Asia-Pacific
Economic Cooperation

Utilization and Protection of Water Resources

Case Studies on River Basin Management and Pollution Prevention

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APEC Center for Technology Transfer

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Foreword

Water resources are the very important issue globally. One of the most needed and lacking resources in the 21st century is water resources. Furthermore, water resources are extremely important for human beings and the development of the whole world. The lack of water resources are partly because of the uneven regional distribution, partly because of the worsening water pollution caused by human activities.

In face of the water shortage and pollution, policy makers from all nations and regions tried to handle the problems properly. However, inconsistent standards for water quality and water use, a failure to coordinate among jurisdictional departments and other organizations involved in water management have long been the obstacles to solutions. Therefore, National water strategies and regional water policies, including water pricing, water rights identification, policies concerning agricultural irrigation remain experimental and defective. Besides, Sewage water, industrial wastewater and irrigation water polluted by pesticides have rendered the problem worse and worse.

To solve the problems of water shortage and water pollution, different nations and territories have made great efforts to build up effective water policies that facilitates more efficient responses to current and emerging challenges and threats, and have provided a great number of funds to the research of water treatment and developed a variety of wastewater treatment technologies. In addition, some countries and regions establish water utilization projects and create water coordination module that will improve water supply and management.

With the case studies of jurisdictions and technologies that have developed, or are in the process of developing, insights about the forms of water strategies and polices, about the better choice of water treatment and water utilization would be revealed.

The objectives of this project are to do research on how to make use of the limited precious water resources, share the advanced technology on water utilization programs and wastewater treatment methods in each APEC member economies, synthesize and integrate water resources utilization and protection strategies and polices, achieve more collaboration in this area, and to build up an experts and technology network and database on the water resources website of APEC Center for Technology Transfer.

After being submitted to the due processes in the APEC Science and Technology Working Group (ISTWG), the project was approved and additional funding was endorsed from the APEC Support Fund as complement to the funding from the Ministry of Science and Technology of China, Department of Science and Technology of Jiangsu Province, Suzhou Science and Technology Bureau and China Science and Technology Exchange Center.

The study of the project involved a publication and online survey, researches and reports of experts, a symposium for presentation and discussion and a concluding research.

1. January 2009 to March 2009, a publication and online survey
2. April 2009 to June 2009, identification of research experts
3. June 2009 to September 2009, research based on the themes of the project
4. September 22-23 2009, a symposium held in Suzhou, China
5. October 2009 to December 2009, conclusion of the whole research work and project

The symposium was supported by presentations of the research experts and many of them have also contributed reports on relevant areas. All the available material has been collected in this book and available in the attached CD-ROM. The co-sponsors would like to thank the many participants, more than 90 from 14 APEC member economies, for their participation and devotion of time and efforts to make the symposium and the project successful and productive.

APEC Center for Technology Transfer

Acknowledgement

This project could not be achieved without the help and support from many organizations and people. First, APEC Center for Technology Transfer would like to express our gratitude to Asia-Pacific Economic Cooperation (APEC), the Ministry of Science and Technology, Department of Science and Technology of Jiangsu Province, Suzhou Science and Technology Bureau and China Science and Technology Exchange Center for the precious funding and support to the project.

We would like to acknowledge People's Government of Suzhou Municipality, Tsinghua University, Hohai University, Suzhou University of Science and Technology, International Water Technologies Group (Hong Kong, China) for providing facilities and technological advice in the process of the project. Special thanks must be given to the consultants and researchers. They are: Dr. Perry McCarty, Mr. Igor Korshenko, Dr. Liu Xiang, Dr. Shiang Fu, Dr. Sang Chun Lee, Dr. Vu Hoang Hoa, Dr. Surajate Boonya-aroonnet, Dr. Shang-Lien Lo, Dr. Edwin D. Ongley, Dr. Li Xin, Mr. Dai Jinming, Dr. Tatiana Selivanova and Dr. Cui Guangbai.

Gratitude is given to all of the co-sponsoring economies: Australia, Hong Kong China, Korea, The Russian Federation, Chinese Taipei, Thailand and Viet Nam. Special appreciations should be given to Dr. Shiang Fu for his suggestions and recommendations of researchers, Dr. Myung-Jin Lee for his opening remark addressed and support for the project and Ms. Churdchan Juangbhanich for her support in announcing the Letter of Proposal in the closing ceremony. Last but not least, the Center would like to acknowledge, with much appreciation, all the participants to this project for all ideas and discussions from the symposium and whole project.

Executive Summary

Project Implementation

APEC Project- Utilization and Protection of Water Resources (APEC IST01/2009A) was endorsed in 2009 for implementation and funded by APEC Industrial Science and Technology Working Group. It was co-sponsored by: Australia, Hong Kong China, Korea, the Russian Federation, Chinese Taipei, Thailand and Viet Nam.

The project conducts the following principal activities:
1. Collection of data and research outcomes from both prints and official web pages
2. Defining concept of the project and locate suitable researchers
3. Exchange of ideas among the researchers and consultants on current research
4. Organization of the symposium and related events
5. Establishment of web portal to disseminate the outcomes and facilitate further development of the project in APEC region

The project has provided five key deliverables:
1. Database on utilization and protection of water resources containing papers and research findings by experts among APEC economies
2. A list of researchers and professionals and a network of multinational institutes and organizations in this area
3. A final report based on the collected data and research outcomes of researchers
4. Two-day APEC Symposium on Utilization and Protection of Water Resources
5. Web portal for dissemination of project output (www.apectt.cn/water)

Water Resources Management

Dr. Perry L. McCarty's research attaches importance on the principal area of water scarcity and management. With a broad perspective of water resources in light of water footprint, the water scarcity in a nation or city can be measured in a more scientific way.
Comparing with the traditional perspective that wastewater is a waste, a new perspective to view wastewater as a resources is a new breakthrough. More applications of wastewater are to be found, which can offset the burning of fossil fuels and provide renewable energy for the sustainable development of human beings.

Dr. Edward Ongley's research focuses on the comparison between China's legislative, operational and management systems and that of the western APEC economies. Some APEC member economies, represented by China, are still in the course of building sound legislative and management systems. Much experience of the western economies, especially of Australia, Canada and the US, are beneficial and inspirational.

APEC member economies with low latitude are constantly the victims of flood and draughts. Dr. Surajate Boonya-aroonnet's report on *risk management of water resources under the threat of climate change* attempts the exploration towards the comprehensive management of the region suffering from both flood and draughts, which has seldom been notified before, based on the output of former researches.

Water Treatment in river basin

Dr. Shiang Fu supplies consultation of the present treatment of Industrial wastewater, water pollution and drinking water and forecast of the highly desirable technologies for the wastewater treatment. With the expertise and studies of the solutions in the area, his advised direction will help the further development of water treatment technologies in APEC region. Technologies with high efficiency and lost cost and easy operation and maintenance will have the greatest potential of success in China.

In Dr. Liu Xiang's paper, it emphasized on the main problem of water environmental resources in the process of urbanization of city in China. By Comparison between the water resources consumption and contamination yield, the main source and load could be sorted out in Taihu watershed. The solutions for the urban water environmental problems were exposited.

Dr. Sang Chun Lee has conducted a research on comparison of organochlorine pesticides in sediments of four major rivers in Korea with a number of other major rivers in selected APEC member economies. The report could be informative for recognition of the present problems and further research on water pollution.

Dr. Tatiana Selivanova' research features hydrological and ecological condition of water in the rivers of Russian Far Eastern rivers and its influence on the environment of the Russian Far East as well as the industrial impact on surface water in Primorsky region.

Solution

Dr. Tran Phuong Dong's report attaches importance to the situation of discharged waste water in the Nhue River and methods of pollution estimation. Some solutions were proposed to improve the situation in the future, which could inspire other economies for water treatment in river basins.

Dr. Shang-Lien Lo's report has introduced some practical solutions for river basin in Chinese Taipei and best management practices and artificial floating islands are advocated for non-point source pollution. This research brings new ideas to water treatment and management in river basins.

Letter of Proposal

Currently, the ever-increasingly serious problem of water resources shortage and water pollution has become one of the major impediments to world economic development. Effective treatment of water pollution and management of the limited water resources so as to form a water resources environment for the sake of sustainable development is a common challenge confronting the human kind.

From September 22 to September 23, 2009, the APEC Symposium on Utilization and Protection of Water Resources was held in Suzhou, China.

At the symposium, relevant regulations, laws, measures, engineering effort on river basin water resources allocation and treatment of river basin water environment by member economies were discussed. Successful experience on water resources allocation and management were shared, advanced water treatment methods were introduced to all participants. Efforts were also made to promote exchanges and cooperation among member economy governments, water authorities, research institutes and enterprises. More than 80 experts, scholars and water workers from the APEC member economies held serious discussions and exchanges on the above-mentioned issues, with the treatment of river basin water environment and utilization and protection of water resources in particular. With in-depth discussion on some technique issues, they have come up with some innovative ideas. Generally speaking, the symposium accomplished its goal and ended successfully.

To further expand results of the symposium, determine follow-up actions and to further consolidate and enhance exchanges and cooperation on utilization and protection of water resources within the framework of APEC, we propose as follows:

1. All APEC member economies should further strengthen their efforts in raising the general awareness of the public and enterprises on water resources protection;

2. All APEC member economy governments and relevant water authorities and agencies are urged to actively conduct exchanges on laws and regulations concerning water resources allocation;

3. Relevant research institutes, experts and scholars in all APEC member economies should further strengthen their exchanges and cooperation, assist each other and share the latest developments and technology in the field of utilization and protection of water resources;

4. With this symposium as the starting point, the ISTWG should proceed with project cooperation on utilization and protection of water resources and gradually expand it into specific technique fields.

Let’s join hands in utilizing and protecting the water resources which are essential to our survival.

All participants to the symposium

Suzhou, China
September 23, 2009

Challenges and Opportunities in Addressing Water Scarcity, Quality Degradation, and Sustainability

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One of the most important water resources is groundwater, which makes up 98% if the liquid freshwater supply on Earth. Worldwide, 50% of the water for domestic needs comes from groundwater. Unfortunately, as is too common, the important groundwater resources are being over exploited and contaminated by unwise waste disposal practices. Water is used for agricultural, industrial, and domestic purposes. Importantly, it also provides important ecosystem services. Agricultural water is consumed through evapotranspiration so that it cannot be used again. However, through domestic and industrial use, water is generally dirtied, but not consumed. It can be cleaned by modern techniques to any degree needed and used again.

Used water should not be considered as a waste, but as a resource – a resource for its heat energy and for the production of biofuel or renewable energy, for plant nutrients, and as a source of water for reuse. Properly reclaimed wastewater can appropriately be used for domestic as well as for agricultural and industrial purposes as illustrated by several examples in the United States, especially in California. Conservation and more efficient use of water for agriculture, domestic and industrial purposes with recognition of the limits imposed to achieve sustainable demand in a given area is essential for the future, as are management practices that provide adequate protection to available water resources and ecosystems from domestic, agricultural, and industrial contamination.

The water requirement for human activities is often defined as the quantity of freshwater used to produce the goods and services consumed by an individual. Basic uses are for agriculture to produce the food and fiber that we need, for industry to manufacture the products that we use, and for domestic purposes to supply the water required for drinking, cooking, bathing, washing, landscape irrigation and other uses in our homes. The largest need is for agriculture. This requirement varies from about 1.8 to 4.0 m^3/cap/d, with a world average of 2.9 m^3/cap/d. A vegetarian diet results in a smaller agricultural water footprint, near 2 m^3/cap/d, while a diet rich in meat requires as high as 4 m^3/cap/d.

Greater variation occurs in the industrial and domestic water footprints. Higher industrial water footprint is related to high consumption of goods. Higher domestic water footprint is reflective of greater direct access to freshwater. Easy continuous access through a piped supply to the home results in much higher domestic use of water than if one has to hand carry the water from a community supply. Differences in domestic water footprint are illustrated in Figure 2 (Hoekstra and Chapagain 2007). The world average of 0.16 m^3/cap/d is to high to be carried from a distant well each day. For many countries such as China (0.073 m^3/cap/d) the domestic demand is much less than this, but is likely to grow with the growth in economic development and with it an increased demand for a convenient piped supply to individual residences.

Interestingly, the countries with the highest domestic and overall water footprint, Australia and the USA, are often cited for their major water droughts. Partly, this dichotomy results because they are large countries with plentiful water in some parts of the country, but great deficiencies in others. These countries are major growers and exporters of food crops, which represent water consumption, not to satisfy their own needs, but that of others. Manufactured and agricultural products can be imported. Thus, the “virtual water” used in their production can be located in a different country, which is not true of domestic water, since the cost of moving water compared with its value is much too high to be transported far.

Thus, the water footprint of one country does not necessarily reflect usage of its own water resources to satisfy that need. For example, with Germany, the Republic of Korea, Italy, and the United Kingdom, the external water footprint is greater than the internal water footprint. They depend to a greater extent on freshwater supplies in other countries to satisfy their water footprint needs. Generally, this becomes the case when water to meet their needs is scarce. The water scarcity represents the fraction of a country's total water footprint divided by the total renewable water resources available within that country. Water scarcity is greater than 50 percent in most countries with an external water footprint greater than 50 percent. Water scarcity perhaps can be dealt with through international trade, but it is also prudent to reduce such dependence through greater efficiency in water use. One aspect of helping to achieve that is wastewater reuse.

Table 1. Water scarcity for various countries, after Chapagain and Hoekstra (2004)

	m^3/capita/d				
Economies	Total renewable water resources	Internal water footprint	External water footprint	Total water footprint	Water scarcity (Percent)
Australia	70.68	3.13	0.69	3.82	5
Canada	259.41	4.47	1.15	5.61	2
China	6.31	1.80	0.13	1.92	30
Germany	5.13	2.00	2.24	4.23	82
Japan	9.30	1.12	2.04	3.16	34
Korea, Republic of	4.08	1.23	2.00	3.23	79
Italy	9.08	3.13	3.26	6.39	70
USA	30.00	5.53	1.27	6.80	23
United Kingdom	6.86	1.01	2.40	3.41	50

Water as a resouce

Wastewater reuse is widely practiced in order to meet a deficiency in water availability. The cost of converting domestic wastewater into a product that is safe for indirect potable use has decreased dramatically, largely through the development of cost-effective membranes for separation of dissolved as well as suspended constituents in wastewaters. Water quality requirements for irrigation of vegetable crops are not as stringent as for direct potable use, but nevertheless for safety this requires advanced treatment including filtration and disinfection, as well as efficient biological treatment. Irrigation, often the major use for water in water short areas is consumptive, most of the water is lost through evapotranspiration. Much of the water to satisfy domestic and manufacturing needs is not consumed, but simply degraded in quality. Through proper treatment, it can be used again, helping to extend a limited water supply. With water shortage, a major advantage can be obtained by using water first for domestic or manufacturing purposes, and then through reuse, for agriculture.

A large wastewater reuse project for agriculture in the USA is in Monterey County, California, where 130 million m^3 of wastewater has been reclaimed for irrigation of 5,000 hectares of vegetable crops since 1997. Freshwater is limited here and groundwater did represent the major supply, but overuse led to the intrusion of seawater, rendering this source unsuitable for irrigation. The wastewater treatment plant was located nearby, so transport to the agricultural fields became an economical alternative. Biological treatment, sand filtration and disinfection were sufficient to meet the rigorous water quality requirements for this use.

For agricultural use, wastewater treatment facilities need to lie near or else up gradient from the point of withdrawal. Use of more distributed or satellite wastewater treatment facilities located up gradient from the ocean is a concept now being encouraged in order to make reuse of wastewaters more economical.

The Whittier Narrows Treatment Plant operated by the Sanitary Districts of Los Angeles Country (SDLAC), California, has used advanced wastewater treatment since 1962 for discharge of 57,000 m^3/d into basins so that the treated water can further be treated by percolation through the soil to mix with groundwater that is used domestically. In 1971, the nearby San Jose Treatment facility was built to reclaim another 380,000 m^3/d, which is used both for local irrigation as well as for reuse by surface spreading. These large treatment facilities are located up gradient from a major wastewater treatment operated by the District, and were built as satellite facilities to take advantage of reuse potential. Biosolids from these plants are discharged back to the trunk sewer lines for treatment at the main facility near the ocean.

In Orange County, California, overuse of the groundwater led to seawater intrusion, which was threatening to render this supply unusable. In order to address this problem before it was too late, reclaimed wastewater was injected into the groundwater near the ocean to provide a mound of freshwater and thus prevent seawater intrusion. An exceptionally high degree of treatment was required for this purpose in order to protect public health and to prevent well clogging. Toward this end the Orange County Water District pioneered in 1976 the then most advanced system for wastewater treatment following biological treatment, that is physical-chemical removal by chemical precipitation, air stripping, activated carbon adsorption, multimedia filtration, and application of a new process, reverse osmosis, prior to disinfection. This 19,000 m^3/d facility was highly successful, spawning much research on membranes and other processes to achieve similar goals. Because of significant advances since then, excellent effluent quality can now be achieved through use of microfiltration membranes to replace the extensive chemical and physical treatment processes used originally in Orange County, followed by improved reverse osmosis membranes that greatly reduce energy costs and membrane clogging potential.

Use of membrane treatment systems for producing potable quality drinking water is widespread and growing such as in Singapore and Los Angeles. Following treatment, water is generally mixed with groundwater or placed in a basin for a period of time, perhaps a year, to provide an additional protective barrier for public health and to achieve additional natural water purification. In 2008, the Orange County Water District replaced Water Factory 21 with a much larger facility that uses the newer membrane approach to produce 190,000 m^3/d of reclaimed wastewater, about 50 percent of which is injected to provide a barrier to seawater intrusion and another 50% for recharge in its river basin.

A newer approach to reclaiming wastewater for use as a non-potable resource is the membrane bioreactor (MBR), which has a much smaller footprint than more traditional advanced treatment systems. The MBR uses a microfiltration or ultimate filtration membrane, which in effect replaces the final settling tank and filtration systems used in the traditional plants. There is a higher energy cost with the MBR as required to drive water through the membrane and to keep it free of clogging, but this is often offset by elimination of energy for pumping water from a distant centralized plant. The higher construction cost for the membrane system is offset by the need for a smaller biological reactor and the elimination of the settler and filtration systems. MBR usage is growing rapidly, and many have now been installed as satellite treatment facilities to treat wastewater where it can be used locally for such purposes as irrigation, fire protection, cooling, toilet flushing, and soil percolation. Here, excess wastewater and biosolids resulting from MBR treatment are allowed to flow through a truck sewer to a downgradient central treatment plant. The satellite systems produce useable water where needed without the costly piping and pumping costs that would be required to deliver comparably treated water from a central plant. The satellite systems reduce the loading on a central plant, with the central plant serving to offer treatment redundancy in case of a need to shut down a satellite system. The concentration of biosolids handling at the central plant allows for more cost-effective energy recovery from the biosolids as found in the Los Angeles County case noted in the following.

There are a growing number of such small satellite MBR systems located within individual apartment buildings. An example is The Solaire, a 293-unit apartment complex on Manhattan Island, New York City, that was opened in 2003 and uses a MBR followed by disinfection to produce 95 m^3/day of reclaimed water that is used for toilet flushing, cooling, and irrigation of its rooftop gardens. Several other similar systems are in use in New York. This helps the city meet the water demands of a population approaching 9 million people.

Energy and Nutrient Recovery

There is worldwide concern over climate change impacts of fossil fuel usage. One aspect of importance in making decisions about water resources today is changes that may occur such as sea level rise and freshwater availability for domestic, industrial, and agricultural purposes. Current models suggest seawater is likely to rise on the order of one meter during the coming century and that rainfall distribution throughout the world will change significantly. Projected seawater rise needs consideration in structures to be built near the coast, potential seawater intrusion into aquifers and estuaries, and future energy costs for pumping and disposal of treated wastewater to the sea. Projected less rainfall means that areas having sufficient fresh water now may have a deficiency in the future. Thus, while there may be little need now for advanced treatment of wastewater as required for its reuse, the significantly greater cost such treatment entails may be more justified in the future. Designs today should have sufficient flexibility to successfully meet these potential future impacts.

Wastewater contains organic materials that can be biologically converted to methane or biogas, a useful renewable fuel that can help offset the impact of fossil fuels on climate change. At SDLAC the recovery of valuable resources such as energy, reclaimed water, and recyclable materials from solid and liquid wastes has been a core part of their mission for decades. The use of satellite wastewater treatment systems by SDLAC to reclaim water for landscape irrigation and groundwater replenishment has already been mentioned. Simultaneously at 12 renewable energy power plants, SDLAC generates 127 megawatts of power from their separate solid and liquid wastes, transmitting 98 megawatts to the local electric grid while using 29 megawatts for operation of their facilities. As a result, $US 21.3 million of energy purchase was avoided and net energy sales of $US 23 million were made in fiscal year 2006-2007. As in many other sanitary districts, they continually strive to recover energy, water, and nutrient resources from wastes, while protecting the environment, including a more recent emphasis on reducing greenhouse gas impacts.

The energy derived from digester gas at the SDLAC wastewater treatment plants is all used on-site. These plants typically require additional import of power. Even when the energy content of wastewater is used to the maximum, it is still insufficient to completely satisfy that needed to operate the SDLAC wastewater treatment systems. The excess energy generated from their separate facilities for handling solid wastes does, however, make up for the deficiency in energy generated by biosolids digestion at their wastewater treatment plant. This is not a direct transfer of energy, but is achieved through simultaneous sale and purchase from the power grid. The operation of the district's wastewater treatment facilities require 39 megawatts, significantly more than the 23 megawatts produced from the anaerobic digesters at the facilities.

Numerous other examples of energy, water, and nutrient recovery from solid and liquid wastes at municipalities exist in California and elsewhere to support this view. Typically, only about 50% of the energy required for secondary wastewater treatment is available from wastewater biosolids digestion. Because of increasing energy costs and greenhouse gas concerns, greater efforts are being made through newer technological approaches to bring this closer to 100 %. But the examples used in this article demonstrate that modern wastewater treatment plants are already fully capable of producing usable water, energy, and plant nutrients to help meet the resource needs of a sustainable world into the future.

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Comparative Analysis of Chinese and Western APEC Experience in Integrated River / Lake Basin Pollution Management

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1. Introduction

The current international focus on water resources management is that of “integrated water resources management” (IWRM), or “integrated river basin management” (IRBM). In China, as elsewhere, there is recognition of the requirements for IRBM. In China’s legislative system, the major laws on water resources and water pollution management all contain provisions for “unified” and “comprehensive” management which is usually translated as “integrated” management. However, as we note below, integrated management remains elusive with the two major ministries, Ministry of Water Resources (MWR) and the Ministry of Environmental Protection (MEP) having differences of opinion over mandate and jurisdiction, and manage their respective responsibilities in isolation of each other. In most (but not all) western countries, while this was the model many years ago, contemporary water management is carried out collaboratively with new administrative structures to achieve inter-sectoral and inter-jurisdictional integration.

2. International Customary Law on Shared River and Lake Systems

Over the years the International Law Association (ILA) and the International Law Commission (ILC) of the United Nations have developed frameworks for shared watercourses and lakes, and for international aquifers. The 1966 Helsinki Rules were the first to codify “customary” law dealing with shared aquatic systems. The principles of the Helsinki Rules were included into, variously, the 1992: UN-ECE Helsinki Convention on Protection and Use of Transboundary Watercourses and International Lakes and the 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses. In 2004, recognising that customary law had matured considerably since 1966, the ILA published the Berlin Rules in 2004 that deals with shared groundwater, surface water, pollution management, etc., both between and within countries.

Application to China: Content of customary law that is commonly used in bi- and multi-lateral water treaties includes: equitable and shared use; avoidance of environmental harm; unified management; integrated water resources management (IWRM); reasonable access to information; sustainable use; rights of persons (pubic participation, right of access to water, duty to compensate); protection of aquatic environments (ecological integrity, ecological flows, pollution, water quality standards, enforcement, etc.); co-operation and administration (shared information, harmonizing of laws and procedures, notification, minimum requirements for basin-wide management, compliance review) and dispute settlement. These have particular applicability to China where each province tends to behave as a mini-state in regards to water and pollution management.

3. Legislative Systems

When one looks at the detail of the two main laws, the 2002 Water Law and the 2009 revision of the Water Pollution Prevention and Control Law (WPPC Law), and the cultural milieu that dominates the management system in China, the reasons for failure to achieve IWRM/IRBM is quite obvious. These contrast sharply with current practices in Australia, Canada and the United States in which the enabling conditions for IWRM/IRBM have existed for many years.

3.1 China

(i) The Chinese constitution devolves authority for managing natural resources to “local” government (“local” means provincial or below). There is no obligation in the constitution or in law for one province to pay attention to the needs of other provinces for water quantity or pollution levels. The principles of customary international law, such as the Berlin Rules, that obligate jurisdictions not to cause harm to downstream jurisdictions, to share data, etc., have never been incorporated into formal law in China. In the past 30 years, each province has been in a race to improve its GDP, usually at the environmental cost of its downstream neighbours.

(ii) The legislative system is complicated by the fact that, as many Chinese scholars have noted, it is not only incomplete, but laws are typically quite short and consist of statements of principles, are not good examples of modern law, and lead to confusion and conflict between ministries. For example, laws in water or environmental fields do not contain definitions, so there is a difference of opinion between the (MWR) and (MEP) over the definition of “water resources”. For MWR it is all-inclusive, where as for MEP it is restricted to water quantity and maintains that it alone has jurisdiction over pollution management. This leads to planning and management failures that are identified in this paper.

(iii) For IWRM/IRBM the Water Law explicitly combines management by administrative area and management by watershed. Article 12 stipulates that relevant ***water departments*** are “in charge of the unified administration and supervision of water resources” and Article 17 provides for comprehensive watershed planning for important rivers and lakes of which Taihu is one such lake. In contrast, the WPPC Law identifies that ***environmental protection departments*** of the people's governments at or above the county level exercise unified supervision and management of water pollution. Article 15 deals with transjurisdictional river basins and provides that plans for the prevention and control of water pollution … shall be prepared by the ***environmental protection department*** of the people’s government of the province, autonomous region or municipality under the Central Government together with the competent department of water administration at the same level. What we see here are two plans being prepared at the basin level – one for water resources management by the water department, and one for pollution control by the environment department. Both are submitted separately to the State Council and there is no obligation to integrate these two plans.

(iv) One of the fundamental principles of IWRM/IBRM is the sharing of data and information[ii]. Regrettably, data exchange is extremely limited, even between groups within a single ministry. Data have been commoditized so that data may be made available for a fee. There are three reasons for this. (1) selling of data is linked to financial gain for the originating unit and/or for private profit of officials; (2) ministries frequently claim the data such as routine monitoring data are a “State Secret” to justify non-release of data; and (3) a policy conflict exists between the State Secrets Law of 1989 in which almost everything is considered a State Secret, and the 2007 Open Government Law which requires all data collected by ministries (with specific exceptions) to be made available to the public (*“…information made or obtained by administrative agencies in the course of exercising their responsibilities and recorded and stored in a given form.”*) This conflict is recognized by the government and efforts to modernize the State Secrets Law have been in progress for a number of years but without resolution thus far. Some progress is being made in that MEP initiated in 2009 real-time and on-line access to data for some transjurisdictional monitoring sites. For the most part, however, access to Chinese data is restricted to annual summaries prepared by national and provincial environment and water departments, but without access to raw data. This applies both to monitoring data and pollution load data, and to water discharge data, and seriously handicaps public discussion or research into pollution control strategies and options.

3.2 Australia, Canada, America

Environmental legislation in these countries are extremely detailed and prescriptive: The US Clean Water Act (CWA) of 1972 is 234 pages, the Australian 2007 Water Act is 517 pages, and the Canadian Environmental Protection Law is 257 pages (compare with 22 [English] pages for China’s revised WPPC Law and 20 pages for the 2002 Water Law). Section 103 of the CWA identifies transjurisdictional pollution management. It also identifies roles of other agencies such as that of the U.S. Corps of Engineers in wetlands management. The interactions between the national and state governments are clearly described as is the authority of the EPA in dispute resolution. The CWA, like all legislation in these APEC countries is extensively cross referenced with other laws to ensure there are no overlaps or contradictions. A large part of the Australian Water Act deals with integrated river basin management and provides a legislative basis for integrated and comprehensive IRBM, for the roles of various agencies, the allocation of powers between national and state governments, and the role of the public.

Australia, Canada and the USA all have “open government” or “access to information” legislation that requires government-held information and data to be released to the public on request. Access to information is considered in these countries to be a "right" and is enforced by the courts and by officials (ombudsmen) who are engaged by the government to ensure that the regulations are followed by government officials. This is in contrast with China that, although having open government legislation, has achieved little progress in making data available to the public. In these three APEC countries there are specific requirements and rules for public participation, for dispute resolution, for data, etc..

4. Water and Environment Management Systems

4.1 China

China's management system has changed little in recent years apart from elevating SEPA to ministerial status (MEP) in 2008. There has been much written on this subject by Chinese and foreign scholars which is captured in the following bullets:

- **Planning**: fragmented planning with much overlap and inconsistencies by MWR and MEP. In general, MWR planning is carried out at the basin level and this is transposed to provincial water plans (or visa-versa). In contrast, MEP pollution control planning is mainly focused at the provincial level. Indeed, the Five Year Planning (FYP) process for total load reduction has been mainly a bureaucratic exercise which has no relationship to other objectives in the FYP such as water quality standards/objectives stated in the FYP. This causes many basin problems when downstream jurisdictions bring actions against upstream jurisdictions for failing to comply with the transjurisdictional water quality standard. Indeed, transjurisdictional pollution disputes between provinces are many, and most remain unresolved due to lack of detailed administrative mechanisms for dealing comprehensively with this issue. This lack of mechanism or over-arching authority results in the State Council having to become directly involved in extreme cases such as the 1994 pollution emergency in the Huai River (Wang C, 2004).
- **Institutions**: MWR is represented in major river basins (such as Taihu, Yangtze, Yellow, etc.) by river basin commissions. These are organs of MWR and have no representation from provinces within the basin. It has been argued by many Chinese scholars that China cannot have IWRM or IRBM until these basin agencies are removed from MWR and given independent mandates and are representative of their stakeholders (especially provincial governments). In fact, these basin agencies have limited basin management powers except for flood control and river water routing. Although the basin agencies do draw up basin-level pollution plans, these are generally disregarded by MEP on the grounds that MWR has no authority for pollution management. In contrast, MEP has no representation at the basin level (except for an early agreement with MWR to co-manage the Water Resources Protection Bureaus of each basin agency and from which MEP informally resigned some years ago). This has led to a form of institutional paralysis in which both these ministries and their provincial counterparts have no effective coordination.
- **Operations**: The institutional separation of MEP and MWR at the provincial level is manifested in many ways that effectively prevent IWRM/IRBM:
  - duplicate monitoring systems and duplicate reporting (expensive, wasteful, and inefficient) and has led to intensive competition for funds to further build up competitive monitoring systems.
  - Two separate water management unit systems – water function zone for MWR and water environment function zone for MEP. Both claim legislative legitimacy for their system, however the fact is that lack of harmonization or coordination of these two systems leads to dysfunctional water management across all of China.
  - Separate permitting systems (water withdrawal, wastewater discharge) which, in most countries must be harmonized to achieve effective water pollution control.
  - Different requirements for assimilative capacity with the same reach of river.
- **Total Load Control**: China's approach to pollution load control has changed significantly in the 11th Five Year Plan (FYP) in which total load control has become a central management feature for pollution control. Nevertheless, this is not linked to IRBM as it is implemented at provincial levels without regard for river basin conditions, or for linking load reduction to water quality standards/objectives, especially at provincial boundaries within the basin. MEP has been

considering moving towards the USA's Total Maximum Daily Load (TMDL) approach, however this poses some serious challenges when used in China. The main differences are noted in Table 1. Generally, China must overcome most of these deficiencies before it can seriously consider implementing a TMDL approach. For Taihu, current efforts to achieve total load control are likely to produce the best results however problems of data accuracy must be addressed as noted below.

Table 1: difference between usa and china for tmdl application.

USA	CHINA
TMDL links load reduction at source, to in-stream water quality objectives.	Load reduction is not linked to in-stream water quality objectives
Uses a complete river basin (watershed) approach to pollution load reduction	Water pollution not managed by river basin.
High flow, low pollution	Low flow and high pollution (N. China)
Increasing flow downstream adds assimilation capacity downstream	Decreasing flow downstream and loss of assimilation capacity (N. China)
Flow is mostly "natural"	Flow is mostly artificial (N. China)
Very accurate loadings data	Loadings data are uncertain
High degree of compliance	Much non-compliance by polluters
May include non-point sources	China has little experience with non-point source management
Water quality & quantity managed together and all data is shared.	Quantity & quality managed separately; data not shared[iii].
Extensive use of calibrated models	Most models are not designed for Chinese situation, and are poorly calibrated for water quality due to lack of data and model constraints

- **Compliance:** Compliance with the WPPC law in China is a major problem. Compliance failure can account for waste loadings that are very much higher than what would exist if there was full compliance. We rarely see explicit analysis of this problem however it is widely discussed by academics, in the Chinese media, in the National People's Congress, etc.. Compliance has to be the first step in achieving an IRBM plan, with reasons for compliance failure fully understood as a basis for actions against non-compliant enterprises.

- **Science-based decision making for IRBM**: Chinese water and environmental science is fragmented. Each ministry tends to rely on its own research institutes. Actions by ministries are not much affected by work of external institutions such as those of the Chinese Academy of Sciences or institutions of other ministries. Furthermore, science in large systems such as the Taihu area is not coordinated, there are no mechanisms to achieve scientific consensus, scientists tend not to collaborate outside their own institutions, and one study is rarely linked to another. For Taihu there has been no comprehensive synthesis of the existing science, weeding out "bad" or "flawed" science, and leading to policy recommendations. A major scientific conference on Taihu in 2005 (Qin et al. 2007) explored many issues but did not answer any of the key issues required for lake management. The consequence is that rehabilitation plans of the government have been launched, at great expense for two decades yet the lake only gets worse. Chinese scientists tell me privately that the current rehabilitation plan of the National Development and Reform Commission suffers from the same problems. This situation contrasts with western experience as noted below in which science advice drives the policy recommendations and provides a basis for predicting the likely outcomes of the interventions, the time-frame for rehabilitation, and the most cost-effective types of interventions.

- **Economic Options**: China is beginning to experiment with economic management systems based on market principles. In fact, China is a leader in development of Payment for Ecological Services (PES) systems. However, the lack of a legislative basis for water rights and wastewater discharge rights, in which there is a clear and consistent set of rules, impairs the ability to move quickly in this direction. Some provinces such as Zhejiang, have made significant progress in these areas even in the absence of national legislation. Provinces of the Pearl River Delta have recently agreed on an economic framework of compensation to manage water quality in upstream areas for the benefit of downstream areas. The combination of command-and-control and economic systems is likely to produce rapid progress in pollution control at the basin level for those basins in which provinces can agree on, and enforce, a common set of rules.

- **Accountability**: IWRM/IRBM is not possible without a system of accountability for government agencies and officials. Since 2007, much has changed in China with the introduction of evaluation criteria for local officials based on environmental progress. However, there is no independent auditing of agency performance as exists formally in Australia, Canada, and America.

4.2 Australia, Canada, America

- **Planning**: None of these countries has a formalized five year planning system like that of China. In general, river basin planning is based (i) on a rolling plan in order to allow adaptive management, (ii) based on scientific assessment of what is possible over specific periods of time, and (iii) integrated with all relevant agencies in a single plan. While one agency may be given the lead role, transparency in the planning process, the involvement of the public, and reporting by the media, preclude any one agency making decisions that will likely offend or disregard another agency. It was not always like this when, a generation ago, command-and-control by individual agencies was the norm. Over the years, this has given way to cooperative basin planning and management, and with the participation of national governments for transjurisdictional river basins. An example of integrated planning is the requirement by 2011 for an integrated "sustainable development plan" for the Murray-Darling Basin that will include jurisdictions and all sectors.

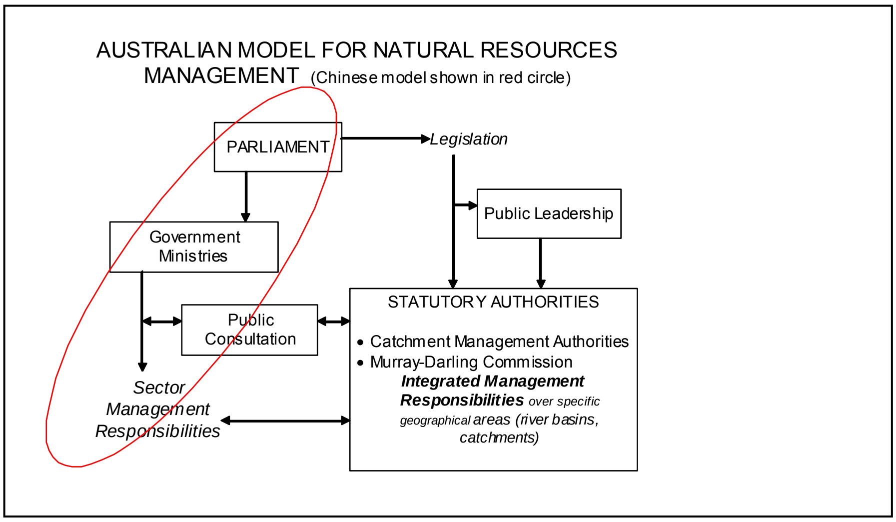

Figure 1: Typical institutional model in western countries. Red outlines that part that applies in China.

- **Institutions:** Institutional arrangements in the three western countries have little impact on IWRM/IRBM because institutional cooperation is the norm, not the exception. Australia, Canada and the USA all have legislative systems that allow for agencies that are independent of line ministries. Figure 1 illustrates this for Australia. Sector institutions are represented by the red circled component and is typical in all countries, including China. However, in these western countries, Parliament establishes legislation through which statutory independent basin agencies are established. These are accountable to Parliament though a minister, but are not directly managed by any one ministry. Consequently, these statutory authorities are able to provide multi-sectoral management, are accountable to their basin constituents, and operate in a highly transparent manner.

- **Operations**: Functions of monitoring, permitting and enforcement are normally integrated amongst water and environment agencies to the extent that is required for IRBM.

- **Managing Total Load**: Except for the USA which uses a TMDL approach when rivers or lakes cannot meet their specified water quality objective, neither Canada nor Australia have a formalized total load reduction strategy except in specific waterbodies that are under stress. Mainly this reflects a much lower level of water pollution and full compliance by waste dischargers. In Australia, salt load reduction is the main focus in the Murray-Darling basin. In cases such as the Great Lakes where phosphorus reduction was required, total allowable P load was based on extensive research on primary productivity (e.g. blue-green algae), then the allowable load was partitioned by tributary river. Each jurisdiction had freedom to adjust waste loadings to achieve the allocated load. In all three countries, the objective was to adjust total load so that rivers and lakes could achieve their target water quality objective.

- **Data Errors and Uncertainty:** In none of these three countries would large differences in reported loadings by two ministries be tolerated either by the government or by the public. In fact, such differences do not exist because of the effort made for cooperative investigations and reporting (also between Canada and the USA), analysis of error and uncertainty by the scientific community, and the high standard of accountability that is imposed upon agencies by the public.

- **Compliance:** Compliance failure is mainly non-existent for waste dischargers due to the very high cost of non-compliance and the very likely reporting of non-compliance by the public. Rule of Law and public scrutiny means that there are few exceptions made for non-compliant dischargers except in unique situations involving specific timeframes given to non-compliant discharges to meet the regulations. In all three countries, the cost of non-compliance is far higher than meeting discharge permit conditions. This contrasts with China where the penalties for non-compliance remains less than the cost of compliance.

- **Science-Based Decision Making**: Large river basins and lake basins such as the Murray-Darling Basin and the Great Lakes Basin of North America (shared by Canada and USA), are subject to intensive and coordinated research before the government decides on specific management policies. For example, the pollution “crisis” of the 1970s in the Great Lakes prompted a 10 year research program, under the management of the independent International Joint Commission, involving hundreds of scientists from many different institutions in the USA and Canada, and that led to the policies and interventions that led to remediation of Lakes Ontario and Erie. These are widely regards as the world’s largest and most successful of large lake/basin management interventions. Taihu could benefit much from that experience.

- **Economic Options**: The Australian example of water markets amongst the four states and one territory comprising the Murray-Darling River Basin is a mature example of water markets that have allowed Australia to deal more effectively with water scarcity. Water markets are based on a set of rules that apply to everyone, including the national government. It has had the effect of moving water from low value use to high value use, and from water intensive crops such as rice, to high value crops such as grapes (for wine). Fundamental to water markets is the ownership of water rights. This is not the case in China and is still being debated as to how to effectively bring a water market into existence in the absence of secure rights by individual water users. Similar legal problems make the development of a discharge “rights” trading system difficult in China.

- **Accountability**: Transparency and accountability are requirements for IWRM/IRBM. In these three countries the public demands these. Accountability is further enhanced by independent audit of the government’s role in pollution control and water resources management. In Australia, the National Water Commission is independent of any ministry and audits ministry performance and reports this to parliament and to the public. In the USA and Canada, the independent International Joint Commission provides oversight and audit of both governments’ actions for all boundary waters between Canada and the USA, including the Great Lakes. Because the public is often sceptical of the government, the independence of these audit functions is extremely important and leads to strong public confidence in the actions of their government. China has no similar characteristic and, while public supervision is contained in almost all environmental and water laws, proactive public supervision of government or officials’ performance is not encouraged.

5. Summary and Conclusions

While there are many similarities in water and pollution control between china and APEC countries of Australia, Canada and USA, there are also profound differences. in china, the principal impediment to effective IWRM/IRBM is an institutional impasse between MWR and MEP in which neither is willing to share authority, and the general lack of effective coordination between environment and water departments at provincial levels. In contrast, in the western APEC countries, inter-sector cooperation and coordination has become the norm and is supported by an enabling legislative framework that is lacking in china. While administrative coordination is the optimal solution for china, the long history of vertical administrative "power" and several failed examples of administrative coordination, suggests that coordination mechanisms usually do not work well. as it is now unlikely that the state council will amalgamate MWR and MEP into a single ministry, it may be time for provinces to consider amalgamating EPBS and water resources bureaus at the provincial level, in much the same way that Hunan, for example, has integrated several diverse bureaus in Dongting lake, in order to create an institutional framework in which coordination becomes possible, duplication is eliminated, and water and water environment are management as an integrated whole. At the basin level, IRBM is unlikely to be achieved without the creation of new and independent basin agencies that represent their constituent provinces. Attempts by MWR to expand the mandate of basin agencies within the MWR organizational structure are likely to be counterproductive. IRBM also requires that many technical issues be resolved, especially those of data sharing, harmonized water and pollution permitting, harmonization of functions zones, etc.. Finally, planning needs to rest upon comprehensive scientific understanding so that basin plans have a reasonable chance of technical success.

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Risk Management of Water Resources in Thailand under the Threat of Climate Change

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1. Introduction

Water is essential for human activities, food security, ecosystems and national economics. Water should be thought of as an exhaustible resource. Unplanned uses of water resources can have a considerable negative impact on humans and the environment.

Risks in water resource management can stem from natural causes or poor management. The most well-known risks from natural disasters are flooding and drought, which are associated with extreme events. Flooding is a natural process that plays an important role in shaping the natural environment, but it can also cause substantial damage to property and threaten human life. Floods cannot be prevented entirely, but their effects can be reduced. At the other extreme, drought is an extended period of months, or even years, when a region notes a deficiency in the water supply due to consistently below average rainfall. The impact on the ecosystem and agriculture can be substantial and intense drought can cause significant damage and harm the local economy. Therefore, risk management of natural disasters has received a great deal of attention, since sustainable and integrated water resource development and management can enable all potential uncertainties and threats to be managed in order to reduce the negative effects of a temporal and spatial unavailability of water resources.

Additionally, global warming poses a severe threat (Figures 1 and 2). Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. It affects the function and operation of existing water infrastructure (reservoirs, structural flood defenses, and urban drainage and irrigation systems) as well as water management practices. The adverse effects of climate change on freshwater systems also aggravate the impact of other stresses such as population growth, changing economic activity, changes in land use and urbanization. Globally, demand for water will grow in the coming decades, primarily due to population growth and increasing affluence; on a regional level, large changes in demand for irrigation water as a result of climate change are expected. Therefore, the provision of a water supply and sanitation, securing food for growing populations and maintaining ecosystems are all enormous challenges.

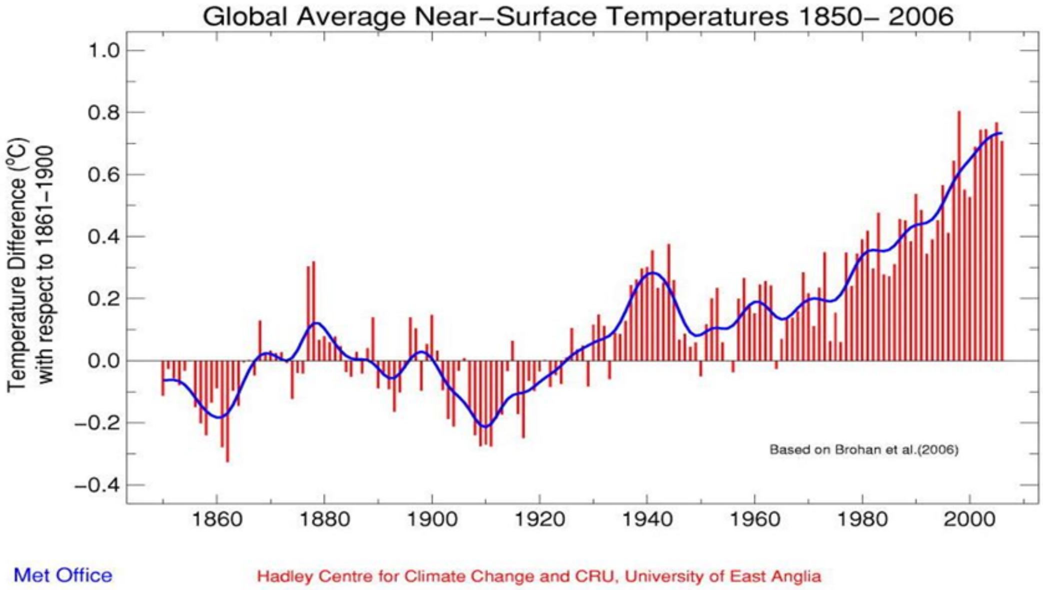


Figure 1 Global average surface temperatures have increased by 0.74°C over the last hundred years (1906-2005), with particularly strong warming recorded since the 1970s (Brohan et al., 2006)

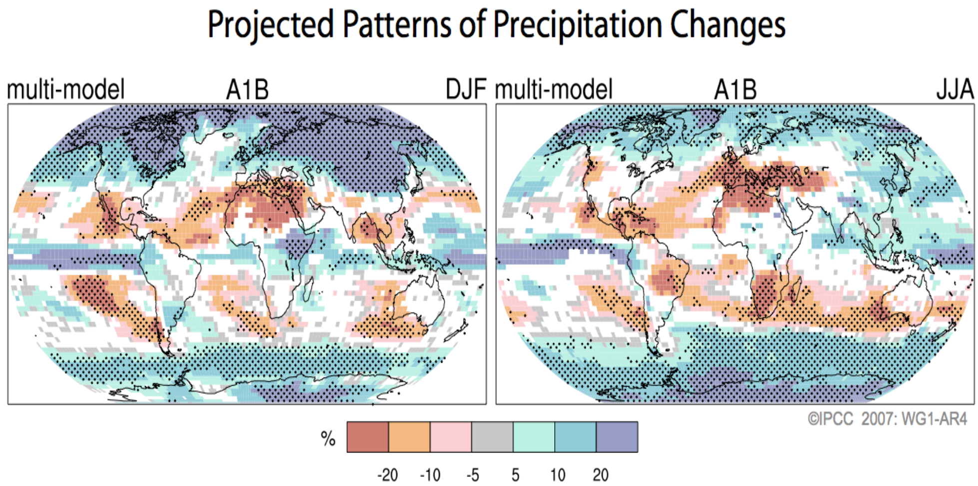
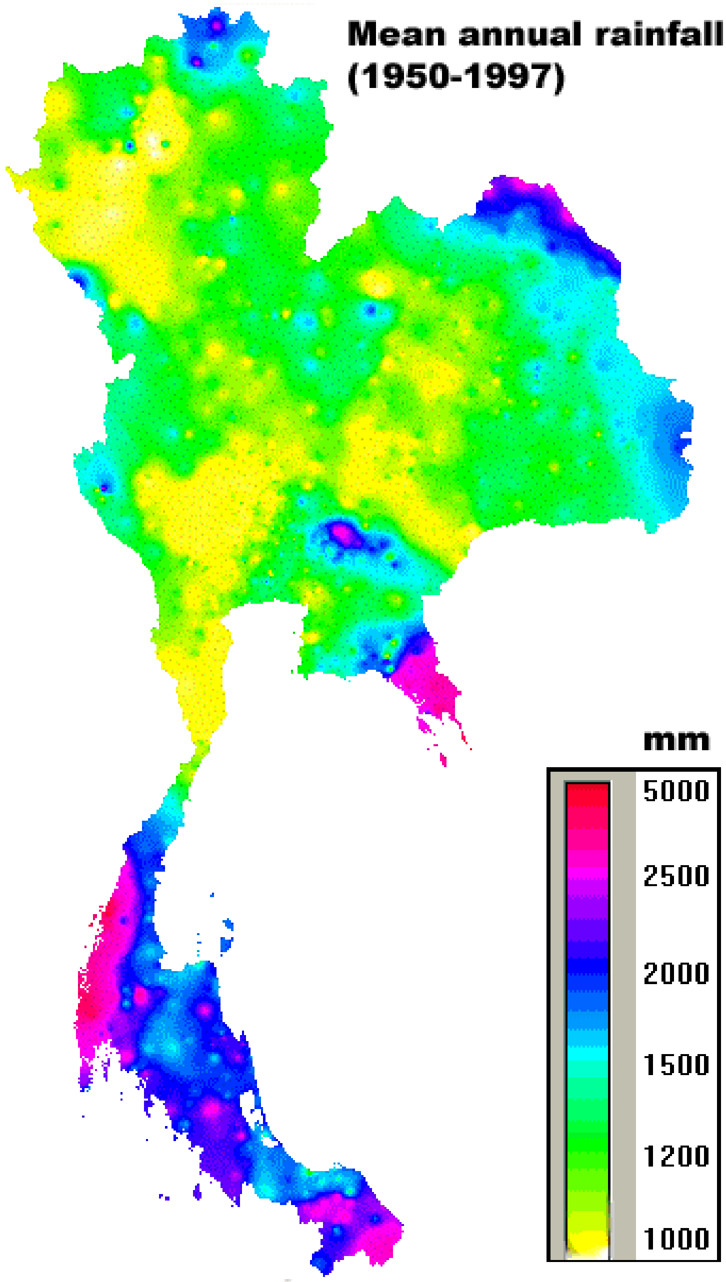


Figure 2 The projected pattern of precipitation changes from multi-model results with the emissions scenario A1B (IPCC, 2007). The left picture shows a dryer winter (Dec-Jan-Feb) in the Great Mekong Subregion (GMS), while the right picture shows a wetter rainy season (Jun-Jul-Aug). This emphasizes that the GMS would face a more severe drought in summer and severe flood in rainy season.

Figure 2 shows a tendency that the climate change would cause more severe drought in summer and more severe flood in rainy season in Thailand. Current water management practices as well as infrastructures may not be sufficiently robust to cope with the impact of climate change on the reliability of water supply, the risk of flooding, and on health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope even with current climate variations, so that large flood and drought damage occurs. Therefore, the incorporation of information about current climate variability into risk management of water resources would assist the process of adaptation to longer-term climate change impacts.

Thailand has an average annual rainfall of over 1,300 mm; however, some parts of the country continue to suffer drought problems due to the uneven distribution of rainfall. Thailand has frequently suffered from flood and drought as shown in Figure 3. Flooding usually occurs during the monsoon season (September-October) when there is intense precipitation. Drought (mainly water shortages for irrigation purposes) occurs in summer or when rainfall is delayed in the early part of the rainy season (July). Some particular areas experience both flooding and drought conditions in a single year, due to temporal and spatial uncertainties in the monthly rainfall or the poor management of the conveyance infrastructure. The common practice in Thailand is to manage the risks after considering which areas are likely to be vulnerable to either flood or drought. Failure to manage risk by addressing one aspect at a time can lead to adverse results; for example, importing water from other basins to boost water supply multiplies the risk of flooding in the downstream area. This approach is not favorable because the country would have to spend on redundant investments in importing water and on flood protection measures. Therefore, managing flood and drought risks is a new challenge in Thailand and is becoming increasingly important as a result of global warming.



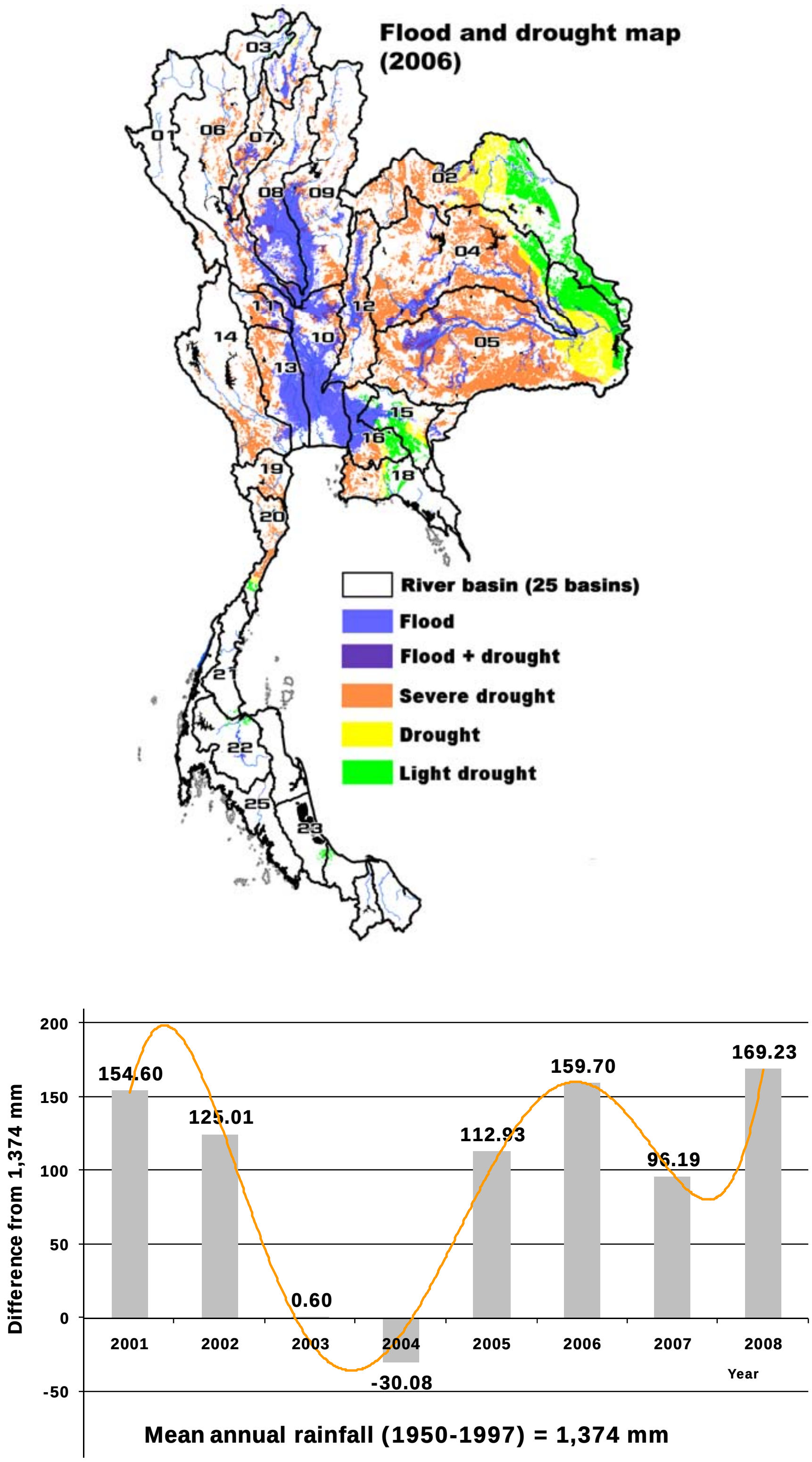


Figure 3 (Left) The distribution of annual rainfall averaged from 1950 to 1997; (Right) flood and drought map in 2006; and (Bottom) recent changes (2001-2008) in the amount of annual rainfall in Thailand.

This paper presents a risk management approach for the sustainable development of water resources by taking flood and drought risks, as well as climate change, into account in the planning process. Then, regional and sub-regional spatial strategies can be identified to ensure that risks do not increase and to prevent duplicating investments. The risk assessment will categorize an area to be regarded as vulnerable according to one of the three types of risks i.e. flood risk, drought risk and combined risk. Therefore, this will enable suitable policies and local measures to be chosen according to the different types of local risks.

2. Risk Management Framework

The risk management framework involves collecting information, establishing the context, identifying the risks, assessing the risks, and treating the risks (Figure 4). At each step, stakeholders should communicate, review and monitor the progress and performance of the management framework.

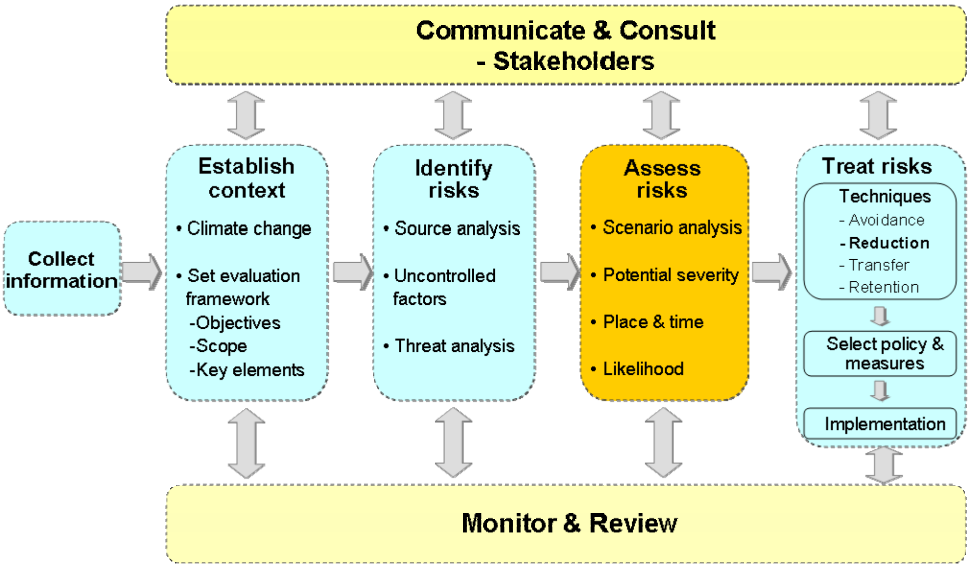


Figure 4 Risk management framework.

2.1 Context establishment and risk identification

The impact of climate change needs to be addressed when establishing the context and must continue to be considered throughout the risk management framework. The major source of risk in water resources, especially water supply, is rainfall. We cannot control where, when, and how much it will rain, and these factors are what causes flooding and drought risks. These risks pose a threat to economic development, from rain-fed agriculture to water utilization in the industrial sector. As for flooding threats, the highest loss was 13,385 million Baht in 2002[iv], with a total of 72 provinces affected.

2.2 Risk assessment

Risk assessment features an analysis of the types of risk in an area, the time of year when the risk is likely to occur, its potential severity, and the likelihood of it occurring. This article focuses only on the physiographical assessment of risk, whereas the bigger picture includes the additional evaluation of social, economic, and environmental factors.

Traditional methods and drawbacks

Traditional methods of risk assessment such as rainfall analysis, flood and risk map creation, and water balance (the balance of water supply and demand) are often conducted in the following ways:

(1) Annual basis. The annual water balance may conceal drought problem since the total annual water supply may exceed annual demand, but, in any particular month, demand may overshoot the supply, especially in the month of sporadic rain such as July or August.

(2) Use of averages. Frequently, spatial and temporal variability is not considered. For example the Thailand nationwide average precipitation for 2008 was 1,543 mm, 5% higher than the value in 2007 which may seem insignificant. However, when analyzing spatial variation in rainfall, the 2008 precipitation in the east region was 16% higher than the 2007 value; in contrast, the 2008 precipitation in the south region was 10% lower than the 2007 value.

(3) Flood and drought risks are handled separately. This is justified where the area faces single problem either flood or drought. However, in the places where both problems arise, it may lead to a wrong decision for example investment for increasing drainage capacity to remove unwanted water

in wet season while importing water supply or pumping groundwater in dry season. Constructing retention storage is more logical to solve both problems.

Innovative approach

This paper proposes an innovative approach for risk assessment with the following steps:

(1) Scenario analysis. Wet, normal, and dry years are evaluated based on annual rainfall amount.

(2) Analyze risk type by conducting monthly water balance. Monthly water balance is calculated for all scenarios. When the balance is positive, the basin is considered having flooding potential, with the degree of flooding severity proportional to the magnitude of the surplus. Vice versa, drought occurs when the balance is negative, with the severity level corresponding to the shortage values.

(3) Accounting for the spatial heterogeneity of a basin. The area is divided into sub-basins and monthly water balance is simulated, rather than considering a basin as a homogenous system.

This approach provides us with five key answers.

(1) Types of local risk (flood, drought, or both problems)

(2) Risk timeframes. This paper finds that both flooding and drought occur in the same place for several sub-basins. In the Northeast, the risk of drought exists in June and July whereas the risk of flooding is highest in September and October. Monthly water supply for each scenario reveals different climatic patterns. Therefore, different risk timeframes could be expected for each scenario.

(3) Level or magnitude of threats. Being able to quantify the potential severity (volume of water) of shortage and flood is crucial in selecting proper total infrastructure capacities to solve problems.

(4) Probability of occurrence. This is another vital factor in choosing optimum infrastructure sizes.

(5) Assignment of priority. Area with both floods and drought has highest priority.

2.3 Risk treatment: policy framework

Typical risk treatment techniques include avoidance, reduction, transfer, and retention. Because the risk factors in water supply are not controllable, risk avoidance or total prevention is impossible. Though water demand is another risk factor, we focus on the supply side with emphasis on risk reduction. Area-based policies, strategies, and measures are proposed to mitigate risks based on the area's threat groups (both flood and drought threats, drought only, and flood only) and the potential severity in individual areas. The risk reduction framework consists of macro and micro-management (Figure 5). The setting of policies and measures should conform to this structure, and the impact of climate change shall be considered and integrated into the policies and their implementation.

3. Policy Making for Risk Management

Macro-management aims to handle inter-basin and basin management, with the responsible bodies being national and regional governmental agencies. The macro-management approach should target quantitative goals such as water security and water balance. Therefore, the policies and measures primarily involve the development of the main infrastructure such as large and medium-sized reservoirs, dams, and water distribution systems (Figure 6).

Micro-management aims at developing sub-infrastructure including secondary and emergency supply systems. Another important component is community water management. These local systems provide flexibility and act as a buffer against risks. Consequently, the measures are customized to the local situation such as the adjustment of water allocation, water usage efficiency and cropping patterns. Major stakeholders are local governmental agencies, cities, and communities. The key to success is the adaptive capability and the collaboration and participation of all parties.

In summary, the policies and measures which address risk management should consider both macro and micro-management, taking care of local as well as regional needs.

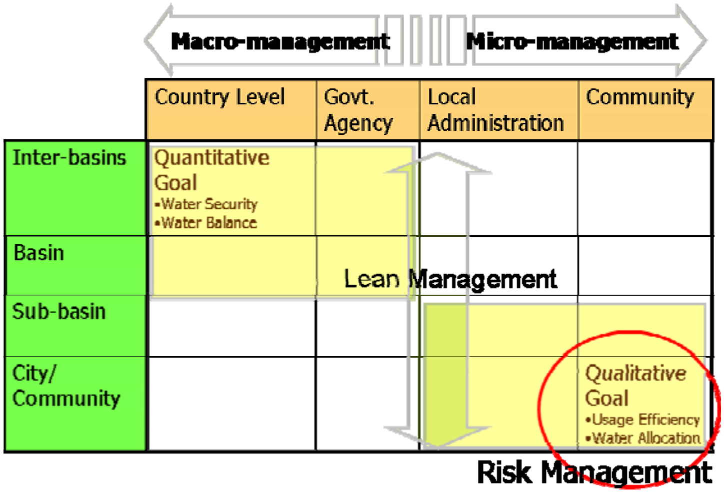


Figure 5 Macro and micro-management as part of risk management

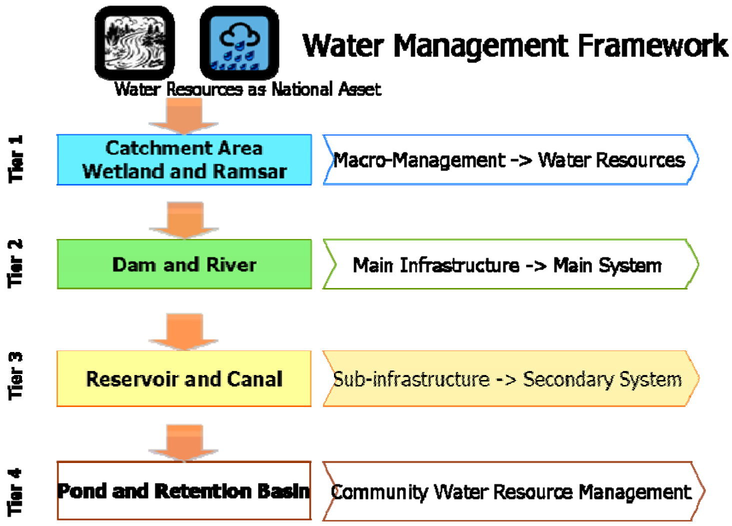


Figure 6 Tiers of water management systems

4. Case Study: Risk Management for Klong Yai and West Rayong Basins

4.1 Background of study area

West Rayong is home to several huge industrial estates, including the Mab Ta Phut Industrial Estate, whose focus is on petrochemicals and heavy industries. Major water supply comes from Klong Yai basin through Dok Krai, Nong Pla Lai, and Klong Yai reservoirs. In 2005, severe drought in the region led to a conflict in water resource allocation among the agricultural, industrial, and domestic consumption sectors. It was so severe that the industrial sector had to hunt for every drop of water from any sources it could find, including shipping water by truck from nearby regions.

4.2 Results of risk assessment

The conflict in this area highlights the importance of risk management for water security, not only for West Rayong but also for the greater region. We conducted a risk assessment for the Klong Yai and West Rayong basins using the water balance and scenario analysis. The study area is divided into five sub-basins or blocks (Figure 8). The results are as followed:

(1) Scenario analysis shows that most of the study area has two distinct climatic patterns. In the dry years, sporadic rainfall occurs in July and August and heavy rain occurs in September and October. In contrast, the wet years have continuous rainfall throughout the rainy season. The monthly rainfall values and the ranges also differ among scenarios. Examples are shown in Figure 7

for Klong Yai basin above the Klong Yai Dam. April rainfall is very volatile for the dry years whereas those of the wet years have a narrower range. May, August, September, and October are months with the greatest difference in the rainfall between the dry and the wet years.

(2) Monthly water balance indicates that in Klong Yai basin above the Klong Yai Dam, drought occurs in all scenarios from November to March (Figure 7). In April and July, water shortage occurs for the dry year. September has the greatest excess water supply but the magnitude is very small, about the same as that of a single month of drought. Therefore, this area likely has drought-only problem and collecting its own excess water alone may not be enough to solve the drought problem. Extreme drought and flood for each subbasin can be derived from the monthly water balance (Table 1). The result appeared that all subbasins have both drought and flood problems, except the irrigated area below 3 dams which does have drought problem.

(3) Flood and drought risk maps (Figure 8), generated from the information on extreme conditions, reveals that the Mab Ta Phut area (block 1) typically has a drought risk whereas two out of three areas supplying water to Mab Ta Phut (block 3, 4 and 5 in Figure 8) have a severe drought risk and one of them (block 4) also has a flood risk. Therefore, policy makers are advised that area 4 with both flood and drought issues should have the highest priority for management (Figure 9).

4.3 Policy implementation

Recommended measures to reduce risks for each basin are listed in Table 1. Example of projects proposed by various agencies such as the Royal Irrigation Department and the Water Resource Department for implementation during 2009-2011 are illustrated in Figure 9. Once the projects are completed, the potential severity of both floods and droughts will be somewhat reduced (Figure 10). The caution is that certain measures such as trans-boundary water transfer must be carefully exercised to ensure that the risk is not transferred from one area to another. Besides, the size of the infrastructure such as reservoirs must be designed for the optimized cost versus benefits.

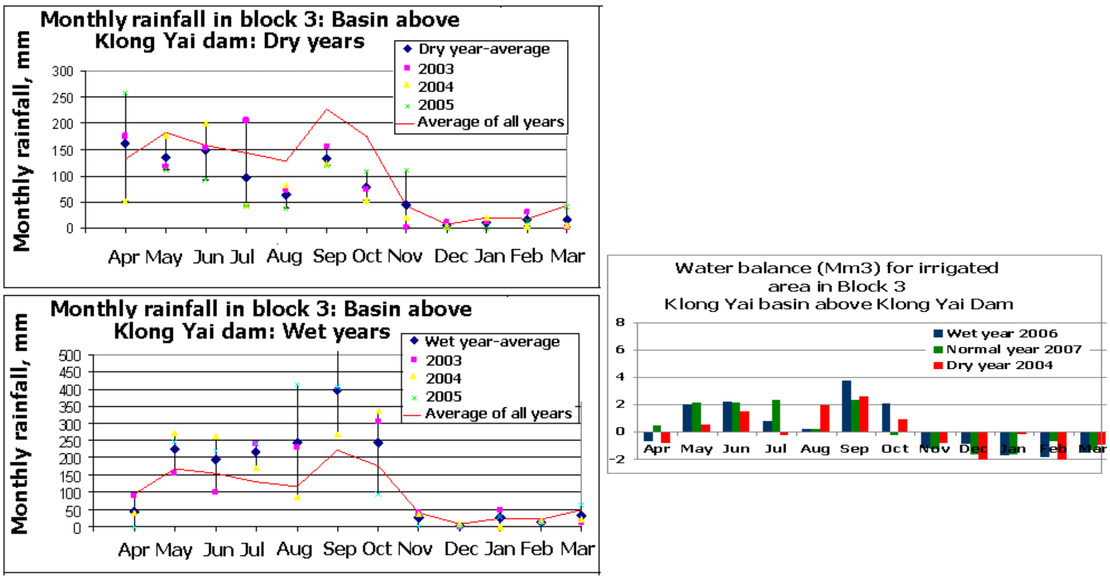


Figure 7 (Left) Monthly rainfall pattern for dry and wet year scenarios (data from 1994-2008); (Right) monthly water balance (2003-2007) for irrigated area in Klong Yai Basin above Klong Yai Dam. (HAII, 2008-b)

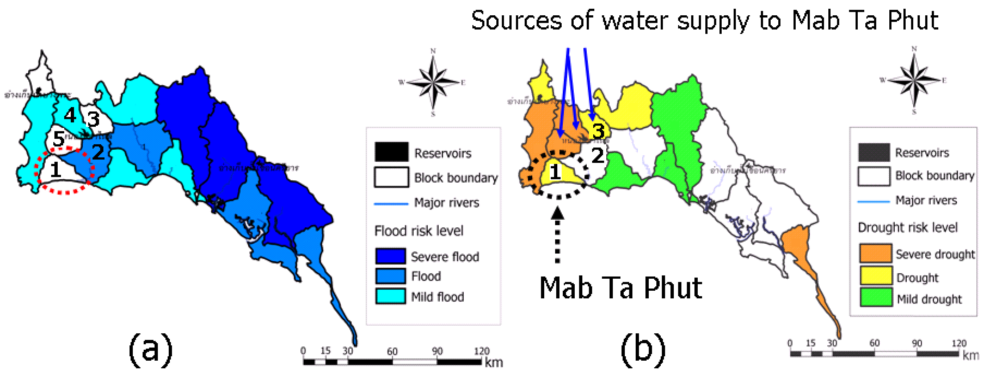


Figure 8 (a) Flood and (b) drought risk maps of the East Coast - Gulf Basin emphasizing on Klong Yai and West Rayong basins (numbered). (HAII, 2008-b)

Table 1 Quantitative analysis of flood and drought severity and proposed measures to reduce risks. (HAII, 2008-a)

Area	Maximum water shortage (Mm^3)		Maximum oversupply (Mm^3)	Measures	
	Irrigated	Rain-fed	All areas	Area-based local measures	All-area measures
1. West Rayong basin - Mab Ta Phut	1.21	16.29	46	Development of new reservoirs; development of water distribution system	Conservation of headwaters and use of check dams; Community water management
2. Klong Yai basin below 3 reservoirs	No problem	32.04	226	Retention basins; trans-boundary water transfer; adjustment of cropping calendar	Rehabilitation of water resources
3. Klong Yai basin above Klong Yai Reservoir	2.06	26.40	34	Development of new reservoirs; development of water distribution system	Conservation of headwaters and use of check dams; Community water management
4. Klong Yai basin above Nhong Pla Lai Reservoir	4.06	43.33	52	Cascade reservoirs; Increase in water reservation capacity; Development of new reservoirs; Development of water Distribution system; Retention basins; Adjustment of cropping calendar	Rehabilitation of water resources

Area	Maximum water shortage (Mm^3)		Maximum oversupply (Mm^3)	Measures	
	Irrigated	Rain-fed	All areas	Area-based local measures	All-area measures
5. Klong Yai basin above Dok Krai Reservoir	3.39	36.17	37	Trans-boundary water transfer; Development of new reservoirs; Development of water distribution system	Conservation of headwaters; Rehabilitation of water resources; Community water management

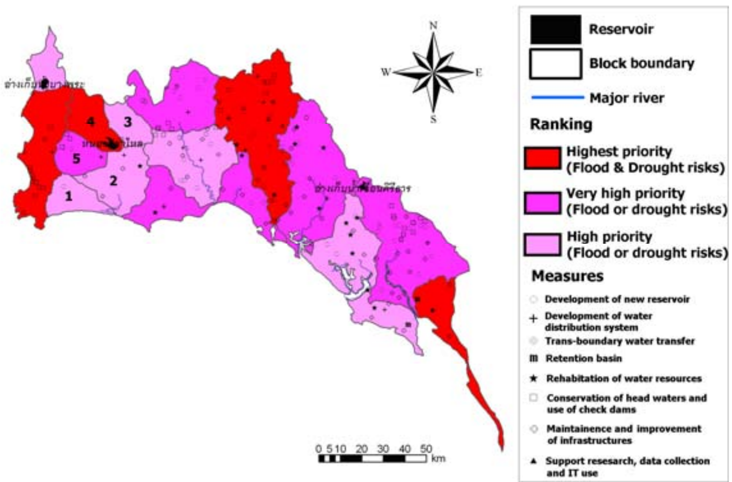


Figure 9 Priority ranking based on flood and drought risk levels and examples of projects to mitigate risks.
(Water Resource and Irrigation Development and Management Committee, 2008)

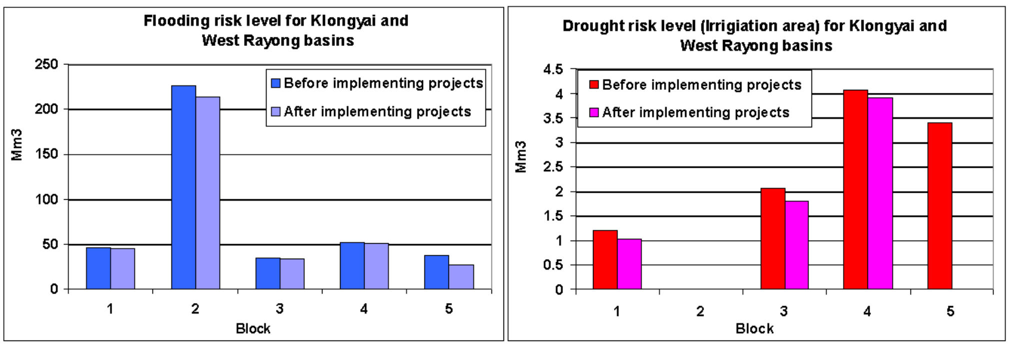


Figure 10 Potential severities of (left) flood and (right) drought in the study area before and after implementing the projects according to appropriate measures.

5. CONCLUSIONS

Risk management of water resources is comprised of an organized framework to manage the uncertainty or threats and involves federal and local agencies following procedures and using tools or measures conforming to the risk management policies. Risk in water resource is due to rainfall, and its uncontrolled factors are place, time and the volume of water. These factors cause drought or flood problems on different scales of severity.

One finding for Thailand is that several areas, especially in north-eastern Thailand, experience both drought and flood in the same location. This information tells us that we need to devise solutions that can solve both drought and flood problems; otherwise, it may result in conflicting strategies that could potentially undermine each other's effectiveness. A comprehensive understanding of the nature of the problems and their potential severity helps in risk management planning and investment in flood/drought mitigation. This is truly crucial in this era of climate change as it leads to greater variations in the climate pattern and, potentially, higher flood or drought risks and threats. Macro and micro-management provide a portfolio of primary, secondary, and emergency systems to act as a buffer against the impact of climate change.

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Appropriate Technologies for Waste Water Treatment in China

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Water pollution, water scarcity, and access to water resources are growing problems throughout the world. China's economic growth over the last two decades has been tremendous. In the same time period, China's economic growth has led to environmental degradation. "China's pollution problem, like the speed and scale of its rise as an economic power, has shattered all precedents" (New York Time, 2008). Most experts would agree that 80% of the rivers in China are polluted. The worsening pollution and population growth will stretch the water supply to the limit by 2030 as the nation's rivers, lakes and ground water have been severely polluted. Facing all these problems, the central government of China has been making the environment a higher a priority. The government big stimulus package for economic recovery and grow includes investment for wastewater treatment and water resource protection.

The basic problems in water pollution in particular are wastewater discharged from industrial sources are either not fully treated or discharged below the required standards. Beside comprehensive management policies, regulations and enforcement of policies and regulations, wastewater treatment is critical for water resource protection. The industrial wastewater is extremely complex in China, the majority of the wastewater is high strength, salting containing complex mixtures. This calls for cost-effective and highly efficient treatment technologies. High efficiency treatment technologies are needed in both the water and wastewater sectors.

The following technologies are highly desirable for the wastewater treatment in China.

- Cost effective and efficient treatment technologies and equipment for high-concentration organic wastewater treatment
- Cost effective and efficient treatment technologies for salt-containing high strength mixed waste treatment
- Cost effective and efficient biological denitrification and phosphorous removal
- Membrane separation and manufacturing technologies and equipment
- Advanced and efficient anaerobic biological reactors for high strength organic wastewater treatment
- Series-standard water and wastewater treatment equipment with high efficiency
- Decentralized modular treatment processes for small townships
- Water-saving technologies and equipment
- Monitoring equipment
- Natural water body rehabilitation technologies

On the wastewater side, large-scale and wide spread pollution caused by algal bloom in lakes and rivers has called for tougher standards on phosphorous and nitrogen in wastewater discharge. Local municipalities such as Suzhou have enacted more stringent standards for phosphorous in comparison to the national standard. The earlier built wastewater treatment plants lack the capability for P and N removal and now the central and local governments have called for renovations on wastewater treatments plants to be capable of nutrients removal. Efficient removal processes for N and P removal for wastewater are also highly desired. Integrated technologies and processes are now available for cost effective removal of both N and P.

Wastewater is considered a resource and wastewater reclamation is of great importance for China.

Some successful cases in building and operating wastewater reuse projects include a Dalian company to construct a wastewater reclamation project with production of over 50, 000 cubic meter per day. There are several other successful examples in the country. Wastewater reclamation requires advanced treatment technologies and equipment. Technologies with high efficiency and lost cost and easy operation and maintenance will have the greatest potential of success in China. Water reclamation also requires new pricing on water and the current water price is still considered to be low in not only water resource rich south but also in water-scarcity areas in the north. Unless changes in water pricing policy, there is a fundamental lack of market drive for water reclamation.

On the water side, the new drinking water standards that was just launched by the Ministry of Construction, the Chinese metropolitan areas will invest billions of dollars to update water treatment technologies in order to meet the standards. Now with better quality and low cost membranes, advanced filtration will see big application for enhancing the drinking water quality in China.

Solutions for the Urban Water Environmental Problems in Taihu Watershed

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Background

Nowadays, with the intensification of urbanization, besides the quick economic development and living standard improvement, some negative byproducts become to raise our concern, such as population expansion, environmental pollution and resources consumption.

Due to rapid urbanization and associated environmental issues, including the discharges of untreated water directly into the river network and the unreasonable water resources consumption, many major watersheds in China have been seriously contaminated.

Large-scale watershed pollution would not only trigger drinking water security problem, but also greatly curb the economic development. In order to keep balance of economic benefit and environmental benefit, measures should be taken to adopt an intensive urban development pattern.

So in this paper, by studying the current situation of urban economic development and major pollution contributors, several solutions are proposed to resolve the water environmental problem.

1 Relationship between Watershed Pollution Load and Economic Development

Based on the consideration of water resources Possession in a watershed, the state of Economic Development has some potential in China Compared in terms of the Rhine River watershed(Figure 1).

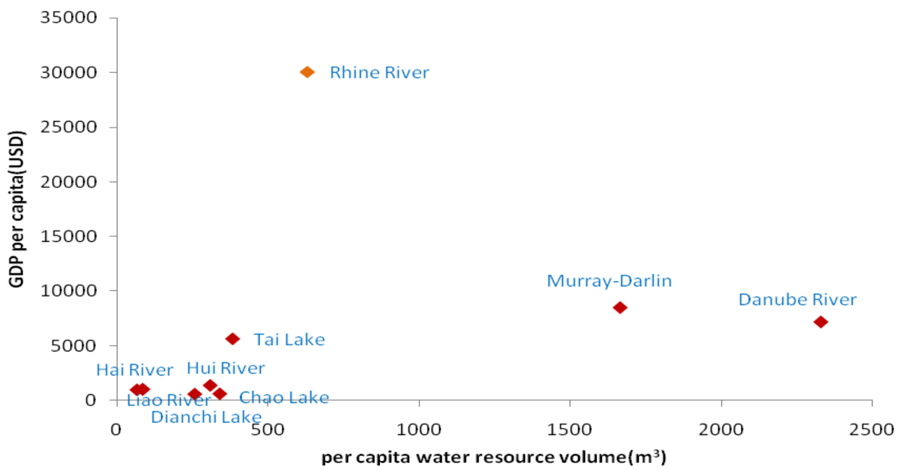

Figure 1 Relationship between economy and water resources

As far as we know, China is abundant in total amount of water resources, but poor in per-capita resource volume, which becomes the bottle-neck restriction for urban development in China. Figure 1 indicates that compared to other foreign watersheds, the development for several major Chinese watersheds still remains at relatively low level. With its per-capita water resource volume nearly resembling its Chinese counterparts, Rhine River is a good paragon for us to mimic its urban development pattern. Following Rhine River’s example, we should increase the utilization efficacy for limited resources to gain more GDP increase.

Similarly, this principle can also be applied to land utilization (figure 2). For instance, some new-emerging industries should serve as a highly-efficient substitution for agriculture which yields many pollutants but few profits

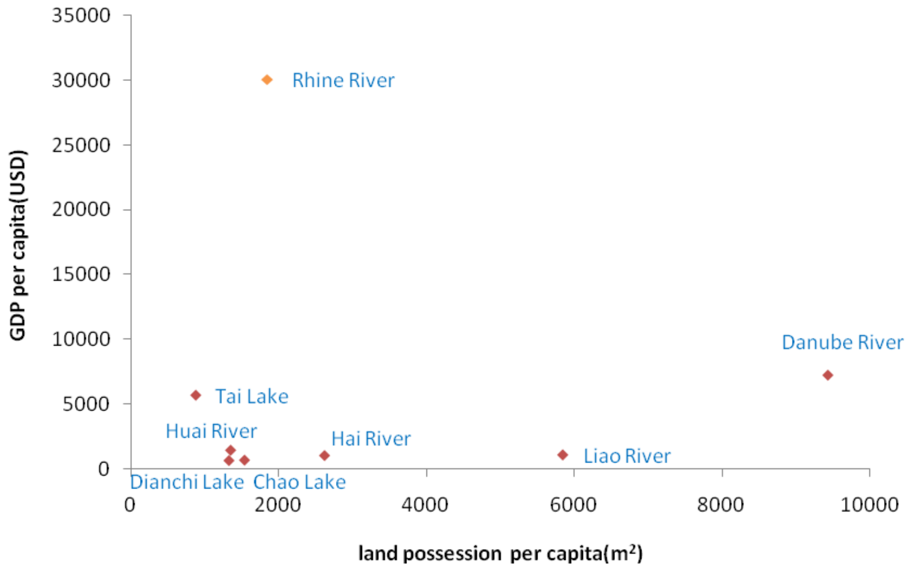

Figure 2 Relationship between economy and land resource

2 Major Contributors for Water Environmental Pollution

In order to optimize the urban development pattern, our first priority is to find out the biggest contributor for watershed pollution. From table 2, we can see COD from urban sources(including industrial sources and urban non-point sources) accounts for 80.19% of the total pollutants that are discharged into rivers. In terms of NH3-N,TN and TP, urban sources greatly overwhelms rural source in the same manner. So for an optimal urban development pattern, an effective solution to the city-related problems deserves our immediate and broad attention.

Table 1 Pollution load production distribution of sources

Pollution source / pollutant	Industrial source (%)	Urban municipal source(%)	Rural source (%)
COD	31.13	23.71	45.16
NH_3-N	34.04	22.51	43.44
TN	29.31	19.35	51.34
TP	4.91	27.58	67.51

Considering the actual effects of the polluted source to water environment, Emission efficiency coefficient of urban sources and rural sources are 0.9 and 0.3 respectively. The actual Source distribution for pollutants discharged into rivers is showed as in Figure 2.

Table 2 Source distribution for pollutants discharged into rivers

Pollution source / pollutant	Urban sources		Rural sources
	Industrial source (%)	Municipal sources (%)	Rural source (%)
COD	45.52	34.67	19.81
	80.19		
NH_3-N	48.92	32.35	18.73
	81.27		
TN	45.75	30.21	24.04
	75.96		
TP	9.31	52.29	38.40
	61.60		

3 Urban Development Trends in the Process of Urbanization

As we all know that traditional industries used to sacrifice the environment for the economic development. Such an extensive development pattern would yield a good mount of contaminants and consume large resources, which would eventually curb the economic development. Yet fortunately figure 3 indicates an optimistic momentum of development with transformation from an extensive style into an intensive style.

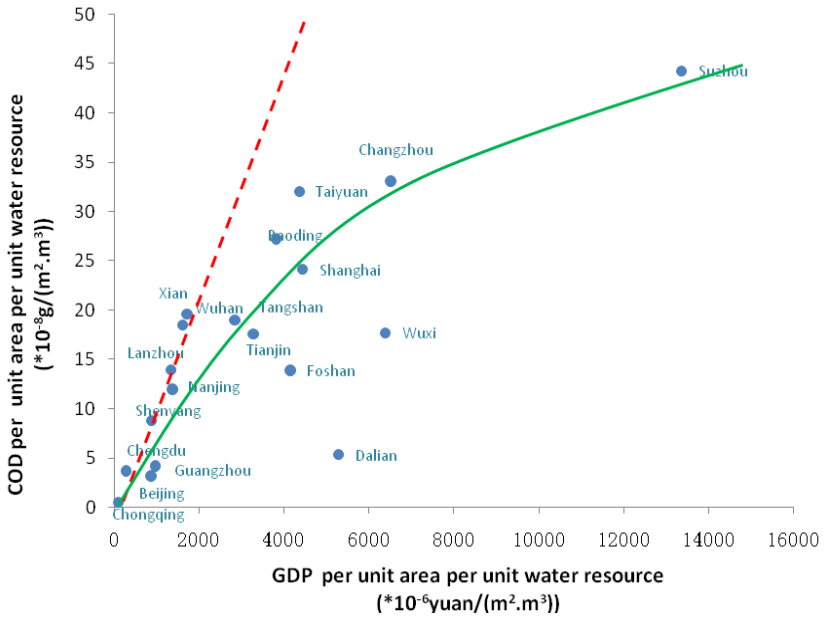

Figure 3 Relationship between pollution load and economy

Nowadays, In the process of urbanization, a larger rural population migrates into big cities, which triggers a series of urban problems, such as environmental population, social instability and worsening polarization between urban and rural regions. Figure 4 shows that a larger population would inevitably cause more COD release. So the large migrating rural population should be distributed in cities of different sizes to control the population density in the big cities. Moreover, we should not accelerate urbanization process sheer by the means of population migration, and other measures could also be adopted, such as transformation of rural life style, etc.

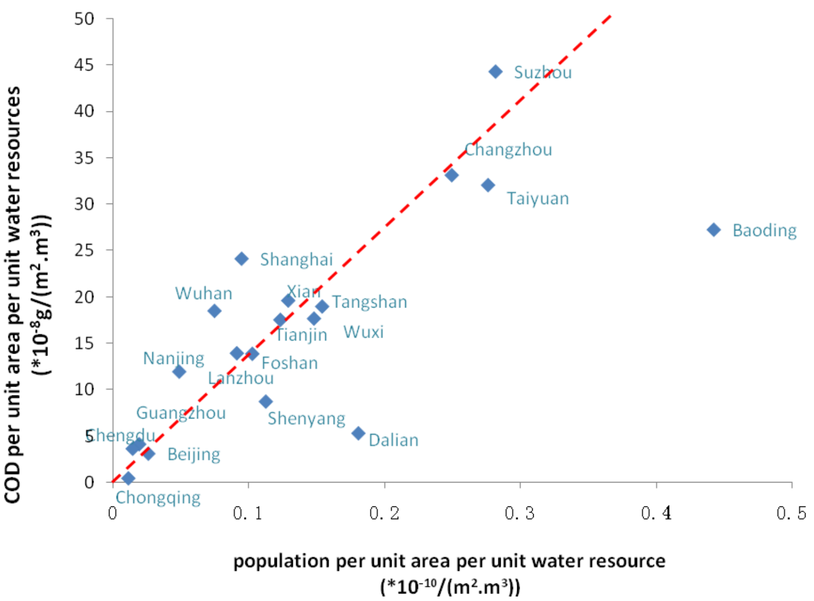

Figure 4 Relationship between pollution load and population

4 Urban Polluted sources and their distribution

By detecting the output of main contaminants and nutrients, such as COD, NH3-N, TN and TP, in urban areas, the pollution sources and their distribution are listed as in table 3.

Table 3 Urban Pollution sources and their distribution

Pollution source / pollutant	Industrial source (%)	Wastewater Treatment Plant Effluent (%)	Urban non-point source (%)	Sediment release (%)
COD	56.8	30.1	9.5	3.6
NH_3-N	60.2	26.5	3.2	10.1
TN	60.3	26.6	5.8	7.3
TP	15.1	77.2	5.3	2.4

In main pollution sources, industrial source is still the largest contributor, and Wastewater Treatment Plant Effluent also played great impact. Urban non-point source and sediment release should not be ignored to control COD and NH3-N.

According to the water environmental improvement objectives of Taihu Lake, to control requirements of major pollutants is expected in table 4.

Table 4 Main pollutants control requirements in Taihu Watershed

pollutant	Actual emissions (10^6kg/year)	Permitted emissions (10^6kg/year)	Demand removal (%)
COD	850.3	524.2	38.4
NH_3-N	91.7	37.9	58.7
TP	141.6	58.6	58.6

5 Conclusion and discussion

Through the discussion of major pollution sources and their distribution to the Taihu Lake, urban water pollution control is primary way to improve the water environment of Taihu watershed. After establishment of industrial parks and completion of industrial wastewater treatment, the urban municipal sewage treatment plant effluent and non-point source will be major objects to be controlled.

Comparison with Organochlorine Pesticides, PCDD/Fs, Dioxin-like PCBs and HCB in Sediments of Four Major Rivers in Korea

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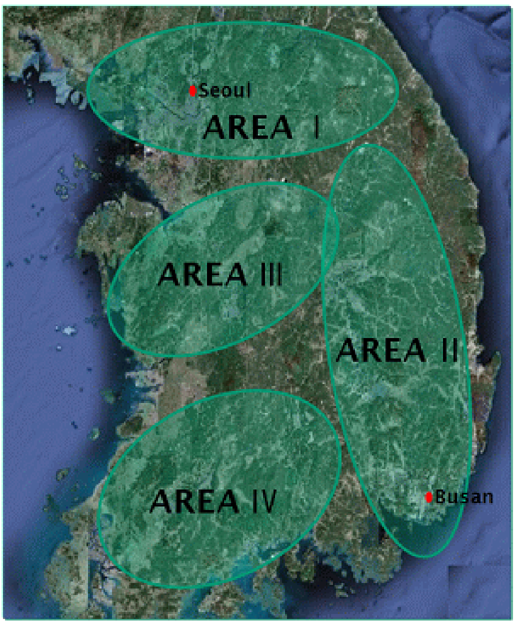
1. Introduction

After Korea ratified the Stockholm convention on persistent organic pollutants (POPs) in 2007, the public concern relating to the efficient management of POPs in the environment, as well as ecosystems, has increased. Therefore, a special law on POPs, containing regulation on emission, monitoring, environmentally sound treatment and management of POPs stockpiles, management of contaminated soil and international cooperation became effective in January 2008. The twelve POPs identified at the Stockholm convention can be divided into three groups: organo chlorine pesticides (OCPs), unintentional POPs (UPOPs) and PCBs, which include UPOPs as well as commercial products, such as Aroclor and Kanechlor, etc. Of the OCPs, aldrin, dieldrin, endrin, chlordane, heptachlor and DDT were widely used during the 1950s-1970s, but mirex and HCB have never been used or produced in the past, and PCBs were only ever been imported to Korea between 1975 and 1984 (Hong et al. ,2003). In this study These compounds, such as OCPs, PCBs are excluded. The use and production of most OCPs, with the exceptions of mirex and HCB, have been restricted by the agricultural chemicals control act since the 1970s, with restrictions on PCBs and PCDD/Fs by the toxic chemical control act since 1979 and 2001, respectively.

POPs are hydrophobic and therefore, easily bind to the particle phase in water systems, are then deposited via sedimentation processes, where they remain for a very long in the sediment due to their long half-life times (Rawn et al., 2001). The sediment plays the role of a first supplier to benthic animals, and consequently POPs can be biomagnified through the aquatic food chains to higher trophic levels. It is important to survey POPs in aquatic systems because humans, the end consumer, may be exposed to POPs via the ingestion of contaminated fish and shellfish (Ross and Brinbaum, 2003).

POP monitoring studies in sediment samples in Korea have previously been reported (Khim et al., 2001; Koh et al., 2002; Hong et al., 2003; Oh et al., 2003; Hong et al., 2006; Kim et al., 2007; Kim et al., 2008b), which focused on POPs in the sediment collected from coastal and bay regions, but not from rivers.



AREA Ⅰ: Han River

AREA Ⅱ: Nakdong River

AREA Ⅲ: Geum River

AREA Ⅳ: Yungsan and Seomjin River

Four major river systems in Korea

Korea has enjoyed and evolved various lives including politics, economics, society and culture around 4 major rivers. The area size and length by each water system is as follows.

	Area size	length
Han River	35,770Km^2	494.4Km,
Nakdong River	23,384Km^2	506.2Km
Geum River	9,912Km^2	394.8Km
Young San River	3,467Km^2	138.5Km

The average precipitation of four major rivers of Korea maintains a similar level annually. The rainfall is concentrated by season and by region, and when the drought continues for a long period of time, the river suffers from lack of rain water and thus the water pollution is increased. The water pollution of major four rivers which has improved since the peak of 1988 got worse from 1994, and although the water pollution slightly improved in 1997 compared to the previous year, some parts of Young San River is still at the 4 grade water quality. The Ministry of Environment has been conducted POPs residual status monitoring from 1999 and has secured basic data on air, water, soil and river organisms, there are no POPs residual status research result that acts as the 1st food chain to organisms in bottom sediments in the floor of river and lakes and marshes. Furthermore, following the adoption of Stockholm convention on the reduction of persistent POPs, the concerned nations need to establish an environment monitoring system on 12 subject substances according to the convention article 16 (convention implementation and effect evaluation) regulation. Based on such domestic and international demand, this research was conducted from 2005 till 2009, and the result will be used as basic material to establish a monitoring system.

2. POPs Distribution Comparison by Water system Region

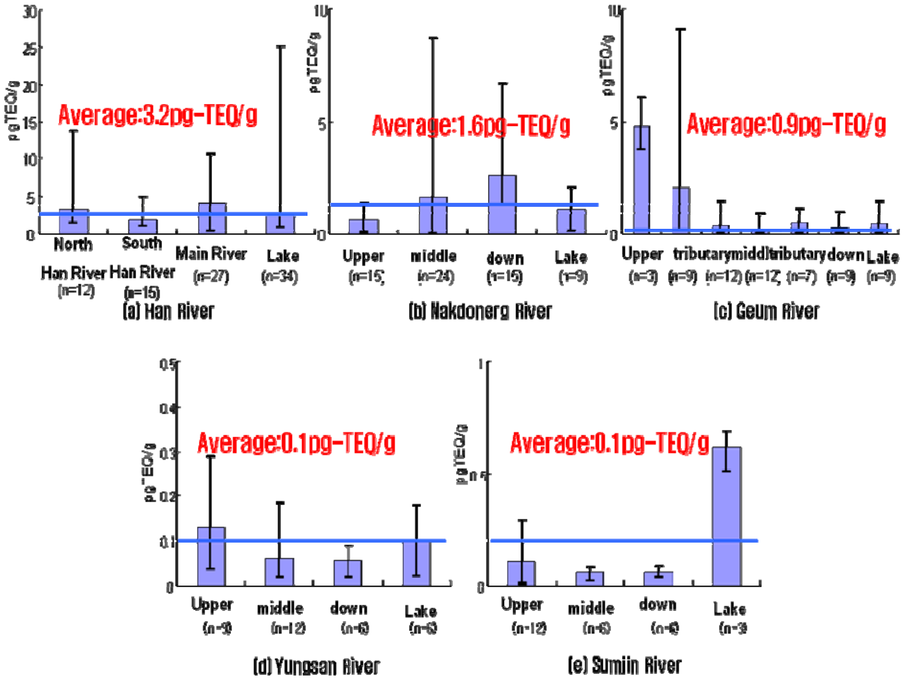
2.1 Comparison of concentration by substance among sediment in 4 major rivers

This paper has examined the pollution level by comparing with existing domestic and international materials to compare the POPs residual concentration among water system sediments of Korea's 4 major rivers (Han River, Nakdong River, Geum River, Young San River and Seomjin River) which has started from 2005.

This paper has considered and selected surrounding pollutants centered on existing water quality measuring point for river and estuary dams for sample collection points, and in case of lakes and marshes, the point was considered and selected by reflecting the connection point of rivers tributary, potential pollutants in the surrounding area and easy access to sample collection. Therefore, in the first year, the Han River water system was classified into North Han River (n=12), South Han River (n=15), Han Main River (n=27), influx part (n=17), outflow part (n=17) and a total 197 samples were collected and analyzed. In the second year, a total 164 samples were collected and analyzed for the water system of Nakdong River centered on Nakdong Main River and upper stream(n=15), midstream(n=24), lower stream(n=15) and Upo wetland(n=9). In the third year, a total 161 samples were collected for Geum River water system based on upper stream(n=3), Gap river(n=9), Miho river(n=12), midstream(n=12), Nonsan river(n=7), lower stream(n=9), lakes and marshes(n=9). In the fourth year a total 53 and 87 samples were collected for Young San River and Seomjin River water system, respectively. For Young San River water system samples were collected from upper stream(n=9), midstream(n=12), lower stream(n=6), lakes and marshes(n=7), and for Seomjin River water system samples were collected from upper stream(n=12), midstream(n=6), lower stream(n=6), lakes and marshes(n=6).

2.1.1 Dioxin

The dioxin TEQ concentration level of 4 major rivers and lakes and marshes surface sediments were compared as Fig.2.1.



[**Fig. 2.1**] PCDD/DFs TEQ concentration comparison (horizontal distribution) among 4 major rivers and lakes and marshes surface sediments

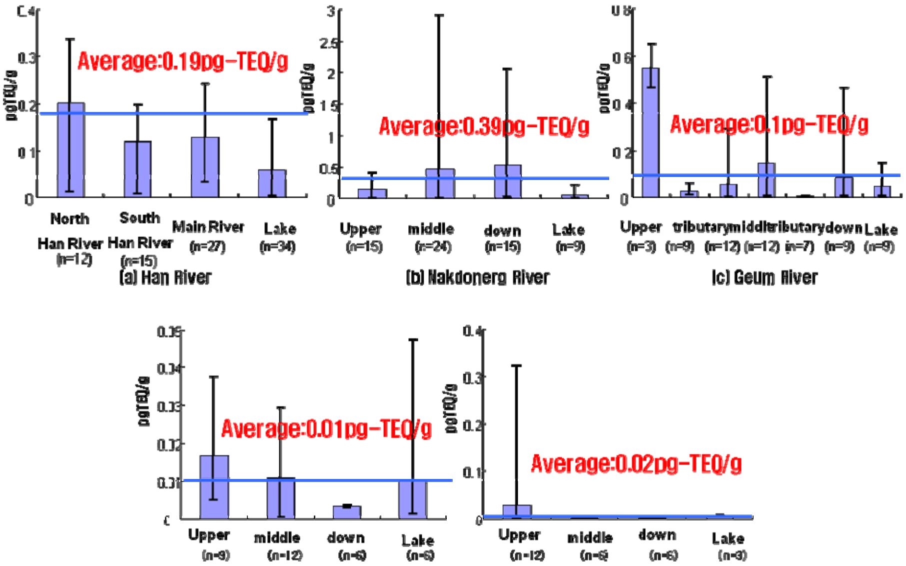
In the first year, the dioxin of Han River water system showed 60.03~250.80 (average 100.81) pg/g at North Han River(n=12), 63.32~179.48 (average 103.21) pg/g at South Han River(n=15), and 18.07~397.26 (average 160.16) pg/g at Han Main River(n=27), in case of centered on Chungpyeong Lake (lakes and marshes) the result was 28.43~280.84 (average 69.13) pg/g and 66.25~162.43 (average 93.78) pg/g, respectively, and as the Co-PCBs case, the concentration was highest at Han Main River the point where Anyang River connects. The dioxin TEQ concentration showed a range of 0.35~25.09 pg-TEQ/g and the TEQ concentration was highest at Chungpyeong Lake influx part.

In the second year for Nakdong River water system, the upper stream(n=15) was 31.54~97.65 (average 55.85) pg/g, midstream(n=24) at 4.08~283.85 (average 92.59) pg/g, and lower stream(n=15) at 110.48~230.51 (average 159.29) pg/g showing the increasing of dioxin concentration on average the lower farther down to the lower stream. The Upo wetland(n=9) was 72.50~105.12 (average 88.41) pg/g. The dioxin TEQ concentration recorded a range of 0.06~9.10 pg-TEQ/g, and showed the highest concentration at Dalsung (Baksukjingyo) and Nam River(Geumsan) point at lower stream and midstream point.

In the third year for Geum River water system, the upper stream(n=3) was 173.94~226.16 (average 193.47) pg/g, Gap river(n=9) at 50.02~307.79 (average 134.92) pg/g, Miho river(n=12) at non-detected~107.81 (average 55.59) pg/g, midstream(n=12) at non-detected~122.15 (average 61.42) pg/g, Nonsan river(n=7) at 47.23~132.42 (average 84.38) pg/g, and lower stream(n=9) at 5.70~157.29 (average 69.21) pg/g, showing a relatively higher concentration at upper stream and Gap river. The lakes and marshes(n=9) recorded16.17~116.41 (average 73.05) pg/g. The dioxin TEQ concentration showed a ranged non-detected~9.13 pg-TEQ/g and the concentration excluding upper stream and Gap river was found to be overall lower than Han River and Nakdong River.

In the fourth year for Young San River water system, the upper stream(n=9) was 20.3~74.8 (average 45.3) pg/g, midstream(n=12) at 9.5~85.9 (average 35.7) pg/g, lower stream(n=6) at 16.2~89.8 (average 43.9) pg/g, and lakes and marshes(n=6) at 19.1~3181.8 (average 568.0) pg/g, showing a similar pollution level in upper stream, midstream, lower stream except lakes and marshes. The river TEQ concentration showed a range of 0.02~0.29 pg-TEQ/g, and the upper stream reflected the highest concentration, while the midstream and lower stream were found to be at a similar level. In case of lakes and marshes, the result was 0.02~7.87 (average 1.39) pg-TEQ/g.

In case of Seomjin River water system, the upper stream(n=12) was 4.8~129.4 (average 39.8) pg/g, midstream(n=6) at 8.1~35.7 (average 23.3) pg/g, and lower stream at 12.9~34.6 (average 24.5) pg/g, which on average value the upper stream was slightly more polluted than midstream or lower stream. In case of lakes and marshes (n=3), the result was 347.2~462.0 (average 412) pg/g, showing a 10~15 times higher concentration than rivers. For the TEQ concentration, in case of rivers, the result was 0.01~4.35 pg-TEQ/g range of which the upper stream was highest, while the midstream and lower stream was similar. In case of lakes and marshes, the concentration was approximately 3 times higher than rivers.



[**Fig. 2.2**] Co-PCBs TEQ concentration comparison (horizontal distribution) in 4 major rivers and lakes and marshes surface sediments

2.1.2 Co-PCBs

In the first year, Co-PCBs for Han River water system was for North Han River(n=12) 49.38~137.22 (average 77.51) pg/g, South Han River(n=15) at 48.32~283.87 (average 99.46) pg/g, Han Main River (n=27) at 19.18~4,918.15 (average 1,005.99) pg/g, the concentration of influx part(n=17) and outflow part(n=17) centered on Chungpyeong Lake(lakes and marshes) was each 20.63~114.51(average 49.95) pg/g, and 42.47~79.55 (average 62.11) pg/g, and showed the highest concentration at Han Main River, the connection point of Anyang River. TEQ concentration sowed a range of 0.00~0.67 pg-TEQ/g and showed the highest concentration at the connection point of Anyang River of Han Main River.

In the second year, Co-PCBs of upper stream (n=15) was 17.66~132.61 (average 85.51) pg/g, midstream (n=24) at 2.89~6,550.42 (average 749.94) pg/g, and lower stream (n=15) at 61.93~1,743.84 (average 519.75) pg/g and showed the highest concentration at Geumho River (JaecheonKyo). Upo wetland(n=9) was detected at 38.84~101.19 (average 59.63) pg/g. TEQ concentration showed a range of 0.00~2.91 pg-TEQ/g and as the total concentration, the highest concentration was found at Geumho River (JaecheonKyo) and was found to be the highest among Han River, Nakdong River, and Geum River water system.

In the third year, in case of Geum River water system, the upper stream(n=3) was 48.67~65.61 (average 59.10) pg/g, Gap river(n=9) at 65.30~460.23 (average 208.47) pg/g, Miho river(n=12) at non-detected~234.17 (average 92.31) pg/g, midstream(n=12) at 35.80~332.33 (average 130.42) pg/g, and in the Nonsan river(n=7), it was detected at 25.35~50.70 (average 41.35) pg/g, lower stream(n=9) at 24.87~167.41 (average 97.73) pg/g, showing a relatively higher concentration at Gap river. Lakes and marshes (n=9) were detected at 27.57~70.62 (average 46.57) pg/g, and TEQ concentration showed a range of non-detected~0.65 pg-TEQ/g

In the fourth year, in case of Young San River water system, upper stream(n=9) was found at 32.9~264.2 (average 117.8) pg/g, midstream(n=12) at 4.5~201.3 (average 75.3) pg/g, lower stream(n=6) at 21.9~29.5 (average 25.5) pg/g, lakes and marshes(n=6) at 9.7~41.4 (average 24.1) pg/g, and in case of river, the concentration was in the order of upper stream > midstream > lower stream, and in case of lakes and marshes, it was similar to lower stream of river. TEQ concentration showed a range of 0.0004~0.05 pg-TEQ/g, and considering the median value, the concentration level was in the order of upper stream > midstream > lower stream, and lakes and marshes showed a similar level as lower stream.

In case of Seomjin River water system, upper stream (n=12) was found at 4.9~46.0 (average 19.5) pg/g, midstream (n=6) at 7.8~18.1 (average 14.6) pg/g, lower stream at 8.4~36.1 (average 19.9) pg/g and showed a similar overall pollution level. However, in case of lakes and marshes (n=3), it showed a higher concentration of approximately 2.5 times compared to rivers at 35.5~65.4 (average 49.6) pg/g and showed a similar trend as dioxin pollution distribution. TEQ concentration showed a range of 0.0007~0.3 pg-TEQ/g, and considering a median value, upper stream, midstream, lower stream all showed a similar level of concentration, while lakes and marshes showed approximately 3 times higher concentration compared to rivers and showed a similar trend as dioxin pollution distribution,.
As dioxin, the highest concentration was found at Donggye (Dowang Village).

2.1.3 HCB

In the first year, HCB at Han River water system, North Han River(n=12) was 1.1~2.8 (average 1.7) ng/g, South Han River(n=15) at 0.5~2.7 (average 1.3) ng/g, Han Main River (n=27) at 0.4~4.3 (average 1.4) ng/g, and influx part(n=17) and outflow part(n=17) of HCB concentration centered on Chungpyeong Lake(lakes and marshes) was each 0.8~4.4(average 1.5) ng/g and, 1.5~2.6 (average 1.8) ng/g, showing not significant difference between influx and outflow part.

In the second year, HCB at Nakdong River water system showed at upper stream(n=15) of 0.09~0.46 (average 0.24) ng/g, midstream(n=24) at 0.05~6.09 (average 0.62) ng/g, lower stream(n=15) at 0.10~8.13 (average 1.54) ng/g, as such HCB concentration increased the farther down to lower stream. Upo wetland (n=9) was found at 0.17~1.00 (average 0.49) ng/g.

In the third year, in case at Geum River water system, upper stream(n=3) showed non-detected, Gap river(n=9) at non-detected~0.97 (average 0.74) ng/g, Miho river(n=12) at non-detected~0.17 (average 0.17) ng/g, midstream(n=12) at non-detected~0.19 (average 0.16) ng/g, Nonsan river (n=7) at non-detected~0.22 (average 0.17) ng/g, and lower stream(n=9) at non-detected~0.31 (average 0.13) ng/g, showing a relatively higher concentration at Gap river. Lakes and marshes (n=9) was found at 0.04~0.05 (average 0.04) ng/g.

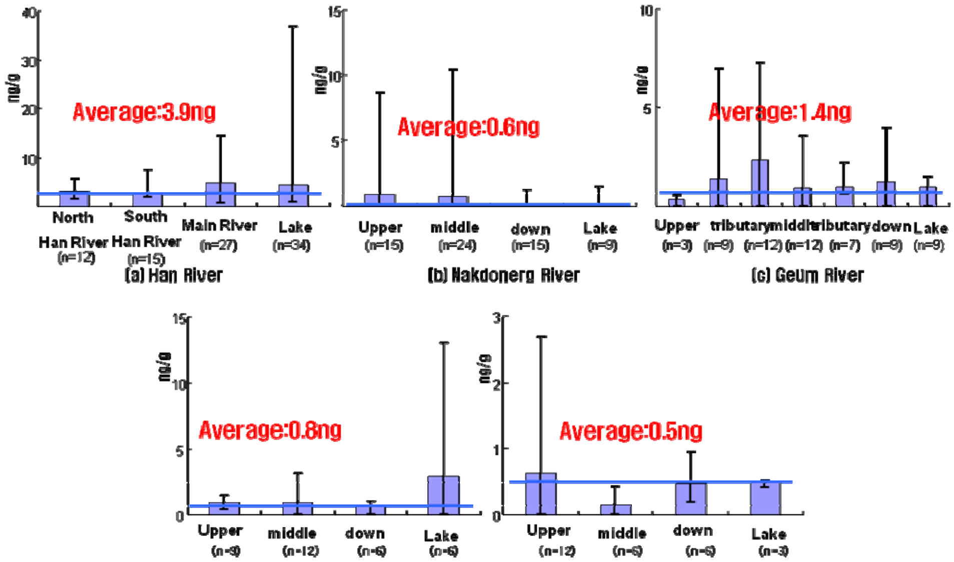
In the fourth year, in case of Young San River water system, upper stream(n=9) was found at 0.29~0.93 (average 0.54) ng/g, midstream(n=12) at 0.27~0.49 (average 0.38) ng/g, lower stream(n=6) at 0.39~0.49 (average 0.44) ng/g, and lakes and marshes(n=6) at 0.22~0.45 (average 0.35) ng/g, showing a high concentration at upper stream like PCDD/DFs and Co-PCBs, and midstream, lower stream and lakes and marshes showed a similar level of pollution.

In case of Seomjin River water system, upper stream(n=12) was found at 0.23~0.44 (average 0.30) ng/g, midstream(n=6) at 0.29~0.42 (average 0.35) ng/g, lower stream(n=6) at 0.30~0.48 (average 0.35) ng/g, and lakes and marshes(n=3) at 0.50~0.67 (average 0.60) ng/g, and as such did not show significant difference between upper stream, midstream, and lower stream. In case of lakes and marshes, the concentration was higher compared to rivers similar to the case of PCDD/DFs and Co-PCBs.

2.1.4 DDTs

In the first year, DDTs at Han River water system, North Han River (n=12) was found at 1.5~5.6 (average 3.2) ng/g, South Han River (n=15) at 1.9~7.4 (average 2.9) ng/g, and Han Main River (n=27) at 0.7~14.2(average 4.8) ng/g, while DDT concentration of influx part (n=17) and outflow part(n=17) centered on Chungpyeong Lake(lakes and marshes) was each 0.8~36.6 (average 5.3) ng/g and 2.2~4.3 (average 3.4) ng/g, showing a relatively higher figure at influx part than outflow part.

In the second year, in case of Nakdong River water system, DDTs at upper stream (n=15) was 0.00~8.60 (average 0.91) ng/g, midstream(n=24) at 0.00~10.36 (average 0.75) ng/g, lower stream(n=15) at 0.00~1.23 (average 0.14) ng/g, and as such showing a decreasing DDT average concentration the farther down to lower stream. Upo wetland (n=9) was found at 0.00~1.45 (average 0.25) ng/g.



[**Fig. 2.3**] ∑DDTs concentration comparison(horizontal distribution) of surface sediments in 4 major rivers and lakes and marshes

In the third year, in case of Geum River water system, upper stream(n=3) was non-detected~0.56 (average 0.56) ng/g, Gap river (n=9) at non-detected~6.93 (average 2.06) ng/g, Miho river(n=12) at non-detected~7.26 (average 3.49) ng/g, midstream(n=12) at non-detected~03.52 (average 1.25) ng/g , Nonsan river (n=7) 0.62~2.17 (average 0.97) ng/g, lower stream(n=9) at non-detected~3.91 (average 3.86) ng/g showing a relatively higher figure at Miho river and lower stream.

In the fourth year, in case of Young San River water system, upper stream(n=9) was non-detected~1.48 (average 0.62, median value 0.55) ng/g, midstream(n=12) at non-detected~2.85 (average 0.88, median value 0.83) ng/g, lower stream(n=6) at non-detected~0.56 (average 0.27, median value 0.26) ng/g, lakes and marshes(n=6) at non-detected~12.8 (average 2.62, median value non-detected) ng/g, the concentration decreased the farther down from upper stream to lower stream. In case of Seomjin River water system, upper stream(n=12) was non-detected~2.35 (average 0.50, median value non-detected) ng/g, midstream(n=6) were all non-detected, lower stream(n=6) was non-detected~0.81 (average 0.14, median value non-detected) ng/g, and lakes and marshes(n=3) was non-detected~0.52 (average 0.17, median value non-detected) ng/g, and from median value aspect, unlike Young San River water system, the concentration increased the farther down from upper stream to lower stream.

2.2 POPs concentration comparison of river surface sediment

This section has compared the pollution level of PCDD/DFs, Co-PCBs, dioxin, HCB and DDTs and agricultural chemicals of Korea's 4 major river water system sediments with overseas river sediments

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2.2.1 PCDD/DFs

In case of PCDD/DFs, the level was similar to China's Yangtze river (0.29~0.78 pg-TEQ/g) and Haihe river(1.3~26 pg-TEQ/g), Japan's Akita(0.022~5.3 pg-TEQ/g), but showed a lower pollution level compared to other foreign countries' rivers sediments (U.S. Detroit 1.02~284 pg-TEQ/g, U.S. Southern Mississippi 1.3~619 pg-TEQ/g, Australia Port Jackson 31.5~4352.5 pg-TEQ/g) and previously reported Korea's Hyungsan river (0.38~1037 pg-TEQ/g) and coast sediments(2.3~90 pg-TEQ/g). In case of Co-PCBs, the level was lower compared to foreign countries (China Dagu

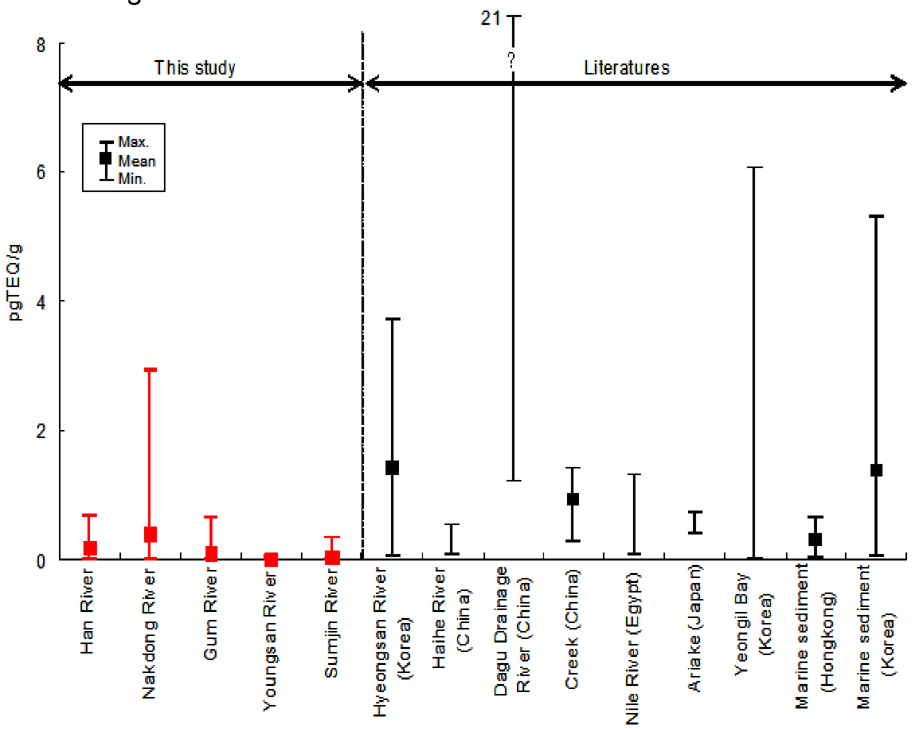
Drainage 1.2~21 pg-TEQ/g), showing that PCDD/DFs and Co-PCBs pollution level of domestic rivers sediments was not higher compared to foreign countries.

2.2.2 Co-PCBs and dioxin

This section has compared rivers Co-PCBs and dioxin concentration (total concentration and TEQ concentration) range among surface sediments by water system and showed the result in Fig. 2.4.

In case of dioxin, by average value, Han River (131 pg/g), Nakdong River (101 pg/g), Geum River(85pg/g) were similar and Young San River and Seomjin River was each 41 pg/g and, 32 pg/g, showing a 1/2~1/4 higher level to Han River, Nakdong River and Geum River.

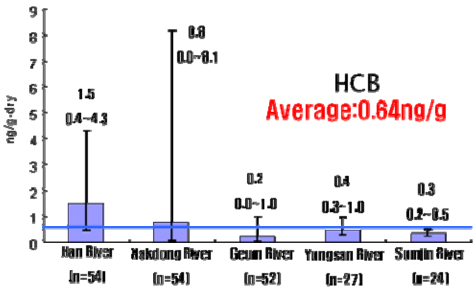
In case of Co-PCBs, Han River (548 pg/g) and Nakdong River (501 pg/g), Geum River (113 pg/g) and Young San River (78 pg/g) showed a similar pollution level, while Seomjin River (18 pg/g) showed a relatively lower level than other water systems. TEQ concentration was similar for Han River and Geum River, Young San River and Seomjin River, while Nakdong River was approximately 2 times higher than Han River and Geum River.

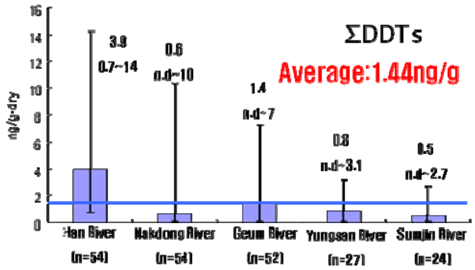


[**Fig. 2.4**] Co-PCBs pollution level comparison of non-domestic rivers surface sediments
Source: Koh et al., (2004), Liu et al., (2007), Liu et al., (2007), Li et al., (2007), El-Kady et al., (2007), Kim et al., (2008), Koh et al., (2006), Terauchi et al., (2009), Terauchi et al., (2009)

2.2.3 HCB and DDTs

Fig. 2.5 is a comparison of concentration of HCB and DDTs by water system in rivers surface sediments. HCB in Han River was 0.4~4.3 (average 1.5) ng/g, Nakdong River at 0.0~8.1 (average 0.8) ng/g, Geum River at 0.0~1.0 (average 0.2) ng/g, Young San River at 0.3~0.9 (average 0.4) ng/g, and Seomjin River at 0.2~0.5 (average 0.3) ng/g, and as such from average concentration the order was Han River > Nakdong River > Young San River > Seomjin River > Geum River. ∑DDTs(DDE+DDD+DDT) concentration was found in Han River at 0.7~14.2 (average 3.9) ng/g, Nakdong River at n.d~10.4 (average 0.6) ng/g, Geum River at n.d~7.3 (average 2.0) ng/g, Young San River at n.d~2.9 (average 0.7) ng/g, and Seomjin River at n.d~2.4 (average 0.3) ng/g.





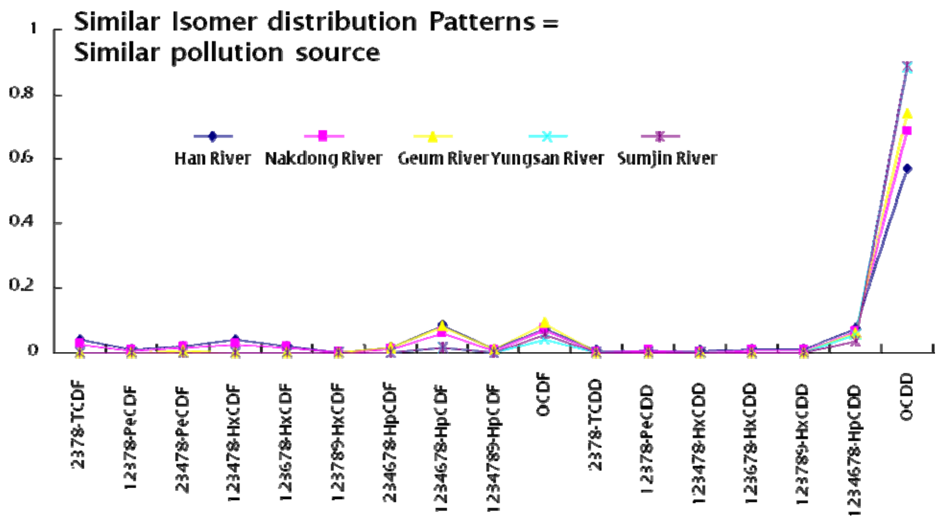
[**Fig. 2.5**] ∑DDTs concentration comparison by water system of rivers surface sediments

2.2.4 Agricultural Chemicals

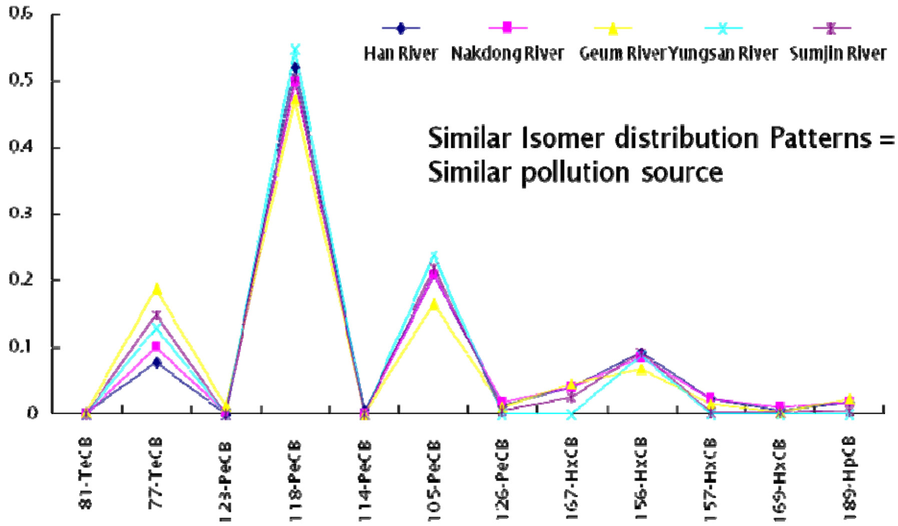
In case of other agricultural chemicals, the level was n.d. in most sediment, and for chlordane (∑α-, β- chlordane) the level was found in Geum River water system at n.d~1.18 (average 0.22) ng/g, Young San Riverwater system at n.d~0.32 (average 0.09) ng/g, and Seomjin River water system at n.d~0.52 (average 0.07) ng/g. In addition nonachlor (∑cis-, trans-) was found at Geum River water system at n.d~0.55 (average 0.09) ng/g.

2.2.5. PCDD/DFs and Co-PCBs isomer distribution of major rivers and lakes and marshes surface sediments

Fig. 2.6 ~2.7 demonstrated the isomer distribution of dioxin and Co-PCBs of 4 major rivers and lakes and marshes surface sediments examined in this research. As seen in the image, in case of dioxin and PCB, rivers and lakes and marshes sediments each showed similar trends and the isomer distribution was also similar by water system. Therefore, considering that dioxin and PCB are relatively stable chemical compounds in the environment, dioxin and Co-PCBs pollutants in Korea's 4 major rivers and lakes and marshes surface sediments are expected to be similar and this is also backed up in statistical interpretation result (refer to each 1st ~3rd report).



[**Fig. 2.6**] PCDD/DFs isomer distribution of major rivers surface sediments



(a) rivers sediments

[Fig. 2.7] Co-PCBs isomer distribution of 4 major rivers surface sediments

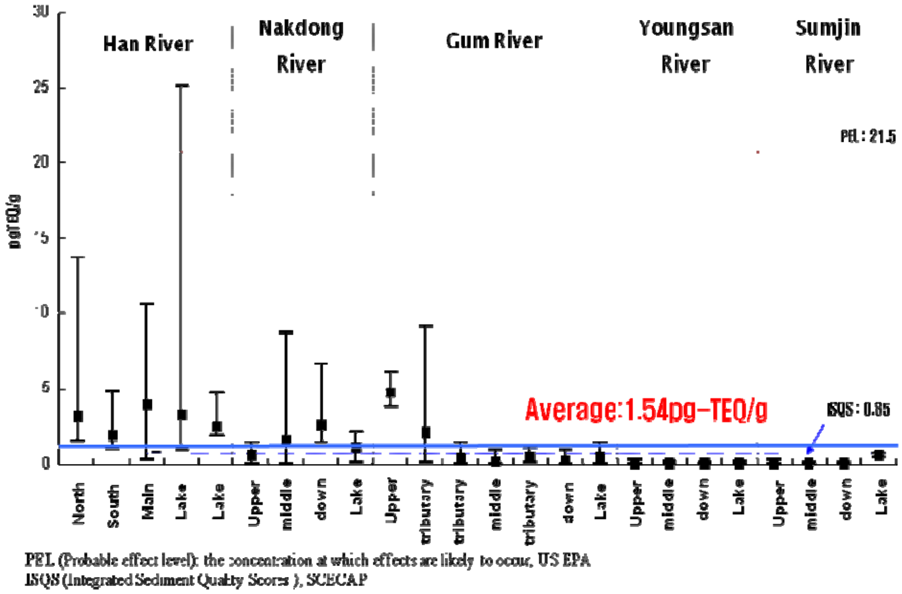
2.4 Comparison with foreign countries sediments recommended level

Organic pollution remaining on sediments can directly act as pollutants of benthic organism living on sedimentary level. Therefore, numerous studies have been conducted on the impact of organic pollution remaining on sedimentary level to benthic organism, to present recommendation level of organic pollution concentration in sediments (Long et al. 1995; CCME(The Canadian Council of Ministers of the Environment) 1999; ANZECC(Australian and New Zealand Environment and Conservation Council) and ARMCANZ(The Agriculture and Resource Management Council of Australia and New Zealand) 2000; MacDonald et al. 2000a, 2000b).

2.4.1 Dioxin and PCBs pollution level and foreign countries environment level comparison in sediments

In case of Korea, environment recommendation level and standard on organic pollution remaining on sediments have not yet been provided. In order to assess the ecotoxicological significance of POPs remaining concentration accumulated on 4 major rivers' water system sediments, this section has compared for dioxin, the sediments recommendation level of Canada's Ministry of Environment (Fig. 2.8), and for PCBs, compared with sediments recommendation standard provided by U.S. (NOAA, National Oceanic and Atmospheric Administration).

Canada Ministry of Environment presents the guideline on dioxin of potential sediments recommendation standard (ISQS) and adverse impact expectation level (PEL) at each 0.85 pg-TEQ/g-dry and 21.5 pg-TEQ/g-dry. While Chungpyeong Lake influx part 1 point of Han River water system was found at 25.09 pg-TEQ/g-dry, exceeding PEL, other points showed a lower figure than the recommendation by Canada Ministry of Environment.



[**Fig. 2.8**] Comparison with foreign countries' recommendation level (dioxin TEQ concentration)

NOAA has considered the impact of chemical substance pollution within low level sediments to benthic organism and has presented effect range low (ERL) and effect range median(ERM) value. Concentration below ERL is concentration of chemical substance that rarely is observed of harmful impact, and concentration above ERM is the concentration of chemical substance that frequently shows harmful impact.

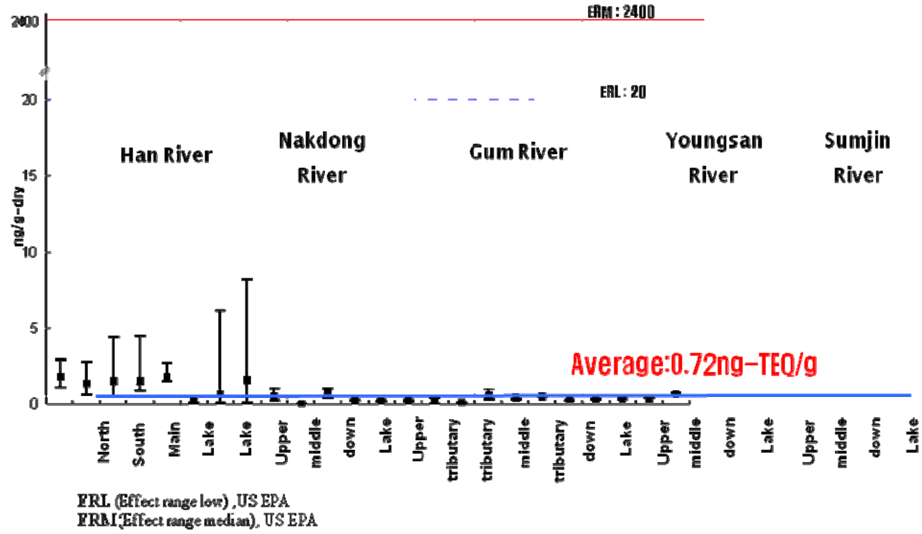
Canada (CCME 1999) and Australia/New Zealand (ANZECC and ARMCANZ 2000) also presents similar sediments recommendation level as NOAA. PCBs' ERL and ERM presented by NOAA is on total PCBs and is each 22.7 ng/g-dry and 180 ng/g-dry.

This study was conducted on total 12 types of Co-PCBs, and although it is difficult to directly compare with NOAA recommendation level, it is expected to be lower than the recommendation level. However, in case of Nakdong River water system Geumho River point and Han River water system Anyang River connection point, the figure was found at each 6.5 ng/g-dry and 4.9 ng/g-dry, therefore, it is believed that a continuous observation is required for these two points in the future.

According to the comparison of dioxin and PCBs recommendation level of foreign countries' sediments, the result was overall lower than the recommendation level, however since the recommendation level presented by U.S., Canada, Australia/New Zealand, the level was set by reflecting the toxicological impact of organisms in foreign countries, therefore there is a limit in directly comparing with pollution substance remaining volume and bio-toxicity. Therefore, going forward, it is necessary to build materials on toxicological impact using domestic organisms and an independent recommendation level of pollution substance will need to be established.

2.4.2 Organo chlorine pesticides agricultural chemical pollution level of sediments and foreign countries environment level comparison

In order to assess the Ecotoxicological significance of HCB and DDT in organo chlorine pesticides and agricultural chemicals, Fig. 2.9 compared HCB chemical substance concentration found in Geum River and the recommendation level presented by U.S. NOAA. In case of HCB chemical substance, NOAA's sediments recommendation level for ERL, ERM value is each presented at 20 ng/g~24000 ng/g. The HCB concentration of 4 major rivers and lakes and marshes surface sediments was found not be impact ERL value



[**Fig. 2.9**] HCB recommendation level comparison with foreign countries' sediments

In case of DDT chemical substance, the ERL, ERM values are each presented at 1.58 ng/g, and 46.1 ng/g. The concentration of all points of 4 major rivers and lakes and marshes surface sediments was found to be higher or similar level to ERL, but was found not to have much impact on ERM concentration.

3. Conclusion

This study has studied POPs remaining concentration of sediments in Korea's 4 major rivers (Han River, Nakdong River, Geum River, Young San River and Seomjin River) water systems and has examined the pollution level by comparing with the above results to existing non-domestic materials.

3.1 PCDD/DFs and Co-PCBs

In case of PCDD/DFs, the level was similar to China's Yangtze river (0.29~0.78 pg-TEQ/g) and Haihe river(1.3~26 pg-TEQ/g), and Japan's Akita(0.022~5.3 pg-TEQ/g), however showed a lower pollution level compared to other foreign countries rivers sediments(U.S. Detroit 1.02~284 pg-TEQ/g, U.S. Southern Mississippi 1.3~619 pg-TEQ/g, Australia Port Jackson 31.5~4352.5 pg-TEQ/g) and previously reported Korea's Hyungsan River(0.38~1037 pg-TEQ/g) and coast sediments(2.3~90 pg-TEQ/g). In case of Co-PCBs, the level was lower compared to foreign countries (China Dagu Drainage 1.2~21 pg-TEQ/g) (domestic 4 major rivers and lakes and marshes sediments: 0.001~0.211 pg-TEQ/g), demonstrating that PCDD/DFs and Co-PCBs pollution level in domestic rivers sediments is not higher than foreign countries.

3.2 Dioxin

In case of dioxin, by average value, Han River (131 pg/g), Nakdong River (101 pg/g), Geum River (85pg/g) were at similar level and Young San River and Seomjin River was each 41 pg/g and 32 pg/g, and as such showing an approximately 1/2~1/4 level to Han River, Nakdong River and Geum River.

In case of Han River water system, in the Chungpyeong Lake influx part 1 point (I-14) the level was found at 25.09 pg-TEQ/g-dry, exceeding PEL level and in other points the level was lower than Canada's Ministry of Environment recommendation level.

3.3 HCB and DDTs

In case of HCB, Han River was found at 0.4~4.3 (average 1.5) ng/g, Nakdong River at 0.0~8.1 (average 0.8) ng/g, Geum River at 0.0~1.0 (average 0.2) ng/g, Young San River at 0.3~0.9 (average 0.4) ng/g, and Seomjin River at 0.2~0.5 (average 0.3) ng/g and from average concentration aspect, the order was found at Han River>Nakdong River>Young San River>Seomjin River>Geum River. ∑DDTs(DDE+DDD+DDT) concentration in Han River was found at 0.7~14.2 (average 3.9) ng/g, Nakdong River at n.d~10.4 (average 0.6) ng/g, Geum River at n.d~7.3 (average 2.0) ng/g, Young San River at n.d~2.9 (average 0.7) ng/g, and Seomjin River at n.d~2.4 (average 0.3) ng/g.

3.4 Agricultural Chemicals

In case of other agricultural chemicals, the level was found in most sediments as non-detected, and in case of DDT chemical substance, concentration at 4 major rivers and lakes and marshes surface sediments points was higher or similar than ERL, however did not much impact ERM concentration level, and HCB concentration was all found not to largely impact ERL value.

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Cause of Water Pollution of Russian Far Easter Rivers

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1. Environment condition of Russian Far Eastern Rivers

1.1 Hydrological Features of the Russian Far Eastern Rivers

There are located some largest and famous rivers in the Russian Far East. One of them is River Lena. It begins in the Eastern Siberia, but it mostly runs on Yakutia area, involving more than a half of this territory. Its total length is 4 400km and the area of the basin is 2,490 thousand square km. River flow in the creek is 17 000м3/ sec and average annual flowing is 488м3.

The next big transboundary river is Amur that flows out of Mongolia, but the most part of the river flows on the Russian territory. The Amur River is one of the largest rivers of Russia. Its long is 4 440km and 2 800km of it belong to the Russia. The area of the river basin is 1 855 000km2. The average flow of several years standing of the Amur River basin is 1.85l sec/ km. The volume of the annual flow of the Amur River in the mouth is 346m3. The rivers of the Amur basin are full-flowing, it results from monsoon climate, little evaporation and considerable woodiness of the territory. More than 550 floods, of which 54 are catastrophic, have been registrated in the Amur River basin for the recent 60 years.

The river system in Russian Far East is very brunching; its density is 0.42km/km2. Permafrost, a little absorption of water by the soil, mountainous relief and sharply continental climate has a great influence on the water regime of the rivers basin. As opposed to river's regime located in the Russian European part, the water content of the rivers in the Russian Far East region changes sharply during a year. The floods, formed by downpour rain in summer-autumn periods are typical for the region's rivers.

The area of Russian Far East is 6 215 900km2, it is one third part of all territory of Russian Federation. But the population of Far East is only 6 593 000, including citizens – 5 011 000 and villagers – 1 582 000. So the anthropogenic impact on the environment at the Russian Far East is light one. For example, the quantity of the water the River Lena takes the 9-th place

in the world and the 2-d place in Russia, being inferior only to the Yenisei River.

So low-density population, light anthropogenic impact on environment brunching river system, mountainous relief and full-flowing to specify favorable environment condition in the Russian Far East.

1.2 Ecological condition of river water and their influence on environment of Russian Far East.

Despite of favorable environment condition there are some environmental problems in the Russian Far East. It should be noted pollution of fresh-water and reduction of number of coastal sea fishes. In comparison with 1940 mid-annual catch in the rivers of Amur Basin have decreased in 8.3 times, and catch of salmon fishes has decreased in 70 times. For 50 years more than 200 rivers in Kolyma river basin have lost the fish economical meaning because of extraction of gold deposits. The following should be mentioned the quantity of the floods (high waters) has increased in 6 times as a result of deforestation within hundred years in the Russian Far East.

Drinking water is one of the nutrients which determine the basis of the internal environment of an organism. As for chemical contents, natural waters of the Russian North-East are lightly mineralized and have deficit in calcium, potassium, magnesium with low contents of such important elements as fluorine, manganese, cooper, zinc. The misbalance in microelement picture (deficit of Ca, Co,Cu,Mg,Mn,Se,Zn,J) of the North children was differed.

The most density of population (14 people/km2) and the most anthropogenic impact on environment among Far Eastern areas Primorskiy Region has. So we investigated more detailed modern environment condition of surface water of Primorskiy Region.

1. Geographical location of Primorskiy Region and its important in environment balance of north-eastern Asia

The Primorskiy region is situated on the Russian extreme south-east between 42-48 degrees of the northern latitude and 130-139 degrees of the eastern longitude. The mountainous relief takes 80% of the region's territory. The system of mountain ridge Cihote-Aline, extended along the seashore of the East Sea, takes the most part of it. The distance between extreme northern and southern points is 900 km. The territory of Primorsky Region, which square is 165 900km2 including plural islands of the Peter's Great bay, besides the continent part of the Eurasia. The largest islands of them are Russkyi, Popov, Reineke, Rikorda, Askold, Putytin, Petrova, Rimskogo-Korsakova.

The region's geographical placement in the southern latitude of the temperate zone at the turn of the continent and ocean stipulates the advantage its nature. The mountain system Sikhote-Aline and the spurs of the Eastern-Manchuria mountain territory, the plain Prihankaiskay are main forms of the region's relief. The climate of region is temperate monsoon, damp. The plural number of sunny days is monitored in winter, when there is cold and dry weather.

Located on north of Primorskiy Region the Bikin River valley is boundary between the north boreal biota and the southern

Manchurian biota in the Far East. So there are so unique biodiversity in Primorskiy Region, represented by the following:

- 25 percent of all Russian Federation biodiversity;
- One third of all Red data book species of Russia;
- 10 percent of the world's gene pool;
- 77 percent of the fauna of the Far East (over 70 species) are concentrated in the southern half of the Primoriy Region;
- Primoriy is home to 350 bird species;
- The Primoriy Region is the northern range boundary for nearly 100 bird species.

One-hundred species of fish inhabit the rivers and lakes and one-fifth of these are endemic, found only in Lake Hanka / Xingkai and the Amur basin. The famous taiga Ussurriskay is performed by broad-leaved woods with prevalence of maple, linden, ash-tree, oak, Mongolian nut, hornbeam, yew-tree, birch and also the considerable part of the aralias family. The Korean cedar, wholly deciduous silver fir, fir-tree are grown there.

Primorskiy Region area is boundary between the north boreal biota and the southern Manchurian biota where a unique relict species are represented there. Primorskyi Region is a glacial refugium and harbors plants and animals, including many Pleistocene and even tertiary relict species, found nowhere else in all of North Eastern Asia.

1. Hydrological Features of Surface water of Primorskiy Region

The surface water of Primorskiy Region is represented by rivers, lakes and bags.

3.1 The rivers of Primorskiy Region

There are more than 6 000 rivers, but only 91 of them have the length more than 50km in the territory of the region. The territory of Primorskiy region includes the river basin Ussuri (in the bound of the Primorsky region) and the basins of the rivers fallen to the East Sea from the frontier with China in the south-west to the watershed of the rivers Samarga-Nelma in the north-east.

The river net in the territory of the Primosky region is developed quite well. The total length of all rivers is more than 120 000km, the average coefficient of the river's system thickness is equal to 0,73km/km2. The most meaningful rivers are Razdolnay, Ilistay, Samarga, Partizanskay, Malinovka and others, besides the river Ussuri and its tributaries. The river net in the territory of the region distributes highly irregular. The more dense river system (1,0-1,2km/km2) is typical for the south-west part of the Primorskiy Region. Especially it's marked in the basins of the river, fallen in the Great Peter's bay, where the coefficient of the river system's thickness reaches

1,6-1,8km/km2. The high modules of annual flow (15-25 liters/second-km2) are typical for the basins of these rivers. The territory of the west Primorskiy's plain (the rivers of the basin Ussuri) is characterized by the least thickness of the river system. The annual modules of water flow exceed 0, 5-1,0 liters/second-km2.

The rivers of Primorskiy Region zigzag and have many old channels and canals that can merge into a single channel during high waters. Also it is necessary to note the significant tortuosity of the river channel and the thresholds in middle stream sector. Mud sedimentation in the riverbeds causes various hydraulic connections between surfaces and underground waters. The silt capacity decreases from 5-10 cm in river mouth and upstream to 2-2.5 m downstream. Underground water drainage to the river takes place in winter.

The main feature of the stream conditions of all rivers in Primorski Krai is high waters caused by abundant atmospheric precipitates. Summer storm high waters are often accompanied by sudden water rise even flood. Stable mean water is absent. Such feature of the river stream may be accounted for the following factors:

- The big steepness of the valley slopes and the big longitudinal slope of the rivers in the basin;
- A combination effect of high density of drainage and meandering river courses.
- Oversaturated moist soil by previous rains.

Bases on hydrological features of Primorskiy Region rivers is possible to conclude that the region's rivers have low level of anthropogenic impact resistant. There are probably developments of deep and lateral channel erosion and sea water intrusions in the region's rivers either.

3.2 The lakes and the bags of Primorskiy Region

The lakes are situated highly irregular along the territory of the Primorskiy region. The most amounts of them concentrated in the bound of the west-Primorskiy plain, but the lakes in mountain regions are met rarely.

Among the large lakes in the Primorskiy region we should mark only the lake Hanka, which is situated in the middle part of the West-Primorskiy plain. The floor area of the lake's Hanka's basin composes 16 890km2. The floor area of the water surface during average standing level 68,90m – 4 070km2, including in the bound of Russia – 3 030km2. The average breath of the lake is 45km, the average depth is 4,5m, the large depth is 6,50m.

In the basin of the river Ussuri the most amount of lakes is situated in the bound of the lowland Prihankaiskay (1 163 lakes). There are 426 lakes in the basin of the river Bolshay Ussurka, 146 ones in the in the overhead stream, 160 ones in the basin of the river Arsenyevka, 82 ones in the basin of the river Bikin. The lakes in the basin of the river Razdolnay – 514 lakes are the most extended, whereas there are only 15 lakes in the basin of the river Samarga.

Bags and swamped territories are mainly developed on the surface of the West-Primorskiy plain, where its square is about 2 500km2 or 38% of the total square of the bags. The total area of the bags on the territory of Primorskiy Region makes up about 6 600km2. The marsh missives are situated separately from each other and they don't have landscape making meaning.

3.3. Hydrological features of Primorskiy Region Rivers that promotes the distribution of salty sea water upstream

Fast-going economic development, increasing artificial use in length of coastal line, and intensive agro-industrial drainage of local communities on ancient sea terraces will promote the increase of seawater intrusion into coastal underground water horizons.

The movement of back-and-forth tidal current in relation to astronomical and meteorological conditions in the Primorskiy Region gulfs change the salinization in the river mouth water.

The increase in water take-out from the River Partizanskay reach areas would decrease the underground water level to the minimum at 170 m, which would result in river water leaking into the groundwater pool. In the case of the river mouth area, the marine-influenced salty river water would increase the salinization of the groundwater even a small inflow. Hydrological features Primorskiy Region Rivers that promotes the distribution of salty waters upstream, namely:

- Fast rise of the river water level and sharp recession of flood in typhoon events;
- Small depth of the river (especially in the river mouth region) and big width of the mouth region especially in flood event;
- The small river flow;
- Mud sedimentation and accumulation on river beds.

Thresholds and high curvature of the river would block the seawater flow upstream.
During winter, the salted underground water spills back to the river, making greater salinization of the river water.

For the optimal operation mode, a decision must be made for the sake of the protection of river waters from salinization. In the mode, we can use the water resource in a full scale but not change the salinity of the water. Therefore, a well-designed water supply system such as volume and outlet locality is necessary to guarantee the sustainable use of the groundwater resource. The following issues must be studied:

- To determine parameters of salty water-invaded zone (or zones of salinization) in various hydrological conditions of the river;
- To calculate the direction and size of horizontal and vertical components of speed-vectors, and the salinity distribution in space and time in the river channel;
- To estimate the intensity of seawater and freshwater mixing in vertical and horizontal directions in entire salty water impacted zone of the river channel;
- To define the chemo-physical forces at the interface between seawater and freshwater in the river channel. With the forces defined, the movement and pattern of salty water-invasion can be described.

Many theoretical and experimental researches on this subject have been conducted by Keulegan G.Y., Ippen A.T., Harleman D., Taylor G.I. The available researches show that physical and mathematical simulation on hydrology of the river-basin has been carried out up to deep river channels to simulate the real case of the rivers in Primorskiy region. They are shallow rivers, and the ratio of depth/width is 0.01 and 0.0005 in the mouth area. However, the previous simulation used big flowing water volume 100-1000 times of the Primorskiy's rivers; therefore, the results of their simulation are not applicable in our region in deferent hydrogeological conditions. Losses of kinetic energy of movement in all routes of salty water-invaded zone are caused by dynamic friction between the saline water and the bottom surface, additional to other types of forces. This is especially important in our case of shallow rivers, in which we cannot neglect the friction force. It is necessary to take into account not only the channel roughness coefficient, but also changes in whole routes of the salty water-invaded zone in research on the dynamics of seawater intrusion.

For the Primirskiy's Rivers temperature difference makes from 0 up to 20-23 degrees that will considerably influence on kinematic viscosity coefficient for density difference liquids. Using a temperature parameter is absent in earlier researches. Deformation and distributional pattern of salty water-invaded zone are caused by morphological and hydro-geological features of the river channel also.

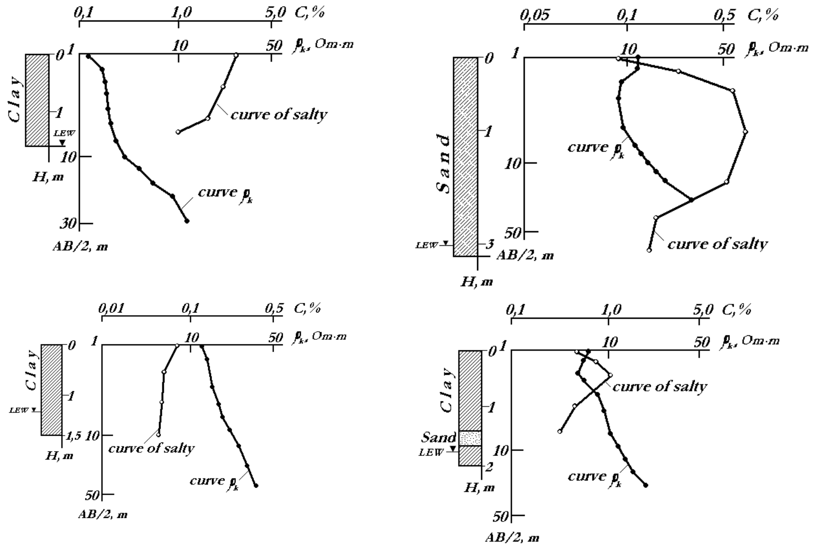
The channel of the Primorskiy Region Rivers is meandering, frequently branching on some armlets, forming islands. On the average and lower course of the River crosses a load thickness. Pebble spits are the typical phenomenon in the lower watercourse.

Unfortunately, a channel morphology was not taken into account in the previous researches. The special hydrological regime of the river is spring up on the rifts. Due to the big speeds on the rifts sea water transmission into river water becomes limited.

All above-stated hydrological features of Primorskiy Region rivers it will be essential to influence dynamics of sea water transmission, on the form of salty water-invaded zone, on spacing of water speeds and intensity of fresh and sea water mixing.

Use of available theoretical development in subject of sea water's intrusion into coastal fresh waters is not always applicable to conditions of Primorskiy's rivers and frequently results in overestimate of speed and lengths of salty water-invaded zone penetration into fresh water horizons in some times. It causes necessity of revision of theoretical bases of dynamics sea water's intrusion in view of regional hydrological features.

During of investigation carrying out in the frame of the project the authors had attempted to assess the capabilities of application of resistivity and induced polarization sounding methods on ground water salinity research in Partizanskay river basin (Primorskiy Region).
Figure 1: Comparison curves of apparent resistance and salinity for aeration zones.



3.4 The Factors Determining Dynamic of the Channel Erosion in the Primorskiy Region

Generally the geological sections of Primorskiy river's basins are represented by well washed away loamy, sandy, clay, sandy-argeillaceous sediments. Litological structures properties of such geological section are determining the intensive dynamic of channel erosion in Promorskiy Region.

Rather stable the tectonically condition of the region (weak lowering) in a combination gently sloping biases of the river channel causes the big tortuosity (1.6-3) of the rivers that make for channel erosion of the rivers. Often and long time floods at which speed of water current increase in 1.5-2 time, very slight down gradient of the river channels (about 20 %) will promotes development of lateral erosion. One of the best reasons of the channel erosion development in Promorskiy Region is Tumangan Ribver, where the average rate river channel migration during the period 1950-2002 was 2.04m.

As a result of lateral erosion, in the Russian side, 1.21 hectare of land was washed away every year. The displacement of coastal edge of the river in 2000 is 60-70m for high water.

3. Industrial impact on surface water in Primorskiy Region

3.1 Region's economy

The advantageous geographical position and great natural resources are the main conditions of the region's economy development. The base of the region's economy is the basis industry branches: timber and woodworking, electro energetic, coal, fish, food, as well as construction, rural farm, trade and social nourishment.

About 30% of the Far-East social-economical potential is concentrated in Primorskiy Region. The population of the region is about 2.06 million people, 78,2% of them are citizens. There are 12 cities, 45 settlements, 639 villages and 24 administrative districts.

Nowadays there are 547 enterprises of sundry forms of property, making different ways of water use on the 1 639 water objects, including the surface water objects, territorial sea and the interior sea waters in the Primorskiy Region.

In territory of Primorskiy Region more than 300 placer deposits located in valleys of the rivers, on slopes and countries between two rivers are extracted.

The territories of large cities of the region - Vladivostok, Nahodka, Ussuriisk, Spassk-Dalnii, Dalnegorsk, Partizansk, Luchegorsk in which the most part of the population and the majority of the large industrial enterprises is concentrated, are subject to the greatest loading on the environment because of great volume of formation and accommodation of the firm domestic and industrial wastes.

Especially the largest stress accounts to the territory of Vladivostok: in the city's boundaries there are the dumps of domestic waste products, long-term accumulation of toxic waste products of the 1 - 3 classes of danger on the industrial territories of the enterprises. The operative in Vladivostok, the unique in the region, the incinerate factory on which about 30 % of the city's domestic waste products are neutralized, does not improve the situation.

Annually in the territory of Primorskiy Region about 51 million tones of the waste products are formed: about 0,8 million tones of them are waste products of consumption, about 8,3 million tones of dangerous waste, and about 42 million tones of practically harmless industrial wastes. There are registered 317 kinds of waste products in Primorskiy Region. The annual gain of volumes of accumulation of dangerous waste products makes approximately 2 %.

There are the following types of dumps in Primorskiy region:
307 long term-dumps,
85 lawful dumping,
48 unlawful dumping of the solid domestic wastes,
17 tailing dumps,
7 ash-dumps,
28 dung-yards.
The greatest volumes of waste are formed at the enterprises of electric power industry (71 % from total amount), the enterprises of the coal industry (14 %), the mining and mining enterprises of nonferrous metallurgy (8,4 %), the chemical industry (3,7 %). Only five percent of the formed dangerous waste products are sent for processing.

3.1. Ecological condition of the superficial water objects

The ecological condition of the superficial water objects in the territory of Primorskiy Region is characterized by a class of quality from polluted up to dirty. The most unsuccessful ecological situation has developed on the rivers Spacious, Rakovka, Komarovka, Rudnay and Hanka Lake.

Construction of moorings, dams and other port constructions across a coastal line of the sea have led to offshore abrasion and subject to seawater intrusion into fresh surface and ground water. The device of water-fences, development of coastal slopes, clearing the river beds for navigation rendered essential influence on change of the hydrological parameters of the rivers and accordingly on their erosive activity.

The majority of the enterprises of the given branch have the clearing constructions of biological clearing, but, in the majority cases their condition is such, that the constructions do not consult with the purpose and the maintenance of polluting substances in the sewage considerably exceeds the maximum permissible concentration. At many enterprises the clearing constructions projected as the clearing constructions of biological clearing, actually work in a mode of mechanical clearing. The low overall performance of the clearing constructions is connected, basically, with absence of means for carrying out of their scheduled repair and reconstruction.

The hydro chemical condition of the waters of the surface water objects are appointed by many factors as types of water object (surface reservoirs, surface streams, dam ponds, interior sea waters, territorial Russian sea); types of water use (diversion capacity, withdrawal of foul waters, using of the water area or accommodation of the hydro technical constructions and so on; availability of the cleaning constructions and their working effectiveness on the enterprises, quantity and quality of the foul waters, thrown in to the water objects).

As an obvious example could be the hydro chemical composition of the river Rudnay. There are located some mining enterprises in Rudnay River basin. The hydro chemical composition of the water is formed under the influence of the pollution substances – zinc, lead, cadmium and boron, thrown into the water by these water users. As the result there is a high and an extremely high pollution of the water (zinc – 52-84 of the maximum permissible concentration; cadmium – 2, 4 of the maximum permissible concentration; cadmium; copper – 7, 0-11, 00 of the maximum permissible concentration) in the river. Respectively, the quality of the river water “mild-foul” to “highly-foul”.

There is a strain situation in the river Rakovka and Komarovka, in the inflows of the river Razdolnay. In spite of the high effectiveness of the treatment works in the city Ussurisk, in the marked water objects they visualize the cases of great relative height of the extremely possible concentration of the polluting substances in the water. In the result the both rivers are placed among the category of the “foul” rivers.

There are not good environment conditions in the Hanka Lake. Disposal by dilution of water from paddy fields give place to accumulation the soluble mineral fertilizers and pesticides into the Hanka Lake. Discharging sewage into the Hanka Lake contains 37 ton of mineral phosphate and 2 888 organic phosphate.

Phosphate content surpasses maximum concentration limit in 3-5 times there. Mercury content surpasses maximum concentration limit in 3-5 times there.

5. Creation of State natural Reserves as means toward environmental safety in Primorskiy Region

Some state natural reserves were created for preservation of unique natural complexes in Primorskiy region and for improvement of the environment. The total area of all especially protected natural territories is 2061,8 thousand hectares, including reservoirs and sea water areas, it makes 12,42 % from all area of Primorskiy Region. One of the most important and famous state natural reserve is “Hanka Lake”. “Hanka Lake” Reserve is the international wetland of high level meaning.

The state natural reserve “Hanka Lake” carries out the primary goal - preservation of the natural complex which is taking place under protection of the international convention « About water-marsh grounds, having the international value mainly as habitats of a waterfowl » (the convention Ramsarskay. 1971), and also the improvements of ecological conditions in pool of the lake.

International Reserve “Hanka Lake”, jointed Russian reserve “Hankaiskiy” and Chineese reserve “Sinkai-Hu”, was created in 1996. In June, 2004 there was an expansion of the territory of the reserve “Hanka Lake” and its guard zone (over 5520,1 hectares and 3066,6 hectares accordingly) at the regional level.

The reserve mainly includes the marshland (grassy bogs and meadow vegetative communities) on coast of the Lake Khanka, and also its gulfs and a coastal strip of water area. In the territory there are 619 kinds of vascular plants, including 49 rare and disappearing kinds (lotus Komarova, evriala frightening, brazeniy Shrebera, etc.) grow and also 523 kinds of seaweed. 334 kinds of birds are registered. In the territory of Russia there is no other site comparable on the sizes where a plenty of kinds of the birds included in the Red data book of Russia – 44 kinds, 11 kinds from them are nesting (including a Far East stork, Japanese and cranes Daurskiy, reed sutora, blacken Bera, courser, etc.), which are absent on nesting in the other reserves of the Far East.

CONCLUSION

So low-density population, light anthropogenic impact on environment brunching river system, mountainous relief and full-flowing to specify favorable environment condition in the Russian Far East. The most density of population (14 people/km^2) and the most anthropogenic impact on environment among Far Eastern areas Primorskiy Region has.

Primorskiy Region area is boundary between the north boreal biota and the southern Manchurian biota where a unique relict species are represented there. Primorskyi Region is a glacial refugium and harbors plants and animals, including many Pleistocene and even tertiary relict species, found nowhere else in all of North Eastern Asia. The rivers of Primorskiy Region zigzag and have many old channels and canals that can merge into a single channel during high waters. Also it is necessary to note the significant tortuosity of the river channel and the thresholds in middle stream sector. Mud sedimentation in the riverbeds causes various hydraulic connections between surfaces and underground waters. The main feature of the stream conditions of all rivers in Primorski Krai is high waters caused by abundant atmospheric precipitates. Summer storm high waters are often accompanied by sudden water rise even flood. Bases on hydrological features of Primorskiy Region rivers is possible to conclude that the region's rivers have low level of anthropogenic impact resistant. There are probably developments of deep and lateral channel erosion and sea water intrusions in the region's rivers either. Among the large lakes in the Primorskiy region we should mark only the lake Hanka.

Fast-going economic development, increasing artificial use in length of coastal line, and intensive agro-industrial drainage of local communities on ancient sea terraces will promote the increase of seawater intrusion into coastal underground water horizons. In the case of the river mouth area, the marine-influenced salty river water would increase the salinization of the groundwater even a small inflow. Hydrological features Primorskiy Region Rivers that promotes the intrusion of salty waters are following: fast rise of the river water level and sharp recession of flood in typhoon events; small depth of the river (especially in the river mouth region) and big width of the mouth region especially in flood event; the small river flow; mud sedimentation and accumulation on river beds.

Many theoretical and experimental researches on this subject have been conducted. Use of available theoretical development in subject of sea water's intrusion into coastal fresh waters is not always applicable to conditions of Primorskiy's rivers and frequently results in overestimate of speed and lengths of salty water-invaded zone penetration into fresh water horizons in some times. It causes necessity of revision of theoretical bases of dynamics sea water's intrusion in view of regional hydrological features.

Generally the geological sections of Primorskiy river's basins are represented by well washed away sediments. Litological structures properties of such geological section are determining the intensive dynamic of channel erosion in Promorskiy Region. Rather stable the tectonically condition of the region in a combination gently sloping biases of the river channel causes the big tortuosity of the rivers that make for channel erosion of the rivers. Often and long time floods at which speed of water current increase, very slight down gradient of the river channels will promotes development of lateral erosion.

The advantageous geographical position and great natural resources are the main conditions of the region's economy development. About 30% of the Far-East social-economical potential is concentrated in Primorskiy Region. The ecological condition of the superficial water objects in the territory of Primorskiy Region is characterized by a class of quality from polluted up to dirty. Construction of moorings, dams and other port constructions across a coastal line of the sea have led to offshore abrasion and subject to seawater intrusion into fresh surface and ground water. The device of water-fences, development of coastal slopes, clearing the river beds for navigation rendered essential influence on change of the hydrological parameters of the rivers and accordingly on their erosive activity. The hydro chemical condition of the waters of the surface water objects are appointed by many factors as types of water object; types of water use; availability of the cleaning constructions and their working effectiveness on the enterprises, quantity and quality of the foul waters, thrown in to the water objects.

Some state natural reserves were created for preservation of unique natural complexes in Primorskiy region and for improvement of the environment.

One of the most important and famous state natural reserve is “Hanka Lake”.

Hydrological, hydrogeological features of Primorskiy Region’s rivers, present environment condition of the region, availability of numerous natural reserves should be to take into account in further economical development of the Primorskiy Region.

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Study Report: Pollution from Capital Urbanization to the Nhue River: Proposed Solutions

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1. The Nhue River and site description

1.1. The Nhue-To Lich river basins

The Nhue River, as a branch of the Red river, takes its source from the Red River at the Thuy Phuong Gate (N1) to the north west of Ha Noi (Figure 1). Like other rivers running in the northern delta of Viet Nam, the Nhue River flows south and southeast throughout its course without abrupt redirection or disruption. At several portions, its course was straightly rebuilt during French colonization for irrigation and waterway transportation. The river basin is bordered by the Red river to the north and the east, the Day River to the west, the Chau Giang River to the south. To the west, the Day River almost runs parallel with the Nhue River at the distance of 10 km. To the south, the Nhue River joins the Chau Giang River at the Luong Co gate, 72 km from its source. To the east, the Nhue basin is actually limited by the national highway number 1 and this highway also runs parallel with the river. The distance between river and the high way varies between 5 and 10 km. The basin elevation is gradually reduced from 9 m north to 1 m south. The area under 3 m elevation, called the low land area, accounts for 49.6% of total basin. In general, the basin topography is high in the north and low in the south with highest areas near the Day and Red Rivers and lowest near the Nhue at the center (Ngo Ngoc Cat, 2001).

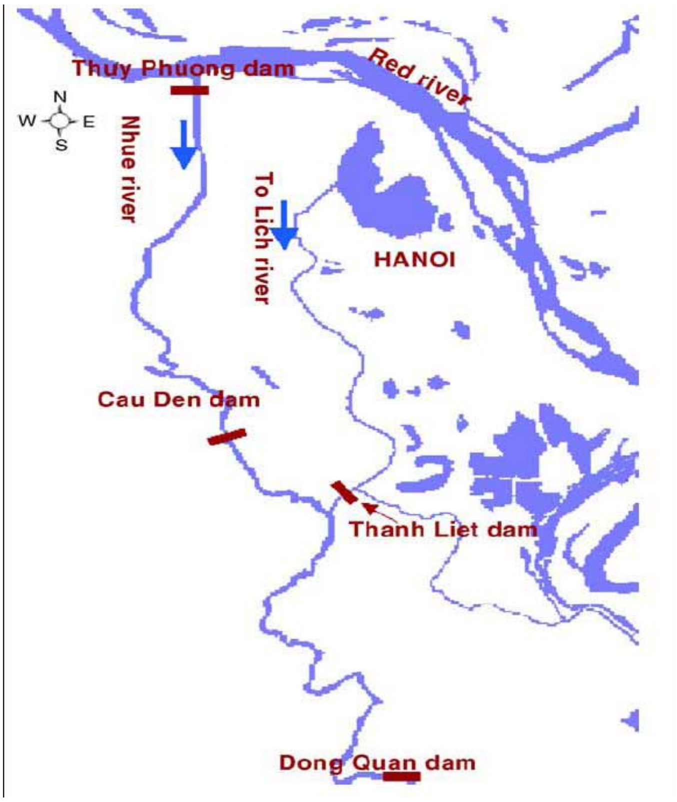

Figure 1: Map of the Nhue River

The river has also several significant inflows such as La Khe, To Lich, and Van Dinh. Of which La Khe, Van Dinh are outward canals while the To Lich River, a tributary of the Nhue River, is reportedly responsible for 77.5 (km2) portion of Ha Noi area. The La Khe and Van Dinh Canals connect the Nhue River to the Day River at distances of 15 and 40 km calculated from the Nhue River source, respectively and they were built and canalized for irrigation and drainage of the surrounding paddy fields. In order to prevent flood and to ensure irrigation during crop season, the discharge in the river system is entirely regulated by dams/sluice gates (Table 1).

Table 1: Technical configuration of dams in the Nhue River system; designed configuration but have been upgraded several times to cope with new situations

No	Name	Distance from junction with the Red river (km)	Bottom elevation (m)	Designed capacity (m^3/s)	Function
1	Thuy Phuong	0.12	+1.00	20.15	Inflow
2	La Khe	6.73	+0.40	20.00	Outflow
3	Cau Den	15.90	-0.81	30.00	Control
4	Dong Quan	43.75	-2.23	50.00	Control
5	Van Dinh	11.79	-0.55	20.00	Outflow

The irrigation water is supplied from the Red river through the Thuy Phuong dam. Water level at the Thuy Phuong Dam in dry season corresponding to frequency of 75% is 3.16 m and 3.77 m for low and high irrigation, respectively. The consultant conditions for irrigation of winter/spring crops are shown in Table 2.

Table 2: Hydraulic conditions for regulating the dam during Winter/spring crop (Ngo Ngoc Cat, 2001)

Gate	At the start irrigation			At the end irrigation		
	Operation	Up (m)	Down (m)	Operation	Up (m)	Down (m)
Thuy Phuong	Open	3.72	4.00	Close		
La Khe	Close			Open	2.40	2.50
Ha Dong	Regulating	3.56	3.54	Open		2.40
Dong Quan	Regulating	3.40	3.56	Open		1.66

All along its course, the river basin presents a netted canalization system in charge of irrigation for villages and paddy fields. It is observed that irrigation canals spread all over the river basin and hook up to the Nhue every 2 or 3 km. The area is located on flat terrain on a river delta with elevation ranging about 4 m above sea level. Drainage is very difficult as there are many lowland areas. The elevation of the urban area is particularly low compared to the Red River water level. As a consequence, Ha Noi area is regularly threatened by inundation despite having the most complex and enduring banking system.

As centered in the Red River delta, the Nhue River basin inherits a fairly flat topology thanks to some quaternary alluvial sediment deposited over 120000 years. The total height of the sediment layers can be up to few hundred meters. This very thick layer of alluvial deposits gives Ha Noi area a natural richness in ground waters. According to the recent surveys, 90% people in suburban area exploit groundwater for their domestic use. It is generally said that the aquifer near the ground in the urban area is polluted but with the wells drilled to the depth of 24-31 m, the water is safe and consumable without prior treatment.

The general meteorology relevant for the study area is observed at the Lang meteorological station in the center of Ha Noi (105°48’E, 21°01’N), about 5 km northeast from the Nhue-To Lich confluence, and the Ha Dong Station (105°46’E, 21°58’N), 15 km south from the upstream point. In fact, the climate of the Ha Noi region is typical monsoon. The monthly average temperature recorded at the two meteorological station mentioned above for two consecutive years (2001 and

2002) increases from 15°C in winter (December to January) to 30°C in summer (June to July). The average annual rainfall for years 2001 and 2002 in the area is about 1800-2200 mm, 80% of which occurs during the rainy season from May to October. The rainfall of July, August and September accounts for 60% of total annual rainfall. In dry season from November to February, rainfall is only 8% of the total annual. Monthly evaporation varies from 60 mm to 100 mm throughout the year, while the mean monthly temperature fluctuates between 16°C and 28°C. Evaporation reaches maximum in July as the summer temperature is maximum. Over the whole year, the monthly average solar hours increases sharply from April or May due to monsoon and decrease gradually from October to December due to movement of the earth. The solar hours stay high till October.

According to JICA (1995), the To Lich river basin accounts for 7,750 ha and includes 7 urban districts and parts of suburban districts – Tu Liem and Thanh Tri. About 3500 ha or 45 % of the total area is used for residential purposes, which reflects the rapid urbanization of the Ha Noi urban and suburban area (figure 2). It must be noted that at the year 2002 and 2003, this percentage reaches over one half of the total area. The ancient city area, government offices and public area occupy about 9% of the total area, while industrial area accounts for only 5%. About 26% of the total basin is occupied by lakes, ponds and water canals. Agricultural area is only 13% (JICA, 1995).

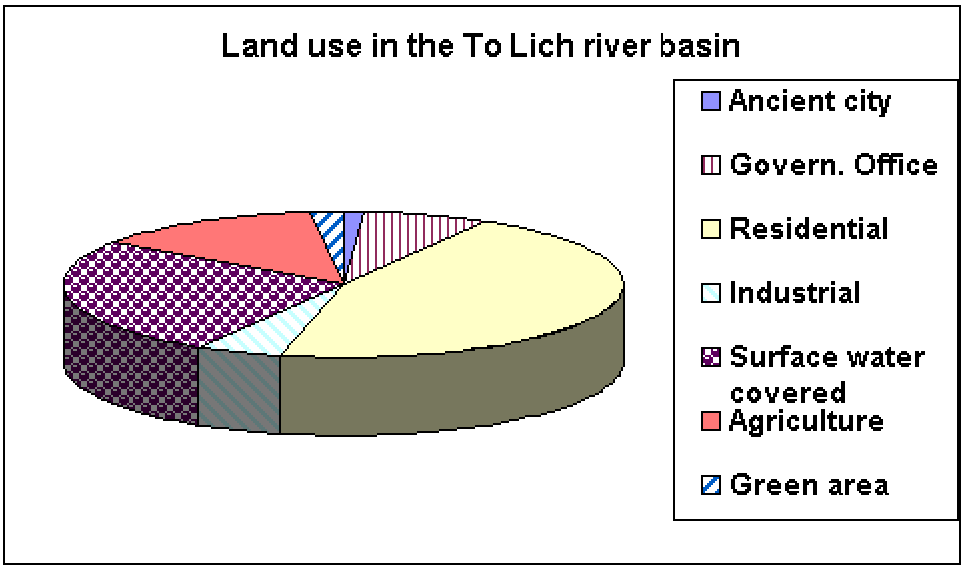

Figure 2: Pie chart of land use in the To Lich river basin

Assuming that impermeable area of the river basin includes all artificial construction areas, 58.6% of the To Lich area is impermeable. The rest 41.4% including surface water coverage and natural landscape area is permeable. Majority, the soil in the Nhue basin consists of mud/sand in the areas close to the Day and Red Rivers, and mud or mud/clay in the areas around the Nhue River. This is favorable for agricultural production with rice, potatoes, sweet potatoes, and vegeTables. Total agricultural area in the basin is 81,790 ha. The Nhue River basin with its fertilized soil is considered as an inter-province hydro-agriculture system with different industrial and agricultural zones. The Nhue hydro-agriculture system is responsible for activate irrigation of 81,710 ha in normal condition and inundation relief of 107,530 ha with designed frequency of 10%, particularly 10 l/s/ha of Ha Noi.

1.2. Environmental state of the Nhue River and its tributaries

It is very clear that inadequate drainage system which relies mainly on the transport capability of natural waterways running inside the city is causing great risk to the To Lich and Nhue Rivers' water.

Figure 3: Solid waste and fresh excreta released to the To Lich River

Domestic and industrial wastewater from Ha Noi mainly discharges to the To Lich River without prior treatment and the river is effectively the principal open-air-sewer of the city. The Nhue River, as a branch of the Red River, takes its source from the Red River about 11 km to the north west of Ha Noi and is joined with the To Lich some 20 km downstream of Ha Noi. The mean in-flow to the Nhue River from the Red River is 26 m^3/s and it typically receives around 5.8 m^3/s of untreated wastewater from the To Lich River. In the course of the present report, water discharge flowing from the To Lich River to the Nhue River was recorded as having doubled, from 5.8 m^3/s in 2002 to 11.0 m^3/s in 2006. This discharge has increased with the urbanization development of Ha Noi.

In detail, in the Ha Noi's suburb rivers and channels, water quality does not meet the Vietnamese standards (TCVN) for surface water (TCVN 5942-1995, type B). Typically, at some places water quality even does not meet the standards for domestic wastewater (TCVN 6772-2000, level IV). In dry period, the quality deteriorates even further. The monitoring results conducted in late 2005 show that the DO value was very low; the COD content exceeded permitted level by 7-8 times; the BOD5 content - 7 times (figure 4); the coliform concentration was higher than the TCVN 5942-1995 (type B) standard. Another infrastructural problem for the city is that rain water and wastewater share the same pipelines and flow to the surrounding waterways by gravity. This water mixture then outflows to the To Lich which ultimately discharges to the Nhue River through the Thanh Liet Dam. Recently as the Yen So Regulation Lake has been operated, this lake receives regularly a significant part of the To Lich River's water which then pumps to the Red River after some preliminary/simple treatment. This lake operates mainly in the dry season as in rainy season water from the To Lich River must be discharged to the Nhue River for the security reason which bring most pollutants to the Nhue River without treatment or partly diversion.

Because of the To Lich River's water, the Nhue River is severely polluted after the confluence between the two rivers. Although the upstream of the confluence is less impacted, water quality of the river section from the Ha Dong Town to the confluence point is increasingly deteriorated due to the increase of urbanization and industrial development. BOD5 and COD exceeded the standards (TCVN 5942-1995) by 3-4 times. Water downstream the confluence is totally polluted with quality characterized of untreated sewage. It could only be ameliorated in heavily rainy periods. In addition, as the irrigation role of the Nhue River to the upstream watershed is reduced (this area has been fast urbanized over the last several years), the Thuy Phuong Dam which regulates water flow from the Red River to the Nhue River is usually closed leading to the low water volume regulated upstream and concentrating polluted water throughout water course. In rainy season, although The Nhue River receives supplement rain water, the typical pollution indicators such as BOD5, COD, nutrients, and coliforms are still higher than the TCVN 5942 - 995 (type B) standards. From the confluence with To Lich River downstream, water quality is slightly and gradually improved due to the self – purifying process though it is still higher than the TCVN 5942 - 1995 (type B) standards. Although in the dry season, water from the To Lich River has been partly diverted to the Yen So Regulation Lake and the Red River, the pollution level in The Nhue River still worsens every year due to fast urbanization and economic development (Figure 6).

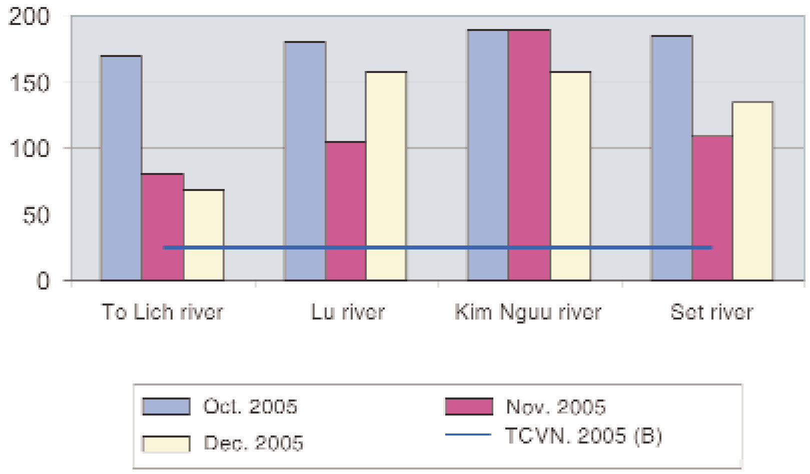

Figure 4: BOD5 content in some rivers in the inner part of Ha Noi (VEPA, 2005)

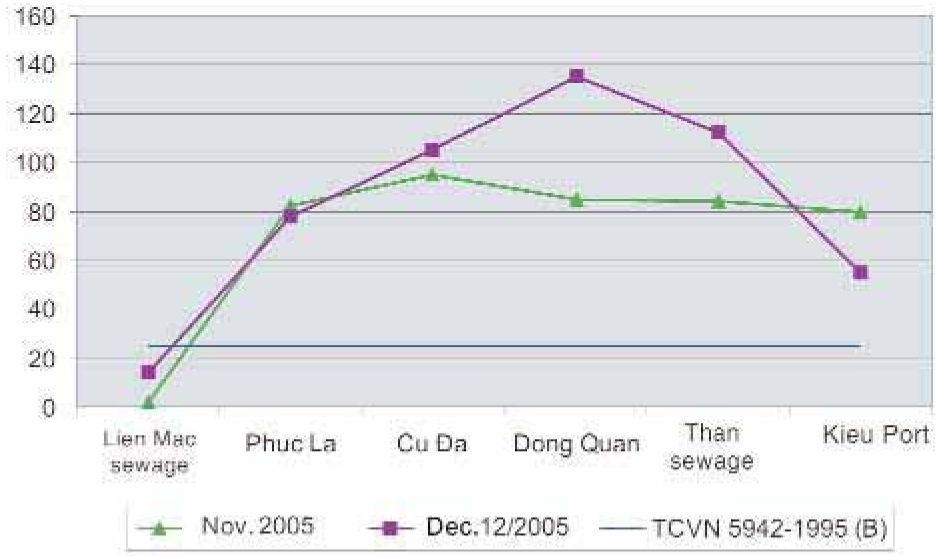

Figure 5: BOD5 trends in the Nhue River (in some pollution-peak times of 2005) (VEPA, 2005)

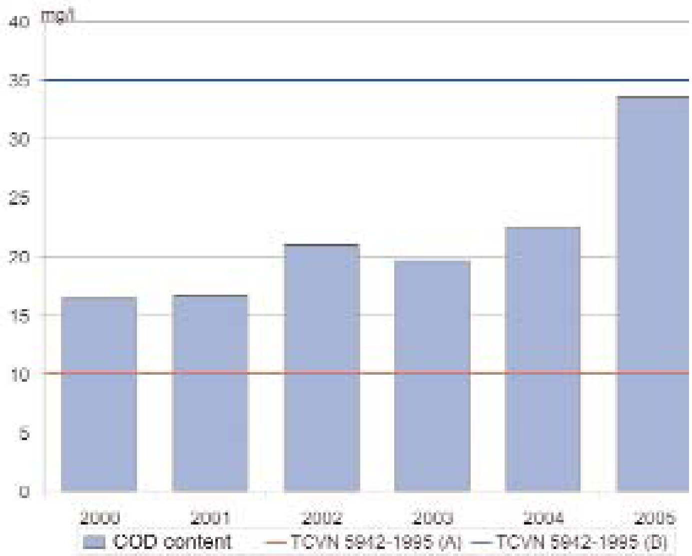

Figure 6: COD trends (annual average content) over several years at Nhat Tuu, Ha Nam (Ha Nam DONRE, 2006)

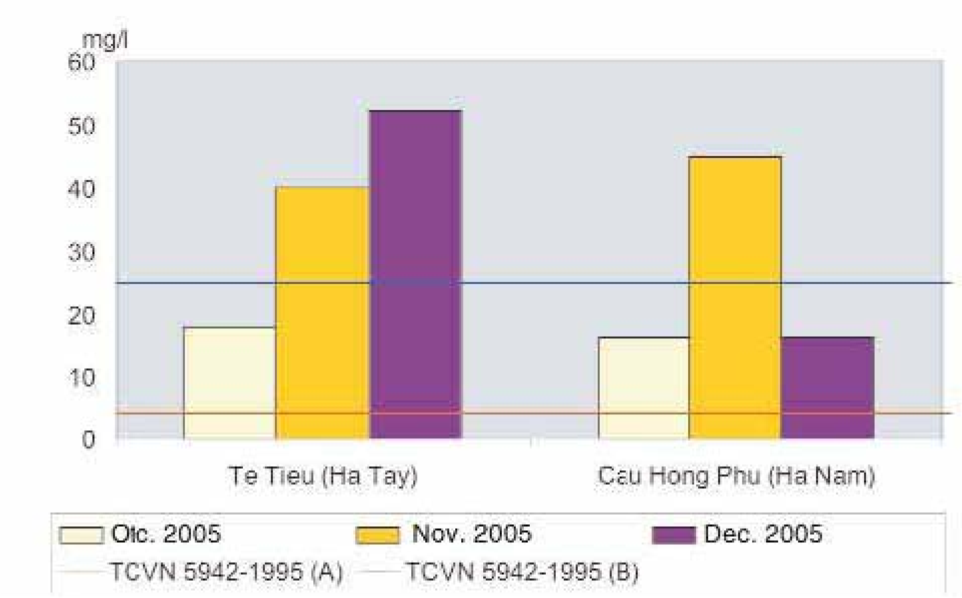

Figure 7: BOD5 trends at Te Tieu and Hong Phu bridge (the confluence of Nhue, Day and Chau Giang rivers) (VEPA, 2005)

2. Sources of pollution discharged to the Nhue River

The pollution sources in the Nhue River basin come from various activities of human which are categorized as domestic waste, hospital waste, industrial waste, agricultural waste, and craft village waste. Of which, domestic waste contributes most with more than 50% in volume (Figure 8).

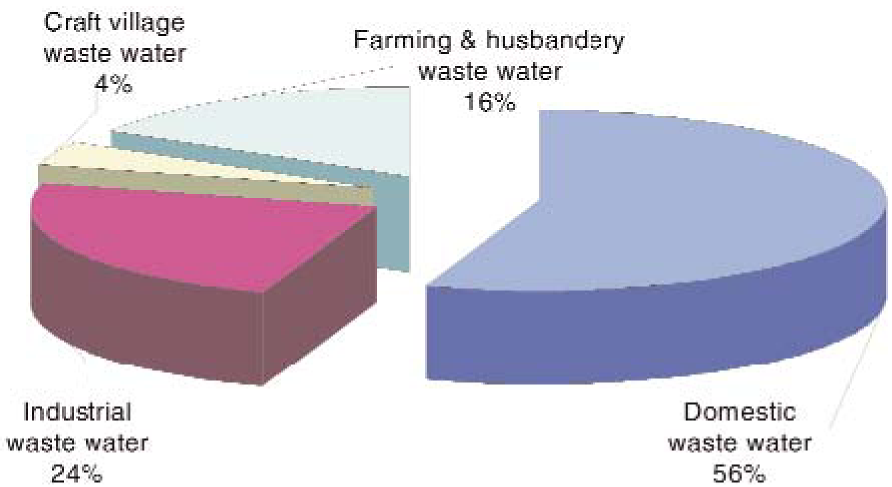

Figure 8: The percentage of waste sources per waste volume in the Nhue river basin (VEPA, 2006)

2.1. Domestic wastewater

Domestic wastewater in high volume and concentrated organic matter has made the water quality of the Nhue River severely polluted. In fact, the Ha Noi downtown contributes 71% of the total domestic wastewater. With the high average population density and high population growth, the wastewater volume in the Nhue river basin is consequently increasing. The rapid urbanization, accompanied by the incompatibly developed urban technical infrastructure, has led to the increased pollution resulted from domestic wastewater. Most of the domestic wastewater is directly discharged to rivers, lakes in the basin without prior treatment and this is the most important cause for the increased water pollution of the Nhue River basin.

2.2. Hospital wastewater

Hospital wastewater is a categorized as hazardous and should be completely treated in proper manner before dumping. However to date most of medical establishments have no accepTable treatment systems for hospital wastewater. The wastewater is directly discharged to the receiving bodies and then to surface water sources of the river basin. At the moment, in the whole basin, there are more than 20000 patient beds (of which Ha Noi contributes 47%) in nearly 1400 medical establishments, with the average wastewater of 100000 m^3/day.

2.3. Industrial wastewater

Statistical data revealed that in the Nhue river basin there are nearly 4000 industrial facilities (of which Ha Noi contributed 67% of the total) (the General Statistic Directorate, 2005). These industrial facilities generate significant amount of waste (solid, liquid and airborne) which causes pollution and has great impacts on the environment of the Nhue river basin. This pollution is an important factor deteriorating the water quality in the region. Taking wastewater volume into account, Ha Noi generates the largest part, (about 180000 m^3/day, comprising 55% of the total). According to the recent surveyed results of more than 200 large scale production facilities contributing wastewater to the Nhue and partly the Day Rivers, the mechanical industry contributes up to 33% (Figure 9). Wastewater of different industries has different features and levels of impact on water quality. Wastewater from the mechanical industry contains oil and hardly settling suspended solids (SS) and wastewater from the food processing sector contains many organic matters. Wastewater from textile and dying industry consists of many environmentally damaging chemicals such as alkali, detergent, alumni, pine resin, and artificial coloring agents.

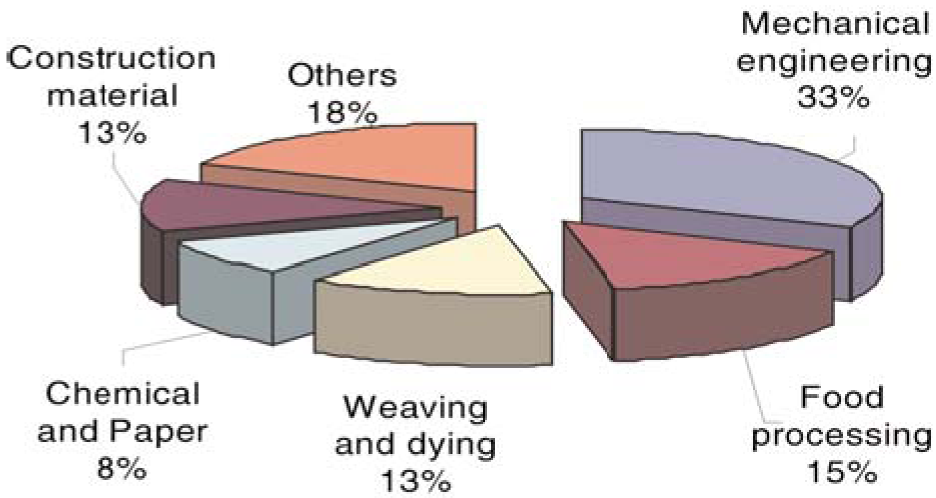

Figure 9: Production establishments per main waste generating industries in the Nhue River basin (Cu, 2005)

2.4. Agricultural production activities

As urbanization is getting the pace, number of households participating in agricultural production activities is shrinking along with the agricultural area. In fact, canal network in Nhue river basin once serve as a provincial irrigation system supplying water for agricultural production in the whole region. The flow regimes once regulated for agricultural purposes is now mostly served to drain the urbanized watershed. As the water regime is strictly controlled by the dams and sluice gates setup around the confluences of the outlets/inlets, the operation of this water flow regulation system has strong influence on the water quality of the basin. Livestock rise is an important fraction of total agricultural production in the basin as it is encouraged to serve the dense population in the area. The number of livestock is steadily increasing. The increasing livestock number correspondingly leads to the increase of wastewater volume. Regrettably, to date, even the large husbandry facilities in the area have limited treatment system. Therefore, most of the waste, especially wastewater, is discharged to the surrounding surface waters, which ultimately contaminates the Nhue River.

2.5. Wastewater from craft villages

According to statistics of the relevant provincial departments of Natural Resources and Environment, there are approximately 400 craft villages in the whole basin and they also contribute to the deterioration of water quality of the river. Production activities of the craft villages generate about 45000 m3/day of wastewater. Most of the small production establishments in craft villages are developed spontaneously to meet the market demands. They are characterized by simple equipment, outdated technologies, small workplaces and limited investment in wastewater treatment facilities. The wastewater from these craft villages is usually discharged to receiving sources without prior treatment. This leads to severe pollution of the surface water sources. Some investments have been made in building central wastewater treatment facilities for numerous villages though the effectiveness is insignificant. The surface water pollution caused by production activities of craft villages in Nhue river basin has become relatively severe with different characteristics featuring different types of manufactures. Of the craft villages active in the river basin, agricultural food processing villages are among the biggest wastewater generators, causing huge impacts to the surface water environment of the basin. In most of the craft villages in the basin the water quality parameters have totally exceeded permitted standards. Though the contamination is high locally, total contribution of the wastewater from craft villages comprises only 4% of wastewater of the whole basin.

2.6. Solid waste

Solid waste is one of the polluting sources of the surface water in the basin. Along with the economic development, urbanization, and population growth, total amount of solid waste in the basin has been continuously increasing (especially in urban areas). Of the total amount of solid waste, domestic waste comprises 80% and the rest is waste from industrial production establishments. Although they are small in amount, industrial and hospital wastes are hazardous and harmful to the environment and human health unless proper treatment procedures are in place. The average waste collection rate is rather low. In rural area, the collection rate in very low (averaging at 20%). In big cities the collection rate of domestic solid waste is higher. Solid waste is dumped in an indiscriminate manner with some is piled on banks of water ways, resulting in pollution of the surface water in the basin. On the other hand, floods produce a flushing effect on streets and channels, carrying away dust sediments, and solid waste upstream of the Nhue River, this cause damage to living condition and human health. The collection and transportation of urban and industrial solid waste has not yet met requirements. Except for Nam Son Landfill site of Ha Noi, other landfill sites in Nhue river basin are using outdated burying technologies leading to surface and ground water pollution in the basin.

3. Review of simulation and forecasts of pollution by modeling

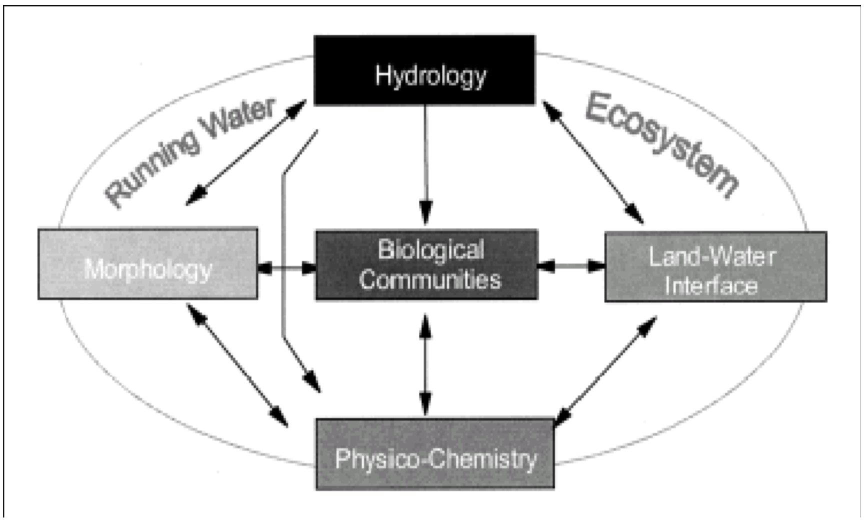

Figure 10: Structure of running water ecosystem (Shanahan, 2001)

As illustrated in Figure 10, an all-round conceptual model of running water ecosystems consists of abiotic and biotic elements linked within a hydrological continuum. Processes within and between elements are complex and can be described by a series of physicochemical, hydro-morphological, and biological parameters. The abiotic and biotic structures of running waters are characterized by longitudinal, vertical, lateral, and temporal gradients.

3.1. Mass transport in river water

Water quality changes in rivers due to physical transport and mixing processes (such as advection and diffusion/dispersion, the description of which requires one way or another the application of a hydraulic model as an input) and biological, chemical, biochemical, and physical conversion processes. The above processes in the water phase are governed by a set of well-known extended transport equations (see e.g. Somlyódy and van Straten, 1986).

$$\frac{\partial c}{\partial t} = -u\frac{\partial c}{\partial x} - v\frac{\partial c}{\partial y} - w\frac{\partial c}{\partial z} + \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial c}{\partial y}\right)\frac{\partial}{\partial z}\left(\varepsilon z \frac{\partial c}{\partial z}\right) + r(c,p) \qquad (1)$$

where c - n-dimensional mass concentration vector for the n state variables;
t - time; x, y, and z - spatial coordinates;
u, v, and w - corresponding velocity components;
εx, εy, and εz - turbulent diffusion coefficients for the directions x, y and z, respectively;
r - n-dimensional vector of rates of change of state variables due to biological, chemical, and other conversion processes as a function of concentrations, c, and model parameters, p (subject to calibration).

Equation 1 offers not only the basic governing equation of water quality models, but it also specifies a useful framework and the main model elements. These are the following: The hydrodynamic model for deriving velocity components u, v, and w, and turbulent diffusion coefficients εx, εy, and εz; The transport (or advection-diffusion) equation (describing the behavior of so-called conservative substances) and its solution; The conversion process, r(c,p). It has much less solid theoretical grounds than hydrodynamics and, thus, for its development an adequate combination of theoretical and empirical knowledge is needed. For the latter purpose, methodologies such as calibration, validation, identification, sensitivity, and uncertainty analyses are required (Beck, 1987) which aid model selection and testing. The model that is fully designed on the basis of the above steps and elements may require a powerful computer and variety of supporting software (and hardware) (Rauch, 1998).

3.2. Hydrodynamics and hydraulics

Flow of water in a river is described by the continuity and momentum equations. The latter is known as the Navier-Stokes or Reynolds equation. The actual form of a hydrodynamic model depends on assumptions made on characterizing turbulence. Methods vary from the use of eddy viscosity as known parameters to the application of the so called k-ε theory (see Bedford et al., 1988 or Rodi, 1993 for an overview of the state of the art of turbulence models). Complex models are available (see e.g. Abbott, 1979; Naot and Rodi, 1982) but for water quality purposes mostly the well-known, cross-sectionally integrated (1D) Saint Venant equations or approximations to these equations are used (see e.g. Mahmood and Yevjevich, 1975; Abbott, 1979).

Many different forms and approximations to the St. Venant equations are known, depending upon whether the flow is steady or unsteady and which simplifications are made. Thus, for water quality studies often the equation of steady, gradually variable flow is employed (which may be further simplified to the so-called Manning equation). Unsteady models include the kinematic, diffusive, and dynamic wave approaches, all based on the continuity and momentum equations. The difference stems from simplifications of the latter: dynamic wave models solve the full equation, diffusive ones exclude the acceleration terms, while kinematic ones disregard also the pressure gradient term that is essential for the description of backwater effects.

The hydrodynamic equations are generally solved by efficient finite difference methods (see e.g. Mahmood and Yevjevich, 1975). For water quality issues the acceleration terms in the momentum equation rarely play a significant role and the typical time scales are amplified by conversion processes. For these reasons, the diffusive wave approach is often a satisfactory approximation.

Before the introduction to the employed computer program, the selection objective is deliberated. Initially, it should be mentioned that there are numerous computer programs dealing with quality of running water bodies. In principal, they resolve simultaneously the transport equation and the conversion processes. However, the above discussion has raised 3 problems to be solved for one computer program: (1) its flexibility in model construction, (2) its capability in performing sensitivity analysis and (3) its function of performing parameter estimation. Usually, a computer program is objectively built to resolve only the first problem; the model construction. The latter problems are more or less mistreated or ignored. So, it is preferable if three problems are resolved by a unique computer program (or a series of compatible programs).

3.3. Approach to river water quality modeling

River water quality models seek to describe the spatial and temporal changes of constituents of concern. Components or state variables have been gradually incorporated into models over the past seven decades following the evolution of water quality problems. Water quality models characterize among others oxygen household, nutrients and eutrophication, toxic materials, and so on. The complexity covers a broad range from the simple Streeter-Phelps model (Streeter and Phelps, 1925) with two state variables to QUAL2 and similar tools describing comprehensively O, N and P cycling with about ten state variables (Brown and Barnwell, 1987), to ecosystem models that may consider suspended solids, several classes of algae, zooplankton, invertebrates, plants, and fish (Boling et al., 1975). The model choice depends on many different factors such as the objectives of the analysis, as well as data and time availability. Among the objectives two broad categories are usually distinguished: understanding/research and management/practice. Stemming from our goals, the Task Group has limited its attention to only models handling the "traditional" constituents O, N, and P. Water quality changes in rivers due to physical transport and exchange processes (such as advection and diffusion/dispersion, the description of which requires one way or another the application of a hydraulic model as an input) and biological, chemical, biochemical, and physical conversion processes. The above processes in the water phase are governed by a set of well-known extended transport equations (see e.g. Somlyódy and van Straten, 1986).

3.4. Software and computer program

Other than the simplest approaches, all mathematical models for prediction of water quality in rivers require the use of a computer to be worked with. Due to the considerable effort needed to develop and implement a site-specific model, the use of existing computer programs is preferred whenever possible. The following classification only aims to give an overview of the most important computer programs and is by no means meant to be exhaustive. Relevant features for classification are the description of hydrodynamics and transport, model structure (important variables, processes and submodels), software structure (open/closed - meaning that the user can change the model structure), and systems analytic features supported by the program. Table 3 gives an overview of some important software products for river water quality modelling.

Table 3: Computer programs: 1 = QUAL2 (US EPA; Brown and Barnwell, 1987); 2 = WASP5 (US EPA; Ambrose et al. 1988); 3 = CE-QUAL-ICM (US Army Engineer Waterways Experiment Station; Cerco and Cole, 1995); 4 = HEC5Q (US Army Engineer Hydrologic Engineering Center, HEC 1986); 5 = MIKE11 (Danish ydraulic Institute; DHI 1992); 6 = ATV Model (ATV, Germany; ATV, 1996); 7 = Salmon-Q (HR Wallingford, UK; Wallingford Software 1994); 8 = DUFLOW (University of Wageningen, The Netherlands, Aalderink et al ., 1995); 9 = AQUASIM (EAWAG, Switzerland; Reichert, 1998); 10 = DESERT (IIASA; Ivanov et al., 1996).

	Program	1	2	3	4	5	6	7	8	9	10
Hydrodynamic	External input	Y	Y	N	N	Y	N	N	N	N	Y
	Simulated	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Control structure	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Transport	Advection	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Dispersion	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sediment	Quality model	N	Y	Y	N	Y	Y	N	N	Open structure	Y
Water quality	Temperature	Y	N	Y	Y	Y	Y	Y	Open structure		N
	Bacteria	N	N	Y	Y	Y	Y	Y			N
	DO-BOD	Y	Y	Y	Y	Y	Y	Y			Y
	Nitrogen	Y	Y	Y	Y	Y	Y	Y			Y
	Phosphorus	Y	Y	Y	Y	Y	Y	Y			Y
	Silicon	N	N	Y	N	Y	Y	Y			N
	Phytoplankton	Y	Y	Y	Y	Y	Y	Y			Y
	Zooplankton	N	N	Y	N	Y	Y	N			N
	Benthic algae	N	N	N	N	Y	Y	Y			N
System analysis	Parameter estimation	N								Y	Y
	Sensitivity analysis	Y								Y	Y

4. Proposed solutions

4.1 Legal acts

4.1.1 Development and improvement of legal regulations, policies and institutions

− To revise the Law on Water Resources toward integrated management with clearer definition of responsibilities and coordination mechanisms between central and local authorities, among ministries, and among local governments of related provinces;

− To promulgate a Decree on integrated management of river basin, which shall address the duplication in the functions of state management on water resources (belonging to Ministry of Natural Resource and Environment-MONRE) and the state management of river basins of Ministry of Agriculture and Rural Development (MARD) stated in the Decree No. 86/2004/ND-CP;

− To promulgate environmental protection mechanisms for the river basin with clear indication of environmental problems and provision of codes of conduct for relevant parties, including management agencies, businesses and local communities;

− To develop zoning plans of water resource exploitation and wastewater discharge systems for each sub-watershed. This will be the foundation for the issue of wastewater discharge permits based on the assessment of the self-purification capacity and specific standards of each sub-watershed in the basin.

4.1.2 Inspection and monitoring of law enforcement

− To concentrate on the enterprises that seriously pollute the environment as listed in Decision No. 64/2003/QD-TTg of the Prime Minister. To continue the investigation to identify sources of environmental pollution in river basin to be dealt with in accordance with Decision No. 64/2003/QD-TTg;

− To resolutely prevent the occurrence of new pollution sources. To ban new constructions which threaten to pollute the environment and generate environmental incidents. Depending on specific areas, investment in some production types that potentially pollute the environment should be limited;

- To carry out regular environmental inspection and investigation. To prescribe measures to enforce enterprises to implement self-monitoring programs and other regulations according to the Law on Environmental Protection 2005;
- To immediately design integrated measures on gradual reduction of pollution generated from urban domestic wastewater;
- To strengthen the water quality monitoring, focusing on monitoring and evaluating of the inorganic pollution level. To develop databases of river basin water environment to provide to, and share with, all relevant stakeholders at central and local levels.

4.1.3 Application of economic tools, scientific and technological solutions

- To revise and issue fees on wastewater discharge based on the principle "polluters pay";
- To carry out a comprehensive study on the hydraulic regimes of the waterways in the basin and propose technical solutions on changing environmental currents, supplementing water source and strengthening the self-purification capacity to protect the water environment of the river;
- To carry out a comprehensive assessment of the impacts of irrigation works and domestic activities in order to propose measures to prevent and reduce landslides and sedimentation and to recover river landscapes and eco-balance.

4.1.4 Capacity strengthening

- To issue clearer policies and mechanisms on the operation of staff performing environmental protection task with focus on the quality and quantity of staff and financial resources for effective operation of committees to ensure the benefit of all river basins;
- Local authorities should allocate resources for the environmental protection of river basin from the 1%- of annual-State- budget funds for environmental protection. The resources must be spent for appropriate purposes and in an effective manner;
- To create favorable conditions for enterprises to access loan sources from Viet Nam's Environmental Protection Fund as well as other financial sources;
- To diversify investment sources, increasing the share of official development assistance sources in the total investment in environmental protection;
- To mobilize financial sources from international organizations and other countries to invest in river basin environmental protection.

4.1.5 Public participation and responsibility

- To develop mechanisms to attract participation of all relevant stakeholders, including local communities in planning and the development of plans and in the implementation of measures to protect the river basin environment;
- To enhance active roles of communities in water sources management and utilization;
- To publicly disseminate through mass media information and data concerning the pollution status and pollution sources in the river basins.

4.1.6 International cooperation

- To develop cooperation mechanisms in preventing and addressing water environmental pollution in transboundary rivers;
- To expand international cooperation on regional river basin protection in forms of bilateral and multilateral programs and projects. To further strengthen the cooperation with international, governmental and non-governmental organizations in order to take advantage of international assistance in all forms as well as experience and techniques in river basin environmental protection.

4.1.7 Proposed explicit methods for the Nhue River Basin

- To concentrate on treatment of domestic wastewater, especially in Ha Noi capital; industrial wastewater in Ha Noi and Ha Nam; and wastewater from craft villages in Ha Noi and Ha Nam;
- To strictly control the seriously polluted areas in the river basin:

− To Lich river and lakes and rivers in the inner part of Ha Noi;
− The section of The Nhue River from the Ha Dong town to Phu Ly, the Ha Nam province.
− To accelerated the development of the Master Scheme on the environmental protection of the Nhue river basin to submit to the Government for approval;
− To limit the number of investment permits for 5 industrial types that threaten to generate serious pollution of the environment, including: cassava starch processing, basic chemicals production, dying, leather tanning and paper pulp production;
− To coordinate the regulation of river water in the dry and flood seasons, to ensure the source of fresh water for domestic use, agricultural production, and flood drainage and the self-purification capacities of rivers in the basin;
− To zone some vegeTable safety areas, and warn people not to use polluted water sources for agricultural production.

4.2. Pollution forecast/simulation toward best management practices

Within the scope of this study, an established guidance/tool, the total maximum daily load (TMDL), is used to quantitatively evaluate several possible management alternatives. In principle, a TMDL is the sum of the individual waste load allocations (WLA) for point sources and load allocations for non-point sources (LA) and natural background with a margin of safety, MOS (USEPA, 1999). It is described as TMDL =PWLA +PLA + MOS. Here, the PWLA is identified as wastewater impact from the To Lich River. The PLA is equal to total loadings of the Nhue's upstream input and lateral wastewater inflow along the Nhue to the confluence point. In this case study, the Margin of Safety is expressed as two causes: increase of population in the study area and the evapotranspiration and infiltration. The former was taken as 5% of the total discharge since the population increase was about 5% per year (Cu and Cham, 2006) and this calculation was derived the annual average. The latter was estimated as 2% of the total discharge based on the annual fluctuations of precipitation/evapotranspiration and water Table level in the area. Thus, since the calculation did not take into account these two factors, the MOS is totally taken as 7% of TMDL. Also based on the above analysis, the water quality parameters of major concern are BOD, DO, SS, NH4 and NO3. At average flow, the TMDL, the current PWLA, and the current PLA of the considered parameters were calculated and represented in Table 4. The results indicate that BOD, NH4, and partly DO have severely violated water quality regulation/consents.

The management method herein focuses on reducing the loadings of NH4 and BOD while maintain reasonable levels of SS and NO3 (DO is not necessarily considered because if the levels of NH4 and BOD are low, the level of DO will automatically be high). Most BOD and NH4 are derived from WLA (the To Lich River) and therefore management must focus on reduce the loadings from WLA. In this case study, the model was used to evaluate the applicability of management alternatives by calculating levels of parameters at defined position; 5 km downstream the impact zone. The idea behind the choice of 5 km point is to let the system stabilise after mixing of two different water masses (Trinh et al., 2006b; McAvoy et al., 2003). Since the loading five km downstream of the confluence has changed compared with it at the confluence due to biogeochemical activities (e.g. NH4 is oxidized and reduced or BOD reduces), the model is needed to precisely calculate this loading change at different management alternatives.

Three management alternatives practicable in this study site are proposed, the rationale for the analysis for the three approaches were as follows.

Treatment of the To Lich wastewater

A wastewater treatment plant (WWTP) was constructed at the Thanh Liet dam to treat the wastewater of the To Lich River's water before rejecting to the The Nhue River. One factor needs to be established for this management alternative is the change in amounts of materials and micro-organisms before and after treatment by WWTP (treatment efficiency). Such a change is evaluated as the content ratios between treated and untreated wastewater and shown in Table 5 – the ratios were manipulated from the study of Servais et al. (1999). Moreover, because sewer system in Ha Noi collected both wastewater and rainwater, the scenario was assessed under dry and rainy conditions. For the dry period, the treatment volume was set up as 90% of the total water input. Correspondingly, during the rainy period treatment volume was taken as 50% of the total river water input. To Lich discharges were set as 5.82 and 15 m^3/s in dry and rainy conditions, respectively. The seasonal variation is not considered here because in this river portion, hydrology is strictly regulated by human and therefore barely dependent from hydrology of the watershed as a whole.

Reduce the discharge of the To Lich water

Based on the calculation of current load allocations and water quality standards (Table 4), the discharge reduction by one third was selected for calculation since it would apparently reduce NH4 closely to the allowable loadings.

Increase the upstream discharge of the Nhue River (polluted water flushing)

For this alternative, the upstream discharge was set at of 50 (m^3/s) – this value is the maximum possible discharge not causing flooding in the watershed. The increase of discharge dilutes the pollutant contents to meet standards. Because the water discharges applied for these management alternatives are different, the simulation results are shown in concentration units instead of loading for an easy comparison (Table 6). The results of this exercise indicate that the first and second methods would lead to similar outcomes since most parameters met the standards. For the third alternative, the two parameters NH4 and SS did not meet the standards. Therefore, load allocations were computed for the first two management alternatives (three scenarios) and represented in Table 7. For the treatment in dry period, the WLA of NH4 and BOD were equal to only one third and a half of the present WLA, respectively. For the other two scenarios, after the loadings were normalised by discharge for comparing with present average flow condition, the WLA of NH4 and BOD of these two scenarios were equal or less than a half of the present WLA. Therefore, in order to meet the water quality standards, the point source loadings of the pollutants BOD and NH4 should be diminished by at least twice of the current loadings, respectively.

Table 4: The Total Maximum Daily Load (TMDL), the current Wastewater Load Allocation (ΣWLA), and the current Load Allocation (ΣLA)

Environmental parameters	Surface water standards for purposes other than domestic water supply (mg /l)	TMDL (ton/d)	Current LA	Current WLA
BOD	< 30	70.1	64.2	62.8
DO	> 2	5.6	14.9	0.7
SS	< 80	224.2	156.0	38.0
NH4+ (as N)	< 1.5	4.2	1.7	6.3
NO3-(as N)	< 3.4	9.5	1.6	0.2

Bold: Current loads do not meet the Vietnamese standards for surface water

Table 5: Fractions of contents of nutrients, organic matter and organisms between treated and untreated wastewater employed in the treatment scenario

No	Variable	Ratio	No	Variable	Ratio
1	Phytoplankton	1.00	7	Nitrifying bacteria	0.65
2	Dissolved degradable organic matter	0.30	8	NH4	0.53
3	Particulate degradable organic matter	0.09	9	NO3	33.90
4	Inert particulate organic matter	0.19	10	PO4	0.99
5	Inert dissolved organic matter	0.94	11	pH	1.00
6	Heterotrophic bacteria	0.13	12	DO	1

Table 6: Water quality indicators at different management alternatives simulated by the ecological model

Parameters	Unit	Sim. Treated of TL water dry	Sim. Treated of TL water rainy	Reduce TL disch.	Ups. Disch. 50 m^3/s
BOD5	mg/l	30.6	25.2	33.8	30.4
DO	mg/l	6.1	4.9	5.7	6.0
SS	mg/l	59.7	62.4	58.2	96.7
NH4+ (as N)	mg/l	1.4	1.4	1.4	1.6
NO3-(as N)	mg/l	2.9	1.2	0.7	0.7

Bold: The indicators do not meet the Vietnamese standards for surface water

Table 7: Allocations of loadings at accepTable management alternatives for two parameters NH4 and BOD; MOS is taken implicitly as 7% of TMDL

	Treated in dry period		Treated in rainy period		Decrease To Lich's flow	
	BOD	NH4	BOD	NH4	BOD	NH4
TMDL(ton/d)	85.8	3.8	90.5	5.0	83.4	3.4
LA (ton/d)	49.8	1.2	44.2	0.5	58.8	1.4
WLA (ton/d)	30.0	2.4	39.9	4.2	18.8	1.8

5. CONCLUSION

With the help of the modelling tool, the pollutant load reduction requirements were determined according to the TMDLs and allocated to each parameter. The requirements show that the current environmental state failed to meet the TMDL goals for BOD, DO, and NH4. From this evaluation, the followings were concluded and recommended to satisfy/achieve the TMDLs from the current environmental state:

1. The existing runoff and flow regime of the Nhue River can no longer cope with the untreated domestic wastewater loads of more than 3 million people in Ha Noi city today.
2. The organic matter in the To Lich's wastewater need to be minimised and a WWTP for To Lich water treatment is highly recommended.
3. If recommendations 1 and 2 are not used, two third of the current To Lich water discharge should be diverted to other water bodies, for instance the Red River, in order to stop pollution in the Nhue water. This diversion would not alter the environmental state of the Red River because the very high discharge in the Red River (average 3577 m^3/s; Quynh et al., 2005) would greatly dilute To Lich domestic wastewater.

This evaluation implies that the management alternatives should be proposed and evaluated based on the water quality criteria, practical aspects, and a calibrated model which then identify the Best Management Practice (BMPs) among possible alternatives, allowing the TMDL program to be complemented more effectively.

It is concluded that there are straight-forward means of alleviating the problem and that this is shown by a combination of measurement (with hydrochemical interpretation such as end-member mixing analysis), laboratory experimentation of rates of change in pollution with contaminated sediment loading and modelling.

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The Eutrophication of Reservoirs in Chinese Taipei and Water Pollution Control for the Sun Moon Lake

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Introduction

Although the average annual rainfall in Chinese Taipei (CT) (2500 mm/yr) is approximately 2.5 times that of the global average, the precipitation index per capita per year is one-sixth lower than that of the world average because of a heavy population density. Natural factors that make water management in CT difficult include steep river slopes, fragile topsoil in watersheds, and significantly uneven temporal and spatial distribution of precipitation. According to hydrological statistics[1], the rainfall from May to October accounts for 78% of the total annual precipitation. The precipitation from November to April, which is the so-called dry season, accounts for 22% only. In southern Chinese Taipei, the rainfall during the wet season is as high as 90% of the total annual precipitation. Such an uneven rainfall distribution pattern creates difficulties in efforts to utilize water resources.

The total annual average given volume of water resources (annual average precipitation minus evaporation volume) in CT is 71.4 billion cubic meters, of which 21% (18.9 billion cubic meters) is consumed and the remaining 73% flows directly into the sea. Water for consumption is derived mainly from rivers, which supply 9.0 billion cubic meters, and from ground water and reservoirs, which provide 6.3 and 3.6 billion cubic meters, respectively. Since population and economic activity are mostly concentrated in the northern and southern ends of western CT, water shortages occur in these areas when the supply cannot meet the demand. During the dry season, nearly all of the water in the rivers is utilized, and the rivers in the southwest are almost dry except during the typhoon season. Thus, the construction of reservoirs along river systems has long been considered an important approach to fulfill the demands of fresh water supply.

Storage Capacity and Siltation

In CT, the original capacity of all forty reservoirs is 2.736 billion cubic meters[2], and 44.12% of the total capacity is in southern Chinese Taipei (Table 1). In 1997, the total capacity of all forty reservoirs decreased to 2.294 billion cubic meters. The average annual decrease in capacity is 15.04 million cubic meters due to siltation. With regards to useful capacity, the original useful capacity is 2.324 billion cubic meters. In 2008, the useful capacity was reduced to 2.014 billion cubic meters. The average useful capacity decreases annually by 7.69 million cubic meters.

Table 1: Regional reservoir capacity. Units:10^6 m^3

Regions	Total Capacity					Useful Capacity				
	Original capacity	%	1997	%	Average annual decrease in capacity	Original useful capacity	%	2008	%	Average annual decrease in capacity
Northern	738.84	27.01	660.12	29.03	3.05	632.52	27.22	563.82	27.99	2.37
Central	770.73	28.17	659.20	28.73	3.11	660.30	28.42	523.88	26.01	2.78
Southern	1,226.08	44.12	975.20	42.50	8.88	1,030.87	44.36	926.39	46.00	2.54
Total	2,735.65	100.00	2,294.52	100.00	15.04	2,323.69	100.00	2,014.09	100.00	7.69

Table 2: Sediment accumulation in ten major reservoirs.

Name	Drainage area (km^2)	Capacity (10^6 m^3)		Sediment (10^6 m^3)		Loss of storage (%)	Year of construction
		Original	2008	Total	Annual yield		
Feitsui	303.00	344.1	335.8	8.2	0.41	2.38	1987
Shiemen	763.40	251.9	209.0	42.9	1.00	17.03	1964
Liyutan*	53.45	126.0	116.0	10.0	0.67	7.94	1992
Teiki	592.00	182.0	155.9	26.1	0.77	14.34	1973
Wushe	219.00	146.0	55.3	90.7	1.85	62.12	1958
Sun Moon*	501.30	151.1	139.1	12.0	0.17	7.94	1934
Rernyihtan*	3.66	27.3	25.1	2.2	0.11	8.06	1986
Tzenwen	481.00	631.2	583.1	48.1	1.46	7.62	1973
Wushantou*	60.00	154.2	80.8	73.4	0.98	47.60	1930
Nanhua*	104.00	149.5	132.4	17.1	1.32	11.44	1994

*off-stream reservoirs

Table 2 shows the sediment accumulation in ten major reservoirs in CT. The annual scouring depth (annual sediment yield/drainage area) range from 0.15 cm to 0.84 cm. Because of high annual scouring depth problems, the Wushantou reservoir and the Wushe reservoir have lost storage capacity by 47.60% and 62.12%, respectively. The siltation problem is believed to result from CT's geography and climate. The steep mountain terrain, loose soil, intense storms, and earthquakes all contribute to a high potential of erosion and siltation. However, human activity in the watersheds has also been found to be very much responsible for erosion. Extensive highland farming, road construction, and community development destroy the vegetation cover of watershed areas. Excessive use of pesticides and fertilizers and the seasonal use of river banks or beds as cultivating grounds bring nutrients and other pollutants to the streams and reservoirs.

Trophic Status

Many reservoirs in CT have been found either to have eutrophication problems or are in danger of becoming eutrophic. Most of the reservoirs in CT are public water supply sources. Protecting the quality of these water bodies is very important to maintain a sufficient drinking water supply as well as to ensure continuing social and economic development. Lush vegetation, a high concentration of salts, and high turbidity are the defining characteristics of eutrophication. When reservoirs are polluted with large amounts of nitrogen and phosphorus, however, rapid growth of algae and eutrophication occur, thereby causing the water quality to deteriorate and increasing the cost of water treatment[3]. The trophic state index is often based on total phosphorus (TP) concentration, chlorophyll a (chl a) concentration, and Secchi disk depth (SD). Of these three factors, chl a plays the most important role, followed by TP.

In a single-variable index, a physicochemical parameter that is representative of these characteristics is chosen and its threshold value is set as the trophic standard. Application of this method often produces inconsistent results when different parameters are chosen. Since eutrophication involves complex changes in the water, the results obtained from using only one parameter may easily mislead or bias the user. For this reason, the multivariable trophic state indexing methods were developed. The most commonly used multivariable indices are the Carlson[4], Morihiri[5], and North Carolina[6] indices. The Environmental Protection Administration (EPA) of CT used the Carlson trophic state index to conduct an overall assessment of water quality in all reservoirs:

$$\mathrm{CTSI} = \frac{1}{3}\left[\mathrm{TSI(SD)} + \mathrm{TSI(TP)} + \mathrm{TSI(chl\,a)}\right] \quad (1)$$

$$\mathrm{TSI(SD)} = 60 - 14.41\ln(\mathrm{SD}) \quad (2)$$

$$\mathrm{TSI(TP)} = 14.42\ln(\mathrm{TP}) + 4.15 \quad (3)$$

$$\mathrm{TSI(chl\,a)} = 9.81\ln(\mathrm{chl\,a}) + 30.6 \quad (4)$$

where SD is the transparency measured by Secchi disk depth (m), TP is the total phosphorus concentration, and chl a is the chlorophyll a concentration. The status of the reservoir water is oligotrophic if CTSI is less than 40, is eutrophic if CTSI is greater than 50, and is mesotrophic if CTSI is between 40~50. Table 3 shows the investigation results of the Carlson trophic state index of 19 major reservoirs in Chinese Taipei. The water quality in the reservoirs of Feitsui, Teiki, Wushe and Sun Moon Lake fluctuated between oligotrophic and mesotrophic; that in the reservoirs of Paoshan and Mintei changed from mesotrophic to eutrophic; that in the reservoirs of Shiemen, Yeonghoshan, Liyutan, Lantan, Rernyihtan, Tzenwen, Wushantou and Nanhua fluctuated between mesotrophic and eutrophic; and that in the reservoirs of Paiho, Chingmien, Akungtien, Chengchinghu, and Fengshan, all of which are in southern Chinese Taipei, was seriously eutrophic.

Table 3: Carlson trophic state index of major reservoirs in Chinese Taipei.

Reservoir	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Feitsui	41.1	37.6	38.7	45.9	44.7	44.6	45.2	39.2	48.0	45.2	42.8	35.3	38.2	42.0	43.8	38.9
Shiemen	54.4	47.9	47.5	51.2	49.3	50.3	42.0	43.4	49.4	49.9	47.5	52.2	48.4	51.6	48.2	49.2
Paoshan	47.7	48.3	50.7	50.5	51.2	54.8	49.3	50.2	54.0	48.0	50.2	53.6	51.4	52.6	50.3	50.0
Yeonghoshan	47.7	45.4	43.9	49.8	51.7	54.7	47.6	45.9	47.3	54.7	52.1	47.1	46.0	45.1	44.2	44.3
Mintei	54.7	47.5	47.1	47.4	52.2	52.3	48.0	51.0	51.7	50.7	54.2	48.6	50.8	49.1	49.1	50.3
Teiki	47.1	43.6	42.1	46.4	54.8	59.5	38.8	37.0	45.9	42.3	37.0	40.7	46.2	41.2	41.3	40.7
Wushe	41.6	41.3	42.3	42.4	50.9	46.1	42.8	41.7	45.9	47.2	49.2	38.9	40.3	40.3	39.1	40.4
Liyutan	—	48.5	48.7	48.7	54.3	54.0	51.1	57.2	50.2	48.0	49.6	49.2	51.0	50.6	44.2	45.9
Sun Moon	36.0	35.0	35.5	38.4	42.5	47.1	43.0	37.2	44.9	40.1	34.1	33.9	39.4	31.7	35.9	38.2
Rernyihtan	57.5	54.9	47.3	47.6	55.6	57.8	50.6	52.6	55.6	54.0	53.2	52.0	49.1	48.6	45.2	44.2
Lantan	52.0	47.7	43.5	48.0	57.4	—	53.9	51.8	51.4	49.5	52.8	52.0	48.9	49.3	46.3	44.0
Paiho	53.2	52.7	50.3	55.9	55.2	56.0	53.6	52.4	57.9	54.0	55.0	52.4	49.6	52.3	51.3	52.1
Tzenwen	49.9	44.4	43.5	47.1	51.6	50.3	44.5	44.8	46.9	47.8	48.1	50.1	48.4	48.6	43.7	44.3
Wushantou	48.6	47.1	45.4	54.9	47.6	47.2	43.0	42.8	47.6	47.3	45.1	48.4	45.3	44.4	44.0	44.0
Nanhua	—	44.0	45.7	50.8	53.7	51.5	44.1	45.7	52.3	47.8	44.1	44.5	48.7	50.3	45.6	49.6
Chingmien	57.2	51.4	44.8	51.7	59.7	51.6	55.2	50.3	57.6	54.8	51.7	55.8	53.1	53.7	—	54.8
Akungtien	77.9	75.2	76.2	84.4	79.1	77.3	*	*	*	*	*	*	*	*	57.4	59.1
Chengchinghu	68.1	67.6	67.4	72.8	74.6	69.3	66.6	66.7	67.7	61.3	59.7	51.5	55.6	55.8	54.7	51.4
Fengshan	75.6	74.8	76.2	79.0	75.5	78.3	74.7	74.3	80.5	73.8	75.7	73.8	72.4	73.0	76.1	71.9

*during reservoir renewal project period

Multivariable indexing allows for a more thorough investigation of water quality and a more continuous description of the eutrophication, but several problems are inherent in this method. The first problem is that geographical and atmospheric factors influence eutrophication, causing the standards for each area to differ. Consequently, the three aforementioned indices are heavily regional in nature. Another problem involves unreasonable classification standards. For example, the Carlson index gives CTSI = 49 and CTSI = 50 different classifications but CTSI = 39 and CTSI = 49 the same. A further problem with multivariables is that it gives different weights to each parameter. Lu et al.[7] developed a fuzzy synthetic evaluation method and illustrated the method with a case study of trophic status assessment for the Feitsui Reservoir in CT. The results showed that the long-term change of water quality and the overturn phenomenon cannot be observed with the Carlson index but is expressed by fuzzy synthetic evaluation. Fuzzy synthetic evaluation is better suited than the Carlson index to rating the trophic status of self-sustaining reservoirs.

NPSP Control Strategy

Eutrophication not only hurts the ecology of the water body and the natural landscape but also disturbs the water treatment process and downgrades tap water quality. The best solution to eutrophication is to control and eliminate the external sources of pollution[8]. External loads originate from point or nonpoint source pollutants, the latter of which are carried by runoff from storm events. The CT has proposed a series of sewage system projects to collect and treat all point source pollutants from the upstream of reservoirs and then discharge the treated effluents into the downstream reaches of reservoirs.

Many laws and regulations for preventing nonpoint source pollution (NPSP) have been established in CT to protect water supply watershed areas of reservoirs. The effectiveness of these laws and regulations has been small because of meaninglessly low fines and penalties and implementation problems. Other challenges CT must deal with in terms of NPSP control include the lack of basic data, institutional and organizational problems, public awareness and commitment, a stable and continuing funding source, and, most importantly, how to find a way to balance environmental protection with the economic benefits of developing upstream areas.

In a previous study[9], a thorough review of nonpoint source control literature was made and discussions were held with water quality control officials, environmental practitioners, and scholars in CT. The purpose was to develop a consensus for establishing a nonpoint source pollution control strategy for CT. The following observations were made after the review and the discussions:

1. CT is an island region with a very large population. The "economic miracle" has brought to CT an enormous foreign reserve and made it one of the fastest-growing economies in the world. On the other hand, the environment has suffered due to years of neglect. It is time for CT to pay more attention to protecting the environment and to enhance the quality of life for its people and future generations.

2. Economic growth must continue. Development in the watersheds cannot and should not be prohibited. However, the "best" technology should be used and strictly enforced upon developers (public or private) so that all potential "added-on" pollution is controlled or eliminated. Therefore, a "limited" development strategy should be promoted instead of one of "no development."

In order to ensure an effective control of nonpoint source pollution, a "three-pronged" approach has been proposed. The first approach is to start an extensive collection of basic data immediately, especially with regards to water quality. Stormwater runoff data will provide the basis for nonpoint pollution model calibration and verification. Data on the performance of certain BMPs will allow BMP selection to be made and design guidelines to be developed to suit CT's conditions. The second approach is to initiate demonstration studies in selected watersheds on pollution source identification and quantification, model application, and BMP effectiveness. The third very important approach is to examine the institutional, organizational, and legal needs for implementing a full-scale nonpoint source control program in CT. It is suggested that the three elements of the nonpoint control strategy be initiated at the same time and as soon as possible. Although point sources of pollution have not been very well controlled in CT, nonpoint control measures cannot be delayed until after point sources have been controlled because the latter effort may take many years to achieve. In the meantime, reservoirs may be rendered useless because of nonpoint pollution and siltation.

Sun Moon Lake – A Magical Crystal Lake

Sun Moon Lake (or Jihyuehtan) is located in the center of CT and is the island's largest lake. It is a beautiful alpine lake, divided by the tiny Lalu Island. The eastern portion of the lake is round like the sun and the western side is supposedly shaped like a crescent moon, hence the name. Its beauty is created by the combination of mountains and water, and its 760-meter elevation helps give the impression of a Chinese landcape painting of mist-laden water and clearly defined levels of mountains. The constant changes of mists and moods on the lake cause visitors to linger. The beauty of the lake, form dawn to dusk and from spring and summer to autumn and winter, whether it is bathed in sunlight or shrouded in mist, exudes such an aura of enchantment, the viewers never tire of looking at and sighing over it.

According to legend, a long time ago a group of Thao hunters chased a rare and beautiful white deer for days and days, up river valleys and across mountain ridges, until finally they entered the mountains of a place called Sarisen. There they discovered the deep green waters of Sun Moon Lake, and moved their entire tribe to this beautiful place. The entire area around Sun Moon Lake, including today's Yuchih, Toushe, and Puli, was once known as Sarisen. The Thao who first settled here were joined during the Qing Dynasty by large numbers of Han Chinese and flatland aborigines who moved in to cultivate the land, thus forming the cultural diversity of the area.

When the Japanese occupied CT they channeled water from the upper Jhuoshuei River into the lake for the purpose of hydropower generation, substantially raising the water level (from 6m to 27m) and increasing the area of the lake's surface (from 4.55km^2 to 7.73km^2). Then the water in Sun Moon Lake was drawn to Menpai Lake, a 320-meter drop in height was used to generate electricity, creating 100,000 kilowatts of electric power. The Daguan hydropower plant construction was completed in 1934. The construction of the Daguan Power Plant cost 68.5 million yen, and in all, around 2,544,000 laborers were employed. The railroad and roads the Japanese built to facilitate hydroelectric construction made travel to the area much more convenient, stimulating tourism at the lake and the development of the surrounding area.

However, more electricity was still needed. In 1935, the construction of Jyukong Power Plant began. It drew water from the reservoir of the Daguan Power Plant, using a drop of 140m to generate 43,000 kilowatts of electricity. The construction was completed in 1939. The Wanda power station, using water from the Wanda River, a branch of the Jhuoshuei River, generating 15,000 kilowatts was built in 1943. During the Pacific War, the Daguan Power Plant was bombed. The generators were seriously damaged, and electricity generation came to a complete standstill.

After retrocession from the Japanese, the CT repaired the generators, and the Sun Moon Lake area became the most important electricity generation area in CT. In 1985, the Minghu Pump-Storage Power Plant was built. It was the first pump-storage power plant in the Far East. It draws water to Sun Moon Lake in the early hours of the morning , and then releases water during the day time, generating 1,000,000 kilowatts. The Mingtan Power Plant was completed in 1995, which is the largest pump-storage generating plant in Asia (1,602,000 kilowatts). The cycle of water release and pumping create rare lake tides in Sun Moon Lake. Table 4 is a summary of all hydropower plants in Sun Moon Lake area.

Table 4: Summary of hydropower plants in the Sun Moon Lake area.

Name	Generators	Installation capacity (10^3KW)	Source of water	Year of construction
Daguan	5	110	Sun Moon Lake	1934
Jyukong	2	43.5	Tail water of Daguan	1939
Wanda	1	15.3	Wanda River	1943
Wushe	2	20.7	Wushe Reservoir	1957
Minghu	4	1000	Sun Moon Lake	1985
Mingtan	6	1602	Sun Moon Lake	1995
Shueili	1	12.8	Mingtan Reservoir	1992
Total		2804.3		

Water Pollution Controls

Because of many beautiful faces, mysterious Thao culture and ecological diversity of the area, the Sun Moon Lake attracts over 1.1 million tourists a year. The Sun Moon Lake is also a public water supply source to nearby regions. Water pollution controls for both point and nonpoint external loads are very important to meet all functions. An auto-monitoring system (Hydrolab, USA) for water quality was built in 2002. Table 5 shows measuring results for different sampling sites during May 2008 to March 2009.[10] From these results, the CTSI ranges from 33.5 to 44.5, fluctuating between oligotrophic and mesotrophic. The overall water quality belongs to class A of suface waterstandards in CT (suitable for all kind uses).

Residential and touristic sewages are two major point pollution sources. Tables 6 and 7 show the prediction of daily sewage amounts for Shueishe and Jihyueh regions, respectively. The total daily sewage flowrates for both regions during the holiday are 890 CMD and 849 CMD. Adding 15% of the daily sewage flow for groundwater infiltration, the design capacity for two wastewater treatment plants are 1100 CMD and 1000 CMD, respectively. Both plants adopt tertiary treatment process in order to maintain class A water quality in the Sun Moon Lake. The sequencing batch reactor (SBR) system with intermittent aeration was used in biological treatment unit. After sand filtration and UV disinfection, the effluent water can be recovered for land application. The whole treatment plant was constructed under the ground, and the ground surface was designed as a water educational park. The construction cost for the Shueishe Treatment Plant is about 410 million NT$ (12.8 million US$)[11].

Table 5: Water quality measuring results for the Sun Moon Lake (2008.5~2009.3).

Sampling sites	Inlet of water treatment plant	Shueishe wharf	Yidashao	Siangshan
DO (mg/L)	6.7-8.8(8.1)	7.2-9.4(8.3)	7.2-8.8(8.2)	6.9-8.8(8.1)
SS (mg/L)	1.5-4.0(2.7)	0.7-6.1(2.6)	0.9-7.3(2.9)	0.4-6.3(2.7)
COD (mg/L)	0-10.4(1.7)	0-15.6(3.3)	0-12.7(2.8)	0-13.0(2.9)
BOD (mg/L)	0.3-0.7(0.5)	0.3-0.5(0.4)	0.2-0.9(0.4)	0.5-0.8(0.7)
Secchi-disk depth (m)	1.8-3.9(2.8)	1.5-3.9(2.6)	2.0-4.5(2.9)	1.5-4.0(2.7)
TP (μg/L)	6.0-9.0(7.1)	5.7-9.5(6.7)	4.4-9.1(6.5)	5.3-12.7(9.4)
NH_3-N (μg/L)	25.3-294.2(106.1)	11.7-331.5(78.0)	8.5-274.5(73.2)	9.0-219.8(58.2)
NO_3^--N (μg/L)	352.8-593.0(479.4)	322.6-581.9(448.9)	337.7-585.6(461.9)	345.3-593.0(457.0)
NO_2^--N (μg/L)	1.5-3.6(2.2)	1.7-3.3(2.3)	1.3-3.1(2.3)	1.0-2.6(2.1)
Chl a (μg/L)	0.8-1.5(1.2)	1.2-2.4(1.8)	1.0-2.1(1.5)	1.1-2.2(1.5)

( ): the average value

Table 6: Prediction of the daily sewage amount for the Shueishe region in 2026.

Types	Population served	Average sewage flow (lpd/cap)	Daily sewage amount (CMD)
Residenter	1001	225	225
Holiday lodger	2553	158	403
tourist	4166	63	262
Workday lodger	361	158	57
tourist	589	63	37

lpd/cap : liters per day per capita
CMD : m^3/day

Table 7: Prediction of the daily sewage amount for the Jihyueh region in 2026.

Types	Population served	Average sewage flow (lpd/cap)	Daily sewage amount (CMD)
Residenter	964	225	217
Holiday lodger	871	158	138
tourist	7835	63	494
Workday lodger	123	158	19
tourist	1108	63	70

Best management practice (BMP) approaches are commonly applied to control NPSP. Wen et al.[12] initiated a five-year comprehensive study on NPSP and its control supported by the CTEPA in 1996. Under their projects, silt fences, vegetative buffer strips, swales, porous pavements, and detention ponds were tested. Table 8 summarizes some of the test results. Wen and Yu[13] investigated the results of an innovative integrated BMP system for a recreational farm in CT. The system consists of a number of BMPs placed in series (Fig. 1). The BMPs include a grassed strip, a swale, wetland vegetation, two check dams, a shallow lotus pond, and two wet detention basins. Results show that the system is capable of reducing flood peaks by 50~75%. As for pollutant removal, the system achieved the following removal rates: BOD, 72~85%; TKN, 23~72%; and TP, 20~80%. In summary, more BMP tests are needed to provide a good database before full-scale implementation can be performed.

Table 8: Removal efficiency of BMP studies under the CTEPA projects.

BMP	Removal efficiency
Silt Fence	TSS: 50-90%
Vegetative buffer strips (4-16 m long, 5-20% slope)	TSS: 81%, COD: 72%, TP: 66%, NH_3-N: 58%, NO_3-N: 34%
Swales (30 m long, 1% slope)	TSS: 70-86%, COD: 46-63%, TN: 14-24%, TP: 34-77%
Porous pavement	TSS: 50-60%
Detention pond (15 m x 5 m x 1.5 m)	TSS: 60%, COD: 45%, TP: 28%

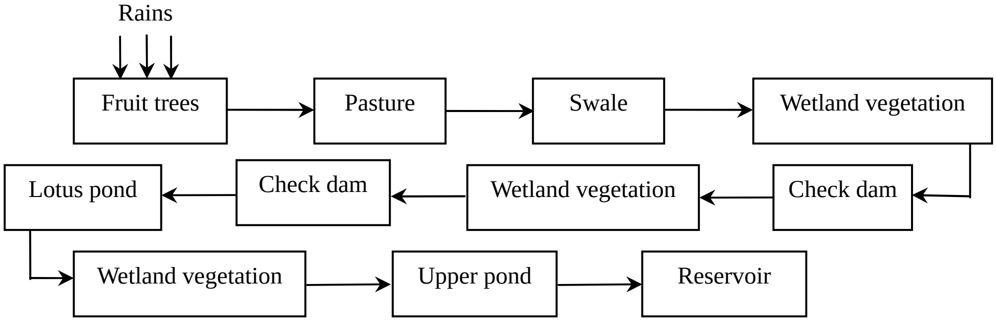

Figure 1: BMPs placed in series.

Wu et al. (2006)[14] investigated water purification and environmental enhancement of artificial floating islands in the Sun Moon Lake (Figures 2 and 3). Three demonstrating testing sites were chosen at Dehuashe, Shueishe and Yuehtan. Each floating island has 100 m^2 (11 m×9.1m) surface area. The total planting area is 37.44 m^2, and was divided into 6 planting regions. *Hygrophila pogonocalyx*, *Gymnocoronis spilanthoides*, *Typha orientalis*, *Angelonia goyanzensis*, *Celosia argentea* and *Ruellia brittoniana* were planted in each region, separately. Testing results show that

Typha orientalis has maximum absorption rates for nitrogen and phosphorus, reaching 0.122 g-N/m^2-d and 0.017 g-P/m^2-d, respectively. *Angelonia goyanzensis* and *Hygrophila pogonocalyx* also show relatively high aborption rates for N and P.

Figure 2: The artificial floating island in the Sun Moon Lake.

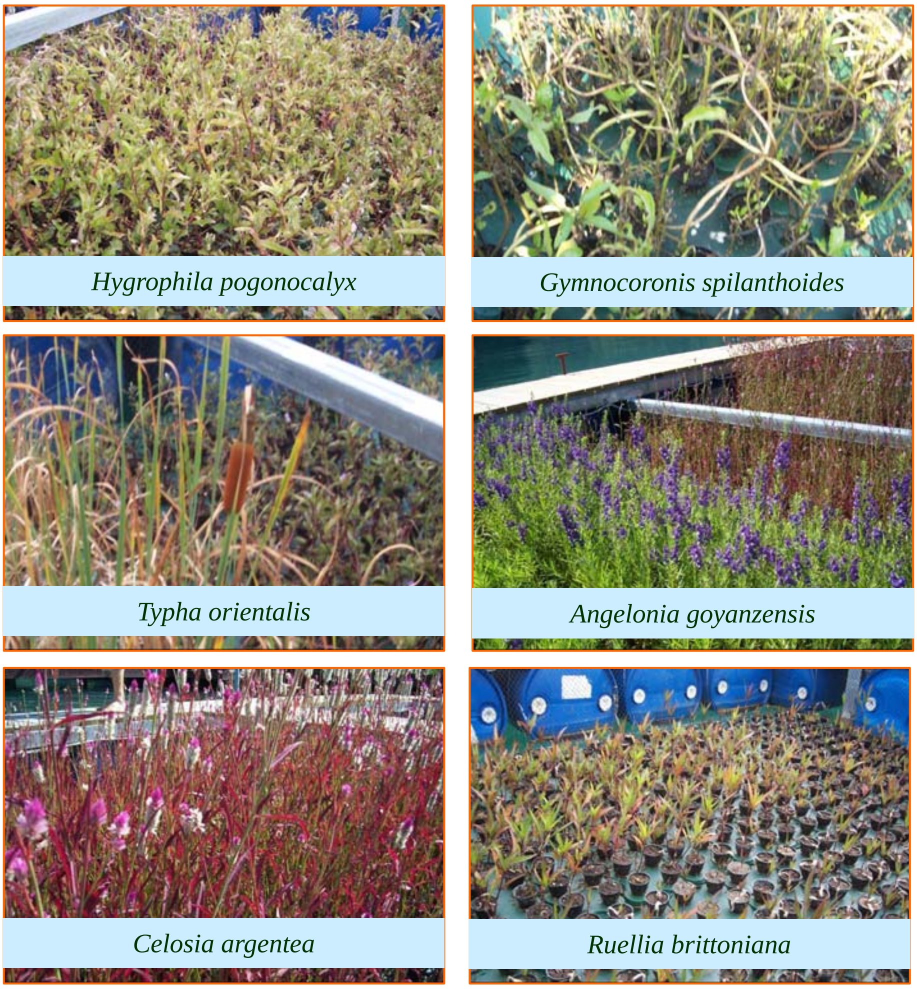

Figure 3: Six floras planted on the artificial floating island.

CONCLUSIONS

The eutrophication of reservoirs has received increasing attention in the past few years in CT. Contamination generated from upstream development and human activities introduces a significant amount of nutrients into reservoirs and thus accelerates eutrophication. Most of the reservoirs in CT are sources of public water supply and the protection of their water quality is of critical concern. Controlling external pollution loadings is a typical strategy to remedy the eutrophic condition. The rivers in CT are mostly short with steep slopes, causing stormwater runoff to flow quickly into the rivers and out to the sea in a matter of hours to a few days. On the other hand, stormwater runoff entering the reservoirs will remain in the reservoirs for a much longer time. Consequently, reservoirs are especially vulnerable to pollution from nonpoint sources, which are mostly storm-induced. Nonpoint pollution control in CT is as urgently needed as point source control. Efforts should begin as soon as possible for basic data collection, testing of control technologies, and formulating an institutional framework for implementation of control strategies.

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