Water Quality Management

On-Farm Water Management Project
At Three Different Location in Myanmar

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1. Importance of water quality monitoring in Irrigation

At the begin of 1950, Thailand is defined to be the agricultural country with population less than 10 million. On this condition, most of the people make there living in farming and agriculture. Under the economic development plane 1 to plane 10 of Thai Government, Thailand has transformed from agricultural to agro-industrial as a new industrial country. This economic explansion has created very large need on water consumption for agriculture, industrial and domestic usage. Irrigation systems has also developed to a point with new intensive cropping which utilizes a lot of water.

All these developments need a lot of water to run the process and also produce large a mount of waste and polluted water. Because of the uncontroled environmental impact procedure during the last decate waste water from all sources are discharge directly into rivers, natural surface water and lakes without treatment.

On the upstream area where the water come from natural sources: precipitations, forestries, mountains and ground water recharges, water quality has a good condition. In contrast, lower river basins where the river flows through the towns, community, agricultural land and industrial estates, water quality are polluted by waste discharge from all sources. The pollution is increased over the limit to ultilize for domestic comsumptions, industrial used or agriculture plantation.

Water quality is not only effected by the waste water, salinity is the other water quality problem to all sectors. Water salinity does not occur only in the main rivers that flow into the sea caused by salt water intrudsion during summer seasons, but it is also found in the Northeastern area where the rock salt is under lies the area

To protect and solve these problems, the Royal Irrigation department is assigned for water monitoring and controlling the water quality. To implement, the department has established the Office of Hydrology and Water Management, Hydrology Division, Sediment and Water Quality Group. On the major river basins monitoring stations have been built to measure the water quality both on site record and laboratory analysis. To control the pollution, regulation for discharge water standard was issued. However when the problem goes beyond the limit of quality standard, water in reservoir will be discharge for dilution the waste water and protect salt water intrusion.

2. The importance of water

Water can be classified into 4 usages

2.1 water for domestic consumption and living conditions

2.2 water for agricultural in term of plantation, livestock, fishery and soil conservation

2.3 water for industries, electric generators, transportation and tourism

2.4 water for ecology to maintain the water level in rivers which has importance as a past way conjugate between land ecology and ocean ecology

The water management is very important to conserve and maintain the balance of water usage in all sectors covering the whole country.

3. Source of polluted water

Thailand has three major sources of polluted water, industry, community (housing) and agriculture in which each source can generate plenty of waste water. The statistic of Thailand indicated, there are 120,000 industrial estates which can produce 6.8 million cubic

meters of waste water every day. These will create polluted water in an organic form, 2,700 tons BOD per day. (PCD, 2006)

3.1 Cities and communities in large metropolis, municipal, local council have produced waste water about 9 million cubic meter each day. These have generated organic matter about 2,600 ton BOD per day. (PCD, 2006)

3.2 Agriculture also produced waste water, from pig farming, livestock, fishery and plantation, about 114 million cubic meters per day which produce waste water in the form of organic matter around 890 ton BOD per day. (PCD, 2006)

3.3 The pollution from industries and communities produce great amount of pollution with small quantity of water, contrasts to agriculture, which produces large amount of waste water but less dirty.

4. Water quaily monitoring

4.1 Objectives

4.1.1 Acquisition data for appropriate water quality management for surface runoff.

4.1.2 Acquisition data for planning protection and solving the water quality problems.

4.2 Water quality monitoring is classified into two categories.

4.2.1 monitoring in water resources

4.2.2 monitoring in waste or polluted water

4.3 Water quality parameter or index there are 3 aspects: physical quality, chemical quality **and** biological quality

4.3.1 Physical parameters: Temperature, Turbidity, Taste, Odor and Color

4.3.2 Chemical parameters:

- pH range 6-8
- Acidity: CO_2, HCO_3^-, $H_2CO_3^-$
- Alkalinity: OH^-, CO_3^{2-}, HCO_3^-
- Hardness: carbonate and non-carbonate
- Chloride
- Conductivity
- Dissolved oxygen
- Fe, Ca, Cu, Zn, Na
- Chemical parameters
- Nitrogen: NH_3, NO_2^-, NO_3^-
- Sulfat
- Solids
- Fluoride, Silica
- Phenolic cpd.
- Toxic metals eg. Cd, As, Cr
- Detergents
- Organochlorine cpd., PCB
- Radioactive
- Oxygen demand e.g. BOD, COD, PV

4.3.3 Biological parameters

- Total plate count
- Coliform bacteria (MPN)
- E. coli
- Enteric pathogen

4.4 Water quality parameter index survey can be classified into 2 methods

- Water quality parameter that need to analysis, because some parameters will be change rapidly, if samples are taken from river such as pH, EC, Temperature.
- Water quality parameter that will be analysed in laboratory. Most of these factor can not analyes in field, water sample is taken from natural water for lab analysis, include COD, BOD, Toxic metals, poison, arsenic. Water should be sampling in the direct method, some reagent will be put into samples' for reservation.

4.5 Sampling water procedure for analysis consists of:

- equipment and water sampling tool
- water container

- sampling point or station
- method of water sampling

- procedure to correct sample
- label of water samples
- water preservation
- document on samples detail
- water quantity
- field record of sample
- water box
- detail of sample, time of sampling and surrouding condition during the sampling should be recorded.

Fig. 1 Water Quality monitoring, equipments and procedure

5. Water quality of sureface runoff

Water quality monitoring data by Pollution Control Department in 2007. The 48 major rivers, 1 distributary and 4 lakes (kwan Phayao, Bung Bora-phet, Nong Han and Songkhla Lake) were monitored by 368 stations indicated that the standard water quality together with water quality index of surface runoff in Thailand showing 19% are in good quality, 35% in moderate quality, 44% in poor condition and 2% in worst condition.

Table showing the water quality in surface runoff in Thailand year 2007

Water Quality Index	Northern Region	Central Region	Northeastern Region	Eastern Region	Southern Region	Percentage of total water resources
Good	Li, Ing, Mae Chang	Kwae Noi	-	Chanthaburi, Waru, Prasae	Upper Tapi, Saiburi, Phumduang, Pattani, Lang Suan	19
Moderate quality	Kok, Ping, Wang, Yom, Nan	Upper Phetchabun, Khwae Yai,Upper Chao Phraya, Middle Chao Phraya, Mae Klong	Un, Phong, Chi, Songkhram, Lam Pao, Upper Lam Takhong, Nong Han	Trad, Phang Rat, Upper Rayong	Lower Tapi, Chumphon	35
Bad condition	Kwaung, Kwan Phayao, Bueng Boraphet	Lop Buri, Sakae Krang, Lower Phetchaburi, Pran Buri, Pasak, Noi, Upper Tha Chin, Middle Tha Chin, Lower Chao Phraya, Lower Tha Chin, Kui Buri	Mun, Lam Chi, Sieo, Loei	Lower Rayong, Nakhon Nayok, Pran Buri, Bang Prakong		44
Worst condition	-	-	Lower Lam Takhong	-	-	2

Source: Annual report 2007, Pollution Control Department

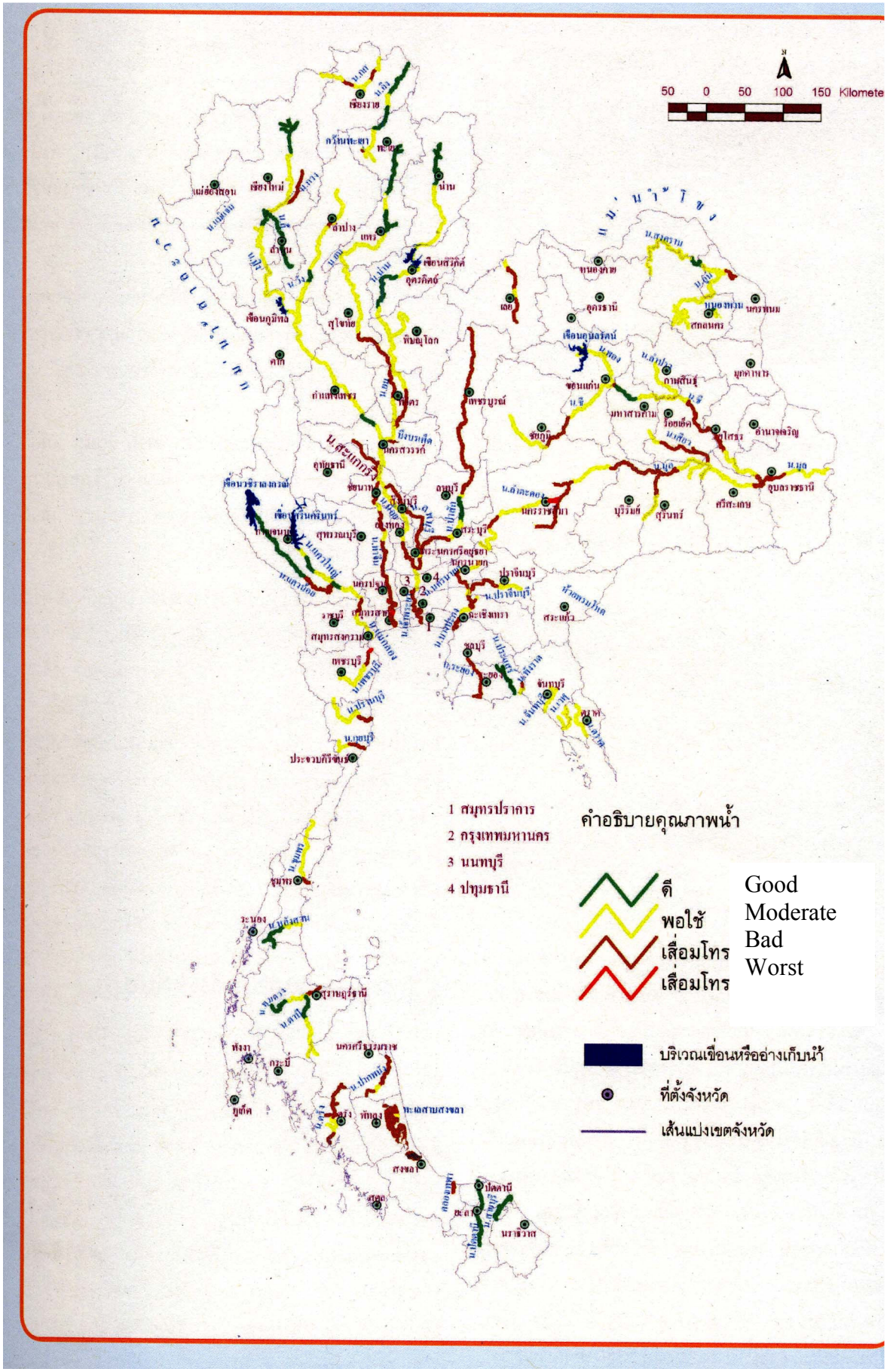

Fig.2 Map showing water quality of surface runoff in Thailand (source: annual report PCD, 2007

Comparing the water quality from 2004 – 2006, the index indicated that water quality have pollute to serious conditions by the number of poor conditions and worst conditions rapidly increasing especially in Upstream Tha Chin River, Kui Buri River, Mun River, Chi River, Seao River, loei River, Nakhon Nayok River, Rayong River, Bang Pra Kong River, Prachin Buri River, Pak Phanang River, Thale Noi, Thale Luang, and Trang River which have poor condition. The bad condition surface runoff includes the Lower Lam Takhlong River in Muaeng District, Nakhon Ratchasima Province caused by the waste drainage into rivers 70% from housing, 20% from industrials and 10% from agriculture products.

The details from water monitoring stations indicated that the worst parameter index in surface water show reduced quality in terms of 30% Biochemical Oxygen Demand: BOD, 19% Dissolved Oxygen: DO, 17% Fecal Coliform Bacteria: FCB, 17% Ammonia: NH_3 and 16% total Coliform Bacteria contamination.

6. Water Quality Standard

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Classification and Objectives	
Classification	**Objectives/Condition and Beneficial Usage**
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment process before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process before using (2) industry
Class 5	The sources which are not classification in class 1-4 and used for navigation.

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Surface Water Quality Standards								
Parameter[1/]	Units	Statistics	Standard Value for Class[2/]					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
1. Colour,Odour and Taste	-	-	n	n'	n'	N'	-	-
2. Temperature	C°	-	n	n'	n'	N'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
4. Dissolved Oxygen (DO)[2/]	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
5. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C , 5 days
6. Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
7. Fecal Coliform Bateria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
8. NO_3 -N	mg/l	-	n		5.0		-	Cadmium Reduction
9. NH_3 -N	mg/l	-	n		0.5		-	Distillation Nesslerization
10.Phenols	mg/l	-	n		0.005		-	Distillation,4-Amino antipyrene
11.Copper (Cu)	mg/l	-	n		0.1		-	Atomic Absorption -Direct Aspiration
12.Nickle (Ni)	mg/l	-	n		0.1		-	Atomic Absorption -Direct Aspiration
13.Manganese (Mn)	mg/l	-	n		1.0		-	Atomic Absorption -Direct Aspiration
14.Zinc (Zn)	mg/l	-	n		1.0		-	Atomic Absorption -Direct Aspiration
15.Cadmium (Cd)	mg/l	-	n		0.005* 0.05**		-	Atomic Absorption -Direct Aspiration
16.Chromium Hexavalent	mg/l	-	n		0.05		-	Atomic Absorption -Direct Aspiration

17.Lead (Pb)	mg/l	-	n	0.05	-	Atomic Absorption -Direct Aspiration
18.Total Mercury (Total Hg)	mg/l	-	n	0.002	-	Atomic Absorption-Cold Vapour Technique
19.Arsenic (As)	mg/l	-	n	0.01	-	Atomic Absorption -Direct Aspiration
20.Cyanide (Cyanide)	mg/l	-	n	0.005	-	Pyridine-Barbituric Acid
21.Radioactivity - Alpha - Beta	Becqurel/l	-	n	0.1 1.0	-	Gas-Chromatography
22.Total Organochlorine Pesticides	mg/l	-	n	0.05	-	Gas-Chromatography
23.DDT	µg/l	-	n	1.0	-	Gas-Chromatography
24.Alpha-BHC	µg/l	-	n	0.02	-	Gas-Chromatography
25.Dieldrin	µg/l	-	n	0.1	-	Gas-Chromatography
26.Aldrin	µg/l	-	n	0.1	-	Gas-Chromatography
27.Heptachlor & Heptachlorepoxide	µg/l	-	n	0.2	-	Gas-Chromatography
28.Endrin	µg/l	-	n	None	-	Gas-Chromatography

Remark : [1/]กำหนดค่ามาตรฐานเฉพาะในแหล่งน้ำประเภทที่ 2-4 สำหรับแหล่งน้ำประเภทที่ 1 ให้เป็นไปตามธรรมชาติ และแหล่งน้ำประเภทที่ 5 ไม่กำหนดค่า
[2/] ค่า DO เป็นเกณฑ์มาตรฐานต่ำสุด

P Percentile value

n Naturally

n' naturally but changing not more than 3°C

* when water hardness not more than 100 mg/l as $CaCO_3$

** when water hardness more than 100 mg/l as $CaCO_3$

Based on Standard Methods for the Examination of Water and Wastewater recommended by APHA : American Public Health Association, AWWA : American Water Works Association and WPCF : Water Pollution Control Federation

Source : Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

7. Water quality standards for water discharged into the irrigation systems

Since Thailand has transferred from an agricultural country to a new agro-industrial country, the economic growth has caused rapid development in the estate industry and housing areas. These expansions has modified agricultural land into economic communities, factories, shopping centers and real estates, which discharge huge amounts of waste water into the irrigation water resources. Waste water polluted water quality and has an impact on the growth rate of plants, domestic consumption, and fishery. This problem tends to be increasing in severity. The government needs to issue a new regulation to control and define the quality standards of water discharged into the irrigation systems. This regulation will also reinforce the protection of water from pollution that will occur in water resources.

Reasons to define the standard quality for water discharged into the irrigation systems

During drought period, water shortage and less circulation have occurred in the irrigation systems. So the definition of standard quality of water for irrigation has higher standards than industrial waste water limit especially for salinity control, which is importance to water utilization in agricultural, proposing the factor $ECx10^6$ and TDS has a direct effect to plant growth rate and domestic consumption of water. The other factors such as pH should range between 6.5 – 8.5 which is suitable for all kinds of plants. Cadmium and lead are defined less than industrial standards because it is harmful to health. The other contaminants are

defined according to the industrial standards, such as BOD, Permanganate value, which should be suitable for waste water treatment system.

Water Characteristics Discharged into Irrigation System		
Parameters	**Units**	**Standard Values (Range or Maximum Permitted Values)**
1. pH	-	6.5-8.5
2. Conductivity	µMole/cm	2,000
3. Total Dissolved Solids (TDS)	mg/l	1,300
4. Biochemical Oxygen Demand (BOD5)	mg/l	20
5. Suspended solids (SS)	mg/l	30
6. Permanganate (PV)	mg/l	6.0
7. Sulphide (as H2S)	mg/l	1.0
8. Cyanide (as HCN)	mg/l	0.2
9. Fat ,Oil and Grease	mg/l	5.0
10.Formaldehyde	mg/l	1.0
11.Phenol & Cresols	mg/l	1.0
12.Free chlorine	mg/l	1.0
13.Pesticides	mg/l	None
14.Radioactivity	mg/l	None
15.Colour and Odour	-	Not objectionable
16.Tar	-	None
17. Heavy metals - Zinc (Zn) - Chromium (Hexavalent) - Arsenic (As) - Copper (Cu) - Mercury (Hg) - Cadmium (Cd) - Barium (Ba) - Selenium (Se) - Lead (Pb) - Nickel (Ni) - Manganese (Mn)	mg/l	 5.0 0.3 0.25 1.0 0.005 0.03 1.0 0.02 0.1 0.2 0.5

Source : Summarized from Royal Irrigation Deparment Order No. 883/2532 (1989) , dated 19 December B. E. 2532 (1989) 2532

8. Irrigation Water Quality Standards and Salinity Management

Nearly all waters contain dissolved salts and trace elements, many of which results from the natural weathering of the earth's surface. In addition, drainage waters from irrigated lands and effluent from city sewage and industrial waste water can impact water quality. In most irrigation situations, the primary water quality concerns is salinity levels, since salts can affect both the soil structure and crop yield. However, a number of trace elements are found in water which can limit its use for irrigation.

Most salinity problems in agriculture results directly from the salts carried in the irrigation water. As water evaporates, the dissolved salts remain, resulting in a solution with a higher concentration of salt. The same process occurs in soils. Salts as well as other dissolved substances begin to accumulate as water evaporates from the surface and as crops withdraw water.

Numerous parameters are used to define irrigation water quality, to assess salinity hazards, and to determine appropriate management strategies. A complete water quality analysis will include the determination of

1) the total concentration of soluble salts.
2) the relative proportion of sodium to the other cations

3) the bicarbonate concentration as related to the concentration of calcium and magnesium, and
4) the concentrations of specific elements and compounds.

Salinity in main rivers of Thailand

Because most of the major rivers in Thailand flow directly into the Gulf of Thailand, these rivers employ as the major source of fresh water for the great Central Plane where the agricultures, livestocks, fisheries, industrials community and human activity are settle down. The rivers consist of Chao Phraya, Tha Chin Mae Klong, Bang Pakong, Phet Buri and Khlong Chai Tha lae. During the dry period, there is salt water intrusion from sea level rising along these major rivers several kilometers in land between January to June each year. The salt water intrusion has effect directly to agricultural areas, industries and people who living along the river bank on domestic consumptive use.

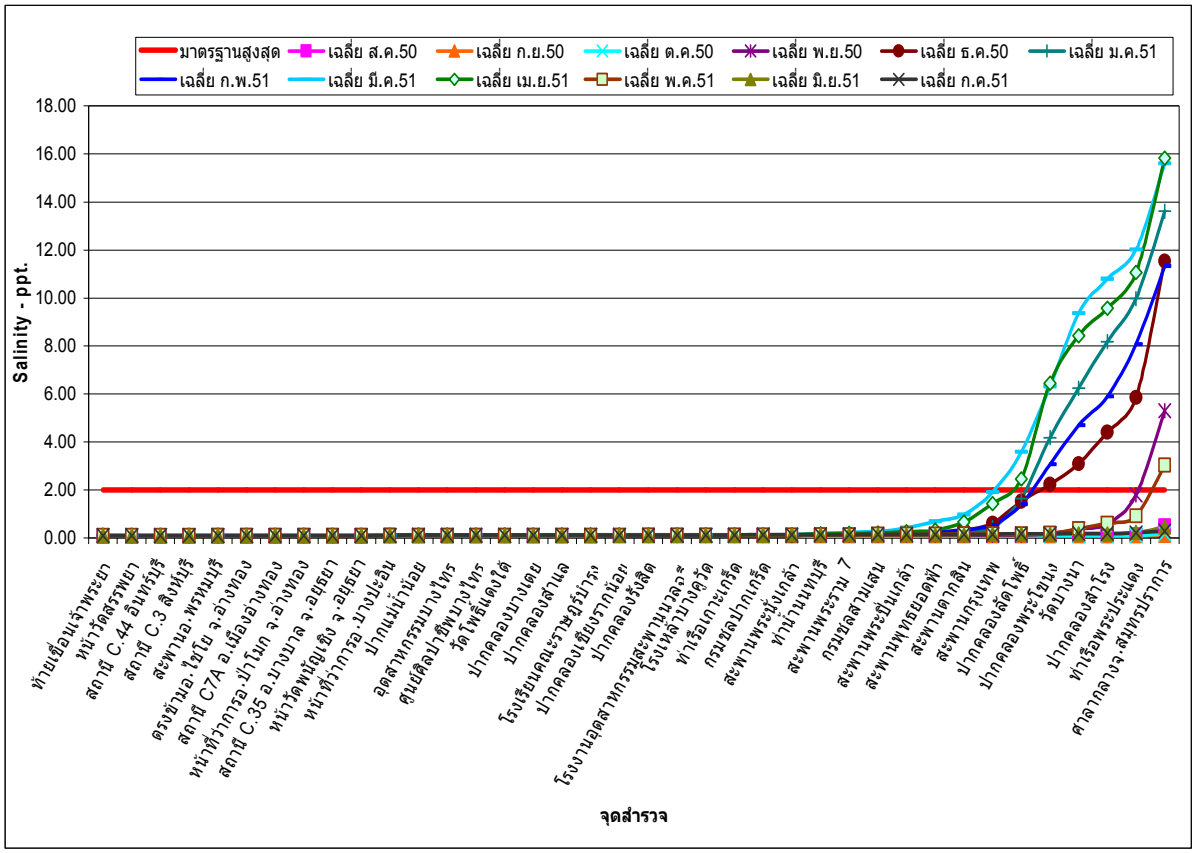
Objectives:

- To monitor and give warning regarding to the salinity of water
- Analysis salinity that effected plantation
- To formulated the master plan to control the quality of water in major rivers of Thailand
- Implementation to policies, plans, projects and the management and control of water quality

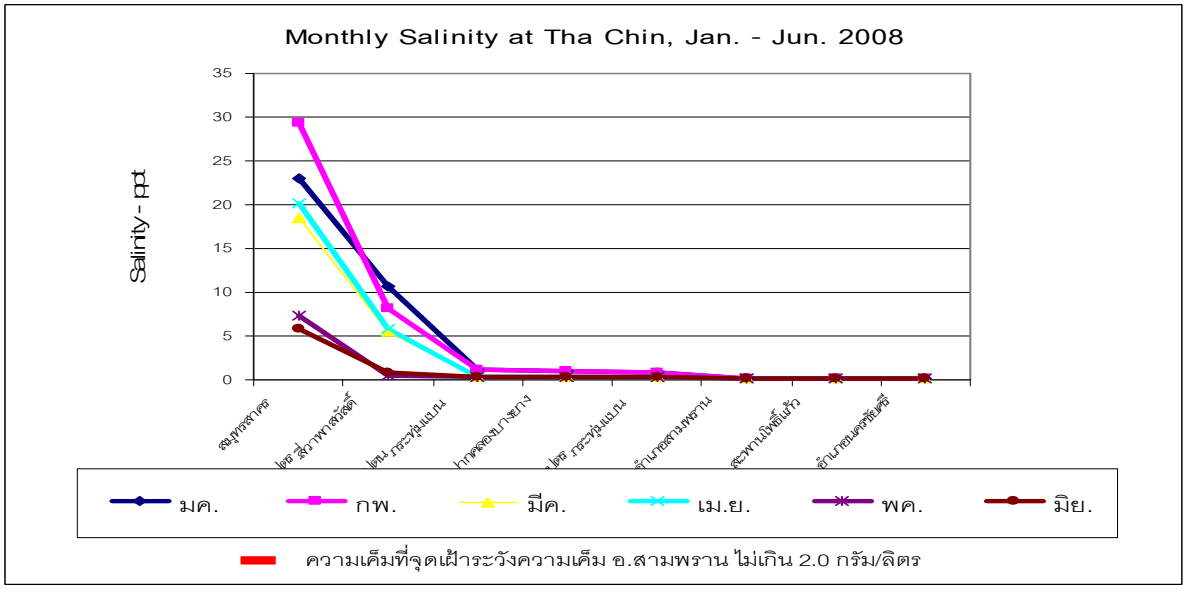
Chao Phraya River is the major river of Thailand. It is originated from 4 major tributaries which have the watershed area in the Northern part of Thailand joining together at Pak Nam Pho, Nakhon Sawan Province. The river flows past Chainat Province, where a large irrigation Dam, Chao Phraya Dam was build in 1957, then Sing Buri Province, Ang Thong Province, Ayutthaya Province, Prathum Thani Province, Nontha Buri Province, Bangkok and Samut Prakan Province with total length of 380 kilometers. The water quality monitoring have employed by 38 stations to detect the salinity of water. If the salt water has intruded upstream and have effect beyond the control point Tha Nam Nonthaburi, Choa Phraya dam will discharge an amount of fresh water to dilute the salinity and control the salinity not greater than 2 ppt at Nontha Buri station.

Fig.3 Boat for water quality monitoring at Chao Phraya River

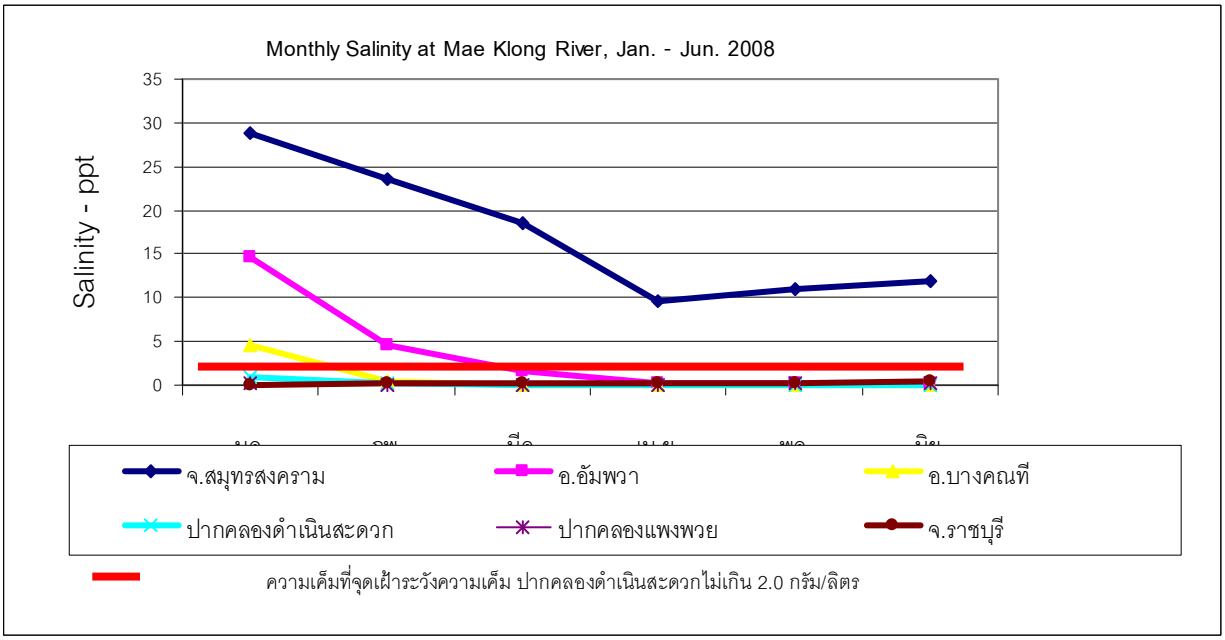
Fig.4 monthly salinity at Chao Phraya River, Year 2008



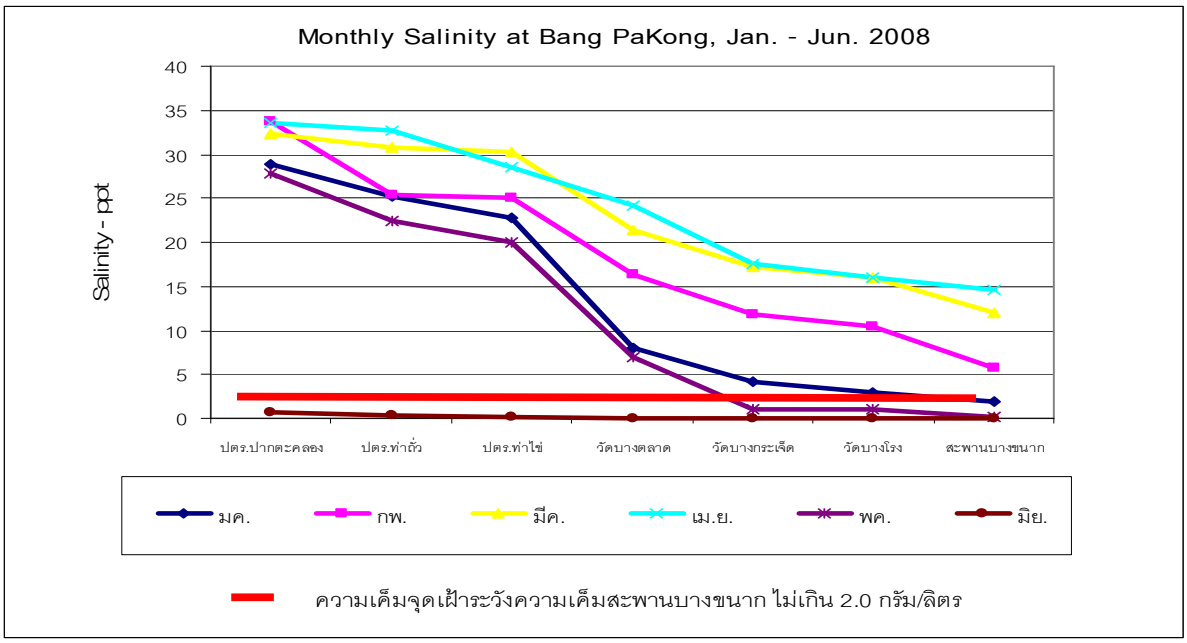
Tha Chin River is the 2nd major river in the Central Plane. It flows separately from Chao Phraya River at Wat Sing district, Chainat Province then past Suphan Buri, Nakhon Sawan, Pathum Thani and met Thai Gulf at Samut Sakhon with the total length of 325 kilometers. There are 7 water quality monitoring stations to control salinity in this river. If the salt water intrusion upstream becomes over the limit 2 ppt at Amphoe Samphran, the fresh water from Pho Phraya Irrigation Dam will discharge to control the salinity.



Mae Klong River, the western region main river, has originated from the Western Mountain Range that divides Thailand and Burma. Mae Klong River is the combination of river Khwae Noi and Khwae Yai River and flow past Kanchanaburi, Ratchaburi into the Gulf of Thailand at Samut Songkhlam with total length of 140 kilometers. The river has 6 monitoring stations to detect the salinity where dilution starts when the salinity goes over 2 ppt at Pak Khlong Dam Noen Sa Duak in Ratchanaburi Province.



Bang Pakong River is the major river in the Eastern Region in which the river is the combination of Prachin Buri River and Nakhon Nayok River at Ban Shang, Prachin Buri Province. The river flows from Nakhon Nayok Province, Prachin Buri Province, Chashoengsao Province where it meets the Gulf of Thailand with the total length of 122 kilomerters. There are 8 water quality monitoring stations to detect the salinity where dilution starts when the salinity goes over 2 ppt at Bang Khanak Bridge. The salinity in this river is controlled by Bang Prakong Dam.



9. Pollution water control Procedure

In the last decade, the natural surface water bodies (rivers, streams, lakes) are invaded and polluted by human activity, which created an environmental impact and degrading water resources especially the streams, rivers, lakes and shore lines. These will generate an impact to the ecology system and ocean environment. In Thailand, the affected area are concentrated in the same sites every year such as lower Chao Phraya River, lower Tha Chin River, lower Lam Ta Khlong River and the inner Gulf of Thailand. This is caused by the waste water from industrial areas, Bangkok metropolis and agricultural areas in the central plain. Thai government is highly concerned on these problems. For recovery of the water resources management, they implement programs which have been done for a few years under a number of government agencies such as Pollution Control Department, Office of Natural Resources Environment Policy and Planning, Royal Irrigation Department, Bankok Metropolitance Council, and the Local Council.

9.1 Priority reclaimation for waste water management in crisis watershed areas:

9.1.1 Community waste water system management

9.1.2 Agricultural waste water pollution control

9.1.3 Industrial waste water management

9.1.4 Salinity water control management

9.2 control and audit the discharge polluted and waste water from originate sources using the law enforcement together with public participation.

9.3 Supporting the local community and public participation in term of involvement and communication for understanding and knowledge management in waste water control for severe water, agriculture and industrial polluted water.

10. Waste water management target during 2008-2012

Number of bad and worst water quality resources are not greater than 25 areas in 2008
Number of bad and worst water quality resources are not greater than 23 areas in 2009
Number of bad and worst water quality resources are not greater than 20 areas in 2010
Number of bad and worst water quality resources are not greater than 17 areas in 2011
Number of bad and worst water quality resources are not greater than 15 areas in 2012

Source: DWR, 2006