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Concerned Aspects in Large Drainage Project: A Case Study of the Mun River Bypass Project in Thailand

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Abstract

Flooding from Mun river in Ubon Ratchathani has periodically occurred as the province locates in one of the largest water basins in Thailand. In 2002, a destructive flooding with a flood period of 73 days occurred in Ubon Ratchathani in which agricultural division and business were strongly affected. Feasibility of Mun river bypass project was studied to accelerate flow rate during the flooding period. The present paper shows historical review of several bypass channel projects in Thailand and intensively presents systematical study on critical concerned aspects, including hydraulic engineering, irrigation system, groundwater and economic of the Moon River Bypass project with an estimated cost of US$ 110 millions.

Introduction

Ubon Ratchathani is approximately 630 kilometers Northeast of Bangkok, Thailand, and 68 meters above sea level. The province is bordered to the East by the Me Khong river, a border between Thailand and the Laos People's Democratic Republic, to the South by Cambodia, to the West by Yasothon and Sisaket Provinces and to the North by Amnat Charoen Province. Ubon Ratchathani is a plateau sloping to the East to meet Me Khong river. Two major rivers in the area are the Chi river and Mun river, Figure 1. Rainfall collected by water basins of these two rivers, results one of the biggest basins in Thailand, is directed pass Ubon Ratchathani down to Me Khong river. Maximum flow capacity of Mun river in Ubon Ratchathani is 2400 m^3/sec with the water surface at +112 meter above mean sea level. In 2002, according to obviously high storm rainfall, the recorded maximum flow rate in Mun river was as high as 6,800 m^3/sec with the water surface at +115.76 meter above mean sea level. This led to broadly flooding in Ubon Ratchathani and surrounding areas for 73 days and, therefore, strongly destructive effects in agricultural division and overall business structure of the province. This was over US$ 45 millions in total.

The "Feasibility study of Mun river Bypass project" was originated in December 2003 to accelerate flow rate in Mun river by directing the current of approximately 500 to1,000 m^3/sec to steer clear of large cataract areas in the Mun river and to develop large irrigation area along the bypass channel, Figure 1. The bypass, with a total length of 24 kilometers, was conceptually located approximately 47 kilometers from the province center. Five sub-canals illustrated in Figure 1 were considered in completing the drainage system. Initially sub-canal 1 or 2 would be chosen to drain excess current from Mun river. Sub-canal 3 is actually natural water channel, which can be re-excavated to remove bed sediment and, therefore, occupy higher flow capacity. Eventually sub-canal 4 or 5 would be chosen to bring the current back to Mun river before connecting to Me Khong river at the most East of Thailand.

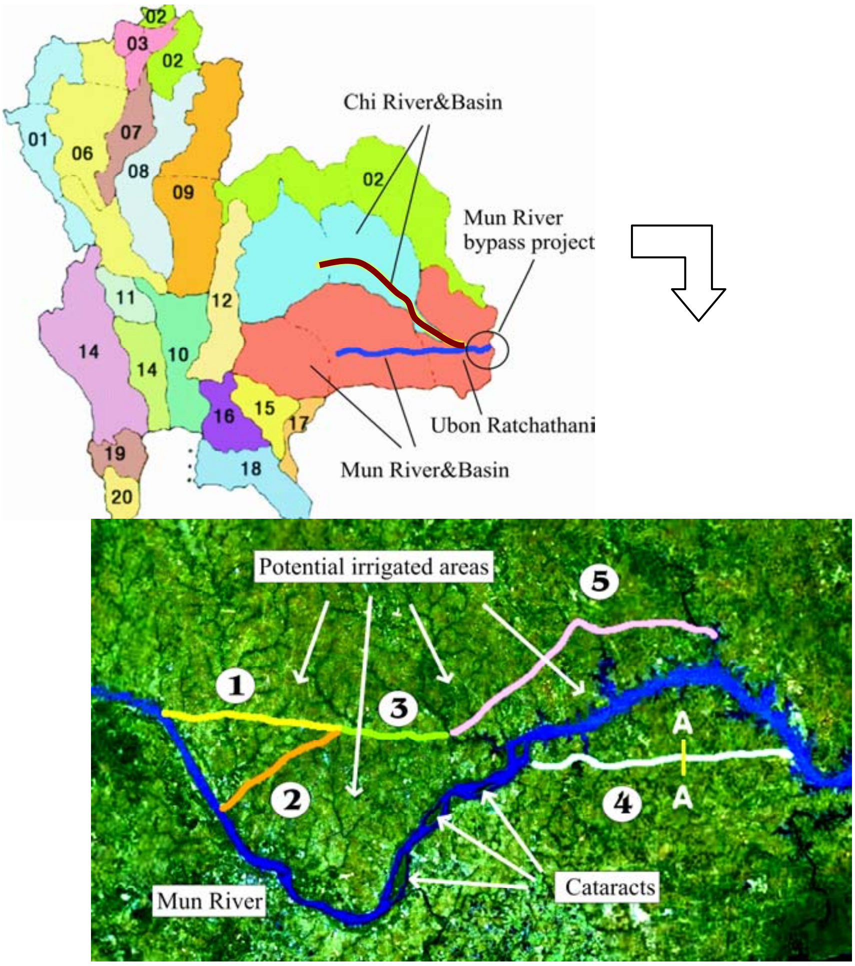


Figure 1. Location of the Mun River bypass project, water basins, sub-canals and potential irrigated areas

Kaeng Saphue "The Invaluable Natural Dam"

Kaeng stands for cataracts in a river. "Kaeng Saphue", which has been known as the most beautiful cataract in Ubon Ratchathani, lies across the Mun river near amphur, subdivision of a province, Phibun Mangsahan approximately 50 kilometers from Ubon Ratchathani. During drought period, Kaeng Saphue has been a natural dam storing water for people in Ubon Ratchathani for hundred years. Furthermore, Kaeng Saphue is a lively target for tourists visiting Ubon Ratchathani during summer. Figure 2 illustrates location of cataract area including Kaeng Saphue, Mun riverbed and riverbank profile and recent flood level in 2002. It could be seen that flooding occurred only at upstream side of the cataract area. However, intensive consideration shows that flooding in Ubon Ratchathani always occurs only in the Mun river existing flood plain. Or, in another word, only people living in the flood plain have been suffered from the flooding.

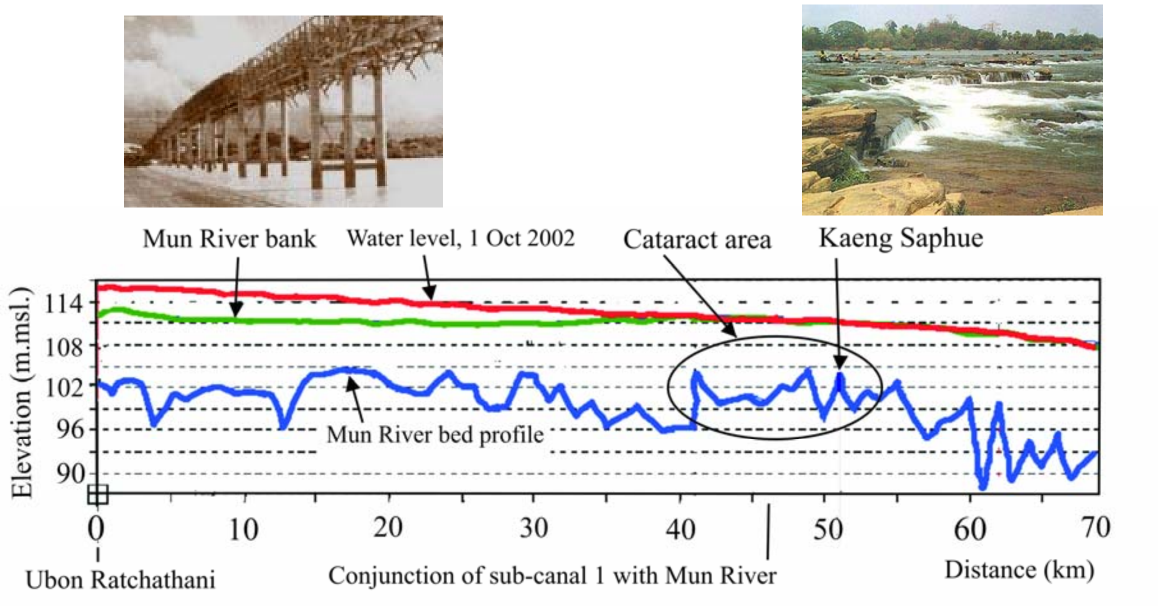


Figure 2. Mun river profile from Ubon Ratchathani to Kaeng Saphue

Historical Review of Excavated Canal in Thailand

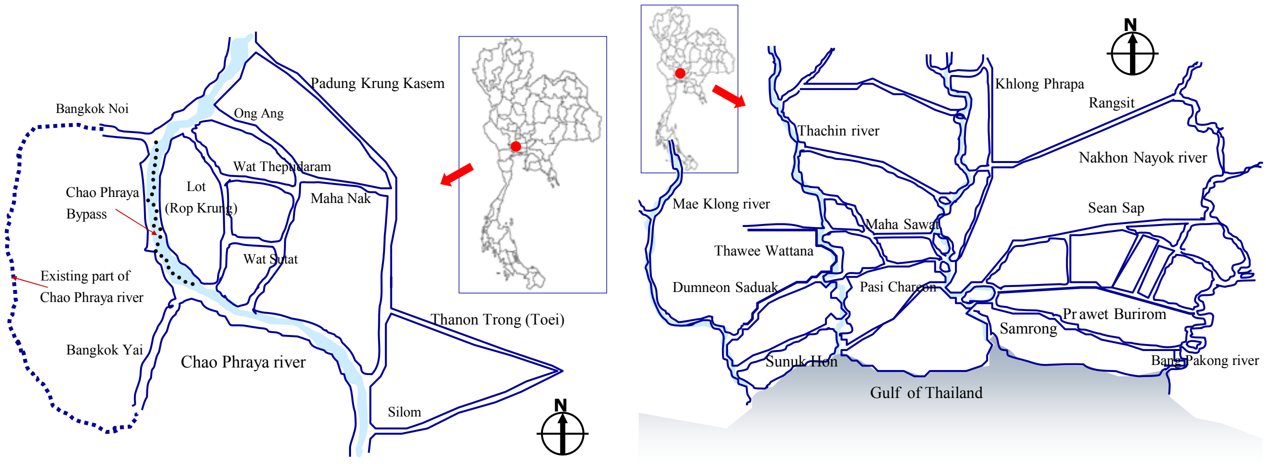
Canal excavation in Thailand has been done since Davaravadi Kingdom (B.C.12), it provided numerous functions *i.e.* flood prevention, irrigation, domestic consumption, water transportation, recreation and defense. In the past, community settlement, town location and planning were based on the mentioned multi-purposes, while the canals were excavated in rather typical pattern *i.e.* digging the earth to form the moats around the town meanwhile, filling the earth to form the flood protection dike or perhaps, constructing the masonry wall around the town in parallel with the moat. Numbers of reservoir and waterway network (called canal or channel or in Thai it is "Khlong"). Almost all the excavations were based on labor intensive with partly contribution from the animal forces and simple manually operated equipment. The existing dike or moat therefore, presents the evidence of ancient towns, civilization as well as technology of the people in the past. In Sukhothai Kingdom (B.C.17), twin moats were dug parallely around the city with the earth fill embankment and wall in between the moats to function the defense purpose. During King Ramkhamhaeng the Great, the earth dike, spillway and pipe culvert had also been constructed and installed to form the reservoir and bypass system to supply the water for domestic consumption inside the city while providing the irrigation for sub-urban, numbers of small reservoirs or ponds had also been excavated around the city in order to store the water. All the excavations were based on the labor and animal intensive.

Figure 3. Existing Moat, bypass and Earth embankment of Sukhothai Kingdom.

In 1350, King Rama I constituted the new capital named Ayathaya, which is bounded by three rivers (Lopburi, Pasak and Chaophraya). This proper location made Ayuthaya a harbor city and large community and the main passage for business and trade. The King Chai Rajathiraj (1534–1547) provided the bypass of "Chao Phraya river" which is nowadays becomes the main part of the Chao Phraya while the existing main river has becomes the smaller canals ("Khlong Bangkok Noi" and "Khlong Bangkok Yai"). King Naresuan the Great (1590-1605) had an idea to connect the Indian and Pacific Ocean at the upper South of Thailand by excavating the bypass called "Khong Khra" during the long period of wars with the surrounding Kingdoms but it had not been implemented. The King Narai the Great (1656-1788) provided the first water supply plant and system *i.e.* the intake structure and pipe culvert to bypass the raw water from reservoir to treat and supply in the royal palace (Lopburi province). The King Sanpetch VIII (1703-1709) provided the bypass from "Khlong Kok Kham" to connect with the "Tha Chin river", it has been called "Khlong Maha Chai" or "Khlong Sanam Chai" or "Khlong Than" and used as the main gate between the capital and the sea. The bypasses formed a large delta and land plots on the both banks have been called "Tha Chalom" and "Maha Chai". By the end of Ayuthaya Kingdom (beginning of the Thonburi Kingdom), the King Taksin the Great (1767-1782) used the bypasses as the main passages for moving the troop during several wars. The first moat in Bangkok named "Khlong Lot" had also been excavated to join with the "Chao Phraya river" and form "Rattanakosin Island", where the present capital of Thailand namely, "Rattanakosin" (or the more well-known name "Bangkok") is situated on.

The first King Rama I the Great of Rattanakosin (1782–1809) provided the new moat or bypass in parallel with the existing moat ("Khlong Rop Khrung" or "Khlong Rattanakosin"), it has different names according to the locations (*e.g.* "Khlong Bang Lamphu", "Khlong Sapan Han", "Khlong Wat Cheng len" or "Khlong Ong Ang"). Other famous bypasses are "North Khlong Lot" (or "Khlong Wat Buranasiri" or "Khlong Wat Theptidaram") and "South Khlong Lot" (or "Khlong Wat Ratchabopit" or "Khlong Wat Suthat" or "Khlong Talad") and "Khlong Maha Nak". The King Rama I the Great had also been reconsidered the excavation of "Khlong Khra" bypass but no further progress. In 1817, the King Rama II provided the excavation of "Khlong Lad Luang" and "Khlong Sunak Hon" to connect the "Mae Klong" and "Thachin" rivers nearby the exit to the Gulf of Thailand. During the period of the King RAMA III, there was the critical flooding in Bangkok, so about 100 bypasses were dug in the Bangkok and sub-urban, the most important canals is

“Khlong Saen Saep” (or “Khlong Bang Kanak”) in 1787 which is 56 kilometer in length.



(a) in Bangkok (b) in Sub-urban

Figure 4. Schematic Famous Bypasses in Bangkok and Sub-urban during 1782 - 1936.

The King Rama IV provided numbers of canal and bypass, the most famous bypass is the “Khlong Damneonsaduak” which consists of about 200 sub-canals and bypasses. During this period, excavations of some canals and bypasses are still based on labor intensive. Again, the idea of “Khlong Khra” had been revisit several times during 1858-1868 but no decision according to the security and defense reasons. Due to the water shortage in 1890-1891, the King Rama V the Great gave the permission to an expatriate contractor to excavate the 15 irrigation canals called “Khlong Rangsit” by means of modern equipment. The King Rama V the Great also provided the first water supply plant in Bangkok (Sam Saen) which consists of the intake bypass from the “Chao Phraya river” (in Pratum Thani province) through “Noi river” (at Chiang Rak), the main bypass is called “Khlong Prapa”. In 1872 the company which completed the excavation of “Suez canal” did ask the permission to perform the excavation of “Khlong Khra” but no decision was made. During the period of the King Rama VI (1910-1925), the water transportation had been out of fashion and construction of the first irrigation dam called Rama VI dam had been completed in 1916 and numbers of critical flooding in middle part of Thailand since 1917. Dredging of the “Chao Phraya river” had been done and completed during 1934-1936, the period of the King Rama VII.

Nowadays in Thailand, large numbers of hydraulic infrastructures and projects including the flood prevention, dam, irrigation and bypass are performed. A classical case-study is the bypass “Chao Phraya II project”, which was planed to excavate 100 kilometer of bypass to divert the water from upstream of the “Chao Phraya Dam” in Chainat province to the sea. The project includes constructing several reservoirs with minimum total capacity $100x10^6$ m^3 to intercept and store the water in the lower Northern part and upper Middle part of Thailand, constructing the 80 kilometer flood prevention dike along the bypass and excavating the bypass nearby the exit to the sea.

Main purpose of the project is to prevent the flood in Bangkok and surrounding provinces, by the way, it is also the means to provide the efficient irrigation in other areas in dry seasons. So far, only bypass nearby the exit to the sea had been completed and it is efficiently used for protecting the Bangkok and sub-urban from flooding.

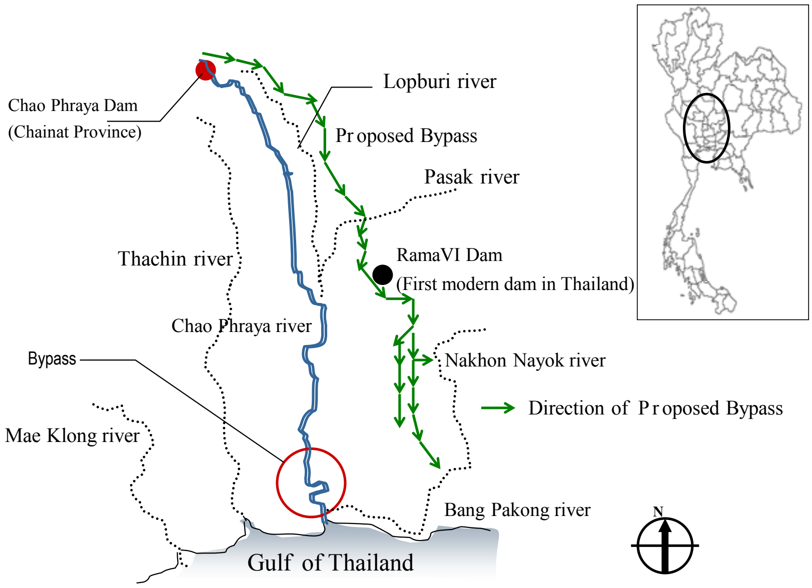


Figure 5. Schematic Proposed Chao Phraya Bypass Project.

In 2003, the idea of bypass has been brought to resolve the flooding in Ubon Ratchathani province. However, there are various different circumstances and constraints of applying the bypass as the Ubon Ratchathani is situated in the flood plain near the West end of the “Korat Plateau”, the largest basin in Thailand which is bounded by the two big rivers *i.e.* Mun and Chi rivers those consist of numbers of sub-rivers. The Chi river join the Mun river in Ubon Rtchathani while its only an exit to “Mae Kong river” is confined by the mountaineous topography along the West boundary. So far, serious floodings have periodically occurred but they did not cause any serious effects to the people in the past as they survived by cultivating along the banks and fishing while settled there houses or communities on the higher level. The periodic flooding and dry seasons makes the identical ecology in this watershed area. Because of rapid increasing of population in Ubonratchathani nowadays, some of the people may have their houses or cultivated area or farm in the flood plain. Hence, they have always been affected by periodic critical flooding. One proposal to resolve the problem is to provide the by-pass canal to divert the excessive run-off in the waterway or flood plain, specially, during the peak of flow toward the downstream (40 kilometers from the town). Possibility or feasibility of the bypass project may be based on the various aspects or reasons *e.g.* the investment, benefit, and environmental impacts such as changes in natural resources or ecologies as well as social impacts.

The Study Methodology of Mun River bypass Project

In approximately a year, feasibility study of the Mun river bypass project are composed of collecting land used and topography information, ground exploration, computer modeling of flow characteristics in Mun river with bypass canal, evaluating efficiency of the canal system in shortening flooding period in Ubon Ratchathani, studying effects of the bypass canal excavation on surrounding ground water system, analyzing economical benefit of the project in terms of drainage system and irrigation system. Preliminary observation showed that the decision making of the project would critically base on efficiency of drainage and irrigation system with obvious difficulties due to high elevation of the project area. Furthermore, ground water, the essential public water resource, was considered to be possibly affected by the bypass canal excavation. To draw the conclusion of the study, clear evidences concerning worth of the project is needed. The procedure applied in the studies is illustrated in the following diagram.

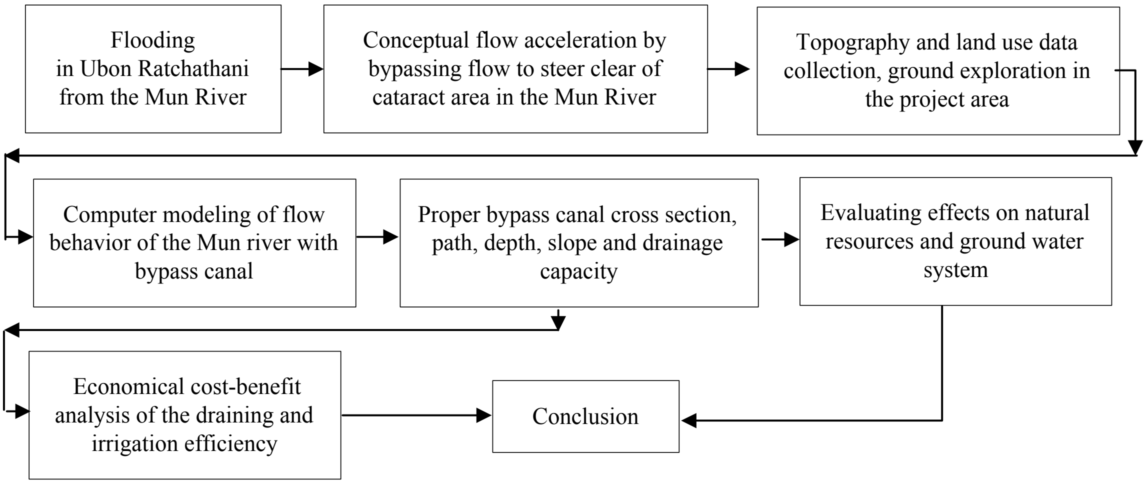


Figure 6. Diagram of the Mun river bypass project study procedures

Hydraulic Engineering of The Bypass Canal

There are three amphurs over which the bypass canal will be crossing. Total population in these amphurs is 6,027 in 1,446 families. Major profession of the people is farming especially rice cropping. It has been well known that Ubon Ratchathani is one of the best areas producing jasmine rice. Over 30 square kilometers in the mentioned three amphurs are rice fields producing rice 156 to 250 tons per square kilometer per year. Farmers in this area traditionally relied on rain in monsoon season from May to October for rain-fed rice cropping. Construction of this large drainage canal possibly provides a chance of cropping irrigated rice in this area.

Due to the fact that drainage efficiency and possibility of the irrigation system are the most important reason supporting feasibility of the project, hydraulic engineering play important rule leading to engineering feasibility evaluation and cost estimation of the project. Cross section and slope of the bypass canal have to be determined to meet the drainage capacity requirement and, consequently, used for the project construction cost estimation.

As it was described earlier, flooding in Ubon Ratchathani is mainly due to excessive flow in Mun river. However, it would not be possible to direct all the excess water to the bypass canal whose cross section area, especially the broadness, is limited by occupied surrounding lands. In the studies, capacity of the bypass was, therefore, assumed to be two possible values of either 500 or 1,000 m^3/second. Two computer modeling software, HEC2 and InfoWork RS, were used to simulate drainage characteristic of the bypass canal and flow in the Mun river for various assigned water level. Concerning distance, excavation work and minimum disturbance on natural water channels, sub-canals 1, 3 and 4 were considered as optimum composition for the complete bypass system and were chosen for computer simulation. Initially, with a particular bypass canal cross section, general manning equation was applied to generate rating curves showing flow rate of the canal with a corresponding water level. With the specified flow rate, HEC2 was then used to simulate and verify flow continuity in the bypass canal. Water level in the bypass canal was compare and gradually adjusted so that it match to the water level in the Mun river at both inlet point (sub-canal 1) and outlet point (sub-canal 4) shown in Figure1. The water levels in the Mun river at the point connecting to bypass were calculated by InfoWork RS to which ground profiles, the Mun river cross sections, water level in 2002 at the reference point (M7 station close to Ubon Ratchathani city center) and slope with other hydraulic parameters of the Mun river have to be inputted. The water level obtained from computer modeling was then calibrated with that collected in the field using Global Positioning System (GPS) and images taken by the LANSAT7 satellite from 1st July to 31st November 2002. The simulation shows that maximum flow, with good flow continuity, capacity of the bypass is 900 and 1,300 m^3/second for the initial assumed value of 500 and 1,000 m^3/second respectively. These additional capacities are due to natural high land topography of the riverbank allowing higher water level to be possible without flooding. The computer modeling also predicted that, with the mentioned maximum flow rates of 900 and 1,300 m^3/second in the bypass canal, flooding period of Ubon Ratchathani in 2002, which was 73 days, could be shorten by 6% and 9% respectively.

Effects Due to Canal Excavation on Ground Water System

Main water resources for people in the project area are from rain and tube wells. Data obtained from Department of Ground Water Resources in Ubon Ratchathani shows that in 2004 there are 626 private wells and 50 public wells distributing in 3 amphurs along the project area. During drought period, tube well is essential water resource apart from tanks and jars storing rainwater. The households who have both jars and well prefer to use the jar water for drinking and cooking and well water for other domestic uses. The record shows that only few villages in the area have their own public main water supply. Field survey carried in March 2005 shows that two types of wells, shallow depth tube well with a large diameter and deep tube well with a small diameter (4 to 6 inches) and manually mechanical pump installed to deeper aquifer, are commonly used. However, almost all of them are the later type.

To estimate effects of bypass canal construction on groundwater and, therefore, tube well water system, ground and ground water profile along the bypass canal layout line is needed. For the ground profile, 19 points of refraction seismic survey were spreading performed along sub-canal 1 to 5 layout line in July 2004. It was found that loose topsoil varies between the depth of 1 to 4 meters and very dense soil and weathered rock with thickness of 3.5 to 20 meters are beneath the topsoil. Depth to hard bedrock from the ground surface varies from only 2.1 to more than 20 meters as shown in Figure 7.

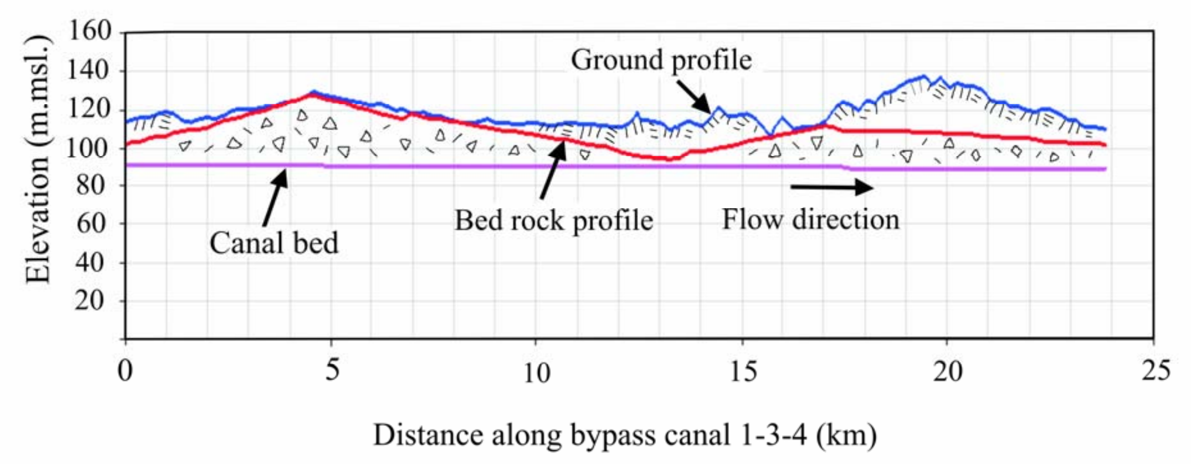


Figure 7. Ground profile and rock profile along bypass canal 1, 3 and 4

Profiles of the groundwater were obtained by measuring electrical resistance of ground using earth resistivity meter. High ground resistivity indicates rock or very dense soil with low water content and, on the other hand, low ground resistivity indicates the zone submerged with water or the aquifers. Total of 11 resistivity images were plotted from the data obtained along 11 test lines, 130 points, crossing 1 to 5 sub-canals. Section A-A in Figure 1 is an example of a test line crossing sub-canal 4. The resistivity image, Figure 8, shows that aquifers in the investigated area are mainly discontinuous bedrock cracks storing rain and surface water seeping down during rainy season. The aquifers can provide water at a rate of 2-10 m^3 per hour. These aquifers can be found at shallow depth until up to 60 meters under ground surface. It could be seen from Figure 8 that excavation of the canal can directly disturb the aquifer from which water will flow into the canal, even with highest storage level, at the side or the base. This phenomenon also presents in other several sections of the bypass canals.

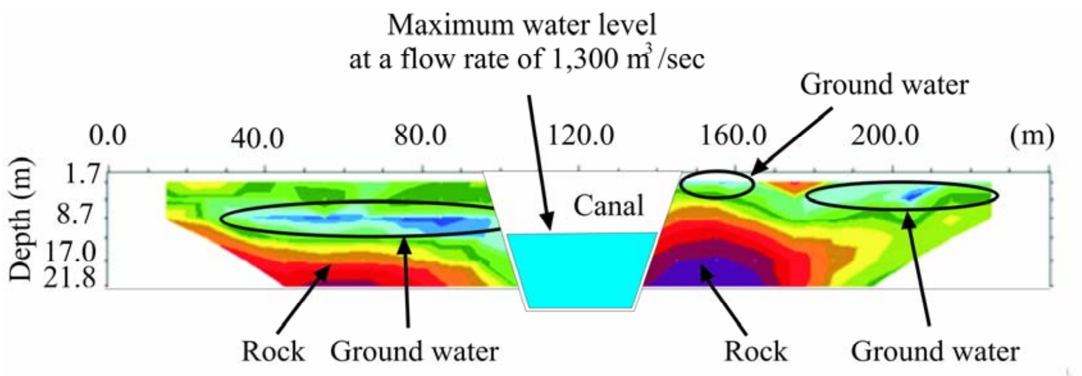


Figure 8. Effect of canal excavation on groundwater at section A-A, sub-canal 4

Economical Evaluation

Cost and benefit are critical factors in the project economical evaluation. Cost of the project was divided as a) relevant cost consisting of canal excavation cost, land surrendering cost, contingency allowances (2.5% inflation and 7.5% physical contingency allowance) and irrigation system with maintenance cost and b) opportunity cost calculated by using appropriate discount rate of 5.15% which is referring to yield to maturity of government bonds of Thailand. Total cost of the bypass canal could be presented with or without irrigation system to clearly compare their value of project worth indicator as shown in Table 1. To calculate benefit of the project, two issues intensively focused are a) effectiveness of the bypass system in shortening flooding period in Ubon Ratchathani and, therefore, minimize the destructive effects and b) benefit due to irrigation system in terms of additional rice product and domestic water. For the first item, as it was mentioned earlier, the computer simulations showed that the canals can shorten flooding period in Ubon Ratchathaini, *e.g.* 73 days in 2002, by either 6% or 9% depending on cross section area. These equals to deduction of the overall flooding-caused damage of US$ 47.32 million in 2002 to US$ 44.48 million or US$ 43.06 million

Cost and benefit of the project was then evaluated by using three project worth indicators: the net present value (NPV), the benefit-cost ratio (B/C Ratio or BCR) and the economic internal rate of return (EIRR). The criteria indicating that the project is economical acceptable is NPV>0, BCR>1 and EIRR > appropriate discount rate of 5.15%. Table 1 summarizes the project worth indicators obtained from economical evaluation.

Table 1. Summary of project worth indicators in economical evaluation

Drainage path sub-canal No.	Case drain capacity 1000m^3/sec	Cost Million US$	NPV Million US$	BCR	EIRR (%)
1-3-4	without irrigation system	113	-42.025	0.59	2.17
	with irrigation system	164.6	-66.775	0.56	1.89
2-3-4	without irrigation system	95.25	-26.45	0.69	2.98
	with irrigation system	144.125	-48.75	0.63	2.49
1-3-5	without irrigation system	137.1	-63.1	0.49	1.34
	with irrigation system	370.35	-84.1	0.5	1.43
2-3-5	without irrigation system	135.55	-61.75	0.5	1.39
	with irrigation system	236.475	-80.3	0.51	1.53

Discussion and Conclusion Remarks

It was clearly shown that the project is not economical acceptable. Many reasons led to this disappointing result. Firstly effectiveness of the bypass canal in shortening flooding period in Ubon Ratchathani is less than expectation because, in the computer simulation, the diverted current from Mun river is eventually converted back to Mun river again. This situation produces backwater effect upward along bypass canal and slow down the flow rate. If the diverted current can be drain to the sea or close to the sea, like "Chao Phraya II bypass project" in the review, higher drainage efficiency could be obtained. Secondly, excavation of the canal is mainly in rock, Figure 7, so the construction cost is much higher than that in soil. Secondly, elevation of the potential irrigated area is much higher than that of the water resource, *i.e.* in the bypass canal, so cost of the irrigation system, *e.g.* pump stations, pipes, water gate and maintenance cost is remarkably high. Furthermore, even with the irrigation system, calculated from size of potential irrigated land and present virtual production capability of the farmers, additional amount of irrigated rice production is not satisfactory. This is because the natural soil in the project area is not adequately fertile. The topsoil is the area is mainly residual soil or short distance transported soil weathered from sandstone or laterite with low pH varying from 4.5 to 6. The soil also has a high permeability and, due to steep slope (2-20%) of the area and low cohesion of the soil, has a high degree of progressive erosion.

Possible impact of the bypass construction on the groundwater system is another critical reason indicating that the project is too risky to be proceeded at present. Compensation on removing initially resident people from the area in which groundwater could be affected may not be the enduring solution. Change of "initial lifestyle" of rural people could lead to unpredictable situation.

Today, in many circumstances, solving engineering problems or environmental problems is considered rather simpler than solving social problems that are more complicated. Many mega projects in Thailand end up with long exhaustive process to solve social problem caused by changing of people lifestyle.

Canals or "Khlong" have been harmonizing with Thai life for centuries. Khlong, both natural and excavated, play invaluable rules in transportation, trading, flood prevention, irrigation, defense, encouraging social activities and so on. Many important canals in history of Thailand are excavated canals and, interestingly, originated by Kings of the country as shown in the review. For many mega projects in the past, according to sacred government, *e.g.* absolute monarchy, and faithfully respect of Thai to the royal contemplate, it was not too difficult to crumbles any objections generated by social and, especially, political division in the country.

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