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Ref.No.5136/ 660 6 September 1996

Dr. Alain Gares
Director General
SICOVAL (Innopole-Labege)
BP 136, 31676 Labege, Cedex France
Paris
France

FAX: (33)61 39 20 45

RE: SUBMISSION OF MANUSCRIPT

GREETINGS FROM SURANAREE UNIVERSITY OF TECHNOLOGY!!

We have sent you in early August a letter requesting for the final manuscript of the paper you presented last July at the Suranaree Seminar. No doubt you have a very busy schedule that is why we are infinitely grateful for your kind attention and consideration. The Proceedings will not be complete without your contribution. As mentioned earlier, we would like to publish the Proceedings as it is going to be a very valuable reference material.

Please send to CIA your manuscript at the latest the end of this month.

Thank you.

Yours Sincerely,

Prof.Dr.Ruben C. Umaly
Director, Center for International Affairs

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06 SEP 1996

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Ref.No.5136/ 661 6 September 1996

Dr. E (Ted) Rhodes,
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Ref.No.5136/ 662 6 September 1996

Prof.Dr.Kasem Jankaew
Faculty of Forestry
Kasetsart University
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FAX:02 5790172

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17 Manor Way, Belasis Hall Technology Park
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Ref.No.5136/ 651 5 September 1996

Ms.Catriona Moir
Department of the Environment
University of Nova Scotia
Halifax, NS
Canada

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University of Nova Scotia
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Ref.No.5136/655 6 September 1996

Bruce Mitchell
Department of Geography
University of Waterloo
Waterloo , ON
Canada

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305 465 Cereal and Legume Product Technology **3(1-6-2)**

Prerequisite : Postharvest Changes of Biological Materials and Food Processing II or consent of lecturer

Course Description : Chemical composition and quality of cereals and legumes used for processing with emphasis on rice, corn, wheat, soybeans and mung bean; processing with emphasis on non-fat products; keeping quality of products, utilization of by-products, and factory tour.

Course Outline :

1. Chemical composition and use of properties by the food industry (3)
   - 1.1 Rice
   - 1.2 Wheat
   - 1.3 Barley
   - 1.4 Corn
   - 1.5 Soybeans and mung beans
2. Processing of basic products (2)
   - 2.1 Milling
   - 2.2 Wet and dry milling
   - 2.3 Separation of protein and starch
3. Cereal product technology (4)
   - 3.1 Noodle food products
   - 3.2 Bakery products
   - 3.3 Alcoholic products
   - 3.4 Other products
4. Legume product technology (2)
   - 4.1 Noodle food products
   - 4.2 Artificial meat products
   - 4.3 Fermented food products
   - 4.4 Other products
5. Storage of products (1)
   - 5.1 Slowing quality degradation

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Ref.No.5136/ 657 6 September 1996

Dr.Songtam Suksawang
Forest Environment Research and Development Division
Royal Forest Department
61 Phaholyothin Road
Bangkok

FAX: 02 5794336

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10. Trends in the baking industry (1)

Laboratory :

1. Introduction to equipment and techniques in the bakery industry
2. Formulation, calculation and processing
3. Pan bread making
4. Sweet breads, filled breads, buns and rolls
5. Fancy breads
6. Foam cake
7. Butter cake
8. Crispy cookies, butter cookies, sugar cookies
9. Soft cookies
10. Puff pastry (stuffed and non-stuffed)
11. Danish pastry and croissants
12. Pies, tarts
13. Cream puffs and eclairs
14. Doughnut, pancake, waffles
15. Pizza
16. Cake decoration equipment
17. Cake decoration
    - Fondany, fudge
    - Butter cream, whipped cream
    - Meringue-type
18. Fillings
    - Custards
    - Bavarian cream
    - Fruit fillings
19. Composition and simple cake decoration (layer cakes, cheese cakes, cup cakes)
20. Techniques of cake decoration for special occasions

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6 September 1996

Prof.Dr.Kasem Jankaew
Faculty of Forestry
Kasetsart University
50 Phaholyothin , Jatujak
Bangkok
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2. Properties and functions of ingredients (3)

    2.1 Wheat flour and water

    2.2 Salt, sugar and fat

    2.3 Milk and eggs

    2.4 Leavening agents

    2.5 Flavor additives

    2.6 Chemicals for quality improvement

3. Equipment and techniques used in industry (2)

    3.1 Mixing and dough formation

    3.2 Fermentation

    3.3 Shape formation

    3.4 Baking

    3.5 Packing

4. Techniques of making products using yeast (2)

    4.1 Bread

    4.2 Doughnuts

    4.3 Danish pastry

5. Techniques of making products using leavening agents (1)

    5.1 Cakes

    5.2 Cookies

6. Techniques for making other products (1)

    6.1 Pies

    6.2 Pastry

    6.3 Pizza

7. Techniques of making fillings and cake frostings (1)

    7.1 Fillings for various baked products

    7.2 Cake frostings

8. Storage of bakery products (1)

    8.1 Retardation of quality changes

    8.2 Selection of packaging materials

9. Bakery manufacture management (1)

Water Resources Management Strategies in Thailand

Pramote Maiklad*

1. Background

Thailand can be divided into four geographical regions: north, central, north-east and south. The total country area is approximately 513,000 square kilometers. The population is about 60 million.

The average annual rainfall of the whole country is about 1,700 mm, ranges from 1,200 mm annully in the north and central plane and up to 2,000-2,700 mm in the western part of the south and the eastern part of the country. Less than 20% of the surface runoff, approximately 38,000 mcm annually, are kept in various sizes of about 400 large and medium scale together with 60,000 small scale water resources development projects all over the Kingdom, covering about 3.4 million ha irrigable area. The present water demand is estimated to be 39,000 mcm/year and expected to be 45,000 mcm/year in 2000.

At present, there are many problems concerning the water situation in Thailand, such as water shortages in the dry season, floods causing damage to crops and communities in the rainy season, and environmental problems rendering the quality of water in many urban areas useless. Each of these problems annually harms people, animals, crops and property. Thus, it is necessary to manage water resources, water sources and adjacent areas, and related natural resources to prevent and alleviate these problems. It is also necessary to conserve and develop water resources along the waterways so that they are not destroyed or so that their problems are minimized to the greatest possible extent.

In order to make people aware of the country's water problems and the concepts to deal with them, His Majesty King Bhumibol Adulyadej made a Royal address on the occasion of the opening of the Third Princess Chulabhorn Science Congress at the

*Inspector General, Ministry of Agriculture and Cooperatives

Director, Office of the National Water Resources Committee

Shangri-La Hotel, in Bangkok, on 11 December 1995. His speech was entitled "***Water and Developement : Water is Life***" and the text from the speech follows.

"***...On this occasion, I would like to raise some ideas for this meeting to consider. The major principle in the development of water resources is to control the quantity and quality of water according to that which is required. Thus, if there is too much water, means must be found to drain off this excess in time, and not to allow it to cause distress and damage. On the other hand, in times of shortage, there must be sufficient reserves of water with suitable quality for agriculture, industry, and consumption. The problem is that the development of water resources may have some effects on the environment. However, without sufficiently good control of water, whenever there is a natural disaster, this will cause hardship and losses, both in terms of the economy an in the way of life of the people, accompanied by terrible consequences in the damage caused to the environment. Thus, in the major flooding that occurred in Thailand this year, apart from the disasterous losses suffered, much of the tapped water became heavily polluted, causing additional indirect effects. Thus, when the sustainable benefits are considered, along with the damage that can arise from natural disasters, the development of water resources is important and essential. I hope that the results from this meeting will provide new knowledge and indeas, that may be applied to the development of water resources, so as to achieve sustainable benefits for mankind forthwith ...***"

Moreover, H.R.H. Princess Maha Chakri Sirindhorn also made an important address on the occasion of the Fourteenth World Food Day celebration at the FAO Asia - Pacific Region Headquarters in Bangkok on 17 October 1994. Her speech was entitled "*Water for Life*" and it discussed both the nature of the problems and the undertakings being made to solve these problems as follows.

"...Water is needed for food and other manufacturing products which contribute to a healthy life. Scarcity of poor quality of water can have a dramatic impact not only on the quality of life but on survival itself.

In the past two decades, world population has increased rapidly, especially in Asian and the Pacific region countries. Population growth contributes to water scarcity simply because the available must be divided among more and more people, for home consumption as well as agriculture and other development activities. It is impossible to find substitution for water. As yet there is no alternative but for each country to provide sufficient supply of water to meet the ever increasing demand. This means more efficient management of water sources, greater appreciation of the value of water on the part of water users, as well as a better system of waste water to prevent the pollution and degradation of the environment.

As this year's theme implies : Water is Life. Every country has faced the problem of water in different ways and in different degrees. I believe the water problem can be summed up as follows : water scarcity, surplus water and water pollution.

Let me first touch briefly on the second and third problems. Relation to surplus water, every year there are reports of floods due to heavy rainfalls causing damages in agricultural as well as residential areas in many countries, especially in the tropical zone such as Asia and the Pacific. Sometimes the same country suffers from floods as well as drought in the same year, due to natural variation in rainfalls. Take for example the case of Thailand. In the last few years we have faced the crisis of water scarcity because rainfalls had been below average for 2-3 consecutive years, but this year there have been very heavy rainfalls in the North, about 50% above average, resulting in floods which have caused damage in large agricultural areas. And yet, this same region had suffered severely from acute water shortage earlier in the year.

Water pollution can also lead directly to human misery. Dirty water is a major cause of disease and death. Agriculture itself contributes to the pollution problem due to excessive use of pesticides and chemical fertilizers. Since the past few decades pollution

of natural water sources has begun to produce an adverse effect on human life and the ecology. Expansion of cities, economic growth and construction of industrial plants in or near residential areas, all contribute to the problem.

These are serious and urgent problems. The government, non-governmental organizations and institutions, as the people of each country must be firm in their determination to join efforts to solve by concrete, efficient and above all, sustained measures suitable to each location and region.

In the remaining time available I would like to return to the first problem-water scarcity, which is an important problem facing many countries at present, including Thailand, and expected to become more serious in the future. Efficient management of water resources is therefore of the utmost importance.

Chronic water scarcity is mainly faced by countries in North and Sub-Saharan Africa and the Near East. In our own region a number of countries face serious marginal water scarcity in drought years, and where scarcity is less of problem at the national level, water shortages are causing difficulties in specific regions within the countries. This has somber overtones. At present Asia accounts for over half of the world's water withdrawals. Forecasts suggest that Asia will consume 60% of the world's water by year 2,000 but water availability per person per year will decline drastically by the end of the present decade.

Water scarcity in each country results from similar causes such as infrequent and unreliable rainfalls, population growth and rapid multidevelopment activities all requiring increasing demand of available water supply; the ecology of natural water sources destroyed by deforestation and destruction of watershed, causing the drying up of rivers and streams in the dry seasons and flash floods caused by heavy rains running off the land which has lost its vegetation cover. This perhaps helps to explain the apparent enigma frequently experienced in Bangkok and other cities in Thailand when only a trickle of tap water is available in our homes while outside flood water is up to our knees. Lack of water storage such as ponds and reservoirs in the plains and river basin for use in

the dry season, allowing the heavy rainfalls to be lost to rivers and eventually the seas; misuse and waste is endemic among water users both for agriculture and domestic consumption; cities and industries generate domestic sewage, municipal waste and agro-industrial effluent are allowed to drain into water sources untreated; all these contribute to the problems of water scarcity and water pollution.

To sum up, the water problem has been critical for human survival. In Thailand serious efforts are being made to find concrete sustained solutions in all parts of the country. His Majesty's warning has been taken to heart:

*"**Water is life. The principle is that there must be water for home consumption and for agriculture because life depends on it. With water man will survive, without water we will not.**"*

*...In all these and other matters, the human factor is crucial and therefore vigorous and continuous campaigns for water saving and against misuse of water are imperative. Perhaps the best way of making sustainable use of water resources is to empower all users to manage their own supplies. We are all water users and therefore have a responsibility for ensuring that our children and our children's children grow to live in a would, not of water scarcity, but of water security. A world where again **"there are fish in water and rice in the fields."***

2. Water Problems in Thailand

Thailand has faced the problems of water in different ways and different degrees. They are:-

- water scarcity facing many provinces throughout the country at present and expected to become more serious in the future
- surplus water causing damages in urban and agricultural areas, and
- the problem of degradation of the water quality.

2.1 Water Shortage Problems

There are three types of water shortage problems in Thailand.

1) Shortage of water for domestic consumption.

2) Shortage of water for agriculture

3) Shortage of water for industry and other uses.

In the past, it seems that Thailand rarely experienced shortages of water for sustenance or severe water shortage crises. Recently, however, changes in the lifestyles of people all over the country and the greatly increasing population have drastically changed natural conditions and have caused a crisis regarding the water sources on which people depend to make a living. People in the countryside, in the cities, and in industrial zones have an ever grater demand for water, but the amount and quality of consumable water is pitiably low especially during the dry season.

There exist many problems and obstacles concerning the setting up of more water resources development projects. Most significant however, concerns the lack of unity and cooperation between the government and private organizations to find and implement crucial solutions. It seems that the problem of water shortages will not be resolved in the near future, and the needs of people in various areas will go unmet. The nature of significant problems and obstacles follow.

1) Runoff in waterways, streams and rivers in each river basin must be collected and utilized to the utmost by **water resources development** or systematic management to bring water to be used in various fields as much as possible. But as of now, the runoff in different rivers are collected and utilized inefficiently, with a national average of not more than twenty percent of the total amount of runoff around the country. Thus, if in any year rains little, the rain ends earlier than normal, it does not rain in season, the rain is sporadic or there is a long dry spell interval during the rainy season, then the management of the water sources becomes even more of a problems and a water shortage would certainly ensue.

2) Another important cause of water shortages is deforestation, especially near the watersheds. This causes areas upstream to be unable to absorb and collect enough rain in the soil, Thus many creeks, streams, rivers, and canals are waterless or near waterless in the dry season. It is therefore urgent that forests around river basins be preserved and depleted areas be reforested. This task, unfortunately, is full of its own related problems and obstacles.

3) The lack of reservoirs to collect surface water is a major problem, but the topography, water sources, and environments are often unfavorable to the development of reservoirs around the river basins.

4) Natural water sources, such as marshes, canals, and swamps which used to provide water for agriculture and domestic consumption often become shallow due to negligence and abuse on the part of water users. Also these areas are often trespassed for personal use, and many obstacles exist concerning the amending of laws concerned with trespassing in order to develop public waterways.

5) The expansion of agricultural and industrial sectors in the provinces, in addition to the progress of the country and increasing population, causes a continual rise in demand for water. People most often seem to lack awareness of the need to economize water and so are undisciplined in their use of water. Even those who are aware, often do not know how to conserve water in the correct way.

6) As long as people remain unaware of the nature of the country's water problems and of plans for solving theses problems, and as long as development projects are delayed or stopped because obstacles cannot be overcome, the severity of water shortages will increase each passing year, causing damage to all living things, and to the country as a whole.

2.2 Flood Problems

Too much water in the river basin areas result in floods, which then cause damage, sometimes massively, to agricultural land, local communities and urban areas.

Floods are natural phenomena caused by rain which falls in great amounts for many consecutive days for long periods over the catchment areas. This results in the flowing of water over the ground down to the waterways. As this great amount of water flows along the water courses, and the volume increases, the waterways overflow their banks and many areas or communities lacking adequate drainage systems are flooded. Each time it rains heavily for long periods, floods ensue, damaging farmland and property.

When there are big floods in residential areas or over farmlands a great amount of property, crops, and construction are damaged. The big floods in the lower Chao Phraya River Basin which occur time and time again and cause great damage to Bangkok and the outlying areas are examples of this.

The main factors causing floods depend primarily on the physical features of the areas and quirks of nature, such as heavy rain and rising tides. But in some areas, human factors like the expansion of communities, the destruction of natural drainage systems, the overuse of artesian water-causing the land to sink-and deforestation near watersheds and in catchment areas contribute significantly to the severity of floods.

Flood prevention or alleviation is therefore a type of water resources management which bears economic importance in communities and the country as a whole. Its purpose is to solve or alleviate flood related problems, preventing water in rivers and canals from overflowing and flooding adjacent areas. It also aims to drain rainwater collected and flooding over some areas, due to insufficient natural drainage systems, and leading it to rivers, other waterways, or the sea by using whatever methods found to be most suitable to the physical features and nature of the areas.

2.3 Water Quality Problems

The severity of quality problems in water sources increases daily. For instance, salt farming in many areas in the northeastern provinces often proceeds without supervision. The salt-farmers let saline water flow into the natural waterways, causing water in these brooks or streams to fill with brine and thus, become harmful to paddy farms. Moreover,

untreated waste water from houses and industrial plants pollutes water sources in both urban and rural areas, creating health problems for many people who live near these areas. These problems, which can be remedied and prevented, are caused by negligent or ignorant people. Often people are not aware that their actions bring serious and perhaps irreparable harm to the public.

3. Some Problems Encountered in Water Resources Development and Management

At present, the accomplishment of water resources development and management in many river basins still does not meet the target and keep abreast with the growing demands from all water users. A great attempt has been made to expedite both water resources development and management with the conerete national plan as a basic guide. However, in the efforts to attain the objectives, there are existing problems and constraints which shall be remedied before any effective implementation of the plan can be expected. Some major problems and constraints are:

1) In the past few years, the water shortage was spread over most part of the country, especially the Chao Phraya river basin, the drainage area is about 32 percent of the whole country area, due to inconsistent rainfall and runoff pattern and duration. There were scarcity of flow in the rivers and insuficient amount of water stored in the reservoirs for the rapid increase of water demands from all sectors. Facing on the trend of water utilization with demand more than supply, aside from the effort to continue water resources development through construction of large and medium scale projects, to improve water use efficiency in the existing project area is one of the most important issues. However at present, the irrigation water management can not be achieved as proposed in most of the irrigation project area.

2) The demand of water users in the important river basins close to the available amount of supply indicating need of continuation of water resources development. Furthermore, due to concentration of development conducted during the past, future development potential in some river basins has become rather limited. In order to meet

future demands in these areas, water resources development and management plan needs to cover much wider area with more comprehensive planning consideration.

3) The rapid and high growth rates of the economic development achieved in every basin during the past were associated with extensive exploitation and destruction of the natural resources particularly those land, forest, water and mineral resources. Insufficient resources management has contributed to a more rapid deterioration and depletion. In addition, expansion of the economic activities to cover industry and tourism coupled with population growth and water consumption have resulted in increasing seriousness of pollution problems of various items such as contaminated water, polluted air and industrial wastes etc. Those factors affect the water quality in the major rivers.

4) Future water resources development shall give more emphasis on conservation of natural resources and environment. Accordingly, implementation of the water resources development especially the large scale projects will be rather difficult in order to conform with the specific social and environmental requirements.

5) Major purpose to emphasize water resources management is to attain sustainability of water resources availability and utilization in the river basin. The effort toward this objective includes need of watershed management, prevention of water quality deterioration, increasing water use efficiency and establisment of discipline and coporation among water users.

6) There is no single agency with full authority and legal power to administrate, manage, coordinate and supervise the water resources projects both in development and management aspects. As a consequence, the concerning agencies are engaged in more construction works than management. Therefore, it creates low efficiency and less effective water utilization in most of the water resources development projects because of lacking integrated water management plan for the whole river basin.

4. Policies and Measures to Solve Water Problems

At present, Thailand has faced various aspects of water problems such as water shortage for domestic consumption, agriculture, industry, etc., flood annually damaging cultivated areas and communities and low quality of water. In order to effectively solve all aspects of water problems, the water resources management should be clarified into 5 policies. They are

- water resources development policy
- water resources allocation and water use policy
- water resources conservation policy
- flood mitigation policy and
- polluted water treatment policy

Each policy should be practically to attain the target goal. In practice, all policies should suit local communities and provinces, work plans, and perform the works effectively and in conformity with the requirement of each province.

4.1 Water Resources Development Policy

The policy for water resources development is to accelerate the development and provision of water from suitable resources, i.e. surface and underground, for the purposes to solve the water shortage problem for domestic consumption, agriculture, electricity generation, industry, etc. in the potential basin as well as for national economic development both in urgent and long term period.

Measures of water provision for domestic consumption :

1) Surveying all villages throughout the basin which suffer from severe drought consume water below standard and need help. After that a study and suitable planning is to be implemented for each basin and village.

2) Repairing existing pumps, artesian wells and other vessels and clean the shallow wells.

3) Drilling the artesian wells where the groundwater sources are suitable, and developing the waterworks system in each village, if possible.

4) Providing a large vessel in each village to serve as a water bank together with the water trucks for water distribution to the villages, where there is no any water resource in the dry season, upon request.

5) Dredging existing natural canals, swamps, etc. for villages where there are canals and swamps.

6) Excavating ponds for villages at the suitable sites near-by villages.

7) Constructing the small weirs and reservoirs at the suitable sites and suitable basin.

8) Developing the potential surface or underground water resources to be the waterworks system for each village, if possible.

9) Establishing or expanding the Provincial Water Works Authority service area as we have generally implemented throughout the country.

Measures of water provision for agriculture :

1) Providing the non - irrigated areas with pumps.

2) Studying and preparing the water resources development plan basing on the river basin development programs, and set their priority together with those plans as clearly as possible.

3) Dredging existing natural canals, swamps, etc.

4) Excavating a farm pond for individual farmer.

5) Constructing small scale, medium scale and large scale reservoirs at the basins which do not destroy the ecology and life pattern of people in the area.

6) Constructing diversion dams or weirs at river which we cannot construct reservoir project.

7) Establishing electric pumping plants at rivers which we cannot construct gravity projects

8) Diverting water from near-by river basin into that with less water.

9) Developing underground water for cultivation. This measure has been implemented in some basins, so that the area where there is suitable aquifer, underground water development for agriculture should be implemented.

Measures of water provision for power generation :

1) Constructing the large scale dam project in the river basin with sound engineering, economic potential and acceptable impact mitigation.

2) Establishing a reversible hydro-power generation project at the suitable reservoir.

Measures of water provision for industry :

1) Providing or expanding the waterworks system in the service area for industry if possible.

2) Constructing reservoir projects.

3) Encouraging the industrial factory owners to construct their own ponds.

4.2 Water Resources Allocation and Utilization Policy

The general concept of this policy is to manage the allocation and utilization of seasonal available water resources, both natural and constructed by the government in small scale and multi-purpose projects, for the full benefits. Besides, the water could be equally shared among the activities and societies, and used efficiently and economically.

The measures consist of the followings :

1) Giving priority of activities which require water from the constructed sources and clearly define the water allocation ratio as below :

○ to supplement water for wet season cropping in the irrigated area as the first priority,

○ to plan the water allocation in dry season for the following activities in order :

- domestic consumption, as the first priority,
- cultivation as the second priority
- industry as the third priority and others as appropriate.

2) Establishing people's organizations and to encourage them to participate in managing water use at river basin and farm levels.

3) Encouraging the water users to realize on the water shortage problem, especially in the dry season, so that they would utilize water economically and know the value of water.

4) Encouraging the farmers to grow short-lived crops in the dry season instead of dry season rice growing in some basin.

5) Formulating the water law which will be useful for efficient allocation and use of water.

4.3 Water Resources Conservation Policy

The general policy consists of the conservation, improvement and rehabilitation of both natural and constructed water resources not to be deteriorated by nature or man-made so that such resources could be used as long as possible and the environmental conditions would be maintained as well.

The master plan or measures to attain the target goals consist of the followings :

1) Maintaining natural and constructed water resources and to prevent pollution with full attention and on a regular basis. The works shall be clearly defined and assigned

to the responsible agencies in each region with full support of manpower, equipment and budget. The works include :

- water hyacinth and weed control in all rivers, canals, waterways and water resources throughout the basin.
- effective control and prevention of water resources from disposal of garbages, waste water of industrial factories and homesteads.

2) Maintaining and reshaping all natural water resources, protecting them from invaded, not to be in bad shape and dry up.

3) Conserving and stop destroying the forest in upstream watershed area together with reforestation scheme in order to conserve natural water resources for use throughout the year.

4.4 Flood Mitigation Policy

The general policy is aimed to accelerate the flood mitigation in the communities and cultivated areas where the water logging and flood often cause damages to the people and economic condition.

The master plan or measures should consist of the followings :

1) Studying and analysing the topography, rainfall, flood and water logging data for further planning throughout the basin. Thus, a method for flood mitigation suitable for such topography, social condition and relevant impacts and investment cost will be determined prior to submission to the government for further execution.

2) Constructing flood control projects in various river basins to protect the agricultural and urban areas. These structural measures are to be supplemented with adequate non-structural measures such as flood forecasting and warning systems, flood plain management, flood disaster emergency plans, flood fighting, flood operation and updating of flood hydrology to determine current levels of flood protection.

3) At present, there is no specific agency at policy level and executing agency to be fully responsible for flood control in Thailand, so the government should support the permanent manpower and budget until this problem is completely overcome.

4.5 Polluted Water Treatment Policy

The Ministry of Science, Technology and Environment has completely set the policy, master plan and measures for the resolution of water pollution problem both in urban and rural areas. However, the results of implementation were not quite clear as the responsible agencies may not have unity of work performance.

All of these measures in every policy should be practiced at the same time or one from another depend on the environment, circumstance and situation in each basin. Anyhow, in order to make the matter successfully and efficiently it would be organized rationally into distinguished level : the national level, the ministerial level and the project level.

5. His Majesty's Activities on Water Resources Management

His Majesty's activities in alleviating the hardships and promoting the well-being of his subjects have long been evident to the general public. His visits to the people in various provinces throughout the Kingdom made him realize the actual problems and hardships of the people who are mostly agriculturists. Therefore, he has been trying to help them, without discrimination of their races or religions, through establishment of various development projects.

One important activity is water resources development to which His Majesty has given full devotion. His Majesty's interest in water does not involve only developing water sources so that his people may have ample water for home consumption and agriculture in all seasons, but also the management of water resources to create an

equilibrium between the quantity and quality of water which is considered the most important factor in the livelihood of the Thai people.

During each visit to the people in the rural area His Majesty would introduce some initiatives to develop the water resources for the benefits of the people in the area. Some of them are derived from his own ideas and some from the requests of the people themselves.

With regard to his own initiatives, His Majesty would make the preliminary studies and planning of the project by himself. Then he would convey his ideas or concepts of the project to officials of the Government agencies concerned so that they would further implement that project step by step from feasibility studies and project planning to the construction of the project.

Some Royal initiative project would come about in response to verbal requests by the people, or through written petitions for assistance which at times would be presented with detailed requirements or with rough-drawn maps. Sometimes people would make petition for several things; e.g. water resources, roadways, electricity, schools, etc. Concerning the water resources aspect in particular, if His Majesty considers a project feasible, he would propose his idea to the accompanying officials of the Government agencies concerned to consider the appropriate programme to be carried out at an appropriate time. However, if any project could not be determined as to the time limit, it would be kept for consideration after more information has been obtained and further studies made so that proper assistance could be extended.

The Royal initiatives concerning water resources development, conveyed to the Goverment agencies concerned are only guidelines for their further consideration in accordance with technical principles and procedures. The proposed projects can be scrapped if considered unsuitable; such as, for high construction cost due to poor dam foundation. Sometimes the project might appear suitable when drafted in the 1 : 50,000 scale map but after a reconnaissance the topographical conditions may be not what

appeared in the map due to some error. In such case the Government agencies concerned may also consider scrapping the projects.

5.1 His Majesty's Solving Water Shortage problems

His Majesty learns that most of the people who are farmers often face troubles concerning water shortages and cannot successfully pursue their careers as farmers. The majority of people in remote areas are poverty stricken without sufficient food. Therefore, His Majesty has been trying to solve the problems of water shortages by providing sufficient water for agriculture and for consumption for these people through various methods suitable to the nature of each locality.

5.1.1 The Management of Water Resources in the Atmosphere

Water resources management in the atmosphere is a process in which water in the atmosphere is brought into use by inducing the moisture in the atmosphere to precipitate into spray. When the spray amasses, clouds form. Then the clouds are stimulated to amass and increase in volume until it rains. This process is called ***Artificial Rain-making***. It is just one method of increasing the amount of water in water sources and increasing moisture in the areas in addition to what can be done by natural rainfall.

His Majesty is greatly interested in the Artificial Rain Project since he is aware that during the period when it does not rain or when there is a long dry spell interval, the farmlands without natural water sources or irrigation projects suffer from a lack of rainwater. Each year this causes extreme damage to crops. Having studied the nature of water in the atmosphere in the form of humidity or natural vapor, His Majesty believes that it is possible that Thailand can manage water resources in the atmosphere during the time when humidity in the atmosphere is suitable for inducing rainfall out of the normal season. Thus, he first gave the initiative to academics and officials in the Ministry of Agriculture in 1956 to develop scientific technologies to turn vapor in the atmosphere into clouds and speed up the amassing process of these clouds until it rained at a specified

time. This project was given the auspicious name of ***Royal Rain Project*** by His Majesty in 1969 and since then, the different groups of the ***Royal Rain Project*** committee have experimented with trial flights in order to make studies and research to find suitable ways to make artificial rain in conjunction with doing field jobs to help people in the areas plagued by water shortages. The Royal Rain Project has played an important role in efficiently solving water shortage crises in different regions of the country.

○ Procedures in the Making of Royal Rain

At present, artificial rain, or *Royal Rain*, is produced by first strewing chemicals by plane to cause water vapor in the atmosphere to gather and form clouds, and then by nurturing these clouds to grow. The last step is to attack these clouds so that they break up into rain over the target areas. His Majesty has laid down the following procedures for makng artificial rain.

Step 1 : Agitating

The first step begins with the creation of clouds until they form in a vertical direction. This is done by dispersing chemicals to stimulate the air mass to float upward, and then the water vapor would be induced to gather and form clouds. The ideal time for operation is normally in the morning before ten o'clock by throwing chemicals upwind of the target area that can absorb vapor from the air mass and stimulate cloud formation. When the clouds begin to form they grow vertically. Then chemicals with vapor-absorbing ability are strewn in circle downward to stimulate the formation of the clouds which will be the nuclei in the operation area for use as a center to build up rain clouds in the next step.

Step 2 : Fattening

This is the step to make the clouds develop to their maximum size. The operation in this step is of the utmost importance. Operators in the planes must use the technology,

experience and art of *Royal Rain-making* to make a correct decision in dispersing chemicals in the clouds to fatten them up. That is, they need to know what kinds and amounts of chemicals need to be dispersed on what part of the clouds so that do not dissolve and instead increase in size up to the desired level.

Step 3 : Attacking

This is last step of the *Royal rain-making* procedure. When the clouds are dense and about to precipitate into rain there will be many large drops of water within the clouds. If a plane is flown into these clouds, thick drops of water would cling to the wings and fuselage of the plane. At this stage of operation, it must be considered whether the objective is to increase the amount of rainfall in general or to make it rain over the target areas because the method of attack and the chemical used will be different in each case.

○ The Techniques of Planning the Royal Rain Operations

The academician who makes a good planner of the Royal Rain operation should be a person with unflinching determination in carrying out the operation. He should be firm, cheerful, with an artistic inclination, that is, a thoroughness in observing the changes in the atmosphere, a willingness to understand the role and natural mechanisms of clouds and rain-forming processes. He shouls also employ a high level of psychology in relating to other people in order to create unity in group work.

He should be able to perform the following :

1) Study the objectives and scope of the Royal Rain operation area beforehand on each occasion.

2) Study and analyze the physical features in the target area of operation and nearby areas to see how they relate to the distribution and volume of rain in order to specify principal and secondary target areas.

3) Select an aea with an environment most favorable for producing rainfall as the principal target. Such areas as forests, mountain ranges, and cultivated lands that

are still lush and have statistically greater rainfall than other areas should be chosen to create patches of humidity. Then the scope of operation is subsequenty extended. The areas less favorable for producing rainfall are secondary target areas which reinforce the operations, when they are covered by thick rain clouds.

4) Choose the area where natural clouds are most likely to form as areas of operation for chemical disbursement. This area is to be used as a center from which clouds are conveyed into the target areas, such as mountain ranges or high summits, thus making the most out of nature.

5) Take into consideration the formation of middle-and upper-level clouds covering both irrigated and non-irrigated areas in the event that no suitable area of operation for the disbursement of chemicals can be found when the target area needing the rain is an extensive plain and the direction or velocity of winds are not favorable for use in the desired areas. Then the formation of middle-and upper-level clouds, covering irrigated and non irrigated areas must also be considered since they have an impact on the change in direction and velocity of wind at each level, and also on the uplift pull in each locality.

6) Study and analyze daily the relationship between comprehensive meteorological data and local meteorological data to see whether they are favorable to the fall of rain in the area and at what level. The comprehensive meteorological data provide knowledge about the characteristics of times when clouds are formed and the changes in the distribution and amount of rainfall which add to the accuracy of the local meteorological data. The local meteorological data provide knowledge about the places where clouds form, the characteristics, types and amounts of clouds, as well as the periods when it rains in the areas. These data include the velocity and direction of upper level currents, relative humidity, the atmospheric temperatures in each level, etc. (The places where clouds and rain occured need to be studied and predicted daily to increase the expertise of rainmaking in each area.)

7) Study the power and number of planes availble for daily operations in the process of chemical disbursement to make artificial rain in order to adapt to the operation plans to suit the changes in the rain clouds effectively. Continuous operations are emphasized for effectiveness in inducement of rain clouds.

8) Follow regularly the results of the operations by radar sightings and cooperate effectively with local units about reports of rainfall observation. The data received are used to study and analyze the results of the operations in order to improve the plans of operation for the following days.

5.1.2 Surface Water Resources Development

The development of surface water resources is the procurement and conveyance of water from natural surface water sources for use to solve the problems of water shortages and for other purposes through appropriate means.

The surface water resources projects initiated by His Majesty and operated by various agencies consist of many types. The details of each project can be summed as below.

○ Reservoir Projects

Reservoirs store water that flows along natural channels or waterways by building dams in mountain passes or between hills. These dams are called *Impounding Dams*. The collected water forms various sizes of reservoirs.

Most of the impounding dams in the Royal Initiative reservoir projects for consumption and agriculture are not so high. Thus, they are popularly built with compacted earthfill. An impounding dam of this type is called an *Earthfill Dam*. Every step in choosing the site, surveying, planning and constructing the earthfill dam must be done according to engineering technologies to ensure that the dam is stable and durable.

The reservoir storages will vary according to the height of the dams. The water will be distributed for rice cultivation, cash crops, pasture for livestock and for domestic

consumption of the villagers as required. Moreover, the reservoirs will be utilized for fish culture and prawn farming as well as for flood protection and alleviation of flooding of the cultivated areas on both banks downstream.

Most of the reservoir projects effectively solve problems of water shortages in areas where water from streams and creeks flow only in the rainy season. The reservoirs store the abundant rainfall excess for use all throuhg the dry season.

Areas where water shortages occur regularly exist in every region of the country, especially in the northeastern region. Thus, many reservoir projects according to Royal initiation are set up in these areas, enabling farmers in the project areas to increase their production. With sufficient water, the farmers can grow crops well, both in the rainy and dry seasons. Rural people in areas where seasonal farming used to be unproductive and cultivation during the dry season impossible are now able to increase the production of crops in the rainy season and have water for cultivation in the dry season.

As for water for consumption, when the Royal initiative reservoirs are built in various areas, people who used to suffer from water shortages in the dry season no longer worry about their water supplies and their livestock have plenty of clean water for use all year round. The villagers become more healthy and they are better able to supplement their incomes by raising more livestock. And in some cases, livestock farming can provide the main source of income for families. Besides providing water for consumption and agriculture, reservoirs are excellent places to breed aquatic animals. When His Majesty visits and inspects the finished reservoirs, he sets baby fish and shrimp in each reservoir as an initiating gesture so that people in these areas may have fish and shrimp for consumption.

○ Marsh and Swamp Dredging Projects

These are projects to dredge shallow natural marshes and swamps so that may be deep enough to hold more water. By nature, most marshes and swamps are depressions or lowlands that have a natural balance to collect an amount of water. If in any year it

rains so much that the amount of rainfall that goes into the marshes exceeds the normal amount, the excess water would be naturally drained through the drainage channels in the low areas so that the level of water in store would be the level of the crest of the water channels.

Most marshes and swamps are flat and shallow since the rainfall excess usually erodes the soil and deposits it in the waterways every year, causing many of them to be unable to hold much water, which will not be sufficient for use throughout the dry season due to evaporation.

Dredging marshes and swamps to make them deeper is one way to increase the amount of reserved water to meet the demand. This method enables the amount of water in marshes and swamps to increase while the level of water remains the same. Nevertheless, expenses must be considered carefully, since the amount of soil from the bottom of the marshes and swamps that is dug out must be the same as the increased volume of water.

Water in the marshes and swamps can be pumped up to grow vegetable gardens or field crops, to raise livestock, or to use for consumption within the villages. The marshes and swamps themselves can be used to breed fish.

At present, many of the aforementioned natural water sources that previously provided water for consumption and agriculture have dried up or been entered by force, leaving villagers with insufficient water for use through the year. Therefore, His Majesty has given his advice that in areas where there are marshes and swamps, these places are to act like natural reservoirs to store water in the flood season so that there will be water available for use in the dry season. When these marshes and swamps become shallow and unusable, and when many areas are occupied unfairly, suffering ensues in the communities requiring the water.

His Majesty has thus given his Royal initative to various agencies to dredge and restore the natural marshes and swamps in many provinces in the nostheastern and central regions.

○ Pond Projects

Ponds are constructed to store rainwater, runoff, or water seeping from the ground by digging in the ground to create them. The length, width and depth of these ponds are in proportion to the amount of water needed to be stored for use.

Most of these ponds have small water capacities. They are commonly dug in areas where no natural waterways exist or the physical features are not favorable for the construction of water reservoirs or other types of water storage.

The water kept in these ponds may be surface water flowing through narrow channels and water seeping or gushing from the ground. Most of the stored water level is only a little higher than the adjacent soil. In some areas the water is kept at a level lower than the natural ground surface. Water from these ponds is used to grow vegetable gardens, raise livestock, and be consumed by people.

His Majesty is aware that villages and cultivated areas with water shortage problems exist in every region of the country. He knows that every area cannot be aided by a reservoir, diversion weir, or marsh and swamp dredging project, as there are limitations concerning the physical features, natural water sources, the environment, and socio-economic conditions in each area. Thus, His Majesty is interested in providing water to support cultivated areas by digging ponds for each farm in every area where the rainwater entrapped in the fields in the rainy season facilitates rice farming but where there is no water in the dry season. When ponds are dug in the cultivated areas, enough of the abundant water in the rainy season can be stored to be used for consumption and integrated farming in the dry season.His Majesty initated the idea of providing water for approximately 6 acre of cultivated land by allotting 25-30% of the overall area for pond digging-ponds being 3.5-4 meters deep-with the remaining area divided 30% for rice farming, 30% for fruit and field crops, and the final 10% for houses and some facilities. According to His Majesty, this type of pond is a "*New Theory*" for solving water shortage problems for rural people in various areas. The provision of water according to this "*New Theory*" was first introduced on a piece of land about 6 acre in area belonging

to the Chaipattana Foundation near Wat Mongkhol Chaipattana, Amphoe Muang Saraburi, Saraburi Province. It has since expanded to areas owned by more than one hundred villagers at Amphoe Khao Wong, Kalasin Province. The results have been satisfactory and now each farmer has water to work on his integrated farm, bringing a stable income to his family.

His Majesty's activities in the management of water resources, especially the development of water sources by utilizing surface water to solve water shortage problems have resulted in many Royal initiative water resources development projects scattered in different areas in every region of the country. In proposing his initiatives to be carried out by involved agencies, His Majesty always considers the suitability of the physical features, the conditions of the water sources, economic and social aspects.

5.2 His Majesty's Solving Flood Problems

Preventing and solving flood problems are water resources management projects that bear great economic significance on the whole nation. His Majesty's initiatives instruct the involved agencies to carry out the prevention or abatement of floods. In the flood season when the water level in the waterways is high so that it cannot inundate cultivated lands causing damage to crops or flooding residential areas. Water is also drained from lowlands or waterlogged areas that have become unfit for cultivation so that they may become arable again by using locally accepted methods.

The various agencies charged with carrying out royal initiative projects to solve flood problems employ various methods, each being different in terms of suitability to the physical features of the areas and capabilities in preventing or solving flood conditions, as well as expenses.

- Construction of dikes or levees along both banks of rivers.
- Construction of diversion channels or by-pass systems.
- Improvement of waterways features by improving and enhancing the waterways to facilitate the flow of water.

○ Construction of impounding dams. Impounding dams are generally built of different sizes. Some large impounding dams can be utilized in many ways, such as for producing electricity, irrigation, waterborne communication, fish and shrimp breeding in the reservoirs, and flood relief. This type of impounding dam is called a *Multipurpose Dam*.

○ Drainage of water from waterlogged areas. To drain water from waterlogged areas, an important undertaking is the digging or improving of drainage canals within specified areas so that a large amount of water can be conveniently drained out of the areas to large waterways or the sea, lowering the level of waterlogging or enabling the use of the areas for cultivation when needed after all the water has been drained out.

At the end of drainage canals there normally are water gates or drainage pipes to control the storage of water within the canal and prevent a high level of water from the outer area to flow back into the drainage canal areas. To drain water from community areas or from some important areas for cultivation, a large water-pumping station sometimes needs to be built to pump the water in the areas out at times when the level of water outside the area is high.

His Majesty is greatly concerned with the problem of waterlogging, especially the almost annual waterlogging in Bangkok and its outlying areas. Thus, he has proposed ways to help solve or ease the problems of floods and waterlogging in Bangkok and the vicinity east of the city. The agencies involved, namely the Royal Irrigation Department, the Bangkok Motropolitan Adminstration, the Department of Highways, and the State Railway of Thailand have cooperated to study the ways to solve the problems in detail and have built a system of flood prevention and drainage to comply with his Majesty's wishes. The project, once finished, succeeded in abating the flood problems and draining water from most areas in Bangkok and its vicinity.

5.3 His Majesty's Solving Water Quality Problems

His Majesty is concerned about natural water sources in each region that have deteriorated both from natural elements and human hands. Thus, he has proposed that the involved agencies study, experiment on, and carry out the solution for this problem in a concrete way both in Bangkok and in the countryside. From his initiatives, His Majesty puts an emphasis on simple methods that cost little to carry out for they should be tried first until appropriate feasible methods can be found. Then they can be expanded into large projects to suit the nature of problems in each locality.

5.3.1 Solving the Problems of Saline and Brackish Water

His Majesty has given Royal initiatives for concerned agencies to solve problems of saline and brackish water in many instances and areas. There have been several significant initiatives.

1) Royal initiatives in solving saline water problems caused by salt farming in the northeast. The salt farmers usually allow saline water from the salt spread yard or rainwater that falls over the salt spread yard to flow along the water channels and creeks in nearby areas without adequate control. Saline water then spreads so extensively over these areas so that the land cannot be used to grow rice, or the quantity of rice produced decreases, causing hardships for rice farmers.

His Majesty has proposed ways to enable salt farmers to work on their farms without causing damage to nearby rice farms. Salt farmers must allot a section of the salt spread yard for digging a large pond to contain the saline water released from the salt spread yard. This water is kept in the pond until it evaporates or flows into the ground through small tube wells that have been dug to drain water down to the level of underground saline water that has been pumped up.

2) **Royal initiatives on preventing saline water from spreading into waterways.** In order to enable the people along the banks of the rivers and tributaries in the south to

have fresh water for consumption and agriculture year round, His Majesty proposed ideas to consider ways to solve the problem fo saline water entering many rivers. The finished product is the Royally Initiated Bang Nara River Basin Development Project in Narathiwat Province, and the project in operation is the Royally Initiated Pak Phanang River Basin Development Project in Nakhon Si Thammarat Province.

The Bang Nara River Basin Development Project is a large scale water resources project in the south that the Royal Irrigation Department has carried out to comply with His Majesty's wishes. His Majesty has suggested the construction of two watergates to control the water at the mouths of the Bang Nara River to prevent saline water from entering the river and to store up fresh water for year round use. The Japanese government has provided aid to study the suitability of the project and paid for the cost of building the two watergates, namely the Upper Bang Nara Watergate and the Lower Bang Nara Watergate. These two watergates, completed in 1990, are able to prevent saline water from entering the river system, store fresh water to benefit 42,000 acre of cultivated land in the project area, and provide ample fresh water for people on both sides of the river for year round use.

5.3.2 Solving Problems of Polluted Water

During the past few decades, the problems of polluted water in water sources and communities in every region of Thailand have begun to made a distinct impat on people's lives and the environment. As a result of developments following the progress of the country and economic expansion, a geat number fo industrial plants have been set up in community areas without adequate treatment of waste water. Before waste water is released into natural water sources, it should meet certain standard criteria. Some of the watste water is expelled from dwellings without being treated first. This is a serious matter about which the people who are involved, or the affected communities, must take urgent measures to amend the situation.

Besides being dirty, smelly, and dark, polluted water may also contain toxic chemicals. When it flows into natural watercourses, such as rivers, canals, marshes, and swamps, it contaminates the clean water sources so that the water becomes polluted and cannot any longer be used. It may also exude foul smells which spread around, endangering the health and livelihood of people who live in those areas. Aquatic animals in the watercourses may die or be forced to migrate elsewhere. This harm thus affects both people's health as well as the economy of the country.

His Majesty, being concerned about the livelihood of people living near polluted water sources, has given initiatives for treating polluted water through the use of several methods.

- **Treatment of Polluted Water with Water Hyacinths** His Majesty is interrested in developing existing water sources like marshes and swamps and turning them into centers to treat polluted water coming from the canals be using water hyacinths, as has been done in the Royal initiative Makkasan Swamp Project.

In the swamp, water hyacinths are grown in wooden enclosures, floating at intervals across the swamp to absorb toxins, chemicals, heavy metals and organic substances suspended in the water. The water hyacinths successfully remove offfensive materials in the water, making it clearer and to a certain degree better in condition. By testing the quality of water in the swamp that has been filtered, it has been found that the amount of oxygen dissolved in the water has increased, showing that the water flowing into the swamp after it has been filtered by the water hyacinths is of a better quality than before.

- **Waste Water Treatment Using the Aerated Device** At present, the polluted conditions of water in many areas have been aggravated. Water in canals and public water sources has become malodorous and hazardous to health. To treat this problem, it is thus necessary to use mechanical devices to add air to polluted water to increase the amount of oxygen. His Majesty, with an interest in an apparatus for adding air of oxygen to polluted water, has presented a model that is simple, economical and capable of being

used as a prototype for the agencies to easily build for general use. He has arranged for the Chaipattana Foundation to subsidize a study and research of such an invention and cooperate with the Royal Irrigation Department to build an apparatus to treat polluted water. The aerating device widely known as the *Chaipattana Aerator* is quite popular and is currently being used almost everywhere in the country.

The aerating device widely known as the *Chaipattana Aerator* is an apparatus designed to revolve slowly like a floating buoy and fill oxygen in the water surface. It is also effective for air circulation. It can be adjusted according to the rising and falling levels of water in polluted areas. The main components consist of a twelve-sided aerator structure with a two meter diameter with six trapezoidal water buckets. each capable of holding 110 liters of water, affixed at even spaces around the aerator structure. These water buckets are porous to disperse the water into spray. Installed on the floating buoy is an axle on which the aerator structure revolves. A power generator spins the aerator structure, causing it to scoop up water and let itfall back down. In this way, the water comes in contact with air, thus increasing its oxygen content.

The contact area between the water surface and the air is great enough to enable oxygen in the air to be absorbed quickly into the water. At the same time that polluted water is being splashed up into contact with the air and is falling back to strike the surface of the water, fresh air bubbles are being forecd and pressed down into the water. While the water buckets are moving down and passing through the water, the trapped air is compressed within the buckets and absorbed into the water, thus increasing the circulation of oxygen. Water which has already been aerated is propelled out by the spinning water buckets at a flow rate of approximately 0.20 meters per second up to a distance of about 10 meters.

Additionally, the rocking motion of the floating buoy at work enables the hydrofoil sheets attached to the submerged part of the buoy to push the water and mix it with the oxygen. Thus, the process of aerating, blending, and flowing of polluted water into the specified direction occur simultaneously.

The Chaipattana foundation, in cooperation with the Royal Irrigation Department (Hydro Equipment Research and Development Office) and the Royal Thai Navy, has manufactured the aerating device, the *Chaipattana Aerator* to comply with His Majesty's initiative for use in the solving of water pollution problems in community water sources, such as temples, schools and hospitals. At present, the foundation is contemplating cooperation from technical colleges and various institutes to help with the manufactuing in order to expand the operations in solving the problems of water pollution for the benefit of the masses. This is a pressing problem requiring serious and cooperative effort.

The *Chaipattana Aerator* can be industrially manufactured. Its treatment of water pollution is ideal for many situations. It can be used to treat waste water from communities, industries and agriculture, by increasing the amount of oxygen in the water to improve water quality. It also allows for increased water volumes in aquatic animal ponds, further benefiting farmers.

The Department of Intellectual Properties in the Ministry of Commerce has issued a patent, No 3127, for this device under His Majesty's name. His Majesty graciously granted an occasion for H.R.H. Princess Sirindhorn to receive the patent on his behalf from the Minister of Commerce and his party at Chitralada Palace on 2 July 1993. The *Chaipattana Aerator* is the ninth aerating device in the world to be patented.

July 15, 1996

INTERNATIONAL COLLOQUIUM ON SCIENCE PARK FOR MEETING TECHNOLOGICAL CHALLENGES OF THE 21ST CENTURY

26 JULY 1996

PROGRAM

0730-0845	**REGISTRATION**
0900-0910	**OPENING AND WELCOME REMARKS** **Prof. Dr. Wichit Srisa-an, Rector**
0910-1000	**KEYNOTE ADDRESS** ***University/Industry Technology Transfer*** ***A Process That Really Works!*** Dr. E (Ted) Rhodes,- President, Technical University of Nova Scotia
1000-1015	**Break**
	PANEL PRESENTATIONS
1015-1200	***British Experiences in Science Park Operation and Management*** Mr. George Hunter, Chief Executive Belasis Hall Technology Park ***The Science Park of Labege Innopole*** ***: From High Tech.Development To Social Integration*** Dr. Alain Gares, Director General SICOVAL Innopole- Labege, Toulouse ***University / Industry Linkage in Thailand:*** ***Critical Concept of Education Reform*** Dr. Peter Brimble, Brookers Co.,Ltd. Bangkok Dr.Chatri Sripaipan, Chulalongkorn University
1200-1300	**Lunch**
1315-1430	**PANEL PRESENTATION** (continued) ***Technology Transfer from Universities and Research Centers to the Private Sector*** ***: Case study: Quebec-Canada*** Dr. Michel Khalil, University of Quebec at Rimouski ***Industry-University Linkage: INP de Toulouse's experience*** Dr.Christophe Haunold, Institut National Polytechnique, Toulouse.
1430-1500	**PAPER PRESENTATION** ***TECHNOPOLIS: SUT SCIENCE PARK*** Asst. Prof. Dr. Weerapun Sriboonlue Vice Rector for Development, Suranaree University of Technology
1500	**CLOSING REMARKS** Asst. Prof. Dr. Weerapun Sriboonlue Vice Rector for Development, Suranaree University of Technology
1515	**Coffee Break**

WATER USE / DEVELOPMENT POLICIES AND REGULATIONS

CHUANPIT DHAMASIRI
GOVERNOR, METROPOLITAN WATERWORKS AUTHORITY
BANGKOK, THAILAND

A UTILISATION OF WATER RESOURCES :

1. INTRODUCTION

The Siam Waterworks which comprised the Khlong Prapa (a raw water canal) was initiated during the reign of His Majesty King Rama V. The inception of the water supply system reflected His Majesty's concern over the water from natural sources especially the Chao Phraya River declining in its purity and thus unsuitable for consumption. The quality of the river water was also threatened by sea water intrusion, especially during the dry season. This problem coupled with the tendency of higher pollution due to the growth of the communities resulted in the quality of the river water being deteriorated.

On 13 July 1909, His Majesty King Rama V issued a Royal Proclamation, instructing the Department of Sanitation to supply water in Bangkok under the following procedures (Figure 1) :

1. Build a reservoir at Chiang Rak Canal in Pratumthani as the area is beyond sea water intrusion in all seasons,
2. Construct a canal from the reservoir to the north of Khlong Sam Sen along the railway line,
3. Construct a pump station at the above location to deliver raw water to the water purification system and distribute to the areas in Bangkok.

A total land area of 1,097 Rai, 3 Ngan and 43 square Wah (approximately 439 acres) was purchased for the construction of pump station, raw water canal and Sam Sen Water Treatment Plant. The average land price was 30 Satang per square Wah. As the project benefited the general public, 33 landlords had also joined in with a total land of 24 Rai, 3 Ngan and 28 square Wah (approximately 10 acres) being donated.

Basin and Raw Water Canal

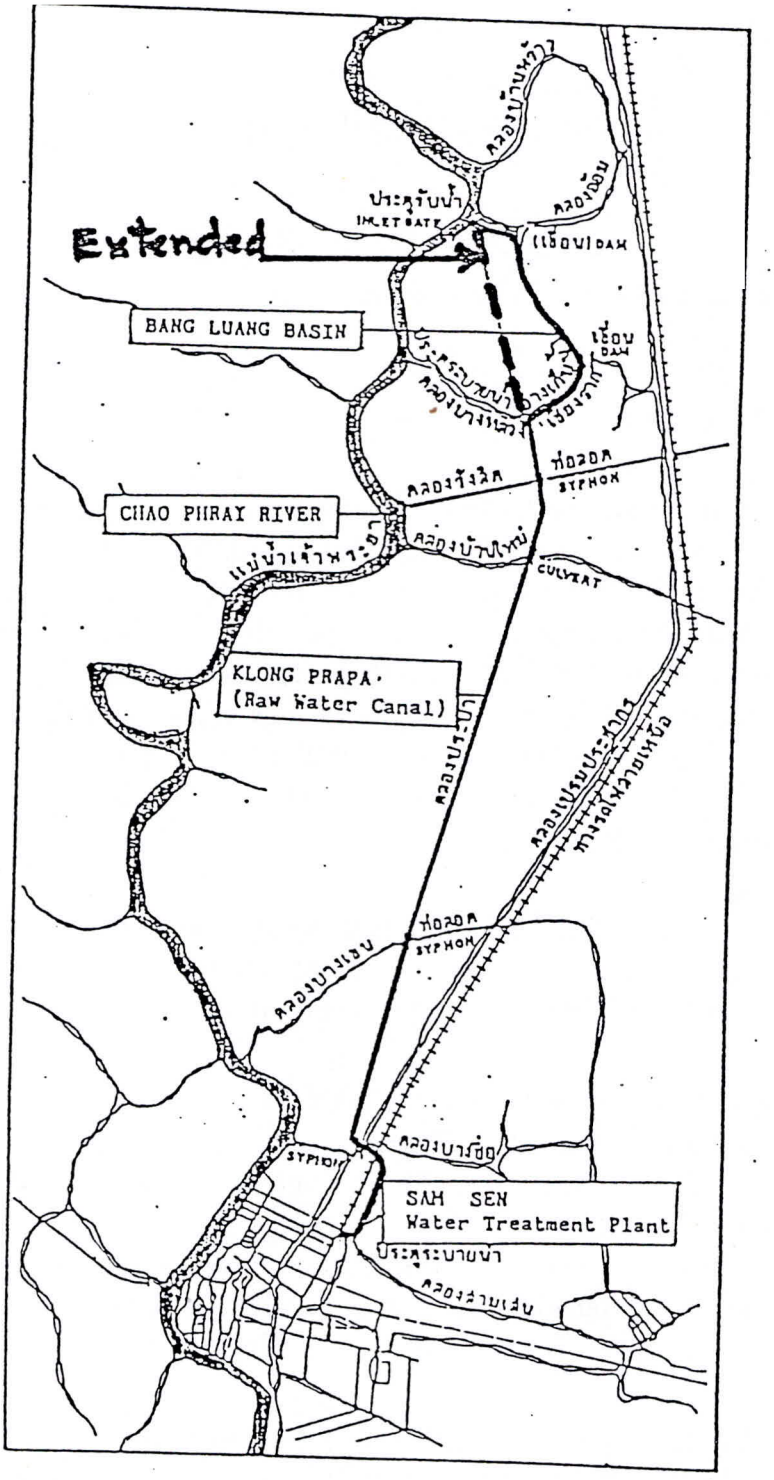


Figure 1

The first stretch of the Khlong Prapa approximately 25 kilometers long was constructed from the reservoir canal at Bang Poon District parallel to the Khlong Prem Prachakorn to the Sam Sen Water Treatment Plant. The flow through the 25 km Khlong exposed the water to air and sunlight which helped improve the quality of water. Construction work was completed in October 1913 and the Khlong Prapa Act was promulgated in the same year. The main objective of the Act was to prohibit fishing, bathing, washing clothes or dumping garbage in the canal. Violators were subjected to heavy fine.

In 1980, MWA extended the Khlong Prapa to a total length of 31 kilometers to draw water directly from the Chao Phraya River at Sam Lae District. This was due to the amount of raw water withdrawn from the reservoir canal being unable to cope with the ever increasing requirements of the water treatment plants.

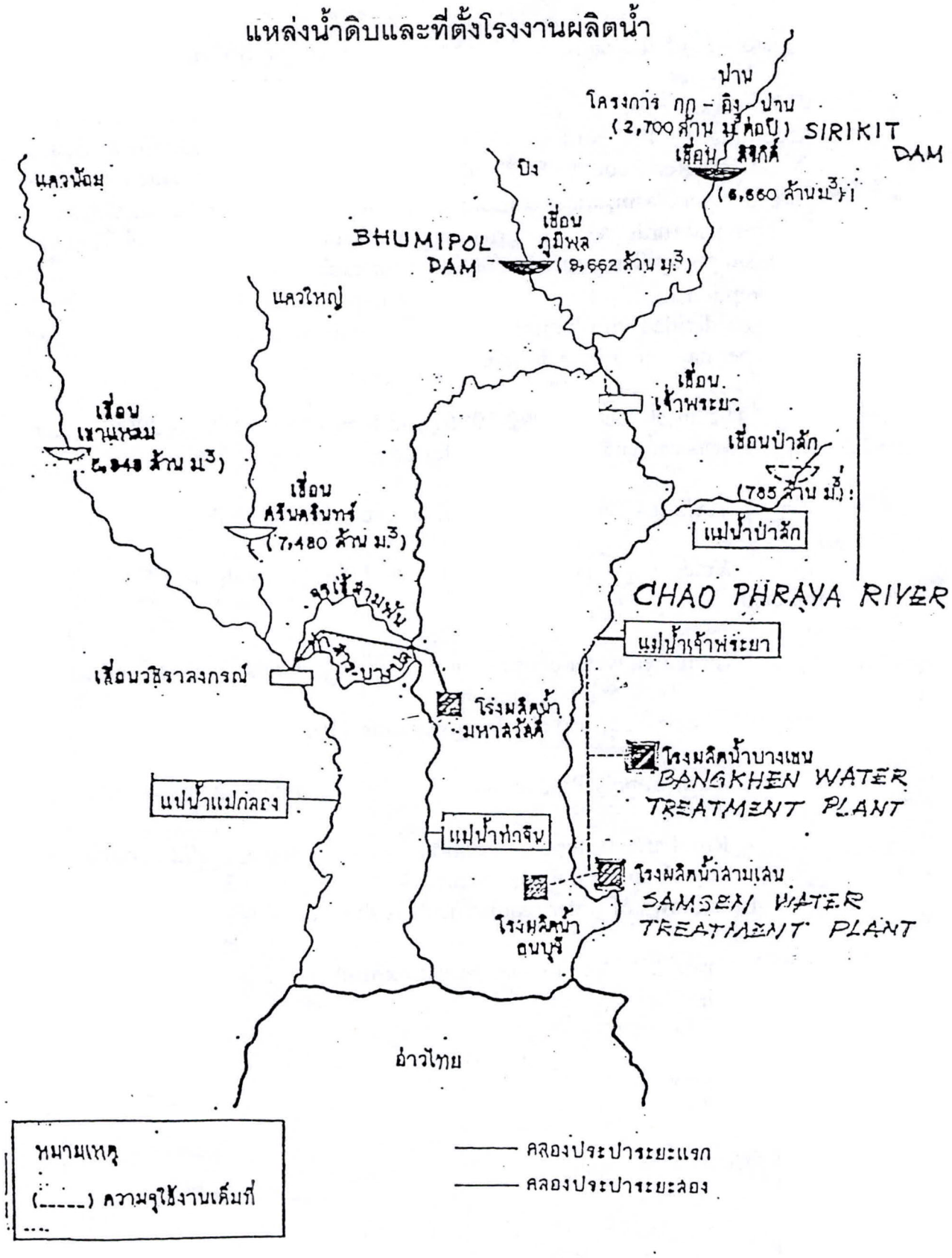
2. WATER REQUIREMENTS FROM THE CHAO PHRAYA RIVER BASIN

The water requirements from the Chao Phraya River Basin can be divided into various types such as consumption, agricultural, industrial and tourism uses as well as for the downstream ecological preservation. The major water user is the agricultural group, consuming approximately 80 per cent of the total amount discharged from the basin's reservoirs. In the Chao Phraya River Basin, there are 2 major reservoirs that is Sirikit and Bhumipol Dams. As the amount of rainfall collected during the 6 months period was not sufficient for agriculture, there has been a reduction in the agricultural produce in the past years. Water utilisation management for the above resorvoirs was rather a difficult task as the rainfall above the dam varied considerably. The evident case was in 1994 when the amount of rainfall was limited, a severe drought had occured in the country. While in 1995 the amount of rainfall was abundant exceeding

Figure 2 CENTRAL RIVER BASIN



Figure 3 RAW WATER SOURCE AND WATER TREATMENT PLAN



the storage of the dams which resulted in a major flooding. The second largest water user is for consumption especially by the Provincial Waterworks Authority and the Metropolitan Waterworks Authority. According to the National Economic and Social Development Board (NESDB)'s Report on the Study of Data and Potential Improvement of Chao Phraya River Basin, water consumption requirements could be characterised as urban and rural uses. The urban water consumption requirement from the water supply system averages 200 litres per capita per day. The rural water consumption mostly from the natural waterway, canal or irrigation canal could be divided into human consumption which averages 50 litres per capita per day and 5 litres for animal consumption.

The short - term (1992-1996) and long - term (1997 - 2006) water requirements can be summarised as follows:

(1) Short - Term Water Requirements (1992-1996)

- Water supply production(MWA and PWA) totals 1,565.4 mil.cu.m

- Rural area water consumption totals 150.5 mil.cu.m
Total annual requirement 1,715.9 mil.cu.m

(2) Long - Term Water Requirements (1997-2006)

- Water Supply Production totals 2,907.4 mil.cu.m

- Rural area water consumption totals 172.8 mil.cu.m
Total annual requirement 3,080.2 mil.cu.m

Breakdown of water requirements is shown in Table 1.

Table 2 shows MWA's raw water requirements up to the target year of the Master Plan.

Table 1 Total Water Requirements in the Chao Phraya River Basin (Short Term and long Term)

Plan	Area (Province)	Waterworks Authority *		Water Consumption in Rural Areas * *				Total Water Requirements (Mil.cu.m/yr)
		MWA (Mil.cu.m/yr)	PWA (Mil.cu.m/yr)	Population (million)	Quantity (Mil.eu.m/yr)	Animal Population (Million)	Quantity (Mil.cu.m/yr)	
Short Term (1992-1996)	11	1,482.2 (Only in the metropolita area and its perimeter)	83.2	6.7	121.5	15.9	29.0	1,715.9
Long Term (1997-2006)	11	2,649.0	258.4	7.6	138.6	18.7	34.2	3,080.2

* According to the implementation plan of the concerned Authority

**According to the estimate of growth rate of population at 1.5 per cent per annum and that of the animal of 2 per cent per annum

Table 2 MWA's Raw Water Requirements from the Chao Phraya River Basin

Year	East Bank (Mil.cu.m./yr)	West Bank (Mil.cu.m./yr)	Total (Mil.cu.m./yr)	Total (Mil.cu.m.day)	Total (cu.m./sec)
1993	1,314.0	-	1,314.0	3.6	41.7
1995	1,324.5	157.7	1,482.2	4.06	47.0
1997	1,324.5	157.7	1,482.2	4.06	47.0
2002	1,482.2	473.1	1,955.3	5.36	62.0
2007	1,671.4	977.6	2,649.0	7.26	84.0
2017	2,080.5	1,062.1	3,142.6	8.61	99.7

B DEVELOPMENT POLICIES

Due to a rapid increase of the population, demand of water will be about double within the next 30 years. Since the government has a policy to minimize the use of groundwater in order to arrest or reduce the land subsidence rate to Bangkok Metropolis, MWA is executing a plan to abandon the groundwater wells especially that of the central system. This cause the demand of surface water to be triple of the present situation within the next 30 years requiring 8.61 million m 3/d in the year 2017.

More surface water will be required from the Chao Phraya River to supply the forecasted demand. Since the Chao Phraya River is a multipurpose river serving various water use activities such as agriculture, navigation, salinity, and pollution control, domestic and industrial use, the water has to be allocated fairly to minimize the conflict between the water use sectors. As the results of the water allocation conducted by the Royal Irrigation Department (RID) the agency responsible for the operation of the Chao Phraya irrigation system, which is the major water use sector, raw water of 5.18 million m 3/d was allocation for the water supply system of MWA.

1. WATER REQUIREMENTS FROM THE MAE KLONG RIVER BASIN

To obtain more raw water from the other sources to meet with the increasing demand, MWA is carrying out a study on raw water resources of the Chao Phraya , Mae Klong basins to identify possible options on raw water resource development for the demand above the allocated 5.18 million m3/d which will be reached in 1997. Mae Klong basin is found to have surplus water after being used by the activities within its basin, and it is found that the water of 2.60 million m3/d can be transferred from the Mae Klong basin to the Chao Phraya basin to satisfy the raw water demand of Bangkok. With consideration on water reliability and water quality, a raw water canal of about 100 km long is planned to transfer the raw water from Vajiralongkorn diversion dam in the Mae Klong basin to the new treatment plant on the west bank service area of MWA as presented in Fig. 4.

The new raw water canal is now under construction. During intial stage of the plant 's water supply production, the first stretch of the raw water canal(Maha Sawat-Tha Chin) will feed the plant with raw water from the Tha Chin River. The raw water canal from Mae Klong River to the Tha Chin River will be further constructed and scheduled for completion in the year 1999 (2542).

Moreover, as part of long term plan, after the year 2017, the study indicates that MWA needs to construct its own surface water storage somewhere in the north or the west of the country to secure guaranteed raw water supply for the population of more than 15 million.

2. WATER REQUIREMENTS FROM PASAK DAM

His Majesty King Bhumipol had remarked on the drought which would have a repercussion on water supply production for Metropolitan Bangkok particularly during the next 7- 8 years (year 2000) when water requirements would reach 5.5 million CMD that the limited availability of the Chao Phraya River water during the dry season could be made up for by the amount of water discharged from the Pasak Reservoir currently under construction. However, the amount may not be sufficient should the dam's storage be less than 785 million cubic meters (MCM) soconsideration should be made.

In response to His Majesty the King's remarks, MWA has carried out a preliminary study for the utilisation of raw water from Pasak Reservoir via Khlong Rapeepat and Rama IX Reservoir for water supply production. Due to lack of information from the Royal Irrigation Department (RID) regarding the definite allocation of water from Pasak Reservoir, MWA has therefore sought cooperation from the Asian Institute of Technology (AIT) to conduct feasibility study on the utilisation of the Pasak Reservoir water as a supplementary source of raw water supply to cope with the water shortage problem, as well as study for construction of water treatment plant to serve population in its neighbourhood.

The result of study show that, according to the flow data(1987-1991), the existing diversion of flow (averaged from the mentioned period) from the Chao Phraya river at the Chao Phraya diversion dam via Khlong Chai Nat - Pasak is 942 for the 6 months dry period from January to June. From the previous study the Pasak reservoir can provide water of 661 MCM to partly supplement the water volume diverted from the Chao Phraya river during the dry period. Therefore the diversion requirement from the Chao Phraya river during the dry period can be reduced from 942 MCM under the existing condition to 281 MCM when the Pasak reservoir is operated.

In order to obtain additional raw water supply for Bangkok Metropolis, the raw water volume of 661 MCM of the Pasak reservoir may be utilized for the water supply purpose. Consequently, this implies that the existing diversion from the Chao Phraya river via Khlong Chai Nat - Pasak has to be maintained at 942 MCM for the dry period.

PASAK RESERVOIR FOR MWA

In the far eastem part of the serving area of the MWA, such as in the area of Min Buri and Lat Krabang districts, the low pressure pipe water is always experienced. In these areas, the MWA has planned to construct pump stations to increase pressure in the pipe lines. The proposed pump

stations considered in this study are those at Min Buri and Lat Krabang (Second Phase) where water demand is relatively high. The planned demand of these two pump stations in the target year 2007 and 2017 is 535,000 CMD and 1,159,000 CMD respectively. The treated water transmitted to these two pump stations cited in the MWA master planning study is from the Bang Khen WTP where raw water source is from the Chao Phraya river.

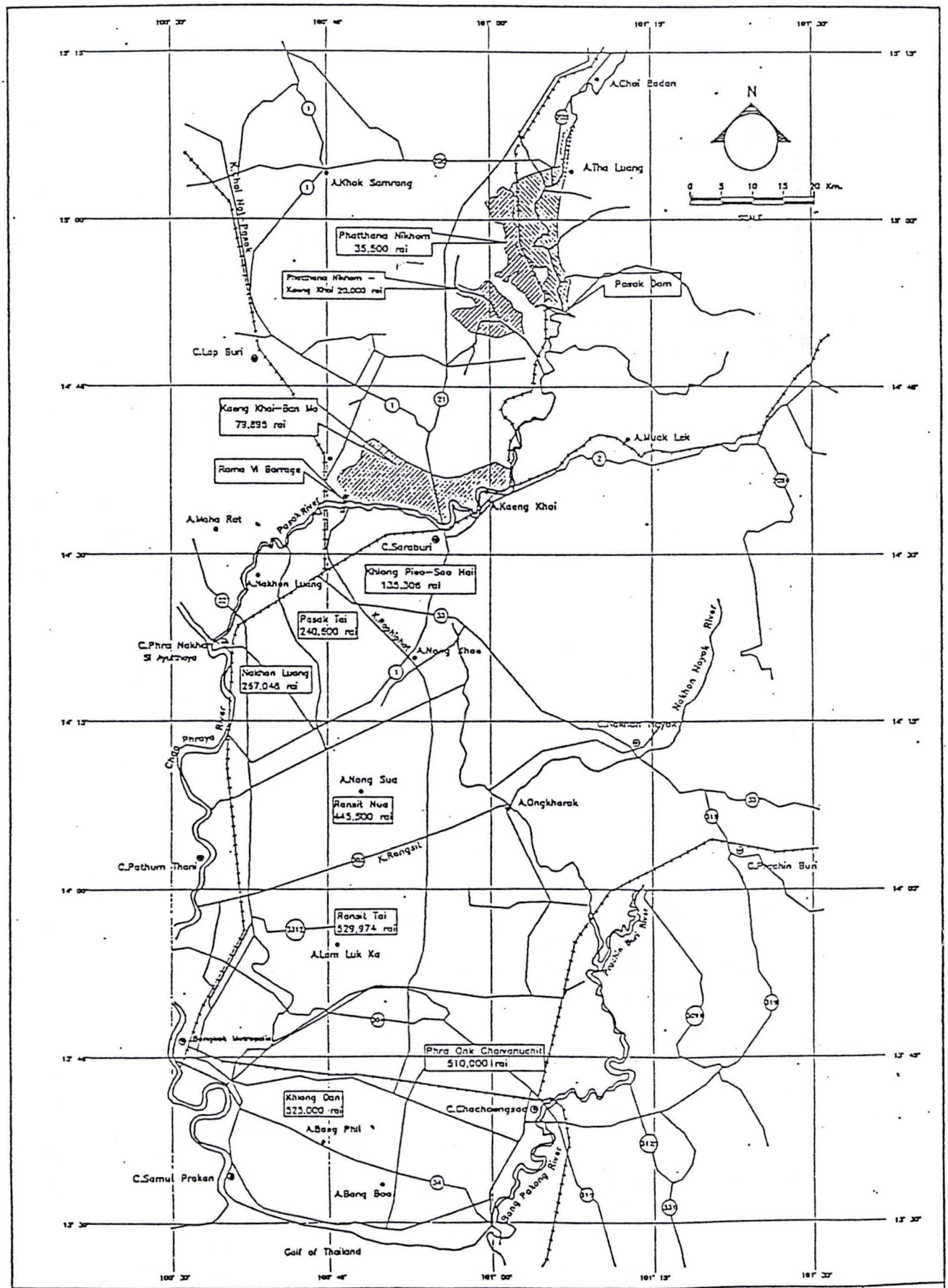
At present on the east bank of Chao Phraya river, the water supply in the service area is entirely dependent upon the Chao Phraya river. To secure the risk of uncertainty of Chao Phraya river flow due to its water quality problem and to the high demand for agriculture particularly during the dry period, the MWA has planned to find another reliable raw water soure. The Pasak reservoir project is considered to be a prominent altermative as it is reliable and is not far away from the target areas.

Based on the MWA master planning study, the water demand in the serving area of the proposed Min Buri and Lat Krabang (Second Phase) pump stations and the raw water requirement for the proposed water treatment plant are summarized as follows :

Description	1997	2007	2017
Water Demand at Min Buri	-	352,000	609,000
Water Demand at Lat Krabang (Second Phase)	-	183,000	550,000
Total	-	535,000	1,159,000
Factor for Raw Water		1.684	1.617
Raw Water Requirement		900,940	1,874,103
Rounded Raw Water Requirement		1,000,000	2,000,000

According to the raw water requirement presented above, the monthly raw water needed from the Pasak reservoir is about 30 MCM in 2007 and 60 MCM in 2017. This would not alter the objective of the Pasak reservoir project except the water saved from the Chao Phraya river would have been reduced from 661 MCM to 301 MCM (Table 3) during the dry period (January to June)

For the wet period (July to December), no water shortage is expected as there is abundant flow in the Chao Phraya and Pasak rivers. If it is necessary, however, the additional flow from the Chao Phraya river can be diverted via Khlong Chai Nat-Pasak. The additional flow of 60 MCM/month would raise the peak month flow of the Khlong from 353 MCM to 413 MCM (see Table 3) which is still under its capacity.



ROYAL INITIATIVE PROJECTS ON WATER RESOURCES DEVELOPMENT FOR METROPOLITAN WATERWORKS AUTHORITY	Beneficial Irrigation Area Under Planned Pasak Reservoir Project	Fig. 5

Table 3

Comparison of Diverted Flow from Chao Phraya River via Khlong Chai Nat-Pasak due to Pasak Reservoir Development

Month	Diverted Flow from Chao Phraya River via Khlong Chai Nat-Pasak			Chao Phraya River Flow at Tail of Chao Phraya Barrage (C.13) 4/
	Existing Condition 1/	Pasak W/O MWA 2/	Pasak W/ MWA 3/	
Apr	259	57	117	240
May	169	53	113	436
Jun	140	62	122	622
Jul	75	75	75	522
Aug	153	153	153	790
Sep	353	353	353	1,767
Oct	190	190	190	3,060
Nov	223	223	223	1,450
Dec	244	244	244	820
Jan	78	32	92	319
Feb	87	27	87	227
Mar	209	50	110	237
Dry (Jan-Jun)	942	281	641	2,081
Wet (Jul-Dec)	1,238	1,238	1,238	8,409

Note : 1/ Averaged values from 1987-1991

2/ Diverted flow during dry season is calculated by proportioning water shortage to the irrigation demand

3/ Estimated values for 2017

4/ Record period from 1971-1993

C REGULATIONS

1. MWA ACT

According to the MWA Act, the functions and responsibilities of the MWA are as follows :

1) To explore and locate raw water sources ; and procure raw water for waterworks purposes.

2) To produce, distribute, and sell water-supply in the Bankok Metropolitan area as well as in Nonthaburi and Samut Prakarn Provinces.

3) To operate other types of business that are relevant to otherwise beneficial to organization.

2. MEASURE ON RAW WATER CONSERVATION FOR MWA

The raw water intake at MWA's Sam Lae Raw Water Pump Station is situated only 90 kilometers from the Chao Phraya River's estuary. As the quality of the river water became deteriorating due to the rapid growth of communities and the industrial factories particularly upstream of Prathumthani Province, MWA in conjunction with the National Environment Board had put forward "Measure on Raw Water Conservation for MWA". The move was made to protect the raw water source at Sam Lae Pump Station from being further deteriorated. It prohibits construction or expansion of certain kind of industrial factories (whose effluent contains heavy metal, toxic chemical substance or high BOD content) within an area of 200 square kilometers around the pump station. The Cabinet at its meeting on April 17, 1979 approved in principle the above measure and instructed all the concerned ministries and departments to take action accordingly.

As the water quality of the Chiang Rak Canal which flows to the Chao Phraya River near the Sam Lae Raw Water Pump Station was affected by industrial waste discharged to the Chiang Rak's tributaries in the area near the above conservation zone, especially along the North Railway Line and Phrahol Yothin Road, expansion of the MWA's raw water conservation area by another 150 square kilometers was therefore proposed to cover parts of the Prathumthani and Ayuthaya provinces (Figure 6). The Cabinet approved the proposal on January 12, 1988.

In addition, the Cabinet, at its meeting on July 3, 1990 approved proposal made by the National Water Resources Council on the provision of additional water resource for water supply and industrial use, and on the approach to remedy the Khlong Prapa's pollution. It suggested that MWA oversee the use of Khlong Prapa's dikes and prohibit construction of new road or expansion of the existing road along the canal, and after the Khlong Prapa has fully been expanded, concrete walls along the canal should be constructed to prevent wastewater leakage into the canal.

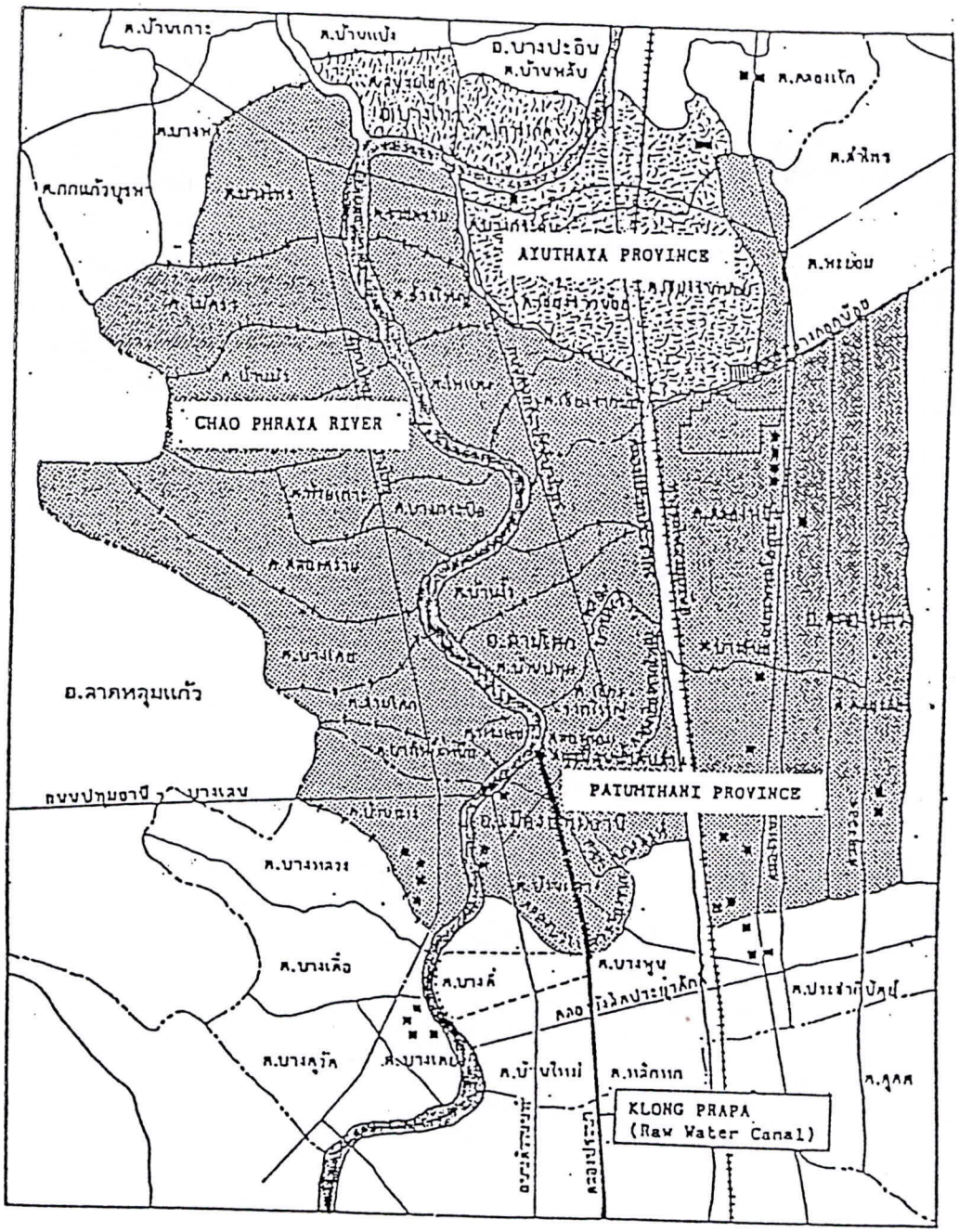


Figure 6 THE RAW WATER CONSERVATION AREA

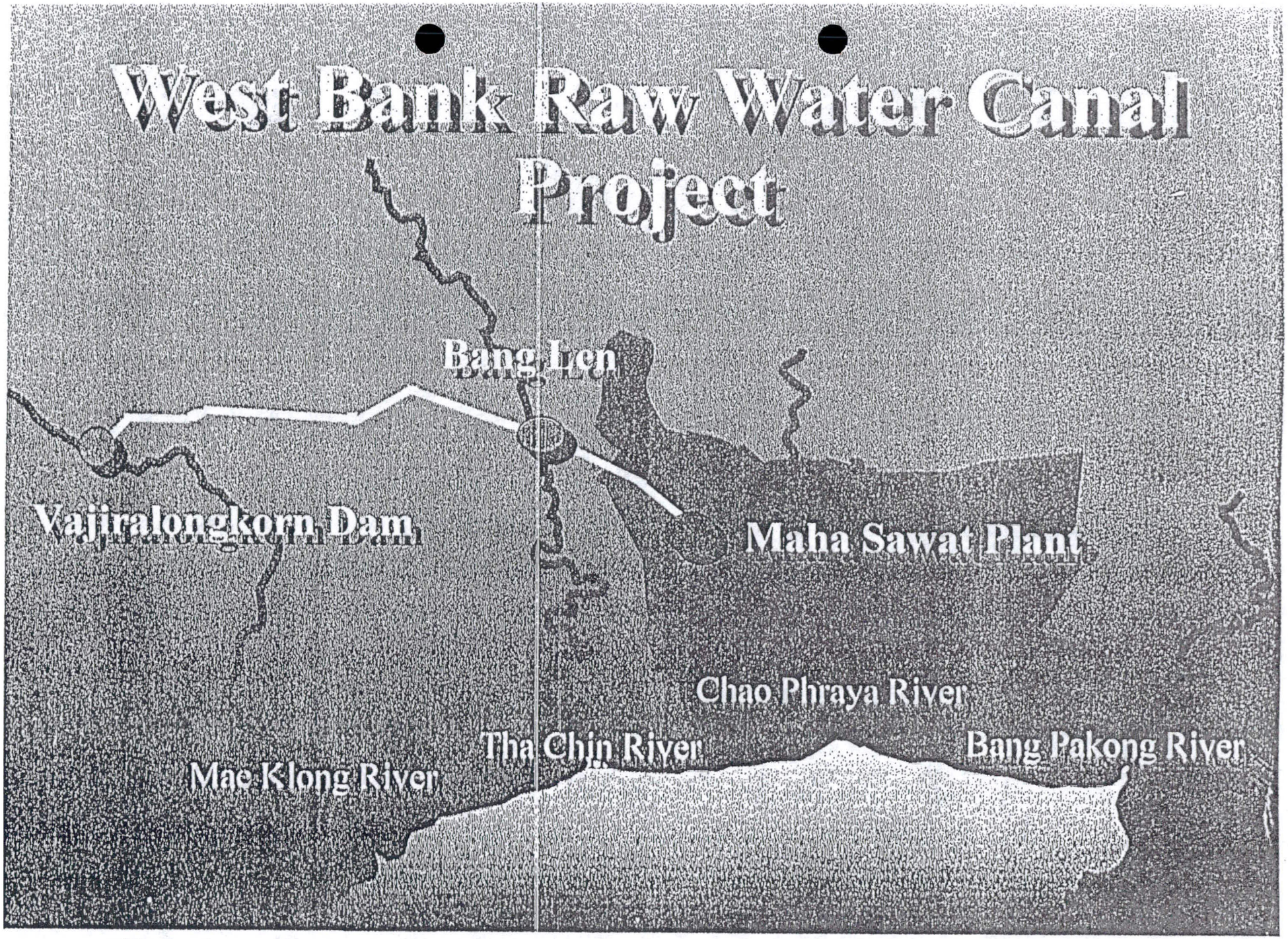


Figure 4 NEW RAW WATER CANAL

Environmental Imact Audit Techniques: Thailand Experience

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Environmental Impact Audit Techniques : Thailand Experience

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I. Euamolachat

Abstract

Environmental Impact Assessment (EIA) is implemented since 1981. Up to now, there are 22 types and sites of project that requiring EIA report . Division of Environmental Impact Evaluation, Office of Environmental Policy and Planning under Ministry of Science Technology and Environment responsible for administration of EIA process. The EIA report composed of 5 parts: project description, existing environment, impact evaluation, mitigation measure and monitoring program. After EIA report had been approve, the mitigation measure and monitoring program will be recommend to authorize agency for the license. The mitigation measure and monitoring program have to attach as term and condition with the license of the approval project. The project proponent must operate this conditions. The monitoring data such as water quality, air quality will be submit to OEPP every 3 months or 6 months depend on the how significance the impact of the project. OEPP will random check the mitigation measure and monitoring program. At present the term Environmental Auditing is widespread in Environmental Management System in Thailand. The compliance with term and condition in EIA is sub-task in Environmental Management System as well, therefore, last year, OEPP, by the support of Government of Denmark, consulted with Danish expert drafted "Guidance Document on Environmental Audit of Development Projects." This drafted guidance on Environmental Audit consisted of: pre-audit activities; 4 EA step (Planning, on site auditing, evaluation of the results, reporting of the audit finding and follow-up activities. The auditing team can be OEPP or third party which will accredit by OEPP This Drafted Guidance Audit is in the trial an error stage. The revision of this guidance should to be done as best as possible for Thailand context.

Environmental Impact Audit Techniques : Thailand experience

N. Watcharasin *

I.Euamolachat**

1. Introduction

Since 1981, Environmental Impact Assessment implemented in Thailand. Office of the Environmental Policy and Planning (OEPP) under Ministry of Science Technology and Environment is responsible for administration of the EIA process. By the notification of types and sizes of projects or activities requiring EIA reports, there are 22 types of projects which the project proponents have to submit EIA reports. The projects listed can be summarised into 6 groups : Water resources; Infrasfuchure; housing, mining; Industry and Energy (detail described in attachment 1).

Division Environmental Impact Evaluation (DEIE), OEPP will examine and make preliminary review EIA reports. The report together with the preliminary comments will be submitted to Technical Review Committee (TRC) for final consideration. The committee will be composed of expert members who are qualified or specialized in various technical fields including representatives of relevance agencies, permitting agency and NGOs. TRC may approve or reject report for the private project but for Government or State Enterprise project the National

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Environmental Board will be make decision. Besides, TRC may ask for report revision or additional information. The EIA review process can be summarized as attachment 2.

The other groups concerning EIA system are consultants and permitting agency. It is enforced that EIA reports have to be prepared by the consultant firms who registered with OEPP. Up to now, there are 48 consultant firms have licenses to conduct EIA reports.

For the permitting agency who is legally authorized to grant a permit to any proponent, the law stipulate that the agency shall withhold the granting of permission until having been notified the result of consideration pertaining to the review of EIA reports by OEPP.

2. Definition of Environmental Impact Assessment (EIA), Environmental Audit (EA) and Environmental Impact Audit

At present, Environmental Impact Assessment (EIA) become more popular in Thailand. The term "EIA" is now widely used however it is difficult to provide a single answer acceptable to everybody. Some definition can be given below.

EIA is an assessment of all relevant environmental and resulting social effects which would result from a project. (Battelle Institute, 1978)

EIA is the systematic examination of the environmental, social and economic consequence of projects, plans and policies (Clark, 1979)

Environmental impact assessment (EIA) is an environmental Management tool for development projects. It consists of a sequence of actions for : predicting the likely environmental impact of a project;

Finding ways to reduce unacceptable impacts; shaping the project to make it suitable for the environment and presenting these predictions to the decision maker (United Nations 1985). Thus, EIA is an environmental management tool the benefits of which generally outweigh the cost (Wathern 1985).

Environmental Audit means different things to different people. Environmental Audit means "a check on some aspect of environmental management".

USEPA defined its as systematic, documented, periodic and objective review by a firm of facitity, operations and practices related to meeting applicable requirements. (The Institute of Environmental Research Chulalongkorn University, 1995). In Thailand, Environmental Audit is a relatively new term but its widespread especially in industry area.

Environmental Impact Audit presented in this paper means an Environmental Audit (EA) of a development project that is initiated after acceptance of an environmental impact assessment (EIA) report. It is defined as management tool comprising a systematic, documented periodic and objective evaluation of the compliance with acceptable requirements specified in the licence (VKI Water Quality Institute,1996). This type of audit may also be named an environmental compliance audit as especially the compliance with the specifications or requirements in the licence is evaluated.

3. Environmental Monitoring and Auditing within OEPP Context

EIA reports compose of 5 part: project description such as location, process and etc; existing data which consist of primary or secondary data about environment in the project area and its vicinity;

environmental impact evaluation of the projects; mitigation measures of the projects to prevent or minimize environmental damage monitoring program for signiticance environmental impact such as water, air, noise, etc.

Problem with Follow up Monitoring and Audit in Thailand

Monitoring is an important step in the EIA procedure. Monitoring data can identify harmful trends before it is too late to ameliorate or prevent them. It is an early stage warning device. Monitoring reports from sampling takes place under apparently similar licensing conditions, the result are often different. Many project proponents have a misconception the after EIA is prepared and approved, the environmental effects of a project are managed. As a consequence, most of them are not in compliance with mitigation measures and monitoring programmes in accordance with the conditions that are attached to the licence after approval. There should be provisions for continuous monitoring of compliance with the recommendation and the permitting agency should be empowered to intervene if the licence is not being complied with . DEIE has an inadequate number of staff to monitor.

According to present mandatory provisions in the 1992 Act, only new construction projects need to submit EIA and only for projects which OEPP suspect may lead to impacts. Then, OEPP can request an EIA for the project. This does not include renewals of licences. The old Act specified that, every 3 years, the developer must submit an EIA report to OEPP for review in order to renew and extend a license for a private project such as hotels, industries and ports even though there is no construction. Monitoring is costly for project proponents, so monitoring is usually neglected. The project proponent is not generally prepared to produce and submit an EIA for a renewal license for the

existing project. In addition OEPP lack staff to monitor. It is the permitting agencies which have the authority to close down a firm if it is not meeting its approval conditions, not OEPP. Similar projects may be useful for confirming impacts and for designing effective follow up studies. In Thailand, monitoring of impacts is often recommend in EIAs, but is not implemented on account of a shortage of resources. This is not surprising, given the large number of EIAs prepared (about 400 EIA per year).

However, some monitoring reports have been prepared because some project proponents have had to submit reports on, for example air quality or water quality. Most monitoring programmes concentrate on physical aspects such as water quality and air quality. It could be undertaken by the project proponent, a consulting firm or a university. A report on the monitoring must be submitted to OEPP. OEPP also has the responsiblity to spot check and monitor the conditions in an EIA report. This task was appointed by law that OEPP shall control, monitor and evaluate project activities related to mitigation measures. The role of monitoring by OEPP is very closely to the term of "Auditing" because its Compose of checking, or inspecting records submitted by project proponents and investigation the effectiveness of mitigation measures. It also tells us the appropriateness of mitigation measures as well as the accuracy of monitoring results. This paper will define this activities as "environmental impact audit" Because of work load and limitations on skill resources, in conjunction with the lack of systematic method and sensitive equipment, monitoring has been neglected.

Recently, OEPP and TRC, pay more attention to environmental impact audit. For examples in case of Phoenix Pulp & Paper Public Company Limited which approval of EIA, OEPP and TRC stipulate condition that the proponent shall do Environmental Audit especially air emission, liquid effluent, solid waste and environmental hazard management every 6 months. The audit report must be submitted 1 month after the audit finished. The first audit report of Phoenix Pulp had prepared and submitted to OEPP already. (Jaakko Poyey, 1996).

Besides this, EIA of Panjapal Pulp Industry Company Limited and EIA of PP & HDPE production of Thai Petrochemical Industry Public Company Limited are the other examples that OEPP and TRC stipulate additional condition in submitting audit report.

As mentioned, mitigation measures proposed in EIA should be audit by OEPP, however, mitigation measures proposed in EIA become legal condition attach to project licence. Industries, for example, may be monitored by other agency such as Department of Industrial Works (DIW).

Not only the condition from OEPP but also from National Environmental Quality Act B.E.2535, there are provisions related to environmental audit which mention in Section 80 and Section 81.

section 80, the owner of the point source of pollution who has his own facility for treatment of polluted air, equipment for control of the discharge of polluted air or other pollutants shall have duty to collect statistics and data showing the daily functioning of those eqiupment and make detailed notes as recorded evidence at the site. Summarized report of the facility functioning results shall be submitted to local official at least once a month.

section 81 the local official shall gather the reports received according to section 80 and send to the Pollution Control Official at least once a month.

However, the role of the monitoring is under jurisdiction of Pollution Control Department (PCD)

4. Draft Guidance for Environmental Impact Audit Techniques

Recently, OEPP, by the supportance of the Government of Denmark, consulted with Danish expert drafted "Guidance Document on Environmental Audit of Development Projects". The audit process should be performed in a number of steps in order to ensure the efficient use of personel resources in appropriate methods. In the drafted guidance, audit process consists of; pre-audit activities; 4 EA Step (Planning, On site auditing, Evaluation of the results, Reporting of audit finding and follow-up activities.

Auditing process - Pre - auditing activities
- EA step 1 : Planning
- EA step 2 : On-site activities
- EA step 3 : Evaluation
- EA step 4 : Reporting
- Audit follow - up

Pre - audit activities

OEPP auditing team or the consultant acting on behalf of OEPP must be appointed. The audit team must be experienced in the evaluation of environmental impacts of the development project. Size of auditing team depends on complexity of the project, however, as EIA reports are only

required for larger projects so at least 3 persons should be included in the auditing team. the Team should select the team leader or project management, others should be assigned specific tasks to be undertaken in the audit

EA Step 1 : Planning

The auditing plan should be made and agreed by the auditing team as well as top management of the company. It must be ensured that the appropriate resources are allocated for a thorough audit such as staff involved are informed, relevant material and necessary facitities must be available. Detailed planning of the audit should be undertaken the plan should include.

* time schedule for on-site auditing
* scheduled meetings
* identification of mitigation measure to be audited
* identification of monitoring data to be audited
* identification of relevant documents, including additional data that should be obtained by the company
* etc.

EA step 2 : On-site auditing

The On-site auditing include series of activities as followed :

1. Start-up meeting with the site management and environmental staff to discuss the objectives and scope of the audit, time schedule, however, audit plan may be revised

2. Interview managers and operators about the implementation and operation of mitigation measures and monitoring program in accordance with the condition in the licence.

3. Inspect documentation of mitigation measures and monitoring results. i.e. results of wastewater, air emissions, noise, etc. Moreover, it should be considered the sampling site, sampling method, sampling period and auditing team can make additional sampling and analysis.

EA step 3 : Evaluation of results

The auditing team should evaluate all findings during the site visit. The following topics should be considered.

1. The presence of mitigation measures requiring installations as well as documentation for correct function or performance

2. Correction of monitoring program such as sampling sites, sampling techniques, analytical methods, calculation of results.

3. Comparision of additional sampling analysis result with the data obtained from the company in order to evaluate the validity of company's own monitoring result.

4. Evaluation of the compliance with the conditions specified in the licence.

EA step 4 : Reporting of audit findings. A written report should be prepared in order to ensure a formal reporting of the audit findings and conclusion at the end of the audit.

Audit follow-up

If mitigation measures or monitoring activities are incompliance with the condition in the licence, appropriate corrective action should be considered. A time schedule for the implementation of the corrective actions should be settled. The next audit should be decided.

Conclusion

Environmental Audit has been increasingly interested in Thailand. Various organizations implement environmental audit for their purposes. OEPP is the direct agency who responses in Environmental Impact Audit for development project or activity that submit EIA. Unfortunately, lack of resources in various aspects such as personel, equipment, budget, etc. effects Auditing System in EIA process in Thailand. Nevenrtheless, the drafted guidance for auditing will be use as a tool for Environmental Impact audit in Thailand context in the near future.

The systematic recording, well-planned auditing, reporting of audit finding and follow-up activities shall be performed. However, Environmental Impact Audit can be catagorized in compliance audit. Willingness of project proponents in revealing their own data and activities is an the important obstracle for government agency to do audit. ISO 14000, new environmental standard for Environmental Management System is voluntary basis, soon is being drafted.If its complete and implement, It include a lot of requirements; identification of legal requirements, checking and corrective action of monitoring and measurement, prevention action, environmental records.Moreover, ISO 14012 describes qualification criteria for environmental auditors and lead auditors. Thus, the companies certified according to ISO 14000, will be accepted that they meet requirement for systematic environmental impact audit in Thailand.

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Notification

of

The Ministry of Sciences, Technology and Environment

Re: Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment

---

By virtue of Section 46 and Section 51 of the Enhancement and Conservation of National Environmental Quality Act B.E.2535, the Minister of Sciences, Technology and Environment hereby issues Notification with the approval of the National Environment Board, specifying government agencies, state enterprises and private persons likely to prepare projects or activities or likely to expand projects or activities as listed at the end of this Ministerial Notification, shall prepare reports on environmental assessment for submission to seek opinion from the Office of Environmental Policy and Planning in accordance with the provisions of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 including projects, or activities which are required for submission to seek approval of the Cabinet and projects or activities which are required to obtain permission from the competent authority.

The environmental impact assessment reports mentioned above must be prepared by a licensed expert in the environmental impact assessment.

Given on the 24th day of August, B.E.2535

No.

Paijitra Auetaweekul

(Mr. Paijitra Auetaweekul)

Minister of Sciences, Technology and Environment

Published in the Government Gazette Vol. 109 No. 130.
dated 8th October, B.E. 2535

List of Projects or Activities

Ltems	Types of Projects or Activities	Size
1	Dam or Reservoir	Storage volume 100,000,000 cubic meters or more or storage surfac area 15 square kilometers or more
2	Irrigation	Irrigated area 80,000 rais (12,800 hectares) or more
3	Commercial Airport	All sizes
4	Hotel or Resort Facilities located in areas adjacent to rivers, coastal areas, lakes or beaches or in the vicinity of national parks or historical parks	80 rooms or more
5	Mass Transit System under the Mass Transit System and Expressway Act or project as the same characteristic or Mass Transit which use rail	All sizes
6	Mining as defined by the Mineral Act	All sizes
7	Industrial Estate as defined by the Industrial Estate Authority of Thailand Act or projects with similar feature	All sizes

Ltems	Types of Projects or Activities	Size
8	Commercial Port	With capacity for vessels of 500 gross tons or more
9	Thermal Power Plant	Capacity 10 MW. or more
10	Industries	
	(1) Petrochemical Industry	Using raw materials which is produced from oil refinery and/ or natural gas seperation with production capacity of 100 tons/day or more
	(2) Oil Refinery	All sizes
	(3) Natural Gas Separation or Processing	All sizes
	(4) Chlor-Alkaline Industry requiring Sodium Chloride (NaCl) as raw material for production of Sodium Carbonate (Na_2CO_3), Sodium Hydroxide (NaOH), Hydro Chloric Acid (HCl), Chlorine (Cl_2), Sodium hypo-chloride (NaOCl) and Bleaching Powder	Production capacity of each or combined Products of 100 tons/ day or more
	(5) Irons and/or Steel Industry	Production capacity of 100 tons/day or more (production capacity shall be calculated by using furnaces capacity of ton/day multiply by 24 hours)

Ltems	Types of Projects or Activities	Size
10	(6) Cement Industry	All sizes
	(7) Smelting industry other than Iron and Steel	Production capacity 50 tons/day or more
	(8) Pulp Industry	Production capacity 50 tons/day or more
11	All types of projects located in the areas where it has been approved by the Cabinet to be watershed area as class 1 B	All sizes

Notification

of

The Ministry of Sciences, Technology and Environment

Re : Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment

No.2 (B.E. 2535)

To become additional the specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment as listed at the end of the Notification of the Ministry of Sciences, Technology and Environment re : specifying types and sizes projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment on the 24th day of August, B.E. 2535

By virture of Section 46 and Section 51 of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535, the Minister of Sciences , Technology and Environment with the approval of the National Environment Board hereby issues types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assesssment additional as listed at the end of this Ministerial Notification.

Given on the 9th day of September, B.E. 2535

Paijitra Auetaweekul

(Mr. Paijitra Auetaweekul)

Minister of Sciences, Technology and Environment

Published in the Government Gazette Vol.109 No.136,
dated 22th October, B.E. 2535

Items	Types of Projects or Activities	Size
1.	Coastal reclamation	All sizes
2.	Building in areas adjacent to rivers, coastal areas, lakes or beaches or in the vicinity of National Parks or Historical Park	1. Height of 23 meters or more, or 2. Total floor area or any floor area in the building is 10,000 square meters or more
3.	Residential Condominium as defined by the Condominium Act	80 Units or more
4.	Land allocation for residential or commercial purpose	500 land plots or more or total developed area exceed 100 rais (16 hectares)
5.	Hospital which located 1) in area adjacent to rivers, coastal areas, lakes or beaches 2) In area other than (a)	5.1) in-patient's bed of 30 beds or more 5.2) in-patient's bed of 60 beds or more
6.	Pesticide Industry or Industry producing Active Ingredient by chemical process	All sizes
7.	Chemical Fertilizes Industry using chemical process in production	All sizes

Items	Types of Projects or Activities	Size
8.	Highway or road as defined by the Highway Act, passing through following areas 1) Wildlife Sanctuaries and Wildlife Non-Hunting Areas as defined by the Wildlife Conservation and Protection Act 2) National park as defined by the National Park Act 3) Watershed area classified as class 2 by the Cabinet Resolution 4) Mangrove Forests Designated as the National Forest Reserve 5) Coastal Area within 50 meters from the Maximum Sea Level	All projects with equivalents to or above the minimum standard of rural highway including roaded expansion

Notification

The Ministry of Sciences, Technology and Environment

Re : Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment No.3 (B.E. 2539)

Items	Types of Project or Activities	Size
1	Hotel or resort	80 rooms or more
2	Flat or apartment	80 rooms or more
3	Hazardous Waste Treatment Center	all sizes
4	Sugar Industry	
	(1) producing raw sugar, white sugar, refined sugar	all sized
	(2) producing glucose, dextrose, fructose or the like	production capacity of 20 tons/day or more
5	Petroleum Development	
	(1) Geophysical drilling exploration and/or production	all sizes
	(2) Oil and gas pipeline system	all sizes

APPROVAL PROCESS FOR EIA OF PRIVATE SECTOR PROJECT

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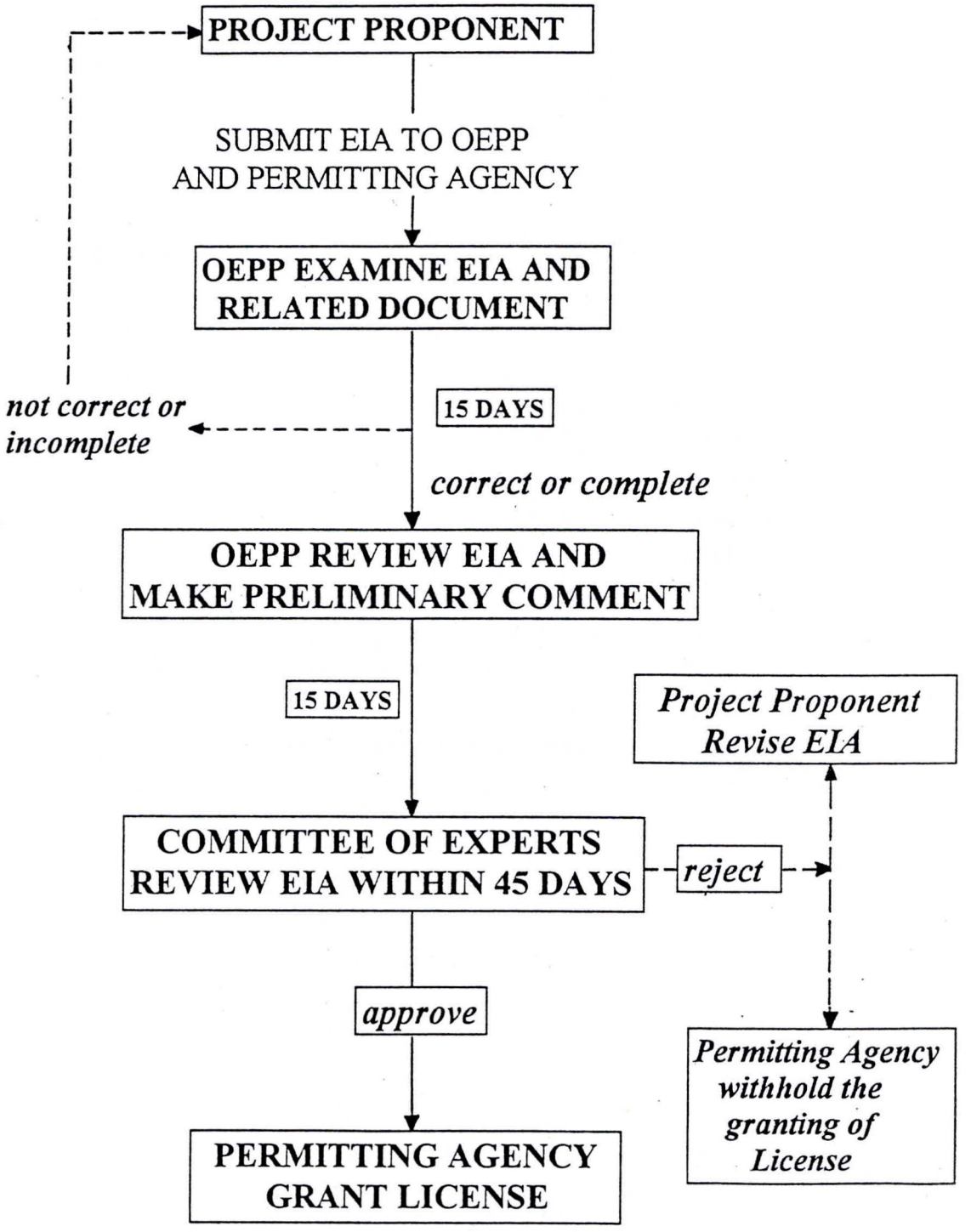

APPROVAL PROCESS FOR EIA OF PRIVATE SECTOR PROJECTS
(REVISION PROCESS)

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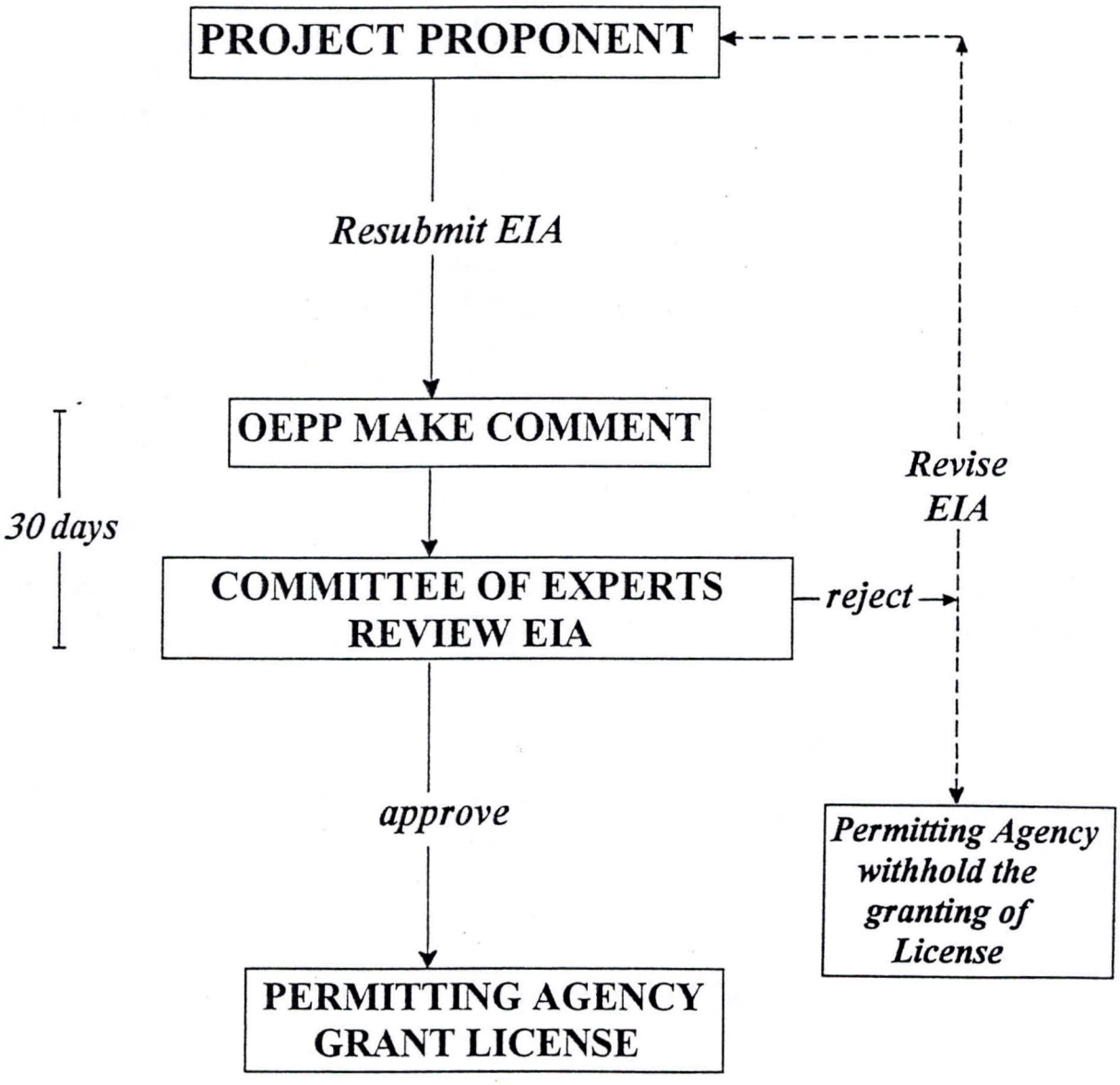

APPROVAL PROCESS FOR EIA OF GOVERNMENT AGENCY STATE ENTERPRISE OR TO BE JOINTLY UNDERTAKEN WITH PRIVATE ENTERPRISE

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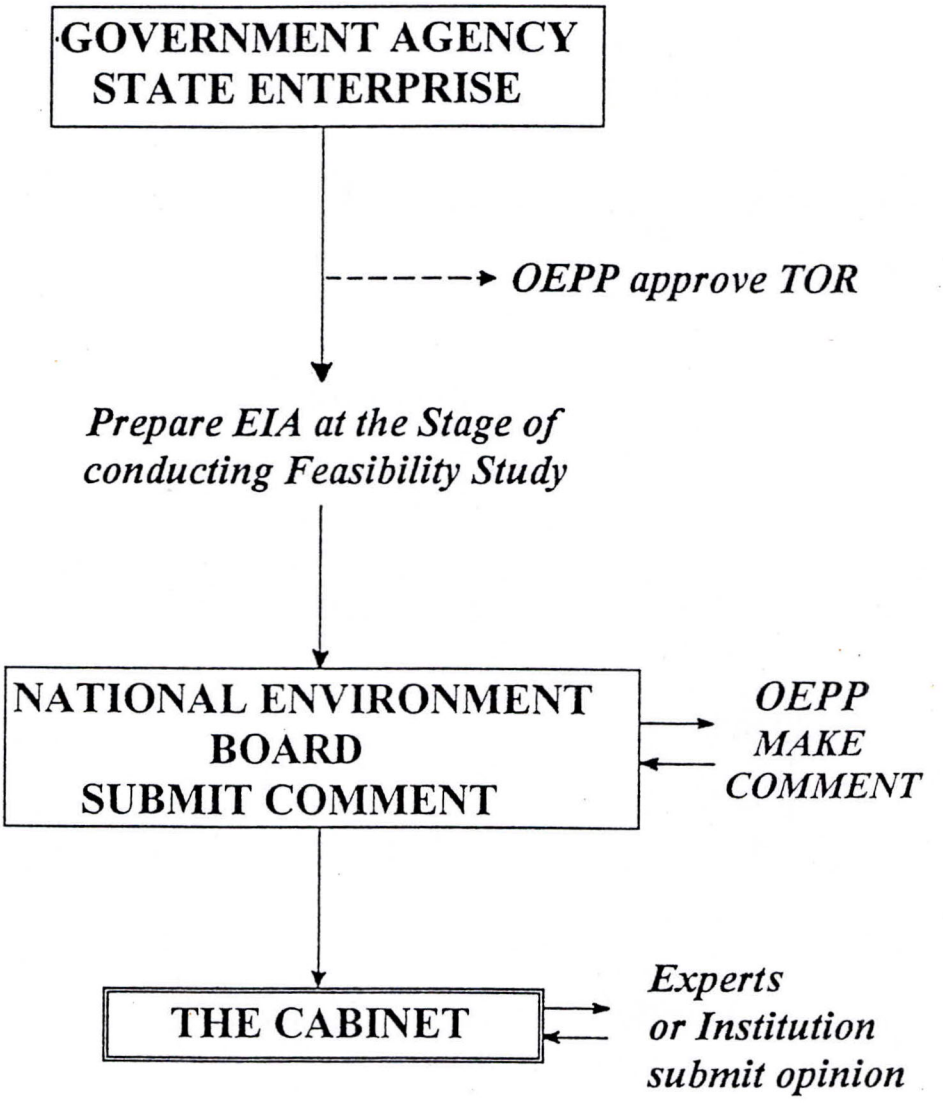


Using Environmental Management Systems To Strengthen Environmental Programs Of Industry

-:-

John K. Underwood Ph.D. NSPI
William C. Hart Ph.D. TUNS

PROCESS

Review

Result

PERMIT

REGULATION

COMPLIANCE AUDIT

COMMAND CONTROL (EXTERNAL)

MONITORING

ISSUE AUDIT

QUALITY ASSURANCE

MANAGEMENT AUDIT (INTERNAL)

ENVIRONMENTAL MANAGEMENT SYSTEMS

INTERNAL CONTROL (VOLUNTARY)

-: DUE DILIGENCE :-

)14000 AUDIT :XTERNAL)

ISO 14000

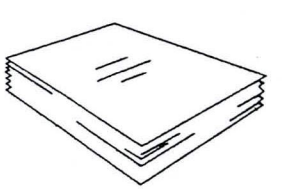
Regulations and Licenses

There is 1 Environment Act and 21 Regulations Administered by NSDOE.

The mandate of Environment Canada is primarily defined under CEPA and its 35 Regulations, but it does include sections of the Fisheries Act and Navigable Waters Protection Act.

Activities covered by the Act and Regulations include:

- Transportation of Dangerous Goods
- Storage of Dangerous Goods and Hazardous Wastes
- Petroleum Storage and Handling
- Air Quality Monitoring
- Water Quality Monitoring
- Alterations to Fish Habitat
- Emergency Spill Regulation
- Environmental Assessment

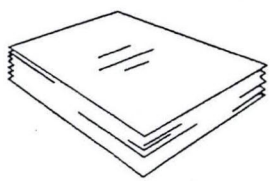


Regulations and Licenses (cont'd)

In addition to regulations, many activities require permitting and licensing.

Licenses and Permits required under the Environmental Protection Act include:

- Comprehensive Industrial Permits
- Watercourse alterations
- Water withdrawal authorization
- Pest Control Products
- Hazardous waste storage sites
- Sewage treatment systems



ISO GUIDE 25
(General Requirements for the Competence of Calibration and Testing Laboratories)

The Quality Manual and Documentation Shall Contain:

- a quality policy statement by top management, including objectives and commitments;
- the organization and management structure of the laboratory, its place in any parent organization and relevant organizational charts;

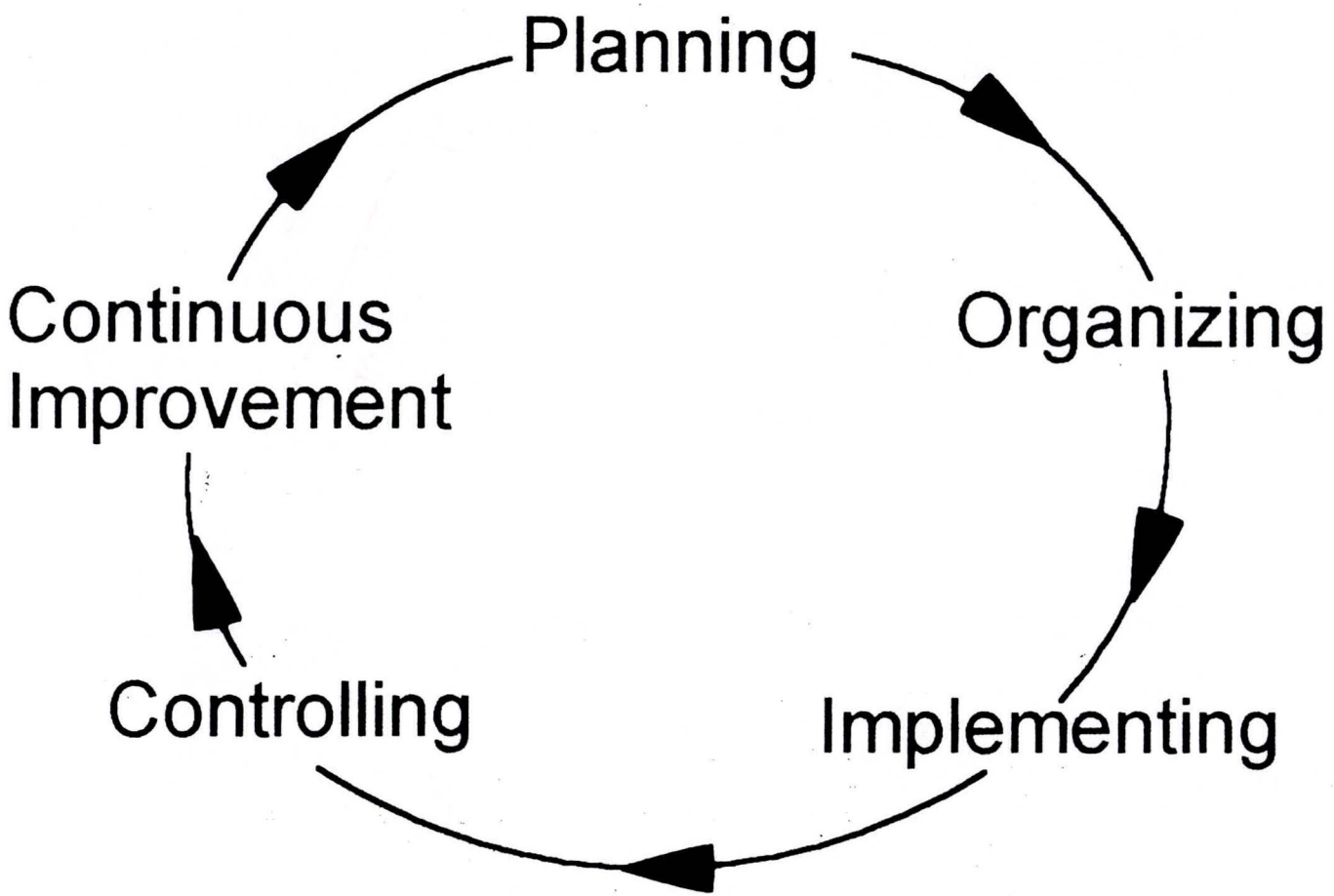
- the relations between management, technical operations, support services and the quality system;
- procedures for control and maintenance of documentation;
- job descriptions of key staff and reference to the job descriptions of other staff;
- identification of the laboratory's approved signatories (where appropriate);
- the laboratory's procedures for achieving traceability of measurements;
- the laboratory's scope of calibrations and/or tests;

- arrangements for ensuring that the laboratory reviews all new work to ensure that it has the appropriate facilities and resources before commencing such work;
- reference to the calibration, verification and/or test procedures used;
- procedures for handling calibration and test items;
- reference to the major equipment and reference standards used;
- reference to procedures for calibration, verification and maintenance of equipment;

- reference to verification practices including interlaboratory comparisons, proficiency testing programs, use of reference materials and internal quality control schemes;
- procedures to be followed for feedback and corrective action whenever testing discrepancies are detected, or departures from documented policies and procedures occur;
- the laboratory management arrangements for exceptionally permitting departures from documented policies and procedures or from standard specification;

- procedures for dealing with complaints;
- procedures for protecting confidentiality and proprietary rights
- procedures for audit and review.

ENVIRONMENTAL MANAGEMENT SYSTEM FUNCTIONS



FIVE CORE ELEMENTS OF AN ISO 14 000 EMS

(1) Commitment and Policy - The company must have an environmental policy endorsed by top management.

(2) Planning - The company must know and document all environmental requirements, establish objectives and targets, designate responsibilities, and identify timeframes over which objectives are to be achieved.

(3) Implementation and Operation - The company must define, document, and communicate roles, responsibilities, and authority. Personnel must be properly trained. Internal and external communication systems and emergency preparedness and response programs must be established. All elements of EMS implementation must be documented.

(4) Measurement and Evaluation - A company must monitor its adherence to requirements and correct any deviations. Periodic EMS auditing must be conducted.

(5) Review and Improvement - The company's top management must review the EMS on a regular basis to ensure continuing suitability, adequacy, and effectiveness.

ISO 14000 SERIES OF ENVIRONMENTAL MANAGEMENT DOCUMENTS
as of August 28, 1995

ISO 14000	EMS - General Guidelines on Principles, Systems and Supporting Techniques	SC1/WG2	DIS	Fall '96
ISO 14001	EMS - Specification with Guidance for Use	SC1/WG1	DIS	Fall '96
ISO 14010	EA - General Principles of Environmental Auditing	SC2/WG1	DIS	Fall '96
ISO 14011.1	EA - Audit procedures - Part 1: Auditing of EMS	SC2/WG2	DIS	Fall '96
ISO 14012	EA - Qualification Criteria for Environmental Auditors	SC2/WG3	DIS	Fall '96
ISO 14041	LCA - Goal and Definition/Scope and Inventory Assessment	SC5/WG2 & 3	Working Draft	Fall '96

EMERGING

Governing Principles

- Best environmental quality is ultimately best for all sectors

- Polluter pays

- Total cost accounting

- Economic Instruments

- Accountability
  - Public
  - Industry
  - Government

- No net loss

Galvanic Corrosion

Galvanic corrosion occurs when two electrodes of dissimilar materials are electrically connected and exposed in an electrolyte. An example is the common flashlight cell (Figure 10-1). When the cell is connected in a circuit, current flows from the zinc case (the anode) into the electrolyte, carrying ionized atoms of zinc with it. As soon as the zinc ions are dissolved in the electrolyte, they lose their ionic charge, passing it on by ionizing atoms of hydrogen. The ionic charge (the electric current) flows through the electrolyte to the carbon rod (the cathode). There, the hydrogen ions are reduced to atoms of hydrogen, which combine to form hydrogen gas. The current flow through the circuit, therefore, is from the zinc anode to the electrolyte, to the carbon rod cathode, and back to the zinc anode through the electrical conductor connecting the anode to the cathode. As the current flows, the zinc is destroyed but the carbon is unharmed. In other words, the anode is destroyed but the cathode is protected.

If the hydrogen gas formed in the galvanic cell collects on the cathode, it will insulate the cathode from the electrolyte and stop the flow of current. As long as the hydrogen film is maintained, corrosion will be prevented. Removal or destruction of the hydrogen film will allow corrosion to start again at the original rate. Formation of the film is called polarization; its removal, depolarization. Corrosion cells normally formed in highly corrosive soils or waters are such that the hydrogen formed on the cathode escapes as a gas and combines with dissolved oxygen in the electrolyte, thus depolarizing the cathode and allowing corrosion to proceed.

In the flashlight battery, the zinc case is attacked and the carbon is not. However, zinc or any other metal may be attacked when in circuit with one metal, but not attacked when in circuit with another. A metal listed in Table 10-1 will be attacked if connected in a circuit with one listed beneath it in the table, if they are placed in a common electrolytic environment such as water or moist soil.

The order in Table 10-1 is known as the galvanic series; it generally holds true for neutral electrolytes. Changes in the composition or temperature of the electrolyte, however, may cause certain metals listed to shift positions or actually reverse positions in the table. For example, zinc is listed above iron in the table, and zinc will corrode when connected to iron in fresh water at normal temperature. But when the temperature of the water is above

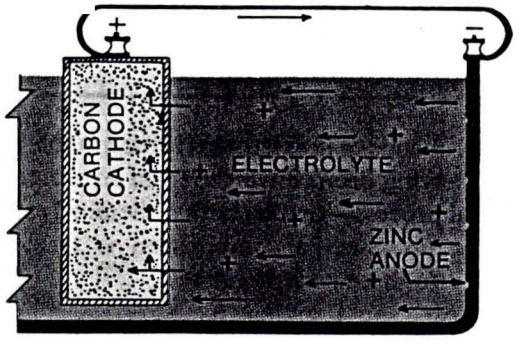


Figure 10-1 Galvanic Cell—Dissimilar Metals

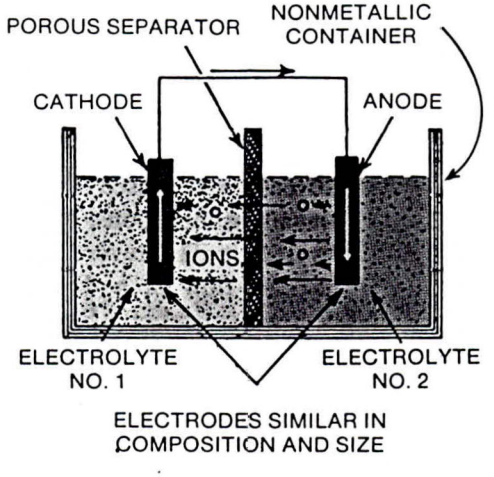


Figure 10-2 Galvanic Cell—Dissimilar Electrolytes

Environmental Impacts in Watersheds

Human activities cause changes in:

- Water quality
  - Chemicals and particulates
  - Point and Non-Point Sources
- Water quantity/distribution
  - Local/regional changes in storage/flow

Upstream/upgradient activities affect downstream users

Negative impacts related to:

- Terrestrial and aquatic ecosystem health
- Human health

Avoidance of ongoing negative impacts

- Appropriate Planning - avoiding contamination
- Clean up of contaminated sites

Table 10-1 Galvanic Series of Metals and Alloys*

Magnesium and magnesium alloys	Anodic or Corroded End
Zinc	
Aluminum 2S	
Cadmium Aluminum 17ST†	
Steel or iron	
Cast iron	
Chromium-iron (active)	
Ni-Resist†	
18-8 Stainless steel (active)† 18-8-3 Stainless steel (active)†	
Hastelloy C†	
Lead-tin solders Lead Tin	
Nickel (active) Inconel (active)†	
Hastelloy A† Hastelloy B†	Cathodic or Protected End
Brass Copper Bronzes Copper-nickel alloy Monel†	
Silver solder	
Nickel (passive) Inconel (passive)	
Chromium-iron (passive) 18-8 Stainless steel (passive) 18-8-3 Stainless steel (passive)	
Silver	
Graphite Gold Platinum	

*A "passive" metal has a surface film of absorbed oxygen or hydrogen. A metal may be initially "active" and become "passive" to the other metal when the protective film is formed.

†Composition of items is as follows: Aluminum 17ST—95% Al, 4% Cu, 0.5% Mn, 0.5% Mg; Ni-Resist, International Nickel Co., New York, N.Y.—austenitic nickel and cast iron; 18-8 stainless steel—18% Cr, 8% Ni; 18-8-3 stainless steel—18% Cr, 8% Ni, 3% Mo; Hastelloy C, Union Carbide Carbon Co., Niagara Falls, N.Y.—59% Ni, 17% Mo, 14% Cr, 5% Fe, 5% W; Inconel International Nickel Co., New York, N.Y.—59–80% Ni, 10–20% Cr, 0–23% Fe; Hastelloy A—60% Ni, 20% Mo, 20% Fe; Hastelloy B—65% Ni, 30% Mo, 5% Fe; Monel—63–67% Ni, 29–30% Cu, 1–2% Fe, 0.4–1.1% Mn.

Source: Hertzberg, L.B. Suggested Non-technical Manual on Corrosion for Water Works Operators. *Jour. AWWA*, 48:7:9 (June 1956).

Environmental Assessment

- Regulatory Process
- Specific Industries/Developments
- Specific responsibilities
  - Industry (Developer)
  - Government time frames, overall health
  - Public experience, knowledge

Site Remediation/Decommissioning

- Contaminated sites
- In response to downstream effects.
- "Orphan" sites

Do It Now - Environmental Assessment

Benefits

- Total Cost Accounting
- Viability/Sustainability
- Environmental thinking
- Involves Public Attitudes /Knowledge
- Encourages contingency planning
- Design for prevention/control

Do It Now - Environmental Assessment

Costs

Delay in Implementation

Lost opportunities (?)

Design changes

Participants' Time

Public consultation

Contingency plans

Additional equipment

Do It Later - Decommission/Clean Up

Benefits

- Deferred O&M costs to operator
- Short Term jobs/taxes
- Political benefit

Costs

- Public Costs
- Lower ecosystem and human health
- Reduced tax revenue
- Bankruptcy - job loss
-

Typical Direct Costs of EIA

	($000,000 CAD)
Expert advice	0.03 - 0.10
Additional Equipment/ Design Change	0.50 - 1.50
O & M of Additional Equipment (25 years)	0.25 - 0.50
Total	0.78 - 2.10

Metal Recycling Site

Soil - Groundwater - Lake
contamination by PCB

	($000,000 CAD)
Initial cleanup/capping	1.3
Monitoring (5 years)	0.2
"Hot Spot" cleanup	3.0 - 5.0
Regulatory Compliance for entire lake	12.0 - 20.0
Total	$16.5 - 26.5

Sydney Tar Ponds

Most contaminated orphan site in Canada.

Long term coal coking operation resulted in PAH and PCB contaminiation of estuary.

	($000,000 CAD)
Phase I - attempted removal and incineration	55.0
Proposal A: Site Capping	20.4
Proposal B: Incineration	120.0
Total	$75.4 - 140.0

WASTEWATER TREATMENT TECHNOLOGIES: EXPERIENCES AND CHALLENGE IN THAILAND

Chongrak Polprasert, Thammarat Koottatep and Nawa Raj Khatiwada

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PO. Box 4, Klong Laung, Pathumthani, Thailand 12120

ABSTRACT

Due to rapid urbanization and industrialization, water pollution has become increasing problems in Thailand during the past decades. Technologies for wastewater treatment employed in Thailand range from energy-intensive processes such as activated sludge, rotating biological contactors, and oxidation ditches, etc., to less energy-intensive processes such as waste stabilization ponds and on-site septic tanks and cesspools. Although the energy-intensive processes can achieve high treatment performances and requiring less land area, they are expensive to operate and maintain and produce sludge residues which need to be properly stabilized prior to disposal. Because Thailand is located in tropical region and land areas in the suburbs and provinces are still not very expensive, wastewater technologies that allow for the recycling of nutrients contained in the wastes should be considered. Examples of these waste recycling technologies are: waste-fed fish ponds, constructed wetlands, composting and land treatment. These technologies are low-cost to operate and the recycled products become incentives for the plant operators. Waste recycling technologies should be considered as alternatives for the conventional technologies of wastewater treatment, wherever possible.

INTRODUCTION

Significant challenge confronting environmental engineers and scientists in developing countries is the search for appropriate wastewater treatment and management technology which are reliable and economic. The current technologies of wastewater treatment, are mainly the waterborne sewerage and conventional waste treatment system. However, the above system do not appear to be applicable or effective in solving the sanitation and water pollution problems in developing countries. As shown in Table 1, although the percentages of population served with adequate water supply and sanitation increased during the past decades, due to rapid population and urbanization, these percentages for the urban areas are expected to decrease in the year 2000. The same trends are observed both for the Asia and Pacific region and globally. another concern for rapid population growth is the pressure exerted on our fixed arable land area on earth. Table 2 projects the ratio of arable land area over world population in the year 2063 to be one-third of that in the year 2000. There is an obvious need to either control population growth or produce more resources for human needs.

Like other newly industrialized countries, Thailand is also facing water pollution problems caused by rapid urbanization and industrialization. This paper outlines the present practices of water pollution control in Thailand and some alternatives of wastewater treatment and recycling applicable for tropical conditions.

Table 1 Water supply and sanitation coverage

Region	Percent covered in year		
	1980	1990	2000
Asia and Pacific			
Urban water	73	77	71
Rural water	28	67	99
Urban sanitation	65	65	58
Rural sanitation	42	54	65
Global totals			
Urban water	77	82	77
Rural water	30	63	89
Urban sanitation	69	72	67
Rural sanitation	37	49	58

Table 2 Population growth and arable land.

Year	Estimated population (billion)	Arable land ha/capita
2000	6	1
2020	10	0.6
2063	22	0.3
2100	?	0.1-0.2

PROBLEMS OF WATER POLLUTION

The major sources and types of water pollution are described below.

Sources of pollution

Basically, most of water resources are being polluted by both point and non-point sources of pollution. Domestic sewage and industrial effluent are major point sources of pollution, while the major non-point sources include agricultural run-off, soil erosion and mining. Examples of the pollution sources, are:

a) Domestic sewage

The classical cause of water pollution is household sewage. Sewage poses a threat not only to human health, but also increases the load of nutrients in the water body. In Pakistan, municipal waste is four times greater than waste emitted by the industrial sector and most of it is discharged directly into rivers (UNEP, 1990). Likewise, Department of Health (DOH), Thailand, in 1993 stated that 60-70% of pollutants discharged into the Chao Phraya River are mainly from the domestic wastewater.

b) Industrial effluent

The rapid industrialization has resulted in the emission of new industrial effluents which cause water pollution and bringing about previously unknown risks to human health and endangering aquatic life. These effluent may contain non-degradable and toxic materials such as heavy metals, acids and other corrosive chemicals. By failing to install waste treatment facilities, many new industries have exacerbated water

pollution. In Delhi, for instance, 19,000 m^3/d of industrial effluents, including 500 m^3/d of DDT, are discharged into the Jamuna River every day as it pass through the city (UNEP, 1990).

c) Run-off from land-use activities

Land-use activities such as agriculture, mining and urbanization typically generate run-off which substantially affects the quality of rivers, lakes, reservoirs and underground water. Leaching of agricultural chemicals, including fertilizers, pesticides, and herbicides, into the water bodies can cause water pollution. Manure and silt from arable lands are also major sources of pollution. In case of mining, many of the mining processes release a variety of metals into water bodies and, even when these activities cease, drainage water and wastes heaps continue to produce pollutants.

Types of pollution

a) Pathogens

Bacteriological contamination of the water resources are measured by indicator organisms as pathogens. The pathogens concern mainly on human health risks. Although, the World Health Organization (WHO) guidelines for safe drinking water call for 98% of all samples to be free from coliform bacteria, few developing countries can meet this standard. As shown in Table 3, twenty percent of the river samples from Asia and the Pacific have a high or very high coliform content, compared to those of North America (UNEP, 1990). For example, faecal coliform counts in the downstream of the Chao Phraya River, Bangkok, range from 9,500-255,000 per mL (DOH, 1993)

Table 3 Faecal coliforms in selected rivers (UNEP, 1990)

Number of faecal coliforms per 100 mL	Number of rivers in each region			
	North America	Central and South America	Europe	Asia and the Pacific
10	8	0	1	1
100	4	1	3	2
1,000	8	10	9	14
10,000	3	9	11	10
100,000	0	2	7	2
1,000,000	0	2	0	3
Total no. of rivers	23	24	31	32

b) Organic matters

The largest amount of any pollutant group discharged into water courses are organic compounds, either dissolved in the effluent or associated with suspended matter. As the BOD level of 6.5 mg/L is the threshold of pollution (UNEP, 1990), water quality of the Chao Phraya and Pasak River in Thailand are in good shape (Table 4). Considering water quality data of the down stream of the Chao Phraya River, BOD and DO levels were in the range of 2.5-4.7 and 1.2-1.7 mg/L, respectively (DOH, 1993). However, because of the high SS and faecal coliform concentrations, this part of the Chao Phraya River would be classified to Class no. 5 which can serve for only transportation.

Table 4 Water quality monitoring data for selected rivers (UNEP, 1990).

Rivers	Country	Water temp ^{o}C	pH range	SS mg/L	BOD max. mg/L	Faecal Coliform. no./100 mL
Safami	Japan	4.5-24.8	7.0-7.4	3-119	4	130-4,900
Sefid	Iran I.R.	0.0-29.5	7.7-8.3	36-31,700	**	170-16,000
Sabarmarti	India	23.0-37.0	7.0-8.8	**	284	20,000-9,900,000
Narmada	India	19.0-32.0	7.0-8.8	**	11	9-900,000
Chao Phraya	Thailand	24.0-32.0	5.5-8.0	25-280	3	50-35,000
Pasak	Thailand	23.0-32.5	6.5-9.8	4-72	3	49-11,000

** Not available

c) Nutrients

Some inorganic chemicals present in natural fresh water acts as nutrients which are vital for the growth of aquatic life. However, their quantities are being increased above their natural balances, resulting in eutrophication and algal blooms, with subsequent detrimental consequences for oxygen balance, organic loads, fisheries and drinking water. Previously, eutrophication used to be a feature only of lakes and reservoirs, but now it is also affecting rivers (UNEP, 1990). In the downstream of Chao Phraya River, the eutrophication is causing concern because of low level of oxygen and ammonia nitrogen is greater than 0.5 mg/L (DOH, 1993).

d) Heavy metal and toxic chemicals

An emerging source of water pollution in developing and newly industrialized countries is the release of chemicals into water bodies. Heavy metals and synthetic organic chemicals are of major concern. Even at relatively small concentrations they have adversely effects on organisms. High levels of heavy metals and toxic organic compounds have been recorded in several rivers in Asian countries. In Australia, for example, the Derwent River estuary has high concentrations of zinc (12-1,500 μg/L), cadmium (0.5-15 μg/L) and mercury (116 μg/L) which are reported to be among the highest in the world. Similarly, in Thailand, data of heavy metals in downstream of the Chao Phraya River in 1993 showed that zinc, cadmium, mercury and l[redacted] concentrations of 90-230, 2-17, 0.26-0.48 and 32-120 μg/L, respectively, which were above the stream quality standard (DOH, 1993).

EXISTING PRACTICES AND TREATMENT TECHNOLOGIES

In Thailand, several wastewater treatment plants have been constructed and operated to treat either domestic or industrial wastes. Most of the wastewater treatment plants employ conventional technologies, such as activated sludge, rotating biological contactors (RBC) and oxidation ditches; but some treatment plants, especially in provincial area; utilize natural treatment technologies such as waste stabilization ponds and on-site septic tanks and cesspools.

Conventional waste treatment systems

Bangkok installed its first central wastewater treatment plant in 1994 at the capacity of 30,000 m^3/d, serving only 150,000 people. Other five central treatment plants at a total capacity of 992,000 m^3/d and serving about 3 millions people, will have been constructed by the year of 2000. The construction costs of these

wastewater treatment plants are estimated at 23,000 million baht (Klunkrong, 1995). Some types of activated sludge systems such as extended aeration, deep shaft tanks, etc., will be employed in some of these treatment plants which typically comprising of pumping stations, aeration tanks, sedimentation tanks, screening and sludge dewatering units. In the year of 2000, sludge production from these wastewater treatment plants is estimated to be 100 tons dry solids/day (Stoll, 1995). The construction costs of these activated sludge units is 7,700 baht per capita, excluding costs of land area.

Natural waste treatment systems

Hard Yai District, Songkla province, a city in the south of Thailand, is constructing a new central wastewater treatment plant, comprising of 4-primary facultative ponds, 4-secondary facultative ponds, 4-maturation ponds and 2-constructed wetlands. The treatment plant has a total capacity of 69,088 m^3/d, serving 220,000 capita in the municipality of Hard Yai for the next decade. Construction costs of this plant amount to 1,200 million baht and requiring land area of 1,500 rai or 240 ha (Panapawuthikul, 1996). The construction cost is 5,500 baht per capita which is less than those of the conventional systems. Moreover, low operational and maintenance costs for these natural treatment systems are an advantage because no energy is required in the operation of the treatment system.

POTENTIAL OF WASTE RECYCLING TECHNOLOGIES

There are a number of waste recycling technologies which can be employed for the treatment, reclamation and reuse, but the choice is rather dictated by geographical position and local situations. In case of a rapidly developing country like Thailand the most appropriate technology should not only fit to its climatic conditions but also be commercially viable and as well as be suitable for small to large scale operation. These scenarios eventually lead to four most appropriate recycling technologies in the context of Thailand, they are: waste-fed fish ponds, constructed wetlands, composting and land treatment. A brief description of these technologies along with the criteria of application are given below.

Waste-fed fish ponds

Among several waste recycling methods, the reuse of human and animal wastes for the production of algae and fish has been extensively investigated. Although the algal cells photosynthetically produced during sewage treatment contain about 50% protein, their use is limited because of the harvesting problem and low digestibility. Thus the culture of herbivorous fish in the same pond to graze on the algae, or feeding the algal-laden water to herbivorous-fish ponds is attractive, in order to produce the fish protein biomass which is easily harvestable for animal (or human) feed.

There are basically three techniques for reusing organic wastes in aquaculture: by fertilization of fish ponds with excreta, sludge or manure; by rearing fish in effluent-fertilized fish ponds; and by rearing fish directly in waste stabilization ponds (such as in maturation ponds). The main objectives of the waste recycling through aquaculture are waste stabilization and nutrient recycling and upgrading effluent from waste stabilization ponds so that high food conversion is obtained at relatively low cost.

Fish to be reared in waste-fed ponds should be tolerant to low DO level, diseases and other adverse environmental conditions and as well as be herbivorous or omnivorous in nature to feed on the waste-grown phytoplankton. Some species such as Tilapia, Chinese carp, and Indian carp have been widely used in waste recycling practices. Organic wastes, including septage, could provide sufficient nutrients to promote the growth of phytoplankton and consequently of zooplankton which are natural food of these fish (Polprasert et

al., 1984). Among these species, Tilapia needs to be particularly mentioned, for its being used widely in waste recycling in the tropical and sub-tropical areas because, it feeds directly on algae and other primary aquatic vegetation, grows rapidly and multiplies abundantly and posses better tolerance to low DO level and resistance to diseases.

The growth of fish in waste-fed ponds is influenced by a variety of environmental parameters such as light, temperature, dissolved oxygen (DO), ammonia concentration, pH, carbon dioxide, stocking density, hydrogen sulfide (HS), heavy metals and pesticides. To enhance the growth of fish these parameters should be properly maintained or acquired in the ponds.

Almost all kinds of organic wastes can be fed to fish ponds. These wastes can be in any of the following forms: raw sewage, effluents from wastewater treatment plants or high-rate algal ponds, nightsoil and septage, biogas slurry, composted products, animal manure, and agro-industrial wastewaters. Fish may be reared directly in waste stabilization ponds. In any case, organic loadings to be applied to waste-fed fish ponds should be in the range that anaerobic conditions do not prevail in the ponds. Well-operated fish ponds fed with wastewater have organic loadings in the range of 25-75 kg BOD_5/(ha-day), while those fed with organic solids e.g. septage or biogas slurry have organic loadings from 50 to 150 kg COD/(ha-day). Data of fish yields vary widely depending on the modes of pond operation, climates, fish species and stocking densities employed. However, these fish yield data were reported to be at least comparable to or better than those ponds fed with conventional fish feed.

Polyculture of fish (such as herbivores and carnivores) is not advisable in waste-fed ponds because of public health considerations due to direct contact of all these fish to the wastewater, even though it utilizes all part of the aquatic environment. It is not practical to design a waste-fed pond to rear different species of fish because their tolerance levels to low DO are different.

To produce trash fish for animal feed, stocking density of 10 or more fish/m^2 is recommended and the period of fish culture may be as short as 3 months. Ponds producing marketable-size fish, for possible use as human food, should be stocked at a lower density such as 1-2 fish/m^2 or even less, but the rearing period may be up to 1 year or longer.

Water supply should be sufficient in quantity and of good quality since ponds fed with solid or semi-solid organic wastes e.g. animal manure or nightsoil, need a certain amount of water to compensate for losses through evaporation and seepage. Ponds fed with sewage or effluent of wastewater treatment plant sometimes need dilution water. The quality of water should be in the permissible range for fish growth.

Generally pond depth of 1-1.5 m is suitable for fish with the provision of free board of 0.3 to 0.6 m. In rain-fed pond, if the organic input is in solid form, deeper water level should be provided to compensate the water loss during dry season. A polyculture fish pond is recommended to have 2-3 m depth with an area of manageable size; normally the 1,000-4,000 m^2 pond area is suitable in the tropics. The width of ponds should not exceed 30 m to facilitate seining operation. Separate water supply and drainage system should be provided in each pond.

Constructed Wetlands

Constructed wetlands which represent an emerging ecotechnological treatment and recycling systems are defined as engineered structures of saturated substrates , emergent and submergent vegetation , animal life and water that simulates natural wetlands. A constructed wetland (Fig. 1) performs better than natural

wetlands because of the graded bottom and controlled hydraulic regime. Among other aquatic treatment recycling systems, constructed wetlands tolerate greater organic loading rates, have shorter hydraulic retention times and produce better effluent quality. Two types constructed wetlands are being extensively used free water surface (FWS) systems with shallow water depths and subsurface flow (SF) or vegetated submerged bed (VSB) systems with water flowing laterally through the sand or gravel (Polprasert, 1996).

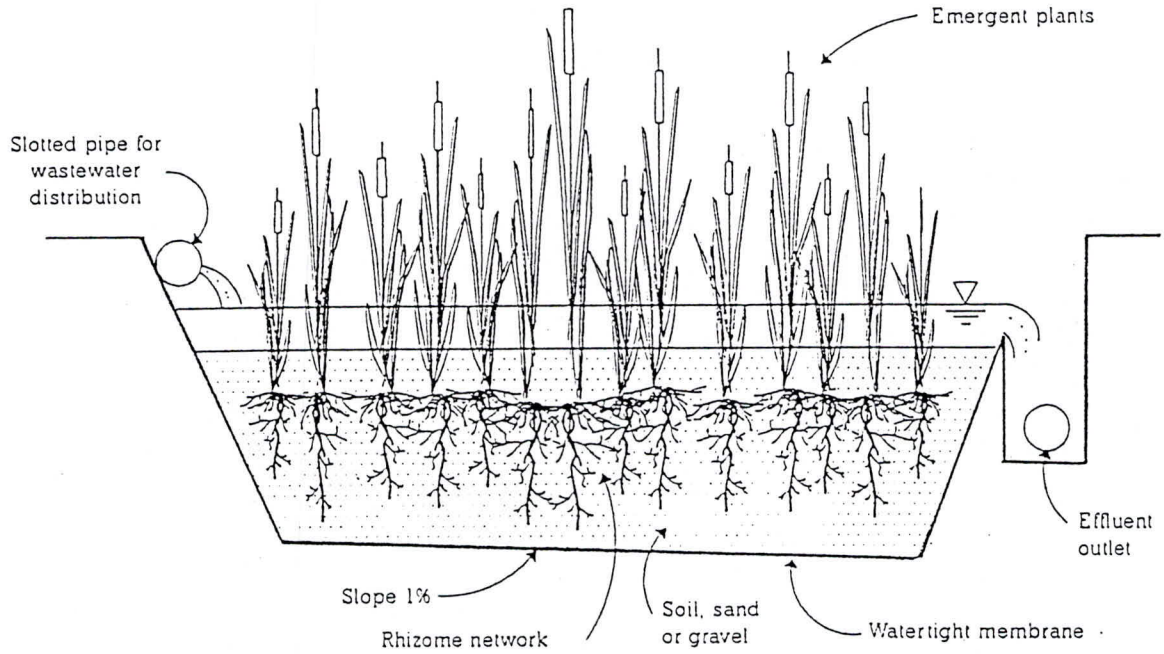

Figure 1 Schematic diagram of constructed wetlands.

All constructed wetland systems can be considered to be attached growth biological reactors, and their performance can be described with first order plug-flow kinetics. Design equations normally employed for both FWS and FS systems should give a reasonable, and hopefully conservative, estimate of design requirements. However, a pilot test is strongly recommended for large-scale projects. Because grading and excavating represent a major cost factor, topography is an important consideration in the selection of an appropriate site. In selecting a site for an FWS wetland, the most desirable soil permeability is 10^{-6} to 10^{-7} m/s. Sandy clays and silty clay loams can be suitable when compacted. In heavy soils, additions of peat moss or top soil will improve soil permeability and accelerate initial plant growth. A slope of 0.5% or less, as limited by construction tolerances, is recommended for an FWS system. Some slope is needed to drain the cell for maintenance and possible mosquito control. SF bed slopes should be 2% or less based on the initial hydraulic conductivity of the substrate. A level substrate surface is recommended for an SF system to facilitate vegetation planting and to control weed by flooding the bed. Bed slopes greater than 4% would cause most of the flow to be on the surface due to poor hydraulic conductivity, with channeling, treatment, and vegetation management problems (Steiner and Freeman, 1989).

If groundwater contamination or water conservation is a concern, an impermeable liner below the substrate is required. Possible materials are compacted in situ soil (permeability less than 10^{-6} cm/sec); bentonite; asphalt; synthetic butyl rubber; or plastic membranes. The liner must be strong, thick, and smooth to prevent root penetration and attachment (Steiner and Freeman, 1989). Both of the constructed wetlands are normally designed at a loading rate of 100 kg/(ha-day) or less. The hydraulic loading rate varies from 1 - 8 cm/day

depending upon the local conditions. The optimum hydraulic retention time is 5-15 days in both of the systems.

Composting

Composting is a controlled aerobic process carried out by successive microbial populations combining both mesophilic and thermophilic activities, leading to the production of carbon dioxide, water, minerals, and stabilized organic matter. Generally, composting is applied to solid and semi-solid organic wastes such as nightsoil, sludge, animal manure, agricultural residues, and municipal refuse.

Aerobic composting is the decomposition of organic wastes in the presence of oxygen (air); the end-products of biological metabolism are carbon dioxide (CO_2), NH_3, water and heat. Anaerobic composting is the decomposition of organic wastes in the absence of oxygen; the end-products are methane (CH_4), CO_2, NH_3, trace amounts of other gases, and other low-molecular-weight organic acids. NH_3 is furthered oxidized to become nitrate (NO_3^-) by the nitrifying bacteria during the maturation or curing phase. Because it can release more heat energy resulting in a rapid decomposition rate, aerobic composting has been a prefer[illegible] technology for stabilizing large quantities of organic wastes. Anaerobic composting is a slow process and can produce obnoxious odors originating from the intermediate metabolites such as mercaptans and sulfides. Depending on the methods of operation, anaerobic composting can produce temperatures near to or at thermophilic levels. Because of its simplicity, anaerobic composting has found some applications in many rural areas of developing countries in the stabilization of wastes generated from households and farms.

Using technology as the key, composting can be classified into 'mechanical' and 'non-mechanical' processes, or 'on-site' and 'off-site' processes. Composting can also be divided with respect to the modes of operation, i.e. batch operation and continuous or semi-continuous operation. When temperature is the basis, composting can be divided into 'mesophilic' composting and 'thermophilic' composting.

The main purposes of the composting are waste stabilization, pathogen inactivation, nutrient and land reclamation and sludge drying. The effectiveness of a composting process is dependent upon the groups of organisms that inhabit and stabilize the organic wastes. Thus a number of environmental parameters such as nutrient balance, moisture content, aeration, temperature and pH needed to be properly controlled in the operation of composting processes.

The most important nutrient parameter is carbon/nitrogen (C/N) ratio, which should be between 20 - 40 initially. A higher C/N ratio prolongs the composting duration where as lower one will tend to the loss of nutrients. A moisture content of between 50 and 70 percent (average 60 percent) is most suitable for composting and should be maintained during the periods of active bacterial reactions. An optimum compost temperature of approx. 55°C will maximize the decomposition rate and inactivate the pathogen effectively where as a neutral pH will favour the composting process. To facilitate the decomposition rate smaller particle size of the feed materials and structural support of compost pile are equally important (Polprasert, 1996).

Land treatment

Land treatment is defined as the controlled application of wastes on to the land surface to achieve a specified degree of treatment through natural physical, chemical and biological processes within the plant-soil-water matrix. Land treatment of wastewater and sludge has been practiced for long time and it has received considerable attention nowadays as an alternative treatment to other existing treatment processes. In

developing countries, where land is available, land treatment is considered as a less expensive treatment method (Polprasert, 1996).

In the past, the objective of land treatment was simply to dispose of the wastes, but the current trend of this practice has included the utilization of nutrients in the wastewater and sludge for crop production and tertiary (advanced) treatment of wastewater or to recharge groundwater. Slow rate process (SR), rapid infiltration process (RI) and over land process (OF) are three types of which are normally employed for the wastewater treatment. USEPA design criteria for land treatment of wastewater is outlined in Table 5.

Table 5 Comparison of typical design features for land treatment processes (EPA, 1981).

Feature	Slow rate	Rapid infiltration	Overland flow
Application techniques	Sprinkler or surface[a]	Usually surface	Sprinkler or surface
Annual loading rate, m	0.5-6	6-125	3-20
Field area required, ha[b]	23-280	3-23	6.5 - 44
Typical weekly loading rate, cm	1.3-10	10-20	6-40[c]
BOD_5 loading [d], kg/(ha-yr)	370-1830	8000-46000	2000-7500

a. Includes ridge-and-furrow and border strip.
b. Field area in hectares not including buffer area, roads, or ditches for 3,785 m^3/day (1 Mgal/day) flow.
c. Range includes raw wastewater to secondary effluent, higher rates for higher level of pre-application treatment.
d. Range for municipal wastewater.

Agriculture utilization, forest utilization, land reclamation and land disposal are the four major application of sludge land application systems. The design of land treatment of sludge is usually based on the limiting design parameter (LDP). LDP is the design value in which other constraints such as nutrient requirements or public health problems will be overcome. For example, the annual sludge application rate on an agricultural land may be determined by N or P requirement, and the useful life of the site may be limited by cadmium (Cd) loading. Sludge should be applied to agricultural land at a rate equal to the N uptake rate of the crop unless less application rates are required because of cadmium limitations. The basis for N loading criteria is to minimize nitrate leaching to groundwater. The annual limit for Cd loading is to minimize crop uptake and the potential long-term, sub-clinical adverse effects on human health. The lifetime limit of a land application site is established on the basis of maximum cumulative loadings of heavy metals such as lead (Pb), zinc (Zn), copper (Cu), nickel (Ni) and Cd. These limits are designed to allow for growth and use of food-chain crops at future dates (Polprasert, 1996).

A preliminary estimate of the land area required for screening purposes can be determined for municipal sludge with Table 6. Estimates of soil treatment area for industrial sludge should be based on the critical LDP such as metal concentration, etc.

Table 6 Estimated land area for municipal sludge applications.

Option	Application period	Reported range (dry tons/ha)	Typical rate (dry tons/ha)
Agriculture	Annual	0.4 - 12	2
Forest	One application or at 3-5 yr. intervals	1.6 - 40.5	8
Site reclamation	One application	1.2 - 81	20

Application of composting in pig farms

A brief outline of the composting of the waste generated from pig farms in order to produce fertilizer is given as an example of the waste recycling technologies. A detail feasibility study of the total treatment and recovery system for the pig farm wastes was undertaken at Environmental Engineering Division, AIT (AIT, 1991). The pig manure was digested in a modified two-stage anaerobic reactor, and the wastewater obtained as farm waste was treated in a water hyacinth ponds. The water hyacinth plants along with pig manure, leaves and digested sludge from the anaerobic reactor were mixed together to obtained a C/N ratio of 25/1 - 30/1 and composted in piles. The moisture content in the piles were maintained 60-70% by water spraying and the composting procedure was done in natural aeration condition. Highest temperature of 58°C was recorded in the pile of C/N content as 30:1 resulting with better die-off of the pathogenic microorganisms. The study recommended a C/N ratio of 30:1 and composting period of 40 days for the better performance. The products obtained were recommended to use as soil conditioner/fertilizer and as a substitute for fish feed for some herbivorous fish such as tilapia. A complete scheme of the total treatment and recovery system of a pig farm waste is shown in Fig. 2.

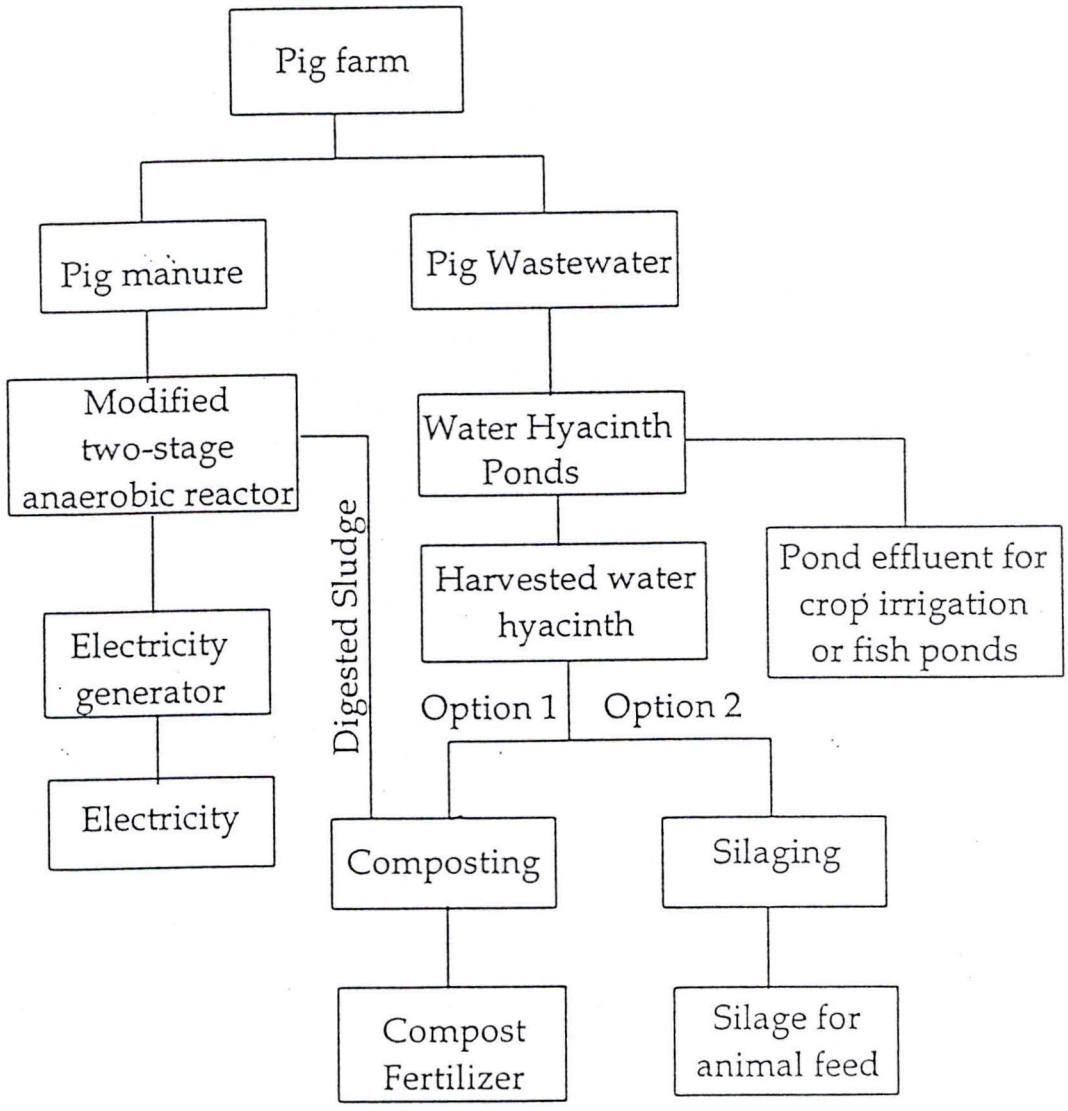

Figure 2 Schematic diagram of total treatment and recovery system of a pig farm waste

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WASTEWATER TREATMENT TECHNOLOGIES USED IN QUEBEC (CANADA)

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SUMMARY

Wastewater from different sources as domestic sewage, commercial, industrial or storm water are treated. We will discuss the properties of wastewater as physical, chemical, biological and microbiological characteristics depending on their origin. Parameters such as total suspended solids, BOD, COD, TOC, organic nitrogen, phosphorus, ammonia content, etc, will be elucidated. Primary, secondary and advanced or tertiary treatments will be discussed.

A special emphasis of the conference will be made on wastewater recycling for aquaculture purposes using biofilters. A follow-up of the evolution of Ammonia, Nitrites and Nitrates concentrations in a recycling system are indications of performance. Finally an example of aquacultured trout and/or salmon using completely recycled water will be shown.

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INTRODUCTION

Wastewater is not constant in character from place to place nor from time to time. The combination of inherent variability and experimental error produce considerable uncertainty regarding the actual characteristics in any given situation, and extensive testing programs may be necessary to determine the actual nature of the waste. The "typical" values which are presented here and in other texts are national averages which should never be assumed to represent the waste of a particular community.

As sewage passes through the collection system, solid organic material will tend to be solubilized by microbial action and some solids may be removed by sedimentation, while grease and oils will tend to move to the upper surface and, perhaps, to be deposited along the walls of the pipes.

Analyzing a flow which is variable in time requires that a large number of samples be taken in order to define the range of concentrations to be expected. Wastewater characterization studies are seldom sufficiently detailed to establish the variability with much certainty, hence engineers must be very cautious in designing systems intended to treat domestic wastes. Wastewater could have different origins: storm water, industrial, commercial or domestic sewage. A projected water consumption in the year 2000 shown in Table 1.

Use	Liters/ capita/ day	% of total
Domestic	300	44
Industrial	160	24
Commercial	100	15
Public	60	9
Loss and waste	50	8
TOTAL	670	100

TABLE 1: PROJECTED CONSUMPTION OF WATER IN THE YEAR 2000

1.0 DOMESTIC SEWAGE CHARACTERISTICS

1.1 Physical characteristics

Sewage is over 99.9 percent water. Fresh domestic sewage has a slightly soapy or oily odor, is cloudy, and contains recognizable solids, often of considerable size. As the waste ages, its character changes as a result of biological and chemical phenomena. Stale sewage has a pronounced odor of hydrogen sulfide, is dark gray, and contains smaller but occasionally recognizable solids.

The change from fresh to stale requires 2 to 6 h at a temperature of 20° C, with the time depending primarily on the concentration of organic matter. The concentration varies with per capita water use, infiltration, and the quantity of industrial waste which enters the collection system. The quantity of domestic waste produced per person is relatively invariant on a dry solids basis.

The solids in sewage may be either suspended or dissolved. Biological action will tend to dissolve some of the suspended organic material as it passes through the sewer. Volatile solids are those solids ignitable at 550° C. The concentration of total volatile solids is considered to be a rough measure of organic content, while suspended volatile solids, in some instances, is considered a measure of the concentration of biological solids such as bacteria and protozoa.

1.2 Chemical characteristics

Wastewater contains both inorganic and organic chemicals. The inorganic constituents are present in the carriage water and increase because of water use. Ordinary sewage treatment is not directed toward altering the concentration of inorganic contaminants, although the concentrations of phosphorus and nitrogen are sometimes significant in biological treatment processes. Nitrogen may be present in wastewater in both inorganic and organic forms and in both reduced and oxidized states. In untreated wastewater it is chiefly present as ammonia. *Phosphorus* is primarily present in wastewater in the form of phosphates.

2.0 CLASSIFICATION OF WASTEWATER TREATMENT SYSTEMS

2.1 Preliminary treatment systems

Wastewater treatment has been separated into preliminary, primary, secondary, and advanced systems. Preliminary systems include measurement and regulation of the incoming flow and removal of large floating solids, grit, and perhaps grease. The quality of the wastewater is not substantially improved by primary systems. Rather, the operation of subsequent processes iS enhanced through measurement and control of the flow and by removal of materials which might interfere with mechanical, chemical, or biological treatment.

2.1.1 Racks and Coarse Screens

The racks and screens used in preliminary treatment are intended to remove only fairly large suspended solids. The screening are sometimes fed directly to a grinder, which reduces their size so that they will not interfere with subsequent treatment. The ground screening are then returned to the flow or combined with primary sludge. Other methods of managing this material include anaerobic digestion, incineration, and burial. Before incineration it is desirable to dewater the screening as much as possible, since they normally are about 80 percent water by weigh. Incineration is usually carried out in conjunction with management of other sewage solids.

2.1.2 Comminutors

Instead of removing large suspended solids, comminutors reduce them in size so they will not interfere with other systems. The chopped or ground solids are then removed from the flow in subsequent sedimentation process. Comminutors consist of a fixed screen and a moving cutter.

2.1.3 Grit Removal

A portion of the suspended solids in municipal sewage consists of inert inorganic material such as sand, metal fragments, eggshells, etc. This grit is not benefited by secondary treatment or sludge processing techniques and can block conduits and promote excessive wear of mechanical equipment.

2.1.4 Grease Removal

Excessive quantities of grease may plug trickling filters or coat biological floc in activated sludge processes. Grease in removed to a degree by surface skimming devices in primary sedimentation tanks, but communities with particularly high concentrations of grease or treatment plants which omit primary clarification may need other processes. Skimming tanks employ baffled subsurface entrance and exit structures which permit floating material to be retained. Retention times are 15 min or less, and continuous mechanical skimming is usually employed.

2.1.5 Preaeration

Aeration of sewage before any other treatment is provided can have a number of desirable effects. First, aeration will strip volatile compounds and increase the dissolved oxygen content of the flow. Both of these effects will tend to reduce odor production. Aeration, through the mixing which it provides, may also improve grease removal slightly, offer additional opportunity for flocculation of suspended solids, and help to make the flow uniform in character as it enters subsequent processes.

2.2 Primary treatment systems

2.2.1 Purpose

Primary treatment processes are originally designed to remove suspended solids in wastewater prior to its discharge, since these were the most obvious source of pollution. Additional treatment methods developed to remove dissolved and colloidal solids were called secondary processes. Primary treatment usually involves a simple sedimentation process and chemicals are sometimes added to assist in removal of finely divided or colloidal solids or to precipitate phosphorus.

2.2.2 Sedimentation

Sedimentation processes in wastewater treatment include all three types. Grit removal in gravity basins and plain sedimentation approximate discrete settling processes; secondary settling following activated sludge processes is usually flocculent, and waste sludge thickeners exhibit hindered settling, as may the lower levels of other clarification processes.

2.2.3 Chemical Coagulation

Addition of the common metallic coagulants and polymeric coagulants will increase the removal of suspended solids in primary clarifiers. When this technique is applied to wastewater in modern practice, the major goal is usually phosphate precipitation. Suspended solids removals in such processes range from 70 to 90 percent.

2.2.4 Fine Screens

Screens can serve the purpose of removing fairly large solids which might create nuisance conditions in biological processes, but it is unwise to depend on them for high removals of solids or BOD or for removal of grease.

2.3 Secondary treatment systems

2.3.1 Purpose of Secondary Treatment

Secondary treatment systems are intended to remove the soluble and colloidal organic matter which remains after primary treatment. While removal of this material can be effected by physicochemical means, secondary treatment is usually understood to imply a biological process. The bulk of the suspended solids which enter a wastewater treatment plant and the waste solids generated in biological treatment must be handled as sludge at some point in the treatment process. The choice of primary and secondary processes may thus be influenced by anticipated problems with sludge handling. The sludge from municipal treatment plants is likely to contain microorganisms which may contribute to the transmission of disease as well as organic and inorganic contaminants which may be hazardous or toxic to humans or have detrimental effects on the environment in general.

2.3.3 Sludge Conditioning

Sludge conditioning includes a variety of processes, some biological, some chemical, and some physical, which may be applied to favorably alter the physical and chemical characteristics of sludge to improve its dewaterability. The biological and thermal processes also provide some decrease (perhaps as much as 50 percent) in the total mass of solids. Conditioning processes include aerobic and anaerobic sludge digestion, composting, chemical addition, and heat treatment.

2.4 Advanded wastewater treatment

2.4.1 Prupose of Advanced Wastewater Treatment

It impossible to treat wastewater to whatever degree may be desired - to covert sewage into potable or even chemically pure water. Advanced wastewater treatment encompasses those techniques which are applied in order to improve the quality of wastewater beyond that usually achieved in secondary treatment.

2.4.2 Suspended Solids Removal

The suspended solids in treated wastewater are in part colloidal and in part discrete, ranging in size from 10^{-3} to 100 μm. None of this material settles readily or it would be removed in secondary clarification. The techniques which have been applied to reduction of suspended solids in secondary effluents include chemical coagulation followed by sedimentation or dissolved air flotation, microscreens, diatomaceous earth filters, granular media filters, and ultrafiltration. Chemical coagulation of water is applicable in wastewater treatment as well. The coagulants used include lime, alum, iron salts, and polymers. Metallic coagulants also have a role in the removal of phosphorus, and lime is employed for pH adjustment in some ammonia-removal methods.

2.4.3 Nitrogen Removal

Nitrogen in wastewater is found as organic nitrogen, ammonia, and nitrate. Each milligram of ammonia (as N) exerts an oxygen demand of about 4.6 mg. It is apparent from this that the nitrogenous oxygen demand of a waste can be a large fraction of the total oxygen demand. Nitrogen in the form of ammonia is also toxic to some fish. Most nitrogen which enters the environment will eventually be oxidized to nitrate, in which state it may be used as a nutrient by microscopic and macroscopic plants. Nitrate itself is a pollutant with respect to public water supplies.

2.4.4 Phosphorus Removal

Phosphorus, like nitrogen, is a nutrient of microscopic and macroscopic plants, and thus can contribute to the eutrophication of surface waters. Phosphorus may be removed biologically and chemically. In some instances, chemicals may be added to biological reactors instead of being used in separate processes, while in others, biologically concentrated phosphorus may be chemically precipitated.

2.4.5 Refractory Organics

Refractory organics are those which are not removed in biological systems operating under ordinary conditions of sludge age, liquid retention time, etc. Examples of such substances include lignin, cellulose, and other polysaccharides, fats, phenolic compounds, etc. Removal of refractory organics can generally be provided by absorption on activated carbon.

2.4.6 Dissolved Solids

Dissolved mineral species such as nitrate, nitrite, selenium, arsenic, and heavy metals may cause health problems, while others such as chloride or hardness may be esthetically or economically undesirable. Metals may be removed by ion exchange, precipitation, reverse osmosis, etc. Polyelectrolytes with a soluble fraction precipitated by metal have been used to remove heavy metals from solution and coagulate them in a single step.

2.5 Modern technology in wastewater treatment

Relying on the same basic approach of wastewater treatment, scientists and engineers constructed special devices in order to enhance water quality released after the treatment. Four systems are in use by Queneco company in Canada. They are Altox, Altair, Deneb and Triton.

2.5.1 Altox

Altox is a biological purification process using pure oxygen conceived to increase the capacity of existing biological stations and to treat highly contaminated effluents or those liable to important load variations. The principle of biological purification is to grow a biomass (aerobic microorganisms or activated sludge) in a substratum (wastewater). This biomass growth goes along with metabolizing dissolved or colloidal organics and inorganics. Oxygen is consumed to fulfill the biomass breathing needs. Globally the object of the Altox process is to increase biological activity and concentration of biomass in the reactor of an activated sludge secondary treatment. Additional needs in oxygen are satisfied by supplying pure oxygen, using specially conceived equipment permitting maximum efficiency for the use of oxygen. This process can be integrated to an existing secondary treatment to increase its purifying capacity.

2.5.2 Altair

Altair is a biological purification process of an intensive type, conceived for the treatment of effluents which BOD5 is smaller that 500 mg/L. The principle of this purification method is to grow in wastewater a biomass comprising a variety of aerobic microorganisms called activated sludge. The biomass growth goes along with metabolizing dissolved or colloidal organics and inorganics; oxygen is consumed to fulfill the biomass breathing needs. The polluted water and biomass are maintained in contact in the biological reactor for a 24 hour period to allow the organic matter to metabolize itself. At the same time, the supply of oxygen necessary for the growth and maintenance of the microorganisms is made by air insufflation coming from diffusers placed at the bottom of the activation tank. The air diffusing equipment also allows the mixture of biomass and polluted water, or mixed liquor, to homogenize, therefore avoiding sedimentation of activated sludge in the reactor.

2.5.3 Deneb

Deneb is a gravity settling process of cylindral-conical type. The conception of the settling-tank is carried out depending on the flow of effluent, its concentration in solids and the nature of the particles. The continuous splitting of suspended solids and buoyants contained in the effluent can be divided in four zones. The cyclindrical parts help to slow down and render the flow uniform while the cone placed at the base of the settling-tank receives the settled solids. The settling takes place in the square section of the settling tank and the clarified water is drained at the surface.

Solids and buoyants accumulated at the basis and at the surface of the settling-tank are extracted continuously by an air lift driving system. For certain applications, adding of an air diffuser, of tranquilizers or of a strip settling zone in the square section of the decanter permits to obtain a high level of efficiency.

2.5.4 Triton

Triton combines the coagulation, flocculation and gravity settling processes to eliminate dissolved or colloidal particles and fine solids from residual waters. Coagulation's main object is to chemically unstabilize particles in suspension therefore permitting agglomeration. This step of the treatment consists in injecting one or many coagulants and ensure their dispersion in effluent.

Concretely, thè coagulant(s) is injected by a dosing pump into a pipe equipped with a static mixer, created turbulence ensures a rapid and complete dispersion of the products. The mix enters in the first section of the clarifier equipped with an aerator or an agitator where the floc is formed by means of a slow mix. The floc is then separated from the clarified effluent into a settling section. The chemical sludges are continuously evacuated while the clarified liquid is poured at the surface. Time of stay is approximately one hour.

3.0 WASTEWATER RECYCLE FOR AQUACULTURE

Intensive fish culture systems can be classified as flow-through or recirculating. In the former, clean water is typically directed in a single pass through the production unit and discharged or dispersed thereafter. These systems are used to produce both fresh water, brackish water and marine species. Freshwater flow-through or open systems are found in regions with an ample supply of clean water (e.g. trout farming in Idaho, USA). Tidal, earthen ponds for shrimp farming (Southeat Asia) are an example to brackish water flow-through systems, while cage culture is the foremost representative of marine flow-through systems and is the main form of aquaculture in many countries (e.g. Norway, Chile, Canada, Japan). A drawback of open systems is that, apart from their site specificity, they may contaminate recipient water bodies and may therefore become limited by envronmentally sound as water input is minimized, little water is discharged and this can itself be treated. However, adequate water quality control is essential for the successful operation of recirculating systems. In this context, biological control by algae and bacteria has so far been the most economically feasible approach.

The main biological process configurations presently applied in recirculating systems are compared with those involved in converting fish metabolites in static-water fish ponds. It is concluded from this that most treatment facilities applied in recirculating systems achieve only partial water purification since, in comparison with static ponds, they do not remove nitrate and organic matter.

3.1 Biological water quality control in static ponds

Control of water in intensive fish culture systems is often the bottleneck for their successful operation. The most common water quality problems in such systems are oxygen depletion and accumulation of organic matter, inorganic, nitrogen, particularly ammonia, and CO_2. As with industrial, agricultural and urban wastewater treatment, biological treatment of intensive fish culture systems has so far been considered the most economically feasible. The processes that can be utilized to prevent water quality deterioration in intensive systems are also similar to those which occur in static fish ponds. Here, a combination of physical, chemical and biological processes prevent oxygen depletion and accumulation of harmful compounds.

Dissolved oxygen (DO) is typically the fisrt water quality variable to limit production in closed or semi-closed culture systems. This limitation stems from the relatively high oxygen demand imposed by aerobic organisms within the system, the relatively low solubility of oxygen in water, and the deliberate reduction of two natural sources of DO: photosysthesis and freshwater exchange. Dissolved oxygen supplementation has also been achieved by sparying air below the water's surface or through use of propeller type surface agitators. Currently, DO supplementation is more frequently achieved by exposing water to oxygen-enriched gas within equipment designed to provide large gas-liquid interfacial areas. Equipment of this type has the unique ability to supersaturate water with oxygen, while concurrently stripping dissolved nitrogen (DN). Use of water supersaturated with DO can substantially increase allowable fish loading or rearing density that, in turn, act to lower production costs by minimizing rearing tank volumes, required water circulation rates, and the size of treatment units based on hydraulic loading. Dissolved nitrogen stripping allows for the addition of oxygen without exceeding total dissolved gas pressure.

3.2 Nitrification and solids removal

Treatment based on solids removal and nitrification is probably the most widely used amongst today's recirculating systems. Solids removal is accomplished by sedimentation or mechanical filtration. Une of commercially available screen filters has increased in the last 5 years. Despite these highly improved filtration methods, small suspended solids tend to accumulate in recirculating systems. High concentrations of suspended solids should be avoided as they form an additional source of ammonia, which in its unionized form is highly toxic to fish. Furthermore, they may cause gill damage by fouling, resulting in stress and increased

susceptibility to diseases. Removal of small suspended solids can be accomplished by either chemical or biological oxidation. Chemical oxidation by ozonation can be applied to reduce the organic load in conventional wastewater treatment. However, in a circulating system for fish culture ozonation did not lead to a significant decrease of organic matter (expressed as BOD). As an alternative to chemical oxidation fine suspended material can be removed by biological oxidation. Nitrification is typically carried out in a variety of systems, of different types: submerged filters, trickling filters and fluidized bed reactors. The ideal material (a) has a high surface area per volume, (b) is low in cost, (c) is durable, (d) does not clog easily and (e) promotes a uniform spread of water to be treated. Plastic materials fulfill most of these criteria and are increasingly being used.

3.3 Solids and nitrate accumulation and their control in recirculating systems

3.1.1 Solids

In terms of BOD, production of 1 t of fish was estimated to produce organic matter equivalent to the untreated sewage load from 20 people. Given an annual production of 15 million tons, solids output by aquaculture is significant. In Norway, for example, it was estimated that the waste output by salmonid farming in 1989 was comparable to a pollution load by a human population of 2.7 million.

Uneaten feed and excreta are the main sources of solids in aquaculture. Production from non-utilized feed can be reduced by implementing more sophisticated feeding methods. Fecal production of salmonids, catfish, carps and shrimps ranged from 26 to 46 % of the ingested feed (on a dry weight basis).

Filtration methods lead to a sludge concentrate which is commonly discharged with the effluent water. Application of liquid aquaculture sludge to fertilize agricultural crops is being conducted. However, thickening of aquaculture sludge prior to its use as fertilizer is preferred since it reduces the loss of sludge to ground water. Composting as with manure from animal husbandry, and its subsequent use as fertilizer, has been only partially explored.

Biological degradation of aquaculture solids has received little attention to date. The chemical composition of solids from aquaculture was found to be similar to that from sewage plants. As such, classical methods such as aerobic degradation in oxidation ponds, anaerobic degradation in septic tanks or a combination of both, by means of activated sludge treatment, may be applied. Oxidation pond have also been used to degrade aquaculture solids.

3.3.2 Nitrate

As the final product of ammonia oxidation, nitrate reaches remarkably high concentration in nitrifying recirculating systems. Although meant to be aerobic, most recirculating systems harbor anoxic zones which develop mainly in areas where organic matter accumulates. This is common in nitrifying filters used for wastewater treatment and has also been demonstrated in aquaculture facilities. Unlike ammonia and nitrite, nitrate is relatively non-toxic to aquatic species. An additional factor favoring the use of denitrification is its ability to stabilize the buffering capacity of culture water.

3.3.3 Nitrogen cycle

The decomposition of nitrogenous compounds is of particular importance in aquaculture because ammonia, nitrite and, to a more limited extent, nitrate are toxic to the cultured crop. Nitrogen bound in an organic form is broken down via the nitrogen cycle (Figure 1) by heterotrophic bacteria from complex organic compounds to simpler organic compounds and then to ammonia, which is usually the first inorganic breakdown product. Ammonia is further oxidized by several genera of autotrophic bacteria, the most important being *Nitrosomonas*, into nitrite (NO_2). Nitrite is then oxidized to nitrate (NO_3) by several other genera of bacteria, the most important to which is *Nitrobacter*.

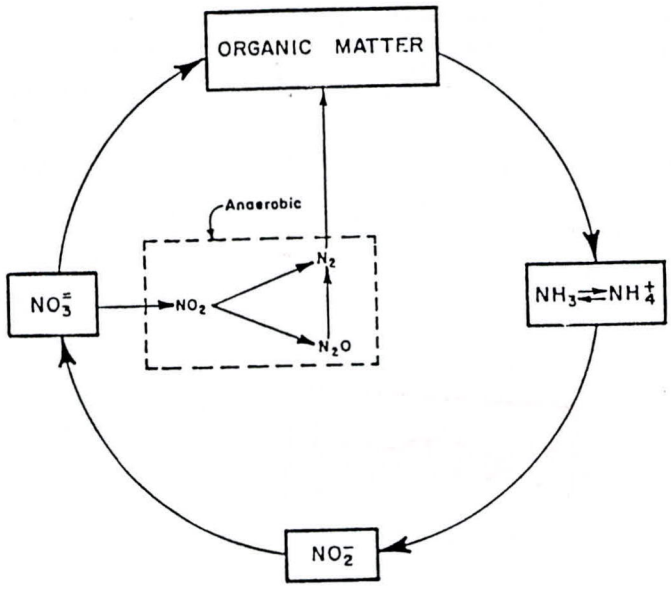

Figure 1: Nitrogen cycle: the reactions within the dotted box are anaerobic; all other reactions aerobic

Within a nitrifying filter, it is desirable to limit bacterial conversions to the ammonia to nitrate portion of the nitrogen cycle. Heterotrophic bacteria rely on carbon based compounds for their energy source, as compared to autotrophic bacteria that rely on inorganic nitrogen as an energy source. The quality of water in an aquacultural system as measured by carbonaceous oxygen demand will profoundly a effect the nitrifying performance of a nitrification filter.

3.4 Biofiltration systems

Nitrification is a complex process carried out by living organisms. Theses biological processes are controlled by the organisms, i.e. bacteria in this case. Like all living systems, environmental variables determine to a large degree the bacteria's metabolic rate. The bacteria's metabolic rate and the bacterial species composition and population density determine how fast ammonia is converted to nitrite and nitrite is converted to nitrate in the nitrification filter. Chemical factors determining these conversion rate include pH, alkalinity, oxygen and ammonia/nitrite concentrations, particulate concentration, gas diffusion rate, and salinity.

Controlling physical variables include temperature, filter cross sectional area, specific surface area, filter depth, media size and type, presence or absence of light, and hydraulic loading rate. Biological parameters include cell yield and biomass density. Thus, predicting nitrification rate in a nitrification filter is a complex process. Mathematical models of nitrification filters appear to be one of the best methods available to relate the many variables involved in nitrification. Some progress has been made in developing such models but much remains to be done.

3.5 Major factors affecting biofilter performance

3.5.1 Physical factors

3.5.1.1 Temperature

Nitrification bacteria will adapt to a variety of temperatures provided they are given time to do so. There is a linear relationship between ammonia oxidation rate and temperature, and between the oxidation of ammonia to nitrate, almost all aquaculture nitrification filter applications will fall within this temperature range. Table 3 shows the effect of temperature on oxidation of ammonia.

3.5.1.2 Media Type and Size

Media is a solid material placed into a nitrification filter to provide surface area on which bacterial growth can occur. There are hundreds of media types that may be used for nitrification filters ranging from sand and rocks to plastic media. Almost any solid material that is non-toxic to the nitrifiers and the crop to be raised can be used as media. The type of media selected usually is a function of desired media diameter and specific surface area, cost, availability, and weight per unit volume. Plastic materials are light in weight, will last almost indefinitely if not exposed to sunlight, but are expensive per unit volume. Fluidized beds require relatively small diameter, heavy media to provide high surface area per unit volume and to prevent washout of the media. Sand is an excellent fluidized bed media.

3.5.2 Chemical factors

The pH optimum for nitrification filters is in the range of 6 to 9. However, for a specific filter the optimum range is narrower, the specific range being a function of adaptation of the bacteria in the filter to pH. Thus, maintaining pH levels above 6 is a recommended practice. However, since the percentage to unionized ammonia increases as pH (the toxic form to fish), it is also a good practice to maintain pH near the lower end of the optimum pH for the nitrifying bacteria to minimize ammonia stress on the cultured fish species.

Rapid pH changes, i.e. over a few minutes, of more that 0.5 to 1.0 pH unit will greatly reduce the filtering efficiency of the bactaria (and the filter) until they adapt to the new conditions.

3.5.2.1 Alkalinity

The conversion of NH_4^+ to nitrate consumes alkalinity. Bicarbonate alkalinity may be critical for nitrifier growth. In fact, alkalinity in the form of carbonate and bicarbonate is a nutrient element for nitrifying bacteria. It is obvious that alkalinity is necessary to prevent pH changes due to acid production in the nitrification process. In nitrifying filters used in municipal wastewater treatment, alkalinity of at least 1.5 meq/L is sufficient to maintain maximum nitrification rate.

3.5.2.2 Oxygen

Nitrification rates in nitrifying filters decrease when insufficient oxygen is available to the nitrifying bacteria. The limiting concentration for oxygen is a function of several variables including temperature, concentration of organics in the filter feed water, and bacterial biomass present. Practical filters contain heterotrophs as well as nitrifiers. Because the nitrogen cycle moves from organic compounds to ammonia to nitrite to nitrate, the filter volume receiving the culture water first tends to have a high percentage of heterotrophs. Most information on limiting oxygen concentrations in nitrification filters comes from research on municipal wastewater treatment.

3.5.2.3 Ammonia/Nitrite Concentrations

It has been shown that excessively high ammonia and/or nitrite concentrations are toxic to nitrification filter operation. Aquaculture nitrification filters operate at very low ammonia and nitrite concentrations compared to municipal wastewater nitrification filters.

3.5.2.4 Particulates and Dissolved organics

Particulates have three effects on nitrification filters: clogging, providing specific surface area, and the addition of organics. Particles larger than the pore sizes in the filter media will clog the filter. High head loss or reduced flow rate will result along with the risk of creating anaerobic pockets in the filter due to lack of water or air flow. Organic particulates also provide substrate for heterotrophic bacteria that compete with nitrifies for growing space.

Ammonia removal is influenced by organic loading with ammonia removal rates decreasing as organic loading increased. Inhibition of ammonia removal in the first stage of a four stage reactor is proportional to the organic loading rate.

3.5.3 Biological parameters

Biomass Density

Biomass density is a measure of the mass of bacterial cells per unit volume of biofiltre. The biomass density is a function of nutrient availability, water velocity over the film, cell characteristics and other variables. In commercial nitrification filters biomass density probably varies considerably from location to location within a single filter and even more so between filters.

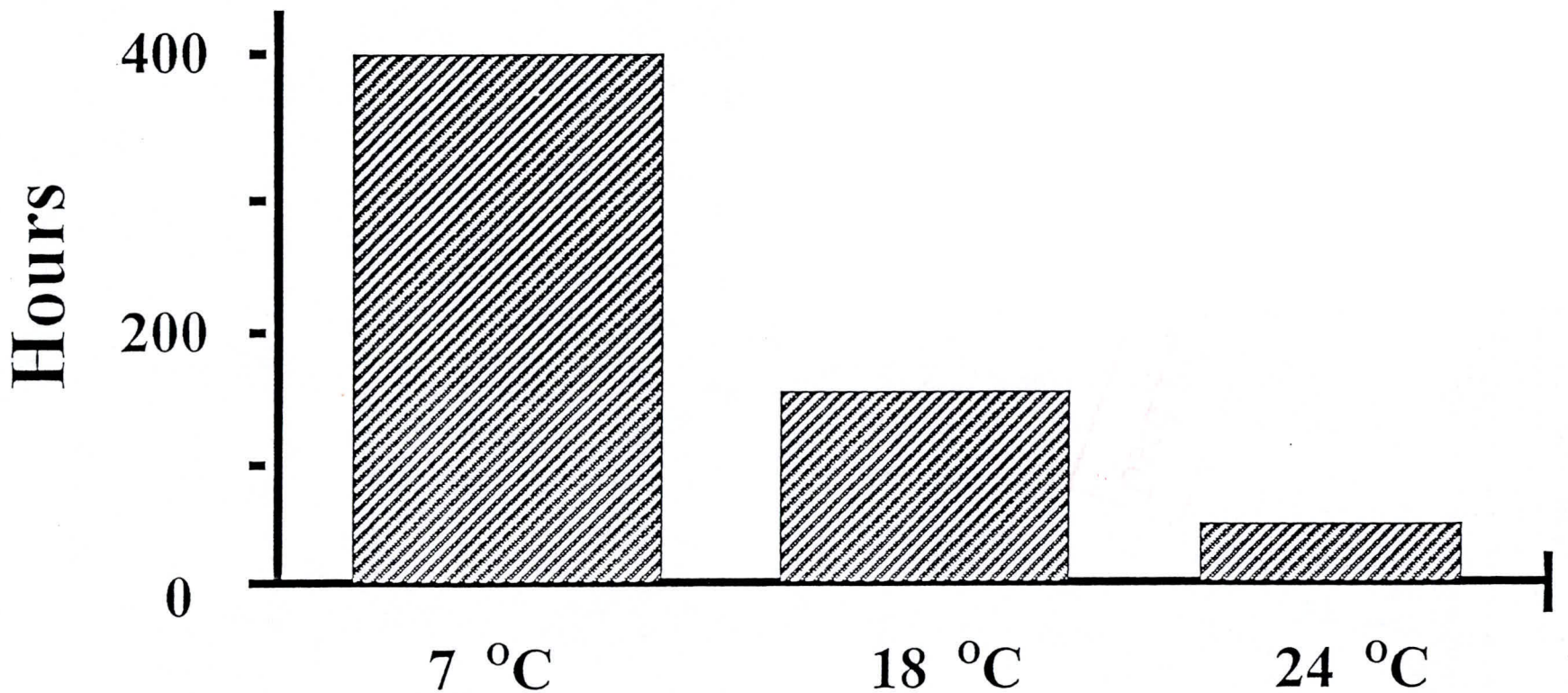

TABLE 3: EFFECT OF TEMPERATURE ON OXIDATION TIME OF 24 mg OF AMMONIA ($N\text{-}NH_4^+$)

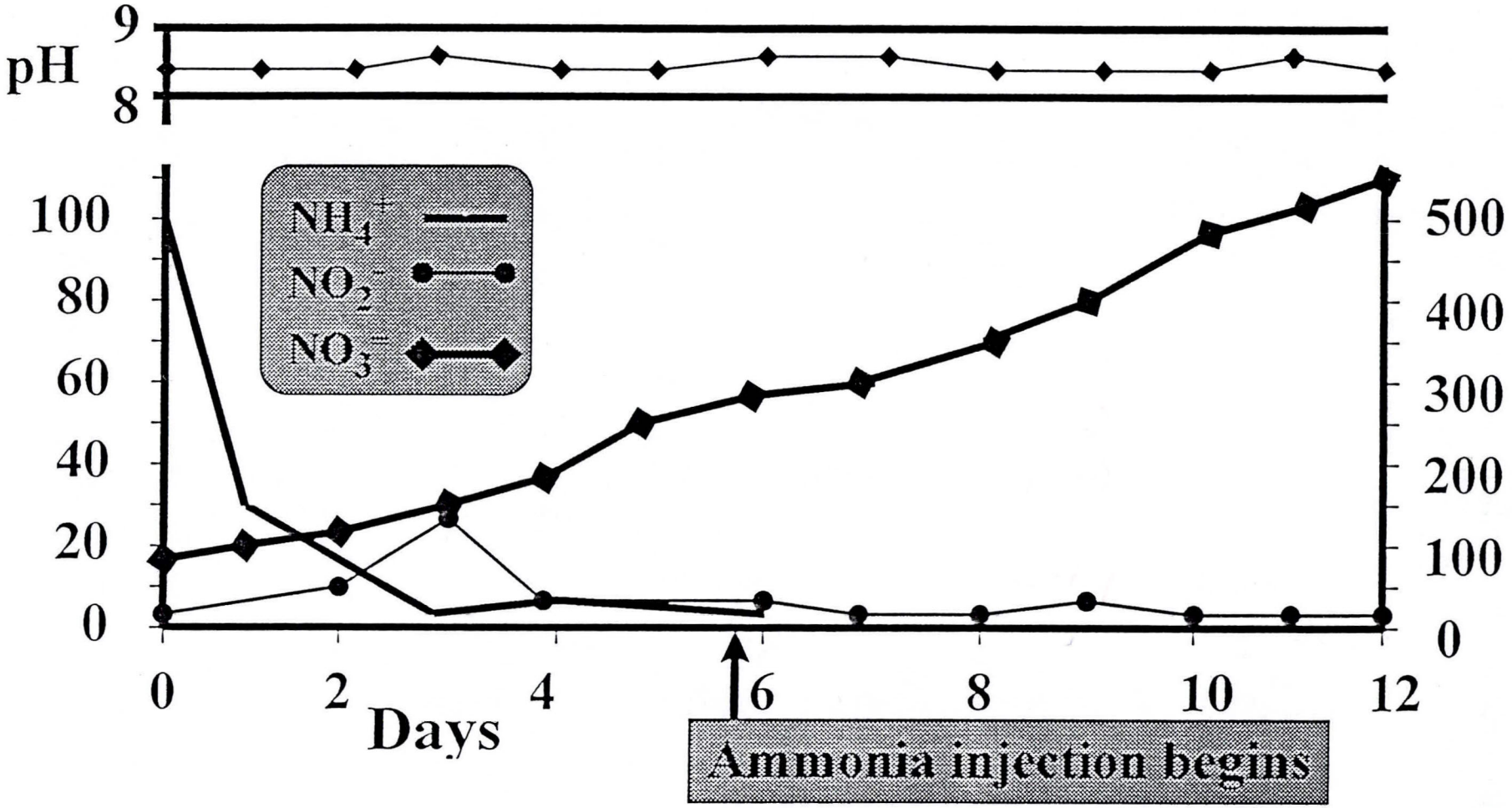

TABLE 4: EVOLUTION OF AMMONIA, NITRITE AND NITRATE CONCENTRATION (mg/L) DURING BIOFILTER ACTIVATION

3.6 Fluidized bed biofilters

Fluidized beds consist of a cylindrical type with fitting on one end to admit water and on the other to release water (Fig. 2). The tube is filled with some fairly heavy, small sized particulate media, e.g. sand, that has a high specific surface area per unit volume. A perforated plate located somewhat above the water inlet supports the media when the water is not flowing through the filter. This plate prevents the media from settling into and plugging the water inlet during filter down times. Water is pumped into the bottom of the filter at as sufficient flow rate to suspend, i.e. fluidize, all the filter media particles in the rising stream. Thus, the filter must operate with a flow velocity that is sufficient to fluidize the media but is insufficient to wash the media out of the filter. Bacteria grow on the fluidized bed media and remove ammonia from the water flowing past. Oxygen for these filters is supplied from the water, but the flow rates are usually high enough that, if the influent is nearly saturated with oxygen, sufficient oxygen is available for the filter (Fig. 3).

3.7 Trickling Biofilters

Trickling filters look and operate much like a downflow submerged filter except the media are kept wet but not submerged (Fig. 2). Because the filter is not filled with water, air can circulate though the filter bringing oxygen to the bacteria. Air contains 210 000 ppm of oxygen and saturated water contains at most 15 ppm of oxygen. Thus, air circulation through the filter provides most of the oxygen needed by the filter. Energy use in these filters consists mainly of the energy to pump water to the top of the filter and, in some designs, to force air through the filter. Trickling filter depths vary from 0.15 to about 5 m in depth, depending on the media used, the design, and other factors. Required pumping head will be directly proportional to the filter depth in most designs. Some additional energy may occasionally be need to backwash the filter, although backwashing should be infrequent or unnecessary (Fig. 3).

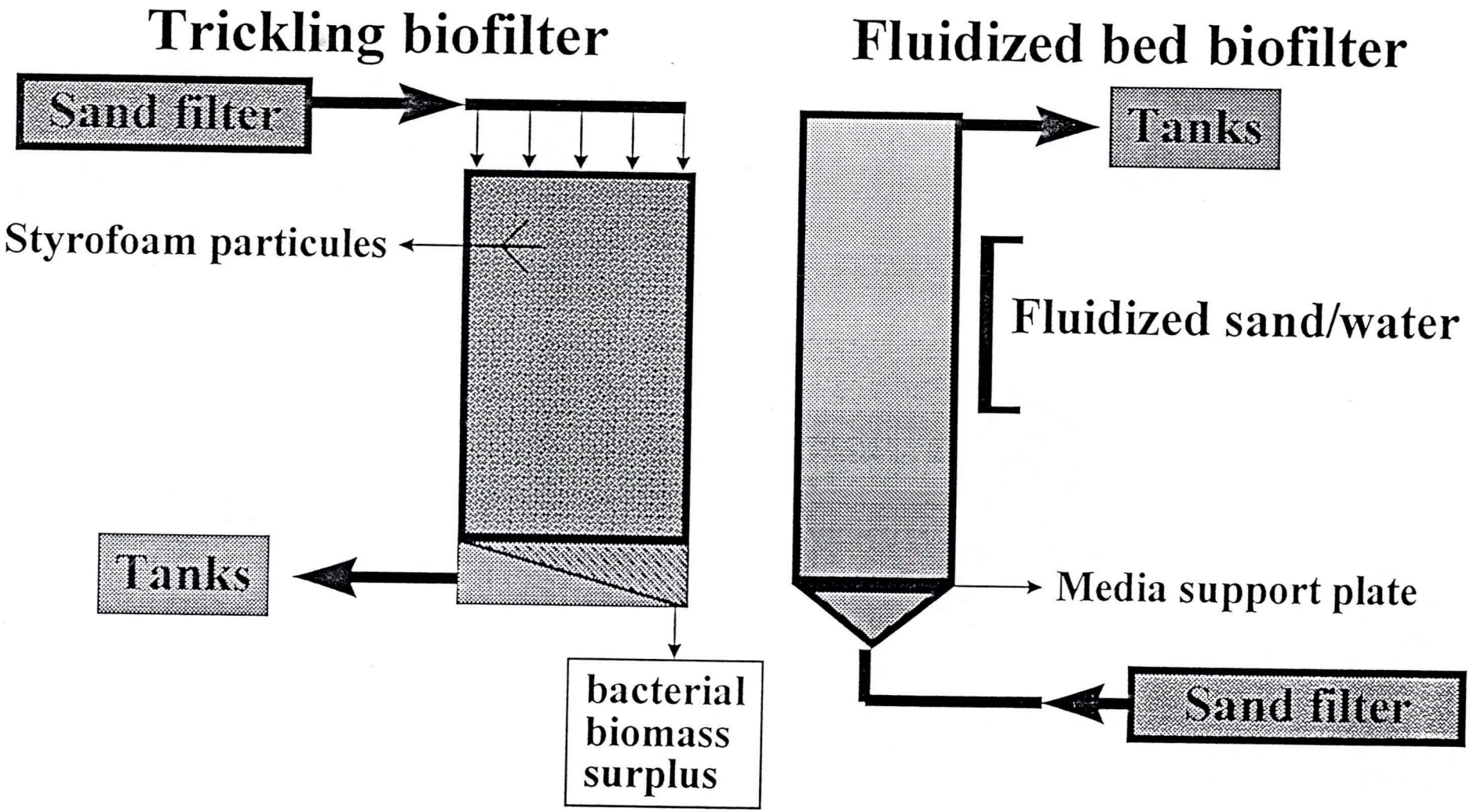

FIGURE 2 : TRICKLING & FLUIDIZED BED BIOFILTERS

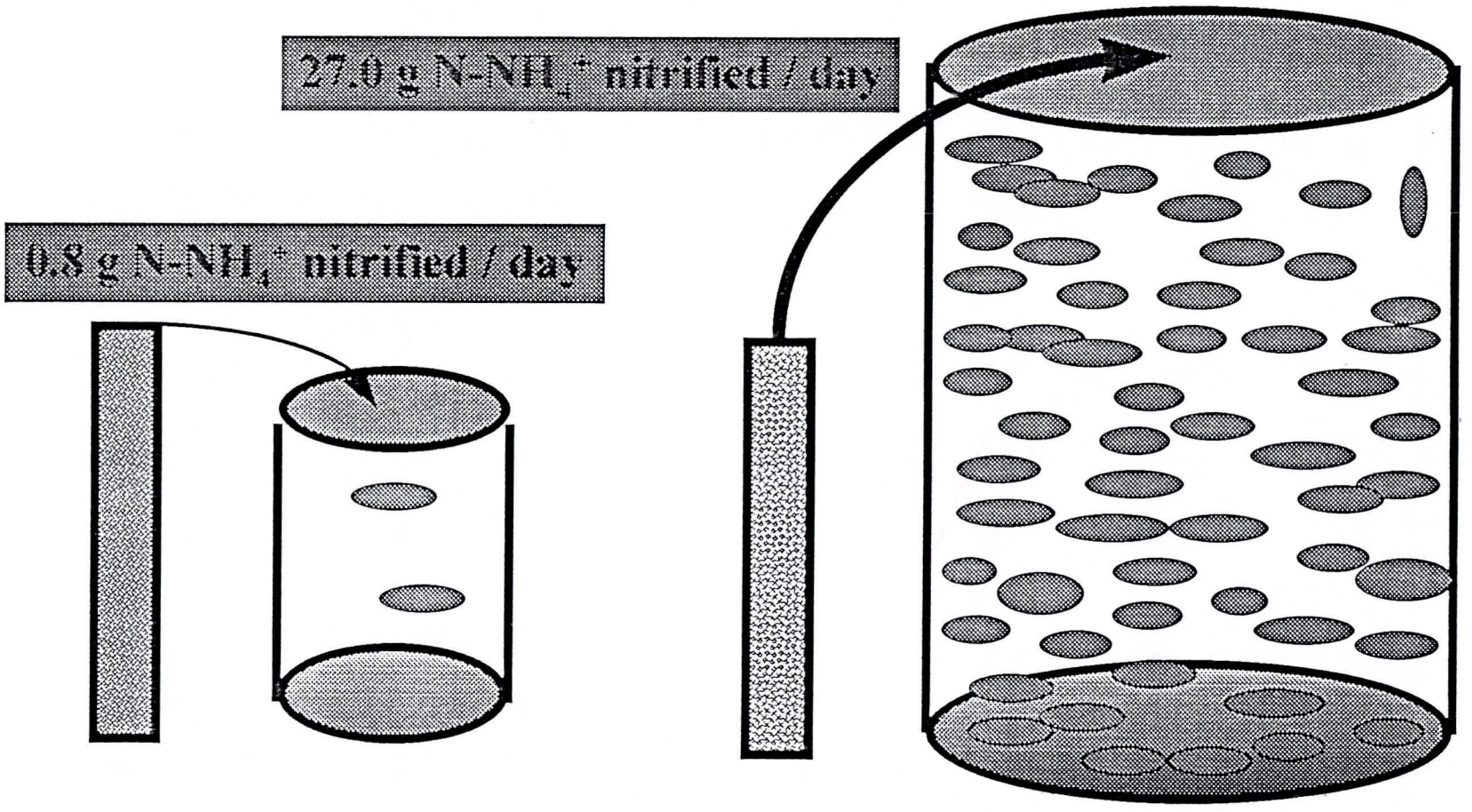

FIGURE 3: NITRIFYING CAPACITIES OF A FLUIDIZED BED AND A TRICKLING FILTER OF IDENTICAL VOLUME (30 L)

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Computer Based Tools for Water Management: Our Experience with the RAISON System

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ABSTRACT

In this paper, we will elaborate on the research, carried out jointly with Canada's National Water Research Institute, on Regional Analysis by Intelligent Systems ON computer (RAISON), where we have attempted, to the best of our resources, to build the tools necessary for bringing spatial, temporal and expert information into a single decision support framework for water management on various (local, regional) scales.

1. Introduction and Background

One of the greatest sources of difficulty in water and watershed management is the management of data and knowledge. Since water management is not a new concept, there is much available in print, and a large body of experts with whom to consult. The measurement of data and information is also well-understood. Quantity and quality measurements are increasing in accuracy and sophistication.

What is less well-understood, it appears, is the need for comprehensive, computer-based storage and recall of the data, information and knowledge required for the management process to be sustained for long periods.

Our experiences in developing various versions of RAISON have given us considerable insight into the problems of computer-based environmental management and decision support.

2. Hardware and Software Considerations

In the eleven years that we have been developing modelling, monitoring and decision support systems for the environment, the hardware and software inventories have changed tremendously. We started with Personal Computers (PCs) with very limited memory and disk capability to what is now available. We evolved through the growth in the personal computer (speed, memory and storage, networking) and the UNIX workstation, to arrive at our current Windows based systems. Each growth cycle left us wanting something which was not yet achievable. Such is the nature of applied research - the best system is slightly larger than the one currently being developed, and when it is

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completed, somehow the needs are expanded ever so slightly into the next generation, for which the hardware tools are still not yet sufficient for a completely satisfactory implementation.

The following Table 1. Summarizes the changes, and one or two key features of the good side and the bad side of the hardware / software involved as our system grew.

Historical Period	Hardware / Software	Main Problems	Good side / bad side
1985-1988	**PC/AT,CGA/EGA graphics 10MEG hard drive, DOS operating system, no networking**	**Insufficient memory,** **coarse graphics.** **compilers and graphics libraries not compatible,** **software development largely concentrated on larger mainframes and minicomputers.**	**Tight limits on size of computer system, number of different functions** **graphical objects (e.g. maps) very coarse,** **shortage of good models and data management systems**
1988-1991	**PC/386 or 486, VGA graphics, 30-100MEG hard drive, file sharing networks, limited extended / expanded memory**	**Memory fragmented by DOS and PC architecture,** **graphics still very difficult,** **print engines not standardized.**	**good maps and pictures now possible, *but*** **limits on size of each application, and on overall system,** **most major engineering models occupy whole machine - no room for our system and models to co-exist.**
1989-1993	**UNIX domain (IBM, SGI, HP, Wang)**	**Lack of finished word processor, spreadsheet.** **Expensive software and hardware**	**Engineering models well-established,** **Graphics engines standardized, *but*** **shortage of productivity tools for general programmer base,** **limited audience for system**
1993-1996	**Windows 3.1 and 3.11, Visual Basic, beginnings of World-Wide Web,** **Windows NT and Windows 95.**	**Security,** **stability (until NT and 95),** **size of computer code.**	**Many products now available for personal computers (Oracle, Microsoft and Borland Development kits),** **good expert systems shells transported down from UNIX world,** **Many models implemented (e.g., AGNPS, SWMM4) for PCs.**
1996-?	??	??	??

3. Data, Information and Knowledge

The availability, transportability and storage of data, information and knowledge is an important aspect of computer-based management of the environment.

Data collections do not often receive wide distribution. They are single-purpose collected and may indeed remain with their collecting organization. As a result there is

much duplication and little of a common standard. Many times, data is not even transcribed into electronic format, but rather left in paper form.

As important as the data is the ***meta-data***, the data about the data. Who collected it, when, where ? By what method or methods was analysis carried out? These questions may have several answers **within a single data set!** As data moves around, the meta-data may get "detached" from the original data. This occurs when data re consolidated, or rolled into a new system from an old one.

Automated data collection more widely used, but it can produce large amounts of data which has no important result.

Inexpensive sources of data are also possible: schools, volunteers. This is being tried extensively in Canada, as the money for organized data gathering is lost to budget cutting. The amount of data is greater, but new quality problems may arise.

Information and knowledge, whether descriptive or in the form of **rules**, can permit inclusion in a management system of "deep" or traditional knowledge or the advice of experts. We have had experience with this, in the selecting of the appropriate models for acidification of lakes, in the assessment of the impact of acid rain in Eastern Canada.

The next three sub-sections outline the added role that a modern information system can give to the data and information input to decision making. The management of water is not the only place where these principles and tools can be applied, but that is where most of our experience lies.

Data manipulation tools in a comprehensive system must consist of: database / data storage software / hardware, data manipulation (spreadsheet), visualization / presentation, data transmission, and (finally) word processing tools. The internal data formats for each of these software units must in some sense be ***inter-operable.*** We have had to construct, in the RAISON system, translation utilities for a large number of GIS, database, communications, spreadsheeet and decision support packages. As well, data modification tools have also had to be constructed. Some of our work has required the construction of "tight package wrapping" - a tight line encompassing a set of data points in space or on a graph. Another required a tenfold reduction of the number of points in the outline of a map of soil types, without loss of features. When these utilities become a requirement in many systems (as each of these have) then they are incorporated into the RAISON systems data management modules.

3.1 Spatial Data

Spatial information, such as elevations, land-use, soil types, water-courses, presence of man-made hazards, form one aspect of good management. A good inventory of industry in a watershed, particularly of those which pollute (such as animal feedlots, electro-chemical industries, urbanizing zones) is a prerequisite. Such an inventory can lead to a better deployment of scarce monitoring resources.

The simple act of recording where a piece of data or information has been gathered can vastly increase its worth. Geographical referencing of data is at the same time part of

the meta-data *and* an important added bit of knowledge. Together with background information on the geography, the location of the data source can give major insight into the state of things.

3.2 Temporal Data and Information

Temporal information is also critical. In many places long time-series of data may not be present. Current conditions may serve to give good expert opinion about the past. Even where the long time series data are present, they are inevitably changes in measurement, and statistical techniques are available for "smoothing out" transitions which are apparent, but are artifacts of changing technology.

There is an urgent need for analysis tools for temporal data. The data are often noisy. Changes in techniques of measurement (which might lower the detection limit) may give a false impression that some pollutant is being reduced, when this is merely an artifact of the lowered limit. Therefore, besides the typical statistical (parametric and non-parametric) tests, a combination of trend analysis and changing-point analysis is indispensible. Combining these tools can give the person doing the time-series analysis the option of determining whether the trend line is continuous or a jump caused by a change in measurement.

Missing data, caused by equipment outages or corruption in a data set over time, can sometimes be "healed" by the application of expert systems or neural networks. The noise characteristics of the data may be modelled by a neural network. Then a simulated data replacement has similar characteristics to real, measured data, so that statistical tests are not invalidated by some form of auto-correlation.

This replacement approach can also be used with spatial data. The analogy lies in the field of image-processing, but rather than visual images of a scene, we have ***visualizations*** of a state of some entity.

3.3 Models

Models for both point source and nonpoint source pollution have been built in many research projects, and are of high quality. They allow a peek "into the future". They are often difficult to use, and require the utmost care if they are to make sense.

There are many levels and classes of models which are applicable in the water management field. We propose to classify at least some that we have encountered, and built into our computer system. We have basically two types of models, prescriptive and normative.

Prescriptive models have some underlying physical principle for production or transport of chemical species. Prescriptive models may be continuous, stochastic or discrete. They may be qualitative or quantitative There is usually a well-defined set of inputs, and these inputs may be introduced into the models at more than one point in the model running.

For prescriptive, quantitative modelling, we have incorporated a layered database into our system for geographical visualization. Thus, the inputs to an agricultural model such as soil type, land use, crops, neighbouring farming and other land use, terrain and hydrology, are all available to engineering models such as AGNPS.

Prescriptive, qualitative modelling usually requires the use of a so-called ***expert system.*** We are using several: rule based (ID3 and C4.5, fuzzy), and probabilistic (Bayesian Bel;ief Network).

For normative and statistical modelling, we have incorporated contouring, boxplots, statistical tests, expert systems and text processing tools into our system. Scale changes (either up or down) require normative modelling approaches. Pollution models do which do not typically work on the point scale treat a whole **grid cell** as an entity which trades concentration or flow with its neighbours in some systematic way. Scaling up or down requires a management of uncertainty about a predicted, cell-based value. Thus the model is **constrained** to follow the results of the grid cell in a point-by point fashion in a consistent or **normative** way. Even the outputs can be tested for "reality" and the choice of model altered *a posteriori* (which operation is certainly a normative one).

4. Interface

The "look and feel" of each sub-section of a comprehensive modelling , monitoring and decision support system must be consistent across several different sub-systems. That comes with experience.

The Windows environment is very helpful with that consistency. Even colour choice is not a decision.

Help becomes an important consideration in a comprehensive system. Instructions must include not only the "which buttons to push" type of instructions, but also a discussion of the validity of statistical tests, the quality of the results, the applicability of models, and so forth. Even data dependent help is possible with expert systems. Advice on whether to accept a trend line or impose a changing point or jump in the analysis can be accomplished with expert systems support.

5. Conclusion

The short time and space for this workshop, the issues must be treated rather generically. They all are "common sense". However they have been traditionally neglected in favour of the physical scientific discussion. To maximize the value of data which is often produced at great expense, and to present findings in a most efficient way, systems such as RAISON must continue to be fore-runners in the design of computer-based water management and decision support.

1

Computer Based Tools for Water Management: Our Experience with RAISON

D.A.Swayne and D.C.L. Lam

University of Guelph and National Water Research Institute

CANADA

2

Organization of Talk

- Hardware and Software for Information Systems
- Data, information, knowledge
- Spatial data
- Temporal data
- Models
- Conclusions

3

Hardware and Software

Most common platform - PC

Most common operating system - Windows 3.11 / Windows 95 / Windows NT

Most common information system tools - Microsoft Office

Most common communication tool - World-Wide Web

4

Hardware and Software

Most common database system - Oracle

Most common GIS?

large systems - ArcInfo, Grass

small systems IDRISI, MapInfo, Spans

Many high quality models available for urban and rural pollution modelling eg. AGNPS, SWMM4

5

Development Software

C/C++, Visual Basic, Delphi

ODBC / InterBase (SQL)

Client / Server

Cold Fusion

Internet Assistant

EasyHelp

6

Data, Information. Knowledge

Data from nay sources, registry needed (a data *catalogue*)

Data format in one of many database formats or spreadsheet formats

Our own generic database / spreadheets must converse with all of the formats

Lotus, dBase 4, SQL

7 ☐ **Data and Meta-Data**

Difficult questions - who created the data, how was it measured, were there special remarks? (e.g. below detection limits)

Denzer and Guettler (Saarbruecken) Sirius system. - metacatalogue.

Often lost in the conversions, from lack of documentation or understanding

8 ☐ **Forensic Tools**

Example - ionic balance

There is always noise

Miss one item, can't sum the others - auto-correlation. Neural networks can learn a "satisfactory" noise pattern to make the dataset useable

9 ☐ **Geo-referencing**

We use our own vector / raster system

Map system requires input - use existing Geographical Information System

Added value - where did the data come from

can display and see conclusions - just like descriptive statistics

our interface to AGNPS - uses "grid-cell", but

10 ☐ **Geographical Information**

We are NOT a GIS!

Project jointly with University of Waterloo - Map Mosaic - a Geographical interface to the World Wide Web.

heritage properties

volunteers

customers

11 ☐ **Time Series**

Is it a trend, or is it a change-point?

What about missing data?

Smoothing, seasonal adjustment

Visualization, descriptive statistics

Parametric and non-parametric testing

Sophisticated help file

12 ## Models

Many steps to input

A lot of engineering parameters

Mix of soil and land use types within a grid (as in AGNPS)

Automated system

Sample problem - map file of 15M must be pruned by factor of 10 without data loss.

13 ## Models

Use of "wizards" to assist in step-by-step preparation

Expert systems - a form of model

assertions, which if true cause particular outcomes

IF (wetland) THEN apply_wetland-correction

Many rules - which can combine

14 ## Conclusion

All preparatory and organizational work involves similar activity

Spreadsheet, GIS, Database and expert systems do not assist in combining the various aspects of decision support

This is what we (Environment Canada, University of Guelph and Waterloo) are attempting to do

Center for International Affairs
No. 1312/39
Date 14 W.E. 2539
Time 9.30

Return-Path: <moreau@ensat.fr>
Date: Wed, 13 Nov 96 14:45:59 +0100
X-Sender: moreau@flora.ensat.fr
To: cenintaf@ccs.sut.ac.th
From: Moreau Jacques <moreau@ensat.fr>
Subject: Re:

At 08:49 13/11/1996, you wrote:
>Dear Professor Umaly,

I am surprised about your message and request for figures. I did give all of
them to you in a brown enveloppe when I was in your office before leaving
S.U.T. Can you confirm ??

,Regards

Jacques MOREAU>
>

Somsai: I remember him giving this envelope!

IMPACT OF EUTROPHICATION AND OTHER DEGRADATION PROCESS OF WATER QUALITY ON TROPICAL AQUATIC ECOSYSTEMS

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A B S T R A C T

Tropical aquatic ecosystems are threatened by various processes of water quality degradation: increasing human settlement near the shores, toxic urban and industrial waste deposition, inappropriate waste treatment, use of fertilizers for agriculture development leading to eutrophication, deforestation and erosion and associated siltation,....

The first part of this paper is a presentation of the situation in some particular places of interest: Laguna de Bay (Philippines), Ubolratana reservoir (Thailand) Parakrama Samudra lake (Sri Lanka). Some examples are also provided from Africa: Lake Victoria, Lake Tanganyka, Kariba man made lake.

For these aquatic ecosystems a review of the general situation of living communities and of their possible evolution is given in relationship with the type of water quality degradation they experience.

A software called ECOPATH II is briefly presented which allows to describe the trophic relationships among the various groups of living organisms inside aquatic ecosystems. This software also helps to identify disfunctioning of these ecosystems and to relate them to water quality as expressed by primary and secundary production.

In addition, because of recent improvements, this software allows to simulate possible changes and evolution which could take place after significant modifications of the general conditions: eutrophication, increasing fishing effort towards a particular species, decreasing biodiversity.. Some examples are provided in order to illustrate this approach on well known and investigated tropical ecosystems, mainly in Asia.

The conclusion points out the necessary multidisciplinary researches for a proper management of aquatic environment and also the necessity of avoiding long term effects of water pollutions even if they are not immediately very spectacular.

INTRODUCTION

Freshwater either in surface or ground water is a vital renewable community resource that is limited in amount and is subject to conflicting and ever increasing demand. An equitable distribution for domestic, industrial, agricultural municipal and recreational uses is not always easy to obtain.

Proper water resource management involves both quality and quantity assurance. It is a complexe and enormous task requiring integrated activities of many sectors of the community and various government agencies. It involves different activities from provision of high quality potable water supply to management of dams and reservoirs for agriculture, fisheries and energy generation purposes, control of canals and drainage systems to prevent floods and conserve rain water, protection of ground water from salt water intrusion and seepage and even forest conservation.

Within the framework of this seminar, the present contribution will deal with the influence of water quality variations on aquatic ecosystems i.e. living communities which are interacting in the water bodies. Fish but also other types of these organisms are of potential interest for riparian populations mainly, but not only, for food. Any variations in their abundance might have detrimental effects on the living standard of these human communities.

The aims of this paper are

1) To briefly review various kinds of pollutions which significantly alter water quality but also living aquatic communities;

2) To describe the present situation of important asian and african water bodies regarding pollutions;

3) To introduce a recent model and associated software which help to quantify the trophic relationships in aquatic ecosystems and their modification under various possible alterations of water quality.

MAIN POLLUTIONS

Pollution is increasing with the rapid population growth in any water body catchment area resulting in a decrease of the water quality resulting in a simultaneous deterioration of the social and economic welfare of riparian populations (Müler and Lloyd 1994).

Pollution is caused by a variety of sources. Of particular concern in Asia are agricultural activities, agro based industries (mainly small scale food processing plants and paper mills) and urban centers which adversely affect the water quality of the rivers draining into lakes and reservoirs contributing to their contamination. Serious problems are due to sewage discharge and industrial effluents containing heavy metals, toxic and oxygen demanding substances (Alabaster 1986). Such substances in excess will cause de-oxygenation of the water column and, sometimes, massive fish kills (see Müler and Llyod 1994 for review).

Land use in the catchment and riparian zones of water bodies plays a major role in the pollution process. Increasing pressure on land leads to high rates of deforestation resulting in increased soil erosion and high loads of silt and nutrients being transported through rivers draining into the lakes, thus contributing to their "eutrophication" as well.

The concept of eutrophication of waters appeared as early as in 1918 (Leger 1918 in Dussart 1966, Hutchinson 1957) An eutrophic water is characterized by high contents of nutrients, mainly phosphates and nitrates, a low transparency and dense phytoplankton. Littoral waters can be fringed with rooted vegetation.

Eutrophication is usually considered as undesirable since its effects can interfere significantly with man's use of the water for many purposes (drinking water supply, recreational use, irrigation, etc). However, it should be noticed that the increased productivity at all trophic levels inherent to eutrophication can be a positive feature under some conditions.

Finally, aquaculture itself has an environmental impact in terms of demand for resources (land, water, feed,..) and in terms of waste outputs: fecal and urinary wastes, uneaten food, therapeutants and other chemicals, pathogenic organisms and parasites. Intensive production without water reuse can result in eutrophication and severe pollutions of receiving waters. Misuse of chemicals and therapeutants, accidental and otherwise, is fairly widespread, particularly among more profitable sectors of this activity (see for instance, review by Beveridge and Phillips 1993).

P R E S E N T S I T U A T I O N O F S O M E E C O S Y S T E M S

Laguna de Bay:

Laguna de Bay (911 km2) is the largest lake in the Philippines and lies southeast of Metropolitan Manila. Early descriptions of the lake mentioned the presence of crocodiles!! (Pauly 1982 in Delos Reyes 1993) but pollution has been responsible for a

depletion of wildlife resources and decline of general biodiversity.

In the early sixties, 23 fish species were identified; two third of them were omnivorous and the rest carnivorous. In the pre-fishpen period, fisheries production was high in term of bulk but consisted of small fish of low market value. By altering the environment of the lake, biological food chains have been modified in order to provide more food for humans and the economic resources use has been changed during the last three decades. This is because the introduction of milkfish culture in pens enclosures in the seventies coupled with the development of Tilapia culture in cages in the early eighties, have changed the situation of the lake. in 1985, almost one third of the lake area was covered with fish farms (Figure 1). Since then, there have been a decreasing trend (Delos Reyes 1993).

Insert figure 1 here

Since the eighties, Metro Manila residents often describe Laguna Lake as a"dying lake". Situated in the densest region of the country, the lake has become a convenient sink for domestic and industrial sewage for more than 8 millions people and over 1,200 industrial establishments located around the lake, despite its primary use for fisheries. Illegal lodging is a problem in the area resulting in land erosion of the watershed and siltation in the lake. The southern part of the lake is mostly agricultural and here, use of chemical fertilizers and pesticides has been a routine since the sixties. The net result is water pollution, fish kills and diseases, decreased productivity, low income and lowering in the socioeconomic status of fishers and their families (various contributions quoted in Delos Reyes 1993). New industries having a high potential for pollution are prohibited wihin a 80 km radius of Manila.

the Nam Pong basin and Ubolratana reservoir (Figure 2):

Ubolratana reservoir, (latitude 0° 45' S, longitude 36° 20' E, altitude 182 m. above sea level and area of approximately 410 km^2) is a large shallow and eutrophic reservoir created by damming the confluence of the Pong and Chern Rivers in North East Province, Thailand, about 500 km from Bangkok (Bhukaswan 1980). It is located in a broad valley and is the largest reservoir in Thailand. The reservoir is drawn down yearly to 176 m M.S.L. and the area shrinks to about 160 km^2. At 182 m M.S.L. the mean depth is 12 m. The dam was closed in January 1965 and reached its equilibrium level two years after.

Insert figure 2 here

The catchment area of the Ubolratana reservoir has been managed through the Nam-Pong River Development Project in the sixties which included the building of the dam, the implementation of

irrigation shemes, land reclamation for resettlement of farmers who losed their land (Petr 1985). In this area, pollutions and decrease of water quality come mainly from agriculture development through siltation resulting from erosion and use of fertilizers and pesticides, the concentration of which is now increasing in the whole Nam-Pong River. In Ubolratana reservoir, the water quality has decreased as turbidity increased with the amount of suspended particles coming from erosion. In addition, the decomposition of flooded plant and organic matter in the newly inundated areas had also to be mentioned. It contributes to decrease the total dissolved oxygen.

Some oxidizeable organic wastes also originate from agriculture based small scale industries such as food processing plants. However, paper mills and textile factories ware another main source fo water pollution having caused de-oxygenation and fish kills (Alabaster 1986).

The Parakrama Samudra reservoir and the Mahaweli basin, Sri Lanka (Figure 3):

To a smaller extent, the various sources of pollutions mentioned above also appear in the watershed of Parakrama Samudra reservoir. For instance DDT has been used for nearly 30 years in this region, initially sprayed to control mosquito vectors of malaria parasites and later as a pesticide for paddy and other cultivations. Other organo chlorid compounds as well have been extensively used (Petr 1985). They tend to accumulate along the food chain. Despite significant efforts in environnement preservation in the Mahaweli basin, increasing number of settlements and intensified land cultivation led to some deforestation and simultaneous siltation and increase of nutrients in the lake (Schiemer 1983).

Insert figure 3 here TO BE PROVIDED LATER

African examples:

Lake Victoria:

Lake Victoria, the largest lake of Africa (69,000 km2) is shared by three eastern african countries: Kenya, Uganda and Tanzania (Figure 4). It is the most important fresh water resource for the people living in the vicinity of the lake. However, it has become a depository for waste (Crul 1993). Pollution is increasing with the rapid population growth in the lake basin resulting in degradation of health conditions, spreading of water-borne diseases and reduced benefits to riparian populations from using the lake as a source of drinking water and for fishing.

Insert figure 4 here to be provided later

Pollution in the lake is caused by a variety of sources. In Kenya, pollution comes mainly from agricultural activities, agro based industries and urban centers. The Entebbe and Kampala areas in Uganda and the Mwanza area in Tanzania have also been identified as areas with serious problems due to sewage discharge and industrial effluents containing toxic and oxygen demanding substances.

In Tanzania, an additional pollution issue deals with the gold rush occurring east and south of Musoma and west and south of Mwanza, where settlements have grown in the last several years to 6000 people and mercury used to recover gold is released into the environment.

Increased pressure on land in the three countries has led to high rates of deforestation resulting in increased soil erosion and high loads of silt and nutrients being transported through rivers into the lake, thus contributing to its eutrophication. Wetlands bordering the lake are being converted into agricultural land or land for industrial use and are therefore increasingly unable to act as natural filters for nutrient and silt, to provide breeding and nursery grounds for many fish species and to play an important role for bird life.

The regular occurence of fish kills has been an important issue since the early 80' as they are the cause of considerable loss of exploitable fish. It appeared that this massive dying is caused by anoxing conditions resulting from sudden destratification of the water column and plankton blooms which are more and more frequent because of the accelerated eutrophication of the lake (Talling 1987, Crul 1993).

Lake Tanganyika

Lake Tanganyika (23, 000 km2) is one of the world greatest lakes and play an important role in the economics of 4 riparian african countries: Burundi, Tanzania, Zaire and Zambia (Figure 5 a). It possesses perhaps the highest biodiversity of any lake on earth: 1 300 species of fish, invertebrates, plants have been recorded, some 500 of which are strictly endemic (Coulter 1991). However, this lake is highly vulnerable to pollution. The most immediat threats to the lake environment and biotas are pollutions from excess load of sediments and nutrients caused by erosion in the watershed as a result of deforestation and agriculture practises. A severe siltation already occurs in the Burundeese sector. Furthermore, chemical pollution is occurring increasingly from urban and industrial sources mainly in the Burundeese and Zambian sectors. These sorts of pollution alter the nutrient balance of the lake, causing eutrophication (Coulter 1991).

Insert figure 5a to be provided later

Insert figure 5b and 5c also here, on the same page

Intensive oil exploration in the past decade is believed to have indicated petroleum resources in the basin and in the lake sediments. This rises the possibilities of oil spill in the future, as leaks and losses of oil incidental to lake transportation have already occurred. As summarized on figure it has been realized through simulation of usual winds and water current that a small oil slick (30 000 tonnes) would irreversibly damage the littoral area and various communities around the northern part of the lake within about three weeks (Coulter 1991).

Lake Kariba (Figure 6):

Lake Kariba (5200 km2), a large man made lake in Zimbabwe, Southern Africa, is polluted by spill of leaded petrol from boats in an increasing shipping traffic and by waters coming from mining zones in the catchment area which leads to discharges of heavy metals into the lake, and also by regular use of DDT in order to control malaria and other pesticides for agricultural purposes (Figure 7). These pesticides and heavy metals are bio accumulated in every organism as summarized on figures 8 and 9). Potential health hazard cannot be excluded in a near future as the local people depend much on fish consumption (Berg *et al.* 1995).

Insert Figures 6, 7 8 and 9 here

GENERAL BIOLOGICAL INFLUENCE OF EUTROPHICATION:

On an ecosystem level, the various pollutions quoted above have long term influences through eutrophication and change in the structure of the different communities through lethal and/or sublethal effects (see Alabaster 1986, Müller and Lloyd 1994 for review).

Eutrophication concerns first shallow water bodies which can experience, at least at some seasons, a stratification of the water column, leading to oxygen depletion in the deepest parts. The total mineral content can become very high, more particularly for nitrogen and phosphorus which are of first concern here. In tropical lakes, low values of the ratio N/P are often noticed and N content might become a limiting factor of primary production (see various contributions quoted in Smith and Shapiro 1981, Hecky and Kling 1987, Hecky and Bugenyi 1992)

The turbidity of the water increases in waters under eutrophication most often as an effect of important siltation which can be variable from one year to the other in relationship with rainfall patterns in the catchment area (Kapetsky and Petr 1984).

In eutrophic waters, the phytoplankton biomass is concentrated in the surface water because of limited transparency and primary production in deep waters. The composition of the phytoplankton is strongly modified as blue green algae (e.g. Cyanophyceae) and Diatoms (e.g. Bacillariophyceae) are dominating over green algae (e.g. mostly Chlorophyceae). The biomass is increasing and sudden blooms of phytoplankton become more and more frequent. However, this does not mean automatically an increase of primary production or even of production at any higher trophic level. This is because of the change of digestibility and attractive power for the potential predators: zooplankton and phytoplanktophagous fish. A lot of field work have demonstrated that communities of phytoplanktofeeders are extremely sensitive, in term of biodiversity and relative abundance of main organisms, to the variations of the composition of phytoplankton (see for instance review by Lauzanne (1988) for tropical fish and by Marshall (1980 and 1982) and Masundire (1989) for zooplankton. Some spectacular changes related to modification in micro-organismes were also noticed for birds communities as documented for Lake Nakuru Kenya, (Vareschi and Jacob 1984) and summarized on Table 1).

Table 1: Variations of production P and biomass B of several groups in Lake Naivasha, following a sudden change in water quality and simultaneous primary production (tonnes year-1)

	Before Change		After Change	
Group	P	B	P	B
Spirulina	*650,000*	*152,800*	*108,000*	*27,600*
Other Primary producers	46,000	2,300	184,000	9,200
Copepods	25,600	1,620	3.3	0.2
Rotifers	14,000	70	50,000	330
Zooplankton	31,800	1,026	9,200	205
Heteropters	230	35	0	0
Tilapias	**1,420**	**420**	**240**	**120**
Pelicans	**50**	**40**	**55**	**77**
Flamingos	**370**	**1,470**	**72**	**310**

Littoral aquatic weeds are most often abundant except in case of strong and unexpected variations of the water level which prevents permanent settlement of this vegetation as occurred in with Salvenia mats in Lake Kariba (Marshall and Junor 1981, see also figure 10) and with various plants communities in Lake Naivasha, Kenya (Harper 1984 and figure 11).

Insert Figure 10 here, to be provided later

Insert figure 11 here also

Among benthic invertebrates some are indicators of pollutions and eutrophication because of their abundance or because of their diappearance. For instance, the bottom of eutrophic tropical waters is usually colonized by Chironomids (see Marshall 1978, Schiemer 1983, for review).

Fish communities will be dominated by surface dwelling fish, quite tolerant to low oxygen contents and feeding mostly on small organisms, and also by non predatory fish. Predatory fish most often require clear oxygenated water to establish abundant populations. Consequently, they remain of marginal importance in eutrophic waters.

T O W A R D S A M A N A G E M E N T O R I E N T E D E C O S Y S T E M A P P R O A C H :

Ecosystems are evolving as they are submitted to human influences but a proper management and possible attempts to decrease the impact of human activities need the influences of these ones to be quantitatively assessed on an ecosystem basis. This means that we need to understand the functioning of the ecosystem as a whole which has by itself to be described quantitatively. One way is to use what is called now trophic models, the most popular of which is ECOPATH designed by Polovina (1984) and extended by Christensen and Pauly (1992 and 1993).

The ECOPATH model:

Définitions:

An ECOPATH model (name given by J.J. Polovina 1984) is a system of linear equations which has always the same structure (Polovina 1984, Christensen and Pauly 1992)

The basic equation which applied to any box in the model is expressed as follows:

$$Bi * P/Bi * EEi = \sum_{j} Bj * Q/Bj * DCij + Yi \qquad ...1)$$

This means that the biomass of a group (or a box) i multiplied by the Production/Biomass ratio (P/B) and by what is called " ecotrophic efficiency" (see below) is equal to the biomass consumed by every predator j of this group multiplied by the relative consumption of food of any predator j (Q/B j) and by the percentage of this box in the diet of the predator j. When suitable, the fish yield Yi has to be added.

This equation holds true if and only if we are in general equilibrium conditions. It should be reminded that this is the key starting hypothesis.

In an ecosystem with a limited number of species, a box can include a single species: for instance a tilapiine species which is largely dominant in the catches. When a lot of species have to be considered, a box will include several ones e.g. for instance several tilapiine species. This requires the species to be homogenous e.g. they have similar characteristics in terms of demography and feeding habits.

Bi is the biomass of box i expressed here as fresh weight.

The P/B ratio:

As shown by Allen (1971), under the equilibrium conditions, and when the von Bertalanffy growth function (VBGF) (von Bertalanffy 1938) can be assumed (as is here the case) and when the decrease of the number of individuals of a cohort is described by a negative exponential function, the Production/ Biomass ratio is equal to the total mortality Z as defined in fisheries sciences and as it has been measured here. Fisheries scientists use quite always the VBGF to describe both length and weight growth in fishes (Moreau 1987, Merona *et al.* 1988). This holds true as well when studying growth of other aquatic animals (Lévêque *et al.* 1977) and even for phytoplankton (Cousins 1985).

The ecotrophic efficiency (EE):

The ecotrophic efficiency (EEi) is the fraction of the total production of any group that is consumed by all its predators (consumers) within the system or caught by fisheries or exported. Note that ECOPATH directs the fraction 1 - EEi of production towards the detritus, a feature that is of relevance when attempts are made to equilibrate an ECOPATH model. The concept of ecotrophic efficiency is easy to understand; however, EEi is difficult to estimate and is usually assumed to range between low values (0.6 in apex predators) to 0.95 in heavily exploited and/or predated group (Ricker 1969). When using ECOPATH, EE can be computed when all other parameters are known. Otherwise, EE values have to be chosen according to the knowledge of the intensity of predation on each box.

The relative food consumption Q/B:

Q/B is the annual relative consumption of food i.e. the food consumption Q per unit biomass B. Within a population under equilibrium conditions, young individuals are more numerous than old ones and consume much more food (compared to their weight) than old fish.

One possible approach for obtaining values of Q/B involves estimations of the daily ration pertaining to one or several size/age classes and their subsequent extrapolation to a wide range of size/age representing an age structured population exposed to a constant or variable mortality (Pauly and Palomares 1987, Palomares and Pauly 1989). The daily ration Rd can be obtained through the analysis of the daily variations of stomach content as illustrated on figure 12 (Jarre *et al.* 1990, Palomares 1991).

Insert figure 12 here to be provided later

In laboratory or pond experiments, it is usually possible to estimate the gross efficiency K1 which is expressed:

$$K1 = \text{Daily weight growth} / Rd \qquad ...2)$$

The daily growth can be also computed as the derivative (dW/dt) of the VBGF for weight growth.

Even if they are easy to handle, these methods require data which can be difficult to collect. For this reason, an holistic method has been implemented for estimation of Q/B using regressions for prediction of Q/B from some easy-to-quantify characteristics of the animal for which Q/B values are required:

One such recent model for finfish is (Palomares 1991):

$$\log_{10}(Q/B) = 0.261 - 0.165*\log_{10}(Woo) + 0.7591*\log_{10}(T) + 0.405*\log_{10}(A) + 0.530*H + 0.466*D + 0.294*P \qquad ...3)$$

For each parameter the decimal logarithm is used.

- Q/B is the annual food consumption/biomass ratio (see above),
- Woo is the asymptotic (or maximum) weight of the fish in question (wet weight in gr)
- T is the mean habitat temperature for the same fish
- A is an index of activity of the fish refering to the shape of the caudal fin which is related to the level of mobility of the fish (see Jarre et al 1990 and Christensen and Pauly 1992 for detailed justification of this parameter).

Finally, the parameters H, D and P (not their log) express the diet: 10

H = 1 for a phytophagous species (d= 0 and p = 0)
D = 1 for a detritivorous species(H = 0 and P = 0)
P = 1 for fishes growing in aquaculture systems
(h = 0 and D = 0)

More recently, a new model has been proposed by Lek *et al.* (1996) whic implies to use a neuronal network taking into account the non linear relations between Q/B and some parameters, mainly Woo.

The diet composition (DCi):

The whole set of values of DCij of equation (1) describes the diet of all predators for which a feeding matrix has to be implemented. This feeding matrix will incorporate all the boxes or groups of the model and only these ones. The whole ecosystem is summarized as boxes related through consumption or predation.

The different methods used to express the diet composition of fishes have been reviewed and discussed for instance by Hellawell and Abel (1971) or Lauzanne (1978 and 1988). For the ECOPATH model, the diet composition should be expressed as the proportion (weight or volume) each prey i contributes to the overall diet of the predator j.

Experience showed that the implementation of a correct feeding matrix is the most difficult task when using ECOPATH (Christensen and Pauly 1993). It is often needed to have an iterative approach i.e. to work by trials and errors and to have several runs of ECOPATH before obtaining the relevant results. This mainly holds true for the lower part of the trophic network which includes invertebrates, the feeding habits of which has been often poorly investigated and documented (Opitz 1991).

The fish yield:

In a model of an ecosystem exploited by a fishery, the catches are the total withdrawals over the time period. They are expressed here, as fish yield, like other flows in metric tonnes km-2 yr-1. The evaluations of actual catches are based on landing statistics for each species or group of species included in a box; usually this is available from Departments of Fisheries of the countries or similar structures such as the Bureau of Fisheries and Aquatic resources (BFAR) in the Philippines.

Balancing of model:

The equilibrium assumption implicit to equation (1) is very important here in that it strongly constraints the possible solution, i.e. the range of parameters that will satisfy a set of simultaneous equations such as (1). Thus, an acceptable solution will require the least modifications of the initial input (mostly the feeding matrix) and yet generate biologically and thermodynamically possible outputs (i.e. all EE < 1)

Example of Ubolratana reservoir (Thailand):

Ae quoted above, Ubolratana is an "open water reservoir" with a large pelagic zone. The commercial fisheries are quite active and deal with many fish species among them some introduced : mostly Asian cyprinids which are stocked on a yearly basis (Bhukaswan 1980, Baluyut 1983). From 1975, a pelagic clupeid species, *Clupeichthys aesarnensis* (previously known as *Corica goniognatus*), has had a continuously increasing importance in the fisheries (Costa-Pierce and Soemarwoto 1990), most likely due to the lacustrinisation of previously running waters.

Implementation of the model:

The model has been implemented from various sources as described below.

Fisheries Catches (Y):

Catch estimates were obtained, for the fish groups in tables 2 and 3 from records of the National Inland Fisheries Institute (N.I.F.I.), Dept. of Fisheries of Thailand or from published literature (Bhukaswan and Pholprasit 1977 ; Benchakaen *et al.* 1989). They are expressed here, like all other flows, in mt km^{-2} $year^{-1}$ (wet weight).

Two periods of study could be considered which are separated by 15 years of various human influences (see above). Those two periods are characterized by :

1) A similar total catch which is close to the maximum catch of about 2300 mt $year^{-1}$ e.g. about 6 mt km^{-2} $year^{-1}$ was observed in both periods.
2) The large importance of predatory fishes in the catches just after the impoundment (period one) and the collapse of these species in the middle of the eighties (period two).

3) The increasing contribution to more than 10 % of the total catch of a pelagic clupeid *Clupeichtys aesarnensis*.

Tables 2 and 3 to be inserted here

Production/biomass ratio (P/B):

Some values could be made available from the literature (Mekong Secretary 1982, 1984). When necessary, we have estimated this parameter for fish from length frequency data as outlined in Gayanilo *et al.* (1989). For a few fish groups, P/B was obtained from estimates of Q/B and reasonably selected values of the gross efficiency (e.g. the ratio between P/B and Q/B) taking into account the kind of food ingested by those fishes. For groups other than fishes, literature values were taken, most of which from Winberg (1971) and Payne (1986).

Diet composition (DC):

The average composition of the food of each considered consumer group refers to weights, and was assembled from published information and personal observations. Tables 4 and 5 present the diet matrixes used for the two situations considered here

Table 4 and 5 to be inserted here

Food consumption (Q/B):

Estimates of Q/B are provided on tables 2 and 3. A necessary input for the model of Palomares (1991) is the asymptotic weight of all the fishes considered here ; this parameter was available from the literature (Mekong Secretary 1984, Sidithimunka 1973).

Results:

Estimates of biomass, gross conversion efficiency, food consumption and flow to detritus and trophic level obtained from the above-mentioned input parameters are presented in tables 2 and 3; the trophic relationships are summarized on figures 13 and 14.

Insert figures 13 and 14 here

Just after the closing of the dam, the total biomass of fishes was 18.8 t km^{-2}. The food sources were expected as fully exploited except zooplankton (assumed EE is 0.50) and phytoplankton (EE = 0.70). The computed ratio between predators and prey biomasses is 0.66. It was 0.5 in the rivers before the impoundment (Sidithimanka *et al.* 1978). The gross efficiency of the fisheries (actual catch/primary production) was 0.0029, which is very low when compared to other inland water bodies considered by Christensen and Pauly (1993).

For the eighties, the total computed biomass of fishes was reduced to 7.2 t km^{-2}. An important feature here is the increased biomass of the pelagic clupeid *Clupeichtys aesarnensis*. The computed ratio between biomasses of predator and prey fishes is

0.16, a remarkable decrease, most likely due to the overfishing of predators which have high market demand but also to the general decrease of water quality (see above). Every food sources, except the benthic producers are clearly underutilized. The gross efficiency of the fisheries is still low (0.0031).

Example of Laguna de Bay (Figure 15 and 16):

Most of the information necessary for development of an ECOPATH model on Laguna de Bay was collected from literature issued by the Laguna Lake Development Authority (LLDA) quoted in Delos Reyes (1993). See tables 6 and 7 for details

Insert tables 6 and 7 here

As shown on table 7, the Laguna de Bay open water fisheries in 1968 generated an annual average catch of 45 t km-2 of fish and 108 t km-2 of snails. The total biomass of fish was 16 t km-2

Milkfish production in 1980 amounted to 42 t km-2; 31 t km-2 should be added, coming from all other fish species combined. The catch of snails increased to 199 t km-2. The total finfish biomass increased up to 21 t km-2. However, there was a considerable decrease in fish production of the open fisheries from 1968 to 1980, resulting in lower income for fishermen housefolks. The following might have contributed to this decline:
1) a reduction of the available open water areas for fishing due to the expansion of fishpens,
2) the limited circulation of lake water in congested areas resulting in the depletion of food organisms and simultaneous poor fish growth.
3) more generally, during the height of fish pen proliferation, the carrying capacity of the lake was reached, resulting in death or, at least growth reduction of any fish.

Insert figures 15 and 16 here

In Laguna de Bay, the main issue is the decrease of the calculated net primary production from 22,195 t km-2 in 1968 to 8,950 t km-2 in 1980. The reduced value during the fishpen period indicates that the presence of milkfish and tilapia may have contributed to the decline. Milkfish and Tilapias feed by filtering plankton from the water flowing freely through pens and cages and they indirectly depress the primary production. There is also a tendency towards shifted species composition of phytoplankton creating an excess of small phytoplankton as a result of fish grazing. It is clear that other factors have induced a limited primary production: turbidity, low oxygen contents, fish excreta raising the level of ammonia inside and near the fishpens and cages.

D I S C U S S I O N

The Ecopath model and software

Polovina (1984) and Polovina and Ow (1985) described on the sensitivity of ECOPATH, to variations of P/B values, mainly for groups at high trophic level (predators). The possible influence of variations of Q/B has been assessed by Moreau and Nyakageni (1988). In addition, the importance of the feeding matrix and of EE for accurate evaluations of biomass should be emphasized (Opitz 1991, Chookajorn et al. 1994). One must quantify properly the qualitative information available on the diet composition of each group. This is usually possible by taking into account several sources of information available from the literature following previous estimations as suggested by Palomares (1991). Cannibalism, when it occurs, must be expressed as very low (most often less than 5 % of the diet) as proposed by Christensen and Pauly (1992) otherwise the biomass estimates of the group under consideration and its preys become, in an unrealistic way, too high.

As already mentioned, the ECOPATH model was developed for static situations under general equilibrium conditions. We assumed that this holds true for the situations of the ecosystems presented here. Two models were to be implemented in order to assess the influence and human activities on these ecosystems. In reality, equilibrium states in fish communities are rarely observed for long period of times as ecosystems are sensitive to perturbations caused by fishing or ecological modifications. It is one reason why Christensen and Pauly (1992) designed the mixed trophic impact routine of ECOPATH II based on Ulanowicz and Puccia (1990). However, in the present stage of the software, it cannot be an instrument for long term predictions (Christensen and Pauly 1992).

The evaluation of human influences (Table 8)

The impact of human influences can be assessed by the variations of computed parameters such as biomass, productions, and ecotrophic efficiency. They can also result in necessary changes in the input parameters including the feeding matrix when such changes have been really documented. This can be seen in table 8 in which the main changes of key parameters (e.g. Biomass, Productions and EE) are recorded. In this aspect, any decrease of EE value means that the food source under consideration is less utilised and this shows an increased disorganization of the foodweb which could be corrected by appropriate environmental improvement. Finally, with a proper knowledge of the evolution of the water quality obtained separately, the relative importance of various kind of changes in this water quality can be assessed.

Table 8 to be inserted here

C O N C L U S I O N:

This contribution introducing the ECOPATH model and software illustrates the usefulness of a multidisciplinary approach by specialists of various groups and disciplines for a proper understanding of the overall ecology of aquatic ecosystems. It also incidentally appears as a way of integration of the large amount of data, all obtained on the same ecosystem by several researchers working, even separately, on different groups. The accuracy fo these data can be checked by ensuring the mutual compatibility of estimates of biomasses and productions, as expressed in the same units for every considered group.

Because of its structure and the required informations, ECOPATH appears as a useful tool for investigation and description of the impact of human activities and related pollutions and eutrophication of aquatic ecosystems. Consequently, this contribution indirectly points out the long term importance of waste water management. Sewage, agricultural and industrial waste effluents must not pollute aquatic ecosystems and new technologies must be developed and applied so that polluting properties of waste water could be minimized if not completely removed (see various contributions, this volume).

A good example of that are the clean technologies which can be implemented for paper mills. The continuously increasing demand for paper as well as the difficulty to reach primary and secundary forests in Northern America and Europe led to design new processes of paper pulp production issued from straws of annual plants (rice, wheat, barley, fiber sorghum) and from sugar plants bagasse (sugar cane, sweet sorghum). This biomass utilization can be integrated by coupling a paper pulp and a sugar mill as already performed in Thailand (M. Delmas, pers. comm.).

In addition, a paper pulp factory is usually very polluting because of use of chlorine compounds for bleaching. However, these kinds of pollution can now be avoided by clean processes e.g. an alkalin process which allow the bleaching without chlorine and chlorinated compounds but using ozone and peroxides. The quality of the paper obtained is similar to what is obtained from hardwood and even from softwood.

A C K N O W L E D G E M E N T S

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L I S T O F F I G U R E S

Figure 1: Map of Laguna de Bay, Philippines, right inset shows extent of fishpens in the mid 1980s

Figure 2: General map of Thailand with the inset of Ubolratana reservoir. Redrawn from Benchakhen *et al.* (1989)

Figure 3: Parakrama Samudra catchment area. Redrawn from Petr (1985)

Figure 4: Lake Victoria. Redrawn from Crul 1993

Figure 5a: Lake Tanganyika. Redrawn from Moreau and Nyakageni (1988)

Figure 5b: Movement of oil slick resulting from the influence of 3% of the usual wind speed combined with 100 % of the usual current speed simulation of the impact of a 30 000 tonnes oil spill

Figure 5c: Speculative scenario on Lake Tanganyka, June-August (period of southerly winds), 32,000 tonnes spill of oil
A: After one day B: After 10 days C: After 20 days

Figure 6: Lake Kariba (Zambia/Zimbabwe, Southern Africa). Redrawn from Berg (1995).

Figure 7: The main input of DDT in the Zimbabwean zone of Lake Kariba from 1967 to 1989 before it was banned. Redrawn from Berg (1995).

Figure 8: Mean level of DDT (ppb in fat) in the foodweb of Lake Kariba when DDT was still in use (from Berg 1995)

Figure 9: Transport of heavy metals from sediments through plants to herbivorous fish of Lake Kariba, focusing on Cadmium, Lead and Cupper (from Berg et al 1995). Figures in rectangles give mean levels of metal (ug g-1 dry weight; mg l-3 for water). Figures in circles give the ratio between concentrations found at two successive level along the food chain, thus indicating possible accumulation.

Figure 10: Changes in the development of various communities in Lake Kariba in relation to changing water chemistry and lake level fluctuations. Application to *Salvinia molesta* (from Marshall and Junor 1987)

Figure 11: General map of Lake Naivasha, Kenya, showing the evolution of vascular plants communities as described by Harper (1987).

Figure 12: Two examples of daily feeding pattern of african fishes (Palomares 1991). The quantitative data (e.g. fresh weight of the stomach content have been fitted by the method of Jarre et al (1990) using the relevant MAXIMS software.

A: Oreochromis niloticus, one meal per day between 7 h and 16 h.

B: Bagrus dogmac, two meals per day one at dawn one at dusk (as it usually occurs in ichtyophagous fishes).

Figure 13: ECOPATH II model of Lake Ubolratana for the period 1968-70, indicating relative biomass of each group (area proportional to log B in t km^{-2}) and the major flows connecting them. Less important fows are omited as are backflows to the detritus box and fishery catches, for clarity sake.

The horizontal axis of symetry of each box is aligned with the functional trophic level of this box (see Christensen and Pauly 1992 for detail on this concept).

Figure 14: ECOPATH II model of Lake Ubolratana for the period 1985-88. See figure 13 for details of the legend.

Figure 15: ECOPATH II model of Laguna de Bay, Philippines, prior to the fishpen period (1968), from Delos Reyes (1993).

Figure 16: ECOPATH II model of Laguna de Bay, Philippines, during the height of the fishpen period in the mid 1980's, from Delos Reyes (1993).

L I S T O F T A B L E S

Table 1: Variations of abundance of some groups including birds in Lake Nakuru, Kenya, as influenced by variations of primary production.

Table 2: Key features of an ECOPATH model for Ubolratana reservoir (1968-71).

Table 3: Key features of an ECOPATH model for Ubolratana reservoir (1984-87).

Table 4: Feeding matrix for Ubolratana reservoir (1968-71).

Table 5: Feeding matrix for Ubolratana reservoir (1984-87).

Table 6: Key features of the ECOPATH model for Laguna de Bay, periods 1968 and 1985. Parameters between brackets are estimated by the program. (from Delos Reyes 1993).

Table 7: Feeding matrix for Laguna de Bay for periods 1968 and 1985; group 15 is phytoplankton, group 17 detritus (from Delos Reyes).

Table 8: Comparison of some key feature of ECOPATH in Lake Ubolratana and in Laguna de Bay; assessment of human impact of trophic networks.

Features	Ubolratana (Phase 1)	Ubolratana (Phase 2)	Laguna de Bay (Phase 1)	Laguna de Bay (Phase 2)
Predators				
Biomass	**7.49**	**.99**	**11.7**	**8.6**
Production	**8.63**	**1.97**	**34.2**	**21.3**
Prey fishes				
Biomass	**11.33**	**6.14**	**4.2**	**12.2**
Production	**18.06**	**11.3**	**13.8**	**51.5**
Zooplankton				
Biomass	6.93	6.29	**12.0**	**17.0**
Production	207.90	188.76	**840.0**	**1530.0**
EE	0.50	0.50	0.20	0.20
Zoobenthos				
Biomass	14.84	15.69	53.3	53.3
Production	96.10	102.07	**171.0**	**224.0**
EE	**0.95**	**0.55**	0.95	0.95
Phyto-plankton				
Biomass	5.40	4.90	**82.0**	**60.0**
Production	1992.90	1788.50	**22195.0**	**8950.0**
EE	0.70	0.70	**0.75**	**0.95**
Actual catch	5.81	6.19	**45.0**	**73.0**
Gross efficiency of fisheries	0.0029	0.0035	**0.0022**	**0.0100**

Table 2. Key features of an ECOPATH model for Ubolratana reservoir (1968-72).

	Groups	Catches[b]	Biomass[a]	P/B[c]	Q/B[d]	EE[e]	Gross efficiency[f]	Flow to detritus[a]	Trophic level[a]
1	- *Ophicephalus*	0.67	1.515	1.00	5.64	0.95	0.18	1.78	3.39
2	- *Wallagonia* sp.	0.49	1.657	0.75	4.21	0.95	0.18	1.46	3.36
3	- *Oxyeleotris*	0.31	0.670	1.50	8.90	0.95	0.17	1.24	3.21
4	- *Kryptopterus*	0.24	0.470	1.80	11.90	0.95	0.15	1.16	3.24
5	- *Notopterus* n.	0.43	1.643	1.05	7.70	0.95	0.14	2.67	3.02
6	- *Mystus* spp	0.31	0.953	1.50	11.50	0.95	0.13	2.26	3.04
7	- *Hampala* spp	0.18	0.588	1.50	10.70	0.95	0.14	1.30	3.03
8	- *Morilis* sp	0.31	2.419	0.70	9.10	0.95	0.08	4.48	2.27
9	- *Puntius* spp	1.53	4.708	2.00	24.40	0.95	0.08	23.45	2.34
10	- *Osteochilus* sp	0.55	2.202	1.30	15.60	0.95	0.08	7.01	2.09
11	- *Puntioplites*	0.12	0.449	1.60	16.20	0.95	0.10	1.49	2.37
12	- *Cirrhinus* j.	0.61	1.492	2.10	40.00	0.95	0.05	12.09	2.16
13	- Clupeids	0.06	0.060	4.00	38.00	0.90	0.10	0.48	2.59
14	- Zooplankton	-	6.930	30.00	200.00[f]	0.50	0.15	384.32	2.05
15	- Insects	-	10.960	7.00	50.00[f]	0.95	0.14	113.34	2.16
16	- Crustaceans	-	3.877	5.00	40.00[f]	0.95	0.12	31.11	2.19
17	- Phytoplankton	-	5.460	365.00	-	0.70	-	597.60	1.00
18	- Benthic producers	-	54.942	4.50	-	0.95	-	12.38	1.00
19	- Detritus	-	-	-	-	-	-	-	1.00

[a]Computed by ECOPATH II
[b]Chookajorn and Pawapootanon (1976), Bhukaswan and Pholprasith (1977), Pawapootanon (1987)
[c]Computed as P/B = Q/B Gross efficiency for fishes + Payne (1986) and Winberg (1971) for other groups
[d]Model of Palomares (1991)
[e]Fixed values
[f]Fixed values according to feeding habits

Table 3 Key features of an ECOPATH model for Ubolratana reservoir (1985-88).

	Groups	Catches[b]	Biomass[a]	P/B[c]	Q/B[c]	EE[c]	Gross efficiency[f]	Flow to detritus[a]	Trophic level[a]
1	- *Ophicephalus*	0.10	0.165	1.00	5.64	0.80	0.18	0.22	3.23
2	- *Wallagonia* sp	0.03	0.103	0.75	4.21	0.80	0.18	0.10	3.23
3	- *Oxyeleotris*	0.12	0.138	1.50	8.90	0.80	0.17	0.28	3.14
4	- *Kryptopterus*	0.03	0.047	1.80	11.90	0.80	0.15	0.13	3.17
5	- *Notopterus* n.	0.21	0.319	1.05	7.70	0.80	0.14	0.56	2.94
6	- *Mystus* spp	0.12	0.151	1.50	11.50	0.80	0.13	0.39	3.00
7	- *Hampala* spp	0.04	0.065	1.50	10.70	0.80	0.14	0.16	3.00
8	- *Morilius* sp	0.19	0.508	0.70	9.10	0.70	0.08	1.03	2.26
9	- *Puntius* spp	1.53	1.732	2.00	24.40	0.70	0.08	9.49	2.28
10	- *Osteochilus* sp	0.44	0.659	1.30	15.60	0.70	0.08	2.31	2.07
11	- *Puntioplites*	1.30	1.543	1.60	16.20	0.70	0.10	5.74	2.36
12	- *Cirrhinus* j.	1.36	1.354	2.10	40.00	0.70	0.05	11.68	2.11
13	- Clupeids	0.72	0.338	4.00	38.00	0.80	0.10	2.84	2.58
14	- Zooplankton	-	6.292	30.00	200.00	0.50	0.15	346.15	2.05
15	- Insects	-	11.797	7.00	50.00	0.55	0.14	155.13	2.06
16	- Crustaceans	-	3.898	5.00	40.00	0.55	0.12	39.97	2.10
17	- Phytoplankton	-	4.900	365.00	-	0.70	-	536.50	1.00
18	- Benthic producers	-	53.528	4.50	-	0.90	-	24.08	1.00
19	- Detritus	-	-	-	-	-	-	-	1.00

[a]Computed by ECOPATH II
[b]From Benchaken et al. 1989
[c]See legend of Table 1

Table 4. Feeding matrix for Ubolratana reservoir (1968-71).

	Oph	Wal	Oxy	Kry	Not	Mys	Ham	Mor	Pun	Ost	Ppl	Cir	Clu	Zoo	Ins	Cru	Phy	Ben	Det
Ophicephalus	5	4	3	3	4	3	2	4	14	5	1	5	1	5	25	11	2	2	1
Wallagonia sp.	4	5	3	2	4	3	2	3	16	5	1	6	1	8	20	10	1	4	2
Oxyeleotris			3		4	3		3	15	5	1	5		4	25	25	2	2	3
Kryptopterus				3	4	3	2	4	16	5	2	6		10	20	20	1	2	2
Notopterus n.									1					10	66	11	2	8	2
Mystus spp.						1	1	2	10	4	1	4		1	47	15	1	10	3
Hampala spp.	1				2	2	2	2	15	6	2	6		18	2	22	1	2	17
Morilius sp.														25			53	18	5
Puntius spp.									1					5	20		10	30	34
Osteochilus sp.														5		2	65	18	10
Puntioplites												1		25	7	1	46	15	5
Cirrhinus j.														10			30	20	40
Clupeids														50	5		45		
Zooplankton														5			95		
Insects														1	4	1	1	25	68
Crustaceans														2	5	2	2	25	64

Quantitative data for fishes are derived from studies by Mekong Secretary (1984) Wongtirawatana (1981) and Sricharoendam (pers. observations unpubl.).
For other groups: suggestions by Christensen and Pauly (1993).

Table 5 Feeding matrix for Ubolratana reservoir (1984-87).

	Oph	Wal	Oxy	Kry	Not	Mys	Ham	Mor	Pun	Ost	Ppl	Cir	Clu	Zoo	Ins	Cru	Phy	Ben	Det
Ophicephalus	3	2	1	1	2	1	1	2	9	5	9	9	9	5	25	11	2	2	1
Wallagonia sp.	1	3	1	1	2	1	1	2	10	5	10	10	10	8	20	10	1	3	1
Oxyeleotris			2	1	1	1		1	10	2	9	5	7	4	25	25	2	2	3
Kryptopterus				2	2	2		1	10	2	10	9	7	10	20	20	1	2	2
Notopterus n.									1					10	66	11	2	8	2
Mystus spp.						1	1		5	2	5	5	4	1	47	15	1	10	3
Hampala spp.			1		1	1	1	2	8	3	7	8	6	18	2	22	1	2	17
Morilius sp.													25			53	17	5	
Puntius spp.									1					5	20		10	30	34
Osteochiles sp.														5		2	65	18	10
Puntioplites												1		25	7	1	46	15	5
Cirrhinus j.														10			30	20	

Quantitative data for fishes are derived from studies by Mekong Secretary (1984) Wongtirawatana (1981) and Sricharoendam (pers. observations unpubl.).
For other groups: suggestions by Christensen and Pauly (1993).

Table 6. Parameters inputted (without brackets) in the ECOPATH II model for the periods 1968 and 1980 in Laguna de Bay. Parameters in brackets are estimated by the program.

Common/scientific names	Catch		Biomass		P/B		Q/B		EE	
	1968[a]	1980[b]	1968	1980	1968	1980	1968	1980	1968	1980
1. Grunter/*Terapon plumbeus*	29.60	18.50	(7.87)	(7.39)	3.98	2.64	9.42[p]	8.65	.95	.95
2. Goby/*Glossogobius giurus*	11.30	4.20	(3.22)	(1.65)	3.77	2.72	7.67[p]	7.23	.95	.95
3. Catfish/*Arius* sp. *Clarias batrachus*	0.59	1.25	(0.40)	1.32	1.55	1.55	4.31[r]	4.64	.95	-
4. Common carp/*Cyprinus carpio*	0.79	0.07	(0.67)	0.06	1.24	1.24	8.30[n]	8.30	.95	-
5. Mudfish/*Channa striata*	2.04	0.10	(3.36)	0.14	0.75	0.75	5.02[q]	5.02	.95	.95
6. Tilapia/*Oreochromis* spp.	0.30	7.21	(0.26)	1.42	1.20	1.20	24.53[r]	24.53	.95	-
7. Milkfish/*Chanos chanos*	0.00	41.656	-	9.13[f]	-	4.800	-	41.52	-	-
8. Shrimps/2 species, dominant: *Macrobrachium lanceifrons*	30.61	8.189	12.0	12.00	(3.16)	(0.94)	(12.64)	(3.77)	.95	.95
9. Snails/5 families, dominant: Family Malaniidae	107.43	199.70	40.0	40.00	(2.88)	(5.27)	(11.53)	(21.07)	.95	.95
10. Midges/7 species, dominant: Family Chironomidae	0.00	0.00	1.6	1.60	(3.92)	(1.69)	(15.70)	(6.76)	.95	.95
11. Annelids/2 species, dominant: Family Tubificidae	0.00	0.00	0.7	0.70	(13.09)	(3.50)	(52.35)	(13.99)	.95	.95
12. Microcrustaceans	0.00	0.00	2.0[c]	2.00	(28.53)	(14.98)	(114.12)	(59.91)	.95	.95
13. Higher aquatic plants/ water hyacinth	0.00	0.00	11.0[c]	11.10	5.00	5.00	0.00	0.00	-	-
14. Zooplankton	0.00	0.00	12.0	16.90	70.00	89.70	282.00	358.00	.20	.20
15. Phytoplankton	0.00	0.00	82.0	60.55	268.36	146.90	0.00	0.00	-	-
16. Juvenile fish	0.00	0.00	(4.3)	(1.97)	3.00	3.00	8.00	8.00	.95	.95

	Predator	Year	Prey										
			1	2	8	9	10	11	12	14	15	16	17
1.	Grunter	1968	0.1	0.2			0.4		30.0	40.0	29.3		
		1980		0.1			0.4		30.0	39.5	30.0		
2.	Goby	1968			13.7						30.0	56.3	
		1980			10.0						40.0	50.0	
3.	Catfish	1968	0.5		20.0	8.0	35.5		2.0		14.0	20.0	
		1980	0.4		20.0	6.1	35.5		2.0		10.0	26.0	
4.	Carp	1968				20.0		5.0	15.0	10.0	15.0	35.0	
		1980				20.0		10.0	10.0	10.0	15.0	35.0	
5.	Mudfish	1968	0.5	0.5	10.0	5.0	30.0	5.0	4.5	22.0	22.5		
		1980	0.6	0.7	20.0		20.0	2.2	10.0	25.0	21.5		
6.	Tilapia	1968								5.0	90.0	5.0	
		1980								5.0	90.0		5.0
7.	Milkfish	1980									100.0		
8.	Shrimps	1968 + 1980						5.0	20.0	20.0	10.0		45.0
9.	Snails	1968 + 1980									10.0		90.0
10.	Midges	1968								20.0	5.0		75.0
		1980								10.0	5.0		85.0
11.	Annelids	1968								5.0	10.0		85.0
		1980								2.5	10.0		87.5
12.	Microcrustaceans	1968 + 1980									50.0		50.0
14.	Zooplankton	1968 + 1980							5.0	9.50			
16.	Juvenile fish	1968 + 1980							80.0	10.0		10.0	

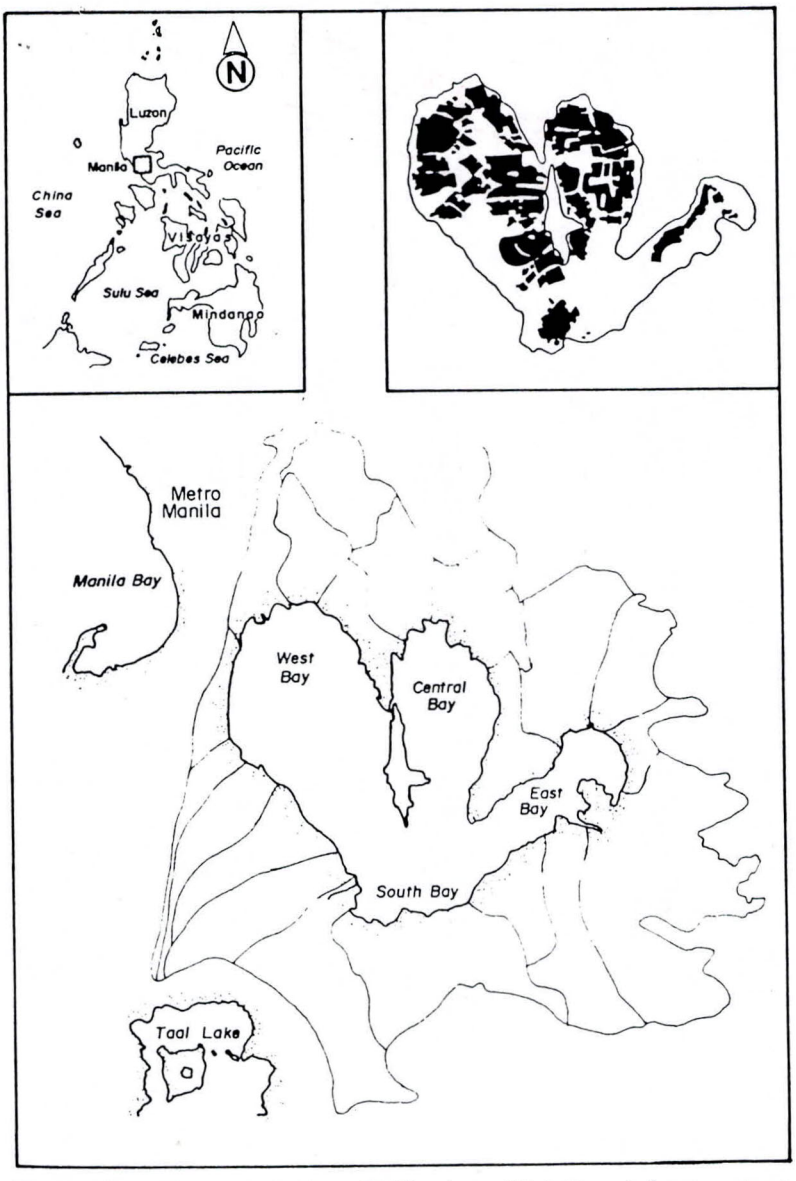
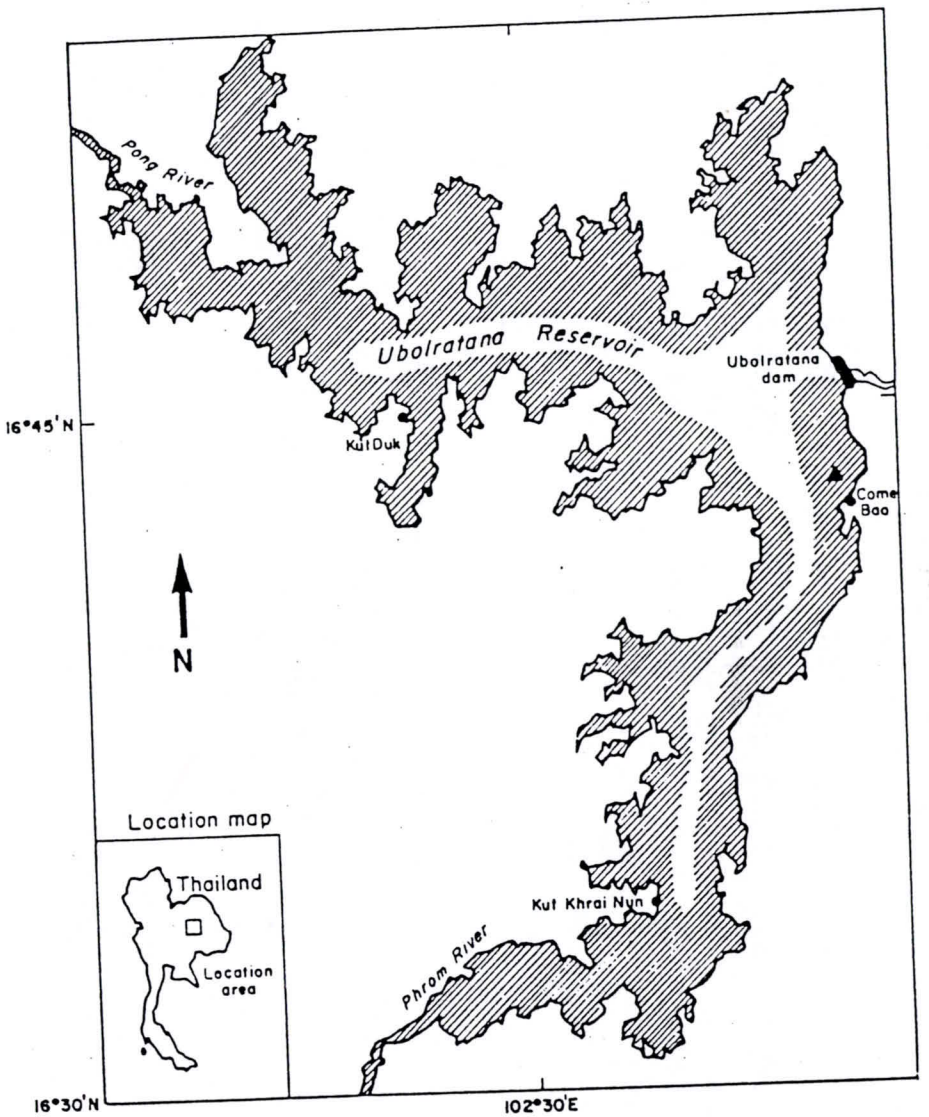


Fig. 1. Map of Laguna de Bay, Philippines. Right inset shows extent of fishpens in the mid-1980s.


Pong River
Ubolratana Reservoir
Ubolratana dam
16°45'N
Kut Duk
Come Bao
N
Location map
Thailand
Location area
Kut Khrai Nun
Phrom River
16°30'N
102°30'E

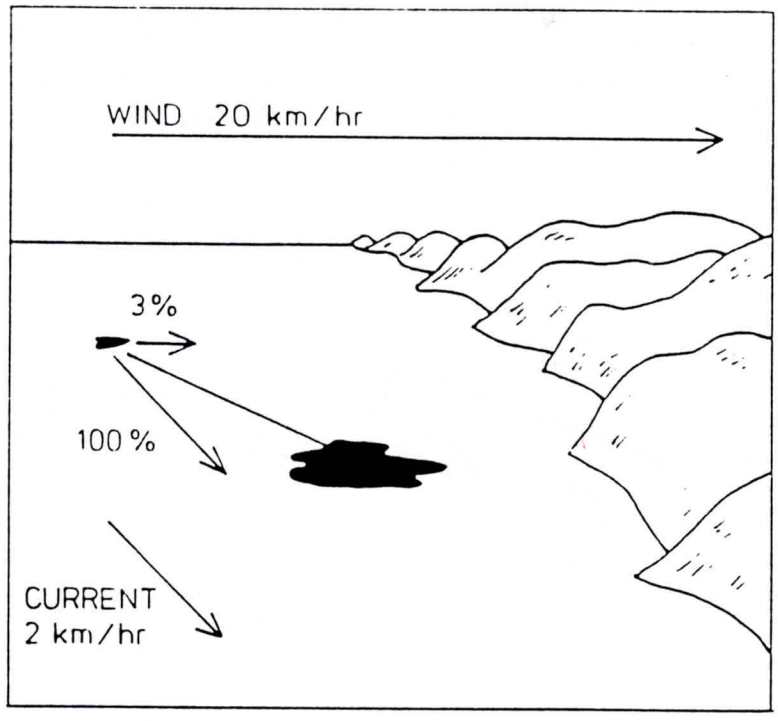
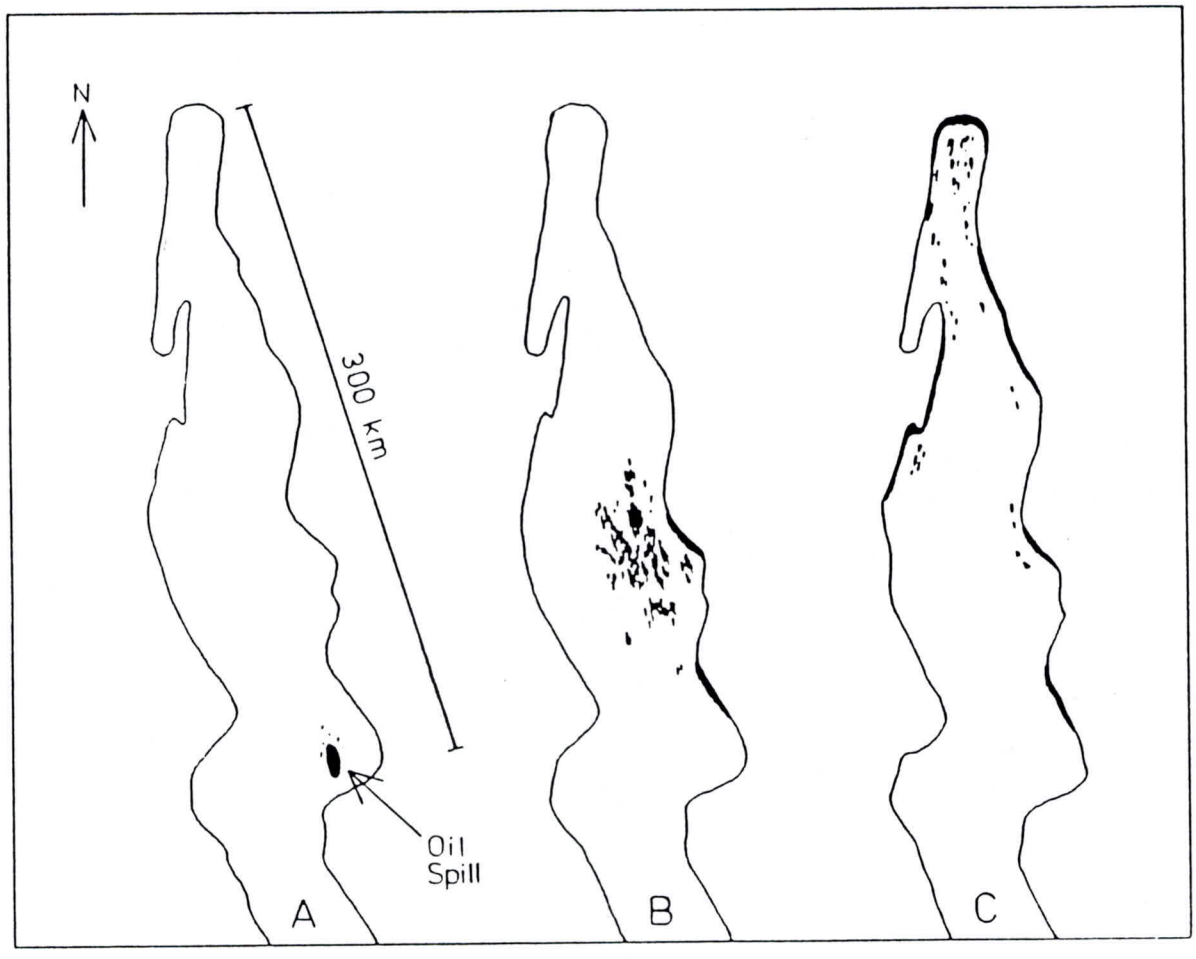


Fig. 5b Movement of oil slick resulting from the influence of 3 % of the wind speed combined with 100 % of the current speed.



ig-5C
g. 5. Speculative Lake Tanganyika scenario, June – August (period of southerly winds). 30,000 tonnes spill o
l. A – After 1 day, B – After 10 days, C – After 20 days.

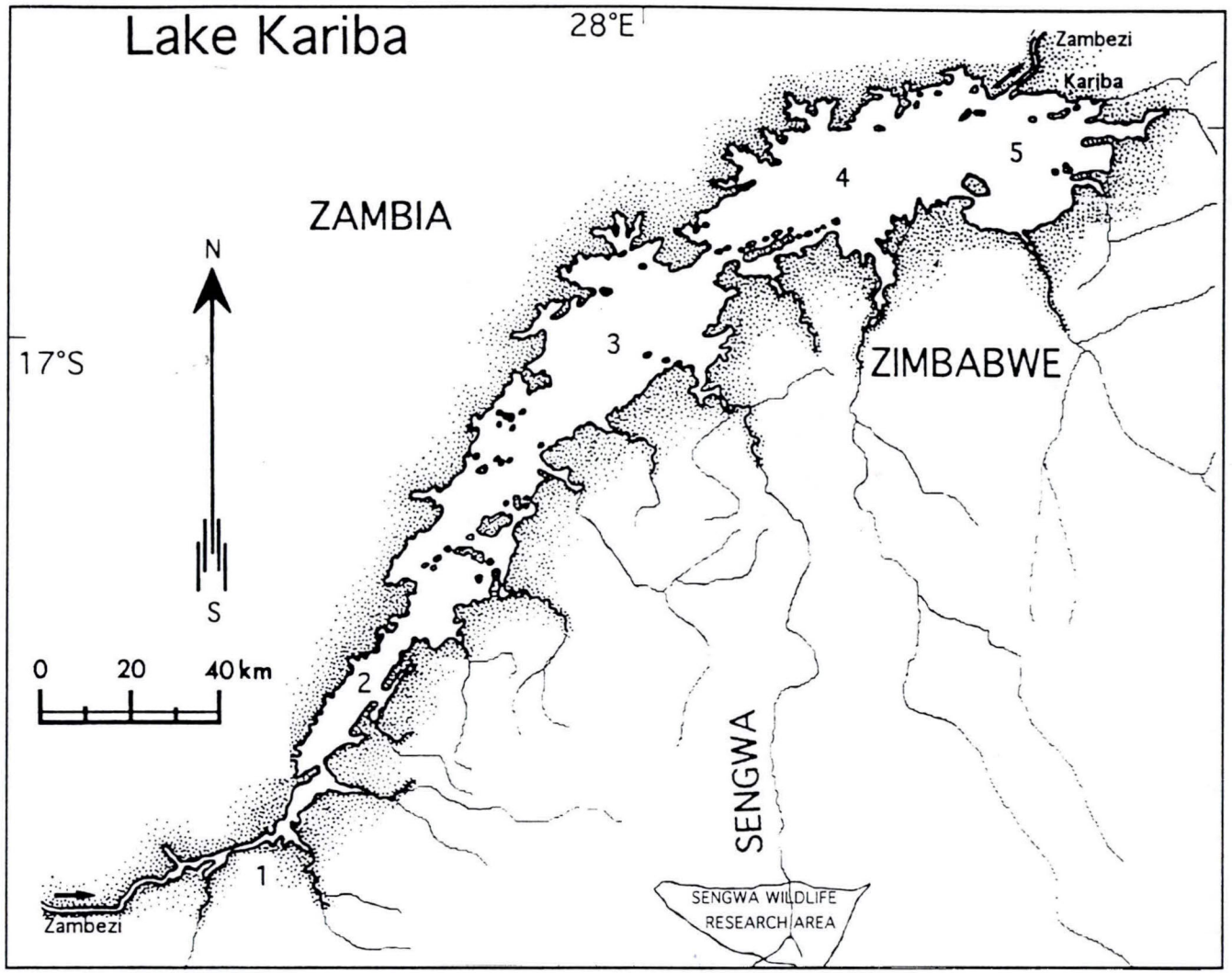
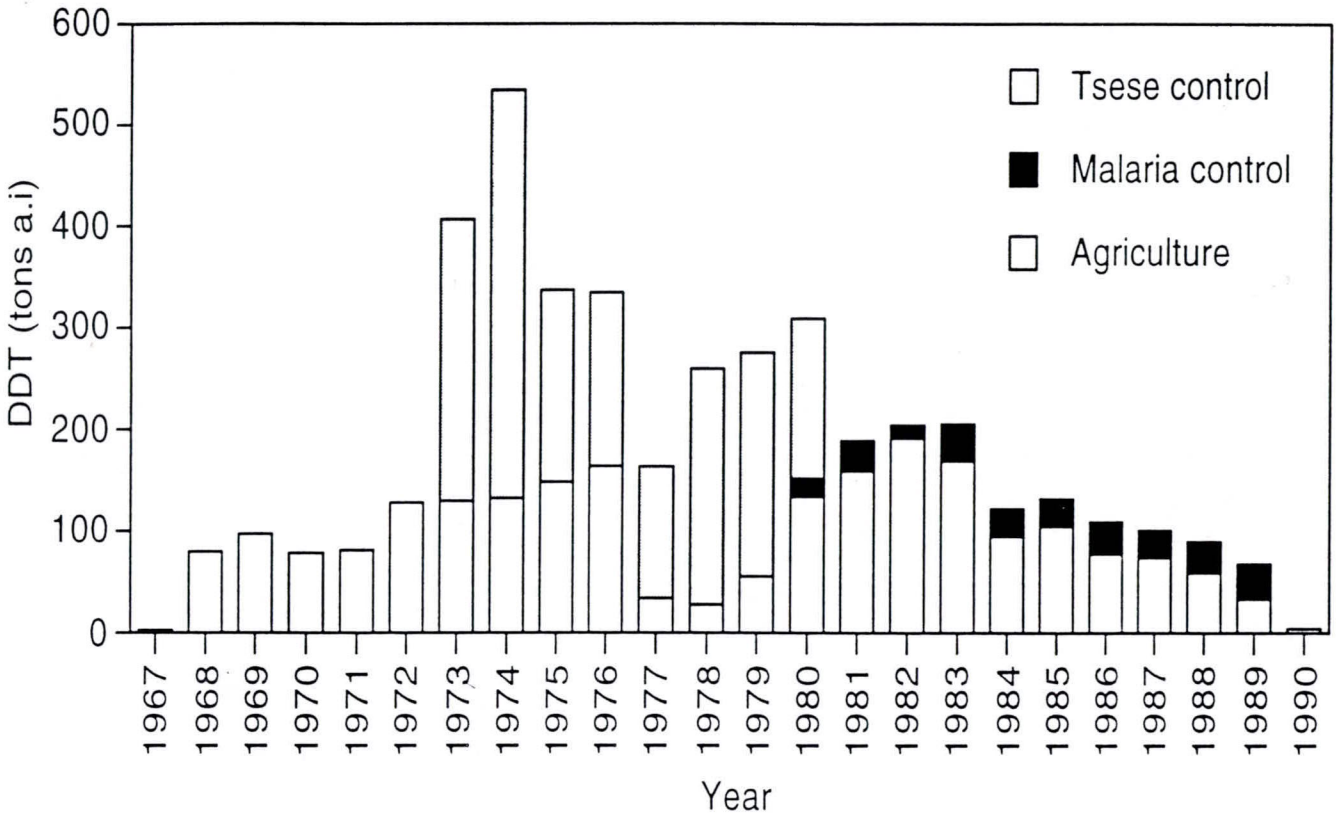
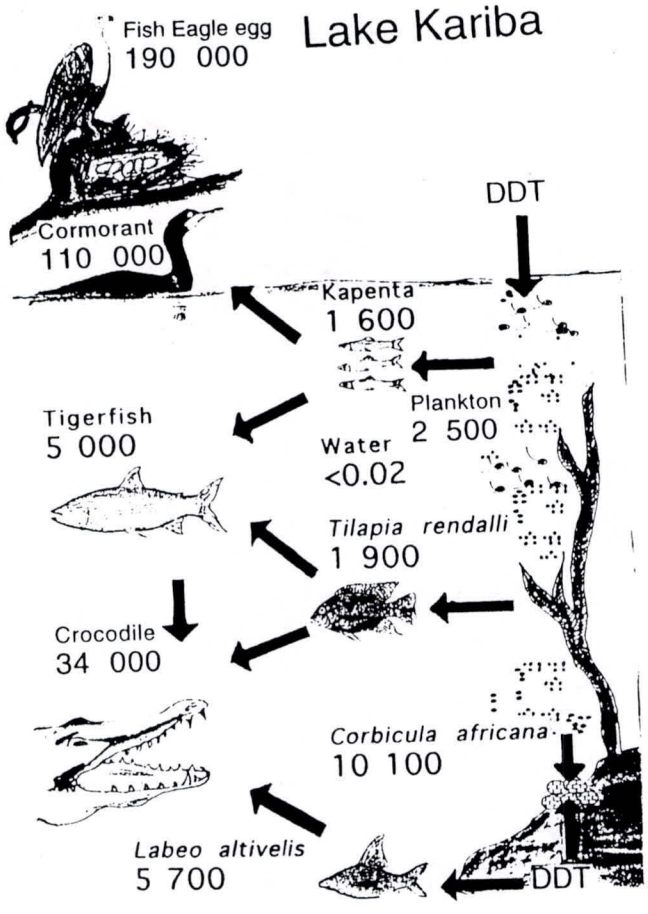


Fig. 6 Lake Kariba with its five main basins. The lake is 320 km long and has an area of 5 364 km^2 (Balon & Coche 1974). The catchment area on the Zimbabwean side covers the area where most of the DDT was applied between 1967 and 1990


600
500
400
300
200
100
0
DDT (tons a.i)
Tsese control
Malaria control
Agriculture
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year


Lake Kariba
Fish Eagle egg
190 000
Cormorant
110 000
DDT
Kapenta
1 600
Plankton
2 500
Water
<0.02
Tigerfish
5 000
Tilapia rendalli
1 900
Crocodile
34 000
Corbicula africana
10 100
Labeo altivelis
5 700
DDT

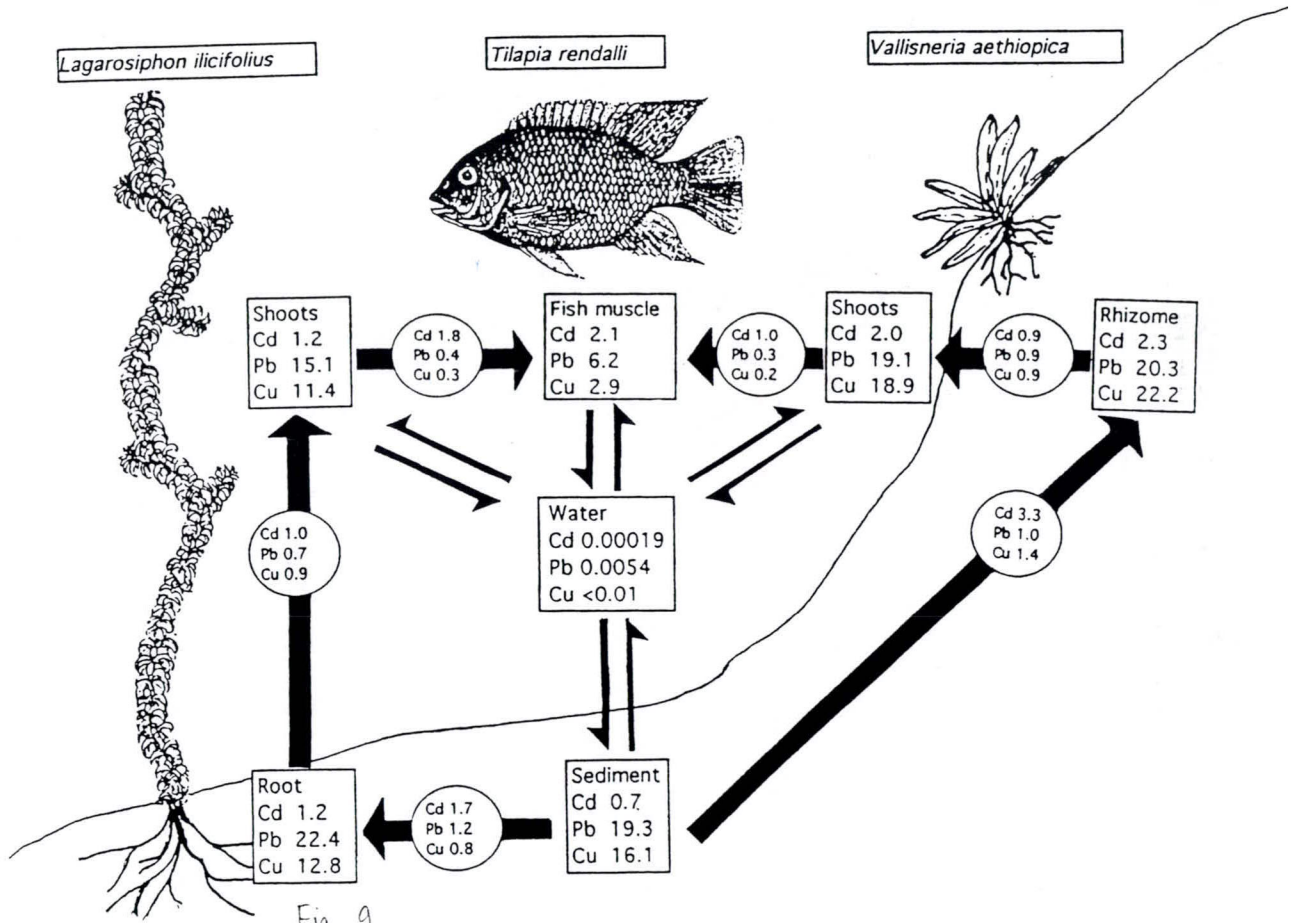

Lagarosiphon ilicifolius
Tilapia rendalli
Vallisneria aethiopica
Shoots
Cd 1.2
Pb 15.1
Cu 11.4
Cd 1.8
Pb 0.4
Cu 0.3
Fish muscle
Cd 2.1
Pb 6.2
Cu 2.9
Cd 1.0
Pb 0.3
Cu 0.2
Shoots
Cd 2.0
Pb 19.1
Cu 18.9
Cd 0.9
Pb 0.9
Cu 0.9
Rhizome
Cd 2.3
Pb 20.3
Cu 22.2
Water
Cd 0.00019
Pb 0.0054
Cu <0.01
Cd 1.0
Pb 0.7
Cu 0.9
Cd 3.3
Pb 1.0
Cu 1.4
Root
Cd 1.2
Pb 22.4
Cu 12.8
Cd 1.7
Pb 1.2
Cu 0.8
Sediment
Cd 0.7
Pb 19.3
Cu 16.1

Fig. 9

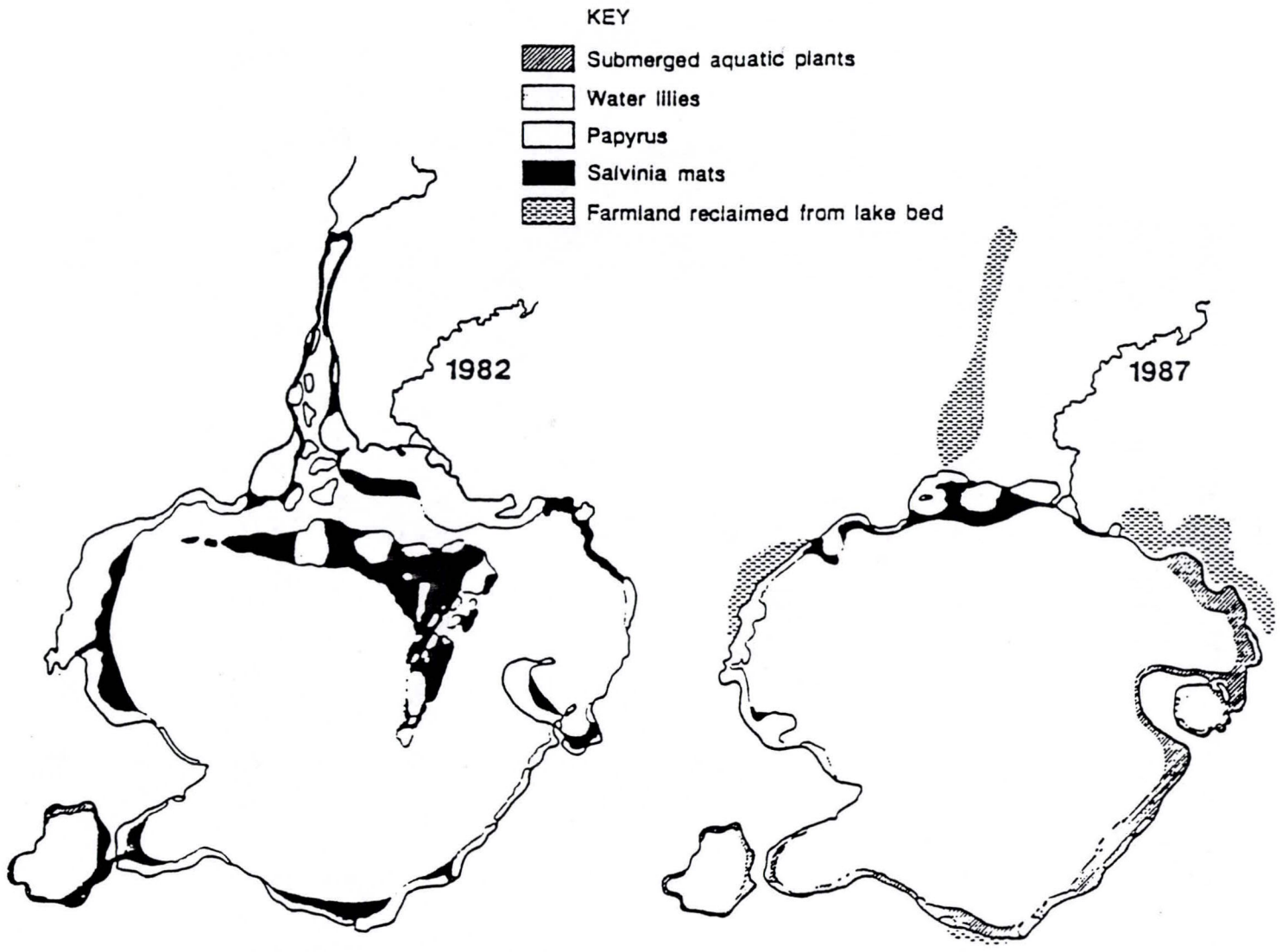


Fig. 11 General map of Lake Naivasha showing the recent evolution of the lake as described by Harper (1992).

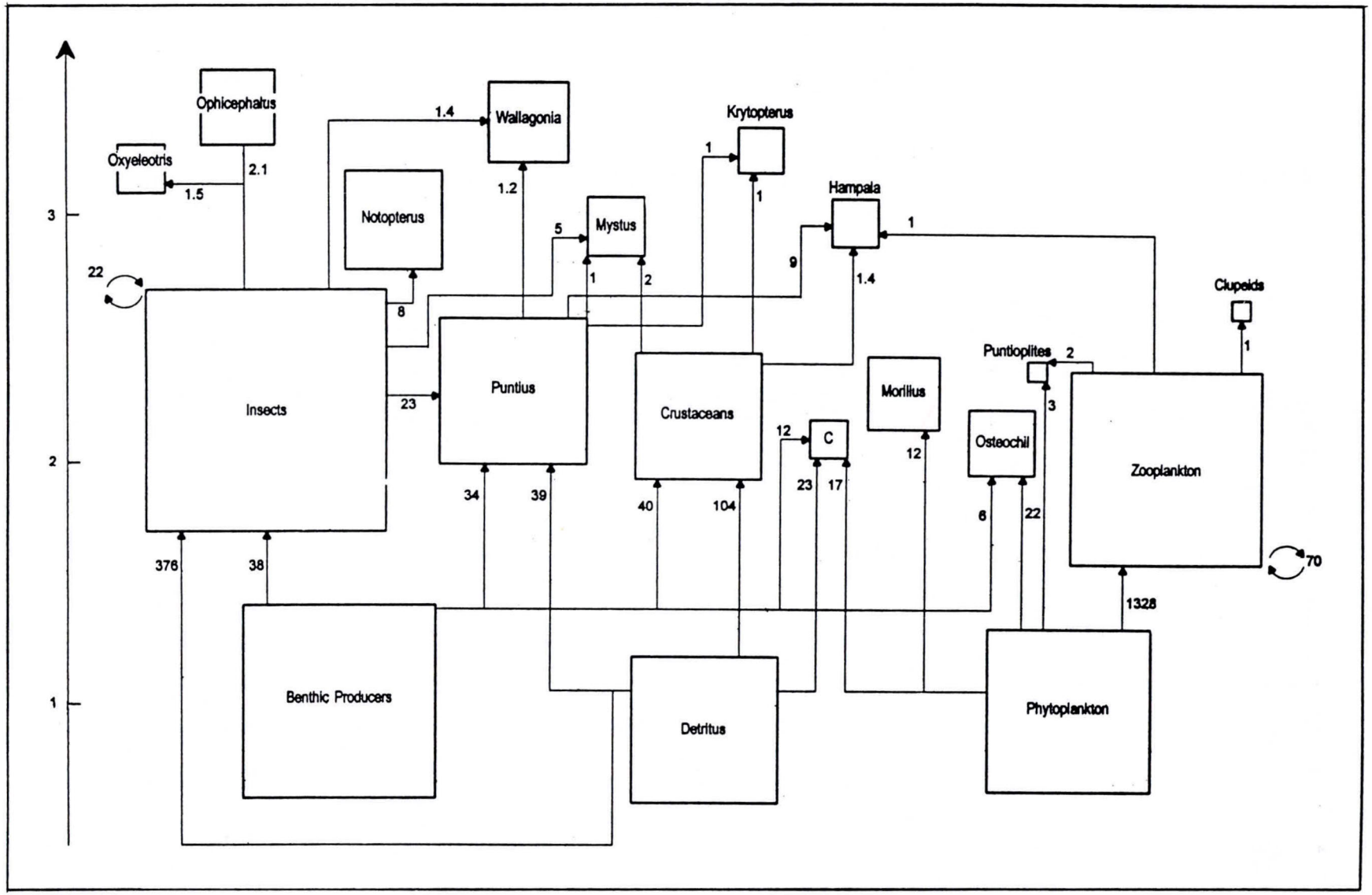


Fig. 12 ECOPATH II model of Lake Ubolratana for 1968-70, indicating the relative biomass of each group (area proportional to log B in t km^{-2}) and the major flows connecting them. For clarity, less important flows are omitted as are backflows to the detritus box and fishery catches. The horizontal axis of symmetry of each box is aligned with the functional trophic level of this box (see Christensen and Pauly 1992 for details).

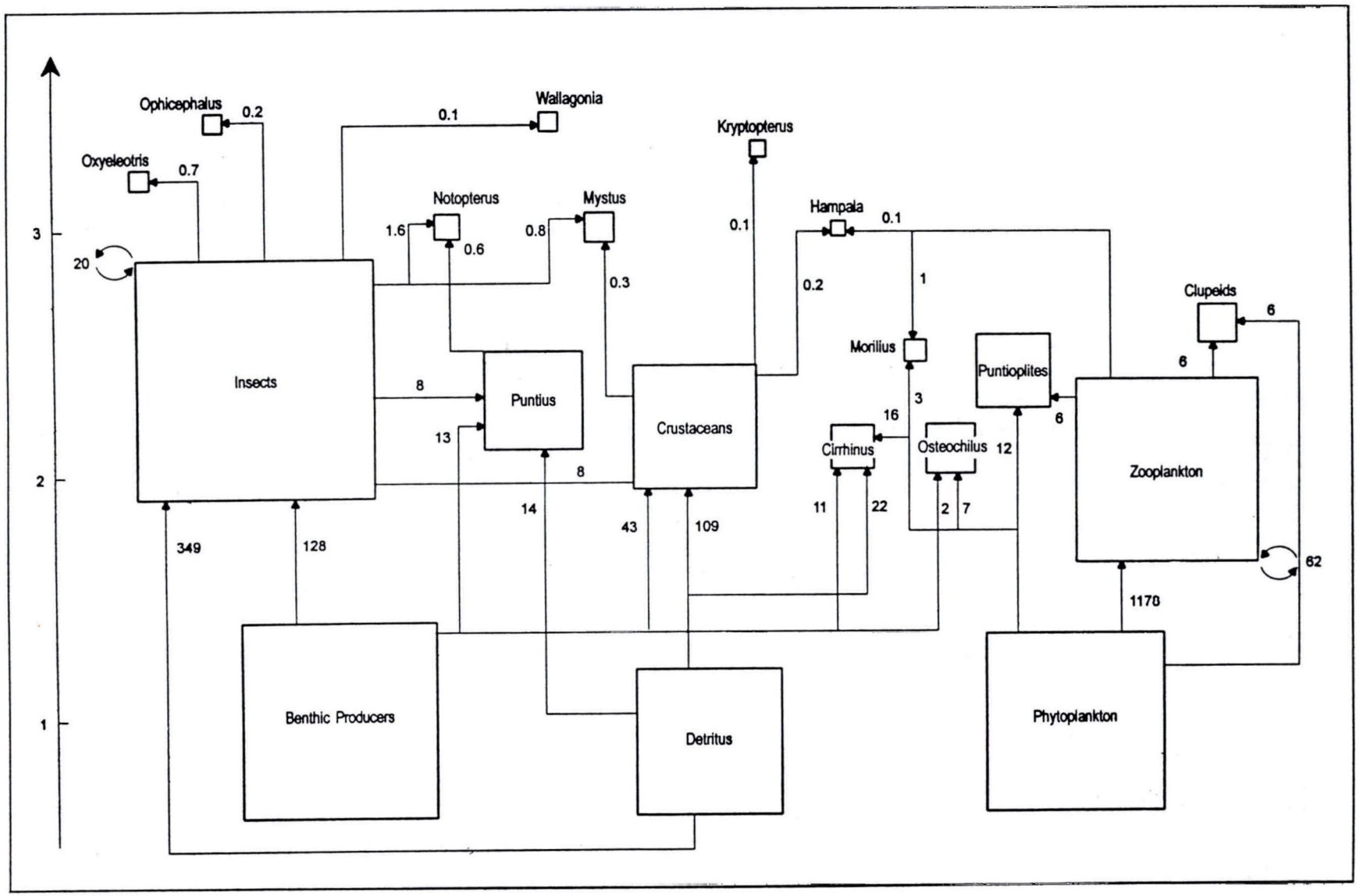


Fig 12 ECOPATH II model of Lake Ubolratana for 1985-88. See Fig 13 for details of the legend.

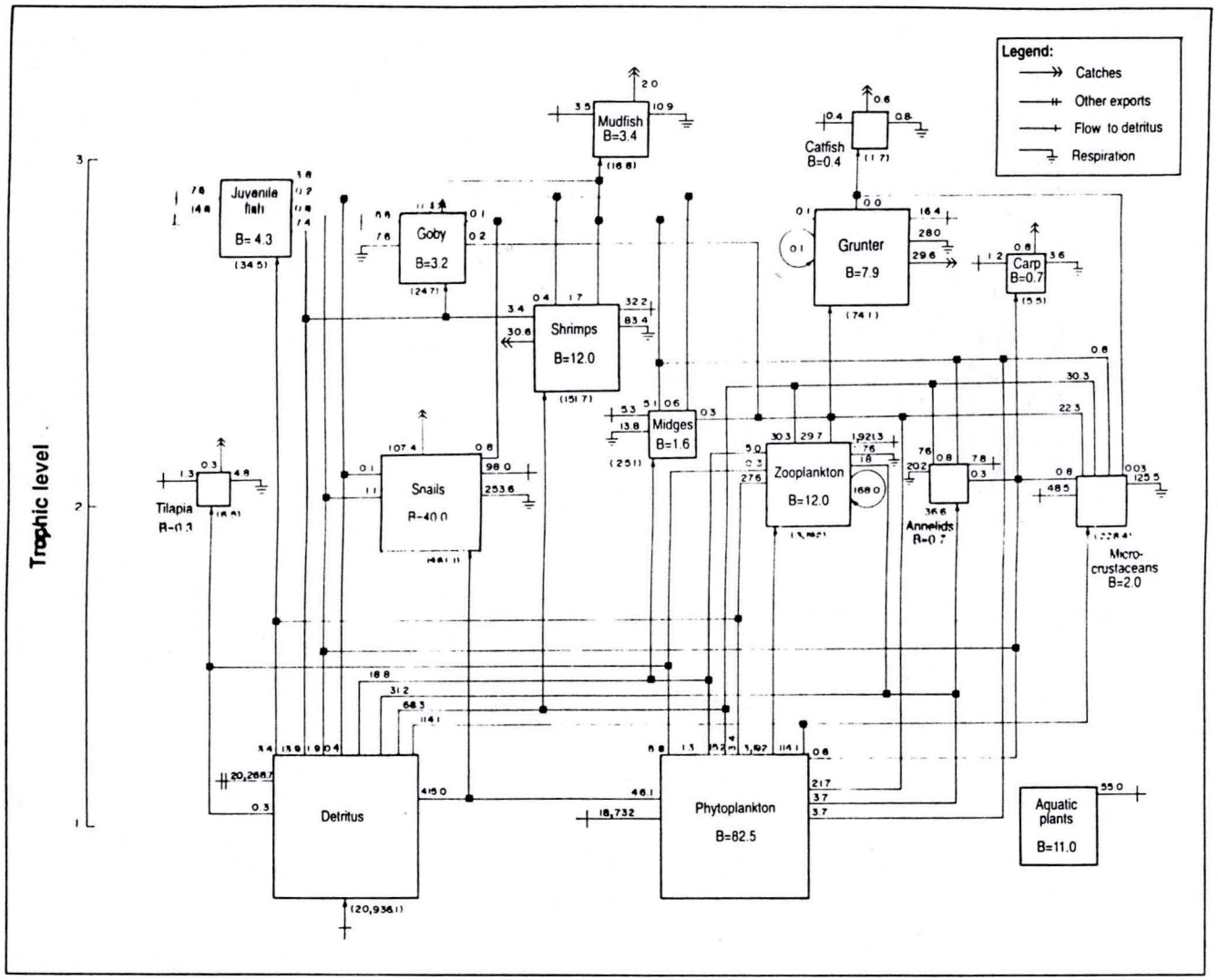


Fig. 15 ECOPATH II model of Laguna de Bay, Philippines, prior to the fishpen period (1968).

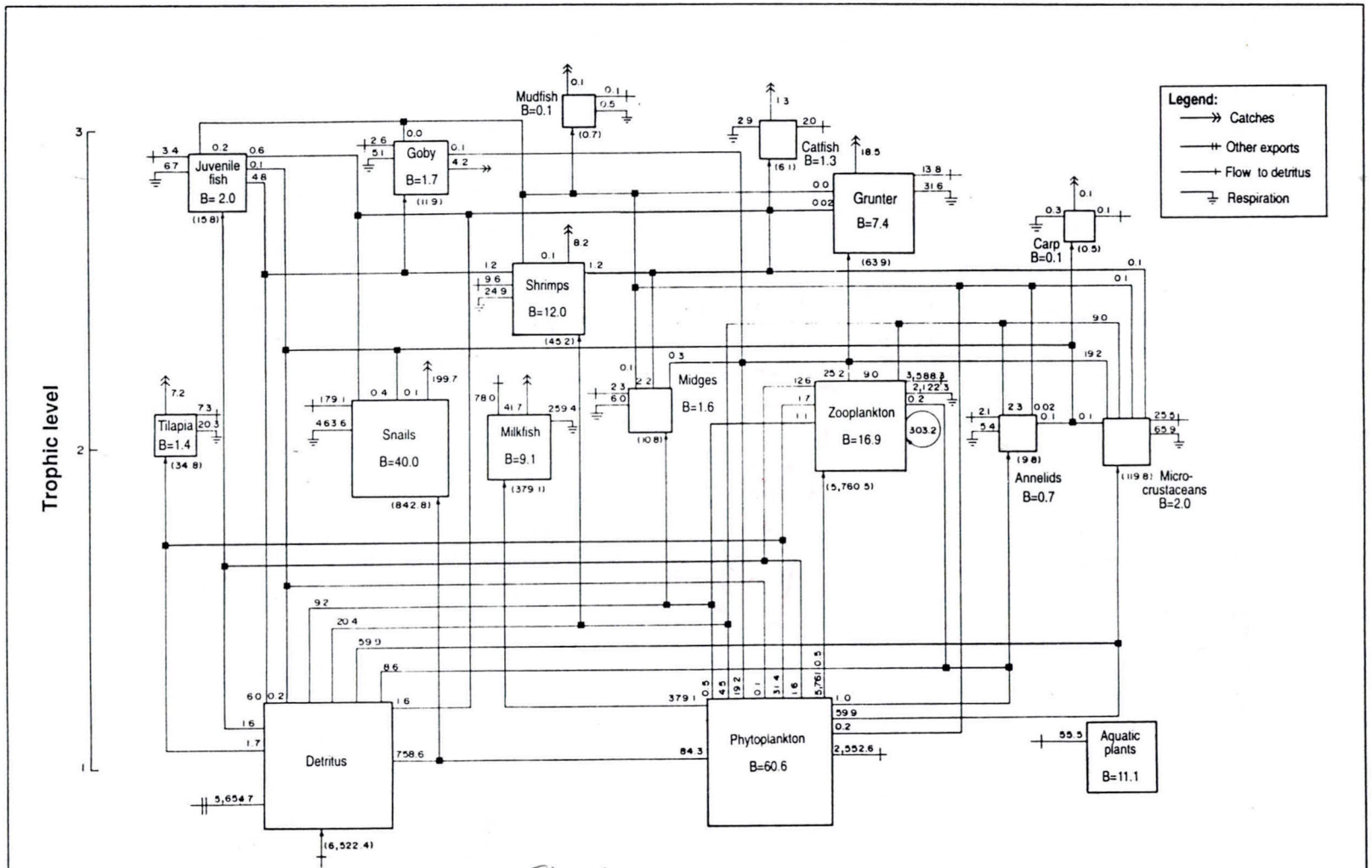

Trophic level
3
2
1
Legend:
Catches
Other exports
Flow to detritus
Respiration
Mudfish
B=0.1
Catfish
B=1.3
Grunter
B=7.4
Goby
B=1.7
Juvenile
fish
B= 2.0
Carp
B=0.1
Shrimps
B=12.0
Midges
B=1.6
Zooplankton
B=16.9
Tilapia
B=1.4
Snails
B=40.0
Milkfish
B=9.1
Annelids
B=0.7
Micro-
crustaceans
B=2.0
Detritus
Phytoplankton
B=60.6
Aquatic
plants
B=11.1

Fig. 16

Watershed Classification : The Macro Land-use Planning for the Sustainable Development of Water Resources[1/]

Nipon Tangtham[2/]

Abstract :

Water resources development and watershed management are recognized as unseparated activities for Thailand's socio-economic and environmental development plan. Problems of water resources in terms of water shortage in dry season and flood with unfavorable water quality during the wet season caused by watershed degradation led the government to promulgate the Cabinet Resolution namely "Watershed Classification". This resolution classified watershed area in Thailand in to 5 zones with the first (WSC1) and the second (WSC2) are preserved as protection and commercial forests respectively and the rests (WSC3-WSC5) belong to agricultural and other purposes with appropriate conservation and mitigation measures. The classification scheme employed five parameters, i.e., Slope, Elevation, Landform, Soil and Geology which were agreed by agencies concerned to derive watershed class equation for particular region with additional condition of forest or non-forest existing for assigning WSC1A and WSC1B. In national scale, about 17.86 percent of the country area was classified as WSC1 in which about 16.1, 0.26, 1.40 and 0.13 percent are identified as WSC1A, WSC1AR, WSC1B and WSC1BR respectively. About 8.3, 7.54, 16.0 and 50.3 percent was classified as WSC2, WSC3, WSC4 and WSC5 respectively. Although it was designed as macro-land-use planning for better quality of environment, water quality and flow regiment are the main aim of this project. This resolution is expected to be very beneficial to most of water resources development project in the future if it could be efficiently implemented. It will not only to reduce reservoir sedimentation but also to help decrease chemical pollutants contamination of stream water supply to downstream.

1. Introduction:

Water resource development and watershed management are unseparated activities which play very significant role in socio-economic development of the developed and developing countries especially for those using agriculture and industry as a base for generating the national income. For the developing countries having abundant water resource as Thailand, the forest, land and water resources as well as environment could be mutually constructive utilized in sustainable ways if land could be suitably used.

The most recent statement from the Worldwatch Institute concerning water and its related natural resources development is that "for all its impressive engineering, modern water development has been governed by a fairly simple calculus: - estimate the demand for water and then build a new supply to meet it." It is an equation that ignores the complexity of the natural world, question of human equity,

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1/ Paper presented in International Seminar Workshop on "Advances in Water Resources Management and Wastewater Treatment Technologies" 22-25 July 1996, on the occasion of 6th Anniversary SURANAREE UNIVERSITYOF TECHNOLOGY.

2/ Associate Professor in Watershed Management, Department of Conservation, Faculty of Forestry, Kasetsart University, Bangkok 10903.

concerns about other species, and welfare of future generation. In a world of resource abundance, it may have served humanity adequately. But in a world of scarcity, it is a recipe for trouble. Agenda 21 - Earth Summit in Rio, 1992 and the Conference in Dublin, Ireland, requested the World Bank to call for "recognition of the links between economic development and protection of natural ecosystems, for water to be treated more as an economic good, and for water planning to involve fuller public participation". (Postel, 1996)

Watershed classification in Thailand is the macro-land-use planning project initiated in 1979 by the Royal Thai Government (RTG) which coresponds to that agreement made in Agenda 21 and that of the Worldwatch Institute statement. It was the initial step to conserve the watershed ecosystems of the country by the wise use of natural resources concept. This project has been a RTG's effort to make land owners use their land as compatible as possible with the feature of environment and to mitigate any probable adverse effect especially that of water resources. The RTG had spent 7 years for completing the whole country area with land-use practices regulation. Watershed classification is thus anticipated as a useful tool for management of watershed ecosystems to produced good quality of water resources with appropriate utilization of land and forest and other natural resources.

The main aim of this paper is to ascribe the benefits of watershed classification for water resources development in Thailand. To do this, the water resource situation was described. Upstream-downstream relationship as an approach to environmentally sound management of water resources was reviewed so that watershed classification can be linked to water resource management. Brief characteristics of watershed classification and its land-use practices resolution were informed. Areal watershed classes distribution and forest as well as water resources in 25 main basins of the country were presented and discussed. Finally, the benefits that water resource development could be obtained from watershed classification was concluded.

2. Thailand Water Resources Situation

2.1 The Demand and Supply of Water Resources

2.1.1 National Scale

Thailand Development Research Institute, (TDRI) estimated the national requirement for water use in three main types, i.e., domestic, industrial and agriculture up to the year 2010 at about 167 billion cubic meters (BCM) per annum (Phantumvanit and Panayotou, 1990). It was also reported by Office of National Environmental Board-ONEB (1990) based on the Royal Irrigation Department (RID) that the surface water produced by the main basins in Thailand is almost 200 BCM per year. Out of an estimated 200 BCM/yr of such renewable water resources, about 40 BCM are with drawn annually for agriculture, 2 BCM for domestic use, and 2 BCM for industry. It was also further estimated basing on the current trend that the corresponding figures would be 144, 15 and 8 BCM/yr respectively by the year 2010. (Phantumvanit and Panayotou, 1990).

2.1.2 Regional and Basin Scale

The predicted average water demand and supply previously described reflect the macro water picture which ignores the regional and basin variation. In fact, the Northeast is considerably dryer and the South is wetter than the rest of the country. The Northeast even suffers from excessive water and floods during tropical storm period, water shortage has been always occurred every dry season. These macro projections also ignore yearly variation of climatic condition and changes in land-use and urbanization.

In order to reflect, regional and basin variation in both the demand and supply and their trends to year 2010, average annual runoff produced by 25 main basins and predicted demand for all sectors were estimated based on water yield map provided by RID and TDRI method of water demand calculation. The results are shown in Table 1. The irrigated areas and small and large reservoirs developed by RID and the multipurpose reservoirs in each of those basins are presented in Table 2.

Estimated trend of water demand in the national scale shows that demand is still less than the amount of renewable water existing in all basins of this country. The basin estimation however indicates insufficient supply in the central region especially in the lower Chao Phraya basin and Tha Chin basin by the year 2010.

2.1.3 Existing Problems

Problems of water resources encountered by people in this country can be identified in three aspects, i.e., insufficiency, fluctuation of water regime and water quality. The problems have been stated by the Technical Committee of Thailand National Hydrology Committee for IHP (1989) as follows:

1) Insufficient: The water shortage problems are frequently occurred even in the rainy season especially in the Northeastern and Northern regions. Incoastal area of the Eastern region, insufficiency of water are widely found not only for domestic and agricultural uses but also in promotion of industry for the Eastern Sea Board projects.

2) Fluctuation of Water Regime: This problem has been occurred in accordance with the change of environment in the upper watersheds. The changes of natural vegetation by ways of deforestation have caused fluctuation of flow not only in downstreams but also in the upper catchments. In the past, stream water was quite normal in terms of seasonal flow-distribution. Only the last decade, the peak flow was quite high and very rapid while the summer flow was considerably low and frequently shortage throughout the country.

3) Water Quality: Quality of surface water has been gradually declined in all important rivers and tributaries. Problems of sediment and chemicals transportation are seriously found in the North and Northeast with high concentration of toxicity. Most of the watersheds have the tendency of increasing the problems of water

quality and the other forms of water pollution. This is due to the expansion of agricultural and industrial development without sufficient measures in water quality control.

2.2 Conflicts in Water Use:

Besides the critical problems previously mentioned, conflicts in water use between upstream and downstream people are becoming more apparent in almost all regions of the country. The conflicts are, however, mostly originated from water shortage.

In overall situation, conflict in using water for agriculture, energy, industrial and municipal, tourism, and fresh water fish production including the recently popular golf course projects can be found in a number of basins and subbasins. Highland development projects such as poppy replacement programs in the North are leading to direct competition with already established communal and public irrigation systems, and are particularly problematic. In addition, efforts to promote international tourism and economic development in the more isolated parts of the North are stretching available water supplies and are bringing about conflict with local ethnic groups as well as farmers (Sethaputra, 1990).

The greater chance of conflict between upland development project such as small storage reservoirs developed by government agencies and local farmers and the downstream reservoirs for irrigation projects and/or for electricity generation projects or multipurpose dams has been occurred and will be increased in the future.

It has been observed by EGAT and RID that the inflow in almost operated reservoirs has been recently declined due to those upstream development activities. The conflict between farmers in the upstream and downstream zones during the dry months has been frequently occurred in the North. The matters of conflict are not only insufficient water for domestic used in dry period but also others additional problems, i.e., irrigation water shortage, sedimentation, toxic chemical runoff and poisoned drinking water.

In the Northeast, a major source of conflict is evolving when situations where agricultural development for cassava replacement and reforestation programs are leading to direct competition with already established irrigation systems. The efforts to promote tourism and economic development are also seriously stretching the limited water supplies of the region, especially the supplies in the medium-scale irrigation reservoirs. These problems are particularly acute in the Northeast, where the climatic condition and geologic formation are limiting factors producing low runoff potential and deforestation has been the most severe (Sethaputra, 1990).

In the Eastern region where the Eastern Sea Board Project has been established and is expanding for future industrial area, competition in using water for fruit tree orchards and industrial purpose has been a serious conflict leading to the confrontation between the farmers and those people in the tourism and industrial business.

The Eastern has been recognized as the region producing good quality of tropical fruits such as durian, mangosteen, and logan, etc. The farmers have utilized natural stream water for their orchards for centuries. Only the last decade when the tourism development and Eastern Sea Board Project have been evolved as well as its own urbanization, large amount of water from natural channels including from those man - made reservoirs has been drawn for tourism and industrial development purposes. The water shortage has become more serious and frequently in all provinces of this region. Several open-deep ground water wells have been dug for fruit orchard irrigation. Insufficient water for the tourists in the hotels at Pattaya as well as Rayong and Chonburi is normally apparent during the summer period. The farmers pays higher price of water for irrigating their orchards. It was escalated that without careful plan of water resource development for this region, both fruit orchard and other development projects (tourism and industry) will be mutually destructive to inadequate water for both activities and the consequent impact of air and water pollution.

Conflict in water use of the other regions has not been seriously apparent. Only few conflict between the golf course developers and downstream farmers/occupants has been mentioned in newspaper and discussed among water resource persons. It was reported that each golf course needs about 2-3 MCM per year for maintenance. The water use for this kind of project is mostly drawn from upstream by small storage dams. This causes insufficient water for downstream irrigation and domestic uses during the dry period. It is expected that the conflict stemming from water shortage will be compounded by deforestation that results in microclimatic changes and longer hydrological drought.

In conclusion, although water resources in Thailand are adequate in terms of quantity, the quality and flow regime are becoming more critical in all regions due to insufficient management intention from the government and private entrepreneur. Besides water shortage which has been frequently occurred, several tributaries are now being polluted by excessive fertilizer and chemical substances drained from non-conservation farming and irresponsible industrial manufactures. Conflict in water use between farmers and industrial groups in also becoming more serious in the future.

3. Upstream-Downstream Relationships and Water Resources Management:

For several decades, the engineers, who involves in water resources development, have paid less attention to upstream activities where water in the reservoirs come from. It seems that water quantity in terms of demand and supply is what they need for planning. Perhaps water flows downhill in the former day was always clean and adequate for people's needs, changes in quantity and quality were almost a low priority in planning consideration. Now-a-day, both quantity and quality are becoming worse and worse every where in the world. The concept of sustainable development is thus introduced into water resource development planning.

Kuiper (1971) stated in his process of water resources planning that "since the water runs downhill, one may expect that any interference with natural flow regime will have repercussion all the way down till the river reaches the sea. Therefore the planning of any water development project must be coordinated with other projects in the drainage basin that may be affected by, or that may have some effect upon, the project under consideration".

It was stated by Golubev (1988) that the conventional approaches to water resources management have dealt only with demand-supply interactions with little consideration for the environmental and social side-effects of development. Water should be considered not only as a resource but also a major factor in any ecosystem as a carrier of matters in the global biogeochemical cycles. These functions of actor put it in the center of practically every territorial system in such a way that neither economic development of land nor water management of it are possible without due mutual regard. Understanding of this relationship suggests the need of basinwide management where the links between various parts and components of a basin as a system are taken into account.

In Hufschmidt and McCauley (1988)'s article, the river/lake basin approach is mentioned as an appropriate spatial unit for scientific understanding of natural processes, planning of water resources development, and assessing its environmental and social impacts. The systems-oriented conceptual framework that can be usefully adopted for analyzing water resources management issues and problems is made up of three dimensions, i.e., (1) the management process, (2) management activities, and (3) management system elements. The last dimension consists of linked activities, involving **upper watershed management,** irrigation management and others in the systems.

Experiences in monitoring water quality flowing to lake Biwa in Japan led Kira (1988) emphasized in his article that forests serve to remove nutrients from rainwater. Wetland and paddy fields serve to enhance the deposition of silt and sand transported by water before they enter rivers and lakes, precipitate certain nutrients such as dissolved phosphates and organic matter, and absorb part of nutrients. However, environmental impacts of development, particularly in areas significantly affected by industrialization and urbanization, are apparently beyond the recovery capacities of natural processes, a proper combination of the **ecological principles of watershed management** and technological measures, such as the installation of large-scale sewerage system, is indispensable in eutrophication control. The mentioned principles of ecological watershed management are: (1) utilize as far as possible such functions of natural and semi-natural ecosystem as soil erosion control, water retention, trapping and decomposition of pollutants, etc., for buffering and improving watershed and aquatic environments; (2) minimize the destruction of ecosystems and conserve them so as to maintain their natural processes, biological diversity, productivity and aesthetic values; (3) optimize the allocation of natural ecosystems, agricultural and grazing lands, human settlements and industrial activities over space so as to ensure the sustainability of development in the watershed.

In order to meet such principles, Shimazu (1988) who examined some important issues and problems involved with environmental planning and management in the context of regional development in Japan suggested the developing countries to adopt what he calls "soft approach" to manage their watershed and water resources. This approach is characterized as being (a) manageable by local government officials; (b) responsive to the vulnerability of local communities; and (c) incremental and bottom-up in decision making.

4. Watershed Classification and Its Land-use Practices Resolution:

The problems of water resource previously mentioned together with the worse situation of head-watershed degradation in Thailand highlight the critical need for land-use planning which can properly allocate land areas to have various uses with mitigation measures for improving water resource for downstream people. As matter of fact, the upstream-downstream impacts relationship and such conservation plan have been recognized by RTG for over 20 years, but only in recent years has a vigorous project been pursued.

In January, 1975 the Ministry of Agriculture and Cooperatives proposed to the Cabinet the criteria for classifying the Mae Ping watershed in the North into 3 classes. These proposed criteria assigning about 60% of high altitude land (above 700 m. MSL) of the Mae Pring watershed as Class 1. It was also recommended that areas in this class be protected from any utilization of natural resources except rehabilitation for watershed protection. All residents occupying this zone would be evacuated. Watershed classes 2 to 3 proposed for lower land could be utilized for mining, forestry, agriculture, etc., if approved by a committee set by the Cabinet. Since there were many mining operations and hilltribe villages already in areas proposed as Class 1, considerable conflict and controversy developed among government agencies. The Ministry of Industry, which is responsible for mining operation, thus requested the proposed criteria for watershed classification be revised.

A new Watershed Classification Committee (WCC) was appointed by the Cabinet in October 1979. The National Economic and Social Development Board (NESDB) provided funds to Kasetsart University (KU) through the Office of National Environmental Board (ONEB) for conduct of a watershed classification project. The ONEB retained a technical panel of technical experts (the WCC) for advice on technical aspects of the project. While the Project is mainly funded by the RTG, funds for technical assistance have been provided by the government of Sweden, through the International Union for Conservation of Nature (IUCN), Conservation for Development Center.

4.1 Objective of Watershed Classification

Watershed classification is an extension of land-use planning for forest areas, which will properly allocate land of various uses. For Thailand, specific objectives of this project can be listed as to :

1) Develop a method for assigning watershed class (WSC) numbers to land areas.

2) Distinguish between areas to be permanently protected as forest watershed cover or used for commercial forests, and areas open for utilization of all resources or conversion to agronomic uses.

3) Immediately obtain watershed class maps of all watersheds in the country using the existing data and a method of manipulation the data to provide numerical classifications of lands into watershed classes.

4) Recommend appropriate land-use practices to be promulgated as Cabinet Resolution.

4.2 Definition, characteristics and Watershed Classes Prediction Equation

4.2.1 Definition

Watershed classification initiated by the WCC is defined as the identification of inherent capacity of landscape unit to be managed and produced, either plants or animals. The terms "WSC" used by the WCC is synonymous with land use planning for watershed areas. It is an effort to make man's uses of land as compatible as possible with the features of the environment and to mitigate on-site and off-site effect of use.

4.2.2 Watershed Class Characteristics

Based on the agreement among government agencies, the WCC (1983) classified area in the watersheds into 5 classes using SLOPE. ELEVATION, LANDFORM, SOIL, GEOLOGY and FOREST as modeling parameters. The hypothetical characteristics of each watershed class can be described as follows:

WSC 1 : **Protected or Conservation forest and headwater source.** This class is divided into 2 subclasses:

WSC 1A : are protected forest areas and include the headwaters of rivers. The areas are usually at high elevations and have very steep slopes and should remain in permanent forest cover.

WSC 1B : are those areas which have similar physical and environmental features to WSC 1A, however portion of these areas have already been cleared for agricultural use of occupation. These areas may be followed or cultivated ; they therefore require special soil conservation protection measures. Where possible, they should be replanted to forest or maintain in permanent agro-forestry.

WSC 2 : Commercial forest:
These areas are designed for protection and/or commercial forests where mining and logging will be allowed within legal boundaries, usually at high elevations with steep to very steep slopes.Landforms usually result in less erosion than WSC 1A and WSC 1B. The areas may be used for grazing or crop production if accompanied by appropriate soil protection measures.

WSC 3 : Fruit-tree plantation:
These areas covers uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.

WSC 4 : Upland farming:
This class describes those areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for few soil conservation measures.

WSC 5 : Lowland farming:
WSC 5 are gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restriction.

Pictorial model of watershed classes and recommended land-use and conservation measures are illustrated in Figure 1.

4.2.3 Prediction Equations:

Based on the mentioned hypothetical characteristics and the lesson from unaccepted watershed classification maps proposed by RID due to using only one parameter (i.e., elevation) as variable, new strategy employed by WCC was thus the one that can compromise all benefits of agencies concerned. All WCC members were asked to propose the parameters which are thought to be meaningful in characterizing watershed classes and must be available or can be made available in short period. Also constraints required for mapping large area of country (40 million ha) with limited time and computer system (PC) were informed to WCC members. It was agreed that parameters used in deriving prediction models must be stable in space and time and equally good data and must be numerically scaled to establish a mathematical relationship with WSC and for efficient production of WSC maps. Five variables were selected from more than 20 parameters initially proposed by concerned agencies. They are SLOPE, ELEVATION, LANDFORM, GEOLOGY and soil. Values for the five variables were read either from 1:50,000 topographic maps, or soil and geologic maps for each of 1x1 sq.km grid. A multi-variable analysis was employed to develop the mathematical relationships of variables with assigned WSC values for each region and/or basin. Detailed information on prediction equation derivation, field test and mapping procedures was described by Tangtham (1992a). The prediction equations for each region and ranges of WSC values for class determination were presented in Table 3 and Table 4 respectively. Example of computer map and final watershed classes map adjusted based on topographic and forest map were shown in Fig.2 and Fig.3 respectively.

4.3 Resolution for Land-use Practices in Watershed Area:

Regarding Land-use practices in the watershed area, the government also developed a set of resource utilization and management practices for each operating unit within each major watershed class. The general recommendation for land use practices in each watershed class are as follows:

In WSC 1A:

1) No forest product be permitted to harvest for any case. It must be strictly kept permanently as headwater source.
2) Forest protection activity is the first priority of RTG in these areas.
3) Immediate reforestation program must be undertaken by RTG on the abundonated shifting areas.
4) Areas converted to permanent settlement (but classified as 1A due to misidentified by LANDSAT) must be strictly supervised by the concerned agencies for future development.

In WSC 1B:

1) Areas converted into agricultural land must be practiced in accordance with the national economic, social and environmental policies.
2) Those areas which have been developed for recreation and resorts should be harmonically managed to keep ecological balance and natural sceneries.
3) Reforestation on denuded areas especially those where are unsuitable for agriculture or any other purposes should be immediately undertaken by the concerned agencies.
4) Erosion control measures should be practiced on the areas subjected to road construction and mining by the responsible agencies.
5) Permission can be made for the unavoidable projects which are very important to the national economy and security but the EIA must be prepared by the agencies concerned and approved by the Office of Environmental Policy and Planning (formerly named as: ONEB).

In WSC 2:

1) Forestry and mining activities can be normally allowed but should be closely and strictly supervised by the concerned agencies.
2) Agricultural practices are strictly prohibited.
3) Immediate reforestation programme must be conducted by concerned agencies.

In WSC 3:

1) Land utilization for forestry, mining, agriculture and other can be permitted but soil and water conservation measures are strictly required.
2) Areas with soil depth greater than 50 cm are recommended for fruit- tree and orchards or economic plantation or permanent cash crops, but appropriate soil and water conservation practices are needed.

In WSC 4:

1) Forestry, mining and other land-use activities are normally followed with close supervision of RTG.

2) Areas with slope in the range 18-25% and soil depth less than 50 cm are recommended for fruit-tree plantation and forestry. Those areas having slope between 6-18% should be used for agronomic crops with the application of suitable soil conservation measures.

In WSC 5:

1) All kinds of land use practices can be allowed as usual.
2) Areas with soil depth less than 50 cm are recommended for agronomic crops, private wooldlots, fruit-trees, and ranges or recreational purpose.
3) Areas having soil deeper than 50 cm should be utilized as paddy field and agronomic production.
4) Lands with high potential of agricultural production should be avoided for industrial development.

This watershed classification and its land-use practices resolution have been implemented since 1985 for the northern watershed areas and effective for the whole country area in 1991.

4.4 Watershed Classes Distribution and Forest Resources Status in 25 Main Basins

The watershed area classified for different classes by basin and region including its resources status in terms of the remaining forest coverage, annual runoff and suspended sediment are presented in Table 5.

In national scale, about 17.86 percent of country area was classified as WSC1. Of this figure, about 16.07, 0.26, 1.40 and 0.13 percent are identified as WSC1A, WSC1AR (forest was identified by RFD while it was mapped by Rubber Research Institute as rubber growing areas), WSC1B and WSC1BR respectively. About 8.3 percent was classified as areas provided for commercial forestry and restricted mining areas (WSC2). The rest of about 73.7 percent was classified as area devoted for agricultural and other purposes (WSC3-WSC5). About 50.3 percent is WSC5 which is mainly non-restricted for all kind of land-use development. Simple conservation measures for erosion control are needed for about 16.0 percent of country area (WSC4) and more intensive measures for erosion and pollution control are required for about 7.54 percent of WSC3.

In regional scale, about 47.7 percent of the North was classified as WSC1 and WSC2 which is assigned to be forested area of which about 30.2 percent is watershed protection forest and 15% is identified as WSC2. About 2.5% of regional area mainly in WSC1 has been occupied and used as farmland (WSC1B). The rest of about 52.2 percent

of regional area was classified as WSC3-WSC5 which has already been used for agricultural purpose and others. This could be confirmed by the remaining forest area of about 47.6 percent of northern region detected by Landsat imageries in 1988 and about 45 percent in 1991 (Forest Statistics Sub-Division, FSS; 1994).

The most serious region in terms of having the least forest cover and head-water source area is the Northeast. Only 6.2 percent of regional area was classified as WSC1A with about 1.2 and 2.5 percent were identified as WSC1B and WSC2. About 90 percent of the Northeast was classified for supporting agricultural and other purposes. Of this figure, about 64.5 percent was classified as WSC5 with 22 and 3.6 percent as WSC4 and WSC3 respectively. It could be stated that all of WSC3 to WSC5 area has been utilized for agriculture and others since only 14% of regional area was mapped as forest area remaining in 1988 by RFD. Recent information indicates about 12.9 percent was reported as forested area in 1991 (FSS, 1994). The forests on the hilly and mountainous areas which are considered as the roof of the Northeast have been almost totally damaged and rather difficult to reclaim for better head-water sources.

The central plain although having about 10.5 percent of regional area classified as WSC1 to WSC2 and greater amount of 89.5 percent as WSC3 to WSC5, the later WSC areas have recieved abundant of water from the northern river basins. The remaining forest area of about 12.4 percent of regional area seems to be adequate for protecting WSC1 and WSC2 areas exist in the basins of this region.

Watershed classification map of the East shows that about 88 percent of this region was identified as WSC3 to WSC5. Only 6.7 percent was classified as WSC1 with 6.4 percent is WSC1A. About 5.2 percent falls in WSC2 assigning for commercial forest area. Area classified as head-water source for the East is rather small portion considering from the increasing demand of good quality water for domestic and industrial uses in the future. The forest cover in this region was reported at 19.7 percent in 1988 and recently remained at about 19.5 percent in all basins of this region.

River basins in western region consist of about 34.8 percent of WSC1 of which 34.4 percent belongs to WSC1A and the other 0.4 percent was replaced by shifting cultivation and rubber plantation. About 11.4 percent was classified as WSC2 and the rest of about 52.3 percent was identified as WSC3-WSC5. The remaining forest in 1988 was about 50 percent of this region. It is fortunate that the long-narrowed basins of the western region are bounded by the neibouring country's borders and difficult to access due to having rugged terrain. The forest covers of almost 50 percent of the basins are still remain and supplying adequate water with good quality to downstream and even to produce hydrant water for Bangkok people in the near future.

The southern peninsula basins consist of 28.7 percent of regional area classified as WSC1 and WSC2 which supposed to be forested area. Of this figure, about 13.37, 1.61, 0.95 and 0.93 percent was identified based on forest map and rubber

plantation map as WSC1A, WSC1AR, WSC1B and WSC1BR respectively. Another 11.8 percent was WSC2 which assigned as commercial forest area. The rest of 71 percent was classified as WSC3 (9.77%), WSC4 (16.30%) and (44.93%). Considering from heavy rainfall characteristics and short river systems of this region, the remaining forest area of

25 percent in 1988 and about 23 percent recently should not be adequate to protect watershed ecosystem of this region. Fortunately, the large portion in WSC3 to WSC5 in this region has been replaced by rubber plantation in which might not compensate the hydro-ecological role of the original moist evergreen forest but still a lot better than those in other regions where most of WSC3 to WSC5 have been permanently converted to annual crops and orchards.

5. Benefits of Watershed Classification on Water Resource Management:

The environmental degradation in forms of water shortage, flood and water pollution caused by the mis-management of natural resources and industrial development have influenced the RTG to establish a new policy on natural resources utilization. The watershed classification-a macro land-use plan as shown in Figure 1, which is the first step of country's land-use planning, was the most current land-use model often employed by the agencies concerned as a base for the present and future development. According to the regulation promulgated by the Cabinet, those areas classified as Watershed Class 1A (WSC 1A) must be kept as permanent forest for protecting head-water sources. The areas identified as WSC 2 could be tutilized for commercial forest but other activities such as mining could be operated. The WSC 3, WSC 4 and WSC 5 are devoted for agricultural purpose but recommended for fruit-tree orchards, upland farming and lowland farming respectively. The WSC 1B, where they have the same characteristics as WSC 1A but without forest cover, could be utilized for specific purposes under government permission. This type of land-use model has been assigned to be practiced by the government agencies concerned in all regions since 1985.

Presently, most of concerned agencies cautiously consider their land utilization by avoiding to disturbed WSC 1A. Mining in areas classified as WSC 1A is not allowed. Reservoir construction for any purpose has also tried to avoid inundation of WSC 1A.

As more pressure is expected to increase in the next 10 to 20 years from increasing population, the regulation on watershed classification would be impractical for the agencies concerned and be ignored by the watershed occupants. The intensive or comprehensive land use planning for small watershed using community as a target area is included in the 8th National Economic and Social Development Plan (from 1997 to 2001). The patterns of land use plan in such planning unit, however, would be more or less the same as that assigned in watershed classification but would be modified according to what the community needs but should not exceed its carrying capacity. For those planning units where forest in the headwater source were denuded, reforestation for soil and water conservation must be undertaken to reduce soil erosion and improve the ecological environment. The medium slopes in the planning unit, fruit trees and fuel wood should be planted instead of commercial forest. In the lower part of the slope, as it is gentle and the thick soil layer is rich in water resources, farmlands would be allowed with storage reservoirs, ponds and check dams.

Although, watershed classification was initiated for the purpose of watershed-ecosystem conservation, it consequences in long term will contribute to the better quality of streamwater for downstream people as well as other environmental

condition. Downstream water resources developments in the future are expected to gain the benefit from this project if it could be effectively implemented throughout the country.

6. Conclusion

Currently, the demand of water resources for three major sectors, i.e., agriculture, industry and domestic is estimated at about 43 BCM per annum. The prediction of demand up to year 2010 will be at 167 BCM. The supply of surface water determined using the average of the country annual runoff is about 199 BCM. There will be therefore no serious problem of water supply in terms of water quantity in holistic view. The regional and seasonal distribution are, however, the problems of water shortage and flood in almost all regions. Water quality is recently becoming more and more serious problem in those rivers which the urban and industry are being rapidly developed especially in the Central and Eastern regions. Conflict in water use is also increasing due to the development of golf resorts and industries on the upstreams of fruit orchards and lowland farming areas. All afforementioned problems are expected to be compounded by the mis-use of land and deforestation which so far have been continuously practiced throughout the country.

Realizing these problems, the RTG initiated the Watershed Classification Project with Cabinet Regulation on land-use practices aiming at improving streamwater quality and flow timing from upland watersheds. This regulation classified watershed areas into 5 classes with the first and second classes assigned for conservation and commercial forest respectively. The rest classes are recommended for agricultural production with intensive soil conservation measures in class 3 and more simpler measures in the fourth class. The fifth class is devoted mainly for the paddy and other uses. Some of the area classified as class 1 and 2, however, have been occupied and utilized for cultivation and resort development. These villages and their surrounding cultivated lands are impractical to be managed using watershed classification regulation. The small watershed management concept using the community-based and people participatory land use planning will be employed in watershed rehabilitation programme.

It could be anticipated that, the watershed classification regulation will contribute long term benefits to water resources development project if it could be efficiently implemented throughout the country. Rate of reservoir sedimentation as well as pollutant contamination in streamwater is expected to be decreased due to more appropriate use of land in watershed area. Activities concerning natural resources utilization must be carefully planned and operated by agencies concerned with closely monitored by the ONEB.

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Table 1 : Average runoff produced and water quantity required by region and by main basin of Thailand

Basin Code and Name	Drainage area (sq.km.)	Average Annual runoff (BCM)	Predicted Population in 2000	Predicted Population in 2010	Predicted Water Demand for all Sectors 2000 (BCM)	Predicted Water Demand for all Sectors 2010 (BCM)
♦ NORTHERN REGION						
01 - SALAWIN BASIN	17,920	6.27	326,356	391,665	0.130	0.192
02 - KHONG 1 BASIN	9,920	5.95	603,492	662,681	0.761	1.497
03 - MAE KOK BASIN	7,895	4.84	725,130	802,582	0.836	1.645
04 - PING BASIN	33,898	6.14	2,451,503	2,729,510	6.026	11.854
05 - WANG BASIN	10,791	1.92	732,880	806,355	0.652	1.283
06 - YOM BASIN	23,616	3.54	2,355,024	2,487,803	1.609	3.165
07 - NAN BASIN	34,330	12.02	2,275,273	2,528,287	4.692	9.230
Regional Total	138,370	40.96	9,469,688	10,408,883	14.706	28.867
♦ NORTHEASTERN REGION						
02 - KHONG 2 BASIN	47,502	16.63	5,752,456	6,545,574	2.638	5.189
04 - CHI BASIN	49,477	9.40	6,170,556	6,802,647	4.705	9.255
05 - MUN BASIN	69,701	11.15	9,533,006	10,783,288	4.500	8.852
Regional Total	166,680	37.18	21,456,018	24,131,509	11.843	23.296
♦ CENTRAL REGION						
10 - CHAO PHRAYA BASIN	20,125	3.97	11,651,995	12,807,475	27.717	54.523
11 - SAKAE KRANG BASIN	5,192	0.98	419,891	466,122	0.833	1.639
12 - PASAK BASIN	16,292	2.77	1,822,137	2,002,830	0.875	1.721
13 - THA CHIN BASIN	13,682	1.73	2,796,221	3,172,339	8.522	15.262
Regional Total	55,291	9.45	16,690,244	18,448,766	37.947	73.145
♦ EASTERN REGION						
15 - PRACHINBURI BASIN	10,481	6.28	885,323	1,012,370	1.605	2.614
16 - BANG PAKONG BASIN	7,978	2.26	956,975	1,046,675	4.679	9.204
17 - TONLE SAP BASIN	4,150	1.24	130,034	148,694	0.035	0.057
18 - EAST COAST GULF BASIN	13,829	11.34	2,591,715	3,055,542	1.006	1.979
Regional Total	36,438	21.13	4,564,047	5,263,281	7.325	13.854
♦ WESTERN REGION						
14 - MAE KLONG BASIN	30,837	13.61	2,387,843	2,648,129	4.823	9.488
19 - PHETCHABURI BASIN	5,603	0.88	474,167	519,126	1.285	2.528
20 - PRACHUAPKHIRI KHAN COAST	6,745	2.11	475,750	526,565	0.935	1.839
Regional Total	43,185	16.61	3,337,760	3,693,820	7.043	13.855
♦ SOUTHERN REGION						
21 - PENINSULA-EAST COAST	26,352	26.59	4,101,088	4,768,866	4.898	9.635
22 - TAPI BASIN	12,225	15.43	989,395	1,161,880	0.215	0.423
23 - THALE SAP SONGKHLA BASIN	8,495	8.04	841,387	949,858	1.963	3.862
24 - PATTANI BASIN	3,858	2.43	476,869	590,483	0.593	1.062
25 - PENINSULA-WEST COAST	21,172	23.37	2,101,762	2,602,509	0.476	0.852
Regional Total	72,102	75.86	8,510,501	10,073,596	8.145	15.834
Country Total	**512,066**	201.18	**64,028,258**	**72,019,855**	**87.009**	**168.850**

Source : Modified from Tangtham (1992b)

Table 2 : Irrigation Project ,Irrigated Area and Multipurpose Reserviors in 25 Main Basins of Thailand

Basin Code and Name	Drainage area (sq.km.)	Irrigated Area (in 1989) (rai)	Large and Medium Irrigation Projects		Multipurpose Reserviors		
			No.	Capacity (MCM)	No.	Capacity (MCM)	Electricity generated (Mega W./hr)
♦ NORTHERN REGION							
01 - SALAWIN BASIN	17,920	34,060	12.0	13.08	0	0	0
02 - KHONG 1 BASIN	9,920	191,150	23.0	76.36	0	0	0
03 - MAE KOK BASIN	7,895	196,000	6.0	?	0	0	0
04 - PING BASIN	33,898	1,453,200	50.0	357.75	1	13,462	1,414
05 - WANG BASIN	10,791	161,700	8.0	125.74	0	0	0
06 - YOM BASIN	23,616	383,552	20.0	32.62	0	0	0
07 - NAN BASIN	34,330	1,112,130	60.0	17.38	1	9,510	960
Regional Total	138,370	3,531,792	179.0	622.93	2	22,972	2,374
♦ NORTHEASTERN REGION							
02 - KHONG 2 BASIN	47,502	579,475	78.0	876.25	1	165	17
04 - CHI BASIN	49,477	996,183	68.0	2589.36	2	2,452	205
05 - MUN BASIN	69,701	892,905	102.0	1343.21	1	1,966	90
Regional Total	166,680	2,468,568	248.0	3808.82	4	4,583	312
♦ CENTRAL REGION							
10 - CHAO PHRAYA BASIN	20,125	5,925,003	34.0	25.84	0	0	0
11 - SAKAE KRANG BASIN	5,192	243,500	5.0	160.00	0	0	0
12 - PASAK BASIN	16,292	202,550	12.0	45.12	0	0	0
13 - THA CHIN BASIN	13,682	2,276,046	16.0	251.08	0	0	0
Regional Total	55,291	8,647,099	67.0	482.04	0	0	0
♦ EASTERN REGION							
15 - PRACHINBURI BASIN	10,481	467,215	15.0	22.07	0	0	0
16 - BANG PAKONG BASIN	7,978	1,145,140	13.0	17.90	0	0	0
17 - TONLE SAP BASIN	4,150	5,500	5.0	6.50	0	0	0
18 - EAST COAST GULF BASIN	13,829	201,000	26.0	237.73	1	97	27
Regional Total	36,438	1,818,855	59.0	284.20	1	97	27
♦ WESTERN REGION							
14 - MAE KLONG BASIN	30,837	1,145,000	17.00	7.78	3	26,660	2,268
19 - PHETCHABURI BASIN	5,603	342,330	8.00	4.39	1	710	81
20 - PRACHUAPKHIRI KHAN COAST	6,745	246,855	14.00	516.79	0	0	0
Regional Total	43,185	1,734,685	40.00	1238.96	4	27,370	2,349
♦ SOUTHERN REGION							
21 - PENINSULA-EAST COAST	26,352	1,051,500	27.00	2.00	0	0	0
22 - TAPI BASIN	12,225	37,215	16.00	25.18	1	5,640	554
23 - THALE SAP SONGKHLA BASIN	8,495	467,800	17.00	26.42	0	0	0
24 - PATTANI BASIN	3,858	154,403	3.00	-	1	1,404	200
25 - PENINSULA-WEST COAST	21,172	96,000	14.00	19.00	0	0	0
Regional Total	72,102	1,806,918	77.00	72.60	2	7,044	754
Country Total	512,066	20,007,917	670.00	6509.55	13	62,066	5,816

Source : Modified from Tangtham (1992b)

Table 3 : Prediction equations derived for identifying watershed classes in various basins and regions of Thailand

Region and Basin Name	Prediction Equation
NORTHERN :	
Ping - Wang - Yom - Nan [1] :	WSC = 1.929 + 0.048 SLOPE - 0.0036 ELEV + 0.1067 LFORM + 0.1159 GEOL + 0.1925 SOIL + (FOR)
Kok - Ing - Moei :	WSC = 1.93 - 0.048 SLOPE - 0.044 ELEV + 0.107 LFORM + 0.116 GEOL + 0.193 SOIL + (FOR + MIN.)
NORTHEASTERN:	
Mun - Chi[1] :	WSC = 1.071 - 0.019 SLOPE + 0.001 ELEV + 0.190 LFORM + 0.049 GEOL - 0.013 SOIL (if ELEV. > 500 m.MSL , WSC = 1)
Songkhram - Loei[2] :	WSC = 1.071 - 0.019 SLOPE + 0.001 ELEV + 0.190 LFORM + 0.049 GEOL - 0.013 SOIL + (FOR + MIN.)
SOUTHERN [2] :	
All basins :	WSC = 2.341 - 0.026 SLOPE - 0.011 ELEV + 0.156 LFORM - 0.088 GEOL - 0.230 SOIL + (FOR + MIN)
EASTERN [1] :	
All basins :	WSC = -0.054 - 0.024 SLOPE + 0.024 ELEV + 0.209 LFORM -0.018 GEOL + 0.017 SOIL + (FOR)
CENTRAL - WESTERN [1] :	WSC = 2.416 - 0.023 SLOPE - 0.019 ELEV + 0.138 LFORM -0.214 GEOL - 0.132 SOIL + (FOR)

Sources : [1] Tangtham and Boonyawat (1988)

[2] Chunkao et al (1991)

Table 4 : Ranges of WSC values assigned for determining watershed class in each region

Region and Basin Name	Range of WSC values for class No.				
	1	2	3	4	5
NORTHERN :					
Ping - Wang - Yom - Nan [1] :	< 1.50	1.50-2.20	2.21-3.20	3.21-3.99	> 3.99
Kok - Ing - Moei [2] :	< 1.50	1.50-2.20	2.21-3.20	3.21-3.99	> 3.99
NORTHEASTERN :					
Mun - Chi [1]	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
Songkhram - Loei [2]	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
SOUTHERN [1] :					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
EASTERN [1] :					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
CENTRAL - WESTERN [1]					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75

Sources : [1] Tangtham and Boonyawat (1988)

[2] Chunkao et al (1991)

Table 5 : Drainage area , areal distribution of Watershed Classes , remaining forest area and annual runoff and suspended sediment in 25 main basins of Thailand

Basin Code and Name	Drainage area (sq.km.)	Watershed class distribution % 1A	1AR	1B	1BR	2	3	4	5	Remaining forest in 1988 (% of basin)	Estimated annual runoff and suspended sediment runoff (BCM)	sediment (Ton/sq.km.)
NORTHERN												
01 - SALAWIN BASIN	17,920	61.0		8.0		14.0	9.0	5.0	3.0	75.0	6.27	62
02 - KHONG 1 BASIN	9,920	18.2		4.6		13.0	13.6	12.2	38.4	37.0	5.95	77
03 - MAE KOK BASIN	7,895	36.0		4.0		16.0	12.4	11.6	20.0	38.0	4.84	116
04 - PING BASIN	33,898	36.5		2.0		14.5	9.5	9.0	28.5	49.0	6.14	62
05 - WANG BASIN	10,791	23.5		0.8		14.3	11.4	13.5	36.5	61.0	1.92	374
06 - YOM BASIN	23,616	18.0		1.0		13.0	11.0	10.0	47.0	33.0	3.54	66
07 - NAN BASIN	34,330	20.5		0.6		18.2	11.5	9.7	39.5	43.0	12.02	67
Region	138,370	30.2		2.5		15.0	10.8	9.5	31.9	47.6	40.96	-
NORTHEASTERN												
02 - KHONG 2 BASIN	47,502	8.5		2.6		4.8	6.5	22.8	54.8	20.0	16.63	42
04 - CHI BASIN	49,477	10.0		0.7		2.6	3.0	24.0	59.7	14.0	9.40	29
05 - MUN BASIN	69,701	2.0		0.5		0.9	2.0	20.0	74.6	10.0	11.15	27
Region	166,680	6.2		1.2		2.5	3.6	22.0	64.5	14.0	37.18	-
CENTRAL												
10 - CHAO PHRAYA BASIN	20,125	1.5		0.4		0.8	3.5	3.8	90.0	1.5	3.97	63
11 - SAKAE KRANG BASIN	5,192	9.0		0.1		7.0	3.8	4.0	76.1	28.0	0.98	
12 - PASAK BASIN	16,292	10.5		4.1		6.8	9.1	10.4	59.1	18.0	2.77	18
13 - THA CHIN BASIN	13,682	5.5		0.1		1.3	4.5	12.4	76.2	16.0	1.73	
Region	55,291	5.8		1.4		3.3	5.4	7.9	76.2	12.4	9.45	-
EASTERN												
15 - PRACHINBURI BASIN	10,481	8.7		0.4		4.1	7.6	14.4	64.8	22.0	6.28	65
16 - BANG PAKONG BASIN	7,978	5.6		0.3		2.1	3.6	24.3	64.1	19.5	2.26	117
17 - TONLE SAP BASIN	4,150	1.7		0.2		3.6	6.0	23.2	65.3	38.0	1.24	85
18 - EAST COAST GULF BASIN	13,829	6.5		0.2		8.2	12.1	36.4	36.6	12.5	11.34	59
Region	36,438	6.4		0.3		5.2	8.2	25.9	54.0	19.7	21.13	-
WESTERN												
14 - MAE KLONG BASIN	30,837	38.6		0.3		14.3	10.9	15.3	18.6	53.0	13.61	145
19 - PHETCHABURI BASIN	5,603	43.0		0.10		6.0	7.8	6.1	37.0	41.0	0.88	33
20 - PRACHUAPKHIRI KHAN COAST	6,745	8.5	0.17	0.47	0.18	2.6	13.7	17.2	57.2	43.0	2.11	312
Region	43,185	34.4	0.03	0.3	0.03	11.4	10.9	14.4	27.0	49.88	16.61	-
SOUTHERN												
21 - PENINSULA-EAST COAST	26,352	8.4	1.02	1.07	0.81	7.7	9.0	13.0	59.0	13.0	26.59	134
22 - TAPI BASIN	12,225	10.0	1.16	0.74	0.90	8.4	12.0	21.1	45.7	24.0	15.43	134
23 - THALE SAP SONGKHLA BASIN	8,495	10.1	2.35	1.08	1.27	8.9	5.5	29.2	41.6	9.0	8.04	48
24 - PATTANI BASIN	3,858	10.7	2.43	1.17	1.20	5.9	1.8	16.7	60.1	34.0	2.43	150
25 - PENINSULA-WEST COAST	21,172	23.3	2.16	0.84	0.90	21.1	12.6	12.4	26.7	45.0	23.37	179
Region	72,102	13.37	1.61	0.95	0.93	11.80	9.77	16.30	44.93	25.0	75.86	-
Country	**512,066**	**16.07**	**0.26**	**1.40**	**0.13**	**8.30**	**7.54**	**16.00**	**50.30**	**28.0**	**201.18**	-

Source : Modified from Tangtham (1992b)

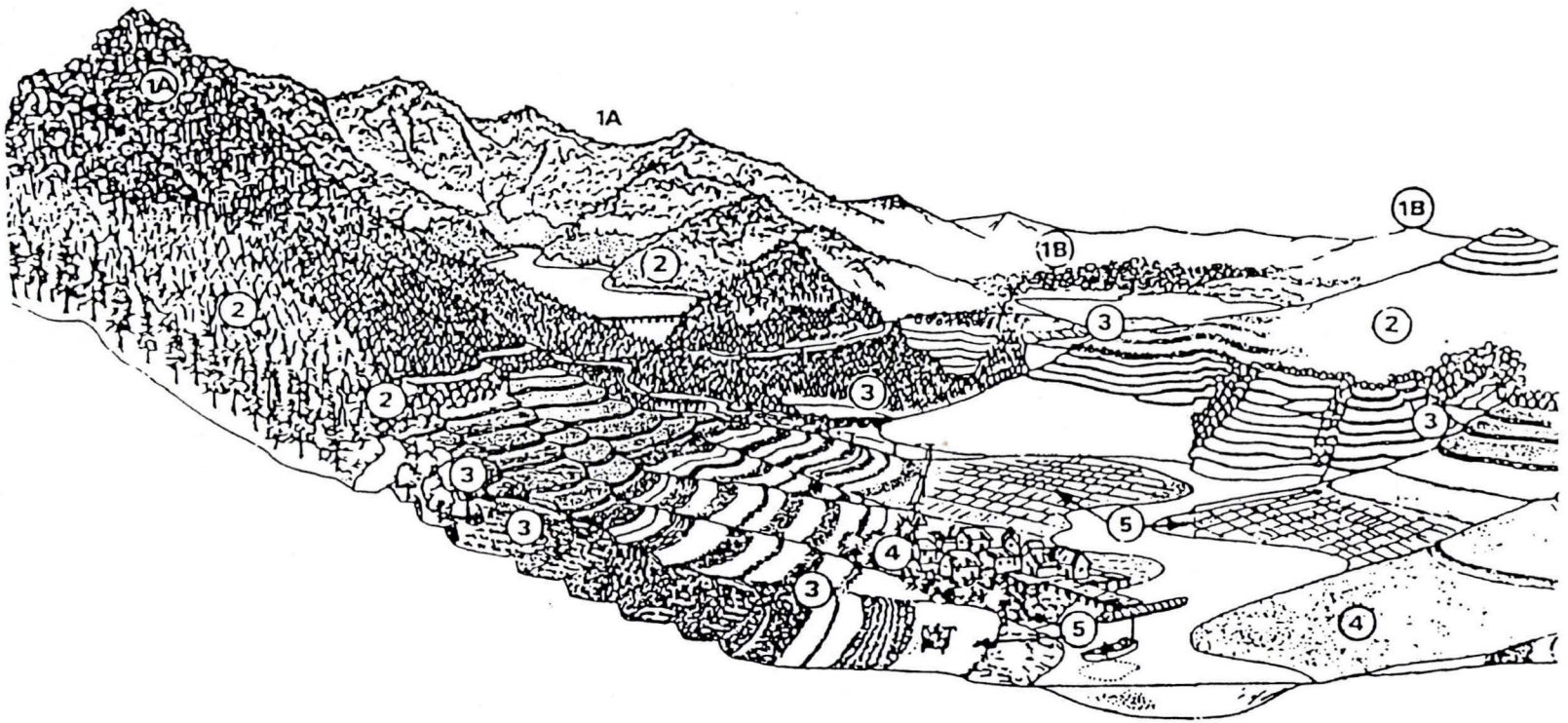
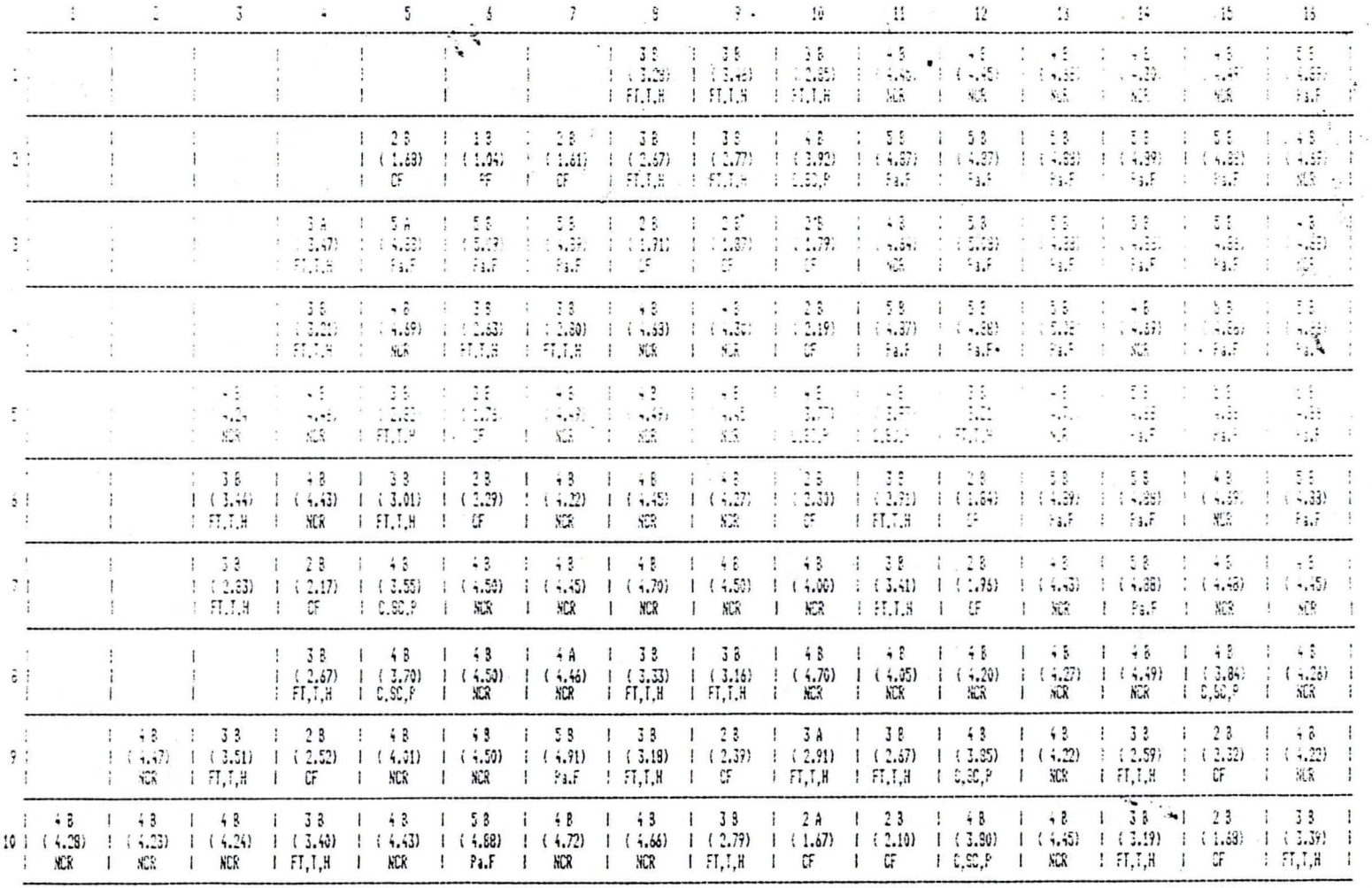


Figure 1 Pictorial guide to "Watershed Classification" and land use practices in Thailand : **WSC 1-A** :- areas of protection forest and headwater source, usually at higher elevation with very steep slope. **WSC1-B** :- are those areas of similar physical features and environment to WSC 1-A but portion of the area have been cleared for agricultural use or occupied by villages. These areas require special soil conservation measures and where possible should be replanted for forest or maintained in permanent agroforestry. **WSC 2** :- are areas designated as commercial forest, usually at high elevation with steep slopes. Landform are less erosive than WSC 1. **WSC 3** :- are area of upland with moderately steep slopes and less erosive landform. They may be used for commercial forest, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures. **WSC 4** :- are areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for a few soil conservation measures. **WSC 5** :- are gentle to flat areas used for paddy fields or other agricultural uses with few restrictions

Fig. 2. An example of computer map of watershed classes based on the derived equation and selected parameters in 1×1 sq.km grids.



TOTAL AREA= 133.00 Sq.km.: WSCH 1 AREA= 1.00 Sq.km. = 0.75 % WSCH 2 AREA= 18.00 Sq.km. = 13.53 % WSCH 3 AREA= 28.00 Sq.km. = 21.05 % WSCH 4 AREA= 59.00 Sq.km. = 44.36 % WSCH 5 AREA= 27.00 Sq.km. = 20.30 %

SOIL CONSERVATION REQUIRED: PF=Protection Forest; RF=Reserved Forest; CF=Commercial Forest; FT=Fruit Trees; T=Terracing; H=Hillside Ditch; C=Contour Cultivation; SC=Strip Cropping; P=Pasture; NCR=No Conservation Required; Pa.F=Paddy Field

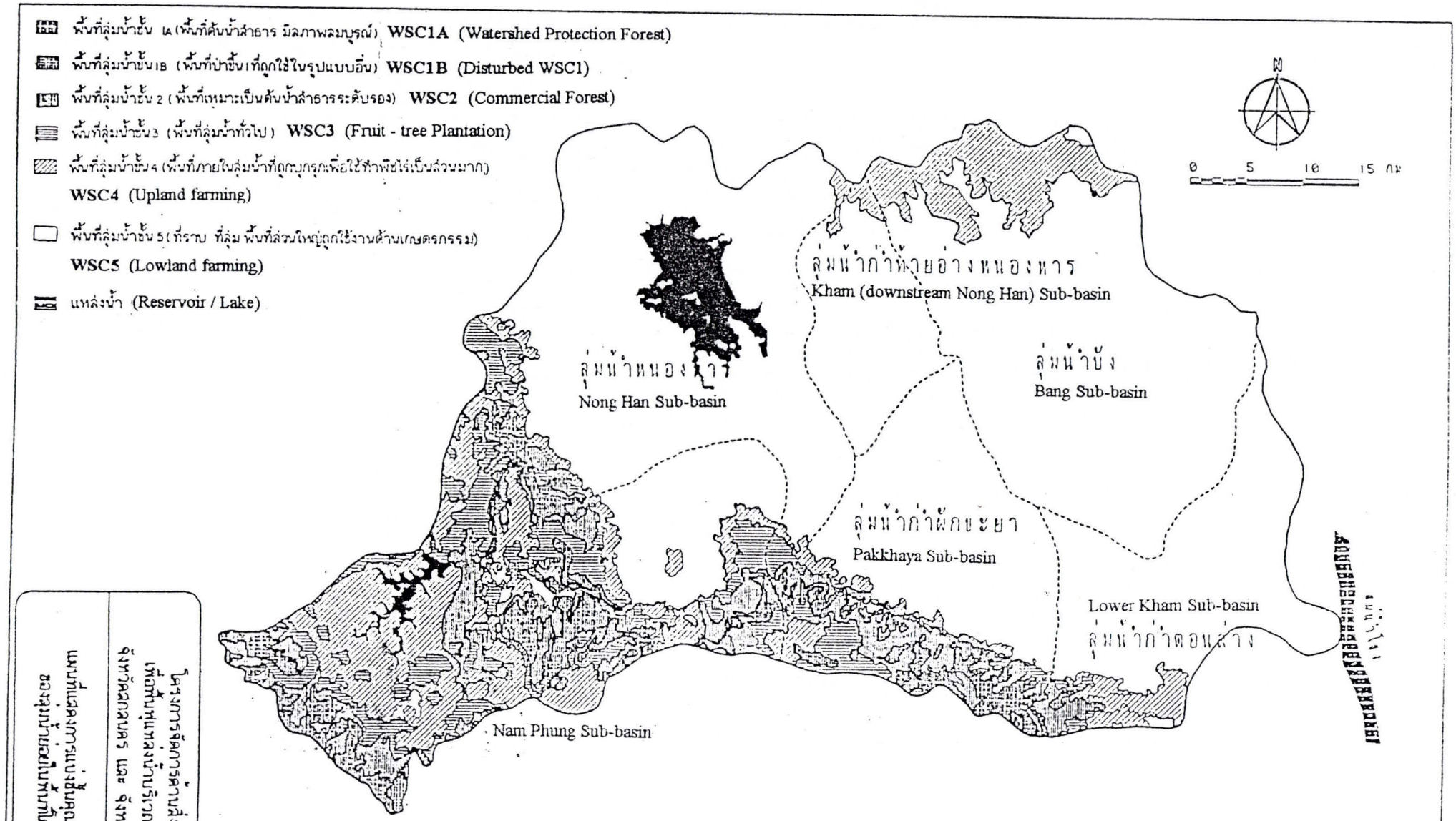


Fig. 3. An example of watershed classes map after final adjustment based on contour map and forest map.

THE KOK RIVER BASIN DEVELOPMENTS: PAST AND PRESENT

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Abstract
Located in the northern part of Thailand, the Kok River is a tributary of the Mekong River. Thirty percent of the Kok River Basin is irrigable, the rest is mountainous. The oldest development project in the Kok Basin went into operation in 1963. Since 1972, several independent groups have proposed a variety of "stand alone" development schemes. It was not until 1982 that such groups started to move in the direction of integrated proposals and transbasin development schemes. Interestingly enough, all of the development proposals for this basin tend to involve the diversion of water from the Kok Basin to other Thai basins where irrigation water shortages exist. However to date, none of the proposed diversion schemes have been implemented because substantial pressures have been put forth by both local and national pressure groups. This study seeks to review all the development proposals for the Kok River Basin.

1. Brief Background

1.1 Kok Basin

The Kok River, as shown in Figure 1, is located in the northern part of Thailand. The Kok River Basin extends from 19° to 21° northern latitude and from approximately 99° to 100° east longitude. This river originates in Myanmar at an elevation of about 1,600 m MSL and flows through the Myanmar highlands in a southward direction. After a course of 180 km, it reaches Thailand near Ban Tha Don, Chiang Mai. Here, the river changes its course and runs eastward. Then, as it enters the Chiang Rai Valley, it follows a north-east course until it flows into the Mekong River about 10 km downstream from the Chiang Saen District. The total length of the Kok River is about 360 km. The catchment area for the Kok River is approximately 1,087,500 hectares (ha). About 340,000 ha of its watershed is in Myanmar and the remaining 747,500 ha is in Thailand.

Within Thailand, the only large tributaries of the Kok River are the Fang River (Drainage area = 194,500 ha) and the Mae Lao River (Drainage area = 320,000 ha). These two rivers flow from the south and join the Kok River in the Mae Ai District and the Muang (Chiang Rai) District, respectively.

1.2 Ing Basin

The Ing River Basin has a catchment area of 711,900 ha and lies to the south of the Kok River Basin. The Ing River originates in the border area between the provinces of Chiang Rai and Phayao. The Ing River flows southward to Phayao and then northeast until it flows into the Mekong River as shown in Figure 1. The flood plains for the Mae Lao and the Ing Rivers tend to overlap. Hence it is difficult to assess the water distribution between these two flood plains.

2. Climate and Hydrology

The Kok Basin is situated within the monsoon region of South East Asia. Three separate seasons can be distinguished as a result of the air mass movements: a hot season from mid-February until mid-May, a rainy season from mid-May until mid-October, and a cold season during the remaining four months. About 90% of the total annual rainfall falls between the months of May and October. Most of the Kok Basin receives an average annual rainfall of

1,000-2,000 millimeters (mm). The largest city in the Kok Basin is the city of Chiang Rai. At the Chiang Rai Station, the number of days with rainfall each month increases from 17.1 in May to 23.9 in August. The average annual precipitation is 1,733 mm. The average annual pan evaporation is 1,382 mm. January is the coldest month. A record low of +1.5°C was recorded in Chiang Rai on January 14, 1955. The annual average temperature is 24.0°C, the low 18.6°C, and the high 30.7°C.

The Kok Basin has 35 streamflow stations. The average specific yields noted at these stations range from 5 to 44 l/sec/sq.km. The recorded annual runoffs for the Upper Kok (the portion of the Kok River which is located in Myanmar), the Fang, the Mae Lao and the Kok Rivers are 2,105, 1,060, 930 and 1,381 MCM, respectively. The estimated annual discharge of the Kok River is 5,280 MCM. The total annual water demand for the whole basin in 1993 was 404 MCM (Saowapon, et al 1994). Translated, this demand could be met by using only 7.6% of the available surface water. The return flow from the large and medium scale irrigation projects to the natural streams is estimated to be 80 MCM. Therefore, it seems reasonable to conclude that the Kok River discharges, on average, about 4,956 MCM of water into the Mekong River annually.

3. General concerns in the Kok and Ing Basins

The main surface water concerns for the Kok and Ing Basins are water shortages in the dry season and flooding during the rainy season. The Ing Watershed has the most severe dry season water shortage problems. The Mae Lao Irrigation Project (MLIP), operational since 1963, which diverts water from the Kok Basin to the Ing Basin helps to some extent. However, it is not considered a "diversion scheme" in the real sense of these words because the flood plains of these two basins overlap considerably. Several diversion project proposals are under consideration to divert additional water from the Kok Basin to the Ing Basin. Proposals which are discussed to a greater extent in Section 5.

Flooding is a wet season concern in the both the Kok and the Ing Basins. The effects of flooding during the last two wet seasons (1994 and 1995) caused heavy financial loses in all sectors. The Chiang Rai and Phayao Provinces each incurred debts totaling in the neighborhood of one billion Baht. The areas which experienced the most flooding were the lowlands of the Mae Lao, the Ing and the Kok Rivers. The situation was compounded in the Kok Basin because the terrain is predominantly mountainous and there are no large reservoirs. During a wet year water in the Mae Lao River, a tributary of the Kok River, rises above its banks and floods several parts of the Chiang Rai Province including the city of Chiang Rai. In the Ing Basin, there is a large reservoir at Phayao, namely Kwan Phayao (Phayao Lake), that could be used to reduce the effects of flooding. However, this reservoir is currently operated by the Fisheries Department whose main concern is the fish stock. To date, this reservoir has not been regulated to reduce wet season flooding below the reservoir so flooding remains an annual concern.

4. Existing Water Resource Development Projects

More than 240 projects covering an irrigation area of 91,250 ha have been developed in the Kok Basin. To date, 72% of the irrigable land in this basin is irrigated. Table 1 gives the break down of these projects by size. Small scale irrigation projects cover approximately 50% of the irrigable area. The large scale and medium scale irrigation projects are weir type projects. Presently, there are no large reservoirs in the Kok River Basin and thus no means of eliminating or controlling the existing water shortages or flooding problems. There are two large scale irrigation projects, two medium scale irrigation projects and three small hydropower projects in operation in the Kok Basin. The locations of these projects are as noted in Figure 2, a more detailed description follows.

4.1 Mae Lao Irrigation Project

The Mae Lao Irrigation Project (MLIP) is a large scale irrigation project run by the Royal Irrigation Department (RID). This project is the oldest project in the Kok Basin and has been operational since 1963. The main structure in the MLIP is a diversion weir on the Mae Lao River about 12 km downstream from the Mae Suai District, Chiang Rai. The weir is 2.5 m high and has a 30.5 m long crest. The command area for this project covers an area of 26,560 ha for the wet season and 7,170 ha for the dry season.

4.2 Chiang Rai Weir

The Chiang Rai weir is a Department of Energy Development and Promotion (DEDP) project. The principle component of this project is a regulator weir on the Kok River, at Ban Pa Yang Mon, about 10 km downstream from the city of Chiang Rai. The weir is located immediately upstream from the confluence of the Mae Lao and Mae Kok Rivers. The weir is 4.0 m high with 11x8.00 meter radial steel gates. The main weir was completed in 1994 and the irrigation canals are currently under construction. When finished, the command area for this project will be 11,312 ha for the wet season and 5,656 ha for the dry season.

4.3 Mae Sao Irrigation Project

The Mae Sao River is a tributary of the Fang River. The Mae Sao Irrigation Project is located in the Fang Sub-basin. The principle component of this project is a regulator weir on the Mae Sao River located at Mae Ai District, Chiang Mai. The weir is 8.5 m high and has a 23 m long crest. The command area for this project is 2,400 ha during the wet season and 1,600 ha during the dry season. This project has been operational since 1981.

4.4 Chai Sombat Weir

The Chai Sombat Weir is located in the Lower Mae Lao Sub-basin. This project supplies irrigation water to an area of 5,600 ha during the wet season and 1,600 ha during the dry season. This project provides irrigation water for Muang Chiang Rai District and Wiang Chai District. The principle component of this project is a regulator weir on the Mae Lao River, located near Tha Sai Sub-district, Muang Chiang Rai District. The weir is 2.7 m high and has a 50 m long crest.

4.5 Small Hydropower Projects

There are three small hydropower projects within the project area. All are located within in the Fang Sub-basin. Two of the three, the Mae Khum Luang and the Mae Mao Projects, were built and are operated by the DEDP. The installed capacity of these two projects are 3,200 kW and 4,600 kW, respectively. The third, the Mae Chai project, is operated by the Provincial Electricity Authority. The installed capacity of this project is 875 kW. The locations of these projects are as noted in Figure 2.

5. Proposed Development Plans

Todate, the development of Thailand's water resources has been undertaken by several government agencies. Unfortunately, the lack of coordination between these groups has left them and their proposals open to criticism. Further, in the past, the full potential of the known water resources in any particular river basin had not been evaluated and development plans had been proposed without such knowledge. In fact, several projects have gone ahead which do not utilize the full potential of the resources they draw on. During the 1989-1993 period, dry season water shortages in several parts of the country forced the Thai government to reconsider the nations stategy for water resource development. In 1992, the Office of the National Economic and Social Development Board initiated its long delayed *"Study of*

Potential Development of Water Resources in the 25 River Basins". The full potential, of the known water resources in the Kok Basin, was evaluated by Saowapon, et al. in 1994.

The discussion which follows highlights some of the many proposed projects, their benefits and their short comings. It is important to remember that todate none of these proposals have been implemented.

5.1 The Mae Lao Scheme

The strategy behind the Mae Lao Scheme is basically to increase dry season irrigation supply in the MLIP area. The MLIP was developed to ensure a sufficient water supply for the wet season rice crop. During the dry season the project provides a relatively small amount of water for irrigation purposes. Saowapon, et al (1994) estimated that this project could supply irrigation water to an area of 25,600 ha during the wet season and 6,910 ha during the dry season. The command areas noted above involve two watersheds: the Mae Lao Sub-basin and the Upper Ing Sub-basin since these watersheds overlap.

In 1972, Electro-Watt/Motor-Columbus (EWMC, 1972) proposed the Mae Lao Scheme which would further enhance the MLIP by increasing the irrigated areas in the Mae Lao and the Upper Ing Basins. Figure 3 summarizes the EWMC scheme. Their proposal suggests that water be conveyed from the Mae Lao River through a 130 km long canal with a 35 m^3/sec capacity at its weir site. The gross area commanded by this new canal would amount to 28,750 ha. This canal would be feasible only if built in conjunction with several new reservoirs, namely, the Mae Pun Luang and Mae Suai reservoirs. The storage capacities for these reservoirs would be 130 MCM and 52 MCM, respectively. In summary, the EWMC proposal would increase the water supply in the MLIP area during the dry season to the currently obtainable wet season irrigation levels.

Further, EWMC proposed the development of two additional reservoirs in the Ing Basin. The Mae Tam reservoir with a storage capacity of 28 MCM and the Mae Pum reservoir with a storage capacity of 24 MCM. These reservoirs would be capable of irrigating 8,000 ha and 5,370 ha, respectively, and would improve the water shortage problems in the Ing Basin.

The Phayao Lake proposal could be considered an extension of the Mae Lao Scheme. The Phayao Lake proposal suggests that Phayao Lake be used as a compensatory reservoir. The proposed structures were the Mae Pun Luang Dam and a feeder canal which would transport water from the Mae Lao River into the Ing River and eventually Phayao Lake. The commanded area south-east of Phayao amounts to 9,600 ha.

If the entire EWMC scheme went ahead approximately 70,000 ha could be irrigated in the wet season and 62,000 ha in the dry season. To date, however, the EWMC proposal has not been implemented. The Mae Tam and the Mae Pum reservoirs with storage capacities of 33.5 MCM and 43.0 MCM, respectively were built by the Royal Irrigation Department (RID), but not as proposed by EWMC. Currently, the Mae Tam reservoir irrigates 6,400 ha during the wet season and 1,600 ha during the dry season while the Mae Pum reservoir irrigates 7,300 ha during the wet season and 4,000 ha during the dry season.

5.2 Fang Sub-Basin Development Plan

The irrigable area in the Fang Sub-basin includes 34,530 ha. This represents 17% of the total area of the basin. About 87% of this irrigable area has been developed. Salzgitter (1973) proposed a development plan for the Upper Fang, the Mae Na Wang, the Mae Mao, the Huai Khrai, and the Mao Sao rivers. The locations of the projects for these rivers are as illustrated in Figure 4. To date, only the Mae Sao and the Mae Mao rivers had been developed.

5.2.1 Upper Fang Project

The Upper Fang Project would included the construction of an earth dam, 57 m high, with a 592 m MSL crest elevation, on the upper part of the Fang River. This project would create a

50 MCM reservoir capable of generating about 1,200 kW of power. The irrigation area for this project was not well defined. Saowapon et al. (1994), using the HEC 3 program, estimated that this project could supply irrigation water to an area of 2,900 ha during the wet season and 1,190 ha during the dry season. The dam could also serve as a raw water supply source for domestic consumption in the Chai Prakarn district. One draw back is that the dam would require the Chiang Mai-Fang highway to be relocated about 2.5 km from its current location. This would necessitate the construction of 8 km of new road, part of which would be located in the Chiang Dao National Reserve Forest. Therefore, at this time, the project is not considered environmentally feasible.

5.2.2 Huai Krai Project

The Huai Krai River joins the Fang River 4 km downstream of Ban Sop Kra. This project consists of a dam 20m high with a crest length of 500 m. The project would create a 48.5 MCM reservoir. Saowapon et al. (1994) estimated that this project could supply irrigation water to an area of 4,480 ha during the wet season and 1,610 ha during the dry season. However, the construction of this project would require relocating about 8 km of the Fang-Wiang Pa Pao road. This would necessitate the construction of 15 km of new road at a location which is currently not considered appropriate environmentally.

5.2.3 Nam Mae Na Wang

Salzgitter (1973) proposed an earth dam type project at Ban Pa Deang, about 15 km east of Fang. Such a dam would have a crest height of 27.5 m at an elevation of 528 m MSL. The storage volume at the normal elevation would be 36.2 MCM. This project would supply irrigation water to an area of 2,880 ha. The installed capacity for such a project would be about 680 kW with an annual electricity output of 1.95×10^6 units. A 1.52 MCM reservoir, with an irrigation area of 640 ha, was built by RID in 1993 about 5 km upstream of this proposed project. The Pa Deang Weir was built at the proposed dam site and is only able to irrigate an area of 110 ha.

The city of Fang is a rapidly growing urban area. From the Saowapon et al. (1994) study, the domestic water supply for Fang will become a major concern in Fang in the near future. This project would be located just 15 km east of Fang. Hence, Saowapon et al. (1994) recommended that project originally proposed by Salzgitter be built. Saowapon et al. (1994) estimated such a project would be able to supply irrigation water to an area of 2,080 ha during the wet season and 845 ha during the dry season. If the current irrigation area is kept at its present level (110 ha), the extra water could be transported to the Provincial Water Authority water treatment plant in Fang.

5.3 Mae Kok Project

Salzgitter (1975) proposed a concrete gravity wall in combination with a rockfilled dam at Ban Pong Na Kham, about 10 km upstream of the city of Chiang Rai. The location of this project and its command area are illustrated in Figure 5. The dam would consist of two main structures. First, a right abutment that consists of a concrete gravity wall with a crest length of 165 m. Second, adjacent to the wall, a rockfilled dam with a 295 m crest length which would extend up to a left abutment at an elevation of 427.5 m MSL. The elevation of the top of the dam structure would be 29.70 m above the river bottom. The proposed total storage and active storage capacities would be 150 MCM and 95 MCM, respectively. At its maximum elevation, 425.0 m MSL, the reservoir surface would be 11.5 km^2 in surface area. The back-water influence at this storage elevation would not affect the Fang Basin, which is located appoximately 40 km upstream of the dam site. The command area of this project would extend north and south of Chiang Rai as seen in Figure 5. This project would have the capacity to supply irrigation water to an area of 18,650 ha (116,560 rai) in the wet season and 14,950 ha (93,440 rai) in the dry season. The installed capacity of such a project would be

about 16 MW with an annual electricity output of 63 Gwh of which 14.7 Gwh would be considered firm energy.

At present, most of the command area discussed above receives irrigation water as a result of the Chiang Rai Weir project and pumping irrigation projects. Only 4,290 ha is as yet unirrigated. Considering the enviromental impact of this proposal, the recommendation is that the project should be abandoned.

5.4 Kok-Ing-Yom Project

This project was to initiated to examine a proposal to divert a small part of the flood season flow in the Mekong River, via the Kok and Ing Rivers, to the Yom and Nan Rivers. Howard Humphreys and Hunting Technical Services (1982) initially proposed the diversion scheme (refer to Figure 6). An earthfilled dam was to be constructed on the Kok River at Pong Na Kham Village, 10 km upstream of the city of Chiang Rai. The proposed storage capacity was 480 MCM. The dams installed capacity would be 40 MW with an annual electricity output of 194 units.

Water was to be diverted through a 105 km long earth canal downstream of the dam site. Water would flow by gravity from the Kok River to the Ing and Yom River Basins and then flow through the proposed Thoeng-Pong canal to the Nan River Basin. The final 8 km of the new canal would be located in hilly terrain along the catchment divide and this canal would terminate at the head pond of the Pong dam. In addition, a 35 km long canal, extending from the main dam on the Kok River, would have to be constructed to supply additional water to the MLIP.

The Kok-Pong canal could provide irrigation water to the Kok River as well as to the MLIP. An area of 45,190 ha would benefit in both the wet and dry seasons. The annual volume of water diverted from the Kok River would be 468 MCM and the annual volume of water diverted to the Yom Basin was 2,119 MCM.

To complete the above proposal, the controversial Kaeng Sua Tem Dam with a storage capacity 4,700 MCM would have to be built on the Yom River. Water from the Yom River could then be diverted downstream of the Kaeng Sua Tem Dam into the Sirikit Dam on the Nan River through a 42.5 km concrete-lined canal and a 32.6 km tunnel. It was the construction of the Kaeng Sua Tem Dam that came under strong attack from several pressure groups and in the end saw the Electricity Generating Authority of Thailand (EGAT) abandon the entire Kok-Ing-Yom Project.

5.5 Kok-Ing-Nan Project

During the 1989-1993 period, dry season water shortages in the Chao Phraya River Basin forced the Thai government to reconsider the Kok-Ing-Yom Project. At this time the RID had taken the responsibility over from EGAT. The new schemes which were discussed tended to avoid the diversion of water through the Yom Basin because the Yom Basin did not have a large storage reservoir. Water was instead to be diverted from the Kok Basin directly into the Nan Basin where the Sirikit Dam already existed.

SANYU (1992) proposed the construction of a concrete weir on the Kok River 10 km downstream from the city of Chiang Rai. Water would be diverted through the 50 km long Kok-Ing feeder canal at a rate of $120m^3$/sec to the Ing River to the Nan River. This proposal would include a combination of open canals, siphons, culverts and tunnels as illustrated in Figure 7. The diverted water would be stored in the Sirikit Reservoir and then used to supply the Chao Phraya River Basin.

Preliminary studies for the Kok-Ing-Nan Project have been accepted and a more detailed feasibility study is now in progress.

6. Conclusion

The Kok Basin is a river basin which to date has no regulating reservoirs. Since the watershed area is predominantly mountainous, fast flooding is the major concern during the wet season. The Ing Basin, the Kok Basin's southern neighbor, faces water shortage problems during its dry season. Currently, the MLIP diverts a small amount of water from the Kok Basin to the Ing Basin. This study shows that several reservoirs could be built on the tributaries of the Mae Lao River. Reservoirs which could be utilized to assist the irrigation needs in the Ing Basin.

Summarizing Section 5 one notes that most all of the proposed development plans for the Kok Basin involve the diversion of water from the Kok Basin to neighboring basins. The results of the water balance conducted for the year 1993 concluded that basically all of the existing water demands in the Kok River Basin can be satisfied without a significant water shortage. Further, it is reasonable to conclude that there is in fact a water surplus situation in the Kok Basin and this fact allows consideration to be given to diversion projects.

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Table 1 Existing Projects

Project Type	Number of Projects	Irrigation Area (ha)	Installed Capacity
large scale irrigation	2	37,870	-
medium scale irrigation	2	4,000	-
small scale irrigation	227	45,360	-
pumping irrigation	14	3,270	-
small hydropower	3	-	8,675
Total	248	90,500	8,675

Table 2 The irrigated areas in the Kok Basin (area in ha)

Sub-basin (1)	Catchment Area (2)	Irrigable Area (3)	Irrigated Area (4)	Unirrigated Area (3)-(4)	% Irrigated (4)/(3)
Fang	194,500	34,530	25,730	8,800	75
Mae Lao	320,000	52,300	41,170	11,130	79
Lower Kok	233,000	55,330	23,460	31,870	42
Total	747,500	142,160	90,360	51,800	64

Figure 1 Location Map of the Kok and Ing River Basins

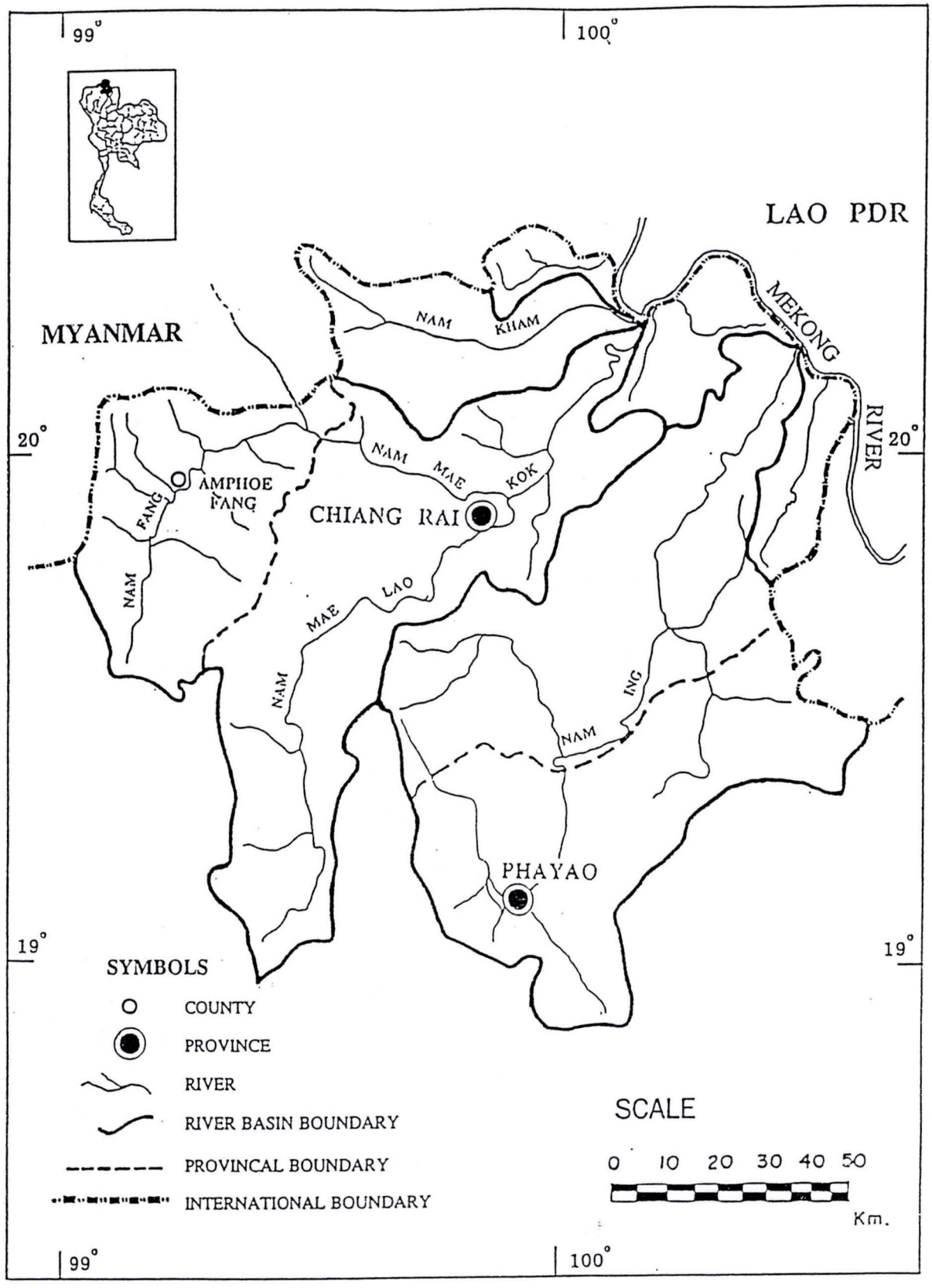


Figure 2 Large, Medium -Scale and Hydropower Projects in the Kok and Ing River Basins

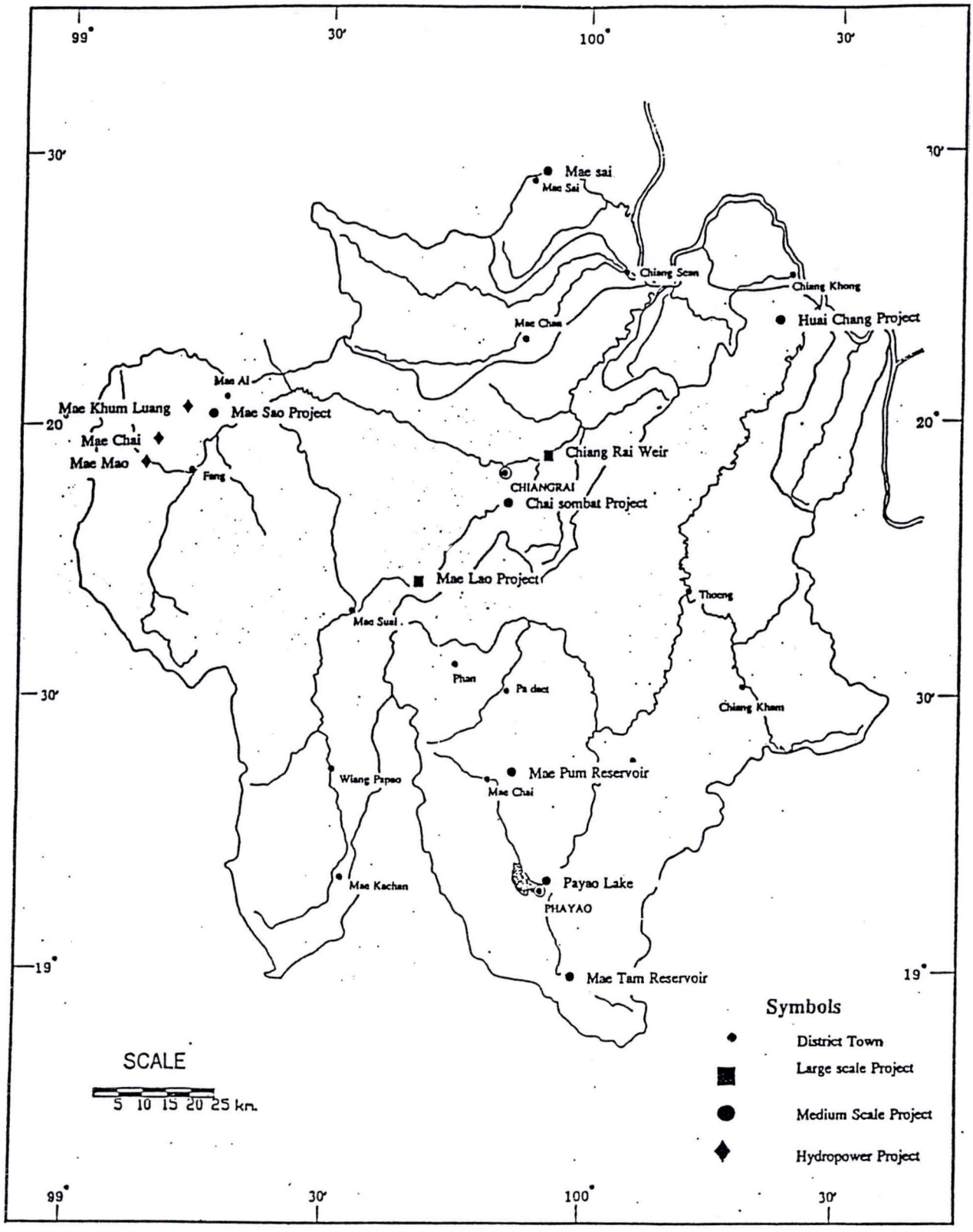
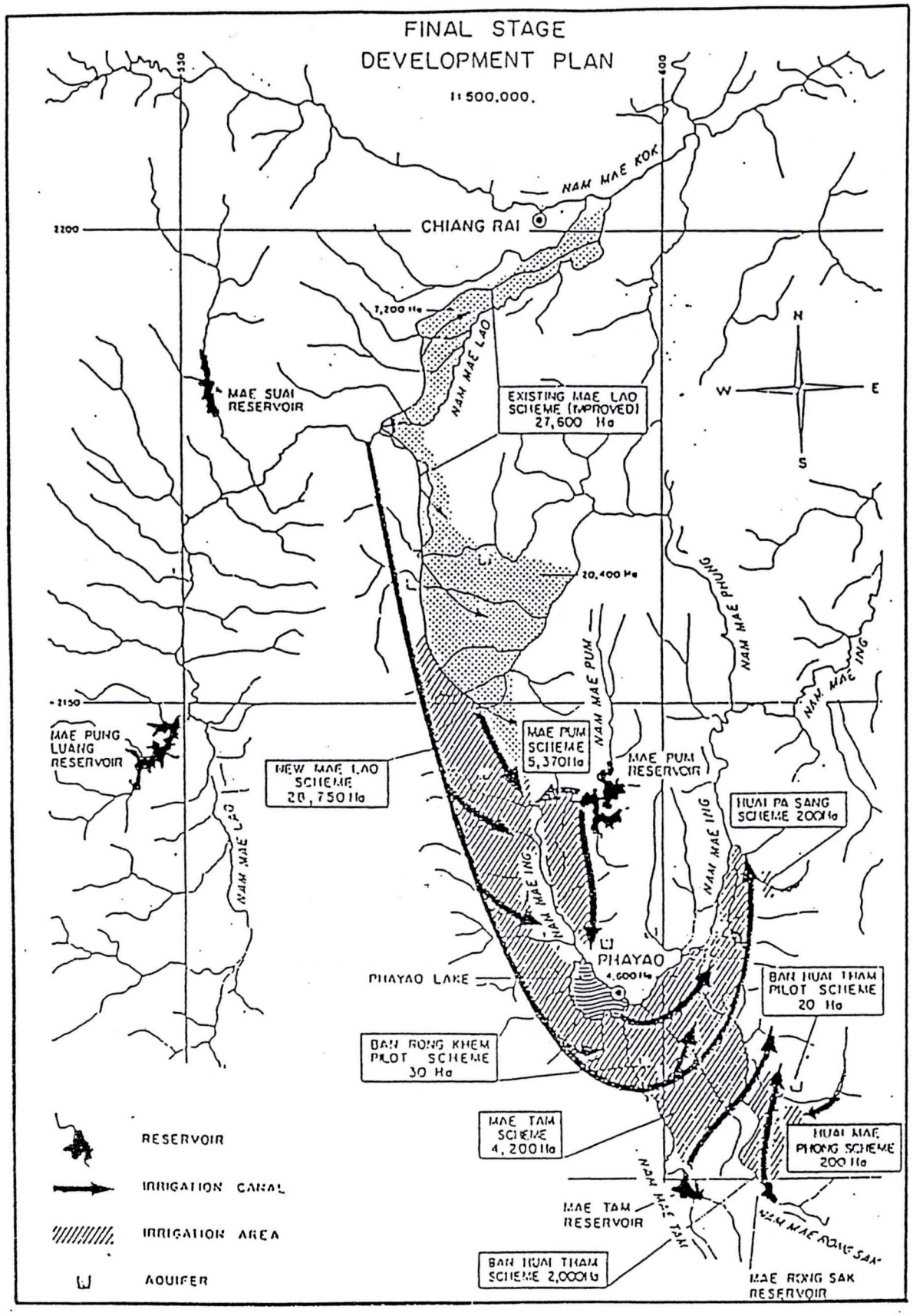
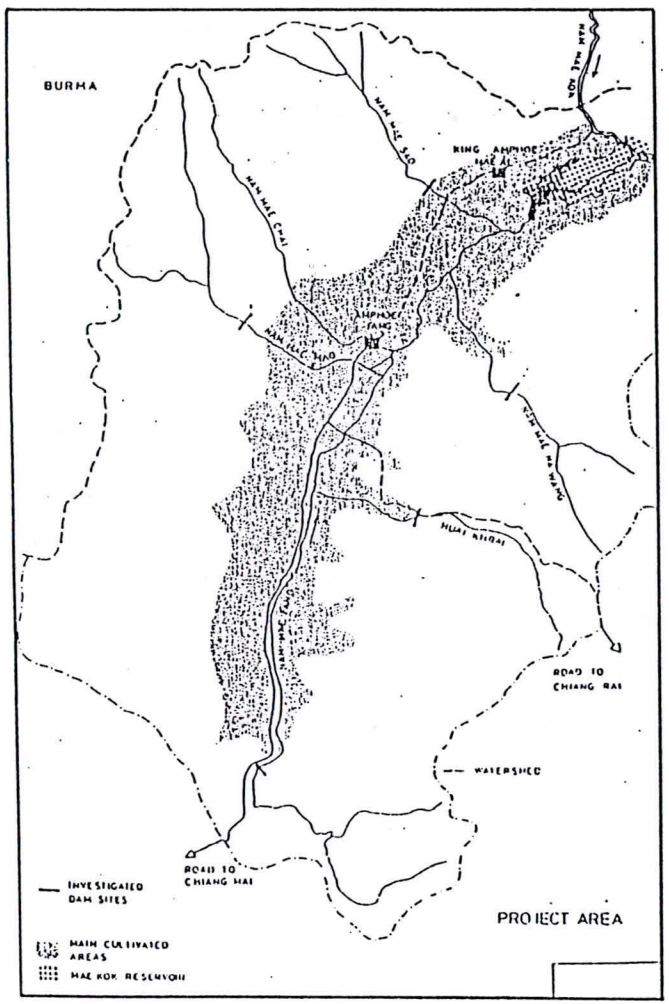


Figure 3 The Mae Lao Scheme



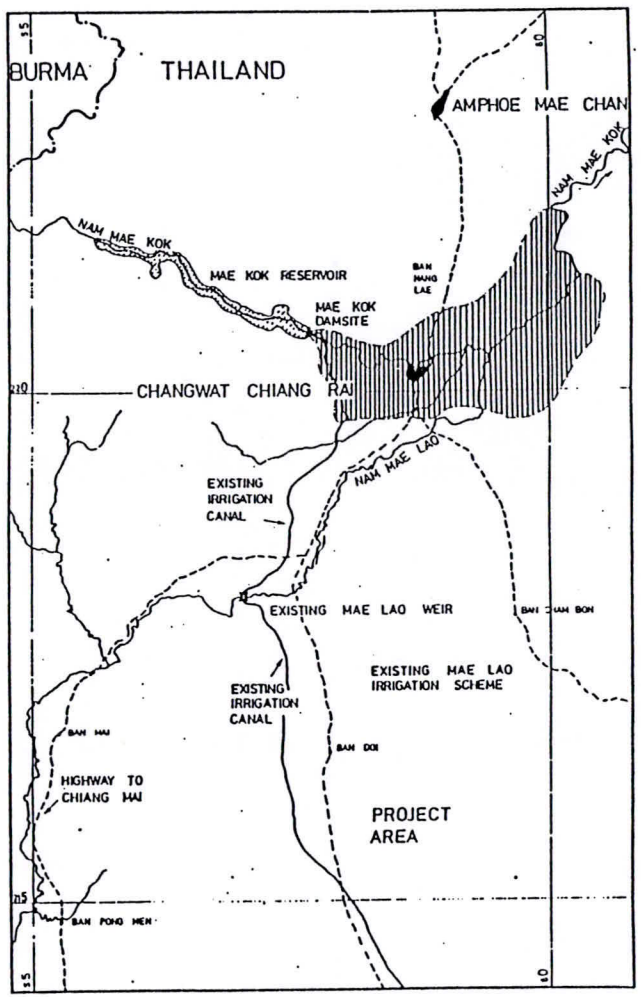
Source: Electro-Watt/Motor-Columbus (1972)

Figure 4 Development Plan for the Fang Sub-basin



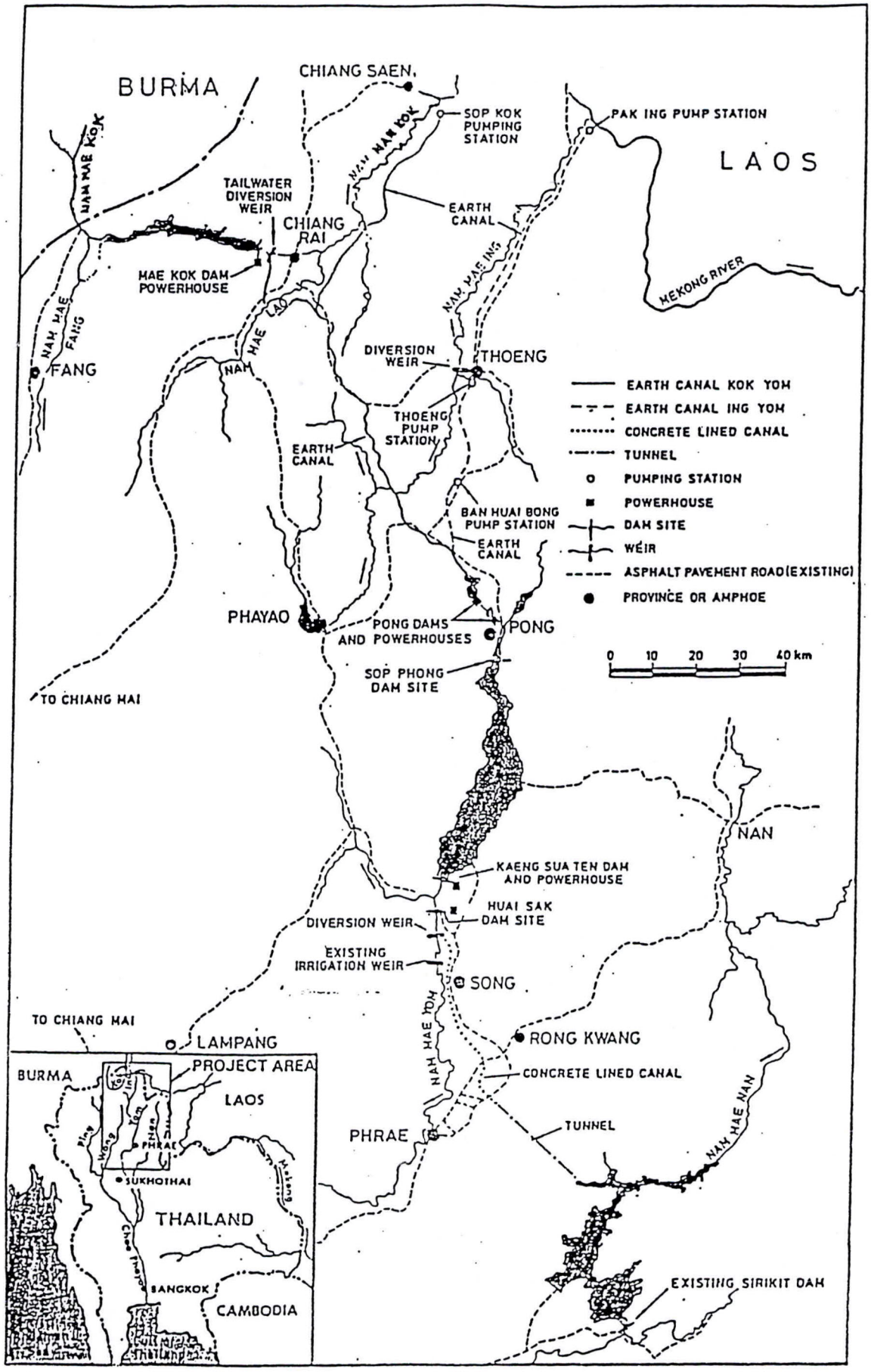
Source: Salzgitter GMbH (1973)

Figure 5 Mae Kok Project



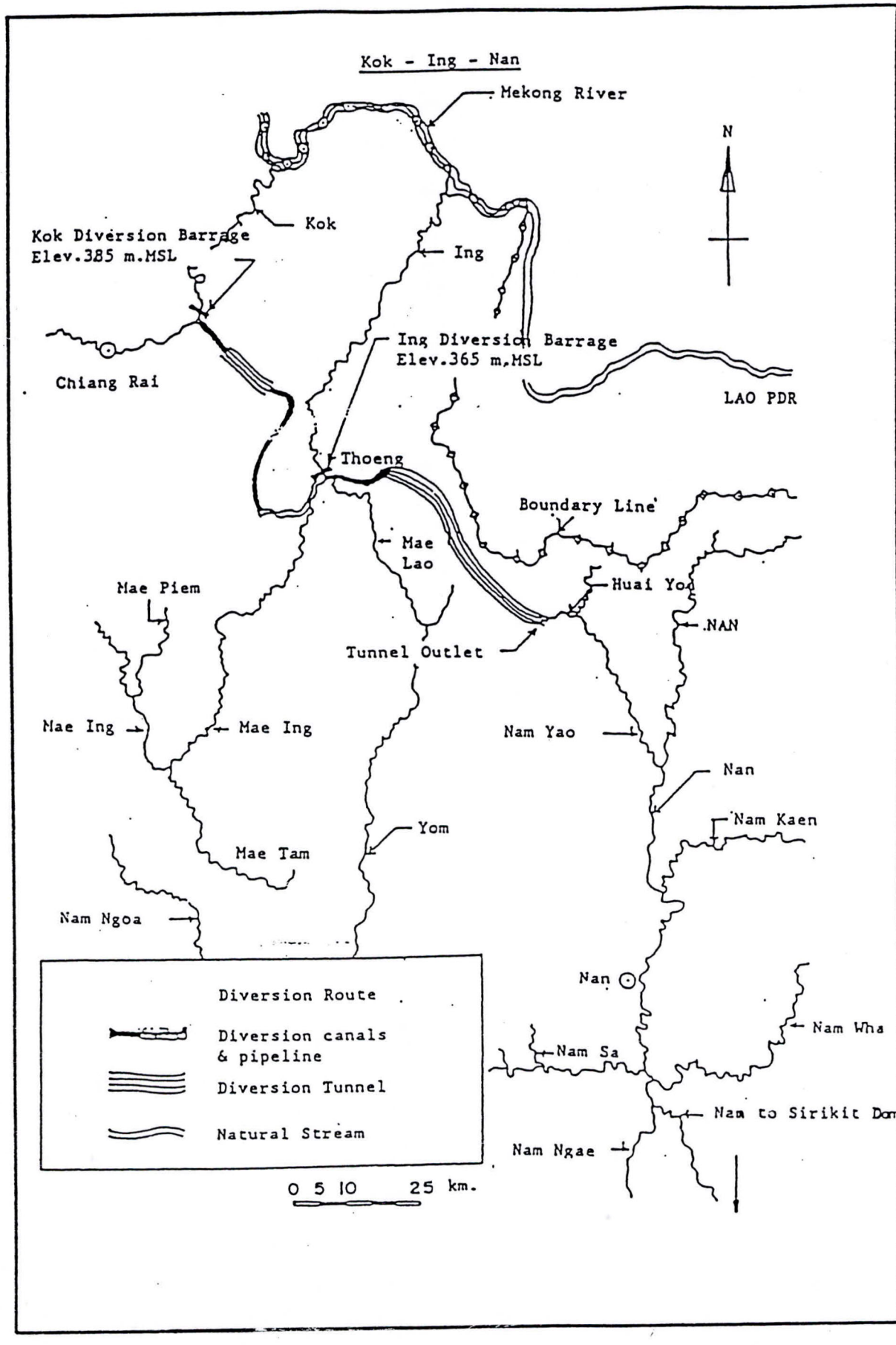
Source: Salzgitter (1975)

Figure 6 Kok-Ing -Yom Project



Source: Howard Humphreys & Partners (1982)

Figure 7 Kok-Ing -Nan Project



Source: SANYU (1992)

ANTHROPOLOGICAL METHODOLOGIES IN THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF SIX PROPOSED HYDROELECTRIC POWER PROJECTS OF THE NATIONAL POWER CORPORATION

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1. INTRODUCTION

The Anthropological Studies of the Proposed Hydroelectric Power Projects of the National Power Corporation in the Philippines is a research endeavor involving both the archeology and ethnography of six proposed hydroelectric power (HEP) project sites, namely: Addalam Small Hydropower Project (SHyp) in Cabarroguis and Aglipay, Quirino; Bakun SHyP in Alilem, Ilocos Sur; Agbulu HEP in Calanasan and Kabugao, Apayao; San Roque Multipurpose Project in San Manuel and San Nicolas, Pangasinan and Benguet Province; Aglubang SHyP in Calapan, Oriental Mindoro and Sablayan, Occidental Mindoro; and Timbaban HEP in Madalag, Aklan. The research covered the period June 1994 to January 1996.

The Studies were undertaken as part of an Environmental Impact Assessment (EIA) to determine the environmental effects of the proposed HEPs and to recommend measures needed to make it suitable to its environment. In particular, the EIA requires that an archeological survey and assessment be made to ascertain if the proposed Project Sites are historically and archeologically significant. If found to be so, safeguards to ensure that these cultural artifacts are properly retrieved and studied would be recommended. Furthermore, the EIA should include a detailed study on the host community and its environs and an assessment of the possible social, cultural, economic, and ecological impact of the proposed Projects HEPs on the community. The latter is crucial since the Project Sites are presently occupied by communities who trace their ancestry to the Ifugaos, Isnags, Kankanays, Mangyans, Pangsinanes, Ilocanos, and Aklanons.

2. ARCHEOLOGICAL STUDIES

Archeology is the study of past cultures. The evidences, artifacts, are man-made objects or human alterations of the environment. When recovered, preferably intact and in context, the artifacts can provide information about the people who used them, as well as the condition of their existence. Besides yielding data on the physical, biological, and social conditions of a given place, insights into certain aspects of human behavior useful for charting events in the present or in the future can also be generated.

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2.1 Rationale

Republic Act No. 4846, known as the Cultural Properties and Protection Act, enacted on June, 1966, and amended by Presidential Decree No. 374, signed on June, 1974, provides for the protection and preservation of the country's cultural resources. The Philippine Environment Policy, Presidential Decree No. 1151 enacted on June, 1977, requires the Environmental Impact Statement (EIS) for all environmentally critical areas and projects prior to the issuance of an Environmental Compliance Certificate (ECC). It further specifies the preservation of historical and cultural resources. In compliance with the EIS system, an Archeological Survey and Assessment is required to identify and preserve the cultural resources, an important part of the nation's resource base.

2.2 Objectives

The objectives of the archeological surveys and assessments are:

- to identify and map out the location of archeological sites and artifacts in the Project Areas;
- to assess the significance of areas identified as archeological sites; and
- to formulate a program for the retrieval and final disposition of archeological artifacts and sites, if any are found in the Project Areas.

2.3 Methodology

The methodological approach for the archeological surveys and assessments of the six proposed HEPs are the following:

- Study of the soil and topographic maps: both 1:50,000 for the accurate plotting of the sites and 1:250,000 for location reference. The study of the topographic maps leads to possible sites.
- Review of literature on historical references and all previous archeological work conducted on the areas to be affected by the hydrolectric projects: Direct Impact Areas (DIAs), the location of the Projects' structures and facilities; Secondary Impact Zones (SIZs), areas between the dam/weir and powerhouse sites; Regional Impact Zones (RIZs), municipalities which may be affected by the Projects.
- Conduct of scoping sessions to discuss the rationale and objectives of the archeological and ethnographic studies and to elicit information on observations which may be archeologically significant.
- Interviews with local residents to share and establish the significance of archeological artifacts and sites as well as to elicit data of historic and folkloric nature. Likewise, information about chance discoveries of artifacts and sites are sought from the communities.
- Field walking or actual inspection of the terrain. The Archeological Team explored on foot the areas which will be affected by the construction and operation of the six proposed HEPs.
- Inspection of previous excavations, eroded areas, river cut terraces, road cuts, and sand gullies.

- Showing of a collection of archeological materials to the communities as part of the "Cultural Property Awareness Program" so that the local populace can see and touch artifacts which may help in the development of a keen appreciation of their archeological resources. This also serves as a source of information in case similar finds may have been accidentally uncovered by informants in the course of their daily activities.

3. ETHNOGRAPHIC STUDIES

Anthropological research is the process of observing human behavior, including verbal behavior, in space and time. Anthropologists who specialize in the study of contemporary societies and cultures "produce" what is called an ethnography. An ethnography is a "written report summarizing the behaviors and the beliefs, understandings, attitudes, and values they imply, of a group of interacting people" (Berreman, 1968:337). In sum, an ethnography gives an overall view of the culture of the people about whom it is written. In practice, it cannot cover all aspects of a culture of a given society. At best, the ethnographer emphasizes the main features which contribute to the understanding of the culture under study.

The underlying assumption made in the following ethnographic exposition is that culture is an adaptive system. Marvin Harris, an exponent of the cultural ecology appraoch in Anthropology, draws from A. R. Radcliffe-Brown's work entitled *Structure and Function in Primitive Society* (1952) to elaborate on the cultural ecology formulation. Harris (1971) explains that there are three adaptive aspects of the total social system: (1) ecology, or the way the system is adapted to the physical environment; (2) the social structure, or "the arrangements by which social life is maintained"; and (3) the mental characteristics that fit people to their social structure and their ecology or ideology.

Using the above framework, the presentation of the ethnographic studies begins with an introductory section on the geographical and historical setting of the people to be studied These provide the background for the ethnic, linguistic, and cultural affinities with other groups in the area.

The first portion provides a brief description of the people as distinct indigenous cultural communities. Subsequent sections deal with details of their social organization including family, kinship, social stratification' the people's means of making a living given the conditions of their specific habitat including the tools and techniques of production and distribution; and political organization. Equally important is information on resource use and management, popualtion, and age and sex composition. These are among the relevant data needed for assessing the impact of development programs. Again, the relationship between the environment and the system of production and various social groupings is explored.

Lastly, the segment on religious organization shows the interconnected beliefs regulating man's relationship with his environment, with other men, and the supernatural. Anthropologists view these beliefs as working positively, for instance, in maintaining health, ecological balance, and harmonious relationships in social groupings.

3.1 Objectives

The objectives of the ethnographic studies are:

- o to establish/identify/document/summarize the existing socio-cultural conditions/characteristics of the people within the Study Areas;
- o to determine to what manner and to what extent the way of life life of communities may/will be affected by the Projects;
- o to determine the anticipated responses of affected individuals or the whole community to the entire Project or to certain Project components; and
- o to formulate a management/enhancement and monitoring plan.

3.2 Methodology

Various methods were employed by the UGAT Research Team to gather ethnographic data on the communities. The information would enable the Team to make a well-founded and sound assessment of the potential impact of the proposed HEPs on the communities.

The methodologies utilized in the production of a basic ethnography about the affected communities, including the indigenous cultural communities, as well as an assessment of the impact of the proposed HEPs on the culture are following:

- o conduct of scoping sessions and discussions of the Studies' objectives with the local government units (LGUs) and the Studies' population;
- o review of literature;
- o focused walk;
- o community mapping and profiling;
- o participant observation;
- o socio-economic survey;
- o focus group discussions (FGDs);
- o unstructured interviews;
- o in-depth key informant interviews with village leaders; and
- o community meetings or assembly of relevant groupings;

3.2.1 Scoping Session and Discussion of Studies' Objectives with Local Government Units (LGUs) and Studies' Population

Before the start of research activities in the communities, the UGAT Research Team organized ocular visits to the proposed Project Areas. The purpose of the trips was to explain to the local government officials and community leaders the objectives of the anthropological research. Formal scoping sessions with the local communities were likewise conducted. The Project Proponent explained the proposed Project (description, effects, and benefits). The UGAT Team, on the other hand, introduced themselves as anthropologists and members of the UGAT. They added that a government corporation, the National Power Coporation (NPC) had asked UGAT to consult with the community regarding the proposed HEPs to be built in their areas. The Team emphasized that the community's views on this matter was crucial because residents best understand their situation.

The Research Team introduced the Studies' objectives, then asked permission from the local leaders to consult with the communities. The process which followed was the recording of views and knowledge of the problems and potential solutions with reference to the proposed dams so these could be integrated prior to the implementation of the HEPs.

The barangay captains were also informed about the planned activities of the Archeological and Ethnographic Research Team: conduct of surveys in the proposed powerhouse and dam sites as well as the areas in between, by the Archeological Group, and key informant interviews, focus group discussions, and community mapping by the Ethnographic Team.

3.2.2 Review of Literature

Relevant ethnographies, published papers and articles on the indigenous cultural communities were reviewed to provide the Research Team with a comprehensive overview of the area, its people, and culture. Previous studies on the communities served as a starting point in indetifying several research gaps as well as in understanding the process of culture change in the areas.

Census reports from the National Statistics Office (NSO), municipal and barangay profiles from the Municipal Planning and Development Office (MPDO) also served as sources of information. Basic data on demography, health situation, and other relevant information were culled from these reports.

Materials pertaining to the planned HEPs were also obtained from NPC. Petition letters of opposition groups, proceedings of meetings of peoples' organizations (POs), documents of the LGU, and correspondence among various organizations and agencies were also collected.

3.2.3 Focused Walks

The objective of the method is to observe the different activities in the areas of functional relevance to resource access and use including activities in the DIA and SIZ.

Observations made verified information gathered in the course of community mapping and profiling.

The Team walked with one to three local residents who pointed out and explained aspects of the functional areas and those to be affected by the HEPs. These included ricefields, swiddens, irrigation systems, drinking sources, pathways, the barangay hall, school, churches, playground, as well as the different sitios.

The researchers then noted down the locations of the different functional sites, the ongoing activity or work at different times of the day, and the individuals involved in the tasks.

3.2.4 Community Mapping and Profiling

The researchers made a rough sketch of the general areas and plotted out the "significant aspects" to locate the infrastructures (types of residential units, schools, medical facilities, water supply, and waste disposal system) and resource locations (fields, springs, river, forest). Help from some barangay officials was also solicited.

3.2.5 Participant Observation

Two activities are involved in this method: observing and recording the behavior of the community and participating in as many activities as the chance appears. Thus, the researcher joins in harvesting and threshing the rice or in fishing. In addition, the method allows him/her to establish rapport.

The researchers stayed in the communities for a certain period -- from three weeks to two months -- in order to directly observe and document family and village life. The disparity between formal and polite responses in interviews and non-verbal but obvious attitudes toward the HEPs was observed using this anthropological technique.

3.2.6 Socio-Economic Survey

The household surveys covered the Direct Impact Areas (DIA) of the proposed HEPs, in particular those projects which will inundate more than five sitios or five barangays, affecting more than a hundred households. Priority was given to households that are situated near the river banks because these are the areas that would most likely be affected by the proposed HEPs. An interview schedule was utilized in the conduct of the survey. It must be mentioned that the questionnaires were used as guides in the conduct of semi-structured "informal" talks. This meant to avoid a situation where respondents would feel threatened by the questions, considering the sensitivity of the issues involved. Moreover, the respondents were guaranteed that their replies would be confidential and their names would remain anonymous.

No house-to-house surveys were conducted in Project Areas that would affect less than 20 households. Rather, the focus was to ascertain the households which would be directly affected by the proposed HEPs. The household heads and when possible, with their spouses, were interviewed intensively to elicit their views on how the proposed HEPs will affect their households. Guide questions rather than survey forms were used.

3.2.7 Focus Group Discussions (FGDs)

Traditionally, the FGD was called focus group because its composition is relatively homogenous, e.g., women, men, and children. Nowadays, it means a group of people whose discussion is focused on certain issues because their social characteristics and activities predispose them "to know" (local expertise) about the issues being discussed. The FGDs were conducted in the communities to get more qualitative responses about the people's perceptions towards the proposed HEPs. The number of participants ranged from 10-20 for each discussion group.

3.2.8 Unstructured Interviews

The term "unstructured" refers more to its being "opportunistic". The researcher seizes every chance to engage residents in a conversation or simply an exchange of pleasantries. The purpose is to establish rapport. The questions asked are meant more to stimulate discussion on a significant subject. The researcher can then probe into the issue with other residents or key informants. Sometimes, the types of questions raised are influenced by the age and sex of the interviewee. Women are generally asked about family, health, nutrition, and education while information about crop production and barangay affairs is sought from men.

3.2.9 Key Informant (In-Depth) Interviews

The key informant is a person who has a good knowledge of the community and its culture. The individual may be an elder with strong roots in the community. He/she may also be a person with "specialized" knowledge about a particular aspect of the culture. In the settlement of disputes, the elders or barangay captains may be the key informants. In matters of rituals and ceremonies, the native priest and priestess would be the source of data.

3.2.10 Community Meetings or Assembly of Relevant Groupings

Before finalizing the results of the Studies for submission to NPC, the UGAT Research Team presented the report to the communities for their comments and additional insights. Among the objectives of the validation sessions is to ensure that the perceptions were documented fairly. In addition, the meeting may move the community to pursue a program of action in the light of the results presented.

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Wastewater Treatment in Huaxi

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ABSTRACT

A survey of the situation of surface water and wastewater treatment in Huaxi district of Guiyang city has been made. This paper discusses the used processes and their effects, the impact of industry development on water resources, and the increasing need for environmental protection.

1. Introduction

Huaxi is a suburban district situated to the south of Guiyang city, Guizhou province, China. There are more than 300,000 people in 1,000 square kilometers.

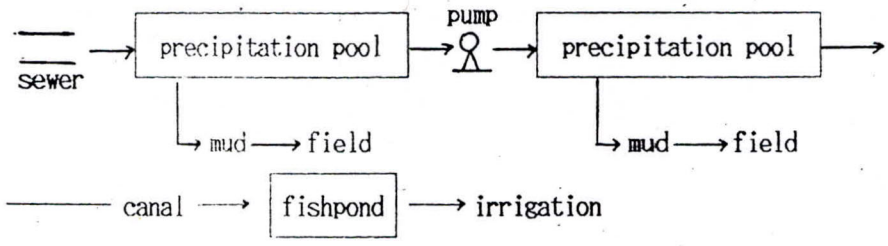
Huaxi is a famous summer resort for its mild climate, green hills and clear water. This district has plenty of water resources. There are two major rivers and tree reservoirs.

Because Huaxi town is a scenic spot, the local government has put special emphasis on environmental protection. In order to protect the source of potable water, construction of factories which may pollute the water is prohibited at the upper reaches of Huaxi river. Domestic sewage must be disposed of at the sewage treatment station.

2. Wastewater Treatment

(I) Domestic Sewage

Wastewater from residences, hotels, restaurants, hospitals and dairies is treated at the Huaxi sewage treatment station. The station can deal with 600 tons of water per hour. The treated water is used for irrigation. The processes are shown as below.

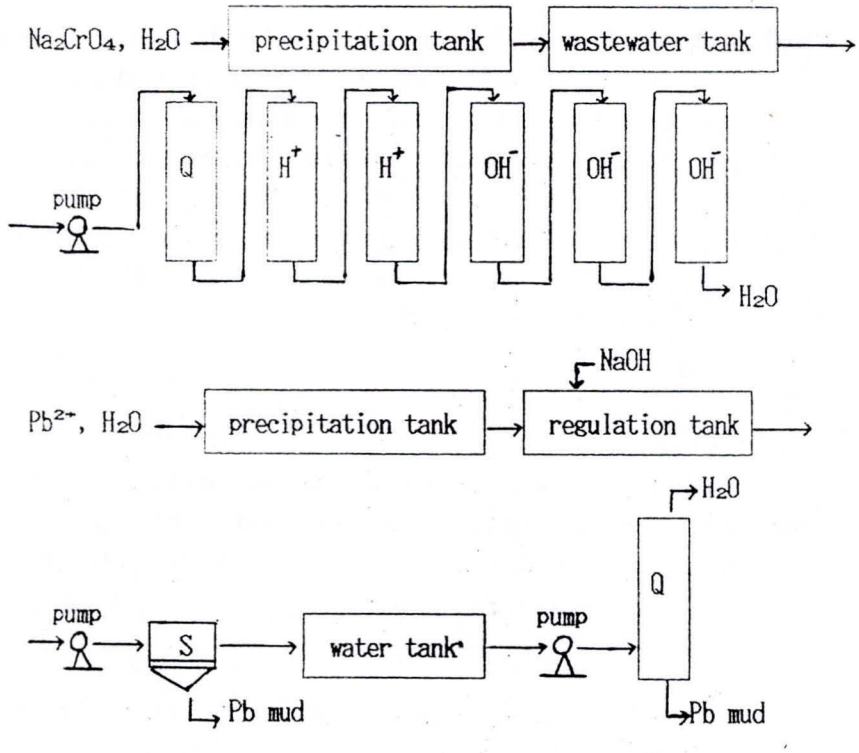


Wastewater with organic contaminants is utilized for farming after deposition and biodegration. This procedure not only protects the river but also fertilizes the farm fields.

(II) Industrial Effluents

Huaxi is a district of agriculture and tourism where severe restrictions are imposed on industrial effluents. Wastewater from factores must be treated and even the treated water is not allowed to enter the Huaxi river directly.

Let's take the Guiyang Miner's Lamp Factory for an example. This factory produces miner's lamps and batteries. It has a variety of wastewater containing chromium, lead, copper, nickel and acids. Processes of water treatment include ion exchange, neutralization and filtration. Followings are the flow chart of the processes of the Cr^{6+} water and the Pb^{2+} water treatment



Q ---- quartz sand filter
H^+/OH^- ---- cation/anion exchange column
S ---- sloping baffle filter

The treated water meets the national standard of discharge water (Cr^{6+} < 0.5 mg/l, Pb^{2+} < 1 mg/l). The lead mud is recovered at the smeltry. But there is not an effective method to dispose of the chromium-containing water from the regeneration of the ion exchange resin.

3. Impact of Urban Development

Although the local government has made every efforts to protect environment, water resources are facing an everincreasing threat of pollution for the following reasons.

(I) Population growth

The number of inhabitants has increased a lot in recent years. An extension of the sewage treatment station is under consideration.

Moreover, most of the inhabitants use coal for cooking (especially in winter). It makes air pollution and acid rain become serious.

(II) Industry development

Township enterprises have developed rapidly these years. Some of them cannot afford to dispose of the wastes.

(III) Tourism increase

Nowadays more and more travellers come to Huaxi. At weekends people from the urban area come to Huaxi for swimming, fishing or picnic. Some of the visitors litter everywhere.

As a whole, The protection of water resources in Huaxi has made good progress. But there is still a lot of work to do. Government should build more environmental protection facilities and help enterprises dispose of wastewater at a reasonable cost.

Possibility of Cattail for Waste-water Treatment

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Abstract

Cattail (*Typha* sp.) is a perennial aquatic weed which grows and spreads very fast in ponds, canals and reservoirs throughout tropical and temperate zones. It can tolerate in some degree of salinity, acidity and alkaline environment. The important properties of cattail are high natural productivity and has ability to absorp large amount of nutrients and heavy metals. So the possibility of cattail utilization to waste-water treatment was investigated. Cattail can produce large quantities of biomass, the total annual productivity approximately 56.6 ton/ha. The biomass above ground and below ground are in the range 3.8-52.7 and 9.7-101.4 ton/ha respectively. Cattail is effective in nutrients removal. The removal nutrients capacity of nitrogen and phosphorus are 760 and 60 kg/ha. respectively. The comparison studies of the elements content in organs of broad-leaf cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*) indicated that above ground and below ground of *Typha* species are diffrent. Element content; N, P, K, Ca, Mg, Na, Mn, Zn, and Cu in every organs of broad-leaf cattail are larger than narrow-leaved cattail and the highest nutrients of above ground organs are N, K, Ca, Mg and Mn. The maximum nutrient content of below ground organs are Na, Zn and Cu. The largest N content in both *Typha* sp. are in the range 2.5-2.9% but the lowest P concentration is found in leaf-blade and leaf-sheath. *Typha* sp. is rather high capacity to adsorp the heavy metals such as Mn, Zn and Cu. The elements accumulated in broad-leaf cattail more larger than narrow-leaved cattail. Seasonal dynamic also has affected to chemical elements and biomass in cattail. The maximum leaf-area of broad-leaf cattail and narrow-leaved cattial are in August which resulted the largest N , P, K content and also biomass of above ground organs in summer. The peak of nutrient content of N, P and K below ground organ is in final fall. The biomass above ground of broad-leaf cattail is more

larger than narrow - leaved cattail but biomass below ground of broad - leaf cattail is smaller than narrow-leaved cattail. The largest biomass below ground is in the begining of winter. Cattail can be used as water purification and it should be harvested during summer for waste-water treatment.

Key words : Cattail Broad-leaf cattail, Narrow leaved cattail, *Typha* sp, *Typha latifolia*, *Typha angustifolia*

Introduction

Generally aquatic weeds cause a serious problems to the environments such as obstruct the water way which promoted silting, reduce water discharge capacity and it is lost the land for agriculture. Cattail (*Typha* sp.) is one of the most noxious aquatic weed. Borad-leaf cattail or *Typha latifolia* (Hotchkiss, 1972) and narrow-leaved cattail or *Typha angustifolia* (Alex.et.al.,1980) are commonly found together in marsh, ponds, canals and reservoirs (Fassett and Colhun, 1952). There are serveral methods of aquatic weed managements such as mechanical harvesting, biological control, environmental change and chemical control. The farmers spend a lot of money for eradication this weed by the way of mechanical and chemical control. The use of herbicide will give residual effect to water quality and living things (Mani et al.1976). Although this weed gives a lot of problems to the environments but cattail has the ability to adsorp the dissolved nutrients from polluted water and produces large amount of biomass (Ulrich and Buaton, 1985 a). This is the important criteria of cattail to use in polluted water for water purification.

The purpose of this paper is to evaluate the possibility of cattail for waste-water treatment.

The biology of cattail

Cattail is a perennial aquatic weed with creeping rhizome. Flower consists of unisexual spike upper spike male and lower spike female(Backer and Bankhuizen Van Den Brinks, 1968). Seeds are very small and subtened by copius hair which could be carried by wind and germinate in soil just above water level (Gracce, 1985; March, 1962). Broad-leaf cattail is an erect rhizomatous, stem 1-3 m. tall, leave long, linear, largely flat usually 8-15 mm. wide. Narrow-leaved cattail is also an erect rhizomatous, stem 1-3 m. tall, leave long, linear strongly planoconvex, 3-8 mm. wide. The two species normally are found together which

may be segregated according to water depth with broad-leaf cattail in shallow water and narrow-leaved cattail in deep water.

Result and discussion

The most important criteria of aquatic weeds is to produce large amount of natural productivity. *Typha* sp. has ability to produce the annual productivity more larger than *Eichhornia crassipes* and *Phragmites commumis* which are used in waste-water treatment. Currently, the use of aquatic weeds in Japan such as *Eichhornia crassipes* and *Phragmites communis* have recieved increasing attention in both natural and artificial land for waste water treatment. The total annual biomass of *Typha* sp., *Eichhornia crassipes* and *Phragmites communis* are 56.6, 37.8 and 33.5 ton/ha. respectively (table 2). The above ground biomass of *Typha* sp. and *Phragmites communis* are in the range 3.8-52.7, 3.8-4.0 and below ground biomass are in the range 1.6-48.7 and 3.7-88.9 ton/ha respectively (table 1). The capacity of nutrients accumulation of nitrogen and phosphous in *Typha* sp. and *Phragmites communis* are 760, 90, 490, and 50 kg/ha respectively (table 2). A copmparative studies of aquatic weeds among *Eichhornia cassipes*, *Typha* sp. and *Phragmites communis* which related to COD, inorganic N and inorganic P can be show the water quality (table 2). The quality of water bodies which cultivated by *Typha* sp. has COD, inorganic N and inorganic P approximately 0.54, 0.12 and 0.02 mg./l. respectively. The quality of water which occupied by *Typha* sp. is better than *Eichhornia cassipes*. *Typha* sp. shows prominent capacity in waste water treatment. Normally COD uses to detect the heavy metals such as Cd, Cr, Pb and Hg in waste water from dyeing factory and battery factory. The standard of COD in waste water is not over than 60 mg./l. It can be concluded that cattail is possible to use as water purification when it compares among the other aquatic weeds.

The comparision between Typha latifolia and Typha angustifolia

Nutrients uptake by *Typha* sp.

A comperative studies between *Typha* sp. are found that the element content of above and below ground organs of *Typha* sp. are differents (table 3). The N contents is highest in leaf-blade 2.5-2.9% for both species, and the lowest P accumulation is in leaf-blade and leaf-sheath are 0.26-0.34 and 0.19-0.36 % respectively. The organs of *T. latifolia* contain more larger N and P than those of

T. angustifolia (table 3). Leaf area between *T. latifolia* and *T. angustifolia* show that leaf area of *Typha latifolia* is more larger than *Typha angustifolia* at every time of harvesting (table 6). Therefore *T. latifolia* is heigher growth rate than *T. angustifolia* which effected the nutrient accumulation of *Typha* sp. The above ground organs of both *Typha* sp. have the lowest P concentration.

Among the organs of *Typha* sp., the least amount of K is in root, the lowest Ca concentration is found in rhizome while leaf-blade has the lowest Na concentration (table 3). Higher K, Ca and Na concentration are indicated in *T. latifolia* Mg and Mn nutrients in *T. latifolia* are presented more larger in *T. angustifolia.*

Cu and Zn occur in 7-8 time higher quantities in root of both species than other organs. The concentration of these toxic elements seem higher in both species. The result indicates that elements accumulation in *T. latifolia* is more larger quantites than *T. angustifolia* which can be evaluated that *T. latifolia* is more effective for waste-water treatment than *T. angustifolia.*

Seasonal dynamic of elements in *Typha* sp

The dynamic of nutrients cycling between above and below *Typha* sp tissue must be understood if natural or cultivated wetland are to be managed for waste-water treatment. Seasonal dynamic effects to the elements accumulation of *T. latifolia* and *T. angustifolia which showed in table 4.* The least of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* in the beginning of growing season are 0.2, 0.1, 0.4, 0.1, 0 and 0.1% which sharply increased until summer and gradually decreased until October (table 4). The largest quantites of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* are 10.2, 2.8, 11.2, 4.2, 0.8 and 5.5% respectively due to leaf area of both *Typha* sp. are also in the peak of this month. The maximum of leaf-area of *T. latifolia* and *T. angustifolia* are 1,515.08 and 1,983.60 cm2 respectively (table 6). The largest nutrients content emerged during the most favourable period as to climate from June to August, when the solar energy input is abundant and high temperature. The period of maximum nutrients accumulation in under ground organs of both *Typha* sp. in final fall because the nutrients are translocated to the rhizome just prior to the onset of dormancy.

Biomass production of *Typha* sp

Data on growth rate and production are also very useful for evaluating the harvesting time of *Typha* sp. in waste-water treatment to get the greatest of biomass and nutrients removal from *Typha* sp. The biomass above ground production of *T. latifolia* and *T. angustifolia* increases from June, 3-August, 26 and decreases from October, 7 until December, 30 due to the seasonal change. The largest biomass above ground of *T. latifolia* and *T. angustifolia* in August, 26 are 77.53 and 55.43 gm. respectively (table 5). The tendency of above ground biomass production of *T. latifolia* more greater than *T. angustifolia*. The increment of dry weight below ground production of both *Typha* sp. are during June, 3 until November, 8, the maximum biomass of *T. latifolia* and *T. angustigolia* are 149.8 and 158.6 gm. The tendency of dry weight below ground production of *T. latifolia* is less than *T. angustifolia*.

Conclusion

1. *Typha* sp is possible to use as water purification compare with the other aquatic weeds. It produces large amount of biomass and has high capacity to adsorp nutrients uptake from polluted water when compared with among with *Eichhornia crassipes* and *Phragmites communis*. Normally,*Eichhonia crassipes* and *Phragmites communis* are used in waste water treatment.. Water quality which cultured by T*yhpha* sp. is lower inorg-N and inorg-P than *Eichhornia crassipess* and *Phragmites communis*. COD is lower from standard therefore *Typha* sp.is effective in waste water treatment.

2 The comparison stduies indicated that *T. latifolia* is more effective in nutrients removal than *T. angustifolia* The element contents such as N,P,K,Ca, Mg,Na, Mn,Zn and Cu in every organs of *T.latifolia* is more larger than *T. angustifolia* thus *T. latifolia* is more effective in nutrient removal than *T. angustifolia*The study of nutrients uptakes in *Typha sp.* . shows effective in nutrients uptakes. N. and Mn are the highest in above ground organs . The least K concentration is found in root.

3. Seasonal change effected to nutrients accummulation in T. latifolia and *T. angustifolia*. The maximum N,P and K. content of above ground organs are

in summer. The maximum period of nutrients uptake below ground organs is in final fall.

Seanonal change effected to biomass production in both *Typha* sp. The largest biomass above ground is in summer and below ground is in winter, In order to get the highest of nutrients removal and biomass production., the suitable harvesting time of above ground organs are in summer

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Table 1 Annual productivity of aquatic plant (Lakshman, 1987)

Species	Above ground	Below ground	Total
	ton(dry wt) / ha		
Eichhornia crassipes	4.6-212.0	-	4.6-212.0
Typha sp	3.8-52.7	1.6-48.7	9.7-101.4
Phragmites communis	3.8-4.0	3.7-88.9	8.2-122.9
Corex sp	2.2-22.3	1.5-11.7	-
Scirpus sp	2.0-24.3	12.0-18.7	2.5-25

Table 2 Estimated nutrient removal, annual productivity and water quality

Spicices	Annual productivity (dry matter ton/ha)	Nutrient removal by weeds (kg/ha)		COD (mg/l)	Inorg-N (mg/l)	Inorg-P (mg/l)
		N	P			
	1	1	1	2	2	2
Eichhornia crassipes	37.8	1,400	140	6.30	0.96	0.17
Typha sp	56.6	760	90	5.54	0.12	0.02
Pharmites communis	33.5	490	50	4.78	0.59	0.11

Souce : 1 Steward, 1970

2. Oki et.al, 1988 b

Study area

Chemical properties	Water mg/l	Sediment mg/g
pH	7.2	-
total-N	2.2	0.67
total-P	0.61	0.50
Mg	4,251	0.17
Ca	50.81	0.78
K	13.69	0.05
Na	46.11	0.04
Mn	0.05	0.06
Zn	0.12	0.01
Cu	0.03	-

Table 3 Mean elements contents in organs of aquatic weeds from April to September (Dinka, 1986)

Element	leaf-blade	leaf-sheath	rhizome	root
Typha latifolia				
N %	2.91	1.14	2.22	1.57
P %	0.34	0.36	0.45	0.42
Ca %	1.10	1.29	0.48	1.06
K %	1.69	1.92	1.45	0.72
Na %	0.43	1.02	1.13	0.68
Mg %	0.47	0.58	0.28	0.37
Mn mg/kg	249.80	116.50	77.20	183.40
Zn mg/kg	26.00	25.00	24.40	95.60
Cu mg/kg	4.70	3.50	5.20	15.00
Typha angustifolia				
N %	2.52	0.87	1.79	1.33
P %	0.26	0.19	0.31	1.36
Ca %	0.50	0.82	0.53	1.27
K %	1.04	1.23	1.04	0.62
Na %	0.68	1.12	0.77	0.21
Mg %	0.37	0.34	0.39	0.35
Mn mg/kg	151.60	69.00	64.40	164.60
Zn mg/kg	17.20	11.00	11.80	88.2
Cu mg/kg	4.20	3.00	3.40	14.60

Table 4 Change in element composition of *T. latifolia* and *T. angustifolia* (Grace,et.al, 1988)

	T. latifolia			*T. angustifolia*		
	N	P	K	N	P	K
	%					
May, 12						
Above ground	0.2	0.1	0.4	0.1	0	0.1
Below ground	6.5	1.7	5.9	4.0	1.1	4.9
June, 9						
Above ground	1.7	0.3	2.1	0.4	0.1	0.5
Below ground	4.8	1.3	3.8	3.4	1.0	5.8
July, 7						
Above ground	7.5	1.8	7.3	4.2	1.0	5.3
Below ground	2.4	1.2	2.4	2.4	0.9	3.7
August, 4						
Above ground	10.2	2.8	11.2	4.2	0.8	5.5
Below ground	2.4	1.6	3.0	1.2	0.7	2.3
September, 2						
Above ground	8.4	2.1	10.0	3.8	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3

September, 29						
Above ground	6.3	1.7	6.4	4.9	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3
October, 27						
Above ground	7.1	2.3	7.8	3.4	0.5	0.2
Below ground	5.2	1.8	5.2	7.0	2.9	5.9

Table 5 Averge dry weight of above ground and below ground production compare between *Typha latifolia* and *Typha angustifolia* (Junrungreang, 1992)

Month	Above ground(gm)		Below ground(gm)	
	T.latifolia	*T.angustifolia*	*T.latifolia*	*T.angustifolia*
June, 3	2.57	8.24	0.44	6.84
July, 15	49.79	18.70	56.58	20.79
August, 26	77.53	55.73	87.99	60.77
October, 7	76.31	45.43	133.38	146.04
November, 8	67.42	38.72	149.84	158.06
December, 30	61.21	35.30	128.74	112.33

Table 6 Leaf area and specific leaf area of *T.latifolia* and *T.angustifolia* (Junrungreang, 1992)

Species	Leaf area (cm^2)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	1718.47	1983.60	1687.05	942.29
T. angustifolia	713.20	1515.08	1262.14	777.17

	Specific leaf area (cm^2/gm)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	34.51	25.59	22.11	13.98
T. angustifolia	38.14	33.35	22.65	20.07

Possibility of Cattail for Waste-water Treatment

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larger than narrow - leaved cattail but biomass below ground of broad - leaf cattail is smaller than narrow-leaved cattail. The largest biomass below ground is in the begining of winter. Cattail can be used as water purification and it should be harvested during summer for waste-water treatment.

Key words : Cattail Broad-leaf cattail, Narrow leaved cattail, *Typha* sp, *Typha latifolia, Typha angustifolia*

Introduction

Generally aquatic weeds cause a serious problems to the environments such as obstruct the water way which promoted silting, reduce water discharge capacity and it is lost the land for agriculture. Cattail (*Typha* sp.) is one of the most noxious aquatic weed. Borad-leaf cattail or *Typha latifolia* (Hotchkiss, 1972) and narrow-leaved cattail or *Typha angustifolia* (Alex.et.al.,1980) are commonly found together in marsh, ponds, canals and reservoirs (Fassett and Colhun, 1952). There are serveral methods of aquatic weed managements such as mechanical harvesting, biological control, environmental change and chemical control. The farmers spend a lot of money for eradication this weed by the way of mechanical and chemical control. The use of herbicide will give residual effect to water quality and living things (Mani et al.1976). Although this weed gives a lot of problems to the environments but cattail has the ability to adsorp the dissolved nutrients from polluted water and produces large amount of biomass (Ulrich and Buaton, 1985 a). This is the important criteria of cattail to use in polluted water for water purification.

The purpose of this paper is to evaluate the possibility of cattail for waste-water treatment.

The biology of cattail

Cattail is a perennial aquatic weed with creeping rhizome. Flower consists of unisexual spike upper spike male and lower spike female(Backer and Bankhuizen Van Den Brinks, 1968). Seeds are very small and subtened by copius hair which could be carried by wind and germinate in soil just above water level (Gracce, 1985; March, 1962). Broad-leaf cattail is an erect rhizomatous, stem 1-3 m. tall, leave long, linear, largely flat usually 8-15 mm. wide. Narrow-leaved cattail is also an erect rhizomatous, stem 1-3 m. tall, leave long, linear strongly planoconvex, 3-8 mm. wide. The two species normally are found together which

may be segregated according to water depth with broad-leaf cattail in shallow water and narrow-leaved cattail in deep water.

Result and discussion

The most important criteria of aquatic weeds is to produce large amount of natural productivity. *Typha* sp. has ability to produce the annual productivity more larger than *Eichhornia crassipes* and *Phragmites commumis* which are used in waste-water treatment. Currently, the use of aquatic weeds in Japan such as *Eichhornia crassipes* and *Phragmites communis* have recieved increasing attention in both natural and artificial land for waste water treatment. The total annual biomass of *Typha* sp., *Eichhornia crassipes* and *Phragmites communis* are 56.6, 37.8 and 33.5 ton/ha. respectively (table 2). The above ground biomass of *Typha* sp. and *Phragmites communis* are in the range 3.8-52.7, 3.8-4.0 and below ground biomass are in the range 1.6-48.7 and 3.7-88.9 ton/ha respectively (table 1). The capacity of nutrients accumulation of nitrogen and phosphous in *Typha* sp. and *Phragmites communis* are 760, 90, 490, and 50 kg/ha respectively (table 2). A copmparative studies of aquatic weeds among *Eichhornia cassipes*, *Typha* sp. and *Phragmites communis* which related to COD, inorganic N and inorganic P can be show the water quality (table 2). The quality of water bodies which cultivated by *Typha* sp. has COD, inorganic N and inorganic P approximately 0.54, 0.12 and 0.02 mg./l. respectively. The quality of water which occupied by *Typha* sp. is better than *Eichhornia cassipes*. *Typha* sp. shows prominent capacity in waste water treatment. Normally COD uses to detect the heavy metals such as Cd, Cr, Pb and Hg in waste water from dyeing factory and battery factory. The standard of COD in waste water is not over than 60 mg./l. It can be concluded that cattail is possible to use as water purification when it compares among the other aquatic weeds.

The comparision between Typha latifolia and Typha angustifolia

Nutrients uptake by *Typha* sp.

A comperative studies between *Typha* sp. are found that the element content of above and below ground organs of *Typha* sp. are differents (table 3). The N contents is highest in leaf-blade 2.5-2.9% for both species, and the lowest P accumulation is in leaf-blade and leaf-sheath are 0.26-0.34 and 0.19-0.36 % respectively. The organs of *T. latifolia* contain more larger N and P than those of

T. angustifolia (table 3). Leaf area between *T. latifolia* and *T. angustifolia* show that leaf area of *Typha latifolia* is more larger than *Typha angustifolia* at every time of harvesting (table 6). Therefore *T. latifolia* is heigher growth rate than *T. angustifolia* which effected the nutrient accumulation of *Typha* sp. The above ground organs of both *Typha* sp. have the lowest P concentration.

Among the organs of *Typha* sp., the least amount of K is in root, the lowest Ca concentration is found in rhizome while leaf-blade has the lowest Na concentration (table 3). Higher K, Ca and Na concentration are indicated in *T. latifolia* Mg and Mn nutrients in *T. latifolia* are presented more larger in *T. angustifolia.*

Cu and Zn occur in 7-8 time higher quantities in root of both species than other organs. The concentration of these toxic elements seem higher in both species. The result indicates that elements accumulation in *T. latifolia* is more larger quantites than *T. angustifolia* which can be evaluated that *T. latifolia* is more effective for waste-water treatment than *T. angustifolia.*

Seasonal dynamic of elements In *Typha* sp

The dynamic of nutrients cycling between above and below *Typha* sp tissue must be understood if natural or cultivated wetland are to be managed for waste-water treatment. Seasonal dynamic effects to the elements accumulation of *T. latifolia* and *T. angustifolia which showed in table 4.* The least of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* in the beginning of growing season are 0.2, 0.1, 0.4, 0.1, 0 and 0.1% which sharply increased until summer and gradually decreased until October (table 4). The largest quantites of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* are 10.2, 2.8, 11.2, 4.2, 0.8 and 5.5% respectively due to leaf area of both *Typha* sp. are also in the peak of this month. The maximum of leaf-area of *T. latifolia* and *T. angustifolia* are 1,515.08 and 1,983.60 cm2 respectively (table 6). The largest nutrients content emerged during the most favourable period as to climate from June to August, when the solar energy input is abundant and high temperature. The period of maximum nutrients accumulation in under ground organs of both *Typha* sp. in final fall because the nutrients are translocated to the rhizome just prior to the onset of dormancy.

Biomass production of *Typha* sp

Data on growth rate and production are also very useful for evaluating the harvesting time of *Typha* sp. in waste-water treatment to get the greatest of biomass and nutrients removal from *Typha* sp. The biomass above ground production of *T. latifolia* and *T. angustifolia* increases from June, 3-August, 26 and decreases from October, 7 until December, 30 due to the seasonal change. The largest biomass above ground of *T. latifolia* and *T. angustifolia* in August, 26 are 77.53 and 55.43 gm. respectively (table 5). The tendency of above ground biomass production of *T. latifolia* more greater than *T. angustifolia*. The increment of dry weight below ground production of both *Typha* sp. are during June, 3 until November, 8, the maximum biomass of *T. latifolia* and *T. angustigolia* are 149.8 and 158.6 gm. The tendency of dry weight below ground production of *T. latifolia* is less than *T. angustifolia.*

Conclusion

1. *Typha* sp is possible to use as water purification compare with the other aquatic weeds. It produces large amount of biomass and has high capacity to adsorp nutrients uptake from polluted water when compared with among with *Eichhornia crassipes* and *Phragmites communis*. Normally,*Eichhonia crassipes* and *Phragmites communis* are used in waste water treatment.. Water quality which cultured by T*yhpha* sp. is lower inorg-N and inorg-P than *Eichhornia crassipess* and *Phragmites communis*. COD is lower from standard therefore *Typha* sp.is effective in waste water treatment.

2 The comparison stduies indicated that *T. latifolia* is more effective in nutrients removal than *T. angustifolia* The element contents such as N,P,K,Ca, Mg,Na, Mn,Zn and Cu in every organs of *T.latifolia* is more larger than *T. angustifolia* thus *T. latifolia* is more effective in nutrient removal than *T. angustifolia*The study of nutrients uptakes in *Typha sp.* . shows effective in nutrients uptakes. N. and Mn are the highest in above ground organs . The least K concentration is found in root.

3. Seasonal change effected to nutrients accummulation in T. latifolia and *T. angustifolia*. The maximum N,P and K. content of above ground organs are

in summer. The maximum period of nutrients uptake below ground organs is in final fall.

Seanonal change effected to biomass production in both *Typha* sp. The largest biomass above ground is in summer and below ground is in winter, In order to get the highest of nutrients removal and biomass production., the suitable harvesting time of above ground organs are in summer

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Table 1 Annual productivity of aquatic plant (Lakshman, 1987)

Species	Above ground	Below ground	Total
	ton(dry wt) / ha		
Eichhornia crassipes	4.6-212.0	-	4.6-212.0
Typha sp	3.8-52.7	1.6-48.7	9.7-101.4
Phragmites communis	3.8-4.0	3.7-88.9	8.2-122.9
Corex sp	2.2-22.3	1.5-11.7	-
Scirpus sp	2.0-24.3	12.0-18.7	2.5-25

Table 2 Estimated nutrient removal, annual productivity and water quality

Spicices	Annual productivity (dry matter ton/ha)	Nutrient removal by weeds (kg/ha)		COD (mg/l)	Inorg-N (mg/l)	Inorg-P (mg/l)
		N	P			
	1	1	1	2	2	2
Eichhornia crassipes	37.8	1,400	140	6.30	0.96	0.17
Typha sp	56.6	760	90	5.54	0.12	0.02
Pharmites communis	33.5	490	50	4.78	0.59	0.11

Souce : 1 Steward, 1970

2. Oki et.al, 1988 b

Study area

Chemical properties	Water mg/l	Sediment mg/g
pH	7.2	-
total-N	2.2	0.67
total-P	0.61	0.50
Mg	4,251	0.17
Ca	50.81	0.78
K	13.69	0.05
Na	46.11	0.04
Mn	0.05	0.06
Zn	0.12	0.01
Cu	0.03	-

Table 3 Mean elements contents in organs of aquatic weeds from April to September (Dinka, 1986)

Element	leaf-blade	leaf-sheath	rhizome	root
Typha latifolia				
N %	2.91	1.14	2.22	1.57
P %	0.34	0.36	0.45	0.42
Ca %	1.10	1.29	0.48	1.06
K %	1.69	1.92	1.45	0.72
Na %	0.43	1.02	1.13	0.68
Mg %	0.47	0.58	0.28	0.37
Mn mg/kg	249.80	116.50	77.20	183.40
Zn mg/kg	26.00	25.00	24.40	95.60
Cu mg/kg	4.70	3.50	5.20	15.00
Typha angustifolia				
N %	2.52	0.87	1.79	1.33
P %	0.26	0.19	0.31	1.36
Ca %	0.50	0.82	0.53	1.27
K %	1.04	1.23	1.04	0.62
Na %	0.68	1.12	0.77	0.21
Mg %	0.37	0.34	0.39	0.35
Mn mg/kg	151.60	69.00	64.40	164.60
Zn mg/kg	17.20	11.00	11.80	88.2
Cu mg/kg	4.20	3.00	3.40	14.60

Table 4 Change in element composition of *T. latifolia* and *T. angustifolia* (Grace,et.al, 1988)

	T. latifolia			*T. angustifolia*		
	N	P	K	N	P	K
	%					
May, 12						
Above ground	0.2	0.1	0.4	0.1	0	0.1
Below ground	6.5	1.7	5.9	4.0	1.1	4.9
June, 9						
Above ground	1.7	0.3	2.1	0.4	0.1	0.5
Below ground	4.8	1.3	3.8	3.4	1.0	5.8
July, 7						
Above ground	7.5	1.8	7.3	4.2	1.0	5.3
Below ground	2.4	1.2	2.4	2.4	0.9	3.7
August, 4						
Above ground	10.2	2.8	11.2	4.2	0.8	5.5
Below ground	2.4	1.6	3.0	1.2	0.7	2.3
September, 2						
Above ground	8.4	2.1	10.0	3.8	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3

September, 29						
Above ground	6.3	1.7	6.4	4.9	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3
October, 27						
Above ground	7.1	2.3	7.8	3.4	0.5	0.2
Below ground	5.2	1.8	5.2	7.0	2.9	5.9

Table 5 Averge dry weight of above ground and below ground production compare between *Typha latifolia* and *Typha angustifolia* (Junrungreang, 1992)

Month	Above ground(gm)		Below ground(gm)	
	T.latifolia	*T.angustifolia*	*T.latifolia*	*T.angustifolia*
June, 3	2.57	8.24	0.44	6.84
July, 15	49.79	18.70	56.58	20.79
August, 26	77.53	55.73	87.99	60.77
October, 7	76.31	45.43	133.38	146.04
November, 8	67.42	38.72	149.84	158.06
December, 30	61.21	35.30	128.74	112.33

Table 6 Leaf area and specific leaf area of *T.latifolia* and *T.angustifolia* (Junrungreang, 1992)

Species	Leaf area (cm^2)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	1718.47	1983.60	1687.05	942.29
T. angustifolia	713.20	1515.08	1262.14	777.17

	Specific leaf area (cm^2/gm)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	34.51	25.59	22.11	13.98
T. angustifolia	38.14	33.35	22.65	20.07

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Minimizing Environmental Impact: Do It Now or Do It Later

Presented at the International Seminar Workshop: Advances in Water Resources Management and Wastewater Treatment Technologies

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INTRODUCTION

This paper considers some of the current thinking with regard to environmental impacts and impact assessment in Canada. It provides an overview of water-related environmental impacts on watersheds; reviews some governing principles of environmental management and environmental assessment; the benefits and costs of using environmental assessment or decommissioning and cleanup and finally; two brief case studies.

ENVIRONMENTAL IMPACTS WITHIN WATERSHEDS

Human Activities

Human activities almost invariably cause changes in water quality, water quantity, or the areal distribution of water. These changes may be environmentally positive (more water may be stored in reservoirs to supplement flow for sensitive fisheries, etc.) or negative (nutrient additions that accelerate the eutrophication process). Changes in water quality tend to be considered in terms of their sources, whether they are unique or limited in number, in which case they may be considered single point sources; or generalized, non point source additions of materials to the hydrologic system. From an engineering and regulatory perspective we have tended to focus on changes in the concentration of chemical and particulate substances in surface and groundwater, rather than ecosystem or hydrologic effects.

Human activities can affect the quantity of flow, as well as the geographic and temporal distribution of flow throughout the year. Emplacement of control structures such as dams can lead to retention of significant quantities of water at the land surface, which may result in changes in the behaviour of aquifers and receiving streams. Deforestation, land clearance, and surface mining can accelerate the rate and quantity of runoff due to changes in the retention capacity of surficial deposits, resulting in greater seasonal variation in water availability with consequent negative effects on local and regional hydrology, ecosystems, and human populations.

Although, it should be intuitively obvious that water movement and storage in undisturbed watersheds is the result of gravity, topography, and bedrock geology, much of the

regulatory framework surrounding water management is related to reminding us that activities which occur upgradient affect water users at lower altitudes. This has been especially true in recent years in Canada, as the effects of improper storage and disposal of chemicals have become evident in groundwater supplies that are now less useful due to contamination.

Negative Impacts

As discussed by Dr. Mitchell in his paper at this conference, current Canadian methods of watershed management are based on an ecosystem approach. However, much of our regulatory framework and engineering solutions are based on human health considerations, rather than the health of the terrestrial and aquatic ecosystems that depend on water. This has led to a variety of counter-intuitive results that have degraded ecosystem quality as the result of efforts to enhance the quality of human health. Examples are: the collection and treatment of human septic waste and its deposition in surface water systems and; the chlorination of various human water-borne wastes in order to reduce bacterial loading, which has led to the degradation of aquatic ecosystems.

In many countries the cleanup of sites contaminated with toxic chemicals, or high levels of non-toxic chemicals, has become a major growth sector for environmental industries. It is becoming obvious that appropriate planning prior to new development is an environmentally, socially, and economically appropriate method of avoiding future costs.

GOVERNING PRINCIPLES

Canadian environmental management is continually evolving and developing new governing principles. At the present time the following six principles have been generally accepted:

Multi Sectorial Approach

The overarching principle of Canadian environmental management is that improvements in environmental quality are ultimately best for all sectors. This principle is based on an increasing understanding that preservation of healthy ecosystems ultimately benefits the general public and private enterprise. As a result, environmental managers attempt to involve all appropriate public and private sector groups in the decision making process.

Polluter Pay

Over the past 30 years it has become more and more acceptable to require the individual or institution that creates pollution to pay for the remediation or correction of problems resulting from that pollution. This is in contrast to older methods of cost accounting whereby the user of the environment, or the ecosystem itself, ultimately paid for environmental degration caused by individual pollution sources. Related to this principle is the principle of total cost accounting that endeavours to incorporate the real environmental cost of human activities into the price of a good or commodity. As a result, the financial and environmental costs of resource extraction, processing, distribution of "product", and the removal of that product from the economic system are incorporated into the cost of the

item to the consumer. The application of this principle will be even more noticeable as many countries and industries adopt to the ISO 14 000 standards.

Economic Instruments

The fourth principle is that economic instruments that are unrelated to taxation can be effective in reducing human impacts on the environment. Economic instruments range from appropriate costing of water treatment and sewage treatment facilities in urban areas, to the use of tradeable pollution permits by various industries. One of the assumptions in the use of non-tax economic instruments is that their application will reduce the use of resources. Therefore, the output of waste products to the environment will also decrease. One example of the use of economic instruments in Canada is the appropriate pricing of water supplied by central treatment facilities which has led to decreases in water use. Reduced use has led to reduced demand on sewer infrastructure and sewage treatment facilities. Lower demand results in better treatment, and decreased need for additional infrastructure. Another example is the reduction of ground level ozone through the use of tradeable permits.

Public and Private Accountability

This principle requires that the public, industry, and government all have a role to play in maintaining environmental quality in watersheds, and a responsibility to communicate their goals and objectives to each other. The role of government has often been that of reacting to environmental problems rather than avoiding problems by co-ordinating public needs and the needs of industry. Government is often responsible for developments that affect watersheds and their environmental quality. For instance, government may be responsible for the construction and maintenance of highways, housing developments, and setting zoning regulations, all of which can cause direct problems or can lead to problems if appropriate planning is not carried out. Industry has tended to work to the limits of any regulatory framework rather than investigating innovative methods of reducing or preventing pollution. In recent years, industry has become more interested in finding new methods that will reduce negative outputs from manufacturing by finding new processes that will utilize fewer resources or result in more easily recycled and reused products. The public has historically been the indicator of some forms of environmental degradation, insofar as many public health issues have not been dealt with until public pressure was brought to bear on government or industry. The public has also been in the position of needing employment while, at the same time, being affected by pollution outputs from the production process. Increasingly, the Canadian public is being involved in the early stages of planning by both government and industry, to determine the appropriate balance between increased economic activity and preservation of environmental quality and human health.

No Net Loss

In Canada it has become obvious that there are situations where a change in land use or the installation of a new development is extremely important for increasing the physical or economic well being of the human population. In such cases it may be impossible to avoid

destruction of habitat, or interference with the hydrologic cycle. The principle of no net loss suggests that it is acceptable to cause disruption or destruction of small parts of the environment, as long as an equal amount new habitat is created nearby. It is too soon to tell whether the creation of new habitat can, in fact, reproduce the complexity and biological usefulness of the original.

ENVIRONMENTAL ASSESSMENT

In Canada, environmental assessment (EA) is part of the federal and provincial regulatory process that applies to specific industries or types of development. The requirement for an environmental impact assessment varies from one jurisdiction to another, and often depends on the source of funding or the ownership of lands to be developed. Areas of federal jurisdiction have requirements for EA that may differ from adjacent, provincially controlled areas.

Environmental assessment regulations are being modified to better serve the public, industries, and government. In recent years the EA process has been streamlined by setting out specific responsibilities for the proponent of development and the government agencies involved. Proponents now have clearer guidelines for preparing an assessment, and several governments have committed themselves to well defined time frames and sequential processing of assessment reports. There is increasing use of public experience and knowledge in the assessment process, and this indicates a realization that individuals who have lived in an area or used the area for agriculture, hunting, or fishing, may have much more detailed knowledge of local environmental conditions and trends than do outside experts.

REMEDIATION AND DECOMMISSIONING

In contrast to EA which endeavours to prevent or avoid future environmental problems, site remediation and site decommissioning are methods used to reverse negative effects of environmental contamination and to avoid ongoing environmental problems. Site remediation is often used in response to negative downstream effects on ecosystem or human health. Responding to such problems often means cleanup of the source of contamination, as well as extensive and often extremely expensive cleanup efforts in downstream portions of affected watersheds.

In Canada the legal liability from the sale of land that has been contaminated has led to a new branch of consulting activity that specialises in the remediation of contamination prior to the sale of property. This has resulted from a variety of court cases in which the purchaser was held responsible for cleanup of problems caused by previous owners. Such clean-up can take years to accomplish, and in extreme cases, contaminated sites have never been sold.

There are a number of "orphan" sites in Canada that have resulted from the dissolution or bankruptcy of former owners. These sites have been "adopted" by various levels of government because they pose ongoing threats to human or ecosystem health. Two such sites will be considered in the case study portion of this presentation.

DO IT NOW OR DO IT LATER?

Environmental assessment represents a preventative "Do it Now" strategy that is aimed at preserving environmental quality and highlighting potential problems before they occur. Perceived benefits and costs associated with the process are presented in Table 1.

Table 1. Benefits and Costs of Environmental Assessment

Benefits	Costs
– Total Cost Accounting	– Delay in Implementation
– Viability/Sustainability	– Lost opportunities ?
– Environmental thinking	– Design changes
– Public Involves	– Participants' Time
– Encourages contingency planning	– Public consultation
– Design for prevention/control	– Contingency plans
	– Additional equipment

The benefits of environmental assessment include total cost accounting, whereby the entire development and its anticipated products are considered from both economic and environmental points of view. Environmental assessment encourages proponents of development to think about the environment as it relates to their proposed development. This type of thinking may represent a new way of approaching problems for a particular individual or industry. The process involves the public in determining the acceptability and viability of the proposed development, which may be an important consideration in eventual acceptance of the development. It also involves the public in providing information, knowledge, and attitudes about the environment as it now exists, and as the public would like it to exist in the future. The process encourages contingency planning on the part of the proponent and government, which can be important in avoiding or dealing with emergency situations. The process also encourages the design of the development to include integral pollution control equipment and process engineering at the beginning of the design process. Appropriate design at an early stage can lead to significant savings in the long term. All of the above benefits allow the proponent to make decisions regarding the viability and sustainability of the proposed development.

Costs associated with environmental assessment include delays in project implementation, which may cause the loss of short term funding or added expense of borrowed funds. There is the possibility of the abandonment of the proposed development, which may represent a lost opportunity for the proponent or the community. However, one must question whether a truly viable development would suffer from the time delay represented by the assessment process. Changes in proposed design can represent direct costs in terms of additional pollution control or in-plant equipment needs. However, such costs should be of ultimate benefit to the proponent. There is a very real, but difficult to quantify, cost in terms of the time required by the proponent, government, and the public in preparing for and attending public meetings. The process is time consuming and can be wearing on the

patience of all concerned. Although contingency plans and the need for additional equipment are listed as benefits, they can also be seen as costs to the proponent due to the time and the money required to put plans and equipment in place.

The alternative to environmental assessment is the historical method of development, that is, put the development in place and worry about problems at a later date--"Do It Later". The number and extent of environmental problems associated with this strategy are, in large part, what led to the adoption of the environmental assessment process in many jurisdictions. The benefits and costs of this "Do it Later" strategy are presented in Table 2.

Table 2. Benefits and Costs of Site Decommissioning/Clean Up

Benefits	Costs
– Deferred O&M costs to operator	– Lower ecosystem and human health
– Short Term jobs/taxes	– Public Costs
–	– Reduced tax revenue
– Political benefit	– Bankruptcy - job loss

Benefits accrue primarily to the proponent of a development, and include deferred operation and maintenance (O&M) costs that were not incurred to avoid long term pollution. Short term benefits may accrue to both the proponent and the community due to the provision of employment and tax revenue from the development. There is also the likelihood of political benefit to jurisdictions, political parties, or individuals, due to the provision of jobs and services to the community.

Costs associated with this strategy include lowered ecosystem and human health due to long term pollution during and after the operation of the development. In the long term this can become a public cost either to government or to individuals due to reduced property values and the cost of health care. In many cases the requirement for clean-up has led to bankruptcy of corporations or the abandonment of communities. In addition there may be reduced tax revenue due to businesses which have closed.

CASE STUDIES

Two case studies will be briefly considered in this section. The first is an abandoned metal recycling site that operated for approximately 25 years in the vicinity of Halifax, Nova Scotia, Canada. At some point during the operation of this facility, electrical transformers were recycled, and polychlorinated biphenyl (PCB) coolant was drained directly onto the soil surface. PCB contamination was first noted in nearby residential domestic well water, and was later detected in nearby lakes. The contaminated soil was isolated from the surrounding environment by a combination of excavation and storage in sealed containers, and impervious capping of the spill site. Costs associated with clean-up activities to date, as well as future requirements are shown in Table 3. Costs include the initial site cleanup and capping ($0.3 million), groundwater and soil monitoring for a minimum five year period ($0.2 million), cleanup of sediments in the most affected area of a near-by lake ($3.0 - 5.0 million) and, if required, regulatory compliance for the remainder of the most

affected lake ($12.0 - 20.0 million) bringing the total cost to $16.5 - 26.5 million for complete cleanup. This amount represents 10 - 100 times the likely total income from the facility's operation and will be completely at public expense due to the inability of the former operator to fund any portion of the cleanup activity.

Table 3. Costs Associated with the Eventual Cleanup of PCB Contamination at a Metal Recycling Facility near Halifax, N.S., Canada

	($000,000 CAD)
Initial cleanup/capping	1.3
Monitoring (5 years)	0.2
"Hot Spot" cleanup	3.0 - 5.0
Regulatory Compliance for entire lake	12.0 - 20.0
Total	$16.5 - 26.5

The second case study is the "Tarponds", located in Sydney, Nova Scotia, Canada. The tarponds are located on a small tributary draining into Sydney Harbour. The tarponds received a variety of outputs from a steel mill and coal coking operation adjacent to the tributary over a period of approximately 100 years. The site is presently considered an orphan site, and has been designated the most contaminated site in Canada. Sediment in the ponds is highly contaminated with polyaromatic hydrocarbons (PAH) and (PCB).

The original attempt to clean up the site involved the pumping of sediment to a nearby high temperature incinerator. After several years of attempting to utilize this technology, this remediation plan was abandoned in 1995 after spending $55 million. At the present time two alternative proposals are being considered. The first is to place an impervious cap over the tarponds with appropriate diversion of runoff from the watershed into Sydney Harbour. The cost of capping and diversion is estimated to be $20.4 million.

The second alternative is a different removal and incineration technique which will cost at least $120.0 million, bringing the total cost of final cleanup to between $75.4 and $140 million--again, at public expense (Table 4).

Table 4. Actual Cost of Attempted Cleanup of the Sydney "Tar Ponds" (Phase I), and anticipated costs of two alternative remediation methods

	($000,000 CAD)
Phase I: Attempted removal and incineration	55.0

Phase II	
Proposal A: Site Capping	20.4
Proposal B: Incineration	120.0
Total	$75.4 - 140.0

In contrast to the cost associated with decommissioning, typical direct costs of performing environmental assessment are presented in (Table 5). These include the provision of expert advice during the assessment process ($0.03 - 0.10 million), additional equipment and design changes ($0.50 - 1.50 million), and operation and maintenance of additional equipment for a 25 year project life span ($0.25 - 0.50 million), for a total of $0.78 - 2.10 million. The additional equipment category may relate to machinery, in the case of a production facility, or to more effective surface drainage and treatment facilities in the case of a transportation or housing development. In any event, the cost to the proponent is at least one order of magnitude less than the cost of either cleanup scenario presented in the case studies.

Table 5. Typical Direct Costs of EIA

	($000,000 CAD)
Expert advice	0.03 - 0.10
Additional Equipment/ Design Change	0.50 - 1.50
O & M of Additional Equipment (25 years)	0.25 - 0.50
Total	0.78 - 2.10

Summary

Canadian governments are attempting to avoid future environmental degradation by using an ecosystem approach and environmental assessment before allowing some new developments to take place. Based on two case studies, the potential direct public cost of decommissioning orphan sites can be at least one order of magnitude greater than the cost of environmental assessment. If reduced ecosystem and human health costs were included, the costs would be higher although this presentation has not attempted to determine how much higher. However, it is obvious that the environmental assessment process makes economic sense and should continue to be utilised.

Minimizing Environmental Impact
Dr. William Hart, Technical University of Nova Scotia

EMERGING

Governing Principles

- Best environmental quality is ultimately best for all sectors
- Polluter pays
- Total cost accounting
- Economic Instruments
- Accountability
  - Public
  - Industry
  - Government
- No net loss

Environmental Impacts in Watersheds

Human activities cause changes in:

- Water quality
  - Chemicals and particulates
  - Point and Non-Point Sources
- Water quantity/distribution
  - Local/regional changes in storage/flow

Upstream/upgradient activities affect downstream users

Negative impacts related to:

- Terrestrial and aquatic ecosystem health
- Human health

Avoidance of ongoing negative impacts

- Appropriate Planning - avoiding contamination
- Clean up of contaminated sites

Environmental Assessment

- Regulatory Process
- Specific Industries/Developments
- Specific responsibilities
  - Industry (Developer)
  - Government time frames, overall health
  - Public experience, knowledge

Site Remediation/Decommissioning

- Contaminated sites
- In response to downstream effects.
- "Orphan" sites

Do It Now - Environmental Assessment

Benefits

- Total Cost Accounting
- Viability/Sustainability
- Environmental thinking
- Involves Public Attitudes /Knowledge
- Encourages contingency planning
- Design for prevention/control

Do It Now - Environmental Assessment

Costs

Delay in Implementation

Lost opportunities (?)

Design changes

Participants' Time

Public consultation

Contingency plans

Additional equipment

Do It Later - Decommission/Clean Up

Benefits

- Deferred O&M costs to operator
- Short Term jobs/taxes
- Political benefit

Costs

- Public Costs
- Lower ecosystem and human health
- Reduced tax revenue
- Bankruptcy - job loss
-

Typical Direct Costs of EIA

	($000,000 CAD)
Expert advice	0.03 - 0.10
Additional Equipment/ Design Change	0.50 - 1.50
O & M of Additional Equipment (25 years)	0.25 - 0.50
Total	0.78 - 2.10

Metal Recycling Site

Soil - Groundwater - Lake
contamination by PCB

	($000,000 CAD)
Initial cleanup/capping	1.3
Monitoring (5 years)	0.2
"Hot Spot" cleanup	3.0 - 5.0
Regulatory Compliance for entire lake	12.0 - 20.0
Total	$16.5 - 26.5

Sydney Tar Ponds

Most contaminated orphan site in Canada.

Long term coal coking operation resulted in PAH and PCB contaminiation of estuary.

	($000,000 CAD)
Phase I - attempted removal and incineration	55.0
Proposal A: Site Capping	20.4
Proposal B: Incineration	120.0
Total	$75.4 - 140.0

IMPACTS OF VARIOUS LANDUSES IN FORESTED WATERSHED ON WATER QUALITY AT MAE KLONG HEAD WATERSHED AREA , KANCHANABURI, THAILAND.

SONGTAM SUKSAWANG[1],Ph.D

ABSTRACT

The study on the impacts of various land uses on water quality in Mae Klong head watershed area,Kanchanaburi was conducted from April 1993 to March 1994. Water samples have been collected in small disturbed sub-watershed which had been partially converted by local people for various of land uses such as residential and agricultural area in the upland area,Shifting cultivation area, Animal raising area and temporary housing with Agricultural area in lowland The water samples had also been coolected from undisturbed forested watershed areas as well. Analytical activities of water quality have been done at the Department of Agriculture and Department of Fishery,Ministry of Agriculture and cooperatives in Bangkok.

The result obtained from this study indicated that after the small forested watershed have been disturbed at certained level by human activities,there still be no evident sign to in dicate that physical water quality and nutrient constituents being affected discernbly.However,its biological water quality has been affected in some areas near or within residential premise,grazing area and agricultural and where number of fecal coliform,fecal streptococi and other coliform bacteria were higher than nutural level.

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INTRODUCTION

The quality of water flowing from undisturbed forested watersheds is generally regarded as high. When forests are removed by clear-cutting, this quality is almost invariably affected. Early studies indicated that once roads are built and the protective influence of the forest is removed. increases in streamflow, stream sediment levels , maximum stream temperatures and dissolved nutrient chemicals may occur, while dissolved oxygen levels may decrease These results have been reinforced by more recent studies as summarized by Bruijnzeel (1990)

Water pollution from various land-based activities is the most widespread environmental problem in the Asian and Pacific region (ESCAP 1992). The demand for water continues to rise rapidly across all sectors, locked up with the growth in urban areas, industry, and irrigarion systems and hydroelectric power. Also, the associated costs of long-term water resource cleanup and sustainable management are most likely the highest of any resource. Water pollution is responsible for substantial mortality and sickness in the region, particularly among children. The overall impacts of water pollution in both urban and rural areas are especially telling on the poor.

Forest clearing in Thailand was done by landless people and shifting cultivation practiced by nomadic hilltribes in Thailand seem to be the chronic and unsolvable problem. Forest lands are state property which being managed by the Royal Forest Department (RFD). Deforestation by means of conversion of forests into agricultural and other uses occurred in the alarming rate More than half of the existing forest area in 1960 has been converted for other uses mainly for agriculture. The need for agricultural lands increased along with population growth.

Land use activities caused various impacts on both quality and quantity of the water. Most important impacts and seemed to be escalated are siltation, water-borne diseases, pesticides, water-borne pollutants, feces, industrial and agricultural wastes, heavy metals, leachates from garbage pile, piggery, poultry farm, corral, etc.

Extensive deforestation in the catchment areas of all river basins caused flash flood, landslide and heavy erosion during rainy season. Crop and domestic animals have been destroyed

annually. Top soils along slope have been leached and lost their fertilities rapidly. Many streams turned into wadis in dry season. Most reservoirs and dams are shallow up by siltation faster than speculated. Water levels in most main river are very fluctuated. Many of them can be waded across in dry season, whereas water level increases up several meters above river bed in wet season. Water shortage occurred in many areas. All of these destructive phenomena have been generated from unwise land uses without soil conservation measures and forest clearing. This paper try to investigate the impacts of various land uses on water quality in Maeklong head watershed areas , western Thailand.

THE STUDY AREAS

The area of this study is located at Mae-Klong Watershed Research Station(MKWRS). Kanchanaburi Province Western Thailand.Experimental watersheds consists of five small watersheds,namely Nikuhu(Residential and agricultural area in the upland) ,Thata(Shifting cultivation area), Thaiye (Animal raising area) Lintin(temporary housing with Agricultural area in lowland) and ,Ta-ave (natural forest watershed) as the control watershed..The average slope is 30 % which is ranges from 100 to 950 m asl. Geographically,the watershed area is underlain the parent material of Rachaburi and Kanchanaburi series and composed of granite,limestone,sandstond,and shale.The geological age fall into Permian and Carboniferous period. The soil contains a reddish brown lateritic soil from the parent material of residium and colluvium of sandstone,limestone,shale and quartzite.The mainly vegetation is Mixed Deciduous Forest with an annual rainfall of 1600-2000 mm and daily temperatures with an average of 40' C for the warmest month and 8'C for the coldest month.

METHODS

Water samples were collected at the outlet of four small disturbed forested watershed which had been encroaching by people for various of land uses i.e. Residential and agricultural area

in the upland ,Shifting cultivation area, Animal raising area and Residential and Agricultural area in lowland comparing with one undisturbed forested watershed (natural forest watershed) as the control watershed. Water sample had been analysed of physical,chemical and biological water quality at Department of Agriculture and Department of Fishery,Ministry of Agriculture and cooperatives in Bangkok with in 24 hours.

RESULT

The study on impacts of various land use in forested watershed on water quality at Mae Klong head watershed area,Kanchanaburi,Thailand can be identified as follows.

1) Physical water quality.

Physical water quality parameters in various pattern of land uses in small disurbed forested watershed were analysed to assess the changes resulting from residential and agricultural area in the upland, shifting cultivation area,animal raising 1area, residential and agricultural area in the lowland comparing with Natural forest area.The result found that, in each landuses the average of pH were 7.5, 7.8, 7.8, 7.5, and 7.6; temperature were 24, 24, 26, 25, and 24 ^{o}C ;Electrical conductivity were 284,215 ,85 398,and 177 mmho/cm and dissolved oxygen were 8, 8.8, 8.9, 8.1, 8.4 and 8.6 mg/l respectively;

2.Chemical water quality.

The chemical water quality in various pattern of land uses in small disurbed forested watershed such as ;residential and agricultural area in the upland, shifting cultivation area,animal raising 1area, residential and agricultural area in the lowland comparing with Natural forest area ,the results were respectively shown in each land uses as follows ;,the losses of nutrient in form of NO^{-}_{3} were 0.11,0.075,0.082,0.261,and 0.048 mg/l ; NH_3 were 0.019,0.020 ,0.048,0.019 and 0.028 mg/l;PO^{3-}_{4} were 0.007,0.006,0.006,0.009 and 0.003 mg/l ;K were 1.09, 1.60, 2.26, 1.55 and 2.45 mg/l ; Ca were 56.45, 47.12, 8.60,67.7 and 25.82 mg/l ; Mg were 5.27,5.57,1.29,17.63 and 2.78 mg/l.

3.Biological water quality

However,the result of the biological water quality in various pattern of land uses in small disurbed forested watershed such as ;residential and agricultural area in the upland, shifting cultivation area,animal raising 1area, residential and agricultural area in the lowland comparing with Natural forest area are as follow ; total bacterial count at 20 ^{o} C were 6.54 x 10^{3}, 9.13 x 10^{3}, 9.43 x 10^{3}, 9.24 x 10^{3}, 6.74 x 10^{3} and 6.46 x 10^{3} cells/ml; Total bacterial count at 37 ^{o} C were 8.65 x10^{3} 6.55 x 10^{3}, 6.87 x 10^{3}, 4.45 x 10^{3}, 1.60 x 10^{4} and 6.63 x 10^{3} cells/ml.

DISCUSSION

The monthly variation of selected paraters are shown in Figure 1 and 2.Higher value of electrical conductivity,nitrate,calcium,magnesium,biochemical oxigen demand,Fecal streptococi count were observed in residential and agricultural area in the upland and lowland comparing with undisturbed forest area especially during rainy season. It was expected that the impact of landuses would be more obvious when the landuses were still in progress or immediately after but the trends did not reflect the situation probrably due to the lack of sampling during high flow.Higher monthly mean value for electrical conductivity,ammonia and phosphate generally coincided with the wet month in all landuses except undisturbed forest area.(Figure 1)This demonstrates the role of surface runoff in tranporting the dissolved and solid materials into the stream.

The degradation of water quality due to land development in head watershed area will directly or indirectly affact the water usage downstream(Mekong secretariat,1994). However,from the result of this study after changed of forest area to various land uses in small forest watershed did not impact on any physical and chemial water quality but its affected on some biological water quality especially in residential and agricultural area in the upland and lowland. This is because many corrals, pigsties, poultries in residential area are located near streams. The chance of wastes from this agricultural activity will be leached to the streams.Many kinds of bacteria and parasite will be transported by surface runoff to downstream.So, some value of biological water quality parameters exceeded the standard of water during and after landuses activities. In addition,many rural

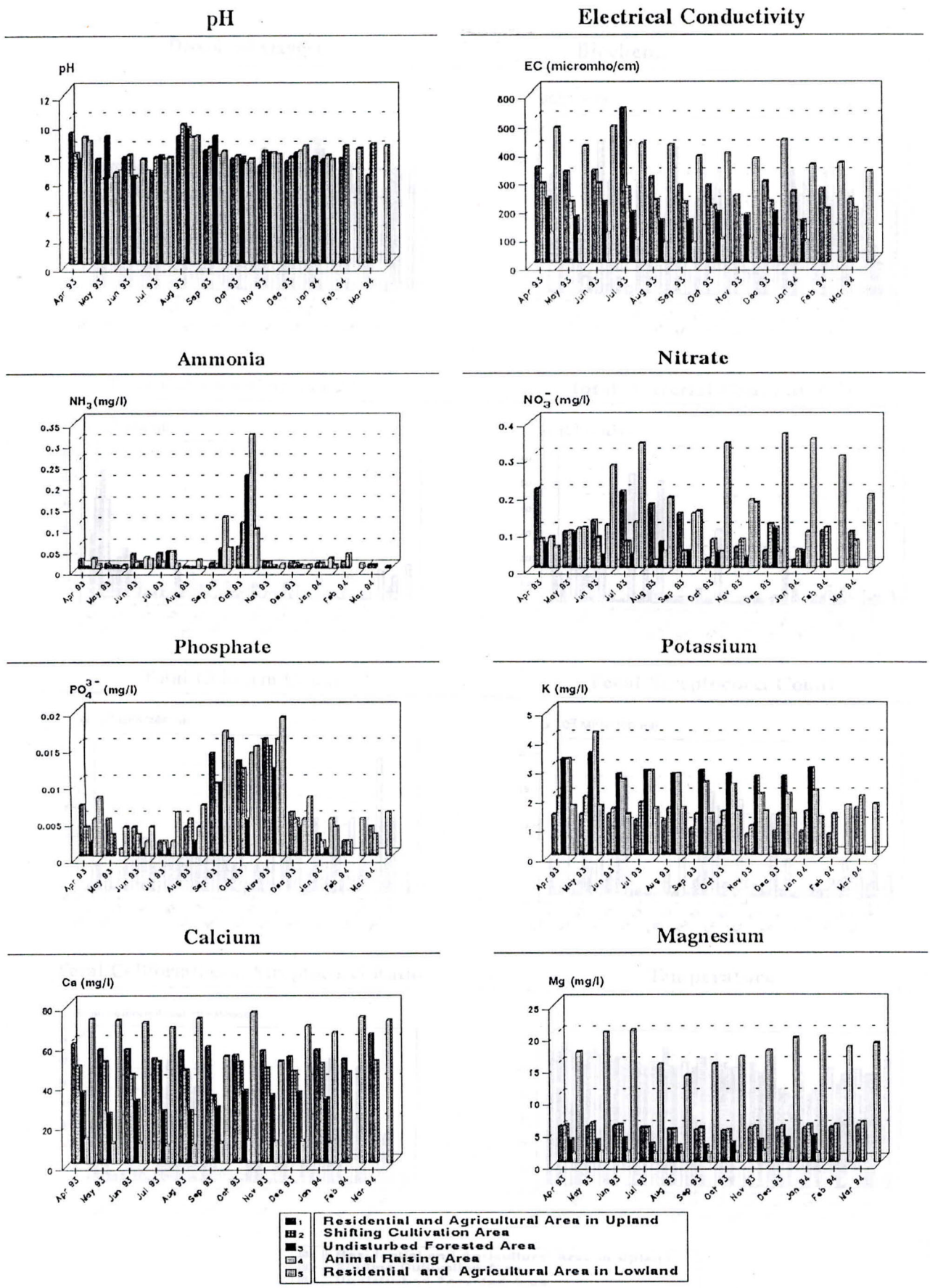

Figure 1 Water Quality after Land Uses Changed in Forested Watershed, Kanchanaburi Thailand

communities of the country including hilltribe villages still have no toilet to collect feces. The local people practically excrete the wastes on the ground behind the bushes. Dog, pig or chicken may finish them. But some may be washed away by surface runoff in the rainy season. Bacteria, parasites and worm eggs will be transported to water body downstream.

CONCLUSION

The study on the impacts of various land uses on water quality in Mae Klong head watershed area,Kanchanaburi. The result obtained from this study indicated that after the small forested watershed have been disturbed at certained level by human activities,there still be no evident sign to in dicate that physical water quality and nutrient constituents being affected discernbly.However,its biological water quality has been affected in some areas near or within residential premise,grazing area and agricultural and where number of fecal coliform,fecal streptococi and other coliform bacteria were higher than nutural level.However,if we let new communities settle up scatteringly over the entire watershed.They might be developed from small villages and turned to be big communities.These communities always settled along the streams. Surface runoff water passing through these communities in rainy season will transport wastes, pollutants, diseases, bacteria, etc into nearby rivers or streams. Water quality in lower part of stream may be remarkably poorer than the upper part of community in head Mae klong watershed.

RECOMMENDATION

1.Bureaucratic land use selection for the most suitable land use as macro plan in Mae Klong head watershed area in the form of Watershed Classification and land use Regulation is proposed.

2.A water quality monitoring system should be continue for decade with only minor modification.

3. The water quality monitoring should not be limited to stream water quality only,but should also include hydrology,geohydrology,meteorology, and landuse as well as coordinating other human activities.

4.Data from water quality monitoring in head Mae-Klong watershed area should be integrated into watershed/environmental management planning for sustainable development of Mae Klong Watershed and its related resources.

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19 August 1996

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Dear Bill,

Enclosed is a hard copy and file on a diskette of my "paper" given at Suranaree University of Technology. As best I can recall, the text does reflect what I said.

If, after having read it, you believe that anything significant has been left out, I would be very happy if you would not tell me. Seriously, if you believe some changes are necessary, I will certainly consider any suggestions you might make. I hope that will not become necessary.

I also have included quite a few references, as numeous people mentioned that they would be really interested to see what other publications were pertinent to my talk.

I would be grateful if you could let me know by e-mail that you received this material. Trust that you have been able to enjoy the balance of the summer. When will TUNS take over Dalhousie, if that is still a possibility?

Best wishes.

Sincerely yours,

Bruce

Bruce Mitchell
Professor

INNOVATIONS IN WATER RESOURCES MANAGEMENT: THE CONCEPT OF INTEGRATED MANAGEMENT AND THE NEED FOR NEW CAPACITY IN PLANNERS AND MANAGERS

Presented at the International Seminar Workshop: Advances in Water Resources Management and Wastewater Treatment Technologies
Suranaree University of Technology
Nakhon Ratchasima, Thailand

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INTRODUCTION

This paper has a number of purposes. First, some suggestions are offered regarding desirable characteristics for people being educated to become water planners or managers with ability to design and implement an integrated approach. Second, the concept of integrated water management is described and analysed. Third, experience with implementing integrated water management in Canada is reviewed. Fourth, the strategic implications for water management are considered.

KEY CONCEPTS FOR HUMAN RESOURCE DEVELOPMENT REGARDING INTEGRATED MANAGEMENT

At the International Seminar Workshop, Mr. Boonchoo Treethong, Minister of University Affairs for Thailand, presented an opening address via teleconferencing technology. In his comments, the Minister indicated that the King of Thailand was interested in sustainable water management on a watershed basis because water is viewed as a basic requirement for life. The Minister also highlighted the need for developing mechanisms for the equitable allocation of

water, of requiring capacity to address both water quantity and quality issues, of improving understanding about the environmental impacts of water development projects, of creating effective partnerships for water management among universities, government agencies, the private sector, and non-government organizations, and for achieving coordination and collaboration among various agencies with responsibilities for water. In concluding, he indicated that he looked forward to seeing recommendations from the workshop.

The areas which the Minister identified as needing attention in Thailand, and his request for recommendations, lead to the following observations about desirable characteristics for future water planners and water managers. More specifically, it is suggested that education and training programs should prepare planners and managers to be able to deal with *change*, *complexity*, *uncertainty*, *conflict*, and *collaboration*.

It is becoming increasingly apparent that rapid *change* is one of the defining attributes of management situations. Indeed, when Alvin Toffler coined the phrase 'future shock", he did so from a belief that it was "the roaring current of change, a current so powerful today that it overturns institutions, shifts our values and shrivels our roots." Continuing, he observed that "change is the process by which the future invades our lives", and furthermore that "the concept of future shock - and the theory of adaptation that derives from it - strongly suggests that there must be balance, not merely between rates of change in different sectors, but between the pace of environmental change and the limited pace of human response. For future shock grows out of the increasing lag between the two" (Toffler, 1971, 1-4).

For water planners and managers, there are significant implications. First, the context for management can be best be characterized with words such as *turbulence* and *surprise*. Second,

given rapidly changing conditions, it is unlikely that an approach of rational comprehensive planning which leads to set master plans will be adequate for addressing water issues. Instead, we require approaches that emphasize capacity to be *adaptive*, exemplified by the approach known as "adaptive environmental management and assessment" (Holling, 1978; Walters, 1986). One of the best examples of an adaptive approach is the experience with the Columbia River basin in the Pacific Northwest of the United States (Lee, 1993: Volkman and McConnach, 1993).

The main point is that future planners and managers must be comfortable with continuously adapting and modifying relative to changing conditions. Furthermore, time must be spent in helping planners and managers to understand how they can become effective agents to induce positive change.

The ideas of change, turbulence and surprise are closely related to the concept of *complexity* (Waldrop, 1992). Indeed, the most important biophysical, economic or social problems today are often described as *messes* or *meta-problems*, or as *wicked problems*. In other words, it increasingly is being recognized that it is essential to understand interacting systems which collectively create management problems. As an example, flooding problems often are caused by activity on land, such as encroachment of flood plains, and removal of vegetation (trees and wetlands). Water pollution problems also usually originate from land-based activities, whether it be fertilizers, pesticides and herbicides being placed on agricultural fields, or waste being generated in homes, shops or factories in cities. Thus, whether dealing with flooding or pollution, the water manager must also address patterns of use on the land as well as deal with water systems.

The recognition of complexity has encouraged increasing attention to the use of an

ecosystem approach by water managers. Water managers should be comfortable with such a systems approach because they have always been trained to understand the unity represented by catchments or watersheds, and the hydrological cycle. However, notwithstanding such training, water managers too often have allowed their activities to become compartmentalized and fragmented, with clean water specialists rarely talking to dirty water specialists, and neither of them talking to specialists in urban planning, agriculture or forestry. Around the world, government agencies have often been structured with a focus on single resource sectors, such as forests, agriculture, minerals, fish, wildlife and water. The ecosystem approach requires attention to all relevant aspects of these interacting systems, and we are just learning how we can use the ecosystem approach in a practical and effective manner.

Uncertainty is another key concept closely related to the concepts of change and complexity (Dover and Handmer, 1992; Gibson, 1992). For water management, it is usual for situations to be characterized by incomplete information and imperfect understanding of the phenomena to be managed. Indeed, there are degrees of incompleteness, and Wynne (1992) argued that at least four categories can be identified: (1) risk, when we know the odds; (2) uncertainty, when we do not know the odds but may know the key variables and their parameters; (3) ignorance, when we do not know what we should know, and do not even know what questions we should be asking; and, (4) indeterminacy, when causal chains or networks are open, so understanding is not possible. It is important for water planners and managers to have the ability to recognize which of the four types of incomplete understanding is involved in a given problem-solving situation, as different approaches may be appropriate. For example, Collingridge (1983) has argued that different approaches (*hedging, flexing*) are appropriate under conditions

of uncertainty and ignorance. And, Gleick (1987) and Cohen and Stewart (1994) have indicated that the combination of complexity and uncertainty can lead to conditions best described as *chaotic*, and for which new strategies will be required.

The *Precautionary Principle* has emerged in the last five years as an increasingly accepted concept to deal with uncertain conditions. As Principle 15 from the Rio Declaration on the Environment and Development states

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scale scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The Precautionary Principle reminds managers that we must make decisions, even when we do not have complete understanding of the complex and rapidly changing systems with which we are dealing. Uncertainty should not be used as an excuse to postpone necessary but difficult decisions.

Conflict is a core element of management. Indeed, in many situations, water planners and managers are more likely to be managing the human interactions with aquatic systems than they are to be managing the aquatic system itself. When human interactions with aquatic systems are to be managed, then very quickly the salience of different but legitimate interests becomes apparent. Planners and managers need to be trained to view conflict as positive rather than as negative, and something to be used to identify weaknesses and to use as a departure point to find innovative solutions to problems. Fisher and Ury (1981) have argued that the used of principled rather than positional negotiation can help to overcome conflicts among groups. This will be discussed in more detail in a later section.

Finally, if change, complexity, uncertainty and conflict are central elements of water planning and management, then it follows that no one individual or agency is likely to have all of the expertise and understanding to develop solutions. Consequently, the ability and willingness to seek *collaboration* with other participants (individuals and organizations) will be increasingly needed for effective planning and management. Such an approach is characterized by words such as *stakeholders, partnerships* and *participatory planning*, and by growing efforts to incorporate *local* or *indigenous knowledge* with scientific understanding about water and related systems (Grimble and Chan, 1995: Hofmann and Mitchell, 1995; Selin and Chavez, 1995).

Thus, the water planners and managers of the future should be well prepared to deal with change, complexity, uncertainty, conflict and collaboration. If college and university programs do not introduce students to these concepts, we will be doing a dis-service to the people we are trying to prepare to develop plans and strategies, and to participate in decisions, about water resources management and development.

CONCEPT OF INTEGRATED WATER MANAGEMENT

The concept of integrated water management has not been well defined (Mitchell, 1990; Downs, Gregory and Brookes, 1991; Born and Sonzogni, 1995; Margerum and Born, 1995; Montgomery, Grant and Sullivan, 1995). However, at a basic level, integrated water management involves joint consideration of water quantity and quality; surface and ground water; water, land and other environmental resources; and, water related to economic and cultural systems. In other words, an integrated approach stipulates that aquatic systems be addressed in a *holistic* manner, and that is often best done through an *ecosystem approach*.

A catchment, river basin or watershed often serves as the most appropriate spatial unit for

an integrated approach, since decisions or actions taken in the upper part of a catchment can have direct consequences for the downstream environment and people. However, it is important to remember that the boundaries of a surface catchment may not be the same as the boundaries of one or more connected aquifers. As a result, if an integrated approach is to include the links between surface and ground water, we should not get so focused upon the surface catchment that we overlook the complexity of relationships with ground water systems.

We also need to recognize that a catchment cannot be isolated from larger ecosystems of which it is a part. For example, the Great Lakes basin in North America represents a watershed. However, if all significant aspects of water quality are to be addressed within that ecosystem, it is necessary to understand that considerable long-range transport of air pollutants, specifically acid rain, is generated by industrial activity in the Ohio and Tennessee River valleys, which are catchments "outside" of the Great Lakes basin. Thus, concentration only on the Great Lakes ecosystem will not be sufficient to address the water quality challenges there. Such an example reminds us that there are hierarchies of ecosystems, with smaller systems being embedded within larger ones. In determining the most appropriate spatial unit for management, we must be sensitive to such hierarchies.

Integrated water management is not a revolutionary or new concept. It was endorsed as the first of four basic principles at the International Conference on Water and the Environment (also known as the Dublin Conference) in January 1992, which was the key lead-in meeting for water management prior to the Earth Summit in Rio de Janeiro in June 1992. The Dublin Conference attracted over 500 participants from 114 countries, 28 United Nations agencies and bodies, and 58 non-government and inter-governmental organizations. The principles which were

developed and endorsed at the Dublin Conference are shown in Table 1. The important point here is to appreciate that integrated water management was endorsed as *the* fundamental principle for water management for the twenty-first century.

In parallel with the four Dublin Principles, other countries have developed guidelines for sustainable water management, which also emphasize the importance of an integrated approach (Mitchell and Pigram, 1989; Mitchell and Hollick, 1993; Ontario, 1993a and 1993b; Orie, 1996; Watson, Mitchell and Mulamoottil, 1996). Table 2 shows the sustainability principles for water management in Canada developed by the Canadian Water Resources Association, the major non-government water management organization in that country. As with the Dublin Principles, the concept of an integrated approach is the first and fundamental principle.

If it is agreed that an integrated approach has been accepted in or is being advocated by many countries, then it is appropriate to consider what we know from experience in actually implementing the concept.

LESSONS FROM CANADIAN EXPERIENCE WITH INTEGRATED APPROACHES

Canada has considerable experience with an integrated approach to watershed-based management (Child and Armour, 1995). For example, in 1946, the Ontario Conservation Authorities were established as resource management agencies based on river basins, were created only when local initiative was involved, and included partnerships of municipal and provincial governments (Mitchell and Shrubsole, 1992). During the 1970s, the federal and provincial governments collaborated in various joint comprehensive river basin planning exercises across the country (Mitchell and Gardner, 1983). During the 1980s, Canada shared in the development of RAPs, or Remedial Action Plans, with the United States to address water quality problems in

strategically selected coastal ecosystems in the Great Lakes basin (Hartig and Zarull, 1992). And, in the 1990s, notable initiatives were the initiation of the Fraser River Action Plan in British Columbia as a joint federal-provincial-local government venture (Dorcey, 1991a and 1991b; Pomeroy, 1995), the completion of the analysis of the Toronto city waterfront based on a bioregional approach (Royal Commission on the Future of the Toronto Waterfront, 1992), and the introduction of a subwatershed planning process in Ontario (Ontario, 1993a and 1993b; Hardy et al, 1994). These are but some of the experiences from Canada, and Kate Moir will be providing further comments about experiences in both the Atlantic Canada provinces, and Alberta.

A number of general lessons have been learned from the experience of implementing an ecosystem-based approach to water management. First, it is important to differentiate between a *comprehensive* and an *integrated* interpretation of an ecosystem-based approach (Mitchell, 1983; 1990). A *comprehensive* interpretation, used in the 1970s and early 1980s in Canada, strives to understand the entire ecosystem, by conducting an analysis which is as complete (comprehensive) as possible regarding all the variables and connections within a watershed. It was found that such an approach usually resulted in the following problems: (1) studies took an average of three years to complete, with the outcome that they often were not helpful tools for addressing problems since conditions often changed over the period in which the study was done, making them more academic that practical documents, (2) given the broad scope of the analysis, the recommendations were often too many and undifferentiated, leaving managers with little sense of relative importance and priority among the actions being suggested, and also little sense of a logical sequence for implementation of the many recommendations, (3) the recommendations too

often did not relate to the financial capacity of government agencies responsible for implementation, and therefore were beyond the means of governments to implement, and (4) often, there was not an appropriate implementing organization which could take a basin-wide perspective relative to the recommendations which usually touched upon a number of resource sectors.

Another point which emerged was that if public participation or consultation were to be a core component of comprehensive river basin planning, then, using conventional methods of consultation, considerable time was needed to facilitate collecting information, sharing it with the public, and obtaining further information and commentary from the public about priority issues and problems, and preferred solutions. And, yet, at the same time there were growing complaints that the comprehensive watershed planning process was taking too long, and pressure was mounting to find ways to accelerate the process in order to reduce the time needed for analysis and planning. This situation generated debates about the role of and most desirable methods for public involvement.

Based on the perceived problems with a *comprehensive* interpretation of an ecosystem or holistic approach to watershed management, some people began using the term *integrated*. The distinction was that an integrated approach was more selective and focused, while still maintaining attention to systems, components within a system, and the connections among the components. In other words, it was argued that it was not necessary to study all the variables and relationships within a basin because, due to uncertainty and complexity, it would never be possible to understand all the causes of variation in a system. Indeed, it was argued that often a small number of variables account for a large portion of the variation in a system, and that therefore if those

variables could be identified and understood, then that would be sufficient for most planning and management purposes. The extra time and effort required to understand the many other variables which collectively contributed to a relatively small amount of variation in the system were difficult to justify, when it was accepted that systems were changing anyway and contained considerable uncertainty. It was argued that if by understanding 20 percent of the variables we could account for 80 percent of the variation in a system, we usually could develop a management strategy that would be more than sufficient and adequate. The experience during the 1990s in Ontario with subwatershed planning directly reflects the attempt to become more focused and practical in catchment-based planning and management (Hardy et al, 1994).

In summary, therefore, experience in Canada indicates that an ecosystem-based approach is appropriate if we are to overcome the traditional fragmented jurisdiction of roles and responsibility for water management in a state or country. However, a more practical and productive interpretation is one of *integrated* (focused and selective, but system based) rather than *comprehensive* (complete and all inclusive). This distinction is not simply an academic playing with words, but has profound implications for determining the expectations and scope of an ecosystem-based analysis of water and related systems.

IMPLICATIONS

If an integrated approach to water management is to be implementable, experience suggests a number of considerations deserve attention. These are identified in Figure 1, and each is discussed below, based on Mitchell (1990). It is important to emphasize here that all of the following matters deserve attention. Effective handling of any one will usually not be sufficient to ensure the effective implementation of integrated water management.

Context: It is important to recognize that there is no single model for an integrated approach. Effective implementation requires attention and sensitivity to conditions in a place and time, emphasizing the need to custom design to meet the needs in a local situation. In that regard, it is important first to give attention to the *state of the natural environment* to determine which aspects (scarcity of water? degradation of quality?) deserve priority attention. Second, awareness of prevailing *ideologies* is necessary, as these should influence the choice of goals, objectives and strategies, and particularly the potential roles for the public and the private sectors. Third, *economic conditions* are important, since they often influence the (un)willingness to consider new ideas or to take initiatives. Approaches should never be designed in isolation from the economic reality affecting potential implementing organizations. Fourth, consideration should be given to *legal*, *administrative* and *financial* arrangements, as these provide both opportunities and constraints on what may be possible.

Legitmation or Credibility: The concept of integrated water management will remain as an ideal unless there is visible and substantive commitment to have it implemented. Commitment can take a number of forms, and the goal for those interested in using an integrated approach is to strive to ensure that as many sources or types of commitment as possible are obtained.

Political commitment is extremely important, and involves ongoing interest and public commitment by the hereditary, appointed or elected leaders in a jurisdiction. If the King of Thailand or the elected leader (President, Prime Minister) in a jurisdiction publicly declares support for the concept, and indicates that he or she expects it will be used during water planning and management, then legitimacy is provided. Another source of credibility comes from *statutory* or *legal* support for the concept. If a law stipulates that public agencies will use an integrated

approach, then any agency encountering opposition to its use of the concept can point to the law as justification for using an integrated approach. A third source of legitimacy can be an *administrative* or *bureaucratic* policy which stipulates that an organization or agency will use an integrated approach. And, a fourth source is *allocation of financial resources* to support integration. Ideally, legitimation or credibility is highest if an organization can point to all four sources as the rationale for using an integrated approach. Conversely, if none of those exists, the probability of successfully implementing an integrated approach will be low. And if only one source of credibility is in place, those interested in seeing an integrated approach being used need to consider how they might be able to obtain one or more of the other sources of credibility.

Functions: Often there is confusion or lack of clear thinking about which management functions should be integrated. It does not always follow that all management functions should be "integrated" within one agency. For example, in many nations there is a tradition of separating development, regulatory and enforcement functions, in order to provide credibility for the organization responsible for enforcement. It usually is not viewed as credible if the development agency is required to regulate itself.

There is also the issue as to how management functions might be shared between the public and the private sector. For example, commodity-like functions of water management, such as the provision of potable water, or the collection and treatment of sewage and waste, could conceivably be handled by the private sector as in both situations there is a measurable commodity which must meet specified quality standards. Allocating such functions to the private sector would not be a decision to destroy an integrated approach, as long as those functions were designed to fit into an overall management system. In both France and Britain, water supply and

sewage collection/treatment functions are handled primarily by the private sector.

Another consideration is which functions are allocated to central governments, and which ones to regional or local levels of government. A practice which is gaining increasing support is to allocate management functions to that level of government which is closest to the users of the service, on the belief that such an arrangement will require the provider of the service to be most sensitive and responsive to the needs of the users. Again, such a division of functions among various levels of government, or between levels of government and the private sector, need not be viewed as being counter to an integrated approach, as long as there is an overall design or perspective to establish how they link with one another.

The functions that need to be considered relative to integration can be divided into two kinds. First, there are *generic* functions, such as policy development, data collection, planning, development, regulation, monitoring, and enforcement. Second, there are *substantive* management functions which include water supply, sewage treatment and collection, pollution control, flood damage reduction, erosion control, drainage, wetland protection, navigation, hydroelectric production, recreation and other non-consumptive uses, and industrial production. The purpose should be to align various functions as effectively as possible to the different scales or hierarchies of management to which they can be most effectively managed.

Structures: Administrative structures normally should be established after arrangements have been made for management functions. However, in reality, there always is a historical legacy of administrative structures which often constrain how management functions will be divided among or be allocated to various agencies.

However, there are basic choices between at least two extremes on a continuum. At one

end of the continuum, there could be one or a small number of highly centralized and large multiple-purpose agencies. The perceived benefits of such a structure would be economies of scale as a result of size, and the realization of coordination by facilitating discussion within an organization. The disadvantages may be that an organization becomes so big that it becomes slow and cumbersome in making decisions, and that it becomes too far removed from the people or constituents that it is intended to serve.

The alternative at the other end of the spectrum is to have a large number of highly decentralized and single-purpose agencies. The benefits would be streamlined agencies that can react quickly to problems and opportunities, and that are able to maintain close contact with their clients. Furthermore, a large number of agencies ensures that each can watch and be a built-in critic of other agencies, and in that way no organization can become unduly powerful. The disadvantages are that economies of scale may be lost or foregone, and the nature of criticism and competition may become counter productive.

The key point regarding structures it to recognize that there alternatives, and that no structure is perfect. More importantly, no structure deals well with what are called *edge* or *boundary* problems, or those problems which overlap the interests and mandates of more than one organization. Re-arranging structures never eliminates such problems, but simply moves them from being *inter-organizational* to being *intra-organizational* problems. As a result, governments' propensity for continuous structural reorganization is often wasteful, if the purpose is to improve the capacity to deal with edge or boundary problems. Structural changes by themselves will never be adequate to deal with such issues. They can be part of the solution, but not the entire solution.

Processes and Mechanisms: The most careful design of functions and structures can never assure that there will not be "loose ends" or poor fits. As a result, it is necessary to determine how various processes and mechanisms can be used to bridge or handle such poor fits. At the *political* level, it is possible to use inter-ministerial councils or commissions of elected officials to search for and achieve coordination of the policies and actions of various agencies. Elected officials also can become members of committees of investigation to examine the performance of public agencies relative to a specific problem, or to consider what changes might be made.

At an *administrative* or *bureaucratic* level, interdepartmental committees often are used to provide a forum for public servants to consider how to harmonize and coordinate policies, programs and activities. There always is a danger, however, that such committees have little power or influence, or will be unable to make hard or clear decisions. With regard to the latter aspect, Paterson (1986: 101) has described them as the "interdepartmental committee of fudges and compromises" which are usually ineffective.

Various processes also can be used to ensure that edge or boundary issues receive systematic attention. Some of the usual processes include *public participation*, *environmental impact assessments*, *environmental audits* (about which John Underwood will have more to say), and *life-cycle assessment*. One or more of these processes or techniques can be incorporated into planning or management, to help cross over issues which transcend the interests of various departments.

Organizational Culture and Participant Attitudes: No matter what amount of attention and effort is devoted to designing legitimation, functions, structures, or processes and mechanisms, it will be people working in organizations who will have to make an integrated approach successful.

Table 2

CANADIAN WATER RESOURCES ASSOCIATION SUSTAINABILITY PRINCIPLES FOR WATER MANAGEMENT IN CANADA

SUSTAINABILITY ETHIC

Wise management of water resources must be achieved by genuine commitment to:

* ecological integrity and biological diversity to ensure a healthy environment;
* a dynamic economy; and
* social equity for present and future generations.

WATER MANAGEMENT PRINCIPLES

Accepting this sustainability ethic, the CWRA will:

1. Practice integrated resource management by:
* linking water quality, quantity and the management of other resources;
* recognizing hydrological, ecological, social and institutional systems; and
* recognizing the importance of watershed and aquifer boundaries.

2. Encourage water conservation and the protection of water quality by:
* recognizing the value and limits of water resources, and the cost of providing it in adequate quantity and quality;
* acknowledging its consumptive and non-consumptive values to both humans and other species; and
* balancing education, market forces, and regulatory systems to promote choice and recognition of the responsibility of beneficiaries to pay for the use of the resource.

3. Resolve water management issues by:
* employing planning, monitoring and research;
* providing multi-disciplinary information for decision making;
* encouraging active consultation and participation among all members of the public;
* using negotiation and mediation to seek consensus; and
*ensuring accountability through open communication, education and public access to information.

Source: Mitchell and Shrubsole, 1994: 5

for Business Excellence have been won by the Centre. The paper concludes that "strong market pull" is the most important ingredient of success in technology transfer. Universities should preferably invest technology transfer dollars in protection of intellectual property. Key words: technology transfer, intellectual property, biotechnology, polymer technology, grain drying, ash monitoring.

EDWARD (TED) RHODES, PH.D., P.ENG.

Dr. E. (Ted) Rhodes was appointed President of the Technical University of Nova Scotia in January 1994. Between 1990 and 1993, he was Dean of Engineering at the University of Calgary. Previously he was Corporate Vice-President, Technology of Polysar Ltd., a major international petrochemical company. His role in industry included leadership in acquisition and development of new technology, commercialization, strategy development of technology-based companies, and international joint ventures.

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Marine Vessel Design
Fish. Tech
Water Resources
Vehicle Safety
Minerals Engr

Library Service for Engr, Comp Sci

Continuing Educ – (life-long learning)
comp + indiv pay –

Computer + Com. Services

TUNS – President's Associates Prog Fund 1994
(1000 $ fee)

Pres + Pg make presentations –

Centre for Process Dev (Chem Engr)

Must be market-pull rather than researcher-push
go out + sell to univ – market the univ
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Organizational Culture and Participant Attitudes: No matter what amount of attention and effort is devoted to designing legitimation, functions, structures, or processes and mechanisms, it will be people working in organizations who will have to make an integrated approach successful.

As a result, it essential that such people are prepared to deal with change, complexity, uncertainty, conflict and collaboration, and especially with the latter two. A "culture" within management organizations has to be created, nurtured and maintained which gives priority to sharing, openness and transparency, rather than upon competition, protection of "turf", and building of "empires". For example, as Grindle and Hilderbrand (1995: 444) have observed,

> ... organizational culture is more important as a determinant of performance than structures for remuneration and control. Most organizations that perform well are ones that have cultures stressing flexibility, problem-sovling, participation, teamwork, shared professional norms and a strong sense of mission. Moreover, despite the evidence that the roots of performance deficits often lie outside the purview of specific organizations charged with accomplishing specific tasks, organizational culture can compensate for constraints that are rooted in more general problems.

Leadership at the highest political and administrative levels regarding the need for sharing and mutual support, and therefore of coordination and collaboration, become very important for an integrated approach. Conversely, when such commitment of leaders is absent, the task of implementation becomes even more challenging than it normally is (Mitchell, 1994). Furthermore, it unfortunately is the situation that "much of the so-called conflict is nothing but self-indulgent skirmishing, deriving out of a system which has provided little or no alternative" (Eddison, 1985: 150). However, as Senge (1996: 56-57) has noted, the necessary change will not occur if only hierarchial authority is relied upon. In his words, for complext issues "there are no simple causes, no simple "fixes." There is no one villain to blame. There will be no magic pill. Significant change will require imagination, perseverance, dialogue, deep caring, and a willingness to change...".

Regarding conflicts which may emerge, we should not forget that "most decisions

involving water resources are made on the basis of bargaining, negotiation and compromise" (Ingram, Mann, Weatherford and Cortner, 1985: 328). In this regard, it is important that water planners and managers develop mediation and negotiating skills, especially related to conflict resolution (Dorcey, 1986; Handmer, Dorcey and Smith, 1991). In that regard, the work of Fisher and Ury (1981) regarding principled negotiation is worthy of more attention by water professionals. They argued that in dealing with conflicts it is important to (1) separate the people from the problem, and be hard on the problem but soft on the people, (2) distinguish between positions and interests, (3) search for solutions which provide mutual gain, and (4) make choices relative to pre-determined and agreed upon "objective" criteria. These types of guidelines for bargaining, and thereby the resolution of conflicts, are teachable skills, which once learned can be very supportive of an organizational culture and participant attitudes which reinforce sharing, collaboration and coordination. It is urged that water management organizations therefore should devote more resources to help staff receive training in such bargaining skills.

Overview: Attention to each of context, legitimation, functions, structure, processes and mechanisms, and organizational culture and participant attitudes is important if the ground work is to be laid which will be lead to the successful implementation of an integrated approach. The value of such a framework or checklist also can be to help remind us that we must continuously be scanning for those leverage points or conditions which can be strengthened in order to enhance the likelihood of effective integration.

CONCLUDING REMARKS

At the opening of the International Seminar Workshop, Dr. Wichit Srisa-an, Rector of Suranaree University of Technology (SUT), explained that at SUT there was great interest in

water management, sustainable development and an ecosystem approach. In this paper, ideas and experience associated with integrated water management have been identified and examined, in the spirit of sharing one Canadian's perspective on how it might be possible to be more effective in water management, and thereby achieve sustainable development and an ecosystem approach. Key requirements in that regard are to ensure that we have well educated people who are conversant and comfortable with change, complexity, uncertainty, conflict and collaboration. In addition, it is suggested that an integrated rather than a comprehensive interpretation of an ecosystem or holistic approach is more likely to result in practical way to address water planning and management problems. It is hoped that some of these ideas will be of use as people in Thailand consider what should be in the university curriculum for programs related to water planning and management, and what ideas and approaches should be emphasized in actual water planning and management.

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Table 1

THE DUBLIN STATEMENT ON WATER AND SUSTAINABLE DEVELOPMENT

GUIDING PRINCIPLES

Principle No. 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment areas or groundwater aquifer.

Principle No. 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

Principle No. 3: Women play a central part in the provision, management and safeguarding of water.

This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water management programmes, including decision-making and implementation, in ways defined by them.

Principle No. 4: Water has an economic value in all its competing uses and should be recognized as an economic good.

Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmental damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

Source: Young, Dooge and Rodda, 1994: 162

Christophe HAUNOLD

born 30 March 1966, French

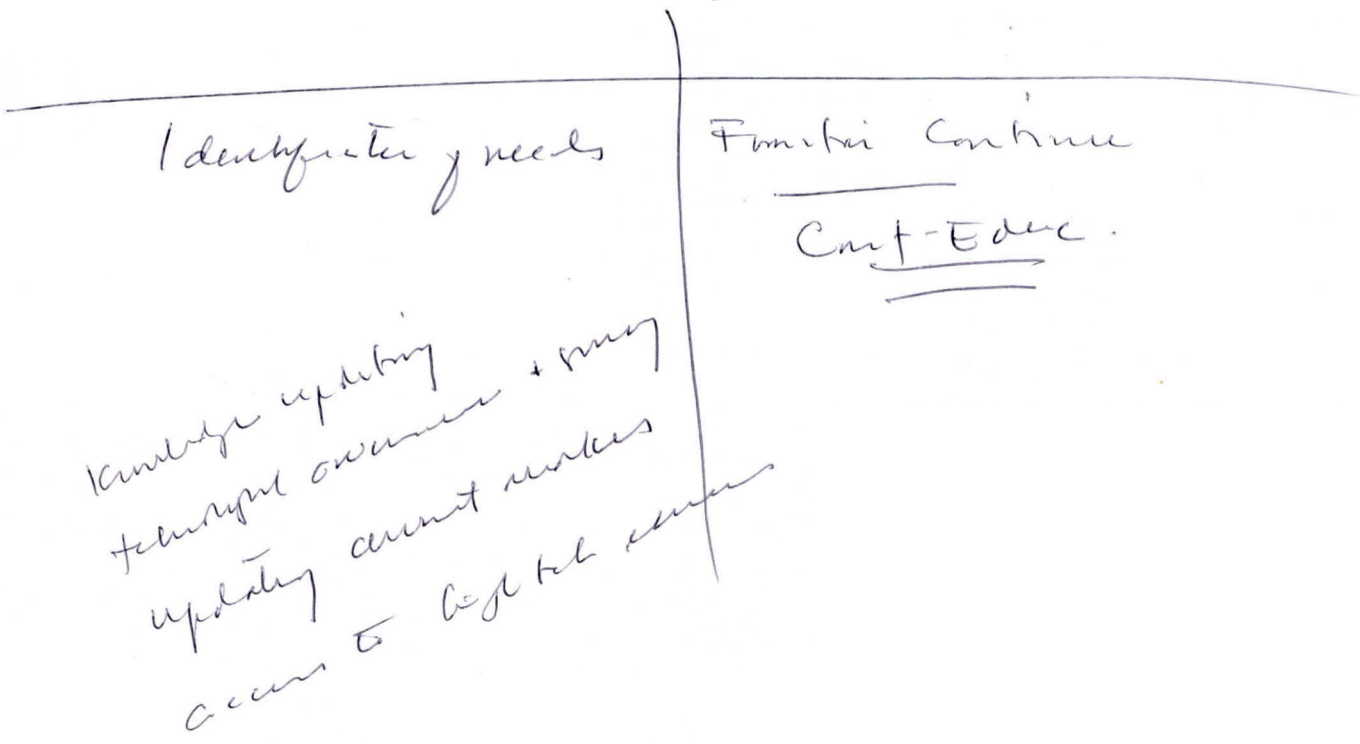
Chemical Engineer (1985, ENSIGC Toulouse)

Doctor in Process Engineering (1991)

Research experience in England
Industrial experience during the PhD (partly financed by a private company)

Assistant to the Scientific Counsellor at the French Embassy in Australia (1991-1992)
Participation to the design of an Industrial Research scheme between france and Australia (FAIR program)

Industry Liaison Officer at INP Toulouse since 1992
Contracts, Patents
Cooperation with mediteranean countries on Methodologies for Technology Transfer



CV. Michel Khalil

B.s. Chemistry & Botany

M.Sc. Organic Chemistry University of Alexandria Egypt

Ph.D. 1970 Chemistry of Natural Products Laval University Canada

1970-1992 Professor of Chemistry and Chemical Oceanography at the Universite Du Quebec at Rimouski (UQAR)

Since - 1992 Acting Director of Division BUREAU Industry University

-Responsible for the cooperation between Biotrop Center at Bogor-Indonesia, SEAMEO and UQAR

-Coordinator of a Research Project on Water Quality Management Related to the Aquaculture of Shrimp in Indonesia

-in cooperation with a Canadian Wastewater Treatment Company in Montreal "Queneco" and on their behalf Dr. Khalil will present this conference titled: Advances in Wastewater Treatment Technologies used in Canada

driving force:

- popularization – clientele bigger 25
- liberalization – self-suff
- internationalization
- modernization

1:15
25
1:40

a/Person session

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EDUCATION

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M.S. in Civil Engineering (1975), University of Texas at Arlington, Arlington, Texas, USA

B.Eng. in Civil Engineering (1971), Khonkaen University, Khonkaen, Thailand

PROFESSIONAL BACKGROUND

Professional Engineer Registration in Thailand and in the States of Texas and Pennsylvania, USA

November 1993 - Present Assistant Professor
Assistant Rector for Academic Affairs and
Chair, School of Civil Engineering
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Suranaree University of Technology
Nakhonrachasima 30000, Thailand

May 1992 - October 1993 Faculty Member and
Director of The Graduate Study Program
Civil Engineering Department
Rangsit University
Phatumthani, Thailand

Direct the Civil Engineering Graduate Study Program. Course teaching includes Prestressed Concrete Design and Building Design.

July 1992 - October 1993 Senior Consulting Engineer
49 Engineering Consultant Ltd.
Bangkok, Thailand.

Consulting for the Structural Design Department. Responsibility includes reviewing the structural design concepts, structural design methods and calculations, and structural details for a large scale and high-rise buildings

October 1990 - April 1992 Engineering Director
Pead Corporation Limited
Bangkok, Thailand.

Direct the Structural Design and Construction Management Departments.

May 1990 - Nov. 1990 Senior Engineer
Project Planning Service Co., Ltd.
Bangkok, Thailand.

Structural Advisor for a Construction Management Company.

January 1987 - May 1990 Assistant Professor
Department of Civil Engineering
Villanova University
Villanova, Pennsylvania, USA.

Undergraduate course teaching includes Statics, Mechanics of Materials, Structural Mechanics, Reinforced Concrete Theory and Design I, and Reinforced Concrete Theory and Design II. Graduate course teaching includes The Behavior and Design of Reinforced Concrete, Prestressed Concrete Design, and Structural Masonry and Timber Design.

January 1981 - Dec. 1986 Structural Engineer
Barnes and Associates Structural Engineers Inc.
Arlington, Texas, USA.

Six years of structural design experience. Design of highway bridges, commercial, industrial, institutional, and residential buildings. Design experience included steel, reinforced concrete, Prestressed concrete, masonry, timber, and structural light gage steel structures. Responsibility includes managing the design department, contract drawing coordination, structural shop drawing review, and field inspection.

January 1979 - Dec. 1980 Graduate Teaching Associate
The University of Texas at Arlington
Arlington, Texas, USA.

Taught undergraduate courses in Statics, Mechanics of Materials, and Material Laboratory.

August 1977 - Dec. 1978 Graduate Research Associate
The University of Texas at Arlington
Arlington, Texas, USA.

One of teams that worked to provide research documents of Remedial Measures for Houses Damaged by Expansive Clay. The project sponsored by the US. Department of Housing and Urban Development.

January 1976 - July 1977 Graduate Research Assistant
The University of Texas at Arlington
Arlington, Texas, USA.

Conducted the experimental research in the area of Fiber Reinforced Concrete and Mortar. The project sponsored by the PPG Industries Inc.

July 1971 - July 1974 Engineer
Planning Division
Highway Department
Bangkok, Thailand

One of teams that worked on a feasibility study of highways and bridges in Thailand.

TECHNICAL REPORTS AND PUBLICATIONS

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Sriboonlue, W., and Matthys, J.H. , "Torsional Behavior of Reinforced Brick Masonry Beams, " Journal of Structural Engineering, American Society of Civil Engineering (ASCE) , Vol. 116, No. 6, June 1990. The paper was selected by the ASTM C-15 Committee to be the 1990 best publication published internationally in the English language on masonry. The Alan H. Yorkdale Award presented in June 27, 1991, Atlantic City, New Jersey.

Sriboonlue, W., Wallo, E.M., "The Effect of Constituent Proportions on Tensile Strength of Portland Cement - Line Mortar and Grout," Proceeding, The Fifth North American Masonry Conference, University of Illinois at Urbana-Champaign, Illinois, June 1990.

AWARDS

1988 Farrell Award

In recognition of the outstanding service to the College of Engineering, Villanova University, Villanova, Pennsylvania, USA

1990 Alan H. Yorkdale Memorial Award

In recognition of the outstanding paper concerning masonry published in the English language during the perlod from July 1, 1989 to June 30, 1990. The Award presented by the American Society of Testing and Materials (ASTM) through Committee C-15 on Manufactured Masonry Units.

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- Graduated in Economics at E.S.S.E.C. Business School (Paris, France) M.A. in Regional Economics at the Wharton School of Finance, University of Pennsylvania, U.S.A.
- With the city planning agency of Toulouse (France), started The Science Park of Labege-Innopole in 1974-1980
- Worked in Industrial and Technological Development with the Region (Midi-Pyrenees, France), Then with the Government (Ministry of Industry, Paris). was in the staff of the Minister of Energy (84.86)
- Started a software company specalized in artificial intelligence in 1988- Fields of Application: Space, Automobile, Telecom, Medicine...was CEO until 1994
- Since 1994, manager of Sicoval, an association of cities near Toulouse develops and runs the Science Park of Labege-Innopole.

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- GRADUATED IN ECONOMICS AT E.S.S.E.C. BUSINESS SCHOOL (PARIS, FRANCE)
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- WITH THE CITY PLANNING AGENCY OF TOULOUSE (FRANCE), STARTED THE SCIENCE PARK OF LABEGE-INNOPOLE IN 1974 TO 80
- WORKED IN INDUSTRIAL AND TECHNOLOGICAL DEVELOPMENT WITH THE REGION (MIDI-PYRENEES, FRANCE), THEN WITH THE GOVERNMENT (MINISTRY OF INDUSTRY, PARIS).
  WAS IN THE STAFF OF THE MINISTER OF ENERGY (84-86).
- STARTED A SOFTWARE COMPANY SPECIALIZED IN ARTIFICIAL (Artificial) INTELLIGENCE IN 1988 - FIELDS OF APPLICATION : SPACE, AUTOMOBILE, TELECOM, MEDECINE... WAS CEO UNTIL 1994 (SPACE, MEDECINE, CEO)
- SINCE 1994, MANAGER OF SICOVAL, AN ASSOCIATION OF CITIES NEAR TOULOUSE (cities NEAR Toulouse), DEVELOPS AND RUNS THE SCIENCE PARK OF LABEGE-INNOPOLE (Develops, RUNS, LABEGE).

BIODATA

Peter Brimble and Chatri Sripaipan

Peter Brimble. Dr. Brimble is the President of The Brooker Group Ltd., one of Thailand's foremost business and policy research consulting operations. He is an economics graduate from the London School of Economics, Georgetown University, the University of Sussex, and Johns Hopkins University. His Ph.D. thesis examined the productivity performance of Thai manufacturing firms.

A British national, Dr.Brimble has worked as an industrial policy analyst at the World Bank, a visiting professor at Thammasat University, a partner in SEAMICO Ltd., and an advisor to many sections of the Thai government. In the past 10 years, he has carried out extensive research on industrial and technological development issues in Thailand and the region-working for various agencies, including the International Finance Corporation, the Asian Development Bank, the Harvard Institute for International Development, the United Nations, and the Thai Board of Investment. He has served as advisor to a number of private companies and senior Thai policy makers, interpreting the impacts of industrial development and related policies on private business.

Dr. Brimble presently serves as team leader on a major Asian Development Bank project looking at the science and technology higher education sector in Thailand, focusing in particular on ways to enhance linkages between universities and the productive sector. He has also been actively seeking to promote cooperation between university in the Greater Mekong Subregion as a means to accelerate economic cooperation and social development.

Chatri Sripaipan. Dr. Chatri Sripaipan is an Associate Professor in the Department of Electrical Engineering of Chulalongkorn University, where he is presently serving as Head of the Department. He received his education in electrical engineering at the bachelor's and master's levels in Australia and completed his Ph.D. in the United States in 1976 after a short teaching stint.

Since 1980, he became more and more involved in policy research work, particularly in electronics and engineering industries and issues relating to science and technology. Between 1986 to 1989, he served as the first Director of Chula Unisearch--The consultancy arm of Chulalongkorn University. After that he took up the position of Program Director of the Science and Technology Development Program at the Thailand Development Research Institute, where he conducted policy research on many issues including science and technology policy, industrial policy, S&T manpower, etc. In September 1993 he returned to his present position at the University.

Building on his long-time interest in promoting collaboration between universities and the productive sector, Dr. Chatri recently carried out research for the Asian Development Bank on university-industry linkages as part of a major research profect focusing on science and technology higher education in Thailand.

CV of Dr.Bruce Mitchell :

Dr. Mitchell is Professor of Geography at the University of Waterloo, Waterloo, Ontario, Canada. He has 30 years of experience in Canadian and Global watershed management, has been active in international development, and is a past president of the Canadian Water Resources Association. He has just completed a 2-month assignment as a water advisor in Indonesia.

CV of Dr. Catriona Moir :

Ms. Moir is presently Manager, Ecosystem & Risk Assessment for the Nova Scotia Department of Environment. Prior to assuming her present position she was been employed as senior policy advisor, municipal planner, assistant manager of the Shubenacadie- Stewiacke River Basin Board, and the Alberta Water Resources.

CV of Prof. Dr.Chongrak Polprasert :

Prof. Dr. Chongrak is presently Professor of Environmental Engineering at Asian Institute of Technology.He has long experience in Water and Wastewater Engineering and Environmental Technology and Management. He has been awarded by the National Research Council of Thailand, "The Outstanding Researcher Award in Engineering and Industry" in 1995.

Remarks.

have not received CV. of Dr. Khalil

CV of Dr. Songtam Suksawang

Dr. Songtam Suksawang is the Chief of Mae-Klong Watershed Research Station, Forest Environment Research and Development Division, Royal Forest Department. He is also lecturer of Kasetsart University, Chiang Mai University and Mahidol University.

During last 12 years, his research interest has been in Watershed Management, Forest Hydrology, Ecology, and Forest Environmental issues. Now, he is going on the research project with Science and Technology Agency (STA) of Japan.

FOR DR. SAM-ARNG SRINILTA, Vice Rector for Academics

INTRODUCTION OF MR. PRAMOTE MAIKLAD

for the SEMINAR ON WATER RESOURCES MANAGEMENT AND WASTEWATER TREATMENT

Mr. Pramote Maiklad is presently an Inspector General from the Office of the Permanent Secretary, Ministry of Agriculture and Cooperatives, Thailand. He hails from Bangkok.

After obtaining an honors Bachelor's degree in Irrigation Engineering from Kasetsart University, he pursued an M.S. degree in the same field of Irrigation Engineering at the University of California.

He started his professional career in 1968 as an Engineer of the Academic Division of the royal Irrigation Department of the Ministry of Agriculture and Cooperatives. With his strong academic preparation and dedication to work, he climbed the professional ladder and in recognition for his achievements, he was appointed in 1993, Chief Engineer for Special Affairs of the Royal Irrigation Department where he took responsibility for the Water Resources Development Project of the Royal Initiative Project. He will include in his presentation some of the major activities of the said project.

His work has brought him for training and study tours to many countries like Australia, Japan, Chile, Canada, Korea and Spain, just to mention a few. He is a member of may government committees involved in water resources development.

As an adherent of the value of life-long education, he still found time inspite his heavy schedule, to further his studies and in 1994 he was awarded a Ph.D. degree in Engineering by King Mongkut Institute of Technology, North Bangkok.

Ladies and Gentlemen, it is my pleasure to request Mr. Pramote Maiklad to present his keynote address.

Thank you.

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CLOSING REMARKS: PROF.DR. WICHIT SRISA-AN
SEMINAR ON WATER RESOURCES MANAGEMENT AND WASTEWATER TREATMENT,
25 JULY 1996

Distinguished Paper Presenters and Participants, Ladies and Gentlemen

I would like, on behalf of Suranaree University of Technology and on my own behalf, to congratulate and thank the paper presenters, participants and organizers, for their invaluable contributions to the success of ~~the to be concluded~~ this seminar international seminar on Advances in Water Resources Management and Wastewater Treatment Technologies. Therefore, please accept SUT's and my personal appreciation and gratitude.

I also would like to thank the administrators and staff of SEAGATE, Lam Thakong Reservoir and Jim Thompson Silk Factory for their hospitality and assistance during the visit of the participants as part of the field trip.

It is with regret that other equally important engagements in Bangkok, prompted my absence for two days during the seminar. I was, however, kept updated of the informative and scholarly papers presented by both foreign and Thai participants.

I share with H.E. Minister Boonchoo Treethong, the eager anticipation of receiving the publication of the Proceedings the soonest possible for an even greater sharing of the experiences and ideas presented by those unable to personally participate in this seminar.

I hope this seminar also would lead not only to sustained water resources development but more importantly to sustained bonds of friendship and spirit of cooperation for advancement of science and technology and the improvement in the quality of life in the region.

I hope the cultural show last Monday evening and the fieldtrip yesterday not only allowed for the participants to know better each other and the SUT staff, but it also enabled our guest from abroad and other regions of Thailand to have a glimpse of the rich Thai

LIST OF PARTICIPANTS

International Seminar Workshop on Advances in Water Resources Management and Wastewater Treatment Technologies

22-25 July 1996

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5.	Ms.Luisa Umaly UGAT, Anthropological Association of the Philippines	Philippines	R.M. 208 Philippine Social Science Center Commonwealth Ave. U.P. Diliman, Quezon City Philippines 1101 Fax:920-2197
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7.	Dr. Lourdes Agbing Graduate Dean Miriam College	Philippines	
8.	Ms. Lennie Borja Miriam College	Philippines	
9.	Ms. Vilma Umaly Miriam College	Philippines	

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10.	Prof. Andriano A. Bordalo Instituto de Ciencias Biomedicas De Abel Salazar - Universidade do Porto Portugal	Portugal	
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30.	Mr. Banhan Charukalas Geotechnical Division, Royal Irrigation Department,Pakkred	Thailand	Royal Irrigation Department Pakred, Nontaburi 11120 Tel 583-9268 Fax:5839268
31.	Mr. Winai Meemitkit Geotechnical Division, Royal Irrigation Department,Pakkred	Thailand	Royal Irrigation Department Pakred, Nontaburi 11120 Tel 583-9268 Fax:5839268
32.	Mr. Prasit Sithiyos Geotechnical Division, Royal Irrigation Department,Pakkred	Thailand	Royal Irrigation Department Pakred, Nontaburi 11120 Tel 583-9268 Fax:5839268
33.	Mr. Dhiravit Subhadhira Asia Modified Starch Co.Ltd. Nakhon Ratchasima	Thailand	61 Moo 3 Tambol Nongjabok Ratchasima-Pakthongchai Road Amphur Muang, Nakornratchasima 30000 Tel (044)211101-3 Fax: 211104
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36.	Mr. Supachart Wannawong Royal Forest Department	Thailand	กรมป่าไม้ 61 ถนนพหลโยธิน เขตจตุจักร ก.ท.ม.10900 Tel 579-5271 Fax 579-5342
37.	Ms. Sam-ang Seubsman CommunityDevelopmentDept. Ministry of Interior	Thailand	Community Development Department Ministry of Interior, Asdang Road Bangkok Tel 222-4266 Fax: 222-9187 Email Samang@loxinfo.co.th
38.	Mr. Sirichai Santiworarak Bangkok Farm Co.Ltd.	Thailand	Bangkok farm Co,Ltd. 11/1 Bangna-Trad Highway km 2.5 Bangna Prakanong Bangkok 12060 Tel (02)746-9731-8 Fax:746-9757
39.	Mr. Mesak Milintawisamai Environmental Research & Training Technopolis, Klongluang	Thailand	Technopolis, Amphoe Klong Luang Pathumthani 12120 Tel 577-1136-7 Fax:577-1138
40.	Ms. Sirirat Suwanidcharoen Sukothai Thammathirat Open University	Thailand	
41.	Mr. Amornthep Ngam-sombat Betagro Hybrid International Co Ltd	Thailand	
42.	Ms. Sansanee Chawanakul Ubon Ratchathani University	Thailand	

Curriculum Vitae

H.E. Mr. Boonchoo Treethong

Minister of University Affairs

Date of Birth	21 May 1945
Place of Birth	Maehongsorn
Marital Status	Married with Mrs. Prisna Treethong
Present Address	999/2-4 Suanbangkhen Village
	Viphavadee Rangsit Soi 60
	Donmuang, Bangkok 10210
Education	
Primary	Banchongcome School, Maehongsorn
Secondary	Boonyavadvidhayalai, Lampang
Bachelor's Degree	B.A. of Education (Physics)
	Srinakarinwiroj, Prasarnmitr
Certificate	- Project Planning, World Bank
	- Telecommunication, Germany
Honors	Honorary Docterate of Policy and Management of
	Finance, Southeastern University, U.S.A.
	(London Campus)
Experience	
1968-1969	Teacher: Amnuayvid School, Samutraprakarn
1969-1984	Telecomunication Network Department,
	Telephone Organization of Thailand
1975-1984	Telecomunication Engineering Consultant
1983-1987	Advisor to the Minister of University Affairs
1984-1992	Managing Director, STS Sirin Technology Co..Ltd.
1992-1994	Member of the House of the Representatives, and
	Deputy Minister of Finance
1995 to date	Member of the House of the Representatives, and
	Minister of University Affairs

Highlights of His Achievements

Mr. Boonchoo while serving as the Minister of University Affairs he realizing the national and regional need for high quality manpower stressed the important task of higher education to produce graduates with quality and quantity competitive in the international arena. He initiated and devoted his time to convince all parties concerned for the project to set up new regional campuses for the well-established universities. The target has been set for the total of the 30 within 1998 capable absorb students. To cope with university manpower shortage he has engineered for the installation of information technology infrastructure and interactive teleteaching system for universities as well as the project on "Reverse Brain Drain" to attract Thai professionals and academicians working aboard to assist in high technology transfer to strengthen capabilities of university staff both on a short-term and permanent basis. On higher education quality assurance he has been working closely with universities and the Budget Bureau to develop proper mechanisms. And last but not least he adopted the policy to promote the internationalization of higher education. The exchange of students and staff with overseas universities project, the establishment of the ASEAN University Network, the support for Regional Institute for Higher Education Development, the promotion of linkages with universities all over the world emphasizing on neighboring countries in the ASEAN region, are among outstanding tasks he has been steering.

Questionnaire Evaluation for International Colloquium on "Science Park for Meeting Technological Challenges of the 21st Century"

(1) How did you know of the seminar / colloquium ?

- Personal contact	5
- mailed brochure	2
- World Wide Web (www)	-
- others	2
	—
	9

(2) How did you travel to the seminar site from Bangkok and/or home town?

- Coach	1
- Train	-
- Air	4
- Private car	2
- others	1
	—
	8

(3) How did you find your travel?

- Excellent	2
- Very Good	2
- Good	3
- others	-
	—
	7

(4) How much travelling information did you get from the organiser beforehand?

- Much	2
- Just enough	-
- Not enough	3

- none 2

—

7

(5) How well were the seminar registration procedures?

- Excellent 2
- Very Good 5
- Needs improvement 1

—

8

(6) How appropriate was the seminar theater used for the meeting?

- Excellent 3
- Very good 3
- Good 3
- Not appropriate -

—

9

(7) Facilities in the seminar theater

7.1) Air conditioning

- Too cool 2
- Cool 4
- Comfortable 3
- Warm -
- Too warm -

—

9

7.2) Audio visual

- Excellent 4
- Very good 2
- Good 3
- Could hardly hear/see -

—

9

7.3) Lighting

- Excellent	2
- Very good	4
- Good	3
- Needs improvement	-
	9

7.4) Presentation Equipment

- Excellent	3
- Very good	3
- Good	3
- Needs improvement	-
	9

(8) How was the time arranged for each session?

- Suitable	6
- Too long	1
- Too short	2
	9

(9) Were the discussion topics appropriate to the seminar's title?

- Excellent	4
- Very good	3
- Good	2
- Not appropriate	-
	9

(10) Qualification of the speakers

- Excellent	4
- Very good	2
- Good	1

- others	2
	—
	9

(11) What kind of food did you expect to have?

- Typical Thai food	1
- Local food	1
- Mixed cuisine	1
- European food	-
- others	-
	—
	3

(12) For food only

12.1 Quality

- Excellent	1
- Very good	2
- Good	1
- Needs improvement	-
	—
	4

12.2 Quantity

- Excellent	1
- Very good	3
- Good	-
- Needs improvement	-
	—
	4

12.3 Services

- Excellent	1
- Very good	2
- Good	1
- Needs improvement	-
	—
	4

(13) Accommodation

- Excellent	1
- Very good	-
- Good	-
- Needs improvement	1
	—
	2

(14) The benefit you got from the seminar / colloquium was the same as you expected before coming.

- Yes	4
- No	-
- others	-
	—
	4

(15) Other comments:

- have to leave about 14.30 P.M., have not hear the last 3 papers

Thank you for your cooperation.

Organisation Committee

Chr. Samany
Rep Unely

CURICULUM VITAE

OF

MR. PRAMOTE MAIKLAD

Date of Birth: 3 May 1940

Place of Birth: Bangkok, Thailand

Education:

- Bs.in Irrigation Engineering (Honor), Kasetsart University
- Ms. in Irrigation Engineering, University of California, USA
- National Defense College (36th Batch)

Training/Study Tour:

- In 1967 10-month-training in irrigation at Bureau of Reclamation, USA
- June to July 1976 attended in meeting and studied tour on Dispersive Soil which effects to soil dam construction in USA and Australia
- April to May 1982 visited Japan to study in Irrigation
- October 1985 participated in Conference on International Commission on Irrigation and Drainage (ICID) and studied tour on irrigation in Chile
- June 1989 participated in Conference on International Commission on Irrigation and Drainage (ICID) and studied tour on irrigation in Canada
- January 1991 visited Australia to study in wastewater treatment
- June 1991 visited association of water irrigation consumer in Korea
- October 1992 participated in Conference on International Commission on Large Dam (ICOLD) and visited huge dam construction in Spain

Outstanding Awards:

1. In 1993 KU awarded PhD. in Irrigation Engineering
2. In 1994 KMIT (North Bangkok) awarded PhD. in Engineering
3. 1993 Outstanding Alumnus of Faculty of Engineering, KU
4. 1993 National Outstanding Person in Science and Technology
5. 1995 Outstanding Alumnus of KU

Career History:

1968 Engineer of Academic Division, the Royal Irrigation Department, Ministry of Agriculture and Cooperatives

1973 Chief of Section of Academic Division, the Royal Irrigation Department

1975 Civil Engineer 6 of Division of Design, the Royal Irrigation Department

1980 Civil Engineer 7 of Division of Design, the Royal Irrigation Department

1984 Irrigation Engineer 8, Director of Office of Special Affairs, the Royal Irrigation Department

1991 Special Expert (Irrigation Engineer 9) for Operation and Maintenance, the Royal Irrigation Department

1993 Chief Engineer for Special Affairs, the Royal Irrigation Department, takes responsibility in Water Resource Development Project for the Royal Initiative Project

1994 Inspector-General (Administrative Officer 10), Office of the Permanent Secretary, Ministry of Agriculture and Cooperatives

Special Career:

1. Keyperson of KU to evaluate academic work which faculty staff proposes for being prof., assoc. prof. and assist. prof.
2. Committee in the Irrigation and Drainage of Thailand
3. Consultant committee of faculty of engineering, KU
4. Committee in agricultural division of Anandhamahidol Foundation
5. Committee in Chaipattana Foundation

6. President of sub-committee for digging of Rama IX general-proposed reservior under the royal initiative of Chaipattana Foundation
7. Committee in the agricultural irrigation section of Association of Agricultural Science and Technology under the royal patronage
8. Committee in the Return Nature to Land Project
9. Committee and assist. secretary of the special committee for water resolution
10. Committee and assist. secretary of the administrative committee for Pak Panang river development project under the royal initiative
11. Deputy president of the dam project of Nakorn Nayok river
12. Director of the center for special affairs for water resolution, the Secretariat of the Prime Minister
13. Committee and assist. secretary of the administrative committee for Pa Sak river development project under the royal initiative
14. Director of center for operation coordinater of Pa Sak river development project under the royal patronage
15. Committee and assist. secretary of National Water Resources Committee
16. Directer of the National Water Resources Committee, the Secretariat of the Prime Minister

Contact Address:

- Office of the Permanent Secretary, Ministry of Agriculture and Cooperatives, Tel. 2810857
- Center for Special Affairs for Water Resolution, Office of the Prime Minister, Tel. 2801604-5

CV of Dr.Bruce Mitchell :

Dr. Mitchell is Professor of Geography at the University of Waterloo, Waterloo, Ontario, Canada. He has 30 years of experience in Canadian and Global watershed management, has been active in international development, and is a past president of the Canadian Water Resources Association. He has just completed a 2-month assignment as a water advisor in Indonesia.

Chr. Ron
Rap. O. [illegible]

CV of Dr. John K. Underwood :

Dr. Underwood is presently Senior Advisor, Environmental Quality Control, Nova Scotia Power Incorporated. He has 20 years of experience in the public and private sectors as an environmental manager and researcher. Dr. Underwood is president of the Association for Professional Environmental Auditing in Nova Scotia, and is on the Board of the Canadian Environmental Auditing Association. His research interests include acid deposition, watershed management, environmental auditing and environmental management systems.

CV of Dr. Catriona Moir :

Ms. Moir is presently Manager, Ecosystem & Risk Assessment for the Nova Scotia Department of Environment. Prior to assuming her present position she was been employed as senior policy advisor, municipal planner, assistant manager of the Shubenacadie- Stewiacke River Basin Board, and the Alberta Water Resources.

Chr. Ron
Rap. 0.03m0

CV of Dr. William Hart :

Dr. Hart is Associate Director of the Centre for Water Resources Studies, and Associate Research Professor, Technical University of Nova Scotia. He was been a private environmental consultant before taking his present position. His research interests include international development training related to watershed management, acid deposition, and eutrophication.

Chr. Ms. Galang
Rap

CV of Dr. David Swayne :

Dr. Swayne is a Professor of Computer Science in the Department of Computing and Information Science, University of Guelph. He is also an Adjunct Professor at the University of Waterloo, and holds a joint appointment with the School of Engineering at Guelph. His speciality is environmental decision support systems and environmental software engineering, principally the incorporation of uncertainty management environmental decision support systems and environmental software engineering. He is a principal investigator in Environment Canada's RAISON project. Application areas for the RAISON research have included: acid rain reduction, climate change, well water assessment, mining effluent modelling, and long range transport of atmospheric pollutants. Dr. Swayne is also active in agricultural and environmental applications of the WORLD-Wide WEB for information dissemination, and crisis management expert systems for police tactical teams involved with hostage takings.

chr. Dr. Umaly
Rap. Dr. Vorapot.

CV of Prof. Dr.Chongrak Polprasert :

Prof. Dr. Chongrak is presently Professor of Environmental Engineering at Asian Institute of Technology.He has long experience in Water and Wastewater Engineering and Environmental Technology and Management. He has been awarded by the National Research Council of Thailand, "The Outstanding Researcher Award in Engineering and Industry" in 1995.

Remarks.

have not received CV. of Dr. Khalil.

Biodata

Name	Ms. Nipaporn Watcharasin
Address	Environmental Impact Evaluation Division 60/1 Pibulwatana 7 Rama VI Road, Bangkok, Thailand Tel. (662) 2792792 Fax (662) 2713226
Date of birth	04/12/52
Gender	Female
Marital status	Single
National	Thai

Education

School attended	Date of attendance
Triam Udom Suksa Phayathai Bangkok	1969-1970

University/ College	Dates of attendance From	to	Main subjects	Qualification
Changmai University Changmai Thailand	1971-	1975	Biology	B.Sc.
Chulalongkorn University,Bangkok Thailand	1976-	1979	Biology	M.Sc
Limnologische Institute, Vienna Austrai	1981 (9 months)		Limnology	Cert.
University of Wales Aberythwyth United Kingdom	1994-	1995	Environmental Impact Assessment (EIA)	M Sc.

CV. of Prof. Jacques Moreau

Professor Jacques Moreau is the Vice Dean for International Affairs in the College of Agriculture, National Polytechnical Institute of Toulouse (France)

During the last 25 years, his research interest has been fisheries biology and ecology, fisheries management and more recently, ecosystem ecology and aquatic environment issues. His experience of tropical countries includes several years of field work in Africa but also common research programs through regular cooperation with scientific partners in .. in South East Asia Thailand Philippines and Sri Lanka.

CV. Michel Khalil

B.s. Chemistry & Botany

M.Sc. Organic Chemistry University of Alexandria Egypt

Ph.D. 1970 Chemistry of Natural Products Laval University Canada

1970-1992 Professor of Chemistry and Chemical Oceanography at the Universite Du Quebec at Rimouski (UQAR)

Since - 1992 Acting Director of Division BUREAU Industry University

-Responsible for the cooperation between Biotrop Center at Bogor-Indonesia, SEAMEO and UQAR

-Coordinator of a Research Project on Water Quality Management Related to the Aquaculture of Shrimp in Indonesia

-in cooperation with a Canadian Wastewater Treatment Company in Montreal "Queneco" and on their behalf Dr. Khalil will present this conference titled: Advances in Wastewater Treatment Technologies used in Canada

CV of Assoc. Prof. Nipon Tangtham

Presently : Associate Prof. at Faculty of Forestry, Kasetsart University, Bangkok.
: Former Head Department: Dept.of Conservation,Faculty of Forestry, Kasetsart University.

During the last 28 years, his research interest has been in Watershed Management, Forest Hydrology, Soil and Water Conservation, and Environmental issues.

His experience is mostly in Thailand.

CV of Dr. Songtam Suksawang

Dr. Songtam Suksawang is the Chief of Mae-Klong Watershed Research Station, Forest Environment Research and Development Division, Royal Forest Department. He is also lecturer of Kasetsart University, Chiang Mai University and Mahidol University.

During last 12 years, his research interest has been in Watershed Management, Forest Hydrology, Ecology, and Forest Environmental issues. Now, he is going on the research project with Science and Technology Agency (STA) of Japan.

CV. of Dr. Chaithawat Saowapon

Undergraduate Study : Chiang Mai University
Graduate Study: University of Waterloo
Waterloo, Ontario, CANADA

Work Experience

1. Civil Engineering (2 years from 1984-1986)
   Water Resources Planning Division
   National Energy Administration
   now (Department of Energy Promotion and Development)
2. Lecturer (1990-Present)
   Civil Engineering Department
   Chiang Mai University
3. Associate Dean for Student Affairs (1991-Present)

Research Works

1. Using Remote Sensing in Hydrology
2. Turbulent flow in Vegetated Channel
3. Water Resources Management in Northern Thailand

Ms. Supaporn Junrmgreang

Experience Work in Organic Recycling Project,
Soil and Water Couservation Div.,
Land Development Dept.,

Training
1. Environmental Impact Assessment in Germany
2. Biogass Training in China
3. Utilization of Agricultural Waste in Japan

Mrs. Ma, Luisa Umaly obtained her. Bachelor of arts dedgree at the University of the Philippines, Diliman. She has conducted research among the peasants and small coconut famous of the Philippines. The has ..... a primer on the issue of ancestral domain, our of the most pressing issues confronting the indigenous ..... communities in the country, which will be published this September. She is currently an associate anthropologist of the organizations anthropological studies of proposal Hydeoelcetirec prower siks

REVISED PROGRAM FOR THURSDAY, 25 JULY

25 July Thursday

0830 - 1000	**PLENARY SESSION VII :** **OPEN FORUM WITH THE SPEAKERS**
1000 - 1030	**COFFEE BREAK**
1030 - 1200	**PLENARY SESSION VIII :** **CONTRIBUTED PAPERS ON** **WATERQUALITY ASSESSMENT AND** **WASTEWATER TREATMENT** ***Application of Anthropological Assessment in Water Resources Management*** by Maria Luisa Umaly and Maria Luisa Lucas Fernan Anthropological Association of the Philippines ***Removal of Ca, Cr. Ni, Zn Ions by Amidoximated Cellulose*** by Asst. Prof. Winai Somboon KMIT, Thonlburi ***Possibility of Narrow-leaved Cattail for Wastewater Treatment*** by Ms. Supaporn Junrungreang, et al. Land Development Program
1200	CLOSING REMAKRS Prof. Dr. Wichit Srisa-an Rector, Suranaree University of Technology
1215	CLOSING LUNCH

REMARKS: Prof. Dr. Wichit Srisa-an

DINNER RECEPTION FOR THE SPEAKERS AND PARTICIPANTS OF THE INTERNATIONAL SEMINAR ON ADVANCES IN WATER RESOURCES MANAGEMENT AND WASTEWATER TREATMENT TECHNOLOGIES.

Allow me to reiterate my warm welcome to the paper presenters and participants of the international seminar on advances in water resources management and wastewater treatment technologies.

I hope your are enjoying the Thai buffet dinner tendered in your honour by the University as token of our appreciation of your participation in the seminar and visit to Thailand.

I was informed that the paper presentation during the rest of the day had been most informative and useful for the planning of water resources development and management in the region.

I wish you all a pleasant stay for the remaining days of the seminar and most of all enjoy the country side and handicraft stores during your field trip on Wednesday.

Once again, thank you for honouring our invitation and enjoy the rest of evening making new friends and renewing the old ones.

Thank you.

a:spwidise:dir 005:19/7/96

บันทึกข้อความ

มหาวิทยาลัยเทคโนโลยีสุรนารี

ส่วนราชการ ฝ่ายวางแผน สำนักงานอธิการบดี

ที่ วันที่ 22 กรกฎาคม 39

เรื่อง การใช้รถพยาบาลในช่วงของสัปดาห์การจัดสัมมนา

เรียน ท่านรองฯ ฝ่ายวิชาการ.

เนื่องจากช่วงการจัดสัมมนาวิชาการ จะมีผู้เข้าร่วมสัมมนามาพักอาศัยอยู่ที่สุรสัมมนาคาร ประมาณ 80 คน เป็นเวลา 4-5 วัน ทางผู้จัดการสุรสัมมนาคาร มาปรึกษาผมว่ามีความจำเป็นที่จะต้องเช่ารถบริการ มาประจำอยู่ที่สุรสัมมนาคารหรือไม่ กระผมเห็นว่าไม่น่าจะมีความจำเป็นพึงขนาดนั้น เพียงแต่ให้รถพยาบาลของ มทส. ซึ่งประจำอยู่ที่หอพัก นศ. หากได้รับการร้องขอจากสุรสัมมนาคาร ในกรณีที่มีเหตุที่ไม่ได้คาดไว้เกิดขึ้น ขอให้ช่วยบริการด้วย

จึงเรียนมาเพื่อโปรดพิจารณาสั่งการหรือกรุณาให้คำปรึกษาเพิ่มเติม

PRESENT ROUTINE ACTIVITIES AND FUNCTIONS OF THE CENTER

1. Initiate and coordinate the implementation of memorandum of agreement and cooperative programs with other universities
   e.g. the SUT - CUTC Cooperation
   ASIA-UNINET
   THAI-AUSTRALIAN Program
   APEC:ASIAN;
   University of Birmingham, University of Edinburgh, University of Maryland, Griffith University, Edith Cowan University
2. Coordinate the promotion and implementation management of the international academic programs (IUP) in cooperation with the various Institutes e.g. IUP
3. Serve as co-advisers to IUP students
4. Facilitate and coordinate the cooperation between SUT and international professional organizations specially those of which SUT is a member e.g. IAU, ASAIHL, UMAP, WACE, CIEE, AUAP Secretariat
5. Organize international symposia, seminars, colloquia and conferences either regularly or an ad hoc basis as well as publish the proceedings e.g.
   *During University Foundation anniversaries (regular)
   *other university Activities e.g. Worldtech'95 (ad hoc)
   *International seminar in cooperation with international organizations (ESCAP, UNESCO) etc. and professional organizations (Mathematics, Physics, Remote Sensing, etc)
6. Establish linkages with teams from SUT and specific agencies or countries on areas and activities of mutual interest and benefit
   e.g. establishment of linkage of the various Institutes with industries both locally and abroad
7. Represent SUT in international organizations
8. Facilitate visits of international guests to the University

Curriculum Vitae

NAME	:	MRS. CHUANPIT DHAMASIRI
AGE	:	58
NATIONALITY	:	Thai
EDUCATION	:	M. Eng. (Public Health), 1968, Asian Institute of Technology
		B. Eng. (Civil), 1966, Chulalongkorn University
		Degree National Defence College, 1990
TRAINING	:	Water Supply Engineering, Tokyo, Japan
		Water Purification, Paris, France
		Certificate of Senior Management Executive, Ministry of Interior, 1995

PROFESSIONAL EXPERIENCE

Present	:	Governor, Metropolitan Waterworks Authority (MWA)
1995 - 1989	:	Deputy Governor (Engineering), MWA
1989 - 1988	:	Deputy Governor (Planning and Development), MWA
1988 - 1985	:	Director of Planning and Development Office, MWA
1984 - 1983	:	Director of Survey and Design Department, MWA
		Chief Engineer, Samsen - Thonburi / WaterTreatment Plant Department, MWA
1981 - 1979	:	Director of Training Center, MWA
		Director of Engineering and Planning Department, MWA
1971 - 1968	:	Chief of Research and Development Division, MWA
		Chief of Planning Section, MWA

SOCIAL FUNCTIONS

1996	:	Appointed as Specialist attached to the House of Representatives' Committee on Policy and Follow-up on National Budget
1995	:	Voted as Outstanding Executive (Public Utilities)
1994	:	Voted as One of the Ten Outstanding Female Executives
1993	:	Serving as President, Asian Institute of Technology Alumni Association
1993 - 1991	:	Serving as President, Asian Institute of Technology Alumni Association of Thailand
1990	:	Voted as Outstanding Alumna of St. Joseph Convent School
OTHERS	:	Serving as Player of the National Bridge Team for various years

WATER USE / DEVELOPMENT POLICIES AND REGULATIONS

CHUANPIT DHAMASIRI
GOVERNOR, METROPOLITAN WATERWORKS AUTHORITY
BANGKOK, THAILAND

A UTILISATION OF WATER RESOURCES :

1. INTRODUCTION

The Siam Waterworks which comprised the Khlong Prapa (a raw water canal) was initiated during the reign of His Majesty King Rama V. The inception of the water supply system reflected His Majesty's concern over the water from natural sources especially the Chao Phraya River declining in its purity and thus unsuitable for consumption. The quality of the river water was also threatened by sea water intrusion, especially during the dry season. This problem coupled with the tendency of higher pollution due to the growth of the communities resulted in the quality of the river water being deteriorated.

On 13 July 1909, His Majesty King Rama V issued a Royal Proclamation, instructing the Department of Sanitation to supply water in Bangkok under the following procedures (Figure 1) :

1. Build a reservoir at Chiang Rak Canal in Pratumthani as the area is beyond sea water intrusion in all seasons,
2. Construct a canal from the reservoir to the north of Khlong Sam Sen along the railway line,
3. Construct a pump station at the above location to deliver raw water to the water purification system and distribute to the areas in Bangkok.

A total land area of 1,097 Rai, 3 Ngan and 43 square Wah (approximately 439 acres) was purchased for the construction of pump station, raw water canal and Sam Sen Water Treatment Plant. The average land price was 30 Satang per square Wah. As the project benefited the general public, 33 landlords had also joined in with a total land of 24 Rai, 3 Ngan and 28 square Wah (approximately 10 acres) being donated.

Basin and Raw Water Canal

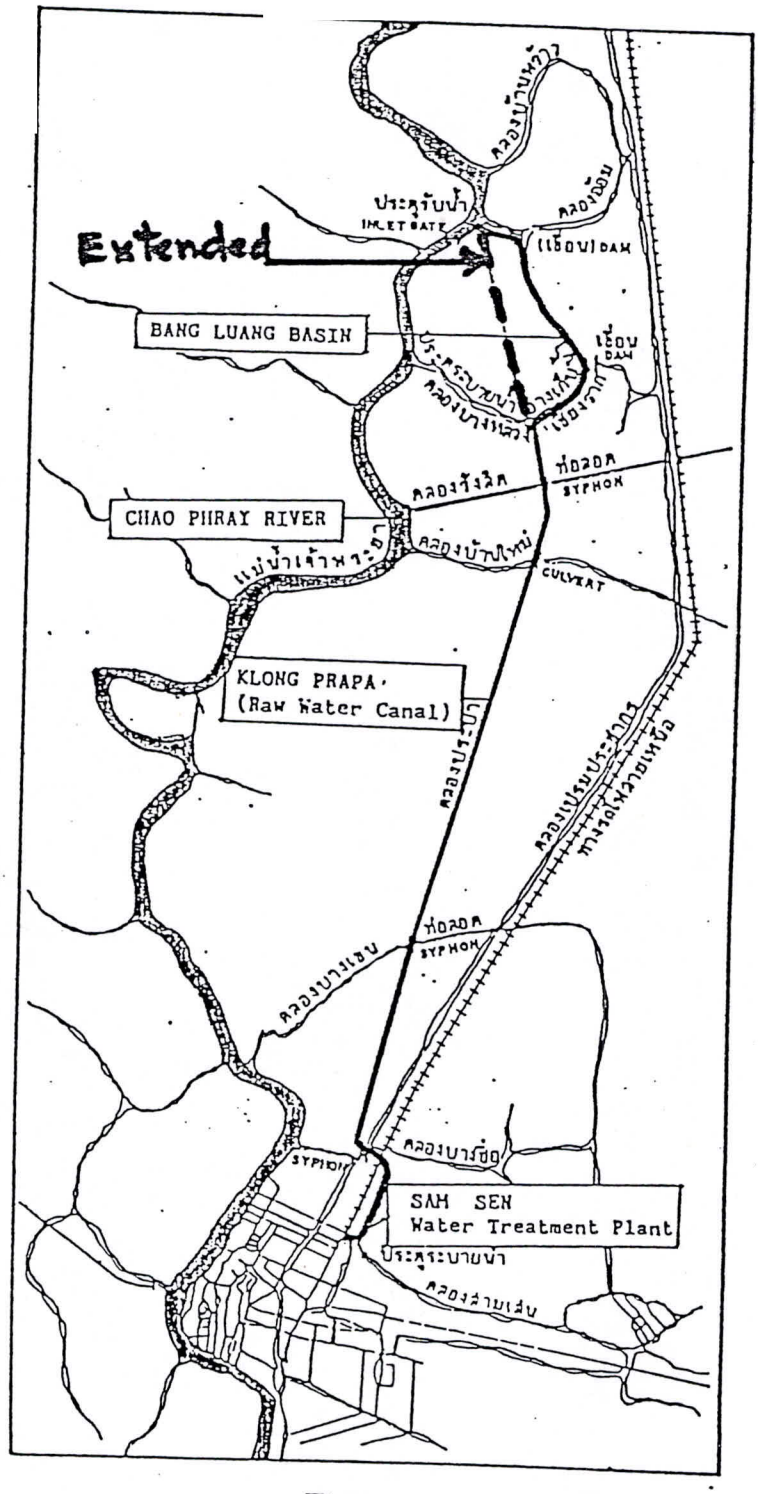


Figure 1

The first stretch of the Khlong Prapa approximately 25 kilometers long was constructed from the reservoir canal at Bang Poon District parallel to the Khlong Prem Prachakorn to the Sam Sen Water Treatment Plant. The flow through the 25 km Khlong exposed the water to air and sunlight which helped improve the quality of water. Construction work was completed in October 1913 and the Khlong Prapa Act was promulgated in the same year. The main objective of the Act was to prohibit fishing, bathing, washing clothes or dumping garbage in the canal. Violators were subjected to heavy fine.

In 1980, MWA extended the Khlong Prapa to a total length of 31 kilometers to draw water directly from the Chao Phraya River at Sam Lae District. This was due to the amount of raw water withdrawn from the reservoir canal being unable to cope with the ever increasing requirements of the water treatment plants.

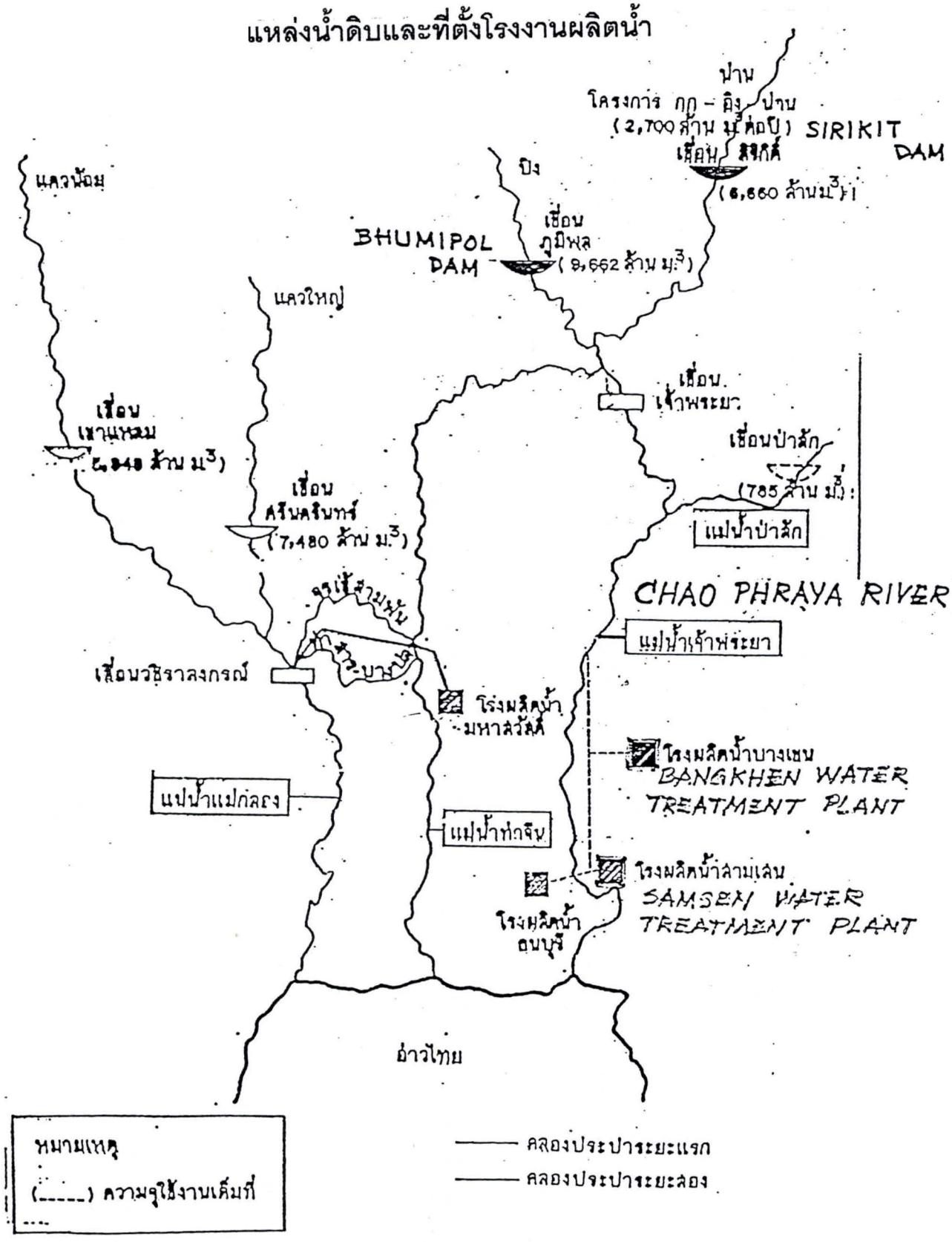
2. WATER REQUIREMENTS FROM THE CHAO PHRAYA RIVER BASIN

The water requirements from the Chao Phraya River Basin can be divided into various types such as consumption, agricultural, industrial and tourism uses as well as for the downstream ecological preservation. The major water user is the agricultural group, consuming approximately 80 per cent of the total amount discharged from the basin's reservoirs. In the Chao Phraya River Basin, there are 2 major reservoirs that is Sirikit and Bhumipol Dams. As the amount of rainfall collected during the 6 months period was not sufficient for agriculture, there has been a reduction in the agricultural produce in the past years. Water utilisation management for the above resorvoirs was rather a difficult task as the rainfall above the dam varied considerably. The evident case was in 1994 when the amount of rainfall was limited, a severe drought had occured in the country. While in 1995 the amount of rainfall was abundant exceeding

Figure 2 CENTRAL RIVER BASIN



Figure 3 RAW WATER SOURCE AND WATER TREATMENT PLAN



the storage of the dams which resulted in a major flooding. The second largest water user is for consumption especially by the Provincial Waterworks Authority and the Metropolitan Waterworks Authority. According to the National Economic and Social Development Board (NESDB)'s Report on the Study of Data and Potential Improvement of Chao Phraya River Basin, water consumption requirements could be characterised as urban and rural uses. The urban water consumption requirement from the water supply system averages 200 litres per capita per day. The rural water consumption mostly from the natural waterway, canal or irrigation canal could be divided into human consumption which averages 50 litres per capita per day and 5 litres for animal consumption.

The short - term (1992-1996) and long - term (1997 - 2006) water requirements can be summarised as follows:

(1) Short - Term Water Requirements (1992-1996)

- Water supply production(MWA and PWA) totals 1,565.4 mil.cu.m

- Rural area water consumption totals 150.5 mil.cu.m
Total annual requirement 1,715.9 mil.cu.m

(2) Long - Term Water Requirements (1997-2006)

- Water Supply Production totals 2,907.4 mil.cu.m

- Rural area water consumption totals 172.8 mil.cu.m
Total annual requirement 3,080.2 mil.cu.m

Breakdown of water requirements is shown in Table 1.

Table 2 shows MWA's raw water requirements up to the target year of the Master Plan.

Table 1 Total Water Requirements in the Chao Phraya River Basin (Short Term and long Term)

Plan	Area (Province)	Waterworks Authority *		Water Consumption in Rural Areas * *				Total Water Requirements (Mil.cu.m/yr)
		MWA (Mil.cu.m/yr)	PWA (Mil.cu.m/yr)	Population (million)	Quantity (Mil.eu.m/yr)	Animal Population (Million)	Quantity (Mil.cu.m/yr)	
Short Term (1992-1996)	11	1,482.2 (Only in the metropolita area and its perimeter)	83.2	6.7	121.5	15.9	29.0	1,715.9
Long Term (1997-2006)	11	2,649.0	258.4	7.6	138.6	18.7	34.2	3,080.2

* According to the implementation plan of the concerned Authority

**According to the estimate of growth rate of population at 1.5 per cent per annum and that of the animal of 2 per cent per annum

Table 2 MWA's Raw Water Requirements from the Chao Phraya River Basin

Year	East Bank (Mil.cu.m./yr)	West Bank (Mil.cu.m./yr)	Total (Mil.cu.m./yr)	Total (Mil.cu.m.day)	Total (cu.m./sec)
1993	1,314.0	-	1,314.0	3.6	41.7
1995	1,324.5	157.7	1,482.2	4.06	47.0
1997	1,324.5	157.7	1,482.2	4.06	47.0
2002	1,482.2	473.1	1,955.3	5.36	62.0
2007	1,671.4	977.6	2,649.0	7.26	84.0
2017	2,080.5	1,062.1	3,142.6	8.61	99.7

B DEVELOPMENT POLICIES

Due to a rapid increase of the population, demand of water will be about double within the next 30 years. Since the government has a policy to minimize the use of groundwater in order to arrest or reduce the land subsidence rate to Bangkok Metropolis, MWA is executing a plan to abandon the groundwater wells especially that of the central system. This cause the demand of surface water to be triple of the present situation within the next 30 years requiring 8.61 million m 3/d in the year 2017.

More surface water will be required from the Chao Phraya River to supply the forecasted demand. Since the Chao Phraya River is a multipurpose river serving various water use activities such as agriculture, navigation, salinity, and pollution control, domestic and industrial use, the water has to be allocated fairly to minimize the conflict between the water use sectors. As the results of the water allocation conducted by the Royal Irrigation Department (RID) the agency responsible for the operation of the Chao Phraya irrigation system, which is the major water use sector, raw water of 5.18 million m 3/d was allocation for the water supply system of MWA.

1. WATER REQUIREMENTS FROM THE MAE KLONG RIVER BASIN

To obtain more raw water from the other sources to meet with the increasing demand, MWA is carrying out a study on raw water resources of the Chao Phraya , Mae Klong basins to identify possible options on raw water resource development for the demand above the allocated 5.18 million m3/d which will be reached in 1997. Mae Klong basin is found to have surplus water after being used by the activities within its basin, and it is found that the water of 2.60 million m3/d can be transferred from the Mae Klong basin to the Chao Phraya basin to satisfy the raw water demand of Bangkok. With consideration on water reliability and water quality, a raw water canal of about 100 km long is planned to transfer the raw water from Vajiralongkorn diversion dam in the Mae Klong basin to the new treatment plant on the west bank service area of MWA as presented in Fig. 4.

The new raw water canal is now under construction. During intial stage of the plant 's water supply production, the first stretch of the raw water canal(Maha Sawat-Tha Chin) will feed the plant with raw water from the Tha Chin River. The raw water canal from Mae Klong River to the Tha Chin River will be further constructed and scheduled for completion in the year 1999 (2542).

Moreover, as part of long term plan, after the year 2017, the study indicates that MWA needs to construct its own surface water storage somewhere in the north or the west of the country to secure guaranteed raw water supply for the population of more than 15 million.

2. WATER REQUIREMENTS FROM PASAK DAM

His Majesty King Bhumipol had remarked on the drought which would have a repercussion on water supply production for Metropolitan Bangkok particularly during the next 7- 8 years (year 2000) when water requirements would reach 5.5 million CMD that the limited availability of the Chao Phraya River water during the dry season could be made up for by the amount of water discharged from the Pasak Reservoir currently under construction. However, the amount may not be sufficient should the dam's storage be less than 785 million cubic meters (MCM) soconsideration should be made.

In response to His Majesty the King's remarks, MWA has carried out a preliminary study for the utilisation of raw water from Pasak Reservoir via Khlong Rapeepat and Rama IX Reservoir for water supply production. Due to lack of information from the Royal Irrigation Department (RID) regarding the definite allocation of water from Pasak Reservoir, MWA has therefore sought cooperation from the Asian Institute of Technology (AIT) to conduct feasibility study on the utilisation of the Pasak Reservoir water as a supplementary source of raw water supply to cope with the water shortage problem, as well as study for construction of water treatment plant to serve population in its neighbourhood.

The result of study show that, according to the flow data(1987-1991), the existing diversion of flow (averaged from the mentioned period) from the Chao Phraya river at the Chao Phraya diversion dam via Khlong Chai Nat - Pasak is 942 for the 6 months dry period from January to June. From the previous study the Pasak reservoir can provide water of 661 MCM to partly supplement the water volume diverted from the Chao Phraya river during the dry period. Therefore the diversion requirement from the Chao Phraya river during the dry period can be reduced from 942 MCM under the existing condition to 281 MCM when the Pasak reservoir is operated.

In order to obtain additional raw water supply for Bangkok Metropolis, the raw water volume of 661 MCM of the Pasak reservoir may be utilized for the water supply purpose. Consequently, this implies that the existing diversion from the Chao Phraya river via Khlong Chai Nat - Pasak has to be maintained at 942 MCM for the dry period.

PASAK RESERVOIR FOR MWA

In the far eastem part of the serving area of the MWA, such as in the area of Min Buri and Lat Krabang districts, the low pressure pipe water is always experienced. In these areas, the MWA has planned to construct pump stations to increase pressure in the pipe lines. The proposed pump

stations considered in this study are those at Min Buri and Lat Krabang (Second Phase) where water demand is relatively high. The planned demand of these two pump stations in the target year 2007 and 2017 is 535,000 CMD and 1,159,000 CMD respectively. The treated water transmitted to these two pump stations cited in the MWA master planning study is from the Bang Khen WTP where raw water source is from the Chao Phraya river.

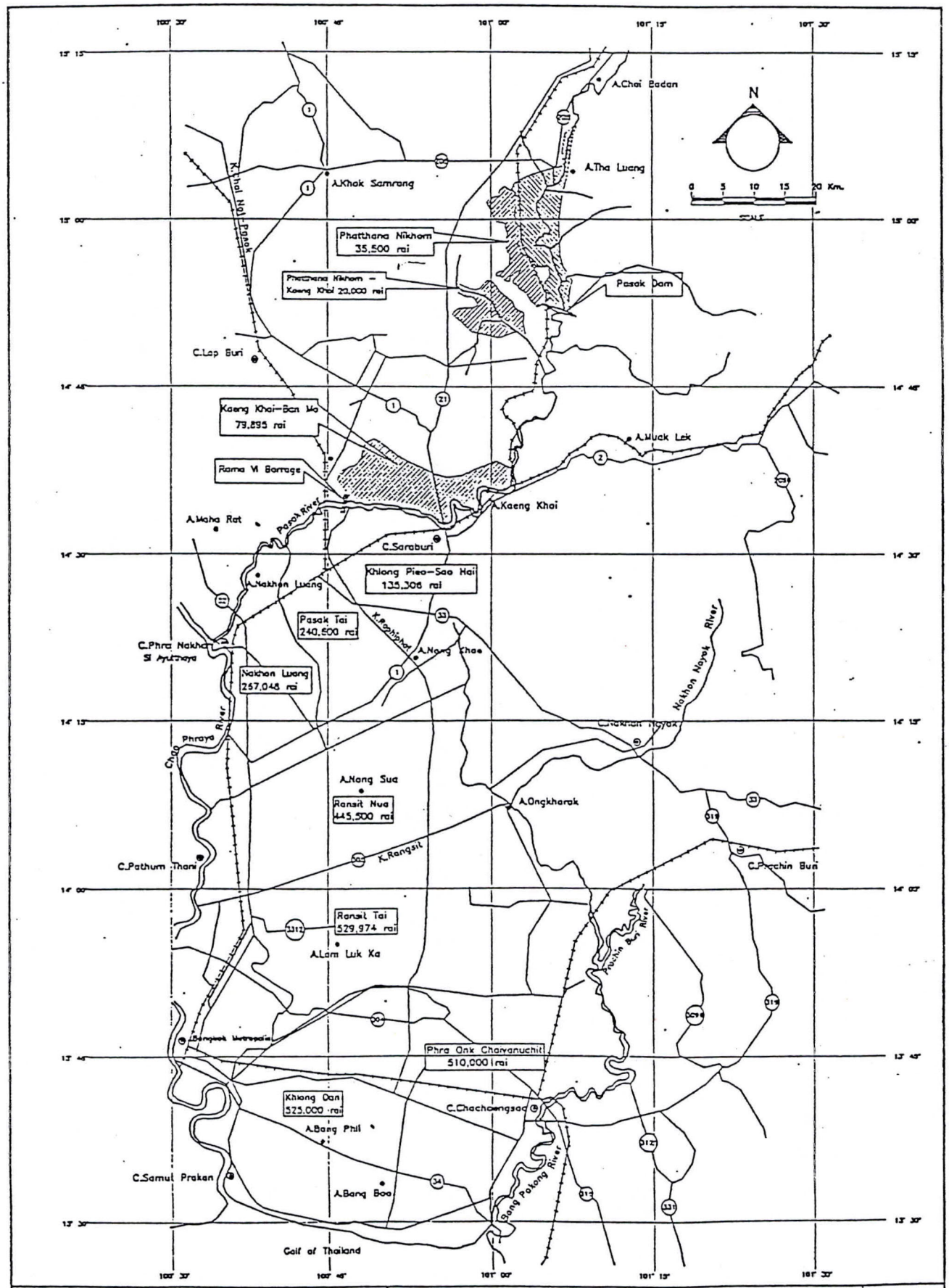
At present on the east bank of Chao Phraya river, the water supply in the service area is entirely dependent upon the Chao Phraya river. To secure the risk of uncertainty of Chao Phraya river flow due to its water quality problem and to the high demand for agriculture particularly during the dry period, the MWA has planned to find another reliable raw water soure. The Pasak reservoir project is considered to be a prominent altermative as it is reliable and is not far away from the target areas.

Based on the MWA master planning study, the water demand in the serving area of the proposed Min Buri and Lat Krabang (Second Phase) pump stations and the raw water requirement for the proposed water treatment plant are summarized as follows :

Description	1997	2007	2017
Water Demand at Min Buri	-	352,000	609,000
Water Demand at Lat Krabang (Second Phase)	-	183,000	550,000
Total	-	535,000	1,159,000
Factor for Raw Water		1.684	1.617
Raw Water Requirement		900,940	1,874,103
Rounded Raw Water Requirement		1,000,000	2,000,000

According to the raw water requirement presented above, the monthly raw water needed from the Pasak reservoir is about 30 MCM in 2007 and 60 MCM in 2017. This would not alter the objective of the Pasak reservoir project except the water saved from the Chao Phraya river would have been reduced from 661 MCM to 301 MCM (Table 3) during the dry period (January to June)

For the wet period (July to December), no water shortage is expected as there is abundant flow in the Chao Phraya and Pasak rivers. If it is necessary, however, the additional flow from the Chao Phraya river can be diverted via Khlong Chai Nat-Pasak. The additional flow of 60 MCM/month would raise the peak month flow of the Khlong from 353 MCM to 413 MCM (see Table 3) which is still under its capacity.



ROYAL INITIATIVE PROJECTS ON WATER RESOURCES DEVELOPMENT FOR METROPOLITAN WATERWORKS AUTHORITY	Beneficial Irrigation Area Under Planned Pasak Reservoir Project	Fig. 5

Table 3

Comparison of Diverted Flow from Chao Phraya River via Khlong Chai Nat-Pasak due to Pasak Reservoir Development

Month	Diverted Flow from Chao Phraya River via Khlong Chai Nat-Pasak			Chao Phraya River Flow at Tail of Chao Phraya Barrage (C.13) 4/
	Existing Condition 1/	Pasak W/O MWA 2/	Pasak W/ MWA 3/	
Apr	259	57	117	240
May	169	53	113	436
Jun	140	62	122	622
Jul	75	75	75	522
Aug	153	153	153	790
Sep	353	353	353	1,767
Oct	190	190	190	3,060
Nov	223	223	223	1,450
Dec	244	244	244	820
Jan	78	32	92	319
Feb	87	27	87	227
Mar	209	50	110	237
Dry (Jan-Jun)	942	281	641	2,081
Wet (Jul-Dec)	1,238	1,238	1,238	8,409

Note : 1/ Averaged values from 1987-1991

2/ Diverted flow during dry season is calculated by proportioning water shortage to the irrigation demand

3/ Estimated values for 2017

4/ Record period from 1971-1993

C REGULATIONS

1. MWA ACT

According to the MWA Act, the functions and responsibilities of the MWA are as follows :

1) To explore and locate raw water sources ; and procure raw water for waterworks purposes.

2) To produce, distribute, and sell water-supply in the Bankok Metropolitan area as well as in Nonthaburi and Samut Prakarn Provinces.

3) To operate other types of business that are relevant to otherwise beneficial to organization.

2. MEASURE ON RAW WATER CONSERVATION FOR MWA

The raw water intake at MWA's Sam Lae Raw Water Pump Station is situated only 90 kilometers from the Chao Phraya River's estuary. As the quality of the river water became deteriorating due to the rapid growth of communities and the industrial factories particularly upstream of Prathumthani Province, MWA in conjunction with the National Environment Board had put forward "Measure on Raw Water Conservation for MWA". The move was made to protect the raw water source at Sam Lae Pump Station from being further deteriorated. It prohibits construction or expansion of certain kind of industrial factories (whose effluent contains heavy metal, toxic chemical substance or high BOD content) within an area of 200 square kilometers around the pump station. The Cabinet at its meeting on April 17, 1979 approved in principle the above measure and instructed all the concerned ministries and departments to take action accordingly.

As the water quality of the Chiang Rak Canal which flows to the Chao Phraya River near the Sam Lae Raw Water Pump Station was affected by industrial waste discharged to the Chiang Rak's tributaries in the area near the above conservation zone, especially along the North Railway Line and Phrahol Yothin Road, expansion of the MWA's raw water conservation area by another 150 square kilometers was therefore proposed to cover parts of the Prathumthani and Ayuthaya provinces (Figure 6). The Cabinet approved the proposal on January 12, 1988.

In addition, the Cabinet, at its meeting on July 3, 1990 approved proposal made by the National Water Resources Council on the provision of additional water resource for water supply and industrial use, and on the approach to remedy the Khlong Prapa's pollution. It suggested that MWA oversee the use of Khlong Prapa's dikes and prohibit construction of new road or expansion of the existing road along the canal, and after the Khlong Prapa has fully been expanded, concrete walls along the canal should be constructed to prevent wastewater leakage into the canal.

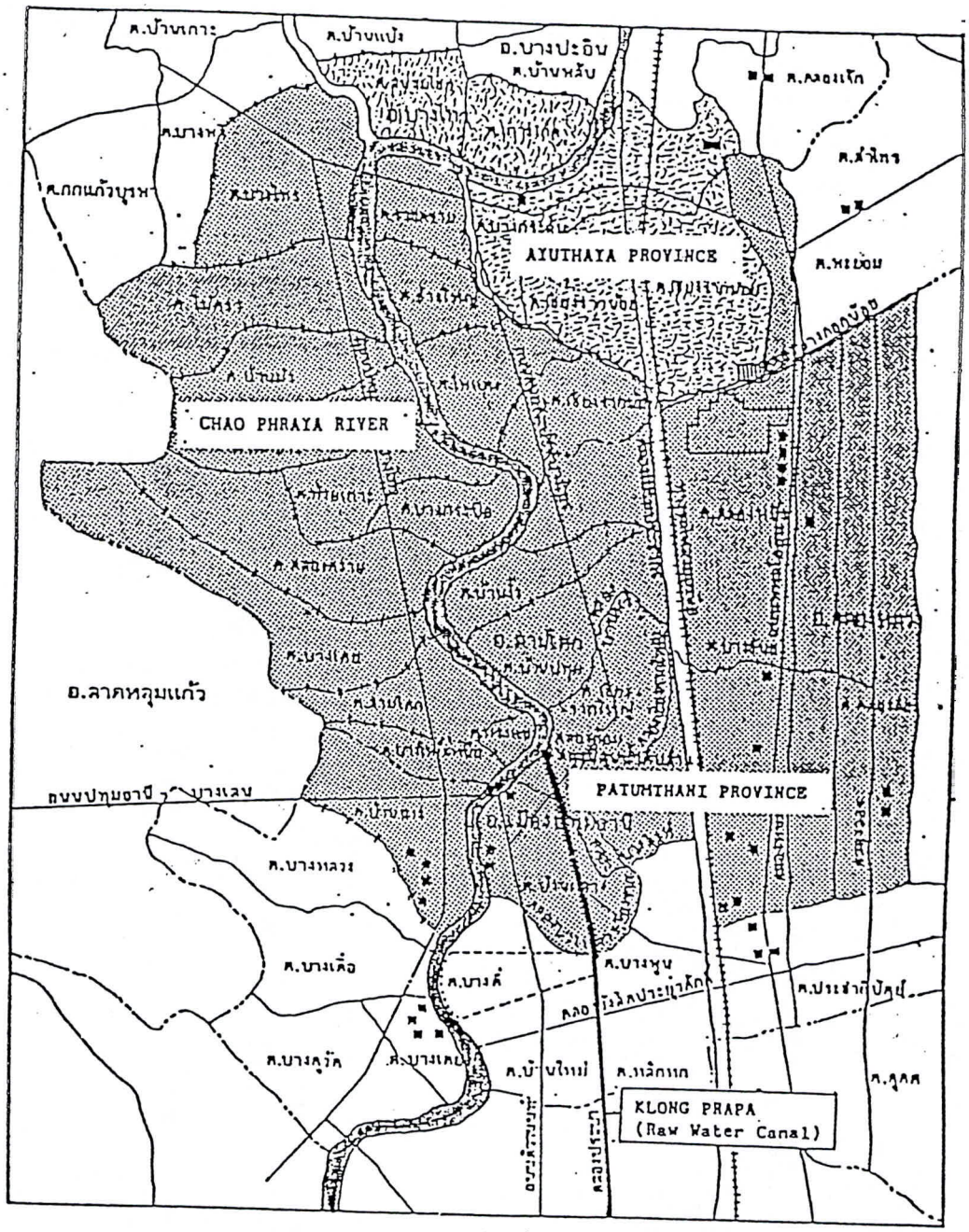


Figure 6 THE RAW WATER CONSERVATION AREA

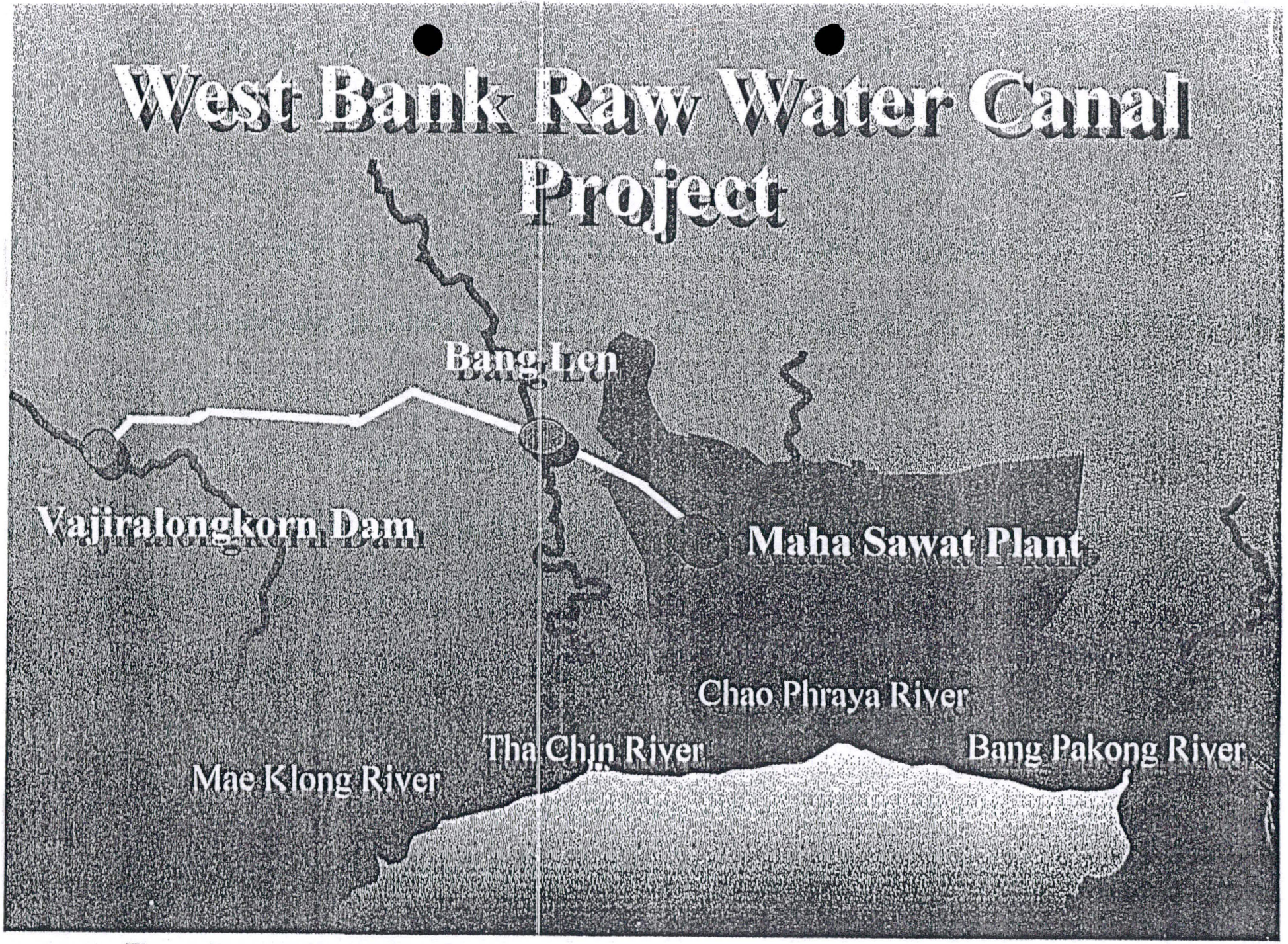


Figure 4 NEW RAW WATER CANAL

Wastewater Treatment in Huaxi

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ABSTRACT

A survey of the situation of surface water and wastewater treatment in Huaxi district of Guiyang city has been made. This paper discusses the used processes and their effects, the impact of industry development on water resources, and the increasing need for environmental protection.

1. Introduction

Huaxi is a suburban district situated to the south of Guiyang city, Guizhou province, China. There are more than 300,000 people in 1,000 square kilometers.

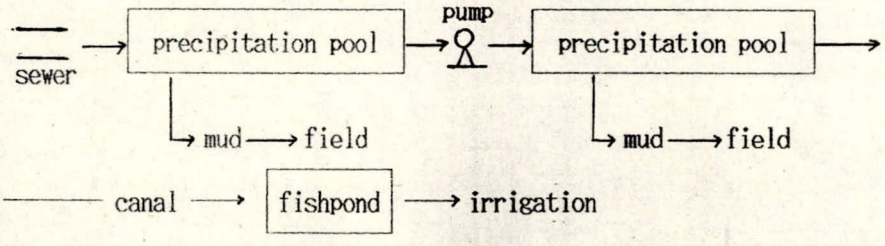
Huaxi is a famous summer resort for its mild climate, green hills and clear water. This district has plenty of water resources. There are two major rivers and tree reservoirs.

Because Huaxi town is a scenic spot, the local government has put special emphasis on environmental protection. In order to protect the source of potable water, construction of factories which may pollute the water is prohibited at the upper reaches of Huaxi river. Domestic sewage must be disposed of at the sewage treatment station.

2. Wastewater Treatment

(I) Domestic Sewage

Wastewater from residences, hotels, restaurants, hospitals and dairies is treated at the Huaxi sewage treatment station. The station can deal with 600 tons of water per hour. The treated water is used for irrigation. The processes are shown as below.

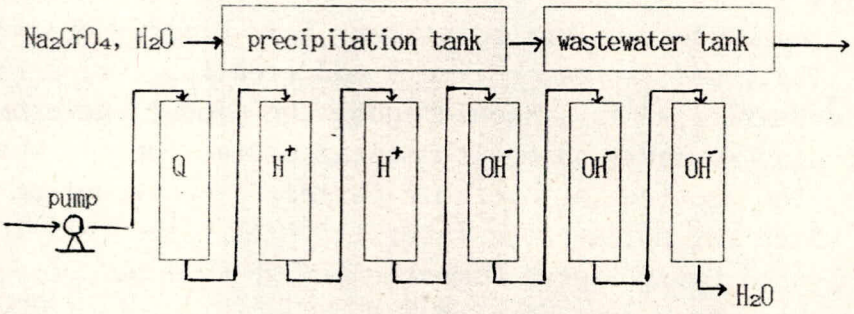


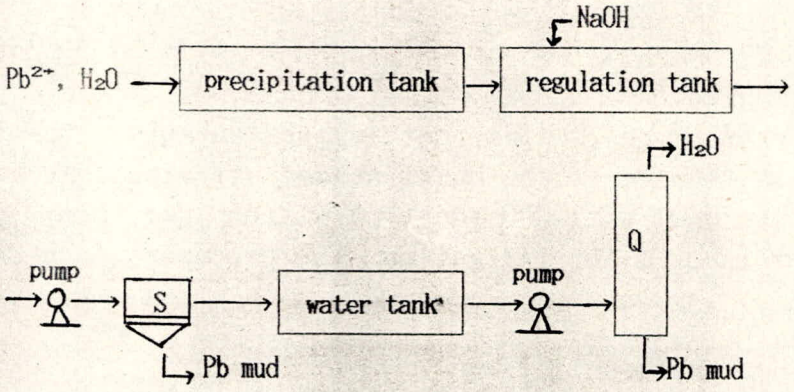
Wastewater with organic contaminants is utilized for farming after deposition and biodegration. This procedure not only protects the river but also fertilizes the farm fields.

(II) Industrial Effluents

Huaxi is a district of agriculture and tourism where severe restrictions are imposed on industrial effluents. Wastewater from factores must be treated and even the treated water is not allowed to enter the Huaxi river directly.

Let's take the Guiyang Miner's Lamp Factory for an example. This factory produces miner's lamps and batteries. It has a variety of wastewater containing chromium, lead, copper, nickel and acids. Processes of water treatment include ion exchange, neutralization and filtration. Followings are the flow chart of the processes of the Cr^{6+} water and the Pb^{2+} water treatment.





Q ---- quartz sand filter
H^+/OH^- ---- cation/anion exchange column
S ---- sloping baffle filter

The treated water meets the national standard of discharge water ($Cr^{6+} < 0.5$ mg/l, $Pb^{2+} < 1$ mg/l). The lead mud is recovered at the smeltry. But there is not an effective method to dispose of the chromium-containing water from the regeneration of the ion exchange resin.

3. Impact of Urban Development

Although the local government has made every efforts to protect environment, water resources are facing an everincreasing threat of pollution for the following reasons.

(I) Population growth

The number of inhabitants has increased a lot in recent years. An extension of the sewage treatment station is under consideration.

Moreover, most of the inhabitants use coal for cooking (especially in winter). It makes air pollution and acid rain become serious.

(II) Industry development

Township enterprises have developed rapidly these years. Some of them cannot afford to dispose of the wastes.

(III) Tourism increase

Nowadays more and more travellers come to Huaxi. At weekends people from the urban area come to Huaxi for swimming, fishing or picnic. Some of the visitors litter everywhere.

As a whole, The protection of water resources in Huaxi has made good progress. But there is still a lot of work to do. Government should build more environmental protection facilities and help enterprises dispose of wastewater at a reasonable cost.

Possibility of Cattail for Waste-water Treatment

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Abstract

Cattail (*Typha* sp.) is a perennial aquatic weed which grows and spreads very fast in ponds, canals and reservoirs throughout tropical and temperate zones. It can tolerate in some degree of salinity, acidity and alkaline environment. The important properties of cattail are high natural productivity and has ability to absorp large amount of nutrients and heavy metals. So the possibility of cattail utilization to waste-water treatment was investigated. Cattail can produce large quantities of biomass, the total annual productivity approximately 56.6 ton/ha. The biomass above ground and below ground are in the range 3.8-52.7 and 9.7-101.4 ton/ha respectively. Cattail is effective in nutrients removal. The removal nutrients capacity of nitrogen and phosphorus are 760 and 60 kg/ha. respectively. The comparison studies of the elements content in organs of broad-leaf cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*) indicated that above ground and below ground of *Typha* species are diffrent. Element content; N, P, K, Ca, Mg, Na, Mn, Zn, and Cu in every organs of broad-leaf cattail are larger than narrow-leaved cattail and the highest nutrients of above ground organs are N, K, Ca, Mg and Mn. The maximum nutrient content of below ground organs are Na, Zn and Cu. The largest N content in both *Typha* sp. are in the range 2.5-2.9% but the lowest P concentration is found in leaf-blade and leaf-sheath. *Typha* sp. is rather high capacity to adsorp the heavy metals such as Mn, Zn and Cu. The elements accumulated in broad-leaf cattail more larger than narrow-leaved cattail. Seasonal dynamic also has affected to chemical elements and biomass in cattail. The maximum leaf-area of broad-leaf cattail and narrow-leaved cattial are in August which resulted the largest N , P, K content and also biomass of above ground organs in summer. The peak of nutrient content of N, P and K below ground organ is in final fall. The biomass above ground of broad-leaf cattail is more

larger than narrow - leaved cattail but biomass below ground of broad - leaf cattail is smaller than narrow-leaved cattail. The largest biomass below ground is in the begining of winter. Cattail can be used as water purification and it should be harvested during summer for waste-water treatment.

Key words : Cattail Broad-leaf cattail, Narrow leaved cattail, *Typha* sp, *Typha latifolia, Typha angustifolia*

Introduction

Generally aquatic weeds cause a serious problems to the environments such as obstruct the water way which promoted silting, reduce water discharge capacity and it is lost the land for agriculture. Cattail (*Typha* sp.) is one of the most noxious aquatic weed. Borad-leaf cattail or *Typha latifolia* (Hotchkiss, 1972) and narrow-leaved cattail or *Typha angustifolia* (Alex.et.al.,1980) are commonly found together in marsh, ponds, canals and reservoirs (Fassett and Colhun, 1952). There are serveral methods of aquatic weed managements such as mechanical harvesting, biological control, environmental change and chemical control. The farmers spend a lot of money for eradication this weed by the way of mechanical and chemical control. The use of herbicide will give residual effect to water quality and living things (Mani et al.1976). Although this weed gives a lot of problems to the environments but cattail has the ability to adsorp the dissolved nutrients from polluted water and produces large amount of biomass (Ulrich and Buaton, 1985 a). This is the important criteria of cattail to use in polluted water for water purification.

The purpose of this paper is to evaluate the possibility of cattail for waste-water treatment.

The biology of cattail

Cattail is a perennial aquatic weed with creeping rhizome. Flower consists of unisexual spike upper spike male and lower spike female(Backer and Bankhuizen Van Den Brinks, 1968). Seeds are very small and subtened by copius hair which could be carried by wind and germinate in soil just above water level (Gracce, 1985; March, 1962). Broad-leaf cattail is an erect rhizomatous, stem 1-3 m. tall, leave long, linear, largely flat usually 8-15 mm. wide. Narrow-leaved cattail is also an erect rhizomatous, stem 1-3 m. tall, leave long, linear strongly planoconvex, 3-8 mm. wide. The two species normally are found together which

may be segregated according to water depth with broad-leaf cattail in shallow water and narrow-leaved cattail in deep water.

Result and discussion

The most important criteria of aquatic weeds is to produce large amount of natural productivity. *Typha* sp. has ability to produce the annual productivity more larger than *Eichhornia crassipes* and *Phragmites commumis* which are used in waste-water treatment. Currently, the use of aquatic weeds in Japan such as *Eichhornia crassipes* and *Phragmites communis* have recieved increasing attention in both natural and artificial land for waste water treatment. The total annual biomass of *Typha* sp., *Eichhornia crassipes* and *Phragmites communis* are 56.6, 37.8 and 33.5 ton/ha. respectively (table 2). The above ground biomass of *Typha* sp. and *Phragmites communis* are in the range 3.8-52.7, 3.8-4.0 and below ground biomass are in the range 1.6-48.7 and 3.7-88.9 ton/ha respectively (table 1). The capacity of nutrients accumulation of nitrogen and phosphous in *Typha* sp. and *Phragmites communis* are 760, 90, 490, and 50 kg/ha respectively (table 2). A copmparative studies of aquatic weeds among *Eichhornia cassipes*, *Typha* sp. and *Phragmites communis* which related to COD, inorganic N and inorganic P can be show the water quality (table 2). The quality of water bodies which cultivated by *Typha* sp. has COD, inorganic N and inorganic P approximately 0.54, 0.12 and 0.02 mg./l. respectively. The quality of water which occupied by *Typha* sp. is better than *Eichhornia cassipes*. *Typha* sp. shows prominent capacity in waste water treatment. Normally COD uses to detect the heavy metals such as Cd, Cr, Pb and Hg in waste water from dyeing factory and battery factory. The standard of COD in waste water is not over than 60 mg./l. It can be concluded that cattail is possible to use as water purification when it compares among the other aquatic weeds.

The comparision between Typha latifolia and Typha angustifolia

Nutrients uptake by *Typha* sp.

A comperative studies between *Typha* sp. are found that the element content of above and below ground organs of *Typha* sp. are differents (table 3). The N contents is highest in leaf-blade 2.5-2.9% for both species, and the lowest P accumulation is in leaf-blade and leaf-sheath are 0.26-0.34 and 0.19-0.36 % respectively. The organs of *T. latifolia* contain more larger N and P than those of

T. angustifolia (table 3). Leaf area between *T. latifolia* and *T. angustifolia* show that leaf area of *Typha latifolia* is more larger than *Typha angustifolia* at every time of harvesting (table 6). Therefore *T. latifolia* is heigher growth rate than *T. angustifolia* which effected the nutrient accumulation of *Typha* sp. The above ground organs of both *Typha* sp. have the lowest P concentration.

Among the organs of *Typha* sp., the least amount of K is in root, the lowest Ca concentration is found in rhizome while leaf-blade has the lowest Na concentration (table 3). Higher K, Ca and Na concentration are indicated in *T. latifolia* Mg and Mn nutrients in *T. latifolia* are presented more larger in *T. angustifolia.*

Cu and Zn occur in 7-8 time higher quantities in root of both species than other organs. The concentration of these toxic elements seem higher in both species. The result indicates that elements accumulation in *T. latifolia* is more larger quantites than *T. angustifolia* which can be evaluated that *T. latifolia* is more effective for waste-water treatment than *T. angustifolia.*

Seasonal dynamic of elements in *Typha* sp

The dynamic of nutrients cycling between above and below *Typha* sp tissue must be understood if natural or cultivated wetland are to be managed for waste-water treatment. Seasonal dynamic effects to the elements accumulation of *T. latifolia* and *T. angustifolia which showed in table 4*. The least of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* in the beginning of growing season are 0.2, 0.1, 0.4, 0.1, 0 and 0.1% which sharply increased until summer and gradually decreased until October (table 4). The largest quantites of N, P and K contents of above ground organs of *T. latifolia* and *T. angustifolia* are 10.2, 2.8, 11.2, 4.2, 0.8 and 5.5% respectively due to leaf area of both *Typha* sp. are also in the peak of this month. The maximum of leaf-area of *T. latifolia* and *T. angustifolia* are 1,515.08 and 1,983.60 cm2 respectively (table 6). The largest nutrients content emerged during the most favourable period as to climate from June to August, when the solar energy input is abundant and high temperature. The period of maximum nutrients accumulation in under ground organs of both *Typha* sp. in final fall because the nutrients are translocated to the rhizome just prior to the onset of dormancy.

Biomass production of *Typha* sp

Data on growth rate and production are also very useful for evaluating the harvesting time of *Typha* sp. in waste-water treatment to get the greatest of biomass and nutrients removal from *Typha* sp. The biomass above ground production of *T. latifolia* and *T. angustifolia* increases from June, 3-August, 26 and decreases from October, 7 until December, 30 due to the seasonal change. The largest biomass above ground of *T. latifolia* and *T. angustifolia* in August, 26 are 77.53 and 55.43 gm. respectively (table 5). The tendency of above ground biomass production of *T. latifolia* more greater than *T. angustifolia*. The increment of dry weight below ground production of both *Typha* sp. are during June, 3 until November, 8, the maximum biomass of *T. latifolia* and *T. angustigolia* are 149.8 and 158.6 gm. The tendency of dry weight below ground production of *T. latifolia* is less than *T. angustifolia.*

Conclusion

1. *Typha* sp is possible to use as water purification compare with the other aquatic weeds. It produces large amount of biomass and has high capacity to adsorp nutrients uptake from polluted water when compared with among with *Eichhornia crassipes* and *Phragmites communis*. Normally,*Eichhonia crassipes* and *Phragmites communis* are used in waste water treatment.. Water quality which cultured by T*yhpha* sp. is lower inorg-N and inorg-P than *Eichhornia crassipess* and *Phragmites communis*. COD is lower from standard therefore *Typha* sp.is effective in waste water treatment.

2 The comparison stduies indicated that *T. latifolia* is more effective in nutrients removal than *T. angustifolia* The element contents such as N,P,K,Ca, Mg,Na, Mn,Zn and Cu in every organs of *T.latifolia* is more larger than *T. angustifolia* thus *T. latifolia* is more effective in nutrient removal than *T. angustifolia*The study of nutrients uptakes in *Typha sp.* . shows effective in nutrients uptakes. N. and Mn are the highest in above ground organs . The least K concentration is found in root.

3. Seasonal change effected to nutrients accummulation in T. latifolia and *T. angustifolia*. The maximum N,P and K. content of above ground organs are

in summer. The maximum period of nutrients uptake below ground organs is in final fall.

Seanonal change effected to biomass production in both *Typha* sp. The largest biomass above ground is in summer and below ground is in winter, In order to get the highest of nutrients removal and biomass production., the suitable harvesting time of above ground organs are in summer

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Table 1 Annual productivity of aquatic plant (Lakshman, 1987)

Species	Above ground	Below ground	Total
	ton(dry wt) / ha		
Eichhornia crassipes	4.6-212.0	-	4.6-212.0
Typha sp	3.8-52.7	1.6-48.7	9.7-101.4
Phragmites communis	3.8-4.0	3.7-88.9	8.2-122.9
Corex sp	2.2-22.3	1.5-11.7	-
Scirpus sp	2.0-24.3	12.0-18.7	2.5-25

Table 2 Estimated nutrient removal, annual productivity and water quality

Spicices	Annual productivity (dry matter ton/ha)	Nutrient removal by weeds (kg/ha)		COD (mg/l)	Inorg-N (mg/l)	Inorg-P (mg/l)
		N	P			
	1	1	1	2	2	2
Eichhornia crassipes	37.8	1,400	140	6.30	0.96	0.17
Typha sp	56.6	760	90	5.54	0.12	0.02
Pharmites communis	33.5	490	50	4.78	0.59	0.11

Souce : 1 Steward, 1970

2. Oki et.al, 1988 b

Study area

Chemical properties	Water mg/l	Sediment mg/g
pH	7.2	-
total-N	2.2	0.67
total-P	0.61	0.50
Mg	4,251	0.17
Ca	50.81	0.78
K	13.69	0.05
Na	46.11	0.04
Mn	0.05	0.06
Zn	0.12	0.01
Cu	0.03	-

Table 3 Mean elements contents in organs of aquatic weeds from April to September (Dinka, 1986)

Element	leaf-blade	leaf-sheath	rhizome	root
Typha latifolia				
N %	2.91	1.14	2.22	1.57
P %	0.34	0.36	0.45	0.42
Ca %	1.10	1.29	0.48	1.06
K %	1.69	1.92	1.45	0.72
Na %	0.43	1.02	1.13	0.68
Mg %	0.47	0.58	0.28	0.37
Mn mg/kg	249.80	116.50	77.20	183.40
Zn mg/kg	26.00	25.00	24.40	95.60
Cu mg/kg	4.70	3.50	5.20	15.00
Typha angustifolia				
N %	2.52	0.87	1.79	1.33
P %	0.26	0.19	0.31	1.36
Ca %	0.50	0.82	0.53	1.27
K %	1.04	1.23	1.04	0.62
Na %	0.68	1.12	0.77	0.21
Mg %	0.37	0.34	0.39	0.35
Mn mg/kg	151.60	69.00	64.40	164.60
Zn mg/kg	17.20	11.00	11.80	88.2
Cu mg/kg	4.20	3.00	3.40	14.60

Table 4 Change in element composition of *T. latifolia* and *T. angustifolia* (Grace,et.al, 1988)

	T. latifolia			*T. angustifolia*		
	N	P	K	N	P	K
	%					
May, 12						
Above ground	0.2	0.1	0.4	0.1	0	0.1
Below ground	6.5	1.7	5.9	4.0	1.1	4.9
June, 9						
Above ground	1.7	0.3	2.1	0.4	0.1	0.5
Below ground	4.8	1.3	3.8	3.4	1.0	5.8
July, 7						
Above ground	7.5	1.8	7.3	4.2	1.0	5.3
Below ground	2.4	1.2	2.4	2.4	0.9	3.7
August, 4						
Above ground	10.2	2.8	11.2	4.2	0.8	5.5
Below ground	2.4	1.6	3.0	1.2	0.7	2.3
September, 2						
Above ground	8.4	2.1	10.0	3.8	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3

September, 29						
Above ground	6.3	1.7	6.4	4.9	0.7	3.0
Below ground	5.2	1.8	5.6	5.6	2.2	6.3
October, 27						
Above ground	7.1	2.3	7.8	3.4	0.5	0.2
Below ground	5.2	1.8	5.2	7.0	2.9	5.9

Table 5 Averge dry weight of above ground and below ground production compare between *Typha latifolia* and *Typha angustifolia* (Junrungreang, 1992)

Month	Above ground(gm)		Below ground(gm)	
	T.latifolia	*T.angustifolia*	*T.latifolia*	*T.angustifolia*
June, 3	2.57	8.24	0.44	6.84
July, 15	49.79	18.70	56.58	20.79
August, 26	77.53	55.73	87.99	60.77
October, 7	76.31	45.43	133.38	146.04
November, 8	67.42	38.72	149.84	158.06
December, 30	61.21	35.30	128.74	112.33

Table 6 Leaf area and specific leaf area of *T.latifolia* and *T.angustifolia* (Junrungreang, 1992)

Species	Leaf area (cm^2)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	1718.47	1983.60	1687.05	942.29
T. angustifolia	713.20	1515.08	1262.14	777.17

	Specific leaf area (cm^2/gm)			
	July, 15	August, 26	October, 7	November, 8
T. latifolia	34.51	25.59	22.11	13.98
T. angustifolia	38.14	33.35	22.65	20.07

Environmental Imact Audit Techniques: Thailand Experience

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Environmental Impact Audit Techniques : Thailand Experience

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Abstract

Environmental Impact Assessment (EIA) is implemented since 1981. Up to now, there are 22 types and sites of project that requiring EIA report . Division of Environmental Impact Evaluation, Office of Environmental Policy and Planning under Ministry of Science Technology and Environment responsible for administration of EIA process. The EIA report composed of 5 parts: project description, existing environment, impact evaluation, mitigation measure and monitoring program. After EIA report had been approve, the mitigation measure and monitoring program will be recommend to authorize agency for the license. The mitigation measure and monitoring program have to attach as term and condition with the license of the approval project. The project proponent must operate this conditions. The monitoring data such as water quality, air quality will be submit to OEPP every 3 months or 6 months depend on the how significance the impact of the project. OEPP will random check the mitigation measure and monitoring program. At present the term Environmental Auditing is widespread in Environmental Management System in Thailand. The compliance with term and condition in EIA is sub-task in Environmental Management System as well, therefore, last year, OEPP, by the support of Government of Denmark, consulted with Danish expert drafted "Guidance Document on Environmental Audit of Development Projects." This drafted guidance on Environmental Audit consisted of: pre-audit activities; 4 EA step (Planning, on site auditing, evaluation of the results, reporting of the audit finding and follow-up activities. The auditing team can be OEPP or third party which will accredit by OEPP This Drafted Guidance Audit is in the trial an error stage. The revision of this guidance should to be done as best as possible for Thailand context.

Environmental Impact Audit Techniques : Thailand experience

N. Watcharasin *

I.Euamolachat**

1. Introduction

Since 1981, Environmental Impact Assessment implemented in Thailand. Office of the Environmental Policy and Planning (OEPP) under Ministry of Science Technology and Environment is responsible for administration of the EIA process. By the notification of types and sizes of projects or activities requiring EIA reports, there are 22 types of projects which the project proponents have to submit EIA reports. The projects listed can be summarised into 6 groups : Water resources; Infrasfuchure; housing, mining; Industry and Energy (detail described in attachment 1).

Division Environmental Impact Evaluation (DEIE), OEPP will examine and make preliminary review EIA reports. The report together with the preliminary comments will be submitted to Technical Review Committee (TRC) for final consideration. The committee will be composed of expert members who are qualified or specialized in various technical fields including representatives of relevance agencies, permitting agency and NGOs. TRC may approve or reject report for the private project but for Government or State Enterprise project the National

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Environmental Board will be make decision. Besides, TRC may ask for report revision or additional information. The EIA review process can be summarized as attachment 2.

The other groups concerning EIA system are consultants and permitting agency. It is enforced that EIA reports have to be prepared by the consultant firms who registered with OEPP. Up to now, there are 48 consultant firms have licenses to conduct EIA reports.

For the permitting agency who is legally authorized to grant a permit to any proponent, the law stipulate that the agency shall withhold the granting of permission until having been notified the result of consideration pertaining to the review of EIA reports by OEPP.

2. Definition of Environmental Impact Assessment (EIA), Environmental Audit (EA) and Environmental Impact Audit

At present, Environmental Impact Assessment (EIA) become more popular in Thailand. The term "EIA" is now widely used however it is difficult to provide a single answer acceptable to everybody. Some definition can be given below.

EIA is an assessment of all relevant environmental and resulting social effects which would result from a project. (Battelle Institute, 1978)

EIA is the systematic examination of the environmental, social and economic consequence of projects, plans and policies (Clark, 1979)

Environmental impact assessment (EIA) is an environmental Management tool for development projects. It consists of a sequence of actions for : predicting the likely environmental impact of a project;

Finding ways to reduce unacceptable impacts; shaping the project to make it suitable for the environment and presenting these predictions to the decision maker (United Nations 1985). Thus, EIA is an environmental management tool the benefits of which generally outweigh the cost (Wathern 1985).

Environmental Audit means different things to different people. Environmental Audit means "a check on some aspect of environmental management".

USEPA defined its as systematic, documented, periodic and objective review by a firm of facitity, operations and practices related to meeting applicable requirements. (The Institute of Environmental Research Chulalongkorn University, 1995). In Thailand, Environmental Audit is a relatively new term but its widespread especially in industry area.

Environmental Impact Audit presented in this paper means an Environmental Audit (EA) of a development project that is initiated after acceptance of an environmental impact assessment (EIA) report. It is defined as management tool comprising a systematic, documented periodic and objective evaluation of the compliance with acceptable requirements specified in the licence (VKI Water Quality Institute,1996). This type of audit may also be named an environmental compliance audit as especially the compliance with the specifications or requirements in the licence is evaluated.

3. Environmental Monitoring and Auditing within OEPP Context

EIA reports compose of 5 part: project description such as location, process and etc; existing data which consist of primary or secondary data about environment in the project area and its vicinity;

environmental impact evaluation of the projects; mitigation measures of the projects to prevent or minimize environmental damage monitoring program for signiticance environmental impact such as water, air, noise, etc.

Problem with Follow up Monitoring and Audit in Thailand

Monitoring is an important step in the EIA procedure. Monitoring data can identify harmful trends before it is too late to ameliorate or prevent them. It is an early stage warning device. Monitoring reports from sampling takes place under apparently similar licensing conditions, the result are often different. Many project proponents have a misconception the after EIA is prepared and approved, the environmental effects of a project are managed. As a consequence, most of them are not in compliance with mitigation measures and monitoring programmes in accordance with the conditions that are attached to the licence after approval. There should be provisions for continuous monitoring of compliance with the recommendation and the permitting agency should be empowered to intervene if the licence is not being complied with . DEIE has an inadequate number of staff to monitor.

According to present mandatory provisions in the 1992 Act, only new construction projects need to submit EIA and only for projects which OEPP suspect may lead to impacts. Then, OEPP can request an EIA for the project. This does not include renewals of licences. The old Act specified that, every 3 years, the developer must submit an EIA report to OEPP for review in order to renew and extend a license for a private project such as hotels, industries and ports even though there is no construction. Monitoring is costly for project proponents, so monitoring is usually neglected. The project proponent is not generally prepared to produce and submit an EIA for a renewal license for the

existing project. In addition OEPP lack staff to monitor. It is the permitting agencies which have the authority to close down a firm if it is not meeting its approval conditions, not OEPP. Similar projects may be useful for confirming impacts and for designing effective follow up studies. In Thailand, monitoring of impacts is often recommend in EIAs, but is not implemented on account of a shortage of resources. This is not surprising, given the large number of EIAs prepared (about 400 EIA per year).

However, some monitoring reports have been prepared because some project proponents have had to submit reports on, for example air quality or water quality. Most monitoring programmes concentrate on physical aspects such as water quality and air quality. It could be undertaken by the project proponent, a consulting firm or a university. A report on the monitoring must be submitted to OEPP. OEPP also has the responsiblity to spot check and monitor the conditions in an EIA report. This task was appointed by law that OEPP shall control, monitor and evaluate project activities related to mitigation measures. The role of monitoring by OEPP is very closely to the term of "Auditing" because its Compose of checking, or inspecting records submitted by project proponents and investigation the effectiveness of mitigation measures. It also tells us the appropriateness of mitigation measures as well as the accuracy of monitoring results. This paper will define this activities as "environmental impact audit" Because of work load and limitations on skill resources, in conjunction with the lack of systematic method and sensitive equipment, monitoring has been neglected.

Recently, OEPP and TRC, pay more attention to environmental impact audit. For examples in case of Phoenix Pulp & Paper Public Company Limited which approval of EIA, OEPP and TRC stipulate condition that the proponent shall do Environmental Audit especially air emission, liquid effluent, solid waste and environmental hazard management every 6 months. The audit report must be submitted 1 month after the audit finished. The first audit report of Phoenix Pulp had prepared and submitted to OEPP already. (Jaakko Poyey, 1996).

Besides this, EIA of Panjapal Pulp Industry Company Limited and EIA of PP & HDPE production of Thai Petrochemical Industry Public Company Limited are the other examples that OEPP and TRC stipulate additional condition in submitting audit report.

As mentioned, mitigation measures proposed in EIA should be audit by OEPP, however, mitigation measures proposed in EIA become legal condition attach to project licence. Industries, for example, may be monitored by other agency such as Department of Industrial Works (DIW).

Not only the condition from OEPP but also from National Environmental Quality Act B.E.2535, there are provisions related to environmental audit which mention in Section 80 and Section 81.

section 80, the owner of the point source of pollution who has his own facility for treatment of polluted air, equipment for control of the discharge of polluted air or other pollutants shall have duty to collect statistics and data showing the daily functioning of those eqiupment and make detailed notes as recorded evidence at the site. Summarized report of the facility functioning results shall be submitted to local official at least once a month.

section 81 the local official shall gather the reports received according to section 80 and send to the Pollution Control Official at least once a month.

However, the role of the monitoring is under jurisdiction of Pollution Control Department (PCD)

4. Draft Guidance for Environmental Impact Audit Techniques

Recently, OEPP, by the supportance of the Government of Denmark, consulted with Danish expert drafted "Guidance Document on Environmental Audit of Development Projects". The audit process should be performed in a number of steps in order to ensure the efficient use of personel resources in appropriate methods. In the drafted guidance, audit process consists of; pre-audit activities; 4 EA Step (Planning, On site auditing, Evaluation of the results, Reporting of audit finding and follow-up activities.

Auditing process - Pre - auditing activities
- EA step 1 : Planning
- EA step 2 : On-site activities
- EA step 3 : Evaluation
- EA step 4 : Reporting
- Audit follow - up

Pre - audit activities

OEPP auditing team or the consultant acting on behalf of OEPP must be appointed. The audit team must be experienced in the evaluation of environmental impacts of the development project. Size of auditing team depends on complexity of the project, however, as EIA reports are only

required for larger projects so at least 3 persons should be included in the auditing team. the Team should select the team leader or project management, others should be assigned specific tasks to be undertaken in the audit

EA Step 1 : Planning

The auditing plan should be made and agreed by the auditing team as well as top management of the company. It must be ensured that the appropriate resources are allocated for a thorough audit such as staff involved are informed, relevant material and necessary facitities must be available. Detailed planning of the audit should be undertaken the plan should include.

* time schedule for on-site auditing
* scheduled meetings
* identification of mitigation measure to be audited
* identification of monitoring data to be audited
* identification of relevant documents, including additional data that should be obtained by the company
* etc.

EA step 2 : On-site auditing

The On-site auditing include series of activities as followed :

1. Start-up meeting with the site management and environmental staff to discuss the objectives and scope of the audit, time schedule, however, audit plan may be revised

2. Interview managers and operators about the implementation and operation of mitigation measures and monitoring program in accordance with the condition in the licence.

3. Inspect documentation of mitigation measures and monitoring results. i.e. results of wastewater, air emissions, noise, etc. Moreover, it should be considered the sampling site, sampling method, sampling period and auditing team can make additional sampling and analysis.

EA step 3 : Evaluation of results

The auditing team should evaluate all findings during the site visit. The following topics should be considered.

1. The presence of mitigation measures requiring installations as well as documentation for correct function or performance

2. Correction of monitoring program such as sampling sites, sampling techniques, analytical methods, calculation of results.

3. Comparision of additional sampling analysis result with the data obtained from the company in order to evaluate the validity of company's own monitoring result.

4. Evaluation of the compliance with the conditions specified in the licence.

EA step 4 : Reporting of audit findings. A written report should be prepared in order to ensure a formal reporting of the audit findings and conclusion at the end of the audit.

Audit follow-up

If mitigation measures or monitoring activities are incompliance with the condition in the licence, appropriate corrective action should be considered. A time schedule for the implementation of the corrective actions should be settled. The next audit should be decided.

Conclusion

Environmental Audit has been increasingly interested in Thailand. Various organizations implement environmental audit for their purposes. OEPP is the direct agency who responses in Environmental Impact Audit for development project or activity that submit EIA. Unfortunately, lack of resources in various aspects such as personel, equipment, budget, etc. effects Auditing System in EIA process in Thailand. Nevenrtheless, the drafted guidance for auditing will be use as a tool for Environmental Impact audit in Thailand context in the near future.

The systematic recording, well-planned auditing, reporting of audit finding and follow-up activities shall be performed. However, Environmental Impact Audit can be catagorized in compliance audit. Willingness of project proponents in revealing their own data and activities is an the important obstracle for government agency to do audit. ISO 14000, new environmental standard for Environmental Management System is voluntary basis, soon is being drafted.If its complete and implement, It include a lot of requirements; identification of legal requirements, checking and corrective action of monitoring and measurement, prevention action, environmental records.Moreover, ISO 14012 describes qualification criteria for environmental auditors and lead auditors. Thus, the companies certified according to ISO 14000, will be accepted that they meet requirement for systematic environmental impact audit in Thailand.

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Notification

of

The Ministry of Sciences, Technology and Environment

Re: Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment

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By virtue of Section 46 and Section 51 of the Enhancement and Conservation of National Environmental Quality Act B.E.2535, the Minister of Sciences, Technology and Environment hereby issues Notification with the approval of the National Environment Board, specifying government agencies, state enterprises and private persons likely to prepare projects or activities or likely to expand projects or activities as listed at the end of this Ministerial Notification, shall prepare reports on environmental assessment for submission to seek opinion from the Office of Environmental Policy and Planning in accordance with the provisions of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 including projects, or activities which are required for submission to seek approval of the Cabinet and projects or activities which are required to obtain permission from the competent authority.

The environmental impact assessment reports mentioned above must be prepared by a licensed expert in the environmental impact assessment.

Given on the 24th day of August, B.E.2535

No.

Paijitra Auetaweekul

(Mr. Paijitra Auetaweekul)

Minister of Sciences, Technology and Environment

Published in the Government Gazette Vol. 109 No. 130.
dated 8th October, B.E. 2535

List of Projects or Activities

Ltems	Types of Projects or Activities	Size
1	Dam or Reservoir	Storage volume 100,000,000 cubic meters or more or storage surface area 15 square kilometers or more
2	Irrigation	Irrigated area 80,000 rais (12,800 hectares) or more
3	Commercial Airport	All sizes
4	Hotel or Resort Facilities located in areas adjacent to rivers, coastal areas, lakes or beaches or in the vicinity of national parks or historical parks	80 rooms or more
5	Mass Transit System under the Mass Transit System and Expressway Act or project as the same characteristic or Mass Transit which use rail	All sizes
6	Mining as defined by the Mineral Act	All sizes
7	Industrial Estate as defined by the Industrial Estate Authority of Thailand Act or projects with similar feature	All sizes

Ltems	Types of Projects or Activities	Size
8	Commercial Port	With capacity for vessels of 500 gross tons or more
9	Thermal Power Plant	Capacity 10 MW. or more
10	Industries	
	(1) Petrochemical Industry	Using raw materials which is produced from oil refinery and/ or natural gas seperation with production capacity of 100 tons/day or more
	(2) Oil Refinery	All sizes
	(3) Natural Gas Separation or Processing	All sizes
	(4) Chlor-Alkaline Industry requiring Sodium Chloride (NaCl) as raw material for production of Sodium Carbonate (Na_2CO_3), Sodium Hydroxide (NaOH), Hydro Chloric Acid (HCl), Chlorine (Cl_2), Sodium hypo-chloride (NaOCl) and Bleaching Powder	Production capacity of each or combined Products of 100 tons/ day or more
	(5) Irons and/or Steel Industry	Production capacity of 100 tons/day or more (production capacity shall be calculated by using furnaces capacity of ton/day multiply by 24 hours)

Ltems	Types of Projects or Activities	Size
10	(6) Cement Industry	All sizes
	(7) Smelting industry other than Iron and Steel	Production capacity 50 tons/day or more
	(8) Pulp Industry	Production capacity 50 tons/day or more
11	All types of projects located in the areas where it has been approved by the Cabinet to be watershed area as class 1 B	All sizes

Notification

of

The Ministry of Sciences, Technology and Environment

Re : Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment

No.2 (B.E. 2535)

To become additional the specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment as listed at the end of the Notification of the Ministry of Sciences, Technology and Environment re : specifying types and sizes projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment on the 24th day of August, B.E. 2535

By virture of Section 46 and Section 51 of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535, the Minister of Sciences , Technology and Environment with the approval of the National Environment Board hereby issues types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assesssment additional as listed at the end of this Ministerial Notification.

Given on the 9th day of September, B.E. 2535

Paijitra Auetaweekul

(Mr. Paijitra Auetaweekul)

Minister of Sciences, Technology and Environment

Published in the Government Gazette Vol.109 No.136,
dated 22th October, B.E. 2535

Items	Types of Projects or Activities	Size
8.	Highway or road as defined by the Highway Act, passing through following areas 1) Wildlife Sanctuaries and Wildlife Non-Hunting Areas as defined by the Wildlife Conservation and Protection Act 2) National park as defined by the National Park Act 3) Watershed area classified as class 2 by the Cabinet Resolution 4) Mangrove Forests Designated as the National Forest Reserve 5) Coastal Area within 50 meters from the Maximum Sea Level	All projects with equivalents to or above the minimum standard of rural highway including roaded expansion

Notification

The Ministry of Sciences, Technology and Environment

Re : Specifying types and sizes of projects or activities of government agency, state enterprise or private person which are required to prepare reports on environmental impact assessment No.3 (B.E. 2539)

Items	Types of Project or Activities	Size
1	Hotel or resort	80 rooms or more
2	Flat or apartment	80 rooms or more
3	Hazardous Waste Treatment Center	all sizes
4	Sugar Industry	
	(1) producing raw sugar, white sugar, refined sugar	all sized
	(2) producing glucose, dextrose, fructose or the like	production capacity of 20 tons/day or more
5	Petroleum Development	
	(1) Geophysical drilling exploration and/or production	all sizes
	(2) Oil and gas pipeline system	all sizes

APPROVAL PROCESS FOR EIA OF PRIVATE SECTOR PROJECT

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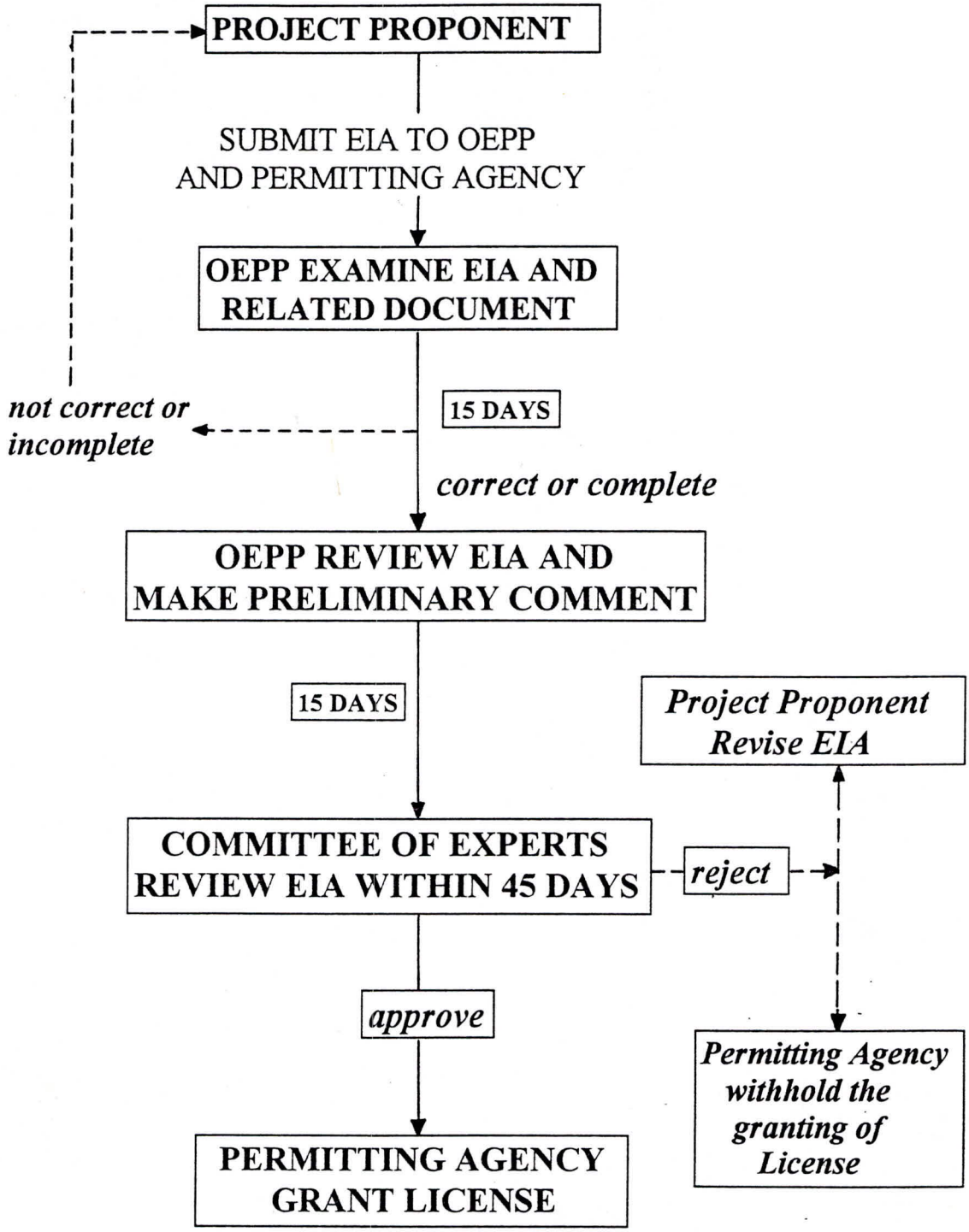

APPROVAL PROCESS FOR EIA OF PRIVATE SECTOR PROJECTS
(REVISION PROCESS)

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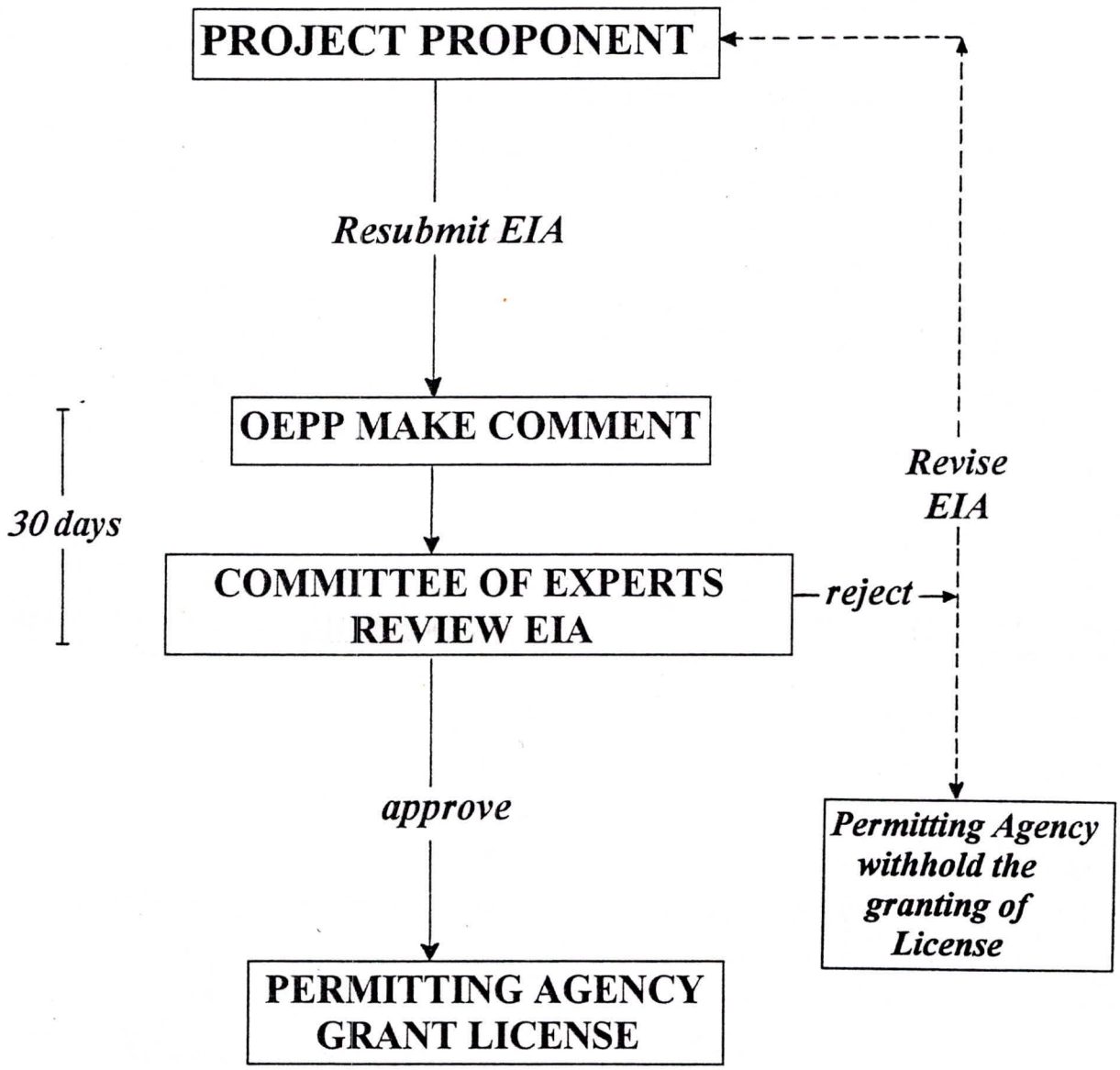

APPROVAL PROCESS FOR EIA OF GOVERNMENT AGENCY STATE ENTERPRISE OR TO BE JOINTLY UNDERTAKEN WITH PRIVATE ENTERPRISE

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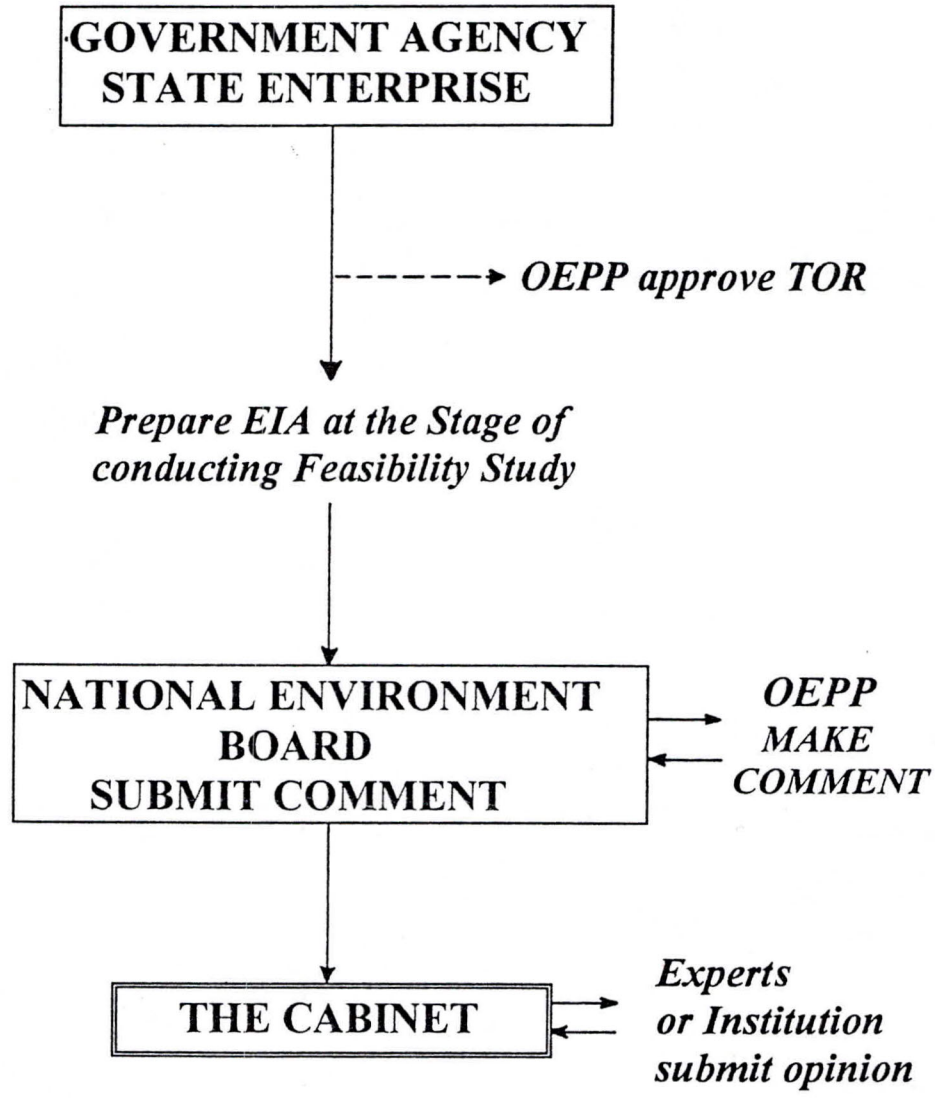

Watershed Classification : The Macro Land-use Planning for the Sustainable Development of Water Resources[1/]

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Abstract :

Water resources development and watershed management are recognized as unseparated activities for Thailand's socio-economic and environmental development plan. Problems of water resources in terms of water shortage in dry season and flood with unfavorable water quality during the wet season caused by watershed degradation led the government to promulgate the Cabinet Resolution namely "Watershed Classification". This resolution classified watershed area in Thailand in to 5 zones with the first (WSC1) and the second (WSC2) are preserved as protection and commercial forests respectively and the rests (WSC3-WSC5) belong to agricultural and other purposes with appropriate conservation and mitigation measures. The classification scheme employed five parameters, i.e., Slope, Elevation, Landform, Soil and Geology which were agreed by agencies concerned to derive watershed class equation for particular region with additional condition of forest or non-forest existing for assigning WSC1A and WSC1B. In national scale, about 17.86 percent of the country area was classified as WSC1 in which about 16.1, 0.26, 1.40 and 0.13 percent are identified as WSC1A, WSC1AR, WSC1B and WSC1BR respectively. About 8.3, 7.54, 16.0 and 50.3 percent was classified as WSC2, WSC3, WSC4 and WSC5 respectively. Although it was designed as macro-land-use planning for better quality of environment, water quality and flow regiment are the main aim of this project. This resolution is expected to be very beneficial to most of water resources development project in the future if it could be efficiently implemented. It will not only to reduce reservoir sedimentation but also to help decrease chemical pollutants contamination of stream water supply to downstream.

1. Introduction:

Water resource development and watershed management are unseparated activities which play very significant role in socio-economic development of the developed and developing countries especially for those using agriculture and industry as a base for generating the national income. For the developing countries having abundant water resource as Thailand, the forest, land and water resources as well as environment could be mutually constructive utilized in sustainable ways if land could be suitably used.

The most recent statement from the Worldwatch Institute concerning water and its related natural resources development is that "for all its impressive engineering, modern water development has been governed by a fairly simple calculus: - estimate the demand for water and then build a new supply to meet it." It is an equation that ignores the complexity of the natural world, question of human equity,

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concerns about other species, and welfare of future generation. In a world of resource abundance, it may have served humanity adequately. But in a world of scarcity, it is a recipe for trouble. Agenda 21 - Earth Summit in Rio, 1992 and the Conference in Dublin, Ireland, requested the World Bank to call for "recognition of the links between economic development and protection of natural ecosystems, for water to be treated more as an economic good, and for water planning to involve fuller public participation". (Postel, 1996)

Watershed classification in Thailand is the macro-land-use planning project initiated in 1979 by the Royal Thai Government (RTG) which coresponds to that agreement made in Agenda 21 and that of the Worldwatch Institute statement. It was the initial step to conserve the watershed ecosystems of the country by the wise use of natural resources concept. This project has been a RTG's effort to make land owners use their land as compatible as possible with the feature of environment and to mitigate any probable adverse effect especially that of water resources. The RTG had spent 7 years for completing the whole country area with land-use practices regulation. Watershed classification is thus anticipated as a useful tool for management of watershed ecosystems to produced good quality of water resources with appropriate utilization of land and forest and other natural resources.

The main aim of this paper is to ascribe the benefits of watershed classification for water resources development in Thailand. To do this, the water resource situation was described. Upstream-downstream relationship as an approach to environmentally sound management of water resources was reviewed so that watershed classification can be linked to water resource management. Brief characteristics of watershed classification and its land-use practices resolution were informed. Areal watershed classes distribution and forest as well as water resources in 25 main basins of the country were presented and discussed. Finally, the benefits that water resource development could be obtained from watershed classification was concluded.

2. Thailand Water Resources Situation

2.1 The Demand and Supply of Water Resources

2.1.1 National Scale

Thailand Development Research Institute, (TDRI) estimated the national requirement for water use in three main types, i.e., domestic, industrial and agriculture up to the year 2010 at about 167 billion cubic meters (BCM) per annum (Phantumvanit and Panayotou, 1990). It was also reported by Office of National Environmental Board-ONEB (1990) based on the Royal Irrigation Department (RID) that the surface water produced by the main basins in Thailand is almost 200 BCM per year. Out of an estimated 200 BCM/yr of such renewable water resources, about 40 BCM are with drawn annually for agriculture, 2 BCM for domestic use, and 2 BCM for industry. It was also further estimated basing on the current trend that the corresponding figures would be 144, 15 and 8 BCM/yr respectively by the year 2010. (Phantumvanit and Panayotou, 1990).

2.1.2 Regional and Basin Scale

The predicted average water demand and supply previously described reflect the macro water picture which ignores the regional and basin variation. In fact, the Northeast is considerably dryer and the South is wetter than the rest of the country. The Northeast even suffers from excessive water and floods during tropical storm period, water shortage has been always occurred every dry season. These macro projections also ignore yearly variation of climatic condition and changes in land-use and urbanization.

In order to reflect, regional and basin variation in both the demand and supply and their trends to year 2010, average annual runoff produced by 25 main basins and predicted demand for all sectors were estimated based on water yield map provided by RID and TDRI method of water demand calculation. The results are shown in Table 1. The irrigated areas and small and large reservoirs developed by RID and the multipurpose reservoirs in each of those basins are presented in Table 2.

Estimated trend of water demand in the national scale shows that demand is still less than the amount of renewable water existing in all basins of this country. The basin estimation however indicates insufficient supply in the central region especially in the lower Chao Phraya basin and Tha Chin basin by the year 2010.

2.1.3 Existing Problems

Problems of water resources encountered by people in this country can be identified in three aspects, i.e., insufficiency, fluctuation of water regime and water quality. The problems have been stated by the Technical Committee of Thailand National Hydrology Committee for IHP (1989) as follows:

1) Insufficient: The water shortage problems are frequently occurred even in the rainy season especially in the Northeastern and Northern regions. Incoastal area of the Eastern region, insufficiency of water are widely found not only for domestic and agricultural uses but also in promotion of industry for the Eastern Sea Board projects.

2) Fluctuation of Water Regime: This problem has been occurred in accordance with the change of environment in the upper watersheds. The changes of natural vegetation by ways of deforestation have caused fluctuation of flow not only in downstreams but also in the upper catchments. In the past, stream water was quite normal in terms of seasonal flow-distribution. Only the last decade, the peak flow was quite high and very rapid while the summer flow was considerably low and frequently shortage throughout the country.

3) Water Quality: Quality of surface water has been gradually declined in all important rivers and tributaries. Problems of sediment and chemicals transportation are seriously found in the North and Northeast with high concentration of toxicity. Most of the watersheds have the tendency of increasing the problems of water

quality and the other forms of water pollution. This is due to the expansion of agricultural and industrial development without sufficient measures in water quality control.

2.2 Conflicts in Water Use:

Besides the critical problems previously mentioned, conflicts in water use between upstream and downstream people are becoming more apparent in almost all regions of the country. The conflicts are, however, mostly originated from water shortage.

In overall situation, conflict in using water for agriculture, energy, industrial and municipal, tourism, and fresh water fish production including the recently popular golf course projects can be found in a number of basins and subbasins. Highland development projects such as poppy replacement programs in the North are leading to direct competition with already established communal and public irrigation systems, and are particularly problematic. In addition, efforts to promote international tourism and economic development in the more isolated parts of the North are stretching available water supplies and are bringing about conflict with local ethnic groups as well as farmers (Sethaputra, 1990).

The greater chance of conflict between upland development project such as small storage reservoirs developed by government agencies and local farmers and the downstream reservoirs for irrigation projects and/or for electricity generation projects or multipurpose dams has been occurred and will be increased in the future.

It has been observed by EGAT and RID that the inflow in almost operated reservoirs has been recently declined due to those upstream development activities. The conflict between farmers in the upstream and downstream zones during the dry months has been frequently occurred in the North. The matters of conflict are not only insufficient water for domestic used in dry period but also others additional problems, i.e., irrigation water shortage, sedimentation, toxic chemical runoff and poisoned drinking water.

In the Northeast, a major source of conflict is evolving when situations where agricultural development for cassava replacement and reforestation programs are leading to direct competition with already established irrigation systems. The efforts to promote tourism and economic development are also seriously stretching the limited water supplies of the region, especially the supplies in the medium-scale irrigation reservoirs. These problems are particularly acute in the Northeast, where the climatic condition and geologic formation are limiting factors producing low runoff potential and deforestation has been the most severe (Sethaputra, 1990).

In the Eastern region where the Eastern Sea Board Project has been established and is expanding for future industrial area, competition in using water for fruit tree orchards and industrial purpose has been a serious conflict leading to the confrontation between the farmers and those people in the tourism and industrial business.

The Eastern has been recognized as the region producing good quality of tropical fruits such as durian, mangosteen, and logan, etc. The farmers have utilized natural stream water for their orchards for centuries. Only the last decade when the tourism development and Eastern Sea Board Project have been evolved as well as its own urbanization, large amount of water from natural channels including from those man - made reservoirs has been drawn for tourism and industrial development purposes. The water shortage has become more serious and frequently in all provinces of this region. Several open-deep ground water wells have been dug for fruit orchard irrigation. Insufficient water for the tourists in the hotels at Pattaya as well as Rayong and Chonburi is normally apparent during the summer period. The farmers pays higher price of water for irrigating their orchards. It was escalated that without careful plan of water resource development for this region, both fruit orchard and other development projects (tourism and industry) will be mutually destructive to inadequate water for both activities and the consequent impact of air and water pollution.

Conflict in water use of the other regions has not been seriously apparent. Only few conflict between the golf course developers and downstream farmers/occupants has been mentioned in newspaper and discussed among water resource persons. It was reported that each golf course needs about 2-3 MCM per year for maintenance. The water use for this kind of project is mostly drawn from upstream by small storage dams. This causes insufficient water for downstream irrigation and domestic uses during the dry period. It is expected that the conflict stemming from water shortage will be compounded by deforestation that results in microclimatic changes and longer hydrological drought.

In conclusion, although water resources in Thailand are adequate in terms of quantity, the quality and flow regime are becoming more critical in all regions due to insufficient management intention from the government and private entrepreneur. Besides water shortage which has been frequently occurred, several tributaries are now being polluted by excessive fertilizer and chemical substances drained from non-conservation farming and irresponsible industrial manufactures. Conflict in water use between farmers and industrial groups in also becoming more serious in the future.

3. Upstream-Downstream Relationships and Water Resources Management:

For several decades, the engineers, who involves in water resources development, have paid less attention to upstream activities where water in the reservoirs come from. It seems that water quantity in terms of demand and supply is what they need for planning. Perhaps water flows downhill in the former day was always clean and adequate for people's needs, changes in quantity and quality were almost a low priority in planning consideration. Now-a-day, both quantity and quality are becoming worse and worse every where in the world. The concept of sustainable development is thus introduced into water resource development planning.

Kuiper (1971) stated in his process of water resources planning that "since the water runs downhill, one may expect that any interference with natural flow regime will have repercussion all the way down till the river reaches the sea. Therefore the planning of any water development project must be coordinated with other projects in the drainage basin that may be affected by, or that may have some effect upon, the project under consideration".

It was stated by Golubev (1988) that the conventional approaches to water resources management have dealt only with demand-supply interactions with little consideration for the environmental and social side-effects of development. Water should be considered not only as a resource but also a major factor in any ecosystem as a carrier of matters in the global biogeochemical cycles. These functions of actor put it in the center of practically every territorial system in such a way that neither economic development of land nor water management of it are possible without due mutual regard. Understanding of this relationship suggests the need of basinwide management where the links between various parts and components of a basin as a system are taken into account.

In Hufschmidt and McCauley (1988)'s article, the river/lake basin approach is mentioned as an appropriate spatial unit for scientific understanding of natural processes, planning of water resources development, and assessing its environmental and social impacts. The systems-oriented conceptual framework that can be usefully adopted for analyzing water resources management issues and problems is made up of three dimensions, i.e., (1) the management process, (2) management activities, and (3) management system elements. The last dimension consists of linked activities, involving **upper watershed management,** irrigation management and others in the systems.

Experiences in monitoring water quality flowing to lake Biwa in Japan led Kira (1988) emphasized in his article that forests serve to remove nutrients from rainwater. Wetland and paddy fields serve to enhance the deposition of silt and sand transported by water before they enter rivers and lakes, precipitate certain nutrients such as dissolved phosphates and organic matter, and absorb part of nutrients. However, environmental impacts of development, particularly in areas significantly affected by industrialization and urbanization, are apparently beyond the recovery capacities of natural processes, a proper combination of the **ecological principles of watershed management** and technological measures, such as the installation of large-scale sewerage system, is indispensable in eutrophication control. The mentioned principles of ecological watershed management are: (1) utilize as far as possible such functions of natural and semi-natural ecosystem as soil erosion control, water retention, trapping and decomposition of pollutants, etc., for buffering and improving watershed and aquatic environments; (2) minimize the destruction of ecosystems and conserve them so as to maintain their natural processes, biological diversity, productivity and aesthetic values; (3) optimize the allocation of natural ecosystems, agricultural and grazing lands, human settlements and industrial activities over space so as to ensure the sustainability of development in the watershed.

In order to meet such principles, Shimazu (1988) who examined some important issues and problems involved with environmental planning and management in the context of regional development in Japan suggested the developing countries to adopt what he calls "soft approach" to manage their watershed and water resources. This approach is characterized as being (a) manageable by local government officials; (b) responsive to the vulnerability of local communities; and (c) incremental and bottom-up in decision making.

4. Watershed Classification and Its Land-use Practices Resolution:

The problems of water resource previously mentioned together with the worse situation of head-watershed degradation in Thailand highlight the critical need for land-use planning which can properly allocate land areas to have various uses with mitigation measures for improving water resource for downstream people. As matter of fact, the upstream-downstream impacts relationship and such conservation plan have been recognized by RTG for over 20 years, but only in recent years has a vigorous project been pursued.

In January, 1975 the Ministry of Agriculture and Cooperatives proposed to the Cabinet the criteria for classifying the Mae Ping watershed in the North into 3 classes. These proposed criteria assigning about 60% of high altitude land (above 700 m. MSL) of the Mae Pring watershed as Class 1. It was also recommended that areas in this class be protected from any utilization of natural resources except rehabilitation for watershed protection. All residents occupying this zone would be evacuated. Watershed classes 2 to 3 proposed for lower land could be utilized for mining, forestry, agriculture, etc., if approved by a committee set by the Cabinet. Since there were many mining operations and hilltribe villages already in areas proposed as Class 1, considerable conflict and controversy developed among government agencies. The Ministry of Industry, which is responsible for mining operation, thus requested the proposed criteria for watershed classification be revised.

A new Watershed Classification Committee (WCC) was appointed by the Cabinet in October 1979. The National Economic and Social Development Board (NESDB) provided funds to Kasetsart University (KU) through the Office of National Environmental Board (ONEB) for conduct of a watershed classification project. The ONEB retained a technical panel of technical experts (the WCC) for advice on technical aspects of the project. While the Project is mainly funded by the RTG, funds for technical assistance have been provided by the government of Sweden, through the International Union for Conservation of Nature (IUCN), Conservation for Development Center.

4.1 Objective of Watershed Classification

Watershed classification is an extension of land-use planning for forest areas, which will properly allocate land of various uses. For Thailand, specific objectives of this project can be listed as to :

1) Develop a method for assigning watershed class (WSC) numbers to land areas.

2) Distinguish between areas to be permanently protected as forest watershed cover or used for commercial forests, and areas open for utilization of all resources or conversion to agronomic uses.

3) Immediately obtain watershed class maps of all watersheds in the country using the existing data and a method of manipulation the data to provide numerical classifications of lands into watershed classes.

4) Recommend appropriate land-use practices to be promulgated as Cabinet Resolution.

4.2 Definition, characteristics and Watershed Classes Prediction Equation

4.2.1 Definition

Watershed classification initiated by the WCC is defined as the identification of inherent capacity of landscape unit to be managed and produced, either plants or animals. The terms "WSC" used by the WCC is synonymous with land use planning for watershed areas. It is an effort to make man's uses of land as compatible as possible with the features of the environment and to mitigate on-site and off-site effect of use.

4.2.2 Watershed Class Characteristics

Based on the agreement among government agencies, the WCC (1983) classified area in the watersheds into 5 classes using SLOPE. ELEVATION, LANDFORM, SOIL, GEOLOGY and FOREST as modeling parameters. The hypothetical characteristics of each watershed class can be described as follows:

WSC 1 : **Protected or Conservation forest and headwater source.** This class is divided into 2 subclasses:

WSC 1A : are protected forest areas and include the headwaters of rivers. The areas are usually at high elevations and have very steep slopes and should remain in permanent forest cover.

WSC 1B : are those areas which have similar physical and environmental features to WSC 1A, however portion of these areas have already been cleared for agricultural use of occupation. These areas may be followed or cultivated ; they therefore require special soil conservation protection measures. Where possible, they should be replanted to forest or maintain in permanent agro-forestry.

WSC 2 : Commercial forest:
These areas are designed for protection and/or commercial forests where mining and logging will be allowed within legal boundaries, usually at high elevations with steep to very steep slopes.Landforms usually result in less erosion than WSC 1A and WSC 1B. The areas may be used for grazing or crop production if accompanied by appropriate soil protection measures.

WSC 3 : Fruit-tree plantation:
These areas covers uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.

WSC 4 : Upland farming:
This class describes those areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for few soil conservation measures.

WSC 5 : Lowland farming:
WSC 5 are gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restriction.

Pictorial model of watershed classes and recommended land-use and conservation measures are illustrated in Figure 1.

4.2.3 Prediction Equations:

Based on the mentioned hypothetical characteristics and the lesson from unaccepted watershed classification maps proposed by RID due to using only one parameter (i.e., elevation) as variable, new strategy employed by WCC was thus the one that can compromise all benefits of agencies concerned. All WCC members were asked to propose the parameters which are thought to be meaningful in characterizing watershed classes and must be available or can be made available in short period. Also constraints required for mapping large area of country (40 million ha) with limited time and computer system (PC) were informed to WCC members. It was agreed that parameters used in deriving prediction models must be stable in space and time and equally good data and must be numerically scaled to establish a mathematical relationship with WSC and for efficient production of WSC maps. Five variables were selected from more than 20 parameters initially proposed by concerned agencies. They are SLOPE, ELEVATION, LANDFORM, GEOLOGY and soil. Values for the five variables were read either from 1:50,000 topographic maps, or soil and geologic maps for each of 1x1 sq.km grid. A multi-variable analysis was employed to develop the mathematical relationships of variables with assigned WSC values for each region and/or basin. Detailed information on prediction equation derivation, field test and mapping procedures was described by Tangtham (1992a). The prediction equations for each region and ranges of WSC values for class determination were presented in Table 3 and Table 4 respectively. Example of computer map and final watershed classes map adjusted based on topographic and forest map were shown in Fig.2 and Fig.3 respectively.

4.3 Resolution for Land-use Practices in Watershed Area:

Regarding Land-use practices in the watershed area, the government also developed a set of resource utilization and management practices for each operating unit within each major watershed class. The general recommendation for land use practices in each watershed class are as follows:

In WSC 1A:

1) No forest product be permitted to harvest for any case. It must be strictly kept permanently as headwater source.
2) Forest protection activity is the first priority of RTG in these areas.
3) Immediate reforestation program must be undertaken by RTG on the abundonated shifting areas.
4) Areas converted to permanent settlement (but classified as 1A due to misidentified by LANDSAT) must be strictly supervised by the concerned agencies for future development.

In WSC 1B:

1) Areas converted into agricultural land must be practiced in accordance with the national economic, social and environmental policies.
2) Those areas which have been developed for recreation and resorts should be harmonically managed to keep ecological balance and natural sceneries.
3) Reforestation on denuded areas especially those where are unsuitable for agriculture or any other purposes should be immediately undertaken by the concerned agencies.
4) Erosion control measures should be practiced on the areas subjected to road construction and mining by the responsible agencies.
5) Permission can be made for the unavoidable projects which are very important to the national economy and security but the EIA must be prepared by the agencies concerned and approved by the Office of Environmental Policy and Planning (formerly named as: ONEB).

In WSC 2:

1) Forestry and mining activities can be normally allowed but should be closely and strictly supervised by the concerned agencies.
2) Agricultural practices are strictly prohibited.
3) Immediate reforestation programme must be conducted by concerned agencies.

In WSC 3:

1) Land utilization for forestry, mining, agriculture and other can be permitted but soil and water conservation measures are strictly required.
2) Areas with soil depth greater than 50 cm are recommended for fruit- tree and orchards or economic plantation or permanent cash crops, but appropriate soil and water conservation practices are needed.

In WSC 4:

1) Forestry, mining and other land-use activities are normally followed with close supervision of RTG.

2) Areas with slope in the range 18-25% and soil depth less than 50 cm are recommended for fruit-tree plantation and forestry. Those areas having slope between 6-18% should be used for agronomic crops with the application of suitable soil conservation measures.

In WSC 5:

1) All kinds of land use practices can be allowed as usual.
2) Areas with soil depth less than 50 cm are recommended for agronomic crops, private wooldlots, fruit-trees, and ranges or recreational purpose.
3) Areas having soil deeper than 50 cm should be utilized as paddy field and agronomic production.
4) Lands with high potential of agricultural production should be avoided for industrial development.

This watershed classification and its land-use practices resolution have been implemented since 1985 for the northern watershed areas and effective for the whole country area in 1991.

4.4 Watershed Classes Distribution and Forest Resources Status in 25 Main Basins

The watershed area classified for different classes by basin and region including its resources status in terms of the remaining forest coverage, annual runoff and suspended sediment are presented in Table 5.

In national scale, about 17.86 percent of country area was classified as WSC1. Of this figure, about 16.07, 0.26, 1.40 and 0.13 percent are identified as WSC1A, WSC1AR (forest was identified by RFD while it was mapped by Rubber Research Institute as rubber growing areas), WSC1B and WSC1BR respectively. About 8.3 percent was classified as areas provided for commercial forestry and restricted mining areas (WSC2). The rest of about 73.7 percent was classified as area devoted for agricultural and other purposes (WSC3-WSC5). About 50.3 percent is WSC5 which is mainly non-restricted for all kind of land-use development. Simple conservation measures for erosion control are needed for about 16.0 percent of country area (WSC4) and more intensive measures for erosion and pollution control are required for about 7.54 percent of WSC3.

In regional scale, about 47.7 percent of the North was classified as WSC1 and WSC2 which is assigned to be forested area of which about 30.2 percent is watershed protection forest and 15% is identified as WSC2. About 2.5% of regional area mainly in WSC1 has been occupied and used as farmland (WSC1B). The rest of about 52.2 percent

of regional area was classified as WSC3-WSC5 which has already been used for agricultural purpose and others. This could be confirmed by the remaining forest area of about 47.6 percent of northern region detected by Landsat imageries in 1988 and about 45 percent in 1991 (Forest Statistics Sub-Division, FSS; 1994).

The most serious region in terms of having the least forest cover and head-water source area is the Northeast. Only 6.2 percent of regional area was classified as WSC1A with about 1.2 and 2.5 percent were identified as WSC1B and WSC2. About 90 percent of the Northeast was classified for supporting agricultural and other purposes. Of this figure, about 64.5 percent was classified as WSC5 with 22 and 3.6 percent as WSC4 and WSC3 respectively. It could be stated that all of WSC3 to WSC5 area has been utilized for agriculture and others since only 14% of regional area was mapped as forest area remaining in 1988 by RFD. Recent information indicates about 12.9 percent was reported as forested area in 1991 (FSS, 1994). The forests on the hilly and mountainous areas which are considered as the roof of the Northeast have been almost totally damaged and rather difficult to reclaim for better head-water sources.

The central plain although having about 10.5 percent of regional area classified as WSC1 to WSC2 and greater amount of 89.5 percent as WSC3 to WSC5, the later WSC areas have recieved abundant of water from the northern river basins. The remaining forest area of about 12.4 percent of regional area seems to be adequate for protecting WSC1 and WSC2 areas exist in the basins of this region.

Watershed classification map of the East shows that about 88 percent of this region was identified as WSC3 to WSC5. Only 6.7 percent was classified as WSC1 with 6.4 percent is WSC1A. About 5.2 percent falls in WSC2 assigning for commercial forest area. Area classified as head-water source for the East is rather small portion considering from the increasing demand of good quality water for domestic and industrial uses in the future. The forest cover in this region was reported at 19.7 percent in 1988 and recently remained at about 19.5 percent in all basins of this region.

River basins in western region consist of about 34.8 percent of WSC1 of which 34.4 percent belongs to WSC1A and the other 0.4 percent was replaced by shifting cultivation and rubber plantation. About 11.4 percent was classified as WSC2 and the rest of about 52.3 percent was identified as WSC3-WSC5. The remaining forest in 1988 was about 50 percent of this region. It is fortunate that the long-narrowed basins of the western region are bounded by the neibouring country's borders and difficult to access due to having rugged terrain. The forest covers of almost 50 percent of the basins are still remain and supplying adequate water with good quality to downstream and even to produce hydrant water for Bangkok people in the near future.

The southern peninsula basins consist of 28.7 percent of regional area classified as WSC1 and WSC2 which supposed to be forested area. Of this figure, about 13.37, 1.61, 0.95 and 0.93 percent was identified based on forest map and rubber

plantation map as WSC1A, WSC1AR, WSC1B and WSC1BR respectively. Another 11.8 percent was WSC2 which assigned as commercial forest area. The rest of 71 percent was classified as WSC3 (9.77%), WSC4 (16.30%) and (44.93%). Considering from heavy rainfall characteristics and short river systems of this region, the remaining forest area of

25 percent in 1988 and about 23 percent recently should not be adequate to protect watershed ecosystem of this region. Fortunately, the large portion in WSC3 to WSC5 in this region has been replaced by rubber plantation in which might not compensate the hydro-ecological role of the original moist evergreen forest but still a lot better than those in other regions where most of WSC3 to WSC5 have been permanently converted to annual crops and orchards.

5. Benefits of Watershed Classification on Water Resource Management:

The environmental degradation in forms of water shortage, flood and water pollution caused by the mis-management of natural resources and industrial development have influenced the RTG to establish a new policy on natural resources utilization. The watershed classification-a macro land-use plan as shown in Figure 1, which is the first step of country's land-use planning, was the most current land-use model often employed by the agencies concerned as a base for the present and future development. According to the regulation promulgated by the Cabinet, those areas classified as Watershed Class 1A (WSC 1A) must be kept as permanent forest for protecting head-water sources. The areas identified as WSC 2 could be tutilized for commercial forest but other activities such as mining could be operated. The WSC 3, WSC 4 and WSC 5 are devoted for agricultural purpose but recommended for fruit-tree orchards, upland farming and lowland farming respectively. The WSC 1B, where they have the same characteristics as WSC 1A but without forest cover, could be utilized for specific purposes under government permission. This type of land-use model has been assigned to be practiced by the government agencies concerned in all regions since 1985.

Presently, most of concerned agencies cautiously consider their land utilization by avoiding to disturbed WSC 1A. Mining in areas classified as WSC 1A is not allowed. Reservoir construction for any purpose has also tried to avoid inundation of WSC 1A.

As more pressure is expected to increase in the next 10 to 20 years from increasing population, the regulation on watershed classification would be impractical for the agencies concerned and be ignored by the watershed occupants. The intensive or comprehensive land use planning for small watershed using community as a target area is included in the 8th National Economic and Social Development Plan (from 1997 to 2001). The patterns of land use plan in such planning unit, however, would be more or less the same as that assigned in watershed classification but would be modified according to what the community needs but should not exceed its carrying capacity. For those planning units where forest in the headwater source were denuded, reforestation for soil and water conservation must be undertaken to reduce soil erosion and improve the ecological environment. The medium slopes in the planning unit, fruit trees and fuel wood should be planted instead of commercial forest. In the lower part of the slope, as it is gentle and the thick soil layer is rich in water resources, farmlands would be allowed with storage reservoirs, ponds and check dams.

Although, watershed classification was initiated for the purpose of watershed-ecosystem conservation, it consequences in long term will contribute to the better quality of streamwater for downstream people as well as other environmental

condition. Downstream water resources developments in the future are expected to gain the benefit from this project if it could be effectively implemented throughout the country.

6. Conclusion

Currently, the demand of water resources for three major sectors, i.e., agriculture, industry and domestic is estimated at about 43 BCM per annum. The prediction of demand up to year 2010 will be at 167 BCM. The supply of surface water determined using the average of the country annual runoff is about 199 BCM. There will be therefore no serious problem of water supply in terms of water quantity in holistic view. The regional and seasonal distribution are, however, the problems of water shortage and flood in almost all regions. Water quality is recently becoming more and more serious problem in those rivers which the urban and industry are being rapidly developed especially in the Central and Eastern regions. Conflict in water use is also increasing due to the development of golf resorts and industries on the upstreams of fruit orchards and lowland farming areas. All afforementioned problems are expected to be compounded by the mis-use of land and deforestation which so far have been continuously practiced throughout the country.

Realizing these problems, the RTG initiated the Watershed Classification Project with Cabinet Regulation on land-use practices aiming at improving streamwater quality and flow timing from upland watersheds. This regulation classified watershed areas into 5 classes with the first and second classes assigned for conservation and commercial forest respectively. The rest classes are recommended for agricultural production with intensive soil conservation measures in class 3 and more simpler measures in the fourth class. The fifth class is devoted mainly for the paddy and other uses. Some of the area classified as class 1 and 2, however, have been occupied and utilized for cultivation and resort development. These villages and their surrounding cultivated lands are impractical to be managed using watershed classification regulation. The small watershed management concept using the community-based and people participatory land use planning will be employed in watershed rehabilitation programme.

It could be anticipated that, the watershed classification regulation will contribute long term benefits to water resources development project if it could be efficiently implemented throughout the country. Rate of reservoir sedimentation as well as pollutant contamination in streamwater is expected to be decreased due to more appropriate use of land in watershed area. Activities concerning natural resources utilization must be carefully planned and operated by agencies concerned with closely monitored by the ONEB.

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Table 1 : Average runoff produced and water quantity required by region and by main basin of Thailand

Basin Code and Name	Drainage area (sq.km.)	Average Annual runoff (BCM)	Predicted Population in 2000	Predicted Population in 2010	Predicted Water Demand for all Sectors 2000 (BCM)	Predicted Water Demand for all Sectors 2010 (BCM)
♦ **NORTHERN REGION**						
01 - SALAWIN BASIN	17,920	6.27	326,356	391,665	0.130	0.192
02 - KHONG 1 BASIN	9,920	5.95	603,492	662,681	0.761	1.497
03 - MAE KOK BASIN	7,895	4.84	725,130	802,582	0.836	1.645
04 - PING BASIN	33,898	6.14	2,451,503	2,729,510	6.026	11.854
05 - WANG BASIN	10,791	1.92	732,880	806,355	0.652	1.283
06 - YOM BASIN	23,616	3.54	2,355,024	2,487,803	1.609	3.165
07 - NAN BASIN	34,330	12.02	2,275,273	2,528,287	4.692	9.230
Regional Total	138,370	40.96	9,469,688	10,408,883	14.706	28.867
♦ **NORTHEASTERN REGION**						
02 - KHONG 2 BASIN	47,502	16.63	5,752,456	6,545,574	2.638	5.189
04 - CHI BASIN	49,477	9.40	6,170,556	6,802,647	4.705	9.255
05 - MUN BASIN	69,701	11.15	9,533,006	10,783,288	4.500	8.852
Regional Total	166,680	37.18	21,456,018	24,131,509	11.843	23.296
♦ **CENTRAL REGION**						
10 - CHAO PHRAYA BASIN	20,125	3.97	11,651,995	12,807,475	27.717	54.523
11 - SAKAE KRANG BASIN	5,192	0.98	419,891	466,122	0.833	1.639
12 - PASAK BASIN	16,292	2.77	1,822,137	2,002,830	0.875	1.721
13 - THA CHIN BASIN	13,682	1.73	2,796,221	3,172,339	8.522	15.262
Regional Total	55,291	9.45	16,690,244	18,448,766	37.947	73.145
♦ **EASTERN REGION**						
15 - PRACHINBURI BASIN	10,481	6.28	885,323	1,012,370	1.605	2.614
16 - BANG PAKONG BASIN	7,978	2.26	956,975	1,046,675	4.679	9.204
17 - TONLE SAP BASIN	4,150	1.24	130,034	148,694	0.035	0.057
18 - EAST COAST GULF BASIN	13,829	11.34	2,591,715	3,055,542	1.006	1.979
Regional Total	36,438	21.13	4,564,047	5,263,281	7.325	13.854
♦ **WESTERN REGION**						
14 - MAE KLONG BASIN	30,837	13.61	2,387,843	2,648,129	4.823	9.488
19 - PHETCHABURI BASIN	5,603	0.88	474,167	519,126	1.285	2.528
20 - PRACHUAPKHIRI KHAN COAST	6,745	2.11	475,750	526,565	0.935	1.839
Regional Total	43,185	16.61	3,337,760	3,693,820	7.043	13.855
♦ **SOUTHERN REGION**						
21 - PENINSULA-EAST COAST	26,352	26.59	4,101,088	4,768,866	4.898	9.635
22 - TAPI BASIN	12,225	15.43	989,395	1,161,880	0.215	0.423
23 - THALE SAP SONGKHLA BASIN	8,495	8.04	841,387	949,858	1.963	3.862
24 - PATTANI BASIN	3,858	2.43	476,869	590,483	0.593	1.062
25 - PENINSULA-WEST COAST	21,172	23.37	2,101,762	2,602,509	0.476	0.852
Regional Total	72,102	75.86	8,510,501	10,073,596	8.145	15.834
Country Total	**512,066**	201.18	**64,028,258**	**72,019,855**	**87.009**	**168.850**

Source : Modified from Tangtham (1992b)

Table 2 : Irrigation Project ,Irrigated Area and Multipurpose Reserviors in 25 Main Basins of Thailand

Basin Code and Name	Drainage area (sq.km.)	Irrigated Area (in 1989) (rai)	Large and Medium Irrigation Projects		Multipurpose Reserviors		
			No.	Capacity (MCM)	No.	Capacity (MCM)	Electricity generated (Mega W./hr)
◆ **NORTHERN REGION**							
01 - SALAWIN BASIN	17,920	34,060	12.0	13.08	0	0	0
02 - KHONG 1 BASIN	9,920	191,150	23.0	76.36	0	0	0
03 - MAE KOK BASIN	7,895	196,000	6.0	?	0	0	0
04 - PING BASIN	33,898	1,453,200	50.0	357.75	1	13,462	1,414
05 - WANG BASIN	10,791	161,700	8.0	125.74	0	0	0
06 - YOM BASIN	23,616	383,552	20.0	32.62	0	0	0
07 - NAN BASIN	34,330	1,112,130	60.0	17.38	1	9,510	960
Regional Total	138,370	3,531,792	179.0	622.93	2	22,972	2,374
◆ **NORTHEASTERN REGION**							
02 - KHONG 2 BASIN	47,502	579,475	78.0	876.25	1	165	17
04 - CHI BASIN	49,477	996,183	68.0	2589.36	2	2,452	205
05 - MUN BASIN	69,701	892,905	102.0	1343.21	1	1,966	90
Regional Total	166,680	2,468,568	248.0	3808.82	4	4,583	312
◆ **CENTRAL REGION**							
10 - CHAO PHRAYA BASIN	20,125	5,925,003	34.0	25.84	0	0	0
11 - SAKAE KRANG BASIN	5,192	243,500	5.0	160.00	0	0	0
12 - PASAK BASIN	16,292	202,550	12.0	45.12	0	0	0
13 - THA CHIN BASIN	13,682	2,276,046	16.0	251.08	0	0	0
Regional Total	55,291	8,647,099	67.0	482.04	0	0	0
◆ **EASTERN REGION**							
15 - PRACHINBURI BASIN	10,481	467,215	15.0	22.07	0	0	0
16 - BANG PAKONG BASIN	7,978	1,145,140	13.0	17.90	0	0	0
17 - TONLE SAP BASIN	4,150	5,500	5.0	6.50	0	0	0
18 - EAST COAST GULF BASIN	13,829	201,000	26.0	237.73	1	97	27
Regional Total	36,438	1,818,855	59.0	284.20	1	97	27
◆ **WESTERN REGION**							
14 - MAE KLONG BASIN	30,837	1,145,000	17.00	7.78	3	26,660	2,268
19 - PHETCHABURI BASIN	5,603	342,330	8.00	4.39	1	710	81
20 - PRACHUAPKHIRI KHAN COAST	6,745	246,855	14.00	516.79	0	0	0
Regional Total	43,185	1,734,685	40.00	1238.96	4	27,370	2,349
◆ **SOUTHERN REGION**							
21 - PENINSULA-EAST COAST	26,352	1,051,500	27.00	2.00	0	0	0
22 - TAPI BASIN	12,225	37,215	16.00	25.18	1	5,640	554
23 - THALE SAP SONGKHLA BASIN	8,495	467,800	17.00	26.42	0	0	0
24 - PATTANI BASIN	3,858	154,403	3.00	-	1	1,404	200
25 - PENINSULA-WEST COAST	21,172	96,000	14.00	19.00	0	0	0
Regional Total	72,102	1,806,918	77.00	72.60	2	7,044	754
Country Total	512,066	20,007,917	670.00	6509.55	13	62,066	5,816

Source : Modified from Tangtham (1992b)

Table 3 : Prediction equations derived for identifying watershed classes in various basins and regions of Thailand

Region and Basin Name	Prediction Equation
NORTHERN :	
Ping - Wang - Yom - Nan [1)]	WSC = 1.929 + 0.048 SLOPE - 0.0036 ELEV + 0.1067 LFORM + 0.1159 GEOL + 0.1925 SOIL + (FOR)
Kok - Ing - Moei :	WSC = 1.93 - 0.048 SLOPE - 0.044 ELEV + 0.107 LFORM + 0.116 GEOL + 0.193 SOIL + (FOR + MIN.)
NORTHEASTERN:	
Mun - Chi[1)] :	WSC = 1.071 - 0.019 SLOPE + 0.001 ELEV + 0.190 LFORM + 0.049 GEOL - 0.013 SOIL (if ELEV. > 500 m.MSL , WSC = 1)
Songkhram - Loei[2)] :	WSC = 1.071 - 0.019 SLOPE + 0.001 ELEV + 0.190 LFORM + 0.049 GEOL - 0.013 SOIL + (FOR + MIN.)
SOUTHERN [2)] :	
All basins :	WSC = 2.341 - 0.026 SLOPE - 0.011 ELEV + 0.156 LFORM - 0.088 GEOL - 0.230 SOIL + (FOR + MIN)
EASTERN [1)] :	
All basins :	WSC = -0.054 - 0.024 SLOPE + 0.024 ELEV + 0.209 LFORM -0.018 GEOL + 0.017 SOIL + (FOR)
CENTRAL - WESTERN [1)] :	WSC = 2.416 - 0.023 SLOPE - 0.019 ELEV + 0.138 LFORM -0.214 GEOL - 0.132 SOIL + (FOR)

Sources : [1)] Tangtham and Boonyawat (1988)

[2)] Chunkao et al (1991)

Table 4 : Ranges of WSC values assigned for determining watershed class in each region

Region and Basin Name	Range of WSC values for class No.				
	1	2	3	4	5
NORTHERN :					
Ping - Wang - Yom - Nan [1] :	< 1.50	1.50-2.20	2.21-3.20	3.21-3.99	> 3.99
Kok - Ing - Moei [2] :	< 1.50	1.50-2.20	2.21-3.20	3.21-3.99	> 3.99
NORTHEASTERN :					
Mun - Chi [1]	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
Songkhram - Loei [2]	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
SOUTHERN [1] :					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
EASTERN [1] :					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75
CENTRAL - WESTERN [1]					
All basins	< 1.55	1.56-2.55	2.56-3.55	3.56-4.75	> 4.75

Sources : [1] Tangtham and Boonyawat (1988)

[2] Chunkao et al (1991)

Table 5 : Drainage area , areal distribution of Watershed Classes , remaining forest area and annual runoff and suspended sediment in 25 main basins of Thailand

Basin Code and Name	Drainage area	Watershed class distribution %								Remaining forest in 1988	Estimated annual runoff and suspended sediment	
											runoff	sediment
	(sq.km.)	1A	1AR	1B	1BR	2	3	4	5	(% of basin)	(BCM)	(Ton/sq.km.)
NORTHERN												
01 - SALAWIN BASIN	17,920	61.0		8.0		14.0	9.0	5.0	3.0	75.0	6.27	62
02 - KHONG 1 BASIN	9,920	18.2		4.6		13.0	13.6	12.2	38.4	37.0	5.95	77
03 - MAE KOK BASIN	7,895	36.0		4.0		16.0	12.4	11.6	20.0	38.0	4.84	116
04 - PING BASIN	33,898	36.5		2.0		14.5	9.5	9.0	28.5	49.0	6.14	62
05 - WANG BASIN	10,791	23.5		0.8		14.3	11.4	13.5	36.5	61.0	1.92	374
06 - YOM BASIN	23,616	18.0		1.0		13.0	11.0	10.0	47.0	33.0	3.54	66
07 - NAN BASIN	34,330	20.5		0.6		18.2	11.5	9.7	39.5	43.0	12.02	67
Region	138,370	30.2		2.5		15.0	10.8	9.5	31.9	47.6	40.96	-
NORTHEASTERN												
02 - KHONG 2 BASIN	47,502	8.5		2.6		4.8	6.5	22.8	54.8	20.0	16.63	42
04 - CHI BASIN	49,477	10.0		0.7		2.6	3.0	24.0	59.7	14.0	9.40	29
05 - MUN BASIN	69,701	2.0		0.5		0.9	2.0	20.0	74.6	10.0	11.15	27
Region	166,680	6.2		1.2		2.5	3.6	22.0	64.5	14.0	37.18	-
CENTRAL												
10 - CHAO PHRAYA BASIN	20,125	1.5		0.4		0.8	3.5	3.8	90.0	1.5	3.97	63
11 - SAKAE KRANG BASIN	5,192	9.0		0.1		7.0	3.8	4.0	76.1	28.0	0.98	
12 - PASAK BASIN	16,292	10.5		4.1		6.8	9.1	10.4	59.1	18.0	2.77	18
13 - THA CHIN BASIN	13,682	5.5		0.1		1.3	4.5	12.4	76.2	16.0	1.73	
Region	55,291	5.8		1.4		3.3	5.4	7.9	76.2	12.4	9.45	-
EASTERN												
15 - PRACHINBURI BASIN	10,481	8.7		0.4		4.1	7.6	14.4	64.8	22.0	6.28	65
16 - BANG PAKONG BASIN	7,978	5.6		0.3		2.1	3.6	24.3	64.1	19.5	2.26	117
17 - TONLE SAP BASIN	4,150	1.7		0.2		3.6	6.0	23.2	65.3	38.0	1.24	85
18 - EAST COAST GULF BASIN	13,829	6.5		0.2		8.2	12.1	36.4	36.6	12.5	11.34	59
Region	36,438	6.4		0.3		5.2	8.2	25.9	54.0	19.7	21.13	-
WESTERN												
14 - MAE KLONG BASIN	30,837	38.6		0.3		14.3	10.9	15.3	18.6	53.0	13.61	145
19 - PHETCHABURI BASIN	5,603	43.0		0.10		6.0	7.8	6.1	37.0	41.0	0.88	33
20 - PRACHUAPKHIRI KHAN COAST	6,745	8.5	0.17	0.47	0.18	2.6	13.7	17.2	57.2	43.0	2.11	312
Region	43,185	34.4	0.03	0.3	0.03	11.4	10.9	14.4	27.0	49.88	16.61	-
SOUTHERN												
21 - PENINSULA-EAST COAST	26,352	8.4	1.02	1.07	0.81	7.7	9.0	13.0	59.0	13.0	26.59	134
22 - TAPI BASIN	12,225	10.0	1.16	0.74	0.90	8.4	12.0	21.1	45.7	24.0	15.43	134
23 - THALE SAP SONGKHLA BASIN	8,495	10.1	2.35	1.08	1.27	8.9	5.5	29.2	41.6	9.0	8.04	48
24 - PATTANI BASIN	3,858	10.7	2.43	1.17	1.20	5.9	1.8	16.7	60.1	34.0	2.43	150
25 - PENINSULA-WEST COAST	21,172	23.3	2.16	0.84	0.90	21.1	12.6	12.4	26.7	45.0	23.37	179
Region	72,102	13.37	1.61	0.95	0.93	11.80	9.77	16.30	44.93	25.0	75.86	-
Country	**512,066**	**16.07**	**0.26**	**1.40**	**0.13**	**8.30**	**7.54**	**16.00**	**50.30**	**28.0**	**201.18**	**-**

Source : Modified from Tangtham (1992b)



Figure 1 Pictorial guide to "Watershed Classification" and land use practices in Thailand : **WSC 1-A** :- areas of protection forest and headwater source, usually at higher elevation with very steep slope. **WSC1-B** :- are those areas of similar physical features and environment to WSC 1-A but portion of the area have been cleared for agricultural use or occupied by villages. These areas require special soil conservation measures and where possible should be replanted for forest or maintained in permanent agroforestry. **WSC 2** :- are areas designated as commercial forest, usually at high elevation with steep slopes. Landform are less erosive than WSC 1. **WSC 3** :- are area of upland with moderately steep slopes and less erosive landform. They may be used for commercial forest, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures. **WSC 4** :- are areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for a few soil conservation measures. **WSC 5** :- are gentle to flat areas used for paddy fields or other agricultural uses with few restrictions

Fig. 2. An example of computer map of watershed classes based on the derived equation and selected parameters in 1×1 sq.km grids.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1								3 B (3.29) FT,T,H	3 B (3.46) FT,T,H	3 B (2.85) FT,T,H	4 B (4.45) NCR	4 B (4.45) NCR	4 B (4.22) NCR	4 B (4.20) NCR	4 B (4.47) NCR	5 B (4.69) Pa.F
2					2 B (1.68) CF	1 B (1.04) PF	2 B (1.81) CF	3 B (2.67) FT,T,H	3 B (2.77) FT,T,H	4 B (3.92) C,SC,P	5 B (4.87) Pa.F	5 B (4.87) Pa.F	5 B (4.89) Pa.F	5 B (4.89) Pa.F	5 B (4.85) Pa.F	4 B (4.69) NCR
3				3 A (3.47) FT,T,H	5 A (4.88) Pa.F	5 B (5.09) Pa.F	5 B (4.89) Pa.F	2 B (1.91) CF	2 B (1.87) CF	2 B (1.79) CF	4 B (4.84) NCR	5 B (5.09) Pa.F	5 B (4.88) Pa.F	5 B (4.85) Pa.F	5 B (4.88) Pa.F	4 B (4.69) NCR
4				3 B (3.21) FT,T,H	4 B (4.89) NCR	3 B (2.63) FT,T,H	3 B (2.80) FT,T,H	4 B (4.63) NCR	4 B (4.35) NCR	2 B (2.19) CF	5 B (4.87) Pa.F	5 B (4.88) Pa.F	5 B (5.02) Pa.F	4 B (4.87) NCR	5 B (4.88) Pa.F	5 B (4.88) Pa.F
5			4 B (4.24) NCR	4 B (4.46) NCR	3 B (2.82) FT,T,H	2 B (1.78) CF	4 B (4.49) NCR	4 B (4.47) NCR	4 B (4.52) NCR	4 B (3.77) C,SC,P	4 B (3.87) C,SC,P	3 B (3.22) FT,T,H	4 B (4.33) NCR	5 B (4.88) Pa.F	5 B (4.88) Pa.F	5 B (4.88) Pa.F
6			3 B (3.44) FT,T,H	4 B (4.43) NCR	3 B (3.01) FT,T,H	2 B (2.29) CF	4 B (4.22) NCR	4 B (4.45) NCR	4 B (4.27) NCR	2 B (2.30) CF	3 B (3.91) FT,T,H	2 B (1.84) CF	5 B (4.89) Pa.F	5 B (4.88) Pa.F	4 B (4.69) NCR	5 B (4.88) Pa.F
7			3 B (2.83) FT,T,H	2 B (2.17) CF	4 B (3.55) C,SC,P	4 B (4.50) NCR	4 B (4.45) NCR	4 B (4.70) NCR	4 B (4.50) NCR	4 B (4.00) NCR	3 B (3.41) FT,T,H	2 B (1.96) CF	4 B (4.43) NCR	5 B (4.88) Pa.F	4 B (4.48) NCR	4 B (4.45) NCR
8				3 B (2.67) FT,T,H	4 B (3.70) C,SC,P	4 B (4.50) NCR	4 A (4.46) NCR	3 B (3.33) FT,T,H	3 B (3.16) FT,T,H	4 B (4.70) NCR	4 B (4.05) NCR	4 B (4.20) NCR	4 B (4.27) NCR	4 B (4.49) NCR	4 B (3.84) C,SC,P	4 B (4.26) NCR
9		4 B (4.47) NCR	3 B (3.51) FT,T,H	2 B (2.52) CF	4 B (4.01) NCR	4 B (4.50) NCR	5 B (4.91) Pa.F	3 B (3.18) FT,T,H	2 B (2.39) CF	3 A (2.91) FT,T,H	3 B (2.67) FT,T,H	4 B (3.85) C,SC,P	4 B (4.22) NCR	3 B (2.59) FT,T,H	2 B (2.32) CF	4 B (4.22) NCR
10	4 B (4.28) NCR	4 B (4.23) NCR	4 B (4.24) NCR	3 B (3.40) FT,T,H	4 B (4.43) NCR	5 B (4.88) Pa.F	4 B (4.72) NCR	4 B (4.66) NCR	3 B (2.79) FT,T,H	2 A (1.67) CF	2 B (2.10) CF	4 B (3.80) C,SC,P	4 B (4.45) NCR	3 B (3.19) FT,T,H	2 B (1.88) CF	3 B (3.39) FT,T,H

TOTAL AREA= 133.00 Sq.km.: WSC# 1 AREA= 1.00 Sq.km. = 0.75 % WSC# 2 AREA= 18.00 Sq.km. = 13.53 % WSC# 3 AREA= 28.00 Sq.km. = 21.05 % WSC# 4 AREA= 59.00 Sq.km. = 44.36 % WSC# 5 AREA= 27.00 Sq.km. = 20.30 %

SOIL CONSERVATION REQUIRED: PF=Protection Forest; RF=Reserved Forest; CF=Commercial Forest; FT=Fruit Trees; T=Terrcing; H=Hillside Ditch; C=Contour Cultivation; SC=Strip Cropping; P=Pasture; NCR=No Conservation Required; Pa.F=Paddy Field

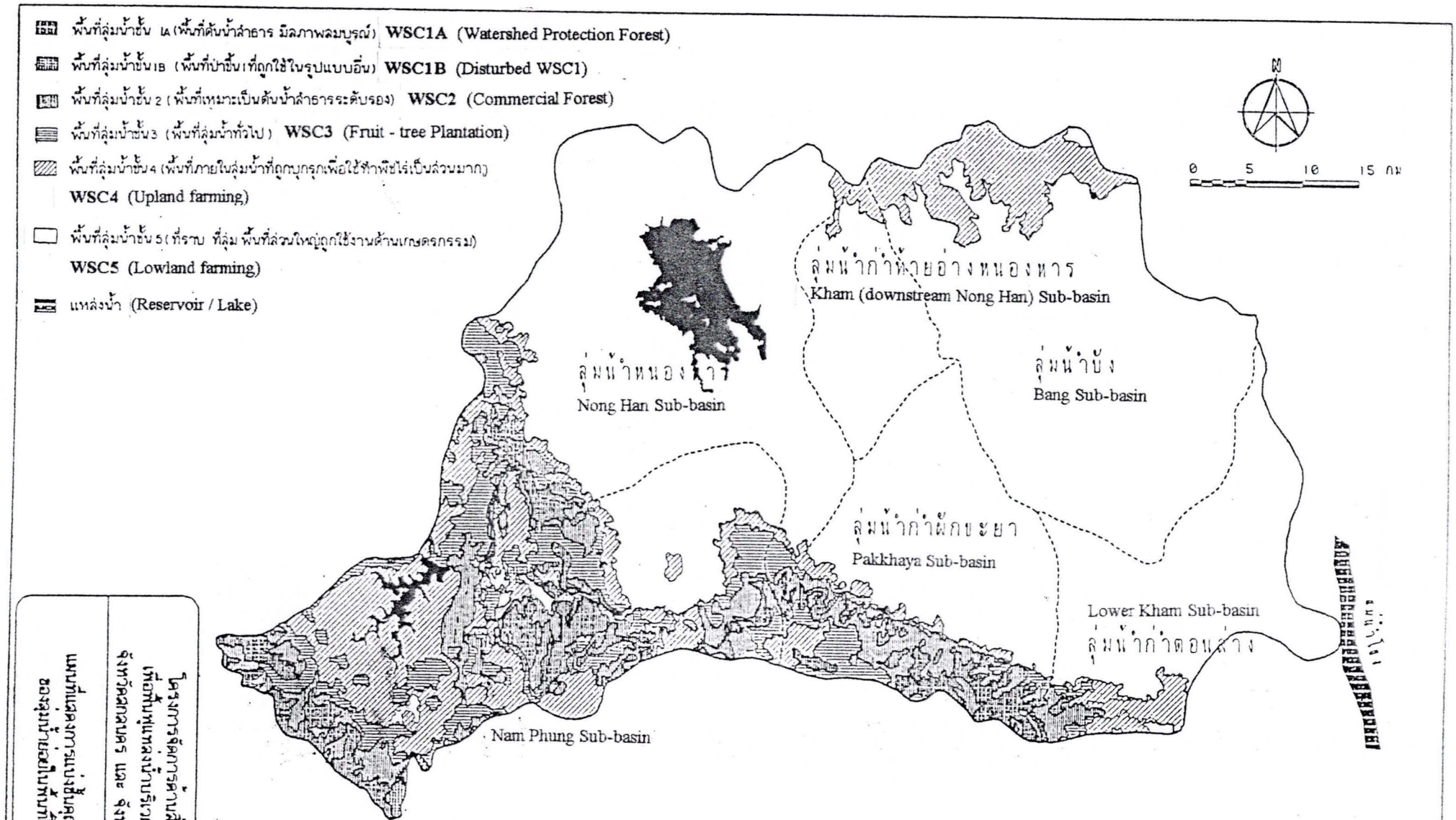

Fig. 3. An example of watershed classes map after final adjustment based on contour map and forest map.

รูปที่ 4-2

ANTHROPOLOGICAL METHODOLOGIES IN THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF SIX PROPOSED HYDROELECTRIC POWER PROJECTS OF THE NATIONAL POWER CORPORATION

Ma. Luisa C. Umaly*
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1. INTRODUCTION

The Anthropological Studies of the Proposed Hydroelectric Power Projects of the National Power Corporation in the Philippines is a research endeavor involving both the archeology and ethnography of six proposed hydroelectric power (HEP) project sites, namely: Addalam Small Hydropower Project (SHyp) in Cabarroguis and Aglipay, Quirino; Bakun SHyP in Alilem, Ilocos Sur; Agbulu HEP in Calanasan and Kabugao, Apayao; San Roque Multipurpose Project in San Manuel and San Nicolas, Pangasinan and Benguet Province; Aglubang SHyP in Calapan, Oriental Mindoro and Sablayan, Occidental Mindoro; and Timbaban HEP in Madalag, Aklan. The research covered the period June 1994 to January 1996.

The Studies were undertaken as part of an Environmental Impact Assessment (EIA) to determine the environmental effects of the proposed HEPs and to recommend measures needed to make it suitable to its environment. In particular, the EIA requires that an archeological survey and assessment be made to ascertain if the proposed Project Sites are historically and archeologically significant. If found to be so, safeguards to ensure that these cultural artifacts are properly retrieved and studied would be recommended. Furthermore, the EIA should include a detailed study on the host community and its environs and an assessment of the possible social, cultural, economic, and ecological impact of the proposed Projects HEPs on the community. The latter is crucial since the Project Sites are presently occupied by communities who trace their ancestry to the Ifugaos, Isnags, Kankanays, Mangyans, Pangsinanes, Ilocanos, and Aklanons.

2. ARCHEOLOGICAL STUDIES

Archeology is the study of past cultures. The evidences, artifacts, are man-made objects or human alterations of the environment. When recovered, preferably intact and in context, the artifacts can provide information about the people who used them, as well as the condition of their existence. Besides yielding data on the physical, biological, and social conditions of a given place, insights into certain aspects of human behavior useful for charting events in the present or in the future can also be generated.

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- Showing of a collection of archeological materials to the communities as part of the "Cultural Property Awareness Program" so that the local populace can see and touch artifacts which may help in the development of a keen appreciation of their archeological resources. This also serves as a source of information in case similar finds may have been accidentally uncovered by informants in the course of their daily activities.

3. ETHNOGRAPHIC STUDIES

Anthropological research is the process of observing human behavior, including verbal behavior, in space and time. Anthropologists who specialize in the study of contemporary societies and cultures "produce" what is called an ethnography. An ethnography is a "written report summarizing the behaviors and the beliefs, understandings, attitudes, and values they imply, of a group of interacting people" (Berreman, 1968:337). In sum, an ethnography gives an overall view of the culture of the people about whom it is written. In practice, it cannot cover all aspects of a culture of a given society. At best, the ethnographer emphasizes the main features which contribute to the understanding of the culture under study.

The underlying assumption made in the following ethnographic exposition is that culture is an adaptive system. Marvin Harris, an exponent of the cultural ecology appraoch in Anthropology, draws from A. R. Radcliffe-Brown's work entitled *Structure and Function in Primitive Society* (1952) to elaborate on the cultural ecology formulation. Harris (1971) explains that there are three adaptive aspects of the total social system: (1) ecology, or the way the system is adapted to the physical environment; (2) the social structure, or "the arrangements by which social life is maintained"; and (3) the mental characteristics that fit people to their social structure and their ecology or ideology.

Using the above framework, the presentation of the ethnographic studies begins with an introductory section on the geographical and historical setting of the people to be studied These provide the background for the ethnic, linguistic, and cultural affinities with other groups in the area.

The first portion provides a brief description of the people as distinct indigenous cultural communities. Subsequent sections deal with details of their social organization including family, kinship, social stratification' the people's means of making a living given the conditions of their specific habitat including the tools and techniques of production and distribution; and political organization. Equally important is information on resource use and management, popualtion, and age and sex composition. These are among the relevant data needed for assessing the impact of development programs. Again, the relationship between the environment and the system of production and various social groupings is explored.

Lastly, the segment on religious organization shows the interconnected beliefs regulating man's relationship with his environment, with other men, and the supernatural. Anthropologists view these beliefs as working positively, for instance, in maintaining health, ecological balance, and harmonious relationships in social groupings.

The Research Team introduced the Studies' objectives, then asked permission from the local leaders to consult with the communities. The process which followed was the recording of views and knowledge of the problems and potential solutions with reference to the proposed dams so these could be integrated prior to the implementation of the HEPs.

The barangay captains were also informed about the planned activities of the Archeological and Ethnographic Research Team: conduct of surveys in the proposed powerhouse and dam sites as well as the areas in between, by the Archeological Group, and key informant interviews, focus group discussions, and community mapping by the Ethnographic Team.

3.2.2 Review of Literature

Relevant ethnographies, published papers and articles on the indigenous cultural communities were reviewed to provide the Research Team with a comprehensive overview of the area, its people, and culture. Previous studies on the communities served as a starting point in indetifying several research gaps as well as in understanding the process of culture change in the areas.

Census reports from the National Statistics Office (NSO), municipal and barangay profiles from the Municipal Planning and Development Office (MPDO) also served as sources of information. Basic data on demography, health situation, and other relevant information were culled from these reports.

Materials pertaining to the planned HEPs were also obtained from NPC. Petition letters of opposition groups, proceedings of meetings of peoples' organizations (POs), documents of the LGU, and correspondence among various organizations and agencies were also collected.

3.2.3 Focused Walks

The objective of the method is to observe the different activities in the areas of functional relevance to resource access and use including activities in the DIA and SIZ.

Observations made verified information gathered in the course of community mapping and profiling.

The Team walked with one to three local residents who pointed out and explained aspects of the functional areas and those to be affected by the HEPs. These included ricefields, swiddens, irrigation systems, drinking sources, pathways, the barangay hall, school, churches, playground, as well as the different sitios.

The researchers then noted down the locations of the different functional sites, the ongoing activity or work at different times of the day, and the individuals involved in the tasks.

3.2.4 Community Mapping and Profiling

The researchers made a rough sketch of the general areas and plotted out the "significant aspects" to locate the infrastructures (types of residential units, schools, medical facilities, water supply, and waste disposal system) and resource locations (fields, springs, river, forest). Help from some barangay officials was also solicited.

3.2.5 Participant Observation

Two activities are involved in this method: observing and recording the behavior of the community and participating in as many activities as the chance appears. Thus, the researcher joins in harvesting and threshing the rice or in fishing. In addition, the method allows him/her to establish rapport.

The researchers stayed in the communities for a certain period -- from three weeks to two months -- in order to directly observe and document family and village life. The disparity between formal and polite responses in interviews and non-verbal but obvious attitudes toward the HEPs was observed using this anthropological technique.

3.2.6 Socio-Economic Survey

The household surveys covered the Direct Impact Areas (DIA) of the proposed HEPs, in particular those projects which will inundate more than five sitios or five barangays, affecting more than a hundred households. Priority was given to households that are situated near the river banks because these are the areas that would most likely be affected by the proposed HEPs. An interview schedule was utilized in the conduct of the survey. It must be mentioned that the questionnaires were used as guides in the conduct of semi-structured "informal" talks. This meant to avoid a situation where respondents would feel threatened by the questions, considering the sensitivity of the issues involved. Moreover, the respondents were guaranteed that their replies would be confidential and their names would remain anonymous.

No house-to-house surveys were conducted in Project Areas that would affect less than 20 households. Rather, the focus was to ascertain the households which would be directly affected by the proposed HEPs. The household heads and when possible, with their spouses, were interviewed intensively to elicit their views on how the proposed HEPs will affect their households. Guide questions rather than survey forms were used.

3.2.7 Focus Group Discussions (FGDs)

Traditionally, the FGD was called focus group because its composition is relatively homogenous, e.g., women, men, and children. Nowadays, it means a group of people whose discussion is focused on certain issues because their social characteristics and activities predispose them "to know" (local expertise) about the issues being discussed. The FGDs were conducted in the communities to get more qualitative responses about the people's perceptions towards the proposed HEPs. The number of participants ranged from 10-20 for each discussion group.

3.2.8 Unstructured Interviews

The term "unstructured" refers more to its being "opportunistic". The researcher seizes every chance to engage residents in a conversation or simply an exchange of pleasantries. The purpose is to establish rapport. The questions asked are meant more to stimulate discussion on a significant subject. The researcher can then probe into the issue with other residents or key informants. Sometimes, the types of questions raised are influenced by the age and sex of the interviewee. Women are generally asked about family, health, nutrition, and education while information about crop production and barangay affairs is sought from men.

3.2.9 Key Informant (In-Depth) Interviews

The key informant is a person who has a good knowledge of the community and its culture. The individual may be an elder with strong roots in the community. He/she may also be a person with "specialized" knowledge about a particular aspect of the culture. In the settlement of disputes, the elders or barangay captains may be the key informants. In matters of rituals and ceremonies, the native priest and priestess would be the source of data.

3.2.10 Community Meetings or Assembly of Relevant Groupings

Before finalizing the results of the Studies for submission to NPC, the UGAT Research Team presented the report to the communities for their comments and additional insights. Among the objectives of the validation sessions is to ensure that the perceptions were documented fairly. In addition, the meeting may move the community to pursue a program of action in the light of the results presented.

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2.1 Rationale

Republic Act No. 4846, known as the Cultural Properties and Protection Act, enacted on June, 1966, and amended by Presidential Decree No. 374, signed on June, 1974, provides for the protection and preservation of the country's cultural resources. The Philippine Environment Policy, Presidential Decree No. 1151 enacted on June, 1977, requires the Environmental Impact Statement (EIS) for all environmentally critical areas and projects prior to the issuance of an Environmental Compliance Certificate (ECC). It further specifies the preservation of historical and cultural resources. In compliance with the EIS system, an Archeological Survey and Assessment is required to identify and preserve the cultural resources, an important part of the nation's resource base.

2.2 Objectives

The objectives of the archeological surveys and assessments are:

- to identify and map out the location of archeological sites and artifacts in the Project Areas;
- to assess the significance of areas identified as archeological sites; and
- to formulate a program for the retrieval and final disposition of archeological artifacts and sites, if any are found in the Project Areas.

2.3 Methodology

The methodological approach for the archeological surveys and assessments of the six proposed HEPs are the following:

- Study of the soil and topographic maps: both 1:50,000 for the accurate plotting of the sites and 1:250,000 for location reference. The study of the topographic maps leads to possible sites.
- Review of literature on historical references and all previous archeological work conducted on the areas to be affected by the hydrolectric projects: Direct Impact Areas (DIAs), the location of the Projects' structures and facilities; Secondary Impact Zones (SIZs), areas between the dam/weir and powerhouse sites; Regional Impact Zones (RIZs), municipalities which may be affected by the Projects.
- Conduct of scoping sessions to discuss the rationale and objectives of the archeological and ethnographic studies and to elicit information on observations which may be archeologically significant.
- Interviews with local residents to share and establish the significance of archeological artifacts and sites as well as to elicit data of historic and folkloric nature. Likewise, information about chance discoveries of artifacts and sites are sought from the communities.
- Field walking or actual inspection of the terrain. The Archeological Team explored on foot the areas which will be affected by the construction and operation of the six proposed HEPs.
- Inspection of previous excavations, eroded areas, river cut terraces, road cuts, and sand gullies.