

# Water Supply Management in urban areas in Laos



A Comparative Study of Ground Water and Surface Water  
in an Economic, Financial and Environmental Perspective

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A Minor Field Study



## **PREFACE BY THE SUPERVISORS**

Water supply in the Mekong Region is to a large extent based on water resources that are exposed to significant risks and the security of both surface and groundwater supplies are in many cases poor. Although surface water is more common as a supply source, groundwater is assumed to play an increasingly large role in the future, due to low treatment costs and local accessibility.

Based on the Dublin Principles and the definition of Integrated Water Resource Management (IWRM)<sup>1</sup>, groundwater protection should be implemented in a framework addressing social, economic and ecological factors. In addition, IWRM thinking clearly states that the entire hydrological cycle and its interaction with society should be included in developing water management strategies. The Dublin Principles further state that water should be regarded as an economic good. While it is essential that this concept does not lead to low-income groups in society being marginalized it is important that the value of water is being recognized. Furthermore, without an economic thinking it is likely that incentives to promote various groundwater protection strategies will be ineffective.

The focus of the Chalmers research project “Security of Water Supply in the Mekong Region - Developing Strategies for Sustainable Groundwater Protection” is on improved strategies for sustainable groundwater protection in the Mekong region. One important part of this work is, in accordance with the Dublin Principles, to assess the economical aspects of using groundwater compared to surface water in urban water supply systems.

Maria and Kjerstin has carried out a number of evaluations for five urban areas in Lao PDR and gained important insight on performing economical and financial studies of water resources in the country. They have identified many of the limitations and possibilities of performing such studies in the Lao PDR economical system. From this study it is evident that cultural and social factors strongly impacts the economical valuations of water resources, in many cases more so than technical and administrative factors. Their results will be of great value to the research project.

Maria and Kjerstin have performed their work in a very positive spirit and with a great deal of initiative. They have planned and carried out their study in a well-structured manner. As supervisors, it is a pleasure to congratulate them to the completion of their Master thesis.

Göteborg June 4, 2004

Lars Rosén, Ph.D

Per Sander, Ph.D

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<sup>1</sup> "IWRM is a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP Technical Advisory Committee, 2000)

## **PREFACE BY THE AUTHORS**

This thesis was performed as a part of a Master of Science degree of Industrial Engineering and Management at Chalmers University of Technology in Gothenburg. The study was carried out at the department of Geo engineering at Chalmers University of technology in cooperation with the Water Supply Authority at the Ministry of Construction, Transport, Post and Communication in Laos. The Swedish International Development Cooperation Agency, SIDA, financed the study within the Minor Field Study programme. The study included three months field work in Laos. The study is a part of a larger study of water supply in the Mekong Delta, conducted by scientists at Chalmers University of Technology.

Many persons have helped and supported us during this study and we would like to express our appreciation. First of all, many thanks to Dr. Lars Rosén and Dr. Per Sander, Department of Geo engineering, who made this master thesis possible. They have been our supervisors at Chalmers, put us in contact with the Water Supply Authority in Laos and given us useful input during the last stages of the work.

Mr. Noupheuk Virabouth, Director General of Water Supply Authority and Mrs Kongsay Ounchith, Deputy Project Manager of Department of Housing and Urban Planning were our supervisors in Laos. Without their support this thesis could not have been performed. They supplied us with necessary equipment, guidance and introduced us to Lao customs.

Dr. Somphone Dethoudom, Director of Department of Housing and Urban Planning gave us useful feedback on our work in Laos. Many others have helped us with our investigations and made our stay in Laos to an unforgettable visit.

We received useful information from several persons before we went to Laos, for example Kjell Kihlberg, Borås, Claes Wångsell, Göteborg, Boris Gabriellsson and Ulf Karlsson, both Kungsbacka. Furthermore, prof. Gilbert Svensson, Chalmers, introduced us to the key performance indicators of Swedish Water Development.

Finally, we would like to thank SIDA for giving us the opportunity to perform our Master thesis in Laos. This study has given us many unforgettable memories, new friends and valuable experiences.

Göteborg 19<sup>th</sup> of May 2004

Maria Forsell

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## **ABSTRACT**

The urban areas along the Mekong River in Laos has traditionally used surface water as a source for water supply. The purification process of surface water is expensive due to chemical usage and therefore, the authorities have shown interest in an alternative source of raw water, such as ground water. Local authorities have shown scepticisms towards ground water as a source for raw water supply, mainly because of earlier unsuccessful ground water projects.

The objective of this thesis was to perform an economical, financial and environmental comparative study of ground water and surface water as a source for raw water supply in urban areas along the Mekong River in Laos.

Suitable methods for comparing ground water and surface water from an economical, financial and environmental perspective have been defined. Operational and financial key performance indicators have been defined. Using these methods five water supply schemes in urban areas have been compared. Differences that can be derived to the source of raw water have been searched for.

A field study in the five different areas was performed to collect facts about the five water supply schemes. Interviews with directors of the local water authorities were held. Consultant reports and financial reports were studied.

The report identifies factors that complicate a comparison of surface water and ground water as a source of raw water supply in the five studied areas, such as deficiencies in routines for operation and chemical dosing. Further hindrances for the comparison are that the wells and water plants are not optimally maintained. The statistical selection is too small to offer any general conclusions on raw water sources for the whole of Laos.

The main result of this study is that the cost of chemical is significant higher for surface water supplied water schemes. It is stated that environmental impact is low no matter what raw water source is used. It is hard to draw any conclusions on economical and financial differences between surface water and ground water from this study.

The report recommends the authorities to continue their work on education at all levels within the water authority organisation. An increased knowledge transfer between management and operators is to strive for. To improve the consumers' trust in the water authorities, the communication and information to the public must be improved. A financial and operational reporting system for generating comparative statistics should be implemented in order to evaluate the performance of local water authorities.

## SAMMANFATTNING

Traditionellt har de urbana områdena utmed Mekongfloden i Laos använt ytvatten som vattenförsörjningskälla. Reningsprocessen av ytvatten är kostsam på grund av kemikalieanvändningen och därför har man från myndigheternas håll visat intresse för alternativa vattenförsörjningskällor, såsom grundvatten. Lokala myndigheter har visat skepticism mot grundvatten som källa till vattenförsörjning, främst på grund av tidigare mindre lyckade brunnprojekt.

Denna rapport har syftat till att göra en ekonomisk, finansiell och miljömässig jämförande studie av ytvatten och grundvatten som källa för vattenförsörjning i urbana områden utmed Mekongfloden i Laos.

Passande metoder för jämförelse av grundvatten och ytvatten ur ett ekonomiskt, finansiellt och miljömässigt perspektiv har definierats, liksom operativa och finansiella nyckeltal. Genom att använda dessa metoder har fem vattenförsörjningssystem undersökts och skillnader som kan härledas till råvattenkälla har eftersökts.

För att inhämta fakta om de fem vattenförsörjningssystemen har en fältstudie i de olika områdena genomförts. Intervjuer med direktörer på de lokala vattenmyndigheterna har utförts. Konsultrapporter och årsredovisningar har studerats.

I rapporten identifieras de faktorer som försvårar en jämförelse av yt- och grundvatten som vattenförsörjningskälla i de fem studerade områdena, bland annat bristfälliga rapporteringssystem samt bristfällig driftsrutin och kemikaliedosering. Vidare försvåras jämförelsen av att brunnar och vattenreningsverk inte underhålls optimalt. Det statistiska underlaget är för litet för att möjliggöra några generella slutsatser om lämpliga råvattenkällor för hela Laos.

Studien har visat att kemikalieförbrukningen i de fem studerade städerna är väsentligt högre för ytvattenförsörjda vattensystem. Det har konstaterats att miljöpåverkan är låg oavsett källa och i övrigt är det svårt att dra några slutsatser om ekonomiska och finansiella skillnader mellan ytvatten och grundvatten.

I rapporten rekommenderas att man från myndighetshåll ska satsa på fortsatta utbildningsinsatser på alla nivåer inom vattenmyndigheternas organisation. En ökad kunskapsöverföring mellan ledning och operatörer är att eftersträva. För att råda bot på allmänhetens misstro mot vattenmyndigheten rekommenderas en förbättrad kommunikation med kunderna. Ett finansiellt och operationellt rapporteringssystem för generering av jämförelsebar statistik bör införas för att kunna utvärdera de olika vattenmyndigheternas prestationer.

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## ABBREVIATIONS

<b>ADB</b>	Asian Development Bank
<b>CAEP</b>	Community awareness and Education Program
<b>DHUP</b>	Department of Housing and Urban Planning
<b>EIRR</b>	Economic Internal Rate of Return
<b>FIRR</b>	Financial Internal Rate of Return
<b>IEE</b>	Initial Environmental Examination
<b>MCTPC</b>	Ministry of Construction, Transportation, Post and Communication
<b>MUSD</b>	Million US dollar
<b>NPTWSSP</b>	Northern Provincial Towns Water Supply and Sanitation Project
<b>NPV</b>	Net Present Value
<b>PCR</b>	Project Completion Report
<b>PNP</b>	Provincial Nam Papa
<b>PNP</b>	Provincial Nam Papa
<b>PPAR</b>	Project Performance Audit Report
<b>RRP</b>	Report and Recommendation of the President for the Project
<b>STEA</b>	Science Technology and Environmental Agency
<b>STWSSP</b>	Small Towns Water Supply and Sanitation Project
<b>UNEP</b>	United Nations Environmental Program
<b>WACC</b>	Weighted Average Cost of Capital

## WORDLIST

<b>Economic cost benefit analysis</b>	Regards costs and benefits of the society
<b>Financial cost benefit analysis</b>	Regards costs and benefits of the specific and isolated project
<b>Flocculation</b>	The process where particles in water flocks to enable sedimentation
<b>Nam Papa</b>	State owned Water Enterprise
<b>Nam Papa Lao</b>	Former governmental water supply authority, today called Nam Papa Vientiane
<b>Nam Saat</b>	National Centre of Health and Water Supply, responsible for water supply in rural areas
<b>Service Area</b>	An area in which the population are supplied with water from the public distribution net
<b>Turbidity</b>	Measurement of particles and organic material in water
<b>Water scheme</b>	The water purification system including the intake



# 1 INTRODUCTION

This thesis focuses on water supply for urban areas in Laos. These areas are mainly concentrated along the Mekong River and the river has, traditionally, been used as a source of water supply. Since there is an abundance of surface water, the search for an alternative source of water supply has been given low priority. The major disadvantage with surface water is that it needs severe purification and chemical treatment before usage. Due to high costs for chemicals and operation, this is an expensive process and the less resource demanding ground water option, has become of high interest to the national authorities.

In the near future, Laos will develop or rehabilitate the water supply system in many urban areas. The governmental goal is that 80% of the population will have access to clean water by the year 2015. In 2002, 55% had access to improved water (WASA, DHUP, URI, 2002).

There is a general scepticism towards ground water among local enterprises, the local authorities and the government in Laos. The reason might be earlier failures in ground water projects in combination with lack of understanding and education (Knudsen, 2003 and MCTPC, 2004). The government and other stakeholders have shown interest in finding evidence that ground water is more cost effective than surface water as water source (MCTPC, 2004).

International research (UNEP, 2003) shows that ground water is relatively easy and cheap to use as source for water supply when available, mainly because of technical aspects. At present, there is no such study carried out especially for Laos. The economical and environmental aspects of ground water and surface water as source of water supply have been investigated in pre-studies of projects in Laos, but never before as a main issue. The aim of this report is to provide a start for further investigation on an important topic and not to perform a complete investigation.

The study was performed in cooperation with the Water Supply Authority, WASA, at the Ministry of Communication, Transport, Post and Construction, MCTPC, in Vientiane, Laos. WASA is one of the main stakeholders in water supply systems in urban areas in Laos and also the target reader of the thesis in Laos.

## 1.1 Objectives

The main objective of this thesis was to make an economical, financial and environmental comparison of groundwater and surface water as sustainable sources for water supply in urban areas in Laos.

The specific objectives was to:

- Define suitable methods for comparing ground water and surface water from an economical, financial and environmental perspective

- Define suitable key performance indicators for comparison of the five schemes.
- To evaluate the condition of water schemes in five urban areas in Laos according to defined methods and indicators

The aim was to perform an investment assessment of different water treatment schemes in urban areas in Laos.

The goal of the study was to find a general indication on which type of raw water source that is the most suitable for water supply in urban areas in Laos.

### **1.2 Methodology**

Different methods for economical, financial and environmental analysis have been studied and suitable methods for this kind of study have been defined. Key performance indicators have been defined and used for comparison. The key performance indicators are chosen because of their ability to show the difference in costs of operation and maintenance, chemical usage, personnel and electricity for the different raw water sources.

Information was gathered in Laos in December 2003 to February 2004. In order to perform this comparison five urban areas along the Mekong River were chosen to represent different sources of water and different sizes of population. The main source of information has been earlier reports and studies, but also interviews during a field study. The methodology in the field study is further described in chapter Methodology in field study. Financial reports and statistical information was gathered during the field study. Statistics on population, water balance, economics and personnel have been compiled and evaluated.

### **1.3 Assumptions**

It is assumed that the technical aspects of the water schemes function as planned and that the water supply is sufficient. Further, it is assumed that there is a sufficient amount of ground water available, and that the discharge is satisfactory. This is not always the case, but it was a necessary assumption for the scope of this project.

As a starting point ground water and surface water are regarded as equally suitable as sources for water supply from an economical, financial and environmental point of view, until something else is shown in the study.

### **1.4 Limitations**

In this thesis, the term water supply systems covers raw water supply, pump equipment, water storage tanks, water treatment equipment, distribution net, and electrical installations. Only the water scheme, including raw water supply treatment equipment, is studied.

The study has only investigated the water supply in the urban areas because these areas will have the largest growth rate and therefore the largest increase in water demand. The economic impact of a wrong investment will therefore be more significant the larger the investment. This is not a sustainability study, but since sustainability in water supply systems is necessary and the considered aspects in this report can be a start of a sustainability study.

The technical aspects have not been included at all in this report. The study does not include the distribution system from the water scheme to the connections in the households, because the net is not dependent on the source of raw water. The quality of the water is not evaluated, although it is a vital factor. The quality is not given high priority in Laos today as the tap water in general is boiled before drinking. The water quality is seldom known since laboratory equipment for water quality tests are not always available at the treatment plants.

The study aims to compare the characteristics of ground water and surface water supply systems, not the financial status of water enterprises. The financial reporting has not been subject to comparison.

## 2 THE STUDY AREAS

In this chapter, background information on Laos and specific information on the five urban areas that were chosen for this study. The state owned water enterprise is called Nam Papa in Lao and hereafter called Nam Papa.

### 2.1 About Laos

Laos is a landlocked country in the South East Asia with a population of about 5.4 million inhabitants. The area is about 236 800 km<sup>2</sup>. Only 20% of the inhabitants live in urban areas. The five major settlements, Vientiane, Luang Prabang, Thakhek, Pakse and Savannakhet, are situated along the Mekong River and these five account for 45% of the total urban population. The rest of the urban population, about 600 000 persons, live in provincial or district centres (WASA, DHUP, URI, 2002). Laos is one of the least developed countries in Asia, and in the world.

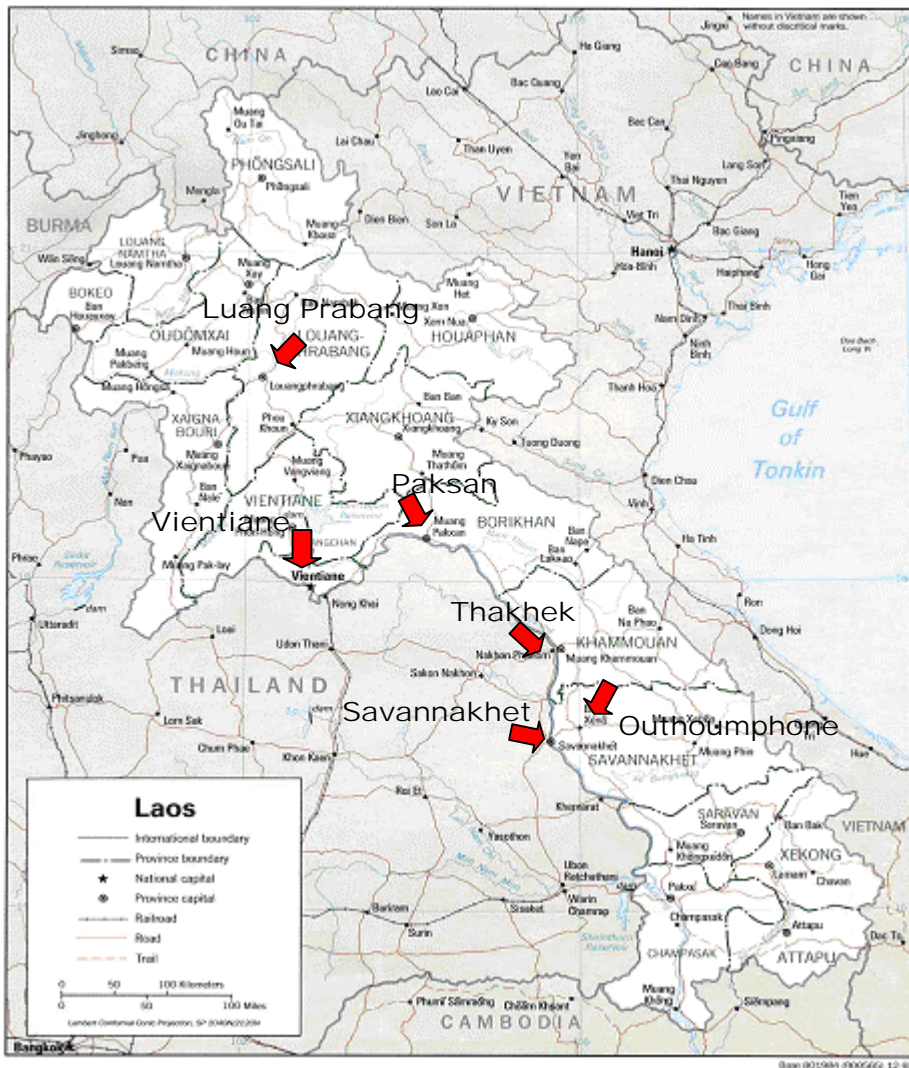


Figure 2-1 Laos. The arrows points out the five studied towns ([www.travel-images.com](http://www.travel-images.com), 2004)

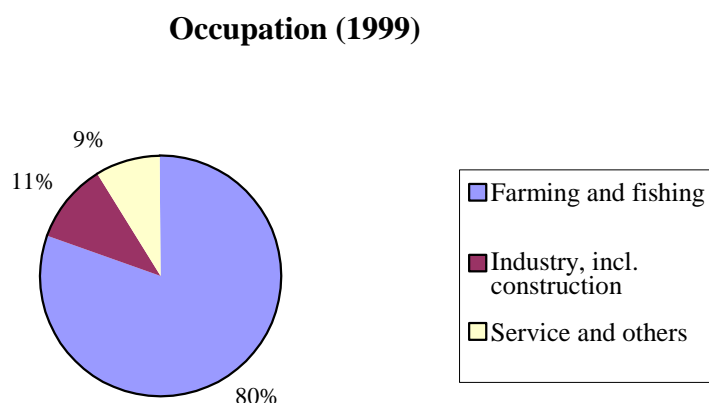
The Mekong River is the main river in Laos. It flows for about 1 900 km in the country and about 80% of the Laos's territory is located in the Mekong basin. The water level in the Mekong River may fluctuate by up to 20 m between wet and dry season. The Mekong plain is mainly occupied by the Indonesian strata, which consist of sandstone, siltstone, shale, mudstone, limestone, conglomerate and basalt (www.laos-energy.com, 2003). About half of the area of Laos is covered with forest. The north and the eastern part of Laos are mountainous and east of the Mekong River lays fertile plains (Swedish Foreign political institute, 2002). Laos have an abundance of water, both surface water and ground water.

In Table 2-1 general facts about Laos and Sweden are presented. The population density is similar to Sweden, but the population growth rate is higher. If the growth remain constant for the coming years, in 2020, the population in Laos is estimated to be 8,5 millions. The relatively low expected length of life is related to the high child mortality.

	Short facts about Laos	Short facts about Sweden
Population	5.4 millions (2001)	8.9 millions (2001)
Natural population growth	2.4% (1999)	-0.04% (1997)
Expected length of life, 1999	Women 56 years, Men 54 years	Women 82 years, Men 77 years
Literacy	47.5% (1999)	100%
GDP/ capita	US\$ 321 (2000)	US\$ 27 382 (1999)
Natural resources	Hydropower, Forest, Minerals	Forest, Minerals

**Table 2-1 Short facts about Laos (Swedish Foreign Political Institute, 2002)**

The main occupation is farming, which can be seen in Figure 2-2. The main use of water in Laos is agriculture. An estimation of the total withdrawal of water is 82% agriculture, 10% industry sector and 8% domestic use (www.laos-energy.com, 2003).



**Figure 2-2 Occupation in Laos (Swedish Foreign Political Institute, 2002)**

South East Asia is facing severe water pollution problems and Asian rivers such as Yellow River in China and Ganges in India is two of the world's most

polluted rivers (UNEP and Earthscan, 2002). Mekong River, however, is relatively clean. There are no big industries or cities upstream the river that can pollute the water.

Almost 90% of the electricity in Laos is hydropower and Laos is exporting energy to its neighbour countries and this is the main source of income for the country. In 2002, the Swedish foreign political institute estimated that 1/5 of the population had access to electricity and that the main energy source in rural areas was wood (Swedish Foreign political institute, 2002).

The amount of socio-economical facts about the five towns differs. There is no possibility to receive up-dated information on the towns from the national Centre of Statistic. Detailed statistical information is only available from 1985 and 1995 (National Centre of Statistics, 2004). ADB has however done detailed investigations on the socio-economical situation in Paksan in 1993 and a similar study in Outhoumphone (ADB, 1993; ADB, 1999a). This means that the found facts on socio-economical issues are significantly more detailed for Paksan and Outhoumphone than for the other towns. Many of the facts described about Paksan and Outhoumphone can be assumed to be similar in other urban areas.

### **2.1.1 Paksan**

Paksan is situated 146 km east of Vientiane in the province of Bolikhamxay. The town stretches along the Mekong River on the river brink and road 13 passes the town. Road 13 is the largest road in Laos and goes from Vientiane to Pakse in the south.

In 2002, the population was 11 153 persons and in 2005 it is estimated to be 12 500 (ADB, 2003a). The average population growth is estimated to 2.4%, during the years 2005 to 2012, calculated on the estimated population from the Director of state owned water enterprise in Paksan. The average number of household members has decreased during the last years from 6.5 in 1998 till 5.55 in 2002, according to ADB (2003b)

Most people in Paksan earn their living from small-scale farming. In the nineties, ADB estimated that most people work seven days a week, eight hours a day on farming when trying to calculate the value of time saved on not having to fetch water outside the house (ADB, 2003a). In 2003 about half of the population had refrigerator and radio, but almost every household had a television (ADB, 2003b), which is probably a general state for the country.

### **2.1.2 Thakhek**

Thakhek is provincial capital in Khammouane Province and is situated along the Mekong River. The town lies in the junction between road 13 and road 12 to Vietnam. In 2002 the population in Khammouane prefecture was 79 000 persons, of which 43 500 lived within the service area in Thakhek. In 2020 the population will be 125 000 persons. The town has traditionally been a trading point for Thailand, Vietnam and other Lao provinces along the river. The

tourism is a growing business and especially the transit tourism is increasing ([www.ambafrance-laos.org](http://www.ambafrance-laos.org), 2004).

### 2.1.3 Savannakhet

Savannakhet is the capital in the province with the same name, 450 km south of Vientiane. Highway 13 passes through the town, and the town is situated on the shore of the Mekong River. The service area is restricted to 35 villages. (Nihon Suido, 2001). The town is one of the largest in Laos and there is a connecting road to Vietnam.

The population in the service area of Savannakhet was 76 000 in 2003. According to the state owned water enterprise in Savannakhet, 81% of them were served of the public water supply system. The population in 1999 in the service area was 62 000 persons (Nihon Suido, 2001), which gives a rate of population growth of 5.5% per year. The forecasted population growth is 2.9% per year until 2008 and thereafter 3.3%, according to Nihon Suido (2001).

Savannakhet is a Special Economic Zone, which means the government have forecasted rapid development of the area and invested in the area. An industrial estate is planned for 2004 under the Development Plan for the Special Economic Zone (Nihon Suido, 2001). Typical industries in the area are processing of food, wood and agricultural products.

When this study was carried out, it was not decided whether the estate would construct its own water supply system. However, the building of such an estate will certainly affect the area, in terms of for example working opportunities and further urbanisation.

### 2.1.4 Luang Prabang

Luang Prabang is situated in the northern parts of Laos, along the Mekong River, in the province with the same name. The area is mountainous and the altitude of the town is 287 meters above sea level.

Luang Prabang was the capital of Laos until the 20<sup>th</sup> century when the French made Vientiane to capital. Luang Prabang has a long history. In the 14 century the first Lao kingdom was consolidated here. In 1995 the town was entitled World Heritage by UNESCO. Luang Prabang is one of the main tourist attractions in Laos and the economy of the town is heavily dependent of tourism. ([www.lao.ch](http://www.lao.ch), 2004)

Luang Prabang consists of 66 villages. In 2002, the municipality of Luang Prabang had 44 000 inhabitants. 93% of them were served with water from the public water supply system. The average family had almost six members, according to the Director of the state owned water enterprise in Luang Prabang. The average number of persons was 8.8 per connection (Interconsult, 2001), which is significantly higher then the average number of household's members. The high number is due to the tourist industry, according to the state owned

water enterprise. It is estimated that the population will be twice as large in 2020 (WASA, DHUP, URI, 2002)

A new hospital is being built, and a new university is planned. The tourism is increasing by 10% per year. In 2003, approximately 100 000 tourists visited Luang Prabang and the water demand of the tourists is about 30-50 m<sup>3</sup>/day, according to the Director of Nam Papa Luang Prabang.

### **2.1.5 Outhoumphone**

Outhoumphone is situated 25 kilometres east of Savannakhet, in the Savannakhet province. It lies on the junction of Highway 13, leading from north to south in Laos, and Highway 9, leading east to Vietnam from Savannakhet (Montgomery Watson 1999). The town is also called Xeno or Seno, a French abbreviation of Sur, Est, Nord, Ouest, which refers to the road junction.

The rate of population growth varies between different sources.

- The district officials forecasted the population growth rate to be larger than average country rate (Nam Papa Savannakhet, 2003)
- Norconsult has in the project Water Supply and Sanitation Sector Project used the population growth rate of 2.8% (1999-2010) and 2.5% (2011-2020), when forecasting the future water demand (Norconsult et al, 2001)
- Montgomery Watson (1999) estimated the population growth rate to be 3.5% in 1997 and 3.0% in 2010 and 2020
- In ADB's memorandum of Understanding of Appraisal Mission for the proposed Water Supply and Sanitation Sector Project, the population growth rate is estimated to 4% per annum. However, ADB state that the growth is constrained by lack of clean piped water (ADB, 1999b).

The Lao Government has identified Outhoumphone as high priority under the Sector Investment Plan and the local Urban Development Plan. The strategic position of Outhoumphone gives the town the status of Special Economic Zone, the same as Savannakhet. This means that the government is investing in infrastructure in and around the town and it augments the fact that the migration to the urban centre will increase (MCTPC, 2004)

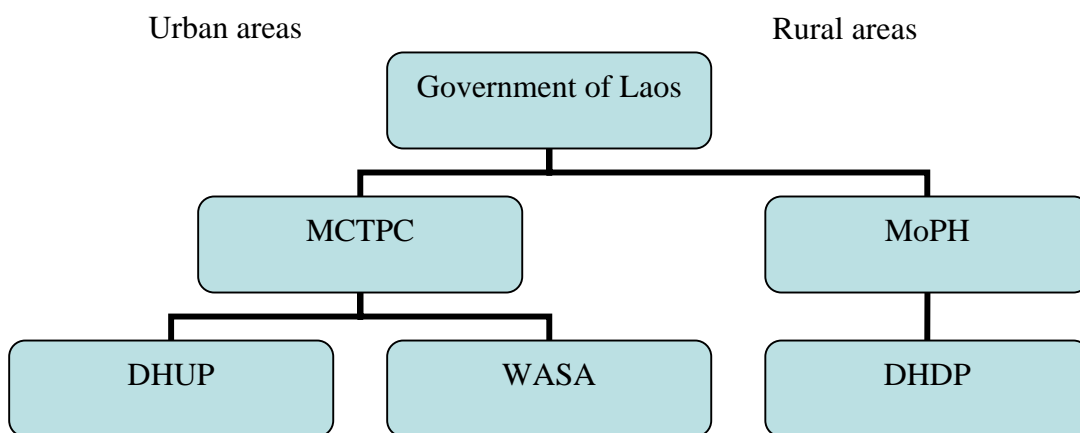
Approximately half of the households in Outhoumphone had latrines and 80% had access to electricity in 1999 (ADB, 1999b). In 1998, just over half of the households had toilets, mainly lined latrines or toilets connected to a septic tank. One third of the households had some formal drainage; others generally dispose their waste-water (non-toilet) to land surrounding the house (Montgomery Watson, 1999).

## **2.2 Water Supply Management in Laos**

This chapter gives a description of how water supply management is handled in Laos today and before the decentralization a few years ago. Laos has developed

considerably during the last years. The access to water supply systems, access to electricity, access to transportation and roads etc was underdeveloped ten years ago. The institutions are therefore young and the management structure is still developing. All information in this chapter is received from Ministry of Construction, Transport, Post and Communication (2004).

The management of water supply system in Laos is separate for rural and urban areas. Laos started to decentralize the water management in 1999. In urban areas, the Department of Housing and Urban Planning, DHUP, is responsible for planning, implementation, and construction of water supply systems at a national level. The Water Supply Authority, WASA, is responsible for regulation. Both are sub-coordinated under the Ministry of Construction, Transport, Post and Communication, as can be seen in Figure 2-3. In rural areas the Nam Saat, National Centre of Health and Water Supply, is responsible. Nam Saat is sub-coordinated the Ministry of Public Health.



**Figure 2-3 Central Organization of Water Supply in Laos**

At provincial and district level the state-owned water enterprises, the provincial Nam Papa, are responsible for operation and maintenance of water supply within the border of the province. The responsibility of the water supply systems is handed over from DHUP to Nam Papa when all construction work is finished. The provincial Nam Papas are responsible for urban water supply and wastewater as well as for urban water quality. They are also responsible for strategies in the provinces as well as for financing and planning in respective urban area.

Before the decentralization, there was only one national state owned water enterprise, Nam Papa Lao, situated in Vientiane. Nam Papa Lao, now called Nam Papa Vientiane, was responsible for the water supply in urban areas in the whole country. Nam Papa Vientiane is the most experienced Nam Papa in Laos and has the best laboratory equipment of the water plants in Laos. The other Nam Papas will in the future send water samples to Nam Papa Vientiane for monthly controls and staffs from provincial Nam Papas receive education in Nam Papa Vientiane. In many towns, where no water supply system existed a

few years ago, there can be a problem with finding skilled and experienced personnel to the Nam Papa.

WASA was established in 1999. At that time they had responsibility for project implementation, which is not the case any longer. In 2003, the former Director was transferred to the position of Director of the DHUP. At the same time WASA started functioning in the role of regulator for the water supply sector. The structure of WASA is not yet clearly defined.

According to the Annual Water Sector Performance Report 2002, there is a general lack of awareness of many water-related questions in Laos. People are generally not aware of the decentralization of responsibility and tariffs system. People still refer to Nam Papa Vientiane instead of the Provincial Nam Papa.

### 3 WATER SUPPLY AND SUSTAINABILITY

This chapter contains information on drinking water quality, water treatment, chemicals used in the treatment process and distribution net. A brief discussion about sustainability and water supply is also included.

The World Health Organisation has set standards for quality of drinking water ([www.who.org](http://www.who.org), 2004). The standards only concern the quality of water. Good water for domestic purpose should fulfil the following demands in Sweden (VAV, 1991):

- Safe and healthy
- Good taste, no smell, esthetical look
- Versatile for household purpose i e cooking, hygiene, washing, disking and cleaning
- Price worthy

In Sweden, it is taken for granted that the tap water should fulfill these demands and tap water is considered as a provision. In Laos, on the other hand, the tap water is solely used for washing and hygienic purposes and the demands are significantly lower. There can, however, be problems with untreated tap water with high content of organic material or iron because of the discoloring of clothes and zins. Water for cooking and drinking is either boiled and purified with small domestic systems or bought from water vendors.

The hydrological cycle is fundamental for the understanding of correlation between ground water and surface water. The hydrologic cycle and methods for exploration and evaluation of ground water sources are described in appendix 1.

#### 3.1 Ground water treatment process

The ground water is being pumped from the well and lead through a tank where disinfectants are being blended. The mostly used disinfectant is chlorine, but the water can also be treated with UV-light or ozone. The disadvantage with these methods is that they, unlike chlorine, do not leave a residual that protects the water in the distribution system. If the ground water contains high levels of iron and manganese, it needs additional treatment. Oxidation by adding potassium permanganate or chlorine is commonly used, and aeration is another method. These treatment methods are also used for reducing taste and odour caused by dissolved gases, biological growths, or by inorganic or organic contaminants. Water softener is needed if the ground water contains high concentration of calcium and magnesium. The most popular method of hardness removal is the ion exchange process, where sodium is blended in the water. After the treatment process, the water is being pumped to an elevated reservoir, before distribution to the customers. (water.montana.edu, 2004)

### 3.2 Surface Water- Treatment Process

Generally, the treatment process of surface water is more complicated than for ground water. Surface water can seldom be used as drinking water without treatment. The raw water often contains humus substances, organic (e.g. algae) and non-organic (e.g. clay) material, and bacteria. Furthermore, the water often has some colour, odour and taste. The temperature of the raw water influences the treatment process. The amount of chemicals used depends on the quality of the raw water and factors such as turbidity and amount of organic material in the raw water. ([www.excelwater.com](http://www.excelwater.com), 2004)

A strain by the in-take prevents branches, fishes and other obstacles from entering the treatment system. Surface water normally contains more or less humus substances, which discolour the water. Sedimentation and filtration is not always enough for removing the substances, because the size of the particles is too small to sediment. Therefore, chemicals, often alum<sup>2</sup>, are added to the water. The alum coagulates and flocculates with smaller particles into larger flocks, which sediment in the following basin. Afterwards, finer material is removed in sand filters and finally, the water is chlorinated and stored in reservoirs before distribution to consumers. ([www.excelwater.com](http://www.excelwater.com), 2004) The process is illustrated in Figure 3-1.

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<sup>2</sup> Alum is used as an abbreviation for aluminium sulphate

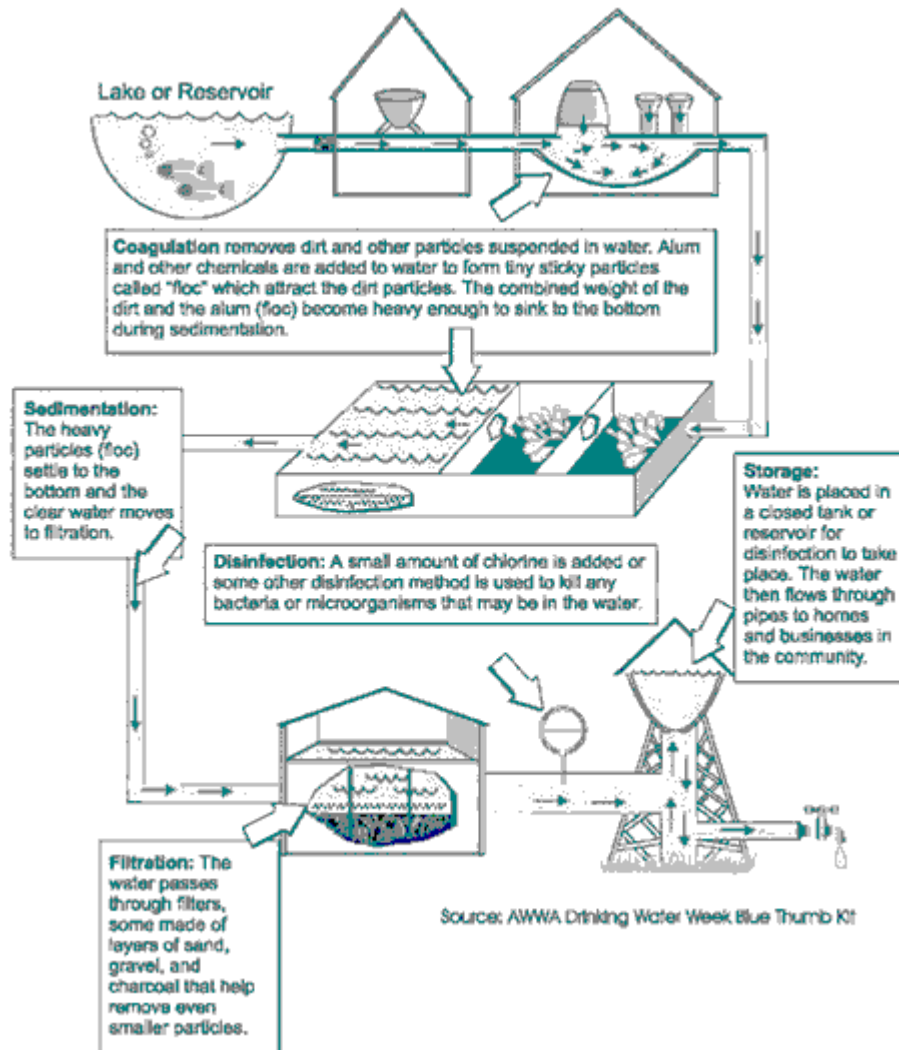


Figure 3-1 Treatment process for Surface water. ([www.excelwater.com](http://www.excelwater.com) 2004)

The treatment process of surface water often requires more chemicals and more energy, than the treatment of ground water.

### 3.2.1 Sludge

In the surface water treatment process, sludge containing alum is a rest product. In Sweden, the sludge has earlier been disposed in nearby streams and lakes (VAV, 1992). Today the sludge is disposed in wastewater treatment plants or landfill sites. In the visited water treatment plants, the sludge was either disposed near the treatment plant or washed into the river near the intake. None of the visited treatment plants in Laos could estimate the amount of sludge produced per year. On page 108 in VAV P72 a formula for estimating the produced amount of sludge is presented:

$$\text{Amount of sludge (g suspended substance)} = 0.5 * \text{dose of aluminium sulphate (g/m}^3\text{)}$$

The formula will be used in chapter 5 Conditions in The Study Areas to estimate the amount of sludge.

Stup Consultants (1992) discuss how to dispose the sludge. In cases where sludge is produced with coagulants in higher quantities, the disposal can be done in the following two ways:

1 *Lagooning*

The sludge is drawn from the filter/ clarifier and is led to a lagoon of about 1 meter deep. Its operation is simple and cost effective. For small water supplies, this can be adopted when sludge are not permitted to be discharged into watercourse (Stup Consultants 1992). This is an easy and cheap method. The report does not mention if the lagoon needs to be clear or how leakage from the lagoon is avoided. This method was used in two of three of the surface water plants interviewed.

2 *Sludge concentration and drying*

This is common method of sludge disposal for larger treatment works. The sludge is led to a concentration tank. Supernatant water is decanted off from the top of the tank after a setting period of about six hours. While thickened sludge at about 4% solids is pumped to drying beds and left to dry until the solids content reaches 20-25%, it is then removed and disposed off on land.

The last alternative has not been used in any of the visited towns, but might be an interesting alternative in the future. The alternative used in Luang Prabang, where the sludge was flushed out into the river, was not mentioned.

In Sweden, a dialogue about the possibility to use the flocculation sludge in agriculture is held. The nitrogen is needed as fertilizer. The sludge has a low concentration of pollutants. Alum binds phosphor hard to the ground, which is more negative than the positive effects of nitrogen and is therefore not used yet. Another possible way disposing the sludge is in road construction (road slopes, noise walls and filling material). Disposal on dump should be avoided and only done when absolutely no other alternatives are possible (VAV, 1992).

### **3.3 Chemicals used in process**

The chemical usage is one of the aspects of drinking water production that has environmental impacts, both on humans and on the environment. The chemicals used most frequent in the treatment process in Laos are alum and chlorine. In Sweden, sodium hydroxide or lime is used for raising the pH, but that is not frequent in the five treatment plants visited in Laos.

#### **Aluminium**

Aluminium is used in the flocculation process. Aluminium is soluble at very low or very high pH. The rivers in Laos generally have high values of pH, according to Hans Lann, STEA, and he estimates the risk of dispersion of aluminium in the rivers as low. At pH 6, the solubility is a minimum. Problem

with dispersion of aluminium is more frequent in Sweden, where many lakes, rivers and streams are acid.

There has been a discussion in Sweden about the correlations between aluminium and Alzheimer's disease. Investigations have almost excluded any correlation. No other health effects from use of aluminium in the water treatment process have been found either (Hult, 1998). The Swedish Environmental Protection Agency's report 4721 on Alzheimer's disease and risk in relation to aluminium exposure (Bjertnes and Alexander, 1997) found that the role of aluminium in Alzheimer's disease could not be totally ruled out. Since both epidemiological and biological evidence are weak or do not support a correlation, it is, however, "unlikely that aluminium is a risk factor of Alzheimer's disease" (Bjertnes and Alexander, 1997).

### **Chlorine**

Chlorination is the most common method for disinfection and is mainly used for microbial disinfection. It can be used before the treatment process, but is mainly used after the treatment before it enters the distribution net. The chlorine has a lasting effect, which means that bacteria's will be eliminated in stagnant water. The dose of chlorine depends on the amount of iron, manganese and organic material in the water. These substances create a chlorine demand and the dose of chlorine should be sufficient to satisfy this demand and leave free available chlorine residual at any measured place at the distribution net. There are two disadvantages of chlorination. First of all, the water gets a slight after-taste and secondly, if chlorine is applied in too large dose, it will have a corrosive effect on most metals (Grundfos, 1988)

Chlorine can react with organic substances in the water and sometimes form trihalomethanes (THM). With a sufficient amount in the water and a sufficient long period of intake the THM can cause cancer. The Swedish National Food Administration investigated the issue in 1995-1996 and found that the advantages of chlorination are well above the disadvantage. In the cases where high values of THM were found in Swedish water treatment plants, it was mostly due to improper dosing (Hult, 1998). The routines for dosing of chlorine and measuring residual chlorine could be improved in most of the water supply systems visited in Laos. Overdosing of chlorine is noticed by smell and taste of water and therefore there is no or small risk of intoxication.

### **Lime**

Lime is mainly used for pH-adjustment. It is commonly used in Sweden where the pH is low, but none of the five visited water treatment plants in Laos use lime. Savannakhet, however, had lime in store.

## **3.4 Distribution net**

The distribution net in a water supply system is important for the quality of tap water. The condition of the distribution net highly affects the quality of water and a poorly maintained pipe system can cause problems. Some factors that has influence on water is material and dimensions of pipes, stagnant water or

long turn over time of water, temperature of water, microbiologic processes in pipes, pollution intrusion when pipes are being repaired. A certain leakage due to deterioration and corrosion is common and acceptable. As long as the pressure in the pipe system is high enough, this prevents intrusion of bacteria and algae. The most efficient way to minimize the presence of microorganism in the net is to reduce the proportion of organic material in the water and one way of doing this is by occasionally flushing the net with water and air. (VAV, 1991)

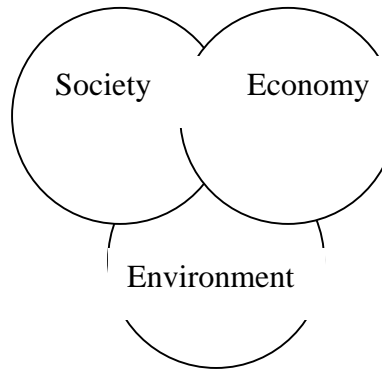
When a water plant stalls, and the capacity of the water reservoir is not enough to cover the consumer's need, this can cause a pressure fall in the distribution net. Then, intrusion of bacteria and particles in the net is possible. Another issue that affects the pressure in the net is the dimension of the pipes and the net and the use of pressure stations on the net.

The distribution net in Laos is fairly new in the studied towns, except in Luang Prabang. The leakage of water from the net is therefore not as large as in areas with an old and deteriorated distribution net.

### **3.5 Sustainability in water supply**

Laos has large water resources that are about to be exploited, both for hydropower, irrigation and water supply in rapidly growing urban areas. For achieving a sustainable use of water resources a long term and broad perspective is necessary. The water resources must be available for many interest, not only for hydropower and water supply, but also for farming, fishing and recreation.

The concept of Sustainable development is commonly defined as in the report "Our common future", also known as the Brundtland report, (WCED, 1987): *Development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations.* The World commission writes our common future on Environment and Development. Three joined circles representing the social, economical and environmental dimension often visualize sustainable development, see Figure 3-2. All three dimensions must be taken into account for achieving sustainability. The aim of sustainable development is human well-being, which is very subjective.



**Figure 3-2 A common illustration of Sustainable Development**

The urban water system is essential for economic development as well as for human health and endurance in the systems is necessary. Many reports have been written about sustainability and urban water system. Lundin (2003) and Palme (2004) have described indicators for measuring sustainability in existing urban water systems. Sustainable development indicators, SDI, are used for guiding and promoting development in the desired direction (Palme, 2004). In Laos, where many water supply systems are still to be developed, it is important to perform a sustainability analysis in the strategic planning. Palme (2004) describes three kinds of future oriented SDIs; Balanced Scorecard, Global Reporting Initiative, GRI, and Environmental Management Systems, EMS. They are not described further in this thesis.

ADB mentions sustainable development in the Guide for Economic evaluation: *Projects are sustainable if their net benefits or positive effects endure as expected throughout the life of the project. Sustainability is enhanced if environmental effects are internalised, and if financial returns provide an adequate incentive for project-related producers and consumers.* The main objective of this study is to compare ground water and surface water economically, financially and environmentally. In order to execute the economical and financial analysis and comparison, the concepts are explained and suitable methods are described in theory.

## **4 DEFINED METHODS OF ANALYSIS IS ASSESSMENT**

This chapter contains methods found suitable for comparing two alternatives of raw water source from an economic, financial and environmental perspective.

### **4.1 Economical and financial analysis**

The least cost analysis is used for choosing between two or more alternatives. It is not used in this report, but essential when a new project is about to start and therefore described here. The concepts *economic* and *financial* are described and then a financial cost benefit analysis and an economical cost benefit analysis are described. An investment assessment is necessary to do before expansion, rehabilitation or new investments. One part of the investment assessment is the cost benefit analysis, which is described below.

#### **4.1.1 Least cost analysis**

The least cost analysis is used for comparing two or more investment alternatives that are mutually exclusive. The alternatives should supply the same quality and quantity of water (ADB economic guidelines). As discount rate, the opportunity cost of capital should be used when possible. The analysis should be carried out over the lifetime of the project.

The average incremental economic cost, AIEC, for the different options can be calculated with the result of the least cost analysis. Average incremental cost is calculated from the present value of investment and operation costs, divided by the present value of the quantity of output. The result, in the case of water projects, can be in unit "cost per cubic metre".

The calculations in the least cost analysis are also used later in the economical analysis. Because of the type of the comparison of different kinds of water plants, no complete and comparative least cost analysis will be performed in this thesis. It should however always be done in the start-up of a water supply project. Since the least cost analysis does not give any indication if costs exceed benefit, it does not show if the options are economically feasible. Therefore, further analysis regarding the financial and economic viability is needed after the least cost analysis.

#### **4.1.2 Economic analysis or financial analysis?**

The differences between financial and economical analysis need to be defined. First of all, financial prices are market prices of any goods or service. Economic prices are the prices of goods or services, which reflect their values or opportunity cost to the economy as a whole (ADB economic guidelines).

The financial and economic analyses complement each other and are strongly connected. The financial analysis of a project estimates the profit of the project-operating group, whereas the objective of an economic analysis is to investigate the viability in a project in economic terms on a national level. A project cannot be economically viable if it is not financially sustainable and economically efficient. (ADB economic guidelines)

One major difference between financial and economic analysis lies in the definition of costs and benefits. In the financial analysis all expenditures incurred during the project and revenues resulting from it are taken into account. (ADB economic guidelines) The purpose with a financial analysis (ADB Economic guidelines, point 29):

- Assess the degree to which a project will generate revenues sufficient to meet its financial obligations
- Assess the incentives for producers
- Ensure demand or output forecasts on which the economic analysis is based are consistent with financial charges or available budget resources.

The financial analysis puts the project owners interest in focus. The economical analysis, on the other hand, includes the impact of the project on a national level. Quoting ADB Economic guidelines, point 30:

*“Economic analysis includes all members of society, and measures the project's positive and negative impacts in terms of willingness to pay for units of increased consumption, and to accept compensation for foregone units of consumption.”*

This is because the project has impacts that are non-marketed, such as biodiversity, or are incomplete marketed, e.g. water supply and sanitation benefits. Thus, some form of non-market value must be estimated. Economical analyses include the interest of the surrounding society and the environment, not only the project-owners or the beneficiaries of the project and is also more complicated to perform.

A cost-benefit analysis is useful when comparing two or more alternatives before choosing source of raw water for water supply. The financial and economical cost-benefit analyses are described in appendix 2.

### **4.1.3 Investment Assessment**

An investment assessment includes investment costs, and net present value for all costs and benefits for the whole economic or technical life length of the investment. Either economical or financial cost benefits can be used in the assessment. For a project to be accepted, the sum of the net present value of the investment and the net cash flow must be positive, or the project will not be economic nor financial viable. An investment assessment can be made before new investments, rehabilitations, or up gradings. The information on financial and economical analysis can be found at [www.fao.com](http://www.fao.com) (2004).

#### 4.1.4 Modern equivalent value

To compare values of existing assets, the asset can be re-valued to their modern equivalent asset, MEA. The MEA value is defined as (WASA, 2004):

$$\frac{\text{Total investment} * \text{inflation factor} * (\text{technical life length of asset} - \text{age of asset})}{\text{Technical life length of asset}}$$

One idea in this thesis was to calculate the value of the investment per connection and year by using the modern equivalent asset value divided by number of connections in the following equation:

$$\frac{\text{Total investment} * \text{inflation factor} * (\text{technical life length of asset} - \text{age of asset})}{\text{Technical life length of asset} * \text{Number of connections}}$$

This result of this equation was expected to give an indication of what would be the most cost effective investment per connection, among the five studied schemes. This equation can only be used if the remaining technical life length is known at the time of each reinvestment.

## 4.2 Environmental analysis

The environmental assessment regulation is fairly new in Laos and described in appendix 3. Within this study no environmental analysis has been performed. Instead consultant reports have been studied. The most suitable method for comparing ground water and surface water as source for water supply is Life Cycle Assessment, LCA, as it includes all parts of the process. An LCA is however too vast to perform in this study. Before water supply projects in Laos, an Initial Environmental Examination is often performed. If there are any negative environmental impacts, an Environmental Impact Assessment is carried out. This has not been done in the cases studied. These methods are described in Appendix 4.

## 4.3 Key Performance Indicators

In Sweden, the branch organization Swedish Water Development has produced a statistical system for the Water and Sanitation sector, consisting of data from the water plants. The following data are reported into a database:

- Administrative and technical
- Environmental
- Water Balance
- Personnel and organisation
- Operation
- Quality, service and availability
- Financial
- Investments, rehabilitation and upgrading

Yearly, a report of key performance indicators is generated to compare efficiency and performance of the Swedish water suppliers. The World Bank has also developed indicators for the water and sanitation sector. The indicators are separated in operational and financial areas, and are used for reporting on the condition of water supply utilities in the world (World Bank, 1999). The key performance indicators used in this report are inspired by the Swedish statistical system, VASS, and the World Bank report. The World Bank states in the pre-word to Water & Wastewater utilities (1999) that indicators should be used selectively and that they are as good as the data base from which they are derived.

### 4.4 Defined Key Performance Indicators

Key performance indicators are defined to suit this comparison and they are based on basis of Swedish Water Development's ([www.svensktvatten.se](http://www.svensktvatten.se), 2004) and the World Bank's (1999) performance indicators. The indicators have been chosen in order to perform an adequate comparison of ground water and surface water as a source for water supply. The indicators have been divided into two groups, financial and operational indicators. The comparison does only include operationally and financially related indicators, and not indicators that concern the quality of water and technical performance. This chapter gives a description of the used indicators.

#### 4.4.1 Financial indicators

These indicators are chosen to show the financial performance of the local water authorities, without evaluating the financial status.

1 *Cost of Chemicals per produced  $m^3$  (Kip /  $m^3$ )*

This indicator gives the annual cost of all chemicals used in water treatment divided with the produced amount of water. This indicator was expected to show the largest difference between ground water and surface water.

This figure is only relevant if the proper amount of chemicals is used. The necessary amount of chemicals is generally higher for surface water than for ground water. It is not clear what price the Nam Papa is paying per kilo. Chemicals can sometimes be subsidized in developing countries, according to Prof. Svensson, Chalmers, but there have been no indications on that in Laos.

2 *Cost of operation and maintenance per produced  $m^3$  (Kip /  $m^3$ )*

The indicator shows the average cost per produced  $m^3$  of water. It was expected show which type of purification process that was the most expensive. The cost for operation and maintenance includes several posts, such as chemicals, staff, maintenance, energy, administration etc. All costs that do not create a value at the end of the year should be included. This means for example that investments are not included.

A problem in using this indicator at the Nam Papas in Laos is that in many reports it is unclear what is included in costs for operation and maintenance. Therefore the indicator cannot be used at this stage, but it is recommended that it is used in future comparisons.

In Sweden the water treatment plants use preventive maintenance, as a stop in the process is very costly. On the distribution net, on the other hand, emergency maintenance is used due to the difficulty of finding leakages on the pipes under ground. In Laos almost no maintenance is done preventively.

3 *Energy cost per produced m<sup>3</sup> (Kip / m<sup>3</sup>)*

This figure shows the expense for power per produced m<sup>3</sup> water. The problem in Laos is that power is subsidized and therefore it is difficult to predict the actual cost of energy. In a few years time the subsidized will cease and the electricity will be more expensive for the Nam Papas. Generally, the largest energy consumption is in the distribution process, according to Prof. Svensson (2004).

4 *Income from water sales (Kip)*

This indicator shows how large part of incomes from water sale that is used to cover for expenditures on water production. In expenditures power, chemicals, fuel and maintenance are included. Personnel costs are not included, as costs for personnel in water production is unavailable. These are not the only expenditures in water production, but they cover a lot of the costs for water production. Other water related incomes, such as meter rental and connection fees, are not included. If tariffs were set in order to cover for expenditures on water production in Laos, this indicator could have given a hint on the actual cost of producing one m<sup>3</sup> of water. In Laos the tariffs should at least cover operation and maintenance, but this is not always the case. In Sweden the tariffs should cover the actual costs for water production, and reasonable savings for future investments.

#### **4.4.2 Operational indicators**

These indicators are used to show the operational aspects where differences between ground water and surface water as a source for water supply might be found.

1 *Constitutional ratio*

The constitutional ratio shows how many percent of the total expenditures that are put on chemicals, power and personnel respectively. It is interesting to see how big part of the expenditures the different posts take. In the comparison, the figures from the Annual Financial report 2002 are used for all four towns, except Outhoumphone, where estimated figures for 2010 are used instead. The Annual Financial report is for the local water authority. In the financial report, the local water authority in Khammouane includes figures for both the town Thakhek and the town Mahaxay.

2                    *Produced m<sup>3</sup> per number of staff (m<sup>3</sup> / staff)*

This indicator says something about how effective the organisation is, as it illustrates how many personnel that are necessary at the different water plants. It only includes staff working at water schemes, not at the whole Nam Papa. Generally, surface water schemes require more staff.

Another indicator could be the cost of staff per average cost of produced m<sup>3</sup>. In the annual reports from Nam Papas, the cost of staff is only reported for the whole organization and not for the treatment plant and therefore we are not able to use that indicator.

3                    *Energy consumption per m<sup>3</sup> (kWh / m<sup>3</sup>)*

Energy consumption per cubic meter is another way to compare energy consumption. Since the energy is subsidized in Laos, the cost of energy is not a very reliable key performance indicator.

## **5 CONDITIONS IN THE STUDY AREAS**

This chapter contains the information compiled in Laos. In Laos, a field study to different water treatment plants and the responsible Nam Papas, state owned water enterprises, was conducted. First of all, the methodology of the field studies is described and then problems and general issues about the towns. Thereafter, the water supply systems in each of the towns are described separately. The information about the urban areas comes from project reports and the visits. Two Swedish towns are presented as a reference for readers in the following diagrams and analysis. Subjects like sludge and distribution net are commented. Finally, the key performance indicators are described and the results are presented in diagrams.

### **5.1 Methodology in field study**

As described earlier, five urban areas in Laos were chosen for the study in cooperation with WASA. The five towns vary in size and have different kinds of raw water source. Savannakhet is supplied by surface water, Paksan and Outhoumphone are supplied by ground water, Luang Prabang is supplied by spring water and surface water and finally, Thakhek is supplied by both groundwater and surface water. Common for the towns is that they have a growing population and have recently expanded or rehabilitated the water supply system, or need to expand the water supply system rather soon. They have all been involved in water supply projects during the last ten years.

The main work in Laos was performed at Water Supply Authority, WASA, at Ministry of Communication, Transport, Post and Construction in Vientiane. Five water treatment plants and respective responsible Nam Papas were visited during two field studies. Longer interviews were held with the Directors of the Nam Papas. Approximately one day was spent in every town, except for Savannakhet and Outhoumphone where half a day was spent in total.

Ms Kongsay Ounchith, deputy project manager at DHUP participated in the first field trip when Nam Papas of Paksan, Thakhek and Savannakhet were visited. Outhoumphone is situated in the province of Savannakhet, and Nam Papa Savannakhet is responsible for their water supply. At a later stage, Outhoumphone will have a separate Nam Papa. The field study was performed soon after the arrival to Laos and the preparations at MCTPC mainly consisted of reading reports at hand. Luang Prabang was visited on the second trip and then staff from MCTPC did not participate. For further communication with the directors, telefax has been used.

The English skills in Laos are generally low and it would have been preferable to undertake interviews in Lao. That was not possible in this study. In Thakhek, Savannakhet and Luang Prabang, interviews were held in English and in Paksan Ms. Kongsay Ounchith translated the questions to Lao.

Almost all figures have been given in Kip and for making the comparison easier for external readers almost all posts have been exchanged to US\$. Where no other rate is given, the exchange rate of December 2003, 1US\$ = 10400 Kip has been used.

### 5.1.1 Problems with the field studies

The language is one of the major problems at the interviews, because English not is the mother tongue of neither interviewers nor interviewees. The questions were sometimes misunderstood. Misunderstandings were common, but mostly cleared out.

Lack of time was another problem. The interviews were held in a few hours and the possibility to ask further questions later was small. Since Internet is not widely spread outside Vientiane, there was no or little possibility to use e-mail for communications.

The interviews covered many different areas instead of focusing on the objective in the study. This was due to short time for preparations of the field trip. The outline of the thesis was not completely finished and therefore more information than needed was gathered during the field study. If the preparation of the field study had been longer, the interviews would probably have been more concise.

Generally for all interviews and reports is that figures varies form one source to another. This might be due to lack of guidelines for reporting or different ways of doing surveys. In some consultant reports, this problem is mentioned. In this study, when figures varied, either the most frequent figures were used or an estimation was made.

## 5.2 General issues

There are many similarities between the water supply schemes. Here follows some examples of similarities:

- The lack of manuals and instructions in Lao and/ or English
- Laboratory equipment not complete
- Deteriorated distribution net
- High competence level among directors, but not among operators
- All basins at surface water plants were outdoor, roofless, with sometimes degraded material

Luang Prabang is however an exception, with significantly higher standard and more routines.

The tap water is never or seldom consumed without boiling. This is due to uncertain quality, but also tradition and status. The matter of drinking tap water is a social issue. Only poor families drink the tap water today and it will take many years before it gets socially acceptable to drink tap water. The

ability to buy bottled water is a matter of status. WASA is planning for future campaigns to promote tap water.

The Director of Savannakhet Water Treatment Plant was asked about the possibility to have morning meeting with the staff, a common method in Sweden to gain information about the operation and maintenance and pinpoint recurrent problems. The Director did not think it would be a suitable method in Laos, because of cultural issues. It is not a Lao custom for a worker to point out errors and faults in routines or equipment to a superior.

Another general issue for the water supply sector in Laos is the lack of dialogue and communication with the consumers. None of the visited Nam Papas had continuous dialogue with the consumers. Furthermore, there was no way of informing the consumers on operational stall or quality problems.

The water tariffs are set by the provincial Nam Papas and approved by the government. The tariff is not dependent on the source of raw water, but very important for the economy of the Nam Papa as it is the major source of income. The tariffs in Laos today do unfortunately not always cover for expenses. Many of the Nam Papas do not have surplus which limits their possibilities to do continuous improvements etc. In Paksan, domestic and non-domestic users have a similar tariff, but in Luang Prabang, the tariff varies for different categories. Industries and hotels have a higher tariff than domestic users and commercial users (WASA, 2003).

Traditionally, the communication between different levels of society is not encouraged. The communication between water supply authorities and consumers is mostly non-existent in the visited towns. Here follows two examples from Thakhek.

- Untreated water from the Mekong River was distributed to consumers meanwhile the treatment plant was built. There was no information to consumers before or after the untreated water was distributed.
- The main pipe from the wells to the water plant runs next to a road. A few years ago there was an accident, when a truck slid off the road and overturned on the pipe. During the three days it took to repair the pipe, the city of Thakhek had no piped water. There was no information to the consumers when the water plant closed down, but no one complained either, according to Nam Papa Paksan.

### **5.3 Source of information**

Figures differ a lot between different sources. This is a problem when studying reports and doing interviews. In the comparison, year 2002 is used, because the figures in the annual financial report are the most reliable. The annual reports have not been used throughout however. The two Swedish towns Borås and Halmstad are used for placing the Lao towns in a Swedish context.

The Swedish towns are relatively small in Sweden, but still significantly larger than the Lao towns. The sources of information as well as tables of the data used are found in appendix 5.

When different sources report different values, the most reasonable has been chosen. For Outhoumphone year 2010 is used in the comparisons, because the well field is not taken in use until 2004. In year 2010 the well field has been in operation for a few years and eventual initial problems should be solved.

The first complete Annual Financial Report for all the Nam Papas was done in 2002. The report Annual Water Sector Performance Report 2002 was ready in July 2003 and contains (WASA, 2003):

- Financial data, notably profit and loss statements and balance sheets
- Technical data, notably service coverage, water quality, leakage etc.
- Managerial data, notably staffing levels.

Education in accounting and economics has been given to the staff at most Nam Papas in the last years. In 2001, the institutional capacities in Nam Papas varied between extremely weak to fairly good, according to Burwell and Vongnouboutham (2001). Earlier, reporting has been inconsequent because of the lack of standardisation.

### 5.4 Studied objects

The examined towns vary in size. They all are among the largest towns in Laos, but in international terms still small towns. As can be seen in Figure 5-1 Savannakhet is the largest and Paksan the smallest of the Lao towns.

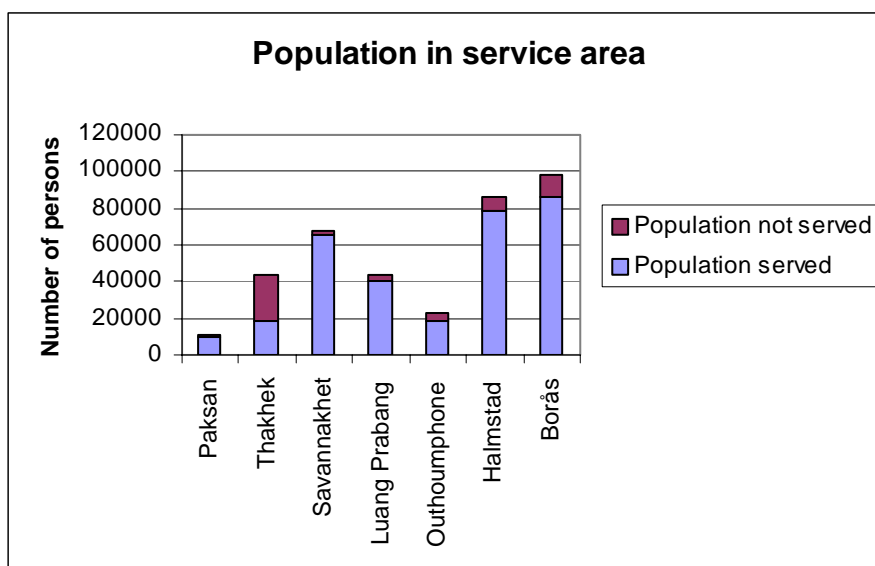


Figure 5-1 Population statistics year 2002, Outhoumphone for 2010

The strategic governmental goal for Laos is to achieve 80% service coverage of safe water in 2015. This goal is in accordance with UN's millennium goal, to half the number of persons without access to safe water by year 2015. The service coverage in the studied towns was as follows in 2002/2003:

<b>Town</b>	<b>Calculated</b>	<b>Nam Papa</b>
<b>Paksan</b>	87%	79%
<b>Thakhek</b>	56%	60%
<b>Savannakhet</b>	98%	78%
<b>Luang Prabang</b>	93%	87%
<b>Outhoumphone</b>	80%	
<b>Halmstad</b>	91%	
<b>Borås</b>	87%	

**Table 5-1 Service coverage of water supply, both calculated values and values received from Nam Papa**

The service degree that Nam Papas stated differ from the service coverage that can be calculated from stated value on population in service area and population served. The Nam Papas stated the service coverage for year 2003 and service coverage in year 2002 has been calculated. Therefore, it is strange that Nam Papa Paksan, Savannakhet and Luang Prabang stated lower coverage than the one that have been calculated. According to the interviews with Nam Papa Savannakhet the service coverage in 2003 was 78% and their estimation is 100% in 2005. The calculation shows that they almost had reached their target in 2002. Luang Prabang also has high service degree. In Thakhek the service degree is still just around 60%. Hospitals, offices, hotels etc. are included in these numbers. According to Nam Papa Paksan, hotels, offices, hotels etc. are included in the 79% coverage. The estimation is that Outhoumphone will have 80% service coverage in 2010. The two Swedish towns have service coverage at around 90%.

#### **5.4.1 Water supply in Paksan**

Paksan is supplied with water from a well field, situated four kilometres from the centre of the town. Only five out of seven drilled wells are in operation today. The wells are situated along a village road, and nearby is a reservoir and a site office where chlorination and surveillance is done. The traffic is low but domestic animals stroll around. The wellheads are placed in concrete chambers with an unlocked lockable steel cover. There are no security fences or other protection for the wellheads. The water supply system is run by hydropower only.

#### **Background and development**

There was no public water supply system in Paksan before 1993, when the national project called Northern Provincial Towns Water Supply and Sanitation Project started. The project included seven towns in Laos. The initial plan in Paksan was to build a pontoon based abstraction system on the San River that would pump raw water to a rapid sand filtration facility (Beture & Nam Papa Lao, 1994). The contract for implementing the project in Paksan

was signed by Beture, a French consultant company. Beture, however, found that it would be more economically suitable to drill seven deep wells (Beture & Nam Papa Lao, 1994). The ground for the decision to drill wells, instead of building a surface water plant, is still unclear. Reports from hydrogeological investigation done by Beture are not to be found in Vientiane. In the interviews, Nam Papa Paksan referred to the investigations of Beture when stating that ground water is cheaper than surface water and also said that if the water supply system needs expansion, surface water is not interesting. No further hydrogeological investigations has been performed since the completion of the project. Beture has been criticized by ADB for not leaving enough materials behind (ADB, 2003a).

The national water supply project, where Paksan was included, contained three parts (ADB 1993 and ADB 2000):

**Part A:** Water Supply Systems Development (water source development, construction of water intake, water treatment facilities etc.)

**Part B:** Environmental Improvements (provision of improved sanitation facilities, including drainage channels, and one public toilet block in each town)

**Part C:** Implementing Assistance and Institutional Strengthening (provision of Project

Management Support including consulting services, staff training and implementation of Community awareness and education program, CAEP).

In Paksan, the following was done in Part A:

- Construction of seven deep wells complete with submersible pumps
- A pump control house with chlorination facilities
- Some 48.2 km pipeline and storage tanks
- Installation of 1140 metered house connections

Part B of the project was not completed as planned. The drainage channels were largely abandoned, mainly due to lack of demand. The project constructed more public toilets than planned, but not as many public wash areas as planned (ADB, 2003a). During the field study, it was found that Part C had not been implemented successfully in Paksan. There were no manuals for operation and maintenance, there were shortage in staff training and low awareness of risk management, and as the CAEP had apparently not been performed at all.

When the project was completed in 1998, 60% of the population in Paksan was served with the new public water supply system. The system is assumed to have a useful life of 25 years and full capacity utilization is expected by 2012 (ADB, 2003a). According to the interviews, the normal service of water in 2003 is 24 hours per day. The water supply system in Paksan is designed for a maximum of 2200 connections, but the original design was 1819 in 2012 (ADB, 2003 a).

The skill of the operators is discussed by ADB (1999a). Since there was no water supply system in Paksan before the project, Nam Papa Paksan had no experience of operation and maintenance when they took over the responsibility. The sustainability of the water supply system is exposed to a major risk when the transfer of responsibility of the system is done before the Provincial Nam Papa has adequate training and experience. Quoting ADB (1999a):

*The Government's extensive assistance and close monitoring of their operations should be continued until PNP<sup>3</sup> staff have been fully familiarized and obtained adequate skills to satisfactorily operate their systems. The skill and knowledge of PNP staff appears very limited without sufficient academic and practical knowledge and experience in O & M of water supply system. Staffs are being trained by NPL<sup>4</sup>, but are still far below the required level.*

It can therefore not be excluded that problems with operation and maintenance and the wells stems from institutional problems.

Technical problems in Paksan are reported already in the Project Completion Report (ADB 2000) that was made in the year of the commission. Nam Papa Paksan said that the flow meters did not function and pump operation controllers in the operation panel were frequently out of order. Two of the pumps were and are still being operated in two-hour intervals, and the start and stop process is likely to be energy consuming. Another issue that is affected with an operation like this is the water quality, and the state of the distribution net. When a pump is started after a stall, there is turbulence in the water that whirl up sand and other material. Therefore, the first cubic meters that are being pumped after a stall are supposed to be "pumped to waste". This means that the water not is pumped into the distribution net and is to reduce the occurrence of sand and material in the net. This was not done in Paksan.

ADB criticized the whole project in the Project Performance Audit Report (ADB, 2003a). All seven towns were in 2003 producing and distributing water and the installation of service connections was on schedule. However, the water was not chlorinated adequately.

Within the national water supply, the consultants gave the employees education on operation and maintenance. ADB gave harsh critic on operation and maintenance in the Project Performance Audit Report. In spite the fact that all utilities in the seven towns are routinely producing and selling water, there are weaknesses in their operation and maintenance (ADB, 2003 a):

- PNP staffs appear inadequately trained regarding technical demands
- Staff do not have manuals for operation and maintenance in Lao or in English
- Chemical treatment is not done in correct manner

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<sup>3</sup> PNP Provincial Nam Papa

<sup>4</sup> NPL Nam Papa Lao, now called Nam Papa Vientiane

- Staff do not perform routine tests frequently enough and hardly ever send samples to laboratory.

Overall, operation and maintenance is inadequate in the seven towns. Though it is general, it is nevertheless true for Paksan during the visit.

**Water balance**

The capacity of the wells is 1 900 m<sup>3</sup>/day, but actual production in 2003 was 1 500 m<sup>3</sup>/day. Design capacity in 1993 was 3 888 m<sup>3</sup>/day (ADB, 2003 a). Nam Papa Paksan said during the interview that five wells would be enough even in 2010, if the population does not grow too fast but they are not sure. In one of the non-operating wells, pH is to low and in the other turbidity is too high.

The production of water has almost doubled in the last four year. The population served has increased with about 40% in the same period (ADB, 2003a). The result is shown in Figure 5-2.

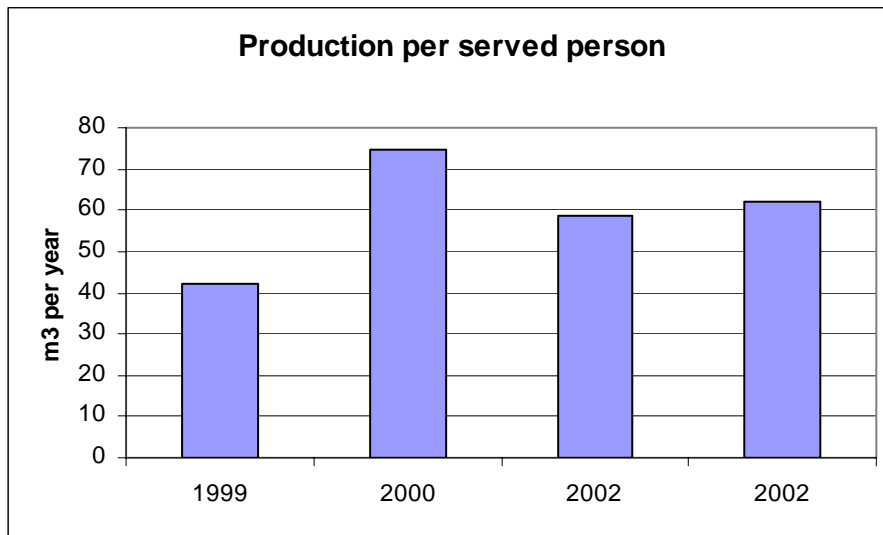


Figure 5-2 Production per served persons

According to the PPAR, the actual production is 8% higher than assumed in the appraisal for 2002.

**Water treatment**

Water treatment consists only of chlorination and is done in a building near the wells. According to Nam Papa Paksan the dosing was done on a “per day” basis, and not dependent of the amount of produced water. The cost for chemicals has varied the last four years, and reached an unexplainable minimum in 2000.

	1999	2000	2001	2002
<b>Chemicals (Kip/year)</b>	3362580	560590	2509200	3776386
<b>Chemicals (US\$/year)</b>	323	54	241	363

Table 5-2 Cost for chemicals for years 1999-2002, exchange rate of December 2003

In 2003, Nam Papa Paksan mixed 10 kg of calcium hypochlorite solution to 0.5 m<sup>3</sup> of water, instead of the designed 25 kg/ 0.5 m<sup>3</sup> (ADB, 1999b). The dose is 40% of the recommended dose. In diagrams in chapter 6.4 it is assumed that the dose was 40% of the recommended dose in 2002 as well.

No manuals for operation and maintenance were available and no tests of residual chlorine were done regularly. The site office was not equipped with laboratory equipment; hence no water analysis could be performed. The quality of the raw water was sometimes bad because of high content of iron and manganese.

### **Investments and finances**

The water supply system in Paksan is financed with a loan from ADB, within the national water supply and sanitation project. The grace period was five years and in 2002, the town had not yet started to repay the loan interest. The sub project in Paksan were given a loan of MUS\$ 0.5 in 2002 years constant value. A rehabilitation of the system is planned for 2012, for US\$ 280 173 (ADB, 2003 a). As per ADB covenants, cost recovery for operation and maintenance should rely entirely on water tariffs and revenue collection (ADB, 2003b). Nam Papa Paksan made a profit year 2002 of US\$ 290 (WASA, 2003).

The costs for operation and maintenance for the last three years is shown in Table 5-3. The cost varies between period 1 and 2. Nam Papa Paksan explained that it was due to large investments during some periods, and not related to season. The cost for operation and maintenance has not increased to the extent of water production.

<b>Year</b>	<b>Period 1</b>	<b>Period 2</b>	<b>Total</b>
<b>2000</b>	67 605 578	35 744 887	103 350 465
<b>2001</b>	68 685 404	39 095 986	107 781 390
<b>2002</b>	70 727 777	39 901 820	110 629 597

**Table 5-3 Cost for operation and maintenance (Nam Papa Paksan, 2003)**

### **Personnel and organizations**

Nam Papa Paksan has 23 employees, of which seven is working with water production, according to the Director:

- 2 persons with O&M in production
- 3 persons with maintenance and repair
- 2 persons in technical division (chief and deputy)

Salary costs for Nam Papa or for the specific persons working with water production could not be provided, during the interview with Nam Papa Paksan. The cost for personnel was 37 % of the total cost in year 2002 (WASA, 2003).

### 5.4.2 Water supply in Thakhek

The water supply system in Thakhek uses both surface water from the Mekong River and groundwater from three deep wells located about 10 km from town. The water is mixed before treatment in the water treatment plant. Initially, ground water was the only source of raw water, but when problems with the wells arose a complement was necessary. The state owned water enterprise, Nam Papa Khammouane, in the region is divided into two subgroups. Nam Papa Khammouane is responsible for Thakhek and Nam Papa Mahaxay for the town with the same name, in the eastern parts of the province.

#### **Background & Development**

Shortly after the commission of the well field in 1998, one of the wells started to produce turbid water. Soon after, the surrounding ground collapsed. This well can still be used occasionally and at those moments a pump is installed. One well is running constantly and the third is only being used in the rainy season. In order to meet the water demand Thakhek needed an additional water source. Since there have been problems with the ground water, the provincial authorities did not want to invest in more wells. No further hydrogeological investigations were made. Even though the river as a water source was rejected in the first investigation, it was decided to build a surface water scheme.

While the new scheme was under construction, untreated water from Mekong River was blended with chlorinated ground water and delivered to the consumers. The water plant was financed by governmental institutions and was finished in 2001.

#### **Water balance**

The yield of the wells has been reduced to avoid pumping out turbid water and therefore the capacity is lower than planned. The total yield of the boreholes varies from 2000 m<sup>3</sup>/day in the dry season and 4000 m<sup>3</sup>/day in the wet season. The total capacity of the water plant is 7000 m<sup>3</sup>/day during the rainy season and 5000 m<sup>3</sup>/day dry season. In dry season, surface water is mostly used (Interconsult, 2001).

The delivered amount of water is estimated to increase by 24 % during the next two years. According to hydrogeological investigations it is possible for the wells to yield sufficient amounts of water during wet season to meet the demand even in 2005 (IGIP, 1992).

The sludge produced in the treatment process is disposed in a pit in the backyard, only 15 meters from the office building. The employees do not know the amount of sludge that is produced per year. The sludge is drying up during the dry season but it is likely that the alum is washed out during rainy season.

#### **Water treatment**

Ground water from the wells and surface water from Mekong River is pumped to the water plant in Thakhek where it is treated with flocculation,

sedimentation and filtering through rapid sand filtration. Both alum and chlorine is being used. The yearly consumption of chemicals in Thakhek is 16 800 kg alum and 1 080 kg of chlorine. This means a yearly cost of 88 555 000 Kip or 8 515 USD (2002). The dose of alum is held constant in dry season at an amount of 40 kg /day, and in rainy season 60 kg/day, regardless the amount of water being produced. According to the director of Nam Papa Khammouane the dose of chlorine is 3 kg /day and the chlorine is added after the ground water and the surface water has been blended. This treatment is not sufficient to handle micro bacteria and parasites. The tap water is not potable, but Nam Papa Khammouane does not claim to have such ambitions. At the construction of the surface water scheme, a UV-filter was acquired, but it is unlikely that it will be implemented (Interconsult, 2001).

When the wells were the only water source, daily analyses were made at the borehole and pH, turbidity, chlorine and calcium were tested (Interconsult, 2001). When the new scheme was under construction Nam Papa planned to test pH, turbidity and residual chlorine at the new scheme (Interconsult, 2001), but at the visit they only tested turbidity. This was because tablets for testing pH were too old and new equipment could not be afforded.

### Investment

The ground water system was commissioned in 1998 with funds from EU. The grant was of US\$ 3 900 000. The Lao Government financed the new surface water scheme in 2001 for US\$ 3 175 780. Nam Papa Khammouane and Department of Communication Transport Post and Construction in Khammouane were responsible for the surface water plant until it was completely implemented i.e. until Final report was finished (Interconsult, 2001). Nam Papa is only responsible for operation and maintenance.

### Personnel and organizations

Nam Papa Khammouane has 50 employees of which 13 are working with the water production, as can be seen in table 5-4 and table 5-4.

Director	1
Deputy Managing Directors	2
Financial and goods department	8
Commercial division	8
General administration	5
Technical	13
<i>Factory</i>	<i>13</i>
<b>Total</b>	<b>50</b>

**Table 5-4 Number of employees at Nam Papa Khammouane- Mahaxay branch excluded (Nam Papa Khammouane, 2003)**

Factory	1
Control Factory	1
Water Production at Plant	4
Pump G W Production	2
Pump S W Production	2
Watch men (2 night, 1 day)	3
<b>Total</b>	<b>13</b>

**Table 5-5**Number of employees working with water production (Nam Papa Khammouane, 2003)

Staff at the upper management level has been trained in Vientiane for operation of water supply and has good engineering experience. The operators at the water plant have no adequate professional training, but most of them has been working several years with water supplies and therefore have obtained some practical experience, according to Interconsult (2001).

Watchmen at boreholes have only one task and that is to measure the water level in the wells twice a day and report to the water plant via cell phone. According to Nam Papa Khammouane it would have been more economic to have a computer, but the installation cost is too high.

### **5.4.3 Water supply in Savannakhet**

Savannakhet is supplied with water from the Mekong River and the water treatment plant, called Nake treatment plant, is situated on the riverside. The intake tower is placed close to the shore and the water intake is just above the bottom of the river. The water line of the river varies with up to 13 meters between dry and rainy season. On the riverbank, several buffaloes were grazing. No locks were seen by the pump house and there were only an open gate to the bridge. There was no fence around the area of the water intake.

#### **Background & Development**

The first water supply facilities in Savannakhet were commissioned in 1977. The capacity was 15 000 m<sup>3</sup>/day. After 20 years of operation, the capacity had decreased to 12 000 m<sup>3</sup>/day in 2000, mainly because of deterioration of plant and equipment.

In June 2001, a project for rehabilitation of the Nake Water Treatment Plant was agreed between the Government of Laos and Government of Japan. The objective of the project was “to rehabilitate the existing treatment facilities of Nake Water Treatment Plant in order to revive the production capacity of 15 000 m<sup>3</sup>/day to ensure stable, sufficient and reliable water supply for Savannakhet Area” (Nihon Suido, 2003b). The project started in February 2002 and was completed in March one year later.

The project consisted of three parts (Nihon Suido, 2003a):

- 1) Rehabilitation of Nake Water Treatment Plant consisting of improvement/ modification and remedy works for existing mechanical and electrical facilities/equipment
- 2) Procurement of laboratory equipment for Nake water treatment plan
- 3) Management guidance for the staff of Nam Papa Savannakhet

The third point was essential to realize the project's effect and to maintain its sustainability. The contract was signed by a Japanese Consultant company.

### Water balance

The capacity of the treatment plant is 15000 m<sup>3</sup>/day, but the actual production varies between 16000 and 18000 m<sup>3</sup>/day. The water demand is higher than the actual capacity so the operators feel forced to produce more than the actual design capacity. Because the water is led too fast through the scheme, the flocculation and sedimentation is not completely processed and at times, the red light for exceeding capacity was lit constantly on the control panel.

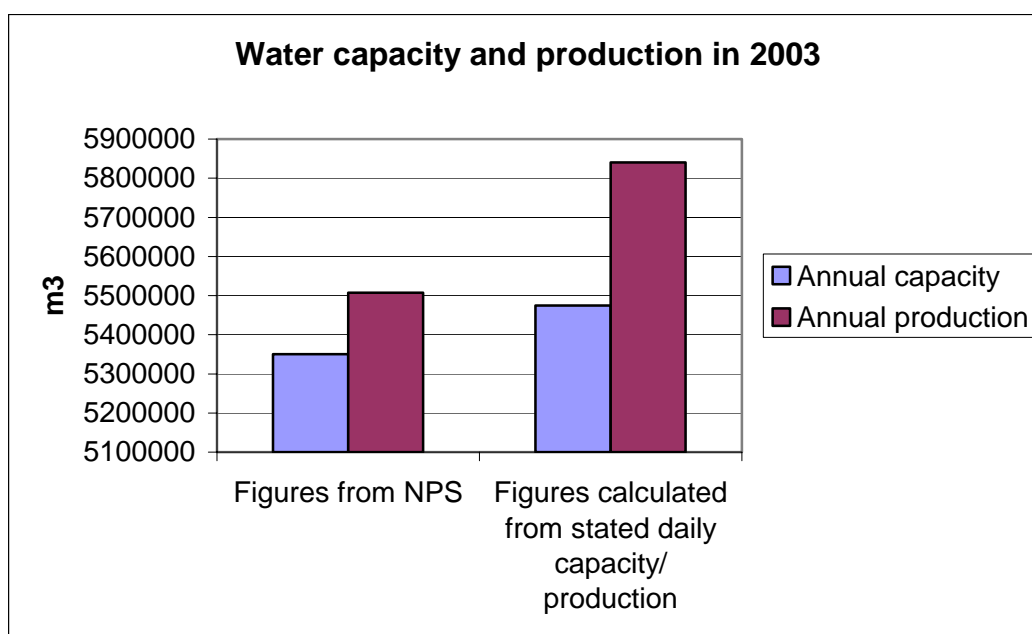


Figure 5-3 Discrepancies in water production

The figures in Figure 5-3 show the discrepancy between capacity and actual production at Nake water treatment plant. The figures from Nam Papa Savannakhet were received in a fax. They are placed in relation to the capacity and actual production calculated from stated capacity 15 000 m<sup>3</sup>/day and production 16 000 m<sup>3</sup>/day. The actual production is significantly lower than 16 000 m<sup>3</sup>/day. (Nam Papa Savannakhet, 2003)

The production capacity has increased during 2003, because of the rehabilitation. The capacity has increased from 12 000 m<sup>3</sup>/day to 15 000 m<sup>3</sup>/day. The actual production, however, increased a lot from year 2002 to 2003 but the delivered amount of water did only increased slightly. The rate of unaccounted for water also increased from 13% to 18% between 2002 and 2003, according to Nam Papa Savannakhet.

**Water treatment**

The water from the Mekong River is pumped to the Nake water plant and is lead through flocculation, sedimentation and rapid sand filtration and finally chlorination. The only chemicals added are alum for the flocculation and chlorination for disinfection.

Nam Papa Savannakhet has stated different amount of chemicals used in the process. During the interview in the beginning of December it was stated that the amount of chlorine is the same in dry and rainy season, 20 kg per day. Furthermore, the amount of alum varied from 400 kg/day during dry season and 900 kg/day during rainy season. When the treatment process is insufficient (if noticed in the lab tests) a larger amount of chemicals is mixed into the water as compensation for the rapid passage through the process.

The cost of chemicals in Savannakhet in 2003 is shown in Table 5-6 as stated during the interviews. The price is exchanged from Kip to US\$ using the rate of December 2003.

<b>Chemicals</b>	<b>Amount kg</b>	<b>US\$ / kg</b>	<b>Cost total US\$</b>
<b>Alum</b>	204 000	0,240	49 038
<b>Chlorine</b>	7 300	2,529	18 461
<b>Total</b>			67 499

**Table 5-6 Yearly cost for chemicals in Savannakhet 2003. (Nam Papa Savannakhet, 2003)**

Nake Water Treatment Plant has a laboratory for water tests. Tests are done daily on temperature, pH, chlorine, alum and turbidity. There is no test on micro bacteriological tests or treatment.

It is not known how much sludge is produced per year at Nake Water Treatment Plant. The sludge is flushed out through a pipe to a small pond outside the plant area. The pond is situated between a spot where local farmers garden vegetable and a their houses. There is no fence around the pond and ducks swam in the pond. On questions about illnesses related to alum, the director told that the farmers living nearby the treatment plant have lived there for a very long time and they are not sick. They do not have any problems with illness among the employees either. This is probably the common view of the alum sludge at many Nam Papas.

**Investment in water scheme**

The rehabilitation was financed by a grant from JICA. The terms of the grant are not known, but Savannakhet applied for grant both for rehabilitation and for an extension, as the water demand is well above the capacity of Nake Water Treatment Plant today. However, only the rehabilitation project was approved.

The consultant's recommendation after the completion of the project was (Nihon Suido, 2003a):

- 1) Budget for operation and maintenance
- 2) Failure of operation and maintenance can cause problems with the water quality and reduction of the production capacity. Therefore, Nam Papa Savannakhet shall arrange for an adequate budget for each year for operation and maintenance. For this purpose the operators should report the condition of all equipment periodically, and prepare lists of necessary parts and cost estimates prior to the budget allocation. Preventive maintenance mainly based on the daily inspection, should be introduced.
- 3) Training for Technical knowledge on operation and maintenance
- 4) The importance of adequate training for operators was pointed out. Both in-house training as well as national training program is recommended.

In December 2003, there was no budget done. The Director of the Treatment Plant had just arrived back from training course in Bangkok. At a later meeting, he mentioned the problems with insufficient time for transferring the knowledge to the operators.

#### **Personnel and organisations**

At Nam Papa Savannakhet, 84 persons worked in 2003. 15 of them worked at the water treatment plant, see Table 5-7.

	<b>As for 2000</b>	<b>After rehabilitation</b>
<b>Total Number of Staff at Nam Papa Savannakhet</b>	80	84
<b>Personnel cost (US\$ per year)</b>	12 808	13 654
<b>Average cost for personnel (US\$ per year)</b>	160	163

**Table 5-7 Personnel and organisation**

The cost of personnel was given in Kip and the exchange rate 1 US\$= 10 400 Kip has been used (rate of December 2003). The average salary for the staff at Nam Papa is \$163 per year or \$13.6 per month. This is significantly lower than in Luang Prabang, where the average salary was about \$70 for the upper management staff at Nam Papa, according to the Director at Nam Papa Luang Prabang. Nam Papa Savannakhet has more staff after the rehabilitation, but it is not clear whether that actually depends on the rehabilitation.

#### **5.4.4 Water supply in Luang Prabang**

The water supply system is dependent on two water sources; springs in Phou Pheung in the surrounding mountains, and surface water from the Nam Khan River. The water consumption is slightly higher per capita in Luang Prabang than average in Laos because of the tourist industry. On the other hand, Nam Papa Luang Prabang has an advantageous economic position from the tourist industry (Burwell and Vongnouboutham, 2001). The Director claimed during the interview that the present water supply is not enough for future demand

when the new hospital and university is built. The piped water supply system in Luang Prabang is the only one in the province (ADB, 1999b).

### **Background & Development**

Nam Papa Luang Prabang was established in 1932 and is the oldest Nam Papa in Laos. The water source was the springing Phou Pheung and the water was led to a pump in the centre of town. In 1968-1969, a larger water supply scheme was designed with grant of 3,600,000 DM from German government. The water supply scheme included two intake buildings for two different springs, a plant, a filter basin and a reservoir of 1400 m<sup>3</sup>, to meet the demand of 15 000 persons in Luang Prabang. The production capacity was 4500-6000 m<sup>3</sup>/day.

In 1996, the Luang Prabang Water Supply System Rehabilitation and Extension Project started. The project got financial aid from the German government. Phase 1 included surveys, design and estimations of rehabilitation of the Phou Pheung plant and of a new plant. In Phase 2, the water treatment plant of Phou Pheung was rehabilitated, a new water treatment plant for surface water was built at Nam Khan River and the distribution net was repaired and extended. The surface water was especially needed in the dry season. The water treatment plant of Nam Khan was taken in use in 2001.

The Phou Pheung water plant together with the Nam Khan River water plant are designed to provide sufficient amount of water for approximately 60,000 persons, which is the estimated population served in Luang Prabang in year 2015 (Interconsult, 2002).

In February 2002, Interconsult noted a lack of manuals for the old water supply, but detailed documentation was available for the new water scheme (Interconsult, 2002). Furthermore, all documentation at the time was in English/German. (Interconsult, 2002) There seem to have been no or little progress since then. During the visit in December 2003, manuals for cleaning the basins, written in Lao, were posted on a door at the water treatment plant at Nam Khan River. At both treatment plants, manuals for laboratory tests were available.

No reports on hydrogeological investigations have been found. If the option of ground water from wells were taken into account before the expansion in 1996 is not known.

### **Water balance**

The spring yields 4000 m<sup>3</sup>/day in the dry season and 6000 m<sup>3</sup>/day in the rainy season (Interconsult, 2002). During the rainy season, the water plant of Nam Khan is only operating eight hours a day as the spring yields enough water. The capacity of the old water supply and the additional new scheme is 15 000 m<sup>3</sup>/day in the rainy season and 13 000 m<sup>3</sup>/day in the dry season (Interconsult, 2002). The water balance in Luang Prabang is shown in Figure 5-4.

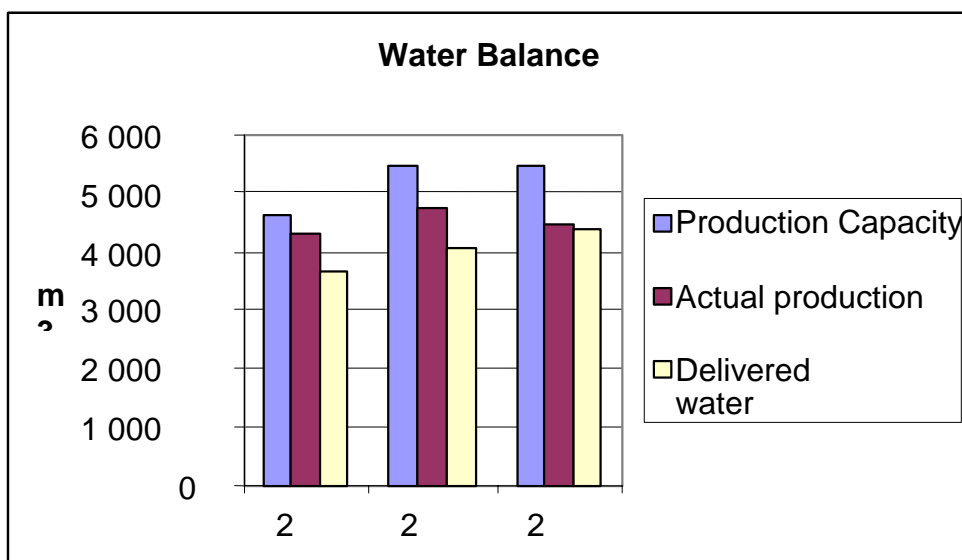


Figure 5-4 Water balance in Luang Prabang

### Water treatment

The quality of spring water is good, but gets poorer in the rainy season (Interconsult, 2002). The treatment of the spring water plant includes flocculation, rapid sand filter and chlorination. In the dry season, rapid sand filter and chlorination is enough treatment. In the rainy season however, when the turbidity of the spring water is higher, flocculation is necessary and then alum is used. (Interconsult, 2002)

The quality of the Nam Khan River water is not as good as the spring water. The new water treatment plant at Nam Khan River comprises flocculation, sedimentation, rapid sand filter and chlorination. (Interconsult, 2002) The plant has a well equipped laboratory, where daily analysis of turbidity of raw water and treated water together with pH and residual chlorine are carried out and recorded. According to Interconsult, daily jar tests are carried out for determining the correct amount of coagulants to be used to get the maximum treatment result. This is the only water treatment plant of the visited that used the daily tests in this way. The spring water plant uses the laboratory at Nam Khan to carry out water tests.

The cost of chemicals in year 2002 was US\$ 12 356, which was 7% of their total expenditure. 500 kg of chlorine and 17 700 kg of alum was used that year.

The sludge is flushed out into the river, a few meters downstream of the intake tower. However, there seemed to be no circulating streams around the tower, so the risk of getting the alum-containing sludge in the water intake should be minimal. The current is approximately 0.5-1 m/s in the dry season and probably higher in the rainy season.

### Investments

According to the contract of Luang Prabang Water Supply Project Phase 2-Lot 2 (DM Construction & WABAG, 1998), the total sub-project cost was

1,950,303,451 Kip. The cost for building a new water treatment plant at Nam Khan River was 814,580,705 Kip more expensive than rehabilitation of the old spring fed plant.

The financial situation of Nam Papa Luang Prabang was in 2001 one of the best of all Nam Papas in Laos due the tourist industry, according to Keith Burwell (Burwell and Vongnoubontham, 2001).

### **Personnel and organizations**

In 2002 67 persons worked in Nam Papa Luang Prabang and 35 of them worked with water production, according to Nam Papa Luang Prabang (2003). Nam Papa Luang Prabang spends 23% of the total expenditure on personnel.

### **5.4.5 Water supply in Outhoumphone**

The water supply system in Outhoumphone is still under construction. The wells will be taken in use in June 2004. The project is important for DHUP because it will statue as good example of successful ground water usage for the rest of Laos. Figures used for comparisons in this study stems from prognosis of the project and the accuracy must be evaluated in the future.

The well field is located in a rice paddy and even though the wells have high concrete lining there might be a risk that fertilizers contaminate the wells. The wells were locked with padlocks.

### **Background & Development**

In 1997, the population of Outhoumphone was 14 330 persons and the existing water system was not enough even for the central area. Outhoumphone was supplied by a combination of shallow wells, simple hand pumps and a small groundwater based piped system built by the Health Department with UNICEF assistance (ADB, 1999b). About 300 households were connected to the piped water supply system. The system had working water meters to measure the water consumption for each household (Montgomery Watson, 1999). Demand exceeded supply and water was only available for a few hours a day and at very low pressure. An army camp nearby the town sold some of their excess water to villagers from the camps own well (Montgomery Watson, 1999). In 1999, part of the old water supply system was still in use, but not in 2001. This was mainly because the distribution net was in bad shape. Mostly air came out of the water pipes and the air activated the meters, which gave faulty values of the water consumption (Norconsult et al, 2001).

Outhoumphone is one of five towns in Phase I in Small Towns Water Supply and Sanitation Project, STWSSP, where Norconsult are consultants and the contractors is a joint venture of China-Geo and Phetsamone Construction. The water supply system consists of deep-drilled wells on a well field outside the town and reservoirs in the centre. The source of water is 43 wells, with possibility to take seven additional wells in use in the future. During the pre-study, the option of taking raw water from The Mekong River, 25 km away was also investigated. The option was not selected, since ground water showed to be both economically and technically preferable in the Norconsult

Feasibility Report, 1999. (Norconsult et al, 2001) At the time of the visit 2003, the well field was not ready enough to connect any households. Neither electricity nor pumps had been installed.

### **Water demand**

The design population in 2010 is 18 000 and the per capita demand of water 120 litres per day. Design flow (including 25% UFW) is 3 180 m<sup>3</sup> per day. (Lao PDR & ADB, 2000)

### **Water treatment**

When the water supply system is taken in use, the water treatment will be chlorination at reservoir and softening. The amount of chemicals that will be used is not known, since the well field is not taken in use yet. The estimated cost in 2005, the year of the commission, is 4 240 USD, and in 2010, the cost is 6 620 USD.

### **Investment**

The STWSS project is financed by a loan from ADB where the Government of Laos is borrower. The terms of loan are 32 years, including a grace period of 8 years (ADB, 1999c). The total loan is of 16.5 millions USD and the Lao Governments contribution is approximately 9.0 million USD. The interest charge is 1.0% per annum during the grace period and 1.5% per annum thereafter to be paid semi annually. The result of the economic evaluation from Report and Recommendations of the President (ADB, 1999c) showed that EIRR would be 20.9%.

The total cost of the hydrogeological survey and test drilling for groundwater was 0.12 million USD or 400 000 Norwegian crowns. According to Norconsult the total investment cost for the water supply system in Outhomphone is estimated to 1,9 million USD (Norconsult, 2001). The capacity building project is led by Interconsult and financed by Norwegian government. (Interconsult, 2002)

### **Personnel and organizations**

In 2010, the number of Nam Papa employees is estimated at nine persons of whom two is working with the water production. The estimated cost for personnel in 2010 is 2 800 USD.

### **Initial Environmental Examination**

Before the Outhoumphone water supply project was started an initial environmental examination, IEE, was performed. The IEE was presented in the 1999 Feasibility report and included investigations of:

- one ground water option
- one surface water option
- piped water supply scheme
- new water sealed pit latrines, septic tank and improved sewage water drainage for 1 200 households

The findings and recommendation of the IEE was that the environmental impacts were not assessed to be of sufficiently serious nature to warrant a full-scale environmental impact assessment.. The establishment of an Environmental Management Plan, including guidelines for ground water protection measures and possibly a HIV/AIDS prevention initiative, will suffice as environmental documentation (Norconsult et al, 2001).

### **Proposed Water Supply and Sanitation System**

The Feasibility Report in 1999 concluded that there was a reasonable probability to find good quality ground water in sufficient quantities in Outhoumphone district for the whole area, and that a ground water scheme would be significantly cheaper than a scheme based on surface water. This chapter will describe the options evaluated and all facts are from Norconsult Package A: Feasibility Studies, Detailed Design and Construction Supervision, July 2001 (Norconsult et al, 2001).

The two alternatives investigated in Outhoumphone were:

- Groundwater Option
- Surface water from Mekong River

The nearest perennial surface water is Mekong River, which is at least 25 km away. The investigation included two different intake positions. Ground water investigations were carried out during December 2000- May 2001. The work consisted of electrical resistivity imaging to map subsurface, measuring ground water levels and testing water quality in existing ground water wells etc. The investigations showed that the three primary constraints that affect the ground water potential are:

- 1) Levels of evaporates (ions), calcium ( $\text{Ca}^{2+}$ ), Chloride (Cl) and sulphate ( $\text{SO}_4^{2-}$ ) in ground water
- 2) Sustainable yields in individual wells
- 3) Recharge levels as determined by precipitation

The ground water quality was good, when measured in the boreholes after test pumping, but the mineral occurrence was high. The quality of surface water varies with season. The suspended sediment load is high, especially in the rainy season.

Cost estimations were done on capital costs and on O&M costs. For the ground water alternative, the capital cost was less than half of the surface water option. For the O&M cost the surface water alternative was 55% more expensive the first year and after five years 51% more expensive.

A least cost analysis was carried out on the two most reasonable options, one for ground water and one for surface water. Capital cost, O&M cost and non-market costs (e.g. environmental costs) were included. The analysis was done in three steps (Norconsult 2001, pp 14):

- 1) Find technologically feasible options

- 2) Calculate life cycle costs (the capital cost as well as the O&M costs are disbursed over the life cycle and converted to economic costs and non-markets costs like environmental impact is included)
- 3) Data on required production capacity

The result, shown in Table 5-8, shows that the ground water option produces water at less than half the cost.

Key Indicator	Surface water	Ground water
AIEC	6 081 Kip/m <sup>3</sup>	2 803 Kip/m <sup>3</sup>

**Table 5-8 Average Incremental Economic Cost**

There was no doubt in this case that ground water was environmentally and economically more suitable.

The purpose with a Financial Benefit- Cost Analysis is to obtain (Norconsult 2001, pp 20):

- An indication of the unit cost of water in form of average incremental financial cost (AIFC)
- An estimate of the level of subsidy implied as reflected by the difference between the AIFC and the average tariff based on the existing tariff level
- A basis to calculate the revised tariff required under the recovery requirements

The estimates are done recovery period until 2010. Included in the financial revenues are water sales, connection fee and meter rentals. The financial costs are taken from the Least-Cost Analysis. The result is presented in Table 5-9 and show that the financial net present value, FNPV, is two and a half time higher for the surface water option. None of the alternatives give a positive financial net present value, when the water tariff is as low as present. The water will need financial subsidy; surface water more than twice as much as ground water

Key parameters:	Surface water scheme	Ground water scheme
	<i>(Millions Kip)</i>	<i>(Millions Kip)</i>
<b>Total Project revenues</b>	4 367	4 367
<b>Total Project Costs</b>	37 481	17 786
<b>FNPV</b>	-33 114	-13 419
	<i>(Kip/m<sup>3</sup>)</i>	<i>(Kip/m<sup>3</sup>)</i>
<b>Average Incremental Financial Cost</b>	7 341	3 484
<b>Average Tariff (incl. Connection fee)</b>	855	855
<b>Implied Financial Subsidy</b>	6 486	2 629

**Table 5-9 Financial Cost-Benefit Analysis (Norconsult et al, 1999)**

## Conditions in The Study Areas

The objective of the Economic Cost Benefit Analyses is to investigate the viability of the alternatives in economic terms i.e. from the perspective of the economy as a whole. The result of the ECBA is shown in Table 5-10.

<b>Parameters</b>	<b>Surface water</b>	<b>Ground water</b>
<b>ENPV</b>	-6 071 Million Kip	12 510 Million Kip
<b>EIRR</b>	9,90%	20,10%
<b>EOCC</b>	12,00%	12,00%

**Table 5-10 Economic Cost- Benefit Analysis (Norconsult et al), 2001**

The result of the economic cost benefit analysis shows that the ground water was the most suitable alternative.

### 5.4.6 Swedish reference towns

To give a reference to Swedish conditions, two Swedish water supply systems, Halmstad and Borås, are described. In Table 5-11, figures from Halmstad and Borås are presented.

	<b>Halmstad</b>	<b>Borås</b>
<b>Population</b>	85 742	98 150
<b>Persons connected to the distribution net</b>	79 000	85 750
<b>Number of connections</b>	21 300	16 051
<b>Number of surface water plants</b>	0	1
<b>Number of ground water treatment plants</b>	21	7
<b>Sludge deposit: Tonnes of dry sludge</b>	1,2	0
<b>Delivered amount of water</b>	8 564 497	8 689 872
<b>Number of employees</b>	51,5	63
<b>Number of chemical tests on tap water 2002</b>	65	62
<b>Number of micro biological tests on tap water</b>	200	1

**Table 5-11 Conditions in Halmstad and Borås**

Halmstad municipality has 86585 citizens. 79 000 or 92,14 % of the citizens is provided with water from the public water supply system. The raw water comes from ground water that is extracted from 21 wells placed in different locations in the commune.

The average production is 8 564 497 m<sup>3</sup>/year. The population in the town doubles in the summer months and therefore, the water production is almost twice as high during these months (Anderson, Halmstad, 2004). The average consumption in Halmstad is 258 liter per day. Since the raw water in Halmstad has a very high quality, the need for chemicals is very limited. The water is purified with a sand filter and chlorinated for the distribution net. No chlorination is necessary, but lime is used to raise pH, according to the

technical Office in Halmstad. Pipes are chlorinated before taken in use, but that is only once.

Borås municipality has 98150 citizens and the municipal water supply system provides about 85750 citizens or 87,4% with water. The water comes from seven water plants of which Sjöbo water plant is the largest. The raw water used by Sjöbo water plant comes from Lake Öresjö. The water is flocculated, sedimented and filtered through active carbon filters that remove taste and odor from the water. The average production is 8 689 872 m<sup>3</sup>/year and the average consumption in Borås is 212 liters per day.

#### 5.4.7 Sludge

In Dricksvattenteknik (VAV, 1992) a formula is presented for estimating the produced amount of sludge.

$$\text{Amount of sludge (g suspended substance)} = 0.5 * \text{dose of aluminium sulphate (g/m}^3\text{)}$$

<b>Aluminium dosing and sludge</b>			
	<b>Thakhek</b>	<b>Savannakhet</b>	<b>Luang Prabang</b>
<b>Produced water (m<sup>3</sup> /year)</b>	1 789 363	4 981 432	4 044 017
<b>Amount of alum per year (kg/year)</b>	16 800	204 000	17 700
<b>Dosing (g/m<sup>3</sup>)</b>	9 389	40 952	4 377
<b>Amount of alum sludge/ produced m<sup>3</sup> (g/m<sup>3</sup>)</b>	4 694	20 476	2 188
<b>Amount of alum sludge (kg/year)</b>	8 400	102 000	8 850

**Table 5-12 Estimation of aluminium sludge produced in 2002**

The formula has in Table 5-12 been used to estimate the produced amount of alum-containing sludge. The estimations is done on three water treatment plants in Laos where surface water is the main source of water (Thakhek also use ground water and Luang Prabang also use spring water). Given from water plants is produced water and amount of alum used per year. Then the dosing can be calculated. When the dosing is known, the amount of sludge per produced volume of water, amount of alum sludge per year and the amount of sludge in total per year can be calculated.

The recommended dose of aluminium in Sweden is 25-75g/m<sup>3</sup>. Savannakhet is in the middle of that interval, but Thakhek and Luang Prabang is significantly lower. The dose in Savannakhet can be expected to be higher than in Thakhek and Luang Prabang, due to the fact that the dose is raised when the treatment is not sufficient because of overproduction. The low dosing in Thakhek can be due to the poor economy of the Nam Papa; they cannot afford to buy more alum. Another reason can be that the mixing of

surface water and ground water dilute the organic substances so the less treatment is needed. In Luang Prabang, alum is only used in the spring water plant in the rainy season. In the dry season the turbidity is low enough.

When using the formula for calculation the amount of sludge produced in Thakhek and Savannakhet, it is notable that the dose of aluminium in Savannakhet is four times higher than in Thakhek. The dose is calculated from the amount used per day in the dry respective the rainy season and the approximation that the dry season is eight months long and the rainy season is four months.

The dosing in Savannakhet is four times higher, but the amount of sludge produced is only 25% higher. Alum is mainly used in surface water treatment plant. Paksan does not use alum and neither will Outhoumphone.

The dosing of alum varies a lot in the three towns. Therefore, it is hard to evaluate how big impact the use of alum has. Test on residual alum in the tap water is seldom done and the risks with alum intake in water are not common knowledge in Laos. The discussion about risks with alum has not been going on in Laos.

The sludge is disposed in the river or in ponds in the yard today. In Sweden, the treatment of the sludge is a cost for the treatments plants. It is possible that in the future the legislation in Laos will be harder and the sludge must be taken care off.

### **5.4.8 Distribution net**

Savannakhet has a large distribution net with many narrow pipes. The production manager stated that this contributed to higher energy consumption, because the water plant pumps had to work harder to press the water out to the end pipes.

In Thakhek, after the Nam Papa had distributed untreated water from the Mekong River in the net, a thorough cleaning and flushing of the net should have been done to reduce the organic material and pollution, but this was not done.

Paksan has an approximately ten-year-old distribution net and the water losses in the net are relatively small. It is unknown what kind of maintenance that is done on the distribution net.

## 6 RESULT AND DISCUSSION

The initial objective turned out to be too extensive for this master thesis. The outcome of this study consists of a few indications on differences between groundwater and surface, but mainly recommendations for the water authorities in Laos. An environmental, financial and economical comparison of ground water and surface water as a source for water supply would need more time than twenty weeks to perform. In this chapter, we present the uncertainties of the study and the comparisons that we have performed. We also comment the methods we planned to use and explain why they could not be used in this case.

Our intention with this study was to find out what source of raw water that would be the most financially and economically viable in the long run. However, with the material and facts we have received and the large fluctuation in the Lao currency it is very hard to make any credible evaluations about the upgradings and rehabilitations of the water supply systems that has been done in the past. The variety of investments in the studied schemes makes it hard to compare the cost of the initial investments. It is not possible to estimate the cost of building a new water treatment plant or well field, because e.g. site, hydrogeological conditions, and water demand vary.

### 6.1 Uncertainties

Before the results and analysis, we illustrate the major uncertainties in this study.

- The statistical selection is far too small. Far more water supply schemes ought to have been studied to give a valid indication for the whole country.
- The five towns in Laos were chosen in cooperation with MCTPC, because of their suitability for field study, the size of the towns and source of raw water. The two towns with surface water have probably advantages from economy of scale. The result might have turned out different if other towns would have been used.
- Another problem has been the language. Since we do not speak Lao, and many of the interviewees spoke only a little English, we have used an interpreter. In some cases it has been hard to explain what type of material we need. Much of the material from the Provincial Nam Papis is in Lao and has had to be interpreted and in some cases, there have been misunderstandings.
- We were prepared on cultural differences, but the major difference was the culture of not sharing information. Exactly the right thing has to be required otherwise it is not delivered.
- Furthermore, the lack of archiving procedures is a problem when searching for adequate information.

The consequences of these uncertainties ought to be considered while reading the result of the study.

## **6.2 Result of financial and economical comparison**

One of the objectives of the thesis was to analyse and compare water supply systems in an economical and financial perspective. This is a wide definition of a study and after examining the available material, we came to the conclusion that the material is not sufficient for performing the analysis.

The intention was to make an investment assessment consisting of an economical and a financial cost benefit analysis. It is very hard to assess economic benefits in general, and in Laos in particular. There is no tradition in valuing time or human life, as it is in Sweden. Since most people are self-sufficient farmers, lost income because of sickness is not as easy to estimate as for employed people. Furthermore, the benefits of tap water are hard to value, since consumers choose to boil water before consuming anyway. An economical cost benefit analysis has therefore not been done. We do not have the possibility to assess the economic cost either.

A financial analysis does not include benefits and costs regarding the surrounding society and should therefore be easier to execute. When comparing ground water and surface water, the incomes are not relevant as they do not depend on the source of raw water and the water tariff is not equal among the investigated towns, in some cases it is not even related to the actual expenses. Therefore, the initial thought was to exclude incomes from the analysis and instead focus on a financial cost assessment. However, it turned out to be very difficult to compare investment costs because of reasons described in chapter 6.2.1 Investment assessment.

### **6.2.1 Investment assessment**

The initial plan was to find a break-even point for the costs of a ground water and a surface water option. Our hypothesis was that even though one of the options would have cheaper investment costs, the higher costs for operation and maintenance would make the other option cheaper in a lifetime perspective. To illustrate this, we hoped to be able to use the figures from the investment assessment to make a diagram that shows the accumulated costs over time. The diagram would illustrate the break-even point for the two options. In Figure 6-1 we have made an example of the type of diagram we expected to create.

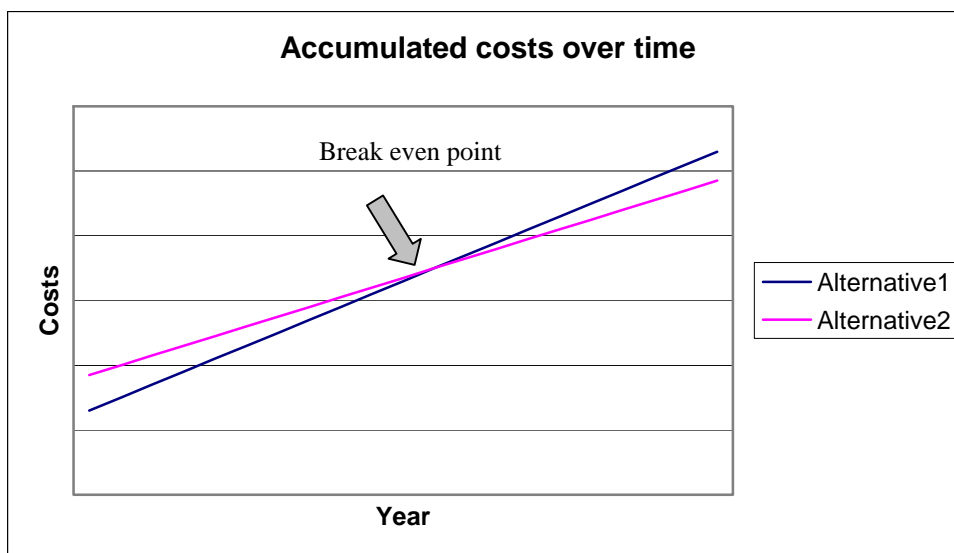


Figure 6-1 Expected break-even point of the two alternatives

However, we found that it is not possible to add the investment costs for the different water plants and receive a valid result.

Several issues complicated the assessment. Some of the major obstacles are listed below:

- The water supply systems were commissioned within a time range of thirty-five years and some of them have been rehabilitated and upgraded several times. It is not possible to add up the different investment cost over time from the five towns and then perform a comparison on a basis of number of connections or annual water production.
- A comparison could have been made on a basis of the financial report from the Nam Papas, but lack of standards for depreciation of the fixed assets makes it hard to compare the actual value of the assets. We do not know how large part of the assets that consist of the actual treatment plant or well field and how large part for the distribution net.
- The actual outcomes of the investments have not always resulted in the expected performance. In some cases the achieved capacity turned out to be lower than planned. This may result in expensive ad hoc solutions to cover the additional water demand.
- Deterioration caused by deficiency in operation and maintenance leads to unnecessary costs for repair and rehabilitation. It also decreases the life span of the investments. The cost for operation and maintenance might be lower than it should be if properly operated.
- Laos has been given loans and grants in different currencies. Fluctuation in the Lao currency and difference in inflation rates in the currencies of the loan giving countries. Therefore it is hard to perform a financial comparison in a uniform currency.
- Advantages in economy of scale and the experience of the older Nam Papas affects the performance of the systems. This gives

Savannakhet and Luang Prabang advantages in all kind of comparisons.

Because of the mentioned issues we have not performed our comparison as planned.

We planned to use the MEA formula described in chapter 4.1.4 Modern equivalent value to find the value of the investment per connection. Since the technical life length of the different investments were not known, this was not possible to do. The only town we could perform the calculation for was Paksan.

Investment cost:	5062,5 M KIP
Inflation factor:	1,24
Life length:	Assumed 20 years
Age of asset:	4 years
Number of connections:	1885

$$\text{MEA/ connection} = (5062,5 * 10^6 * 1,24 * (20-4)) / (20 * 1885) = 2,7 \text{ MKIP}$$

Paksan is the only of the five studied towns with a fairly new scheme with no reinvestments made. The technical life span is usually determined in the appraisal, but the actual technical life span is hard to determine and in case of reinvestments, the life span is increased.

### **6.3 Result of environmental comparison**

To decide what alternative that is the most environmentally sustainable of ground water and surface water, a life cycle assessment should be performed, but that is a too large mission to be carried out within the scope of this thesis. We have studied the performed initial environmental examinations that were done in Paksan and Outhoumphone and both showed that the negative impacts from water supply schemes were minor. A life cycle assessment could however be the object of a future study. We have focused on the chemical usage in water production and that is found in the chapter about key performance indicators. The improper dosage of chemicals can however be a threat to the consumer's health. Earlier studies have shown that the major negative environmental impact from water plants is the energy consumption and the origin of the electricity. In Laos however, electricity comes from hydropower and that is considered as an environmentally friendly energy source.

### **6.4 Result of Key Performance Indicators**

In this chapter, the result of the key performance indicators defined in chapter 4.4 Defined Key Performance Indicators is presented in diagrams. Figures from year 2002 are used for Paksan, Thakhek, Savannakhet, Luang Prabang, Halmstad and Borås. For Outhoumphone, estimated figures for year 2010 are

used. Two Swedish towns Borås and Halmstad are sometimes included in the diagrams to be placed in relation to the Lao result.

It is important to notice that the costs of the two Swedish towns are reported in Swedish crowns, SEK. This is because the exchange from SEK to US\$ to 1000 KIP would approximately give the same values. These towns are only represented in the diagrams to place the Lao towns in a context for Swedish readers and they are not analysed. All figures from Laos are in 1000 Kip, except the investment costs that is presented in US dollar. The purchasing power in the Lao currency is significantly higher than in the Swedish currency. This means that any comparison of costs is irrelevant. The costs of the Swedish water plants are only used in absolute value.

It is important to keep in mind when analysing the situation at water plants in Laos today, that the process is not always performed in an optimal way. The manufacturers and the consultant's recommendations are not always followed. This affects the performance, life span of water plants and well fields as well as the financial outcome.

### Financial indicators

The first indicator is cost of chemicals per produced cubic meter, seen in Figure 6-2. We are not taking the cost price into account, but only the annual expenditures on chemicals for the Nam Papa. There is no central purchase of chemicals among Nam Papas in Laos and cost prices probably vary. It seems like Nam Papa Savannakhet buy alum in Laos and chlorine in Thailand. Where the other Nam Papa buy their chemical is unclear, but it is probably done in a similar way. It is impossible to calculate the cost price of alum and chlorine from figures received in reports, because the annual amounts of chemicals vary a lot. However, the expenditures on chemicals are interesting even though the cost price is not known.

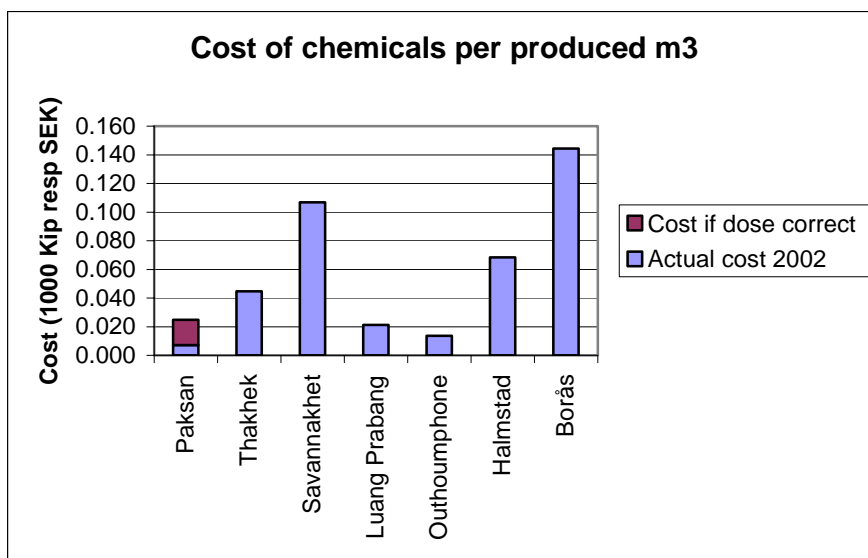


Figure 6-2 Cost of chemicals per m<sup>3</sup>

Paksan uses much less chemicals than they should, considering the quality of the water. Therefore, we have added what they should have paid for chemicals if the right amount was used, to the diagram. As for the Swedish water schemes, the ground water based system in Halmstad has only half the cost for chemicals per produced m<sup>3</sup> compared to surface water supplied Borås. Borås pays more for chemicals than the rest of towns. Savannakhet has the highest expenditure on chemicals of the investigated towns in Laos, but they have the only water plant that exclusively uses surface water.

Chlorine is almost ten times as expensive as alum. Neither Paksan nor Outhoumphone uses alum, but solely chlorine. They still have the lowest cost of chemical per produced m<sup>3</sup> of water and thereby we conclude that they use least amount of chemicals for their ground water based water supply system.

Luang Prabang and Thakhek blend the surface water with spring water and ground water. They have significantly lower cost for chemicals than Savannakhet that only uses surface water. Hereby we draw the conclusion that groundwater based systems has a lower cost for chemicals.

The second financial key performance indicator is cost of operation and maintenance per produced cubic meter. The relevance of this indicator can, and should, be questioned in this case. In the Annual Financial Report of Nam Papa, only costs for maintenance is stated. There is no specific post for both operation and maintenance. For Outhoumphones prognosis financial report, Montgomery Watson states maintenance and repair, instead of operation and maintenance. Because we do not have the figures for cost of operation and maintenance, we have chosen to use cost of only maintenance per produced cubic meter. The result is found in Figure 6-3. For Outhoumphone repair is included in the post.

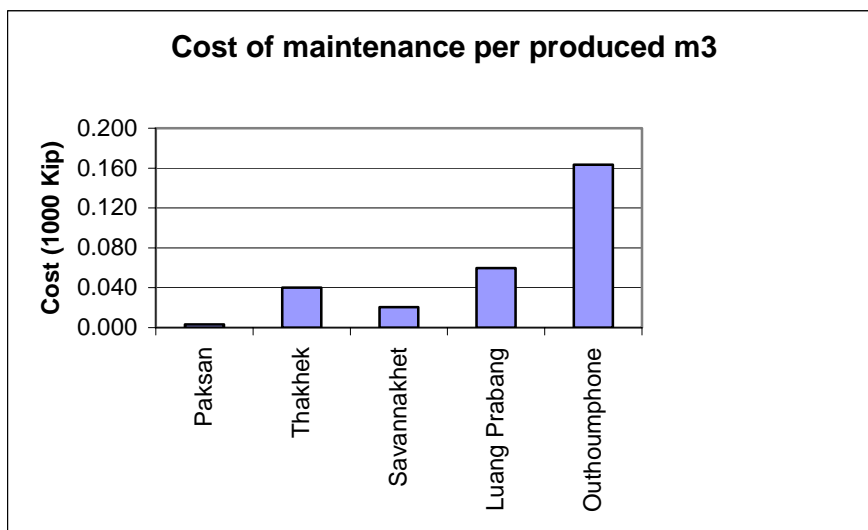


Figure 6-3 Cost of maintenance per produced m<sup>3</sup>

The cost of operation and maintenance would give a more interesting view of differences between surface water and ground water. We have received cost for operation and maintenance for Borås and Halmstad, and that is

significantly higher than the cost of maintenance in Laos. The difference is about 50 times. The Swedish towns are therefore excluded from the diagram.

In year 2010, Outhoumphone will place a large part of the expenditures on maintenance and repair. This post is very large during the first years in operation in Outhoumphone. It is not clear in Montgomery Watson's report (1999) when this post will diminish. If the surface water alternative had been implemented in Outhoumphone instead, the costs for maintenance and repair would be 20% more expensive.

Since we are aware of the fact that operation and maintenance is not performed as it ought to, we do not want to draw any conclusions from this indicator.

The third indicator is power cost per produced cubic meter, seen in Figure 6-4. Here, the power cost is often for the whole Nam Papa, which means that it includes the administrative building as well. However, the cost of power is larger in the water plants or well field than in administrative buildings.

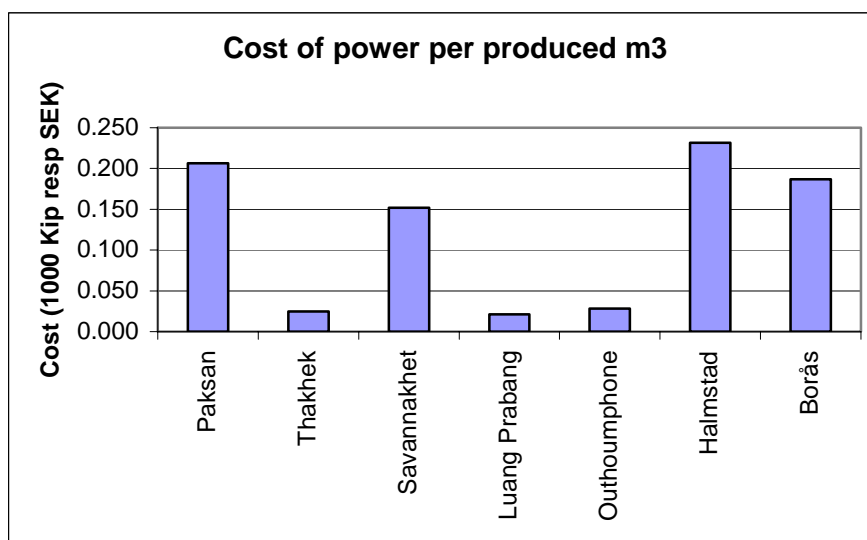


Figure 6-4 Cost of power per produced m<sup>3</sup>

The cost of power per produced cubic meter is higher in Paksan and Savannakhet than in the other towns in Laos. The result of the indicator is similar in Thakhek, Luang Prabang and Outhoumphone. One plausible explanation for Paksan's high costs of energy is the energy consuming interval pumping. One probable cause for the high costs for energy in Savannakhet is that the pipe system is poorly planned and consists of many narrow pipes which has been connected to the distribution net in an inadequate way. To pump out water in a net like the one in Savannakhet is extremely energy consuming. Luang Prabang has very low energy cost due to their gravity fed distribution net. There is no sign indicating that ground water would have a lower power costs than surface water or the other way around.

The fourth and final financial indicator is income of water sales, where a histogram illustrates how large proportion of the income that covers expenditures and how large proportion is surplus. Financial posts that are related to water production are not included in expenditures. Borås and Halmstad are not included in the diagram.

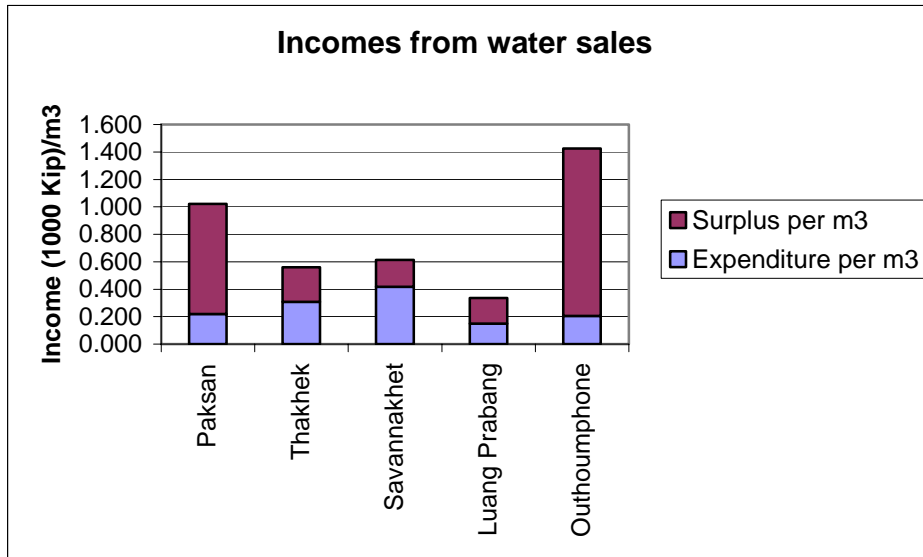


Figure 6-5 Income from water sales per m<sup>3</sup>

Outhoumphone and Paksan have higher incomes per sold quantity of water than the other, which can be related to the water tariff. The expenditures seem to be very high as well and the surplus from water sales is relatively small. The water tariff is almost twice as high in Paksan than in Luang Prabang. Since the tariff is different in the Lao towns, the incomes per cubic meter water sold vary and conclusions regarding water source cannot be drawn.

**Operational Indicators**

The first operational indicator is constitutional ratio. The staple illustrates total expenditures of Nam Papa, and power, chemicals and personnel are illustrated in different colours. The green part that illustrates other financial posts includes for example management, administration and installation costs. Financial costs are not included.

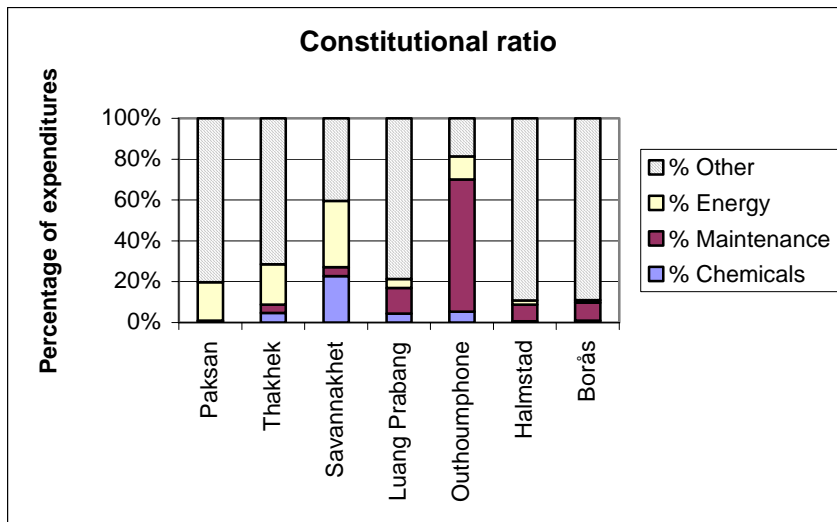


Figure 6-6 Constitutional ratio

The chart shows that the different proportions of Nam Papis expenditures. It is not fair to compare the Lao towns with Halmstad and Borås in this diagram. We have only access to expenditures and cost of personnel for the whole enterprise of water and sanitation for the Swedish towns. The costs of power, chemicals and personnel for the water plants are only a minor part. The diagram is only an illustration of how the expenditures are divided and we will not analyse it further.

The second operational indicator is produced cubic meter per number of staff. The efficiency of the organisation is not significantly higher in Sweden than in Laos, opposite to what we expected. Borås and Outhoumphone produce the same amount of water per staff. The amount of produced water can be used in many other indicators, for example produced  $m^3$ /consumed  $m^3$  and produced  $m^3$ /charged  $m^3$ .

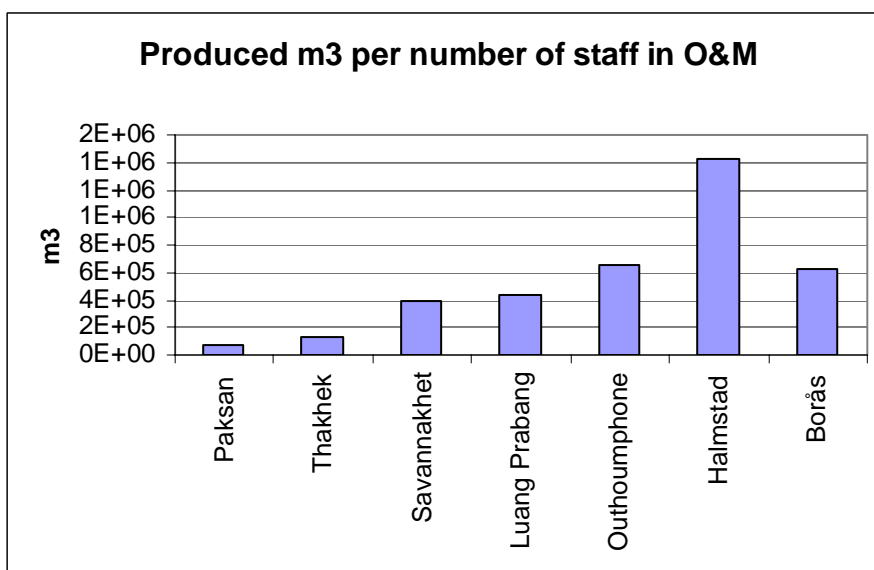


Figure 6-7 Produced  $m^3$  per number of staff in operation and maintenance

Paksan is the organisation where least water is produced per number of staff in operation and maintenance, but Thakhek only produces slightly more. Savannakhet and Luang Prabang are both rather large water plants, and their efficiency is also higher. The fact that Paksan and Thakhek has about twice as many employees in water production per 1000 connections as Savannakhet and Luang Prabang illustrates that the latter have advantages of economy of scale in operation. The production per staff in operation and maintenance seems to be connected to the size of the plant, rather than to source of water.

The third operational indicator is energy consumption per produced cubic meter, in kWh/m<sup>3</sup>. The energy consumption in Luang Prabang and Outhoumphone is unknown. For Halmstad and Borås, the electricity usage for water plants, raising of pressure and reservoirs are included. For the Lao towns, distribution is probably also included.

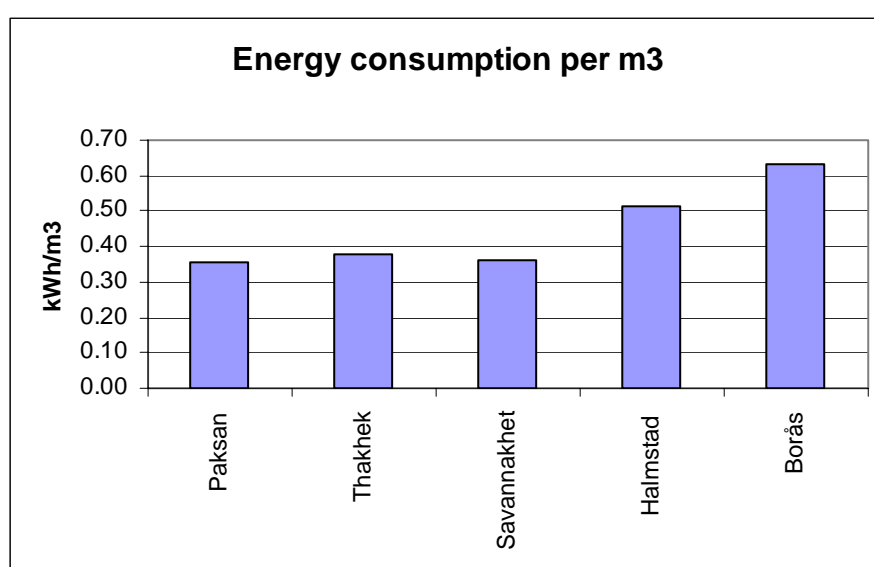


Figure 6-8 Energy consumption in kWh/m<sup>3</sup>

It is unclear why Borås and Halmstad use more energy than the Lao towns. The most probable reason lies in the definition of limitations of the studied system. We expected to find larger differences in energy consumption between the raw water sources.

To summarise the result of the key performance indicators, the only indicators that shows a difference that can be derived from source of raw water is chemical cost per produced m<sup>3</sup>. In the other indicators, the differences between the five towns probably depend on economy of scale and differences in experience and knowledge.

### 6.5 Further discussion

The goal of the study was to find general indications on what source of raw water that was the most suitable in urban areas in Laos. Our intention was to investigate investments costs and costs for operation and maintenance as well

as environmental issues for already operating water schemes. However, we do not think that a general indication would be valid for the whole country. The circumstances differ and other aspects than economical and technical must be considered. The source of raw water must be chosen with regard to local circumstances.

Explanations to why local authorities prefer surface water are often social or cultural. Traditions and culture often influence decisionmakers more than they even know themselves. Furthermore, the experience and knowledge of people concerned can also be a major cost if the need to be educated and convinced. Therefore it is not only economical and financial aspects that affect what is most suitable as water source. To achieve sustainable water supply systems, the costs of educating staff and authorities should be included in the investment analysis. Even though international research show that ground water is a suitable source, it might not be that easy in the specific case of Laos because of cultural factors, rather than technical.

This study has shown how complicated the issue of sustainability is. Even though we only aimed to investigate some parts of the wide range of aspects that are included in sustainable development, we failed to perform the analysis we planned to do. To assess the sustainability of a system, many more aspects are necessary. Economical, financial and environmental aspects are rather well defined compared to the social aspects, but they can also be very complex. Simplifications are necessary to perform any kind of realistic analysis or comparison, but the analyser risks to simplify so much so that the analysis is not valuable any longer.

During our work at the Ministry of Communication, Transport, Post and Construction, MCTPC in Laos, we understood that there is a demand for evidence that show the economical and financial advantages of ground water, to provide to the local authorities. Such evidence already exists in international studies as well as in consultant reports made in different investigations in Laos. The problem is not that local authorities think that ground water is more expensive, but lack of experience and knowledge on hydrogeology and hydrology. It appears to be a wide spread fear that ground water aquifers will cease to yield water. Another effect of this way of thinking is that provincial Nam Papas seems to consider hydrogeological and hydrological investments to be a large and burdensome expense if consultants do not find aquifers that are large enough to provide the supply system with water.

There is a conceptual confusion about the term "safe water". The governmental goal is that 80% of the population will have access to safe water by year 2015. Today 55% have access to improved water. In other reports, safe drinking water or clean water are mentioned. We have not found any definition of what the ideas represent exactly. Does access to safe water mean drinking water in the tap in the house or just weekly deliverance of bottled water?

A discussion about the quality of tap water is essential at the moment. Consumers prefer to buy bottled water from vendors for drinking today and

## Result and Discussion

tap water is always boiled or purified before use. There is no information to consumers about the water quality, therefore the trust in tap water is low. A campaign would be necessary if the government want to promote drinking of tap water, but to convince the population will not be easy. As the situation is today, it might not be relevant to aim for potable tap water in 2015. Instead, supply the population with tap water, but not so high quality. That would be more realistic at this stage, and the quality can be improved further in the future.

There are several areas in the five studied towns in Laos that need improvements. We have identified the following deficiencies in water production and listed them in Table 6-1 together with probable causes and consequences.

<b>Deficiency</b>	<b>Cause</b>	<b>Consequences</b>
maintenance of pumps	lack of knowledge	pumps break too soon
maintenance of wells	lack of knowledge	filter clogs
maintenance of water plants	lack of manuals and routines	low performing process and decrease capacity
incorrect dosing of chemicals, too low	short-term economical thinking, "can't afford" or lack of manuals or knowledge	low quality water, distribution net is deteriorating due to organic material, people do not buy water in the long run
incorrect dosing of chemicals, too high	over production, water demand exceeds capacity	alum in tap water, high costs of chemicals
no preventive maintenance	culture and custom	stops in production, deterioration
no routines or standards for reporting problems and deviation in O&M	culture and custom	difficult to notice malfunction and failures at an early stage
financial reporting has been unexisting or incomplete	low education in financial reporting	not possible to compare figures or to overview progress
no general picture of the process	deficiency in education, culture is not to intervene with other parts and people	low understanding of the process, operators are not able to see their part in the whole process
no dialogue with consumers and other stakeholders	culture	no feedback on outcome of process, consumers do not feel responsible or that they have an impact
lack of understanding in hydrogeological processes and investigations	lack of education	unwillingness of considering ground water as a source for water supply

**Table 6-1 Cause and consequences of deficiency in studied water schemes**

This study shows that there is a general lack of knowledge on both operation and the importance of continuous maintenance among the staff at the water treatment plants in Laos. We have found deficiencies in both operation of water plants and well pumps as well as chemical dosing. On the basis of this study, we recommend the authorities in Laos to continue their work with education of staff and improving routines for operation and maintenance. The ongoing work with introducing standards for financial reporting is very important, because it will facilitate the possibility to compare the financial performance, and need therefore all support from MCTPC.

An annual statistical report of operation would be an effective complement for comparing operational performance. Another finding is the consumers' generally low confidence in the local Nam Papas. We recommend the local Nam Papas to improve the communication with the consumers, in order to raise the population's confidence in Nam Papa. Regarding the low knowledge in ground water and hydrogeology, it is hard to make any other recommendations than further education at all levels in the water supply sector.

## 7 CONCLUSION AND RECOMMENDATIONS

This master thesis has shown that in the five studied area it is not possible to find indications on whether ground water or surface water is the most suitable source of raw water. The thesis show that chemical cost per produced m<sup>3</sup> is lower for ground water based systems. Other factors than source of raw water affect the performance and outcome of water plants. Economy of scale and experience probably explain some of differences seen in the key performance indicators.

Financial and operative key performance indicators are useful when comparing the performance of existing water schemes. We have found the following methods of analysis suitable before deciding water source;

- Investment assessment, both financial and economical including Cost- benefit Analysis
- Initial Environmental Examination, if necessary followed by an Environmental Impact Assessment

The above have not been performed in this study since the access to and reliability of information were unsatisfactory.

Besides technical, economical, financial and environmental aspects of raw water source, we have concluded that other aspects must be considered in the process. Even if we had been able to draw conclusions from our comparisons, we question if the investigated aspects are enough to recommend a most suitable solution for water supply. Cultural and social aspects influence the decision-makers and consumers.

Our recommendations to the national authorities in Laos to;

- continue their work with education of staff; both management and operators
- improve routines for
  - operation and maintenance
  - financial and operational reporting
  - communication with consumers
- continue the discussion about necessary and required quality of tap water

For further investigation we recommend a LCA regarding raw water intake, chemicals and treatment process. Another interesting investigation would be a study of attitudes to drinking water as well as cultural and social aspects.

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## **Appendices**

Hydrogeology- an introduction	Appendix 1
Financial Cost- benefit Analysis	Appendix 2
Environmental Assessment Regulation in Laos	Appendix 3
Environmental Assessment Methods	Appendix 4
Used data and source of information	Appendix 5

## Hydrogeology- An introduction

The movement of water is referred to as the hydrologic cycle. The hydrologic cycle can be seen in Figure A1-1. It is divided into the following phases: precipitation such as rain and snow, evaporation/ transpiration, and runoff (surface runoff and subsurface infiltration). Ground water is defined as the subsurface part of the hydrologic cycle. It is formed, or recharged, by infiltration of rain, precipitation, or by water that leaks through lake- and river bottoms. In turn, ground water flows into streams and lakes and feeds surface waters.

Surface water includes seas, lakes, rivers and streams. The surface of the ground water is called the water table and the level of the water table may vary depending on the topography and found deep for example under a hillside and shallow in a valley. During rainy season the recharge increases and the water table rises, and in dry season or if the discharge exceeds the recharge the water table falls.

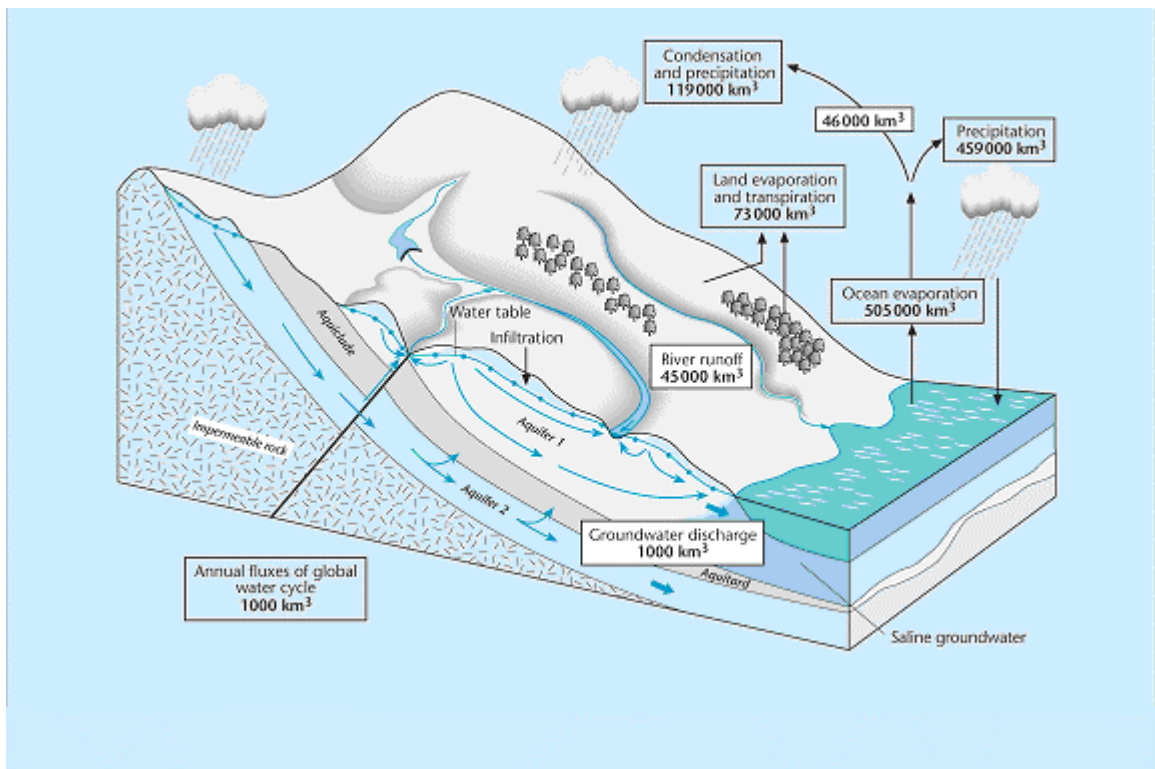


Figure A1-1 The hydrologic cycle (UNEP and Earthscan, 2002)

The ground water is found underneath the surface in various shapes, both tied to soil and mineral and fluent in larger cracks and spaces. An aquifer is a ground water bearing, subsurface formation where ground water is found in such amount that is possible to extract water in usable quantities.

Depending on the surroundings and the material of the aquifer ground water can contain various types of pollutions such as:

- Particles from clay

- Organic disposal from vegetation and animals
- Organisms, bacteria and plankton
- Calcium, carbonate, chlorides, sulphate, iron, manganese
- Industrial and agricultural disposal and waste water

Contamination of ground water is not only a health risk, but can also cause inconvenience such as corrosion and pipes, stains on clothes and zincs and bring a bad taste to beverage.

Ground water is generally considered as a high quality source of raw water and many aquifers offer natural protection from contamination. There are however some cases in which the ground water can have a lower quality. A high ground water level can cause acid water that is rich on metals and organic material. An intense agricultural land usage contributes to higher levels of nitrate in the ground water and nearby rivers and streams. When wells are located in rice paddies as it is in Outhoumphone, there is always a risk of contamination caused by fertilizers. Saline intrusion in wells is another problem that affects not only the tap water quality, but also increase the corrosion in the pipes. In a landlocked country like Laos, the saline intrusion is caused by fossil water, and not by salt water from the ocean. The saline intrusion in a well can be caused by placing the well at an inappropriate depth i.e., in a layer which holds fossil water, and by exceeding the capacity of the well. The following text can be found on [www.laoshydrogeology.com](http://www.laoshydrogeology.com): *"The alluvial deposits underlying almost all of Laos' waterways contain large quantities of ground water; a virtually limitless and sustainable source of water due to the proximity and potential recharge from surface water bodies. However the use of ground water is not without problems. Even though most of the deposits of the alluvial floodplains have high porosities and permeabilities, not all of these sediments have a texture that are suitable for drilling water wells."* ([www.laoshydrogeology.com](http://www.laoshydrogeology.com), 2004) Therefore it is necessary to locate and determine the characteristics of aquifers. Hydro geologic investigations give information about location, quality and capacity of a ground water resource. (Knutsson & Morfeldt, 2002, [www.usgs.gov](http://www.usgs.gov), 2004, [www.pca.state.mn.us](http://www.pca.state.mn.us), 2004)

In Laos the rainy season lasts about four months and the remaining eight months is referred to as dry season (MCTPC, 2004). This differs from one year to another, but this approximation that is used in this report.

### **Exploration and evaluation of ground water sources**

To locate an aquifer there are several methods that can be used. First, geological methods where the geology is investigated with tectonic and topographic maps, field studies and stratigraphical surveys are used.

Second, there are hydrological methods where the precipitation is measured during a longer time and mapping where the run off is defined. Investigation of the infiltration in the terrain, investigation of wells, springs and ground water leakage and test from wells and springs are performed to determine the quality of the ground water.

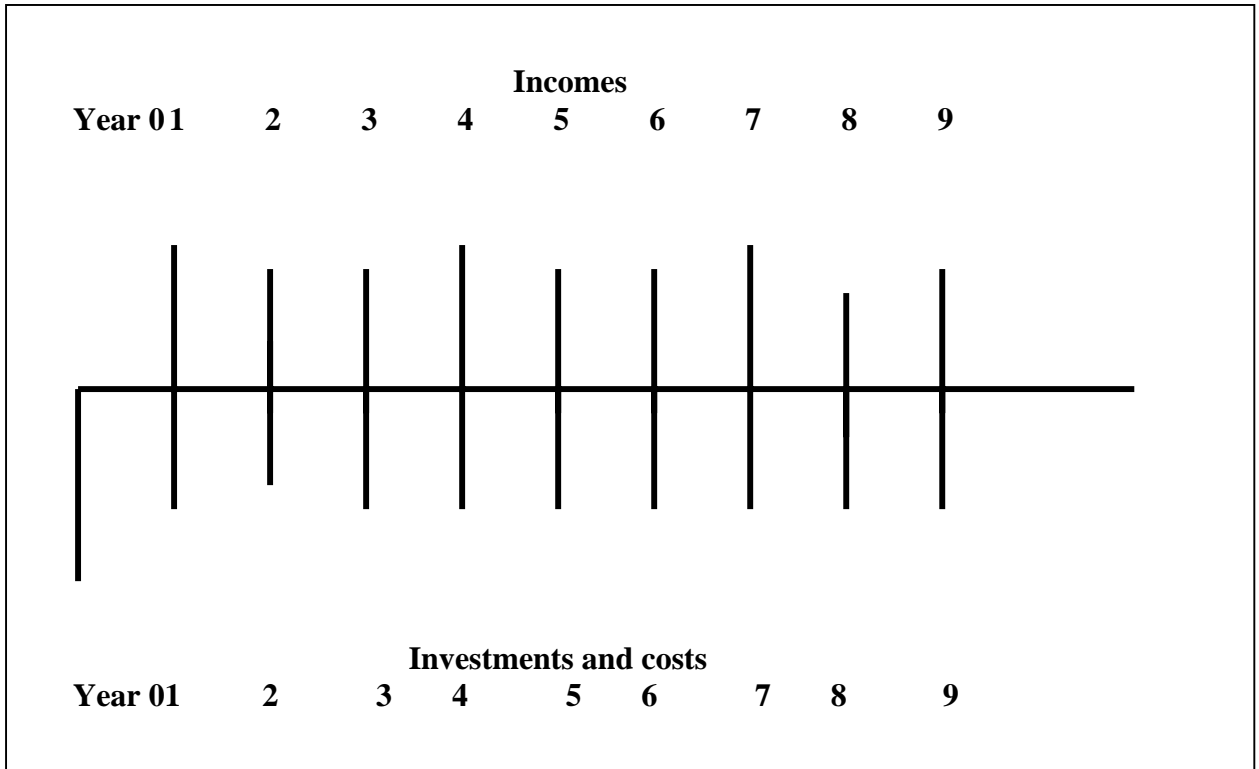
## Appendix 1

The third way to investigate the subsurface layers is by using geophysical methods that analyses the various layers and materials different characteristics. This includes seismic refraction measuring that uses the fact that pressure waves from a detonating charge is moving at different speed depending on the material, and is reflected when hitting different type of material.

Another geophysical method is electrical resistivity survey, where the different layers can be determined because of their different ability to lead electrical current. Electromagnetic methods such as georadar are also used. To determine the characteristics of the aquifer and decide if it yields enough for the intended purposes, more specific tests are needed. Test drilling and test pumping during various length of time are made to determine the ground water level and the hydraulic characteristics of the water bearing layers or crack zones. (Knutsson & Morfeldt, 2002; water.usgs.gov, 2002; [www.pca.state.mn.us](http://www.pca.state.mn.us), 2002)

## Financial Cost- Benefit analysis

The financial cost-benefit analysis is used for calculating the financial internal rate of return, FIRR, that would be achieved on all project costs and benefits measured in financial prices over a specified period of time. The incomes and expenses are counted at the end of each year, as seen in Figure A2-1.



**Figure A2-1** Commonly used time axis that shows incomes and expenses over time. Investment is made at year 0 and the incomes and expenses are counted at the end of each year

First of all, financial revenues and financial costs counted at the end of each year are calculated, Figure A2-1. Financial revenues for water supply projects are water sales, connection fees and meter rentals. Financial costs are capital costs and O&M costs. The net cash flows are derived and the net present value, NPV, calculated. The net present value of a project is the difference between the benefit stream and the cost stream at present value. The NPV for a project should be positive in order to be accepted. To calculate NPV a discount rate must be taken into account. The discount rate is a percentage, which represent the rate at which the value of benefits and costs decrease in value in the future compared to present. Norconsult used the discount rate of 10% in the financial analysis of Outhoumphone and ADB normally use 10-12 % discount rate in Laos.

$$NPV = \frac{C_1}{I+r} + \frac{C_2}{(I+r)^2} + \frac{C_3}{(I+r)^3} + \dots + \frac{C_n \dots I_0}{(I+r)^n}$$

$$NPV = \sum_{t=1}^n \frac{C_t}{(I+r)^t} - I_0$$

where:

$C_t$  = the net cash receipt at the end of year  $t$

$I_0$  = the initial investment outlay

$r$  = the discount rate/the required minimum rate of return on investment

$n$  = the project/investment's duration in years.

$NPV > 0$  accept investment

$NPV < 0$  reject investment

### FIRR

NPV and FIRR methods are closely related because both are time-adjusted measures of profitability. To obtain the FIRR the present value of investments is equated to present value of net incomes. The FIRR is the discount rate at which the net present value for a project equals zero Figure A2-2. This rate means that the present value of the cash inflows for the project would equal the present value of its outflows. The FIRR is the break-even discount rate and it is found by trial and error.

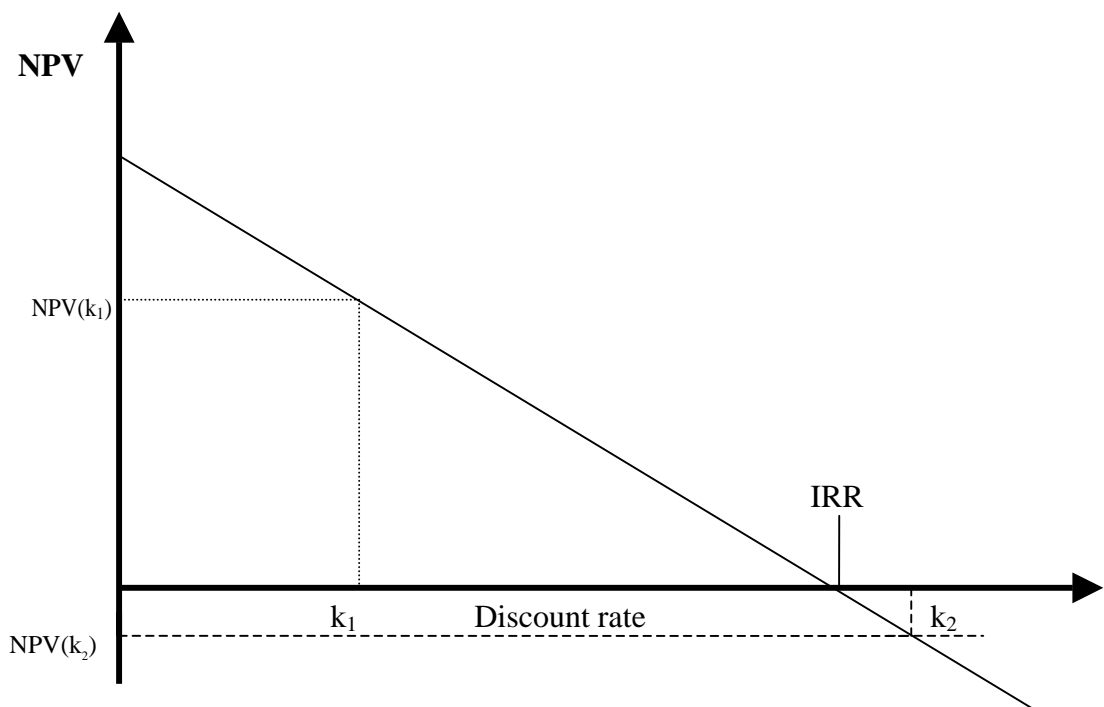


Figure A2-2 NPV versus Discount rate ([www.fao.org](http://www.fao.org), 2004)

The horizontal axis represents the discount rate, and the vertical axis shows the net present value. In the figure,  $k_1$  is the discount rate where the NPV is positive and at discount rate  $k_2$  the NPV is negative. If NPV is positive, as  $NPV(k_1)$  in the figure, and FIRR is larger than  $k_1$ , the project should be accepted, and if NPV is negative, as  $NPV(k_2)$  in the figure, and FIRR is lower than the project should be rejected.

For a project to be acceptable, the NPV must be positive, i.e.

## Appendix 2

$$NPV = \sum_{t=1}^n \frac{C_t}{(I+k)^t} - I_0 > 0 \text{ or } NPV = \sum_{t=1}^n \frac{C_t}{(I+R)^t} - I_0 > I_0$$

Similarly for the same project to be acceptable:

$$\sum_{t=1}^n \frac{C_t}{(I+R)^t} = I_0$$

where:

$C_t$  = the net cash receipt at the end of year  $t$

$I_0$  = the initial investment outlay

$r$  = the discount rate/the required minimum rate of return on investment

$n$  = the project/investment's duration in years.

### **AIFC**

The average incremental financial cost, AIFC, is the present value of the investment and operation costs at financial prices divided by the present value of the quantity of the output sold. Costs and outputs are calculated from the differences in the with- and without project situation. In the financial analysis of a water supply project, the AIFC is the average cost of producing water where investments and O&M are included.

According to ADB, a project is financially sustainable when the following criteria's are fulfilled (ADB economic guidelines):

- have sufficient funds to meet all its resource and financing obligations, whether these funds come from user charges or budget sources
- provide sufficient incentive to maintain the participation of all project participants
- be able to respond to adverse changes in financial conditions.

There are two ways of performing a financial analysis; one is to compare the outcome of the analysis with the results of other water supply enterprises, and another is to watch past tendency/ trend of the result. As there are no reliable figures from earlier other years than 2002, the only possible method in this case is to compare the water enterprises. The financial cost benefit analysis is a useful method for comparing investments in ground water schemes contra surface water schemes because it gives an immediate indication of which is the most viable, as it includes both all the costs and expenses as well as the expected incomes from the project.

## **Economic Cost-Benefit analysis**

The difference between financial and economic cost benefit analysis, is that economic cost benefit analysis uses economic values instead of financial. The economic cost- benefit analysis is used for estimating the economic internal rate of return, EIRR, and NPV of the project costs and benefits measured in economic prices over a specified period of time. We were not able to calculate the EIRR for the water supply systems, but will show consultants calculations in chapter 5.4.5 Water supply in Outhoumphone. There are four basic steps to analysing the economic viability of a project (ADB economic guidelines, point 39):

- identify the economic costs and benefits;
- quantify the costs and benefits, as much as possible;
- value the costs and benefits; and
- compare the benefits with the costs.

The first two steps can often be undertaken together. To identify the costs and benefits of the project, the situation with and without the project is compared. When the costs and benefits have been identified, quantified and valued, the next step is to compare the alternatives. Parameters that can be used are for example economic net present value, economic internal rate of return, and economic opportunity cost of capital, EOCC. ADB's criterion for accepting an alternative is EIRR 12% and a positive ENPV. Calculations are similar to the above mentioned. Some examples of benefits with water supply projects are:

- time-saving when not having to fetch water outside the house
- higher quality of the water leads to less water-borne diseases and deaths
- less taste and odour of the water
- small scale irrigation possible, which leads to increased possibility to garden vegetables

The economic cost- benefit is useful when evaluate what project that needs the least input for a given output. All resources have an opportunity cost and the project that uses the resources most effectively should be chosen. When comparing ground water and surface water, the major differences is within the costs for investment and O&M and therefore the financial analysis is more suitable. Economic benefits are not always possible to translate into financial figures as in the case of clean and potable tap water where the benefits are the same, no matter what source of raw water is used.

## **Environmental Assessment Regulation in Laos**

The regulatory agency in Laos is Science Technology Environmental Agency, STEA, who comes under the Prime Ministers Office. STEA has the overall responsibility for environmental policy and planning in Laos and their role is to certificate, comply and monitor initiated and ongoing projects (Lann, H, STEA, 2004)

In many countries Environmental Impact Assessments, EIA, has been mandatory for many years according to law. In Laos, however, the regulation on EIA was implemented in 2000 and routines are still developing. The regulation on EIA follows the new Environment Protection Law from 1999 and will ensure that *“investment and development projects are environmentally sound and sustainable, enhancing quality of growth and preventing poverty”* (STEA).

In the beginning of 2004, STEA visited the Governmental Line Agencies to inform them about the new regulation (Lann, H, STEA, 2004). One of the findings at the visit to Department of Housing and Urban Planning was that there is no person working with environmental issues at the department and that DHUP not are following the EAR at the moment. The regulation is more often followed in international projects than in the national projects, according to Lann.

All projects must be certificated by STEA. The regulation is applied in a three-step approach (STEA):

- 1) Environmental screening in project description
- 2) Initial Environmental Examination, IEE
- 3) Environmental Impact assessment, EIA

If there are no harmful environmental impacts in the first step STEA approve the project. Otherwise, an IEE must be performed and maybe an EIA. If the EIA show that harmful impacts cannot be mitigated with an Environmental Management Plan, then STEA will reject the project. The latter steps are described further in Appendix 4.

## **Environmental Assessment Methods**

### **Initial Environmental Examination**

The Initial Environmental Examination, IEE, is done during the pre-study of projects. The objective of the IEE is to assess (Norconsult et al, 2001):

- The potential for both positive and negative impacts that may arise from the implementation
- The ranges of measures that might be incorporated into the project to mitigate negative impacts, if there are any
- The need or otherwise for further studies or a full environmental impact assessment

The IEE performed in Outhoumphone, includes the following issues:

- Mining or permanent lowering of the ground water aquifer to be used for the source of water supply
- Sludge and back wash water disposal for the surface water option
- Wastewater pollution from increased volumes of water to be provided
- Wastewater pollution from increased sewage water
- Disturbance, disruption and pollution during construction
- Possible increased HIV/AIDS infections through contractors imported labour force
- Increased risk of criminal activities, traffic accidents etc

The IEE is a brief Environmental Impact Assessment, EIA, and the result shows whether an EIA is necessary before accepting the project. An IEE was performed in both Paksan and in Outhoumphone and both showed that an EIA was not necessary, because the negative environmental impacts were small. None of the water supply projects mention LCA

## **Environmental Impact Assessment**

Environmental Impact Assessment is a method as well as a report and a process, where positive and negative impacts of a project are investigated. To be certificated by STEA, the negative impact should be none or minimal. This is achieved by following an Environmental Management Plan, which details the management process that is used to mitigate environmental damage.

The process of EIA involves all stakeholders, such as public, business developers and project owners, STEA and the line agencies. The Government line agencies have full responsibility for projects within their organisation, to ensure that the environmental assessment regulation is followed. In the case of Projects on Water Supply and Sanitation, the Department of Housing and Urban Planning is responsible for ensuring that Environmental Impact Assessments are done and that the negative impact of the project is minimized.

In an Environmental Impact Assessment of a water supply scheme examples of key issues are:

- Quality of raw water
- Location of water intake/ wells
- Location of wells/treatment plant
- Disposal of sludge
- Energy consumption

None of the water supply projects has completed an EIA. In projects where ADB or Norconsult has been involved, an IEE has been performed. In the two cases when an Initial Environmental Examination was done, the result was that a deeper Environmental Impact Assessment was not necessary as the negative impacts of the projects were minor. In the other cases, there is no information to be found on EIA or IEE.

## **Life Cycle Assessment**

In order to identify the most suitable source for water supply a life cycle perspective of the water production and distribution is necessary. The life cycle perspective is used in the Life Cycle Assessment, LCA. LCA is a method for gathering and processing environmental data for a product or a process, from cradle to grave. All energy and material flows are taken into account (Palme, 2004). The boundaries of the LCA are very important for the outcome of the study. If all inputs and outputs necessary to the process should be completely included, it should result in a very complicated study. The system boundaries should therefore be chosen according to the purpose of the study (Lundin, 2003). In the case, when ground water and surface water is compared, the system boundaries should for example include production of chemicals, generation of electricity, raw water intake and the treatment process. Distribution is not included, because it is similar for the different sources.

There have been more LCA studies performed on waste water systems than of drinking water systems, according to her report. Palme's report (2004) focuses on both urban drinking water systems and waste water systems. The general result of LCA on production of drinking water systems is that the major environmental impact is the generation of electricity and emission to air and water related to electricity generation. Chemicals in the treatment process are not mentioned at all by Palme (2004). In this study, LCA will not be performed, as it requires much more time and details than what were available in this project.

## Used data and source of information

Figures are gathered from different kinds of sources:

- Paksan: Project Performance Audit Report and Benefit Monitoring Evaluation, both from ADB, and annual financial Report (WASA 2003)
  - Thakhek: most information comes from fax from Nam Papa Thakhek
  - Savannakhet: technical information and water balance from Nihon Suido, and from interviews with Nam Papa Savannakhet. Financial information from the Annual Financial Report 2002
  - Outhoumphone: estimations for 2010 by Montgomery Watson
  - Luang Prabang: technical information from the fax from Nam Papa Luang Prabang and financial information from the Annual Financial report
  - Borås: Swedish Water Development Operation Statistic 2002
- Halmstad: Swedish Water Development Operation Statistic 2002

## Appendix 5

<b>Per year</b>	<b>Paksan 2002</b>	<b>Thakhek 2002</b>	<b>Xeno 2010</b>	<b>Savannakhet 2002</b>
<b>Administrative data</b>				
Population in old service area	11153	43511	20828	67200
Population served	9749	18912	16663	65858
Number of connections	1885	3152	1997	9582
Persons/connection	6	6	8	7
<b>Environmental data</b>				
Chemicals used:				
Chlorine kg/year	1744			145400
Alum kg/year				3670
Lime kg/year				0
<b>Water balance m3/year</b>				
Number of wells	5			
Number of surface water plants				
Production capacity	532122	2044000	720000	4860000
Actual production	532136	1789396		4380000
Delivered amount of water		1433058		4328466
Total amount of charged pipe water	472548	1432990		4338466
Internal use of water		20030		
Unaccounted for water	11	0		13
Water sold/person/day l/p/d	93	200	120	206
<b>Personnel and organisation</b>				
Number of employees in Nam Papa	23	50	9	66
Number of employees in water production	7	13	2	11
<b>Financial data</b>				
Total income	1211299	1352209		2259117
Income from water sales	570,838	1,000,868		1867394
Total expenditure	583,792	1,725,744		2054471
Chemicals	3,776	80,137		468032
Operation and maintenance	441,501			89524
Electricity	109,836	340,286		665030
Total profit	627,507			54204

**Table A5-1 Data used in the study**

## Appendix 5

<b>Per year</b>	<b>Luang Prabang 2002</b>	<b>Halmstad 2002</b>	<b>Borås 2002</b>
<b>Administrative data</b>			
Population in old service area	43685	86585	98150
Population served	40500	79000	85750
Number of connections	6318	21300	16051
Persons/connection	6	4	5
<b>Environmental data</b>			
Chemicals used:		0	676 000
Chlorine kg/year	500		
Alum kg/year	17700		
Lime kg/year			
<b>Water balance m3/year</b>			
Number of wells			
Number of surface water plants			
Production capacity	5465628		8689872
Actual production	4728825	8564497	
Delivered amount of water	4044017	8564497	8689872
Total amount of charged pipe water		7442155	6637654
Internal use of water	3263379	93180	0
Unaccounted for water	4570		
Water sold/person/day l/p/d	221	258	212
<b>Personnel and organisation</b>			
Number of employees in Nam Papa	67	52	63
Number of employees in water production	35	6	
<b>Financial data</b>			
Total income	2411879000	97328	142600000
Income from water sales	1,443,723,810	89,908	111,709,000
Total expenditure	2,171,141,170	97,567	141,630,000
Chemicals	128,507,000	586	1,254,000
Operation and maintenance	1,942,206,980	54,797	88,800,000
Electricity	100,427,190	1,984	1,623,000
Total profit			

**Table A5-2 Data used in the study**