. Infrastructure and Utilities
vi. Transportation
vii. Plantation

The unit damage rate used to estimate the monetary damage may be reffered to authorized reports and studies conducted which are comparable to the study area economic and geographical location.

Details to calculate flood damage assessment can be referred to the Guideline for Flood Risk Assessment (CIDB, 2019) and Manual for Flood Risk Assessment and Flood Vulnerability Index for Critical Infrastructure (CIDB, 2021).

4.3 Flood Risk Map

The flood risk maps for the specified ARIs must clearly indicate flood risk zone, flood extent, location of flood evacuation centres, major towns, transportation network and points of interest. The flood risk zone shall be denoted by the colour scheme as shown in Table 4.

Table 4: Flood Risk Map Colour Scheme

Colour	Flood Risk Class	Range	Colour Scheme Name	Color Code Combination			General Description
				R	G	B	
	Very Low Risk	< 50	Grey	178	178	178	No structural and contents damage is expected. The recovery process is fast with no human casualty. Evacuation is not needed, and no recovery cost is expected.
	Low Risk	51–1,000	Sky Blue	135	206	235	No structural damage is expected; However, building properties and fittings may be affected (wet of furniture at ground floor). Evacuation may not be necessary.
	Medium Risk	1,001–5,000	Yellow Green	154	205	50	The building may be slightly damaged, but no human casualty is expected. A building can recover after floodwater drains with minimal damage. Evacuation of building properties on the ground floor is expected. Evacuation should be considered to avoid unexpected casualties.
	High Risk	5,001–25,000	Orange	255	170	0	A significant amount of damage is expected with the loss of properties, and the recovery process is expected to be very slow and after significant repair. Human casualty is also expected with injuries and possible death. Evacuation is necessary to avoid human casualties.
	Very High Risk	> 25,000	Red	225	0	0	Buildings under this class can experience total collapse or wash away by the floodwater with a very high possibility of death casualties.

The flood risk values are categorized into five risk classes according to severity of damage as shown in column three in Table 4. In order to ensure that the range for all risk classes is valid, the set of data points must not only represent a variety of return periods, but also include all the major landuse within the flooded area.

SECTION 5: CALCULATING FLOOD VULNERABILITY INDEX

5.1 Flood Vulnerability Index Calculation

The recommended vulnerability dimension should include social, economic, and physical factors. Other potential vulnerability dimensions such as institutional, environmental, and cultural factors may also be considered.

To identify the most critical and significant vulnerability indicators, the indicators may be ranked using multi-criteria decision making tools such as the Analytical Hierarchical Process (AHP) method. Subsequently, qualitative analysis on the significance of each vulnerability dimension and indicator can be performed via focused group discussion (FGD). The significance of each vulnerability dimension and indicators may be presented in the form of weightage within parameters of the vulnerabity. Then, the risk is calculated using Equation 2.

More detailed information on the methodology for calculating flood vulnerability index is presented in the Guideline for Flood Risk Assessment (CIDB, 2019) and Manual for Flood Risk Assessment and Flood Vulnerability Index for Critical Infrastructure (CIDB, 2021).

5.1.1 Land-use Vulnerability Assessment

A land-use vulnerability assessment method to conduct the vulnerability index analysis is recommended based on the methodology used in the guideline (CIDB, 2019).

The method recommends the use of available land-use data easily to be obtained from relevant authorities. The recommended land-use classification are; Infrastructure and utilities, transportation, institution and public facilities, residential, commercial, industrial, and agriculture.

The rank of the Vulnerability indices or scores of each land-use or building type associated to the vulnerability dimension of Social, Physical and Economic can be referred in the guideline (CIDB, 2019).

5.2 Flood Vulnerability Map

Flood vulnerability mapping is the process of determining the degree of susceptibility and exposure in the flood prone area (Danumah et al., 2016). The degree of the vulnerability is valued geospatially within a specific geographic location of features and boundaries.

he vulnerability map should contain the legend indicating the vulnerability class and following color format.

Table 5: Vulnerability Map Colour Scheme

Colour	Vulnerability Class	Colour Name	R	G	B
	Very Low	Lawn Green	56	167	1
	Low	Yellow - Green	122	201	0
	Low Medium	Greenish - Yellow	208	236	1
	High Medium	Orangy - Yellow	254	205	0
	High	Orange	255	102	5
	Very High	Bright Red	254	0	0

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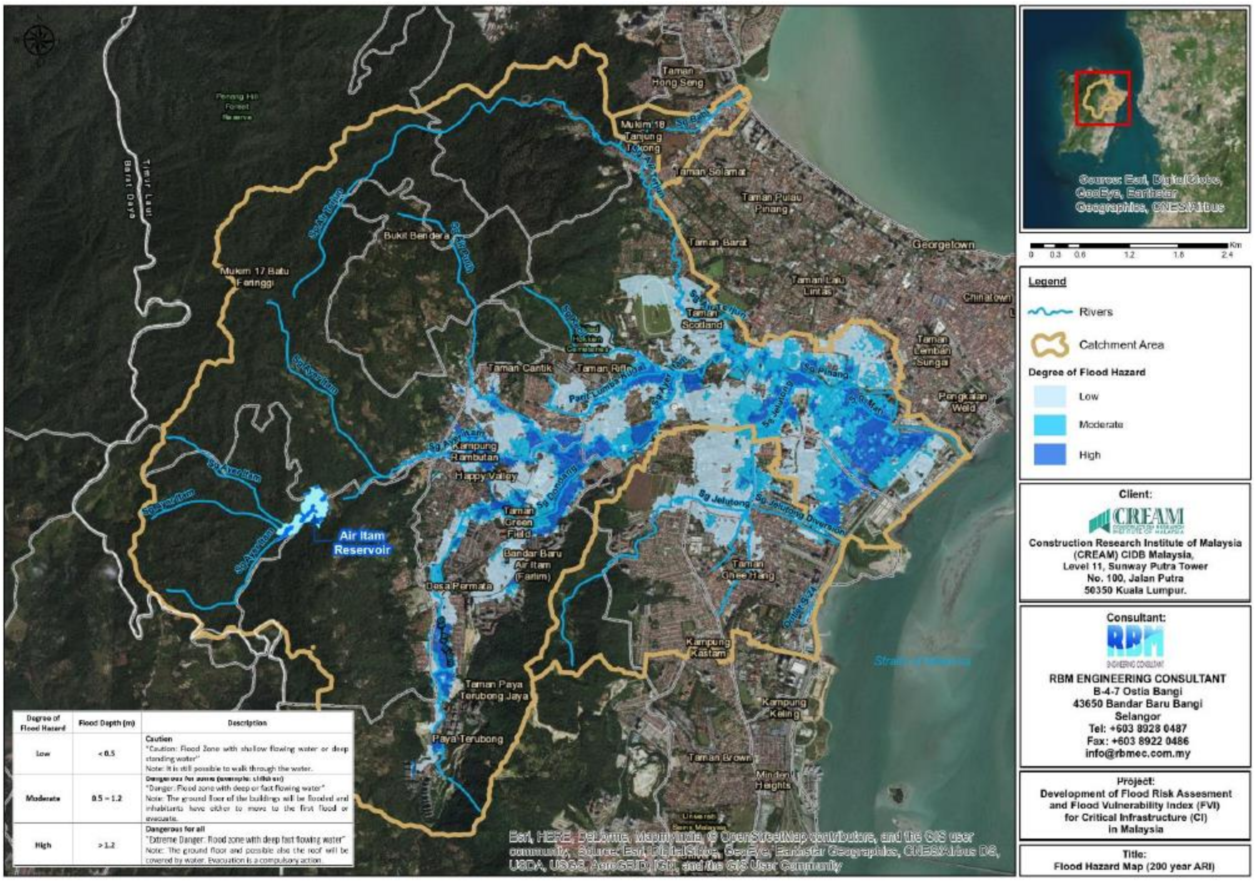
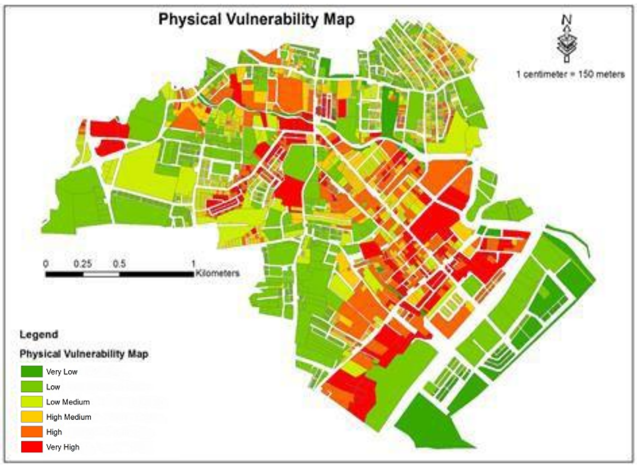
APPPENDIX A
(informative)

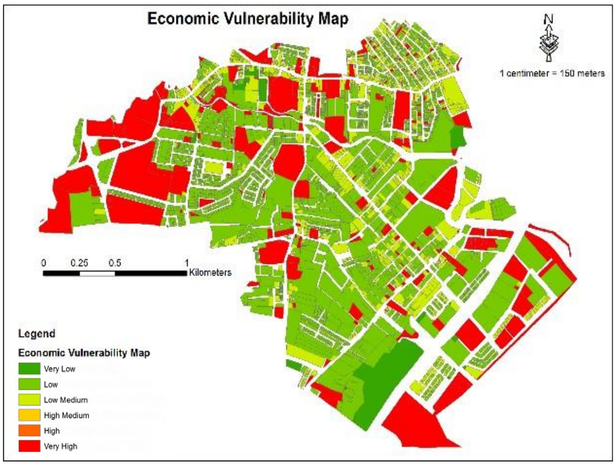
Example of Flood Hazard Map of Sg Penang

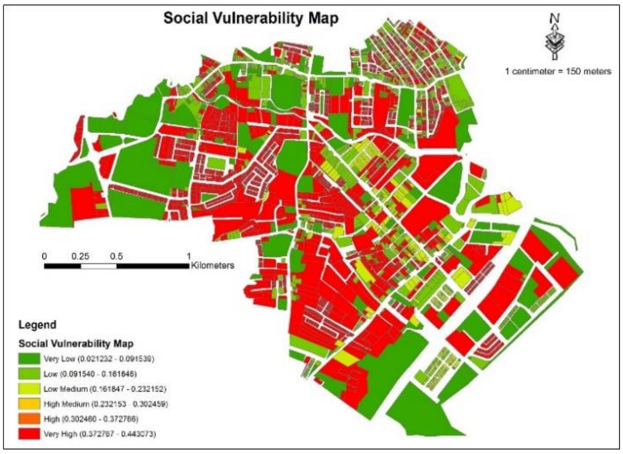


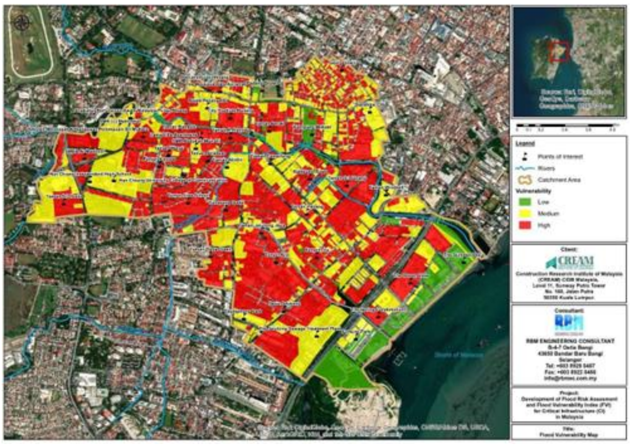
APPPENDIX B
(informative)

Example of Flood Vulnerability Map of Sg Penang



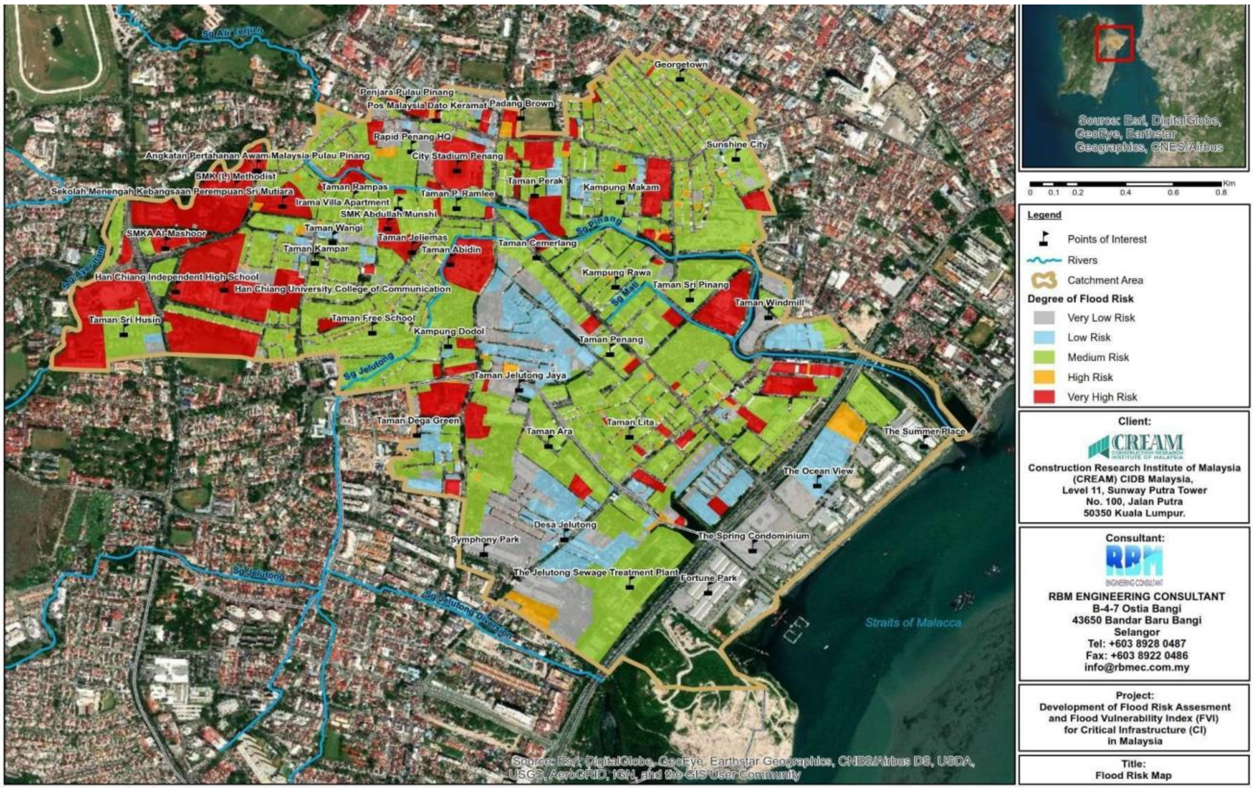






APPPENDIX C
(informative)

Example of Flood Risk Map of Sg Penang



Colour	Flood Risk Class	Range	Colour Name	R	G	B
	Very Low Risk	< 50	Grey	178	178	178
	Low Risk	51–1,000	Sky Blue	135	206	235
	Medium Risk	1,001–5,000	Yellow Green	154	205	50
	High Risk	5,001–25,000	Orange	255	170	0
	Very High Risk	> 25,000	Red	225	0	0

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