AN INTEGRATED DECISION MAKING FOR WATER ALLOCATION USING ANALYTICAL HIERARCHY PROCESS: A CASE STUDY OF LAM PRA PLERNG IRRIGATION PROJECT

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ABSTRACT

The most appropriate alternative for water allocation of the Lam Pra Plerng Irrigation Project during water shortage is an alternative that generates maximum satisfaction and water utilization for all activities. The alternative should also be capable of minimizing water conflicts among users.

In this study, economic, social, and engineering criteria are used to evaluate the best solution out of 8 alternative options. It is found that alternative 3, which allows maximum water supply for consumption purposes, results in 44% and 7.56% reduction in the total agricultural productivity and minimum level of water storage of reservoirs, is ranked as the best alternative.

The sensitivity analysis suggests that alternative option 3 is the most appropriate solution to the current problems in water management at the Upper Mun River Basin due to its insensitivity to fluctuation and adjustment of priority weighting scores of each criterion.

KEY WORDS: DECISION MAKING FOR WATER ALLOCATION /
ANALYTICAL HIERARCHY PROCESS (AHP) /
LAM PRA PLERNG IRRIGATION PROJECT

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การจัดสรรน้ำเพื่อการเพาะปลูกในพื้นที่ลุ่มน้ำมูลตอนบนด้วยกระบวนการวิเคราะห์ตามลำดับชั้น กรณีศึกษา: โครงการส่งน้ำและบำรุงรักษาลำพระเพลิง (AN INTEGRATED DECISION MAKING FOR WATER ALLOCATION USING ANALYTICAL HIERARCHY PROCESS: A CASE STUDY OF LAM PRA PLERNG IRRIGATION PROJECT).

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คณะกรรมการควบคุมวิทยานิพนธ์: กัมปนาท ภักดีกุล, (Ph.D.), จำลอง อรุณเลิศอารีย์, (Ph.D.), ทองเปลว กองจันทร์, (Ph.D.).

บทคัดย่อ

ทางเลือกที่เหมาะสมในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงภายใต้ภาวะที่น้ำขาดแคลน คือ ทางเลือกที่ก่อให้เกิดความพึงพอใจและเกิดประโยชน์มากที่สุดในทุกกิจกรรมการใช้น้ำ และควรเป็นทางเลือกที่มีการประนีประนอมระหว่างกิจกรรมการใช้น้ำต่างๆ เพื่อลดความขัดแย้งจากการขาดแคลนน้ำ การศึกษาในครั้งนี้จึงใช้เกณฑ์ 3 เกณฑ์ คือ เศรษฐกิจ สังคม และวิศวกรรม ตามลำดับ สำหรับใช้วิเคราะห์เพื่อคัดเลือกหาทางเลือกที่ดีที่สุดจาก 8 ทางเลือกโดยใช้กระบวนการวิเคราะห์ตามลำดับชั้นในการวิเคราะห์เพื่อคัดเลือกทางเลือก โดยที่ทางเลือกที่ 3 ได้น้ำหนักความสำคัญมากที่สุด ซึ่งเป็นทางเลือกที่ให้มีน้ำสำหรับใช้เพื่อการอุปโภค บริโภคได้ตามปกติ หรือไม่ขาดน้ำเลย ยอมให้ปริมาณน้ำที่ใช้ในการรักษาสมดุลของระบบนิเวศด้านท้ายอ่างเก็บน้ำลดลง 7.56% ของระดับน้ำที่รักษาไว้ต่ำสุด และยอมให้การเกษตรได้ผลผลิตเฉลี่ย 56% จากผลผลิตสูงสุด

และเมื่อวิเคราะห์ความอ่อนไหว พบว่า ทางเลือกที่ 3 มีความเหมาะสมที่สุด เนื่องจากไม่อ่อนไหวต่อน้ำหนักความสำคัญของเกณฑ์ทั้ง 3 เกณฑ์ ไม่ว่าจะเป็นเกณฑ์ด้านเศรษฐกิจ เกณฑ์ด้านสังคม และเกณฑ์ด้านวิศวกรรมแม้จะมีการเปลี่ยนแปลงน้ำหนักความสำคัญของเกณฑ์ทั้ง 3 เกณฑ์จากน้อยที่สุดถึงมากที่สุด

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CHAPTER 1
INTRODUCTION

1.1 Introduction and Background of the Study

Thailand has long been an agricultural nation where majority of population are rice farmers due to massive sources of natural water supply. For centuries, water had been plentiful and giving life to Thai farmers. The water crisises in the past were largely caused by dry seasons. In the meantime, the Government's role in irrigation water management was to provide more water supplies in dry seasons. Therefore, the main duty of the Royal Irrigation Department of Thailand was to acquire new sources of water by constructing reservoirs and dams. Building local weir was another means to solve water crisis in the communities where water allocation was managed by community members.

With increases in populations and more intensive economic activities, the demands for water are increasing substantially. Therefore, water shortage has occurred more frequently. Royal Irrigation Department; one of the Thailand's water management organizations, has been facing more and more problems in water management, namely the protest against dam construction concerning compensations for affected communities and negative effects on ecosystem. As the water shortage has become more serious in dry seasons, Royal Irrigation Department of Thailand has to expand its role form water provision functions to water allocation functions. According to the Development of Water Efficiency Plan included in the Eighth National Developmental Plan, it is aimed that development and maintenance of irrigation system and development of natural resources must be conducted to utilise water more effectively and to further develop sources of water for agriculture, consumption, industry, flood mitigation, ecosystem stability (Royal Irrigation Department of Thailand, 2002). However, Thailand's water management institutions are lack of regulations and procedures to deal with water allocation issues (Mingsan Khaosaart, 1994).

Although all the past governments were aware of the importance of water management in terms of water command and control, they only focused on allocation issues and considered related problems as results of dysfunctional cooperation between government agencies and insufficient dams and water reservoirs.

The governments still lack a clear answer to what principle to use in order to effectively allocate water and maximize the benefits of water to society. In addition, allocation equitable should be applied to all users and a sustainable reservation of water resources should also be of paramount concern (Mingsan Khaosaart, 2001).

Many river basins of Thailand are experiencing stresses on their water resources from the perspective of quantity. Compared to the 65% of Thai population who are in agricultural sector, which consume large percentage of water supplies, 27% storage of rain water collected by natural storage ponds or pools is considerably inadequate. Delayed rain in rainy seasons intensifies the shortage of water for agriculture, consumption, industry and tourism, which result in the loss of agricultural productions and national economy (The Office of Natural Resources and Environmental Policy and Planning, 2003).

According to a dry report of the Ministry of Agriculture and Cooperatives on 6th December, 2004, there were 26,916 million cubic meters of usable storage water available in all large reservoirs of the country, accounting for 61% of the storage capacity.

The critically low storage reservoirs are Lam Ta Kong and Lam Pra Plerng reservoirs in the northeast region, accounting for 15% and 9% of the total storage. In the central region, Kraseaw and Tubsalao reservoirs account for 1% and 10% of the total storage. In addition, Bhumiphol and Sirikit reservoirs have usable storage water of 4,301 and 5,985 million cubic meters, accounting for 45% and 90% of the storage capacity respectively.

During 1 May to 16 November, 2004, it was found that there were as much as 24.50 millions rais of agricultural land were affected by dry. More than 16 millions of rai were projected to be destroyed and 11.89 millions rais were completely destroyed, generating the loss of 2,716 millions baths. The most affected province was Nakorn Ratchasima losing 2,397,053 rais, followed by Khon Kaen losing 1,698,707 rais (Water Monitoring and Coordinating Center, 2004).

Due to the delayed rain during September to October, 2004, the quantity of usable storage water in the beginning of year was less than those of the same period last year by 2,500 millions cubic meters. In having to manage water allocation according to the plan, the Royal Irrigation Department of Thailand, therefore, has to concentrate on supplying water for consumption, tap water production, and ecosystem stability. Moreover, agricultural areas must be strategically determined by taking quantity of local storage water into consideration (Water Monitoring and Coordinating Center, 2005).

The northeastern region covers three major river basins, which are Khong river basin, Chi river basin, and Mun river basin (Figure 1-1). All of which consists of 68 sub-river basin with the total area of 176,599 sq. km. The average rainfall is higher than other regions by 237,578 millions cubic meters per year. In addition, the average usable water rate per person per year is lower than the standard rate by 828 cubic meters. The current water storage in reservoirs can collect rainwater of 4,374 million cubic meters per year or only 5.8% of the annual rainfall. This rainwater can be irrigated to 5.5 millions rais of agricultural land, representing only 10% of the total agricultural land. Despite having higher rainfall than other regions, scatter rains and loose soils make it difficult to store sufficient rainwater for the rest of the agricultural areas in northeastern Thailand, which have more than of 57.43 millions rais. The most affected areas are Mun river basin, Chi river basin and Khong river basin respectively (The Office of Natural Resources and Environmental Policy and Planning, 2004).

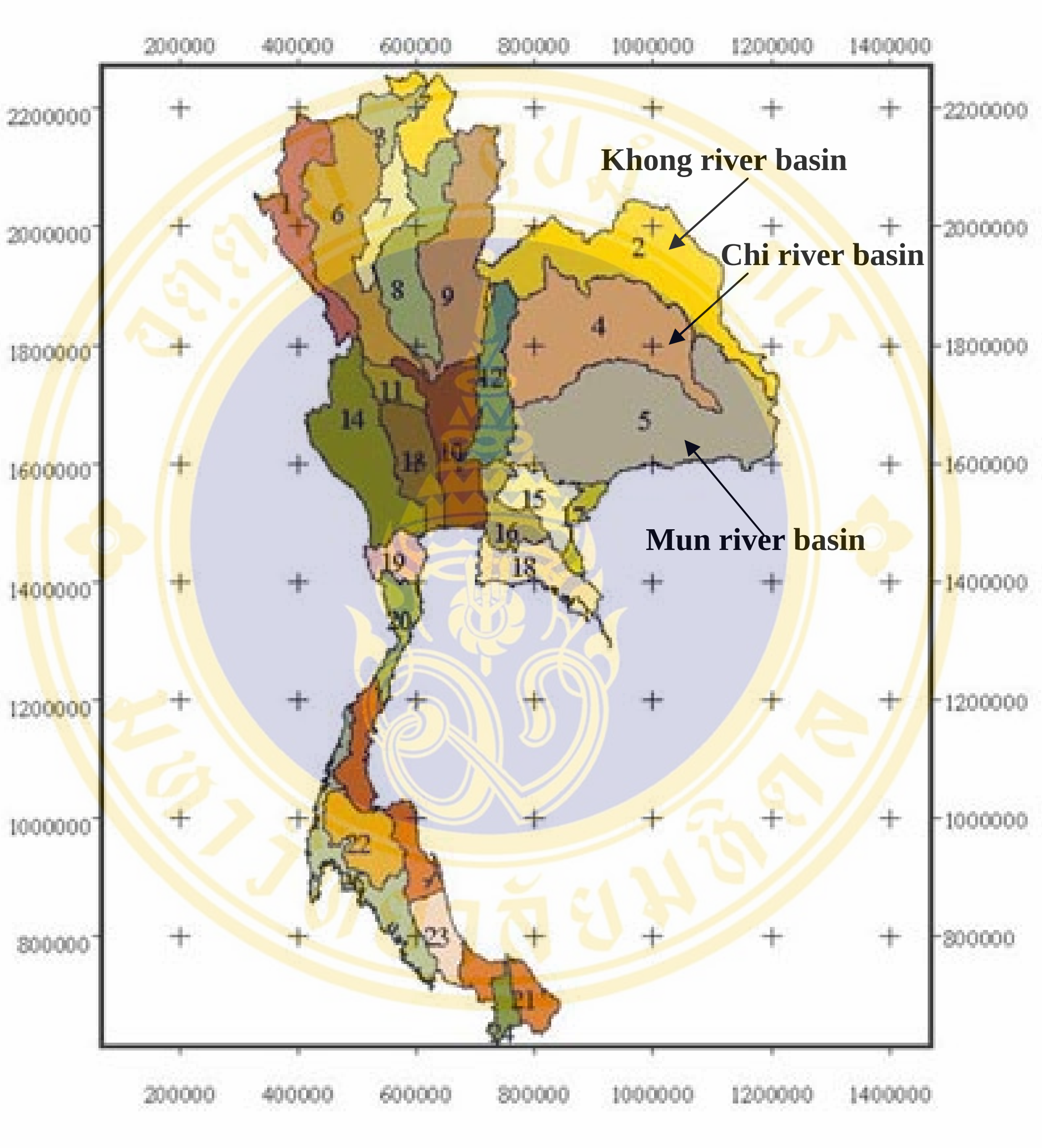

Figure 1-1: Major River Basin in the Northeastern Region

(Source: Office of Project Management, 2004)

Mun river basin covers the area of 69,701 sq. km. or 43.56 millions rais in 10 provinces. The provinces which wholly located on the Mun river basin are Buri Ram and Surin. The provinces which partially located the Mun river basin are

Si Sa Ket, Ubon Ratchathani, Nakhon Ratchasima, Maha Sarakham, Yasothon, Khon Kean, Roi Et, and Amnat Charoen (Figure 1-2).

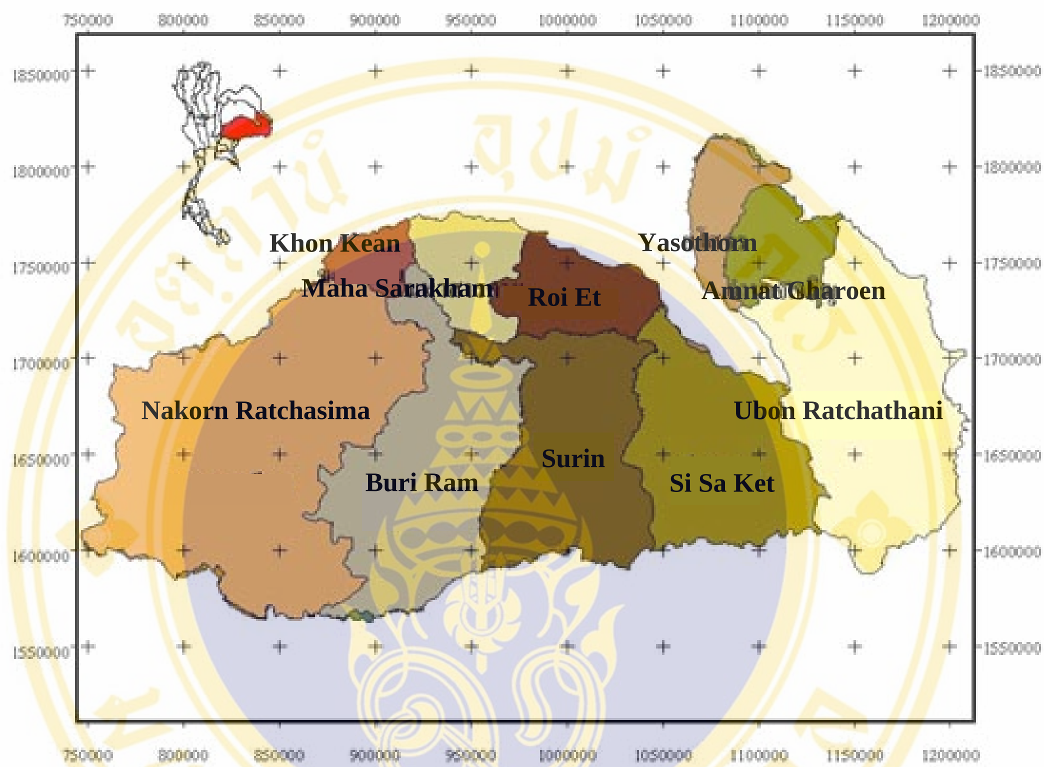

Figure 1-2: Mun River Basin

(Source: Office of Project Management, 2004)

The Upper Mun river basin in Nakorn Ratchasima covering 20,136 sq.km. of 28.89% of the total area is divided into 9 sub-river basins which are Lam Ta Kong, Lam Pra Plerng, Mun Bon-Lam Sae, Upper Lam Plai Mat, Lam Chak Ka Rat, Lam Chiang Krai, Lam Sa Tad, Lower Lam Plai Mat, and Lam Tha Main Chai. The major reservoirs are Lam Ta Kong, Lam Pra Plerng, Mun Bon, and Lam Sae (Figure 1-3) (Regional Irrigation Office 6, 1998)

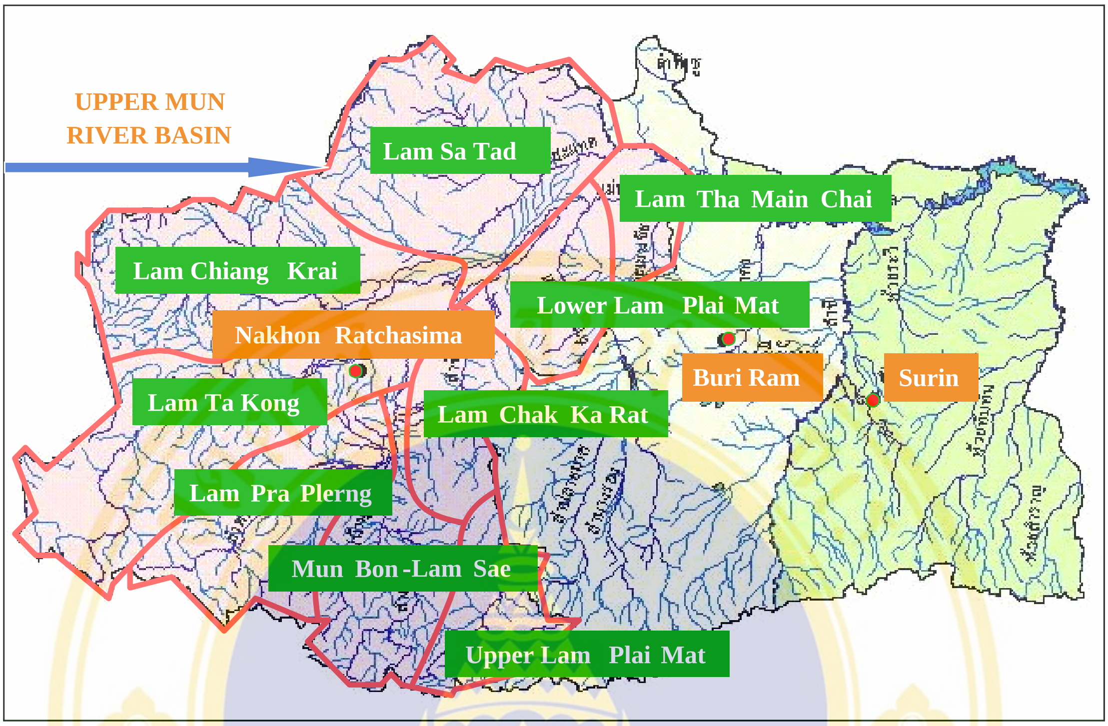

Figure 1-3: Sub-river Basin

(Source: Department of Environmental Quality Promotion, 2002)

With the 92% dependency of rainwater in agriculture coupled with loose sandy soil condition, Nakon Ratchasima experienced dry condition due to long dry spell and delayed rain in 2004.

The total agricultural areas of 8,964,000 rais can be categorised into the following types of agricultural purposes: 4,270,000 rais of rice fields, 4,080,000 rais of crop fields, 441,000 rais of perennial fields, and 173,000 rais of vegetable fields. The major agricultural productions of Nakhon Ratchasima during year 2004 to 2005 were rice (4,053,300 rais), corn (859,600 rais), and sugar cane (783,500 rais). The dry-damaged areas cover 2,403,759 rais including rice (1,639,238 rais), corn (611,852 rais), cassava (25,920 rais), sugar cane (84,412 rais), and orchards and others (42,337 rais) (Director of Nakhon Ratchasima Provincial Agricultural Extension Office have Brainstorming for helping agriculturist during dry season, 2005)

According to the study of Thongplew Kongjun (2003), it was found that the average demands for water from Lam Pra Plerng reservoir are 134.48 million cubic meters per year. Of these are used for agricultural, domestic, ecosystem stabilizing purposes, accounting for 127.04, 3.57 and 5.88 million cubic meters respectively. However, water released from the reservoir is insufficient especially during September and October 2004 when the amount of water decreased as low as 10 millions cubic meters. (Figure 1-4).

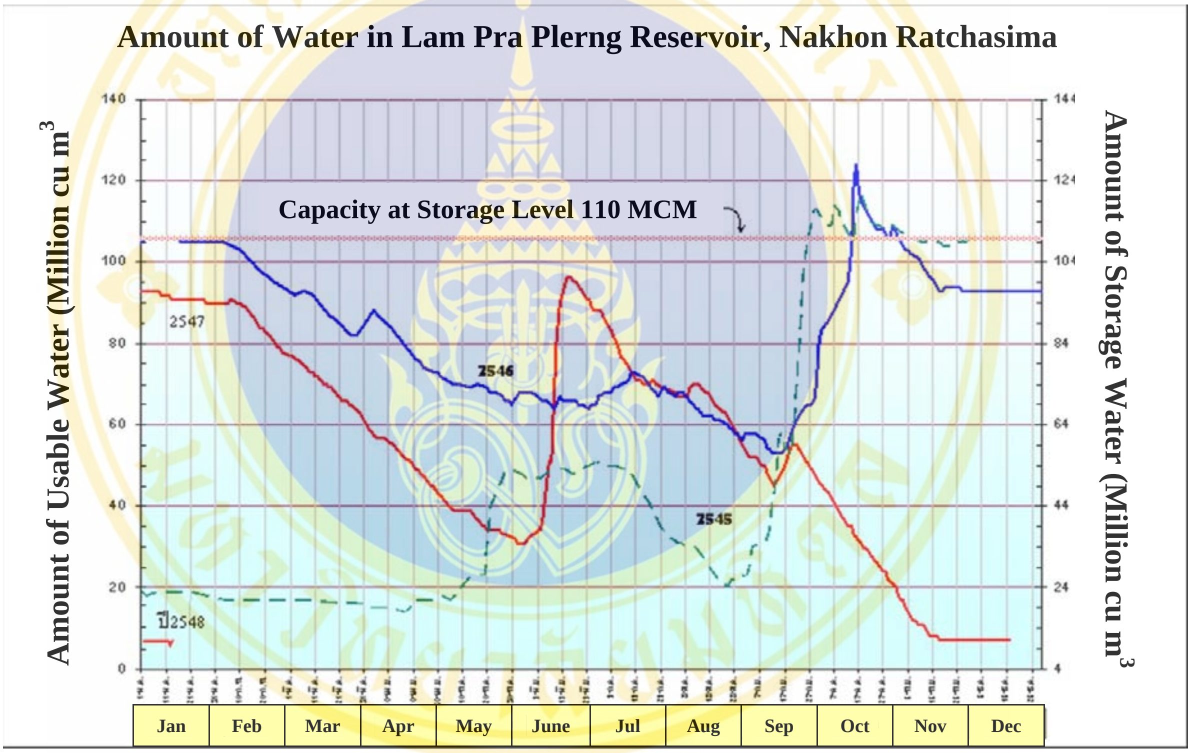

Figure 1-4: Amount of Water in Lam Pra Plerng Reservoir

(Source: http://203.150.73.19/flood/pics/lpp.html, 2005)

Directions of water management for irrigation since 1982 aimed at maximizing efficiency of water usage of developed irrigating system instead of increasing amount of reservoirs. The primary objective is to support the efficiency of water usage as well as to lessen water conflicts between farmers in dry season. The vision for water management in 2025 will focus on the availability of quality and quantity of water though management and laws on sustainable water resource usage by involving all interested parties and concerning about their quality of life (Office of National Water Resource Committee, 2000).

Dinar et al (1999) states that equity and economic value are required in water allocation. The principles for water allocation concerning security, opportunity cost, outcome, equity, and political issues. In accomplishing the objectives of water management, balance between water demand and supply must be reached. In setting appropriate policies for different circumstances, there are two factors to be taken into consideration. Firstly, how the information on the projected demand and supply for water are processed and developed into action plan. Secondly, how to sufficiently allocate water in the present circumstances, to which is likely to cause future problems (Dinar et al., 1999 cited in Thongplew Kongjun, 2003).

For above reasons, the researcher takes interest in adopting Analytical Hierarchy Process (AHP) in the determination of applied water management for agriculture in Upper Mun River Basin. The case study involves water distribution and maintenance of Lam Pra Plerng River. The process will assist in selecting the best solution to achieve set objectives.

1.2 Conceptual Framework

In conducting the study of An Integrated Decision Making for Water Allocation Using Analytical Hierarchy Process: A Case Study of Lam Pra Plerng Irrigation Project, Upper Mun River Basin. Analytical Hierarchy Process is adopted to determine the best solution. A conceptual model for the study is depicted in Figure 1-5.

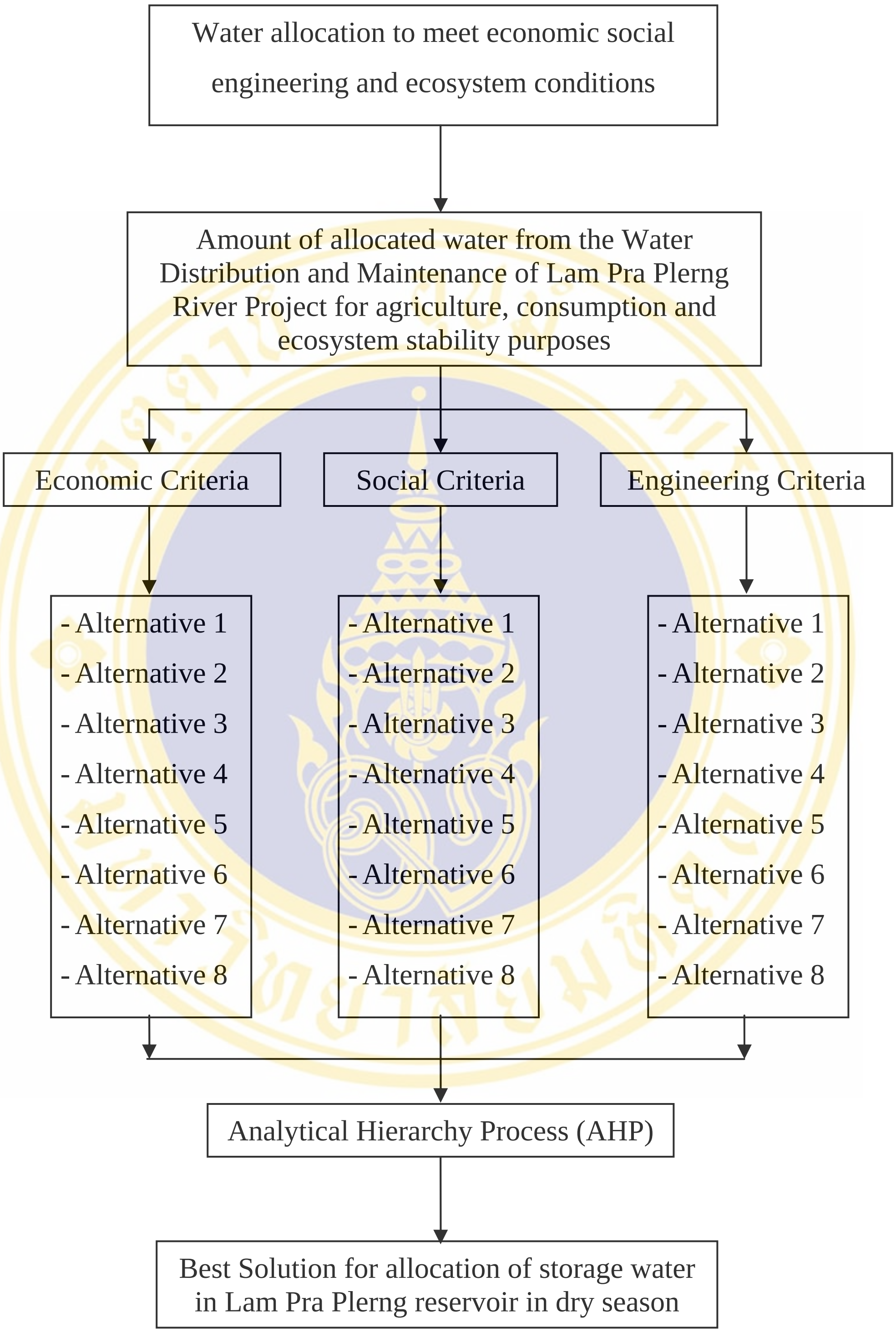

Figure 1-5: A Conceptual Framework

1.3 Objectives of the Study

The objectives of the study of An Integrated Decision Making for Water Allocation Using Analytical Hierarchy Process: A Case Study of Lam Pra Plerng Irrigation Project, Upper Mun River Basin are to:

1.3.1 Investigate the problem of water allocation in the Upper Mun River Basin.

1.3.2 Apply the implementation of Analytical Hierarchy Process (AHP) to evaluate alternative options for the best solution for the study.

1.4 Scopes of the Study

The following are key scopes of the study:

1.4.1 The study area is located in the irrigation area of Lam Pra Plerng Irrigation Project.

1.4.2 The study population is the chief of water user groups in Lam Pra Plerng Irrigation Project.

1.4.3 The study time frame is during dry season starting on January to April , 2004

1.5 Expected Outcome

The most appropriate option for applied water management for agriculture in Upper Mun River Basin is recognised and is effectively implemented by taking economic, social and engineering factors into consideration.

CHAPTER 2
LITERATURE REVIEW

In this study, the researcher has reviewed a number of documents concerning an Integrated Decision Making for Water Allocation for Agriculture in the Upper Mun River Basin, a case study of Lam Pra Plerng Irrigation Project. The literature reviews are therefore relating to the following topics:

2.1 Lam Pra Plerng Irrigation Project
2.2 Water Allocation from Major Reservoirs
2.3 Multi-purposes Decision Making Process
2.4 Analytical Hierarchy Process (AHP)
2.5 Development of Alternative Options for Water Allocation
2.6 Relevant Studies

2.1 Lam Pra Plerng Irrigation Project

Lam Pra Plerng Irrigation Project is a reservoir project where water is conveyed by gravity to agricultural areas covering the area of 89,720 rais. The dam was constructed in Lam Pra Plerng River in Ta Khob sub-district of Pak Thong Chai district of Nakhon Ratchasima province. Construction started in 1963 and was completed in 1967. The dam is an earth fill embankment and wholly located in Nakhon Ratchasima province at Latitude 14°35′38″ N and Longitude 101°50′30″ E, as shown in figure 2-1. The dam is approximately 30 kilometers far from Pak Thongchai district, and 320 kilometers far from Bangkok. The other bordering areas are: (Regional Irrigation Office 8, n.d.)

- Sung Noen and Mueng Nakhon Ratchasima Districts in the North
- Pak Thong Chai and Choke Chai Districts in the South
- Mun River in Choke Chai District in the East
- Pak Chong and Sung Noen Districts in the West.

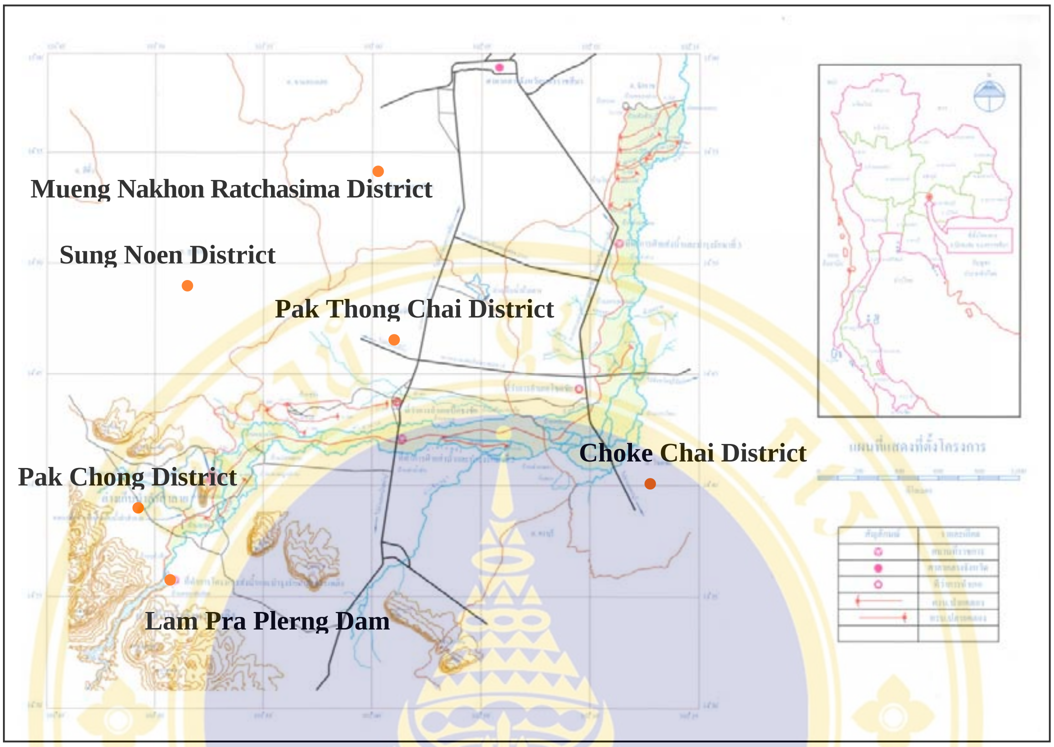

Figure 2-1: Location of Lam Pra Plerng Irrigation Project
(Source: Regional Irrigation Office 8, n.d.)

The crest width is 6 meters and the crest length is 575 meters. The structural height of the dam is 49 meters and the full storage capacity of the reservoir is 242 millions cubic meters. The highest and lowest levels of water are +263 and +240 meters respectively. Its morning glory and overflow spillways are 5.50 meters in diameter and 167 meters long. Its normal maximum discharge is 450 cubic meters per second. Moreover, its emergency spillway is a concrete overflow and chute approximately 47 meters wide with a maximum discharge rate of 1,130 cubic meters per second, as shown in figure 2-2 (Regional Irrigation Office 8, n.d.).

Currently, it is found that there has been a diminishing amount of water in the Lam Pra Plerng Reservoir. Comparing to the capacity of 150 millions cubic meters in year 1970 when the Reservoir was finished, the reservoir storage capacity was dropped to as low as 121 and 108 millions cubic meters in year 1983 and 1991 respectively. In other words, the storage capacity had declined by 29 millions cubic meters during year 1970 to 1983 and by 13 millions cubic meters in year 1983 through 1991. In the past 21 years during year 1970 to 1991, the total amount of declining storage capacity of Lam Pra Plerng Reservoir was as much as 42 millions cubic meters (Somchai Nai-anand, 1992).

Figure 2-2: Lam Pra Plerng Dam

(Source: Regional Irrigation Office 8, n.d.)

2.1.1 Geography

The reservoir is located in the mountain ranges of Khao So, Khao Shalong Tong, Khao Yai, Khao Pong Chanuan, Khao Jun and Khao San Kamphaeng where Lam Pra Plerng and Lam Ta Kong Rivers are originated. There are plains in the back of the dam approximately 12 kilometers far from the dam (Regional Irrigation Office 8, n.d.).

2.1.2 Climate

The dam is located in a tropical low rainfall, wet-dry monsoonal and tropical Savannah climates. During November to February the north western monsoon winds bring the cold air masses down to the dam areas. In addition, monsoon south western winds bring tropical moistures from the India Ocean during May to September (Regional Irrigation Office 8, n.d.).

Rainy season starts from May to mid-October. Heavy rain is in August-October. Rain in Nakhon Ratchasima is mostly due to depression storm which moves from Tang Kia Gulf of South China Sea and passes Vietnam to northeast of Thailand. If any year, depression from South China Sea scarcely enters through northeast, that year, northeastern region and Nakorn Ratchsima will be dry and has little rainfall. But normally, depression will move over northeast around 3-4 times which brings good level of rainfall. Rain caused by southwestern monsoon is little because Nakhon Ratchasima province has Petchaboon and Dong Payayen mountain range in the west and San Kamphaeng and Panomdongrak mountain range in the south which are impedance of southwest monsoon. Thus, rain occurs mostly in the west and south of the mountain. When monsoon pass these mountain ranges to northeastern region, it reduces substantially steam quantity in the weather so rainfall is little. Nakhon Ratchasima province is in rain shadow of northeastern region.

Winter starts from December to January, which is influenced by north eastern monsoon bringing cold and dry winds from China. Temperature is lowest in December around 16-17 °C.

Summer starts from February to May, which is influenced by south eastern monsoon bringing hot and dry air masses from South China Sea and gulf of Thailand. Normally, highest temperature in April is 39.7 °C

2.1.3 Hydrography Characteristics

Rainfall

Rainfall in the dam areas is influenced by south western monsoon winds starting from late April. Late rain occurs during June to July and heavy rain occurs during September and October (Regional Irrigation Office 8, n.d.).

The average rainfall measured by Lam Pra Plerng Dam Station during year 1973 to 2003 is around 1,129.10 mm. A heaviest rainfall year is 1991, measuring at 1,548.30 mm. and a lightest rainfall year is 1985, measuring at 758.10 mm (Appendix 1).

Runoff

The Surface areas in front of the dam cover 807 sq. km. The average volume of inflow between year 1973 to 2003 is 178.1 millions cubic meters. The lowest and highest volume of inflow is in year 1981 and 1983, accounting for 59 and 418.90 millions cubic meters respectively (Appendix 2) (Regional Irrigation Office 8, n.d.).

2.1.4 Stream Characteristics

Lam Pra Plerng stream is a branch of the Mun River originated form San Kamphaeng Mountain. From the origin to Ban Bu Hua Chang, the stream is approximately 60 kilometers long with a slope of 1:300. There are more plains areas on the left side of Mun River Bank to the right. From Ban Bu Hua Chang to the Mun River, the stream is 120 kilometers long, passing through Pak Thongchai and Choke Chai Districts (Regional Irrigation Office 8, n.d.).

2.1.5 Soil Characteristics

The soils in the project areas of the project are partly loose and sandy, and partly clay. According to the map of potential land for agriculture in the north eastern region developed by the Land Development Department in 1984, the characteristics of soils in the areas of the project can be classified into: (Regional Irrigation Office 8, n.d.)

Zones 1 and 2 have rich deep soils that drain well and moderately delicate. The soil is suitable for many crop cultivations such as corn, millet, cotton, tobacco, sugar cane etc.

Zones 3 and 4 have deep soils with poor draining ability. The clay is rich in minerals and most suitable for rice and vegetable cultivations in dry season.

Zones 5, 6 and 7 have rich deep soils that drain well but poor in the mineral nutrients necessary for plants. It is suitable for corn, millet, and sugarcane, castor oil plantations.

2.1.6 Soil Utilization and Agriculture Development

The hillside plain areas within 30 kilometers from the dam are used for rice and crops cultivations, accounting for 20% of the irrigation areas.

Agriculture development of Lam Pra Plerng Irrigation Project started since year 1968 by supplying water to 29,500 and 27,500 rais of rice and crop fields. After year 1970, the farmers had expanded beyond their agricultural areas and traditional crops. More farmers were resort to do rice farming. By the year 1972, farmers started doing second rice and crop farming. Figure 2-3 illustrates the calendar of agriculture in the irrigation areas of Lam Pra Plerng Irrigation Project.

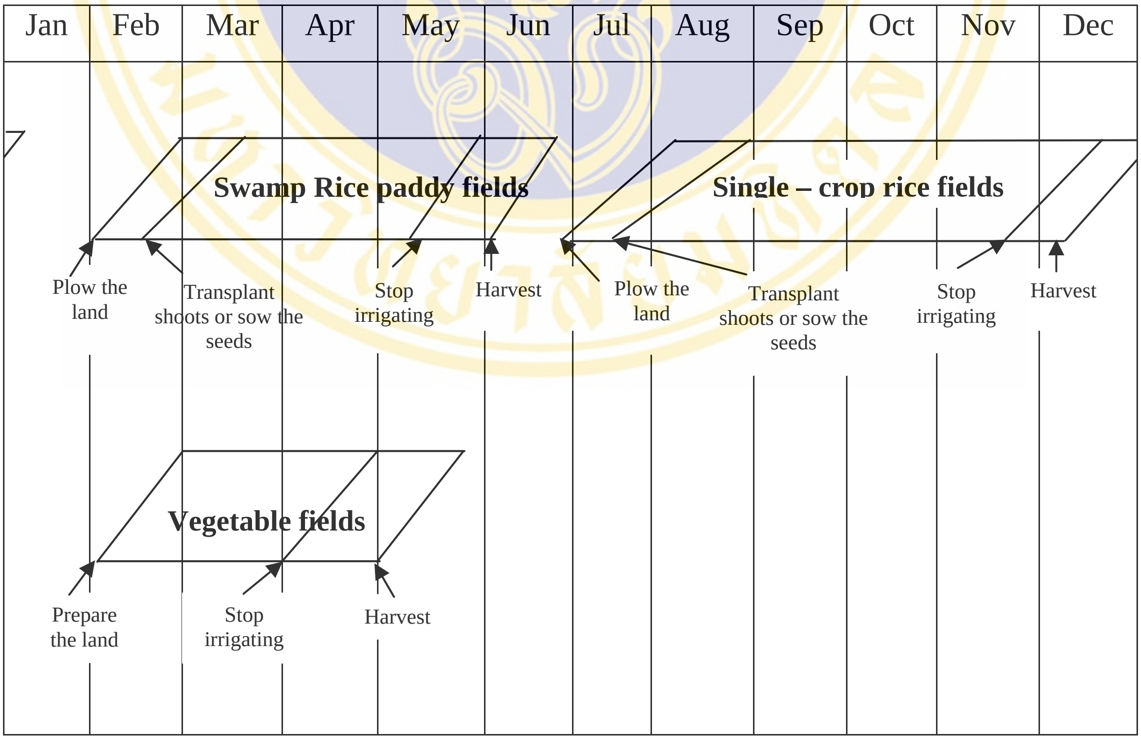

Figure 2-3: Crop Calendar

(Source: Regional Irrigation Office 8, n.d.)

2.1.7 Water Supply Requirements

According to the study of Thongplew Kongjun (2003), it is founded that the total amount of water required from the Lam Pra Plerng reservoir is 134.48 millions cubic meters per year. The total water supply requirements can be divided into 3 categories which are agriculture, industry, and ecosystem stability, accounting for 127.04, 1.42, and 5.88 millions cubic meters per year respectively.

2.1.8 Previous Water Allocation Schemes

During February to June year 2003-2004, the total amount of water allocation was 59,572,800 cubic meters, which was 19,353,600 cubic meters higher than that of between 2002-2003. The water was allocated for agriculture, consumption and ecosystem stability, accounting for 57,720,400, 3000,000, and 1,552,400 cubic meters respectively (Regional Irrigation Office 8, n.d.). (Table 2-1 and Table 2-2)

Table 2-1: Water Allocation Plan of Lam Pra Plerng Reservoir during Dry Season in Year 2002/03 (Regional Irrigation Office 8, n.d.).

Month	Agriculture (Cubic Meter)	Consumption (Cubic Meter)	Tab Water Production (Cubic Meter)	Total Amount (Cubic Meter)
Feb 2003	9,376,800	100,000	200,000	9,676,800
Mar 2003	10,388,600	40,000	285,000	10,713,600
Apr 2003	8,924,800	60,000	260,000	9,244,800
May 2003	7,680,200	100,000	255,000	8,035,200
Jun 2003	2,246,400	-	302,400	2,548,800
Total	38,616,800	300,000	1,302,400	40,219,200

Table 2-2: Water Allocation Plan of Lam Pra Plerng Reservoir during Dry Season in Year 2003/04 (Regional Irrigation Office 8, n.d.).

Month	Agriculture (Cubic Meter)	Consumption (Cubic Meter)	Tab Water Production (Cubic Meter)	Total Amount (Cubic Meter)
Feb 2004	14,165,200	100,000	250,000	14,515,200
Mar 2004	15,820,400	-	250,000	16,070,400
Apr 2004	12,955,600	100,000	250,000	13,305,600

Table 2-2: Water Allocation Plan of Lam Pra Plerng Reservoir during Dry Season in Year 2003/04 (Regional Irrigation Office 8, n.d.). (cont.)

Month	Agriculture (Cubic Meter)	Consumption (Cubic Meter)	Tab Water Production (Cubic Meter)	Total Amount (Cubic Meter)
May 2004	11,409,600	100,000	500,000	12,009,600
Jun 2004	3,369,600	-	302,400	3,672,000
Total	57,720,400	300,000	1,552,400	59,572,800

2.1.9 Problems in Water Allocation and Distribution (Regional Irrigation Office 8, n.d.).

- Insufficient storage water causes ineffectiveness in water allocation.
- Inability to allocate water to users in timely manner.
- Obsolete irrigation stations causes ineffectiveness in water discharge.
- Damaged irrigation stations and ditches cause significant loss of distributed water.
- Accumulated sediments in the bottom of the reservoir and irrigation canals.

2.2 Water Allocation from Major Reservoirs

2.2.1 Major Reservoirs

Reservoir is a lake-like area where water is kept until it is needed. It is built for a variety of reasons, for example an additional drinking water supply, flood control, maintain water levels in canals that are travel ways, water for hydroelectric plants, irrigation etc.

a. Functions of Reservoir (Varawoot Vudhivanich, 1998)

A reservoir is a man-made body of water, which is formed after a dam, is built on a river, and is used for the collection and storage of water for the following purposes:

- Providing water supplies for municipal uses;
- Providing water supplies for industrial uses;
- Providing water supplies for irrigation;

- Providing water supplies for generating electricity;
- Providing water supplies for preventing salinity intrusion in dry season;
- Providing water supplies for water transportation;
- Providing flood control;
- Providing habitat for marine lives; and
- Providing recreational areas.

b. Types of Reservoir

Reservoirs can be classified into many categories depending on objective of classifiers. According to Department of landscape Architecture, Faculty of Architecture, Chulalongkorn University (1990), reservoirs can be classified as:

- Natural reservoir; and
- Man-made reservoir.

According to the international principles, reservoirs can be classified as:

- Reservoir in highland;
- Reservoir for agricultural purpose;
- Reservoir for new communities purpose;
- Reservoir for municipal purpose;
- Reservoir for reserving purpose;
- Reservoir for forestry purpose;
- Reservoir for recreational purpose; and
- Reservoir for natural habitat conservation.

A reservoir can be classified by its construction, which are:

- Excavated reservoir; and
- Reservoir of dam.

Viraphol Taesombut (1988) suggests the broad functions of reservoir as a single-purpose reservoir and a multi-purpose reservoir.

c. Components of Reservoir

In general, reservoir consists of the three major components, which are impoundment reservoir, spillway, and outlet works (Varawoot Vudhivanich, 1998).

(1) Impoundment Reservoir can be constructed by building dam between one mountain to another. In order to determine the amount of storage in a raw water reservoir, a reservoir storage curve must be developed so that the water may be converted to storage. Reservoir storage curves are generally developed by taking soundings across a number of cross sections of the reservoir. A contour map of the reservoir bottom may then be plotted and storage volumes computed for given elevations.

A general reservoir for water storage collects different level of water for different uses which are:

- **Minimum Pool Level** is the lowest elevation to which the pool is to be drawn under normal conditions. This level may be fixed by the elevation of the lowest outlet in the dam or in the case of hydroelectric reservoirs by conditions of operating efficiency for the turbines. The storage volume between the minimum and normal pool levels is called the useful storage. Water held below minimum pool level is called dead storage.
- **Normal Pool Level** is the maximum elevation to which the reservoir surface will rise during ordinary operating condition. For most reservoirs normal pool is determined by the elevation of the spillway crest or the spillway gates.
- **Maximum Water Surface** is the highest level of water allowed when flood water is flowing to the reservoir. During flood discharge over the spillway may cause the water level to rise above normal pool level. This surcharge storage is normally uncontrolled .Let it exists only while a flood is occurring and cannot be retained for later use.
- **Freeboard** is the vertical distance between a design maximum water level and the top of a structure such as a channel, dike, floodwall, dam, or other control surface. The freeboard is a safety factor intended to accommodate the possible effect

of unpredictable obstructions, such as debris blockage, that could increase stages above the design water surface. Figure 2-4 illustrates the classification of pool level.

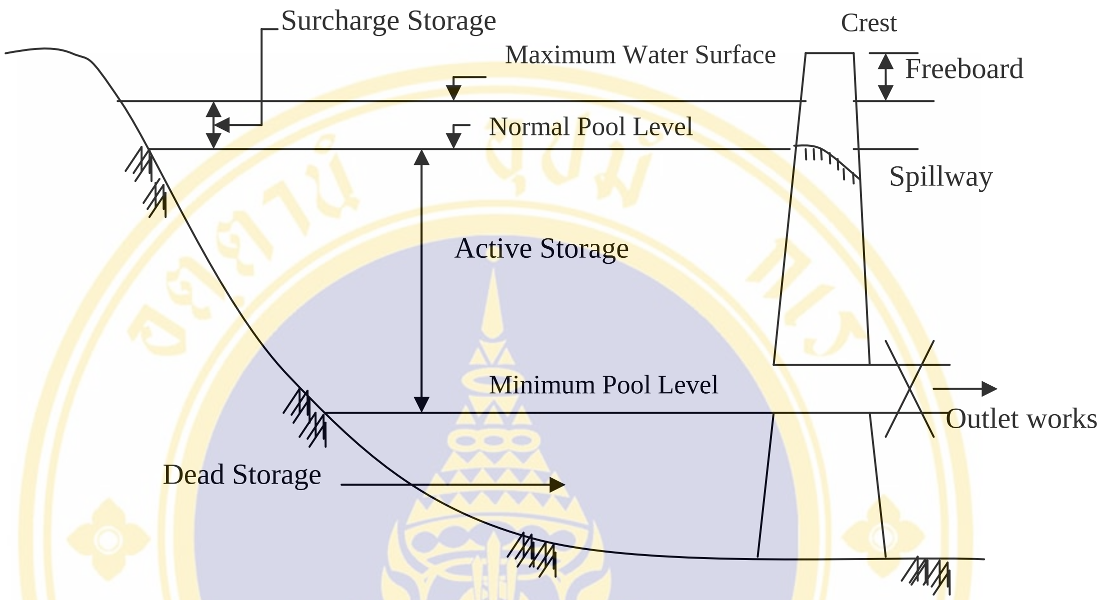

Figure 2-4: Classification of Pool Level at the Reservoir

(Source: Varawoot Vudhivanich, 1998)

(2) Spillway is used as a bypass when the water in the impoundment reservoir exceeds the set flood capacity of the dam. Water that flows over a dam may wash out the dam, causing a considerable amount of erosion. A spillway is therefore used to protect the dam from damage. The spillway is a wide, gradually sloped path of undisturbed soil located next to the dam that allows excess water to travel around the dam.

(3) Outlet Works serves to regulate or release water impounded by a dam. It may release coming flows at a reduced rate. Outlet structure can be classified according to their purposes, their physical and structural arrangement. Low level outlets are provided to maintain down stream flows for all level of the reservoir operational pool. The outlet may also serve to empty reservoir to permit inspection, to make needed repair, or to maintain the upstream face of the dam or other structures normally inundated.

2.2.2 Problems in Water Allocation from Major Reservoirs

The water shortage in dry season coupled with high demands for water suppliers for various activities causes conflicts of unequal water allocation. Paiboon Jujailum (1995) states the 2 major problems in water allocation.

a. Conflict over water allocation within agricultural sector.

The conflict is likely to occur between users during dry season. Stealing water by illegally connecting a pipe to the aqueduct, pumping water from reservoirs and blocking waterways, which results in inadequate water supplies for users at downstream areas. In addition debris blockage and accumulated sediments often clog waterways resulting in water passage difficulty.

Furthermore, the conflict can be triggered by capitalists who acquire large scales of agricultural land that require a large amount of water supply and are not aware of the conventional rule for water allocation within the community. According to the study Tanet Charoenmuang (1994), it had been reported that at weir Prayakum, there was a retired government officer attempted to bring water form public pound to irrigate his longan orchard by disregarding community laws on water allocation. As a result, there have been conflicts between local farmers and was a retired government officer since.

b. Conflict over water allocation between farmers and government agencies.

According to Tanet Charoenmuang (1994), the conflict over water allocation between farmers and government agencies is caused when the government replaces the conventional weir system with a state of the art irrigation system. Despite having set rules and instructions for using the new system, conflicts over water allocation still occur due to lack of understanding in community of the new system as well as lack of officers to train them. Another case is when the Rural Development Department constructs a cement weir over an old clay weir resulting in community's declining sense of ownership and leads to ignorance of maintenance of local users.

2.2.3 Concept of Water Allocation from Major Reservoirs

Water allocation is an attempt to bring water from the source and irrigate for agricultural production purpose. Principles for water management include planning, implementation, monitoring, and evaluation (Varawoot Vudhivanich, 1989).

In planning for water allocation and distribution it is necessary to consider who and how should water be distributed, and how much water should be allocated. Varawoot Vudhivanich (1989) identifies key considerations for water allocation and distribution as follows:

- Water resource: should be adequate and reliable.
- Water requirements: should be appropriate in timely manner.
- Water irrigation system: should be considering for its capacity and efficiency.
- Human resource: should be equipped with planning, implementing, and evaluating capabilities and including water users.

Varawoot Vudhivanich (1982) describes the three levels of water project management as follows:

- Management of water source for the irrigation projects, for exmple dams or reservoirs or ground water.
- Management of water allocation through irrigation system in an accurate and timely manner.
- Management of water distribution to agricultural areas through irrigation canals, ditches, and laterals in an adequate and equally manner.

The three levels of water project management are continuing systems that must be cohesively implemented at all time, otherwise the problems concerning water management and maintenance of the project will arise.

The project officers will be in charge of water management and maintenance at water source and irrigation system levels in terms of administrative and budgeting issues. At the agricultural-area level, farmers will responsible for water distribution and maintenance under the supervision of project officers.

The four majors' roadblocks to successful water noted by Apichat Anukulumphai, et al. (1981) are:

- Unequal and inadequate distribution of water to upstream and downstream users.
- Lack of cooperation from farmers causing, frustrations and indiscipline in the implementation of water distribution plan.
- Under expected agricultural productions.
- Under expected irrigation efficiency.

The primary purpose of water management is to equally and adequately provide water to all users on an equitable basis in order to enhance productivity. The water management can be categorised by components in which it is involved:

- Engineering component involves the improvement of irrigation system and method to meet water requirements of crops in timely and efficiently manner.
- Economic and social components engage the collaboration of farmers in water allocation aiming at minimising conflicts among users as well as maximising satisfaction and equitableness of water allocation.
- An agricultural component intends to better utilise water through new techniques which assist in selecting the right crops for local soil, water, and market.

According to Bancha Kwanyune (1998), an effective water management must be capable of:

- delivering water in timely manner;
- delivering adequate water;
- providing reliability on water distribution and allocation;
- ensuring equitableness in water distribution; and
- sustaining the safety of water source

Above objectives concern planning, implementation and monitoring processes of water management. The measurement of effectiveness of reservoir project can be conducted through monitoring and evaluation of all components. The goal of the project also helps in assessing the effectiveness of the implementation.

Evidently, goal and target are critical in assessing efficiency of the project. Both direct and indirect goals of the project ought to be translated into achievable target for implementation and ultimately be extracted into efficiency indicators (Varawoot Vudhivanich, 1994).

In the perspective of irrigation management, there are five goals to be achieved (Abernethy, 1990).

- Productivity-Irrigation system should provide productive food and fiber productions through the equilibrium between input water, land and human resources and output annual productions.
- Equity-Irrigation system is a source of benefit to water users. Equity does not only imply to equity in water distribution, but also in water allocation by considering priority of need, location and soil characteristics.
- Profitability-irrigation system should generate satisfying profits to all stakeholders.
- Sustainability-Performance of irrigation system management should be sustainable in terms of quality of soil and water.
- Quality of life-Irrigation system should accelerate the quality of life, which includes health, employment, community development, effects on women and children, disadvantages of downstream water users, and changes and amount of outflow water.

Pramote Maiklad (1991) suggests approaches to maximize the irrigation efficiency as follows:

a. Plan of Water Distribution System

The plan includes details of description of water distribution and time frame for irrigating water to all areas of the project. The plan should also include the identification of water requirements and amount of water and timetable for distributing water to each irrigation channel. The principle of irrigation planning is to take control of amount of allocated water at three exits, which are pipes to agricultural areas, pipes to distributing channels, and main water gates.

Therefore water distribution plan should cover three sub plans:

(1) Plan for distributing water through pipes to agricultural areas.

- Water distribution in rainy season should consider types of crop, water consumption of crops, and amount of rainwater used by crops.

- Water distribution in dry season should consider amount of water resource, types of crop, contingency plan for water shortage.

(2) Plan for distributing water to irrigation channels can be implemented after plan for distributing water through pipes to agricultural areas by computing the total water demands and then develop a weekly water distribution plan.

(3) Plan for distributing water at the water gate relates to the total amount of water resources. It can be implemented after a plan for distributing water to irrigation channels.

b. Methods of Irrigation

- Continuous Irrigation is the delivery of an uninterrupted stream of irrigant to the agricultural areas. It is suitable for daily high water consumption areas. The advantage of this method is that less officers and farmers are required for operation. However, disadvantages of this method are loss of water to ground water and inequitableness of water distribution during peak periods.

- Timely Irrigation is the delivery of water supply to agricultural areas in accordance with timetable. The advantages of this method are the reduction in loss of irrigated water and conflicts over water distribution during water shortage, and to ensure equitableness of water allocation of all activities.

- User-dependent Irrigation is the delivery of water supply by depending on the water requirements of users. This method is popular in developed countries where canal and ditch systems are larger than those of above 2 methods. In doing so, water resources must be adequate and appropriate so that the irrigation project can collect fees from users for the purpose of conservation.

2.2.4 Simulation of Water Allocation from Reservoirs

The simulation is divided into a behavioral study of river basins and an optimization study by taking objectives, constraints, hydrographic and economic issues, and Geographic Information System (GIS) into data processing process for efficiency enhancement (McKinney, et al., 1999).

2.3 Multi-objective Decision Making Process

In efficiently managing water allocation and distribution, cooperation from the authorities is required. The hypotheses of decision making is based on compromise and lower cost of analysis compared to cost of effect of decision making. The solutions to decision making process can be divided into 4 alternatives (Bancha Kwanyune, 1998).

- Single objective: Single decision maker
- Multi objectives: Single decision maker
- Single objective: Multi decision makers
- Multi objectives: Multi decision makers

Single objective decision making by single decision maker is the easiest approach. Conversely, multi objectives decision making by multi decision makers is the hardest method to conduct due to numbers of alternative options, changes in target and increases in limitation of consideration, and various rationales and influential factors affecting decision making process (Huizingh & Veolijk, 1994).

Multi objective Decision Making techniques start by implementing a search for efficient solutions. Once these have been identified, they then move into a second phase in which different solutions are explicitly compared using the range of objective functions that are defined for the problem in question. Often this will involve explicit interaction with the user, who, directly or indirectly, will ultimately have to input views on the trade-offs or other measures of relative importance that he/she holds as between the competing objectives (Sahoo,1998).

Multi objective Decision Making techniques can be divided into 3 alternatives (Goicoechea, et al., 1982)

2.3.1 Constructing the alternatives

The alternatives are based on Pareto optimality approach. That is, if the benefits of one objective increase, those of others decline. The approach mot only constructs the diversity of group alternatives, but it also includes the problem of facts. However, users should clearly understand the constraint of each objective. The approaches of alternative designs are Weighting method, ε-Constraint method, Phillip's linear multiobjective method, Zeleny's linear multiobjective method, etc.

2.3.2 The weighting approach of advanced objective

It is used for alternatives suitable for problem constraints as well as the satisfaction of each objective. Through the weighting specification of importance in each advanced objective, the alternatives become less and easy to decision making. However, the outcomes largely depend upon weighting of each objective. The approaches of weighting the advanced objective are Weighted Average, Electre I, Electre II, Determination of Relative Weights, etc.

2.3.3 The progressive approach

Under the alternative formulation, the decision makers select the best solution resulting from sharing information each other. Although, the approach requires many decision makers, trial and error and time-consuming, it offers the appropriate and acceptable alternative. These approaches are the Step Method (stem), the Method of Geoffrion, the Method of Zionts-Wallenius, etc.

2.4 Analytical Hierarchy Process (AHP)

2.4.1 Principle of Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, AHP not only helps decision makers arrive at the best decision, but also provides a clear rationale that it is the best. Designed to reflect the way people actually think, AHP was developed in the 1970's by Dr. Thomas Saaty, while he was a professor at the Wharton School of Business, and continues to be the most highly regarded and widely used decision-making theory (Vitoon Tansirikongkon, 1999) (Figure 2-5).

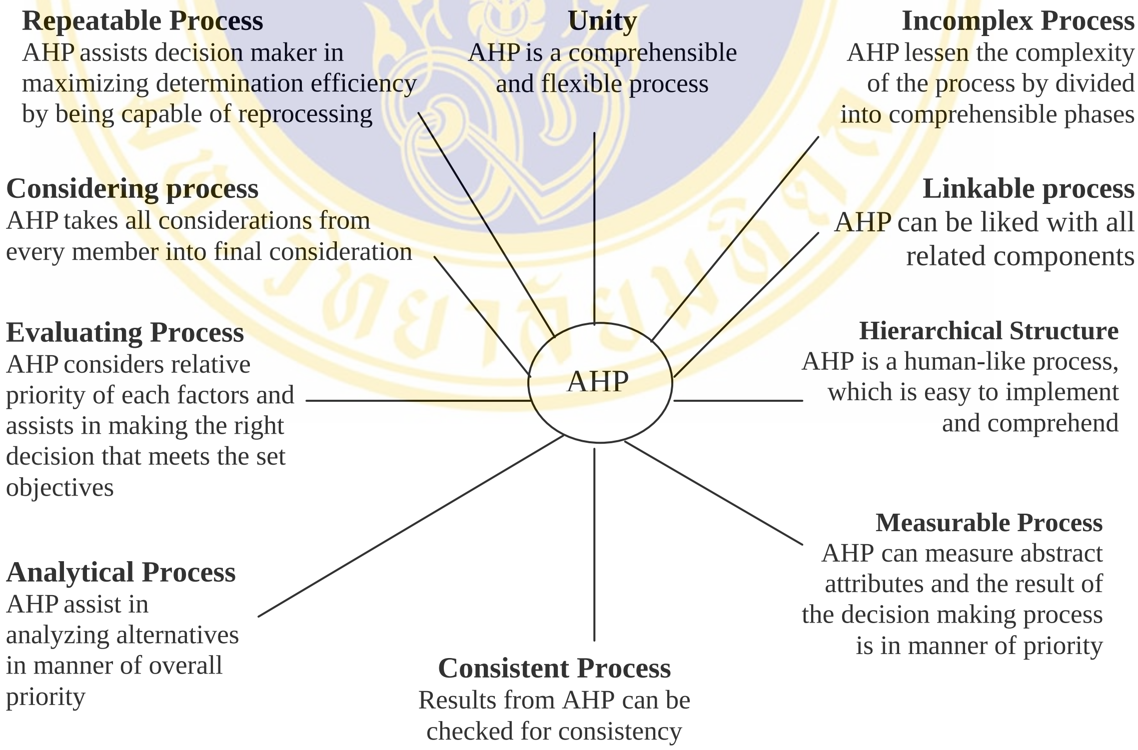

Figure 2-5: Benefits of Analytical Hierarchy process

(Source: Vitoon Tansirikongkon, 1999)

Huizingh & Vrolijk (1994) explains that the determination of relative weights can be done by dividing structure of problems into goal, criteria, and alternatives and then comparing them to discover the weight of each pairwise. Finally, the alternative with the highest weighting scores is selected.

2.4.2 Hierarchical Structure

In the decision making process for the best solution, determination will be divided into levels, which are goal, criteria, sub criteria, and alternative. Within each level, there can be as many criteria and sub criteria as required (Vitoon Tansirikongkon, 1999) (Figure 2-6).

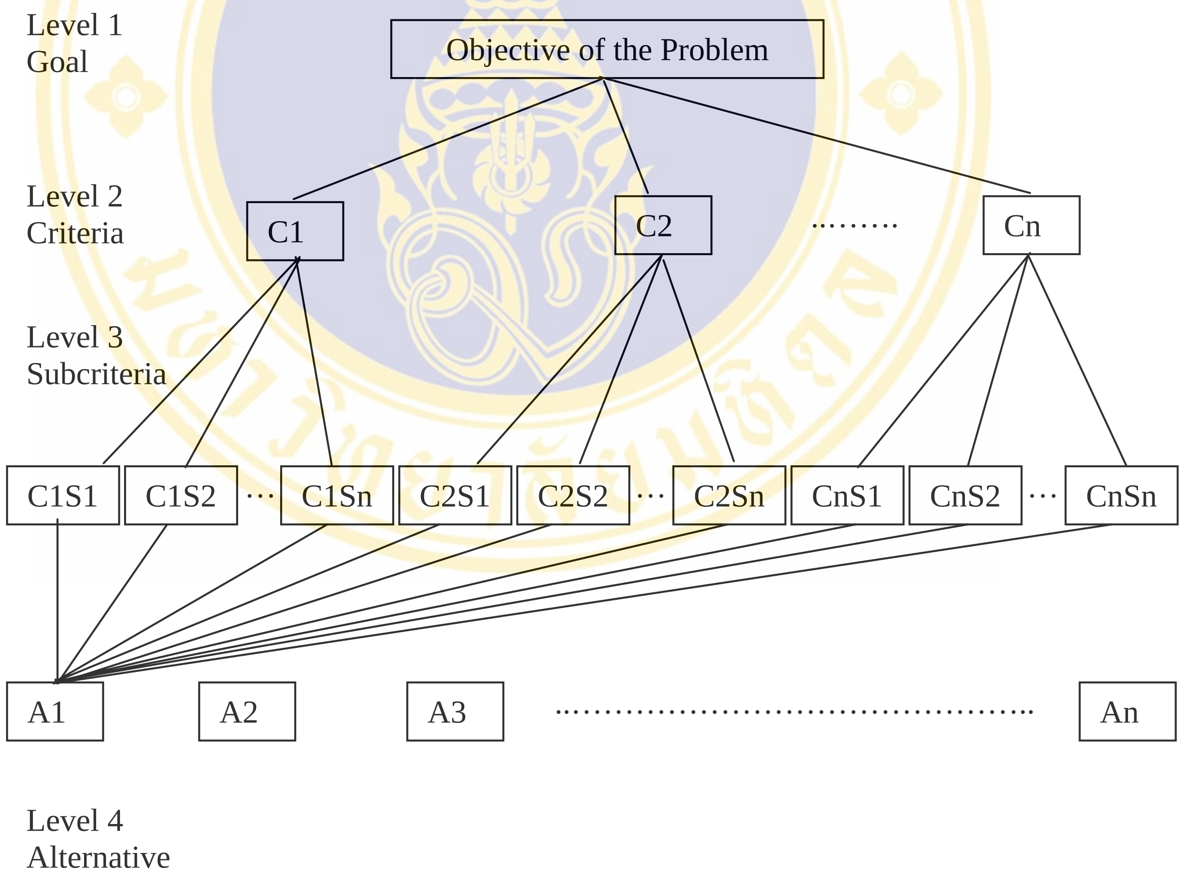

Figure 2-6: Levels of Analytical Hierarchy Process

(Source: Sahoo, 1998)

2.4.3 Priority Setting

In each level, authority or top management is asked to rank priority by criteria and to compare pairwise starting from top level to the fourth level. The Measurement scale is divided into 9 levels as shown in table 2-3. Then the calculation of relative priority is done from the top level to the fourth level respectively (Vitoon Tansirikongkon, 1999).

Table 2-3: Scale of Relative Priority Comparison (Saaty, 1980)

Comparative Importance	Definition	Explanation
1	Equally important	Two decision elements (e.g., indicators) equally influence the parent decision element.
3	Moderately more important	One decision element is moderately more influential than the other.
5	Strongly more important	One decision element has stronger influence than the other.
7	Very strongly more important	One decision element has significantly more influence over the other.
9	Extremely more important	The difference between influences of the two decision elements is extremely significant.
2,4,6,8	Intermediate judgment values	Judgment values between equally, moderately, strongly, very strongly, and extremely.
Reciprocals: If v is the judgment value when i is compared to j, then 1/v is the judgment value when j is compared to i.		

The calculation of weight of compare pairwise is conducted by using the principle of Eigenvalue and Eigenvector (Saaty, 1980).

$$[A]x = \lambda x$$

where $[A]$ = Square matrix indicates comparison with comparative scale

x = Eigenvector indicates weight of relative priority in the same level

λ = Eigenvalue of matrix $[A]$

2.4.4 Principle of Consistency

Considerations from management or expertise derived from relative priority scores can sometime be inconsistent or found error (Vitoon Tansirikongkon, 1999).

Therefore consistency test is required to ensure the soundness of determinations. Saaty (1980) suggests equation for consistency testing as follows:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}$$

where CI = Consistency index

λ_{max} = Maximum eigenvalue

n = Dimension of matrix)

The Consistency Ratio (CR) is obtained from the above analysis by having Consistency Index CI divided by Random Consistency Index (RI). As shown in table 2-4.

$$CR = \frac{CI}{RI}$$

where CR = Consistency ratio

CI = Consistency index

RI = Random consistency index

An acceptable CR must not exceed 0.1. If CR is higher than 0.1 then the determination is considered inconsistent and will not be given effect (Vitoon Tansirikongkon, 1999).

Table 2-4: Random Consistency Index (RI) (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49	1.51	1.48	1.56	1.57	1.59

Vitoon Tansirikongkon (1999) identifies steps in conducting Analytical Hierarchy Process as follows:

- Define problems and related elements
- Develop criteria
- Determine accessing criteria
- Develop alternatives
- Determine priority setting in each criteria
- Calculate for the best solution by considering the priority as a key determinant

2.5 Development of Alternative Options for Water Allocation

According to the study by Thongplew Kongjun (2003), linear programming (LP) is used with the technique of ε-constraint in developing alternative options for water allocation. The stages in the development of alternative options for water allocation are discussed below.

2.5.1 Identify Maximum and Minimum Points of Water Usage in Each Activity

a. Maximum Points of Water Usage in Each Activity

- Water for agricultural activity will be at maximum when water for ecosystem stability is not allocated. Surcharge water from agricultural activity will be allocated to consumption activity.

- Water for consumption activity will be at maximum when water supplies are firstly allocated to consumption activity then allocated to agriculture and ecosystem stability activities.

- Water for ecosystem stability activity will be at maximum when water supplies are firstly allocated to ecosystem stability activity then allocated to agriculture and consumption activities.

b. Minimum Points of Water Usage in Each Activity

- Water for agricultural activity will be at minimum when water for ecosystem stability is allocated. Then Surcharge water from ecosystem stability will be allocated to agricultural activity.

- Water for consumption activity will be at minimum when water supplies are allocated to agricultural activity then allocated to consumption activities at the amount of monthly demands.

- Water for ecosystem stability activity will be at minimum when water supplies are allocated to agricultural activity then allocated to consumption activities at the amount of monthly demands.

2.5.2 Ranges of Minimum and Maximum Points of Water Usage in Each Activity

The ranges of minimum and maximum points of water usage in each activity can be calculated from the following equation.

$$\varepsilon_k = Z_k(x)_{\min.} + \frac{[t]}{(r-1)}[Z_k(x)_{\max.} - Z_k(x)_{\min.}]$$

where $Z_k(x)_{\min.} \le \varepsilon_k \le Z_k(x)_{\max.}$

$Z_k(x)_{\min.}$ = Minimum point of water usage in each activity

$Z_k(x)_{\max.}$ = Maximum point of water usage in each activity

p = Numbers of activity

k = Order of activity equals to 1, 2, 3… p

ε_k = Order of range of each activity

r = Order of ε_k of range of each activity

t = Range of each activity equals to 0, 1, 2, …, $r-1$

All alternatives are equal to r^{p-1}

2.5.3 Development of Alternative Options by Using ε-constraint Technique

a. Maximum and minimum points of water usage in each activity are to be obtained from the yearly data of lowest volume of water inflow. The result of the calculation conducted by Thongplew Kongjun (2003) is shown in table 2-5.

Table 2-5: Minimum and Maximum Point of Water Usage in Each Activity Obtained by the Calculation of Linear Program (Thongplew Kongjun, 2003)

Agriculture Productivity (% of the max.)		Consumption Water shortage (Million Cubic Meters)		Ecosystem Stability Water shortage (Million Cubic Meters)	
Max.	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
49.00	60.00	0.00	15.12	0.00	55.43

b. Alternative options for water allocation can be developed by dividing the maximum and minimum points of water usage in each activity into ranges (*t*) as required. The number of alternative will depend upon the number of (*t*). In this study, the maximum and minimum points of water usage in each activity are divided into 3 ranges (t = 0-3). Hence, the order of range of each activity (ε_k) equals to 4 (r = 4). The result of the calculation conducted by Thongplew Kongjun (2003) is shown in table 2-6.

Table 2-6: Activity Values Used in the Study (Thongplew Kongjun, 2003)

Activity Values			
ε_k	**Agriculture Productivity (% of the max.)**	**Consumption Water shortage (Million Cubic Meters)**	**Ecosystem Stability Water shortage (Million Cubic Meters)**
1	49.00	0.00	0.00
2	53.00	5.04	18.48
3	56.00	10.08	16.95
4	60.00	15.12	55.43

According to table 2-6, ε_k of each activity increases by 1/3 of the difference between maximum and minimum points. It is founded that the calculation provides great difference in consumption activity due to its greater sensitivity to water shortage. Therefore, the most affected activity is required to be divided into more ranges. Alternative options can be developed by trading off ε_k .

The eight alternatives for water allocation during water shortage are then selected. The results of each alternative are depicted in table 2-7.

Table 2-7: Alternatives for Water Allocation by Trade-off (Thongplew Kongjun, 2003)

Alternatives	Agriculture		Consumption		Ecosystem Stability	
	Max Productivity (% of the max.)	Decrease in Productivity (% of the max.)	Water shortage (MCM)	Reduction in Consumption Water (%)	Water shortage (MCM)	Reduction in level of Water (%)
1	60	40	15.12	54.32	55.43	7.56
2	59	41	10.08	36.21	55.43	7.56
3	57	43	5.04	18.11	55.43	7.56
4	56	44	0.00	0.00	55.43	7.56
5	58	42	15.12	54.32	36.95	4.16
6	56	44	10.08	36.21	36.95	4.16
7	55	45	5.04	18.11	36.95	4.16
8	54	46	0.00	0.00	36.95	4.16
9	55	45	15.12	54.32	18.48	1.99
10	54	46	10.08	36.21	18.48	1.99
11	52	48	5.04	18.11	18.48	1.99
12	51	49	0.00	0.00	18.48	1.99
13	53	47	15.12	54.32	0.00	0.00
14	51	49	10.08	36.21	0.00	0.00
15	50	50	5.04	18.11	0.00	0.00
16	49	51	0.00	0.00	0.00	0.00

2.6 Relevant Studies

The studies relating to the study of an Integrated Decision Making for Water Allocation for Agriculture are:

2.6.1 Relevant Studies of Water Allocation System

Molden (1997) study of Nile River Basin of Egypt has conducted water accounting in the simulation in order to study productivity and efficiency of water usage in each activity. This paper presents a conceptual framework for water accounting and provides generic terminologies and procedures to describe the status of water resource use and consequences of water resources related actions. The framework applies to water resource use at three levels of analysis: a use level such as an irrigated field or household, a service level such as an irrigation or water supply system, and a water basin level that may include several uses. Water accounting terminology and performance indicators are developed and presented with examples at all the three levels. Concepts and terminologies presented are developed to be supportive in a number of activities including: identification if opportunities for water savings and increasing water productivity; developing a better understanding of present patterns of water use and impacts of interventions; improving communication among professionals and communication to non-water professionals; and improving the rationale for allocation of water among uses. It is expected that with further application , these water accounting concepts will evolve into a robust, supporting methodology for water basin analysis.

Sasitorn Mapracha (2000) the objective of this research is to develop a decision support system for water resource management in order to store, save, edit and search for information about surface runoff, rainfall and reservoir storage. This system can be used for forecasting the rainfall and runoff according to the probability occurrence by means of plotting position, Weibull and Gumbel probability density function. The relationship between rainfall and runoff can be calculated via Linear Regression and Multiple Regression. This decision support system for water resource management includes data of surface runoff, rainfall and reservoir storage. Database of this research is the relational database. This research uses Microsoft Access 97 to create and develop the database system of rainfall, database system of surface runoff, database system of reservoir storage, forecast system and uses Microsoft Visual Basic 6.0 to link the database system and the forecast system. The developed system was evaluated by three groups of people, experts in analysis and design systems, experts in hydrology and, the users. The results show that the developed system is simple to operates resulting in increased work efficiency, decision in correct calculation and the capability to be used as support system for water resource management

Mingsan Khaosaart, et al (2001) has undertaken a study of Alternative Options for Peasants in Dry Season: a Case study of Chao Praya and Mae Klong River Basins by conducting a survey on alternatives for agricultural activities during dry season. It is founded that the majority of agricultural land used are rice fields and the number of the rice fields are expanding far beyond the irrigation plan due to their expertise in rice farming techniques and limited skills in cultivating other types of crops.

The study discovers that under the limited supply of water in the reservoirs, peasants in the upper western Chao Praya river bank are not interested in cultivating alternative crops and prefer doing their agricultural activities in a traditional manner due to the plentiful of water supply in a secondary source of water, for example river or underground water. However, peasants in the upper eastern Chao Praya river bank are incline to alter their agricultural pattern to less water-required activities due to the lack of secondary source of water supply.

The data obtained from the survey assist in explaining the rationale for changes in peasants' behavior in doing agricultural activities during dry season. Changes in cultivation patterns including cultivation of less consuming crops and reduction in cultivating areas in order to maximize the use of limited water supply indicate the factors affecting the choice of alternative agricultural activities during dry season of peasants, which are beneficial for future study.

Chayutpong Amrungsuk (2001) have to investigate the water usage behavior of farmers in Lam Pra Plerng Irrigation Project. Due to the limitation of water supply for dry season in study year. The farmer are not cultivation following the project irrigation recommendation planning. They grow various kinds of crop depending on their dexterity, the condition of cultivated area, products' price, and neighborhood's cultivation. From the study results, it is recommended that the farmers should have more involvement in operating and maintenance. They should come to participate from the beginning as; in water allocation planning, monitoring and maintenance, especially at on-farmland.

Dai and Labadie (2001) use MODSIMQ, a simulation of optimization, to study and compare alternatives options for water allocation between water resources and ground water in lower Arkansas River basin. Found that an application of MODSIMQ to the lower Arkansas River basin in Colorado successfully models the complex legal and administrative issues under Colorado water law and the Arkansas River Compact, including the many water exchange mechanisms governing use of off-stream reservoirs in the basin. Model calibration exercises conducted for the case study confirm that MODSIMQ reasonably reproduces both historical flows and salinity levels for the calibration period. Results from various management scenarios indicate that appropriate conjunctive use of surface and groundwater can simultaneously satisfy water demands for users while enhancing control of salinization.

Surachai Sompoptrakul (2001) the objectives of this study were to evaluate efficiency and equity of water allocation in the level of ditch and lateral canal of Nakornprathom Irrigation Project. In this study, efficiency, delivery performance ratio (DPR) and equity were selected as the indicators. Evaluation was done in the level of ditch and lateral canal during wet season of the year 1990 and dry season of the year 1990-2000. The irrigation efficiency in ditch level of canal 1R-1R-5L were between 36-57%, canal 6R-5L between 36-61%, canal 9R-5L between 30-52%, and canal 10R-5L between 29-54%. The irrigation efficiency in canal level were ranged between 39-62%, 39-43%, 33-35%, and 38-52% respectively. The values of DPR for all ditches and canals were ranged between 1.00-2.00 and 1.44-1.87 respectively. These values are higher than one, which indicate that the amount of water allocated for the all canals were greater than the requirement. These result agree with the system physical survey which identified that some of irrigation structures and canals were deteriorated, some parts of the ditches were shallow or obstructed by weeds, moreover water was also stolen by some farmers. From the head-tail equity ratio, results were ranged between 0.89-1.54, which mean that the amount of water received by the farmers at the beginning of canal and at the end of the canal were different, majority the farmers at the beginning of canal received over.

Chutiwan Sittilert (2003) this field research study was done to understand ideas, social organization and implements that water users' organizations use to manage water. It was conducted by studying organizations as an open system and studying their capability through five basic activities of irrigation i.e. water usage, water allocation, system maintenance, labor and resource mobilization, and conflict management. The sample group was the Water Administration Group, Zone 2. Data were collected by surveying, in-depth interview and group discussion. Resulted revealed that a water users' organization had different ideas in water management according to the objectives of production and type of crop, but had no different ideas in types of land ownership because those ideas depend on water allocation from each irrigation project. As a consequence, the social organizations had more formal aspects and reflected the different organizations in the Muang-Fai system and were related to the old water users' organizations. The basic activities of irrigation revealed that the organization had the capability to manage water by themselves, while their implementation of water management was a sense of ethics and conscience. These findings suggested that irrigation projects should allow water users' organizations to participate in water management at every step and supporting the capability of those existing to become more empowered, including establishing strategies to move water management over to water users' organizations in the future.

Aunnop Arirat (2004) Damnoen Saduak is a very productive agricultural area which deserves the best possible water management. Irrigationist as providers have many duties such as controlling water levels to prevent contamination by seawater ensuring adequate water in times of shortage; and draining water from upper areas into the sea. Performance of these duties, however, has sometimes brought them into conflict with water users who feel their interest, have not been adequately considered. This field research study was undertaken to define and understand the views of, and the relationship between, water users and irrigationists. This research was also intended to provide a rationale for irrigationists' actions. The investigation focused on the attitudes, perceptions, conflicts and alternatives of water users and irrigationists or providers. It addressed such matters as the water allocation system, water quality and management and the extend to which water users and irrigationists are satisfied with the current management, of existing of water problems. Data were collected by questionnaires and in-depth interview. Results revealed that there are some significant differences of perception and attitude between water users and irrgationists. Water users often perceive that providers manage water without regard to users' needs. Some water users believe that the water allocation system is inefficient and ineffective and that such problems are compounded by ab inadequate budget and budgetary inefficiency. By contrast, irrigationists or providers believe that they provide the best service for water users despite many constraints and limitations. These findings suggest that irrigation projects should allow water users to participate in every level of water management and also promote more information interchange between users and providers. Joining hands and participation between stakeholders is an essential strategy to improve water management, in the study area foe maximum satisfaction.

2.6.2 Relevant Studies of Analytical Hierarchy Process (AHP)

Noppadol Horthiwong (1996) identifies the appropriate criteria for decision-making in a government agency that supports research, development and engineering projects in the industrial sector. The case study was selected from a government agency. Started with a survey of foreign agencies with similarities to that in the case study, an interview of the project evaluating committee, and observations of the project evaluation meeting. The decision criteria obtained were divided into groups based on theoretical considerations and the decision structure determined according to the Analytic Hierarchy Process (AHP). The criteria were divided into two sets, the first set being to screen the proposals before project evaluation and the second, to evaluate the projects that passed the screening process. The latter set of criteria may be divided into two main criteria. (1) potential of the project which consists of (a) potential of the company that proposed the project and (b) potential of the technology in the project and (2) benefits of the project which consists of (a) technology development benefits (b) financial benefits and (c) social benefits. In order to test the software and the sample projects by this decision structure, the next step was weighing the importance of the evaluation criteria by pair wise comparisons. From the results, the project evaluating committee, on average, found that the importance of the potential of the project was close to importance of benefits of the project. Applying the same procedure to the two sub criteria under the project potential criterion showed that the potential of the company that proposed the project was more important than the potential of the technology in the project. As for the sub criteria under the project benefits criterion, it was found that the technology development benefits sub criterion was most important, while the financial benefits criterion was close in importance to the social benefits. This decision structure was applied to the case examples. When the committee was asked of its opinion concerning this decision-making process, most members responded that AHP and the criteria used to evaluate the project produce results that conform to the results obtained when not using AHP, and it is a very good decision-making process. Although the result of weighing the importance of the criteria may not be used in general since the sample size is small and the results are statistically insignificant, it may be concluded from this research that AHP is a good method in evaluating the research, development, and engineering project proposals.

Prapasri Swasdi-ampairaks (1999) in this study, Analytical Hierarchy Process (AHP) is employed to select an appropriate site for a packaging company. In this case study, AHP is being employed, as a tool to arrive at a Multi-Criteria Decision-Making which will include both monetary and non-monetary related factors. AHP is a non-complicated process, being able to show levels of importance of criteria.

This study is comprised of factors affecting the site selection and the decision criteria being employed would touch on the overall completeness, practicality decomposition non-duplication and the appropriate numbers of criteria. It is found that the main factors are land cost, transportation cost, manufacturing cost, market, infrastructure, working environment, community/society, and state supports. The primary choices being scrutinized on suitability are Bangpoo Industrial Estate, Navanakorn Industrial Estate, Bang pa-in Industrial Estate and Hi-Tech Industrial Estate. In this research study, factors and selection choices are being employed to create a multi-level structure selection process so as to select an appropriate site for a packaging company and for the compilation of decisions from people concerned. It is found that the decision maker give the weight on transportation cost as the first, market as the second, manufacturing cost as the third, land cost as the forth, infrastructure as the fifth, state support as the sixth, working environment as the seventh, and community/society as the last. From the choices cited, it can be concluded that the most suitable site is Navanakorn; followed by Hi-Tech, Bang pa-in, and Bangpoo.

Jirachai Sakchanalaya (1999) to identify the criteria for adapting the manufacturing and distribution plans in the adjustment of linear programming (LP) solutions. The research began by studying the problems in the process of adjusting LP solutions by the decision makers, who used certain criteria other than those formulated in the LP model. To clear up the LP solutions adjustment process and make sure that it is the result of the group decisions, this study will analyze the data and establish the decision criteria according to the analytic hierarchy process (AHP), by applying them to a case study of cement distribution management in the Logistics Division of a large cement company in Thailand. The objective of the decision is to select cement distribution centers according to the establish criteria. The study started with the interviewing the managers of the Logistics Division and gathering those results and grouping them using the affinity diagram and the decision structure constructed by the AHP model. The model consists of two main criteria. The first main criterion is Distribution service level with the two sub-criteria: (1.1) Capability of distribution management, which consists of (a) Scheduling capability (b) Fleet management capability (c) Fleet Controlling difficulty (d) Shipment volume suitability (e)

Communication and coordination comfort and (1.2) Readiness of facilities which consists of (a) Truck fleet available (b) Parking area available (c) Truck ban constraint. The second main criterion is a Transportation Cost constraint which consists of (a) Minimum truck load capacity (b) Task Allocation to each transportation sub-contractors. The next step was weighing the importance of the evaluation criteria by pair wise comparisons. After that AHP software was used to test the consistency ratio and calculate the weight for each criterion based on the sample group of decision makers and get the scale of intensities for evaluating the choices under the various criteria. This decision structure was applied to the case example. Results obtained from the opinions concerning this decision making process show that the assessors see benefits of having consistent and clear decision criteria, improving the customer service level, and enabling more accurate production and distribution planning.

Rutjarek Kanjanarutjawiwat (1999) Quality function Deployment (QFD) is a technique used for assisting manufacturers in planning their products. The mechanism of QFD begins with identifying customers' requirements and deploying through their demands at any time. Technical demand, design demand, critical characteristics of parts of the product, critical processes, and operational planning needs are facilitated by putting them in matrix format. These plans are arranged according to their importance depending on the relationships between demand and its associated weight of importance of the demand. Important values are obtained from opinion of customers and team of manufacturers. Conventionally, important values are given in absolute points. This approach has many disadvantages, for example, decision inconsistency, different bases used while making different decisions, and that decision makers can't consider many needs at the same time and hence think that all the needs are of equal important. This research is focused on the improvement of mechanism used in conventional QFD. It is recommended that the decision makers should provide points of importance by using AHP (analytical hierarchy process). Although this approach can reduce the weakness of the conventional point scoring, from the research experiments, it is found that this approach has disadvantages. Complicated calculations are needed while perhaps causing confusion to the users who do not have much knowledge about the theory of AHP. In addition, the characteristics of pair wise-comparison that bring about the limitation in terms of the number of needs that can be compared for each question of interest. The research finds that using AHP in making decisions in QFD is better than what is doing in conventional QFD. This can facilitate better data collection and reflect the real feeling of decision makers and customers. Their drawbacks can be reduced by sending more questionnaires to customers and choosing only data that are consistent and acceptable as well as using computers in reducing the burden in complex calculations.

Juthaporn Booranaosot (2000) The purposes of this thesis were (1) to develop the factors for evaluating students' thesis of the Faculty of Education, Chulalongkorn University; (2) to determine the weight of importance assigned to each factor using the average weight and AHP techniques; (3) to compare the difference of the weights between average weight and AHP techniques; (4) to compare the quality of the two techniques using factor analysis method as a criterion; (5) to determine the criteria for evaluating students' theses for each department of the Faculty of Education, and (6) to study the opinions of the experts regarding credibility and satisfaction of the two techniques. Subjects of the study were 159 faculty members of the Faculty of Education in Chulalongkorn University, Kasetsat University, Silapakorn University, and Srinakharinwirot University, and 67 faculty members in graduate programs of the Faculty of Education, Chulalongkorn University. The results of the study were as follows: 1. Six factors for evaluating students' these were (1) statement of research problem and objectives, (2) review of literature, (3) conceptual framework, (4) research method, (5) presentation of research findings, and (5) significance of the study. 2. The most important weights given by factor analysis, average weight and AHP techniques were research method factor (research design, sampling design, measurement design, data analysis design, and data interpretation). The weights assigned by each of the three techniques were 49.81%, 45.90%, and 41.25%, respectively. 3. The weights given to review of literature factor as derived by the three methods, i.e. factor analysis, average weight, and AHP techniques, yielded similar results (10.70%, 10.40% and 11.63%, respectively). 4. The weighting results given by AHP technique was closer to those by factor analysis than the average weight techniques. 5. The criteria used for judging the quality of the students' theses were different among departments. As a whole, the range of scores representing the 3 levels of thesis quality was: very good (85<very good<100), good (70<good<85), and pass (60<pass<70). 6. The experts were satisfied with both techniques. Upon their opinions, average weight technique was easier and more convenient than AHP technique. But, the latter was more suitable for the complex decision.

Kittiphong Photaranon (2000) To study the key factors and develops the decision support system by applying the analytic hierarchy process for selecting new refractory products in the cement and steel industries for development to suit the business environment of one of the largest refractory manufacturers in Thailand. The determination of the key factors was derived by collecting the various factors to be considered from published articles in management and administration and the brain storming of members of the product development committee. These items were then grouped into related factors using affinity diagram and relation diagram and consequently transformed to be in the form of the hierarchy model. As for the weights of the factors, the pair wise comparison questionnaire was developed and answered by the seven-member new product development team of the company. The answers were evaluated by using the expert choice software and the weights of factors, which are network related, were calculated. The results show that there are six significant factors that influence the new product selecting process. These are quality (22.2% weight), selling price relative to variable cost (18%) environmental impact (9.3%), know-how for the development (8.7%), installation friendly (4.6%) and time for competitors to develop the same product (4.2%), these six factors gain 71.2% of total weight. The standard scores for the assessment of new product development were defined using the utility function approach in order to make it clear and minimize the bias of the assessors especially in terms of desired quality, which was derived from the forecasting of future technology demanded by the customers and transformed into the quantifiable refractory properties using matrix diagram. Using expert choice software, the calculation of total weight score for developed products is done and the relative priorities of new product for development which will offer the best benefit to the company are assigned, together with the sensitivity analysis for the weights of the factors. In conclusion, the most important criteria of the decision process of selecting new product to be developed are the determination of key factors which must conform to the objective of the company, calculating the weight of the key factors, determinating the standard score to minimize the bias of the assessors and the processing of the results must be clear and simple to analyze for the strength and weakness of each product for future improvement. The analytic hierarchy process is able to accommodate all these requirements in a satisfactory manner.

Claudia Ringler (2001) The Mekong River is the dominant geo-hydrological structure in mainland Southeast Asia, originating in China and flowing through or bordering Myanmar, Laos, Thailand, Cambodia, and Vietnam. Whereas water resources in the wet season are more than adequate to fulfill basin needs, there are regional water shortages during the dry season, when only 1-2% of the annual flow reaches the Delta. Recent rapid agricultural and economic development in the basin has led to increasing competition among the riparian countries for Mekong waters. This development calls for a structured approach to the management of the basin, including efficient, equitable, and environmentally sustainable water allocation mechanisms that support the socioeconomic development in the region. Institutional mechanisms for Mekong cooperation among the riparian in the lower basin have been in place since 1957, and were revived in 1995. However, comprehensive water allocation mechanisms for the (lower) basin have not been developed to date. In this study, multi-country and intersectoral analyses of water allocation and use are carried out for the Mekong River Basin with the objective to determine tradeoffs and complementarities in water usage and strategies for the efficient allocation of water resources. An aggregate economic-hydrologic model for the basin is developed that allows for the analysis of water allocation and use under alternative policy scenarios. Results from the analytical framework indicate that although competition for Mekong water still appears to be very low, there are substantial tradeoffs between in stream and off-stream water uses. An analysis of alternative water allocation mechanisms shows that to achieve both equitable and large benefits from water uses across countries and sectors, the ideal strategy would be to strive for optimal basin water use benefits and then to redistribute these benefits instead of the water resource. The development of such an integrated framework of analysis can be a critical first step to overcome some of the obstacles to effective management and joint cooperation in the Mekong River Basin. It could also facilitate the upcoming negotiations of water allocation rules in the lower basin and thus contribute to the reasonable and equitable utilization of Mekong River waters, as envisioned in the 1995 Mekong Agreement.

Thoedtida Thipparat (2001) to introduce a safety index model used in construction by applying the fault tree analysis and the analytical hierarchy process. By use of fault tree analysis, the safety index is derived by means of the relationship between the probability of accidents calculated from the fault tree analysis and the severity from accidents calculated from lost working days. By use of analytical hierarchy process, the probability of causes of accidents can be calculated from the fault tree diagram. Safety index model can analyzes the probability of causes of accidents, fault tree diagram and safety index values which can be used to assess risks of accidents as well as the effectiveness of safety management. As a result of the application of the analytical model for accidents from a form scaffolding from 8 construction sites in Bangkok, the significant causes of accident are recklessness, lack of personal protection equipment (PPE), lack of training of safety, and lack of controlling, respectively. Finally, the probability of accident from working with scaffolding is 0.078 occurrence per 200,000 man-hour and safety index is 0.803 workday per 200,000 man-hour.

Manatsawee Nonhuwro (2002) to assessment the composite indicators for sub educational standards that's learners standards, process standards, factor standards and the composite indicators major educational standards an application of analytic hierarchy process technique. The research instruments were questionnaire developed be the researcher, using indicators for educational standards assessment of basic education institution as a framework. Data were analyzed be frequencies, percentage, mean, eigenvector and Pair wise Comparisons Matrix. The research finding were summarized as follows 1) A composite of important weights major standards : the finding a first rank were learners standards have weight .400, second rank were process standards have weight .332 and last were factor standards have weight .269 2) A composite of important weights sub standards : the finding, learners standards in sub standards 11, 9 and 1 have weight .101, .092 and .091, respectively, process standards in sub standards 18, 16 and 17 have weight .203, .169 and .169, respectively and factor standards in sub standards 22, 23 and 21 have weights .126, .126 and .125, respectively. 3) an assessment composite indicators for sub educational standards : the finding, learners standards have 19 indicators, process standards have 12 indicators and factor standards have 11 indicators. 4) The composite indicators for major educational standards have 42 indicators, most important weights .060, and .041, respectively: that's a development curriculum to be in line with position and need locality to share community. Don't to take a drug and to be free from drugs and don't to seek benefit. Use of resource, to save and worthwhile.

Thongplew Kongjun (2003) the purpose of this study was to identify the water shortages by simulating the multi-reservoir system of the Upper Mun basin including Lam Sae, Mun Bon, Lam Pra Plerng and Lam Ta Kong reservoirs. The ε-constraint linear programming was used to generate the optimum water allocation alternatives. The alternatives were selected by the analytical hierarchy process. The artificial neural network was applied to develop the simplified water allocation model. It was found that the average annual water shortage over the whole basin was 14.88%. It occurred during the dry spell in rainy season (June-September) and in dry season (January-May). The frequency of water shortage was 54%. 16 water allocation alternatives under shortage conditions were generated. The best water allocation alternative was selected by the multi-criteria decision making process. The analysis showed that the priority weight for profitability, reliability and equity were 41.0, 32.3 and 26.7% respectively. The highest ranked alternative giving the priority weight of 29.38% was the alternative that did not allow water shortage for the municipal and industrial sector, allowed the shortage for the downstream ecology balance requirements up to 55.43 million cubic meters and allowed the agricultural product to be maintained at 56% of the maximum yield.

CHAPTER 3
METHODOLOGY

The study of An Integrated Decision Making for Water Allocation Using Analytical Hierarchy Process: A Case Study of Lam Pra Plerng Irrigation Project, Upper Mun River Basin aims at investigating the problems of water management and then applying the Analytical Hierarchy Process (AHP) in the alternative comparative evaluation by considering economic, social, and environmental factors in order to obtain the best solution for the implementation of Applied Water Management for Agriculture. The followings are methodologies used in the study:

3.1 Selection of Sample Populations
3.2 Analytical Tools
3.3 Data Gathering
3.4 Generating Alternatives
3.5 Data Analysis

3.1 Selection of Sample Populations

198 of water users residing in the areas of Lam Pra Plerng Irrigation Project is a sample population for the study.

The sample size of the study is obtained through Yamane formula (Yamane, 1973, cited in Theerawut Ekakul, 2000).

$$n = \frac{N}{1 + Ne^2}$$

where n = Sample size

N = Population number

e = Variations (0.05 or 0.01)

The calculation results reveal that 133 sample populations are in the category of agriculture, consumption, and ecosystem, consisting of 126, 1, and 6 populations respectively representing farmers, tab water manufacturers and representative provincial administration organization respectively.

3.2 Analytical Tools

Questionnaire is used to collect data required for the analysis. The questionnaires include open questions and relative weighting priority of each criterion. The questionnaire consists of two parts which are:

Part I includes general information regarding name, occupation, address, purpose of water usage, current problems found in water service and recommendations for water service of the respondents.

Part II includes relative weighting priority of multi criteria for water allocation of Lam Pra Plerng reservoir in dry season. The criteria for the water allocation are based on economic, social, and environmental factors aiming at achieving maximum satisfaction of water users. In achieving so, key indicators should be set as follows:

1. Economic Satisfaction uses profitability as a key indicator, for example what activity should water be supplied during water shortage for maximum profits or return.

2. Social Satisfaction uses equitable as a key indicator, for example water should be equally allocated to all users in different activities and when it comes to water shortage, water should also be equally scarce to users of all activities.

3. Engineering Satisfaction uses efficiency as a key indicator, for example how much water be allocated to each activities to achieve effectiveness in terms of loss minimization.

3.3 Data Gathering

In this study, data gathering is divided into two approaches, which are:

3.3.1 General data gathering is a process, which collect secondary data from all related agencies include:

a. Physical characteristics of Lam Pra Plerng Irrigation Project.

b. General information of Lam Pra Plerng Reservoir including latitude and longitude of location, rain storage areas, minimum level of water, level of usable storage water, and irrigation areas.

c. Information on meteorology and hydrography including volume of rain water, monthly and yearly rainwater inflow to reservoirs during year 1973-2003

d. Pattern and calendar of agriculture

e. Water usage activities

f. Water usage requirement

g. Previous water allocation system

h. Problems in allocating and distributing water

i. Alternatives for water allocation derived from the study of Thongplew Kongjun (2003) which covers the same studied areas. The researcher has selected 8 out of 16 alternatives that there are suggested in the study. In evaluating the best alternative among 16 alternatives suggested alternatives, threshold levels of water allocation for consumption purpose are defined at minimum and maximum point. The 16 alternatives are therefore exacted into 8 potential alternatives.

3.3.2 Data collection conducted in the study area is the collection of primary data through questionnaire with the cooperation of related officers and target populations.

3.4 Generating Alternatives

According to Thongplew Kongjun (2003), the worst case scenario, when the volume of water inflow to the reservoirs is at minimum, is used as the basis for achieving maximum outcome in water allocation during dry season in terms of profitability, equitableness, and efficiency. The researcher has selected 8 options out of 16 options proposed by Thongplew Kongjun (2003) aiming at making the questionnaire more comprehensible and convenience to the respondents. (Table 3-1 and Figure 3-1)

The study conducted by Thongplew Kongjun (2003) on alternative options for water allocation suggests that when the maximum agricultural productivity is considered as the top priority, for example the productivity is dropped by 40% of the maximum productivity, then water allocated for consumption and ecosystem stabilizing purposes will be at the minimum levels, accounting for 54.32% reduction in regular demand for water supply for consumption and 7.56% reduction in minimum level of water storage of reservoirs. It can be concluded that having supplied maximum water required by a particular activity to users in that activity will leave minimum amount of water to supply to other activities, which will cause the highest degree of conflict over water allocation issues. Therefore, compromising in water allocation for all users in all activities should be reached to resolve such conflicts and to maximize benefits to all parties.

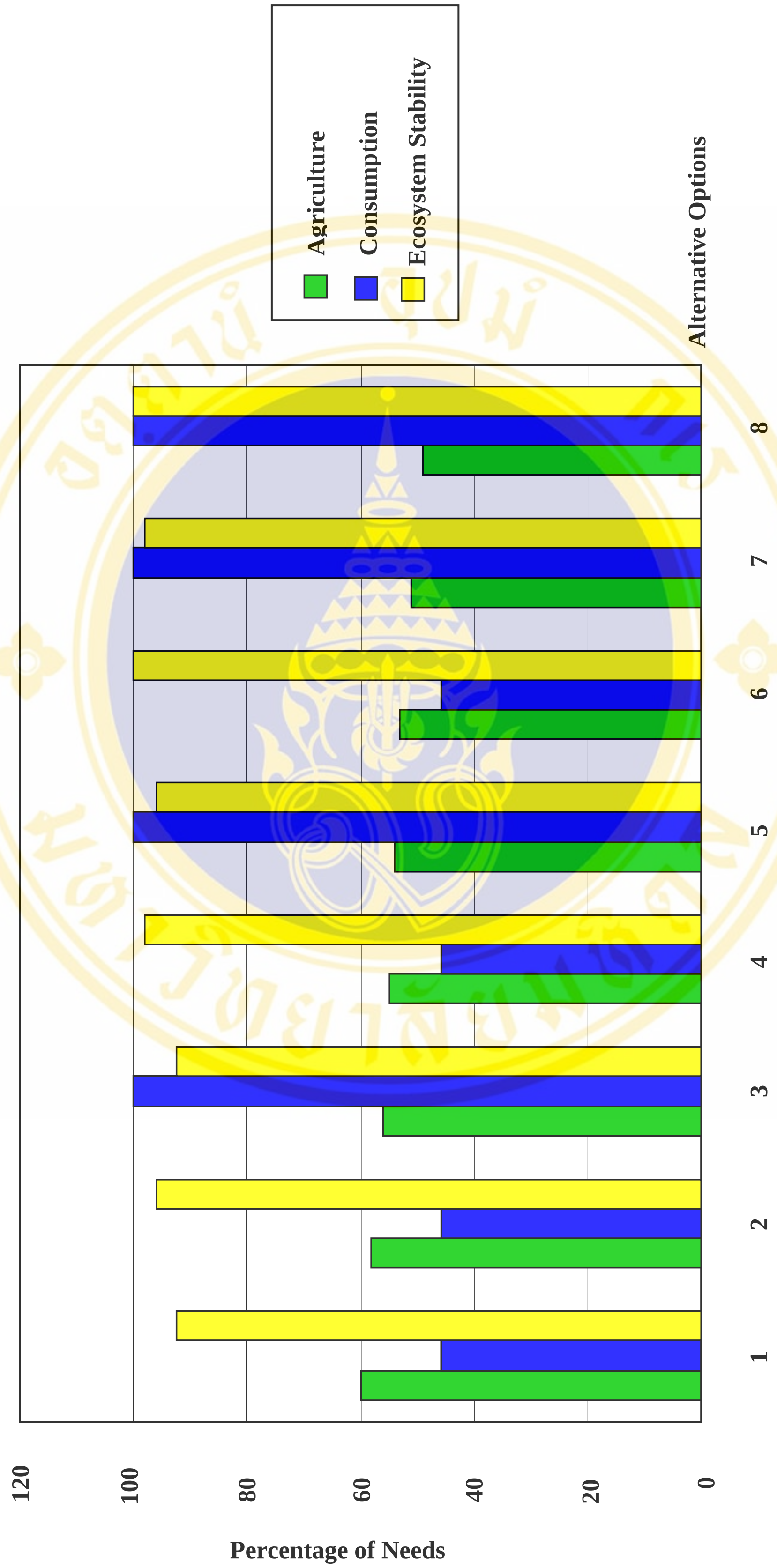

Figure 3-1: Alternative Options for Water Allocation from Reservoirs

Table 3-1: Alternative Options for Applied Water Management (Thongplew Kongjun, 2003)

Alternative	**Agriculture** Reduce in productivity (% of the maximum productivity)	**Consumption** Reduce in usage (% of the regular usage)	**Ecosystem Stability** Reduce in level of water (% of the minimum level of water storage)
1	40	54.32	7.56
2	42	54.32	4.16
3	44	0.00	7.56
4	45	54.32	1.99
5	46	0.00	4.16
6	47	54.32	0.00
7	49	0.00	1.99
8	51	0.00	0.00

Determination criteria for alternative water allocation of Lam Pra Plerng reservoir during dry season to all users in all activities will be based on economic, social, and engineering factors. The key indicators of maximum satisfaction in water allocation are:

a. Economic Satisfaction uses profitability as a key indicator, for example what activity should water be supplied during water shortage for maximum profits or return.

b. Social Satisfaction uses equitable as a key indicator, for example water should be equally allocated to all users in different activities and when it comes to water shortage, water should also be equally scarce to users of all activities.

c. Engineering Satisfaction uses efficiency as a key indicator, for example how much water be allocated to each activities to achieve effectiveness in terms of loss minimization.

Dependency on a particular criterion in the determination process will cause inequality of water allocation. A multi-criteria approach will therefore assist in making the right decision in water allocation in order to settle conflicts over water allocation among users and between users and officers.

3.5 Data Analysis

In determining the best solution among 8 alternative options, Analytical Hierarchy Process (AHP) is used to ensure the maximum satisfaction of water users of all activities. The details of AHP are discussed in figure 3-2.

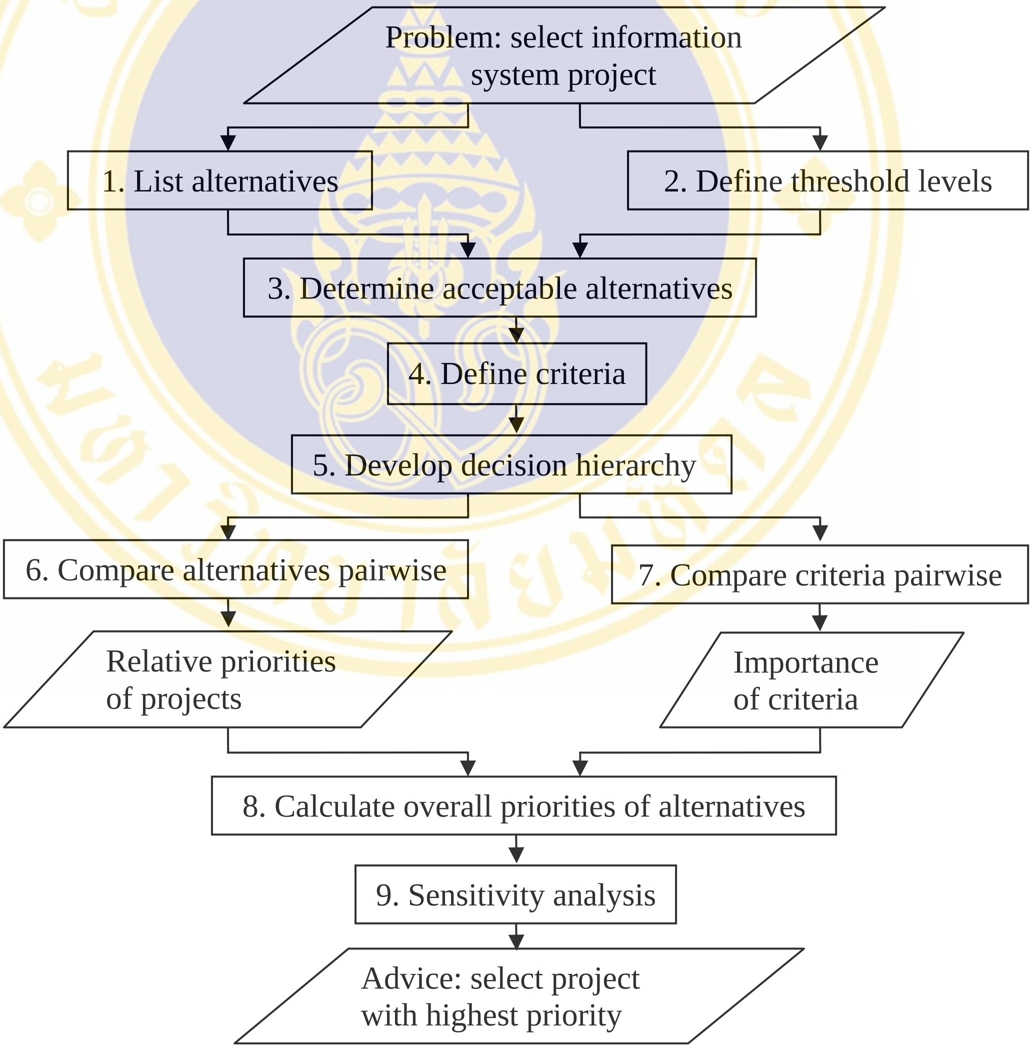

Figure 3-2: Nine Phases of Analytic Hierarchy Process (Huizingh & Vrolijk, 1994)

3.5.1 Hierarchical Structure

Hierarchical structure is divided into 3 levels. The top level is the objective of the research, which is to allocate water from reservoirs during dry season. The second level includes economic, social, and engineering criteria. The third level presents alternative options for applied water allocation. The hierarchy structure is shown in figure 3-3.

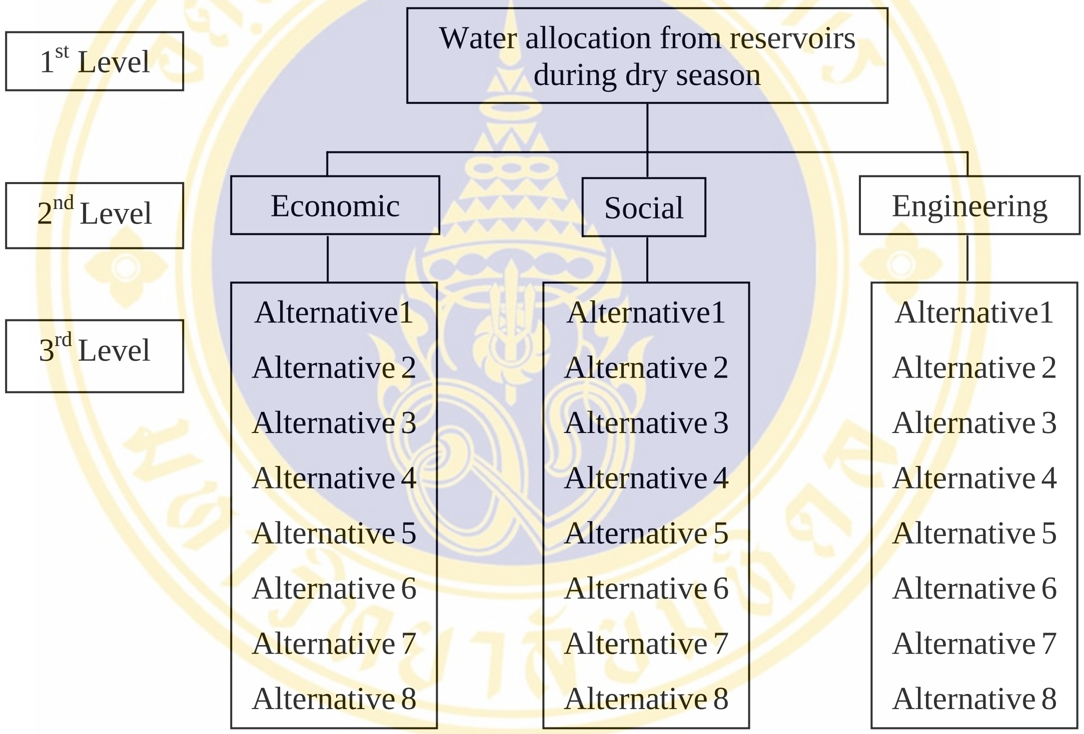

Figure 3-3: Priority Setting of Analytical Hierarchy Process

3.5.2 Priority Setting

Priority setting can be done after completing the collection of primary data from respondents. The analysis will be conducted by comparing each factor under the particular criterion. The analysis begins from the top level of the hierarchy. The weighting scales vary from 1 to 9 representing the levels of satisfaction.

Once the levels of satisfaction are identified, the relative priority of each level of alternative option can be developed. It is noted that the top priority option should undertake consistency test at all levels. The Consistency Ratio (CR) should not exceed 0.1.

3.5.3 Sensitivity Analysis

Reliability of data is critical in evaluating the best solution since the inconsistent data may cause changes in priority setting. In order to ensure the soundness of the selected option, sensitivity analysis should be conducted.

CHAPTER 4
RESULTS

4.1 Problem of Water Allocation in the Lam Pra Plerng Irrigation Project

Major problems found in Lam Pra Plerng Irrigation Project are:

- Insufficient storage water causes ineffectiveness in water allocation.
- Inability to allocate water to users in timely manner.
- Obsolete irrigation stations causes ineffectiveness in water discharge.
- Damaged irrigation stations and ditches cause significant loss of distributed water.
- Accumulated sediments in the bottom of the reservoir and in irrigation canals.
- Overlong irrigation canals and ditches decrease irrigation efficiency.

These problems account for declining effectiveness of irrigation, which is caused by significant loss of water through transportation. Furthermore, Chayuthphong Aumrungsuk (2001) suggests in his study that during dry season farmers often question the equity in water allocation. Therefore, it is recommended that farmers should participate in crop cultivation and water distribution planning. The participation should also include monitoring and maintenancing the irrigation system. Surachai Somphobtakul (2001) finds that efficiency rate of irrigation depends upon the amount of storage water, conditions of irrigation office and canals, and timely water management decisions.

Owing to the accumulated sediments in the bottom of the reservoir and irrigation canals, the water storage capacity of the project has been decreasing by 42 million cubic meters after the opening of the reservoirs in year 1970. The changes in amount of water storage significantly affect the future irrigation planning.

The 133 sample populations are obtained from the calculation of Yamane Formula at a variance rate of 5%. The questionnaires are distributed to 126, 1, and 6 users in agricultural, consumption, and ecosystem sectors representing farmers, tabwater manufacturers and representative provincial administration organization respectively.

It is founded that 131 questionnaires are completely filled out by respondents, accounting for 98.5% of the total. Therefore, there are sufficient quality data collected to undertake the Analytical Hierarchy Process (AHP).

4.2 Level of Hierarchical Structure

The hierarchical structure can be divided into 3 levels.

1. Goal is to allocate water from reservoirs during dry season.
2. Criteria include profitability, equitableness, and efficiency and the 8 alternative options.
3. Top-down ordering of alternative options.

The level of hierarchical structure is shown in figure 4-1.

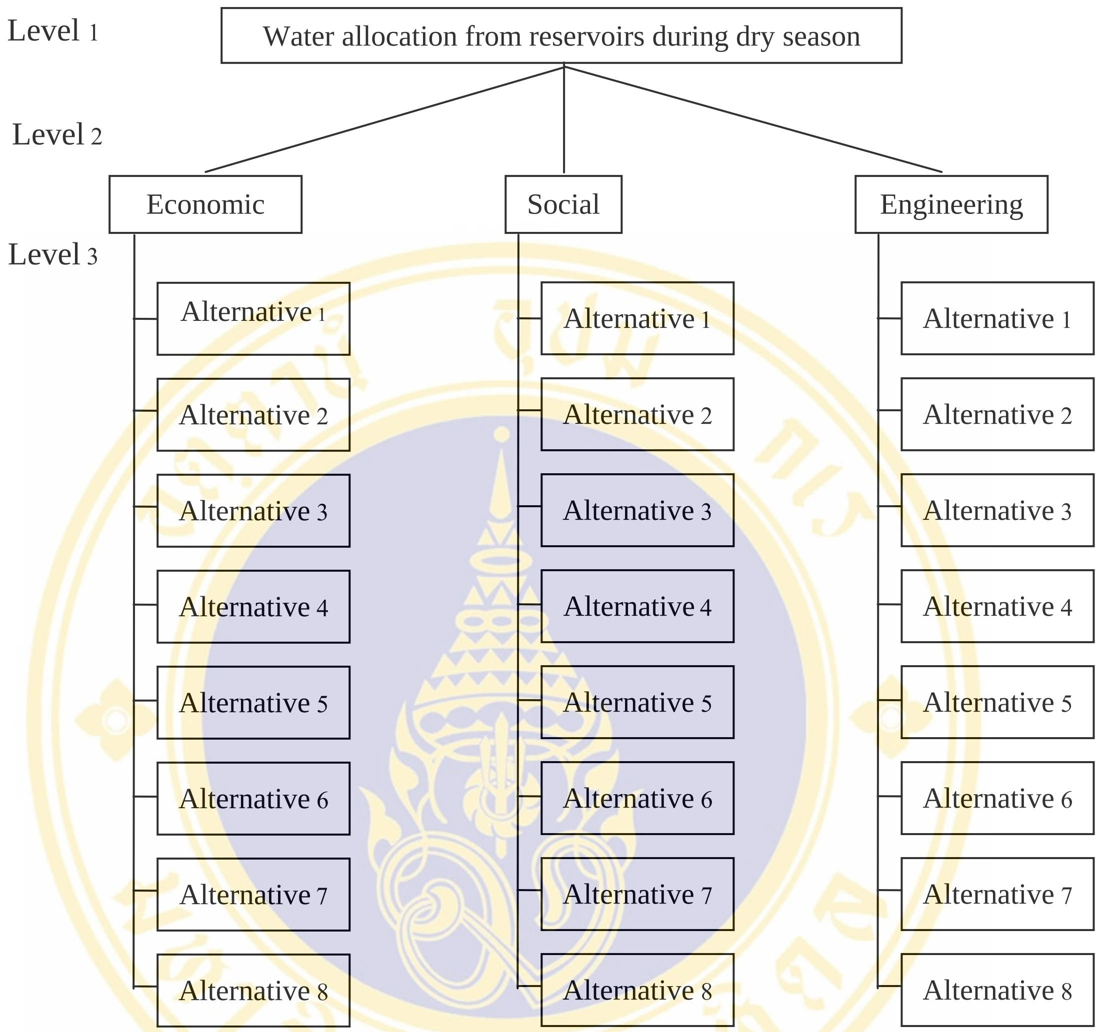

Figure 4-1: The Level of Hierarchical Structure in the Analytical Hierarchy Process

4.3 Calculation Results of Relative Priority Ranking in Water Allocation

Data gathered from 131 questionnaires consisting of data obtained from 124 respondents from agricultural sector, 1 respondent from industrial sector, and 6 respondents from ecosystem sector. Each of respondents is asked to rank priority of accessing criteria for water allocation. Then consistency test is undertaken by allowing CR rate at 0.1 or lower. The calculation results of relative priority of water allocation obtained from AHP are depicted in Appendix 3.

4.4 Statement of Alternative Options from the Analysis of Relative Priority Ranking

Criteria used in this study are economic, social, and engineering criteria. Each of which is weighed at 0.200, 0.401 and 0.399 respectively (Appendix 3). It is founded that the priority ranking scores of social and engineering criteria are very close. The two criteria therefore have to be tested with Paired Samples T-Test to find out whether the weighting scores are significantly different. The result reveals that the weighting scores of social and engineering criteria are insignificantly different from one another at the rate Confidence Interval of the Difference at 0.05. Therefore, both of social and engineering criteria can be simultaneously taken into account. Details of Paired Samples Test are shown in table 4-1.

Table 4-1: Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Social-Engineering	.001740	.298488	.026079	-.049854	.053335	.067	130	.947

The respondents were asked to select 4 alternatives out of the 8 alternatives in the questionnaire and then rank the selected alternatives by priority of importance of evaluating criteria, which are economic, social, and engineering. The calculation results reveals that for alternative 3, economic, social, and engineering criteria were raked at the highest priority level, accounting for 24.1%, 21.4% and 23.4% respectively, as shown in figure 4-2.

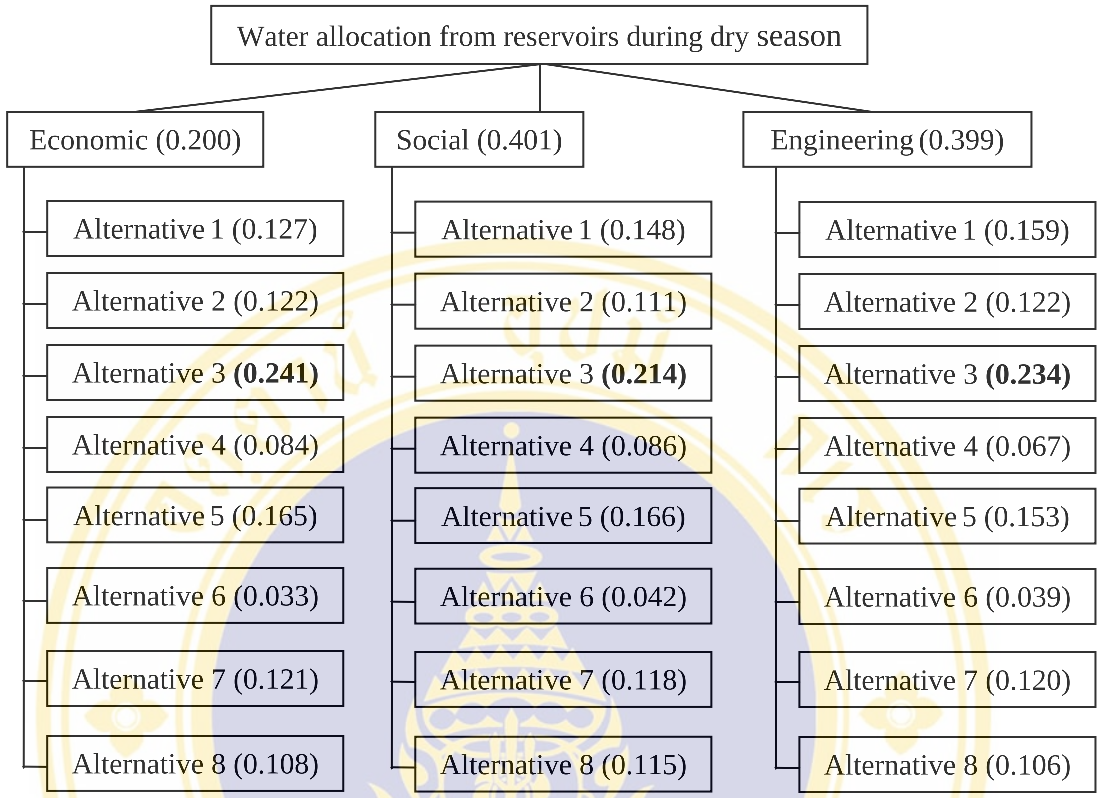

Figure 4-2: Relative Priority Ranking of Each Level of Hierarchical Structure

The total priority ranking scores of all criteria illustrated in table 4-2 are obtained by multiplying alternative priority weighting scores to criteria weighting scores. The results will be added to the total priority ranking scores of each criterion. It is found that alternative 3 is raked as the top priority; accounting for 22.7% of the total weighting scores (Appendix 4 to 7).

Table 4-2: Results of the Total Priority Ranking Scores of all Criteria

Alternatives	**Economic** (0.200)	**Social** (0.401)	**Engineering** (0.399)	**Total Priority Ranking Scores**	**Order**
1	0.127	0.148	0.159	[(0.200*0.127)+ (0.401*0.148)+ (0.399*0.159)] = 0.148	3
2	0.121	0.111	0.122	[(0.200*0.121)+ (0.401*0.111)+ (0.399*0.122)] = 0.118	5
3	0.241	0.214	0.234	[(0.200*0.241)+ (0.401*0.214)+ (0.399*0.234)] = **0.227**	**1**

Table 4-2: Results of the Total Priority Ranking Scores of all Criteria (cont**.)**

Alternatives	Economic (0.200)	Social (0.401)	Engineering (0.399)	Total Priority Ranking Scores	Order
4	0.084	0.086	0.067	[(0.200*0.084)+ (0.401*0.086)+ (0.399*0.067)] = 0.078	7
5	0.165	0.166	0.153	[(0.200*0.165)+ (0.401*0.166)+ (0.399*0.153)] = 0.161	2
6	0.033	0.042	0.039	[(0.200*0.033)+ (0.401*0.042)+ (0.399*0.039)] = 0.039	8
7	0.121	0.118	0.120	[(0.200*0.121)+ (0.401*0.118)+ (0.399*0.120)] = 0.119	4
8	0.108	0.115	0.106	[(0.200*0.108)+ (0.401*0.115)+ (0.399*0.106)] = 0.110	6

4.5 Sensitivity Analysis

Sensitivity analysis is a process used for testing the robustness of a selected alternative option to see the extent to which the result will change if priority weighting scores are changed. As shown in figure 4-3, 4-4, 4-5, 4-6, 4-7, 4-8, 4-9, and 4-10 economic, social, and engineering criteria are not sensitive to fluctuation of priority ranking scores ranging from high to low.

The sensitivity analysis can be conducted through the adjustment of priority weighting scores of each criterion. The adjustment will range from maximum to minimum scores to determine all situations. Having completed the analysis, alternative 3 remains at the top priority and proves to be the bet solution for the management of Lam Pra Plerng Irrigation Project.

Base on above analyses, the researcher proposes that alternative option 3 is the most appropriate solution to the current problems in water management at the Upper Mun River Basin due to its insensitivity to fluctuation of priority scores of each criterion. According to table 3-1, the alternative 3 options to maximise water supply for consumption purpose, which results in 44% and 7.56% reduction in the total agricultural productivity and minimum level of water storage of reservoirs respectively

The solution suggested in this report can be implemented to the irrigation management of Lam Pra Plerng Irrigation project during dry season when active water storage is insufficient. However, if the active water storage in the dry season is sufficient, this alternative may not necessarily be implemented.

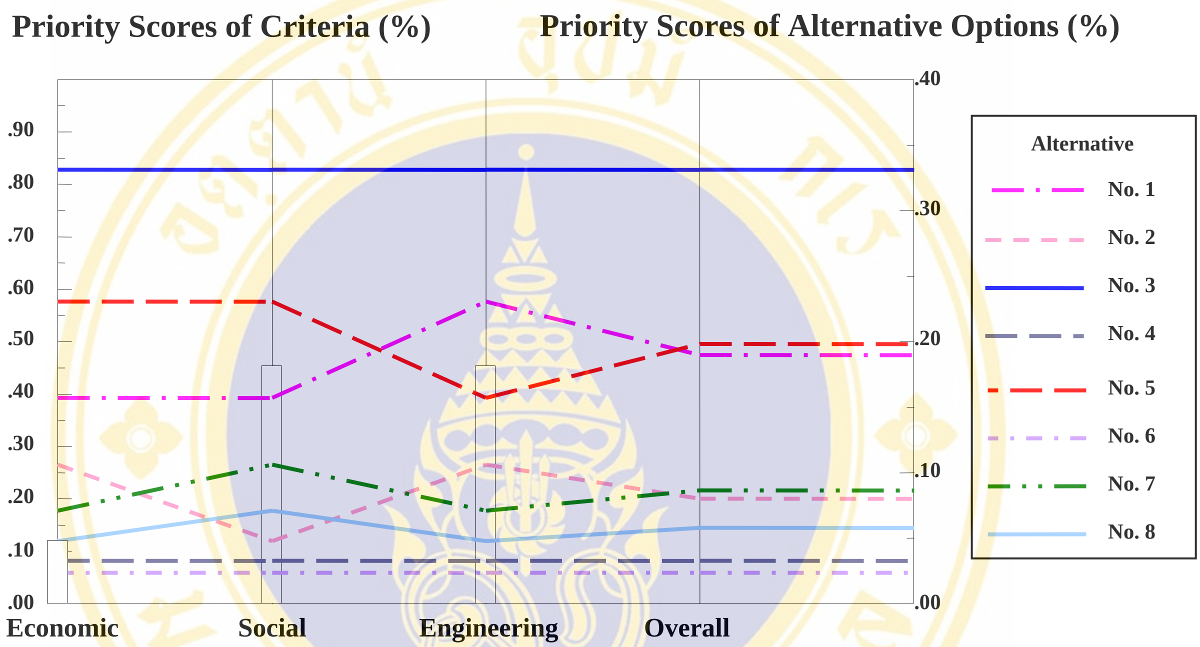

Figure 4-3: Sensitivity Analysis of Alternative Options

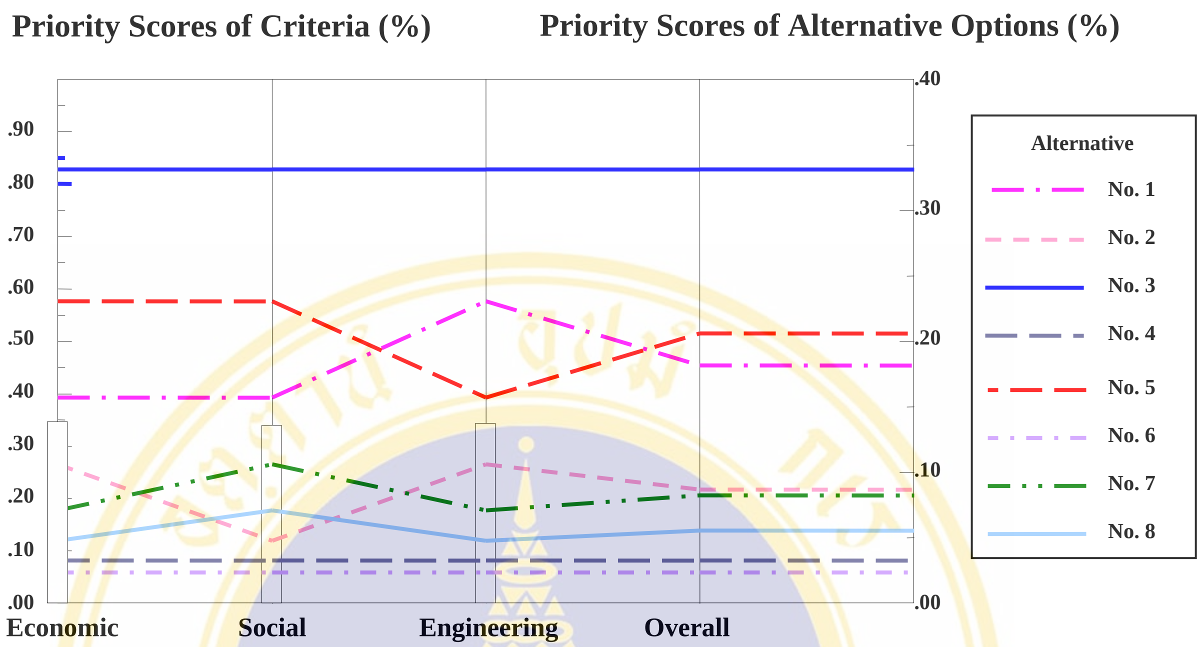

Figure 4-4: Sensitivity Analysis of Alternative Options when priority weighting scores are equal.

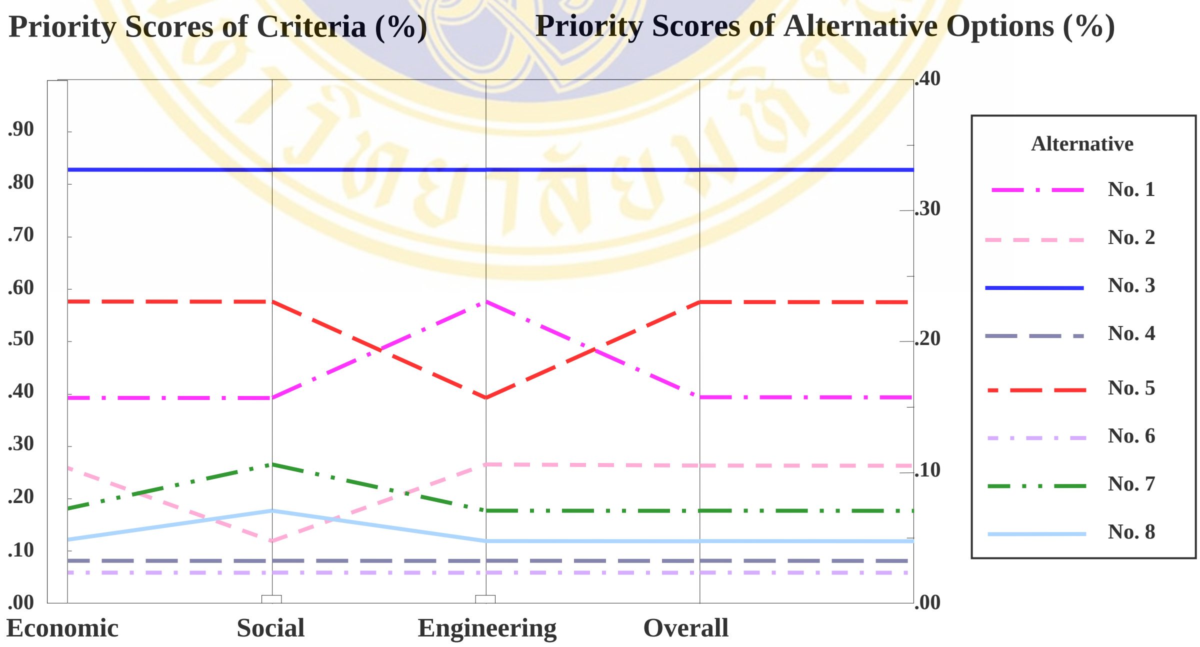

Figure 4-5: Sensitivity Analysis of Alternative Options when Economic Criteria has maximum priority weighting scores.

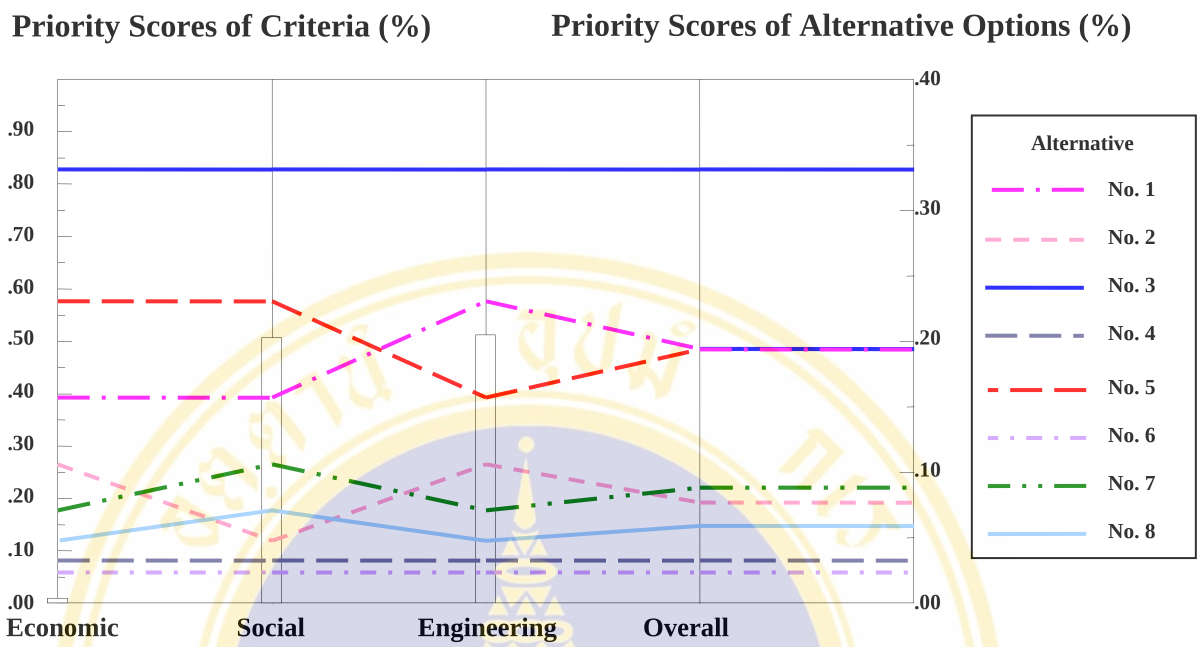

Figure 4-6: Sensitivity Analysis of Alternative Options when Economic Criteria has minimum priority weighting scores.

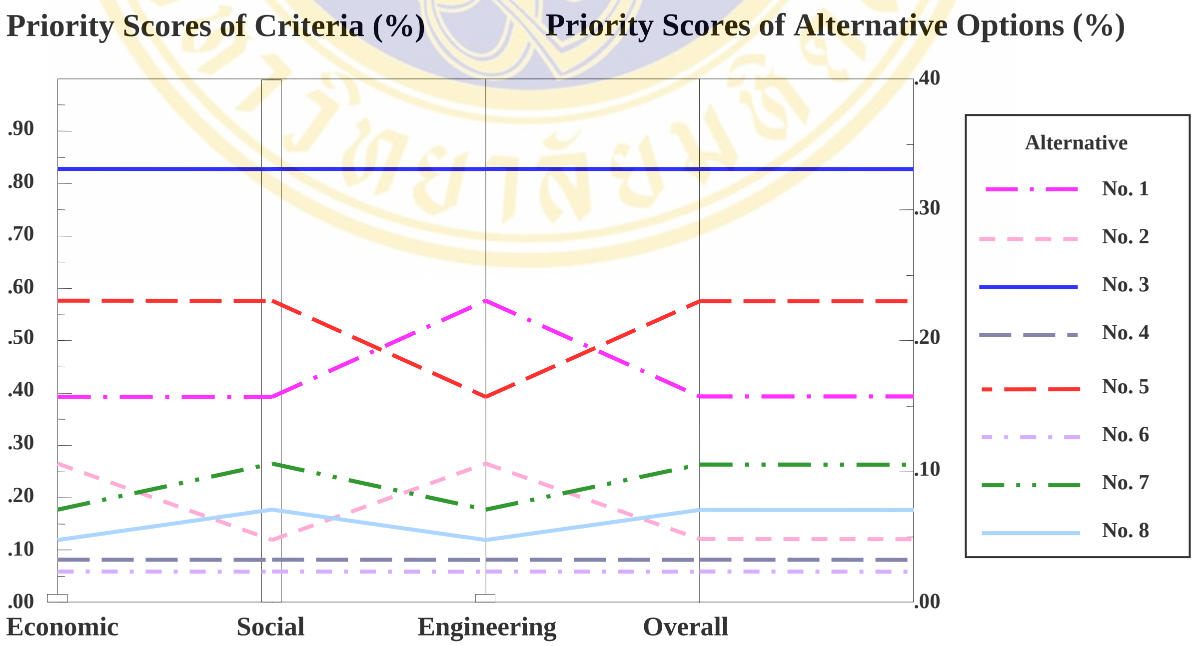

Figure 4-7: Sensitivity Analysis of Alternative Options when Social Criteria has maximum priority weighting scores.

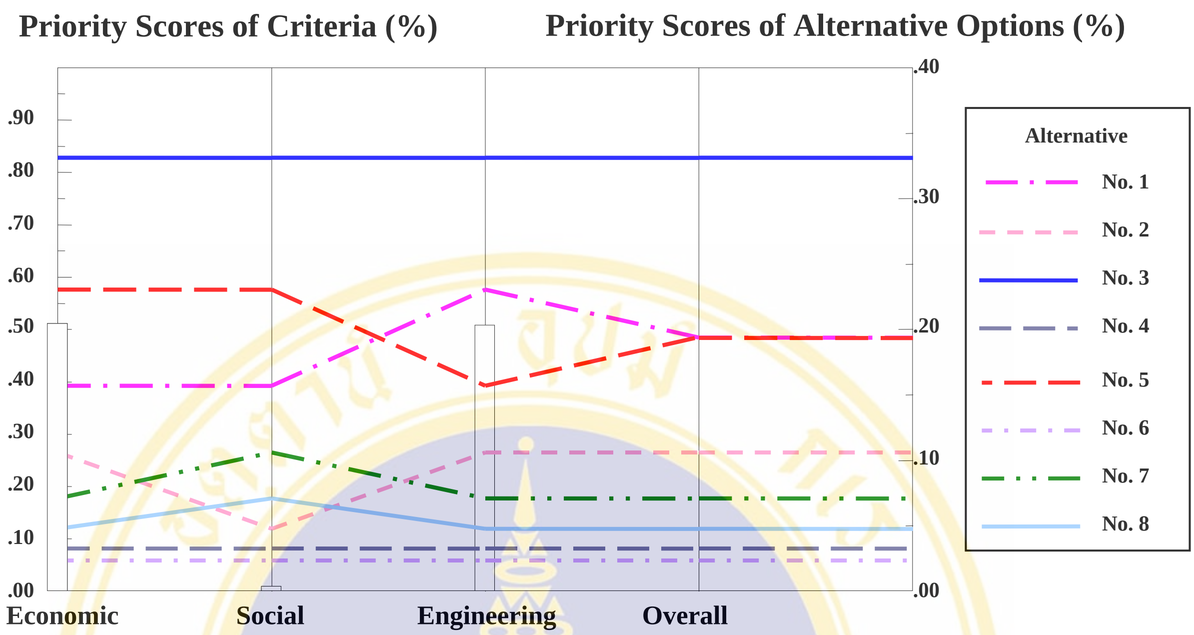

Figure 4-8: Sensitivity Analysis of Alternative Options when Social Criteria has minimum priority weighting scores.

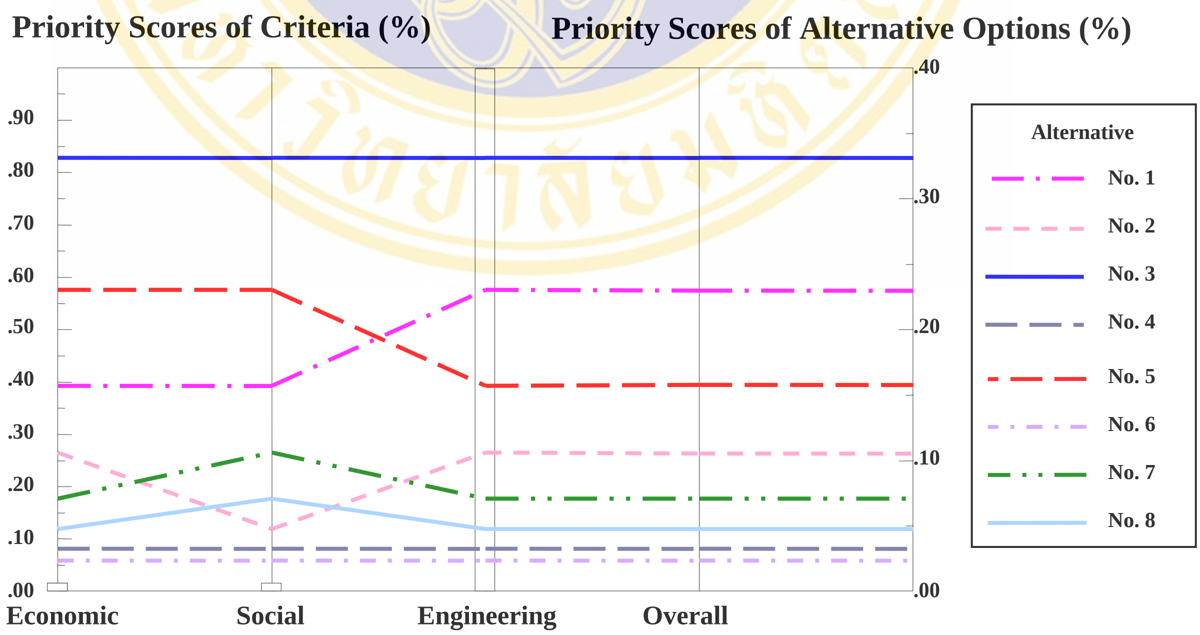

Figure 4-9: Sensitivity Analysis of Alternative Options when Engineering Criteria has maximum priority weighting scores.

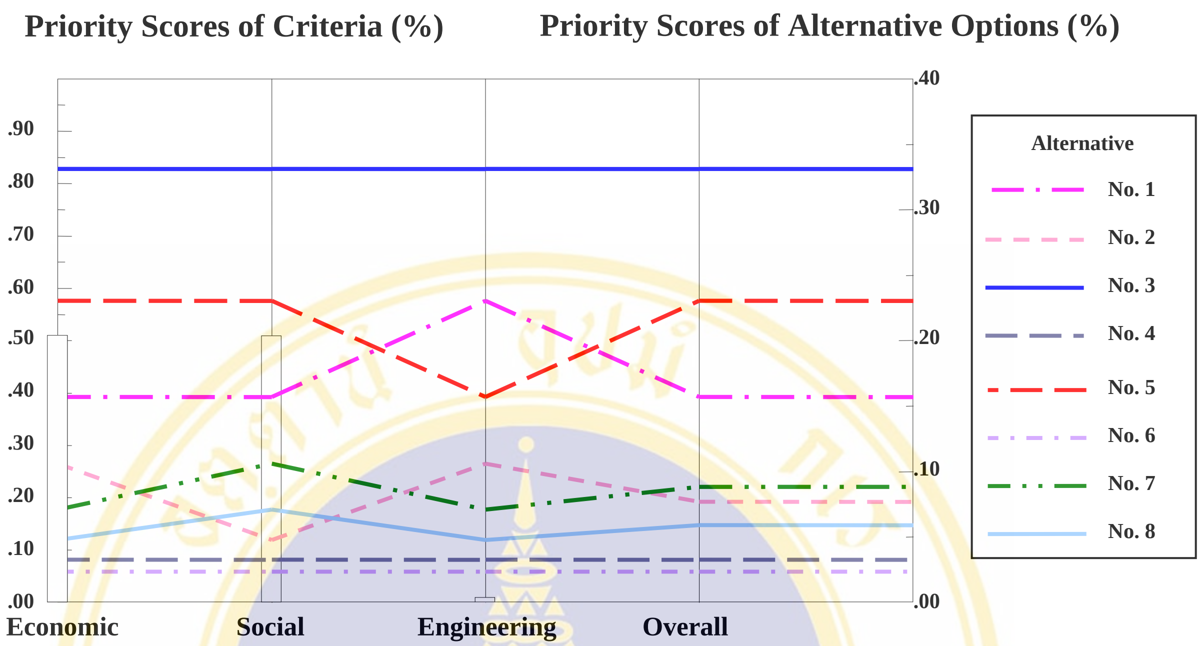

Figure 4-10: Sensitivity Analysis of Alternative Options when Engineering Criteria has maximum priority weighting scores.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

It can be concluded that the most appropriate approach to water allocation at Lam Pra Plerng reservoir during water shortage be the one that provide maximum satisfaction and benefits to users of all activities in the studied area of the Upper Mun River Basin. Compromising water allocation will be beneficial to all related parties and minimizing conflicts over water allocation during dry season. The key criteria used in this study are profitability, equitableness, and efficiency, which represent as key indicators for economic, social and engineering satisfactions.

The Analytical Hierarchy Process is used to determine the best alternative out of 8 options. It is founded that relative priority scores of social, engineering, and economic are 40.1, 39.9, and 20.0% respectively. It is noted that water allocation, social and engineering criteria should be evenly considered against the decision on alternative options. The highest priority scores are given to alternative 3, which option to provide maximum water supply to meet regular demands for water consumption, accounting for 22.7% of the total scores. Results from this study is in accordance with the previous study by Thongplew Kongjun (2003), who suggests the top priority is not to allow housing and industrial sectors to encounter water shortage. In addition, he state that the minimum level of water storage at reservoirs can be maintained at 55.43 millions cubic meters, decreasing by 7.56%, and the total agricultural productivity is allowed to decrease by 44%.

In addition, the study of Chayuthphong Aumrungsuk (2001) highlights that water allocation of the Lam Pra Plerng Irrigation Project is still lack of equity that there should be taking equity into consideration.

The selected alternative is also in accordance with the water allocation plan of the Royal Irrigation Department for water shortage to which support water allocation for consumption and ecosystem stability purposes.

However, it is recommended that this alternative be implemented when the level of active water storage is in a critical state. It is optional to implement this alternative when the active water storage in the dry season is sufficient.

The Analytical Hierarchy Process assists in evaluating alternative options by comparing various factors in the system and undertaking consistency testing in order to select the most appropriate alternative among the possible options. The process is flexible in terms of criteria addition and data collecting process is not complicate. However, the calculation process requires careful consideration, extensive calculation due to many involving factors such as criteria, hierarchy and the scale of relative priority comparison has many scales, difficult to make decision.

5.2 Recommendations

1. It is recommended that the sample size of the study in terms of number of participants in consumption and ecosystem stability groups be extended to representatives from village chiefs and local authorities to achieve greater equilibrium of data.

2. It is recommended that needs of water for agriculture, housing and industrial consumption, and ecosystem stability be identified to develop appropriate alternative options for a specific area.

3. It is recommended that the amount of accumulated sediment be taken into the calculation of annual water storage capacity.

4. It is recommended that the Analytical Hierarchy Process be applied to the water management for most water required activity.

5. It is recommended that the Analytical Hierarchy Process be applied to other water distribution and maintenance projects under water shortage conditions to achieve maximum satisfaction and minimum conflicts among users and between users and officers.

6. It is recommended that data gathering process be well-defined in scope and time frame due to complexity of questionnaire.

7. It is recommended that the alternative options be different upon specify the condition of water management.

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APPENDIX

Appendix 1: สถิติข้อมูลปริมาณน้ำฝนรายเดือน (มิลลิเมตร) ที่สถานีหัวงานโครงการส่งน้ำและบำรุงรักษาลำพระเพลิง

เดือน / ปี พ.ศ.	เม.ย.	พ.ค.	มิ.ย.	ก.ค.	ส.ค.	ก.ย.	ต.ค.	พ.ย.	ธ.ค.	ม.ค.	ก.พ.	มี.ค.	รวม
2516	93.60	114.10	61.30	64.00	85.50	280.80	129.90	41.80	-	6.30	67.20	63.80	1,008.30
2517	81.10	132.90	84.20	65.50	65.30	165.40	254.00	137.20	-	45.00	27.50	231.60	1,289.70
2518	32.70	95.20	44.90	241.70	28.50	283.60	249.60	12.70	6.20	-	2.40	95.60	1,093.10
2519	122.20	183.70	58.60	68.00	143.20	188.90	305.10	32.00	-	-	-	77.10	1,178.80
2520	19.50	114.20	91.00	102.00	153.40	359.20	94.50	96.30	4.00	14.20	8.70	167.10	1,224.10
2521	46.30	146.20	85.70	209.40	57.80	226.40	132.10	-	0.50	14.30	5.70	-	924.40
2522	99.70	156.60	123.90	64.00	15.70	257.10	12.20	-	-	-	41.90	72.80	843.90
2523	213.10	91.30	178.10	110.20	168.80	320.70	284.70	16.00	-	-	30.50	-	1,413.40
2524	57.80	97.50	43.00	81.90	31.70	215.00	128.60	98.40	-	-	28.50	99.60	882.00
2525	38.90	149.30	82.80	66.60	87.80	351.00	69.80	33.10	0.40	0.50	-	-	880.20
2526	21.90	150.80	45.00	133.40	287.10	364.60	424.20	26.50	-	-	18.30	7.10	1,478.90
2527	96.90	93.70	41.90	53.10	119.10	128.80	137.70	17.50	-	54.80	13.60	28.00	785.10
2528	241.50	184.90	27.70	184.00	109.20	331.50	180.20	66.30	-	-	2.70	41.20	1,369.20
2529	102.70	142.80	49.40	40.80	141.30	159.90	326.00	-	-	-	1.20	8.20	972.30
2530	62.30	61.80	48.40	31.90	83.10	376.80	165.60	108.00	-	-	88.40	6.00	1,032.30
2531	247.50	211.10	90.80	215.20	33.20	327.90	165.70	-	-	10.90	1.80	47.30	1,351.40
2532	6.20	174.20	78.60	119.80	143.70	118.90	182.70	20.20	-	13.60	-	46.70	904.60
2533	78.20	173.90	169.20	66.90	110.40	362.10	476.70	69.90	-	10.60	26.10	4.30	1,548.30
2534	40.40	170.60	78.60	84.10	80.60	154.40	228.20	3.30	19.50	23.90	-	10.60	894.20
2535	19.50	123.00	120.00	170.00	124.20	98.80	303.40	-	-	55.50	-	31.40	1,045.80
2536	59.90	93.40	31.40	61.30	106.00	268.50	193.00	-	37.60	-	77.80	92.40	1,021.30
2537	63.50	244.00	164.10	29.80	442.00	130.60	143.00	2.60	-	-	17.00	30.70	1,267.30
2538	75.90	110.70	119.80	217.70	115.70	318.30	114.70	8.70	-	-	70.20	28.60	1,180.30

Appendix 1: สถิติข้อมูลปริมาณน้ำฝนรายเดือน (มิลลิเมตร) ที่สถานีหัวงานโครงการส่งน้ำและบำรุงรักษาลำพระเพลิง (ต่อ)

เดือน / ปี พ.ศ.	เม.ย.	พ.ค.	มิ.ย.	ก.ค.	ส.ค.	ก.ย.	ต.ค.	พ.ย.	ธ.ค.	ม.ค.	ก.พ.	มี.ค.	รวม
2539	141.60	223.10	71.30	107.50	94.40	255.10	270.50	35.30	-	-	-	69.90	1,268.70
2540	116.70	207.20	3.10	53.70	264.50	275.20	108.50	2.10	-	-	47.60	69.90	1,148.50
2541	109.40	124.80	78.70	132.10	223.60	315.40	69.50	96.70	0.40	1.80	2.80	116.00	1,271.20
2542	238.70	214.60	110.90	25.10	129.00	140.50	254.20	72.50	-	1.70	40.30	1.70	1,229.20
2543	139.70	89.60	77.90	37.40	207.40	248.10	131.60	-	-	-	-	162.40	1,094.10
2544	24.00	203.30	50.50	61.50	74.40	213.00	258.30	38.00	-	-	6.10	61.70	990.80
2545	112.70	163.80	59.60	48.80	164.50	332.50	198.90	66.00	-	0.80	21.30	71.00	1,239.90
2546	17.30	234.10	139.20	126.70	116.10	205.40	240.50	-	-	-	61.60	29.80	1,170.70
สูงสุด	247.50	244.00	289.00	241.70	442.00	376.80	476.70	137.20	37.60	55.50	88.40	231.60	1,548.30
ต่ำสุด	6.20	61.80	3.10	25.10	15.70	98.80	12.20	2.10	0.40	0.50	1.20	1.70	785.10
เฉลี่ย	91.71	148.18	87.46	98.39	126.64	246.76	195.53	48.27	9.80	18.14	29.55	63.30	1,129.10

ที่มา: ศูนย์ปฏิบัติการจัดสรรน้ำ กรมชลประทาน (สำนักงานชลประทาน 8)

Appendix 2: ปริมาณน้ำไหลลงอ่างเก็บน้ำเขื่อนลำพระเพลิงรายเดือน (หน่วย: ล้าน ลบ.ม.)

เดือน / ปี พ.ศ.	ม.ค.	ก.พ.	มี.ค.	เม.ย.	พ.ค.	มิ.ย.	ก.ค.	ส.ค.	ก.ย.	ต.ค.	พ.ย.	ธ.ค.	รวม
2516	-	-	-	1.00	1.00	1.00	1.00	-	42.00	37.00	-	-	83.00
2517	-	-	1.00	-	2.00	1.00	-	1.00	12.00	75.00	45.00	3.00	140.00
2518	1.00	-	-	-	1.00	5.00	22.00	-	48.00	76.00	6.00	-	159.00
2519	0.50	-	2.00	1.00	-	-	4.00	37.00	66.00	79.00	22.00	5.00	216.50
2520	5.00	5.00	-	4.00	14.00	3.00	4.00	7.00	38.00	12.00	-	2.00	94.00
2521	0.90	-	-	2.40	20.00	8.70	78.60	18.40	51.30	45.20	-	-	225.50
2522	2.10	-	-	4.60	7.60	6.80	7.00	-	48.20	16.10	-	-	92.40
2523	0.50	-	0.20	6.40	9.30	20.10	-	2.80	57.30	93.80	7.20	1.80	199.40
2524	-	-	-	10.60	3.80	0.70	0.10	-	12.00	23.30	5.70	2.80	59.00
2525	0.40	1.00	7.80	3.50	12.00	1.20	-	-	65.80	43.90	3.40	5.00	144.00
2526	2.00	-	-	-	8.40	7.80	1.60	93.20	95.30	188.80	19.70	2.10	418.90
2527	1.80	2.20	-	4.00	6.40	3.50	2.70	1.70	4.60	103.20	2.00	2.10	134.20
2528	3.10	-	-	10.40	56.50	12.60	22.90	5.50	49.50	33.80	6.60	4.90	205.80
2529	1.80	-	-	10.10	42.80	7.80	0.20	1.30	41.20	114.00	4.30	2.00	225.50
2530	1.40	-	-	1.90	11.90	2.00	-	-	102.90	26.30	10.30	1.50	158.20
2531	1.40	0.80	-	-	10.90	5.90	8.90	-	56.10	90.10	2.90	0.50	177.50
2532	0.60	-	-	-	6.40	13.50	10.20	11.50	30.70	22.60	0.90	0.70	97.10
2533	-	-	4.10	7.80	13.20	8.70	-	-	29.40	179.00	14.30	-	256.50
2534	1.20	-	-	-	19.70	18.10	8.10	19.30	67.90	68.50	0.70	1.30	204.80
2535	1.20	-	-	-	5.20	4.90	13.70	39.20	10.00	59.20	10.00	0.20	143.60
2536	0.90	-	1.30	11.40	4.30	6.00	-	-	73.60	46.50	-	-	144.00
2537	-	-	1.80	2.50	36.50	21.50	30.20	14.00	22.20	12.60	-	-	141.30
2538	-	-	-	2.30	8.00	6.20	10.90	22.50	85.70	30.30	4.00	1.10	171.00
2539	0.70	2.80	3.20	6.10	25.30	13.10	10.10	14.70	97.00	84.70	6.90	2.10	266.70
2540	1.10	1.70	2.80	7.10	7.80	2.90	2.40	12.90	38.30	18.10	1.50	0.90	97.50
2541	0.50	0.70	1.40	1.90	12.90	1.60	3.10	20.80	25.20	23.20	3.00	1.40	95.70
2542	1.00	0.90	2.20	11.10	65.60	15.50	6.80	17.90	58.70	81.40	32.30	2.10	295.50
2543	1.60	3.40	1.90	32.30	33.00	23.20	18.70	40.50	60.00	79.50	8.00	1.60	303.70
2544	1.20	4.50	11.20	3.60	7.20	3.00	2.00	8.20	17.20	20.00	6.70	0.80	85.60

Appendix 2: ปริมาณน้ำไหลลงอ่างเก็บน้ำเขื่อนลำพระเพลิงรายเดือน (หน่วย: ล้าน ลบ.ม.) (ต่อ)

เดือน / ปี พ.ศ.	ม.ค.	ก.พ.	มี.ค.	เม.ย.	พ.ค.	มิ.ย.	ก.ค.	ส.ค.	ก.ย.	ต.ค.	พ.ย.	ธ.ค.	รวม
2545	0.54	0.38	1.42	5.00	35.13	6.43	1.95	10.40	105.76	74.37	8.61	2.96	252.95
2546	1.33	1.48	9.08	6.40	11.21	8.45	23.05	14.72	59.29	88.77	4.60	7.13	235.51
เฉลี่ย	1.35	2.07	3.43	6.56	16.63	8.01	11.77	18.84	50.68	62.78	9.46	2.29	178.21
สูงสุด	5.00	5.00	11.20	32.30	65.60	23.20	78.60	93.20	105.76	188.80	45.00	7.13	418.90
ต่ำสุด	0.40	0.38	0.20	1.00	1.00	0.70	0.10	1.00	4.60	12.00	0.70	0.20	59.00

ที่มา: ศูนย์ปฏิบัติการจัดสรรน้ำ กรมชลประทาน (สำนักงานชลประทาน 8)

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
1	2001	0.056	0.463	0.481
2	2002	0.778	0.111	0.111
3	2003	0.150	0.517	0.333
4	2004	0.057	0.597	0.346
5	2005	0.210	0.240	0.550
6	2006	0.090	0.455	0.455
7	2007	0.342	0.577	0.081
8	2008	0.193	0.523	0.284
9	2009	0.143	0.714	0.143
10	2010	0.550	0.210	0.240
11	2011	0.054	0.571	0.375
12	2012	0.051	0.582	0.367
13	2013	0.709	0.231	0.060
14	2014	0.413	0.327	0.260
15	2015	0.089	0.323	0.588
16	2016	0.472	0.444	0.084
17	2017	0.054	0.357	0.589
18	2018	0.070	0.326	0.604
19	2020	0.142	0.429	0.429
20	2021	0.184	0.584	0.232
21	2022	0.333	0.333	0.333
22	2023	0.367	0.051	0.582
23	2024	0.063	0.265	0.672

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
24	2025	0.054	0.357	0.589
25	2026	0.163	0.540	0.297
26	2027	0.122	0.558	0.320
27	2028	0.140	0.527	0.333
28	2029	0.122	0.558	0.320
29	2030	0.122	0.558	0.320
30	2031	0.105	0.637	0.258
31	2032	0.058	0.383	0.559
32	2033	0.052	0.474	0.474
33	2034	0.055	0.655	0.290
34	2035	0.051	0.367	0.582
35	2037	0.056	0.481	0.463
36	2038	0.290	0.655	0.055
37	2039	0.413	0.327	0.260
38	2040	0.051	0.582	0.367
39	2041	0.127	0.104	0.769
40	2042	0.070	0.604	0.326
41	2043	0.082	0.315	0.603
42	2044	0.265	0.672	0.063
43	2045	0.140	0.527	0.333
44	2046	0.042	0.778	0.180
45	2047	0.078	0.171	0.751
46	2048	0.232	0.184	0.584

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
47	2049	0.067	0.661	0.272
48	2050	0.078	0.205	0.717
49	2051	0.060	0.709	0.231
50	2053	0.052	0.474	0.474
51	2054	0.081	0.188	0.731
52	2055	0.109	0.345	0.546
53	2056	0.333	0.333	0.333
54	2057	0.063	0.672	0.265
55	2058	0.056	0.701	0.243
56	2059	0.051	0.367	0.582
57	2060	0.060	0.709	0.231
58	2061	0.149	0.377	0.474
59	2062	0.297	0.540	0.163
60	2063	0.429	0.429	0.142
61	2064	0.054	0.589	0.357
62	2065	0.064	0.798	0.138
63	2066	0.064	0.500	0.436
64	2068	0.109	0.345	0.546
65	2069	0.089	0.352	0.559
66	2070	0.093	0.167	0.740
67	2071	0.118	0.268	0.614
68	2072	0.051	0.367	0.582
69	2073	0.051	0.367	0.582

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
70	2074	0.064	0.500	0.436
71	2075	0.054	0.357	0.589
72	2076	0.051	0.367	0.582
73	2077	0.413	0.260	0.327
74	2078	0.500	0.250	0.250
75	2080	0.051	0.367	0.582
76	2081	0.367	0.051	0.582
77	2082	0.474	0.052	0.474
78	2083	0.818	0.091	0.091
79	2084	0.589	0.357	0.054
80	2085	0.051	0.367	0.582
81	2086	0.367	0.051	0.582
82	2087	0.058	0.278	0.664
83	2088	0.056	0.481	0.463
84	2089	0.196	0.311	0.493
85	2090	0.333	0.333	0.333
86	2092	0.333	0.333	0.333
87	2093	0.051	0.367	0.582
88	2094	0.142	0.429	0.429
89	2095	0.064	0.500	0.436
90	2096	0.054	0.589	0.357
91	2097	0.346	0.057	0.597
92	2098	0.051	0.367	0.582

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
93	2099	0.052	0.474	0.474
94	2100	0.444	0.387	0.169
95	2101	0.333	0.333	0.333
96	2102	0.400	0.200	0.400
97	2103	0.444	0.387	0.169
98	2104	0.143	0.571	0.286
99	2105	0.327	0.260	0.413
100	2106	0.333	0.333	0.333
101	2107	0.333	0.333	0.333
102	2108	0.052	0.648	0.300
103	2109	0.655	0.290	0.055
104	2110	0.400	0.400	0.200
105	2111	0.260	0.327	0.413
106	2112	0.067	0.444	0.489
107	2113	0.500	0.427	0.073
108	2114	0.413	0.260	0.327
109	2115	0.163	0.297	0.540
110	2116	0.169	0.387	0.444
111	2117	0.111	0.222	0.667
112	2118	0.413	0.327	0.260
113	2119	0.413	0.327	0.260
114	2120	0.500	0.250	0.250
115	2121	0.067	0.444	0.489

Appendix 3: การวิเคราะห์น้ำหนักความสำคัญของเกณฑ์ที่ใช้ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	เกณฑ์		
		เศรษฐกิจ	สังคม	วิศวกรรม
116	2122	0.101	0.644	0.255
117	2123	0.052	0.474	0.474
118	2124	0.101	0.433	0.466
119	2125	0.091	0.091	0.818
120	2126	0.051	0.582	0.367
121	2127	0.153	0.596	0.251
122	2128	0.333	0.333	0.333
123	2129	0.058	0.278	0.664
124	2130	0.054	0.357	0.589
125	2131	0.058	0.278	0.664
126	2132	0.597	0.346	0.057
127	2133	0.112	0.444	0.444
128	2134	0.333	0.333	0.333
129	2135	0.333	0.333	0.333
130	2136	0.101	0.433	0.466
131	2137	0.101	0.433	0.466
Mean		**0.200**	**0.401**	**0.399**

Appendix 4: การวิเคราะห์น้ำหนักความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
1	2001			0.080		0.140		0.230	0.530
2	2002			0.480		0.310		0.140	0.050
3	2003	0.320		0.140		0.160		0.360	
4	2004	0.220	0.250		0.230		0.200		
5	2005	0.330	0.480	0.120			0.040		
6	2006	0.390		0.240		0.260		0.090	
7	2007	0.310	0.150	0.470	0.050				
8	2008			0.520		0.310		0.130	0.030
9	2009			0.450		0.320		0.170	0.050
10	2010	0.440	0.290	0.170	0.080				
11	2011	0.290	0.080	0.360	0.250				
12	2012	0.400	0.030	0.400	0.150				
13	2013	0.080		0.170		0.340			0.390
14	2014		0.400	0.360		0.190			0.030
15	2015				0.490	0.290		0.130	0.070
16	2016		0.200	0.200		0.290			0.290
17	2017	0.480		0.170		0.030			0.300
18	2018			0.480		0.280		0.190	0.030
19	2020	0.120		0.420		0.220			0.220
20	2021			0.150		0.050		0.300	0.480
21	2022		0.340	0.200		0.240			0.200
22	2023	0.500	0.320	0.130	0.040				
23	2024	0.410	0.140	0.310	0.130				
24	2025	0.060	0.350		0.090	0.480			
25	2026			0.390		0.360		0.160	0.080
26	2027			0.390		0.360		0.160	0.080
27	2028			0.390		0.360		0.160	0.080
28	2029			0.390		0.360		0.160	0.080

Appendix 4: การวิเคราะห์น้ำหนักความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
29	2030			0.390		0.360		0.160	0.080
30	2031			0.390		0.360		0.160	0.080
31	2032			0.490		0.160		0.250	0.070
32	2033			0.035		0.129		0.288	0.540
33	2034			0.034		0.195		0.297	0.473
34	2035	0.347		0.419		0.057		0.177	
35	2037	0.037				0.363		0.402	0.197
36	2038	0.036		0.227		0.364		0.373	
37	2039			0.087		0.212		0.234	0.467
38	2040	0.527		0.273	0.273			0.164	
39	2041		0.347		0.246		0.204	0.204	
40	2042			0.450	0.050	0.450	0.050		
41	2043		0.034	0.195				0.297	0.473
42	2044	0.325		0.186		0.285		0.203	
43	2045	0.488		0.339	0.045	0.127			
44	2046			0.268		0.035		0.381	0.315
45	2047	0.037		0.144		0.323			0.496
46	2048	0.293		0.042		0.215		0.450	
47	2049			0.040			0.513	0.281	0.165
48	2050			0.530		0.302		0.133	0.035
49	2051			0.034		0.170	0.331		0.465
50	2053		0.036	0.505	0.168		0.292		
51	2054			0.540		0.270		0.150	0.030
52	2055	0.488	0.399	0.127		0.045			
53	2056	0.593	0.238	0.119		0.049			
54	2057			0.033		0.462		0.176	0.329
55	2058			0.568		0.261		0.129	0.042
56	2059	0.500	0.280	0.180		0.030			

Appendix 4: การวิเคราะห์น้ำหนักความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
57	2060			0.370		0.370		0.224	0.035
58	2061			0.045		0.269		0.450	0.236
59	2062			0.516		0.274		0.168	0.042
60	2063					0.311	0.035	0.513	0.141
61	2064			0.347		0.237		0.180	0.237
62	2065			0.385		0.422		0.152	0.040
63	2066			0.313		0.159		0.492	0.035
64	2068	0.397	0.382		0.161		0.059		
65	2069			0.443		0.280		0.197	0.081
66	2070			0.540		0.256		0.094	0.110
67	2071	0.046	0.388	0.343	0.222				
68	2072	0.072	0.303	0.321	0.303				
69	2073	0.038	0.248	0.449	0.266				
70	2074	0.037	0.423	0.227	0.313				
71	2075	0.072	0.234	0.394	0.300				
72	2076	0.041	0.252	0.455	0.252				
73	2077	0.038	0.211	0.376	0.376				
74	2078	0.189	0.351	0.351	0.109				
75	2080	0.058	0.236	0.457	0.250				
76	2081	0.065	0.249	0.312	0.373				
77	2082	0.034	0.131	0.333	0.502				
78	2083	0.396	0.367	0.122	0.114				
79	2084	0.439	0.344	0.161	0.056				
80	2085	0.166	0.439	0.358	0.038				
81	2086	0.036	0.168	0.505	0.292				
82	2087	0.035	0.206	0.245	0.514				
83	2088	0.135	0.516	0.313	0.036				
84	2089	0.178	0.400	0.278	0.144				

Appendix 4: การวิเคราะห์น้ำหนักความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
85	2090	0.292	0.292	0.062	0.353				
86	2092	0.322	0.433	0.203	0.042				
87	2093	0.411	0.364	0.188	0.037				
88	2094	0.429	0.439		0.089	0.043			
89	2095			0.148		0.231		0.426	0.195
90	2096			0.370		0.370		0.035	0.224
91	2097	0.449		0.248		0.266			0.038
92	2098			0.269		0.451		0.240	0.039
93	2099			0.036		0.416		0.385	0.163
94	2100			0.045		0.125		0.328	0.502
95	2101	0.370		0.224		0.370			0.035
96	2102			0.367		0.404		0.190	0.038
97	2103			0.368		0.368		0.193	0.070
98	2104			0.038		0.211		0.376	0.376
99	2105			0.526		0.282		0.156	0.035
100	2106	0.455	0.294	0.207	0.044				
101	2107			0.385		0.381		0.183	0.050
102	2108	0.451	0.240	0.269		0.039			
103	2109			0.500			0.040	0.130	0.320
104	2110	0.038		0.518		0.316		0.128	
105	2111	0.102	0.270		0.248		0.380		
106	2112			0.034		0.162		0.280	0.542
107	2113	0.511		0.288		0.166		0.035	
108	2114	0.053					0.316	0.316	0.316
109	2115	0.062	0.246	0.384	0.308				
110	2116	0.037	0.188	0.364	0.411				
111	2117			0.038	0.146	0.317	0.499		
112	2118			0.216		0.280		0.151	0.352

Appendix 4: การวิเคราะห์น้ำหนักความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
113	2119			0.366		0.038		0.376	0.220
114	2120			0.247		0.247		0.054	0.453
115	2121			0.041		0.141		0.524	0.294
116	2122			0.190		0.430		0.240	0.120
117	2123			0.070		0.090		0.360	0.470
118	2124	0.289	0.289	0.175		0.246			
119	2125	0.200	0.368		0.282		0.150		
120	2126	0.043	0.234			0.457			0.266
121	2127	0.232	0.161			0.103		0.503	
122	2128		0.290		0.290	0.290			0.290
123	2129		0.515	0.319		0.115	0.051		
124	2130		0.511		0.307	0.126	0.056		
125	2131			0.497	0.323	0.129	0.050		
126	2132	0.298	0.210		0.246		0.246		
127	2133	0.298	0.210		0.246		0.246		
128	2134		0.146		0.244	0.512		0.098	
129	2135	0.330		0.125		0.347		0.198	
130	2136	0.250			0.250		0.250		0.250
131	2137	0.250			0.250		0.250		0.250
Mean		**0.127**	**0.121**	**0.241**	**0.084**	**0.165**	**0.033**	**0.121**	**0.108**

Appendix 5: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์สังคม

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
1	2001			0.484		0.307		0.169	0.040
2	2002			0.034		0.490		0.157	0.319
3	2003	0.070		0.180		0.270		0.480	
4	2004	0.460	0.300		0.160		0.080		
5	2005	0.210	0.450	0.070			0.270		
6	2006	0.300		0.550		0.120		0.030	
7	2007	0.250	0.250	0.250	0.250				
8	2008			0.169		0.288		0.205	0.338
9	2009			0.315		0.037		0.324	0.324
10	2010	0.180	0.050	0.340	0.430				
11	2011	0.410	0.200	0.040	0.350				
12	2012	0.350	0.380	0.200	0.070				
13	2013	0.250		0.250		0.250			0.250
14	2014		0.204	0.245		0.204			0.347
15	2015				0.250	0.250		0.250	0.250
16	2016		0.289	0.175		0.246			0.289
17	2017	0.440		0.250		0.210			0.100
18	2018			0.033		0.523		0.276	0.168
19	2020	0.170		0.290		0.090			0.450
20	2021			0.035		0.370		0.225	0.370
21	2022		0.207	0.330		0.175			0.288
22	2023	0.520	0.240	0.180	0.060				
23	2024	0.235	0.305	0.230	0.230				
24	2025	0.430	0.160	0.030	0.380				
25	2026			0.326		0.356		0.124	0.194
26	2027			0.540		0.327		0.092	0.041
27	2028			0.281		0.176		0.298	0.245

Appendix 5: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์สังคม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
28	2029			0.194		0.326		0.356	0.124
29	2030			0.041		0.454		0.263	0.242
30	2031			0.051		0.244		0.449	0.256
31	2032			0.351		0.109		0.351	0.189
32	2033			0.395		0.340		0.218	0.047
33	2034			0.124		0.233		0.366	0.277
34	2035	0.380		0.270		0.260		0.090	
35	2037	0.040				0.100		0.550	0.310
36	2038	0.250		0.250		0.250		0.250	
37	2039			0.034		0.156		0.455	0.355
38	2040	0.522		0.320	0.150			0.008	
39	2041		0.205		0.169		0.288	0.338	
40	2042			0.321	0.321	0.321	0.037		
41	2043		0.200	0.308				0.357	0.135
42	2044	0.260		0.130		0.280		0.330	
43	2045	0.240		0.160	0.300	0.300			
44	2046			0.439		0.357		0.166	0.038
45	2047	0.120		0.240		0.390			0.250
46	2048	0.400		0.420		0.140		0.040	
47	2049			0.039			0.168	0.351	0.442
48	2050			0.040		0.133		0.376	0.451
49	2051			0.524		0.239	0.197		0.040
50	2053		0.246	0.308	0.384		0.062		
51	2054			0.520		0.320		0.130	0.030
52	2055	0.290	0.310	0.360		0.040			
53	2056	0.312	0.294	0.224		0.170			
54	2057			0.442		0.334		0.172	0.052

Appendix 5: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์สังคม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
55	2058			0.452		0.384		0.109	0.055
56	2059	0.590	0.220	0.130		0.060			
57	2060			0.490		0.319		0.157	0.034
58	2061			0.045		0.450		0.351	0.154
59	2062			0.250		0.250		0.250	0.250
60	2063					0.250	0.250	0.250	0.250
61	2064			0.042		0.271		0.361	0.326
62	2065			0.146		0.439		0.037	0.378
63	2066			0.082		0.200		0.359	0.359
64	2068	0.425	0.270		0.195		0.110		
65	2069			0.154		0.270		0.237	0.338
66	2070			0.338		0.169		0.205	0.288
67	2071	0.390	0.360	0.170	0.080				
68	2072	0.390	0.370	0.160	0.080				
69	2073	0.390	0.370	0.160	0.080				
70	2074	0.390	0.360	0.160	0.090				
71	2075	0.390	0.360	0.160	0.090				
72	2076	0.130	0.700	0.090	0.080				
73	2077	0.130	0.200	0.270	0.400				
74	2078	0.260	0.038	0.250	0.452				
75	2080	0.242	0.243	0.343	0.172				
76	2081	0.048	0.381	0.225	0.346				
77	2082	0.039	0.214	0.369	0.378				
78	2083	0.155	0.156	0.271	0.418				
79	2084	0.158	0.516	0.042	0.284				
80	2085	0.521	0.049	0.291	0.139				
81	2086	0.450	0.050	0.450	0.050				

Appendix 5: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์สังคม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
82	2087	0.037	0.176	0.389	0.398				
83	2088	0.285	0.413	0.248	0.054				
84	2089	0.205	0.421	0.055	0.319				
85	2090	0.528	0.286	0.150	0.036				
86	2092	0.042	0.215	0.293	0.450				
87	2093	0.231	0.195	0.148	0.426				
88	2094	0.508	0.037		0.179	0.276			
89	2095			0.176		0.245		0.281	0.298
90	2096			0.243		0.171		0.243	0.343
91	2097	0.395		0.395		0.175			0.035
92	2098			0.246		0.247		0.054	0.453
93	2099			0.250		0.250		0.250	0.250
94	2100			0.325		0.285		0.204	0.186
95	2101	0.293		0.207		0.207			0.293
96	2102			0.440		0.328		0.168	0.063
97	2103			0.246		0.289		0.289	0.175
98	2104			0.320		0.320		0.320	0.040
99	2105			0.250		0.250		0.250	0.250
100	2106	0.038	0.578	0.266	0.118				
101	2107			0.478		0.295		0.154	0.073
102	2108	0.507	0.310	0.130		0.053			
103	2109			0.480			0.050	0.150	0.320
104	2110	0.176		0.037		0.291		0.496	
105	2111	0.270	0.119		0.119		0.492		
106	2112			0.491		0.317		0.135	0.057
107	2113	0.483		0.297		0.175		0.045	
108	2114	0.110					0.215	0.245	0.430

Appendix 5: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์สังคม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
109	2115	0.354	0.131	0.161	0.354				
110	2116	0.484	0.211	0.245	0.060				
111	2117			0.045	0.116	0.319	0.520		
112	2118			0.418		0.404		0.131	0.047
113	2119			0.250		0.250		0.250	0.250
114	2120			0.250		0.250		0.250	0.250
115	2121			0.153		0.306		0.433	0.108
116	2122			0.250		0.250		0.250	0.250
117	2123			0.390		0.390		0.060	0.160
118	2124	0.299	0.034	0.528		0.139			
119	2125	0.035	0.121		0.297		0.547		
120	2126	0.308	0.384			0.246			0.062
121	2127	0.500	0.355			0.096		0.049	
122	2128		0.176			0.289	0.246		0.289
123	2129		0.169	0.205		0.338	0.288		
124	2130		0.055		0.104	0.256	0.585		
125	2131			0.277	0.117	0.385	0.221		
126	2132	0.227	0.424		0.227		0.122		
127	2133	0.319	0.243		0.281		0.157		
128	2134		0.347		0.204	0.245		0.204	
129	2135	0.395		0.395		0.175		0.035	
130	2136	0.035			0.174		0.396		0.395
131	2137	0.111			0.366		0.156		0.367
Mean		**0.148**	**0.111**	**0.214**	**0.086**	**0.166**	**0.042**	**0.118**	**0.115**

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
1	2001			0.460		0.310		0.160	0.060
2	2002			0.460		0.300		0.160	0.060
3	2003	0.260		0.210		0.090		0.430	
4	2004	0.250	0.250		0.250		0.250		
5	2005	0.190	0.350	0.390			0.050		
6	2006	0.270		0.150		0.450		0.100	
7	2007	0.260	0.300	0.080	0.340				
8	2008			0.440		0.270		0.180	0.090
9	2009			0.250		0.250		0.250	0.250
10	2010	0.440	0.290	0.170	0.080				
11	2011	0.490	0.240	0.060	0.190				
12	2012	0.460	0.170	0.320	0.030				
13	2013	0.560		0.040		0.300			0.080
14	2014		0.519	0.287		0.149			0.045
15	2015				0.479	0.280		0.190	0.040
16	2016		0.130	0.380		0.080			0.400
17	2017	0.360		0.180		0.030			0.410
18	2018			0.490		0.280		0.150	0.070
19	2020	0.290		0.210		0.240			0.240
20	2021			0.170		0.190		0.190	0.430
21	2022		0.100	0.540		0.290			0.050
22	2023	0.520	0.270	0.150	0.030				
23	2024	0.420	0.060	0.220	0.290				

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
24	2025	0.360	0.230		0.340	0.050			
25	2026			0.390		0.360		0.160	0.080
26	2027			0.390		0.360		0.160	0.080
27	2028			0.390		0.360		0.160	0.080
28	2029			0.390		0.360		0.160	0.080
29	2030			0.390		0.360		0.160	0.080
30	2031			0.390		0.360		0.160	0.080
31	2032			0.090		0.700		0.150	0.050
32	2033			0.050		0.130		0.360	0.440
33	2034			0.037		0.197		0.355	0.412
34	2035	0.040		0.483	0.280			0.198	
35	2037	0.455				0.051		0.290	0.204
36	2038	0.047		0.465		0.250		0.238	
37	2039			0.333		0.333		0.167	0.167
38	2040	0.273		0.508	0.052			0.168	
39	2041		0.298		0.246		0.210	0.246	
40	2042			0.450		0.050		0.450	0.050
41	2043		0.034	0.195				0.297	0.473
42	2044	0.498		0.288		0.048		0.166	
43	2045	0.127		0.305		0.036	0.532		
44	2046			0.219		0.219		0.036	0.526
45	2047	0.162		0.265		0.088			0.485
46	2048	0.253		0.209		0.299		0.239	

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
47	2049			0.289			0.175	0.289	0.246
48	2050			0.395		0.395		0.174	0.035
49	2051			0.036		0.143	0.305		0.516
50	2053		0.043	0.410	0.389		0.158		
51	2054			0.520		0.270		0.160	0.030
52	2055	0.500	0.313	0.132		0.055			
53	2056	0.320	0.330	0.310		0.040			
54	2057			0.035		0.213		0.311	0.441
55	2058			0.483		0.286		0.186	0.045
56	2059	0.500	0.330	0.130		0.030			
57	2060			0.157		0.037		0.426	0.380
58	2061			0.042		0.303		0.151	0.504
59	2062			0.197		0.394		0.327	0.081
60	2063					0.551	0.038	0.263	0.147
61	2064			0.033		0.176		0.329	0.462
62	2065			0.339		0.455		0.163	0.044
63	2066			0.281		0.245		0.176	0.298
64	2068	0.230	0.563		0.135		0.072		
65	2069			0.392		0.320		0.144	0.144
66	2070			0.524		0.271		0.135	0.070
67	2071	0.281	0.062	0.108	0.550				
68	2072	0.513	0.173	0.283	0.030				
69	2073	0.452	0.260	0.250	0.039				

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
70	2074	0.167	0.260	0.250	0.039				
71	2075	0.347	0.409	0.379	0.045				
72	2076	0.243	0.380	0.206	0.066				
73	2077	0.321	0.379	0.319	0.058				
74	2078	0.316	0.321	0.321	0.036				
75	2080	0.333	0.302	0.329	0.053				
76	2081	0.176	0.323	0.302	0.042				
77	2082	0.036	0.445	0.297	0.082				
78	2083	0.501	0.168	0.398	0.398				
79	2084	0.431	0.278	0.149	0.072				
80	2085	0.405	0.400	0.124	0.044				
81	2086	0.293	0.293	0.207	0.207				
82	2087	0.041	0.436	0.421	0.102				
83	2088	0.200	0.400	0.200	0.200				
84	2089	0.289	0.246	0.289	0.175				
85	2090	0.319	0.243	0.281	0.157				
86	2092	0.314	0.377	0.254	0.054				
87	2093	0.231	0.148	0.195	0.426				
88	2094	0.250	0.250	0.250	0.250				
89	2095			0.549		0.235		0.116	0.100
90	2096			0.175		0.330		0.207	0.288
91	2097	0.243		0.379		0.197		0.182	
92	2098			0.530		0.373		0.049	0.049

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	2	3	4	5	6	7	8
93	2099			0.326		0.470		0.037	0.166
94	2100			0.040		0.183		0.361	0.416
95	2101	0.168		0.395		0.198		0.239	
96	2102			0.562		0.200		0.198	0.040
97	2103			0.531		0.272		0.143	0.054
98	2104			0.041		0.156		0.396	0.406
99	2105			0.039		0.168		0.351	0.442
100	2106	0.395	0.416	0.141	0.048				
101	2107			0.308		0.308		0.308	0.077
102	2108	0.370	0.370	0.224		0.035			
103	2109			0.080			0.480	0.350	0.070
104	2110	0.440		0.392		0.417		0.147	
105	2111	0.035	0.315		0.268		0.381		
106	2112			0.065		0.237		0.398	0.300
107	2113	0.168		0.198		0.239		0.395	
108	2114	0.429					0.071	0.207	0.293
109	2115	0.315	0.381	0.268	0.035				
110	2116	0.321	0.321	0.321	0.036				
111	2117			0.051	0.149	0.252	0.548		
112	2118			0.220		0.086		0.309	0.385
113	2119			0.287		0.137		0.046	0.530
114	2120			0.283		0.183		0.482	0.053
115	2121			0.101		0.351		0.320	0.227

Appendix 6: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์วิศวกรรม (ต่อ)

ลำดับที่	รหัสแบบสอบถาม	ทางเลือก							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
116	2122			0.280		0.360		0.200	0.150
117	2123			0.140		0.500		0.300	0.040
118	2124	0.299	0.253	0.209		0.239			
119	2125	0.274	0.239		0.145		0.343		
120	2126	0.643	0.185			0.066			0.106
121	2127	0.550	0.202			0.104		0.143	
122	2128		0.290			0.290	0.290		0.290
123	2129		0.520	0.295		0.119	0.067		
124	2130		0.508		0.265	0.151	0.075		
125	2131			0.523	0.328	0.112	0.037		
126	2132	0.250	0.250		0.250		0.250		
127	2133	0.250	0.250		0.250		0.250		
128	2134		0.139		0.241	0.516		0.103	
129	2135	0.210		0.298		0.246		0.246	
130	2136	0.250			0.250		0.250		0.250
131	2137	0.250			0.250		0.250		0.250
Mean		**0.159**	**0.122**	**0.234**	**0.067**	**0.153**	**0.039**	**0.120**	**0.106**

Appendix 7: การวิเคราะห์ลำดับความสำคัญของทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในเกณฑ์เศรษฐกิจ สังคม และวิศวกรรม

ทางเลือกที่	เกณฑ์เศรษฐกิจ (ค่าน้ำหนัก = 0.200)	เกณฑ์สังคม (ค่าน้ำหนัก = 0.401)	เกณฑ์วิศวกรรม (ค่าน้ำหนัก = 0.399)	น้ำหนักความสำคัญรวม	ลำดับที่
1	0.127	0.148	0.159	**0.148**	3
2	0.121	0.111	0.122	**0.118**	5
3	0.241	0.214	0.234	**0.227**	1
4	0.084	0.086	0.067	**0.078**	7
5	0.165	0.166	0.153	**0.161**	2
6	0.033	0.042	0.039	**0.039**	8
7	0.121	0.118	0.120	**0.119**	4
8	0.108	0.115	0.106	**0.110**	6
รวม	**1.000**	**1.000**	**1.000**	**1.000**	

แบบสอบถามส่วนที่ 1

ข้อมูลทั่วไปของผู้ตอบแบบสอบถาม

1. ชื่อ..สกุล..

2. อาชีพ..3. ใช้น้ำจากอ่างเก็บน้ำสำหรับ...................................

4. ที่อยู่...

5.ปัญหาจากการรับการบริการใช้น้ำ...

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6. ข้อเสนอแนะในการให้บริการการใช้น้ำ..

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แบบสอบถามส่วนที่ 2

คำอธิบายประกอบแบบสอบถามในการให้น้ำหนักความสำคัญของการตัดสินใจแบบหลายเกณฑ์ในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ

เกณฑ์ที่ใช้ในการตัดสินใจสำหรับการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงให้กับผู้ใช้น้ำในกิจกรรมการเกษตร การอุปโภค บริโภค และการรักษาระบบนิเวศนั้นจะบูรณาการในเกณฑ์ด้านเศรษฐกิจ สังคม และวิศวกรรม โดยมีเป้าหมายเพื่อให้การจัดสรรน้ำนั้นเกิดความพึงพอใจต่อผู้ใช้น้ำมากที่สุด ดังนั้นจำเป็นต้องมีดัชนีที่เป็นตัวแทนในแต่ละด้าน ดังนี้

1.เศรษฐกิจ (Economic) ใช้ผลประโยชน์(Profitability) เป็นดัชนีชี้วัด เช่น การจัดสรรน้ำในภาวะขาดแคลนน้ำให้กับกิจกรรมใด จึงจะก่อให้เกิดรายได้ หรือผลตอบแทนสูงสุด

2. สังคม (Social) ใช้ความเท่าเทียม(Equitable) เป็นดัชนีชี้วัด เช่น การจัดสรรน้ำนั้นจะต้องให้เกิดความเท่าเทียมซึ่งกันและกันของผู้ใช้น้ำในแต่ละกิจกรรม หรืออีกนัยหนึ่งกล่าวได้ว่า ถ้าขาดแคลนน้ำก็ขาดแคลนในสัดส่วนเท่าๆกัน

3. วิศวกรรม (Engineering) ใช้ความมีประสิทธิภาพ(Efficiency) เป็นดัชนีชี้วัด เช่น การจัดสรรน้ำให้กับกิจกรรมต่างๆในปริมาณเท่าใดจึงจะมีประสิทธิภาพ นั่นคือเกิดการสูญเสียน้อยที่สุด

ถ้าหากพิจารณาเพียงเกณฑ์ใดเกณฑ์หนึ่งสำหรับการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำก็จะก่อให้เกิดปัญหาของผู้ใช้น้ำในแต่ละกิจกรรมอย่างแน่นอน เช่น ถ้าจะพิจารณาเพียงผลประโยชน์ ปริมาณน้ำสำหรับการรักษาระบบนิเวศ แทบกล่าวได้ว่าอาจจะไม่ต้องจัดสรรน้ำให้เลย หรือการเกษตรก็ต้องลดพื้นที่ลง ซึ่งถือว่า ไม่มีความเท่าเทียมจากการจัดสรรน้ำเป็นต้น ดังนั้นจึงจำเป็นต้องพิจารณาแบบหลายเกณฑ์ในการตัดสินใจเพื่อจัดสรรน้ำจึงจะลดปัญหาความขัดแย้งระหว่างผู้ใช้น้ำ และผู้ใช้น้ำกับเจ้าหน้าที่

ตัวอย่างการจับคู่ทางเลือก

เช่น เลือกทางเลือก ก ข ค ง จะจับคู่ได้เป็น

ก ⟵⟶ ข

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การพิจารณาการให้คะแนน

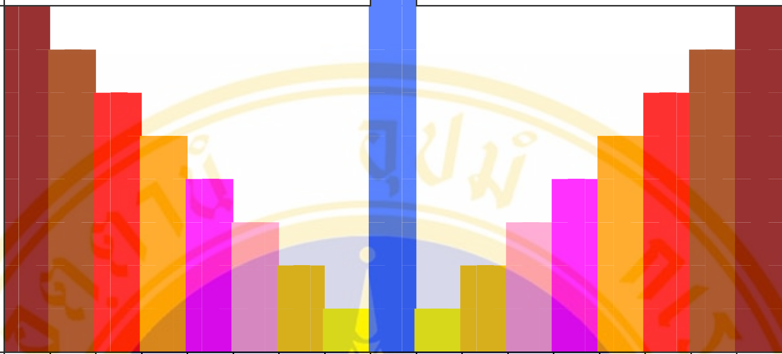
1. เลือกตัดสินใจว่าทางเลือกไหนสำคัญกว่ากัน (เช่น ทางเลือก ก สำคัญกว่าทางเลือก ข หรือ ทางเลือก ข สำคัญกว่าทางเลือก ก)
2. เลือกขนาดของความสำคัญโดยการให้คะแนน 1-9

คำอธิบายประกอบแบบสอบถามในส่วนของการคัดเลือกทางเลือกในการจัดสรรน้ำเพื่อใช้ในการวิเคราะห์จัดลำดับความสำคัญ และเกณฑ์ในการจัดสรรน้ำในสภาวะวิกฤต

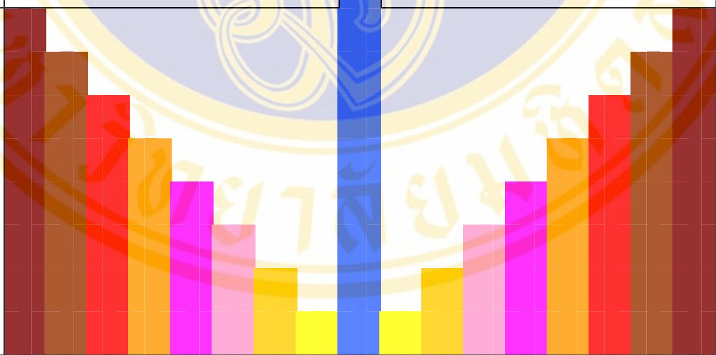
ทางเลือกในการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิง ให้กับผู้ใช้น้ำในแต่ละกิจกรรม คือ การเกษตร การอุปโภค บริโภค และการรักษาระบบนิเวศ ในกรณีปีที่มีปริมาณน้ำในระบบอ่างเก็บน้ำน้อย หรือเป็นปีแล้ง (Dry) เพื่อให้เกิดประโยชน์ (Profitability) มีความเท่าเทียม (Equity) และมีประสิทธิภาพ (Efficiency) สูงสุด จากทางเลือกตัวอย่างที่สร้างไว้จำนวน 8 ทางเลือก โดยให้ผู้ใช้น้ำในแต่ละกิจกรรม **คัดเลือกเพียง 4 ทางเลือก** จาก 8 ทางเลือก ดังนี้

ทางเลือกที่	**การเกษตร ผลผลิตลดลง (%ของผลผลิตสูงสุด)**	**การอุปโภค บริโภค การใช้น้ำลดลง (%ของการใช้น้ำปกติ)**	**การรักษาระบบนิเวศ ระดับน้ำลดลง (%ของระดับน้ำที่รักษาไว้ต่ำสุด)**
1	40	54.32	7.56
2	42	54.32	4.16
3	44	0.00	7.56
4	45	54.32	1.99
5	46	0.00	4.16
6	47	54.32	0.00
7	49	0.00	1.99
8	51	0.00	0.00

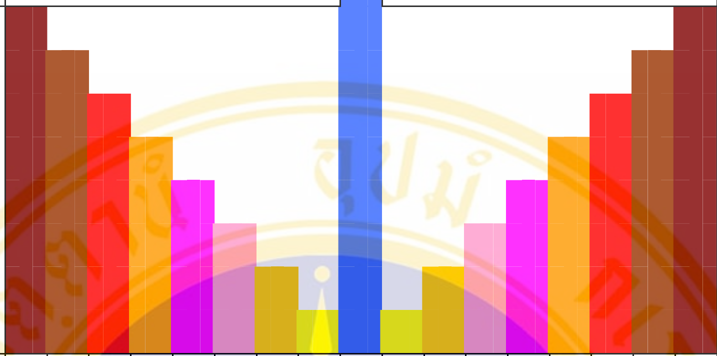
แบบสอบถามเพื่อให้น้ำหนักความสำคัญของเกณฑ์การจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำ

เกณฑ์ A	ความสำคัญของ A มากกว่า B									ความสำคัญของ B มากกว่า A								เกณฑ์ B
																		
เศรษฐกิจ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	สังคม
เศรษฐกิจ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	วิศวกรรม
สังคม	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	วิศวกรรม

แบบสอบถามเพื่อเลือกทางเลือกของการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำในเกณฑ์เศรษฐกิจ

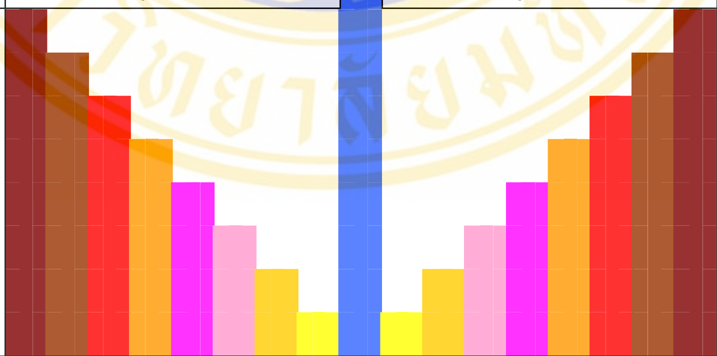
ทางเลือก A	ความสำคัญของ A มากกว่า B									ความสำคัญของ B มากกว่า A								ทางเลือก B
																		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

แบบสอบถามเพื่อเลือกทางเลือกของการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำในเกณฑ์สังคม



ทางเลือก A	ความสำคัญของ A มากกว่า B									ความสำคัญของ B มากกว่า A								ทางเลือก B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

แบบสอบถามเพื่อเลือกทางเลือกของการจัดสรรน้ำจากอ่างเก็บน้ำลำพระเพลิงในภาวะขาดแคลนน้ำในเกณฑ์วิศวกรรม



ทางเลือก A	ความสำคัญของ A มากกว่า B									ความสำคัญของ B มากกว่า A								ทางเลือก B
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

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