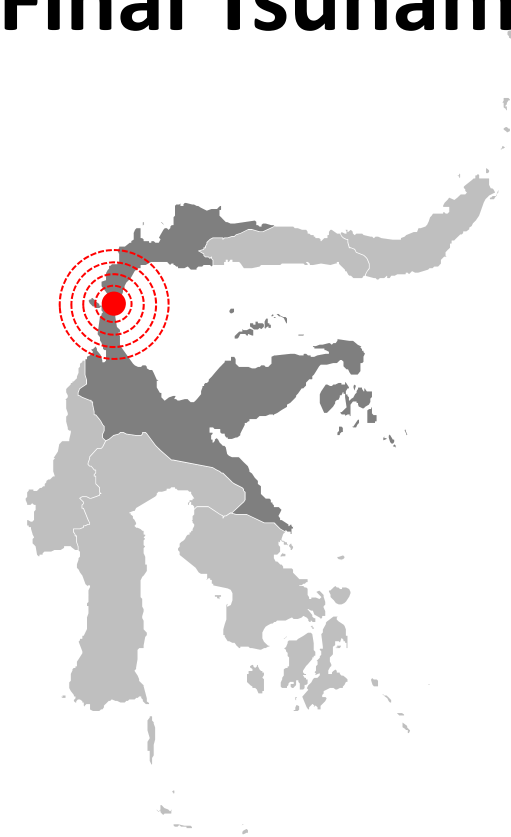
JICA Technical Corporation Project

The Project for Regional Disaster Risk Resilience Plan in Central Sulawesi Province of the Republic of Indonesia

Final Tsunami Panel Expert Meeting



The 2nd Meeting Presentation

August 8, 2019

Tsunami Hazard Map in Central Sulawesi

1. How to Elaborate Tsunami Hazard Map
2. Tsunami Hazard Map and Comparison with ZRB
3. Schedule for Tsunami Countermeasures

JICA 3BCS project team

August 8th, 2019

1. How to Elaborate Tsunami Hazard Map

1. Tsunami Hazard Map

■ Tsunami hazard map

- When preparing a tsunami hazard map, it is necessary to set the scale and return period of the target hazard.
- It is common to set the target hazard based on statistical data, such as past inundation history, and to predict the hazard area by simulation

→However, the existing data of the target area are not enough and have reliability issues; the only reliable historical data are the records of the 2018 tsunami in Palu.

■ Sources for tsunami hazard map

1. Hazard Map based on the 2018 Tsunami by JICA
   : the JICA hazard map refinement is based on the 2018 tsunami, which was mainly caused by landslide.
2. Hazard Map in 2016 by BG
   : the Geological Agency (BG) prepared a hazard map in 2016 by simulating tsunami due to an earthquake in the Makassar Strait

→The reviewed tsunami hazard map prepared by JICA should be combined with the hazard map by BG in 2016 for refinement of the final tsunami hazard map.

1. Flow of Reviewing Tsunami Hazard Map

The flow of reviewing tsunami hazard map consists of the following 3 steps.

i) Data Collection

↓

ii) Identification of Inundation Area

↓

iii) Assessment and Formulation of Tsunami Hazard Map

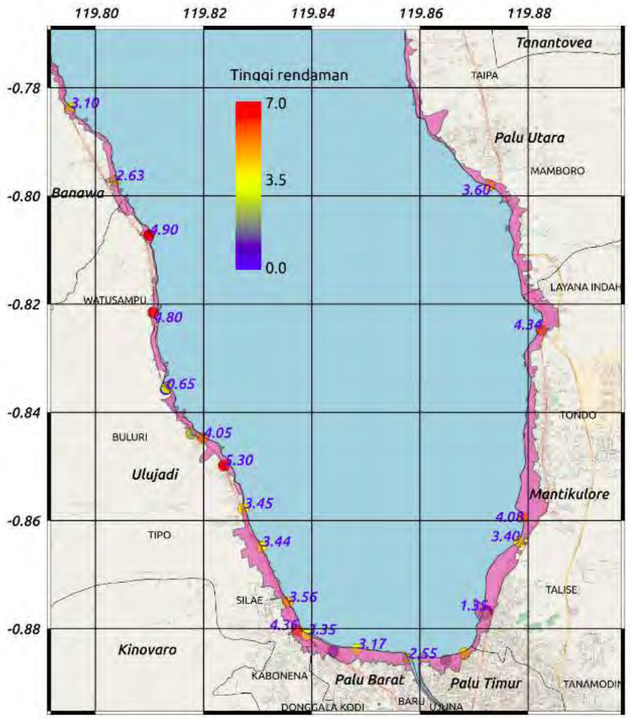
i) Data Collection

The following 3 major data were collected for the tsunami hazard map.

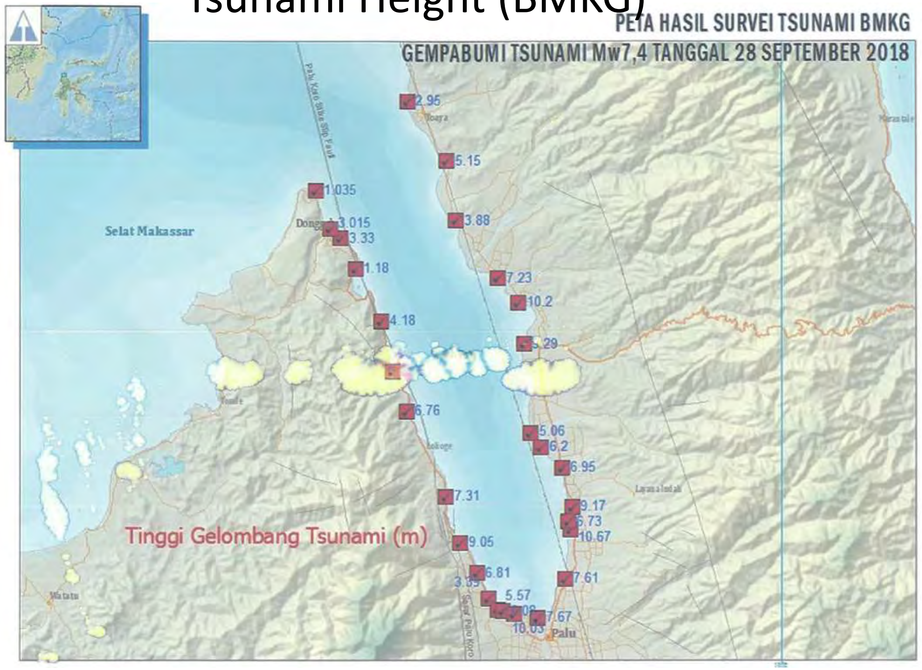
	Title of the data	Source
1	Water mark survey results	BG,BMKG, KKP, Tohoku/Chuo Univ. PCKK
2	Inundation area of 2018 tsunami	ATR, Tohoku Univ., PASCO
3	Topography Data	BIG, PASCO

1. i) Data Collection

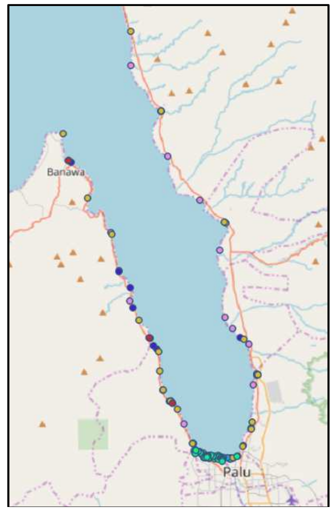
Inundation depth (BG)



Tsunami Height (BMKG)



All water mark survey results



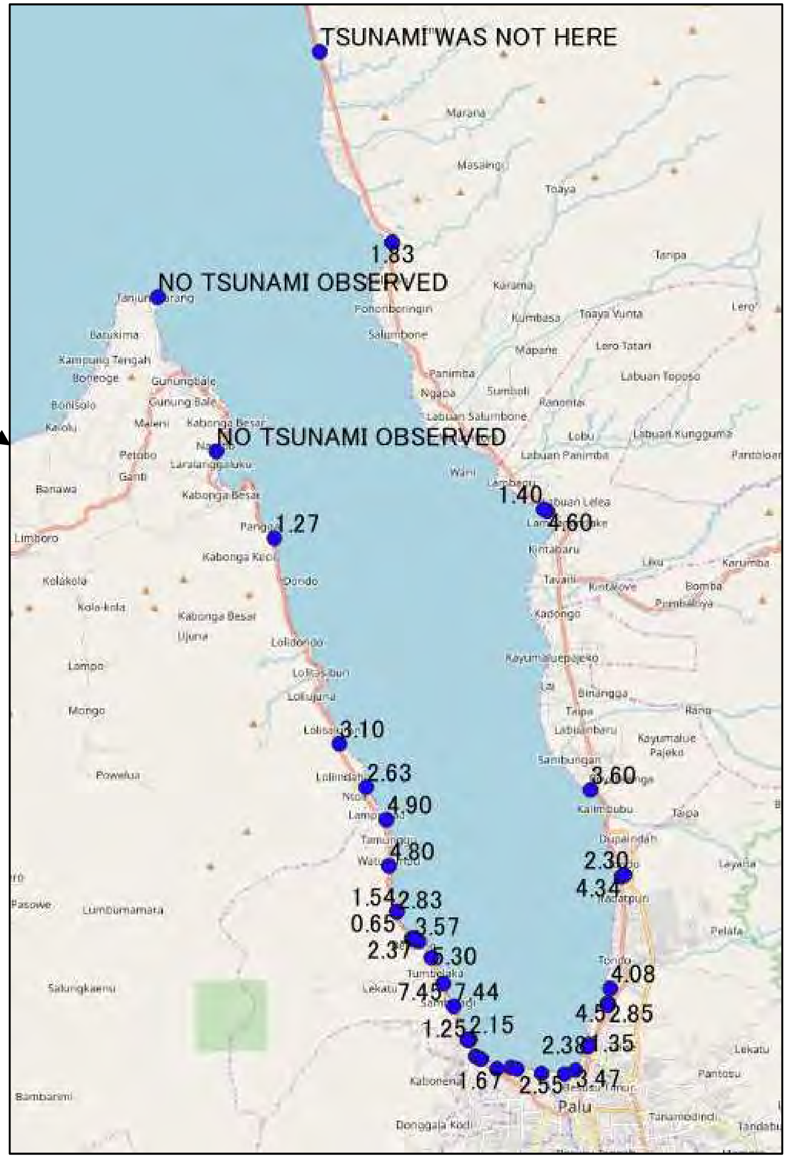
The results of the water mark surveys by BG, BMKG, KKP, Tohoku/Chuo Univ., PCKK have been collected.

Summary of water mark surveys including tsunami heights and inundation depths

1. i) Data Collection

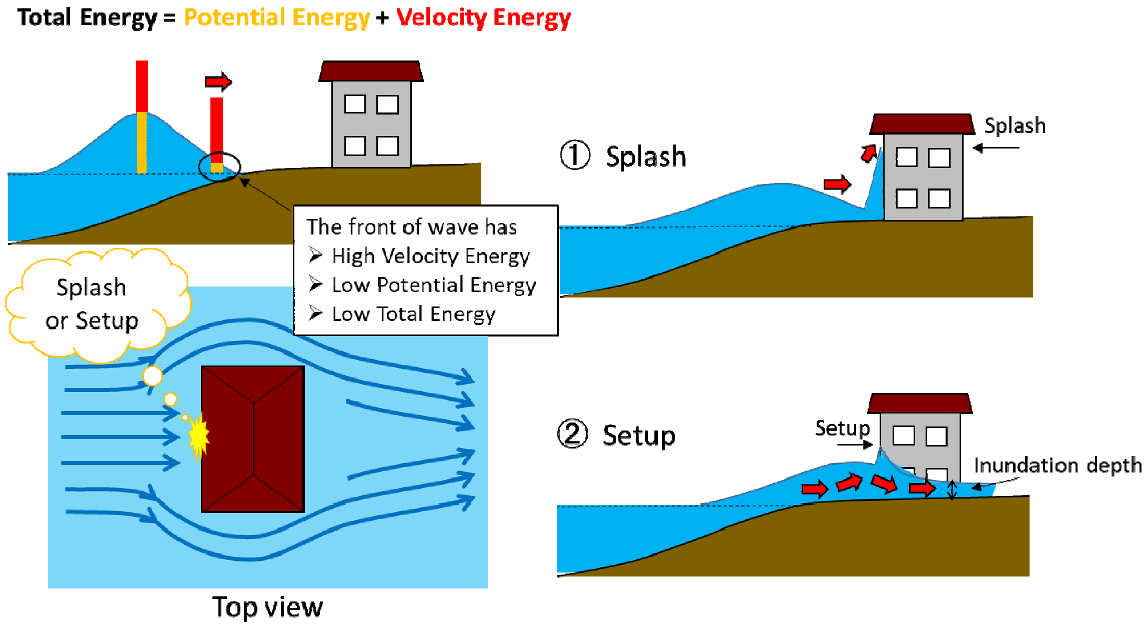
For the analysis of tsunami hazards, inundation depth data are the most important, because the depth indicates the potential of damage to people, buildings and so on.
Therefore, JICA team had tried to extract the inundation depths of water marks from all data for tsunami hazard map.
However, because these inundation data may still include splash and/or setup effects, the JICA team conducted an additional survey with interviewing the local people.

ATR issued the ZRB December 2018 which uniformly designed about 100/200 m wide sections along the coastline as red (ZRB4).
But there are many areas which have not affected by the 2018 tsunami and even not inundated.



Inundation depths

1. ii) Identification of Inundation Area



- When tsunami waves pass through a building, part of the energy forms to a splash or setup at the front side (seaside) of the building. In order to measure the real body of the tsunami energy, inundation depth is adequate.

- In order to supplement with the inundation results by the previous survey, JICA Study Team conducted the additional water mark survey based on inundation depth (i.e. excluding splash and setup).

The additional survey measured the inundation depth inside or backside of structures with interviewing the residential people.

1. ii) Additional Survey in Palu Bay East

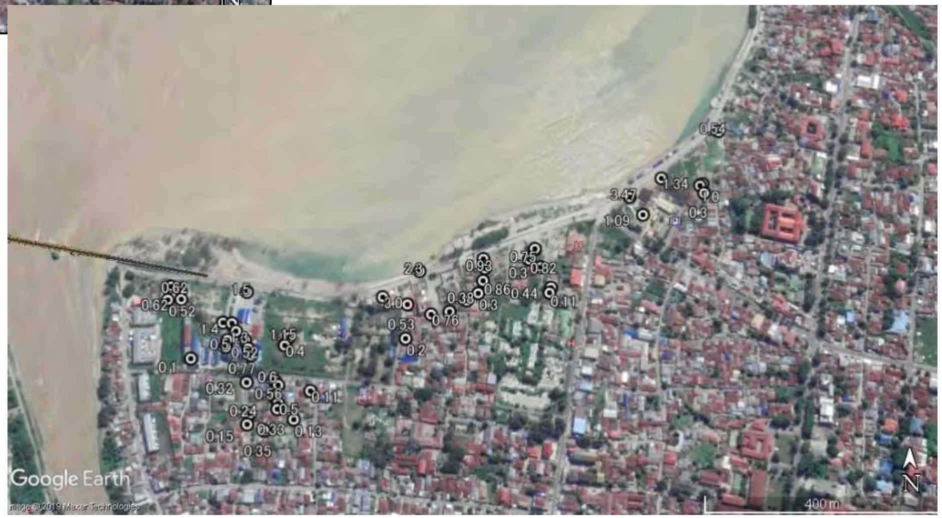
◉ Inundation depth which is not including splash or setup

1. ii) Additional Survey in Palu Bay West

◉ Inundation depth which is not including splash or setup

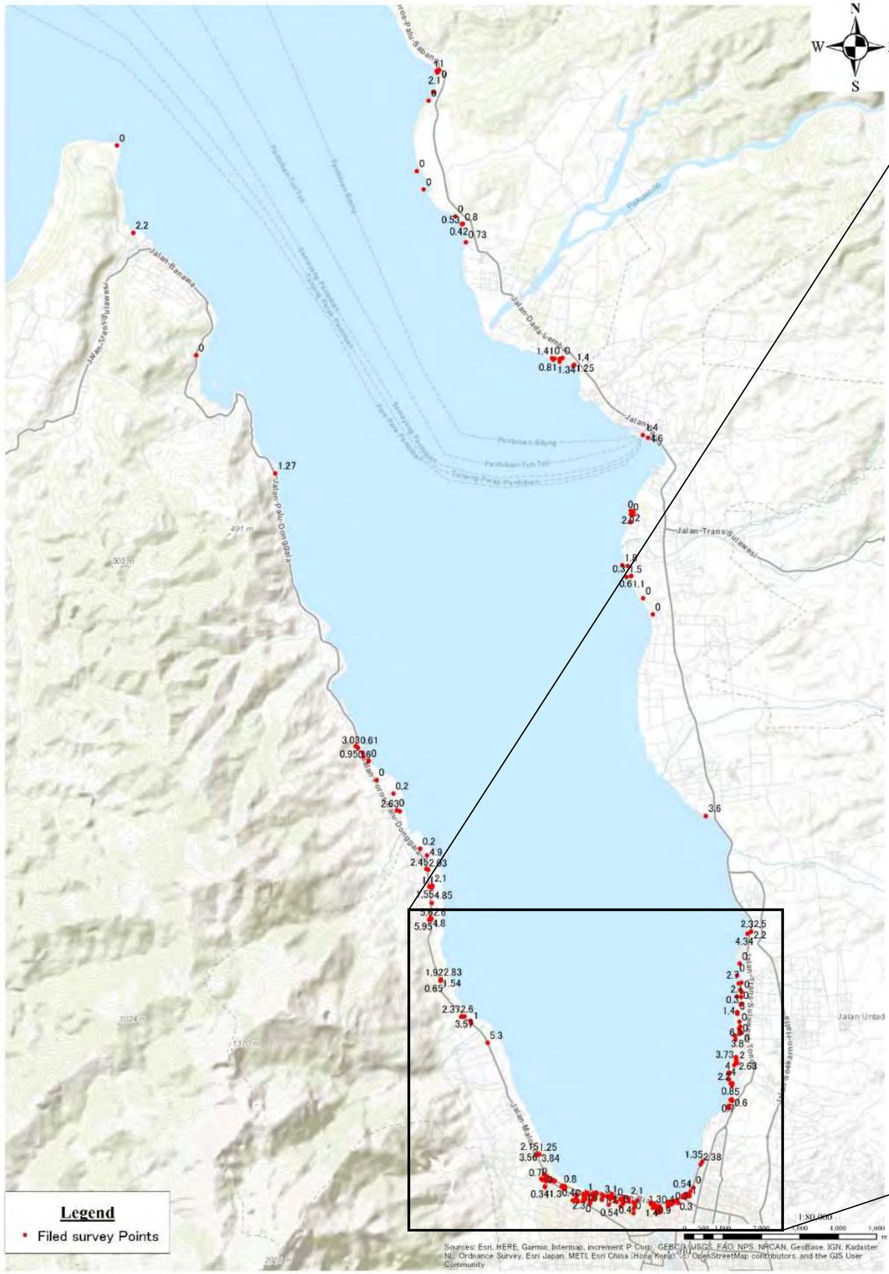
1. ii) Summary of Additional Survey in Palu Bay

East side

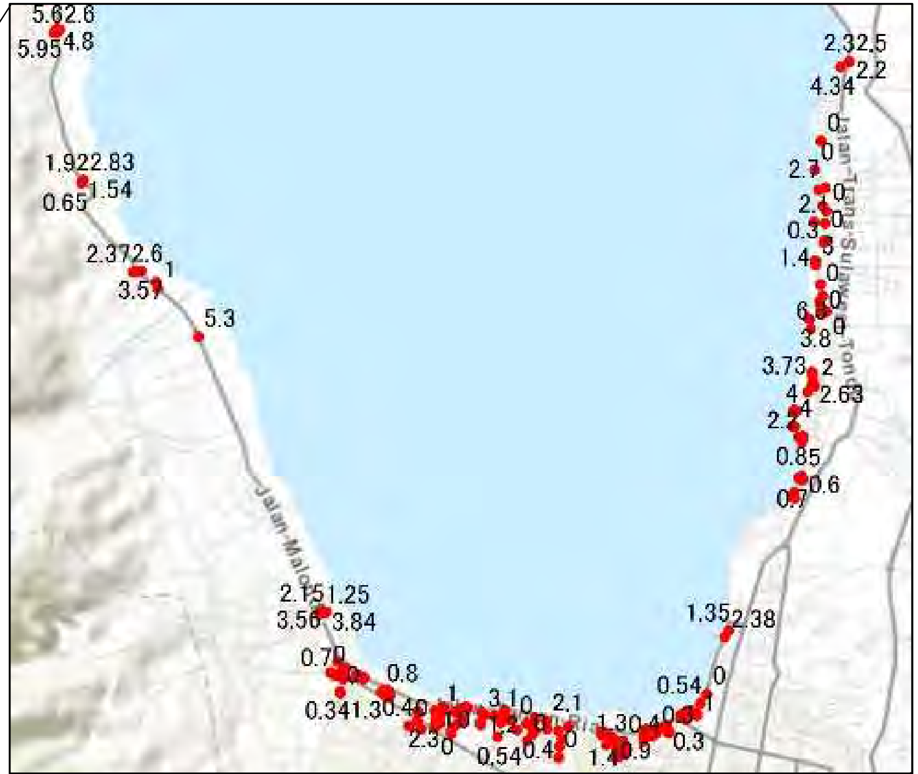


West side

1. ii) Inundation Depth in Palu Bay



The water mark survey results including the additional survey by JICA team



1. iii) Assessment of Tsunami Hazard Map

Inundation depth	Tsunami Damage Situation: People	Tsunami Damage Situation: Buildings
(above 2.0m; 3.0m mark)	➢ Only People on the upper floor can survive	➢ Almost all Buildings with weak structure like wooden houses would collapse ➢ Upper floors would submerge even if buildings remain ➢ More than half of buildings with weak structure would collapse ➢ Ground floor would submerge
2.0m – 1.0m	➢ People cannot evacuate on foot ➢ Some people cannot survive on the ground floor or outside	➢ Some of buildings with weak structure would collapse
1.0m – 0.3m	➢ People can evacuate on foot, but with difficulty	➢ Buildings would have miner damage
below 0.3m	➢ People can evacuate on foot with ease	

Source : Japanese guideline and data from tsunami in 2011

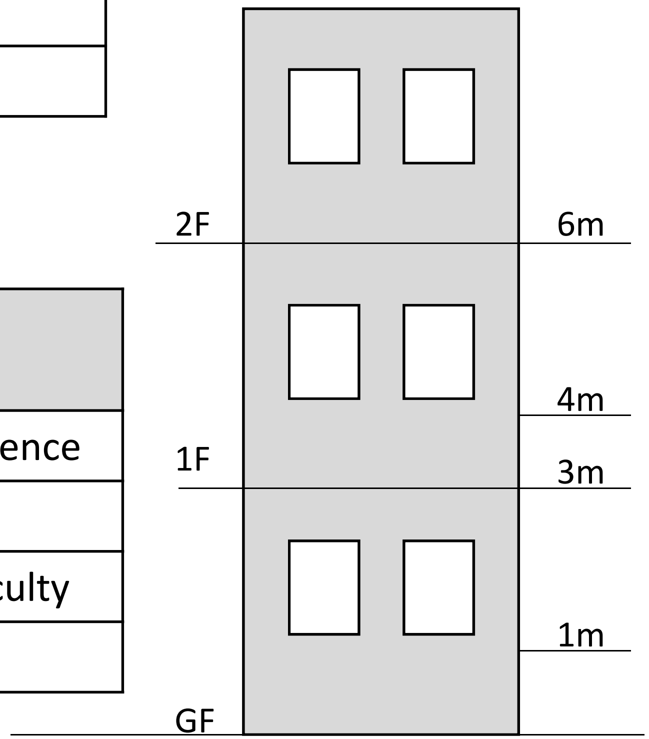
1. iii) Criteria for Tsunami Hazard Map

For Tsunami induced by Fault --> Evacuation Time (20min)

Hazard Level		Inundation depth	Comments
4	Extremely High	> 4m	Not Good for Residence
3	High	3-4m	Evacuate to inland
2	Medium	1-3m	Evacuate to 1F
1	Low	0-1m	Easy to evacuate

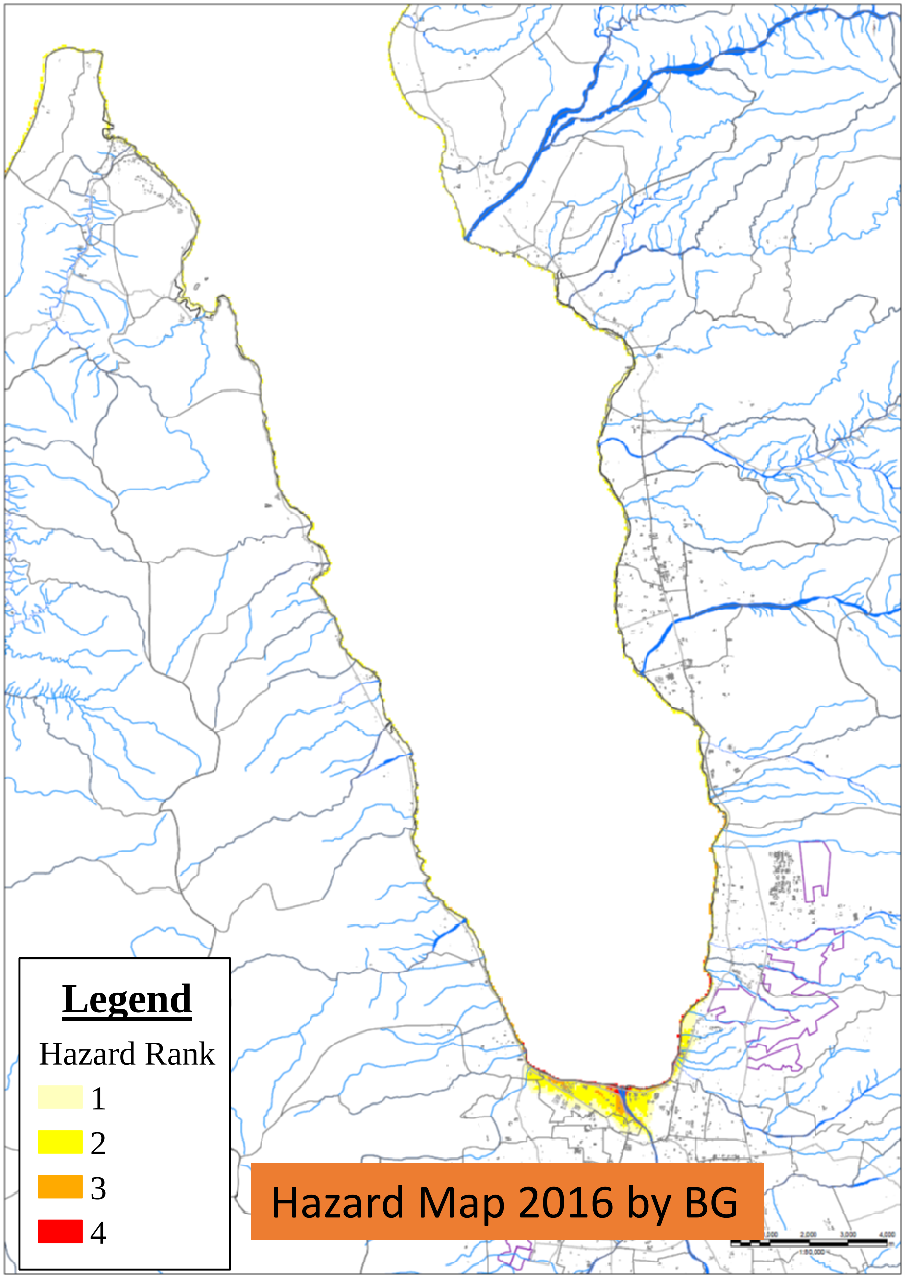
For Tsunami induced by Landslide --> Evacuation Time (3-5min)

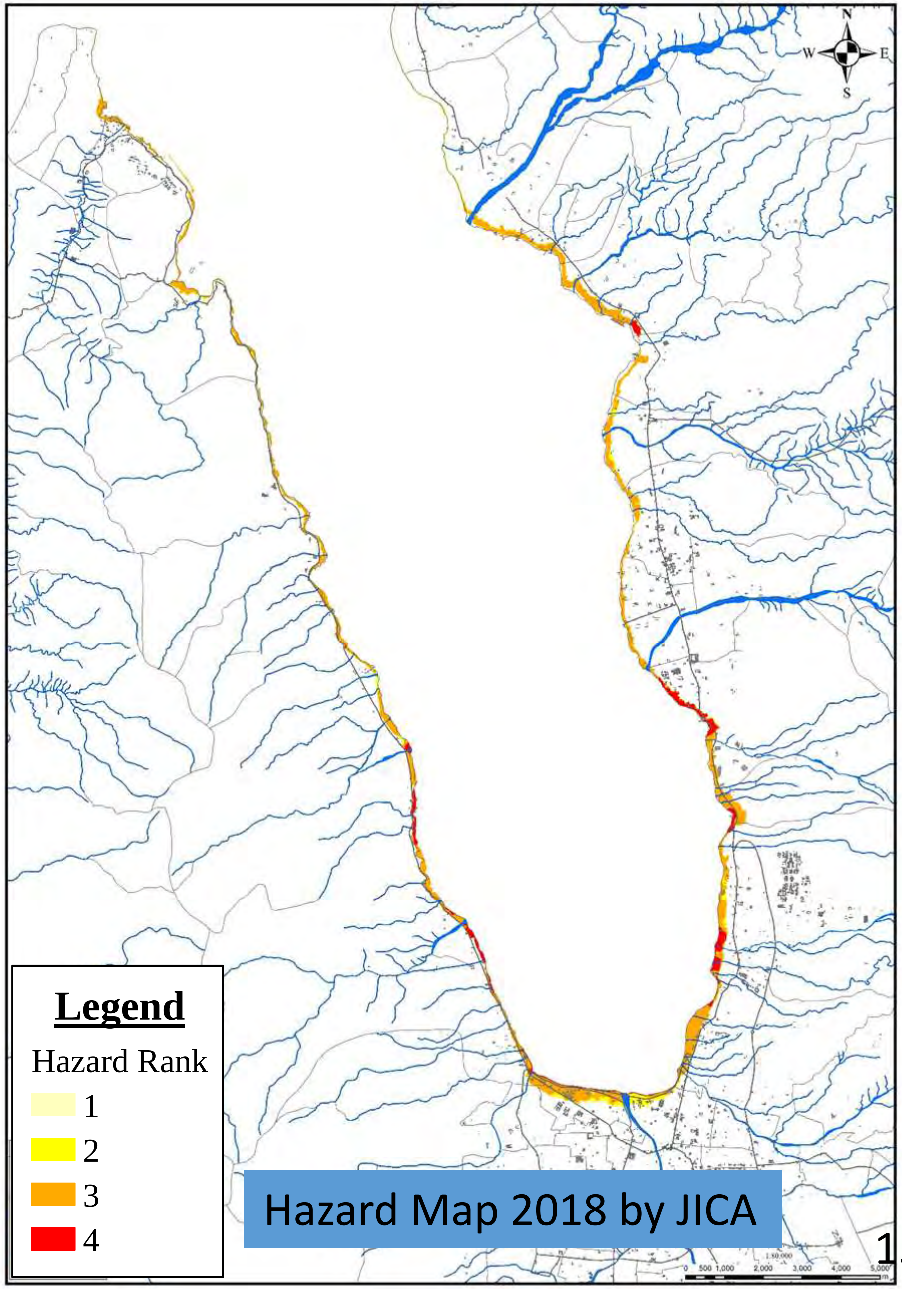
Hazard Level		Inundation depth	Comments
4	Extremely High	> 3m	Not Good for Residence
3	High	1-3m	Evacuate to 1F
2	Medium	0.3-1m	Evacuate with difficulty
1	Low	0-0.3m	Easy to evacuate



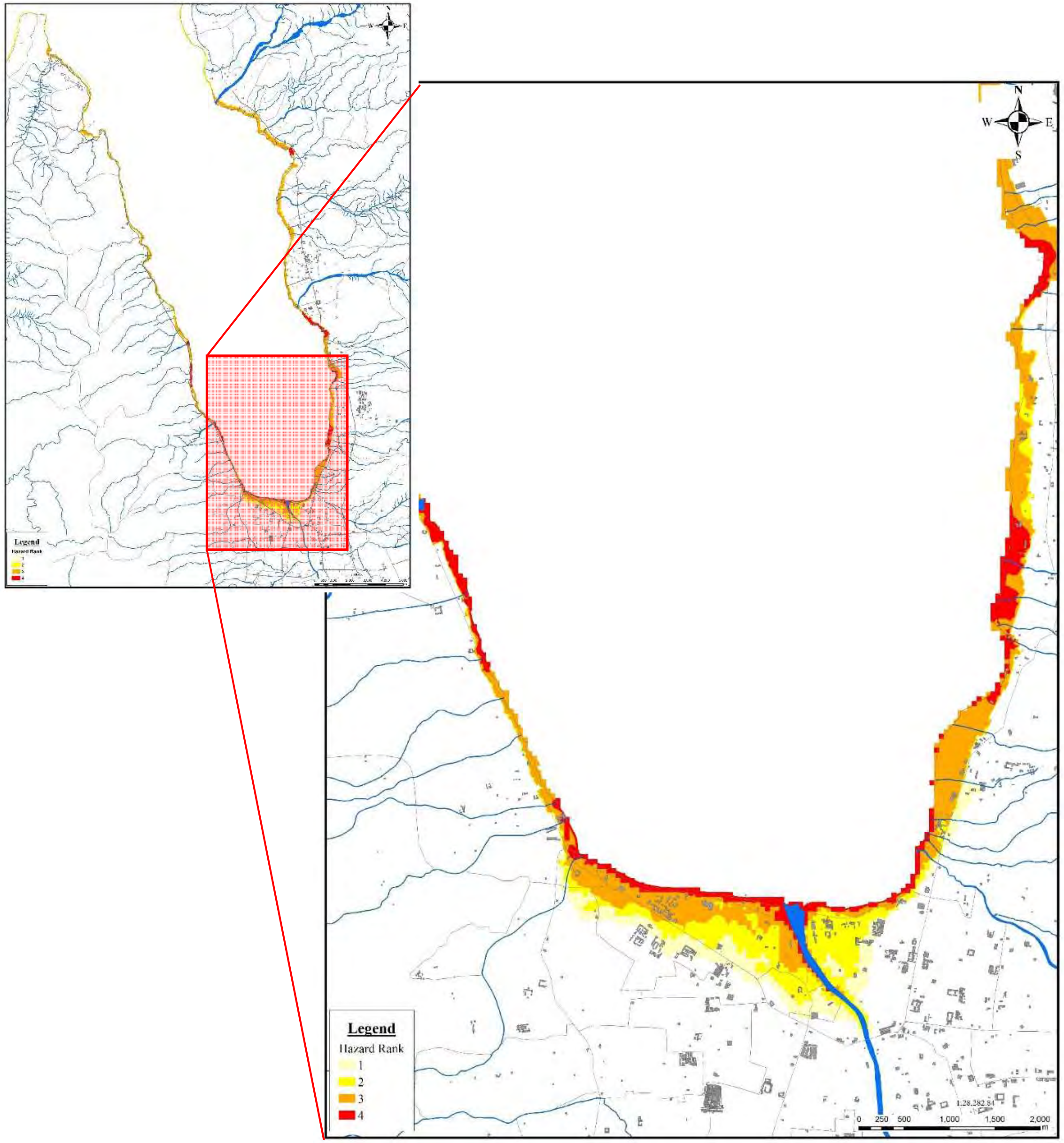
2. Tsunami Hazard Map and Comparison with ZRB

2. Tsunami Hazard Map





2. Integrated Tsunami Hazard Map (JICA+BG)

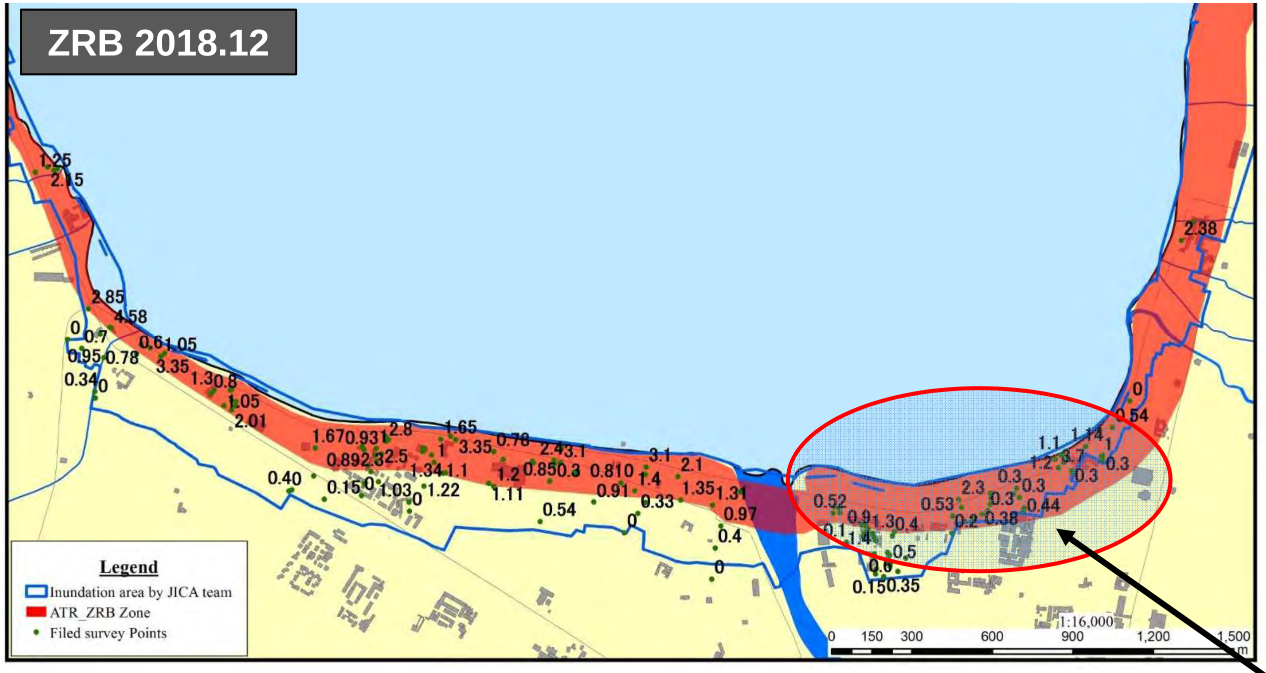


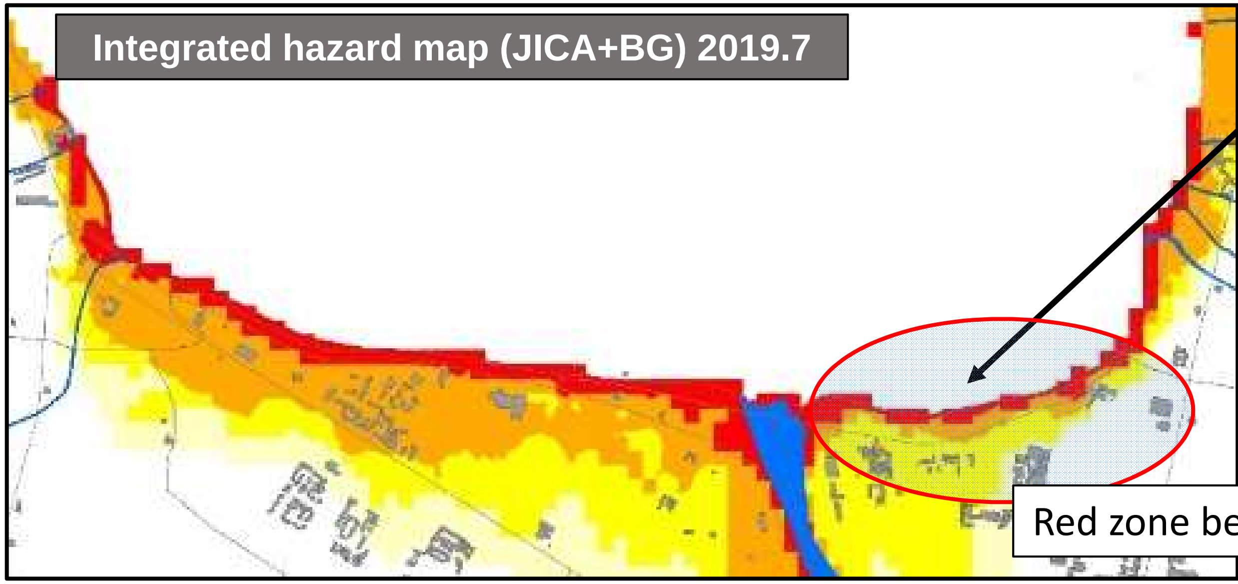
The inundation trace data of the tsunami damage in September 2018 was collected in more details to set the hazard map (Excluded splash and setup trace values).

BG has agreed to combine hazard map after adjusting hazard level between BG and JICA maps.

Integrated tsunami hazard map (JICA+BG)

2. Comparison of ZRB & Tsunami Hazard Map





In ZRB 2018, the red zone is uniformly set as 200m, 100m wide, however the actual affected area by the tsunami is much smaller.

Legend

Hazard Rank

- 1
- 2
- 3
- 4

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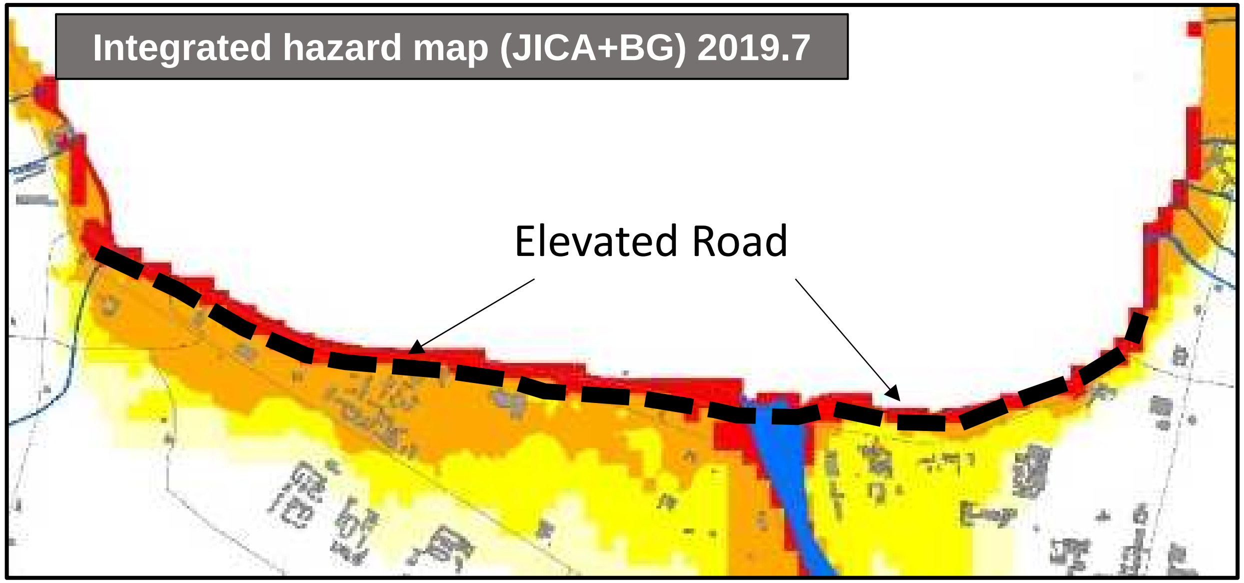
2. Elevated Road for Tsunami Countermeasures

Legend

Hazard Rank

1
2
3
4



The planned elevated road can reduce the tsunami inundation depth inside the road.

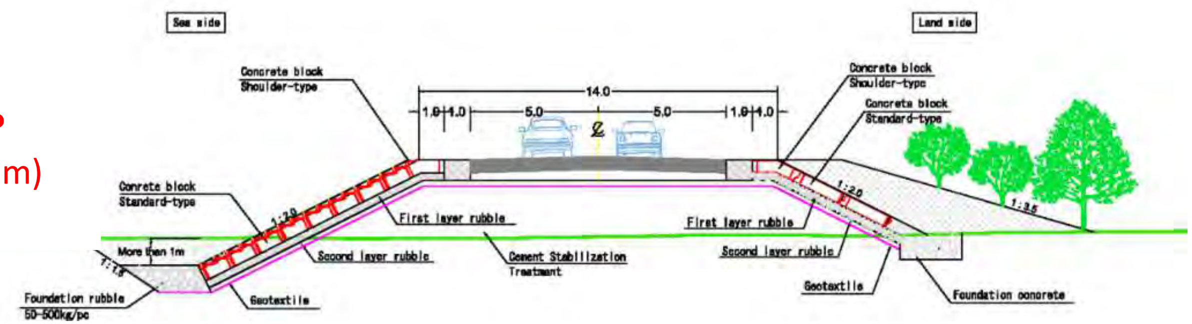
Because the height of the elevated road and the mitigation effect of mangrove can affect the hazard level at the inside area, the hazard map should be reflected taken into consideration such effect of tsunami mitigation after determining the detailed cross section of the elevated road.

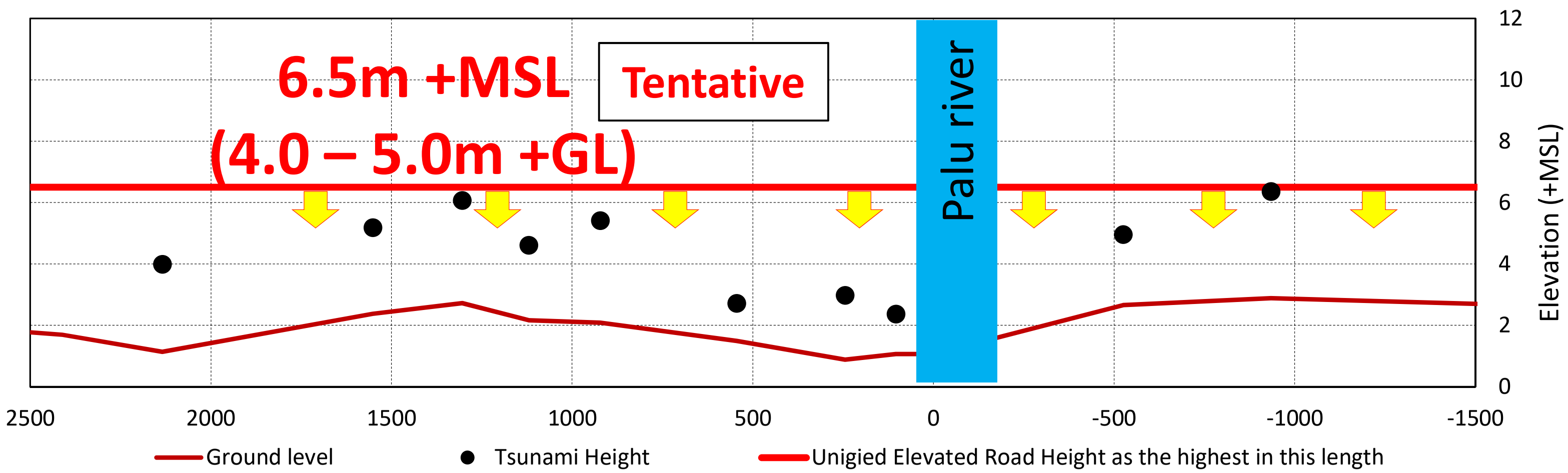
However, further discussion about how to set the ZRB ranks of the area inside the elevated road which are set as ZRB 2 or 3 without countermeasures is necessary.

2. Elevated Road for Tsunami Countermeasures

- The additional survey by JICA team can supplement the inundation depths without splash and setup effect.
- Using these results would reduce the elevated road height by 1.0 – 1.5m from the previous one (MSL+6.5m).
- Further discussion about the mitigation effect of mangrove is necessary for the detailed design of the elevated road.

MSL +6.5m (GL +4.0~5.0m) → MSL +5.0m ? (GL +2.5~3.5m)





3. Schedule for Tsunami Countermeasures

3. Schedule for Tsunami Countermeasures

Date	Activity	Result
June 26th, 2019	National Panel	
July, 2019	**To start stakeholders meeting for spatial planning**	**Spatial planning should be finished by the end of 2019**
Aug 7-9th, 2019	National Panel	If necessary, Panel should be held at any time
	Hydraulic Model Experiments by Indonesian & Japanese Research Institutes	
November, 2019	To confirm the effects and the conditions of vegetation quantitatively	
January, 2020	**To complete the detailed design of countermeasures**	
February, 2020	To start the contract procedure for the construction	**The Construction should be finished by the end of 2020**

Deadline | Mile Stone | Advice by Expert Panel

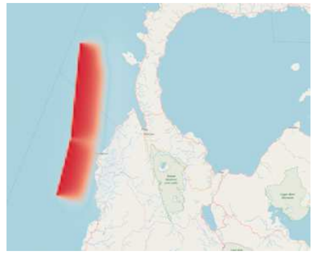
Reference

Hazard Map (2016) by PVMBG

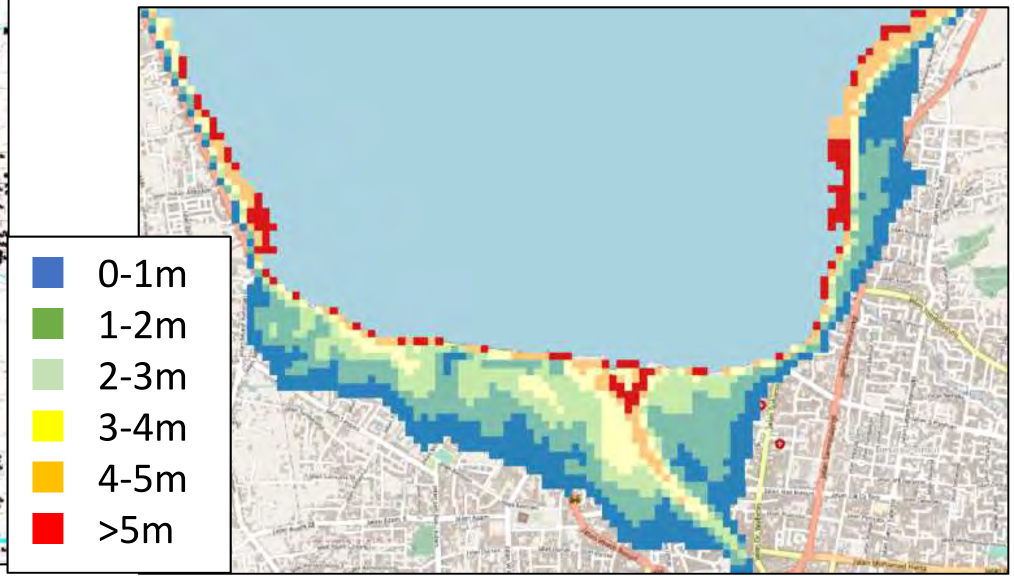
Setting Conditions *River bank is not considered

Items	Setting
Bathymetry	GEBCO and TCarta
Topography	Intermap and SRTM
Epicenter	Mw=7.9 (slip*1.5) > Mw 5.0 (1973-2013) from NEIC-USGC
Tsunami Modelling	Probabilistic Tsunami Hazard Assessment (PTHA)
Coastal line	DEM with high resolution

Tsunami Sources:
Makassar Strait
Mw=7.9



Hazard Map 2016 by PVMBG



1. iii) Assessment of Tsunami Hazard Map

Tsunami hazard map is a map showing the vulnerability or hazard level of an area, which is determined by using certain criteria, such as classification of the area by inundation depth.

Classification in ZRB

ZRB	Definition by ATR
ZRB4	Tsunami risk zone of at least 100-200 m from the highest tide point (100m for Palu Bay, except for Lere, Besusu Barat, and Talise which is set at 200m)
ZRB3	High tsunami risk zone
ZRB2	Medium tsunami risk zone
ZRB1	Low tsunami risk zone

Classification in Hazard Map by BG

Hazard Level	Definition by BG
High	Inundation depth: more than 3m Intensity scale: VII or more
Medium	Inundation depth: 1m to 3m Intensity scale: V- VI
Low	Inundation depth: less than 1m Intensity scale: V or less

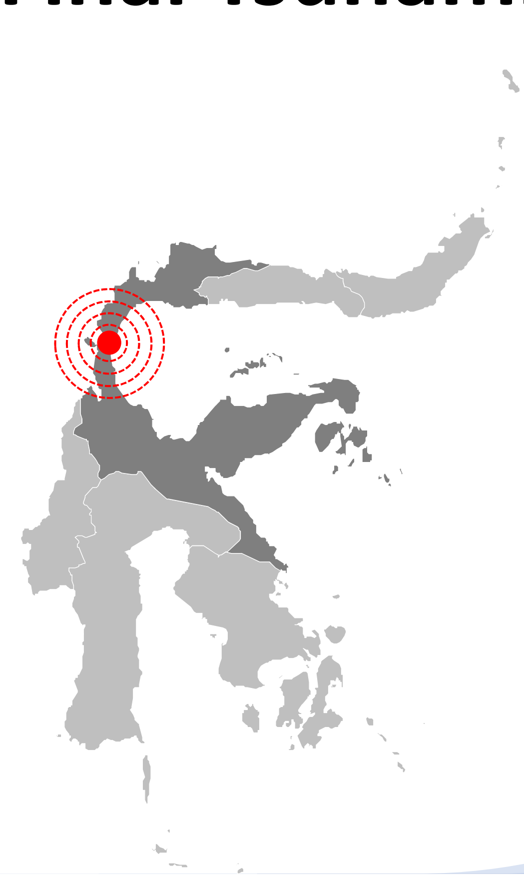
2. iii) Proposed Building Regulations

Hazard Level	Building Regulations
4	✧ Construction, renovation, extension of any building is prohibited ✧ Construction of temporary / emergency building / structure particular to coastal area such as ports and fishery facilities, if not for residential use, may be allowed ✧ Building construction for the purpose of disaster prevention, mitigation and reduction, or for maintaining security and safety may be allowed ✧ All building constructions shall comply with the requirements of the seismic codes SNI1726, shall be tsunami-resistant, shall have appropriate measures for evacuation to ensure life safety and shall not have any basement
3	✧ Construction of single story building is prohibited ✧ Construction of basement (i.e. floor below ground level) is prohibited ✧ Construction of Important building as defined in SNI1726 is prohibited ✧ Use of the ground floor (1st Story) and any space below the height of 3m from the adjacent road as residence or gest room is prohibited ✧ All building construction shall comply with the requirements of the seismic code SNI1726 ✧ The ground floor (1st Story) and any part below the height of 3m from the adjacent road shall be made of tsunami-resistant structure as follows ➢ Piloti or tsunami-resistant structure verified by calculations ➢ Reinforced Concrete (RC), Steel Reinforced Concrete (SRC) and / or Steel (S) structures ✧ Renovation and / or extension of existing building is considered equivalent to construction and shall comply with the above requirements
2	✧ Construction, renovation, extension of any building is allowed ✧ It is recommended to follow the requirements for Hazard Level 3 or to raise the ground floor level by 1m (e.g. raise foundation and / or earth filling)
1	✧ Construction, renovation, extension of any building is allowed ✧ It is recommended to raise the ground floor level by 0.3m (e.g. raise foundation or earth filling)

JICA Technical Corporation Project

The Project for Regional Disaster Risk Resilience Plan in Central Sulawesi Province of the Republic of Indonesia

Final Tsunami Panel Expert Meeting



The 3rd Meeting Presentation

February 9, 2021

Contents

1. Purpose of the Final Tsunami Panel Expert Meeting
2. Discussions at the Past Tsunami Panel Meeting
3. Basic Concept of Tsunami Countermeasures in Palu
4. Report on Results of Tsunami Model Tests
5. JICA-TC recommendations
6. Tsunami Damage Reduction System

1. Purpose of the Final Tsunami Panel Expert Meeting

The purpose of holding the final meeting of the final meeting.
Until the last TSUNAMI Panel Meeting, the following points were discussed;

1. **The mechanism of tsunami generation, the current status of tsunami damage and analysis results**
2. **About the basic policy of tsunami mitigation measures to be taken**
3. **Necessary tsunami damage reduction measures (draft)**

In this panel meeting, we will report on the following three points that have remained as issues in the past panel meetings.

- ✓ Conduct **additional tsunami height surveys** and **plan tsunami countermeasure facility (elevated road) based on the results.**
- ✓ The **tsunami mitigation effect of vegetation(mangrove)** will be confirmed by **physical model test (*by Balai Pantai*)** and **simulation analysis (*by Prof. Arikawa*),** and **reflected in tsunami countermeasures.**
- ✓ **Check the impact of tsunami on the coastal protection** supported by ADB.

2. Discussions at the Past Tsunami Panel Meeting

Date	Agenda	Discussion Point
1st Panel June 26, 2019	① Outline of JICA Assistance ② Experience in Japan ③ 2018 Disaster and Tsunami in Palu ④ Basic Concept of Tsunami Countermeasures in Palu ⑤ Vegetation (Mangrove, etc.) ⑥ Harmonization between ADB Coastal Protection, Elevated Road and Vegetation	▪Countermeasures to reinforce evacuation is required ▪Tsunami in 2018 is suitable for "Target Tsunami" of countermeasures ▪"Palu Bay South" should be firstly prioritized for structural countermeasures ▪1m of inundation depth (overflowing) can be acceptable in order to keep down the cost ▪The height of Elevated Road should be determined with further consideration ▪Reclamation for vegetation could be considered only in West side of Palu Bay South ▪There is a risk of scattering of masonry coastal protection by tsunami. ▪Comprehensive tsunami damage reduction measures need to be evaluated, including mangrove vegetation effects.
2nd Panel August 8, 2019	①Elevated Road for Tsunami Countermeasures ②Schedule for Tsunami Countermeasures (Discuss with hazard map)	▪Additional survey on the inundation depth is expected that the height of the elevated road can be lowered by about 1m (MSL+6.5m). ▪With the support of JICA TC, a planting in reducing tsunami damage. model experiment will be conducted by PUPR-SDA and Balai Pantai to confirm the effectiveness of mangrove

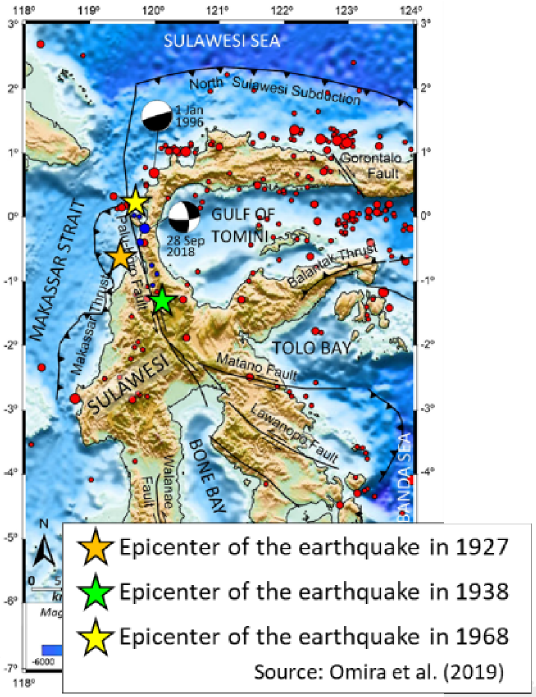
3. Basic Concept of Tsunami Countermeasures in Palu (1)

➢ Target Tsunami

Because countermeasures will take a certain budget, we have to determine "Target Tsunami"

Tsunami in 2018 is suitable for "Target Tsunami" of countermeasures.

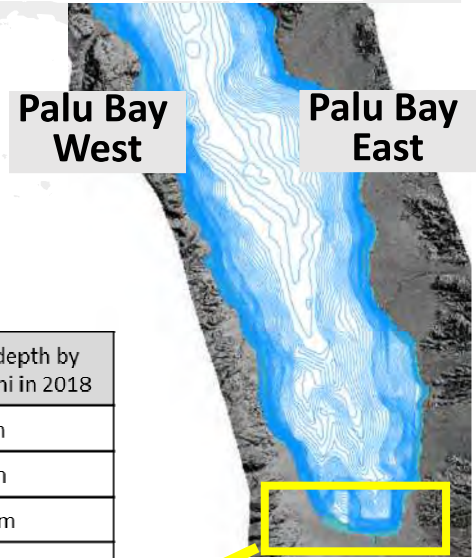
- ✓ **Confirmed tsunami records for the past 100 years and set considering reliability**
- ✓ **Simulation by Japanese researchers indicates scale of Tsunami in 2018 corresponds to high or middle frequency**

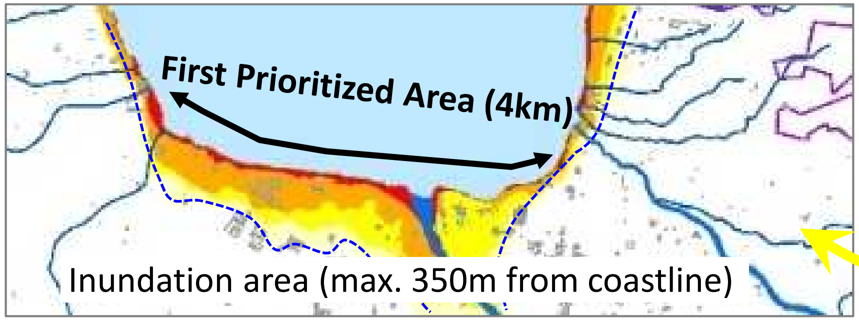


➢ Tsunami Mitigation Strategy

"Palu Bay South" should be firstly prioritized for structural countermeasures.

- ✓ **High Density of Population and Buildings**
- ✓ **Wide and Deep Inundation area**
- ✓ **For tsunamis larger than the target tsunami, disaster mitigation measures by multiple defenses such as evacuation action, evacuation facilities, disaster prevention facilities, etc. [Same as Japan's latest tsunami countermeasures]**



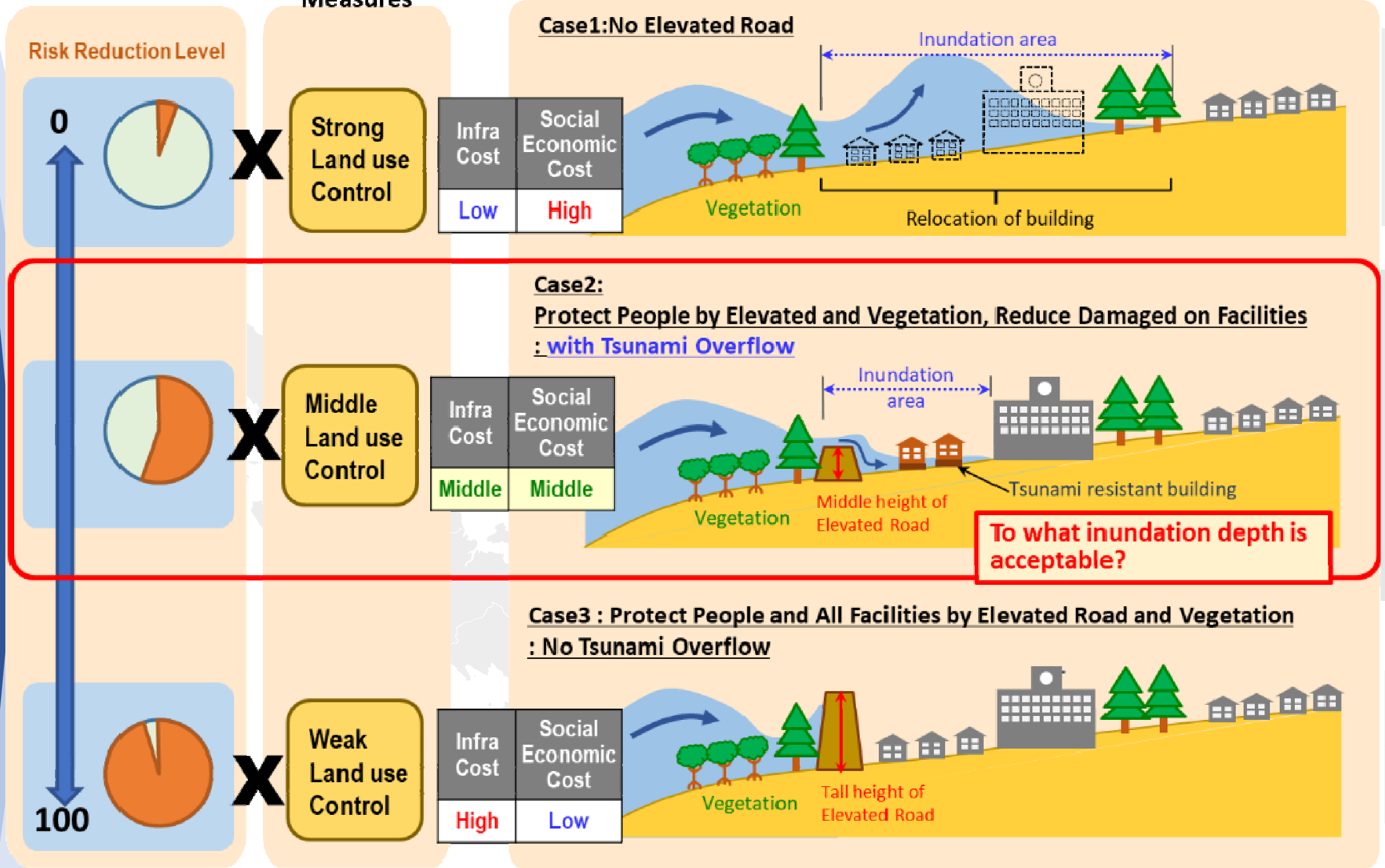


	Inundation depth by actual tsunami in 2018
4	> 3m
3	1-3m
2	0.3-1m
1	0-0.3m

5

3. Basic Concept of Tsunami Countermeasures in Palu (2)

Tsunami occurrence scenario



→Without structural measures, the social economic cost will increase.

→The selection was based on the **balance between construction cost and social economic cost**, as well as the **landscape aspect of Palu Bay**.

→Structural measures alone will increase construction costs

If inundation depth can be decreased to **less than 1m**,
- Almost all buildings would not collapse
- Set building regulations and adapt to short evacuation times

4. Report on Results of Tsunami Model Tests

a. Planning of tsunami damage reduction facilities
(*Setting the height of elevated road*)

b. How to confirm the tsunami mitigation effect of mangrove vegetation

c. Verification of tsunami mitigation effect of vegetation [Method I]
(*Physical Model Test by PUPR-SDA & BALAI Pantai*)

d. Verification of tsunami mitigation effect of vegetation [Method Ⅱ]
(*Simulation Analysis by Chuo Univ. Prof. ARIKAWA*)

(Report from the October 5, 2020 JICA team to BAPPENAS)

4. Report on Results of Tsunami Model Tests

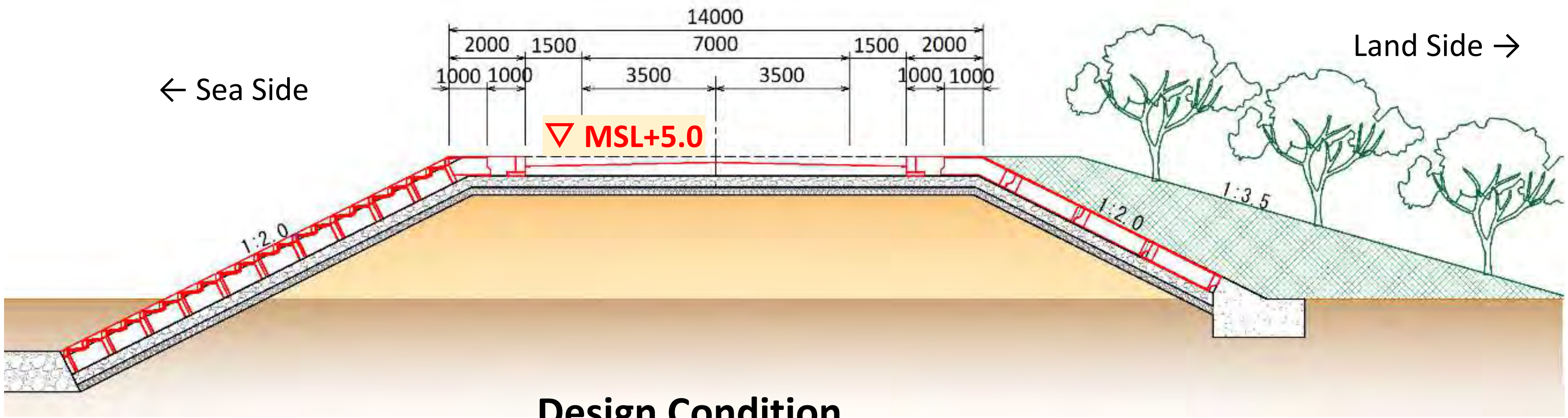
a. **Planning of tsunami damage reduction facilities (Setting the height of elevated road)**

(Report from the October 5, 2020 JICA team to BAPPENAS)

Basic plan of the Elevated road

Elevated road height required as a structural measure (excluding the effect of vegetation) → MSL+5.0m

Standard Cross Section



Design Condition

Road Condition		Tsunami Condition	
Road Width	14.0m	Wave Height	MSL+5.5 *
Effective Road Width	10.0m	Wave Period	3.5min *
Road Height	MSL+5.0m	Tide Level	MSL+0.7m *
Length	4.0km	Overflow for Elevated Road	Allow **
Design Speed	60km/h	Inundation Depth	Less than 1.0m **

* : Set based on the 2018 tsunami , ** : Basic concept for tsunami countermeasures

Basic plan of the Elevated road

➢ Flow of the elevated road height determination

[1] Field survey (Tsunami Height)

Determine the design tsunami height excluding splash and setup

↓

[2] Numerical calculation (Relationship between elevated height and tsunami height)

Determine the relationship between the elevated road height and the tsunami height in order to calculate the required elevated road height at each point.

↓

[3] Calculation of required road height

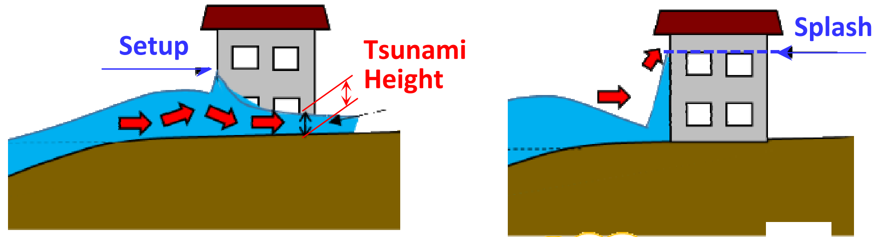
Using the results of [1],[2], calculate the required elevated road height at each point of the target area.

↓

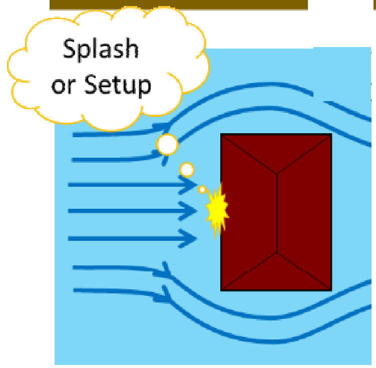
[4] Setting of the Elevated Road height

➢ [1] Field survey (Tsunami Height)

JICA Study Team conducted the tsunami height survey excluding splash and setup.



The survey measured the tsunami height inside or backside of structures with interviewing the residential people.

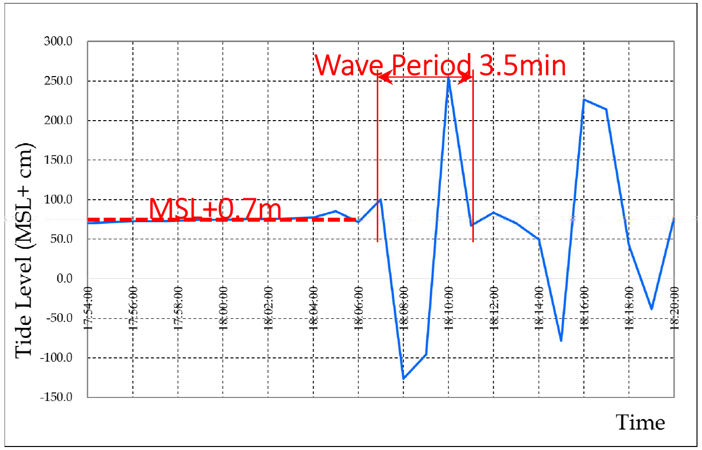


Total Survey Point : **188**

➢ [2] Numerical calculation (Relationship between elevated height and tsunami height)

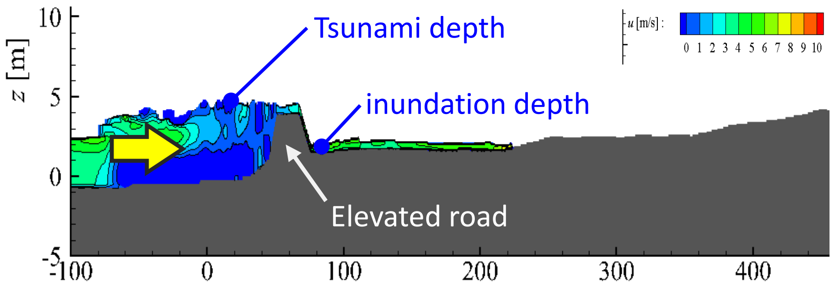
◆ Conditions

Items	Values or Method to Set	
Input waves	Sin-curve model	Based on the record in 2018 Tsunami
Tide	MSL+0.7m	
Wave Period	3.5 min	

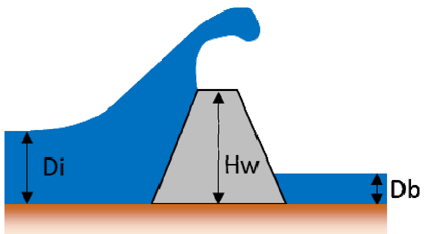


Recorded in the Pantoloan tide station in 2018 tsunami

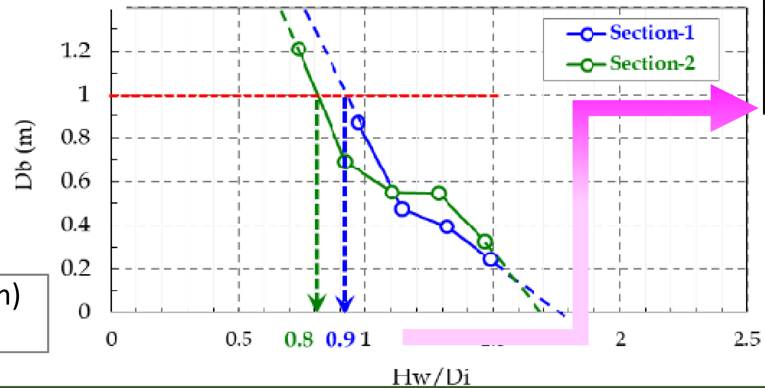
◆ Relationship between Hw and Di



exa. : Calculation Result (West / Hw=4.0m)



Di: Tsunami height (m) , **Hw**: Elevated road height (m)
Db: inundation depth (m)



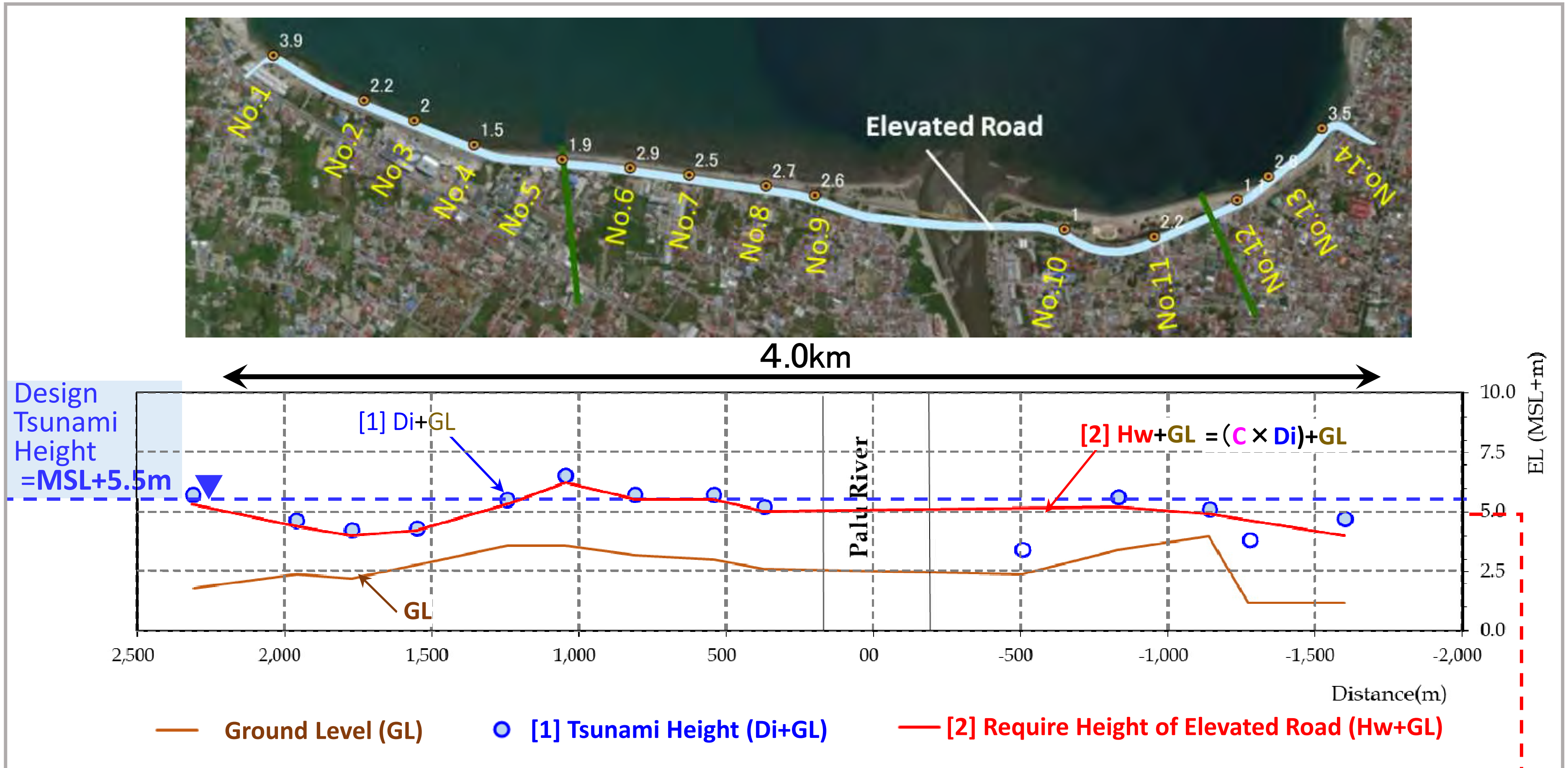
Section No.	C
Section-1	0.91
Section-2	0.80

Hw = C × Di   C: constant

Relationship between tsunami Height and elevated road height at 1m inundation depth.

Basic plan of the Elevated road

➢ [3] Calculation of required road height

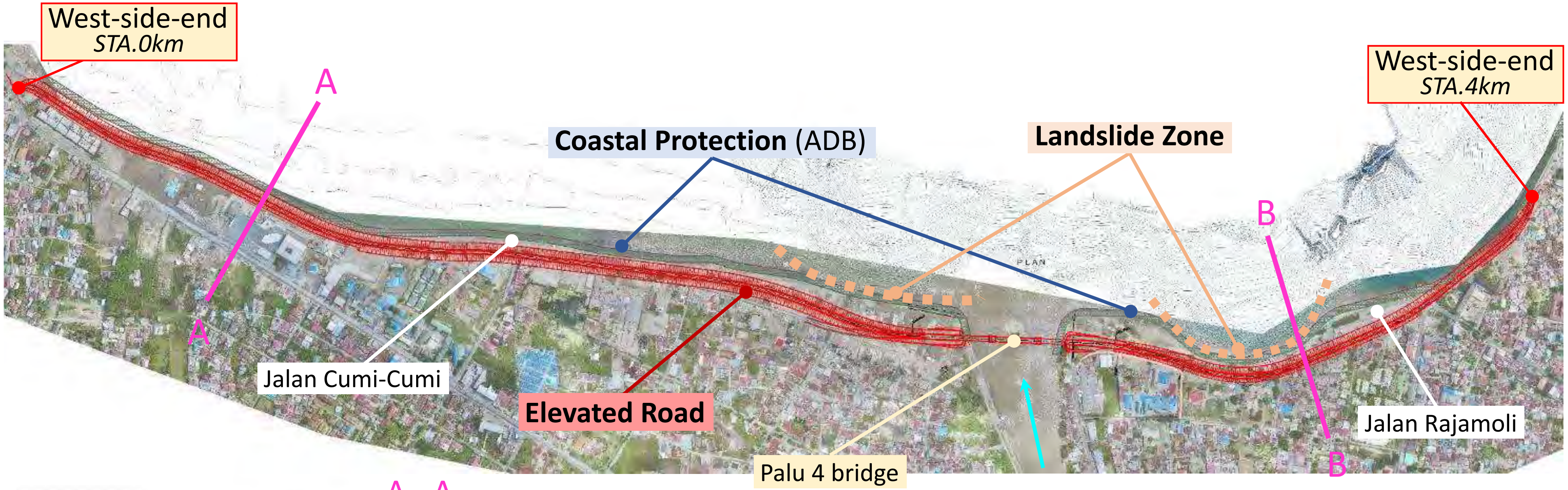


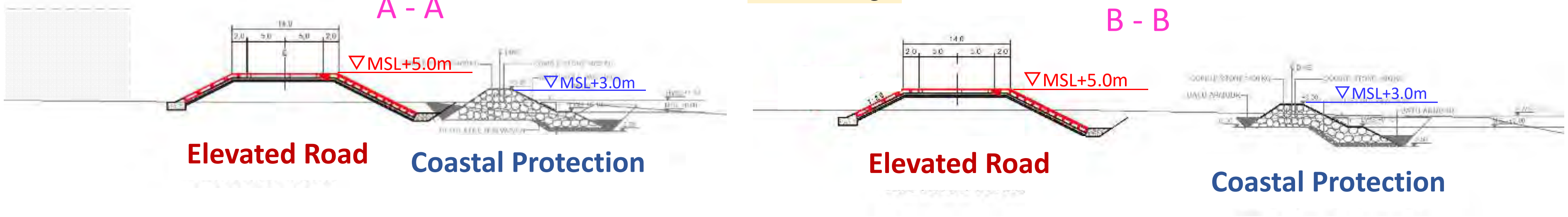
➢ [4]Setting of the elevated road height

MSL+5.0m ← Required Height of Elevated Road
Calculated Value = **MSL+4.98m**

* Initial Setting : MSL+6.5m (+1.5m)
when using the tsunami height including splash and setup

Basic plan of the Elevated road





**Road height from ground level is about 2.5 to 3m*

■**Road alignment** conditions for elevated roads:

✓ Keep away form coastal protection and probable landslide zones

✓ Minimize relocation of existing prominent buildings as much as possible

■**Notes**:

✓ In order to keep the inundation depth to 1 m or less, it is necessary to pay attention to the material selection and construction method of the embankment so that secures the height of the elevated road even in the event of an earthquake.

4. Report on Results of Tsunami Model Tests

b. **How to confirm the tsunami mitigation effect of mangrove vegetation**

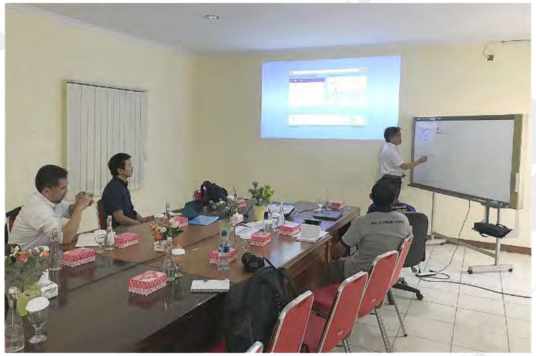
Method Ⅰ : Physical Model Test
[*by Balai Pantai Laboratory*]

Method Ⅱ : Simulation Analysis
[*by Chuou Univ. Prof. Arikawa*]

(Report from the October 5, 2020 JICA team to BAPPENAS)

4. Report on Results of Tsunami Model Tests

c. **Verification of tsunami mitigation effect of vegetation [Method I]**
(Physical Model Test by PUPR-SDA & BALAI Pantai)



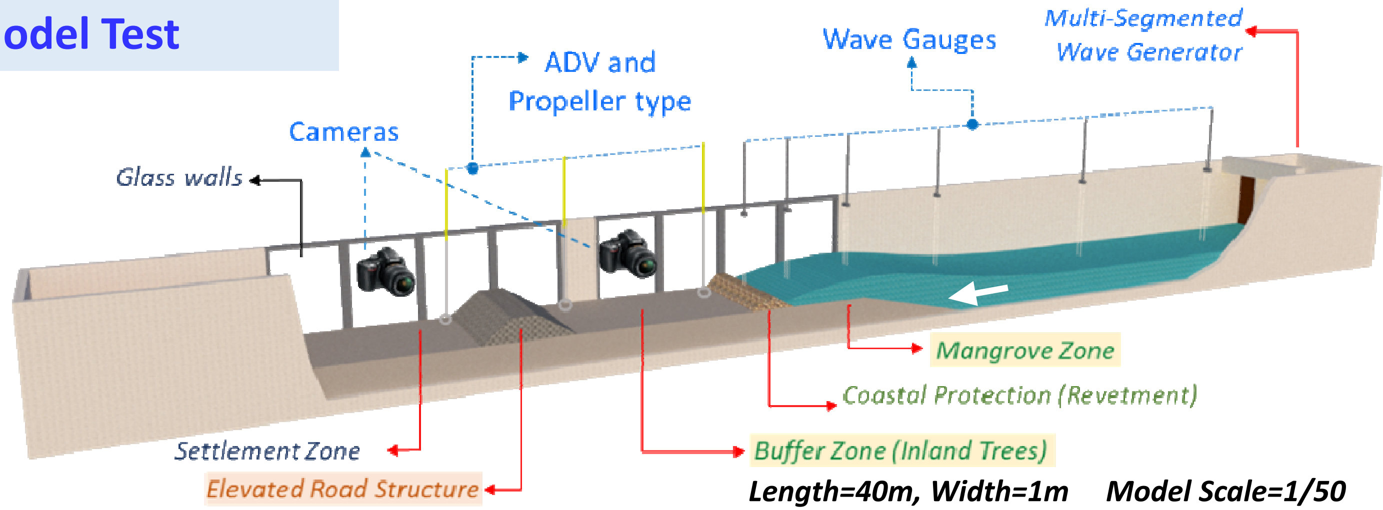
Balai Pantai / November 15, 2019

Verification of tsunami mitigation effect by vegetation

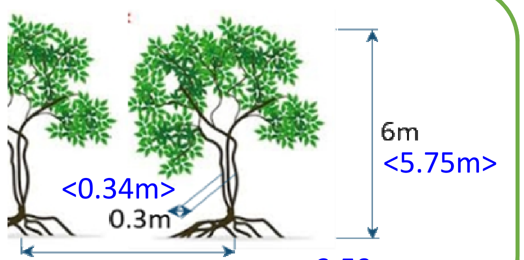
Method Ⅰ : Physical Model Test

➢ **Model Test Facilities**

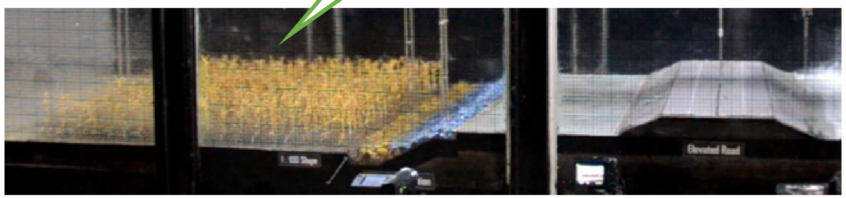
Wave Period : Approx. 1 min
(Depends on generator capacity)

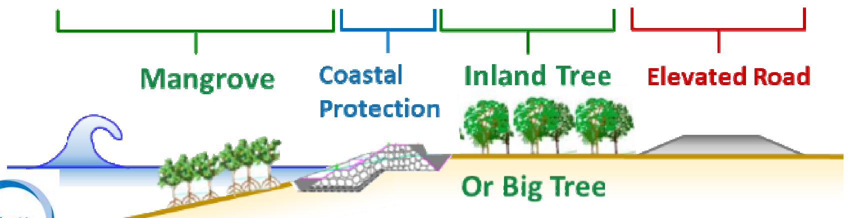


Length=40m, Width=1m Model Scale=1/50



➢ **Model Scenarios**





Total scenarios :
More than 80 with different tide levels and wave height

Parameter	:	Scenario	
◆ Tide Level	:	MSL+0.7m	Condition of 2018 Tsunami
◆ Target Wage	:	MSL+5.5m	
◆ Elevated Road	:	MSL+5.0m	
◆ Mangrove	:	Interval : 2.5, 3.0m, Width : 20m, 35m, 50m	
◆ Inland Tree	:	ϕ=1m, Interval : 7.5m	Set from vegetation records, etc.
◆ Inland Tree (Big Tree, BNPB request)	:	ϕ=14m, Interval : 50m	

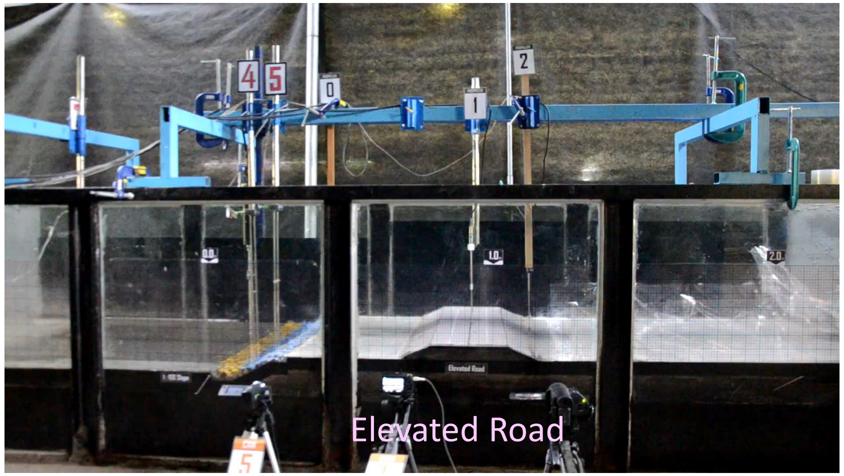
Verification of tsunami mitigation effect by vegetation

Method Ⅰ : Physical Model Test

- **Model Test Result (Overflow situation of elevated road)**

Tide Level : MSL+0.7m **Wage Height : MSL+5.5m**

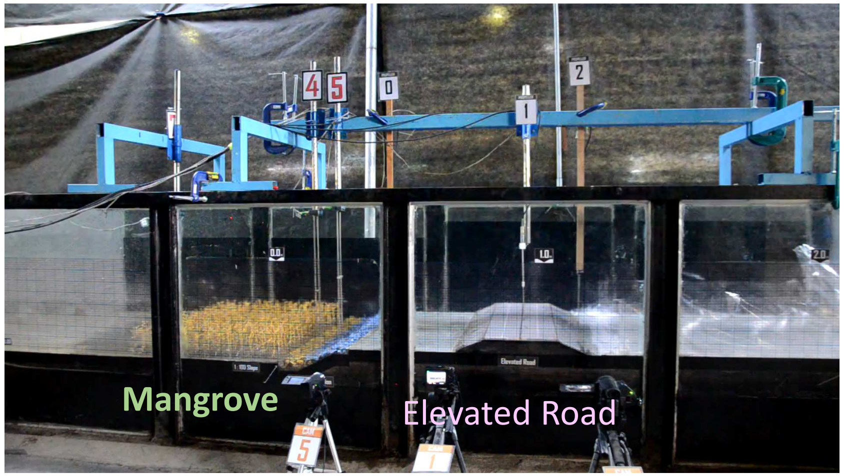
Without Vegetation



With Mangrove

Mangrove density : 2.5m
3.5m

Mangrove Width : 20m
35m
50m



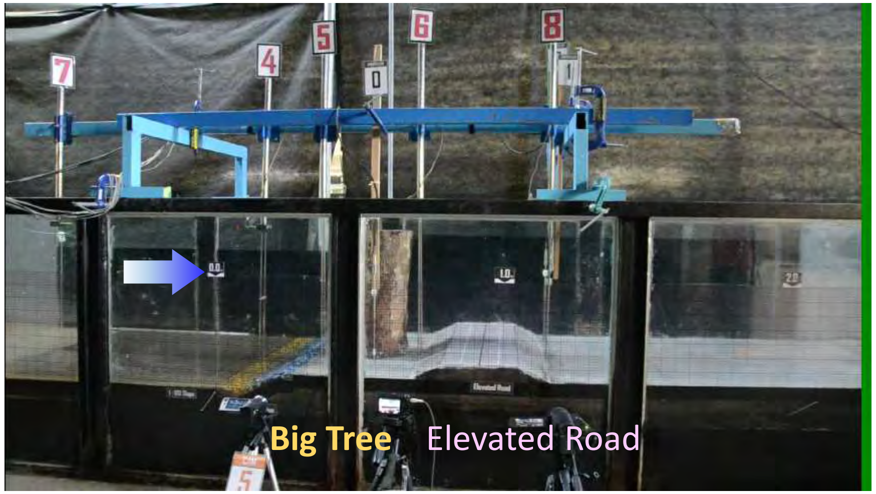
Verification of tsunami mitigation effect by vegetation

Method Ⅰ : Physical Model Test

➢ **Model Test Situation (Inland Tree, Big Tree)**

Inland Tree

Big Tree



Verification of tsunami mitigation effect by vegetation

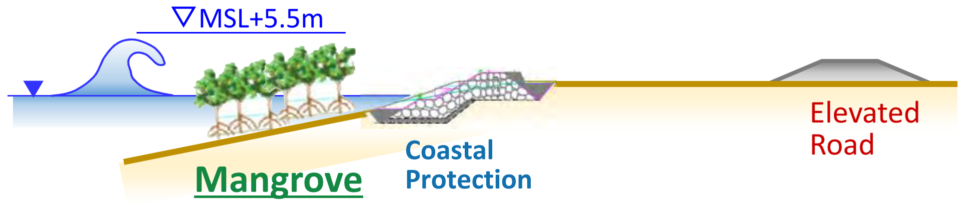
Method Ⅰ : Physical Model Test

➢ **Model Test Result**

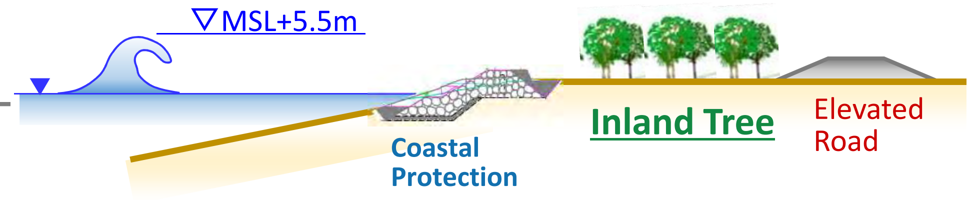
Overflow or Not — **Overflow the elevated road in all scenarios with vegetation**

Wave Height , m	Without Vegetation		
MSL+5.5m		YES	

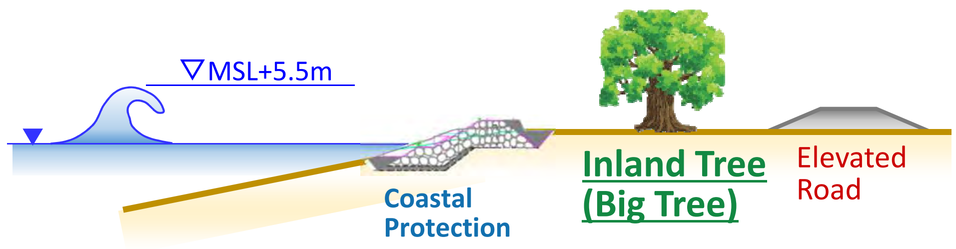
Wave Height , m	Mangrove		
	Width (m)	Interval (m) 2.5m	Interval (m) 3.0m
MSL+5.5m	20	YES	YES
	35	YES	YES
	50	YES	YES



Wave Height , m	Inland Tree		
	Width (m)	Interval (m) 7.5m	Interval (m) -
MSL+5.5m	25	YES	-



Wave Height , m	Inland Tree (Big Tree)		
	Diameter (m)	Interval (m) 50m	Interval (m) -
MSL+5.5m	14	YES	-



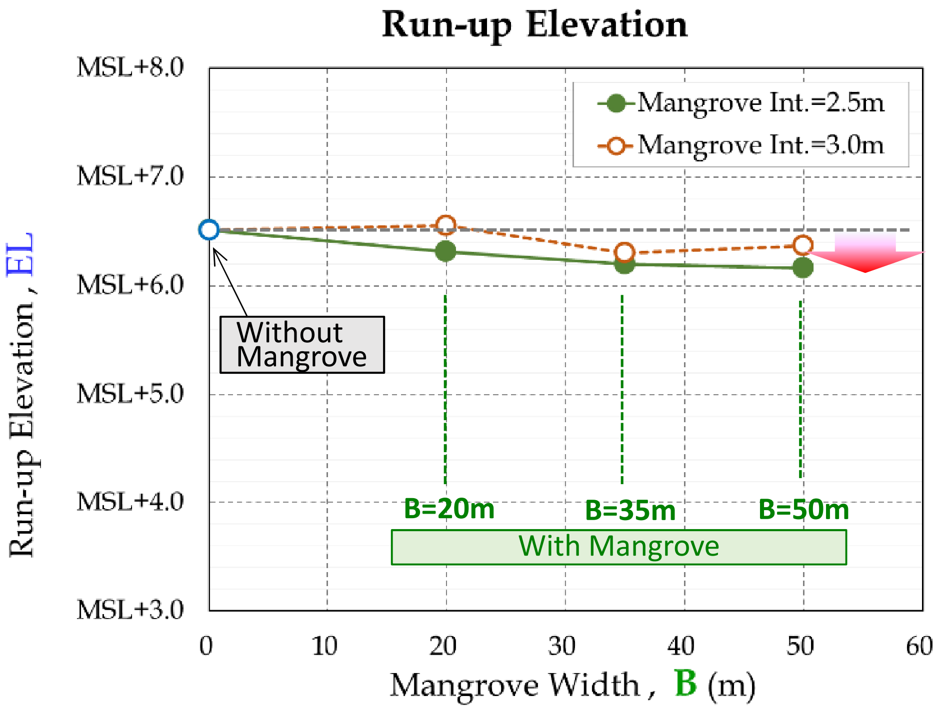
Legend
YES – Overflow , NO - Not Overflow

Verification of tsunami mitigation effect by vegetation

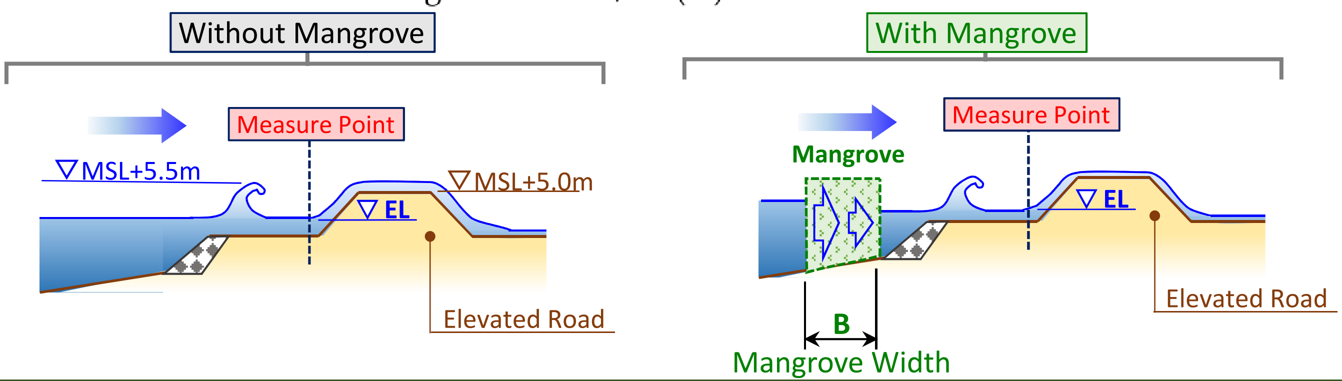
Method Ⅰ : Physical Model Test

➢ **Model Test Result**

Mangrove **Run-up Elevation tends to decrease in the presence of mangrove.**



・This graph indicates the results of comparing the run-up elevation in front of the elevated road with and without mangrove.
・Maximum reduction rate of the run-up elevation is about 5%.

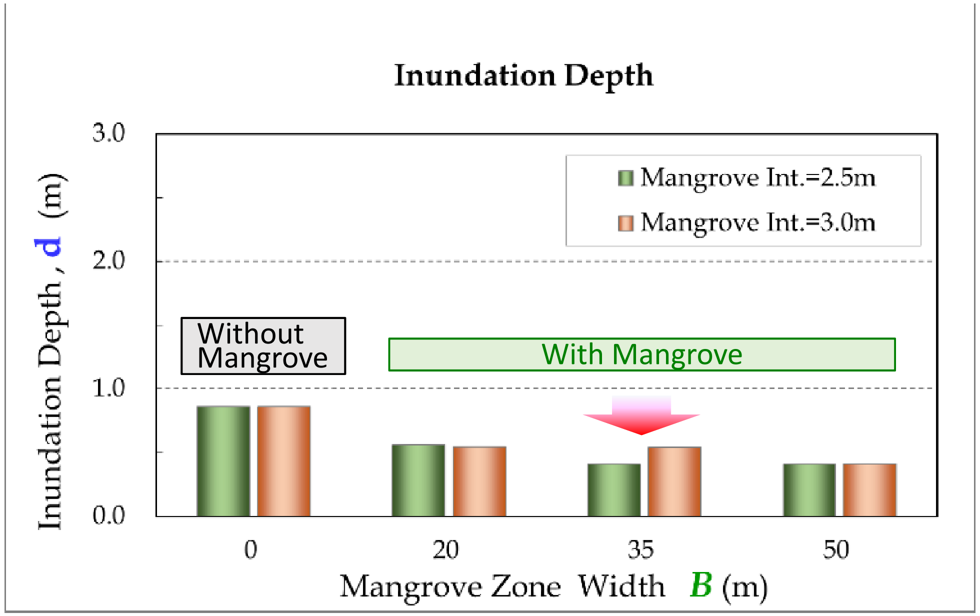


Verification of tsunami mitigation effect by vegetation

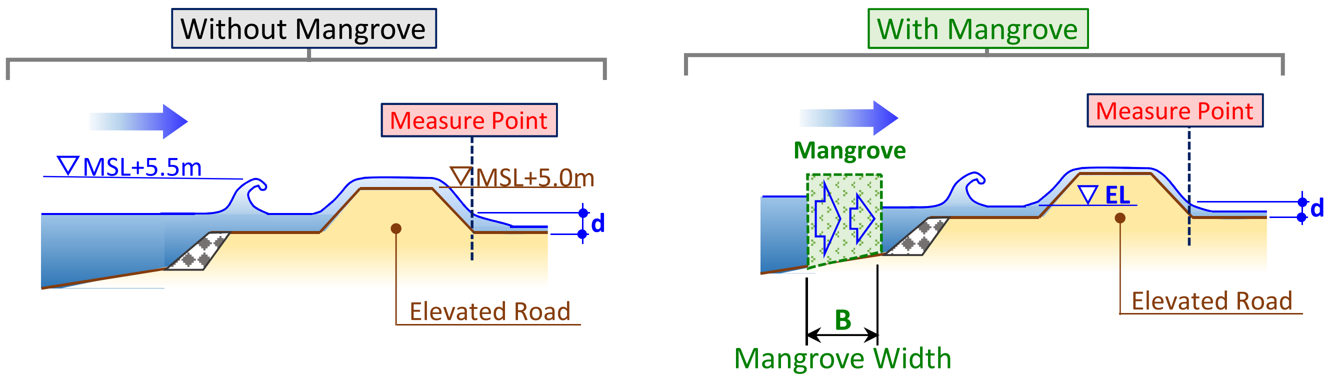
Method Ⅰ : Physical Model Test

➢ **Model Test Result**

Mangrove **Inundation depth tend to decrease in the presence of mangrove.**



・This graph indicates the results of comparing the inundation depth behind the elevated road with and without mangrove.
・The amount of decrease in inundation depth by vegetation is almost the same as the amount of decrease in run-up elevation.

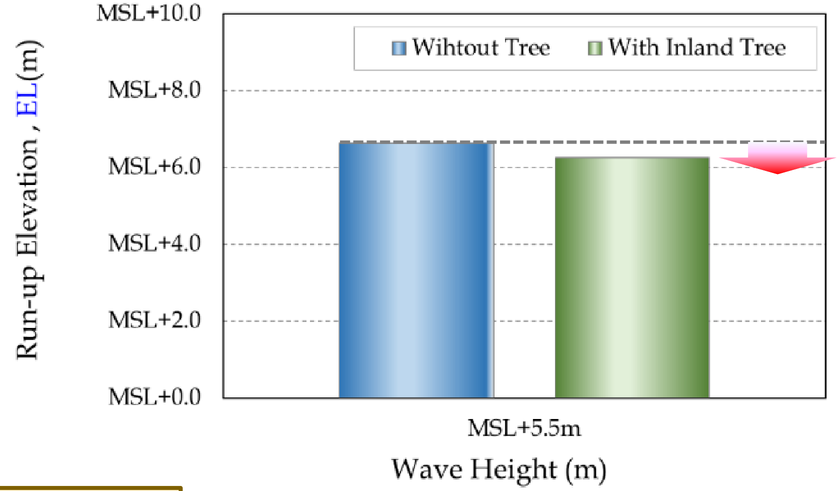


Verification of tsunami mitigation effect by vegetation

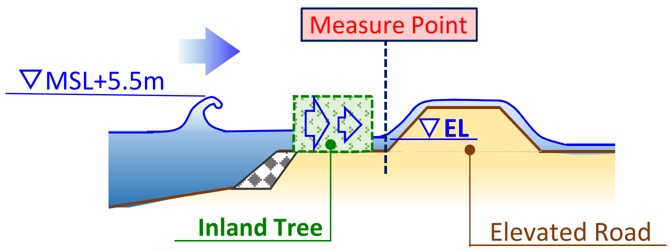
Method Ⅰ : Physical Model Test

➢ **Model Test Result**

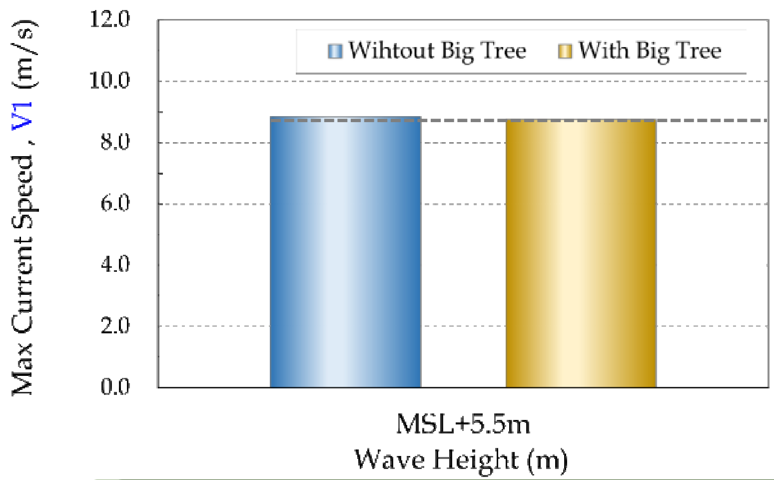
Inland Tree **Run-up Elevation tend to slight decrease in the presence of inland trees.**



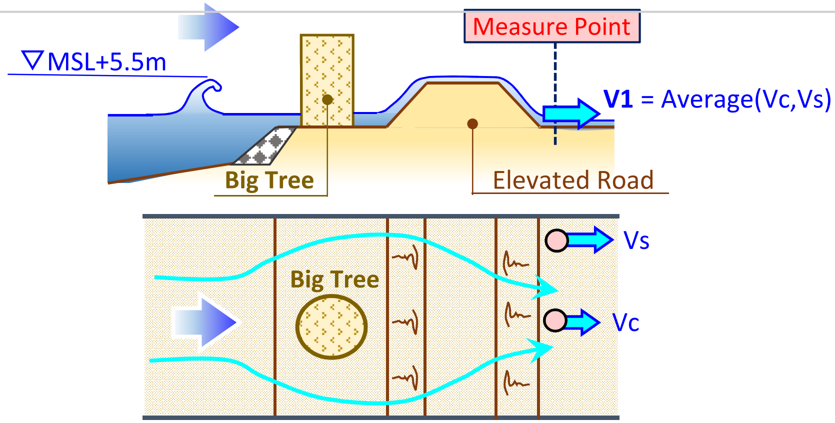
This graph indicates the results of comparing the run-up elevation with and without the inland tree.



Big Tree **Current speed is almost same in the presence of big trees.**



This graph indicates the results of comparing the current speed with and without the big tree.



4. Report on Results of Tsunami Model Tests

d. **Verification of tsunami mitigation effect of vegetation [Method Ⅱ]**
(Simulation Analysis by Chuo Univ. Prof. ARIKAWA)

(Report from the October 5, 2020 JICA team to BAPPENAS)

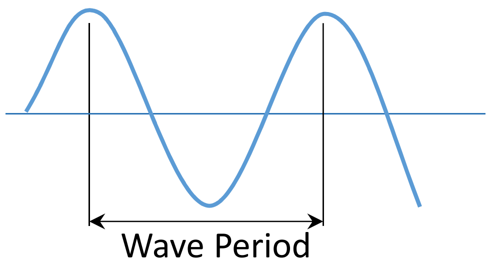
Verification of tsunami mitigation effect by vegetation

Method Ⅱ : Simulation Analysis

➢ Purpose of Simulation Analysis

Reproduce the 2018 tsunami wave (wave period is approx. 3.5min) in the simulation analysis and confirm the mitigation effect of mangrove under this condition.

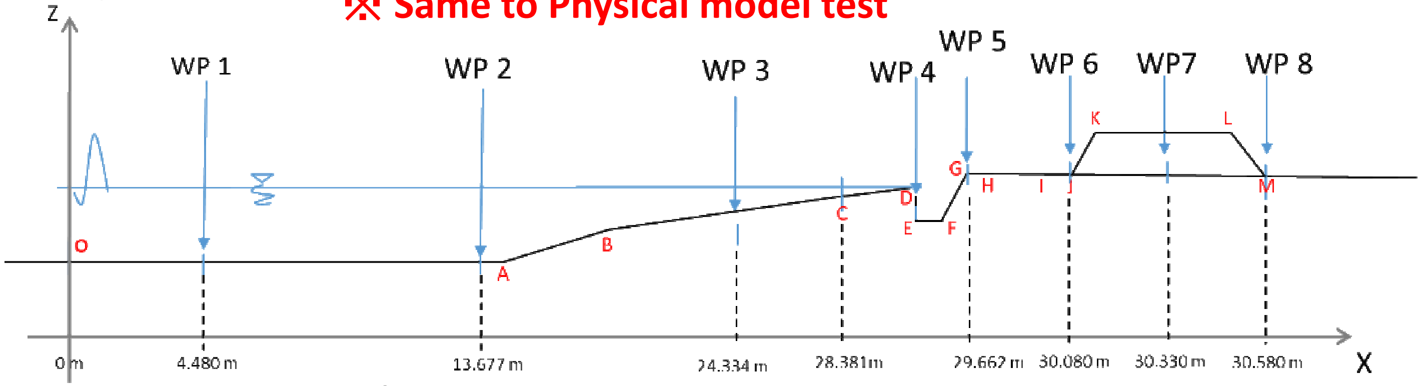
	Wave Period	Remark
2018 Tsunami	Approx. 3.5min	Pantoloan tide station data
Physical Model Test	Approx. 1.0min	based on equipment capacity of Balai Pantai



Model Test (1min) ▼	2018 Tsunami (3.5min) ▼
Wave Period	Short ⇔ Long
Current Speed	Fast ⇔ Slow
Wave Energy	Small ⇔ Large
Mitigation Effect	? ⇔ ?

➢ Analysis Condition and Model

(1) Analysis Model ※ Same to Physical model test



- Porosity of Mangrove = 98% *Based on the mangrove model

Verification of tsunami mitigation effect by vegetation

Method Ⅱ : Simulation Analysis

(2) Analysis Scenario

* Only focus to Mangrove effect, Mangrove Interval=3m

Scenario	Incident Wave	Mangrove Width [m]
1	Incident Wave-1: Physical Model Test Wave	0
2		20
3		35
4		50

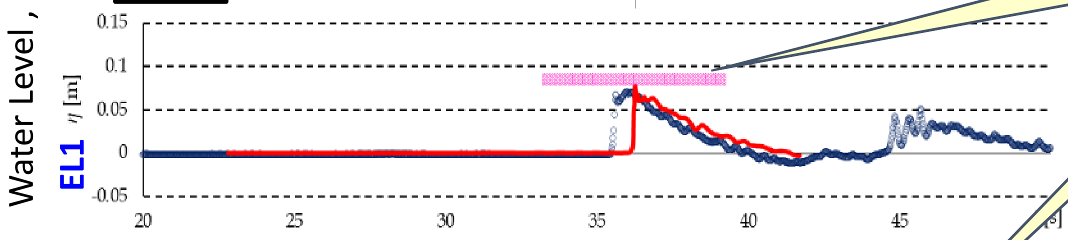
Scenario	Incident Wave	Mangrove Width [m]
5	Incident Wave-2 2018 Tsunami Wave	0
6		20
-		-
7		50

- **Result of Simulation Analysis**

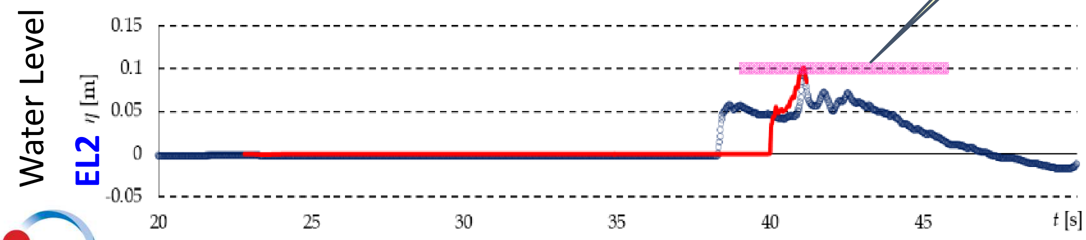
Confirmation of reproducibility of physical model test

Scenario 2 : Mangrove width-20m

WP3 - Front of the mangrove

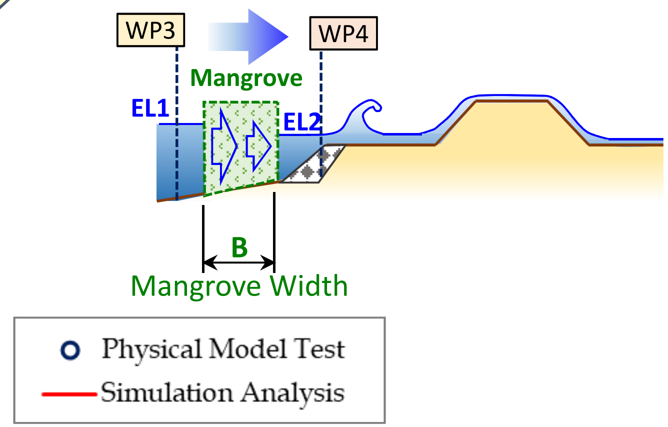


WP4 - Behind the mangrove



Confirmed that the water levels in the model test and analysis are almost the same.

→ Simulation analysis is able to reproduce the model test

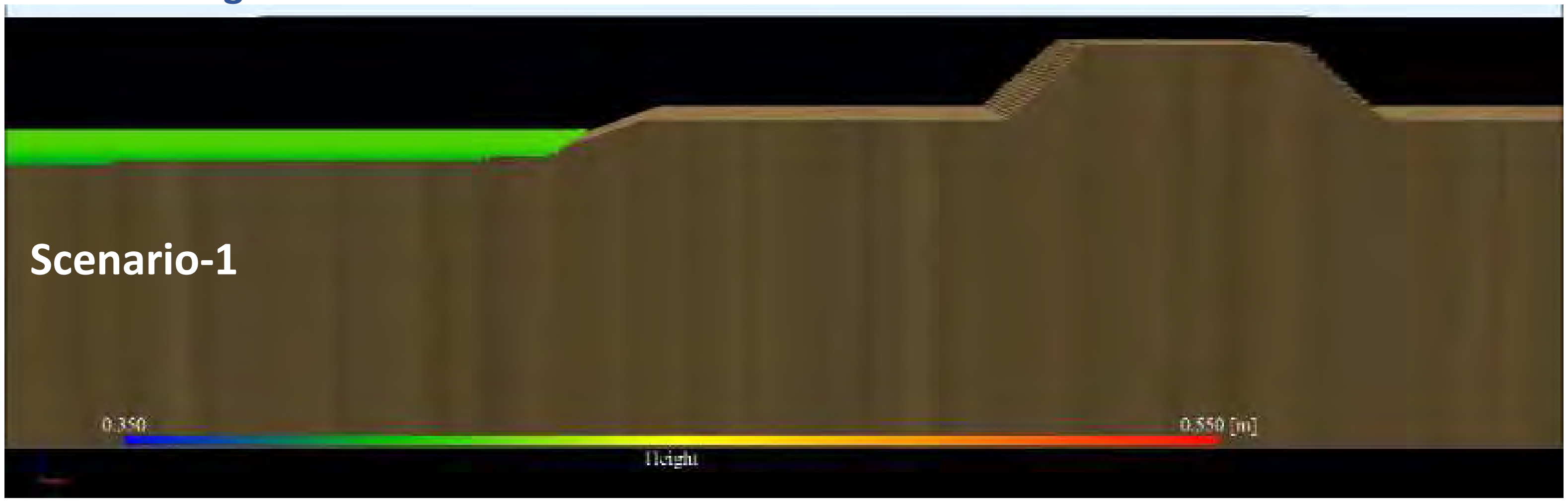


Verification of tsunami mitigation effect by vegetation

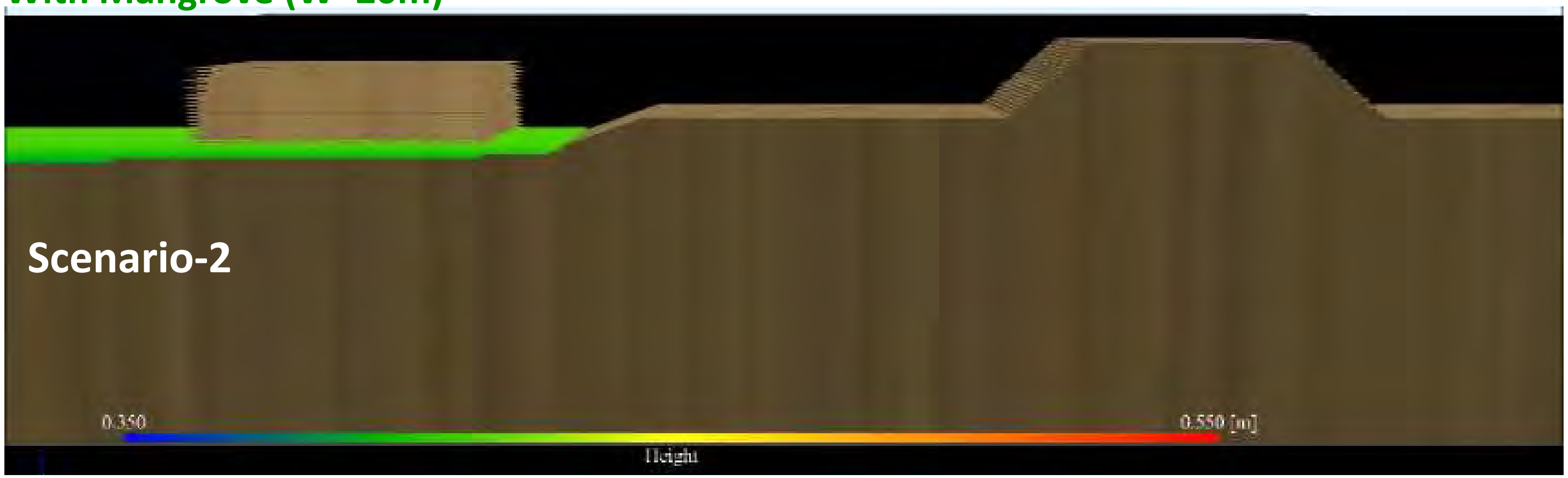
Method Ⅱ：Simulation Analysis

➢ **Result of Simulation Analysis** [Incident wave -1 : Physical model test wave]

◆ **Without Mangrove**



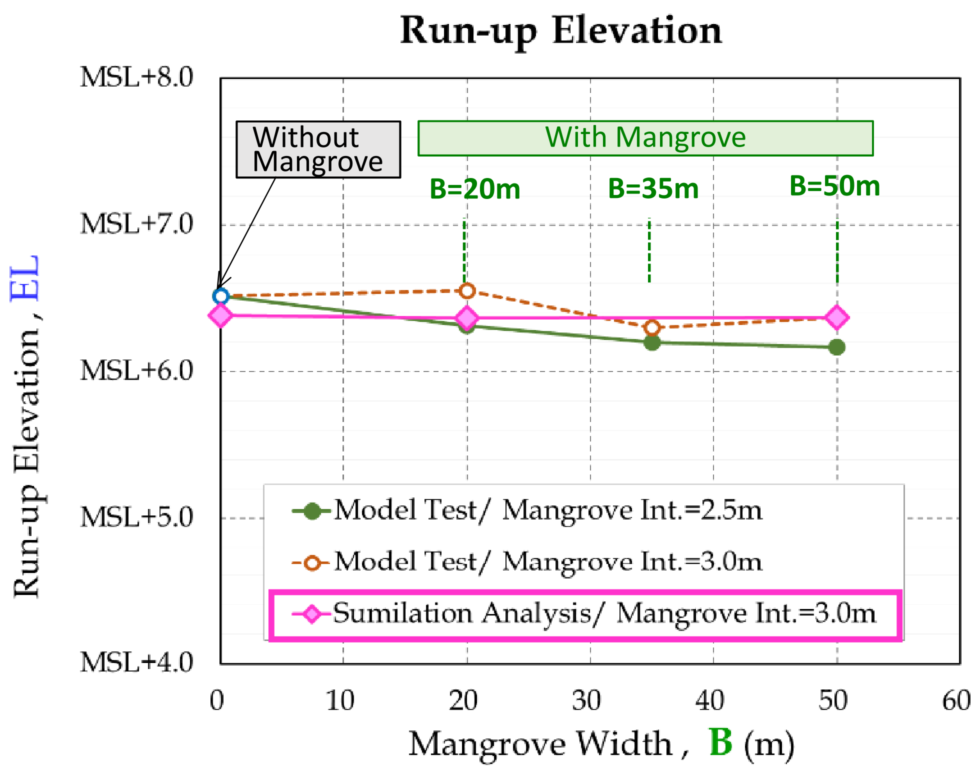
◆ **With Mangrove (W=20m)**



Verification of tsunami mitigation effect by vegetation

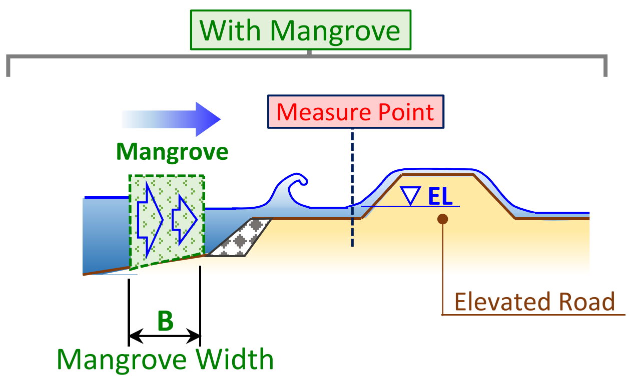
Method Ⅱ : Simulation Analysis

➢ **Result of Simulation Analysis (Mitigation effect of Mangrove)**



・This graph indicates the results of comparing the run-up elevation in front of the elevated road with and without mangrove.

・An analysis using a tsunami with a longer wave period than the model test did not confirm a clear tsunami mitigation effect by mangroves.



JICA-TC recommendations
and
Considerations for The Restoration Project

①Setting the height of elevated roads and vegetation areas

②Confirmation of safety for coastal protection

③Proposal for basic evacuation method from tsunami

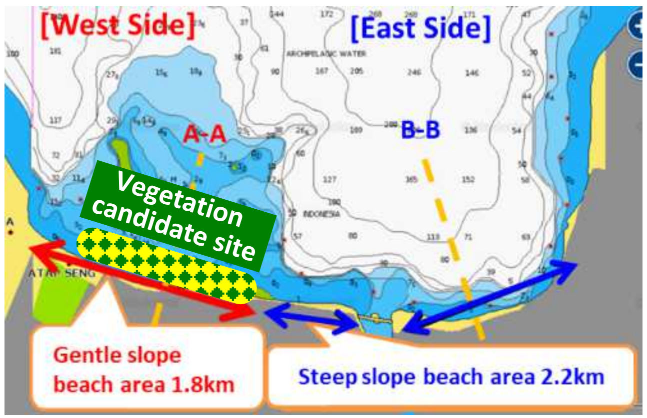
[Recommendation] ① Setting the height of elevated roads and vegetation areas

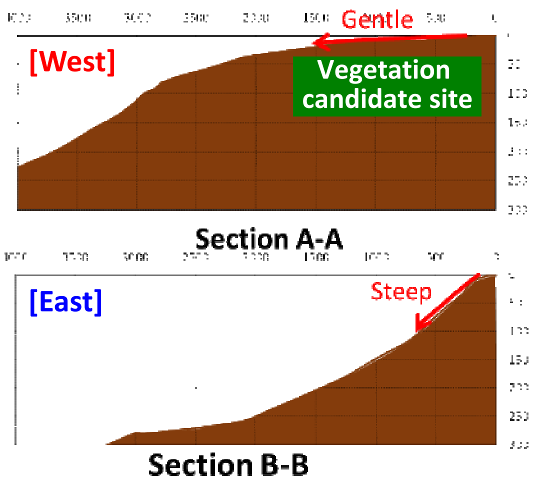
Recommendation ①

- A certain tsunami mitigation effect by vegetation was confirmed by physical model , But the effect could not be confirmed by the analysis that reproduced the 2018 tsunami.
- Considering not only the above result but also the concern things of Palu Bay shown below 1)～4), the JICA survey team recommends that the **height of the elevated road should not be lower than MSL + 5.0 m in anticipation of the effects of vegetation**.

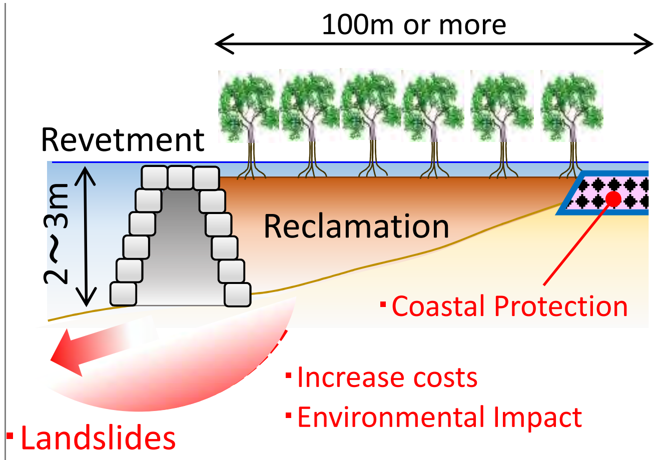
1) **Topographical features** : Vegetation cannot be applied to the entire target section due to steep topography. Vegetation limited to the west side, and only about 16% of the tsunami countermeasure extension can secure a mangrove width of 50m or more.

2) **Reclamation for vegetation** : The reclamation is required to secure a more mangrove area, but it is concerned to further landslides, increased costs, coastal protection and environmental impact.





1) Topographical Features of Palu Bay

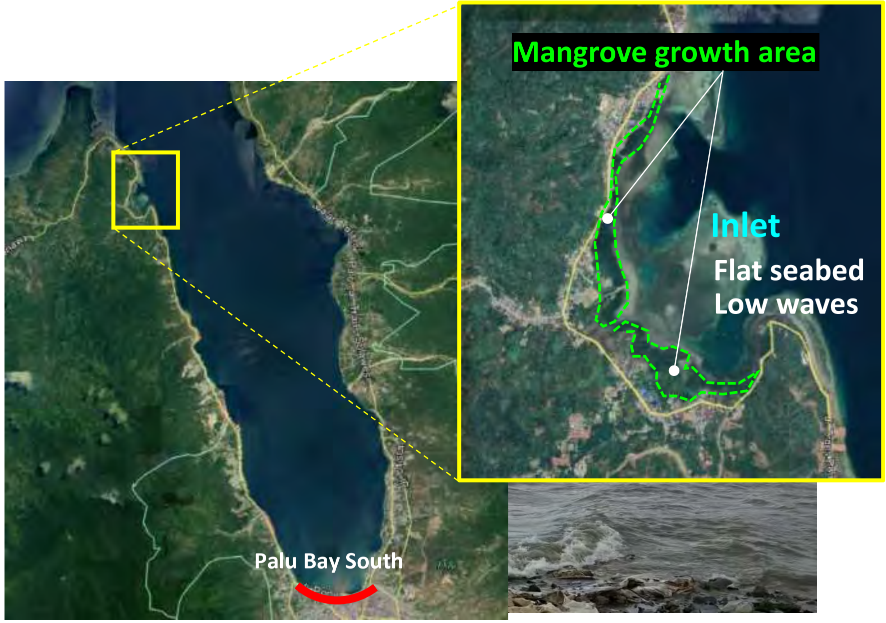


2) Reclamation for Vegetation

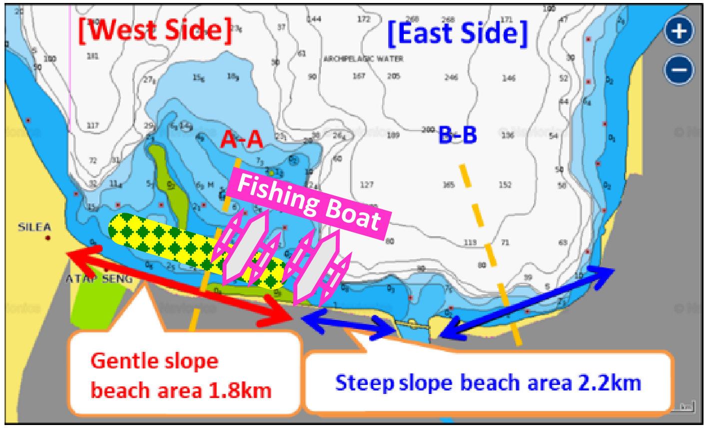
[Recommendation] ① Setting the height of elevated roads and vegetation areas

3) **Growth environment** : It takes 10 years or more to growing up, and as it is a natural plant, it is affected by various environmental effects such as soil, water depth, waves and so on. Mangrove growth was confirmed only in the northern cove in Palu Bay.

4) **Fishing boats** : Coordination with local fishing boats is necessary even on the west side of Palu Bay where mangrove vegetation is possible.



3) Growth environment



4) Fishing boats

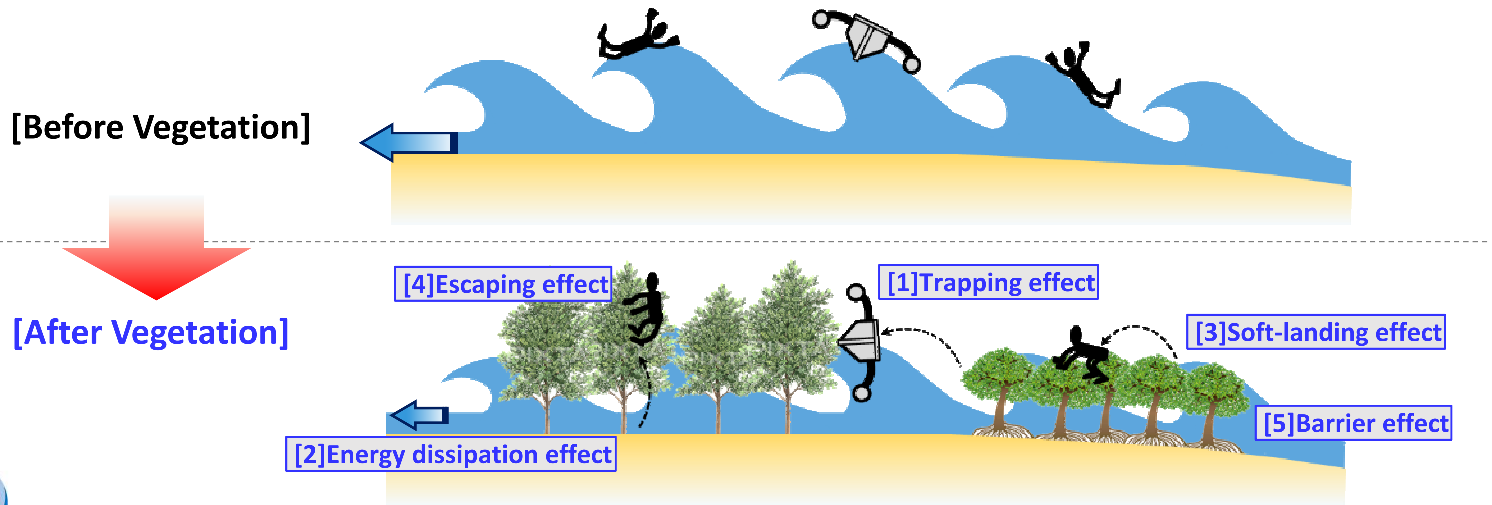
Recommendation ②

・Vegetation can be expected to have effects other than tsunami mitigation, so **JICA survey team recommends vegetation as much as possible areas.**

[Recommendation] ① Setting the height of elevated roads and vegetation areas

Vegetation Effect	Contents
[1] Trapping effect	the effect to stop driftwoods (fallen trees, *etc.*), debris (destroyed houses, *etc.*)and other floatage (boats, *etc.*)
[2] Energy dissipation effect	the effect to reduce water flow velocity, flow pressure and inundation water depth
[3] Soft-landing effect	the effect to provide a life-saving means for people to catch tree branches when carried off by tsunamis
[4] Escaping effect	the effect to provide “a way” of escaping by climbing trees from the ground or from the second floor of a building
[5] Barrier effect	the effect to collect wind-blown sand and raise dunes which act as natural barriers against tsunamis
[6] Good landscape effect	the effect to provide a scenic moisture and peace
[7] Habitat environment improvement effect	the effect to providing coastal fauna and flora habitat and breeding environment

Source : ISSN 0386-5878 Technical Note of PWRI No.4177
Planning and Design of TSUNAMI-MITIGATIVE COASTAL VEGETATION BELTS, ICHARM Publication No.18, August 2010

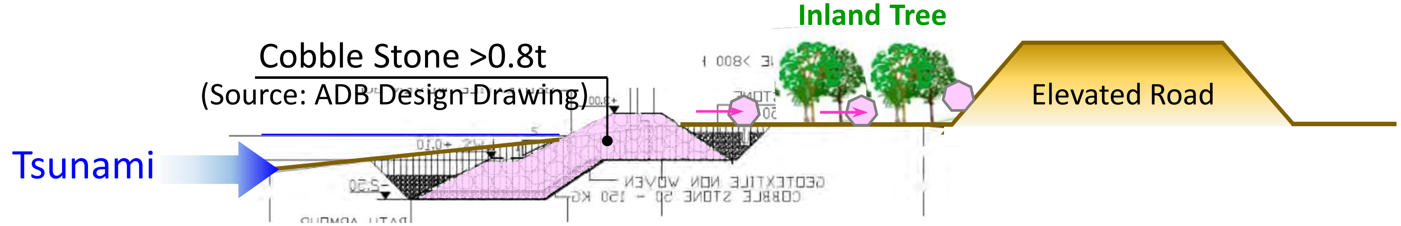


[Recommendation] ② Confirmation of safety for coastal protection

➢ Stable Confirmation of Coastal Protection by Tsunami

・The safety of coastal protection under tsunami action was confirmed using the result of simulation analysis by Prof. Arikawa and Japanese standards.

・As a result of the inspection, it was confirmed that the current speed that occurred around the coastal protection was below the limit current speed. In addition, due to differences in conditions such as stone weight, even if stones move, it is assumed that elevated roads and inland trees will prevent this.



◆ **Calculation Formula for Limit Current Speed (which the stone moves)** -------- Based on Japanese port standards

$$M = \frac{\pi \rho_r U^6}{48 g^3 y^6 (S_r - 1)^3 (\cos\theta - \sin\theta)^3}$$ -------- *Isbash formula*

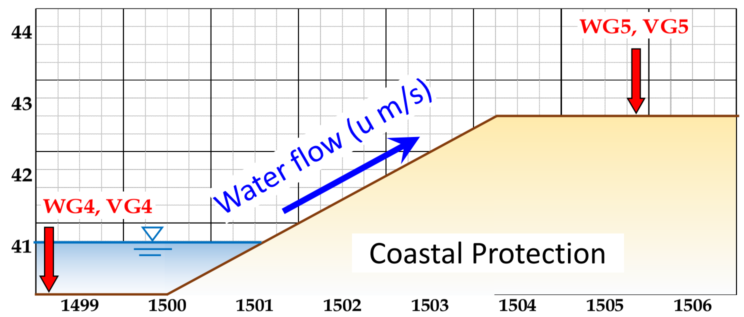
$$U_{Lim} = \left\{ \frac{M \cdot 48 g^3 y^6 (S_r - 1)^3 (\cos\theta - \sin\theta)^3}{\pi \cdot \rho_r} \right\}^{1/6}$$

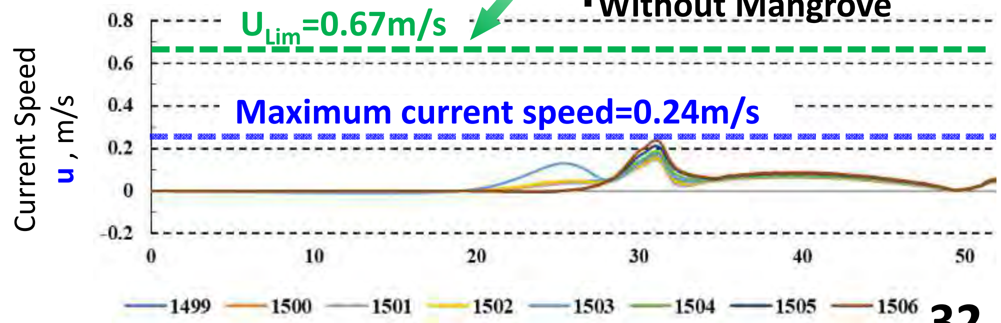
- U_{lim} : Limit current speed
- M : Stone weight (=0.8t)
- ρ_r : Stone density
- y : Isbash constant value
- θ : Slope angle

U_{Lim} = 4.7m/s (Full-scale)
= 0.67m/s (Model-scale)

◆ **Current Speed near the Coastal Protection by Simulation Analysis**

・Incident wave :2018 Wave
・Without Mangrove

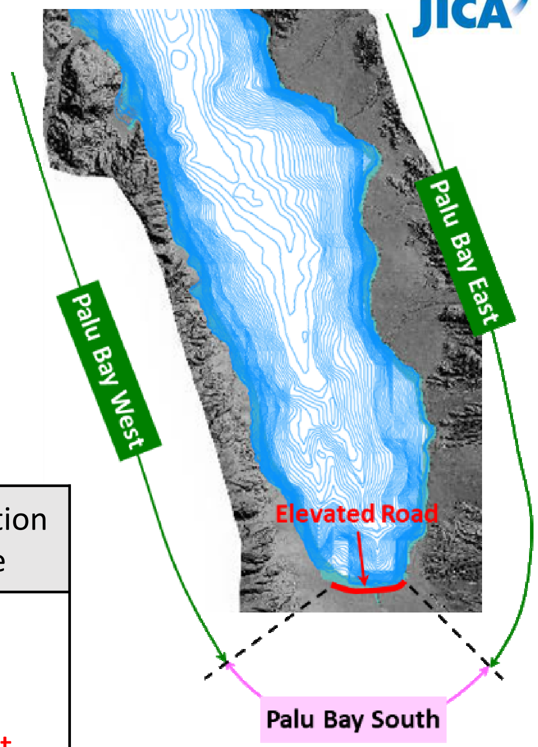




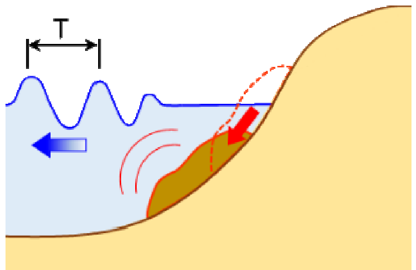
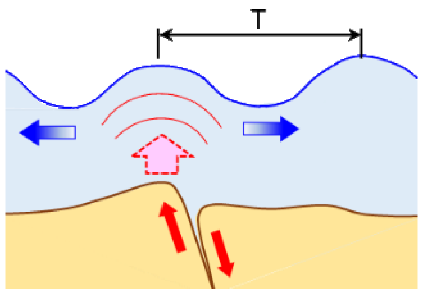
[Recommendation] ③ Proposal for basic evacuation method from tsunami

(1)Basic Policy of Evacuation Plan

- ✓ The evacuation plan considers two types of tsunamis due to the coastal landslide attributed to an earthquake and fault rupture of earthquake.
- ✓ Evacuation plans can be mainly classified into two areas: Palu bay south area where elevated roads are planned and other areas.

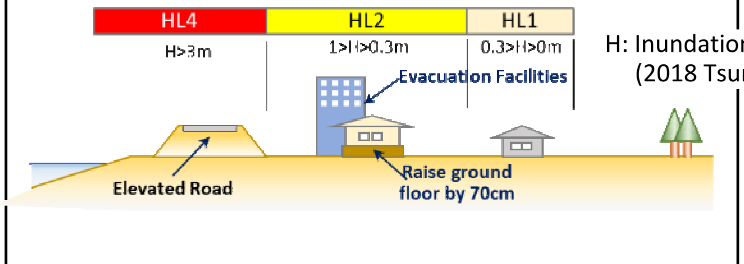
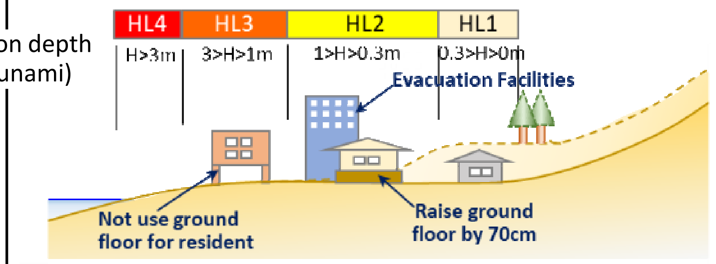
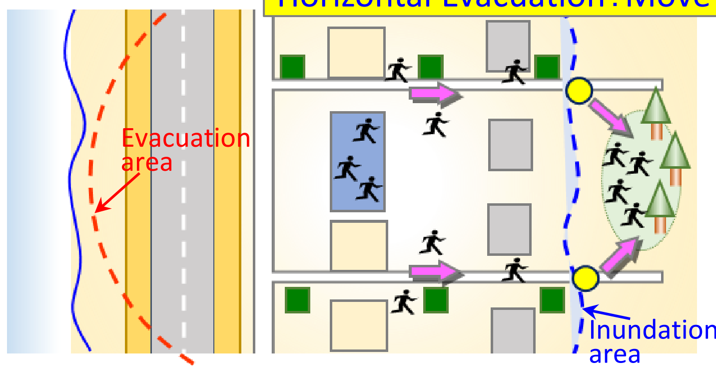
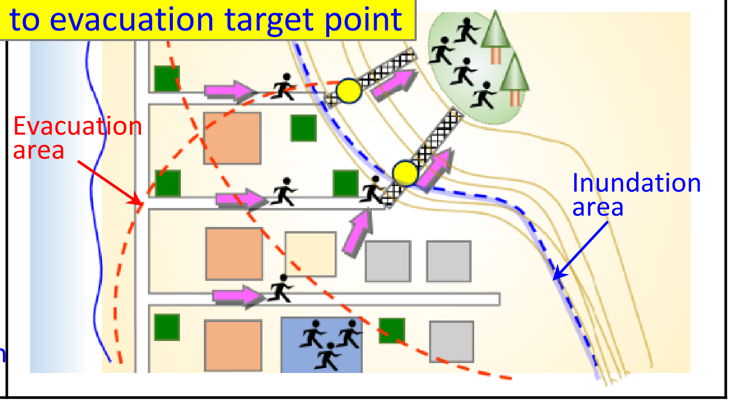
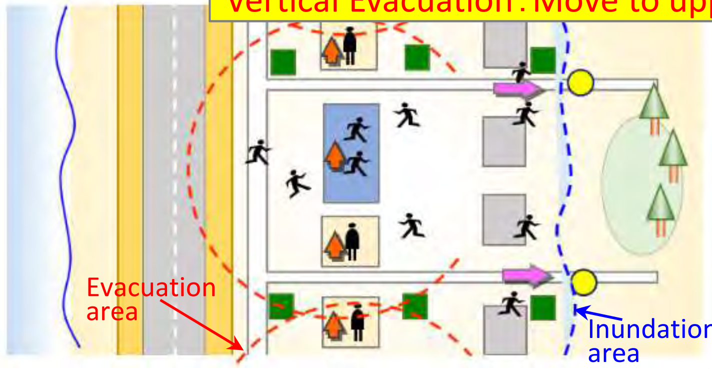
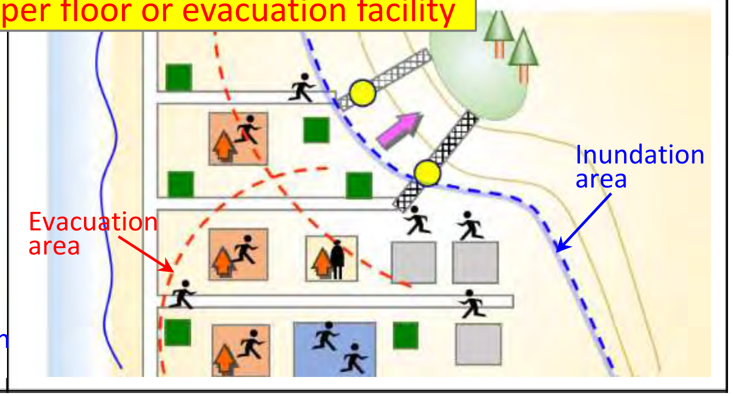


(2) Characteristics of Two Tsunami

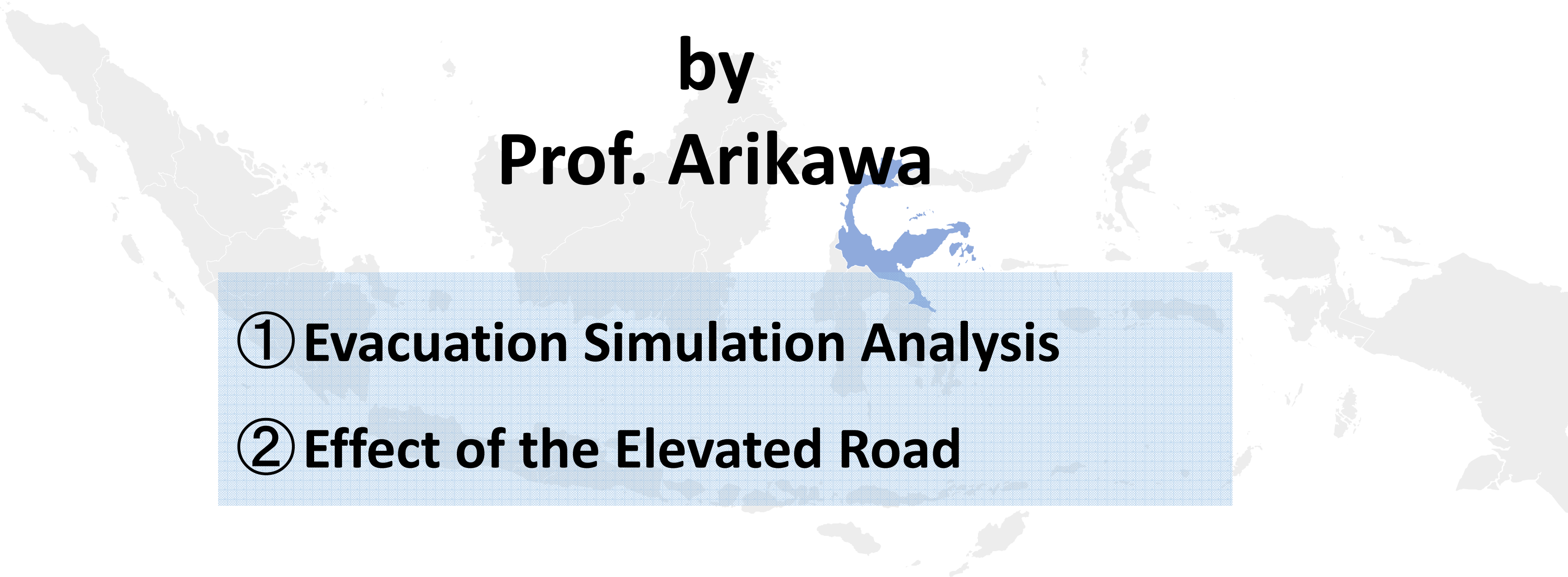
Type of Tsunami		Couse Image	Wave Length (T)	Tsunami Arrival Time	Evacuation Time
Type of Tsunami	Coastal Landslides (Sep. 2018)		Short	Quick Approx. 5min	Short
Type of Tsunami	Fault Rupture		Long	Slow Approx. 20min	Long

[Recommendation] ③ Proposal for basic evacuation method from tsunami

(3) Basic Evacuation Plan [Draft]

Area of Pal Bay	Palu Bay **South**	Palu Bay **West, East**
Side View	 H: Inundation depth (2018 Tsunami)	
Basic Action Just after earthquake [Supposed Tsunami] **Fault Rupture** Evacuation Time - **Long**	Horizontal Evacuation : Move to evacuation target point 	
Optional Action If the tsunami arrival is confirmed [Supposed Tsunami] **Coastal Landslides** (Sep.2018) Evacuation Time - **Short**	Vertical Evacuation : Move to upper floor or evacuation facility 	

Additional Consideration
by
Prof. Arikawa



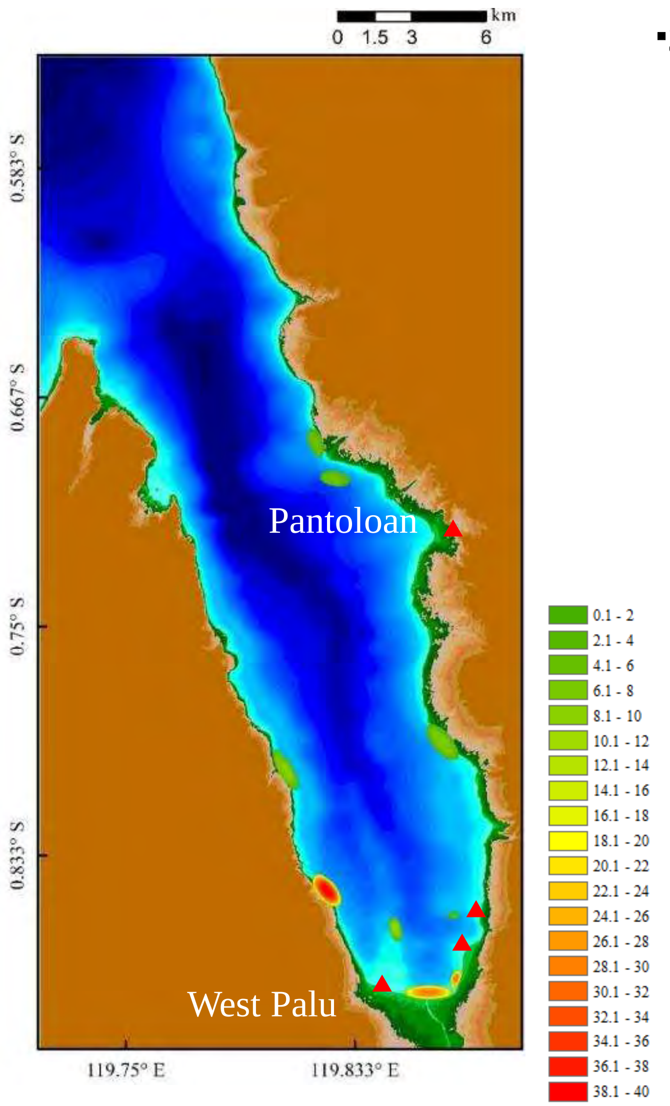
①Evacuation Simulation Analysis

②Effect of the Elevated Road

[Additional Consideration/ ① Evacuation Simulation Analysis]

[1] Tsunami Simulation

Source: Arikawa Lab.

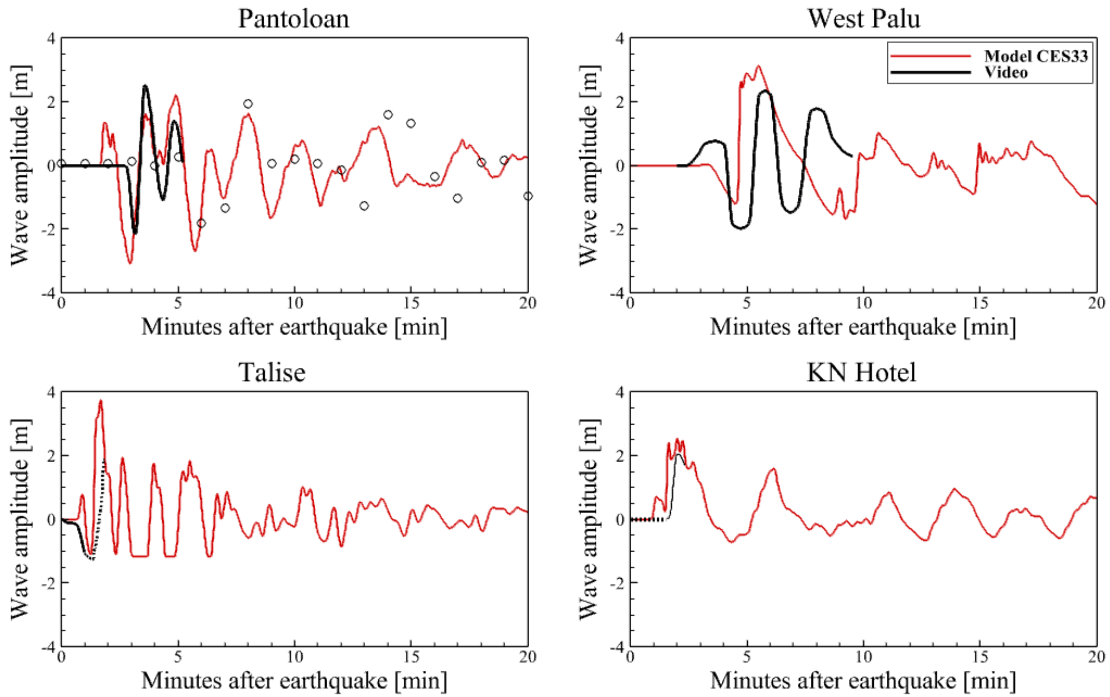


･Simulation Condition

(Nagai et al. 2021)

GRID SIZE (m)	30 m
Simulation time (min)	20
Time step (sec)	0.01
Density of mass (kg/m^3)	1500
Initial water level (m)	0.7

･Landslide simulation using two-layer model

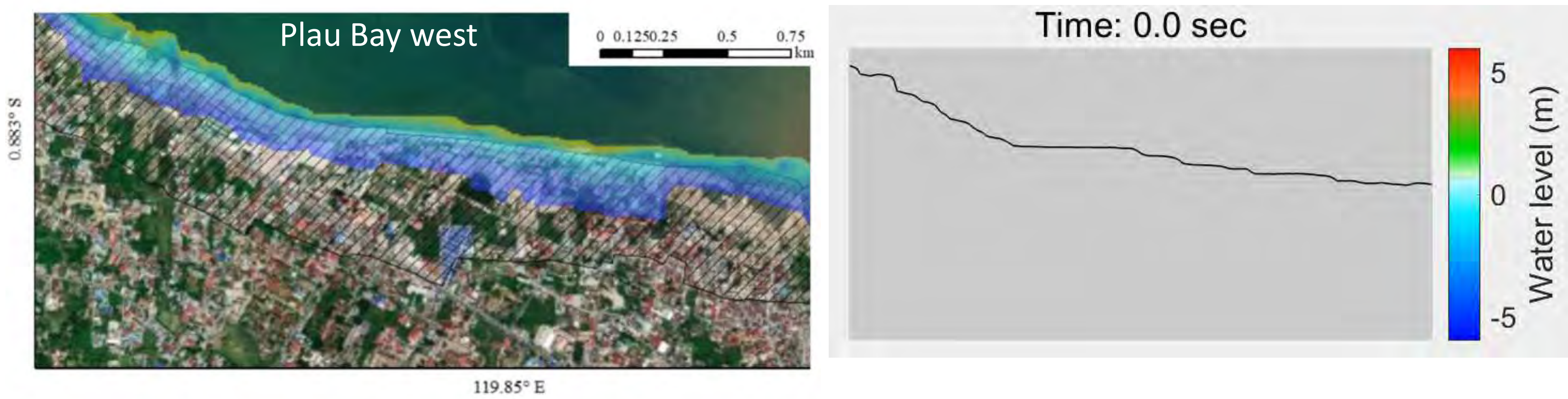


[Additional Consideration/ ① Evacuation Simulation Analysis]

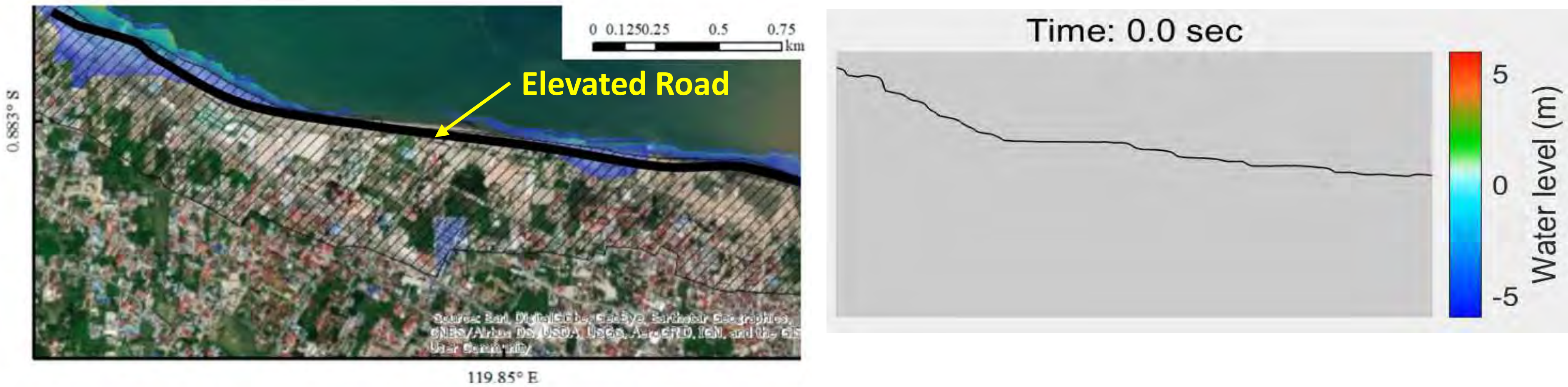
[1] Tsunami Simulation

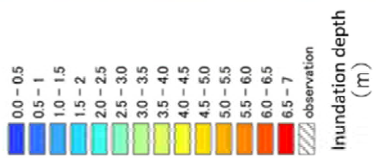
Source: Arikawa Lab.

(1) Without Elevated Road



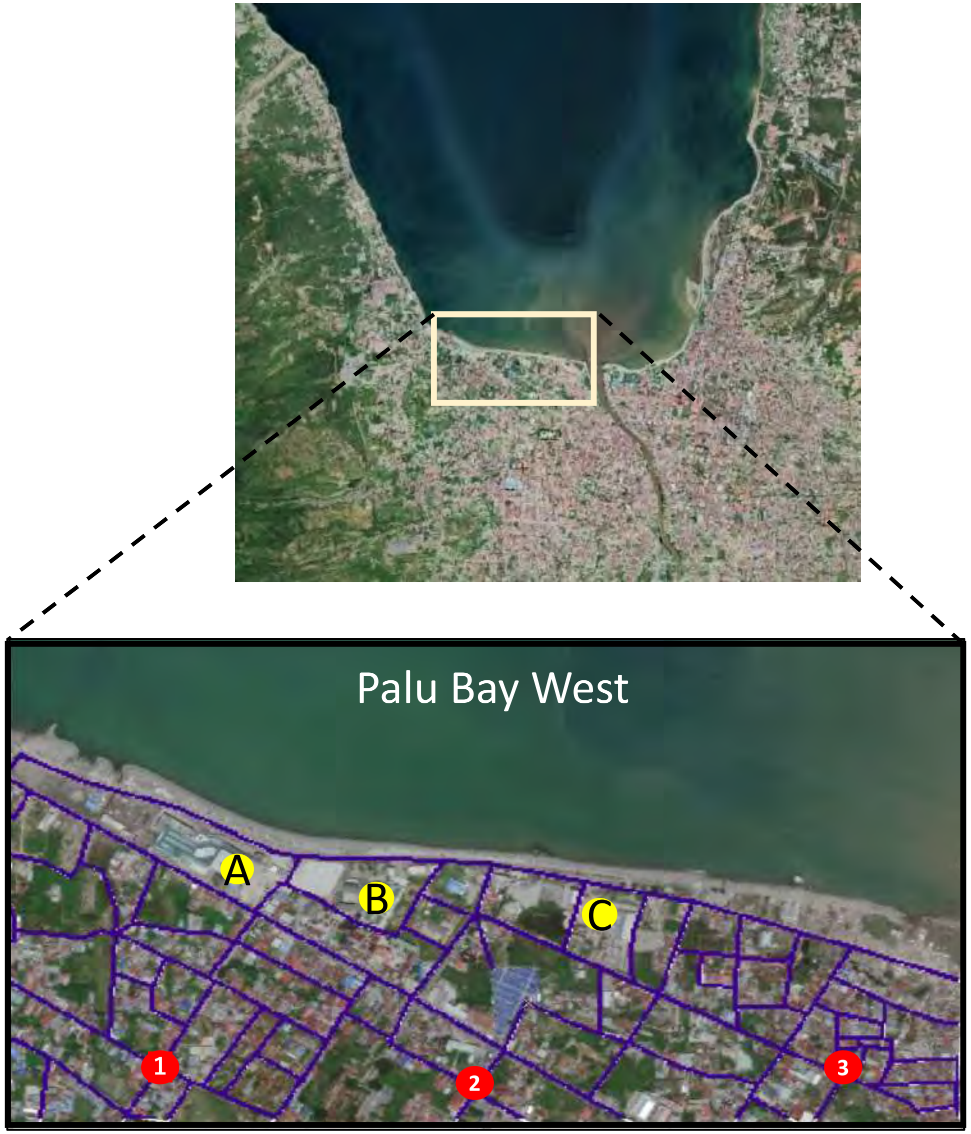
(2) With Elevated Road





[2] MAS(Multi Agent System) Calculation

Source: Arikawa Lab.



MAS Calculation Condition

Article	Detail
Evacuation Root	(purple line)
Evacuation Shelter	(yellow) -A,B,C (red) -1,2,3
Grid Size	5.0 m
Number of Grid	400×200
Time Step Interval	0.1 s
Calculation Time	1200s
Evacuation Start Time	Every 30s Between 0s s and 660 s
Evacuee	1700
Death judgment water depth	1.0m
Initial Placement of Evacuees	Random Set on Evacuation Route

[Additional Consideration/ ① Evacuation Simulation Analysis]

Source: Arikawa Lab.

[2] MAS Calculation

Evacuation Shelter : A 1 2 3

(1) Without Elevated Road

(2) With Elevated Road

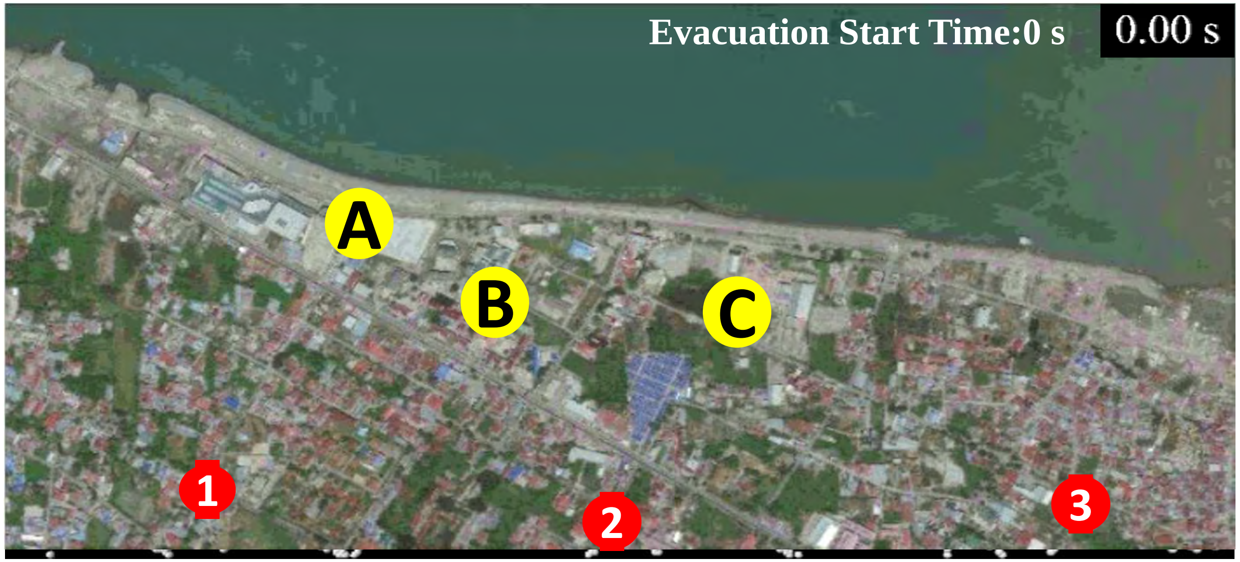
[Additional Consideration/ ① Evacuation Simulation Analysis]

[2] MAS Calculation

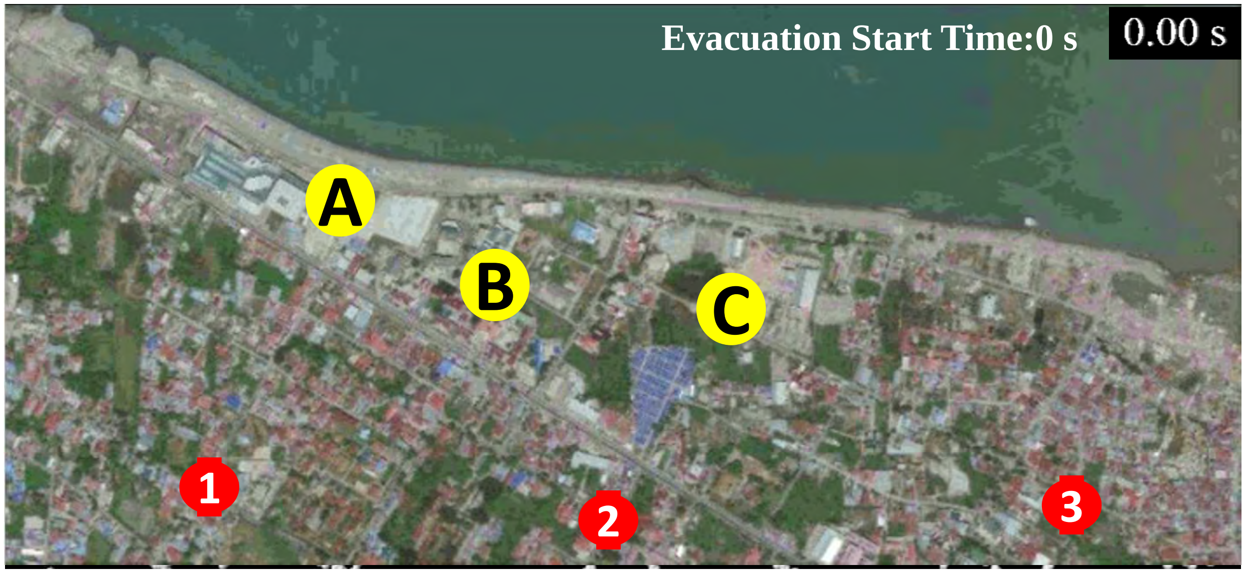
Evacuation Shelter : A B C 1 2 3

Source: Arikawa Lab.

(1) Without Elevated Road



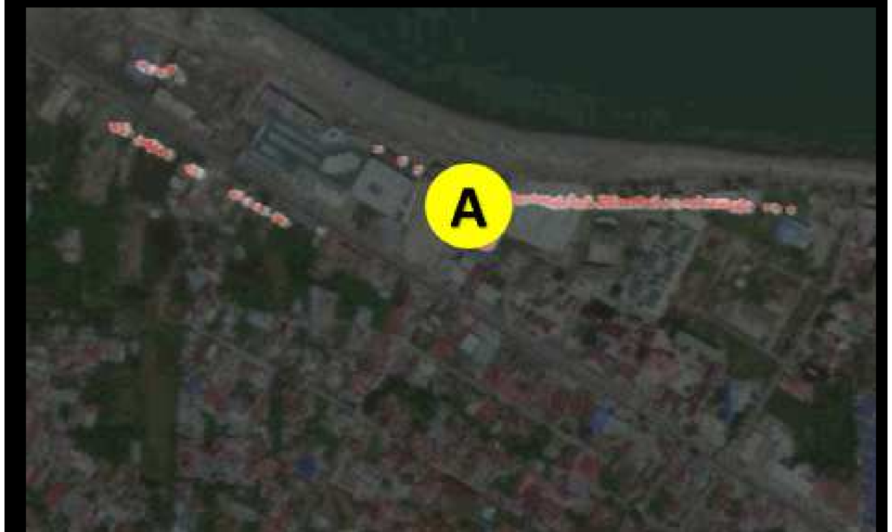
(2) With Elevated Road



[Additional Consideration/ ① Evacuation Simulation Analysis]

[2] MAS Calculation

Source: Arikawa Lab.

	Shelter : A (+1,2,3)	Shelter : A,B,C (+1,2,3)
(1) Without Elevated Road		
(2) With Elevated Road		

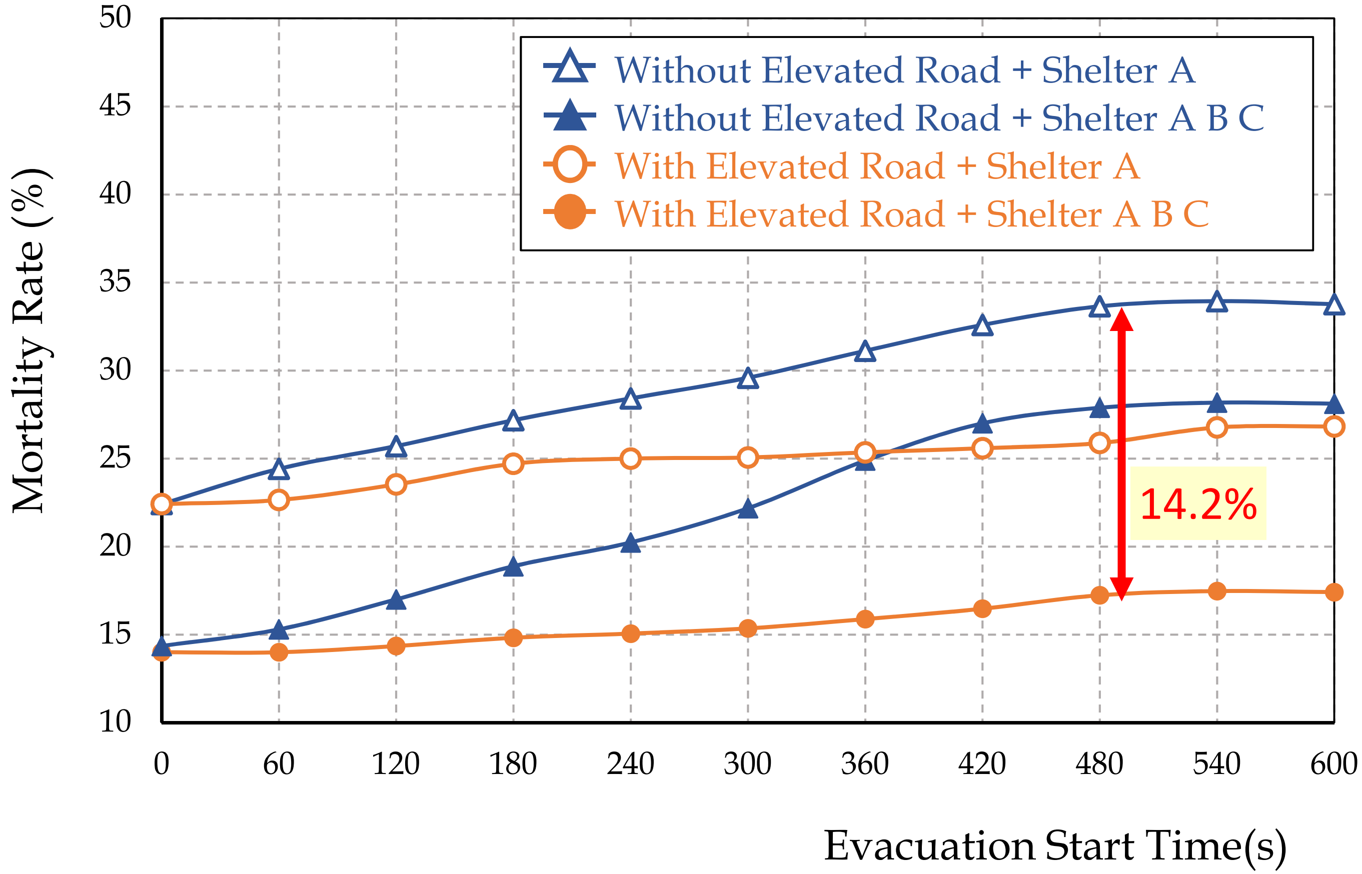
[Additional Consideration/ ① Evacuation Simulation Analysis]

[3] Conclusions *(Tentative)*

Source: Arikawa Lab.

[Mortality Rate]

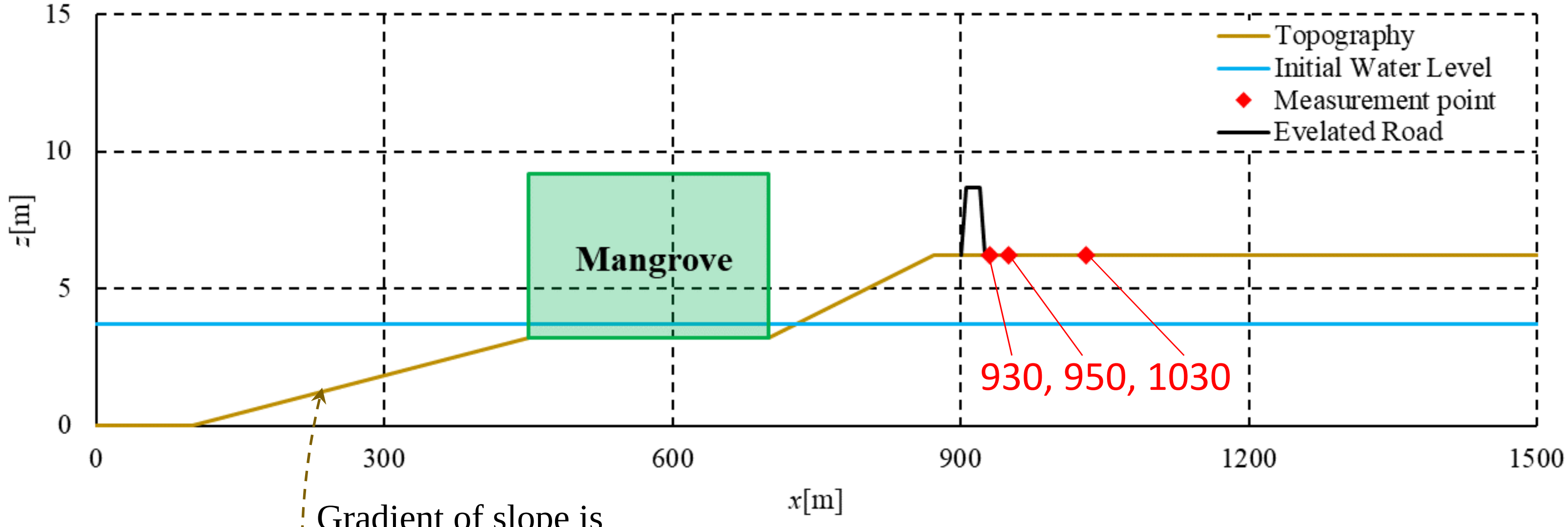
- Elevated road and increasing shelters can reduce mortality by up to 14.2%
- The presence of a elevated road can significantly reduce the mortality rate.

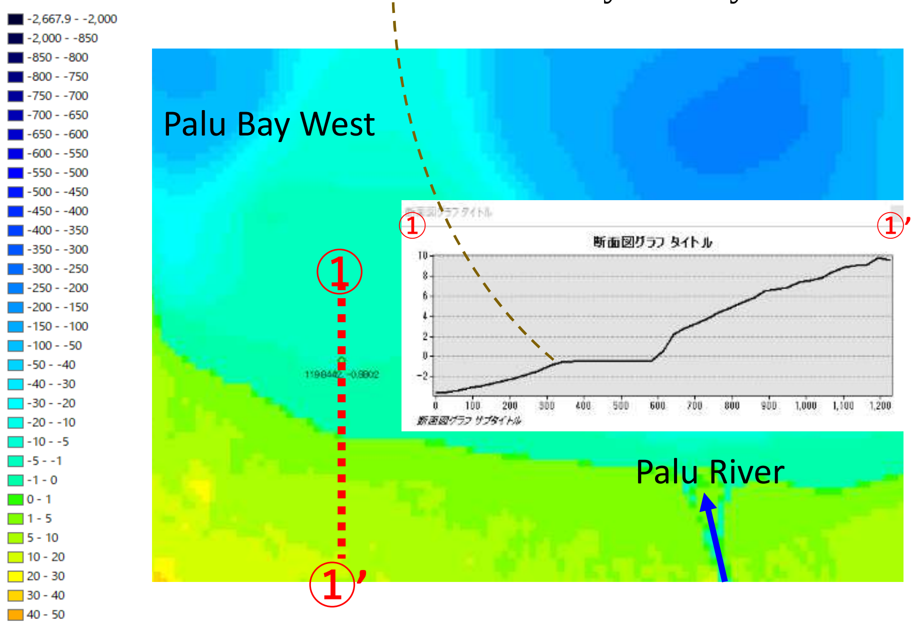


[Additional Consideration/ ② Effect of the Elevated Road]

Source: Arikawa Lab.

[1] Calculation Conditions





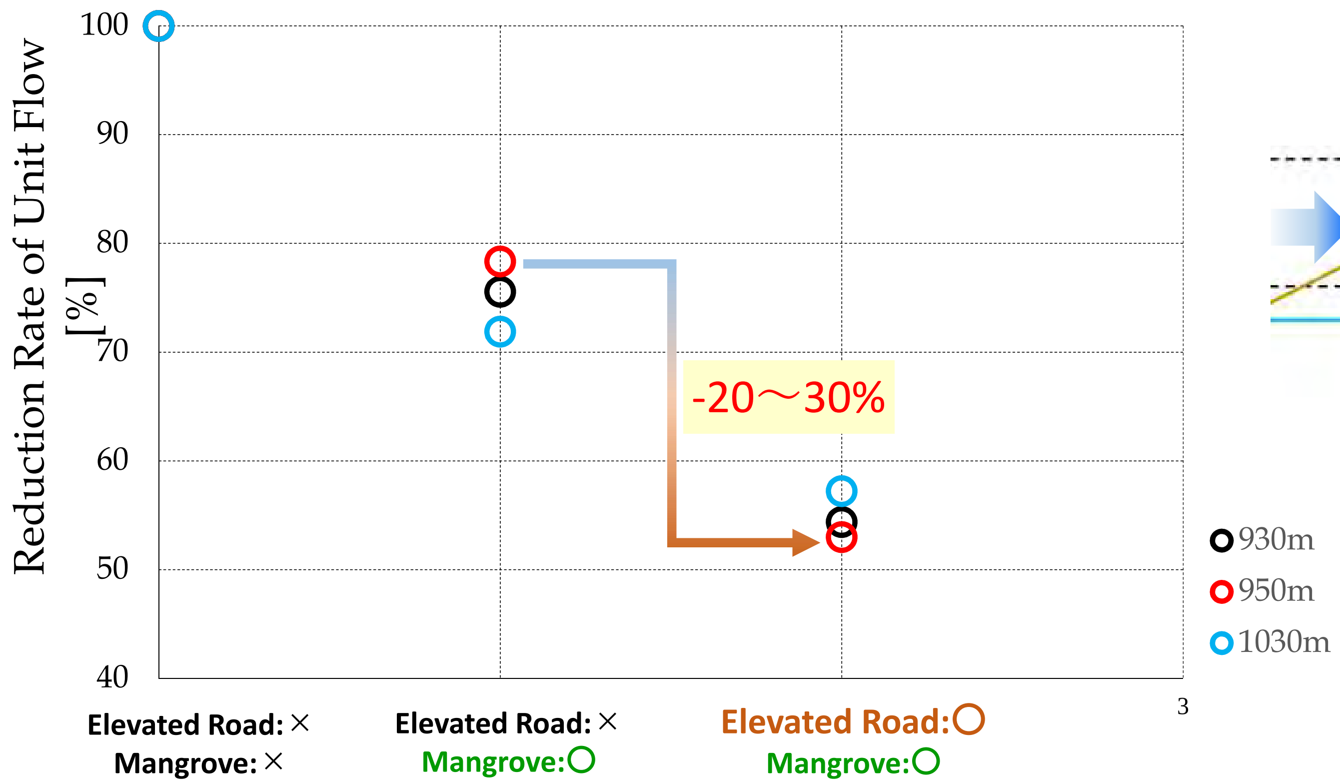
	Range[m]	Grid Size[m]	Number of grid
x	0〜1800	1.0	1800
y	0〜50	5	10
z	0〜3	0.5	6
	3〜15	0.1	120

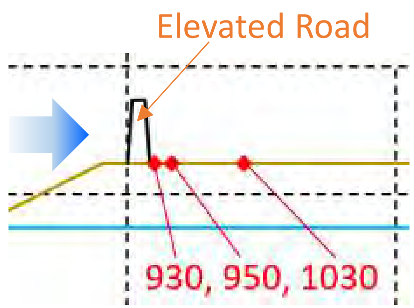
[Additional Consideration/ ② Effect of the Elevated Road]

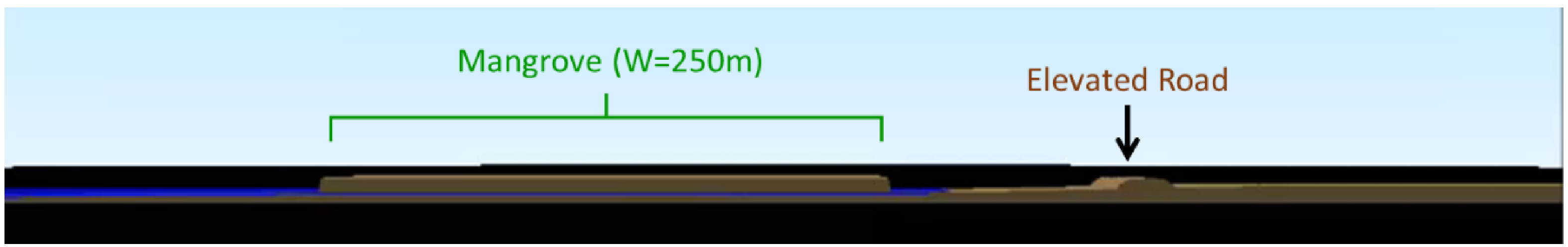
[3] Conclusions

Source: Arikawa Lab.

The elevated road itself has an effect of reducing the unit flow rate by about 20 to 30%.







Tsunami Damage Reduction System

- Elevated Road *
- Drainage System*
- Vegetation (Mangrove, Inland Tree & Big Tree)
- Evacuation System (Road, Building, EWS, Drill)

* Scope of JICA Loan Project

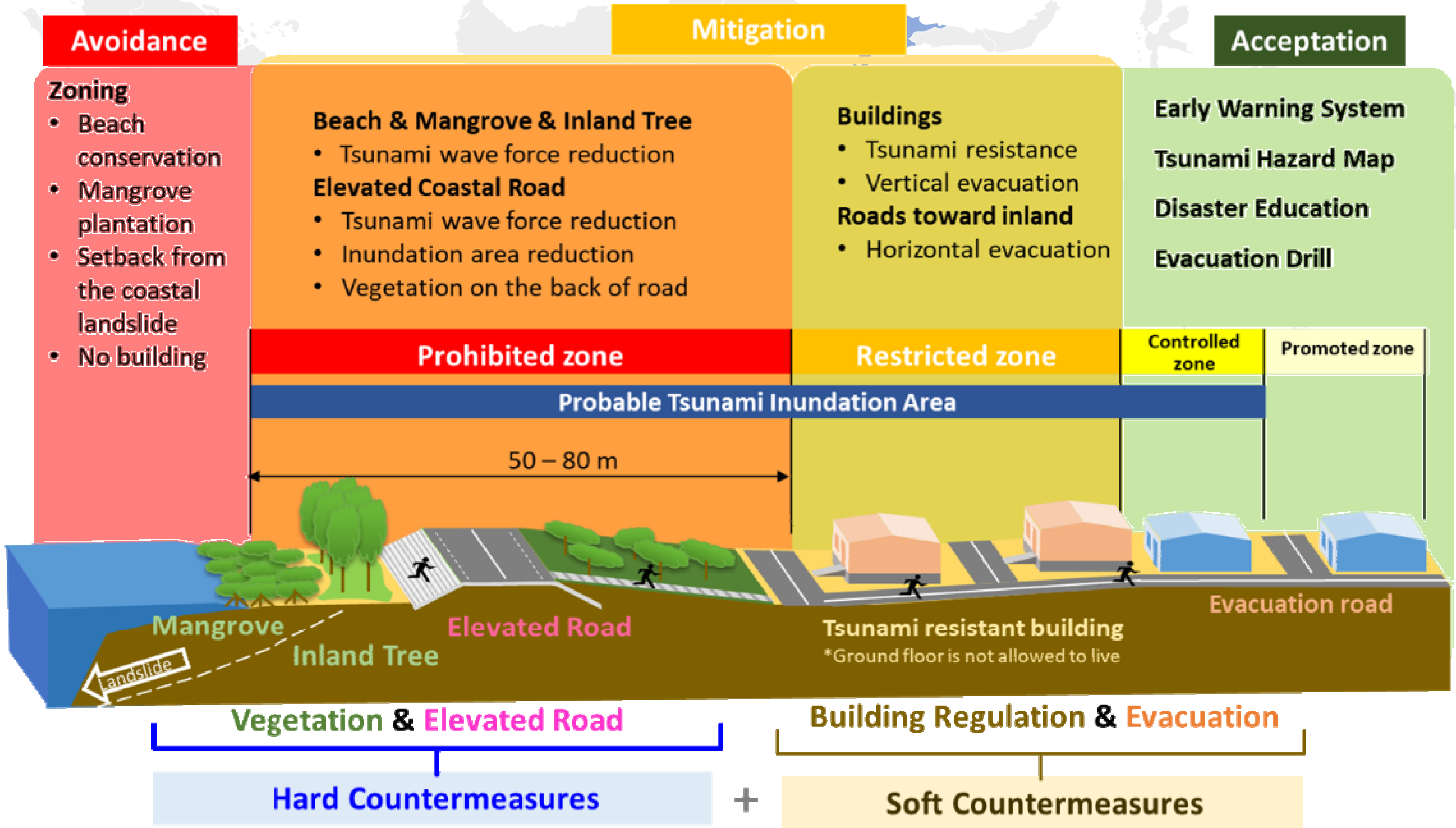
Other Facilities of Palu Bay South

- Huntap(LERE)
- Coastal Protection
- Fishing Boat Mooring Facility

Basic Concept of Tsunami Damage Reduction System

The basic policy for Tsunami countermeasures in Palu Bay, which was confirmed at the panel meeting in August last year, is as follows:

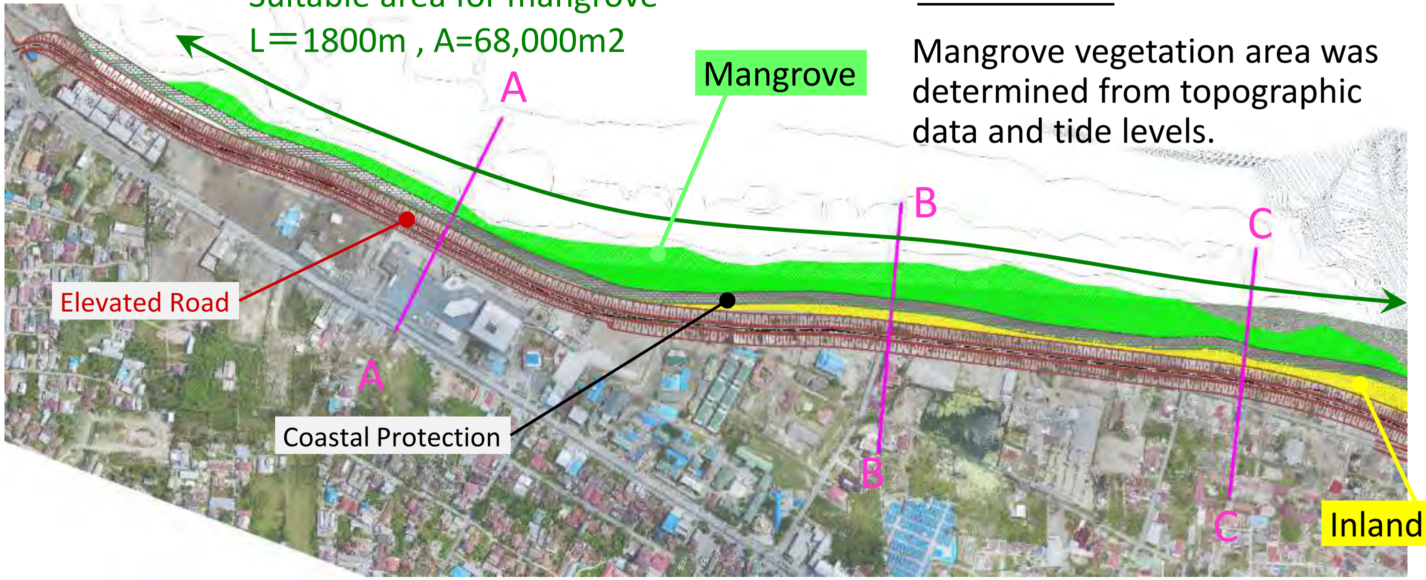
- ***The Tsunami countermeasure policy is based on a comprehensive combination of multiple facilities to reduce Tsunami energy include vegetation, elevated road, and other soft countermeasures such as evacuation policy and building regulations, rather than relying on only one hard countermeasure.***



Draft Combination Countermeasure with Vegetation & Elevated Road

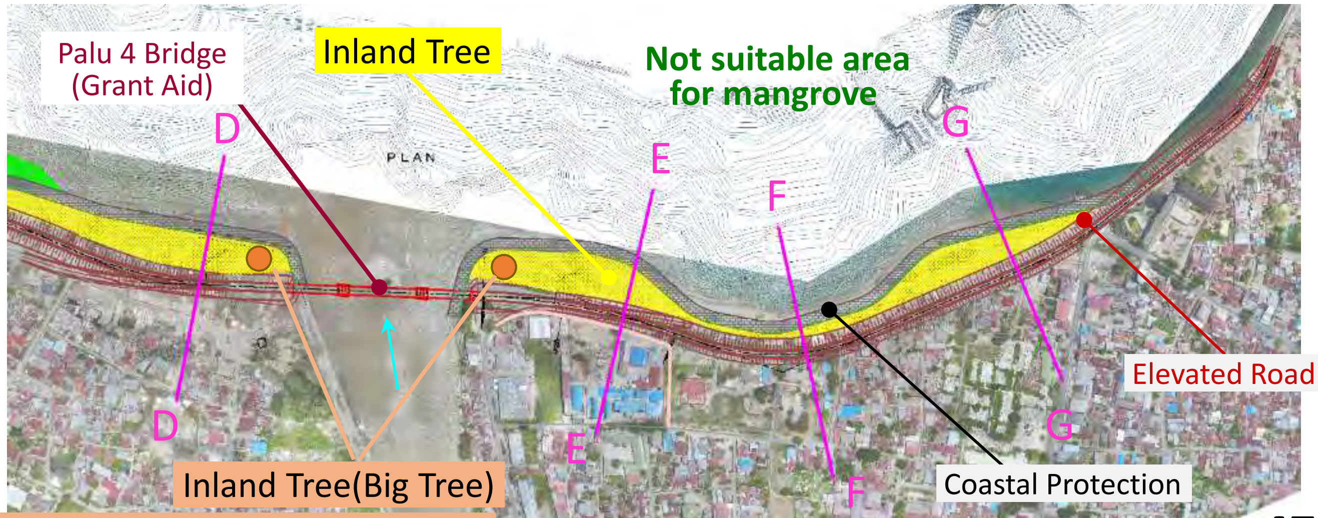
West Side

Mangrove vegetation area was determined from topographic data and tide levels.



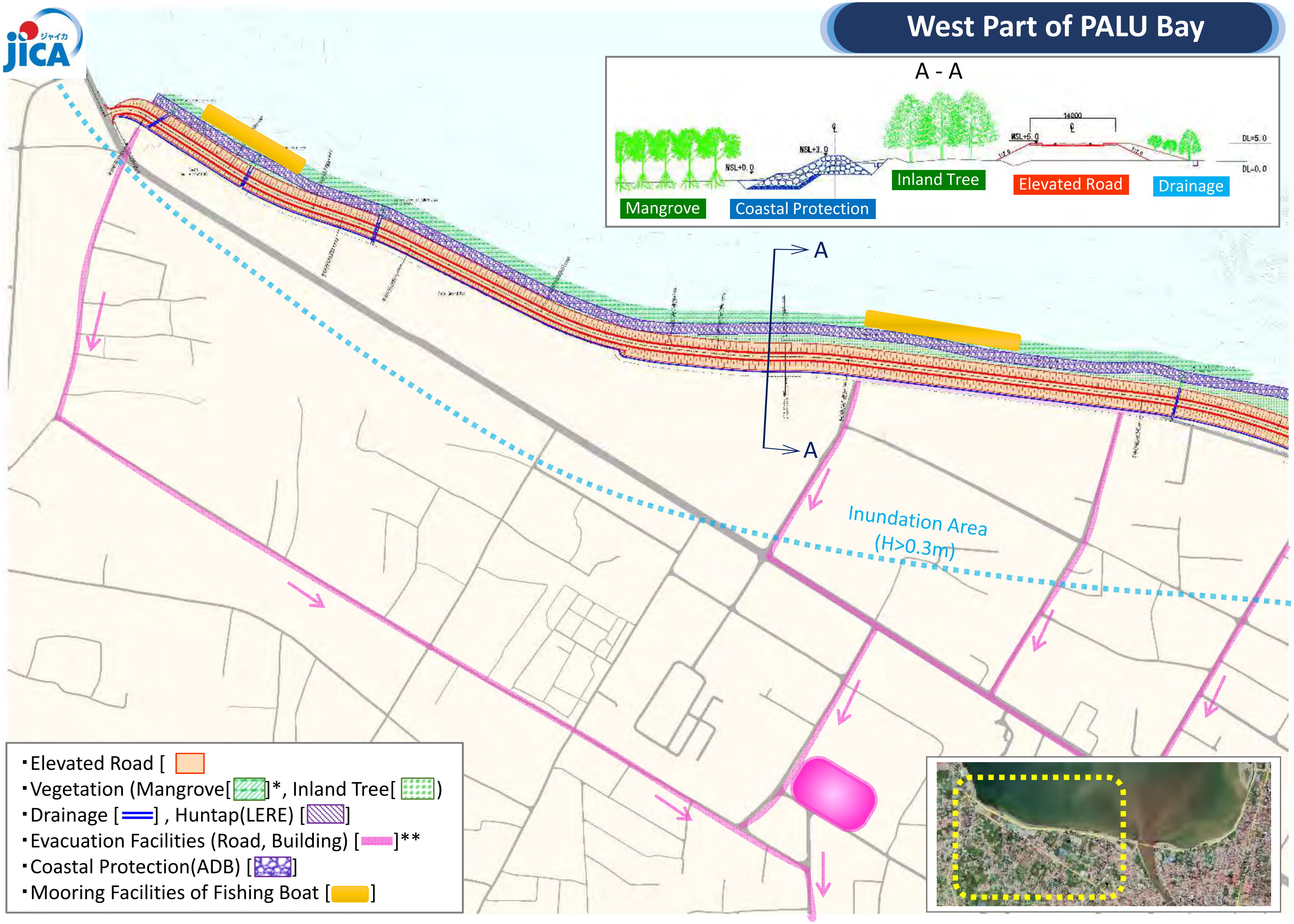
Inland Tree
West Side : 31,000m2
East Side : 30,500m2

East Side



As a park monument with Palu 4 Bridge

West Part of PALU Bay

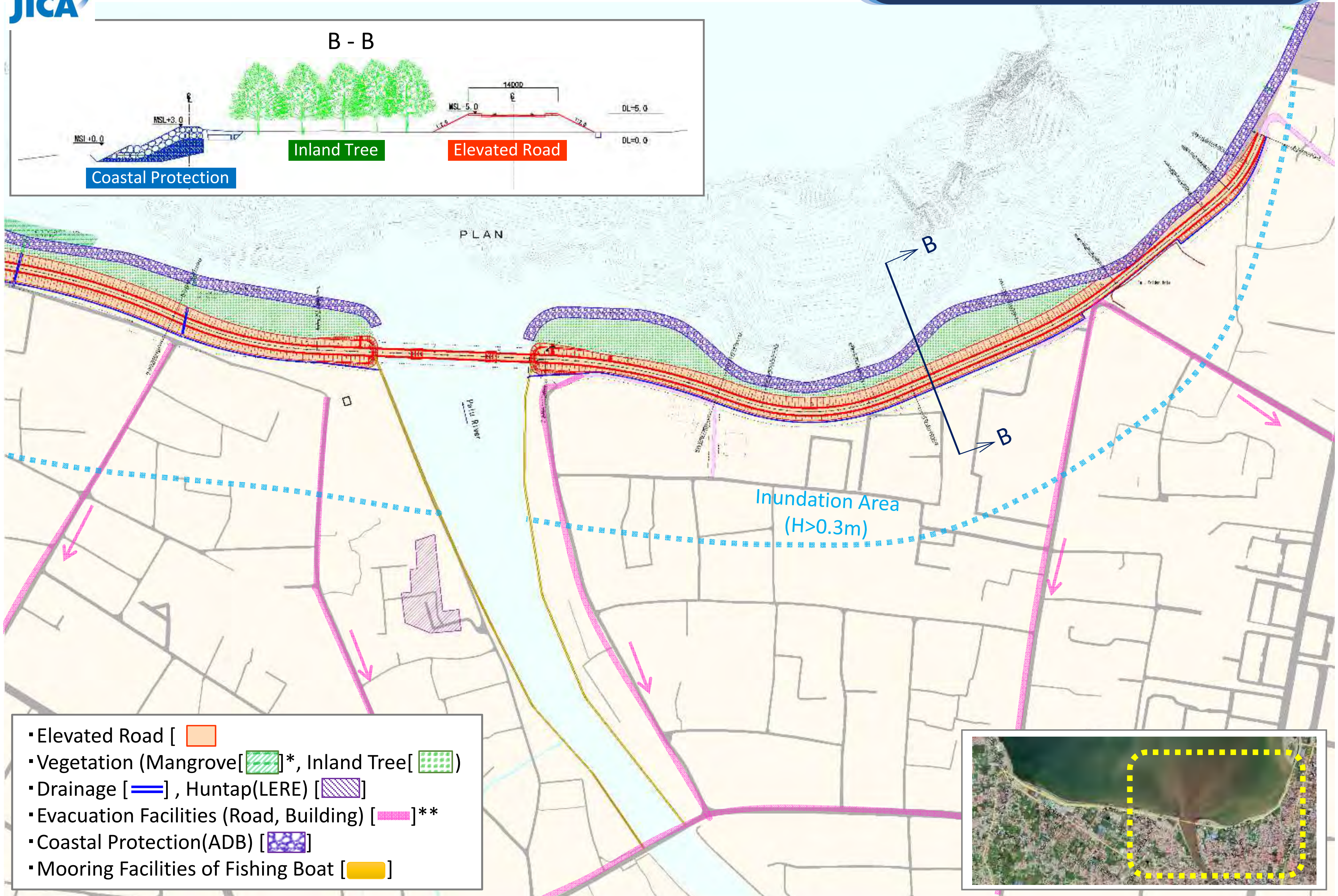


- Elevated Road [ ]
- Vegetation (Mangrove[ ]*, Inland Tree[ ])
- Drainage [ ] , Huntap(LERE) [ ]
- Evacuation Facilities (Road, Building) [ ]**
- Coastal Protection(ADB) [ ]
- Mooring Facilities of Fishing Boat [ ]

*The mangrove plan was based on the drawing with the project name "Flood Management in Selected River Basin Sector Project Loan No,.3440-INO".

**The evacuation facilities were based on the BPBD planning in 2017.

East Part of PALU Bay



- Elevated Road [ ]
- Vegetation (Mangrove[ ]*, Inland Tree[ ])
- Drainage [ ] , Huntap(LERE) [ ]
- Evacuation Facilities (Road, Building) [ ]**
- Coastal Protection(ADB) [ ]
- Mooring Facilities of Fishing Boat [ ]

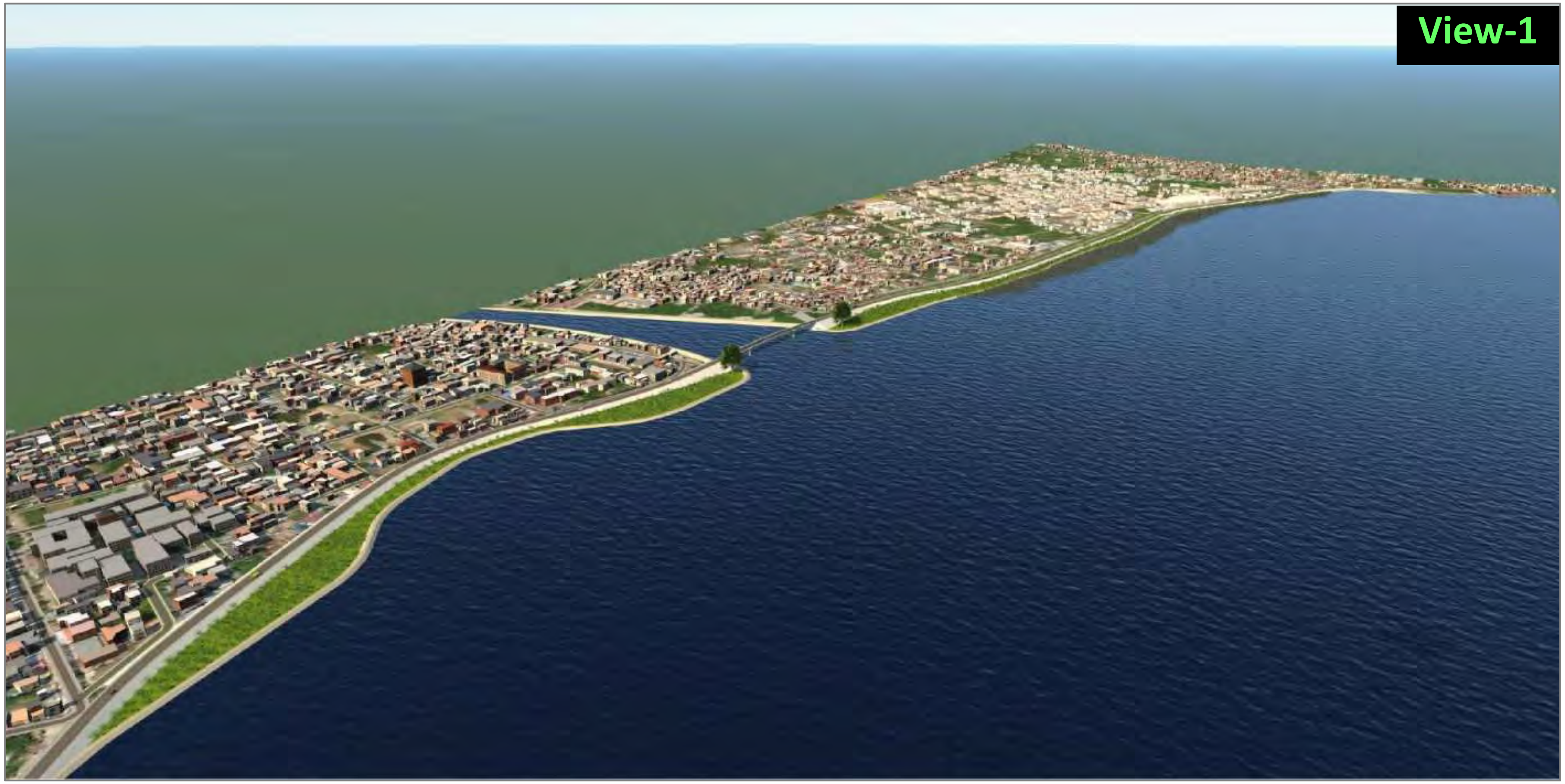
*The mangrove plan was based on the drawing with the project name "Flood Management in Selected River Basin Sector Project Loan No,.3440-INO".

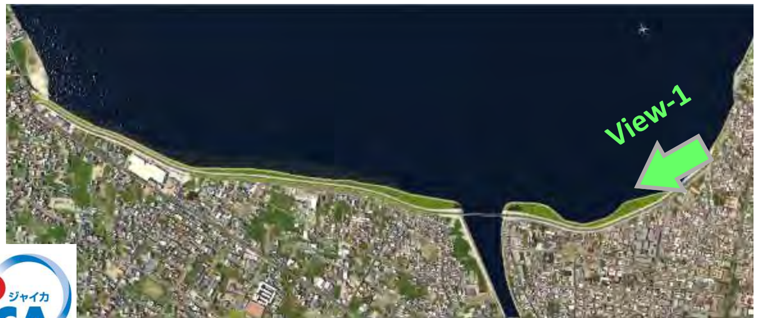
**The evacuation facilities were based on the BPBD planning in 2017.

A multi stakeholders collaboration is necessary [*Tentative*]

No	Name	In charge Institutions	Remarks
1	**Elevated Road & Palu IV Bridge**	**JICA Project (IRSL) & PUPR (BM)**	Start mid 2021 (estimated)
2	**Coastal Protection**	**ADB Project & PUPR (SDA)**	On going project
3	**Vegetation (Mangrove, Inland Tree & Big Tree)**	**PUPR (SDA) & BNPB**	Sand nourishment & mangrove planting need continues monitoring
4	**Fishing Boat Mooring Facility *(Tambatan Perahu)***	**PUPR (SDA) & Palu City**	Need to coordinate with mangrove vegetation area
5	**Drainage Network System**	**PUPR (Cipta Karya) & Palu City & JICA Project (IRSL)**	incl. polder system behind elevated road for overflown Tsunami's water
6	**Building Regulation**	**Palu City**	• Land use regulations based on new Tsunami Hazard Map • Piloti house (Ruko type)
7	**EWS (Early Warning System)**	**BMKG, BNPB & Palu City (BPBD)**	Local Tsunami (3-5min golden time)
8	**Evacuation System**	**BNPB & Palu City (BPBD)**	Routes, Signboard, utilization of existing building as vertical TES, etc
9	**Evacuation Drills & Disaster Education**	**BNPB, Palu City (BPBD)**	• Develop a sustainable drills system, by considering the financial aspect of local government. • To include disaster education into school curriculum • Prepare contingency plan, SOP • Conduct drills on regular basis, etc.

Basic concept for tsunami countermeasures





*Buildings behind the elevated road and park facilities are under consideration separately

Basic concept for tsunami countermeasures

*Buildings behind the elevated road and park facilities are under consideration separately

Basic concept for tsunami countermeasures

*Buildings behind the elevated road and park facilities are under consideration separately

F I N

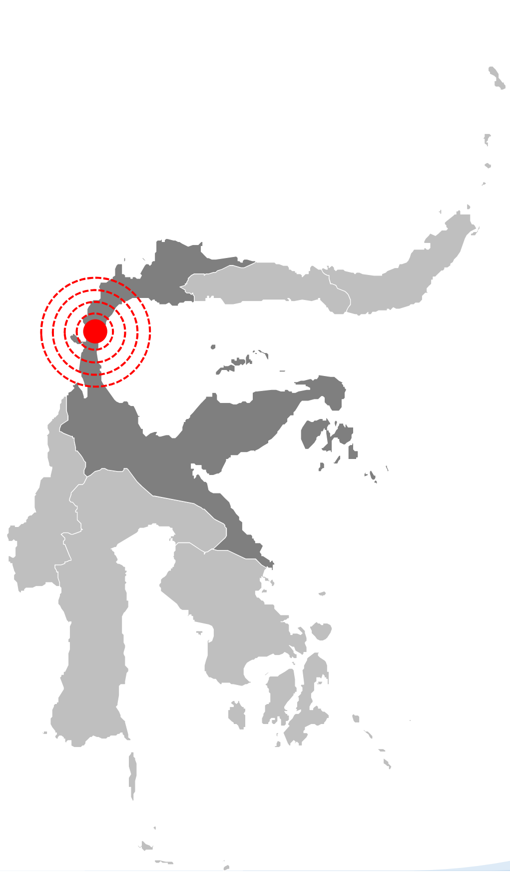
Thank you for your attention

Terima kasih untuk perhatiannya

JICA Technical Corporation Project

The Project for Regional Disaster Risk Resilience Plan in Central Sulawesi Province of the Republic of Indonesia

Final Tsunami Panel Expert Meeting



The 3rd Meeting

– Reference –

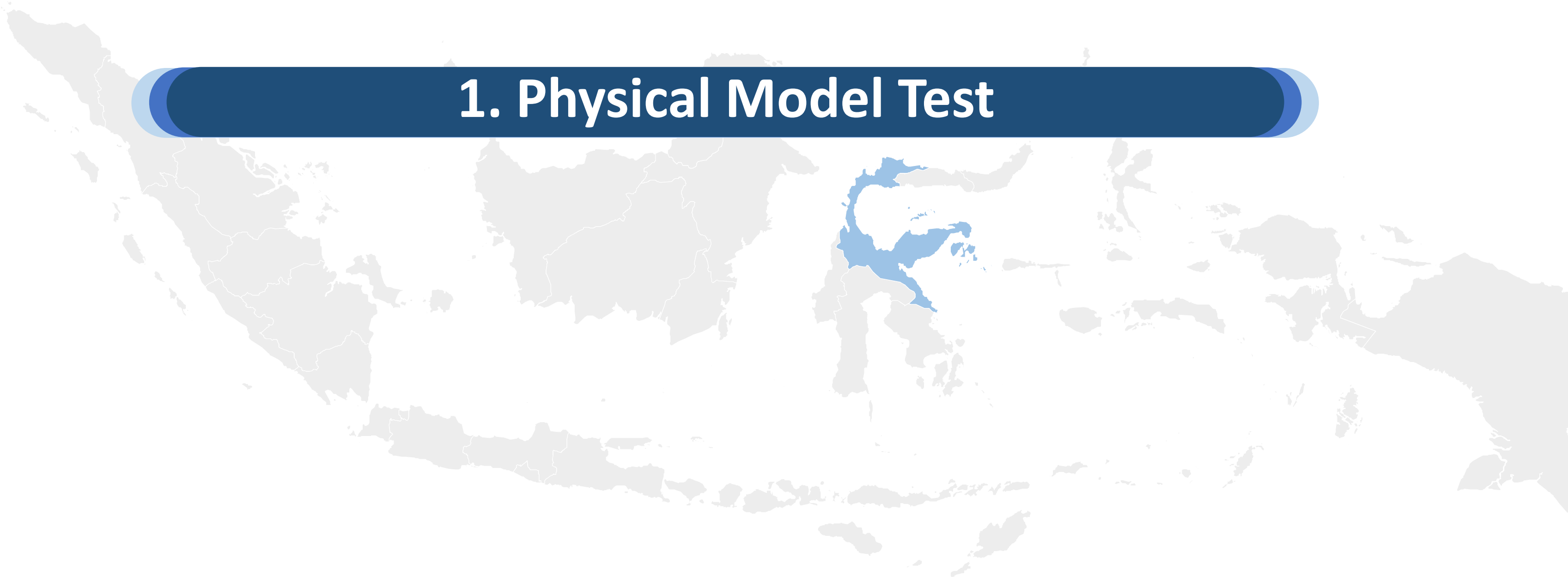
Physical Model Test

January, 2021

Contents

1. Physical Model Test
2. Survey for vegetation models

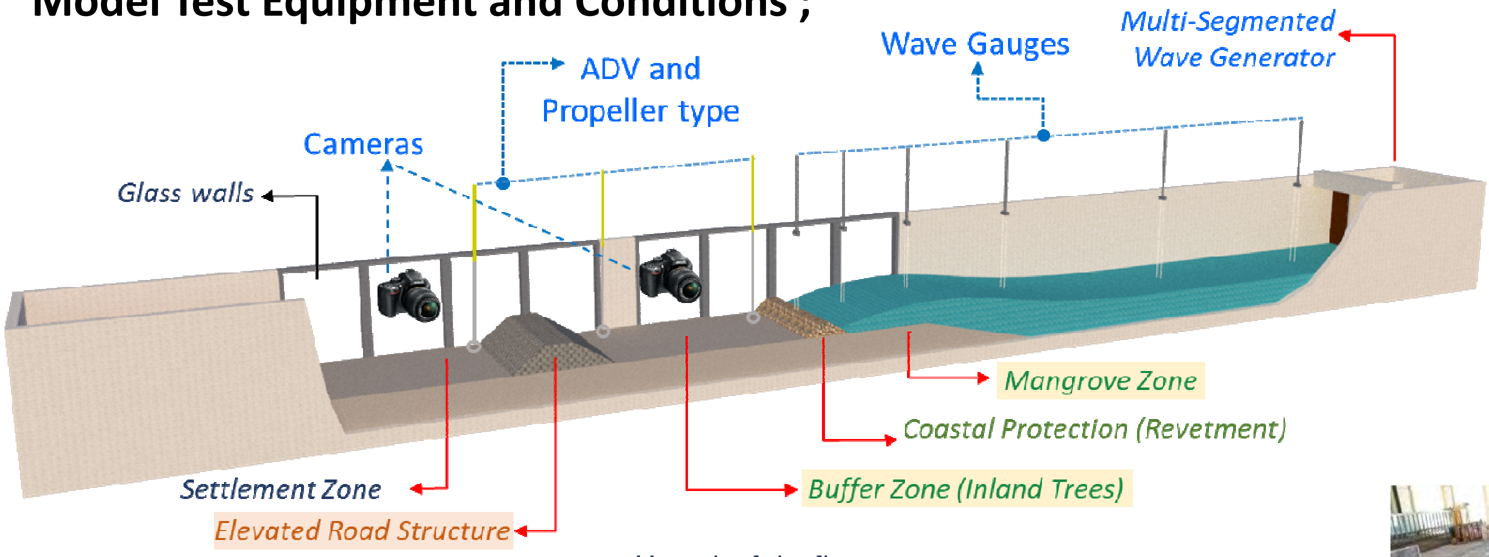
1. Physical Model Test



Physical Model Test

- **Purpose** ; The tsunami mitigation effect of vegetation (mangroves, trees) will be confirmed by a physical model test. Until now, there is no research on short-term tsunamis in 2018.

- **Model Test Equipment and Conditions ;**



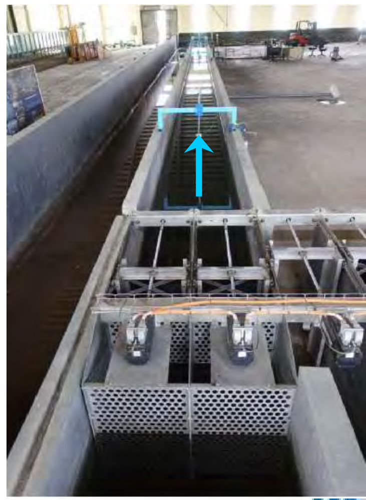
Overview of model test equipment

Model scale and others

Aquarium	L= 40m, W=1.0m
Scale	1/S = 1/ 50
Slope of sea bed	1:100 (left bank)
Wave machine	Paddle type

Model scale relationship

Item	Symbol	Scale
Length, Width	S	50
Time	$\sqrt{S}$	7.07
Velocity	$\sqrt{S}$	7.07

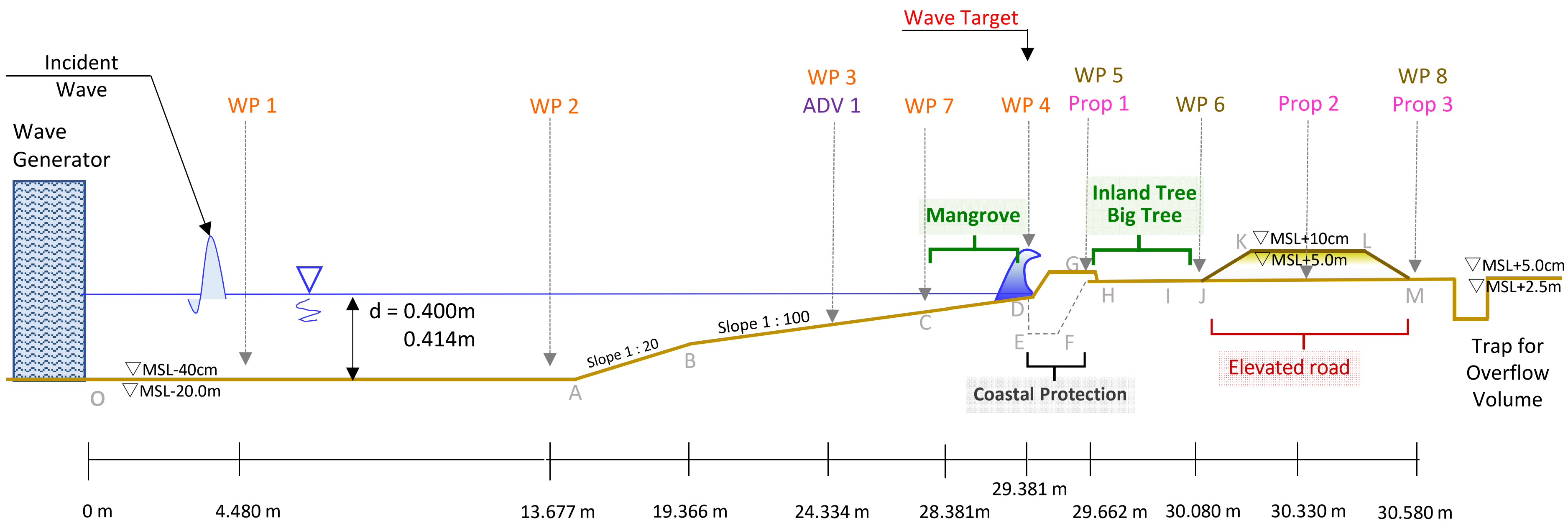


Equipment situation

4

Physical Model Test

➢ Side View of the Model Test Equipment



Legend
- WP1, 2, 3, 4, 7 : Water depth (Probe sensor)
- WP5, 6, 8 : Water depth (Camera)
- ADV1, 2 : Flow velocity (Acoustic doppler sensor)
- Prop1, 2, 3 : Flow velocity (propeller type)

3BCS Project Build Back Better Central Sulawesi

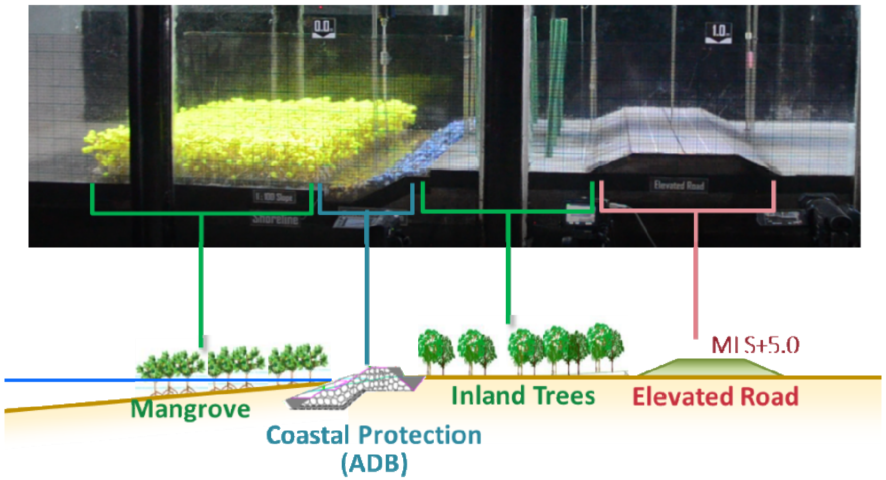
JICA

Physical Model Test

➢ Table of Model Test Scenario

Scenario	Tide	Vegetation	Wave Height Level	Remarks
Scenario-A	MSL+0.7	Mangrove	MSL+ 3.5, 4.5, 5.5m	Focus to Mangrove ① Tide Level：**2018 disaster**
Scenario-B	MSL+0.0	Mangrove	MSL+ 3.5, 4.5, 5.5m	Focus to Mangrove ② [Reference] Tide Level：Mean Sea Level
Scenario-C	MSL+0.7	Inland Tree	MSL+ 3.5, 4.5, 5.5m	Focus to Inland Tree Tide Level：**2018 disaster**
Scenario-D	MSL+0.7	Big Tree	MSL+ 3.5, 4.5, 5.5m	Focus to Big Tree *BNPB request Tide Level：**2018 disaster**

※Design wave height level in the 2018 disaster is MSL + 5.5m



Physical Model Test

➢ **Model Test Scenario (Scenario-A ～D)**

< Legend >
D : Interval
W: Width

Scenario-A

Reproduction of the 2018 tsunami

Scenario-B

Scenario-C

Physical Model Test

➢ **Model Test Scenario (Scenario-D)**

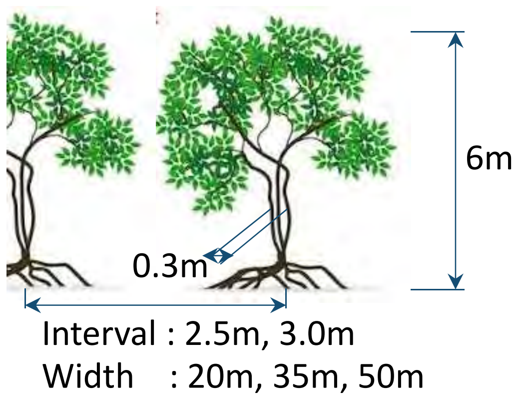
Scenario-D

Physical Model Test

➢ Model Planning (Scenario-A～C)

◆ Mangrove

・Set dimensions, density and width based on a survey of in Palu Bay
・Material: Steel wire



Mangrove model

Site Survey Result of Mangrove

・Interval: 2.59m
→ 2.5m[5cm]
・Trunk: 0.34m
→0.3m[6mm]
・Height: 5.75m
→6.0m[12cm]

*[] Model Dimension

◆ Inland Tree

・The trunk diameter is set to 1m from the tree species grown in Indonesia (tree species: Ketapang). The tree crown is 10 m, and the tree spacing is set to 7.5 m in consideration of the 1/4 overlap of the tree crown, referring to the planting standards.
・The width of the tree is set to 25m from the planned average value in Palu Bay
・Material: wood

◆ Coastal Protection

・Reflects the outer dimensions of the coastal protection by ADB. However, the model is fixed because one's stability is outside the scope of this model test.
・Material: stone

Physical Model Test

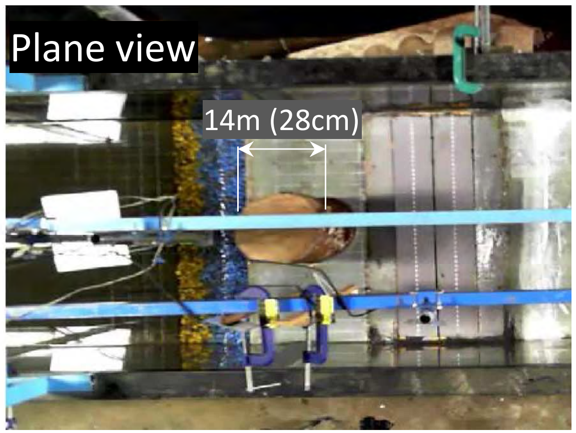
➢ Model Test Scenario (Scenario-D)

➢ Model Planning (Scenario-D)

◆ Big Tree

・A relatively large tree species was selected from the huge trees that grow in Indonesia (tree species: Palaka). The trunk diameter is set to 14m from the selected tree species.

・Material: wood



Physical Model Test

➢ Model Test Result

(1) Overflow Situation of Elevated Road

Without Vegetation

Wave Height,(m) Wabe Elevation, MSL+	Tide Level : MSL+0.7m Without Vegetation
2.8m (MSL+3.5m)	YES
3.8m (MSL+4.5m)	YES
4.8m (MSL+5.5m)	YES

Wave Height,(m) Wabe Elevation, MSL+	Tide Level : MSL+0.0m Without Vegetation
3.5m (MSL+3.5m)	NO
4.5m (MSL+4.5m)	YES
5.5m (MSL+5.5m)	YES

With Vegetation

Scenario-A — Tide Level : MSL+0.7m — Mangrove

Wave Height,(m) Wabe Elevation, MSL+	Width (m)	Interval (m) 2.5m	Interval (m) 3.0m
2.8m (MLS+3.5m)	20	NO	NO
	35	NO	NO
	50	NO	NO
3.8m (MLS+4.5m)	20	YES	YES
	35	YES	YES
	50	YES	YES
4.8m (MLS+5.5m)	20	YES	YES
	35	YES	YES
	50	YES	YES

Scenario-B — Tide Level : MSL+0.0m — Mangrove

Wave Height,(m) Wabe Elevation, MSL+	Width (m)	Interval (m) 2.5m	Interval (m) 3.0m
3.5m (MLS+3.5m)	20	NO	NO
	35	NO	NO
	50	NO	NO
4.5m (MLS+4.5m)	20	NO	YES
	35	NO	NO
	50	NO	NO
5.5m (MLS+5.5m)	20	YES	YES
	35	YES	YES
	50	YES	YES

Scenario-C — Tide Level : MSL+0.7m — Inland Tree

Wave Height,(m) Wabe Elevation, MSL+	Width (m)	Interval (m) 7.5m	Interval (m) -
2.8m (MSL+3.5m)	25	NO	-
3.8m (MSL+4.5m)	25	YES	-
4.8m (MSL+5.5m)	25	YES	-

Scenario-D — Tide Level : MSL+0.7m — Inland Tree (Big Tree)

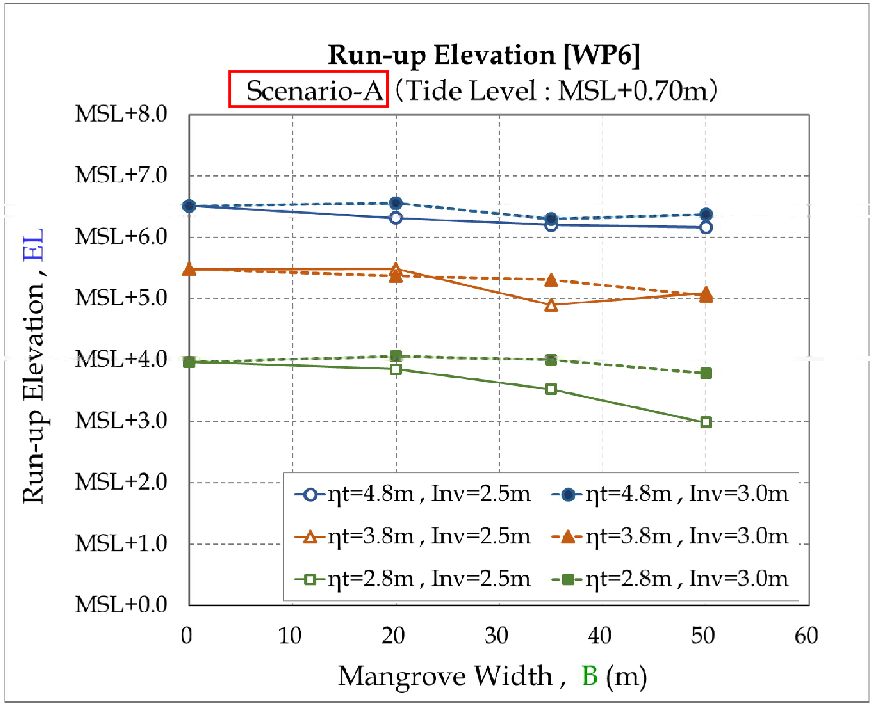
Wave Height,(m) Wabe Elevation, MSL+	Diameter (m)	Interval (m) 50m	Interval (m) -
2.8m (MSL+3.5m)	14	YES	-
3.8m (MSL+4.5m)	14	YES	-
4.8m (MSL+5.5m)	14	YES	-

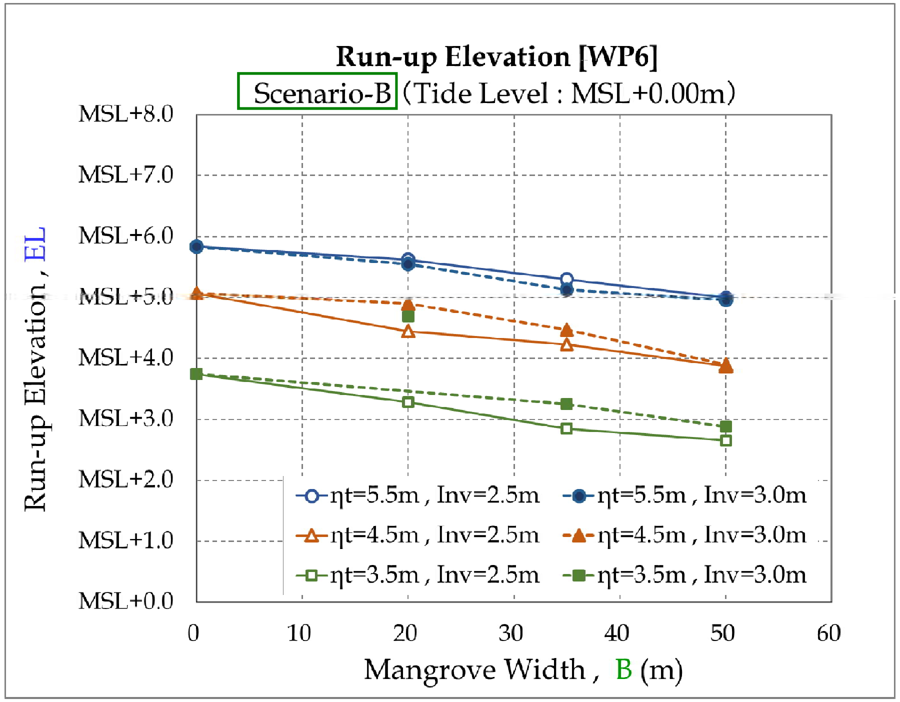
Legend
YES – Overflow , NO - Not Overflow

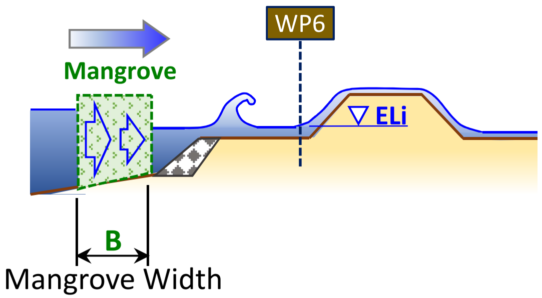
Physical Model Test

➢ Model Test Result

(2) Measured data/ Scenario-A,B / Run-up Elevation





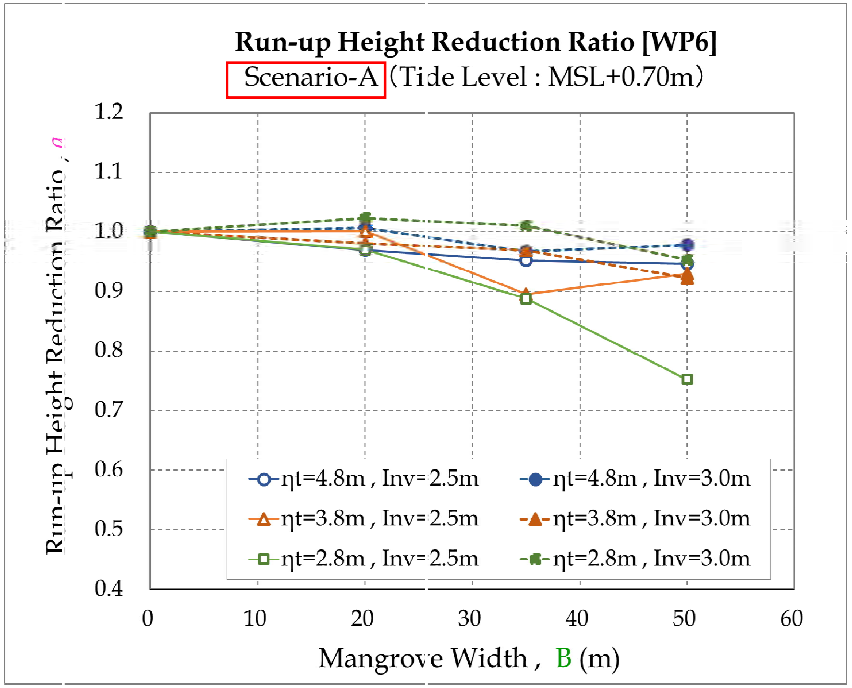


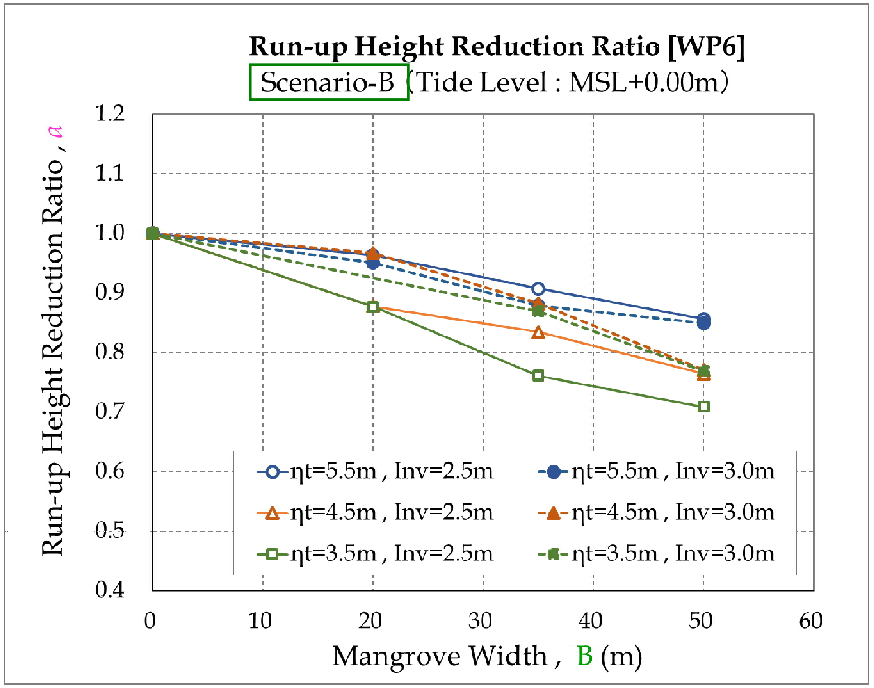
[Comments]
-The lower the wave height, the greater the mitigation effect by vegetation.
-The lower the tide level, the lower the run-up elevation.
-The lower the tide level, the greater the mitigation effect by vegetation.

Physical Model Test

➢ Model Test Result

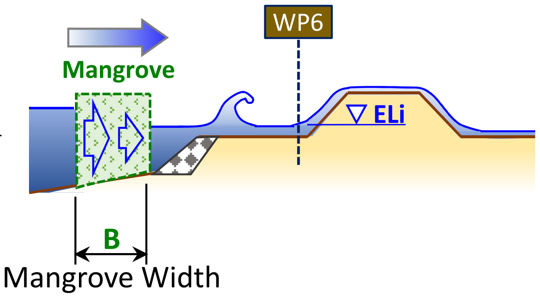
(2) Measured data/ Scenario-A,B / Run-up Elevation → Run-up Reduction Ratio





Run-up Reduction Ratio (α)

$$= \frac{\text{Run-up EL with Mangrove (ELx)}}{\text{Run-up EL without Mangrove (ELy)}}$$



[Comments]
-The lower the wave height, the greater the mitigation effect by vegetation.
-The lower the tide level, the greater the mitigation effect by vegetation.