EVALUATION OF APPROPRIATENESS OF THE TECHNOLOGY USED IN KHULNA-JESSORE DRAINAGE REHABILITATION PROJECT

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BUET

February, 2009

INSTITUTE OF WATER AND FLOOD MANAGEMENT (IWFM)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

EVALUATION OF APPROPRIATENESS OF THE TECHNOLOGY USED IN KHULNA-JESSORE DRAINAGE REHABILITATION PROJECT

by

Rowshon Ara

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The thesis titled **'Evaluation of Appropriateness of the Technology used in Khulna-Jessore Drainage Rehabilitation Process'** submitted by ***Rowshon Ara***, Roll No-MF0428033, Session: April, 2004 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of M.Sc. in Water Resources Development in February 01, 2009.

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TABLE OF CONTENTS

	Page No.
LIST OF TABLES	x
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS	xv
ACKNOWLEDGEMENT	xvii
ABSTRACT	xviii

CHAPTER ONE: INTRODUCTION

1.1	Background of the Problem	1
	1.1.1 General background	1
	1.1.2 Project objectives	2
1.2	Objectives of the Present Research	2
1.3	Methodology	3
	1.3.1 General methodology	3
	1.3.2 Methodology of the study	5
	1.3.2.1 FHDM Method	5
	1.3.2.2 Analytical Hierarchy Process (AHP)	6
1.4	Scope of the Study	6
1.5	Limitations of the Study	6
1.6	Organization of the Thesis	7

CHAPTER TWO: OVERVIEW OF THE STUDY AREA

2.1	Background	8
2.2	Objective of the Project	8
2.3	Description of the Project Area	13

2.3.1 Definition of project area 13

2.3.2 General information 13

2.3.2.1 Administrative control 14

2.3.2.2 Socio-economic conditions 14

2.3.2.3 Topography 16

2.3.2.4 Climate and water resources 16

2.3.2.5 Transportation 17

2.3.2.6 Agricultural and fisheries resources 18

2.3.3 River system/ Basin of the project area 21

2.3.3.1 Hari river system 23

2.3.3.2 Upper Bhadra river system 31

2.3 3.3 South-eastern system 35

CHAPTER THREE: LITERATURE RIVIEW

3.1 General Background of Project 41

3.1.1 Project history 41

3.1.2 Project objectives 43

3.1.3 Current status 43

3.1.4 Project characteristics 46

3.1.4.1Geography 46

3.1.4.2 Administrative 46

3.1.4.3 Topography 46

3.1.4.4 Tidal Range 46

3.1.4.5 Salinity concentrations 48

3.1.4.6 Sediment concentration 48

3.1.4.7 Agriculture 48

3.1.4.8 Fisheries 49

3.1.5 Drainage System 49

3.1.5.1 Southeastern system 50

3.1.5.2 Hari River system 50

3.1.5.3 Upper Bhadra system 50

3.1.6 Infrastructure 51

3.1.7 Project Achievement 54

3.1.8 Description of Additional Project Works Required 56

3.1.9 Towards a Broader Objectives 57

3.2 General Background of Technology Assessment 58

3.2.1 Attributes of technology 58

3.2.2 The need & purposes 59

3.2.3 Basic components of technology 60

3.2.4 Technology assessment 61

3.2.5 Objectives of technology assessment 61

3.2.6 Various purposes of assessment 62

3.2.8 The characteristics of technology assessment 63

3.2.9 Factors to be considered 64

3.2.10 The process of technology assessment 64

3.2.11 Tools and techniques of technology assessment 66

CHAPTER FOUR: METHODOLOGY

4.1 Introduction 69

4.2 The Process and Characteristics of Technology Assessment 69

4.3 Methodology of the Study 70

4.3.1 Section one 72

Fuzzy Hierarchical Decision Making (FHDM Method)

4.3.2 Section two 74

Analytical Hierarchy Process (AHP)

4.3.3 Section three 79

Field survey and Focus Group Discussion (FGD)

CHAPTER FIVE : ANALYSIS

5.1	Introduction	82
5.2	Analysis 1	83
	5.2.1 Analytical Hierarchy Process (AHP) for KJDRP and Non-KJDRP Option	83
	5.2.2 Analytical Hierarchy Process (AHP) for TRM and Non-TRM Option	113
5.3	Analysis 2	117
	5.3.1 Fuzzy Hierarchical Decision Making (FHDM)	117
5.4	Analysis 3	136
	5.4.1 Field Survey and FGD	136

CHAPTER SIX: RESULT AND DISCUSSION

6.1	Introduction	138
6.2	Score Found for Option KJDRP and Non-KJDRP in Different Methods	139
	a) AHP Method	139
	b) FHDM Method	141
	c) Field Data (FGD)	142
6.3	Comparison of Ranking value of 1st Order Criteria in Two Different Methods	142
	a) AHP Method	143
	b) FHDM Method	143
6.4	Comparison of Ranking Value of 2nd & 3rd Order Criteria in Two Different Methods	144
	a) AHP Method	144
	b) FHDM Method	145
6.5	Score Found for Option TRM and Non-TRM in AHP Method	146

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 Observation 149
7.2 Recommendations 151
7.3 Suggestions for Future Study 152

REFERRENCE 153

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

LIST OF TABLES

		Page No.
Table 2.1 :	Administrative Units within the Project Area	14
Table 2.2 :	Results of Survey of Boat Traffic Using Rivers	18
Table 2.3 :	Details of Fisheries Production in the Project Area	21
Table 2.4 :	Details of Fisheries Production in Dumuria Thana	21
Table 3.1 :	Infrastructure Present in the Study Area	51
Table 3.2 :	Infrastructure Present in the Study Area	54
Table 4.1 :	Pair-wise Comparison Scale for AHP Preferences	73
Table 4.2:	Average Random Consistency	73
Table 4.3:	Linguistic Scale and its Triangle Fuzzy Number Conversion	78
Table 5.2.1:	Pair wise comparison scale for AHP preferences	86
Table 5.2.2:	Pair-wise comparisons of criteria and sub-criteria and options against each criteria and sub-criteria.	86
Table 5.2.2.A:	Pair-wise Comparison Matrix for the 1st Level Criteria (for Expert-1)	87
Table 5.2 2.B:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Resource)	87
Table 5.2 2.C:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Population)	87
Table 5.2.2.D:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Environment)	88
Table 5.2.2.E:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Socio-culture)	88
Table 5.2.2.F:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Technology)	88
Table 5.2.2.G:	Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Economic)	89
Table 5.2.2.H:	Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Fish Production)	89
Table 5.2.2.I:	Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Agricultural Productiou)	89

Table 5.2.3.A : Computational Process of Priority Vector (1st Level Criteria) 89
Table 5.2.3.B: Computational Process of Priority Vector (2nd Level Criteria Under Resource) 89
Table 5.2.3.C: Computational Process of Priority Vector (2nd Level Criteria Under Population) 90
Table 5.2.3.D: Computational Process of Priority Vector (2nd Level Criteria Under Environment) 90
Table 5.2.3.E: Computational Process of Priority Vector (2nd Level Criteria Under Socio-culture) 91
Table 5.2.3.F: Computational Process of Priority Vector (2nd Level Criteria Under Technology) 91
Table 5.2.3.G: Computational Process of Priority Vector (2nd Level Criteria Under Economic) 91
Table 5.2.3.H: Computational Process of Priority Vector (3rd Level Criteria Under Fish Production) 91
Table 5.2.3.I: Computational Process of Priority Vector (3rd Level Criteria Under Agricultural Production) 92
Table 5.2.4.A: Matrix of 1st Level Criteria 92
Table 5.2.4.B: Matrix of 2nd Level Criteria (Under Resource) 92
Table 5.2.4.C: Matrix of 2nd Level Criteria (Under Population) 93
Table 5.2.4.D: Matrix of 2nd Level Criteria (Under Environment) 93
Table 5.2.4.E: Matrix of 2nd Level Criteria (Under Socio-culture) 93
Table 5.2.4.F: Matrix of 2nd Level Criteria (Under Technology) 93
Table 5.2.4.G: Matrix of 2nd Level Criteria (Under Economic) 94
Table 5.2.4.H: Matrix of 3rd Level Criteria (Under Fish Production) 94
Table 5.2.4.I: Matrix of 3rd Level Criteria (Under Agricultural Production) 94
Table 5.2.5.A: Matrix of Normalized Values (1st Level Criteria) 94
Table 5.2.5.B: Matrix of Normalized Values (2nd Level Criteria Under Resource) 94
Table 5.2.5.C: Matrix of Normalized Values (2nd Level Criteria Under Population) 95
Table 5.2.5.D: Matrix of Normalized Values (2nd Level Criteria Under Environment) 95
Table 5.2.5.E: Matrix of Normalized Values (2nd Level Criteria

Under Socio-culture) 95

Table 5.2.5.F: Matrix of Normalized Values (2nd Level Criteria Under Technology) 95

Table 5.2.5.G: Matrix of Normalized Values (2nd Level Criteria Under Economic) 96

Table 5.2.5.H: Matrix of Normalized Values (3rd Level Criteria Under Fish Production) 96

Table 5.2.5.I: Matrix of Normalized Values (3rd Level Criteria Under AgriculturalProduction) 96

Table 5.2.6.A: Priority Vector of Each Criteria (for Expert-1) 96

Table 5.2.6.B: Priority vector of each criterion (for Expert-1, Expert-2 and Expert-3) 97

Table 5.2.7.A: Priority Vector of Criterion against Each Option (KJDRP, Non-KJDRP, TRM. Non-TRM) (for Expert-1) 99

Table 5.2.7.B: Priority vector of criteria under the option of KJDRP and Non-KJDRP (for Expert-1, Expert-2 and Expert-3) 101

Table 5.2.7.C: Priority vector of criteria under the option of TRM and Non-TRM (for Expert-1, Expert-2 and Expert-3) 104

Table 5.2.8: Overall summary of Priority Vector (PV.) (From Expert-1, Expert-2 and Expert-3) 106

Table 5.2.9: Priority vector (PV.) with real performance value 108

Table 5.2.10: Priority vector (PV.) from experts' choice and the real priority vector found from KJDRP and Non- KJDRP options 109

Table 5.2.11: Score obtained for different criteria under KJDRP and Non-KJDRP options in AHP Method 112

Table 5.2.12: Priority vector found from experts' choice for TRM and Non-TRM options 113

Table 5.2.13: Score found for different criteria under TRM and Non-TRM options in AHP Method 116

Table 5.3.1: Linguistic Scale and its Triangle Fuzzy Number Conversion 118

Table 5.3.2: Expert's opinions on relative importance of first level criteria 119

Table 5.3.3: The pair wise importance criteria 119

Table 5.3.4 : The Fuzzy Reciprocal Matrix 119

Table 5.3.5 : Geometric Row Mean Values And The Importance Weight 120
Table 5.3.6 : Importance weights of criteriaTable 5.3.8 :Global importance weight of criteria 121
Table 5.3.7 : Importance Weight of Resource Criteria 122
Table 5.3.8 : Global importance weight of criteria 123
Table 5.3.9: Importance weight and global weight of criteria 124
Table 5.3.10(a): Fuzzy Conversion of Field Data (Non-KJDRP) 125
Table 5.3.10(b) : Fuzzy Conversion of Field Data (KJDRP) 126
Table 5.3.11: (combination of a and b) 127
Table 5.3.12 : Appropriateness weight of alternatives 128
Table 5.3 13(a): The Fuzzy Choice Index of Non- KJDRP 130
Table 5.3.13(b): The Fuzzy Choice Index of KJDRP 131
Table 5.3.14: (Combination of a and b) The Fuzzy Choice Index of Alternatives (for sub-criteria) 132
Table 5.3.15: FCI of Alternatives 133
Table 5.3.16: Ranking Values, Preferential Weights and Preferential Ranks of Alternatives 134
Table-5.4.1: Critical Factors (with Numerical Value) used in Questionnaire (R' for Respondent) 136
Table-6.1: AHP data 139
Table-6.2· AHP Score 140
Table-6.3: Fuzzy Choice Index (FCI) of KJDRP and Non-KJDRP 141
Table-6.4: Priority Vector for Different Criteria 143
Table-6.5: FHDM Method: Global Weight and Preferential Weight 143
Table-6.6 AHP Method: Priority Vectors of 2nd and 3rd Order Criteria 144
Table-6.7: FHDM Method: Priority Vectors of 2nd and 3rd Order Criteria 145
Table-6.8 AHP Score for TRM and Non-TRM 146

LIST OF FIGURES

		Page No.
Figure 2.1 :	Project Area Location Map	10
Figure 2.2 :	KJDRP Administrative Unit	15
Figure 2.3:	Wet lands Present in the KJDRP Area	22
Figure 3.1	KJDRP Water Management Zones	47
Figure 3.2 :	Khuna Jessore Drainage Rehabilitation Project Recommended Overall Drainage Plan (South-Eastern Part)	52
Figure 3.3 :	Khuna Jessore Drainage Rehabilitation Project Recommended Overall Drainage Plan (North-West Part)	53
Figure 4.1:	Hierarchical Structure of Technology Assessment	78
Figure 4.2:	Membership Function of Linguistic Scale	79
Figure 4.3:	Linguistic Assessment Converted into Numeric Values	81
Figure. 5.1 :	Technology Assessment Criteria Hierarchy	85
Figure 5.2:	Comparison of criteria under KJDRP and Non- KJDRP Options	113
Figure 5.3:	Score for KJDRP and Non-KJDRP Options in AHP Method	113
Figure 5.4:	Comparison of criteria under TRM and Non-TRM Options	116
Figure 5.5:	Score for TRM and Non-TRM Options in AHP Method	116

ABBREVIATIONS

ADB	-	Asian Development Bank
AHP	-	Analytical Hierarchy Process
BBTB	-	Beel Bhaina Tidal Basin
BKTB	-	Beel Kedaria Tidal Basin
BME	-	Benefit Monitoring and Evaluation
BWDB	-	Bangladesh Water Development Board
CEGIS	-	Centre for Environmental and Geographic Information Systems
CEP	-	Coastal Embankment Project
CERP	-	Coastal Embankment Rehabilitation Project
DAE	-	Department of Agricultural Extension
DAF	-	Department of Fisheries
EIA	-	Environmental Impact Assessment
EGIS (CEGIS)	-	Environmental Geographic Information System
ESMP	-	Environmental and Social Management plan
FAP	-	Flood Action Plan
FHDM	-	Fuzzy Hierarchical Decision Making
GOB	-	Government of Bangladesh
ha	-	Hectare (1 hectare =10,000 m^2)
IPM	-	Integrated Pest Management
IWM	-	Institute of Water Modelling
HYV	-	High Yielding Varieties
KJDRP	-	Khulna-Jessore Drainage Rehabilitation Project
Km	-	Kilometre
MIS	-	Management Information System
MoWR		Ministry of Water Resource
MCDM	-	Multi Criteria Decision Making
NGO	-	Non-Government Organization
O&M	-	Operation and Maintenance
PCR	-	Project Completion Report
ppt	-	Parts per thousand
RRP	-	Report and Recommendation of the President (of ADB)

SIA	-	Social Impact Assessment
SMEC	-	Snowy Mountains Engineering Corporation
SWMC (IWM)	-	Surface Water Modelling Centre (now changed to IWM)
TOR	-	Terms of Reference
TRM	-	Tidal River Management
WMA	-	Water Management Association
WMC	-	Water Management Committee
WMD	-	Water Management Directorate, BWDB
WMF	-	Water Management Federation
WMG	-	Water Management Group

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ABSTRACT

The objective of the present research aims at assessment of appropriateness of technology that was used in Khulna-Jessore Drainage Rehabilitation Project (KJDRP). The project area is characterized by sediment laden tidal rivers having some major problems over recent years such as drainage congestion, flooding and salinity etc., causing a decline in agricultural production and other socio-economic anomalies. KJDRP was implemented to mitigate drainage, salinity and other problems with an aim to reduce poverty through greater employment in the agriculture and increased agricultural production in the project area. In this research, the technology that was used in KJDRP was evaluated using three models/methods: i) Analytical Hierarchic Process (AHP) ii) Fuzzy Hierarchical Decision Making Method (FHDM) and iii) Field Survey and Focus Group Discussion (FGD). The objective is to make an application of the (Multi criteria Decision Making) MCDM model to evaluate whether the technology used in KJDRP is appropriate or not for that very particular surrounding environment, because technology is very surrounding specific. From AHP method, result shows that the total score for KJDRP is 596 where score for Non-KJDRP is 173. Thus in AHP method, KJDRP got 1st ranking value and Non-KJDRP got 2nd ranking value. In Fuzzy method, the result shows that KJDRP option scored 1st in preferential ranking value where Non-KJDRP option scored 2nd ranking value. From Focus Group Discussion (FGD) and Field Survey, it is evident that the performance of criteria under KJDRP option is positive and it scored 2216.5 in the scale range from (-) 4080 to (+) 4080. However from three analytical points of views, KJDRP got highest value which indicates that KJDRP with its performance was appropriate to reduce the existing water logging problem and to encourage the socio-economic development of the project area. KJDRP is successful in these few prime objectives of the project.

A set of recommendations enaminated evolved based on the research result: i) Action is required to be taken for restoration of the Hamkura river and development of TRM for improvement of the drainage condition. ii) Implementation of a new TRM in the Khuksia beel is required to be taken up or continue the existing beel Kedaria TRM for sustaining drainage condition of the Hari River. The east Khuksia beel is feasible for TRM and would be more effective to maintain proper drainage condition in the Hari river. The west Khuksia is also technically feasible for acting as a tidal basin but it required more land than that of east beel Khuksia. It generates more than 4.87 Mm3

tidal volume, which is considerably higher than the required tidal volume for the sustainability of the Hari river. iii) to restore the full function of the beel Kedaria TRM and sustain the required drainage capacity of the Hari river, it is suggested to dredge the Hari river at its design capacity of the Hari river at its design section from Bhabodaha regulator to Sholgati (about 9 km reach). iv) in order to maintain proper drainage capacity of the Hari river & to avoid severe drainage congestion in the North-Western part of the KJDRP area, east beel khuksia needs to be brought under operation as a tidal basin. It is technically feasible and socially acceptable. v) it is suggested to dredge the Teka-hari river at its design section from 600m u/s of Teka Bridge to Ranai (about 17 km reach). vi) A continuous monitoring is necessary for assessment of new tidal basin. identification of problems of mitigation measures.

Opinion from some of the experts who think that TRM (Tidal River Management) as a part of KJDRP is not appropriate technology. According to them, it is useless to enlighten a village by throwing the remaining village in darkness. Why the people in the beel area will be deprived for three years during the operation period of the beels, and who will provide their compensation for that time period? Establishment of regulator in the narroe channel must result in failure due to lower velocity of the water and siltation caused by it. They suggested that regulator in Madhukhali or further downstream rather than the narrow channel will be effective as it joins the large river and will prevent siltation due to huge flow of water. They propose that Hari river can join Dakatia river through a canal networking and thus drainage from Hari river is possible through Sholmari regulator. The technology used in KJDRP didn't consider the importance of wetland. But wetland is very crucial for sustenance of the ecosystem of fisheries. So what is needed is to proper management of the wetland. Regulator in Madhukhali can be a better option, as it will prevent saline water intrusion during tidal period when the gate is closed, on the other hand, it will drain excess river water during monsoon, and thus will remove the drainage problem and at the same time, will maintain minimum water for sustenance of the wetland. Implementation of this option may require high initial cost due to dredging requirement, but still it seems to be minimum when compared with the huge cost involved due to operation of TRM in a single beel. However, TRM considers siltation in wetlands with a view to keep the river navigable and to grow more food concept. Thus in the present analysis, it is successful and appropriate with the target fixed by it.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

1.1.1 General background

The Khulna-Jessore Drainage Rehabilitation Project (KJDRP) is located in the south-west part of Bangladesh in Khulna and Jessore Districts. The Project area covers 100,600 ha and is a part of the deltaic area of the Ganges and Brahmaputra river system. The area is characterized by sediment laden tidal rivers. In the recent years, drainage congestion problems have given rise to a question about the performance of KJDRP with respects to its objectives.

In the late 1960s and early 1970s, the Government of Bangladesh (GOB) had constructed a series of polders under the Coastal Embankment Project (CEP) that created the scope for growing agricultural crops by preventing intrusion of saline water. The creation of polders simplified the existing drainage network, which was comprised of a large number of tidal creeks and rivers. This resulted to a substantial decrease in the tidal volume accompanied by an increase in tidal range. After more than a decade of good productivity, drainage congestion began to increasingly affect the most of the northern polders.

In the early 1980s, drainage congestion in the polder areas was recognized as a serious problem, when the rivers and creeks in these areas silted up to such an extent as to render them inoperative. This resulted in large areas remaining waterlogged throughout the entire year. Drainage congestion, flooding, salinity intrusion and water logging have all been major problems over recent years, causing a serious decline in agricultural production and living conditions in the area.

In response to this situation the Government of Bangladesh (GOB), with financial support from the Asian Development Bank (ADB Loan No. 1289-BAN(SF)), arranged to undertake KJDRP Project. The project commenced in early 1994 and was successfully completed on 31 December 2002. Finance of the project was from an Asian

Development Bank Loan and Government of Bangladesh. The principal Executing agency was the Bangladesh Water Development Board.

1.1.2 Project objectives

The basic aim of the project was the reduction of poverty among the rural poor in the project area, which covers a largely agricultural area of 1,000 km^2 lying between the cities of Jessore and Khulna. The population of the project area is about 1,000,000 mainly poor people. Poverty alleviation will be achieved by the construction of improved drainage works, which will substantially reduced dry season drainage congestion thereby allowing agricultural and fisheries production to increase substantially and other economic activity to expand.

1.2 Objectives of the Present Research

Basic purpose of KJDRP was to remove drainage congestion and simultaneously to enhance the process of poverty reduction by increased agricultural production In the recent years, drainage congestion has given rise to a number of questions pertaining to the project. Upto what extent the project is successful. what benefit and losses are being incurred after implementation of KJDRP. So an evaluation of the appropriateness of the project is necessary. This research has undertaken with a view to assess the appropriateness of the technology of KJDRP, whether the technology has been able to meet various demand of the objective.

Technology assessment is an important part of technology planning. Its main purpose is to identify right kind of technologies for development through comprehensive evaluation of their strengths, weaknesses and implications from national perspective. The choice of technology requires consideration of not only techno-economic factors but also environmental, social, population and similar other factors. This means, technology assessment should be based on multi criteria decision making (MCDM) approach. So, the objectives can be summarized as follows:

General objectives:

- To evaluate up to what extent the project is successful
- To assess the appropriateness of the technology of KJDRP comparative to Non-KJDRP

Specific objectives:

- To analyze and identify the criteria that associates the choice of technology
- To generate assessment criteria hierarchy
- To make the application of assessment tools of Technology.
- To assess the success or failure of KJDRP
- To justify whether the methodology applied in KJDRP is in-line or not comparing with real performance
- To identify the applicability of the tool whether it can be applied to other project with similar problem.

The objective of the present research is to make an application of the MCDM model to evaluate whether the technology used in KJDRP is appropriate or not for that very particular surrounding environment, because technology is very surrounding specific.

1.3 Methodology

1.3.1 General methodology

The general steps in the assessment process are as follows.

Step 1: ***Identification of the problem***

- Stock taking of existing situation and regulations.

- Determination of time horizon and level of analysis.

- Setting boundaries and objectives.

Step 2: ***Description of alternatives being assessed.***

- Inventory of relevant technological alternatives

- Current state-of-the-art.

- Technological forecasting.

Step 3: ***Establishment of assessment factors***

- Description of relevant factors.

- Identification of variables and types of effects.

- Classification of variables.

Step 4: Evaluation of expected effects

- Analysis and measurement of effects.

- Representation of various effects.

- Integration of all expected effects.

Step 5: ***Formulation of action options***

- Identification of all possible action options.
- Development of programs for action.
- Analysis of consequences for each option

Step 6: ***Choice of suitable action***

- Influence of various decision makers
- Justification for the final choice.
- Choice of the most suitable alternative.

Factors to be considered

Since there exist interaction between technology and human surroundings, and as the major components that constitute the human surroundings are economic, resources, environmental, population, socio-cultural and politico-legal systems. The following factors are to be considered for technology assessment.

1. ***Technological Factors***
   - Technical utility (capability, reliability, efficiency)
   - Options of technology (flexibility, scale).
   - Availability of infrastructure (support, services).
2. ***Economic Factors***
   - Economic feasibility (cost-benefit)
   - Improvement in productivity (capital. resources)
   - Market potentials (size, elasticity)
3. ***Resource Factors***
   - Availability of material and energy resources
   - Availability of financial resources
   - Availability of skilled manpower
4. ***Environmental Factors***
   - Impact on physical environment (air, water, land)
   - Impact on living conditions (comfort, noise)
   - Impact on life (safety, health)
5. ***Population Factors***
   - Growth of population (rate, life expectancy)
   - Level of education (literacy rate)
   - Labor characteristics (unemployment, structure)

6. ***Socio-Cultural Factors***
   - Impact on individual (life quality)
   - Impact on society (values)
   - Compatibility with existing culture
7. ***Politico-Legal Factors***
   - Political acceptability
   - Mass need satisfaction
   - Compatibility with institutions and policies.

It can be observed from the above that technology assessment is a part of creative activities, and should not be approached as search for formulae and models but rather an art which depends on talent, experience, as well as tools and techniques. Moreover, due to the fact that TA problems are very complex, dynamic and multi-disciplinary in nature, it seems to call for a particularly cautious methodical approach.

1.3.2 Methodology of the study:

In the current research, the methodology contains three parts for the assessment of the technology. Each part can be described under the following heads:

1. Section-1: Analysis using Analytical Hierachic Process (AHP)
2. Section-2: Analysis using Fuzzy Hierarchy Decision Making (FHDM) Method
3. Section-3: Focus Group Discussion (FGD) and Field Survey.

Section-1 and Section-2 describes *Multi Criteria Decision Making* approach, where Section-1 deals with AHP (Analytical Hierarchy Process) method and Section-2 deals with FHDM (Fuzzy Hierarchy Decision Making) method. Section-3 deals with assessment of technology based on Focus Group Discussion and field survey.

1.3.2.1 Analytical Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a decision – aiding method developed by Satty. It provides a systematic, explicit, rigorous and robust mechanism for eliciting and quantifying subjective judgments. It is widely applicable because of its inherent capability to handle both quantitative and qualitative attributes and data uncertainty.

The steps of AHP, developed by Satty, are as follows:

1) Define the decision problem and determine its object
2) Set up decision hierarchy
3) Make pair wise comparisons of attributes and alternatives
4) Transform the comparisons into weights
5) Use the weights to obtain scores for the different options and make a provisional decision.

1.3.2.2 FHDM Method

In FHDM (Fuzzy Hierarchy Decision Making) method, a procedure is evolved by synthesizing and extending the ideas proposed in the existing fuzzy MCDM methods. It considers

1) Pair-wise comparison of alternative criteria
2) Linguistic variables rather than numbers
3) Subjective as well as objective factors
4) Triangular fuzzy numbers
5) More than two levels of hierarchy of the criteria

1.4 Scope of the Study

The scope of the study incorporates a numerical analysis of the two renowned hierarchical decision making methods namely AHP and FHDM by using the available data. The study is based on an important water resource project namely KJDRP. A survey research with field values to be done to cross check the numerical analysis. Thus the scope of the study is to find whether the tools such as AHP and FHDM has got applicability in the water resource project of Bangladesh.

1.5 Limitations of the Study:

- Technology assessment through AHP method needs experts' judgments and it considers crisp values for subjective judgment. It is easy for the experts to give their opinion in linguistic variables such as high, low, medium, but for final evaluation, it is necessary to convert these linguistic variables into numbers. Assigning the exact number may not be appropriate.
- The linear scale used in AHP does not always translate well the marginal difference of importance of the factors.

- Number of attributes are very large, thus comparison matrix table become very large in the current study.
- The present study is based on some selected major criteria proposed by some selected experts; it was not possible to cover all the factors involved in the project.
- Correlation and Sensitivity analysis among various factors were not considered here.

1.6 Organization of the Thesis

Chapter 1 Introduction : Devotes to preliminaries (Brief summary of the problem, background of the study, objectives and the organization of the thesis).

Chapter 2 : Overview of the Study Area : It describes the objective of the project, description of the project area, general information of the project area and river system of the project area.

Chapter 3 : Literature Review: It delineate about the sources of problem, details of the problem and the methods have been tried to solve it. The section comprises of discussions of these queries.

Chapter 4 : Methodology setting (What is Technology Assessment, methods applied in assessment of technology). In this chapter, the applied three methods have been incorporated and the methods are described under three different sections.

Chapter 5: Analysis

Chapter 6 : Results and Discussions

Chapter 7 : Observation and Recommendations

Chapter 8 : Conclusions

CHAPTER TWO

OVERVIEW OF THE STUDY AREA

2.1 Background

The Khulna-Jessore Drainage Rehabilitation Project is located in Khulna and Jessore Districts in the southwest part of Bangladesh, as shown on Figure 2.1. The project area (as originally defined) covers an area of slightly more than 100,000 hectares of mainly agricultural lands and is part of the deltaic area of the Ganges and Brahmaputra river system. The major cities of Khulna and Jessore are located just outside the project area to the north and southeast, respectively.

The project area is characterised by sediment laden tidal rivers and drainage congestion problems. The cycles of flooding and draining in the project area are a natural process, which has resulted in the building-up of fertile agriculture land. While these natural processes have been recognised, in the late 1960s and early 1970s. The Government of Bangladesh (GOB) found it necessary to construct flood protection embankments and various types of drainage structures to safeguard urban and agricultural lands from damage due to frequent tidal inundation and monsoon flooding. The intrusion of saline water also caused problems to agricultural production. Although the embankments and structures have reduced river flooding, they can also impede the natural drainage of monsoon rains and interfere with the natural processes of sediment transport and deposition. As a result drainage congestion, flooding and salinity have all been major problems over recent years, causing a decline in agricultural production and a loss of amenity for many of the rural people. In response to this situation the GOB, with financial support from the Asian Development Bank (ADB Loan No. 1289-BAN(SF)), has arranged to undertake this project.

2.2 Objective of the Project

As stated in the Consultant's terms of reference (TOR) the project objective is as follows:

> *"The principal objective of the project is poverty reduction through increased agricultural production in the project area. The increased*

agricultural production will be achieved by (i) mobilising beneficiary participation for project design and implementation, and for subsequent operation and maintenance (O&M) of the project facilities; (ii) rehabilitation the existing drainage infrastructure to reduce drainage congestion and to protect the project area from tidal and seasonal flooding; (iii) providing support for the expansion of agricultural extension services that will be necessary as flooded lands are returned to agricultural productivity; and (iv) improving management of fisheries in polder areas to ensure a continuing supply of black fish species "

To ensure attainment of the project objective, the project has been established with a wide base and, in addition to the usual range of engineering inputs. Other inputs were sociological, environmental, agricultural and fisheries activities and investigations. The success pertaining to project implementation is contingent on close interaction and coordination of each other amongst the various consultants and government agencies involved in the project components with the local communities affected by the project. Thus during the course of the project, it was necessary for the various consultants engaged by the GOB, namely SMEC and Associates, Institute of Water Modelling (IWM) and Centre for Environmental and Geographic Information Services (CEGIS), to work very closely. The close cooperation between consultants assisted in the successful implementation of the project. The Consultant has made a very deliberative effort in all of its project activities, and is involved in the consultation processes at all community levels in the project area and with government agencies and other organizations concerned with the project (SMEC, 2002)

At the start of the project in 1995 the organisational structure was broken down into four parts, as envisaged in the Loan Agreement. These were as follows:

Part A- Mobilization of Beneficiary Participation

Part B- Rehabilitation works (Engineering)

Part C- Agricultural Development

Part D- Fisheries Management

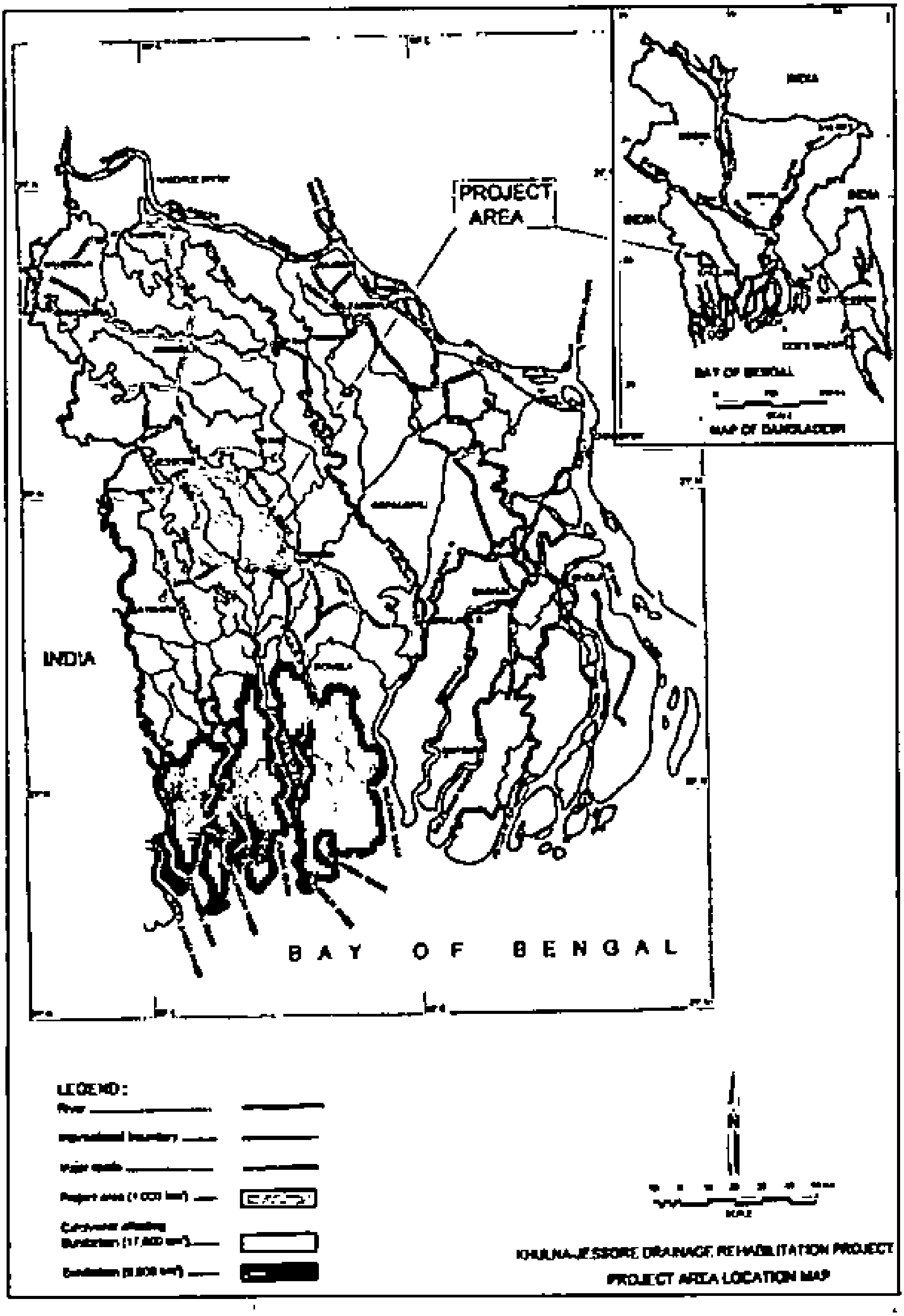


Figure 2.1 : Project Area Location Map

The Executive Agency for Parts A and B was the Bangladesh Water Development Board (BWDB), while for Parts C and D the executive agencies were the Department of Agricultural Extension (DAE) and the Department of Agricultural Extension (DAE) and the Department of Fisheries (DOF), respectively. Early in the course of implementation of the engineering works (Part B), the Consultant, SMEC and Associates, engaged the Institute of Water Modelling (IWM) [erst while Surface Water Modelling Centre (SWMC)] to undertake two important sub-contracts for the collection of data relating to the transport of cohesive sediment in the project area. Since that time SWMC has been deeply involved in hydraulic modelling studies and field monitoring of rivers and tidal basins under contract of BWDB. Similarly, commencing with the environmental and social impact studies of the project in mid-1997, CEGIS became closely involved in all the project's environmental, social and institutional aspects until the end of the project (SMEC, 2002)..

The Original Coastal Embankment Project (CEP)

The original Coastal Embankment Project (CEP) was a massive undertaking aimed at improving agricultural production in the coastal strip covering an area of some 1 4 million ha. Agricultural production was improved by reducing tidal and monsoonal flooding and the effects of salinity. This was achieved by the construction of polders an area covered by embankment to prevent intrusion of saline water) including Polders 24, 25, 27 and 28 in the project area. The construction works were undertaken in the 1960s and 1970s and for many years so that the people can be benefited from the project (EGIS, 2002). It is interesting to note that in the 1991 Coastal Embankment Project (CEP) report, (International Engineering Company. Inc) it is stated that:

"The yields of Aman rice are estimated to be 14, 12, 11 and 15 maunds of paddy, or unhusked rice, per acre in the Khulna, Bakerganj, Noakhali and Chittagong Districts, respectively."

For Khulna the above figure of 14 maunds/acre for Aman is equal to 1.29 ton/ha, while for Aus the 1961 figure was given as 12 maunds/acre (1.10 tons/ha). For the project area conditions existing today, paddy yields are at least one ton/ha higher than in 1961. Furthermore, the 1961 report states the cropping intensity for the Khulna District was only 1.08. According to Department of Agriculture Extension statistics, for the project area in 1994 and 1995 the cropping intensity was 1.41 and 1.43, respectively (EGIS, 1998), While increases in yields and cropping intensities are due to many factors, it does appear that the project area is still benefiting from the CEP, despite the widespread drainage congestion problems, which have existed since the mid-eighties.

The existing coastal embankments have been condemned in recent years by some environmental groups, especially in areas comprising the project area where drainage congestion problems have been developed. It does not seem that these groups have a real appreciation of the improved conditions existing now with respect to that existed prior to the embankments, the benefits that have been derived from the construction of polders and they do not feel the unreality of returning to pre-polder conditions. The Coastal Embankment Project. as described in the 1961 report, came about because the people of the coastal areas had been trying to protect their lands from tidal and monsoon flooding and salinity for many decades. The 1961 report describes the early history of embankments (dikes) as follows:

> *"The history dates back to the era of the "Zamindars", or large land owners, who also served as principal revenue agents for the government. Under this system the tenant farmers had to pay large portions of their income, usually a percentage of the crop, to the Zamindars. Since their income depended largely on crop production, the Zamindars had dikes constructed and maintained around the arable land. They were, however, of poor quality and required considerable maintenance each year. In 1951 the Zamindari system was abolished by the "East Bengal State Acquisition and Tenancy Act, 1950", and the Zamindars were relieved of their power and authority. Many had been living in other countries and did not return to the area; some residing in the area left; and those who remained were stripped of their power. As a result, there was no one to assume the responsibility for the repair and maintenance of existing dikes or the construction of new ones. Gradually they deteriorated, were breached and over-topped by tides, and became practically useless."*

Various attempts were made during the 1950s to improve the conditions in the coastal areas but it was not until the 1960s, with financial assistance from the United States of America, that positive steps were taken for a long term solution to the problems (EGIS, 2001),

2.3 Description of the Project Area

2.3.1 Definition of project area

In this report, the project area described in the original TOR for this study is referred to as the "original" project area in order to distinguish it from an extended project area, which pertains to Options 2, 3 and 5. In other words, the original project area is the area studied by Haskoning and Associates (1993) and includes 1,006 km^2 within its boundary (Figure 2.1). This project area also applies for Options 1A, 1B, 4 and 6. However, for the remaining options, the project area would have to be extended to the south to include an additional area. The boundaries of the original project area and the extended project areas are shown in Figure 2.1 and the project areas corresponding to each of the proposals under study are as follows : (EGIS, 1998)

- Option 1 - Without project situation ---------- 1,006 km^2
- Option 1A - CERP (Coastal Embankment Rehabilitation Project) with tidal basin ------------------------------ 1,006 km^2
- Option 1B - CERP with smaller tidal basin -- 1,006 km^2
- Option 2 - FAP 4 proposal --------------------- 1,306 km^2
- Option 3 - Madhukhali Regulator proposal -- 1,166 km^2
- Option 4 - Kharinia Regulator proposal------- 1,006 km^2
- Option 5 - Shibnagar Regulator proposal----- 1,126 km^2
- Option 6 - Tidal river management ------------ 1,006 km^2

Tidal River Management (TRM) has been found effective and environment friendly approach in maintaining drainage capacity of the Teka-Hari River. TRM involves taking full advantage of the natural tide movement in rivers. During flood tide, tide is allowed to enter into an embanked low-lying area (tidal basin) where the sediments carried in by flood tide are deposited. During ebb tide, water flows out of the tidal basin with greatly reduced sediment load and eventually erodes the downstream riverbed. The natural movement of flood and ebb tide into the tidal basin and along the tidal basin and along the downstream river maintains a proper drainage capacity in that river.

2.3.2 General information

The following information relates to conditions within the project area at the time of commencement of project, i.e. during 1996-1997:

2.3.2.1 Administrative control

The project area is located in the southwest region of Bangladesh within the Khulna Division and comes under the administrative jurisdiction of the districts of Jessore, Khulna, and Satkhira. The divisional, district and thana boundaries within the project area are shown on Figure 2.2 while a break-down of the districts into thana and unions is given in Table 2.1

2.3.2.2 Socio-economic conditions

Most of the people of the project area are involved in agricultural production either directly or indirectly. According to the 1981 census, the total population of the project area was 666,311 which gives an average population density in the order of 662 people per km^2. There are 107 males for every 100 females according to this census. Based on an annual growth rate of 2.17%, it is estimated that the 1997 population would be about 960.000 or about 950 people per km^2 (EGIS. 2002)

Table 2.1 - Administrative Units Within the Project Area

For Original Project Area

District	Thana	No. of Unions	District	Thana	No. of Unions
Khulna	Dumuria	7	Jessore	Abhaynagar	4
	Phultala	3		Keshabpur	8
	Khulna Metro	1		Monirampur	16
	Batiaghata	1		Jessore Sadar	2

The following socio-economic conditions are known to exist in the project area:

- Persistent water logging problems exist in many areas creating inhuman living conditions, the spread of disease and lack of employment opportunities
- The professional fisherman community are extremely poor and earn only about Tk. 80 per day because catches have reduced in the rivers and beels due to over-fishing and fish diseases. They also lack the capital required to change their profession
- The majority of the active population are engaged in agriculture, irrespective of land holding or social status. A majority of the landless and marginal farmers work as agricultural labourers while farmers with medium and large size land holdings mostly cultivate their own land, and

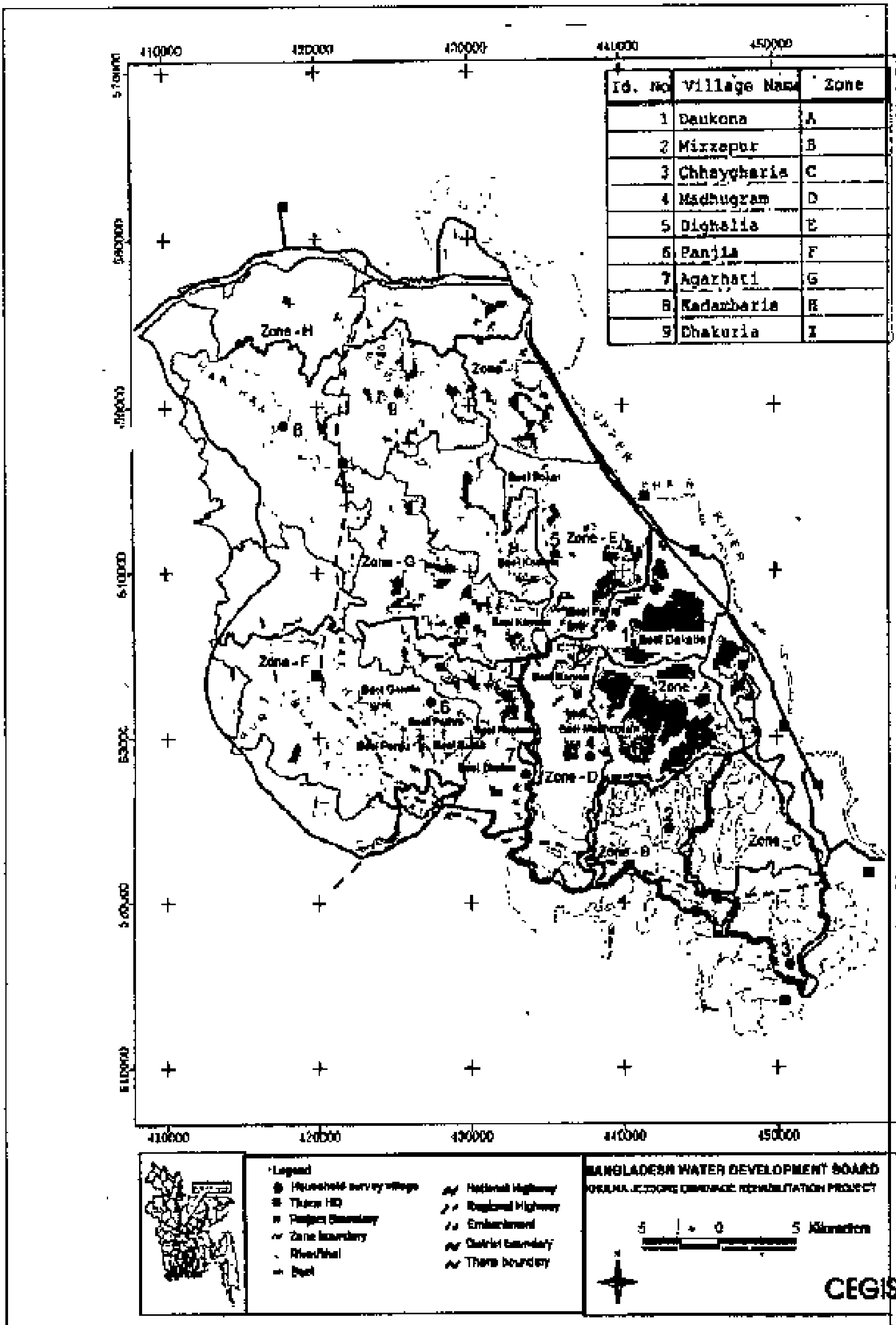


Figure 2.2 : KJDRP Administrative Unit

- Brackish water shrimp farming has gradually increased in some areas in recent times. This has greatly affected the environment and has caused the groundwater to gradually become saline in some localities. Social conflicts have occurred between rice cultivators and brackish water shrimp farmers because of conflicting interests.

2.3.2.3 Topography

The project areas corresponding to the various proposals are delineated on Figure 2.1. The northern part of the project area near Jessore is comparatively high to medium type high land with a gentle rolling topography. It drops from an elevation of 14 m (PWD) to 6 m (PWD) at an average slope of 1 in 7,500 (EGIS, 2002), This area is relatively free of drainage congestion and flooding problems.

To the south of Monirampur and Nowapara, the topography becomes very flat and the central and southern parts of the project area contain a large number of beels and low lying areas, including Beel Dakatia which has received a large amount of publicity over the last decade because of its severe drainage congestion problems. These parts of the project area contain the main drainage congestion problems and will benefit the most from the project.

To the south of the original project area, the environmentally important Sundarbans is located. This mangrove forest area is characterised by a number of very large interconnected tidal rivers. The conservation of the forest, wild life and aquatic resources of the Sundarbans Reserve Forest is a high priority for Bangladesh.

2.3.2.4 Climate and water resources

The project area has a typical monsoon climate with a warm, dry season from March to May followed by a rainy season from June to October and a cool period from November to February. The mean annual rainfall in the area is 1,750 mm of which approximately 70% occurs during the, monsoon season. Potential evapo-transpiration rates are of the order of 1,500 mm and exceed the rainfall rates from November to May. The area has a relative humidity, which varies from about 70% in March to 90% in July. The mean annual temperature is 26°C with peaks of over 30°C in May. The temperature in winter can fall to 5°C in January. The climate is favourable for various agricultural activities throughout the year (EGIS, 2002).

The area is vulnerable to cyclones usually either prior to or soon after the monsoon season when storm surges can cause dramatic increases in water level of up to 4 m above tide and seasonal levels. However, the project area is protected to some extent by the dampening effects of the Sundarbans although surges do move up in to the major rivers.

Surface water resources fall into two main categories: the first is that which is associated with flows across the regional boundaries and the second is runoff, which is the consequence of rainfall falling within the region. Rivers adjacent to the eastern boundary of project area receive upstream wet seasons flows from the Ganges River, but the rivers in the project area and to the west are only rain fed and, as the rainfall is seasonal, the catchments runoff follows a similar pattern. The runoff during the months of January to April is negligible and thus the salinity level in the rivers of the project area increases during this period.

Groundwater quality is generally good but because the area is near the coast, there is a saline-freshwater interface. There is always a risk in such circumstances that groundwater development will cause movement of the saline front towards inland. There is evidence of this process occurring in water supply wells in Khulna. However, most groundwater movement within the project area is vertical. In the dry season water is lost by capillary rise, evaporation and, in areas of groundwater irrigation, by well abstraction. This depletion in storage is replaced by recharge during the wet season. Although there are some base flow losses, and regional groundwater flow patterns can be identified, hydraulic gradients are low, because the permeability of the surface layers is also low, and the lateral volumetric transfer of water is comparatively small.

2.3.2.5 Transportation

The main highway between Jessore and Khulna is a very important road transport link and a railway runs parallel to this transport route. Another important road link is from Khulna through Dumuria to Chuknagar, then on further to the west to Satkhira or onwards to the north via Keshabpur and Monirampur to Jessore. Between these two main roads, other minor roads traverse the project area. Apart from roads, the main means of transportation in the area is along rivers by country boats and along un-metalled country roads by non-motorised vehicles. There are some metalled roads connecting the main towns in the area but to the south of the original project area the network of roads gradually decreases and fewer roads are metalled.

River transport is important within the project area and river traffic will be affected by project. Based upon sample surveys made at three points, namely, Koya, Dumuria and Kharnia, the traffic pattern along the main project rivers in the south is as shown in Table 2.2.

It can be seen from Table 2.2 that the Koya Boat Landing (*Ghat*) is a very important river station. Goods arrive at this ghat from places as far south as Paikgacha and Deluti. The other two ghats are slowly dying because of the siltation of the channels and also because road communication is improving (EGIS, 2002).

Table 2.2- Results of Survey of Boat Traffic Using Rivers

Name of Boat Landing	No. of Boats Plying per day	Yearly Revenue from Boat Landing	Commodities Transported	Remarks on Navigability of Rivers
Koya	100-105	Tk. 30,000	Fish,wheat,vegetable, rice, stone chips, coal and people	Throughout the day
Dumuria	4-5	Tk. 18,000	Fish, people	3-4 hours/day
Kharnia	8-10	Not Available	Rice. flour, people	3-4 hours/day

2.3.2.6 Agricultural and fisheries resources

(a) ***General***

The agricultural and fisheries resources of the area are the most important resources to the livelihoods of the people. While agricultural resources are more important than fisheries resources in the project area, it is noted (in 1996) that national concern is being increased about declining fisheries resources in Bangladesh. The importance of fish is being increased as a source of protein for the people. In the project area, fish is produced both for the people and at the same time, it is being an important export commodity. In these circumstances, while efficient drainage is important to agriculture, the Overall Drainage Plan does not preclude the future expansion of fisheries should this be in the interests of the people of the project area and Bangladesh.

(b) Agricultural resources

According to field data the net cultivated area in 1991-92 was 77,935 ha with single, double and triple cropped areas of 55,814 ha, 15,163 ha and 6,958 ha, respectively. The distribution of areas under different crops was as follows:

- Aus, Aman and Boro rice were grown on 87% of the gross area, (1991-1992)
- Rabi crops such as wheat, oilseeds, pulses, potato and vegetables occupied 15% of the land, (1991-1992) (Haskoning report, 1993).

According to the Haskoning report (1993). it is found that among seasonal rice, Aman was grown on the largest area (50,864 ha), followed by Boro (23,617 ha) and the remaining Rabi crops (14,704 ha). The net cropped area of 77,935 ha provided a total cropped area of 107,014 ha in 1992-93 and thus the cropping intensity was 137%. It was stated in the Haskoning report (1993) that Option 1, the CERP proposal, would raise the cropping intensity from 137% to 157% by converting more single cropped and double cropped areas into, respectively, double and triple cropping Increases in the flood free areas would also contribute to an increase in cropping intensity.

In contrast to the Haskoning (1993) report, data obtained from the Dumuria Thana agricultural extension office indicates that at present the cropping intensity is only 122% with only one rice crop being grown in the area (July- December).

(c) Fisheries resources

In the project area fisheries comprise capture fisheries, culture fisheries and brackish water shrimp farming. The open water capture fisheries in the area comprise the river system. beels and seasonally inundated flood plains. Although culture fisheries in freshwater ponds in the area has increased in recent years, the yields per hectare are still relatively low, averaging about 500 kg/ha/yr overall (1998-2001) (EGIS, 2001). Yields of over 4,000 kg/ha/yr are feasible.

According the Hasconing and Associates (1993), the project area as many as of 21,305 ponds and tanks, covering a total area of about 2,800 ha comprise pond fisheries. Carp poly-culture is practised in 96% of the total pond area. Shrimp culture needing saline water has developed mostly in the south of the project area along the Sholmari, Bhadra and Salta Rivers.

Haskoning (1993) estimated that out of the total fish production of 5,158 tons, culture fisheries contribute 2,369 tons (about 46%) of which pond fisheries alone contribute 2.148 tons (about 42%) i.e. pond fisheries provide over 90% of the culture fisheries production. While only a small proportion of ponds are derelict it has been seen that production has been falling since 1992.

Although the shrimp farms cover more than 1.000 hectare. The shrimp fisheries in the project area contribute only 9% to the culture fisheries production. The average yield of 220 kg/ha appears to be low. There are many difficulties and constraints to the development of shrimp fisheries such as control by "outsiders", politico-economic problems, social issues, risk of theft and those relating to cultural practices. The latter include pond preparation. feed and fertilization, nursery management, stocking, pest control, water management, etc.

There are conflicts of interest between shrimp cultivation and rice growing. Shrimp culture delays rice cultivation and does not allow more than one crop a year on a field. The shrimp cultivators cut polder embankments to take brackish and saline water and BWDB has only limited control over these activities. The shrimp industry is controlled by "outsiders" and this has resulted in adverse effects on the employment and income of the rural poor, as well as creating other socio-economic negative impacts on livestock, drinking water, fruit trees. etc.

The capture fisheries in the project area appear to be much less than the national average. Furthermore, the low yield is an indication of very poor productivity. Haskoning (1993) estimated that, capture fisheries cover an estimated area of 19.000 hectare within the project area. The river and estuaries comprise about 19% of this area, while the other components, which include beels, flooded land and canals, form about 81%. Exploitation of open fisheries goes on throughout the year but intensifies considerably during the monsoon months. The total annual fish catch from these open surface waters is estimated at 2,500 tons. The average unit catch is estimated to be 147 kg/ha of which 172 kg/ha is in rivers and 141 kg/ha in other components of the system. Table 2.3 summarises the position for fisheries production in the original project area.

Table 2.3 - Details of Fisheries Production in the Project Area

Type	Area (ha)	Production (MT)	Yield (kg/ha)
Marine Shrimp/Fresh Water Prawn	1,000	221	221
Pond Fish	2,800	2,148	767
Capture Fish	19,000	2,500	147

Source : Upazilla Fisheries Office

Table 2.4 - Details of Fisheries Production in Dumuria Thana

Type	Area (ha)	Production (MT)	Yield (kg/ha)
Marine Shrimp	4000	1328	322
	650	219	337
Fresh Water Prawn	1000	1000	1000
Pond Fish	-	500	-
Natural Production			

Note: Data collected from Dumuria Thana Fisheries Office

2.3.3 River systems / Basin of the project area

The river system/basin in the project area can be divided under three following heading

1. Hari river system

2. Upper bhadra river system

3. Southeastern system

Each system can be described with following heading:

1. Hydromorphology
2. Agricultural system
3. Fisheries
4. Ecosystem

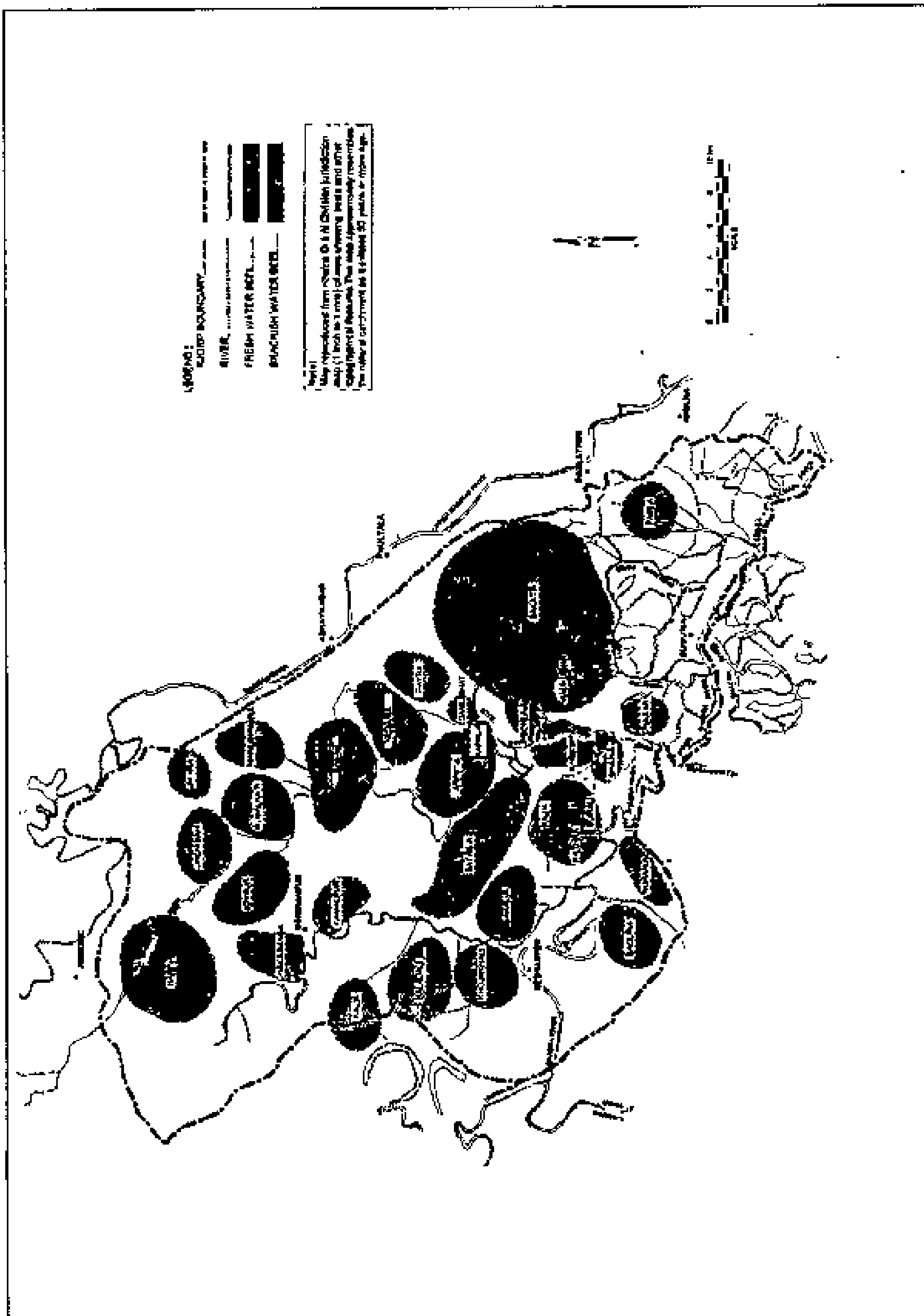


Figure 2.3: Wet lands Present in the KJDRP Area

2.3.3.1 Hari river system

a) Hydro-morphology

Hari drainage system is the largest among the three main drainage systems in the study area. This system drains about 53,000 ha of land, which is about half of the project area. The system comprises of the Hari and Mukteswari rivers as its main drainage arteries. The Mukteswari River and Teka Nadi collect water from 33,000 ha of land and drain it to the Hari River through the Bhabadaha regulator. The Hari River remains free from interventions at the downstream. In addition to the area drained by the Mukteswari River and Teka Nadi, Hari itself drains beels like the Khuksia, Bhaina, Kapalia, and several other adjoining beels with an area of about 20,000 ha. Since the 80's, the river started to decline in cross sections with the reduction of its tidal volume. In the 90's, the sedimentation in the Hari River impeded the drainage of its catchment area. In the second half of the 90's, it became difficult to maintain the river section even by manual or mechanical dredging. In this situation, people around Beel Bhaina cut the BWDB embankment at two locations for relief from water congestion in November 1997. Since then, a different phase of development has continued to take place in this area (IWM, 2001).

Two local cuts were made on the BWDB embankment of Beel Bhaina along the Hari River, one at the Agarhati village and another 1.5 km north of the Agarhati cut. Initially these cuts were narrow and shallow. But gradually the size of the local cut had become more than 200 sq. meter and that of the second cut about 50 sq. meter. The corresponding tidal volume entering the beel as estimated in May 1999 was 4 million cubic meter. This huge tidal volume caused the erosion of the bed and bank of the Hari River. Five kilometres long stretches of the Hari River downstream of Agarhati is deepened by 5m, while further downstream, 6km long stretches of the Telegati River is deepened by 2m. Since the observation of May 1999, the Hari River has widened by 10 to 15 m, but no significant widening has been noticed in the Teligati river. The volume of erosion of the rivers is equivalent to 1 Mm^3(one million meter cube). The cross-sectional areas of the Hari and Teligati rivers are more than the estimated design area. At present, the cross-sectional areas of the Hari river reach downstream of the Beel Bakar Tidal Basin (BBTB) below 2 m+PWD is about 500 m2, whereas the corresponding design area at the same location was estimated to be about 300m2. The increased cross-sectional area allows about 10 Mm3 of tidal volume (estimated from

SWMC measurement in 2000) (IWM, 2002).

The tidal flow movement into the Beel Bhaina cause sedimentation, the magnitude of which is higher at the entrance of the beel and which gradually diminishes towards the far end. The monitoring of the discharge and sediment concentration at Ranai downstream of the BBTB as performed by SWMC in 2000 shows that during neap tide, sediment transport both in flood and ebb tides are nearly the same, indicating no net deposition within the system. On the other hand, during spring tide, the difference between sediment transport in flood and ebb tides is very significant, indicating that a huge amount of sediment is deposited in the upstream tidal basin during spring tide. It was further observed that sedimentation in the tidal basin also depends on salinity. The monitoring of these types of parameter will allow a fair understanding of the physical process of the system.

Since 1998, it has become a practice to build a cross-dam in the Hari River just upstream of the second public cut of Beel Bhaina to protect the sediments in the upstream reaches of the river. Recent experience reveals that temporary cross dams worked well to prevent sedimentation in the dead end stretches of the river. The opening of Beel Bhaina for tidal movement and rehabilitation of the internal drainage system has been improving the drainage situation of the Hari system since 1998. Although situation related to drainage congestion has improved significantly, there remain some site-specific problems.

Closure of the local cuts in Beel Bhaina without opening a new tidal basin will cause huge sedimentation in the Hari and Teligati rivers. This may cause severe drainage congestation in the Hari river and the Upper Bhadra system, thus bring back the earlier problems.

Beel Kadaria Tidal Basin (BKTB)

Opening the BKTB will allow tidal movement into the Hari and Mukteswari rivers. Based o current knowledge, it can be said that the opening of the BKTB is enough to maintain the design section of the rivers downstream of the basin. However, availability of monitoring data on the BBTB can provide further insight into the system. It is not unlikely for the tidal volumes passing through the Hari and Mukteswari rivers to increase the size of the river by eroding its bank.

Salinity intrusion is evident from the tidal intrusion into the basin. From the experience of the BBTB, it can be estimated that the maximum salinity in the BKTB will be roughly within the range of 10 to 15 ppt. This salinity range may be observed during the period between the end of April to mid May (IWM, 2002).

The tide will propagate through the Mukteswari river beyond the BKTB. Allowing tidal movement into the Mukteswari river upstream of the tidal basin, may result in sedimentation of the river bed, and thus may require maintenance and dredging of the river. Sedimentation is likely in the tidal basin but its annual rate would be much lower than what was the case in Beel Bhaina. This assumption is based on the fact that the estimated tidal volume in the Kedaria beel will be at least 4 to 5 times lower than that in Beel Bhaina. The sedimentation pattern in the basin would be almost the same i.e., higher at the opening and lower at the tail end of the basin.

The peripheral embankment of the tidal basin may obstruct overland flow through agricultural fields and may disrupt drainage of the rest of the Kedaria Beel. On the other hand, the tidal basin itself will create the opportunity to drain other beels through the Mukteswari and Hari rivers.

b) Agriculture

Most of the beels under Hari River system have shown improvement in their drainage performance. The Jikra and Dumuria beels are almost fully reclaimed. The major crops grow in the areas are broadcast Aman and Boro. Significant improvements have also been observed in the Khulsia beel, where about 60% of land has already been reclaimed, and the boro crop is being practiced using irrigation. Part of it is also used for fish culture in the monsoon season. Similar types of improvement has also been noticed in the Chechuria and Shingra beels, where about 70% of the area is under the boro rice crop, which is followed mostly by fishing practices. In beel Bhaina, the upper part is used for the T. Aman(Transplanted Aman)-Boro crop (about 40%) and the lower part for Boro-fish (about 10%). Most of the remaining areas remain inundated throughout the year. Soil salinity has developed in this beel as a result of unplanned TRM(Tidal River Management) practice. The major parts of the Kappalia and Rudhagara beels are facing drainage congestion, and only 25 to 35 % of the areas are under agricultural crops. A very slight improvement has been observed in beel Kedaria and Baker. The single boro crop is being rotated with fish culture on 10 to 15 % of the land. Farmers intend to use part of the reclaimed land for Aus and Aman crops in the subsequent years. No improvement has been observed at the Damukhali beel. Farmers use fertilizers and pesticides for the boro crop. Fertilizers are used more (about 490 Urea kg/ha) in the Shingra beel than in the other beels, where they are used within a range of 118 to 290 kg/ha. The drainage condition of this system will be improved due to an improvement of the conveyance capacity of the Hari River. Consequently, most of the beels under this river system are expected to be fully reclaimed. There will not be any major limitation on crop cultivation. It is likely that farmers will store Aus and Aman cultivation in the higher parts of these beels and irrigated rice crop in the lower parts in rotation with fish culture. The beels, having tidal flushing during the monsoon season, will receive fresh silt laden sediments from the river. These sediments will enrich the soil nutrients. Seasonal flooding in the rice fields will contribute to nutrient enrichment in the form of nitrogen fixation by blue green algae. This kind of tidal flooding will remove the residual effects of fertilizers and pesticides on the soils. The beels, which will not receive monsoon tidal flooding, will be deprived of the nutrients from the sediments. These soils will be degraded when intensive cultivation will be restored. Due to continuous siltation, the highest part of the ridges of these beels will remain above the flood level in the monsoon season. This will cause a significant drop in soil moisture and nutrients. Short rooted crops and trees will be affected by drought (EGIS 2001).

The beels, which will have tidal basins, would be different from other beels with respect to the hydrological situation. These will remain inundated throughout the year. The area will be without agricultural crop due to perennial wetness and strong salinity of the soils. However, the area will receive river sediments, which will convert deeply land into mainly shallowly flooded land and in some cases, into non-flooded land. As soon as these raised lands will become salt free by rainwater flushing, farmers will restore intensive agricultural practices.

c) Fisheries

The present situation of the whole system, with some exceptions (e.g., beel Bhaina under TBM) of TBM and TB can be considered as a non-tidal situation, which makes beel resident species dominant in the beels of the system. In recent years, golda cultivation has become wide sprade during monsoon.

The present TBM in beel Bhaina reveals that this type of management would bring considerable benefit to fisheries and biodiversity. This was evident from the situation observed in the Hari River system near the Sholgati bazaar,. where brackish water capture fisheries have regained its hold after many years and where about 400 professional fishermen, who left their village earlier abandoning their traditional profession, have reinstated themselves in their old profession. The locals have reported that during the first and second year of the cut, there was a tremendous rise in open water capture fisheries. The sedimentation process of TBM has converted the low-lying areas into high lands, which are now being used by the community for agriculture and fish/shrimp production. The present salinity level at the point of the second local cu of beel Bhaina is good enough to produce rice as well as shrimp (Golda), while in some parts of bagda production has been tried by the new/old fish farmers with some success.

Open water capture fisheries is expected to increase with the improvement in the quality of the wetlands and maintenance of the migratory routes in the Hari River system upto beel Kedaria. The nature of capture fishery will be changed from beel resident species to free eco-system mixing patterns with higher productivity and higher unit value.

The pressure for shrimp cultivation is expected to grow. In the tidal basins both *bagda* and *golda* culture will increase due to good water exchange facilities ensuring moderate salinity and adequate water quality. In the distant areas, there will be more golda cultivation and in the areas near the estuary, there will be more *bagda* cultivation. In both cases, the salinity will be ideal for the twin culture system.

d) Ecosystem

The existing condition of the study area can be recognized as being an imperfect stagnant ecosystem of the mixed tidal and non-tidal Ganges flood plain. It is imperfect because parts of the floodplain or basin have been drained step-wise from a stagnant condition.

To date, beel Baker of this system could neither be drained nor properly flushed by tidal water. As a result, the wetland of this beel remains at a poor condition compared to the ecosystem of any other beels of the study area. Prolonged stagnation of water has made the water body totally anaerobic.

The Dumur, Jikra, Damukhali, Boruna, Payra, Harina,Rudhagara and Kedaria beels under the Hari river system are in a comparatively better ecological condition. These are the beels which could be partly or fully drained through the Hari river system. Part of these beels which still cannot be drained remains as a wetland of a semi-anaerobic condition. Some portion of these beels are used as shrimp farm creating water quality problems due to a lack of flushing facilities.

The Hari river upto the second local cut of beel Bhaina is currently under tidal conditions. However, a closer just above the cuts makes the upper part of the river non-tidal during the dry season. As the Hari river remains non-tidal during the dry season. migratory aquatic species cannot get access to floodplains. A good part of the Bhaina beel remains as a wetland connected with the main river stream. An uneven deposition of sediments in the beels provides the scope for multiple land use like agriculture, fish, shrimp. farming, etc. The change has provided temporary-grazing land for wetland dependent birds. especially for shoreline birds.

The biological diversity of plants and wildlife is expected to be further improved from the present conditions. This is in spite of the fact that the total wetland area would be reduced as people use more and more land for agricultural practices. such as for paddy or shrimp. It is expected that where land would remain available as wetland (seasonal/perennial), the improved drainage and flushing conditions would result in better water quality, recharged nutrients, and increased stock of fish and other aquatic life forms. Terrestrial plants are dying due to water stagnation. would return, while wetland dependent wildlife would reappear and start razing over land and water. Improvements are especially expected for water hens, herons, mudskippers and sand pipers.

Conversion of agricultural land to shrimp farm in the study areas needs to be considered as one of the major ecological alterations. In some parts of the beels in Khulsia, Bhaina and Rudhagara, local people are converting their agricultural land almost permanently to shrimp farms. In the longer term, it might have an impact on the ecological balance of the project area, especially due to the abstraction of the snails from nature. Moreover. use of extra feed for shrimps will create water quality problems. The situation will worsen in those beels where flushing facilities are poor or absent. It is to be noted that the cultivation of the golda along with rice or other crops is not as environmentally damaging as the culture of the bagda alone (EGIS, 2001).

e) ***Social and Institutional:***

The inflow of saline water and consequent inundation of Beel Bhaina prevented cultivation of crops in the beel. However, as new land developed due to sedimentation caused by the intake of tidal water, such land gradually became available for agriculture. In the situation of the increased volume of water within the beel, opportunities for capture fisheries increased. The opportunities influence some in setting up *Ghers* for fish culture.

The uneven sedimentation has caused drainage congestion in many parts of the beel. Since the water coming in from the Hari river was not confined within any perimeter embankment, the salinity of the surface water affected extensive areas. This created adverse impacts for homestead vegetation. Many trees were reported to have died on homestead land. Areas at the far end from the openings were subjected to inundation of homestead land. particularly during spring tide. Greater availability of saline water during the dry season encouraged Bagda farming. With the availability of water throughout the year, Golda farming also increased in certain parts of the beels which gets less saline during the wet season.

The opening of beel improved waterway navigation and boats could ply in and out of the beel to distant places. The navigability of the Hari river downstream of the openings has been improved. The people within Beel Bhaina are now clamouring for the closure of the openings. They feel that further land development could not be generally beneficial to them. The shortage of land for cattle rearing and collection of fodder under conditions of innundation also creat a problem. It is even difficult to have enough dry land for poultry raising in the homestead.

Initially, the people within the beel Bhina were happy within the fish available to them. Thus inability to cultivate rice crop did not hurt them much. However, as the siltation of different canals adversely affected the migration of fish and their production, people became interested in closing the openings and creating a situation whereby it would be possible to grow rice and other rice and other crops in the beels. It is also to be noted that people who had no land on the newly accreted land mass were not able to cultivate any crop. Therefore, the urgings were quite strong for the closures of the openings.

The width of the river immediately downstream of the openings increased by eroding areas near the Kharnia and Sholgati markets. The temporary protection measures in those areas were not proving to be effective, and therefore, the drainage plan included some more permanent measures of protections.

Most of the people of Beel Bhaina had to shift their occupation from agriculture to fishing or trading activities. The price as well as the mortgage value of the land that remained low within the beel went down. Road communication was adversely affected, creating problems in accessing educational and health facilities. Although boat communication was improved, not every household owned boats.

The drainage of areas in beel Kedaria has improved significantly. This was made possible due to the greater capacity of the river downstream of Beel Bhaina and also due to the rehabilitation of the Bhobodah Regulator to allow better drainage of water. Besides. the dredging work downstream of this regulator enabled better drainage. Under such circumstances, it has been possible to devote more land to agriculture. This has resulted in greater employment opportunities in agriculture. Capture fisheries activities have reduced due to a reduced availability of water during the dry season.

Some people of field think that the perimeter embankment will choke some of the creeks. In that situation, they fear that the area adjacent to the basin would get inundated. Therefore their suggestion is to establish small pipes along the perimeter to allow the outflow of water during the monsoon season. However, the current drainage plan recommends the cutting of appropriate sections of the embankment during monsoon to facilitate the desired drainage and to close the embankment sections after monsoon to prevent upstream saline intrusion. The people remain apprehensive over whether this will be done properly by the authorities.

The socio-economic impacts of implementing the tidal basin concept would of course be felt within the whole basin. However, the immediate impacts within Beel Bhaina and Beel Kedaria would assume a character different from that within the rest of the basin The socio-economic impacts of continuing with the present situation in Beel Bhaina and implementing a tidal basin in Beel Kedaia would be felt mainly in the activities relating to agriculture and fisheries.

As for Beel Kedaria, the area to be brought under the tidal basin would uot be available for agriculture during the period for which it is to serve as a tidal basin. The land under the tidal basin within the rotational scheme would not be permanently lost to the concerned landowners. However, some adverse effects could be expected within the interim period.

Introduction of tidal basins in some beels would eliminate the problem of water logging for other beels within the basin. This would lead to significant shifts from capture fishing activities to agricultural operations and fish cultivations. Apart from other miscellaneous problems associated with persistent inundation, the quality of water in the waterlogged area is not very conducive to either fish production or catch. Therefore, the prospective shift from fishing to agricultural activities is awaited by the local people as a welcome change (EGIS, 2001).

2.3.3.2 Upper Bhadra river system

a) Hydro-morphology

The total area of land that drains through this system is about 33,000 ha and mainly comprises the Harihar and Upper Bhadra river drainage systems. Physical intervention in the Upper Bhadra system is minimum compared to the other two systems. Only the re-excavation of the main rivers and internal canal system is the major component of interventions in this system. The other components are construction of bridge and culverts, and temporary closures.

The re-excavation of the rivers and internal canals has already improved the drainage situation in the Upper Bhadra system. The operation of beel Bhaina as a tidal basin has also helped to improve drainage though the Upper Bhadra and Teligati rivers (IWM, 2002).

Most of the beels in this system drain through flap gates to the rivers. The rivers are dominated by tidal movement except during a few months (February to May) when a temporary cross-dam at Kashimpur is in place to prevent tidal movement into the river. Since 1998, this cross-dam has been built every year at the beginning of the dry season and removed just before the monsoon. The cross-dam prevents the build up of sedimentation in the system. With the implementation of the draiuage plan, the drainage situation in the system is expected to improve further. However, floods of the magnitude of the year 2000 may be problematic.

The Kashimpur cross-dam has been able to reduce sedimentation I the river reach upstream of the cross-dam. Sedimentation in the downstream of the cross-dam has also been minimal probably due to the operation of the BBTB. In the long run, however, introduction of TRM may be necessary to contain sedimentation in the river downstream of the cross-dam.

All the regulators in this system remain as conventional flap gates. Therefore, these can only drain and are unable to retain fresh water in the beels without special arrangements. Unlike the Hari river system, sedimentation at the downstream of the regulators in this system would be minimal (IWM, 2002).

b) Agriculture

The beels under the Upper Bhadra river system have shown significant drainage improvement Previously, about 60% to 80% of the total beel areas remained fallow due to waterlogged conditions. Presently, there is no major limitation on agricultural practice in the Buruli, Pajia-Pathra, Garalia beels. The farmers in Buruli practice the mix Aus and Aman crop on the higher part of the beel (About 50 %) and boro followed by fish in the lower parts (about 50%). Crop production has increased 100% since 1997. The single crop boro followed by fish is practiced in the Pajia-Pathra beels. Presently, due to the practice of the High Yield Variety (HYV) boro, crop production has increased by 300% compared to the past. Similar types of improvement have been observed in the Garalia beel. Farmers are using fertilizers for all of their crops. The rate of application of the urea fertilizer for boro and Transplanted Aman (T. Aman) crops range between 180 to 250 kg/ha (EGIS, 2001).

The beels of the areas will receive tidal river water during the monsoon season, as there will not be any closure in the Upper Bhadra river. But the seasonal closure on the upper Bhadra River will not allow water to enter the beels during the dry season. If these hydrological characteristics could be sustained, both the ridges and basin soils will be benefited from agricultural practices. The ridges could be used for diversified rabi crops in the dry season and rain fed rice crops in the monsoon season. The basin will be used for irrigated rice crops.

As the beels will have complete closure during the dry season to meet irrigation requirements, the deepest part of the basins may develop drainage congestion, which may restrict the agricultural practice.

c) Fisheries

The basin area in this system has been reclaimed. As a result, all the beels now become dry during dry season limiting the opportunities for capture fisheries. On the other hand, culture fishery has been developing in many places. The Garalia, Buruli and Pajia-Pathra beels are under the white fish and shrimp cultivation. The excreta of fish are good fertilizer and the rice-cum-shrimp farms need less chemical fertilizers for agriculture production.

A better water exchange facility in the internal canal system will help to bring new species composition both from fresh and estuarine habitats during the wet season when the river remains open. However, during the dry season the river will remain closed by the cross-dam at Kashimpur . The present trend of dominant beel resident species will be reduced and the overall bio-diversity will be improved. However, the loss of Aman floodplains to golda ghers will reduce capture fisheries.

d) Ecology

All the beels under the Bhadra river system has already been under improved drainage conditions But the construction of a temporary closure at Kashimpur has restricted the scope of flushing during dry months.

The ecosystem of the Pajia, Pathra and Buruli beels can be currently described as being an artificial ecosystem. The local people of these areas have compartmentalized the beels. The area can be classified into the following systems:

- Drainage canal
- Field dykes and
- Agricultural land

Rainwater is retained within the canals for irrigation and fish/shrimp Ghers. Canal water is almost devoid of natural aquatic vegetation. Field dykes are built as high as possible and remain without vegetation. Agricultural land is utilized only for rice monoculture.

CHAPTER THREE

LITERATURE REVIEW

3.1 General Background of Project

The Khulna-Jessore Drainage Rehabilitation Project (KJDRP) was taken up to solve the problem of water logging and drainage congestion in the project area situated in parts of the Khulna and Jessore Districts in the southwest region of Bangladesh. The area is characterized by sediment laden tidal rivers and in recent year's drainage congestion problems.

In the late 1960s and early 1970s, the Government of Bangladesh (GOB) constructed a series of polders under the Coastal Embankment Project (CEP) that created the scope for growing agricultural crops by preventing intrusion of saline water. The creation of polders simplified the existing drainage network, which was comprised of a large number of tidal creeks and rivers. This resulted in a substantial decrease in the tidal volume accompanied by an increase in tidal range. After more than a decade of good productivity, drainage congestion began to increasingly affect most of the northern polders.

In the early 1980s. drainage congestion in the polder areas was recognized as a serious problem, when the rivers and creeks in these areas silted up to such an extent as to render them inoperative This resulted in large areas remaining waterlogged throughout the entire year. Drainage congestion, flooding, salinity intrusion and water logging have all been major problems over recent years, causing a serious decline in agricultural production and living conditions in the area.

3.1.1 Project history

In response to declining agricultural production and deteriorating living conditions in the project area, the GOB with financial support from the Asian Development Bank (ADB

Loan No. 1289-BAN(SF)) arranged to undertake the Khulna - Jessore Drainage Rehabilitation Project (KJDRP). The overall project objective is to reduce poverty, primarily by increasing agricultural production in the area. In addition to the usual range of engineering inputs, the project has included sociological. environmental, agriculture and fisheries investigations to ensure its successful implementation.

The four major components of KJDRP are as follows.

Part-A Beneficiary Participation

Part-B Drainage Rehabilitation Works

Part-C Agriculture Development

Part-D Fisheries Management

Snowy Mountain Engineering Corporation (SMEC) and Associates was selected as the consultant for the Part B component and started their work on 25 September 1995. Based in part on an accumulation of knowledge from a number of previous studies, SMEC prepared an "Overall Drainage Plan" in April 1998. This plan identified a range of possible interventions. Subsequently, the Tidal River Management (TRM) option was selected for implementation, being both technically feasible and also attractive from a social and environmental perspective.

The TRM option proposed a 600 ha tidal basin in Beel Kedaria to keep the Hari River downstream of the basin alive and to raise the basin area through sedimentation. Using sophisticated numerical modelling techniques by Surface Water Modelling Centre (SWMC). it is projected that the Beel Kedaria tidal basin will allow sufficient tidal movement along the Hari River to maintain its design section downstream of the basin. In January 2002, the Kedaria tidal basin was put into operation (SMEC, 2002)

A number of studies are being carried out to further contribute to the planning and implementation of the KJDRP drainage plan and to promote a sustainable approach for integrated, interactive and iterative water resource management. Environment and GIS Support Project for Water Sector Planning (EGIS) has been engaged to monitor and evaluate a plan for environmental, social-economic and institutional arrangements. Surface Water Modelling Centre (SWMC) has been engaged to perform special monitoring of the TRM process to gain more insight into the physical processes at work in the Hari River system and to develop models that support management decisions with respect to drainage performance.

3.1.2 Project objectives

As stated in the Consultant's terms of reference, the project objective is as follows:

"The principal objective of the project is poverty reduction through increased agricultural production in the project area. The increased agricultural production will be achieved by (i) mobilizing beneficiary participation for project design and implementation, and for subsequent operation and maintenance (O&M) of the project facilities: (ii) rehabilitation of the existing drainage infrastructure to reduce drainage congestion and to protect the project area from tidal and seasonal flooding; (iii) providing support for the expansion of agricultural extension services that will be necessary as flooded lands are returned to agricultural productivity: and (iv) improving management of fisheries in polder areas to ensure a continuing supply of black fish species."

To ensure attainment of the project objectives, the project has been established with a wide base and in addition to the usual range of engineering inputs, includes sociological, environmental, agricultural and fisheries activities and investigations. Successful project implementation requires the various consultants and governmental agencies involved in the project components to interact c losely with one another and with the local communities affected by the project.

3.1.3 Current status

Initially, the project was scheduled to be completed on 31st December 2002. All major components in the project's three drainage systems had been completed. In the Southeastern system, the two major regulators, at Sholmari and Ramdia, have been completed and are in operation. In the Hari River System, the entrance to the Bhaina tidal basin was closed in December 2001, and the Kedaria tidal basin started operation at the end of January 2002. In the Upper Bhadra System, the seasonal Kashimpur cross-dam was successfully completed in January 2002. It was breached on 18 February and subsequently closed on 22 February 2002 (SMEC, 2002).

The BWDB's Part-B Engineering Component had already completed about 85% of project works. The construction program for the 2001/02 fiscal year includes 5 bridges, 9 culverts. 30 footbridges, 8 pipe outlets, 21 drainage outlets, 2 closures and 14 sluice rehabilitations. During this fiscal year, the Part-B Consultant had completed 141 designs in consultation with water management organizations, and the works are in the process of implementation. The Part-B Consultant had started construction supervision for this year's work program. BWDB is optimistic that most of the works can be completed by June 2002 .

Under the project. two cutter suction dredgers had been procured: one 300 mm diameter and one 450 mm diameter. Both dredgers are presently working within the project. One amphibious soft terrain excavator and one long range excavator were used. The Part-B Consultants finished its training to Site Supervision Inspectors for all 9 WMAs (Water Management Associates) within January 2002. The BWDB's Part-A Beneficiary Participation Component, through its Consultants and non-government organizations (NGOs), had completed forming all water management organizations in the project area. Efforts were continued to improve the institutional capacity of those organizations. In total. 1 Water Management Federation (WMF), 9 Water Management Associations (WMAs), 58 Water Management Committees (WMCs) and 507 Water Management Groups (WMGs) had been formed to perform water resource management activities in the project area (EGIS 2002).

The BWDB's Part-A Component, with assistance of its Consultant, was involved in: Finalizing agreements between WMAs and BWDB for sharing O&M activities

-Facilitating transfer of BWDB property to WMAs

-Implementing a revised WMA training program

-Undertaking a new information campaign

-Organizing LCSs for implementation of works programs

-Making provisions for micro-credit for fishing families

SWMC had conducted a program to monitor the TRM along the Hari River System to gain more insight into the physical processes at work and to develop models to support management decisions. Its program is scheduled to be completed in December 2002. Based on its data collection activities over the past two years, it intends to develop and calibrate three numeric models:

- A hydrodynamic model for the Hari river catchment to predict tidal basin performance.

- A cohesive sediment model for the Hari river catchment to investigate sedimentation processes.

- A hydraulic model for the entire project to investigate drainage performance

EGIS is currently executing a program for monitoring and integration of the environmental and socio-economic impacts of implementing the TRM. The project started in July 2001 and will continue until December 2002. The program is divided into 3 components:

- Environmental, socio-economic and institutional monitoring

- Framework development for Management Information System (MIS) and Community MIS (COMMIS)

- Preparation of a sustainable integrated water management plan

The third component of the current EGIS program, that deals with institutional arrangements, is particularly important for the sustainability of operation and maintenance (O&M) activities. An integrated water resource management plan for post-project conditions will be prepared through intensive interaction with the WMAs. One of its outputs is a design of institutional arrangements, with special focus on the mandates and tasks, procedures and financial arrangements.

3.1.4 Project characteristics

3.1.4.1 Geography

KJDRP is a flood control and drainage project located in southwestern Bangladesh. The area is characterized by sediment laden tidal rivers and, in recent years, drainage congestion problems. The total project area covers around 100,600 ha. It is part of the deltaic area of the Ganges and Brahmaputra river system. The Jessore - Khulna Railway line on the north and east, the Lower Sholmari, Salta and Upper Bhadra Rivers on the south, and the Kobadak River catchment on the west, roughly bound the project area.

3.1.4.2 Administrative

KJDRP includes parts of Khulna and Jessore Districts. There are eight thanas included in the project and 42 unions. The total population of the project area was estimated to be over one million in 1997. The project has been divided into three drainage systems. and further divided into nine water management zones (Figure 3.1)

Southeastern System Zones A, B & C

Hari River System Zones D, E, G & I

Upper Bhadra System Zones F & H

3.1.4.3 Topography

The northern part of the project area near Jessore is comparatively high land with a gentle rolling topography. This area is relatively free of drainage congestion and flooding problems. To the south of Monirampur and Nowapara, the topography becomes very flat and the central and southern parts of the project area contain a large number of beels and low-lying area. including Beel Dakatia. These parts of the project area contain the main drainage congestion problems and will benefit most from the project.

3.1.4.4 Tidal range

The maximum spring tidal ranges vary from 2.5 to 3.5 m in the project area. During neap tide, the variation ranges from 1.5 to 2.5 m. The tidal ranges are higher in the rivers

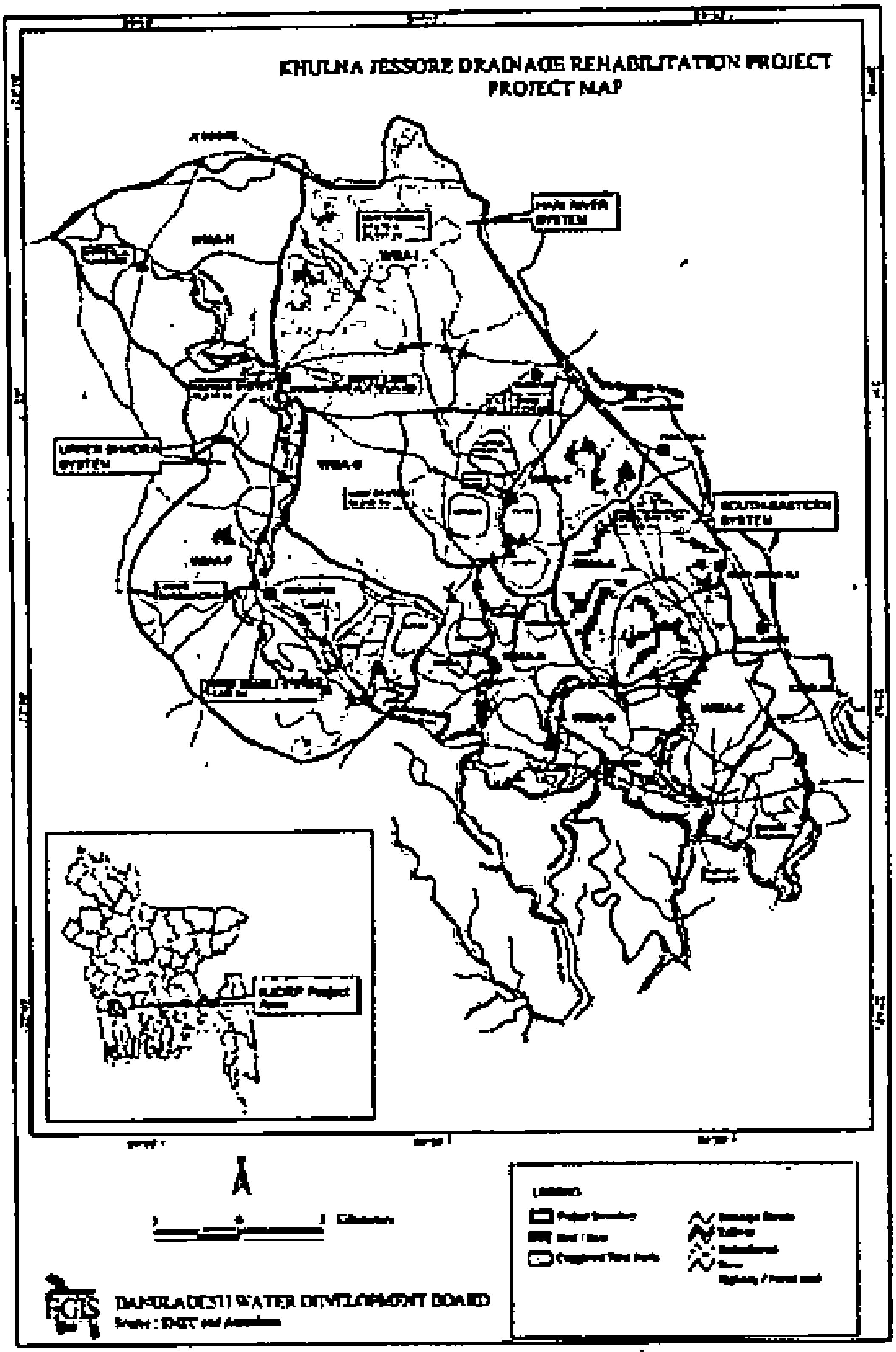


Figure 3.1 KJDRP Water Management Zones

immediately south of the project area than they are in areas closer to the Bay of Bengal. The tidal ranges are 10 to 30 cm higher during the wet season than in the dry season.

3.1.4.5 Salinity concentrations

Salinity in the southwest region begins to increase from December and reaches its peak in March to May. Maximum salinity in the Bay of Bengal is between 25 and 30 g/l, while in the rivers immediately south of the project area it is between 15 and 20 g/l. Readings during 2001 show that surface water salinity at both Ranai and Dohori along the Hari River increased from 4 g/l at the end of March to 13 g/l in mid May and then decreased to 5 g/l by the end of June (IWM 2002).

3.1.4.6 Sediment concentration

Sediment in the project is transported upstream from the Bay of Bengal on the rising tide. Sediment consists mainly of cohesive silt and clay. The sediment concentration increases during the dry season. In the rivers immediately south of the project area the sediment concentration generally varies from 1,500 mg/l in the wet season to 2,000 mg/l in the dry season. Much higher concentration is observed during the dry season in the smaller rivers like Hari. SWMC found that the concentration in the Hari River at its confluence with Upper Bhadra to be 8,000 mg/l during April 1996. During the wet season the average concentrations was only 2,200 mg/l. Readings during March 2001 show a concentration of 4,900 mg/l at Ranai along the Hari River. The concentrations were ten times greater during the spring tide compared to the neap tide (IWM 2002).

3.1.4.7 Agriculture

According to an EGIS 1998 report, Transplanted Aman (T. Aman) is the major crop in the project area. It is cultivated on about 70 percent of the net cultivatable area. A little over half of the T. Aman is high yielding varieties (HYV). The cropping intensity is only 137 percent, which is well below the regional average of 168 percent. This low cropping intensity is due primarily to non-availability of cultivatable land, due to waterlogging. The total annual paddy production is about 350,000 tons.

Significant improvements to the agricultural production in the project beels have already been recorded in recent years due to the improved drainage system. Crop production in these beel areas during the waterlogged period in 1997 was only 6,200 tons, while in 2001 production rose to 45,900 tons. Since 1998, production of Boro crop has increased by 60,431 tons, T-Aman by 48,997 tons and Aus by 11,948 tons with a total of 121,376 tons while project target was 63,000 tons per annum. Thereby the cropping intercity increased to 188% as against the project target 157% (EGIS, 2002).

3.1.4.8 Fisheries

The open-water fish resources in the project area derive from beels, floodplains and fresh water as well as brackish water rivers. A total of 54,600 ha of floodplain and beels are available for open-water fisheries:

Shallowly flooded 16,900 ha

Moderately flooded 28,300 ha

Deeply flooded 9,400 ha

The production of open-water fish, which constitutes about 75% of the total fish production, is estimated at 8,260 tons.

As the drainage system improves and beels are reclaimed for agricultural purposes the potential for fisheries especially during the dry season is expected to decrease. However, the opportunity for culture fisheries and bio-diversity is expected to increase because of improved water management measures. The Kedaria tidal basin offers the opportunity for improved open water captures fisheries.

3.1.5 Drainage system

The project area comprises numerous tidal rivers, channels and beels. The main rivers are the Upper Sholmari, Mukteswari-Teka-Hari and Harihar-Upper Bhadra. The main rivers to the south of the project are the Lower Sholmari, Lower Salta, Bhadra and Teligati. The project can be divided into three drainage systems (refer to Figure 3.1):

Southeastern System (Upper Sholmari River)	27,200 (ha)
Hari River System (Mukteswari-Teka-Hari River)	45,200 (ha)
Upper Bhadra System (Harihar-Upper Bhadra River)	28,200 (ha)
	100,600 (ha)

A brief description of each drainage system is given below.

3.1.5.1 Southeastern system

The Southeastern System is comprised of three main catchments: Beel Dakatia or Polder 25 (14,300 ha), Polder 27 (4,900 ha) and Polder 28 (8,000 ha). Previously the western part of Polder 27 drained towards the Hamkura River. This river is no longer functioning, and all drainage has been diverted into the Upper Sholmari River. Beel Dakatia also drains into the Upper Sholmari River, which is protected from tidal influence by the Sholmari Regulator. Polder 28 drains into the newly constructed Ramdia-Joykhali Khal and is protected from tidal influence by the Ramdia Regulator (IWM 2002).

3.1.5.2 Hari River system

The Hari River System is comprised of two main catchments: Mukteswari (29,200 ha) and the Hari (16,000 ha) (EGIS 2001). The Bhabadah Regulator protects the Mukteswari river from tidal influence. Previously the eastern part of the Hari catchment drained towards the Hamkura River. This river is no longer functioning, and all drainage has been diverted into the Hari River. The Hari River drains its own catchment, plus the discharge from the Mukteswari. The Kedaria tidal basin is supposed to allow sufficient tidal volume to maintain the design section for Hari River. The Bhaina tidal basin has been permanently closed.

3.1.5.3 Upper Bhadra system

The Upper Bhadra System is comprised of 2 main catchments: Harihar (16,500 ha), and Upper Bhadra (11,700 ha). The Upper Bhadra River drains its own catchment, plus the discharge from the Harihar. A seasonal cross-dam across the Upper Bhadra River at Kashimpur inhibits tidal influence during the peak sediment period January - June. Figure 3.2 and 3.3 shows the three drainage systems with their key drainage infrastructure.

3.1.6 Infrastructure

Table 3.1: Infrastructure Present in the Study Area

Structures	**Nos.**
Regulators	47
Pipe Sluice	9
Pipe Outlet	41
Culverts	21
Bridges	17
Foot bridge	30
Embankments	**Kms.**
Flood Embk	123.3
Marginal Dyke	19.1
Perimeter Embk.	10.0
Roads	**Kms.**
Macadam	2.10
Asphalt Road	2.48
HBB Road	106.42
Drainage	
Rivers	113.4
Channels	348.6
Other	**Kms.**
River Protection	2.50
Boat Berth	1

Source: WMA (Water Management Associates) Assessment 2002

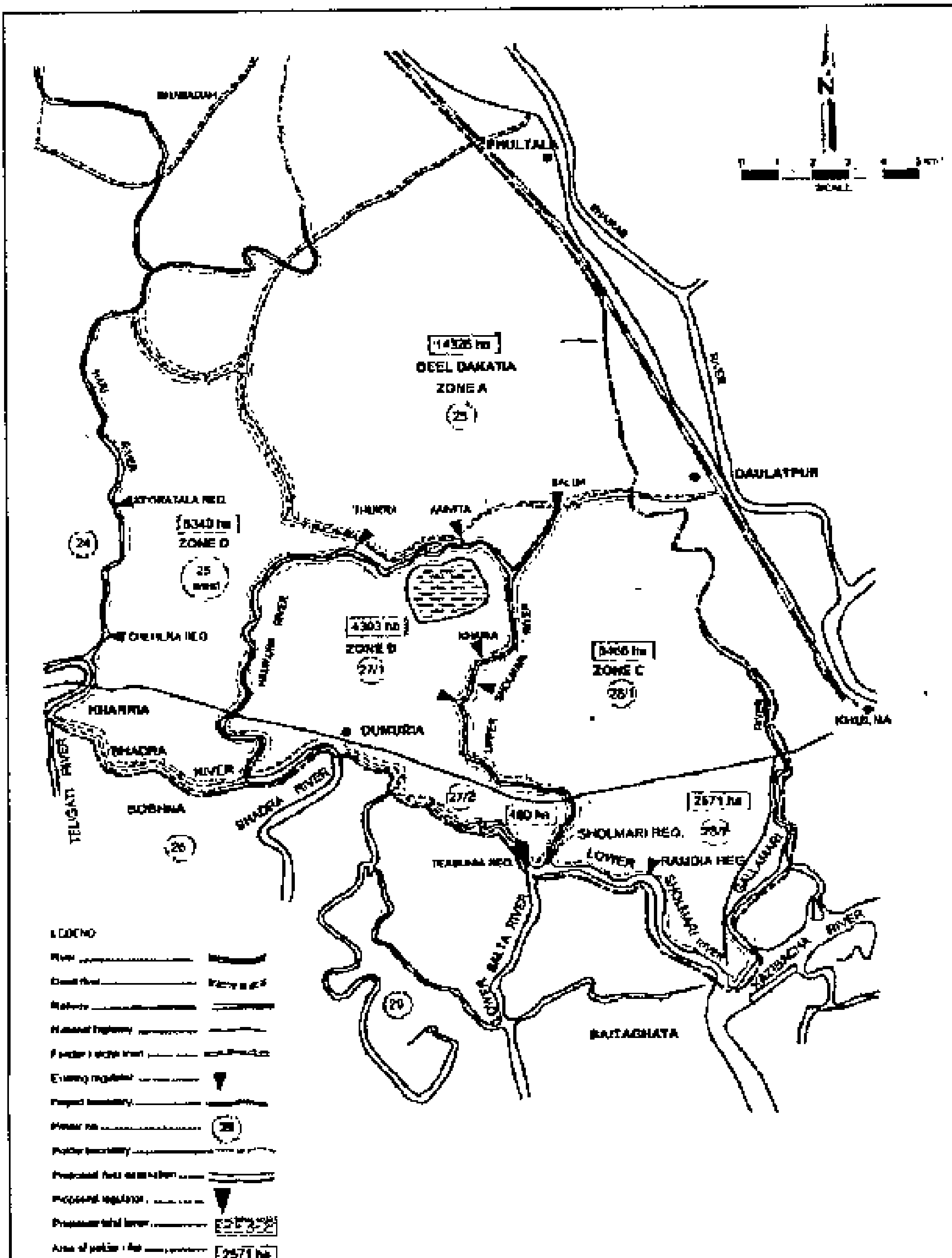


Figure 3.2 : Khuna Jessore Drainage Rehabilitation Project Recommended Overall Drainage Plan (South-Eastern Part)

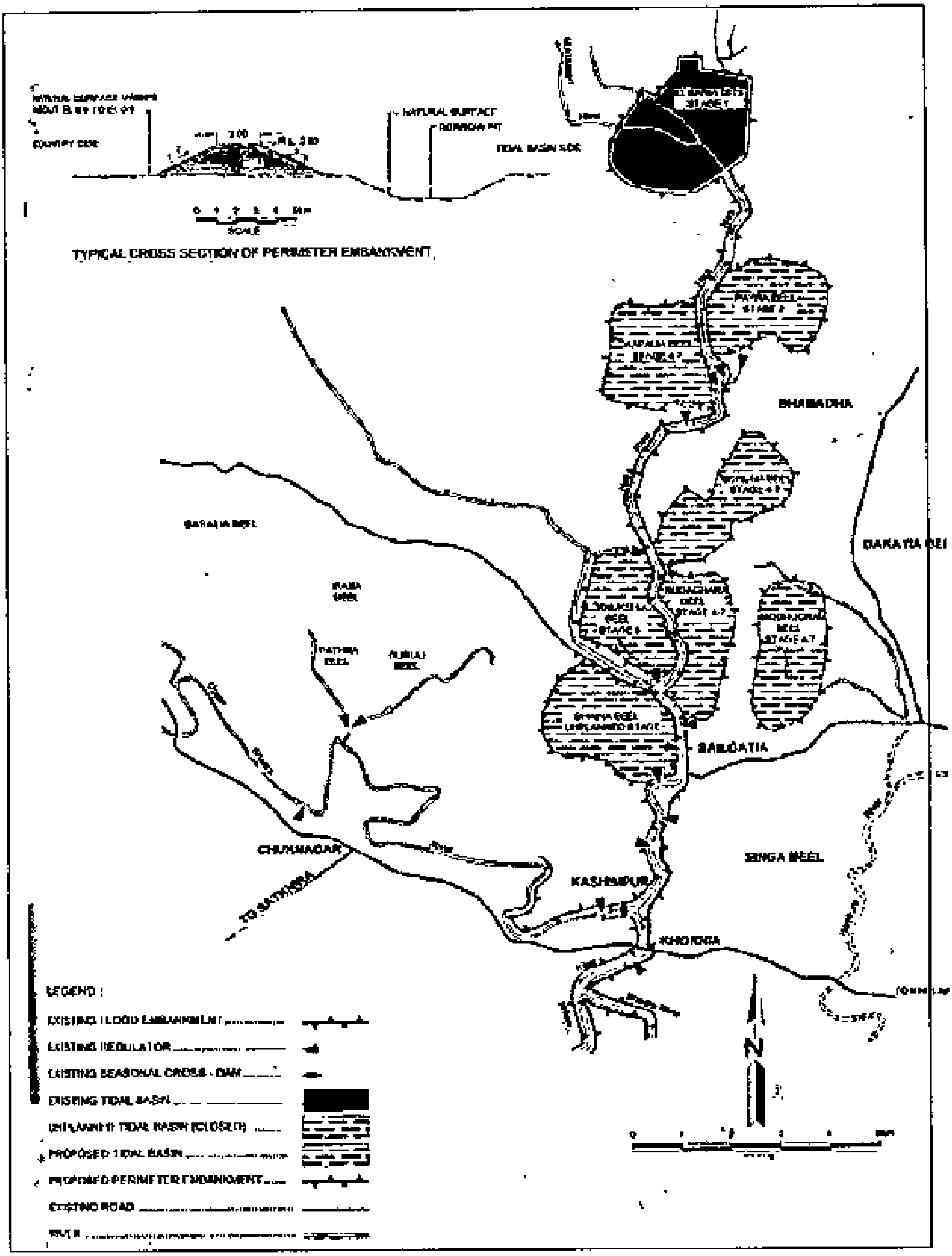


Figure 3.3 : Khuna Jessore Drainage Rehabilitation Project Recommended Overall Drainage Plan (North-West Part)

Table 3.2 : Infrastructure Present in the Study Area

Id. No.	Zone	Village
1	A	Daukona
2	B	Mirzapur
3	C	Chhaygharia
4	D	Madhugram
5	E	Dighalia
6	F	Panjia
7	G	Agarhati
8	H	Kadambaria
9	I	Dhakuria

Source: KJDRP Project Completion Report December 2002 (Final)

3.1.7 Project achievement

Prior to commencement of work on the project in 1994 the most well known drainage problem in the project area was the severe drainage congestion in Beel Dakatia. The people of Beel Dakatia had suffered drainage congestion, over a period of 10 years or more, as a result of sedimentation in upper sholmari river and Hamkura River which are the natural drainage outlets of the beels.in 1990, in a desperate attempt to improve there situation, the people cut the flood embankment at several locations to allow the entry of tidal water into the beel. This made the drainage problem even worse. To solve the drainage problem, the project constructed the 10-vent Sholmari Regulator, which discharges into the Lower Sholmari River and, by re-excavation, improved upstream drainage channels. Other similar works were constructed to drain polder 28 through Ramdia Regulator, while polder 27 is temporarily draining through the Sholmari Regulator. These traditional drainage measures have greatly improved the drainage in the southeast part of the project area.

At the commencement of the project severe drainage congestion developed in the northwest portion of the project area due to extensive sedimentation along the Hari and Upper Bhadra

Rivers. These two rivers were re-excaveted, and for the first time in Bangladesh, tidal river management (TRM) was introduced along the Hari River with view to naturally enlarging the river cross section and inducing sedimentation in beels. At the time of closer of the project the drainage congestion problems had been substantially reduced, although monitoring of TRM was continuing to determine whether its continued operation would be fully successful. Other works in the northwest part of the project area included the construction of new drainage regulators, re-excavation of drainage channels and the construction of a seasonal cross dam on Upper Bhadra River to reduce sedimentation along that river.

Due to difficulties in gaining agreement to a major part of the original project design from the beneficiaries, the project had to be re-planned and this resulted in it being extended by three years. All the parties closely involved in KJDRP considered it to be an unusually difficult project because of the complexities and interrelated nature of the many technical. environmental and social problems arising over some of the works proposed and implemented Eventually most difficulties were resolved and satisfactory solutions determined.

However. due to uncertainities and the lack of full agreement of water management organizations with some of the proposed works, a decision was made in the mid-stages of the project that these proposed project works should be postponed indefinitely. Towards the end of the project the situation became much more clear. As a result, the engineers. environmentalists and sociologists working on the project, who had worked in close and reguar consultation with the people of the project area and the water management organizations. were able to develop a broad outline for the works required to complete the project. These proposed works are recommended for inclusion in a new feasibility study in the near future and involve both the southeast part of the project area and the northwest part (Figure-3.3). If the feasibility study gives a positive outcome, then the additional works would form a second, smaller phase of the project to be known as KJDRP-2.

3.1.8 Description of additional project works requires:

There are two possible solutions to the remaining problems in the southeast portion of the project area as shown on Figure- 3.2. The simplest solution is to complete the plan as proposed by Haskoning and Associates (1993) and modified slightly by SMEC and Associates (April 1998). The plan involved constructing three new large regulators on the sustainable Lower Sholmari River to ensure satisfactory drainage for:

- Beel Dakatia only through Sholmari Regulator
- Polder 28 only through Ramdia Regulator
- Polder 27 only through Teabunia Regulator

However, the people objected to the construction of Teabunia Regulator after construction work had commenced, leaving Beel Dakatia and most of polder 27 draining through Sholmari Regulator. As a result the Sholmari Regulator is required to drain a greater area than intended in its design.

An alternative to the construction of Teabunia Regulator exists and recently the project proposed to BWDB management that a feasibility study be undertaken to investigate re-establishing the Hamkura River by partial excavation and the construction of a (rotating) tidal basin of area 600 ha in the northern part of polder 27/1.

Like the TRM on Hari River the proposal has considerable merit as it will revive Hamkura River and contribute to on increase in tidal volume in the downstream tidal river system, including the sundarban. Therefore, benefits from the proposal are not confined to KJDRP. A feasibility study would, however, need to show how the proposal could be made sustainable. If only one tidal basin is possible then the scheme has a life of only three years and that is not acceptable. Either more basins are required or the proposed basin must become permanent with provision for a fisheries development and a plan for managing excessive sedimentation.

The present drainage plan for the northwestern portion of the project area has followed the plan approved by BWDB for the Hari River but on Upper Bhadra River the proposed large regulator at Kashimpur was not constructed. Instead, a seasonal cross-dam was constructed each year in February and open again in June.

At the time of investigation of the Kashimpur Regulator it is recommended that consideration should also be given to the alternative location for this structure. If it appears that the people prefer to use Buruli, Pathra and Pajia beels as tidal basins in rotation (or would even consider a single permanent basin in this beel area) then this alternative regulator location may have merit. In these circumstances, it must be seriously considered as an alternative to the Kashimpur Regulator proposal in the new feasibility studies.

To ensure the successful implementation of these additional works from the time of their initial planning and through the design and construction phases, it will be essential for the next phase of the project to be strongly supported by similar beneficiary participation inputs to those provided by Part A on the current project. Also, further hydraulic modeling studies and environmental studies will be required to ensure that the engineering works are designed so that they do not contain unacceptable impacts either in the project area or in downstream areas. It is recommended that KJDRP-Phase 2 be implemented by a small team of specialist consultants working at the project site.

3.1.9 Towards a broader objective:

Near the end of the project it was concluded for environmental reasons that, in addition to the need for improved drainage, a greater vision for the project area and surrounding area draining through the sundarban was required. The project therefore recommends that the BWDB and the Government of the Bangladesh give serious consideration to the following, partly additional, water resources works in KJDRP area and the total catchment area of the Sundarban:

- Continuing the scheduled construction of rotating tidal basin along Hari River. This will ensure where possible that land owners in beels receive the benefit of land raising by sedimentation and, at the same time, further erosion of downstream riverbeds due to increased tidal flow continues to occur.

- Replication of KJDRP project, especially the use of tidal basin, at many other locations through out the area of tidal influence draining through the sundarban.
- With the concurrence of the Water Management Federation in KJDRP, the possibility of construction of one permanent tidal basin on each of Hari river or Upper Bhadra River may be explored. These two basins would increase the sustainability of the temporary rotating basins and reduce the risk of failure of the TRM option. Under this proposal, these two tidal basins would then become permanent brackish water basins for migratory waterfowls, flora and fauna, natural fish species and the people, including the fisherman of the surrounding area. Most of the areas of the two tidal basins would be utilized for fishing, but selected parts would be set aside as fish sanctuaries to conserve the fish resources of the remaining beel areas and downstream rivers. In addition, the accumulation of sediments in the two permanent beels should be examined as a potential resource of material for brick manufacturing, land filling in the villages and along local roads and, in more distant locations, urban land developments. Once it is shown that permanent tidal basins can be developed into an economically attractive multifaceted development the people will give enthusiastic support (SMEC, 2002).

To develop a broader plan involving replication of tidal river management principles within KJDRP and in adjacent and downstream areas, as well as other conservation works in freshwater beels, requires a reconnaissance level study. It is recommended that a small multi-disciplinary team of specialist consultants be appointed to undertake this study for BWDB.

3.2 General Background of Technology Assessment

3.2.1 1 Attributes of technology

As technology can be embodied in various forms, such as machinery, equipment, documents, process and skills, it conveys different meanings to various people under different context. In order to avoid any ambiguity, technology is defined here with respect to origin, purpose and characteristics.

Technology is man-made. It is a means to enhance the physical and mental capabilities of human beings. Some special features of technology are:

It is produced in R & D institutes of both private and public sectors,

- It has market value,
- It is not given away free,
- Its price depends on bargaining strength,
- It is new form of currency,
- It provides comparative advantage.

3.2.2 The Need & Purposes

Obviously, there is a need for collating the lessons learned and the experiences gained by the countries which have attempted planned development and have succeeded in varying degrees in recent years. Such planned efforts towards technological self reliance and economic development need to be analyzed to identify the common problems, the proven criteria for success, the opportunities and strategies available to those who have not succeeded, and the extent of the political will to accept technology as an important strategic variable for development.

Technology production has been a continuous process of accumulating knowledge about the tricks of the trade which have been transformed from generation to generation. Modern age has sharpened the issues involved in the search for comparative advantage and made it somewhat complex through the introduction of trading in technology and goods with increasing technology content. Consequently, the search for comparative advantage today essentially amounts to looking through the technology shelf- its sources and markets.

Thus, the purpose of technology production are as follows:

- Satisfying the whole range of human needs(albeit, with a tendency for creation of new needs which may be satisfied by an innovation)
- Gaining competitive edge in the market

- Achieving strategic self reliance and
- Increasing human capability and productivity.

3.2.3 Basic components of technology:

Technologies are often categorized in many ways

-. High and low technologies

-. Modern and traditional technologies,

-. Capital-intensive and labor intensive technologies.

-. Advanced and intermediate technologies etc.

However, all these categorizations imply that technology is a combination of hardware and software with the relative proportions of each varying from one extreme to another. There are four basic components of technology which appear in different forms. The components are:

a). Physical Facilities or Technoware- which include equipment. machineries. tools. structures etc. these may be referred to as the object embodied technology .

b) Human Abilities or Humanware- which include creativity, expertise, proficiency, skills etc. this is the human embodied form of technology.

c) Recorded Facts or Infoware- which include theories. relations. designs, specifications. blue prints, manuals etc.this is the document embodied accumulated knowledge.

d) Organizational Frameworks or Orgaware- which refers to management practices. linkages. organizational arrangement etc. to facilitate the effective integration of facilities. abilities and facts (Satty. 1980).

Resource transformation can take place only when all four components of technology are present at least at certain minimum level. Facilities need operators with certain abilities. Abilities have to be strengthened gradually from operation to improvement and generation of facilities. Facts representing accumulated knowledge need to be upgraded regularly, while the frameworks have to continually evolve to meet changing requirements. All four components of technology are complementary and interdependent. Development should ensure growth in all the four components at the same time.

3.2.4 Technology Assessment:

There is no unique operational definition of technology assessment. Again the assessment vary widely depending upon their subject matter, the normative factors included in them and the policy work to which they pertain.

Following are a few versions of the definition of technology assessment.

- Technology assessment is a form of policy research which provides a comprehensive evaluation of technology to decision makers. It identifies the policy issues, assess the consequences of alternative courses of action, and presents findings as guidelines for decision making.
- Technology assessment can be defined as both an intellectual and socio-political process of exploring, evaluating and selecting options made possible by technology, including those technologies which will actually be developed, applied and diffused.
- Technology assessment consists of ascertaining the trend of technological change and the resulting implications for all relevant sectors of society; systematically evaluating the consequences (direct and indirect, intended and unintended, beneficial and adverse) o such developments in terms of their probability, severity, and distribution; attempting to forecast the possible future trends and consequences, and making or recommending social decisions compatible with choosing the alternative for the future that would maximize desired benefits and minimize negative effects, according to the normative policies one wishes to effectuate (Ramanujam. and. Satty, 1994).

3.2.5 Objectives of Technology Assessment

The objective of TA, in order to gain full competitive advantage, is to consider technology in its full context, and with all its opportunities, possibilities and ramifications for the firm and the environment in which its operates.

3.2.6 Various purposes of Assessment:

In general, an assessment may have numerous consequences, some of which include:

- Support for a technological development
- Stimulation of relevant research in scientific, technological, or social policy areas.
- Deferral or prohibition of the implementation of a given technology .

Or simply, provision of an information base for use by all interested individuals or groups. To the extent feasible, the comprehensive technology assessment involves treatment of "higher order" as well as direct impacts, and seeks to evaluate them from the point of view of all interested groups involved, not only from those who most prominently involved. Such analytical objectives are obviously ambitious ones, and often they are neither feasible nor cost-effective to attempt. Thus, it is natural to think of a range of approaches to assessment having more limited objectives.

Macro-assessment (comprehensive, full-scale):

Full range of implications and policies considered in depth (on the order of magnitude) of 5 person years work for technology oriented to 10 person years for problem oriented assessment).

Mini-assessment:

Narrow in-depth, or broad but shallow focus (about an order of magnitude smaller than the macro-assessment in work effort)

Micro-assessment:

A thought experiment, or brain storming assessment exercise, to identify the key issues or establish the broad dimensions of a problem (about an order of magnitude smaller than the mini-assessment, say, 1 person-month of effort).

Monitoring

Ongoing gathering of selected information on a topic, e.g. radioactive emissions from a nuclear plant or industrial energy use profiles. May e done formally or informally a result of a prior assessment identifying critical uncertainties and / or as a way to identify critical changes that warrant a new assessment.

Evaluation:

Evaluation of ongoing projects and programs can determine whether alterations or new programs are needed. In addition, these can provide feedback as to the validity of previous TA/EIA predictions. Still a different type of assessment study, however, is what may be termed a "brief" or a "focused" TA. Although perhaps not represent an important class of assessments whose singular characteristics is that they must be done quickly for a particular purpose typically to inform a policy decision soon to be made. They require the formulation of a unique approach and methodology to fit their context, and usually focus quite specifically on the impacts or policy implications of interest to a given client or target audience. Although such abbreviated studies may often be conceptually located between the "mini" and "micro" assessments identified in table. They differ in that they may not attempt to involve all of the major stages of a TA (Ramanujam and. Satty, 1994)

3.2.8 The characteristics of Technology Assessment

The main characteristics of the process of technology assessment are:

- ***Includes multi-variate analysis***. many variables with different units of measures are considered.
- ***Concerned with multi-order impacts***. direct as well as indirect impacts are considered.
- ***Incorporate multi-consistency effect***. needs of a wide range of social groups are concerned.
- ***Implies multi-disciplinary approach:*** all aspects of human life are considered.
- ***Demands multi-timeframe balancing***: both short term wants and long term needs are considered.
- ***Requires multi-criteria optimization:*** both maximization of positive and minimization of negative effects are considered.
- ***Involves dynamic features:*** continues interaction between technology and surroundings are considered.

3.2.9 Factors to be considered

Since there exist interaction between technology and human surroundings, and as the major components that constitute the human surroundings are economic, resources, environmental, population, socio-cultural and politico-legal systems. The following factors are to be considered for technology assessment.

- Technological factor- Technical utility (capability, reliability, efficiency), options of technology flexibility, scale, availability of infrastructure (support, services);
- Economic factors- Economic feasibility, improvement in productivity (capital, resources), market potentials (size, elasticity);
- Resource factors- Availability of material and energy resources, availability of financial resources, availability of skilled manpower;
- Environmental factors- Impact on physical environment (air, water, land), impact on living conditions (comfort, noise), impact on life (safely, health);
- Population factors- Growth of population (rate, life expectancy), level of education /literacy rate), labor characteristics (unemployment, structure);
- Socio-cultural factor- Impact on individual life (life quality), impact on society (values), compatibility with existing culture;
- Politico-legal factors- Political acceptability, mass need satisfaction, compatibility with institutions and policies (Satty, 1980)

It can be observed from the above that technology assessment is a part of creative activities, and should not be approached as search for formulae and models but rather an art, which depends on talent, experience, as well as tools and techniques. Moreover, due to the fact that TA problems are very complex, dynamic and multi-disciplinary in nature, it seems to call for a particularly cautious methodical approach.

3. 2.10 The process of Technology Assessment:

The general steps in the assessment process are as follows.

Step 1: ***Identification of the problem***

- Stock taking of existing situation and regulations.
- Determination of time horizon and level of analysis.
- Setting boundaries and objectives.

Step 2: ***Description of alternatives being assessed.***

- Inventory of relevant technological alternatives.
- Current state-of-the-art.
- Technological forecasting.

Step 3: ***Establishment of assessment factors***

- Description of relevant factors.
- Identification of variables and types of effects.
- Classification of variables.

Step 4: Evaluation of expected effects

- Analysis and measurement of effects.
- Representation of various effects.
- Integration of all expected effects.

Step 5: ***Formulation of action options***

- Identification of all possible action options.
- Development of programs for action.
- Analysis of consequences for each option

Step 6: ***Choice of suitable action***

- Influence of various decision makers
- Justification for the final choice.
- Choice of the most suitable alternative.

3.2.11 Tools and techniques of Technology Assessment

There is no validated, universally accepted methodology in the sense of a readily replicated technique for technology assessment. The specific methodology needed for technology assessment will vary case by case in terms of objectives and focus, depending upon the stage of development of the technology and the type of technology. For example, at the introduction phase the objective of TA is to evaluate the likely consequences of possible impacts (which are technology direct and first order impacts). However, in the growth phase of technology, TA should consider all higher order impacts and analyze measures to alleviate those. Similarly, the contents of TA for a process technology will be different from that for a product (end use technology).

Various tools and techniques evolving from engineering, the social science disciplines, and the areas of decision theory and future research are suitable as building blocks in technology assessment. One important step in the technology assessment process is the evaluation of various effects of a technology with respect to the total human surroundings. For this evaluation process, we need to consider a wide variety of factors. Some of these factors can be measured in quantitative terms, while others, which defy such measurements, can only be treated in quantitative manner. Therefore, the available tools and techniques for TA are also are basically of two types- some are quantitative in nature and others are qualitative in nature.

Available tools and techniques for technology assessment may be classify into five groups (Satty, 1980), viz.

- *General Intutive Methods,*
- *Important Components Methods*
- *Structural Decomposition Methods, and*
- *Holistic Composition Methods.*
- *Multi Criteria Decision Making Approach (MCDMA)*

Such a classification of some of the common techniques used for technology assessment are:

General Intuitive Methods

-Expert opinion

-Polls and panels

-Delphi technique

-Cross-impact analysis

Important Component Methods

-Ad hoc

-Checklist

-Matrices

Structural Decomposition Methods

-Relevance tree

-Morphological analysis

-Analytical hierarchy

-Networks

Holistic Composition Methods

-Indices

-Cost-benefit analysis

-Scenario generation

-Simulation model

Multi Criteria Decision Making Approach (MCDMA)

- Analytical Hierarchy Process (AHP)

- Fuzzy Hierarchical Decision Making (FHDM)

It may be realized from above that the problem of technology assessment is essentially a multi criteria decision-making (MCDM) problem. The tools and techniques that have been developed so far are varied in nature depending upon the objectives and focus, the type of technology and the stage of development of the technology.

CHAPTER FOUR
METHODOLOGY

4.1 Introduction

It has been recognized that the adoption of modern technologies in various sectors of economy is the key to economic progress and national development. The role of technology has been further enhanced because of intense global competition ensued from globalization, free trade agreements, deregulation and other trade related factors. The major objective of technology planning is to identify or develop right kinds of technologies and apply them in productive activities. Accomplishment of the objective of course requires knowledge about the strengths, weaknesses and implications of technologies in various sectors of developments. This means that technology assessment is an important first step towards disciplining the technology initiative Consideration has to be given also to technology diffusion and technology absorption. Therefore, it is imperative that the policy planners and decision-makers understand the inherent characteristics of technology and its potential impacts on the socio-economic development.

4.2 The Process and Characteristics of Technology Assessment

Technology assessment can take on different forms from simple evaluation of ongoing projects and programs to macro-assessment involving selection of technology for development and evaluation of appropriateness of technologies for transfer and adaptation. The general steps in the assessment process are as follows:

Step 1: Identification of the problem
Step 2: Description of the problem
Step 3: Establishment of assessment factors
Step 4: Evaluation of expected effects
Step 5: Formulation of action options
Step 6: Choice of suitable action

Some important characteristics of the process of technology assessment are:

a) It includes multi-variant analysis (many variables with different metrics have to be considered;

b) It requires multi-criteria optimization,

c) It requires multi-disciplinary approach (consideration has to be given to all aspects of human life);

d) It involves dynamic features (continuous interaction between technology and surroundings are considered).

It may be realized from above that the problem of technology assessment is essentially a multi criteria decision-making (MCDM) problem. The tools and techniques that have been developed so far are varied in nature depending upon the objectives and focus, the type of technology and the stage of development of the technology.

4.3 Methodology of the Study:

The methodology contains three sections for the assessment of the technology. Each section can be described under the following heads,

Section One: ***Analytical Hierarchy Process (AHP)***

Section Two: ***Fuzzy Hierarchical Decision Making (FHDM)***

Section Three: ***Field Survey and Focus Group Discussions (FGD)***

Section one and section two describes Multi Criteria Decision Making approach, where section one deals with AHP method and section two deals with FHDM method. Section three deals with assessment of technology based on focus group discussion and field survey. Finally, results obtained from section one (AHP) and section two (FHDM) will be compared with section three (field data) to crosscheck the consistency and reliability of the methods used in Technology Assessment of KJDRP. The methods and the steps of the methods used in the methodology will be discussed in this chapter whereas the analysis of the performance of the project (with statistical values) through these methods will be discussed in the Analysis chapter.

In Analysis Chapter, analysis of the project will be discussed under the following headings.

1. ***Analysis 1:*** **(AHP)**
2. ***Analysis 2:*** **(FHDM)**
3. ***Analysis 3:*** **(FGD)**

Multi Criteria Decision Making Approach

It has already been mentioned in the introduction that technology choice is a complex decision problem involving many criteria, resource criteria, etc. The multi-criteria decision analysis (MCDA) for structuring decision problem and evaluating alternatives provides a rich collection of methods. In most management and decision making problems the management team has already a well defined goal that must be achieved. In order to reach that aim always it is necessary to choose from a number of options. These options, in the field of the MCDA, are referred to as alternatives. The decision makers consider the existing alternatives which have different attributes and characteristics and the final job is to choose the best among them. Choosing among the alternatives is done by considering the impact of these alternatives on the quality of the final result alongside with shortcomings of every alternative. Therefore effects of alternatives on different issues such as environmental issues, financial matters and cost and benefit considerations, social considerations, technical problems, etc give rise to consideration of several criteria which play important roles in finalizing the project.

MCDM models such as AHP, SMART and FHDM provide a framework for rational choice of technology by identifying the relevant criteria, measuring the performance of each alternative on each criterion, determining the importance weight of each criterion and finally evaluating a weighted score for each alternative that reflects strength of preference of an alternative. The model differs in the way the weightings of the attributes/criteria and the ratings of the alternatives are determined. But the central idea behind MCDM approach remains same, that is, splitting a decision problem into small parts, dealing with each party separately and then using a formal mechanism for integrating the results. It may be noted that the MCDM models mentioned above permit tradeoffs among attributes and therefore, classified as compensatory models.

Multi criteria decision making techniques like ranking, rating etc are employed for sustainability analysis. As this process incorporates expert's knowledge and judgments by decision makers at various levels it is very much subjective in nature. Although techniques like Analytical Hierarchy Process (AHP) incorporates expert's knowledge but fails to address the inherent uncertainity in them. Many parameters vary continuously over space and it is not possible to model as it is. The complex interdependent interaction of this attributes of a water resource project brings on the opportunity to use FHDM method. This method of decision making is quiet successful in many prospective fields.

The Fuzzy Hierarchical Decision Making method is such a method of MCDA which includes decision making in situations where the fuzziness exists as an inherent property in the attributes of alternatives. This particular research will descritize the inherent attributes associated with a water resource project and then give a sustainable decision making of appropriate alternatives.

Economic considerations are the basis for most of the decisions about technology choice, even today. The environmental aspects are then considered in order to satisfy the statutory norms. This process may not lead to the overall optimization of capital investment and profitability. The political and social aspects are dealt with separately, leading to unforeseen expenditure and thereby and an escalation of costs. It is reorganized that all these aspects have to be considered together while choosing a technology in order to optimize the overall costs and to provide better and safer technology-based good to society.

4.3.1 Section one

Analytical Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a decision – aiding method developed by Satty, (1980) It provides a systematic, explicit, rigorous and robust mechanism for eliciting and quantifying subjective judgments. It is widely applicable because of its inherent capability to handle both quantitative and qualitative attributes and data uncertainty. The steps of AHP, developed by ***Satty***, are as follows:

1. Define the decision problem and determine its object.
2. Define the decision criteria in the form of a hierarchy of objectives. This hierarchical structure consists of different levels. The top level is the objective to be achieved. This top level consists of intermediate levels of criteria and sub-criteria, which depend on subsequent levels. The lowest level consists of list of alternatives.
3. For making pair-wise comparisons, structure a matrix of size (n*n). The number of judgments required to develop the set of matrix is given by n(n-1)/2.

4. Obtain the importance of the criteria and sub criteria from experts' judgment by making pair wise comparison. The comparison is made for all levels. Verbal judgments of preferences are shown in table 4.1

5. Determine the weight of each criterion. By hierarchical synthesis, the priority vectors are calculated. These values are the normalized eigenvectors of the matrix.

Table 4.1 :Pair-wise Comparison Scale for AHP Preferences

Numerical rating	Verbal judgments of preferences
9	Extremely preferred/ Important
8	Very strongly to Extremely
7	Very strongly preferred/ important
6	Strongly to very strongly
5	Strongly preferred / important
4	Moderately to strongly
3	Moderately preferred / Important
2	Equally to moderately
1	Equally preferred / important

Table 4.2: Average Random Consistency

Size of Matrix (n*n)	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

6. The consistency is determined by using the eigenvalue, λ_{max}. For finding the consistency index, CI, the formula used is; $CI = (\lambda_{max} - n)/(n-1)$, where n is the size of the matrix. The judgment consistency is checked from the appropriate value in table 4.3. The consistency ratio (CR) is simply the ratio of CI to average random consistency (RC). The CR is acceptable, if it does not exceed 0.10. if it is more, the judgment matrix is inconsistent; then the matrix has to be reviewed to obtain a consistent matrix. These are calculated for all the matrices structured from the hierarchy. Some computer packages are available nowadays to implement this calculation procedure.

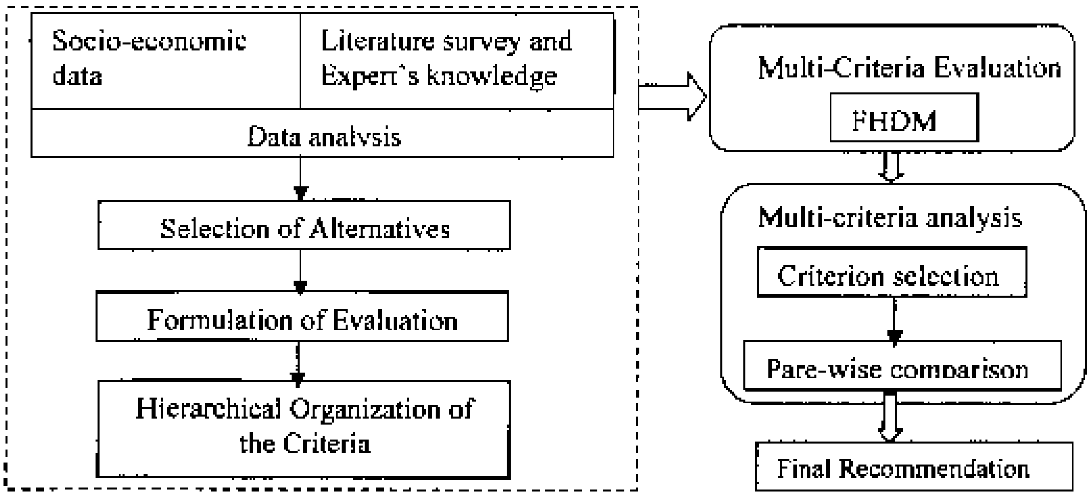
4.3.2 Section two

Fuzzy Hierarchical Decision Making (FHDM Method)

The fuzzy hierarchical decision-making (FHDM) method is suitable and advantageous to many problems solving situation. FHDM also has better characteristic than fuzzy MCDM methods. It collects expert's opinions directly using fuzzy numbers, which is difficult, as the respondents may not have the knowledge of fuzzy numbers. Here expert's opinions were obtained using linguistic variables. Pair wise comparison which makes it easy to give a subjective linguistic judgment was not used. Fuzzy MCDM method is more powerful for managerial decisions because of its ability to deal with all kinds of uncertainties, and its ability to deal with all kinds of uncertainties, and its ability to represent linguistic alternatives in a meaningful way. Moreover the fuzzy MCDM methods, so far used, considered only two levels of hierarchy. They consider pair-wise comparison data of the elements while collecting the experts' opinion on the importance of criteria/sub criteria. and the importance of alternatives under each subjective criteria. In FHDM. a procedure is evolved by synthesizing and extending the ideas proposed in the existing fuzzy MCDM methods. It considers

1) Pair-wise comparison of alternative criteria
2) Linguistic variables rather than numbers
3) Subjective as well as objective factors
4) Triangular fuzzy numbers
5) More than two levels of hierarchy of the criteria

The FHDM method is briefly described in this paper, while presenting the case. The method consists of nine steps and the same steps are applied to this case study. However. the overall methodology design is presented below



***Step-1**: Formation of a committee of experts and identification of various available alternative technologies and various criteria that will influence the choice of technology.*

The selected group of experts is academicians, consultants, engineers, and researchers. Most of them are involved in the decision making for selecting appropriate technology. The experts' opinions were sought on the importance of the identified criteria for KJDRP. A questionnaire was designed in a flexible way so that the experts could add or remove any criteria from the questionnaire if they think it necessary. The questionnaires were sent to the experts. Most of the experts were contacted personally, and the importance of the consideration of each of the identifiable criteria was discussed with them. Based on their responses, the final criteria were selected for the evaluation of the appropriateness of KJDRP.

***Step-2**: Fixation of criteria hierarchically and formation of technology choice criteria hierarchy*

From literature of technology choice and literature review of KJDRP, criteria as many as possible that influence the choice of KJDRP were identified. Questionnaires were prepared and sent to the experts seeking their opinion on the importance of the identified criteria and allowing them to add or remove any criteria. Based on the responses and personal contact and through discussion, final criteria were selected. The criteria were exploded heretically using hierarchical structural analysis as shown in the figure 4 !

Various criteria or sub-criteria that is important for the evaluation of the appropriateness of the technology used in KJDRP are defined here. and a brief explanation for each of them is given to indicate their influence on the choice.

Economic criteria: it considers various financial aspects that are required to assess the performance of the technology, and includes fish production, agricultural production, crop damage, agricultural production in beel, cropping intensity, O & M cost etc. The fisheries activities in the project area comprises open-water fisheries, pond fisheries as well as fresh water shrimp and brackish water shrimp farming. Open water fishing is important to the subsistence of the local population in terms of employment and food supply. Agricultural production is important to increase the food grain. Crop damage information includes the affected area, production and causes of damage. Cropping intensity is directly correlated with crop production in the project area. O & M involves the operation and maintenance cost of the technology used in KJDRP

Social criteria: this is the impact of technology change on the society due to the introduction of the project. The sub criteria includes poverty reduction, occupation etc. The project has direct impact on poverty reduction. Poverty in the project area needs to be dropped below the target. Introduction of a new technology has influence on creating new employment opportunities.

Environmental criteria: considers various environmental aspects of the technology that include pH , salinity, dissolved oxygen, monsoon submergence, dry submergence, duration of water logging, depth of water level in the deepest point, area of water logging etc. Surface water salinity has direct impact on fish resources. Brackish water environment enhances fish biodiversity and is especially favorable for the larval stages of many fish and crustaceans. On the other hand, river salinity adversely affecting the recruitment of fresh water fishes from rivers, beels. Surface water level in the project area is important to improve the drainage of the waterlogged agricultural and settlement areas. Changes in water levels and flood conditions determine changes in land type, which are based on depth of inundation.

Resource factor: The assessment of the sedimentation in the tidal basins is important in assessing the lifetime of the tidal basin. High sedimentation rates would shorten the period during which a selected area could effectively function as a tidal basin. On the other hand, low-lying beel areas will profit from high sedimentation rates (at least from an agricultural point of view). Sedimentation in rivers is important for the drainage of the upstream of the project area.

Population criteria: It includes population involvement in the project, labor involvement, livestock population etc. People's participation requires involvement and is essential for adequate insight, understanding and commitment.

Technological criteria: It includes the performance of technology. It considers the effectiveness of technology that covers discharge, post monsoon drainage, agricultural land during dry season, dredging, water level in river etc. Lower water level in the water system coincide with major changes in the distribution of land types. Reduction of wetland area have major repercussions on the fish productivity. Post monsoon drainage is necessary to review the performance of the present drainage system properly through application of technology in the project

Step-3: *Set up of proper linguistic scales (high, medium, low) and ask experts to give their judgment by pair-wise comparison of criteria and alternatives under each subjective criterion. Alternatively, experts may give their judgments in triangle fuzzy numbers.*

Step-4. *Conversion of the linguistic variables into triangle fuzzy numbers by a convenient scale, if the experts have expressed their judgments only in linguistic variables.*

Step-5. *Aggregation of the experts' opinions by a statistical measure (geometric mean, arithmetic mean, mode or median operator), and form the fuzzy reciprocal matrix. The elements of fuzzy reciprocal matrix are such that the products of each upper triangle element with its corresponding lower triangle element should approximately be equal to 1*

Step-6. *Normalization of the geometric row means of fuzzy reciprocal matrix and find the importance in terms of weights.*

If $A = [a_{uv}]_{k \times k}$ is fuzzy reciprocal matrix then

Geometric row mean $r_u = (a_{u1} * a_{u2} * \ldots a_{uk})^{1/k}$ (1)

The total of geometric row mean values $= (r_1 + r_2 + r_3 + \ldots + r_k)$ (2)

Using (1) and (2), the importance weights of each criteria w_u, and the importance weight of each sub criteria under its main criteria are calculated.

Normalized geometric row mean or Importance Weight $W_u = r_u/(r_1 + r_2 + \ldots + r_k)$ (3)

Then by combining importance weight of each criterion, Global weight of each criterion is calculated.

Step-7: *collection of the operating and the performance data on alternatives to find the appropriateness weights of the alternatives under each criterion. Appropriateness weights of the alternatives under each criterion are found using (1) and (2).*

Step-8: *Fuzzy choice Index is then calculated for each criterion.*

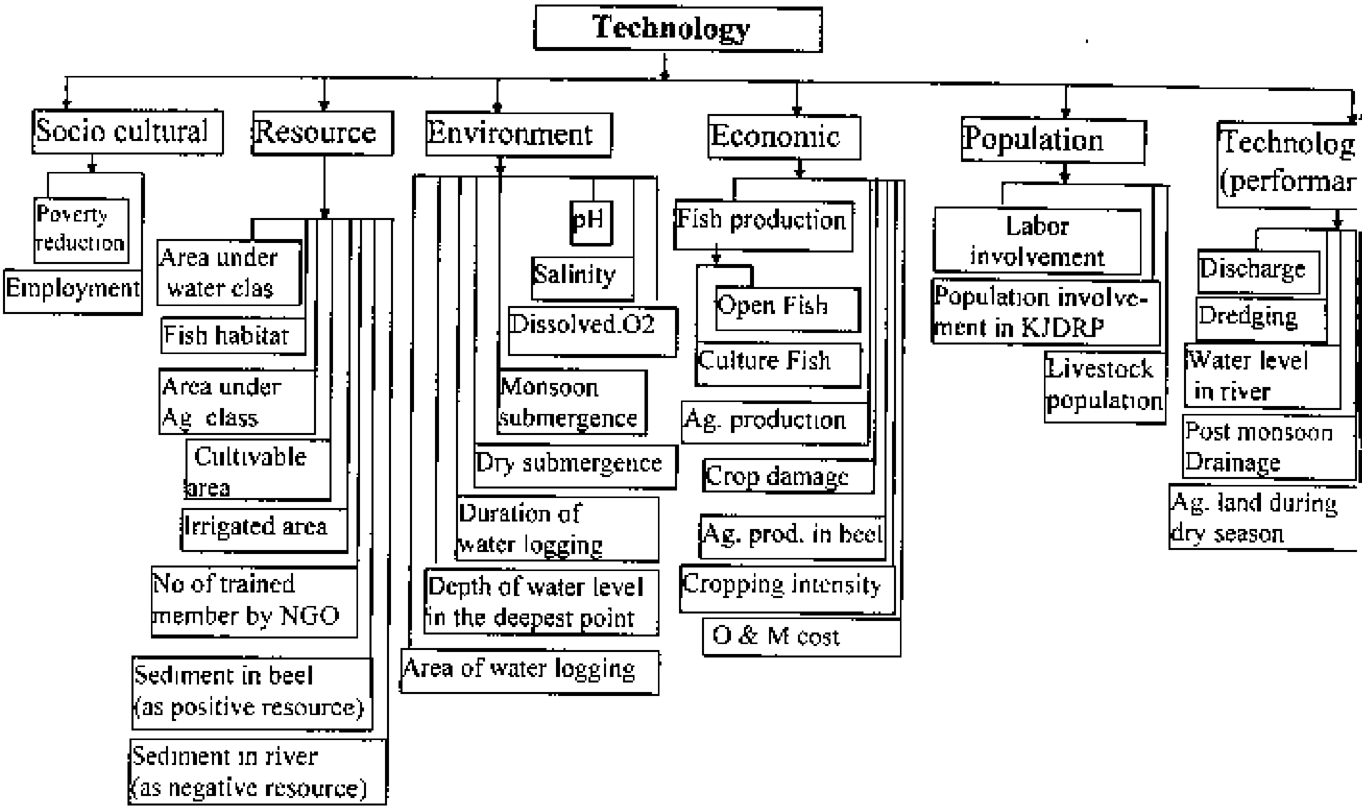


Figure 4.1: Hierarchical Structure of Technology Assessment

Table 4.3: Linguistic Scale and its Triangle Fuzzy Number Conversion

Serial Number	Description	Linguistic Scale	Triangle Fuzzy Scale
1	Very High	VH	(8, 9, 9)
2	Between Very High and High	VH & H	(6, 7, 8)
3	High	H	(4, 5, 6)
4	Between High and Medium	H & M	(2, 3, 4)
5	Medium, Almost Equally	M	(1/2, 1, 2)
6	Exactly Equal	EQ	(1, 1, 1)
7	Between Medium and Low	M &L	(1/4, 1/3, 1/2)
8	Low	L	(1/6, 1/5, 1/4)
9	Between Low and Very Low	L & VL	(1/8, 1/7, 1/6)
10	Very Low	VL	(1/9, 1/9, 1/8)

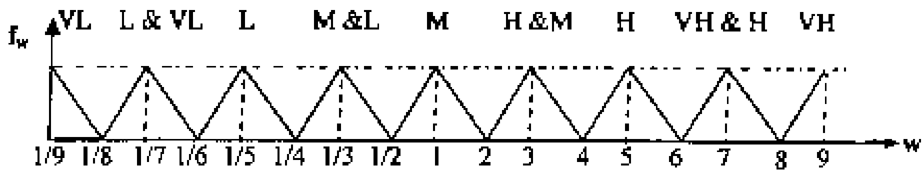


Figure 4.2: Membership Function of Linguistic Scale

The appropriateness weights of the alternatives based on each criterion or sub-criterion is multiplies with that criterion's or sub criterion's global importance weight. and the composite weights are determined. All such composite weights of each alternative are summed up to get the fuzzy choice index values of the alternatives.

FCI = $\sum_i$(Appropriate weight * Global weight for each criterion)
Where i = each criterion

Step-9. By using Kim and Park method, ranking of Fuzzy Choice Index is made. The ranks represent the final preference order of alternatives.

Using the Kim and Park method, FCI are ranked and the ranking values of alternatives are calculated according to the following procedure.

Ranking value $U_T(F_i)$ $\cong$

$$\frac{1}{2}\left[\left[\frac{(Z_i - x_1)}{(x_2 - x_1 - Q_i + Z_i)}\right] + \left[1 - \frac{(x_2 - Y_i)}{(x_2 - x_1 + Q_i - Y_i)}\right]\right]$$

Where F_i is fuzzy choice index of alternative A_i

$(F_i) \cong (Y_i, Q_i, Z_i)$ for i = 1, 2, 3, ...m

Where

$x_1 = \min.\{ Y_1, Y_2, \ldots, Y_m \}$

$x_2 = \max.\{ Z_1, Z_2, \ldots, Z_m \}$

Preferential Weights Calculation: The preferential weights of alternatives based on each expert's opinions are calculated as follows.

Preferential Weights = $U_T(F_i)/[U_T(F_1) + U_T(F_2) + \ldots\ldots\ldots + U_T(F_n)$

4.3.3 Section three

Field Survey (FS) and Focus Group Discussion (FGD)

Field survey and focus group discussion (FGD) was made as a part of thesis. Around eighty-five samples was taken for field survey. The samples were mostly collected from the respondents of Beel Kedaria, Beel Khuksia and Beel Bhaina and the concerned person of the project.

The respondents are Superintendent Engineer, Executive Engineer, Deputy Director, Deputy Chief Extension Officer of Bangladesh Water Development Boar, Senior Consultant of Water & Environment, from ACE Consultants Limited, Chairman, Community organizer and mostly inhabitants and stakeholders of different beels who are directly influenced by the project activities.

The beels were selected on the basis of the level of TRM practice.

Beel Kedaria: Here TRM practice was initiated in 2001, then after a few days, the operation was closed due to the protest from local people. Now there exists pre project condition.

Beel Bhaina: TRM practice was successful in this beel.

Beel Khuksia: TRM practice is going to be initiated considering the performance of TRM in Beel Kedaria and Beel Bhaina.

Name of beels	***Sample size***
1. Beel Kedaria	28
2. Beel Bhaina	28
3. Beel Khuksia	29
Total	85

Some open and closed end questions were prepared on major factors for sampling survey Each question contains some options. Each options were graded with some quantifiable numeric values. The values ranges from (+) ve 3 to (-) ve 3. A scale of 7 points (+3 to -3) was chosen to convert linguistic opinion to numerical values for each question has three positive answers and three negative answers. According to degree of positivity and negativity, marking can be given. Thus the scale of +s to –s has been chosen. The values for each options were given on judgment basis in the field. Responses against each factor were recorded and the response was converted into numeric values. Then the score against each factor was calculated. The total positive value and negative values were placed on a scale marked with highest and lowest possible range of scale. (Fig 4.3)

Numerical Scale	Linguistic Assessment
3	Improved/Increased Highly
2	Improved/Increased Moderately
1	Little Improvement/Increase
0	No Significant Change at all
-1	Deteriorated/Decreased Slightly
-2	Deteriorated/Decreased Moderately
-3	Deteriorated /Decreased Highly

Figure : 4.3: Linguistic Assessment Converted into Numeric Values

The highest scale is determined as [highest range of values for each question]* [total no of questions asked to the respondent]* [no of respondents]. Again, the lowest scale is determined as [lowest range of values for each question]* [total no of questions asked to the respondent]* [no of respondents]. The positive score indicates the positive performance of KJDRP project.

CHAPTER FIVE
ANALYSIS

5.1 Introduction

In 1995, the government of Bangladesh (GoB), with financial support from the Asian Development Bank (ADB), initiated the KJDRP to find more permanent relief to the suffering of the local people. In May 1997, EGIS was approached by the Ministry of Water Resources (MoWR) for an independent Environmental Impact Assessment and Social impact Assessment (EIA/SIA) study of two technical alternatives: regulator options and tidal basin options. The options for intervention were in very different stages of preparation and technical elaboration. The regulator options were well defined and available from a feasible study, while the tidal basin options were introduced as a concept.

In this study, ***KJDRP*** has been nomenclatured having both the options. These two alternative options were considered in which the dynamics of tidal system would be maintained and fixed major structures such as regulators would be avoided as much as possible and applied only on a local scale. Two different concept of solving the drainage problem in the project area: the regulator concept versus the tidal basin concept.

Non-KJDRP means 'absence of KJDRP' situation in that area. It includes the situation it assumes the condition of the project area by the early 1990's to commencement of KJDRP project in 1997. The creation of polders greatly simplified the existing drainage network in the project area which comprised a very large number of tidal creeks and rivers of all sizes resulting in substantial decrease in the tidal volume accompanied by an increased tidal range. After more than a decade of good productivity, drainage congestion began to increasingly affect the northern most polders from the 1980's when the rivers and creeks silted up to such an extent that most of them became inoperative. This resulted in vast tracks of land remaining water logged round the year. Local people cut the embankments in Beel Dakatia and got immediate benefit through the removal of stagnant water. However, the situation worsened with the intrusion of saline water through these cuts. The saline water became trapped and the consequent environmental degradation led to a dramatic worsening of living conditions in the project area by the early 1990's.

TRM involves taking full advantage of the natural tide movement in rivers. During flood tide, tide is allowed to enter into an embanked low-lying area (tidal basin) where the sediments carried in by flood tide are deposited. During ebb tide, water flows out of the tidal basin with greatly reduced sediment load and eventually erodes the downstream riverbed. The natural movement of flood and ebb tide into the tidal basin and along the downstream river maintains a proper drainage capacity in that river.

Non-TRM means absence of TRM, it may include performance of regulator options.

5.2 Analysis 1:

5.2.1 Analytical Hierarchy Process (AHP) for KJDRP and Non-KJDRP option

Provides a systematic, explicit, rigorous and robust mechanism for eliciting and quantifying subjective judgments. It is widely applicable because of its inherent capability to handle both quantitative and qualitative attributes and data uncertainty.

Step-1: Define the decision problem and determine its object

Failures of different aspect of water development projects can be attributed to the wrong choice of technology, inappropriate technology planning & control and its management. With the above consideration, a water resource project [KJDRP (Khulna-Jessore Drainage Rehabilitation Project)] has been selected to conduct rescareh work on the above-mentioned aspects of the project. It can be mentioned shortly that in 1960, a series of polders were constructed under CEP (Coastal Embankment Project). After more than a decade, severe drainage congestion and trapping of salinity occurred in the project area. In 1995, Government undertook the project KJDRP to solve problems. (CEGIS, 2003). The project comprise of series of polders, regulators introducing TRM (Tidal River Management) system. But after implementation of the project, the KJDRP could not fulfilled all of its objectives, especially, the drainage congestion, salinity, etc are still some of the significant problems in the area. The aim of the proposed research is to address some of the selected aspects of the project whether the technology choice was in order and whether the output of the project satisfies the fundamental requirement of the objectives set for the project.

Step-2: Set up decision hierarchy

- Once the decision maker and the alternative courses of action have been identified, the next step is to define the decision criteria in the form of hierarchy of objectives

- Top level : Objective to be achieved

  Intermediate levels: Criteria and sub-criteria

  Low level : list of alternatives.

Step-3: Make pair wise comparisons of attributes and alternatives

- This is used to determine the relative importance of attributes/criteria and sub-criteria and also to compare how well the options perform on the different attributes.
- Judgments are obtained from experts in the relevant area or decision maker if he/she is knowledgeable.
- Judgments are verbal.
- For an attributes to be compared, matrix size is (n*n) and the number of judgments needed is n*(n-1)/2

Total 13 Nos. of experts were selected in the pool of expert. The selected groups of experts chosen were mainly academicians, consultants, engineers, researchers, etc. They are fully aware of KJDRP. Some of them were directly involved in the project implementation. Most of them are involved in the decision making for selecting appropriate technology. All the experts have given their opinion. They have also selected the criteria and sub-criteria for assessment of the alternative technologies. Among the 13 experts, three were chosen for giving there verbal judgments of preference.

Name of the Experts and Resource Person:

1. *Sheikh Nurul Ala*

   Superintendent Engineer, Bangladesh Water Development Board.

2. *Shofi Uddin Ahmed*

   Senior Consultant, Water & Environment, ACE Consultants Limited,

3. *Md Zahirul Haque Khan*

   Division Head, Coast, Port & Estuary and River Engineering Division, (IWM)

4. *Md. Masud Karim*

   Deputy Chief Extension Officer, Bangladesh Water Development Board.

5. *Abdul Malek*

   Executive Engineer, Khulna Division-1, Bangladesh Water Development Board.

6. *Sheikh Wajed Ali*

Deputy Director, Bangladesh Water Development Board.

7. *A K. M. Shafiqul Islam*

   Chairman, Khulna-Jessore Water Management Federation, Village- VorotVaina

8. *Md. Khairul Islam*

   Chairman, Zone-G, Katakhali, Keshobpur, Jessore

9. *Kohinur Nahar*

   Joint Secratary, Khulna-Jessore Water Management Federation.

10. *Amitesh Das*

    Community Organiser, Water Management Association (WMA), Keshobpur, Jessore

11. *Afser Ali Sarder,*

    Chairman, Union-08, Keshbpur, Jessore.

12. *Aboni Biswas*

    Editor, Zone-E, KJDRP, Monirampur, Jessore.

13. *Md. Badruzzaman*

    Editor B. N. P Beel Khulsia, Keshobpur, Jessore.

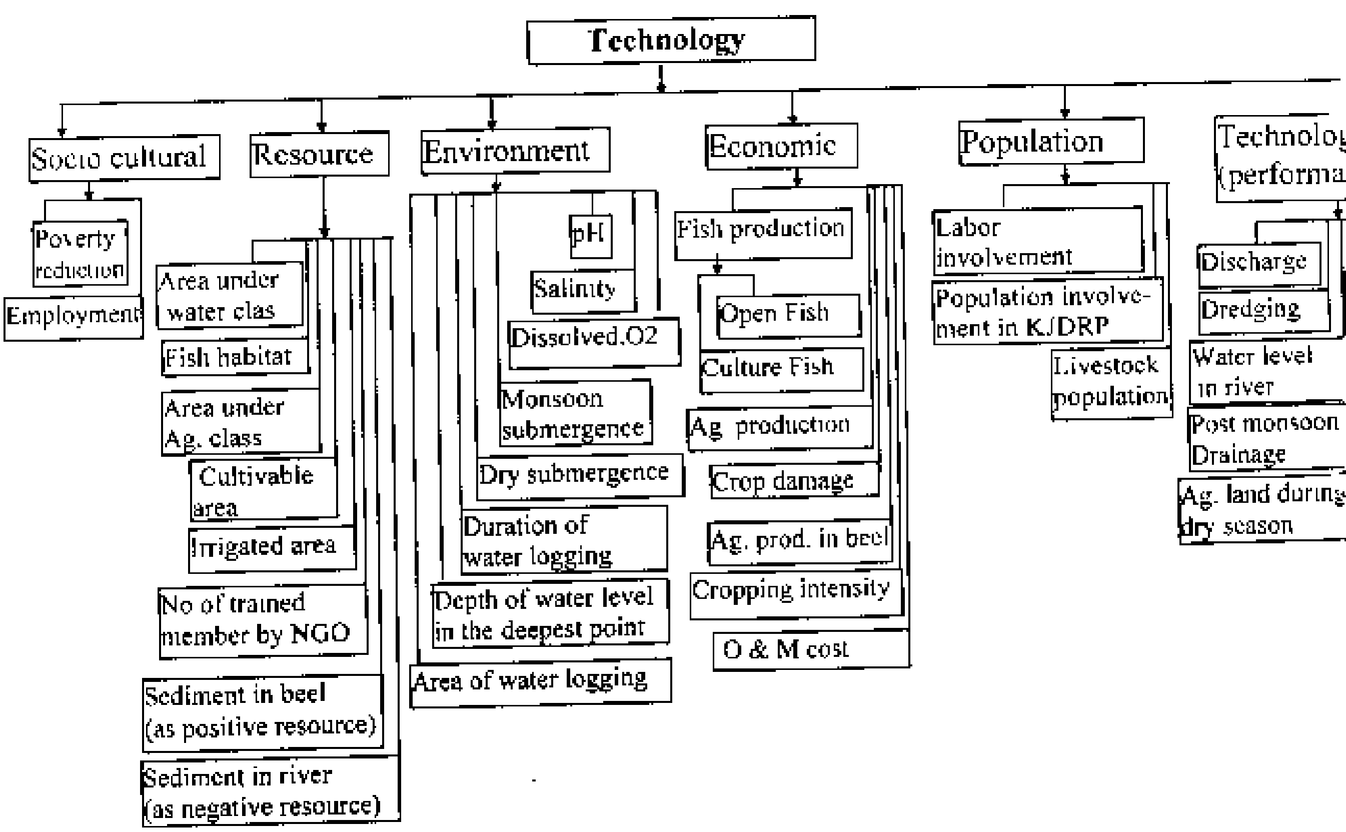


Figure. 5.1 : Technology Assessment Criteria Hierarchy

Table 5.2.1 : Pair wise comparison scale for AHP preferences

Numerical rating	*Verbal judgments of preferences*
9	Extremely preferred/Important
8	Very strongly to Extremely
7	Very strongly preferred/Important
6	Strongly to very strongly
5	Strongly preferred/Important
4	Moderately to strongly
3	Moderately preferred/Important
2	Equally to moderately
1	Equally preferred/Important

Table 5.2.2 Pair-wise comparisons of criteria and sub-criteria and options against each criteria and sub-criteria.

Numerical rating	*Verbal judgments of preferences*
9	Extremely preferred/Important
1/9	Extremely opposed
8	Very strongly to Extremely
1/8	Extremely to very strongly
7	Very strongly preferred/Important
1/7	Very strongly opposed
6	Strongly to very strongly
1/6	Very strongly to strongly
5	Strongly preferred/Important
1/5	Strongly opposed
4	Moderately to strongly
1/4	Strongly to moderately
3	Moderately preferred/Important
1/3	Moderately opposed
2	Equally to moderately
1/2	Moderately to equally
1	Equally preferred/Important

Table 5.2.2.A: Pair-wise Comparison Matrix for the 1st Level Criteria (for Expert-1)

	Resources	Population	Environment	Socio-cultural	Technology	Economic
Resources		5	1	5	1/3	1/3
Population			1/5	1	1	1/3
Environment				5	1	5
Socio-cultural					1/5	1/5
Technology						5
Economic						

Table 5.2.2.B: Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Resource)

	Area under water class	Fish habitat	Area under agriculture class	Cultivable area	Irrigated area	Sediment in-beels	Sediment in rivers	Train men
Area under water class	1	5	1/5	1/3	1	1/5	1/5	7
Fish habitat		1	1/5	1/5	1/5	1/5	5	7
Area under agriculture class			1	1	1/3	1/3	1/7	1/9
Cultiviable area				1	5	1/5	1/3	7
Irrigated area					1	1/3	1/3	7
Sediment in-beels						1	1	7
Sediment in rivers							1	7
Trained member								1

Table 5.2.2.C: Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Population)

	Labor involvement	Population involvement	Livestock
Labor involvement	1	1	7
Population involvement		1	7
Livestock			1

[redacted] : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Environment)

	Salinity	pH	Dissolved Oxygen	Dry sub-mergence	Monsoon submergence	Duration of water logging	Depth in the deepest point	A[illegible] w[illegible] lo[illegible]
Salinity	1	1	1/5	7	1/5	1/5	1	1/7
pH		1	1	5	1/7	1/5	1/5	1/
Dissolved Oxygen			1	5	5	1/5	1/5	1/
Dry submergence				1	1/7	1/7	1/7	1/
Monsoon submergence					1	1/5	1/7	1/
Duration of water logging						1	5	1
Depth in the deepest point							1	1/
Area of water logging								1

Table 5.2.2.E: Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Socio-culture)

	Poverty reduction	Employment
Poverty reduction	1	1
Employment		1

Table 5.2.2.F : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Technology)

	Discharge	Dredging	High water level in river	Post monsoon drainage	Ag land during dry season
Discharge	1	5	1/5	1/3	5
Dredging		1	1/3	1/5	1/5
High water level in river			1	5	5
Post monsoon drainage				1	5
Ag land during dry season					1

[redacted]: Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Economic)

	Fish production	Agricultural production	Crop damage	OM Cost
Fish production	1	1/3	1/3	1/5
Agricultural production		1	1	1/5
Crop damage			1	1/5
OM Cost				1

Table 5.2.2.H : Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Fish Production)

	Open fish	Culture fish
Open fish	1	1/3
Culture fish		1

Table 5.2.2.I: Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Agricultural Production)

	Agri production in beels	Cropping intensity
Agri production in beels	1	5
Cropping intensity		1

Step-4: Transform the comparisons into weights

Table 5.2.3.A : Computational Process of Priority Vector (1st Level Criteria)

	Resources	Population	Environment	Socio-cultural	Technology	Economic
Resources	1.00	5 00	1.00	5 00	0 33	0.33
Population	0.20	1.00	0.20	1 00	1.00	0.33
Environment	1.00	5.00	1.00	5.00	1 00	5 00
Socio-cultural	0 20	1.00	0.20	1.00	0 20	0.20
Technology	3 00	1.00	1 00	5 00	1.00	5 00
Economic	3.00	3 00	0.20	0 20	0.20	1.00
Column sum	8.40	16.00	3 60	17.20	3 73	11.87

Table 5.2.3.B: Computational Process of Priority Vector (2nd Level Criteria Under Resource)

	Area under water class	Fish habitat	Area under agriculture class	Cultivable area	Irrigated area	Sediment in-beels	Sediment in rivers	Train... mem...
Area under water class	[redacted]	5.00	0.20	0.33	1.00	0.20	0.20	7.00

Fish habitat	0.20	1.00	0.20	0 20	0.20	0.20	5.00	7.00
Area under agriculture class	5.00	5.00	1.00	1.00	0 33	0.33	0 14	0 11
Cultivable area	3.00	5 00	1.00	1.00	5.00	0.20	0.33	7.00
Irrigated area	1.00	5 00	3 00	0.20	1.00	0 33	0.33	7.00
Sediment in beels	5.00	5.00	3.00	5.00	3 00	1.00	1.00	7.00
Sediment in rivers	5.00	0.20	7.00	3.00	3 00	1 00	1.00	7.00
Trained member	0.14	0.14	9.00	0.14	0 14	0.14	0 14	1.00
Column sum	20 34	26 34	24 40	10.88	13 68	3.41	8 15	43 11

Table 5.2.3.C: Computational Process of Priority Vector (2nd Level Criteria Under Population)

	Labor involvement	Population involvement	Livestock
Labor involvement	1 00	1 00	7 00
Population involvement	1 00	1.00	7.00
Livestock	0 14	0 14	1.00
Column sum	2 14	2 14	15 00

Table 5.2.3.D: Computational Process of Priority Vector (2nd Level Criteria Under Environment)

	Salinity	P^H	Dissolved Oxygen	Dry sub-mergence	Monsoon sub-mergence	Duration of water logging	Depth in deepest point	Area of water logging
Salinity	1.00	1.00	0 20	7 00	0 20	0 20	1 00	0 20
P^H	1.00	1.00	1.00	5.00	0.14	0.20	0 20	0.20
Dissolved Oxygen	5.00	1 00	1.00	5 00	5 00	0 20	0.20	0 20
Dry submergence	0.14	0 20	0.20	1.00	0 14	0.14	0.14	0 14
Monsoon submergence	5 00	7 00	0 20	7 00	1.00	0.20	0 14	0 20
Duration of water logging	5.00	5 00	5 00	7 00	5.00	1.00	5 00	1 00
Depth in the deepest point	1.00	5 00	5.00	7.00	7.00	0 20	1.00	0 20

Area of water logging	5.00	5.00	5.00	7 00	5.00	1 00	5.00	1.00
Column sum	23 14	25.20	17.60	46.00	23.49	3 14	12.69	3.14

Table 5.2.3.E: Computational Process of Priority Vector (2nd Level Criteria Under Socio-culture)

	Poverty reduction	Employment
Poverty reduction	1.00	1 00
Employment	1.00	1.00
Column sum	2.00	2.00

Table 5.2.3.F: Computational Process of Priority Vector (2nd Level Criteria Under Technology)

	Discharge	Dredging	High water level in river	Post monsoon drainage	Ag land during dry season
Discharge	1.00	5 00	0 20	0 33	5.00
Dredging	0.20	1.00	0.33	0 20	0.20
High water level in river	5 00	3.00	1 00	5.00	5.00
Post monsoon drainage	3.00	5.00	0.20	1.00	5 00
Ag land during dry season	0.20	5 00	0 20	0 20	1.00
Column sum	9 40	19 00	1 93	6.73	16.20

Table 5.2.3.G: Computational Process of Priority Vector (2nd Level Criteria Under Economic)

	Fish production	Agricultural production	Crop damage	OM Cost
Fish production	1.00	0.33	0 33	0 20
Agricultural production	3.00	1.00	1.00	0.20
Crop damage	3.00	1.00	1.00	0.20
OM Cost	5 00	5.00	5 00	1.00
Column sum	12 00	7 33	7.33	1.60

Table 5.2.3.H: Computational Process of Priority Vector (3rd Level Criteria Under Fish Production)

	Open fish	Culture fish

Open fish	1.00	0.33
Culture fish	3.00	1.00
Column sum	4.00	1.33

Table 5.2.3.I: Computational Process of Priority Vector (3rd Level Criteria Under Agricultural Production)

	Agri production in beels	Cropping intensity
Agri production in beels	1.00	5.00
Cropping intensity	0.20	1.00
Column sum	1.20	6.00

Step-4A: Divide each cell by column sum and form a matrix

Table 5.2.4.A: Matrix of 1st Level Criteria

	Resources	Population	Environment	Socio-cultural	Technology	Economic
Resources	0.12	0.31	0.28	0.29	0.09	0.03
Population	0.02	0.06	0.06	0.06	0.27	0.03
Environment	0.12	0.31	0.28	0.29	0.27	0.42
Socio-cultural	0.02	0.06	0.06	0.06	0.05	0.02
Technology	0.36	0.06	0.28	0.29	0.27	0.42
Economic	0.36	0.19	0.06	0.01	0.05	0.08

Table 5.2.4.B: Matrix of 2nd Level Criteria (Under Resource)

	Area under water class	Fish habitat	Area under agriculture class	Cultivable area	Irrigated area	Sediment in beels	Sediment in rivers	Train mem
Area under water class	0.05	0.19	0.01	0.03	0.07	0.06	0.02	0.16
Fish habitat	0.01	0.04	0.01	0.02	0.01	0.06	0.61	0.16
Area under agri class	0.25	0.19	0.04	0.09	0.02	0.10	0.02	0.00
Cultivable area	0.15	0.19	0.04	0.09	0.37	0.06	0.04	0.16
Irrigated area	0.05	0.19	0.12	0.02	0.07	0.10	0.04	0.16
Sediment in beels	0.25	0.19	0.12	0.46	0.22	0.29	0.12	0.16
Sediment in rivers	0.25	0.01	0.29	0.28	0.22	0.29	0.12	0.16
Trained member	0.01	0.01	0.37	0.01	0.01	0.04	0.02	0.02

Table 5.2.4.C: Matrix of 2nd Level Criteria (Under Population)

	Labor involvement	Population involvement	Life-stock
Labor involvement	0 47	0.47	0.47
Population involvement	0 47	0.47	0.47
Livestock	0.07	0.07	0.07

Table 5.2.4.D: Matrix of 2nd Level Criteria (Under Environment)

	Salinity	P^H	Dissolved Oxygen	Dry sub-mergence	Monsoon submergence	Duration of water logging	Depth in the deepest point	Area of water logging
Salinity	0 04	0.04	0 01	0 15	0.01	0.06	0 08	0.06
P^H	0 04	0.04	0 06	0 11	0.01	0.06	0.02	0.06
Dissolved Oxygen	0.22	0.04	0.06	0 11	0 21	0 06	0 02	0.06
Dry submergence	0 01	0 01	0 01	0.02	0.01	0.05	0.01	0 05
Monsoon submergence	0 22	0 28	0.01	0 15	0.04	0.06	0 01	0.06
Duration of water logging	0 22	0.20	0.28	0 15	0.21	0 32	0 39	0 32
Depth in the deepest point	0 04	0 20	0 28	0.15	0 30	0.06	0 08	0 06
Area of water logging	0 22	0 20	0 28	0.15	0 21	0.32	0.39	0.32

Table 5.2.4.E: Matrix of 2nd Level Criteria (Under Socio-culture)

	Poverty reduction	Employment
Poverty reduction	0 5	0.5
Employment	0 5	0 5

Table 5.2.4.F: Matrix of 2nd Level Criteria (Under Technology)

	Discharge	Dredging	High water level in river	Post monsoon drainage	Ag land during dry season
Discharge	0.11	0 26	0 10	0 05	0 31
Dredging	0.02	0.05	0 17	0.03	0 01
High water level in river	0.53	0.16	0.52	0 74	0 31
Post monsoon drainage	0 32	0.26	0 10	0 15	0 31
Ag land during dry season	0 02	0.26	0.10	0 03	0.06

Table 5.2.4.G: Matrix of 2nd Level Criteria (Under Economic)

	Fish production	Agricultural production	Crop damage	OM Cost
Fish production	0.08	0 05	0.05	0.13
Agricultural production	0.25	0 14	0.14	0.13
Crop damage	0.25	0.14	0.14	0.13
OM Cost	0.42	0.68	0.68	0.63

Table 5.2.4.H: Matrix of 3rd Level Criteria (Under Fish Production)

	Open fish	Culture fish
Open fish	0 25	0 25
Culture fish	0 75	0 75

Table 5.2.4.I: Matrix of 3rd Level Criteria (Under Agricultural Production)

	Agri production in beels	Cropping intensity
Agri production in beels	0 833	0 833
Cropping intensity	0.166	0 166

Step-4B: **Calculate row sum for each factor and normalize these values by dividing each factor value by column sum**

Table 5.2.5.A: Matrix of Normalized Values (1st Level Criteria)

	Row sum	Priority vector
Resources	1 12	0.19
Population	0 50	0 08
Environment	1 69	0.28
Socio-cultural	0.27	0 05
Technology	1.68	0 28
Economic	0.75	0.12
Column sum	**6**	**1**

Table 5.2.5.B: Matrix of Normalized Values (2nd Level Criteria Under Resource)

	Row sum	Priority vector
Area under water class	0.60	0 07
Fish habitat	0.92	0.12
Area under agriculture class	0.71	0.09
Cultivable area	1.10	0 14
Irrigated area	0.75	0.09
Sediment in-beels	1.82	0.23

Sediment in rivers	1 61	0 20
Trained member	0 49	0.06
Column sum	**8**	**1**

Table 5.2.5.C: Matrix of Normalized Values (2nd Level Criteria Under Population)

	Row sum	**Priority vector**
Labor involvement	1 40	0 47
Population involvement	1.40	0 47
Livestock	0.20	0 07
Column sum	**3**	**1**

Table 5.2.5.D: Matrix of Normalized Values (2nd Level Criteria Under Environment)

	Row sum	**Priority vector**
Salinity	0.46	0 06
P^H	0.40	0 05
Dissolved Oxygen	0.78	0 10
Dry submergence	0.16	0 02
Monsoon submergence	0.84	0 10
Duration of water logging	2.09	0.26
Depth in the deepest point	1 18	0 15
Area of water logging	2 09	0 26
Column sum	8	1

Table 5.2.5.E: Matrix of Normalized Values (2nd Level Criteria Under Socio-culture)

	Row sum	**Priority vector**
Poverty reduction	1	0 5
Employment	1	0 5
Column sum	**2**	**1**

Table 5.2.5.F: Matrix of Normalized Values (2nd Level Criteria Under Technology)

	Row sum	**Priority vector**
Discharge	0.83	0.17
Dredging	0.29	0.06
High water level in river	2 26	0.45
Post monsoon drainage	1.14	0.23
Ag land during dry season	0.48	0.10
Column sum	**5**	**1**

Table 5.2.5.G: Matrix of Normalized Values (2nd Level Criteria Under Economic)

	Row sum	Priority vector
Fish production	0 30	0.07
Agricultural production	0.65	0.16
Crop damage	0.65	0.16
OM Cost	2.41	0.60
Column sum	**4**	**1**

Table 5.2.5.H: Matrix of Normalized Values (3rd Level Criteria Under Fish Production)

	Row sum	Priority vector
Open fish	0.5	0 25
Culture fish	1.5	0.75
Column sum	**2**	**1**

Table 5.2.5.I: Matrix of Normalized Values (3rd Level Criteria Under Agricultural Production)

	Row sum	Priority vector
Agri production in beels	1.67	0 83
Cropping intensity	0.33	0 17
Column sum	**2**	**1**

Following the computational process, the priority vector of each criterion and the criteria against each option for Expert-1 is found.

Table 5.2.6.A: Priority Vector of Each Criteria (for Expert-1)

	Priority vector
Resources	0.186233
Population	0.082659
Environment	0 281538
Socio-cultural	0.045072
Technology	0 279554
Economic	0 124945
Area under water class	0.074561
Fish habitat	0.115419
Area under agriculture class	0.088845
Cultivable area	0 137215

Irrigated area	0 094306
Sediment in-beels	0 226994
Sediment in rivers	0.201723
Trained member	0.060937
Labor involvement	0.466667
Population involvement	0.466667
Life-stock	0 066667
Salinity	0.057631
P^H	0 049691
Dissolved Oxygen	0 097147
Dry submergence	0 019433
Monsoon submergence	0.10481
Duration of water logging	0.261766
Depth in the deepest point	0.147755
Area of water logging	0 261766
Poverty reduction	0 5
Employment	0.5
Discharge	0 166227
Dredging	0.057674
High water level in river	0.451653
Post monsoon drainage	0 228582
Ag land during dry season	0 095863
Fish production	0 074811
Agricultural production	0 161932
Crop damage	0 161932
OM Cost	0 601326
Open fish	0.25
Culture fish	0.75
Agri production in beels	0.833333
Cropping intensity	0 166667

Table 5.2.6.B: Priority vector of each criterion (for Expert-1, Expert-2 and Expert-3)

	Expert-1	Expert-2	Expert-3	*Geometric mean*
	Priority vector	**Priority vector**	**Priority vector**	**Priority vector**
Resources	0.186233	0.248473	0.186233	**0.205020689**
Population	0.082659	0 055185	0 082659	**0.072243458**
Environment	0 281538	0 191655	0 281538	**0.247665043**
Socio-cultural	0 045072	0 138529	0 045072	**0.065214498**

Technology	0 279554	0.206806	0.279554	**0.252831823**
Economic	0 124945	0 161352	0 124945	**0.1360618**
Area under water class	0.074561	0.182096	0.074561	**0.100409647**
Fish habitat	0 115419	0.08985	0.115419	**0.106175181**
Area under agriculture class	0.088845	0.08394	0 088845	**0.087178939**
Cultivable area	0 137215	0 157187	0 137215	**0.143573408**
Irrigated area	0.094306	0.086112	0.094306	**0.09149119**
Sediment in-beels	0 226994	0.156003	0.226994	**0.200318186**
Sediment in rivers	0.201723	0.211719	0 201723	**0.205001722**
Trained member	0.060937	0.033093	0.060937	**0.049716302**
Labor involvement	0.466667	0 454545	0.466667	**0.462590767**
Population involvement	0 466667	0.454545	0 466667	**0.462590767**
Livestock	0 066667	0.090909	0 066667	**0.073927882**
Salinity	0.057631	0.184843	0.057631	**0.084990745**
P^H	0 049691	0.02733	0.049691	**0.040712682**
Dissolved Oxygen	0 097147	0.026497	0 097147	**0.063001555**
Dry submergence	0 019433	0 076466	0 019433	**0.030679712**
Monsoon submergence	0.10481	0.156706	0.10481	**0.119847551**
Duration of water logging	0.261766	0 216249	0.261766	**0.245618272**
Depth in the deepest point	0 147755	0.088579	0 147755	**0.124587081**
Area of water logging	0 261766	0.22333	0.261766	**0.248270391**
Poverty reduction	0.5	0 5	0 5	**0.5**
Employment	0 5	0 5	0 5	**0.5**
Discharge	0 166227	0 349449	0.166227	**0.212942606**
Dredging	0.057674	0 132697	0.057674	**0.076139011**
High water level in river	0.451653	0 291036	0.451653	**0.390108843**
Post monsoon drainage	0 228582	0 142824	0 228582	**0.19541694**
Ag land during dry season	0 095863	0.083995	0.095863	**0.091731296**
Fish production	0 074811	0 177083	0 074811	**0.09970142**
Agricultural production	0.161932	0 239583	0.161932	**0.184518676**
Crop damage	0 161932	0.177083	0.161932	**0.166832513**
OM Cost	0 601326	0 40625	0.601326	**0.527639941**
Open fish	0.25	0.25	0 25	**0.25**
Culture fish	0.75	0.75	0.75	**0.75**
Agri production in beels	0 833333	0 5	0 833333	**0.702860554**
Cropping intensity	0.166667	0 5	0.166667	**0.240374928**

Table 5.2.7.A: Priority Vector of Criterion against Each Option (KJDRP, Non-KJDRP, TRM, Non-TRM) (for Expert-1)

Area under water class	Priority vector	*Area under water class*	Priority vector
KJDRP	0.833	TRM	0 833
Non-KJDRP	0 166	Non-TRM	0 166
Fish habitat		*Fish habitat*	
KJDRP	0 833	TRM	0 833
Non-KJDRP	0.166	Non-TRM	0.166
Area under agriculture class		*Area under agriculture class*	
KJDRP	0.833	TRM	0 833
Non-KJDRP	0 166	Non-TRM	0.166
Cultivable area		*Cultivable area*	
KJDRP	0.833	TRM	0 833
Non-KJDRP	0.166	Non-TRM	0 166
Irrigated area		*Irrigated area*	
KJDRP	0.833	TRM	0 833
Non-KJDRP	0 166	Non-TRM	0.166
Sediment in beels		*Sediment in beels*	
KJDRP	0.875	TRM	0.875
Non-KJDRP	0 125	Non-TRM	0 125
Sediment in rivers		*Sediment in rivers*	
KJDRP	0.833	TRM	0.833
Non-KJDRP	0 166	Non-TRM	0 166
Trained members		*Trained members*	
KJDRP	0 75	TRM	0 75
Non-KJDRP	0 25	Non-TRM	0 25
Labor involvement		*Labor involvement*	
KJDRP	0.833	TRM	0.75
Non-KJDRP	0 166	Non-TRM	0.25
Population involvement		*Population involvement*	
KJDRP	0.75	TRM	0 75
Non-KJDRP	0.25	Non-TRM	0 25
Livestock		*Livestock*	
KJDRP	0 75	TRM	0 75
Non-KJDRP	0.25	Non-TRM	0.25
Salinity		*Salinity*	
KJDRP	0 5	TRM	0 833
Non-KJDRP	0.5	Non-TRM	0.166
P^H		P^H	

KJDRP	0 75	TRM	0.75
Non-KJDRP	0.25	Non-TRM	0.25
Dissolved Oxygen		***Dissolved Oxygen***	
KJDRP	0.833	TRM	0 833
Non-KJDRP	0.166	Non-TRM	0.166
Dry Submergence		***Dry Submergence***	
KJDRP	0.875	TRM	0.875
Non-KJDRP	0.125	Non-TRM	0.125
Monsoon submergence		***Monsoon submergence***	
KJDRP	0 833	TRM	0.833
Non-KJDRP	0 166	Non-TRM	0.166
Water logging		***Water logging***	
KJDRP	0.833	TRM	0.833
Non-KJDRP	0.166	Non-TRM	0 166
Depth in the deepest point		***Depth in the deepest point***	
KJDRP	0.833	TRM	0.833
Non-KJDRP	0.166	Non-TRM	0.166
Area of water logging		***Area of water logging***	
KJDRP	0.875	TRM	0 833
Non-KJDRP	0 125	Non-TRM	0 166
Poverty reduction		***Poverty reduction***	
KJDRP	0 833	TRM	0.833
Non-KJDRP	0 166	Non-TRM	0.166
Employment		***Employment***	
KJDRP	0 833	TRM	0 833
Non-KJDRP	0 166	Non-TRM	0 166
Discharge		***Discharge***	
KJDRP	0 9	TRM	0 875
Non-KJDRP	0.1	Non-TRM	0.125
Dredging		***Dredging***	
KJDRP	0 75	TRM	0.090
Non-KJDRP	0 25	Non-TRM	0 909
High water level in river		***High water level in river***	
KJDRP	0 833	TRM	0.833
Non-KJDRP	0 166	Non-TRM	0.166
Post monsoon drainage		***Post monsoon drainage***	
KJDRP	0 875	TRM	0 833
Non-KJDRP	0.125	Non-TRM	0 166
Ag land during dry season		***Ag land during dry season***	

KJDRP	0 875	TRM	0.833
Non-KJDRP	0.125	Non-TRM	0.166
Open fish		***Open fish***	
KJDRP	0 166	TRM	0.875
Non-KJDRP	0 833	Non-TRM	0.125
Culture fish		***Culture fish***	
KJDRP	0.833	TRM	0.833
Non-KJDRP	0 166	Non-TRM	0 166
Ag production in beels		***Ag production in beels***	
KJDRP	0.833	TRM	0 833
Non-KJDRP	0 166	Non-TRM	0 166
Cropping intensity		***Cropping intensity***	
KJDRP	0 833	TRM	0.833
Non-KJDRP	0.166	Non-TRM	0.166
Crop damage		***Crop damage***	
KJDRP	0.833	TRM	0.833
Non-KJDRP	0.166	Non-TRM	0.166
O & M Cost		***O & M Cost***	
KJDRP	0.875	TRM	0.75
Non-KJDRP	0.125	Non-TRM	0 25

Similar calculation was made for Expert-2 and Expert-3, and finally the priority vectors found from three experts was combined into one by geometric row mean method.

Table 5.2.7.B: Priority vector of criteria under the option of KJDRP and Non-KJDRP (for Expert-1, Expert-2 and Expert-3)

	Expert-1	**Expert-2**	**Expert-3**	**Geometric mean**
Area under water class	*Priority vector*	*Priority vector*	*Priority vector*	*Priority vector*
KJDRP	0 8333	0.9	0 8333	**0.8549**
Non-KJDRP	0.1666	0 1	0.1666	**0.1405**
Fish habitat				
KJDRP	0.8333	0.8333	0 8333	**0.8333**
Non-KJDRP	0.1666	0.1666	0.1666	**0.1666**
Area under agriculture class				
KJDRP	0.8333	0 875	0 8333	**0.8469**
Non-KJDRP	0.1666	0 125	0 1666	**0.1514**
Cultivable area				
KJDRP	0.8333	0 875	0 8333	**0.8469**

Non-KJDRP	0.1666	0.125	0.1666	**0.1514**
Irrigated area				
KJDRP	0.8333	0.75	0.8333	**0.8045**
Non-KJDRP	0.1666	0.25	0 1666	**0.1907**
Sediment in beels				
KJDRP	0.875	0 25	0 875	**0.5763**
Non-KJDRP	0.125	0 75	0 125	**0.22714**
Sediment in rivers				
KJDRP	0.8333	0 8333	0 8333	**0.8333**
Non-KJDRP	0 1666	0.1666	0.1666	**0.1666**
Trained members				
KJDRP	0.75	0 8333	0.75	**0.7768**
Non-KJDRP	0 25	0 1666	0 25	**0.2183**
Labor involvement				
KJDRP	0 8333	0.875	0 8333	**0.8469**
Non-KJDRP	0 1666	0 125	0.1666	**0.1514**
Population involvement				
KJDRP	0 75	0 8333	0.75	**0.7768**
Non-KJDRP	0 25	0.1666	0 25	**0.2183**
Livestock				
KJDRP	0 75	0 8333	0 75	**0.7768**
Non-KJDRP	0 25	0.1666	0 25	**0.2183**
Salinity				
KJDRP	0 5	0 75	0 5	**0.5723**
Non-KJDRP	0 5	0 25	0.5	**0.3968**
P^H				
KJDRP	0.75	0.8333	0.75	**0.7768**
Non-KJDRP	0 25	0 1666	0 25	**0.2183**
Dissolved Oxygen				
KJDRP	0.8333	0 8333	0 8333	**0.8333**
Non-KJDRP	0.1666	0.1666	0.1666	**0.1666**
Dry Submergence				
KJDRP	0 875	0.75	0 875	**0.8311**
Non-KJDRP	0 125	0.25	0 125	**0.15749**
Monsoon submergence				
KJDRP	0.8333	0.8333	0.8333	**0.8333**
Non-KJDRP	0.1666	0 1666	0.1666	**0.1666**
Water logging				
KJDRP	0 8333	0.875	0 8333	**0.8469**

Non-KJDRP	0.1666	0.125	0.1666	**0.1514**
Depth in the deepest point				
KJDRP	0 8333	0.75	0.833333	**0.8045**
Non-KJDRP	0.1666	0.25	0 166667	**0.1907**
Area of water logging				
KJDRP	0.875	0.875	0 875	**0.875**
Non-KJDRP	0.125	0.125	0.125	**0.125**
Poverty reduction				
KJDRP	0.8333	0.875	0.8333	**0.8469**
Non-KJDRP	0.1666	0.125	0.1666	**0.1514**
Employment				
KJDRP	0 8333	0.8333	0.8333	**0.8333**
Non-KJDRP	0.1666	0 1666	0 1666	**0.1666**
Discharge				
KJDRP	0.9	0 75	0.9	**0.8469**
Non-KJDRP	0 1	0.25	0.1	**0.1357**
Dredging				
KJDRP	0 75	0.75	0 75	**0.75**
Non-KJDRP	0.25	0 25	0.25	**0.25**
High water level in river				
KJDRP	0 8333	0.8333	0.8333	**0.8333**
Non-KJDRP	0 1666	0.1666	0 1666	**0.1666**
Post monsoon drainage				
KJDRP	0.875	0 8333	0.875	**0.8608**
Non-KJDRP	0 125	0.1666	0 125	**0.1375**
Ag land during dry season				
KJDRP	0.875	0.8333	0.875	**0.8608**
Non-KJDRP	0.125	0 1666	0.125	**0.1375**
Open fish				
KJDRP	0.1666	0 8333	0 1666	**0.2849**
Non-KJDRP	0.8333	0.1666	0 8333	**0.4873**
Culture fish				
KJDRP	0.8333	0 875	0.8333	**0.8469**
Non-KJDRP	0.1666	0.125	0.1666	**0.1514**
Ag production in beels				
KJDRP	0 8333	0.5	0.8333	**0.7028**
Non-KJDRP	0.1666	0 5	0.1666	**0.2403**

Cropping intensity				
KJDRP	0.8333	0.875	0.8333	**0.8469**
Non-KJDRP	0.1666	0.125	0.1666	**0.1514**
Crop damage				
KJDRP	0 8333	0 8333	0.8333	**0.8333**
Non-KJDRP	0.1666	0.1666	0 1666	**0.1666**
O & M Cost				
KJDRP	0 875	0.75	0.875	**0.8311**
Non-KJDRP	0.125	0.25	0.125	**0.15749**

Table 5.2.7.C: Priority vector of criteria under the option of TRM and Non-TRM (for Expert-1, Expert-2 and Expert-3)

	Expert-1	**Expert-2**	**Expert-3**	**Geometric mean**
Area under water class	*Priority vector*	*Priority vector*	*Priority vector*	*Priority vector*
TRM	0.8333	0.875	0 8333	**0.8469**
Non-TRM	0.1667	0 125	0.1667	**0.1514**
Fish habitat				
TRM	0 8333	0.8333	0 8333	**0.8333**
Non-TRM	0 1667	0.1666	0.1667	**0.1666**
Area under agriculture class				
TRM	0 8333	0.8333	0.8333	**0.8333**
Non-TRM	0 1667	0 1666	0 1667	**0.1666**
Cultivable area				
TRM	0.8333	0.75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0 1667	**0.1907**
Irrigated area				
TRM	0.8333	0.8333	0.8333	**0.8333**
Non-TRM	0.1667	0 1666	0 1667	**0.1666**
Sediment in beels				
TRM	0.875	0 875	0 875	**0.875**
Non-TRM	0 125	0 125	0 125	**0.125**
Sediment in rivers				
TRM	0.8333	0 875	0 8333	**0.8469**
Non-TRM	0.1667	0.125	0.1667	**0.1514**
Trained members				
TRM	0.75	0.75	0 75	**0.75**
Non-TRM	0.25	0.25	0 25	**0.25**
Labor involvement				

TRM	0.75	0 75	0.75	**0.75**
Non-TRM	0 25	0.25	0.25	**0.25**
Population involvement				
TRM	0 75	0.875	0.75	**0.7895**
Non-TRM	0 25	0.125	0.25	**0.1984**
Livestock				
TRM	0.75	0.5	0.75	**0.6551**
Non-TRM	0.25	0.5	0.25	**0.3149**
Salinity				
TRM	0.8333	0.8333	0 8333	**0.8333**
Non-TRM	0.1667	0 1666	0.1667	**0.1666**
P^H				
TRM	0 75	0.75	0.75	**0.75**
Non-TRM	0 25	0.25	0 25	**0.25**
Dissolved Oxygen				
TRM	0 8333	0.8333	0 8333	**0.8333**
Non-TRM	0 1667	0.1666	0.1667	**0.1666**
Dry Submergence				
TRM	0.875	0 5	0 875	**0.7260**
Non-TRM	0.125	0 5	0 125	**0.1984**
Monsoon submergence				
TRM	0.8333	0 75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0.1667	**0.1907**
Water logging				
TRM	0 8333	0.5	0 8333	**0.7028**
Non-TRM	0 1667	0.5	0 1667	**0.2403**
Depth in the deepest point				
TRM	0.8333	0 5	0 8333	**0.7028**
Non-TRM	0 1667	0.5	0 1667	**0.2403**
Area of water logging				
TRM	0.8333	0 75	0.8333	**0.8045**
Non-TRM	0.1667	0 25	0 1667	**0.1907**
Poverty reduction				
TRM	0.8333	0.5	0.8333	**0.7028**
Non-TRM	0.1667	0 5	0 1667	**0.2403**
Employment				
TRM	0.8333	0 5	0.8333	**0.7028**
Non-TRM	0.1667	0.5	0.1667	**0.2403**
Discharge				

TRM	0.875	0.8333	0.875	**0.8608**
Non-TRM	0.125	0.1666	0.125	**0.1375**
Dredging				
TRM	0.0909	0.125	0.0909	**0.1010**
Non-TRM	0.9091	0.875	0.9091	**0.8975**
High water level in river				
TRM	0.8333	0.75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0.1667	**0.1907**
Post monsoon drainage				
TRM	0.8333	0.75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0.1667	**0.1907**
Ag land during dry season				
TRM	0.8333	0.75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0.1667	**0.1907**
Open fish				
TRM	0.875	0.8333	0.875	**0.8608**
Non-TRM	0.125	0.1666	0.125	**0.1375**
Culture fish				
TRM	0.8333	0.5	0.8333	**0.7028**
Non-TRM	0.1667	0.5	0.1667	**0.2403**
Ag production in beels				
TRM	0.8333	0.8333	0.8333	**0.8333**
Non-TRM	0.1667	0.1666	0.1667	**0.1666**
Cropping intensity				
TRM	0.8333	0.75	0.8333	**0.8045**
Non-TRM	0.1667	0.25	0.1667	**0.1907**
Crop damage				
TRM	0.8333	0.5	0.8333	**0.7028**
Non-TRM	0.1667	0.5	0.1667	**0.2403**
O & M Cost				
TRM	0.75	0.125	0.75	**0.4127**
Non-TRM	0.25	0.875	0.25	**0.3795**

Table 5.2.8: ***Overall summary of Priority Vector (PV.) (from Expert-1, Expert-2 and Expert-3)***

	PV. (From Expert-1, 2 & 3)	*PV. under KJDRP option*	*PV. under Non-KJDRP option*	*PV. under TRM option*	*PV. under Non-TRM option*

1sr order criteria					
Resources	0 2050				
Population	0 0722				
Environment	0 2476				
Socio-cultural	0.0652				
Technology	0 2528				
Economic	0 1360				
2nd & 3rd order criteria					
Area under water class	0.1004	0.8549	0 1405	0 8469	0.1514
Fish habitat	0.1061	0 8333	0 1666	0 8333	0.1666
Area under agriculture class	0 0871	0 8469	0 1514	0.8333	0 1666
Cultivable area	0 1435	0.8469	0 1514	0 8045	0 1907
Irrigated area	0.0914	0.8045	0 1907	0.8333	0.1666
Sediment in-beels	0.2003	0.5763	0.2271	0.875	0 125
Sediment in rivers	0.2050	0.8333	0.1666	0 8469	0 1514
Trained member	0.0497	0.7768	0 2183	0.75	0.25
Labor involvement	0 4625	0.8469	0.1514	0.75	0 25
Population involvement	0 4625	0 7768	0.2183	0 7895	0.1984
Livestock	0.0739	0.7768	0 2183	0 6551	0 3149
Salinity	0.0849	0 5723	0 3968	0.8333	0 1666
P^H	0 0407	0 7768	0 2183	0 75	0 25
Dissolved Oxygen	0 0630	0 8333	0 1666	0 8333	0 1666
Dry submergence	0.0306	0 8311	0 1574	0 7260	0 1984
Monsoon submergence	0 1198	0 8333	0 1666	0.8045	0 1907
Duration of water logging	0 2456	0 8469	0 1514	0 7028	0.2403
Depth in the deepest point	0.1245	0.8045	0 1907	0 7028	0.2403
Area of water logging	0 2482	0 875	0.125	0 8045	0.1907
Poverty reduction	0.5	0.8469	0 1514	0 7028	0.2403
Employment	0.5	0 8333	0.1666	0.7028	0.2403
Discharge	0.2129	0.8469	0 1357	0 8608	0 1375
Dredging	0 0761	0 75	0 25	0 1010	0 8975
High water level in river	0.3901	0.8333	0.1666	0.8045	0 1907
Post monsoon drainage	0 1954	0.8608	0 1375	0 8045	0.1907
Ag land during dry season	0 0917	0.8608	0.1375	0 8045	0 1907
Crop damage	0.1668	0.8333	0.1666	0 7028	0 2403
OM Cost	0 5276	0.8311	0.1574	0 4127	0 3795
Fish production	0.0997				
Open fish	0 25	0.2849	0.4873	0.8608	0.1375

Culture fish	0 75	0.8469	0.1514	0 7028	0.2403
Agricultural production	0 1845				
Agri production in beels	0 7028	0.7028	0.2403	0 8333	0.1666
Cropping intensity	0.2403	0 8469	0.1514	0.8045	0 1907

Step-5: Use the weights to obtain scores for the different options and make a provisional decision.

The real value (incremental value in percentage) of each criterion is multiplied by the priority vector of each criterion. and then the score for each option is found.

Table 5.2.9: Priority vector (PV.) with real performance value

	Priority vector (PV) (From Expert-1, 2& 3)	***Real incremental value from pre to post project (in %)***	***Sign on judgment basis***	**Real Priority Vector (PV * real incremental value)**
Resources	0.2050			0.2050
Population	0.0722			0 0722
Environment	0 2476			0 2476
Socio-cultural	0 0652			0.0652
Technology	0.2528			0 2528
Economic	0 1360			0.1360
Area under water class	0 1004	-36 9230	36.923	3 7074
Fish habitat	0 1061	114 8429	114.842	12.1934
Area under agriculture class	0.0871	33 75	33.75	2 9422
Cultivable area	0 1435	23.7798	23 779	3 4141
Irrigated area	0.0914	70 4523	70 452	6 4457
Sediment in-beels	0.2003	73 5973	73.597	14 7428
Sediment in rivers	0 2050	-89 3892	89.389	18 3249
Trained member	0 0497	-47.7463	-47.746	-2.3737
Labor involvement	0.4625	1111.75	1111.75	514.2853
Population involvement	0.4625	398.5294	398 529	184.356
Livestock	0.0739	619 9375	619 937	45.8306
Salinity	0.0849	-24.21	24 21	2.0576
P^H	0 0407	5.7951	5.7951	0.2359
Dissolved Oxygen	0.0630	-46.4840	-46 484	-2.9285
Dry submergence	0 0306	-57 0833	57.083	1.7512

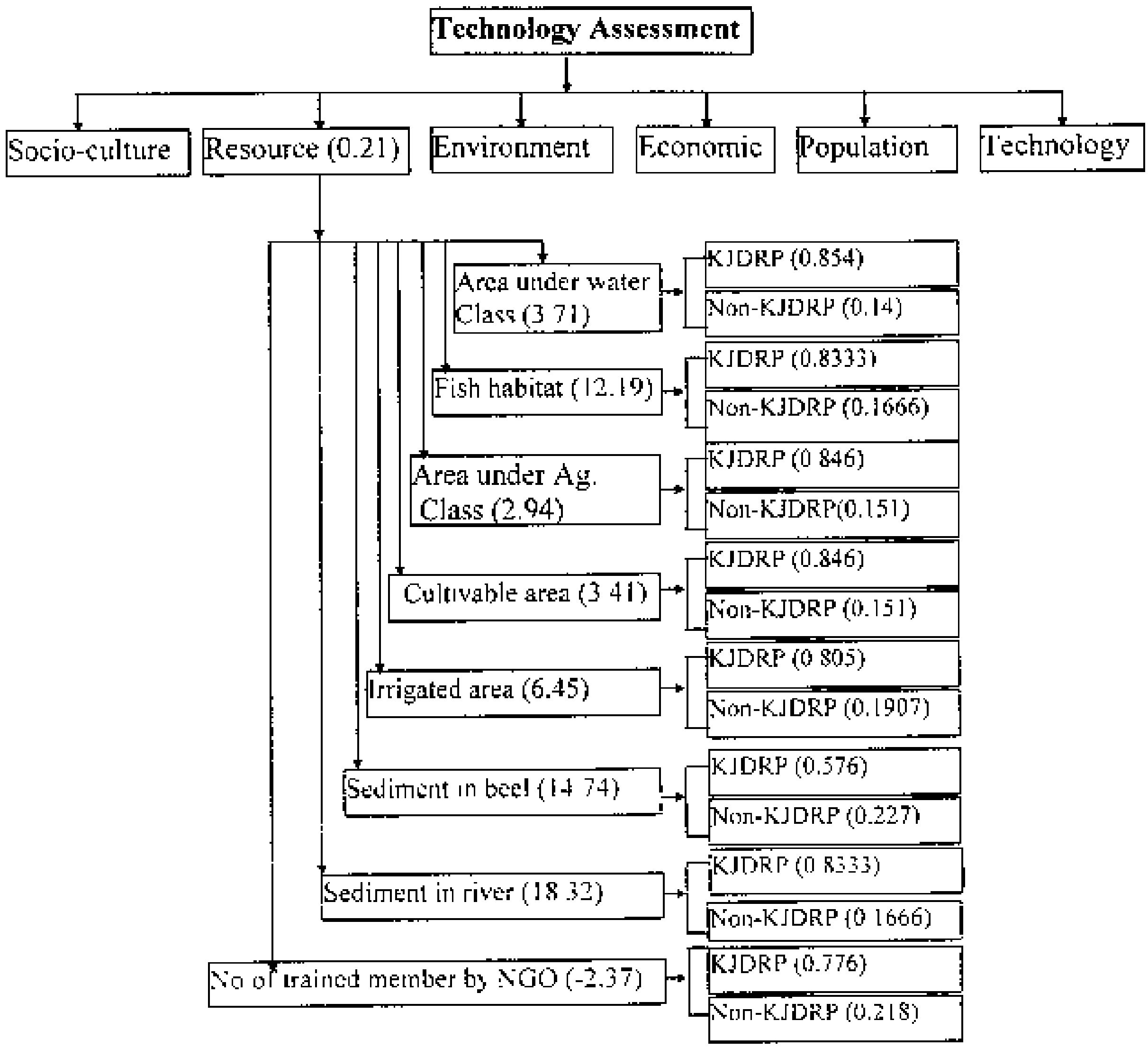
Monsoon submergence	0.1198	-25.7730	25 773	3.0888
Duration of water logging	0.2456	-42.4045	42 4	10.4142
Depth in the deepest point	0 1245	-18.1645	18 1645	2.2630
Area of water logging	0 2482	-65 6863	65.68	16 3064
Poverty reduction	0 5	-25 3333	25.33	12 665
Employment	0 5	43.9214	43.921	21 9607
Discharge	0 2129	190	190	40.4591
Dredging	0.0761	79 7297	-79 729	-6 0704
High water level in river	0 3901	16 3541	16 354	6 3799
Post monsoon drainage	0 1954	45 6666	45 666	8 9240
Ag land during dry season	0.0917	-15.73164	-15.731	-1.4430
Fish production	0.0997	76 8660	76 866	7.6636
Agricultural production	0.1845	41 9791	41.979	7.7459
Crop damage	0.1668	-93.7672	93.76	15 6422
OM Cost	0.5276	-94.0883	94.088	49 6445
Open fish	0.25	24.8420	24.842	6 2105
Culture fish	0 75	128.2766	128 276	96 2075
Agri production in beels	0 7028	727.4739	727 473	511.3127
Cropping intensity	0 2403	9 0017	9.00175	2 1637

Table 5.2.10: Priority vector (PV.) from experts' choice and the real priority vector found from *KJDRP* and Non- *KJDRP* options

	PV. (From Expert-1, Expert-2 & Expert-3)	Real Priority Vector	*PV. under KJDRP option*	*PV. under Non-KJDRP option*
1sr order criteria				
Resources	0 2050	0 2050		
Population	0.0722	0.0722		
Environment	0 2476	0.2476		
Socio-cultural	0 0652	0 0652		
Technology	0 2528	0.2528		
Economic	0 1360	0 1360		
2nd & 3rd order criteria				
Area under water class	0 1004	3 7074	0.8549	0.1405
Fish habitat	0.1061	12 1934	0.8333	0.1666
Area under agriculture class	0.0871	2.9422	0.8469	0.1514

Cultivable area	0 1435	3.4141	0 8469	0.1514
Irrigated area	0 0914	6 4457	0 8045	0.1907
Sediment in-beels	0 2003	14 7428	0.5763	0.2271
Sediment in rivers	0.2050	18.3249	0.8333	0.1666
Trained member	0.0497	-2.3737	0.7768	0.2183
Labor involvement	0.4625	514 2853	0.8469	0.1514
Population involvement	0.4625	184.356	0.7768	0 2183
Livestock	0 0739	45 8306	0 7768	0.2183
Salinity	0 0849	2 0576	0 5723	0.3968
P^H	0.0407	0.2359	0 7768	0.2183
Dissolved Oxygen	0.0630	-2.9285	0 8333	0 1666
Dry submergence	0 0306	1.7512	0.8311	0 1574
Monsoon submergence	0 1198	3 0888	0.8333	0 1666
Duration of water logging	0.2456	10 4142	0.8469	0.1514
Depth in the deepest point	0.1245	2.2630	0.8045	0.1907
Area of water logging	0 2482	16 3064	0.875	0 125
Poverty reduction	0 5	12 665	0 8469	0 1514
Employment	0 5	21.9607	0.8333	0 1666
Discharge	0.2129	40 4591	0 8469	0.1357
Dredging	0.0761	-6 0704	0 75	0 25
High water level in river	0 3901	6.3799	0.8333	0.1666
Post monsoon drainage	0 1954	8 9240	0.8608	0 1375
Ag land during dry season	0 0917	-1 4430	0.8608	0 1375
Crop damage	0.1668	7.6636	0.8333	0.1666
OM Cost	0 5276	7.7459	0 8311	0 1574
Fish production	0.0997	15.6422		
Open fish	0 25	49 6445	0 2849	0 4873
Culture fish	0.75	6 2105	0 8469	0.1514
Agricultural production	0 1845	96.2075		
Agri production in beels	0 7028	511 3127	0 7028	0.2403
Cropping intensity	0 2403	2 1637	0 8469	0 1514

Score of Resource factor under KJDRP & Non-KJDRP :



Here values in bracket indicates the priority vector found from the judgment of the experts and values in bracket of 2nd order criteria indicates the real priority vector found from Table 5 2.10

Calculation:

Score for KJDRP (under Resource Factor)

= 0 854 * 3.71 * 0.21

+ 0 8333 * 12.19 * 0.21

+ 0.846 * 2.94 * 0.21

+ 0 846 * 3.41 * 0 21

+ 0.805 * 6.45 * 0.21

+ 0.576 * 14.74 * 0.21

+ 0.8333 * 18.32 * 0.21

+ 0.776 * (-2.37) * 0.21 = **9.39**

Score for Non- KJDRP (under Resource Factor)

= 0.14 * 3.71 * 0.21

+ 0.1666 * 12.19 * 0.21

+ 0.151 * 2.94 * 0.21

+ 0.151 * 3.41 * 0.21

+ 0.190 * 6.45 * 0.21

+ 0.227 * 14.74 * 0.21

+ 0.1666 * 18.32 * 0.21

+ 0.218 * (-2.37) * 0.21 = **2.179**

Similar calculation can be made to get score of other factors under KJDRP and Non-KJDRP options.

Final score of KJDRP

= ∑ Score of (Resource + Socio-culture +Environment +Economic +Population +Technology)

factors under KJDRP options.

= ∑ (9.394 + 1.89 + + 6 899 + 523 794 + 44.387 +10 484)

= **596.853**

Similarly, **Final score of Non-KJDRP**

= ∑ Score of (Resource + Socio-culture+ Environment +Economic +Population +Technology)

factors under Non-KJDRP options.

= ∑ (2.179 + 0 363 + 1 292 + 158.624 + 9 257 + 1 533)

= **173.251**

Table 5.2.11 : Score obtained for different criteria under KJDRP and Non-KJDRP options in AHP Method

Score	Resourc	Socio culture	Environment	Economic	Population	Technology	TOTAL
For KJDRP	9.394	1.89	6 899	523.794	44.387	10.484	596.85
For Non-KJDRP	2.179	0.363	1.292	158 624	9 257	1.533	173.25

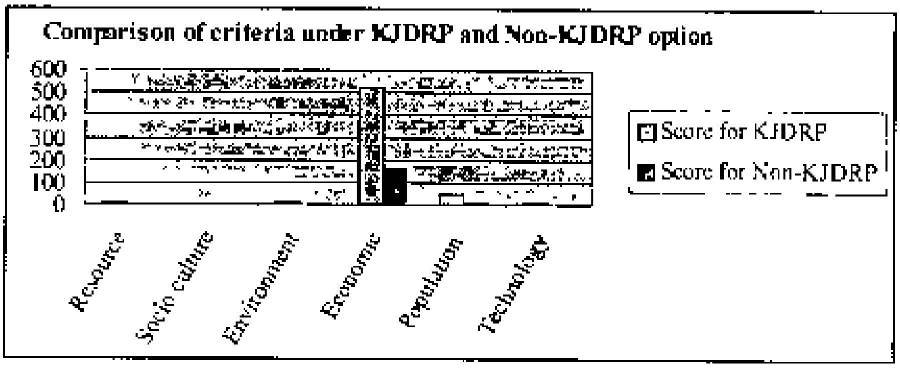


Figure 5.2: Comparison of criteria under KJDRP and Non- KJDRP Options

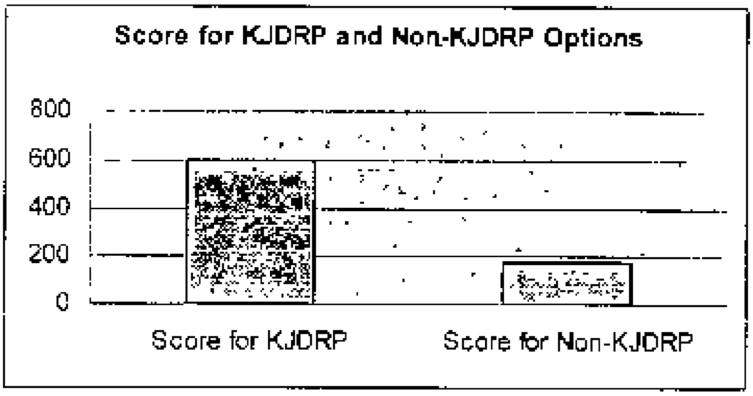


Figure 5.3: Score for KJDRP and Non-KJDRP Options in AHP Method

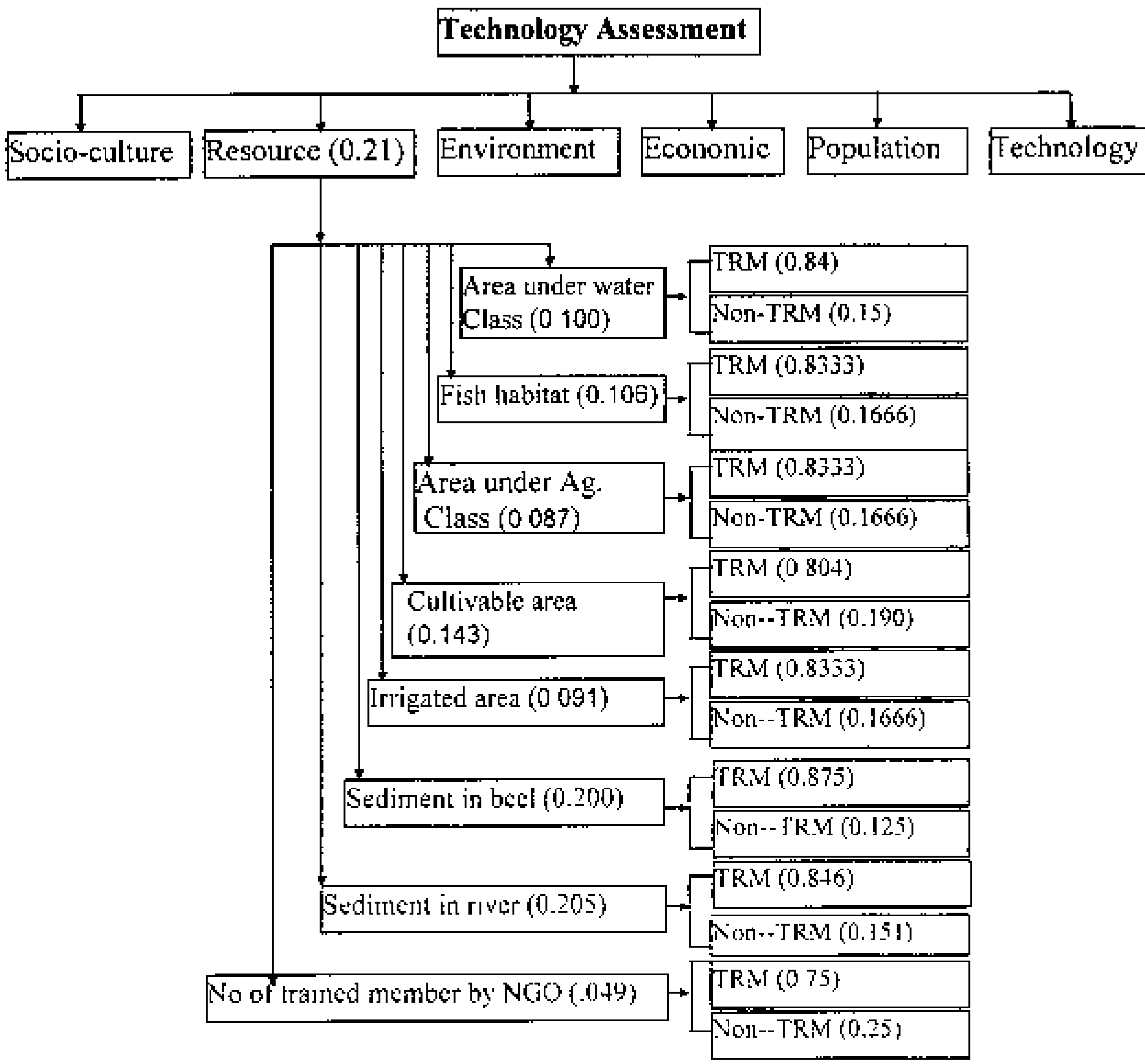
5.2.2 Analytical Hierarchy Process (AHP) for TRM and Non-TRM option

Steps, which are followed in AHP method for KJDRP and Non-KJDRP options, can be followed in case of TRM and Non-TRM options also. The only difference is in later case, the real performance value was not considered. Real performance value due to TRM option was not fully available. So, in this case, only priority vector from different experts' opinions are considered

Table 5.2.12: Priority vector found from experts' choice for TRM and Non-TRM options

	Priority Vector (From Expert-1, Expert-2 & Expert-3)	*Under TRM option*	*Under Non-TRM option*
1sr order criteria			
Resources	0.2050		
Population	0 0722		
Environment	0.2476		
Socio-cultural	0.0652		

Technology	0 2528		
Economic	0 1360		
2nd & 3rd order criteria			
Area under water class	0.1004	0.8469	0 1514
Fish habitat	0.1061	0.8333	0 1666
Area under agriculture class	0 0871	0.8333	0.1666
Cultivable area	0.1435	0.8045	0.1907
Irrigated area	0.0914	0.8333	0 1666
Sediment in-beels	0 2003	0.875	0.125
Sediment in rivers	0 2050	0.8469	0 1514
Trained member	0.0497	0.75	0.25
Labor involvement	0.4625	0.75	0.25
Population involvement	0 4625	0 7895	0 1984
Life-stock	0 0739	0 6551	0 3149
Salinity	0.0849	0 8333	0 1666
P^H	0.0407	0.75	0.25
Dissolved Oxygen	0.0630	0.8333	0.1666
Dry submergence	0.0306	0.7260	0.1984
Monsoon submergence	0.1198	0.8045	0.1907
Duration of water logging	C.2456	0.7028	0.2403
Depth in the deepest point	0.1246	0 7028	0.2403
Area of water logging	0 2482	0 8045	0.1907
Poverty reduction	0.5	0 7028	0 2403
Employment	0 5	0.7028	0.2403
Discharge	0 2129	0.8608	0.13758
Dredging	0.0761	0.10109	0.897582
High water level in river	0 3901	0.8045	0 1907
Post monsoon drainage	0.1954	0.8045	0 1907
Ag land during dry season	0.0917	0 8045	0 1907
Crop damage	0.1668	0.7028	0 2403
OM Cost	0.5276	0.4127	0.3795
Fish production	0 0997		
Open fish	0.25	0.8608	0.1375
Culture fish	0 75	0.7028	0 2403
Agricultural production	0.1845		
Agri production in beels	0.7028	0.8333	0.1666
Cropping intensity	0.2403	0.8045	0.1907



Here values in bracket indicates the priority vector found from the judgment of the experts from Table 5.2.12

Calculation:

Score for TRM (under Resource Factor)

= 0.84 * 0.100 * 0.21

+ 0.8333 * 0.106 * 0.21

+ 0.8333 * 0.087 * 0.21

+ 0.804 * 0.143 * 0.21

+ 0.8333 * 0.091 * 0.21

+ 0.875 * 0.200 * 0.21

+ 0.846 * 0.205 * 0.21

+ 0.75 * (0.049) * 0.21 = 0.168

Similarly, Score for Non-TRM (under Resource Factor)

= 0.15 * 0.100 * 0.21

+ 0.1666 * 0.106 * 0.21

+ 0.1666 * 0.087 * 0.21

+ 0.190 * 0.143 * 0.21

+ 0.1666 * 0.091 * 0.21

+ 0.125 * 0.200 * 0.21

+ 0.151 * 0.205 * 0.21

+ 0.25 * (0.049) * 0.21 = 0.032

Table 5.2.13: Score found for different criteria under TRM and Non-TRM options in AHP Method

	Resource	Socio-culture	Environment	Economic	Population	Technology	TOTAL
Score for TRM	0.1689	0.0543	0.1971	0.1039	0.0541	0.1915	0.7700
Score for Non-TRM	0.0327	0.0108	0.0400	0.0277	0.0180	0.0527	0.1822

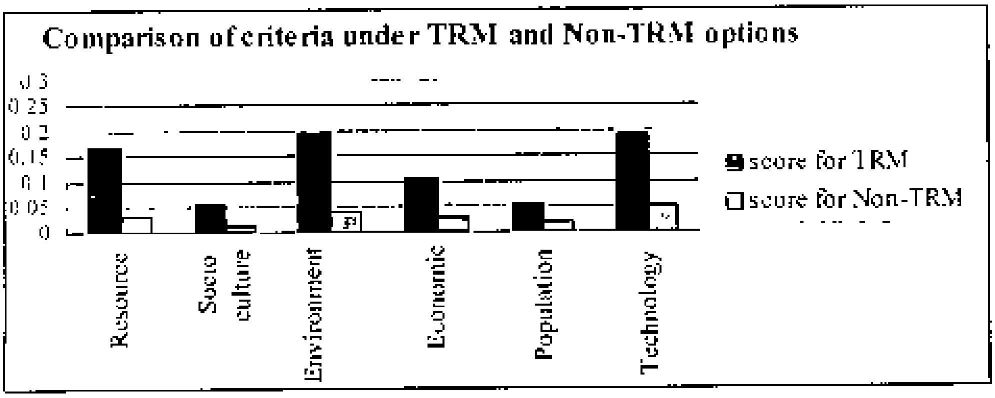


Figure 5.4: Comparison of criteria under TRM and Non-TRM Options

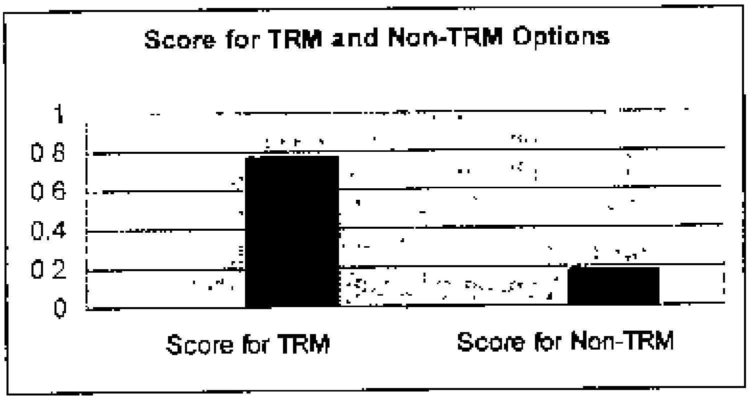


Figure 5.5: Score for TRM and Non-TRM Options in AHP Method

5.3 Analyses 2:

5.3.1 Fuzzy Hierarchical Decision Making (FHDM)

Step-1: *Formation of a committee of experts and identification of various available alternative technologies and various criteria that will influence the choice of technology.*

Total 13 Nos. of experts were selected in the pool of expert in AHP method. Among them, three experts were chosen in the pool of experts in Fuzzy method. The selected groups of experts chosen were mainly consultants, engineers, researchers, etc. They are fully aware of KJDRP. Some of them were directly involved in the project implementation. Most of them are involved in the decision making for selecting appropriate technology. They have given their opinion.

Name of the Experts and Resource Person:

1. *Shofi Uddin Ahmed*

   Senior Consultant, Water & Environment, ACE Consultants Limited.

2. *Sheikh Nurul Ala*

   Superintendent Engineer, Bangladesh Water Development Board.

3. *Md. Zahirul Haque Khan*

   Division Head, Coast, Port & Estuary and River Engineering Division, (IWM)

Step-2 *Fixation of criteria hierarchically and formation of technology choice criteria hierarchy.*

The criteria were exploded hierarchically using hierarchical structural analysis as shown in the Figure 5.3.1. Experts have put their criteria of preferences in the survey questionnaire which have been reflected in the Figure 5.3.1

Step-3 *: Set up of proper linguistic scales (high, medium, low) and ask experts to give their judgment by pair-wise comparison of criteria and alternatives under each subjective criteria. Alternatively, experts may give their judgments in triangle fuzzy numbers.*

Pair wise Comparison: When two individual subjective criteria are compared by an expert to find choice of preferences, it is called pair wise comparison.

***Step-4**: Conversion of the linguistic variables into triangle fuzzy numbers by a convenient scale, if the experts have expressed their judgments only in linguistic variables*

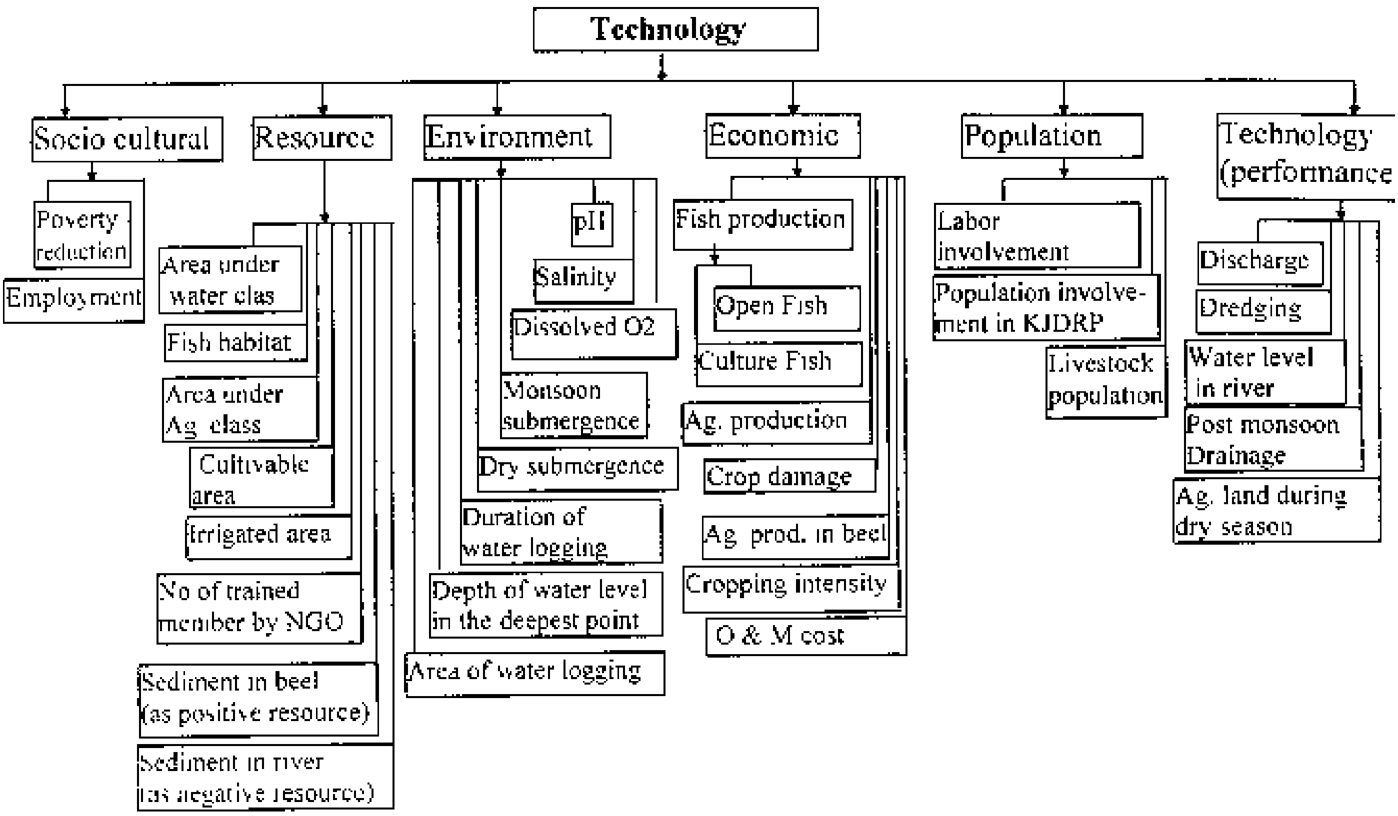


Figure. 5.3.1 : Technology Assessment Criteria Hierarchy

During field survey, the questionnaire was filled up with the linguistic opinion which later converted into triangular Fuzzy number.

Table. 5.3.1 : Linguistic Scale and its Triangle Fuzzy Number Conversion

Serial Number	*Description*	*Linguistic Scale*	*Triangle Fuzzy Scale*
1	Very High	VH	(8, 9, 9)
2	Between Very High and High	VH & H	(6, 7, 8)
3	High	H	(4, 5, 6)
4	Between High and Medium	H & M	(2, 3, 4)
5	Medium, Almost Equally	M	(1/2, 1, 2)
6	Exactly Equal	EQ	(1, 1, 1)

7	Between Medium and Low	M &L	(1/4, 1/3, 1/2)
8	Low	L	(1/6, 1/5, 1/4)
9	Between Low and Very Low	L & VL	(1/8, 1/7, 1/6)
10	Very Low	VL	(1/9, 1/9, 1/8)

Table-5.3.2 : Expert's opinions on relative importance of first level criteria

	Resources	Population	Environment	Socio-cultural	Technology	Economic
Resources	**6**	5	8	7	6	5
Population		**6**	7	8	9	8
Environment			**6**	5	4	6
Socio-cultural				**6**	5	6
Technology					**6**	6
Economic						**6**

Table 5.3.3 The pair wise importance criteria

	Resources	Population	Environment	Socio-cultural	Technology	Economic
Resources	6	5	8	7	6	5
Population	6	**6**	7	8	9	8
Environment	3	4	**6**	5	4	6
Socio-cultural	4	3	6	**6**	5	6
Technology	5	2	7	6	**6**	6
Economic	6	3	5	5	5	**6**

(Number 6 stands for comparison of a criterion with itself. (Table 5.3.1)

Table 5.3.4 :The Fuzzy Reciprocal Matrix

	Resources	Population	Environment	Socio-cultural	Technology	Economi
Resources	**(1,1,1)**	(1/2,1,2)	(1/6,1/5,1/4)	(1/4,1/3, 1/2)	(1,1,1)	(½,1 2)
Population	(1/2,1,2)	**(1,1,1)**	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5 1
Environment	(4,5,6)	(2,3,4)	**(1,1,1)**	(1/2,1,2)	(2,3,4)	(1,1,1)
Socio-cultural	(2,3,4)	(4,5,6)	(1/2, 1,2)	**(1,1,1)**	1/2,1,2)	(1,1,1)
Technology	(1/2,1,2)	(6,7,8)	(1/4, 1/3,1/2)	(1/2,1, 2)	**(1,1,1)**	(1,1,1)
Economic	(1/2,1,2)	(4,5,6)	(1/2,1,2)	(1/2,1,2)	1/2,1,2)	**(1,1,1)**

Upper triangle element* lower triangle element = 1

e.g Environment vs Population is (2, 3, 4) * (1/4, 1/3, ½)

Thus, 2*1/2 =1,

3*1/3=1,

4*1/4=1

Step-5: *Aggregation of the experts opinions by a statistical measure (geometric mean), and form the fuzzy reciprocal matrix. The elements of fuzzy reciprocal matrix are such that the products of each upper triangle element with its corresponding lower triangle element should approximately be equal to 1.*

Step-6: *Normalization of the geometric row means of fuzzy reciprocal matrix and find the importance in terms of weights. If $A = [a_{uv}]_{k*k}$ is fuzzy reciprocal matrix then*

Geometric row mean $r_u = (a_{u1} * a_{u2} * \ldots\ldots a_{uk})^{1/k}$ (1)

The total of geometric row mean values $= (r_1 + r_2 + r_3 + \ldots\ldots + r_k)$ (2)

Using (1) and (2), the importance weights of each criteria w_u, *and the importance weight of each sub criteria under its main criteria is calculated.*

Normalized geometric row mean or Importance Weight $W_u = r_u/(r_1 + r_2 + \ldots + r_k)$ (3)

Then by combining importance weight of each criteria, Global weight of each criteria is calculated.

Table 5.3.5 : Geometric Row Mean Values And The Importance Weight

	Geometric row mean	Importance weight
Resources	(0 467328, 0 636773, 0 890899)	(0 048543, 0 092225, 0 181001)
Population	(0 275161, 0 352079, 0.467328)	(0.028582, 0 050992, 0.094946)
Environment	(1.414214, 1.885973, 2.401874)	(0 146898, 0 273148, 0 487982)
Socio-cultural	(1.122462, 1 570418, 2 139826)	(0.116593, 0 227446, 0 434742)
Technology	(0 849191, 1.151674, 1.587401)	(0 088208, 0.166799, 0.322508)
Economic	(0.793701, 1.30766, 2 139826)	(0 082444, 0 18939, 0 434742)
Column Sum	**(4.922055, 6.904577, 9.627154)**	

Calculation:

Geometric mean of first row:

The Geometric mean value of first row (Resource criteria) is

(1,1,1) * (1/2,1,2) * (1/6,1/5,1/4)* (1/4,1/3, 1/2)* (1,1,1) * (½,1,2)

$= (0.01^{1/6}, 0\ 066^{1/6}, 0.5^{1/6})$

= (0 467328, 0.636773, 0.890899)

The total of geometric row mean values = (4.922055, 6.904577, 9.627154)

Importance Weight of resource criteria= (0.4678/9.6271, 0.6367/6.9045, 0.8908/4 9220)

= (0.048543, 0 092225, 0.181001)

The above exercise will be repeated for each level of criterion for each expert separately.

Table 5.3.6 : Importance weights of criteria

	Expert-2			Expert-1			Expert-3			Geometric Mean		
Criteria	Importance weight			Importance weight			Importance weight			Importance weight		
Resources	0 127	0.247	0.4675	0 049	0.092	0.176	0.09	0.159	0.288	0 083	0.154	0 28
Population	0 023	0.05	0.091	0 029	0.051	0 092	0 04	0.065	0 112	0.032	0 055	0 09
Environment	0 105	0.195	0.3537	0 147	0 273	0.475	0.19	0.3	0.489	0 142	0.252	0 43
Socio-cultural	0.06	0 124	0 2624	0 117	0.227	0.423	0.03	0 046	0 079	0 058	0 109	0 20
Technology	0.114	0.206	0.3711	0 102	0 167	0.314	0 15	0.276	0 513	0 119	0.212	0 39
Economic	0.075	0.179	0 4165	0.082	0 189	0 423	0.09	0.154	0 231	0.082	0 173	0 34
Area under water class	0 082	0.17	0 3523	0.107	0 179	0 297	0 05	0.073	0 112	0.076	0.131	0 22
Fish habitat	0.044	0.085	0 1674	0 048	0.082	0 141	0 04	0.056	0.086	0 043	0 073	0 12
Area under agriculture class	0.043	0 085	0.1699	0.056	0 097	0.174	0.05	0 067	0 102	0.048	0 082	0 14
Cultivable area	0 068	0 147	0 3116	0.039	0 071	0 134	0 09	0.153	0 256	0.063	0.117	0 22
Irrigated area	0.042	0 091	0 2021	0 107	0.197	0.354	0 07	0 109	0 188	0 066	0.125	0.23
Sediment in-beels	0 078	0 163	0 3398	0 044	0 082	0 154	0 18	0 302	0.494	0 085	0 159	0 29
Sediment in rivers	0 129	0 236	0 4162	0 146	0 268	0.483	238	0 21	0.344	1.651	0 237	0 41
Trained member	0 014	0.022	0.0378	0 015	0.023	0 037	0	0 03	0.043	0 001	0 025	0.03
Labor involvement	0 253	0 455	0.8111	0.089	0 143	0 234	0.38	0.467	0.57	0 204	0.312	0 47
Population involvement	0 253	0.455	0 8111	0 515	0.714	0 973	0 3	0.467	0 718	0 339	0.533	0.82
Life-stock	0 061	0.091	0.1406	0.089	0 143	0.234	0.05	0.067	0.086	0.066	0 095	0 14
Salinity	0 106	0.179	0.2975	0.119	0 238	0.466	0 03	0.049	0.074	0 075	0 128	0 21
P^H	0 016	0.026	0 0409	0.049	0.095	0.186	0.03	0.045	0 074	0.028	0.048	0 08
Dissolved Oxygen	0.016	0 025	0.0436	0.049	0.095	0 186	0 06	0 085	0.133	0 035	0.059	0 10
Dry submergence	0.042	0 07	0 1189	0.024	0 055	0 101	0.01	0.017	0.024	0.023	0.04	0 06
Monsoon submergence	0.086	0 152	0 2728	0 056	0.124	0 277	0 05	0.073	0.105	0 063	0 111	0 19
Duration of water	0.131	0.226	0.3833	0 071	0.17	0.406	0.21	0 297	0.416	0.124	0.225	0.40

logging												
Depth in the deepest point	0.046	0 085	0 1622	0 047	0.108	0.254	0.09	0.138	0.212	0.058	0.108	0.2
Area of water logging	0.126	0 236	0 4333	0.052	0 116	0.263	0.19	0.297	0.453	0.108	0 201	0 3
Poverty reduction	0.414	0.5	0 5858	0 207	0 634	1 886	0 25	0 5	1	0.278	0.541	1 0
Employment	0.293	0 5	0 8284	0 104	0.366	1.333	0.25	0.5	1	0.196	0 451	1 0.
Discharge	0 202	0.357	0.6072	0.332	0.521	0 794	0 14	0 194	0.287	0.21	0 33	0.5
Dredging	0 057	0.116	0 28	0 067	0.126	0 236	0 04	0 053	0.08	0.053	0 092	0 1
High water level in river	0 141	0 301	0 6072	0 116	0.205	0.366	0.4	0 572	0.821	0 186	0 328	0.5
Post monsoon drainage	0 061	0.141	0.3216	0.041	0.07	0 128	0 13	0 181	0.23	0.069	0 121	0 2
Ag land during dry season	0 043	0.086	0.1703	0.043	0.078	0 147	0	0	0	0	0	0
Fish production	0 081	0.179	0.4106	0 204	0.402	0 753	0.05	0.07	0.11	0 093	0.172	0.3
Agricultural production	0 115	0.235	0.4883	0.144	0.232	0.377	0.12	0.16	0.22	0.124	0 206	0 3
Crop damage	0.081	0.179	0.4106	0 072	0 134	0.266	0 1	0.16	0 262	0.083	0.157	0 3
OM Cost	0 193	0.407	0.8212	0 121	0 232	0 448	0.43	0.609	0 843	0.216	0 386	0.6
Open Fish	0.185	0.25	0 3694	0 185	0 25	0.369	0 18	0 25	0 369	0.185	0 25	0 3
Culture fish	0 522	0.75	1.0448	0 522	0.75	1 045	0 52	0 75	1.045	0.522	0 75	1.0
Agri production in beels	0 25	0.5	1	0 185	0 25	0 369	0.68	0 833	1 017	0.315	0.471	0 7
Cropping intensity	0 25	0.5	1	0.522	0 75	1 045	0.14	0.167	0 208	0.262	0 397	0 6

Calculation:

Table : 5.3.7 Importance Weight of Resource Criteria

Expert 1	0 049, 0.092, 0.176
Expert 2	0.127, 0.247, 0 468
Expert 3	0 093, 0.159, 0 288

The Expert's opinions (importance weight) are now averaged by Geometric Mean.

eg. $(0\ 049 * 0.127 * 0\ 093)^{1/3}$, $(0\ 092 * 0\ 247 * 0\ 159)^{1/3}$, $(0\ 176 * 0.468 * 0\ 288)^{1/3}$

=(0.083, 0 1537, 0.2874)

Similar tables will be prepared for each criterion.

Global weight: Global Importance Weight is obtained by multiplying all importance weight of criteria elements from lower level to upper level

Table 5.3.8 :Global importance weight of criteria

	Global weight		
Resources	0.083039	0.153676	0 28739
Population	0 031801	0.054867	0.098053
Environment	0 142369	0 251773	0.434846
Socio-cultural	0.057954	0.108979	0.206489
Technology	0.119409	0 211544	0.391077
Economic	0.082497	0.173277	0.344118
Area under water class	0.006295	0.020067	0 06522
Fish habitat	0.003584	0.011252	0 036424
Area under agriculture class	0 003994	0 012606	0.041581
Cultivable area	0 005205	0.017992	0.063363
Irrigated area	0.005515	0.01924	0 068275
Sediment in-beels	0.007066	0.024451	0 084996
Sediment in rivers	0.137119	0.036415	0.117932
Trained member	0 000121	0 003827	0 01133
Labor involvement	0.006496	0.017106	0 046711
Population involvement	0.010787	0.02925	0.081141
Livestock	0 002085	0 005229	0.013882
Salinity	0 010612	0.032109	0 094461
P^H	0.004012	0 012099	0.035906
Dissolved Oxygen	0 004995	0 014795	0.04458
Dry submergence	0.00331	0.01015	0 028827
Monsoon submergence	0 008968	0.027899	0 086621
Duration of water logging	0.017722	0.056676	0.174571
Depth in the deepest point	0.008323	0 027224	0.089598
Area of water logging	0.015339	0.050629	0.162013
Poverty reduction	0.016102	0.058977	0.21345
Employment	0 011386	0.049109	0 21345
Discharge	0 023389	0.065458	0.189933
Dredging	0.005868	0 01822	0.06409
High water level in river	0.020756	0.065087	0 208324
Post monsoon drainage	0.008964	0.028397	0.096048
Ag land during dry season	0.005642	0 017094	0 053274
Fish production	0.007692	0.029731	0.111492

Agricultural production	0.010267	0.035706	0 118122
Crop damage	0.006852	0.02713	0.105234
OM Cost	0.017861	0 066909	0.232922
Open fish	0.001421	0.007433	0 041185
Culture fish	0 004018	0.022299	0.116489
Agri production in beels	0 026002	0.08153	0.248311
Cropping intensity	0.021651	0.068765	0.206765

Calculation:

Global Weight of 2nd level Resource Criteria (Area under water class)

= Importance weight of *Area under water class* * Importance weight of *Resource Criteria*

= (0 075812, 0.130578, 0 226938)*(0.083039, 0 153676, 0.28739)

= (0.075812*0 083039, 0.130578*0.153676, 0.226938*0.28739)

= (0 006295, 0 020067, 0 06522)

Table 5.3.9: Importance weight and global weight of criteria

	(Importance weight)			Global weight		
Resources	0 083039	0 153676	0 28739	0 083039	0 153676	0.28739
Population	0.031801	0.054867	0.098053	0.031801	0.054867	0 098053
Environment	0.142369	0.251773	0.434846	0.142369	0.251773	0 434846
Socio-cultural	0.057954	0 108979	0 206489	0.057954	0.108979	0.206489
Technology	0 119409	0.211544	0.391077	0 119409	0 211544	0 391077
Economic	0 082497	0 173277	0.344118	0 082497	0.173277	0.344118
Area under water class	0.075812	0.130578	0.226938	0.006295	0 020067	0.06522
Fish habitat	0.043155	0 073217	0.126741	0.003584	0.011252	0.036424
Area under agriculture class	0 048098	0 082033	0 144686	0 003994	0.012606	0 041581
Cultivable area	0 062682	0 117079	0.220478	0.005205	0.017992	0 063363
Irrigated area	0.06641	0.1252	0 237568	0 005515	0.01924	0 068275
Sediment in-beels	0.085097	0.159111	0 295751	0.007066	0 024451	0.084996
Sediment in rivers	1.651259	0 236962	0.410356	0.137119	0 036415	0 117932
Trained member	0 001458	0 024901	0.039423	0 000121	0.003827	0 01133
Labor involvement	0.204269	0 311766	0.476388	0.006496	0.017106	0.046711
Population involvement	0.339199	0.533112	0 827521	0 010787	0.02925	0.081141
Life-stock	0.065567	0.09531	0 141578	0.002085	0 005229	0.013882
Salinity	0.07454	0.12753	0.217228	0.010612	0.032109	0 094461

pH	0 02818	0.048056	0.082572	0.004012	0.012099	0.035906
Dissolved Oxygen	0.035082	0.058765	0.102518	0.004995	0.014795	0.04458
Dry submergence	0.023249	0.040313	0.066293	0.00331	0 01015	0.028827
Monsoon submergence	0.062989	0.11081	0.199199	0.008968	0.027899	0.086621
Duration of water logging	0 124476	0.225109	0.401455	0 017722	0.056676	0.174571
Depth in the deepest point	0.058457	0 108129	0 206045	0.008323	0.027224	0 089598
Area of water logging	0.107739	0.201089	0 372575	0.015339	0.050629	0.162013
Poverty reduction	0.277835	0.541174	1.033708	0 016102	0 058977	0 21345
Employment	0.196459	0.450627	1.033708	0 011386	0.049109	0.21345
Discharge	0 195876	0.309428	0 485667	0 023389	0.065458	0.189933
Dredging	0.049139	0 086129	0 163881	0 005868	0.01822	0 06409
High water level in river	0.173822	0.307676	0 532692	0.020756	0 065087	0.208324
Post monsoon drainage	0.075069	0.134237	0.2456	0 008964	0.028397	0.096048
Ag land during dry season	0.047251	0.080805	0 136224	0.005642	0 017094	0 053274
Fish production	0 093235	0 171583	0.323994	0.007692	0.029731	0 111492
Agricultural production	0.124454	0 20606	0.343259	0 010267	0.035706	0.118122
Crop damage	0.083063	0.156572	0.305809	0 006852	0.02713	0.105234
OM Cost	0.216498	0.386139	0 676868	0 017861	0 066909	0 232922
Open fish	0 184699	0.25	0 369398	0 001421	0 007433	0 041185
Culture fish	0 522408	0 75	1 044815	0.004018	0.022299	0.116489
Agri production in beels	0 315183	0 470518	0 721589	0 026002	0 08153	0 248311
Cropping intensity	0.262447	0 39685	0.600855	0.021651	0.068765	0.206765

Step-7: Collection of the operating and the performance data on alternatives to find the appropriateness weights of the alternatives under each criterion. Appropriateness weights of the alternatives under each criterion are found using (1) and (2).

Table 5.3.10 (a): Fuzzy Conversion of Field Data (Non-KJDRP)

	Pre Project values	Triangle Fuzzy Conversion			Inverse value		
Area under water class	26	24	26	28	0.035714	0.038462	0.041667
Fish habitat	22800	21800	22800	23800	4.2E-05	4.39E-05	4.59E-05
Area under agriculture class	32	30	32	34	0 029412	0.03125	0.033333
Cultivable area	87353	80353	87353	94353	1.06E-05	1.14E-05	1.24E-05
Irrigated area	24295	22295	24295	26295	3.8E-05	4.12E-05	4 49E-05
Sediment in-beels	1.01	0.9	1	1.1	0.909091	1	1.111111

Sediment in rivers	61070	55070	61070	67070	1.49E-05	1 64E-05	1.82E-05
Trained member	15708	14708	15708	16708	5.99E-05	6.37E-05	6.8E-05
Labor involvement	200	190	200	210	0.004762	0.005	0.005263
Population involvement	136	126	136	146	0 006849	0.007353	0.007937
Life-stock	400000	360000	400000	440000	2.27E-06	2.5E-06	2.78E-06
Salinity	9.5	8.5	9.5	10.5	0 095238	0.105263	0 117647
P^H	7.42	6.42	7 42	8.42	0.118765	0.134771	0.155763
Dissolved Oxygen	10.95	9.95	10.95	11 95	0.083682	0.091324	0.100503
Dry submergence	16000	15000	16000	17000	5.88E-05	6.25E-05	6.67E-05
Monsoon submergence	48510	44510	48510	52510	1.9E-05	2.06E-05	2.25E-05
Duration of water logging	220	200	220	240	0 004167	0 004545	0 005
Depth in the deepest point	19 75	17 75	19.75	21 75	0 045977	0.050633	0.056338
Area of water logging	987	900	987	1074	0.000931	0 001013	0.001111
Poverty reduction	75	70	75	80	0 0125	0.013333	0 014286
Employment	59	54	59	64	0 015625	0 016949	0.018519
Discharge	30	28	30	32	0.03125	0.033333	0 035714
Dredging	240500	210500	240500	270500	3 7E-06	4.16E-06	4 75E-06
High water level in river	2.4	2 1	2.4	2 7	0.37037	0.416667	0.47619
Post monsoon drainage	60	55	60	65	0.015385	0 016667	0.018182
Ag land during dry season	39500	34500	39500	44500	2 25E-05	2.53E-05	2 9E-05
Fish production	5158	4658	5158	5658	0.000177	0.000194	0 000215
Agricultural production	293070	263070	293070	323070	3 1E-06	3.41E-06	3 8E-06
Crop damage	73258	68258	73258	78258	1.28E-05	1.37E-05	1 47E-05
OM Cost	4E+07	3E+07	4E+07	4E+07	2.49E-08	2.84E-08	3 31E-08
Open fish	2800	2500	2800	3100	0.000323	0 000357	0 0004
Culture fish	2369	2069	2369	2669	0.000375	0 000422	0.000483
Agri production in beels	503	453	503	553	0 001808	0.001988	0.002208
Cropping intensity	142	122	142	162	0.006173	0.007042	0 008197
	Column sum				**1.788861**	**1.976876**	**2.210399**

Table 5.3.10(b) : Fuzzy Conversion of Field Data (KJDRP)

	Post Project values	Triangular Fuzzy Conversion			Inverse value		
Area under water class	16.4	15	16.4	17.8	0 0561798	0.0609756	0.06666667
Fish habitat	48984	43984	48984	53984	1.852E-05	2 041E-05	2.2736E-05
Area under agriculture class	42 8	40	42.8	45.6	0.0219298	0 0233645	0 025
Cultivable area	108125	100125	108125	116125	8.611E-06	9 249E-06	9.9875E-06
Irrigated area	41411.4	36411.4	41411.4	46411 4	2.155E-05	2.415E-05	2 7464E-05
Sediment in beels	1.75	0.85	1.75	2.65	0.3773585	0.5714286	1.17647059

Sediment in rivers	6480	6000	6480	6960	0 0001437	0.0001543	0.00016667
Trained member	8208	7208	8208	9208	0.0001086	0.0001218	0.00013873
Labor involvement	2423	2100	2423	2746	0.0003642	0.0004127	0.00047619
Population involvement	678	600	678	756	0.0013228	0.0014749	0.00166667
Livestock	2879	2479	2879	3279	0.000305	0.0003473	0.00040339
Salinity	6.89	6	6 89	7.78	0 1285347	0 1451379	0.16666667
P^H	7.85	7	7.85	8 7	0.1149425	0.1273885	0.14285714
Dissolved Oxygen	5 86	5	5.86	6.72	0.1488095	0 1706485	0 2
Dry submergence	6866	6000	6866	7732	0.0001293	0.0001456	0 00016667
Monsoon submergence	36007	31007	36007	41007	2.439E-05	2 777E-05	3.2251E-05
Duration of water logging	127	107	127	147	0.0068027	0.007874	0.00934579
Depth in the deepest point	16.16	16	16 16	16.32	0.0612745	0 0618812	0 0625
Area of water logging	338	300	338	376	0.0026596	0.0029586	0.00333333
Poverty reduction	56	50	56	62	0.016129	0.0178571	0.02
Employment	85	72 9	85	97.1	0.0102987	0.0117647	0.01371742
Discharge	220	200	220	240	0.0041667	0.0045455	0.005
Dredging	432250	402250	432250	462250	2 163E-06	2.313E-06	2.486E-06
High water level in river	2.79	2 39	2 79	3.19	0.3134796	0.3584229	0 41841004
Post monsoon drainage	87	80	87	94	0.0106383	0.0114943	0 0125
Area reclaimed during dry season	33286	30286	33286	36286	2.756E-05	3.004E-05	3.3019E-05
Fish production	9122	8622	9122	9622	0.0001039	0.0001096	0 00011598
Agricultural production	336718	306718	336718	366718	2.727E-06	2.97E-06	3.2603E-06
Crop damage	4566	4000	4566	5132	0 0001949	0 000219	0 00025
OM Cost	2080100	1900000	2080100	2260200	4 424E-07	4.807E-07	5.3632E-07
Open fish	3495	3000	3495	3990	0.0002506	0.0002861	0.00033333
Culture fish	5407	5000	5407	5814	0.000172	0 0001849	0 0002
Agri production in beels	4169	3869	4169	4469	0 0002238	0 0002399	0 00025846
Cropping intensity	155	133	155	177	0.0056497	0.0064516	0.0075188
	Column sum				**1.2822783**	**1.5860072**	**2.33429428**

Table 5.3.11 (combination of a and b)

	For Non-KJDRP			For KJDRP		
	Inverse value			**Inverse value**		
Area under water class	0.035714	0.038462	0 041667	0.05618	0 060976	0.066667
Fish habitat	4.2E-05	4.39E-05	4.59E-05	1.85E-05	2 04E-05	2.27E-05
Area under agriculture class	0.029412	0.03125	0.033333	0.02193	0.023364	0.025
Cultivable area	1.06E-05	1.14E-05	1 24E-05	8 61E-06	9.25E-06	9.99E-06

Irrigated area	3.8E-05	4.12E-05	4.49E-05	2.15E-05	2.41E-05	2.75E-05
Sediment in-beels	0.909091	1	1.111111	0.377358	0.571429	1.176471
Sediment in rivers	1.49E-05	1.64E-05	1.82E-05	0.000144	0.000154	0.000167
Trained member	5.99E-05	6.37E-05	6.8E-05	0.000109	0.000122	0.000139
Labor involvement	0.004762	0.005	0.005263	0.000364	0.000413	0.000476
Population involvement	0.006849	0.007353	0.007937	0.001323	0.001475	0.001667
Livesstock	2.27E-06	2.5E-06	2.78E-06	0.000305	0.000347	0.000403
Salinity	0.095238	0.105263	0.117647	0.128535	0.145138	0.166667
P^H	0.118765	0.134771	0.155763	0.114943	0.127389	0.142857
Dissolved Oxygen	0.083682	0.091324	0.100503	0.14881	0.170648	0.2
Dry submergence	5.88E-05	6.25E-05	6.67E-05	0.000129	0.000146	0.000167
Monsoon submergence	1.9E-05	2.06E-05	2.25E-05	2.44E-05	2.78E-05	3.23E-05
Duration of water logging	0.004167	0.004545	0.005	0.006803	0.007874	0.009346
Depth in the deepest point	0.045977	0.050633	0.056338	0.061275	0.061881	0.0625
Area of water logging	0.000931	0.001013	0.001111	0.00266	0.002959	0.003333
Poverty reduction	0.0125	0.013333	0.014286	0.016129	0.017857	0.02
Employment	0.015625	0.016949	0.018519	0.010299	0.011765	0.013717
Discharge	0.03125	0.033333	0.035714	0.004167	0.004545	0.005
Dredging	3.7E-06	4.16E-06	4.75E-06	2.16E-06	2.31E-06	2.49E-06
High water level in river	0.37037	0.416667	0.47619	0.31348	0.358423	0.41841
Post monsoon drainage	0.015385	0.016667	0.018182	0.010638	0.011494	0.0125
Ag land during dry season	2.25E-05	2.53E-05	2.9E-05	2.76E-05	3E-05	3.3E-05
Fish production	0.000177	0.000194	0.000215	0.000104	0.00011	0.000116
Agricultural production	3.1E-06	3.41E-06	3.8E-06	2.73E-06	2.97E-06	3.26E-06
Crop damage	1.28E-05	1.37E-05	1.47E-05	0.000195	0.000219	0.00025
OM Cost	2.49E-08	2.84E-08	3.31E-08	4.42E-07	4.81E-07	5.36E-07
Open fish	0.000323	0.000357	0.0004	0.000251	0.000286	0.000333
Culture fish	0.000375	0.000422	0.000483	0.000172	0.000185	0.0002
Agri production in beels	0.001808	0.001988	0.002208	0.000224	0.00024	0.000258
Cropping intensity	0.006173	0.007042	0.008197	0.00565	0.006452	0.007519
Column sum	1.788861	1.976876	2.210399	1.282278	1.586007	2.334294

Table 5.3.12 : Appropriateness weight of alternatives

	For Non-KJDRP			For KJDRP		
Area under water class	0.01616	0.019464	0.023304	0.02407	0.038446	0.052002
Fish habitat	1.9E-05	2.22E-05	2.57E-05	7.94E-06	1.29E-05	1.77E-05
Area under agriculture class	0.013308	0.015815	0.018643	0.009396	0.014732	0.019501
Cultivable area	4.8E-06	5.79E-06	6.96E-06	3.69E-06	5.83E-06	7.79E-06
Irrigated area	1.72E-05	2.08E-05	2.51E-05	9.23E-06	1.52E-05	2.14E-05

Sediment in-beels	0.411353	0.506073	0.621427	0.161679	0.360295	0.917684
Sediment in rivers	6.75E-06	8.29E-06	1.02E-05	6 16E-05	9.73E-05	0.00013
Trained member	2.71E-05	3.22E-05	3 8E-05	4.65E-05	7.68E-05	0.000108
Labor involvement	0.002155	0 00253	0.002944	0.000156	0 00026	0.000371
Population involvement	0.003099	0.003721	0.004439	0 000567	0.00093	0.0013
Livestock	1.03E-06	1.27E-06	1.55E-06	0.000131	0.000219	0.000315
Salinity	0.043094	0.053271	0.065798	0 055071	0.091512	0 130005
P^H	0.05374	0 068204	0 087116	0.049247	0 080321	0.111433
Dissolved Oxygen	0.037865	0.046217	0 056209	0.063757	0.107597	0 156006
Dry submergence	2.66E-05	3.16E-05	3.73E-05	5.54E-05	9 18E-05	0.00013
Monsoon submergence	8.62E-06	1.04E-05	1.26E-05	1.04E-05	1 75E-05	2.52E-05
Duration of water logging	0.001885	0.0023	0.002796	0.002915	0.004965	0.00729
Depth in the deepest point	0.020804	0 025624	0 031509	0.026253	0.039017	0 048752
Area of water logging	0 000421	0.000513	0.000621	0.001139	0 001865	0.0026
Poverty reduction	0.005656	0 006748	0.00799	0.00691	0.011259	0.015601
Employment	0.00707	0.008578	0 010357	0.004412	0.007418	0 0107
Discharge	0.01414	0.016869	0.019974	0 001785	0 002866	0 0039
Dredging	1 67E-06	2 1E-06	2 66E-06	9.27E-07	1.46E-06	1.94E-06
High water level in river	0.167588	0 210864	0.266326	0 13431	0.225992	0.326373
Post monsoon drainage	0 006961	0.008435	0.010169	0 004558	0.007247	0 00975
Ag land during dry season	1.02E-05	1.28E-05	1.62E-05	1 18E-05	1.89E-05	2.58E-05
Fish production	8E-05	9.81E-05	0.00012	4 45E-05	6 91E-05	9 05E-05
Agricultural production	1 4E-06	1 73E-06	2 13E-06	1.17E-06	1.87E-06	2.54E-06
Crop damage	5 78E-06	6.91E-06	8.19E-06	8.35E-05	0.000138	0 000195
OM Cost	1.13E-08	1.44E-08	1.85E-08	1 9E-07	3.03E-07	4.11E-07
Open fish	0.000146	0.000181	0 000224	0 000107	0.00018	0 00026
Culture fish	0.00017	0 000214	0 00027	7.37E-05	0 000117	0.000156
Agri production in beels	0.000818	0 001006	0.001235	9.59E-05	0.000151	0.000202
Cropping intensity	0.002793	0.003564	0.004584	0 002421	0 004068	0.005865

Calculation:

Appropriate Weight of Area under water class (under Non-KJDR)

= (0.035714/2.210399, 0 038462/1.976876, 0.041667/1.788861)

= (0 01616, 0 019464, 0.023304)

Step-8: *Fuzzy choice Index is then calculated for each criterion.*

The appropriateness weight s of the alternatives based on each criterion or sub-criterion is multiplies with that criterion's or sub criterion's global importance weight, and the composite weights are determined. All such composite weights of each alternative are summed up to get the fuzzy choice index values of the alternatives.

$$FCI = \sum_{i}(\text{Appropriate weight} * \text{Global weight for each criterion})$$

Where i = each criterion

Table 5.3.13(f): The Fuzzy Choice Index of Non- KJDRP

	Global weight			Appropriate weight for Non-KJDRP			FCI for Non-KJDRP		
							Y	Q	Z
Area under water class	0.0063	0 0201	0.06522	0.01616	0.01946	0 02330	0.0001	0.00039	0.00152
Fish habitat	0.00358	0.0113	0.03642	0 00002	0.00002	0.00003	6.8E-08	2 5E-07	9.34E-07
Area under agriculture class	0.00399	0.0126	0 04158	0.01331	0 01581	0 01864	5 3E-05	0 0002	0 000775
Cultivable area	0.00521	0 018	0.06336	0.00000	0 00001	0.00001	2 5E-08	1E-07	4 41E-07
Irrigated area	0.00551	0.0192	0.06827	0.00002	0.00002	0 00003	9.5E-08	4E-07	1 71E-06
Sediment in-beels	0.00707	0 0245	0 085	0 41135	0 50607	0.62143	0.00291	0.01237	0 052819
Sediment in rivers	0 13712	0 0364	0.11793	0 00001	0.00001	0.00001	9.3E-07	3E-07	1.2E-06
Trained member	0.00012	0.0038	0.01133	0.00003	0.00003	0 00004	3 3E-09	1.2E-07	4 31E-07
Labor involvement	0 0065	0.0171	0.04671	0 00215	0.00253	0 00294	1.4E-05	4.3E-05	0.000137
Population involvement	0 01079	0 0293	0 08114	0.00310	0 00372	0 00444	3 3E-05	0 00011	0 00036
Life-stock(,000)	0.00209	0.0052	0.01388	0.00000	0.00000	0.00000	2 1E-09	6.6E-09	2.16E-08
Salinity	0 01061	0.0321	0.09446	0 04309	0.05327	0 06580	0.00046	0 00171	0 006215
P^H	0 00401	0.0121	0 03591	0.05374	0 06820	0.08712	0.00022	0 00083	0 003128
Dissolved Oxygen	0.00499	0 0148	0.04458	0 03787	0 04622	0.05621	0 00019	0 00068	0.002506
Dry submergence	0.00331	0.0101	0.02883	0 00003	0 00003	0.00004	8 8E-08	3.2E-07	1.07E-06
Monsoon submergence	0.00897	0 0279	0 08662	0.00001	0 00001	0.00001	7 7E-08	2.9E-07	1.09E-06
Duration of water logging	0.01772	0.0567	0 17457	0.00189	0 00230	0.00280	3.3E-05	0 00013	0.000488
Depth in the deepest point	0.00832	0 0272	0 0896	0.02080	0.02562	0 03151	0.00017	0.0007	0.002823
Area of water logging	0.01534	0.0506	0.16201	0.00042	0.00051	0 00062	6.5E-06	2 6E-05	0.000101
Poverty	0.0161	0.059	0.21345	0.00566	0.00675	0.00799	9.1E-05	0.0004	0.001705

Employment	0.01139	0 0491	0.21345	0.00707	0.00858	0.01036	8E-05	0.00042	0.002211
Discharge	0.02339	0.0655	0.18993	0.01414	0.01687	0.01997	0.00033	0 0011	0.003794
Dredging	0.00587	0.0182	0.06409	0.00000	0.00000	0.00000	9 8E-09	3.8E-08	1.7E-07
High water level in river	0.02076	0.0651	0.20832	0 16759	0.21086	0.26633	0 00348	0.01372	0.055482
Post monsoon drainage	0 00896	0.0284	0.09605	0.00696	0.00843	0 01017	6.2E-05	0.00024	0.000977
Area reclaimed during dry season	0 00564	0 0171	0.05327	0.00001	0 00001	0.00002	5.7E-08	2.2E-07	8.64E-07
Fish production	0 00769	0.0297	0.11149	0.00008	0 00010	0 00012	6.2E-07	2 9E-06	1.34E-05
Agricultural production	0 01027	0.0357	0.11812	0.00000	0.00000	0.00000	1.4E-08	6.2E-08	2.51E-07
Crop damage	0.00685	0 0271	0.10523	0.00001	0 00001	0 00001	4E-08	1 9E-07	8.62E-07
OM Cost	0.01786	0.0669	0.23292	0.00000	0 00000	0 00000	2E-10	9.6E-10	4.32E-09
Open fish	0.00142	0.0074	0.04118	0.00015	0 00018	0 00022	2.1E-07	1.3E-06	9 21E-06
Culture fish	0 00402	0.0223	0.11649	0.00017	0.00021	0.00027	6.8E-07	4.8E-06	3.15E-05
Agri production in beels	0 026	0.0815	0 24831	0 00082	0.00101	0 00123	2 1E-05	8 2E-05	0 000307
Cropping intensity	0.02165	0.0688	0.20676	0.00279	0.00356	0.00458	6E-05	0.00025	0 000948
						Column sum	**0.00831**	**0.03342**	**0.136359**

Table-5.3.13(b) The Fuzzy Choice Index of KJDRP

	Global weight			**Appropriate weight for KJDRP**			**FCI for KJDRP**		
							Y	Q	Z
Area under water class	0 0063	0.02007	0 06522	0.02407	0 03845	0.052	0 000152	0 0008	0 00339
Fish habitat	0 00358	0.01125	0.03642	7.9E-06	1.3E-05	1.8E-05	2 84E-08	1E-07	6.5E-07
Area under agriculture class	0 00399	0 01261	0 04158	0.0094	0.01473	0 0195	3 75E-05	0.0002	0.00081
Cultivable area	0.00521	0 01799	0.06336	3.7E-06	5.8E-06	7 8E-06	1.92E-08	1E-07	4 9E-07
Irrigated area	0 00551	0.01924	0.06827	9 2E-06	1.5E-05	2.1E-05	5.09E-08	3E-07	1 5E-06
Sediment in-beels	0 00707	0.02445	0.085	0.16168	0.3603	0.91768	0 001142	0.0088	0.078
Sediment in rivers	0.13712	0 03642	0.11793	6.2E-05	9.7E-05	0.00013	8 44E-06	4E-06	1.5E-05
Trained member	0 00012	0.00383	0.01133	4.7E-05	7.7E-05	0.00011	5.63E-09	3E-07	1.2E-06
Labor involvement	0 0065	0.01711	0.04671	0.00016	0.00026	0.00037	1.01E-06	4E-06	1.7E-05
Population involvement	0 01079	0.02925	0.08114	0.00057	0.00093	0.0013	6.11E-06	3E-05	0.0001
Livestock(,000)	0.00209	0 00523	0.01388	0.00013	0.00022	0.00031	2 72E-07	1E-06	4.4E-06
Salinity	0 01061	0.03211	0.09446	0.05507	0.09151	0.13001	0.000584	0.0029	0.01228
p^H	0.00401	0.0121	0.03591	0 04925	0.08032	0.11143	0 000198	0.001	0.004

Dissolved Oxygen	0.00499	0.0148	0.04458	0.06376	0.1076	0.15601	0.000318	0.0016	0.006
Dry submergence	0.00331	0.01015	0.02883	5.5E-05	9.2E-05	0.00013	1.83E-07	9E-07	3.7E-
Monsoon submergence	0.00897	0.0279	0.08662	1E-05	1.8E-05	2.5E-05	9.37E-08	5E-07	2.2E-
Duration of water logging	0.01772	0 05668	0.17457	0.00291	0.00496	0.00729	5.17E-05	0.0003	0.0012
Depth in the deepest point	0 00832	0.02722	0.0896	0.02625	0.03902	0.04875	0.000218	0.0011	0.0043
Area of water logging	0.01534	0.05063	0.16201	0.00114	0.00187	0.0026	1.75E-05	9E-05	0.0004
Poverty	0.0161	0.05898	0 21345	0.00691	0 01126	0.0156	0 000111	0.0007	0.0033
Employment	0.01139	0.04911	0 21345	0.00441	0.00742	0.0107	5 02E-05	0.0004	0.0022
Discharge	0.02339	0.06546	0 18993	0.00179	0.00287	0 0039	4.18E-05	0.0002	0.0007
Dredging	0 00587	0.01822	0.06409	9.3E-07	1.5E-06	1 9E-06	5 44E-09	3E-08	1 2E-0
High water level in river	0.02076	0.06509	0.20832	0.13431	0 22599	0 32637	0.002788	0.0147	0.0679
Post monsoon drainage	0.00896	0.0284	0.09605	0 00456	0.00725	0.00975	4 09E-05	0.0002	0.0009
Area reclaimed during dry season	0.00564	0 01709	0.05327	1 2E-05	1.9E-05	2.6E-05	6.66E-08	3E-07	1.4E-0
Fish production	0 00769	0 02973	0 11149	4.5E-05	6.9E-05	9E-05	3 42E-07	2E-06	1E-05
Agricultural production	0.01027	0 03571	0 11812	1.2E-06	1.9E-06	2.5E-06	1 2E-08	7E-08	3E-07
Crop damage	0.00685	0.02713	0.10523	8.3E-05	0 00014	0.0002	5 72E-07	4E-06	2 1E-0
OM Cost	0.01786	0.06691	0.23292	1 9E-07	3E-07	4.1E-07	3 39E-09	2E-08	9 6E-0
Open fish	0.00142	0 00743	0 04118	0.00011	0.00018	0 00026	1.53E-07	1E-06	1.1E-0
Culture fish	0 00402	0 0223	0.11649	7 4E-05	0 00012	0.00016	2 96E-07	3E-06	1.8E-0
Agri production in beels	0 026	0 08153	0.24831	9.6E-05	0 00015	0 0002	2.49E-06	1E-05	5E-05
Cropping intensity	0.02165	0.06877	0.20676	0.00242	0 00407	0.00586	5 34E-05	0 0003	0 0012
					Column sum		**0.005824**	**0.0332**	**0.1882**

Calculations:

Fuzzy Choice Index of criteria area under water class (under Non-KJDRP)

Appropriate Weight* Global Weight

= (0.006295387, 0.020067, 0.06522)*(0.01616, 0.019464, 0.023304)

= (0.000102, 0.000391, 0.00152)

Table-5.3.14 Combination of a and b)

The Fuzzy Choice Index of Alternatives (for sub-criteria)

	FCI for Non-KJDRP			FCI for KJDRP		
	Y	Q	Z	Y	Q	Z
Area under water class	0.000102	0.0004	0.00151985	0.000152	0.000771	0.003392
Fish habitat	6.81E-08	2E-07	9.34471E-07	2.84E-08	1.45E-07	6.46E-07
Area under agriculture class	5.32E-05	0.0002	0.000775193	3.75E-05	0.000186	0.000811

Cultivable area	2.5E-08	1E-07	4.41029E-07	1.92E-08	1 05E-07	4.94E-07
Irrigated area	9.49E-08	4E-07	1.71271E-06	5.09E-08	2.93E-07	1.46E-06
Sediment in-beels	0.002907	0.0124	0.052818629	0.001142	0.00881	0.077999
Sediment in rivers	9.25E-07	3E-07	1.1977E-06	8.44E-06	3.54E-06	1 53E-05
Trained member	3.28E-09	1E-07	4 30825E-07	5.63E-09	2 94E-07	1 23E-06
Labor involvement	1 4E-05	4E-05	0 000137499	1.01E-06	4.45E-06	1 74E-05
Population involvement	3.34E-05	0.0001	0.000360165	6 11E-06	2 72E-05	0.000105
Life-stock(,000)	2 14E-09	7E-09	2 15668E-08	2.72E-07	1.15E-06	4 37E-06
Salinity	0.000457	0 0017	0 006215337	0 000584	0 002938	0.01228
P^H	0.000216	0.0008	0.003127973	0 000198	0.000972	0.004001
Dissolved Oxygen	0 000189	0.0007	0 00250579	0.000318	0 001592	0.006955
Dry submergence	8 81E-08	3E-07	1.07484E-06	1.83E-07	9.32E-07	3 75E-06
Monsoon submergence	7.73E-08	3E-07	1.08842E-06	9.37E-08	4 89E-07	2 18E-06
Duration of water logging	3.34E-05	0.0001	0.000488174	5.17E-05	0 000281	0.001273
Depth in the deepest point	0.000173	0.0007	0.002823129	0.000218	0 001062	0.004368
Area of water logging	6 46E-06	3E-05	0.000100679	1.75E-05	9.44E-05	0.000421
Poverty	9 11E-05	0.0004	0.001705414	0 000111	0 000664	0.00333
Employment	8.05E-05	0.0004	0.002210722	5 02E-05	0.000364	0 002284
Discharge	0 000331	0.0011	0.003793812	4.18E-05	0.000188	0 000741
Dredging	9.82E-09	4E-08	1 70283E-07	5 44E-09	2.66E-08	1.24E-07
High water level in river	0 003478	0.0137	0 055481969	0 002788	0.014709	0 067991
Post monsoon drainage	6 24E-05	0.0002	0.000976698	4.09E-05	0 000206	0.000937
Area reclaimed during dry season	5.74E-08	2E-07	8.63635E-07	(6.66E-08, 3 24E-07, 1 37E-06)		
Fish production	6.15E-07	3E-06	1.33868E-05	3.42E-07	2 06E-06	1 01E-05
Agricultural production	1.44E-08	6E-08	2.51126E-07	1.2E-08	6 69E-08	3E-07
Crop damage	3.96E-08	2E-07	8.62257E-07	5.72E-07	3 75E-06	2.05E-05
OM Cost	2.01E-10	1E-09	4.31547E-09	3.39E-09	2.03E-08	9.56E-08
Open fish	2.07E-07	1E-06	9 21363E-06	1 53E-07	1.34E-06	1.07E-05
Culture fish	6.81E-07	5E-06	3.14888E-05	2 96E-07	2 6E-06	1 82E-05
Agri production in beels	2.13E-05	8E-05	0.000306571	2 49E-06	1 23E-05	5.01E-05
Cropping intensity	6.05E-05	0.0002	0 000947871	5.34E-05	0 00028	0.001213
Sum	**0.008312**	**0.0334**	**0.136358617**	**0.005824**	**0.033179**	**0.188258**

Table 5.3.15: FCI of Alternatives

	Y	Q	Z
KJDRP	**0.005824**	**0.033178723**	**0.188258**
Non-KJDRP	**0.008312**	**0.033415508**	**0.136359**

Step-9: By using Kim and Park method, ranking of Fuzzy Choice Index is made. The ranks represent the final preference order of alternatives.

Using the Kim and Park method, FCI are ranked and the ranking values of alternatives are calculated according to the following procedure.

$$\text{Ranking value } U_T(F_i) \cong \frac{1}{2}\left[\left[\frac{(Z_i - x_1)}{(x_2 - x_1 - Q_i + Z_i)}\right] + \left[1 - \frac{(x_2 - Y_i)}{(x_2 - x_1 + Q_i - Y_i)}\right]\right]$$

Where F_i is fuzzy choice index of alternative A_i

$(F_i) \cong (Y_i, Q_i, Z_i)$ for i = 1, 2, 3, ...m

Where

$x_1 = \min.\{Y_1, Y_2 \ldots, Y_m\}$

$x_2 = \max.\{Z_1, Z_2 \ldots, Z_m\}$

Preferential Weights Calculation: The preferential weights of alternatives based on each expert's opinions are calculated as follows.

Preferential Weights = $U_T(F_i)/[U_T(F_1) + U_T(F_2) + \ldots\ldots\ldots\ldots + U_T(F_n)$

Table-5.3.16: Ranking Values, Preferential Weights and Preferential Ranks of Alternatives

	Y	Q	Z	Ranking Value	Preferential Weight	Preferential Rank
FCI for KJDRP	0.0058	0.0331	0.1882	0.3354	0.5319	1
FCI for Non- KJDRP	0.0083	0.0334	0.1363	0.2951	0.4680	2
	Sum			0.6305		

Calculation:

Ranking value for KJDRP

$$=1/2[[\frac{(0.188258 - 0.005824)}{(0.188258 - 0.005824 - 0.033178723 + 0.188258)}$$

$$+[1 - \frac{(0.188258 - 0.005824)}{0.188258 - 0.005824 + 0.033178723 - 0.005824}]]$$

x_1 = **0.005824**

X_2 = **0.188258**

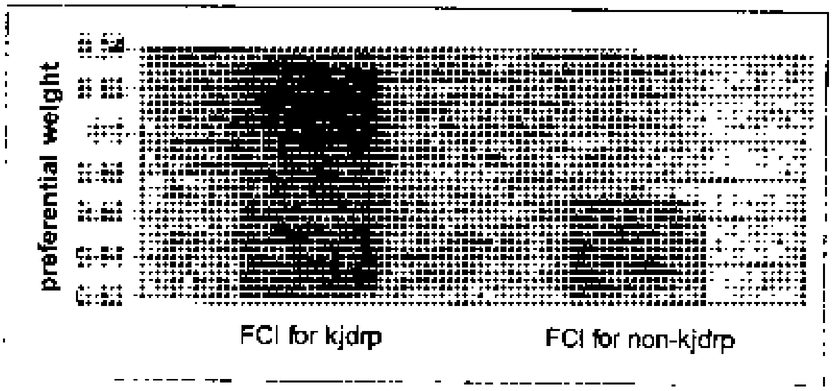


Figure 5.3.2 Score of KJDRP and Non-KJDRP in Fuzzy Method

5.4 Analysis 3:

5.4.1 Field Survey and FGD

In the field survey method, some opened end and closed end questions were formed which is given in Appendix A. The performance of the project is then justified by the respondents. The questionnaire is grouped into two categories, subjective, and objective type. Closed end questions remain in objective type categories. Weightage was given to each objective type question on judgment basis. The highest range of weightage was given using the following formula:

The highest scale is determined as [highest range of values for each question]* [total no of questions asked to the respondent]* [no of respondents].

Highest range of values for each question =3

Total no of questions asked to the respondent =16

No of respondents = 85.

Thus highest scale is determined as 3*16*85 = (+)4080

Table-5.4.1 Critical Factors (with Numerical Value) used in Questionnaire (R' for Respondent)

Ques. No	Factors	R1	R2	R3	R4	R5	R6	R7	R8		R85	Row total
1	Ag productivity	3	3	3	2	2	2	2	3	----------	3	217
2	Salinity	3	-1	-1	-2	1	-1	-3	-1	----------	-1	-30
3	Fertility	0	2	3	3	0	2	2	1	----------	2	123
4	Water logging	2	3	2	2	3	2	3	3	----------	2	195
5	Fish Availability	3	3	2	2	-2	2	2	2	----------	2	177
6	Increase of saline fish	0	2	2	3	0		2	1	----------	1	84
7	Emergence of new crops	3	3	3	3	-3	3	-3	3	----------	3	57
8	Flood intensity	0	0	2	2	2	1	1	2	----------	1.5	51
9	Drinking water availability	2	2	2	2	2	2	0	0	----------	2	85
10	Employment generation	3	3	2	2	2	2	3	3	----------	2	201
11	Change in land value	3	3	3	3	3	3	3	3	----------	3	183
12	Water transport facility	3	3	2	2	2	3	2	2	----------	2	190
13	Land transport facility	0	3	3	3	3	3	3	3	----------	3	174
14	Impact on environment	3	3	2	2	2	2	2	2	----------	3	187
15	Poverty alleviation	3	3	2	2	2	1	2	3		1	197
16	Role played	3	2	2	2	2	2	2	3		1	120
											Column Total	2211

Again, the lowest scale is determined as [lowest range of values for each question]* [total no of questions asked to the respondent]* [no of respondents]. The positive score indicates the positive performance of KJDRP project.

Lowest range of values for each question = -3

Total no of questions asked to the respondent =16

No of respondents =85].

Again, the lowest scale is determined as -3*16*85 = (-)4080

CHAPTER SIX

RESULT AND DISCUSSION

6.1 Introduction

The choice of technology is generally based on a techno-economic feasibility study. The scenario at the local, as well as at global level is changing, and that necessitates the consideration of factors, such as environmental and social, in addition to the techno-economic factors. This leads to a multi-criteria decision making (MCDM) situation. Analytical Hierarchy Process (AHP) and Fuzzy Hierarchy Decision Making (FHDM) method can be mentioned in this regard.

The Analytic Hierarchy Process has a neat way to estimate a so-called inconsistency index for each comparison matrix. However, AHP method has certain limitations- the biggest disadvantage of using the analytic hierarchy process is that the number of comparison tables can become very large if one use a lot of comparison attributes. This can lead to a tendency to exclude valid comparison attributes in order to keep the number of calculations manageable. Another disadvantage of the analytic hierarchy's subjective scale is that it is vulnerable to human psychology—there is a tendency to want to see improvement in builds and so one must be careful not to subconsciously inflate rankings of more recent builds. As always, the final metrics will be as good as the input data

Fuzzy Hierarchical Decision Making (FHDM) method synthesizes the concepts of MCDM methodology and fuzzy analysis. A fuzzy concept is a concept of which the content, value, or boundaries of application can vary according to context or conditions, instead of being fixed once and for all. The analysis here involves the experts' judgments and non-availability of exact data on technologies that necessitate the use of fuzzy analysis. The origin of fuzzy concepts is partly due to the fact that the human brain does not operate like a computer, i.e. it is capable of making all kinds of neural associations according to all kinds of ordering principles in patterns which are not logical, but nevertheless meaningful. Something can be meaningful although one cannot name it, or one might only be able to name it and nothing else.FHDM can be used to analyze technologies in any country or location by inputting the pertinent data.

6.2 Score Found for Option KJDRP and Non-KJDRP in Different Methods

a) AHP Method

Table-6.1 AHP data

Factor/Criteria	Priority Vector (PV)	Real Incremental value (in %)	Sign on judgment basis	Real Priority Vector (PV. * Incremental Value)
Resources	0.205			0.205
Population	0.072			0.072
Environment	0.247			0.247
Socio-cultural	0.065			0.065
Technology	0 252			0.252
Economic	0 136			0 136
Area under water class	0 100	-36.923	36.923	3.707
Fish habitat	0.106	114 842	114.84	12.193
Area under agriculture class	0 087	33.75	33 75	2.942
Cultivable area	0.143	23 779	23 779	3.414
Irrigated area	0 091	70.452	70 452	6.445
Sediment in beels	0.200	73.597	73 597	14 742
Sediment in rivers	0.205	-89.389	89 389	18 324
Trained member	0.049	-47 746	-47.746	-2.373
Labor involvement	0.462	1111 75	1111 75	514 285
Population involvement	0.462	398.529	398 529	184.356
Livestock	0 073	619.937	619 937	45 830
Salinity	0 084	-24.21	24.21	2.057
P^H	0.040	5.795	5 795	0.235
Dissolved Oxygen	0 063	-46 484	-46 484	-2 928
Dry submergence	0 030	-57.083	57 083	1.751
Monsoon submergence	0.119	-25.773	25 773	3.088
Duration of water logging	0.245	-42.404	42 4	10.414
Depth in the deepest point	0.124	-18.164	18.164	2 263
Area of water logging	0.248	-65.686	65.68	16.306
Poverty	0.5	-25.333	25 33	12.665
Employment	0.5	43.921	43.921	21 960
Discharge	0 212	190	190	40 459
Dredging	0.0761	79.729	-79.729	-6.070

High water level in river	0.390	16.354	16.354	6 379
Post monsoon drainage	0.195	45.666	45.666	8.924
Ag land during dry season	0 091	-15 731	-15.731	-1.443
Fish production	0.099	76.866	76.866	7.663
Agricultural production	0.184	41 979	41 979	7.745
Crop damage	0.166	-93.767	93.76	15.642
OM Cost	0 527	-94 088	94.088	49.644
Open fish	0.25	24.842	24 842	6.210
Culture fish	0.75	128 276	128.276	96.207
Agri production in beels	0 702	727.473	727.473	511 312
Cropping intensity	0.240	9.00	9 001	2 163

Table-6.2 AHP Score

	Resource	*Socio culture*	*Environment*	*Economic*	*Population*	*Technology*	*TOT*
Score KJDRP	9.3949	1 8930	6 8999	523.794	44.387	10.4849	**596.**
Score of Non-KJDRP	2 1793	0.3637	1.2922	158.6242	9.2578	1.5336	**173.**

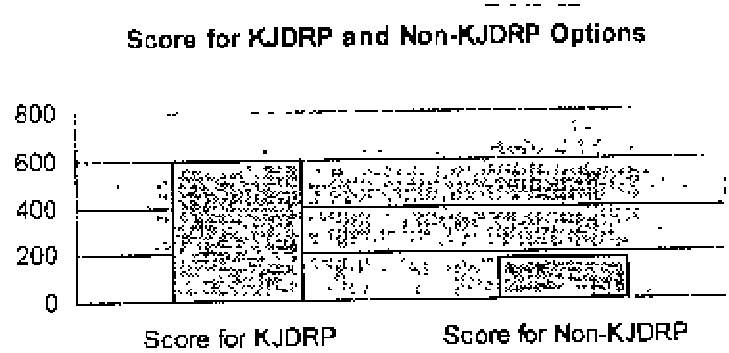


Figure-6.1 Score of KJDRP and Non-KJDRP in AHP Method

- From AHP method, it is seen that the total score for KJDRP is 596 where score for Non-KJDRP is 173. Thus, in AHP method, KJDRP got 1st ranking value and Non-KJDRP got 2nd ranking value.
- From the table 6.1, it is seen that the criteria under Economic factor got significant value. This is because the real performance value of Ag. production in beel, culture fish

production, O&M cost and crop damage was very high. It means that under KJDRP option, these criteria shown significant improvements, and ultimately the economic factor got the highest score comparative to other.

- Second higher score is found in population factor. This is due to real performance of labor and population involvement under KJDRP option. So, it can be concluded that under KJDRP option, employment opportunity was far more than Non-KJDRP option and people get benefited from KJDRP option. This can be cross checked by seeing the performance value of employment criteria under socio-economic factor.
- Third higher score is found in technology factor. And it is obvious that this score is ten times more than Non-KJDRP. This is due to incremental discharge performance under KJDRP option.
- Again, it is seen that some criteria got negative value depending on performance under this option. eg, no. of trained member, dredging etc. Before initiation of the project, huge people were trained in pre project condition, so it got negative value in post project condition. In post project condition, huge amount of dredging were required to start functioning of the project, and for that it got negative value in KJDRP option.

b) FHDM Method

Table-6.3 Fuzzy Choice Index (FCI) of KJDRP and Non-KJDRP

	Y	Q	Z	Ranking value	Preferential weight	Rank
FCI for KJDRP	0.0058	0.033	0.188	0 335457593	0.531935362	1
FCI for Non-KJDRP	0.0083	0.033	0.136	0.295178415	0 468064638	2
			Sum	0.630636008		

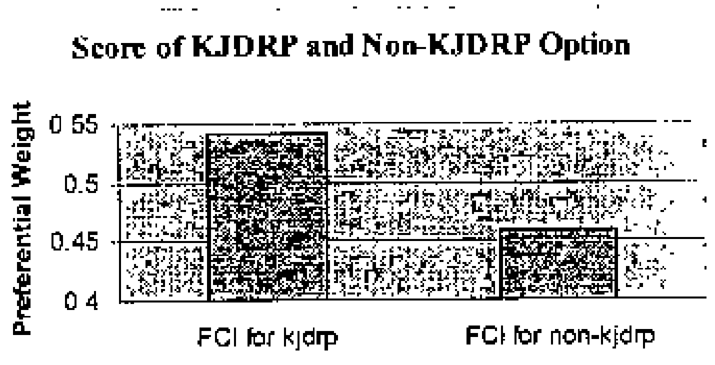


Figure-6.2 Score of KJDRP and Non-KJDRP in Fuzzy Method

In Fuzzy method, it is seen that KJDRP option scored 1st in preferential ranking value where Non-KJDRP option scored 2nd ranking value.

c) **Field Survey (FS) and Focus Group Discussion (FGD)**

Performance score found from the field survey [Limit from +4080 to –4080]

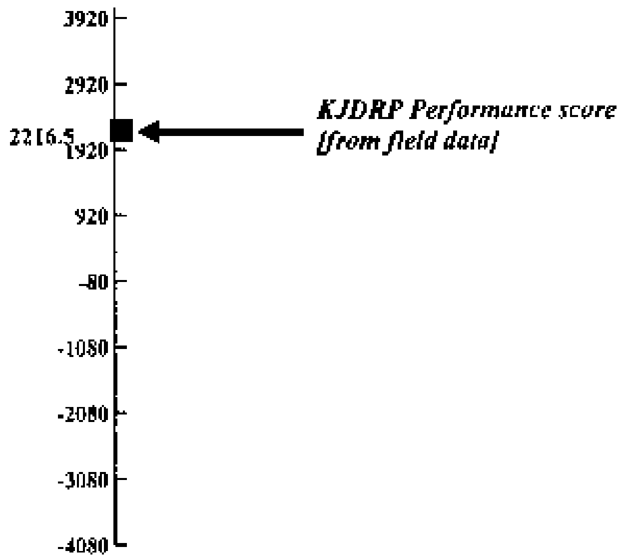


Figure-6.3 Performance Score Obtained from Field Survey

From Focus Group Discussion (FGD) and Field Survey, it is evident that the performance of criteria under KJDRP option is positive and it scored 2216.5 in the scale range from (-) 4080 to (+) 4080 where the highest and lowest range of values were determined in 5.3.1

Remark:

From the above analysis, one thing is getting clear that KJDRP option get preference over non-KJDRP option. And the score tell of the truth. Thus, from the perspective of Technological Assessment, KJDRP was appropriate for that very condition.

6.3 Comparison of Ranking value of 1st Order Criteria in Two Different Methods

Ranking value in AHP method is based on preferential weight found from Expert's opinion, whereas in Fuzzy method, ranking value is calculated on the basis of global weight found from Expert's opinion.

In both AHP and Fuzzy method, the ranking value found from Expert's opinion is similar. In AHP method, Technology factor ranked 1st whereas the same factor ranked 2nd in Fuzzy method. In AHP method, Environment factor ranked 2nd where it ranked 1st in Fuzzy method.

In both methods, Economic criteria got 3rd to 4th ranking value, but due to its real performance value, it shows significant score in AHP method (Table-6.2).

a) **AHP Method**

Table-6.4 Priority Vector for Different Criteria

1st order criteria	Priority vector	Rank
Technology	0.252831823	1
Environment	0.247665043	2
Resources	0 205020689	3
Economic	0.1360618	4
Population	0 072243458	5
Socio-cultural	0 065214498	6

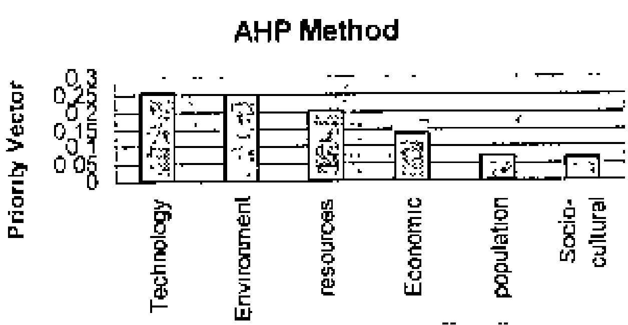


Figure-6.4 Priority Vectors of 1st Order Criteria under AHP Method

b) **FHDM Method**

Table-6.5 FHDM Method: Global Weight and Preferential Weight

	Global weight			Preferential weight	Rank
1st order criteria	Y	Q	Z		
Environment	0.14236923	0.251773	0.434846	0 073365002	1
Technology	0.11940911	0 211544	0 391077	0.064351427	2
Economic	0.08249733	0.173277	0 344118	0.054565525	3
Resources	0.08303892	0.153676	0.28739	0.04817811	4
Socio-cultural	0 05795396	0.108979	0.206489	0.034088174	5
Population	0.03180108	0.054867	0 098053	0 013307968	6

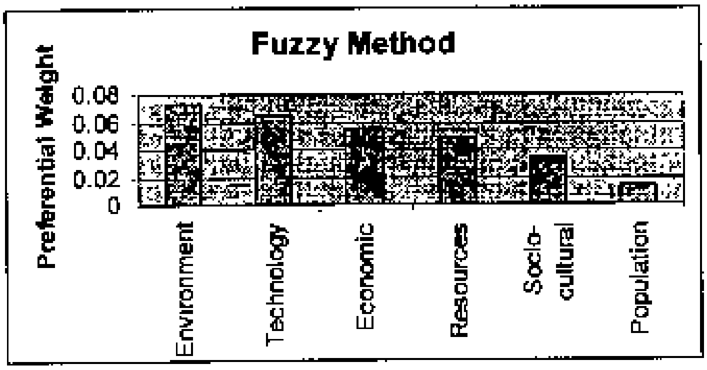


Figure-6.5 Preferential Weight of 1st Order Criteria under Fuzzy Method

6.4 Comparison of Ranking Value of 2nd & 3rd Order Criteria in Two Different Methods

a) AHP Method

In AHP method, culture fish ranked 1st whereas in Fuzzy method, open fish ranked 1st. The 2nd and 3rd ranking is same in both method, i.e. Ag. Production in beels and O&M criteria. In Fuzzy method, discharge scored 6th position whereas 10th in AHP method. Again croping intensity scored 4th position in Fuzzy method whereas 12th in AHP method. Duration of water logging scored almost similar position in two methods.

Table-6.6 AHP Method: Priority Vectors of 2nd and 3rd Order Criteria

2nd & 3rd order criteria	Priority vector	Rank
Culture fish	0.75	1
Agri production in beels	0 702	2
O&M Cost	0.527	3
Poverty reduction	0.5	4
Employment	0.5	5
Labor involvement	0 462	6
Population involvement	0.462	7
High water level in river	0.390	8
Open fish	0 25	9
Area of water logging	0.248	10
Duration of water logging	0.245	11
Cropping intensity	0.240	12
Discharge	0 212	13
Sediment in rivers	0 205	14

Sediment in beels	0.200	15
Post monsoon drainage	0.195	16
Agricultural production	0.184	17
Crop damage	0.166	18
Cultivable area	0 143	19
Depth in the deepest point	0.124	20
Monsoon submergence	0.119	21
Fish habitat	0 106	22
Area under water class	0.100	23
Fish production	0.099	24
Ag land during dry season	0.091	25
Irrigated area	0 091	26
Area under agriculture class	0.087	27
Salinity	0.084	28
Dredging	0.076	29
Livestock	0 073	30
Dissolved Oxygen	0 063	31
Trained member	0 049	32
P^H	0.040	33
Dry submergence	0 030	34

b) FHDM Method

Table-6.7 FHDM Method: Priority Vectors of 2nd and 3rd Order Criteria

2nd & 3rd order criteria	Preferential weight	Rank
Open fish	0 075	1
Agri production in beels	0 056	2
O&M Cost	0.051	3
Cropping intensity	0 050	4
High water level in river	0.049	5
Discharge	0.048	6
Poverty	0.048	7
Employment	0 045	8
Duration of water logging	0.044	9
Area of water logging	0.041	10
Sediment in rivers	0.039	11
Agricultural production	0 031	12
Fish production	0.029	13
Culture fish	0.027	14
Crop damage	0 027	15

Salinity	0.027	16
Post monsoon drainage	0.026	17
Depth in the deepest point	0.025	18
Monsoon submergence	0.025	19
Population involvement	0.024	20
Sediment in-beels	0.024	21
Irrigated area	0.019	22
Area under water class	0 019	23
Dredging	0.018	24
Cultivable area	0.018	25
Area reclaimed during dry season	0 016	26
Labor involvement	0.015	27
Dissolved Oxygen	0 014	28
Area under agriculture class	0.013	29
P^H	0 011	30
Fish habitat	0.011	31
Dry submergence	0.009	32
Livestock (,000)	0.004	33
Trained member	0.003	34

6.5 Score Found for Option TRM and Non-TRM in AHP Method

Table-6.8 AHP Score for TRM and Non-TRM

	Resource	*Socio-culture*	*Environment*	*Economic*	*Population*	*Technology*	TOTAL
Score for TRM	0.1689	0.0543	0.1971	0 1039	0 0541	0 1915	**0.77006**
Score for Non-TRM	0.0327	0 0108	0 0400	0.0277	0.0180	0.0527	**0.18229**

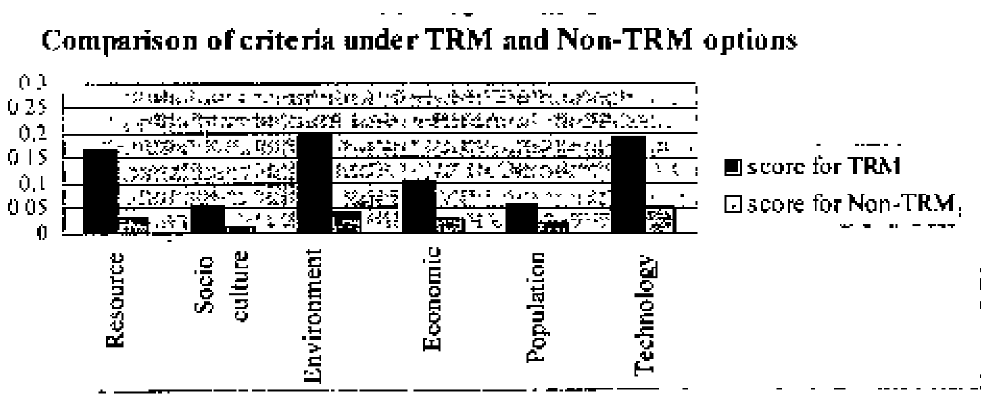


Figure 6.6 : Comparison of criteria under of TRM and Non-TRM Options

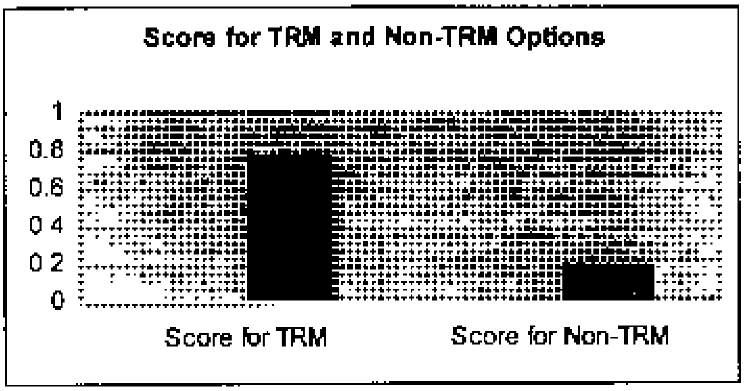


Figure-6.7 Score for TRM and Non-TRM Option

In case of TRM and Non-TRM options, the real performance value was not considered. Real performance value due to TRM option was not fully available. Thus, only priority vector from different experts' opinions were considered. However, in all respects, TRM option got priority over Non-TRM option.

6.5 Observation

The public cut along Hari river into Beel Bhaina on 29 September 1997 provided an opportunity to explore the effectiveness of the tidal basin approach. The Tidal River Management (TRM) in Beel Bhaina improved the width and depth of the Hari river downstream of the public cut and promoted the sediment deposition in the basin. That did not necessitate dredging of the river for the last four and a half years. The fisheries became a profitable business in the first two years. The intensity of sediment deposition and the fishing activity were gradually reducing. It was expected that the TRM would have little benefit seize to provide any further benefit in the coming years. It was therefore felt that TRM in another basin would have to be started forthwith for accruing benefit to Beel Bhaina TRM in order to keep the sustainability of the Hari River.

Beel Kedaria Tidal basin (BKTB) for TRM was implemented in accordance with the recommendation of Hydraulic modelling and EIA studies and was brought under operation on 31st January 2002. During (2002-2004) the effective operation of this tidal basin the proper drainage capacity of the Hari river was maintained and consequently there was no drainage congestion in the project area.

Beel Kedaria's function as a tidal basin was stopped by the local people for crop cultivation in the beel and as a consequence severe siltation took place during 2005. Severe sedimentation took place in the upper reach of the Teka-Hari-Teligati (from Bhabodaha to Solgati) during March/May 2005 due to non-functioning of beel Kedaria TRM. Depth of siltation up to 18th April 2005 at immediate downstream of Bhabadaha Regulator, Chechuri & Ranai is about 3.5m, 2.74m and 1.00m respectively.

KJDRP was successful in the respect of its objectives, but still there are some opinions from some of the experts who think that TRM as a part of KJDRP is not appropriate technology. According to them. it is useless to enlighten a village by throwing the remaining village in darkness. Why the people of the beel area will be deprived for three years during the operation period of the beels, and who will provide their compensation for that time period? And what if there will be no tidal basin available to sustain the TRM option after 25 years?

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

KJDRP project has been chosen as a case study to find out what type of technologies has been used in the project and how was the performance. Then by applying AHP and FHDM method, quantitative analysis has been made to find out the appropriate choice of technology.

The result of technology assessment should generally provide a direction for the policy planners to formulate appropriate strategies of technology development or acquisition. There are a number of government and private bodies which are concerned with this activity, such as highest political authority national planning agency, national science and technology councils, research and development institutions, management and technical consultants, etc. these bodies are the ones to benefit most from the results of the technology assessment. The decision support tools for technology assessment may be used at appropriate levels of activities.

- However, AHP method in the current research paper shows that the total score for KJDRP is 596 where score for Non-KJDRP is 173. Thus, in AHP method, KJDRP got 1st ranking value and Non-KJDRP got 2nd ranking value.
- In Fuzzy method, it is seen that KJDRP option scored 1st in preferential ranking value where Non-KJDRP option scored 2nd ranking value.
- From Focus Group Discussion (FGD) and Field Survey, it is evident that the performance of criteria under KJDRP option is positive and it scored 2216.5 in the scale range from (-) 4080 to (+) 4080

- From three analytical points of views, KJDRP got highest values which indicates that KJDRP with its performance was appropriate to reduce the existing water logging problem and to encourage the socio-economic development of the project area. KJDRP was successful in this respect, but still it has some limitations. It did not consider some ecological consequences.

KJDRP deals with two technical alternatives, regulator option and TRM option. The regulator option will have some limitations. The major regulator will have a very significant impact on the upstream hydrology, tidal movement will halt and salinity will decrease, thereby transforming the upstream dynamic saline water river system into mostly slow moving or stagnant fresh water bodies, although fresh water run-off and flow to downstream areas will remain. What are the consequences on plant and animal life in particular fish on which the local population depend? Will proliferous water weeds such as Water Hyacinth, already present in the project area, clog water courses, thereby creating adverse conditions for other aquatic life. Again with the ceasing of daily tidal flushing of upstream watercourses, what will be the effect of poor sanitary facilities, fertilizer and pesticide run-off from agriculture lands and discharges from aquatic pond on the water quality. Will uncontrolled use lead to channels becoming a sink for such substances?

On the other hand, there are some opinions against TRM option from some of the experts who think that TRM as a part of KJDRP is not appropriate technology. According to them, it is useless to enlighten a village by throwing the remaining village in darkness. Why the people of the beel area will be deprived for three years during the operation period of the beels, and who will provide their compensation for that time period?. TRM in each basin may keep the river system sustainable for at least three years. Thus sustainability of the river may be maintained for at least 25 years. But what if there will be no tidal basin available to sustain the TRM option after 25 years?

Construction of one permanent tidal basin on each of Hari river and Upper Bhadra River may be a solution of the potential problem. These two basins would increase the sustainability of the temporary rotating basins and reduce the risk of failure of the TRM option as suggested in section 3.1.9.

Another proposal as suggested under option-3 in section 2.3.1 may be establishment of regulator in Madhukhali or further downstream rather than the narrow channel will be effective as it joins the large river and will prevent siltation due to huge flow of water. Because, establishment of regulator in the narrow channel must result in failure due to lower velocity of the water and siltation caused by it. Along with the proposal, Hari river can join Dakatia river through a canal networking and thus drainage from Hari river is possible through Sholmari regulator. The technology used in KJDRP didn't consider the importance of wetland. But wetland is very crucial for sustenance of the ecosystem of fisheries. So what is needed is to proper management of the wetland. Regulator in Madhukhali can be a better option, as it will prevent saline water intrusion during tidal period when the gate is closed, on the other hand, it will drain excess river water during monsoon, and thus will remove the drainage problem and at the same time, will maintain minimum water for sustenance of the wetland. Implementation of this option may require high initial cost due to dredging requirement, but still it seems minimum when compared with the huge cost involved due to operation of TRM in a single beel. Appropriateness of this option may be determined by another research work

However. the project is now complete with achievements more than the target. Its success depends on sustainable O & M of the project facilities. Thus in the present analysis. it is successful and appropriate with the target fixed by it.

7.2 Recommendations

Based on the experiences on TRM in Beel Bhaina, it is recommended that in order to restore and maintain proper drainage capacity of the Hari river, it is essential to bring under operation a new beel as a tidal basin from beginning of March 2006 as a part of the TRM strategy. TRM in each basin may keep the river system sustainable for at least three years. Thus sustainability of the river may be maintained for at least 25 years. Some other recommendations for revival of Hamkura-Bhadra river system are as follows:

1. Action is required to be taken for restoration of the Hamkura river and development of TRM for improvement of the drainage condition.
2. Implementation of a new TRM in the Khuksia beel is required to be taken up or continue the existing beel Kedaria TRM for sustaining drainage conditions of the Hari River. The east Khuksia beel is feasible for TRM and would be more effective to maintain proper drainage condition in the Hari river. The west Khuksia is also technically feasible for acting as a tidal basin but it requires more land than that of east beel Khuksia. It generates more

than 4.87 Mm3 tidal volume, which is considerably higher than the required tidal volume for the sustainability of the Hari river.

3. To restore the full function of the beel Kedaria TRM and sustain the required drainage capacity of the Hari River, it is suggested to dredge the Hari river at its design capacity of the Hari River at its design section from Bhabodaha regulator to Sholgati (about 9 km reach).
4. In order to maintain proper drainage capacity of the Hari river & to avoid severe drainage congestion in the North-Western part of the KJDRP area, east beel khuksia needs to be brought under operation as a tidal basin. It is technically feasible and socially acceptable
5. It is suggested to dredge the Teka-hari river at its design section from 600m u/s of Teka Bridge to Ranai (about 17 km reach).
6. A continuous monitoring is necessary for assessment of new tidal basin. identification of problems of mitigation measures.
7. In this regard, construction of one permanent tidal basin on each of Hari river and Upper Bhadra River may be a solution of the potential problem. These two basins would increase the sustainability of the temporary rotating basins and reduce the risk of failure of the TRM option as suggested in section 3.1.9.

7.3 Suggestions for Future Study

There are a lot of scope to make such technology assessment in KJDRP. There are sme new technics which can be applied for future study. these are as follows:

- *General Intuitive Methods,*
- *Important Components Methods*
- *Structural Decomposition Methods, and*
- *Holistic Composition Methods.*

In this study, the attribute selected by the experts have been considered, but there are some other attributes beyond this, which can be considered also. Cross-Impact Analysis can be done to understand the cross-effects of major technological attributes.

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APPENDIX A

QUESTIONNAIRE

Name : **Date**

Designation:

Address :

PART- A (Put a Tick Mark)

1) What is the condition of the agricultural productivity now in comparison to productivity before TRM?

   - Improved highly
   - Moderate Improvement
   - Little Improvement
   - No significant change at all
   - Deteriorated slightly
   - Deteriorated moderately
   - Deteriorated Highly

2) What is the condition of salinity in the agricultural field after the adoption of KJDRP?

   - Increased highly
   - Increased moderately
   - Increased slightly
   - No significant change at all
   - Decreased slightly
   - Decreased moderately
   - Decreased highly

3) What is the condition of fertility of the agricultural field after adoption of TRM?

   - Increased highly
   - Increased moderately
   - Increased slightly
   - No significant change at all
   - Decreased slightly
   - Decreased moderately
   - Decreased highly

4) What about the water logging condition in residential area after adoption of TRM?

   - Improved highly
   - Improved moderately
   - Little improvement
   - No significant change at all
   - Little deterioration
   - Deteriorated moderately
   - Deteriorated highly

5) After adoption of TRM, is there any change in availability of fishes?

- Increased highly
- Increased moderately
- Increased slightly
- No significant change at all
- Decreased slightly
- Decreased moderately
- Decreased highly

6) Is there any increase in saline water fishes?

- Increased highly
- Increased moderately
- Increased slightly
- No significant change at all
- Decreased slightly
- Decreased moderately
- Decreased highly

7) After adoption of TRM, is there any emergence of new type of crops or old crops went off?

- Emerged Highly
- Emerged Moderately
- Emerged Slightly
- No significant change
- Old crop went off slightly
- Old crop went off Moderately
- Old crop went off seriously

8) What about the intensity of flood after adoption of KJDRP?

- Increased highly
- Increased moderately
- Increased slightly
- No significant change at all
- Decreased slightly
- Decreased moderately
- Decreased highly

9) What do you think about the drinking water availability after adoption of KJDRP?

- Highly available
- Moderately available
- Available
- No significant change at all
- Rare
- Moderately Rare
- Very Rare

10) What change have caused by KJDRP in employment generation in KJDRP?

- Increased highly
- Increased moderately
- Increased slightly
- No significant change at all
- Decreased slightly
- Decreased moderately
- Decreased highly

11) Is there any change in land value after adoption of KJDRP?

- Increased highly
- Increased moderately
- Increased slightly

■ No significant change at all ■ Decreased slightly ■ Decreased moderately ■ Decreased highly

12) What about the water transportation facility after adoption of KJDRP?

■ Improved highly ■ Moderate Improvement ■ Little Improvement

■ No significant change at all ■ Little deterioration ■ Deteriorated moderately ■ Deteriorated Highly

13) What about the land transportation facility after adoption of KJDRP?

■ Improved highly ■ Moderate Improvement ■ Little Improvement

■ No significant change at all ■ Little deterioration ■ Deteriorated moderately

■ Deteriorated Highly

14) Is there any impact on environment after adoption of KJDRP?

■ Improved highly ■ Moderate Improvement ■ Little Improvement

■ No significant change at all ■ Little deterioration ■ Deteriorated moderately

■ Deteriorated Highly

15) Is there any success in poverty alleviation after completion of the project?

■ Improved highly ■ Moderate Improvement ■ Little Improvement

■ No significant change at all ■ Little deterioration ■ Deteriorated moderately

■ Deteriorated Highly

16) 'KJDRP has played a vital role in solving the existing problem'-whats yours views about the success or failure of the project?

■ Highly successful ■ Moderate successful ■ Successful

■ No change at all ■ Little Deterioration ■ Deteriorated moderately ■ Deteriorated Highly

PART- B (Answer Shortly)

17) What change have occurred in the types of the soil?

■ Soil turns to sandy ■ Soil turns to silty ■ Soil turns to clayey

■ No significant change at all

18) Is there any change in land use pattern after adoption of KJDRP?

■ From agri. Land to fish pond (*gher*) ■ From fish pond to agri. Land

■ Both agriculture and fisheries are used

■ No significant change at all ■ Others

19) Name if there is any availability of new fishes or extinction of old fishes?

■ New fishes ■ Extinct fishes

20) Name the type of crops whose productivity has been increased and decreased after TRM practice

■ Increased ■ Decreased

21) What is the overall positive effect of TRM?

Comments:

22) What is the overall negative effect of TRM?

Comments :

23) Have any new problem raised after adoption of KJDRP, which was not present before?

Comments:

24) Is the any change in life style pattern after adoption of this project? (comment, if any)

Comments:

APPENDIX B

Pair-wise comparison scale for Fuzzy Number Conversion

Serial No	Description	Linguistic Scale	Triangle Fuzzy Scale
1	Very high	VH	8, 9, 9
2	Between Very High and High	VH & H	6, 7, 8
3	High	H	4, 5, 6
4	Between High and Medium	H & M	2, 3, 4
5	Medium, Almost Equally	M	½, 1, 2
6	Exactly Equal	EQ	1, 1, 1,
7	Between Medium and Low	M & L	¼, 1/3, 1/2
8	Low	L	1/6, 1/5, 1/4
9	Between Low and Very Low	L & VL	1/8, 1/7, 1/6
10	Very Low	VL	1/9, 1/9, 1/8

Table : Pair-wise Comparison Matrix for the 1st Level Criteria

Factors	Resource	Population	Environment	Socio- cultural	Technology	Economic
Resource						
Population						
Environment						
Socio-cultural						
Technology						
Economic						

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Resource)

	Area under water class (%)	Fish Habitat	Area under Ag. class (%)	Cultivable area (kharif)	Irrigated area	Sediment in beels	Sediment in rivers	No of trained member by NGO
Area under water class (%)								
Fish habitat								
Area under Ag.class (%)								

Cultivable Area (kharif)								
Irrigated area								
Sediment in beels								
Sediment in rivers								
No of trained member by NGO								

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Population)

	Labor Involvement in KJDRP	Population involvement in KJDRP	Livestock Population
Labor involvement in KJDRP			
Population involvement in KJDRP			
Livestock Population			

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Environment)

	Salinity	pH	Dissolved O_2	Dry sub-mergence	Monsoon submergence	Duration of water logging	Depth of water in the beel in the deepest point	Area of water logging
Salinity								
pH								
Dissolved O_2								
Dry season submergence								
Monsoon submergence								
Duration of water logging								
Depth of water in the beel in the deepest point								
Area of water logging								

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Socio-culture)

	Poverty reduction	Employment	Drinking water tubewell
Poverty reduction			
Employment			
Drinking water tubewell			

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Technology)

	Discharge	Dredging	High water level in river	Post monsoon drainage	Ag. land during dry season	Channel bed improvement	Seepage improvem through embankme
Discharge							
Dredging							
High water level in river							
Post monsoon drainage							
Ag. land during dry season							
Channel bed improvement							
Seepage improvement through embankment							

Table : Pair-wise Comparison Matrix for the 2nd Level Criteria (Under Economic Factor)

	Fish Production	Ag Production	Crop Damage	O & M Cost
Fish Production				
Ag Production				
Crop Damage				
O & M Cost				

Table : Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Fish Production)

	Open Fish	Culture Fish
Open Fish		
Culture Fish		

Table : Pair-wise Comparison Matrix for the 3rd Level Criteria (Under Ag. Production)

	Ag. Production in the beels	Cropping Intensity
Ag. Production in the beels		
Cropping Intensity		

The following table should be fulfilled with the consideration of 'How the specific criteria is influenced by the option'

Table : Pair-wise Comparison Matrix for Area under water class (%)

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Fish habitat

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Area under Ag. class (%)

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Cultivable Area (Kharif)

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Irrigated Area

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Sediment in beels

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Sediment in rivers

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for No of trained member by NGO

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Labor Involvement in KJDRP

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Population involvement in KJDRP

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Livestock Population

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Salinity

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for pH

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Dissolved O_2

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Dry submergence

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Monsoon submergence

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Duration of water logging

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Depth of water in the beel in the deepest point

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Area of water logging

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Poverty Reduction

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Employment generation

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Drinking water tubewell

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Discharge

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Dredging

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for High water level in river**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Post monsoon drainage**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Ag. land during dry season**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Channel bed improvement**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Seepage improvement through embankment**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Open Fish**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Culture Fish**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Ag. Production in the beels**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : **Pair-wise Comparison Matrix for Cropping Intensity**

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for Crop damage

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

Table : Pair-wise Comparison Matrix for O & M Cost

	KJDRP	Non-KJDRP
KJDRP		
Non-KJDRP		

	TRM	Non-TRM
TRM		
Non-TRM		

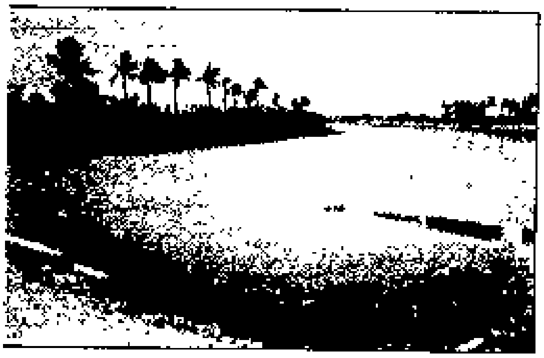
APPENDIX C

PHOTOGRAPHS

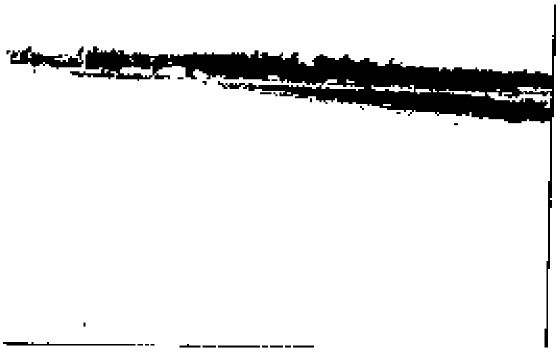
Photograph 1 : Hari River

Photograph 2 : Construction of Sholmari Regulator

Photograph 3 : Siltation at Bhabadah



Photograph 4: River Bed Siltation



Photograph 5: Hamkura Dying (1995)

Photograph 6: Hamkura River Bed

Photograph 7: Bhadra River Dying(2002)

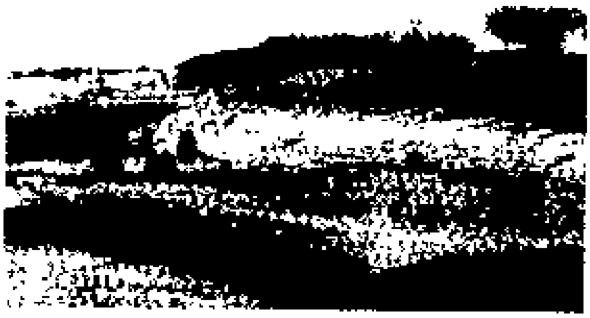
Photograph 8: Water logging in Beel Dakatia

Photograph 9: Innundation

Photograph 10: Innundated Land Turned to Paddy Field

Photograph 11 : River Closer

Photograph 12: River Bank Protection



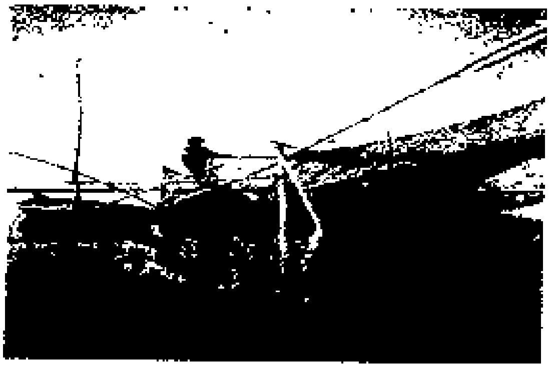
Photograph 13 : Manual Re-excavation of River

Photograph 14: Closure of Beel Bhaina Public Cut

Photograph 15: Siltation in Beel Bhaina

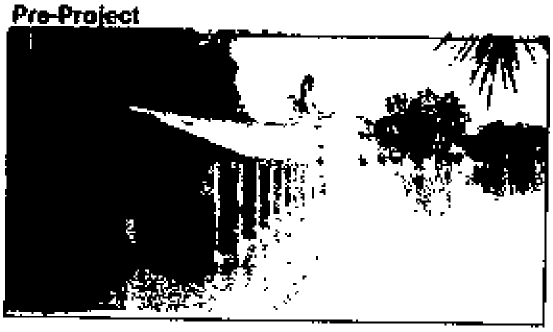
Photograph 16: Re-excavation of Hari River

Photograph 17: Increased Agricultural Production (October 2002)

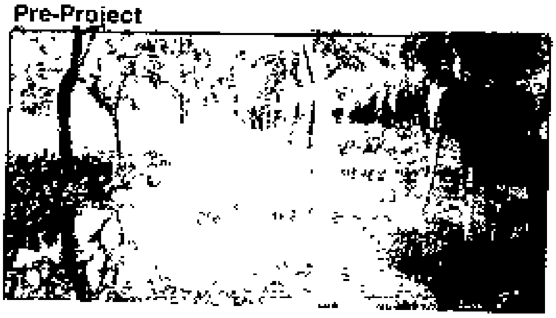


Photograph 18 : Increased Fish Production

Pre-Project

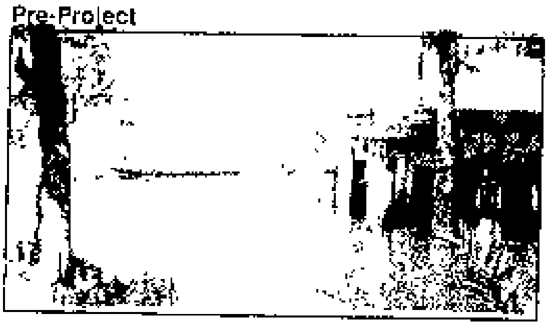


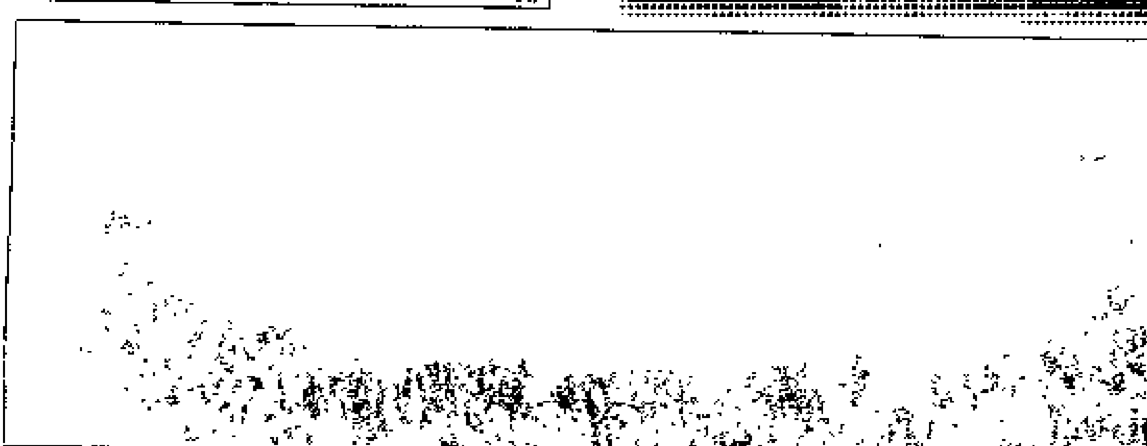
Pre-Project



Post-Project

Pre-Project





Inundated land turned to paddy field

Photograph 19: Comparison of Pre-project and Post-project Situation

Photograph 20: Beel Khuksia as a new tidal basin

Photograph 21: Opening of Beel Khuksia

APPENDIX D

Baseline database of Pre-project and Post-project

Area submergence during monsoon					
Pre project [year]	*ha*	*Post project [year]*	*ha*	*Increment from pre project*	*Increment [%]*
97	48510	98	35985	-12525	-25 81941868
97	48510	99	35690	-12820	-26 42754071
97	48510	2000	37155	-11355	-23 40754484
97	48510	2001	35200	-13310	-27.43764172
				Average increment	-25 77303649
Dredging (m3)					
Pre project [year]	*m3*	*Post project [year]*	*m3*	*Increment from pre project*	*Increment [%]*
from 93-97	240500	97-98	1550000	1309500	544 4906445
	240500	98-99	32000	-208500	-86 69438669
	240500	99-2000	62000	-178500	-74 22037422
	240500	2000-2001	85000	-155500	-64 65696466
				Average increment	79 72972973
Labor involvement in KJDRP					
Pre project [year]	*No*	*Post project [year]*	*No*	*Increment from pre project*	*Increment [%]*
From 97-98	200	98-99	403	203	101 5
	200	99-00	718	518	259
	200	00-01	1946	1746	873
	200	00-02	6627	6427	3213 5
				Average increment	1111 75
Area [%] under Ag class					
Pre project [year]	*%*	*Post project [year]*	*%*	*Increment from pre project*	*Increment [%]*
97	32	98	36	4	12.5
97	32	99	46	14	43 75
97	32	2000	44	12	37.5
97	32	2001	45	13	40.625
97	32	2002	43	11	34.375
				Average increment	33.75
Annual food grain production (Rice+Wheat)					
Pre project [year]	*ton*	*Post project [year]*	*ton*	*Increment from pre project*	*Increment [%]*
92	293070	98	300370	7300	2 490872488
92	293070	99	397851	104781	35 7528918
92	293070	2000	441083	148013	50.50431637
92	293070	2001	446909	153839	52.49223735
92	293070	2002	494278	201208	68.65527007
				Average increment	41 97811762

Total Fish production					
Pre project [year]	*ton*	*Post project [year]*	*ton*	*Increment from pre project*	*Increment [%]*
92	5158	98	8129	2971	57 5998449
92	5158	99	9258	4100	79 48817371
92	5158	2000	9140	3982	77 2004653
92	5158	2001	9964	4806	93 17564948
				Average increment	76 86603335
Area of fish habitat					
Pre project [year]	*ha*	*Post project [year]*	*ha*	*Increment from pre project*	*Increment [%]*
92	22800	98	51569	28769	126 1798246
92	22800	99	52701	29901	131 1447368
92	22800	2000	42555	19755	86.64473684
92	22800	2001	43297	20497	89.89912281
92	22800	2002	54799	31999	140 3464912
				Average increment	114.8429825
Open fish production					
Pre project [year]	*ton*	*Post project [year]*	*ton*	*Increment from pre project*	*Increment [%]*
92	2800	98	3129.84	329.84	11 78
92	2800	99	3005 723	205.723	7 34725
92	2800	2000	4082.68	1282.68	45.81
92	2800	2001	3764 062	964.062	34.43078571
				Average increment	24.84200893
Culture Fish production					
Pre project [year]	*ton*	*Post project [year]*	*ton*	*Increment from pre project*	*Increment [%]*
92	2369	98	4999 3	2630.3	111.0299705
92	2369	99	5377 8	3008.8	127 007176
92	2369	2000	5058 2	2689.2	113.5162516
92	2369	2001	6196.2	3827.2	161.5533981
				Average increment	128.276699
Duration of water logging					
Pre project [year]	*days*	*Post project [year]*	*days*	*Increment from pre project*	*Increment [%]*
97	220	98	172.92	-47.08	-21.4
97	220	99	118.57	-101 43	-46 10454545
97	220	2000	111.78	-108 22	-49.19090909
97	220	2001	103.57	-116 43	-52.92272727
				Average increment	-42.40454545
Livestock population(,000)					
Pre project [year]	*No*	*Post project [year]*	*No*	*Increment from pre project*	*Increment [%]*
97	400	98	1476	1076	269
97	400	99	4253	3853	963.25
97	400	2000	2825	2425	606.25
97	400	2001	2965	2565	641 25

				Average increment	619.9375
Ag production in beels					
Pre project [year]	*ton*	*Post project [year]*	*ton*	*Increment from pre project*	*Increment [%]*
97	503 86	2001	4169 31	3665 45	727.4739015
Trained people in Kjdrp					
Pre project [year]	*No*	*Post project [year]*	*No*	*Increment from pre project*	*Increment [%]*
92	15708	98	1987	-13721	-87.3503947
92	15708	99	4001	-11707	-74.52890247
92	15708	2000	6387	-9321	-59 33919022
92	15708	2001	11466	-4242	-27 00534759
92	15708	2002	17199	1491	9 49197861
				Average increment	-47 74637128
Section average sediment concentration. at Ranai					
Pre project [year]	*mg/l*	*Post project [year]*	*mg/l*	*Increment from pre project*	*Increment [%]*
96	61070	2000	5370	-55700	-91.20681186
96	61070	2001	7590	-53480	-87.5716391
				Average increment	-89.38922548
Sediment in beels (Bhaina)					
Pre project [year]	*m3*	*Post project [year]*	*m3*	*Increment from pre project*	*Increment [%]*
98	1.01	1999	1.07	0 06	5.940594059
98	1 01	2000	2.46	1 45	143.5643564
98	1.01	2001	1.73	0 72	71.28712871
				Average increment	73.59735974
River water level in Hari					
Pre project [year]	*m*	*Post project [year]*	*m*	*Increment from pre project*	*Increment [%]*
97	2 4	98	2.65	0.25	10.41666667
97	2 4	99	2.8	0.4	16.66666667
97	2.4	2000	2.81	0.41	17.08333333
97	2.4	2001	2.91	0.51	21.25
				Average increment	16.35416667