SUSTAINABLE INDICATORS OF WATER RESOURCES DEVELOPMENT PROJECTS IN CONSERVATION AREAS, THAILAND

UDOMSOOK SURACHARTTUMRONGRAT

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UDOMSOOK SURACHARTTUMRONGRAT
The Graduate School of Environmental Development Administration

..... Major Advisor
(Professor Chamlong Poboon, Ph.D.)

..... Co-Advisor
(Assistant Professor Karika Kunta, Dr.sc.ETH Zurich)

The Examining Committee Approved This Dissertation Submitted in Partial Fulfillment of Requirements for the Degree of Doctor of Philosophy (Environmental Management).

..... Committee Chairperson
(Associate Professor Samakkee Boonyawat, Ph.D.)

..... Committee
(Associate Professor Chutarat Chompunth, Ph.D.)

..... Committee
(Professor Chamlong Poboon, Ph.D.)

..... Committee
(Assistant Professor Karika Kunta, Dr.sc.ETH Zurich)

..... Committee
(Assistant Professor Napong Nophaket, Ph.D.)

ABSTRACT

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Author	Mr. UDOMSOOK SURACHARTTUMRONGRAT
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Water resources development in Thailand is essential due to high variation of hydrologic regime, responsible agencies have to sufficiently provide good quality raw water for basic needs including water supply, agriculture, as well as industrial and other uses. Development of a water reservoir is one of efficient measures even some limitations. Unfortunately the appropriate locations of potential reservoirs are mostly located in natural resources conservation area where natural resources and ecology are in good condition which can lead to conflicts of interest between the agencies responsible for water resources development and those in charge of natural resources conservation. Despite state laws and policies specify to promote sustainable and environmentally friendly water resource development, specific guidelines and standards for quantity-based consideration of sustainability together with balance between resources development and conservation of a potential project have not been defined in detail.

Consequently, quantitative criteria to establish a sustainable water resource development indicators, applying the principles of self-sufficiency economic, transitioning from extremely benefit-based development with high corresponding impacts into a moderate way with self-sustaining development, will ensure that future water resource projects are sustainable in all aspects and can be carried out successfully and effectively.

The study of the sustainable indicators for water resource development is a qualitative research conducted by reviewing related documents such as referenced from relevant researches, governmental agencies' regulations and announcements, interviewing experts and using the Del Phi method. The Del Phi's panel comprises

selective 20 experts from various related fields, both from government agencies and independent academics. These experts provided their opinions on main dimensions, important factors, key indicators, corresponding weight factors and scoring ranges of the indicators. Data analyzed for proposed indicators scoring ranges were compiled from data in environmental impact assessment reports of 30 reservoir development projects.

The study results indicated that the relative importance weighting of the four dimensions to be considered were: engineering (20%), natural resources and environments (35%), society (25%), and economics (20%). This research identified 14 main factors of which 7 factors having high significance, including 1) wildlife, 2) forests, 3) ecology system, 4) number of impacted people, 5) quality of life, 6) feasibility, and 7) social opposition. These 14 factors comprise a total of 29 key indicators, with 12 highly significant indicators including 1) uniqueness, 2) number of opponents, 3) affected water quality, 4) annual cultivated area per reservoir capacity, 5) design flood rate per reservoir capacity, 6) environmental economic feasibility, 7) economic feasibility, 8) proportion of beneficiaries on sufferers, 9) conservation area type, 10) No. of evacuated households per reservoir capacity, 11) endangered wildlife, and 12) bio-diversity of wildlife. In addition, total sustainability scoring ranges of each dimension as well as overall project be defined as very good level when greater than 75%, good level at >65-75%, moderate level at >55-65%, moderate low level at 45-55%, and low level for less than 45% respectively. A project that providing total all dimensions scores in good level and each dimension scores not less than moderate level would be appropriate for further consideration among the concerning government agencies. Furthermore, in case of the project area experienced frequent and severe draught hard, the sustainability level could be allowed to be lessen from good to moderate level. Consequently, additional group of indicators verifying water scarcity level of the target area are considered in parallel with the sustainable indicators. The results summarized that five key factors namely geographic, level of existing development , hydrologic variation, water demand, and poverty play significant effects to the water scarcity level with respectively weightage of 20 : 15 : 20 : 20 : 25. Finally, recommendations of applying project indicators to improve project sizing scale and

project components, or alternate reservoir location, would result better sustainability and less impacts to conserved natural resources and social dimensions.

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UDOMSOOK SURACHARTTUMRONGRAT

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TABLE OF CONTENTS

Page

ABSTRACT iii
ACKNOWLEDGEMENTS vi
TABLE OF CONTENTS vii
LIST OF TABLES xiii
LIST OF FIGURES 1
ABBREVATIONS 1
CHAPTER 1 INTRODUCTION 1
1.1 Background and Significance of the Study 1
1.2 Research Question 3
1.3 Objectives 3
1.4 Definitions 4
1.4.1 Sustainable Development: 4
1.4.1.1 Geography and engineering dimension 6
1.4.1.2 Natural resources and environment dimension 6
1.4.1.3 Society dimension 6
1.4.1.4 Economy dimension: 7
1.4.2 Water Development Projects 7
1.4.3 Conservation Areas 8
1.4.4 Biodiversity 8
1.4.5 Carrying Capacity 8
CHAPTER 2 LITERATURE REVIEW 9
2.1 Laws Pertaining to the Rights and Responsibilities of Citizens and the State in the Development and Conservation of Natural Resources 10
2.1.1 Constitution of the Kingdom of Thailand, B.E.2560 10
2.1.2 National Reform Plans on Natural Resources and Environment 12

2.1.3 Strategies for Utilization and Conservation of Natural Resources and River Basin Management 13

2.1.3.1 The 20-Year National Strategy (B.E.2561-2580) for promoting growth in the quality of life that is environmentally friendly (Strategy 4.5) 14

2.1.3.2 Natural resources and environment ministry's 20-year strategic plan (B.E. 2561- 2580)…… 15

2.1.3.3 Ministry of agriculture and cooperatives' s 20-year strategy (B.E.2561-2580)…… 17

2.1.3.4 The Royal Irrigation Department's 20-year strategy (B.E. 2561-2580)……19

2.1.4 Natural Resource and Environmental Management Master Plan 20

2.1.4.1 Master plan in accordance with the 20-year Strategy of the Ministry of Natural Resources and Environment (B.E.2561-2580)…….. 20

2.1.4.2 Biodiversity management integration plan (B.E.2558-2564) 21

2.1.4.3 Water resources management master plan for 20 years (B.E. 2561-2580)…….. 22

2.1.5 Natural Resource, Environmental, and Water Resource Operation Plans23

2.1.5.1 The 12th National economic and social development plan (B.E.2560-2564) 24

2.1.5.2 The Environmental Quality Management Plan for the Years B.E.2560-2565.....24

2.1.5.3 Biodiversity Management Action Plan, B.E.2560-2564 26

2.2 Relevant Legislation for Natural Resource Conservation and Environmental Protection.....28

2.2.1 Legislation Related to Natural Resource Conservation 28

2.2.1.1 National Reserved Forest Act of B.E.2559 (Version 4) and B.E.2507 28

2.2.1.2 National Parks Act of B.E.2562 29

2.2.1.3 Wildlife Reservation and Protection Act B.E.2562.....31

2.2.2 Relevant Legislation on Water Resource Development, Conservation, and Management 34

2.2.2.1 Water Resources Act of B.E.2561 34
2.2.3 Relevant Royal Acts on Environmental Promotion and Conservation 39
2.2.3.1 National Environmental Promotion and Conservation Act of B.E.2561. 39
2.3 Government Agencies with the Objectives of Water Resources Development 45
2.3.1 Government Agencies with the Objectives of Developing and Managing the Utilization of Water Resources 45
2.3.2 Regulatory agencies in the water sector 48
2.3.3 Water project coordination units 49
2.4 Study Standards for Developing Water Resource Development Reports 50
2.5 Reviewing the Sustainability Indicator of Natural Resources, Water Development, and Water Resources Management 54
2.6 Guidelines of EIA Report Preparation for Water Resource Development Projects by the ONEP, B.E 2566 64
2.7 Indicator Development Framework 67
2.7.1 Connectivity of Sustainable Indicators to Sustainable Development Goals 68
2.7.2 Indicator Development Method of the National Statistical Office 75
2.8 Conclusion 75
CHAPTER 3 RESEARCH METHODOLOGY 78
3.1 Introduction 78
3.2 Conceptual Framework 79
3.2.1 Framework for Identifying Key Dimensions and Factors Affecting the Sustainability of Water Resources Development 79
3.2.2 Framework for Identifying Factor Assessing Water Scarcity Level 80
3.3 Research Design: 81
3.3.1 Study procedures 81
3.3.2 Data Collection and Review 83
3.3.3 Establishment of Key Informants 85
3.3.4 Research Tools 88
3.3.5 Data Reliability Verification 88

3.4 Data Analysis....89
CHAPTER 4 RESULTS AND DISCUSSION....91
4.1 Establishment of the 1st Draft Indicators....91
4.1.1 The Results of Literature Review of Legislation....92
4.1.1.1 Constitution of the Kingdom of Thailand, B.E.2560....92
4.1.1.2 National Reform plans on natural resources and environment....92
4.1.1.3 Strategies and plans for utilization and conservation of natural resources and river basin management....93
4.1.2 Relevant Legislation for Natural Resources Conservation and Environmental Protection....93
4.1.2.1 Legislation related to natural resource conservation....93
4.1.2.2 Relevant legislation on water resource development, conservation, and management....94
4.1.2.3 Relevant acts on Environmental promotion and conservation....94
4.1.3 Government Agencies Responsible for Development and Management of Water resources....95
4.1.3.1 Operation agencies for development and management of water resources....95
4.1.3.2 Regulatory agencies in the water sector....96
4.1.3.3 Co-ordination agencies of the royal resources development Office of the Royal Development Projects Board (ORDPB)....96
4.1.4 Guidelines for Preparing Feasibility Reports of Water Resource Development Project....97
4.1.5 Literature on Sustainability Indicators of Natural Resources, Water Resources Development, and Water Resources Management....97
4.1.6 Conclusion of the First Draft of Sustainable Indicators....104
4.2 Development of the 2nd Draft Indicators....109
4.2.1 Results of In-Depth Interviews....109
4.2.2 Conclusion of the in-depth interview are as follows:....114
4.2.3 Results of Indicators from EIA Reports....115

4.2.4 Results From Research Studies, Documentations, and Announcements of Related agencies 131
4.2.5 Results from Review of Water Resource Development Necessity or Water scarcity 131
4.2.6 Results of the 2nd Draft of Sustainable Indicators and Ranging Scores . 132
4.2.6.1 Sustainable indicators of the water resource development projects 132
4.2.6.2 Factors and indicators of the assessment of water scarcity level 149
4.3 Development of the Final Indicators 154
4.3.1 Results of the Del Phi's First-Round Questionnaire 154
4.3.1.1 Section 1: Evaluation of weightings for dimensions, factors, and indicators of project sustainability 154
4.3.1.2 Section 2: Establishing criteria for sustainability ratings in dimensions 177
4.3.1.3 Summary of the assessment of water scarcity or necessity of water source development 177
4.3.1.4 Summary of clarification to additional comments from the first questionnaire response of the Del Phi panel (June-July 2023)... 184
4.3.2 Results of the Del Phi's Second Round Questionnaire 193
4.3.2.1 Results of weighting factor of sustainability indicators 193
4.3.2.2 Results of project's water scarcity level or water resources development necessity 195
4.3.2.3 Conclusion of the final indicators 196
4.4 Application of the Developed Sustainability Indicators 200
4.5 Application and verification with 30 reservoirs projects can be summarized as follows: 228
CHAPTER 5 CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS 231
5.1 Conclusions 231
5.1.1 Development of the 1st Draft Indicators 232
5.1.2 Development of the 2nd Draft Indicators 237
5.1.3 Final Sustainable Indicators From Del Phi 247

5.1.3.1 Results of the sustainability indicators of water resource development projects in the conservation areas. 247
5.1.3.2 Results of the indicators of water scarcity level of the proposed project area. 247
5.2 Discussion.....248
5.2.1 Indicators for Water Resources Development.....248
5.2.2 The Advantage of the Developed Indicators.....252
5.2.3 Compliance to Indicator Development Method 253
5.2.4 Compliance to Sufficient Economy Philosophy 256
5.2.5 Project Enhancement for Sustainability 257
5.2.6 Application of Relationship Between Engineering and Economic Data 258
5.3 Recommendations 260
5.3.1 Recommendations from Study Results 260
5.3.2 Recommendations for Further Studies 262
5.4 Limitations of the Study 263
BIBLIOGRAPHY.....264
APPENDICES 268
Appendix A Data Summary of 30 Water Resource (reservoir) Development Project 269
Appendix B Data Summary of Water Scarcity Factors and Other Related Maps .288
Appendix C Classification of Project Indicators' Scoring Ranges.....300
Appendix D Questionnaire 313
Appendix E Indicator's Sustainability Levels in Various Dimensions 358
Appendix F Multiple regression of EIRR and engineering indicators 389
BIOGRAPHY 393

LIST OF TABLES

Page

Table 2.1 Goals, Targets and Indicators of Sustainable Development Related to Sustainable Consumption and Production Indicators 69

Table 3.1 Summary of Data Collection, Tools, and Analysis Methods..... 84

Table 4.1 List of Indicators in Previous Related Studies..... 99

Table 4.2 Summarized Indicators Referenced from Concerned Research Studies and Those First Draft Indicators Selected for the Study Classified by Dimensions and Factors..... 102

Table 4.3 Selection of the 1st Draft Indicators Concerning Water Resources Development According to Literature Review by Dimensions and Factors 106

Table 4.4 Summary of In-Depth Interview's Suggestion on Sustainable Indicators Consideration 110

Table 4.5 Engineering Data of 30 Reservoir Projects..... 116

Table 4.6 Natural Resources and Environment Data of 30 Reservoir Projects (Forest)..... 117

Table 4.7 Natural Resources and Environment Data of 30 Reservoir Projects (Wildlife)..... 119

Table 4.8 Social Data of 30 Reservoir Projects 121

Table 4.9 Economic Data of each 30 Selective Projects..... 124

Table 4.10 Stage of Indicators Establishment..... 129

Table 4.11 Selected Project Sustainable Factors and Indicators with Scoring Ranges Applied..... 147

Table 4.12 Summary of Water Scarcity Factors and Indicators with Scoring Ranges. 153

Table 4.13 Summary of Dimension Weightage from Del Phi's Questionnaire 155

Table 4.14 Summary of Factor Weightage in Geography and Engineering Dimension from Del Phi's Questionnaire 157
Table 4.15 Summary of Factor Weightage in Natural Resource and Environment Dimension from Del Phi's Questionnaire 159
Table 4.16 Summary of Factor Weightage in Social Dimension from Del Phi's Questionnaire 161
Table 4.17 Summary of Factor Weightage in Economic Dimension From Del Phi's Questionnaire 163
Table 4.18 Summary of Indicator Weightage in Geography and Engineering Dimension from Del Phi's Questionnaire 166
Table 4.19 Summary of Indicator Weightage in Natural Resource and Environment Dimension from Del Phi's Questionnaire 170
Table 4.20 Summary of Indicator Weightage in Social Dimension from Del Phi's Questionnaire 173
Table 4.21 Summary of Indicator Weightage in Economic Dimension from Del Phi's Questionnaire 176
Table 4.22 Summary of Sustainability Score and Levels from Del Phi's Questionnaire 177
Table 4.23 Summary of 1st Round Results from Del Phi Panel on Water Scarcity Factors 179
Table 4.24 Summary of Results from Del Phi Panel on Weightage of indicators for Water Scarcity Level 182
Table 4.25 Summary of Del Phi's 1st Round Comments on Indicators 188
Table 4.26 Summary of Basic Project Components of 30 Reservoir Projects 201
Table 4.27 Summary of Key Factors, Indicators and Weighting Scores of Projects Sustainability 202
Table 4.28 Summary of Factors, Indicators, and Weighting Scores for Water Scarcity Level Assessment 204
Table 4.29 Sustainability Level of 30 Selective Projects 215
Table 4.30 Water Scarcity Level of 30 Selective Projects 222

Table 5.1 Summarized Indicators Referenced From Concerned Research Studies and the First Draft Indicators Selected Classified by Dimensions and Factors.....234
Table 5.2 Stage of Indicators Establishment.....239
Table 5.3 Selected Factors and Indicators with Scoring Ranges Applied for Sustainability Assessment.....243
Table 5.4 Summary of Factors and Indicators with Scoring Ranges for Assessment of the Project's Water Scarcity Level.....246
Table 5.5 Indicators' Compliance to Sustainability.....254

LIST OF FIGURES

Page

Figure 3.1 Study Approaches and Procedures....82
Figure 4.1 Location map of 30 selective projects 126
Figure 4.2 Resulted Sustainable Indicators for Water Resource Development Projects....199
Figure 4.3 Flow Chart of Assessing Sustainable for Water Resources Development Potentials....200
Figure 4.4 Summary of Sustainability Level of 30 Water Resources Development Projects....208
Figure 4.5 Results of 30 Projects' Water Resources Necessity Level (Water Scarcity) 212
Figure 4.6 An Example of Indicators' Sustainable Score Levels of Khlong Yai Project 230
Figure 5.1 Relationship Between Dam Section to Storage and EIRR....260

ABBREVATIONS

Abbreviation	Equivalence
DMR	Department Of Mineral Resources
DNP	Department of National Parks, Wildlife and Plant Conservation
DWR	Department of Water Resources
NESDC	Office of the National Economic and Social Development Council
ONEP	Office of Natural Resources and Environmental Policy and Planning
ORDPB	Office of the Royal Development Projects Board
RFD	Royal Forest Department
RID	Royal Irrigation Department

CHAPTER 1

INTRODUCTION

1.1 Background and Significance of the Study

Thailand is an agriculture predominant country, where agricultural area encompasses approximately 178.55 million rai, which is equivalent to 56 percent of the total national area. Forest area covers 104 million rai, accounting for 32 percent of the country's total area (Department of Land Development, 2019)

Therefore, government agencies responsible for water resources development have to develop water storage sources to ensure sufficient water supply for whole year round not only for agriculture, but also for community's consumption and other water uses. Constructing reservoirs is one effective and efficient type of water storage in terms of engineering. However, due to limitations in reservoir construction, feasible locations for reservoirs are often situated in hilly areas, mostly are conservation areas where are in good conditional natural resources and ecosystems. Consequently, the diverse roles and responsibilities of different government agencies have led to conflicts in operational approaches between development and conservation sectors.

Furthermore, the development of water resource projects in many locations has encountered difficulties due to the adverse effects of reservoir construction by inundation in occupied area and housing, leading to significant social impacts on their living occupation, live values, and culture. An acceptable comprehensive mitigation plan resulting from people participation activities should be implemented otherwise conflicts between the affected individuals and development agencies shall occur and lead to project suspension.

In addition, in several project areas, the development of water resource projects has had implications for natural resources, the environment, and the way of life of communities and leading groups in the affected regions. These regions often have alliances with non-government organizations or NGOs, which amplify their role and mass power in opposing or resisting project development. This occurs especially when

the projects are perceived to have genuine conservation objectives or when they are suspected of having hidden or misunderstood intentions. Consequently, conflicts arise between the public, NGOs, and government development agencies, preventing the construction of the projects.

As a result of the aforementioned issues and conflicts, the government is deprived of opportunities, time, and budget that would be used for studying, planning, and preparing project reports, including engineering feasibility studies and environmental impact assessments, for numerous water development projects. Consequently, the government is unable to develop water resources in accordance with the national economic and social development plans and fails to respond to policies aimed at promoting income generation and improving the livelihoods of farmers, who constitute a significant portion of the population. Additionally, these conflicts have led to a negative attitude and a crisis of confidence between the public and the government, as well as problems in coordinating the operations among different government agencies.

Two common problems that often arise during project implementation are social impact issues, such as the loss of traditional ways of life and displacement from residential and agricultural areas, and environmental impact issues, such as deforestation, loss of wildlife, and degradation of ecosystems.

Social problems are from households who were affected on loss of land and assets dissatisfaction and lack of clarity in compensation and the lack of comprehension participation during the study process and decision-making process for project development. Principles that should be used to address social problems include collaborating with environmental management and involving the public participation, with a focus on sustainable development principles, sufficiency economy principles, and good governance principles.

Environmental problems often arise in the process of permission of conserved lands from government agencies. The underlying cause is the lack of sustainable development standards or indicators to guide decision-making regarding the utilization of land for constructing reservoirs within conservation areas. This leads to development agencies being unaware of criteria or limitations in development. Therefore, the study and planning of projects in the past are conducted in a manner of fully utilization of the

potential of geography and natural resources for the maximum benefits of society and the economy. Despite the presence of measures to mitigate environmental and social impacts in all aspects, they may not align with sustainable development policies encompassing economic, social, and environmental dimensions.

Therefore, the development of projects that transit from maximizing the potential of geography and natural resources to sustainable development requires consideration of the following aspects: 1) Balancing the dimensions of social, environmental, and economic factors, while adhering to the principles of economic self-sufficiency and emphasizing 2) the participation of the public in decision-making at every stage. Additionally, 3) the establishment of sustainable development criteria, limitations specifications requirements, or indicators covering all dimensions (economic, social, and environmental) that serve as clear and standardized guidelines. This approach ensures a balanced development between natural resources conservation and socio-economic development be acceptable, by all stakeholders involved, including both the government and the public sectors. It becomes a crucial factor for resolving conflicts and contributing to the success of future project development. However, the decision of the project development would also depend on another important factor that is water scarcity level in target area. This factor would be considered in parallel with the project's sustainability level to accomplish the appropriate sufficiency solution.

1.2 Research Question

What criteria and indicators should be considered for the development of water resource projects in conservation areas to ensure sustainability in all aspects including natural resources and environments, social and economic dimension

1.3 Objectives

1.3.1 To develop key factors and indicators for assessing the sustainability of water resources development projects in conservation areas.

1.3.2 To develop key factors and indicators for assessing the water scarcity level or water resources development necessity level of the target area.

1.3.3 To define appropriate project's sustainability level requirements for water resource development in various water scarcity levels of the target area.

1.4 Definitions

1.4.1 Sustainable Development:

"Sustainable development refers to the development that promotes the income, and quality of life of people in a balanced and environmentally friendly manner. It entails the economic progress based on the principles of using, conserving, and restoring natural resources in a proper manner, by preservation of biodiversity and the prevention of environmental pollution beyond the carrying capacity of the ecosystem to mitigate and remedy."

In this context, sustainable development is considered in relation to water resource development, focusing on three crucial dimensions: economic, social, and environment. It aligns with the 17 Sustainable Development Goals set forth in the National 20-Year Strategic Plan (BE 2561-2580) and serves as a framework for studying the relevant key factors and indicators for further evaluation.

Framework of the 17 Sustainable Development Goals includes:

Goal 1: End poverty

Goal2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture for all at all ages

Goal 3: Ensure healthy lives and promote well-being for all at all ages

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5: Achieve gender equality and empower all women and girls

Goal 6: Ensure availability and sustainable management of water and sanitation for all

Goal 7: Ensure access to affordable, reliable, sustainable, and modern energy for all.

Goal 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Goal 9: Build resilient infrastructure, promote inclusive and sustainable

industrialization, and foster innovation.

Goal 10: Reduce inequality within and among countries.

Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable.

Goal 12: Ensure sustainable consumption and production patterns.

Goal 13: Take urgent action to combat climate change and its impacts.

Goal 14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

The development of sustainable water sources contributes to the economic goals outlined in targets 8, 9, 11, and 12. To establish these goals, it is important to apply a sustainable economic framework, to examine balanced and sufficient economic indicators, and ensure the project's sustainability in all dimensions.

Regarding sustainable goals related to natural resources and the environment, targets 6, 7, 13, and 15 play a significant role. These four targets have guidelines for determining factors and indicators of sustainability, utilizing resources in balance with the rate of natural resource growth, preserving ecosystems and biodiversity, and avoiding environmental pollution beyond the carrying capacity of the environment.

Sustainable goals in the social domain, involve the targets 1, 2, 3, 4, 10, and 16. The social sustainability goals aim to achieve a high quality of life, to determine factors and indicators of social sustainability should applying participatory decision-making, and utilize economic principles of sufficiency.

In addition, according to the guidelines of water resources development planning study, by responsible agencies four key dimensions are applied for optimizing project size and location selection comprising (1) geography and engineering, (2)

environments (3) social, and (4) economic. They are complied with the guideline of The Office of Natural Resources and Environmental Policy and Planning (ONEP)'s Environment Impact Assessment (EIA) Report Preparation. The geography and engineering dimension is consequently added to three principally sustainable dimensions comprising economic, social, and environments for the study.

In this context, sustainability is defined across various dimensions as follows:

1.4.1.1 Geography and engineering dimension

1) Project components must be safety, stability, economic, and efficiency.

2) Project provide resilience which could be affordable to uncertain situations, i.e. climate change, river flow fluctuation, drought and flood situation.

3) Project provide efficient operation system, minimal water losses, and environmental conservation.

1.4.1.2 Natural resources and environment dimension

1) The rate of depletion does not exceed natural regeneration in the long term, or compensation and restoration measures are in place to maintain the original state.

2) Unique and vulnerable ecosystems are not destroyed or lost, or they can be rehabilitated and restored.

3) Long-term preservation of the abundance and bio-diversity is ensured.

4) Habitat and food sources for endangered and near-extinct wildlife are not diminished below the threshold for their survival.

5) Avoidance of environmental pollution exceeding current levels or the carrying capacity of nature's ability to recover to its original state.

1.4.1.3 Society dimension

1) Participation of stakeholders is ensured from the beginning of project implementation.

2) Social conflicts and opposition to projects are effectively managed, promoting peace, security, and safety for life and property.

3) The public has equal and widespread access to project benefits.

4) It improves public health and enhances overall quality of life.

5) It creates employment opportunities with higher income levels beyond the country's poverty line, ensuring long-term income stability and reducing migration.

6) It has minimal impact on the preservation of unique or distinctive ethnic, community traditions, customs, and cultures, as well as natural resources, tourism, mineral resources, geologic and archaeologic places.

1.4.1.4 Economy dimension:

1) Investment is worthwhile in the long term, considering environmental and social costs.

2) The economy is flexible, stable, and resilient, reducing risks from natural disasters (such as droughts and floods) and accommodating changes. It is capable of scaling down projects and has effective management and good governance.

3) Demand and supply management takes into account natural resource and environmental conservation.

4) It fosters continuous and sustainable economic growth in the project area.

1.4.2 Water Development Projects

Refers to the construction of dams or hydraulic structures that impede natural watercourses, causing water to accumulate and create larger retention areas to achieve a balance among the physical, hydrological, natural resources and environment, economic and social aspects. These projects aim to store excess water during the rainy season in sufficient and sustainable quantities to serve various human needs during the dry season or throughout the year. These needs include consumption, domestic use, irrigation, agriculture, industry, hydropower generation, ecology conservation, water transportation, and desalination. Herein, the water resources development projects are mainly aimed for irrigation purpose.

Size of water resource development projects according to the Royal Irrigation Department (RID) are categorized based on their storage capacity as follows: (1) Large-scale reservoir projects with a capacity more than 99 million cubic meters, (2) Medium-scale reservoir projects with a capacity ranging from 2 to 99 million cubic meters. (3) Small-scale reservoir projects with a capacity less than 0.1 to 2.0 million cubic meters.

1.4.3 Conservation Areas

Refer to areas that possess remarkable natural beauty, biodiversity, environmental ecology systems, natural resources, wildlife, geological, and cultural heritage that deserve to be reserved or conserved for the benefit of future generations. In this context, it includes national parks, wildlife sanctuaries, and other protected areas designated to preserve and maintain the natural state as mandated by law. This also encompasses national reserved forest in conservation zone (Zone C), and watershed classification in class 1 excluding wetland areas, world heritage sites, and coastal and marine resource conservation areas.

1.4.4 Biodiversity

In this context, it refers to the presence of a wide variety of plants and animal species in significant quantities and diverse genetic variations within an ecosystem.

1.4.5 Carrying Capacity

Refers to the rate of growth, replenishment of natural resources, ecology systems, and biodiversity in a natural state or the capacity of an ecosystem to sustainably withstand the impacts of development or restore the ecosystem to its original condition.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the study of literature reviews and research works in the past that are relevant to the current study. It covers various topics and issues as follows,

2.1 Laws related to the rights and responsibilities of citizens and the state in the development and conservation of natural resources and environmental quality

2.1.1 Constitution of the Kingdom of Thailand, B.E.2560

2.1.2 National Reform Plan on Natural Resources and Environment.

2.1.3 National Strategies related to the utilization and conservation of Natural Resources and watershed management

2.1.4 Master Plan on water resources management and policies to Promote and preserve environmental quality

2.1.5 Environmental Action Plans

2.1.5.1 National Economic and Social Development Plan No.12 (B.E.2560 - 2564)

2.1.5.2 Environmental Quality Management Plan (B.E.2560-2565)

2.1.5.3 Biodiversity Management Action Plan (B.E.2560-2564)

2.2 Relevant Royal Acts on the Conservation of Natural Resources and Environmental Preservation

2.2.1 Royal Acts related to the conservation of natural resources

2.2.1.1 National Reserved Forest Royal Act, B.E.2559

2.2.1.2 National Park Royal Act, B.E.2562

2.2.1.3 Wildlife Reserve and Protection Royal Act, B.E.2562

2.2.2 Royal Acts related to the development, conservation, and management of water resources

2.2.2.1 Water Resources Royal Act, B.E.2561

2.3.1 Royal Acts related to the promotion and preservation of environmental quality

2.3.1.1 National Environmental Promotion and Preservation Royal Act, B.E. 2561

2.3 Organizations with the objective of procuring and managing the utilization of water resources

2.4 Guidelines for preparing water resources project development reports

2.5 Sustainability indices in natural resource management, water resource development, and water resource management

2.1 Laws Pertaining to the Rights and Responsibilities of Citizens and the State in the Development and Conservation of Natural Resources

2.1.1 Constitution of the Kingdom of Thailand, B.E.2560

The Constitution has prescribed the rights and responsibilities of citizens in utilizing, managing, and conserving natural resources.

The responsibilities of citizens in utilizing and conserving natural resources, namely;

The rights and freedoms of the Thai people, Section 3 of Article 43 (2), stipulate that " individuals and communities have the right to manage, preserve, and benefit from natural resources, the environment, and biodiversity in a balanced and sustainable manner, as prescribed by law".

In addition, under Section 3 of Article 43 (3), individuals or communities have the right to collectively submit proposals to state agencies for any actions that would be beneficial to the public or the community, or to refrain from any actions that may impact the peaceful existence of the public or the community. They are entitled to receive prompt notification of the decision. In all cases, state agencies must consider such proposals by involving the relevant public in the decision-making process in accordance with the procedures prescribed by law".

As for the responsibilities of the Thai people towards the conservation of natural resources, it is specified in Section 4 of Article 50 (8), stating that "individuals have the

duty to collaborate and support the conservation and protection of the environment, natural resources, biodiversity, and cultural heritage".

The responsibility of the state in managing and governing natural resources.

The Constitution of the Kingdom of Thailand, B.E.2560, has outlined the duties of the state in managing natural resources as follows:

Duties of the state, Section 5 as per Article 57 (2), stipulates that “the state must conserve, protect, preserve, restore, manage, and utilize or arrange for the utilization of natural resources, the environment, and biodiversity to yield balanced and sustainable benefits. This must involve the participation of the local people and communities concerned in the implementation and benefits derived from such actions”, as prescribed by law,

Section 6, State Policies, outlined in Article 72 states that “the state shall take action on land, water resources, and energy as follows: (4) Ensure an adequate and quality water supply for the consumption needs of the public, as well as for agriculture, industry, and other purposes”.

Furthermore, the constitution has stipulated reforms in other areas. In Section 16, which addresses reforms in other areas, it states, “Efficient, justice, and sustainable management systems for water resources shall be implemented, taking into account the comprehensive needs for water usage, as well as the changes in the environment and climate conditions”.

In summary, the people have the right to manage and utilize natural resources in a balanced and sustainable manner, particularly in the context of developing water sources. In this regard, the government is required to provide or facilitate public involvement in the decision-making process. At the same time, citizens have the responsibility to collaborate and support the conservation of these resources, while the government is obligated to carry out these actions in a balanced, sustainable, and efficient manner.

Although the Constitution of the Kingdom of Thailand, B.E.2560, has established the rights to utilize and the responsibilities to conserve natural resources for the public, as well as the roles of the state in provision, management, conservation, restoration, and utilization of natural resources, it is a broadly framed provision. The government is mandated to set goals, guidelines, and detailed procedures in secondary

laws and regulations, ensuring clarity in both development and conservation aspects simultaneously. This is aimed at achieving balanced and sustainable benefits, with active public participation.

2.1.2 National Reform Plans on Natural Resources and Environment

To align with the Constitution of the Kingdom of Thailand B.E.2560, outlining the rights and responsibilities of the public and the state in resource management, the constitution has mandated the development of relevant reform plans. These plans encompass 4 key areas: water resources, biodiversity, environment, and the management of natural resources and the environment as follows:

1) Water resource reform: Achieving a balance between conservation efforts, disaster reduction, expediting water source development mechanisms, promoting public participation in resource management, amending relevant royal acts on water resources, establishing collaborative water management areas across all sectors, and implementing mechanisms or tools, such as the 25 river basin plans (currently 22 river basins), and incorporating technology for water management.

2) Biodiversity reform: To establish a distinctive and efficient biodiversity management system, enhance research and innovation in biodiversity, achieve a balanced approach between conservation and utilization, reduce disparities, foster justice and equality in society, align with environmentally-friendly growth, engage public participation in sustainable conservation and utilization, and reap benefits from sustainable biodiversity. This aims to elevate the quality of life, raise awareness of the value and significance of biodiversity, and include indicators such as biodiversity laws, habitat loss rates (especially for critical habitats threatened or endemic species), decreasing by 50%, establishing centralized databases, and having research and development systems for biodiversity personnel.

3) Environmental reform: To establish an efficient pollution management system at its sources, promote environmentally friendly production and consumption of goods, and have relevant indicators. These include ensuring that community wastewater is managed properly, with at least a 50% reduction in improper management. This encourages public participation in monitoring, tracking, and inspecting pollution, along with laws related to climate change.

4) Resource and environmental management reform: Management is conducted based on principles of transparency and justice, aiming to reduce and prevent conflicts in the use of natural resources and the environment. This is for sustainable development with minimal impact on the people and communities. It also aims to create fairness in accessing and benefiting from resources, fostering meaningful participation. Key indicators include having a Strategic Environmental Assessment (SEA) system, an open space plan, green urban areas, and a water drainage plan, with at least one type within the municipal area of each province. Additionally, there should be a budgetary system supporting the master plan.

2.1.3 Strategies for Utilization and Conservation of Natural Resources and River Basin Management

The Constitution of the Kingdom of Thailand B.E.2560, outlines the state's responsibilities in resource management in Section 5, as per Article 57(2), stating that

"The state shall conserve, protect, preserve, restore, manage, and utilize or organize the utilization of natural resources, the environment, and biological diversity for balanced and sustainable benefits. The state must ensure the participation and benefits of the people and local communities involved in the relevant areas".

This is complemented by Section 6, the state's policy direction, detailed in Article 72, which emphasizes

"The state's actions related to land, water resources, and energy, including ensuring water resources are of sufficient quality for public consumption, agriculture, industry, and other purposes".

Additionally, Article 65 of the Constitution mandates that the state establish a national strategy as a sustainable development goal, based on ethical principles, to serve as a framework for aligning and integrating various plans.

The current Thai government has established the 20-Year National Strategy (B.E.2561-2580) for the country's development. The strategy directs state agencies to work towards achieving the vision that "Thailand is prosperous, sustainable, and developed, following the sufficiency economy philosophy". There are 6 strategies, including those related to the utilization and conservation of natural resources, as follows:

2.1.3.1 The 20-Year National Strategy (B.E.2561-2580) for promoting growth in the quality of life that is environmentally friendly (Strategy 4.5)

The core strategy of the national agenda for fostering environmentally friendly quality of life is guided by the sufficiency economy philosophy, emphasizing 3 principles: moderation, reasonableness, and immunity. The goal is to conserve and protect natural resources, enabling the public to benefit and foster sustainable growth based on the capacity of the ecological system.

The focus is on promoting sustainable growth in the green economy through the conservation and restoration of rivers, canals, and natural water sources. Plans for the conservation and restoration of water resources are developed based on maintaining environmental balance. This includes promoting mechanisms for community participation in the management, conservation, and development of rivers, canals, and natural water sources.

Furthermore, there is a dedicated effort to promote the development of water management systems comprehensively, aiming to enhance resilience and contribute to increased productivity in terms of water allocation and utilization across all sectors. This includes a focus on developing watershed management strategies, implementing prevention plans, restoring and maintaining environmental conditions, and preserving natural water sources in designated areas, with an emphasis on global sustainability.

The Cabinet has outlined the master plan under the national strategy through the Office of the National Economic and Social Development Council (NESDC) on March 12, B.E. 2562. It focuses on sustainable growth that is environmentally friendly, particularly addressing 2 key priorities: Item 18, sustainable growth, and Item 19, comprehensive water management within the system.

The strategy under item 18, sustainable growth, includes relevant sub-plans. Sub-plan for fostering sustainable growth in the green economy emphasizes the preservation of protected areas to reduce species loss due to exploitation. It involves managing local forest areas, incorporating innovations and modern technologies to halt encroachment and promote collaborative development in forest resource management, leading to sustainable production and consumption.

The strategy under item 19, comprehensive water management, consists of sub-plans, including the sub-plan for developing integrated watershed management systems. This aims to enhance the country's water security by achieving a balance in water provision, utilization, and conservation for communities and the environment. The management system is designed to be contemporary and high-quality, employing human resource development and social capital technologies. Another sub-plan focuses on conserving and restoring rivers, canals, and natural water sources nationwide, giving importance to surveying and demarcating river and canal boundaries, demolishing illegally constructed structures, fostering public participation across all sectors, and designing both architectural and engineering aspects to conserve and restore rivers, canals, and natural water sources."

2.1.3.2 Natural resources and environment ministry's 20-year strategic plan (B.E. 2561- 2580)

Derived from the national strategy under item 18, the Ministry of Natural Resources and Environment has formulated a 20-year strategic plan encompassing 6 strategic issues. This plan is designed to align with the national strategy and includes the following:

Strategic Issue 1: Conservation, protection, restoration, promotion, and sustainable development of natural resources and biodiversity. This strategy is consisting of 6 objectives.

Objective 1: Prevent, care for, and maintain forest areas to ensure their integrity, prevent intrusion, and be vigilant against wildfires. The specific objectives include conserving protected forest areas covering 80.88 million acres (25% of the national area), conserving national reserve forest areas covering 39.87 million acres, reclaiming 918,000 acres, enforcing strict fire prevention and control measures with a 100% success rate, and developing 500 model forests (300,000 acres) for educational purposes.

Objective 2: Increase forest area from degraded land, creating a forest economy. The objectives include restoring 3.17 million acres of conservation forests, rehabilitating 16.25 million acres of national reserve forest areas (8.42 million acres for degraded forests and 3.83 million acres for forest economy), expanding mangrove forests by no less than 10% (adding 1.68 million acres), and reclaiming 100,000 acres of forest land.

Objective 3: Enhance the fertility of coral reefs, seagrass beds, and marine ecosystems. The goal includes rehabilitating not less than 105,000 acres of mangrove forests and ensuring the protection of marine ecosystem resources in 23 provinces.

Objective 4: Systematically address the issue of encroachment by settlers in forest areas with fairness. The goal involves resolving the problem of settlers engaging in subsistence farming in conservation forest areas, targeting 169,254 individuals or 235,283 plots. Allocate forest reserve land affected by degradation to provide sustainable housing for communities, covering 3,400,000 acres. Additionally, allocate degraded mangrove forest land for sustainable community habitation, not less than 50,000 acres.

Objective 5**:** Significantly reduce the rate of natural resource loss and biodiversity in the country with a key objective of producing widely accepted and beneficial research results.

Objective 6: Manage and sustain natural resources in a balanced manner through active participation and collaboration.

Strategic Issue 2: Manage and govern both surface water and groundwater resources collaboratively, justly, and sustainably**.** The goal is to efficiently manage and conserve water resources to ensure sufficient benefits. Key indicators include the conservation of 3,600 water sources and waterlogged areas, development of 2,085 water sources to alleviate drought, development of 26,424 water sources for agriculture in drought-prone areas, and the management of 25 river basins and 27 artesian wells.

Strategic Issue 3: Prevent, conserve, and restore environmental quality. The key goal is to manage the environment to meet international standards. Key indicators include water quality with 95% compliance for natural water sources and 93% proper management of community wastewater."

Strategic Issue 4: Drive sustainable production and consumption in harmony with the environment. The goal is to develop and manage natural resources and the environment efficiently. The objective is to establish sustainable production and consumption practices, with at least 5 model cities in Thailand and environmental quality meeting international standards.

Strategic Issue 5: Reduce greenhouse gas emissions and mitigate the impacts of climate change and natural disasters. The goal is to reduce greenhouse gas emissions through measures under the Nationally Determined Contributions (NDC) by 140 MtCO2e. Establish an efficient forecasting and early warning system and disaster management for 100% coverage in high-risk areas of landslides. Formulate a comprehensive disaster monitoring network covering 100% of 25 main river basins.

Strategic Issue 6: Develop efficient mechanisms for the management of natural resources and the environment, and ensure organizational management that is both efficient and adaptive to change**.** The objective is to enhance the efficiency of organizational management and develop the management capabilities of the Ministry of Natural Resources and Environment in a transparent and adaptable manner.

2.1.3.3 Ministry of agriculture and cooperatives' s 20-year strategy (B.E.2561-2580**)**

Due to numerous challenges faced by Thailand's agricultural sector, such as the persistent issues of water scarcity, unstable agricultural product prices, inappropriate use of production factors, degradation of natural resources, and household debt problems, the Ministry of Agriculture and Cooperatives has formulated a 20-year strategy for agriculture and cooperatives (B.E. 2561-2580). This strategy serves as a framework for the continuous and efficient development of the agricultural sector, aligning with the National 20-Year Strategy (B.E.2561-2580).

The vision of the strategy is “Resilient farmers, prosperous agricultural sector, and sustainable agricultural resources”.

Resilient farmers refer to the development of knowledge for farmers towards becoming Smart Farmers. It involves enhancing pride and stability in the agricultural profession, applying the principles of self-sufficiency in livelihoods, and developing small-scale farmers into agricultural business entrepreneurs. This is achieved through the utilization of technology and innovation, fostering the formation of farmer groups, and connecting the agricultural institutions into Smart Groups and Smart Enterprises. This initiative strengthens agricultural institutions in terms of production, processing, marketing, and management.

Prosperous agriculture implies promoting and supporting the agricultural sector to enhance competitiveness by driving research, technology, and

innovation, as well as the entire agricultural supply chain, including agricultural products. It also involves expanding roles into the service sector to add value to agricultural products, aiming for Agriculture 4.0 within the framework of Thailand 4.0. Additionally, it aims to develop a modern agricultural information system for use by farmers, private organizations, and the government, promoting sustainable agriculture practices, such as organic farming and integrated agriculture. It also focuses on building intellectual capital for agricultural professionals and state researchers to become Smart Officers and Smart Researchers. Furthermore, it involves connecting and integrating the work of all sectors using a participatory governance mechanism.

Sustainable agricultural resources refer to the sustainable management of agricultural resources in alignment with the Sustainable Development Goals (SDGs) and the promotion of environmentally-friendly agricultural practices. This involves preserving natural resources in tandem with agricultural activities, comprehensive water management, optimizing irrigated areas, promoting judicious water use in agriculture, and enhancing soil fertility for suitable agricultural practices.

The agricultural and cooperative strategy comprises the following strategies:

Strategy 1: Strengthening farmers and agricultural institutions.

Strategy 2: Enhancing production efficiency and elevating product standards.

Strategy 3: Increasing competitiveness in the agricultural sector through technology and innovation.

Strategy 4: Balancing and sustaining agricultural and environmental resource management.

Strategy 5: Developing public sector management systems.

The strategy related to the development and management of natural resources and the environment is Strategy 4: Balancing and Sustaining Agricultural and Environmental Resource Management. The objectives of this strategy include: 1) sustainable agricultural resource management in alignment with SDGs (Sustainable Development Goals) 2) restoration and conservation of agricultural resources for sustainability. Key performance indicators include the following: 1) The amount of agricultural land conserved, improved, and restored 2) The extent of irrigated

agricultural land 3) The extent of areas benefiting from non-irrigated water sources 4) The extent of sustainable agricultural areas.

It can be observed that the Ministry of Agriculture and Cooperatives has sustainable development and improvement strategies for agriculture that are well-balanced with environmental considerations. The key agency responsible for developing water sources and irrigation systems is the Royal Irrigation Department.

2.1.3.4 The Royal Irrigation Department's 20-year strategy (B.E. 2561-2580)

The Royal Irrigation Department has formulated a 20-Year Strategy (B.E. 2560-2579) to drive alignment with national strategies and linkages with the Water Resources Management Strategy and the Ministry of Agriculture and Cooperatives' strategy. This aims to progress towards becoming an intelligent organization, focusing on creating water security to enhance service value by the year B.E.2580. The strategy encompasses 5 key points as follows:

Strategic Issue 1: Development of water sources and expansion of irrigated areas based on the potential of watershed characteristics (Basin-based Approach). The objective is to increase the water storage capacity and irrigated area within a 20-year period. The target is to raise the water storage capacity by 93,655 million cubic meters (an average of 4,683 million cubic meters per year) and expand irrigated areas by no less than 49.5 million acres (an average of 2.475 million acres per year).

Strategic Issue 2: Enhancing the efficiency of integrated water management according to the objectives of water utilization. The goal is to increase the economic value of agriculture in irrigated areas. This involves water management ensuring that all sectors receive water of uniform and fair quality, based on the annual water resource availability (domestic, consumption, agriculture, industry, and environmental conservation). Additionally, the number of households benefiting from irrigation within the irrigation area is targeted to increase by 7,431 million households within a 20-year period. Moreover, there is a plan to optimize water usage in the agricultural sector, involving the restructuring of land and water systems for agriculture, covering no less than 14.46 million acres.

Strategic Issue 3 : Disaster Prevention, Damage Mitigation, and Support for Water-Related Disasters. The objective is to reduce economic losses resulting from floods and droughts. This involves an increase in the percentage or area within the irrigation zone that receives effective disaster prevention and water-related disaster mitigation, not less than 14.1 million acres, within a 20-year period. The water situation predictions should be current and accessible to the target groups of the Royal Irrigation Department responsive to changing circumstances.

Strategic Issue 4**:** Networking and Participation. The goal is to integrate and collaborate with provinces, provincial groups, and local communities in the management of irrigation water at the regional level. This includes expanding the network to cover all user groups (agricultural, domestic, industrial, etc.) and enhancing the level of community and public participation in irrigation management.

Strategic Issue 5: Turnaround to Intelligent Organization. This involves ensuring that irrigation water sources cover all water user groups, the irrigation system is complete, and operations are conducted at full capacity.

2.1.4 Natural Resource and Environmental Management Master Plan

Government agencies responsible for implementing the national strategic plan and national reform plan have developed master plans that align with the 20-year strategy in resource management. These master plans include the Ministry of Natural Resources and Environment's master plan, the Biodiversity Management Master Plan, the Water Resource Management Master Plan, and short-term operational plans related to natural resources, environment, and water management. These plans are integrated with the National Economic and Social Development Plan, the Environmental Quality Management Plan, and the Biodiversity Management Operational Plan as follows:

2.1.4.1 Master plan in accordance with the 20-year Strategy of the Ministry of Natural Resources and Environment (B.E.2561-2580)

The Ministry of Natural Resources and Environment has developed a 20-year master plan consisting of 5 strategic objectives as follows:

Strategic Issue 1: Drive new processes to adapt to future changes, with 3 goals:

Goal 1: Foster desirable characteristics in the public regarding natural resources and the environment for a good quality of life.

Goal 2: Enhance the potential and capacity of areas to sustainably manage natural resources and the environment.

Goal 3: Ensure organizations are ready for new issues that may arise, driving proactive services for service recipients (citizens, government agencies, communities, businesses, and relevant stakeholders) that are fast, accurate, and fair.

Strategic Issue 2: Efficiently and sustainably manage natural resources to achieve balanced benefits, aiming for effective and economically viable natural resource management.

Strategic Issue 3: Establish a sustainable and balanced water resource management for the public, ensuring environmental conservation. The goal is to create a balance between the available water resources and their efficient utilization in line with the context and needs of the population in every area.

Strategic Issue 4: Promote and maintain environmental quality to elevate the quality of life. The goal is to ensure that the population enjoys a high quality of life within the framework of natural resources and the environment, in balance with the principles of the New Economic Model (BCG Economy).

Strategic Issue 5: Enhance organizational capabilities to adapt to new trends and innovations, with the goal of mitigating the impacts of changes in natural resources and the environment.

2.1.4.2 Biodiversity management integration plan (B.E.2558-2564)

The Ministry of Natural Resources and Environment has developed the aforementioned integration plan, consisting of four strategies as follows:

Strategy 1: Harmonize values and manage biodiversity by fostering participation at all levels. This involves raising awareness, providing knowledge, enhancing the efficiency of management, and strengthening the capabilities of relevant sectors to implement improvements in accordance with international agreements, protocols, and relevant treaties. Promote the involvement of communities and various sectors in the sustainable conservation, restoration, and utilization of biodiversity.

Strategy 2: Preserve and restore biodiversity, encompassing the protection, conservation, and restoration of ecosystems, species, and genetic diversity.

Implement initiatives at the provincial, local, and community levels to mitigate threats to biodiversity and habitats.

Strategy 3: Safeguard the country's interests and manage resources to enhance and share the benefits of biodiversity, aligning with the green economic approach. This involves protecting and ensuring the benefits from the sustainable use of biological and genetic resources, promoting sustainable utilization, and encouraging research to add value and build capacity in the development of the bioeconomy.

Strategy 4: Develop knowledge organizations and biodiversity databases to international standards. This involves promoting and developing knowledge management and enhancing and standardizing database systems.

2.1.4.3 Water resources management master plan for 20 years (B.E. 2561-2580)

Announced by the National Water Resources Office on August 28, B.E.2562, the plan comprises 6 strategies as follows:

1) Aspect 1: Domestic Water Management

Includes providing clean water for domestic consumption to communities, every village, or household in urban areas. It also covers essential tourist destinations, significant economic zones, and ensuring access to reserve water sources in areas facing scarcity. Additionally, the plan aims to develop drinking water to meet standards at affordable prices and promote water conservation by reducing household and government water usage.

2) Aspect 2: Building Water Security in the Production Sector

Involves developing water storage sources and transportation systems to their full potential. Additionally, it includes providing water in rain-fed agricultural areas to expand opportunities from small-scale projects and reduce risks in areas with limited potential, reducing risks/damages by 50%. This also encompasses increasing productivity and adjusting water usage structures through collaboration with the national strategy for enhancing competitiveness, creating opportunities, and achieving social equality to enhance water system productivity as a whole.

Aspect 3: Flood and Disaster Management

Aims to enhance water drainage efficiency, establish flood prevention systems for urban communities, manage flood-prone areas and water retention areas, and systematically mitigate disasters at the watershed and area-based levels. This includes major river basins and critical areas. Reduce risks and severity by no less than 60%.

Aspect 4: Water Quality Management and Conservation of Water Resources.

Focuses on developing and enhancing the efficiency of community wastewater collection and treatment systems, recycling wastewater for reuse, preventing and reducing upstream pollution, controlling water flow quantities to maintain environmental systems, and restoring important rivers, canals, and natural water sources comprehensively. This is to conserve, restore, and sustainably utilize water resources nationwide.

Aspect 5: Conservation and Restoration of Degraded Watershed Forests and Prevention of Soil Erosion

Focuses on conserving and restoring degraded watershed forest areas, as well as preventing and reducing soil erosion in watershed and slope areas.

Aspect 6: Management Improvement

Involves updating laws, developing decision support systems (national water reservoir), supporting watershed organizations, promoting information exchange between the public and private sectors in irrigation management services, conducting research and preparedness studies, promoting public relations, and engaging the participation of the public and relevant sectors. It aims to instill awareness of water resource conservation, develop research, innovation, and technology to support value addition in service and production sectors, and enhance water management models at the regional and watershed levels.

2.1.5 Natural Resource, Environmental, and Water Resource Operation Plans

For operational-level plans according to the master plan, related agencies have outlined plans and objectives, including the National Economic and Social

Development Plan, Environmental Quality Management Plan, and Biodiversity Management Plan.

2.1.5.1 The 12th National economic and social development plan (B.E.2560-2564)

Country development in accordance with the 12th National Economic and Social Development Plan is guided by the national vision within the 20-year national strategy. The 12th version of the National Economic and Social Development Plan emphasizes the establishment of the resilience of natural resources and the enhancement of environmental quality. The plan aims to conserve and restore natural resources by enhancing the efficiency of water resource management, addressing environmental crisis issues promptly, and managing to reduce the risks of natural disasters.

In Section 4 of the 12th National Economic and Social Development Plan (B.E.2560-2564), the country's development strategies are outlined with a focus on environmentally friendly growth for sustainable development. The objectives include establishing water resilience and efficiently managing both surface and groundwater resources. Key performance indicators are set to ensure effective water management in all 25 major river basins (currently 22 basins), maintaining a balance between water demand and available resources. This approach aims to address water scarcity issues, enhance the efficiency of water use in production and consumption sectors, and mitigate the impacts of floods and droughts.

2.1.5.2 The Environmental Quality Management Plan for the Years B.E.2560-2565

The Ministry of Natural Resources and Environment has established short-term strategies and objectives for the Environmental Quality Management Plan as follows:

1) Strategy 1: Balanced and just natural resource management

This involves prioritizing the conservation, restoration, and sustainable use of natural resources while considering the limitations and potential for recovery of natural ecosystems. The aim is to maintain the stability of natural resource bases, promoting equilibrium and justice. This includes promoting the conservation,

restoration, and sustainable utilization of natural resources, fostering balanced and just outcomes. The strategy focuses on the conservation, restoration, and sustainable use of natural resources, emphasizing the importance of promoting a balanced and sustainable approach. The key strategies include managing natural resources for conservation, restoration, and sustainable utilization of forest resources, groundwater, soil, land, marine and coastal resources, mineral resources, and biodiversity. Eleven critical indicators have been identified, including maintaining forest coverage at 40% of the country's total area, increasing the level of integrated water resource management, and reducing the loss rate of threatened species and natural habitats.

2) Strategy 2: Effective environmental quality management.

This strategy focuses on preventing, treating, and restoring environmental issues. It emphasizes the importance of preventing environmental problems at their source, reducing waste, and providing opportunities for all stakeholders to participate. Key strategies include pollution prevention, reduction, and elimination, as well as community environmental quality management plans, wastewater management plans, restoration plans for environmentally impacted areas, and community environmental management plans. Key indicators include maintaining good surface water quality at 80%, and ensuring that the green space per person in urban areas is not less than 10 square meters.

3) Strategy 3: Enhancing the efficiency of natural resource and environmental utilization sustainably

This strategy aims to ensure the responsible and sustainable use of natural resources and the environment, minimizing adverse impacts. It encourages all sectors to utilize natural resources efficiently and reduce environmental impact to the minimum. It promotes an economy built on the sustainable use of biodiversity, focusing on key strategies such as promoting sustainable consumption, fostering sustainable production and services, and developing an economy based on sustainable biodiversity. Key indicators include the implementation of regulations governing access to and sharing of benefits from biodiversity resources.

4) Strategy 4: Building capacity to address climate change and natural disasters and promoting international cooperation.

This strategy focuses on enhancing the capacity of communities in vulnerable areas to be prepared and adapt to climate change and occurring natural disasters. It aims to achieve this by fostering knowledge and understanding among the public. Key indicators include the increase in the number of local government organizations incorporating climate change adaptation into local development plans, the growth of organizations or networks supporting climate change adaptation and natural disaster resilience in community areas, a reduction in the number of casualties per 10,000 people due to natural disasters, and an increase in international cooperation each year.

2.1.5.3 Biodiversity Management Action Plan, B.E.2560-2564

The Ministry of Natural Resources and Environment has outlined the short-term operational strategy for biodiversity management as follows:

1) Strategy 1: Integration of Values and Biodiversity Management through Participation at All Levels**.** Including: enhancing operational capabilities for biodiversity management across various sectors at the provincial and local levels. Promoting knowledge, understanding, and awareness comprehensively across all sectors.

2) Strategy 2: Conservation and Restoration of Biodiversity. Including: establishing a balance between conservation and sustainable use of biodiversity by enhancing efficiency in managing protected areas and vital ecosystems such as forests, mangroves, coastal ecosystems, and wetlands. Promoting management through the establishment of environmental corridors, developing mechanisms, and measures for conserving and protecting endemic and endangered species. Conserving genetic diversity used in agriculture and food production, native plant and animal species, and forest gene pools. Accelerating efforts to reduce threats to biodiversity by controlling fishing activities and managing pollution, particularly in marine and freshwater environments. Managing invasive species, promoting sustainable development in agriculture, forestry, and fisheries, and fostering sustainable tourism initiatives.

3) Strategy 3: Safeguarding the Country's Benefits and Managing for Enrichment and Shared Benefits from Biodiversity, in line with the Green Economy approach, includes: accelerating efforts to protect and preserve genetic

resources by establishing mechanisms and regulations to oversee access to genetic resources and local intellectual property. Conducting research and development to generate added value from biological resources. Applying biotechnology in various industries. Returning benefits derived from biodiversity and environmental services to their origins.

4) Strategy 4: Build Capacity to Adapt to Climate Change and Natural Disasters, and Promote International Cooperation, involves creating capabilities for populations in vulnerable areas. This includes preparing and adapting to the changing climate and disasters by fostering knowledge and understanding among the public. Key indicators include an increase in the number of local government organizations incorporating climate change adaptation into their regional development plans, support networks or organizations responding to climate change and natural disasters in local communities, a reduction in the number of casualties per 10,000 people due to natural disasters, and an increase in international cooperation each year.

In examining the national strategy, ministry strategy, master plans, and operational plans of policy-guiding agencies in water resources development, it is evident that there is an effort to create water security. This is achieved by balancing water demand with available resources, reducing damage from floods and droughts. The implementation requires numerous water development projects under environmentally friendly conditions, ensuring sustainability and the participation of stakeholders. Meanwhile, environmental agencies prioritize maintaining a balance between conservation and sustainable utilization of specific resources such as forests, wildlife, ecosystems, and biodiversity. Key performance indicators are defined for national monitoring and assessment, but project-level indicators are lacking. It is crucial to establish comprehensive and sustainable indicators that guide holistic practices at the regional level. From the water resource project studies, it is observed that the development of suitable water sources primarily occurs within natural resource conservation areas. Current regulations protect these resources, imposing limitations on water development. However, permits can be obtained within the framework of conditions set by relevant laws. Noteworthy conservation laws include the National

Forest Reserve Act, the National Park Act, and Acts protecting wildlife reserves. These will be further discussed below.

2.2 Relevant Legislation for Natural Resource Conservation and Environmental Protection

2.2.1 Legislation Related to Natural Resource Conservation

In accordance with the duties assigned to the state under the constitution, the state has the responsibility to reserve, conserve, and control the utilization of natural resources and the environment, as mentioned above. This pertains to issues related to water resource development, including: (1) specifying and withdrawing boundaries of conservation areas under responsibility, (2) controlling and maintaining conditions to prevent degradation, and (3) establishing conditions for resource utilization within the designated areas.

2.2.1.1 National Reserved Forest Act of B.E.2559 (Version 4) and B.E.2507

This is a law related to the control and preservation of national reserved forests. It includes measures for monitoring, promoting reforestation, and restoring national reserved forests. The relevant issues are associated with the following studies:

1) Declaration, modification, or revocation of reserved forest area

Category 1: Designating natural reserved forests, according to Articles 6 and 7, to establish reserved forest areas, including the modification or revocation of such areas, whether in whole or in part, under controlled conditions, to be enacted by ministerial regulations.

2) Control and conservation of national reserved forest utilization

Category 2: Control and conservation of national reserved forest utilization, according to Article 14, to prevent degradation. This is enforced upon individuals who possess, occupy, utilize, or reside on land, construct structures, clear land, burn forests, harvest timber, or engage in any activities that may degrade the

condition of the national reserved forest. This is carried out by the Provincial National Reserved Forest Control and Conservation Committee, with the Provincial Governor serving as the committee's chairman.

3) Consideration of requests for utilization in the national reserved forest area

According to the regulations of the Committee for Consideration of Utilization in the National Reserved Forest Area, regarding criteria, methods, and conditions for land use within the operational areas or for the benefit of government agencies or state units within the National Reserved Forest Area, dated 2020. The Minister of Natural Resources and Environment is the chairperson, as specified in:

Category 2, Section 9 (2): The declared area must not conflict with land use measures in watershed areas, land use measures in watershed forests, and measures for utilizing resources and forest land in the National Reserved Forest Area, as resolved by the Cabinet or as specified by the permit holder.

Category 2, Section 9 (5): It must not conflict with measures set forth in environmentally protected areas according to ministerial regulations or declarations of the Ministry of Natural Resources and Environment.

Category 2, Section 9 (6): It must not violate measures stipulated by other laws; it is a reserved and protected area.

In Category 2, Section 9, for projects that do not meet the criteria but have objectives that generate benefits for the nation and the general public in terms of overall economic, social, security, and genuine national development, which are essential, cannot be avoided by using other areas, and are activities that can be controlled for environmental impact, they shall be carried out according to the criteria, methods, and conditions set forth by the Cabinet's resolution. Additionally, approval must be obtained from the local residents, and endorsement from the local administrative organization.

2.2.1.2 National Parks Act of B.E.2562

1) Establishment or Withdrawal of National Park Boundaries

(1) Article 6: When an area is found to be suitable for designation as a national park, the Department of National Parks, Wildlife, and Plant Conservation shall propose to the Cabinet for approval.

In designating, expanding, or withdrawing any national park area, whether in its entirety or partially, there shall be a process to solicit opinions and involve the affected communities and the public in order to facilitate consideration and decision-making.

(2) Article 7: The expansion or withdrawal of a national park, whether in its entirety or partially, shall be carried out by Royal Decree. In the case of a partial expansion or withdrawal, a map indicating the changed boundaries shall be prepared using a geographic information system or a similar system, and shall be attached to the Royal Decree.

(3) Article 8: The areas designated as national parks under Article 6 must not be privately owned land with title deeds or rights of possession under land laws or other laws, unless they are lands owned by state agencies.

2) Control of Land Use within National Parks

(1) Article 18**:** In the conservation, maintenance, care, and management of each national park, there shall be a management plan developed through the participation of stakeholders, including those who have vested interests. This plan shall include detailed maps and the spatial scope of area management.

(2) Article 19: Within a national park, no person shall engage in any of the following activities:

(2.1) Article 19 (1): Possess, occupy, demolish, construct, encroach, burn forests, or alter the original conditions of the land.

(2.2) Article 19 (2): Engage in any activities that pose a threat or degrade the condition of the park, including trees, soil, rocks, sand, minerals, petroleum, or other natural resources, and any actions that adversely affect the environmental system, biodiversity, and natural resources.

(2.3) Article 19 (3): Lure or remove wildlife or engage in any activities that endanger wildlife.

(2.4) Article 19 (4): Alter waterways or cause water bodies, seas, ponds, wetlands, or groundwater to be polluted, contaminated, dried up, decayed, or toxic.

(2.5) Article 19 (5): Block or obstruct water or land routes.

3) Consideration of utilization within national parks

In accordance with Article 22, officials have the authority to permit individuals to undertake actions specified in Article 19 (2), (5), (6), or (7) within the designated management areas of national parks, under the control and supervision of park officials. Such permission is granted solely for the purpose of exploration, study, research, academic experiments, filming, television, documentary production, nature education, maintenance of basic public utilities, or for energy security and beneficial tourism. It should not cause harm to the national park.

The request for permission to withdraw an area from a national park, as outlined in Article 7, must be considered by the National Park Committee, chaired by the Minister of Natural Resources and Environment, and undergo a participatory process involving stakeholders.

2.2.1.3 Wildlife Reservation and Protection Act B.E.2562

1) Establishment or Withdrawal of Protected Areas for Wildlife Conservation

(1) Article 39 stipulates the formation of a committee known as the "Wildlife Reservation and Protection Committee," comprising the Minister of Natural Resources and Environment as the committee chair, the Permanent Secretary of the Ministry of Natural Resources and Environment as the vice-chair, and not fewer than five but not exceeding seven qualified individuals. The committee also includes the Director-General of the Department of National Parks, Wildlife, and Plant Conservation, who serves as a committee member and secretary.

(2) Article 45 outlines the duties and powers of the committee as follows:

(2.1) Review and approve the designation of areas as wildlife conservation zones or prohibited hunting zones, as well as the expansion or withdrawal of wildlife conservation zones or prohibited hunting zones.

(2.2) Propose policies and necessary measures for the protection, conservation, and management of natural resources and the environment within wildlife conservation zones, prohibited hunting zones, and controlled areas, aiming at wildlife management.

(2.3) Provide approval for the master plan for wildlife conservation management, wildlife conservation zones, and prohibited hunting zones.

(3) Article 47: When it is found that any area possesses natural conditions suitable for providing a safe habitat for wildlife, preserving wildlife species, and conserving natural resources and the environment, or maintaining the original ecosystem for the benefit of wildlife conservation and biodiversity, the Department of National Parks, Wildlife, and Plant Conservation, with the approval of the Wildlife Conservation and Protection Committee, shall propose to the Cabinet for approval by royal decree and provide a map outlining the boundaries. This designated area shall be known as the "Wildlife Conservation Zone". A management plan for wildlife conservation and the Wildlife Conservation Zone shall be developed with the participation of stakeholders.

(4) Article 51**:** The expansion or reduction of the Wildlife Conservation Zone, whether in its entirety or in part, shall be enacted by royal decree. In the case of partial expansion or reduction, a map outlining the changed boundaries shall be attached to the royal decree. This process shall adhere to the provisions of Article 47 and Article 48 (public consultation and stakeholder participation) concerning the expansion or reduction of the Wildlife Conservation Zone with due consideration to sustainability.

Requests for permission to reduce the Wildlife Conservation Zone, as stipulated in Article 47, must undergo scrutiny by the Wildlife Conservation and Protection Committee and pass through the participatory process involving stakeholders, as outlined in Article 48.

2) Regulations for the Conservation, Management, and Protection of Wildlife Conservation Zones

(1) Article 52: establishes a conservation and protection plan for the Wildlife Conservation Zone through collaborative efforts.

(2) Section 4, Part 2, Article 55(2) of this royal decree specifies that within the Wildlife Conservation Zone, no person shall hold or

possess land, clear vegetation, set fires, or engage in any activities that degrade or alter the natural condition of the area. (3) Altering watercourses or causing pollution to rivers, streams, marshes, ponds, or wetlands. (4) Blocking or obstructing waterways or land routes. (5) Extracting or collecting resources in a manner that poses a threat or causes degradation to materials such as wood, soil, stones, minerals, petroleum, or other natural resources. (6) Planting trees or other plant species or introducing or releasing any type of animal into the area is prohibited.

3) Consideration of Utilization within the Wildlife Conservation Zone

(1) Article 55: specifies that activities such as surveys, studies, research, academic experiments, filming, or documentaries, nature education, maintenance of basic public infrastructure, or energy sustainability can be permitted within the designated area. The authorities may grant individuals permission to undertake activities outlined in Article 55(4), (5), or (6) within the specified zone. However, such activities must be under the control and supervision of officials, should not unduly disrupt the natural life of wildlife, and should not cause harm to the Wildlife Conservation Zone.

Criteria, methods, conditions for application, permits, and control and supervision, as stated in paragraph two, must adhere to regulations set by the Director-General of the National Parks, Wildlife, and Plant Conservation Department, with the approval of the committee.

Furthermore, for areas designated as "No-Hunting Zones" in Article 62, any land not covered by land deeds or rights under land laws, unless owned by a state agency, should be conserved as habitats or food sources for specific wildlife species. The committee, with the approval of the minister, may declare such areas as No-Hunting Zones through an announcement in the Royal Gazette, accompanied by a map illustrating the boundaries.

(2) Article 67: Once the Minister has issued a proclamation specifying No-Hunting Zones for certain wildlife species or types, it is strictly prohibited for anyone to seize, possess, or engage in activities such as cutting, felling, burning, or destroying trees, as well as digging for minerals, soil, or raising animals, or altering watercourses, causing harm to water bodies, wetlands, or causing

pollution or danger to wildlife, unless expressly authorized in writing by the Director-General or announced temporarily within a designated No-Hunting Zone.

Upon reviewing the laws and regulations, it is found that although the three acts have outlined a framework for controlling the use of conservation areas, individuals can seek permission to utilize specific areas if necessary. However, clear criteria for considering such permissions are lacking, making it challenging for those involved in planning and developing water resource projects to conduct suitable, sustainable, and balanced studies and project designs that align with both development and natural resource conservation goals.

2.2.2 Relevant Legislation on Water Resource Development, Conservation, and Management

In the realm of water resources, pertinent legislation includes the Water Resources Act of B.E.2561("Thai Royal Government Gazette," 2018, 28 December), which stipulates that the state is responsible for activities related to both development and management for the utilization of water resources and conservation efforts. This act addresses key issues such as delineating boundaries, establishing organizations for management, and controlling the use and conservation of water resources.

2.2.2.1 Water Resources Act of B.E.2561

1) State Authority in Water Resource Development

(1) Section 1, Article 6 of the Water Resources Act: the state the authority to develop, manage, conserve, restore, and preserve water resources for the overall benefit in a balanced and sustainable manner. This includes the power to alter the shape of water sources or expand the area of water sources as deemed necessary.

(2) Section 1, Article 6 of the Water Resources Act: Public Water Resources, excluding irrigation water as defined by irrigation laws, and groundwater as defined by groundwater laws, may be designated by the Prime Minister for any state agency or local government organization to be responsible for controlling, overseeing, and maintaining said public water resources, as proclaimed in the Royal Gazette.

2) The delineation, alteration, or withdrawal of watershed areas.

(1) As stipulated in Article 25 for the purpose of water resource management, shall be enacted by royal decree. In doing so, consideration must be given to meteorological conditions, geographical features, environmental systems, topographical conditions, urban planning, water maps, and administrative boundaries. The royal decree, as per the first paragraph, must include a map illustrating the boundaries of the watershed area, and it should be considered an integral part of the royal decree.

(2) Article 26: Changes or withdrawals of any watershed, whether in whole or in part, may be executed by royal decree. In cases where there are changes or withdrawals of some parts, a map illustrating the altered or withdrawn boundaries must be attached at the end of the royal decree.

3) Organization for Water Resources Management

This Royal Decree establishes the "National Water Resources Committee," abbreviated as "NWRC." The committee is comprised of the Prime Minister as the Chairman, Deputy Prime Ministers designated by the Prime Minister as Vice-Chairmen, and additional members including representatives from the basin committees, water users' organizations, local administrative organizations, and qualified individuals in water resources. Additionally, there are four qualified individuals appointed by the Prime Minister, with the Secretary-General of the National Water Resources Office serving as a committee member and the Secretary-General appointing up to two officials as assistant secretaries.

The NWRC holds authority related to water resources management to achieve objectives, formulate policies, and develop master plans for water resources management. It reviews and approves the work plans of government agencies and local organizations related to water resources.

(1) Article 27: When a royal decree designating a watershed according to Article 25 is issued, a watershed committee for that specific watershed shall be established. The committee shall consist of watershed committee members, including the Provincial Governor within that watershed, representatives from the Pollution Control Department, representatives from the Harbor Department,

representatives from the Irrigation Department, representatives from the Department of Water Resources, representatives from the Groundwater Department, representatives from the Fisheries Department, representatives from the Department of Land, representatives from the Forest Department, representatives from the Land Development Department, representatives from the Town Planning Department, representatives from the Local Administration Promotion Department, and representatives from the National Parks, Wildlife, and Plant Conservation Department. The Provincial Governor is authorized to select the chairman of the watershed committee, and the Director of the National Water Resources Office for the respective region shall appoint officials from the National Water Resources Office as watershed committee members and secretaries.

(2) Article 35: The watershed committee has duties and powers related to the management of water resources within the watershed area. These include the following responsibilities and powers:

(2.1) Develop a master plan for the utilization, development, management, maintenance, restoration, and conservation of water resources within the watershed area and submit it to the National Water Resources Committee (NWRC) for approval.

(2.2) Develop plans to prevent and address drought and flood conditions and submit them to the NWRC for approval.

(2.3) Review water usage quantities, water allocation, and prioritize water usage within the watershed area. Control water usage in accordance with the guidelines, criteria, and directives set by the NWRC.

(2.4) Establish criteria and regulations for the utilization, development, management, maintenance, restoration, and conservation of water resources within the watershed area, within the framework and guidelines stipulated by the NWRC.

(2.5) Approve permits for the use of water of the second type according to Article 43 and the withdrawal of permits for the use of water of the second type according to Article 54.

(2.6) Consider and submit opinions regarding water disputes between watersheds to the NWRC.

(2.7) Submit opinions to the NWRC regarding plans and projects related to water resources in the watershed area.

(2.8) Address and resolve complaints, disputes, and conflicts among water users.

(2.9) Coordinate with relevant state agencies and local authorities in enforcing laws related to the use, development, management, maintenance, restoration, and conservation of water resources, as well as laws related to water pollution in the watershed area.

(2.10) Promote and advocate for public awareness in the use, development, management, maintenance, restoration, and conservation of water resources in the watershed area.

(2.11) Perform any other duties and powers as stipulated in this royal decree or as assigned by the NWRC.

(3) Article 37 establishes the National Water Resources Office at the Regional Office of the National Water Resources Office, under the Office of the Prime Minister. The office serves as the secretariat of the watershed committee and is assigned the following responsibilities and powers:

(3.1) Take responsibility for the administrative work of the watershed committee.

(3.2) Study, analyze, and conduct research on water resources to contribute to the consideration and development of master plans for the use, development, management, maintenance, restoration, and conservation of water resources in the watershed area.

(3.3) Coordinate with state agencies, local authorities, and water users' organizations to enforce laws related to the use, development, management, maintenance, restoration, and conservation of water resources, as well as laws related to water pollution control in the watershed area, in accordance with the master plans for the use, development, management, maintenance, restoration, and conservation of water resources.

(4) Promote and monitor the use of water of the second type in the watershed area in accordance with criteria and conditions approved by the watershed committee.

(5) Propose measures to prevent conflicts and provide guidance on resolving disputes among water users in the watershed area to the watershed committee.

(6) Perform any other duties as assigned by the watershed committee.

2) Water Allocation and Utilization

(1) Article 40: The allocation and use of water in the country should take into consideration water for consumption, hygiene, environmental systems, cultural traditions, disaster relief, transportation, agriculture, industry, commerce, and tourism. In all cases, prioritization should follow the guidelines set by the National Water Resources Committee (NWRC).

(2) Article 41: divides the use of public water resources into three types:

(2.1) Type 1 use includes the use of public water resources for livelihood, household consumption, agriculture or animal husbandry for sustenance, household industry, environmental conservation, cultural traditions, disaster relief, transportation, and small-scale water use.

(2.2) Type 2 use comprises the use of public water resources for industrial purposes, tourism-related industries, electricity generation, water supply, and other activities.

(2.3) Type 3 use involves the use of public water resources for large-scale activities that require a significant amount of water or may have cross-basin impacts or extensive coverage of areas.

(3) Article 42: states that the use of Type 1 water does not require a water usage permit or payment of water fees. The state agencies or local government organizations responsible for the area are required to compile information on the use of Type 1 water.

3) Control of the utilization of public water resources

(1) Article 51: aims to facilitate inspection and control of the use of public water resources. Individuals obtaining permits for Type 2 and Type 3 water use must install measuring tools or assessment devices to measure the quantity of water used. They are also required to collect necessary data for

inspection by officials appointed by the Minister of Agriculture and Cooperatives or the Minister of Natural Resources and Environment, depending on the case. The inspection will be conducted according to criteria and methods specified by the Director-General of the Department of Irrigation, the Director-General of the Department of Water Resources, or the Director of the Groundwater Resources Department, as appropriate, and announced in the Royal Gazette.

4) Conservation and Development of Public Water Resources

(1) Article 73: In cases where the National Water Resources Committee (NWRC) deems that any area has the characteristics of a watershed or water-rich area and should be reserved for the benefit of conserving public water resources, the NWRC shall assign the Minister of the Ministry of Natural Resources and Environment to consider taking action to designate that area as an environmentally protected zone, in accordance with the laws promoting and preserving the national environmental quality.

(2) Article 74: Minister of the Ministry of Interior, with the approval of the NWRC, has the authority to issue ministerial regulations establishing criteria for land use that may impact public water resources to prevent danger or damage to public water resources. This is done for the purpose of conserving or developing public water resources in an appropriate manner.

2.2.3 Relevant Royal Acts on Environmental Promotion and Conservation

In addition to the Royal Acts related to the reservation and protection of natural resources and water resources, there are also Royal Acts pertaining to the promotion and conservation of environmental quality in the year B.E.2561 that apply to areas beyond the scope of the aforementioned Royal Acts.

2.2.3.1 National Environmental Promotion and Conservation Act of B.E.2561.

To examine the relevance of water development with this Royal Act in various aspects, as follows: 1) Rights and responsibilities of the public regarding environmental conservation. 2) State disaster control. 3) Authority and responsibilities

of state organizations responsible for environmental conservation. 4) Designation of conservation and protection areas for the environment. 5) Application for permission to carry out projects with environmental impacts.

1) Rights and Responsibilities of Individuals in Promoting and Preserving the Environmental Quality of the Nation.

(1) In accordance with Article 6 for the collaborative promotion and preservation of the national environmental quality, individuals may have the following rights and responsibilities:

(1.1) Receive information and news from the government regarding the promotion and preservation of environmental quality, unless the information is considered confidential related to national security, personal rights, property rights, trade secrets, or the business of individuals protected by law.

(1.2) Receive compensation for damages or replacements from the state in the event of harm caused by the spread of pollutants or pollution resulting from any government-supported or initiated activities, projects, or ventures.

(1.3) File complaints and accusations against wrongdoers to officials in cases of witnessing any actions that violate laws related to pollution control or natural resource conservation.

(1.4) Cooperate and assist officials in performing duties related to the promotion and preservation of environmental quality.

(1.5) Comply with this Royal Act or other laws related to the promotion and preservation of environmental quality with diligence.

2) Controlling, Suppressing, and Mitigating Natural Disasters or Pollution by the State

(1) Article 9: stipulates that in the event of an emergency or imminent danger to the public resulting from natural disasters or pollution caused by the spread of pollutants, which, if left unchecked, would pose a severe threat to the life, body, or health of the public, or cause significant damage to the property of individuals or the state, the Prime Minister has the authority to order, as deemed appropriate, government agencies, state enterprises, or any person who is or may be in danger or at risk of harm to take any action necessary to control, suppress, or

mitigate the adverse effects of such danger and damage. In cases where it is known that a person is responsible for causing such pollution, the Prime Minister is empowered to order that person not to undertake any actions that may worsen the pollution during the emergency.

In the exercise of authority, in the first paragraph, the Prime Minister may delegate authority to the provincial governor to perform official duties within the province on behalf of the Prime Minister. This delegation includes the issuance of orders and announcements in the Royal Gazette.

Once the Prime Minister has issued a directive in accordance with the first paragraph, or the provincial governor has acted on behalf of the Prime Minister in accordance with the second paragraph, the relevant orders shall be promptly announced in the Royal Gazette without delay.

(2) Article 10: as a preventive measure to address, suspend, or mitigate emergencies or disasters arising from pollution situations according to Article 9, grants the Minister the authority to prescribe preventive measures and formulate emergency plans in advance to address the unfolding situations.

3) The organization responsible for protecting, promoting, and conserving environmental quality.

(1) Article 12: stipulates the establishment of the National Environmental Committee, comprising the Prime Minister as the Committee Chair, and the Permanent Secretary of the Ministry of Natural Resources and Environment as a committee member and secretary.

(2) Article 13: grants the National Environmental Committee the authority and responsibilities as follows:

(2.1) Propose policies and plans to promote and preserve the national environmental quality for approval by the Cabinet.

(2.2) Establish environmental quality standards as stipulated in Article 32.

(2.3) Review and provide approval for the environmental quality management plan proposed by the Cabinet, as per Article 35.

(2.4) Review and provide approval for the action plan on environmental quality management at the provincial level, as per Article 37.

(2.5) Propose financial, treasury, tax, and investment promotion measures to implement the national environmental quality promotion and preservation policies and plans to the Cabinet.

(2.6) Recommend amendments or improvements to laws related to the promotion and preservation of environmental quality to the Cabinet.

(2.7) Consider approval for action plans to prevent or remedy dangers arising from the spread of pollutants or pollution conditions, as proposed by the Pollution Control Committee under Article 53(1).

(2.8) Consider approval for the establishment of pollution control standards from pollution sources proposed by the Minister under Article 55.

(2.9) Supervise and expedite the issuance of royal decrees, ministerial regulations, local ordinances, announcements, rules, and orders as necessary, to ensure that laws related to the promotion and preservation of environmental quality are systematically comprehensive.

(2.10) Present recommendations to the Prime Minister for consideration and issuance of orders in cases where it appears that any government agency or state enterprise violates or fails to comply with laws, regulations, or provisions related to environmental conservation that may cause severe harm.

(2.11) Establish measures to promote cooperation and coordination among government agencies, state enterprises, and private sectors regarding the promotion and preservation of environmental quality.

(2.12) Supervise the management and administration of the fund.

(2.13) Present reports on the country's environmental quality situation to the Cabinet at least once a year.

(2.14) Perform any other duties as specified in this royal decree or other laws as the responsibilities of the National Environmental Board.

4) Designation of conservation and protected environmental areas

(1) Article 42: The protection and management of areas within national parks and wildlife sanctuaries shall comply with the environmental quality management plan as stipulated in Article 35 and relevant laws.

(2) Article 43: In cases where it is found that an area exhibits characteristics such as being a source of rivers, having a natural ecosystem different from other areas, or having a natural ecosystem that may be easily destroyed or impacted by various human activities, or is an area of natural or cultural significance worthy of conservation, and that area has not been declared as a conservation area, the Minister, upon the recommendation of the National Environmental Board, has the authority to issue ministerial regulations designating that area as an environmentally protected area.

(3) Article 44: When issuing ministerial regulations according to Article 43, the following protective measures, either one or multiple, shall be stipulated in the ministerial regulations:

(3.1) Specify land use to preserve the natural conditions or prevent disturbance to the natural ecosystem or the cultural and environmental values of artistic works.

(3.2) Prohibit any actions or activities that may be hazardous or cause an impact leading to alterations in the natural ecosystem of that area or affect the value of environmental art.

(3.3) Define the types and sizes of projects or activities undertaken by government agencies, state enterprises, or private entities in that area, requiring them to submit environmental impact assessment reports.

(3.4) Establish specific management methods for that area, including defining the responsibilities and duties of relevant government agencies to promote cooperation and coordination for efficient operations

in preserving the natural conditions or natural ecosystems or the values of environmental art in that area.

(3.5) Specify any other protective measures deemed suitable and appropriate for the conditions of that area.

(4) Article 45: In any area designated as a conservation zone, comprehensive urban planning zone, specific urban planning zone, building control zone, industrial estate zone under the relevant laws, or pollution control zone as stipulated in this Royal Decree, if there is a severe environmental quality problem reaching a crisis level that requires immediate rectification and the relevant government agency lacks the legal authority or is unable to address the issue, the Minister, with the approval of the National Environmental Board, may propose to the Cabinet to authorize and initiate measures for protection, one or multiple, as stipulated in Article 44, as necessary and appropriate to control and rectify the issues in that area. Once approved by the Cabinet in the first paragraph, the Minister shall announce in the Royal Gazette, specifying the area, details of the protective measures, and the timeframe for their implementation. An extension of the timeframe, as declared in the second paragraph, is permissible with the approval of the National Environmental Board and the Cabinet, announced in the Royal Gazette.

5) Application for permission to undertake projects that impact the environment.

(1) Article 48: For the purpose of promoting and preserving environmental quality, the Minister, with the approval of the National Environmental Board, has the authority to issue a proclamation designating any project, enterprise, or activity that may impact the environment or potentially affect natural resources, environmental quality, health, well-being, or other significant interests of the public or communities or the environment severely. The person or entity undertaking the project or activity or seeking permission must submit an environmental impact assessment report.

(2) Article 51: provides for the National Environmental Committee to appoint a committee of experts to carry out the task of reviewing environmental impact assessment reports. This committee must consist of qualified individuals or experts in various relevant fields. Additionally, there must be

officials with the authority to grant permits for the specific project or activity, which is crucial for its implementation in accordance with the law.

In the case of water development projects, which have environmental impacts, a report on the environmental impact assessment must be prepared for the relevant agency, in this case, the Office of Environmental Policy and Planning. The committee of experts must provide their approval before receiving project approval from the water management, natural resources, and subsequent government agencies.

2.3 Government Agencies with the Objectives of Water Resources Development

2.3.1 Government Agencies with the Objectives of Developing and Managing the Utilization of Water Resources

Currently, there are government agencies with the authority and responsibility for the development, procurement, restoration, maintenance, and management of the utilization of water resources. These agencies include:

1) Royal Irrigation Department

In accordance with the regulations governing the administration of state affairs (4th edition, B.E.2543), the Ministry of Agriculture and Cooperatives, B.E.2557, in Article 8 Chor. of the ministerial regulations dividing government agencies, outlined the roles and responsibilities of the Royal Irrigation Department. The department is tasked with the development of water sources according to the potential of river basins to meet the diverse needs of water users. This includes ensuring equitable and just distribution of water to users of all types. The department is also responsible for activities such as reservoir construction, storage, maintenance, control, release, or allocation of water for agriculture, energy, public utilities, or industrial purposes. Additionally, it oversees measures to prevent damage caused by water, the safety of dams and structures, and water transportation within the irrigation areas.

2) Department of Water Resources

In accordance with the Water Resources Act of B.E.2561, the Department of Water Resources is designated as a state agency under the Ministry of

Natural Resources and Environment. Its responsibilities include providing recommendations for the formulation of policies, plans, and measures related to water resources. The department is tasked with managing, developing, conserving, restoring, and overseeing water resources. It also coordinates, monitors, evaluates performance, and addresses issues related to water resources. Additionally, the department advances expertise, establishes standards, and disseminates water resource technologies at both the overall and watershed levels. Its overarching mission is to manage water resources in a unique and sustainable manner, with the following specific duties and responsibilities:

(1) Serves as the primary agency for proposing policies, master plans, and measures for the management, development, conservation, restoration, utilization, and problem-solving related to water resources. Additionally, it provides guidance and coordination to ensure effective implementation.

(2) Establishes guidelines for the development of operational plans for the management, development, conservation, and restoration of water resources, encouraging public participation.

(3) Engages in the study, research, development, conservation, and restoration of water resources.

(4) Monitors and evaluates the outcomes of water resource management in accordance with policies, master plans, operational plans, and designated measures at both the national and watershed levels.

Presently, by the Cabinet resolution on March 9, B.E.2564, the Department of Water Resources has been assigned the responsibility for managing, developing, conserving, restoring, and controlling the utilization of various watershed areas, replacing the Office of Natural Resources and Environmental Policy and Planning.

3) Local Government Organizations

In accordance with the Act on the Determination of Plans and Procedures for the Delegation of Authority to Local Government Organizations of B.E.2542, local government organizations refer to provincial administrative organizations, municipal administrations, sub-district administrations, the Bangkok

Metropolitan Administration, and Pattaya City. These organizations have the authority and responsibility to maintain public order, ensure basic transportation infrastructure both on land and water, and manage and maintain essential public utilities. This includes overseeing and preserving key public utilities, such as maintaining and developing water sources, rural sanitation systems, and ensuring water supply and drainage systems. Moreover, they are responsible for waste disposal, pollution control, and wastewater treatment systems. Additionally, these organizations are tasked with establishing and maintaining land and water connections, as well as constructing and preserving both land and water infrastructure that links various local government organizations.

4) Provincial Waterworks Authority (PWA)

In accordance with the Provincial Waterworks Authority Act of B.E.2522, the Provincial Waterworks Authority authorities are empowered to conduct surveys, locate raw water sources, and ensure the procurement of raw water for the purpose of water supply, production, distribution, and supply throughout the country, excluding Bangkok, Nonthaburi Province, and Samut Prakan Province. Additionally, they are involved in related business activities or activities beneficial to water supply, always considering the interests of the state and the public.

5) Electricity Generating Authority of Thailand (EGAT)

Pursuant to the Electricity Generating Authority of Thailand Act of B.E.2511, the Electricity Generating Authority of Thailand (EGAT) is entrusted with the primary responsibility of generating electrical power for the public. It has the authority to engage in activities related to the construction and maintenance of dams, whether for water retention, drainage, or water storage basins, or any other equipment associated with these dams, for the purpose of electricity generation or the development of hydropower. This includes controlling water quantities, retaining or releasing water from reservoirs, with the utmost consideration for the maximum benefit derived from managing the river basin where the dam is constructed, as well as the tributaries, rivers, waterways, canals, or channels directly connected to that river basin.

6) Department of Alternative Energy Development and Energy Efficiency

In accordance with the Regulation of the Ministry of Energy, Division of Governmental Administration (Version 4, B.E.2543), which delineates the government agencies under the Ministry of Energy, the Department of Alternative Energy Development and Energy Efficiency (DEDE) was established. The purpose of DEDE is to carry out its mission in the development, promotion, and support of the production and use of clean energy that aligns with the specific conditions of each region, making it valuable and sustainable. DEDE aims to develop commercially viable clean energy technologies for both domestic consumption and export, as well as to build collaborative networks that propel the country towards a knowledgeable society in the field of energy. This is all geared towards ensuring a resilient economy and a sustainable and prosperous society.

Currently, it can be observed that the organizations tasked with the development of water resources for various human activities within the conservation areas, as defined and delimited by this research, include the Department of Royal Irrigation, the Department of Water Resources, the Department of Alternative Energy Development and Efficiency, and the Electricity Generating Authority of Thailand.

As for the Electricity Generating Authority of Thailand, there is currently no policy for developing dams specifically for hydropower generation. This is due to the potential size of projects, which tend to be large and situated in conservation areas, significantly impacting natural resources, the environment, and society. In contrast, major water development projects by regional waterworks and local administrative organizations are generally smaller in scale and located in non-conservation flat areas or outside the research study areas.

2.3.2 Regulatory agencies in the water sector

1) Office of the National Water Resources

The Office of the National Water Resources serves as the regulatory agency for water-related activities, in accordance with the regulations outlined in the Ministry's departmental regulations governing the Office of the National Water Resources, Prime Minister's Office, B.E. 2562, Section 2. The office is mandated with advising on policies, developing master plans, establishing measures for water resource management in the country, and driving implementation. Its responsibilities include

developing water charts, integrating information systems on water resources, project planning, budgeting, coordinating international cooperation on water resources, and monitoring and evaluating water resource management outcomes, with the following duties and authorities:

(1) Assume responsibility for administrative tasks related to the National Water Resources Committee (NWRC), river basin committees, and relevant sub-committees.

(2) Review and provide feedback to the NWRC on the development of policies and master plans regarding water resource management. This includes providing input on action plans, comprehensive budget plans for integrated water resource management, and master plans for development, management, maintenance, restoration, and conservation of water resources in various river basins.

(3) Prepare water charts for presentation to the NWRC for approval.

(4) Coordinate operational activities with river basin committees, government agencies, local authorities, and relevant stakeholders to comply with water resource legislation.

2.3.3 Water project coordination units

Office of the Royal Development Projects Board (ORDPB)

According to the Prime Minister's Office regulations on projects arising from royal initiatives in B.E.2534, the Office of the Royal Development Projects Board (ORDPB) arising from Royal Initiatives is designated to compile royal initiatives, conduct surveys, studies, analyses, and develop plans or projects arising from royal initiatives. Additionally, it is responsible for reviewing and proposing budget allocations to carry out activities related to projects arising from royal initiatives. The office performs academic tasks, organizes information systems, and engages in public relations related to projects arising from royal initiatives. It carries out other duties as assigned by royal commands, the ORDPB, or according to the regulations of the Prime Minister's Office regarding projects arising from royal initiatives.

Government agencies responsible for the development of water sources for various activities and organizations in charge of conserving natural resources and the

environment, as specified in the aforementioned laws, play a role in the development and conservation of water resources. These agencies are stakeholders in both the gains and losses associated with water source development and natural resource conservation. The researchers will select qualified individuals from these agencies, representing various fields, to serve as key informants within the Del Phi team, providing comprehensive and complete information.

2.4 Study Standards for Developing Water Resource Development Reports

The Project Management Office of the Royal Irrigation Department (September B.E.2557) has formulated study standards for preparing project development reports. The guidelines outline the principles and criteria to be considered in the development of water source projects, summarized as follows:

It starts with sequencing the project's background to provide information about the project's origins. This involves examining documents and records related to the project and studying the original issues that led to the request for the Department to investigate the project. Most projects arise from the pressing issues faced by the population, such as the chronic lack of sustainable water sources for agriculture and consumption. The study involves analyzing the project requester's needs, reviewing water development plans, evaluating ongoing watershed development, and assessing the significance and impact of studied projects on overall watershed development.

The study aims to illustrate the relationship between water source development and the area's development policies, as well as future water needs for various activities in the region. It explores watershed development strategies, analyzes water development plans of relevant organizations, checks environmental impacts, assesses potential and feasibility of water development in the targeted area, and ensures compliance with laws and regulations.

1) The study of project engineering comprises the following: Hydraulic and hydrological system study, rainfall distribution, water quantities flowing through the project area, and a study of reservoirs. This includes monthly water demand for various activities in both current and future conditions, focusing on irrigation, water

consumption, industrial water usage, livestock water needs, and maintaining the environmental balance downstream. Evaluation of alternative water development formats such as reservoirs, weirs, sluice gates, and ponds. The selection of the most feasible project with minimal impact is considered to proceed further.

(3) The study involves determining the location and project area boundaries. Determining the project's location is crucial during the project planning phase, considering physical conditions such as topography and climatic characteristics. The geological study of the construction site is conducted, examining the quantity and properties of construction materials.

(4) Project delineation for alternatives is a method of creating options for consideration at various levels, aiming to effectively address the issues of water scarcity among the public, while also minimizing environmental impacts from the project. Starting from small-scale projects to large-scale ones, the delineation process involves aligning the project objectives as targets, then assessing the project's suitability, benefits, and expected impacts. The study employs a water balance analysis, considering water use from potential sources compared to the current and future capacity to deliver water. This aids in decision-making by analyzing alternative project options to ensure the project is cost-effective and maximizes benefits for the benefiting area. In examining the water potential for agricultural use, the study considers acceptable criteria, allowing for a maximum shortage of no more than 20% during the entire 30-year study period.

2) The study of the economic, social, and agricultural aspects of the project.

Includes the affected area, encompassing the average landholding per household, types of land ownership documents, and the agricultural land use of farming households. It assesses the attitudes of farmers in the impacted area regarding the project, their perceptions of the project's effects, and their opinions on land compensation and property payments.

The beneficiary area includes household properties, land tenure, land use, cultivated areas, net income from crop cultivation, household net income, debts, and savings. The study outlines the current crop cultivation plan, production factors, costs, and crop yields.

Social conditions encompass community settlement, household structures, education, and occupational activities.

3) Environmental condition assessments involve examining the project area to determine if it falls within any forest or park zones, as well as studying the forest conditions in the area. It includes evaluating the water basin quality and studying the environmental impacts.

The analysis of development alternatives includes various case studies, such as baseline analyses representing natural conditions or the current state without development. The analysis of reservoir capacities is conducted at multiple levels to assess the benefits, reservoir size, and water surface area for different alternatives. This is achieved by studying the areas with benefits or irrigated areas, with several case studies based on the characteristics of the project area, including geographical, social, and economic conditions.

(1) Baseline scenario: Natural conditions without any development (Without Project) currently serve as agricultural or existing irrigated areas.

(2) Scenario of full irrigation development potential: This involves opening up the full irrigation potential according to the physical conditions of the area or as much as can be developed into irrigated areas.

(3) Scenario considering the appropriate size of irrigated area according to the potential water quantity and storage.

(4) Development or modification scenarios for crop cultivation that differ from the current practice may involve crops with lower or higher water requirements. This includes various economic crops such as field crops, fruit trees, rubber, and vegetables, compared to areas where rice is grown. This analysis should take into account economic, social, and societal aspects along with the direction of societal development.

Finding a balance between water resource quantities and water usage requirements is crucial for analyzing the cost-effectiveness of water utilization.

(5) Selecting the option for reservoir size involves a multidimensional comparison in the fields of engineering, economics, environment, and society. This is achieved by using criteria that weigh the importance of each dimension and factor. Options with higher scores will be further studied and explored in preliminary designs.

4) Economic and financial analysis of the project utilizes criteria to measure the project's suitability, including Net Present Value (NPV), Economic Internal Rate of Return (EIRR), and Benefit-to-Cost Ratio (B/C ratio). This involves direct costs, which comprise investment costs from engineering, land compensation costs, and indirect costs. Indirect costs detail the expenses incurred from project operations that lead to external impacts, resulting in negative effects or societal burdens that need addressing. Additionally, it encompasses direct benefits, such as those directly associated with the project's objectives, including benefits in irrigation, flood mitigation, industrial water supply, tourism, and domestic consumption. Indirect benefits are those occurring beyond the project's objectives. Economic impacts measured in monetary terms use market prices for evaluation, while non-monetary impacts utilize environmental economics tools for assessment.

Furthermore, there should be an analysis of sensitivity in case of uncertainties in increased costs, reduced benefits, construction delays, or a Switching Value Test analysis.

Financial analysis should employ a farm model and may include an Average Incremental Cost (AIC) analysis to further assess the cost-effectiveness per unit of water quantity.

5) Public Participation

To achieve the project's specified objectives, it is imperative to engage in processes related to public relations, mass communication, and public participation. All stakeholders should be informed about the project's progress, fostering accurate and mutual understanding. This involves applying principles and techniques in 3 dimensions: public relations, mass communication, and public participation. Therefore, the public participation process involves a two-way communication that has practical implications for overall objectives. The aim is to facilitate decision-making that is mutually acceptable at all levels. These processes not only align with the provisions of the Constitution of the Kingdom of Thailand in B.E.2560, but also comply with the regulations of the Prime Minister's Office regarding public input in B.E.2548. Moreover, they contribute to transparent project execution.

Criteria for the project management office's public participation meetings are as follows: there will be a total of 3 sessions for project reports.

The first session involves convening a community leaders' meeting, including local administrative organization (LAO) leaders in the area.

The second session is a seminar-style meeting, inviting both community leaders and stakeholders in the project area to receive information and provide feedback.

The third session is a meeting to inform the villagers of the resolutions of the project, allowing them to express agreement or disagreement.

Upon examining the current water development project planning, it is observed that engineering studies adhere to standard processes and guidelines. However, there is no specific indicator indicating a range of scores that denotes suitability or sustainability. The comparison includes selecting the project development format (reservoir or weir), assessing the appropriate project location, and evaluating the size of the reservoir. The study employs principles of analysis and design for stability, strength, safety, cost-effectiveness, ease of maintenance, and efficient management. Some factors are quantifiable, while others involve qualitative comparisons. The Multi-Criteria Assessment (MCA) method is commonly used, involving scoring and weighting criteria for each project individually. The preferred option is the one with the highest overall score, indicating its suitability and potential.

2.5 Reviewing the Sustainability Indicator of Natural Resources, Water Development, and Water Resources Management

Since Gro Harlem Brundtland in 1987 defined Sustainable Development Goals (SDGs), international organizations have collectively agreed to advocate for addressing environmental and natural resource challenges. Seventeen specific goals were established, encouraging global cooperation for their utilization as targets in economic, social, and environmental development to ensure sustainability. Thailand has embraced the SDGs as a framework for policy, strategies, master plans, and operational plans across relevant government agencies.

In the past, numerous research studies have focused on the development of key factors and indicators in sustainable development across various sectors. These studies emphasized balanced development that aligns with natural resource conservation and environmental sustainability. Research in this area has garnered interest internationally,

with a particular focus on water resource development. Water resources are considered crucial for sustaining human and wildlife life, as well as being a primary factor essential for various human activities, production, and economic systems in all sectors.

However, the development of efficient and effective water sources, predominantly located in areas with abundant natural resources and high biodiversity, may lead to consequences impacting the loss of natural resources and biodiversity richness, inevitably affecting the long-term sustainability of the environment.

In the majority of research related to sustainable water development, particularly at the national level, the studies aim to establish criteria and indices for measuring sustainability. These measures are employed to assess the effectiveness and progress of initiatives, examining the sustainability levels in terms of natural resource utilization, water resource development, utilization of water benefits, environmental impact, and water resource management.

Research related to sustainability in natural resources and the environment involves studies aimed at finding indices and indicators for the balanced and sustainable development and utilization of resources. In the context of the Pu Phan National Park, a study conducted by Anucha Piyachana, in B.E.2546, titled "Status of Natural Resources and Environment in the Pu Phan National Park Area and Surrounding Areas," had the objective of presenting a methodology for studying the status of forest resources, land use, and water quality in the overall area of Pu Phan National Park. The study aimed to serve as indicators for measuring the sustainability of development and resource utilization in a balanced manner, proposing three key factors: 1) the status of forest resources, 2) land use practices, and 3) water quality.

Sustainability in project development, or the utilization of land from natural resources, is defined as not exceeding the regenerative capacity or carrying capacity of the environmental system. This considers 3 key factors: 1) Forest resource factors, including the environmental characteristics of the forest (forest types and timber volume in the forest area, as well as annual timber increment), and the value of the forest environmental system. Sustainable utilization principles have been proposed based on the quantity of timber use from the forest that does not exceed the annual timber increment. The study has established annual timber increment values for dry dipterocarp forest mixed deciduous, and dry evergreen forest with percentages of 1.5,

2, and 2.5, respectively. 2) Land use factors, including the proportion of land utilized in unsuitable areas in Class 1A and Class 1B. 3) Water quality factors, including physical, biological, and chemical parameters, as well as pesticide residues.

Pumijumnong and Chareonwong (2017). conducted a study to assess the status of sustainable development goals in the context of Thailand, specifically focusing on the options available through economic, social, and legal measures. The study concentrated on Goal 15 (terrestrial ecosystems) of sustainable development, which involves the sustainable protection, restoration, and utilization of terrestrial ecosystems. This encompasses sustainable forest management, combating desertification, halting and restoring degraded land, and preventing the loss of biodiversity. The goal consists of 12 targets and 14 indicators.

The study findings reveal that Thailand currently lacks clear and comprehensive goals for natural resource management to meet sustainable development. The information for each resource is not well-differentiated, and the indicators in SDG Goal 15, with a moderate to high potential, include (1) the proportion of degraded land to the total area, (2) the proportion of forest area to the total area, (3) the proportion of vital terrestrial and freshwater ecosystems protected, and (4) the progress in sustainable forest management.

Indicators with moderate to low potential include (1) the proportion of wildlife illegally traded, (2) sustainable development assistance, (3) government expenditure on conservation, (4) utilization of sustainable biological and environmental diversity, (5) a list of endangered species, and (6) the green coverage area of the mountains.

This study is a national-level assessment that evaluates the progress in setting plans, goals, and performance indicators for sustainable development in terrestrial ecosystems. The researchers found that Thailand lacks clear goals and complete data in this area, making only some sustainability indices could be assessed, furthermore there also have been no definite sustainability indices with their weight factors and scoring range in projects area level. However some indicators of the study are important and may be applied as metrics for environmental sustainability at the project level, such as the proportion of forest area to the total area, the proportion of conservation area to the total area, and endangered wildlife.

And Noywuli, Sapei, Pandjaitan, and Eriyatno (2019) conducted a study to assess the carrying capacity of river basins in Indonesia, using it as a criterion for evaluating natural resource management. The criteria for assessing carrying capacity were defined based on five factors: 1) land management, 2) water resource management, 3) socio-economic conditions, 4) water-related infrastructure, and 5) utilization of the river basin. Indices were established to measure these factors.

In terms of land management, considerations include (1) the indicator of the proportion of degraded land in the watershed, (2) the proportion of green areas, and (3) the indicator of soil erosion from plant types and agricultural management.

In terms of water resource management, indices such as (1) maximum water quantity, (2) annual average water quantity, (3) annual sedimentation quantity, (4) frequency of flood occurrence, and (5) the proportion of water use per river flow.

In terms of socio-economic aspect, evaluations are based on (1) the proportion of agricultural area per number of farmers, (2) the ratio of households in poverty to total households, and (3) local regulations for watershed conservation.

In terms of development of water source structures, considerations involve (1) the size or type of urban communities, and (2) the proportion of local investment in water-related structures to the total investment.

In terms of resource utilization, considerations are based on (1) the proportion of conservation areas to the watershed area and (2) the proportion of agricultural areas to the watershed area. This study applied the principles of determining the carrying capacity of the watershed based on indicator variables and scoring criteria as stipulated in the laws of Indonesia in the year 2014. The assessment aimed to evaluate the overall condition of the watershed and determine future restoration methods.

The study has proposed additional indices that should be considered, including indices related to water quality and drought.

The utilization of the carrying capacity values for the current water resources and ecology system in the watershed is suggested as a factor in determining the sustainability of water development projects in the watershed. It is recommended that the impact of such projects should not result in the reduced carrying capacity of the current system. However, there are limitations in directly assessing these values. Nevertheless, indices that could be applied in studying carrying capacity and

sustainability include resource-related factors, utilizing indices such as (1) the proportion of conservation areas to the watershed area, (2) the average river flow usage rate per area, (3) the annual precipitation rate, (4) the proportion of agricultural areas to the watershed area, and (5) the proportion of water usage to river flow.

Tang et al. (2020) conducted a study on the changes in the carrying capacity of forest resources at the regional level in the Yangtze River basin, People's Republic of China. The study aimed to establish an indicator for determining the carrying capacity of forest resources, specifically comparing the Forest Ecological Security Indicator (FESI) with the Ideal FESI values assessed at the regional level. This assessment considered the Forest Ecological Location Coefficient (FELC).

The FESI group consisted of significant factors such as 1) Forest State Indicator and 2) Forest Pressure Indicator, while the FELC group was composed of the Forest Location Indicator.

The Forest Security State Indicator consists of (1) a quantitative indicator, (2) a quality indicator, and (3) a damage indicator.

The quantitative indicator includes forest area, the quality indicator encompasses biodiversity, quantity of wood, average age of trees, natural forest proportion, community forest proportion, and mixed forest proportion. The damage indicator involves the proportion of areas affected by forest fires and the proportion of areas damaged by insects.

The Forest Security Pressure Indicator comprises (1) the General Pressure Indicator, which includes population density per area, energy consumption per area, and greenhouse gas (GHG) emissions per area, and (2) the Restoration and Conservation Indicator, which involves the proportion of conserved areas and the investment in forest protection, as well as the proportion of reforested areas.

The Ecological Location Coefficient depends on the location and includes (1) meteorological factors such as annual rainfall, average annual temperature, hours of sunlight, daily average wind speed, and (2) topographical factors such as elevation, slope, and geographic position.

Applying indices that are significant for sustainability in the dimension of natural resources involves considering the proportion of conserved areas in the

watershed, the size of deforested areas due to development, biodiversity, and rainfall quantity.

For Thailand, the National Parks Research and Development Office conducted a study to prioritize the importance of national parks in the B.E.2562. Criteria and factors were established for ranking the significance of national parks in 6 aspects: physical, biological, risk, global importance, recreation and tourism, and complexity of management. The ranking was divided into 3 levels: highly significant (A), significant (B), and moderately significant (C). Key indicators for each aspect include: 1) Physical Aspect : area size, continuity and connectivity with neighboring parks, 2) Biological Aspect: number of forest species, number of wildlife species with high ecological value, presence of unique or vulnerable ecosystems, 3) Risk Aspect: occurrence of forest fires, presence of local communities within the area, population residing in the national park, environmental impact of development projects, area subjected to encroachment 4) Global Importance Aspect, 5) Recreation and Tourism Aspect: number of tourist attractions, diversity of tourist attractions, number of recreational activities, and 6) Management Complexity Aspect.

The study found that the indices used in the aforementioned research emphasize the importance of conserving natural resources, forests, and wildlife in national park areas. These indices serve as a measure of the level of significance in various national park areas, including both terrestrial parks (129 parks) and marine parks (26 parks). The ranking values derived from this study indicate that some key indices can be applied to assess the environmental importance or ecological value of the biodiversity in these areas at the project level.

While another research group will study the sustainability indicator of water resource development, Ethan T. Smith and Harry X. Zhang conducted a study in 2007 (Smith & Zhang, 2007) on the "Evolution of Sustainable Water Resource Indicators." The objective was to find indicators measuring the sustainability of water sources at both regional and national levels. The information gathered from this study aims to support decision-making in conservation and development efforts.

The results of the study by the Sustainable Water Resource Roundtable (SWRR) of the Advisory Committee on Water Information (ACWI), comprised of members from the government, private sector, and NGOs in the USA, propose 8 key indicators

categorized into 4 groups. These groups include: 1) Water Quality: occurrence of newly emerging contaminants, quantity of oil, persistent organic pollutants that are difficult to eliminate and pose environmental risks, 2) Quantity: trends in changing rainfall volume and ratio of water demand to available water supply, 3) Water Use: quantity of water used in different sectors, 4) Geography and Land Use: risks to plant and animal species extinction, risks to water quality due to agricultural land use. The review found that in Thailand, there is still a lack of comprehensive data in several variables. However, there are indicator groups that can be incorporated into the study, particularly in the quantity dimension, such as rainfall quantity, water usage quantity, and in the geography aspect, such as the status of endangered wildlife.

Liang, Zhang, Liu, and Liu (2018) conducted a study titled "Quantitative Measurement of the Sustainable Water Resource Development System in China Inspired by Dissipative Structure Theory." The objective was to create an indicator for assessing sustainable water resource development, focusing on evaluating the societal, economic, and environmental aspects. The study employed the Dissipative Structure Theory, which describes the complexity and dynamics in water resource systems. The Information Entropy Model was utilized as a tool for analyzing water resource development and trends in the evolution of water resource development systems.

The study reveals that the development of water resources must establish a relationship and interconnection between society, economy, and the environment. It seeks to identify the most suitable points of optimization between economic and societal development at a level that does not adversely impact the resources and carrying capacity of the environmental system.

Factors in the socio-economic aspect include the following: 1) GDP per capita, 2) GDP growth rate, 3) water consumption rate per GDP, 4) industrial water usage per GDP, 5) investment in wastewater treatment, 6) investment in water resource development, and 7) investment in conservation through technology. These could be implied that development of water sources that would to increased income and value from production per unit of water used. The higher the unit value, the more cost-effective the development of water resources, including the conservation of low-cost resources.

Factors in the social aspect include: 1) population growth rate, 2) water consumption rate per capita, 3) water consumption rate per agricultural area, 4) community expansion rate, 5) number of projects in the area, and 6) number of personnel in water conservation. These appropriate rates of water usage per agricultural area or community could be essential in sustainable water resources development planning.

Factors in the resource aspect include: 1) proportion of water used per water source, 2) capacity of water resources in the country, 3) reservoir storage at the end of the year, 4) water resources volume per capita, 5) average annual rainfall, 6) specific water yield per catchment area, 7) annual surface water volume, and 8) annual groundwater volume. These indicated that the potential water yield and balance between water storage capabilities and water usage needs would be one of main factors for proper project planning.

Environmental factors in the green aspect include: 1) the volume of water used for environmental conservation, 2) the quantity of wastewater, 3) the community's wastewater treatment capabilities, 4) the extent of land and water loss, and 5) the volume ratio of clear water to wastewater. This entails sustainable water resources development should not lead to environmental degradation issues, such as water quality, loss of land resources, deforestation, wildlife, and ecosystems.

Even though the indices from the research may be applied for the regional level, however, some indices can be applied at the project level. In terms of the economy, examples include the value of investments in water development and the value of investments in conservation. For social indices, such as the rate of water usage per capita and per agricultural area, can be applicable. Water resource indices, such as the proportion of water demand to water availability, annual rainfall, and the river flow’s specific yield per unit area, are relevant. For the environmental and ecosystem indices, for examples including the volume of water for mitigating environmental impacts from development, the soil degradation area, and with the increasing rate of agricultural wastewater, are also significant.

Morris (2019) conducted a study titled "Developing and Exploring Indicators of Water Sustainable Development." The research aimed to establish principles for quantitatively measuring sustainable water development, with the purpose of informing

policies for water resource development to meet the increasing water demands in the future. It also sought to enhance water usage efficiency in alignment with economic, social, and environmental development. The study presented straightforward and uncomplicated national-level indices for assessing sustainable water development.

The research findings indicate that the Water Sustainable Development Indicator (WSDI) can be quantitatively determined based on indices measuring factors, including 1) Water Productivity Indicator (WPI), 2) Life Expectancy Indicator (LEI), 3) Education Indicator (EI), and 4) Income Indicator (II). The assumption is that economic sustainability is incorporated into the WPI and human sustainability development through factors (2), (3), and (4). Additionally, simple indices used at the regional level include (1) Water Productivity Indicator (WPI), which utilizes the GDP per unit of raw water consumed annually, (2) Life Expectancy Indicator (LEI), which employs the average age of the population, (3) Education Indicator (EI), using the number of years of education for children and the population aged over 25, and (4) Income Indicator (II), utilizing GDP per capita.

The study tested the relationship between the Water Sustainable Development Indicator (WSDI) and the Ecological Footprint (EF) and found a strong correlation. This correlation is similar to the relationship between EF and the Social Development Indicator (HSDI), which signifies development that has an impact on the environmental system and minimal resource usage, resulting in sustainable development that benefits both the economy and society.

The aforementioned study aims to create a sustainable water development indicator at the regional or national level. The sustainability indicator could potentially be applied to research projects at a finer scale, such as water productivity and income indices, as well as the ecological footprint. These considerations focus on development that minimally impacts the environmental system.

Furthermore, there is a study conducted by de Almeida Corrêa and do Nascimento Teixeira (2013), titled "Developing Sustainability Indicators for Water Resources Management in TIETÊ-JACARÉ BASIN, BRAZIL" The objective of this study is to establish sustainability indicators for water resources management by the basin committee, consisting of experts and professionals in the field. The research

encompasses an analysis of the problem, the assessment of sustainability indicators, and the evaluation of suitable indices.

The study revealed three significant problems in the crucial watershed, including community wastewater management issues, reforestation challenges, and soil conservation concerns. The sustainability indicators comprise 18 indicators categorized into erosion control, water quality management, development and utilization of water resources, and social aspects such as population growth and conflicts over water usage. Researchers found that in each indicator group, three key measures are essential for sustainable water management: decentralized management, organizational management, and information provision, as well as knowledge-building in water resource management. The study suggested considering sustainability indices for water management, such as the proportion of eroded river length, water quality indicator, agricultural land proportion, proportion of water supply serviceable area, proportion of wastewater treatment serviceable area, conflict level over water usage, and recommended the importance of community involvement in continuous evaluation of these indices in the future.

However, since the mentioned study aims to focus on sustainable water management, there are indices related to water utilization and the development of water sources more than indices related to the conservation of upstream resources, such as forests and ecosystems.

For the sustainable water management study in Thailand conducted by the National Statistical Office (NSO) in B.E.2563, the Water Management Indicator (WMI) was developed under the project of establishing a regional-level basic infrastructure data collection system for sustainable water resource management throughout the country's river basins. This initiative aims to provide decision-makers with essential information for planning the country's water resource management.

By soliciting input from over 40 relevant organizations involved in water management and national development, the study found that there are 59 indicators across 8 dimensions. Examples of significant indicators include:

1) Water Resource: key factors include annual rainfall, annual flow, annual flow per capita, water storage per capita, and water storage per reiver flow, and water quality.

2) Water Management for Domestic Consumption: important metrics include the proportion of water supply serviceable households, the rate of domestic water consumption per capita, and the time duration periods of drought or unserviced.

3) Water Security for Development: vital measures encompass the proportion of agricultural land to total land area, and the water storage per agricultural area.

4) Water Balance: assessing the balance between water resources and water usage.

5) Water Quality and Environmental Management: criteria involve the number of villages with treatment systems, the quality of raw water sources, the density of monitoring systems, and more.

6) Water Disaster Management: this includes the value of damages, the proportion of frequent flooded areas, the ratio of affected population to the total area's populations, duration of flooding, flood depth, and the proportion of frequent drought areas.

7) Forest Conservation and Management: examining the proportion of forested areas and the abundance of forests.

8) Water Resource Management: this entails having water management plans, people participation in water management, the distribution of water management organizations, and existence of meteo-hydrological monitoring systems.

The study found that Thailand's water management indicator is in the "good" range, demonstrating efficiency. It emphasizes the significance of water management over environmental and social conservation. However, certain indicators and indices can be applied at the project level, such as water quantity, water storage per agricultural area, and damage from flooding.

2.6 Guidelines of EIA Report Preparation for Water Resource Development Projects by the ONEP, B.E 2566

The guidelines of EIA report preparation for a new water resource development project is update in accordance with the announcement of the ONEP on the guidelines of EIA report submission as of Apr 5, B.E. 2565.

There are five main topics required comprising 1) project background and necessity, 2) overall project component detailed study, 3) present environmental conditions, 4) environmental impact assessment, and 5) environmental impact mitigation plans and monitoring and evaluation programs. For the first part, main issue comprising a critical target area boundary and location and its conditions of water scarcity and flooding problems, objectives of the project development in the conservation areas including the national reserved forest area (conservation zone), the national park area, the wildlife sanctuation area, watershed classification 1, and others as specified by related laws. Moreover summaries of the water resources development plan of the river basin and the compliance of the studied project with the master plan. Finally, the important issues of alternative and optimization studies of the project component conceptual design are to be considered. The alternative studies should be included type of project development, location of the headwords, size of the project, type of structures, and type of irrigation system. The guideline specifies that the alternative study has to consider methodology and criteria, as well as factors and their weightages in four dimensions including 1) engineering, 2) economic, 3) social, and 4) environment. However the weightages are not definitely specified whereas some indicators of each dimensions are introduced as examples. They are construction cost per unit of water retention, water storage to annual inflow ratio, geologic conditions for the engineering aspect, whereas construction costs of benefit area for the economic aspect, number of households, houses and compensated land, and number of beneficiaries for the social aspect, additionally, the size of impacted area within the conservation area and forested area ratio for environmental aspect. These dimensions and indicators were also determined during the process of sustainable indicator design of this research.

The second part is mainly concerning the results and details a of project components' methodology and design criteria applied. This comprises specifically on the dam's stability and safety from seismicity, as well as on appurtenant structures (spillway and river outlet) and irrigation system, water balance study between water requirement and water resources, construction cost and construction schedule, as well as economic feasibility study and environmental economic study which cover

construction, compensation, and environmental costs and key economic indicators of IRR, NPV and B/C ratio.

For the third part, the study has to present primary and secondary surveyed data methodology, criteria, and analysis results of conditions and situation status of the present natural resources and environments in terms of four categories including 1) physical resources, 2) biological resources, 3) human use values, and 4) life quality values, respectively.

The physical resources consist of topography including slope, altitude, geology comprising geomorphology, leakage, geologic scenery, active faults, landslide, mineral resources, soil suitability, erosion and sedimentation, as well as hydrology including climates, surface water quantity and quality, ground water quantity and quality. In term of terrestrial ecology, it includes forestry type, number of the species, density of the conserved trees, important value index, encroachment, and ecology services. In term of wildlife, it comprises four groups of mammals, birds, amphibians, and reptiles of which density amount, bio-diversity, endangered wildlife status must be provided. In term of aquatic ecology, there should be type, density and endangered aquatic animals and abundance of phytoplankton, and zooplankton, weeds, and benthos.

In term of human use, this covers water resources potentials, water demands, shortage of water, flood prone area and risk map, waterway and drainage capacity, in addition, fishery and aquaculture, land use, industry, energy consumption and supplies, transportation, waste and wastewater conditions.

In term of life quality value, it should include socio-economic conditions of both impacted households and beneficiaries, attitudes, protesting issues, compensation cost, benefit values. In addition, public health conditions, diseases, and sanitation. moreover, existence of tourism places, archaeologic or historic places, and people participation study results should be studied.

In the fourth part, the environmental impact assessment of all aspects due to the project as items described above have to be presented in qualitative way both positive and negative directions from less to high insignificant level.

For the ending part, the environmental impact mitigation plans of all issues would be proposed together with the monitoring and evaluation programs. Both plans

should be covered during construction and implementation periods, providing time schedule, budgets and authorized agencies.

Consequently, the EIA report provide quite sufficient reliable, and necessary data and information for project's impact assessment and provision of EIMP and monitoring and evaluation programs. This could make confidence to all stakeholders obtaining project benefits with minimal losses or adverse effects. However, the guideline does not specify directly the sustainability definitions, indicators and their weightage, ranging scale, and sustainability level. The EIA report present the situation of the existing project conditions in various dimensions, effects of the selected project location and components and suggestion of EIMP basing on the result of alternatives feasibility study of which the sustainability balance among all dimensions may be imprecise. Therefore, study of defining more definite sustainability definition criteria, and its indicators together with there scale and weightage, and justified sustainable conditions would be benefit for optimal project design with balance among all dimensions.

2.7 Indicator Development Framework

The United Nations Commission on Sustainable Development (UNCSD) established an indicator framework based on environmental conservation and sustainable development themes in 1995 for applying as a tool for monitoring sustainable development. The framework could be separated into 4 aspects including social, environmental, economic, and institutional aspects (United Nations Conference on Sustainable Development, 2001 as cited in (Segnestam, 2003). Each aspect defines following issues that should be considered:

1) Social: Equity, Health, Education, Housing, Security, and Population

2) Environmental: Atmosphere, Land, Ocean, seas and coasts, Freshwater, and Biodiversity

3) Economic: Economic structure, and Consumption and production patterns

4) Institutional: Institutional framework and capacity

The last aspect of the indicator framework concerning the institution and its capacity which is appropriate for large scale or national level. Accordingly, this project objectives are on project development level, it is less concerned aspect to account for.

2.7.1 Connectivity of Sustainable Indicators to Sustainable Development Goals

In 2012, The United Nations Conference on Sustainable Development (Rio+20) (Rio + 20) established a sustainable development goal (SDG) covering the area of promoting sustainable production and consumption. In July 2014 the conference of the governmental Working Group on Sustainable Development established a recognize 17 SDG goals and 169 targets. Consequently, a few year later, there was a seminar on details of sustainable development related to 13 goals out of the total 17 goals of which their targets and corresponding sustainable indicators were defined as presented in Table 2.1 (United Nations, Department of Economic and Social Affairs, 2019; United Nations Environment Programme, 2015). The table present connectivity among sustainable development goals, targets and adopted sustainable indicators. This guideline could be applied as a framework for sustainable development indicator establishment of this study.

Table 2.1 Goals, Targets and Indicators of Sustainable Development Related to Sustainable Consumption and Production Indicators

SDG Area	Targets	Indicators
1 Poverty Eradication	1.5 By 2030, build the resilience of the poor and those in vulnerable situations, and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	1.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population 1.5.2 Direct economic loss attributed to disasters in relation to global gross domestic product (GDP) 1.5.3 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 1.5.4 Proportion of local governments that adopt and implement local disaster risk reduction strategies

SDG Area	Targets	Indicators
		in line with national disaster risk reduction strategies
2 End hunger, achieve food security	2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality	2.4.1 Proportion of agricultural area under productive and sustainable agriculture
3 Ensure healthy lives and promote well being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	3.9.1 Mortality rate attributed to household and ambient air pollution
		3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation

SDG Area	Targets	Indicators
		and Hygiene for All (WASH) services)
		3.9.3 Mortality rate attributed to unintentional poisoning
4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.7 By 2030, ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and nonviolence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development	4.7.1 Extent to which (i) global citizenship education and (ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
6 Ensure availability and sustainable management of water	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of fresh water	6.4.1 Change in water-use efficiency over time
		6.4.2 Level of water stress: freshwater withdrawal as a proportion of

SDG Area	Targets	Indicators
	to address water scarcity, and substantially reduce the number of people suffering from water scarcity	available freshwater resources
7 Ensure access to affordable, reliable, sustainable, and modern energy	7.2 Increase substantially the share of renewable energy in the global energy mix by 2030 development	7.2.1 Renewable energy share in the total final energy consumption
	7.3 Double the global rate of improvement in energy efficiency by 2030	7.3.1 Energy intensity measured in terms of primary energy and GDP
8 Promote sustained, inclusive and sustainable economic growth	8.4 Improve progressively through 2030 global resource efficiency in consumption and production, and endeavour to decouple economic growth from environmental degradation in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, with developed countries taking the lead	8.4.1 Material footprint, material footprint per capita, and material footprint per GDP 8.4.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
9 Build resilient infrastructure and	9.4 By 2030, upgrade infrastructure and retrofit	9.4.1 CO2 emission per unit of value added

SDG Area	Targets	Indicators
promote inclusive and sustainable industrialization	industries to make them sustainable, with increased resource use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, all countries taking action in accordance with their respective capabilities	
11 Make cities and human settlements inclusive, safe, resilient and sustainable	11.b By 2020, increase by [x] per cent the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, develop and implement, in line with the forthcoming Hyogo Framework, holistic disaster risk management at all levels	11.b.1 Total resource flows for development, by recipient and donor countries and type of flow (e.g. official development assistance, foreign direct investment and other flows)
14 Conserve and sustainably use oceans, seas and marine resources	14.7 By 2030, increase the economic benefits to SIDS and LDCs from the sustainable use of marine	14.7.1 Sustainable fisheries as a proportion of GDP in small island

SDG Area	Targets	Indicators
	resources, including through sustainable management of fisheries, aquaculture and tourism	developing States, least developed countries and all countries
15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss	15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1 Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems
17 Strengthen the means of implementation for sustainable development	17.16 Enhance international support for implementing effective and targeted capacity building in developing countries to support national plans to implement all sustainable development goals, including through North-South, South- South, and triangular cooperation	17.6.1 Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the Sustainable Development Goals

Source: (United Nations, Department of Economic and Social Affairs, 2019; United Nations Environment Programme, 2015)

2.7.2 Indicator Development Method of the National Statistical Office

Saeng-Arun (2016) a professional statistician of the National Statistical Office defined the indicator development procedure into 5 steps which are applied for the study as follows:

1) Identification of objectives and goals by considering goals definition clearly and what to measure.

2) Analysis of important components reflecting what meets the goals.

3) Development of indicators by using the analyzed components to define indicators and variables that reflect the components. An effective indicator needs direct relevance to objectives, clarity in design, realistic collection or development costs, high quality and reliability as well as place and time suitability. (Segnestam, 2003)

4) Reconsideration of action of the indicators by ensuring contextual consistency, examining the quality of relevant data whether it is complete and reliable as well as creating metadata consisting of definitions, formulas, measurement units, and data details.

5) Verification of the indicators by reviewing relevant data, and observing their trends and consistency by comparing with authentic situations and other sources. This indicators development concepts would be applied for this study.

2.8 Conclusion

From the literature review, it is evident that the current Constitution of B.E.2560 mandates relevant state agencies with responsibilities for sustainable development, utilization, management, and conservation of water resources. The focus is on ensuring local communities are involved and benefit from these initiatives. In terms of national development policies and strategies, the government emphasizes environmentally friendly development, sustainable in economic, social, and environmental dimensions, adhering to principles of self-sufficiency and ethical governance.

In the legal domain, the state has undertaken amendments to statutes, regulations, and directives to align them with the B.E.2560 Constitution and national strategies, particularly emphasizing balanced development with natural resource conservation and

environmental protection. However, many laws, regulations, and directives are still in the process of being implemented.

Despite the comprehensive coverage in development policies, laws, regulations, and directives, there is a lack of detailed specifications regarding criteria, formats, measures, key factors, and sustainable development indices applicable in practical scenarios. These details are crucial for studying and planning the sustainable development of water sources, ensuring economic, social, and environmental viability that is widely accepted by all stakeholders, including the public and governmental development and conservation agencies.

In the development of various water projects that have posed challenges to the environment and society in the past, the application of principles that prioritize the full potential of water resource, topography, and economic viability has been more emphasized than sustainability and value of natural resources, the environment, and societal aspects with lack of the participation of the public in decision-making. This tends to result in challenges and impacts on both the environment and society. Conflicts may arise in cases where projects are developed or discontinued without the active participation of the public. Even when measures are proposed to mitigate environmental and social impacts, gaining approval from conservation agencies becomes difficult because project developers are often unaware of the criteria, factors, and indices used for evaluating sustainability or accepted standards and criteria.

In many projects, there are challenges arising from qualitative environmental and social factors that cannot be quantified. Examples include archaeological sites, biodiversity, environmental systems, endangered species, lifestyles, cultures, and traditions. These factors may pose limitations on water resource development. However, currently, there is no clear and universally accepted criteria for assessing the importance of these factors. Additionally, there is a lack of recognized indices indicating the value or sustainability of a project. These criteria and indices are crucial guidelines for the sustainable development of water resources, ensuring a balance between development and conservation of natural resources, and they are widely accepted by stakeholders involved in the decision-making process.

Upon reviewing studies on factors and sustainability indices related to water development, it was found that most of these studies focus on factors and indices at the

regional or national levels. These factors and indices are utilized for planning, monitoring, and evaluating the government's actions to achieve sustainable development goals. They can be categorized into 3 groups: those emphasizing natural resource considerations, those prioritizing sustainable water resource development factors, and those highlighting sustainable water management. Although these factors and indices are generally at the national or regional levels, they can still be applied and adapted for the purposes of this study.

In the aspect of natural resources, it was identified that crucial factors include forest-related aspects with significant indicators such as forest status, proportion of forested areas, biodiversity, forest encroachment, vulnerability, or uniqueness. Regarding wildlife, vital factors include biodiversity, the status of endangered species, and the importance level of conservation areas. Concerning soil, factors like erosion rates or sedimentation are noteworthy. In the domain of water resources, key indicators encompass average rainfall, average water volume, and the ratio of water usage per water source. On the economic front, considerations include income per capita and environmental cost. Social aspects involve community participation, agricultural areas per population, and conflict rates. In terms of environmental quality, factors like water quality are taken into account.

This research aims to apply and select factors and indices that have been studied in various research contexts suitable for the Thai context. The objective is to investigate key factors and indicators across economic, social, and environmental dimensions. This will provide a framework for studying and planning sustainable water development projects, fostering sustainability in various dimensions. The application of this framework will streamline the approval process from conservation and regulatory agencies, enabling the government to save budgetary resources and time in assessing suitability. Additionally, it ensures that environmental and social impact studies are conducted efficiently, avoiding the need for multiple studies and preventing conflicts with stakeholders. This approach allows for the sustainable development of water sources in economic, social, and natural resource and environmental aspects, addressing public water scarcity issues and contributing to the nation's economic growth, aligned with government policies.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The research study on the indicator of sustainable water resource development in conservation areas of Thailand aims to achieve the following objectives: 1) To examine the current status, potential, and constraints of water resource development projects in conservation areas; 2) To investigate the key factors influencing the sustainable development of water resource projects; and 3) To establish criteria and standards for measuring the indicators of the main factors affecting the sustainable development of water resource projects.

The researchers employed a qualitative research methodology, utilizing a combination of in-depth interviews of the selected expertise informants related to water resources development, and questionnaire surveys of the Del Phi's expert panel. The research data's credibility was examined through an assessment and cross-verification with project documentation. The studied procedure comprises,

1) Data compilation and literature review including research and studies, concerned agencies regulations, orders, announcements, feasibility and environmental impact assessment (EIA) reports, and specialists' in-depth interview.

2) Study and fact finding of water resources development projects including area problems, stakeholders, constraints and limitation, project potential, and factors and indicators concerned.

3) Screening and defining key indicators and scoring ranges of project's sustainability level, and project's water scarcity level or water resources development necessity level.

4) Questionnaire design covering key dimensions, factors, indicators with scoring ranges, and project sustainability level, additionally factors, indicators with scoring ranges, and project water scarcity level.

5) Summarize the results of factors and indicators with their weighting factors by assessing through questionnaires surveys from qualified expertise informants in Del Phi Group at least twice to obtain majority results which equal to or greater than the 75 percentiles.

6) Application of the results with data from environmental impact assessment reports of 30 project studies,

7) Summarizing the results of sustainable indicators and corresponding weighting score level and recommendation.

3.2 Conceptual Framework

3.2.1 Framework for Identifying Key Dimensions and Factors Affecting the Sustainability of Water Resources Development

Determining the crucial dimensions and factors influencing sustainable water resource development, are based on references from a comprehensive literature review, combined with knowledge gathered from in-depth interviews and data analysis from feasibility studies and environmental impact reports of various reservoir development projects.

According to literature review of sustainable development goal, three key dimensions comprising environment, social, and economic are defined, however with project based study, another key dimension of engineering is additionally consider in accordance with the ONEP's guideline of the EIA report preparation.

Consideration of main influencing factors and indicators of each dimensions are manipulated in consequence with sustainability definition and targets of each dimension as referenced to the procedure of indicator establishment (Saeng Arun, 2016). Such factors and indicators are applied from literature review, in-depth interview of selected key experts, project planning practices together with guidelines of EIA report preparation, and finalized by the Del Phi's expert panel.

These factors encompass significant aspects in the dimensions of engineering, natural resources and the environment, society, and economics as follows;

1) Engineering dimension

Engineering dimension consists of 4 key factors:

1.1) Geographic factor

1.2) Hydrologic factor

1.3) Geologic factor

1.4) Engineering factor

2) Natural resources and the environment dimension.

This dimension consists of four factors:

2.1) The forestry factor.

2.2) The wildlife factor.

2.3) The water quality factor

2.4) The ecosystem factor

3) The social dimension.

The social dimension comprises three following factors:

3.1) The project opposition factor

3.2) The affected stakeholders factor

3.3) The factors of quality of life and uniqueness

4) The economic dimension.

The economic dimension comprises three following factors:

4.1) The factors related to project benefits

4.2) The factors related to project costs

4.3) The factors of project feasibility

3.2.2 Framework for Identifying Factor Assessing Water Scarcity Level

The factors are based on general practices of related water resource development agencies to determine water resources necessity of the problem area.

These factors comprise (1) geographic factor (2) existence of water resources development factor (3) hydrologic variation factor (4) water requirement factor and (5) poverty factor

Selected factors and indicators are determined on the basis of (1) data availability and accessibility, (2) simplicity for application, (3) influencing significant

effect, (4) relativeness and representable, and (5) numeric scaling applicable, respectively.

3.3 Research Design:

The research study approach is designed in accordance with the five following issue.

1) Study procedures
2) Data collection
3) Identification of key informants
4) Research tools
5) Data Reliability verification

3.3.1 Study procedures

The study procedures is presented in Figure 3.1 and described as follows,

1) Data compilation and literature review including research and studies, concerned agencies regulations, orders, announcements, feasibility and environmental impact assessment (EIA) reports, and specialists' in-depth interview.

2) Study and fact finding of water resources development projects including area problems, stakeholders, constraints and limitation, project potential, and factors and indicators concerned.

3) Screening and defining key indicators and scoring ranges of project's sustainability level, and project's water scarcity level or water resources development necessity level.

In this procedure, two steps of screening and defining key factors and indicators are manipulated. The first draft of factors and indicators is initially screened from literature review, whereas the second draft additionally significant indicators are supplementary screened from in-depth interview and ONEP's guideline of EIA report preparation and added to conform with the defined sustainable targets of various dimensions.

4) Questionnaire design covering key dimensions, factors, indicators with scoring ranges, and project sustainability level, additionally factors, indicators with scoring ranges, and project water scarcity level.

5) Summarizing the results of factors and indicators with their weighting factors by assessing through questionnaires surveys from qualified expertise informants in Del Phi Group at least twice to obtain majority results which equal to or greater than 75 percentile.

6) Application of the results with data from environmental impact assessment reports of 30 project studies,

7) Summarizing the results of sustainable indicators and corresponding weighting score level and recommendation.

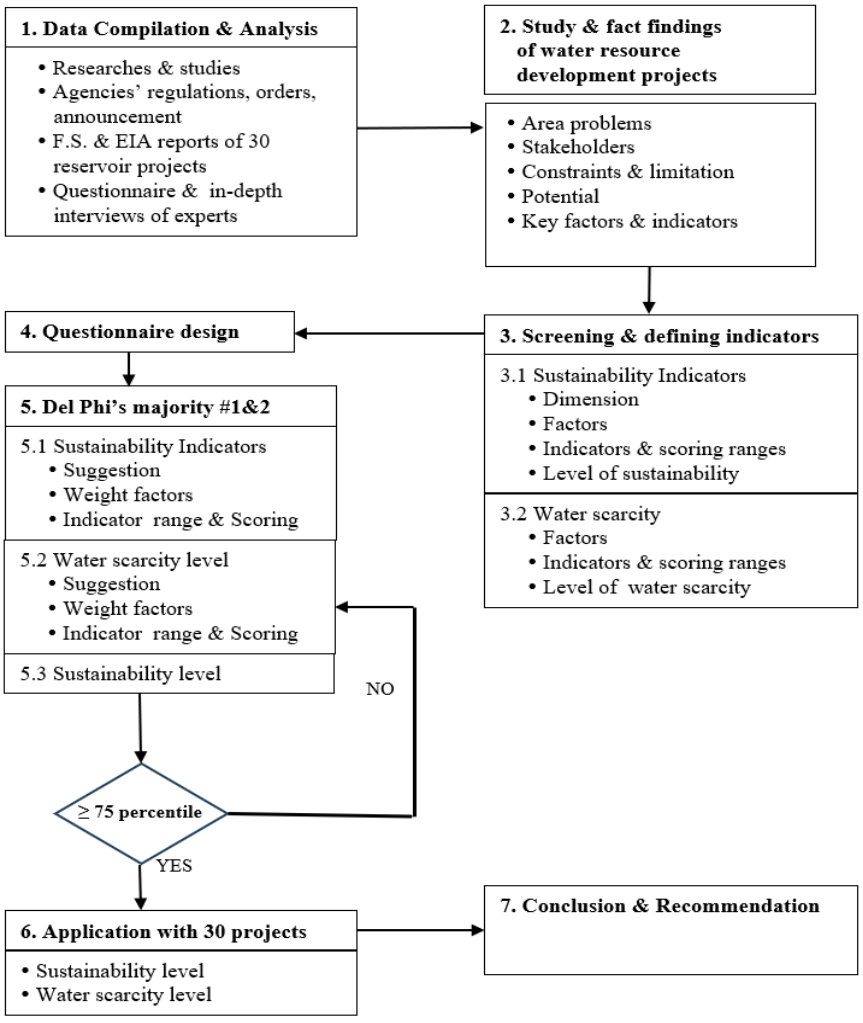

Figure 3.1 Study Approaches and Procedures

3.3.2 Data Collection and Review

Primary and secondary data were compiled.

1) Secondary data includes documents, statistics, project selection criteria of various study reports of both water resources development feasibility and environmental impact assessment.

The data and information were compiled and analyzed to clarify the states of problem issues, barriers and limitation constraints, among deferent contexts of geography, physical factors, natural resources and environments, and socio-economic conditions, Additionally, to develop key factors or variables, indicators and corresponding scoring ranges that most affecting sustainability level of the potential water resources development projects.

Study data were retrieved from environmental impact assessment reports of 30 projects distributed across different regions of Thailand of which locations presented in Fig 2 comprising the northern region for 17 projects (57%), the eastern region for 6 projects (20%), the southern region for 3 projects (10%), the northeastern region for 3 projects (10%), and the central region for 1 project (3%). These projects have storage capacities ranging from 2 to 295 million cubic meters, covering surface areas ranging from 87 to 16,250 rai. Some of these areas are partially located within conservation areas, including national parks, wildlife sanctuaries area, watershed classification level 1, and conservation zone (Zone C) of national reserved forests.

However, there are limitation of the 30 projects' EIA reports obtained from related agencies. They are:

(1) Regional distribution of accessible sampling projects

Unfortunately available and accessible EIA reports of the studied projects are limited and not well distributed in terms of project location and sizing, therefore most of projects' data for establishing indicators' ranging scales and scores are located in northern region or 57% of the total projects due to geographic potentials, whereas residual projects are spreaded over other regions ranging from 3% to 20%.

(2) Project size distribution

Similarly, almost of the projects are medium scale size (2-99 mcm) as classified according to the RID's classification criteria. Since presently there are rare potential sites of large scale projects in Thailand, whereas small scale projects

are mostly having less or insignificant impacts to the conserved areas, resulting less EIA studies are provided.

2) Primary data comprised semi structured in-depth interviews together with open-ended questionnaire survey among key 7 expert informants to analyze principals, concepts, and reasons in projects defining and prioritizing important dimensions, factors, and indicators that affecting projects sustainability.

Table 3.1 Summary of Data Collection, Tools, and Analysis Methods

NO	Objectives	Data Resources /Informants	Tools of data collection	Analysis Methods
1	To study context, concerning factors& indicators, constraints & limitations, and potentials.	1) Secondary data - Researches, agencies' documentations study reports of project feasibility and environment impact assessment, 2) Primary data - In-dept interview questionnaire of 7 experts in engineering, forestry, wildlife, socio- economic, and environment	1) Review of researches, and reports of project feasibility and environment impact assessment, documentations, researches. 2) In-depth interview 3) Review guidelines of EIA report preparation	Descriptive statistics
2	To study dimensions, key factors, indicators and corresponding scoring ranges	20 related expert informants from - Water resources development agencies (RID, WRD, ORDPB) - Natural resources conservation agencies (RFD, DNP, DMR) - Policy and control agencies (ONEP, NESDB, ONWR), Watershed Committee - Related private specialists and consultants	Del Phi 's Questionnaire survey	1) Descriptive statistics 2) Multi Criteria Analysis (MCA) 3) Percentile 4) Exceedance probability
3	To apply indicators with 30 projects	30 study reports of projects feasibility and environmental impact assessment (EIA)	1) Spreadsheets 2) Geographic Information System (GIS)	1) Descriptive statistics 2) MCA 3) Regression

3.3.3 Establishment of Key Informants

Two groups of key informants were specified comprising. 1) experts of questionnaire design, and 2) experts of Del Phi's panel. For the first group, representative informants were specifically invited from five significant fields including engineering, forestry, wildlife, environment, socio-economic, respectively. The second group's 20 informants were also specifically classified from related fields both in governmental and academic sectors. They are representatives from governmental agencies of water resource development, socio-economic, water resources planning and control agency, natural resources conservation and environmental control, as well as related field experts from both academic and private sectors.

Design criteria of qualification of all experts were specified in accordance with both related academic background and working experiences as follow;

Academic:	Bachelor's degree or higher degree
Work experience:	direct or related fields of water resources development projects more than 30 years
Occupation & organization :	government officers, university lecturers, professional and independent consultants.

1) The In-depth interview for questionnaire design group consists of 7 experts from three main aspects,

(1) Engineering: a senior officer of DWR

(2) Natural resources & Environment: 3 senior officers of RFD, DNP and RID and, 2 independent consultants in forestry, and wildlife

(3) Socio & Economic: a senior officer of RID

2) Del Phi's panel group comprising 20 experts from three main aspects,

(1) Engineering: 4 senior government officers of RID, DWR, ORDPB, and ONWR,

(2) Natural resources & Environment: 8 senior government officers of RFD, ONWR, ONEP, DMR, watershed committee, and 4 senior independent consultants in forestry, wildlife, environment, and geology,

(3) Socio & economic : 2 senior government officers of RID, NESDB, and 2 senior independent consultants in social and economic,

3) Selection criteria for selective informants of in-depth interview is set upon the purposes of the study to supplement the previous studies of concerning dimensions and indicators obtained from literature reviews and from key responsible agencies' practices and guideline of water resources development planning and environmental impact assessment. The comments, information, and suggestions obtained would be valuable for questionnaire design prior to the Del Phi's consideration process. Therefore, main stakeholders involving studying and approving procedures of both engineering and natural resources are specific selected from not only key government agencies but also academic experts. These key stakeholder informants are proposed for data triangulation to assure unbiased, coverage, consistency and reliability of information obtained.

The selective expert informants for the in-depth interview should cover key dimension and obstacle issues that mostly experienced from the past project consisting of,

(1) Engineering dimension concerning key issues of engineering planning and design

(2) Natural resources and environmental dimension (main issues on forestry and wildlife and land utilized permission)

(3) Social dimension main issues on project opposition and evacuation

(4) Economic dimension main issues on feasibility of rate of return

Then the selective informants are considered from a senior water resources engineer of the Water Resource Department (WRD) representing for engineering and geographic dimension. For natural resource and environmental dimension, past mostly issues are concerning permission consideration of land use in conserved area which are responsible by The Royal Forestry Department (RFD) and the Department of Nation Parks, Wildlife and Plant Conservation (DNP). Two proposed senior experts are in forestry field one of which from the Reserved Forest Use Permission Division of the RFD, while the other is a senior independent consultant

expert. Additionally, two proposed senior experts are in wildlife field, one of which are appointed from the Office of National Parks of the DNP, While the other is a senior independent consultant expert. For the environmental aspect, a senior environmental officer of the RID responsible on EIA study is selected.

Finally, for the social and economic aspects, a senior socio-economic officer of the Bureau of Project Management of the RID who responsible for both social and economic aspects is considered. Detailed criteria of expert qualification are described in Section 3.3.3.

4) Selection criteria for selective expert informants of the Del Phi's panel. The panel is a group of key expert informants who responsible for establishment of key indicators for assessment of sustainable water resources projects and water scarcity status.

The number of total expert informants of the Del Phi's panel is defined upon the main stakeholders concerning four dimensions with corresponding critical issues that mostly experienced in the past which covers dimensions of engineering, natural resources and environments, social aspect, and economic, respectively. In addition, the experts should also cover from both government agencies with more concerning authorized functions, including controlling, administration and coordination, developing, and conserving, and more academic and professionals for data triangulation process as following details:

(1) Engineering dimension: There are four main agencies comprising two developing agencies (RID, DWR), one coordinating agency (ORDPB), and one controlling agency (ONWR).

(2) Natural resources and environmental dimension: There are five selected main agencies comprising three conservation agencies (RFD, DNP, DMR), two concerned water resources agencies (ONWR, RID), and two controlling agencies (DNEP, and watershed committee). Additionally, four independent professionals in forestry, wildlife, geology, and environments are proposed.

(3) Social and economic dimensions: There are three agencies concerned i.e. NESDC DNEP and RID, additionally one independent professional in social aspect, and one independent professional in economic are proposed.

As a result, total member of expert informants of the Del Phi's panel would be twenty. Details of the Del Phi's expert qualification are described in Section 3.3.3 similarly to those of in depth interview informants.

3.3.4 Research Tools

1) Del Phi Questionnaire: A semi-structured questionnaire with both closed-ended and open-ended questions, addressing the following issues were applied,

(1) General and key factors, including indicators with sustainability justifications.

(2) Main criteria and sub-criteria for determining the importance weight ranking of key factors, indicators, and scoring ranges.

(3) Decision-making criteria and scoring ranges suitable for project's sustainability evaluation and for each dimension's sustainability assessment (social, environmental, economic, and others).

(4) Comments and suggestions regarding the sustainability indicators of the project.

2) In-depth Interviews of selective experts seven qualified individuals are selected (in the fields of environment, forestry, wildlife, economics, and engineering). The key questions include:

Objectives of the in-depth interview are mainly focused on project barrier issues and their causes, key factors and sustainable indicators of the water resource development projects at project based level to supplement to the information and indicators that obtained from literature reviews, prior to the Del' Phi's questionnaire design process.

3.3.5 Data Reliability Verification

In this context, Triangulation is employed as a method to verify the accuracy and reliability of information from various sources, researchers, and research methods. This is manipulated to examine the consistency and discrepancies in the data obtained.

1) Data source Triangulation involves collecting information from different sources, including experts or qualified individuals in the same field. Several individuals, each working in different roles, responsibilities, or professions, are

included in this process. For instance, two experts from the Del Phi committee specializing in forestry, one serving as an academic and the other as a government official responsible for forest conservation. Additionally, numerous environmental experts, comprising both government officials from project development and conservation units, environmental policy oversight units, private sector engineering consultants, were included. For water resources engineering, experts from the Royal Irrigation Department, the Department of Water Resources, and engineering Office of the Royal Development Projects Board were considered.

Another critical data source includes documents and information from credible government reports on the feasibility study and environmental impact assessment reports of water resources development projects. These documents are utilized for cross-verification against the data collected through the survey conducted by the Del Phi's panel.

2) Methodology Triangulation involves collecting data through multiple methods, including the use of both semi-structured open-ended and closed-ended questionnaires, as well as in-depth interviews with experts and qualified individuals. This approach aims to verify the consistency and reliability of the gathered information. Understanding the principles and reasons behind the data provided and the recommendations given in detail, which may not be evident from the questionnaires alone, is crucial. Additionally, the data collection process from qualified individuals involves utilizing the Del Phi method, where respondents provide information independently, ensuring unbiased responses. This is because the respondents' data remains confidential. Moreover, in-depth interviews with key experts individuals are conducted over at least 2-3 different time periods, allowing for the examination of data reliability across various time frames.

3.4 Data Analysis

There are three analysis types applied for data processing, analysis and evaluation. They are (1) descriptive statistics which comprising mean, maximum, minimum, percentile, weighted average factor, (2) probability applying exceedance statistical probability, and (3) regression analysis including multiple regression, and linear regression.

Descriptive statistics are utilized for data processing of 30 water resources development projects EIA reports comprising basic arithmetic and statistic functions of mean, maximum, minimum, percentile, etc. The percentile calculation is for summarizing the majority votes of the Del Phi's questionnaire surveys. The weighted average factor is applied for calculating weighted gross and net scores of the indicators of overall project's sustainability scores and water scarcity scores.

The exceedance probability is applied for indicators' ranging scale classification using data of 30 EIA reports.

The multiple regression analysis is applied for analysis of significant relationship among key independent variables of engineering indicators and the dependent variable of the economic internal rate of return (EIRR), whereas the linear regression is utilized to analyze equation of relationship between the high significant independent variable and the target dependent variable, herein between the dam section per storage and the project's EIRR in order to preliminarily estimate the economic return under the downscaled project size owing to reduction of environmental and social impacts or balancing sustainability among all dimensions.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Establishment of the 1st Draft Indicators

The first draft of sustainable indicators of water resource was established based on literature review of the studies concerning five following categories:

4.1.1 Constitution, national strategies, master plans and action plans

4.1.1.1 Constitution of the Kingdom of Thailand, B.E.2560

4.1.1.2 National Reform Plan on Natural Resources and Environment

4.1.1.3 National Strategies related to the utilization and conservation of Natural Resources and watershed management

4.1.2 Relevant Royal Acts on the Conservation of Natural Resources and Environmental Preservation

4.1.2.1 Royal Acts related to the conservation of natural resources

4.1.2.2 Royal Acts related to the development, conservation, and management of water resources

4.1.3 Organizations with the Objective of Procuring and Managing the Utilization of Water Resources

4.1.3.1 Operation agencies for development and management of water resources

4.1.3.2 Regulatory agencies in the water sector

4.1.3.3 Co-ordination agencies of the royal resources development Office of the Royal Development Projects Board (ORDPB)

4.1.4 Guidelines for Preparing Water Resources Project Development Reports

4.1.5 Sustainability Indices in Natural Resource Management, Water Resource Development, and Water Resource Management

4.1.1 The Results of Literature Review of Legislation

The purposes of legislation review are determination of Thailand's laws including the constitution related to the rights and responsibilities of citizens and the state as well as national strategies, master plans and action plans in development of water resources and conservation of natural resources and environmental quality.

4.1.1.1 Constitution of the Kingdom of Thailand, B.E.2560

The Constitution of the Kingdom of Thailand, B.E.2560, has outlined the duties of the state in managing natural resources that the people have the right to manage and utilize natural resources in a balanced and sustainable manner, particularly in the context of developing water sources. In this regard, the government is required to provide or facilitate public involvement in the decision-making process. At the same time, citizens have the responsibility to collaborate and support the conservation of these resources, while the government is obligated to carry out these actions in a balanced, sustainable, and efficient manner.

Although the Constitution of the Kingdom of Thailand, B.E.2560, has established the rights to utilize and the responsibilities to conserve natural resources for the public, as well as the roles of the state in provision, management, conservation, restoration, and utilization of natural resources, it is a broadly framed provision. The government is mandated to set goals, guidelines, and detailed procedures in secondary laws and regulations, ensuring clarity in both development and conservation aspects simultaneously. This is aimed at achieving balanced and sustainable benefits, with active public participation. However, those regulations have not been completely accomplished.

4.1.1.2 National Reform plans on natural resources and environment

To align with the Constitution of the Kingdom of Thailand B.E.2560, outlining the rights and responsibilities of the public and the state in resource management, the constitution has mandated the development of relevant reform plans. These plans encompass 4 key areas: water resources, biodiversity, environment, and the management of natural resources and the environment.

Four concerning national reform plans include key issues of 1) achieving a balance between conservation and development or utilization

2) establishing and applying collaborative management plan with technology and innovation, and 3) promoting public participation and 4) establishing key indicators to monitor. However, definite details of action plans and indicators have not yet been clearly defined and fully applied.

4.1.1.3 Strategies and plans for utilization and conservation of natural resources and river basin management

In examining the national strategy, ministry strategy, master plans, and operational plans of policy-guiding agencies in water resources development, it is evident that there is an effort to create water security. This is achieved by balancing water demand with available resources, reducing damage from floods and droughts. The implementation requires numerous water development projects under environmentally friendly conditions, ensuring sustainability and the participation of stakeholders. Meanwhile, environmental agencies prioritize maintaining a balance between conservation and sustainable utilization of specific resources such as forests, wildlife, ecosystems, and biodiversity. Key performance indicators are defined for national monitoring and assessment, but project-level indicators are lacking. It is crucial to establish comprehensive and sustainable indicators that guide holistic practices at the regional level. From the water resource project studies, it is observed that the development of suitable water sources primarily occurs within natural resource conservation areas. Current regulations protect these resources, imposing limitations on water development. However, permits can be obtained within the framework of conditions set by relevant laws. Noteworthy conservation laws include the National Forest Reserve Act, the National Park Act, and The Wildlife Protection Acts. These will be further discussed below.

4.1.2 Relevant Legislation for Natural Resources Conservation and Environmental Protection

4.1.2.1 Legislation related to natural resource conservation

In accordance with the duties assigned to the state under the constitution, the state has the responsibility to reserve, conserve, and control the utilization of natural resources and the environment, as mentioned above. This pertains to issues related to water resource development, including: 1) specifying and

withdrawing boundaries of conservation areas under responsibility, 2) controlling and maintaining conditions to prevent degradation, and 3) establishing conditions for resource utilization within the designated areas.

Upon reviewing the laws and regulations, it is found that although the three acts have outlined a framework for controlling the use of conservation areas, individuals can seek permission to utilize specific areas if necessary. However, clear criteria for considering such permissions are lacking, making it challenging for those involved in planning and developing water resource projects to conduct suitable, sustainable, and balanced studies and project designs that align with both development and natural resource conservation goals.

4.1.2.2 Relevant legislation on water resource development, conservation, and management

In the realm of water resources, pertinent legislation includes the Water Resources Act of B.E.2561, which stipulates that the state is responsible for activities related to both development and management for the utilization of water resources and conservation efforts. This act addresses key issues such as delineating boundaries, establishing organizations for development, management, and controlling the use and conservation of water resources under the other natural resources and environmental control acts.

4.1.2.3 Relevant acts on Environmental promotion and conservation

In addition to the royal acts related to the reservation and protection of natural resources and water resources, there are also Royal Acts pertaining to the promotion and conservation of environmental quality in the year B.E.2561 that apply to areas beyond the scope of the aforementioned royal acts.

In the case of water development projects which have environmental impacts, a report on the environmental impact assessment must be prepared for the relevant agency, in this case, the Office of National Environmental Policy and Planning (ONEP). The appointed committee of experts must provide their approval before receiving project approval from the water management, natural resources, and subsequent government agencies.

4.1.3 Government Agencies Responsible for Development and Management of Water resources

4.1.3.1 Operation agencies for development and management of water resources

Currently, it can be observed that the organizations tasked with the development of water resources for various human activities within the conservation areas, as defined and delimited by this research mainly for irrigation purpose, include the Department of Royal Irrigation, and the Department of Water Resources.

As for the Electricity Generating Authority of Thailand, there are currently no policies for developing dams specifically for hydropower generation. This is due to the potential size of projects, which tend to be large and situated in conservation areas, significantly impacting natural resources, the environment, and society. In contrast, major water development projects by regional waterworks and local administrative organizations are generally smaller in scale and located in non-conservation flat areas or outside the research study areas.

1) Royal Irrigation Department

In accordance with the regulations governing the administration of state affairs (4th edition, B.E.2543), the Ministry of Agriculture and Cooperatives, B.E.2557, in Article 8 chor. of the ministerial regulations dividing government agencies, outlined the roles and responsibilities of the Royal Irrigation Department. The department is tasked with the development of water sources according to the potential of river basins to meet the diverse needs of water users. This includes ensuring equitable and just distribution of water to users of all types. The department is also responsible for activities such as reservoir construction, storage, maintenance, control, release, or allocation of water for agriculture, energy, public utilities, or industrial purposes. Additionally, it oversees measures to prevent damage caused by water, the safety of dams and structures, and water distribution within the irrigation areas.

2) Department of Water Resources

In accordance with the Water Resources Act of B.E.2561, the Department of Water Resources is designated as a state agency under the Ministry of Natural Resources and Environment. Its responsibilities include providing

recommendations for the formulation of policies, plans, and measures related to natural water resources. The department is tasked with managing, developing, conserving, restoring, and overseeing water resources. It also coordinates, monitors, evaluates performance, and addresses issues related to water resources. Additionally, the department advances expertise, establishes standards, and disseminates water resource technologies at both the overall and watershed levels. Its overarching mission is to manage water resources in a unique and sustainable manner,

Presently, by the Cabinet resolution on March 9, B.E.2564, the Department of Water Resources has been assigned the responsibility for managing, developing, conserving, restoring, and controlling the utilization of various wetlands instead of the Office of Natural Resources and Environmental Policy and Planning. However, this study does not include wetlands into account.

4.1.3.2 Regulatory agencies in the water sector

1) Office of the National Water Resources

The Office of the National Water Resources serves as the regulatory agency for water-related activities, in accordance with the regulations outlined in the Ministry's departmental regulations governing the Office of the National Water Resources, Prime Minister's Office, B.E. 2562, Section 2. The office is mandated with advising on policies, developing master plans, establishing measures for water resource management, and coordinating with related natural resources agencies, and driving implementation for water concerning agencies.

4.1.3.3 Co-ordination agencies of the royal resources development Office of the Royal Development Projects Board (ORDPB)

According to the Prime Minister Office’s regulations on projects arising from the royal initiatives in B.E.2534, the Office of the Royal Development Projects Board (ORDPB) arising from the royal initiatives is designated to compile the royal initiatives, conduct surveys, studies, analyses, and develop plans or projects arising from royal initiatives. Additionally, it is responsible for reviewing and proposing budget allocations to carry out related activities complying with relevant laws.

In summary government agencies responsible for the development of water sources for various activities and organizations in charge of conserving natural

resources and the environment, as specified in the aforementioned laws, play a role in the development and conservation of natural resources. These agencies are stakeholders in both the gains and losses associated with water source development and natural resource conservation. The researchers will select qualified expertise individuals from these agencies, representing various fields, to serve as key informants within the Del Phi team, providing comprehensive and complete information.

4.1.4 Guidelines for Preparing Feasibility Reports of Water Resource Development Project

Upon examining the current water development project planning, it is observed that engineering studies adhere to standard processes and guidelines. However, there is no specific indicators indicating a range of scores that denotes suitability or sustainability. The comparison includes selecting the project development type (reservoir or weir), selecting the appropriate project location, and optimizing the size of the reservoir. The study employs principles of analysis and design for stability, strength, safety, cost-effectiveness, ease of maintenance, efficient management, by mostly maximize exploit of physical potentials and benefits of socio-economic with less impacts on environments and natural resources. Some factors are quantifiable, while others involve qualitative comparisons. The Multi-Criteria Assessment (MCA) method or economic (internal rate of return (EIRR) is commonly used, involving scoring and weighting criteria for each project individually. The preferred alternative is the one with the highest overall score or EIRR rate, indicating its suitability and feasibility. This approach results in some inappropriate development projects pertaining unsustainability in natural resources and social dimensions.

4.1.5 Literature on Sustainability Indicators of Natural Resources, Water Resources Development, and Water Resources Management

In many projects, there are challenges arising from qualitative environmental and social factors that cannot be quantified. Examples include archaeological sites, biodiversity, environmental systems, endangered species, life values, cultures, and traditions. These factors may pose limitations on water resource development.

However, currently, there is no clear and universally accepted criteria for assessing the importance of these factors. Additionally, there is a lack of recognized indicators indicating the level of sustainability of a project. These criteria and indicators with be crucial guidelines for the sustainable development of water resources, ensuring a balance between development and conservation of natural resources, and they will be widely accepted by stakeholders involved in the decision-making process.

Upon reviewing studies on factors and sustainability indicators related to water resources development, it was found that most of these studies focus on factors and indicators at the regional or national levels. These factors and indicators are utilized for planning, monitoring, and evaluating governments' actions to achieve sustainable development goals. They can be categorized into 3 groups: those emphasizing natural resource considerations, those prioritizing sustainable water resource development factors, and those highlighting sustainable water management. Although these factors and indicators are generally at the national or regional levels, some of them can still be applied and adapted for the purposes of this study.

In the aspect of natural resources, it was identified that crucial factors include forest-related aspects with significant indicators such as forest status, proportion of forested areas, biodiversity, forest encroachment, vulnerability, and uniqueness. Regarding wildlife, vital factors include biodiversity, the status of endangered species, and the importance level of conservation areas. Concerning soil, factors like erosion rates or sedimentation are noteworthy. In the domain of water resources, key indicators encompass average rainfall, average water volume, and the ratio of water usage per water source. On the economic front, considerations include income per capita and environmental cost. Social aspects involve community participation, agricultural areas per population, and conflict level. In terms of environmental quality, a factor like water quality is taken into account.

Table 4.1 and Table 4.2 summarized indicators referenced from concerned research studies and those first draft indicators selected for the study.

Table 4.1 List of Indicators in Previous Related Studies

Title	Author	Dimension	Factor		Indicator
The State of Natural Resources and Environment at Phu Phan National Park and Surrounding Areas	(Piyachana, 2013)	Natural Resource and environment	Forest	1	Forest status
				2	Terrestrial ecology (tree density)
				3	Inappropriate land use (Encroachment)
				4	Annual forest growth
			Environment	5	water quality
		Social	Social	6	People participation
				7	Instinct
				8	Encroachment rate
				9	Water management potential
				10	Water requirement per water resources
				11	Agriculture land per capita
				12	Poverty ratio
The project to survey the status of sustainable development goals in the context of Thailand and options for economic, social, and legal measures. Goal 15	(Pumijamnong, 2017)	Natural Resource	Forest	1	Conservation forest area ratio
				2	Bio- diversity
			Wildlife	3	IUCN's Red list
				4	Illegal hunting ratio
		Management	Management	5	Forestry management
				6	Conservation budget
Assessment of Watershed Carrying Capacity for the Aesesa Flores Watershed Management, East Nusa Tenggara Province of Indonesia	(Noywuli, 2019)	Natural Resource	Forest	1	Conservation forest area ratio
			Soil	2	Soil loss
				3	Erosion rate
				4	Annual sediment load
		Geography Hydrology/ water resources	Geography Hydrology/ water resources	5	Annual flow
				6	Av Flood Peak
				7	Flooding frequency risk
Examining the spatiotemporal change of forest resource carrying capacity of the Yangtze River Economic Belt in China	(Tang, 2020)	Natural Resource	Forest	1	Terrestrial ecology (tree density)
				2	Conservation forest area ratio
				3	Bio- diversity
				4	Loss area
		Geography	Geography	5	Geography

Title	Author	Dimension	Factor		Indicator
		Geography	Hydrology	6	Annual rainfall
				7	Water Use / Water Resource
				8	Raw water per capiton
				9	Specific flow yield
				10	Groundwater yield
		Environment	Environment	11	GHG per area
		Social	Social	12	Population density per area
				13	Energy consumption per area
Evolution of Sustainable Water Resource Indicators	(Smith, 2007),	Natural Resource	Wildlife	1	IUCN's Red list
		Geography	Hydrology	2	Annual rainfall
		Environment	Environment	3	Water Quality
		Social	Social	4	Water usage per capita
Quantitative Measurement of the Sustainable Water Resource Development System in China Inspired by Dissipative Structure Theory	(Liang, 2018)	Natural Resource	Soil	1	Soil loss
		Geography	Hydrology	2	Annual rainfall
		Environment	Environment	3	Wastewater volume
				4	Treated water to wastewater ratio
				5	Water for environment and ecology
				6	Ecology
		Economic	Economic	7	GDP per capita
				8	GDP Growth
		Social	Social	9	Water usage per agriculture area
				10	Population growth rate
				11	Community growth rate
		Management	Management	12	No. of personal
				13	Conservation budget
				14	Water treatment budget
Developing and exploring indicators of water sustainable development	(Morris, 2019)	Environment	Environment	1	Ecology Footprint
		Economic	Economic	2	GDP per capita
				3	GDP per unit of water
		Social	Social	4	Average Age
Developing Sustainability Indicators For Water Resources Management In TIETÊ-JACARÉ BASIN, BRAZIL	(Corrêa, 2013)	Natural Resource	Soil	1	Length of eroded river
		Social	Social	2	Conflict level
		Management	Management	3	Agriculture land per catchment area
				4	Serviceable water supply ratio
				5	Water treatment ability
Prioritization of the National Parks in Thailand.	(National Park) Research Section,	Natural Resource	Forest	1	Conservation forest area ratio
				2	Loss area

Title	Author	Dimension	Factor		Indicator
	2019)			3	Forest connecting zone
				4	Vulnerability, Unique ecology
				5	Globalization
				6	No. of traveling places
				7	Touring diversity
				8	No. of recreation
			Wildlife	9	IUCN's Red list
				10	No. of high value wildlife
		Social	Social	11	Encroachment rate
				12	Community existence
		Management	Management	13	Ecology impacting project
				14	Water management of water supply
				15	Water resources security
				16	Balance of water resources and demands
				17	Water disaster management
Establishment of the water management indicator (WMI) in Thailand	The National Statistical Office of Thailand (NSO), (2023)	Natural Resource	Forest	1	Forested area / Conserved area
		Environment	Environment	1	Water quality
		Social	Social	1	Flooding risk area
				2	Drought risk
				3	Affected area/ Total area
				4	People participation
		Water resources	Water resources	1	Water management potential Rainfall
		Geography	Hydrology	2	Annual flow
				3	Flooding
			Geography	4	Water storage / capita
				5	Water storage / River flow
		Management	Management	1	Water management of water supply
				2	Water resources security
				3	Balance of water resources and demands
				4	Water disaster management
				5	Water storage / agriculture area

Table 4.2 Summarized Indicators Referenced from Concerned Research Studies and Those First Draft Indicators Selected for the Study Classified by Dimensions and Factors

Related Sustainable Indicators from Literature						Remark
Indicator				Applied Indicator		
				Sustainability	Water Scarcity	
I. Natural Resources Dimension						
1	Forestry Factor	1	Forest status	✓		
		2	Terrestrial ecology (tree density)	✓		
		3	Inappropriate land use (Encroachment)	-		
		4	Annual forest growth	-		
		5	Conservation forest area ratio	✓		
		6	Bio- diversity	✓		
		7	Loss area	-		*Including in (3)
		8	Forest connecting zone	-		
		9	Vulnerability, Unique ecology	✓		
		10	Globalization	-		
		11	No. of traveling places	-		
		12	Touring diversity	-		
		13	No. of recreation	-		
2	Wildlife Factor	14	IUCN's Red list	✓		
		15	Illegal hunting ratio	-		
		16	No. of high value wildlife	-		*Including in (14)
3	Soil Factor	17	Soil loss	-		
		18	Erosion rate	-		
		19	Annual sediment load	-		
		20	Length of eroded river	-		
4	Geography - Hydrology/ Water Resources Factor	21	Annual flow	-		
		22	Av Flood Peak	-		*Including in (23)
		23	Flooding frequency risk	✓		
		24	Annual rainfall	✓		
		25	Geography	✓		
		26	Water use / Water resource	✓		
		27	Raw water per capita	-		
		28	Specific flow yield	-		
		29	Groundwater yield		✓	(water scarcity)
II. Environment Dimension						
1	Environment Factor	30	Water quality	✓		
		31	Wastewater volume	-		
		32	Treated water to wastewater ratio	-		
		33	Water for environment and ecology	-		
		34	Ecology footprint	✓		
		35	GHG per area	-		

			Related Sustainable Indicators from Literature Indicator	Applied Indicator		Remark
				Sustainability	Water Scarcity	
III. Economic Dimension						
1	Economic Factor	36	GDP per capita	-		
		37	GDP Growth	-		
		38	GDP per unit of water	-		
IV. Social Dimension						
1	Social Factor	39	People participation	-		
		40	Instinct	-		
		41	Encroachment rate	-		
		42	Water management potential	-		
		43	Water requirement per water resources	-		(similar to (26))
		44	Agriculture land per capita			
		45	Poverty ratio		✓	(water scarcity)
		46	Population density per area	-		
		47	Energy consumption per area	-		
		48	Community existence	-		
		49	Water usage per capita	-		
		50	Water usage per agriculture area demand		✓	(water scarcity)
		51	Population growth rate	-		
		52	Community growth rate	-		
		53	Average Age	-		
		54	Conflict level	✓		
		55	No. of educated years per capita	-		
		56	Agriculture land per catchment area	-		
		57	Serviceable water supply ratio	-		
V. Management Dimension						
1.	Management Factor	58	Forestry management	-		
		59	Conservation budget	-		
		60	Conservation law	-		
		61	Water resources development budget	-		
		62	Ecology impacting project	-		
		63	No. of personal	-		
		64	Conservation budget	-		
		65	Water treatment budget	-		
		66	Water treatment ability	-		
		67	Water management of water supply	-		
		68	Water resources security	-		
		69	Balance of water resources and demands	-		(similar to (26))
		70	Water disaster management	-		

Remarks: ✓ = Applied, - = Not Applied

4.1.6 Conclusion of the First Draft of Sustainable Indicators

The first draft of sustainable indicators were determined from literature review most of which indicators were established for various purposes of the research studies, therefore some indicators could only be generally applied for this study purposes. Some indicators were appropriately modified on the basis of emphasizing important and highly impacting indicators of which mitigation measures could be consequently provided. In addition, they should be uncomplicated assessment, and their data be available and accessible respectively.

Additionally, there were some disadvantage issues of these indicators that needed to be modified due to their limitations upon those previous studies' purposes as follows,

1) Some sustainable indicators from previous studies were established on the regional and national level basis. The indicators did not represent project area based problems including physical and geography suitability, natural resources limitation, social impacts, and economic returns respectively.

2) Some indicators were not accounted for all factors and indicators concerned for this study purposes.e.g. engineering and geographic aspect, economic aspect.

3) Some indicators could not be assessed for application or modification due to their data inaccessibility, data unavailability, and assessment difficulties. Therefore, modification of qualitative indicators into accountable or quantitative figures would be established. e.g. GHG/area, ecology loss, are represented by reservoir area per storage.

4) Some indicators were not directly complied with the research's objectives, scope, concepts, and assumptions as well as sustainability definitions and targets of each dimension. They are not applicable for the study. e.g. GDP's growth rate, people participation.

5) Weightage and ranging scale of indicators from previous studies are mostly incompatible with the study according to their different objectives, area scales, and geographic context, respectively. e.g. conflict level, abundance, bio-diversity, and endangered species of forest and wildlife, engineering data, and social data. Consequently, 30 EIA reports were the source of data for the manipulation.

6) Some of indicators from previous studies were not definitely comply with the project planning's practices of concerning agencies in Thailand, modification of such indicators is therefore should be applied e.g. project engineering data of seismicity, flood per storage, economic return of EIRR, protesting ratio. Moreover, some indicators that affecting less impacts and having unavailable or inaccessible data would be discarded. e.g. erosion impact, hunting rate, encroachment rate, population growth.

7) For social dimension, people or public participation is one of the important factors that every projects are mandated to conform with the regulations of the ONEP, and those of the prime minister's office that are specified in the guideline of EIA's report preparation. Consequently, every projects are actually operated in accordance with the specified people participation and public relation activities. Since there are no significant differences among the people participation activities of the projects, the indicators of people participation is therefore not accounted for this study. However, an indicator of project opposition is proposed instead which would reflect outcomes of the people participation and public relation activities of the projects.

8) For a factor or indicator of community area which effects quantity of the water demand and practically such demand is already included in the total water demand amount during project planning design stage. Additionally, quantity of community water supply is quite small comparable to irrigation demand, therefore this study applies the indicator of irrigation area that representing all water demand required including water supply of concerned communities.

However, for a project that has to supply large volume of water supply for large municipalities e.g. in the eastern economic corridor, where municipalities, tourism, commercials, industrials play more important roles than agriculture, these indicators could be accounted which is recommended for further studies.

9) For water management, it is an essential past of water utilization after the project construction in order to efficiently exploit water resources for various necessarily requirements. According to guidelines of project feasibility study planning and EIA report preparation, water management proposal would also be required, therefore such factor does not effect significant difference among them. This factor is thus not proposed as one of main factors.

Tabel 4.3 presents indicators concerning water resources development according to literature review that be applied and not be applied for the first draft indicators were shown in Table 4.3.

Table 4.3 Selection of the 1st Draft Indicators Concerning Water Resources Development According to Literature Review by Dimensions and Factors

Indicators	Applied	Not Applied
Forest		
1. Forest conditions	Applying density of big trees.	
2. Terrestrial ecology (IVI, density of tree)	Applying density of big tree represents forest abundance.	IVI indicates plant species mostly found in the reservoir. It does not represent the abundance, bio-diversity and rare plants.
3. Encroachment or inappropriate use		There are not available data in most EIA reports. Encroachment area are quite small in all reserved area due to government agencies' strictly control.
4. Forest growth rate		Incompleted data
5. Proportion of forest in reservation area	Adapt reservoir area to conservation area.	
6. Bio-diversity	Apply no. of species found in the reservoir.	
7. Losses forest area		Apply reservoir area to total conservation area.(same as 5.)
8. Connectivity among conservation forests		Apply reservoir's location in the conservation zone instead. (rim or core or headwater).
9. Vulnerability or uniqueness	Apply uniqueness to represent.	
10. Global property		Not defined in the scope of study.
11. No. of tourism places		It is included in the conservation area and uniqueness of tourism.
12. Tourism diversity		The same as 11.
13. No. of recreation activities		The same as 11.
Wildlife		
14. Red list	Apply no. of wildlife species in the reservoir as defined by IUCN's red list to represent endangered wildlife status.	
15. Illegal hunting		Unavailable or incompleted data.
16. No. of high value species		Similar to IUCN's red list. (same as 14.)
Soil		
17. Soil deterioration or losses		Incompleted data.
18. Soil erosion rate		Incompleted data.
19. Sedimentation rate		Incompleted data.
20. Length of eroded river		Incompleted data.
Water resources / Hydrology		
21. Annual flow		Indirect apply by accounting in flood flow. (same as 23.)
22. Average flood peak		Similar to 21.
23. Flood frequency	Apply design flood peak per storage of the reservoir representing appropriate size of reservoir for supporting resilience.	
24. Mean annual rainfall	Apply as variation of dry season rainfall to annual rainfall representing drought risk level (indicator of water scarcity level).	
25. Geography (slope, elevation)	Apply as physical factor adapting retention area comparable to storage volume.	

Indicators	Applied	Not Applied
26. Water use per water reservoir volume	Apply irrigation area representing water use. This indicator represents balance of water demand and supply of a reservoir project.	
27. Reservoir storage volume per capita		Not representing reservoir's main purpose for irrigation, not for water supply.
28. Water yield per area		Similar to annual flow indicator. Same as 21.
29. Groundwater volume	Apply as hydrologic indicator for water scarcity level. This minorly impacted by the project development.	
Environments		
30. Water quality	Apply impacted level of water quality due to the project development.	
31. Waste water volume		Incompleted data and minorly impacted by the project.
32. Clearwater to waste water ratio		Incompleted data and minorly impacted by the project.
33. Water amount for environmental control		Incompleted data and minorly impacted by the project.
34. Ecology footprint	Apply the reservoir area per storage volume for simplicity.	
35. GHG effect per area		Incompleted data and already accounted in the ecology indicators i.e. reservoir area per conserved area, types of conserved area, and location of reservoir.
Economic		
36. GDP per capita		Apply annual cropping area per storage volume for project benefits instead for simplicity application.
37. GDP growth		Similar to 36.
38. GDP per unit of raw water		Similar to 36.
Social		
39. People participation		Apply proportion of protesters instead.
40. People conscious		Incompleted data.
41. Encroachment rate		Incompleted data.
42. Management potential		Incompleted data.
43. Water demand per raw water resources		Similar to 26
44. Agricultural area per capita		Representing farmer's holding area per capita which not affected by the project.
45. Poverty ratio	Apply for assessing water scarcity level or necessity level of water resources development.	
46. Population density		This reflect water supply demand which is much less volume compared to irrigation demand.
47. Energy consumption per area		Hydropower energy demand is excluded.
48. Community existence	Apply no. of houses in reservoir area.	
49. Water supply use per capita		This demand is minor demand according to scope of the study.
50. Water use per area	Apply water demand rate by type of cropping for water scarcity level assessment	
51. Population growth		Similar to 46.
52. Community growth rate		Similar to 46.
53. Average age		Indirect benefits of projects and no data available.
54. Conflict level	Apply no. of protestors to total impacted households.	

Indicators	Applied	Not Applied
55. Education level (no. of year educated)		Not directly related to the project and not sufficient data.
56. Agriculture area per catchment area		This indicates balance of land use proportion or balance of water demand and water resources in term of overall basin not at project level.
57. Water supply serviceable ratio		Similar to 46.
Water Management		
58. Forest management		Insufficient data.
59. Budget for forest conservation		Insufficient data.
60. Conservation law concerned		Not applicable for the study.
61. Budget for water resources development		Not applicable for the study.
62. No. of project impacting ecology		Not applicable for the study.
63. No. of officials and staff		Not applicable for the study.
64. Budget for water conservation		Not applicable for the study.
65. Budget for wastewater treatment		Not applicable for the study.
66. Wastewater treatment capacity		Not applicable for the study.
67. Water supply management		Not applicable for the study.
68. Water resources security		Apply flood discharge per unit of storage instead. Apply drought risk area as an indicator of water scarcity level.
69. Balance of water resources and demand		Similar to 26
70.Water hazard management		Apply flood discharge per unit of storage instead.

4.2 Development of the 2nd Draft Indicators

4.2.1 Results of In-Depth Interviews

In-depth interviews were carried out with 7 experts, including two senior academic experts in wildlife and forestry, and five senior governmental officials in wildlife, forestry, environment, socio-economics and engineering.

Objectives of the in-depth interview are mainly focused on project barrier issues and their causes, key factors and sustainable indicators of the water resource development projects, of which example of in-depth questionnaire is presented in Appendix D.

The remarkable key issues suggested include following items, i.e.: consideration of engineering aspect, the importance priority of the environmental dimension, area uniqueness, recognizing uniqueness of endangered habitat, reservoir location, natural resources abundance and biodiversity, the status of forest resources, the significance level of conservation area types, project conflicts of interest, and social opposition to the project. These issues and indicators are also considered and proposed in the questionnaire design.

Table 4.4 presents summary of in-depth interview's suggestion on sustainable indicators consideration.

Table 4.4 Summary of In-Depth Interview's Suggestion on Sustainable Indicators Consideration

Issue	Main problems of the water resources development projects	Examples of problematic projects	Success factors of the project development	Guidelines or criteria for concerned agencies in developing sustainability for all dimension	Critical issues that the development should not be implemented	Reasons that the project should be developed	Suggestions on indicators and others
No.1	- People participation - Project protestation - Location in conservation area - Law conflict of interest - Environmental economic assessment	Wang Tanod, Huai Satone	Policies of the government	- Establishment of the integrated project planning criteria for sustainability	- World heritage site - Critical extinct wildlife and plants - Uniqueness - Vulnerable area	- Farmer's suffering - Security of societies, and economic - Upgrading quality of life	- Engineering dimension should be determined - Engineering safety should be studied - How to assess sustainability without post evaluation results - Carbon credit would not be considered referenced by one of the ONEP's expert panel - Loss of soil moisture be not determined

Issue	Main problems of the water resources development projects	Examples of problematic projects	Success factors of the project development	Guidelines or criteria for concerned agencies in developing sustainability for all dimension	Critical issues that the development should not be implemented	Reasons that the project should be developed	Suggestions on indicators and others
No.2	- Preservation laws concerned - Consideration for approval of development	na	Similar to 1	Comply with ONEP guidelines and expert panel's comments on EIA reports.	Project that against laws concerned	na	na
No.3	- Existence of endangered wildlife - Reservoir located in core area of preserved area where abundance and bio-diversity of natural resources and ecology are plentiful - Uniqueness of wildlife that can't be replaced or rehabilitated	Mae Moh (Payao Province)	- Location should not situated in preservation area or headwater - Ecology not be disturbed by human - Location should not flooding critical wildlife's habitats	- Uniqueness should not be disturbed - Project must be substantive benefit to social and economic - Avoid headwater area	- Unique wildlife's Habitat that could not be replaced - International agreement - Critical endanger wildlife	- Substantial benefits to pubic - Government policy and Royal's projects - Comply with SEA Plans - Comply with the impacted national park's master plan	- Suggested indicators including: growth rate of forest and wildlife, volume and density of trees, number of plants' species, endangered plants and wildlife, and bio-diversity - Not prioritizing forest type, - Not value assessing of endangered wildlife - Project development in world heritage site must be complied with its defined criteria
No.4	- Rapid growth of socio- economic and technology - Deterioration of natural resources and	Those located in National parks, wildlife sanctuation areas	- Integration development among stakeholders - Sustainable	- Concerning agencies should be reorganized to be in the same minister	- Flooding Community area and public health issues - Location in	na	There should be master plan of water resources development via people participation

Issue	Main problems of the water resources development projects	Examples of problematic projects	Success factors of the project development	Guidelines or criteria for concerned agencies in developing sustainability for all dimension	Critical issues that the development should not be implemented	Reasons that the project should be developed	Suggestions on indicators and others
	environments pollution and social impacts - Social issues and government policy		mitigation plans	- Reducing approval procedures - integration development among concerned agencies	world heritage site and archaeologic site - Forestry, Wildlife, and headwaters		
No.5	- Land and asset compensation - Permission for project development in conservation area - Project protestation - People participation - Impact to headwater area in watershed class 1 and 2 - Impact to wetland	na	Similar to 1	na	Impact on headwater or watershed class 1	na	- Environmental dimension should have more weight than social dimension - suggested indicators: rainfall-runoff ratio, rainfall, prohibited or rare plants, bio-diversity of forest, preserved wildlife, multipurpose uses, life values, biologic indicators
No.6	- Wildlife sanctuation zone - World heritage area - National Park area	Huai Satone	- Dam site location	- Balancing project size and preserved area	- Impact critical endangered wildlife's' habitat area	na	- Indicators suggested: quantity, number of wildlife species abundance, endangered and preserved wildlife, IVI factor, bio-diversity index

Issue	Main problems of the water resources development projects	Examples of problematic projects	Success factors of the project development	Guidelines or criteria for concerned agencies in developing sustainability for all dimension	Critical issues that the development should not be implemented	Reasons that the project should be developed	Suggestions on indicators and others
No.7	- Environmental and ecology impacts - People participation	na	- Integration and balanced development	- Considering environmental impact on ecology and climate change - covering all water requirements.	na	na	- Purposes of the water resources should also cover economic zone, town expansion - Neighbor countries' labor growth and resilience of climate change - Indicators suggested: river length, number of hydraulic structures, density of water projects, and irrigation projects, irrigation efficiency, impacts on wetland, retention area to water storage ratio, - Geologic risk - Hydrology including rainfall and variation, water management, river flow per capita, demand for ecology to river flow

4.2.2 Conclusion of the in-depth interview are as follows:

1) In-depth interviews

The second step of consideration of selecting key dimension factors and indicators was the determination of the in-depth interview of seven selective senior experts in various key concerning fields. Output from in-depth interview included not only key factors and indicators suggested, but also related technically and practically suggestions and comments concerned.

(1) The results showed that most of indicators were close to the ones obtained from literature review whereas some additional important indicators were recommended, as follows,

(1.1) For engineering dimension, “there should be consideration of dam stability and safety especially on seismicity and foundation leakage”,

(1.2) For natural resources dimension especially on wildlife factor, “abundance, bio-diversity, and endangered species of wildlife were proposed as well as their uniqueness, would be the important indicators” whereas on forestry and ecology factors, “type of conservation area should be considered”, moreover, “different type of forest should be considered equal weightage.”

(1.3) For social dimension, “should consider life quality value in term of uniqueness of various resilience factors including archaeology, tourism, valuable mineral resources, geology, and ethnics.”

(1.4) For economic dimension, “environmental economic rate of return should be considered upon reliable and assessable data and information.”

(2) Other than indicators suggestion, concerning comments, consideration issues and suggestion were introduced, i.e.,

(2.1) There are no announced detail standard, criteria, or reference figures in term of quantitative values for assessing sustainability of wildlife and for permission consideration of water resources development in conservation area.

(2.2) There are no researches studied on standard data for classification of wildlife’s abundance, bio-diversity, and endangered distinction in conservation areas of Thailand.

(3) This study therefore applied the available secondary data of the 30 EIA reports to establish ranging scale for weightage of the indicators by basing on simple descriptive statistic method and occurrence probability.

4.2.3 Results of Indicators from EIA Reports

Thirty EIA reports which were studied in compliance to the ONEP's guideline of EIA report preparation are selective sampled basing upon report accessibility. Table 4.5 to Table 4.9 present list of 30 water resource development projects and their main components applied for consideration of key indicators and their corresponding scoring ranges. Figure 4.1 presents their locations scattering every regions of Thailand.

Considering normal practice of most feasible project planning, it would firstly start from selection of type of water resource development structures, selection of appropriate site location and storage capacity respectively. For these selection, four key dimensions are mostly considered comprising (1) geography and engineering (2) environments (3) society, and (4) economic, respectively. These 4 dimensions are also complied to the ONEP's guidelines for EIA report preparation.

For Geography and engineering dimension, main indicators applied are as follows; i.e. retention area per unit of storage, construction cost per unit of storage, geologic conditions, hydrologic conditions, and irrigation area size.

For the environments, indicators mostly applied are size of inundated reservoir area comparable to conservative area, type of conservative areas, abundance or density of trees per area, bio-diversity, status of forest and wildlife, ecology system, and impacted water quality.

For social dimension, indicators mostly concerned are number of impacted households, encroachment area, and project protestors.

For economic dimension, mostly indicators applied are investment cost per unit of storage volume, and internal rate of return.

These indicators were applied and proposed in the first Del Phi's questionnaire.

In addition, some indicators were applied into proportional figures to the storage capacity or percentages for simple interpretation, whereas some appropriate indirect indicators were adopted instead owing to data in availability for assessment. e.g. using the ratio of reservoir area to conserved forest area for representing ecology system losses.

Table 4.5 Engineering Data of 30 Reservoir Projects

NO	Reservoire	Province	Reservoir capacity (mcm)	Reservoir area (Rai)	Mean Annual Inflow (mcm)	Flood Peak Discharge (cms)	Reservoir Catchhment Areac (sq.km)	Seimic by Merculli scal / Distance (km)	Leakage (1-5)	Bedrock (1-5)	Irrigation Area (Rai)	Rain Season Crop Area (Rai)	Dry Season Crop Area (Rai)	Perennal Crop Area (Rai)	Dam Crest Length (m)	Dam Height (m)	Dam Location	
																	Latitude (N) , Y	Longitude (E) , X
1	Khlong Yai	Phattalung	17.5	730.00	33.16	220.00	23.00	1-3 (134)	2	Garnite (L-M)	54,000.00	31,280.00	13,525.00	20,911.00	735.00	41.50	7° 34' 53"	99° 50' 58"
2	Mae Pan	Lam Pang	15.1	600.00	38.81	438.00	89.00	7	4	Garnite (L-H)	9,798.00	9,798.00	1,948.00	-	465.00	53.00	18° 46' 51"	99° 28' 37"
3	Mae Pah Phai	Chiang Mai	20.4	930.00	23.46	339.00	73.00	5	1	Garnite (L)	6,683.00	6,683.00	2,520.00	-	290.00	47.00	18° 04' 07"	98° 26' 04"
4	Mae Bom	Lam Pang	12.5	454.00	25.00	374.00	103.00	7 (0.2)	4	Sand (H)	9,200.00	9,200.00	-	-	798.00	51.00	18° 41' 26"	99° 27' 36"
5	Mae Pang Luang	Chiang Mai	2.1	123.00	2.75	40.00	11.00	5-7 (25)	4	Sand (H)	1,273.00	1,273.00	1,131.00	-	132.50	42.15	18° 53' 57"	98° 40' 24"
6	Mae Phuak	Phrae	9.1	457.00	7.55	111.00	27.00	6-7	2	(L-M)	8,000.00	8,000.00	-	-	160.00	43.00	17° 52' 14.95"	99° 59' 32.86"
7	Khlong Wang Tanode	Chanthaburi	99.5	11,000.00	119.40	464.00	255.00	3(107)	2	Sand (L-M)	87,700.00	7,400.00	6,665.00	80,300.00	3,000.00	25.00	13° 08' 31"	101° 58' 31"
8	Huai Satone	Sa Kaeo	22.3	3,418.00	24.31	296.74	96.00	1-3(22)	2	Sand (L-M)	19,550.00	19,550.00	978.00	-	1,670.00	18.00	14° 06' 13"	102° 35' 25"
9	Khlong Ma Dua	Nakhonsithammarat	85.2	1,534.00	96.40	408.00	62.00	1-2	4	(H)	60,500.00	60,500.00	-	-	705.00	80.00	14° 15' 15"	101° 15' 06"
10	Nam Ki	Phrae	52.3	1,170.00	73.22	356.00	89.00	7(8)	4	Sand (H)	44,120.00	35,650.00	16,796.00	-	820.00	74.50	19° 13' 16.5"	100° 44' 53.5"
11	Nam Yuan	Phayao	30	948.00	53.10	492.00	150.00	6(27)	4	Sand (H)	20,910.00	20,910.00	7,110.00	-	572.00	40.20	19° 30' 34"	100° 23' 25.5"
12	Mae Nueng	Lam Pang	9.2	381.00	14.90	188.00	89.00	5-7(22)	2	(L-M)	7,407.00	7,407.00	5,350.00	-	290.00	57.50	18° 34' 14"	99° 26' 18"
13	Klong Chomphu	Phitsanulok	86.3	2,618.00	150.16	748.00	338.00	5(75)	4	(H)	90,300.00	90,300.00	17,600.00	-	1,100.00	49.50	16° 40' 54.09"	100° 42' 59.25"
14	Huai Sator	Trat	57.27	4,385.00	161.08	461.79	86.00	1-2	2	(L-M)	53,000.00	53,000.00	-	-	900.00	31.00	12° 41' 09"	102° 24' 02"
15	Khlong Khlung Lang	Kamphaeng Phet	21.29	1,915.00	70.87	421.28	165.37	5-7(38)	4	Sand (H-VH)	19,732.00	19,732.00	6,992.00	-	1,040.00	23.00	16° 03' 21"	99° 18' 49"
16	Huai Khayoong	Si Sa Ket	40	3,253.00	77.62	186.40	146.00	5-7(42)	2	(M)	42,500.00	42,500.00	18,800.00	-	620.00	24.35	14° 29' 17"	104° 32' 36"
17	Klong Pla Soi	Kamphaeng Phet	9	402.00	11.25	140.10	26.23	3	4	(H)	4,376.00	4,376.00	1,514.00	-	600.00	33.00	16° 01' 11"	99° 17' 07"
18	Khlong Phet Ja Khor	Kamphaeng Phet	5.18	509.65	6.47	112.61	15.65	5-7(11.5)	4	Sand (M-H)	2,812.00	2,812.00	639.00	-	1,520.00	16.00	16° 17' 45"	99° 15' 39"
19	Nam Pee	Phayao	90.5	3,626.00	127.27	1,343.00	570.00	5	3	(M)	48,000.00	48,000.00	36,800.00	-	810.00	56.00	18° 54' 33"	100° 20' 25"
20	Huai Mae Khon	Phare	11.47	459.00	19.50	201.00	76.28	3	3	(M)	12,000.00	12,000.00	-	-	500.00	40.00	18° 04' 07.65"	100° 13' 18.63"
21	Huai Samoeng	Prachin Buri	295	16,250.00	266.00	1,190.00	443.00	3	3	Sand (L-M)	111,300.00	111,300.00	-	-	2,960.00	13.25	14° 04' 46"	102° 01' 49"
22	Huai Sae Or	Sa Kaeo	2.57	455.21	4.03	94.34	14.85	1-3	4	Sand (M-H)	4,740.00	4,740.00	898.00	-	350.00	11.00	13° 58' 50.23"	102° 31' 51.27"
23	Huai Pao	Phayao	2.35	87.00	2.89	35.56	11.30	4-6	3	Sand/Mud (L-H)	2,310.00	2,310.00	1,623.00	-	320.00	45.00	18° 45' 36.55"	100° 18' 50.23"
24	Khlong Wang Heeb	Nakhonsithammarat	20.1	510.00	27.77	184.24	30.00	3-5	3	Sand-Gra (L-H)	13,014.00	13,014.00	-	-	340.00	65.22	08° 14' 19.21"	99° 40' 46.70"
25	Nong Ta Tang	Ratchburi	48.37	1,729.00	49.95	328.07	254.31	1-3 (73)	3	Sand - Mud (L-M)	39,300.00	39,300.00	-	-	733.00	48.80	13° 20' 43.97"	99° 14' 38.44"
26	Huai Ka Laeng	Chaiyaphum	4.991	602.00	4.02	50.20	16.50	1-3	2	Sand (10-50 Lu)	3,100.00	3,100.00	1,175.00	-	649.00	13.50	16° 16' 20.66"	102° 04' 42.39"
27	Huai Ta Pur	Mukdahan	18.89	2,151.96	25.56	291.52	50.00	1-2	2	Sand (L-M)	10,969.00	10,000.00	2,386.00	-	537.50	23.50	16° 42' 06"	104° 17' 54"
28	Huai Pong Phark	Lampang	19.47	1,312.50	51.82	539.47	266.00	5-7	4	tuff (H)	13,000.00	13,000.00	4,628.00	-	200.00	31.00	17° 31' 03.32"	99° 22' 12.29"
29	Ban Mueng Ta Kua	Phatthalung	10.14	343.75	19.15	120.67	20.27	1-3	2	(L-M)	7,500.00	7,500.00	2,000.00	2,000.00	500.00	48.00	07° 11' 47"	100° 04' 29"
30	Nam Pard	Uttaradit	85.64	2,813.00	117.88	1,428.00	677.00	5-7 (3)	4	Silt (H)	57,822.00	44,259.00	44,187.00	13,563.00	500.00	51.80	18° 03' 54"	100° 55' 39"

Table 4.6 Natural Resources and Environment Data of 30 Reservoir Projects (Forest)

NO	Reservoire	Province	Reservoir Area (Rai)	Full Area (Rai)	Full Area (Rai)		Full Area (Rai)	Location (rim, core)	Abundance / Big Tree Density			Bio-diversity (No.of species)			Prohibited Tree (No. species)			Uniqueness	
					National Parks Area (Rai)	Wildlife Sanc. Area (Rai)	Reserved Forest (C) Area (Rai)		Deciduous forest	Mixed forest	Evergreen forest	Deciduous forest	Mixed forest	Evergreen forest	Total	Type Kor (No.)	Tpe khor (No.)	Total	Yes	NO
1	Khlong Yai	Phattalung	730.00	265,625.00	Tai Rom Yen	Khao Ban Tad	Khao Ban Tad	Rim P			75			144	144	69	0	69		NO
2	Mae Pan	Lam Pang	600.00	480,000.00	Jae Sone		Mae Sook/ Mae Soi	Rim P		20.6			77		77	0	22	22		NO
3	Mae Pah Phai	Chiang Mai	930.00	98,487.00			Mae Jaem / Mae Tuen	Rim C	107	117		63	53		116			0		NO
4	Mae Bom	Lam Pang	454.00	480,000.00	Jae Sonn		Mae TuiFung Khwa	Rim P		15.5					0	49		49		NO
5	Mae Pang Luang	Chiang Mai	123.00	442,500.00	Khun Khan		Samoeng	Rim P		123			67		67	29	1	30		NO
6	Mae Phuak	Phrae	457.00	112,067.00			Mae Phuak	Rim F		87.8			134		134	44	1	45		NO
7	Khlong Wang Tanode	Chanthaburi	11,000.00	75,000.00	Khao Sib Ha Chan			Rim P		12.32			84		84	44	2	46		NO
8	Huai Satone	Sa Kaeo	3,418.00	371,250.00	Ta Pharya			Rim P		116	110		156		156	51	1	52		NO
9	Khlong Ma Dua	Nakhonsithammarat	1,534.00	1,353,475.00	Khao Yai			Rim P			52			145	145	49	0	49		NO
10	Nam Ki	Phrae	1,170.00	1,357,194.00			Nam- Yao- Nam Suad	Rim F		6.8			83		83	23	1	24		NO
11	Nam Yuan	Phayao	948.00	178,049.00	Phu Sang		Nam Puei Nam Yuan Nam Lao	Rim P		178		42	45		87			0		NO
12	Mae Nueng	Lam Pang	381.00	432,551.00	Mae Sook/ Mae Soi		Mae Tui Fung Khwa	Core C		42			90		90	58	1	59		NO
13	Klong Chomphu	Phitsanulok	2,618.00	789,000.00	Laeng Luang			Rim P		49.06					0			0		NO
14	Huai Sator	Trat	4,385.00	616,166.00			Khao Samimg/ Tok Phrom	Rim F			43			53	53	63	0	63		NO
15	Khlong Khlung Lang	Kamphaeng Phet	1,915.00	472,136.00	Mae Wong		Khlong Khlung, Mae Wong/ Khlong Suan Mark	Rim P		64			15		15	8	0	8		NO

NO	Reservoire	Province	Reservoir Area (Rai)	Full Area (Rai)	Full Area (Rai)			Abundance / Big Tree Density			Bio-diversity (No.of species)				Prohibited Tree (No. species)			Uniqueness	
					National Parks Area (Rai)	Wildlife Sanc. Area (Rai)	Reserved Forest (C) Area (Rai)	Location (rim, core)	Deciduous forest	Mixed forest	Evergreen forest	Deciduous forest	Mixed forest	Evergreen forest	Total	Type Kor (No.)	Tpe khor (No.)	Total	Yes	NO
16	Huai Khayoong	Si Sa Ket	3,253.00	211,553.00		Phanom Dong Rak	Khao Phra Wihan	Rim W				49	122	78	249	71	0	71		NO
17	Klong Pla Soi	Kamphaeng Phet	402.00	572,730.00	Mae Wong			Core P		70			55		55	9	0	9		NO
18	Khlong Phet Ja Khor	Kamphaeng Phet	509.65	259,678.00	Khlong Larn		Klong Suan Mark	Rim		20			13		13	5	0	5		NO
19	Nam Pee	Phayao	3,626.00	538,125.00	Doi Phu Nang		Mae Yom	Rim		49.06		82	118		200	51	0	51	Yes Forest Sago Palm (Cyeas Palm)	
20	Huai Mae Khon	Phare	459.00	167,370.00			Mae Kon, Mae Sai	Core C		11.36			25		25	8	0	8		NO
21	Huai Samoeng	Prachin Buri	16,250.00	1,400,000.00	Tap Lan / Pang Sida			RIM			58			19	19	15	0	15		NO
22	Huai Sae Or	Sa Kaeo	455.21	579,427.00	Pang Sida			Core C		34			57		57	8	0	8		NO
23	Huai Pao	Phayao	87.00	284,218.00	Mae Yom		Mae Song	Core P		11.3			75		75	20	0	20		NO
24	Khlong Wang Heeb	Nakhonsithamma	510.00	131,347.00	Nam Tok Yone		Plai Khlong Wang Hib	Core C			36			69	69	18	0	18		NO
25	Nong Ta Tang	Ratchburi	1,729.00	306,777.00		Mae Nam Pha Chi		Core C		52			48		48	17	0	17		NO
26	Huai Ka Laeng	Chaiyaphum	602.00	254,897.00			Phu Saaen Kham Nua / Phu Yuak	Core C		18			13		13	9	0	9		NO
27	Huai Ta Pur	Mukdahan	2,151.96	111,007.00			Phu Sri Tharn	Rim W		15			69		69	43	1	44		NO
28	Huai Pong Phark	Lampang	1,312.50	497,127.00			Mae Mork	Core C	6.1	7.52			21		21			0		NO
29	Ban Mueng Ta Kua	Phatthalung	343.75	702,554.00		Khao Ban Tad		Rim C			82.33			118	118	48	0	48		NO
30	Nam Pard	Uttaradit	2,813.00	1,384,883.00			Nam Pard	Rim		8			53		53	46	0	46		NO

Table 4.7 Natural Resources and Environment Data of 30 Reservoir Projects (Wildlife)

NO	Reservoir	Province	Abundance / No. of low density species	No. of species in reservoir	LUCN's Red List (No.)	(VU+EN+CR)	Uniqueness Yes	Uniqueness NO
1	Khlong Yai	Phattalung	97	155	3	(2VU/1EN/-CR)		
2	Mae Pan	Lam Pang	132	239	3			
3	Mae Pah Phai	Chiang Mai	50	137	3			
4	Mae Bom	Lam Pang	92	178	6			
5	Mae Pang Luang	Chiang Mai	91	168	3			
6	Mae Phuak	Phrae	91	179	0			
7	Khlong Wang Tanode	Chanthaburi	123	184	9			
8	Huai Satone	Sa Kaeo	137	201	14	(8VU/6EN/-CR)		
9	Khlong Ma Dua	Nakhonsithammarat	120	220	15	(12VU/3EN/-CR)		
10	Nam Ki	Phrae	68	140	2	(2VU/-EN/-CR)		
11	Nam Yuan	Phayao	75	215	8	(4VU/4EN/-CR)		
12	Mae Nueng	Lam Pang	77	117	1			
13	Klong Chomphu	Phitsanulok	96	167.45	5			
14	Huai Sator	Trat	90	172	2	1VU/1 EN		
15	Khlong Khlung Lang	Kamphaeng Phet	47	114	0			

NO	Reservoir	Province	Abundance / No. of low density species	No. of species in reservoir	LUCN's Red List (No.)	(VU+EN+CR)	Uniqueness Yes	NO
16	Huai Khayoong	Si Sa Ket	116	186	6	(5VU/1EN/-)		
17	Klong Pla Soi	Kamphaeng Phet	57	143	15	(12VU/3EN/-)		
18	Khlong Phet Ja Khor	Kamphaeng Phet	44	113	2	(1VU/1EN/-)		
19	Nam Pee	Phayao	90	187	2	(-VU/2EN/-)		
20	Huai Mae Khon	Phare	123	128	0			
21	Huai Samoeng	Prachin Buri	86	193	6	(6VU/-EN/-CR)		
22	Huai Sae Or	Sa Kaeo	97	156	3	(2VU/1EN/-CR)		
23	Huai Pao	Phayao	72	120	1	(1VU/-EN/-CR)		
24	Khlong Wang Heeb	Nakhonsithammarat	109	133	2			
25	Nong Ta Tang	Ratchburi	129	247	11	(7VU/4EN/-CR)		
26	Huai Ka Laeng	Chaiyaphum	57	112	3	(2VU/1EN/-CR)		
27	Huai Ta Pur	Mukdahan	77	144	3	(3VU/-EN/-CR)		
28	Huai Pong Phark	Lampang	153	159	0			
29	Ban Mueng Ta Kua	Phatthalung	140	180	4	(2VU/2EN)		
30	Nam Pard	Uttlaradit	140	236	7	(6VU/1CR)		

Table 4.8 Social Data of 30 Reservoir Projects

NO	Reservoir	Province	Impacted HH in Reservoir (No.)	Impacted Houses in Reservoir (No.)	Impacted Land in Reservoir (No.)	No. of Protester HH (No.)	Life Value / Unique	Archaeological Place (No/Yes)	Eco-natural tourist (Yes /No)	Geo Conservation (Yes/No)	Value Mineral Resources (Yes/No)	Ethnic (Yes/No)
1	Khlong Yai	Phattalung	62	9	689.5	24		NO	NO	NO	NO	NO
2	Mae Pan	Lam Pang	39	31	125	1		NO	NO	NO	NO	NO
3	Mae Pah Phai	Chiang Mai	65	0	5.98	2		Rock equipment	NO	NO	NO	NO
4	Mae Bom	Lam Pang	97	0	97	0		San Chao Phor Taen Kaew	NO	NO	NO	NO
5	Mae Pang Luang	Chiang Mai	0	0	0	0		NO	NO	NO	NO	NO
6	Mae Phuak	Phrae	13	0	54.28	0		NO	NO	NO	NO	NO
7	Khlong Wang Tanode	Chanthaburi	324	203	6589	17		NO	No	NO	NO	NO
8	Huai Satone	Sa Kaeo	0	0	0	0		Rock engrave	Thung Krating	NO	NO	NO
9	Khlong Ma Dua	Nakhonsithammarat	76	84	695			NO	NO	NO	NO	NO
10	Nam Ki	Phrae	113	15	1306.12	15		NO	NO	NO	NO	NO
11	Nam Yuan	Phayao	83	22	715	60		NO	NO	NO	NO	Yes Mian /Yao Ethnic
12	Mae Nueng	Lam Pang	344	21	85.6	13		NO	NO	NO	NO	NO
13	Klong Chomphu	Phitsanulok	119.56	1	220	47.824		NO	NO	NO	NO	NO

NO	Reservoir	Province	Impacted HH in Reservoir (No.)	Impacted Houses in Reservoir (No.)	Impacted Land in Reservoir (No.)	No. of Protester HH (No.)	Life Value / Unique	Archaeological Place (No/Yes)	Eco-natural tourist (Yes /No)	Geo Conservation (Yes/No)	Value Mineral Resources (Yes/No)	Ethnic (Yes/No)
14	Huai Sator	Trat	151	83	4297	0		NO	NO	NO	NO	NO
15	Khlong Khlung Lang	Kamphaeng Phet	119.56	17	1816	47.824		Hermitage Wat Prang Khaw San	NO	NO	NO	NO
16	Huai Khayoong	Si Sa Ket	164	105	1905	91		NO	NO	NO	NO	NO
17	Klong Pla Soi	Kamphaeng Phet	9	1	40	37		NO	Mae Wong NP	NO	NO	NO
18	Khlong Phet Ja Khor	Kamphaeng Phet	46	8	927	41		Khun Silom Farm	Phet Ja Khor Water Fall 1.6 Km. apart	NO	NO	NO
19	Nam Pee	Phayao	175	26	496	35		NO	NO	NO	NO	NO
20	Huai Mae Khon	Phare	94	179	482.03	14		NO	NO	NO	NO	NO
21	Huai Samoeng	Prachin Buri	604	926	13450.97	13		Hermitage in Reservoir 3 Ancient Commu in Area	NO	NO	NO	NO
22	Huai Sae Or	Sa Kaeo	119.56	0	216.87	47.824		NO	NO	NO	NO	NO
23	Huai Pao	Phayao	2	0	7	0		NO	NO	NO	NO	NO
24	Khlong Wang Heeb	Nakhonsit hammarat	73	62	660	21		NO	NO	NO	NO	NO
25	Nong Ta Tang	Ratchburi	53	55	339.5	43		NO	NO	NO	Felpar, Fluoride, Tin	NO
26	Huai Ka Laeng	Chaiyaphum	23	15	325	22		NO	NO	NO	NO	NO
27	Huai Ta Pur	Mukdahan	179	0	182.88	1		NO	NO	NO	NO	NO

NO	Reservoir	Province	Impacted HH in Reservoir (No.)	Impacted Houses in Reservoir (No.)	Impacted Land in Reservoir (No.)	No. of Protester HH (No.)	Life Value / Unique	Archaeological Place (No/Yes)	Eco-natural tourist (Yes /No)	Geo Conservation (Yes/No)	Value Mineral Resources (Yes/No)	Ethnic (Yes/No)
28	Huai Pong Phark	Lampang	119.56	28	94.22	47.824		NO	NO	NO	NO	NO
29	Ban Mueng Ta Kua	Phatthalung	79	7	407	2		NO	NO	NO	NO	NO
30	Nam Pard	Uttlaradit	186	41	1016	15		NO	NO	NO	NO	NO

Table 4.9 Economic Data of each 30 Selective Projects

NO.	Reservoir	Province	Construction Cost (MB)	Total Social Compensate Cost (MB)	EIMP Cost (MB)	Total Cost (MB)	EIRR (%)	ENVI EIRR (%)
1	Khlong Yai	Phattalung	918.00	251.73	164.00	1,333.73	16.39	14.10
2	Mae Pan	Lam Pang	1,036.00	22.65	100.00	1,158.65	12.50	9.66
3	Mae Pah Phai	Chiang Mai	519.69	2.65	127.00	649.34	9.39	6.89
4	Mae Bom	Lam Pang	663.01	12.76	106.62	782.39	9.64	7.64
5	Mae Pang Luang	Chiang Mai	302.22	-	3.65	305.87	10.25	9.25
6	Mae Phuak	Phrae	638.00	7.54	102.43	747.97	9.08	9.21
7	Khlong Wang Tanode	Chanthaburi	2,622.63	1,989.68	624.00	5,236.31	17.59	12.70
8	Huai Satone	Sa Kaeo	809.00	13.00	140.00	962.00	13.66	11.66
9	Khlong Ma Dua	Nakhonsi thammarat	5,668.23	1,023.74	180.00	6,871.97	11.51	11.27
10	Nam Ki	Phrae	3,465.00	215.70	191.00	3,871.70	11.26	10.22
11	Nam Yuan	Phayao	1,317.00	153.78	176.00	1,646.78	9.65	8.80
12	Mae Nueng	Lam Pang	448.00	11.08	116.00	575.08	7.14	6.14
13	Klong Chomphu	Phitsanulok	855.48	76.64	30.00	962.12	12.89	11.89
14	Huai Sator	Trat	494.39	763.69	131.50	1,389.58	19.79	9.14
15	Khlong Khlung Lang	Kamphaeng Phet	357.74	105.32	119.86	463.06	19.26	16.26

NO.	Reservoir	Province	Construction Cost (MB)	Total Social Compensate Cost (MB)	EIMP Cost (MB)	Total Cost (MB)	EIRR (%)	ENVI EIRR (%)
16	Huai Khayoong	Si Sa Ket	306.12	249.73	257.12	812.97	15.81	12.52
17	Klong Pla Soi	Kamphaeng Phet	326.59	1.28	16.54	344.41	11.16	10.16
18	Khlong Phet Ja Khor	Kamphaeng Phet	237.07	30.22	24.67	291.96	8.46	7.46
19	Nam Pee	Phayao	2,080.75	53.95	243.12	2,377.82	9.21	7.71
20	Huai Mae Khon	Phare	481.54	98.54	18.76	598.84	4.36	4.24
21	Huai Samoeng	Prachin Buri	3,085.18	1,447.88	48.08	4,581.14	12.06	11.56
22	Huai Sae Or	Sa Kaeo	209.77	9.72	0.82	220.31	8.30	3.30
23	Huai Pao	Phayao	445.00	0.72	26.66	472.38	9.99	8.90
24	Khlong Wang Heeb	Nakhonsithammarat	1,253.06	170.93	57.76	1,481.75	8.75	8.63
25	Nong Ta Tang	Ratchburi	589.70	35.88	126.20	751.78	15.15	11.76
26	Huai Ka Laeng	Chaiyaphum	300.99	13.02	22.94	336.95	10.86	9.85
27	Huai Ta Pur	Mukdahan	148.76	4.35	115.60	268.71	11.56	9.79
28	Huai Pong Phark	Lampang	250.12	11.38	24.66	286.16	12.74	9.79
29	Ban Mueng Ta Kua	Phatthalung	552.25	138.75	29.68	720.68	10.67	9.27
30	Nam Pard	Uttlaradit	4,774.00	143.12	271.08	5,188.20	15.09	14.01

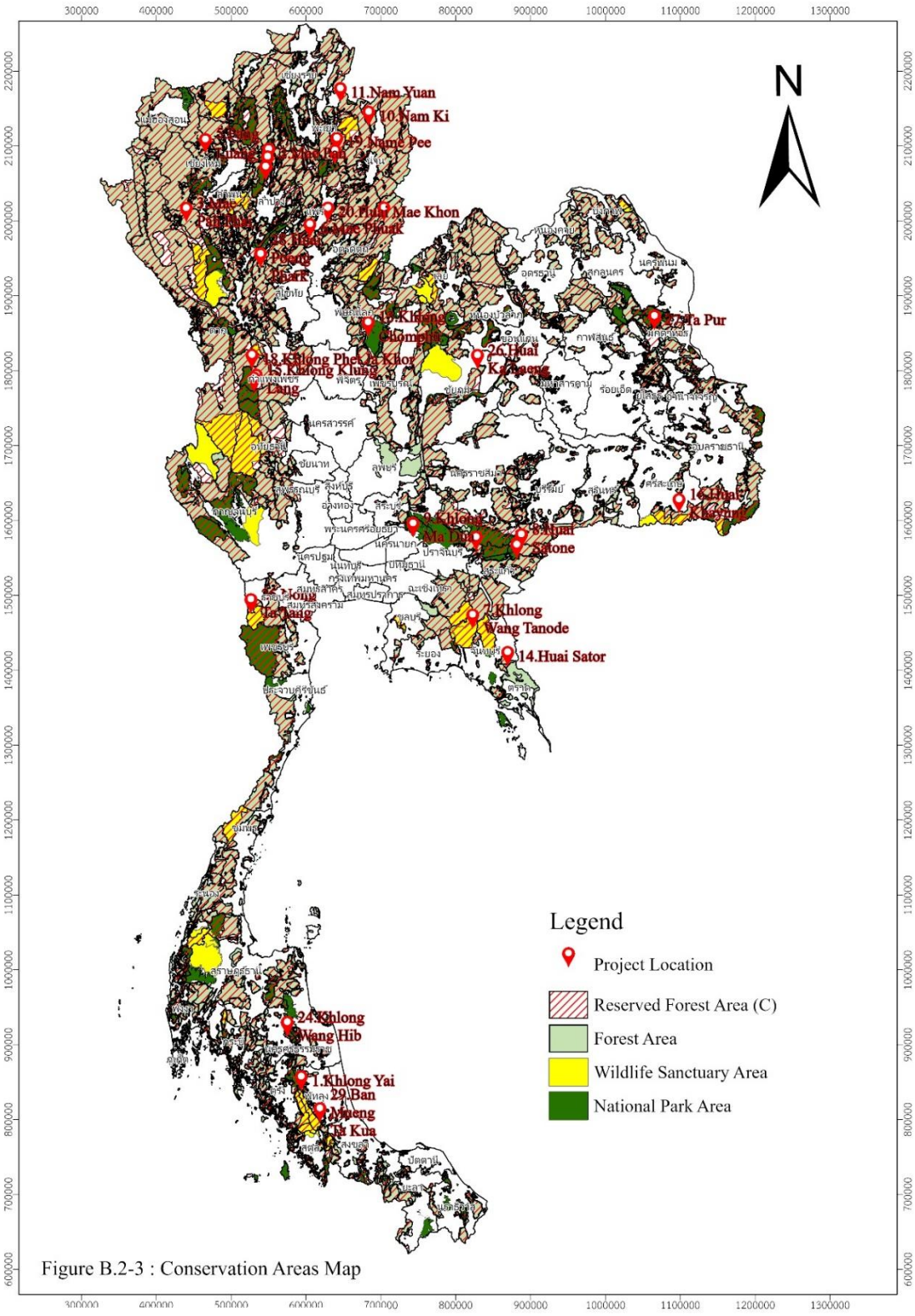

Figure B.2-3 : Conservation Areas Map

Figure 4.1 Location map of 30 selective projects

Conclusions of the indicators from EIA reports are as follows:

EIA reports provided more detail data and information complying with the guidelines of EIA report preparation prescribed by the ONEP. Additionally key indicators and especially their ranging scales are established from the 30 EIA reports.

1) Resulting from the EIA review, augmentation of some missed key indicators were established as follow:

(1) Geographic and engineering dimension; The indicators of dam cross-section, and design flood peak discharge are proposed to cover suitability and sustainability of geography dimension to construct a dam and reservoir.

(2) Social dimension; indicators of number of houses to be evacuated from reservoir, and benefit irrigated area per reservoir area, are proposed to account for the affected households.

(3) Economic dimension; the project benefits of which simplified indicator adapting annual cropping area is proposed, and indicators of cost factor including construction, social compensation, and environmental mitigation plan are additional proposed. Finally, the EIRR indicator is proposed for project feasibility.

Table 4.10 present stage of indicators establishment

2) Data and information from the 30 EIA reports which were both direct and indirect representing selected indicators could be established their ranging scale by basing on simplified statistical method.

3) For assessment of the sustainable indicators and project's priority comparison, most of indicators which are quantitative, applying relative proportion of indicators by compared to one unit of reservoir storage would result a better project comparison understanding than the using total amounts or values.

4) In the case of unavailable data of indicators in some EIA reports, the average values of such indicators would be adopted. After the second draft indicators, all proposed dimension, factors and indicators together with ranging scale and scores were classified and descriptions of indicators were also defined in the questionnaire for Del Phi panel's consideration. It is found that more than 45% of the first-round Del Phi's review agreed with the proposed dimensions, factors and indicators. Whereas more than 75 percentiles of the 2nd - round Del Phi's review agreed with their majority

weighting scores on dimensions, factors, and indicators respectively, as well as classifying sustainability level of projects.

5) According to concerning agencies' practice in consideration of initiating a water reservoir project, assessment of the water scarcity are carried out in term of qualitative determination. The researcher then proposed a semi-quantitative way applying GIS overlaying technique for weighted scoring computation. Key factors and indicators were established in accordance with normal practice of concerning agencies in water resource development project initiation.

Five factors of geography, existing project development, hydrology, water demand upon land use, and poverty are generally applied, however, specific indicators and their weightage and ranging scores adopted in previous studies were not defined.

However, key indicators for assessing water scarcity level of a project were adopted from basic variables that normally applied basing on the condition that data and digital mapping are available.

Indicators's definition and ranging scale and scores of indicators of both sustainability and water scarcity level are statistically manipulated and proposed for Del Phi's consideration. The majority of the Del Phi more than 75 percentile agreed with the proposed scaling ranges.

Table 4.10 Stage of Indicators Establishment

Dimensions	Factors		Items		Indicators: 1st-draft by Literature	Indicators: 2nd-draft by In-depth interview	Indicators: 2nd draft with ranging scale by EIA's report & researcher: EIA	Indicators: 2nd draft with ranging scale by EIA's report & researcher: Researcher	Indicators: Final with weightage by Del Phi's majority
1. Geography and Engineering	1	Geography and Engineering	1	Dam section / storage				✓	✓
			2	Reservoir area / storage	✓		✓		✓
	2	Hydrology	3	Flood flow / storage	✓			✓	✓
	3	Geology	4	Seismicity		✓	✓		✓
			5	Seepage		✓	✓		✓
	4	Engineering	6	Irrigation area / storage	✓			✓	✓
2. Natural Resources and Environments	5	Forest	7	Abundance	✓	✓	✓		✓
			8	Bio-diversity	✓	✓	✓		✓
			9	Prohibited Plants	✓	✓	✓		✓
			10	Uniqueness	✓	✓	✓		✓
	6	Wildlife	11	Abundance		✓	✓		✓
			12	Bio-diversity		✓	✓		✓
			13	Endangered Wildlife	✓	✓	✓		✓
			14	Uniqueness		✓	✓		✓
	7	Water Quality	15	Water Quality	✓		✓		✓
	8	Ecology	16	Type of conserved area		✓	✓		✓

Dimensions		Factors		Item	Indicators				
					1st-draft by Literature	2nd-draft by In-depth interview	2nd draft with ranging scale by EIA's report & researcher		Final with weightage by Del Phi's majority
							EIA	Researcher	
			17	Reservoir area conversation area	✓			✓	✓
			18	Location	✓	✓	✓		✓
3. Social	9	Protestors	19	Protestors / Impacted Households	✓	✓	✓		✓
	10	Impacted Households	20	Houses/ Storage	✓		✓		✓
			21	Compensated land / Storage			✓		✓
			22	Irrigated area / reservoir area		–		✓	✓
	11	Uniqueness	23	- Archaeology site		✓	✓		✓
				- Tourism place					✓
				- Mineral resource					✓
				- Geologist reservation					✓
				- Ethnics					✓
4. Economic	12	Benefits	24	Annual crop area / Storage				✓	✓
	13	Costs	25	Construction cost/ Storage			✓		✓
			26	Social cost / Storage			✓		✓
			27	Environmental cost/ storage			✓		✓
	14	Feasibility	28	EIRR			✓		✓
			29	Env.EIRR		✓	✓		✓

4.2.4 Results From Research Studies, Documentations, and Announcements of Related agencies

Definitions and scoring ranges of some indicators could be obtained from previous research, announcements of related agencies for examples.

1) Prohibited trees and bio- diversity are referenced from the announcement by the DNP regarding the determination of the value of natural resources in protected area, 2020.

2) Abundance of forest is referenced from the Department of Conservation, Faculty of Forestry, Kasetsart University, 2009.

For other indicators, definitions and scoring are manipulated from available data of 30 EIA reports as presented in Appendix C.

4.2.5 Results from Review of Water Resource Development Necessity or Water scarcity

In the past, requests of the water resource development starting mostly from farmers in the risk drought area where lacking of water resources for agriculture and water supply. Responsible agencies have to assess water scarcity level of such area in order to classifying necessity level of water resources development prior to project planning and feasibility study. Factors normally applied comprise five factors. They are (1) geography factor including drought and flood risk areas indicators, (2) the factor of existence of water resources and irrigation system over the target area, (3) hydrologic factor comprising rainfall variation indicator, and ground water potential indicator, (4) water demand factor comprising agriculture type indicator, and (5) poverty factor comprising the ratio of numbers of poor villages to total villages indicator, are proposed.

Therefore, the assessment of water scarcity of the target area should be determined together with the appropriate project sustainability level for project implementation decision.

4.2.6 Results of the 2nd Draft of Sustainable Indicators and Ranging Scores

Results of study of the dimensions, factors, and key sustainable indicators and their scoring ranges from afore mentioned steps are considered as draft components in the 2nd draft sustainable indicator.

There are two groups of indicators proposed in the questionnaire comprising 1) Sustainable factors and indicators of the water resource development projects and 2) Factors and indicators of the assessment of water scarcity level. The details are as follows :

4.2.6.1 Sustainable indicators of the water resource development projects

Conceptual of indicators proposed in the 2nd draft sustainable indicators are as follows:

The main dimensions considered are 4 components consisting of geography and engineering, natural resources and environment, social, and economics.

There are 14 significant factors considered for sustainable aspects as follows; i) engineering dimension comprising 4 factors namely geography, geology, hydrology, and engineering. ii) natural resources and environmental dimension consisting of 4 key factors namely forests, wildlife, water quality, and ecosystem. iii) social dimension concerning 3 core factors namely project opposition, affected stakeholders, and life value or uniqueness. iv) economic dimension comprising 3 factors namely benefits, costs, and feasibility level.

The project sustainable indicators comprise 29 indicators as follows: i) engineering dimension with 6 indicators, ii) natural resources and environmental dimension with 12 indicators, iii) social dimension with 5 indicators, and iv) economic dimension with 6 indicators.

Details of dimensions, factors, and indicators as well as scoring ranges are defined as follows,

1) Geography and engineering dimension

There are 4 main factors including 1) Geography, 2) Hydrology, 3) Geology, and 4) Engineering.

(1) Geographical factors

There are 2 indicators

(1.1) Dam cross-sectional area to reservoir capacity indicator.

(a) The suitability of the geography for developing a reservoir with a small dam cross-section is highlighted. It is suitable in terms of engineering, resulting in better dam stability and safety and lower construction costs per unit of water storage compared to those with a larger dam cross-section.

(b) Representative dam cross-sectional area calculation is simplified by multiplying the length of the dam by its height.

Range (sq.m./mcm)	≤ 500	>500-1000	>1000-1500	>1500-2000	> 2000
Score	5	4	3	2	1

(1.2) Reservoir area/reservoir capacity indicator.

(a) the suitability of the topography for reservoir development helps reducing water losses from evaporation, seepage, and the loss of conservation areas to serve as a reservoir.

(b) The proportion with a small figure is suitable due to its high efficiency in water retention, low water losses from evaporation and seepage, and reduced impact on natural resources, ecology, environments, and associated costs, resulting in a higher score.

Range rai per mcm	≤ 25	>25-50	>50-75	>75-100	> 100
Score	5	4	3	2	1

(2) Hydrological factors

There is one indicator

(2.1) Flood discharge per reservoir capacity indicator

(a) Apply the rate of peak flood flow design (return period of 500 or 1000 years) per unit of reservoir capacity (cu.m./second/ mcm.), which presents the effective size of the reservoir comparing to the hydrologic regime. It also affects the spillway size and investment cost.

(b) A low value indicates that the project area having a higher resilience reservoir resulting a low flood discharge spilled which is well-suited and more safety. It has the potential to effectively support more flood volume and consequently has a shorter spillway with lower construction cost, resulting in a high score.

Range (cms/ mcm)	≤5	>5-10	>10-15	>15-20	> 20
Score	5	4	3	2	1

(3) Geologic factor

There are 2 indicators as follows,

(3.1) Seismicity indicator

(a) Applying the Mercalli's intensity scale (1-7) representing risk of earthquake intensity and occurrences. A higher seismicity level results in higher seismic, and negatively affects the risk of severe earthquakes, leading to damage to dams, hydraulic structures, and downstream flood-prone areas.

(b) The high-level value has a low score of geological suitability.

(c) Reference: Seismic Hazard Level from Thailand's Seismic Hazard Map, 2nd Edition, by the Department of Mineral Resources.

Range	Level	Level	Level	Level	Level
(Mercalli's \intensity)	1-2	3	4	5	6-7
Score	5	4	3	2	1

(3.2) Leakage indicator

(a) The geological condition of the dam foundation affects the dam safety, water losses, and construction cost in preventing water seepage from reservoir.

(b) The low seepage value is suitability, and low construction cost are considered. In this case, taking into account the values obtained from the permeability test (measured in Lugeon) or the type of bedrock layer at the dam foundation, such as granite, metamorphic rock, or the assessment of seepage from project study reports.

(c) A low seepage level results in higher dam safety, less water loss and minimal construction costs for seepage prevention, leading to a high score.

(d) In cases where there is no seepage assessment, evaluations are made based on the types of rock layers in the foundation as follows: Igneous rock exhibits minimal to relatively low seepage, shale, mudstone, and siltstone have relatively low to moderate seepage, and sandstone and conglomerate show moderate to relatively high seepage.

(e) Additionally, metamorphic rocks with fractures, including limestone and sandstone, have moderate to high seepage.

Range (Lugeon)	Low leakage	Relatively low leakage	Moderate leakage	Relatively high leakage	High leakage
	≤1	>1-5	>5-10	>10-50	> 50
Score	5	4	3	2	1

(4) Engineering factors

There is one indicator as follows:

4.1) Irrigation area per reservoir capacity indicator.

(a) The ratio of irrigated area to the unit of water storage capacity reflects the suitability of project planning with balance of the size of irrigation area against the size of the reservoir, and the physical characteristics of the soil, hydrology, and topography of the benefiting area that affecting both water resource security and project benefits.

(b) A higher ratio indicates a well-suited project for irrigation.

Range (rai / mcm.)	>900	>700-900	>500-700	>300-500	≤300
Score	5	4	3	2	1

2) Dimension of natural resources and the environments.

There are 4 main following factors : 1) Forests, 2) Wildlife, 3) Impact on water quality, and 4) Impact on ecosystem.

(1) Forest factor

There are 4 indicators as follows;

(1.1) Forest abundance or density of large trees indicator (trees/rai).

(a) In this context, the density of large trees per 1 rai is applied corresponding to the main forest type in the reservoir area

Range of dry dipterocarp forest (trees/rai)	less abundance ≤14	moderately abundance >14-40	high abundance >40
Score	5	3	1

(b) High density of large trees indicates forest abundance. The project will have more impact on high density forest, resulting in a low suitability score.

Range of mixed deciduous forest (trees/rai)	less abundance ≤ 16	moderately abundance >16-54	high abundance >54
Score	5	3	1

(c) Reference: Department of Conservation Science, Faculty of Forestry, Kasetsart University, B.E.2552. Criteria for assessing the status of forest resources in watershed areas.

Range of hill evergreen forest (trees / rai)	less abundance ≤ 15	moderately abundance >15-45	high abundance >45
Score	5	3	1

(1.2) Forest Biodiversity indicator

(a) Utilize the number of tree species according to the main type of forest in the reservoir area.

Range of dry dipterocarp forest (species / rai)	less variety ≤ 17	moderately variety >17-30	high variety >30
Score	5	3	1

(c) A high number of species indicates a high biodiversity in the forest. The project will have a significant impact, resulting in a lower sustainability score.

Range of mixed deciduous forest (species/rai)	less variety ≤ 25	moderately variety >25-43	high variety >43
Score	5	3	1

(d) Reference: Department of National Parks, Wildlife and Plant Conservation announcement regarding the valuation of natural resources in national parks, B.E.2564.

Range of moist evergreen forest (species/rai)	less variety ≤ 49	moderately variety > 49-84	high variety >84
Score	5	3	1

(1.3) Prohibited and specially prohibited tree species indicator

(a) Utilize prohibited species of trees as listed in the Department of National Parks, Wildlife and Plant Conservation's announcement on valuing natural resources in national parks, B.E. 2564.

(b) The greater the number of prohibited tree species, the higher the value of rare species. Consequently, the project is assigned a lower score.

Range	low	relatively low	moderately	relatively high	high
(species)	1-10	11-20	21-30	31-40	> 40
Score	5	4	3	2	1

(1.4) Uniqueness/Exclusivity of forest indicator

(a) Existence of forest uniqueness at the national level and cannot be created anew or relocated.

Range	Identified distinctiveness in the area.	No distinctiveness found in the area.
Score	0	5

(2) Wildlife factor

There are 4 indicators: 1) Abundance, 2) Biodiversity, 3) Wildlife Status (IUCN’s Red List), 4) Uniqueness and Exclusivity of Wildlife.

(2.1) Abundance indicators

(a) Applying the concept of density as a representation of the level of wildlife abundance, using the number of species with low abundance compared to total species in the reservoir as an indicator.

(b) A high number of species with low abundance indicates a low abundance level for wildlife in the area, resulting in a higher score.

Range (%)	> 60	>40-60	≤ 40
Score	5	3	1

(2.2) Biodiversity indicator

(a) Utilizing the number of wildlife species found in the reservoir area. A high number of wildlife species indicators a high level of biodiversity.

(b) A high number of species reflects high biodiversity, resulting in a low suitability score.

Range (No. of species)	≤ 115	>115-150	>150-185	>185-215	>215
Score	*5*	4	3	2	1

(2.3) Wildlife status indicator rare species

(a) Applying the number of wildlife species protected by the IUCN's Red List in 2015, categorized as VU (Vulnerable), EN (Endangered), and CR (Critical) status.

(b) The high number of Red list wildlife species found in the reservoir area according to the IUCN's Red List indicates the area's significance for sustaining endangered wildlife. The low suitability score of the project is attributed to the presence of high number of endangered and near-extinct wildlife species that warrant conservation.

Range (No. of rare species)	≤ 4	5 - 8	> 8
Score	5	3	1

(2.4) Uniqueness/Exclusivity indicator

(a) Uniqueness in terms of wildlife at the national level, and cannot be replaced or relocated is specified.

Range	Identified distinctiveness in the area.	No distinctiveness found in the area.
Score	0	5

(3) Impact on water quality factor

(3.1) Impacted water quality indicator

(a) The severity level of the impact score from projects that affect the altered water quality. In this case, it includes:

(b) Biology (Liver fluke, Dengue fever, Malaria)

(c) Chemistry (Heavy metals, Pollutants)

Range	No impact or less impact	Moderate impact and can be mitigated	Severe impact and can be significantly mitigated.	Severe impact and can be moderately mitigated.	Severe impact and can be less mitigated.
Score	5	4	3	2	1

(4) Impact on ecosystem factor

(4.1) The type of conservation forest indicator.

(a) The national park class A, B, and C, as well as wildlife sanctuaries area, have a high to very high level of conservation priority.

(b) Watershed classification 1A and 1B are relatively high in importance for head water supply.

(c) Reserved forest zone C holds a moderate level of significance.

(d) Reference: Conservation areas designated by the Department of National Parks, Wildlife, and Plant Conservation (DNP), Royal Forestry Department (RFD), and ONEP.

Range (conservation type)	high to very high priority National park , Wildlife zone	relatively high priority Watershed 1A,1B	moderate priority National reserved forest (C)
Score	1	3	5

(4.2) The proportion of the reservoir affected area size to the total conservation area indicator

(a) The proportion of conserved forest area affected by the project is the ratio of the conserved forest area impacted to the total conserved area.

(b) A higher proportion has a greater impact on the high terrestrial and aquatic ecosystem. A project with a low score indicates an impact on less ecosystem services and the loss of natural resource values,

including less impacts on greenhouse gas absorption. In this context, the evaluation utilizes the proportion of the conserved forest area that be impacted.

Range (%)	≤ 1.0	>1.0-2.0	>2.0-3.0	>3.0-4.0	>4.0
Score	5	4	3	2	1

(4.3) The location of the reservoir within the conservation area indicator

(a) The location of the reservoir within the conservation area indicates the level of ecological and environmental impacts.

(b) The headwaters or core zone of the conservation area are more ecologically and environmentally impacted than the downstream areas. Therefore, projects located within the headwaters area get lower scores.

Range (location)	Low level At the boundary	Moderate level At the boundary to the central area	High level the central area to the headwaters
Score	5	3	1

3) Social dimension

There are 3 main factors as follows; 1) Opposition to the project, 2) Proportion of those beneficiaries and sufferers, 3) Quality of life

(1) Project opposition factor

There is one indicator as;

(1.1) The number of households opposing the project per the total number of households negatively impacted

(a) Applying the proportion of the number of opponents to the total number of households adversely affected.

(b) A higher proportion of opposition leads to conflicts and poses an obstacle to the success of the project, resulting in a lower score.

Range (%)	> 20	>15- 20	>10 – 15	>5 - 10	≤5
Score	1	2	3	4	5

(2) The proportion of those beneficiaries and sufferers factor.

There are 3 indicators as 1) The number of households affected per reservoir capacity, 2) the compensatory area per reservoir capacity, and 3) the irrigation area benefiting per reservoir area

(2.1) The number of households affected per reservoir capacity.

(a) Applying the number of households that are affected per unit of the reservoir capacity.

(b) A high number indicates high social impacts on accommodation, cultivated land and living values which are likely to lead to opposition, conflicts, evacuation and resettlement, high compensation costs, and obstacles to project viability and success. The project is likely to score low.

Range (households/ mcm)	≤ 1	>1.0-2.0	>2.0-3.0	>3.0-4.0	>4.0
Score	5	4	3	2	1

(2.2) The compensatory land area per reservoir capacity indicator

(a) Applying the proportion of compensatory land area to the reservoir capacity of 1 mcm.

(b) A higher proportion results in higher compensation costs and impacts the livelihood of residents, reducing the project's suitability. The project is likely to score low.

Range (Rai/mcm.)	≤ 10	>10-20	20-30	30-40	>40
Score	5	4	3	2	1

(2.3) The irrigation area per reservoir area indicator

(a) Applying the proportion of the benefit area to the area lost due to the reservoir.

(b) A higher proportion of household indicates that the project benefits the society more, with a larger population

of household benefiting than those significantly impacted. The project will receive a higher score.

Range (Times)	≤ 10	>10-20	>20-30	>30-40	>40
Score	1	2	3	4	5

(3) Quality of life and uniqueness factor

There are 6 indicators including 1) Archaeologic or historical sites, 2) Conservation-oriented natural tourist attractions, 3) Significant mineral resources, 4) Unique geology, 5) Ethnic groups

(3.1) Historical sites

(a) In case the reservoir located within the designated area of a national archaeological site declared by the Fine Arts Department (FAD), the score is set as zero indicating inappropriate location.

(b) Reference: National Conservation Area declared by the Fine Arts Department

Range	Located within the designated area	Not within the designated area
Score	0	5

(3.2) Conservation-oriented natural tourist attractions

(a) The project is located in an unique internationally recognized conservation area for tourism purposes, The score is set zero.

(b) Reference: Department of National Parks, Wildlife, and Plant Conservation (DNP).

Range	Located within a conservation area	Not within a conservation area.
Score	0	5

(3.3) Significant mineral resources

(a) In case the project is located in an area with significant mineral resources, which has high value., the score is set zero.

(b) Reference: Department of Mineral Resources (DMR).

Range	Located in the zone area	Not in the zone area.
Score	0	5

(3.4) Geological conservation area

(a) In case the project is located in the area designated for geological conservation., The score is set zero.

(b) Reference: Department of National Parks, Wildlife, and Plant Conservation (DNP).

Range	Located within a conservation area	Not within a conservation area.
Score	0	5

(3.5) Ethnic groups

(a) In case there are diverse ethnic groups in the reservoir area. The project has significant impacts on the living conditions, and cultural traditions of the highly diverse community., the score is set zero

Range	There are ethnic groups within the area.	There are no ethnic groups within the area.
Score	0	5

4) Economic dimension

There are 3 factors comprising: 1) benefits, 2) costs, and 3) feasibility

(1) Benefit factor

(1.1) Evaluate the project benefits based on the annual cultivated area per reservoir capacity

(1.2) A project that efficiently delivers water to the higher proportional annual cultivated area per capacity will have greater benefits, resulting in a higher score.

Range (rai/mcm)	≤ 600	>600-800	>800-1000	>1000-1200	>1200
Score	1	2	3	4	5

(2) Cost factor

There are 3 indicators as 1) Project cost per capacity, 2) Social compensation cost (compensating cost per reservoir capacity), and 3) Environmental impact mitigation plan (EIMP) cost per capacity

(2.1) Project cost per capacity indicator

(a) Considering the proportion of total project cost (engineering, social, environmental) per unit of reservoir capacity.

(b) A high cost per unit of capacity indicates a reduced economic return for the project, resulting in a lower score.

Range (MB/mcm)	≤ 20	>20-40	>40-60	>60-80	>80
Score	5	4	3	2	1

(2.2) Social compensation cost indicator

(a) Considering the land acquisition costs per unit of reservoir capacity.

(b) A high compensation cost indicates a significant social impact and a high project cost, resulting in a lower score.

Range (MB/mcm)	≤ 2	>2-4	>4-6	>6-8	>8
Score	5	4	3	2	1

(2.3) Environmental impact (EIMP) cost per capacity indicator

(a) Considering the budget for reducing the environmental impacts of the project per unit of reservoir capacity.

(b) A high environmental impact (EIMP) cost indicates a significant environmental impact, leading to a high project cost and a lower score.

Range (MB/mcm)	≤ 2	>2-4	>4-6	>6-8	>8
Score	5	4	3	2	1

(3) Feasibility factor

There are 2 indicators including 1) Economic internal rate of return (EIRR) and 2) Environmental economic internal rate of return.

(3.1) Economic internal rate of return (EIRR)

(a) Considering the economic internal rate of return (EIRR) on investment of the project.

(b) A high value indicates that the project is economically viable, leading to a high score.

Range (%)	> 14	>12 -14	>10 -12	>8 – 10	≤ 8
Score	5	4	3	2	1

(3.2) Environmental economic value

(a) Considering the environmental economic internal rate of return (EEIRR) of the project.

(b) A high value indicates that the project has high environmental viability, leading to a high score.

Range (%)	> 12	>10-12	>8-10	>6-8	≤ 6
Score	5	4	3	2	1

Table 4.11 presents the summary of the project sustainable factors and indicators with scoring ranges.

Table 4.11 Selected Project Sustainable Factors and Indicators with Scoring Ranges Applied

Factors / Indicators	Unit	Scores and Ranges 5	4	3	2	1
1. Engineering Dimension						
1.1 Geography Factor						
1.1.1 Dam section/ Res.cap	m^2/mcm.	≤ 500	> 500-1000	> 1000-1500	>1500-2000	> 2000
1.1.2 Res. area / Res.cap	rai/mcm.	≤ 25	> 25-50	> 50-75	> 75- 100	> 100
1.2 Hydrology Factor						
1.2.1 Des. flood/ Res.cap	cms./mcm.	< 5	> 5-10	> 10 -15	> 15-20	> 20
1.3 Geology Factor						
1.3.1 Seismicity	Mercalli scale	Level 1-2	Level 3	Level 4	Level 5	Level 6-7
1.3.2 Leakage	1-5 scale	Low leakage or Lugeon ≤1	Relatively low leakage or Lugeon > 1-5	Moderate leakage or Lugeon >5-10	Relatively high leakage or Lugeon > 10-50	High leakage or Lugeon > 50
1.4 Engineering Factor						
1.4.1 Irrigation area / Res.cap	rai/mcm.	>900	> 700-900	>500-700	>300-500	≤ 300
2. Natural Resources and Environmental Dimension						
2.1 Forestry Factor						
2.1.1 Abundance: Big tree density	No./rai	≤ 14 (less abundance)		> 14-40 (moderately abundance)		> 40 (high abundance)
2.1.2 Biodiversity: No. of total species	No. of species	≤ 17 (less variety)		>17-30 (moderately variety)		>30 (high variety)
2.1.3 Prohibited Trees: No. of species	No. of species	1-10 (low)	>10-20 (relatively low)	>20-30 (moderately)	>30-40 (relatively high)	> 40 (high)
2.1.4 Uniqueness	Yes/No	No distinctiveness found in the area.				Identified distinctiveness in the area.
2.2 Wildlife Factor						
2.2.1 Abundance : No. of low density species /No. of total species	Percent	> 60		> 40-60		≤ 40
2.2.2 Biodiversity : No. of total species	No. of species	≤ 115	> 115-150	> 150-185	> 185-215	>215
2.2.3 Prohibited Wildlife : No. of species by IUCN Red List Level (VU EN and CR)	No. of red list species	≤4		5 - 8		> 8
2.2.4 Uniqueness	Yes/No	No distinctiveness found in the area.				Identified distinctiveness in the area.

Factors / Indicators	Unit	Scores and Ranges 5	4	3	2	1
2.3 Water quality impact factor						
2.3.1 Impacted water quality	Yes/No	No impact or less impact	Moderate impact and can be mitigated	Severe impact and can be significantly mitigated.	Severe impact and can be moderately mitigated.	Severe impact and can be less mitigated.
2.4 Impacted ecology factor						
2.4.1 Conservation area type	NP/WL/1A/RF	moderate (Reserved forest) (C)	-	relatively high (WC,1A)	-	high to very high (National Park& Wildlife zone)
2.4.2 Impacted reservoir area /Total conserved area	Percent	≤ 1.0	> 1-2	> 2-3	> 3-4	> 4
2.4.3 Location in conserved Area	Rim/Inner	Low impact (Rim)	-	Moderate impact (Rim to the central)	-	High impact (Central to the headwaters)
3. Social dimension						
3.1 Opposition factor : No. of opposition/ No. of affected households	Percent	≤ 5	> 5 - 10	> 10 – 15	> 15- 20	> 20
3.2 Impacted Social Factor						
3.2.1 No. of household per Res.cap.	Household/mcm.	≤ 1	>1-2	>2-3	> 3-4	> 4
3.2.2 Compensated Area/ Res.cap.	rai/mcm.	≤ 10	>10-20	> 20-30	> 30-40	> 40
3.2.3 Irrigation area / Reservoir area	-	≤ 10	>10-20	> 20-30	> 30-40	> 40
3.3 Life Value (Uniqueness) Factor						
3.3.1 Uniqueness (Archaeology, Tourism, Mineral, Geology, and Ethnic)	Yes/No	No	-	-	-	Yes
4. Economic dimension						
4.1 Benefit factor						
4.1.1 Annual crop area / Reservoir capacity	rai/mcm.	≤ 600	>600-800	>800-1000	>1000-1200	>1200
4.2 Investment factor						
4.2.1 Construction cost / Res.cap.	MB./mcm.	≤ 20	>20-40	>40-60	>60-80	>80
4.2.2 Social compensation cost / Res.cap.	MB./mcm.	≤ 2	>2-4	>4-6	>6-8	>8
4.2.3 Env. Mitigation cost /Res. cap.	MB./mcm.	≤ 2	>2-4	>4-6	>6-8	>8
4.3 Feasibility Factor						
4.3.1 Economic internal rate of return (EIRR)	Percent	> 14	>12 -14	>10 -12	>8 – 10	≤ 8
4.3.2 Environment economic internal rate of return (EEIRR)	Percent	> 12	>10-12	>8-10	>6-8	≤ 6

Note: NP = National Park, WL = Wildlife Sanctuation Area,

1A = Watershed Class. 1A, RF = Reserved Forest, 1 Rai = 1,600 sq.m.

4.2.6.2 Factors and indicators of the assessment of water scarcity level

There are 5 factors that indicating water scarcity level of the project area. They are 1) geographic factor including drought risk area and flooded risk area indicators, 2) existence of irrigation system factor (and indicator), 3) hydrologic factor comprising rainfall variation indicator and groundwater potential indicator, 4) land use factor (and indicator), and 5) poverty factor (and indicator), respectively.

1) Factor and indicators of water scarcity level

There are 5 factors consisting of 1) Geography, 2) Existence of irrigation development, 3) Hydrogeology of water sources, 4) Land use or water demand, and 5) Poverty.

(1) Geography factor

There are 2 indicators including 1) Drought risk area and 2) Flood risk area

(1.1) Drought risk areas

(a) An area within the drought risk zone, which is considered basing on the frequency or number of occurrences within a 5-year period.

(b) A high frequency indicates a high risk, resulting in a high score.

(c) Reference: GISTDA Drought Risk Map.

Range	4-5 times/5 Years (high score)	2-3 times/ 5 Years (moderate score)	1 time/ 5 Years (low score)
Score	5	3	1

(1.2) Flood risk areas

(a) It is an area within the flood risk zone, which is considered basing on the frequency or number of occurrences within a 10-year period.

(b) A high frequency indicates a high risk, resulting in a high score.

(c) Reference: GISTDA Flood Risk Map.

Range	> 6 times/10 Years (high score)	4-6 times/ 10 Years (moderate score)	<4 times/ 10 Years (low score)
Score	5	3	1

(2) Existence of irrigation development factor

(2.1) Development of water sources and irrigation systems.

(a) Considering that the project agriculture area located outside the existing irrigation zone tends to have more severe problems than those within the irrigation zone.

(b) The criteria for areas outside the existing irrigation zone get high scores. Areas within the zone benefiting from hydraulic structures but without reservoirs get moderate scores, and areas within the irrigation zone and with reservoirs get low scores.

(c) Reference: Irrigation Area Boundary Map by the Department of Irrigation (RID).

Range	Area outside the irrigation zone	Area benefit from weirs, regulators, pumping stations but without reservoirs.	Area in the irrigation zone with a reservoir
Score	5	3	1

(3) Hydrology factor

There are 2 indicators comprising 1) Hydrological variation and 2) Potential of groundwater supply.

(3.1) Hydrological variation indicator

(a) Applying the proportion of average rainfall during the dry season compared to the annual average rainfall of the nearby rain gauge stations.

(b) Low proportion indicates an area having low rainfall and low natural flow during the dry season. Natural water sources in dry season are not reliable. Areas experience with high drought, thus water scarcity score get a higher score.

Range (%)	< 25	25-30	> 30
Score	5	3	1

(3.2) Potential of groundwater indicator

(a) Considering areas where groundwater has the quantity and quality potentials for groundwater supply.

(b) Low groundwater supply yield value of less than 10 liters per hour and a Total Dissolve Solid (TDS) value exceeding 500 units indicate areas having high water scarcity issues. These areas will receive a higher score.

(c) Reference: Groundwater map by the Department of Groundwater Resources.

Range	Yield	< 10 and	>10-20 and	>10-20 and	> 20 and	> 20 and
	TDS	> 500	> 500	≤ 500	> 500	< 500
Score		5	4	3	2	1

(4) Water demand factor

(4.1) The land use area indicator

(a) Considering the water demand via main land use in the benefited area.

(b) Orchard areas, which require water throughout the year in significant quantities and are economically important, receive a high score.

(c) Rice fields, which need more water during low flow period in the rainy season, and during dry season have a high water demand quantities, receive a high score

(d) Field crops areas, which require minimal water and serve as supplementary crops for additional income, receive a moderate score.

(e) Rubber and perennial tree areas, which require minimal water, receive a low score.

(f) Reference: Land use map by the Department of Land Development.

Range	Orchard/ Rice field	Field crops area	Rubber and P perennial trees
Score	5	3	1

(5) Social factor

There is one indicator.

(5.1) The level of poverty indicator

(a) In terms of social aspects, poverty is considered based on income, health, education, living conditions, and access to government services.

(b) Areas with a high proportion of the level of poverty should receive high development necessity scores, resulting in a high score.

(c) The level of poverty is assessed basing on the percentage of the impoverished population compared to the total population at the district level.

(d) Reference: National Electronics and Computer Technology Center (NECTEC), B.E.2565

Range (%)	>10	>7.5-10	> 5-7.5	> 2.5-5	≤2.5
Score	5	4	3	2	1

Table 4.12 presents the summary of the water scarcity factors and indicators with scoring ranges.

Table 4.12 Summary of Water Scarcity Factors and Indicators with Scoring Ranges

Factors / Indicators	Unit	Water Scarcity		
		Low (No. of Proj.)	**Moderate (No. of Proj.)**	**High (No. of Proj.)**
1 Geography factor				
1.1 Drought indicator				
- Frequency in the past 5 years of droughts.	Years	1-2 (18)	3-4 (8)	≥5 (4)
1.2 Flooded index				
- Frequency in the past 12 years of floods.	Years	≤4 (26)	5-8 (3)	>8 (1)
2 Irrigation system existence factor				
- Irrigation system existence indicator	-	Partial Irrigated by reservoir. (5)	Partial Irrigated without reservoir. (2)	No Irrigation system. (23)
3 Hydrology factor				
3.1 Rainfall variation indicator				
- Proportion of dry season rainfall to annual rainfall.	%	> 30 (3)	>25-30 (5)	< 25 (22)
3.2 Groundwater potentials indicator				
- Yield	cu.m./hr,	>20 (5)	> 10-20 (2)	<10 (23)
- Total Dissolved Solids (TDS)	mg/l	<500 (26)	-	>500 (4)
4 Water demand factor				
- Agricultural land use type index	Type	Rubber Perennial Tree (4)	Field Crops (12)	Orchard/Paddy (14)
5 Poverty factor				
- Poverty indicator (Proportion of the poors to district's population.)	%	≤2.5 (15)	>2.5-10 (14)	>10 (1)

4.3 Development of the Final Indicators

4.3.1 Results of the Del Phi's First-Round Questionnaire

The followings are summary of the first-round considerations assigned weights to dimensions, factors, and various indicators, including the score ranges of the indicators obtained from 20 Del Phi panelists. The researchers evaluated the results based on the majority opinions and made some adjustments for clearly comprehension. This information serves as supplementary data for the second round of questionnaire responses, aiming for a percentile greater than 75**.**

4.3.1.1 Section 1: Evaluation of weightings for dimensions, factors, and indicators of project sustainability

1) Dimensions: The assessment of weightings for dimensions revealed the following:

(1) Results of the first-round questionnaires

(1.1) Engineering dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 20%.

(1.2) Natural resources and environment dimension: A majority of 9 out of 20 panelists (45%) assigned a weighting of 35%.

(1.3) Social dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 25%.

(1.4) Economic dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 20%.

(2) Proposal of the second-round questionnaires

For the second round of Del Phi's questionnaires, the proposal draft weightings to the dimensions as follows: Engineering: Natural Resources and Environment: Social: Economic as 20:35:25:20

Table 4.13 presents Del Phi's questionnaire summary on weightage of dimension.

Table 4.13 Summary of Dimension Weightage from Del Phi's Questionnaire

Dimension	1st round	1st round Amount		2nd round	2nd round Amount	
	weightage (%)	No	%	weightage (%)	No	%
1. Geography and Engineering	<20%	0	0%	<20%	0	0%
	20%	12	60%	20%	18	90%
	25%	6	30%			
	>25%	2	10%	>20%	2	10%
2. Natural Resources and Environment	<30%	6	30%	<35%	5	25%
	30%	4	20%	35%	15	75%
	35%	9	45%			
	>35%	1	5%	>35%	0	0
3. Social	<25%	4	20	<25%	1	5%
	25%	12	60	25%	16	80%
	30%	3	15			
	>30%	1	5	>25%	3	15%
4. Economic	<20%	2	10%	<20%	0	0%
	20%	12	60%	20%	20	100%
	25%	6	30%			
	>25%	0	0%	>20%	0	0%

2) Factors: The survey results of weightings for key factors in various dimensions are as follows,

(1) Engineering and physical dimension consisting of 4 key factors: Results of the first round questionnaires

(1.1) Geographic factors

(a) A majority of 9 out of 20 panelists (45%) assigned a weighting of 20%

(b) A majority of 4 out of 20 panelists (20%)

(c) Assigned a weighting of 25%. Combining both, a total of 13 out of 20 panelists (65%) assigned weightings ranging from 20-25%, or with an average of 22.5%.

(1.2) Hydrologic factors

(a) A majority of 5 out of 20 panelists (25%) assigned a weighting of 25%.

(b) Another majority of 5 out of 20 panelists (25%) assigned a weighting of 20%. Combining both, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 20-25%, with an average of 22.5%.

(1.3) Geological factors

(a) A majority of 8 out of 20 panelists (40%) assigned a weighting of 30%.

(b) Another majority of 3 out of 20 panelists (15%) assigned a weighting of 35%.

(c) Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-35%, with an average of 32.5%.

(2) Proposal of the second-round questionnaires

Assigning weightings for Geography and Engineering Factors in terms of Geography : Hydrologic : Geology : Engineering, respectively, as 25 : 25 : 30 : 20

Table 4.14 presents Del Phi's questionnaire summary on factor weightage in geography and engineering dimension.

Table 4.14 Summary of Factor Weightage in Geography and Engineering Dimension from Del Phi's Questionnaire

Factors in Geography and Engineering	**1st round weightage (%)**	**1st round No**	**%**	**2nd round weightage (%)**	**2nd round No**	**%**
1. Geography	<25	3	15%	<25%	1	5%
	25-29%	9	45%	25%	18	90%
	30-35%	6	30%			
	>35%	2	10%	>25%	1	5%
2. Hydrology	<20%	3	15%	<25%	1	5%
	20-25%	10	50%	25%	19	95%
	>25%	7	35%	>25%	0	0
3. Geology	<25%	6	30%	<30%	1	5%
	25-29%	4	20%	30%	19	95%
	30-35%	9	45%			
	>35%	1	5%	>30%	0	0%
4. Engineering	<20%	3	15%	<20%	0	0%
	20-25%	15	75%	20%	18	90%
	>25%	2	10%	>20%	2	10%

(2) Natural resources and environmental dimension have 4 key factors. Results of the first-round questionnaires

(2.1) Main factors related to forests:

(a) A majority of 7 out of 20 panelists (35%) assigned a weighting of 25%.

(b) The next majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.

(c) Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 25-30%, with an average of 27.5%.

(2.2) Main factors related to wildlife:

(a) A majority of 9 out of 20 panelists (45%) assigned a weighting of 25%.

(b) Another majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.

(c) Combining both, a total of 13 out of 20 panelists (65%) assigned weightings ranging from 25-30%, with an average of 27.5%.

(2.3) Factors related to the Impact on Water Quality:

(a) A majority of 8 out of 20 panelists (40%) assigned a weighting of 20%.

(b) Another majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

(c) Combining both, a total of 12 out of 20 panelists (60%) assigned weightings ranging from 20-25%, with an average of 22.5%.

(2.4) Factors related to the impact on ecosystems:

(a) A majority of 7 out of 20 panelists (35%) assigned a weighting of 20%.

(b) Another majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

(c) Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 20-25%, with an average of 22.5%.

Proposal of the second round questionnaires

Assigning weightings to factors related to natural resources and the environment, including Forests : Wildlife : Water Quality: Ecosystems : as 25 : 30 : 20 : 25

Table 4.15 presents Del Phi's questionnaire summary on factor weightage in natural resource and environment dimension.

Table 4.15 Summary of Factor Weightage in Natural Resource and Environment Dimension from Del Phi's Questionnaire

Factors in Natural Resources and Environment	**1st round weightage (%)**	**1st round**		**2nd round weightage (%)**	**2nd round**	
		No	**%**		**No**	**%**
1. Forestry	<25	5	25%	<25%	1	5%
	25%	7	35%	25%	17	85%
	30%	4	20%			
	>30%	4	20%	>25%	2	10%
2. Wildlife	<25%	5	25%	<30%	4	20%
	25%	9	45%	30%	16	80%
	30%	4	20%			
	>30%	2	10%	>30%	0	0
3. Water Quality	<20%	4	20%	<20%	1	5%
	20%	8	40%	20%	19	95%
	25%	4	20%			
	>25%	4	20%	>20%	0	0%
4. Ecology	<20%	3	15%	<25%	1	5%
	20%	7	35%			
	25%	4	20%	25%	17	85%
	30%	4	20%			
	>30%	2	10%	>25%	2	10%

(3) Social dimension comprises 3 key factors. Results of the first-round questionnaires

(3.1) Main factors related to project opposition.

(a) A majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

(b) The next tier, with 2 out of 20 panelists (10%) each, assigned weightings of 30%.

(c) The subsequent tier, with 2 out of 20 panelists (10%) each, assigned weightings of 35%. Combining these, a total of 8 out of 20 panelists (40%) assigned weightings ranging from 25-35%, with an average of 30%.

(3.2) Main factors related to proportion of beneficiaries on sufferers

(a) A majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.

(b) Another majority of 4 out of 20 panelists (20%) assigned a weighting of 35%.

(c) The next tier, with 3 out of 20 panelists (15%), assigned a weighting of 40%.

(d) Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-40%, with an average of 35%.

(3.2) Factors related to quality of life

(a) A majority of 6 out of 20 panelists (30%) assigned a meeting weighting of 30%.

(b) The next tier, with 3 out of 20 panelists (15%), assigned a weighting of 40%.

(c) The subsequent tier, with 2 out of 20 panelists (10%), assigned a weighting of 35%.

(d) Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-40%, with an average of 35%.

Proposal of the second round questionnaires

Assigning weightings for social factors, including Project Opposition : Proportion of Beneficiaries on Sufferers : Quality of Life or Uniqueness, the distribution would be as follows: 30% : 35% : 35%.

Table 4.16 presents Del Phi's questionnaire summary on factor weightage in social dimension.

Table 4.16 Summary of Factor Weightage in Social Dimension from Del Phi's Questionnaire

Factors in Social	**1st round weightage (%)**	**1st round**		**2nd round weightage (%)**	**2nd round**	
		No	**%**		**No**	**%**
1. Protestors	<25%	6	30%	<30%	0	0%
	25%	4	20%			
	30%	2	10%	30%	17	85%
	35%	2	10%			
	>35%	6	30%	>30%	3	15%
2. Beneficiaries to Suffering	<30%	6	30%	<35%	2	10%
	30%	4	20%			
	35%	4	20%	35%	17	85%
	40%	3	15%			
	>40%	3	15%	>35%	1	5%
3. Uniqueness	<30%	7	35%	<35%	4	20%
	30%	5	25%			
	35%	2	10%	35%	15	75%
	40%	3	15%			
	>40%	3	15%	>35%	1	5%

(4) Economic dimension consists of 3 main factors Results of the first round questionnaires

(4.1) Benefits factors

(a) A majority of 8 out of 20 panelists (40%) assigned a weighting of 35%.

(b) The next tier, with 4 out of 20 panelists (20%), assigned a weighting of 30%.

(c) Combining these, a total of 12 out of 20 panelists (60%) assigned weightings ranging from 30-35%, with an average of 32.5%.

(4.2) Cost factors

(a) A majority of 5 out of 20 panelists (25%) assigned a weighting of 25%.

(b) Another majority of 5 out of 20 panelists (25%) assigned a weighting of 30%.

(c) The subsequent tier, with 4 out of 20 panelists (20%), assigned a weighting of 35%.

(d) Combining these, a total of 14 out of 20 panelists (70%) assigned weightings ranging from 25-35%, with an average of 30%.

(4.3) Feasibility factors

(a) A majority of 6 out of 20 panelists (30%) assigned a weighting of 40%.

(b) Another majority of 4 out of 20 panelists (20%) assigned a weighting of 35%.

(c) Combining these, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 35-40%, with an average of 37.5%.

Proposal of the second-round questionnaires

Assigning weightings for economic factors, including Benefits : Costs : Feasibility, the distribution would be as follows: 30% : 30% : 40%.

Table 4.17 presents Del Phi's questionnaire summary on factor weightage in economic dimension.

Table 4.17 Summary of Factor Weightage in Economic Dimension From Del Phi's Questionnaire

Factors in Economic	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
1. Benefit	<30%	4	20%	<30%	0	0%
	30%	4	20%	30%	19	95%
	35%	8	40%			
	>35%	4	20%	>30%	1	5%
2. Cost	<25%	5	25%	<30%	0	0%
	25%	5	25%			
	30%	5	25%	30%	19	95%
	35%	4	20%			
	>35%	1	5%	>30%	1	5%
3. Feasibility	<35%	8	40%	<40%	1	5%
	35%	1	5%			
	40%	6	30%	40%	19	95%
	45%	1	5%			
	>45%	4	20%	>40%	0	0%

3) Indicators: Survey results of weightings for indicators across various factors.

(1) Engineering dimension

Geography factor consists of 2 main indicators: Results of the first-round questionnaires

(1.1) Dam cross-section / Reservoir capacity indicator

(a) A majority of 7 out of 20 panelists (35%) assigned weighting of 40%.

(b) Another majority of 7 out of 20 panelists (35%) assigned a weighting of 50%.

(c) Combining these, a total of 14 out of 20 panelists (70%) assigned weightings ranging from 40- 50%, with an average of 45%.

(1.2) Reservoir area / Capacity indicator

(a) A majority of 7 out of 20 panelists (35%) assigned a weighting of 40%.

(b) Another majority of 7 out of 20 panelists (35%) assigned a weighting of 50%.

(c) Combining these, a total of 14 out of 20 panelists (70%) assigned weightings ranging from 40-50%, with an average of 45%.

Proposal of the second round questionnaires

Assigning weightings indicators of geography factor as follows : Dam cross-section / Capacity : Reservoir area / Capacity would be 45 : 55.

(2) Hydrologic factors comprise a single indicator which is flood discharge per unit of reservoir capacity, hence a weightage of 100%.

Results of the first round questionnaires

18 out of 20 panelists (90%) assigned a weightage of 100%.

Proposal of the second round questionnaire.

The same weight is proposed.

(3) Geological Factor consist of 2 main indicators

Results of the first round questionnaires.

(3.1) Seismic indicator

(a) A majority of 5 out of 20 panelists (25%) assigned a weightage of 50%.

(b) The subsequent tier, with 3 out of 20 panelists (15%), assigned a weightage of 40%.

(c) The next tier, with 2 out of 20 panelists (10%), assigned a weightage of 60%.

(d) Combining these, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 40-60%, with an average of 50%.

(3.2) Leakage indicator

(a) A majority of 6 out of 20 panelists (30%) assigned a weightage of 50%.

(b) The subsequent tier, with 3 out of 20 panelists (15%), assigned a weightage of 60%.

(c) The next tier, with 2 out of 20 panelists (10%), assigned a weightage of 40%.

(d) Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 40-60%, with an average of 50%.

Proposal of the second round questionnaires

Assigning weightings for indicators of geology factor as follows: Seismic indicator: Leakage indicator would be 50 : 50.

(4) Engineering (Irrigation) factor consists of a single indicator, which is the ratio of irrigation area to reservoir capacity, thus carrying a weightage of 100%.

Results of the first round questionnaires

All 20 panelists (100%) assigned a weightage of 100%.

Table 4.18 shows Del Phi's questionnaire summary on indicator weightage in geography and engineering dimension.

Table 4.18 Summary of Indicator Weightage in Geography and Engineering Dimension from Del Phi's Questionnaire

Factors in Geography and Engineering	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
Geography and Engineering						
1. Geography						
1.1 Dam Section / Storage	<40%	3	15%	<45%	2	10%
	40%	7	35%	45%	16	80%
	50%	7	35%			
	>50%	3	15%	>45%	2	10%
1.2 Reservoir Area / Storage	<50%	5	25%	<55%	2	10%
	50%	7	35%	55%	16	80%
	60%	6	30%			
	>60%	2	10%	>55%	2	10%
2. Hydrology						
2.1 Flood discharge / Storage	<100%	2	10%	100%	20	100%
	100%	18	90%			
3. Geology						
3.1 Seismicity	<40%	6	30%	<50%	1	5%
	40-60%	11	55%	50%	18	90%
	60%	3	15%	>50%	1	5%
3.2 Leakage	<40%	8	40	<50%	1	5%
	40-60%	12	60	50%	18	90%
	>60%	0	0	>50%	1	5%
4 Engineering						
4.1 Irrigation Area/ Storage	<100%	3	15%	100%	20	100%
	100%	17	85%			

(2) Natural resources and environmental dimension

(2.1) Forest factor consists of 4 indicators.

Results of the first-round questionnaires

(a) Forest abundance indicator

The majority, 6 out of 20 panelists (30%), assigned a weightage of 25%. The majority, another 6 out of 20 panelists (30%),

assigned a weightage of 30%. (c)or a total of 12 panelists (60%) assigned a weightage in the range of 25-30%, with an average of 27.5%.

(b) Biodiversity indicator

The majority, 8 out of 20 panelists (40%), assigned a weightage of 25%. The next group, 5 out of 20 panelists (25%), assigned a weightage of 30% or a total of 13 panelists (65%) assigned a weightage in the range of 25-30%, with an average of 27.5%.

(c) Forest status indicator (Prohibited tree status indicator).

The majority, 11 out of 20 panelists (55%), assigned a weightage of 20%. The next group, 4 out of 20 panelists (20%), assigned a weightage of 25% or a total of 15 panelists (75%) assigned a weightage in the range of 20-25%, with an average of 22.5.

(d) Uniqueness/Exclusivity indicator

The majority, 5 out of 20 panelists (25%), assigned a weightage of 30%. The next group, 4 out of 20 panelists (20%), assigned a weightage of 35%. Another group, 4 out of 20 panelists (20%), assigned a weightage of 20%. The last group, 3 out of 20 panelists (15%), assigned a weightage of 25% or a total of 16 panelists (80%) assigned a weightage in the range of 20-35%, with an average of 27.5.

Proposal of the second-round questionnaires

Assigning weightage for the forest indicators as follow: Abundance: Biodiversity: Forest Status: Uniqueness would be as 25:25:20:30,

(2.2) Wildlife factor comprises 4 indicators:

Results of the first-round questionnaires

(a) Abundance indicator

The majority, 8 out of 20 panelists (40%), assigned a weightage of 30%. The next group, 3 out of 20 panelists (15%), assigned a weightage of 25% or a total of 11 panelists (55%) assigned a weightage in the range of 25-30%, with an average of 27.5.

(b) Biodiversity indicator

The majority, 7 out of 20 panelists (35%), assigned a weightage of 20%. The next group, 6 out of 20 panelists (30%), assigned a weightage of 25% or a total of 13 panelists (65%) assigned a weightage in the range of 20-25%, with an average of 22.5.

(c) Wildlife status indicator (Endangered wildlife status indicator)

The majority, 8 out of 20 panelists (40%), assigned a weightage of 30%. The next group, 7 out of 20 panelists (35%), assigned a weightage of 20%. The following group, 3 out of 20 panelists (15%), assigned a weightage of 25% or a total of 18 panelists (90%) assigned a weightage in the range of 20-30%, with an average of 25.

(d) Indicator of uniqueness / Distinctiveness

The majority, 4 out of 20 panelists (20%), assigned a weightage of 20%. The next group, 4 out of 20 panelists (20%), assigned a weightage of 25%. The following group, 3 out of 20 panelists (15%), assigned a weightage of 30% or a total of 11 panelists (55%) assigned a weightage in the range of 20-30%, with an average of 25.

Proposal of the second-round questionnaires.

Assigning weights to the wildlife indicator as follows: Abundance: Biodiversity: Wildlife Status: Uniqueness would be 30:20:30:20

(2.3) Impact on water quality factor

Results of the first-round questionnaires

The factor consists of a single indicator, hence, it is weighted 100%, more than 75% agreed the weight.

Proposal of second round questionnaires.

The same weightage was proposed.

(2.4) Ecology impact factors

Results of the first-round questionnaires.

(a) Conservation forest type indicator

The majority, 7 out of 20 panelists (35%), assigned a weightage of 30%. The next group, 5 out of 20 panelists (25%), assigned a weightage of 40%. The following group, 2 out of 20 panelists (10%), assigned a weightage of 50% or a total of 14 panelists (70%) assigned a weightage in the range of 30-50%, with an average of 40.

(b) Proportion of area impact on conservation area indicator

The majority, 9 out of 20 panelists (45%), assigned a weightage of 30%. The next group, 6 out of 20 panelists (30%), assigned a weightage of 35% or a total of 15 panelists (75%) assigned a weightage in the range of 30-35%, with an average of 32.5.

(c) Reservoir location in conservation area indicator

The majority, 7 out of 20 panelists (35%), assigned a weightage of 20%. The next group, 4 out of 20 panelists (20%), assigned a weightage of 30%. The following group, 2 out of 20 panelists (10%), assigned a weightage of 25% or a total of 13 panelists (65%) assigned a weightage in the range of 20-30%, with an average of 25.

Proposal of the second-round questionnaires

Assigning weights to the indicators of the impact on the environmental system as follows: Conservation Forest Types Affected: Proportion of Area Impact on Conservation Areas: Reservoir Location in Conservation Areas would be 40:35:25

Table 4.19 presents Del Phi's questionnaire summary on indicator weightage in natural resource and environment dimension.

Table 4.19 Summary of Indicator Weightage in Natural Resource and Environment Dimension from Del Phi's Questionnaire

Indicator in Natural Resource and Environment	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
Natural Resources and Environment						
1. Forestry						
1.1 Abundance	<20%	3	15%	<25%	2	10%
	20%	2	10%			
	25%	6	30%	25%	16	80%
	30%	6	30%			
	>30%	3	15%	>25	2	10%
1.2 Bio-Diversity	<20%	1	5%	<25%	1	5%
	20%	3	15%			
	25%	8	40%	25%	18	90%
	30%	5	25%			
	>30%	3	15%	>25%	1	5%
1.3 Prohibited Plants	<15%	1	5%	<20%	0	0%
	15%	1	15%			
	20%	11	40%	20%	18	90%
	25%	4	25%			
	>25%	3	15%	>20%	2	10%
1.4 Uniqueness	<25%	7	35%	<30%	2	10%
	25%	3	15%			
	30%	5	25%	30%	17	85%
	35%	4	20%			
	>35%	1	5%	>30%	1	5%
2 Wildlife						
2.1 Abundance	<25%	7	35%	<30%	3	15%
	25%	3	15%			
	30%	8	40%	30%	17	85%
	35%	2	10%			
	>35%	0	0%	>30%	0	0%
2.2 Bio-Diversity	<15%	0	0%	<20%	1	5%
	15%	2	10%			
	20%	7	35%	20%	17	85%
	25%	6	30%			
	30%	3	15%			

Indicator in Natural Resource and Environment	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
	>30%	2	10%	>20%	2	10%
2.3 Endangered Species	<20%	2	10%	<30%	3	15%
	20%	7	35%			
	25%	3	15%	30%	17	85%
	30%	8	40%			
	>30	0	0%	>30%	0	0%
2.4 Uniqueness	<15%	0	0%	<20%	0	0%
	15%	3	15%			
	20%	4	20%	20%	16	80%
	25%	4	20%			
	>30%	9	45%	>20%	4	20%
3 Water Quality						
3.1 Water Quality	<100%	3	15%	<100%	1	5%
	100%	17	85%	100%	19	95%
4 Ecology						
4.1 Conservation Area Type	<30%	4	20%	<40%	3	15%
	30%	7	35%			
	35%	2	10%	40%	16	80%
	40%	5	25%			
	50%	2	10%	>40%	1	5%
4.2 Impacted reservoir area / Conservation Area	<30%	0	0%	<35%	2	10%
	30%	9	45%			
	35%	6	30%	35%	17	85%
	40%	1	5%			
	>40	4	20%	>35%	1	5%
4.3 Reservoir location in Conservation Area	<20%	0	0%	<25%	2	10%
	20%	9	45%			
	25%	6	30%	25%	17	85%
	30%	1	5%			
	>30%	4	20%	>25%	1	5%

(3) Social dimension

(3.1) Project opposition factor

Results of the first-round questionnaires

The factor consists of a single indicator, therefore, it is weighted 100% more than 75 percents agreed.

Proposal of the second-round questionnaires

The same weight was proposed

(3.2) Factor proportion of beneficiaries to sufferers

Results of the first-round questionnaires

(a) Indicator of the number of households affected per reservoir capacity.

The majority, 10 out of 20 panelists (50%), assigned a weightage of 40%.

(b) Indicator of compensated area within reservoir area per reservoir capacity.

The majority, 10 out of 20 panelists (50%), assigned a weightage of 30%.

(c) Indicator of ratio of irrigation area to reservoir area

The majority, 7 out of 20 panelists (35%), assigned a weightage of 30%. The next group, 3 out of 20 panelists (15%), assigned a weightage of 35% or a total of 10 panelists (50%) assigned a weightage in the range of 30-35%, with an average of 32.5.

Proposal of the second-round questionnaires

Assigning weights for the indicators of the proportion of beneficiaries to suffers factor as follows: Number of households affected per reservoir capacity: Compensated area per reservoir capacity: Ratio of irrigation area to reservoir area would be 40:30:30

(3.3) Quality of life and uniqueness/factor

Results of the first-round questionnaires.

There are 5 indicators, namely 1) Archaeological Sites 2) Tourist Attractions 3) Important Mineral Resources 4) Geological Conservation Areas 5) ethnic groups. Each indicator is assigned an equal weightage of 20%. More than 75% agreed.

Proposal of the second-round questionnaires.

The same weightage was proposed.

Table 4.20 presents Del Phi's questionnaire summary on indicator weightage in social dimension.

Table 4.20 Summary of Indicator Weightage in Social Dimension from Del Phi's Questionnaire

Indicator in Social	**1st round weightage (%)**	**1st round No**	**1st round %**	**2nd round weightage (%)**	**2nd round No**	**2nd round %**
Social						
1. Project Protestors						
1.1 Project Protestors	<100%	2	10%	<100%	0	0%
	100%	18	90%	100%	20	100%
2. Impacted						
2.1 Impacted Habitats (Household) per	<35%	4	20%	<40%	2	10%
Storage	35%	3	15%			
	40%	10	50%	40%	18	90%
	45%	1	5%			
	50%	2	10%	>40%	0	0%
2.2 Compensated Land per Storage	<30%	5	25%	<30%	0	0%
	30%	10	50%	30%	19	95%
	>30%	5	25%	>30%	1	5%
2.3 Benefit Area per Reservoir Area	<25%	2	10%	<30%	0	0%
	25%	3	15%			
	30%	7	35%	30%	19	95%
	35%	3	15%			
	>35%	5	25%	>30%	1	5%
3. Life Value or Unique						
3.1 Archaeology	20%	20	100%	20%	19	95%
3.2 Tourism	20%	20	100%	20%	19	95%
3.3 Value Mineral Resource	20%	20	100%	20%	19	95%
3.4 Geologic Conservation	20%	20	100%	20%	19	95%
3.5 Ethnic	20%	20	100%	20%	19	95%

(4) Economic dimension

(4.1) Benefit Factors

Results of the first-round questionnaires.

There is a single indicator, represented by the annual cropping area per reservoir capacity, more than 75% agreed to assigned a weightage of 100%.

Proposal of the second-round questionnaires.

The same weightage was proposed.

(4.2) Cost factors, consisting of 3 indicators:

Results of the first-round questionnaires.

(a) Project cost per capacity indicator

The majority, 6 respondents out of 20 (30%), assign a weightage in the range of 33-35%. The next group, 5 respondents out of 20 (25%), assign a weightage of 30%. This results in a total of 11 respondents (55) assigning a weightage in the range of 30-35%, or an average of 32.5%.

(b) Social compensation per capacity indicator (Compensatory cost per capacity)

The majority, 6 respondents out of 20 (30%), assign a weightage of 30%. The majority, another 6 respondents out of 20 (30%), assign a weightage in the range of 33-35%. This results in a total of 12 respondents (60%) assigning a weightage in the range of 30-35%, or an average of 32.5%.

(c) Environmental mitigation cost per capacity indicator

The majority, 5 respondents out of 20 (30%), assign a weightage of 35%. The majority, another 5 respondents out of 20 (30%), assign a weightage of 40%. The next group, 3 respondents out of 20 (15%), assign a weightage of 30%. This results in a total of 13 respondents (65%) assigning a weightage in the range of 30-35%, or an average of 35.3

Proposal of the second-round questionnaires.

Assigning weightage to the cost factors in the indicators of cost factor as follows ; Project cost per reservoir capacity: Compensatory cost per reservoir capacity: and Environmental impact mitigation plan (EIMP) cost per reservoir capacity would be 30:35:35.

(4.3) Economic feasibility factors consist of 2 indicators:

Results of the first-round questionnaires.

(a) Economic feasibility indicator

The majority, 7 respondents out of 20 (35%), assign a weightage of 40%. The next group, 2 respondents out of 20 (10%), assign a weightage of 45%. The following group, 2 respondents out of 20 (10%), assign a weightage of 50%. This results in a total of 11 respondents (55%) assigning a weightage in the range of 40-50%, or an average of 45%.

(b) Environmental economic feasibility indicator.

The majority, 7 respondents out of 20 (35%), assign a weightage of 60%. The next group, 2 respondents out of 20 (10%), assign a weightage of 55%. The following group, 1 respondent out of 20 (5%), assigns a weightage of 50%. This results in a total of 10 respondents (55%) assigning a weightage in the range of 50-60%, or an average of 55%.

Proposal of the second-round questionnaires.

Assigning weightage for the indicators of the economic feasibility factor as follows; Economic internal rate of return (EIRR) : Environmental economic internal rate of return (EEIRR) would be 45:55.

Table 4.21 presents Del Phi's questionnaire summary on indicator weightage in economic dimension.

Table 4.21 Summary of Indicator Weightage in Economic Dimension from Del Phi's Questionnaire

Indicator in Economic	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
Economic						
1. Benefit : Annual Crop per Storage						
1.1 Benefit : Annual Crop per Storage	<100%	1	5%	100%	20	100%
	100%	19	95%			
2. Cost						
2.1 Construction Cost per Storage	<30%	1	5%	<30%	0	0%
	30%	5	25%	30%	20	100%
	35%	6	30%			
	>35%	8	40%	>30%	0	0%
2.2 Compensation Cost per Storage	<30%	4	20%	<35%	0	0%
	30%	6	30%	35%	19	95%
	35%	6	30%			
	>35%	4	20%	>35%	1	5%
2.3 Environmental Cost per Storage	<30%	7	35%	<35%	1	5%
	30%	3	15%			
	35%	5	25%	35%	19	95%
	40%	5	25%			
	>40%	0	0%	>35%	0	0%
3. Feasibility						
3.1 Economic IRR	<40%	3	15%	<45%	1	5%
	40%	7	35%			
	45%	2	10%	45%	17	85%
	50%	2	10%			
	>50%	6	30%	>45%	2	10%
3.2 Environmental EIRR	<50%	4	20%	<55%	2	10%
	50%	7	35%			
	55%	2	10%	55%	17	85%
	60%	5	25%			
	>60%	2	10%	>55%	1	5%

4.3.1.2 Section 2: Establishing criteria for sustainability ratings in dimensions

1) Results of the first-round questionnaires

The criteria for scoring can be summarized as follows. The majority, 14 out of 20 respondents (70%), express their opinion on categorizing sustainability levels within the score range for the following dimensions:

2) Proposal of the second-round questionnaires.

The specified ranges are set as the first round's result.

As shown in Table 4.22 presents Del Phi's questionnaire summary on sustainability scourge and levels.

Table 4.22 Summary of Sustainability Score and Levels from Del Phi's Questionnaire

Dimension	Low	Moderately Low	Moderate	Good	Very Good	Agree	Disagree
1. Engineering	≤35%	>35-45%	>45-55%	>55-65%	>65%	14	6
2. Natural Resources and Environmental	≤35%	>35-45%	>45-55%	>55-65%	>65%	14	6
3. Social	≤35%	>35-45%	>45-55%	>55-65%	>65%	14	6
4. Economic	≤35%	>35-45%	>45-55%	>55-65%	>65%	14	6
All Dimensions	≤35%	>35-45%	>45-55%	>55-65%	>65%	14	6

4.3.1.3 Summary of the assessment of water scarcity or necessity of water source development

1) Factors: The assessment of the severity of the water scarcity and the necessity of water source development involves a total of 5 factors.

(1) Results of the first-round questionnaires.

(1.1) Geographic factor

(a) Majority, 5 out of 20 respondents (25%), assigned a weight of 15%.

(b) Majority, another 5 out of 20 respondents (25%), assigned a weight of 20%.

(c) Majority, 4 out of 20 respondents (20%), assigned a weight of 25%.

(d) Overall, 14 respondents (70%) allocated weights in the range of 15-25%, with an average of 20%.

(1.2) Existence of development factor

(a) Majority, 7 out of 20 respondents (35%), assigned a weight of 10%.

(b) Majority, another 7 out of 20 respondents (35%), assigned a weight of 20%.

(c) Majority, 2 out of 20 respondents (10%), assigned a weight of 15%.

(d) Overall, 16 respondents (80%) allocated weights in the range of 10-20%, with an average of 15%.

(1.3) Hydrologic and ground water potential factor:

(a) The majority, 9 out of 20 respondents (45%), assigned a weight of 20%.

(b) Another majority, 4 out of 20 respondents (20%), assigned a weight of 25%.

(c) Another majority, 4 out of 20 respondents (20%), assigned a weight of 15%.

(d) Overall, 17 respondents (85%) allocated weights in the range of 15-25%, with an average of 20%.

(1.4) Water demand factors:

(a) The majority, 9 out of 20 respondents (45%), assigned a weight of 20%.

(b) Another majority, 4 out of 20 respondents (20%), assigned a weight of 25%.

(c) Another majority, 4 out of 20 respondents (20%), assigned a weight of 15%.

(d) Overall, 17 respondents (85%) allocated weights in the range of 15-25%, with an average of 20%.

(1.5) Poverty factor:

(a) The majority, 6 out of 20 respondents (30%), assigned a weight of 20%.

(b) The next majority, 4 out of 20 respondents (20%), assigned a weight of 30%.

(c) The next majority, 3 out of 20 respondents (15%), assigned a weight of 25%.

(d) Overall, 13 respondents (65%) allocated weights in the range of 20-30%, with an average of 25%.

(2) Proposal of the second-round questionnaires

Assigning weights for the water scarcity factors, as follows; Geography: Existence of development: Hydrology and ground water potential: Water demand: Poverty, would be 20:15:20:20:25

Table 4.23 presents summary of 1st round results Del Phi panel on water scarcity factors.

Table 4.23 Summary of 1st Round Results from Del Phi Panel on Water Scarcity Factors

Factor	1st round weightage Range (%)	1st round agreed No	%	2nd round weightage Range (%)	2nd round agreed No	%
1. Geography	<15%	1	5%	<20%	1	5%
	15-25%	15	75%	20%	18	90%
	>25%	4	20%	>20%	1	5%
2. Existence of	<10%	0	0%	<15%	0	0%
Development	10-20%	17	85%	15%	18	90%
	>20%	3	15%	>15%	2	10%
3. Hydrology	<15%	1	5%	<20%	1	5%
	15-25%	13	65%	20%	19	95%
	>25%	6	30%	>20%	0	0%
4. Water Demand	<15%	1	10%	<20%	1	5%
	15-25%	13	60%	20%	19	95%
	>25	6	30%	>20%	0	0%
5. Poverty	<20%	7	35%	<25%	0	0%
	20-30%	13	65%	25%	19	95%
	>30%	0	0%	>25%	1	5%

2) Indicators:

(1) Geographic factor: comprising 2 indicators

(1.1) Results of the first-round questionnaires

(a) Drought risk area indicator:

The majority, 6 out of 20 respondents (30%), assigned a weight of 50%. The next majority, 5 out of 20 respondents (25%), assigned a weight of 55-60%. Overall, 11 respondents (55%) allocated weights in the range of 50-60%, with an average of 55%.

(b) Flood risk area indicator:

The majority, 6 out of 20 respondents (30%), assigned a weight of 50%. The next majority, 5 out of 20 respondents (25%), assigned a weight of 40-45%. Overall, 11 respondents (55%) allocated weights in the range of 40-50%, with an average of 45%.

(1.2) Proposal of the second-round questionnaires

Assigning weights for the geographic indicators as : drought risk area indicator: flood risk area would be 55:45

(2) Existence of development factor:

(2.1) Results of the first-round questionnaires

There is only one indicator, which is the existence development of water resources and irrigation systems, thus carrying a weight of 100% and more than 75% agreed.

(2.2) Proposal of the second-round questionnaires

The same weightage was proposed.

(3) Hydrological Factor: Consisting of 2 Indicators

(3.1) Results of the first-round questionnaires

(a) Hydrologic variation indicator:

The majority, 8 out of 20 respondents (40%), assigned a weight of 60%. The next majority, 3 out of 20 respondents (15%), assigned a weight of 75%. Overall, 11 respondents (55%) allocated weights in the range of 60-75%, with an average of 67.5%.

(b) Potential for groundwater use indicator:

The majority, 8 out of 20 respondents (40%), assigned a weight of 40%. The next majority, 3 out of 20 respondents (15%), assigned a weight of 25%. Overall, 11 respondents (55%) allocated weights in the range of 25-40%, with an average of 32.5%.

(3.2) Proposal of the second-round questionnaires

Assigning weights for indicators of the hydrological factor as follows : Hydrologic variation : Potential of groundwater would be 65:35.

(4) Water demand factor:

(4.1) Results of the first-round questionnaires

There is only one indicator, which cropping land use is applied for the amount of water demand, thus carrying a weight of 100% and more than 75% agreed

(4.2) Proposal of the second-round questionnaires

The same weightage was proposed.

(5) Poverty factor:

(5.1) Results of the first-round questionnaires

There is only one indicator, which is the poverty level of residents in the area, thus carrying a weight of 100%.

(5.2) Proposal of the second-round questionnaires

The same weightage was proposed.

Table 4.24 presents summary of results Del Phi panel on weightage of indicators for water scarcity level.

Table 4.24 Summary of Results from Del Phi Panel on Weightage of indicators for Water Scarcity Level

Indicators of Water Scarcity	1st round weightage (%)	1st round No	1st round %	2nd round weightage (%)	2nd round No	2nd round %
1. Geography						
1.1 Drought Risk	<50%	6	30%	<55%	1	5%
	50-60%	11	55%	55%	17	85%
	>60	3	15%	>55%	2	10%
1.2 Flood Risk	<40%	4	20%	<45%	2	10%
	40-50%	13	65%	45%	17	85%
	>50%	3	15%	>45%	1	5%
2. Development Existence						
2.1 Development Existence	<100%	0	0%	100%	20	100%
	100%	20	100%			
3. Hydrology						
3.1 Hydrology Variation	<60	7	35%	<65%	2	10%
	60-70 %	8	40%	65%	18	90%
	>70%	5	25%	>65%	0	0%
3.2 Groundwater Potential	<30%	6	30	<35%	0	0%
	30-40%	8	40	35%	18	90%
	>40%	6	30	>35%	2	10%
4. Water Demand						
4.1 Water demand	<100%	3	15%	100%	20	100%
	100%	17	85%			
5. Poverty						
5.1 Poverty	<100%	0	0%	100%	20	100%
	100%	20	100%			

3) Water scarcity levels of the project area:

(1) Results of the first-round questionnaires

The majority of respondents, totaling 19 individuals (95%), agree with the severity levels as follows:

≤ 33% : Low severity of issues

>33-67% : Moderate severity of issues

>67% : High severity of issues

(2) Proposal of the second-round questionnaires

Some weightage was proposed.

4) Proposal of project sustainability level corresponding to the water scarcity level.

(1) General Case**:** For the overall sustainability score, it should be classified as good, and the criteria should include:

(1.1) Results of the first-round questionnaires

(a) The overall score of indicators in all dimensions should fall within the good range (> 65-75%) or higher.

(b) The total score of indicators in each dimension should be at least moderate (> 55-65%) or higher.

(c) Most of them agreed

(1.2) Proposal of the second-round questionnaires

(a) The same weightage would be proposed

(2) Specific Case**:** In cases where the area faces moderate to high water scarcity and requires water development, and if the overall sustainability score in any dimension is below the moderate threshold (less than 55%)

The project should undergo improvements in each component to achieve a overall project sustainable rating of at least moderate level.

(2.1) Results of the first round questionnaires

(a) More than 75% agreed

(2.2) Proposal of the second-round questionnaires

(a) The same criteria was proposed

4.3.1.4 Summary of clarification to additional comments from the first questionnaire response of the Del Phi panel (June-July 2023)

There are some additional indicators commented by the Del Phi that were not be adopted as key indicators for the study as presented in Table 4.25. Reasons of not applying such indicators were described and informed in the second round of Del Phi's questionnaire survey and majority of experts agreed with.

1) Engineering Dimension

(1) The Geological indicator should include distance from the active fault line, which affects the dam's stability (3 respondents).

Explanation:

(1.1) Researchers applied the Mercalli indicator to rank the risk of earthquakes. The map of this indicator considered the coverage of the active fault and the statistical magnitude of the earthquake's intensity.

(1.2) The use of the distance from active fault indicator may be employed as a secondary indicator to study and compare alternative dam locations (Project optimum location study) within the same project. Meanwhile, whereas the Mercalli indicator is utilized for comparing projects located in different geographical regions which is the objective of the current research.

(2) Using the irrigation area per reservoir capacity indicator does not account for other water usage types (1 respondent).

Explanation:

In the standards for design of water resource development projects, calculations for the water demand are required for all necessary activities, including various water losses from reservoirs. Therefore, the reservoir capacity derive from the feasibility study already covers water usage in all activities. Additionally, establishing indicators for this research purposes, aims to apply significant and highly weighted indicators for assess the sustainability of projects. This is to prevent such many excessively complicated indicators that required more

consuming of time that may pose challenges in data preparation and analysis. Moreover, the agricultural water demand volume is significantly higher compared to other sectors, consequently the agricultural irrigation area per unit of reservoir capacity is chosen as a representative for engineering feasibility.

(3) Hydrological indicator. It is suggested to consider the indicator of annual inflow per reservoir capacity (1 respondent).

Explanation:

Currently, the study criteria determines an appropriate reservoir size by considering the capacity of a reservoir that does not exceed the average annual water volume. This indicator may have a value equal to or greater than 1 in almost every reservoir project. However, normally average annual flow is related with flood flow into the reservoir which is already adopted as an indicator representing hydrologic and engineering design viability

2) Natural resources and environment dimension

(1) Environmental system. The indicator of the forested area conditions should be determined (1 respondent).

Explanation:

The researcher has applied the reservoir area size per reservoir capacity as an indicator of the impact on the forest ecology system. Since almost all of the project areas, as defined, are within conservation areas which posses moderate to good forest ecology conditions, and the reservoir areas are generally close to forested areas, therefore, the reservoir area size is applied as a representation of forested areas. Additionally, forest conditions are also represented by forest abundance indicator which is already purposed.

(2) It is advisable to determine the biodiversity indicator of the conservation area in factors impacting the ecology system (1 respondent).

Explanation:

For the study, the bio-diversity of the conservation area has been considered and is included in the indicator of types of conservation forests. The indicator also takes into account the project's location indicator in the conservation area. Due to data limitations regarding the biodiversity of conservation

areas in each location, the researcher has established indicators for the biodiversity of the forest and wildlife in the project's reservoir area. These indicators also serve as indicators of the project's impact on the ecology system.

(3) It is suggested to consider the indicator of the water ecology system (1 respondent).

Explanation:

The researcher has defined that water ecology is integrated as part of the overall ecology system. The location of reservoir within the conservation area is used as a representative of abundance and biodiversity in the overall ecology.

3) Social dimension

(1) It is advisable to exclude the factors of opposition and disagreement towards project development due to uncertainty of the information (1 respondent).

Explanation:

The information on opposition to the project obtained from the socio-economic survey report may change depending on the situation and time. Nevertheless, it can be used as an indicator indicating the level of conflict in the project area and attitudes opposing project development which is a crucial factor for success in development. It provides insights into the constraints and obstacles of the project, serving as essential data for studying ways to address issues in future project development.

4) Economic dimension

(1) Factors of project feasibility value: It is advisable to include the indicator of increased agricultural households income.

Explanation:

The increased income of agricultural households is considered a primary benefit derived from the project. This results in agricultural producers in the area achieving increased agricultural productivity and income. Therefore, the researchers use the project's benefits, specifically the increased income of agricultural households multiplied by the number of households in the project area,

as an indicator for comparing the value, covering the increased income indicator of agricultural households.

(2) Factors of Project's feasibility value: It is suggested to consider the well-being, happiness, and improved quality of life.

Explanation:

Since the indicator consists of 5 significant components, comprising 1) income, 2) health, 3) occupation, 4) access to government welfare, and 5) housing, there are limitations in collecting and analyzing data for these components. Additionally, the results obtained from project development in the environmental impact and feasibility assessment report indicate that almost every water development project can upgrade the level of well-being, happiness, and overall quality of life. However, quantitative data for these components for comparative purposes are not available. Therefore, the researchers use the Internal Rate of Return (IRR) in the economic and environmental economic aspects of the project and the project benefit increased income resulting from project development as a representative measure for comparing the project's feasibility value.

Table 4.25 Summary of Del Phi's 1st Round Comments on Indicators

Dimension	1. Geography & Engineering Dimension		2.Natural Resource & Environment Dimension		3. Social Dimension		4. Economic Dimension	
Del Phi's Panel	Comment on factors	Comment on indicators	Comment on factors	Comment on indicators	Comment on factors	Comment on indicators	Comment on factors	Comment on indicators
No.1								
No.2		The Geological Index should include distance from the active fault line, which affects the dam's stability						
No.3			Main factors should be considered firstly, then should sub-factors be followed	1. Specific forest e.g. swamp forest should be ranked as the Third. 2. Wildlife index should include density or abundance level. 3. Reservoir size should be applied as an indicator reflecting ecology impact.				

Dimension	1. Geography & Engineering Dimension		2.Natural Resource & Environment Dimension		3. Social Dimension		4. Economic Dimension	
Del Phi's Panel	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**
No.4		1. Only irrigation area per storage will not cover all water demand 2. Using the irrigation area per reservoir capacity index does not account for other water usage types 3. There should be a indicator of water for maintaining ecology and environments		1. In case of reservoir is located in wetland area, bio-diversity and abundance should be considered. 2. Some Wetland are conserved , and essential to ecology.		There should be sub index of wetland became of their significant eco service, uniqueness, and quality of life value.		
No.5				It is advisable to determine the biodiversity index of the conservation area in factors impacting the ecology system				
No.6								Factors of Project feasibility Value: It is advisable to include the index of increased agricultural households income.
No.7								
No.8								

Dimension	1. Geography & Engineering Dimension		2.Natural Resource & Environment Dimension		3. Social Dimension		4. Economic Dimension	
Del Phi's Panel	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**
No.9	Geography, hydrology, and engineering will be key factors of the development.		Significant of Forest Wildlife should be equal.					
No.10		1. Hydrological Index. It is suggested to consider the index of annual inflow per reservoir capacity 2. The Geological Index should include distance from the active fault line, which affects the dam's stability		Environmental System. The indicator of the forested area type should be determined				
No.11	Location be proposed as an indicator in engineering dimension			Reservoir location in conservation area should be one of main indicators.				
No.12					It is advisable to exclude the factors of opposition and disagreement towards project development due to uncertainty in the information			

Dimension	1. Geography & Engineering Dimension		2.Natural Resource & Environment Dimension		3. Social Dimension		4. Economic Dimension	
Del Phi's Panel	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**
No.13		The Geological Index should include distance from the active fault line, which affects the dam's stability		Give definition of uniqueness and rare species				
No.14				It is advisable to determine the biodiversity index of the conservation area in factors impacting the ecology system				1. Project feasibility should be covering social feasible returns from community return (%) and income. - Factors of Project feasibility Value : It is advisable to include the index of increased agricultural households income.
No.15								
No.16								Factors of Project's Feasibility value: It is suggested to consider the well-being, happiness, and improved quality of life.

Dimension	1. Geography & Engineering Dimension		2.Natural Resource & Environment Dimension		3. Social Dimension		4. Economic Dimension	
Del Phi's Panel	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**	**Comment on factors**	**Comment on indicators**
No.17		Adding landslide indicator (25%) and sinkhole indicator (25%)	Adding aquatic creatures (20%)					
No.18	(25: 30 : 25 :20) Water resource potential should be the most important than other factors.		(25: 25 :20 :30) Ecology should be the most important factor.	(15:20:30:35) Uniqueness should be the most important factor.	(30:30:40) Quality of life is the most important factor.			
No.19								
No.20								

4.3.2 Results of the Del Phi's Second Round Questionnaire

4.3.2.1 Results of weighting factor of sustainability indicators

The 75 percentile majority results from the 2nd round of the Del Phi's 20 specified experts regarding the selected key dimensions, factors, indicators, and their weighting factor values can be summarized as follows.

1) Dimensions

The dimension's weighting factor values among engineering dimension, natural resources and environment dimension, social dimension, and economic dimension are 20 : 35 : 25 : 20, respectively.

2) Factors

(1) The physical and engineering dimension. The factors's weighting values among geography, hydrology, geology, and engineering are 25 : 25 : 30 : 20, respectively.

(2) The natural resources and environmental dimension. The factors's weighting values among factors of forestry, wildlife, water quality, and ecology are 25 : 30 : 20 : 25, respectively.

(3) The social dimension. The factors's weighting values among project opposition, the number of beneficiaries to sufferers and the impact on quality of life are 30 : 35 : 35, respectively.

(4) The economic dimension. The factors's weighting values among project benefit, project costs, and project feasibility are 30 : 30 : 40, respectively.

3) Indicators

(1) Indicators of the physical and engineering dimension.

(1.1) The geographical factor includes two indicators: the corresponding weighting values between the dam's cross-section area per unit of reservoir capacity and the reservoir area per unit of reservoir capacity are 45 : 55.

(1.2) The hydrological factor includes one indicator: that is the design flood peak discharge per unit of reservoir capacity, resulting the weighting value of 100.

(1.3) The geological factor includes two indicators: the weighting values between seismic risk and leakage are 50 : 50.

(1.4) The engineering factors (irrigation) include only one indicator: it is the irrigation area per unit of reservoir capacity, resulting the weighting value of 100.

(2) Indicators of the natural resources and environmental dimension.

(2.1) The forest factor includes four indicators: the weighting values among abundance, biological diversity, prohibited trees, and uniqueness are 25 : 25 : 20 : 30, respectively.

(2.2) The wildlife factor includes four indicators: the weighting values among abundance, biological diversity, wildlife endangered status, and uniqueness are 30 : 20 : 30 : 20, respectively.

(2.3) The water quality factor includes one indicator: which is the impact on water quality, resulting weighting value of 100.

(2.4) The ecology system factor includes three indicators: the weighting values among the conservation area type indicator, the proportion of impacted area and the conservation area indicator, and the reservoir location indicator are 40 : 35 : 25, respectively.

(3) Indicators of the social dimension

(3.1) The factor related to project opposition comprises only one indicator which is the proportion of the number of oppositions to the impacted households, resulting the weighting value of 100.

(3.2) The factor related to the affected and beneficiaries includes three indicators: the weighting values among the impacted households per unit of reservoir capacity, the encroached area per unit of reservoir capacity, and the proportion of irrigation area and the reservoir area, are 40 : 30 : 30, respectively.

(3.3) The factor related to quality of life concerns one indicator: which is the existence of distinctiveness value across either different aspects (archaeologic sites, tourism site, significant minerals resources, geologic conservative site, ethnic groups) resulting the weighting value of 100.

(4) Indicators of economic dimension

(4.1) The factor related to project benefit includes only one indicator: which is the year-round cultivated area per unit of reservoir capacity, resulting the weighting value of 100.

(4.2) The factor related to project costs includes three indicators: the weighting values among engineering costs per unit of reservoir capacity, social replacement costs per unit of reservoir capacity indicator, and environmental mitigation costs per unit of reservoir capacity indicator are 30 : 35 : 35, respectively.

(4.3) The factor related to project feasibility includes two indicators: the weighting values of economic internal rate of return indicator, and environmental economic internal rate of return indicator are 45:55.

4) Consideration of sustainable water resources development project.

Any proposed project that be developed should provide overall sustainable point in good level (>65-75%) whereas each dimension point be in moderate level (>55-65%).

4.3.2.2 Results of project's water scarcity level or water resources development necessity

Result of the study revealed that five main factors were used for the assessment of necessity level of water resource development. They are geography, the existence of water resources and irrigation development, hydrology, water demand, and poverty. The weightage of these factors is distributed as 20 : 15 : 20 : 20 : 25, respectively.

1) The geographic factor consists of two indicators: the drought risk area indicator and the flood risk area indicator. The weightage is distributed as 55 : 45, and the reference maps applied are based on the drought and flood risk level mapping by Geo-Informatics and Space Technology Development Agency (GISTDA).

2) The existence of water resources and irrigation development factor consists of a single indicator, resulting a weightage of 100. The reference

map is based on the Royal Irrigation Department (RID)'s present reservoir and irrigation areas map.

3) The hydrologic factor includes two indicators: the weighting value of hydrological variation indicator and groundwater recharge indicator, are 65 and 35, respectively. The indicators are based on data from rain gauge stations provided by the RID and the groundwater yield map provided by the Department of Groundwater Resources (DGR).

4) The water demand factor consists of a single indicator which is the agricultural water demand indicator, resulting the weighting value of 100. This indicator is referenced from the land use map provided by the Department of Land Development (DLD).

5) The poverty factor consists of a single indicator which is the household poverty indicator, resulting the weighting value of 100. This indicator is established from data of the National Electronics and Computer Technology Center (NECTEC) in 2022.

6) The results from the Del Phi's experts indicate that a project with a scarcity score or water resources necessity score of less than 33 is considered a low water scarcity level. For scarcity point of a project falling within the range of >33-67, it is considered a moderate level, while a project scoring >67 or higher is considered a significant high water scarcity.

7) For consideration of water resource development decision in case the project water scarcity level is moderate to high, it is advisable to undergo further development. However, if the overall project has sustainability scores below the moderate threshold (less than 55), it is recommended to revise project size, to alter dam location, to improve project components to achieve a total higher sustainability rating at least within the moderate range.

4.3.2.3 Conclusion of the final indicators

These final indicators were Del Phi's results from the second draft one which are described as follows,

1) The Del Phi's first round

(1) Most of Del Phi's panelists agreed with proposed dimensions, factors, and indicators for sustainability assessment. Some

additional indicators are suggested e.g. distance from active faults, annual flow to storage volume, aqua ecology, increasing household income, and quality of life. Whereas most of them also agreed with proposed factors, and indicators of water scarcity assessment.

(2) These suggested indicators were reconsidered after the first round questionnaire evaluation. However, these indicators were described their reasons of not being applied (as described in Chapter 4) and reported in the second round questionnaire for Del Phi Panel' information and consideration.

(3) For the weightage of factors and indicators of both the project's sustainability and the water scarcity level, in the first-round questionnaire, the summarized results showed that most of the Del Phi's panelists with more than 45 percents to 70 percents had specified even different values but within the same ranges of weighting scores. These weighted scores of factors and their indicators were then manipulated basing on average value of scaling range and reproposed the weighted among factors and indicators in the second-round questionnaire.

(4) For the determination of sustainability level classification and water scarcity level classification, most of the Del Phi's panelists with more than 70 percents agreed with the proposed scaling ranges. The same proposed of the ranges were proposed in the second-round questionnaire for reconfirmation.

(5) For the criteria of evaluation of project development potential, most of Del Phi' panelist with more than 75 percents agreed with the proposal concerning sustainability levels of requirements, not only each dimension and overall project, but also project area's water scarcity status level. However, the same proposal criteria was presented for reconsideration in the second round questionnaire.

2) The Del Phi's second round questionnaire

(1) Most of Del Phi's panelists still agreed with the proposed factors and indicators.

(2) For the weightage of factors and indicators of the project and water scarcity level, the second-round results show that more than 75 percentile agreed with the proposed weighting factors.

(3) For the sustainability level classification and water scarcity level classification, more than 75 percentile of the experts agreed with the proposed scoring ranges.

(4) For the evaluation criteria of project development potentials, more than 75 percentiles agreed with the proposed criteria. Finally, the adopted final sets of indicators of the project sustainability and water scarcity of the water resources development are summarized as shown in Figure 4.2 and Figure 4.3, respectively.

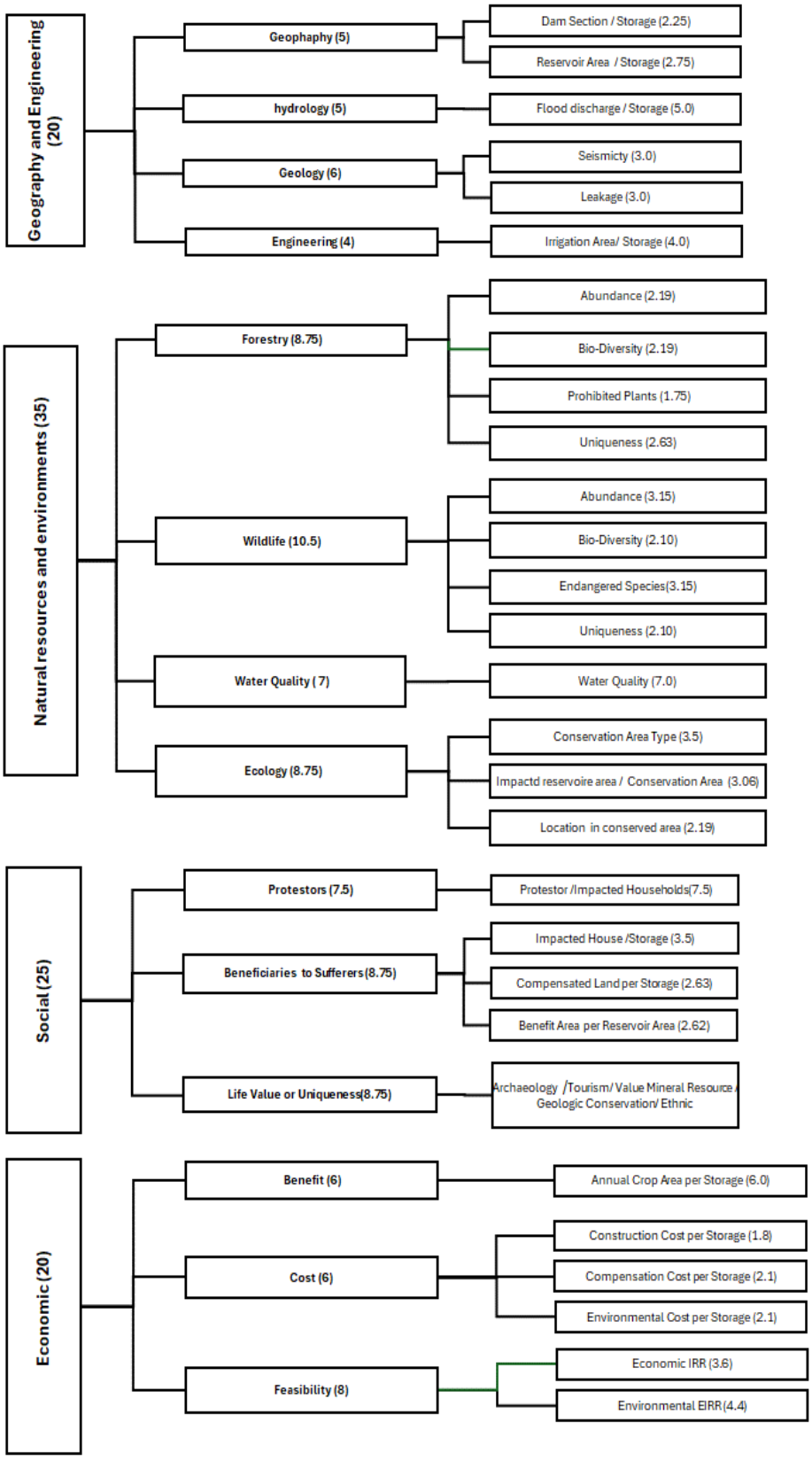

Figure 4.2 Resulted Sustainable Indicators for Water Resource Development Projects

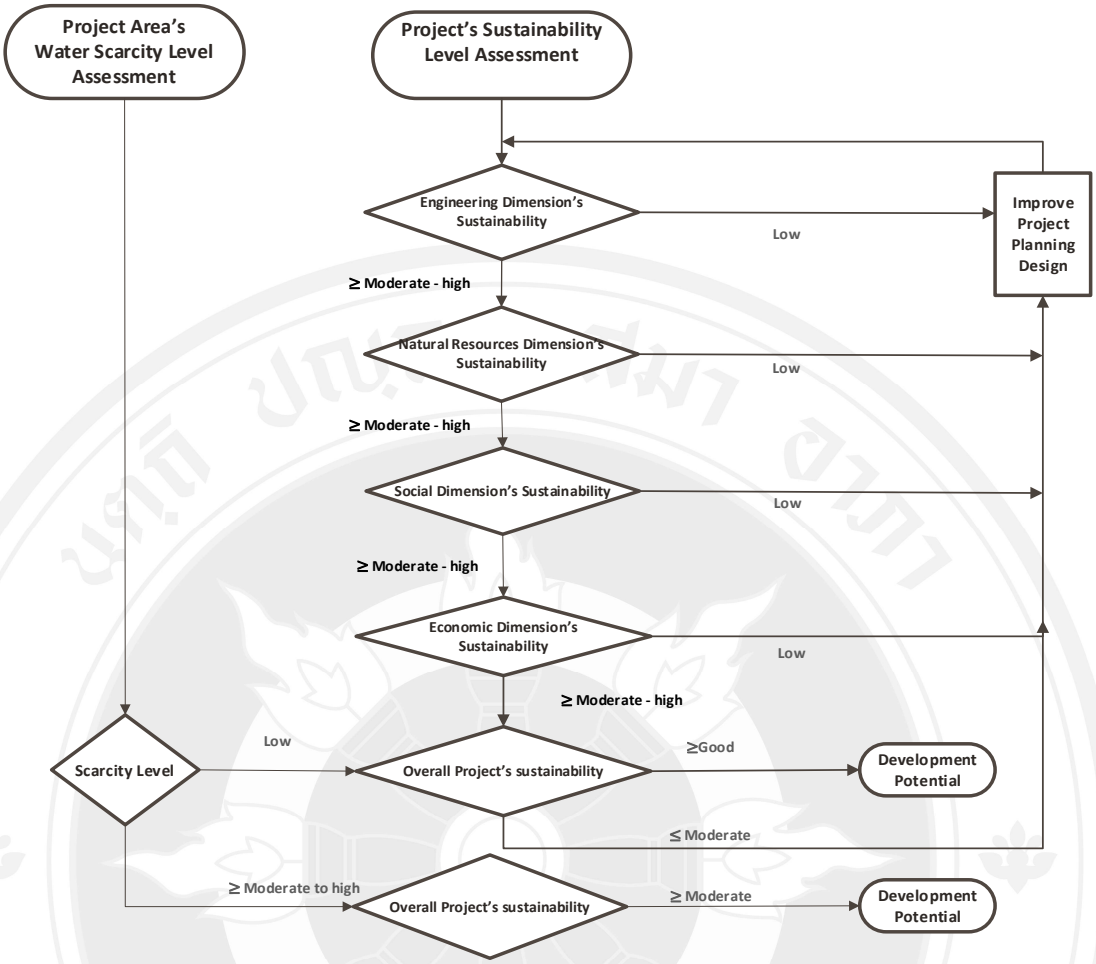

Figure 4.3 Flow Chart of Assessing Sustainable for Water Resources Development Potentials

4.4 Application of the Developed Sustainability Indicators

Table 4.26 presents summary of 30 reservoir projects basic components applied for the study. Table 4.27 summarizes factors of the results of sustainability indicators. Table 4.28 summarizes weighting factors of the water scarcity level's indicators.

The resulted indicators were applied to the 30 reservoir projects of which sustainability levels were presented in Figure 4.4 and Figure 4.5 and summarized as follows;

For projects water scarcity level assessment, the resulted indicators were applied to the 30 reservoir's beneficial areas of which water scarcity levels were presented in Figure 4.5 The results indicated that only two projects namely Huai Pang

Luang and Khlong Chom Phoo are defined as high level whereas the others are as middle level.

In summary the established sustainable indicators are applicable complied with the threats and barrier as well as potential and strength of the projects. This would be utilized as a tool to guide the concerning agencies in water resource development project could apply the indicators to determine the weakness point and to review either project size, location, or types of structures into the optimum project planning with balanced sustainability in all aspects.

Table 4.26 Summary of Basic Project Components of 30 Reservoir Projects

Item	Project Features	Unit	Min	Max	Mean
1	Storage Volume	mcm	2.1	295	40.1
2	Retention Area	Rai	87	16,250	2,172
3	Irrigation Area	Rai	1,273	111,300	28,831
4	Dam Crest Length	m.	133	3,000	794
5	Dam Height	m.	11	80	40
6	Construction Cost	mb	149	5,668	1,172
7	Catchment Area	sq.km	11	677	142
8	Mean Annual Flow	mcm/yr	2.8	266	57
9	Inflow Flood Discharge	cms	35.6	1,428	387

Note: 1 Rai = 1,600 sq.m.

Table 4.27 Summary of Key Factors, Indicators and Weighting Scores of Projects Sustainability

Factors/ Indicators	Unit	Min	Max	Mean	Gross Weighting Score (%)	Net Weighting Score (%)
1. Engineering dimension					100.00	20.00
1.1 Geography factor						
1.1.1 Dam section/ Res.cap	m^2/mcm.	132.95	6,127.66	1,465.25	11.25	2.25
1.1.2 Res. area / Res.cap	rai/mcm.	18.00	177.12	61.66	13.75	2.75
1.2 Hydrology factor						
1.2.1 Des. flood/ Res.cap	cms./mcm.	4.03	36.71	15.01	25.00	5.00
1.3 Geology factor						
1.3.1 Seismicity	Mercalli scale	2	7	4.83	15.00	3.00
1.3.2 Leakage	1-5 scale	1	4	3.03	15.00	3.00
1.4 Engineering factor						
1.4.1 Irrigation area / Res.cap	rai/mcm.	327.60	3,085.71	852.44	20.00	4.00
2. Natural resources and environment dimension					100.00	35.00
2.1 Forest factor						
2.1.1 Abundance : Big tree density	No./rai	6.8	178.0	52.62	6.25	2.19
2.1.2 Biodiversity : No. of total species	No. of species	13	200	79.64	6.25	2.19
2.1.3 Prohibited trees : No. of species	No. of species	0	71	32.78	5.00	1.75
2.1.4 Uniqueness	Yes/No	No	No (1)	No	7.50	2.63
2.2 Wildlife factor						
2.2.1 Abundance : No. of low density /No. of total species	Percent	35	96	57	9.00	3.15
2.2.2 Biodiversity : No. of total species	No. of species	112	247	167.45	6.00	2.10
2.2.3 Prohibited Wildlife : No. of type by IUCN Red List Level (VU EN and CR)	No. of species	0	15	4.62	9.00	3.15
2.2.4 Uniqueness	Yes/No	No	No (1)	No	6.00	2.10
2.3 Water quality impact factor						
2.3.1 Water quality	Yes/No	No	No	No	20.00	7.00
2.4 Ecology factor						
2.4.1 Conservation area type	NP/WL/1A/RF	RF	NP		10.00	3.50
2.4.2 Impacted area / Conserved area	Percent	0.01	7.47	0.50	8.75	3.06
2.4.3 Location in conserved area	Rim/Inner	Rim	Inner (9)		6.25	2.19

Factors / Indicators	Unit	Min	Max	Mean	Gross Weighting Score (%)	Net Weighting Score (%)
3. Social dimension					100.00	25.00
3.1 Opposition factor : Opposition/ Impacted households	Percent	0	411	32	30.00	7.50
3.2 Impacted value factor						
3.2.1 No. of households / Res.cap.	Household/mcm.	0	47	6	14.00	3.50
3.2.2 Compensated area/ Res.cap.	Rai/mcm.	0	179	31	10.50	2.63
3.2.3 Irrigation area / Res. area	-	2	74	17	10.50	2.63
3.3 Life Value (Uniqueness) factor						
3.3.1 Uniqueness (Archeology, Tourism, Mineral, Geology, and Ethnic)	Yes/No	No	Yes	NO	35.00	8.75
4. Economic dimension					100.00	20.00
4.1 Benefit : Cultivated area/Res. cap.						
4.1.1 Annual crop area / Res.cap	Rai./mcm.	377	3,755	1,079	30.00	6.00
4.2 Investment factor						
4.2.1 Construction Cost / Res.Cap.	MB./mcm.	7.65	189.36	48.12	9.00	1.80
4.2.2 Social Compensation Cost / Res.Cap.	MB./mcm.	0.00	20.00	4.62	10.50	2.10
4.2.3 Env. Mitigation Cost /Res. Cap.	MB./mcm.	0.16	12.61	4.72	10.50	2.10
4.3 Feasibility factor						
4.3.1 Economic Internal Rate of Return (EIRR)	Percent	4.36	19.79	11.81	18.00	3.60
4.3.2 Environment Economic Internal Rate of Return (EEIRR)	Percent	3.30	16.26	9.79	22.00	4.40

Note: NP = National Park Area, RF = Reserved Forest Area,
WL = Wildlife Sanctuation Area, (9) = Number of Project,
1A = Watershed Class 1A, 1 rai = 1,600 sq.m.

Table 4.28 Summary of Factors, Indicators, and Weighting Scores for Water Scarcity Level Assessment

Factors / Indicators	Unit	Water Scarcity			Gross Weighting Score (%)	Net Weighting Score (%)
		Low (No. of Proj.)	Moderate (No. of Proj.)	High (No. of Proj.)		
1 Geography factor					100	
1.1 Drought index						
- Frequency in the past 5 years of droughts.	Years	1-2 (18)	3-4 (8)	≥5 (4)	55	11
1.2 Flooded index						
- Frequency in the past 12 years of floods.	Years	≤4 (26)	5-8 (3)	>8 (1)	45	9
2 Irrigation system existence factor					100	15
- Irrigation system existence index	-	Partial Irrigated by reservoir. (5)	Partial Irrigated without reservoir. (2)	No Irrigation system. (23)	100	15
3 Hydrology factor					100	20
3.1 Rainfall variation index						
- Proportion of dry season rainfall to annual rainfall.	%	> 30 (3)	>25-30 (5)	≤ 25 (22)	65	13
3.2 Groundwater potentials index						
- Yield	cu.m./hr,	>20 (5)	> 10-20 (2)	≤10 (23)	35	7
- Total Dissolved Solids (TDS)	mg/l	≤500 (26)	-	>500 (4)		
4 Water demand factor					100	20
- Agricultural land use type index	Type	Perennial Tree (4)	Field Crops (12)	Orchard/Paddy (14)	100	20
5 Poverty factor					100	25
- Poverty index (Proportion of the poors to district's population.)	%	≤2.5 (15)	>2.5-10 (14)	>10 (1)	100	25

PROJECT		1 Khlong Yai (Phattalung)	2 Mae Pan (Lam Pang)	3 Mae Pah Phai (Chiang Mai)	4 Mae Bom (Lam Pang)	5 Mae Pang Luang (Chiang Mai)	6 Mae Phuak (Phrae)	7 Khlong Wang Tanode (Chanthaburi)
Level		High	High	High	Medium	High	High	High
Sustainability score	100	70.09	66.14	68.19	62.12	70.53	72.90	65.82
1. Engineering Dimension	20	14.90	8.30	11.80	8.65	8.30	12.65	15.35
2. Natural Resources and Environment Dimension	35	23.94	24.24	26.81	23.12	24.64	26.60	20.72
3. Social Dimension	25	15.33	22.03	20.80	21.15	23.43	22.73	15.45
4. Economic Dimension	20	15.92	11.58	8.78	9.20	14.16	10.92	14.30

1. Engineering Dimension	Level	High	Very low	Medium	Very low	Very low	Medium	Very high
	100.00	74.50	41.50	59.00	43.25	41.50	63.25	76.75
1.1 Topography Factor	25.00	15.50	15.50	20.00	13.25	10.50	17.25	11.75
(1) Dam Section/ Res.Cap	11.25	4.50	4.50	9.00	2.25	2.25	9.00	9.00
(2) Res. Area / Res.Cap	13.75	11.00	11.00	11.00	11.00	8.25	8.25	2.75
1.2 Hydrology Factor	25.00	15.00	5.00	10.00	5.00	10.00	15.00	25.00
(1) Des. Flood/ Res.Cap	25.00	15.00	5.00	10.00	5.00	10.00	15.00	25.00
1.3 Geology Factor	30.00	24.00	9.00	21.00	9.00	9.00	15.00	24.00
(1) Earthquake	15.00	12.00	3.00	6.00	3.00	3.00	3.00	12.00
(2) Percolation	15.00	12.00	6.00	15.00	6.00	6.00	12.00	12.00
1.4 Engineering Factor	20.00	20.00	12.00	8.00	16.00	12.00	16.00	16.00
(1) Irrigation Area / Res.Cap	20.00	20.00	12.00	8.00	16.00	12.00	16.00	16.00
2. Natural Resources and Environment Dimension	Level	High	High	Very high	High	High	Very high	Medium
	100.00	68.40	69.25	76.60	66.05	70.40	76.00	59.20
2.1 Forest Factor	25.00	11.00	14.25	10.00	12.25	13.00	11.00	16.00
(1) Abundance : Big tree density	6.25	1.25	2.50	1.25	3.75	1.25	1.25	6.25
(2) Biodiversity : No. of total species	6.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
(3) Prohibited Trees : No. of species	5.00	1.00	3.00	2.00	1.00	3.00	1.00	1.00
(4) Unique	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
2.2 Wildlife Factor	30.00	20.40	18.00	21.60	16.80	20.40	24.00	13.20
(1) Abundance : No. of low density	9.00	1.80	1.80	1.80	1.80	1.80	5.40	1.80
(2) Biodiversity : No. of total species	3.60	3.60	1.20	4.80	3.60	3.60	3.60	3.60
(3) Prohibited Wildlife : No. of type by IUCN Red List Level	9.00	9.00	9.00	9.00	5.40	9.00	9.00	1.80
(4) Unique	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
2.3 Water Quality Impact Factor	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
(1) Water Quality	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2.4 Ecology Factor	25.00	17.00	17.00	25.00	17.00	17.00	21.00	10.00
(1) Conservation area type	10.00	2.00	2.00	10.00	2.00	2.00	6.00	2.00
(2) Impacted area / Conserved Area	8.75	8.75	8.75	8.75	8.75	8.75	8.75	1.75
(3) Location in conserved Area	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
3. Social Dimension	Level	Medium	Very high	Very high	Very high	Very high	Very high	Medium
	100.00	61.30	88.10	83.20	84.60	93.70	90.90	61.80
3.1 Opposition Factor : Opposition/ Affected	30.00	6.00	30.00	30.00	30.00	30.00	30.00	24.00
(1) No. of houses opposing the project / Affected.	30.00	6.00	30.00	30.00	30.00	30.00	30.00	24.00
3.2 Impacted Value Factor	35.00	20.30	23.10	18.20	19.60	28.70	25.90	9.80
(1) No. of house / Res.Cap	14.00	5.60	8.40	5.60	2.80	14.00	11.20	5.60
(2) Compensated Area/ Res.Cap.	10.50	4.20	10.50	10.50	10.50	10.50	10.50	2.10
(3) Irrigation Area / Reservoir Area	10.50	10.50	4.20	2.10	6.30	4.20	4.20	2.10
3.3 Life Value (Uniqueness) Factor	35.00	35.00	35.00	35.00	35.00	35.00	35.00	28.00
(1) Archeology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(2) Tourism	7.00	7.00	7.00	7.00	7.00	7.00	7.00	0.00
(3) Mineral	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(4) Geology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(5) Ethnic	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
4. Economic Dimension	Level	Very high	Medium	Very low	Low	High	Low	High
	100.00	79.60	57.90	43.90	46.00	70.80	54.60	71.50
4.1 Benefit : Cultivated Area/Res. Cap.	30.00	30.00	12.00	6.00	12.00	24.00	18.00	18.00
(1) Benefit Area / Res.Cap	30.00	30.00	12.00	6.00	12.00	24.00	18.00	18.00
4.2 Investment Factor	30.00	9.60	18.30	21.90	18.00	22.80	16.20	13.50
(1) Construction Cost / Res.Cap.	9.00	5.40	3.60	7.20	5.40	1.80	3.60	7.20
(2) Social Compensation Cost / Res.Cap.	10.50	2.10	10.50	10.50	10.50	10.50	10.50	2.10
(3) Env. Mitigation Cost /Res. Cap.	10.50	2.10	4.20	4.20	2.10	10.50	2.10	4.20
4.3 Feasibility Factor	40.00	40.00	27.60	16.00	16.00	24.00	20.40	40.00
(1) Economic Internal Rate of Return (EIRR)	18.00	18.00	14.40	7.20	7.20	10.80	7.20	18.00
(2) Environment Economic Internal Rate of Return (EEIRR	22.00	22.00	13.20	8.80	8.80	13.20	13.20	22.00

PROJECT		8	9	10	11	12	13	14	15
		Huai Satone	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
		(Sa Kaeo)	(Nakhonsithammarat)	(Phrae)	(Phayao)	(Lam Pang)	(Phitsanulok)	(Trat)	(Kamphaeng Phet)
Level		High	High	Very high	Medium	High	NA	Very high	High
Sustainability score	100	69.43	68.17	77.14	59.66	69.29	61.33	79.29	68.09
1. Engineering Dimension	20	12.90	16.95	13.10	10.20	10.30	14.40	16.75	10.25
2. Natural Resources and Environment Dimension	35	21.00	21.84	30.87	24.43	26.29	15.05	28.88	29.19
3. Social Dimension	25	21.15	18.48	19.03	13.75	20.63	13.48	19.93	10.33
4. Economic Dimension	20	14.38	10.90	14.14	11.28	12.08	18.40	13.74	18.32

1. Engineering Dimension	Level	Medium	Very high	High	Low	Low	High	Very high	Low
	100.00	64.50	84.75	65.50	51.00	51.50	72.00	83.75	51.25
1.1 Topography Factor	25.00	9.50	22.75	20.50	20.00	15.50	20.00	16.75	12.25
(1) Dam Section/ Res.Cap	11.25	6.75	9.00	6.75	9.00	4.50	9.00	11.25	6.75
(2) Res. Area / Res.Cap	13.75	2.75	13.75	13.75	11.00	11.00	11.00	5.50	5.50
1.2 Hydrology Factor	25.00	15.00	25.00	20.00	10.00	5.00	20.00	20.00	10.00
(1) Des. Flood/ Res.Cap	25.00	15.00	25.00	20.00	10.00	5.00	20.00	20.00	10.00
1.3 Geology Factor	30.00	24.00	21.00	9.00	9.00	15.00	12.00	27.00	9.00
(1) Earthquake	15.00	12.00	15.00	3.00	3.00	3.00	6.00	15.00	3.00
(2) Percolation	15.00	12.00	6.00	6.00	6.00	12.00	6.00	12.00	6.00
1.4 Engineering Factor	20.00	16.00	16.00	16.00	12.00	16.00	20.00	20.00	20.00
(1) Irrigation Area / Res.Cap	20.00	16.00	16.00	16.00	12.00	16.00	20.00	20.00	20.00
2. Natural Resources and Environment Dimension	Level	Medium	Medium	Very high	High	Very high	NA	Very high	Very high
	100.00	60.00	62.40	88.20	69.80	75.10	43.00	82.50	83.40
2.1 Forest Factor	25.00	11.00	11.00	18.00	10.00	13.50	NA	13.50	20.00
(1) Abundance : Big tree density	6.25	1.25	1.25	6.25	1.25	3.75	3.75	3.75	1.25
(2) Biodiversity : No. of total species	6.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	6.25
(3) Prohibited Trees : No. of species	5.00	1.00	1.00	3.00	2.00	1.00	2.00	1.00	5.00
(4) Unique	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
2.2 Wildlife Factor	30.00	12.00	14.40	25.20	22.80	21.60	6.00	24.00	26.40
(1) Abundance : No. of low density	9.00	1.80	5.40	5.40	9.00	1.80	5.40	5.40	5.40
(2) Biodiversity : No. of total species	3.60	2.40	1.20	4.80	2.40	4.80	3.60	3.60	6.00
(3) Prohibited Wildlife : No. of type by IUCN Red List Level	9.00	1.80	1.80	9.00	5.40	9.00	5.40	9.00	9.00
(4) Unique	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
2.3 Water Quality Impact Factor	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
(1) Water Quality	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2.4 Ecology Factor	25.00	17.00	17.00	25.00	17.00	20.00	17.00	25.00	17.00
(1) Conservation area type	10.00	2.00	2.00	10.00	2.00	10.00	2.00	10.00	2.00
(2) Impacted area / Conserved Area	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
(3) Location in conserved Area	6.25	6.25	6.25	6.25	6.25	1.25	6.25	6.25	6.25
3. Social Dimension	Level	Very high	High	Very high	Low	Very high	NA	Very high	Very low
	100.00	84.60	73.90	76.10	55.00	82.50	53.90	79.70	41.30
3.1 Opposition Factor : Opposition/ Affected	30.00	30.00	6.00	18.00	6.00	30.00	6.00	30.00	6.00
(1) No. of houses opposing the project / Affected.	30.00	30.00	6.00	18.00	6.00	30.00	6.00	30.00	6.00
3.2 Impacted Value Factor	35.00	26.60	32.90	23.10	21.00	17.50	18.90	14.70	6.30
(1) No. of house / Res.Cap	14.00	14.00	14.00	8.40	8.40	2.80	11.20	8.40	2.80
(2) Compensated Area/ Res.Cap.	10.50	10.50	10.50	6.30	6.30	10.50	10.50	2.10	2.10
(3) Irrigation Area / Reservoir Area	10.50	2.10	8.40	8.40	6.30	4.20	8.40	4.20	4.20
3.3 Life Value (Uniqueness) Factor	35.00	28.00	35.00	35.00	28.00	35.00	35.00	35.00	35.00
(1) Archeology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(2) Tourism	7.00	0.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(3) Mineral	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(4) Geology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(5) Ethnic	7.00	7.00	7.00	7.00	0.00	7.00	7.00	7.00	7.00
4. Economic Dimension	Level	High	Low	High	Medium	Medium	Very high	High	Very high
	100.00	71.90	54.50	70.70	56.40	60.40	92.00	68.70	91.60
4.1 Benefit : Cultivated Area/Res. Cap.	30.00	18.00	12.00	24.00	18.00	30.00	30.00	18.00	30.00
(1) Benefit Area / Res.Cap	30.00	18.00	12.00	24.00	18.00	30.00	30.00	18.00	30.00
4.2 Investment Factor	30.00	21.90	14.10	18.30	18.00	18.00	30.00	19.50	21.60
(1) Construction Cost / Res.Cap.	9.00	7.20	3.60	3.60	5.40	5.40	9.00	9.00	9.00
(2) Social Compensation Cost / Res.Cap.	10.50	10.50	2.10	6.30	6.30	10.50	10.50	2.10	6.30
(3) Env. Mitigation Cost /Res. Cap.	10.50	4.20	8.40	8.40	6.30	2.10	10.50	8.40	6.30
4.3 Feasibility Factor	40.00	32.00	28.40	28.40	20.40	12.40	32.00	31.20	40.00
(1) Economic Internal Rate of Return (EIRR)	18.00	14.40	10.80	10.80	7.20	3.60	14.40	18.00	18.00
(2) Environment Economic Internal Rate of Return (EEIRR	22.00	17.60	17.60	17.60	13.20	8.80	17.60	13.20	22.00

PROJECT		16	17	18	19	20	21	22
		Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or
		(Si Sa Ket)	(Kamphaeng Phet)	(Kamphaeng Phet)	(Phayao)	(Phare)	(Prachin Buri)	(Sa Kaeo)
Level		High	Medium	Medium	High	Medium	High	High
Sustainability score	100	67.62	62.73	57.53	66.46	64.94	73.16	68.75
1. Engineering Dimension	20	15.35	9.85	6.75	12.40	13.30	14.70	10.50
2. Natural Resources and Environment Dimension	35	22.26	24.01	31.33	24.34	26.64	26.32	27.27
3. Social Dimension	25	12.53	15.15	10.25	17.70	15.00	20.10	18.53
4. Economic Dimension	20	17.48	13.72	9.20	12.02	10.00	12.04	12.46

1. Engineering Dimension	Level	Very high	Low	Very low	Medium	High	High	Low
	100.00	76.75	49.25	33.75	62.00	66.50	73.50	52.50
1.1 Topography Factor	25.00	16.75	13.25	7.75	20.00	15.50	19.50	9.50
(1) Dam Section/ Res.Cap	11.25	11.25	2.25	2.25	9.00	4.50	11.25	6.75
(2) Res. Area / Res.Cap	13.75	5.50	11.00	5.50	11.00	11.00	8.25	2.75
1.2 Hydrology Factor	25.00	25.00	10.00	5.00	15.00	10.00	25.00	5.00
(1) Des. Flood/ Res.Cap	25.00	25.00	10.00	5.00	15.00	10.00	25.00	5.00
1.3 Geology Factor	30.00	15.00	18.00	9.00	15.00	21.00	21.00	18.00
(1) Earthquake	15.00	3.00	12.00	3.00	6.00	12.00	12.00	12.00
(2) Percolation	15.00	12.00	6.00	6.00	9.00	9.00	9.00	6.00
1.4 Engineering Factor	20.00	20.00	8.00	12.00	12.00	20.00	8.00	20.00
(1) Irrigation Area / Res.Cap	20.00	20.00	8.00	12.00	12.00	20.00	8.00	20.00
2. Natural Resources and Environment Dimension	**Level**	**Medium**	**High**	**Very high**	**High**	**Very high**	**Very high**	**Very high**
	100.00	63.60	68.60	89.50	69.55	76.10	75.20	77.90
2.1 Forest Factor	25.00	11.00	15.00	22.50	9.75	22.50	19.00	17.50
(1) Abundance : Big tree density	6.25	1.25	1.25	3.75	3.75	6.25	1.25	3.75
(2) Biodiversity : No. of total species	6.25	1.25	1.25	6.25	1.25	3.75	6.25	1.25
(3) Prohibited Trees : No. of species	5.00	1.00	5.00	5.00	1.00	5.00	4.00	5.00
(4) Unique	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
2.2 Wildlife Factor	30.00	15.60	21.60	30.00	22.80	21.60	19.20	20.40
(1) Abundance : No. of low density	9.00	1.80	9.00	9.00	5.40	1.80	5.40	1.80
(2) Biodiversity : No. of total species	3.60	2.40	4.80	6.00	2.40	4.80	2.40	3.60
(3) Prohibited Wildlife : No. of type by IUCN Red List Leve	9.00	5.40	1.80	9.00	9.00	9.00	5.40	9.00
(4) Unique	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
2.3 Water Quality Impact Factor	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
(1) Water Quality	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2.4 Ecology Factor	25.00	17.00	12.00	17.00	17.00	12.00	17.00	20.00
(1) Conservation area type	10.00	2.00	2.00	2.00	2.00	2.00	2.00	10.00
(2) Impacted area / Conserved Area	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
(3) Location in conserved Area	6.25	6.25	1.25	6.25	6.25	1.25	6.25	1.25
3. Social Dimension	**Level**	**Low**	**Medium**	**Very low**	**High**	**Medium**	**Very high**	**High**
	100.00	50.10	60.60	41.00	70.80	60.00	80.40	74.10
3.1 Opposition Factor : Opposition / Affected	30.00	6.00	6.00	6.00	12.00	18.00	30.00	30.00
(1) No. of houses opposing the project. / Affected.	30.00	6.00	6.00	6.00	12.00	18.00	30.00	30.00
3.2 Impacted Value Factor	35.00	9.10	26.60	7.00	23.80	7.00	15.40	9.10
(1) No. of house / Res.Cap	14.00	2.80	14.00	2.80	11.20	2.80	11.20	2.80
(2) Compensated Area/ Res.Cap.	10.50	2.10	10.50	2.10	10.50	2.10	2.10	2.10
(3) Irrigation Area / Reservoir Area	10.50	4.20	2.10	2.10	2.10	2.10	2.10	4.20
3.3 Life Value (Uniqueness) Factor	35.00	35.00	28.00	28.00	35.00	35.00	35.00	35.00
(1) Archeology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(2) Tourism	7.00	7.00	0.00	0.00	7.00	7.00	7.00	7.00
(3) Mineral	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(4) Geology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(5) Ethnic	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
4. Economic Dimension	**Level**	**Very high**	**High**	**Low**	**Medium**	**Low**	**Medium**	**Medium**
	100.00	87.40	68.60	46.00	60.10	50.00	60.20	62.30
4.1 Benefit : Cultivated Area/Res. Cap.	30.00	30.00	12.00	12.00	18.00	24.00	6.00	30.00
(1) Benefit Area / Res.Cap	30.00	30.00	12.00	12.00	18.00	24.00	6.00	30.00
4.2 Investment Factor	30.00	17.40	28.20	18.00	26.10	18.00	25.80	20.70
(1) Construction Cost / Res.Cap.	9.00	9.00	7.20	5.40	7.20	5.40	9.00	1.80
(2) Social Compensation Cost / Res.Cap.	10.50	4.20	10.50	6.30	10.50	2.10	6.30	8.40
(3) Env. Mitigation Cost /Res. Cap.	10.50	4.20	10.50	6.30	8.40	10.50	10.50	10.50
4.3 Feasibility Factor	40.00	40.00	28.40	16.00	16.00	8.00	28.40	11.60
(1) Economic Internal Rate of Return (EIRR)	18.00	18.00	10.80	7.20	7.20	3.60	10.80	7.20
(2) Environment Economic Internal Rate of Return (EEIRR)	22.00	22.00	17.60	8.80	8.80	4.40	17.60	4.40

PROJECT		23	24	25	26	27	28	29	30
		Huai Pao	Khlong Wang Heeb	Nong Ta Tang	Huai Ka Laeng	Huai Ta Pur	Huai Pong Phark	Ban Mueng Ta Kua	Nam Pard
		(Phayao)	(Nakhonsithammarat)	(Ratchburi)	(Chaiyaphum)	(Mukdahan)	(Lampang)	(Phatthalung)	(Uttlaradit)
Level		High	Medium	High	High	High	Medium	High	High
Sustainability score	100	74.63	63.86	69.22	65.03	70.23	62.77	68.16	73.33
1. Engineering Dimension	20	11.05	12.95	15.40	12.65	12.15	9.10	13.65	10.65
2. Natural Resources and Environment Dimension	35	26.67	27.34	22.02	28.32	28.68	27.09	22.68	24.85
3. Social Dimension	25	23.95	14.28	15.50	12.00	20.10	14.10	19.05	20.53
4. Economic Dimension	20	12.96	9.30	16.30	12.06	9.30	12.48	12.78	17.30
1. Engineering Dimension	Level	Medium	Medium	Very high	Medium	Medium	Low	High	Low
	100.00	55.25	64.75	77.00	63.25	60.75	45.50	68.25	53.25
1.1 Topography Factor	25.00	13.25	17.75	20.00	7.25	11.75	19.50	13.25	22.25
(1) Dam Section/ Res.Cap	11.25	2.25	6.75	9.00	4.50	9.00	11.25	2.25	11.25
(2) Res. Area / Res.Cap	13.75	11.00	11.00	11.00	2.75	2.75	8.25	11.00	11.00
1.2 Hydrology Factor	25.00	10.00	20.00	20.00	20.00	10.00	5.00	15.00	10.00
(1) Des. Flood/ Res.Cap	25.00	10.00	20.00	20.00	20.00	10.00	5.00	15.00	10.00
1.3 Geology Factor	30.00	12.00	15.00	21.00	24.00	27.00	9.00	24.00	9.00
(1) Earthquake	15.00	3.00	6.00	12.00	12.00	15.00	3.00	12.00	3.00
(2) Percolation	15.00	9.00	9.00	9.00	12.00	12.00	6.00	12.00	6.00
1.4 Engineering Factor	20.00	20.00	12.00	16.00	12.00	12.00	12.00	16.00	12.00
(1) Irrigation Area / Res.Cap	20.00	20.00	12.00	16.00	12.00	12.00	12.00	16.00	12.00
2. Natural Resources and Environment Dimension	Level	Very high	Very high	Medium	Very high	Very high	Very high	Medium	High
	100.00	76.20	78.10	62.90	80.90	81.95	77.40	64.80	71.00
2.1 Forest Factor	25.00	19.00	16.50	16.50	22.50	13.50	25.00	11.00	16.00
(1) Abundance : Big tree density	6.25	6.25	3.75	3.75	3.75	3.75	6.25	1.25	6.25
(2) Biodiversity : No. of total species	6.25	1.25	1.25	1.25	6.25	1.25	6.25	1.25	1.25
(3) Prohibited Trees : No. of species	5.00	4.00	4.00	4.00	5.00	1.00	5.00	1.00	1.00
(4) Unique	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
2.2 Wildlife Factor	30.00	25.20	21.60	14.40	26.40	25.20	20.40	16.80	18.00
(1) Abundance : No. of low density	9.00	5.40	1.80	5.40	5.40	5.40	1.80	1.80	5.40
(2) Biodiversity : No. of total species	3.60	4.80	4.80	1.20	6.00	4.80	3.60	3.60	1.20
(3) Prohibited Wildlife : No. of type by IUCN Red List Leve	9.00	9.00	9.00	1.80	9.00	9.00	9.00	5.40	5.40
(4) Unique	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
2.3 Water Quality Impact Factor	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
(1) Water Quality	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2.4 Ecology Factor	25.00	12.00	20.00	12.00	12.00	23.25	12.00	17.00	17.00
(1) Conservation area type	10.00	2.00	10.00	2.00	2.00	10.00	2.00	2.00	2.00
(2) Impacted area / Conserved Area	8.75	8.75	8.75	8.75	8.75	7.00	8.75	8.75	8.75
(3) Location in conserved Area	6.25	1.25	1.25	1.25	1.25	6.25	1.25	6.25	6.25
3. Social Dimension	Level	Very high	Medium	Medium	Low	Very high	Medium	Very high	Very high
	100.00	95.80	57.10	62.00	48.00	80.40	56.40	76.20	82.10
3.1 Opposition Factor : Opposition / Affected	30.00	30.00	6.00	6.00	6.00	30.00	6.00	30.00	24.00
(1) No. of houses opposing the project. / Affected.	30.00	30.00	6.00	6.00	6.00	30.00	6.00	30.00	24.00
3.2 Impacted Value Factor	35.00	30.80	16.10	28.00	7.00	15.40	15.40	11.20	23.10
(1) No. of house / Res.Cap	14.00	14.00	5.60	11.20	2.80	2.80	2.80	2.80	8.40
(2) Compensated Area/ Res.Cap.	10.50	10.50	4.20	10.50	2.10	10.50	10.50	2.10	8.40
(3) Irrigation Area / Reservoir Area	10.50	6.30	6.30	6.30	2.10	2.10	2.10	6.30	6.30
3.3 Life Value (Uniqueness) Factor	35.00	35.00	35.00	28.00	35.00	35.00	35.00	35.00	35.00
(1) Archeology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(2) Tourism	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(3) Mineral	7.00	7.00	7.00	0.00	7.00	7.00	7.00	7.00	7.00
(4) Geology	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
(5) Ethnic	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
4. Economic Dimension	Level	Medium	Low	Very high	Medium	Low	Medium	Medium	Very high
	100.00	64.80	46.50	81.50	60.30	46.50	62.40	63.90	86.50
4.1 Benefit : Cultivated Area/Res. Cap.	30.00	30.00	12.00	18.00	18.00	12.00	18.00	24.00	24.00
(1) Benefit Area / Res.Cap	30.00	30.00	12.00	18.00	18.00	12.00	18.00	24.00	24.00
4.2 Investment Factor	30.00	14.40	14.10	27.90	18.30	23.70	30.00	15.90	22.50
(1) Construction Cost / Res.Cap.	9.00	1.80	3.60	9.00	3.60	9.00	9.00	5.40	3.60
(2) Social Compensation Cost / Res.Cap.	10.50	10.50	2.10	10.50	8.40	10.50	10.50	2.10	10.50
(3) Env. Mitigation Cost /Res. Cap.	10.50	2.10	8.40	8.40	6.30	4.20	10.50	8.40	8.40
4.3 Feasibility Factor	40.00	20.40	20.40	35.60	24.00	10.80	14.40	24.00	40.00
(1) Economic Internal Rate of Return (EIRR)	18.00	7.20	7.20	18.00	10.80	10.80	14.40	10.80	18.00
(2) Environment Economic Internal Rate of Return (EEIRR)	22.00	13.20	13.20	17.60	13.20	13.20	13.20	13.20	22.00

Figure 4.4 Summary of Sustainability Level of 30 Water Resources Development Projects

PROJECT		1	2	3	4	5	6	7	8
		Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
		(Phattalung)	(Lam Pang)	(Chiang Mai)	(Lam Pang)	(Chiang Mai)	(Phrae)	(Chanthaburi)	(Sa Kaeo)
Water resources necessity level score	Level	Medium	Low	Medium	Medium	High	Medium	Medium	Medium
	100.00	54.92 100	15.00	62.88	54.44	78.36	53.64	55.20	60.92
1. Geography Factor	20.00	4.00 100	4.00	4.00	4.00	4.00	4.00	4.00	12.80
(1) Drought Index	11.00	2.20 100	2.20	2.20	2.20	2.20	2.20	2.20	11.00
(2) Flooded Index	9.00	1.80 100	1.80	1.80	1.80	1.80	1.80	1.80	1.80
2. Irrigation Development Factor	15.00	15.00 100	2.20	15.00	15.00	15.00	15.00	15.00	15.00
(1) Irrigation Development Index	15.00	15.00 100	2.20	15.00	15.00	15.00	15.00	15.00	15.00
3. Hydrology Factor	20.00	6.80 100	4.40	14.80	14.40	20.00	20.00	14.80	14.80
(1) Rainfall Variation Index	13.00	2.60 100	2.20	7.80	13.00	13.00	13.00	7.80	7.80
(2) Groundwater Index	7.00	4.20 100	2.20	7.00	1.40	7.00	7.00	7.00	7.00
4. Water Demand Factor	20.00	14.12 100	2.20	14.08	16.04	14.36	9.64	11.40	13.32
(1) Water Demand Index	20.00	14.12 100	2.20	14.08	16.04	14.36	9.64	11.40	13.32
5. Poverty Factor	25.00	15.00 100	2.20	15.00	5.00	25.00	5.00	10.00	5.00
(1) Poverty Index	25.00	15.00 100	2.20	15.00	5.00	25.00	5.00	10.00	5.00

PROJECT		9	10	11	12	13	14	15
		Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
		(Nakhonsithammarat)	(Phrae)	(Phayao)	(Lam Pang)	(Phitsanulok)	(Trat)	(Kamphaeng Phet)
Water resources necessity level score	**Level**	**Medium**	**Medium**	**Medium**	**Medium**	**High**	**Medium**	**Medium**
	100.00	**56.24**	**66.40**	**63.72**	**51.76**	**70.12**	**55.88**	**61.40**
1. Geography Factor	**20.00**	**16.40**	**8.40**	**4.00**	**4.00**	**20.00**	**4.00**	**12.80**
(1) Drought Index	11.00	11.00	6.60	2.20	2.20	11.00	2.20	11.00
(2) Flooded Index	9.00	5.40	1.80	1.80	1.80	9.00	1.80	1.80
2. Irrigation Development Factor	**15.00**	**3.00**	**15.00**	**15.00**	**15.00**	**9.00**	**15.00**	**3.00**
(1) Irrigation Development Index	15.00	3.00	15.00	15.00	15.00	9.00	15.00	3.00
3. Hydrology Factor	**20.00**	**20.00**	**20.00**	**20.00**	**14.40**	**14.40**	**20.00**	**20.00**
(1) Rainfall Variation Index	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
(2) Groundwater Index	7.00	7.00	7.00	7.00	1.40	1.40	7.00	7.00
4. Water Demand Factor	**20.00**	**11.84**	**13.00**	**14.72**	**13.36**	**11.72**	**11.88**	**15.60**
(1) Water Demand Index	20.00	11.84	13.00	14.72	13.36	11.72	11.88	15.60
5. Poverty Factor	**25.00**	**5.00**	**10.00**	**10.00**	**5.00**	**15.00**	**5.00**	**10.00**
(1) Poverty Index	25.00	5.00	10.00	10.00	5.00	15.00	5.00	10.00

PROJECT		16	17	18	19	20	21	22	23
		Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao
		(Si Sa Ket)	(Kamphaeng Phet)	(Kamphaeng Phet)	(Phayao)	(Phare)	(Prachin Buri)	(Sa Kaeo)	(Phayao)
Water resources necessity level score	Level	Medium	Low	Medium	Medium	Medium	Medium	Medium	Medium
	100.00	54.20 100	15.00	56.68	64.56	43.60	62.84	49.32	63.80
1. Geography Factor	20.00	12.00 100	4.00	8.40	8.40	4.00	12.00	4.00	4.00
(1) Drought Index	11.00	6.60 100	2.20	6.60	6.60	2.20	6.60	2.20	2.20
(2) Flooded Index	9.00	5.40 100	1.80	1.80	1.80	1.80	5.40	1.80	1.80
2. Irrigation Development Factor	15.00	3.00 100	2.20	15.00	15.00	3.00	15.00	15.00	15.00
(1) Irrigation Development Index	15.00	3.00 100	2.20	15.00	15.00	3.00	15.00	15.00	15.00
3. Hydrology Factor	20.00	17.20 100	4.40	20.00	20.00	20.00	20.00	14.80	20.00
(1) Rainfall Variation Index	13.00	13.00 100	2.20	13.00	13.00	13.00	13.00	7.80	13.00
(2) Groundwater Index	7.00	4.20 100	2.20	7.00	7.00	7.00	7.00	7.00	7.00
4. Water Demand Factor	20.00	12.00 100	2.20	8.28	16.16	11.60	10.84	10.52	14.80
(1) Water Demand Index	20.00	12.00 100	2.20	8.28	16.16	11.60	10.84	10.52	14.80
5. Poverty Factor	25.00	10.00 100	2.20	5.00	5.00	5.00	5.00	5.00	10.00
(1) Poverty Index	25.00	10.00 100	2.20	5.00	5.00	5.00	5.00	5.00	10.00

PROJECT		24	25	26	27	28	29	30
		Khlong Wang Heeb	Nong Ta Tang	Huai Ka Laeng	Huai Ta Pur	Huai Pong Phark	Ban Mueng Ta Kua	Nam Pard
		(Nakhonsithammarat)	(Ratchburi)	(Chaiyaphum)	(Mukdahan)	(Lampang)	(Phatthalung)	(Uttlaradit)
Water resources necessity level score	Level	Medium	Medium	Medium	Medium	Medium	Medium	Medium
	100.00	51.56	55.80	62.00	47.32	57.56	49.08	52.68
1. Geography Factor	20.00	4.00	8.40	4.00	4.00	8.40	4.00	8.40
(1) Drought Index	11.00	2.20	6.60	2.20	2.20	6.60	2.20	6.60
(2) Flooded Index	9.00	1.80	1.80	1.80	1.80	1.80	1.80	1.80
2. Irrigation Development Factor	15.00	15.00	15.00	15.00	3.00	15.00	15.00	9.00
(1) Irrigation Development Index	15.00	15.00	15.00	15.00	3.00	15.00	15.00	9.00
3. Hydrology Factor	20.00	9.60	14.80	20.00	20.00	15.80	9.60	20.00
(1) Rainfall Variation Index	13.00	2.60	7.80	13.00	13.00	13.00	2.60	13.00
(2) Groundwater Index	7.00	7.00	7.00	7.00	7.00	2.80	7.00	7.00
4. Water Demand Factor	20.00	12.96	12.60	13.00	15.32	8.36	5.48	10.28
(1) Water Demand Index	20.00	12.96	12.60	13.00	15.32	8.36	5.48	10.28
5. Poverty Factor	25.00	10.00	5.00	10.00	5.00	10.00	15.00	5.00
(1) Poverty Index	25.00	10.00	5.00	10.00	5.00	10.00	15.00	5.00

Figure 4.5 Results of 30 Projects' Water Resources Necessity Level (Water Scarcity)

The resulted indicators were applied to the 30 projects in order to verify assessment results of their water scarcity level and sustainability level.

Summary of project's sustainability assessment and water scarcity level applying the established indicators are shown in Table 4.29 and in Table 4.30, respectively.

Considering both assessment of water scarcity and overall sustainability of each project, the results indicated that all projects could possibly be developed. However, considering in term of dimension, there are some projects having low sustainability as follows.

Considering sustainability score level in term of engineering dimension as shown in Table 31, it is found that in engineering and geographic aspect, there are eleven projects having low level. They are No.2 (Mae Pan), No-4 (Mae Bom), No.5 (Mae Pang Luang), No.11 (Nam Yuen), No.12 (Mae Nueng), No.15 (Khlong Khlung Lang), No.17 (Khlong Pla Soi), No.18 (Khlong Phet Ja Khor), No.22 (Huai Sae Or), No.28(Huai Pong Phak), and No.30 (Nam Pard), respectively.

These projects should have been reviewed to upgrade score level by site relocation, project size or alternative engineering design to recover weakness of low scored indicators. Especially in case of no other appropriate site location, additional special engineering design and construction could be solved such disadvantages but costing more investment budget, consequently additional planning of project benefits should be reviewed to cover the higher cost as well.

For the natural resources and environment dimension, there are one project namely Khlong Chom Phu having low sustainability level score as shown in Table 4.32

The project has to be downscaled of reservoir surface area or storage volume or dam height or site relocation as well as more intensive mitigation plans must be provided.

Considering sustainability score level in term of social dimension as shown in Table 31, it is found that in social dimension, there are six projects having low level. They are No.11 (Nam Yuan), No. 13 (Khlong Chomphu), No.15 (Khlong Khlung Lang), No.16 (Huai Khayoong), No.18 (Khlong Phet Ja Khor), and No.26 (Huai Ka Laeng), respectively.

These projects have to be intensively solved the conflict of interest problems through crucial people participation and public relations activities, conflict management, compensation clarification, and good governance. Additionally, site relocation or downscaling of project size should also be determined.

Considering sustainability score level in term economic dimension as shown in Table 1, it is found that there are eight projects having low level. They are No.3 (Mae Pah Phai), No.4 (Mae Bom), No.6 (Mae Phuak), No.9 (Khlong Ma Dua), No.18 (Khlong Phet Ja Khor), No.20 (Huai Mae Khon), No.24 (Khlong Wang Heeb), and No.27 (Huai Ta Pur), respectively.

These projects should be carefully reviewed of decreasing high investment costs together with O& M cost due to engineering design, reducing environmental mitigation cost and social compensation cost by dam relocation or reservoir size downscaling. Consequently, revision of EIRR and environmental EIRR.

Table 4.29 Sustainability Level of 30 Selective Projects

Dimension	1 Khlong Yai Phattalung	2 Mae Pan Lam Pang	3 Mae Pah Phai Chiang Mai	4 Mae Bom Lam Pang	5 Mae Pang Luang Chiang Mai	6 Mae Phuak Phrae
1. Engineering Dimension						
Score	14.9	8.3	11.8	8.65	8.3	12.65
%	74.5	41.5	59	43.25	41.5	63.25
Level	High	Very low	Moderate	Very low	Very low	Moderate
Low Score Indicators		(Tp1)	(Hd1) (Gl1) (En1)	(Tp1) (Gl1) (Gl2)	(Tp1) (Gl1) (Gl2)	(Gl1)
2. Natural Resources & Environment Dimension						
Score	23.94	24.24	26.81	23.12	24.64	26.6
%	68.4	69.25	76.6	66.05	70.4	76
Level	High	High	Very high	High	High	Very high
Low Score Indicators						
3. Social Dimension						
Score	15.33	22.03	20.8	21.15	23.43	22.73
%	61.3	88.1	83.2	84.6	93.7	90.9
Level	Moderate	Very high	Very high	Very high	Very high	Very high
Low Score Indicators	(Op1) (Ip1) (Ip2)					
4. Economic Dimension						
Score	15.92	11.58	8.78	9.2	14.16	10.92
%	79.6	57.9	43.9	46	70.8	54.6
Level	Very high	Moderate	Very low	Low	High	Low
Low Score Indicators		(Bf1) (Cs1) (Cs3)	(Bf1) (Cs3) (Fs1) (Fs2)	(Bf1) (Cs3) (Fs1) (Fs2)		(Cs1) (Cs3) (Fs1)
Total Score	70.09	66.14	68.19	62.12	70.53	72.9
Level	High	High	High	Moderate	High	High

Dimension	7 Khlong Wang Tanode Chanthaburi	8 Huai Satone Sa Kaeo	9 Khlong Ma Dua Nakhonsithammarat	10 Nam Ki Phrae	11 Nam Yuan Phayao	12 Mae Nueng Lam Pang
1. Engineering Dimension						
Score	15.35	12.9	16.95	13.1	10.2	10.3
%	76.75	64.5	84.75	65.5	51	51.5
Level	Very high	Moderate	Very high	High	Low	Low
Low Score Indicators		(Tp2)			(Hd1) (Gl1) (Gl2)	(Tp1) (Hd1) (Gl2)
2. Natural Resources & Environment Dimension						
Score	20.72	21	21.84	30.87	24.43	26.29
%	59.2	60	62.4	88.2	69.8	75.1
Level	Moderate	Moderate	Moderate	Very high	High	Very high
Low Score Indicators	(Fr2) (Fr3) (Wl1) (Wl3) (Ec1) (Ec2)	(Fr1) (Fr2) (Fr3) (Wl1) (Wl2) (Wl3) (Ec1)	(Fr1) (Fr2) (Fr3) (Wl2) (Wl3) (Ec1)			
3. Social Dimension						
Score	15.45	21.15	18.48	19.03	13.75	20.63
%	61.8	84.6	73.9	76.1	55	82.5
Level	Moderate	Very high	High	Very high	Low	Very high
Low Score Indicators	(Ip1), (Ip2), (Ip3)				(Op1)	
4. Economic Dimension						
Score	14.3	14.38	10.9	14.14	11.28	12.08
%	71.5	71.9	54.5	70.7	56.4	60.4
Level	High	High	Low	High	Moderate	Moderate
Low Score Indicators			(Bf1) (Cs2) (Cs1)		(Fs1)	(Cs3) (Fs1) (Fs2)
Total Score	65.82	69.43	68.17	77.14	59.66	69.29
Level	High	High	High	Very high	Moderate	High

Dimension	13 Klong Chomphu Phitsanulok	14 Huai Sator Trat	15 Khlong Khlung Lang Kamphaeng Phet	16 Huai Khayoong Si Sa Ket	17 Klong Pla Soi Kamphaeng Phet	18 Khlong Phet Ja Khor Kamphaeng Phet
1. Engineering Dimension						
Score	14.4	16.75	10.25	15.35	9.85	6.75
%	72	83.75	51.25	76.75	49.25	33.75
Level	High	Very high	Low	Very high	Low	Very low
Low Score Indicators			(Tp2) (Hd1) (Gl1) (Gl2)		(Tp1) (Hd1) (Gl2)	(Tp1) (Tp2) (Hd1) (Gl1) (Gl2)
2. Natural Resources & Environment Dimension						
Score	15.05	28.88	29.19	22.26	24.01	31.33
%	43	82.5	83.4	63.6	68.6	89.5
Level	Very low	Very high	Very high	Moderate	High	Very high
Low Score Indicators	(Fr2) (Fr3) (Ec1)			(Fr1) (Fr2) (Fr3) (Wl1) (Wl2) (Ec1)		
3. Social Dimension						
Score	13.48	19.93	10.33	12.53	15.15	10.25
%	53.9	79.7	41.3	50.1	60.6	41
Level	Low	Very high	Very low	Low	Moderate	Very low
Low Score Indicators	(Op1)		(Op1) (Ip1) (Ip2) (Ip3)	(Op1) (Ip1) (Ip2) (Ip3)	(Op1) (Ip3)	(Op1) (Ip1) (Ip2) (Ip3)
4. Economic Dimension						
Score	18.4	13.74	18.32	17.48	13.72	9.2
%	92	68.7	91.6	87.4	68.6	46
Level	Very high	High	Very high	Very high	High	Low
Low Score Indicators						(Bf1) (Fs1) (Fs2)
Total Score	61.33	79.29	68.09	67.62	62.73	57.53
Level	Moderate	Very high	High	High	Moderate	Moderate

Dimension	19 Nam Pee Phayao	20 Huai Mae Khon Phare	21 Huai Samoeng Prachin Buri	22 Huai Sae Or Sa Kaeo	23 Huai Pao Phayao	24 Khlong Wang Heeb Nakhonsithammarat
1. Engineering Dimension						
Score	12.4	13.3	14.7	10.5	11.05	12.95
%	62	66.5	73.5	52.5	55.25	64.75
Level	Moderate	High	High	Low	Moderate	Moderate
Low Score Indicators	(Gl1)			(Tp2) (Hd1) (Gl2)	(Tp1) (Hd1) (Gl1)	(Gl1)
2. Natural Resources & Environment Dimension						
Score	24.34	26.64	26.32	27.27	26.67	27.34
%	69.55	76.1	75.2	77.9	76.2	78.1
Level	High	Very high	Very high	Very high	Very high	Very high
Low Score Indicators						
3. Social Dimension						
Score	17.7	15	20.1	18.53	23.95	14.28
%	70.8	60	80.4	74.1	95.8	57.1
Level	High	Moderate	Very high	High	Very high	Moderate
Low Score Indicators		(Ip1) (Ip2) (Ip3)				(Op1) (Ip1) (Ip2)
4. Economic Dimension						
Score	12.02	10	12.04	12.46	12.96	9.3
%	60.1	50	60.2	62.3	64.8	46.5
Level	Moderate	Low	Moderate	Moderate	Moderate	Low
Low Score Indicators	(Fs1) (Fs2)	(Cs2) (Fs1) (Fs2)	(Bf1)	(Cs1) (Fs1) (Fs2)	(Cs1) (Cs3) (Fs1)	(Bf1) (Cs1) (Cs2) (Fs1)
Total Score	66.46	64.94	73.16	68.75	74.63	63.86
Level	High	Moderate	High	High	High	Moderate

Dimension	25 Nong Ta Tang Ratchburi	26 Huai Ka Laeng Chaiyaphum	27 Huai Ta Pur Mukdahan	28 Huai Pong Phark Lampang	29 Ban Mueng Ta Kua Phatthalung	30 Nam Pard Uttlaradit
1. Engineering Dimension						
Score	15.4	12.65	12.15	9.1	13.65	10.65
%	77	63.25	60.75	45.5	68.25	53.25
Level	Very high	Moderate	Moderate	Low	High	Low
Low Score Indicators		(Tp1) (Tp2)	(Tp2) (Hd1)	(Hd1) (Gl1) (Gl2)		(Gl1) (Gl2)
2. Natural Resources & Environment Dimension						
Score	22.02	28.32	28.68	27.09	22.68	24.85
%	62.9	80.9	81.95	77.4	64.8	71
Level	Moderate	Very high	Very high	Very high	Moderate	High
Low Score Indicators	(Fr2) (Wl1) (Wl2) (Wl3) (Ec1) (Ec3)				(Fr1) (Fr2) (Fr3) (Wl1) (Ec1)	
3. Social Dimension						
Score	15.5	12	20.1	14.1	19.05	20.53
%	62	48	80.4	56.4	76.2	82.1
Level	Moderate	Low	Very high	Moderate	Very high	Very high
Low Score Indicators	(Op1)	(Op1) (Ip1) (Ip2) (Ip3)		(Op1) (Ip1) (Ip3)		
4. Economic Dimension						
Score	16.3	12.06	9.3	12.48	12.78	17.3
%	81.5	60.3	46.5	62.4	63.9	86.5
Level	Very high	Moderate	Low	Moderate	Moderate	Very high
Low Score Indicators		(Cs1)	(Bf1) (Cs3)	(Fs2)	(Cs2)	
Total Score	69.22	65.03	70.23	62.77	68.16	73.33
Level	High	High	High	Moderate	High	High

Note :

Dimension and Project Score (%)

≤ 45	Very low
> 45-55	Low
> 55-65	Moderate
> 65-75	High
> 75	Very high

1. Engineering Dimension

Tp	1.1 Topography Factor
Tp1	(1) Dam section/ Res.cap
Tp2	(2) Res. area / Res.cap
Hd	1.2 Hydrology Factor
Hd1	(1) Flood / Res.cap
Gl	1.3 Geology Factor
Gl1	(1) Earthquake
Gl2	(2) Leakage
En	1.4 Engineering Factor
En1	(1) Irrigation area / Res.cap

2. Natural Resources and Environment Dimension

Fr	2.1 Forest Factor
Fr1	(1) Abundance : Big tree density
Fr2	(2) Biodiversity : No. of total species
Fr3	(3) Prohibited Trees : No. of species
Fr4	(4) Unique (Forest)
Wl	2.2 Wildlife Factor
Wl1	(1) Abundance : Low density species ratio
Wl2	(2) Biodiversity : No. of total species
Wl3	(3) Prohibited Wildlife : No. of species by IUCN
Wl4	(4) Unique (Wildlife)
Wq	2.3 Water Quality Impact Factor
Wq1	(1) Water quality
Ec	2.4 Ecology Factor
Ec1	(1) Conservation area type
Ec2	(2) Impacted area / Conserved area
Ec3	(3) Location in conserved area

Note:

3. Social Dimension

Op	3.1 Opposition Factor
Op1	(1) Opposing household / Impacted household
Ip	3.2 Impacted Value Factor
Ip1	(1) No. of house / Res.cap
Ip2	(2) Compensated area/ Res.cap.
Ip3	(3) Irrigation area / Reservoir area
Lv	3.3 Life Value (Uniqueness) Factor
Lv1	(1) Archeology
Lv2	(2) Tourism
Lv3	(3) Mineral
Lv4	(4) Geology
Lv5	(5) Ethnic

4. Economic Dimension

Bf	4.1 Benefit : Cultivated area/ Res. cap.
Bf1	(1) Annual crop area / Res.cap
Cs	4.2 Investment Factor
Cs1	(1) Construction cost / Res.cap.
Cs2	(2) Social compensation cost / Res.cap.
Cs3	(3) Env. mitigation cost / Res. cap.
Fs	4.3 Feasibility Factor
Fs1	(1) Economic internal rate of return (EIRR)
Fs2	(2) Environment economic internal rate of return (EEIRR)

Table 4.30 Water Scarcity Level of 30 Selective Projects

		No.	1	2	3	4	5	6
		Reservoir Projects	**Khlong Yai**	**Mae Pan**	**Mae Pah Phai**	**Mae Bom**	**Mae Pang Luang**	**Mae Phuak**
		Provinces	**Phattalung**	**Lam Pang**	**Chiang Mai**	**Lam Pang**	**Chiang Mai**	**Phrae**
1. Geography Factor	**(20% Weight)**	**Score**	4	4	4	4	4	4
		%	20	20	20	20	20	20
		Level	Very low	Very low	Very low	Very low	Very low	Very low
		Low score indicators	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)
2. Irrigation	**(15% Weight)**	**Score**	15	15	15	15	15	15
Development		**%**	100	100	100	100	100	100
Factor		**Level**	Very high	Very high	Very high	Very high	Very high	Very high
		Low score indicators						
3. Hydrology Factor	**(20% Weight)**	**Score**	6.8	14.4	14.8	14.4	20	20
		%	34	72	74	72	100	100
		Level	Low	High	High	High	Very high	Very high
		Low score indicators	(Hd1)					
4. Water Demand	**(20% Weight)**	**Score**	14.12	14.28	14.08	16.04	14.36	9.64
Factor		**%**	70.6	71.4	70.4	80.2	71.8	48.2
		Level	High	High	High	Very high	High	Moderate
		Low score indicators						(Wd1)
5. Poverty Factor	**(25% Weight)**	**Score**	15	5	15	5	25	5
		%	60	20	60	20	100	20
		Level	Moderate	Very low	Moderate	Very low	Very high	Very low
		Low score indicators	(Pv1)	(Pv1)	(Pv1)	(Pv1)		(Pv1)
Total	**(100% Weight)**	**Score**	54.92	52.68	62.88	54.44	78.36	53.64
		Level	Moderate	Moderate	Moderate	Moderate	High	Moderate

		No.	7	8	9	10	11	12
		Reservoir Projects	**Khlong Wang Tanode**	**Huai Satone**	**Khlong Ma Dua**	**Nam Ki**	**Nam Yuan**	**Mae Nueng**
		Provinces	**Chanthaburi**	**Sa Kaeo**	**Nakhonsith ammarat**	**Phrae**	**Phayao**	**Lam Pang**
1. Geography Factor	**(20% Weight)**	**Score**	4	12.8	16.4	8.4	4	4
		%	20	64	82	42	20	20
		Level	Very low	High	Very high	Moderate	Very low	Very low
		Low score indicators	(Gg1) (Gg2)			(Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)
2. Irrigation Development Factor	**(15% Weight)**	**Score**	15	15	3	15	15	15
		%	100	100	20	100	100	100
		Level	Very high	Very high	Very low	Very high	Very high	Very high
		Low score indicators			(Ir1)			
3. Hydrology Factor	**(20% Weight)**	**Score**	14.8	14.8	20	20	20	14.4
		%	74	74	100	100	100	72
		Level	High	High	Very high	Very high	Very high	High
		Low score indicators						
4. Water Demand Factor	**(20% Weight)**	**Score**	11.4	13.32	11.84	13	14.72	13.36
		%	57	66.6	59.2	65	73.6	66.8
		Level	Moderate	High	Moderate	High	High	High
		Low score indicators	(Wd1)		(Wd1)			
5. Poverty Factor	**(25% Weight)**	**Score**	10	5	5	10	10	5
		%	40	20	20	40	40	20
		Level	Low	Very low	Very low	Low	Low	Very low
		Low score indicators	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)
Total	**(100% Weight)**	**Score**	55.2	60.92	56.24	66.4	63.72	51.76
		Level	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

		No.	13	14	15	16	17	18
		Reservoir Projects	Klong Chomphu	Huai Sator	Khlong Khlung Lang	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor
		Provinces	Phitsanulok	Trat	Kamphaeng Phet	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet
1. Geography Factor	**(20% Weight)**	**Score**	20	4	12.8	12	4	8.4
		%	100	20	64	60	20	42
		Level	Very high	Very low	High	Moderate	Very low	Moderate
		Low score indicators		(Gg1) (Gg2)		(Gg1) Gg2)	(Gg1) (Gg2)	(Gg2)
2. Irrigation Development Factor	**(15% Weight)**	**Score**	9	15	3	3	15	15
		%	60	100	20	20	100	100
		Level	Moderate	Very high	Very low	Very low	Very high	Very high
		Low score indicators	(Ir1)		(Ir1)	(Ir1)		
3. Hydrology Factor	**(20% Weight)**	**Score**	14.4	20	20	17.2	20	20
		%	72	100	100	86	100	100
		Level	High	Very high	Very high	Very high	Very high	Very high
		Low score indicators						
4. Water Demand Factor	**(20% Weight)**	**Score**	11.72	11.88	15.6	12	16.68	8.28
		%	58.6	59.4	78	60	83.4	41.4
		Level	Moderate	Moderate	High	Moderate	Very high	Moderate
		Low score indicators	(Wd1)	(Wd1)		(Wd1)		(Wd1)
5. Poverty Factor	**(25% Weight)**	**Score**	15	5	10	10	10	5
		%	60	20	40	40	40	20
		Level	Moderate	Very low	Low	Low	Low	Very low
		Low score indicators	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)
Total	**(100% Weight)**	**Score**	70.12	55.88	61.4	54.2	65.68	56.68
		Level	High	Moderate	Moderate	Moderate	Moderate	Moderate

		No.	19	20	21	22	23	24
		Reservoir Projects	**Nam Pee**	**Huai Mae Khon**	**Huai Samoeng**	**Huai Sae Or**	**Huai Pao**	**Khlong Wang Heeb**
		Provinces	**Phayao**	**Phare**	**Prachin Buri**	**Sa Kaeo**	**Phayao**	**Nakhonsithammarat**
1. Geography Factor	**(20% Weight)**	**Score**	8.4	4	12	4	4	4
		%	42	20	60	20	20	20
		Level	Moderate	Very low	Moderate	Very low	Very low	Very low
		Low score indicators	(Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)
2. Irrigation	**(15% Weight)**	**Score**	15	3	15	15	15	15
Development		**%**	100	20	100	100	100	100
Factor		**Level**	Very high	Very low	Very high	Very high	Very high	Very high
		Low score indicators		(Ir1)				
3. Hydrology Factor	**(20% Weight)**	**Score**	20	20	20	14.8	20	9.6
		%	100	100	100	74	100	48
		Level	Very high	Very high	Very high	High	Very high	Moderate
		Low score indicators						(Hd1)
4. Water	**(20% Weight)**	**Score**	16.16	11.6	10.84	10.52	14.8	12.96
Demand Factor		**%**	80.8	58	54.2	52.6	74	64.8
		Level	Very high	Moderate	Moderate	Moderate	High	High
		Low score indicators		(Wd1)	(Wd1)	(Wd1)		
5. Poverty Factor	**(25% Weight)**	**Score**	5	5	5	5	10	10
		%	20	20	20	20	40	40
		Level	Very low	Very low	Very low	Very low	Low	Low
		Low score indicators	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)
Total	**(100% Weight)**	**Score**	64.56	43.6	62.84	49.32	63.8	51.56
		Level	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

		No.	25	26	27	28	29	30
		Reservoir Projects	**Nong Ta Tang**	**Huai Ka Laeng**	**Huai Ta Pur**	**Huai Pong Phark**	**Ban Mueng Ta Kua**	**Nam Pard**
		Provinces	**Ratchburi**	**Chaiyaphum**	**Mukdahan**	**Lampang**	**Phatthalung**	**Uttlaradit**
1. Geography Factor	**(20% Weight)**	**Score**	8.4	4	4	8.4	4	8.4
		%	42	20	20	42	20	42
		Level	Moderate	Very low	Very low	Moderate	Very low	Moderate
		Low score indicators	(Gg2)	(Gg1) (Gg2)	(Gg1) (Gg2)	(Gg2)	(Gg1) (Gg2)	(Gg2)
2. Irrigation	**(15% Weight)**	**Score**	15	15	3	15	15	9
Development		**%**	100	100	20	100	100	60
Factor		**Level**	Very high	Very high	Very low	Very high	Very high	Moderate
		Low score indicators			(Ir1)			(Ir1)
3. Hydrology Factor	**(20% Weight)**	**Score**	14.8	20	20	15.8	9.6	20
		%	74	100	100	79	48	100
		Level	High	Very high	Very high	High	Moderate	Very high
		Low score indicators					(Hd1)	
4. Water	**(20% Weight)**	**Score**	12.6	13	15.32	8.36	5.48	10.28
Demand Factor		**%**	63	65	76.6	41.8	27.4	51.4
		Level	High	High	High	Moderate	Low	Moderate
		Low score indicators				(Wd1)	(Wd1)	(Wd1)
5. Poverty Factor	**(25% Weight)**	**Score**	5	10	5	10	15	5
		%	20	40	20	40	60	20
		Level	Very low	Low	Very low	Low	Moderate	Very low
		Low score indicators	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)	(Pv1)
Total	**(100% Weight)**	**Score**	55.8	62	47.32	57.56	49.08	52.68
		Level	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Note:

Factor Score (%)		Total Score (%)	
≤ 20	Very low	≤ 33	Low
> 20-40	Low	>33-67	Moderate
> 40-60	Moderate	>67	High
> 60-80	High		
> 80	Very high		

Gg	1. Geography Factor	Hd1	(1) Rainfall variation
Gg1	(1) Drought area	Hd2	(2) Groundwater potential
Gg2	(2) Flooded area	Wd	4. Water Demand Factor
Ir	2. Irrigation Development Factor	Wd1	(1) Water demand
Ir1	(1) Irrigation development existence	Pv	5. Poverty Factor
Hd	3. Hydrology Factor	Pv1	(1)Poverty

4.5 Application and verification with 30 reservoirs projects can be summarized as follows:

1) By applying factors and indicators with their corresponding weightage and scoring ranges with 30 reservoirs data from EIA reports, it is found that these indicators would reasonably indicate the appropriateness or strength and disadvantages or weakness of the proposed reservoirs in the various dimensions. As a results, those weakness would be pointed out for reconsideration of project's components planning to improve its sustainability level.

2) Results of applying indicators' weighting score for project sustainability assessment are summarized as follows.

(1) Sustainability assessment of engineering dimension, one-third or eleven projects are evaluated as low sustainable level.

(2) Sustainability assessment of natural resources and environmental dimension, and projects were assessed as low sustainable level.

(3) Sustainability assessment of social dimension, six projects were assessed as low level,

(4) Sustainability assessment of economic dimension, eight projects were classified as low level.

(5) Overall project sustainability, there are no projects defined as low sustainable level, whereas two projects are assessed as medium level and suggested to be upgraded or improved namely, Nam Yuan, Huai Phet Ja Khor, and Huai Poeng Phark.

(6) In term of factors concerning natural resources and ecology, There are seven projects that are determined low to moderate level namely Khlong Wang Tanode, Huai Satone, Khlong Ma Dua, Khlong Chom Phoo, Huai Kha Yung, Nong Ta Tang, and Mueng Takua.

(7) For project's water scarcity level, only two projects namely Huai Pang Luang and Khlong Chom Phoo are defined as high level whereas the others are as middle level. In summary the established sustainable indicators are applicable complied with the threats and barrier as well as potential and strength of the projects.

3) In addition, according to data of 30 EIA's reports, some indicators scoring ranges are suggested to adjust for better practice, for example, the ratio of reservoir area to the total conservation area that representing ecology loss should be decreased from the range of 1-4 percents to 0.5-2 percents for more natural resources and ecology conservative purposes. In contrary, the ratio of irrigation area to reservoir area that representing social beneficiaries to sufferers could be decreased for more compliancable with Thailand's most geographic context.

Additionally, sustainability scores of indicators in various dimensions of 30 projects are presented in the Appendix E.

Figure 4.6 depicts the example of the scores of the Khlong Yai project.

1 Khlong Yai-Phattalung

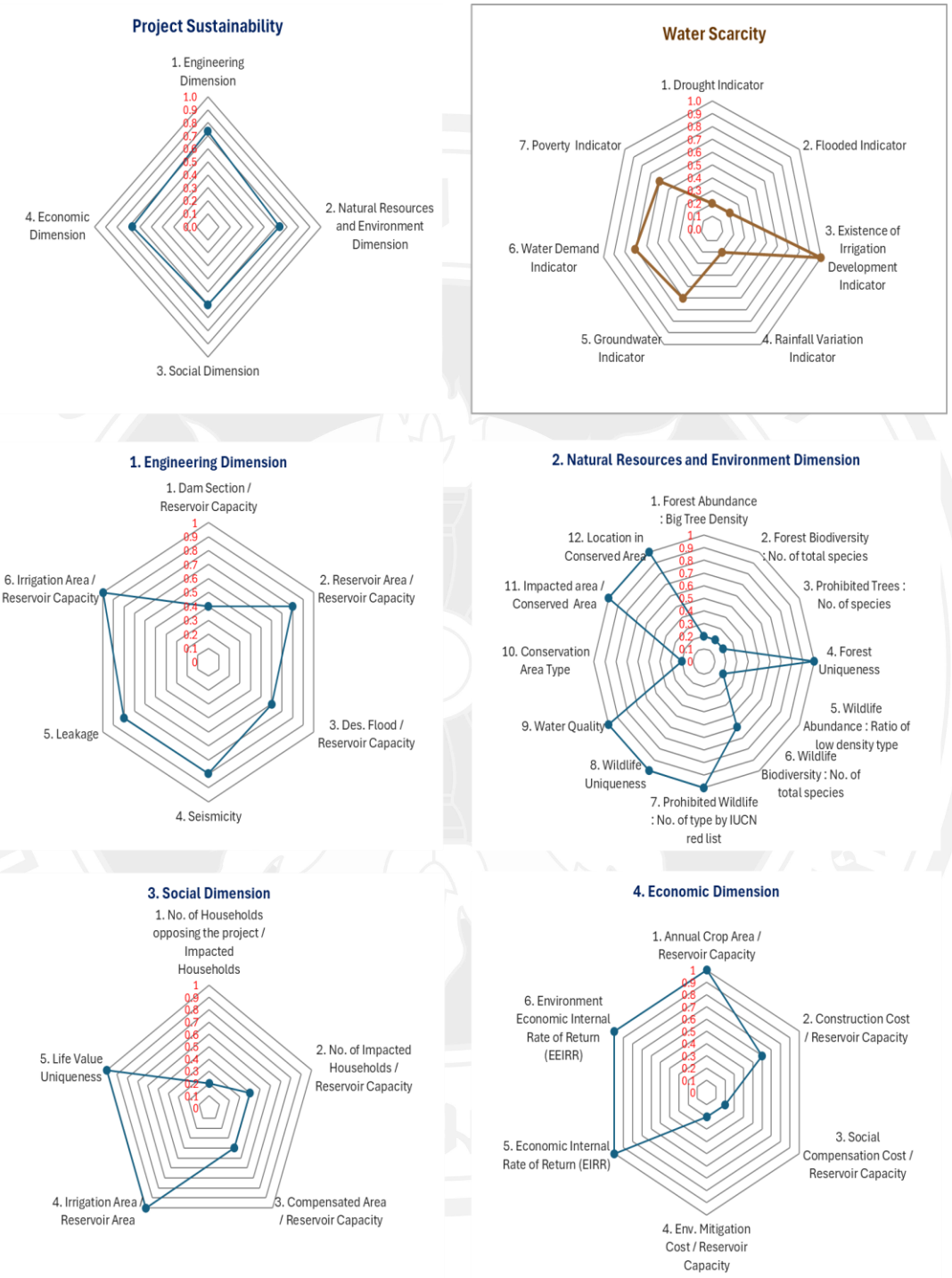

Figure 4.6 An Example of Indicators' Sustainable Score Levels of Khlong Yai Project

CHAPTER 5

CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

5.1 Conclusions

Water resources development in Thailand is a very considerable aspect due to high variation of hydrological regime. Responsible agencies have to sufficiently supply in terms of quantity and quality raw water for various needs including water supply, agriculture, as well as industrial and other uses. Development of a water reservoir is one of the efficient measures as for water source, in spite of some limitations. Unfortunately, appropriate locations of potential reservoirs are mostly located in the natural resource conservation areas occupied with the abundantly good ecological system, which might lead to the conflict of interest between the line agencies of water resources development and natural resources conservation. Despite the national laws and policies specify to promote sustainable water resources development, specific guidelines and standards for quantity-based consideration of sustainability together with the balance between resources development and conservation of a potential project have not yet been defined in details. Consequently, the quantitative criteria to establish the sustainable water resource development indicators, applying the principles of self-sufficiency economy and transitioning from the extreme development of high into moderate impact levels with self-sustaining development, will ensure that the future water resources development can be carried out successfully and effectively towards sustainability.

The study is a qualitative research using the Del Phi method. The Del Phi's panel comprised selective 20 experts of various related fields, governmental agencies and independent academia. The research conducted firstly by defining draft relevant dimensions, factors, and indicators drawn from the previous related researches, and from in-depth interviewing 7 experts of key related fields. Then additional indicators and their scoring range were intensively determined and classified from the data and

information of the 30 reservoirs' environmental impact assessment (EIA) reports as well as those referenced from relevant researches, governmental agencies' regulations and announcements. The draft final indicators and scoring ranges were summarized and proposed to the Del Phi's panel not less than two rounds to obtain their majority conclusion on indicators, weighting factors, scoring ranges and recommendations of sustainability level for the future projects.

The study results indicated that the relative importance weighting of four dimensions to be considered were: engineering (20%), natural resources and environment (35%), society (25%), and economics (20%). This research identified 14 main factors of which 7 factors having high significance, including 1) wildlife, 2) forests, 3) ecology system, 4) number of affected people, 5) quality of life, 6) economic feasibility, and 7) social opposition. These 14 factors comprise a total of 29 key indicators, with 12 highly significant indicators including 1) uniqueness, 2) number of opponents, 3) water quality, 4) annual cultivated area per reservoir capacity, 5) design flood rate per reservoir capacity, 6) environmental economic feasibility, 7) economic feasibility, 8) proportion of beneficiaries on sufferers, 9) conservation area type, 10) Number of evacuated households of reservoir capacity, 11) endangered wildlife, and 12) biodiversity of wildlife.

5.1.1 Development of the 1st Draft Indicators

Upon reviewing studies on factors and sustainability indicators related to water resources development, it was found that most of these studies focused on factors and indicators at the regional or national levels. These factors and indicators are utilized for planning, monitoring, and evaluating the government's actions to achieve sustainable development goals. They can be categorized into 3 groups: those emphasizing natural resource considerations, those prioritizing sustainable water resource development factors, and those highlighting sustainable water management. Although these factors and indicators are generally at the national or regional levels, some of them can still be applied and adapted for the purposes of this study.

In the water resources engineering, key indicators encompass average rainfall, flood discharge, and the ratio of water usage per water resource. In the aspect of natural resources, it was identified that crucial factors included forest-related aspects with

significant indicators such as forest status, proportion of forested areas, biodiversity, vulnerability, and uniqueness. Regarding wildlife, vital factors included biodiversity, the status of endangered species. In terms of environmental quality, factors like water quality was taken into account. Social aspects involved impacted households and conflict level. On the economic front, considerations included income per capita and ecology cost.

Table 5.1 Summarized indicators referenced from concerned research studies and those first draft indicators selected for the study.

Table 5.1 Summarized Indicators Referenced From Concerned Research Studies and the First Draft Indicators Selected Classified by Dimensions and Factors

		Related Sustainable indicators from Literature Indicator		Applied Indicator		Reference
				Sustainability	Water Scarcity	
I. Natural Resources Dimension						
1	Forestry Factor	1	Forest status	✓		(Piyachana, 2013)
		2	Terrestrial ecology (tree density)	✓		(Piyachana, 2013), (Tong, 2020)
		3	Inappropriate land use (Encroachment)	-		(Piyachana, 2013)
		4	Annual forest growth	-		(Piyachana, 2013)
		5	Conservation forest area ratio	✓		(Poomjamnong, 2017), (Noywuli, 2019), (Tong, 2020), and (National Park Research Section, 2019)
		6	Bio- diversity	✓		(Poomjamnong, 2017), (Tong, 2020) (Tong, 2020), (National Park Research Section, 2019)
		7	Loss area (Including in (3))	-		
		8	Forest connecting zone	-		(National Park Research section, 2019)
		9	Vulnerability, Unique ecology	✓		
		10	Globalization	-		
		11	No. of traveling places	-		
		12	Touring diversity	-		
		13	No. of recreation	-		
2	Wildlife Factor	14	IUCN's Red list	✓		(Poomjamnong, 2017), (Smith, 2007), and (National Park Research Section, 2019),
		15	Illegal hunting ratio	-		(Poomjamnong, 2017),
		16	No. of high value wildlife (Including in (14))	-		(National Park Research Section, 2019)
3	Soil Factor	17	Soil loss	-		(Noywuli, 2019) and (Liang, 2018)
		18	Erosion rate	-		(Noywuli, 2019)
		19	Annual sediment load	-		
		20	Length of eroded river	-		(Corrêa, 2013)
II. Geographic, Water resource and Engineering Dimension						
1	Geography – Factor	21	Annual flow	-		(Noywuli, 2019), (NSO, 2023)
		22	Av Flood Peak (Including in (23))	-		(Noywuli, 2019)

Related Sustainable indicators from Literature					
Indicator			Applied Indicator		Reference
			Sustainability	Water Scarcity	
	23	Flooding frequency risk	✓		(Noywuli, 2019), (NSO, 2023)
	24	Annual rainfall	✓		(Tong, 2020), (Smith, 2007), (Liang, 2018), and (NSO, 2023)
	25	Geography	✓		(Tong, 2020)
	26	Water Use / Water Resource	✓		(Tong, 2020), (NSO, 2023)
	27	Raw water per capita	-		(Tong, 2020)
	28	Specific flow yield	-		
	29	Groundwater yield (water scarcity)		✓	
III. Environment Dimension					
1. Environment Factor	30	Water quality	✓		(Piyachana, 2013), (Smith, 2007), and (NSO, 2023)
	31	Wastewater volume	-		(Liang, 2018)
	32	Treated water to wastewater ratio	-		
		Water for environment and ecology	-		
	33	Ecology Footprint	✓		(Morris, 2019)
	34	GHG per area	-		(Tong, 2020)
IV. Economic Dimension					
1 Economic Factor	35	GDP per capita	-		(Liang, 2018), (Morris, 2019)
	36	GDP Growth	-		(Liang, 2018)
	37	GDP per unit of water	-		(Morris, 2019
V. Social Dimension					
1 Social Factor	38	People participation	-		(Piyachana, 2013) and (NSO, 2023)
	39	Instinct	-		
	40	Encroachment rate	-		(Piyachana, 2013), (National Park Research Section, 2019)
	41	Water management potential	-		(Piyachana, 2013), (NSO, 2023)
	42	Water requirement per water resources (similar to (26))	-		
	43	Agriculture land per capita			(Piyachana, 2013)
	44	Poverty ratio (water scarcity)		✓	
	45	Population density per area	-		(Tong, 2020)
	46	Energy consumption per area	-		
	47	Community existence	-		(National Park Research Section, 2019)
	48	Water usage per capita	-		(Smith, 2007), (Liang, 2018), and (NSO, 2023)
	49	Water usage per agriculture area demand (water scarcity)		✓	(Liang, 2018)

Related Sustainable indicators from Literature					
Indicator			Applied Indicator		Reference
			Sustainability	Water Scarcity	
	50	Population growth rate	-		(Liang, 2018), (Corrêa, 2013)
	51	Community growth rate	-		(Liang, 2018)
	52	Average Age	-		(Morris, 2019)
	53	Conflict level	✓		(Corrêa, 2013)
	54	No. of educated years per capita	-		(Morris, 2019)
	55	Agriculture land per catchment area	-		Corrêa, 2013) and
	56	Serviceable water supply ratio	-		(NSO,2023)
VI. Management Dimension					
1. Management Factor	57	Forestry management	-		(Poomjamnong, 2017) and (NSO, 2023)
	58	Conservation budget	-		
	59	Conservation law	-		(Noywuli,2006)
	60	Water resources development budget	-		
	61	Ecology impacting project	-		(National Park Research Section, 2019)
	62	No. of personal	-		(Liang, 2018)
	63	Conservation budget	-		
	64	Water treatment budget.	-		
	66	Water treatment ability	-		(Corrêa, 2013)
	67	Water management of water supply	-		(The National Statistical Office of Thailand,2023)
	68	Water resources security	-		
	69	Balance of water resources and demands (similar to (26))	-		
	70	Water disaster management	-		

Note: ✓ = Applied

- = Not Applied

5.1.2 Development of the 2nd Draft Indicators

There are two steps of indicator establishment as follows:

1) In-depth interviews were carried out with 7 experts, including two senior academic experts in wildlife and forestry, and five senior governmental officials in wildlife, forestry, environment, socio-economics and engineering.

Objectives of the in-depth interview are mainly focused on project barrier issues and their causes, key factors and sustainable indicators of the water resource development projects, of which details of in-depth questionnaire is presented in Appendix D.

The remarkable key issues suggested include following items, i.e. : consideration of engineering aspect, the importance priority of the environmental dimension, area uniqueness, recognizing uniqueness of endangered habitat, reservoir location, natural resources abundance and biodiversity, the status of forest resources, the significance level of conservation area types, project conflicts of interest, and social opposition to the project. These issues and indicators are also considered and proposed in the questionnaire design.

2) Considering normal practices of most feasible project planning and preparation of EIA's reports, concerning dimension, factors, and indicators were reclassified and grouped in accordance with sustainable definition. In the project planning and design, selection of type of water resource development structures, selection of appropriate site location and storage capacity respectively would considering four key dimensions comprising 1) geography and engineering 2) environments, 3) society, and 4) economic, respectively.

For the geography and engineering of which main indicators applied are as follows; i.e. retention area per unit of storage, dam section, geologic conditions, hydrologic conditions, and irrigation area size.

For the environments, indicators mostly applied are size of inundated reservoir area comparable to conservative area, type of conservative areas, abundance or density of trees per area, bio-diversity, status of forest and wildlife, ecology system, and impacted water quality.

For social dimension, indicators mostly concerned are number of impacted households, encroachment area, and project protestors.

For economic dimension, mostly indicators applied are investment cost per unit of storage volume, and economic internal rate of return.

These indicators were applied in the second draft indicators proposed in the first Del Phi's questionnaire.

In addition, some indicators were modified into proportional figures to the storage capacity or percentages for simple interpretation, whereas some appropriate indirect indicators were adopted owing to data availability for assessment.

Table 5.2 presents stage of indicators establishment.

Development, 2019; Land Development Department, 2019; Land Development Department, 2019; Research Section & Development of National Parks, Wildlife and Plant Conservation, 2019; [illegible] 2019; "Thai Rubber Latex Corporation (Thailand) Public Company Limited," 2017, 6 April 2017, National Statistical Office Thailand, 2017

Table 5.2 Stage of Indicators Establishment

Dimensions	Factors		Items		Indicators				
					1st-draft by Literature	2nd-draft by In-depth interview	2nd draft with ranging scale by EIA's report & researcher		Final with weightage by Del Phi's majority
							EIA	Researcher	
1. Geography and Engineering	1	Geography and Engineering	1	Dam section / storage				✓	✓
			2	Reservoir area / storage	✓		✓		✓
	2	Hydrology	3	Flood flow / storage	✓			✓	✓
	3	Geology	4	Seismicity		✓	✓		✓
			5	Seepage		✓	✓		✓
	4	Engineering	6	Irrigation area / storage	✓			✓	✓
2. Natural Resources and Environments	5	Forest	7	Abundance	✓	✓	✓		✓
			8	Bio-diversity	✓	✓	✓		✓
			9	Prohibited Plants	✓	✓	✓		✓
			10	Uniqueness	✓	✓	✓		✓
	6	Wildlife	11	Abundance		✓	✓		✓
			12	Bio-diversity		✓	✓		✓
			13	Endangered Wildlife	✓	✓	✓		✓
			14	Uniqueness		✓	✓		✓
	7	Water Quality	15	Water Quality	✓		✓		✓
	8	Ecology	16	Type of conserved area		✓	✓		✓

Dimensions		Factors		Item	Indicators				
					1st-draft by Literature	2nd-draft by In-depth interview	2nd draft with ranging scale by EIA's report & researcher		Final with weightage by Del Phi's majority
							EIA	Researcher	
			17	Reservoir area conversation area	✓			✓	✓
			18	Location	✓	✓	✓		✓
3. Social	9	Protestors	19	Protestors / Impacted Households	✓	✓	✓		✓
	10	Impacted Households	20	Houses/ Storage	✓		✓		✓
			21	Compensated land / Storage			✓		✓
			22	Irrigated area / reservoir area		–		✓	✓
	11	Uniqueness	23	- Archaeology site		✓	✓		✓
				- Tourism place					✓
				- Mineral resource					✓
				- Geologist reservation					✓
				- Ethnics					✓
4. Economic	12	Benefits	24	Annual crop area / Storage				✓	✓
	13	Costs	25	Construction cost/ Storage			✓		✓
			26	Social cost / Storage			✓		✓
			27	Environmental cost/ storage			✓		✓
	14	Feasibility	28	EIRR			✓		✓
			29	Env.EIRR		✓	✓		✓

3) Establishment of indicators ranging scale.

There are two main sources of data for classification.

(1) Research studies, documentations, regulations, and announcements of related agencies

Definitions and scoring ranges of some indicators could be obtained from previous researches, announcements of related agencies for examples.

Prohibited trees and bio-diversity are referenced from the announcement by the DNP regarding the determination of the value of natural resources in protected areas, 2020

Abundance of forest is referenced (Department of Conservation Science, Faculty of Forestry, & Kasetsart University, 2009)

(2) 30 EIA reports

Ranging scales of the second draft proposed indicators are basically analyzed by descriptive statistics and occurrence probabilities as depicted in Appendix C.

4) Establishment of water scarcity indicators from responsible agencies' practice.

Requests of the water resource development project are starting mostly from farmers in the risk drought area where lacking of water resources for agriculture and water supply. Responsible agencies have to assess water scarcity level of such area in order to classify necessity level of water resources development. Factors normally applied comprise five factors that were applied for this study. They are 1) geography factor including drought and flood risk area indicators, 2) the factor of existence of water resources and irrigation system over the target area, 3) hydrologic factor comprising rainfall variation indicator, and ground water potential indicator, 4) water demand factor comprising cropping type indicator, and 5) poverty factor comprising the ratio of numbers of poor villages to total villages indicator.

The ranging scales of water scarcity assessment are analyzed basing on GIS data maps concerned and their standard criteria as presented in Appendix B.

The proposal of the assessment of water scarcity in addition to the project's sustainability assessment is that determination of appropriate project sustainability level for project implementation decision should consider the condition of water scarcity level of the project area either.

5) Questionnaire Design

Results of study of the second draft of dimensions, factors, and key sustainability indicators and their scoring ranges from afore mentioned steps are considered as a draft proposal in the first questionnaire for Del Phi's panel.

There are two groups of indicators proposed in the questionnaire comprising 1) Sustainable factors and indicators of the water resource development projects and 2) Factors and indicators of the assessment of water scarcity level.

6) Sustainable indicators of the water resource development projects

Conceptual of indicators proposed in the questionnaire are summarized as follows:

(1) The main dimensions considered are 4 components consisting of engineering, natural resources and environment, social, and economics.

(2) There are 14 significant factors considered for sustainable aspects as follows 1) engineering dimension comprising 4 factors namely geography, geology, hydrology, and engineering. 2) natural resources and environmental dimension consisting of 4 key factors namely forests, wildlife, water quality, and ecosystem. 3) social dimension concerning 3 core factors namely project opposition, affected stakeholders, and life value or uniqueness. 4) economic dimension comprising 3 factors namely benefits, costs, and feasibility level.

(3) The project sustainable indicators comprise 29 indicators as follows: 1) engineering dimension with 6 indicators, 2) natural resources and environmental dimension with 12 indicators, 3) social dimension with 5 indicators, and 4) economic dimension with 6 indicators.

Table 5.3 presents selected factors and indicators with scoring ranges applied for sustainability assessment.

7) Indicators of water scarcity assessment

Factors normally applied comprise five factors. They are 1) geography factor including drought and flood risk area indicators, 2) the factor of existence of water resources and irrigation system over the target area, 3) hydrologic factor comprising rainfall variation indicator, and ground water potential indicator, 4) water demand factor comprising agriculture cropping type indicator, and (5) poverty factor comprising the ratio of numbers of poor villages to total villages indicator.

Table 5.4 presents the summary of factors and indicators with scoring ranges for assessment of the project's water scarcity level.

Table 5.3 Selected Factors and Indicators with Scoring Ranges Applied for Sustainability Assessment

Factors / Indices	**Unit**	**Scores and Ranges**				
		5	**4**	**3**	**2**	**1**
1. Engineering dimension						
1.1 Geography factor						
1.1.1 Dam section/ Res.cap	m^2/mcm.	≤500	>500-1000	>1000-1500	>1500-2000	> 2000
1.1.2 Res. area / Res.cap	rai/mcm.	≤25	>25-50	>50-75	>75-100	> 100
1.2 Hydrology factor						
1.2.1 Des. flood/ Res.cap	cms./mcm.	≤ 5	>5-10	>10-15	>15-20	> 20
1.3 Geology factor						
1.3.1 Earthquake (Seismicity)	Mercalli scale	Level 1-2	Level 3	Level 4	Level 5	Level 6-7
1.3.2 Percolation (Leakage)	1-5 scale	Low leakage or Lugeon ≤1	Relatively low leakage or Lugeon >1-5	Moderate leakage or Lugeon >5-10	Relatively high leakage or Lugeon >10-50	High leakage or Lugeon > 50
1.4 Engineering Factor						
1.4.1 Irrigation Area / Res.Cap	rai/mcm.	>900	>700-900	>500-700	>300-500	≤300
2. Natural Resources and Environmental Dimension						
2.1 Forestry Factor						
2.1.1 Abundance : Big tree density	No./rai	≤14 (less abundance)		>14-40 (moderately abundance)		>40 (high abundance)
2.1.2 Biodiversity : No. of total species	No. of species	≤ 17 (less variety)		>17-30 (moderately variety)		>30 (high variety)
2.1.3 Prohibited Trees : No. of species	No. of species	1-10 (low)	>10-20 (relatively low)	>20-30 (moderately)	>30-40 (relatively high)	> 40 (high)
2.1.4 Uniqueness	Yes/No	No distinctiveness found in the area.				Identified distinctiveness in the area.

Factors / Indicators	Unit	Scores and Ranges 5	4	3	2	1
2.2 Wildlife factor						
2.2.1 Abundance : No. of low density species /No. of total species	Percent	> 60		>40-60		≤ 40
2.2.2 Biodiversity : No. of total species	No. of species	≤ 115	>115-150	>150-185	>180-215	>215
2.2.3 Prohibited wildlife : No. of type by IUCN Red List Level (VU EN and CR)	No. of species	≤ 4		5 - 8		> 8
2.2.4 Uniqueness	Yes/No	No distinctiveness found in the area.				Identified distinctiveness in the area.
2.3 Water quality impact Factor						
2.3.1 Impacted water quality	Yes/No	No impact or less impact	Moderate impact and can be mitigated	Severe impact and can be significantly mitigated.	Severe impact and can be moderately mitigated.	Severe impact and can be less mitigated.
2.4 Impacted ecology factor						
2.4.1 Conservation area type	NP/WL/1A/ RF	moderate (Reserved forest) (C)		relatively high (WC,1A)		high to very high (National Park)&Wildlife zone
2.4.2 Impacted reservoir area /Total conserved area	Percent	≤ 1	>1-2	>2-3	>3-4	>4
2.4.3 Location in conserved area	Rim/Inner	Low impact (Rim)	-	Moderate impact (Rim to the central.)	-	High impact (Central to the headwaters.)
3. Social Dimension						
3.1 Opposition factor : No. of opposition/ No. of affected households	Percent	≤5	>5 – 10	>10 – 15	>15- 20	> 20
3.2 Impacted social factor						
3.2.1 No. of household per Res.cap.	Household/mcm.	≤ 1	>1-2	>2-3	>3-4	>4
3.2.2 Compensated area/ Res.cap.	rai/mcm.	≤10	>10-20	>20-30	>30-40	>40
3.2.3 Irrigation area / Reservoir area	Ratio	≤ 10	>10-20	>20-30	>30-40	>40

Factors / Indicators	Unit	Scores and Ranges 5	4	3	2	1
3.3 Life value (Uniqueness) factor						
3.3.1 Uniqueness (Archeology, Tourism, Mineral, Geology, and Ethnic)	Yes/No	No	-	-	-	Yes
4. Economic dimension						
4.1 Benefit factor						
4.1.1 Annual crop area / Reservoir capacity	rai/mcm.	≤ 600	>600-800	>800-1000	>1000-1200	>1200
4.2 Investment factor						
4.2.1 Construction cost / Res.cap.	MB./mcm.	≤ 20	>20-40	>40-60	>60-80	>80
4.2.2 Social Compensation cost / Res.cap.	MB./mcm.	≤ 2	>2-4	>4-6	>6-8	>8
4.2.3 Env. Mitigation cost /Res. cap.	MB./mcm.	≤ 2	>2-4	>4-6	>6-8	>8
4.3 Feasibility factor						
4.3.1 Economic internal rate of return (EIRR)	Percent	> 14	>12 -14	>10 -12	>8 –10	≤ 8
4.3.2 Environment economic internal rate of return (EEIRR)	Percent	> 12	>10-12	>8-10	>6-8	≤ 6

Note: NP = National Park, WL = Wildlife Sanctuation Area,
1A = Watershed Class. 1A, RF = Reserved Forest
1 rai = 1,600 sq.m.

Table 5.4 Summary of Factors and Indicators with Scoring Ranges for Assessment of the Project's Water Scarcity Level

Factors / Indicators	Unit	Water Scarcity		
		Low (No. of Proj.)	**Moderate (No. of Proj.)**	**High (No. of Proj.)**
1 Geography factor				
1.1 Drought index				
- Frequency in the past 5 years of droughts.	Years	1-2 (18)	3-4 (8)	≥5 (4)
1.2 Flooded index				
- Frequency in the past 12 years of floods.	Years	≤4 (26)	5-8 (3)	>8 (1)
2 Irrigation system existence Factor				
- Irrigation system existence index	-	Partial Irrigated by reservoir. (5)	Partial Irrigated without reservoir. (2)	No Irrigation system. (23)
3 Hydrology factor				
3.1 Rainfall variation index				
- Proportion of dry season rainfall to annual rainfall.	%	> 30 (3)	>25-30 (5)	≤ 25 (22)
3.2 Groundwater potentials index				
- Yield	cu.m./hr,	>20 (5)	>10-20 (2)	≤ 10 (23)
- Total Dissolved Solids (TDS)	mg/l	≤ 500 (26)	-	> 500 (4)
4 Water demand factor				
- Agricultural land use type index	Type	Perennial Tree (4)	Field Crops (12)	Orchard/Paddy (14)
5 Poverty factor				
- Poverty index (Proportion of the poors to district's population.)	%	≤2.5 (15)	>2.5-10 (14)	>10 (1)

5.1.3 Final Sustainable Indicators From Del Phi

5.1.3.1 Results of the sustainability indicators of water resource development projects in the conservation areas.

After two rounds of Del Phi's questionnaires, the result indicated majority consideration with more than 75 percentiles agreed with the proposals which could be summarized as follows,

1) Four dimensions including engineering, natural resources and environment, society, and economic are recommended as key dimensions of considering water resource development project's sustainability. The resulted weighting of engineering : natural resources & environment : society : economic is 20 : 35 :25 : 20, respectively. The natural resource and environment is the most significant dimension which is complied with the recommendation of the in-depth interview.

2) There are 14 factors concerning in project sustainability of which seven factors that have more significant weight are wildlife (10.5%), forestry (8.75%), ecology (8.75%), social (8.75%), life value (8.75%), economic feasibility (8%), and opposition (7.5%), respectively.

3) There are 29 indicators concerning the project sustainability. Twelve indicators having more weight are (1) uniqueness, (2) number of opponents, (3) water quality, (4) annual cultivated area per reservoir capacity, (5) design flood rate per reservoir capacity, (6) environmental economic feasibility, (7) economic feasibility, (8) proportion of beneficiaries on sufferers (9) conservation area type, (10) No. of compensated houses per reservoir capacity (11) endangered wildlife, and (12) biodiversity of wildlife.

4) The proposed project that will be developed should provide overall sustainable point in good level (66-75) whereas the sustainable point of each dimension be in moderate level (56-65).

5.1.3.2 Results of the indicators of water scarcity level of the proposed project area.

The status of project's water scarcity issue will be another factor to alleviate sustainability level criteria so that such project could be implemented. The results are summarized as,

1) To identify project's water scarcity or water resources development necessity level, five factors are applied. They are geography, existence of irrigation system, hydrology, water demand, and poverty of which their weighting factors are 20 : 15 :20 :20 :25, respectively.

2) The results from the Del Phi's experts indicated that a project with a scarcity score or water resources necessity score of less than 33 is considered a low water scarcity level. For scarcity point of a project falling within the range of 34-67, it is considered a moderate level, while a project scoring 68 or higher is considered a significant high water scarcity.

In cases where the project has moderate to high level, it is advisable to undergo further development. However, if the project has sustainability scores below the moderate threshold (less than 55), it is recommended to revise project size, to alter dam location, to improve project components to achieve a total higher sustainability rating at least within the moderate range.

5.2 Discussion

5.2.1 Indicators for Water Resources Development

The indicators for water resource development projects were principally developed basing on the three sustainable development dimensions (environments, society, and economic) according to the sustainable development goals of the national 20- year strategic plan (B.E 2561-2580). Another dimension inclusion for this study is engineering which is in compliance with not only normal practice of the development agencies but also the guidelines of EIA report preparation specified by ONEP who responsible for both authorized conservative committees, and government ministers. Therefore, it is appropriate to define the four dimensions as a basis framework for further developing factors and indicators concerned.

The 29 indicators of 14 factors in four dimensions comprise 6 indicators of 1) dam section, 2) reservoir area, 3) design flood discharge, 4) seismicity, 5) leakage, and 6) irrigation area for engineering dimension, and 12 indicators of 1) forest abundance, 2) forest bio-diversity, 3) prohibited trees, 4) forest uniqueness, 5) wildlife abundance, 6) wildlife bio-diversity, 7) endangered wildlife, 8) wildlife uniqueness, 9) water

quality, 10) type of conservation area, 11) impacted area to conservation area, and 12) reservoir location for environment dimension, and 5 indicators of 1) protestors, 2) impacted households, 3) compensated land, 4) irrigation area to reservoir area ratio, for social dimension, and 6 indicators of 1) annual crop area, 2) construction cost, 3) compensation cost, 4) EIMP cost, 5) EIRR, and 6) environmental EIRR for economic dimension, respectively. Most of the indicators were established from literature review of sustainable water resources development and management and natural resources conservation management, as well as output from in-depth interview of key 7 experts, guidelines of EIA report preparation, data from 30 projects' EIA reports, and two rounds of questionnaire survey of Del Phi's 20 specialists panel of which the research design is conformed with the indicator development method of the National Statistical Office (Saeng-Arun, 2016)

The indicators were established in order to comply with objectives of the study and target definition of sustainability specified for each dimension of water resources development.

In engineering dimension, indicators representing stability, safety, efficiency, and resilience were selected from literatures and were additional proposed according to the EIA report's guideline by ONEP (2023), the indicator of reservoir area per storage reflecting sustainable targets of ecology loss and water loss and retention efficiency was referenced to National Park Research Section, (2019), whereas flood discharge per storage representing reservoir resilience, as well as irrigation area per storage reflecting reservoir efficiency was referenced to (Noywuli, Sapei, Pandjaitan, & Eriyatno, 2019). For stability and safety concerned, seismicity and leakage were suggested from in-depth interview and conformed with the guideline of EIA report preparation. Finally, another indicator of dam section per storage representing dam stability and cost effectiveness was added by the researcher.

In environmental dimension, resulted indicators concerning forestry, wildlife, water quality, and ecology are initially complied with those applied in the international researches by (Noywuli et al., 2019), (Tang et al., 2020), (Smith & Zhang, 2007), (Liang, Zhang, Liu, & Liu, 2018) and (Morris, 2019), respectively, and those adapted by Thailand researches of (Piyachana, 2007), (Pumijumnong & Chareonwong, 2017), and the (Department of National parks Wildlife and Plant Conservation, 2019),

respectively. The second draft of indicators were added up in accordance with the in-depth interview suggestion, EIA report guidelines, and 30 EIA reports, respectively.

Four indicators of forestry abundance, bio-diversity, prohibited trees and uniqueness were complied with literatures of (Pumijumnong & Chareonwong, 2017) and (National Park Research Section, 2019), whereas those of wildlife factor only endangered wildlife was referred to by (Pumijumnong & Chareonwong, 2017), (Smith & Zhang, 2007), and the National Park Research Section, (2019) the abundance, bio-diversity and uniqueness were referenced from in-depth interviews and EIA guidelines. Whereas those ecology factor i.e. type of conservation area indicator was suggested by in-depth interview to reflect abundance and bio-diversity of all ecology system, and reservoir location indicator represent conservation area connectivity and bio-diversity of ecology which were referenced to (Pumijumnong & Chareonwong, 2017), and (Tang et al., 2020), respectively. Additionally, the indicator of impacted conserved area to overall conservation area was initiated in this study to represent the appropriate allowable limit of ecology losses due to the reservoir.

For the water quality indicator which reflecting adverse effects due to reservoir, it was referenced to (Piyachana, 2007) and (Smith & Zhang, 2007), respectively.

In the social dimension, the indicator of number of protestors to impacted households was applied to represent conflict level and people participation which referenced to (de Almeida Corrêa & do Nascimento Teixeira, 2013) and also from EIA reports, whereas indicators of number of housing and land to be compensated reflect conflict level, quality of life, and peaceful were referenced to the (National Park Research Section, 2019). The uniqueness indicator of archaeology, tourism, geology, minerals, and ethnic were also referenced to the (National Park Research Section, 2019), in-depth interview and EIA report guideline. An additional indicator of beneficiaries to sufferers ratio representing targets of social equality and water accessibility, quality of life, and employment, was added in this study.

For the economic dimension, all indicators were not specified in literatures due to their nation wide scope of study not for project level. Therefore, all indicators of costs and EIRR were complied with in-depth interview and EIA report guideline except the indicator of annual crop area per storage which were proposed to represent

sustainable targets of project benefits, poverty decreasing, demand – supply balance and project feasibility.

The results of the weighting factors of four dimensions from majority of Del Phi's showed the proportion of engineering: environment: society: economic as 20 : 35 : 25 : 20. The environment aspect is the highest weight followed by social aspect; whereas economic and engineering aspects have equal lower weight which is agreed with results of most of 30 projects EIA reports. Therefore, environments and social issues should be intensively determined more than economic and engineering. For the weighting scores among factors and their indicators, most of the Del Phi's panel assigned weightage trends in the same direction, consequently only two rounds of questionnaire survey could result more than the 75 percentile majority's conclusion of the weight ratios among factors and those of indicators.

For the ranging scale of indicators, there are a few researches or studies concerning standard scales or criteria, therefore most of them were analyzed from data of 30 EIA reports and classified basing on reasonability, reality, science, and statistics of approval projects by the ONEP respectively. These indicators' ranges and scores were also justified by majority of the Del Phi's panel so that they could be applied for assessing indicator scores which implying their sustainability scores.

For sustainability level of each dimension and overall project, they have not been defined and announced by related agencies, this research is therefore carried out through Del Phi's majority opinions of which results indicated that in general condition, sustainability level of each dimension should be moderate level or better, whereas the overall sustainability level of the project be good level or better. However, this study proposed another objective of consideration of water scarcity level or water resource development necessity of the project target area. This would be another criteria for project implementation decision that would provide opportunity for the suffered area to be developed. The water scarcity criteria is normally taken into account in accordance with government's policy, national strategic measures and their corresponding master plans. In case condition of water scarcity level is moderate to high, suggestion of lessening overall project's sustainability level criteria from good level to moderate level would solve those sufferers from drought problem with balance sustainability among all aspects.

The indicators for water scarcity assessment comprise 7 indicators which are drought and flood risk areas, existence of water resources and irrigation development, seasonal rainfall variation, ground water potential, land use, and poverty level. They are actually applied by responsible water development agencies, however explicit criteria, weightage scores, ranges and scoring, and water scarcity level scoring have not been specified and announced, therefore, this study developed a set of key indicators, weightage, and criteria using GIS data of concerning agencies that were justified by the Del Phi's panel. To certify both of indicator sets by application to the 30 projects, it was found that results of both sets are reliable and complied with the strength or weak points of the projects that let the planners could establish all right mitigation plans. Consequently, both sustainability indicators and water scarcity indicators could be beneficially and actually applied for assessing sustainability of water resource development projects and as a supporting information for further improving sustainability level, and decision of project implementation.

5.2.2 The Advantage of the Developed Indicators

Since the previous researches or studies concerning sustainable indicators were mostly developed up on the scope of national level not for project level as specified as the objectives of this study, therefore the developed indicators of the sustainable water resource development projects would be appropriate for consideration of sustainability level of the proposed project in various dimensions. Consequently, they could be applied as a fundamental information guideline, or a tool for supporting optimal project component design and permission determination of concerning agencies.

Such indicators and their weightage and ranging scores were manipulated according to research methodology in details of project level with references from various reliable sources, i.e. previous research studies, announcement of related agencies, guidelines of water resources development feasibility study, guideline of EIA report preparation, EIA reports of 30 reservoir projects, in-depth interviews of key experts and Del Phi's questionnaire results, consequently the developed indicators could be applied with confidence as another tool for project planning decision.

The study has also established decision criteria of project implementation by specified a qualified sustainability levels of each dimensions and overall project. In

addition, the study has established criteria and indicators for classifying a project's water scarcity level or water resources development necessity in order to extend opportunity in development for the higher water scarcity project by lessen overall sustainability level criteria required. This issue is one of normal practices of Thailand's government for project implementation decision.

Additionally, as a results of water scarcity level of the project, concerning GIS maps could be applied for preliminary project investigation in order to assess the water resources necessity level and to avoid duplication of the development.

5.2.3 Compliance to Indicator Development Method

The developed indicators are manipulated in accordance with procedures and methodology as proposed in the research design of which procedures are complied with the indicator development method of the National Statistical Office defined by Saeng-Arun, 2016. Firstly by identifying the sustainability definition and objectives of each dimension , secondly analyzing important factors or components reflecting objectives, thirdly, developing effective indicators by basing on significant affects, reliable and accessible information, budget and time suitability, fourthly, reconsidering the indicators through many procedures including in-depth interview, guidelines of feasibility study planning, guideline of EIA report preparation, and two rounds of Del Phi's questionnaire survey, and finally by verifying indicators with 30 EIA projects of which results showing that the developed sustainable indicators with their weightage, ranging scales, and sustainable criteria of the water resource projects could be compatibly applied.

The studied indicators could be complied to the definition and objectives of sustainability for four dimensions as summarized in Table 5-5.

Table 5.5 Indicators' Compliance to Sustainability

Dimensions	NO	Sustainability Definition	Indicators
1. Geography and Engineering	1	Safety, stability and efficiency of structure.	Dam section / storage, Seismicity, Seepage, and Irrigation area / storage
	2	Efficient system, minimal water ecology losses.	Reservoir area /storage and Seepage
	3	Resilience system, affordable to climate change, inflow fluctuation (Drought and flood)	Flood discharge /storage
2. Natural Resources and Environments	4	Long-term preservation of the abundance and bio-diversity is ensured.	Abundance in Forest and Wildlife, Bio-diversity in forest and Wildlife, Type of conserved area, and Location
	5	Habitat and food sources for endangered and near-extinct wildlife are not diminished below the threshold for their survival.	Prohibited Plants and Endangered Wildlife
	6	Unique and vulnerable ecosystems that can't be rehabilitated and restored are not all destroyed or lost.	Uniqueness in forest and wildlife, Type of conserved area, and location
	7	Avoidance of environmental pollution exceeding current levels or the carrying capacity of nature's ability to recover to its original state.	Water Quality
	8	The rate of depletion does not exceed natural regeneration in the long term, or compensation and restoration measures are in place to maintain the original state.	Reservoir area to conservation area ratio
3. Social	9	Social conflicts and opposition to projects are effectively managed, promoting peace, security, and safety for life and property.	Protestors / Impacted Households, Houses/ Storage, Compensated land / Storage

Dimensions	NO	Sustainability Definition	Indicators
	10	Participation of stakeholders is ensured from the beginning of project implementation.	Protestors / Impacted Households
	11	The public has equal and widespread access to project benefits.	Irrigated area / reservoir area
	12	It improves public health and enhances overall quality of life.	
	13	It creates employment opportunities with higher income levels beyond the country's poverty line, ensuring long-term income stability and reducing migration.	
	14	It has minimal impact on the preservation of unique or distinctive ethnic, community traditions, customs, and cultures, as well as natural resources, tourism, mineral resources, geologic and archaeologic places.	Existence of archaeology site, tourism place, mineral resource 'geologist reservation, and ethnics
4. Economic	15	Investment is worthwhile in the long term, considering environmental and social costs.	Annual crop area / Storage, Construction cost/ Storage, Compensation / Storage, and Environmental cost/ storage, EIRR, and Env.EIRR
	16	Demand and supply management takes into account natural resource and environmental conservation.	Annual crop area / Storage

Dimensions	NO	Sustainability Definition	Indicators
	17	The economy is flexible, stable, and resilient, reducing risks from natural disasters (such as droughts and floods)	EIRR, Env.EIRR
	18	It benefits human well-being and enhances various aspects of quality of life.	EIRR, Env.EIRR, Construction cost/ Storage, Compensation / Storage, and Environmental cost/ storage,
	19	It is capable of scaling down projects and has effective mitigation plans management (EIMP) and good governance.	EIRR, Env.EIRR, Construction cost/ Storage, Compensation / Storage, and Environmental cost/ storage,
	20	Rate that balance between demand & supply and environments and economics.	EIRR, Env.EIRR, Construction cost/ Storage, Compensation / Storage, and Environmental cost/ storage,

5.2.4 Compliance to Sufficient Economy Philosophy

The application of sustainable indicators and criteria of the project sustainability level would result in a sustainable project which be justified with the sufficiency economy in according with the Royal King Rama 9's philosophy. Three basic principles of the sufficiency economic comprises 1) moderation, 2) reasonableness, and 3) self-immunity along with the conditions of morality and knowledge.

Since the indicators and their weighting and ranging scales are manipulated from the basic of higher scores for the project having high sustainability, whereas lower scores for that causes more impacts or losses to natural resources and environments and social dimensions. Therefore each indicators would indicate their sustainable level. Each indicator score or total scores of environments dimension's sustainability level would be guided for the planners to revise engineering design by reducing the project size or altering location to improve environmental sustainability into the better sustainability or justified criteria. This implies the moderation principle by balancing

between benefits from engineering and economic aspects and deficits from environments and social dimensions.

For the reasonableness, the indicators and their ranging scales are determined on various procedures and analyzed upon facts, agencies' statistical data, researches and studies results, and surveyed data of 30 reservoir projects which are theoretically, practically and reasonably studied. The indicators would consequently support project's sustainability with reasonable basis.

For the self-immunity, the process of project design planning is normally considered following issues, i.e. exploiting local supplies and strengthening economic and quality of living of the project area, providing reservoir resilience supporting drought and flood, risk management, EIMP, conflict management, and people participation activities of which some indicators proposed would direct or indirect concerned, such as indicator of flood discharge to storage volume ratio representing resilience level and risk level, whereas cost of EIMP and social cost indicators representing losses and impact level and provision of environmental mitigation plans and compensation schedules to solve local environments and social conflicts. These indicators would be represented for self-immunity concept that the project could be sustainable operated even any unexpected issues occurs.

5.2.5 Project Enhancement for Sustainability

1) By applying the sufficiency economic concept, comprising moderate scale development together with reasonable outcome and risk management with appropriate impact mitigation plans, would solve unbalance or conflict between economic and environments. Therefore, in case a project's environmental sustainability score is low, modification of project scale, reservoir size, dam relocation will be one of the solutions to improve sustainability score level, environmental and social impact, and project feasibility.

2) Reducing the project size by decreasing the storage capacity of the reservoir and the reservoir area in cases where the topography of the reservoir is flat may not significantly affect the sustainability score in the engineering dimension. This is because the index value is relative to the unit capacity, and minor changes in engineering size do not have a significant impact on the range of scores in this dimension.

However, the reduction in project size, especially in terms of reservoir capacity or retention area, would result a better positive impact on natural resources, environments, ecosystem, society, and economic aspects.

3) Nevertheless, in cases where there is no additional revised survey of natural resources due to the reduction in the reservoir area, the sustainability score in the mentioned dimension may not change significantly either, since the scoring interval range of indices have a wider range of which results are analyzed from wider range of size and varieties of geography, natural resources types and socio-economic characteristics from all regions over the country. Consequently, further studies on scoring range of indices especially for each region is recommended.

However, the reduction in project size or reservoir capacity would significantly reduce impacts to natural resources, overall ecology system, environmental, and socio-economic conditions.

5.2.6 Application of Relationship Between Engineering and Economic Data

According to data of 30 EIA studies, relationship between engineering indicators and economic indicators were analyzed. Among six engineering and geographic indicators comprising 1) dam section per storage, 2) reservoir area per storage, 3) design flood per storage, 4) seismicity level, 5) leakage level, 6) irrigation area per storage, It was found that the flood discharge per storage and the dam section per storage have the higher correlation with the economic return or EIRR as detailed in Appendix G. since to the dam section could be simply calculated and be more logically representing the downscaled dam size than flood discharge, therefore dam section is selected for further linear regression analysis of a relationship between dam section per storage and EIRR.

This relationship could be benefit in apply for a quickly preliminary estimation of the project's economic feasibility return in case of reducing dam or reservoir size that having high impacts to the conserved natural resources, environments, and societies. It was found that relationships between dam section per storage denoted as D, and EIRR could be established into three groups for conditions of high, moderate, and low rates of EIRR depending on their benefits either from high value crops or other

high benefits. For simplicity, relationship of three linear equation graphs depending on various economical returns are presented by following equations and as shown in Figure 5.1

For high return group, $IRR_h = -0.0019D + 20.088$, $R^2 = 0.8894$
moderate return group, $IRR_m = -0.0020D + 15.434$, $R^2 = 0.7866$
low return group, $IRR_l = -0.0037D + 12.767$, $R^2 = 0.7461$

Resulted correlation factors are moderate to good level for the three return groups, they could be preliminary applied for estimating the new estimated EIRR due to the decreasing of reservoir storage size for decreasing environmental impacts.

The new dam section area could be calculated from available dam cross-section, whereas new reservoir storage could be estimated from the reservoir's area-storage-elevation curves. In case the potential project was improved, the difference of EIRR between the improved EIRR and original studied EIRR could be added to the original EIRR and adopted for the improved EIRR. Additionally, in case the new EIRR of the improved storage still be within the acceptable value, the project could be scaled-down. This would improve negative impacts as well as more sustainability, and comply with the sufficiency philosophy.

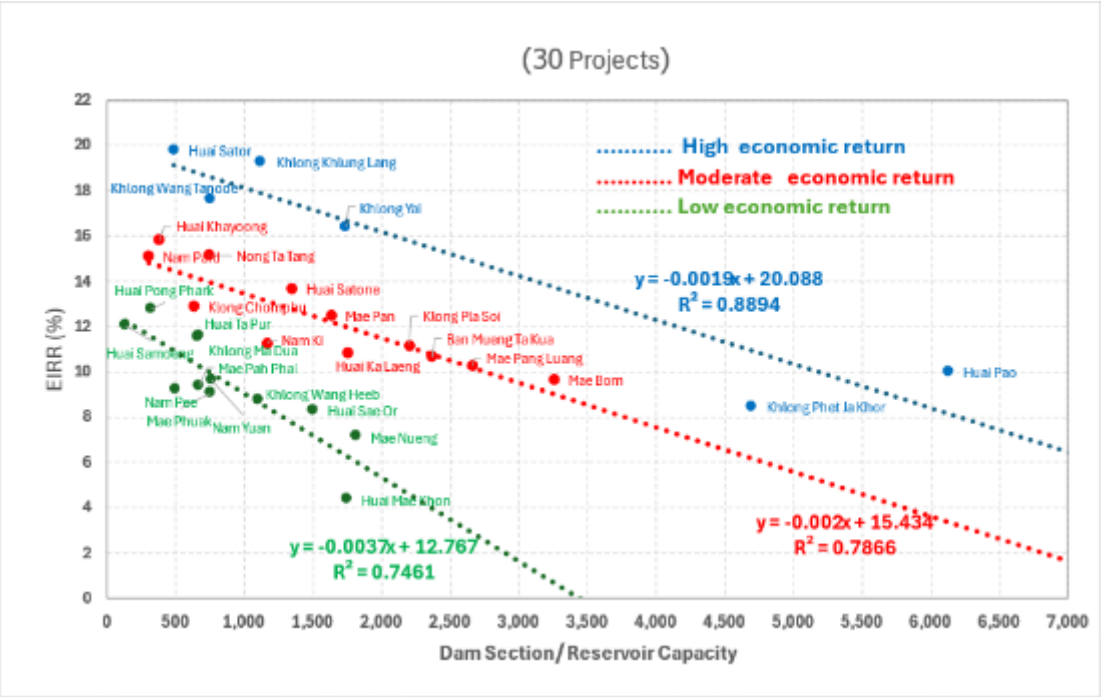

Figure 5.1 Relationship Between Dam Section to Storage and EIRR

5.3 Recommendations

5.3.1 Recommendations from Study Results

Application of the indicators

The study aims to establish a set of key indicators as a tool to assess the suitability and sustainability of water development projects in all dimensions, recommendations for application of these indicators are:

1) To be use as a guideline for development agencies to formulate and identify a potential water resources development considering an acceptable or agreed sustainability results in all aspect dimensions, with reducing iterations of project planning and approval.

2) To be applied as standard criteria for concerning agencies of conservation of natural resource and environments in examining project impacts and viability into a balanced development.

3) A guideline for considering weakness of the project in each dimension in order to revise project planning into a appropriate way to obtain a

balanced sustainability in all aspects, or to prepare proper EIMP to minimize negative impacts.

Figure 4.4 presents an example of indicators sustainable score level in radar graph format.

4) To be applied for prioritization of water resource development projects

5) Inclusion in the evaluation for adjusting project location and sizing for reducing environmental and social impacts to achieve balance and sustainability.

6) Among the four dimensions, the natural resources and environments dimension plays the most weightage of 35%, followed by social (25%), and economic (20%) and engineering (20%), respectively. These results comply with the present government agencies, Thailand's policy, and guideline of EIA's report preparation for natural resources and environment conservation. Consequently, each of indicators and weightage in this water resources and environment dimension are more important and recommended to be emphasized. Even each of weighting score is not distinctively high due to more indicators concerning. The three highest weighting in this dimension is water quality, conservation type, and endangered wildlife.

7) Among 29 indicators, the five highest weighting scores are uniqueness, project opposition in social dimension, water quality in environment dimension, annual crop area per storage in economic dimension, and flood discharge per storage in engineering dimension. These indicators are key representatives that dominate sustainability levels of each dimension. Therefore, responsible agencies should focus on such indicators in project planning.

8) As a results of the study, all indicators are selected basing on data availability and accessibility from the project's EIA study report. However, at reconnaissance study or preliminary study level that some detailed primary surveyed data have not been processed, especially in forestry and wildlife, the indicators could be simply modified for preliminary sustainability assessment. By applying secondary data of the conservation area compiled or adopting significant classification of national parks defined by the responsible agencies, or adopting the type of conservation area, to represent the levels of the abundance, bio-diversity, and endangered species instead.

9) According to EIA's reports, the environmental impact mitigation plans (EIMP) have to be provided for every impact issues , as well as the monitoring and investigation programs of environmental quality control during and after the project implementation, it is recommended that such programs should be strictly operated in accordingly by all responsible agencies and fully supported by the government in order to conserve and protect all residual natural resources still be sustainable toward the far future.

10) In case of the crucial valuable uniqueness of natural resources and human values existed in the inundated reservoir area that whole of the uniqueness would be permanently diminishes or lost and could not be regenerated, recovered, relocated or mitigated, the reservoir site location is suggested to be altered to another appropriate location or to lower retention level to a preservable level.

5.3.2 Recommendations for Further Studies

1) Additional researches on defining appropriate ranges and scoring of unreferenced key indicators should be further studied, such as ranges and scoring of key indicators especially in forestry, wildlife and ecology.

2) Application of the indicators for other purposes of reservoirs should be further studied. e.g. Trans basin water diversion project, hydropower, flood control, industrial, water supply as well as other infrastructures in other conservation area, such as wetland.

3) Multiple correlation analysis of the relationship among concerned indicators due to reduction of reservoir capacity or project size and the economical feasibility return should be further studied, particularly for each region or different contexts by using data from more EIA reports.

4) The appropriate percentage of impacted area to total conservation area indicator should researched for establishing proper ranges and scores.

5) In case of preliminary study which has insufficient data for assessing some indicators, a review of reducing key indicators of sustainability should be further researched. This could be applied for preliminary evaluation of the sustainable water resource development project prior to feasibility and EIA study level.

6) There should be more researches on assessment of various national resources and environments' carrying capacities in Thailand.

5.4 Limitations of the Study

1) Since there have been neither available data nor research studies related to standard ranges and scores of some significant indicators that be referenced i.e. wildlife factor and ecology factor, then available data from 30 EIA reports were analyzed and applied.

2) As EIA reports applied were located in all regions of Thailand, the ranges of indicators defined will be varied wider and not specifically fitted for some regions, or different context, more additional reports should be further studied to obtain more appropriate indicators ranges and score for various conditions.

3) Most of the 30 reservoir projects sizes are starting from medium (2-99 mcm) to large scale (>100 mcm), excluding small scale projects and very large scale projects (>500 mcm). All projects are mainly served for irrigation purpose.

4) The studied conservation area exclude wetlands, and world heritage sites.

5) The studied indicators are based on technically background and concerned agencies' practice in water resources development planning procedures. Politics, military and peaceful security, and international legislation or agreements are excluded.

BIBLIOGRAPHY

Bureau of Project Management of The Royal Irrigation Department. (2014). *Study guideline of water resource development planning*: Bangkok.

de Almeida Corrêa, M., & do Nascimento Teixeira, B. A. (2013). DEVELOPING SUSTAINABILITY INDICATORS FOR WATER RESOURCES MANAGEMENT IN TIETÊ-JACARÉ BASIN, BRAZIL. *Journal of Urban and Environmental Engineering, 7*(1), 8-14. Retrieved from http://www.jstor.org/stable/26203385

Department of Conservation Science, Faculty of Forestry, & Kasetsart University. (2009). *Final Report Watershed Analysis of Huai Isar, and Huai Rang River Uthai Thani Province*. Retrieved from Faculty of Forestry, Kasetsart University, Bangkok,:

Department of Land Development. (2019). Land used. Retrieved from http://www1.ldd.go.th/web_OLP/result/landuse2562-2564.htm

Department of Mineral Resource. (2013). Mercalli's seismic map. Retrieved from https://www.dmr.go.th

Department of National parks Wildlife and Plant Conservation. (2019). *Criteria for the preparation of national park management area service plans under the National Parks Act B.E. 2562*. Department of National parks Wildlife and Plant Conservation,Bangkok: Bangkok.

GISTDA (Cartographer). (2024a). Drought Map. Retrieved from https://drought.gistda.or.th/.

GISTDA (Cartographer). (2024b). Flood map. Retrieved from https://flood.gistda.or.th/.

IUCN. (2015). The IUCN Red List of threatened species. Version 2015.4. . Retrieved from https://iucn.org/resources/conservation-tool/iucn-red-list-threatened-species

Land Development Department (Cartographer). (2024). Land use map. Retrieved from http://sql.ldd.go.th/lddata/mapsoilH2.html. 18 Apr 2024.

Liang, X., Zhang, R., Liu, C., & Liu, H. (2018). Quantitative Measurement of the Sustainable Water Resource Development System in China Inspired by Dissipative Structure Theory. *Sustainability, 10*(11). doi:10.3390/su10113996

Morris, J. (2019). Developing and exploring indicators of water sustainable development. *Heliyon, 5*(5). doi:10.1016/j.heliyon.2019.e01778

National Park Research Section, & Department of National Park Wildlife and Plant Conservation. (2019). *Prioritization of the National Parks in Thailand*. Bankok: National Park Research Section, Nation Park Division, Department of National Park, Wildlife and Plant Conservation,.

NECTEC (Cartographer). (2022). District poverty areas map. Retrieved from https://www.tpmap.in.th/2566/.

Noywuli, N., Sapei, A., Pandjaitan, N., & Eriyatno, E. (2019). Assessment of Watershed Carrying Capacity for the Aesesa Flores Watershed Management, East Nusa Tenggara Province of Indonesia. *Environment and Natural Resources Journal, 17*, 29-39. doi:10.32526/ennrj.17.3.2019.20

Piyachana, A. (2007). The State of Natural Resources and Environment at Phu Phan National Park and Surrounding Areas. *Sripatum Review of Humanities and Social Sciences*. Retrieved from http://dspace.spu.ac.th/handle/123456789/1475

Pumijumnong, N., & Chareonwong, U. (2017). *The project to survey the status of sustainable development goals in the context of Thailand and options for economic, social, and legal measures. Goal 15*. Retrieved from Mahidol University.: https://www.sdgmove.com/wp-content/uploads/2023/08/final-report-sdgs-goal-15.pdf

Royal Irrigation Department. (2005). *Feasibility Study (FS) and Environmental Impact Assessment (EIA) of the Wang Chomphu Reservoir Project, Nernmaprang District, Phitsanulok Province*. Bangkok: Royal .rrigation Department.

Royal Irrigation Department. (2007). *The Environmental Impact Assessment Review Study for the Khlong Madua Reservoir Project, Nakhon Nayok Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2009). *Environmental Impact Analysis Report of the Huai Samong Reservoir Project, Prachinburi Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2010). *Preliminary Environmental Impact Analysis Report of the Huai Phong Phak Reservoir Project, Lampang Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2012a). *Environmental Impact Assessment (EIA) Report for the Ban Nong Ta Tang Reservoir Project, Ratchaburi Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2012b). *Environmental Impact Assessment Report of the Lower Khlong Klung Reservoir Project, Kamphaeng Phet Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2012c). *Preliminary Environmental Impact Assessment Report for the Phet Ja Khor Reservoir Project (Klong Nasuan), Kamphaeng Phet Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2012d). *Preliminary Environmental Impact Assessment Report of the Klong Pla Soi Reservoir Project, Kamphaeng Phet Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2014). *Preliminary Environmental Impact Study Report of the Sae Or Reservoir Project, Watthana Nakhon District, Sa Kaew Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2015a). *The Environmental Impact Assessment (EIA) for the Huai Saton Reservoir Project, Sa Kaeo Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2015b). *Project Review Study to Enhance Capacity and Water Retention Capability of Nam Pee Reservoir Project, Phayao Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2016a). *Feasibility Study (FS) and Environmental Impact Assessment (EIA) Review Study of the Mae Nueang Reservoir Project, Lampang Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2016b). *The feasibility study and environmental impact assessment of the Nam Ki Reservoir Project, Phrae Province*. Bangkok: Royal Irrigation Department.

Royal Irrigation Department. (2016c). *Feasibility Study and Environmental Impact Assessment of the Wang Heeb Project, Nakhon Si Thammarat Province*. Bankok: Royal Irrigation Department.

Royal Irrigation Department. (2018a). *Environmental Impact Analysis Report of the Huai Kra Laeng Reservoir Project, Chaiyaphum Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2018b). *Environmental Impact Assessment (EIA) of the Huai Khayung Reservoir Project, Sisaket Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2019a). *Environmental Impact Analysis Report of the Huai Samong Reservoir Project, Prachinburi Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2019b). *The Environmental Impact Assessment Study of the Mae Pa Phai Reservoir Project, Hod District, Chiang Mai Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2019c). *Review of Environmental Impact Assessment Report of the Huai Sa Tor Reservoir Project, Trat Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2020a). *The Ban Muang Takua Reservoir Project, Pa Bon District, Phatthalung Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2020b). *Environmental Impact Assessment Report for the Mae Pan Reservoir, Lampang Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2020c). *Environmental impact assessment report of the Huai Pang Luang Reservoir Project, Samoeng Subdistrict, Chiang Mai Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2020d). *Preliminary Feasibility Study and Environmental Impact Assessment of the Huai Pao Reservoir Project, Song District, Phrae Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2021a). *Environmental and Health Impact Assessment Report for Wang Tanode Reservoir Project, Chanthaburi Province*. Bangkok: Royal Irrigation Department,
Royal Irrigation Department. (2021b). *Environmental Impact Assessment (EIA) Report for the Mae Phuak Reservoir Project, Phrae Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2021c). *Environmental Impact Assessment of the Huai Ta Pue Reservoir (EIA), Khamcha-E District, Mukdahan Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2021d). *Environmental Impact Assessment Report for the Nam Yuen Reservoir Project, Phayao Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2022). *Environmental Impact Assessment Report of the Nam Pad Reservoir Project, Uttaradit Province*. Bangkok: Royal Irrigation Department.
Royal Irrigation Department. (2023). *The preliminary environmental impact assessment report of the Mae Bom Reservoir Project, Lampang Province*. Bangkok: Royal Irrigation Department,.
Royal Irrigation Department (Cartographer). (2024a). Location Map of Reservoir. Retrieved from https://gis.rid.go.th/beta/services/prjarea_all.php
Royal Irrigation Department. (2024b). *The preliminary environmental impact assessment report of the Khlong Yai Reservoir Project, Ban Na Subdistrict, Si*

Nakharin District, Phatthalung Province. Bangkok: Royal Irrigation Department.

Segnestam, L. (2003). *Indicators of Environment and Sustainable Development Theories and Practical Experience*.

Smith, E., & Zhang, H. (2007). EVOLUTION OF SUSTAINABLE WATER RESOURCES INDICATORS. *Proceedings of the Water Environment Federation, 2007*, 2624-2649. doi:10.2175/193864707787960567

Tang, X., Guan, X., Lu, S., Qin, F., Liu, X., & Zhang, D. (2020). Examining the spatiotemporal change of forest resource carrying capacity of the Yangtze River Economic Belt in China. *Environmental Science and Pollution Research, 27*(17), 21213-21230. doi:10.1007/s11356-020-08408-w

The Enhancement and Conservation of National Environment Quality Act B.E.2535 (1992). Thai Royal Government Gazette, 136 C.F.R. § 71 A (1992).

The Act on National Reserved Forests (No. 4) B.E. 2559. (2016, 24 May). Thai Royal Government Gazette, 133 C.F.R. § 46 A (2016, 24 May).

The Constitution of the Kingdom of Thailand, B.E. 2560. (2017, 6 April). Thai Royal Government Gazette, 134 C.F.R. § 40 A (2017, 6 April).

The Act on Water B.E. 2561. (2018, 28 December). Thai Royal Government Gazette, 135 C.F.R. § 112 A (2018, 28 December).

The Act on National Parks B.E. 2562. (2019, 29 May). Thai Royal Government Gazette,, 136 C.F.R. § 71 A (2019, 29 May).

The announcement regarding the determination of the value of natural resources in National Park, Park, Forest park, and Arboretum 2021 (2021, 9 December). Thai Royal Government Gazette,, 138 C.F.R. § 301 Ngo (2021, 9 December).

The National Statistical Office of Thailand. (2023). *Establishment of the water management indicator (WMI) in Thailand*. Bangkok: The National Statistical Office of Thailand.

APPENDICES

Appendix A

Data Summary of 30 Water Resource (reservoir) Development Project

Table A.1 Summary of Engineering Data of 30 Reservoir Projects

	No.	1	2	3	4	5	6	7	8
	Reservoir	Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
	Province	Phattalung	Lam Pang	Chiang Mai	Lam Pang	Chiang Mai	Phrae	Chanthaburi	Sa Kaeo
1. Engineering Dimension									
1	Reservoir capacity (mcm)	17.50	15.10	20.40	12.50	2.10	9.10	99.50	22.30
2	Reservoir area (Rai)	730.00	600.00	930.00	454.00	123.00	457.00	11,000.00	3,418.00
3	Mean Annual Inflow (mcm)	33.16	38.81	23.46	25.00	2.75	7.55	119.40	24.31
5	Flood Peak Discharge (cms)	220.00	438.00	339.00	374.00	40.00	111.00	464.00	296.74
6	Reservoir Catchment Area (sq.km)	23.00	89.00	73.00	103.00	11.00	27.00	255.00	96.00
7	Seismic by Mercalli scale / Distance (km)	1-3 (134)	7	5	7 (0.2)	5-7 (25)	6-7	3(107)	1-3(22)
8	Leakage (1-5) Bedrock (1-5)	2 Garnite (L-M)	4 Garnite (L-H)	1 Garnite (L)	4 Sand (H)	4 Sand (H)	2 (L-M)	2 Sand (L-M)	2 Sand (L-M)
9	Irrigation Area (Rai)	54,000.00	9,798.00	6,683.00	9,200.00	1,273.00	8,000.00	87,700.00	19,550.00
10	Rain Season Crop Area (Rai)	31,280.00	9,798.00	6,683.00	9,200.00	1,273.00	8,000.00	7,400.00	19,550.00
11	Dry Season Crop Area (Rai)	13,525.00	1,948.00	2,520.00	-	1,131.00	-	6,665.00	978.00
12	Perennial Crop Area (Rai)	20,911.00	-	-	-	-	-	80,300.00	-
14	Dam Crest Length (m)	735.00	465.00	290.00	798.00	132.50	160.00	3,000.00	1,670.00
15	Dam Height (m)	41.50	53.00	47.00	51.00	42.15	43.00	25.00	18.00
16	Dam Location								
	- Latitude (N) , Y	7° 34' 53"	18° 46' 51"	18° 04' 07"	18° 41' 26"	18° 53' 57"	17° 52' 14.95"	13° 08' 31"	14° 06' 13"
	- Longitude (E) , X	99° 50' 58"	99° 28' 37"	98° 26' 04"	99° 27' 36"	98° 40' 24"	99° 59' 32.86"	101° 58' 31"	102° 35' 25"

	No.	9	10	11	12	13	14	15
	Reservoir	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
	Province	Nakhonsi thammarat	Phrae	Phayao	Lam Pang	Phitsanulok	Trat	Kamphaeng Phet
1. Engineering Dimension								
1	Reservoir capacity (mcm)	85.20	52.30	30.00	9.20	86.30	57.27	21.29
2	Reservoir area (Rai)	1,534.00	1,170.00	948.00	381.00	2,618.00	4,385.00	1,915.00
3	Mean Annual Inflow (mcm)	96.40	73.22	53.10	14.90	150.16	161.08	70.87
5	Flood Peak Discharge (cms)	408.00	356.00	492.00	188.00	748.00	461.79	421.28
6	Reservoir Catchment area (sq.km)	62.00	89.00	150.00	89.00	338.00	86.00	165.37
7	Seismic by Mercalli scale / Distance (km)	1-2	7(8)	6(27)	5-7(22)	5(75)	1-2	5-7(38)
8	Leakage (1-5) Bedrock (1-5)	4 (H)	4 Sand (H)	4 Sand (H)	2 (L-M)	4 (H)	2 (L-M)	4 Sand (H-VH)
9	Irrigation Area (Rai)	60,500.00	44,120.00	20,910.00	7,407.00	90,300.00	53,000.00	19,732.00
10	Rain Season Crop Area (Rai)	60,500.00	35,650.00	20,910.00	7,407.00	90,300.00	53,000.00	19,732.00
11	Dry Season Crop Area (Rai)	-	16,796.00	7,110.00	5,350.00	17,600.00	-	6,992.00
12	Perennial Crop Area (Rai)	-	-	-	-	-	-	-
14	Dam Crest Length (m)	705.00	820.00	572.00	290.00	1,100.00	900.00	1,040.00
15	Dam Height (m)	80.00	74.50	40.20	57.50	49.50	31.00	23.00
16	Dam Location							
	- Latitude (N) , Y	14° 15' 15"	19° 13' 16.5"	19° 30' 34"	18° 34' 14"	16° 40' 54.09"	12° 41' 09"	16° 03' 21"
	- Longitude (E) , X	101° 15' 06"	100° 44' 53.5"	100° 23' 25.5"	99° 26' 18"	100° 42' 59.25"	102° 24' 02"	99° 18' 49"

	No.	16	17	18	19	20	21	22	23	24
	Reservoir	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao	Khlong Wang Heeb
	Province	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet	Phayao	Phare	Prachin Buri	Sa Kaeo	Phayao	Nakhonsi thammarat
1. Engineering Dimension										
1	Reservoir capacity (mcm)	40.00	9.00	5.18	90.50	11.47	295.00	2.57	2.35	20.10
2	Reservoir area (Rai)	3,253.00	402.00	509.65	3,626.00	459.00	16,250.00	455.21	87.00	510.00
3	Mean Annual Inflow (mcm)	77.62	11.25	6.47	127.27	19.50	266.00	4.03	2.89	27.77
5	Flood Peak Discharge (cms)	186.40	140.10	112.61	1,343.00	201.00	1,190.00	94.34	35.56	184.24
6	Reservoir Catchment areas (sq.km)	146.00	26.23	15.65	570.00	76.28	443.00	14.85	11.30	30.00
7	Seismic by Mercalli scale / Distance (km)	5-7(42)	3.00	5-7(11.5)	5.00	3.00	3	1-3	4-6	3-5
	Leakage (1-5)	2	4	4	3	3	3	4	3	3
8	Bedrock (1-5)	(M)	(H)	Sand (M-H)	(M)	(M)	Sand (L-M)	Sand (M-H)	Sand/Mud (L-H)	Sand-Gra (L-H)
9	Irrigation Area (Rai)	42,500.00	4,376.00	2,812.00	48,000.00	12,000.00	111,300.00	4,740.00	2,310.00	13,014.00
10	Rain Season Crop Area (Rai)	42,500.00	4,376.00	2,812.00	48,000.00	12,000.00	111,300.00	4,740.00	2,310.00	13,014.00
11	Dry Season Crop Area (Rai)	18,800.00	1,514.00	639.00	36,800.00	-	-	898.00	1,623.00	-
12	Perennial Crop Area (Rai)	-	-	-	-	-	-	-	-	-
14	Dam Crest Length (m)	620.00	600.00	1,520.00	810.00	500.00	2,960.00	350.00	320.00	340.00
15	Dam Height (m)	24.35	33.00	16.00	56.00	40.00	13.25	11.00	45.00	65.22
16	Dam Location									
	- Latitude (N) , Y	14° 29' 17"	16° 01' 11"	16° 17' 45"	18° 54' 33"	18° 04' 07.65"	14° 04' 46"	13° 58' 50.23"	18° 45' 36.55"	08° 14' 19.21"
	- Longitude (E) , X	104° 32' 36"	99° 17' 07"	99° 15' 39"	100° 20' 25"	100° 13' 18.63"	102° 01' 49"	102° 31' 51.27"	100° 18' 50.23"	99° 40' 46.70"

		No.	25	26	27	28	29	30
		Reservoir	Nong Ta Tang	Huai Ka Laeng	Huai Ta Pur	Huai Pong Phark	Ban Mueng Ta Kua	Nam Pard
		Province	Ratchburi	Chaiyaphum	Mukdahan	Lampang	Phatthalung	Uttlaradit
1. Engineering Dimension								
1	Reservoir capacity (mcm)		48.37	4.99	18.89	19.47	10.14	85.64
2	Reservoir area (Rai)		1,729.00	602.00	2,151.96	1,312.50	343.75	2,813.00
3	Mean Annual Inflow (mcm)		49.95	4.02	25.56	51.82	19.15	117.88
5	Flood Peak Discharge (cms)		328.07	50.20	291.52	539.47	120.67	1,428.00
6	Reservoir Catchment Area (sq.km)		254.31	16.50	50.00	266.00	20.27	677.00
7	Seismic by Mercalli scale / Distance (km)		1-3 (73)	1-3	1-2	5-7	1-3	5-7 (3)
	Leakage (1-5)		3	2	2	4	2	4
8	Bedrock (1-5)		Sand - Mud (L-M)	Sand (10-50 Lu)	Sand (L-M)	tuff (H)	(L-M)	Silt (H)
9	Irrigation Area (Rai)		39,300.00	3,100.00	10,969.00	13,000.00	7,500.00	57,822.00
10	Rain Season Crop Area (Rai)		39,300.00	3,100.00	10,000.00	13,000.00	7,500.00	44,259.00
11	Dry Season Crop Area (Rai)		-	1,175.00	2,386.00	4,628.00	2,000.00	44,187.00
12	Perennial Crop Area (Rai)		-	-	-	-	2,000.00	13,563.00
14	Dam Crest Length (m)		733.00	649.00	537.50	200.00	500.00	500.00
15	Dam Height (m)		48.80	13.50	23.50	31.00	48.00	51.80
16	Dam Location							
	- Latitude (N) , Y		13° 20' 43.97"	16° 16' 20.66"	16° 42' 06"	17° 31' 03.32"	07° 11' 47"	18° 03' 54"
	- Longitude (E) , X		99° 14' 38.44"	102° 04' 42.39"	104° 17' 54"	99° 22' 12.29"	100° 04' 29"	100° 55' 39"

Table A.2 Summary of Natural Resources and Environment Data of 30 Reservoir Projects

	No.	1	2	3	4	5	6	7	8
	Reservoir	Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
	Province	Phattalung	Lam Pang	Chiang Mai	Lam Pang	Chiang Mai	Phrae	Chanthaburi	Sa Kaeo
2. Natural Resource and Environment									
	Forestry								
1	Reservoir Area (Rai)	730.00	600.00	930.00	454.00	123.00	457.00	11,000.00	3,418.00
3.1	Impacted National Parks Area (Rai)	394.00	100.00	-	235.00	38.54	-	5,600.00	3,418.00
3.2	Impacted Wildlife Sanc. Area (Rai)	-							
3.3	Impacted Watershed Class 1 Area (Rai)	0	83.00	0	193.00	0	67.00	0	0
3.4	Impacted Reserved Forest (C) Area (Rai)	474.00	484.00	930.00	327.00	74.86	564.00	5,400.00	0
4	Full Area (Rai)	265,625.00	480,000.00	98,487.00	480,000.00	442,500.00	112,067.00	75,000.00	371,250.00
	National Parks Area (Rai)	Tai Rom Yen	Jae Sone		Jae Sonn	Khun Khan		Khao Sib Ha Chan	Ta Pharya
	Wildlife Sanc. Area (Rai)	Khao Ban Tad							
	Reserved Forest (C) Area (Rai)	Khao Ban Tad	Mae Sook/ Mae Soi	Mae Jaem / Mae Tuen	Mae TuiFung Khwa	Samoeng	Mae Phuak		
5	Impacted Area/Full Area	0.15	0.02	0.94	0.05	0.01	0.06	7.47	0.92
6	Location (rim, core)	Rim P	Rim P	Rim C	Rim P	Rim P	Rim F	Rim P	Rim P
7	Abundance / Big Tree Density								
	-Deciduous forest			107.00					
	-Mixed forest		20.60	117.00	15.50	123.00	87.80	12.32	116.00
	- Evergreen forest	75.00							110.00
8	Bio-diversity (No.of species)	144.00	77.00	116.00	83	67.00	134.00	84.00	156.00
	-Deciduous forest			63.00					
	-Mixed forest		77.00	53.00		67.00	134.00	84.00	156.00
	- Evergreen forest	144.0							

	No.	1	2	3	4	5	6	7	8
	Reservoir	Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
	Province	Phattalung	Lam Pang	Chiang Mai	Lam Pang	Chiang Mai	Phrae	Chanthaburi	Sa Kaeo
2. Natural Resource and Environment									
9	Prohibited Tree (No. species)	69.00	22.00	33	49.00	30.00	45.00	46.00	52.00
	Type Kor (No.)	69.00	-		49.00	29.00	44.00	44.00	51.00
	Type khor (No.)	-	22.00			1.00	1.00	2.00	1.00
10	No.Prohibited / Total No. of species	47.92	28.57	28.26	58.93	44.78	33.58	54.76	33.33
11	Uniqueness (Yes / NO)	NO	NO	NO	NO	NO		NO	NO
12	Wildlife								
12.1	Abundance / No. of low density species	97 (ME)	132 (MD)	50(MD,DD)	92 (MD,DD)	91.00	91.00	123 (MD, DE)	137 (MD, DE)
		97.00	132.00	50.00	92.00	91.00	91.00	123.00	137.00
12.2	No. of species in reservoir	155.00	239.00	137.00	178.00	168.00	179.00	184.00	201.00
12.3	LUCN's Red List (No.)	3.00	3.00	3.00	6.00	3.00	0	9.00	14.00
	(VU+EN+CR)	(2VU/1EN/-CR)							(8VU/6EN/-CR)
	% of species in reservoir	63%	55%	36%	52%	54%	51%	67%	68%
13	Uniqueness (Yes / NO)								

	No.	9	10	11	12	13	14	15
	Reservoir	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
	Province	Nakhonsithammarat	Phrae	Phayao	Lam Pang	Phitsanulok	Trat	Kamphaeng Phet
2. Natural Resource and Environment								
	Forestry							
1	Reservoir Area (Rai)	1,534.00	1,170.00	948.00	381.00	2,618.00	4,385.00	1,915.00
3.1	Impacted National Parks Area (Rai)	980.00		127.00		2,905.00	-	42.00
3.2	Impacted Wildlife Sanc. Area (Rai)						-	
3.3	Impacted Watershed Class 1 Area (Rai)	0	0	25.00	0	0	0	0
3.4	Impacted Reserved Forest (C) Area (Rai)	0	1667	833.00	403.00	0	880.00	2235
4	Full Area (Rai)	1,353,475.00	1,357,194.00	178,049.00	432,551.00	789,000.00	616,166.00	472,136.00
	National Parks Area (Rai)	Khao Yai		Phu Sang	Mae Sook/ Mae Soi	Laeng Luang		Mae Wong
	Wildlife Sanc. Area (Rai)							
	Reserved Forest (C) Area (Rai)		Nam- Yao- Nam Suad	Nam Puei Nam Yuan Nam Lao	Mae Tui Fung Khwa		Khao Samimg/ Tok Phrom	Khlong Khlung, Mae Wong/ Khlong Suan Mark
5	Impacted Area/Full Area	0.07	0.12	0.07	0.09	0.37	0.14	0.01
6	Location (rim, core)	Rim P	Rim F	Rim P	Core C	Rim P	Rim F	Rim P
7	Abundance / Big Tree Density							
	-Deciduous forest							
	-Mixed forest		6.80	178.00	42.00	49.06		64.00
	- Evergreen forest	52.00					43.00	
8	Bio-diversity (No.of species)	145.00	83.00	87.00	90.00	83	163.00	15.00
	-Deciduous forest			42.00				
	-Mixed forest		83.00	45.00	90.00			15.00
	- Evergreen forest	145.00					53.00	
9	Prohibited Tree (No. species)	49.00	24.00	33	59.00	33	63.00	8.00
	Type Kor (No.)	49.00	23.00		58.00		63.00	8.00
	Type khor (No.)	-	1.00		1.00		-	-

	No.	9	10	11	12	13	14	15
	Reservoir	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
	Province	Nakhonsithammarat	Phrae	Phayao	Lam Pang	Phitsanulok	Trat	Kamphaeng Phet
10	No.Prohibited / Total No. of species	33.79	28.92	37.68	65.56	39.42	38.65	53.33
11	Uniqueness (Yes / NO)	NO	NO	NO	NO		NO	NO
12	Wildlife							
12.1	Abundance / No. of low density species	120 (MD)	68 (MD)	75 (MD)	77.00	95.86	90 (ME)	47 (MD)
		120.00	68.00	75.00	77.00	95.86	90.00	47.00
2.2	No. of species in reservoir	220.00	140.00	215.00	117.00	167.45	172.00	114.00
12.3	LUCN's Red List (No.)	15.00	2.00	8.00	1.00	4.62	2.00	-
	(VU+EN+CR)	(12VU/3EN/-CR)	(2VU/-EN/-CR)	(4VU/4EN/-CR)			1VU/1 EN	
	% of species in reservoir	55%	49%	35%	66%	57%	52%	41%
13	Uniqueness (Yes / NO)							

	No.	16	17	18	19	20	21	22	23
	Reservoir	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao
	Province	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet	Phayao	Phare	Prachin Buri	Sa Kaeo	Phayao
2. Natural Resource and Environment									
	Forestry								
	Reservoir Area (Rai)	3,253.00	402.00	509.65	3,626.00	459.00	16,250.00	455.21	87.00
1	Impacted National Parks Area (Rai)		390.00	16.00	2,480.00		2,169.00		87.00
3.1	Impacted Wildlife Sanc. Area (Rai)	1,611.00	87.00			22.01	480.00		87.00
3.2	Impacted Watershed Class 1 Area (Rai)	0		-					-
3.3	Impacted Reserved Forest (C) Area (Rai)	2,050.00	100.00	18.00	1,612.00	32.77	2,457.00	455.00	-
3.4	Full Area (Rai)	211,553.00	572,730.00	259,678.00	538,125.00	167,370.00	1,400,000.00	579,427.00	284,218.00
4	National Parks Area (Rai)		Mae Wong	Khlong Larn	Doi Phu Nang		Tap Lan / Pang Sida	Pang Sida	Mae Yom
	Wildlife Sanc. Area (Rai)	Phanom Dong Rak							
	Reserved Forest (C) Area (Rai)	Khao Phra Wihan		Klong Suan Mark	Mae Yom	Mae Kon, Mae Sai			Mae Song
	Impacted Area/Full Area	0.76	0.07	0.01	0.46	0.01	0.15	0.08	0.03
5	Location (rim, core)	Rim W	Core P	Rim	Rim	Core C	RIM	Core C	Core P
6	Abundance / Big Tree Density	110.00							
7	-Deciduous forest -Mixed forest - Evergreen forest		70.00	20.00	49.06	11.36	58 (ต่าง)	34.00	11.30
8	Bio-diversity (No.of species)	249.00	55.00	13.00	200.00	25.00	19.00	57.00	75.00
	-Deciduous forest	49.00			82.00				
	-Mixed forest	122.00	55.00	13.00	118.00	25.00		57.00	75.00
	- Evergreen forest	78.00					19.00		
9	Prohibited Tree (No. species)	71.00	9.00	5.00	51.00	8.00	15.00	8.00	20.00
	Type Kor (No.)	71.00	9.00	5.00	51.00	8.00	15.00	8.00	20.00
	Tpe khor (No.)	-	-	-	-	-	-	-	-

	No.	16	17	18	19	20	21	22	23
	Reservoir	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao
	Province	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet	Phayao	Phare	Prachin Buri	Sa Kaeo	Phayao
2. Natural Resource and Environment									
10	No.Prohibited / Total No. of species	28.51	16.36	38.46	25.50	32.00	78.95	14.04	26.67
11	Uniqueness (Yes / NO)	NO	NO	NO	Forest Sago Palm (Cyeas Palm)	NO	NO	NO	NO
12	Wildlife								
12.1	Abundance / No. of low density species	116.00 116.00	57 (MD) 57.00	44.00 44.00	90 (MD) 90.00	123.00 123.00	86 (DE) 86.00	97.00 97.00	72.00 72.00
12.2	No. of species in reservoir	186.00	143.00	113.00	187.00	128.00	193.00	156.00	120.00
12.3	LUCN's Red List (No.) (VU+EN+CR)	6.00 (5VU/1EN/-)	15.00 (12VU/3EN/-)	2.00 (1VU/1EN/-)	2.00 (-VU/2EN/-)	0	6.00 (6VU/-EN/-CR)	3.00 (2VU/1EN/-CR)	1.00 (1VU/-EN/-CR)
	% of species in reservoir	62%	40%	39%	48%	96%	45%	62%	60%
13	Uniqueness (Yes / NO)								

Table A.3 Summary of Social Data of 30 Reservoir Projects

	No.	1	2	3	4	5	6	7	8
	Reservoir	Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
	Provine	Phattalung	Lam Pang	Chiang Mai	Lam Pang	Chiang Mai	Phrae	Chanthaburi	Sa Kaeo
3. Social Dimension									
1	Reservoir capacity (mcm)	17.50	15.10	20.40	12.50	2.10	9.10	99.50	22.30
2	Reservoir area (Rai)	730.00	600.00	930.00	454.00	123.00	457.00	11,000.00	3,418.00
3	Irrigation Area (Rai)	54,000.00	9,798.00	6,683.00	9,200.00	1,273.00	8,000.00	87,700.00	19,550.00
4	No. of Benefited Vill (No.)	86.00	10.00	11.00	17.00	2.00	21.00	39.00	7.00
5	No. of Benefited HH (No.)	21,226.00	1,788.00	1,753.00	3,353.00	334.00	8,731.00	5,403.00	
6	Benefited Population (No.)	53,020.00	4,200.00	5,097.00	10,146.00	900.00		22,093.00	
7	Impacted HH in Reservoir (No.)	62.00	39.00	65	97.00	0.00	13.00	324.00	0
8	Impacted Houses in Reservoir (No.)	9.00	31.00	0	0.00	0.00	-	203.00	0
9	Impacted Land in Reservoir (No.)	689.50	125.00	5.98	97.00	0.00	54.28	6,589.00	0
10	No. of benefited HH (No.)							4,116.00	900.00
11	No. of Protester HH (No.)	24.00	1.00	2	0.00	0.00	-	17.00	0
		38.71%	2.56%	3.08%	0.00%	0.00%	0.00%	5.25%	0.00%
12	Life Value / Unique								
12.1	Archaeological Place (No/Yes)	NO	NO	rock equipment	San Chao Phor Taen Kaew	NO	NO	NO	Rock engrave
12.2	Eco-natural tourist (Yes /No)	NO	NO	NO	NO	NO	NO	No	Thung Krating
12.3	Geo Conservation (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
12.4	Value Mineral Resources (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
12.5	Ethanoic (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
13	Protestor / Impacted HH	38.71	2.56	3.08	-	0.00%	-	5.25	0.00%
14	No. of HH Impacted / Capacity	3.54	2.58	3.19	7.76	-	1.43	3.26	-
15	Compensated Land Area /Capacity	39.40	8.28	0.29	7.76	-	5.96	66.22	-
16	Benefit Area / Reservoir Area	73.97	16.33	7.19	20.26	10.35	17.51	7.97	5.72

		No.	9	10	11	12	13	14	15
		Reservoir	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
		Provine	Nakhonsithammarat	Phrae	Phayao	Lam Pang	Phitsanulok	Trat	Kamphaeng Phet
3. Social Dimension									
1	Reservoir capacity (mcm)		85.20	52.30	30.00	9.20	86.30	57.27	21.29
2	Reservoir area (Rai)		1,534.00	1,170.00	948.00	381.00	2,618.00	4,385.00	1,915.00
3	Irrigation Area (Rai)		60,500.00	44,120.00	20,910.00	7,407.00	90,300.00	53,000.00	19,732.00
4	No. of Benefited Vill (No.)		41.00	3.00	57.00				8.00
5	No. of Benefited HH (No.)		60,500.00	230.00	7,805.00				1,118.00
6	Benefited Population (No.)								5,366.40
7	Impacted HH in Reservoir (No.)		76.00	113.00	83.00	344.00	119.56	151.00	119.56
8	Impacted Houses in Reservoir (No.)		84.00	15.00	22.00	21.00	1.00	83.00	17.00
9	Impacted Land in Reservoir (No.)		695.00	1,306.12	715.00	85.60	220.00	4,297.00	1,816.00
10	No. of benefited HH (No.)		16.00						
11	No. of Protester HH (No.)			15.00	60.00	13.00	47.82	0.00	47.82
			21.05%	13.27%	72.29%	3.78%	40.00%	0.00%	40.00%
12	Life Value / Unique				-				
12.1	Archaeological Place (No/Yes)		NO	NO	NO	NO	NO	NO	Hermitage Wat Prang Khaw San
12.2	Eco-natural tourist (Yes /No)		NO	NO	NO	NO	NO	NO	NO
12.3	Geo Connservation (Yes/No)		NO	NO	NO	NO	NO	NO	NO
12.4	Value Mineral Resources (Yes/No)		NO	NO	NO	NO	NO	NO	NO
12.5	Ethnoic (Yes/No)		NO	NO	Mian /Yao Ethnic	NO	NO	NO	NO
13	Protestor / Impacted HH		-	13.27	72.29	3.78	40.00	-	40.00
14	No. of HH Impacted / Capacity		0.89	2.16	2.77	37.39	1.39	2.64	5.62
15	Compensated Land Area /Capacity		8.16	24.97	23.83	9.30	2.55	75.03	85.30
16	Benefit Area / Reservoir Area		39.44	37.71	22.06	19.44	34.49	12.09	10.30

	No.	16	17	18	19	20	21	22	23
	Reservoir	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao
	Provine	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet	Phayao	Phare	Prachin Buri	Sa Kaeo	Phayao
3. Social Dimension									
1	Reservoir capacity (mcm)	40.00	9.00	5.18	90.50	11.47	295.00	2.57	2.35
2	Reservoir area (Rai)	3,253.00	402.00	509.65	3,626.00	459.00	16,250.00	455.21	87.00
3	Irrigation Area (Rai)	42,500.00	894.00	2,812.00	28,000.00	1,520.00	111,300.00	4,740.00	2,310.00
4	No. of Benefited Vill (No.)	27.00		3.00		14.00			4.00
5	No. of Benefited HH (No.)	2,873.00	305.00	671.00		2,107.00			677.00
6	Benefited Population (No.)	10,494.00		2,221.01					2,180.00
7	Impacted HH in Reservoir (No.)	164.00	9.00	46.00	175.00	94.00	604.00	119.56	2.00
8	Impacted Houses in Reservoir (No.)	105.00	1.00	8.00	26.00	179.00	926.00	-	0.00
9	Impacted Land in Reservoir (No.)	1,905.00	40.00	927.00	496.00	482.03	13,450.97	216.87	7.00
10	No. of benefited HH (No.)		305.00	350.00					
11	No. of Protester HH (No.)	91.00	37.00	41.00	35.00	14.00	13.00	47.82	0.00
		55.49%	411.11%	89.13%	20.00%	14.89%	2.15%	40.00%	0.00%
12	Life Value / Unique								
12.1	Archaeological Place (No/Yes)	NO	NO	Khun Silom Farm	NO	NO	Hermitage in Reservoir 3 Ancient Commu in Area	NO	NO
12.2	Eco-natural tourist (Yes /No)	NO	Mae Wong NP	Phet Ja Khor Water Fall 1.6 Km. apart	NO	NO	NO	NO	NO
12.3	Geo Conservation (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
12.4	Value Mineral Resources (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
12.5	Ethanoic (Yes/No)	NO	NO	NO	NO	NO	NO	NO	NO
13	Protestor / Impacted HH	55.49	411.11	89.13	20.00	14.89	2.15	40.00	-
14	No. of HH Impacted / Capacity	4.10	1.00	8.88	1.93	8.20	2.05	46.52	0.85
15	Compensated Land Area /Capacity	47.63	4.44	178.96	5.48	42.03	45.60	84.39	2.98
16	Benefit Area / Reservoir Area	13.06	2.22	5.52	7.72	3.31	6.85	10.41	26.55

		No.	24	25	26	27	28	29	30
		Reservoir	Khlong Wang Heeb	Nong Ta Tang	Huai Ka Laeng	Huai Ta Pur	Huai Pong Phark	Ban Mueng Ta Kua	Nam Pard
		Provine	Nakhonsithammarat	Ratchburi	Chaiyaphum	Mukdahan	Lampang	Phatthalung	Uttlaradit
3. Social Dimension									
1	Reservoir capacity (mcm)		20.10	48.37	4.99	18.89	19.47	10.14	85.64
2	Reservoir area (Rai)		510.00	1,729.00	602.00	2,151.96	1,312.50	343.75	2,813.00
3	Irrigation Area (Rai)		13,014.00	39,300.00	3,100.00	10,969.00	13,000.00	7,500.00	59,000.00
4	No. of Benefited Vill (No.)			20.00	3.00	3.00	6.00	19.00	30.00
5	No. of Benefited HH (No.)			1,909.00	509.00		1,162.00		9,702.00
6	Benefited Population (No.)			7,233.00	2,135.00		3,717.00	15,331.00	350,000.00
7	Impacted HH in Reservoir (No.)		73.00	53.00	23.00	179.00	119.56	79.00	186.00
8	Impacted Houses in Reservoir (No.)		62.00	55.00	15.00	0.00	28.00	7.00	41.00
9	Impacted Land in Reservoir (No.)		660.00	339.50	325.00	182.88	94.22	407.00	1,016.00
10	No. of benefited HH (No.)				509.00		1,162.00	NA	NA
11	No. of Protester HH (No.)		21.00	43.00	22.00	1.00	47.82	2.00	15.00
			28.77%	81.13%	95.65%	0.56%	40.00%	2.53%	8.06%
12	Life Value / Unique								
12.1	Archaeological Place (No/Yes)		NO	NO	NO	NO	NO	NO	NO
12.2	Eco-natural tourist (Yes /No)		NO	NO	NO	NO	NO	NO	NO
12.3	Geo Connservation (Yes/No)		NO	NO	NO	NO	NO	NO	NO
12.4	Value Mineral Resources (Yes/No)		NO	Felpar, Fluoride, Tin	NO	NO	NO	NO	NO
12.5	Ethnoic (Yes/No)		NO	NO	NO	NO	NO	NO	NO
13	Protestor / Impacted HH		28.77	81.13	95.65	0.56	40.00	2.53	8.06
14	No. of HH Impacted / Capacity		3.63	1.10	4.61	9.48	6.14	7.79	2.17
15	Compensated Land Area /Capacity		32.84	7.02	65.12	9.68	4.84	40.14	11.86
16	Benefit Area / Reservoir Area		25.52	22.73	5.15	5.10	9.90	21.82	20.97

Table A-4 Summary of Economic Data of 30 Reservoir Projects

	No.	1	2	3	4	5	6	7	8
	Reservoir	Khlong Yai	Mae Pan	Mae Pah Phai	Mae Bom	Mae Pang Luang	Mae Phuak	Khlong Wang Tanode	Huai Satone
	Provine	Phattalung	Lam Pang	Chiang Mai	Lam Pang	Chiang Mai	Phrae	Chanthaburi	Sa Kaeo
4.Economic Dimension									
1	Max. Reservoir area (Rai)	17.50	15.10	20.40	12.50	2.10	9.10	99.50	22.30
2	Irrigation Area (Rai)	54,000.00	9,798.00	6,683.00	9,200.00	1,273.00	8,000.00	87,700.00	19,550.00
3	Construction Cost (MB)	918.00	1,036.00	519.69	663.01	302.22	638.00	2,622.63	809.00
4	Land Compensate Cost (MB)	62.05	12.12	0.57	12.33	0.00	6.51	395.33	11.79
5	Facility Compensate Cost (MB)	1.90	0.35	0.00	0.00	0.00	-	98.25	-
6	Plannt Compensate (MB)	187.78	10.18	2.08	0.43	0.00	1.03	1,496.10	1.21
7	Total Social Compensate Cost (MB)	251.73	22.65	2.65	12.76	-	7.54	1,989.68	13.00
8	EIMP Cost (MB)	164.00	100.00	127.00	106.62	3.65	102.43	624.00	140.00
9	Total Cost (MB)	1,333.73	1,158.65	649.34	782.39	305.87	747.97	5,236.31	962.00
10	B/C Raito	1.45	1.06	1.35	NA	1.14	1.02	2.73	1.38
11	EIRR (%)	16.39	12.50	9.39	9.64	10.25	9.08	17.59	13.66
12	NPV (MB)	318.00	434.00	179.26	NA	20.61	12.12	6,839.25	234.78
13	Construction / Capacity (MB /mcm.)	52.46	68.61	25.48	53.04	143.92	70.11	26.36	36.28
14	Social Cost / Capacity (MB / mcm)	14.38	1.50	0.13	1.02	-	0.83	20.00	0.58
15	EIMP Cost / Capacity (MB / mcm)	9.37	6.62	6.23	8.53	1.74	11.26	6.27	6.28
16	ENVI EIRR (%)	14.10	9.66	6.89	7.64	9.25	9.21	12.70	11.66
17	Annual crop area (Rai)	65,716.00	11,746.00	9,203.00	17,069.00	2,404.00	11,061.00	94,365.00	20,528.00
18	Annual Crop Area (Rai/mcm)	3,755.20	777.88	451.13	1,365.52	1,144.76	1,215.49	948.39	920.54

	No.	9	10	11	12	13	14	15
	Reservoir	Khlong Ma Dua	Nam Ki	Nam Yuan	Mae Nueng	Klong Chomphu	Huai Sator	Khlong Khlung Lang
	Provine	Nakhonsithammarat	Phrae	Phayao	Lam Pang	Phitsanulok	Trat	Kamphaeng Phet
4.Economic Dimension								
1	Max. Reservoir area (Rai)	85.20	52.30	30.00	9.20	86.30	57.27	21.29
2	Irrigation Area (Rai)	60,500.00	44,120.00	20,910.00	7,407.00	90,300.00	53,000.00	926.80
3	Construction Cost (MB)	5,668.23	3,465.00	1,317.00	448.00	855.48	494.39	357.74
4	Land Compensate Cost (MB)	812.32	62.74	107.17	9.81	76.45	133.33	75.84
5	Facility Compensate Cost (MB)	153.45	0.31	4.56	0.23	0.19	23.87	15.70
6	Plant Compensate (MB)	57.97	152.66	42.05	1.04	-	606.49	13.78
7	Total Social Compensate Cost (MB)	1,023.74	215.70	153.78	11.08	76.64	763.69	105.32
8	EIMP Cost (MB)	180.00	191.00	176.00	116.00	30.00	131.50	119.86
9	Total Cost (MB)	6,871.97	3,871.70	1,646.78	575.08	962.12	1,389.58	463.06
10	B/C Raito	1.49	1.30	0.96	0.82	1.39	1.88	2.91
11	EIRR (%)	11.51	11.26	9.65	7.14	12.89	19.79	19.26
12	NPV (MB)	2,217.56	754.30	(45.73)	(199.06)	107.37	38.49	1,199.37
13	Construction / Capacity (MB /mcm.)	66.53	66.25	43.90	48.70	9.91	8.63	16.80
14	Social Cost / Capacity (MB / mcm)	12.02	4.12	5.13	1.20	0.89	13.33	4.95
15	EIMP Cost / Capacity (MB / mcm)	2.11	3.65	5.87	12.61	0.35	2.30	5.63
16	ENVI EIRR (%)	11.27	10.22	8.80	6.14	11.89	9.14	16.26
17	Annual crop area (Rai)	79,531.00	52,446.00	28,020.00	12,757.00	107,900.00	55,147.00	26,724.00
18	Annual Crop Area (Rai/mcm)	933.46	1,002.79	934.00	1,386.63	1,250.29	962.93	1,255.24

	No.	16	17	18	19	20	21	22	23
	Reservoir	Huai Khayoong	Klong Pla Soi	Khlong Phet Ja Khor	Nam Pee	Huai Mae Khon	Huai Samoeng	Huai Sae Or	Huai Pao
	Provine	Si Sa Ket	Kamphaeng Phet	Kamphaeng Phet	Phayao	Phare	Prachin Buri	Sa Kaeo	Phayao
4.Economic Dimension									
1	Max. Reservoir area (Rai)	40.00	9.00	5.18	90.50	11.47	295.00	2.57	2.35
2	Irrigation Area (Rai)	42,500.00	894.00	2,812.00	28,000.00	1,520.00	16,500.00	4,740.00	2,310.00
3	Construction Cost (MB)	306.12	326.59	237.07	2,080.75	481.54	3,085.18	209.77	445.00
4	Land Compensation Cost (MB)	152.40	0.64	22.49	31.39	40.24	403.53	9.14	0.72
5	Facility Compensation Cost (MB)	2.85	0.55	2.58	0.71	38.90	254.21	-	0.00
6	Plannt Compensation (MB)	94.48	0.09	5.15	21.85	19.40	790.14	0.58	0.00
7	Total Social Compensation Cost (MB)	249.73	1.28	30.22	53.95	98.54	1,447.88	9.72	0.72
8	EIMP Cost (MB)	257.12	16.54	24.67	243.12	18.76	48.08	0.82	26.66
9	Total Cost (MB)	812.97	344.41	291.96	2,377.82	598.84	4,581.14	220.31	472.38
10	B/C Raito	2.93	1.54	1.15	1.03	0.63	1.01	1.75	0.82
11	EIRR (%)	15.81	11.16	8.46	9.21	4.36	12.06	8.30	9.99
12	NPV (MB)	2,104.05	155.31	16.17	71.84	(248.38)	27.61	238.63	(71.33)
13	Construction / Capacity (MB /mcm.)	7.65	36.29	45.77	22.99	41.98	10.46	81.62	189.36
14	Social Cost / Capacity (MB / mcm)	6.24	0.14	5.83	0.60	8.59	4.91	3.78	0.31
15	EIMP Cost / Capacity (MB / mcm)	6.43	1.84	4.76	2.69	1.64	0.16	0.32	11.34
16	ENVI EIRR (%)	12.52	10.16	7.46	7.71	4.24	11.56	3.30	8.90
17	Annual crop area (Rai)	61,300.00	5,890.00	3,451.00	84,800.00	3,560.00	160,200.00	5,638.00	3,933.00
18	Annual Crop Area (Rai/mcm)	1,532.50	654.44	666.22	937.02	310.37	543.05	2,193.77	1,673.62

	No.	24	25	26	27	28	29	30
	Reservoir	Khlong Wang Heeb	Nong Ta Tang	Huai Ka Laeng	Huai Ta Pur	Huai Pong Phark	Ban Mueng Ta Kua	Nam Pard
	Provine	Nakhonsithammarat	Ratchburi	Chaiyaphum	Mukdahan	Lampang	Phatthalung	Uttlaradit
4.Economic Dimension								
1	Max. Reservoir area (Rai)	20.10	48.37	4.99	18.89	19.47	10.14	85.64
2	Irrigation Area (Rai)	13,014.00	39,300.00	3,100.00	10,969.00	13,000.00	7,500.00	59,000.00
3	Construction Cost (MB)	1,253.06	589.70	300.99	148.76	250.12	552.25	4,774.00
4	Land Compensation Cost (MB)	42.44	22.77	12.57	3.66	4.55	18.68	97.76
5	Facility Compensation Cost (MB)	22.37	8.63	0.42	-	3.54	11.38	7.79
6	Plannt Compensation (MB)	106.12	4.48	0.03	0.69	3.29	108.69	37.57
7	Total Social Compensation Cost (MB)	170.93	35.88	13.02	4.35	11.38	138.75	143.12
8	EIMP Cost (MB)	57.76	126.20	22.94	115.60	24.66	29.68	271.08
9	Total Cost (MB)	1,481.75	751.78	336.95	268.71	286.16	720.68	5,188.20
10	B/C Raito	1.09	1.29	1.20	1.37	1.28	1.58	1.16
11	EIRR (%)	8.75	15.15	10.86	11.56	12.74	10.67	15.09
12	NPV (MB)	143.18	436.59	53.70	134.71	74.53	533.46	619.96
13	Construction / Capacity (MB /mcm.)	62.34	12.19	60.31	7.88	12.85	54.46	60.58
14	Social Cost / Capacity (MB / mcm)	8.50	0.74	2.61	0.23	0.58	13.68	1.67
15	EIMP Cost / Capacity (MB / mcm)	2.87	2.61	4.60	6.12	1.27	2.93	3.17
16	ENVI EIRR (%)	8.63	11.76	9.85	9.79	9.79	9.27	14.01
17	Annual crop area (Rai)	23,054.00	71,146.00	4,275.00	12,386.00	17,628.00	11,500.00	102,009.00
18	Annual Crop Area (Rai/mcm)	1,146.97	1,470.87	856.54	655.69	905.39	1,134.12	1,191.14

Appendix B

Data Summary of Water Scarcity Factors and Other Related Maps

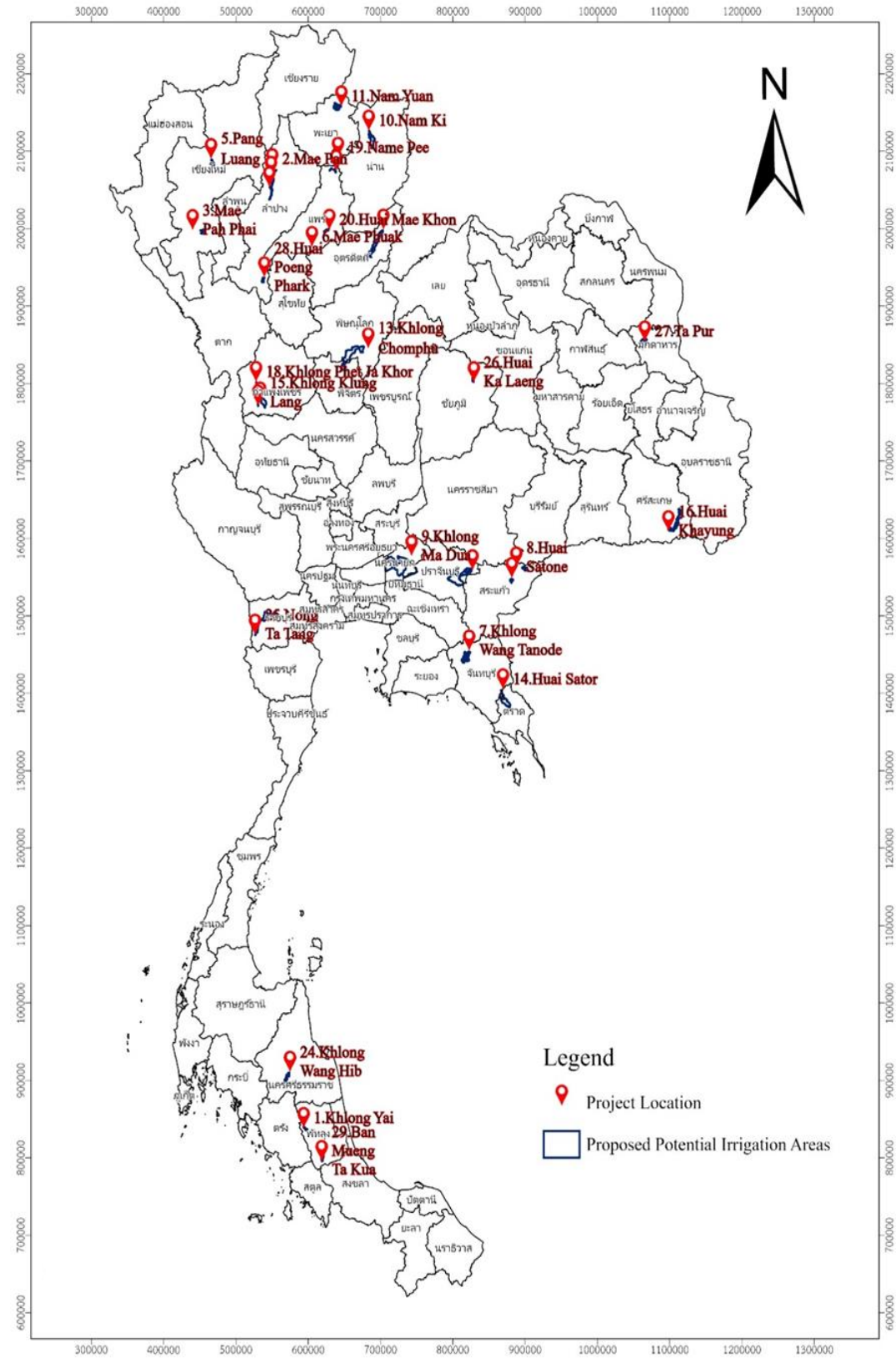

Figure B.1 Location Map of 30 Projects

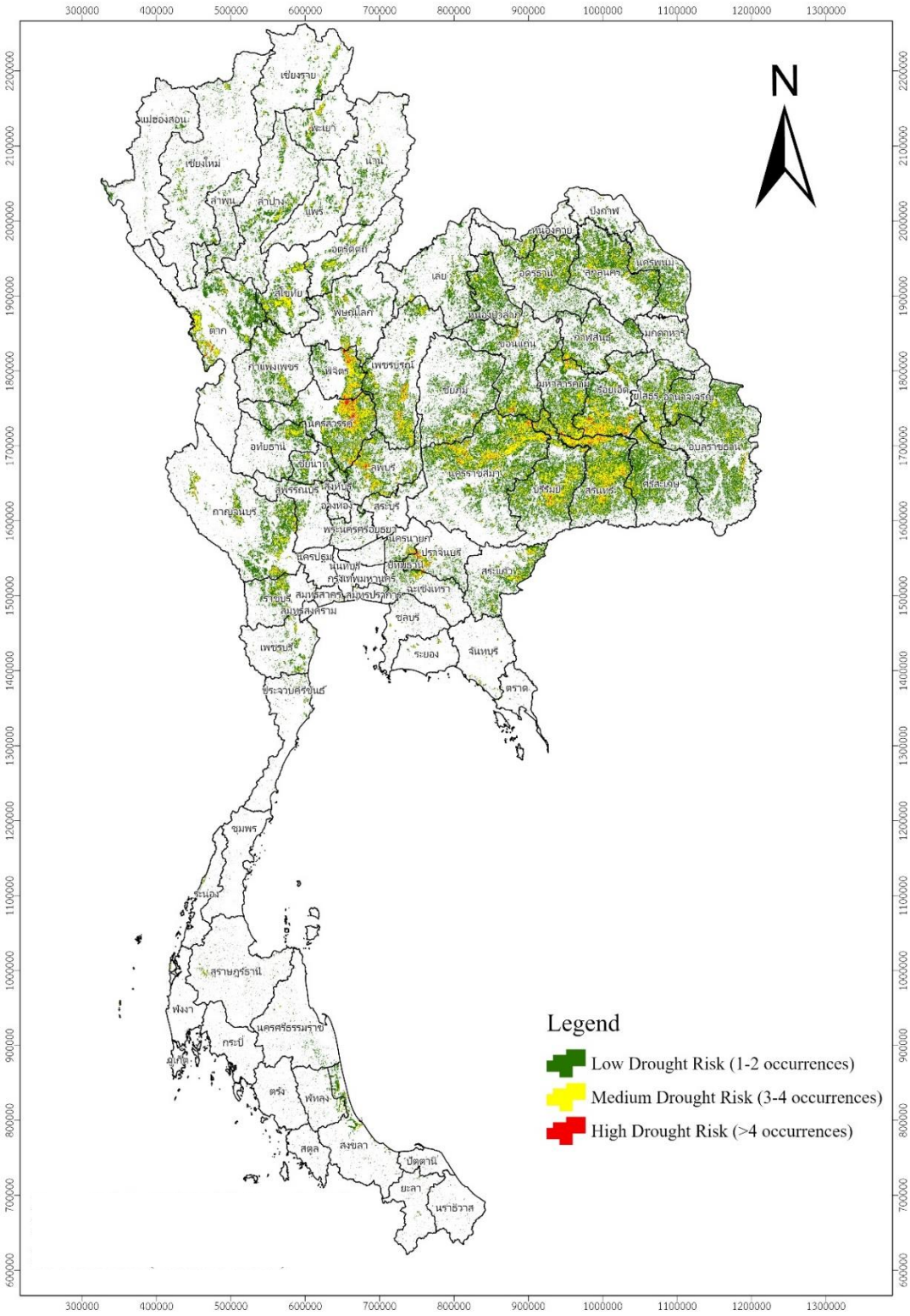

Figure B.2 GISTDA's Drought Risk Map of Thailand

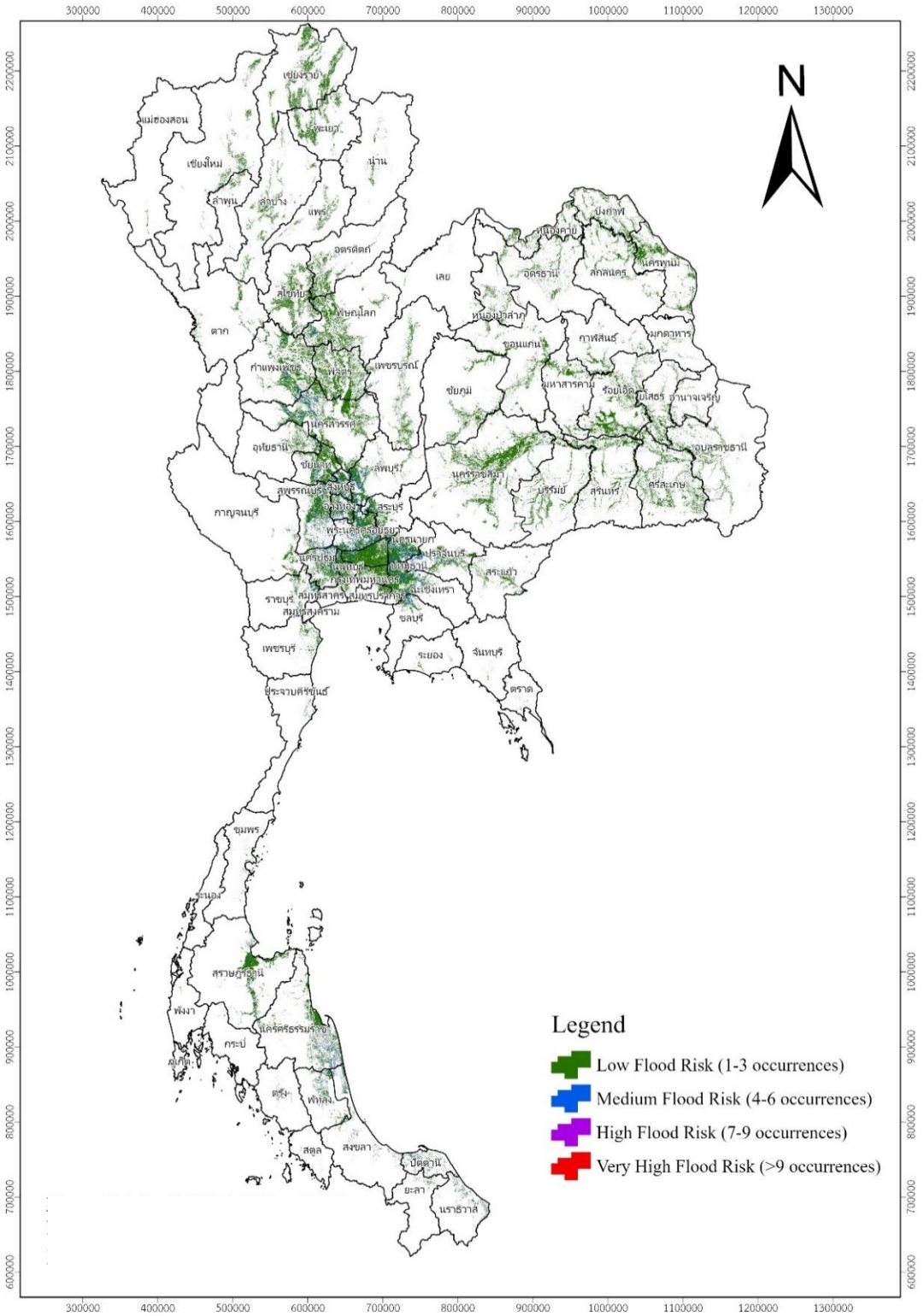

Figure B.3 GISTDA's Flood Risk Map of Thailand

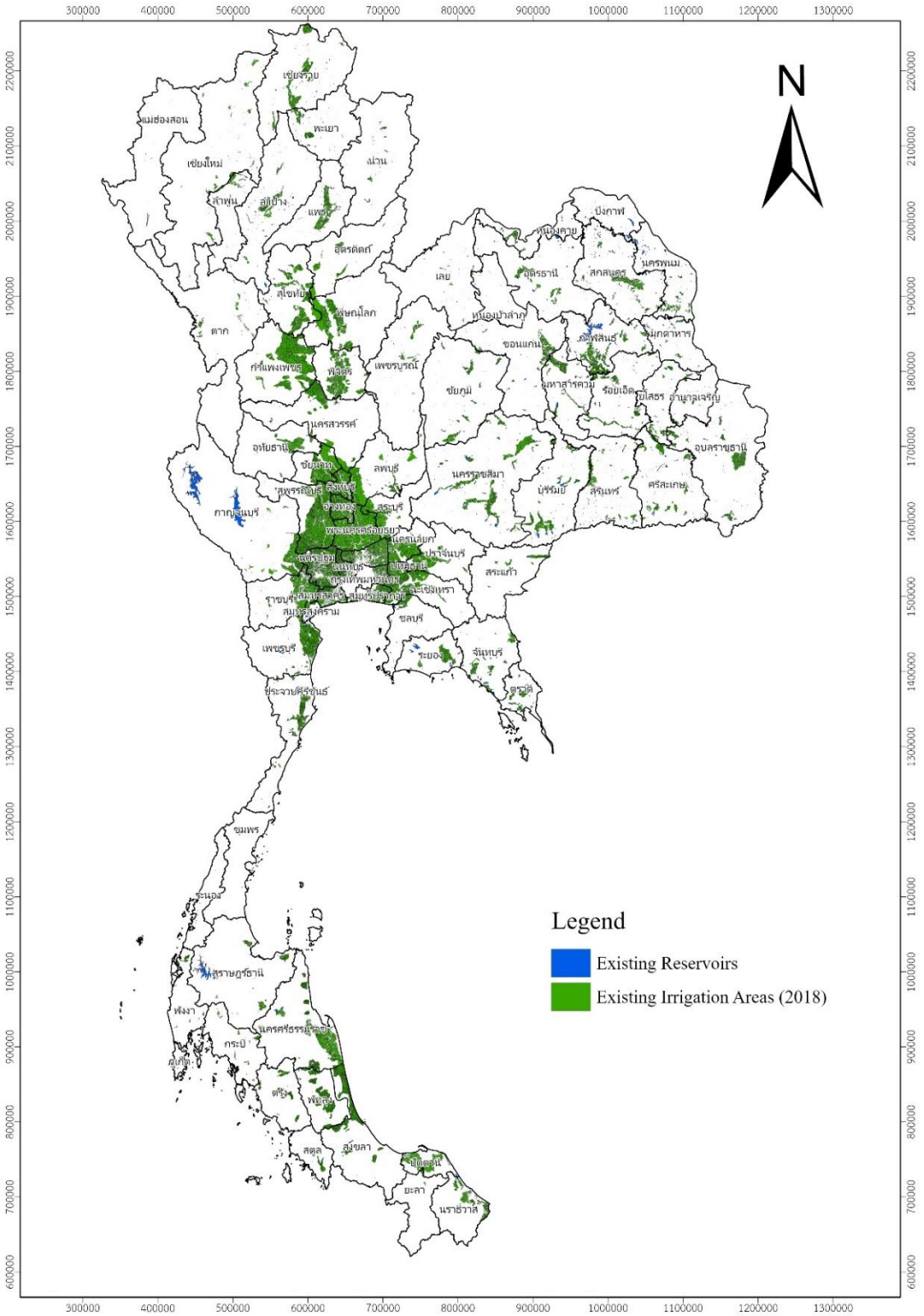

Figure B.4 The Location Map of Irrigation Areas

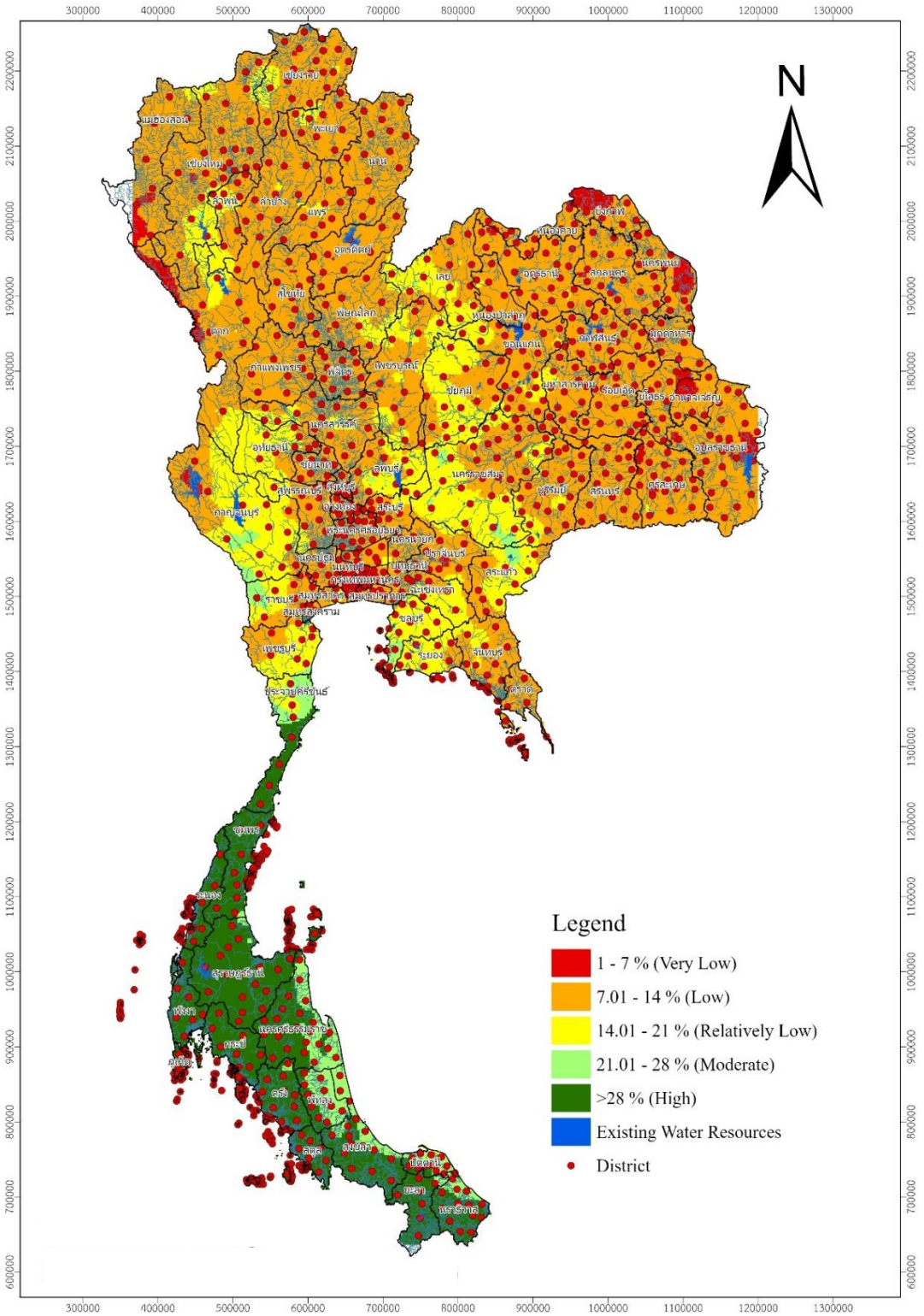

Figure B.5 Dry Seasonal Rainfall to Annual Rainfall Percentage

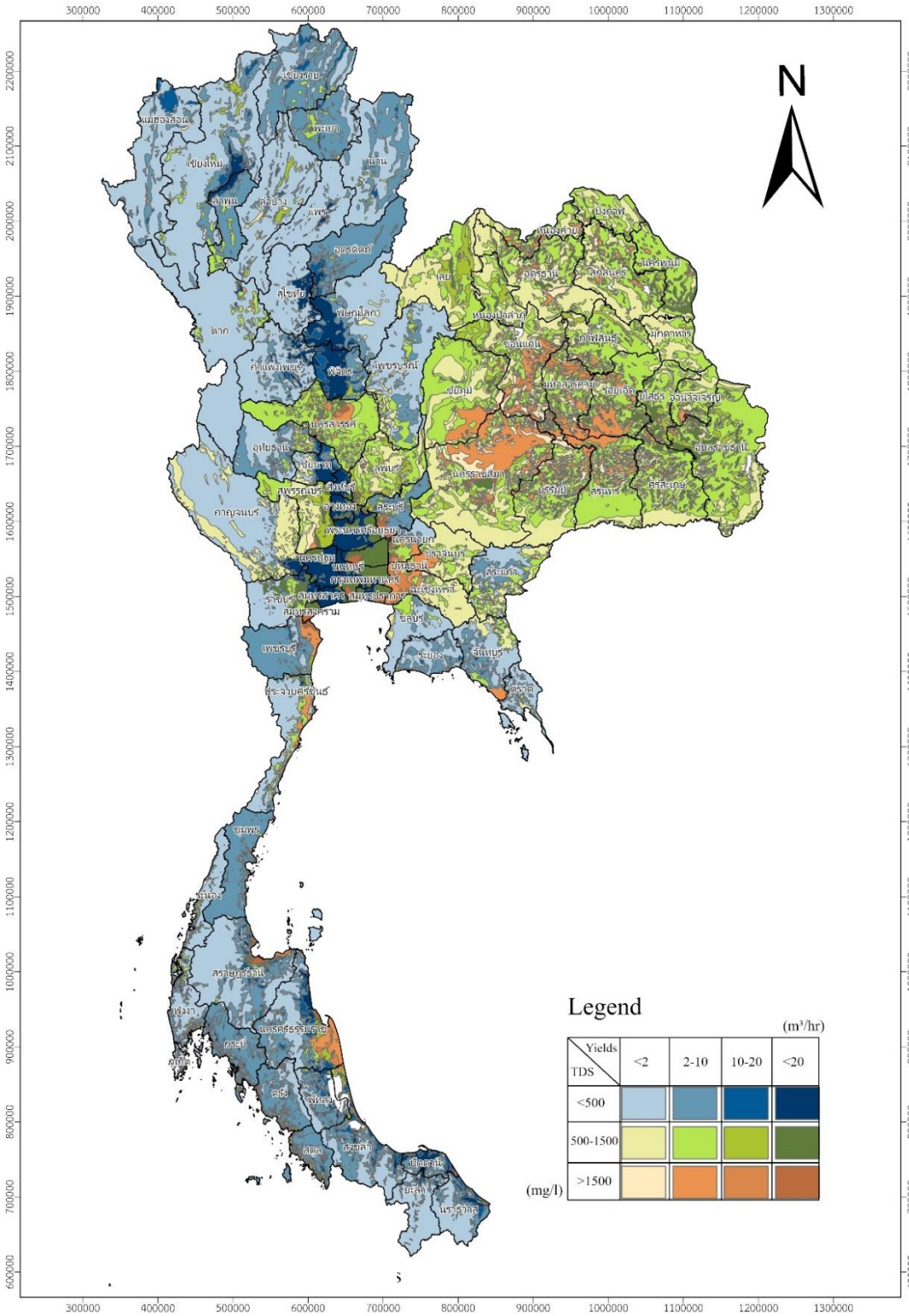

Figure B.6 Groundwater Potential Map

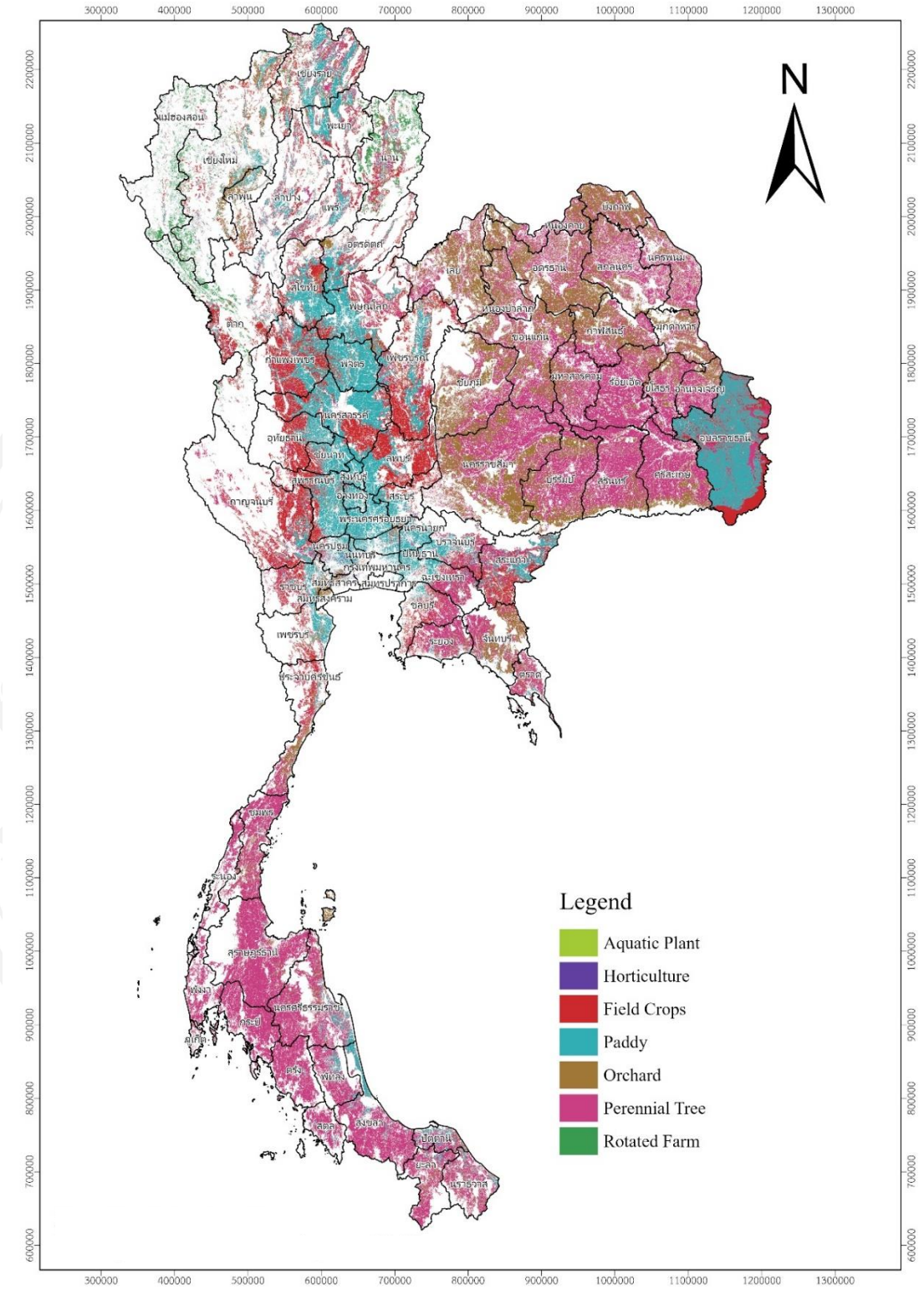

Figure B.7 Land Use Map

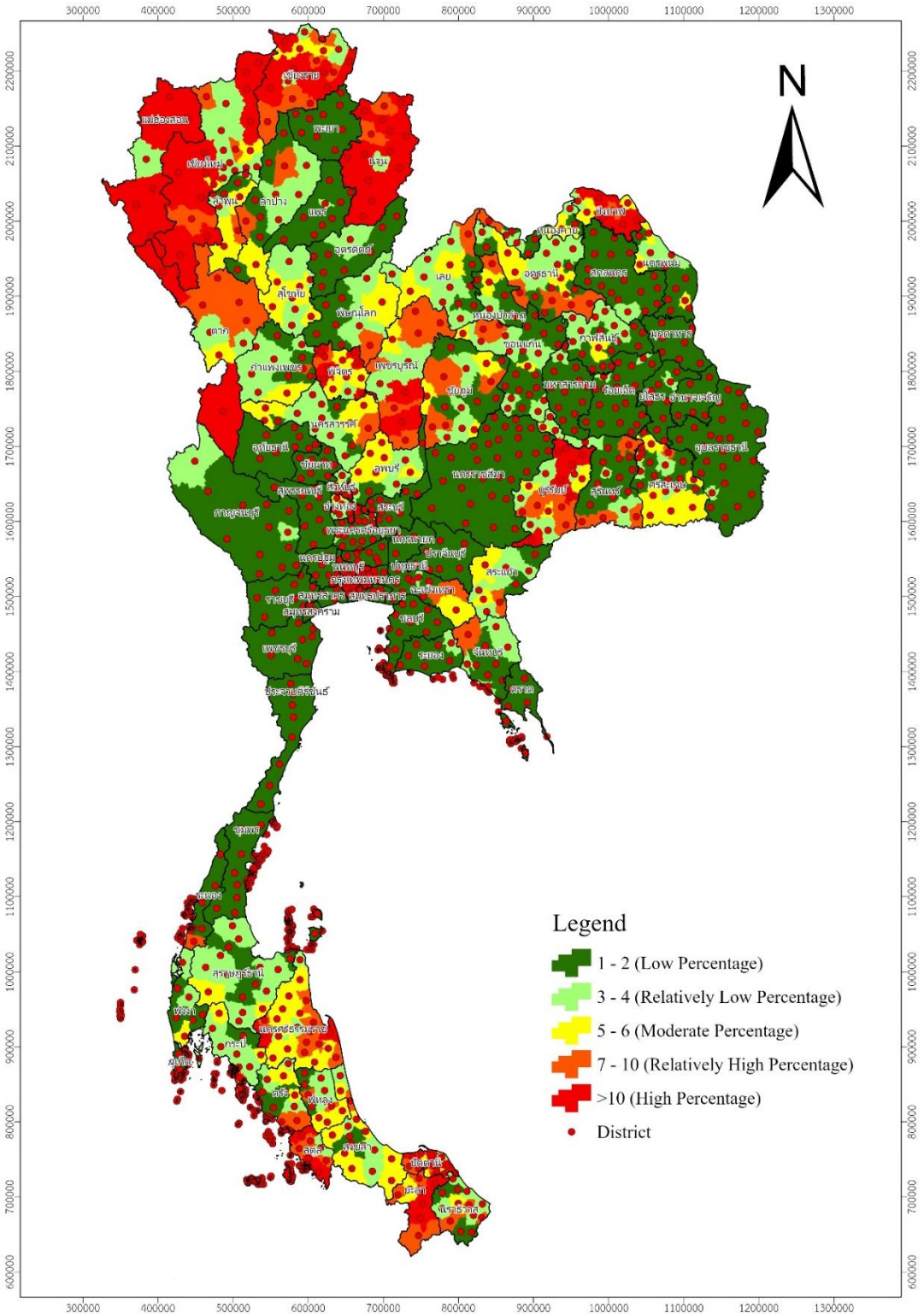

Figure B.8 District Poverty Areas Map

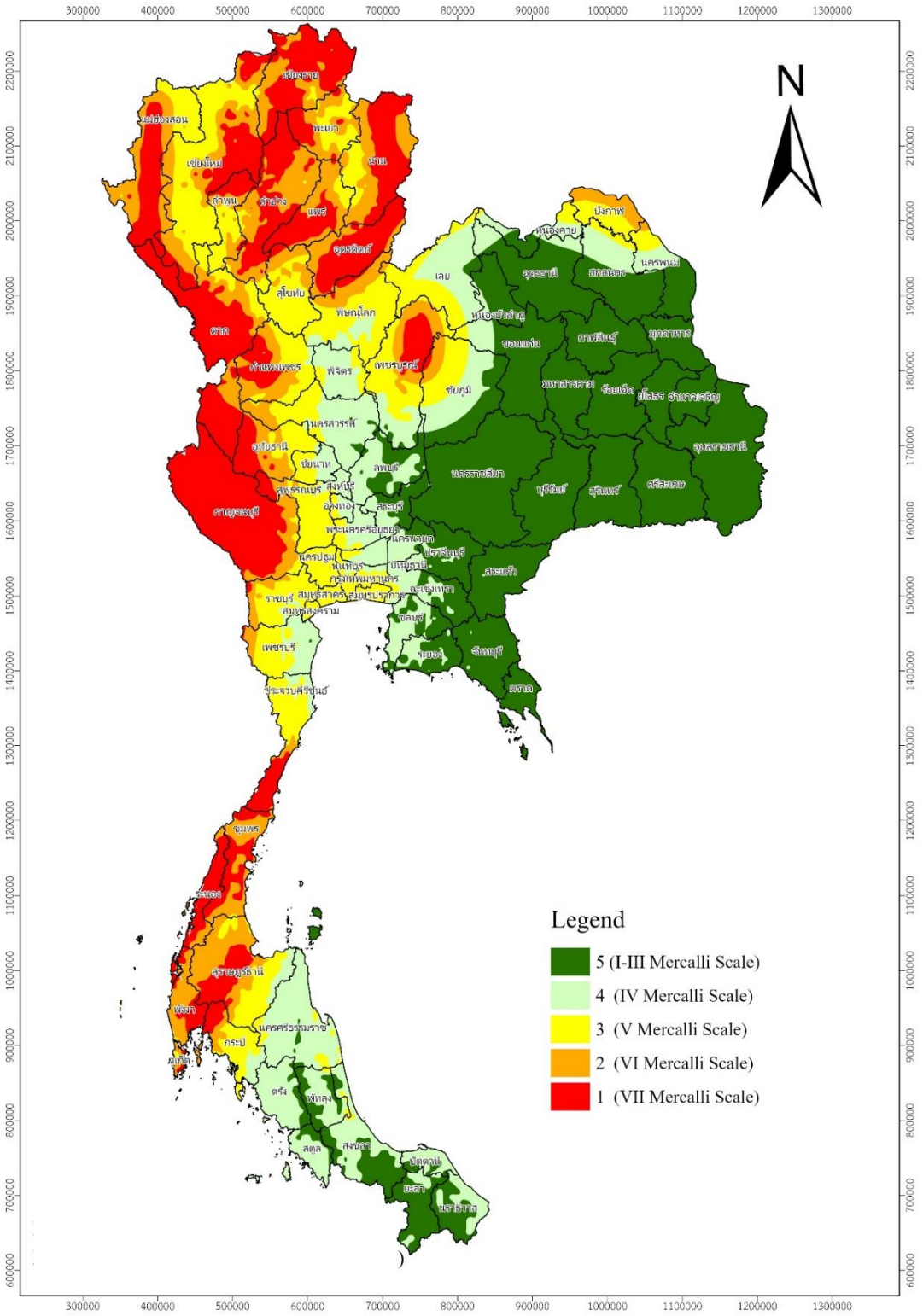

Figure B.9 Mercalli's Seismic Risk Map

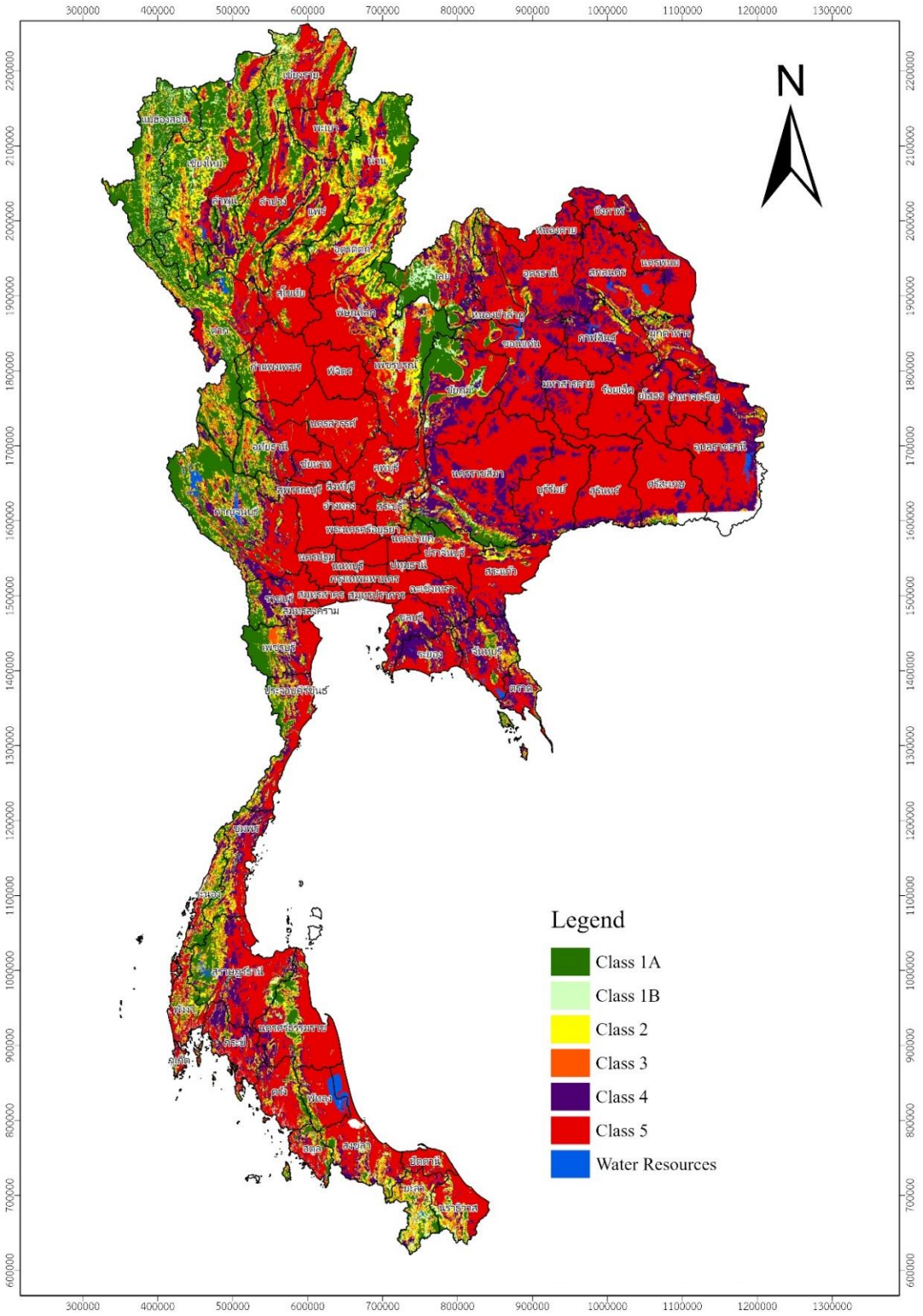

Figure B.10 Watershed Classification Map

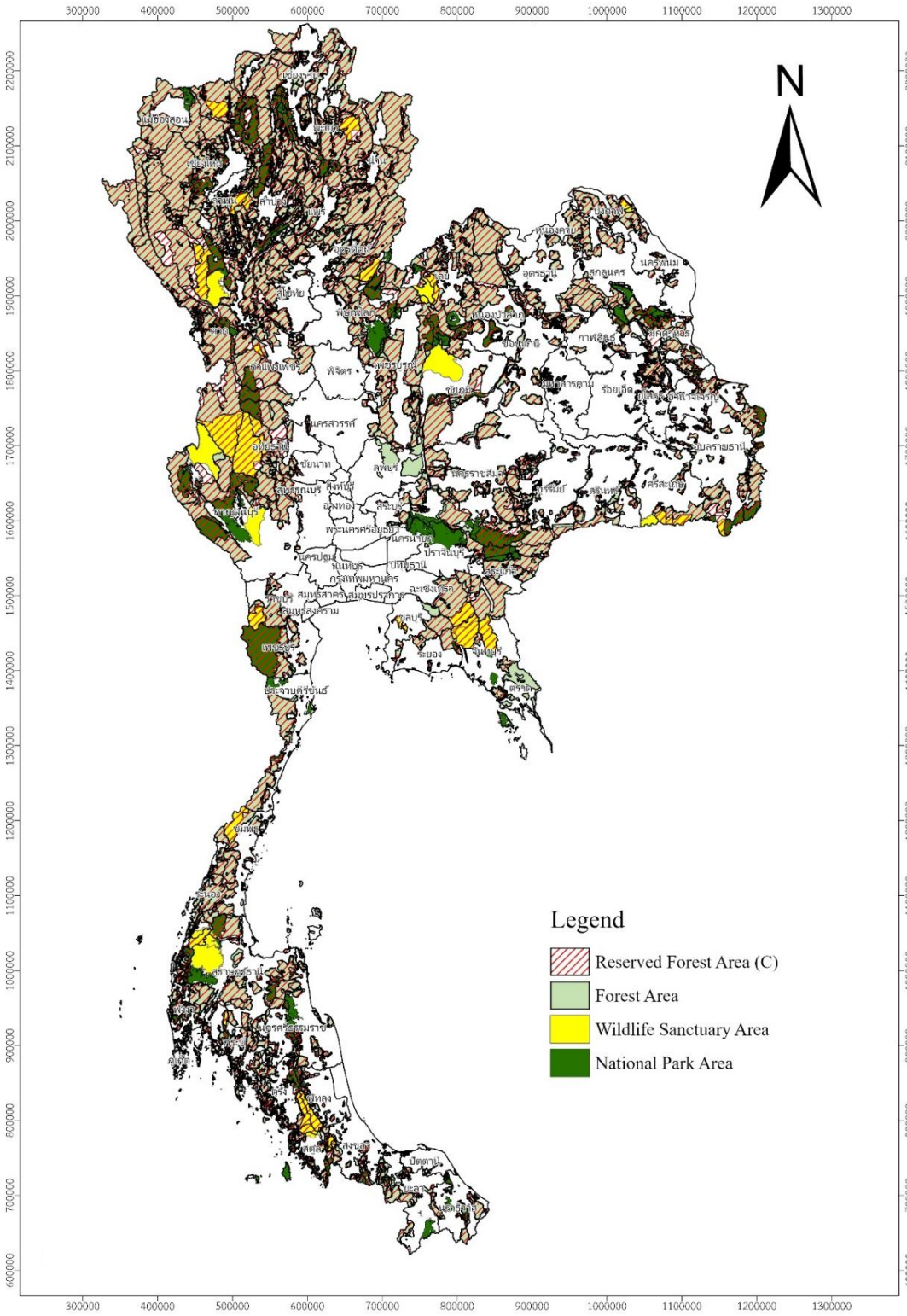

Figure B.11 Conservation Areas Map

Appendix C

Classification of Project Indicators' Scoring Ranges

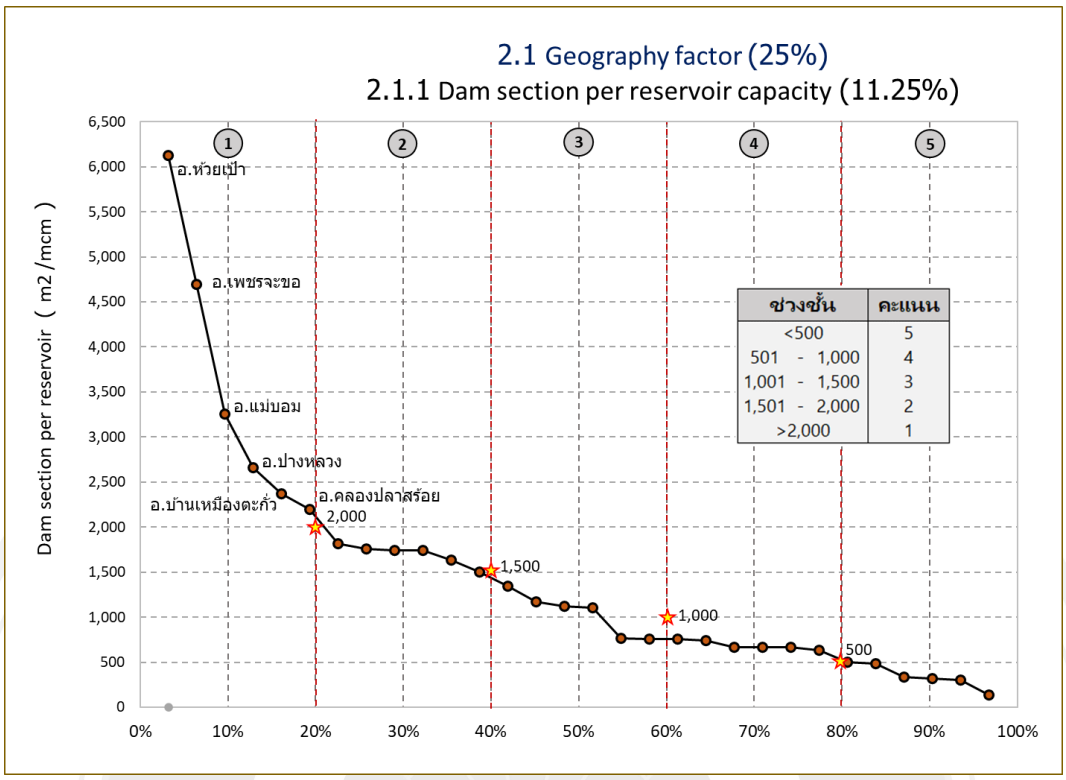

Figure C.1-1 Indicator Ranges and scores of Dam section per reservoir capacity

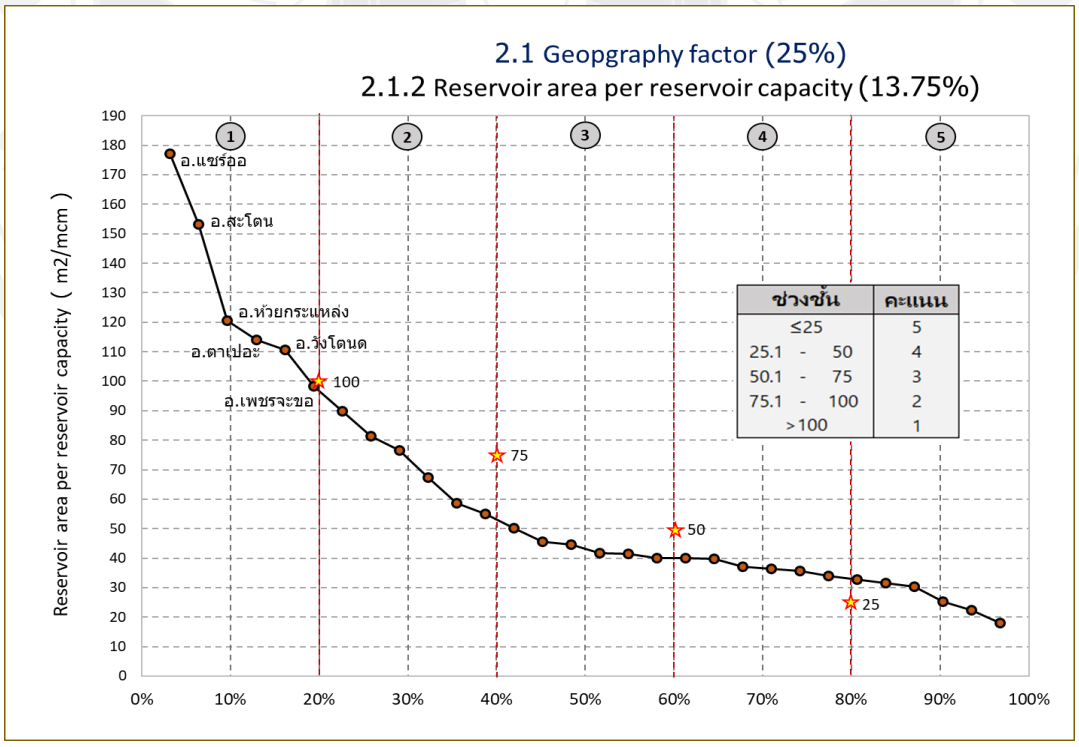

Figure C.1-2 Indicator Ranges and scores of reservoir area per reservoir capacity

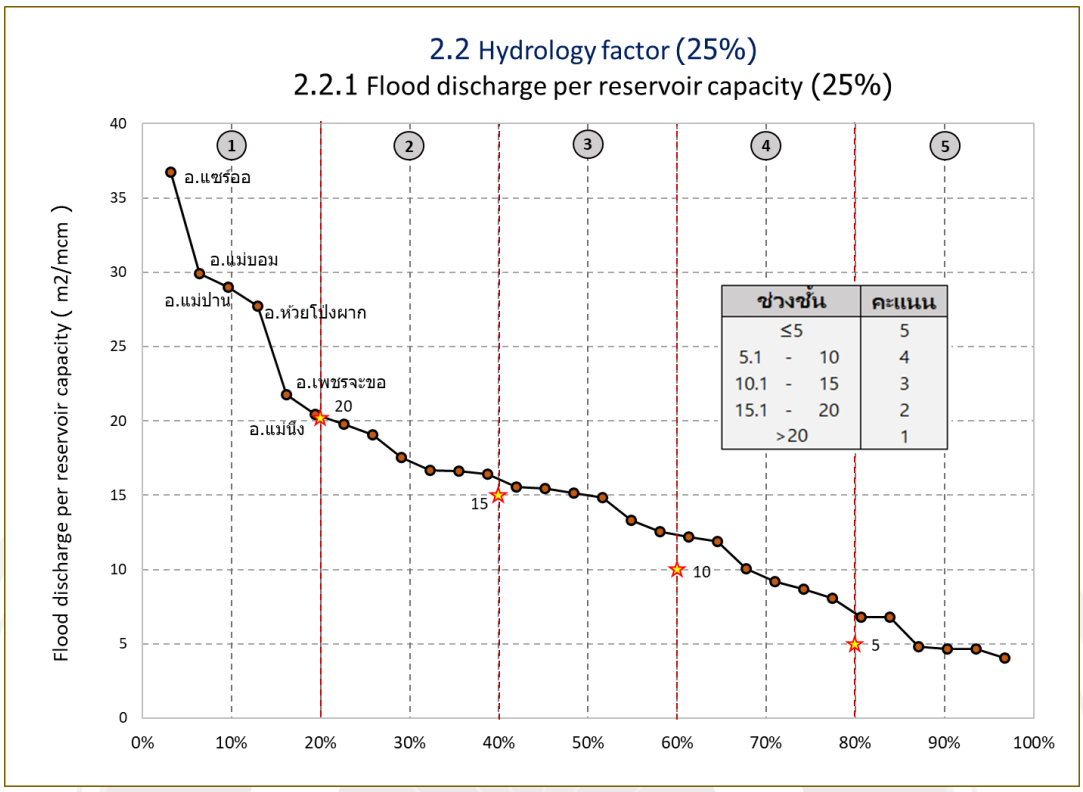

Figure C.1-3 Indicator Ranges and scores of flood discharge per reservoir capacity

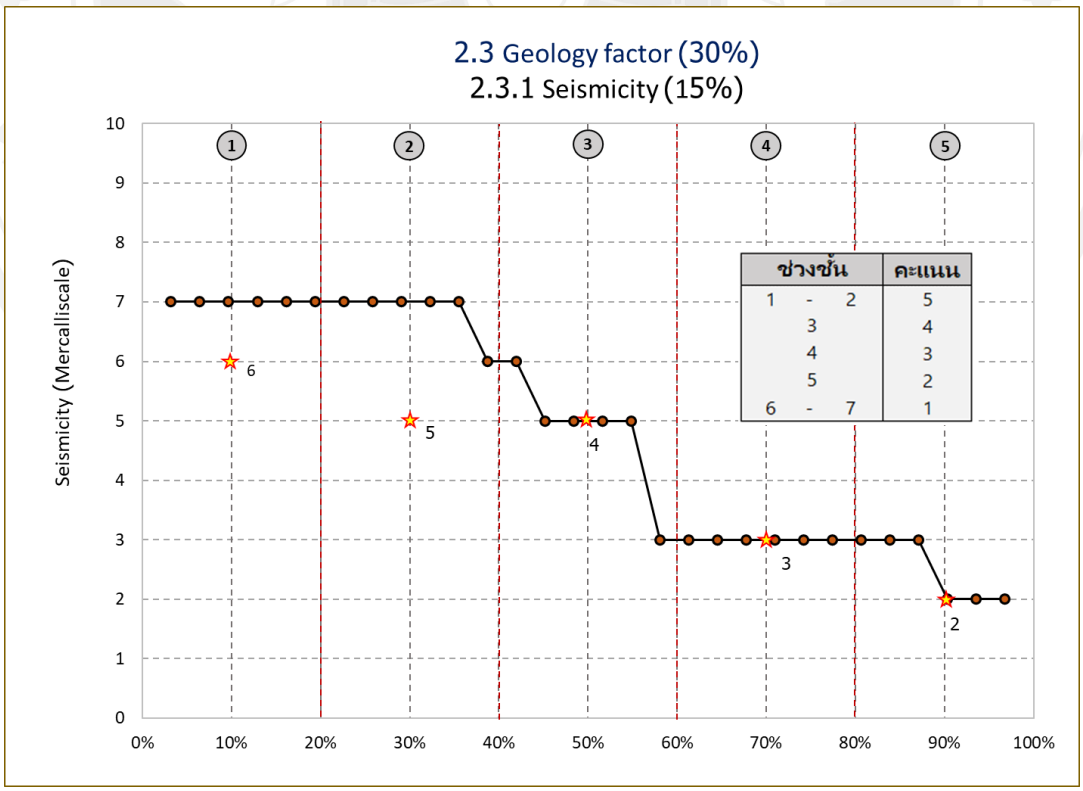

Figure C.1-4 Indicator Ranges and scores of seismicity

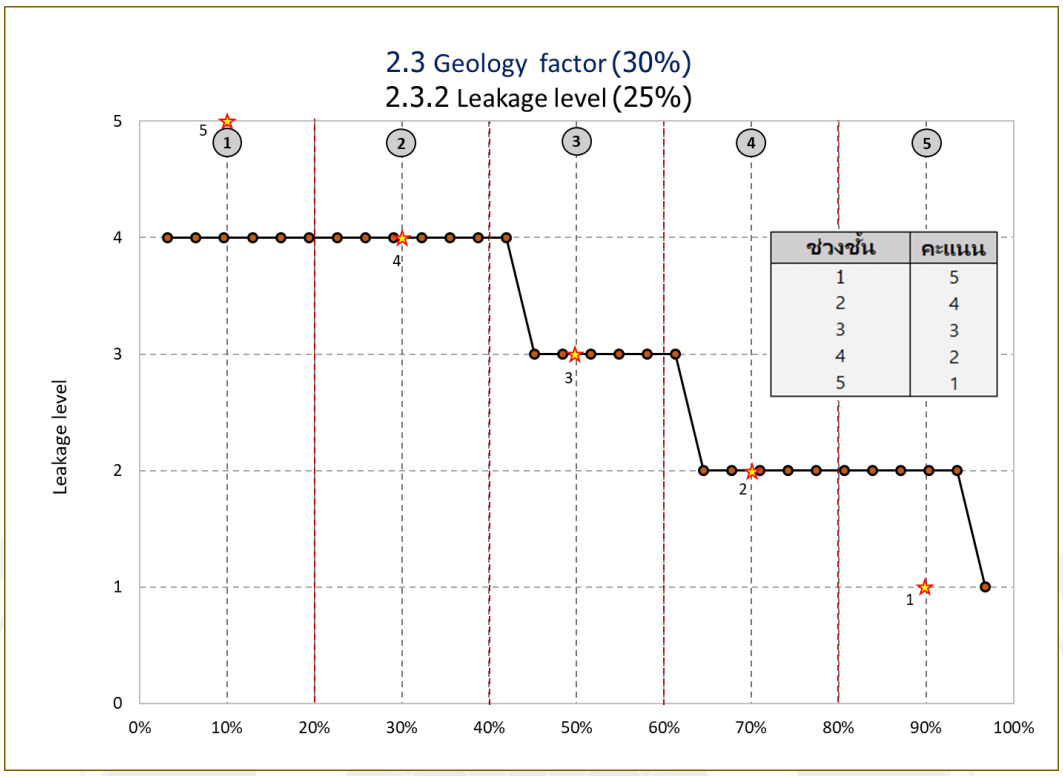

Figure C.1-5 Indicator Ranges and scores of leakage level

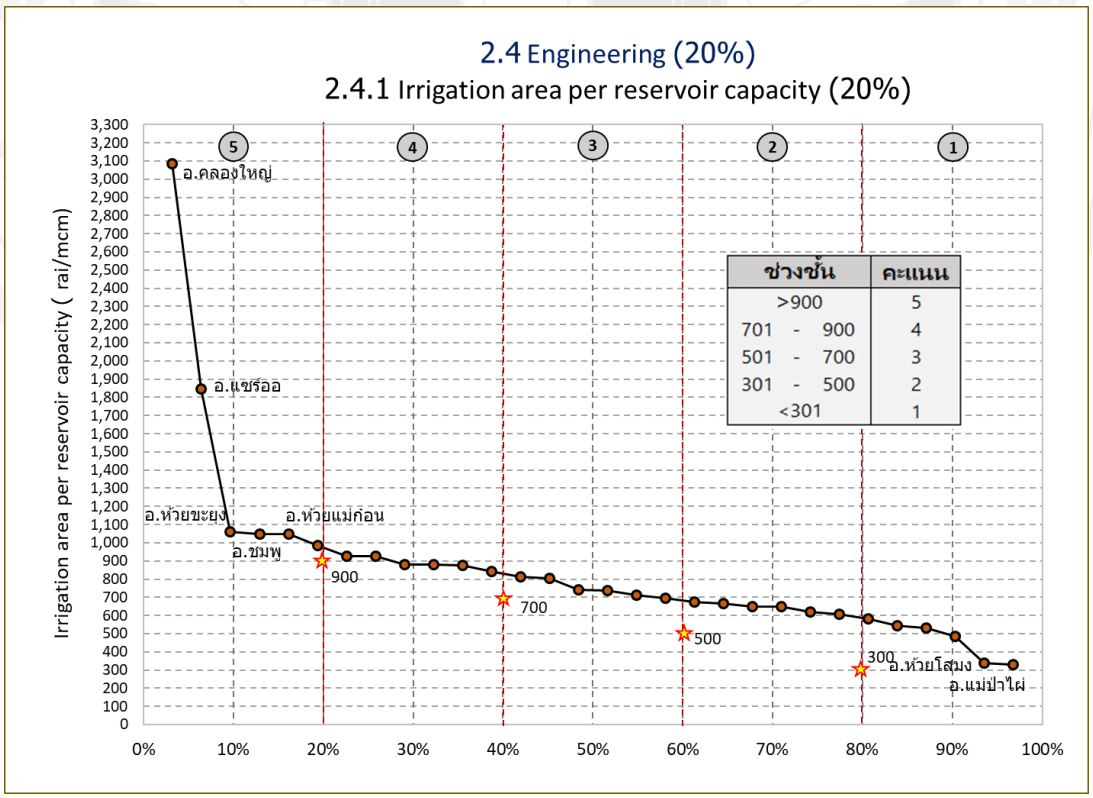

Figure C.1-6 Indicator Ranges and scores of irrigation area per reservoir capacity

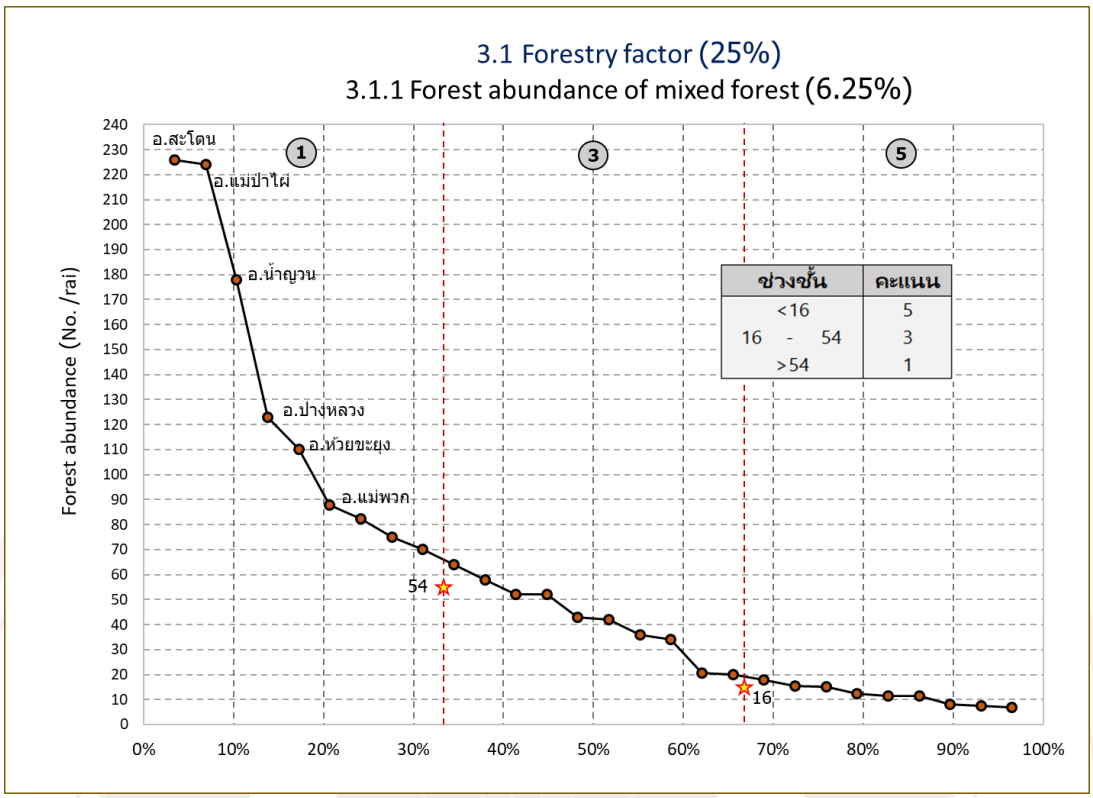

Figure C.2-1 Natural resources indicator range and score of forest abundance

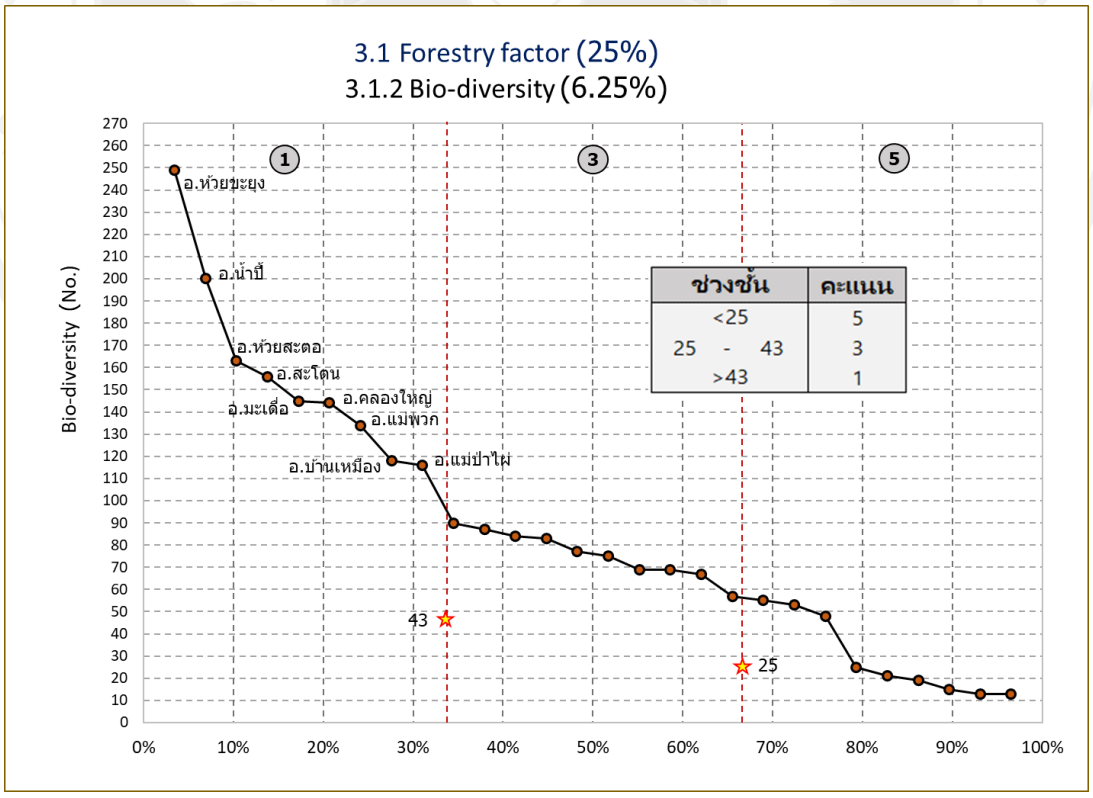

Figure C.2-2 Natural resources indicator range and score of bio-diversity

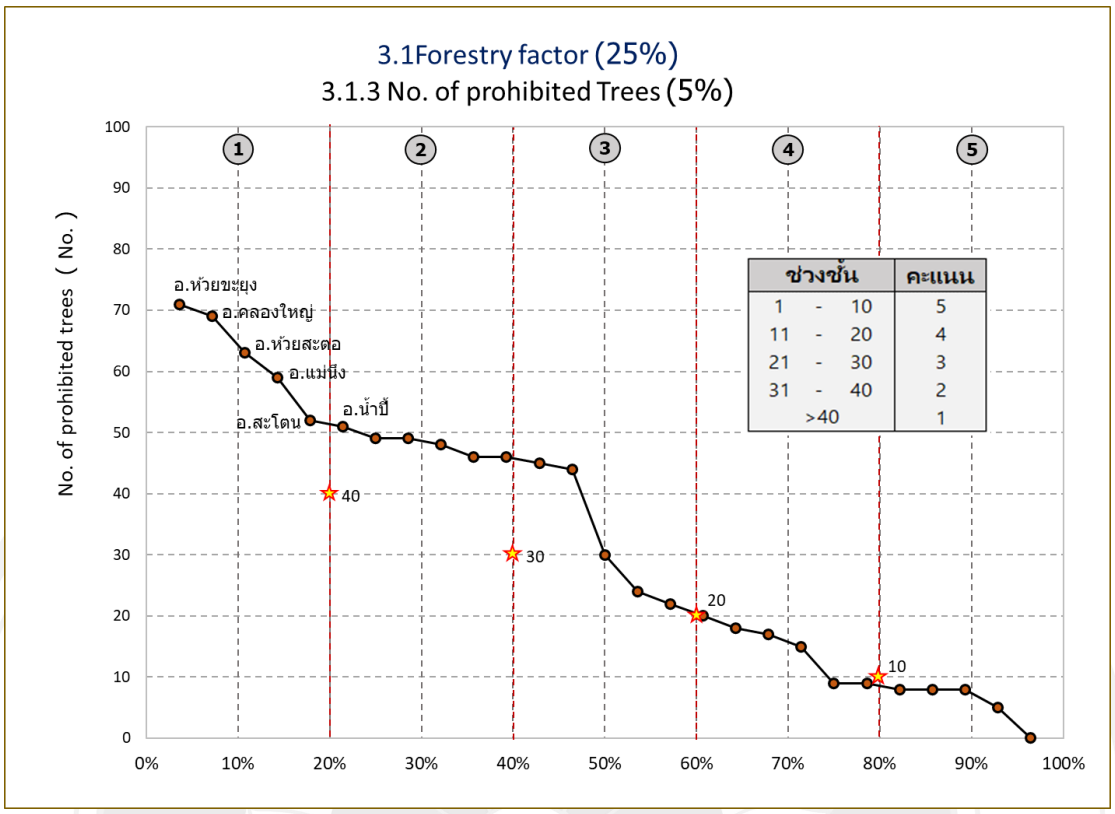

Figure C.2-3 Natural resources indicator range and score of No. of prohibited trees

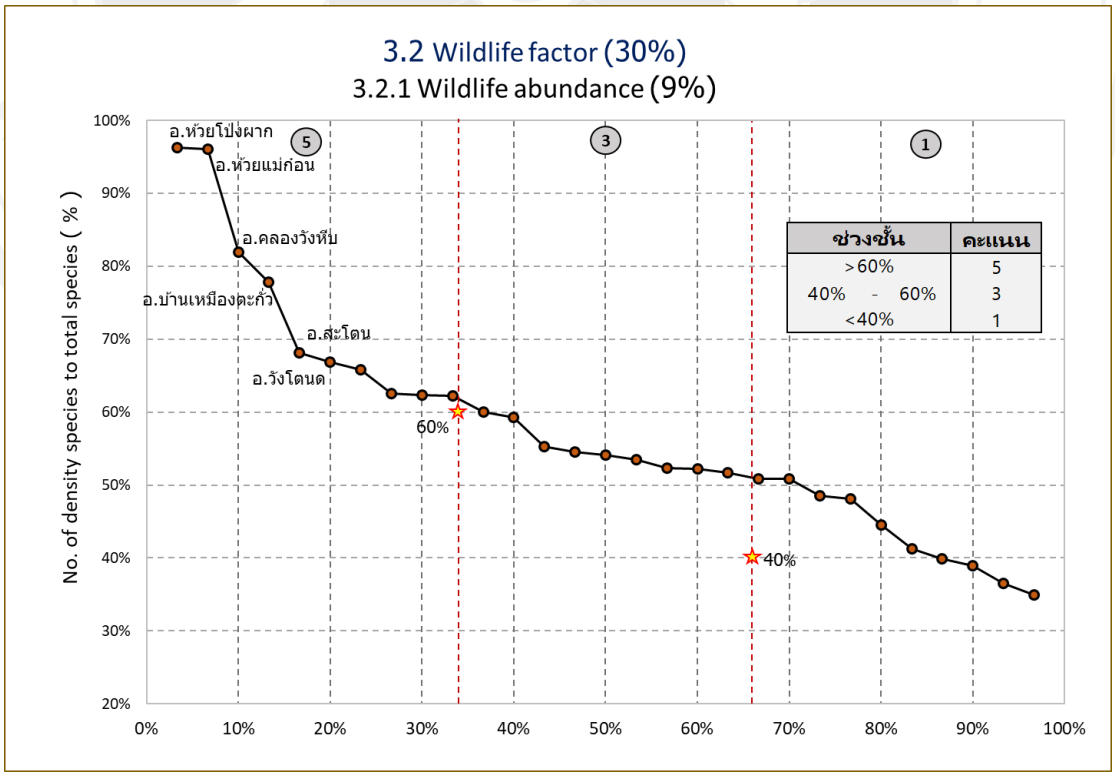

Figure C.2-4 Natural resources indicator range and score of wildlife abundance

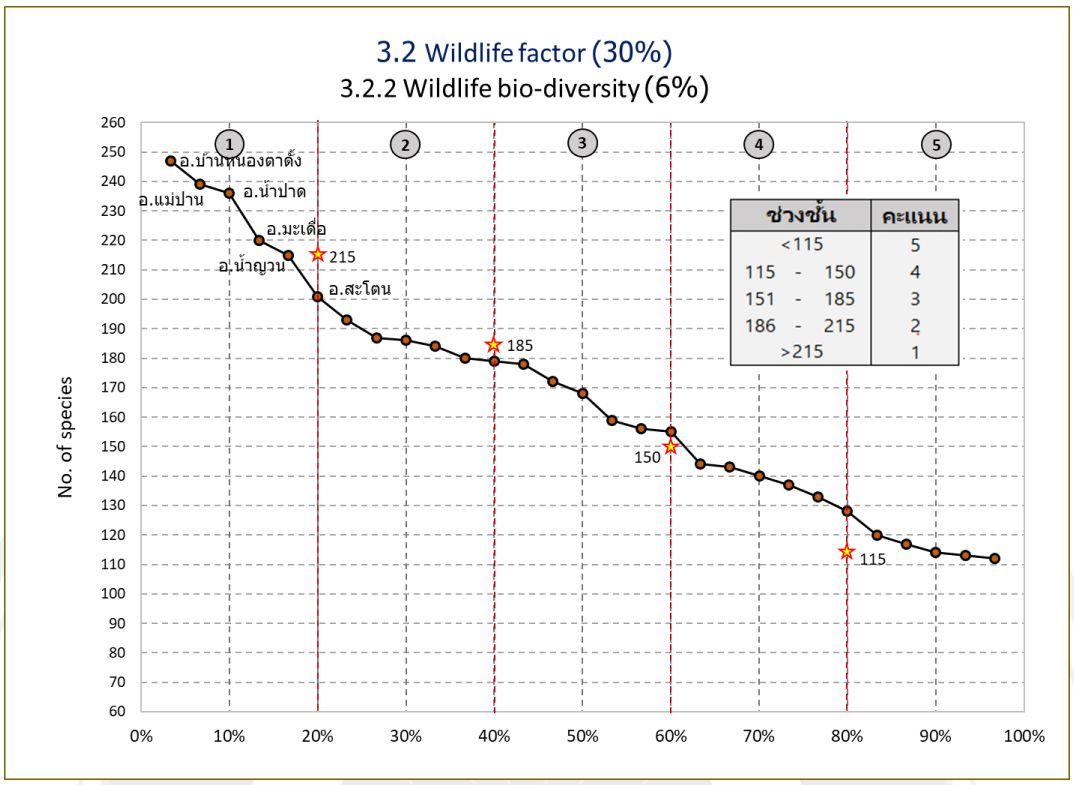

Figure C.2-5 Natural resources indicator range and score of wildlife bio-diversity

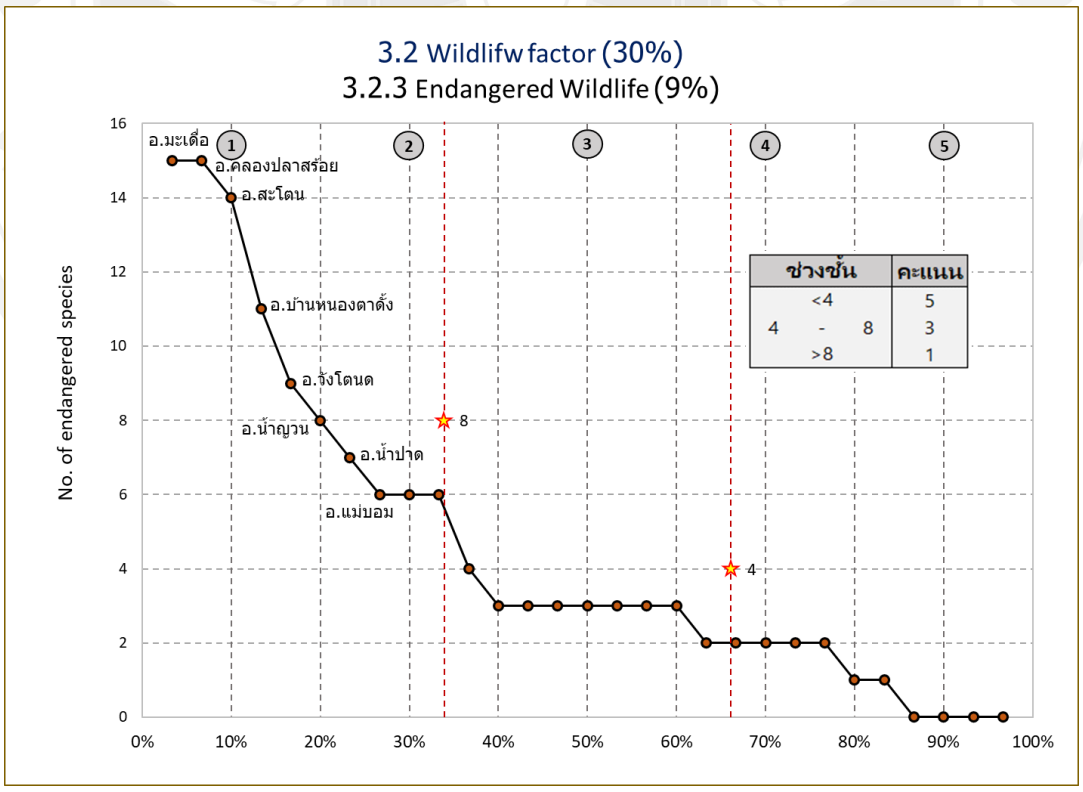

Figure C.2-6 Natural resources indicator range and score of endangered wildlife

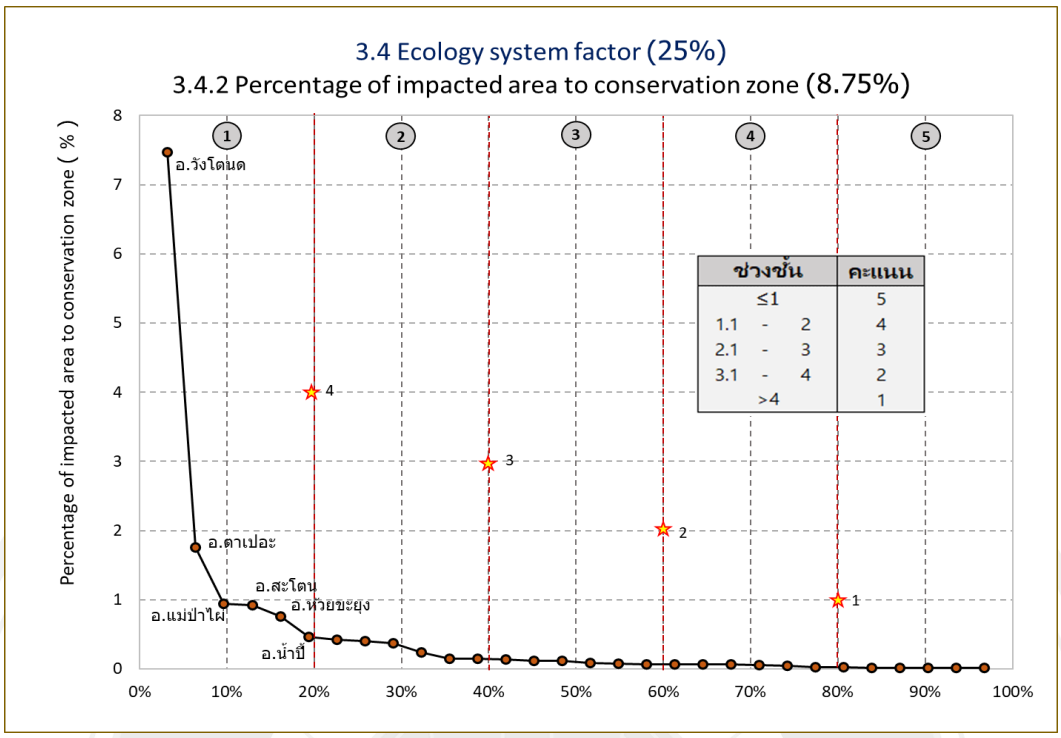

Figure C.2-7 Indicator range and score of percentage of impacted area to conservation zone

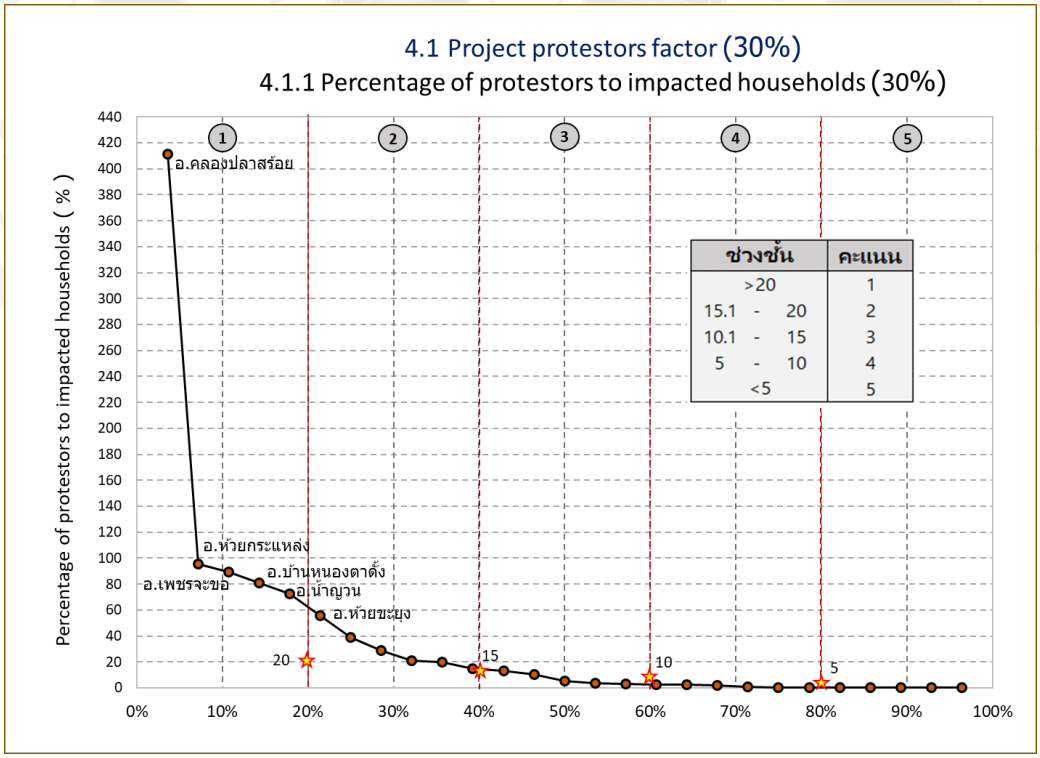

Figure C.3-1 Indicator range and score of percentage of protestors to impacted households

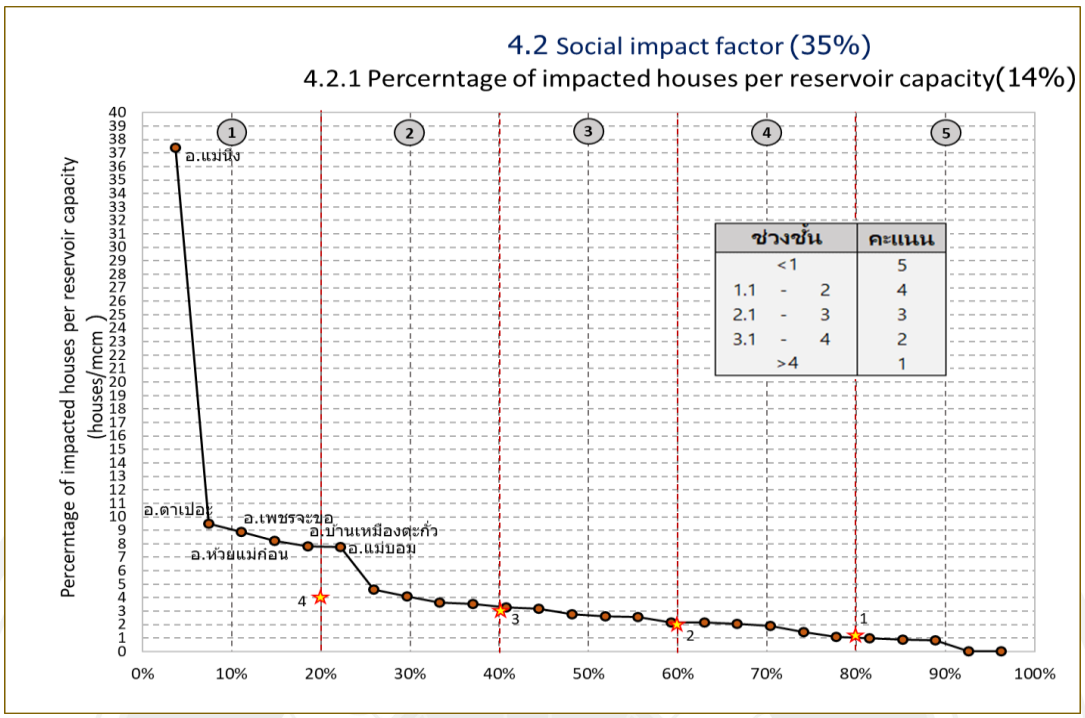

Figure C.3-2 Indicator range and score of percentage of impacted houses per reservoir capacity

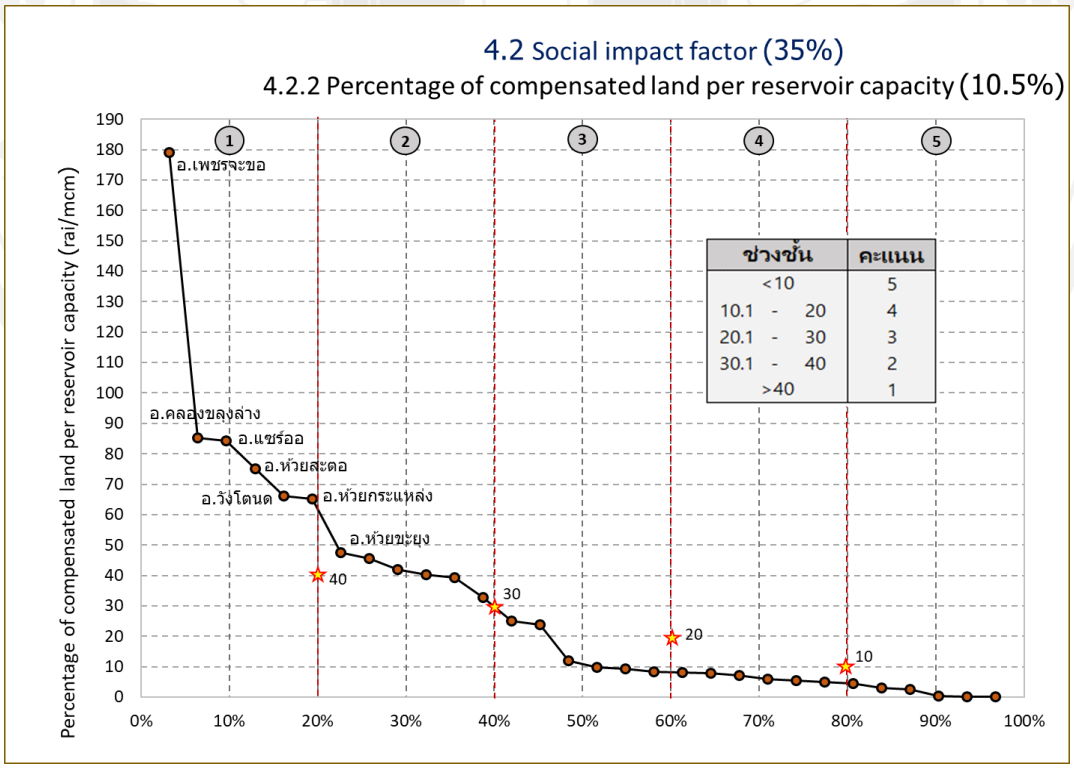

Figure C.3-3 Indicator range and score of percentage of compensated land per reservoir capacity

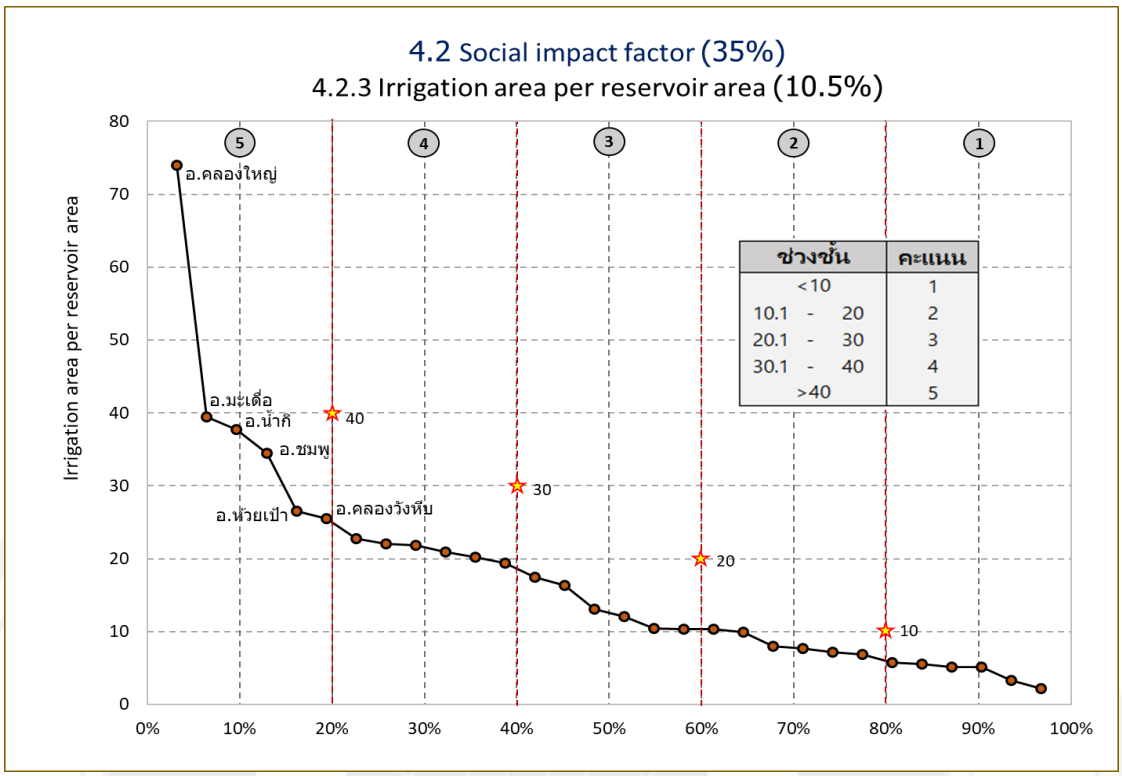

Figure C.3-4 Social impact Indicator range and score of irrigation area per reservoir area

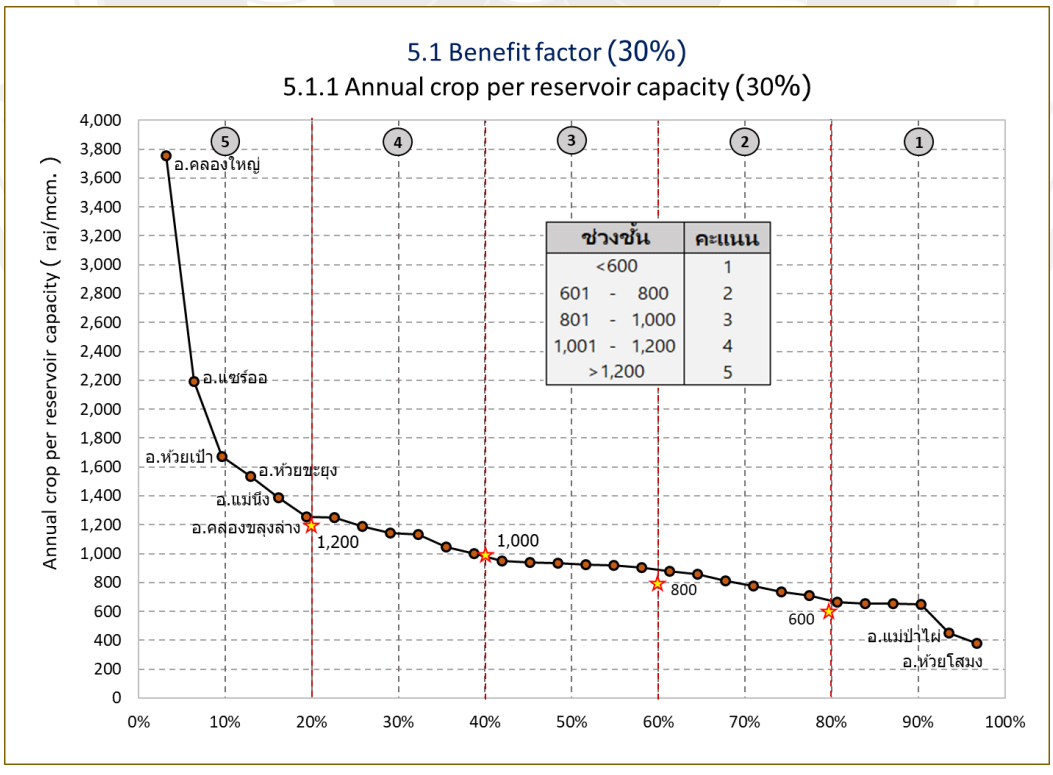

Figure C.4-1 Benefit Indicator range and score of annual crop per reservoir capacity

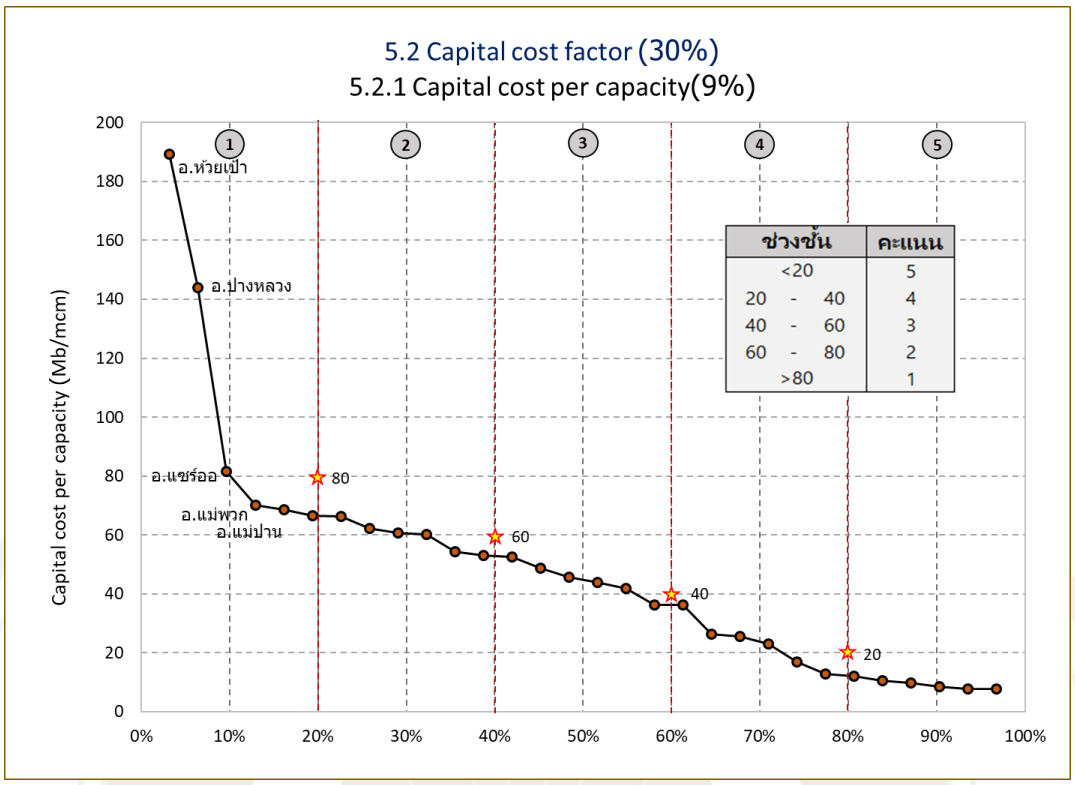

Figure C.4-2 Capital cost Indicator range and score of capital cost per reservoir capacity

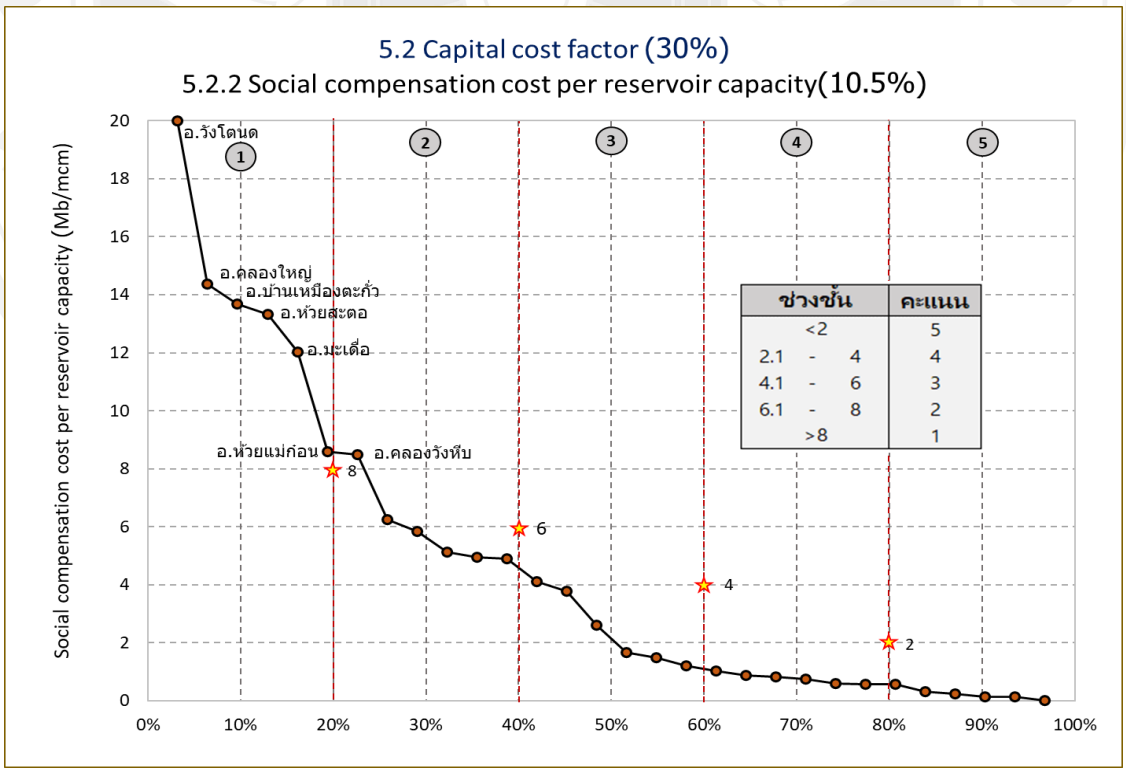

Figure C.4-3 Capital cost Indicator range and score of social compensation cost per reservoir capacity

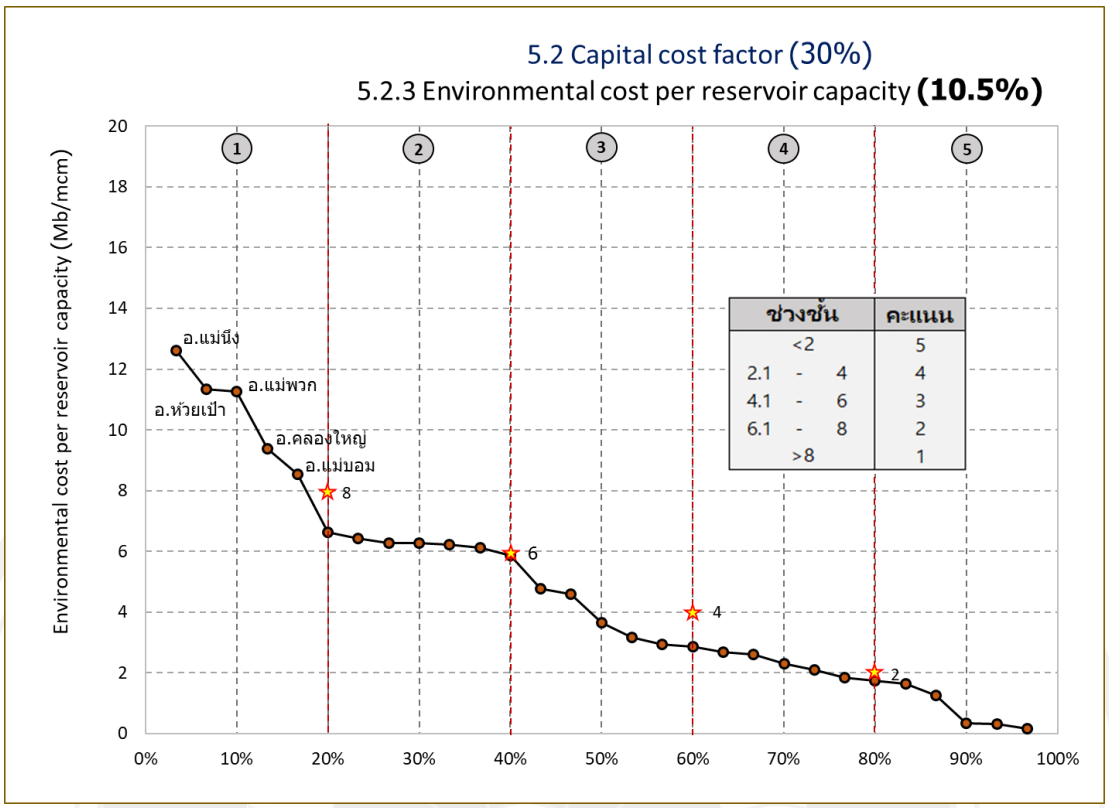

Figure C.4-4 Capital cost Indicator range and score of social compensation cost per reservoir capacity

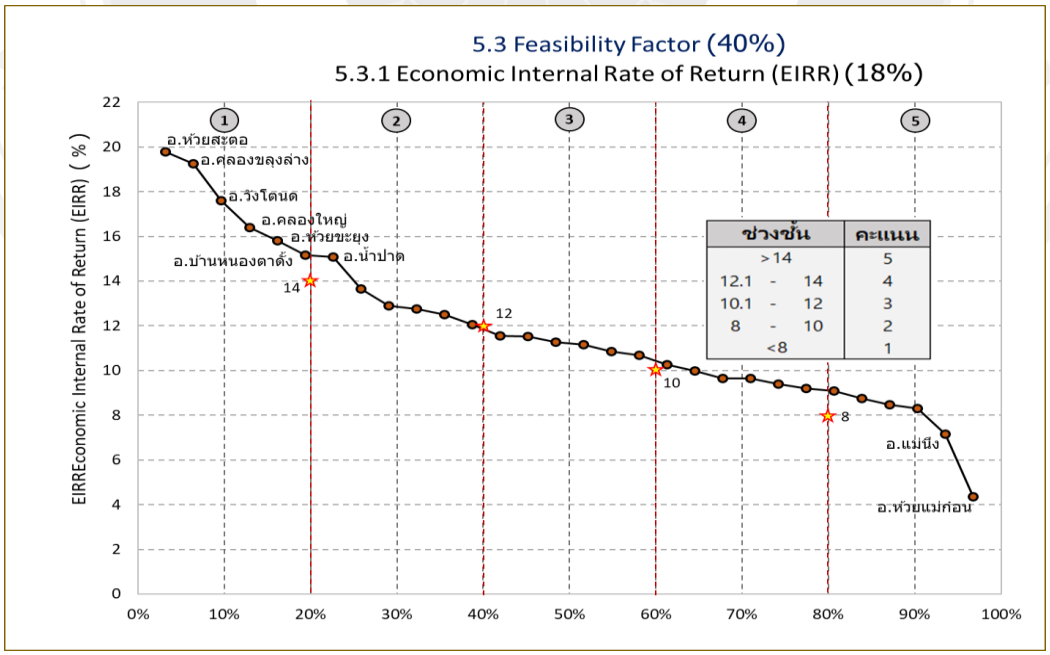

Figure C.5-1 Feasibility Indicator range and score of Economic Internal Rate of Return (EIRR)

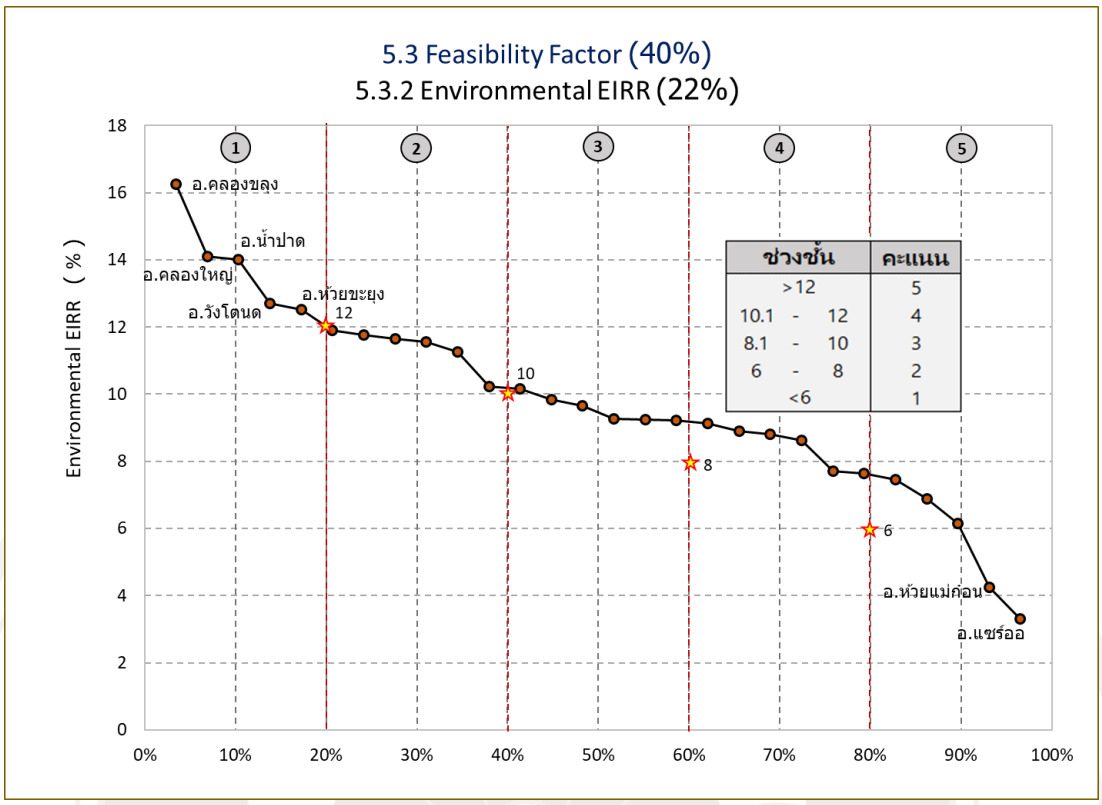

Figure C.5-2 Feasibility Indicator range and score of Environment EIRR

Appendix D

Questionnaire

Appendix D.1

1st Round Questionnaire For Del Phi's Panel Consideration

RESEARCH QUESTIONNAIRE Date.....

SUSTAINABLE INDICES OF WATER RESOURCES DEVELOPMENT PROJECTS IN CONSERVATION AREA, THAILAND. Phase..... No.....

This questionnaire aims to gather opinions and suggestions related to studying the key factors and sustainability indicators of water development projects in the conservation areas of Thailand. The collected feedback will be used to guide the development of state water resources projects, ensuring a balanced and sustainable approach across the four dimensions: engineering, environment, society, and economy. This serves as a framework for evaluating project suitability and the value of utilizing conservation areas for water development. Input is sought from relevant organizations involved in the development process.

The questionnaire comprises 1) Sustainable index creation, 2) Criteria setting for score ranges in various dimensions, and 3) Assessment of the severity of problems in the project area.

The researcher hopes to receive your cooperation in responding to the questionnaire. Given that this research utilizes the Del Phi technique, it is necessary to have multiple responses to the questionnaire. Your willingness to dedicate time to answer the questionnaire is highly appreciated.

Udomsook Suracharttumrongrat

National Institute of Development Administration (NIDA)

Part 1 : Sustainable Index Establishment

1. In sustainable water development in conservation areas, how should the priority order of dimensions be determined? (Choose only one method)

Dimension	Priority Method		Weighted Value Method (%)	
	Example	Opinion	Example	Opinion
1. Engineering	3		or 20	
2. Natural Resources and Environmental	1		35	
3. Social	2		25	
4. Economic	3		20	
5. Other (specified).....				
Total		100%	100%	100%

Notes :

1. Priority order 1 = Highest, 2. Priority order can be the same

3. Weight values for all dimensions combined = 100% 4. Choose only one format between priority order and weight values

5. The method of priority order will be used to calculate weight values using Multi-Criteria Analysis (MCA).

Definition: 1) Water development project refers to the construction of dams or structures to block rivers, storing excess water during the rainy season for various sustainable uses during the dry season or throughout the year.

2) Conservation areas in this context include national parks, wildlife sanctuaries, national reserved forests (Zone C), quality class 1 and 2 watersheds, excluding wetlands, world heritage sites, marine and coastal resource protection areas, and mangrove forest areas.

3) Biodiversity refers to the presence of a diverse array of living organisms, including various plant and animal species with a substantial quantity of genetic diversity, exhibiting a wide range of variations within the ecosystem.

2. In the engineering dimension, what is your opinion on grouping the main factors that affect sustainable water development into 4 factors? These factors are 1) Geography, 2) Hydrology, 3) Geology, and 4) Engineering, 5) Others (Specify.....), and 6) Indices : 1) Dam Cross-Section/Storage, 2) Reservoir Area/Storage, 3) Flood Discharge, 4) Seismicity, 5) Foundation and Seepage, 6) Irrigation Area/Storage, and 7) Other (Specify.....). How should the weighting values be assigned for each of these factors and indices?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Factor	Priority Method	Weighted Value Method	Suggestions/Comments
2.1 Geography			1.
2.2 Hydrology			2.
2.3 Geology			3.
2.4 Engineering			4.
2.5 Others.....			
		100 %	

2.1 In the main factor of geographical aspects, what is your opinion on proposing the following indices: 1) Dam cross-sectional area/capacity, 2) Reservoir area/capacity, 3) Others (Specify.....) and how should the weighting be?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions/Comments
2.1.1 Dam cross-sectional area/ capacity			1.
2.1.2 Reservoir area/capacity			2.
2.1.3 Others.....			

2.1.1 Indices of dam cross-sectional area to reservoir capacity.

1) In the main index related to dam cross-sectional area and reservoir capacity, what is your opinion on proposing a scoring range as follows?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
1.1) Dam cross-sectional area/ Capacity	- The suitability of the geography for developing a reservoir with a small dam cross-section is highlighted. It is suitable in terms of engineering, resulting in better dam stability and safety and lower construction costs per unit of water storage compared to those with a larger dam cross-section.	< 500 sq.m./mcm.	5	
		500-1000	4	
		> 1000-1500	3	
		> 1500-2000	2	
	- Representative dam cross-sectional area calculation is simplified by multiplying the length of the dam by its height.	>2000	1	
	- The researcher analyzed the classification intervals based on environmental study reports from 25 dam projects.			

2.1.2 Indices of reservoir area/storage capacity

1) In the reservoir area to storage capacity index, what is your opinion on proposing a scoring range as follows?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
1.2) Reservoir area/ Storage capacity	- the suitability of the topography for reservoir development helps reduce water loss from evaporation, seepage, and the loss of conservation areas to serve as reservoirs.	(rai per mcm.)		
		< 25	5	
	- The proportion with a small figure is suitable due to its high efficiency in water retention, low water loss from evaporation and seepage, and reduced impact on natural resources, ecology the environments, and associated costs, resulting in a higher score.	25-50	4	
		>50-75	3	
		>75-100	2	
	- Reference: The researcher analyzed the ranges from data of 25 projects.	>100	1	

2.2 In the hydrological factors, what is your opinion on proposing the following indices: 1 flood discharge rate per storage capacity, 2) Other (Specify: .....), and do you agree or disagree with the proposal to have the scoring ranges as follows?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
2.2.1 Flood discharge per storage capacity	- Apply the rate of peak flood flow design (return period of 500 or 1000 years) per unit of	(cu.m./second/ mcm.)		
	reservoir capacity (cu.m./second/ mcm.), which presents the effective size of the reservoir comparing to the hydrologic regime also affects the spillway investment cost.	< 5	5	
	- A low value indicates that the project area has a low flood discharge per unit of storage	5.1-10	4	
	is well- suited and more safety with an appropriately sized reservoir. That has the potential to effectively support.	10.1-15	3	
	more flood volumes and consequently has a shorter spillway with lower construction cost, resulting in a	15.1-20	2	
	high score	>20.1	1	
	- Reference: The researcher analyzed the ranges from data of 25 projects.			
2.2.2 Others (Specify).....				

2.3 In the main factor of geology, what is your opinion on proposing the following indices: 1) Seismicity 2) Leakage of the foundation 3) Other (Specify: .....) And how should the weighting be done?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Factor	Priority Method	Weighted Value Method	Suggestions/Comments
2.3.1 Seismicity			1.
2.3.2 Groundwater leakage of the foundation			2.
2.3.3 Others.....			
		100%	

2.3.1 Indices of seismicity

1) In the seismicity index, what is your opinion on proposing a scoring range as follows?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
2.3.1 Seismicity	- Applying the Mercalli intensity scale (1-7) has an impact on the earthquake resistance construction.	Mercalli intensity	5	
	A higher seismicity level results in higher seismic resistance, and negatively affects the risk	standards level 1-2		
	of severe earthquakes, leading to damage to dams, hydraulic structures, and downstream flood-prone areas.	level 3	4	
	- The high-level value has a low score of geological suitability.	Level 4	3	
	- Reference: Seismic Hazard Level from Thailand's Seismic Hazard Map, 2nd Edition,	Level 5	2	
	by the Department of Mineral Resources.	Level 6-7	1	

2.3.2 Indices of foundation and leakage				
1) In the foundation and leakage index, what is your opinion on proposing a scoring range as follows? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....				
Indices	Indicator Description	Range	Score	Note (Edit as follows)
2.3.2 Leakage of the foundation	- The geological condition of the dam foundation affects the dam safety, water loss, and construction cost in preventing water seepage from reservoir.	Low leakage or Lugeon <1	5	
	- The low seepage value is suitability, and low construction cost are considered in this case, taking into account the values obtained from the permeability test (measured in Lugeon)	Relatively low leakage or Lugeon 1-5	4	
	or the type of rock layer at the dam foundation, such as granite, metamorphic rock, or the assessment of seepage from project study reports.	Moderate leakage or Lugeon 5-10	3	
	- A low seepage level results in higher dam safety, less water loss and minimal construction costs for seepage prevention, leading to a high score.	Relatively high leakage or Lugeon 10-50	2	
	- In cases where there is no seepage assessment, evaluations are made based on the types of rock layers in the foundation as follows: Igneous rock exhibits minimal to relatively low	High leakage or Lugeon >50	1	
	seepage, shale, mudstone, and siltstone have relatively low to moderate seepage, and sandstone and conglomerate show moderate to relatively high seepage. Additionally, metamorphic rocks with fractures, including limestone and sandstone, have moderate to high seepage.			
	- Reference: The researcher evaluated the data range from 25 projects.			

2.4 In the main engineering factors, what is your opinion on proposing the following indices: 1) Area of irrigation per storage capacity,
2) Other (Specify.....) And do you agree or disagree with the proposal for the following score ranges:

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
2.4.1 Irrigation area per storage capacity planed cropping	- The ratio of irrigated area to the unit of water storage capacity reflects the suitability project planning with balance of	(rai / mcm.)		
	the irrigation system against the size of the reservoir, and the physical characteristics of the soil, hydrology	>900	5	
	and topography of the benefiting area affecting both water security and project benefits.	701-900	4	
		501-700	3	
	- A higher ratio indicates a well-suited project for irrigation.	301-500	2	
	- Reference: The researcher analyzed the range from data of 25 projects.	<301	1	

3. In the dimension of natural resources and the environment.

In the dimension of natural resources and the environment , what is your opinion on categorizing the main factors that impact the sustainable development of water sources into four aspects: 1) Forests, 2) Wildlife, 3) Water quality, 4) Ecosystem, and 5) Other (Specify.....).

How should the weighting values be assigned for each of these factors and indices?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Factor	Priority Method	Weighted Value Method		Suggestions/Comments
3.1 Forests				1.
3.2 Wildlife				2.
3.3 Impact on water quality				3.
3.4 Impact on ecosystem				4.
3.5 5 Others.....				
		100 %		

3.1 Main factors related to the forest

1) In the main factors related to the forest, what is your opinion on proposing the following indices? 1) Abundance, 2) Biodiversity, 3) Prohibited and specially prohibited tree species, 4) Uniqueness/Exclusivity, and 5) Other (Specify.....) ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method		Suggestions/Comments
3.1.1 Fertility				1.
3.1.2 Biodiversity				2.
3.1.3 Prohibited and specially prohibited tree species				3.
3.1.4 Uniqueness/Exclusivity				4.
3.1.5 Others.....				
		100%		

1) In the main forest index, what is your opinion on proposing the following score ranges?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
3.1.1 Abundance or density of large trees No.of (trees/rai).	- In this context, the density of large trees per 1 rai is	● Deciduous Forest < 14 trees/rai (less abundance)	3	
	applied corresponding to the main forest type in the reservoir area	14-40 trees/rai (moderately abundance)	2	
	- High density of large trees indicates forest abundance	>40 trees/rai (high abundance)	1	
	The project will have more impact on high density	● Mixed Forest < 16 trees/rai (less abundance)	3	
	forest, resulting in a low suitability score.	16-54 trees/rai (moderately abundance)	2	
	- Reference: Department of Conservation Science,	>54 trees/rai (high abundance)	1	
	Faculty of Forestry, Kasetsart University, B.E.2552.	● Hill Evergreen Forest < 15 trees/rai (less abundance)	3	
	Criteria for assessing the status of forest resources in	15-45 trees/rai (moderately abundance)	2	
	watershed areas.	>45 trees/rai (high abundance)	1	
3.1.2 Biodiversity	- Utilize the number of tree species according to the	■ Deciduous Forest < 17 types /rai (less variety)	3	
	main type of forest in the reservoir area.	17-30 (moderately variety)	2	
	- A high number of species indicates a high biodiversity	>30 (high variety)	1	
	in the forest. The project will have a significant	■ Mixed Forest < 25 types / rai (less variety)	3	
	impact, resulting in a lower sustainability score.	25-43 (moderately variety)	2	
	- Reference: Department of National Parks, Wildlife	>43 (high variety)	1	
	and Plant Conservation announcement regarding the	■ Hill Evergreen Forest < 49 types/ rai (less variety)	3	
	valuation of natural resources in national parks,	49-84 (moderately variety)	2	
	B.E.2564.	>84 (high variety)	1	

Indices	Indicator Description	Range	Score	Note (Edit as follows)
3.1.3 Prohibited and specially prohibited tree species	- Utilize prohibited species of trees as listed in the	1-10 types = low	5	
	Department of National Parks, Wildlife and Plant	11-20 types = relatively low	4	
	Conservation's announcement on valuing natural	21-30 types = moderately	3	
	resources in national parks, B.E. 2564. In this context,	31-40 types = relatively high	2	
	employ tree species with a value exceeding 30,000	> 40 types = high	1	
	Baht/cubic meter.			
	- The greater the number of prohibited tree species,			
	the higher the value of rare species. Consequently,			
	the project is assigned a lower score.			
	- Reference: The researcher evaluated the range based			
	on data from 25 projects			
3.1.4 Uniqueness/ Exclusivity of forest	- Uniqueness at the national level, cannot be created	Identified distinctiveness in the area.	0	
	anew or relocated.	No distinctiveness found in the area.	1	
3.15 Others.....				

3.2 Main factors related to the wildlife

1 In the main factors related to wildlife, what is your opinion on proposing an index with 4 indicators: 1) Fertility, 2) Biodiversity, 3) Wildlife status, 4) Uniqueness and exclusivity of wildlife, and 5) Other (Specify.....). ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions
3.2.1 Fertility or Abundance			1.
3.2.2 Biodiversity			2.
3.2.3 Wildlife Status			3.
3.2.4 Uniqueness and Exclusivity of Wildlife			4.
3.2.5 Others.....			
		100 %	

2)) In the main wildlife index, what is your opinion on proposing the following score ranges? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
3.2.1 Abundance	- Applying the concept of density as a representation of the level of wildlife	> 60 types	3	
	abundance, using the number of species with low abundance in the reservoir as an indicator.	40-60 types	2	
	- A high number of species with low abundance indicates a low abundance level for	< 40 types	1	
	wildlife in the area, resulting in a higher score.			
	- Reference: Compiled by the researcher from statistical data of 25 projects.			
3.2.2 Biodiversity	- Utilizing the number of wildlife species found in the reservoir area. A high number of	< 115 types	5	
	wildlife species indicates a high level of biodiversity.	115-150 types	4	
	- A high number of species suggests high biodiversity, resulting in a low suitability score.	151-185 types	3	
	- Reference: The researcher evaluated the range of species from statistical data of 25	186-215 types	2	

	projects.	>215 types	1	
Indices	**Indicator Description**	**Range**	**Score**	**Note (Edit as follows)**
3.2.3 Wildlife Status	- Applying the number of wildlife species protected by the IUCN Red List in 2015,			
	categorized as VU (Vulnerable), EN (Endangered), and CR (Critical).			
	- The high number of wildlife species found in the reservoir area according to the IUCN			
	Red List indicates	< 4 types	3	
	the area's significance for sustaining biodiversity. The low suitability score of	5 - 8 types	2	
	the project is attributed to the presence of endangered and near-extinct wildlife	> 8 types	1	
	species that warrant conservation.			
	- Reference: Compiled by the researcher from statistical data of 25 projects.			
3.2.4 Uniqueness/ Exclusivity	- Uniqueness in terms of wildlife at the national level, which cannot be replaced or relocated.	Identified distinctiveness in the area.	0	
		No distinctiveness found in the area.	1	
3.2.5 Other (Specify.....)				

3.3 Main factors related to impact on water quality

1) In the main factors related to impact on water quality, what is your opinion on proposing the following score ranges?

❑ **Agree** ❑ **Disagree** ❑ **Should increase / decrease (Specify)..... because.....**

Indices	Indicator Description	Range	Score	Note (Edit as follows)
3.3.1 Water Quality	- The severity level of the impact score from projects that affect	No impact or less impact	5	
	the altered water quality. In this case, it includes:	Moderate impact and can be mitigated	4	
	- Biology (Liver fluke, Dengue fever, Malaria)	Severe impact and can be significantly mitigated.	3	
	- Chemistry (Heavy metals, Pollutants)	Severe impact and can be moderately mitigated.	2	
		Severe impact and can be less mitigated.	1	

3.4 Main factors related to impact on ecosystem.

1) In the main factors related to impact on ecosystem, what is your opinion on proposing the following indices: 1) Types of affected conservation forests, 2) Area impacted per conservation area, 3) Location of the reservoir within the conservation zone, and 4) Other (Specify……). ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)……because……

Indices	Priority Method	Weighted Value Method	Suggestions
1) Types of affected conservation forests			1.
2) Area impacted per conservation area			2.
3) Location of the reservoir within the conservation zone			3.
4) Other			4.
		100%	

Indices	Indicator Description	Range	Score	Note (Edit as follows)
1) The type of conservation forest where the reservoir is located.	- The national park class A, B, and C, as well as wildlife sanctuaries area, have a high to very high level of conservation priority.	high to very high priority	1	
	- Watershed quality classification 1A and 1B are relatively high in importance.	relatively high priority	2	
	- Reserved forest zone C holds a moderate level of significance.	moderate priority	3	
	- Reference: Conservation areas designated by the Department of National Parks, Wildlife, and Plant Conservation, Forestry Department, and ONEP.			
2) The proportion of the affected area size to the conservation area.	- The proportion of conserved forest area affected by the project is the ratio of the conserved forest area	< 1.0%	5	
	impacted to the total conserved area	1.1-2.0%	4	
	- A higher proportion has a greater impact on the high terrestrial and aquatic ecosystem. A project with a low score indicates an	2.1-3.0%	3	
	impact on ecosystem services and the loss of natural resource values, including the severity of impacts on	3.1-4.0%	2	
	greenhouse gas absorption. This is due to the loss of forest cover resulting from project development.	>4.0%	1	
	In this context, the evaluation utilizes the proportion of the conserved forest area impacted.			
	- Reference: Researcher's assessment based on data from 25 projects.			
3) The location of the reservoir within the conservation area.	- The location of the reservoir within the conservation area indicates the level of environmental integrity.	At the boundary, the impact is low.	3	
	- The headwaters in the conservation area are more environmentally impact than the downstream areas. Therefore, projects located within the headwaters area get lower scores.	At the boundary to the central area, the impact is moderate.	2	
		From the central area to the headwaters, the impact is high.	1	

4. In the social dimension, what is your opinion on the classification of key factors that impact sustainable water development? These factors include: 1) Opposition to the project, 2) Proportion of those affected and beneficiaries, 3) Quality of life, and 4) Other (Specify)..... These are further broken down into 5 indices: 1) Number of households opposing the project, 2) Number of households affected in terms of capacity, 3) Compensated area per property capacity, 4) Benefited area per reservoir area, 5) Quality of life, unity, uniqueness, and 6) Other (Specify)..... Do you agree, and how should the weighting be applied?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions
4.1 Opposition to the project			1.
4.2 Proportion of those affected and beneficiaries			2.
4.3 Quality of life			3.
4.4 Other			
		100%	

4.1 In the main factor of project opposition, what is your opinion on proposing an index based on: 1) Number of households opposing the project per the number of affected individuals, 2) Other (Specify)..... And suggesting a scoring range as follows:

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
4.1.1 The number of households opposing the project per the number of individuals negatively impacted.	- Applying the proportion of the number of opponents to the number of individuals adversely affected.	> 20%	1	
		15 - 20 %	2	
	- A higher proportion of opposition leads to conflicts and poses an obstacle to the success of the project, resulting in a lower score.	10 – 15 %	3	
		5 - 10 %	4	
	- Reference: Evaluated by researchers based on data from 25 projects.	<5 %	5	
4.1.2 Other (Specify).....				

4.2 In the main factor related to the proportion of those affected and beneficiaries, what is your opinion on proposing an index consisting of 3 indicators: 1) the number of households affected per capacity, 2) the compensatory property area per capacity, and 3) the area benefiting per reservoir area, and 4) Other (Specify)..... Do you agree or not, and how should the weighting be considered?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions
4.2.1 The number of households affected per capacity			1.
4.2.2 The compensatory property area per capacity			2.
4.2.3 The area benefiting per reservoir area			3.
4.2.4 Other			
		100%	

Indices	Indicator Description	Range	Score	Note (Edit as follows)
4.2.1 The number of households affected per reservoir capacity.	- Applying the number of households that are affected to the reservoir capacity of 1 mcm.	< 1 households / mcm.	5	
	- A high number indicators high social impacts on habitats accommodation, cultivated land and lives values which are likely to lead to opposition, conflicts, evacuation and resettlement, high compensation costs, and	1.1-2.0	4	
	obstacles to project viability and success. The project is likely to score low.	2.1-3.0	3	
	- Reference: Evaluation conducted by researchers based on data from 25 projects.	3.1-4.0	2	
		>4.0	1	
4.2.2 The compensatory land area per reservoir capacity	- Applying the proportion of compensatory land area to the reservoir capacity of 1 mcm.	< 10 acre/mcm.	5	
	- A higher proportion results in higher compensation costs and impacts the livelihood of	10.1-20	4	
	residents, reducing the project's suitability. The project is likely to score low.	21.1-30	3	
	- Reference: Evaluation conducted by researchers based on data from 25 projects.	30.1-40	2	
		>40	1	
4.2.3The area benefiting per reservoir area	- Applying the proportion of the benefit area to the area lost due to the reservoir area.	< 10 times	1	
	- A higher proportion indicates that the project benefits the society more, with a larger	10.1-20 times	2	
	population benefiting than those significantly impacted. The project will receive a higher score.	21.1-30 times	3	

	- Reference: The researchers assessed the range from data of 25 projects.	30.1-40 times	4	
		>40 times	5	

4.3 In the main factor related to the quality of life and uniqueness/diversity, what is your opinion on the proposal of sub-indices as 5 indices, namely: 1) Historical sites, 2) Conservation-oriented natural tourist attractions, 3) Significant mineral resources, 4) Geology, 5) Ethnic groups, 6) Other (Specify).....

Agree or disagree? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Sub Indices	Note		Suggestions
4.3.1 Historical sites	- In the factor related to quality of life and uniqueness,		1.
4.3.2 Conservation-oriented natural tourist attractions	no specific ranking is assigned.		2.
4.3.3 Significant mineral resources	- If it is found that the built-up area is unique in any		3.
4.3.4 Geological conservation area	one index, there will be a score of 0 in this factor.		
4.3.5 Ethnic groups	- And if it does not impact uniqueness, there will be a		
4.3.6 Other (Specify).....	score of 1 in this factor.		

Indices	Indicator Description	Range	Score	Note (Edit as follows)
4.3 Quality of life and uniqueness comprise :				
4.3.1 Historical sites	- Is the project located within the designated area of a national archaeological	Located within the	0	
	site declared by the Fine Arts Department, the score is set as zero indicating	designated area.		
	Inappropriate location.	Not within the	1	
	- Reference: National Conservation Area declared by the Department of Fine Arts.	designated area		
4.3.2 Conservation-oriented natural tourist attractions	- The project is located in an internationally recognized conservation area for	Located within a	0	
	tourism purposes, The score is set zero	conservation area		
		Not within a	1	
	- Reference: Department of National Parks, Wildlife, and Plant Conservation.	conservation area.		

Indices	Indicator Description	Range	Score	Note (Edit as follows)
4.3.3 Significant mineral resources	- In case the project is located in an area with significant mineral resources, which has high value., the score is set zero - Reference: Department of Mineral Resources.	Located in the buffer zone area Not in the buffer zone area	0 1	
4.3.4 Geological conservation area	- In case the project is located in the area designated for geological conservation., The score is set zero. - Reference: Department of Mineral Resources.	Located within a conservation area Not within a conservation area.	0 1	
4.3.5 Ethnic groups	- In case there are diverse ethnic groups, in the reservoir area. The project has significant impacts on the living conditions, and cultural traditions of the highly diverse community., the score is set zero	There are marginalized groups within the area. There are no marginalized groups within the area.	0 1	
4.3.6 Other				

5. In the economic dimension, what is your opinion on the division of the three main factors, namely 1) benefits, 2) costs, and 3) value, into 6 indices that affect the sustainable development of water sources, as follows: 1) Benefits from irrigated areas per capacity, 2) Project costs per capacity, 3) Social compensation value (compensated area per capacity), 4) Environmental Impact (EIMP) value per capacity, 5) Economic viability, 6) Environmental-economic viability, 7) Others (specify)..... Do you agree, and how should the weighting be considered?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Factor	Priority Method	Weighted Value Method	Suggestions
5.1 Benefits			1.
5.2 Costs			2.
5.3 Feasibility /worthy			3.
5.4 Other			
		100%	

5.1 In the main factors related to benefits, what is your opinion on proposing the following score ranges?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note (Edit as follows)
5.1.1 Benefits from annual cultivated areas* per reservoir capacity	- Evaluate the project benefits based on the applied annual cultivated area size per reservoir capacity - A project that efficiently delivers water to the higher proportional annual cultivated area per capacity will have greater benefits, resulting in a higher score. - Reference: Researchers assessed the range from data obtained from 25 projects.	≤ 600 rai/mcm. >600-800 >800-1,000 >1,000-1,200 >1,200	1 2 3 4 5	
	Remarks : * cultivated area is converted from irrigation area plus 300 rai			

5.2 In the main factors related to costs, what is your opinion on dividing the index into three aspects: 1) Project cost per capacity, 2) Social compensation cost (compensating area per capacity), and 3) Environmental Impact (EIMP) cost per capacity, and 4) Others (specify)..... Do you agree or not?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions
5.2.1 Project costs per capacity			1.
5.2.2 Social compensation value (compensated area per capacity)			2.
5.2.3 Environmental Impact (EIMP) value per capacity			3.
5.2.4 Others (specify).....			
		100%	

Indices	Indicator Description	Range	Score	Note (Edit as follows)
5.2.1 Project cost per capacity	- Considering the proportion of total project costs (engineering, social,	< 20 MB./mcm.	5	
	environmental) per unit of reservoir capacity.	20-40	4	
	- High costs per unit of capacity indicate a reduced economic return for	40-60	3	
	the project, resulting in a lower score.	60-80	2	
	- Reference: Researcher's assessment based on data from 25 projects.	>80	1	
5.2.2 Social compensation cost	- Considering the land acquisition costs per unit of	< 2 MB./mcm.	5	
	reservoir capacity	2.1-4	4	
	- High compensation costs indicate a significant social impact and high	4.1-6	3	
	project costs, resulting in a lower score.	6.1-8	2	
	- Reference: Researcher's assessment based on data from 25 projects.	>8	1	
5.2.3 Environmental Impact (EIMP) cost per capacity	- Considering the budget for reducing the environmental impact of the	< 2 MB./mcm.	5	
	project per unit of reservoir capacity.	2.1-4	4	
	- High Environmental Impact (EIMP) cost indicates a significant environmental	4.1-6	3	
	impact, leading to high project costs and a lower score.	6.1-8	2	
	- Reference: Researcher's assessment based on data from 25 projects.	>8	1	

5.3 In the main factor related to value, what is your opinion on dividing the index into two aspects: 1) Economic value, 2) Environmental economic value, and 3) Other (Specify)..... Do you agree or not?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method		Suggestions
5.3.1 Economic value				1.
5.3.2 Environmental economic value				2.
5.3.3 Other (Specify).....				
		100%		

Indices	Indicator Description	Range	Score	Note (Edit as follows)
5.3.1 Economic Internal Rate of Return (EIRR)	- Considering the economic internal rate of return (EIRR) on investment of	> 14 %	5	
	the project	12 -14 %	4	
	- High value indicates that the project is economically viable, leading to	10 -12%	3	
	a high score.	8 – 10 %	2	
	- Reference: Evaluation conducted by researchers based on data from 25 projects.	< 8 %	1	
5.3.2 Environmental economic value	- Considering the environmental economic internal rate of return (EIRR) of	> 12%	5	
	the project	10-12%	4	
	- High value indicates that the project has high environmental viability,	8-10%	3	
	leading to a high score.	6-8 %	2	
	- Reference: Evaluation conducted by researchers based on data from 25 projects.	< 6%	1	
5.3.3 Other				

Part 2 : Comments on the scoring criteria for projects that demonstrate sustainability in various dimensions.

1. How do you think the scoring categories should be organized to determine the sustainability level of a water resource development project in a conservation area across various dimensions?

Dimension	Low	Moderately Low	Moderate	Good	Very Good	Agree	Disagree	Because
1. Engineering	<45%	45-55%	>55-65%	65-75%	>75%			
2. Natural Resources and Environmental	<45%	45-55%	>55-65%	65-75%	>75%			
3. Social	<45%	45-55%	>55-65%	65-75%	>75%			
4. Economic	<45%	45-55%	>55-65%	65-75%	>75%			
5. Total of All Dimensions	<45%	45-55%	>55-65%	65-75%	>75%			

Edit as follows :

Dimension	Low Score	Moderately Low Score	Moderate Score	Good Score	Very Good Score	Agree	Disagree	Because
1. Engineering								
2. Natural Resources and Environment								
3. Social								
4. Economic								
5. Total of All Dimensions								

Part 3: Assessing the severity of the problem and the necessity of the area requiring water development projects.

1. Regarding the severity of the problem in the area, what is your opinion on grouping the main factors that affect the assessment of the severity of the problem and the necessity of the area requiring water development projects into 5 factors, namely: 1) Geography 2) Level of development 3) Hydrogeology of water sources 4) Water demand 5) Society 6) Other (Specify)..... Do you agree, and how should the weighting be?

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Factor	Priority Method	Weighted Value Method	Suggestions
1.1 Geography			1.
1.2 Level of development			2.
1.3 Hydrogeology of water sources			3.
1.4 Water demand			4.
1.5 Society /Poverty			
1.6 Other (Specify).....			
		100%	

1.1 In the main factor of topography, what is your opinion on proposing an index as 1) Drought risk areas, 2) Flood risk areas, and 3) Other (Specify)..... And proposing to have score ranges as follows? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions/Comments
1.1.1 Drought risk area			1.
1.1.2 Flood risk area			2.
1.1.3 Other			
		100%	

Indices	Indicator Description	Range	Score	Note
1.1.1 Drought risk areas	- It is an area within the drought risk zone, which is considered based on the frequency	> 6 times = high score	3	
	or number of occurrences within a 10-year period.	4-6 times = moderate score	2	
	- High frequency indicates a high risk, resulting in a high score.	<4 times = low score	1	
	- Reference: GISDA Drought Risk Map.			
1.1.2 Flood risk areas	- It is an area within the flood risk zone, which is considered based on the frequency or	> 6 times = high score	3	
	number of occurrences within a 10-year period.	4-6 times = moderate score	2	
	- High frequency indicates a high risk, resulting in a high score.	<4 times = low score	1	
	- Reference: GISDA Flood Risk Map.			
1.1.3 Other				

1.2 In the main factor of the level of development, what is your opinion on proposing the index, including 1) Development of water sources and irrigation systems and 2) Others (Specify)....., and suggesting the following score ranges? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note
1.2.1 Development of water sources and irrigation systems	- Considering that the project agriculture area located outside the existing	Outside the irrigation zone	3	
	irrigation zone tend to have more severe problems than those within the irrigation zone.	Located in the area benefiting	2	
	- The criteria for areas outside the existing irrigation zone get high scores. Areas within the	From project type: weir,		
	zone benefiting from hydraulic structures but without reservoirs get moderate	flood gate, pumping station		
	scores, and areas within the irrigation zone with reservoirs 7get low scores.	but without reservoirs.		
	- Reference: Irrigation Zone Boundary Map by the Department of Irrigation.	In the irrigation zone with	1	
		a reservoir		

1.3 In the main factor of hydrology, what is your opinion on proposing an index for 1) hydrological stability, 2) potential for groundwater supply, and 3) others (specify)....., and suggesting the following score ranges? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Priority Method	Weighted Value Method	Suggestions/Comments
1.3.1 Hydrological stability			1.
1.3.2 Potential for groundwater supply			2.
1.3.3 Other			3.
		100 %	

Indices	Indicator Description	Range	Score	Note
1.3.1 Hydrological variation	- Applying the proportion of average rainfall during the dry season compared to the annual average rainfall of the rain gauge stations.	< 25%	3	
		25-30%	2	
	- Low proportion indicates an area having low rainfall and low natural flow during the dry season. Natural water sources in dry season are not reliable. Areas experience with high drought, thus water scarcity score get a higher score.	> 30%	1	
	- Reference: Monthly average rainfall data from the Royal Irrigation Department.			
1.3.2 Potential for groundwater supply	- Considering areas where groundwater has the quantity and quality potentials for groundwater supply.	Yield < 10 and TDS > 500	4	
		10-20 and TDS < 500	3	
	- Low groundwater supply value of less than 10 liters per hour and a Total Dissolve Solid (TDS) value exceeding 1,500 units indicate areas having high water scarcity issues. These areas will receive a higher score.	> 20 and TDS > 500	2	
		> 20 and TDS < 500	1	
	- Reference: Groundwater map by the Department of Groundwater Resources.			
1.3.3 Others (specify).....				

1.4 In the main factors of water demand, what is your opinion on proposing an index, including 1) alignment with water needs in the benefiting area, 2) other (specify)....., and suggesting the following score ranges? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....				
Indices	Indicator Description	Range	Score	Note
1.4.1 Alignment with Crop water demands in the benefiting area	- Considering the water demand in the benefited area.	Orchard	4	
	- Orchard areas, which require water throughout the year in significant quantities and are	Rice field	3	
	economically important, receive a high score.	Farm area	2	
	- Rice fields, which need more water during low flow period in the rainy season, and	Rubber and perennial tree	1	
	during dry season have a high demand in large			
	quantities and are the main crops in the livelihood, receive a high score			
	- Farm areas, which require minimal water and serve as supplementary crops for			
	additional income, receive a moderate score.			
	- Rubber and perennial tree areas, which require minimal water, receive a low score.			
	- Reference: Land use map by the Department of Land Development.			
1.4.2 Others				
1.5 In the main factors of social, what is your opinion on proposing an index based on: 1) The level of poverty of residents in the area, and 2) Other (Specify)..... , and suggesting the following score ranges? ❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....				
Indices	Indicator Description	Range	Score	Note
1.5.1 The level of poverty in the project area	- In terms of social aspects, poverty is considered based on income, health, education,	>10%	5	
	living conditions, and access to government services.	7.5-10%	4	
	- Areas with a high proportion of the level of poverty should receive high development	5-7.5%	3	
	necessity scores, resulting in a high score.	2.5-5%	2	
	- The level of poverty is assessed based on the percentage of the impoverished	0-2.5%	1	
	population compared to the total population at the district level.			
	- Reference: National Electronics and Computer Technology Center (NECTEC), B.E.2565.			
1.5.2 Others				

2. How do you feel about the proposed scoring ranges for the overall severity level of problems in the area, as follows:

❑ Agree ❑ Disagree ❑ Should increase / decrease (Specify)..... because.....

Indices	Indicator Description	Range	Score	Note
2.1 The total score of the water scarcity indicator.	- The overall score of various factors measuring the level of water scarcity of the area is calculated by multiplying the score of each factor by its weight.	< 33% : low level of problems	1.	
		33.1-67% : moderate level of problems	2.	
		>67% : high level of problems	3	
	- Reference: The assessment is based on data from 25 projects conducted by the researchers.			

Appendix D.2

2nd Round Questionnaire For Del Phi's Panel Consideration

Attachment 1

Appendix D.2

2nd Round Questionnaire for Del Phi's Panel Considerations

Objective

This attached document aims to present a summary of the considerations assigned weights to dimensions, factors, and various indicators, including the score ranges of the indicators obtained from the Del Phi's first round questionnaire. The researchers evaluated the results based on the majority opinions and made adjustments for practical application. This information serves as supplementary data for the second round of questionnaire responses to assess the importance of the aforementioned weights, aiming for a percentile greater than 75. (You can also provide feedback on this attached document or in the questionnaire for the second round).

Section 1: Evaluation of Weightings for Dimensions, Factors, and Indicators

1. Dimensions: The assessment of weightings for dimensions revealed the following:

1.1 Engineering Dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 20%.

1.2 Natural Resources and Environment Dimension: A majority of 9 out of 20 panelists (45%) assigned a weighting of 35%.

1.3 Social Dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 25%.

1.4 Economic Dimension: A majority of 12 out of 20 panelists (60%) assigned a weighting of 20%.

If we assign weightings to the dimensions as follows: Engineering: Natural Resources and Environment: Social: Economic = 20:35:25:20, what is your opinion?

( ) Agree ( ) Disagree and suggest the weightings as follows: .....

2. Factors: The survey results of weightings for key factors in various dimensions are as follows:

2.1 Engineering and Physical Dimension consisting of 4 key factors:

2.1.1 Geographic Factors:

- A majority of 9 out of 20 panelists (45%) assigned a weighting of 20%.
- A majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

Combining both, a total of 13 out of 20 panelists (65%) assigned weightings ranging from 20-25%, or with average of 22.5%.

Attachment 1

2.1.2 Hydrologic Factors:

- A majority of 5 out of 20 panelists (25%) assigned a weighting of 25%.
- Another majority of 5 out of 20 panelists (25%) assigned a weighting of 20%.

Combining both, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 20-25%, with an average of 22.5%.

2.1.3 Geological Factors:

- A majority of 8 out of 20 panelists (40%) assigned a weighting of 30%.
- Another majority of 3 out of 20 panelists (15%) assigned a weighting of 35%.

Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-35%, with an average of 32.5%.

2.1.4 Engineering Factors:

- A majority of 9 out of 20 panelists (45%) assigned a weighting of 20%.
- Another majority of 6 out of 20 panelists (30%) assigned a weighting of 25%.

Combining both, a total of 15 out of 20 panelists (75%) assigned weightings ranging from 20-25%, with an average of 22.5%.

If assigning weightings for Geological and Engineering Factors in terms of Geography : Hydrology : Geophysics : Engineering, respectively, as 25 : 25 : 30 : 20, what is your opinion?

( ) Agree ( ) Disagree, and propose weightings as follows: .....

2.2 Natural Resources and Environmental Dimension consisting of 4 key factors:

2.2.1 Main Factors related to Forests:

- A majority of 7 out of 20 panelists (35%) assigned a weighting of 25%.
- The next majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.

Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 25-30%, with an average of 27.5%.

2.2.2 Main Factors related to Wildlife:

- A majority of 9 out of 20 panelists (45%) assigned a weighting of 25%.
- Another majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.

Combining both, a total of 13 out of 20 panelists (65%) assigned weightings ranging from 25-30%, with an average of 27.5%.

2.2.3 Factors related to the Impact on Water Quality:

- A majority of 8 out of 20 panelists (40%) assigned a weighting of 20%.

- Another majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

Combining both, a total of 12 out of 20 panelists (60%) assigned weightings ranging from 20-25%, with an average of 22.5%."

2.2.4 Factors related to the Impact on Ecosystems:

- A majority of 7 out of 20 panelists (35%) assigned a weighting of 20%.
- Another majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.

Combining both, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 20-25%, with an average of 22.5%.

If assigning weightings to factors related to natural resources and the environment, including Forests, Wildlife, Water Quality, and Ecosystems, as 25:30:20:25, what is your opinion?

( ) Agree ( ) Disagree, and suggest the weightings to be .....

2.3 Social Dimension comprises 3 key factors:

2.3.1 Main factors related to Project Opposition:

- A majority of 4 out of 20 panelists (20%) assigned a weighting of 25%.
- The next tier, with 2 out of 20 panelists (10%) each, assigned weightings of 30%.
- The subsequent tier, with 2 out of 20 panelists (10%) each, assigned weightings of 35%. Combining these, a total of 8 out of 20 panelists (40%) assigned weightings ranging from 25-35%, with an average of 30%.

2.3.2 Main factors related to Proportion of Impact on Beneficiaries:

- A majority of 4 out of 20 panelists (20%) assigned a weighting of 30%.
- Another majority of 4 out of 20 panelists (20%) assigned a weighting of 35%.
- The next tier, with 3 out of 20 panelists (15%), assigned a weighting of 40%.

Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-40%, with an average of 35%.

2.3.3 Factors related to Quality of Life:

- A majority of 6 out of 20 panelists (30%) assigned a weighting of 30%.
- The next tier, with 3 out of 20 panelists (15%), assigned a weighting of 40%.
- The subsequent tier, with 2 out of 20 panelists (10%), assigned a weighting of 35%.

Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 30-40%, with an average of 35%.

Attachment 1

If assigning weightings for social factors, including Project Opposition, Proportion of Impact on Beneficiaries, and Quality of Life, the distribution would be as follows: 30% : 35% : 35%. What is your opinion?

( ) Agree ( ) Disagree and propose weightings as follows: .....

2.4 Economic Dimension consists of 3 main factors:

2.4.1 Benefits-related Factors:

- A majority of 8 out of 20 panelists (40%) assigned a weighting of 35%.
- The next tier, with 4 out of 20 panelists (20%), assigned a weighting of 30%.

Combining these, a total of 12 out of 20 panelists (60%) assigned weightings ranging from 30-35%, with an average of 32.5%.

2.4.2 Cost-related Factors:

- A majority of 5 out of 20 panelists (25%) assigned a weighting of 25%.
- Another majority of 5 out of 20 panelists (25%) assigned a weighting of 30%.
- The subsequent tier, with 4 out of 20 panelists (20%), assigned a weighting of 35%.

Combining these, a total of 14 out of 20 panelists (70%) assigned weightings ranging from 25-35%, with an average of 30%.

2.4.3 Value-related or Feasibility Factors:

- A majority of 6 out of 20 panelists (30%) assigned a weighting of 40%.
- Another majority of 4 out of 20 panelists (20%) assigned a weighting of 35%.

Combining these, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 35-40%, with an average of 37.5%.

If assigning weightings for economic factors, including Benefits, Costs, and Feasibility, the distribution would be as follows: 30% : 30% : 40%. What is your opinion?

( ) Agree ( ) Disagree and propose weightings as follows: .....

3. Indicators survey results of weightings for indicators across various factors.

3.1 Engineering Dimension

3.1.1 Factors related to Geography consist of 2 main indicators :

1) Dam Cross-Section Indicator / Capacity
   - A majority of 7 out of 20 panelists (35%) assigned a weighting of 40%.

- Another majority of 7 out of 20 panelists (35%) assigned a weighting of 50%.

Combining these, a total of 14 out of 20 panelists (70%) assigned weightings ranging from 40-50%, with an average of 45%.

2) Reservoir Area Indicator / Capacity

- A majority of 7 out of 20 panelists (35%) assigned a weighting of 50%.

- The subsequent tier, with 6 out of 20 panelists (30%), assigned a weighting of 60%.

Combining these, a total of 13 out of 20 panelists (65%) assigned weightings ranging from 50-60%, with an average of 55%.

If assigning weightings for factors related to Geography in the indicators (Dam Cross-Section / Capacity : Reservoir Area / Capacity), it would be 45 : 55. What is your opinion?

( ) Agree ( ) Disagree and propose weightings as follows: .....

3.1.2 Geological Factors comprise a single indicator, hence a weightage of 100%.

- 18 out of 20 panelists (90%) assigned a weightage of 100%.

3.1.3 Geological Factors consist of 2 main indicators :

1) Seismic Indicator

- A majority of 5 out of 20 panelists (25%) assigned a weightage of 50%.

- The subsequent tier, with 3 out of 20 panelists (15%), assigned a weightage of 40%.

- The next tier, with 2 out of 20 panelists (10%), assigned a weightage of 60%.

Combining these, a total of 10 out of 20 panelists (50%) assigned weightings ranging from 40-60%, with an average of 50%.

2) Permeability Indicator

- A majority of 6 out of 20 panelists (30%) assigned a weightage of 50%.

- The subsequent tier, with 3 out of 20 panelists (15%), assigned a weightage of 60%.

- The next tier, with 2 out of 20 panelists (10%), assigned a weightage of 40%.

Combining these, a total of 11 out of 20 panelists (55%) assigned weightings ranging from 40-60%, with an average of 50%.

If assigning weightings for factors related to Geology in the indicator (Seismic Indicator : Permeability Indicator), it would be 50 : 50. What is your opinion?

( ) Agree ( ) Disagree and propose weightings as follows: .....

Attachment 1

3.1.4 Engineering (Irrigation) Factors consist of a single indicator, which is the ratio of irrigation area to capacity, thus carrying a weightage of 100%.

- All 20 panelists (100%) assigned a weightage of 100%.

3.2 Natural Resources and Environmental Dimension

3.2.1 Forest Factors consist of 4 indicators.

1) Forest Abundance Indicator

- The majority, 6 out of 20 panelists (30%), assigned a weightage of 25%.

- The majority, another 6 out of 20 panelists (30%), assigned a weightage of 30%.

or a total of 12 panelists (60%) assigned a weightage in the range of 25-30%, with an average of 27.5%.

2) Biodiversity Indicator

- The majority, 8 out of 20 panelists (40%), assigned a weightage of 25%.

- The next group, 5 out of 20 panelists (25%), assigned a weightage of 30%.

or a total of 13 panelists (65%) assigned a weightage in the range of 25-30%, with an average of 27.5%.

3) Forest Status Indicator (Prohibited Tree Status Indicator)

- The majority, 11 out of 20 panelists (55%), assigned a weightage of 20%.

- The next group, 4 out of 20 panelists (20%), assigned a weightage of 25%.

or a total of 15 panelists (75%) assigned a weightage in the range of 20-25%, with an average of 22.5.

4) Uniqueness Indicator

- The majority, 5 out of 20 panelists (25%), assigned a weightage of 30%.

- The next group, 4 out of 20 panelists (20%), assigned a weightage of 35%.

- Another group, 4 out of 20 panelists (20%), assigned a weightage of 20%.

- The last group, 3 out of 20 panelists (15%), assigned a weightage of 25%.

or a total of 16 panelists (80%) assigned a weightage in the range of 20-35%, with an average of 27.5.

If assigning weightage to the forest factors in the indicator (Abundance: Biodiversity: Forest Status: Uniqueness) as 25:25:20:30, what is your opinion?

( ) Agree ( ) Disagree, and propose the following weightages: .....

Attachment 1

3.2.2 Wildlife Factor comprises 4 indicators :

1) Abundance Indicator

- The majority, 8 out of 20 panelists (40%), assigned a weightage of 30%.

- The next group, 3 out of 20 panelists (15%), assigned a weightage of 25%.

or a total of 11 panelists (55%) assigned a weightage in the range of 25-30%, with an average of 27.5.

2) Biodiversity Indicator

- The majority, 7 out of 20 panelists (35%), assigned a weightage of 20%.

- The next group, 6 out of 20 panelists (30%), assigned a weightage of 25%.

or a total of 13 panelists (65%) assigned a weightage in the range of 20-25%, with an average of 22.5.

3) Wildlife Status Indicator (Endangered Wildlife Status Indicator)

- The majority, 8 out of 20 panelists (40%), assigned a weightage of 30%.

- The next group, 7 out of 20 panelists (35%), assigned a weightage of 20%.

- The following group, 3 out of 20 panelists (15%), assigned a weightage of 25%.

or a total of 18 panelists (90%) assigned a weightage in the range of 20-30%, with an average of 25.

4) Indicator of Uniqueness

- The majority, 4 out of 20 panelists (20%), assigned a weightage of 20%.

- The next group, 4 out of 20 panelists (20%), assigned a weightage of 25%.

- The following group, 3 out of 20 panelists (15%), assigned a weightage of 30%.

or a total of 11 panelists (55%) assigned a weightage in the range of 20-30%, with an average of 25.

If assigning weights to the wildlife factor in the indicator, Abundance: Biodiversity: Wildlife Status: Uniqueness is 30:20:30:20, what is your opinion?

( ) Agree ( ) Disagree, and suggest assigning weights as follows: .....

3.2.3 Impact Factors on Water Quality Indicator

The factor consists of a single indicator, hence, it is weighted 100%.

3.2.4 Environmental Impact Factors

1) Indicator of Conservation Forest Types Affected

- The majority, 7 out of 20 panelists (35%), assigned a weightage of 30%.

- The next group, 5 out of 20 panelists (25%), assigned a weightage of 40%.

- The following group, 2 out of 20 panelists (10%), assigned a weightage of 50%.

or a total of 14 panelists (70%) assigned a weightage in the range of 30-50%, with an average of 40.

2) Indicator of Proportion of Area Impact on Conservation Areas

- The majority, 9 out of 20 panelists (45%), assigned a weightage of 30%.

- The next group, 6 out of 20 panelists (30%), assigned a weightage of 35%.

or a total of 15 panelists (75%) assigned a weightage in the range of 30-35%, with an average of 32.5.

3) Indicator of Reservoir Location in Conservation Areas

- The majority, 7 out of 20 panelists (35%), assigned a weightage of 20%.

- The next group, 4 out of 20 panelists (20%), assigned a weightage of 30%.

- The following group, 2 out of 20 panelists (10%), assigned a weightage of 25%.

or a total of 13 panelists (65%) assigned a weightage in the range of 20-30%, with an average of 25.

If assigning weights to the impact factors on the environmental system, considering the Indicator of Conservation Forest Types Affected: Proportion of Area Impact on Conservation Areas: Reservoir Location in Conservation Areas as 40:35:25, what is your opinion?

( ) Agree ( ) Disagree, and suggest assigning weights as follows: .....

3.3 Social Dimension

3.3.1 Factors in Project Opposition

The factor consists of a single indicator, therefore, it is weighted 100%.

3.3.2 Factors Regarding the Proportion of Those Affected and Benefiting

1) Indicator of the Number of Households Affected per Reservoir Capacity

- The majority, 10 out of 20 panelists (50%), assigned a weightage of 40%.

2) Indicator of Compensated Area within Reservoir Area per Reservoir Capacity

- The majority, 10 out of 20 panelists (50%), assigned a weightage of 30%.

3) Indicator of Ratio of Area Benefiting to Reservoir Area

- The majority, 7 out of 20 panelists (35%), assigned a weightage of 30%.

- The next group, 3 out of 20 panelists (15%), assigned a weightage of 35%.

or a total of 10 panelists (50%) assigned a weightage in the range of 30-35%, with an average of 32.5.

If assigning weights to the factors related to the proportion of those affected and benefiting in the indicator: Number of Households Affected per Capacity: Compensated Area within Reservoir Area per Capacity: Ratio of Area Benefiting to Reservoir Area as 40:30:30, what is your opinion?

( ) Agree ( ) Disagree, and suggest assigning weights as follows: .....

3.3.3 Factors Related to Quality of Life and Uniqueness/Significance

- There are 5 indicators, namely 1) Archaeological Sites 2) Tourist Attractions 3) Important Mineral Resources 4) Geological Conservation Areas 5) Biodiversity. It is observed that each indicator is assigned an equal weightage of 20%.

3.4 Economic Dimension

3.4.1 Benefit Factors

- There is a single indicator, represented by the annual cropping area per reservoir capacity, thus assigned a weightage of 100%.

3.4.2 Cost Factors, consisting of 3 indicators:

1) Project Cost Indicator per Capacity

- The majority, 6 respondents out of 20 (30%), assign a weightage in the range of 33-35%.

- The next group, 5 respondents out of 20 (25%), assign a weightage of 30%.

This results in a total of 11 respondents (55%) assigning a weightage in the range of 30-35%, or an average of 32.5%.

2) Social Compensation per Capacity Indicator (Compensatory Area per Capacity)

-The majority, 6 respondents out of 20 (30%), assign a weightage of 30%.

-The majority, another 6 respondents out of 20 (30%), assign a weightage in the range of 33-35%.

This results in a total of 12 respondents (60%) assigning a weightage in the range of 30-35%, or an average of 32.5%.

3) Environmental Mitigation Cost per Capacity Indicator

- The majority, 5 respondents out of 20 (30%), assign a weightage of 35%.
- The majority, another 5 respondents out of 20 (30%), assign a weightage of 40%.

-The next group, 3 respondents out of 20 (15%), assign a weightage of 30%.

This results in a total of 13 respondents (75%) assigning a weightage in the range of 30-35%, or an average of 35.

Attachment 1

If assigning weightage to the cost factors in the indicators: Project Cost per Capacity, Social Compensation Indicator(Compensatory Area per Capacity), and Environmental Mitigation Cost per Capacity Indicator, the ratio is 30:35:35. What is your opinion?

( ) Agree ( ) Disagree and suggest the weightage as follows: .....

3.4.3 Economic Viability Factors consist of 2 indicators:

1) Economic Viability Indicator
   - The majority, 7 respondents out of 20 (35%), assign a weightage of 40%.
   - The next group, 2 respondents out of 20 (10%), assign a weightage of 45%.
   - The following group, 2 respondents out of 20 (10%), assign a weightage of 50%.

This results in a total of 11 respondents (55%) assigning a weightage in the range of 40-50%, or an average of 45%.

2) Environmental Economic Viability Indicator
   - The majority, 7 respondents out of 20 (35%), assign a weightage of 60%.
   - The next group, 2 respondents out of 20 (10%), assign a weightage of 55%.
   - The following group, 1 respondent out of 20 (5%), assigns a weightage of 50%.

This results in a total of 10 respondents (55%) assigning a weightage in the range of 50-60%, or an average of 55%.

If assigning weightage to the factors in the Economic Feasibility Indicator: Economic Feasibility and Environmental Economic Feasibility, the ratio is 45:55. What is your opinion?

( ) Agree ( ) Disagree and suggest the weightage as follows: .....

4. Score Range Criteria for Sustainability Level:

It is observed that the majoritiy, over 75%, agree with the proposals in the questionnaire.

Additional Comments:

……
……
……
……
……..

Attachment 3

Section 2: Establishing Criteria for Sustainability Ratings in Dimensions.

The criteria for scoring can be summarized as follows. The majority, 14 out of 20 respondents (70%), express their opinion on categorizing sustainability levels within the score range for the following dimensions:

Dimension	Low	Moderately Low	Moderate	Good	Very Good	Agree	Disagree
1. Engineering	<45%	45-55%	>55-65%	65-75%	>75%	14	6
2. Natural Resources and Environmental	<45%	45-55%	>55-65%	65-75%	>75%	14	6
3. Social	<45%	45-55%	>55-65%	65-75%	>75%	14	6
4. Economic	<45%	45-55%	>55-65%	65-75%	>75%	14	6
Total of All Dimensions	<45%	45-55%	>55-65%	65-75%	>75%	14	6

If the specified ranges are set, what is your opinion?

( ) Agree ( ) Disagree , there should be ranges as follows.....

Dimension	Results from the 1st questionnaire	2nd Opinion Proposal
Low	<45%	
Moderately Low	45-55%	
Moderate	>55-65%	
Good	65-75%	
Very Good	>75%	

Attachment 4

Section 3: Summary of the Evaluation of the Water Scarcity Problem or the Necessity of Water Source Development

1. **Factors:** The assessment of the severity of the water scarcity problem and the necessity of water source development involves a total of 5 factors.

1.1 Geographic Factor

- Majority, 5 out of 20 respondents (25%), assigned a weight of 15%.
- Majority, another 5 out of 20 respondents (25%), assigned a weight of 20%.
- Majority, 4 out of 20 respondents (20%), assigned a weight of 25%.

Overall, 14 respondents (70%) allocated weights in the range of 15-25%, with an average of 20%.

1.2 Level of Development Factor (Existence of irrigation development)

- Majority, 7 out of 20 respondents (35%), assigned a weight of 10%.
- Majority, another 7 out of 20 respondents (35%), assigned a weight of 20%.
- Majority, 2 out of 20 respondents (10%), assigned a weight of 15%.

Overall, 16 respondents (80%) allocated weights in the range of 10-20%, with an average of 15%.

1.3 Hydrologic and Groundwater Potential Factors:

- The majority, 9 out of 20 respondents (45%), assigned a weight of 20%.
- Another majority, 4 out of 20 respondents (20%), assigned a weight of 25%.
- Another majority, 4 out of 20 respondents (20%), assigned a weight of 15%.

Overall, 17 respondents (85%) allocated weights in the range of 15-25%, with an average of 20%.

1.4 Water Demand Factors:

- The majority, 9 out of 20 respondents (45%), assigned a weight of 20%.
- Another majority, 4 out of 20 respondents (20%), assigned a weight of 25%.
- Another majority, 4 out of 20 respondents (20%), assigned a weight of 15%.

Overall, 17 respondents (85%) allocated weights in the range of 15-25%, with an average of 20%.

1.5 Poverty Factors:

- The majority, 6 out of 20 respondents (30%), assigned a weight of 20%.
- The next majority, 4 out of 20 respondents (20%), assigned a weight of 30%.
- The next majority, 3 out of 20 respondents (15%), assigned a weight of 25%.

Overall, 13 respondents (65%) allocated weights in the range of 20-30%, with an average of 25%.

Attachment 4

If assigning weights to the water scarcity factors, in the factors of geography: level of development: hydrology and groundwater potential: water demand: poverty, the suggested weights are 20:15:20:20:25.

What is your opinion?

( ) Agree ( ) Disagree, and propose weights as follows: .....

2. Indicators :

2.1 Geographic Factor: Comprising 2 Indicators

2.1.1 Drought Risk Area Indicator:

- The majority, 6 out of 20 respondents (30%), assigned a weight of 50%.

- The next majority, 5 out of 20 respondents (25%), assigned a weight of 55-60%.

Overall, 11 respondents (55%) allocated weights in the range of 50-60%, with an average of 55%.

2.1.2 Flood Risk Area Indicator:

- The majority, 6 out of 20 respondents (30%), assigned a weight of 50%.

- The next majority, 5 out of 20 respondents (25%), assigned a weight of 40-45%.

Overall, 11 respondents (55%) allocated weights in the range of 40-50%, with an average of 45%.

If assigning weights to the geographic factor for drought risk area indicator: flood risk area Indicator is 55:45. What is your opinion?

( ) Agree ( ) Disagree, and propose weights as follows: .....

2.1.3 Development Level Factor:

There is only one index, which is the development of water resources and irrigation systems, thus carrying a weight of 100%.

2.1.4 Hydrological Factor: Consisting of 2 Indicators

1) Hydrologic Variation Indicator:

- The majority, 8 out of 20 respondents (40%), assigned a weight of 60%.

- The next majority, 3 out of 20 respondents (15%), assigned a weight of 75%.

Overall, 11 respondents (55%) allocated weights in the range of 60-75%, with an average of 67.5%.

2) Potential for Groundwater Use Indicator:

- The majority, 8 out of 20 respondents (40%), assigned a weight of 40%.

- The next majority, 3 out of 20 respondents (15%), assigned a weight of 25%.

Attachment 4

Overall, 11 respondents (55%) allocated weights in the range of 25-40%, with an average of 32.5%.

If assigning weights to the hydrological factor in the hydrologic variation indicator : potential for groundwater use indicator is 65:35. What is your opinion?

( ) Agree ( ) Disagree, and propose weights as follows: .....

2.1.5 Water Demand Factor:

- There is only one indicator, which is the alignment with the water demand in the area of utility, thus carrying a weight of 100%.

2.1.6 Poverty Factor:

- There is only one indicator, which is the poverty level of residents in the area, thus carrying a weight of 100%.

3. Water Scarcity Levels of the Project Area:

The majority of respondents, totaling 19 individuals (95%), agree with the severity levels as follows:

< 33%	:	Low severity of issues
31.1-67%	:	Moderate severity of issues
67%	:	High severity of issues

4. Proposal of project sustainability level corresponding to the water scarcity level

4.1 General Case: For the overall sustainability score, it should be classified as good, and the criteria should include:

1) The overall score of indicators in all dimensions should fall within the good range (55-65%).

2) The total score of indicators in each dimension should be at least moderate (65-75%) or higher.

4.2 Specific Case: In cases where the area faces moderate to high water scarcity and requires water resources development, and if the overall sustainability score in any dimension is below the moderate threshold (less than 55%)

The project should undergo improvements in each dimension overall project sustainability to achieve a rating at least moderate. What is your opinion?

( ) Agree ( ) Disagree, because .....

( ) Suggestions (Specify) .....

Note: The criteria in section 4 aim to assess the suitability and sustainability of the water development project in all dimensions, ensuring (1) a balance between development and conservation of natural resources, (2) a guideline for considering suitable projects, (3) prioritization of projects, and (4) inclusion in the evaluation for adjusting project

placement and reducing environmental and social impacts to achieve balance and sustainability, and (5) more opportunity for the project experienced moderate to high water scarcity to be developed under at least moderate level of overall project sustainability.

Appendix E

Indicator's Sustainability Levels in Various Dimensions

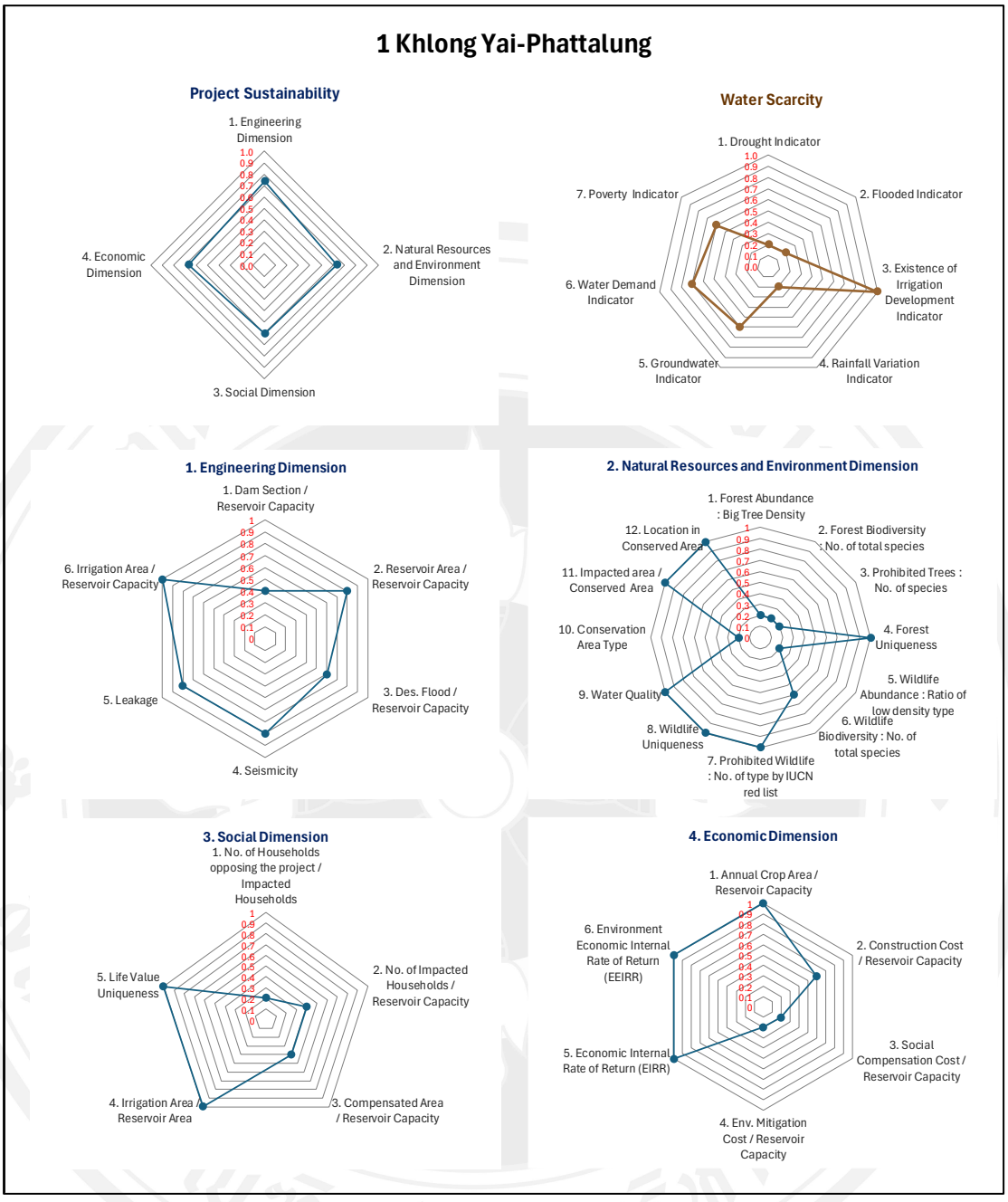

Figure E.1 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Khlong Yai Project, Phattalung Province

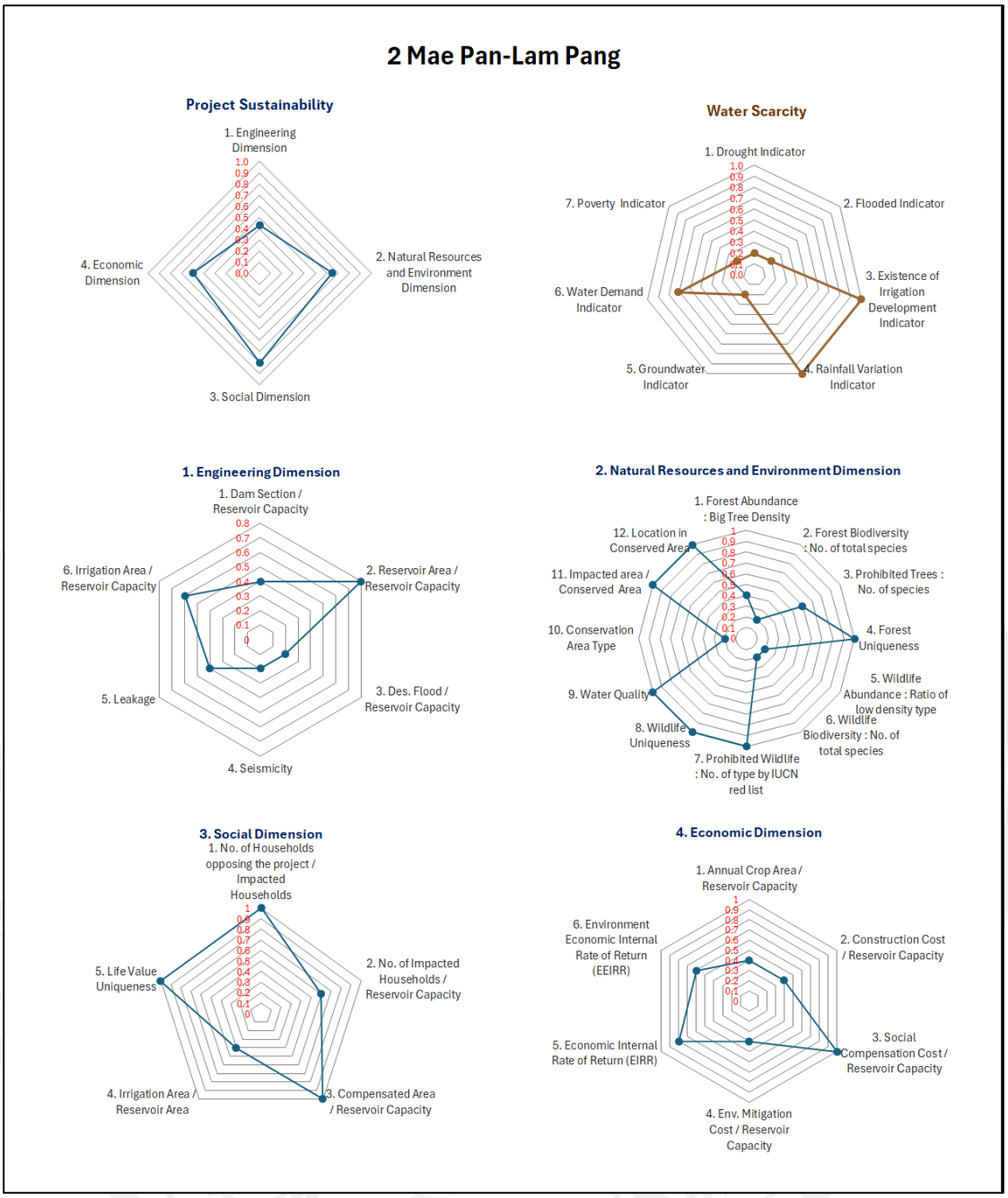

Figure E.2 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Mae Pan Project, Lam Pang Province

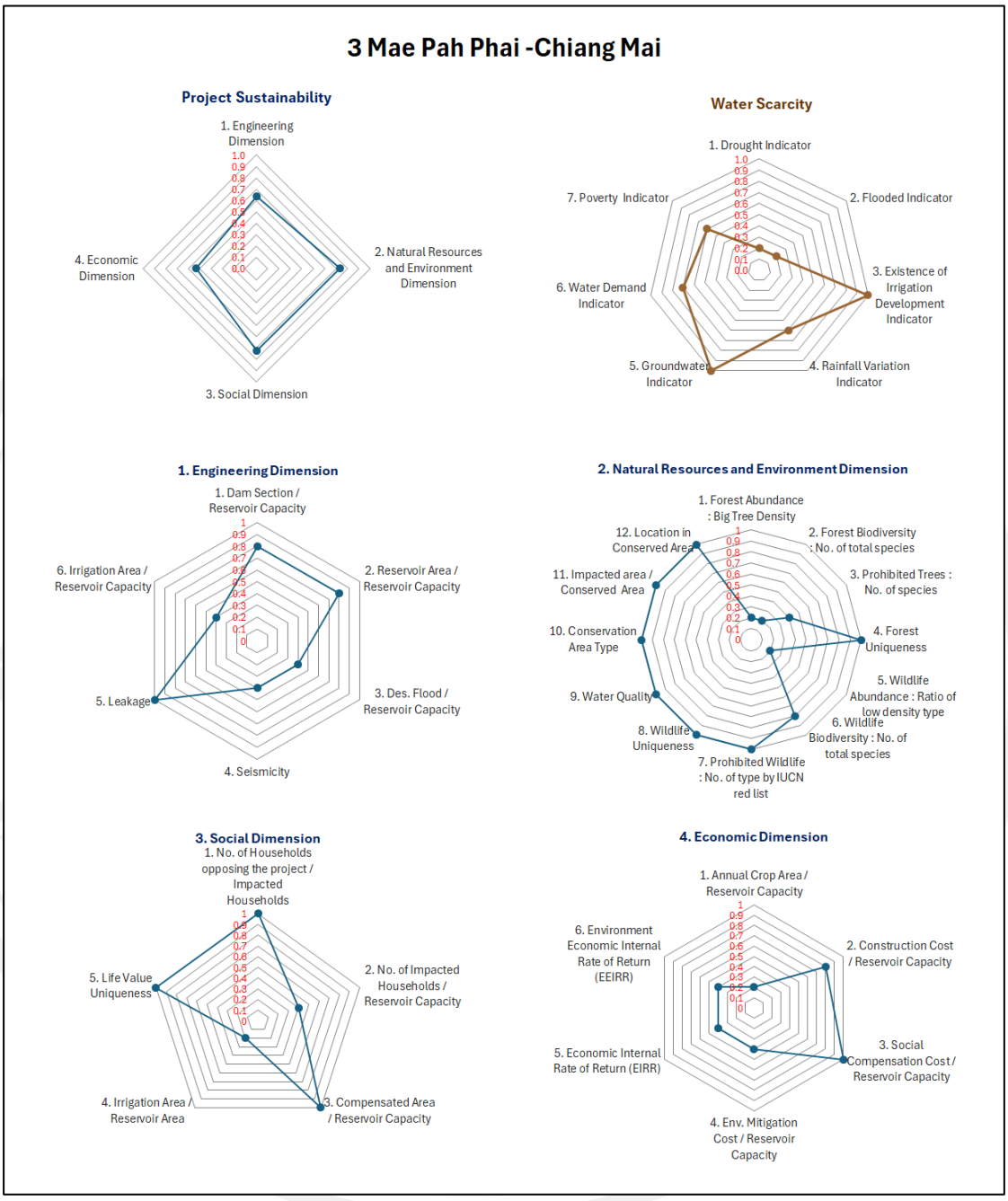

Figure E.3 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Mae Pah Phai project, Chiang Mai province

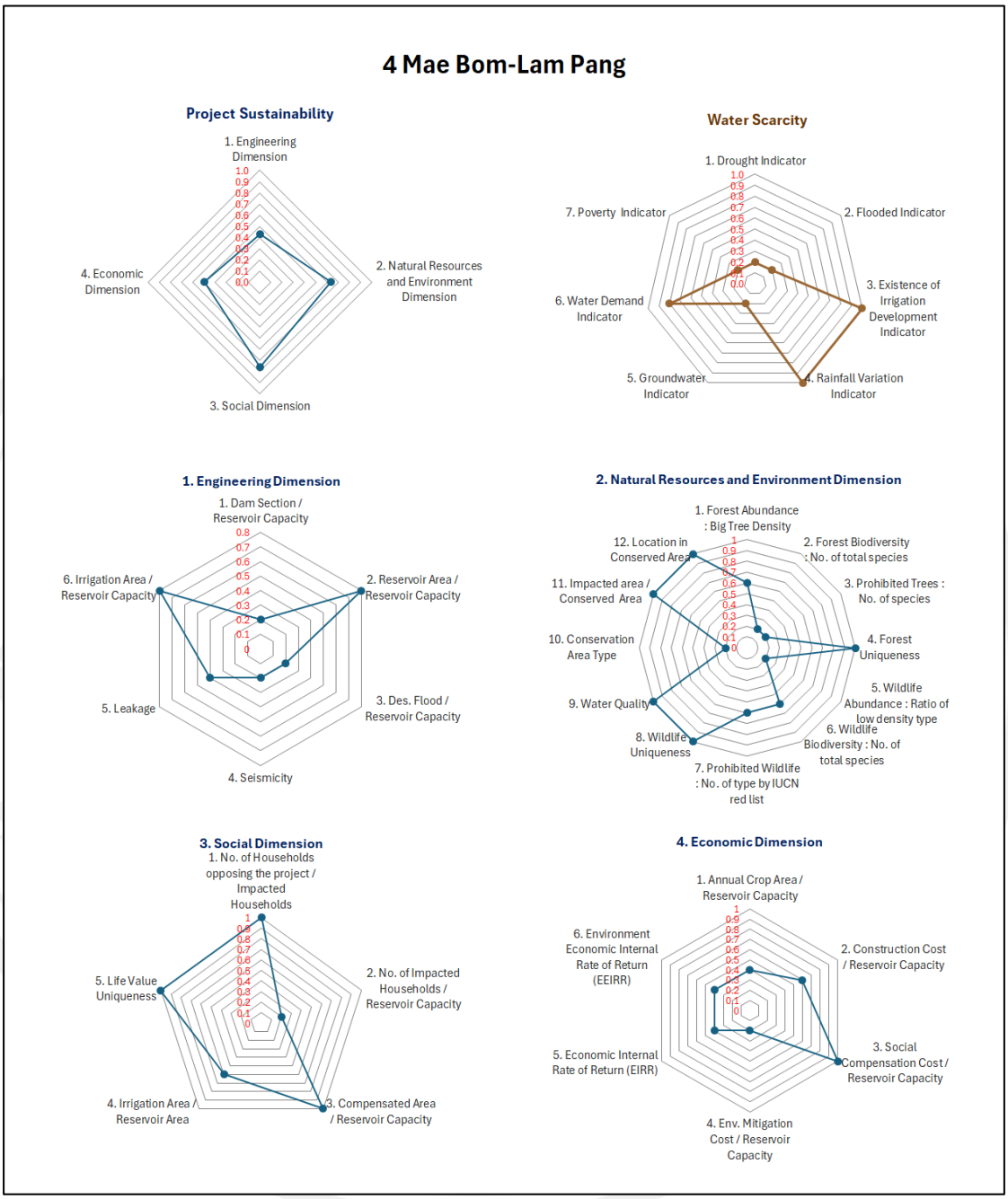

Figure E.4 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Mae Bom Project, Lam Pang Province

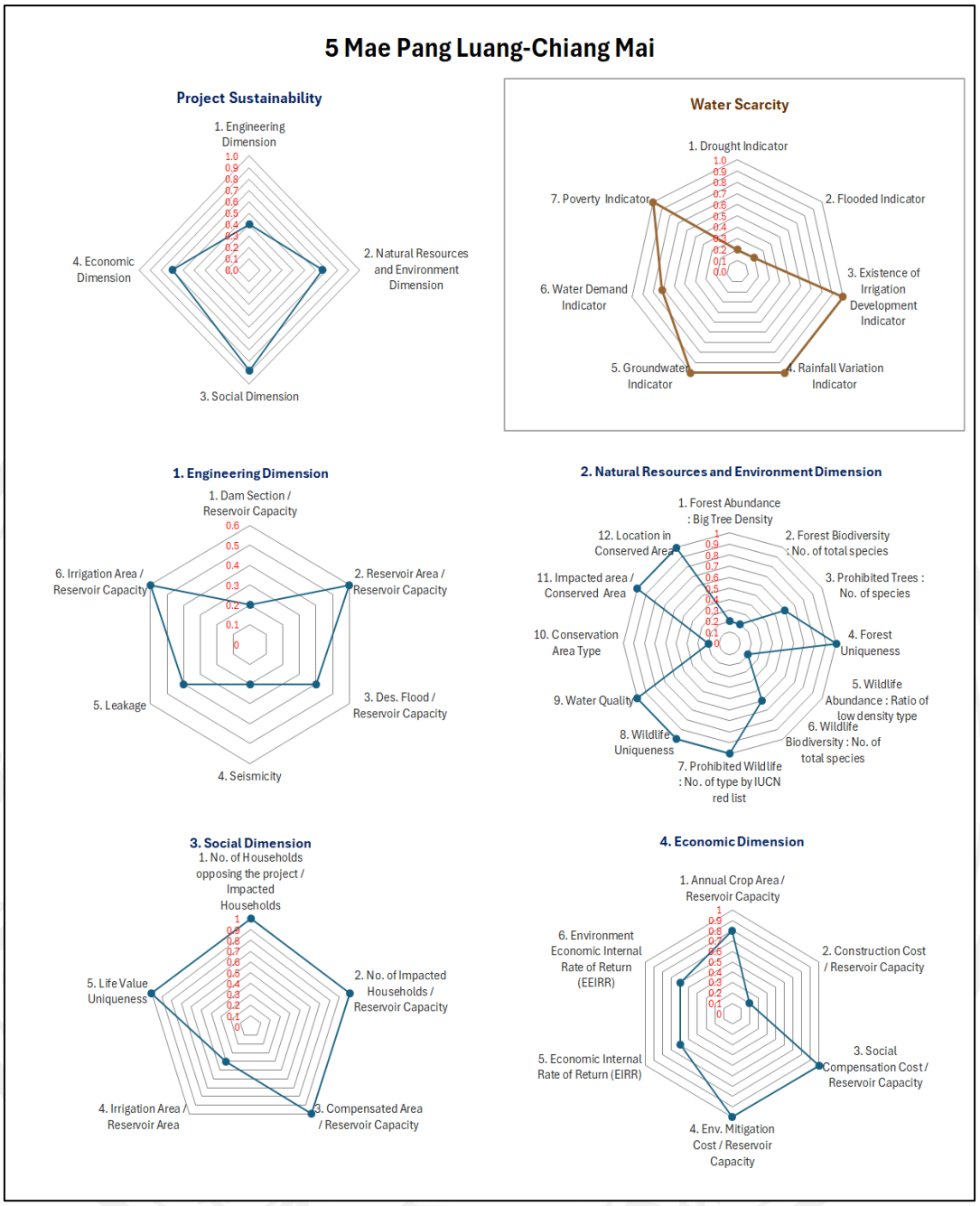

Figure E.5 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Mae Pang Luang Project, Chaing Mai Province

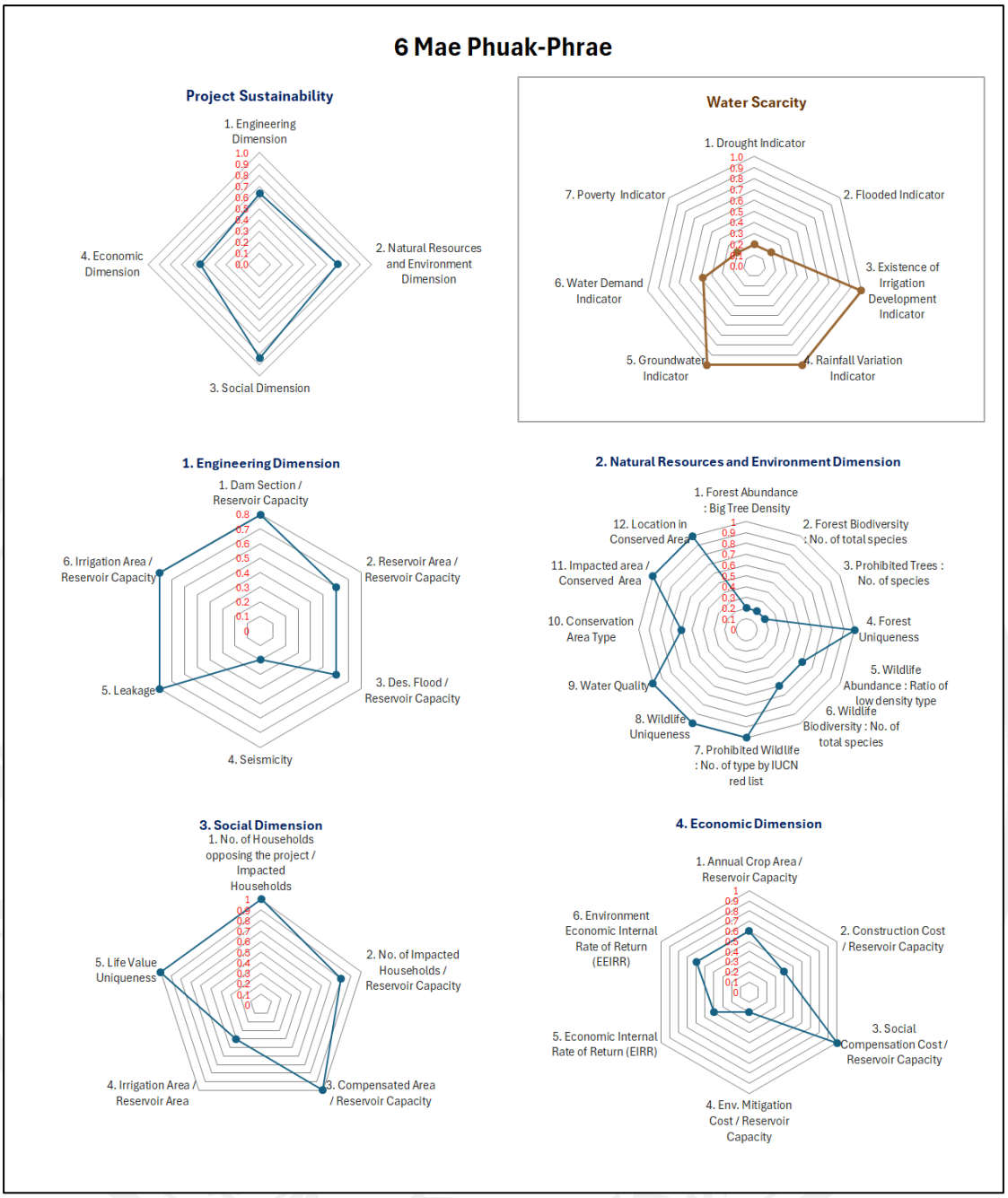

Figure E.6 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Mae Phuak Project, Phare Province

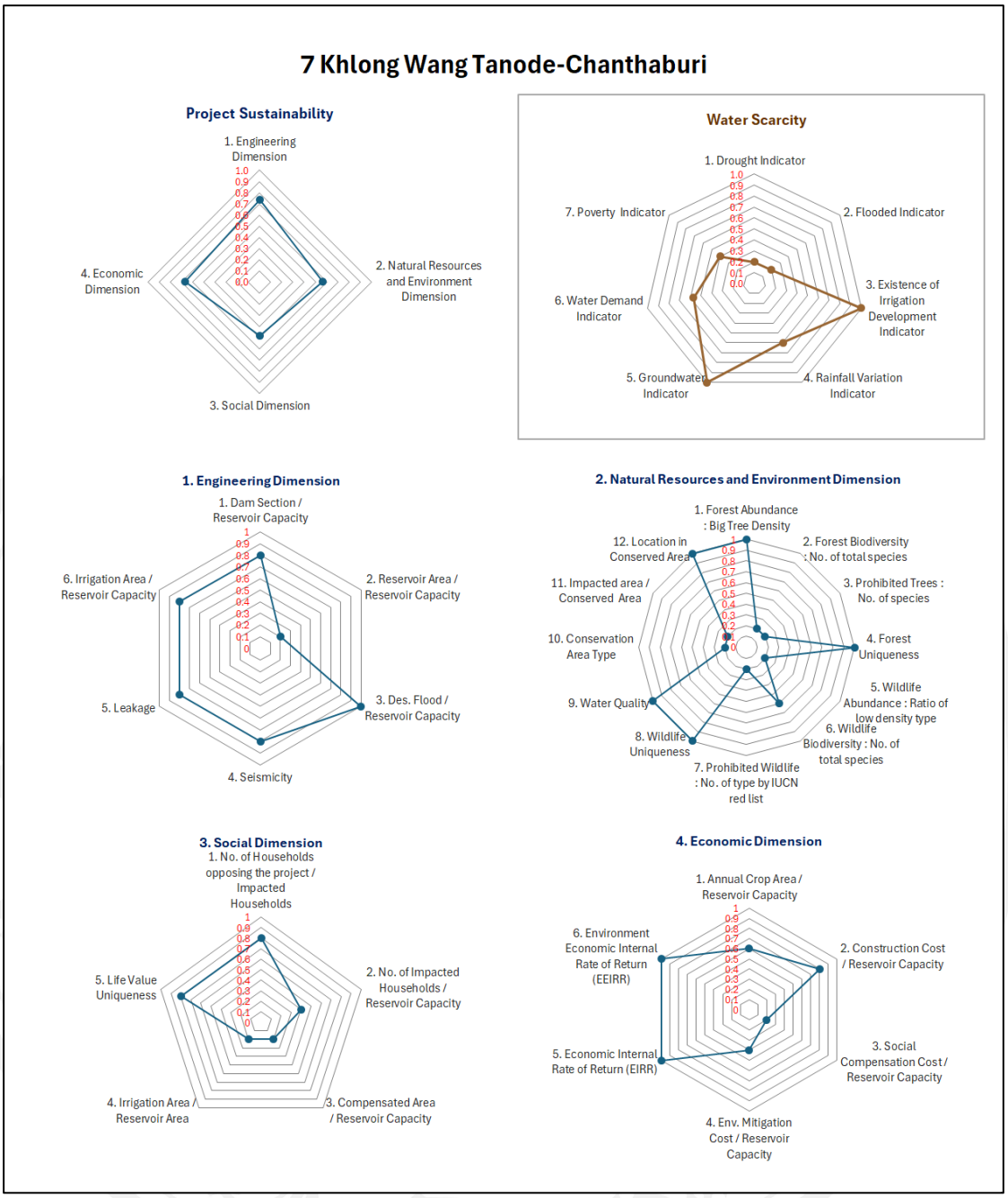

Figure E.7 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Khlong Wang Tanode Project, Phare Province

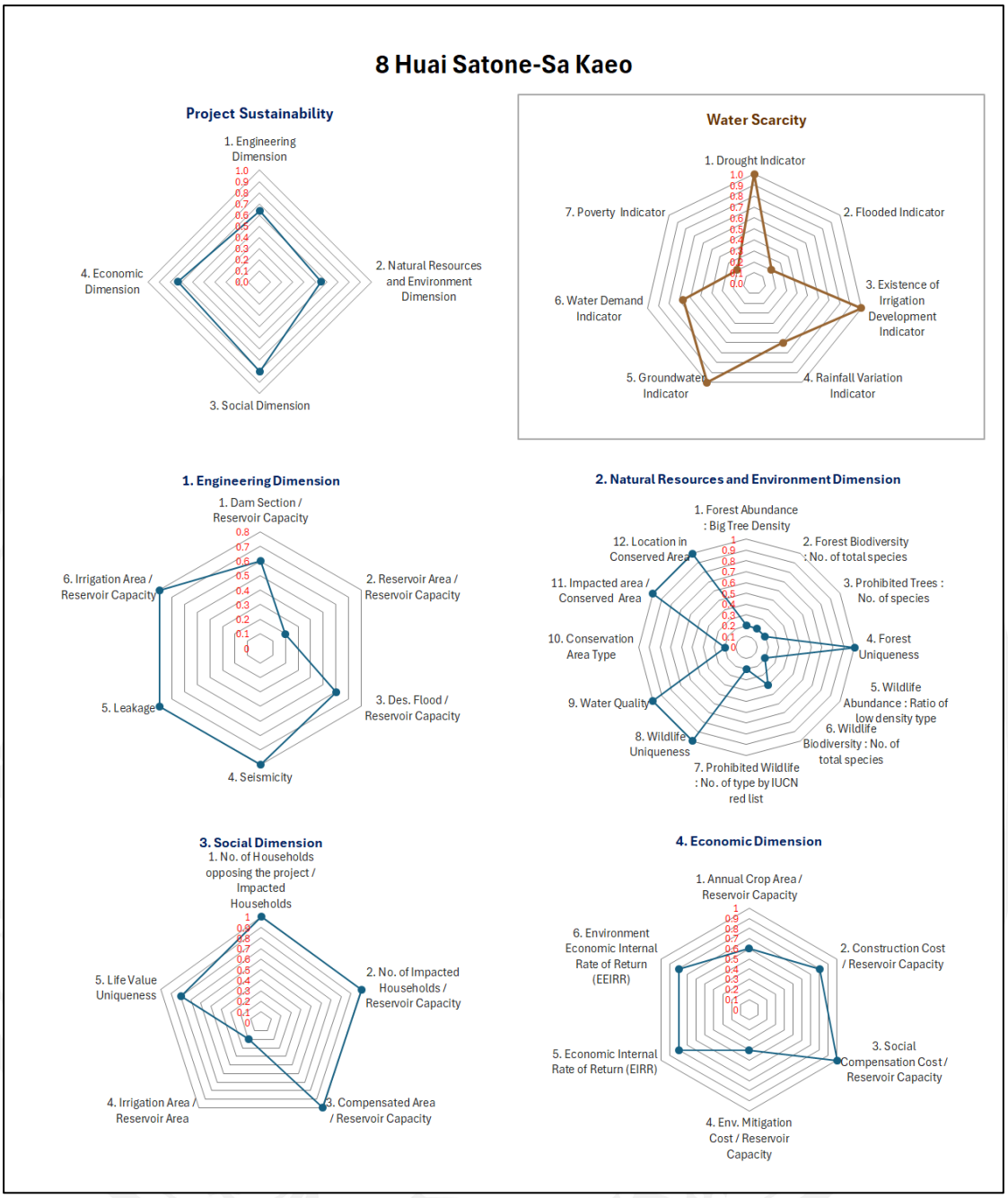

Figure E.8 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Huai Satone Project, Sa Kaeo Province

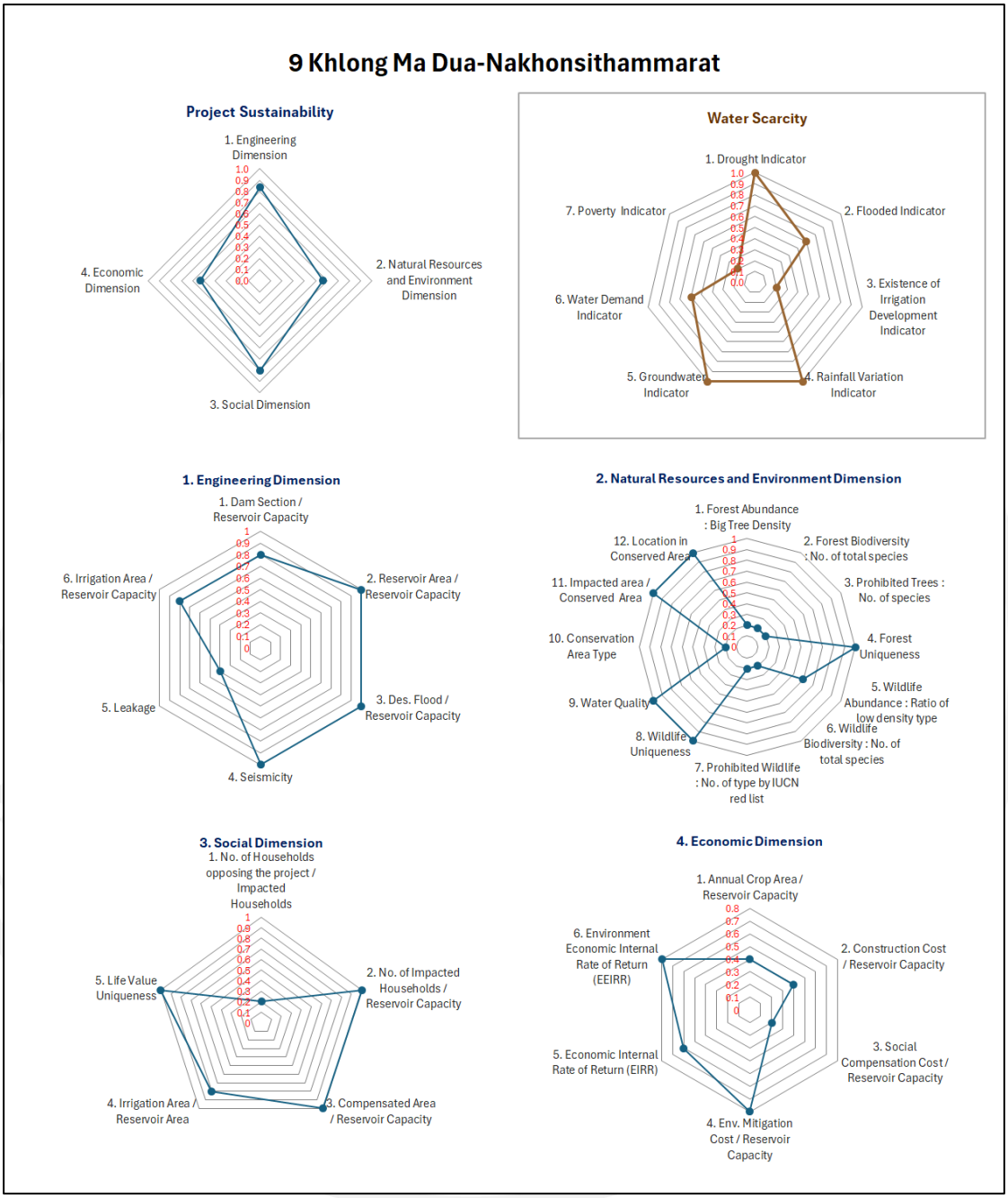

Figure E.9 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Khlong Ma Dua Project, Nakhon Sithammarat Province

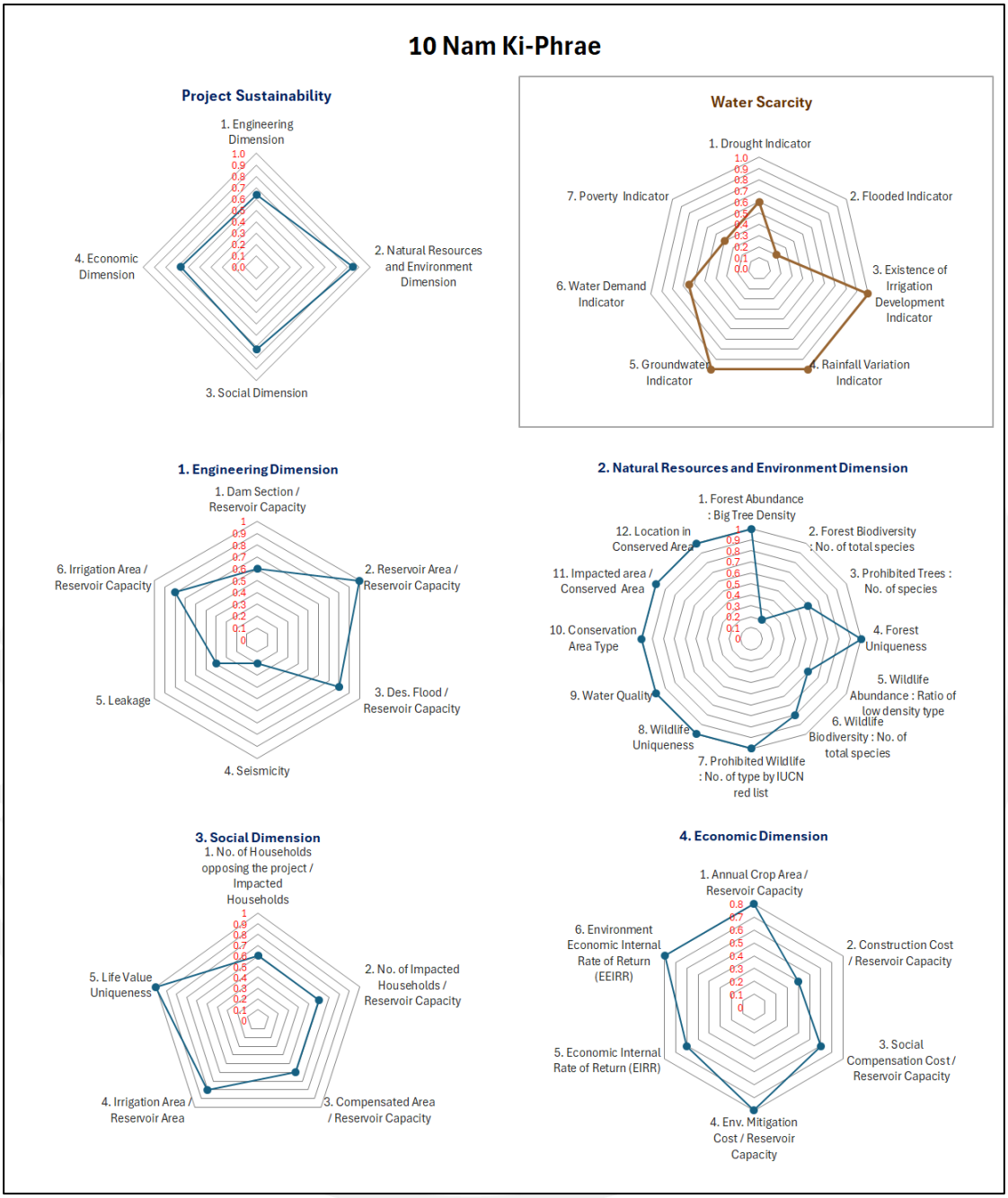

Figure E.10 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Nam Ki Project, Phrae Province

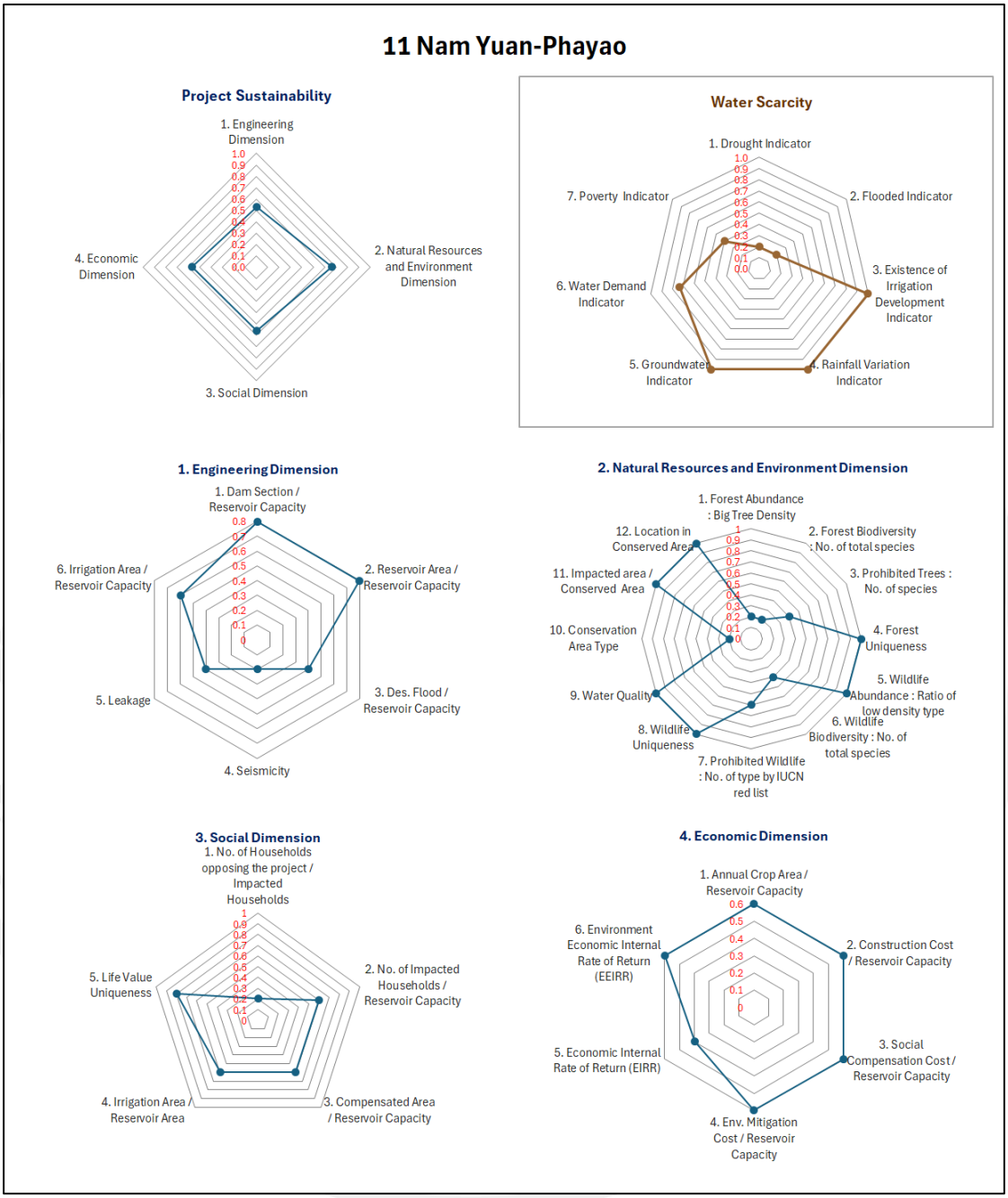

Figure E.11 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Nam Yuan Project, Phayao Province

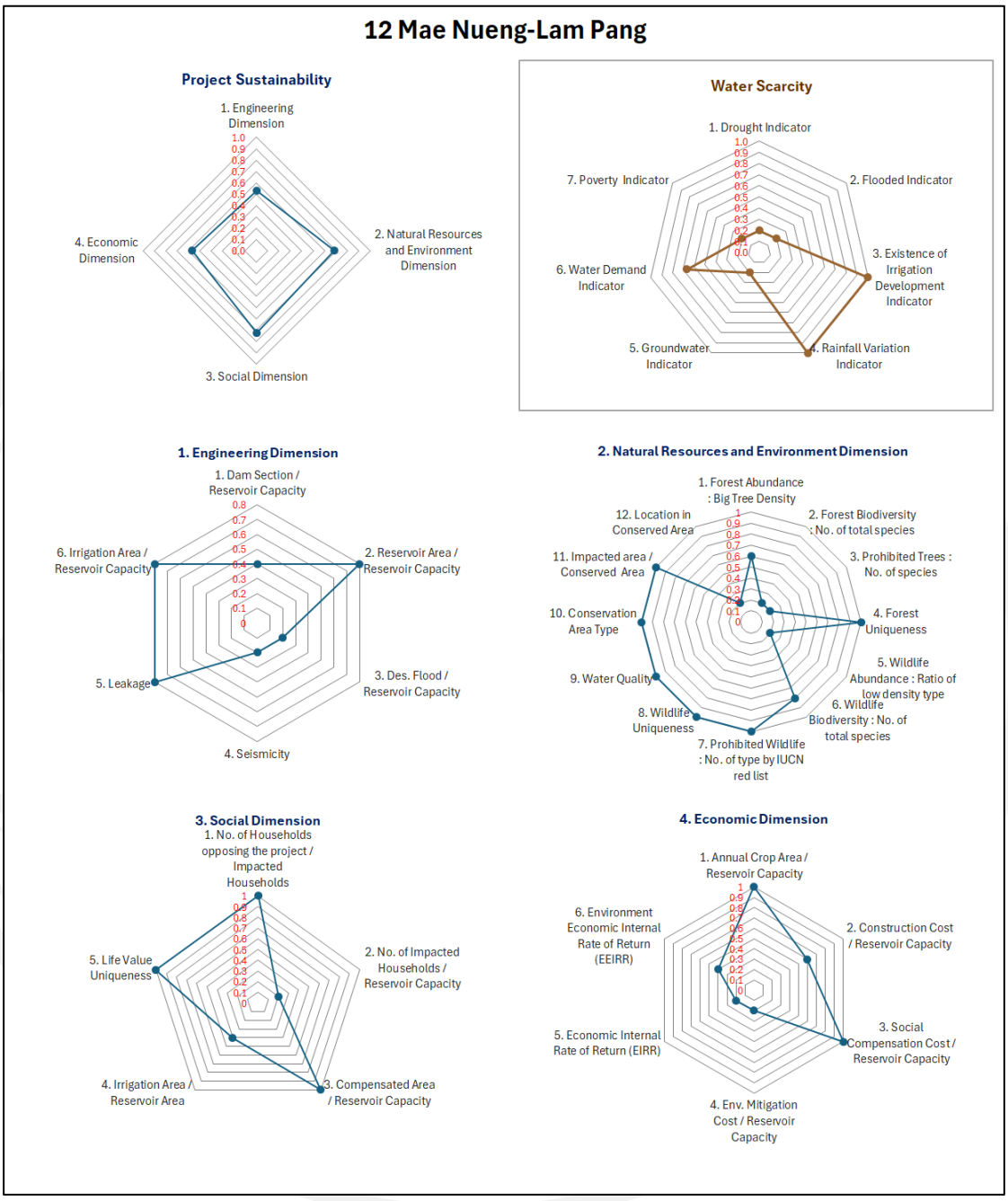

Figure E.12 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Mae Nueng Project, Lam Pang Province

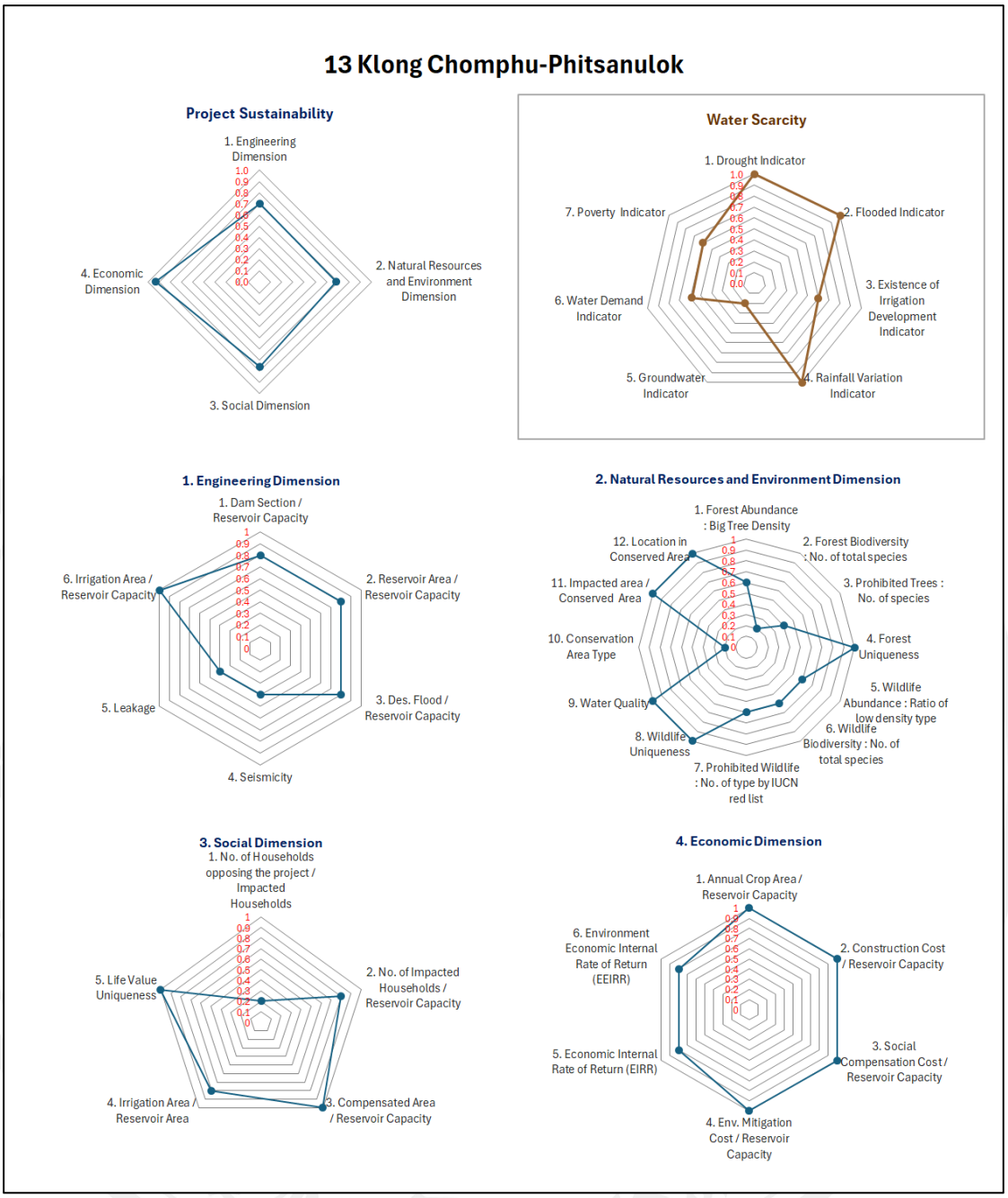

Figure E.13 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Khlong Chomphu Project, Phitsanulok Province

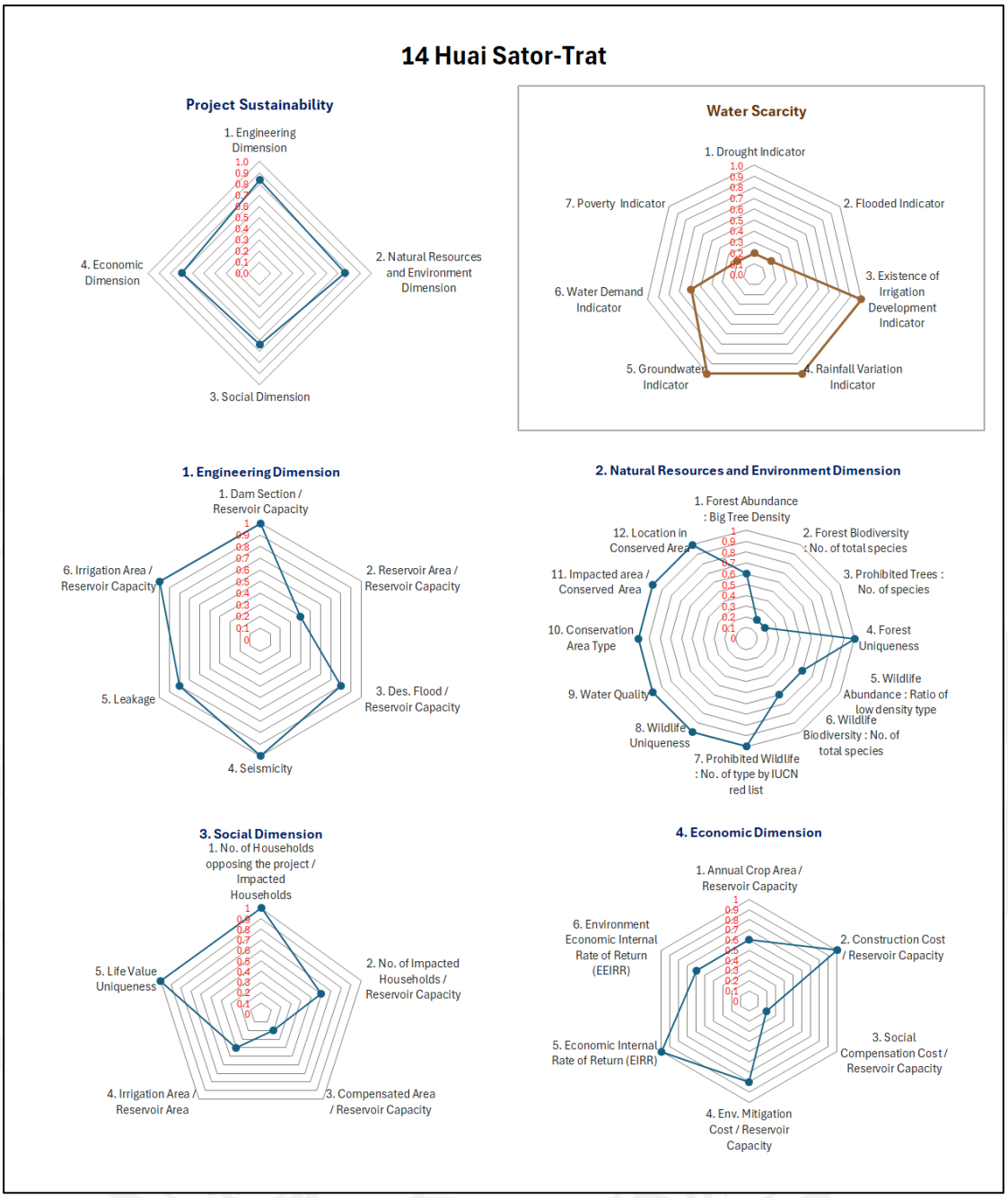

Figure E.14 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Huai Sator Project, Trat Province

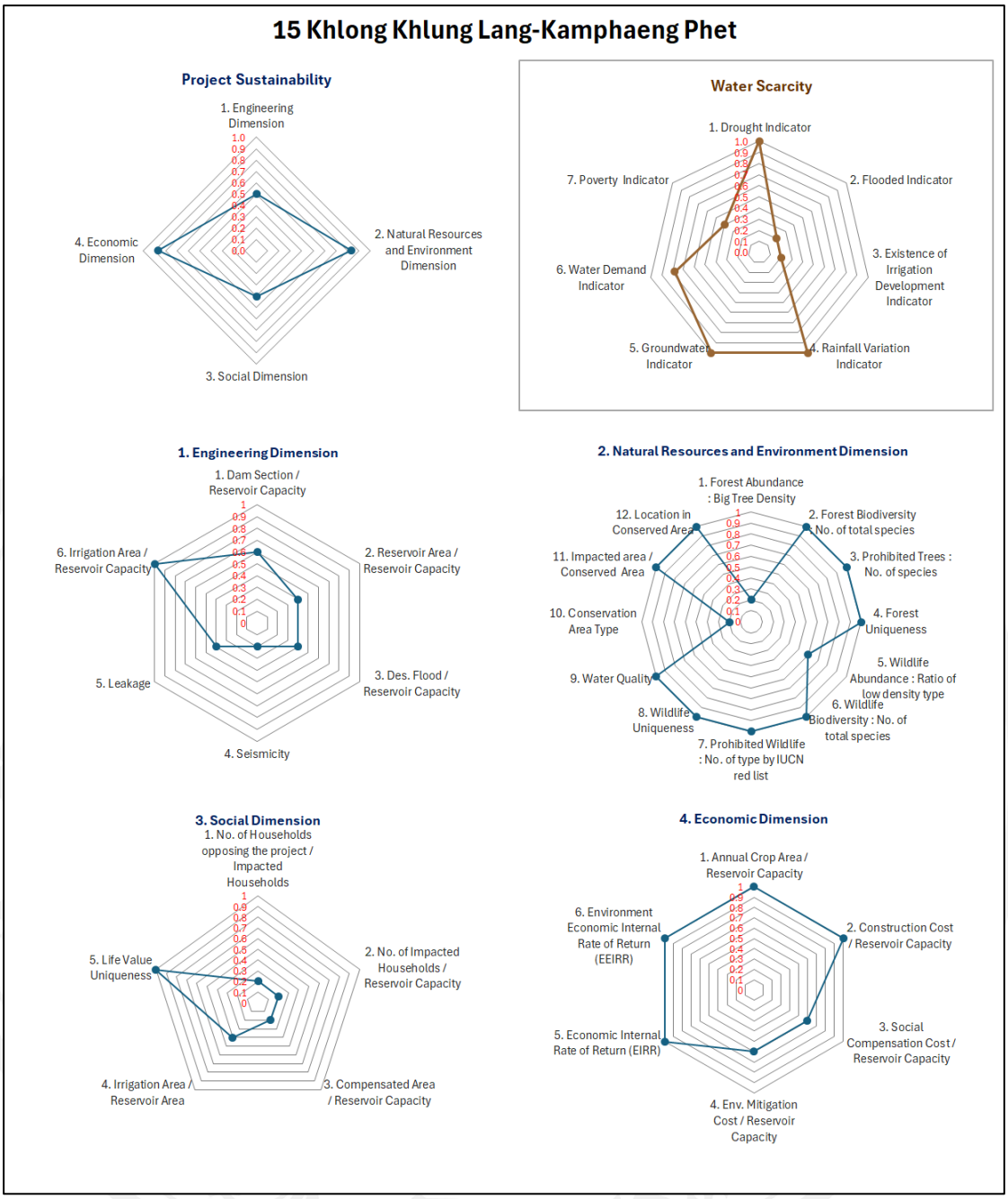

Figure E.15 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores Khlong Khlung Lang Project, Kamplaeng Phet Province

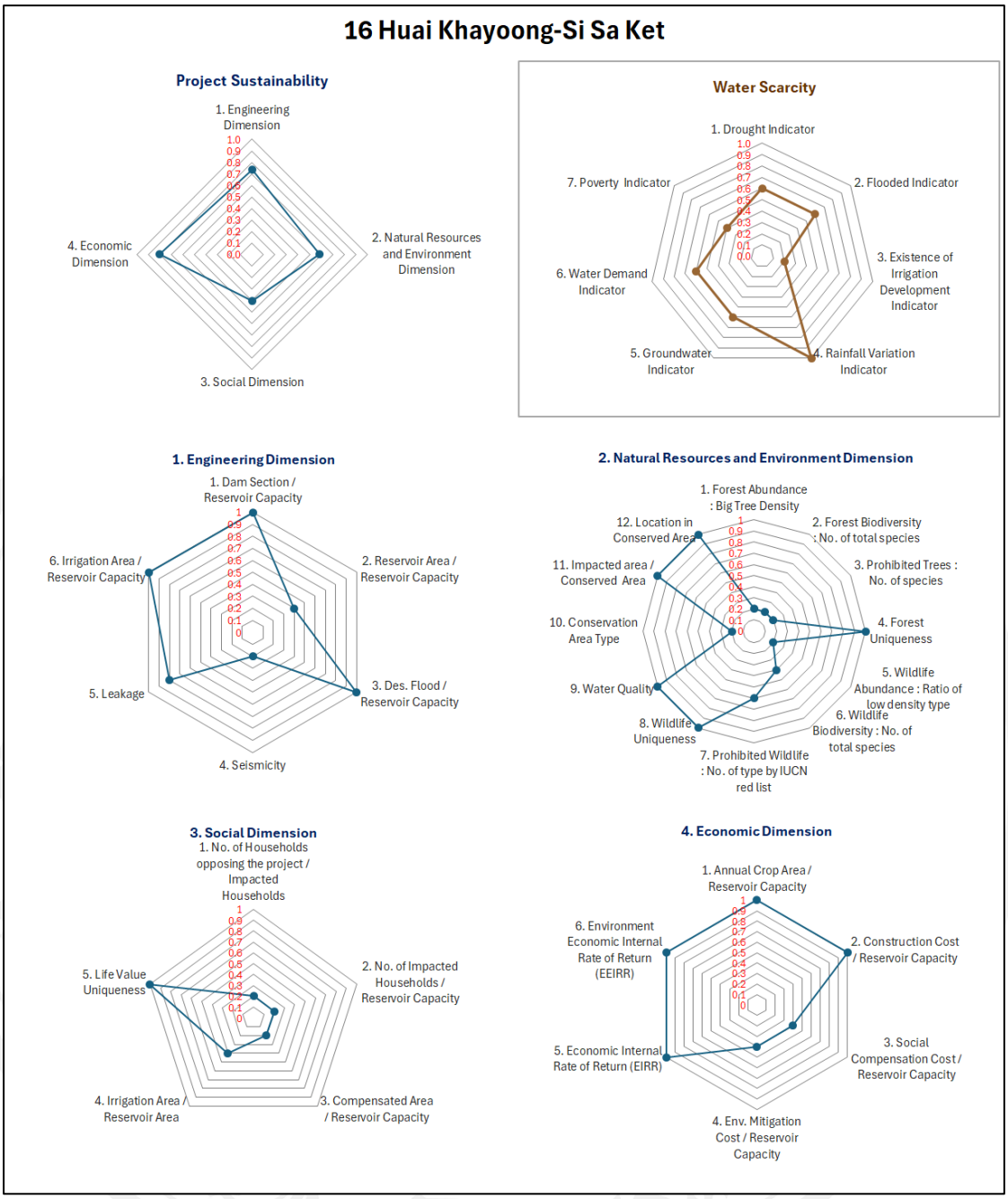

Figure E.16 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Khayoong Project, Si Sa Ket Province

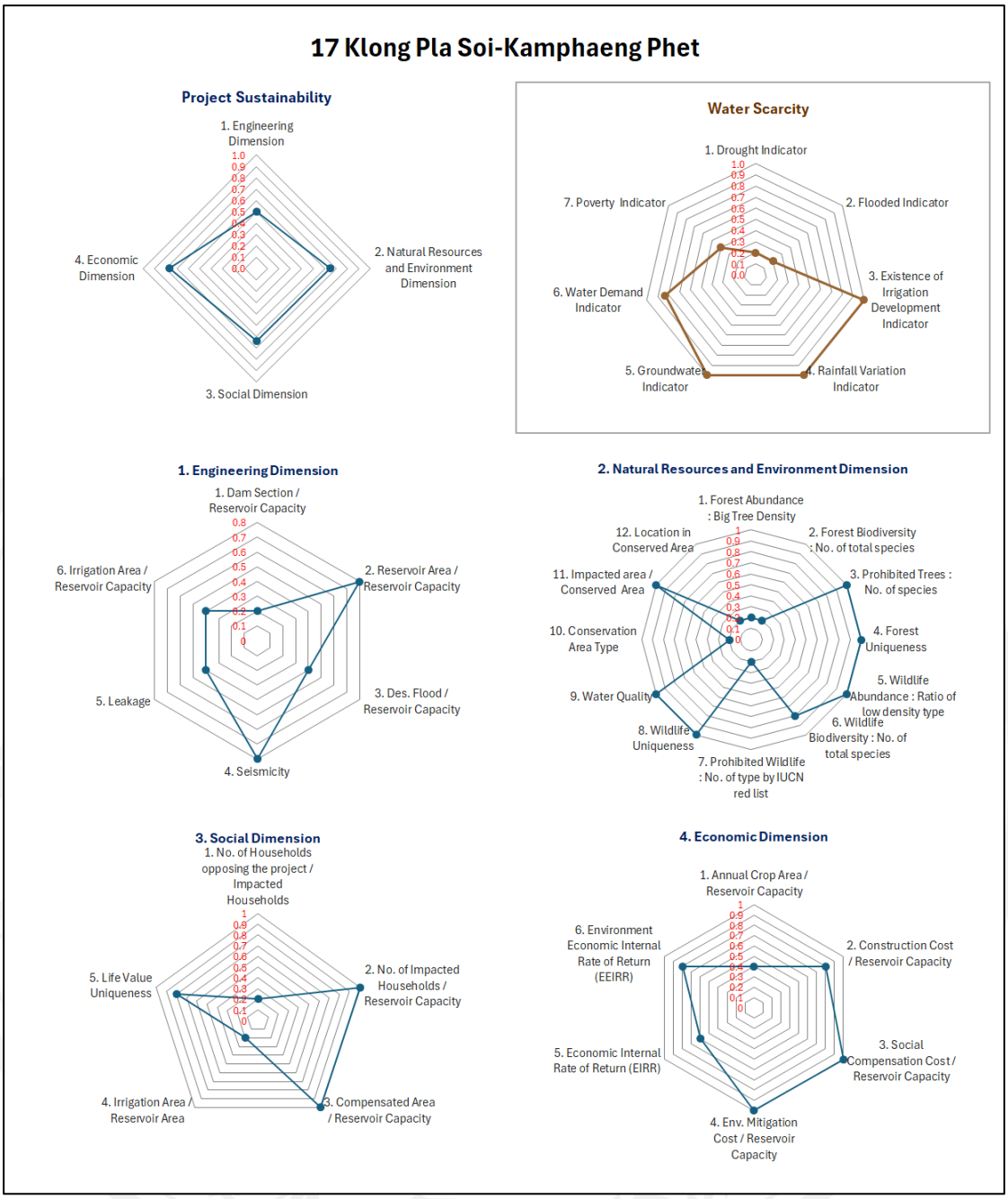

Figure E.17 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Khlong Pla Soi Project, Kamphaeng Phet Province

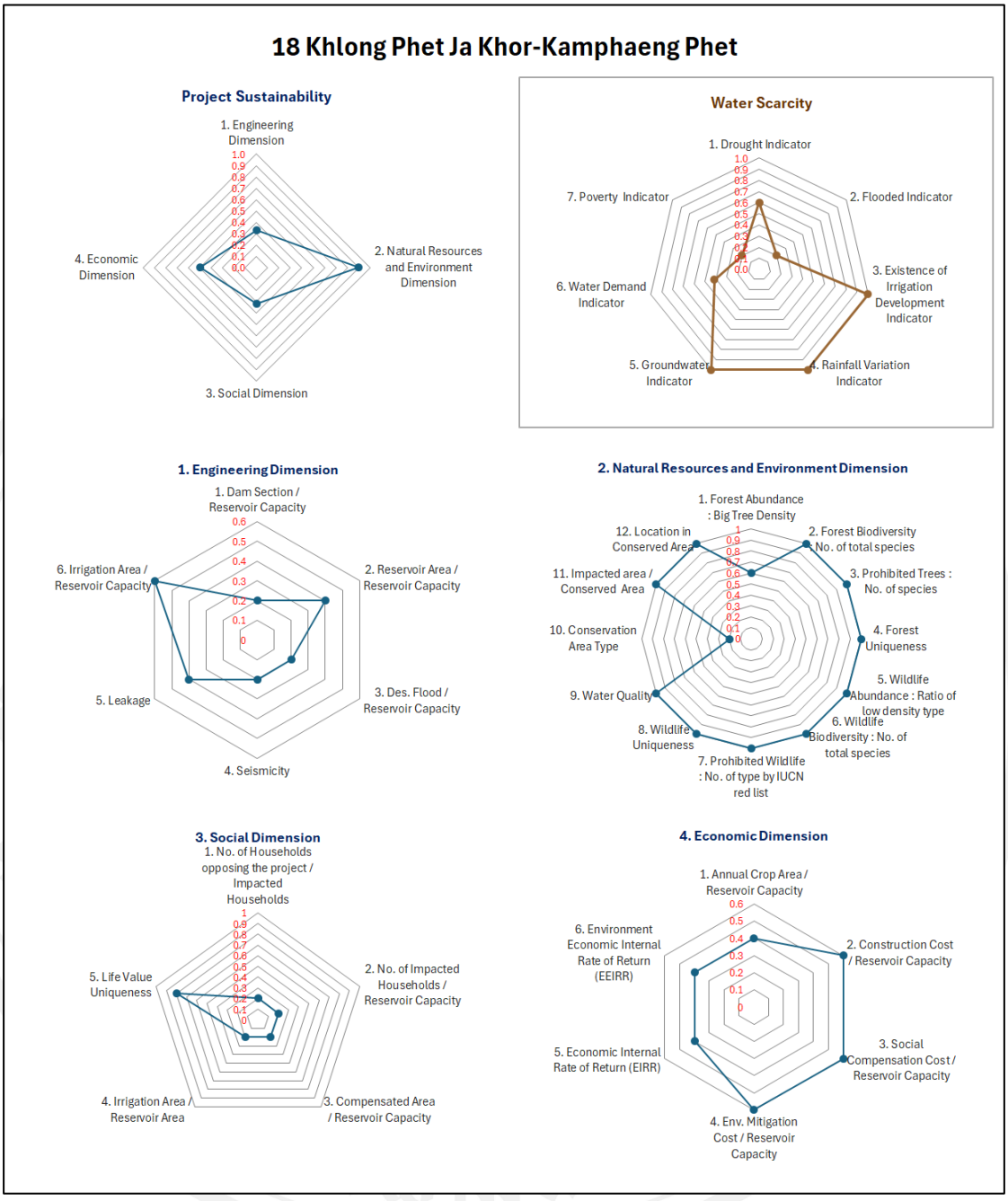

Figure E.18 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Khlong Phet Ja Khor Project, Kamphaeng Phet Province

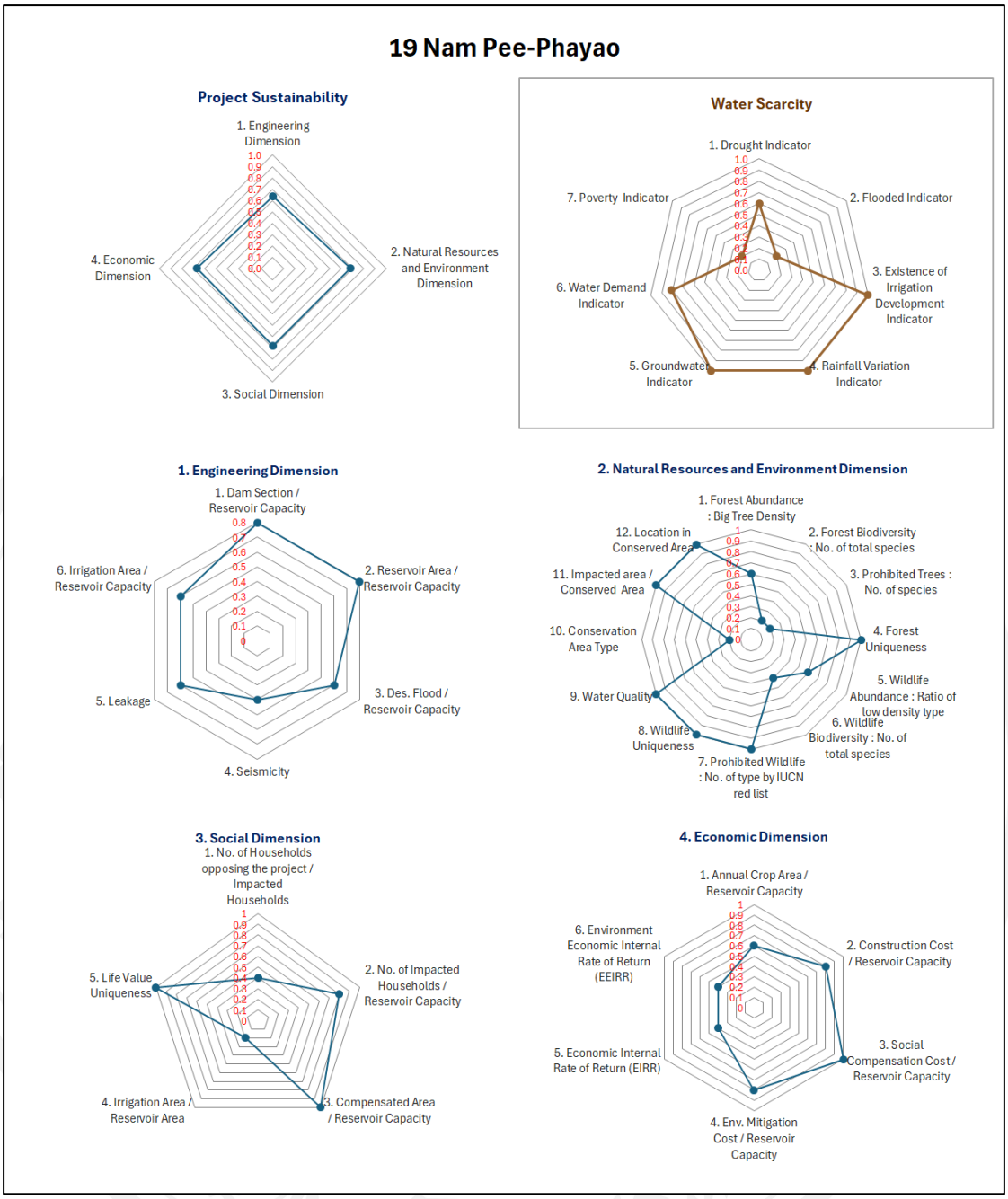

Figure E.19 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Nam Pee Project, Phayao Province

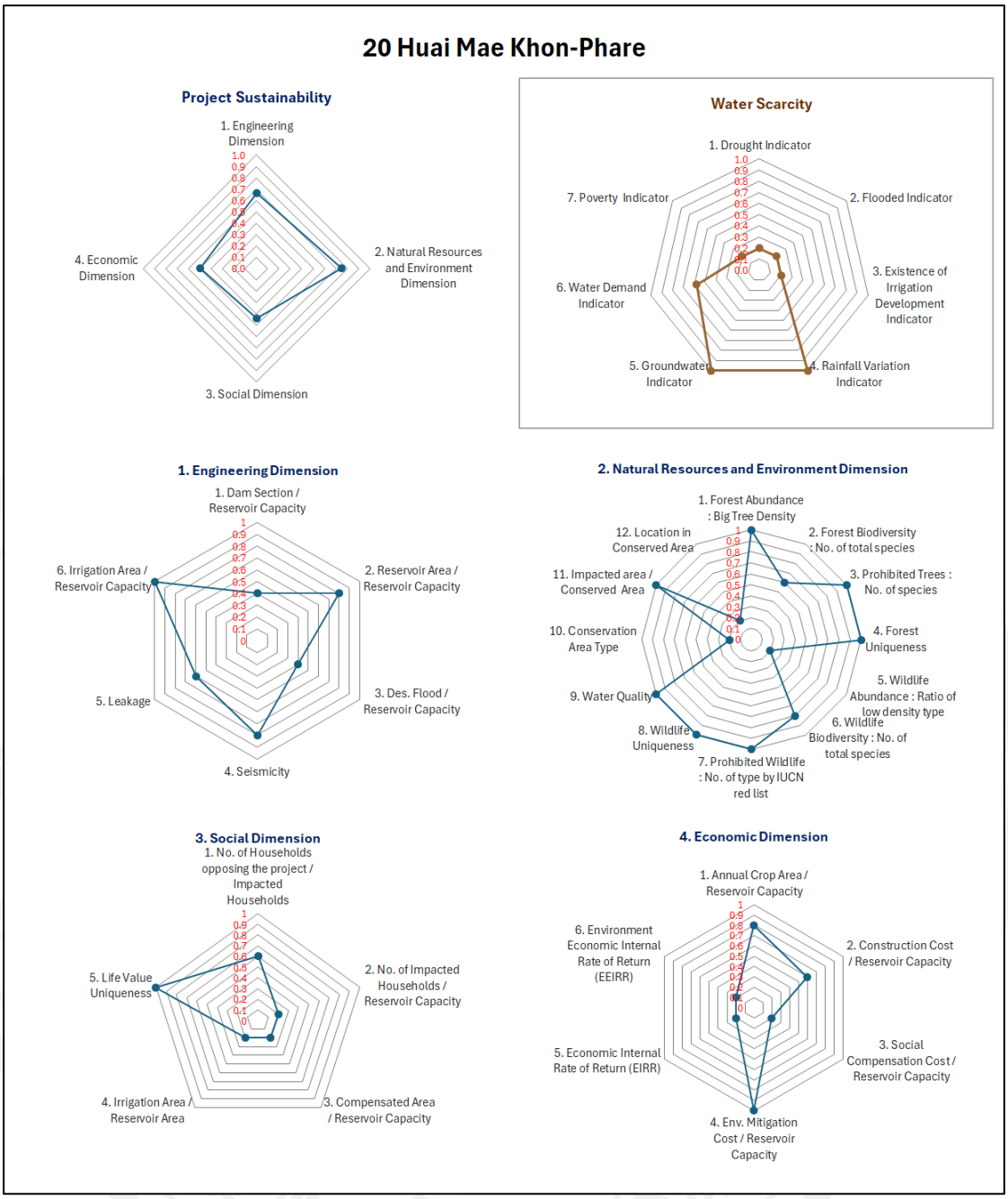

Figure E.20 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Mae Khon Project, Phare Province

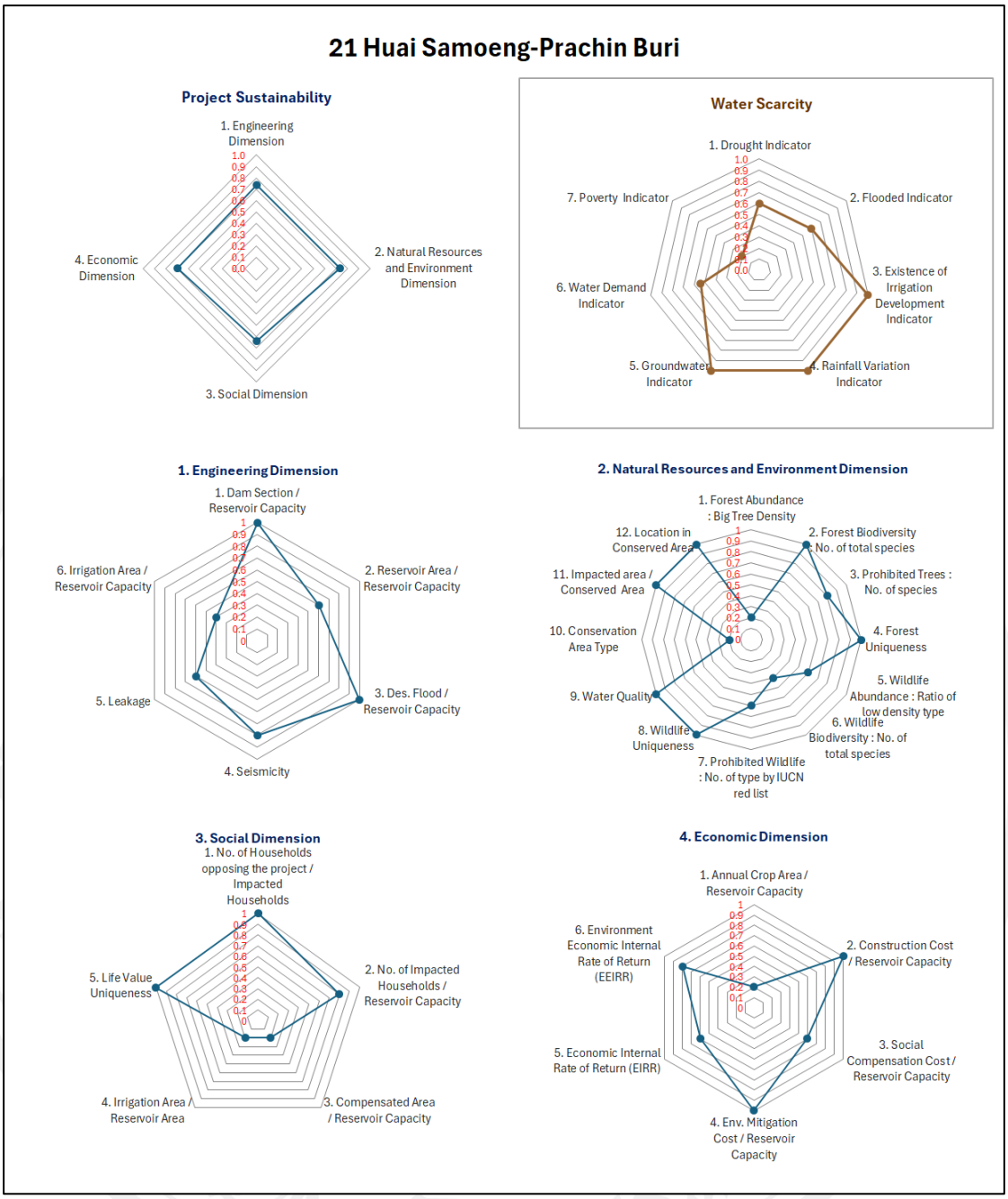

Figure E.21 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Samoeng Project, Prachin Buri Province

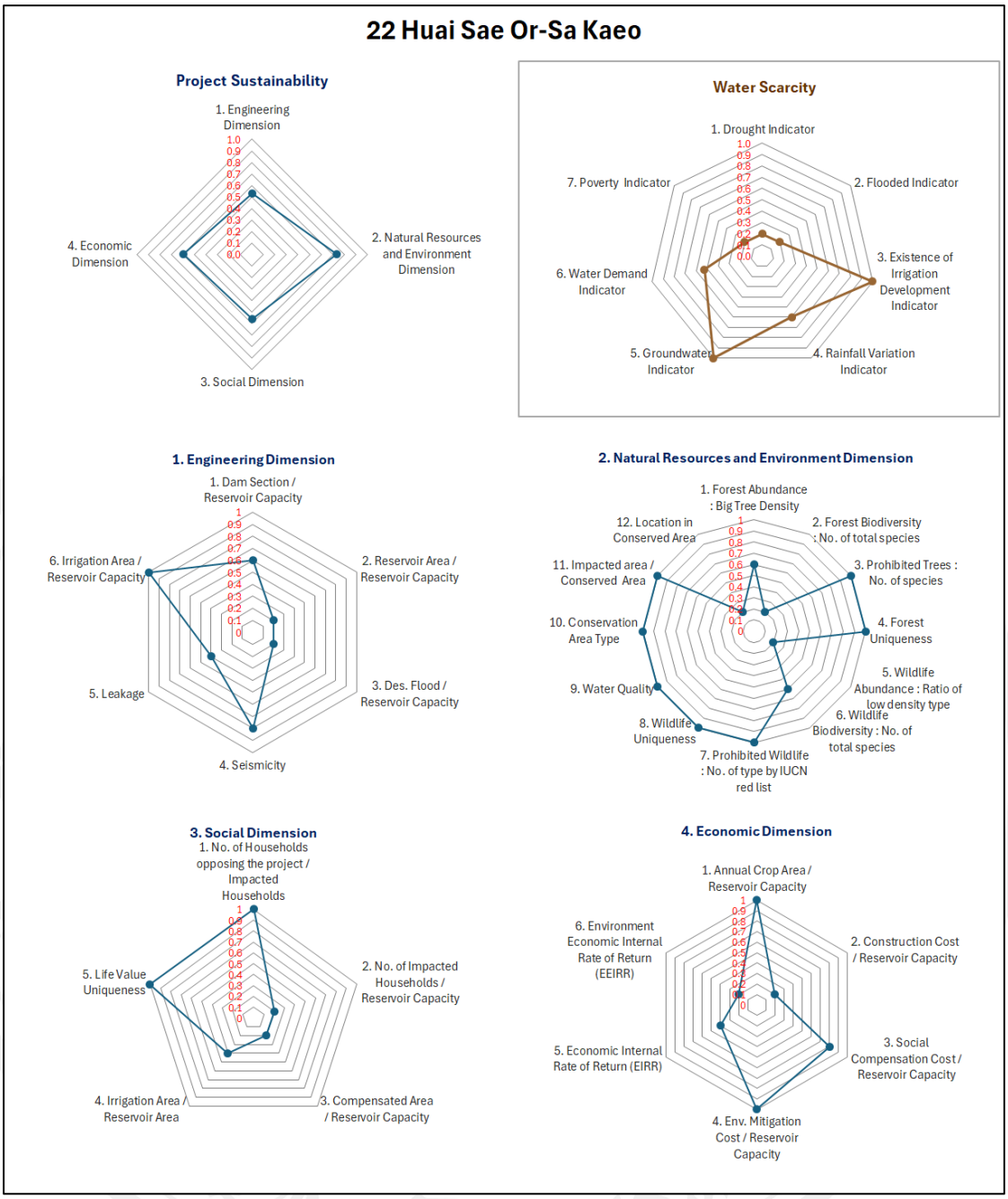

Figure E.22 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Sae Or Project, Sa Kaeo Buri Province

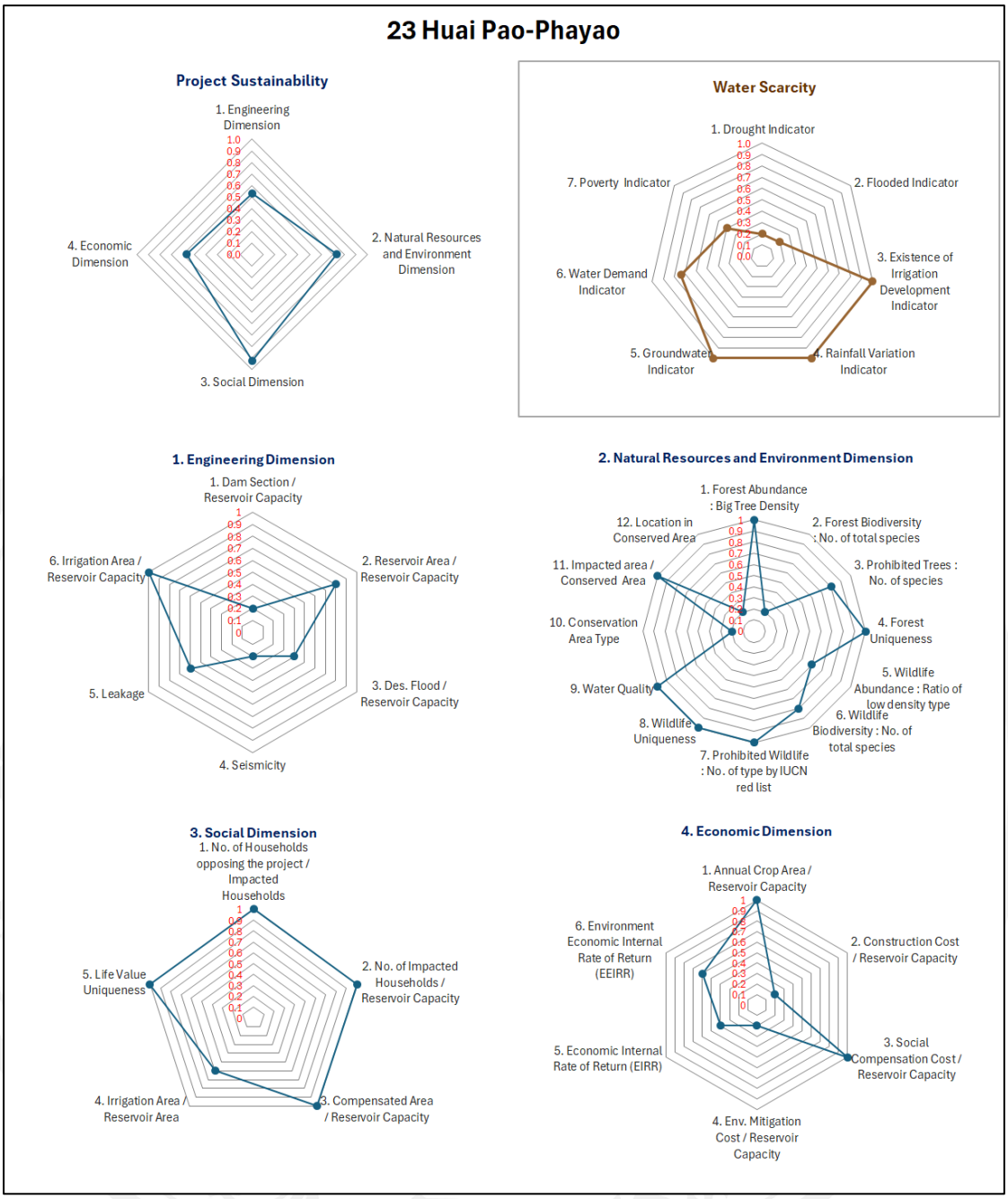

Figure E.23 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Pao Project, Phayao Province

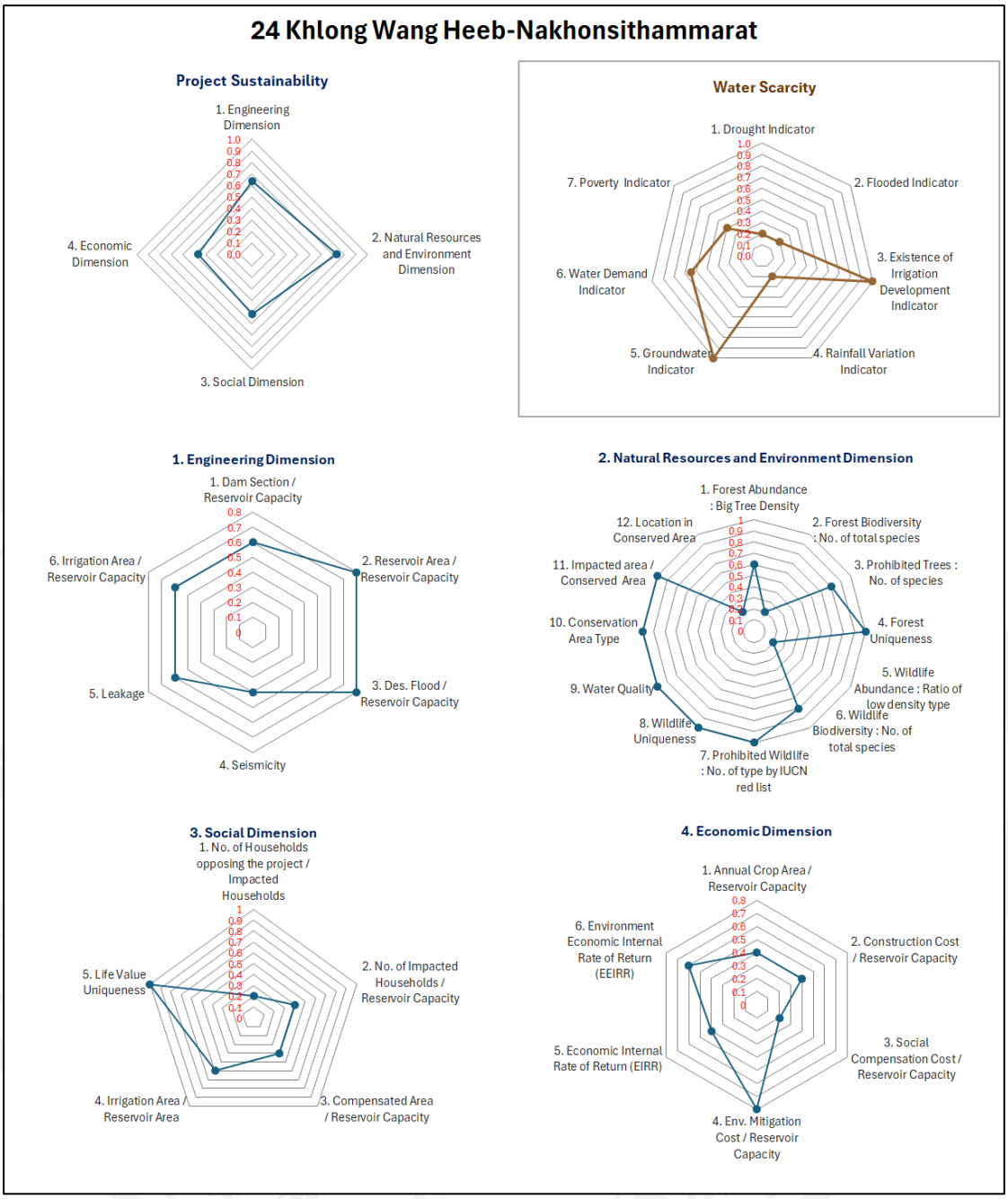

Figure E.24 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Khlong Wang Heeb Project, Nakhon Sithammarat Province

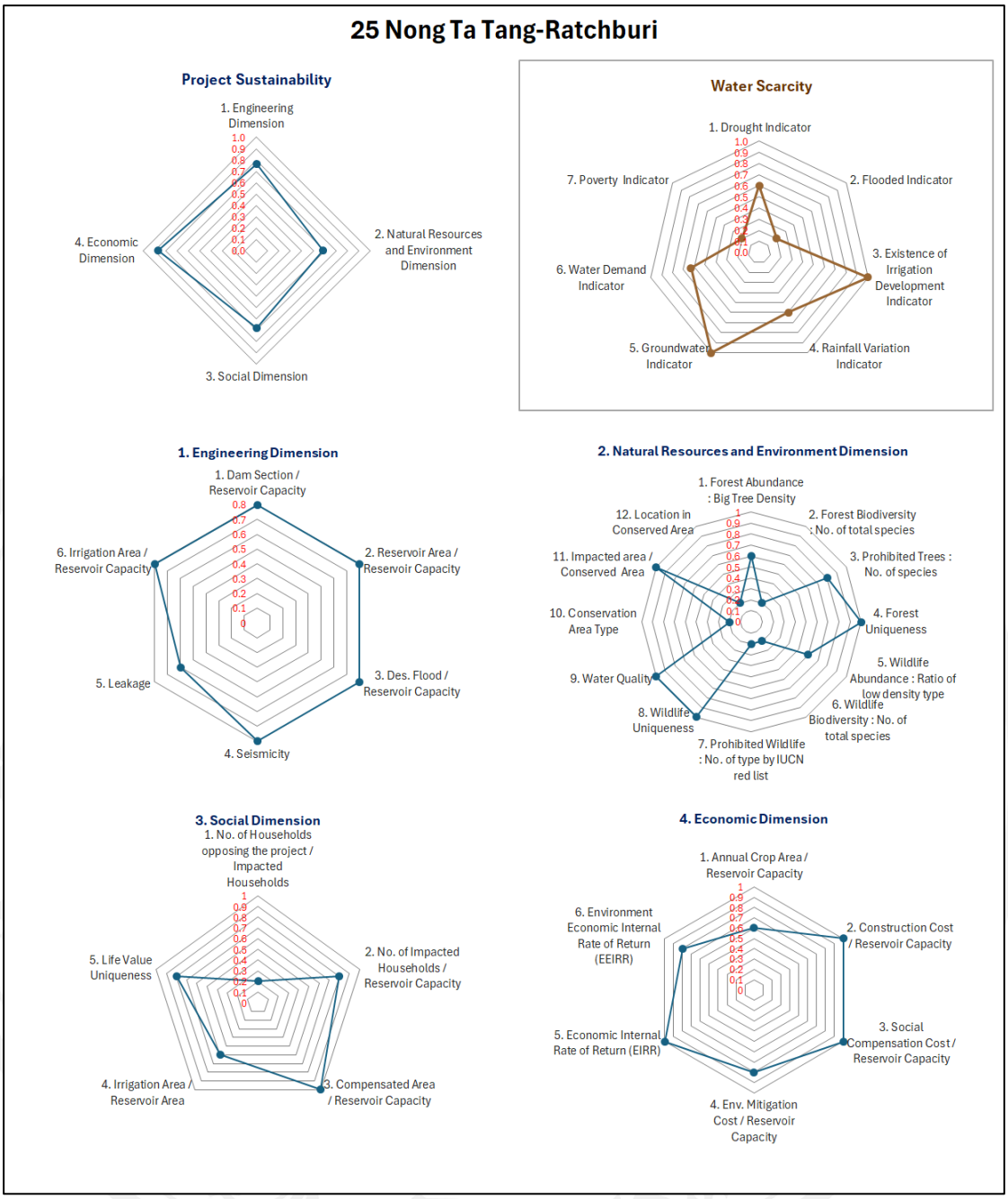

Figure E.25 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Nong Ta Tang Project, Ratchaburi Province

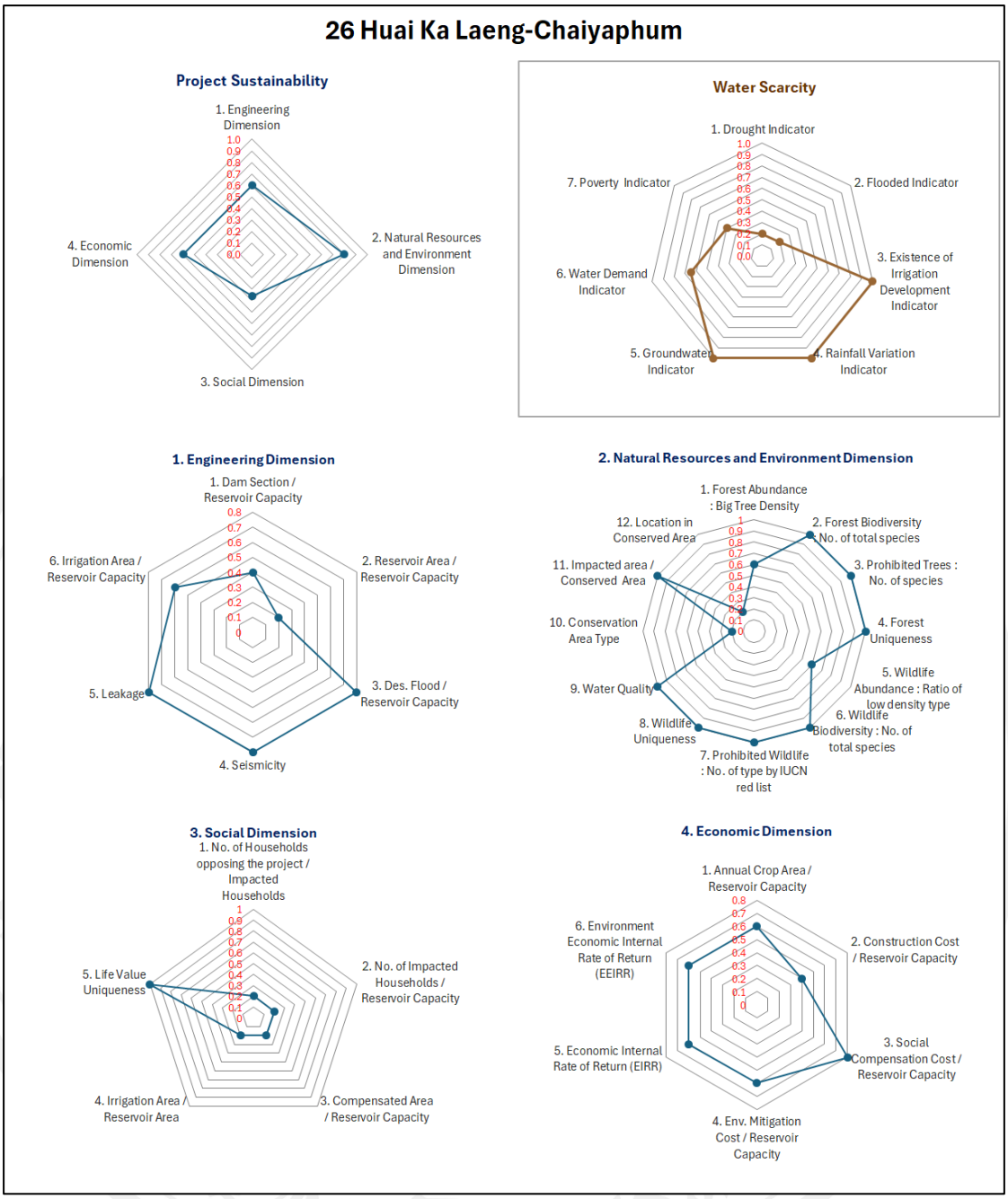

Figure E.26 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Ka Laeng Project, Chaiyaphum Province

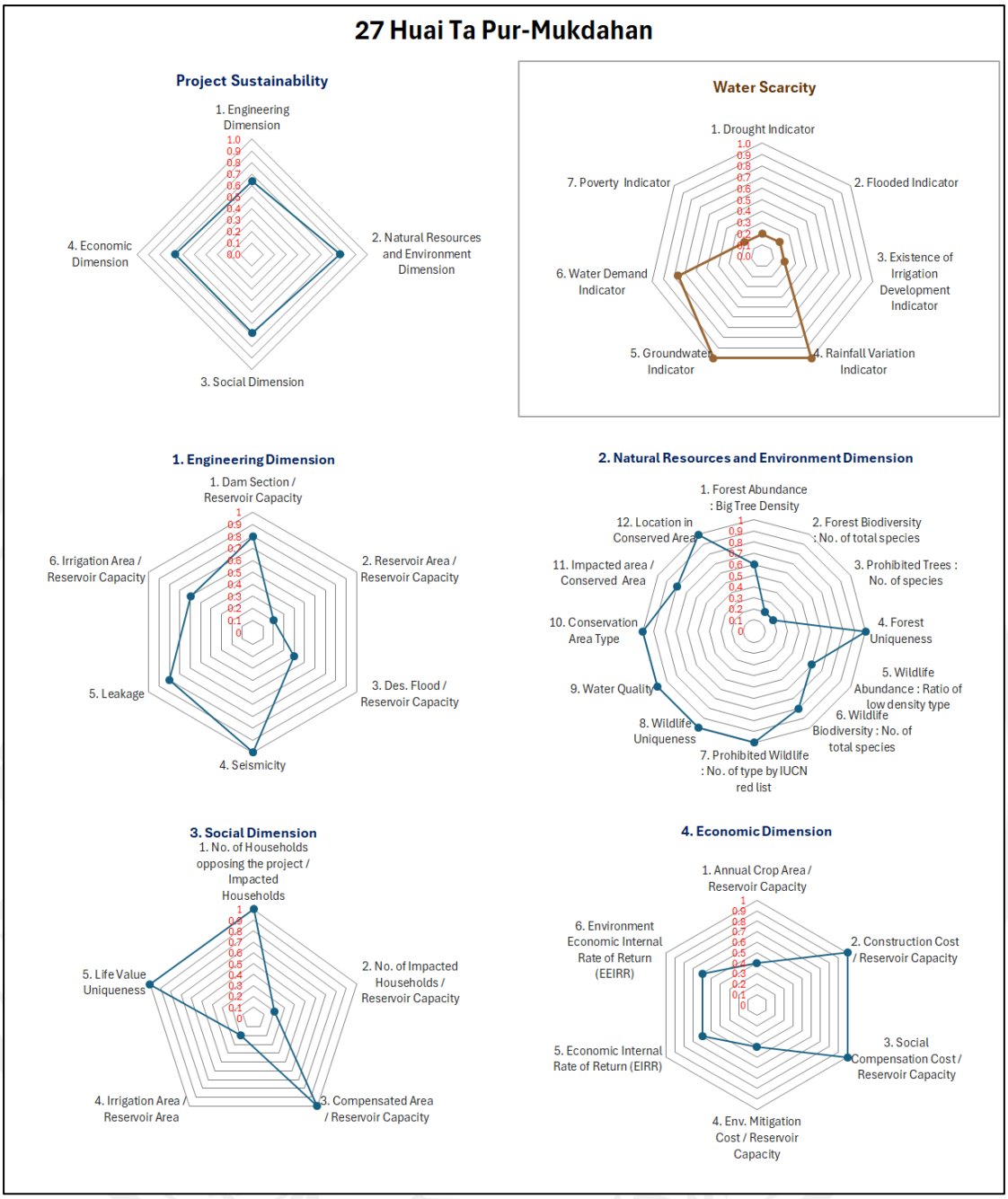

Figure E.27 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Ta Pur Project, Mukdahan Province

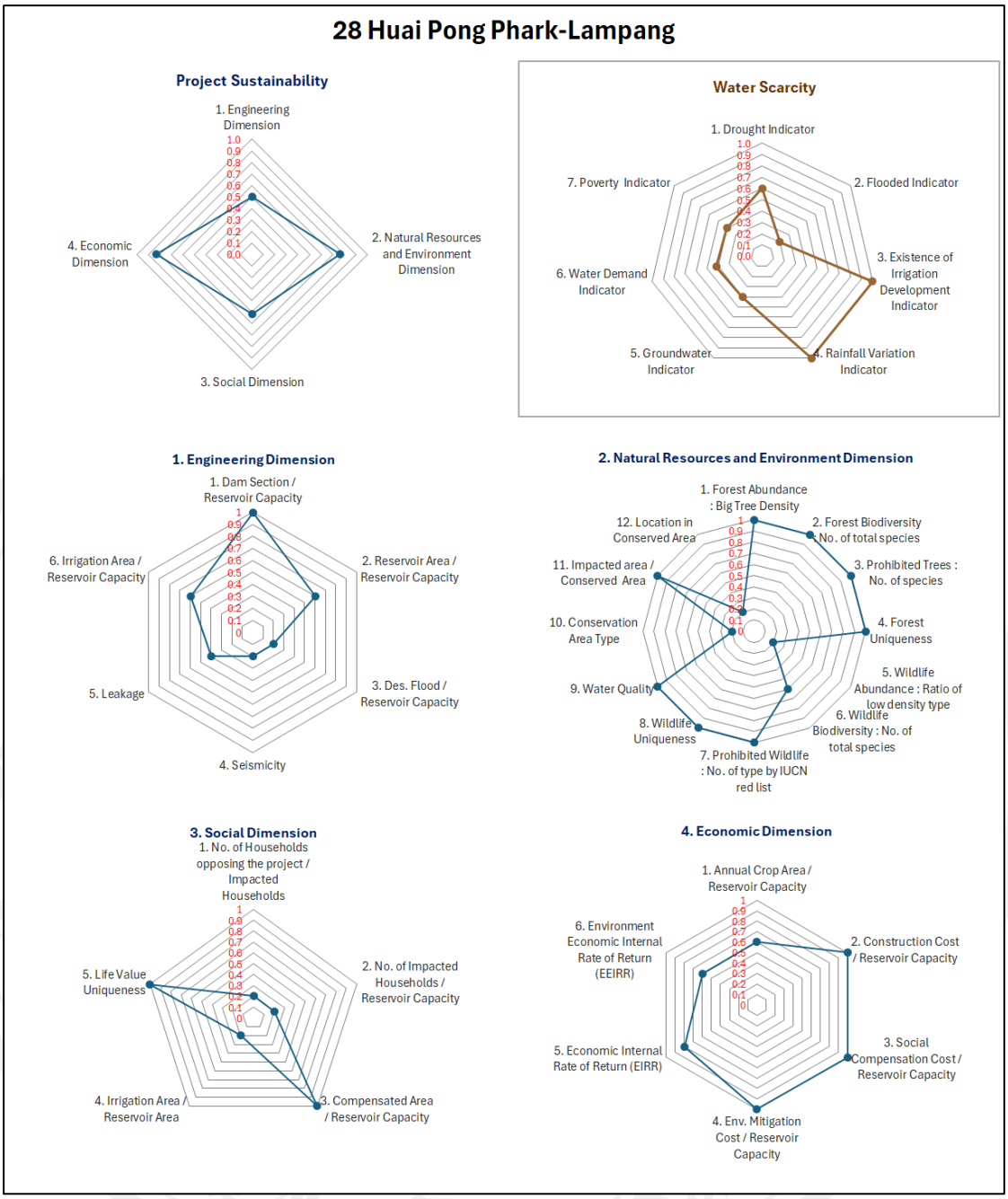

Figure E.28 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Huai Pong Phark Project, Lampang Province

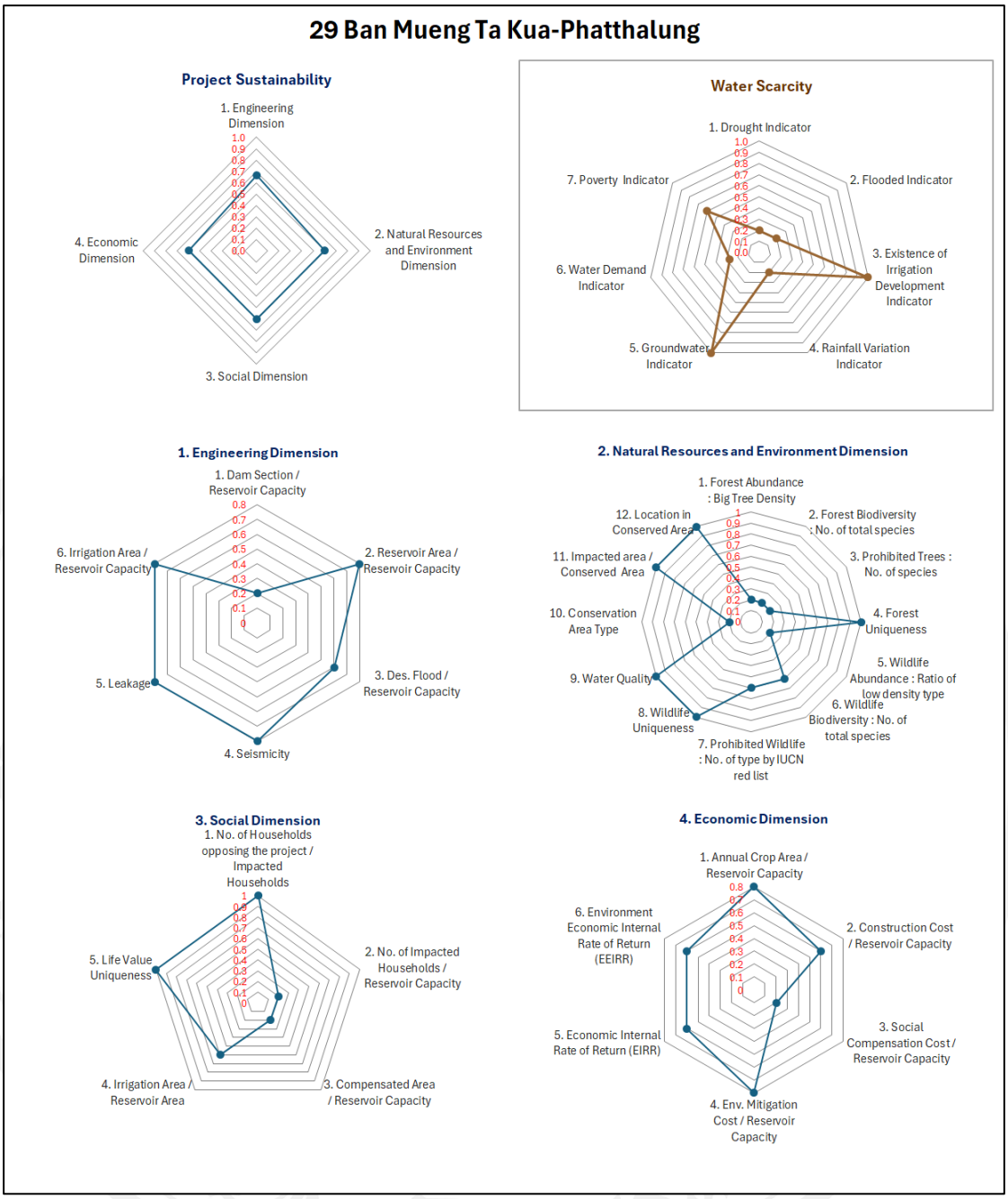

Figure E.29 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Ban Mueng Ta Kua Project, Phatthalung Province

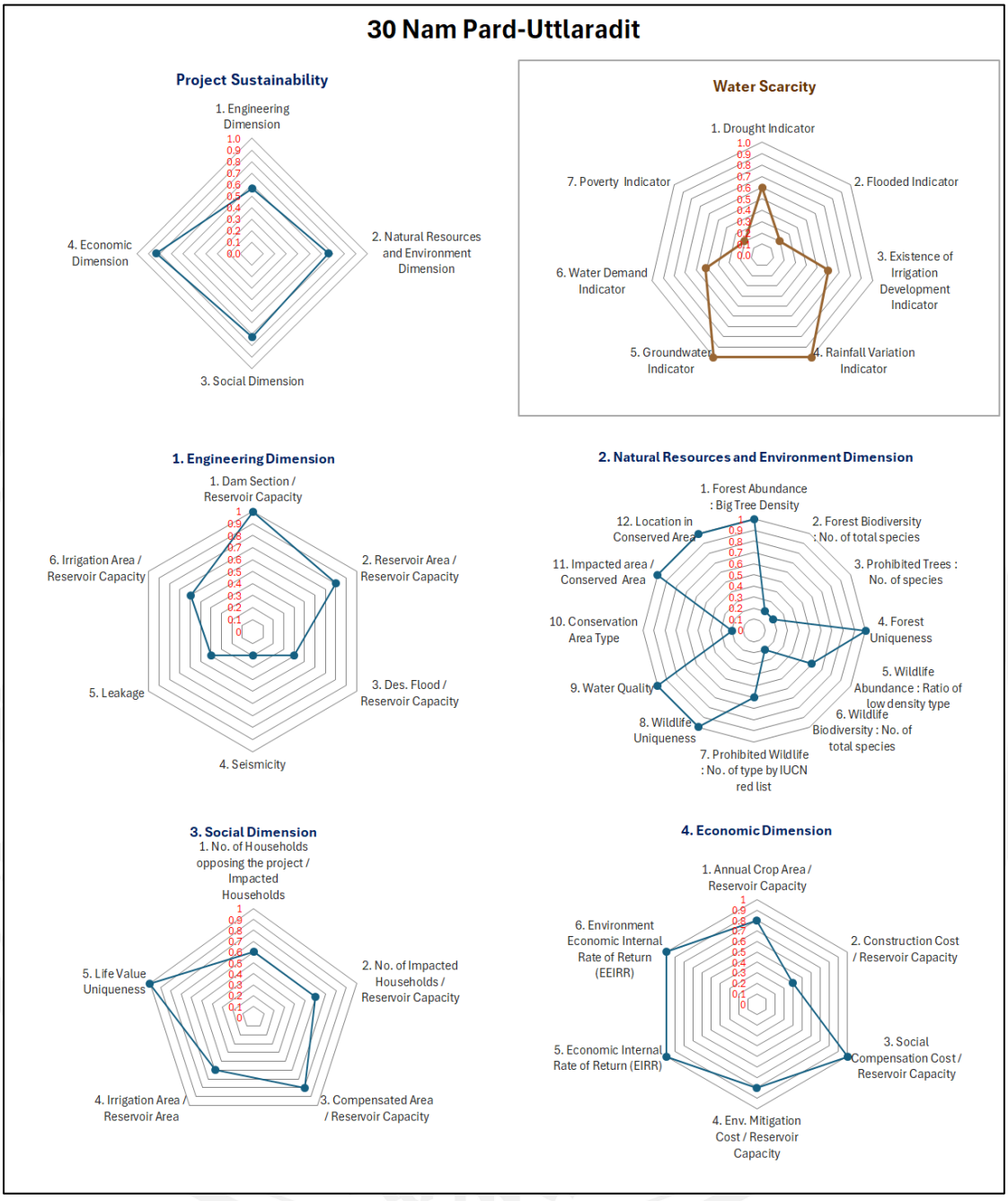

Figure E.30 Sustainability Scores of Indicators in Various Dimensions and Water Scarcity Scores of Nam Pard Project, Uttlaradit Province

Appendix F

Multiple regression of EIRR and engineering indicators

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Cost/ Res.Cap	30	11.15	201.01	57.1090	40.39271
Res.area/ Res.cap	30	18.00	177.12	61.6577	39.93051
Seismicity	30	2.00	7.00	4.4667	1.79527
Irrigation area/ Res.cap	30	327.60	3085.71	853.7683	504.02494
Des. flood/ Res.cap	30	4.03	36.71	15.0070	8.14986
IRR	30	4.36	19.79	11.8057	3.55237
Dam Sec / Res.cap	30	132.95	6127.66	1466.5860	1326.64568
Leakage	30	1.00	4.00	3.0333	0.96431
Valid N (listwise)	30				

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Leakage, Irrigation area/ Res.cap, Dam Sec / Res.cap, Res.area/ Res.cap, Seismicity, Des. flood/ Res.cap, Cost/ Rescope		Enter

a. Dependent Variable: IRR
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.607[a]	0.368	0.167	3.24271

a. Predictors: (Constant), Leakage, Irrigation area/ Res.cap, Dam Sec / Res.cap, Res.area/ Res.cap, Seismicity, Des. flood/ Res.cap, Cost/ Res.Cap

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	134.627	7	19.232	1.829	.132[b]
	Residual	231.333	22	10.515		
	Total	365.961	29			

a. Dependent Variable: IRR

b. Predictors: (Constant), Leakage, Irrigation area/ Res.cap, Dam Sec / Res.cap, Res.area/ Res.cap, Seismicity, Des. flood/ Res.cap, Cost/ Res.Cap

Correlations

		IRR	Cost/ Res.Cap	Res.area/ Res.cap	Seismicity	Irrigation area/ Res.cap	Des. flood/ Res.cap	Dam Sec / Res.cap	Leakage
IRR	Pearson Correlation	1	-0.322	0.167	-0.192	0.229	-0.349	-0.346	-0.105
	Sig. (2-tailed)		0.082	0.379	0.309	0.223	0.059	0.061	0.581
	N	30	30	30	30	30	30	30	30

Cost/ Res.Cap	Pearson Correlation	-0.322	1	-0.126	0.169	0.171	0.176	.702**	0.131
	Sig. (2-tailed)	0.082		0.506	0.372	0.367	0.353	0.000	0.489
	N	30	30	30	30	30	30	30	30
Res.area/ Res.cap	Pearson Correlation	0.167	-0.126	1	-0.330	0.152	0.251	-0.009	-0.205
	Sig. (2-tailed)	0.379	0.506		0.075	0.423	0.181	0.963	0.277
	N	30	30	30	30	30	30	30	30
Seismicity	Pearson Correlation	-0.192	0.169	-0.330	1	-0.265	.368*	0.158	.389*
	Sig. (2-tailed)	0.309	0.372	0.075		0.158	0.045	0.403	0.034
	N	30	30	30	30	30	30	30	30
Irrigation area/ Res.cap	Pearson Correlation	0.229	0.171	0.152	-0.265	1	0.088	0.058	-0.109
	Sig. (2-tailed)	0.223	0.367	0.423	0.158		0.644	0.762	0.567
	N	30	30	30	30	30	30	30	30
Des. flood/ Res.cap	Pearson Correlation	-0.349	0.176	0.251	.368*	0.088	1	0.321	.401*
	Sig. (2-tailed)	0.059	0.353	0.181	0.045	0.644		0.084	0.028
	N	30	30	30	30	30	30	30	30
Dam Sec / Res.cap	Pearson Correlation	-0.346	.702**	-0.009	0.158	0.058	0.321	1	0.163
	Sig. (2-tailed)	0.061	0.000	0.963	0.403	0.762	0.084		0.390
	N	30	30	30	30	30	30	30	30
Leakage	Pearson Correlation	-0.105	0.131	-0.205	.389*	-0.109	.401*	0.163	1
	Sig. (2-tailed)	0.581	0.489	0.277	0.034	0.567	0.028	0.390	
	N	30	30	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	23.6493	161.7249	57.1090	29.61847	30
Residual	-62.98680	64.04989	0.00000	27.46484	30
Std. Predicted Value	-1.130	3.532	0.000	1.000	30
Std. Residual	-2.042	2.077	0.000	0.891	30

a. Dependent Variable: Cost/ Res.Cap

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	9.411	3.216		2.926	0.008
	Cost/ Res.Cap	-0.022	0.022	-0.250	-1.003	0.327
	Res.area/ Res.cap	0.028	0.018	0.311	1.506	0.146
	Seismicity	0.354	0.434	0.179	0.816	0.423
	Irrigation area/ Res.cap	0.002	0.001	0.343	1.844	0.079
	Des. flood/ Res.cap	-0.230	0.101	-0.528	-2.287	0.032
	Dam Sec / Res.cap	0.000	0.001	-0.076	-0.302	0.765
	Leakage	0.676	0.737	0.183	0.918	0.369

a. Dependent Variable: IRR

Management of The Royal Royal Irri Department
2b, 2012c, 20 018b, 2019a, 201
2021a, 2021b, 2021 , 2023, 2024a, 2024b; vernment Gazette,"
Gazette," 2016, 24 Royal Government Gazette," 201 Thai Royal Govern
cember; "Thai Ro nment Gazette,," 2019, 29 May; "Thai Ro nment Gazette,," 2

BIOGRAPHY

Name-Surname	Mr. Udomsook Suracharttumrongrat
Academic Background	B.Eng (Civil Engineering), Chulalongkorn University (1980) M.Eng (Water Resource Engineering), Asian Institute of Technology (1982) M.B.A Chulalongkorn University (1991)
Experience	After master's degree graduation. The researcher had been working as a water resources engineer of engineering consulting firms for more than 15 years. Then founding a consulting engineering company, he has been working as senior engineer and project manager more than 25 years responsible for various water resources project planning including master plan study, feasibility study, detailed design and environmental impact assessment study concerning water resources development, irrigation, flood control, and infrastructures for government agencies and state enterprises. Experienced various problems, barriers, limitations, conflicts of most water resources development projects, he realized the issue of unbalanced between maximizing water resources development for socio-economic purposes and minimizing natural resources usage especially in conservation areas. Even the state's policy of balancing such issue is specified definite criteria has still been unidentified. He decided in studying a research on establishment of appropriate criteria and indicators for assessing sustainable water resources development projects in all aspects of socio-economic, natural resources and environments in conserved areas of which results would benefit to concerning government agencies and stakeholders for applying them in project's sustainability assessment, project planning and implementation states to accomplish sustainable projects.