

**ASSESSMENT OF ENVIRONMENTAL IMPACTS OF WATER DEVELOPMENT
PROJECTS USING OVERLAY TECHNIQUE**



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June, 1998



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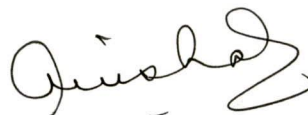


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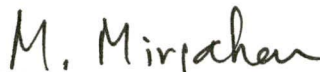
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ABSTRACT

Environmental Impact Assessment (EIA) has been made mandatory for all water development projects in Bangladesh, to be carried out at project planning stage. The main objective of EIA is to identify the probable effects, both beneficial and adverse, resulting from the project. Then through EIA, suggestions are given to the planners so as to minimize and mitigate the negative or adverse impacts and enhance the positive or beneficial impacts. EIA then prepares an Environmental Management Plan (EMP) for future monitoring of the project, both during and after its implementation so that sustainability is ensured.

There are a number of techniques for carrying out EIA namely: Checklist, Matrices, Networks, Environmental Evaluation System, Overlay Technique, Environmental Impact Indices and Cost-benefit Analysis. Besides, many institutions have developed their own guidelines for EIA. Bangladesh has adopted the Weighted Matrix method and a guidelines for carrying out EIA of water development projects has already been developed and adopted. Every method has some advantages and disadvantages in their application. As for example, Network method has been found suitable for identifying secondary and as well as tertiary impacts. Overlay technique is considered suitable for presentation of spatial variation in impacts.

This study was taken up to carryout a comparative study of the various methods of EIA and evaluate whether some elements of Overlay technique can be adopted while presenting findings through Weighted Matrix method in accordance with the approved guidelines. To carry out these objectives, data available from post evaluation of the System Rehabilitation Project (SRP) were used. SRP, during 1990-95, rehabilitated 35 water development projects of the Bangladesh Water Development Board (BWDB). A multidisciplinary Evaluation Team assessed seven SRP projects, using EIA methodology.

In this study, data of two projects were used. GIS based mapping technique was used to produce the Overlays. For comparison with conventional method, some important environmental components (IECs) were chosen, namely: Flood Control, Drainage, Irrigation, Crop Damage and Capture Fisheries. Other IECs, relevant to water resources development and management projects have been identified on the basis of various studies available on evaluation of completed projects. Preliminary assessment of suitability of overlay techniques and availability of data led to selection of the aforesaid five parameters. For this type of projects, modification in flooding characteristics and changes in cropping are most significant parameters.

It has been found that EIA results can be better presented through Overlays for the selected IECs. Impact of probable floods, corresponding to various return periods, and matching with any river water level, on the project area, can be clearly represented by Overlay. Similarly improvement in drainage in post-monsoon condition can be better represented with spatial variations shown on the maps. Impact of the project on potentials as well as actual performance of irrigation were clearly visible in Overlay maps. Impacts on capture fisheries, studied with overlays, clearly demarked the areas of potential conflict between agriculture and fisheries. It was observed that in the projects studied, such conflict was prevalent over small areas. On the other hand flooding pattern has significantly adverse impact on agriculture. These analysis would be of great value in future water management practices.

Finally it can be said that, overlay mapping can have very important role in the EIA process. The conventional method can not assess the impact and quantify the spatial variation. The method is also very flexible and the importance of the time function can be well addressed.

ABBREVIATIONS

ADB	: Asian Development Bank
AEAM	: Adaptive Environmental Assessment and Management
AVHRR	: Advanced Very High Resolution Radiometric
BTM	: Bangladesh Transverse Mercator
BUET	: Bangladesh University of Engineering and Technology
BWDB	: Bangladesh Water Development Board
CIP	: Chandpur Irrigation Project
CPP	: Compartmentalization Pilot Project
CPUA	: Catch Per Unit Area
CSA	: Canadian Space Agency
DEM	: Digital Elevation Model
DN	: Digital Number
DOE	: Department of Environment
DOF	: Directorate of Fisheries
DTW	: Deep Tube Well
EGIS	: Environment and GIS Support Project
EIA	: Environmental Impact Assessment
EIU	: Environmental Impact Unit
ERS-1	: European Remote Sensing Satellite -1
EIRR	: Economic Internal Rate of Return
EIS	: Environmental Impact Statement
EMG	: Embankment Maintenance Group
EMS	: Electro-magnetic Spectrum
EPC	: Engineering and Planning Consultant
ESCAP	: Economic and Social Commission for Asia and the Pacific
FAP	: Flood Action Plan
FCD	: Flood Control and Drainage
FCDI	: Flood Control, Drainage and Irrigation
FES	: Final Evaluation Study
FMM	: Flood Management Model
FPCO	: Flood Plan Coordination Organization
GIS	: Geographic Information System
GISMO	: GIS Modeling Program
GPA	: Guidelines for Project Assessment
HYV	: High Yield Variety
IC	: Important Component
IEC	: Important Environmental Component
IR	: Infrared
ISPAN	: Irrigation Support Project for Asia and the Neareast
IUCN	: International Union for Conservation of Nature and Natural Resources – World Conservation Union
JPL	: Jet Propulsion Laboratories
LAC	: Local Area Coverage
LGED	: Local Government Engineering Department
LLP	: Low Lift Pump
LYV	: Low Yield Variety

MOEF	: Ministry of Environment and Forest
MPO	: Master Plan Organization
MT	: Metric Ton
NASA	: National Aeronautic and Space Administration
NCA	: Net Crop Area
NEPA	: National Environmental Policy Act
NOAA	: National Oceanic and Atmospheric Administration
O&M	: Operation & Maintenance
PIE	: Project Impact Evaluations
PWD	: Public Works Department
R&H	: Road and Highways
RRA	: Rapid Rural Appraisal
SAR	: Synthetic Aperture Radar
SPARRSO	: Space Research and Remote Sensing Organization
SPOT	: Systeme Pour l'Observation de la Terre
SRF	: Slide Falciparum Ratio
SRP	: System Rehabilitation Project
TOR	: Terms of Reference
UCCA	: Upazila Central Co-operative Association
UK	: United Kingdom
USA	: United States of America
USAID	: United State Agency for International Development
UTM	: Universal Transverse Mercator
VIR	: Visible and Infrared
WARPO	: Water Resources Planning Organization
WB	: World Bank
WCS	: Water Control Structure
WHO	: World Health Organization
WRD	: Water Resource Development

CHAPTER- I

INTRODUCTION



1.1 INTRODUCTION

The environment is the sum of all social, biological, physical and chemical factors which compose the surroundings of man. Man is firmly entrenched as part of the global environment which depends on him as much as he depends on it (ESCAP 1985).

The concept of incorporation of environmental protection as a component of the administrative, planning, legislative and executive arms of government has been a recent phenomenon. In the late 1950s and the early 1960s, wildlife conservation groups in United States exerted pressure on the government to upgrade water pollution control activities to a very high level and a severe control activity. Increasing air pollution and a solid waste management activities led to the evaluation, in the late 1960s, of the concept of total environmental protection (ESCAP 1985). The concept of the Environmental Impact Assessment (EIA) was first originated with the passage of the National Environmental Policy Act (NEPA) in the United States in 1969. NEPA established the requirement for an environmental impact statement (EIS) as the principal means of implementing impact assessments (Smith 1993). Figure 1-1 represents the historical development of the use of environmental parameters in development planning in the United States. In the late 1970s, the Asian Development Bank (ADB), along with most other multilateral and bilateral agencies, began to accept that economic development often had adverse impacts upon the natural environment and that it had a responsibility to mitigate these impacts through environmental and natural resources planning and management (ADB 1991).

Recently EIA, has been made mandatory for all development projects in Bangladesh (DOE 1996). For water development project EIA is being carried out since early nineties. Till 1987, the planning approach of water resources development projects in Bangladesh did not pay attention to the environmental issues. Consecutive catastrophic floods of 1987 and 1988, stimulated the production of several studies from 1990-95 to explore ways of mitigating the damaging effects of floods. These studies were carried out under the umbrella of the Flood Action Plan (FAP) (WB 1989, FPCO 1995a). It was made mandatory that all FAP components would require an EIA Report, which would be carried out along with the feasibility study. Towards this, Flood Plan Coordination Organization (FPCO) proposed a Guideline and a Manual for carrying out EIA (FPCO 1992a, FPCO 1995b). FPCO also introduced a guidelines for Project Assessment for which EIA is an essential element (FPCO 1992b). The growing environmental awareness and increasing understanding of development action and possible environmental factors in decision-making process lead to the development of EIA in the process of the project development (Figure 1-2).

There is no general and universal accepted definition of EIA. The following examples will illustrate the great diversity of the definition (Mirza, 1991).

- ° First of all, EIA is a study of the effects of a proposed plan on the environment. In this

context, 'environment' is to include all aspects of natural and human environment.

- Second, EIA seeks to compare the various alternatives which are available for any project or programme. Each alternative will have economic costs and benefits as well as environmental impacts, both adverse and beneficial. Naturally, there must be a trade-off between pluses and minuses. Adverse environmental impacts may be reduced at higher project cost. Conversely, economic benefits may be enhanced at some added cost. EIA seeks to compare all feasible alternatives, and determine which represents an optimum mix of environmental and economic costs and benefit.
- Third, EIA is based on predictions, the technical work involved on estimating the changes in environmental quality which may be expected as a result of the proposed action. In the case of some impacts (e.g., those on the water air quality) prediction can be based on existing mathematical formulae. For others (e.g., standard of living), numerical analysis cannot be employed. However, predictions are essential either qualitatively and quantitatively.
- Forth, EIA attempts to weight environmental effects on a common basis with economic costs and beneficial in the overall project evaluation. If this is done, the decision-maker is less likely inadvertently to overlook an environmental consequences in arriving at his decision.
- Fifth, adverse consequences generated by the development actions need to be monitored carefully which will help formulating mitigation plan. Monitoring is a very important component of EIA. Firstly, to ensure that legal standards for effluents are not exceeded. Secondly, to check the mitigating measures are implemented in the manner described in project proposal. Finally and most important one to provide early warning of any unforeseen/foreseen environmental damage so that appropriate mitigatory actions may be taken.
- Sixth, EIA process involves the risk assessment comprising live stages, hazard identification, hazard analysis, consequences analysis, risk determination and risk evaluation. Risk assessment is an important element of EIA on a wide variety of projects, particularly the process industries, the nuclear industry, civil engineering and transportation engineering projects.
- Finally EIA is a decision-making tool. Its ultimate objective is to aid judgemental decision-making by giving the decision-maker a clear picture of the alternatives which were considered, the environmental changes which may be predicted and the trade-offs of advantages and disadvantages of each alternatives. The document produced, regardless of its format, should, therefore, include a set of recommendation.

EIA will take up important position in future planning process of any water development project. Hence it is important to develop proper understanding of the various methods by which EIA can be conducted.

1.2 EIA GUIDELINES OF BANGLADESH

Bangladesh is a country prone to natural disaster and floods are regularly occurring phenomena. Flood Control, Drainage and Irrigation (FCDI) improvement are needed to increase production in agriculture sector. In earlier days water management projects never looked environmental issues seriously. Rather, these projects created a number of environmental problems including water logging, loss of top soil, misuse of land (borrow pits), loss in open water fishery, increase in

salinity, loss of bio-diversity, loss of wildlife etc. (FPCO 1992a, MOEF 1995, Tasi & Ali 1997, Ali 1997, FPCO 1994a, FPCO 1994b). FCDI projects also caused socio-economic problems, forced people to change their profession, made little effort to resettle the affected people, rarely noticed and solved severance problems (Mirza 1991, Soussan 1997). The impact of FCDI projects on fish migration, breeding, recruitment and production are often negative; they disrupt migratory patterns of fish and due to lowering of the surface water levels, lead to enhanced level of harvesting of fish which further leads to over-fishing in the dry season (Shamsuddin 1994). MPO (1986) identified that FCDI Projects are the major constraint to the viability of the open water capture fisheries. Components of the environment are intricately related through dynamic interdependencies (IUCN 1991). When one component of this relationship is changed or disturbed, the influence is manifested or felt in other parts of the environmental system (IUCN 1993). Thus EIA takes a very important position in water resources development in Bangladesh so that the adverse effects which occur under traditional approaches to FCDI can be identified and mitigated.

A comprehensive set of guidelines for the EIA assessment were published in October 1992 for use in ongoing and future FCDI and water management projects of Bangladesh (FPCO 1995c). They are intended to be used in close conjunction with the guidelines for Project Assessment (GPA) which provide guidance on the economic appraisal of regional and specific project (Figure 1-3).

There are various methods of EIA of which the most important ones are the Checklist, Environmental Evaluation System, Matrices, Networks, Overlay Techniques, Environmental Impact Evaluation, Cost-benefit Analysis and Simulation Modelling Workshops. Bangladesh has adapted Weighted Matrix (FPCO 1992a, LGED 1992). Each method has an advantage and disadvantages and are discussed in chapter-III in details. Since EIA is a recent origin in Bangladesh, there is a need to study the advantages and disadvantages of the methods. Hence the study is taken up.

1.3 OBJECTIVE OF THE STUDY

The objective of this study is:-

- to present the results of assessment of impacts on some Important Environmental Components (IECs) of selected water development projects by using Overlay technique.
- to establish the advantages and limitations of overlay techniques in assessment of environmental impacts of water development projects.
- and to study the relationship between the selected IECs.

CHAPTER - II

ENVIRONMENTAL IMPACT ASSESSMENT

2.1 INTRODUCTION

The main objectives of EIA are to identify environmental impacts of proposed plans, programs and projects thereby assisting decision-makers and their constituents in making informed decisions on project developments and resource allocation. EIA is an integral part of multiple resource development planning and feasibility of the project. It provides for a quantified assessment of the biophysical, economic and social impacts of proposed projects as well as the likelihood of such impact occurring. EIA is not intended to disrupt nor impede development but should enhance development by ensuring that projects are constructed and operated in an environmentally sound manner and do not negatively affect the functioning of essential environmental processes nor the long-term sustainability of resource conservation and human well beings. All EIAs should proceed through ten steps excluding peoples participation which will continue throughout the process as outlined in Figure 2-1. The levels of detail required will differ for pre-feasibility to the feasibility level of study (FPCO 1992a).

The purpose of this chapter is to present a state-of-the-art of review of environmental impact assessment methods.

2.2 ALTERNATIVE METHODS

Any economic development project has some environmental implication, whether beneficial or adverse. Therefore, it is essential to identify changes apparent in the environmental condition along with favourable or adverse impacts resulting from activities associated with the concern project (IUCN 1993). According to Davies and Muller, there are approximately 100 methods for carrying out EIAs but most of these can be divided into just a few classes (ESCAP 1985). Each methodologies displays variety in conceptual framework, data format, data requirements as well as manpower, monetary, and resource requirements. One of the common misconceptions is that only one of the general assessment methodologies need be used in a project EIA (ESCAP 1990). The techniques and procedures to be adopted for environmental impact assessment may vary from one project to another (IUCN 1993). The following are the important methods used for carrying out EIA analysis;

- Checklist
- Environmental Evaluation System
- Matrices
- Networks
- Overlay Techniques
- Environmental Impact Indices
- Cost-Benefit Analysis
- Simulation Modelling Workshops

Each of the methods is subjective to some degree and no one of them is good for every application. The selection of an appropriate method is a matter of judgement and experience. In the final analysis, the application together with constraints on the user – resources, skill and time – and the criteria of importance to the user, is what determines which method is best suited for an application (ESCAP 1985). Besides, each techniques and method for the evaluation of impacts should have the following qualities and characteristic (ESCAP 1990).

1. It should be a systematic approach.
2. It should be able to organise a large mass of heterogeneous data.
3. It should be able to quantify, relatively accurately, the impacts.
4. It should be able to aggregate the data into sets with the least loss of information because of the aggregation.
5. It should have a good predictive capability.
6. It should extract the salient features.
7. It should be able to, finally, display the raw data and the derived information in a meaningful fashion.

It is very important to have a clear understanding about the drawbacks in order to determine the appropriate methods. An earlier evaluation of various methodologies is presented below (Table 2-1).

2.2.1 Checklist

This method starts with the preparation of a list of environmental, social and economical factors which may be affected by the concern project (IUCN 1993). Checklist, in general, are strong in impact identification and are capable of bringing them to the attention and awareness of their audience. Impact identification is the most fundamental function of an EIA and in this respect all types of checklist, simple, descriptive, scaling and weighting checklist, do well (ESCAP 1990). The simple and descriptive checklist merely identify the potential impacts without applying any sort of rating on their relative magnitude. The latter two methods in the checklist do better as they performs measurements and evaluations. It must be remembered however that these values are partly based on subjectivity and represent the value judgements of only the experts. Social values may not be significantly reflected.

Simple Checklist

This is a very simple method used in the IEE level and merely provides a list of environmental parameters with no guidelines on how the parameters are to be measured and interpreted. They work by focusing the attention of those undertaking EIA on the important issues, which may be a subsequent consequences and results from the project impact.

Descriptive Checklist

This includes an identification of environmental parameters and guidelines on how data on the parameters are to be measured (ESCAP 1985).

Scaling checklist

This is similar to the descriptive checklist, but with additional information on the subjective scaling of the parameters (ESCAP 1985). The beneficial and adverse changes in environmental parameters resulting from a project usually expressed in qualitative terms have been plotted in a scale to quantify the environmental alternations (LGED 1992). Figure 2-2 shows the correlation between qualitative statement and proposed quantitative values of environmental changes resulting from the LGRD infrastructure project.

Scale-weighting checklist

This is essentially similar to the scaling checklist, but additional information is provided as to the subjective evaluation of each parameter with respect to all the other parameter (ESCAP 1985). This is because all environmental parameters influenced by the project are not of equal importance or weight. The importance of a parameter varies from country to country depending on the environmental concerns of the country (LGED 1992). Figure 2-3 is an illustration of scaling-weighting checklist related to the LGED infrastructure project have been given different values based on prevailing condition of Bangladesh.

2.2.2 Environmental Evaluation System (EES)

The methodology was developed in the laboratories (USA) for water resources projects and is simply an example of a scaling-weighting checklist. It gives a description of the environmental parameters that are included in the checklist and instructions for their relative scaling with respect to other concern parameters and for the assignment of importance units (ESCAP 1985). An example of this methodology for evaluating a water resources projects in Thailand are given in Figure 2-4.

The expected future condition of the environmental quality both with and without the project can be determined by using this method. The difference in the Environmental Impact Units (EIU) between these two conditions constitute either an adverse impact, which corresponds to a loss EIU units, or a beneficial impacts, which corresponds to a gain in EIU units (ESCAP 1985). A factor analysis-based environmental index approach for assessing impacts is a useful technique, when there is some meaning variation in the data set and, provide proper interpretation and evaluation of the results (ESCAP 1990).

Mathematically this can be represented as follows;

$$E_i = \sum_{i=1}^m (V_i)_1 W_i - \sum_{i=1}^m (V_i)_2 W_i$$

Where

E_i = environmental impact

$(V_i)_1$ = value in environmental quality of parameter i with project

$(V_i)_2$ = value in environmental quality of parameter i without project

W_i = relative weight (importance) of parameter i

m = total number of parameters

There are a number of advantages to be obtained in using this system: it is very comprehensive in that it provides an extensive checklist of environmental characteristics and impacts that should be considered in water resources projects; both spatial and temporal aspects. Equally, the system has some important disadvantages; the aggregation of all values into an overall index tends to lose considerable information; it ignores economic impacts and only partially deals with social impacts.

2.2.3 Matrices

This is an extension to the use of a checklist in that it employs a list of project activities in addition to a list of environmental characteristic or impact indicators (ESCAP 1985). The two are related in a matrix in order to identify cause-and-effect relationships. Leopold, et. al. (1971), designed one of the first matrices used to assist in the evaluation of the environmental impact of a resource project. Each cell in the Leopold matrix requires three operators.

- if an impact is possible, place a diagonal slash across the cell.
- on the upper side of the slash, place a number from 1 (min^m) to 10 (max^m) indicating the magnitude of the possible impact.
- on the lower side of the slash, place a number from 1(min^m) to 10 (max^m) indicating the importance of the possible impact.

Here the magnitude is defined as the degree of extensiveness of scale of the impact, while importance is a weighing of the degree of significance of the impact. The former can be based in fact, while the latter is based on judgement.

When all the relevant boxes have been marked, a simplified matrix is then constructed consisting only those actions and environmental characteristics which are interacting. The method suggest that special note may be taken of boxes with exceptionally high individual numbers. If the alternative actions are under consideration, and a separate matrix is prepared for each action, identical boxes in the two matrices will provide a numerical comparison of the environmental impact of the alternative consideration. The application of the method described by Lepold, et. al. and Lohani and Thanh (1980) of the environmental impact evaluation study of Quae Yai Dam project in Thailand is comparatively shown in Table 2-2. Fischer and Davis expanded the matrix concept to include the steps — an environmental baseline evaluation, compatibility matrix and a decision matrix. In addition to selectively identifying important environmental elements, they also evaluated their present condition (before project) and susceptibility to management.

Phillip and DeFillipi (1976) have developed a modified matrix approach capable of providing a quantitative measurement of the environmental impact. It was initially proposed for the determination of waste water management impacts but could be readily adapted for other uses.

Welch and Lewis (1979) provides a three-dimensional matrix for analysis in land use management. This approach provides, firstly, a system for identifying scientific input needed for the assessment process, and secondly, it quickly highlights those areas where knowledge is lacking.

The systematic listing of development and environmental characteristics is of obvious values to those who are faced with the problem of gathering the information relevant to an impact study, as well as those who have to review and evaluate the report. Most of the practitioners of EIA suggest that one of the main attribute of matrices is their highly visual nature. They can be equally useful in communicating ideas to the public or to decision-makers. Alternatively, because of the general nature (10 possible actions and 20 environmental characteristic giving a total of 200 possible interaction), the Leopold matrix is too cumbersome and often contains little of relevance to mission-oriented agencies.

2.2.4 Networks

Networks are extensions of matrices and which involves the development of a "stepped matrix" of "cause-condition-effect network" to indicate the nature of environmental interrelationships (ESCAP 1985). Networks are capable of identifying direct and indirect impacts, higher-order effects and interactions between impacts and hence, are capable to identify and incorporate mitigation and management measures into the planning stages of a project (ESCAP 1990). To develop a network requires answering a series of questions related to each of the project activities, such as: what are the primary impact areas, what are the primary impacts within these areas, what are the secondary impact areas and what are the secondary impacts within these areas and so on.

Networks generally consider only adverse impacts on the environment and hence decision making in terms of the cost and benefit of a project to a region is not amenable to network analysis. Temporal considerations are not properly accounted for and short-term and long-term impacts are not differentiated to the extend required for easy understanding. Appendix - B is an example of the network method and was evaluated in the Chandpur Irrigation Project (CIP).

The approach cannot be described as a complete assessment system in that there is no explicit consideration of alternative projects, beneficial impacts, nor is there an attempt made to evaluate the magnitude or significance of the impacts. The method is not recommended for regional planning by some authors because display may become so extensive that they are difficult to use.

2.2.5 Overlays

Overlays are very useful for WRD projects EIAs for comparing land capabilities, existing and projected land uses, road route alternatives and other similar parameters (ESCAP 1990). Overlay is a suitable and effective mode of special presentation and display to their audiences. It is not the sole criterion for environmental impact assessment and the social, human and economic aspects are nor accorded any consideration.

The essence of the method involves the use of superimposed transparencies to identify, evaluate, compare and communicate impacts in a geological reference frame. The study area is divided into a number of environmental factors (e.g. topography, vegetation distribution, ecologically sensitive areas, historical sites, etc.). Regional maps are prepared for common factors showing their aerial extent and value. All the maps prepared in this way are made into transparent

negatives, superimposed and photographed. The resulting map shows the simulation of all the values employed and thus the suitability of the area for a given activity. Similar maps are then prepared for the other development activities under consideration.

All the suitability maps are then combined graphically to determine a composite land use map. Complementary maps are first combined and resulting maps are combined again to identify areas of compatibility and conflicts.

A further refinement of the method uses computers to develop a regional data bank and also to produce the mapped overlays since the computer allows large amounts of data and numerous overlays to be manipulated and weighted.

2.2.6 Environmental Impact Indices

A factor analysis-based environmental index approach for assessing impacts is a useful technique in that it enables the grouping and clustering of parameters and components that are complex in nature (ESACP 1990). However factor analysis is useful only when there is some sort of meaningful variation in the data set on hand. Factor analysis identifies components that will be adversely affected by certain project activities and can provide a fair degree of measurement capability of the impact. But factor analysis requires proper interpretation and evaluation of the results by the analyst to be of utility.

Factor analysis is a flexible instrument applicable to a wide range of research designs e.g., hypothesis testing, concept mapping, and for a variety of data types. Although it is possible to factor any matrix, not all matrices will yield scientifically useful factors.

In factor analysis, each of n observed variables is described linearly in terms of m new uncorrelated common factors F , and unique factors $U(J = 1, 2, \dots, n)$.

$$Y_1 = A_{11}F_1 + A_{12}F_2 + \dots + A_{1m}F_m + b_1U_1$$

$$Y_n = A_{n1}F_1 + A_{n2}F_2 + \dots + A_{nm}F_m + b_nU_n$$

Where

- Y_j = a standardized form of a variable with known data
- A_{jm} = the factor loading or weight of each factor
- F_m = a function of some unknown variables
- U_j = a unique factor
- b_j = a unique weight

The variables entering into each function, F_m , are unknown and are related in unknown ways. The equations relating the functions themselves are linear. Each function makes a contribution to the sum of variances of the variables, and in general, a few of the function will account for a large amount of the total variance. The factor analysis techniques provides values for the constant

A_{jm} , called loadings, which represent the extent to which each specific function is related to Y_j .

Once the factor loadings or weights for each variables are determined, the initial set of statistics can be aggregated through the determination of factor scores into a single index in which each variable is weighted proportional to its involvement in a pattern, the greater the weight for a higher involvement. The index I_i constructed from the factor loadings is

$$I_i = \sum_{j=1}^n A_{ji} Y_j$$

The application of the method is useful where it sustain a very complex system of the environments. Urban environment is one of the simplest example in such the relation between the component is extremely complex. Hong (1980) developed a framework for the environmental impact analysis and evaluation of urbanisation project in Asia region.

2.2.7 Cost-benefit Analysis

The ideal EIA methodology would be one, which accurately incorporates the environmental costs and benefits of a project within conventional engineering cost benefit analysis. Cost/benefit analysis provides the nature of expense and benefit accruable from a project in monetary terms. This is a common practice in traditional feasibility study and would be an ideal, because, it would be much easier for decision-makers to comprehend and evaluate the project. UNEP (Test Model) and East-West Centre and others are working on the development of such methodology (ESCAP 1985, ESCAP 1990).

The difficulty encountered in the use of this technique has been that impacts have to be transformed and stated in explicit monetary terms. This is not always possible, especially for intangibles like the monetary value of the damages of health owing to the advent of cholera, etc. Cost/benefit analysis of the type for assessment of natural systems is not merely concerned with the effects on environmental quality, but rather, it seeks the conditions for sustainable use of the natural resources in a region. This type of approach is not useful for small scale development projects, but is better suited for the analysis and evaluation of a regional development plan.

The Test Model sought to develop an assessment system, utilising the natural resources database inherent in the conventional EIA as starting point, but refining it for the purposes of development related decision-making. The approach is therefore more oriented towards a resource use and management approach, more closely related to developmental planning and sought to be more directly linked to a decision-making process.

The framework of the model (ESCAP 1985) involves the following six steps:

- essential project description which set the physical and economical parameters for the analysis.
- itemizing of the resources used in the project, indirectly affected, and residues created
- itemizing of the resources exhausted, depleted or deteriorated
- itemizing of the resource enhanced
- listing of the required additional project components
- summary of the conclusions and formulation of the integrated cost-benefit

presentation.

The methodology developed by the East-West Centre includes two specific approaches which are:

- defining and quantifying the significant natural system factor that can limit the success of development projects, and
- evaluating these factors in economic terms for cost-benefit analysis

The significant criteria includes are:

- a. dependence of development goal on natural system
- b. spatial extent of the effect
- c. degree of irreversibility
- d. urgency or the rate at which problems get worse

The valuation techniques can be classified broadly as market and survey oriented. Economic analysis thus hold great promise for improving environmental quality management. However, economic evaluation relies on the critical understanding and measurement of the physical, chemical and biological aspects of development activities. This methodology is concerned not merely with effects on environmental quality, but rather, it seeks the conditions for sustainable use. It strives to evaluate effects in monetary terms and to express conclusions in an economic, cost-benefit format.

2.2.8 Simulation Modelling Workshops

Many practitioners now believe that the role of prediction in environmental impact assessment has been exaggerated. According to Hilborn (1977) an "assessment team should use the best available techniques to make the best possible predictions, but it should be aware of, and communicate to the group about the assessment, that there will always remain a large number of uncertainties. The problem that environmental managers will be confronted with more and more is not how to make good predictions but how to deal creatively with the uncertainties in the environmental systems they manage" (ESCAP 1985). Adaptive environmental assessment and management (AEAM) combines a method for predicting impacts with an approach which tries to deal with uncertainty by incorporating methods for bringing gaps between

- knowledge and disciplines
- between the various actor groups and institutions that are part of the problem

The approach which broadens the potential of simulation models to evaluate the impacts of alternatives and is beneficial for projects planning, was used by the Mekong Committee in developing and testing their EIA guidelines for tropical river basin development (ESCAP 1990). The AEAM approach centers on a series of alternating workshops and research periods. The workshops participants review and modify, over a fixed period of time, computer model which they have developed to provide environmental options for managers and policy-makers. The models, and therefore the solutions provided by them, are dynamic because they constantly being improved with the provision of new information as soon as it is available. The detailed description including typical schedules for short (three-month) and long (one-year) assessment, is

given in Holling's 1978 text *Adaptive Environmental Assessment and Management*. A brief description of how the approach works is given below;

The process is usually initiated by someone from a government agency with an environmental problem covering a small group meeting. The meeting should include at least one person familiar with AEAM techniques. The object of this meeting is to define the problem, select the team leader, the core group, and prepare a list of potential participants in the workshop.

The core group includes two or three analysts (capable of computer modelling, mathematical analysis, and communication) and two or three persons with expertise in disciplines which will be relevant to solving the particular problem (e.g. wildlife biology, economics, sociology). Both the analyst and specialist should have experience in integrating information through systems techniques as well as experience in co-ordinating team efforts. The core group will run the workshops, do the computer modelling and the policy analysis. Specialist who are not part of the core group are asked to join the workshops when their expertise is required.

Over the course of a year-long assessment three or more workshops may be held varying from three to five days each. The objectives of the first workshop are

- defining the problem
- determining, if only roughly, its boundaries
- determining information gaps and outlining strategies to close them
- identifying conflicting interest.

An important feature of the AEAM process is that all the actors, including high-level decision-makers and managers, are included from the outside, so that they will understand the problem and perceive that their specific concerns are being addressed. In those cases where the core group is experienced and sufficient information is readily available, the team may have a rough model prepared by the end of the workshop session. In this stage the model need not be computerized or involve any kind of mathematical representation; it should reflect, however, the important values and attributes of the system being studied.

The first workshop is followed by a period of independent work by the core specialists. This will lead to a second workshop and possibly more. Early in this sequence the participants concentrate on technical issues like adjusting the model to reflect the results of the specialist studies. Later the effects of all of the participants shift from the technical aspects of the problem to an increasing emphasis on communication to policy advisors and administrators. Communication is achieved through presentation of the results to interest groups and individuals. This emphasis on communication substantially increases the possibilities of moving effectively from planning to implementation either in a pilot or a full-scale programme.

The work of the core group continues, ideally, beyond the submission of the final report. Some members, for example, may be involved in monitoring the implementation of a project. For more modest programmes the core group can often deal with three or four projects simultaneously and the specialists time may be reduced by 50% or more.

The AEAM technique largely overcomes the shortcomings of most other methods in that other methods assume unchanging conditions or project impacts in a single timeframe on statistically-described environmental conditions.

It also overcomes a build-in bias towards compartmentarization and fragmentation of the relationship between project actions, environmental characteristic and likely impacts, while the reality may be that the actual impacts may alter the scale and direction of change within environmental and social systems. The AEAM techniques enables the assessment of developmental projects in the light of the reality of such changes.

The AEAM technique can handle higher-order impacts and interactions between impacts. But it depends on a small group of experts and has generally no avenue for public participation. This aspect is of particularly significant for large-scale development, where the options of interest groups are important.

The technique can be time-consuming and may impose a severe burden on the monetary resources available for the purpose of environmental assessment. Simulation models, especially of ecosystems, are still in an embryonic stage of development, and their accuracy and predictive capacity have yet to be proven. The use of this technique requires input of people trained in its use and functions. This may lead to the need for expatriate expertise in proportions greater than required for other techniques and this may be the limiting constant in developing countries.

2.3 OVERLAY TECHNIQUES

2.3.1 Introduction

In the conventional system of the EIA assessment, the spatial impact distribution and its relationship to other impact is simply not possible to realise. Overlay is a technique, whereby these interrelationship can be established and quantified in place. Of course, overlay analysis requires a very detailed spatial layers of time depended information of the individual IECs both with and without project condition. Overlay analysis is considered as one of the very special type of assessment, whereby, the output from the analysis depends on the reliability of the input data, its resolution, quantity of the spatial data and the possible numbers of combination that could be possible.

The environment in its broader terms the physical, chemical and biological factors are intricately related through dynamic interdependencies. Overlay analysis is therefore plays a very important role in determining the spatial relationship between any interdependencies of the environmental component.

2.3.2 Historical Development of the Overlay Analysis

The overlay approach to impact assessment is commonly associated with Ian McHarg (Wallace-McHarg Associates, 1967). His approach to the ecological planning process and the relationship of the overlay method to that approach is described in detail in his book *Design with Nature*. McHarg's method is flexible, efficient and lends itself to executes by experts. The basic

principles are simple and easy to learn. The emphasis on visual presentation through maps is another distinct advantages of the method; an advantage that is appreciated by practitioner and user alike.

McHarg has had an opportunity to apply this approach to a variety of problems ranging from regional planning and urban planning to the selection of alternative highway routes.

Kraukoph and Bunde, 1972 have developed a computerized version of McHarg's approach which is described as a data management system rather than an environmental impact assessment method. They have applied to other linear or corridor projects such as pipelines, railways, transmission lines, etc.

Dooley have developed an overlay method which has been used in the selection of a corridor for a high-voltage (550-Kv) electric transmission line. The analysis was computerized using a grid square 500 m x 500 m. Information was obtained on a large number of variables for each grid square. Data obtained includes existing roads, pipelines, railways, airport, radio towers, major industries, institutions, commercial areas, and residential areas. Data were also obtained on wildlife and soil capabilities, crop yields, historic sites, moisture, regimes, landlords and recreational areas, and so forth. For each factor and for each grid square, an impact rating was determined. The numerical value to be used was obtained with the aid of a specially developed computer program. Computerized factor maps were produced which indicated degrees of impact "low " to "no go". Township boundaries were used as a reference frame.

Overlay analysis are purely spatial and are very subjective. They rely on the judgement of the analyst to evaluate and assess questions on compatibility relating to the existing land use patters and the prospects of the development activity.

2.3.3 Conventional Overlay Analysis

The essence of the method involves the use of superimposed transparencies to identify, evaluate, compare and communicate impacts in a geographical framework. That is, the area divided into a number on environmental factors. Project maps prepared with the common factors showing their aerial extent and value are made into transparent negatives, superimposed and photographs. The resulting maps shows the simulation of all values employed and thus the suitability of the area for compatibility and conflicts for a given activity is determined.

2.3.4 GIS Overlay Analysis

A further refinement of the overlay techniques becomes possible whereby with the advancement of the computer facilities specially the use of GIS and removes most of all limitations originally prevails in the overlay analysis. As from the meaning GIS, here every environmental feature is in referenced with the geographical framework along with its temporal database. GIS also has its own strong in built overlay analysis capability both in the vector and raster mode. Conceptually, there is nothing any change in the GIS overlay excepting here everything is done in computer and is very much flexible. In the GIS overlay, there is no limitation between the number of overlays and the combination between the primary or secondary overlays.

2.3.5 Database Involves in the GIS Overlay Analysis

Depending on the depth and details of analysis, the spatial data should be developed for GIS overlay analysis of the issues those are suitable under overlay application. Examples of the spatial database are: topography, present land use, water level hydrograph which in turn provide flood level and extent for different condition, ground water table, existing infrastructures, details of the flow distribution system, vegetation distribution, ecologically sensitive areas, historical sites and the classified time series of the satellite images. All of them are very important information for the overlay analysis. Sometimes, in advance, the post-project evaluation of the environmental components (IECs) could be determined by the planning process and the design options under consideration. The spatial layers of the environmental components for different conditions could then be applied for analyzing the impacts as a function of time of the individual components as well as within the components using GIS Overlay analysis.

2.3.6 Advantage over Tabular Form of Database

The spatiality in the overlay analysis is that, it provides the impacts information either positive or negative w.r.to its location and attributes. Depending on the logic, there could be an unlimited number of impact combinations or spatial relationship can be established using overlay analysis. All these analysis are based on the computer operation using different overlay function which in turn provides information of the spatial impact distribution on space with attributes database.

2.4 SUMMARY

There is no one universally acceptable environmental impact assessment method. Any one, or combination of several methods could be effectively used to assess the impact of a development project. It is important to restate that the selected method (s) must be applied with professional judgement and its results must be interpreted using professional judgement (ESCAP 1985).

Most of the techniques currently used are directed towards the evaluation of primary impacts. It is equally important to develop approach, which will predict the secondary effects of project implementation.

There is a need to develop a comprehensive environmental impact assessment process and how it relates to the planning process. Impact assessment methods should be evaluated as to their function in this process.

CHAPTER - III

ENVIRONMENTAL IMPACTS OF THE WATER DEVELOPMENT PROJECTS

3.1 INTRODUCTION

The geographical location of Bangladesh has made the country as one of the most flood vulnerable region in the world (Figure 3-1). In the absence of any other physical resource, the economy is essentially dominated by agriculture, which is in turn, dependent on effective water management. Bangladesh is endowed with huge amount of fresh water supply, both surface and ground water. But the temporal variation is very large (Appendix – A). Thus in monsoon, there is huge surface water flow which just dwindles down in lean months. The annual minimum flow into the Bay of Bengal is only one-twentieth of the peak monsoon discharge. The variation in temporal as well as in spatial occurrence of water is a major impediment to agricultural and ultimately economic development.

Over abundance of water causes widespread flooding that damages standing crops, disrupts normal life and severely restricts farmers choice of cropping during monsoon, while scarcity of water constrains productivity drastically during the dry season. As such, development of the FCDI projects became imperative for the overall national economic development. These projects more or less follows a standard planning approach. Polders are constructed for flood control, pump stations and regulator/sluices are provided for drainage and pumps are use for lifting surface and ground water for irrigation. In this process grain production has gone up but have resulted into many adverse environmental impacts.

3.2 FINDINGS OF STUDIES CARRIED OUT UNDER FAP 12, FCDI/ AGRICULTURAL STUDY

Under the flood action plan (WB 1989) a number of studies were initiated so as to develop understanding of actual performance of already completed FCDI projects. These studies were designated as FAP12, FCDI Agriculture Study. The objective of FAP-12 was to conduct post-evaluations of a total of 17 projects representative, in type and location, of the FCDI projects so far executed in Bangladesh. The results of these evaluations would be used to guide in developing strategies for improved flood control and management for the future. Of the 17 projects for study, 5 was assessed by Project Impact Evaluation (PIE) methods, using a formal questionnaires approach and probability sampling. The remainder was assessed by Rapid Rural Appraisal (RRA) techniques, and RRA was also used for preliminary reconnaissance of the 5 PIE projects.

Rapid Rural Appraisal (RRA).

RRA is a technique of project assessment intended to produce results more quickly than formal interview surveys. RRA consists of selective direct observation and interviews of informed respondents from representative areas of the project by a small team of well-qualified and experienced specialists who can reach informed judgement quickly in the field. Maximum use is made of documentary sources to minimise the amount of data which have to be collected by

interview. In well-conducted RRAs great care is taken to avoid locational biases and socio-economic biases. By its nature RRA is better at obtaining qualitative data than quantitative data. What RRA cannot do is provide statistical validation of how far observations can be generalised over the project area or of differences between areas and time-periods. Its findings must therefore always be interpreted as informed judgements, not as precise statements with known margins of error.

Project Impact Evaluations (PIE)

The project Impact Evaluation (PIEs) involved the comparison of conditions in areas between by the projects (impacted, protected area) with conditions in adjacent areas that may have also been affected by the project (impacted, unprotected areas) and areas where pre-project conditions had been similar, but no project impact was felt (control areas) (FPCO 1992a).

The core of the PIEs was a questionnaire survey of households, using formal probability sampling for selection of households in the main survey. The strength of such an approach, in contrast to RRA and other non-probability survey techniques, is that the results produced can be interpreted with known level of precision and confidence. The PIEs also involved a number of other questionnaire surveys, covering fishermen, traders and operations of other non-farm economic activities.

The PIE surveys were carried out over a five months period (from May to October 1991) and involved over 1800 interviews. The surveys succeeded in providing quantitative data on the key variables related to project impact which are precise enough to permit considerably more confident evaluations than the possible through the RRAs.

Comparability of RRA and PIE Results

The RRAs and PIEs for the five projects studied by both methods are in substantial agreement regarding the agricultural performance of the projects. Exceptions were in Kurigram South, where the PIE and RRA findings on adoption of HYV paddy differed considerably, and in Kolabashukhali, where the PIE found productivity benefits on land cropped pre-project, as well as the extension of cropped area protected by the RRA. The latter in fact would not have been detected by the PIE, pointing to the value of a diagnostic RRA in advance of a formal survey of PIE type.

In the case of the two PIE projects for which EIRR estimates were also made on the basis of RRA data, the estimates from the two methods were quite close. For Meghna-Dhonagoda, RRA gave an EIRR of 5 per cent, compared with 2 per cent from the PIE, while for Kolabashukhali the RRA gave an EIRR of 17 per cent, compared with 24 per cent from the PIE.

PIEs proved to be superior to RRAs for investigation of distributional effects of projects, since RRA group interviews tend to mask the range of variation percent. Differential gender impacts were assessed in both RRA and PIE by using separate interviews conducted by female staff, but again it is likely that the one-to-one PIE interviews detected differences between women (as opposed to differences between women and men) better than RRA group interviews.

The list of the projects evaluated by FAP12

Following are the name of projects evaluated by FAP12

PIE study project

1. Chalan Beel Polder D
2. Kurigram South
3. Meghna Dhonagoda Irrigation Project
4. Zilkar Hour
5. Kolabashukhali Project

RRA Study Projects

1. Protabpur Irrigation Project
2. Nagor River Project
3. Sonamukhi Bonmander Beel Drainage Project
4. Improvement of Sakunia Beel
5. Silimpur-Karati Bridge cum Regulators
6. Khatakhali Khal
7. Halir Hour
8. Kahua Muhuri Embankment
9. Konapara Embankment
10. Polder 17/2
11. BRE Kamarjani Reach
12. BRE Kazipur Reach

Assessment of Overall Project Impact

The project impact was judged by a wide range of criteria, ranging from the direct impact on hydrological conditions to the resulting changes in agriculture, fisheries, livestock, ecological. Social and economic parameters. These impacts were synthesised in two ways.

For the five PIEs, and for some of the RRAs, a Preliminary Environmental Post-evaluation was carried out, bringing together physical, biological and human environmental issues. This level of evaluation used to identify projects, which have had negative environmental impacts that are serious enough to warrant further enquiry (such as "environmental audit"), and to permit identification of any mitigatory measures that are required.

An economic analysis of project impact was also carried out in every case, although in the RRAs the analysis was sometimes based on very broad estimates of costs and/or benefits. The recommended methodology in the FPCO guidelines for economic analysis (1991) was used in the economic analysis.

Impact of Completed FCD/I Projects

a. Planning, Design and Implementation

- Project planning was generally carried out by BWDB or by consultants, with little or no collaboration with other relevant Government Departments or with the intended beneficiaries. However, in few cases when there was local consultation at the planning stage, projects were generally better conceived, and their implementation and subsequent operation were facilitated.
- The planning of some of the projects was carried out without undertaking essential regional hydrological studies. Fortunately the FAP now offers an opportunity to overcome this past weakness.
- Embankment alignments were sometimes poorly planned, leading to failures and frequent retirements. On some occasions there have been proposals at the planning stage to include navigation locks in embankments, but these have almost invariably been discarded before construction.
- Designs of embankments and structures at most projects were generally found to be sound. However designers sometimes had inadequate data on hydrological and subsoil conditions, and as a result their designs have at times proved inappropriate and lead to a physical failures.
- Many of the design problems that have been identified related to drainage. Almost all the projects suffer from moderate to severe drainage congestion due to faulty hydrological assessments and the absence of an adequate drainage network. A common symptom of drainage problems is public cuts and these are often so serious that they compromise the scheme's viability.
- Regulator gates were found to be leaking everywhere and the use of wooden fallboards on some projects was found to be ineffective.
- Most of the projects took longer to implement than the period originally specified, and this usually resulted in cost overruns.
- On several occasions projects were not constructed as designed. Reasons for this could be identified. Embankment compaction was often inadequate. Drainage canal excavation was almost invariably either inadequate or not implemented at all. Internal road development, where planned, was usually curtailed during design and/or construction.

b. Operation and Maintenance

- Inadequate operation and maintenance (O&M) is the most frequent immediate constraint on effective achievement of FCD/I goals. Three key issues relating to O&M are: resource constraints; poor quality of infrastructure maintenance which results partly from lack of finance; and the almost invariable absence of public participation in either operation practice or maintenance.
- Domestic financial resources are limited but the shortage is exacerbated by using them to pay for excessive staff establishments and to cover O&M requirements which are excessively high because of deficiencies in planning, design and implementation. Routine and preventative maintenance is almost non-existent, and is replaced by emergency measures and periodic rehabilitation, which usually funded from external sources, often after a damaging event.

- However the poor quality of the maintenance activities that are carried out suggests that O&M could be significantly improved with the existing resources, particularly if local participation can be directly harnessed for maintenance. O&M manuals that have been prepared are not used. The most important maintenance and repair activities, repairing and retiring embankments, are carried out using FFW resources and are poorly supervised by BWDB. As a result compaction standards are poor and design standards are not followed.
- Most FCD/I structures are operated more or less as anticipated, where their physical condition permits it. However the local committees often envisaged to participate in operation have rarely been established effectively, and operation is frequently carried out under the influence of powerful local individuals. In some areas operating practices are the subject of serious dispute, when different interests, for example shrimp farming and paddy farming, dictate different operating practices.

c. Flooding, Drainage and Irrigation

- Almost all the FCD/I projects evaluated have at least partially achieved their hydrological objectives. The only major exception was the Nagor River Project in the Atrai Basin, which was based on inadequate understanding of the regional hydrology, and is subject to persistent embankment cuts.
- There are numerous parameters to flood control, and each project had site-specific activities. In general attempts to delay floods were usually successful, and in many projects normal monsoon season flood depths were also reduced.
- Projects aimed at salinity exclusion were also generally successful, although they sometimes led to social conflicts between shrimp growers and rice farmers.
- The achievement of drainage objectives was more variable. The poor implementation and maintenance of drainage infrastructure undermined the possibility of achieving these objectives at some projects, and at others the FCD/I infrastructure exacerbated drainage congestion problems.
- Several projects had modest irrigation objectives, which were often achieved. The more ambitious surface irrigation system at Meghna Dhonagoda has had a dramatic impact in the area and is widely used by the beneficiaries. However at some of the other sites subsequent development of groundwater irrigation has replaced the projects irrigation role.

d. Agriculture

- The major impact of FCD/I projects has been on cropping patterns in the kharif season. Reduced flood depths and duration have led to a move from B Aman or Aus/Aman to TL Aman and T Aman HYV, and sometimes from B Aman to Aus followed by T Aman.
- In general, changes in cropping patterns made possible by FCD/I interventions tend to increase the preponderance of paddy, as this is the main monsoon crop and it generally gives the highest financial returns.
- Where flood control has protected the Boro crop from early flash floods this has promoted expansion of L. Boro and adoption of HYV Boro, but this phenomenon is limited to certain geographical locations.
- FCD/I projects have rarely resulted in increased cropping intensities. In many "successful" projects the cropping intensity has actually fallen – when a rabi/Aus cropping pattern is

replaced by a single Boro crop for example. This is, however, an effect of the irrigation, not the FCD, component of such projects.

- Where flood protection is effective there is evidence that increased levels of inputs are applied, both to paddy HYVs and to other crops.
- Coordination between BWDB and DAE in the planning, design implementation and operation of projects has generally been inadequate or absent. This remains an area for future policy intervention.

e. Livestock

- Bovine populations tend to be adversely affected by FCD/I projects as a side-effect of their impact on crop production. Grazing opportunities are reduced where there are fewer crop losses, and switches to HYV paddy varieties lead to poorer fodder supplies. There is no clear pattern of impact on small stock and poultry.
- Draught power requirements have risen with the introduction in larger areas of transplanted Aman., and medium and large farmers in particular are facing draught power shortages which they have tended to meet in the short term by using cows for draught purpose, and in the longer term by switching to power tillers for land preparation.

f. Fisheries

- FCD/I projects have usually had a major negative impact on capture fisheries, resulting from substantial reductions in the areas of regularly inundated floodplains, in the areas of permanent beels and in the blockages to past fish migration routes. Many fishermen have lost their livelihoods, or been diverted to river fisheries, leading to overfishing in these areas which are also adversely affected by the changes in fish migration potential. The magnitude of the losses is generally substantially greater than has been previously estimated, and in some cases is similar in economic values to the agriculture benefit.
- The absence of integrated flood control and fisheries planning has led in some cases to acute social conflicts between fishermen and farmers.
- Flood control has provided opportunities for development of culture fisheries, which are being taken in some areas. However the benefits from these do not go to the disbenefited capture fisheries.

g. Non-Farm Economic Impact

- FCD/I infrastructure both a direct and an indirect impact on non-farm economic activities. The direct impacts relate to communications and to employment in construction. In many projects the embankments provide an important communication network, and have stimulated the development of road transport, and subsequently improve the marketing infrastructure and access to social and other services. Half of the project studied by FAP-12 shows negative impact on navigation.
- The construction and maintenance of the FCD/I infrastructure, and of embankments in particular, has a substantial employment impact and particularly benefits the landless and disadvantaged woman.

- The indirect impacts arises mainly through the projects initial impact on agricultural production. This in turn stimulates input marketing, rice trading, milling and the production of implementation.

h. Social Impact

- The successful FCD/I projects have all stimulated employment, in both agricultural and non-farm activities, and all FCD/I interventions provide substantial employment opportunities in construction. Such employment accrues for the most part to the men and women of wage labour households.
- The benefits from the projects are not, however, evenly spread. Capture Fishermen and boatmen are usually the greatest losers, while agricultural production benefits tend to accrue particularly to the larger landowners. No FCD/I projects have included measures to mitigate the negative impacts on specific groups, even when these were clearly anticipated at the planning stage.
- Land acquisition processes have been a common source of dissatisfaction during FCD/I development.
- FCD/I projects have frequently exacerbated social tensions in the impacted areas, between insiders and outsiders, between farmers and fishermen, between farmers and boatmen and between farmers at different level.
- The important role played by the flood embankments is as safe refuges during flood events.

i. Environmental Impact

Environmental evaluation for all 17 FAP-12 projects was carried out by initial screening and scoping, followed by a more detailed preliminary environmental post-evaluation for the five PIE projects. The most positive environmental impacts were.

- Reduced flooding, in terms of level, timing, rate of rise, duration and extent of floods.
- Improved soil moisture status at critical periods, due to reduced wetness.
- Improved land capabilities through the reduction of flood hazard and increased cropping severity and flexibility.
- Increased land availability due to the reduced extent of wetlands.
- Increased and improved human use for cultivation, other use irrigation, with associated increase in agro-industrial activities.
- Increased opportunities for culture fisheries.
- Improved access and communication
- Greater opportunities for afforestation and other tree-plantation
- Greater protection for infrastructure, with increased human safety and diminished disruption
- Substantial rises in carrying capacity
- Some improvement of health and nutrition
- Substantial, if somewhat inadequate, economic benefits to the people in terms of incomes, employment, land values and credit-worthiness
- Generally favourable social attitudes to the projects, despite many complaints

- Overall improvement in the quality of life due to these positive physical and socio-economic impacts.

The most common negative environmental impacts were

- Cumulative influences in the external areas in increasing river flows, bank erosion and bed scouring, siltation and flooding.
- Drainage congestion due to inadequate design, operation and maintenance of drainage structures and channels
- High risk in specific areas of certain projects of the future catastrophic flooding, with associated hazards to infrastructure, life and property
- Possible decline in the quality of subsurface, river and wetlands water, and thereby domestic water supplies
- Reduced extent of wetlands, which is ecologically negative
- Decline of soil fertility due to diminished aquatic vegetation and micro-biota
- Contribution to the general decline in fish ecology and capture fisheries
- In one or two study areas, contribution to a continuing decline in bird communities and habitats
- Some decrease and deteriorated in the livestock sector
- Loss of land to the embankments and other projects works, often with inadequate compensation
- Disproportionate distribution of project benefits and disbenefits, causing some strains on social cohesion

j. Economic Impact

The economic impact of the projects studied by FAP-12 are summarised in Table 3-1

Recommendation from FAP 12 Study

1. Project planning must take into account not only within project (on site) impacts but also external (off-site) impacts.
2. The planning process must involve wider consultation than has been the case in the past.
3. The planning stage of all FDC/I projects should include a benchmark survey.
4. Embankments for multi-purpose uses structures on submersible embankments designed for operation with sizeable head differences should be designed.
5. The planning and drainage networks and drainage regulators for FCD/I projects requires more intensive investigations of existing drainage conditions than have been carried out in the past.
6. The possibility of using borrow-pits, excavated beels, khals drainage channels as water storage units or fisheries should be considered at the planning and design stages.
7. When planning process in Haor areas, non-structural measures such as safe places for housing, secure in extreme floods, should be considered at the planning and design stage.
8. In major embankments mechanical compaction may be necessary.
9. Analysis of project impact on agricultural production should consider both the effect on quantity and quality (nutritional status) of the incremental output.

10. In future beels should be protected as far as possible, and should be re-excavated and improved instead of being drained, in order to maximise their fishery potential.
11. Sluices and drainage outlets should be designed to facilitate fish passage.
12. Where any social groups are expected to dis-benefit as a result of FDC/I interventions specific mitigatory measures should be included and costed in the project design.
13. External (off-site) ecological and environmental impacts may sometimes be important and should be explicitly anticipated at the planning stage.
14. All benefits and disbenefits, including those flood protection, should be quantified and costed wherever possible.

3.3 FAP 13, OPERATION AND MAINTENANCE

Under the Flood Action Plan (WB 1989) a studies of determining the performance of the Operation and Maintenance to a number already completed FCDI project was done under the umbrella of FAP-13, Operation and Maintenance Study. The study was mobilised in January 1991 and jointly undertaken with FAP-12, with a multi-disciplinary team. The operation and maintenance (O&M) performance and problems were assessed in 17 completed FCD/I projects of different types spread throughout the FAP regions. The assessments followed RRA method. The study combines reviews of the O&M system and initiatives to improve O&M in Bangladesh and other countries, with detailed case studies of completed projects. The FAP-13 team comprises members of the FAP-12 team and works in close collaboration with that study.

Approach Adopted

The key component of the O&M study has been detailed evaluation of O&M performance in 17 FCD/I projects selected for joint evaluation with FAP-12. This has been based on a rapid rural appraisal methodology using multidisciplinary teams from FAP-12 and FAP-13. The 17 projects were selected in consultation with Flood Plan Coordination Organisation (FPCO). They are representative of the different O&M experience in BWDB projects since they cover a range of project types and ages.

Operation Performance

The operating status and problems of the projects are summarised in Table 3-2 and relates largely to operation of water control structures, although cuts in embankments are also made for operational purposes by inside. Virtually all projects had some operating problem, often ultimately because drainage facilities were inadequate or could never be sufficient when embankments keep out high river stages and heavy rainfall occurs over the internal catchment of the project. Often there were also a lack of clear responsibilities for operation, and conflicts between different interest groups. FCD/I projects in general mean that some people gain and other lose. Since project planning never allowed for compensation, other then where land were acquired, this led to conflicts over operation.

Maintenance Performance

The major concerns of the maintenance are earthworks (embankments, khals and canals) and structures. Table 3-3 concentrates on embankments since these are the critical component of FCD projects. Operation problems summarised in Table 3-2 may ultimately be due to

maintenance problems.

Recommendation in the Operation and Maintenance of 17 FCD/I Project

a) Public Participation

Responsibilities and rights need to be clearly defined and divided between public agencies and the beneficiaries and users of the FCD/I projects, with clear lines of communication between both side.

Resources and professional social organisers are needed to facilitate public participation in and to build up local institutions for system management.

An ability to generate resources and greater local control of the resources created by FCD/I is needed to increase local accountability in management.

b) Transition Period

A formal transition and hand over from implementation to management (O&M) division/agency would help in preventing scarce maintenance resources being used for correcting planning, design or implementation.

As-built drawings of project structures and practical guidance on O&M should be handed over to the system management.

Training and technical assistance in this period should cover: training of social organisers and system employees, and practical training and advice for user groups – in operation, routine maintenance, and associated productive enterprises (such as tree or fish cultivation).

c) Maintenance

Routine earthwork maintenance is needed, alternative approaches are employing women's maintenance teams or linking maintenance requirements to productive use of embankments and channels. In this, and in periodic maintenance, greater effort should be made to target employment creation directly to disadvantaged groups.

Regular monitoring of embankments and structures is needed so that danger areas can be upgraded before it is too late, so avoiding excess damage, probably loss of life, and high rehabilitation costs. This will require improved prioritisation of funds, and greater discretionary funds for system managers to speedily carry out preventative emergency repairs.

d) Resource mobilisation

Experiments are needed in mobilising resources for O&M by: payments of fees, leasing of infrastructure use to raise revenue directly for O&M, self-contribution of resources by beneficiaries, and making proper maintenance conditional on use of infrastructure.

Housing on embankments could be permitted if it is planned for, linked with maintenance duties for the settlers, and does not affect the main purpose of the embankment.

Self-sustaining uses of FCD/I infrastructure could reduce O&M costs and create additional benefits. Productive use of embankments, and managed capture or stocked fisheries will require experimental development of suitable institutional arrangements and should not adversely affect the FCD/I objectives of projects.

3.4 FAP 16, ENVIRONMENTAL STUDY

Similar to FAP12/13, a study of determining the environmental impact of the FCDI project were initiated under FAP-16 of the Bangladesh Flood Action Plan (WB 1989). The FAP-16 Environmental Study is one of the 15 supporting studies supported by the U.S. Agency for International Development (USAID) (FPCO 1991). The intention of the study is to fulfil the environmental objectives i.e., any solution to the problems of flooding in Bangladesh should be technically, financially, economically and environmentally sound. It also intends to meet the requirements in the description of the FAP itself, i.e., environmental impact assessment (EIA) need to be made as an integral part of water control projects so that adverse environmental effects are avoided in the design, execution and operation of projects. The study was started on April 1991 and continued till April 1995.

Objective of Environmental Study

FAP-16, the Environmental Study was initiated with a multidisciplinary team from different discipline. The main objective of the environmental study are to assess environmental impacts of water development projects and prepare guidelines so that the adverse impacts are mitigated or avoided in planning, design and operation of FAP projects. The specific objectives of the Environmental Study, as outlined in the TOR:

- identify environmental issues associated with planning and implementation of the FAP.
- prepare guidelines and a users manual for environmental impact assessment of flood control, drainage and irrigation (FCD/I) projects for use in regional and feasibility study.
- assess the likely environmental impacts of flood control projects and develop recommendations so that adverse environmental impacts are avoided in the design, execution and operation of FCD/I projects.
- undertake special studies of specific environmental issues (e.g., impact of FCD/I projects on soil productivity, salinity, public health, ground water recharge and wildlife).
- EIA Training program and Institution Building on EIA methods for FCD/I project.
- organise workshops to discuss the environmental implications of FCD/I projects and to review project report.

Environmental Impact Assessment of Compartmentalization Pilot Project

A complete EIA assessment of the Compartmentalization Pilot Project (CPP) at Tangail has been carried out using the FPCO guideline by the FAP16 Environmental Study component. The main objectives of the case study were to apply the EIA process as specified in the FAP EIA Guidelines, to develop appropriate experience amongst EIA practitioners, and to test the practical

application of a Geographic Information System (GIS) to a typical EIA.

The CPP study area is located in the north-central region of Bangladesh, close to the left bank of Jamuna River, and bounded by the Dhaleswari and Pungli rivers. Total project area is 13,000 ha. The CPP project is a flexible plan comprising compartmentalization of the area with provision of flow control and water management (FPCO, 1992d).

The EIA study process followed that defined in the FAP EIA guidelines and considered of the major steps of project design and description, environmental baseline description, scoping, bounding, major field investigations, impact assessment, evaluation of impacts, development of recommendations for an environmental management plan, feedback to improve project design, and preparation of the EIA report. Some work on people's participation was undertaken to supplement the extensive program undertaken by FAP20. Close cooperation was maintained throughout the study with FAP20.

The environmental impacts predicted for the CPP are summarised in Table 3-4. The main beneficial impacts of the project would be include increases in irrigated area, improvement in agriculture production, reduction in crop damage losses, improvement in homestead security and crop production, increase in culture fish production, improvement in terrestrial habitat availability to wildlife, and improvements in socio-economic factors related to agriculture. Negative impacts would include a reduction in agricultural crop diversity, marked declines in capture fish production and harvests, reductions in aquatic habitats and in wildlife species dependent on such habitats, reduction in water-based transportation, decreases in socio-economic parameters related to fish and fishbased nutrition, and an increase in environmental contamination with pesticides and other agricultural chemicals.

Mitigation of negative environmental impacts would be possible for some impacts, but not all. A relatively large number of impacts would not be adequately mitigated by presently available and practical mitigation measures which are listed in Table 3-5.

The economic benefits of the project appear to exceed the costs by a small margin. Increased employment in project construction and in the agricultural sector account for most of the benefits, while the largest environmental cost is the loss of capture fisheries production and employment. Due to a lack of specific information, such as pesticide and pollution damage, the loss of wetland species and general biological diversity, and the cost of dealing with potential disease epidemics related to the project development were not considered in the economic benefits.

Impacts beyond the boundaries of the CPP would occur due to backwater effects and to flow regulation downstream of the CPP area. These impacts would be limited to the immediate downstream areas bounded by the Dhaleswari and Pungli rivers and to the sub-compartments immediately north of the CPP. These impacts were not assessed in details in this case study, but are considered to be potentially small. Recommendations for an Environmental Management Plan are made in the report and is presented in Table 3-6.

3.5 FAP 17, FISHERIES IMPACT EVALUATION OF THE FCD/I PROJECT

Similar to FAP12/13/16, Fisheries Impact Evaluation of the FCD/I Project (FAP17) under the Flood Action Plan (WB 1989) was initiated to develop an understanding of the actual impacts in the flood plain capture fisheries and the interaction with the development of the water resources project. The study was enabled the regional planners and project designers under FAP to recognize and cater for the interests of fisheries by either enhancing the habitat or at least minimizing adverse impacts on capture fisheries. Starting from 1992 the project continues till June 1994.

Background

According to recent fisheries sector reviews in Bangladesh, fish provides 80% of the dietary intake of animal protein and 7% of the total protein supply. The per capita consumption of fish has reportedly decreased from about 12 kg/year in the early sixties to 7.5 kg/year in the late eighties. About 70-80% of the total population, engage in seasonal subsistence fishing on the floodplain during the wet season. This flood season is the time when many poorer households can gain access to a fishery. The relatively open subsistence fishery therefore adds to the incomes and the animal protein intake of poor rural households. Value adding activities, particularly fish distribution and processing, also generate income and employment. Inland capture fisheries are thus of considerable importance in Bangladesh. The Bangladesh government has also recognized the significance of this resources and, in the sector objectives of the current Fourth Five-Year Plan, include increased fish production for improved nutritional standards and improved environmental management(FPCO 1994a).

The inundation of the floodplain provides the spawning grounds, nursery areas and the major feeding opportunities for many of the 256 species which have been recorded as occurring in Bangladesh (Rahman 1989). The water area survey carried out by the Fisheries Resource Survey System and SPARRSO indicated the area seasonally flooded land tends to be 2,832,792 ha, the area of beels to be 114,163 ha and the area of river and estuary to be 1,031,563 ha (Bangladesh DOF 1988). The total area contributing to the production of the floodplain could, therefore, be the total of all three, or 3,978,818 ha.

The rapid, large-scale expansion of flood control developments during the last three decades caused serious concern about their impact of fisheries. This concern increased during the eighties when estimated catches from floodplains begun to fall. The prospect of future planned expansion of flood control projects under the FAP in nineties resulted in the establishment of the present FAP-17 study (FPCO 1994a).

Overview of FAP-17 Activities

The study is designed to address issues relating to fisheries and aimed to collect, analyze and interpret information on which to make predictions of the impacts of the planned flood control action upon the inland capture fisheries of Bangladesh. To do this, quantitative baseline fisheries and socioeconomic data were collected from inside and outside a range of different types of flood control projects in four regions of the country. A total of eight FCD/I projects was studied and

the results of each study were documented in a series of Supporting Volumes (Fisheries Studies) of the project Draft Final Report. Three further fisheries studies were completed, one of which described the fisheries of the main rivers Jamuna and Padma. The other two investigated the movements of a) adult and juvenile fish and b) fish hatchling in regulated and unregulated rivers and addressed the impact of regulators on these movements. A parallel set of socioeconomic studies was carried out and the results documented in seven village study reports.

The study aims to develop a deeper understanding of the interaction between flood plain capture fisheries and water development projects; a study of the impact of flood control on fisheries must go beyond the biology and mechanics of fish production and look at the total impact of flood control schemes on the livelihoods of people leaving within and around them. This study will enable regional planners and project designers under FAP to recognize and cater for the interests of fisheries by either enhancing the habitat or at least minimizing adverse impacts of capture fisheries (FPCO 1995c). One of the important output from the FAP-17 study was the establishment of a detailed and comprehensive fisheries database which provides quantitative baseline information on inland fish resources and fisheries in Bangladesh. Starting from January 1991, the study (Phase-I) continued till June 1994 including study setting, develop methodology, data sampling, data analysis and upto the preparation of final report. The study cover in all the four FAP region by eight flood control projects and hastling migration in the main river system and house hold survey. The principal objectives of the eight supporting studies are as follows.

1. Evaluation of the effects of different flood control measures on the production of fisheries.
2. Evaluation of the effects of different flood control measures on the movements and populations of fish.
3. Assessment of the feasibility of technical and developmental measures to compensate for or reduce potential losses to fisheries due to flood control.

Summary of the Fishery Impacts Evaluation

1. Loss of catch through loss of habitat

Whenever flood control projects reduce the area of flooded land, there will be a loss of fish production. The results from unregulated floodplains, beel and canals outside eight flood control projects in four FAP regions showed that the annual fish yield or catch per unit area from this lost habitat varied geographically between regions and between different land heights. The yields given here refer to land heights within the flood phase series F2-F4 and ranged from 68 kg/ha to 202 kg/ha with an arithmetic mean value of 119 kg/ha.

2. Reduction in catch per unit area (CPUA):

Prior to the FAP-17 study, the general perception in Bangladesh was that FCD/I development had reduced fish catches through loss of habitat and reduced catch per unit area from the remaining regulated floodplains. The FAP-17 results revealed, however, a more complex relationship between catch, the degree of flood control, fish densities and the amount of fishing effort. Under full flood annual CPUA was reduced by 81%; under controlled flooding for deepwater rice catches increased in two projects due to higher fishing effort, and was reduced in a third by 37%. Under partial flood control, CPUA values were similar inside and outside three projects but were reduced in a fourth by 20% because of restricted entry of fish.

3. Reduced fish density/ abundance

Of the four projects providing full flood control or controlled flooding, statistical analysis revealed that fish densities were significantly lowered in two of them. In two projects which provided only partial flood control, no significant differences in fish densities inside and outside embankments were detected. In a third, significantly lower densities were found prior to cuts in embankment and significantly higher densities later in the year following several cuts which allowed fish through the embankments. It is concluded from these results that flood control can result in a significant reduction in biological productivity by decreasing fish abundance even when sluice gates provide restricted access to floodplains.

4. Increased fishing effort.

Under full flood control, lower flooding substantially reduced the opportunity for fishing and the amount fishing efforts per unit area of floodplain compared with that on unregulated floodplains. In contrast, controlled river flooding provided more stable and predictable hydrological conditions which stimulated increased fishing effort by small-scale subsistence gears along village shorelines. This increase in fishing effort resulted in higher catches from regulated floodplains than on unregulated areas. In three projects providing partial flood control, fishing effort was again higher than outside.

5. Reduced biodiversity.

Full flood control and controlled had an adverse impact on fish diversity. The effect of full flood control was more severe and resulted in a reduction of 33% in the total number of species recorded annually. Projects which used controlled flooding in the North West Region reduced diversities by 19% to 25% while in the South West Region diversity was less affected (4% reduction). Partial flood control has little adverse impact on biodiversity. Comparisons of different fish groups showed that there were greater reductions in diversities of migratory species than floodplain residents. Reductions of 95% and 29-45% were found for migratory species under full flood control and controlled flooding.

6. Reduction in migratory fish.

The contribution to catches by migratory species was substantially reduced by full flood control and controlled flooding but relatively unaffected by partial flood control. The results showed that as the degree of flood control increased, catches of migratory species which included large, high-value species such as major carps and catfish, decreased.

7. Disruption of fish community structure.

Results from analyses of catch compositions revealed that fish community structure in flood control areas was disrupted not only by the loss of riverine and migratory species but also by major changes in the composition of the remaining floodplain resident species.

8. Reduced fish migrations.

Full flood control and controlled flooding reduced lateral migrations between rivers and floodplains in two ways. Firstly, by reducing the number of entry points on to floodplains and thereby concentrating fish into fewer channels where they were more susceptible to

capture, and secondly, by closing gates of regulators for extended periods during the pre-monsoon and monsoon.

9. Increased captured at regulators.

Several examples were seen across all types of flood control in which regulatory structures on rivers and canals were deliberately used to prevent or hinder the passage of fish and facilitate their capture.

10. Reduced opportunity for mitigation measures

Exclusion of external river waters under full flood control for the increased cultivation of HYV T.aman substantially reduces the options available to mitigate against adverse impacts of fisheries compared with those available under control flooding for deepwater Aman

11. Reduced potential for stock enhancement

Whenever flood control results in a reduction in the extent and magnitude of flooding, the area available for potential stock enhancement by stocking floodplains with fish, is reduced.

Recommended Mitigation Measures

Effective planning for mitigation of fisheries losses in flood controlled areas requires an understanding of the nature of the impacts on the diversity and abundance of the fish resources affected. It also requires a knowledge of the rural communities which will be impacted and the magnitude and source of their losses. Finally, it is necessary to have available a range of management strategies and technologies which can be integrated into the overall management of the resources and which are viewed by the impacted communities of people as realistic and viable options.

During the course of the FAP, several short-term fisheries studies recommended aquaculture development as a principal means to compensate for losses to capture fisheries caused by flood control. During FAP-17 studies, a clear distinction was drawn between compensation and mitigation strategies. Compensation measures rely on aquaculture and culture-based methods to increase fish production and thereby compensate, to varying degrees, for the lost tonnage of fish due to flood control. In contrast, mitigation measures are designed to reduce or avoid losses to capture fisheries and, if successful, also reduce or avoid the need for compensatory measures. However, FAP-17 focused attention on the need for mitigation rather than compensation measures. But it does not imply, that aquaculture developments should not be encouraged. The recommended mitigation measures listed below include a series of initiatives for implementation within full control and controlled flooding areas. In addition, recommendations are made that involve institutional development, mainly within BWDB/WARPO, which will facilitate the integration of fisheries development and aquatic resource management into water management and flood control systems.

1. Production of deepwater aman and capture fisheries.

This is the most effective mitigation measures to reduce losses to capture fisheries caused by full flood control and one which has spread through rural communities as a result of farmers needs and preference. The measure is applicable to all lowland floodplains (F2-F4 flood

phase categories) where local rainfall flooding cannot be drained by gravity because of high river levels. These areas cover most of those targeted by the Flood Action Plan.

2. Habitat rehabilitation and protection.

This measure is designed to reduce the negative impact of flood control on fish production caused by loss of winter and pre-monsoon habitats. Important dry season habitats such as perennial beel and baur in which the magnitude, extent and duration of flooding have been severely reduced by flood control, should be rehabilitated by reconnection to original feeder river systems and maintenance of adequate dry season water level.

3. Increased fish migration across flood control structures

This measure is designed to increase fish production by increasing movements of fish and fry between rivers and floodplains. It requires no change to the design of structures but relies upon a modification to the operating schedule of sluice gates. Under full flood control there is little opportunity to introduce this measure as a realistic means of increasing fish recruitment on to floodplains because of the incompatibility of flood level requirement of HYV t.aman. In contrast, the measure offers considerable potential under controlled flooding for deepwater rice where small adjustments in gate operations at critical periods between June and July would allow the entry of major carp hatchling at times when their densities and supply rates are at a maximum.

4. Fisheries conservation: beel management.

This measure is designed to increase the survival of fish broodstock during the dry season, a critical period in their life, when they are vulnerable to over-fishing in flood controlled areas.

5. Fisheries conservation: prohibited fishing zones on regulator.

Flood control structures which block or delay movements of fish in rivers and canals thereby increasing their susceptibility to capture should be classified as prohibited fishing zones.

6. Fisheries conservation: protection of river (duar) fisheries.

Studies carried out by FAP-17 and FAP-6 have demonstrated the great importance of river duar (scour holes) as winter refuges for large species of fish, particularly catfish and major carps.

7. Conversion of full flood control to partial control.

Converting full flood control projects to partial flood control to reduce flood levels and increase deep water aman and fish production.

8. Increase fish mitigation across rural roads.

To reduce the adverse impacts of rural road construction there is a need for institutional changes in the inter-sectoral planning process and a practical change to ensure greater provision of culverts through roads.

3.6 EVALUATION OF THE SYSTEM REHABILITATION PROJECT (SRP)

SRP during 1990-95, under the Bangladesh water development board rehabilitated 35 water resources projects that was deteriorated because of the poor assessment at the beginning and improper operation and maintenance during the past. The objective of SRP is to protect and increase agricultural production, raise the standards of living and minimum degradation of the environmental consequences. To assess the overall impact of post rehabilitation of the SRP project, a multidisciplinary EIA evaluation team was engaged. The team assessed 7 project of the total 35 including Dardaria Khal and Singri beel.

3.6.1 DARDARIA KHAL PROJECT

The Original BWDB Project

The Dardaria Khal Project, commissioned in 1978-79, is a flood control and drainage project, located within Kapasia thana in Gazipur district. The gross-area is 6220 ha with a cultivable land is 4332 ha and is bounded by the Banar river on the south-west and Lakhya river on the south-east. A high terrace demarcates the northern and eastern boundary of the catchment. Land slopes down from north to south and favours drainage towards the Banar River (EPC at. el. 1988).

The objective of the project was to:

- Protect boro crops from damages due to pre-monsoon spill.
- Protect Aua and Aman from monsoon over-bank spill.
- Improve drainage during monsoon and post monsoon.

Conditions Prior to SRP

Partial improvement in terms of flood control and drainage were achieved by 18km long embankment, a 6v regulator near Ekuria and time-to-time re-excavation of the Dardaria khal. Due to poor management, recently, the area suffered from flooding and drainage congestion. As such, the rehabilitation becomes imperative.

SRP Structural Intervention

- Rehabilitation of the project in terms repair of the existing 6v regulator, existing pipe sluice, re-sectioning of the 18km embankment and re-excavation of the Dardaria khal.
- Improvement by dint of construction of 1v(1.5m X 1.8m) regulator and additional depth of re-excavation of the Dardaria khal for facilitating intake of irrigation water. Construction of four new pipe sluice for better flood control and drainage.

Present Status of the Project

During the field visit, the team found that construction of the additional one vent regulator and the repair/replacement work of SRP were almost complete. The rehabilitation work starts in 1994 and continued till 1996.

Important Environmental Components Identified and Evaluated

1. Flood Control and Drainage
2. Irrigation
3. Crop Production
4. Crop Damage
5. Fish Habitat & Species
6. Fish migration
7. Fishing Community
8. Wetland Dependant Flora and Fauna
9. Water Management
10. Embankment Maintenance
11. Transportation

Impact Evaluation

Flood Control and Drainage

With the SRP intervention, the project has been more effective in ensuring flood protection. The drainage situation has improved slightly in the northern part of the project, but is contingent upon the stage of the river allowing such drainage.

Irrigation

Limited provisions for LLP irrigation by re-excavating Dardaria khals and by the construction of a flushing regulator with an invert level of 0.00m PWD were made, such that it maintains the minimum required water level in the Khal even at the lower stage in the river.

As per design in the feasibility report and if proper construction were made, the water would be available for irrigation along a length of 3.81 km in the main and 5.22 km in the branch khal. But the achievement discovered in the field are 1.75 km in the main and 1.10 km in the branch khal are allowing LLP irrigation during 1997. This implies, that the designed re-excavations was not maintained during the construction.

Crop Production

No significant change in the cropping intensity was recorded with the SRP intervention but, the agricultural production has been increased. Reasoning behind, is the application of higher fertilizer doses, safety confidence against flood damage and ever increasing demand of food.

Crop Damage

Following the Boro cultivation, T. Aman or deep water T. Aman is a very common practice elsewhere in Bangladesh. But farmers in the southern part with medium lowlands are still faces a frequent damage of the Aman crop and subsequently less interested and kept it fellow during monsoon. The SRP intervention has, however, not been able to fulfil this expectation.

Fish Habitat and Species

Re-excavation of the canals and improving drainage, affects the reduction of inundation period in the F3F4 landtypes. The original project had adversely affected the size and the quality of water bodies and thereby reducing capture fishery resources. The SRP intervention has accelerated this process and people are now more inclined for culture fisheries.

Fish Migration

By dint of flood control structures developed starting from the BWDBs original project till now, the routes of fish migration specially the carps were successively destroyed. The SRP intervention negatively affects the fish migrations and reduction of the fisheries potential.

Fishing Community

The professional fishing community was adversely affected by the original BWDB project. The SRP intervention has added to their problems. Professional fishermen are continuously changing to their profession now.

Wetland Dependent Flora and Fauna

By the implementation of the project, the process of de-vegetation from the perennial sources initiates and SRP intervention has accelerated this process. The objective behind is to use these khas lands as culture fisheries ground by providing lease. The de-vegetation has directly impacted the wetland dependent flora and fauna.

Water Management

Although, institutionalising the water management among different users group was a prime objective of SRP, however, no such effective developments were observed in the field.

Embankment Maintenance

Prior to SRP, there was a very little attempt at surficial maintenance of embankment. SRP intervention has strengthen the process by employing the Embankment Maintenance Groups (EMGs) formed working within the stretches they were covering.

Transportation

The boat navigation was negatively affected by the original BWDBs project, although over the year, many roads have been constructed and people got adjusted to the situation. Still, there are some boat navigation specially during monsoon. SRP did not paid any attention for improving the boat communication, but indirectly facilitated road transport network by providing water control structures in places on the embankment.

3.6.2 SINGRI BEEL PROJECT

The Original BWDB Project

The Singri beel project, commissioned in 1985-86, is a flood control drainage project, located within Nchaol and Chapai-nawabganj thana of Chapai-nawabganj district. The gross area of the project is 13,543 ha and net benefited area is 4,100 ha. The project area is bounded by the Mahananda river to the west, the Amnura-Nachol railway embankment to the east, Bhitabari Damos project to the north, and the Amnura-Chapai Nawabganj railway line and road to the south (Halcrow at. el 1994).

The objective of the project was to:

- protect project flooding from Mahananda by constructing embankment on the left bank;
- drain excess rainfall runoff to Mahananda by means of drainage regulator during early monsoon and post-monsoon;
- cultivate Boro (HYV) from internal stored water and protect harvesting from early flood; and
- re-excavate internal khals to facilitated irrigation and drainage.

Conditions Prior to SRP

Since from its implementation, the condition of the embankments was deteriorated and the internal khals had suffered from siltation. Flooding would occur from Mahananda river through the openings in the road-cum-embankment (presence of nine bridges and culverts) and due to excessive run-off drainage deficiencies. The siltation of the khals and tail water condition in the river sometimes causes drainage congestion.

SRP Intervention

- re-sectioning of the embankments and the closing of uncontrolled openings;
- rehabilitation of the existing regulators and the Water Control Structures (WCS);
- re-excavation of the internal drainage canals for efficient drainage in pre-monsoon and post-monsoon, and retention of more irrigation water during boro season;
- Provision for additional WCS's in order to store more water for irrigation purposes.
- Construction of 4km internal road-cum-embankment for irrigation.

Present Status of the Project

Repair of 1.20 km embankment out of a planned 5.32 km has been completed. Re-excavating 2.67 km khals out of a planned 5.78 km has been completed. Construction of 3 new WCSs for emphasising irrigation are almost completed.

Important Environmental Components Identified and Evaluated

1. Drainage
2. Irrigation
3. Crop Production
4. Crop Damage

5. Fisheries Resources
6. Water Management
7. Embankment Maintenance Group (EMG)
8. Operation of Gates

Impact Evaluation

Drainage

Before the project starts, the damage of the Aus and Aman crops due to flooding from the Mahananda river and excess run-off generated from the adjoining area of the Barind tract was common. After the BWDB project, the intensity of the small peak flood damages has been reduced. But the drainage congestion in the monsoon remains as before.

After the SRP intervention, the damage initiated from the Mahananda river is reduced substantially but the drainage congestion remains as before. Reason behind, is the shortage of the proper drainage development network and tailwater condition in the Mahananda river.

Irrigation

Irrigation using surface and ground water are almost common in the area. Major source of irrigation water is the Deep tube well (DTW). Depending on the availability of surface water, LLP irrigation are also in practice. SRP has an intention to further explore these idea by using accumulated surface water in the beel and khal by providing control structure.

For developing irrigation facilities from surface water resources stored in the major beels and khals, SRP develops few water control structures at various reach of the internal canals. During field visit, almost all the structures were completed but the 4km internal road-cum-embankment was not done.

Crop Production

T.Aman is the major crop covers 80% of the NCA of the Barind terrace. The second major crop is the Boro, covers 18% of the NCA in the terrace and in the flood plain and irrigated by DTW and LLP. Boro cultivated as a single crop in the medium low (F_2) and Lowland (F_3) and in rotation with T.Aus in the high (F_0) and medium highland (F_1). The existing cropping intensity is 132%.

After the SRP intervention, there has been no significant change in the cropping pattern. But it is likely that crop production will increase as more areas will come under irrigation. These might slightly increase in cropping intensity.

Crop Damage

Before the SRP intervention, protection against damage of the kharif crops from river flood was inadequate and frequently subject to damage. After SRP intervention, the situation was improved. However last year (1996), T.Aus and T.Aman was damaged

prior to T.Aus harvest by overtopping embankment of the flood water. It implies, that the project will not be able to protect floods with the higher peaks. Also, damage may likely to occur with the drainage congestion particularly at the higher stage of the river water level. Protection at the sub-compartment level will however improve situation in one compartment.

Fisheries Resources

Although, BWDBs project has improve some agriculture, but damages much of the traditional open water capture fisheries resources. SRP intervention farther deteriorated the situation for migratory as well as residence fisheries by providing intermediate WCS and leasing some of the major khas beels. The potentiality of the migratory fish will completely destroyed after the successful implementation of SRP. The leasing is somehow need to be stopped, otherwise it would be a total distraction of the fisheries potential.

Embankment Maintenance

The Embankment Maintenance Group (EMG) found working very effectively although, there is a very limited (2km) embankments available for protection from the Mahananda river.

Operation of Gates in Structures

Prior to SRP intervention, there was a conflict of gate operation, specially between fisherman and farmers. With SRP intervention, the conflicts of different sections of the farmer were addressed properly. But the conflict between the farmers and fishermen is still remaining. There are some conflicts in the gate operation were observed in some in the subsidiary intermediate gates, which may cause acquit problem in near feature.

Water Management

Although the process of institutionalization of the water resources management, in terms of the effective water users association at different hierarchy, setting guidelines, coordination between different Government and non-government was initiated by the SRP intervention, but no effective results came out. No agriculture or fisheries extension and training was held although provision was there. People's participation and public opinions were neglected specially where the duplex WC structures was made and development of the 4km embankment-cum-road.

3.7 EVALUATION OF ENVIRONMENTAL IMPACTS OF CHANDPUR IRRIGATION PROJECT (CIP)

Introduction

Recently, Mirza (1991) carried out an assessment of the Chandpur Irrigation Project (CIP) using the primary and secondary data source. The project within 12 year since its commissioning in the year 1978 has generated many positive and negative impacts. Immediately after commissioning, the project benefited tremendously in the agriculture sector and flood plain fisheries has been drastically reduced. Recently, it has become a food deficit area as the production level decreased

mainly due to decreasing soil fertility. Mirza (1991) concentrated the assessment in the field of fishery, agriculture, livestock, vector diseases, diarrhoeal diseases, irrigation, navigation, fertiliser, flood control, maintenance and institutional settings of the Chandpur Irrigation Project (CIP).

Impact of CIP on Environment

Fisheries

The overall fish production in the project declined by 35% within the two years following the operation of the project. However, it increased by 47.9% after 12 years since the operation of the project in 1978. Since 1985, the local varieties increased by 5.88% and the production of major carps increased by 14%. The major contribution of this increment goes to the closed water fishery and development of hatcheries have significantly contributed to this development. The per capita consumption significantly reduced although production was increased. The reason behind this is the population growth and hence the fish consumption is close to national consumption level (20 grams per day/per capita).

The project created a stagnant and stable freshwater environment inside the area. The regulated water body caused either beneficial effect or no effect at all on 65 species of resident freshwater fisheries and became ecological barriers for immigration of 18 species of tidal/estuaries fisheries. The fish fauna inside were changed from a mixture of the tidal/estuarine and resident freshwater form into a almost resident freshwater form. There is an ample scope of increasing fish production in the CIP area. Presently there are only 220.93 ha borrowpit canal is under fish culture, whereas, it has the potentiality over 2800 ha and these could further may increase 3484.00 M.T of the fresh water fisheries.

Agriculture

CIP generated tremendous benefit for agriculture sector as compared to the pre-project irrigation facilities, use of HYVs and agricultural inputs. The initial production of some rice varieties after commissioning of the project was very high. However present production level is almost stagnant although fertilizer and pesticides uses increased substantially and better management facilities have been introduced.

Immediate benefit of CIP started with the rapid change of cropping pattern due to flood free condition and introduction of HYVs and irrigation facilities. During pre-project, the cropping pattern in the area consisted mainly the traditional deep water Aman mixed with Aus jute. Huge area was usually kept fallow or low yielding cash crops were planted. After commissioning of the project, T. Aman (HYV and LYV) has replaced local B.Aman+Aus, and B.Aman(L) within few years of operation of the project. Area under T.Aman(L) and B.Aus+Aman (mixes) was declined by 10.85 and 93.05% respectively after 2 years of the project operation. Changes of cropping pattern has generated bad impacts for rabi crop and jute cultivation. Boro is the 2nd dominant crop after Aman and is the most beneficial crop in the CIP area. During the pre-project condition, there was a only 6.85% area under Boro cultivation, and major portion contribution by HYVs.

However, Boro area sharply increased from 6422.06 to 17507.69 ha (173% increased) within one year of the project operation. Current statistics show that area under boro cultivation increased at a steady level and is not possible to increase farther in the non-irrigated area of the project.

Cropping intensity in the CIP has increased substantially compared to pre-project situations. The present cropping intensity is 244%(1989-90) and which was 166-168% between 1966-76 period.

Before the project operation, annual deficit in the project area was on average 65-90,000 tons. In the year of project commissioning the deficit reduced at 31,373 tons. It becomes a food surplus area within one year of project operation and maximum surplus was recorded in 1982-83 and since then fluctuations in trends have been observed. Since 1982-83, average cropping intensity for Boro and Aman (kharif-II) were roughly 96 and 70% respectively but surplus level randomly raised and declined. It has now becomes a food deficit area.

Livestock

Due to massive depletion of grazing grounds as most of the land has been under year round agriculture practice, substantial reduction in the cows/buffalo's population occurred in the project area. The huge amount of rice straw, on the other hand is considered to be a insufficient source of animal nutrition and is mostly used for fuel and construction material for farmers houses. On the other hand, the number of chicken/ducks have been increasing as the project has ensured the supply of sufficient feed for them.

Land acquisition

In the CIP, slightly more than 2159 ha of agriculture land were acquired and approximately 2000 families were being affected. The land acquisition process and payment method is so complex that an affected person may wait for years for realisation of compensation. Also the realisation amount is very less as compared with the real price. In the CIP, it reveals that the large farmers purchased lands for living inside the project area but small farmers lost the compensation money with passage of time. They are now either working as a rickshaw puller or working as a day labour in the agriculture field.

Spread of Malaria

Temperature, humidity, and rainfall plays an essential part of the ability of the mosquito to develop and transmit malarial infection. Under CIP, 55000 ha of land have been enclosed by a 104km long embankment, so there has been a little chance of flushing out mosquito larvae by the flood wave. Furthermore, localised rainfall contributes to creating more water-pool with the project area and during the whole rainy season, normal practices followed by the CIP authority is that they start cleaning of excess rainwater when it exceeds 9.5m Pwd. Considering altogether, CIP has a very favourable climate setting for mosquito breeding.

The primary malarial sectors identified in the CIP are Plasmodium Vivax and

Plasmodium falciparum. Annual parasite incidence (API), for different upazila within the project area does not maintain a consistent pattern to blood slide collection has not been increased proportional to the population growth. However, slide positivity rate (SPR) of the project area is considerably higher than the adjacent areas.

In 1986, slide positivity rate in the CIP area was 2517% higher than the adjacent areas. In that year within CIP, the SPR was 2.12% while outside the project area it was recorded as 0.081%. However, in the recent times, the gap has been narrowed down but it was as much as 860% higher in the CIP area compared to the adjacent areas in 1989.

The attack of malarial vector *P. falciparum* in the project area is higher than the adjacent areas in 1986. Slide falciparum Ratio (SFR) in the project area was 200% higher than the adjacent localities. In recent times the SFR has been increased substantially. As per available information, in 1989, SFR in the project area was recorded 0.24% which is 485% higher than that the SFR of the adjacent area.

No doubt, CIP accelerated process of creation of favourable environmental condition for malarial disease. The attack of *P. falciparum* in 1983 in the Faridganj area was serious that health authority had to make aerial spray for bringing it under control. In that year slide falciparum ratio (SFR) in the Faridganj upazila was 0.95%, individually, which is ever highest recorded SFR in the CIP.

Water quality

The author initiated an investigation programme for making assessment of water quality of the CIP for three purpose viz: a) Fisheries, b) Drinking and c) Irrigation. From the laboratory test results, it was observed that water quality of samples belonging to area outside of the CIP is to some extent better compared to CIP samples. However, water quality of both inside and outside of CIP is suitable for fish culture but P^H values of CIP samples are almost close to the minimum recommended level. The water quality of CIP area is not up to the standard recommended by the World Health Organization (WHO) but no problem with the surface water quality for irrigation purpose.

Agricultural production costs

The author assessed the cost benefit of some selected crops in the CIP. Table 3-7 shows that the production varies with remarkable magnitude from crop to crop. From BUP (1982) study, it is revealed that cost of seed, fertilizers, pesticides and irrigation was 6.3, 9.3, 3.5 and 6.5% respectively in 1982. However, in 1990, the cost of the said inputs were 6.3, 15.79, 13.54 and 11.89% respectively. So it is seen that investment for pesticides increased with highest margin and irrigation follows next. From field reports, it also appears that sharecroppers has to face loss because they have to bear all the cost involvement for the production.

Use of Inputs in the CIP and its Impact

The agricultural input use has been increased for human labour, animal power, fertilizer and pesticides. BUP conducted survey in 1982 in some villages within CIP and their

findings is given in Table 3-8. The author has also initiated some sample survey regarding agricultural input and also tabulated in the same table. Large change is observed regarding human labour input for boro crop and transplanted aman. The use of urea fertilizer has been increased by 32.25% for Boro, 100% for T.Aman, 80% for wheat in 1990 as compared to input use in 1982. Similarly use of phosphate for Boro, T.Aman and Wheat has respectively been increased by 52.48%, 290% and 71%. Similar is also observed in case of potassium. A new observation is the use of zinc fertilizers in the CIP area. The use of higher doses of fertilizer is attributed to the decreasing soil fertility. The pesticides use for Aus (HYV), Boro (HYV) and T.Aman (HYV) has been increased by 82.67, 100 and 100% respectively.

Flood Control and Drainage

It appears that there is little or even no problem in the case of flood control in the CIP area but there are some major problems for the drainage congestion. The importance of this problem was pointed out in early 1981 to the World Bank and it was decided to carry out a reconnaissance survey to assess the seriousness of the problem. The major two aspects of the problem area;

- a) Flash floods resulting from heavy pre-monsoon rainfall that can seriously affect recently transplanted aus and the mature HYV Boro crop.
- b) Flooding in the monsoon season at lower elevation which occurs at a time when the water level in the Meghna is higher than the internal water level and thus the water cannot be evacuated easily.

To overcome the drainage problems, 6 manually operated sluices have been installed and ring dykes around the low land areas were constructed. Even though the problem is yet to solve completely.

Maintenance

Insufficient allocation of funds has been a problem for proper maintenance of the CIP and declining if the rate of inflation is considered. BWDB stated that 5% of the capital cost of CIP is regulated for annual operation and maintenance, but 2.0-2.50% is provided. In this respect, the approach of BWDB would be to raise funds from the project area through by task collection from the water users. But due to shortage of manpower, such task has not yet been collected.

Public Health

The project has contributed to the outbreak of malaria. There was an outbreak of cholera in 1977 and gastro-enteritis and diarrhoea in 1979 in the Chandpur area. According to the upazila health sources, the possibilities of outbreak are directly related to the stagnancy of water for a longer period in the project area.

Soil Fertility

- ° From the outcomes of the test soil sample (10 nos) in the CIP inside and outside, the following assessment was made.

- Sulphur deficiencies were observed inside the project area as compared with the outside.
- P^H level was found in a range between 5.6 – 7.6 inside of the CIP area and 6.4 – 6.5 to the outside areas. The P^H ranges are suitable for all except sugarcane in the outside project area.
- The NH^4-N were observed to a very low level in the CIP. The optimum level of presence of NH^4-N is very much important for plants growth. The presence of total nitrogen is also very low.
- The presence of micronutrients has been found very optimum. There is no deficiency of micronutrients in the CIP area.

Co-operatives

Two types of co-operatives are working within the CIP. They are formal and informal co-operatives. There are three types of formal co-operatives normally covers a village such as Farmers, Landless and Women's co-operatives. All this co-operatives provides credits loan to individual sectors. The primary co-operatives gives their demands to its manager and these are passed to the Uupazila Central Co-operative Association (UCCA) where the RDB officer checks it and submits a total plan to the local assistant general manager of a commercial bank who makes a decision. The informal groups includes the CIP pump groups, which can be any member of farmers depending on the topographic area and demand for irrigation through originally administered by BWDB directly, pump charges are collected via the UCCA system: the UCCA pays all the higher charges to the BWDB and then collect the charges from the schemes. Altogether the performance of the co-operatives working in the CIP has been appreciated.

Impact in the Outside of the Project Area

Impact assessment outside of the CIP was out of the project objectives. However, there is very limited or any remarkable impacts were not being observed during the project life.

In conclusion and recommendation the author remarked that for the environmental impact evaluation of FCDI projects in Bangladesh, simple Checklist and Network are more suitable techniques. The author also elaborately discussed the effects of the FCDI project in Fig 2-1, in a typical FCDI project of Bangladesh. In the evaluation of the CIP project he pointed out that;

- Implementation of CIP resulted depletion of flood plain fishery although captured fisheries were increased. However the overall fish consumption also decreased.
- Because of continuous monocropic irrigation practices, the soil fertility were decreased.
- The impact of pesticide and fertilizer on fauna results some negative consequences.
- Overall rabi crop has substantially been decreased. However, consumption of vegetable and mustered slightly increased.
- Malerial attack in the CIP has been increased in recent year.
- Attack of pests and water weeds have also been reported and found. Rotational

cropping practices have been identified as an important factor for creating favourable environment for pest and water weed breeding.

- Drainage problem is encountered in many places of the CIP.
- The decreasing trend of number of ruminants is also found. Year the round cropping practices were identified as the leading factor for depletion of grazing ground.
- The overall maintenance of the project was found unsatisfactory.
- Overall coordination among various concerned agencies is found to be poor.

3.8 SUMMARY

In summary, this may be concluded that in most of the cases, the impacts was reported through a descriptive text, although, in the national level, weighted matrix (Appendix – C) was suggested for such purpose. Presently, no standard criteria is followed on selecting the IECs of the water development projects and as such, some components are studied in great details while some are neglected.

From the literature review and the Important Environmental Impacts as identified in the EIA Guidelines, the following are the important environmental issues are associated while developing the water resources project in Bangladesh:

1. Changes in flood depths
2. Impact on drainage congestion
3. Irrigation
4. Crop production
5. Crop damage
6. Changes in crop diversity
7. Cropping intensity
8. Vegetation
9. Impact on capture fisheries
10. Changes in fish diversity
11. Impact on culture fisheries
12. Subsistence fishing
13. Surface water quality
14. Ground water quality
15. Aquatic habitat
16. Terrestrial habitat
17. Endangered species
18. Wetland dependent flora and fauna
19. Impact on road transportation
20. Maintenance of embankment
21. Operation of sluice gate
22. Water management
23. Boat navigation
24. O&M employment

- 25. Nutrition
- 26. Vector base disease
- 27. Spread of malaria resulting from the changes in the hydrological regime
- 28. Livestock
- 29. Sedimentation / siltation
- 30. Soil fertility
- 31. Operation and maintenance

CHAPTER - IV

GIS AND IMAGE PROCESSING APPLICATION IN THE EIA ASSESSMENT

4.1 INTRODUCTION

A GIS is a computer aided software tools and in its simplest terms, integrates computer mapping technology with one or more databases to build a series of digital maps that are related to one another through a common geographical references. The GIS can be used to analyze the various features from different maps and derive new information from their relationships. Image processing of the remotely sensed data are highly important to a broad range of disciplines. The availability of this data, coupled with the computer software necessary to analyze it, provides opportunities to environmental scholars and planners, particularly in the areas of landuse mapping and change detection mapping. The inherent raster structure of remotely sensed data makes it readily compatible with raster GIS, and are designed to perform image processing tasks, and to facilitate the incorporation of the results into GIS analysis.

The application of GIS and image processing is highly important in the EIA assessment whenever there is a question of spatial and temporal variation of the environmental components. The special analytical capabilities of GIS and the Overlay mapping are highly useful in the EIA assessment for determining the spatial relationships among different IECs.

4.2 MAP

A map is an easiest form of presentation and making understanding to the decision makers for the spatial distribution of different features on the earth surface.

4.2.1 The Earth

As a scale model, a map projects a spherical surface onto a plane and represents real features with graphic symbols. Cartographers employ three basic elements to portray spatial distributions and geographic relationships. They are scale, projection, and symbolism. Since most of the maps represent phenomena on the earth, the shape of the planet and its spherical coordinates, latitude and longitude is very important to understand (ISPAN 1993).

Latitude, one of the earths two spherical coordinates, is based on the equator. Longitude is measured east or west of the prime meridian, and ranges from 0 to 180 degrees. Although we usually think of the earth as a perfect sphere, the distance between the poles is actually shorter than the earth's diameter at the equator. The earth is actually an ellipse. Flat maps of the world are conveniently based on less complicated spherical or ellipsoidal models of the earth (Figure 4-1).

4.2.2 Map Scales

Scale is a ratio of distance on the map to linear distance on the earth. When expressed as a ratio, units of distance must be the same and can be omitted. Scale limits both the type of

information portrayed and the size of area shown on a map. Scale indicates actual length on the earth of a distance represented on the map.

4.2.3 Map Projections

Because the earth's surface is basically spherical and thus three-dimensional, it is impossible to represent it on a two-dimensional surface without some form of distortion. These two-dimensional representations or projections are usually the result of simple geometric shapes which can be flattened without stretching. Every type of map projection, therefore, has some form of distortion. One should know what kind of projection he is examining and be aware of the type of distortion associated with that projection. Projections possess varying amounts of distortion exhibited by the following properties:

- Direction (Azimuthality)- Lines represent true direction
- Shape (Conformality)- Shapes are true
- Area (Equal area)- Area on projection equal to area on sphere after scaling
- Distance (Equidistant)- Distances are true along a center line or center point

Usually Conic, Plane and Cylindrical projections are in common use. Some projections are not created using the cone, plane or cylinder, but are the result of complex mathematical formulas. It is important to know the source data projection in order to accurately evaluate data limitations.

But, none of the projection possess all the above four properties or none of the map can be conformal and equal-area (Figure 4-2). Equal-area projections are required whenever the map user might compare the sizes of countries or other territories, such as forest or agricultural land.

Lambert Projection

The Lambert conformal conic projection is a cone type projection. This projection intersects the sphere at two latitude lines which become two standard parallels of the projection (Figure 4-3).

This results in two parallels which lack angular distortion rather than just one parallel lacking angular distortion. The standard characteristics of this type of projection can be summarized as follows:

- All features have true shape (conformal)
- Meridians and parallels (Longitude and Latitude) meet at right angles
- Units can be in meters or feet

This type of projection works well for areas with east-west orientation

Transverse Mercator Projection

The transverse mercator projection is of the cylindrical type (Figure 4-4). The cylinder is turned parallel with the equator and rotates around the sphere placed according to the central

meridian. The standard characteristics of this type of projection can be summarized as follows:

- Projection is fully conformal
- There is minimal distortion in north-south orientations
- Possesses some aspects of true direction. Parallels and meridians maintain true direction and any straight line drawn on the map will meet all meridians at the same angle
- Units can be in meters or feet

This type of projection is suitable for areas with a north-south orientation.

UTM

The most widely used plane-coordinate system is the universal transverse mercator (UTM) grid defined worldwide for all places between 80 degrees S and 84 degrees N. This inter-polar area is divided into 60 long, thin, north-south trending zones each 6 degrees of longitude in width and numbered eastward starting at zone 1 between 180 and 174 degrees W. The UTM plane-coordinate system is based on a transverse mercator projection hence the name. Bangladesh has its own plane coordinate system based on UTM called BTM. BTM is UTM that is shifted so that Bangladesh can fit entirely into one of these zones (6 degrees of longitude wide).

4.3 GEOGRAPHIC INFORMATION SYSTEM (GIS)

4.3.1 Introduction

An information system is a chain of operations that takes from planning the collection of data, storage and analysis of the data, to the use of the derived information in some decision-making process. A GIS is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data (ISPAN 1993).

GIS technology can be used for scientific investigations, resource management, and development planning. For example, a GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, or a GIS might be used to find wetlands that need protection from pollution. In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information.

4.3.2 Why GIS

Geography (and the data describing it), is the more important part of our everyday world; almost every decision we make is constrained, influenced or dictated by some fact of geography. Fire trucks are sent to fires by the fastest available routes, central government grants are often awarded to local governments based on population, and diseases are studied by identifying areas of prevalence and rate of spread. The way maps and other data have been stored or filed as layers of information is a GIS makes it possible to perform complex analysis of;

- Information retrieval
- Topological modeling
- Networks
- Overlay

- Data output

4.3.3 Component of GIS

A GIS requires several operations or components including data acquisition, preprocessing, data management, analysis and product generation. Data acquisition is the creation or procurement of maps and the collection or appropriation of attribute data. Processing involves the manipulation of data so that it may be entered into a GIS. This may involve putting the data into digital format or converting one format to another. Data-management functions to make information available to the users thus it is an extremely important component of GIS. The analytical component of a GIS is used to derive new information from the database contents. The last component of a GIS is product generation. This involves the creation of maps, graphs, or tables which communicate the results of analysis.

4.3.4 Spatial and Attribute Database

GIS uses two kinds of data- spatial data and attribute data. Both kinds of data are related to each other and can be displayed on a map. A geographic database is:

- The core of a GIS. Its completeness and accuracy will affect all applications it supports.
- A collection of data for features located within the same real-world space.
- Organized in such a way as to serve one or more application efficiently.
- Maintained by a set of well-documented and administrated procedures.

To be efficient, different type of data are stored in different structures:

- Attribute data are stored and managed by a database management system
- Spatial data are stored and managed by the GIS software.
- Unique values link spatial and attribute data.

Spatial data and their attributes are linked.

- By their geographic location
- By unique identifier (Figure 4-5).

Identifiers enable both types of geographic data to be stored separately but accessed together. Identifiers are:

- Unique value-usually integers.
- Stored as part of the spatial data structure- as a numeric value.
- Stored as part of the attribute data structure- as a data field.

4.3.5 Geographic Data in GIS

The map is perhaps the most familiar form in which geographic data are presented. Characteristics of a map are:

Information is displayed as groups of points, lines and areas

- Features are positioned to a common coordinate system
- Features are usually represented in two dimensions

- The map legend links spatial with non-spatial data
- Maps serve as means to store data and to present data to the user
- Limitations of maps are:
 - Amount of data that can be represented
 - Expensive if drafted manually
 - Cumbersome to analyze several maps together
 - Compromises in scale and level of information details

In a computer-based GIS, the storage and presentation of geographic data is separate. The storage of information can be at a high level of detail, whereas the representation can be at a more general level and at different scales.

- Its geographic position
- Its attributes
- Its spatial relationships
- Time

or more simply, the four components give information on:

- where it is
- what it is
- what its relationship to other spatial features is
- when the condition or feature exists

4.3.6 Attributes

The information of a phenomenon at a certain geographic location with any particular time step is called attribute information or non-spatial attributes. As geographical data have a certain degree of positional inaccuracy, attributes can have different levels of inaccuracy depending on the scale of data input.

4.3.7 Spatial Relationship

The relationship of geographic features to each other are generally very numerous, complex, and important. For example: It is not only important to know the location of service centers in a district, but also to know how close these services are to potential clients. Or it is important to know the location of good agricultural land, but it is also important to know when this land is inundated by floods.

4.3.8 Time

Geographic information is referenced to a point in time or a period of time. Knowing the time when geographic data were collected can be critical to using those data appropriately. For example: It is important to have data on annual precipitation for an area, but it might be even more important to know the rainfall probability for a certain growing season.

4.4 SPATIAL DATA MODELS

There are two fundamental approaches to the representation of the spatial component of geographic information: the vector model and the raster model. Representations of a landscape in the vector and raster models are shown in Figure 4-6.

4.4.1 The Vector Data Model

In a vector model, objects or conditions in the real world are represented by points, lines, and polygons that define their boundaries. The position of each object is defined by its placement in a map space that is organized by a coordinate reference system. Every position in the map space has a unique coordinate value. The spatial entities in the vector model correspond more or less to the spatial entities that they represent in the real world.

GIS Analysis in the Vector Data Model

There are many different types of analytical tools available. Categories include database queries, map algebra, distance operators, and context operators. Database queries involve questions about where things are or where conditions occur. An overlay can be done to see whether there is correspondence between two or more conditions. This is done by combining more than one map or map layer of the same area. Map algebra also involves overlays but the layers are combined mathematically. Distance operations involve calculations in which distance plays a key role. Distance operations include the creation of buffers, aggregate distance measurements, and least cost path analysis. Context operators are used to create new maps from existing maps based on the context in which features are found on the map.

Database Query

The most fundamental of all tools provided by the vector GIS are those involved with database query. Database query simply asks to see already stored information. In some cases query is by location,--what land use is at this location? In other cases query by attribute- what areas have high levels of radon gas? Sometimes it does simple queries and also complex compounds of conditions such as locate all the wetlands that are larger than 1 hectare and that are adjacent to industrial lands.

In most systems these query operations are undertaken in two steps. The first step, called a reclassification, creates a new map of each individual conditions of interest. For example, if one were looking for residential areas on bedrock associated with high levels of radon gas, the first step would be to create a map of residential areas alone by reclassifying all landuse codes into only two, such as 1 for whenever an area is residential and a 0 for all other cases. The resulting map is known as a boolean map since it shows only true/false relationships. They are sometimes also called binary maps since the image contains only zeros and ones.

Once the residential map has been created, a geology map is then also reclassified to create a boolean map showing areas with high levels of radon gas. At this point the two conditions can be combined using an overlay operation. Overlay is the hallmark of GIS in that it is only a GIS that can combine conditions such as this that involve features with different geographies. Typically, an overlay operation in GIS will allow the production of new maps based on some logical or mathematical combination of two or more input maps. In the case of database query, the key logical operations of interest are the AND and OR relational operators, also known as the INTERSECTION and UNION respectively. Here we are looking for cases of residential land AND high radon gas- the logical intersection of our two boolean maps.

Map Algebra

The second set of tools that a GIS will typically provide is that for combining map layers mathematically. Modeling in particular requires that the ability to combine maps according to various mathematical combinations. For example, one might have an equation that predicts mean annual temperature as a result of altitude. Clearly he needs the ability to modify data values in the maps by various mathematical operations and to combine factors mathematically to produce the final result.

The map algebra tools will typically provide three different kinds of operations:

- The ability to arithmetically modify the attribute data values over space by a constant (eg., scalar arithmetic)
- the ability to mathematically transform attribute data values by a standard operation (such as the trigonometric functions, log transformations and so on)
- the ability to mathematically combine (such as add, subtract, multiply, divide) different data layers to produce a composite result

The third operation is simply another form of overlay- mathematical overlay, as opposed to the logical overlay of database query. To illustrate this, consider a model for potential soil loss:

$$A=R*K*LS*C*P$$

Where, A is potential soil loss, R is erosivity, K is erodibility, LS is a length-slope constant, C is cropping practice, and P is erosion control measures. Given maps of all of these variables one can multiply the maps together through mathematical overlays and the result will be a potential soil loss map. While simple in concept, this ability to treat maps as variables in algebraic formulas is an enormously powerful capability.

Distance Operations

The third tool group provided by GIS consists of the distance operators. As the name suggests, these are a set of techniques where distance plays a key role in the analysis undertaken. Virtually all systems, for example, provide the tools to construct buffer zones- areas within a specified distance of a designated feature type. Some can also evaluate the distance of all locations to the nearest of a set of designated features, while others can even incorporate frictional effects and barriers into distance calculations. When frictional effects are incorporated, the distance calculated is often referred to as a cost distance. The reason for this name is because movement through space can be considered to incur costs, either in money, time or effort. Frictions increase those costs. When the costs of movement from one or more locations are evaluated for an entire region, we often refer to the map that results as a cost surface.

Given this concept of a cost surface, geographic information systems also commonly offer least cost path analysis- another important distance operation. As the name suggests, the concern is to evaluate the least-cost path between two locations. It is the cost surface that provides the needed information that can allow this to be evaluated. Regardless of how distance is evaluated-by straight line distance or by cost distance, another commonly provided tool is

allocation. With allocation, the locations is assigned to the nearest of a set of designated features. For example, planners might establish a set of health facilities and then wish to allocate residents to their nearest facility.

Context Operations

Most geographic information systems provide a variety of context operators (also known as neighborhood or local operators). With context operators, it creates a new map based on the information on an existing map and the context in which each feature is found. One of the simplest examples of this is surface analysis using a digital elevation model and produce a slope map by examining the heights of locations in comparison to the heights of neighbouring locations. In a similar fashion, the aspect (direction of maximum downward slope) can be evaluated.

A second good example of a context operator is a digital filter. Digital filters operate by changing values according to the character of neighbouring values. For example, a surface of terrain heights can be smoothed by replacing values with the average of the original height and all neighbouring heights. Digital filters have a broad range of applications in GIS and remote sensing, ranging from noise removal to visual enhancement of images.

4.4.2 The Raster Data Model

In the raster data model the geographic features are represented by grid cells or pixels. The area mapped is subdivided into cell (usually square in shape). The value stored for each cell indicates the type of feature or condition that is found at that location. The location of each cell or pixel is defined by its row and column numbers within the cell array representing the area of interest.

Sources of Raster Data

- Converting vector files to raster format
- cell by cell entry
 - the values of each cell can be entered one by one within the GIS
 - the value of each cell can be entered into an ASCII file which can then be imported into the GIS
- remote sensing
 - remote sensing generates images, for example satellite images which are already in digital raster form
 - the images when 'classified' may be used as a 'layer' in a raster GIS

Description of the Raster Data File

- Grid cells or pixels in a raster data file are organized in rows and column.
- Each pixel is referred to by its 'data file coordinates'.
- Each pixel has 'map coordinate' associated with it. This is done by georeferencing and associating the file with a projection system.
- Each pixel represents an area on the earth surface. This is known as the 'resolution' of the raster data file. In a raster data file with a resolution of 50m x

50m on the earth surface, each pixel represents an area of 50m x 50m on the earth surface

- ° Each pixel has a 'class value'. The class value describes the area that the pixel represents.
- ° The class value of each pixel is stored in the computer as binary digits or bits. The number of bits used for each pixel is called the 'pixel depth'. If the pixel depth of the raster data file is 4 bits, then each pixel can have $2^4 = 16$ possible values. If it is 8 bits, then each pixel can have $2^8 = 256$ possible value.

Overlay Analysis Using Raster Data Files

- ° In a raster GIS different attributes are stored in separate files. The 'soil types' and 'forest cover' for an area would in be stored as separate 'soil' and 'forest' data files
- ° Each cell in the data file is assigned only one value. For example, in a 'soil' data file, the value assigned to a cell will be a number that represents a specific soil type.
- ° Operation of multiple raster files involve the retrieval and processing of the data from corresponding cell positions in the different data files. Conceptually, the process is like stacking the file as shown in Figure 4-7 and using the vertical stack of cell values to analysis
- ° Raster overlay is simpler and computationally faster than vector overlay.

The Raster GIS Database

Acquiring data for GIS involves creating a database of images that encompass the study area. A data base usually consists of files of the same area that contain different types of information. For example, database for a GIS parks in a metropolitan area may include a data file of park boundaries, municipal boundaries, vegetation types, soil types, drainage, slope, roads, etc. Each of the type of information is called a theme.

To represent each theme, the following is required.

- ° A raster data file
- ° Descriptor data associated with each class.
- ° A color scheme to represent the different classes
- ° Meaningful annotation for the image, etc

The full collection of data that describes a certain theme is called a layer

Extracting Information

Once the database is ready, the files can be processed to extract information. Some information can be extracted by simply looking at the GIS files and visually comparing them to other processed GIS files. However new information can be developed by combining and comparing the different GIS files using the procedures as follows.

- ° **Proximity analysis** is the process of classifying and evaluating pixels based on their distances from pixels in a class or classes

- **Contiguity analysis** allows on identify regions of pixels in the same class, and filter out small regions.
- **Cross tabulating** creates a report of areas in common for every combination of classes in two GIS files.
- **GIS file editing** allows on digitizing new features – polygons, lines and points into a GIS file.
- **Raster modeling** allows combining GIS layers in an unlimited number of ways. An output file created from modeling can represent the desired combination of features from many input GIS layers.
- **Pixel inquiry** allows examining a file pixel by pixel. At a glance, it can be seen the class values, map and file coordinates and descriptor data from several files that corresponds to one pixel.

A comparison between the vector and raster data model is presented in Table 4-1.

Table 4-1: Comparison of Raster and Vector data Models

	Raster Model	Vector Model
Advantage	It is a simple data structure	It provides a more compact data structure than the raster model
	Overlay operations are easily and efficiently implemented	It provides efficient encoding of topology, and as a result, more efficient implementation of operation that requires topological information, such as network analysis
	High spatial variability is efficiently represented in a raster format	The vector model is better suited to support graphics, Maps look like hand drawn
	The raster format is more or less required for efficient manipulation and enhancement of digital image	
	Advanced techniques for data input (Scanning) are best on the raster model	
Disadvantage	The raster data structure is less compact, Therefore more storage space is required.	It has a more complex data structure.
	Topological relationships are more difficult to represent.	Overlay operation are more difficult to operate.
	The maps produced using the raster model are not that legible as those from the vector model	The presentation of high spatial variability is inefficient
	Manipulation and enhancement of line features appear blocky.	More difficult to change projection.
	Expensive for high accuracy	
	Takes long time for plotting.	

The attribute data can be entered into the computer in one of the following ways:

- Enter attributes from the keyboard
- Use existing files already on the computer
- Read existing data stored on tape or diskette

4.5 REMOTE SENSING

4.5.1 Definition

Remote sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without being in contact with it. Human eyes are an excellent example of a remote sensing device. The eyes gather information about the surroundings by gauging the amount and nature of the reflectance of visible light energy from some external source (such as the sun or a light bulb) as it reflects off objects in the field of the eye view. Contrast this with a thermometer, which must be in contact with the phenomenon it measures, and thus is not a remote sensing device (EGIS 1996).

Given this rather general definition, the term remote sensing has come to be associated more specifically with the gauging of interactions between earth surface materials and electromagnetic energy. However, any such attempt at a more specific definition becomes difficult, since it is not always the natural environment that is sensed, the energy type is not always electromagnetic (e.g., solar) and some procedures gauge natural emissions (e.g., thermal infrared) rather than interactions with energy from an independent source (EGIS 1996). The two basic process involved in remote sensing are data acquisition and data analysis. The elements involved in the data acquisition process are functions of energy including.

- Propagation of energy through the atmosphere.
- Energy interactions with earth surface features
- Re-transmission of energy through the atmosphere
- Airborne and/or spaceborne sensors
- Generation of sensor data in pictorial and/or digital form

In short, the sensors record the variations in the way earth surface features reflects and emit electromagnetic energy. The data analysis process involves:

- Examining the data using various viewing interpretation devices to analyze pictorial data, and/or computers to analyze digital sensor data
- Extracting information about the type, extent, location and condition of the various resources in the study area.
- Compiling information in the form of hard copy maps and tables or as computer files that can be merged with other layers of information in a GIS.

4.5.2 Energy Sources and Radiation Principles

Sensors can be divided into broad groups –passive and active. Passive sensors measure ambient levels of existing source of energy, while active ones provide their own source of energy. The majority of remote sensing is done with passive sensors, for which the sun is the major energy source. The earliest example of this is photography. With airborne cameras we have long been able to measure and record the reflection of light off earth features. Aerial photography is still a major form of remote sensing. However, not all passive sensors use energy from the sun.

Thermal infrared and passive microwave sensors both measure natural earth energy emissions. Thus the passive sensors are simply those that do not themselves supply the energy being detected (EGIS 1996).

By contrast, active sensors provide their own source of energy. The most familiar form of this is flash photography. However, in environmental and mapping applications, the best example is radar. Radar systems emit energy in the microwave region of the electromagnetic spectrum. The reflection of that energy by earth surface material is then measured to produce an image of the area sensed (EGIS 1996).

Although names are generally assigned to regions of the electromagnetic spectrum for convenience (such as ultraviolet and microwave), there is no clear-cut dividing line between one nominal spectral region and the next. Divisions of the spectrum have grown out of various methods for sensing each type of radiation more so than from inherent differences in the energy characteristics of various wavelengths. Also, it should be noted that the portions of the electromagnetic spectrum used in remote sensing lie along a continuum characterized by magnitude changes of many powers of ten. Hence, the use of logarithmic plots to depict the electromagnetic spectrum is quite common (Figure 4-8). The visible portion of such a plot is an extremely small one, since the spectral sensitivity of the human eye extends only from about $0.4\ \mu\text{m}$, to approximately $0.7\ \mu\text{m}$. The color blue is ascribed to the approximate range of 0.4 to $0.5\ \mu\text{m}$, green from 0.5 to $0.6\ \mu\text{m}$, and red from 0.6 to $0.7\ \mu\text{m}$. Ultraviolet energy adjoins the blue end of the visible portion of the spectrum. Adjoining the red end of the visible region are three different categories of infrared (IR) waves: near-IR (from 0.7 to $1.3\ \mu\text{m}$), mid-IR (from 1.3 to $3\ \mu\text{m}$), and thermal IR (beyond $3\ \mu\text{m}$). At much longer wavelengths (1mm to 1m) is the microwave portion of the spectrum.

4.5.3 Absorption

Figure 4-9 shows the interrelationship between energy sources and atmospheric absorption characteristics. Figure 4-9(a) shows the spectral distribution of the energy emitted by the sun and by earth features. These two curves represent the most common sources of energy used in remote sensing. In Figure 4-9(b), spectral regions in which the atmosphere blocks energy are shaded. Remote sensing data acquisition is limited to the non-blocked spectral regions, called "atmospheric windows." Figure 4-9(c) is the spectral sensitivity range of the eye (the visible range) coincides both with an atmospheric window and the peak level of energy from the sun. Emittted heat energy from the earth, shown by a small curve in 4-9(a), is sensed through the windows 3 to $5\ \mu\text{m}$ and 8 to $14\ \mu\text{m}$ using such devices as thermal scanners. Multispectral scanners sense simultaneously through multiple, narrow wavelength ranges that can be located at various points in the visible through the thermal spectral region. Radar and passive microwave systems operate through a window in the region 1 mm to 1 m (ISPAN 1993).

The important point to note from Figure 4-9 is the interaction and the interdependence between the primary sources of electromagnetic energy, the atmospheric windows through which source energy may be transmitted to and from earth surface features, and the spectral sensitivity of the sensors available to detect and record the energy. One cannot select the sensor to be used in any given remote sensing task arbitrarily; one must consider instead (1) the spectral sensitivity

of the sensors available, (2) the presence or absence of atmospheric windows in the spectral range(s) in which one wishes to sense, and (3) the source, magnitude, and spectral composition of the energy available in these ranges. Ultimately, however, the choice of spectral range of the sensor must be based on the manner in which the energy interacts with the features under investigation.

4.5.4 Energy Interactions with Earth Surface Features

When electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible. This is illustrated in Figure 4-10 for an element of volume of a water body (ISPAN 1993).

Various fractions of the energy incident on the element are reflected, absorbed, and/or transmitted. Applying the principle of conservation of energy, we can state the interrelationship between these three energy interactions as:

$$E_i(\lambda) = E_r(\lambda) + E_a(\lambda) + E_t(\lambda)$$

where

E_i denotes the incident energy

E_r denotes the reflected energy

E_a denotes the absorbed energy

E_t denotes the transmitted energy

with all energy components being a function of wavelength (λ)

The above equation is an energy balance equation expressing the interrelationship among the mechanisms of reflection, absorption, and transmission.

Two points concerning this relationship should be noted. First, the proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending of their material type and condition. These differences permit us to distinguish different features on an image. Second, the wavelength dependency means that, even within a given feature type, the proportion of reflected, absorbed and transmitted energy will vary at different wavelengths. Thus, two features may be indistinguishable in one spectral range and be very different in another wavelength band. Within the visible portion of the spectrum, these spectral variations result in the visual effect called color. For example, we call objects blue when they reflect highly in the blue portion of the spectrum, green when they reflect highly in the green spectral region, and so on. Thus, the eye utilizes spectral variations in the magnitude of reflected energy to discriminate between various objects.

4.6 DIGITAL IMAGE PROCESSING

Digital image processing involves the manipulation and interpretation of remotely sensed images with the aid of a computer. There are four main components to digital image processing including (EGIS 1996).

- Image rectification and restoration
- Image enhancement

- ° Image classification
- ° Image transformation

4.6.1 Image Rectification and Restoration

These operations aim to correct distorted or degraded image data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically, and to eliminate noise present in the data. Thus, the nature of any particular image restoration process is highly dependent upon the characteristics of the sensor used to acquire the image data. Image rectification and restoration procedures are often termed preprocessing operations because they normally precede further manipulation and analysis of the image data to extract specific information.

4.6.2 Image Enhancement

These procedures are applied to image data in order to more effectively display or record the data for subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in a scene. The objective is to create new images from the original image data in order to increase the amount of information that can be visually interpreted from the data. The enhanced images can be displayed interactively on a monitor or they can be recorded in a hard copy format, either in black and white or in color. There are no simple rules for producing the single best image for a particular application. Often several enhancements made from the same raw image are necessary. Some enhancement techniques include level contrast manipulations (slicing and contrast stretching) and spatial feature manipulation (spatial filtering, convolution, edge enhancement, and Fourier analysis).

4.6.3 Image Classification

The objective of these operations is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This normally involves the analysis of multispectral image data and the application of statistically based decision rules for determining the land cover identity of each pixel in an image. When these decision rules are based solely on the spectral radiances observed in the data, we refer to the classification process as spectral pattern recognition. In contrast, the decision rules may be based on the geometrical shapes, sizes, and patterns present in the image data. These procedures fall into the domain of spatial pattern recognition. In either case, the intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or themes. These categorized data may then be used to produce thematic maps of the land cover present in an image, and/or to produce summary statistics on the areas covered by each land cover type.

4.6.4 Image Transformation

These procedures are used to combine image data for a given geographic area with other geographically referenced data sets for the same area. These other data sets might simply consist of image data generated on other dates by the same sensor, or by other remote sensing systems. Frequently, the intent of data merging is to combine remotely sensed data with other

sources of information in the context of a GIS. For example, image data are often combined with soil, topographic, ownership, zoning, and assessment information.

4.6.5 Conclusion

Remotely sensed data is important to a board range of discipline. This will continue to be the case and will likely grow with the greater availability of data promised by an increasing number of operational systems. The ability of this data, couple with the computer software necessary to analyze it, provides opportunities to environmental scholars and planners, particularly in the areas of landuse mapping and change detection, that would have been unheard of only a few decades ago. To understand, evaluate and compare the environmental cycle, it requires the time dependent spatial information of the environmental components in the area. Digital image processing is therefore has very much special importance for the development of the planning process because it could provide information along with it location and time. Classified image are therefor very important in the EIA evaluation of a project.

4.7 SENSOR/PLATFORM SYSTEMS

With the recent development of the sensors, a variety of platforms are now available for the capture of remotely sensed data. Following are the some reviews of the major sensor/platform combinations that are typically available to the user of remote sensing database.

4.7.1 Aerial Photography

Aerial photography is the oldest and most widely used method of remote sensing. Cameras mounted in light aircraft flying between 200 and 15,000 m capture a large quantity of detailed information. Aerial photos provides an instant visual inventory of a portion of the earth's surface and can be used to create detailed maps. Aerial photographs commonly are taken by commercial photocopy films which own and operate specially modified aircraft equipped with large format (23 cm x 23 cm) mapping quality camera. Aerial photos can also be taken using format cameras (35 mm and 70 mm), hand-held or mounted in unmodified light aircraft.

4.7.2 Satellite System

There are several satellite systems in operation today that collect imagery that is subsequently distributed to users. Several of the most common systems are described below. Each type of satellite data offers specific characteristics that make it more or less appropriate for a particular application.

In general, there are four characteristics that may helps in guide the choice of satellite data, such as, spatial, spectral, radiometric and temporal resolution. The spatial resolution refers to the size of the area on the ground that is summarized by one data value in the imagery. This is the instantaneous Field of View. Spectral resolution refers to the number and width of the spectral bands that the satellite sensor detects.

Landsat Satellite Imagery

NASA and the US Department of Interior began launching Landsat satellites in 1972 and to date there are five. Satellites 1, 2, and 3 weighed about 815 kg and were launched into circular orbits at an altitude of 900 km. The orbits passed within 9 degrees of the North and South Poles. They circled the earth once every 103 minutes, resulting in 14 orbits per day. The satellites had the capability of covering the globe (except the 82 to 90 degrees polar latitudes) once every 18 days or about 20 times per year. At the 103 minute orbital period, the 2760 km equatorial spacing between successive orbits caused the satellites to keep precise pace with the sun's westward progress as the earth rotated. As a result, the satellite always crossed the equator at precisely the same local sun time. This type of orbit is called sun-synchronous. Satellites 4 and 5 orbits were lowered to 705 km and each orbit takes 99 minutes. They cross the equator at 9:45 AM local sun time and there are 14.5 orbits per day.

Landsat -1, -2, and -3 were launched early and many improvements were made before -4 and -5 were launched, therefore, this discussion will include only -4 and -5. Landsat -4 and -5 each have a multispectral scanner (MSS) and a thematic mapper (TM) for data collection. MSS images have an 80 meter resolution, thus, they are inferior to TM images which have a 30 meter resolution. Therefore, TM imagery is used most often. TM imagery is divided into seven bands which each sense a different part of the spectrum.

SPOT

SPOT satellites were first launched in 1985 by the French government. The satellite have a sun-synchronous orbit at an altitude of 832 km. The images have a 20 meter resolution and in the monochromatic mode, the sensor collects a single image with a spatial resolution of 10 meters. Both mode cover a swath 60 km wide.

NOAA-AVHRR

The Advanced Very High Resolution Radiometric (AVHRR) is carried on board a series of satellites operated by the U.S. National Oceanic and Atmospheric Administration (NOAA). It requires data along a 2400 km wide swath each day. AVHRR collect five bands: red, two near infrared, a mid infrared, and a thermal infrared. Spatial resolution of the sensor is 1.1 km and this data is termed Local Area Coverage (LAC). For studying very large areas, a resampled version with resolution of about 4 km is also available, is termed Global Area Coverage (GAC).

RADARSAT

RADARSAT has several imaging modes which gives flexibility to the users in selecting the mode appropriate for the study. The different beam modes offer variability in the incident angle, image resolution and aerial coverage. The principal satellites used for remote sensing projects in Bangladesh are geostationary weather satellites and the sun-synchronous, near-polar orbiting Landsat, SPOT, and NOAA satellites. A common characteristic of all these sensors is that they operate in the visible and infrared (VIR) portion of the electro-magnetic spectrum (EMS). A major drawback to using satellite imagery for flood management is cloud cover. During the monsoon season, when the majority of flooding occurs, cloud cover is at its peak and it is rare that optical sensor satellites can effectively image the landscape. Fortunately, the all-weather

imaging capability of radar satellites has proven an effective tool for collecting data on flooding under adverse atmospheric condition (EGIS 1997).

Without the obvious exception of weather satellite monitoring, remote sensing investigations carried out in Bangladesh have required cloud-free weather conditions. The acquisition of useful VIR data sets, therefore, has been mostly restricted to the dry season between November to May. Change detection studies have used data sets collected before and after the monsoon season to avoid the cloud cover that predominates from May to October. These remote sensing investigations were able to analyze the results of environmental change, but they were not able to record the extent of flooding, let alone the actual process that govern change as a result of monsoon floods. Consequently flooding during monsoon season is not well documented in Bangladesh. There is a critical need to determine not only where the flooding actually occurs, but also to better understanding the processes that determine the morphology of Bangladesh's rivers and extensive flooding.

4.8 APPLICATION RADAR SATELLITE FOR FLOOD MONITORING STUDY

4.8.1 Introduction

Use of the microwave, or radar or more specifically Synthetic Aperture Radar (SAR) is a fairly new and sophisticated valuable tool for monitoring highly dynamic environmental phenomenon and events despite cloud cover, rainfall or darkness. In conjunction with other data sources, radar also could be used in Bangladesh for assessing river morphology, agriculture, land resources, or oceanographic and coastal zone phenomena associated with the development and impact of cyclones. The most important implication is that, it will explore the potential of monitoring the floodplains in Bangladesh during the monsoon season when other sensors are hindered by cloud cover (FPCO 1995d).

4.8.2 Radar Remote Sensing Concepts.

Radar stands for radio detection and ranging. A radar instrument transmit microwave (radio) signals, receives the portion of the signal reflected by the target (called backscatter), and simultaneously measures the intensity and time delay of the returned signals. An imaging radar in its basic form consists of a transmitter, an antenna designed for both transmitting and receiving microwave energy, a receiver, and a data processing and recording unit. The radar imaging parameters that need to be considered include wavelength, polarization, radar look direction and incident angle. The strength and weakness of radar return from the earth's surface depends upon so-called target parameter: surface roughness or smoothness, moisture, and point targets such as corner reflectors.

4.8.3 Satellite SAR Systems

Presently there are several spaceborne SAR missions are in operations. These include the European ERS-1 (1991) and ERS-2 (1995) mission, the Japanese JERS-1 mission (1992), the Canadian RADARSAT mission (1995) the Russian ALMAZ-1 mission and the American Space Shuttle SIR-C mission (1994/95). In principle, these systems acquire SAR imagery with a spatial resolution on the order of 10m to 100m, which matches flood data requirements at the local, regional, and national level of Bangladesh. The main SAR system and operating parameters are

summarized in table 4-2.

Table 4.2: Summary of the Main Satellite SAR System and Operating Parameter

	ERS-1/ ERS-2	JERS-1	SIR-C	ALMA Z	RADARSAT
Country	Europe/SEA	Japan	USA	Russia	Canada
Launched	1991/95	1992	1994/95	1991	1995
Altitude	785km	568 km	225 km	300 km	792 km
Radar bands	C- band	L-band	X/C/L-band	S-band	C-band
Polarizations	VV	HH	HH/VV/VH	HH	HH
Incidence angle	23°	39°	15-55°	30-60°	20-49° (59°)
Swath width	100 km	80 km	15-90 km	40 km	50-500 km
Resolution	25 m	18 m	15-30 m	15-30 m	10-100 m
O/b Recorder	No	No	Yes	Yes	Yes

(Source: modified after Li and Raney, 1991, Raney et al., 1990, and Werle, 1992.)

ERS-1 and ERS-2

ERS-1&2 (European Remote Sensing Satellite) is a new system developed by the European Space Agency. The system provides an interesting complement to the other commercial imagery products in that it offers a variety of radar imagery output formats. For GIS application, the main output of interest will be the side-looking airborne radar (SAR) output that provides 100 km wide swaths with a 30 meter resolution. This should provide to be of considerable interest in a variety of applications, including vegetation studies and mapping projects where could cover is a persistent problem.

JERS-1

In 1992, Japan launched JERS-1. Its payload includes a SAR operating at L-band with horizontal polarization and a fixed radar incidence angle around 35 degrees (± 3 in.) in mid range. JERS-1 SAR data are primarily used in agriculture, forestry, and fisheries, and for monitoring disasters and surveillance of coastal regions. The configuration of the JERS-1 SAR is potentially suitable for flood mapping in Bangladesh. The 80km-wide image swath, however, necessitates a relatively long revisit period of several weeks in order to obtain complete coverage in Bangladesh.

SIR-C

In the United States, the National Aeronautic and Space Administration (NASA) and the Jet Propulsion Laboratories (JPL) are using three Space Shuttle missions to conduct the SIR-C experiment. The swath width may range from 15km to 90km. The resolution of the SRI-C will be approximately 30m in low-resolution mode and 15m in high resolution mode.

RADARSAT

The Canadian RADARSAT launched in 1995 for a five-year mission. The objective of RADARSAT is to generate SAR data of value for both operational application and scientific research on ice, oceans, and natural resources. The incidence angle geometry of RADARSAT

may vary between 20 and 49 degrees for the 500 km-wide swath, and between 49 and 59 degree for the experimental swath. This will provide daily coverage of Arctic and Antarctic latitudes, coverage of the entire Canadian territory within three days. The SAR swath also can be electrically altered in width and spatial resolution (10-55m) to the specifications of a particular application. The swath choices are illustrated in Figure 4-11. The RADARSAT sensor, orbit, and data-relay configuration appear suitable for satisfying SAR data acquisition requirements likely to be encountered for flood mapping and monitoring in Bangladesh.

4.8.4 Review Radar Project Application for Flood Monitoring in Bangladesh

In Bangladesh, the radar applications study project for monitoring monsoon flood extent for 1993 conditions were first initiated through FAP-19. The study includes (1) SAR data acquisition by the European ERS-1 satellite over selected study areas in May, July and August, 1993, and collection of other geographic data sets; (2) design and execution of a ground reference data program; (3) digital SAR image processing and analysis; (4) evaluation of results for a test area and extent of the test results to larger floodplain regions covered by the ERS-1 SAR scenes; and (5) integration of SAR image analysis results with ground reference data and other GIS data sets and assessment of results.

The main study areas coincides with the extent of the ERS-1 SAR scene coverage in the areas of the Ganges/Jamuna rivers confluence in central Bangladesh and Sylhet region in northeastern Bangladesh. The Tangail district was selected as a test area for detailed image analysis and GIS data integration covering the CPP area. The image were then classified based on the principle that the amount of SAR return from standing water is significantly lower than that of soil, vegetation, and other features occurring on dry land. The image classification method used in this study yielded a two-class map of flooded and non-flooded areas.

The classified flooded and non-flooded SAR image were compared with the flood management model (FMM) results for Tangail CPP for the particular dates. Figure 4-12 for July 24 shows an agreement of 67 percent and Figure 4-13 shows an agreement of 73 percent on August 28, 1993 with the FMM results of the Tangail CPP area. A more quantitative assessment of the SAR image was carried out by comparison with information obtained from the ground surveys and shows a very good agreement over 80 percent (FAP-19, 1993).

A similar study (EGIS 1997) was also carried out by the Environment and the GIS Support Project (EGIS) which is a continuation of FAP-19 project for mapping and monitoring Floods with RADARSAT launched by the Canadian Space Agency (CSA) in November 1995. RADARSAT has several imaging modes which gives flexibility to the user in selecting the mode appropriate for the objective of study. The different beam modes offer variability in the incident angle, image resolution and aerial coverage. Consequently, images from two different beam modes were acquired for the study. The study includes acquisition of eight RADARSAT SAR image, four were high resolution (3.125x3.125 m over a 50x50km area) and four of moderate resolution (25x25 m over a 300x300 km area) on April 20/21, July 2/3, August 19/20 and September 12/13 in the central part of the north central part of the country covering Tangail CPP area. The principle objectives were to develop a better understanding of seasonal hydrological changes in the floodplain on a regional and local level, establish relationships between

hydrological regime, vegetation cover/land use and compare with FMM model results.

The usual conventional method of classifying radar images w.r.to the DN value does not however hold true in Bangladesh. The light toned pixels can be a wide range of different objects like flooded agriculture crops, aquatic weeds, and non-flooded lands. For this reason, separate SAR backscatter values were derived for the identification of landcover/landuse classes for both floodmapping and floodmonitoring. A higher (detailed) level classification was developed which was to provide grounds to test the potential of identifying flooded crops/vegetation and other mix of landcover types within the study area. In order of progressively higher DN values, signatures were generated for several classes at the higher level and lower level as shown in Table 4-3 and Table 4-4.

Table 4-3: DN Ranges Used for Classifying SAR Images to Higher Level Classes

Classes	DN Rages for April W2 image	DN Ranges for Aug. W2/F3 & Oct. F3 image	DN Ranges for September W2 image
Water	1 – 7000	1 – 4900	1 – 6500
Bare soil	7000 – 13000	--	--
Aquatic Vegetation	--	4901 – 8000	6501 – 9500
Low biomass	--	8001 – 10000	9501 – 9500
High biomas	--	10001 – 15500	11501 – 16500
Biomass	13001 – 16500	--	--
Trees	16501 – 20000	15501 – 20000	16501 – 20000
Settlements/Corners	> 20000	> 20001	> 20001

Table 4-4: DN Ranges Used for Classifying SAR Images to Lower Level Classes

Classes	DN Ranges for April W2 image	DN Ranges for Aug. & Oct. (W2/W3) images	DN Ranges for September W2 image
Water	1 – 7000	--	--
Flooded	--	1 – 10000	1 – 11500
High Biomass	--	10001 – 15500	11501 – 16500
Dry	> 7000	--	--
Non Flooded	--	> 15500	> 16500

The water class was quite unique in its backscatter properties, always located at the lower end of the DN range. At the other end, the corner reflectors with high DN values were also easier to distinguish. The gradation between the aquatic vegetation and low biomass, and between the high biomass and trees classes was not so distinct in the image, and foreknowledgeable from the field was used to derive these thresholds. The other factors considered in classifying these were the growth stage of the vegetation/crops, their height and canopy covers

4.8.5 Conclusion

Mapping and monitoring monsoon flooding in Bangladesh is a very application for satellite-based radar. The classification of open water with RADARSAT is successful as was the 1993 study using the ERS-1 data. The agreement of SAR open water classification, both with field data for the ERS-1 study (FAP 19, 1995, Martin et., 1996) and this study (EGIS 1997) is listed in Table 4-5.

Table 4-5: Agreement of Field Data and SAR Data for Open Water Classification for ERS-1 and RADARSAT

ERS-1, 1993		RADARSAT, 1996				
Jul 24	Aug 28	Apr 20	Aug 19	Aug 20	Sep 12	Oct 30
89	90	91	90	86	95	82

Though RADARSAT time-series was insufficient as expected initially, eventually, the series provides better understanding of the complexity of the flooding in relation to cropping patterns and crop maturity stages. A better mapping of flood extent and an understanding of the crop growth stages from radar backscatter would have been possible if radar images were acquired every fortnightly starting from May/June (when crop growth is just beginning) until the full monsoon cover. Later in the monsoon season, the crop matures with relatively high biomass that shields the flood water beneath it and makes the classification of flooded crop very difficult without multi-temporal data and analysis.

As seen in this study and others, it is possible to build up signatures patterns of different crops by observing the same fields through time and compiling sequences of backscatter levels associated with the growth stages of the crop. Using this approach it is highly recommended to categorize all the major cropping patterns present in the floodplain area and build a signature database to recognize the various crop sequences. The use of this spatial time series database generated in the process will become a very importance environmental parameters for determining impact assessments of the important issues derives from different time series database. The impact of the environmental components are the function of time and space. The relative environmental impact between different IECs becomes meaningful only when there is a relation with time and space. Thus the acquisition of the spatial radar imagery in the monsoon, classification in terms of land use for different time are highly important both for planning and environmental assessment of the more complex hydro-morphological and agro-ecological behaviour of the environment.

CHAPTER - V

RESEARCH METHODOLOGY & DATA COLLECTION

This chapter deals with the steps and methods that will be followed for determining the evaluation of environmental impacts of the selected IECs using overlay techniques and compare the results with those obtained by conventional methods.

5.1 CRITERIA OF SELECTING IEC's FOR OVERLAY ANALYSIS

All EIA techniques which are currently used is not exclusively suitable for impact assessment for a project or all types of development project due to their limitations of application. The use of any exclusive method in the present EIA assessment is either partial or incomplete evaluation of certain environmental component. The EIA assessment of any project should not be based on any particular method. Rather, the methods will be preferred by the importance of the environmental component. The use of overlay has some spatial role in the impact assessment. Previously there was some practical limitation on the overlay method, which are almost overcome by the application of GIS overlay and with the advancement of modern computer technology. The accuracy and importance of the overlay analysis depends on the comprehensive of the data acquisition.

Overlay methods completely fulfils the criteria of communicability, replicability, space dimension, alternative comparison, people's perception and economy. Besides, the method also partially fulfils the criteria of flexibility, objectivity, aggregation, multi-function, and summary format and manpower requirement. The method is also suitable for a very rapidly changing environment such as, river processes, flood depth and extent and any other environmental monitoring system. Based on the above consideration, the flowing IECs are selected from the list of the IECs as identified in chapter-II.

1. Flood control
2. Drainage
3. Irrigation
4. Crop damage
5. Vegetation
6. Capture fisheries
7. Surface water quality
8. Ground water quality
9. Soil fertility

5.2 CRITERIA OF STUDY AREA

During the last few decades, there are about 200 water resources project were developed under the Bangladesh Water Development Board (BWDB) for making the country food sufficient. All these projects were developed with a very negligible consideration of the environmental importance and disrupting the integrity of the total echo-system. As such, majority of the project

deteriorated badly and requires rehabilitation. SRP under BWDB, rehabilitation 35 WRE projects during 1990-95. The objective of SRP is to increase the agriculture production and to raise the standards of living.

To assess the SRP rehabilitation work, a Final Evaluation Study (FES) was done with a interdisciplinary approach by a multidisciplinary team. The overall objectives of the FES is to assess the impact of the SRP on the sustainable development of water resource management in Bangladesh, including the specific impact of SRP,s project on the people and resources on the localities. In the evaluation process there are 7 projects selected out of the total 35 WRP. In the present study, there are 2 out of 7 project are selected for evaluating the environmental impacts using overlay techniques. The projects are, Dardaria khal project implemented during 1978-79 and the Singri beel project during 1985-86. All the projects were developed as a FCD project under BWDB. The basic criteria for selecting the projects are for better spatial and temporal data availability then others, which is very important for overlay analysis. In addition, EIA team on their assessment develops database, those might be important for impact evaluation and comparison with overlay method. Figure 5-1 represents the location of the project area within Bangladesh.

5.2.1 Dardaria Khal Project

The project area falls within the jurisdiction of Kapasia p.s. under Gazipur district and is bounded by Banar river on the south-west and Lakhya on the south-east. A high terrace demarcates the northern and eastern boundary of the catchment. The topography of the project is generally saucer shaped with the highest lands lying adjacent to the rivers and slopping internally to a series of scattered depressions and beel linked by channels with the Dardaria khal. Land level varies from 2.75m to 15.75m with an average of 7.85 meter Pwd. The general drainage is in favours of the Banar river from north-to-south and get released to the Banar river through Dardaria 6v regulator. As per feasibility report, the gross area is 6220 ha and the cultivable area is 4332 with a total catchment area of 11890 ha (in/c the project area). With the implementation of the project, the protection from damages of the boro crop due to spill of pre-monsoon flood and the over-bank spill from the peripheral river during monsoon to save Aus and Aman crop were partially improved. But due to silting up of its main and branch channel and backwater effect from the Banar river, acute drainage congestion occurs in the project. Also defects in the gates allows entry of flood water and over drainage during the dry season.

As such, SRP during 1993-95 rehabilitate the project through by re-excavation of the Dardaria khal, construction of a new 1v regulator on the Dardaria khal near the 6v Ekuriya regulator, additional 4 pipe sluice along the embankment, re-sectioning of the embankment and rehabilitation of the old structures. Figure 5-2 represents the base map of the Dardaria khal project. The project starts functioning effective from 1996, which can be understand from the water level hydrograph for the last few years (Figure 6-2).

5.2.2 Singri beel Project

The Singri beel project is located in the north west region of Bangladesh, in the Nachol and Chapai-nawabganj thana of Chapai-nawabganj district. As per feasibility report, the gross area of the project is 13543 ha and the net benefited area is 4100 ha. The project is bounded by the

Mahananda river to the west, the Amnula-Nachol railway embankment to the east, Bhitabari Damos project to the north and the Amnura-Chapai-nawabganj railway line and road to the south. Before implementation of the project, the area suffers damage due to flooding from the Mahananda river and excess run-off from the adjoining vast land of the Barind tract to the east. The implementation of the project commenced in 1985 and was declared complete in 1986. During the implementation period, Paglakhali regulator (6v) and the 2.20 km flank embankment were constructed. Later on, the metallic road between Gomostapur to Chapai-nawabganj was constructed by R&H and subsequently Dukhumari and Chachnia regulators (2v and 1v) were constructed during 1989-90. Since from its development, the project were not functioning because of the poor construction of the embankment, flooding through the uncontrolled culverts opening on the R&H highway, drainage congestion due to the high stage of water in the river and siltation in the canals.

As such, SRP during 1994-96 rehabilitate the project through by re-construction of the embankment, repair old sluice structures, construction of new water control structures for the sub-compartment level of protection, re-excavation of the canals, closing the openings of the main highway. Figure 5-3 represents the base map of the Singri beel project. The SRP rehabilitation of the project was found incomplete until May 1997 while doing the field visit. The functionality of the project may be gauged from the hydrograph behaviour for the last three years (Figure 6-5).

5.3 DATA COLLECTION

For post evaluation of the SRP project, the FES team collected data for the SRP project using primary and secondary source, processed the data and analyzed for the impact evaluation with conventional method. For processing the data under GIS, they have also collected the spatial data from different sources, verified the data in the field and organize the data in the GIS format. Important among them are;

- Development of the digital elevation model (DEM) using detailed points elevation data from the old contours map
- Created infrastructure database, such as roads, embankments, location of the hydraulic structures etc.
- Collected and classified the latest available satellite image
- Collected and processed the daily water level data on the structure sides of the project and also those are important ones on the river near the project area

The present study will use the same database for the overlay analysis of the two selected project following with the individual IECs.

5.4 SELECTION OF THE IEC's COMMON FOR OVERLAY ANALYSIS FROM THE SELECTED PROJECT

The study will concentrate its evaluation only those IECs are common, that is, the IECs which are suitable for overlay analysis and are already considered in the post-evaluation of the EIA

process. Table 5-1 is a comparative statement between the Important IECs that could be efficiently handled using Overlay analysis with that of the IECs considered for EIA assessment of the selected project. The rightmost column of Table 5-1 is the final IECs selected for the Overlay analysis afterwards.

Table 5-1: Selected IECs for the Overlay Analysis

Important IEC for Overlay Analysis	IEC Considered in the Dardaria khal Project	IEC Considered in the Singri Beel Project	IEC Selected for the Overlay Analysis
Flood Control	Flood control	-	Flood Control
Drainage	Drainage	Drainage	Drainage
Irrigation	-	Irrigation	Irrigation
Crop damage	Crop damage	Crop damage	Crop damage
Vegetation	-	-	-
Capture fisheries	Fish habitat & species	Fisheries resources	Capture fisheries
Surface water quality	-	-	-
Ground water quality	-	-	-
Soil fertility	-	-	-
	Crop production	Crop production	-
	Fish migration	-	-
	Fishing community	-	-
	Wetland dependent Flora and Fauna	-	-
	Water management	Water management	-
	Embankment maintenance	Embankment maintenance Group (EMG)	-
	Transportation	Operation of Gate	-

5.5 METHOD OF SELECTING TOOLS FOR OVERLAY ANALYSIS

According the available information of the spatial and temporal database and the selected IECs on step5-4, overlay analysis will be done using raster base GIS and are appropriate in these case. Using GISMO (GIS modeling program under raster base GIS) under the raster base GIS (ERDAS 7.5), the overlay application will be carried out. The other important GIS software will be used for completion of the job are Arc/Info and Arc/View. Finally the map composition will be done using Corel draw and Corel photo paint.

5.6 IMPACT ASSESSMENT USING OVERLAY ANALYSIS AND COMPARE

The impact of the selected IECs will be evaluated on two steps. Initially, the temporal variation of the selected IECs will be determined, specially using DEM of the project and the available water level hydrograph by overlay techniques for the pre and post project condition. In this process the changes in the hydrological regime will be evaluated. Lateron, the relative impacts among the IECs will be evaluated. The impact of the IECs will be evaluated based on the information for 1996 condition and because of SRP intervention are expected during the same year. Also the database required for the analysis are available no latter then 1996 condition. The methodology may farther be described as follows:

Step –1: Temporal Variations

Flood Control

- Using the water level records and DEM, the flood depth and extend for the maximum water level condition, condition prior and after 15 days of the maximum water level will be determined for the Dardaria khal project. In the Singri beel project, flood depth and extend will be determined for different return period, because the project found incomplete during 1996. Improvements in the flood control under maximum water level condition in terms of land type changes will be evaluated lateron by overlay analysis.

Drainage

- Drainage condition will be evaluated in the similar way of the flood control using DEM and hydrograph in the Dardaria khal project. Due to lag in the information, no drainage performance will be evaluated or possible in the Singri beel project.

Irrigation

- The pre and post project irrigation will be evaluated using data from the field, DEM and feasibility report both for the Dardaria khal and Singri beel project.

Crop damage

- From the hydrograph analysis and field visit information, there is no significant records of crop damage during 1996 for both the Dardaria khal and Singri beel project. However an assessment of the project benefit in terms of the protection of the monsoon crop will be evaluated using overlay analysis.

Capture fisheries

- Using the land type information, field visit records and DEM, the potential zones of open water fisheries will be evaluated for the pre and post project condition. The project impact on fisheries will be evaluated lateron using overlay analysis.

Step –2 : Relative impacts

- The relative impact between agriculture .vs. fisheries, agriculture .vs. zone of the flood hazards will be evaluated using overlay analysis.

Step –3 : Compare Evaluations from the two methods

- Compare the results on the IECs obtained in the overlay analysis and in the assessment of the SRP evaluation study.

CHAPTER – VI

DATA ANALYSIS, RESULTS

6.1 ANALYSIS

EIA assessment for the important environmental issues, using GIS overlay function as describes in Chapter-V are as follows

6.1.1 Flood Control

a. Dardaria Khal Project

Step-1: Involves the collection of the Digital Elevation Model data and Water Level records on the project site. Using the spot elevations from the contours (4"=1m) map surveyed during 1960-65, the raster base DEM were developed by EGIS (Figure 6-1). The input resolution of the DEM is 100x300m and the output resolution of the DEM is 10x10m. Time series of the water level records were also collected by EGIS from the Ekuria regulator (6v) site, that controls the total hydrology of the project area. Figure 6-2 is the water level hydrograph for the last three years (1994-96) both on the river and country side of the project.

Step-2: To assess the potential improvement of flood due to the project rehabilitation, 1996 hydrological year was considered in the impact analysis. This is because the rehabilitation starts functioning properly effective from 1996. To assess the project impact on flood control, three dates were considered for overlay analysis, such as, July 15, July 30 and August 15 of 96. During 96, the maximum effectiveness on the flood control by the structure shows on July 30 and which is 1.88 meter.

Step-3: Using the ERDAS7.5 overlay function and GIS modeling tool (GISMO), the classified flood depth maps based on the standard land type distribution for six water level condition were prepared. Figure 6-3 represents the flood maps for with and without project condition for those selected dates. Table 6-1 represents the area and percentage of land for different inundation condition.

Step-4: Using overlay, the change of the inundation for with and without project is also calculated for the same dates. Table 6-2 represents the change in the area and percentage of the land of inundation for with and without project on those selected dates.

b. Singri Beel Project

Step-1: Involves the collection of the Digital Elevation Model data and Water Level records on the project site. Using the spot elevations from the contours (8"=1m) map surveyed during 1960-65, the raster base DEM has been developed by EGIS (Figure 6-4). The input resolution of the DEM is 180x180m and the output resolution of the DEM is 10x10m. Time series data of the recorded water levels were also collected at three

structure location (Paglakhari, Chachnia and Dukhumari regulator) by the EGIS team of which Paglakhari (6v) is the most important ones. Figure 6-5 represents the water level hydrograph for 1996 condition on the structure sites. From the hydrograph analysis, it appears that there was an overflow on the Chachnia and Dukhumari regulator for 1996 condition and which was confirmed while doing the field visit during 1997. This implies, that the rehabilitation was incomplete during 1996. As such a different approach has been taken for assessing the future project impact on flood control of the Singri beel project.

Step-2: To assess the future potential flood improvement with the project rehabilitation, the polder water level for different recurrence interval calculated in the feasibility report for the 2, 5, 10 & 20yr return period is used.

Step-3: Using the GIS overlay function, the classified flood depth maps based on the standard land types distribution for four water level condition were produced. Figure 6-6 represents the land type for the 2, 5, 10 & 20yr return flood levels on the project. Table 6-3 represents the area and percentage of land for different inundation condition.

Step-4: Using GIS overlay, the change in the inundation type w.r.to the 2yr return flood with that of the 5, 10 and 20yr flood is determined. Table 6-4 represents the change in the area and percentage of the land for 5, 10 and 20yr flood with respect the average year flood.

6.1.2 Drainage

a. Dardaria Khal Project

Step-1: It has been very difficult to assess the drainage improvement of the project from the hydrograph analysis for the last three years. Also no clear answer was received from the project site for drainage condition and about the cause of the hydrograph for its huge difference in the water level at the falling limb of the hydrograph. It has been apprehended that this is because of the man made control over the gate for some interest group and is a management problem on the Ekuria regulator site. However, using overlay function, the pre and post project drainage deficiencies maps were prepared on the 5th November 1996, which appears as the maximum difference in the falling limb of the hydrograph. Figure 6-7 represents the affected land by drainage congestion due to man made control over the Ekuria regulator after SRP intervention. Table 6-5 represents the affected area due to drainage congestion after post rehabilitation of the Dardaria khal project.

Step-2: Using GIS overlay, the change of the inundation in the form of increasing drainage congestion is determined for with and without project condition (Table 6-6).

b. Singri Beel Project

From the hydrograph analysis for the last three years it appears that there was some man made control on the structure during 1996 causing drainage congestion. But no such conflict appears in the hydrograph for 1995 and 96 condition. One of the major objective of the project rehabilitation is to remove the drainage congestion due to

siltation in the feeder canal, although the rehabilitation does a very minor re-excavation of the feeder canal and alternatively provide intermediate water control structure for blocking water for irrigation. Altogether, it appears that there might some minor drainage congestion from the siltation of the feeder canals. Alternatively this may cause over drainage and a total destruction of the most important flora-fauna in the region. Due to a very conflicting nature of the information and incomplete functioning of the project, no drainage analysis using overlay method is possible in the Singri beel project area.

6.1.3 Irrigation

a. Dardaria Khal Project

Step-1: The project rehabilitation encourage LLP irrigation using water from the Dardaria khal by cutting the canals upto a certain length and lowering the bed such that it allows LLP irrigation to the adjacent land. EGIS had an assessment of irrigation achievement by SRP rehabilitation using GIS and field visit. Figure 6-8 describes the achievement in terms of the target set in the SRP feasibility report (EPC, 1988).

b. Singri beel Project

Step-1: The project rehabilitation encourage LLP irrigation using water from the beel and trapped water within the canals by putting water control structures within the project. Using field information, DEM and water level under the average year condition, an assessment of the future irrigation benefit and disbenefit map is developed for irrigation using overlay analysis (Figure 6-9).

6.1.4 Crop Damage

a. Dardaria Khal Project

Step-1: Using the 2yr return flood level of the project from feasibility report, a classified agricultural important map of the project area is prepared using the DEM and expatriate opinion (Figure 6-10). The area and percentage of the agriculture under different important zone is stated in Table 6-7. The classification is as follows;

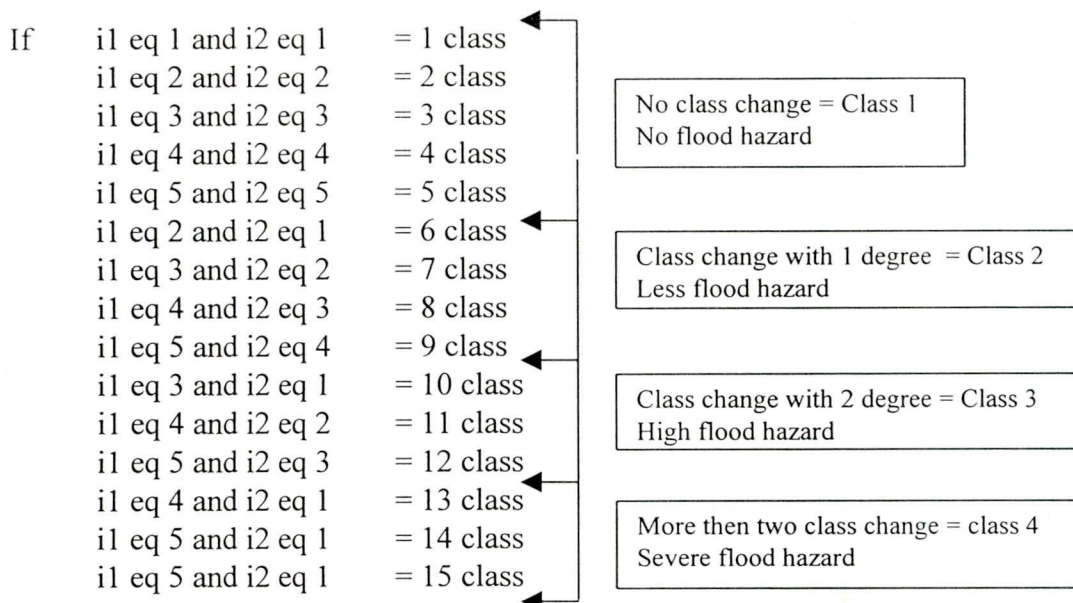
Class 1: Very high agriculture prone area (water depth $\leq 30\text{cm}$)

Class 2: High agriculture prone area ($30 < \text{water depth} \leq 120\text{cm}$)

Class 3: Less agriculture prone area ($120 < \text{water depth} \leq 180\text{cm}$)

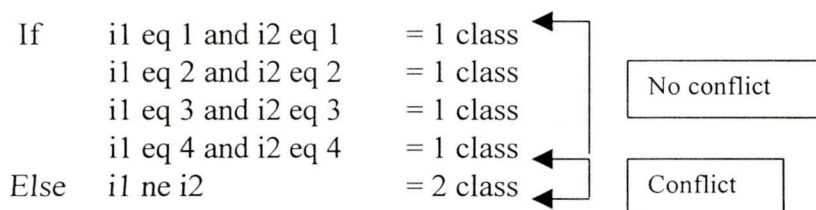
Class 4: Negligible agriculture prone area ($180\text{cm} < \text{water depth}$)

Step-2: A classified flood hazard map is also prepared using water level records on the maximum difference in the water level (July 30, 1996) at Ekuria regulator(c/s and r/s). The process involves 15 possible combination between the pre and post project condition, which may be stated as follows.



Where i1 and i2 are nothing but the information in the water depth of the flood plain for with and without project condition under consideration. Depending on the nature of the Bangladesh general land use pattern and the change in the flood phase for with and without project condition, the 15 class is brought under four class of the flood vulnerable zone (Figure 6-11). The area and percentage of flood hazard zone of the Dardaria khal project is stated in Table 6-8.

Step-3: The potential agriculture zone map in step-1 is overlaid with flood hazard zone map in step-2 to produce the zone of conflict and no conflict between flood and agriculture. The steps may be stated as follows.



Where i1 and i2 are nothing but the class of agriculture important zone and flood hazard zone under consideration.

Step-4: The map produced in step-3 does not considered the importance of deeply flooded land or permanent water bodies, which should be excluded any way with the agriculture conflict. Using maps of the average year condition, the area in the F3 land type has been excluded using overlay analysis (Figure 6-12). The area and percentage of agriculture land that has a conflict with the flood hazard zone may be summarized in Table 6-9.

b. Singri Beel Project

Step-1: Using the average (2yr return period) flood level of the project from feasibility report, a classified agricultural important zone map of the project area is prepared

using the DEM and expatriate opinion (Figure 6-13). The area and percentage under different important agriculture zone is stated in Table 6-10. The classification follows same as stated in the Dardaria khal project.

Step-2: A classified flood hazard map is also prepared using DEM and water level for 2yr and 20yr return period. The process involves 15 possible combination and follows the same procedures as stated earlier in the Dardaria khal. Here the 2yr returned flood has been considered as the normal condition in the monsoon floodplain of the Singri-beel project (Figure 6-14). The area and percentage of flood hazard zone of the Singri beel project is stated in Table 6-11.

Step-3: The classified agriculture important zone in step-1 is overlayed with the flood hazard zone in step-2 to produce the zone of conflict and no conflict between agriculture and flood in the same way as stated earlier in the Dardaria khal.

Step-4: The map produced in step-3 does not considered the importance of deeply flooded land or permanent water bodies, which should be excluded any way with the agriculture conflict. Using maps of the average year condition, the area in the F3 land type has been excluded using overlay analysis (Figure 6-15). The area and percentage of land that has a conflict between agriculture and flood may be summarized in Table 6-12.

6.1.5 Capture Fisheries

a. Dardaria Khal Project

Step-1: Using the average year (2yr return period) flood level of the project from feasibility report, a classified fish zone map of the project area is prepared using the DEM and expatriate opinion (Figure 6-16). The area and percentage of the land of important fish zone is stated in Table 6-13. The classification is as follows;

Class 1: Not important for fisheries (Water depth $\leq$ 0cm)

Class 2: Minor important for fisheries ($0 <$ water depth $\leq$ 90cm)

Class 3: Important for fisheries ($90 <$ water depth $\leq$ 180cm)

Class 4: Highly important for fisheries ($180\text{cm} <$ water depth)

Step-2: The classified fisheries zone map is then overlay with the classified agriculture important zone to produce the map of conflict between agriculture and fisheries. The steps involves may be sated as follows.

Class	Agriculture	Fish	No conflict	Conflict
1	Highly important	Not important	1	
2	Important	Less important	1	
3	Less important	Important	1	
4	Not important	Highly important	1	
Else				2

The conflict between agriculture and fisheries of the Dardaria khal project is presented in Figure 6-17. The area and percentage of land conflicted between agriculture and fisheries are presented in Table 6-14.

b. Singri beel project

Step-1: Using the average year (2yr return period) flood level of the project from feasibility report, a classified fish zone map of the project area is prepared using the DEM and expatriate opinion same as the Dardaria khal project (Figure 6-18). The area and percentage of the land of important fish zone is stated in Table 6-15.

Step-2: The classified fisheries map produced in step-1 is overlay with the classified agriculture important zone map to determine the conflict between agriculture and fisheries similar to the Dardaria khal. The conflict between agriculture and fisheries of the Singri beel project is presented in Figure 6-19. The area and percentage of land conflicted between agriculture and fisheries are presented in Table 6-16.

6.2 COMPARISON OF OVERLAY WITH CONVENTIONAL EIA

The EIA evaluation of the SRP projects is not exactly a conventional method as the study uses GIS facilities for mapping and monitoring the impacts of the environmental issues. In some of the cases, the study also uses the GIS overlay facilities for monitoring impact of the environmental component. Although, the study did not considered overlay for evaluating the impacts assessment of the issues that are suitable under overlay analysis. Following are some of the comparison between overlay analysis with that of the SRP rehabilitation study.

6.2.1 Flood Control

According to the FES, the SRP evaluation on the flood control for the Dardaria khal has been more effective then that of the Singri beel project. Flood control with the higher picks are almost impossible in the existing design condition in the Singri beel. Flood maps using overlay analysis were done for maximum difference in the water level hydrograph in the Dardaria khal for 1995 condition and Singri beel for 1996 condition.

On the contrary, flood control assessment using overlay was done for Dradaria khal for 1996 condition and Singri beel using flood of different return period. The effectiveness of the flood control in terms of land type for pre and post project condition for different time steps were assessed using overlay analysis on the Dardaria khal project. Due to ineffective flood control during 1996, land types with different recurrence interval of flood were assessed for predicting the depth, area and extend variation in the land type. A classified zone of flood hazard map is also developed for both the Dardaria khal for normal flooding condition and Singri beel for extreme flooding condition (Figure 6-11, 6-14). In the latter assessment, the flood impact for different condition showing in the maps and table are highly valuable in the impact assessment.

6.2.2 Drainage

According to the FES, SRP has not performed well in solving problems of the drainage congestion both in the Dardara and Singri beel project. In most cases, the external water condition in the river that controls the monsoon drainage of the project. Besides, the water logging within the project caused by siltation in the canals, man made control on the canals and in the water control structure is not adequately addressed. Although the general drainage network map in terms of the topographical variation were prepared both of the Dardaria (Figure 6-1) and Singri beel project (Figure 6-4).

From the hydrograph analysis for the last few years on the Dardaria and Singri beel project, it appears that until mid of September, there is no way of getting release from the drainage removal. Due to poor and incomplete information, no drainage assessment in the Singri beel project was possible. From the hydrograph analysis and field visit, it has been realized, that there is a man made control of some interest group over the gate of the Dardaria khal for drainage removal. As such, using the hydrograph in the falling limb, the drainage congestion for the Dardaria khal project were assessed indicating the location and extend of the drainage congestion caused by the social conflict by some interest group over the regulator. The latter assessment has made it clear about the location and extend affected by drainage congestion due to the social conflict in the gate operation and which is very important in the EIA process.

6.2.3 Irrigation

According to the FES, the success of SRP in facilitating irrigation has been partial in nature. One impediment has been the silting up of canals causing obstructions for the water in flowing over to certain sections of the canals for the irrigation water to be available there. This problem has been particularly prominent in the Singri beel project. The potential of irrigation that have been achieved in Dardaria khal project had the proposed re-excavation work been taken up, was not realized to that extent since the work done was much less then planned earlier (Figure 6-8).

Besides the FES, the present assessment also included the Singri beel project for the proposed irrigation planned and the secondary defense for flood control and subsequent impact to the outside area (Figure 6-9). This is done using overlay analysis between DEM, land type of the average year condition, infrastructure and field visit information. The actual achievement like in the Dardaria khal project and subsequent impact of the proposed plan was not possible, because, the work was still underway. The maps produced under the FES for the Dardaria khal and Singri beel in the present evaluation has made it clear for the irrigation achievement and impacted areas of irrigation of the two successive project.

6.2.4 Crop Damage

General assessment from the FES indicates that, with more effective controlling of floods through the SRP interventions, crop damage have been reduced substantially in the Dardaria khal and also in the Singri beel with the lower peaks. In the southern part of the Dardaria khal project,

the persisting drainage congestion discourages farmers from growing T.Aman in the medium lowland since chances of crop damage would be too high. In the Singri beel, the rehabilitation will save T.Aus crop grown on the periphery of the beel areas.

Based on the damage information and the standard land use practice elsewhere in Bangladesh, a classified map of important agriculture zoning were prepared using project DEM, average flood level and expatriate opinion, using overlay analysis for both of the Dardaria and Singri beel (Figure 6-10, 6-13). A similar map of the zone of flood hazard was also prepared for both of the project (Figure 6-11, 6-14). Using map of the respective project, the zone of conflict between agriculture and flood hazard has been developed in both of the two project (Figure 6-12, 6-15). In the latter analysis, it has made clear about the area of conflict between agriculture and flood hazard zone and the zone of damage prone area.

6.2.5 Capture Fisheries

According to the FES, the capture fisheries resources were found to have been depleted in most of the project. One major reason for this was the blockages created on the way of migration routes of fishes into the project area. The SRP intervention in Dardaria khal and Singri beel aggravated such blockages. Problems were also created by people who compartmentalized canals in several places for purposes of culture fisheries and thereby interrupting the free flow of water through the canals into the beels.

Based on the habitat characteristic of the capture fisheries in Bangladesh floodplain, a classified map of important fish zoning is prepared using project DEM, average flood level and expatriate opinion and using overlay analysis for both of the Dardaria and Singri beel project (Figure 6-16, 6-18). Using overlay analysis, the zone of conflict between agriculture and fisheries were also assessed (Figure 6-17, 6-19). In the latter analysis, the important area of fisheries potential and the zone of conflict was clearly delineated in the maps and subsequent tabular data.

CHAPTER – VII

CONCLUSIONS AND RECOMMENDATION FOR FUTURE STUDIES

7.1 CONCLUSIONS

One of the major objective of this study is to determine the importance, limitation and prospect of using overlay method in the EIA of water development project in Bangladesh. In view of the above circumstances, the following techniques were reviewed for the water resources development project, such as, Checklist, Matrices, network Analysis, Overlays, Cost Benefit Analysis, Environmental impact Indices and Simulation Modeling Workshops. Every method has some degree of advantage over the other and none of them are exclusively suitable for the impact assessment in the water resources development project. Besides, the conventional method has some degrees of biases and has little mathematical justification. Moreover it can not address the issue right in place and as such social conflicts always remains. In addition, the impact relationship and the zone of conflict between the impacts can not be addressed properly.

For the above reason, the GIS overlay techniques should be included in addition to the conventional method (weighted matrix) in the impact assessment of the water resources project. The following are the major advantages and disadvantages in the overlay analysis.

1. Overlay plays a very important role in assessing the hydrological impact of the flood control structure on the flood plain in terms of the change in the land type and extent at any suitable time step.
2. The quantity and quality of the changes at any time step can be easily determined in the overlay analysis.
3. The conflict between the flood vulnerable zone and the zone of important agriculture can be easily determined using overlay analysis. No such provision is available in the conventional EIA.
4. The conflict between the important fish zone and the zone of important agriculture can be easily determined using overlay analysis.
5. Every overlay operation has an output in the form of map and related database, which is not possible in the conventional EIA.
6. Using overlay analysis, the impact rating of some major issues can be fairly assessed with a mathematical justification, which are suitable under the overlay analysis. Presently these are done using expatriate judgement.
7. The assessment of the environmental impact using overlay are flexible in nature, which is not possible in the conventional system.
8. The importance of the time factor can be well addressed in the overlay analysis.
9. To understand the hydrological behaviour of the floodplain, the importance of DEM and time series records of the water level is highly important in the overlay analysis.

The classified RADAR and satellite images in terms of the land use mapping will open a new door for the impact evaluation in the EIA process.

10. The major limitation of using overlay analysis is that, it requires more resource in terms of expert, computer, software, spatial data, temporal data and field assessment.

7.2 RECOMMENDED FOR FUTURE STUDY

- Using overlay analysis, determine the impact relationship of the major environmental components of the water development project.
- Determine the impact on the flora and fauna in the water resources development project using overlay technique.
- Using digital image processing, determine the relationship between the landuse and Digital Numbering (DN).
- Using overlay analysis, determine the environmental impacts in the coastal development project.

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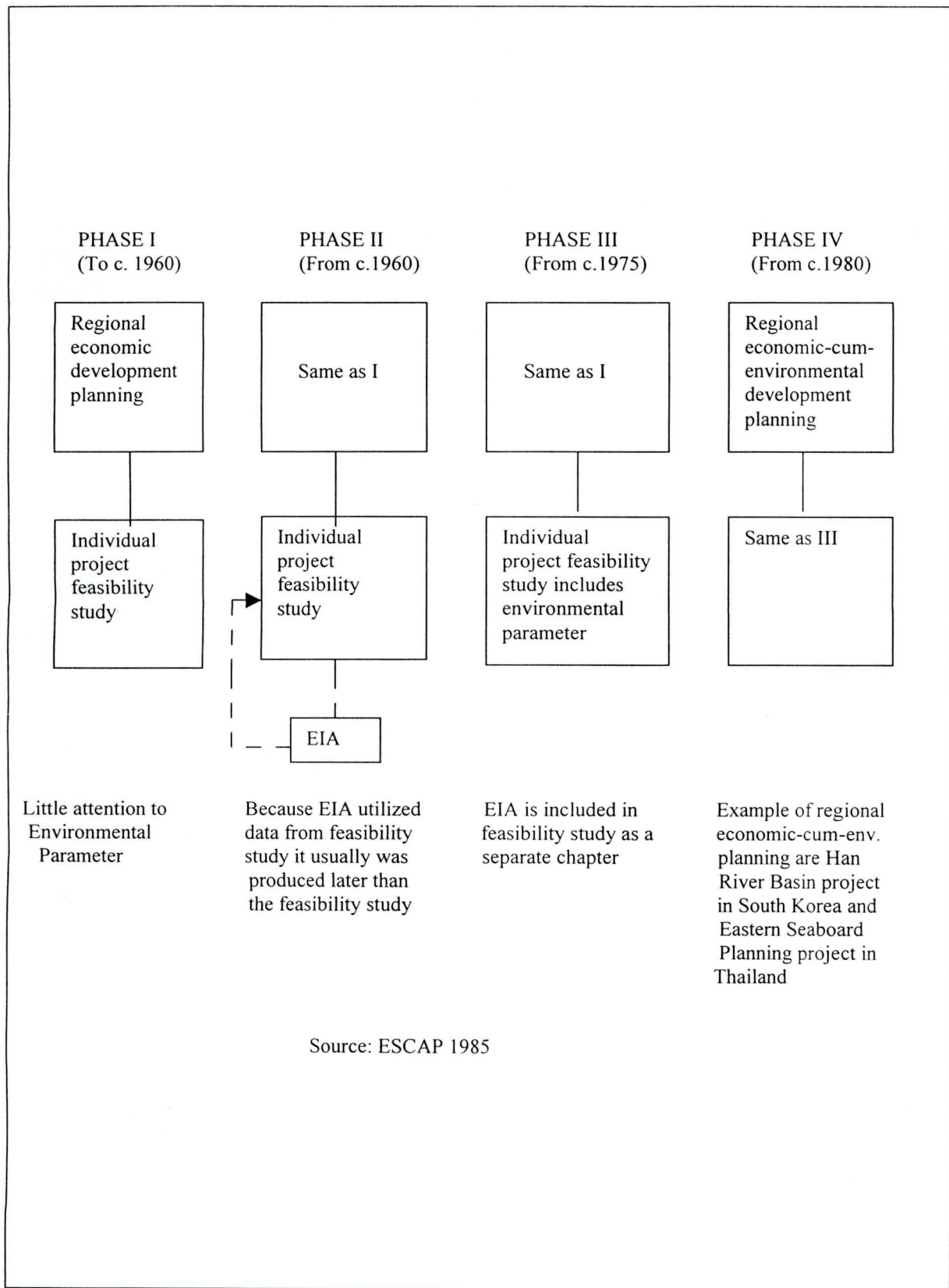
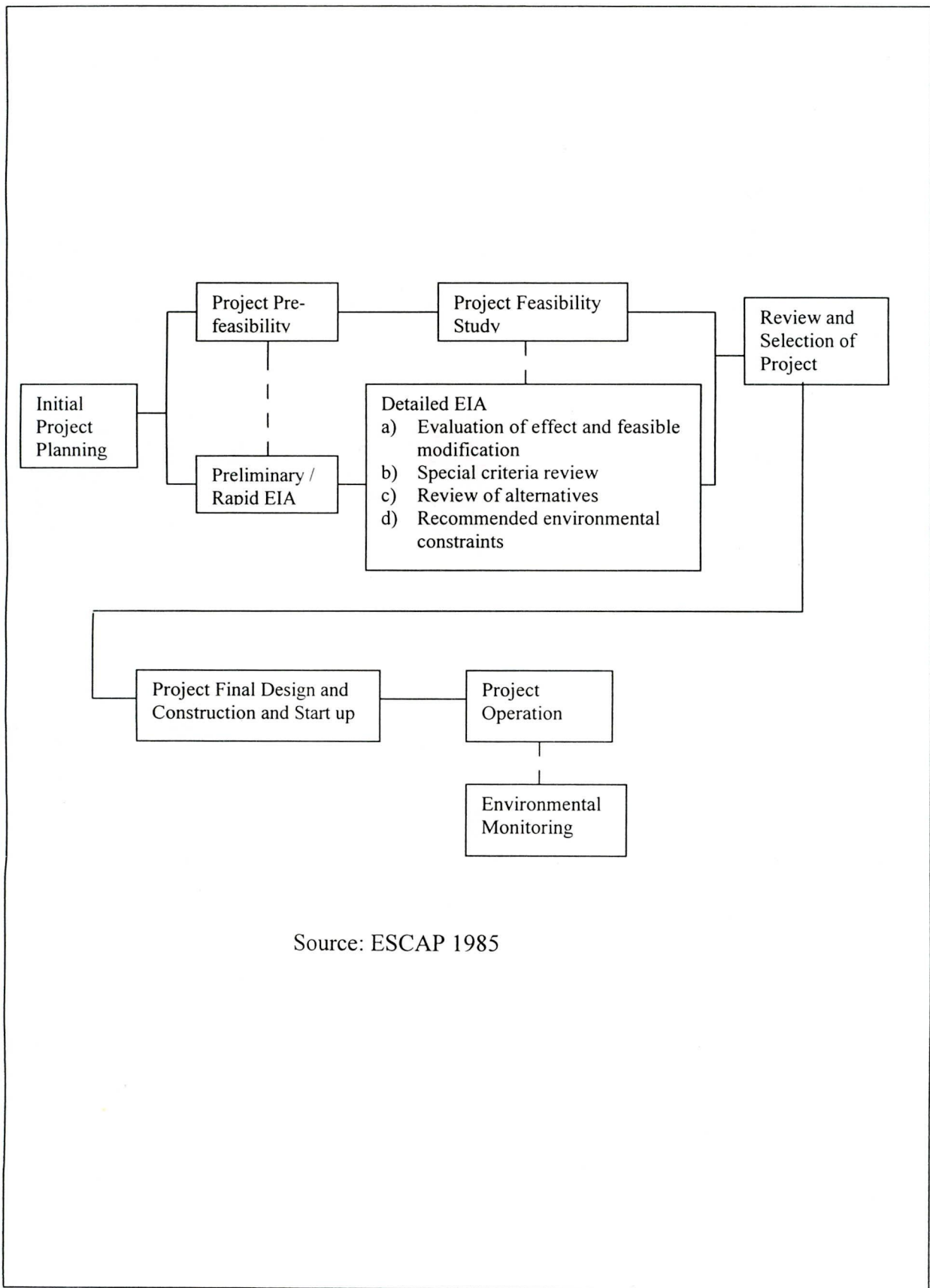


Figure 1-1: History of the use of environmental parameters in development planning in the United States



Source: ESCAP 1985

Figure 1-2: Relationship of EIA Process of Project Planning and Implementation

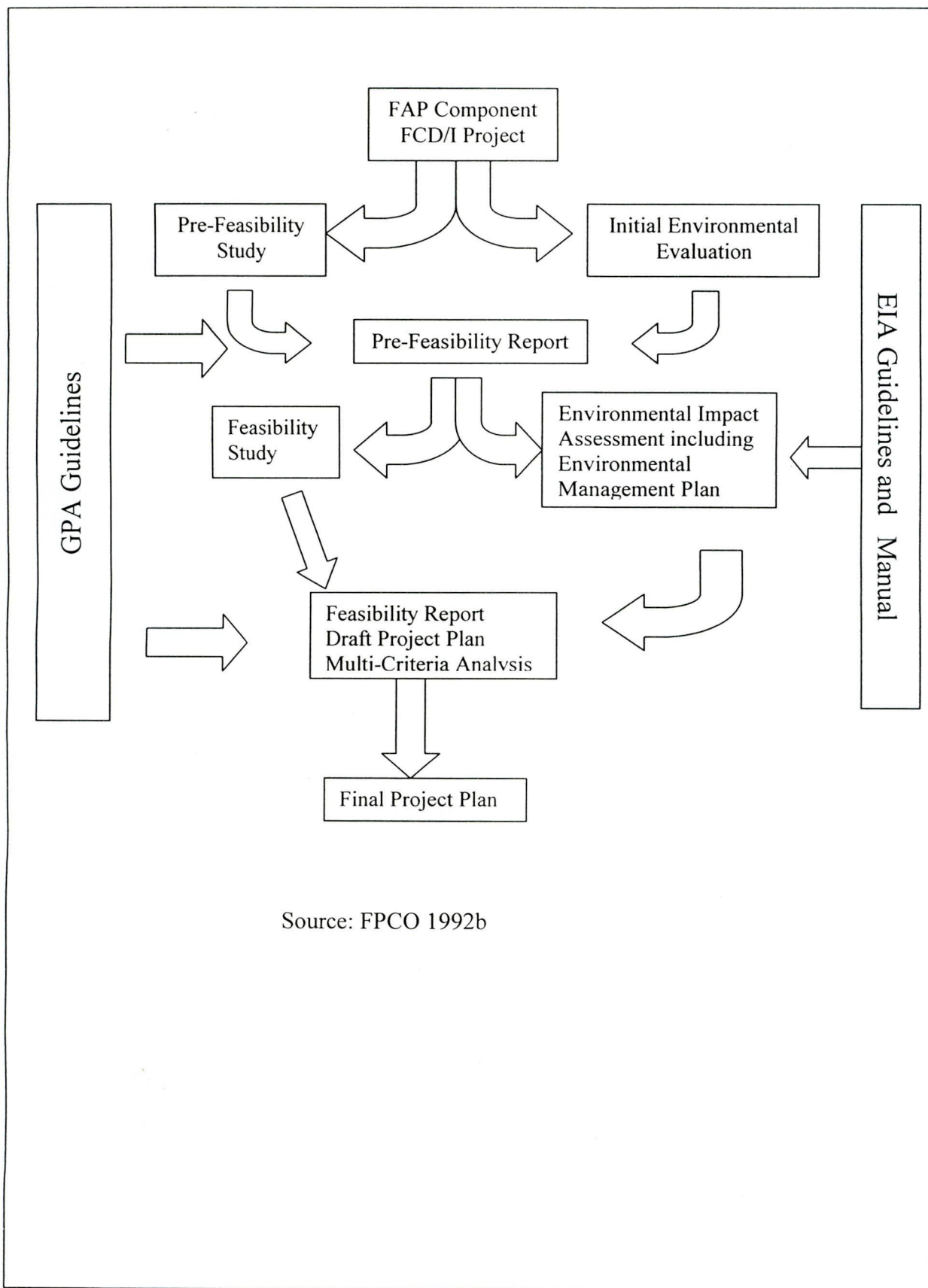


Figure 1-3: Role and Position of EIA Guidelines and EIA Manual in FAP Project Planning Process

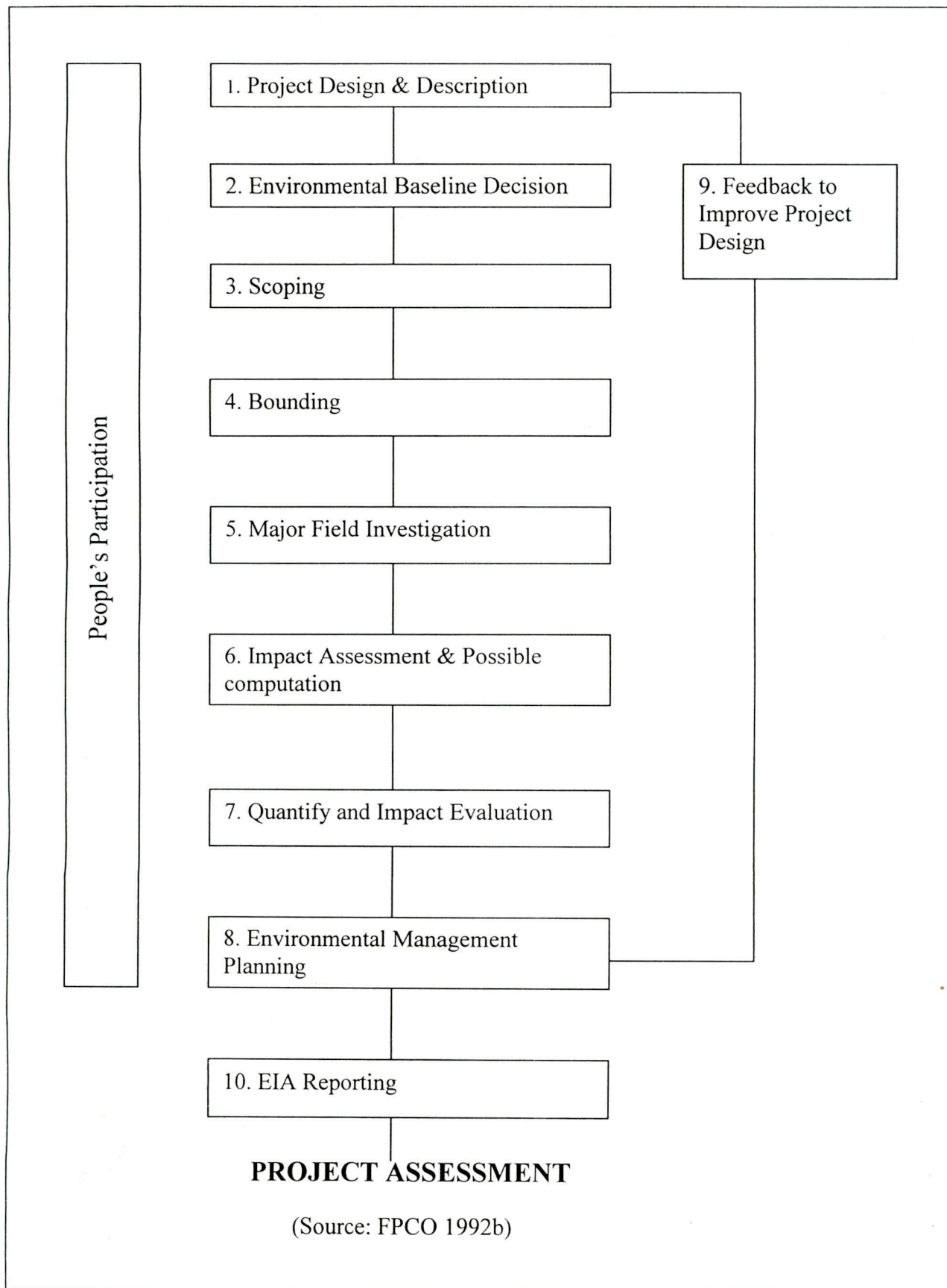
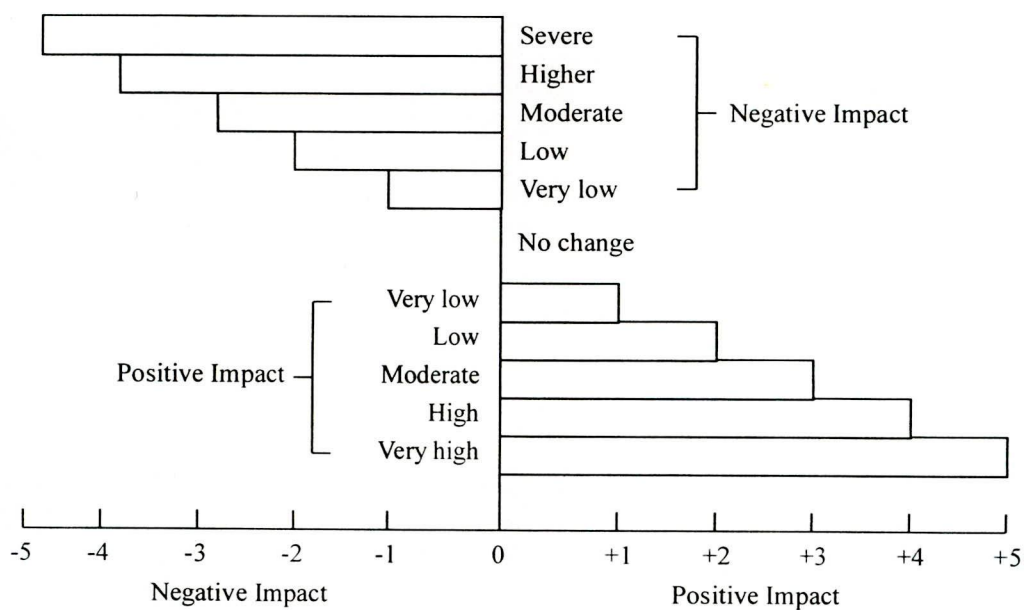


Figure 2-1: Recommended Steps in EIA



Source: LGED 1992

Figure 2-2 : Quantification of the Environment Impact

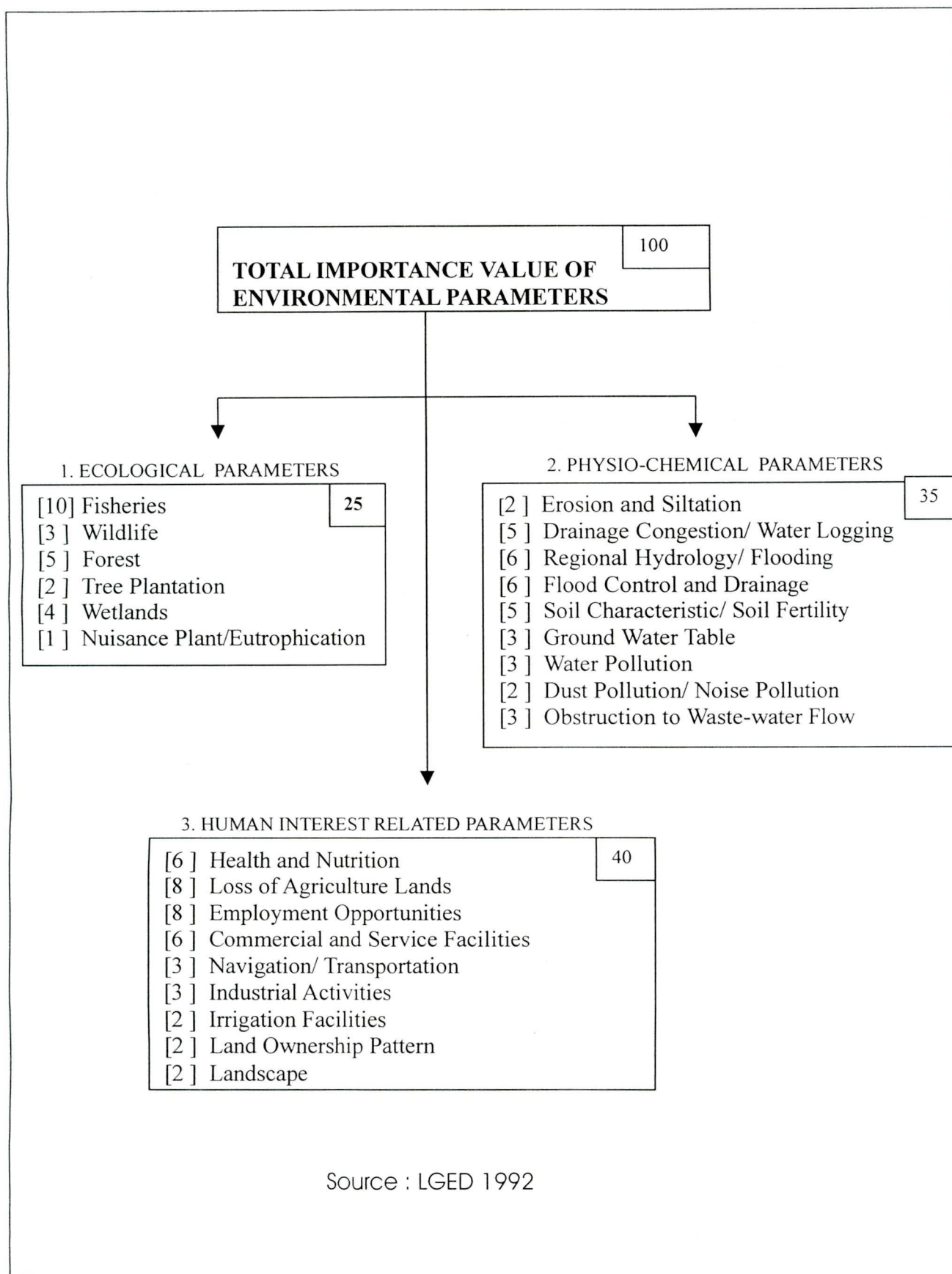


Figure 2-3 : Relative Important Values of Environmental Parameters Related to Infrastructure Projects

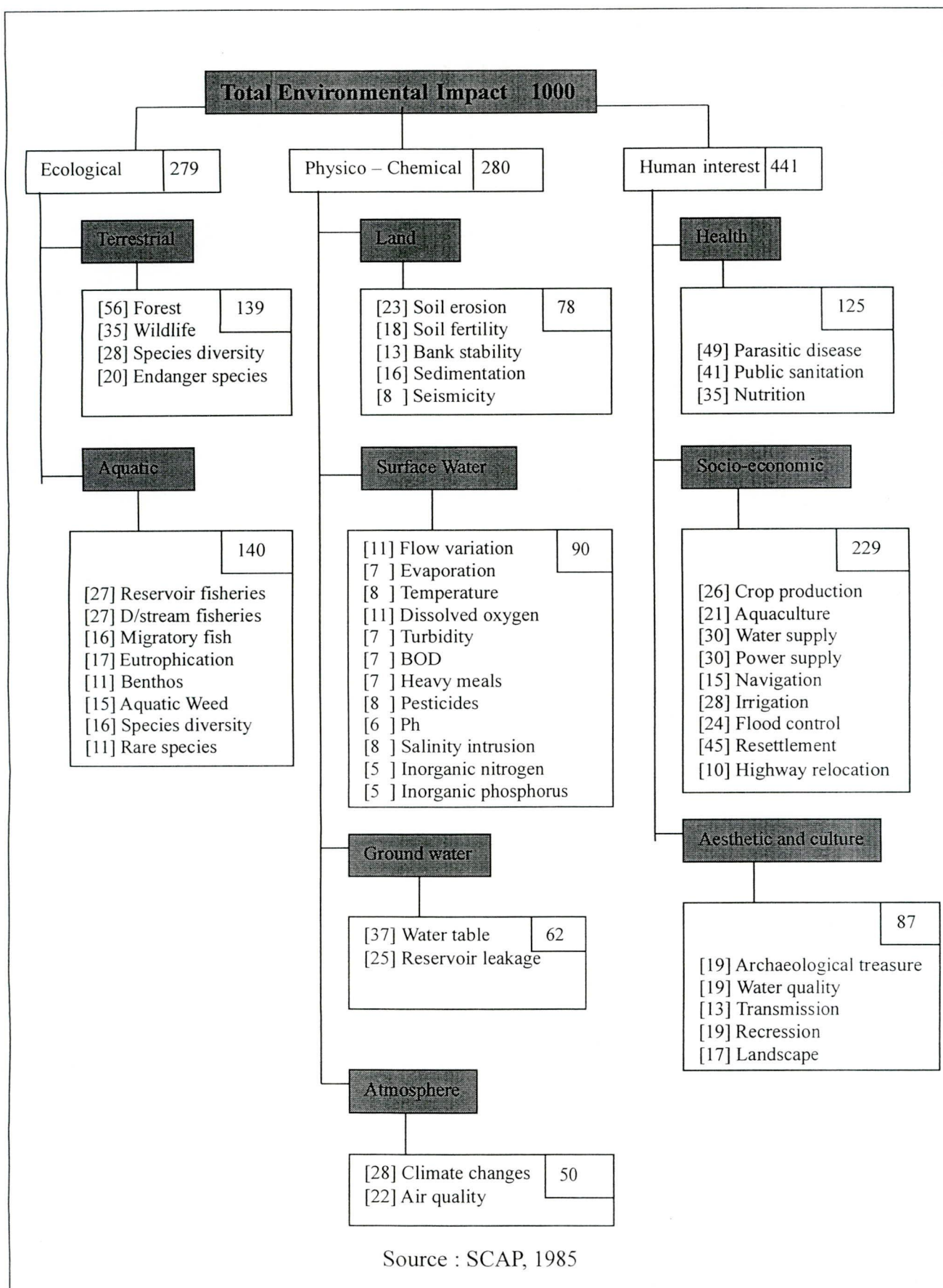
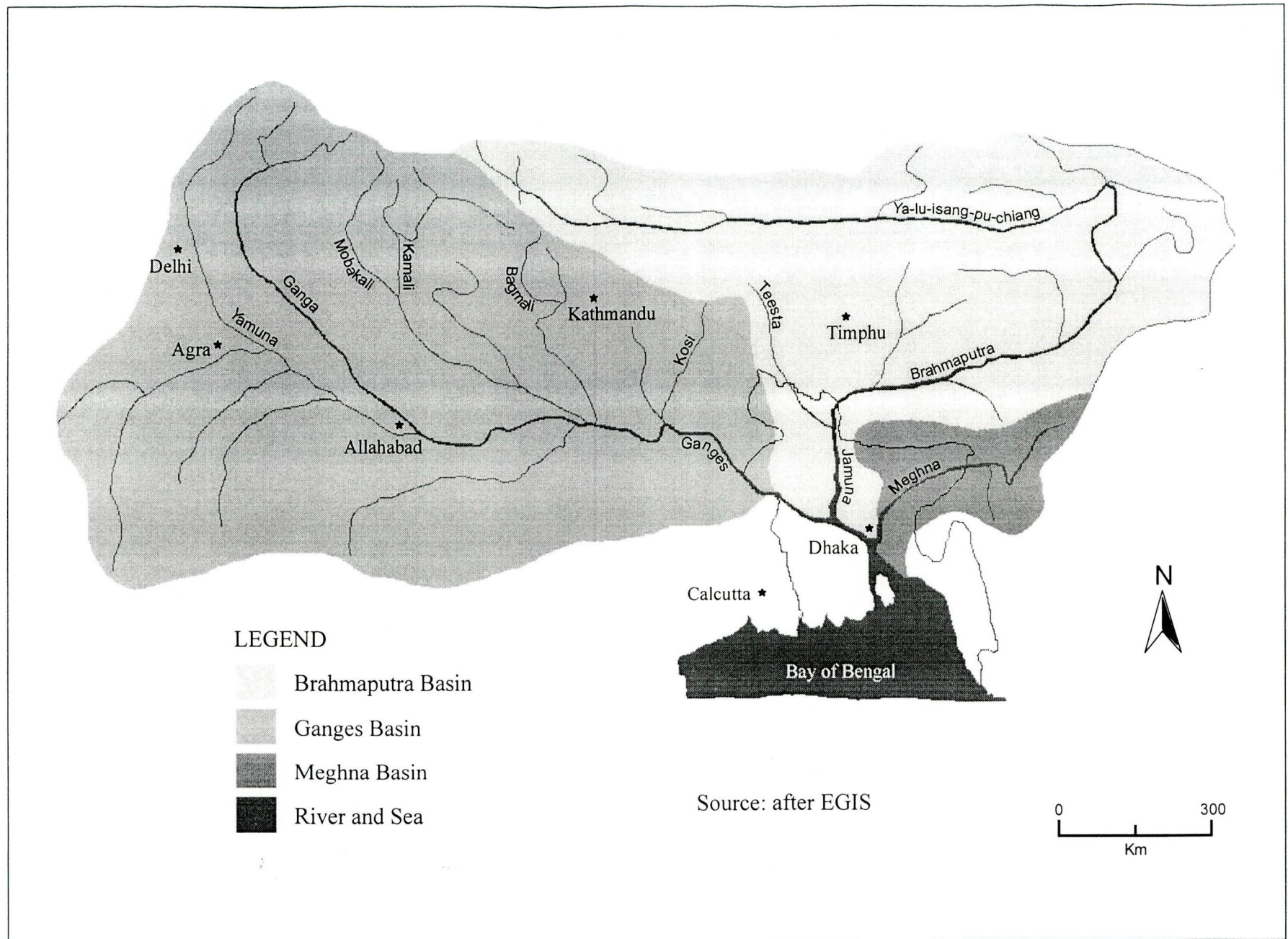


Figure 2-4 : Environmental Impacts of Water Resources Development Projects

Figure 3-1 : The Ganges, Brahmaputra, and Meghna River Catchment Areas



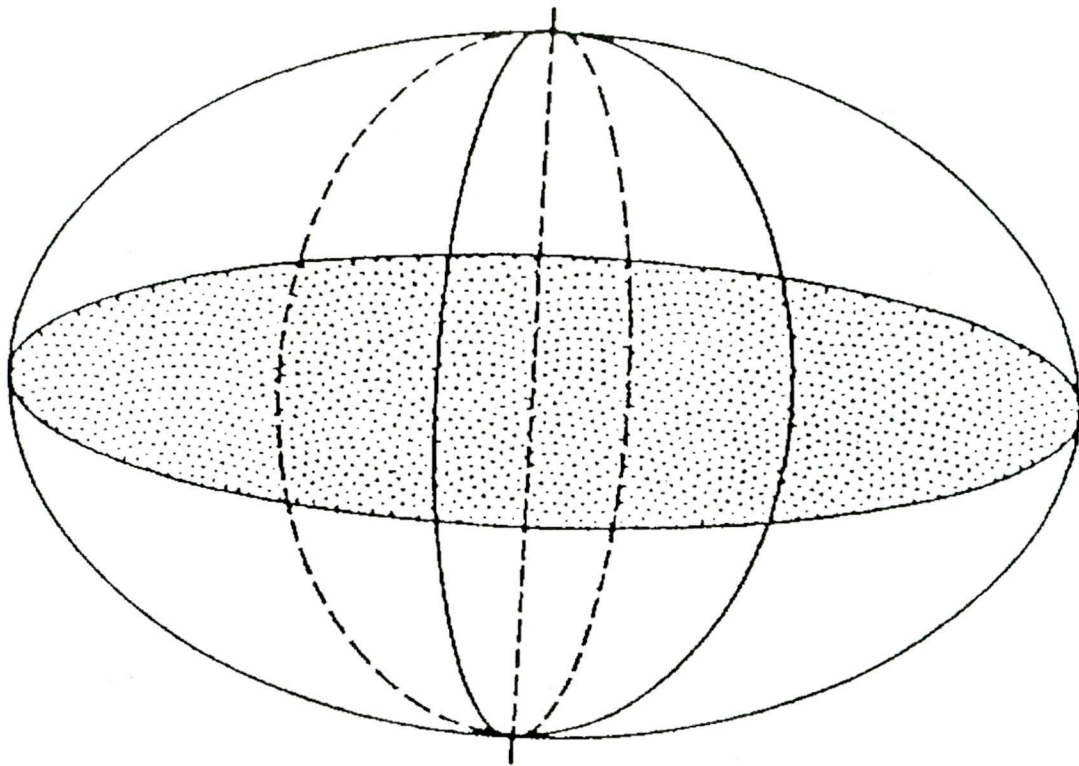


Figure 4-1 : Spherical or ellipsoidal models of the earth

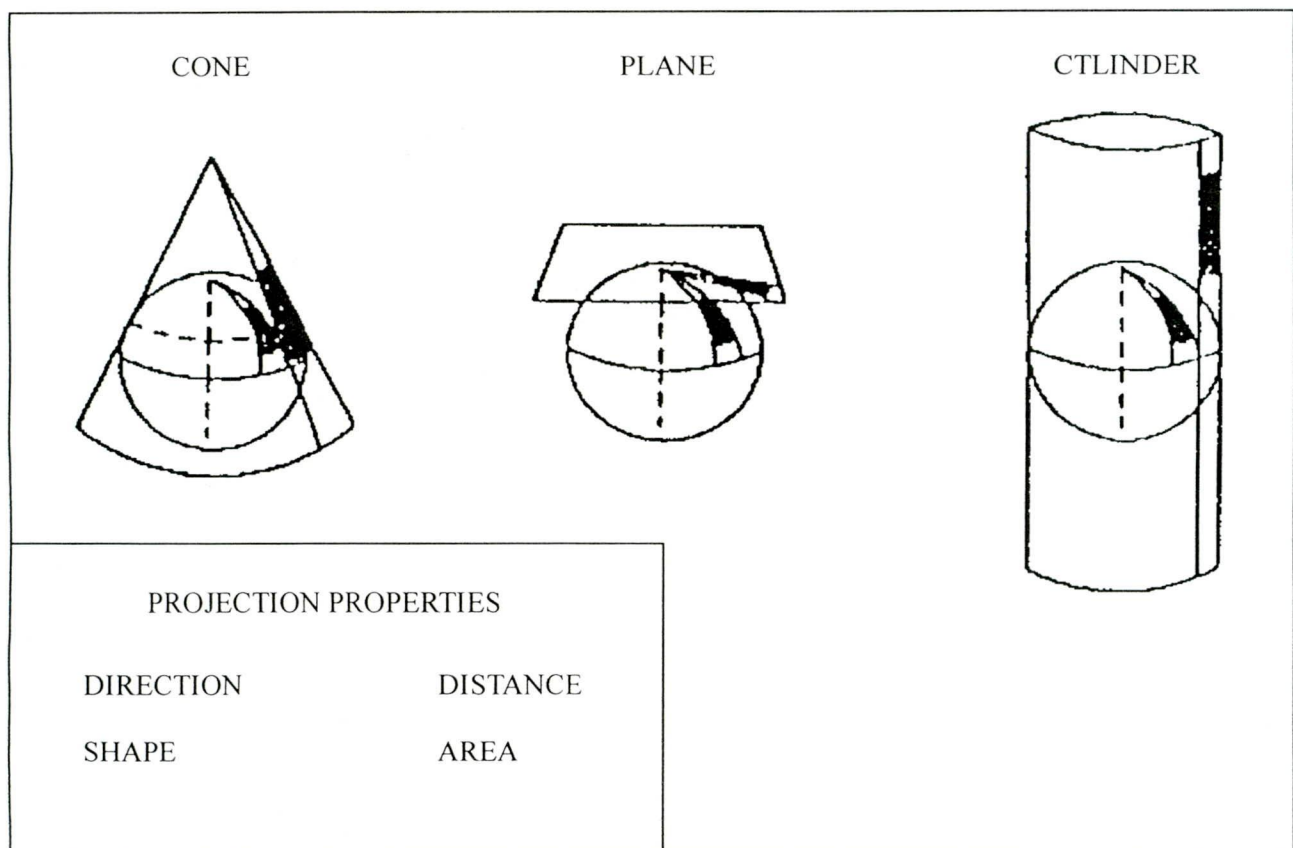


Figure 4-2 : Three developable surfaces

Source : EGIS

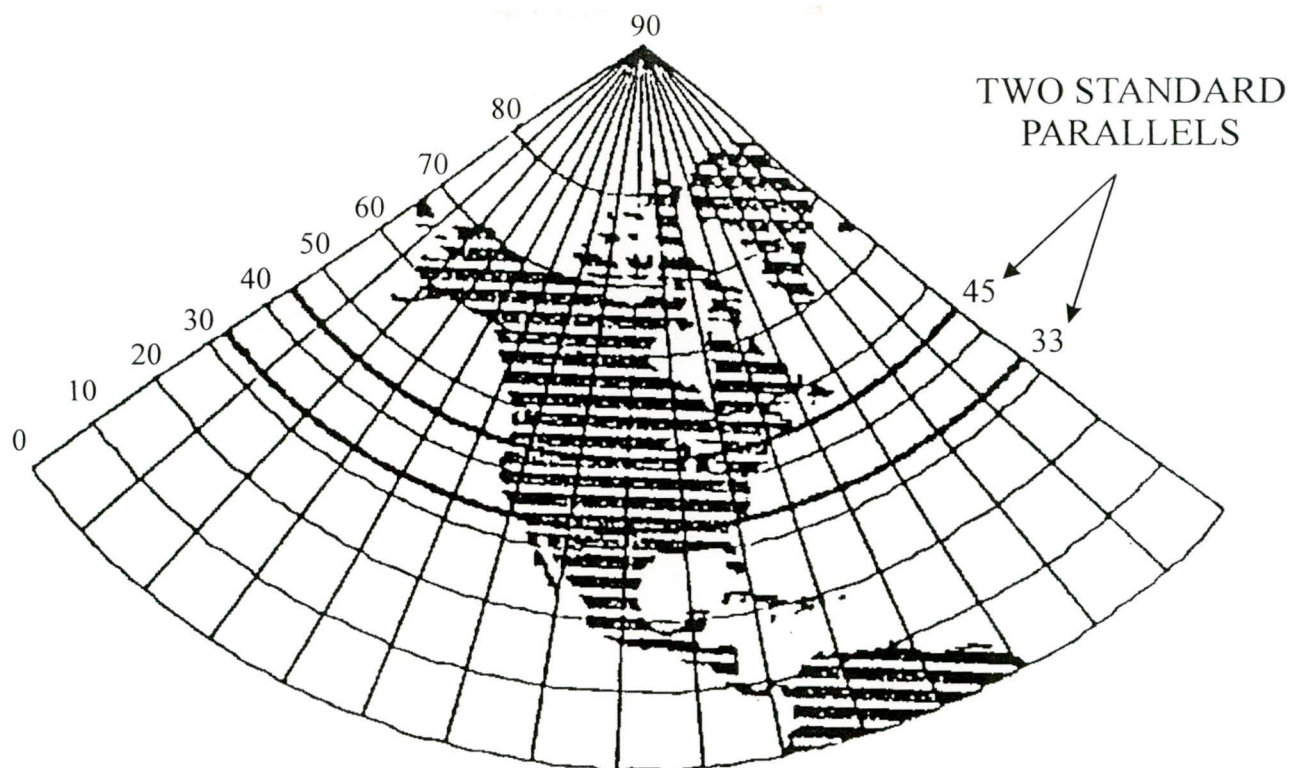


Figure 4-3 : Lambert conformal conic projection

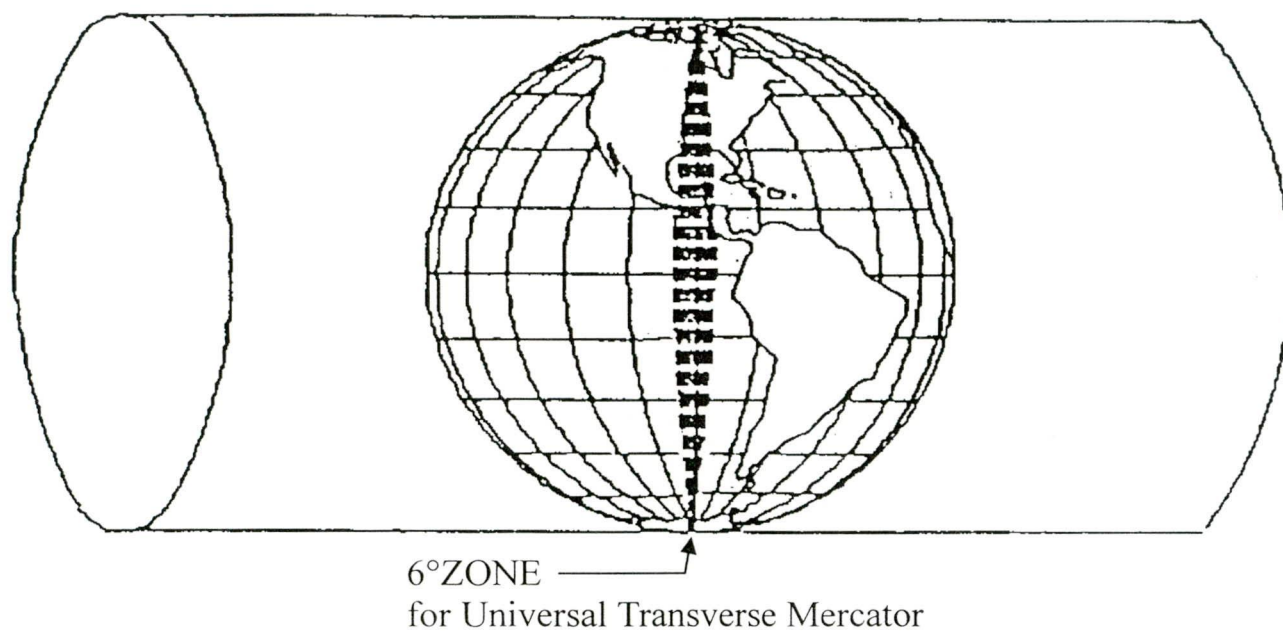
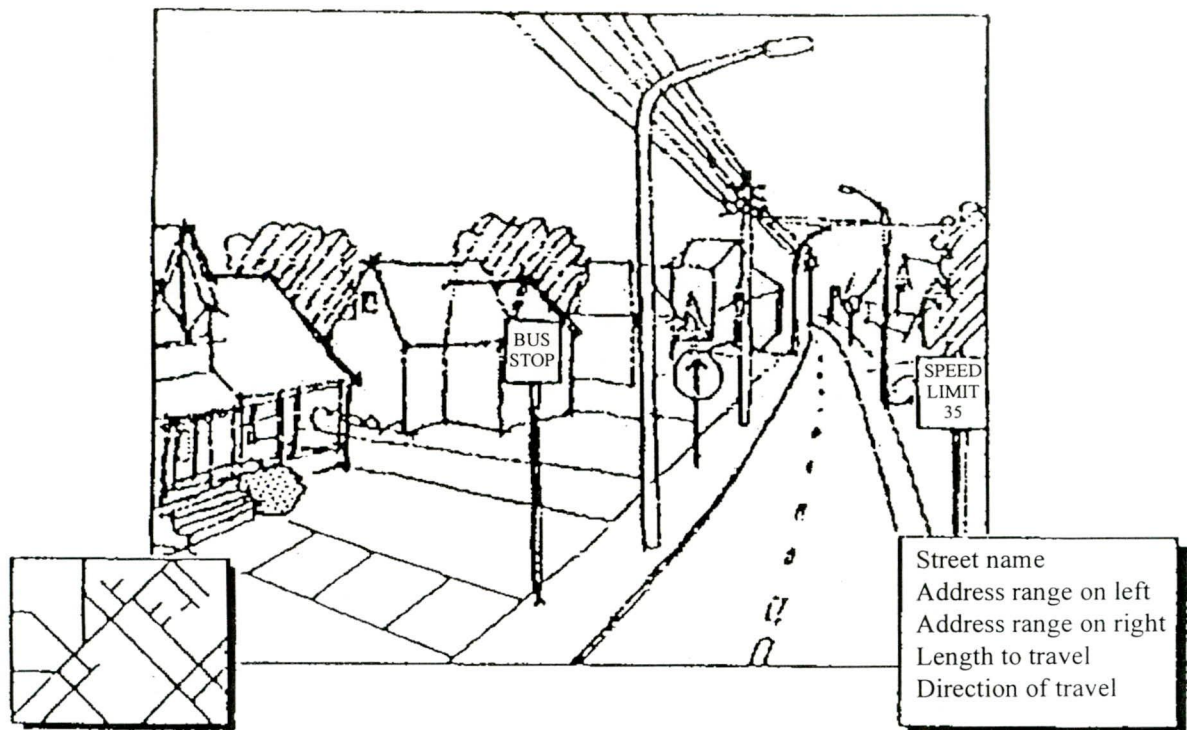


Figure 4-4 : Transverse Mercator : a cylindrical type projection

Source : EGIS



■ Spatial data

■ Attribute data

Figure 4-5 : Spatial and attribute database

THE RASTER AND VECTOR DATA MODELS

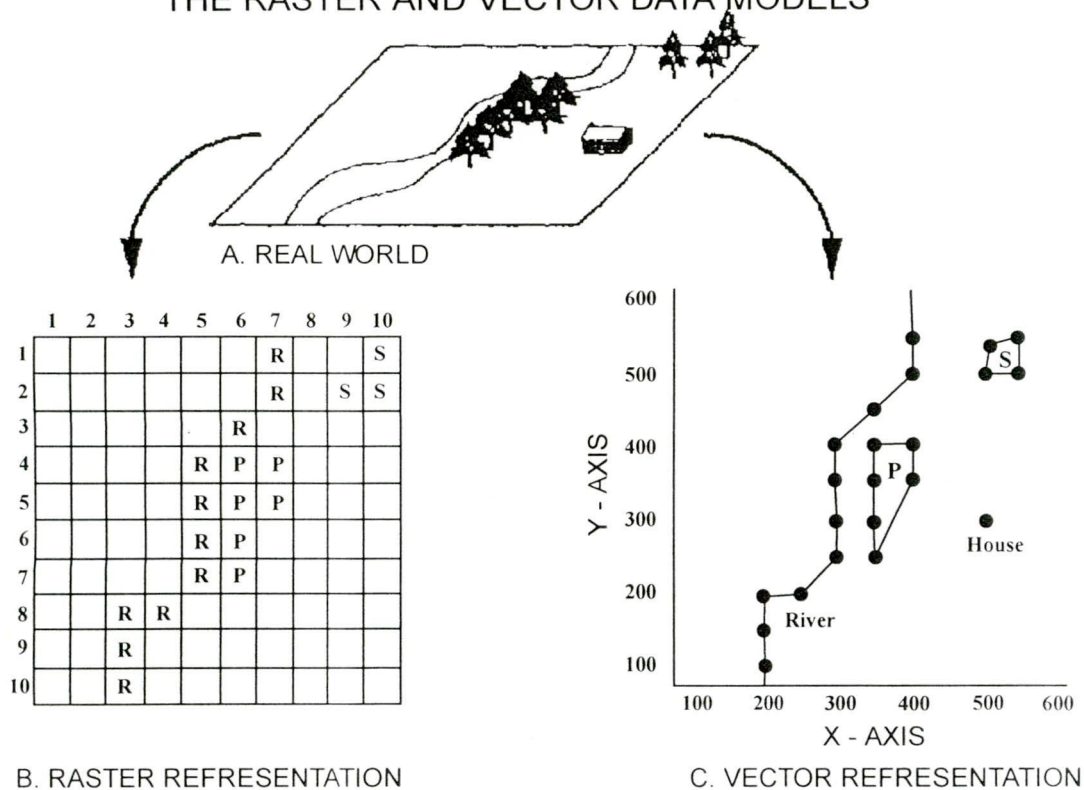
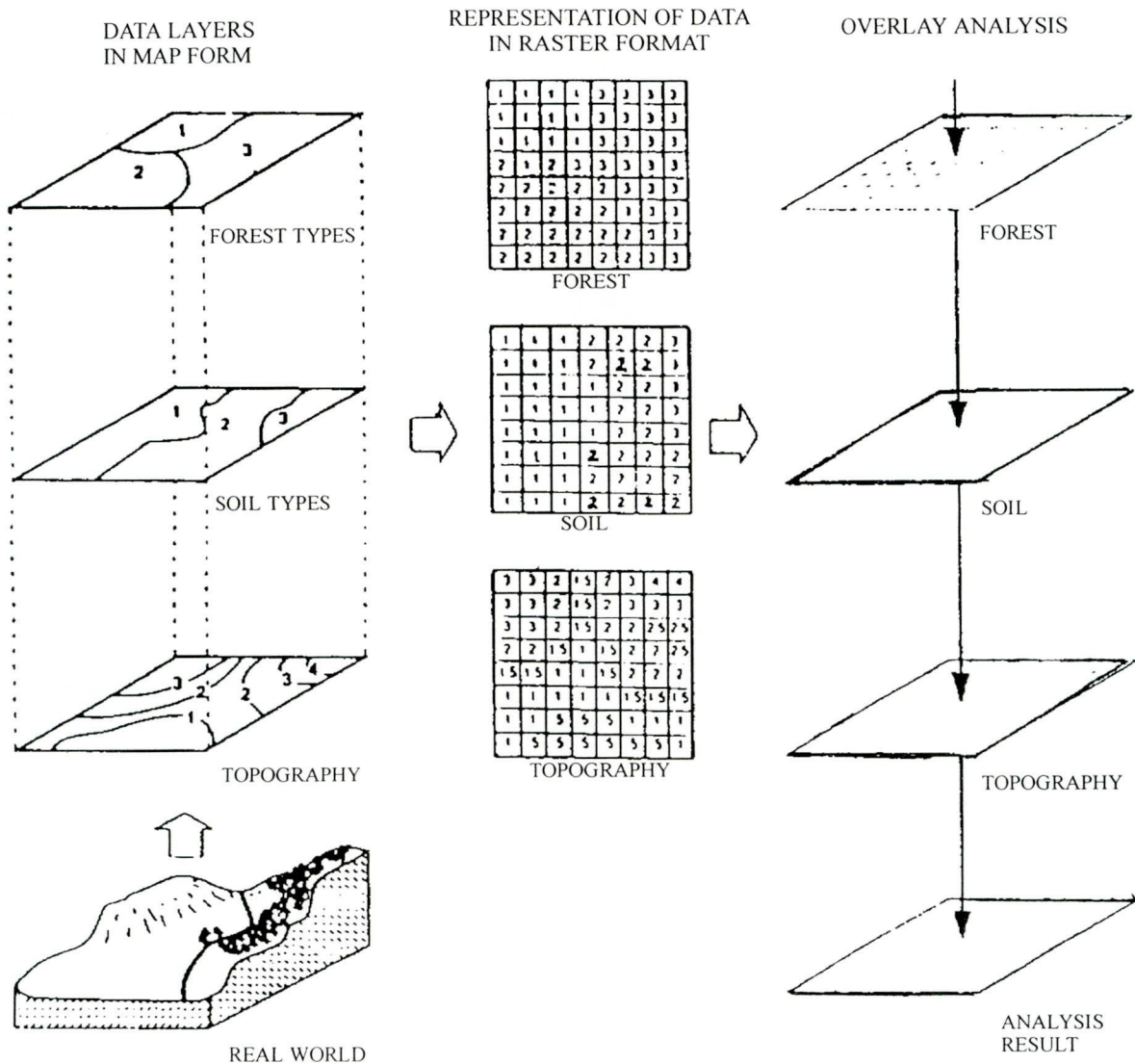


Figure 4-6 : The raster and vector data model

Source : ICIMOD/MENRIS

OVERLAY ANALYSIS USING RASTER DATA



Source : ICIMOD/MENRIS

Figure 4-7 : Overlay concept using raster data files

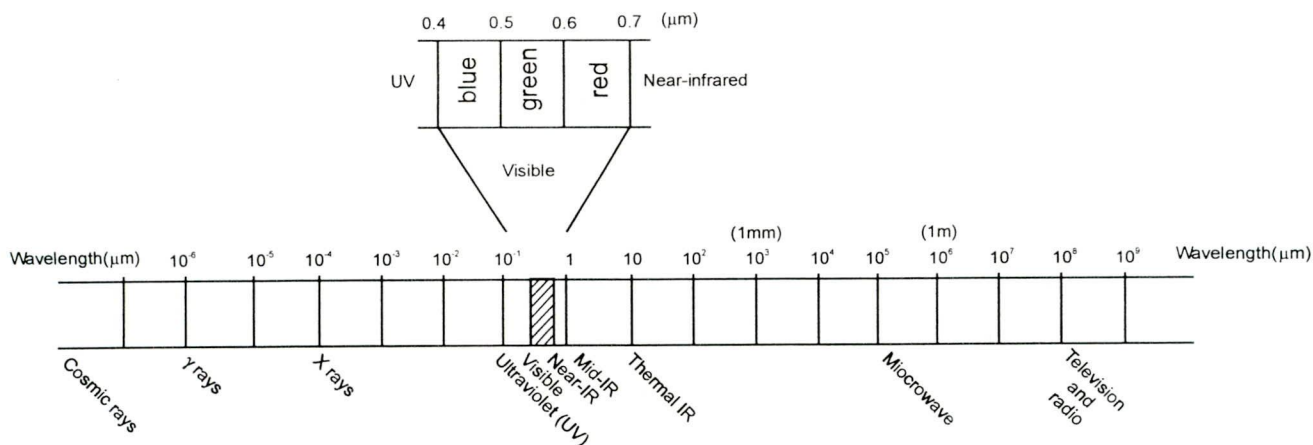


Figure 4-8 : The Electromagnetic spectrum

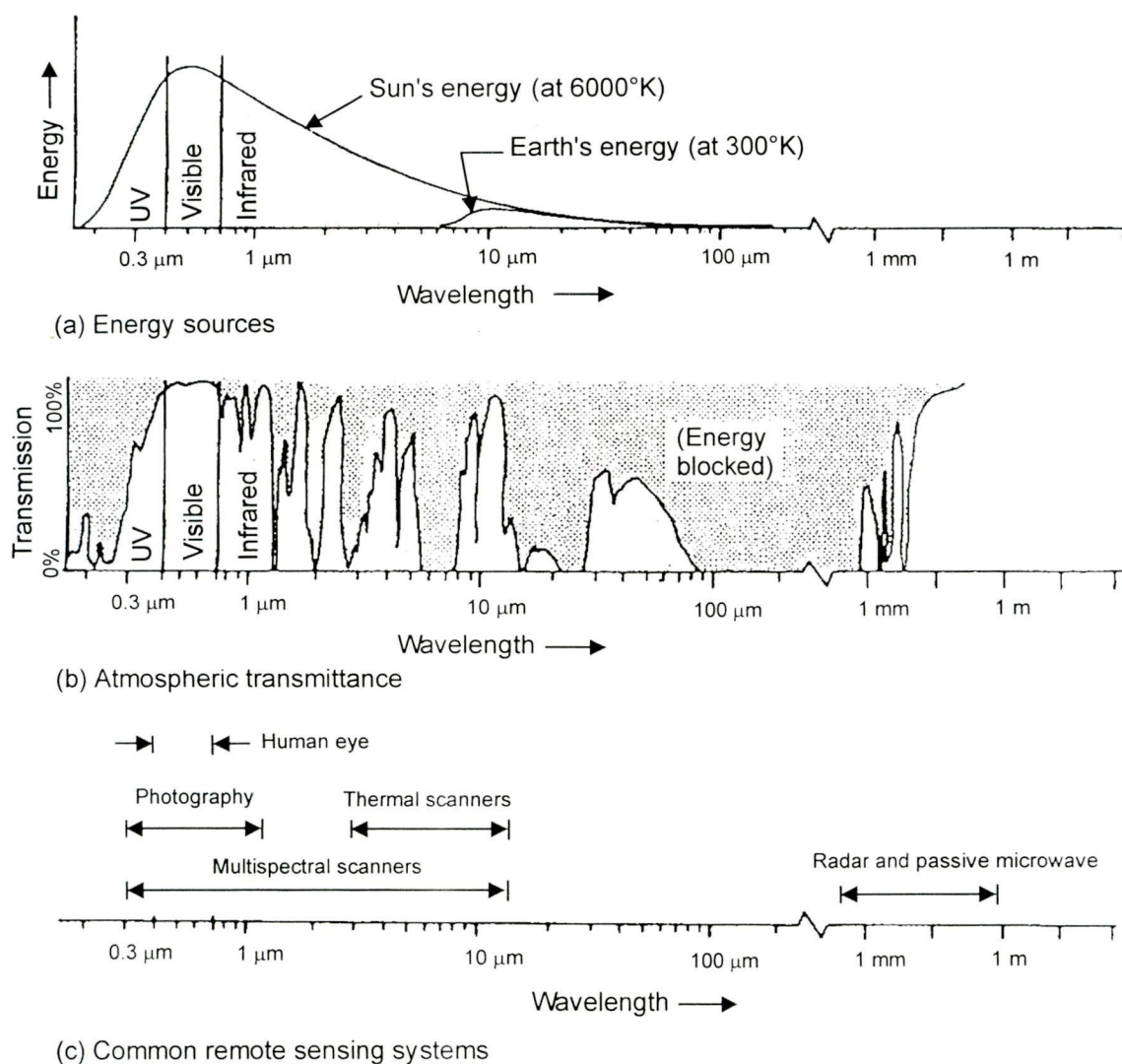


Figure 4-9 : Spectral characteristic of (a) energy sources, (b) atmospheric effects, and (c) sensing system, the Electromagnetic spectrum

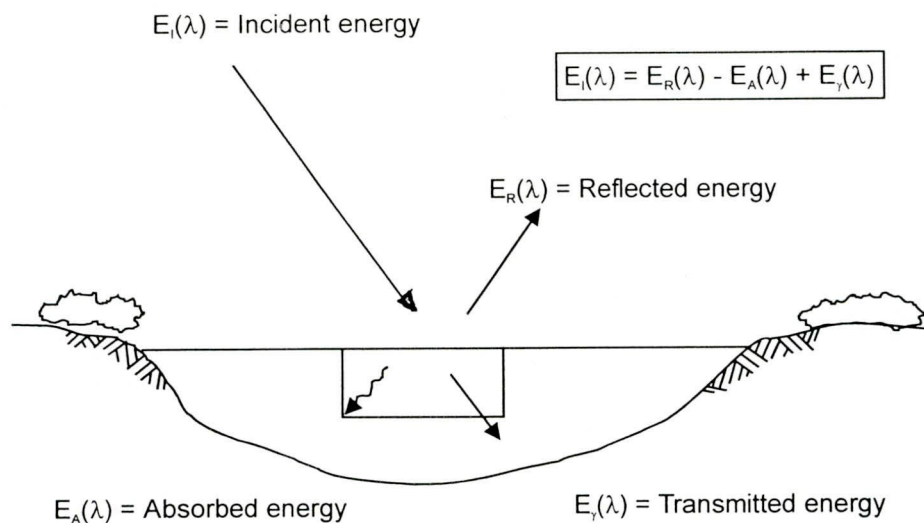


Figure 4-10 : Basic interactions between electromagnetic energy and an earth surface feature

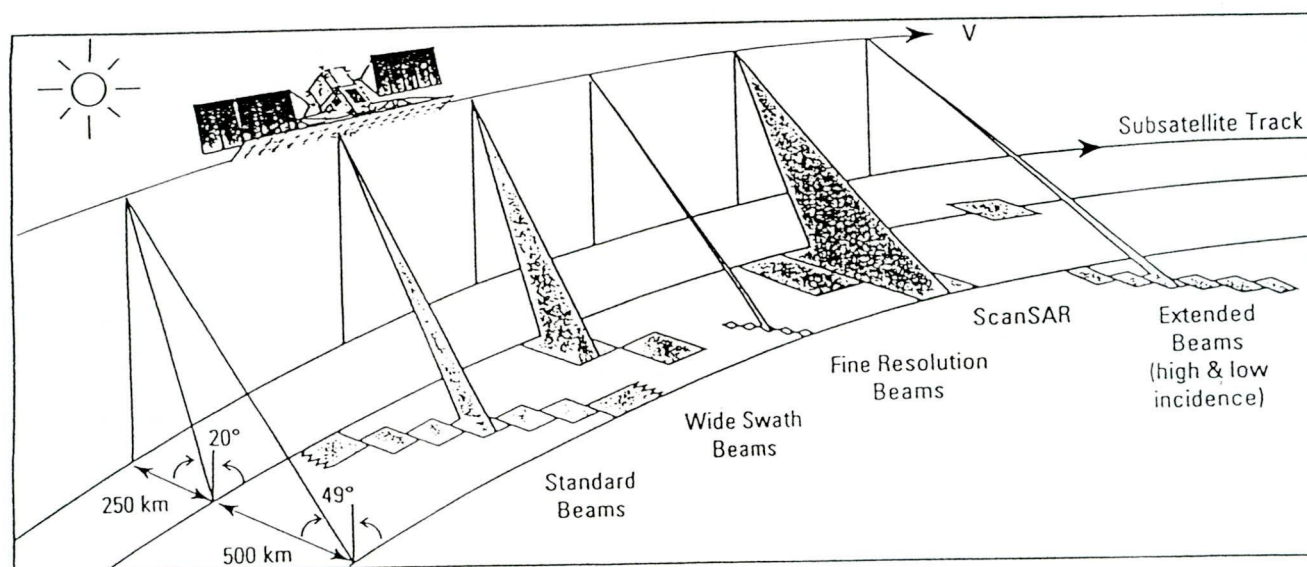


Figure 4-11: RADARSAT SAR Operation Modes
(Source: RADARSAT Project Office/Canadian Space Agency)

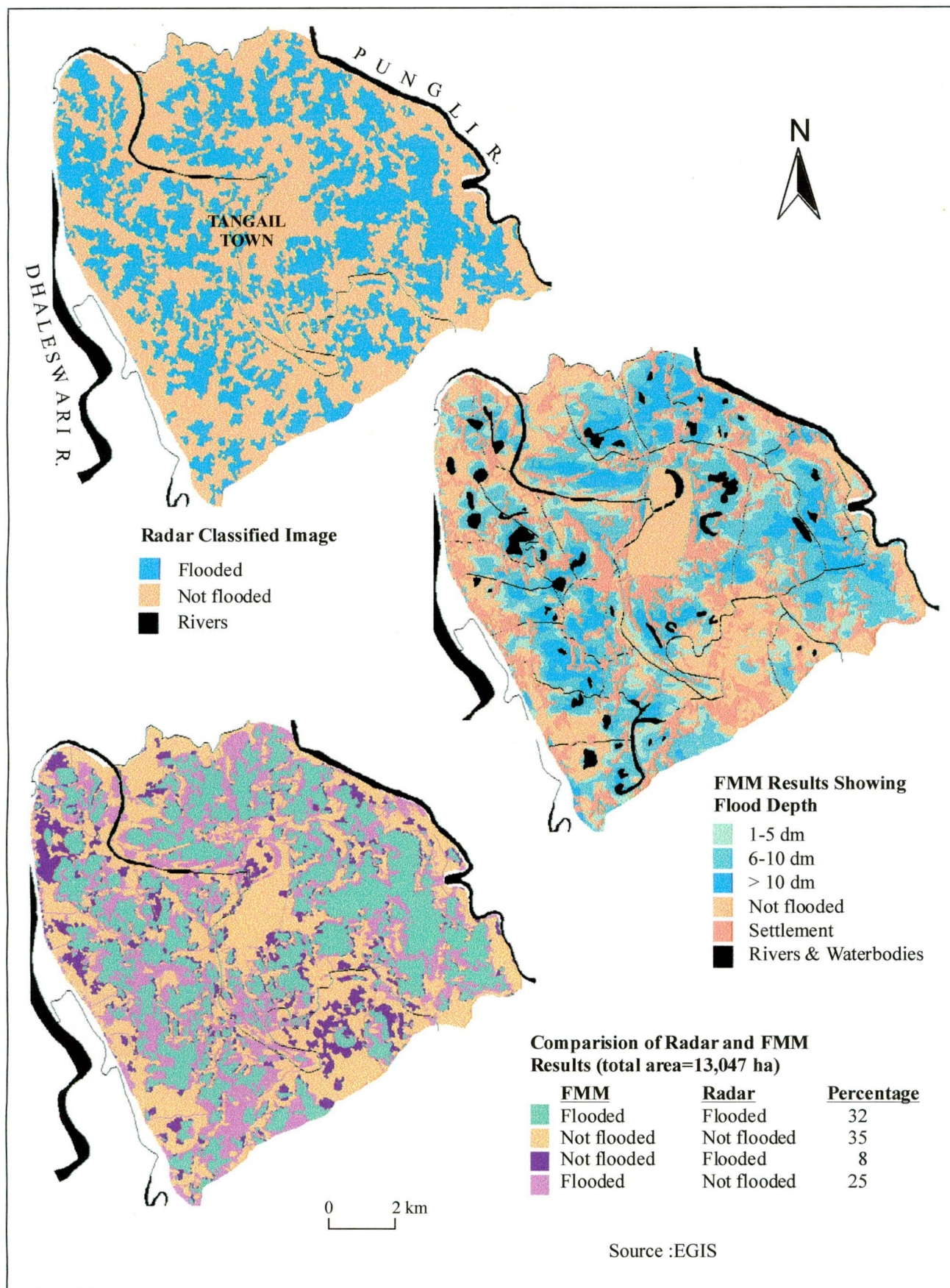


Figure 4-12: Comparison of Results from the Flood Management Model and SAR Image Classification for July 24, 1993.

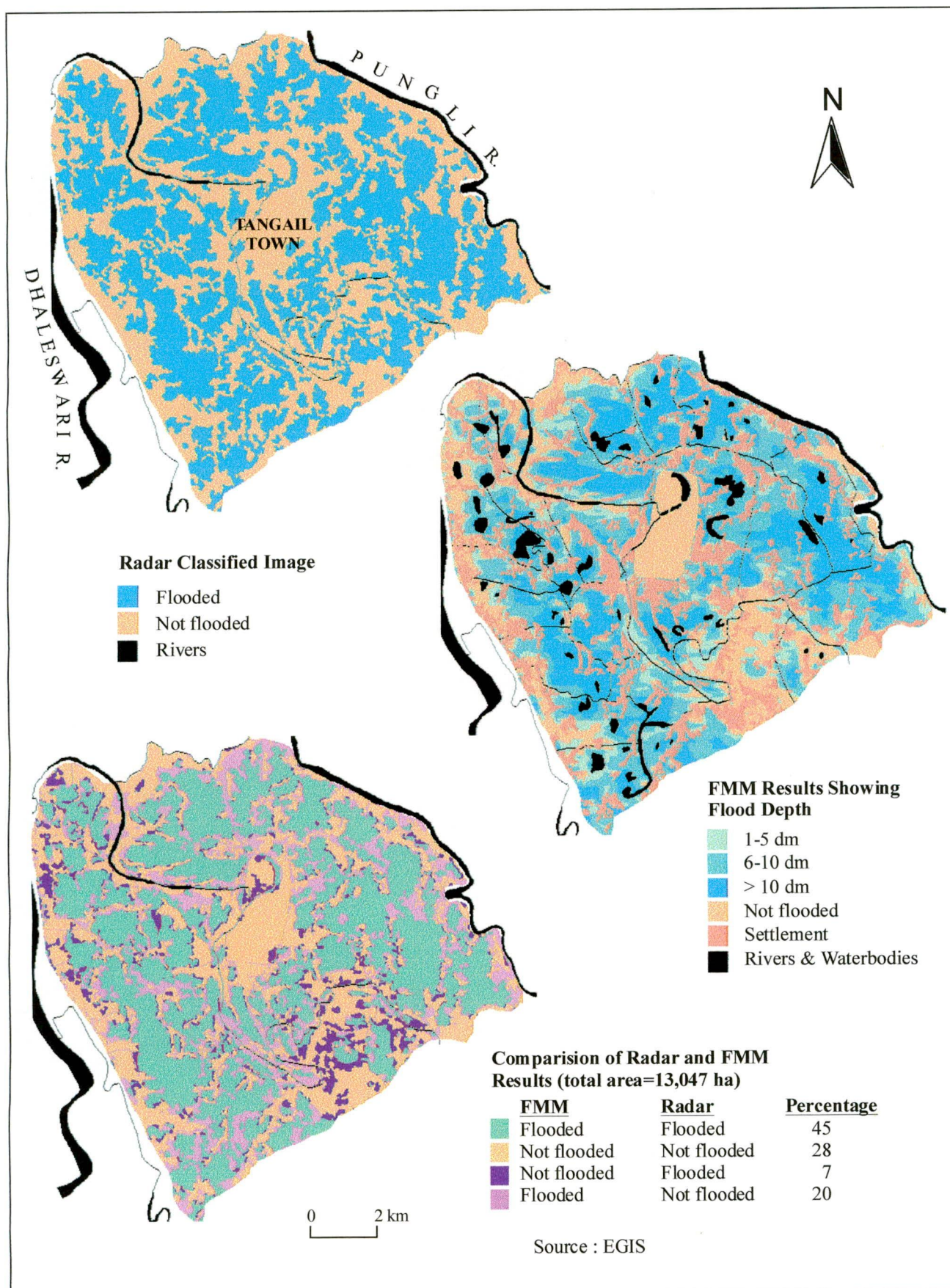


Figure 4-13 : Comparison of Results from the Flood Management Model and SAR Image Classification for August 28, 1993.

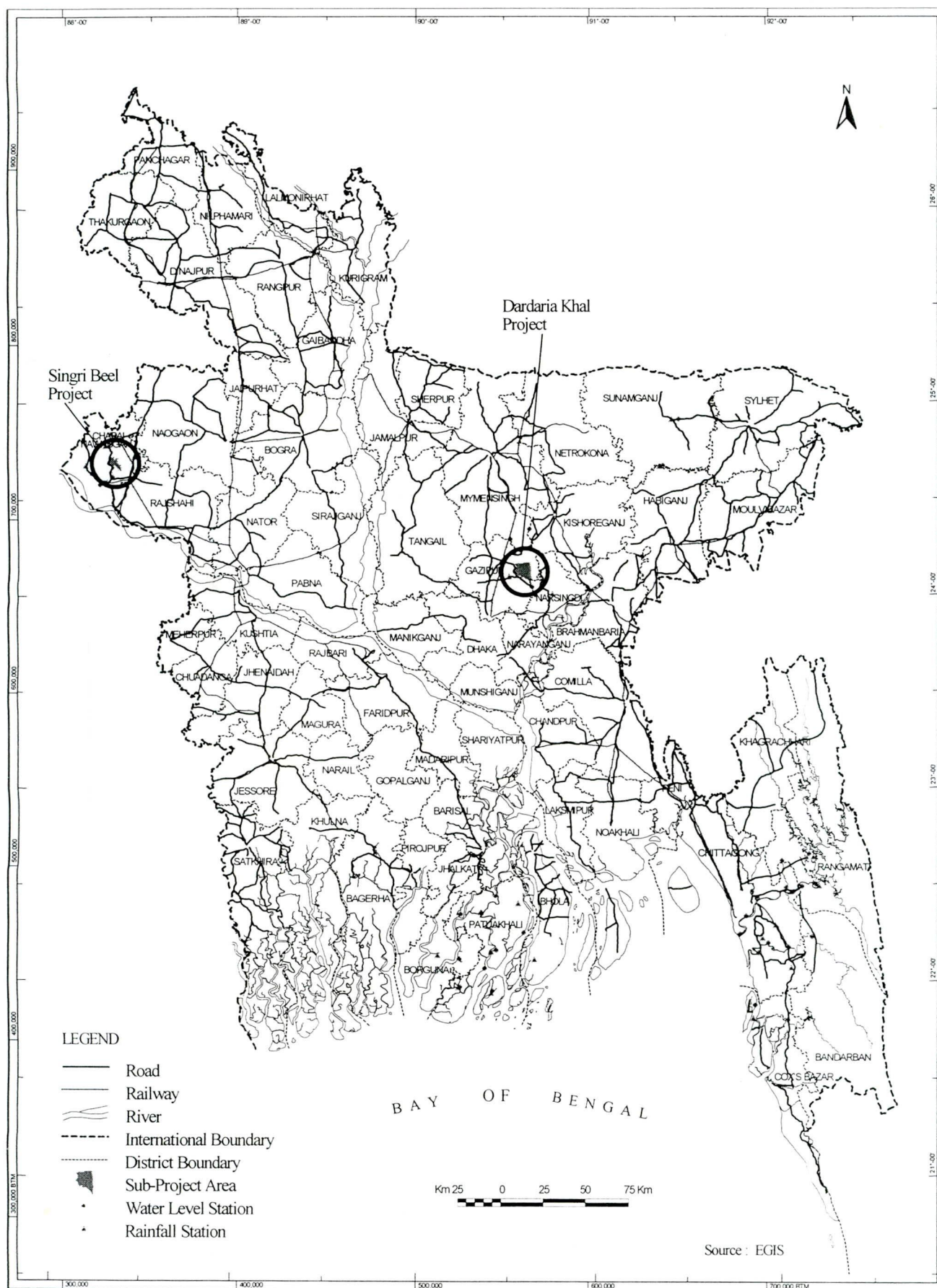


Figure 5-1 : LOCATION OF THE PROJECT AREA

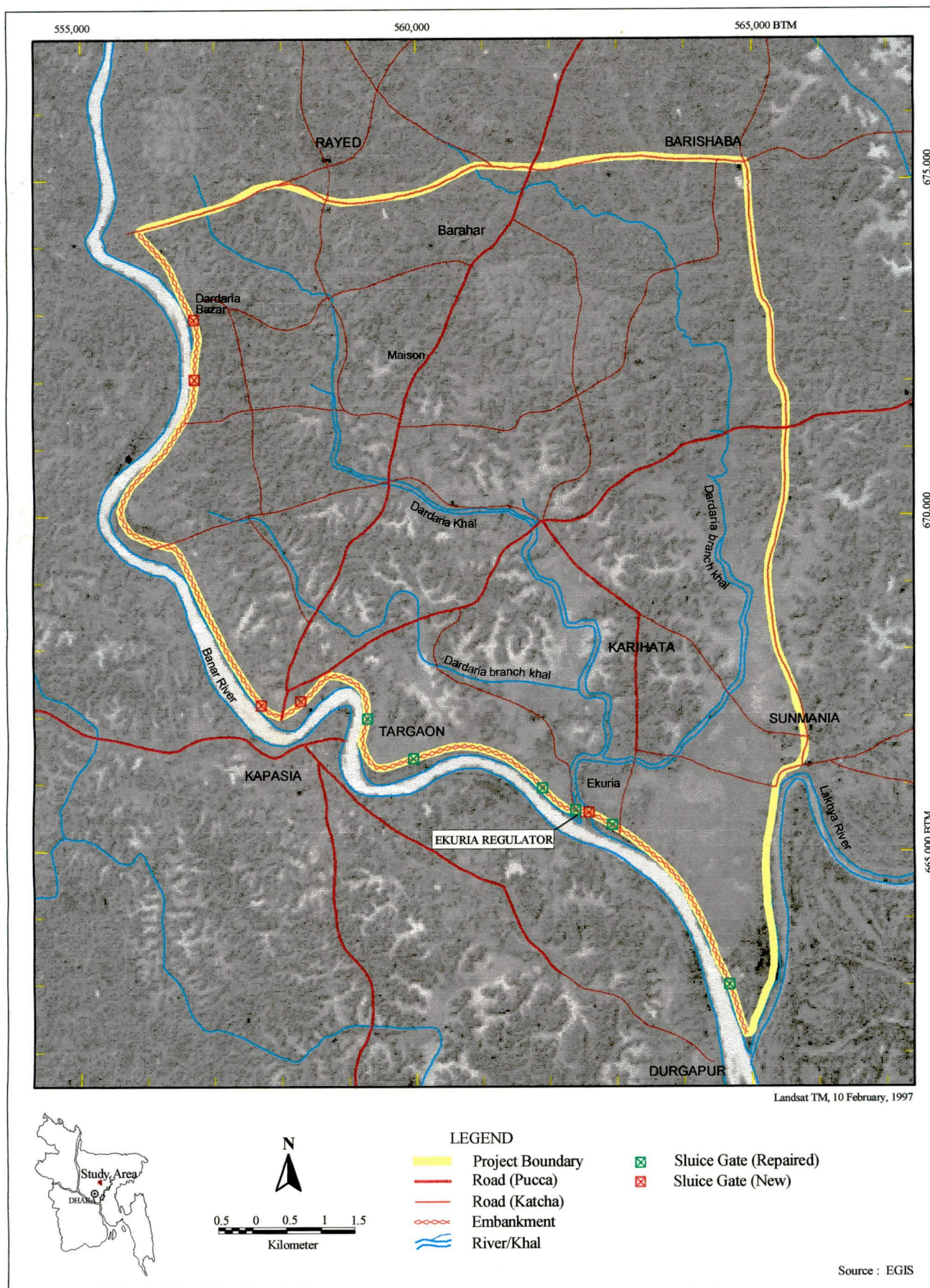


Figure 5-2 : DARDARIA KHAL PROJECT : BASE MAP

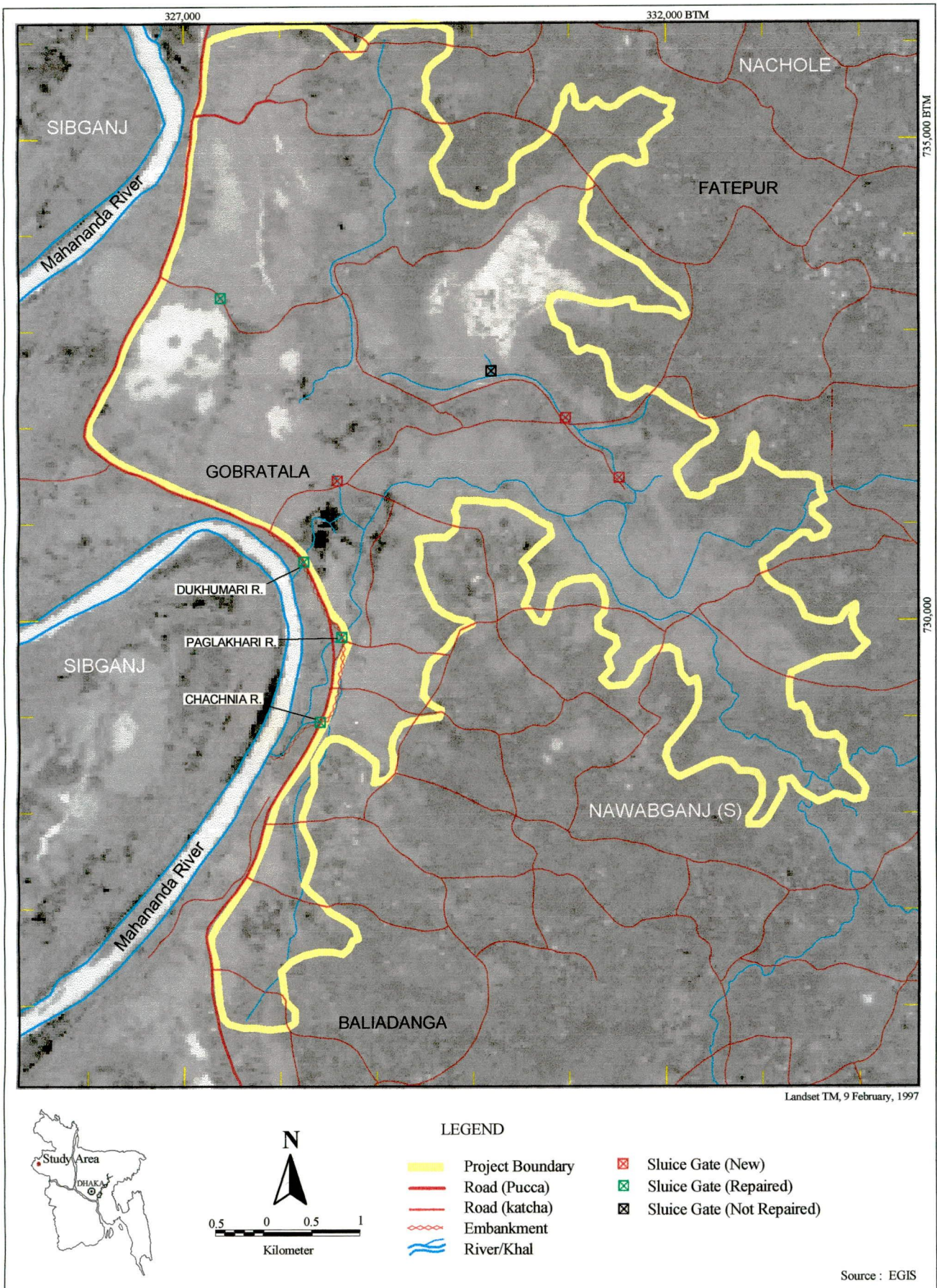


Figure 5-3 : SINGRI BEEL PROJECT : BASE MAP

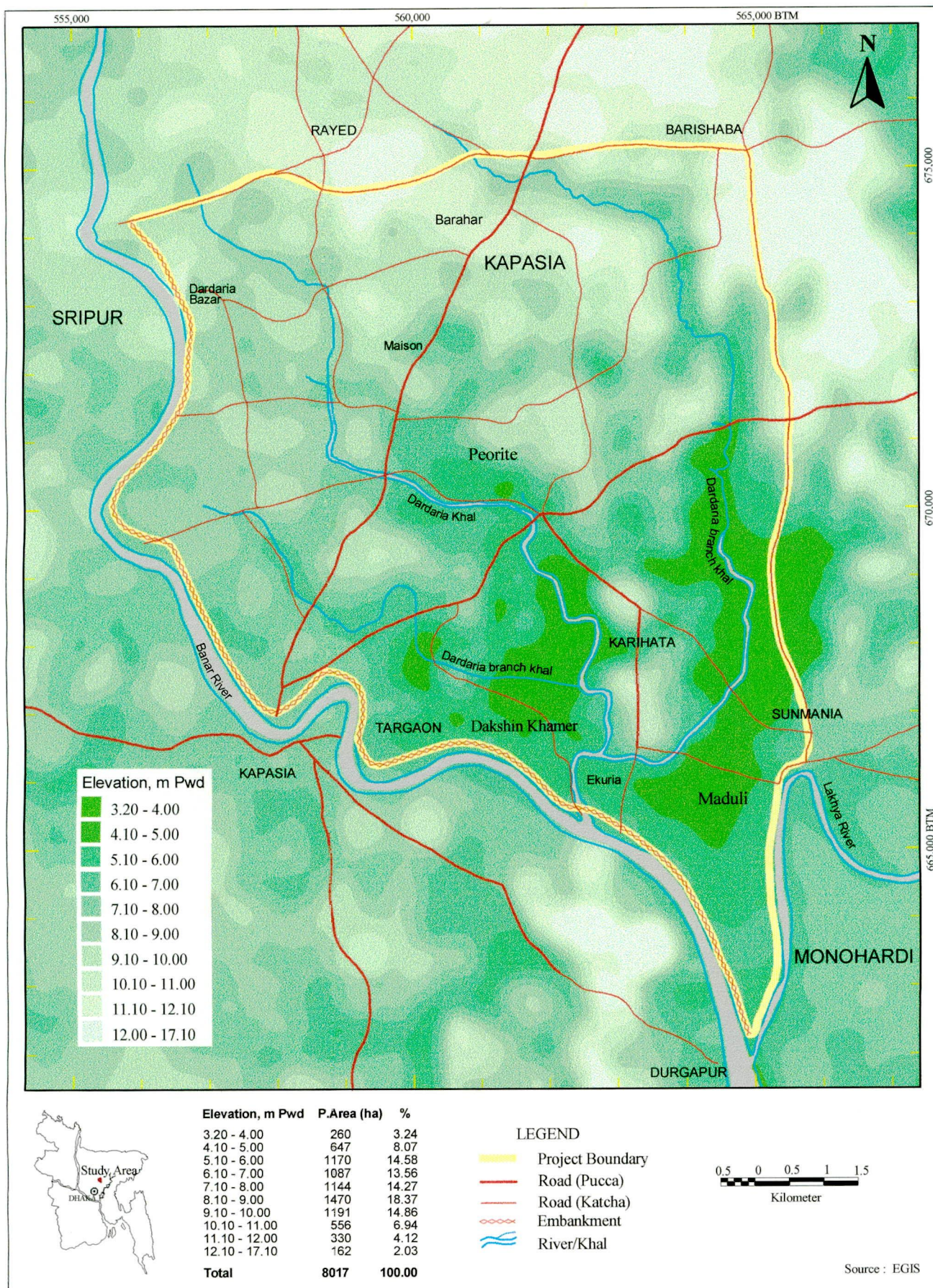


Figure 6-1 : DARDARIA KHAL PROJECT : ELEVATION AND DRAINAGE NETWORK

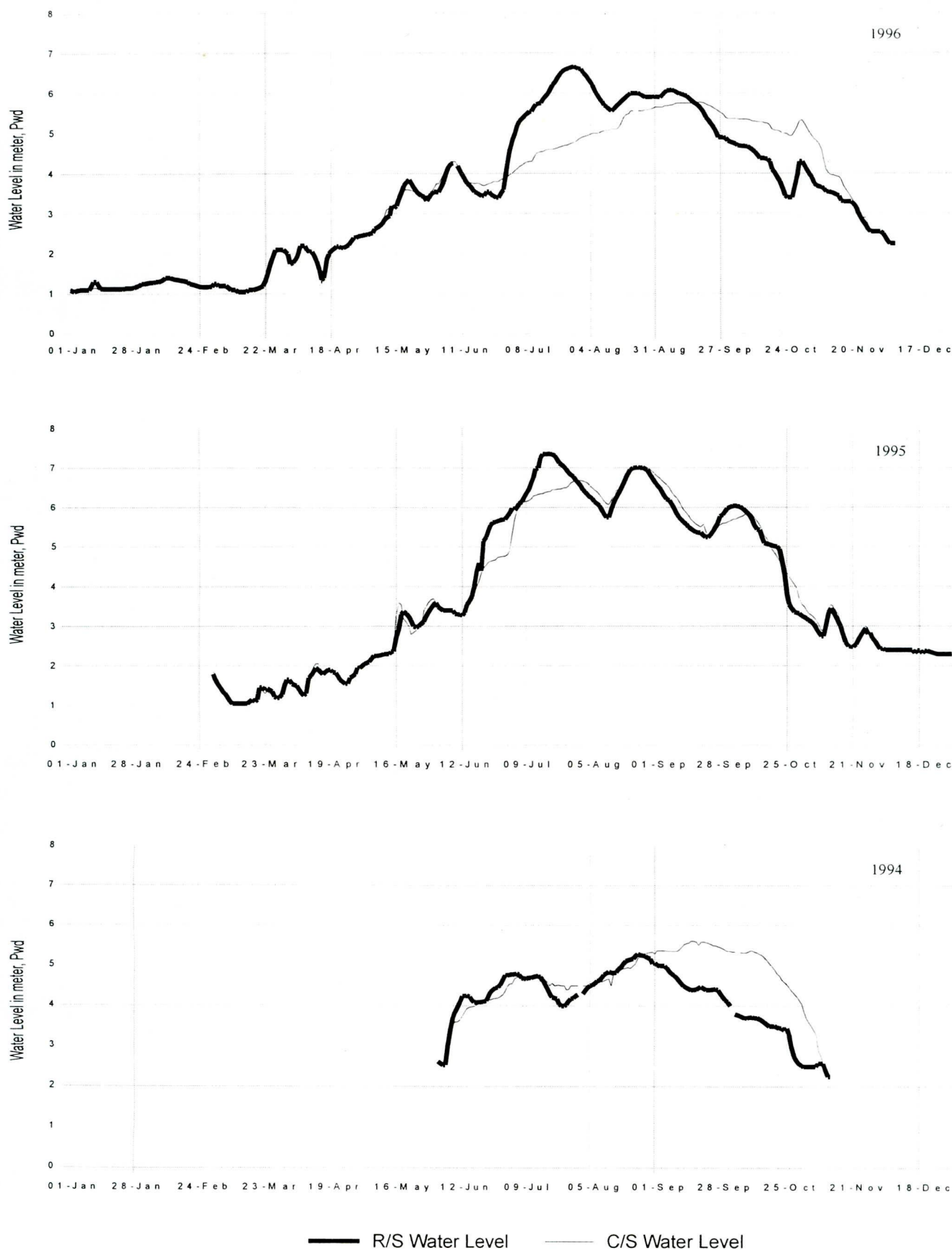


Figure 6.2 : Water level hydrograph at Ekuria regulator for 1994-96 condition, Dardaria Khal Project

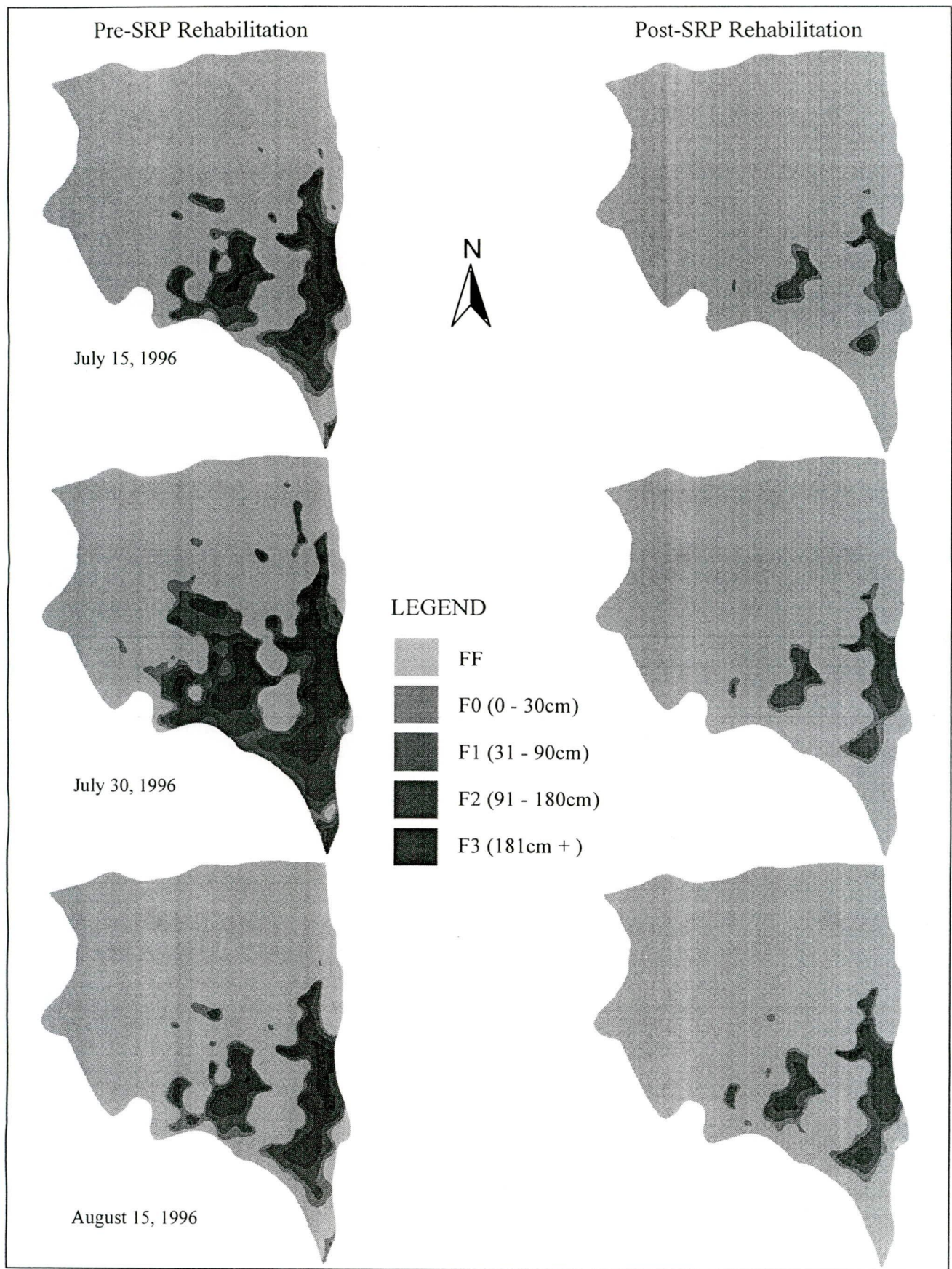


Figure 6-3 : Landtype under pre and post SRP rehabilitation on selected dates for Dardaria Khal project

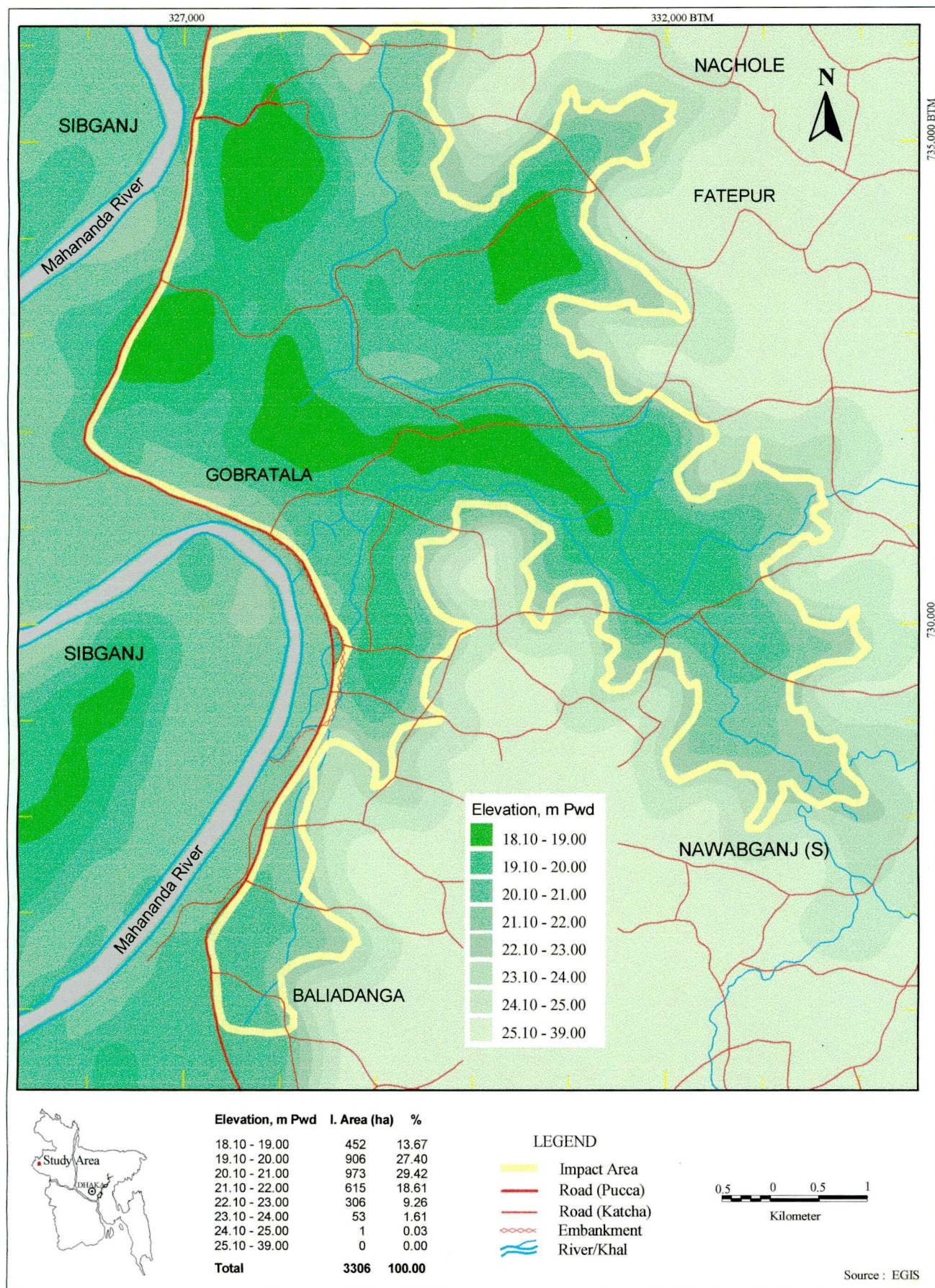


Figure 6-4 : SINGRI BEEL PROJECT : ELEVATION AND DRAINAGE NETWORK

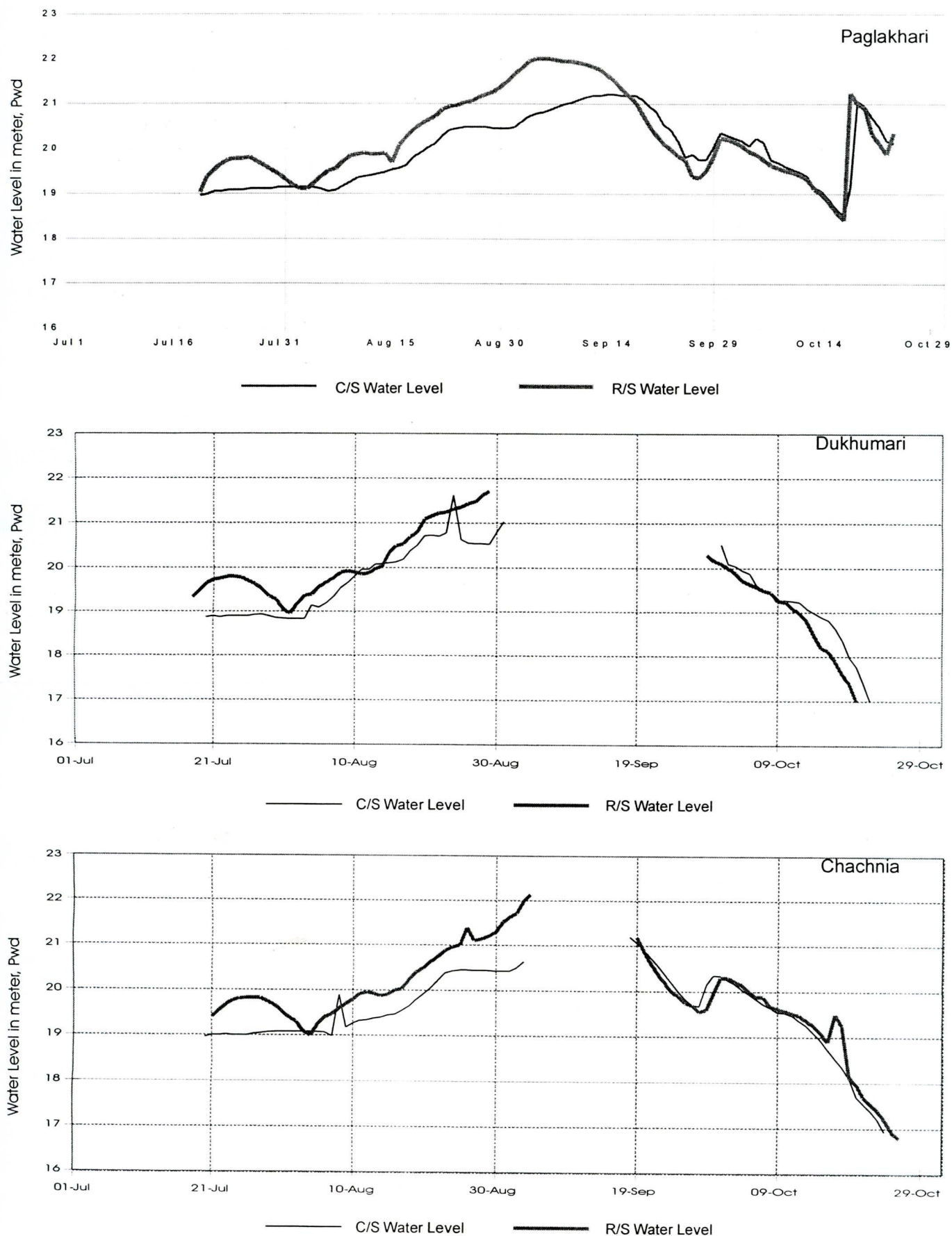


Figure 6-5 : Observed Water Level Hydrograph for 1996 condition on the Regulator Sites of the Singri Beel Project

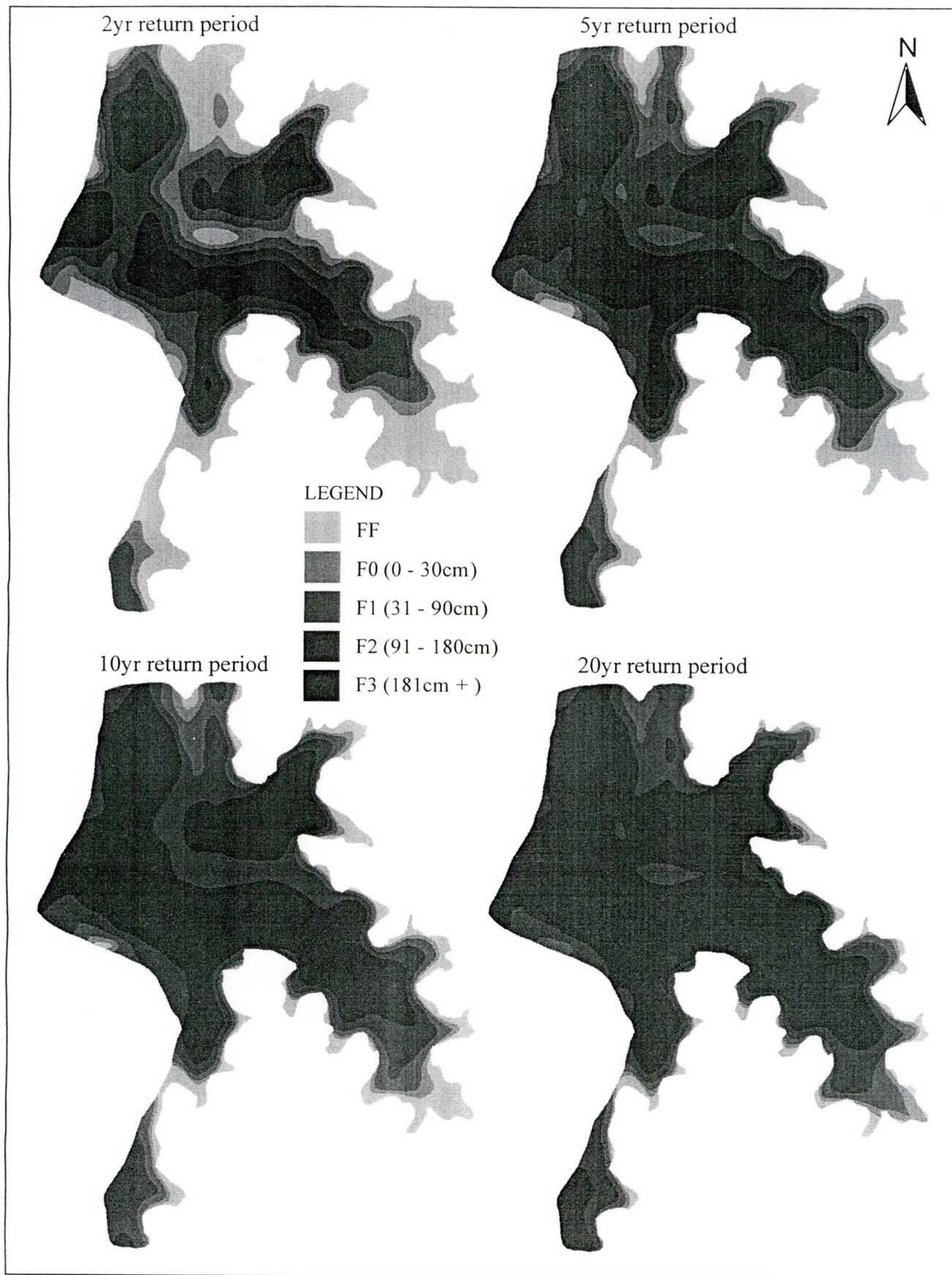


Figure 6-6 : Landtype under different recurrence interval on Singri Beel project

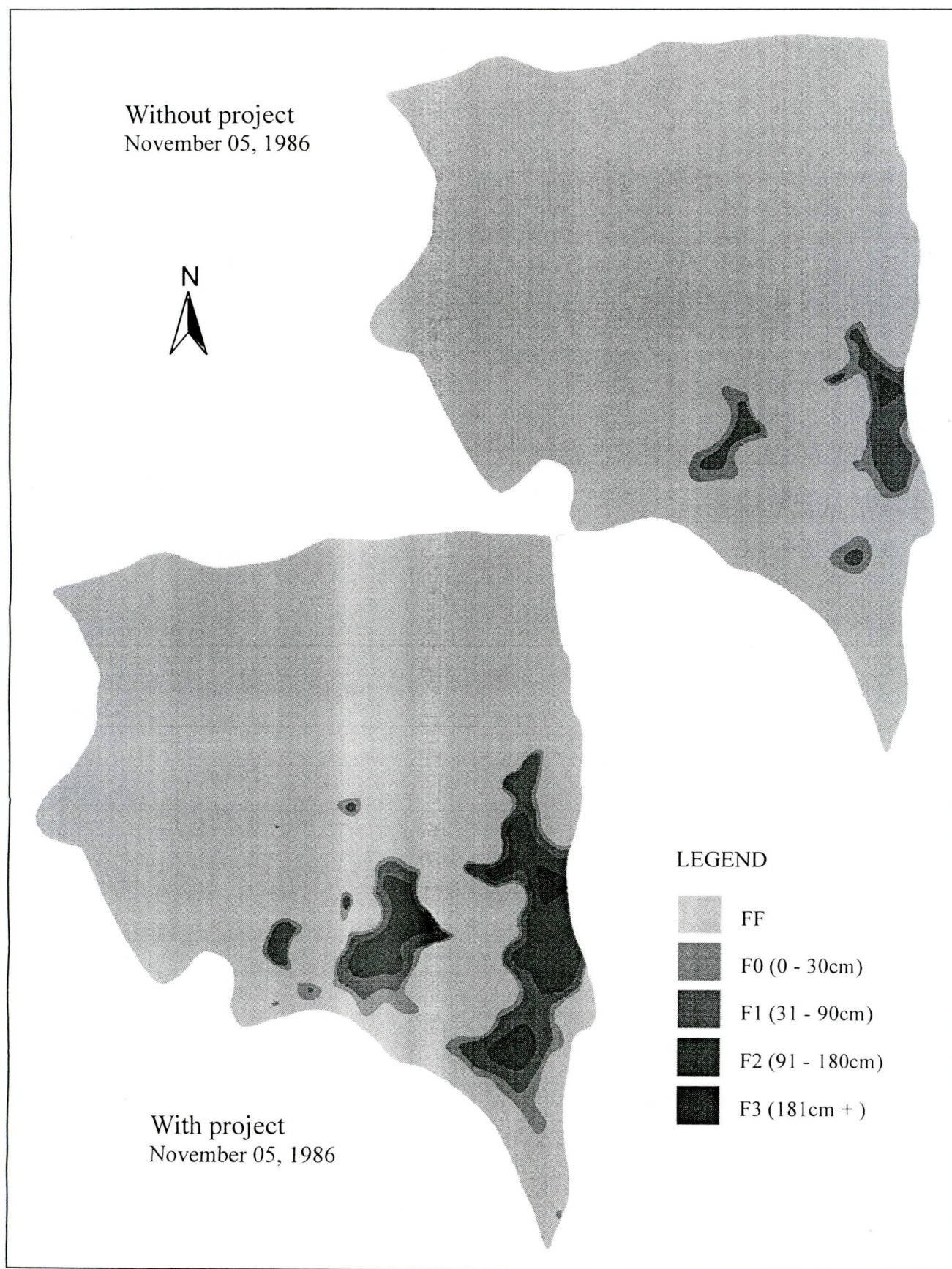


Figure 6-7 : Drainage deficiencies for with and without SRP intervention, Dardaria Khal project

Figure 6-8 : Development scenarios of the irrigation assessments during 1996 for Dardaria Khal project

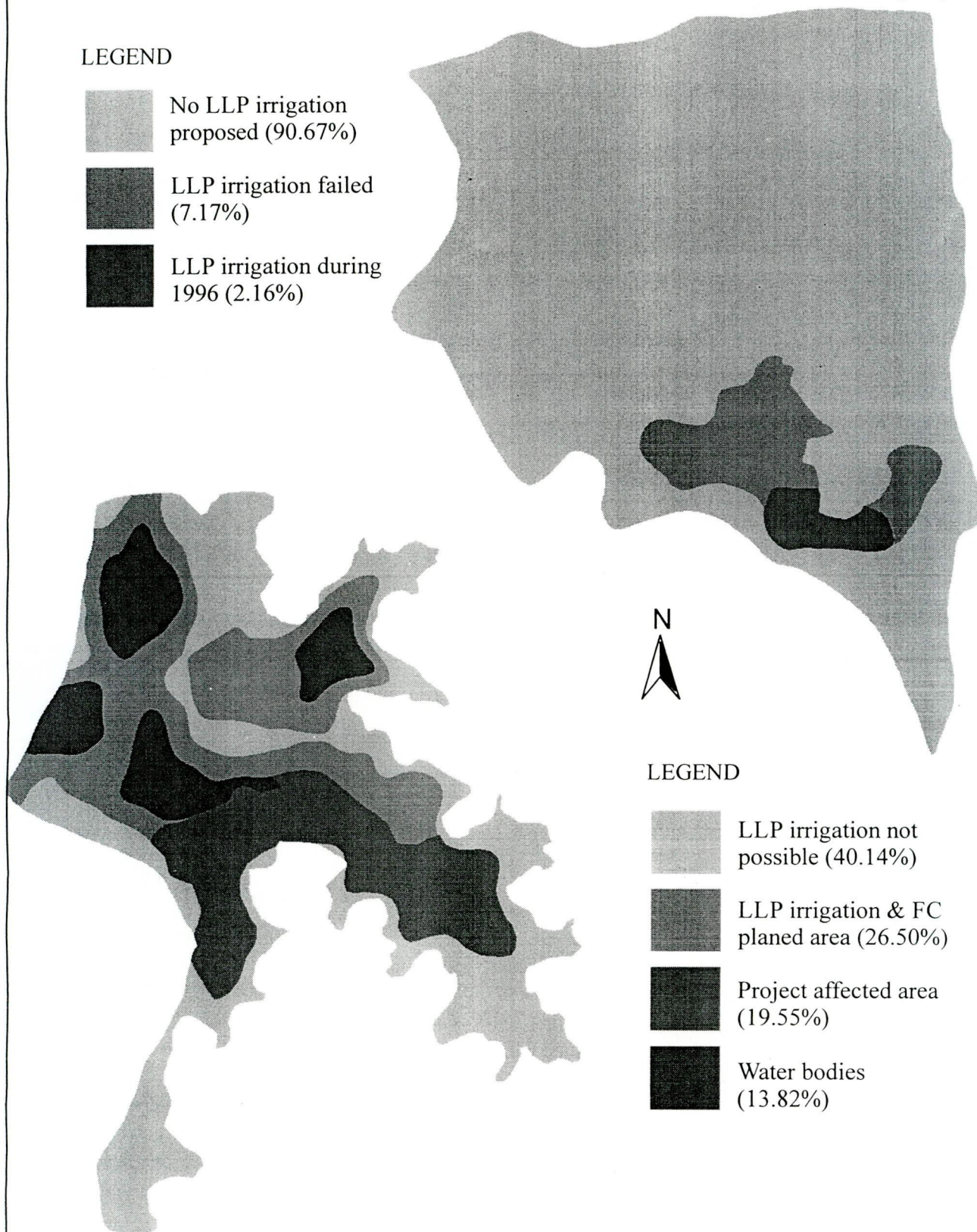


Figure 6-9 : Future development scenarios of the LLP irrigation and flood control in the Singri Beel project

Figure 6-10 : Classified agriculture important zone of the Dardaria Khal Project

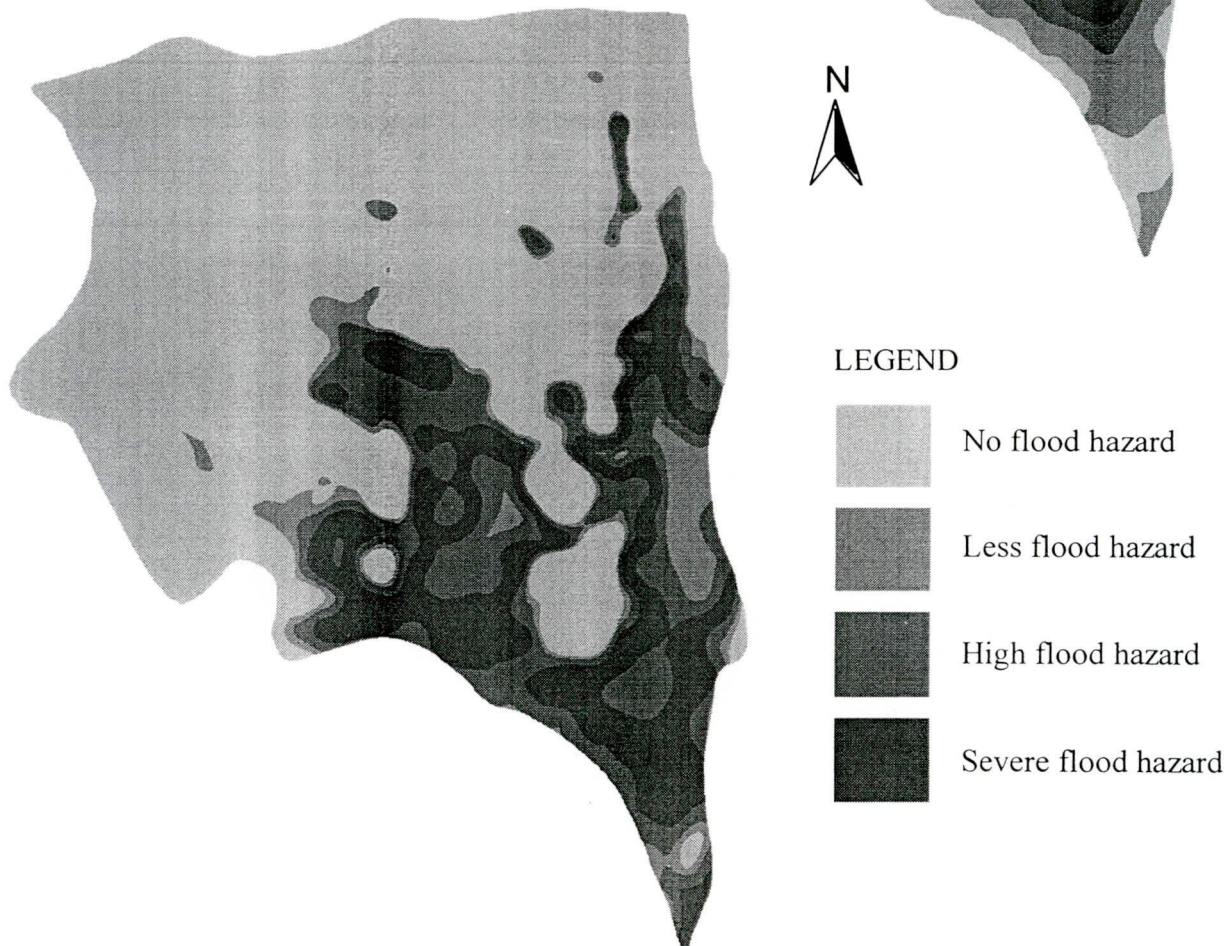
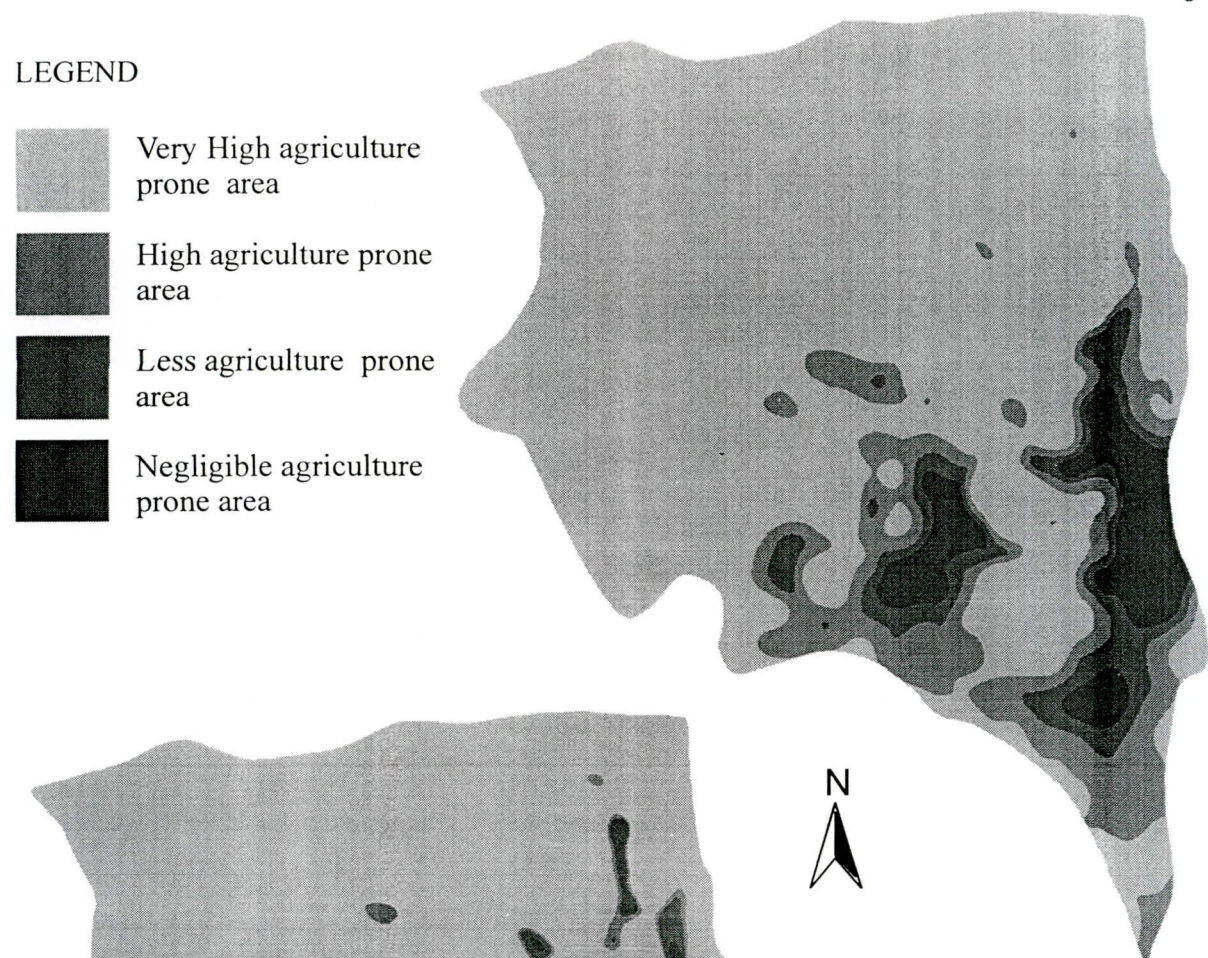


Figure 6-11 : Classified flood hazard zone of the Dardaria Khal project

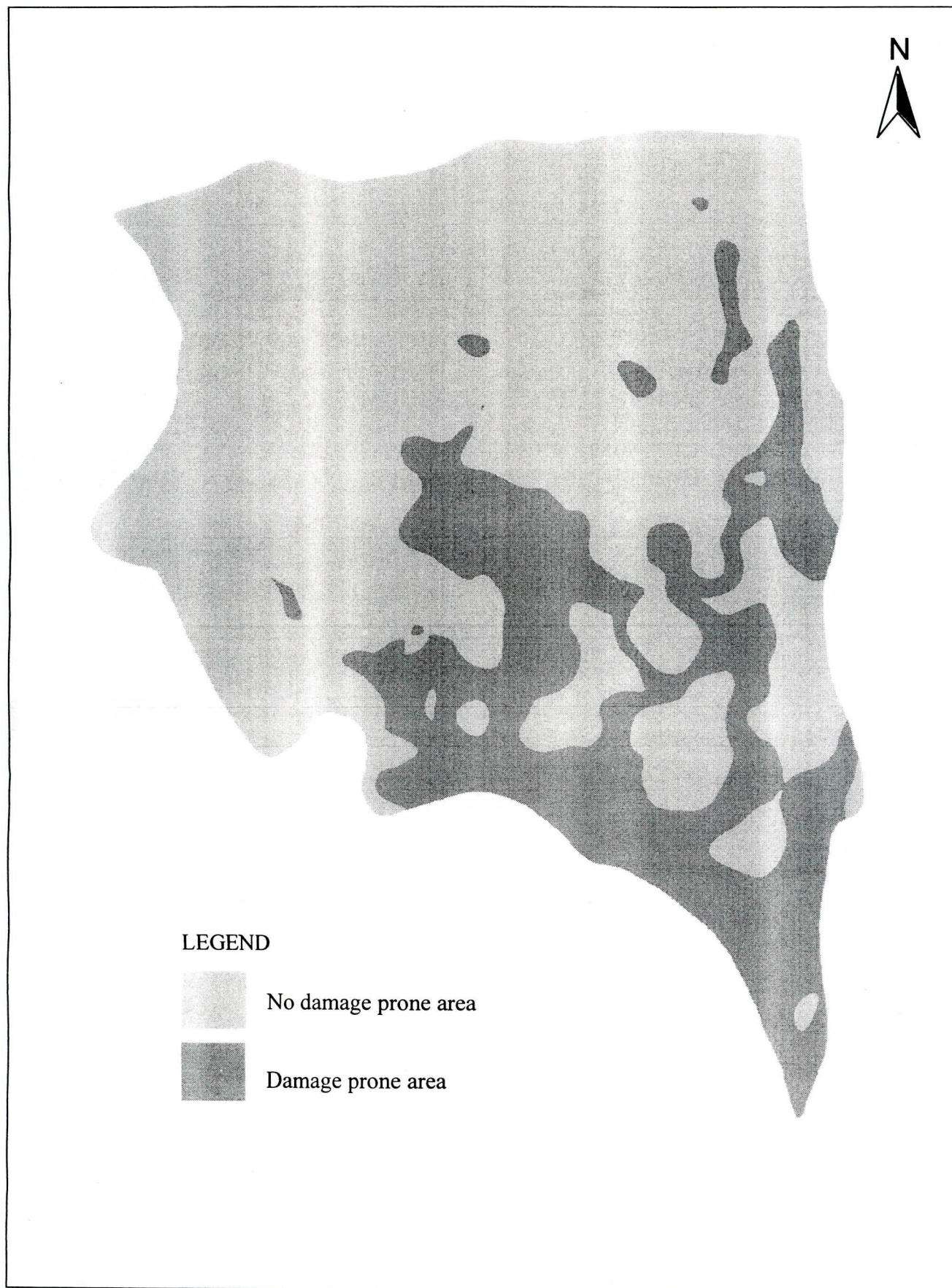


Figure 6-12 : Flood damage zone of the Dardaria Khal Project

Figure 6-13 : Classified agriculture important zone of the Singri Beel project

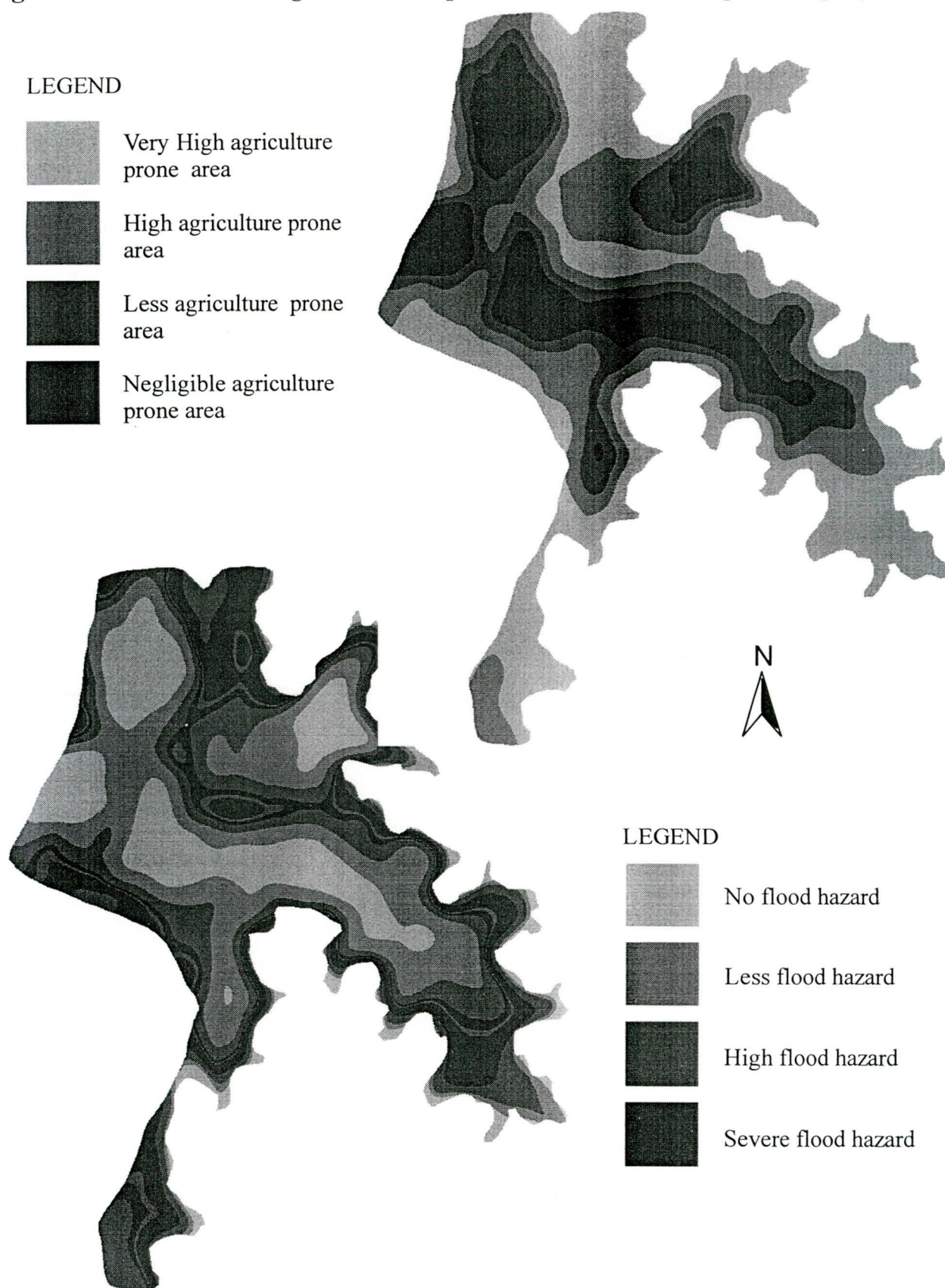


Figure 6-14 : Classified flood hazard zone of the Singri Beel project

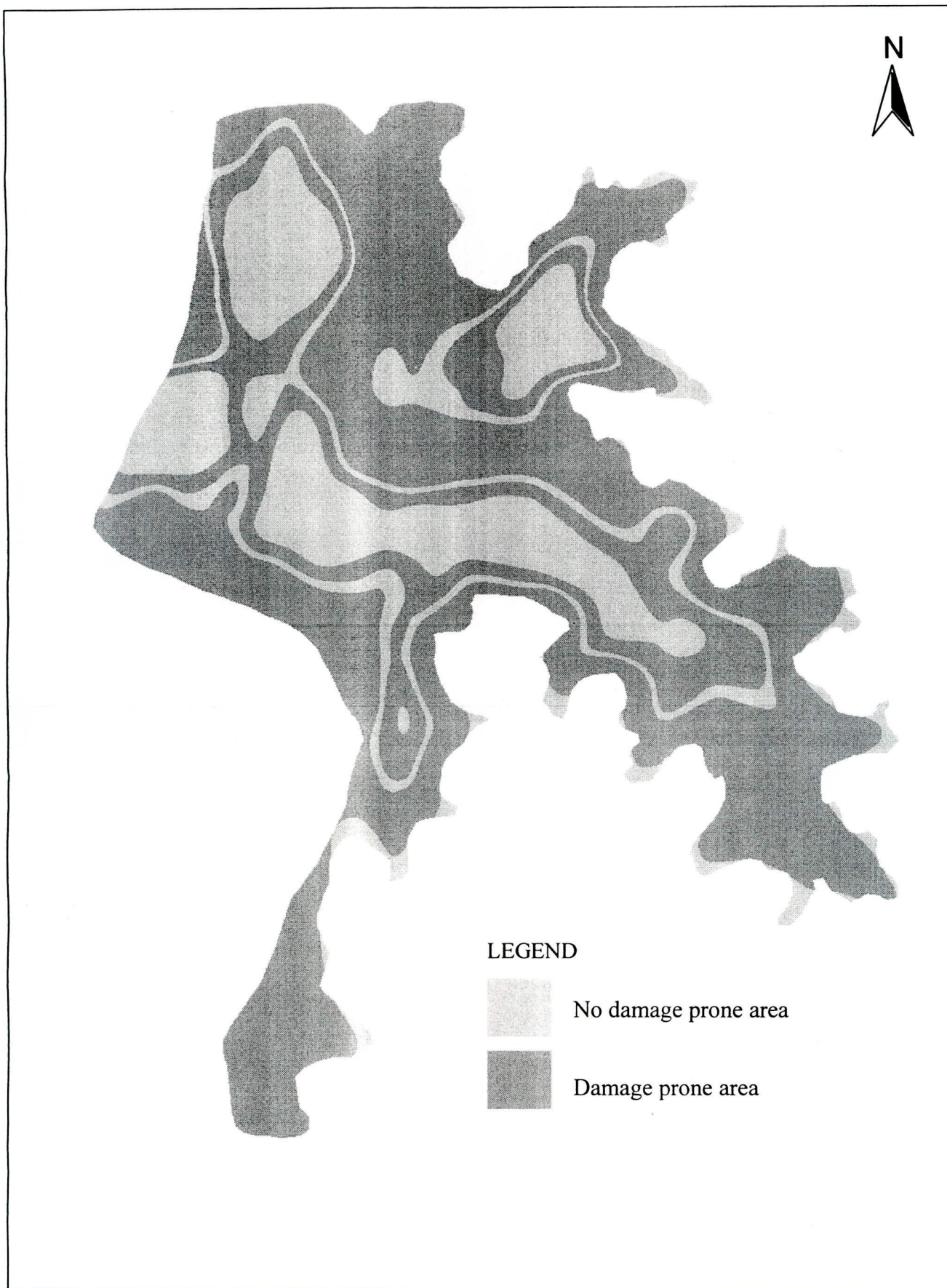


Figure 6-15 : Flood damage zone of the Singri Beel project

Figure 6-16 : Classified fish zone of the Dardaria Khal project

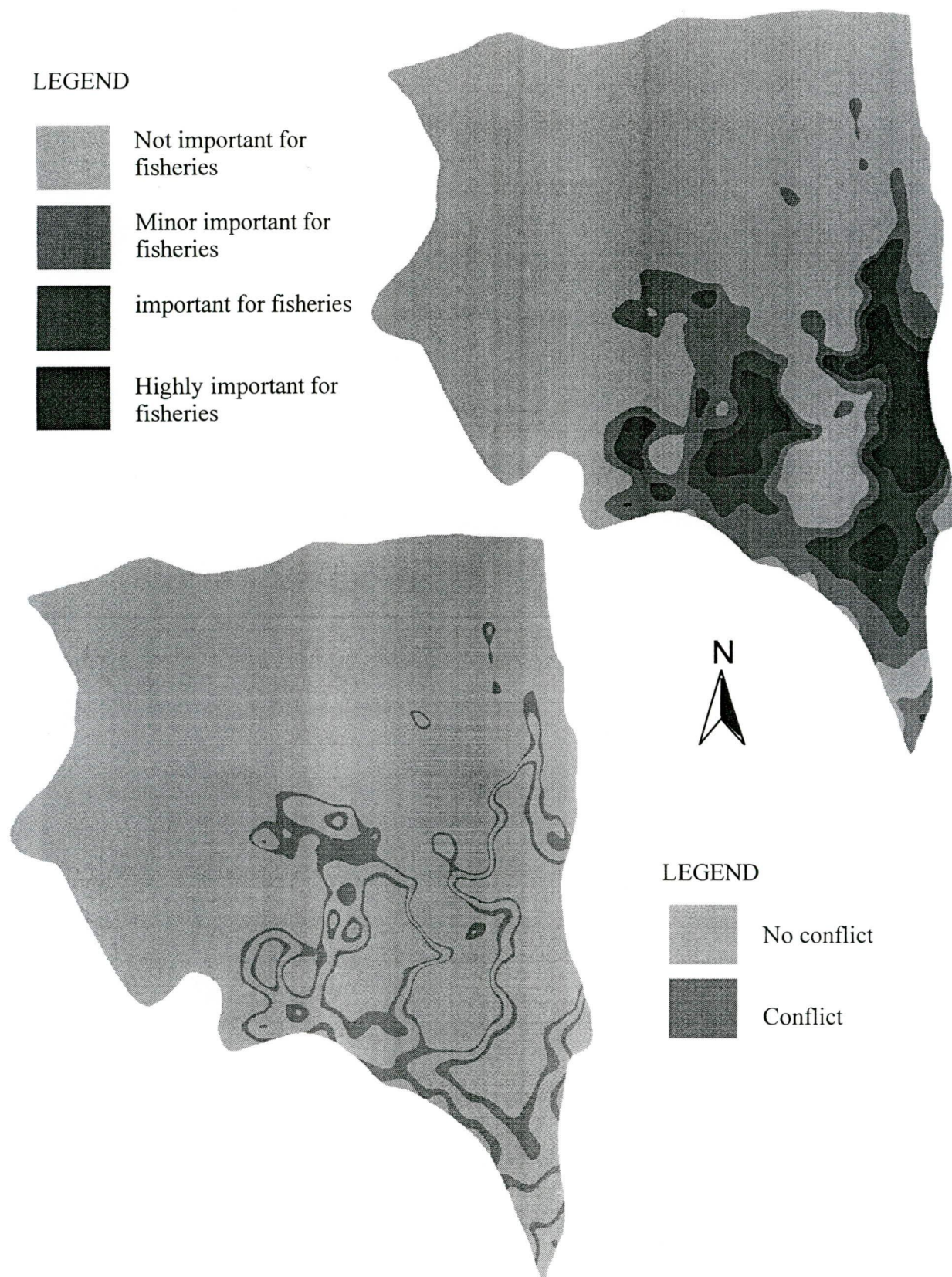


Figure 6-17 : Conflict between agriculture and fisheries of the Dardaria Khal project

Figure 6-18 : Classified fish zone of the Singri Beel project

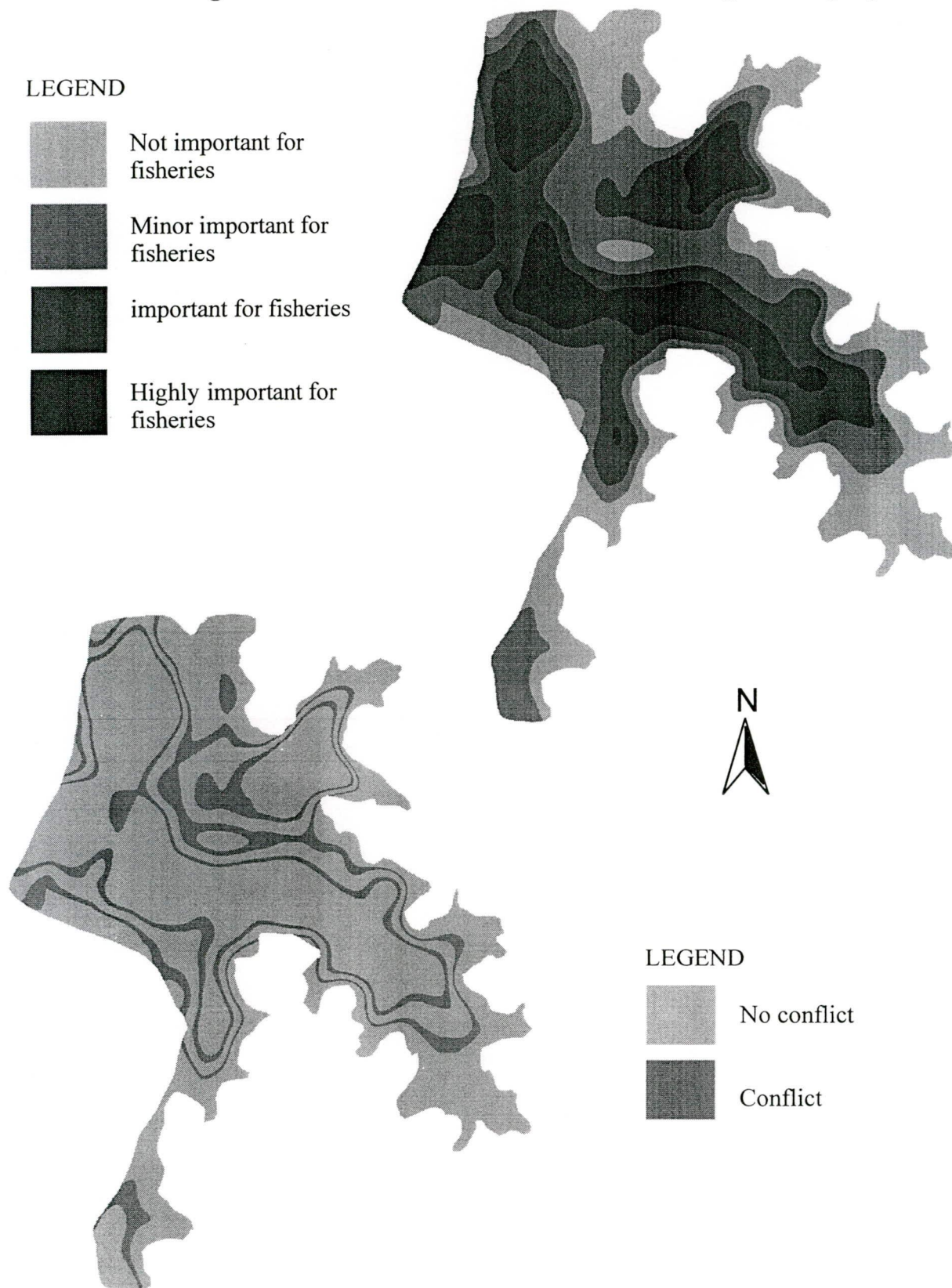


Figure 6-19 : Conflict between agriculture and fisheries of the Singri Beel project

Table 2-1 : Summary of Current EIA Methodology Evaluation

Criteria	Checklist	Overlay	Network	Matrix	Environmental index	Cost/benefit analysis	Simulation modelling workshop
1. Comprehensiveness	S	N	L	S	S	S	L
2. Communicability	L	L	S	L	S	L	L
3. Flexibility	L	S	L	L	S	S	L
4. Objectivity	N	S	S	L	L	L	S
5. Aggregation	N	S	N	N	S	S	N
6. Replicability	S	L	S	S	S	S	S
7. Multi-function	N	S	S	S	S	S	L
8. Uncertainty	N	N	N	N	N	N	S
9. Space-dimension	N	L	N	N	S	N	S
10. Time-dimension	S	N	N	N	S	S	L
11. Data requirement	L	N	S	S	S	N	N
12. Summary format	L	S	S	L	S	L	L
13. Alternative comparison	S	L	L	L	L	L	L
14. Time requirement	L	N	S	S	S	S	N
15. Manpower requirement	L	S	S	S	S	S	N
16. Economy	L	L	L	L	L	L	N

Legend: L = Completely fulfilled, or low resource need

S = Partially fulfilled, or moderate resource need

N = Negligible fulfilled, or high resource need

Source: Environmental Impact Assessment: Guidelines for Planners and Decision Makers,
UN Publication, ST/ESCAP/351, ESCAP, 1985

Table 3-2: Matrix for the impacts of the Quae Yai Dam based on Techniques by Leopold, Lohani and Thanh

Priority Values	Proposed action	Immigration of labour	Dam construction	Transmission line	Reservoir filling	Heavy metal discharge	Growth of aquatic weed	Relocation of inhabitants	Total	
									Leopold Method	Lohani Thann
10	Health	5 8	4 6		5 8	4 7	6 6		24 35	1680
9	Fishery		2 5			2 5			4 10	180
8	Soawning of fish		3 4		3 6	3 7	5 5		14 22	608
7	Archeological artifacts	4 6			8 8				12 14	516
6	Tourism			7 6	7 6				14 12	504
5	D/S water pollution		7 7		7 8	2 4			16 19	565
4	Social and economic aspects							8 7	8 7	224
3	Forestry		4 2						4 2	24
2	Aquatic Plants				6 6				6 6	72
1	Navigation				6 5				6 5	30
Total	Leopold method	9 14	20 24	7 6	42 47	11 25	11 11	8 7		
	Lahani & Thann	64	130	42	286	67	61	56		

Source: Impact of Rural Development and Their Assessment in Southeastern Conservatal
Vol. 7 No. 3 winter, Lohani, B.N. and Thanh, N.C., 1980 (ESCAP 1990)

Table 3.1: Financial and Economic Results (1991 prices)

Project	Net Benefited Area (NBA), (ha)	Capital Cost/ha. (NBA) (Financial) (Tk)	O&M Cost Cost/ha (NBA) (Financial) (Tk)	O&M Cost/ha (% of capital cost/ha.)	Annual Ag. Benefits per ha. (BNA) (Eco. Tk.)	Ag + Fish Benefits per ha. (NBA) (Eco. Tk.)	Estimated Economic IRR (%)	Implementa tion Period (years)
Kahua-Muhuri	2024	11512	235	2.0	12352	12143	96	1
Halir Haor	6686	3671	191	5.2	2372	237	65	1
Sonakukhu-Banmander	7400	6284	314	5.0	10514	10514	65	3
Konapara Embankment	3116	2634	132	5.0	12095	10934	62	3
Protabpur IP	4000	3419	224	6.6	5686	5686	54	4
Zilkar Haor (PIE)	4238	17810	333	1.9	3964	3964	42	3
Katakhali Khal	2520	7548	0	0.0	3925	2722	30	3
KBK (PIE)	18623	12041	624	5.2	4360	3340	28	7
Kurigram South (PIE)	50000	13672	776	5.7	5610	5530	22	10
Sakunia Beel	4400	4787	28	0.6	1023	584	10	4
Silimpur- Karatia	1012	10829	0	0.0	956	956	10	1
MDIP (PIE)	26426	183930	2164	1.2	20860	12520	7	12
BRE Kamarjanj	2157	6619	340	5.1	1547	625	3	10
BRE Kazipur	8788	5461	280	5.1	1500	424	0	10
Polder 17/2 (all)	2792	15136	440	2.9	6229	-2224	Negative	13
Nagor River	9312	7962	n.a	n.a	-1074	-1074	Negative	2
Chalan Beel (PIE)	37235	9196	129	1.4	2036	-1029	9	8

Source : RRA Reports and PIE analysis, Summary and Recommendations, Draft Final Report, FAP-12, 1991

Table 3.2 : Summary of Structures and Operation Status of Projects

Project	Structu res	Comm itees	Function ing	Actually Operated by?	Drainage Problems	Farmers v Fishermen	Conflict v high v v Low	Private Surface Water Management Initiatives
Polder-D, Chalan Beel	Yes	Some	No	BWDB	Yes ⁺⁺	Yes ⁺	Yes ⁺	Irrigation inlets
Kurigram South	Yes	No	Na	BWDB	Yes ⁺⁺⁺	Yes ⁺	Yes ⁺⁺	No
Meghna-Dhonagoda	Yes	Yes	Some	BWDB	No	Yes ⁺⁺	No	Yes LLPs from gravity canals
Zilkar Haor	Yes	Some	One	BWDB	Yes ⁺	Yes ⁺	No	No
Kolabashukhali	Yes	Yes	No	BWDB	Yes ⁺⁺	Yes ⁺	Yes ⁺	1 khal privately opened and closed for irrigation
Protabpur	No	Yes	No longer	No one khalashis missing	No	No	No	LLPs as gravity irrigation not possible from rives
Nagor River	Yes	Some	No	No one only 1 khalashi	Yes ⁺⁺	Yes ⁺⁺⁺	No	No
Sonamukhi-Bonmander	Yes	Yes	No	Anyone influential	Yes ⁺⁺⁺	Yes ⁺⁺	No	Private embankment build, also impact for projects in india
Sakunia Beel	Yes	Yes	Slightly	Committee	Yes ⁺⁺	No	No	LLPs over embankments
Silimpur-Karatia	Yes	No	Na	Not operated	No	No	Yes ⁺	No
Katakhali Khal Project	Yes	Yes	Partly	Influential people	Yes ⁺⁺	Yes ⁺	Yes ⁺⁺	Cuts and inlets for irrigations
Halir Hour	Yes	Yes	Yes but	Influential people	Some	Some	No	Regular cuts and repairs for drainage needed
Konapara Embankment	No ¹	Na	Na	Na	Some	No	Inside v outside	¹ Effectively many private drainage outlets
Kahua Muhuri	Yes ²	Yes	Yes	BWDB	Yes ⁺	No	No	² latera additions irrigation cuts
Polder 17/2	Yes	Yes	Yes ³	BWDB	No	Yes ⁺⁺⁺	Yes ⁺	³ Shrimp farmers have installed many private structures
BRE Kamarjani Reach	Yes	No	Na	BWDB	Yes ⁺⁺	No	Yes ⁺	No
BRE Kazipur Reach	No ⁴	Na	Na	Na	No	No	No	⁴ washed away, retired embankment breaches annually, open drainage

Notes:- Where drainage problems and conflicts occur these have been ranked: + moderate, ++important, +++severe

Table 3-3: Use and condition of embankment, and overall assessment of constraints or problems for O&M

Project	Embankment used for			% in poor Condition	Breaches	Erosion	Cuts by		Key Problem		O&M
	Road	Trees	Houses				Insiders	Outsiders	Plan Design	Construction	
Chalan Beel Polder D	Yes	Yes	No	50	Yes	No	Yes	Yes	**	0	**
Kurigram South	Yes	Yes	Yes	50	Frequent	Yes	Yes	No	**	***	**
Meghna-Dhonagoda IP	Yes	No	Few	20	Yes	Yes	No	No	***	***	**
Zilkar Haor	Yes	No	No	70	No	No	No	No	0	0	**
Kolabashukhali	Yes	Yes	No	50	No	Yes	No	No	*	0	*
Protappur IP	Yes	Yes	Yes	Most	No	Yes	No	No	*	0	**
Nagor River	Yes	Yes	No	85	Yes	Yes	Few	Yes	***	*	***
Sonamukhi-Bonmander	Na – drainage project with short private embankment						No	Yes	***	0	**
Sakunia Beel	Yes	Yes	No	70	Yes	Yes	No	No	0	**	**
Silimpur-Karatia	Yes	Yes	No	15	Yes	Yes	No	No	***	0	0
Katakhali Khal	Yes	No	No	50	Yes	No	Yes	No	*	0	***
Halir Haor	Yes ¹	No	No	33	Yes	No	Yes	No	0	0	**
Kahua Muhuri Emb	Yes	Yes	No	40	Yes	Yes	Yes	No	0	0	**
Konapara Embankment	Yes	Yes	No	60	Yes	Yes	No	Yes	**	0	***
Polder 17/2	Yes	No	No	5	No	No	Yes ²	No	***	***	0
BRE – Kamarjani Reach	Yes	Yes	Yes	70	Yes	Much	Yes	No	** ³	** ³	**
BRE – Kazipur Reach	Yes	Yes	Yes	50	Yes	Much	No	No	0	** ³	***

Notes: * = moderate problem, ** = important problem, *** = severe problem

1 seasonal route for moving harvested paddy before flood

2 installation of water control structures by shrimp farmers

3 applies to retired embankment but not to original one

Table 3.4: Summary List of Environmental Impacts, CPP Area.

Important Environmental Impacts (IEC)	Present Amounts	Impact of CPP	Type of Impact	Impact Rating
Land Type				
F0	576 ha	+1896 ha	SM/HM	+2.5
F1	1821 ha	+1085 ha	SM/HM	+2.5
F2	4248 ha	-787 ha	SM/LM	+1.0
F3	2552 ha	-2194 ha	SM/HM	+2.5
Drainage Congested Area	1549 ha	Decrease	SM/LM	+1.5
Ground Water	Adequate	Decrease in day years	RM/LM	-0.5
Annual Crop Production				
Total area irrigated	5398 ha	+376 ha	SM/HM	+1.5
Total potn. paddy production	37,551 ha	+3276 tonnes	SM/LM	+0.5
Total paddy production	34,376 tonnes	+8077 tonnes	SM/HM	+3.0
Tot Prod. Lost to crop damage	-3,175 tonnes	+4801 tonnes	SM/HM	+3.0
Total rabi production	7,751 toones	+1579 tonnes	SM/HM	+1.5
Total jute production	2,947 toones	+1920 tonnes	SM/HM	+1.5
Crop diversity	1:2.1	Decrease	RM/LM	-1.5
Cropping intensity	196%	+18%	SM/LM	+0.5
Total farm labor	3,011,000 person/d	+292,000 person/days	SM/HM	+1.5
Homesteads				
Housing	1751 ha	+175 ha	SM/LM	+0.5
Garden crop	875 ha	+87 ha	SM/LM	+0.5
Tree crops	875 ha	+87 ha	SM/LM	+0.5
Homestead vegetation damage	-20%	+20%	SM/HM	+3.0
Biomass Energy Shortage	-52%	+50%	SM/HM	+3.0
Capture Fisheries				
Annual production	380 toones	-32 tonnes	IR/LM	-3.5
Prof. Fisherman household prod	720 kg/year	Decrease	IR/LM	-3.5
Subs. Fisherman household prod	8 kg/year	Decrease	IR/LM	-3.5
Fish diversity	56 species	-23 species	IR/HM	-5.0
Culture Fisheries				
Annual production	49 toones	+16 tonnes	SM/HM	+1.5
Total employment	NQ	Large increase	SM/LM	+1.5
Aquatic Habitat				
Pre-monsoon	322 ha	+1875	SM/HM	+1.5
Monsoon	7138 ha	-1130	RM/HM	-1.5
Post-monsoon with drainage cong	8145 ha	-1521	RM/HM	-1.5
Do without drainage congestion	697 ha	+118	SM/LM	+1.0

Table 3.4: Summary List of Environmental Impacts, CPP Area(Continued).

Important Environmental Impacts (IEC)	Present Amounts	Impact of CPP	Type of Impact	Impact Rating
Terrestrial Habitat				
Pre-monsoon	12,678 ha	-1875	RM/HM	-1.5
Monsoon	5,862 ha	+1130	SM/HM	+1.5
Post-monsoon with drainage cong	4,855 ha	+1521	SM/HM	+1.5
Do without drainage congestion	12,303 ha	-118	RM/LM	-0.5
Wildlife				
Presently endangered	7 species	2 will become extinct	IR/HM	-5.0
Presently threatened	10 species	4 will decline	RM/HM	-3.0
Presently common	29 species	13 will decline	RM/HM	-3.0
Pesticide contamination	Prevalent	Increase	RM/HM	-3.0
Road communication	262 km	Improved	S/LM	+0.5
Navigation				
Passengers	245,000 annuals trip	Likely decrease	RM/HM	-2.5
Goods	900 tonnes annually	Small decrease	RM/LM	-0.5
Socio-economic				
Subsistence fishing	2.6-3.5 kg/hh/year	Decrease	IR/LM	-3.5
Crop production, annual wage				
Peak season	135.5 million taka	+44 million taka	SM/HM	+3.0
Lean season	90.3 million taka	+29 million taka	SM/HM	+3.0
Construction employment	Nil	+9533 person/years	NS/HM	+2.0
O&M employment	Nil	+580 jobs	SM/LM	+1.5
Quality of life				
Gender issues	NQ	Improved	SM/LM	+1.0
General health	NQ	Improved	SM/HM	+3.0
Nutrition- crop based	NQ	Improved	SM/HM	+1.5
Nutrition- fish based	NQ	Decrease	IR/HM	-3.5
Vector base disease incidence	NQ	Increase	RM/HM	-1.5
Tangail town				
Drinking water	High iron, manganese	Deteriorates	RM/LM	-0.5
Ground water depletion	0.25 m/yr	Decrease	IR/LM	-1.5
Flooding hazard	High risk	Decrease	SM/HM	+3.0
Drainage problems	Prevalent	Decrease	SM/LM	+1.0
Rural flooding hazards	Prevalent	Decrease	SM/LM	+2.5

*1 SM = sustainable with mitigation, S = sustainable, RM = reversible with mitigation, IR = irreversible;
HM = high magnitude, LM = Low magnitude

*2 Highest beneficial impact = +5.0, maximum negative impact = -5.0

Table 3-5: Residual Impacts Expected after CPP Implementation and Application of Practical Mitigation Measures

Important Environmental Component (IEC)	Present Amounts	Assessed Impact	Impact Magnitude	Reversibility
Fish and aquatic habitats				
Aquatic habitat: monsoon	7138 ha	-1130 ha	High	Reversible
Aquatic habitat: post-monsoon	8145 ha	-1521 ha	High	Reversible
Fish diversity	56 species	-23 species	High	Reversible
Capture fishery production	380 tons/year	-32 tons/year	Low	Irreversible
Professional fishing production	720 kg/hh/year	Decrease	Low	Irreversible
Subsistence fishing	8 kg/hh/year	Decrease	Low	Irreversible
Agriculture				
Crop diversity ratio	1:2.1	Decrease	Low	Reversible
Terrestrial habitats				
Terrestrial habitat: pre-monsoon	12678 ha	-1875 ha	High	Reversible
Terrestrial habitat: post-monsoon	12303 ha	-118 ha	Low	Reversible
Ecosystems				
Pesticide contamination	Prevalent	Increase	High	Reversible
Navigation				
Boat use of waterways	245000 pass/year	Likely decrease	High	Reversible
Cargo use of waterways	900 tons/year	Small decrease	Low	Reversible
Public health concern				
Household subsistence fishing	2.6 – 3.5	Decrease	Low	Irreversible
Nutritional use of fish	NQ	Further decrease	High	Irreversible
Vector-borne disease incidence	NQ	Increase	High	Reversible
Tangail town drinking water	High Fe & Mn	Deteriorates	Low	Reversible
Tangail town groundwater depletion	0.25 m/yr	Decrease	Low	Irreversible

Table 3-6: Main Recommendation for the Environmental Management Plan

Important Issues (ICs)	Environmental Management Plan
Community Participation	Ongoing liaison with all communities and resource user groups in the CPP area
Project O&M	Cuts and britches to the embankments to be inventoried and a detailed maintenance plan established
	Preparation of a flood preparedness plan for the area
Hydrology	Ongoing testing and development of surface water models for use in water management and impact assessment
	Low cost drainage improvement methods to be developed and applied
Ground Water	Systematic study on groundwater recharge under project conditions
Fisheries	Study and design of an effective fish pass on the Lohajang river
	Maintain high water levels after 15 July each year to maintain beel recharging
	Develop and refine the beel concept of fisheries management
	Promote integrated rich-fish culture
Navigation	Develop boat locks on Lohajang river and other important waterways
Infrastructure	Improve road network to facilitate transportation of goods to markets
	Establish a tree plantation program for roads and embankments
Health and Welfare	Educational and clinical programs to safeguard against malaria
	Monitor the incidence of kala ajar
	Establish health education programs on water borne diseases
	Minimize the effects of jute retting on water quality
	Replace lost capture fish protein sources
Institutions	Comparative assessment of impacts on socioeconomic groups
	Development of a strategy for beneficiary participation
	Define the roles and coordination requirements of NGOs in proj. implementation
	Develop training programs for project beneficiaries
	Facilitation of credit delivery systems to landless groups and women
	Enhance agriculture extension services in the area
	Enhance development of small industries in the area
	Preparation of a detailed compensation plan

Table 3-7: Cost and Benefit of Some Selected Crops in the CIP in 1990 (per hectare)

Crops	Human labour	Animal power	Fertilizer	Seed/seedlings	Pesticide	Irrigation	Total cost	Production M.T./ha	Total return	Total profit
Aus(HYV)	7100.00 (42.78)	1976.00 (11.91)	2137.00 (12.87)	1185.60 (7.14)	1976.00 (11.91)	2223.00 (13.39)	16597.50	2.84	18263.47	1665.97
Boro(HYV)	9015.50 (41.43)	2223.00 (10.27)	3902.60 (17.94)	1185.60 (5.44)	3211.00 (14.76)	2223.00 (10.22)	21760.70	4.96	31896.76	10136.06
T.Aman(HYV)	7100.00 (40.09)	1976.00 (11.16)	2815.80 (15.91)	1185.60 (6.69)	2408.25 (13.59)	2223.00 (12.56)	17708.65	4.15	26687.82	8979.17
Wheat	3396.25 (30.18)	1979.00 (17.56)	3458.00 (30.74)	1185.60 (10.54)	1235.00 (10.98)	-	11250.60	2.25	14469.30	3218.70
Pulses	2161.25 (19.38)	1482.00 (13.28)	1580.80 (14.18)	741.00 (6.65)	1235.00 (11.07)	3952.00 (35.44)	11152.05	0.988	19760.00	8607.95

Per Metric ton paddy = Tk. 6430.80 at governments purchase rate

Loss of sharecroppers/hecare

Aus (HYV) = Tk. 7956.76
 Boro (HYV) = Tk. 5812.32
 T.Aman(HYV) = Tk. 4364.74
 Wheat = Tk. 4015.95
 Pulses = Tk. 1272.05

Table 3-8: Utilization of Major Agricultural Inputs/ha for Some selected crops in the CIP for 1982

Crops	Hman labour (Mandays)	Animal power Total (paiddays)	Chemical fertilizer (kg)			Pesticide (kg)*
			N	P	K	
Aus (HYV)	289.00	20.79	172.90	121.25	30.31	3.705
Boro (HYV)	274.17	23.34	205.45	113.39	22.45	4.94
T.Aman (HYV)	183.00	15.38	86.45	34.80	4.49	3.705
Pulses	59.28	2.61	-	-	-	-

Source: BUP 1982

* Evaluated from Field Survey

Table 6-1: Land type for with and without SRP rehabilitation of selected dates during 1996 for Dardaria khal project.

C l s	Land Type (cm)	Pre SRP Rehabilitation						Post SRP Rehabilitation					
		15 th July		30 th July		15 th August		15 th July		30 th July		15 th August	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1	FF(0)	6378	79.34	5283	65.71	6610	82.22	7535	93.72	7335	91.24	7130	88.70
2	F0(0-30)	343	4.27	314	3.91	343	4.27	185	2.31	200	2.48	205	2.55
3	F1(31-90)	551	6.85	781	9.72	443	5.51	274	3.41	366	4.56	385	4.79
4	F2(91-180)	564	7.01	894	11.13	539	6.70	45	0.56	138	1.72	309	3.84
5	F3(181+)	203	2.52	767	9.53	104	1.30	0	0.00	0	0.00	10	0.13
Total		8039	100	8039	100	8039	100	8039	100	8039	100	8039	100

Table 6-2: Change in the land type for with and without SRP rehabilitation of selected dates during 1996 for Dardaria khal project.

Cls	Land Type Change From – To	15 th July 1996		30 th July 1996		15 th August	
		Area	%	Area	%	Area	%
1	FF => FF	6379	79.34	5283	65.71	6610	82.22
2	F0 => F0	0	0.00	0	0.00	0	0
3	F1 => F1	0	0.00	0	0.00	60	0.76
4	F2 => F2	0	0.00	0	0.00	215	2.67
5	F3 => F3	0	0.00	0	0.00	10	0.13
6	F0 => FF	342	4.27	314	3.91	343	4.27
7	F1 => F0	0	0	0	0	205	2.55
8	F2 => F1	117	1.45	0	0	324	4.03
9	F3 => F2	45	0.56	138	1.72	94	1.17
10	F1 => FF	551	6.85	782	9.72	178	2.21
11	F2 => F0	185	2.31	0	0	0	0.00
12	F3 => F1	158	1.96	366	4.56	0	0.00
13	F2 => FF	262	3.26	894	11.13	0	0.00
14	F3 => F0	0	0.00	200	2.48	0	0.00
15	F3 => FF	0	0.00	62	0.78	0	0.00
Total		8039	100	8039	100	8039	100

Table 6-3: Land type for different recurrence interval of flood of the Singri beel project.

Cl s	Land Type	2yr flood		5yr flood		10yr flood		20yr flood	
		Area	%	Area	%	Area	%	Area	%
1	FF(0)	983	29.51	455	13.68	282	8.47	110	3.30
2	F0(0-30)	316	9.48	153	4.59	124	3.73	90	2.72
3	F1(31-90)	569	17.10	476	14.28	332	9.96	225	7.66
4	F2(91-180)	839	25.19	878	26.37	862	25.88	629	18.87
5	F3(181+)	623	18.72	1368	41.08	1730	51.97	2246	67.45
Total		3330	100	3330	100	3330	100	3330	100

Table 6-4: Change in the land type w.r.to the average year condition in the Singri beel project.

Cls	Land Type Change From – To	5yr return period		10yr return period		20yr return period	
		Area	%	Area	%	Area	%
1	FF => FF	456	13.38	282	8.47	110	3.30
2	F0 => F0	0	0.00	0	0.00	0	0.00
3	F1 => F1	0	0.00	0	0.00	0	0.00
4	F2 => F2	95	2.84	0	0.00	0	0.00
5	F3 => F3	624	18.72	623	18.72	624	18.72
6	F0 => FF	153	4.59	124	3.73	90	2.72
7	F1 => F0	101	3.04	0	0.00	0	0.00
8	F2 => F1	569	17.10	301	9.04	0	0.00
9	F3 => F2	744	22.35	839	25.19	839	25.19
10	F1 => FF	374	11.24	332	9.96	255	7.66
11	F2 => F0	214	6.44	316	9.48	101	3.04
12	F3 => F1	0	0.00	268	8.06	570	17.10
13	F2 => FF	0	0.00	245	7.36	527	15.83
14	F3 => F0	0	0.00	0	0.00	214	6.44
15	F3 => FF	0	0.00	0	0.00	0	0.00
Total		3330	100	3330	100	3330	100

Table 6-5:Area under drainage congestion for pre and post SRP rehabilitation of the Dardaria khal project.

Class	Land Type	Pre SRP		Post SRP	
		Area	%	Area	%
1	FF(0cm)	7660	95.28	6953	86.49
2	F0(0-30cm)	177	2.20	253	3.15
3	F1(31-90cm)	184	2.29	396	4.93
4	F2(91-180cm)	18	0.23	410	5.10
5	F3(181cm +)	0	0.00	0.00	0.00
Total		8039	100	8039	100

Table 6-6:Deteriorated drainage condition in terms of the land type change of the Dardaria khal project.

Class	Land Type Change From – To	5 th November 1996	
		Area	Percentage
1	FF => FF	6953	86.49
2	F0 => F0	0	0.00
3	F1 => F1	0	0.00
4	F2 => F2	0	0.00
5	F3 => F3	0	0.00
6	FF => F0	253	3.15
7	F0 => F1	0	0.00
8	F1 => F2	175	2.18
9	F2 => F3	18	0.23
10	FF => F1	396	4.93
11	F0 => F2	177	2.20
12	F1 => F3	92	0.11
13	FF => F2	58	0.72
14	F0 => F3	0	0.00
15	FF => F3	0	0.00
Total		8039	100

Table 6-7:Area and percentage of important agriculture zone of the Dardaria khal project

Class	Area	Percentage	Description
1	6244	77.66	Very high agriculture zone
2	962	11.97	High agriculture zone
3	396	4.93	Low agriculture zone
4	437	5.44	Negligible agriculture
Total	8039	100	

Table 6-8:Area and percentage of flood hazard zone of the Dardaria khal project

Class	Area	Percentage	Description
1	5283	65.71	No flood hazard
2	453	5.63	Less flood hazard
3	1147	14.27	High flood hazard
4	1156	14.38	Very high flood hazard
Total	8039	100	

Table 6-9:Area and percentage of flood damage zone of the Dardaria khal project

Class	Area	Percentage	Description
1	5787	71.99	No conflict
2	2251	28.01	Conflict
Total	8039	100	

Table 6-10: Area and percentage important agriculture zone of the Singri beel project

Class	Area	Percentage	Description
1	1298	38.99	Very high agriculture zone
2	855	25.69	High agriculture zone
3	553	16.60	Low agriculture zone
4	624	18.72	Negligible agriculture
Total	3330	100	

Table 6-11:Area and percentage of flood hazard zone of the Singri beel project

Class	Area	Percentage	Description
1	733	22.02	No flood hazard
2	929	27.91	Less flood hazard
3	926	27.80	High flood hazard
4	742	22.27	Very high flood hazard
Total	3330	100	

Table 6-12:Area and percentage of flood damage zone of the Singri beel project

Class	Area	Percentage	Description
1	1019	30.61	No conflict
2	2311	69.39	Conflict
Total	3330	100	

Table 6-13:Area and percentage of important fish zone of the Dardaria khal project

Class	Area	Percentage	Description
1	5821	72.41	Not important for fish
2	1132	14.08	Less important for fish
3	649	8.08	Important for fish
4	437	5.44	Highly important for fish
Total	8039	100	

Table 6-14: Conflict between agriculture and fisheries of the Dardaria khal project

Class	Area	Percentage	Description
1	7364	91.60	No conflict
2	675	8.40	Conflict
Total	8039	100	

Table 6-15: Area and percentage of important fish zone of the Singri beel project

Class	Area	Percentage	Description
1	1352	40.60	Not important for fish
2	516	15.49	Less important for fish
3	839	25.19	Important for fish
4	623	18.72	Highly important for fish
Total	3330	100	

Table 6-16: Conflict between agriculture and fisheries of the Singri beel project

Class	Area	Percentage	Description
1	2728	81.94	No conflict
2	602	18.06	Conflict
Total	3330	100	

APPENDIX A

FLOOD IN BANGLADESH

Bangladesh, which is mostly a vast flat topography, lies at the confluence of the three mighty rivers of the world, the Ganges, the Brahmanputra, and the Meghna, has shaped the country as one of the most watery regions in the world. The numerous tributaries and distributaries interlace the land inside Bangladesh, draining the total runoff generated within the basin (about 1.6 million Km²) to the Bay of Bengal, of which 7.5 percent lies inside Bangladesh.

The term flood is defined as a level of flow which causes damages to crops and property. Usually a flood is associated with drainage congestion arising from the intense surface flow, heavy overland runoffs caused by higher rainfall in the catchment areas, discharge in excess of channel capacity and every high tidal level. The streams and rivers of Bangladesh drain an average of 870 million maf. – of water per year to the Bay of Bengal (Elahi, 1988). Moreover, the country gets another 203 million maf. – rain water per year. The annual mean rainfall of the country is 1800 mm of which nearly 80% falls during the period from June-September (4 months). Similarly about 80% of the surface flow through Bangladesh is concentrated in these four months. Out of Bangladesh's total land of 1,42,777 Km², 82088Km² (57%) area of the country is considered to be flood vulnerable of which the three major river basin cover 46% (BWDB, 1987). However, the major flood affected areas in the country occupy between 25,000-40,000 Km² land (Table A-1).

Table A-1: Flood Vulnerable Area of Bangladesh (Basin-wise, For 1954-74)

Sl. Basin	Total Area in Bangladesh (Km ²)	Flood Vulnerable Area (Km ²)	% Vulnerable Area by Basin	% Vulnerable area by Total
1. The Brahmaputra	41,049	25,540	62	18
2. The Ganges	53,730	23,165	43	16
3. The Meghna	22,220	17,690	80	12
4. Coastal region	-	8,127	-	6
5. Flash flood area	25,778	6,566	25	5
Total	1,42,777	82,088		57

Source: Working paper, Flood Control Programme, BWDB, Dhaka, 1987

All the above topographic and climatic factors have made Bangladesh to face floods as the usual phenomenon. The earliest recorded flood history in the Bengal is that of the Meghna Basin and this flood was stated by Abul Fazal in his famous Ain-e-Akbari (Choudhury 1988). This flooding occurred in 1584-85 and the area which suffered most was the 'Bogla Sorker' the area corresponded to the southern portion of the present districts of Barisal-Patuakhali of Bangladesh. This deluge had perished about 200,000 lives. It is evident that it was one of the coastal types of floods (Rob 1996). The next recorded flood is the Gomti-flood of 1660 (Majumder 1970) and North Bengal and Assam flood of 1662 (Majumdar, 1978) causes huge damages in the region. During the time of the East Indian Company's rule in Bengal another serious flood took place there

in 1769-70 (Choudhury, 1988). This flood along with the previous year's drought and resultant crop failure for consecutive two years brought the famous killer famine of the Bengal known as 'Chhiattarer Mannanantar', which caused the death of one-third of the total population of Bengal.

In 1784, the Meghna Basin had experienced the occurrence of another disastrous flood (Choudhury, 1988). This inundation was due to excess of precipitation in the catchment area and it affected the district of Sylhet and Tripura (Comilla) seriously. After only a few years, another serious flooding take place in 1787 which devastated almost all parts of the eastern and the northern portions of Bengal (Choudhury, 1988). During this unprecedented flood 'boats were the only means of transportation which could ply on all the streets of Dhaka and in the countryside. People lived on roof-tops for their survival. During this flood the river Teesta and the Atrai changed their courses to be connected with the Brahmaputra. The effects of the flood of 1787 was outstanding and this flood worked to change the courses of many rivers of Bengal.

There are records of numerous other high floods in the last century too. But the trend of the occurrences of inundation has turned into an alarming deterioration in the second half of the current century. Statistics and estimates over the last 50 years show that over a dozen of high floods and 5 severe floods occurred in Bangladesh during the last five decades. The years, 1954, 55, 56, 62, 63, 66, 68, 70, 71, 74, 76, 80, 84, 87 and 1988 experienced high flood while 1954, 70, 74, 87 and 88 experienced very serious high floods (Table A-2). Since the high flood of 1954, the total flood affected areas of the various high floods remain limited within 35,000-42,000 Km² upto 1971. From Table 2-2, it appears that five major floods took place in between 1954 to 1963. But, the last 5 years of the current decade (1984-89) experienced severe floods in three years and two consecutive years in 1987 and 1988. The 1974 flood was considered to be the most devastating one so far Bangladesh witnessed, but the last two floods of 87 and 88 broke all the previous records.

Table A-2: Total Flood Affected Area During Different Floods in Bangladesh

Year	Affected Area (Km ²)	Year	Affected Area (Km ²)
1954	36,780*	1970	42,480*
1955	38,850	1971	36,340
1956	35,840	1974	52,520*
1962	37,300	1984	28,210
1963	35,230	1987	57,270*
1968	37,300	1988	77,700*

* High Floods (Severe). Source: Engineer's Institution, Dhaka and University Research Centre, Dhaka, 1987, 1988.

Although the total flooded area in 1954 was only 36,780 Km², yet it stayed for longer duration and caused very severe damage to lives, livestock and property in the affected area. Moreover it was the high flood which took place in what is now Bangladesh in the 20th century. The flood of 1955 affected 38,850 Km² area of the country. But the depth of flood water was shallow and the inundation was for a short duration. The loss and

damage of this flood was also comparatively lesser.

The analysis of the flood levels of the high floods in Bangladesh during the recent decades reveals that the intensity of floods in the country is increasing alarmingly in the recent time (Table A-3).

Table A-3: Maximum Number of Major Rivers Simultaneously above Danger Levels During Different Floods

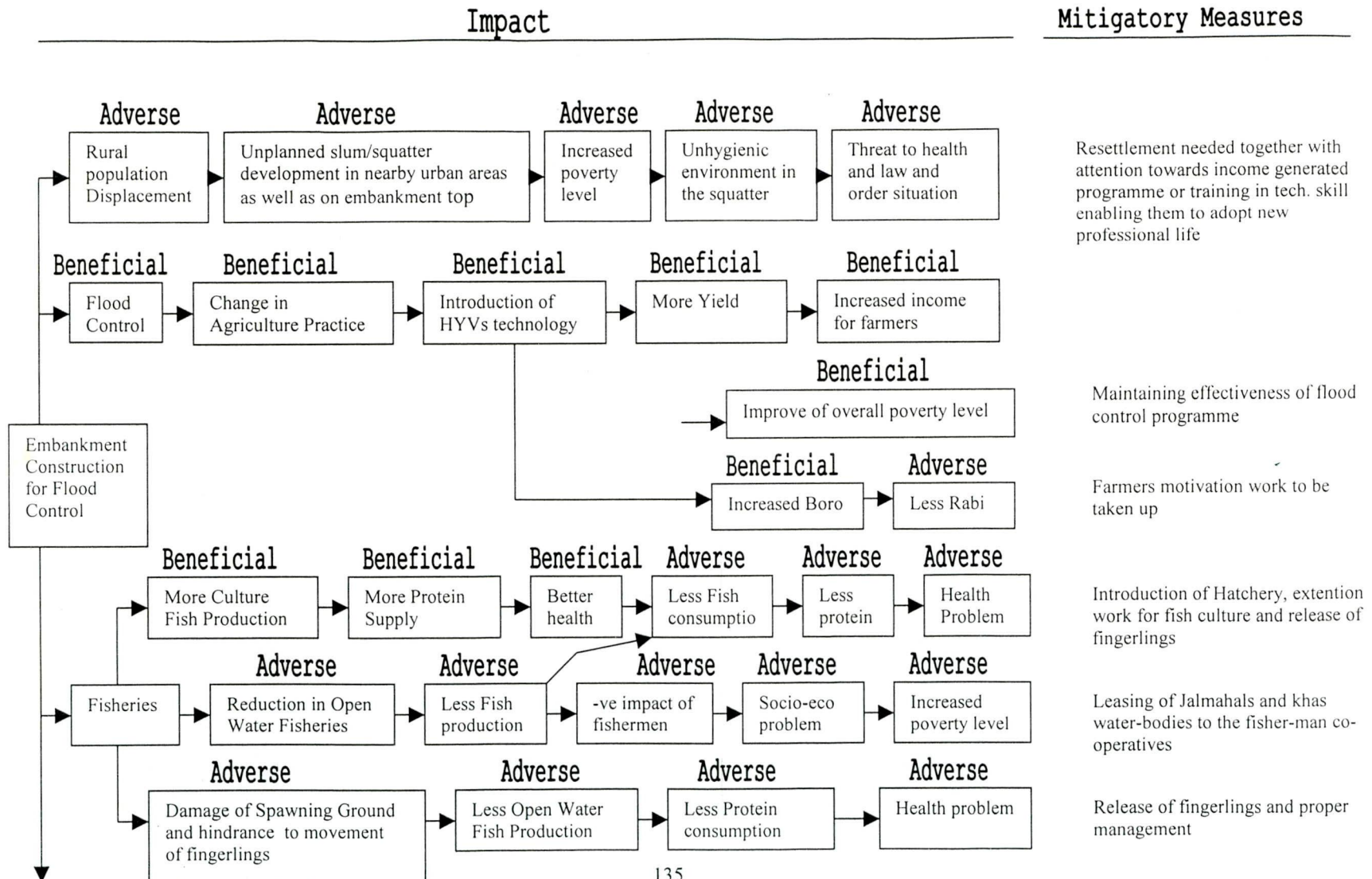
Year	Number of Rivers above Danger Levels
1954	11
1974	16
1984	16
1987	21
1988	30

Source: Engineering Institute, Dhaka and University Research Centre, Dhaka, 1987.

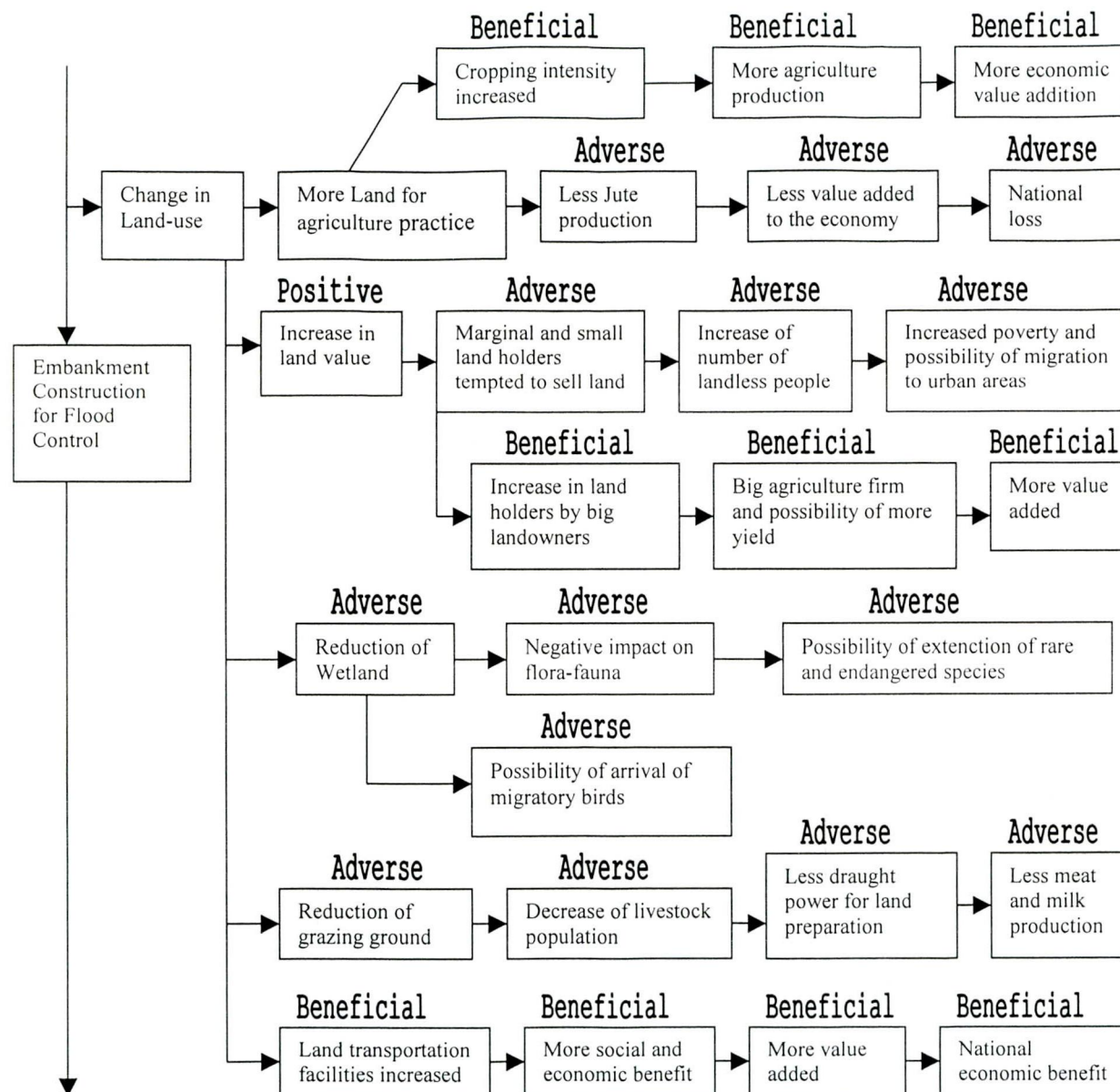
These floods caused immense loss and damage to lives, livestock and property in Bangladesh. As regards loss and damages the floods of 1954, 1974, 1987 and 1988 were the worst. In 1954, floods caused a total loss of Rs.1,500 million of that time (Elahi, 1988). The flood of 1974 takes 28,000 people lives and more then 30,000,000 people of the country were affected. The flood of 1987 affected 41,000,000 people, took 1000 lives (Elahi, 1988) and the loss of the flood in monitary value was estimated at Tk. 35,000 million. The deluge of 1988 engulfed 47 districts, took 1,200 human lives and affected 50,000,000 people of the country. In monitary evaluation the loss caused by this flood stands above Tk.50,000 million (Flood report, 1988).

Appendix -B

Impact Assessment of FCDI Projects General Network Analysis (Source: after Mirza)



Appendix -B (contd)



Mitigation Measures

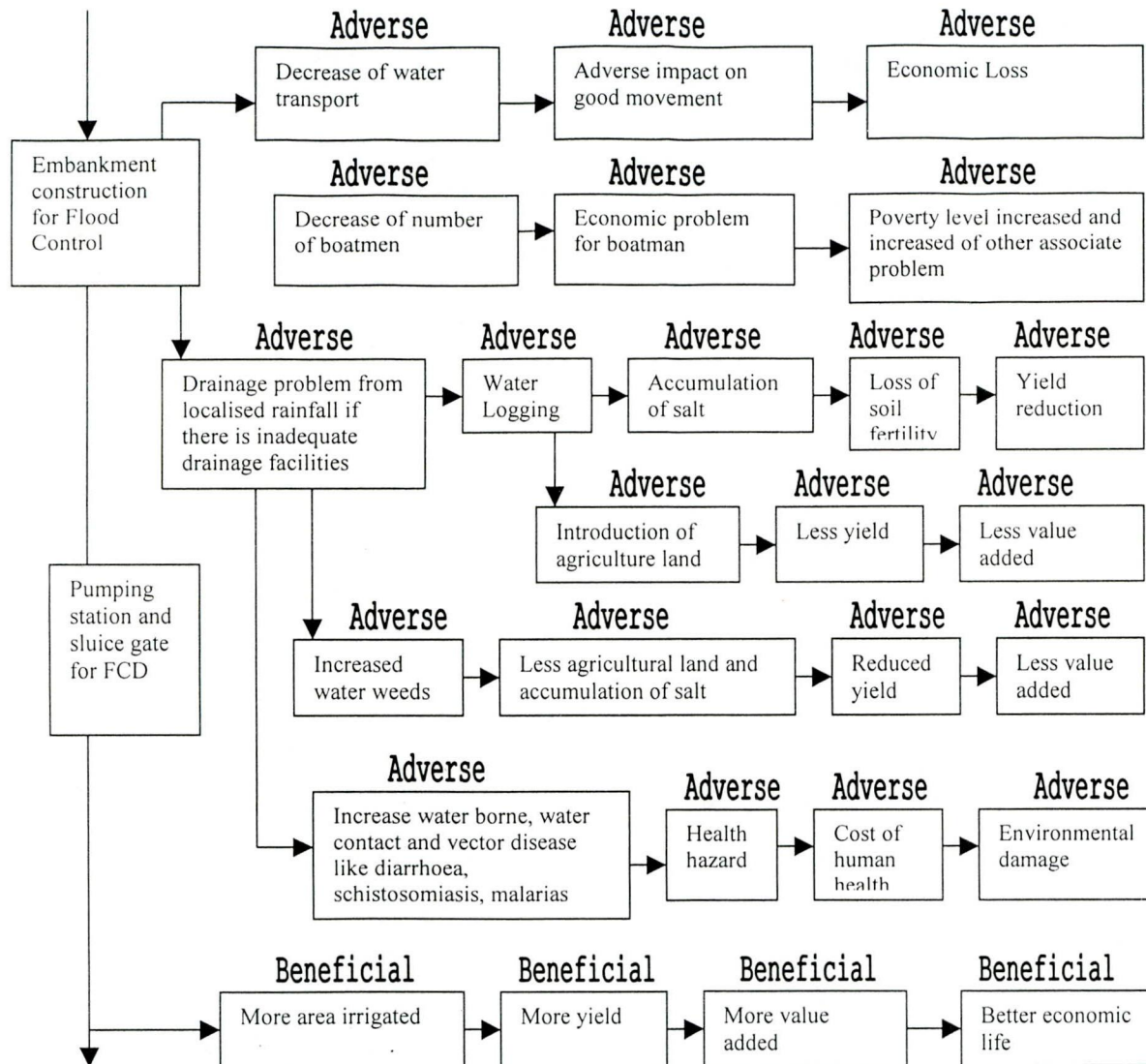
Need of farmers motivation

Legal measurement are necessary to be promulgated

Conservation of wetlands enactment of wildlife protection act, 1973, Reconnaissance of flora-fauna, identification of endangered species

Creation of grazing grounds and cultivation of commercial grass

Appendix –B(contd)



Mitigation Measures

Adequate number of navigation locks and maintenance of canals, cleaning of water hyacinth if there is any presence

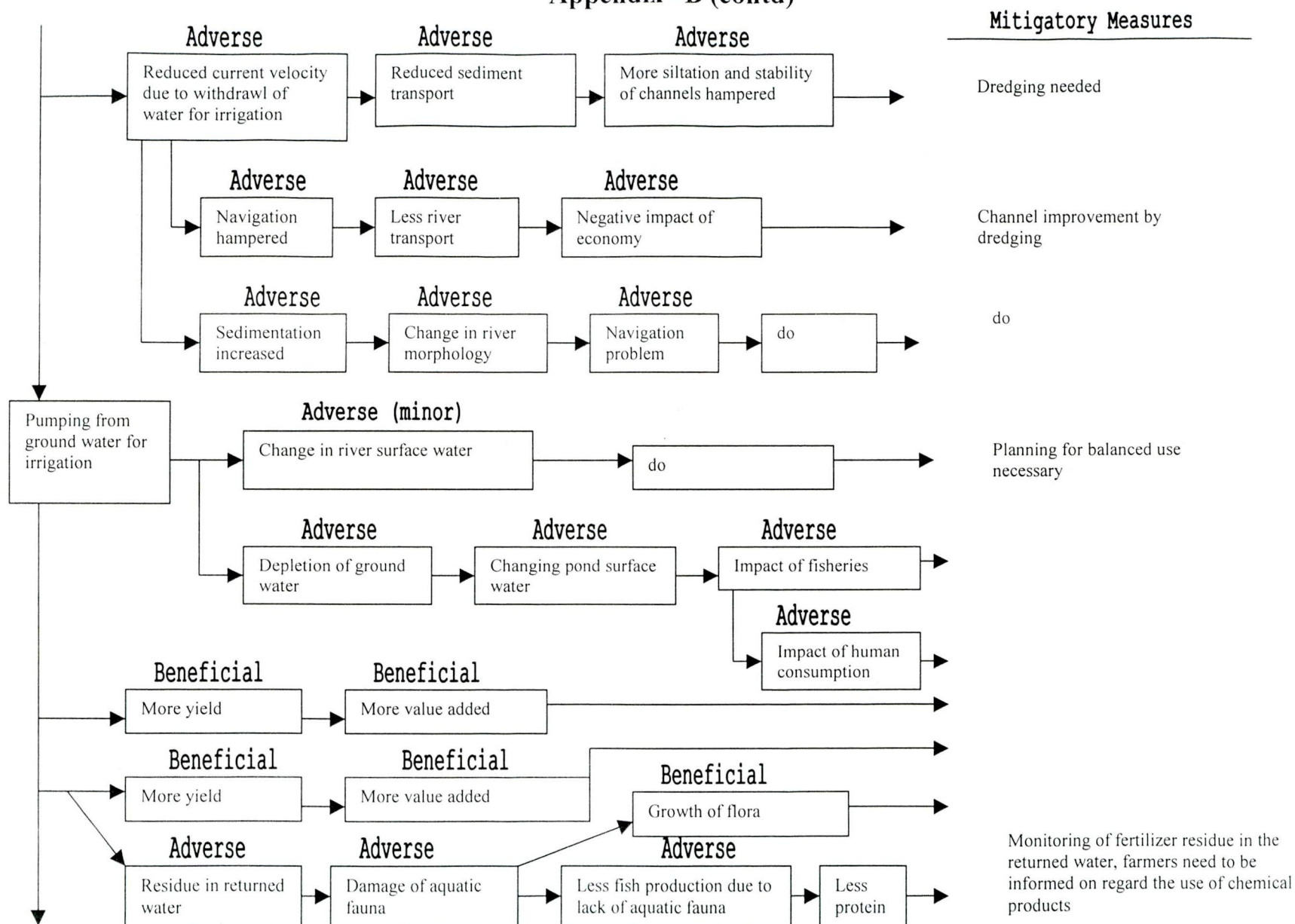
Introduction of adequate drainage facilities

Introduction of adequate drainage facility and control of waterweeds

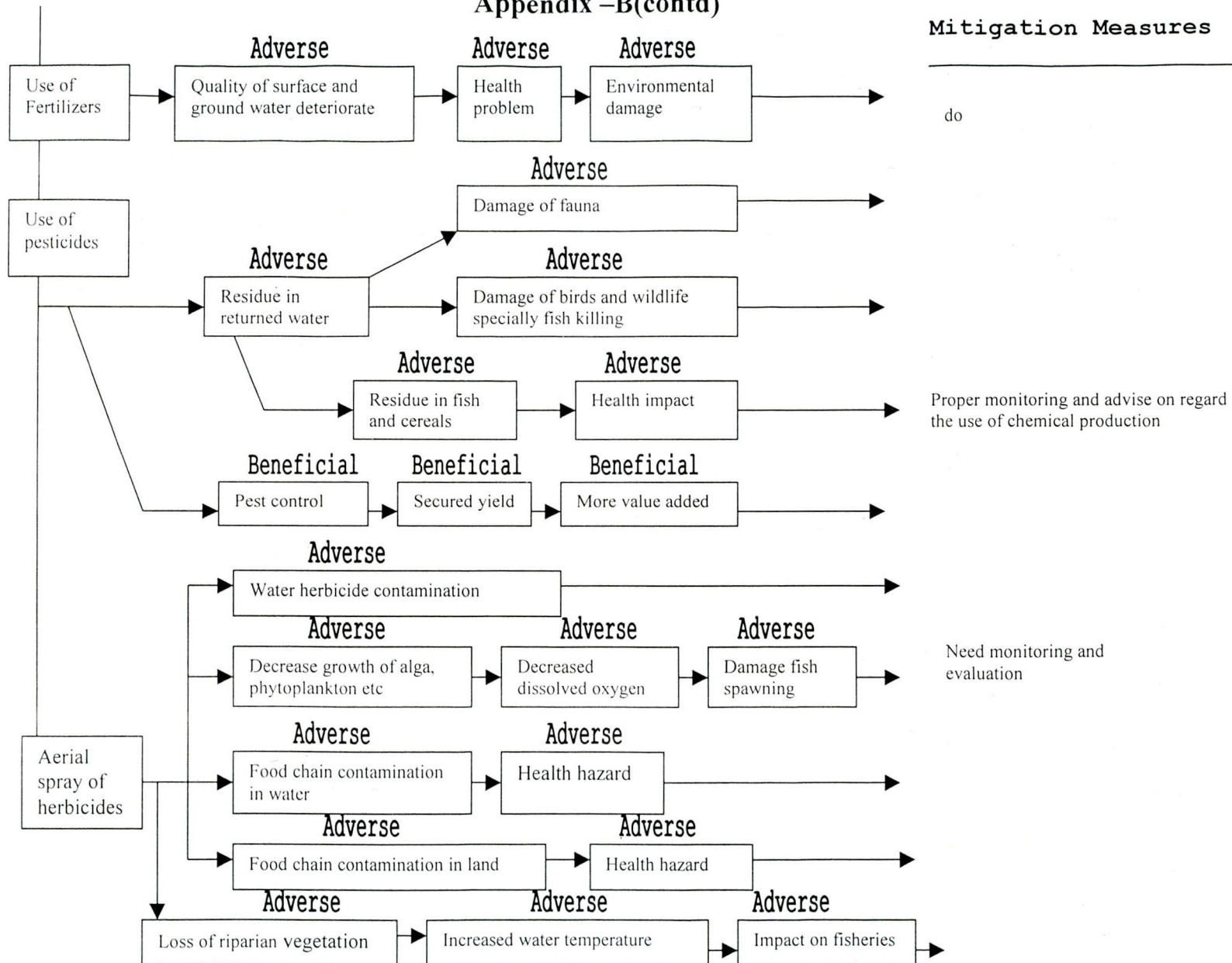
Close monitoring, health education care, introduction of adequate drainage facility

Maintenance of proper irrigation facilities

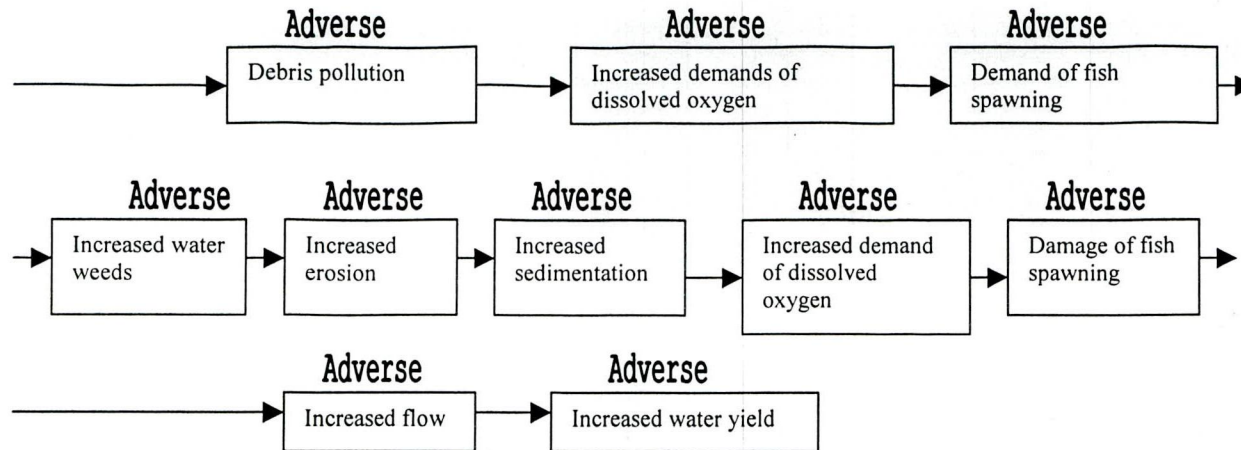
Appendix –B (contd)



Appendix –B(contd)



Appendix –B(contd)



Appendix - C

Weighted Matrix

In the weighted matrices, when preparing the impact matrix, one indicates the relative magnitudes by numbers eg, on a scale of 1 to 10, rather than by symbols or letters. Also one assigns a weight or relative importance to such impact, again by numbers on a numerical scale of 1 to 10 and mentions these two indicative measures in each of the relative boxes as M/I. Of course both the magnitude and importance of the likely impact are dependent entirely on the judgement of the measuring team. Simple calculations have been suggested to assess the total environmental impact of a particular project component or activity (and hence to help planning mitigation measures) or even the overall weighted relative impact of a total project (1992b).

Thus the total impact of the i^{th} component/activity:

$$P_i = \sum_{j=1}^{j=m} (I_{ij} \cdot M_{ij})$$

Where M_{ij} and I_{ij} are respectively the relative magnitude and relative importance (on scales of 1 to 10) for the likely impact of i^{th} component/activity on j^{th} environmental attribute and m is the total number of environmental attributes relevant.

Also the overall relative impact of the project:

$$I = \sum_{i=1}^{i=n} I_i$$

Where n is the total number of project components/activities

