CUMULATIVE EFFECTS ASSESSMENT IN THE PHONG RIVER BASIN

PURPOSE

This case study examines the potential application of cumulative environmental assessment (CEA) as an environmental management tool. Using Thailand's Phong River Basin as an example, limitations of project-specific EIA and inadequacies of conventional approaches to environmental effects monitoring programs are examined. Emphasis is given to the importance of understanding the impacts of multiple anthropogenic activities on the health of riverine aquatic ecosystems in guiding government policy and planning, and regulatory responses.

ETP1 COURSE TOPIC COVERAGE:

- CUMULATIVE EFFECTS ASSESSMENT (CEA)
- ENVIRONMENTAL IMPACT ASSESSMENT (EIA)
- ENVIRONMENTAL SCIENCE IN THE MRB
- ENVIRONMENTAL MONITORING
- CHALLENGES IN APPLYING EIA IN THE MRB
- INTEGRATED RESOURCE AND ENVIRONMENTAL MANAGEMENT (IREM) CONCEPTS AND BENEFITS
- IREM PRACTICAL TOOLS FOR IMPLEMENTATION

ISSUES

Specific issues highlighted in this case study are:

1. Limitations of environmental impacts assessment (EIA) relating to multiple-use water resources
2. Applications of CEA in improving the predictive capability of standard EIA methodologies
3. Application of ERA in improving environmental monitoring programs in support of EIA and CEA
4. Comprehensive assessment of potential environmental impacts in support of policy formulation, environmental planning and decision making
5. Integrated management strategies in responding to complex environmental problems

LEARNING OBJECTIVES

On completion of this case study, participants will be able to:

- Identify limitations of project-specific EIA in assessing potential environmental impacts of industrial operations
- Provide examples of cumulative environmental impacts in the Phong River
- Detail challenges in establishing cause-effect relationships (i.e., specific impacts of a single industry) in a receiving water body which is subject to multiple stresses

- Discuss how scientific uncertainty can limit the predictive capability of EIA
- Characterize the health of the Phong River based in the results of monitoring programs completed to date
- List water use conflicts in the Phong River
- Explain the difference between point-source and non-point sources of contaminants
- Describe the relationship between industry discharge standards and receiving water quality criteria and objectives, and their application in managing aquatic ecosystems
- List and rank contaminant discharges to the Phong River in terms of potential environmental impacts
- Conceptualize potential environmental impacts in the Phong River in terms of stressors and receptors
- Suggest possible ways of controlling and managing contaminant discharges to the Phong River from various sources

PROJECT SUMMARY

Introduction and Background

The Phong River is situated in Khon Kaen province which covers a total area of 10,886 km^2 in northeastern Thailand. The province's population in 1994 was 1,678,546. Its topography is characterized by plateau and mountains in the west giving way in the east to a lowland plain suitable for agricultural.

The Phong River flows for approximately 200 km diagonally from northwest to southeast from Ubonratana district through the Nam Phong and Muang districts. The Ubon Ratana dam located in the middle reach of the river was constructed to create a 2,263.6 million m^3 reservoir for irrigation, electricity generation, and flood protection purposes. Discharges from the dam are controlled to maintain water quality for fisheries, industry, agricultural and drinking water purposes. The Phong River joins the Chi River, a tributary of the Mekong River, southeast of the city of Khon Kaen.

Water Uses and Waste Water Discharges to the Phong River

Widely diverse development activities in the Phong River watershed result in a number of contaminant discharges to the river. The major water uses and waste water discharges to the river are characterized below.

Khon Kaen Municipality

Khon Kaen city is one of twenty-eight municipalities in Thailand's northeastern region and is an important centre for commerce, industry, government and education. Water consumption rates in the municipality are high including both

individual water consumption and use of water in various activities around the city (e.g., 58 schools, 6 universities, 9 hospitals, 3 department stores, 447 restaurants and food shops, 9 theaters and night clubs, 20 hotels, 20 gas stations, 5 markets and 1 slaughter house). The city is serviced by a combined waste water and storm water sewer network and a waste water treatment system. The domestic waste water stream is characterized by high organics and suspended solids loadings.

Industry

A total of 476 Group 3 classification industrial operations currently operate in Khon Kaen province (i.e., based on 1994 figures). Group 3 covers large industries which are likely to cause environmental impacts as compared to Group 1 and 2 industries which use little or no water and are not expected to cause environmental problems. Group 3 industries comprise approximately 10% of all industry in Khon Kaen province. Numerous industries discharging directly to the Phong River in the reach between Ubon Ratana dam and Khon Kaen city constitute a significant source of contaminant loadings as shown in the following table.

INDUSTRIAL TYPE	DISTANCE DOWNSTREAM (km)	WASTE WATER VOLUME (m^3/DAY)	BOD LOADINGS (mg/L)	BOD WEIGHT (kg/DAY)
Pulp & Paper	22.0	12,500[1]	10	125.0
Liquors	38.7	100	(1,350)[3] 31.5	(135) 3.1
Sugar	39.3	250	(26) 20	5.0
Milk Products	78.0	3	1,345	4.0
Cleaning & Dying	88.0	30	(4) 146	4.4
Tapioca Flour	88.0	2,400	(36.6) 62.3	149.5
Khon Kaen WWTP[2]	141.0	25,000	20	500.0

[1] Maximum allowable discharge volume of BOD by Phoenix Pulp & Paper at 10mg/L BOD limit
[2] Municipal waste water treatment plant (WWTP)
[3] Amounts in brackets represent actual results for one sampling event

With the exception of biochemical oxygen demand (BOD) loadings, limited data is available for industry-specific contaminant characteristics. Environmental assessments have been completed for four industries in Khon Kaen province: (i) Phoenix Pulp and Paper; (ii) Mitr Phu Wieng Sugar – Power Generation Project; (iii) Petroleum Authority of Thailand – Nam Phong Natural Gas Sulphur Removal Unit Construction Project; and (iv) Khon Kaen Industrial Estate. Of these operations, only Phoenix Pulp and Paper is a major discharger into the Phong River.

Some insights into contaminant loadings into the Phong River can be gained from examining Phoenix's production process. Raw materials used in their pulp production are bamboo, eucalyptus and fibre crops at volumes of 250,000, 170,000 and 15,000 tonnes/year, respectively. Approximately 250-300 tonnes of paper pulp is produced daily at the plant, averaging 100,000 tonnes per year. Water consumption at the plant is 56,400 m^3/day with input water being pumped from the Phong River. Chemicals used in pulp production include salt cake, caustic soda,

chlorine, chlorine dioxide, lime, sulphur, sodium sulphate, sodium hexa meta-phosphate, defoamer, and hydrochloric acid. Solid and liquid wastes generated during the pulp production and associated processes are summarized in the following table.

PRODUCTION PROCESS	WASTE PRODUCTS
1. Raw Material Preparation (a) dry debarking of wood, (b) wet debarking of wood, (c) chip washing, (d) wet treatment of bagasse, (e) wet cleaning of rice straw, (f) dry cleaning of rice straw	Bark, fibre, dust, noise, waste water, particulates
2. Pulping (a) boiling in chemical mix of Na_2S and NaOH, (b) blow tank, (c) screening, (d) washer	Hydrogen sulphide (H_2S), Mercaptan, heat, noise, waste water, BOD, suspended solids (SS), colour
3. Oxygen Delignification	Waste water, BOD, SS, colour
4. Chlorine Bleaching	Waste water, Cl_2 compounds, particulates
5. Sheeting	Waste water, SS, particulates
6. Drying	Heat, odour
7. Chemical Recovery black liquor evaporator, (b) smelt dissolving tank, (c) lime slaker, (d) screening, (e) clarifier, (f) lime mud washer/filter, (g) lime kiln	Black liquor condensate and sludge, H_2S, Mercaptan, waste water, SO_2, NO_X, CO, H_2SO_4, lime dust, heat
8. Bleaching Chemical Production (a) chlor-alkali plant, (b) HCl synthesis plant, (c) ClO_2 production plant, (d) SO_2 plant	Cl_2, HCl, ClO_2, SO_2, H_2SO_4

Agriculture

Most of the population in Thailand's northeastern region are farmers. Crop agricultural is a primary activity in the Chi and Phong river basins covering approximately 332,435 hectares or 77.84% of the land area in the districts of Muang, Nam Phong , Nong Song Hong and Phu Wieng. Chief economic crops are tapioca, sugar cane and fibre plants. Livestock agriculture is mainly confined to pig farming with a pig population in Muang and Phong districts of 13,221 and 6,942, respectively.

Agricultural activities are a major water consumer in the Phong River basin with the Ubon Ratana reservoir and the smaller Nong Wai irrigation dam and associated irrigation weir being used to divert water to agricultural areas. Crop agricultural waste water is characterized by high loadings of chemical fertilizers and pesticide residues. In addition, processing of sugar cane into sugar produces high BOD loadings. Waste water from livestock-raising activities such as pig farming is characterized by high BOD, solids, and fecal coliforms.

Status Report on Environmental Quality in the Phong River

The Phong River has been regarded as the most polluted river in the northeastern region of Thailand since 1992. Frequent fish kills in the river are suspected to be linked to: (i) releases of sugar dregs and waste water characterized by high sugar content; (ii) run-off from crop agriculture containing chemical fertilizers which cause eutrophication in the river; and (iii) effluent discharges from pulp paper operations. Of these, the Phoenix Pulp and Paper plant has received the most attention – although the Thai industrial effluent quality standard for industry is not more than 20 mg/L BOD, Phoenix is required to achieve the more stringent standard of 10 mg/L BOD.

Responsible agencies have responded to concerns about degraded water quality in the Phong River by undertaking a comprehensive monitoring program. Monitoring results from 1993 to 1997, corresponding to the three sub-reaches of the river downstream from the Ubon Ratana dam, are summarized in the following sections.

Upper Reach – Ubon Ratana Dam to Nong Wai Weir

Water quality in the Phong River immediately downstream of the Ubon Ratana dam is generally low (i.e., approximately Category 3 to 4 according to the Thai Surface Water Quality Standards). In this reach, the river is deep and slow flowing, particularly at the Bung Chode swamp and in front of the Nong Wai irrigation dam. Storage of water behind the Nong Wai dam for irrigation purposes results in a lowering of dissolved oxygen in the river. Numerous waste water discharges to the river, including paper pulp effluents and municipal sewage discharges, also contribute to poor water quality. Major water uses in the upper reach of the Phong River and monitoring results showing overall impacts to water quality and the health of aquatic ecosystems are summarized in the following table.

WATER USES	MONITORING RESULTS
<u>Ubon Ratana Dam</u> <u>Industry</u> Phoenix Pulp and Paper (125 kg/d of BOD loading) <u>Municipal</u> Ubon Ratana dam municipality (77 kg/d BOD loading) Nam Phong municipality (150 kg/d BOD loading) Ubonratana district (17 kg/d BOD loading) <u>Agriculture</u> Irrigation water use and run-off from approximately 20,000 ha of Eucalyptus, sugar canes, fibre crops, beans, sweet potatoes and water melons	1. Water quality in Phong River is generally Category 3 except near the dam, Chode swamp, and the Nong Wai weir where lower Category 3-4 conditions are observed. 2. Dead fish were found from Ban Nong Taa to Kam Bon. The dissolved oxygen (DO) was very low (< 2mg/L), and suspended solids were very high during rainy season. 3. Dead fish were also found in front of the Nong Wai weir. DO was usually lower than 2 to 3 mg/L 4. The fishery in this reach is characterized by low productivity.

Middle and Lower Reaches – Nong Wai Weir to Mahasarakarm Weir

Water quality in the Phong River downstream of the Nong Wai weir has been generally low (i.e., Category 4) over the two years. Contributing factors are waste water discharges and run-off from municipalities, industry and pig farms located along the middle and lower reaches of the river. In addition, flow is disrupted by raising of water levels by the Mahasarakarm weir for irrigation purposes as the Phong River joins the Chi River. Waste water from Khon Kaen municipality is considered the main contaminant input to the lower reaches of the Phong River. Water quality results for the Huai Phra Krue which carries waste water from the municipality to the river indicated very poor water quality (i.e., under Category 5).

Major water uses and corresponding impacts, as indicated by monitoring results, for the middle reach of the Phong River from the Nong Wai weir to Ban Na Pieng village are summarized in the following table.

WATER USES	MONITORING RESULTS
Industry Mahasin Liquor Factory (2 kg/d BOD loading) Khon Kaen Sugar Factory MDF Plywood Factory Khon Kaen Tapioca Flour Factory (discharge to Huai Yai stream connecting to Phong River)	Waste water discharged from liquor and sugar factories may cause water pollution. Water samples from Huai Yai stream contained 20 mg/L BOD, 5.4 mg/L NO_3-N, and 121 mg/L suspended solids. Contaminant sources are likely the flour factory and illegal dumping.
Municipal Wang Chai municipality (138 kg/d BOD loading) discharging to Huai Chan pond Rim Nam village, Nam Phong district (21.4 kg/d BOD loading)	No direct effects from municipal discharges have been observed. Combined agricultural and municipal discharges are possibly linked to problems found at Ta Kraserm village by social/public heath investigation (e.g., dead ducks and fish, bad odour, high suspended solids, skin irritation following bathing in river, high algae).
Agriculture Cantaloupe growing Planted crops (sugar canes, rice, soy beans, vegetables and fruits) Pig farming, livestock (at Hai Sok village, Nam Pong district)	Eutrophication observed in Tung Teao pond and low DO (i.e., 0.7 – 14.7 mg/L) thought to result from high nutrient loadings from agriculture. Insecticides, pesticides and chemical fertilizers are widely used in agricultural. Run-off from pig farms is a problem.

Major water uses and monitoring results showing impacts to water quality and the health of aquatic ecosystems in the lower reach of the Phong River from Ban Na Pieng to the Mahasarakarm weir are summarized in the following table.

WATER USES	MONITORING RESULTS
Small Industry Brick factories at Coke Si village and Ta Hin village Noodle factories at Yang Yong village, Muang district Sausage factories Municipal Rim Nam village, Muang district (26.3 kg/d of BOD loading) Khon Kaen municipality (1,804 kg/d of BOD loading before treatment and discharge) Agriculture Mostly vegetable plantations near the river.	1. Overall fair water quality except at Huai Pra Krue (i.e., 2.2 mg/L DO, 6.6 mg/L BOD, 50 mg/L COD and 0.07 mg/L Pb). 2. Dense water hyacinth growth along river. 3. Litter accumulations observed. 4. Waste water drains from garbage trucks into river. 5. Water is not suitable for bathing.

Overall Environmental Quality Conditions in the Phong River

Monitoring results indicate that the fair to poor water quality observed in the Phong River may be impacting aquatic ecosystems. Sampling of fish populations in the river from the Ubon Ratana dam to the Mahasarakarm weir showed that fisheries resources are generally poor. Few economically important fish species were caught. The majority of species inhabiting the river are non-economically important species such as *Anabas testudineus*, *Trichopsis pumila*, *Trichogaster tricopterus*, *Trichogaster pectoralis*, *Channa etriata* and *Channa lucius*. Planktivorous fish such as *Rosbora borrapetensis*, *Crupeichthys* spp. and *Trichopcis pumila* were also found to be abundant. The forage to carnivore ratio in the Phong River is considered lower than normal.

The observed low dissolved oxygen levels in the Phong River are highly likely to be negatively affecting fish populations. Flowing waters suitable for fish should have DO higher than 4 mg/L but DO concentrations in the Phong River were consistently lower than 3 mg/L.

SITE VISIT METHODOLOGY

Course participants will have an opportunity to learn more about the cumulative effects of industry and other human activities on environmental quality in the Phong River during a site visit. The expected duration of the site visit is two days and will include tours of: (i) the Ubon Ratana dam and power plant; (ii) Phoenix Pulp and Paper; (iii) Khon Kaen Sugar; (iv) agricultural operations; and (v) municipalities. Participants will be accompanied during the site visit by knowledgeable resource persons who can answer questions about ongoing monitoring in the Phong River, and management and regulatory responses.

Participants will be organized into small groups for the site visit. Although each group will be expected to work independently, all groups will be asked to complete the following tasks:

- Assess whether fish populations, as a valued ecosystem component, in the Phong River are being significantly affected by existing water quality conditions
- Describe how best to undertake a CEA to assess potential water quality conditions and identify contaminant sources of concern
- Construct a conceptual model of contaminant fate and effects in the Phong River
- Discuss mitigation needs and follow-up measures to be taken by regulatory agencies to remedy observed problems
- Propose an environmental effects monitoring (EEM) program for the Phong River

On completion of the site visit, small groups will be asked to present their findings to the class with emphasis on the practical lessons learned by participants which reinforce EIA and CEIA theory taught in the course.

TAKE HOME MESSAGES

Anticipated lessons learned by the course participants in completing the case study and site visit might include:

1. Recognizing the need to consider potential environmental impacts on a broader scale in managing natural resources. Currently, few EIA's completed in developing countries adequately assess impacts from the activity or project being assessed and rarely look at incremental impacts on receiving environment's already subject to other stress. Moreover, EIA are commonly undertaken for a relatively small subset of activities and generally do not include small and medium size industry, municipal waste water discharges, and agricultural operations.
2. Clearly stated valued environmental components (VEC) and protection benchmarks should be the starting point for environmental assessment and monitoring. Unless environmental managers, regulators and the public know what they are trying to conserve and protect and what degree of protection is sought then it is difficult to evaluate the severity of environmental impacts and the success of management responses. Establishment of water quality objectives for receiving water bodies corresponding to valued water uses (e.g., drinking, irrigation water, recreational contact, fisheries protection, aesthetic) provide a benchmark against which monitoring results can be compared, assessments of severity of observed impacts judged, and appropriate regulatory and remediation responses considered.
3. Assessment of cumulative impacts is challenging even for experienced EIA practitioners. Receiving water bodies such as the Phong River which receive multiple contaminant discharges from both point and non-point sources are complex to assess. Information gaps due to insufficient monitoring and a lack of understanding of ecosystem responses to contaminant loadings makes it very difficult to distinguish impacts caused by single projects or activities or to predict incremental impacts of proposed new projects. Integrated assessment

tools such as ERA and environmental effects monitoring (EEM) are increasingly being developed and applied by scientists and environmental managers to better understand and respond to cumulative impacts.

4. Integrated planning and policy responses are necessary to effectively address cumulative effects at a basin management level. A multi-faceted response to responding to cumulative impacts might include: (i) more stringent enforcement of existing regulations to minimize additional impacts from known polluters; (ii) requiring EIAs for polluting operations such as municipal waste water treatment plants which may not presently be subject to assessment; (iii) promotion of best management practices to minimize non-point source pollutant loadings such as run-off from pig farms and agro-chemicals in crop agriculture; and (iv) introduction of new requirements to consider cumulative impacts in all environmental assessments.

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