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# Development processes of a master plan for flood protection and mitigation in a community area: A case study of Roi Et province

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**Abstract**

Development processes of a master plan formulation for flood protection and mitigation consists of the selection process of a targeted area based on risk level, developing a present and future flood inundation map and a flood risk map and identify direction and drainage capacity of the targeted area. Main causes of flooding in the area can be identified leading to designing flood protection and a flood drainage system in both structural and non-structural measures, prior to a public hearing process from stakeholders to finalize the master plan to provide maximum benefits and less negative impact. These processes are applied to Roi Et Province. Based on flood risk criteria, 24 municipalities with high risk are selected. The cause of flooding in the municipality area can be combined in 2 groups, flooding from low efficiency of storm drainage capacity and flooding from overbank flow from the Mun, Chi and Yang Rivers. Structural measures for the first and second group are the improvement of the existing system or changing a new drainage system and the improvement of existing river dikes and levees. It is also possible to design and construct a new one. Constructing a polder system for the community area, requires a budget about 3,338 million baht. To support structural measures, non-structural measures are required, for example, a flood warning system, an emergency response plan during flood disaster.

**Keywords:** Flood inundation map, Flood risk map, Drainage capacity, Polder system, Chi river basin, Mun river basin

## 1. Introduction

Flood is a natural significant disaster in Thailand. Most people live on floodplain of major river basins frequently experience flooding. With the same magnitude, flood impact on community area is more severe than on agricultural area. For long term protection and mitigation, planning process is necessary to solve this problem. In the basin on north-east of Thailand, [1] divided flood affected area into 2 groups. For the first group, slow floodwater with slow velocity come from flat area between large hilly area along mountain range and floodplain of Mun and Chi River. The second group is flood inundation occurring between floodplain to river bank of the Mun and Chi Rivers and its tributaries. Flood risk area using Geographic Information System (GIS) was studied by [2]. Flooding boundary and depth was estimated with 10, 25 and 50 years return period and used them to draw flood risk map which was easy to understand. Simulation results was compared to recorded flood boundary from satellite image RADARSAT with SAR system. Although correction ratio is about 28 %, shape of flood boundary is similar. Study results by [3] using GIS for Roi Et province shows that repeated flood risk area with high medium and low risk index are 1,313.1 4,350.2 and 2,050.0 km$^2$.

Proposed methods to solve flood problem, for example, study report of flood mitigation in Selaphum district, [4] referred to the feasibility study of flood mitigation in the Yang River Basin prepared by Southeast Asia Technology Co., Ltd and Eng-Cad Consultant Co., Ltd, September 2003, together with specialist 's comment from many organizations concluded that flood affected area should be divided to 2 parts, (1) upper Yang River where the area is moderate steep slope, flooding come from excess rainfall between June to July convert to flash flood on agricultural area. To prevent flood in this area, structural measures can be used such as constructing bypass channel, dikes and increase drainage capacity by channel dredging to reduce water level. For part (2), lower Yang River is lowland, flood always occur during the end of rainy season and high backwater effect from high water level in the Chi River downstream causing overbank flow. Study results confirmed that using structural measures will create negative impact and no effect on the decrease of river level. Therefore, non-structural measures should be implemented, for example, set up land use regulation to control the development of roads, building and bridges with minimum obstruction to natural channels or allowing high drainage capacity. Study results from [5] presented flood map in Year 1978 using satellite image from LANDSAT. The map showed present and future flood protection projects in the Chi River. Flood peaks for the Chi River were estimated between a junction with the Lam Pao and Yang River for return period 2, 5 and 10 years are 1,009, 1,690 and

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2,152 $m^3$/s, respectively. Flood routing study in the Chi River using Info Works RS model [6] proposed an approach for flood warning system by considering maximum channel capacity of river. Flood mitigation approach was proposed, for example, channel dredging, channel cross-section improvement to trapezoidal shape to allow river to carry more discharge with the reduction of maximum water level. For potential development in the Chi River, [7] suggested that basins with the most deficit water are the Yang, lower Nam Pong and upper Nam Pong, respectively. For the Yang River basin, reservoirs project should be implemented with minimum storage of 40 million $m^3$ at the upper or central part of the basin. Previous studies in the Chi River and its tributaries had been conducted including assessment of channel storage potential of the Chi River Basin [8] and flood alleviation projects in Maha Sarakham province based on integrated plans [9]. From past to present, people in Roi Et is still suffer from flood problem, especially, in wet year. Study processes on how to solve this problem is required to develop master plan of flood protection and mitigation and focusing on community area.

*1.1 Flooding problem from past to present*

Flood damage study in the Chi Basin, in case of Roi Et Province, reported by the office of provincial agriculture [10] showed that affected flood area in year 2004 (779.9 $km^2$), 2006 (134.2 $km^2$), 2007 (311.0 $km^2$), 2008 (170.8 $km^2$), 2009 (95.0 $km^2$), 2010 (276.7 $km^2$) whereas interpretation results from satellite images depicted that the size of affected flood area in year 2004 was less than reported area from farmers. Therefore, it is necessary to incorporate and consider interpretation results from satellite images for estimation of the affected area. For damage assessment, the provincial disaster prevention and mitigation center reported that in year 2004 low monsoon trough on northeast Thailand caused heavy rainfall and high water level flood in Yang agricultural area and community area was inundated by flooding in 5 districts 31 sub-districts 301 villages consist of Selaphum, Pho Chai, Nong Phok, Phon Thong and Moei Wadi District, affected flood agriculture area, people and household were about 48 $km^2$, 75,200 persons and 18,246 households, respectively.

Study results of [10] suggested that capacity of individual farmer and community was limited with low efficiency and beyond their potential. To solve flood problem, systematic measures and integrated operation between government and agencies are required on all levels, community, province and river basin.

*1.2 Physical characteristics of Roi Et province*

Total area of Roi Et is 8,299 $km^2$, divided to 20 districts and 1 Mueang municipality (MM) and 64 sub-district municipalities (SDM). Typical topography is a plateau, average elevation is about 120-160 m from sea level. Northern part is mountain area connect to Pu Phan mountain range. Middle part is flat area. North, central and east of Roi Et is in the Chi River Basin. Lam Pao tributaries flow to join the Chi River before it flows through Roi Et boundary and passing 8 districts, Chang Han, Chiang Khwan, Pho Chai, Thawat Buri, Thung Khao Luang, Selaphum, At Samat and Phanom Phrai, with total length of 210 km. After the Chi River flows out of Roi Et, the Yang River from northern tributary joins the Chi River and flow is continuing between Roi Et and Yasothon Province. South of Roi Et is in the Mun River Basin and its tributaries. Lam Tao joins with Lam Sieo Yai Stream at Kaset Wisai District and Lam Sieo Noi flows to Lam Sieo Yai at Suwannaphum District, prior Lam Sieo Yai joins with the Mun River at about the north of Rasi Salai District, Si Sa Ket Province. Lam Phrub Pha stream is on southern boundary between Roi Et and Surin province, consist of large low land in flat pan shape called Thung Kula Rong Hai, with sizing 128 $km^2$. Overbank flow from the Mun River frequently occurs causing severe impact to people.

For current land use of Roi Et, majority is agricultural area 79.5 % forest 6.4 %, pasture and bush 4.3 % and community and habitat area 5.2 %. Climate characteristic from climatological data 30 year period (1971-2000) are as follow: averaged temperature, relative humidity, atmospheric pressure, pan evaporation, annual rainfall and annual runoff are 26.7 degree Celsius, 71 %, 1,009.1 hecto Pascal, 1,659.3 mm, 1,345.3 mm and 161.0 mm (at station E.18, Chi River, Thung Khao Luang District, Roi Et, 41,187 $km^2$, about 12 % of rainfall) respectively.

## 2. Study criteria

*2.1 Criteria for selection of targeted flood area*

The selection criteria of Roi Et area for proceeding master plan studying is based on 3 main factors as follow:

1. Flood risk factor, total score is 20, consist of (1) topography of community area (floodplain / flat / hilly area), (2) all causes of flooding in past 20 years from records and villager interviewing, (3) population density (dense/medium/low).
2. Severe level of flooding, total score is 50, consist of (1) chance or frequency or return period of overbank flow occurring in main river, (2) inundation depth of flood, (3) inundation duration time.
3. Significance of area, total score is 30, consist of (1) the impact on normal living of people in flood affected area, (2) significance of community area in term of economic, society, art and culture such as ancient and/or religious place, (3) cooperation and participation from local people in problem solving.

Minor factors are considered by giving different weight depending on its significance. Evaluation score is varying from maximum 5 to minimum 1 for each variable of factors, for example, given weight for topography of community area is 1, evaluated score is 5 (area is located in floodplain or a river), 4 (distance from the river is shorter than 1,000 m), 3 (distance from the river is longer than 1,000 m), 2 (it is on flat area far from river), 1 (it is on hilly area). Details of all variables is presented in [11].

*2.2 Criteria for formulation of flood protection system*

Flood protection system can be divided into 2 aspects: land approach and water approach. Flood control using land approach is area protection from flooding. A polder system is designed to prevent overbank or surface runoff flow from neighbor area. Flood control using water approach is the increase of drainage capacity by channel improvement or bypassing water from community area by using diversion channel and hydraulic structure to control excess discharge flowing to community area and seeking detention storage to store excess water. Flood protection measures can be grouped into (1) structural measures consist of constructing embankment of polder system for targeted area, improvement of channels and hydraulic structures to reduce flood impact, improvement of diversion channel, drainage system and constructing reservoir on upstream area etc. (2) non-structural measures or less structural measure consist of implement the regulation of town planning to control land use in flood affected area and the other area, flood warning system, emergency response plan, rehabilitation plan, regulation and organization enforcement and managing integrated and development plan from all organizations.

## 3. Methodology

### *3.1 Data collection for flood problem*

Flood data was collected for problem analysis in two main aspects.

1. Available physical behavior of flood problem in past floods including inundation depth, duration and locations, frequency of flooding and flood damages and losses. Sources of this data is available at provincial and district office, particularly, the provincial disaster prevention and mitigation center. Direct affected people from flooding can provide valuable details of information for flood characteristic and damages. For broad overview of inundation boundary, aerial photos or satellite images of remote sensing data can be used to estimate the boundary and area which it is not difficult to find this data at present. Flood depth and duration can be interpreted from water stage records from gauging stations along the rivers.

2. Physical characteristics of catchment area such as river elevation profile, cross sections of main river and its tributaries, ground elevation of floodplain, shape of hydraulic structure across the river channel, for example, sluice gates, bridges and culverts, exiting dikes and embankments, irrigation canals. These structures can behave as an obstruction of channel flow. Land surface elevation can be obtained from topographic map with scale 1:50,000 produced by Royal Thai Survey Department if the other sources of larger topographic map with smaller scale (<1:10,000) such as municipality map, irrigation map and land taxation map are not available. By using small contour intervals in small scale map, hydraulic analysis will give the imitated results close to what happen in real topography. Cross sections of the channels and the details of hydraulic structures are important required information. If there is no past records and drawing of this information, new surveying is required.

### *3.2 Selection of flood affected area*

Evaluation score was calculated from multiplication of weighting value according to major and minor factors with its score (1 to 5) based on flooding and hydrologic conditions in section 3.1. Summation of the score from all factors were determined. Targeted area was defined and selected if summation of the score is above 50.

### *3.3 Flood inundation map and flood risk map*

Boundary area of flood inundation is depicted by flood inundation map. Overlay of flood map on existing and future land use map, coincided locations between community area with high population density (people per km$^2$) and high flooding situation (high inundation depth, long duration and high flow velocity) can be classified as high risk area. By using this method, flood risk map for all targeted area is constructed and used to assess the results of future flood mitigation if a preventive measure is implemented. Figure 1 demonstrates flood inundation map of Khoaw SDM.

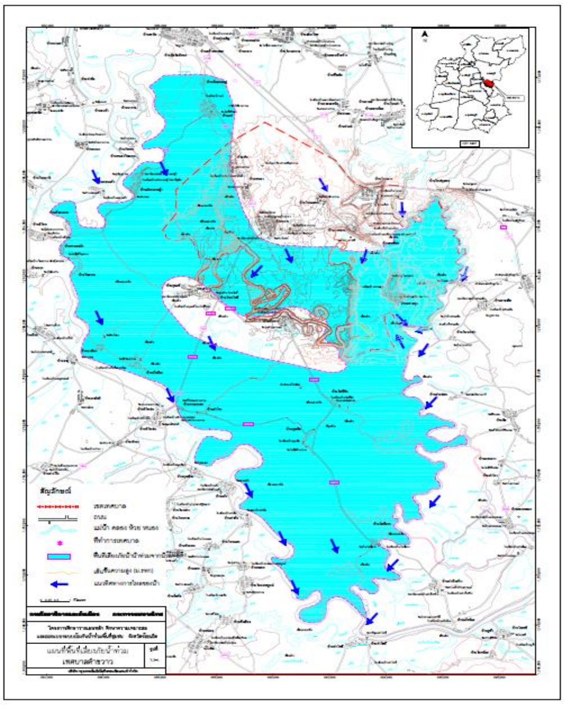

**Figure 1** Flood inundation map of Khaow SDM

### *3.4 Defining of drainage direction and capacity*

Drainage direction of surface flow and runoff can be identified from catchment boundary, stream network and topographic map. Drainage capacity of stream and river channel was estimated based on the principle of steady uniform flow using Manning equation. Drainage capacity of storm sewer was estimated by using Rational method, design maximum rainfall from intensity-duration-frequency curve. In case of flow in stream network, routing hydrograph was calculated by using a hydraulic model such as HEC RAS.

### *3.5 Formulation of master plan*

Based on the review of previous study, the analysis of collected data in all aspects: physical and social condition, environment, meteorology and hydrology, master plan of flood protection and drainage system were formulated and proposed in different alternative ways based on the cause of flooding, topographic and drainage conditions for each community. The preliminary design of structural measures were drawn and cost of investment was estimated.

### *3.6 Priority and emergency plan*

Priority of each SDM and urgent need for flood protection system were considered based on 3 aspects of feasible analysis with different weighting factor. The weighting factor for engineering, economics and socio-economic aspects were 25, 25 and 50 respectively. Targeted area receiving high score have a priority to proceed to feasibility study and detail design.

## 4. Study results and discussions

### *4.1 Selected area*

Total 24 SDM and connecting Subdistrict Aministrative Organization (SAO) were selected consist of Thong Ta Ni, Ko Kaeo, Pak Wan, Muang Lat SAO, Khok Ko Muang, Din Dom, Saen Chat SAO, Cham Pa Khan, Khoaw, Mueang Roi-Et, Thung Kula, Dong Sing, Wang Luang, Hin Kong, Selaphum, Ku Ka Sing, Un Mao, Chom Sa-ard, Mueang Bua, Ni Vet , Suwannaphum, Non Tan, Kaset Wisai and Bung Led. Master plan for these SM MM and SAO for flood protection and drainage system were proceeded to formulate preliminary design, estimate bill of quantity and initial budgets. Location of the selected SDM MM and SAO are shown in Figure 2.

*4.2 Direction and capacity of drainage system*

Topography between the Chi River bank to Roi Et city core area is inclined slope. If the inner area receives heavy rainfall coinciding with high water level in the Chi River and surface runoff from excess rainfall is not effectively drained to the Chi River, flooding will occur, particularly, in the area of the Thung Sang Badan irrigation project. The capacity of the Chi River flowing through Roi Et Province was about 885 $m^3/s$, 9.50 m. water depth. From 10 years historical record of water level at station E18 (Tha Sabeang), average maximum water depth was 9.92 m, maximum discharge was 1,010 $m^3/s$. Because of flood level and discharge higher than the level of channel bank and flow capacity, this area always experienced repeated flooding. The majority of inundated area was agriculture fields in flat floodplain of the Chi River, frequently occur in rainy season during September to October.

*4.3 Cause of flooding*

Typical causes of flooding in Roi Et Province are as follow: (1) heavy rainfall under the influence of south-west monsoon wind and a depression from China sea, (2) flash flood from headwater of the Chi River Basin due to high rate of deforestation and steep slope, (3) inundation flood in flat floodplain area downstream of the Chi River Basin, joining of tributary channels including the Mun and Chi Rivers before flowing to Mekong River, drainage efficiency in this area is reduced if downstream water level in the Mun Chi and Mekong are high, (4) storage and detention basin for attenuation the size of flood hydrograph is not enough, deposition of sediment in the river and land encroachment of river cross sections by people cause the reduction of flow capacity of the river, (5) mismanagement of water in big reservoirs such as Lampao dam reservoir, Kalasin Province, in a wet year, large amount of discharge was released for dam safety reason, combined with released discharge from Ubonratana dam caused severe flooding downstream of the basin.

The main cause of flooding are overbank flowing of main rivers and inundation from storm water due to low efficiency of drainage capacity and degradation of river from sediment deposit and people encroachment. In summary, the main cause of flooding in each SDM MM and SAO is shown in Table 1.

*4.4 Design flood protection and drainage system*

Types of the system are designed based on (1) cause of flooding which can be divided into 2 main groups, overbank flow from main channel of river basin flooding and local flooding from storm rainfall, flood protection system for each community should be designed to fit to its cause and characteristics, (2) dikes and embankments for flood protection are improved from existing local roads and dikes, if it is necessary new route of dikes along river and canal banks, sluice gate and pumping station will be constructed to protect community area, (3) dikes is divided into 2 groups, improved from exiting dikes and roads and constructing new ones, height of the dikes are designed to protect 100 years flood or recorded maximum flood level, (4) to increase drainage capacity of natural channels for effectively receive and drain routing flood, (5) if natural canals are unavailable for primary drainage system, storm sewers along roads are used, (6) all components of drainage systems including sewers, sluice gate, pumping station and sump are sized to receive design rainfall with 2-5 years return period.

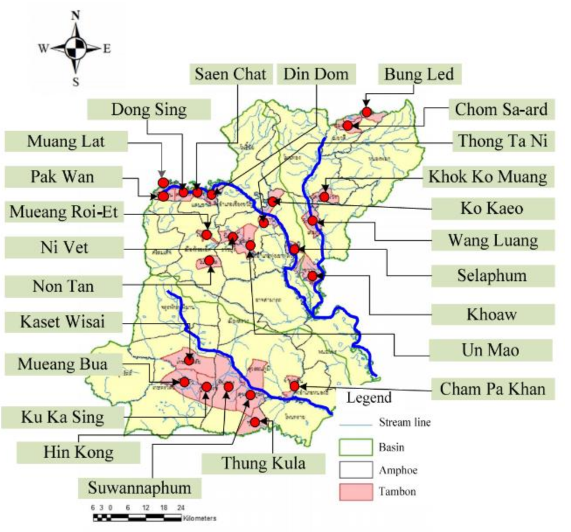


**Figure 2** Location of selected MM SDM and connecting SAO

*4.5 Master plan for flood protection and mitigation*

Table 1 presents the summary of master plan, area grouping based on river basin. Details of flood protection and drainage measures for 24 communities present in [11].

To mitigate flood disaster, only structural measures may not sufficient to confront flood events in all possible flood scenarios. Storm rainfall is natural phenomenon with high uncertainty beyond engineering control. To support the structural measures for sustainable flood protection, non-structural measures are required including (1) providing guild line and regulation of land use based on principle town planning for different levels, (2) enforced by a regulation and organization to encourage people to do following town planning act, (3) integration of flood protection plan to development plan of the Chi and Mun River Basin in short medium and long term plan, (4) defining risk area in case of structural measures are not fully implemented or level of protection is still below design levels, flood risk map for flood warning and emergency response plan are required, (5) preparing rescue operation plan for immediately response when flood is occurring, (6) preparing rehabilitation after flooding, (7) following operation criteria of water management for polder and drainage systems such as keeping low water level in canal and retention basin prior flood coming, (8) organizing public relation to rise people awareness and participation for brain storming and cooperation in all implemented steps of flood protection and drainage system including construction operation and maintenance period, (9) including master plan of flood protection system to master plan of community infrastructure

**Table 1** Brief of causes, flood protection system for each SDM MM SAO grouped by river basins

| Basin | Order | Causes of flooding | Problem solving methods | Name of SMs |
|---|---|---|---|---|
| Chi | 1 | Storm drainage | Improve drainage system, 1 water management area | Thong Ta Ni |
| | 2 | Storm drainage | Improve drainage system, 1 water management area | Selaphum |
| | 3 | Storm drainage | Improve drainage system and dikes, 1 water management | Ko Kaeo |
| | 4 | Storm drainage | Improve drainage system, 2 water management area | Un Mao |
| | 5 | Storm drainage | Improve drainage system, 2 water management area | Ni Vet |
| | 6 | Storm drainage | Improve drainage system, 3 water management area | Bung Led |
| | 7 | Storm drainage | Improve drainage system, 3 water management area | Non Tan |
| | 8 | Storm drainage | Improve drainage system, 5 water management area | Mueang Roi-Et |
| | 9 | Over-bank flow from river | Improve drainage system/ detention basin, 1 water management area | Chom Sa-ard |
| | 10 | Over-bank flow from river | Construct detention basin, 1 polder area | Din Dom |
| | 11 | Over-bank flow from river | Construct dikes, 1 polder area | Khoaw |
| | 12 | Over-bank flow from river | Construct dikes, 1 polder area | Muang Lat |
| | 13 | Over-bank flow from river | Construct dikes, 1 polder area, 1 detention basin | Wang Luang |
| | 14 | Over-bank flow from river | Construct dikes, 1 polder area | Saen Chat |
| | 15 | Over-bank flow from river | Construct dikes, 2 polder area | Pak Wan |
| | 16 | Over-bank flow from river | Construct dikes, 2 polder area | Khok Ko Muang |
| | 17 | Over-bank flow from river | Construct dikes, 3 polder area, 1 detention basin | Dong Sing |
| Mun | 1 | Storm drainage | Improve drainage system, 2 water management area | Suwannaphum |
| | 2 | Storm drainage | Improve drainage system, 2 water management area | Kaset Wisai |
| | 3 | Over-bank flow from river | Improve drainage system, 1 water management area | Ku Ka Sing |
| | 4 | Over-bank flow from river | Improve drainage system, diversion channel, 1 water management area, | Mueang Bua |
| | 5 | Over-bank flow from river | Improve drainage system, 1 water management area | Cham Pa Khan |
| | 6 | Over-bank flow from river | Improve drainage system, 1 water management area | Hin Kong |
| | 7 | Over-bank flow from river | Improve drainage system, 3 water management area | Thung Kula |

development, future utilization of land with inappropriate purpose may cause increase flood problem and losses, (10) integration of flood protection plan between community level to basin level is necessary, for example, construction and water management of new and existing reservoirs for flood mitigation.

## 5. Conclusion

Development processes for master plan of flood protection and mitigation in a case of Roi Et Province consisted of initial risk assessment of all SM, MM and continuing area to SAO, selection of them from its priority based on risk level. One selected MM was Mueang Roi Et, 23 SM and connected SAO were selected from 65 municipalities in total. Flood inundation map and flood risk map were constructed to present level of flood risk, direction of surface runoff and drainage capacity. Main causes of flooding can be divided into 2 groups, flooding from overbank flow from a river and inundation flood in the area with low efficiency of drainage. The master plan for the first group consists of (1) improving/constructing dikes and embankments to complete polder system preventing inflow water to targeted area, (2) dredging river channel in community area, (3) improving hydraulic structure along dikes. Master plan for the second group consist of (1) improvement of drainage system in community area, (2) improvement of detention basin (monkey cheek). For the master plan of structural measures, estimated budget is 3,338 million baht, non-structural measures are necessary to support long term problem solving and effective results.


## 6. Acknowledgements

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