

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This investigation is a study of the integrated ecological approach for sustainable watershed management: a case study on Phetchaburi Watershed management, Thailand.

Ecological condition of subsystems

This study is based on an ecological approach for sustainable watershed management. The study divides Phetchaburi Watershed into three subsystems, subsystem I upstream of the Phetchaburi Watershed; subsystem II, Kaeng Krachan Reservoir; subsystem III, downstream from Kaeng Krachan reservoir to the river mouths. The geography and land use of each subsystem are different, so the effects of land use can change the conditions in each subsystem. The study indicates that the existing conditions in the three subsystems are different. The ecological parameters in the three subsystems are showed in Table 5.1

Subsystem I is the upstream area with forest covered that is legally protected under Kaeng Krachan National Park. There are about 300 agricultural households along the river. The ecological conditions have a trend to be imbalance because the input of ecological indicators is less in correlation to ecosystem function than the output of the system. It obviously indicated that there are high soil erosion and nutrient loading. In addition, the agricultural activities in the subsystem I cause an increase in nutrient concentration in the tributaries. As a result, there was phytoplankton bloom occurring at the end of tributaries that merge into the Kaeng Krachan Reservoir.

Subsystem II, the Kaeng Krachan Reservoir is a lentic ecosystem. The reservoir receives nutrient loading from upstream. There are many agricultural areas and about 200 households surrounding the reservoir. Then, the high nutrient content, combined

with the lentic ecosystem leads to phytoplankton growth. Subsystem II is a balanced system because the input of the subsystem is equal to the output of the system. Apparently, high primary production and blooms of toxic phytoplankton occurred in the wet season.

Table 5.1 Some ecological parameters of three subsystems on Phetchaburi Watershed

Ecological parameters	Subsystem		
	Subsystem I	Subsystem II	Subsystem III
	Minimum-Maximum	Minimum-Maximum	Minimum-Maximum
Transparency depth (m)	0.30 - 1.85	0.90 - 2.50	0.20 - 2.85
Water temperature (°C)	23.4 - 32.0	23.8 - 32.0	21.5 - 34.0
pH	6.4 - 7.9	7.0 - 8.5	5.9 - 7.9
Dissolved oxygen (mg/l)	5.4 - 8.8	4.8 - 8.2	2.8 - 9.8
Salinity (psu)	ND	ND	ND - 27.0
Suspended solid (mg/l)	0.6 - 20.2	0.1 - 12.7	0.2 - 181.4
Ammonium-nitrogen (ug/l)	ND - 9.76	ND - 47.02	ND - 166.76
Nitrite-nitrogen (ug/l)	0.23 - 3.32	ND - 2.24	0.04 - 87.63
Nitrate-nitrogen (ug/l)	0.35 - 110.06	ND - 34.02	ND - 199.20
Phosphate-phosphorus (ug/l)	0.00 - 26.84	ND - 10.44	ND - 132.52
Silica-silicon (mg/l)	2.78 - 14.15	1.80 - 13.50	0.37 - 24.93
Chlorophyll <i>a</i> content (mg/m ³)	0.35 - 20.85	7.28 - 42.40	0.35 - 123.06

Subsystem III lies downstream from Kaeng Krachan Reservoir towards the river mouths, varied in types of land use. Considering the whole subsystem, subsystem III is imbalance because the input of the subsystem is less than the output. Furthermore, the areas at the two river mouths and the estuary usually have phytoplankton blooms.

The study found that the chlorophyll *a* concentration can be a useful ecological parameter for monitoring the health of the whole watershed. Furthermore, nitrate – nitrogen concentration, suspended solid and the dominant of phytoplankton group or species can be considered together for assessing the existing condition in each watershed subsystem.

Table 5.2 The Surface Water Quality Classification and trophic status of the three subsystems on Phetchaburi Watershed

Area boundary in the study	Distance from the river mouth	Standards of Surface Water Quality Classification of Thailand	Trophic status
Subsystem I (upstream)	Head watershed (120 – 210 km)	1	Oligotrophic
	The upper end of Kaeng Krachan Reservoir (120)	2	Mesotrophic-Eutrophic
Subsystem II	Kaeng Krachan Reservoir	2	Mesotrophic-Eutrophic
Subsystem III (Downstream)	Phetchaburi Dam to Kaeng Krachan Reservoir (61 – 118)	2	Mesotrophic
	River Mouths to Phet Dam (0 – 61)	3	Mesotrophic-Eutrophic

The study can classify the categories of the surface water quality and the trophic status of the whole watershed that are showed in Table 5.2. Based on the standard surface water quality of Thailand, the water in the reservoir was classified to be of the second to third category and was relatively suitable for fisheries and water supplies when properly treated. However, by the trophic level, the lotic ecosystem of inland can be classified as an oligotrophic-mesotrophic level, the Kaeng Krachan Reservoir can be classified as a mesotrophic-eutrophic lake and the two river mouths can be classified as a mesotrophic eutrophic level.

Thus, there is general support of **Hypothesis I**, *'Each subsystem has different ecological conditions'*.

Integrating ecological and socio–economic indicators in relation to land use pattern.

The study analyzed the ecological conditions of each subsystem. The surveys for the socio – economic indicators were carried out, using questionnaires to interview 409 respondents who live in each subsystem. All data was analyzed and then integrated with land use patterns, based on land uses of Phetchaburi Province. The study has improved the conceptual plan for sustainable management in Phetchaburi Watershed (Figure 5.1).

General Policy

1. Policy should be responsible and be understandable when put into action. Additionally, there should be a specific policy for each subwatershed and the policy of water resource should consider in term of both quality and quantity. Also, the regulations in practice should conform to other policies of other natural resources, which are situated in the watershed. Any regulations or standards should consider all kinds of living organisms in the watershed ecosystem.
2. The data for watershed management plan should be updated and cover all the basin area, especially all data should be systemically collected in the watershed boundary. At present, the information is still scattered in many government agencies from central offices to provincial offices, which leads to inefficiency data utilization for better management.
3. All government agencies, responsible for land use, should employ and integrate information based on a holistic approach. Good policy and regulations should be understandable, practical and easily and frequently assessed.

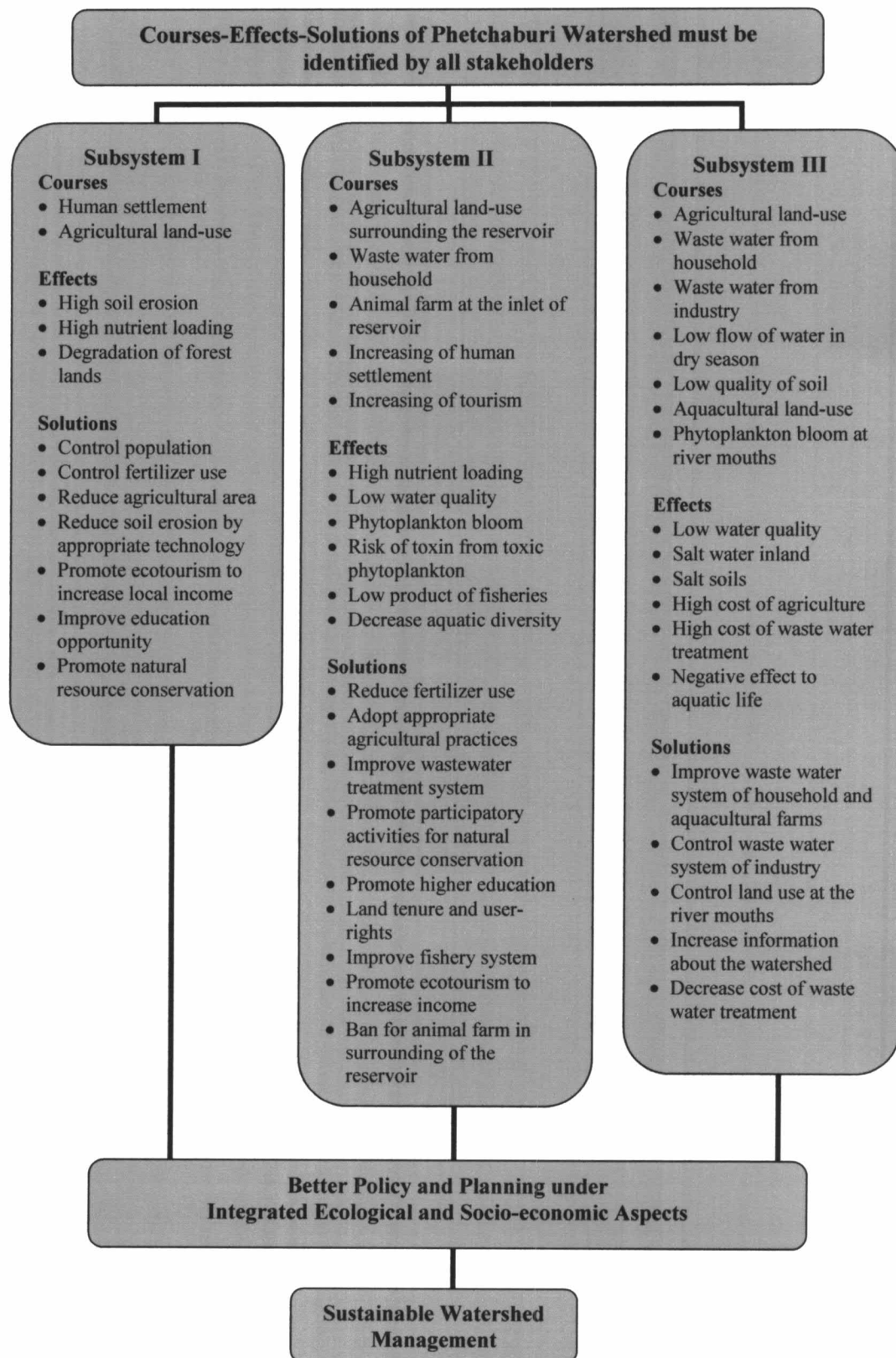


Figure 5.1 Conceptual plan for sustainable watershed management

4. Water Management Division should gather basic data and coordinate with other organizations that work within Phetchaburi Watershed management. Expectedly, the completed data be useful sources of knowledge for providing and better appropriate suggestions to all stakeholders
5. Policy should persuade public participation among all stakeholders. This will create good cooperation in practice among government sectors and private sectors.
6. Policy should support all natural resource conservation activities that exist at all school levels. For example, teachers should add activities into school lessons or have extracurricular activities during class time in order to create concern and awareness on nature conservation of Phetchaburi watershed to students.
7. Policy should support private organizations, which already work on projects in local areas and coordinate them in terms of providing adequate information and sharing ideas of management for harmony in practice.

Specific policy for each subsystem

Subsystem 1 (upstream of the Phetchaburi Watershed)

- 1.1 The officers of Kaeng Krachan National Park should strictly regulate and control the use of chemical fertilizers and pesticides in the agricultural areas that are located upstream of the reservoir.
- 1.2 Land use related organizations should be educated and have more ability to conduct appropriate agricultural activities to local people and find suitable methods to reduce soil erosion problems due to the high slope in this area.

Subsystem 2 (Kaeng Krachan Reservoir)

- 2.1 At present, areas of Kaeng Krachan Reservoir are legally claimed-ownership by the National Park and local people. Therefore, responsible organizations

should cooperate in regulating the use of land appropriately, especially when the land is used for agriculture and animal husbandry.

- 2.2 Wastewater management regulations need to be set up properly, such as septic tank for holding wastewater discharged from households, and prohibiting of discharged wastewater directly into the reservoir.
- 2.3 Since this reservoir is a part of a tourist area in the Kaeng Krachan National Park, the park ranger should provide more adequate information on how to visit and to do activities in the park appropriately to all stakeholders such as tourists and local stalls or merchants in the park.
- 2.4 The schedule of water regulation control from Kaeng Krachan Reservoir should conform and cooperate to Phetchaburi Dam to reduce problems of seawater intrusion into the river.

Subsystem 3 (downstream from Kaeng Krachan Reservoir to the river mouths)

- 3.1 The changes in Mae Prachan sub-watershed need to be considered more closely because the water level of Mae Prachan River declined dramatically in the dry season. Now the Mae Prachan Reservoir has been constructing at its head water. Moreover, this sub-watershed has a high content of suspended solid, which might change the river conditions and harm the river ecosystem in the future.
- 3.2 The information for wastewater management should be provided to all local communities. In the meanwhile, the law for wastewater treatment should be strictly emphasized with the entrepreneur.
- 3.3 At the surrounding area of Ban Laem and Bang Taboon river mouths, the wastewater treatment projects and solid waste management projects should be conducted by local people in these areas, especially in aquacultural areas.

Thus, the conceptual plan is in general support for **Hypothesis II**, *'Integrating ecological and socio – economic indicators in relation to land use patterns can improve the conceptual plan for sustainable management in each subsystem'*.

5.2 Recommendations

Expected Outcomes:

The finding of this research, a sustainable watershed management plan of Phetchaburi Watershed will give direct benefit to this watershed. This study also provides new alternatives of whole-system thinking in watershed management by showing major concerns on the concept of ecological approach and can improve the quality of the watershed in the future. It will be useful for decision-making of sustainable watershed management plans in Thailand. The recommendations of this study are as the following:

1. It should increase environmental concern and awareness on watershed conservation among all stakeholders in the community up to governmental level.
2. It should leave monitoring process on the ecological condition in the watershed annually.
3. It should stimulate and support all stakeholder who have a duty or involvement in carrying out the environmental conservation of the watershed by promoting a participatory approach among all stakeholders, not only at local levels but also at national levels.