Chapter 1
Research Design

1.1 Introduction

While demand for water has been increasing throughout the history of humankind, supply of water has been more or less stable. That is, water recycles within the global system through its three forms, liquid, solid and vapour, and thus the total amount of water on the earth has essentially not changed since the beginning of the earth (Seckler, et al. 1998). As a result, the net available amount of water for each individual decreases as the total demand for water increases. More specifically, in the Asia and the Pacific regions in particular, the demand for water is increasing rapidly, and the per capita availability of water is declining at the rate of approximately 1.6% per annum (ESCAP, 1996a). According to another source, in Asia, per capita availability of water declined by 40-60% between 1990 to 1995 (IRRI, 1995). The most widely used indicator defines 1,700 cubic meters (m^3) per capita per year as the level of water supply above which shortages will be minor. Below 1,000 m^3 per capita per year, water shortage can impede health and economic and human well-being (Seckler, et al. 1998). The figure for Thailand is 602 m^3 per capita, or 24 m^3 for domestic use, 36 m^3 for industrial use and 542 m^3 for irrigation. This may indicate the already existing water shortage in the country.

Hence, once considered an abundant renewable resource, water is becoming increasingly scarce and may no longer be renewable. In the tropics, this may be a result of watershed being exploited beyond its capacity to keep ecological functions intact, coupled with polluted water produced mainly by household use and the industrial sector. Compared to rapidly rising demand, the current supply of fresh water has continued to fall short. It was described that "between 1900 and 1990 total world-wide water withdrawals increased at twice the rate of the population increase while, compared with three centuries ago, water use rose more than 35-fold" (IRRI, 1995:11).

Agriculture world-wide has always been the major consumer of fresh water. Within the total amount of world water demand, a significant portion is used for agricultural purposes, especially for irrigation. On average, around 70% of global water withdrawal are for irrigation agriculture (Klohn and Appelgren, 1999). In Asia, where irrigated agriculture is more widely applied than in other regions, water use for agriculture takes a higher percentage of total water consumption compared to the rest of the world. In Asian countries, agriculture consumes 86% of total annual water withdrawal, compared with 49% in North and Central America and 38% in Europe (IRRI, 1995).

Most of the world irrigation is built to support rice cultivation, which requires much more water compared with other crops as shown in the table below. Rice thrives on water logging, whereas diversified field crops cannot survive through over irrigation and continuous irrigation (Plusquellec and Wickham, 1985). In terms of water consumption, rice can be seen as an inefficient crop compared with most other crops (see Table 1-1). Being the staple for the major part of the world population, however, rice cultivation has been promoted to ensure food security, and water demand for irrigation has subsequently increased. The relationship between development of paddy cropping and growth in water demand is found, for example, in the Green Revolution. Plant-breeding innovations under the Green Revolution were accompanied by increased use of fertiliser and the expansion of irrigation (Jones, 1995). Thai agriculture is no exception. In 1970s, rice production in Thailand increased considerably mainly owing to the development of dry season irrigation especially in the Central region which had the highest potential for promoting irrigated rice production (Plusquellec and Wickham, 1985).

Table 1-1 Approximate average water requirements in Asia for major irrigated crops

Crop	Mm/hectares/crop
Paddy (transplanted)	1,240
Sugarcane	1,600
Cotton	750
Sugar beet	650
Vegetables and annual fruits	450
Other grains	330

Source: Jones, 1995

The declining profitability of irrigation agriculture, especially rice production, has been widely recognised since the 1980s. A series of studies on the public irrigation investments concluded that the decline in the world rice price and the increasing costs per hectare of new irrigation development were the most significant causes of declining investments (Rice, 1997).

1.2 Research Problems

While water for agricultural use during the dry period has been short in supply, current policy response has not been appropriate. That is, "free" water allows farmers to use water wastefully. Farmers tends to over irrigate whenever they can so as to reduce management costs and the risk of drought (Wade and Seckler, 1990). Another two factors causing wasteful use of water are farmers' lack of awareness of wasting scarce water resources and inefficiency of irrigation systems in delivering water. A researcher at the International Rice Research Institute (IRRI) estimates water use efficiency in rice production as low as 30-40% in the wet season and 40-60% in the dry season (IRRI, 1995 and ESCAP, 1996a). Many irrigation systems lack adequate investments in operation and management (O&M), which causes inefficiency and low productivity of the systems. For instance, the U.S. General Accounting Office (GAO) conducted a survey of USAID-funded irrigation projects in Indonesia, Sri Lanka and Thailand and found poor O&M in most of the projects. When irrigation infrastructure is not well maintained, some water is wasted before it is transferred to the crop fields. The research team reported about projects in Thailand as follows:

> In Thailand, at all three irrigation projects we saw silt and weeds in the canals and holes and cracks in the concrete canal linings. Small, unattended problems gradually grow until major repairs are needed (Ostrom, 1992).

In most developing countries, Thailand included, there is no political will to implement water charge, although allowed by water laws. It has been clear that more effective and efficient water management practices are needed in Thailand. In theory, setting a higher price for water can be an effective economic measure to bring growing demand in line with supply, and to increase efficiency in use. The limited supply of water naturally affects agricultural practices in general, and more specifically, hinders expansion of irrigation systems. There is a popular argument that as opportunities for development of new irrigation is becoming scarce and costly, the emphasis should be given to increasing productivity and efficiency of existing irrigation systems (Seckler, et al. 1998, ESCAP, 1996a). As for irrigation, physical, economic and environmental constraints have slowed down expansion of irrigation since 1980s (Klohn and Appelgren, 1999). It is predicted that in future years, increasing water scarcity will affect rice production seriously (IRRI, 1995).

Water is a unique good. In many countries, water is treated differently from other goods and often attached special cultural, religious and social values associated with it (Klohn and Wolter, 1998). Water is also part of the humans' basic needs and is often treated as a public good that is managed and allocated by the state. Being a public good and a basic need, water is often provided for free or at very low prices. In countries where income distribution is a priority over economic efficiency, water is perceived as a public good and allocated at subsidised rates. Many countries in the Asia and Pacific region, including Thailand, belong to this category (EACAP, 1996b).

It has been argued that water should be priced at appropriate levels to reflect increasing production costs and scarcity. It is, however, extremely difficult to determine appropriate prices for water, given the role of water as a basic need, a merit good, and a social, economic, financial and environmental resource (Perry, et al. 1997).

This dilemma of placing water between a public and an economic good is manifested in the situation of irrigation schemes. Irrigation projects, especially large-scale ones, require significant investments. On average, new irrigation schemes in South and Southeast Asia cost around $1,900 - $4,500 per hectare (Asian Productivity Organisation. 1991). Normally it is the state that bears the costs of irrigation development and operation, while beneficiaries of irrigation projects are charged very little for water. Therefore only few countries can recover investment costs of irrigation projects through water charges (ESCAP, 1996a). In Thailand, as well as some of its neighbouring countries such as the Philippines, Indonesia and Nepal, cost recovery rates of government irrigation investments fall below 10 % (Asian Productivity Organisation, 1991).

1.3 Research Objectives

This research attempts to apply pricing mechanisms to an irrigation project in the Northeast region of Thailand, viewing the revenue to subsist and maintain the existing system. This Nong Wai Irrigation serves around 300,000 rai (48,000 ha) in Khon Kaen Province and Mahasarakham Province. In the past, an irrigation water pricing mechanism was introduced, and water fees were collected by an agricultural cooperative through water users' groups. This water fee collection system, however, appears to have been abandoned.

The general objective of this research is to develop an irrigation water pricing mechanism for Nong Wai Irrigation for its future operation and maintenance. Specific objectives are:

1. to calculate the full-cost prices of irrigation water;
2. to verify the validity and acceptance of such prices to irrigation users; and
3. to propose a set of recommendations for the implementation of the calculated prices.

1.4 Research Methods

1.4.1 Tools and Analysis

There is more than one way to price water. Two approaches are discussed below. The marginal productivity approach, popular among agriculturists, hypothesises that water is worth as much as it benefits—in terms of marginal value products. This approach, therefore, tries to estimate the value of the marginal unit of output from one marginal unit of water.

Marginal value product (MVP) is the marginal net return to an increased level of input. A World Bank technical paper on measuring economic benefits for water investments and policies (Young, 1997) cites MVP as a technique to evaluate investments in additional water supplies. Assuming profit-maximising producers would add productive inputs up to the point where value marginal product is equal to the opportunity costs of the inputs; producers' willingness to pay for an increment of water is MVP or the net producer income associated with that increment.

Economic evaluation or economic feasibility tests can be done using present value of net benefits (PVNB).

$$PVNB = [\sum_{t=1}^{T} (B_t - B_0)/(1+r)^t] - [\sum_{t=1}^{T} (I_t + R_t - R_0)/(1+r)^t] - [\sum_{t=1}^{T} D_t/(1+r)^t]$$

where

B_t and B_0 = respective benefit in year t and year 0
I = incremental investment cost between year 0 and year t
R_t and R_0 = respective operation and maintenance cost in year t and year 0
D_t = incremental project induced disbenefit in year t
r = discount rate

Projection of incremental benefit of increased water supply requires the following set of a priori judgements for both the with and without project situations:

1. crop species and acreage of each crop to be grown;
2. the crop response to alternative amounts and timing of water applied; and
3. what irrigation water distribution technologies might be employed (Young 1997).

One of the problems using this method is the crop mix and the ability to control "noises" (i.e., other factors besides water productivity) in estimation. The other problem that arises from using this approach is the variation in prices of crops, whose relative prices in the long run seem to be biased downward, indicating (given fixed technology) the declining productivity of water. That may or may not be true.

The marginal opportunity cost (MOC) approach is more interesting in estimating the "worthiness" of water directly—although it also has its own weakness. In theory, supply of a natural resource should be priced at its full cost that reflects its marginal opportunity cost (Warford, 1994). In this light, the price of irrigation water should be set at its opportunity cost consisting of user cost, production cost and externality cost. Irrigation water in a perfect market economy, therefore, should be priced at the level where marginal cost curve intersects marginal revenue curve (ESCAP, 1996B). An expert group on financial issues of Agenda 21 advocates the same standpoint that sustainable development requires full-cost pricing of resources, one of which is water, that has the following three aspects:

1. reducing subsidies that are damaging to sustainable development, so that consumers and producers face at least the direct production costs of their decisions;
2. raising charges on natural resources to levels that reflect depletion costs; and
3. introducing pollution charges and related instruments (e.g., product charges and tradable permits) to force polluters to pay a price for the

environmental degradation they cause (United Nations, 1996).

According to the concept of full cost pricing using marginal opportunity cost, the price of a resource should include the following components.

Price of a resource = MOC = MUC + MPC + MEC

where
MOC = marginal opportunity cost;
MUC = marginal user cost, reflecting discounted cost of replacing current asset or resource or the net replenished cost;
MPC = marginal production cost; and
MEC = marginal externality cost representing negative environmental impact due to resource use.

Using the concept of marginal opportunity cost, the full-cost prices for irrigation water will be calculated as shown below.

Full-cost price of irrigation water = MOCw = MUCw + MPCw + MECw

MUCw

Water is produced through the process of direct rainfalls and discharge from forest cover. The marginal user cost of water should be zero since extraction of water does not forgo future supply of water through rainfalls and discharge of water from the forest (TEI, 1997). The condition of forest cover in the water sources may affect supply of water, which is taken account in the marginal production cost of water.

MPCw

The marginal production cost of irrigation water is comprised of two components: marginal production cost of water and marginal production cost of irrigation facilities.

The marginal production cost of water is an aggregation of the marginal cost of forest protection (MCFP), the opportunity costs of the water when it is used for other types of usage (OP_w), and the opportunity cost of the storage site for other types of usage (OP_l) (TEI, 1997).

$$MPC_w = MCFP + OP_w + OP_l$$

The marginal production cost of irrigation facilities may include the following costs:

- Variable cost: (1) establishment and operational charges (source costs, transmission costs, local distribution costs); (2) maintenance charges; (3) energy charges;

- Fixed cost: (1) interest on capital cost; (2) depreciation*;
- Charges to generate funds for future expansion of services (new projects) (ESCAP, 1996B).

It should be noted that in some cases, market prices for inputs, outputs and capital may need to be adjusted to reflect social values (Young 1996).

MECw

Externality costs can be estimated by looking at the physical flow of water: "Where is water going? Where is it being consumed? Where is it being reused? What is happening to salt and pollution loading?" (Perry, et al. 1997). For irrigation projects, the analysis of the externality costs will examine the following physical areas of the projects:

1. The water supply source and production zone;
2. Areas used for transmission/storage/treatment; and
3. The consumption zones including distribution facilities. (ESCAP, 1990)

Irrigation development can cause negative environmental impacts including salinity; water pollution by use of agricultural chemicals; loss of wildlife habitats; resettlement of habitats previously living in areas flooded under reservoirs; soil modification, including water logging, water quality and quantity modification; effects on ecology; public health impacts; and other socio-economic impacts (Seckler, et al. 1998 and ESCAP, 1990).

Environmental externalities created by return flows might also be considered. Return flows are "the drainage water from a particular withdrawal that flows back into the system where it can be captured and reused, or recycled within the system," and " in rice irrigation much of the water applied to one field drains to a downstream field where it provides irrigation to that field" (Seckler, et al. 1998). Approximately 70% of water withdrawn into field are drained as return flows (see Table 1-2 below). Return flows contain an increased amount of salt because crops consume only water leaving salt contained in the water. In a similar way, fertilisers and pesticides remain in returned flows, causing water pollution (Perry, et al. 1997). These are considered normal problems faced by irrigation schemes—externalities that have to be taken into account in irrigation water pricing.

* Assuming the normal life of civil works may be taken as 50 to 100 years and that of pumping machinery and ancillaries as 10 years, the depreciation should therefore be taken as 1 to 2 per cent of the capital cost of civil works and 20 per cent of pumping machinery.

Table 1-2 Water multiplier

Cycle	DIV	EVAP	Sinks	Return flow
		20%	10%	70%
1	1000	200	100	700
2	700	140	70	490

Source: Seckler, et al 1998:19

In deriving full-cost prices for natural resources, it is often difficult to calculate the direct marginal opportunity cost price, due to capital invisibility or the lumpiness of capital. When resources are supplied in the amount below the full capacity of the supply system, the cost of providing an additional unit of the resources will be merely operation and maintenance costs. Investment in expanding capacity of the natural resource supply system takes at some intervals in time.

As a solution to the problem of capital invisibility, Warford (1994) proposes to use average incremental costs as a broadly defined marginal opportunity cost. Average incremental costs (AIC) are the discount amount of additional supply of resources to be produced, divided by the discount value of future supply costs.

$$AIC = \frac{\sum_{t=1}^{T} (I_t + R_t - R_0) / (1+r)^t}{\sum_{t=1}^{T} (Q_t - Q_0) / (1+r)^t}$$

where

I_t = incremental investment cost between year 0 and year t
R_t and R_0 = respective operation and maintenance cost in year t and year0
r = discount rate
Q = volume

AIC has been used in the calculation of full-cost price of water resources (refer to TEI, 1997 and TDRI, 1995). This study also employs AIC as the second best alternative of calculating marginal opportunity cost of irrigation water of the Nong Wai Irrigation System.

1. Incremental investment cost

Incremental investment cost was calculated according to the planned investment in the future years based on the workplan for the system improvement of Nong Wai Irrigation.

2. Incremental operational and maintenance cost
   Increased O&M cost for Nong Wai Irrigation in the future years was projected based on the record of O&M cost in the past years.

3. Incremental externality (environment) cost
   The improvement of the drainage system in the future can be taken as the environmental cost of treating wastewater. In this study, it was included as part of the irrigation system improvement costs.

4. Incremental consumption of water
   Incremental amount of irrigation water delivery of Nong Wai Irrigation was estimated based on the trend of water delivery in the past years.

5. Incremental opportunity cost of water
   Based on the incremental consumption of water, incremental opportunity cost of water was calculated.

Average incremental cost of water under the Nong Wai irrigation system is the aggregation of the discounted value of each component of the costs mentioned above.

1.4.2 Data and Information

The price calculation was conducted from the perspective of RID, the owner of the project. Necessary data for the calculation of the full-cost prices of irrigation water was collected from both primary and secondary sources. Primary data for use in assessing the implementation of the calculated price(s) was collected mainly through interviews and meetings with water users. Primary data was also be gathered from the RID offices responsible for the irrigation scheme. The main office of RID is located in Bangkok. The regional office of RID responsible for Nong Wai Irrigation is in the city of Khon Kaen. The RID Nong Wai project office, which directly oversees the irrigation system, is located near the head compound of the irrigation system.

Secondary data were obtained from relevant agencies and institutes such as the Ministry of Agriculture and Cooperatives and the Water Resource and Environment Institute (WREI) of Khon Kaen University. These data include maps; general information and data on irrigation schemes in the region and annual budget and plans of the project.

1.4.3 Population and Samples

All irrigation users are the targeted population for this study. However, a small number of samples were taken out of this population for a preliminary field test, using stratified random sampling technique.

1.4.4 Application of the Calculated Price

Application of the calculated water price to the situation of irrigation users was explored through interaction with the water users. Interviews with the water users will be conducted to assess their willingness to pay for irrigation water.

Possible options of irrigation water pricing mechanisms may be developed reflecting factors including those listed below.

- Purpose of water use/type of crop
- Level of service
- Season in the year and time in the day of use
- Distance from water source
- Affordability and willingness to pay

1.5 Expected Outcomes

It was hoped that the result of the research would provide recommendations for the potential reintroduction of the irrigation water pricing mechanism, which would lead to more efficient use of limited water supply. It is expected, however, that the calculated price might be too high to be acceptable to the irrigation users. Thus, one of the key implications is that the implementation scheme (i.e., charging scheme) is also a crucial issue to be considered if such a modified full-cost pricing scheme is to be implemented.

1.6 Limitations

The research focuses on one irrigation system in Khon Kaen Province and Mahasarakham Province of Thailand. The result of the research, therefore, may not be applicable to other localities or the country in general. To serve a more general purpose, other modifications may have to be made to the calculated price and the enforcement mechanism. Moreover, the price of irrigation water for water users will be calculated based on the concept of marginal opportunity cost pricing, and the price may not necessarily be accepted by the water users. Actual implementation would have to be made to suit many other socio-economic factors. Lastly, the political factor in implementing such pricing scheme also should not be ignored.