FLUVIAL REGIME OF THE MANIPUR RIVER BASIN AND LOKTAK LAKE WITH STUDY OF BACKFLOW

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

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CANDIDATE's DECLARATION

I hereby certify that the work which is being presented in the Dissertation entitled **"FLUVIAL REGIME OF THE MANIPUR RIVER BASIN AND LOKTAK LAKE WITH STUDY OF BACKFLOW "** is in partial fulfilment of the requirement for the award of the degree of Master of Technology and submitted to the Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology Roorkee, Roorkee. The is an authentic record of my own work carried out during the period from July 2005 to June 2006 under the supervision and guidance of *Prof. Dr. Nayan Sharma*, IIT Roorkee, Roorkee (India).

The matter presented in this dissertation has not been submitted by me for the award of any other degree nor to any other institute.

Date : June 27, 2006

Place : Roorkee

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This is to certify that that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEDGEMENTS

The candidate is extremely indebted to his professor Dr. Nayan Sharma, Professor, of the Department for his valued guidance , supervision and encouragement during the course of the research .The candidate is also grateful to the other Professors of the Department and the staff in the Computer lab, Library, and Office for their extending support in the timely completion of this dissertation work.

The candidate owes his gratitude to the LDA (Loktak Development Authority), Manipur as well as the Earth Sciences Department, Manipur University ,for the unladen ground data and values of the study area.

Sincere thanks are extended to Mr R.N. Sankhua, Dy Director , CWC for the inspiration and experiences shared .

The candidate appreciates the support and encouragement lend by his mother and family in the pursuance of the research course. The candidate acknowledges the contribution of his classmates in working with a collective spirit in making the study worthful and in the advancement of scholarship.

Dated : June 27, 2006

Ngangbam Romeji Singh

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SYNOPSIS

The effect of fluvial changes in an intricate river basin is taken up for study. Though observed from decades ago, no system based studies as regards to the sediment-water behaviour has been done in the Manipur River Basin till date. With the availability of coherent data in the last few years, base time scale is adopted as March 2000 to April 2002 for the formulation of parameters in the numerical HEC-6 model .An extensive regression approach to multi-variate neuro-computations are used to check the adequacy as well as the sensitivity of the data variables (viz.,Stage, Discharge,Sediment Discharge,Flow Velocity ,etc).

Appropriate response parameters to the fluvial system as Stage-Discharge, Sediment Discharge Rating, Frequencies of Flow and Sediment ,etc, are then developed on the best tested dataset and fit. Spatial data is used to obtain the morphological values of the rivers and Loktak lake.A method to implement the discharge at which it carries the maximum sediment load – 'Effective Discharge' in each of the rivers under consideration (Imphal / Manipur, Nambul, Nambol, Khordak and Ungamel rivers) in the Basin is designed based on the frequency scales and flow values. An effort to establish the non-equilibrium sediment dynamics between the Inflow and Outflow in the major natural reservoir - Loktak Lake,is presented by blending the boundary conditions on the lines of backflow (inflow) and Outflow ,or bi-directional flows taking place between the main storage – Loktak lake and the main artery channel – Imphal or Manipur river. Some of the sediment properties are prepared on measured records and conventional methods. The effective discharge values and response factors are used as the determining parameter in the model.

A study of peculiar case of backflow (inflow) - Outflow directions over relatively short time periods due to rapidly varying flood events and barrage operations in the two interlink channels between the Lake and the main river is also taken as part and partial of the study. The hydraulic transients in the two

Khordak and Ungamel channels, between the lake body and the Imphal / Manipur River is also modelled with an integrated neurocomputing based multi-variate approach and HEC-6 methodology to coherent the transient behaviour. A built-in procedure is adopted for obtaining separate 'Inflow' and 'Outflow' Stage-Discharges for each of the two channels within the same yearly periods, on the basis of daily measured data and with reference to the cross-section of consideration.

The mean discharges of tributaries are also accorded in the major river G-Q relations during the HEC-6 formulations. The genre output is then linked to a common database for respective sediment load transport comparisons and validation at selected gauging sites such as in the periphery of the Lake and at the main outflow point of the Basin (Ithai). The other geomorphological attributes and the impact of a natural control section in the form af a "submerged rock impediment" (average height of 7 m and extending to about 2.5 kms) along the bed of the main Imphal / Manipur river , 26.6 kms downstream of the barrage is highlighted in a longitudinal representation ,before it traverses into the Chindwin - Irrawady Basin. A spatial interpretation of the Basin refecting the sub-dendritic to sub-parallel drainage network are done along with spatial data abstraction using GIS methodology.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 FLUVIAL HYDRAULICS AND SEDIMENT TRANSPORT

The study of flow of water and associated behavior has been undergoing concerted development. Flow in open channels, as in rivers and channels are intricate by the fact that the position of the free surface is likely to change with respect to time and space and also by the fact that the depth of flow, the discharge and the slopes of the channel bottom and of the free surface are interdependent. To add to the intensity of parameters, a more profound problem defines the flow behavior and attributes i.e., the fact that rivers and other watercourses, in most cases, run through loose material and the water carries/transport some of this material along with it. Generally the loose non-cohesive material through which a river flows is generally termed as "sediment". An accepted definition by the American Geophysical Union-" Fragmented material transported by suspended in, or deposited by water or air or accumulated in the beds by other natural agents; any dentrital accumulation such as loess". Sediment is also referred to as "alluvium". And this branch of engineering science which deals transportable material (sediment or alluvium) and the transportation along with the flow are what is called as "Fluvial Hydraulics or Sediment Engineering". This continuum rises or channels, both natural and man-made, are better the type of the watercourse. The classification/delineation being done on the variation of the surface and flow cross-sections from regular well-defined prismatic sections to that of irregular riverbeds

Efforts have been made (and are still undergoing modifications) movement of the material in running water. Since the pioneering presentation of a rational method by a French engineer, Paul Du Boys in 1879 on the transport of sediment in rivers, numerous research and studies have been conducted till date leading to development of various numerical based computational tools as well as models.

Ranging from large river basins to small basins, the problems associated with sediments are nevertheless the same, in water resources related projects. Some of the major basins in the globe: the Nile basin (Egypt), Yellow river (China), Rio Grande (Mexicio), Mississipi basin (USA), Amazon (South America),Rhine (Germany) and the Gangetic basin in our own country, has engaged the attention of training and harnessing to minimize the adverse effects of sediment flow.

An integrated study in Fluvial Hydraulics and Sediments Transport involves the analysis of the capacity of the river or channel to carry water and sediment, and the corresponding morphological changes in both the main channel and floodplain. Sediment transport in concise, replicates the various aspects of the dynamics of solid particle movement, properties of the transported materials, and characteristics of the transporting medium, which in turn, may be affected by the solids transported.

The origin of sediments and the detachment from landforms, more broadly involves the sciences as geomorphology, geology, geography, chemistry, etc. Yet it is less the involvement of the basic sciences than the enormous number of "boundary conditions" that make "Fluvial hydraulics & sediment transport" as a science so intractable. It also defines the complex processes affecting the geomorphological evolution and changes in the globe. The material transported may range from sizable rocks to colloidal particles. The transporting medium is generally confined to water. Sediment transport processes are sub-divided into three broad categories for preliminary conceptual understanding:

(1) Overland transport
(2) Transport by streams and
(3) Coastal processes (not to forget those surfaces/bodies that occupy two-thirds of the world's surface

Besides, there are five principal aspects to the alluvial river sediment transport: initiation of motion, bed and channel stability (formation of ripples, dunes, meanders etc), channel roughness, bed-load transport, and sediment suspension.

1.2 MANIPUR : A RIVERINE STATE

Manipur is one of the mountainous states in the North-east frontiers of India. The state abounds in middling rivers and streams,. and is replete with a number of wetlands/lakes amongst which Loktak lake is on of the largest freshwater lakes in the country. The state extends over a geographical area of 22,327 sq.km with a total population of 2.38 million (2001 census) and Imphal as the capital. A location map of the state is given if Fig 1.1

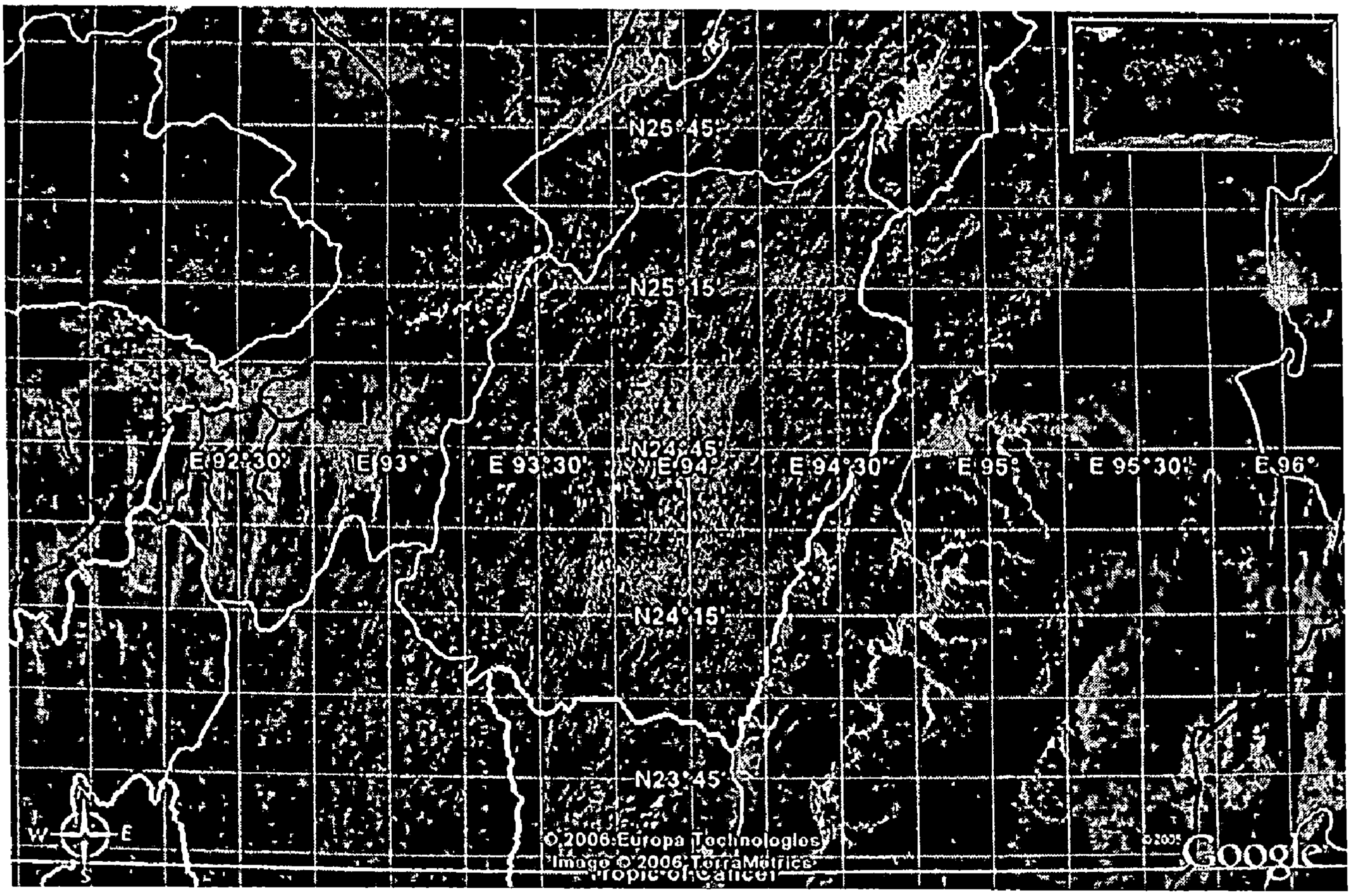


FIG 1.1 Overview location of Manipur (Source-Google 2006)

It has a central oval-shaped valley (covering about 10% of the total area) surrounded by mountains on all its sides. The general elevation (altitude) ascends at 790m (above MSL) at the valley to as high as 3000m in the mountain tracts, which is the birthplace or origin of many of the rivers/streams that traverses through the valley. The valley is about 75 km long along the N-S direction and 35 km wide along the E-W direction and interspersed with residual looking hills. The topography is almost a flat gentle slope from North to South or Southeast, which is then too, the flow direction of most of the major rivers. The state is bounded by Nagaland in the North, Assam in the west, Mizoram in the South and shares an international border with other states to Myanmar in the east. An isometric view map (Google Earth 2006) as in Fig. 4.2 gives a clear picture of the region.

Natural resources forms the base of economy of the state which has a population distribution with 59% of the total living in the valley and the remaining 41% sparsely distributed in the hills. Forest resources accounts for 787% of the total state area and agriculture is the mainstay of the people. The farming pattern can be broadly categorized into shifting cultivation (or jhum/ paamlou as locally termed) and settled agriculture. The former has been a cause of concern with severe impacts on the land-use and forest cover in the state. Besides, a large population living in and around the manifold wetlands and lakes sustains from the rich ecological and bio-diversity of the freshwater existence, mainly as a vital fisheries resource. The rugged topography of the mountainous regions and lack of infrastructure has made the valet (or better known as the Imphal valley) the hub of economic activities of the state.

1.3 MANIPUR: RIVER AND LAKE SYSTEM

A number of rivers and lakes/wetlands are located in the valley covering as nearly as 10% of the total area of the state. The rivers and streams (approximately 30% major and prominent ones) though not of sizable feature as compared to other significant rivers in the globe, contributed to a intricate hydro system prevailing in the valley. They rise and flow from the rivers of parallel mountain ranges running north to south on both the eastern sides of the valley. A majority of the lakes and wetlands are situated in the southern part where the valley slopes down gradually.

The rivers and lakes/wetlands are interconnected through a number of smaller link channels and drains. The inadequacy of the channel discharge capacities as well as embankment flood works, contributes to the merging of periphery and neighboring wetlands to one entity during high floods. A peculiar phenomenon of "two-way flow" in two of the interlink channels between Imphal river and Loktak lake prevails. A study and analysis on this regard is composed in the study taken up. In Manipur there are about 155 wetlands having wide variation of water spread during pre-monsoon and post-monsoon showing distinct hydro periods. Out of these, 21 are lakes, 2 are cutoff meanders, 2 are reservoirs and 130 are waterlogged. The natural and demographic pattern over the last one century showed spectacular change that numerous wetlands have lost. There are only thirteen major lakes (wetlands), which meet the necessary criteria to be regarded as wetland ecosystem based on satellite imagery data taken in 1998.

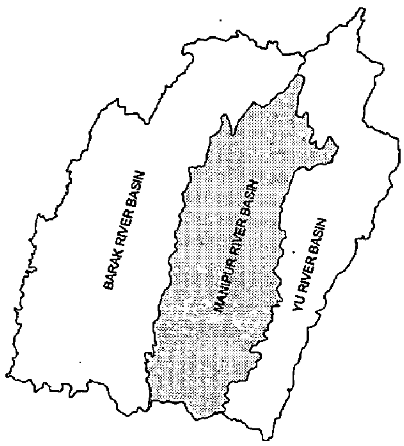
When the flood waters recede, it leaves behind pockets of water in the form of wetlands, swamps, marshes etc which bears a pera-hydrological behavior on the river lake system. The lakes are shallow with maximum depth of about 4 meters (that is measured in Loktak lake, the largest lake).

The Imphal river (which in its lower reaches is known as the Manipur River) serves as the main drainage channel of the valley.

The river and lake composition in the state, has been classified under two distinct river basins/catchments:

(i) The Manipur river basin (approximately 6872 sq.km) and

(ii) The Barak river basin (approx. 15,374 sq.km)



Another basin known as the Yu River Basin, located in the eastern mountain ranges , owes its role to basin of bordering Myanmar (Burma).

As the latter, though of significant area has the Barak river some distance towards the south and western mountain ranges of the state, is not taken up in the study as it does not come into the valley. It traverses westwards and joins major River in Assam.

An overview of the Manipur River basin (MRB) is presented in Fig 1.2

FIG 1.2 Overview of the Manipur River Basin ,MRB (source : Google Earth 2006)

CHAPTER 2

MANIPUR RIVER BASIN : THE STUDY PERSPECTIVE

2.1 DESCRIPTION

The Manipur River Basin has as irresolute fluvial or sediment system from the past. Located between 24^0 to $25^025'$ North (latitude) and $93^036'$ to $94^027'$ east (longitude), it covers an area of 6,872 sq.km (approximately 30.78% of the total area of the state) where it predominates the hydrodynamic behavior and morphology changes since its inception as a valley landform surrounded by young-folded mountains all around. The valley has a general elevation of 760.0 m above MSL with that in the mountains ranging from 2000 to 3000m above MSL. The origin of the basin landform has been studied as early a 1921 by Anandalle et al. Loktak lake which is the main storage entity of the basin, has been suggested to date from the middle of the last glacial period, about 25,000 years ago (Dr Vishnu Mitra, 'Reconstruction of the history of Loktak lake formation'). Whilst the rivers and streams traversing in the basin are the results of the drainage patterns and morphological associations. The valley slopes from north to a south-southeasterly direction which describes the flow path of the main drainage channel- The Imphal or Manipur river (as respectively called in its 'upper' and 'lower' reaches) along with a number of other streams.

The intricacy of the basin system is reflected in both physical (morphological) and hydrodynamic regime. The interspersed residual hills in the valley plain acting as an obstruction; of its channel capacity (as causing it to meander and sometimes causing alleviation in the bed profile). Smaller lakes and wetlands disturb the flow patterns of some of the rivers/streams while falling in the flow path. The peculiarity or uniqueness of the Manipur River Basin (MRB) is further defined by the following two characteristics:-

Unique Features :

The peculiarity or uniqueness of the MRB is further defined by the following two characteristics:-

(i) the hydraulic transients in the two-way (or bidirectional) nature of flows in two interlinking channels of the Loktak lake and Manipur river,

(ii) the presence of a 7 metres high natural control section in the form of a submerged rock impediment in the bed of the Manipur river at its lower reaches.

The other hydrodynamic irrationale prevailing in the basin is the occurrence of unusually high flows/run-offs in the dry weather mouths at irregular spans or periods. For instance in the period between 1957 to 1964, an average flow of 750 cusecs(about 21.25 cumecs) was recorded in the lean January months except for a extreme value of 415 cusecs(40.10 cumecs) was recorded in the Imphal/Manipur river. This value departs from the frequency trend of the highest recorded flood in 1966 in the basin so far and record of observations show it to recur at a irregular interval or spans.

As many as 12 major rivers and 16 minor streams assorted in the number of wetlands (pats) and a number of smaller order non-perennial streams are identified in the Basin. Records of hydrological data of the prominent ones (in lieu of vicinity and importance to Loktak lake) are available for study . The level of study is hitherto defined to major rivers taking into account the tributary discharge as the contributing factor with the Loktak basin in prime focus. The characteristic/sublime features of the Basin are described in the following sections:-

2.2 DRAINAGE AND FLOW STRUCTURE

The Manipur River is a dynamic fluvial river system that transports sediments, erodes existing soil and rock and creates new sediment deposits. The Manipur River Basin has as many as 12 main rivers and streams inter-dispersed with major and minor tributaries, that characterizes the hydrological/hydrodynamic patterns. The wetlands (locally known as "pats") derive their supply as well as drainage through link channels as well as the main rivers/streams. The flow direction of most of the rivers and streams follow the slope of the basin i.e. from a north to south/south-easterly orientation. Some of the streams falls mostly in the hill catchments and tend to be flashy with different flow directions other than what has been described.

Imphal/Manipur River:

The Imphal/Manipur River, which serves as the artery of the drainage network, originates from the hills in the north (near Karong) and thereafter traverses all along the valley. The noteworthy tributaries joining from the east are Iril, Thoubal, Sekmai and Chakpi rivers. The Khuga River joins from the west at Ithai, where a Barrage (subject of debate) has been constructed to maintain required water levels for the Loktak Multipurpose Project. It is where from then, the Imphal river is better known as the Manipur river. The Imphal or Manipur river flows and meanders for a total length of about 170 kms before it crosses the Indian Territory to join the Chindwin river (a tributary of the Irrawaddy river) in Myanmar. Though this river does not fall directly into Loktak Lake, it is interlinked through a few channels or minor streams- Khordak and Ungamel being the prominent and active ones. One striking and unique feature is that the flow through this two natural channels has rapidly varying "hydraulic transients" in its direction of flows. Depending on the relative water levels in the Lake and the Manipur River, flow "*averses and reverses*" its direction as from Lake to the Manipur river or, vice versa. The point in the river which seems to influence this phenomenal hydraulic characteristic is at Ithai in the Manipur River which is the main outflow point of Loktak Lake basin. At this point, the Ungamel link channel connects the Lake and the Manipur River besides contribution from the Khuga River in the increasing the flood discharge. Another remarkable feature is the natural impediment in the flow of the Manipur River at its lower (ending) reaches. A natural rock formation about 7 metres high (27 kms downstream of the Ithai) acts as a barrier to the flow which is carrying most of the outflows of the whole basin. It may be better described as a submerged control section imparting flow recession during low floods.

Other major rivers as the Nambul and Nambol rivers arises from the north-western hills confluenced by a number of minor streams and channels before falling into Loktak Lake. The numerous non-perennial streams with short reaches which carry

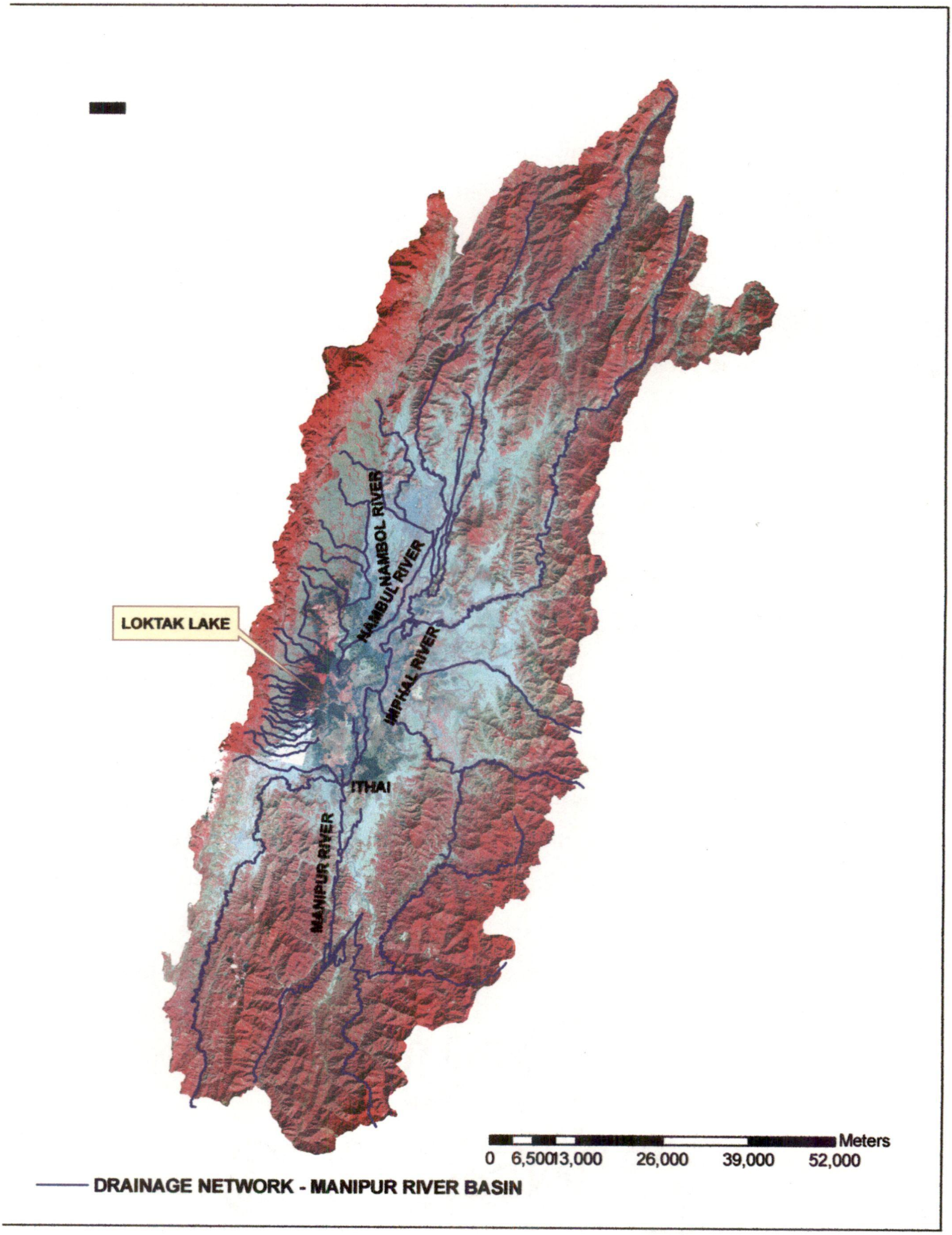


FIG 2.1 Drainage Structure and the Manipur River Basin (IRS 1C LISS-III data)

undulated flows from the severely degraded western-hills share a major contribution of sediment inflows to the Lake. To name a few, are the Thongjaorok, Awang Khujairok, Potsangbam, and Ningthoukhong streams. They mostly experience flows only in the wet season but estimated to transport bulk of the sediment/eroded into Loktak lake. Other streams and minor channels, not in the periphery of Loktak Lake, fall into the distinguished tributaries of the Imphal River, Nambul or Nambol River.

Figure 2.1 gives an extracted representation of the drainage structure along with some of the notable rivers/streams from IRS LISS-III satellite image data. The drainage is seen to be dendritic to sub-dendritic circumscribing a storage unit.

2.3 SUB-BASINS / CATCHMENTS

The Manipur River Basin estimated to have an annual average run-off of 5260 M cum, has been sub-divided into nine major sub-basins or catchments depending on the drainage features (Fig 2.2). The tabulated details as worked out from earlier records and present database are given as:-

Sl.No.	Sub-Basin	Area(sq.km)	Drainage	Avg. Annual Yield (Mcum)	Land Use & other Features
1.	Imphal sub-basin	474.8	Imphal, Nambul rivers(partly)	863.45	Forests-66% shifting cultivation-2%
2.	Upper Iril	758.09	Iril river(upper)	477.87	Forests-81.49% shifting cultivation-12.74% (Jhum)
3.	Lower Iril	633.28	Iril river(lower)	400.01	Forests-51.16% Jhum-12.75%
4.	Thoubal	911.61	Thoubal river	652.21	Forests-66.67% Cultivation (mixed)-20%
5.	Heirok	860.82	Sekmai, Heirok rivers	333.52	Jhum-17% Low forest cover,wetlands-Pumlen and Ikop Pats

6.	Khuga	504.76	Khuga river	293.98	Degraded Forests-70% Jhum-16%
7.	Loktak	1062.96	Nambul, Nambol, Imphal river (vis Khordak and Ungamel channels)	1173.49	Forest cover-21% Wetlands-Loktak Lake, Laphupat along with many others part /partial of Loktak pat
8.	Chakpi	660.00	Chakpi river	790.56	Do not drain directly into the lake, located in the lower reaches of Imphal/Manipur river
9.	Manipur river beyond Ithai	313.20	Manipur river, Tuining river	274.91	Located in the last Manipur river reaches upto the Myanmar border, mostly forested and mountainous

In the above classification, the sub-basin in the upper reaches of the Imphal River has been done on the basis of feature topography and slope. Other rivers as the Tuining River is not taken under a sub-basin on the basis of its nominal contribution to the Manipur River and location (as beyond the Ithai Barrage or Loktak main outflow point). An outline of the sub-basins boundary is given in Fig 2.2

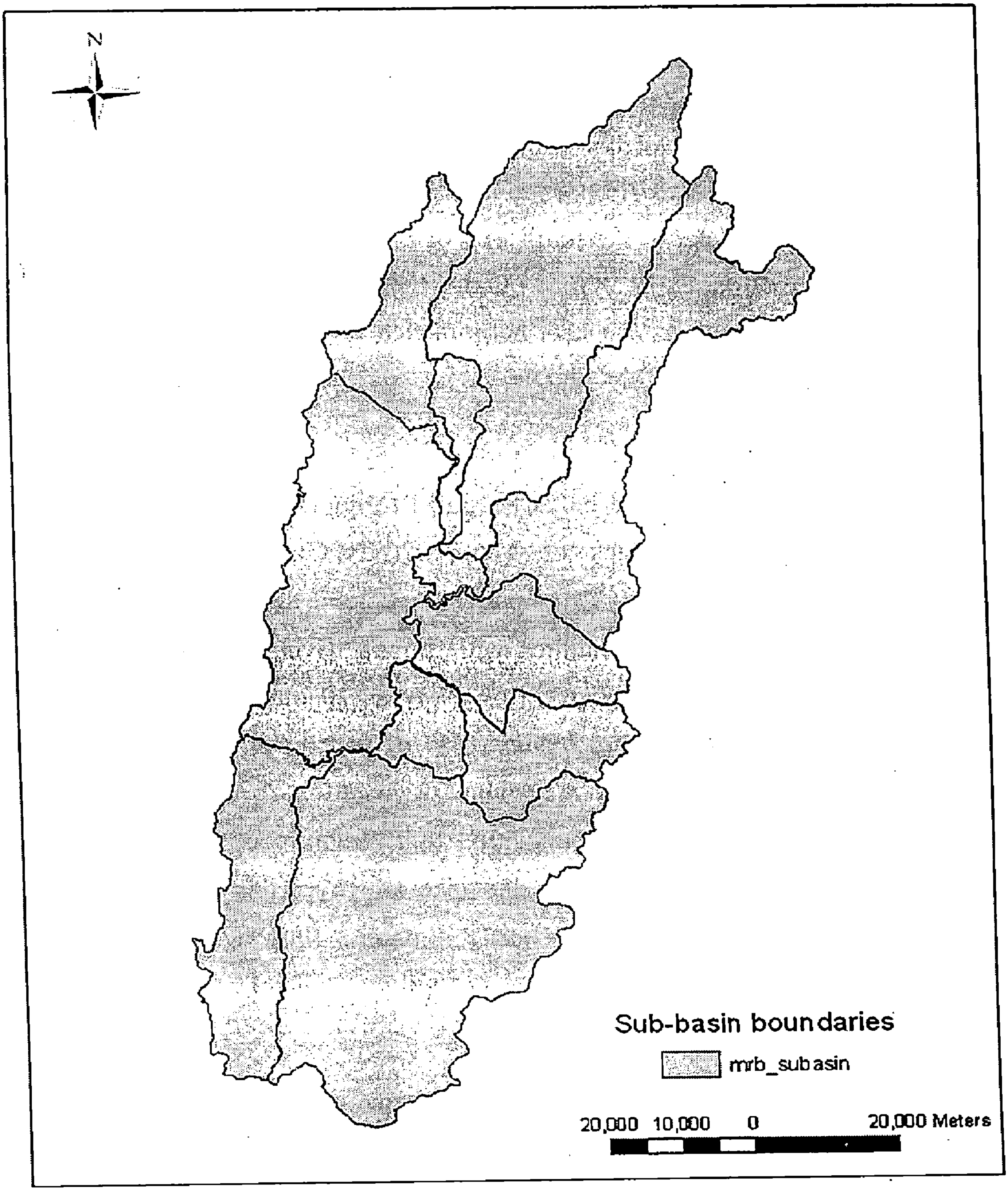


FIG 2.2 Sub-Basin demarcations in the Manipur River Basin

2.4 LOKTAK LAKE SUB-BASIN

A number of lakes/wetlands define the Manipur River basin. The most prominent of them is the Loktak Lake situated all along the western periphery of the Imphal or Manipur River. Wetlands, locally known as Pats, constitute 6.8% of the basin area and Loktak lake (pat) represents 61% of the total identified wetlands in the whole state. It is the largest freshwater lake in the north east of the country and has been designated as a "wetland of International Importance" under the Ramsar convention in 1990. Besides, unique hydrological regime, the lake harbors rich bio-diversity and reflects/inherits the socio-economic livelihood of the people.

Besides being described as "a beautiful turquoise lake set amidst majestic hills and picturesque emerald vales of Manipur"(NHPC), it can be conceived as a floodplain/wetland of the Imphal/Manipur river. Lateral flow from other main rivers and peculiar inflow-outflow hydroynamics with Imphal river mainly influences the water regime in the lake. The lake uncovers as many as 20 other smaller wetlands (Takmu, Ungamen,. Laphupat, Tharopokpi being a few of them) which are generally identified during the lean-flood/dry season at a benchmark elevation of 766m above MSL. After the commissioning of Ithai Barrage (regulating unit structure of the Loktak Multipurpose Project) in 1983, the water levels in the lake which earlier used to experience large fluctuations (that may have possibly been the natural flushing regime of silt) has been refined to more or less gentle levels (a dictated water level of 768.5m being generally maintained in the Barrage).

The Lake spread which provides flood absorbing capacity to the whole Basin accrues an area of 287sq.kms at the dictated level of 768.50m above MSL. A total water spread of 490sq.km was reported during the highest recorded flood in 1966 so far when Pumlen and Lamjaokhong pats merged with Loktak. The main water body of the lake is surrounded by shallow water stagnating over marshes or swamps on all its sides.. The depth of the lake varies intermittently from 0.5m to 4.6m. Cross-sections of the lake (along the transverse east-west and longitudinal north-south) derived from the bathymetry

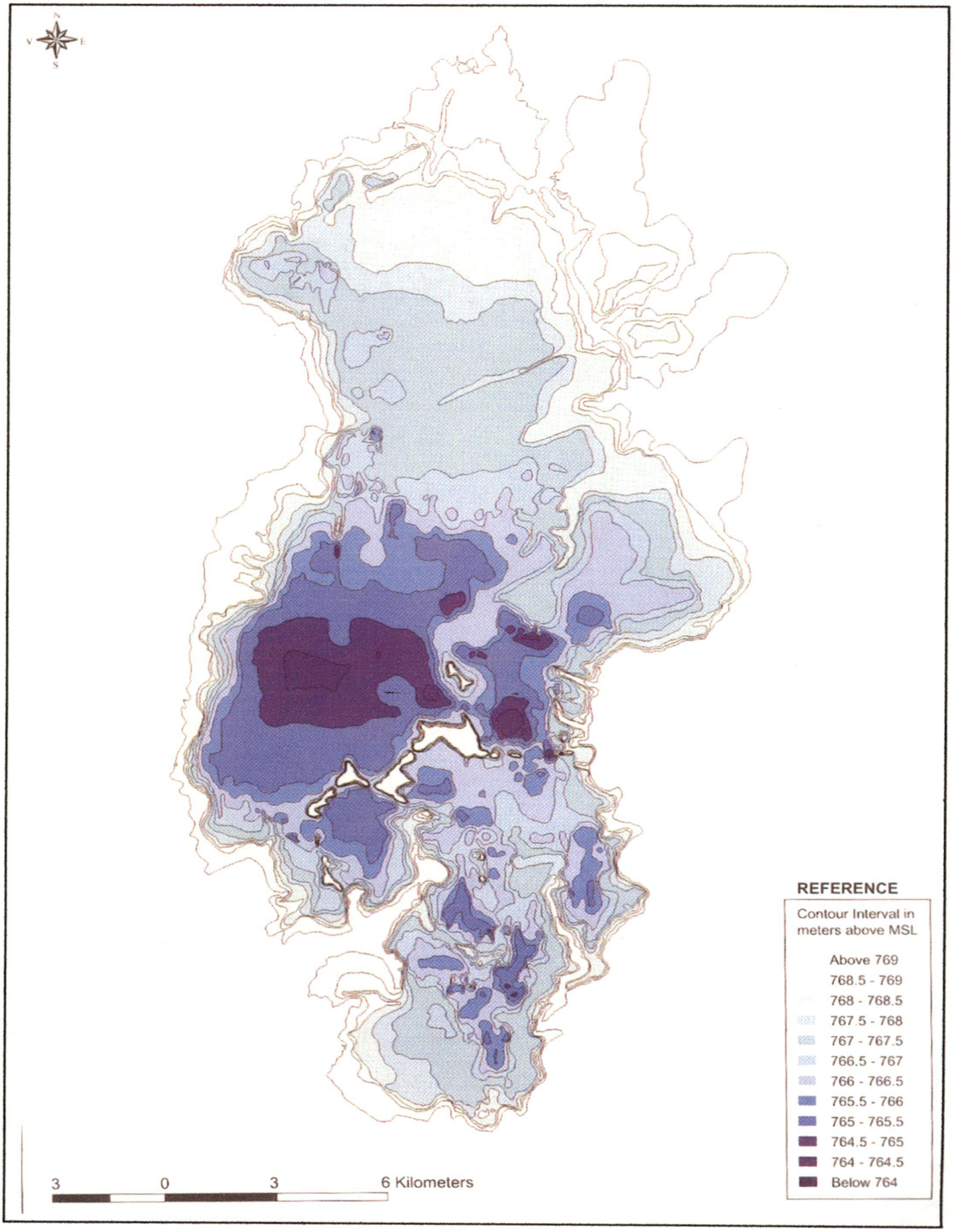


FIG 2.3 Bathymetric feature map of Loktak Lake (reproduced form 'Atlas of Loktak')

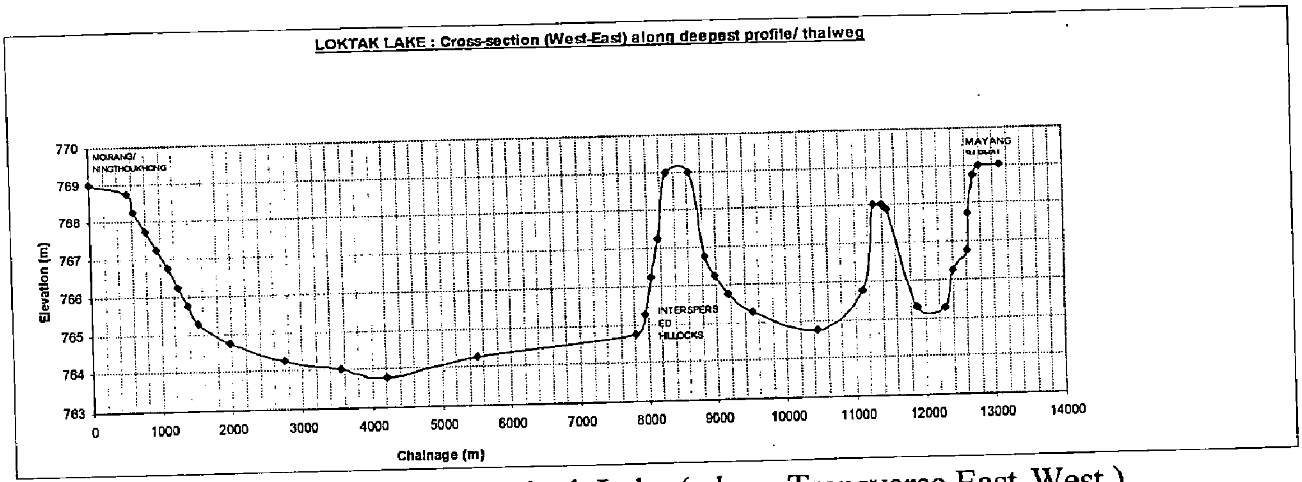


FIG 2.4 Profile of Loktak Lake (along Transverse East-West)

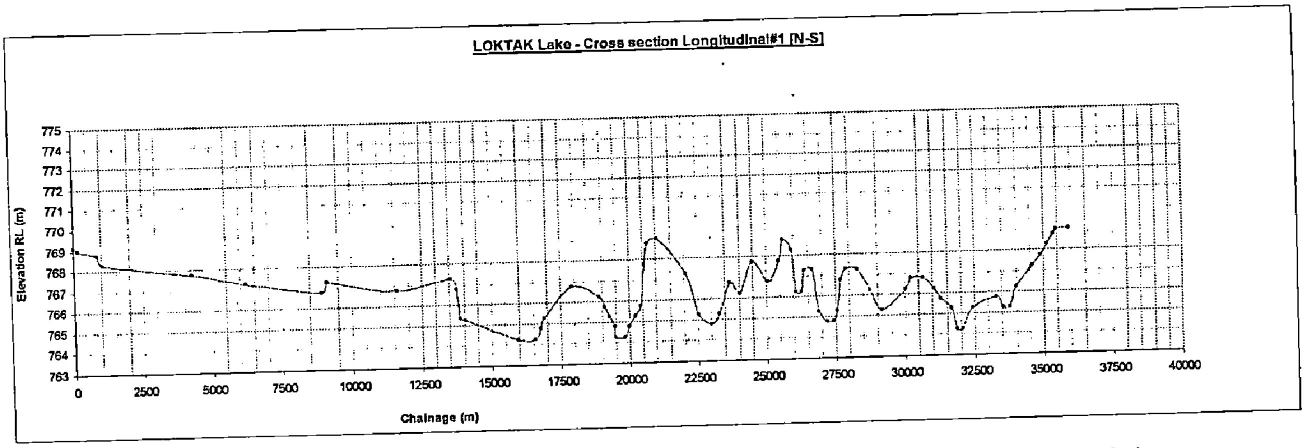


FIG **2.5** Profile of Loktak Lake (along Longitudinal North-South)

Map using ArcGIS and MapINFO tools (Figs 2.3 ,2.4 and 2.5) reflects the irregular bed profile of the lake. Further, Fig 2.6 gives an extent of the lake and the changes that have taken in the last three decades.

The origin of the lake has been dated to the" middle to last" glacial period about 25,000 years ago (Dr.Vishnu Mitra) and its formation as a result of tectonic forces. The lake has thick lacustrine sediment deposits and unique island like hillocks rising steeply from the Palaeo lake margin. There is 14 such hills/island in the lake (Thanga, Ithing and Sendra being the prominent ones). The other characteristic feature is the large presence of heterogenous floating biomass (of soil, vegetation and organic matter) acting as homestead to many nomadic fishermen. They are estimated to occupy over half of the

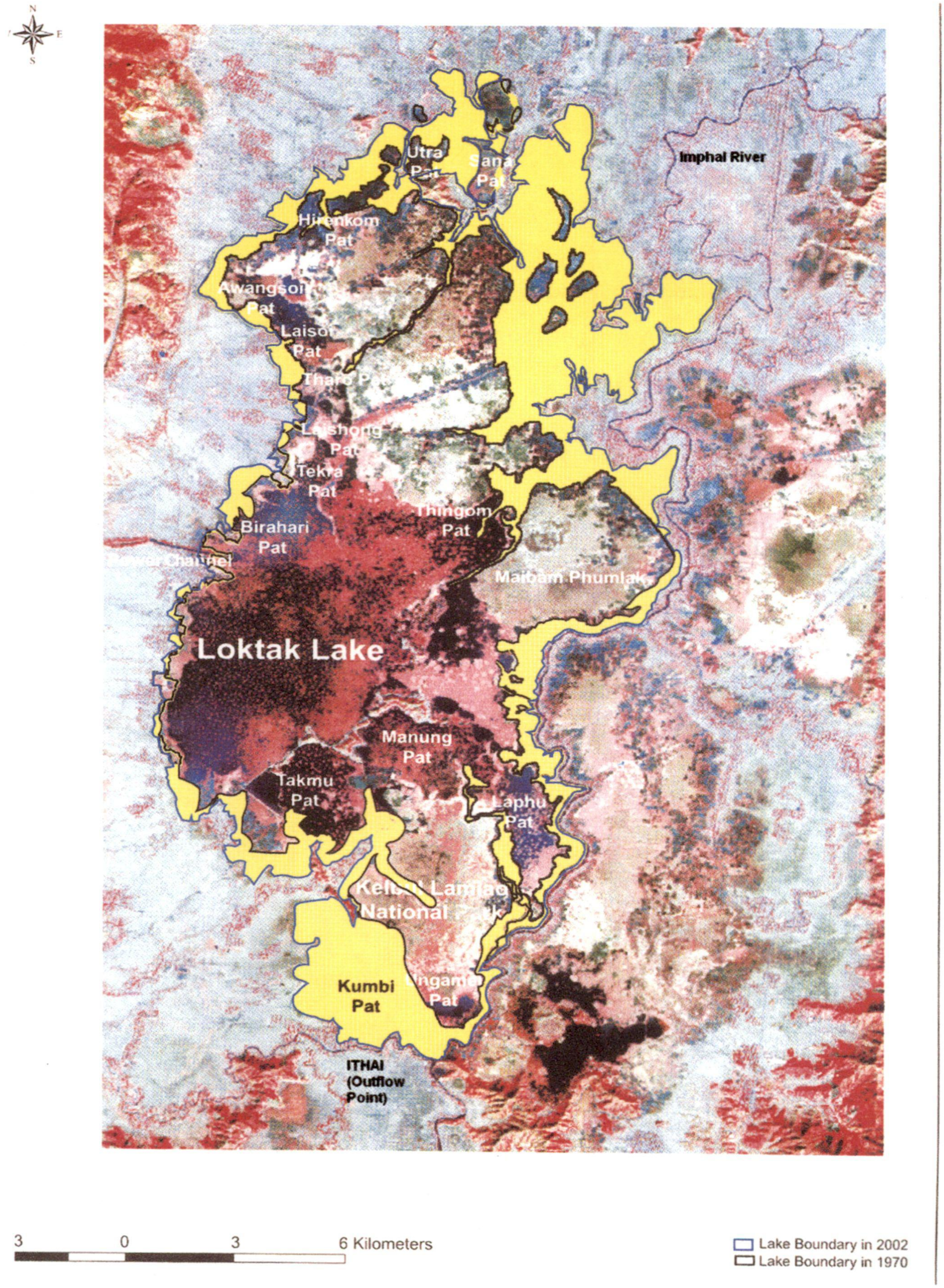


FIG 2.6 Loktak Lake extents and changes in last three decades (source: IRS-1C LISS III)

total lake area and has been the sermon of ecological remediation or *fluvial biology*. The southern portion of the lake serves as the only habitat to the endangered fauna-sangai (brow-antlered) deer which is given the identity of a unique "floating wildlife national park".

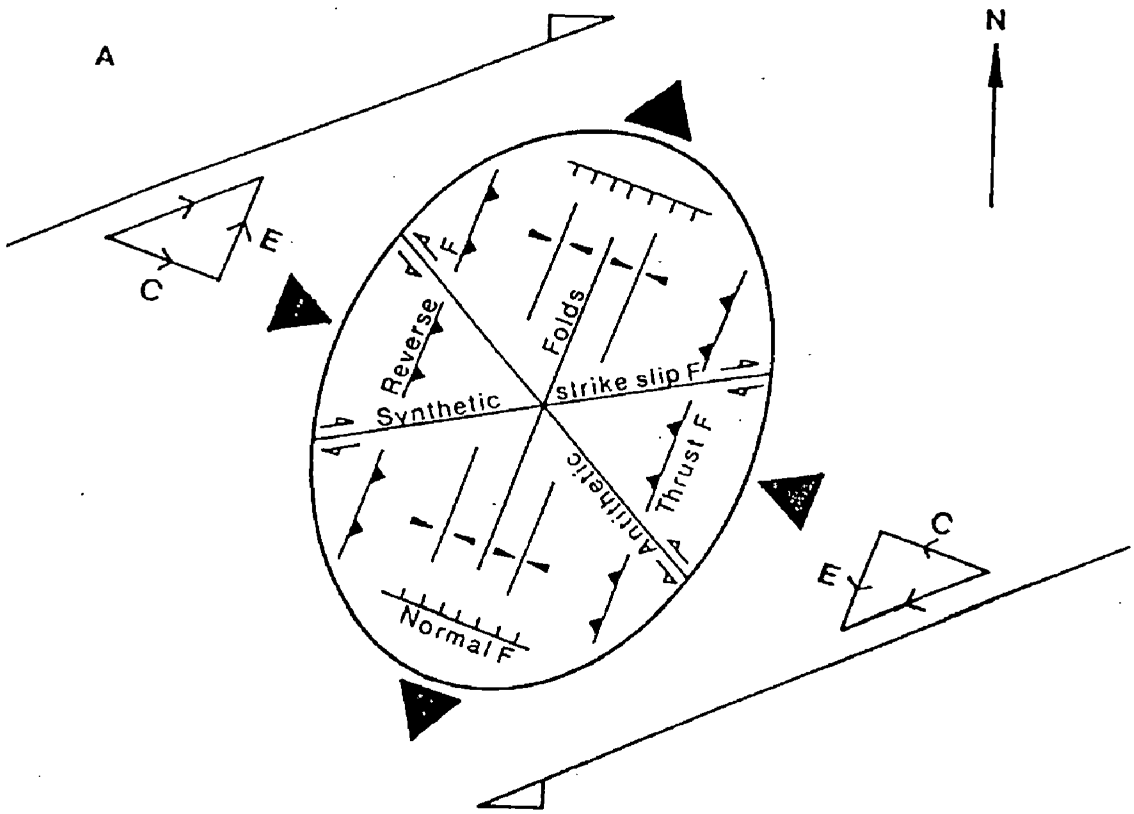
Since the formation of the valley, the Loktak lake sub-basin has been acting as the sediment trap for the whole basin which has hills/mountains composing mainly of erodible shales. The main Imphal river is not directly connected to the lake but a number of streams/channels run down from the north and western hills directly into the lake depositing huge sediment loads.

The sub-basin may be delineated into smaller water-shed units on the basis of the number of streams falling into the lake. Some of the prominent ones: Nambul (217.23 sq.km), Nambol (124.60 sq.km), Thongjaorok (20.98 sq.km), Awang-Khujairok (13.75 sq.km), etc. the network of streams as reflected in the drainage pattern (refer Fig 2.1) may be classified as sub-dendritic to sub-parallel (after Horton R ,1940s ; Strahler E , 1950s).

2.5 GEOMORPHOLOGICAL AND GEOLOGICAL IMPLICATIONS

In dealing with the Fluvial processes and dynamics, a sound trade-off in the geomorphology of the region is necessary. In case of the Manipur River Basin,the rocks of the Imphal Valley and the surrounding hills where the particular study is carried out are predominantly of Disang Flysch sediments. The Disangs are almost of Black shales (brown when weathered) with rhythmic thin interealations with sandstone. There are some exposures of Barail group of rocks also (found generally as thin outlier in the valley and adjoining hills capping the older Disangs). The Barails are predominantly of sandstone with thin interealations with shales. The Imphal valley is a pull apart basin (Soibam,2000). This valley (Basin) is resulted from the dextral simple shear couple (Fig 2.7 a) and slipping along the pre-existing thrust planes of Churachanpur-Mao thrust and Thoubal thrust as illustrated in Fig 2.8 (b).The subsidence is characterized by a number of extrusional step faults (Fig.2.8 a). The Churachandpur-Mao thrust runs almost N-S along the western margin of the valley whereas the Thoubal thrust runs almost parallel along

FIG 2.7 (a) Strain Ellipse resulting from Dextral simple shear ,(b) –Deduction of possible plate motion vector from the shear couple



C - COMPRESSION MOTION VECTOR

E - EXTENSION

P - PLATE

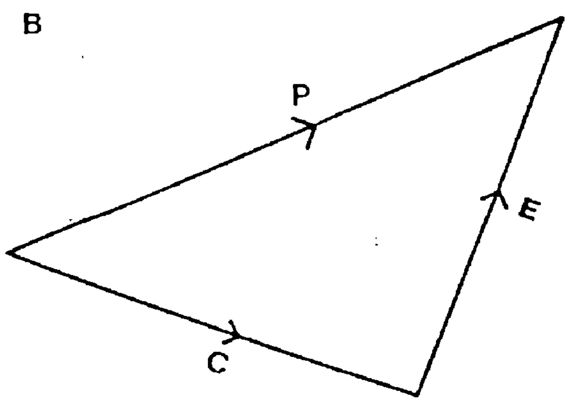


Fig 2.8 (a) Schematic block diagram of a sector along N-S of Imphal valley. Subsidence through a number of step faults is in the form of a pull apart basin induced by the system of tectonic forces controlling the region. The blocks are rocks and overlained by alluvium filling the entire basin.

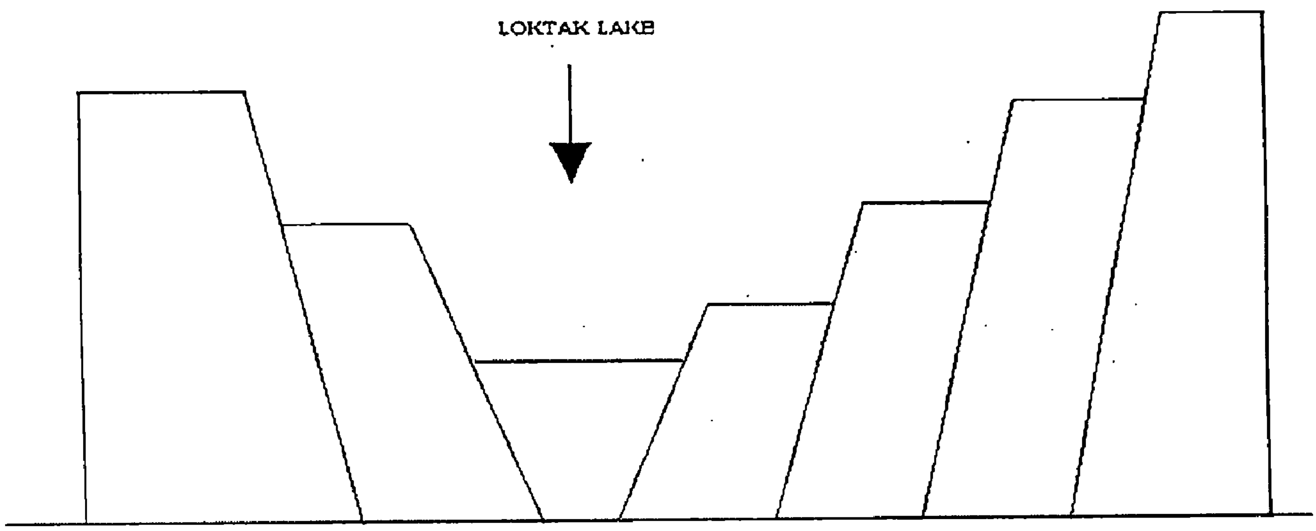
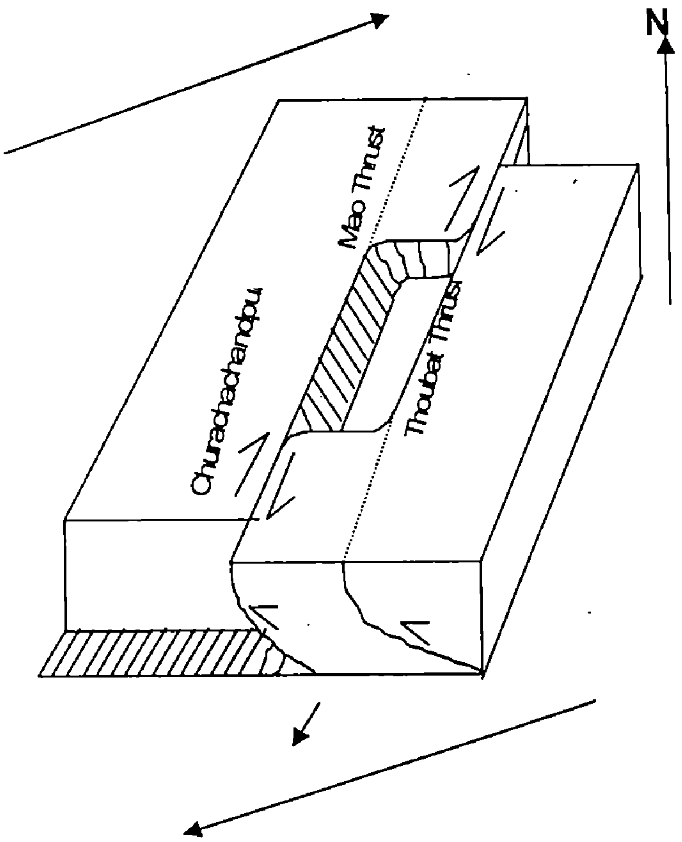


FIG 2.8 (b) Evolutionary Model of the Manipur River Basin (resuting from dextral shear couple slipping along the pre-existing thrust planes). The flat lying nature is due to in-filled alluvium.



the eastern margin of the valley. The system of tectonic forces prevailing in the Indo-Myanmar Range (Indo-Burmese Range) region are responsible for the subsidence of the valley as a pull apart basin. Before subsidence, it was having the topography of hill ranges similar to the present topography of the sorrounding hills. After upliftment as a part of the Indo-Myanmar Range the region was subjected to weathering and erosion giving rise to the thin hill ranges (before subsidence). The subsidence tool place in a pulsating fashion through a number of steps in course of millions of years. The highest peaks of pre-subsidence are the protruding peaks of the valley present (hills) after the formation of the valley. The low lying hills are submerged under alluvium; therefore the basement of the valley is not flat. The pre-subsidence rivers were controlled by the structures of the rocks deformed according to the laws of tectonic compression and extension directions. Some of the rivers run almost N-S along the total axes.

Most of the rivers in the Manipur River Basin in particular and the region as whole in general are therefore oriented along directions of synthetic and autithetic strike slip faults, fold axes etc. the post subsidence rivers in and around the valley are again controlled by the extensional step faults, thereby changing the original course of some of the pre existing rivers. The Khuga river running almost E-W is an example of the deviation from the normal flow path as of the other major rivers in the basin.

The Imphal / Manipur river could take its own course through the infilled alluvium of the valley i.e. the bed of the river raised gradually as subsidence continues. (the river thus by-passing the Loktak lake). The Imphal/Manipur river is one of the pre-existing rivers running along the fold axes along N-S direction and is older than the valley and hence Loktak lake and hence the river is antecedent. The Khordak and Ungamel channels used to serve as a channel for outflow of the excess water (in the flood season) from Loktak through the Manipur river.

Geologically, Tertiary rocks occupy the hills and form the basement for Quaternary sediments. The rocks are essentially of Disang series with some narrow belts of Barails. Disang group rocks are Olive grey and buff coloured splintery shales and are often interbedded with beds of compact sandstone and silestone. The rocks of Olive colour, fine to medium grained sandstone and areceous shales. The quaternary sediments overlie the tertiary rocks unconformably

Geomorphological mapping of the areas in Imphal valley carried out by the Environmental Geology Division of the Geological Survey of India, North Eastern Region Shillong. Salient Geographical aspects, (Report ,Sept 1988).have classified the basin into following units in order of increasing antiquity :

i) Loktak Surface
ii) Lilong Surface
iii) Lamsang Surface
iv) Sekmai Surface
v) Kanglatogbi Surface
vi) Motbung Surface

The first three units form depositional land forms and are of Holocene age and the rest forming erosional land forms are of Pleistocene age (Landforms are classified as Erosional and Depositional). The rocky upland unit of tertiary Pleistocene surfaces are restricted to the western periphery of the valley area. Several river basin features that are not related to water flow may affect aggradation / degradation and lateral/bank erosion.(Simons et.al;1984; corps of engineers report, 1956)

The recognized geomorphological features in the valley are flood plain and their abandoned and weathered terrace channels with point bars enclosed meander loops, levees and back swamps.. The hill slopes on the western periphery of the valley are flanked by large amount of colluvial debris due to mass wasting. The Loktak lake was formed as a result of tectonic forces. It has great thickness of lacustrine sediments, steep shores and mountains raising steeply from Palaco lake margin. The problem of siltation and degradation of Loktak lake suggests that the ecosystem is going through a process of slow death resulting from both natural and anthropogenic causes. The lake basin acts as a sediment trap for the valley surrounded by hills composed mainly of easily erodible shales. Destruction of forests, jhum cultivation and mining activity have accelerated the process. Streams flowing down the barren western hills and falling into the lake carry huge amount of suspended load during monsoons. The flushing out of silt by Imphal river is hindered by Sugnu hump and results in raising of river bed level due to siltation and also carriage of some silt of Lokatak lake. The geological studies suggest that transgression and regression of Loktak lake can be inferred from related lacustrine deposits and from alluvial and colluvial formations.

It may be inferred in this regard that the recessive or recursive flooding patterns mostly in the lower reaches of the Imphal/Manipur River is the result of large-scale degradation / scour in the upper and middle reaches due to alluvial landforms and negligible erosion in the bottom reaches due to the presence of bedrock and lateral rock shales.

2.6 SOIL DESCRIPTION AND BENCHMARK

As marked by the National Bureau of Soil Survey and Land use Planning (ICAR) India, the basin falling in the Assam-Burma ranges roots the present soil composition and characteristics to the final orogenic phase in the early part of the Pleistocene. The region is still unstable with several faults and thrusts (in line/parity to the illustration presented in preceding section 2.5 of this chapter).

The soils in the region have brown to dark brown very strongly acid silty clay loam" A" horizons, brown to dark brown extremely acid silty clay loam:B2t" horizons, which have developed on weathered shale on steeply sloping middle range hill slopes. The "A" type has weak fine granular structure with a pH of 4.5; the "B2t" type has weak medium sub-angular block structure with a pH of 4.4. Both the A and B2t horizon is about 15 to 20 cms thick and has moderate permeability. The soil thrives sub tropical moist deciduous forest though "jhum" cultivation has severed the land-use and soil equilibrium.Going broadly into the classification based on the hills and valley topography- the hill soils in the basin vary from silt loam to clay loam, falling under capability class IV,VI,VII (on account of steepness of slope). The valley soils are deep capability class II whereas the soils adjacent to lake and wetlands are grouped to class V.

The description and nature of soil gives a fair amount of validation to the sediment transportation process in the rivers and streams of the basin. The sediment gradation/distribution plot worked out in the study has thus a fair amount of the judgment above.

Fig 2.9 Pansharpened Liss-III Image- MRB

CHAPTER 3

OBJECTIVES AND COMPOSITION OF THE STUDY

3.1 OBJECTIVES AND PARADIGM

3.1.1 ASPECTS

Sediment transport and the fluvial entity, has been a concern in hydraulics given the many reports on a phenomenon that can be observed particularly during floods, when waters turn brown or gray due to the suspension of loose eroded material in the flow. Once, a flood is over, or in a gradual time span, large changes on the river bed are observed with banks or piers eroded, while other locations get covered or aggraded. It might be impacted that when extremely large floods with limited sediment supplies and high sediment carrying capacities occur in rivers with erodible bed and bank materials, scour will continue to take place within the erosive capacity of the stream till it approaches the minimum/optimum value required to transport the available material.

Traditional approaches have investigated the ways in which streamflows, sediment loads and channel forms vary along a river from headwaters to mouth and with time over periods ranging from hours to years. Represented in their most simple form, rivers have been viewed a unidirectional systems that change progressively from headwaters to mouth. The river continuum concept takes the physical structure of a stream, coupled with the hydrological regime and energy inputs to produce a series of responses (in form as streamflow hydrographs, etc.)

3.1.2 FLUVIAL HYDROSYSTEM

A Fluvial Hydrosystem methodology is adopted to analyse the nested hierarchy of subsystems functional to the whole river continuum in this study. Different levels within the hierarchy are controlled by different rates and types of processes that may be attributed to as the "hydrodyamics" of the system. The primary unit is the drainage basin which is delineated by a topographic divide – the watershed or catchment. The structure and planform of the basin results from geomorphological processes and climate patterns which operate over time-scales of more than 10^4 years. Following Schumm (1977), within the drainage basin an "ideal" river is seen to progress through three zones : the headwater or production zone where water, sediment and other particulate matter pass from the hill slopes to stream channels; the transfer zone through which materials are transported (or routed)' and the storage zone, where materials are deposited and may be retained for a long period of time. The fluvial hydrosystem is applied to the transfer and storage zones (described by Schumm,1977) and recognizes the production zone as a `black box' which necessitates the primary inputs to the system.

The Manipur River Basin system, though of a meso-scale as compared to other known basins, attributes an intricate hydrosystem ranging from its geomorphological history to the present findings, in the development of river-wetland continuum. Lateral linkages between the flow regime which is strongly influenced by water retention on the flood plain / wetlands (Loktak Lake, being the major one) during high floods , and the alluvial streams (Imphal/Manipur River as the Main drainage channel) during low floods, ascertain a **process-response system** to the sediments and other matter that are stored within the floodplain, highly dependent on the interactions between the watershed characteristics, the wetland/floodplain and the main river.

The drainage basin perspective study is taken up because the flow regime and sediment loads determine the morphology of the river channels which has a strong influence on the structure and function of the fluvial hydrosystem as first recognized by Hynes (1970). A complete explanation of a fluvial hydrosystem requires integration of the morphologic and cascading (hydrological) systems. These systems rarely attain exact equilibria and generally the river channel tend toward a mean form, termed as `**quasi-equilibrium**'. When a system is in equilibrium, the inputs and outputs become equal. If the inputs change, the morphologic system will adjust to a new equilibrium condition. For example, an increase in sediment load, with no change of discharge, will induce an increase in channel slope and bed material size, and a reduction of the depth-width ratio.

This variation and time integrated change refers better under '**Non equilibrium sediment transport**' (dealt later in the study). The quantification and regime conditions in the hydrosystem under this approach is conducted with a '**numerical sedimentation model**' providing the computational framework for analysis.

The controlling role of storage zones in the basin, as mentioned earlier, is seldom investigated (Malcolm Newson, 2000). The comprehensive research studies on sediment storages done on the Redwood Creek in northern California in a basin area of 720 sq.km. (Madej, 1984); and it is her findings on the line, that the river system is not 'unidirectional', storage is both part of the feedback system linking to homeostasis and a potentially destabilizing agency because of its intrinsic geomorphological trade markings as a landscape element, as the Manipur River Basin system is (discussed in detail later) – where stored sediments have their own stability criteria and induce conditions for its own remobilization. Studies on the Basin, the noteworthy ones from hydrological/hydrodynamic standpoint : 'Loktak lake Multipurpose Project (Part – I Power)' – the Central Water and Power Commission (CWPC) (1966), 'Geomorphological Mapping in Imphal (Manipur) Valley' – Environmental Geology Division, of the Geological Survey of India, NE Region (September 1988) , Outline of Water Resources Potential in Manipur -Central Water Commission (CWC) 1970s, 'Detailed Project Report for Development of Loktak Lake Sub-Basin, Manipur' – Water and Power Consultancy Services (WAPCOS) April 1993, etc. along with a host of other annual project reports by State Government agencies and Organizations as the Wetlands International (WISA), till date have conducted and exponent studies mainly at operational scales with complimentary use of fluid and stock-in-trade hydrology. The system is left to be compressed as a scheme of 'fluvial auditing' and time signatures of artifices in the Basin system, which however, cost-effective in River basin management and Planning operations. There has however been an inadequacy in the temporal data which has affected the studies conducted to consider the multiplicity of controls on the resolute signatures of the Manipur River Basin system. As referred by a team of WAPCOS inputs (Detailed Project Report, Ch. 1, April 1993) after carrying out reconnaissance survey of the Loktak Lake Sub-basin *"It has been recognized that the data base is grossly inadequate and not of appropriate standard in quantity and quality"*.

In a strategic approach, the basin's sediment system is its fundamental structural system, the foundation for development across its entire surface and the longer-time recipient of many of its impacts, its characteristic space and time signatures should be used to guide development itself [Mitchell (1990, Brookes et. al (1991), Newson (1972), Bogon et. al (1972). Thorne et. al (1993), etc.]. The study projects the basin sediment system as a process-response system with point inputs (from upstream basin).

Thus the temporal control over the basin sediment system operational scales right from basin to particle and the interdependency of its components should be considered at both strategic and operational scales of river basin development.

An important characteristic and peculiar feature of the Manipur River Basin (MRB) system is role of `feedback loops', particularly negative ones, in the form of two (2) prominent interlinking natural channels between the major river (Imphal/Manipur River) and the major storage (Loktak Lake) which has `bi-directional' or `backflow' or `reverse flow' attributes. The fluvial operation of these loops (in the form of rapidly varying flow directions) introduces processes which tend to oppose continued change within the basin system as thereby causing variations and in determining in the `cascade' input, as mentioned earlier. The `peculiarity or uniqueness' is inheritable as to the addition of complexity in the basin system, as the sediment/fluvial system increases intrinsic controls (Schumm, 1977) over its own dynamics through storage-dominated feedbacks; threshold phenomena are therefore common (Newson, 1972).

For instance, the sediment load is a function of both upstream catchments and channel erosion at the base of the slope, increasing slope angle. The increase in sediment supply reduces channel erosion and may induce aggradation. This stabilizes the slope sub-system and reduces upstream sediment supply.

3.1.3 THEME OF STUDY

The study examines the Manipur River Basin as a fluvial hydrosystem. A number of previous studies (highlighted earlier) with scopes that are either germane or similar, are reviewed and substantiated. The hydrologic and hydraulic information within these studies is updated as partial of the study. The capacity for the rivers/streams in the basin to carry water and sediment, and the corresponding morphological changes in both the main channel and floodplain are analyzed and modeled. Self regulation or natural hydrodynamic operations to maintain the quasi-equilibrium and to establish a new quasi-equilibrium condition or "Non-equilibrium condition" with changes and variations in the internal outputs, is the theme of the study. Some of the entities in the theme are :

(i) Hydrodynamic Regime :

The Manipur River Basin has an intricate hydrosystem. The flood waters in the main river and lake flow in or out depending on the relative water levels, but finally drains out through on the main outflow drainage channel-the Imphal/Manipur river, at Ithai where a barrage have been structured. The average availability of surface water is the basin (including that of Loktak Lake) has been assessed at 5192 million cum, whereby the total channel discharge capacity of the Imphal River is 6550 cumecs. Prescription (annual) varies generally between 1000 to 2000mm and forms the major water resource. Sub-surface water occurs in both confined and unconfined conditions- the water table is generally within 5m from the land surface and at a gradient of about 2.2m per km. the average run-off at the main outflow point-Ithai, is estimated to be 3774 Mcum (based on observed discharge data and corresponding annual rainfall from 1923), whereas in the main storage natural reservoir (Loktak lake), an annual average run off of 1172 M cum was assessed. The highest recorded flood so far is 1966 has a reported discharge of 340 cumecs passing the Ithai barrage and corresponds to a flood frequency of 1 in 60 years.

Though precipitation serves as the major hydro input to the basin system, the average annual run-offs/yields of the major drainage river has fluctuating values. A combined plot of the annual rainfall and run-off is given in fig.—the erection and commissioning of medium to minor water resources projects in Imphal/Manipur river as well as in other prominent rivers, have considerably affected the hydro potential in the basin and the water balance in the lake. The Loktak Multipurpose project has a major contribution in outflow from the Table 3.1.1.

The water balance- inflows and outflows between Imphal/Manipur River and Loktak Lake through the link channels have formed a prime control unit in the hydro-regime. A comparison of the inflows and outflows before and after the commissioning of the Loktak project is given as:-

Table 3.1.1

Year/period	Inflow (from Imphal river to Loktak) Mcum	Outflow (vice versa) Mcum
1958	102	375
1959	104	256
2000-01	388.01	170.38

It may be noted that earlier records does not take into account the flow or entity of Ungamel channel. However, the considerable change (as to almost reversals) in the inflow and outflow volumes depicts the effects of a project operation in the Basin and the consequent reduction in water storage capacity of the lake. The natural flushing of the silt-laden flows into the lake has been obstructed to a measurable extent.The present water-balance of Loktak lake may be presented in Table 3.2.2 (as based on data sets 2000-01).

Many other factors can be attributed to the prolonged high water level regime in the lake.The study is aimed at comprehending the conditions prevailing in the basin.

Table 3.2.2

INFLOW	OUTFLOW
• Stream/channels from north & western hills- 52%	• Loktak project obstraction-70%
• Imphal river (via Khordak & Ungamel channels)-23%	• Imphal river (via Khordak and Ungamel channels)-14%
• Direct precipitation-25%	• Evaporation-6.5%
	• Evapotranspiration-9.5%

(ii) Sedimentation Regime :

The sedimentation prevailing in the Manipur river basin has been primarily focused on the Loktak basin. The term "sedimentation" is narrowed to "siltation" on account of the dominance of silt matter in the overall sediment dynamics, in various reports/report matters. The useful life of the natural reservoir as the loktak lake has been reducing alarming primarily because of anthropogenic induced high sediment yields from mountain sub-basins (a majority of which is the western hills sub-catchments contributing to about 65% of the total sediment inflow) and the disturbance of natural flushing patterns (the highly fluctuating water regime, before the structuring of the Loktak project, forcing high volume of outflows to perpetual low levels used to a natural sediment discharging phenomenon). The notable five processes of sedimentation: erosion, entrainment, transport, deposition and consolidation are active in the basin.

The annual average sediment inflow into the lake has been estimated to 650,000 M.T. besides a major contribution from the northern to western hills sub-catchment, there is a fair magnitude of sediment transport taking place between the Imphal/Manipur river and the Lake through the two main interlink channels-Khordak and Ungamel. Inflows from the river to the lake during floods leaves behind a lot of silt while receding as outflows in the leaner periods. With the operation of Loktak project, the flushing of sediment has been considerably reduced with only an average 59 cumecs of outflow taking place (LHEP reports). The natural rock barrier as the "Sugnu Hump" and the acute confluence of Chakpi tributary at the lower reach (after Ithai) causes clogging and disturbances in the flow of the Manipur river and can be comprehended to contribute to the sediment/fluvial process during receding floods.

Besides the main Imphal/Manipur river, the other prominent drainage units falling directly into the lake and having a major share in the sedimentation process are the Nambul and Nambol rivers which takes off from the northern/north-western hills and traverses through the valley; and many minor streams/channels which torrents from the adjacent western hills. Nambul and nambol rivers have total inflows of 87.72 and 52.63 Mcum to the lake, as worked from records 2000-01. The streams/channels from the western hills are of short reaches (most of them between 3.0 to 5.0 kms) and non-perennial. This makes the stream gauging and measurements of these streams mostly confined to sediment-loads. Of these, Thongjaorok streams works out to a sediment discharge of 83.92 MT annually.

The Manipur river basin sediment system transport principally silt and clay, as other courser materials are confined within the mountain reaches. The study of lithological logs by the Geological Survey of India (1969-1971) in the basin reported that the alluvium consisted mainly of clay, silt and sand. Clays and silts are found to vary in the deposition strata, the sand stratum lies in between 6 to 18 meters and lenticular in nature. There are no distinct marked stages in the deposition of alluvium. The whole of the alluvial formation in the valley is described to be one continuous and conformable series of alluvial and subarcal deposits, with deposition still taking place to some extent. On the whole, it can be inferred that the total thickness of the unconsolidated to semi-consolidated sediments is highly variable with no clear demarcation between the alluvium and underlying tertiaries (as Disangs or Barails).

(iii) Siltation Estimates (earlier worked out) :

No observed data of sediment (silt) discharge for the early period in the inflowing streams and rivers were available. Of late since 1990, state authorities have started detail gauging and sediment load measurements. Earlier studies and sedimentation parameters of the basin have been worked out on empirical basis in comparison to the study of other reservoirs/basins in the country.

(i) Siltation Rates:-

(a) Early design practices of reservoirs, applied to the Loktak sub-basin/reservoir was based on an annual siltation rate of 0.0356 Mcum/100 sq.km.

(b) Enveloping curves suggested by Dr.Joglekar in the following formula as

$$Y = \frac{0.597}{A^{0.24}}$$

where, Y= annual siltation rate in Mcum/100 sq.km

A= basin/catchment area (sq.km)

(note that the sub-basin area in earlier times were taken to be 980 sq.km)

which yields a rate of 0.1143 Mcum/100 sq.km

(c) Other suggested enveloping curves by Dr. Varshney and Raichur categories separately as

Mountain rivers $Y = \frac{0.395}{A^{0.311}}$ (variables defined a sabove)

Which worked out to 0.046 Mcum/100sq.km

Plain rivers, $Y = \frac{0.392}{A^{0.202}}$

Which worked out to 0.0975 Mcum/100sq.km

(d) The Indian standards provisions IS:6518-1972 has recommended a siltation rate of 0.10 to 0.20 Mcum per 100 sq.km annually.

(e) Assuming certain rates of erosion in categories of land-use patterns, WAPCOS has worked out an annual siltation rate of 0.45 Mcum per 100 sq km

(ii) Trap Efficiency:

The quantity of sediment retained in the Loktak sub-basin is expressed as a percentage of the total inflow of sediment brought in by the rivers and streams.

(a) As per Gottschalk's curve, where the trap efficiency has been plotted against capacity watershed ratios (worked out to be 538/980 i.e. 0.55 in case of Loktak lake), the trap efficiency is more than 96%.

(b) As per Brune's curve in which the trap efficiency is plotted against capacity inflow ratio (for Loktak lake 538/1172 i.e. 0.46), the trap efficiency also works out more than 96%.

The values may be lower before the instruction of the Loktak Multipurpose Project.

(iii) Sediment load observations:

From records of field data collected by state agencies, the sediment discharge and corresponding flows for the streams/rivers falling directly into the lake is given as:

Year	Discharge (Mcum)	Sediment discharge (cum)
1990-91	430.30	924,746
1991-92	307.50	861,653
2000-01	---	1,095,691

(iv) Backflow or Bi-Directional Flow Regime :

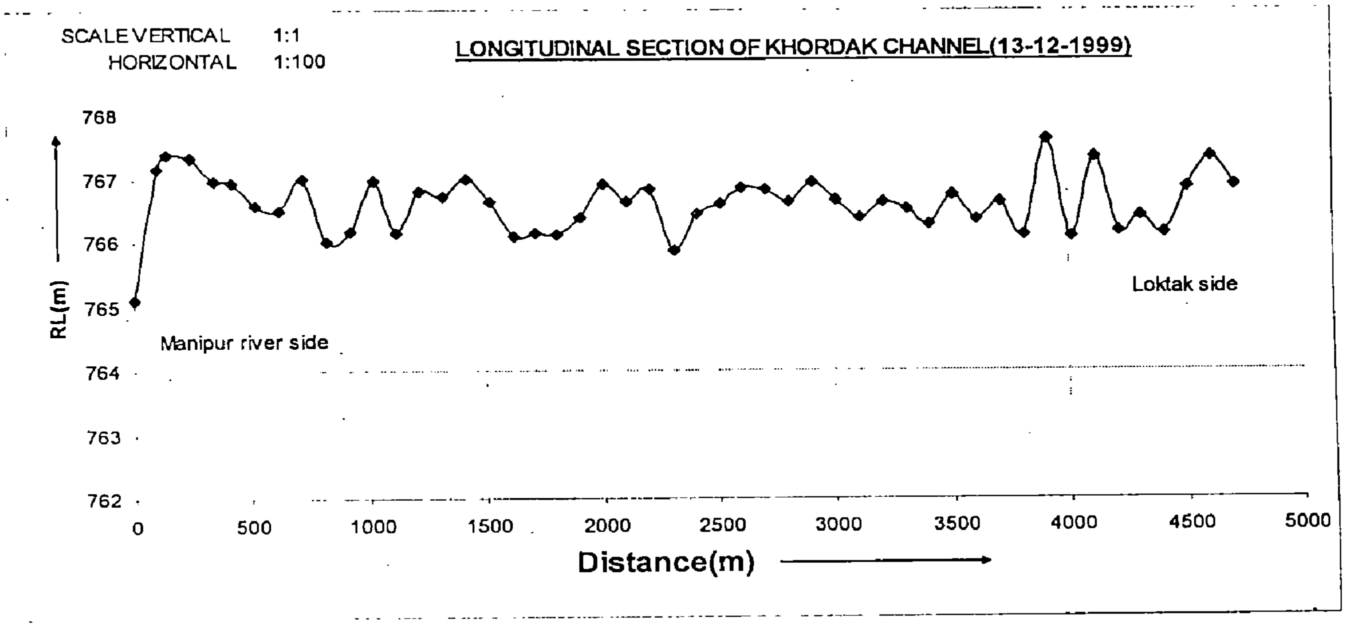
As it has been repeatedly described in the preceding sections, a unique hydraulic regime in the form of what may be termed as "Backflow" in the aspect that the flow is taking place in the opposite direction than the defined normal flow path or to refer it as "Bi-directional flow" in simpler terms considering the movement of water in both ways along the same conveyance channels, perplexes the hydro-system behavior of the

Manipur River Basin. Two natural interlinking channels Khordak and Ungamel are noted to have a key role in the overall water balance in the Basin, and more profoundly as the only functional units of sediment outflows from the Loktak Lake (the abstraction at the power channel of Loktak project is controlled and therefore neglected from sediment discharging aspects). Another regulating unit in this structure is the "Thongrambi" stream which joins the lake with the Imphal River between Hayen and Sekmaijin villages in the eastern periphery of the lake. As the minor stream is not well defined during most of the year and details of flow records are not available. The stream may have had a functional role long before the erection of the Loktak project.

Flow takes place from a higher gradient (head/potential) to a lower gradient (head) the peculiarity in the flow is that this theory does not only adapt to explain the translatory flow directions between Loktak Lake at one point (and the Manipur River at Ithai on the other point. Other hydrodynamic principles need to be assessed to address more to this particular phenomenon). The general bed levels of Loktak at 764.00m above MSL and that of the Manipur river at 762.00m above MSL, seems to support the "outflow" direction from the lake to the river. The commissioning of the Loktak Project-Ithai Barrage unit has disciplined this control by dictating this bi-directional flow in terms of the water surface and energy head relative at the two points. But this may not be the only dictating hydro-conditions as "backflow" from the Imphal/Manipur River to the Loktak Lake has been in prevalence long before the operation of a man made regulating unit. The table (no.3.2.2) presented in this chapter gives a record of the hydraulic translations in the basin. The Longitudinal Profiles of the two channels along with the Imphal / Manipur River is given in Fig 3.1.1.

In this direction an analysis of the flow characteristics in the two interlinked channels is conducted as an important part of this study.

FIG 3.1.1 – Longitudinal Section profiles of Khordak and Ungamel:



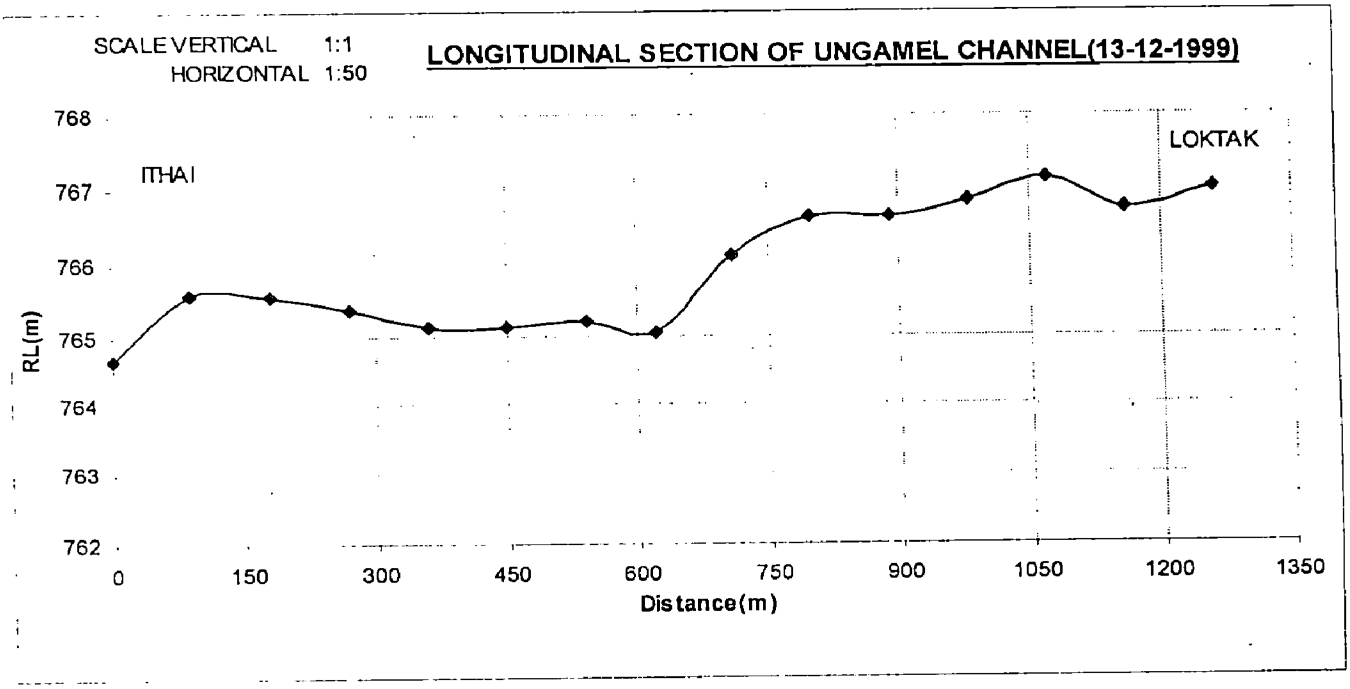
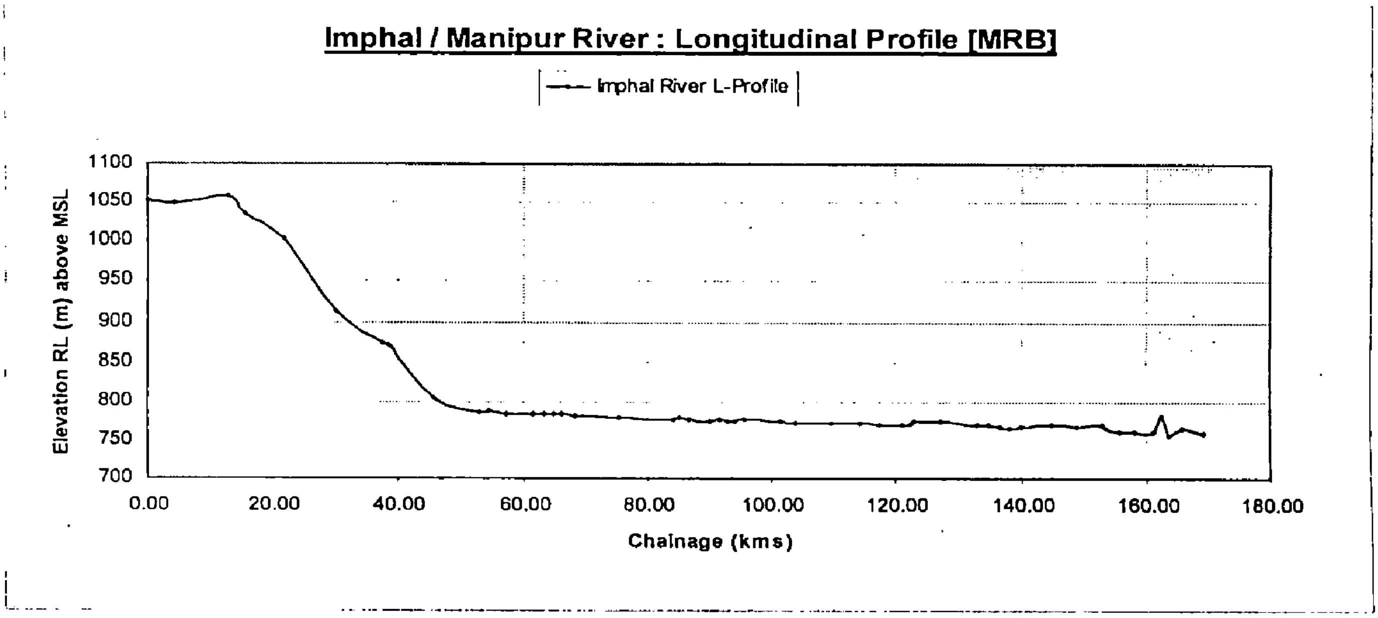


FIG 3.1.2 – Longitudinal Section profiles of Imphal river



3.2 STUDY COMPOSITION - METHODOLOGY & PARAMETERS

3.2.1 DESCRIPTION OF THE SYSTEM

The Manipur River Basin (MRB) as a fluvial hydrosystem is with a process-response system / model for the major rivers and streams sectors. Within each sector, the functional relationships existing in the hydraulic parameters are investigated using regression (both linear and multilinear), frequency analysis and Neural Network based Auto regression techniques, such that a quasi-equilibrium state may be defined over basic time scales. Daily to monthly scale is adopted in the study to coherent the rapidly varying hydraulic transients prevailing in the basin (MRB) impacted upon by frequent flash and high floods due to the tropical climate pattern. The climate normals arranged/averaged by the Regional Meteorological Centre, Guwahati (NE Region) is given in Table 3.2.1.

A framework to establish the links or interrelationships between the channel morphology, stream flow variability and sediment transport across a wide range scales and frequencies (as evident in the frequency charts plotted) of discharge, is directed in the study. Extensive preparation and analysis of observed/measured datasets is regarding the stream flow statistics are taken to be significantly affected by the scale-dependent river channel / floodplain interactions, which in turn are controlled by (and at the same time, actively define) the dominant fluvial processes in the Basin at a given scale. In reality, the controls within each loop (as in the fluvial hydrosystem entity) are only partial. Morphological and other physical changes are associated with many loops linking the variables involved, so that the responses to these changes of the 'external controls' are 'simplified' of its complexity. The involvement of different tributaries and interrelated sectors are looped to the particular functional point inputs. Within each sector of a channel, the morphological dynamics are taken to reflect the sediment supply from the sector immediately upstream (comprising sediment transported through, and eroded from this sector) as well as the influence of local base level changes determined by the next downstream sector.

Table 3.2.1 CLIMATE NORMALS OF IMPHAL VALLEY (MANIPUR RIVER BASIN)

Month	Mean Temperature °C		Mean Total Rainfall (mm)	Mean Number of Rainy Days
	Daily Minimum	Daily Maximum		
Jan	3.7	21.3	12.8	1.3
Feb	6.6	23.3	30.6	2.8
Mar	10.7	27.0	61.1	5.0
Apr	15.3	28.8	101.2	8.8
May	18.3	29.0	145.9	11.1
Jun	20.8	28.8	283.8	16.0
Jul	21.5	28.8	231.4	16.4
Aug	21.3	28.8	196.6	13.6
Sep	20.2	28.9	123.6	8.9
Oct	16.7	27.7	119.7	6.9
Nov	10.4	24.9	36.0	2.4
Dec	5.0	22.1	10.4	0.8

Remarks:

- *Climatological information is based on monthly normals for the 30-year period 1951- 1980.*
- *Mean number of rainy days = Mean number of days with at least 2.5 mm of rain.*

[Source : Regional Meteorological Centre , Guwahati, 2004]

3.2.2 STUDY FORMULATION

Strategically for formulations/model, the basin sediment hydrosystem is adopted as a spontaneous regulation function.; the physical basis of the river basin is the water and sediment transport system, connecting at the storage unit to the outflow unit. The geomorphological or geological factor of `control' in the sediment system is linked closely to the water and sediment functional sector besides considerations as an extrinsic variable. In this regard, recent findings by Dedkov & Moszherin (1992) have suggested that sediment yield in undeveloped (or logically young mountainous basins is 27 times greater than in other regions, but that this reduces to 3.7 times where development of the lowlands have occurred, doubling natural yields there. The hydroclimatic region where the MRB falls, is audited as the classification and yield of source, transfer and depositional zones, and as parametric variables of sediment caliber which synthesizes the intensity and duration of transport events. Geomorphology and fluvial science have been, to date, delving into lateral instability of river and streams. The behaviour of storages in the sediment system producing vertical instability and much larger sediment outputs through feedback to transient flow conditions is realized in the study. A good relevance on this, is the impact on river management of the Colorado extensively documented by Graf (1992).

Beginning broadly, the Manipur River Basin at the basin scale, is structured into a time-scale model effected by depth values. This has been done theoretically by Statham (1977) and empirically from historical investigations by Trimble (1974). Simple graphical techniques as specific guage plots (made by selecting flow discharges and plotting its storage versus time from measured stage-discharge frequencies and ratings) are used to quantify the non-equilibrium sediment transport where the outflowing sediment discharge from a river reach does not equal the inflowing sediment discharge to that reach. A variety of correlations have been developed for this purpose including parametric models for synthesizing the stream flows and sediment discharges as well as interpolation or interpolation of data from respective gauging sites. Assessment of the estimation of streamflows and their statistical properties have been examined by Chow

(1964), Crawford and Liasley (1966), Bever (1989),etc. A numerical based sedimentation/fluvial model is composed for providing the computational framework for analysis of regime values in the Manipur River Basin.

3.2.3 SIMULATION MODEL APPROACH

Determinate simulation and prediction of alluvial river behaviour require the use of numerical based models representing the basic hydrodynamics and sediment transport processes. Many computing computer-based programs/models are available for movable boundary simulations. The boundary values are very important and are selected which depicts past behaviour for model confirmation. Also, a different set of boundary conditions is reflected for future model prototypes. A one-dimensional (1-D) movable bed sediment model developed by the U.S Army Corps of Engineers - 'HEC-6' (USAEHEC 1993) is adopted to formulate the non-equilibrium case. The detail reviews and applications, extensively used throughout the study are presented in the forthcoming chapter.

Essentially, the models are the reflection of the knowledge of the processes. A categorized study to range the usefulness of conceptual mathematical model that have been developed (Leo C. Van Rijn, 1996) is added as a dimension to ascertain the knowledge base. The models are classified into two broad categories:

(A) Process-related Model - These are based on a detail description of all the relevant processes and implement a series of sub-models representing the fluid dynamics, sediment transport rates and bed level changes. These parameters are combined in a loop system to effectuate the dynamic interaction of the process involved. Example and application of the 1-D. HEC-6 model may be thus justified, in respect of other process-related models as 1-D morphological models, 2D river-bed models and 2D suspended-sediment models.

(B) Behaviour-related Models – These models describe the behaviour of morphological features or systems using relatively simple relations (graphical and expressions) to represent the phenomena pertaining in the Basins at larger scales of interest. The basic behaviour is described without much details and all the process-related information and additional empirical information is represented by coefficients, parameterized functional relationships and multivariate mapped (neural network based) solutions. In this way, behaviour-related models can integrate the process-related information representing the basic "driving functions/forces" and the long term phenomenological fluvial regime as based on field observations.

The above processes are coupled through linear, non-linear and multivariate interactions. As most hydrologic processes exhibit a high degree of temporal and spatial variability (as also the case in the Manipur River Basin) further plagued by non-linearity of physical processes conflicting spatial and temporal sales as well as uncertainty in parameter estimates; the extraction of relation between the inputs and outputs of the processes (without the physics being explicitly provided) is regulated with the help of Neurocomputing based tools.

The water quality, ecological or biodiversity standpoints in the Manipur River Basin are not covered in the study. The process models described above are focused on the stream flows and sediment carriage system.

3.2.4 G.I.S. INTERACTION

In proposing the computational framework and strategies to formulate the fluvial regime in respect of the spatial and temporal distributions, statistical averages for the entire study area or only for a certain location (such as watershed outlet) seems sufficient. Geographical Information System (GIS) technology and the numerical based models are linked to resource the data base viz. drainage network, sub-basins, stream morphological descriptions, etc. Where dearth of reliable data (as presented), GIS framework are effectively used to attribute the spatial data sets with validation from Topographic Map features. Topographic maps used to generate the river basin's drainage network structure cannot provide a realistic basis for structuring a changing landform on account of its dimension and dormant field based stratification (Graig N. Goodwin, James Dobrowolski and G. Allen, 2002).

The developments in GIS especially supporting multivariate temporal data processing enables a lucid visualization of the landform process models. The various fields associated with the fluvial processes such as terrain, land cover, soil properties, etc. can be represented in a GIS database in a discrete form as set of points (sites, lines or polygons) or rosters. Depending upon the model required, they can be transformed to continuous representations using expansions in an appropriate basis set such as multivariate component sets (Mitasova et al 1995).

In this study, LISS-III data (4 bands) along with Survey of India (SOI) Topographic data sheets are employed to access the drainage network pattern. The functional sector of the change in the extent of the Lake (the major storage unit) to the basin control is idealized with PAN (Panchromatic) sharpened LISS-III satellite image data (as in Fig 2.9) and the general longitudinal profile of the main - Imphal/Manipur River is derived from Google Earth image 2006, besides other validation of datasets.

3.2.5 SENSITIVITY ANALYSIS

It is desirable during the course of a study to perform a sensitivity analysis of the various data inputs used in the formulations or model. Field research so far has been mainly concerned with measuring bulk parameters such as discharges of water (Q) and sediment (Q_t), energy gradients, depth values (H) and cross-sectional areas (A_i). The values are resulted in a set of sediment transport formulae both analytically and/or numerically. However, the validities of these analyses/computations rely heavily on the input data, and the prediction of flow regimes for unscaled rivers other than producing `ripples or dunes' may not be clear (Van Rijn, 1996).

Quite often certain input data (such as inflowing sediment load) might be subjected to substantial measured errors, corrections at the site are virtually not done. The impact of these uncertainties on the Model (HEC-6) results are studied by modifying the `suspected' input data by standard deviations, regressive, auto-regression methods and re-running the simulation. These initial data preprocessing and checking is applied effectively to exemplify the other complexities of rapidly-varying flow directions in two of the river channels (viz. Khordak and Ungomel) as well as the institution of backwaters/hysteresis effects on the specific Guage-Discharge (G-Q) plots. If wide change in the simulation results the uncertainty in the input data may be negligible. If however, large changes occur, refinement in the input data using the techniques mentioned above along with interpolations and interpolations need to be carried out. Multi-variate transformation based plots of validation results also reflect the sensitivity of the input parameters.

Sensitivity tools and studies performed in this manner will provide sound insight into the prototype's behaviour and should lead to the model description of the `real' fluvial hydrosystem.

3.2.6 SEDIMENT TRANSPORT FACTORS/PARAMETERS

Bulk Sediment Properties

As dealing with the alluvial rivers and streams (the Manipur River basin)not only involves the collection of several individual particles, but also with each particle considered as a separate entity. In other words, the phenomenon of sediment transport in Fluvial hydraulics, needs consideration of the properties of individual particles as well as the bulk properties of the sediments.

Based on the sediment sample analysis records, a 'Sediment Distribution / Gradation' curve is plotted (Fig 3.2.1) which serves the as one of the major baseline to the study.

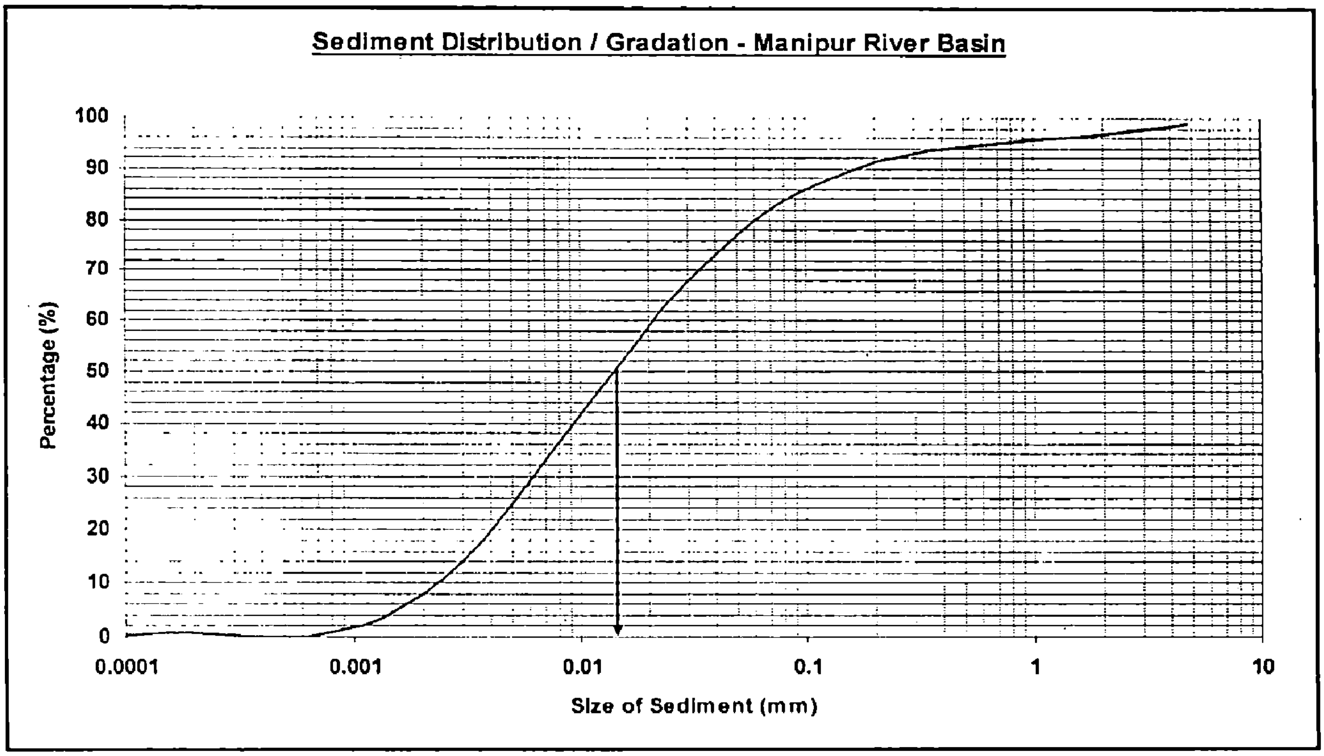


Fig 3.2.1 – Sediment Distribution / Gradation in Manipur River Basin

Referring to the sediment gradation or distribution curve (fig 3.2.1), some of the properties worked out are :-

i) *Arithmetic Standard Deviation*

$$\sigma = d_{50} - d_{15.9} = 0.015 - 0.0033 = 0.0117 mm$$

ii) *Geometric Standard Deviation*

$$\sigma_g = \frac{d_{50}}{d_{15.9}} = \frac{0.015}{0.0033} = 4.545$$ (lying between the normal range of 2.0 to 4.80)

iii) *Sorting coefficient*: (which is a parameter to describe the spread of the frequency distribution curve)

$$S_0 = \sqrt{\frac{d_{75}}{d25}} = \sqrt{\frac{0.044}{0.005}} = 2.9664$$

TABLE 3.2.2: SEDIMENT SIZE DISTRIBUTION, UNIT WEIGHTS - MANIPUR RIVER BASIN (MRB)

Sl.	Classific-ation	Sediment ID (HEC-6)	Size	Geometric mean (d_i)	%(P_i) Distri-bution	In Fractions	Unit (γ_0) weight respective	$\sum d_i \Delta p_i$	$\sum r_{o_i} \Delta p_i$
			(mm)	(mm)	(%)	Col(6)/100	KN/cum	(5)x(6)	(6)x(8)
1	Clay	CLAY	Less than 0.002	0.001 (*assigned*)	8.20	0.082	1.89	0.0082	15.498
2	SILT :								
2.1	Very Fine Silt	SILT I	0.002-0.008	0.004	26.9	0.269	7.56	0.1076	203.364
2.2	Fine silt	SILT 2	0.008-0.016	0.011	17.6	0.176	10.235	0.1936	180.136
2.3	Medium silt	SILT 3	0.016-0.031	0.022	16.5	0.165	10.620	0.363	175.230
2.4	Coarse silt	SILT 4	0.031-0.0625	0.044	14.0 (Percentage Silt *=75.0%*)	0.140	11.39	0.616	159.460
3	SAND :								
3.1	Very fine sand	VFS	0.0625-0.125	0.088	7.75	0.077 (50%) finer demarcation)	12.36 $\sum_{0}^{50} d_i \Delta p_i$	0.682 ***1.9704***	95.79
3.2	Fine sand	FS	0.125-0.250	0.177	4.75	0.048	13.32	0.841	63.27
3.3	Medium sand	MS	0.250-0.500	0.354	2.30	0.023	14.42	0.814	33.166
3.4	Coarse Sand	CS	0.500-1.00	0.707	2.00 (Percentage Sand *=16.8 %*)	0.020	15.21 $\sum_{50}^{100} d_i \Delta p_i$	1.414 ***3.069***	30.420
	Total :								**956.334**

- The Unit weights are obtained from interpolations as given in APPENDIX .

iv) *Kramer's Uniformity coefficient (M)*: (another parameter for frequency distribution of particle sizes)

$$M = \frac{\sum_{0}^{50} d_i \nabla p_i}{\sum_{50}^{100} d_i \nabla p_i} = \frac{1.9704}{3.069} = 0.642 \quad \text{(As per table 3.2.2)}$$

As, M is less than 1.0, the sediment sample is non-uniform.

Notations:

$d_i, d_{50}, d_{15.9}, d_{84.1}, d_{75}, d_{25}$: particle size /diameter at respective percentage distribution (from sediment gradation curve),

∇p_i = percentage weight corresponding to size d_i

iv) *Unit or Specific Weight* : It is defined as the dry weight per unit volume of sediment in place.

For non-uniform materials the specific weight is given as:

$$\gamma_0 = \frac{\sum \gamma_{0i} \nabla p_i}{100} = \frac{956.334}{100} = 9.563\, KN/m^3 \quad \text{(refer to table 3.2.2)}$$

Sediment Transport Factors :

To determine the hydraulic conditions at which the sediment particles of given characteristics and properties starts moving (incipient motion condition), the following factors/parameters are evaluated in respect of the major rivers of the Manipur River Basin

A. Depth of Flow:-

i) *Imphal/Manipur River*

General slope, $S = \frac{1}{7900}$

Relative density of particles =2.65

Kinematic viscosity, $\upsilon = 10^{-6}\, m^2/\text{sec}$

Particle size diameter,adopting median size $d_{50} = 0.015mm$

Adopting the *Critical Tractive Force* approach which is based on the equilibrium of a sediment particle resting on the bed under the action of drag and lift forces caused by the flow and the submerged weight of the particle. It is expressed as,

(a) *Shield's Approach*:-

Average shear stress (τ_0) = critical shear stress(τ_c)

And,

$\tau_0 = \gamma_f RS$ where, γ_f-specific/unit weight of water

R-hydraulic radius

S- channel slope

For wide channels ≅ Depth of flow =D, so that

$\tau_0 = \gamma_f DS$ --- -----------------(i)

τ_c as per Shield's criteria is expressed as,

$\frac{\tau_c}{\nabla\gamma_s d}$ = 0.06 where ,d = median grain size diameter (d_{50})---------(ii)

So, for incipient motion's condition,

$\gamma_f DS = 0.06\nabla\gamma_s d$

i.e.

$$D=\left(\frac{\nabla\gamma_s}{\gamma_f}\right)0.06\frac{d}{S}=\left(\frac{\gamma_s-\gamma_f}{\gamma_f}\right)0.06\frac{d}{S}=\left(\frac{\gamma_s}{\gamma_f}-1\right)0.06\frac{d}{S}=(2.65-1)\times 0.06\times\left(\frac{0.015\times 10^{-3}}{1/7900}\right)=0.012m$$

(b)*Yalin and Kraham approach:-*

The limiting value of the dimensionless critical shear stress $(\tau^*_c)=\frac{\tau_c}{\nabla\gamma_s d}=0.045$

Proceeding in the steps as above,

$D = 0.0088$m

CHAPTER 4

MODEL FORMULATION AND DEVELOPMENT

4.1 DATABASE

Studies and planning done on the Manipur River Basin (MRB) has been experiencing a lack of sufficient and refined hydrological database ; old records are still more dearth . In the 'Identification Report of Development of Loktak Lake' prepared by the WAPCOS (1988), certain suggestions were made to the state authorities for collection / observation of various data. Even the Loktak Multipurpose Project was formulated based upon parametric and assumed data, where for such an intricate hydro-system, a dependable database spread over a fairly large number of years is absolutely necessary to implement any project or basin planning. The Loktak Development Authority (LDA) , a State Government Agency, has been taking up the charge for assimilating detailed observations as guage-discharge on existing stations as well as establishment of stations on unguaged rivers /streams, sediment discharges,cross-sections, water levels, rainfall and other metorological values, etc . The present study is based mostly on the lines of datasets observed by the LDA.

4.2 DATA PRE-PROCESSING

As a certain degree of uncertainty is associated with hydrologic frequency distributions on relative time scales, the sensitive response function of the river / stream as Stage - Discharge (G-Q) relationships , Sediment discharge Rating (Q_t –Q) curves, Streamflow Hydrographs, etc needs to adequately represented from the observed field data. The Manipur River Basin in terms of its complexity calls for well-defined response models. In the study, some of the significant steps followed are outlined as :

Temporal Data :

(i) The first step is the abstraction of outliers and errors in the data sets. Conceptual or statistical tools as regression and curve fitting were implemented on the variables pertaining to each specific river / stream to identify the irrational points, They were either discarded or rectified based on the earlier trends or pattern of the data.

(ii) The datasets are then sorted strictly on a **base time scale. Daily** record data sets pertaining to the main rivers/streams and Loktak lake are chosen for the study as to factor the highly transient hydrodynamic conditions in the basin. For this study, the period between March 2000 to April 2002 gas been adopted as the base time scale for the framing of the channel-basin response parameters and the model formulation .

Spatial Database :

As this data variable is presume to change nominally over time , the morphological parameters in the Manipur River basin (MRB), are derived from IRS-1C LISS III satellite image data. The details of the image are :

Georeferenced to: Geographic (lat/lon)
Spheroid : Everest
Datum : Indian (Bangladesh)
Map Units : DD

Images of 1998 and 2002 were georeferenced to the above geo-position. Topographical index locations of gauging stations and minor features as stream channels were identified and validated with Survey of India -topographic sheets of the region.

4.3 DEVELOPMENT OF HYDROLOGIC AND FLUVIAL RESPONSE PARAMETERS

The hydrologic response of the basin requires an algorithm or rule development to coherent the regime prevailing as observed from the preliminary statistical analysis of the stage-discharge trends and streamflow hydrograph. The long term rainfall and run-off plot (from 1923) in Fig 4.1 gives an idea of the variance.

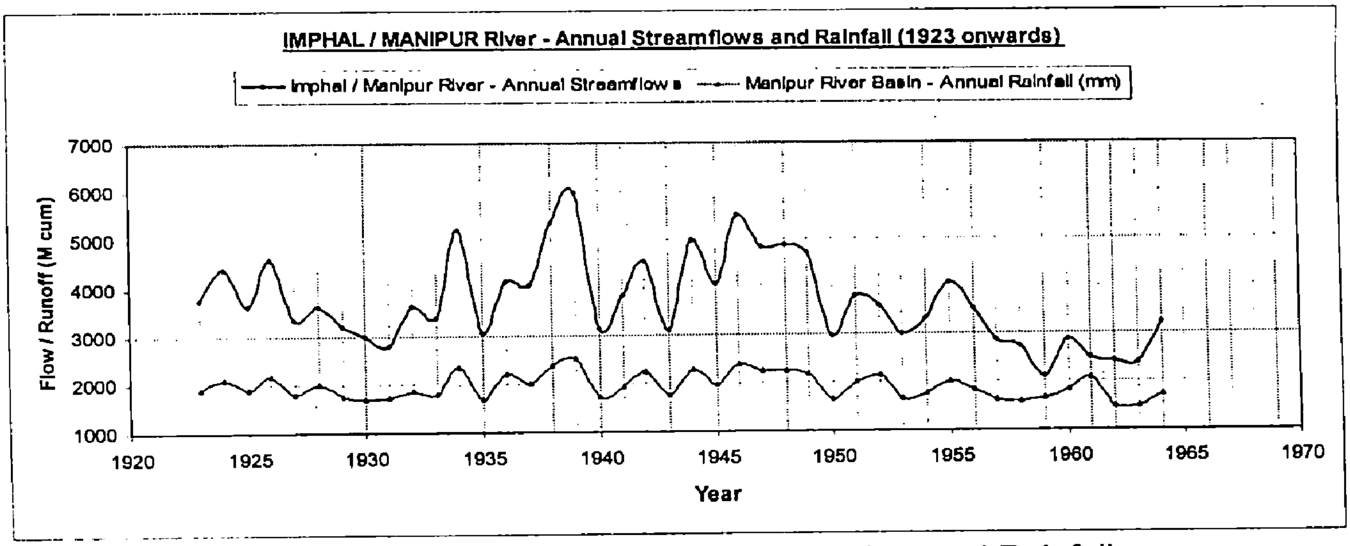


Fig 4.1 Annual Flows in Imphal / Manipur River and Rainfall

It can be further seen that the Rainfall and Flow doesn't follow a frequency as based on simple regression plots as in Figs 4.2 and 4.3 . **Flow Hydrographs** of some of the rivers under the study is plotted in Figs 4.4-1 to 4.4-4. The particular form of a Fourier series translation can be seen in the case of Khordak channel having Inflow(+ve) and Outflow (-ve) discharges (Fig 4.4-3). A Flood Frequency of 1 in 100 years is adopted based on early records .

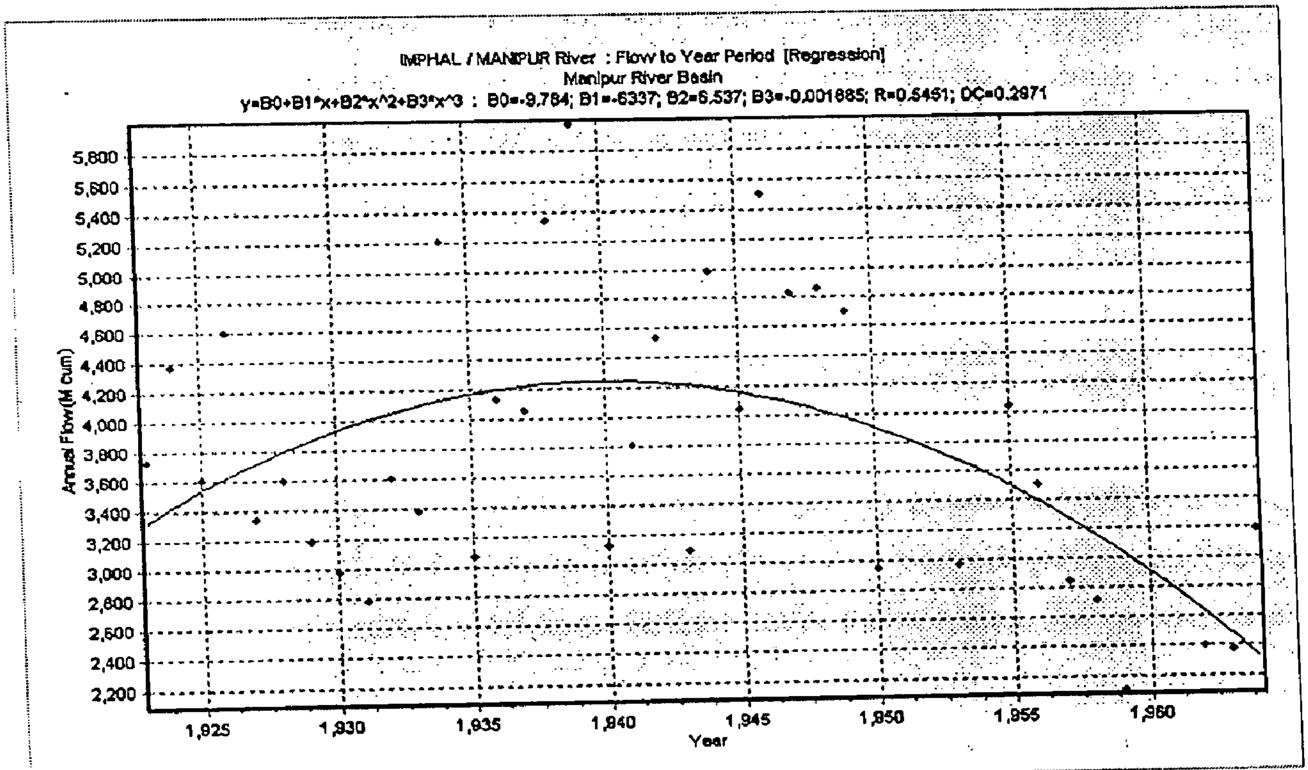


Fig 4.2 Annual Imphal / Manipur River Flow

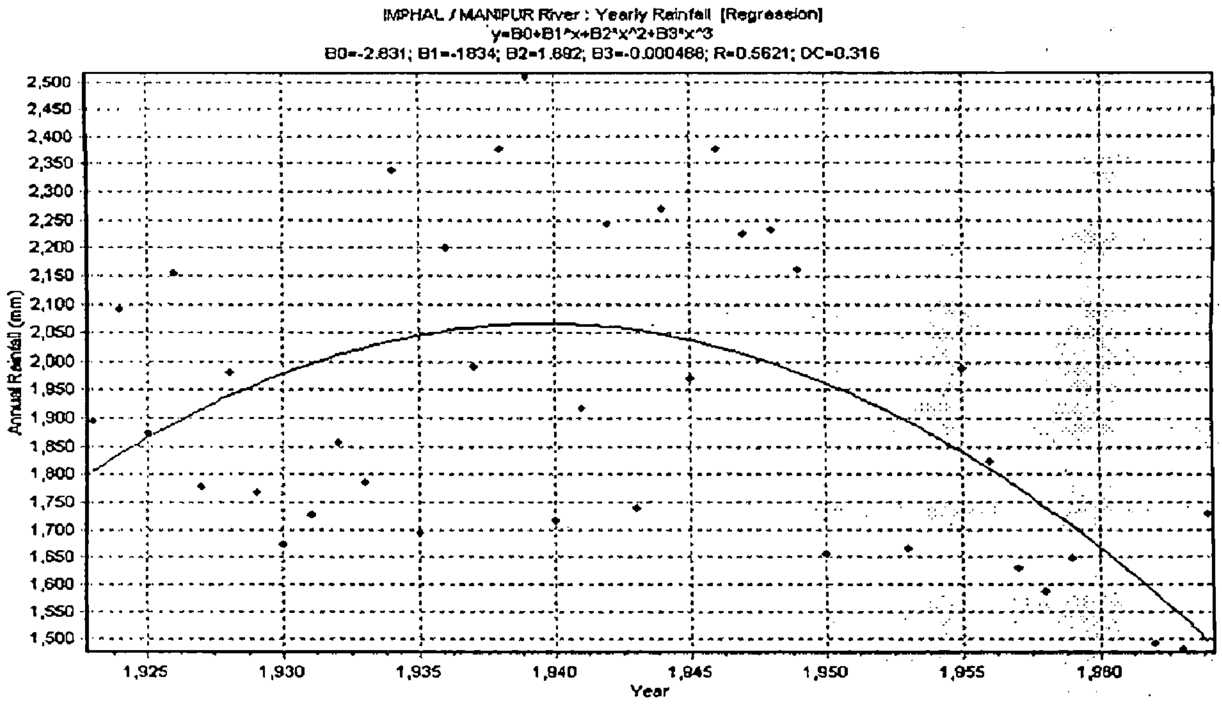


Fig 4.3 Annual Rainfall in the Basin

4.3.1 STAGE-DISCHARGE (G-Q) RELATIONS :

As sensitive inputs to the Model boundary values, the Stage - Discharge relations, the G-Q relations of the major rivers/ streams under consideration needs to sufficiently dictate the hydraulic behaviour . In the course it has been found that simple curve-fitting is not satisfactory. This may be indebted to the hysteresis / loop effects and or other related phenomena characterizing the basin. As ruled by Maha et. al (July, 1997), sometimes the relationship between stage and discharge cannot be represented by a single regression equation, because it exhibits hyteresis.

Multi-variate regressions in the foundation of parallel processing elements or neuro computing backed tool is extensively used to find the best G-Q relation in the major rivers of consideration viz., Imphal river-I (as in the upper reaches) , Imphal / Manipur river-II (in the lower reaches), Nambul river, Nambol river and the two interlink channels- Khordak and Ungamel (the other main rivers as Iril, Thoubal, Sekmai, etc are not taken up as considered of their tributary mean discharge function to the arterial

FIG 4.4-1

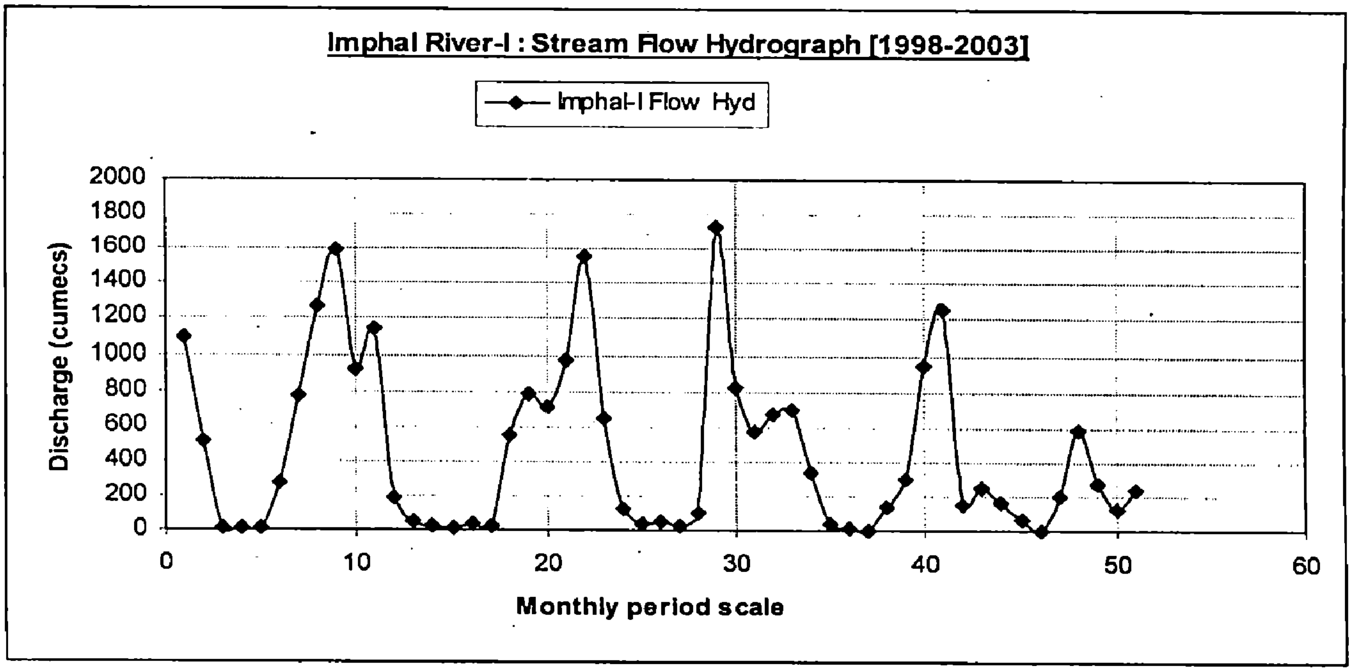


FIG 4.4-2

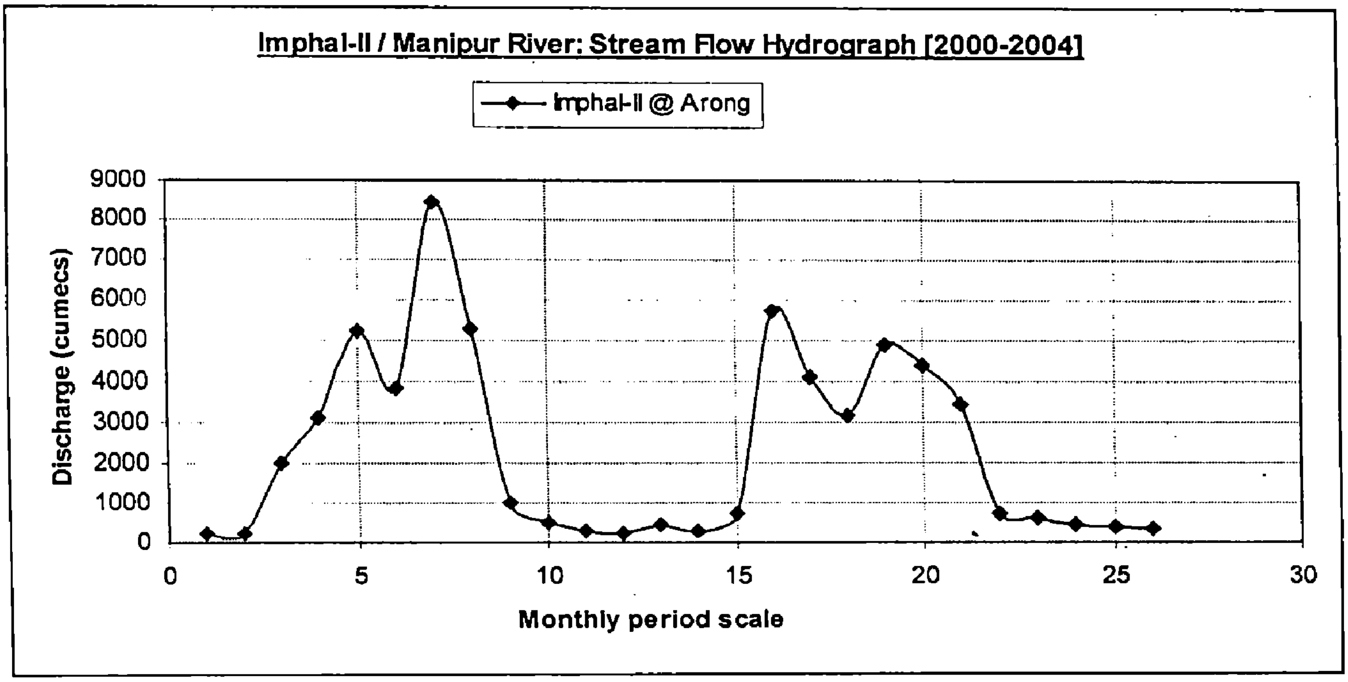


FIG 4.4-3

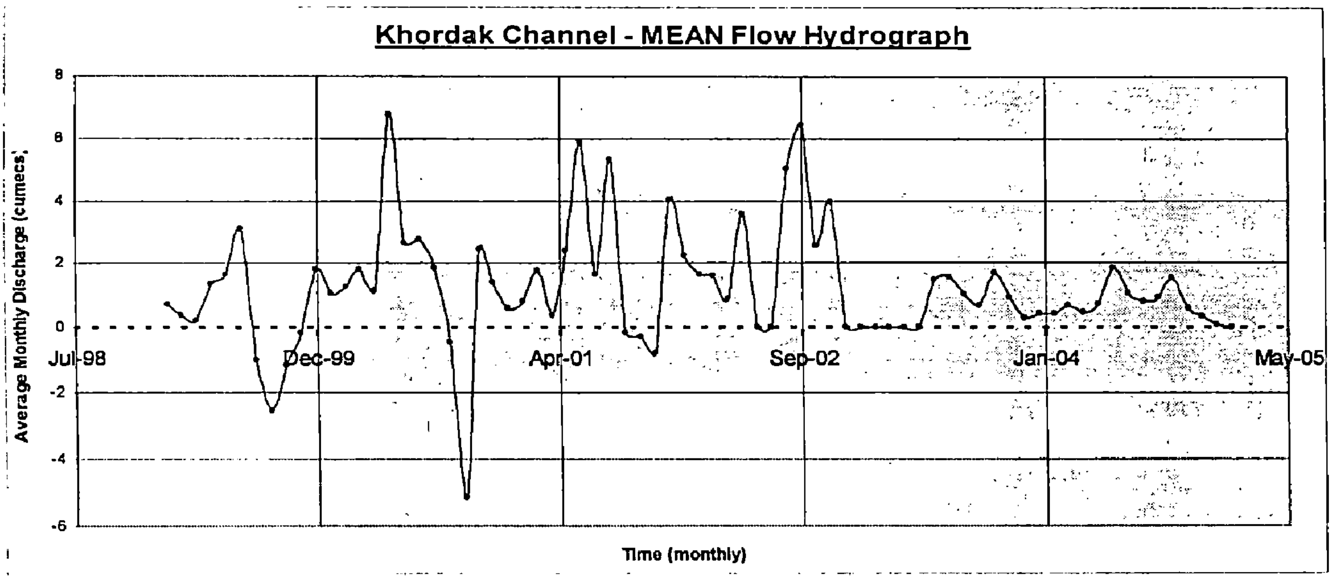
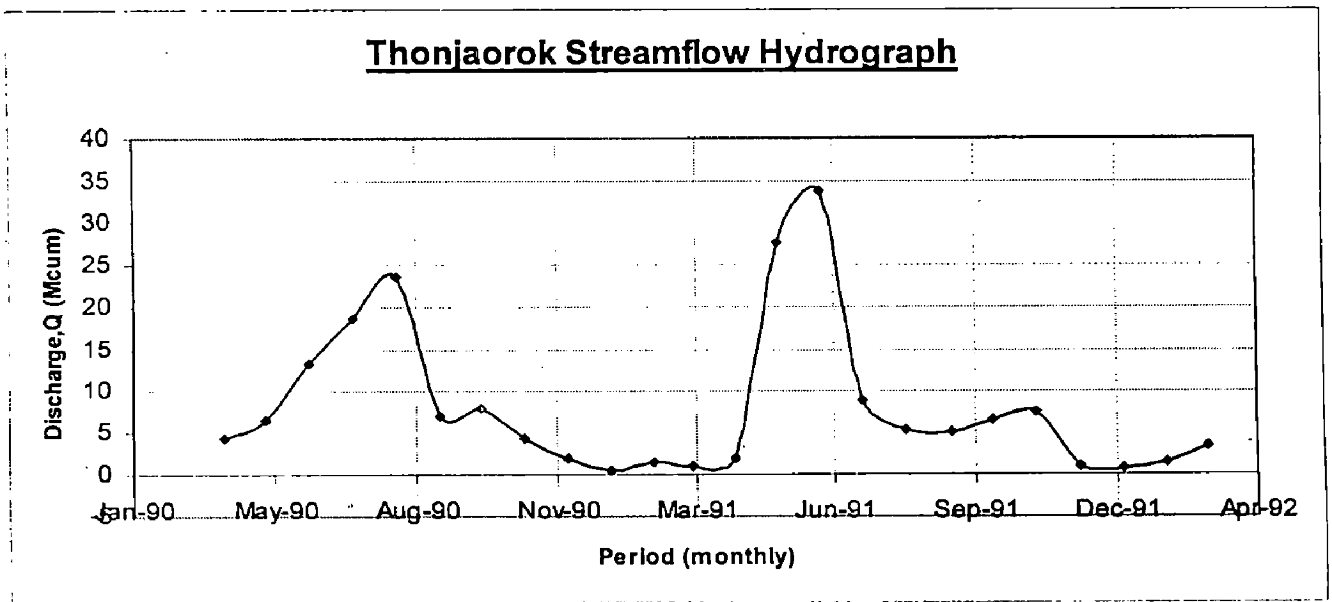


FIG 4.4-4



Imphal / Manipur river in the model). A trial and error procedure was carried out to obtain the best correlation . The G-Q curves are listed in Figs 4.7-1 to 4.7-18. During the process in cases where distinct shifts in the guage records are found, then it was delineated into two or more parts, each partial G-Q relation developed to ascertain the total relation. **Station No-1** is assigned at the section at the **meeting point with the Imphal / Manipur River** and **Station No-2** is assigned at the **Loktak lake confluence reach** in the cases of Khordak and Ungamel channels .

It can be seen that the relation varies in a range of polynomial functions upto the 6^{th} order to inverse functions.

4.3.2 SEDIMENT DISCHARGE RATING (Q_t –Q) CURVES :

To estimate the sediment load transported by the rivers in the basin, respective sediment discharge rating curves are developed based on field measured data. It is a relation between the sediment and streamflow discharge. The average sediment concentrations are not used to plot because of invariability and lack of concise record data. Instead, the sediment discharge quantity (in terms of kgs per day) is used as the main function to develop the sediment rating curves for the major rivers in the MRB. Rating curves have been developed on the premise that a stable relationship between the concentration and discharge, although exhibiting scatter, will allocate the mean sediment yield to be determined on the discharge annals (Archana Sarkar et.al , 2004). Regression relations are used to inhibit the wide scatter by minimizing the sum of squared deviations from the original dataset used. The introduction of bias that underestimates the the sediment load at any discharge may be as much as 50 per cent (Fergusson, 1986).

This relation defines a fluvial entity in the hydraulic characteristics of a river in respect of its sediment carrying capacity.The sediment discharge or the volume of sediment passing through a cross-section per unit time is a function of the supply of sediment, mean velocity and depth of water, and the slope and cross-section of the channel (Gregory C. Ohlmacher et. al , 1998).Generally , a rating equation takes the form : $Q_t = aQ^b$, where S is the sediment load (or concentration) , Q_t is the discharge and a &b are regression coefficients.

Linear to multi-linear regressions are again employed to give the best fitting equation for the major rivers under study at their respective gauging sites. Except for the interlinkchannels – Khordak and Ungamel channels where the fitting equation takes the form :

$$Q_t = Q / (bQ + a),$$

The standpoint equation is reasonably found to give good correlation (R^2) values. Also a one to two order of magnitude variation in the sediment discharges exists for the water discharges in the rivers of the basin.

This response unit is assumed to take care of the upstream or upland erosion sediment yield and transport in the study. The final estimation of annual or monthly sediment loads or budgets are based on the Q_t -Q curves.The variation in the sediment discharge versus the flow is checked for a limit value by adopting multi variables associated with the flow such as velocity, cross-section area, etc. Simons et. al (1984) states that a 5% chance exists that the actual value for the yearly sediment capacity is either 3 to 4 times lower than the calculated value. A 50% chance exists that the actual value is either 1.5 times higher or lower than the calculated value. Evaluations are confined to a daily period (single day) basis in the study.

The Sediment Discharge Rating Curves of the major rivers are given in Figures 4.7-1 to 4.7-18.

4.3.3 SENSITIVITY AND VALIDATION OF THE 'G-Q 'AND 'Q_t–Q' PLOTS

The sensitivity of the flow and hydrologic variables : discharge, stage, sediment discharge, flow velocity, etc are tested on the defined base time scale for each river at their respective gauging sites. The adoption of dependable discharge or run-off of the rivers in the MRB on short term records taking into view the unavailability of long term records is validated with (i) multi-variate regression, (ii) auto-regressive models and (iii) Neural computing (ANN) based optimal algorithm functions.The tools are extensively used to optimize the frequency distributions on the run-off / discharge volumes and sediment discharge.

The interdependency and identities between the hydro-variables are checked with transformations of a particular variate with respect to other respective variables for the same period. For instance , the discharge flow is transformed respectively with the stage, sediment discharge, velocity , etc and the resulting correlation (equations generally of the polynomial order upto 6 in multi-linear and auto-regressions , and mixed exponential and trigonometric functions in case of the Optimal (Genetic) algorithm approach) is compared to the G-Q and Q_t –Q relations of the particular river, as well as old records (if available). In case there is a large variation in the correlated values with respect to the magnitude of the data, then a selected, transformed or additional dataset is used to define the relation better.

The sensitivity tests carried out in some of the main rivers are presented in Figs 4.7-1 to 4.7-18 . Undetermined variance in the plots could be noted in case of the interlink channels, as whereby the correlation value [as high as 0.8995 in case of Khordak (stn-2) outflow was computed and the resulting plot of the transformed discharge values with respect to the other variables show a wide margin in the trends, Fig 4.7-10].

4.3.3 EFFECTIVE DISCHARGE (Q_e):

Restoring streams to a stable form through natural channel design requires detail information about surface water hydrology and the interactions between rainfall and overland flow or runoff. The channel-forming or effective discharge is adopted to be most practical flood discharging value for ascertaining the sediment load transport and sizing of the channel dimension (if the stream restoration requires re-shaping the channel). **Effective discharge** is defined as the discharge that transports the largest percentage of the sediment load over a period of many years. The effective discharge is defined as the flow which transports the most sediment over the period of record (Goodwin P, 2004). Effective discharge is the peak of a curve obtained by multiplying the flood frequency curve and the sediment discharge rating curve (Figure 4.5-1).

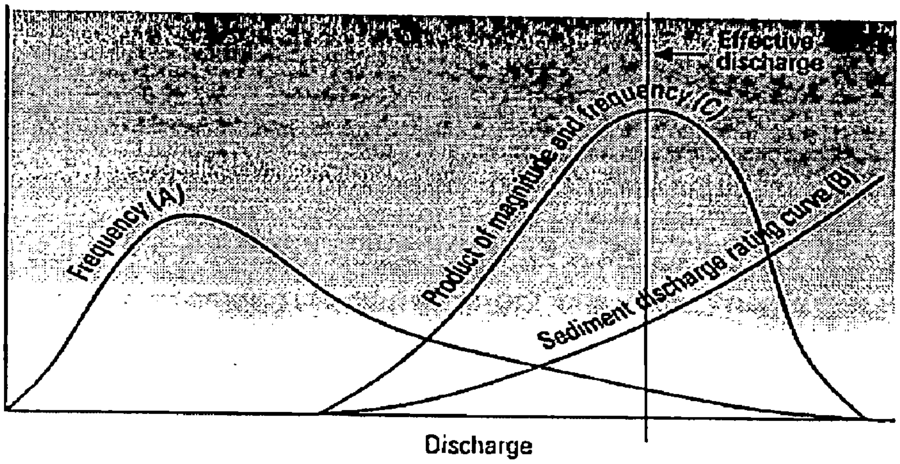
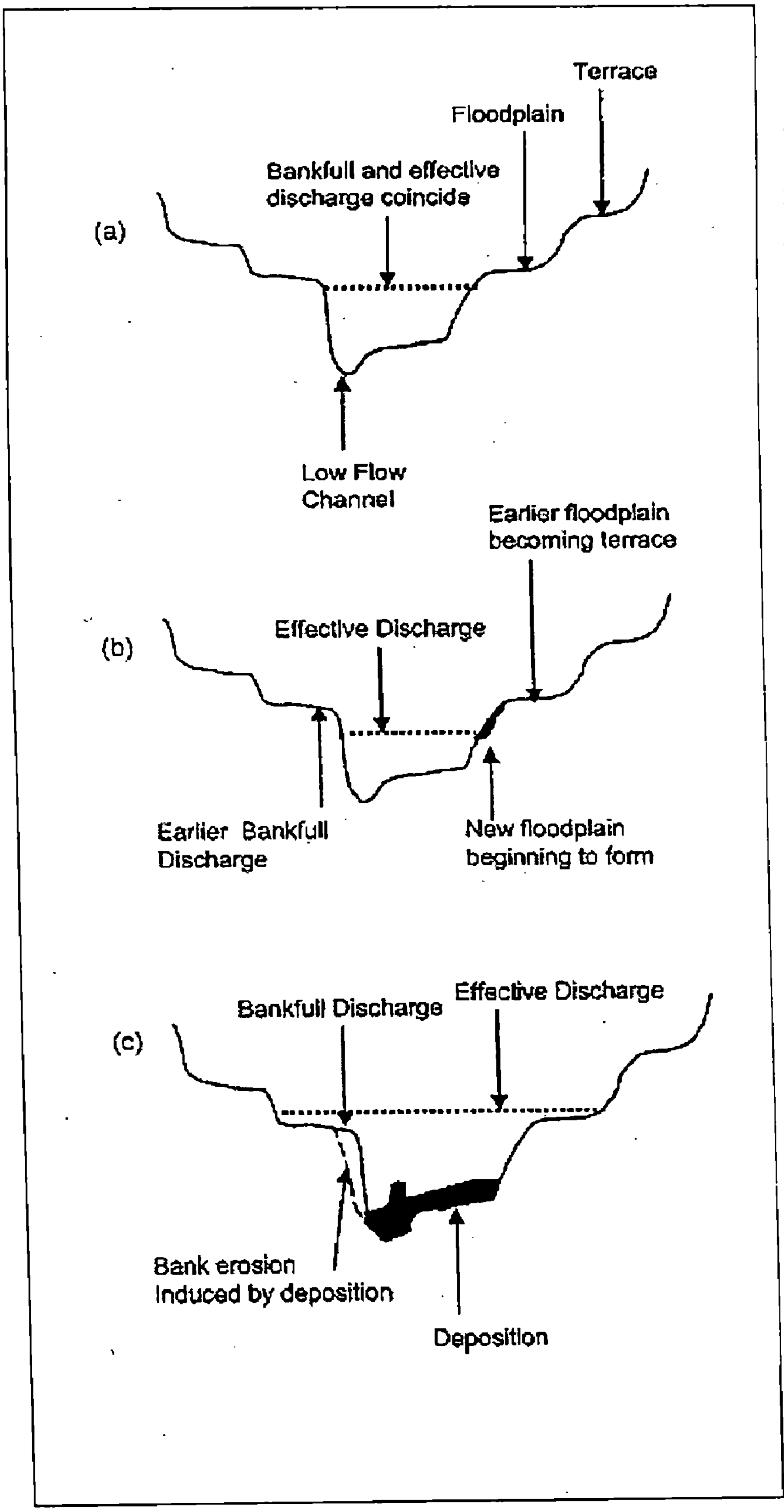


Fig 4.5-1 Effective discharge determination from sediment rating and flow duration curves. The peak of curve C marks the discharge that is most effective in transporting sediment. (Wolman and Miller, 1960)

A discharge with selected recurrence interval or the effective discharge, Qe or function of Qe (Williams, 1998), is the flow that transports the maximum amount of sediment over time. This study model is effectively based on the developed effective discharges underlain on the flow and sediment discharge frequencies of the various major rivers and adopted to be the asymptote of fluvial regime in the basin.

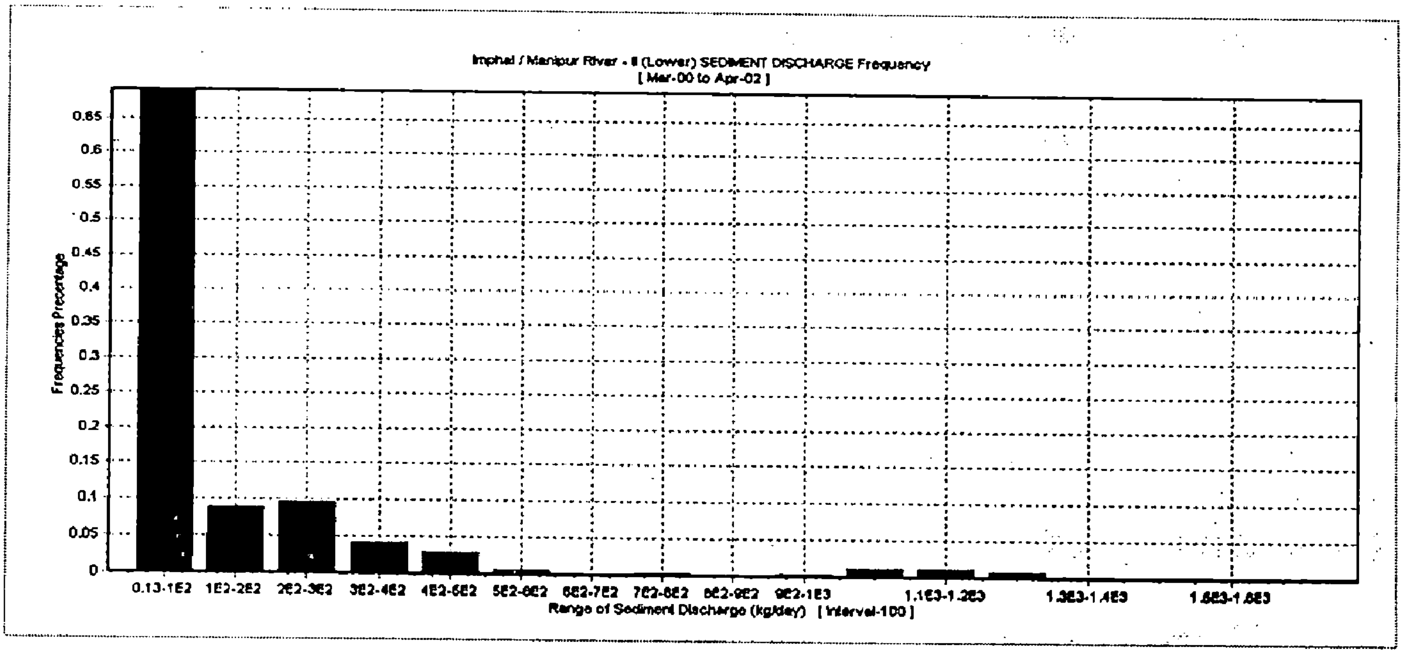
The Effective Discharges developed for input in the sediment transport model are listed in Figures 4.8-1 to 4.8-6. Recurrence intervals are chosen on the appropriate range of discharge and sediment discharges for particular rivers to obtain a fair distribution. An illustration on the method as with the case of the Imphal /Manipur river-II (lower reach) is given in Fig 4.6.



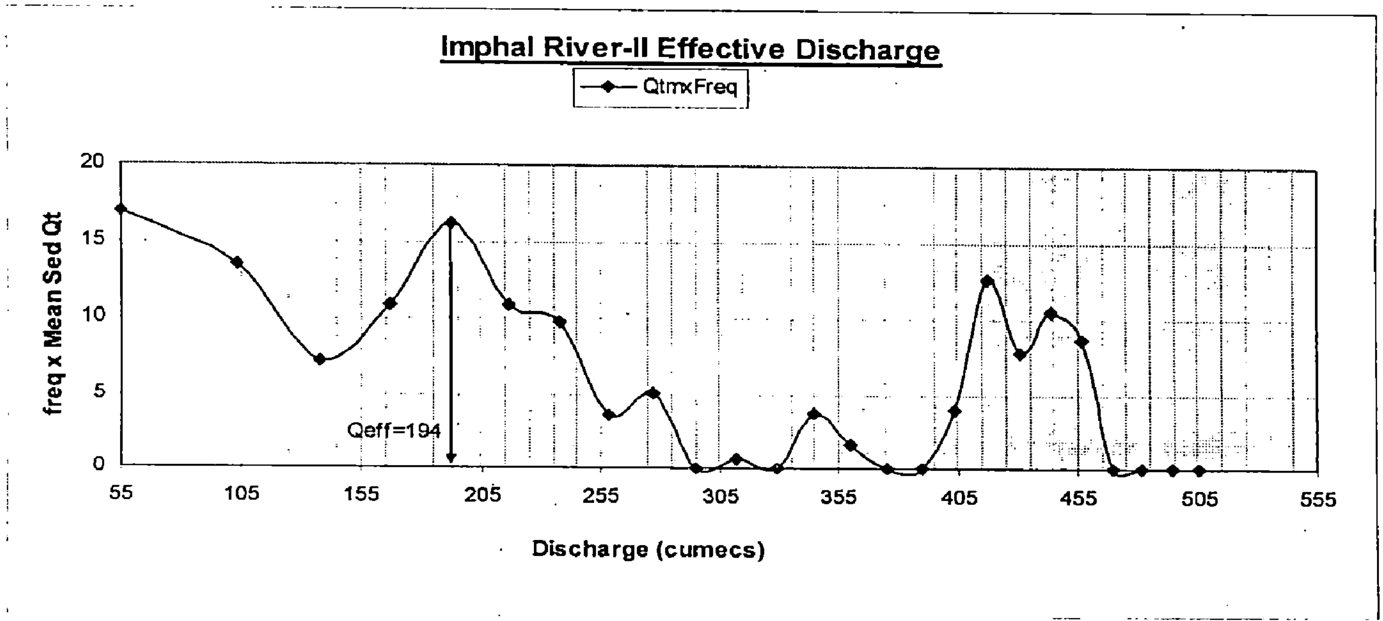
Effective discharge can be based on field measurements, a chosen recurrence interval of flooding or related to the Dominant discharge. Theoretical relation between the effective and bankfull discharges for (a) channel in dynamic equilibrium, (b) incising channel,and (c) aggrading channel are illustrated in Fig 4.5-2.

FIG 4.5.2 Effective and Bankfull Discharge Relations

FIG 4.6 Effective Discharge determination – Sediment Discharge Frequency and combined plot with Flow discharge : (Imphal-II / Manipur River)



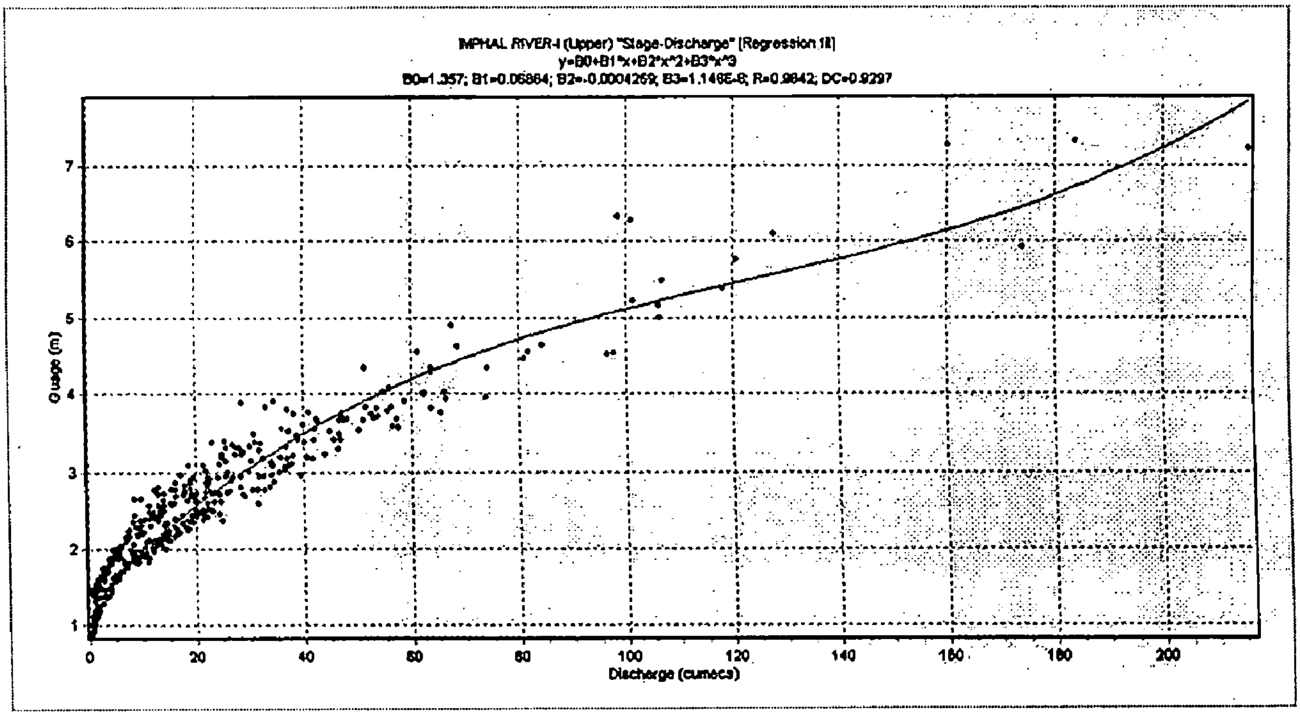
(a) Sediment Discharge frequency (in selected interval)



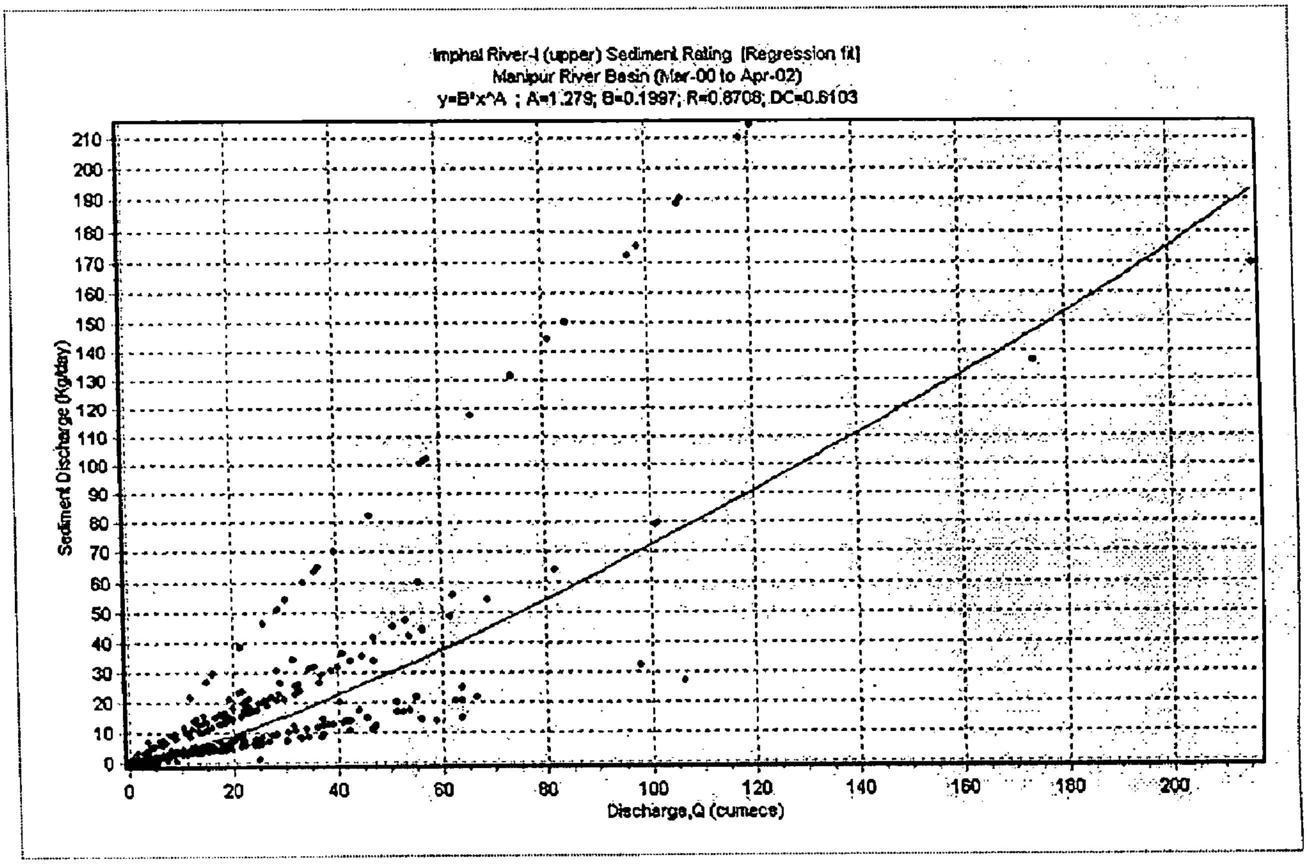
(b) Combined Frequency and Sediment Discharge plotted wrt Discharge

The highest peak in the curve gives the value of Effective Discharge (Q_e).

FIG : 4.7-1 Stage-Discharge and Sediment Discharge Rating – Imphal River-I (upper)

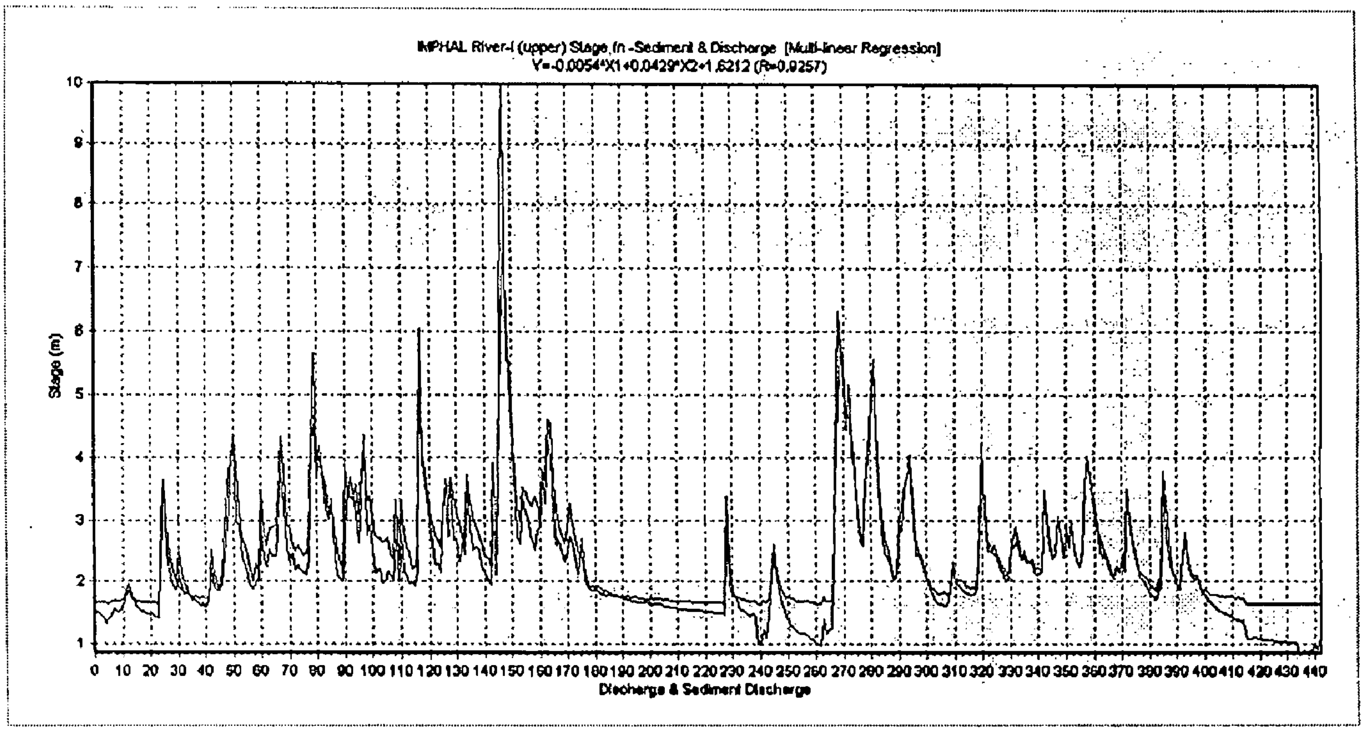


(a)

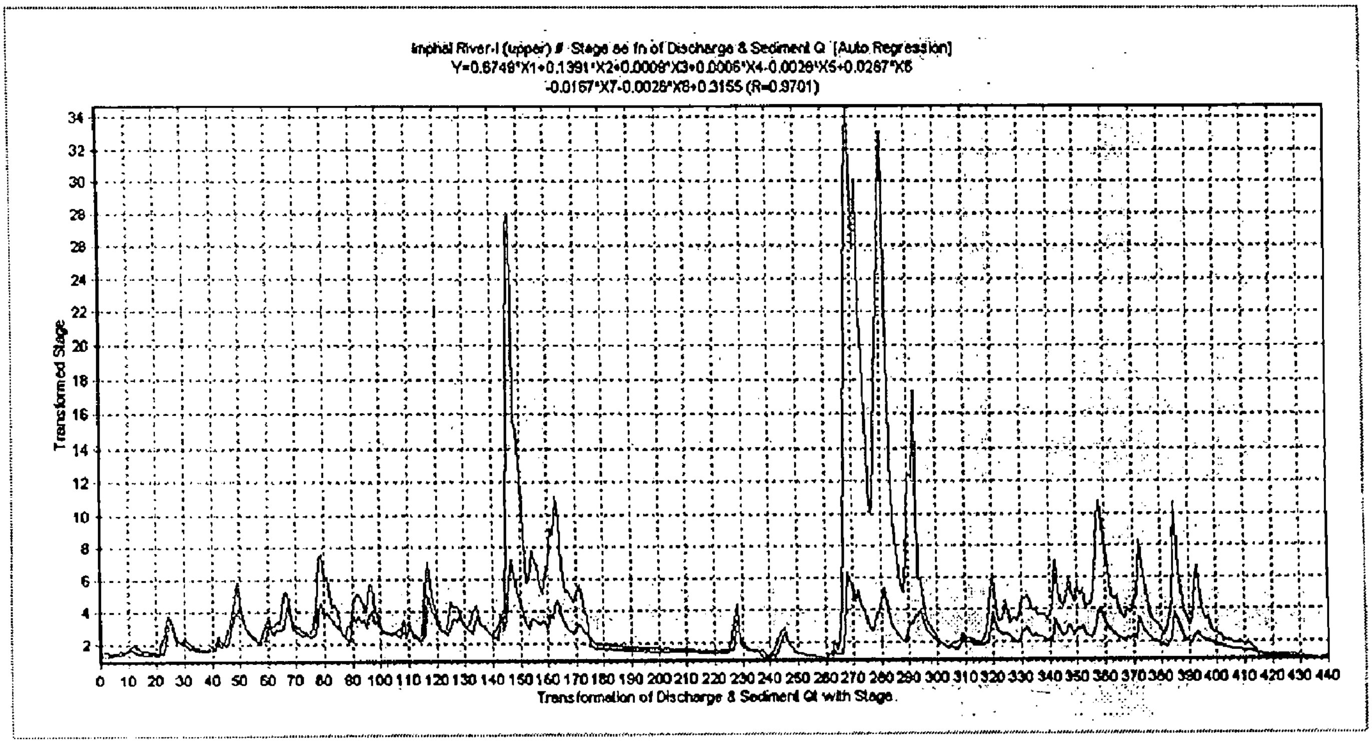


(b)

FIG 4.7-2 Multi-Linear and Auto Regression Models – Imphal River-I

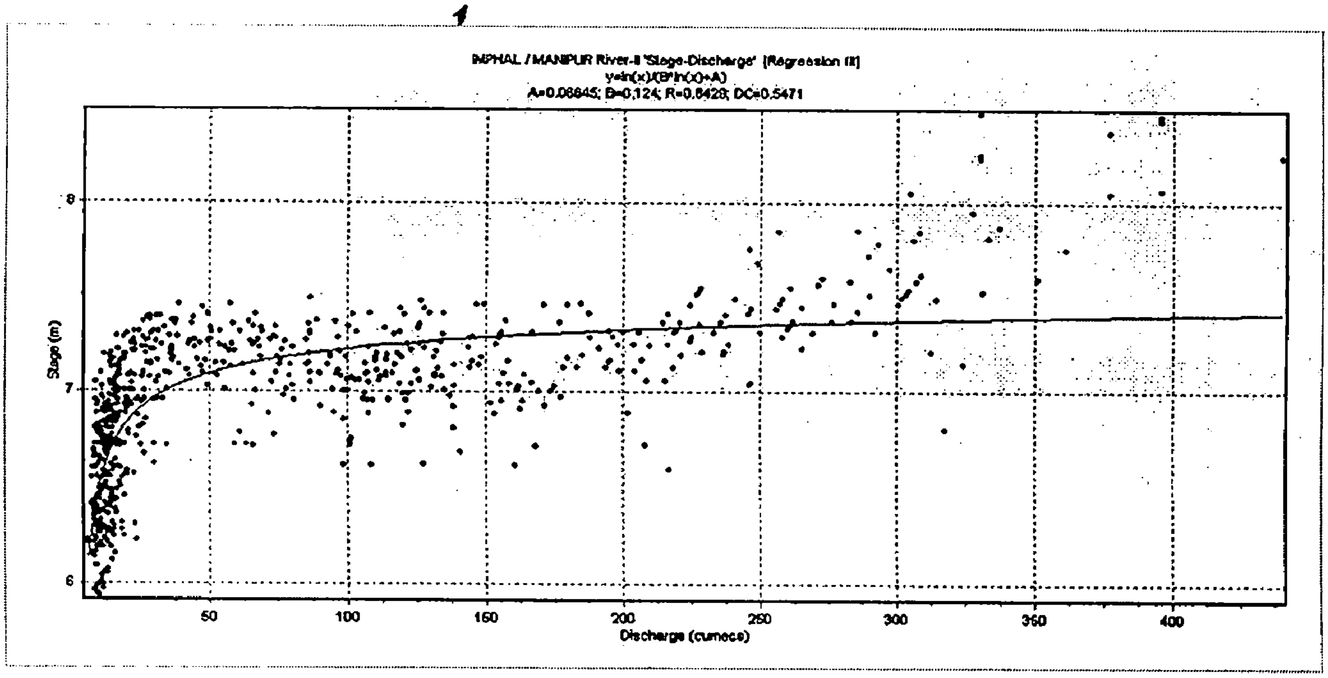


(a)

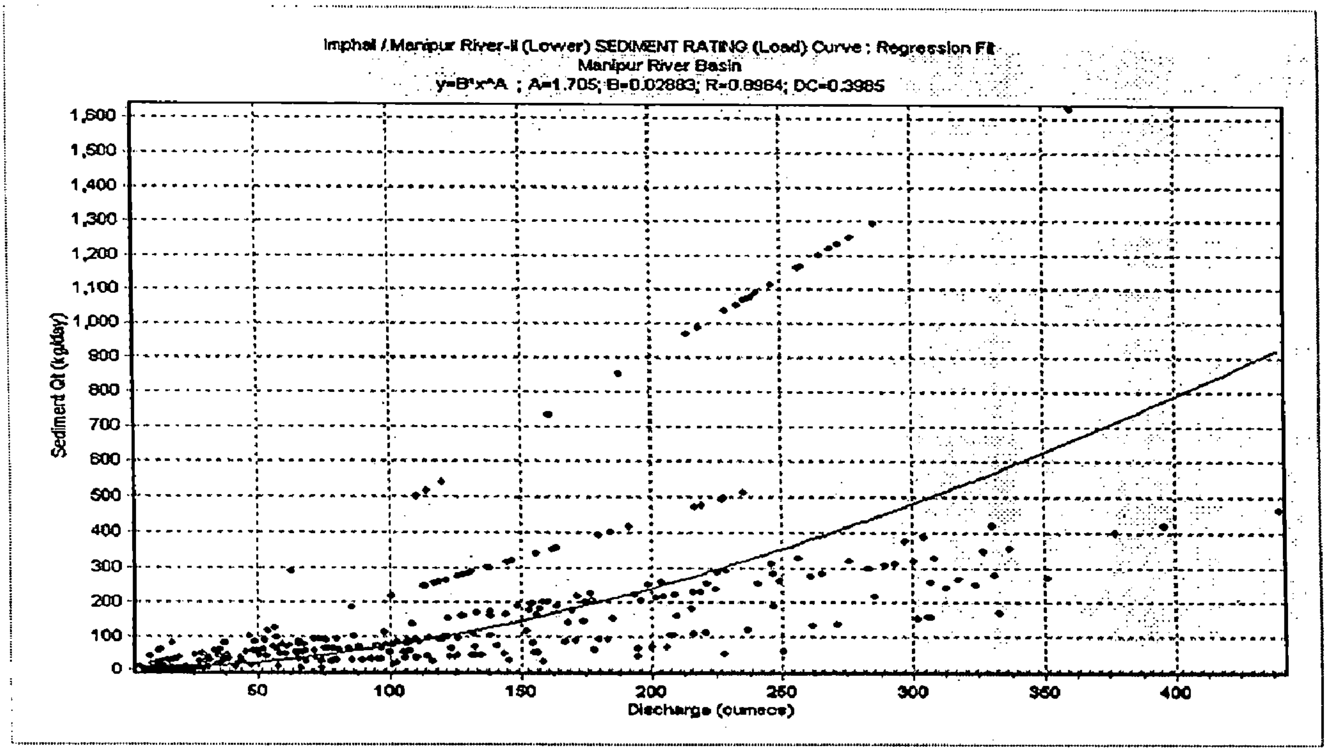


(b)

FIG :4.7-3 Stage-Discharge and Sediment Discharge Rating – Imphal River II (lower)

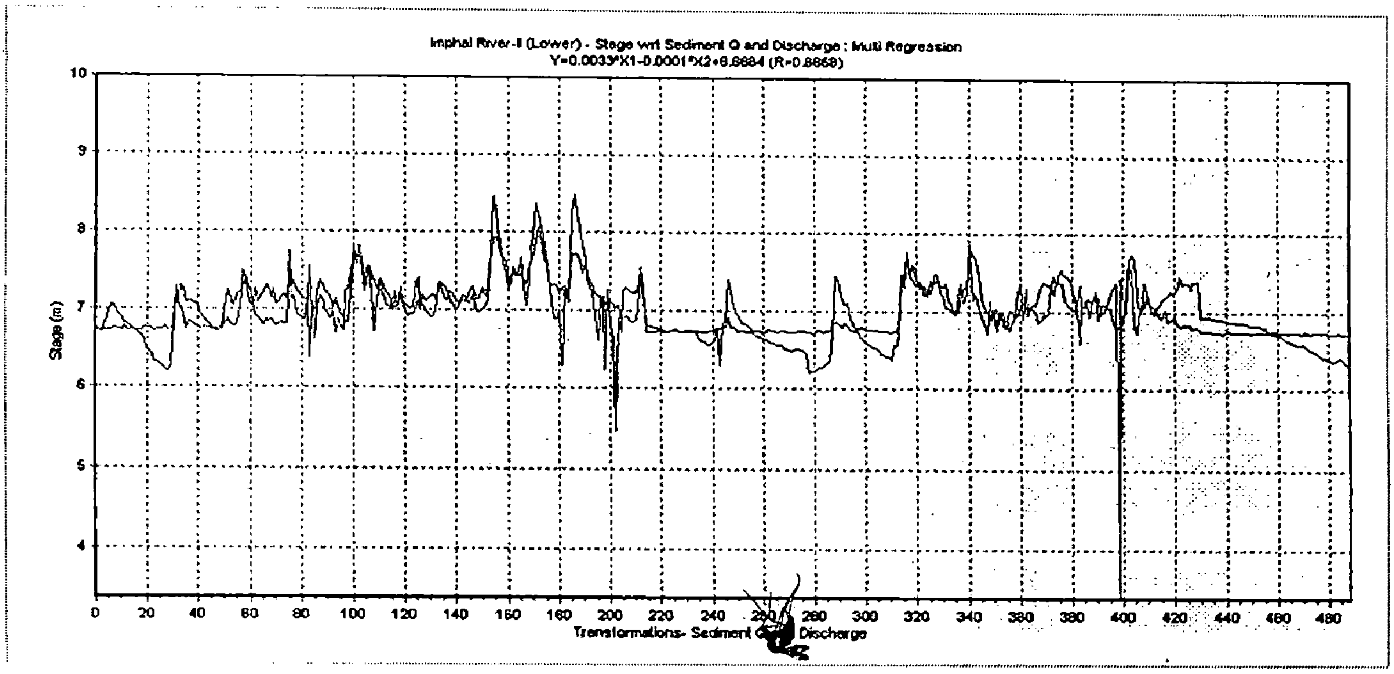


(a)

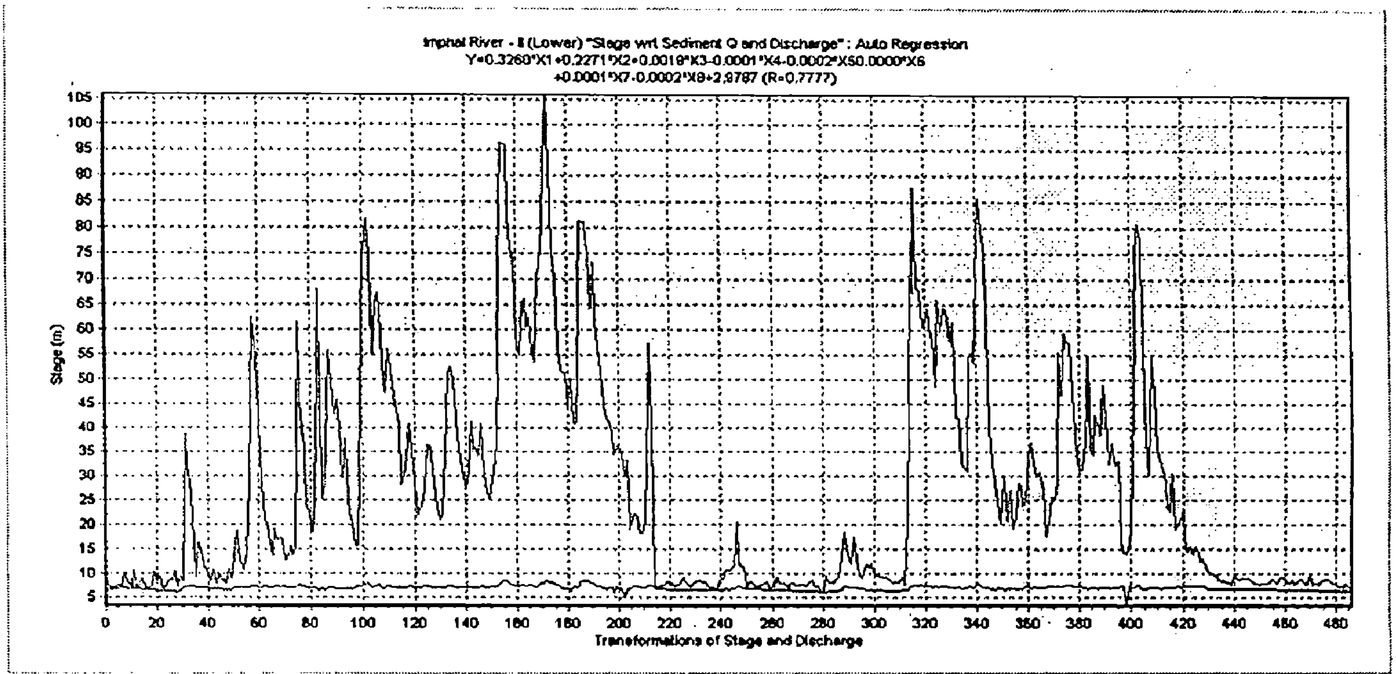


(b)

FIG 4.7-4 Multi-Linear and Auto Regression Models – Imphal River-II (Manipur River)

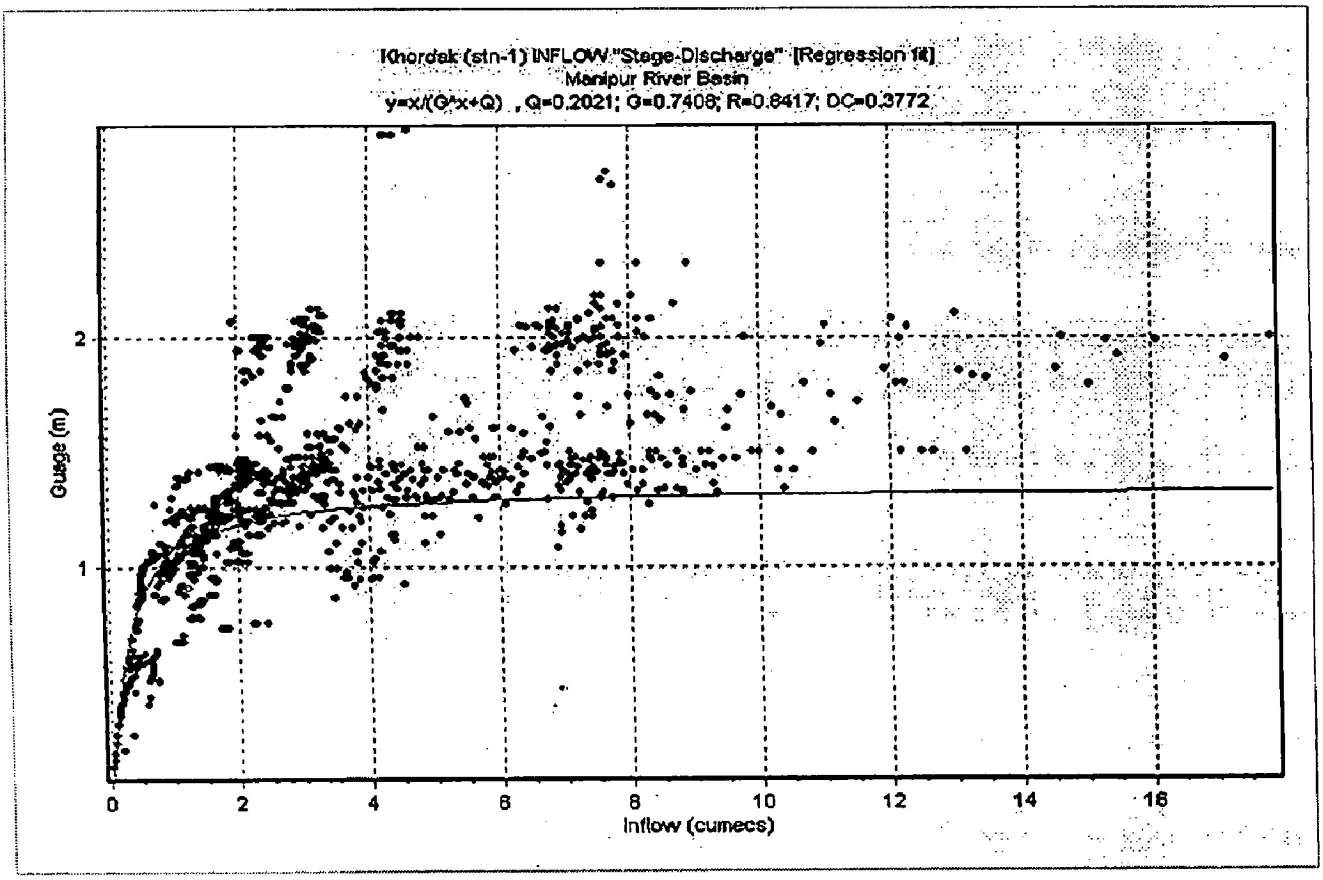


(a)

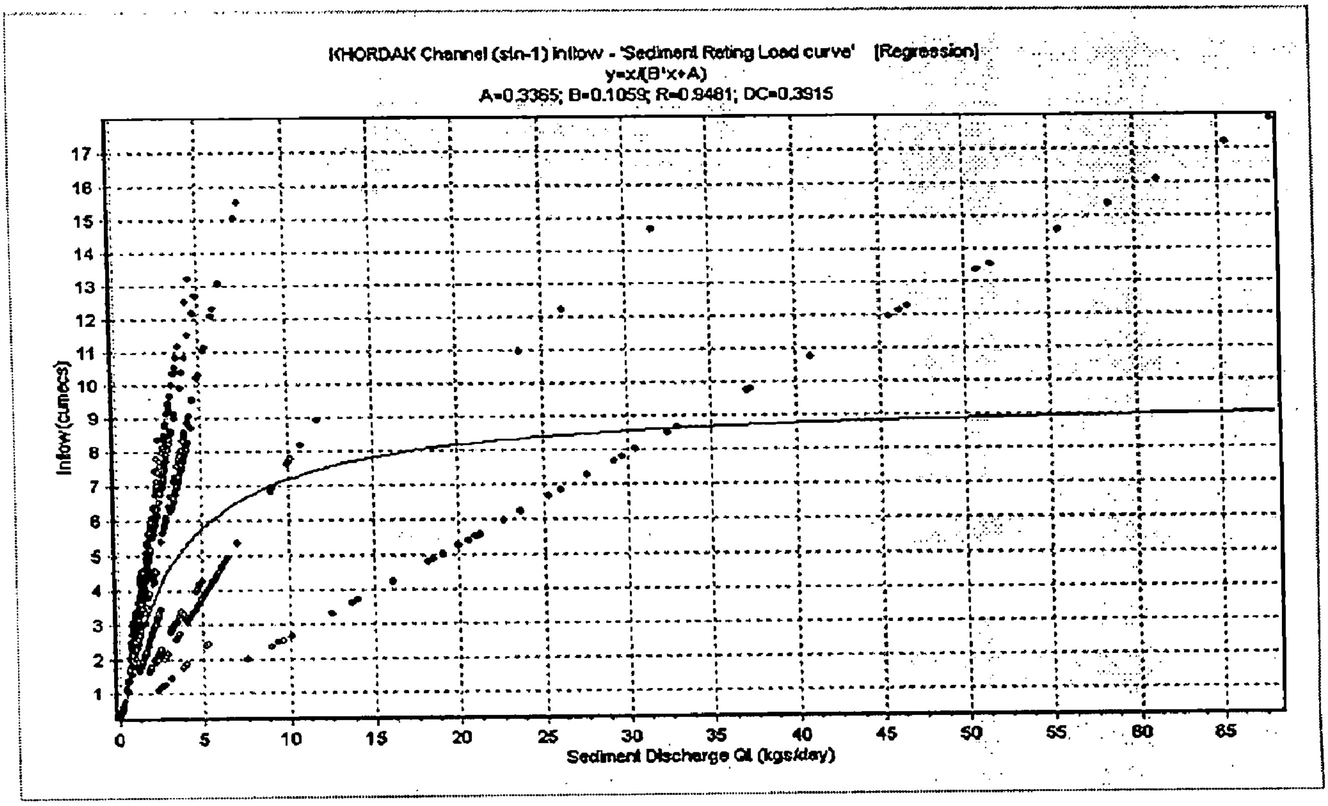


(b)

FIG :4.7-5 Stage-Discharge and Sediment Discharge Rating – Khordak (stn-1) Inflow

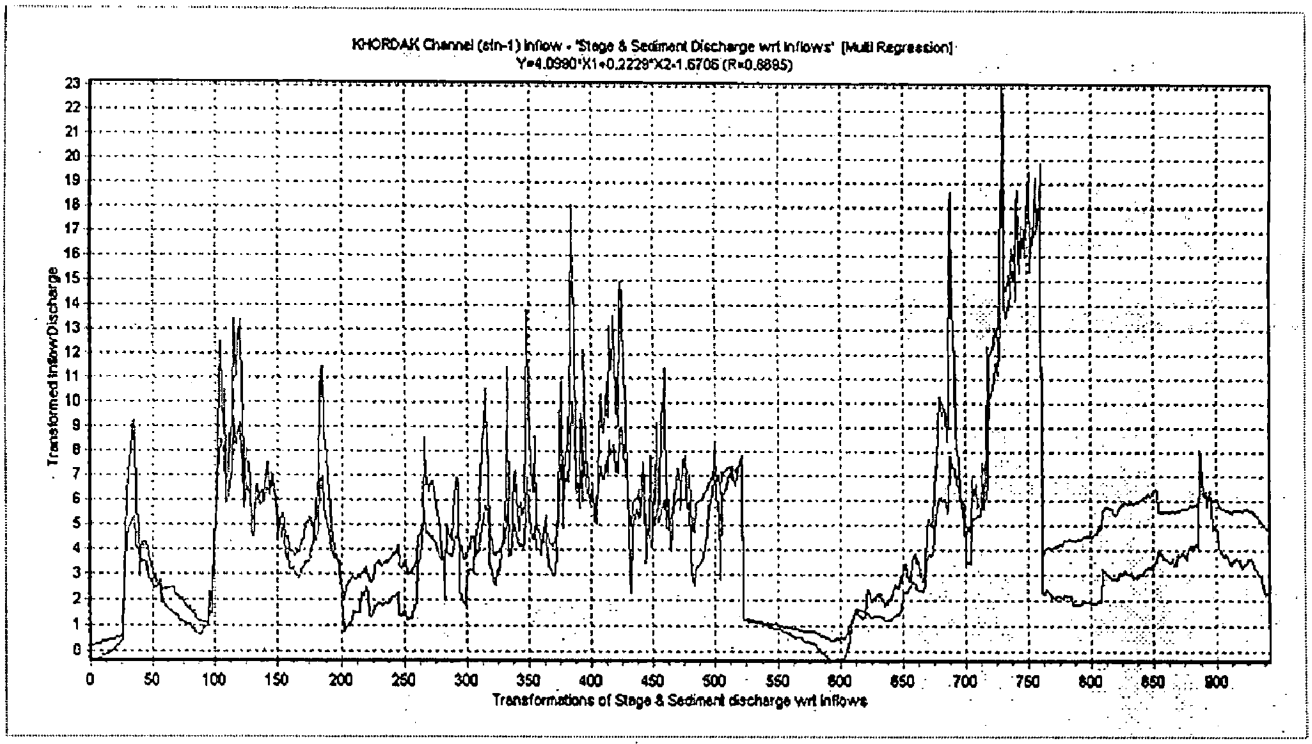


(a)

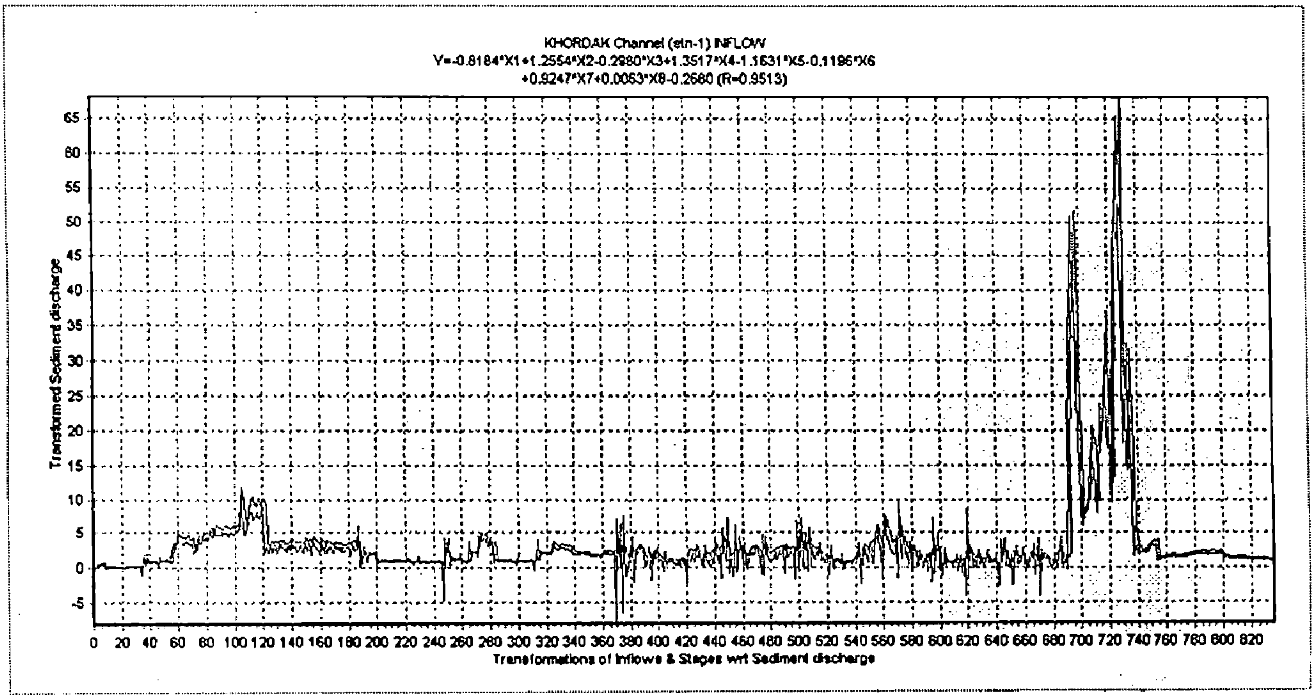


(b)

FIG 4.7-6 Multi-Linear and Auto Regression Models – Khordak (stn-1) Inflow

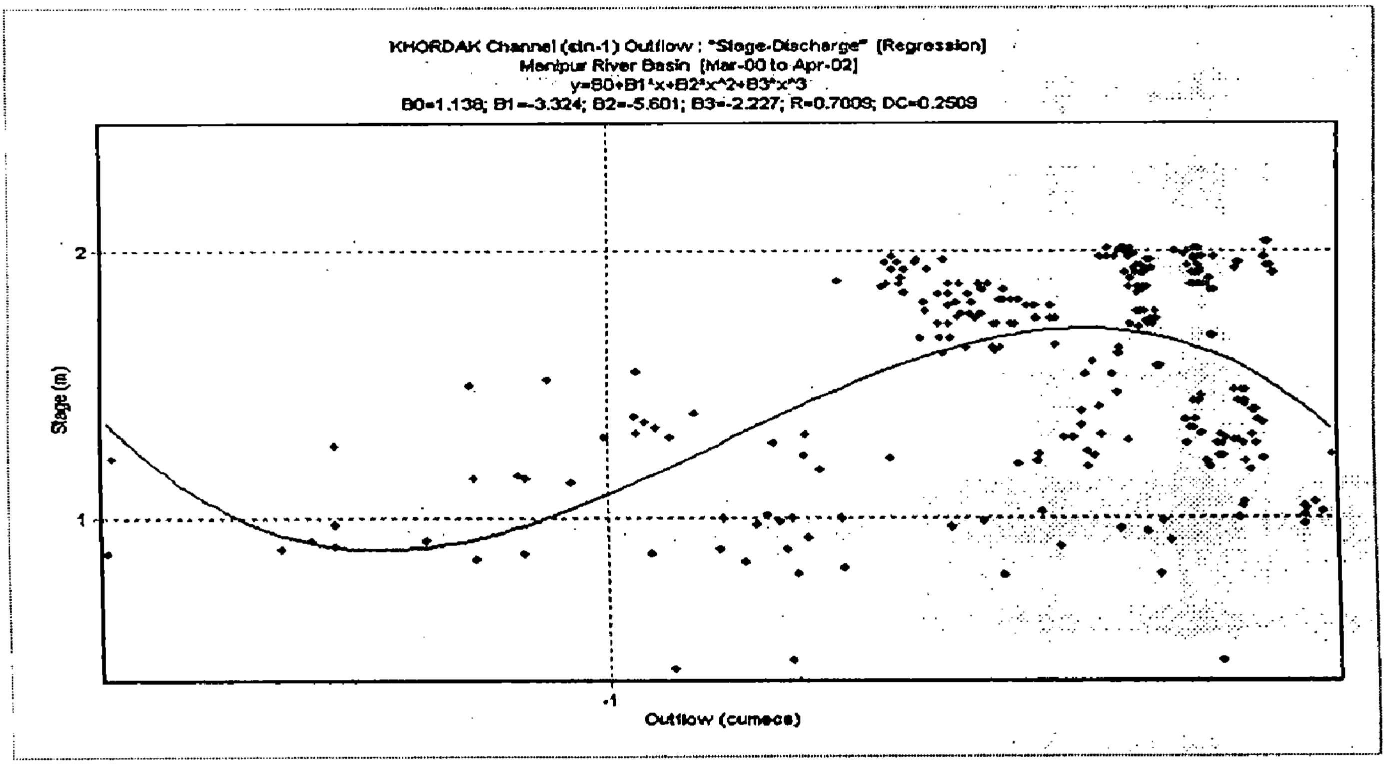


(a)

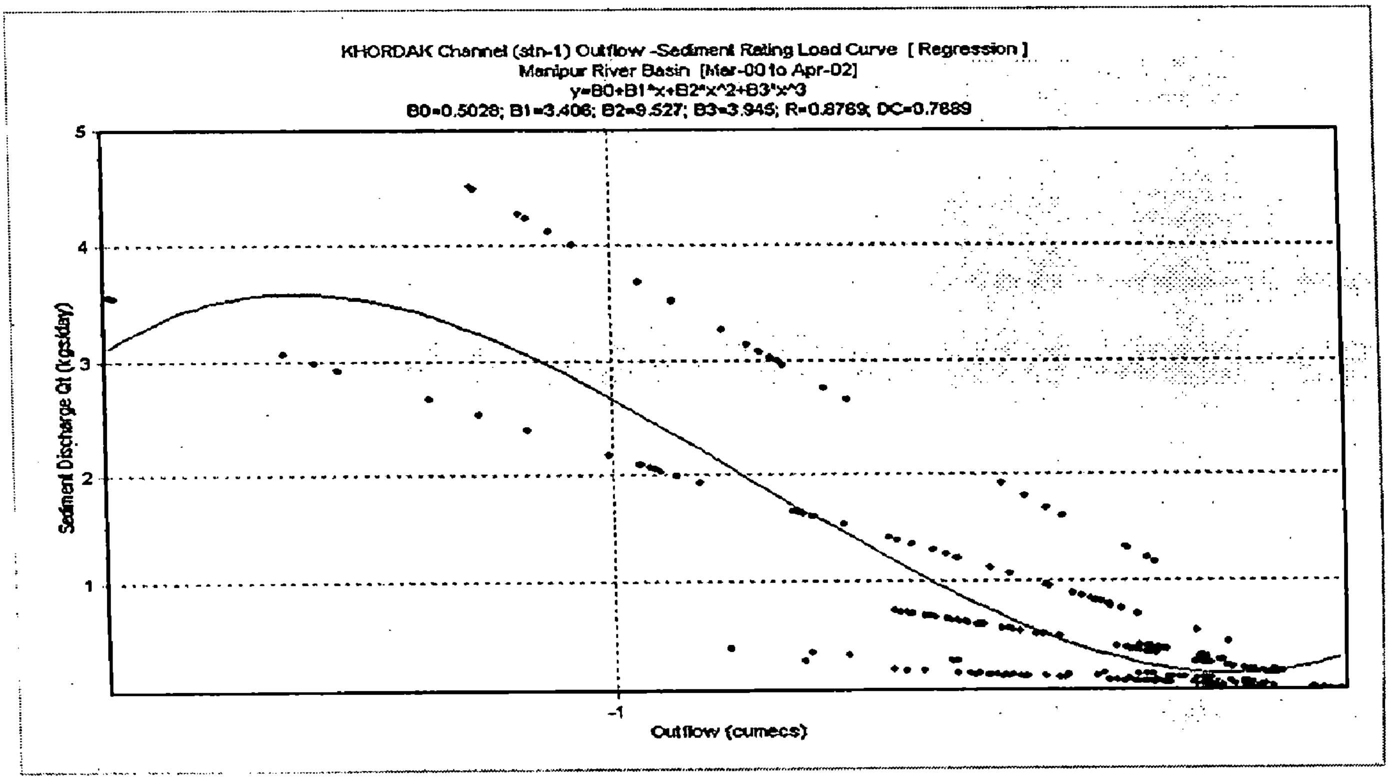


(b)

FIG :4.7-7 Stage-Discharge and Sediment Discharge Rating – Khordak (stn-1) Outflow

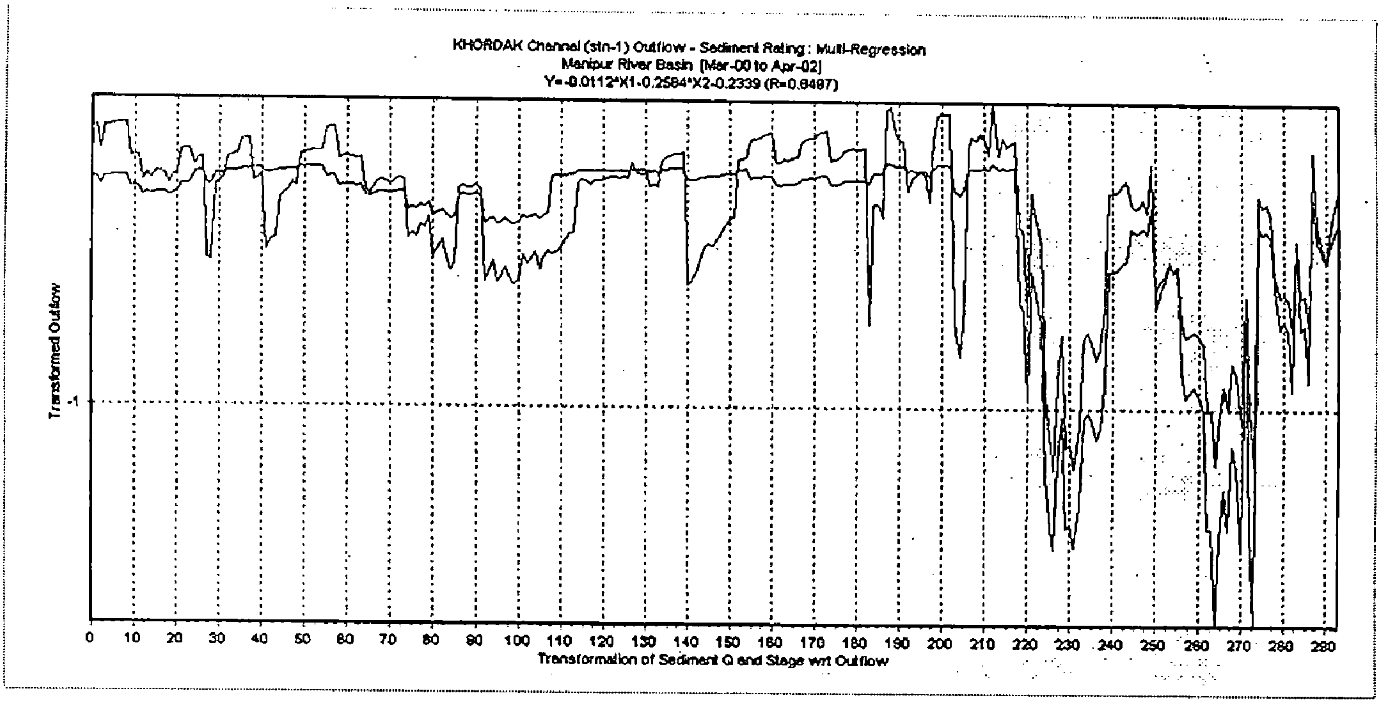


(a)

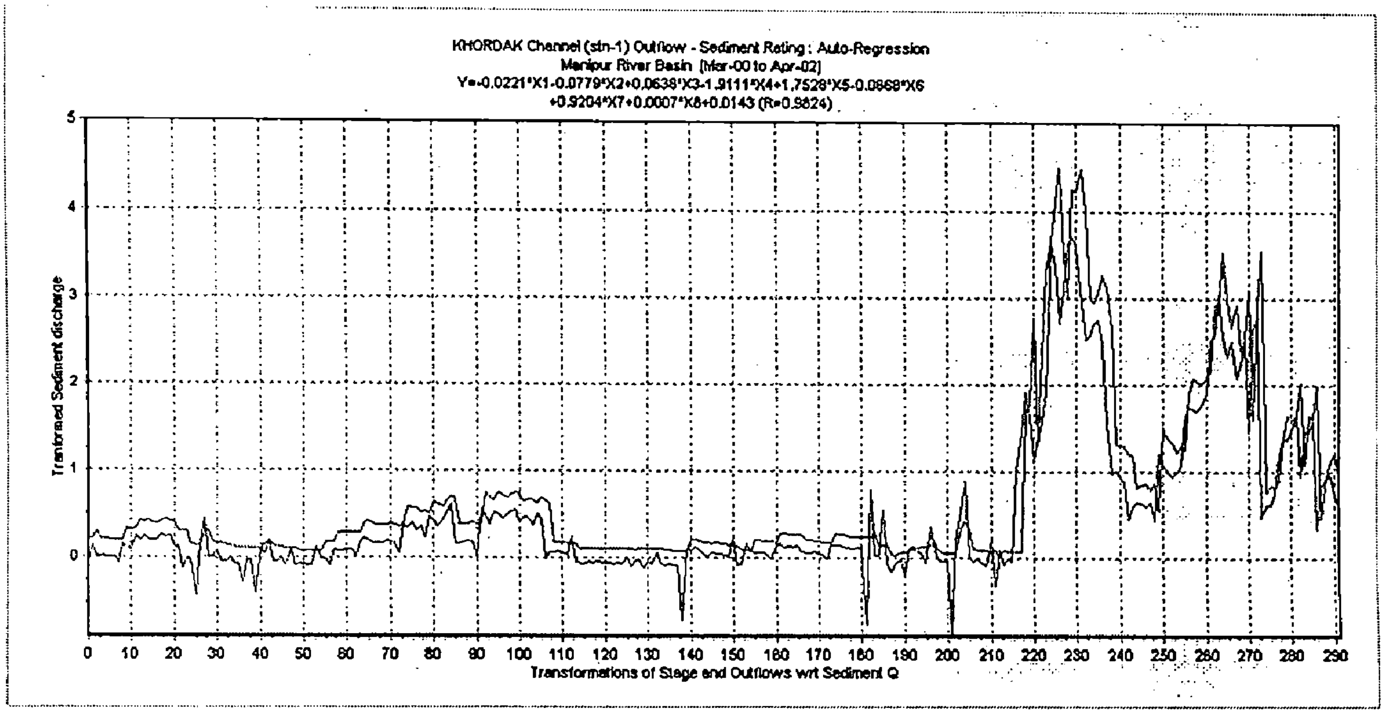


(b)

FIG 4.7-8 Multi-Linear and Auto Regression Models – Khordak (stn-1) Outflow

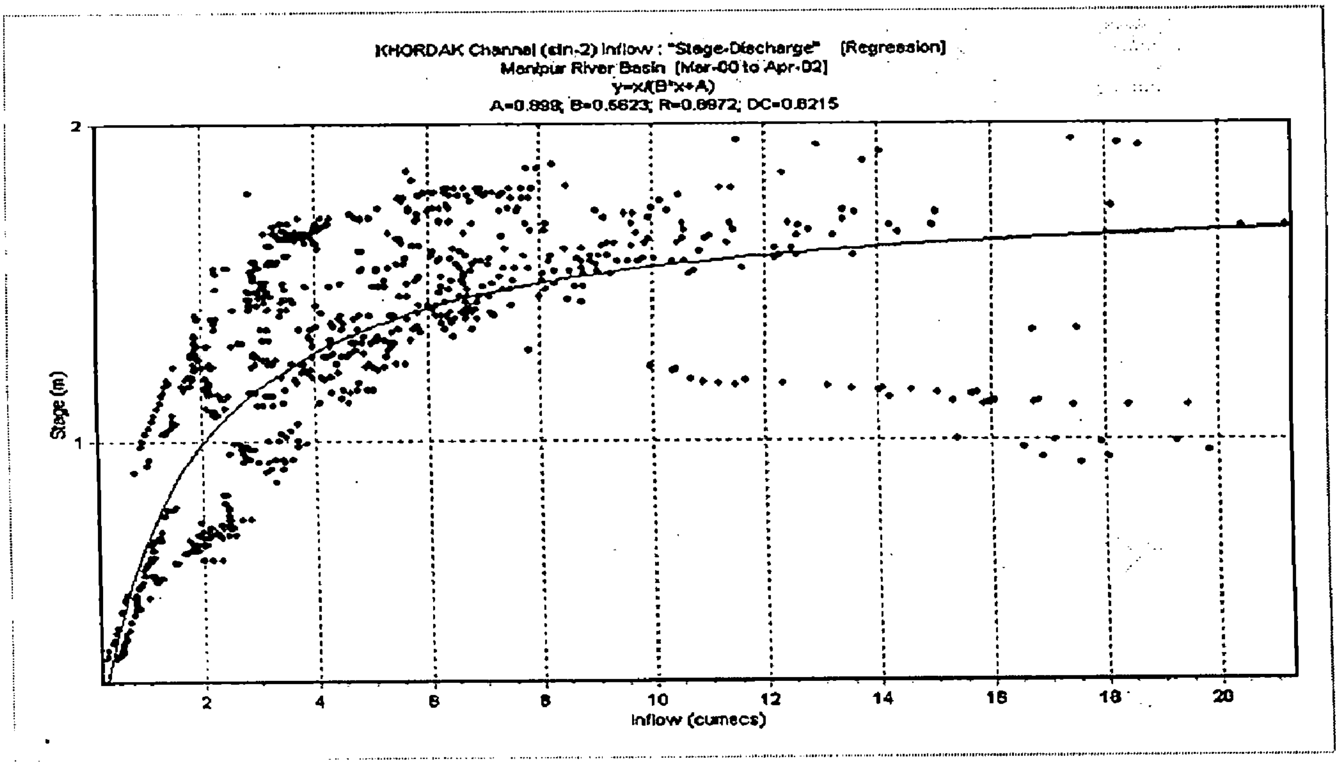


(a)



(b)

FIG : 4.7-9 Stage-Discharge and Sediment Discharge Rating – Khordak (stn-2) Inflow



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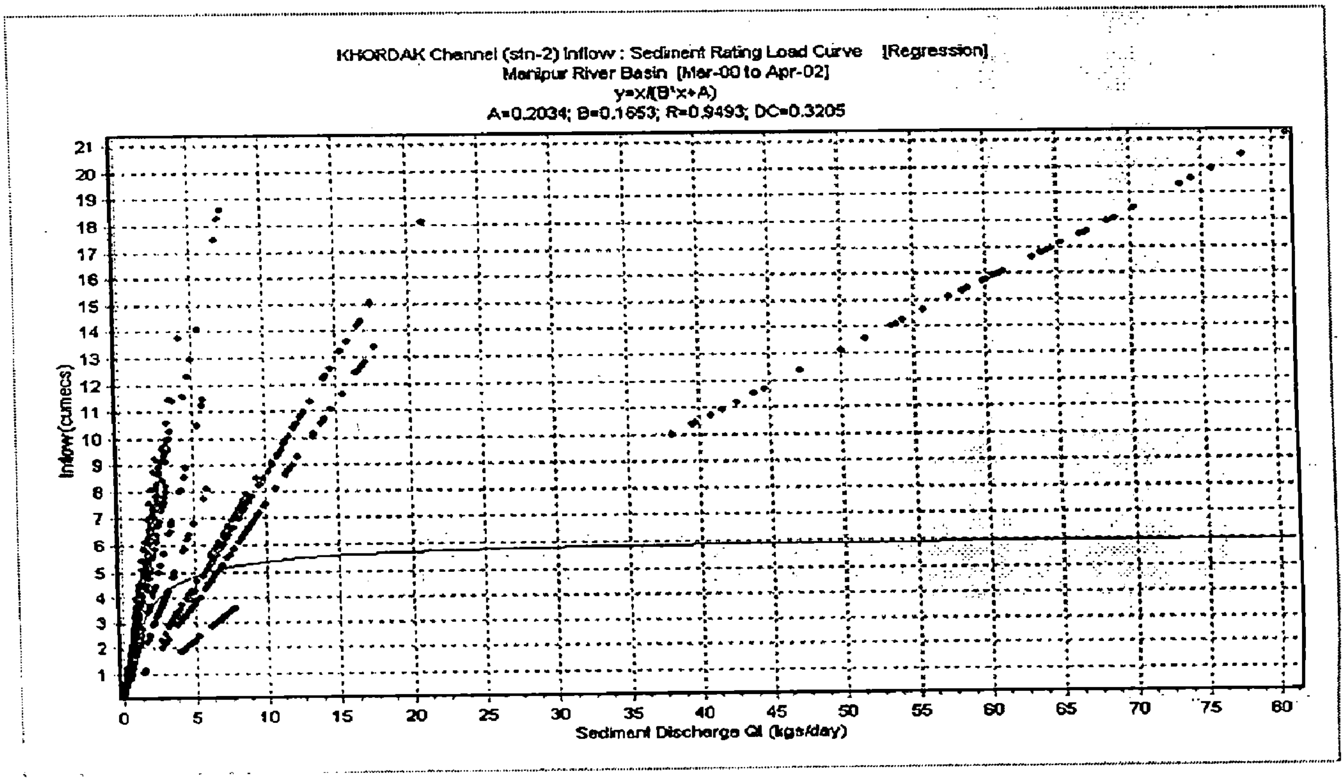
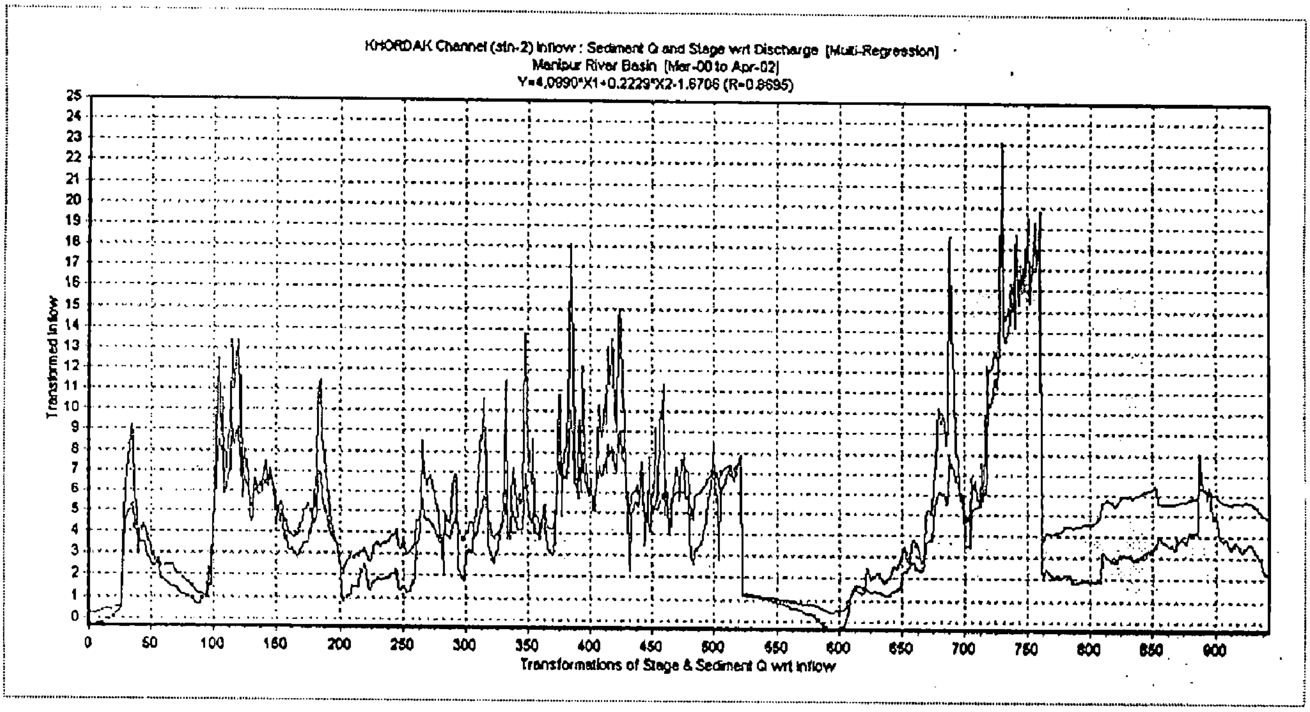
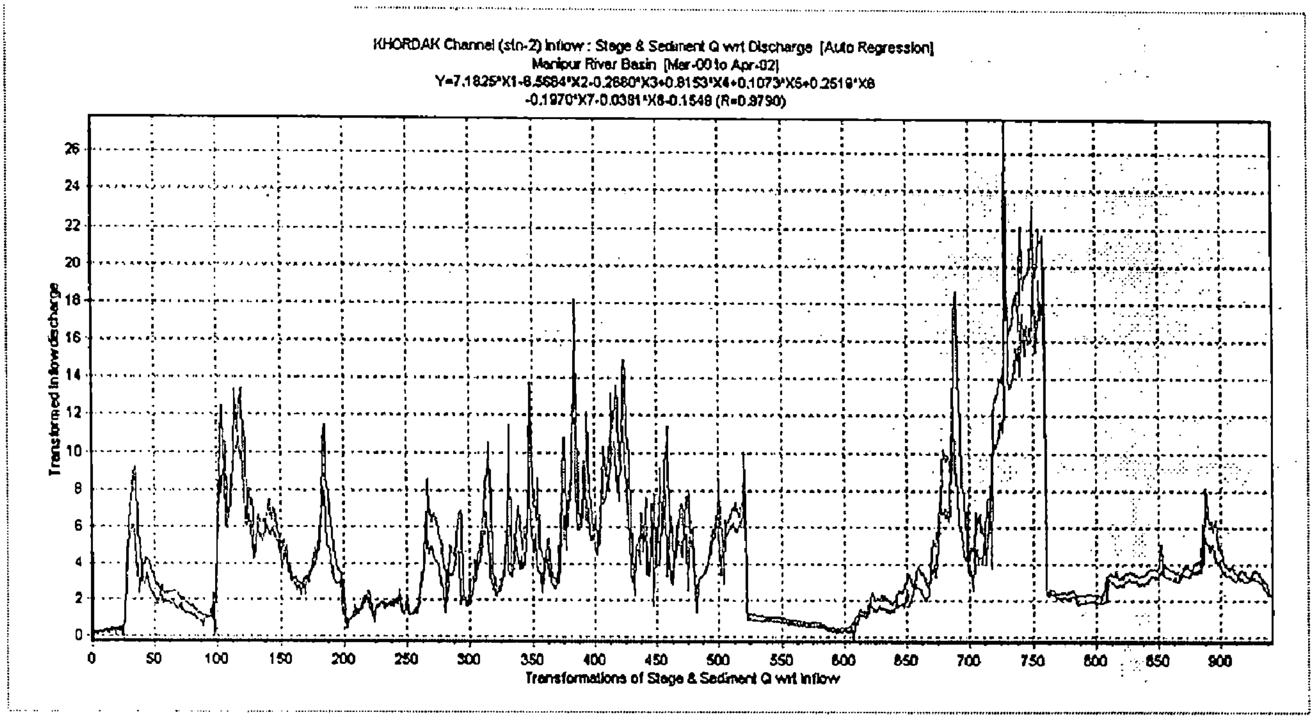


(b)

FIG 4.7-10 Multi-Linear and Auto Regression Models – Khordak (stn-2) Inflow

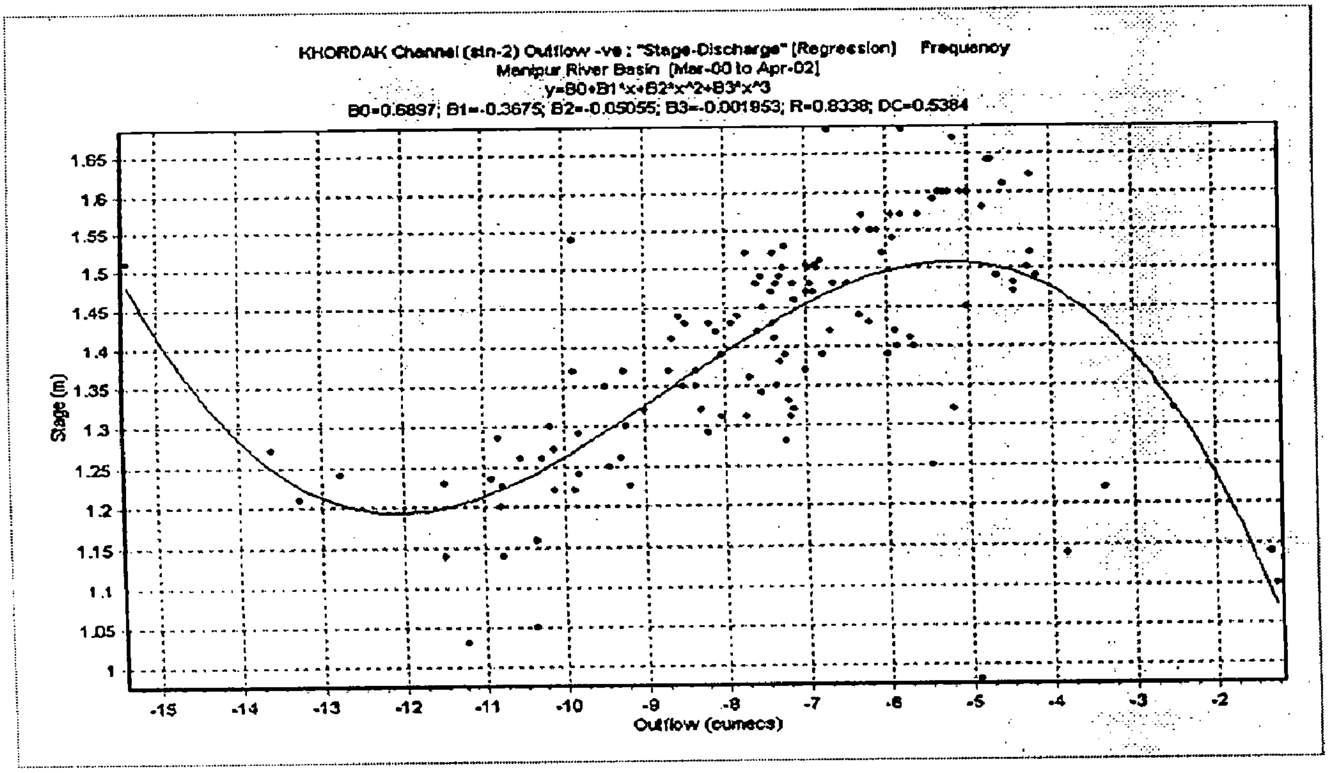


(a)

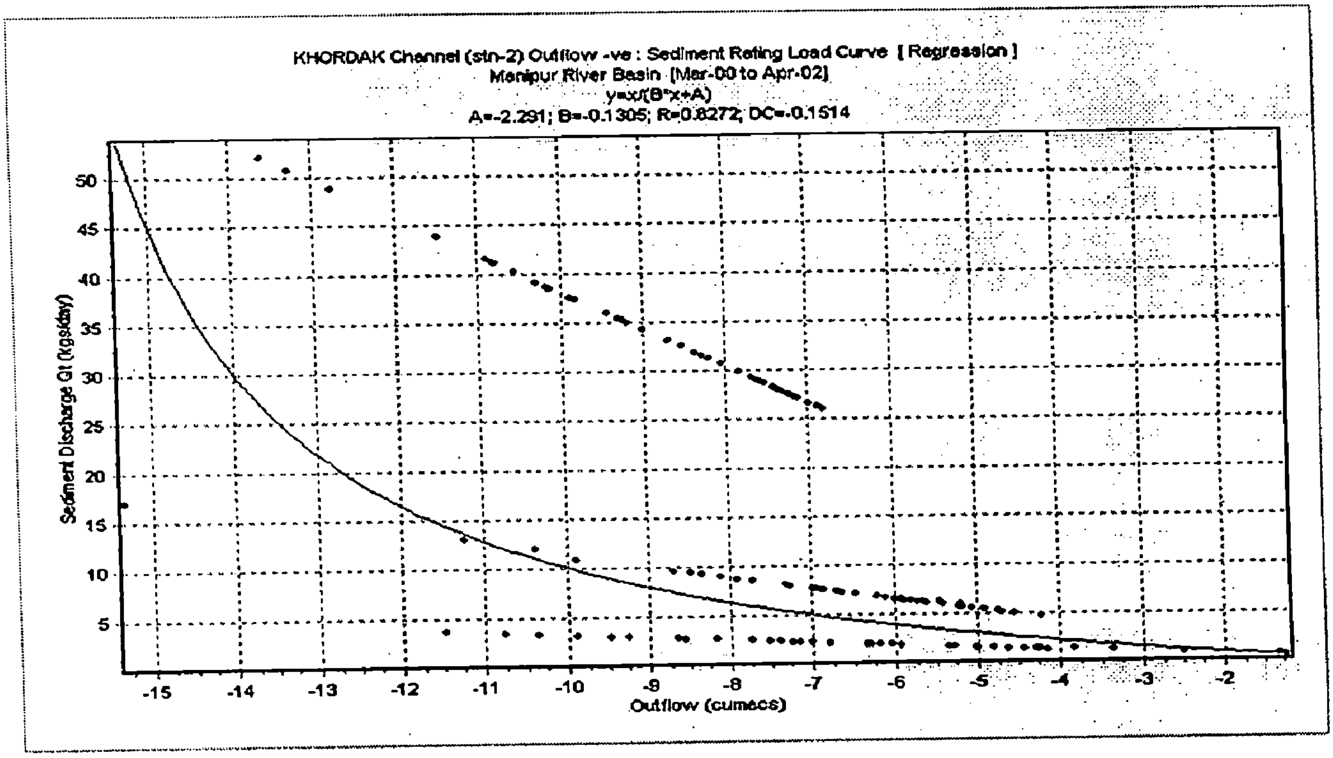


(b)

FIG : 4.7-11 Stage-Discharge and Sediment Discharge Rating – Khordak (stn-2) Outflow

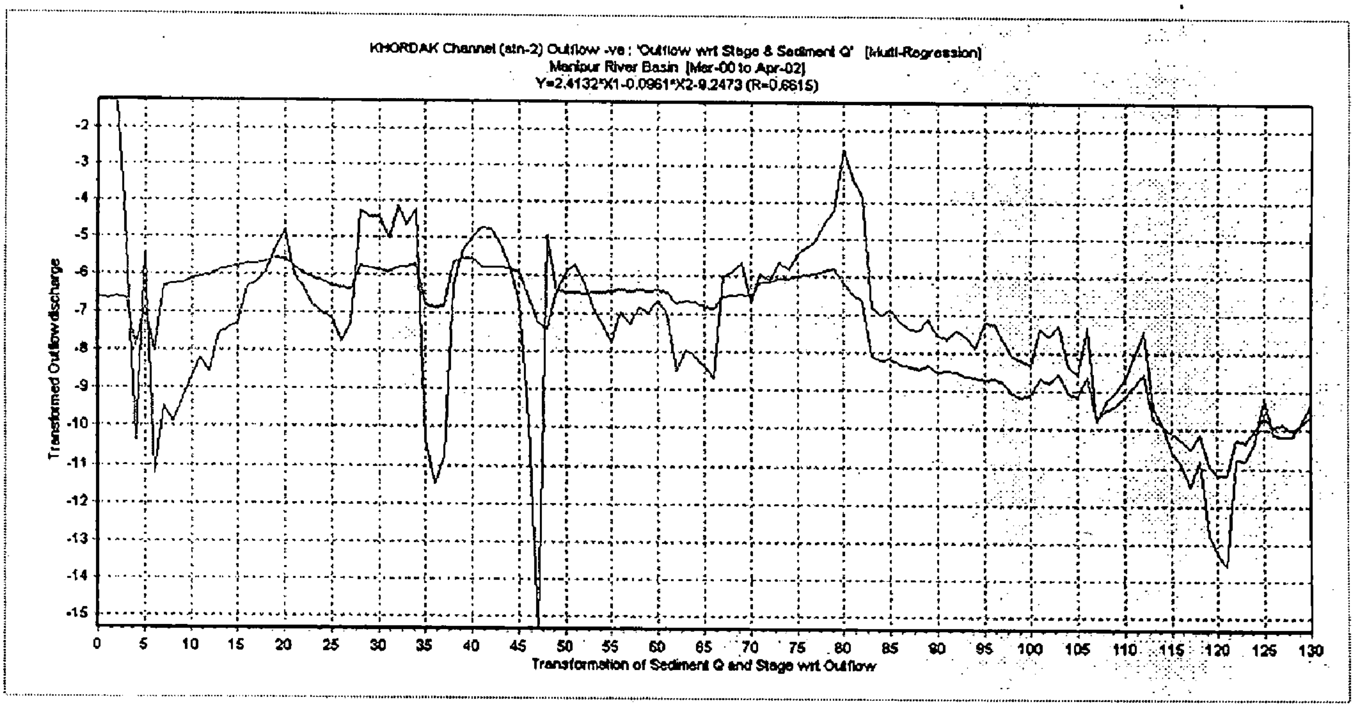


(a)



(b)

FIG 4.7-12 Multi-Linear and Auto Regression Models – Khordak (stn-2) Outflow



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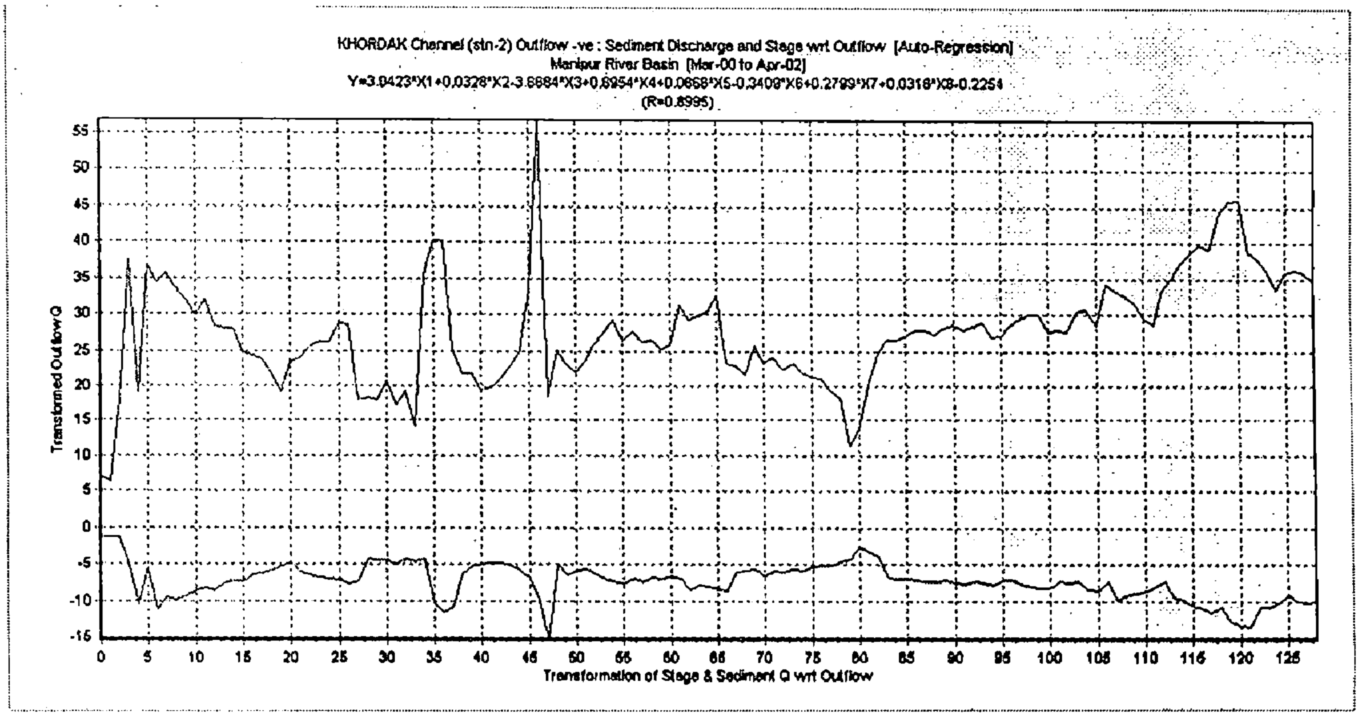
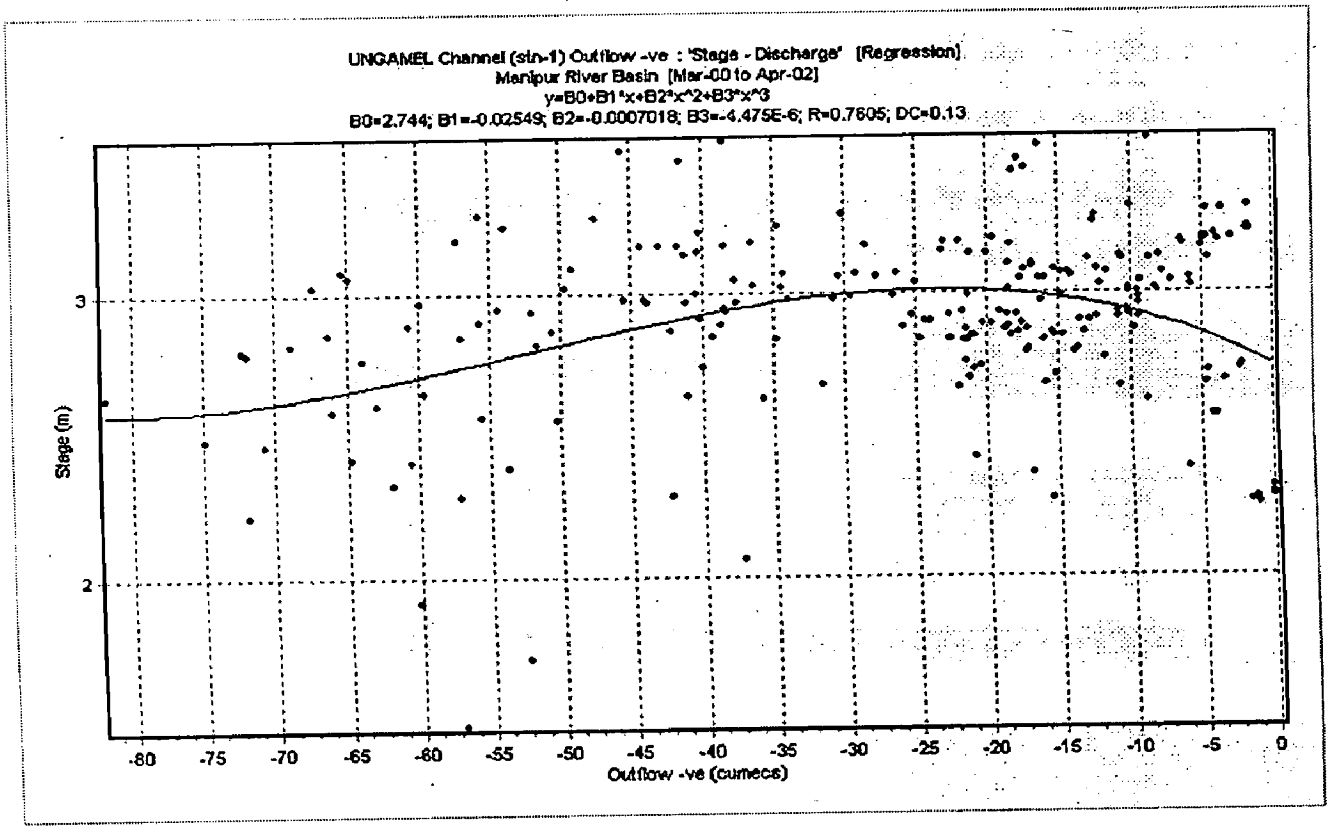
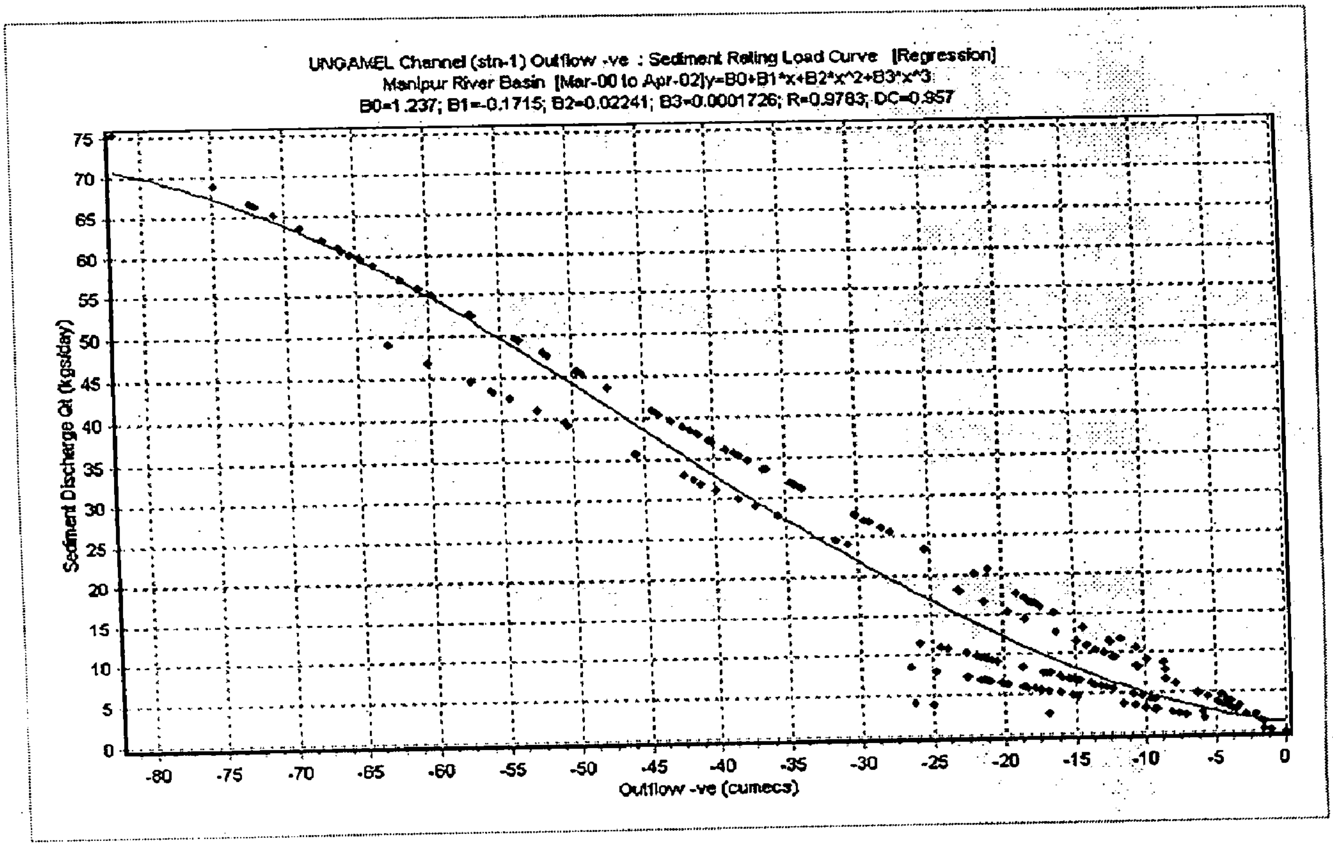


(b)

FIG : 4.7-13 Stage-Discharge and Sediment Discharge Rating –Ungamel (stn-1) Outflow

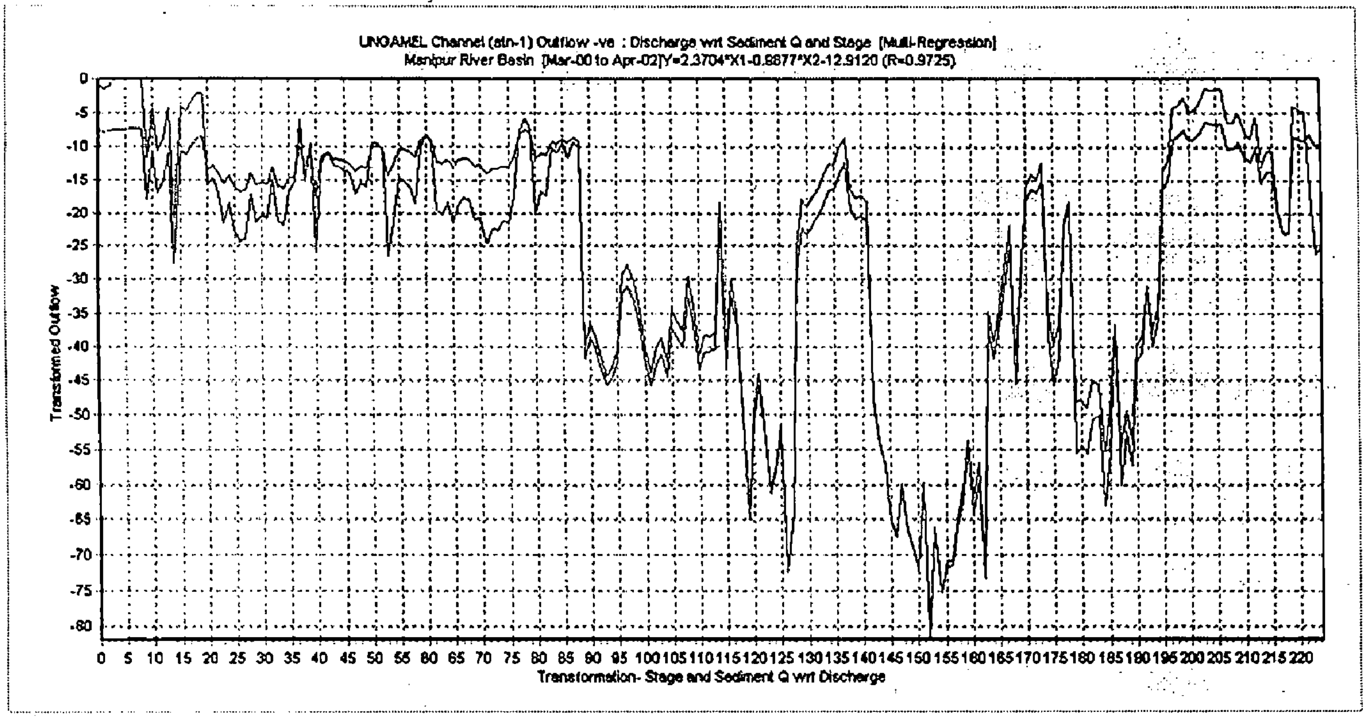


(a)

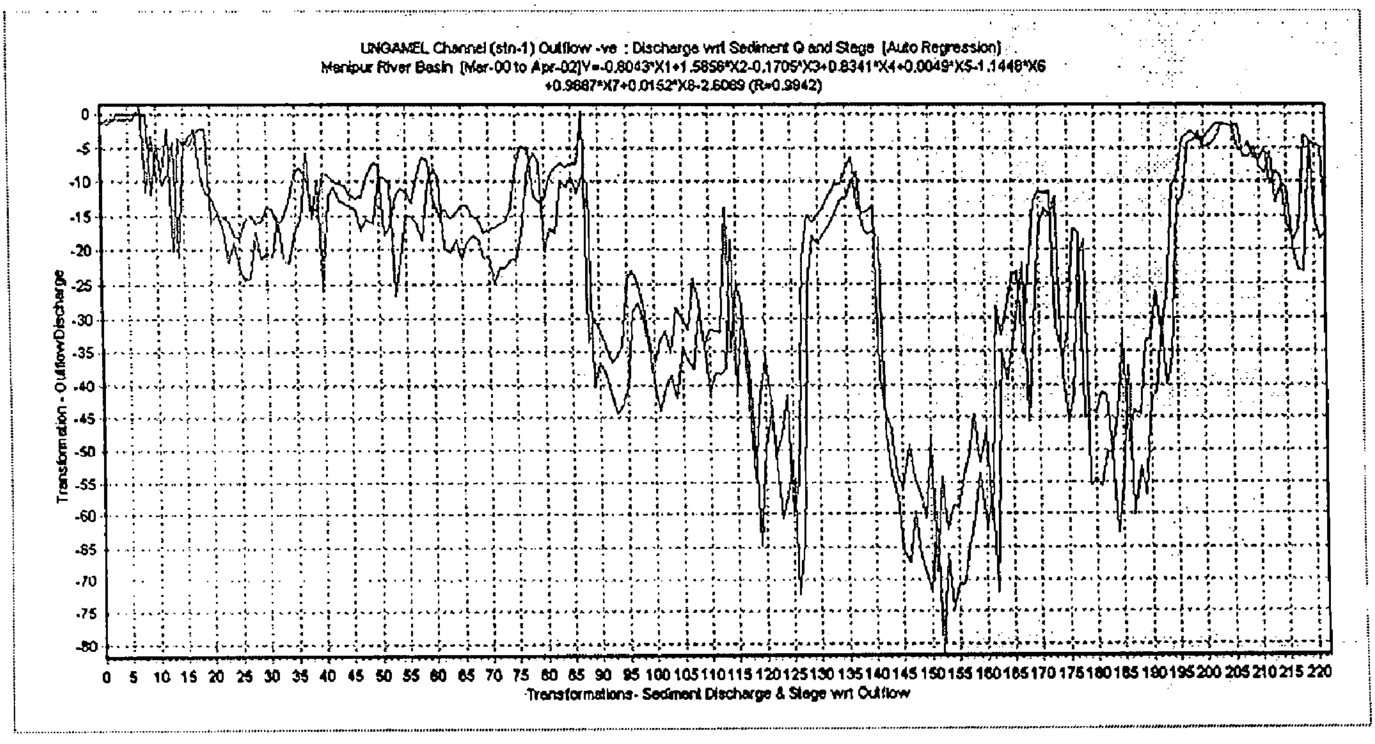


(b)

FIG 4.7-14 Multi-Linear and Auto Regression Models – Ungamel (stn-1) Outflow

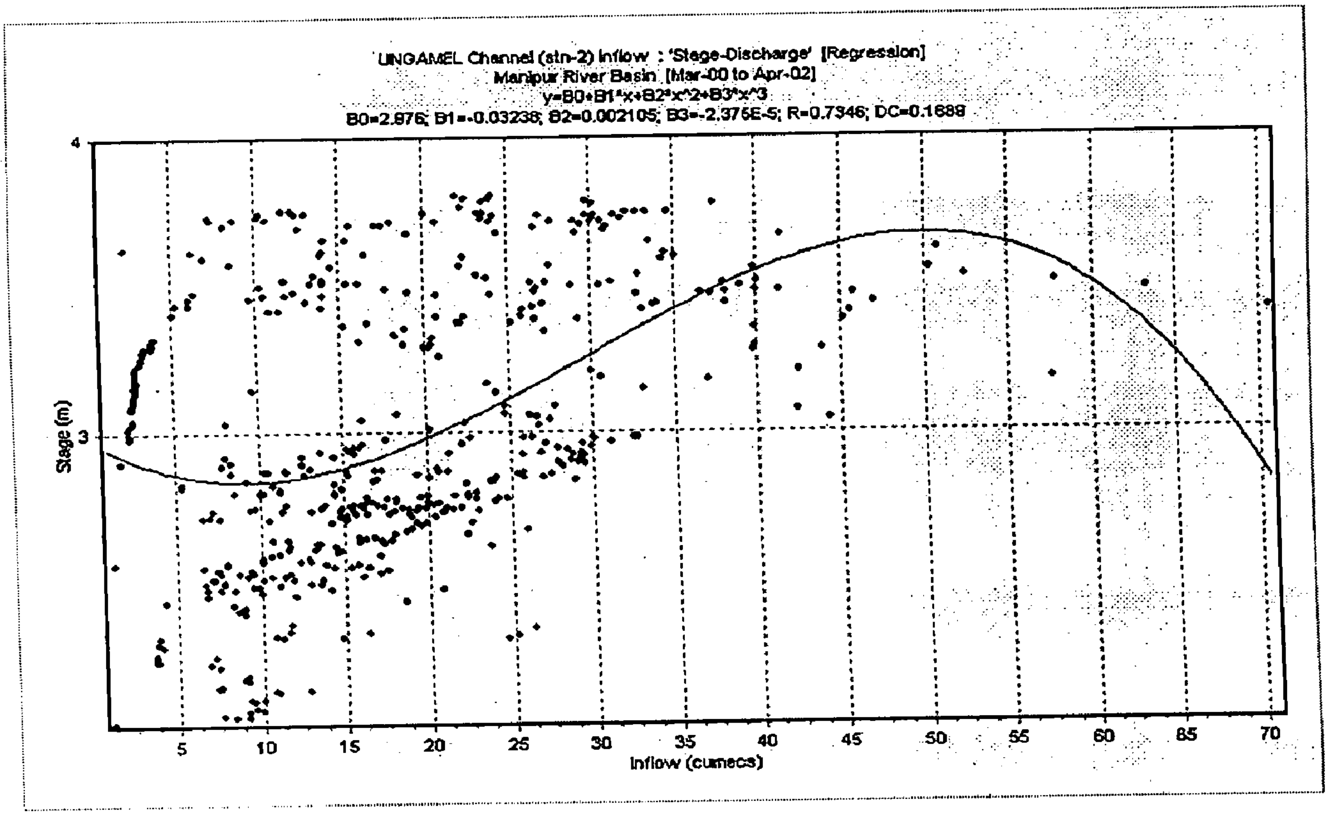


(a)



(b)

FIG : 4.7-15 Stage-Discharge and Sediment Discharge Rating –Ungamel (stn-2) Inflow



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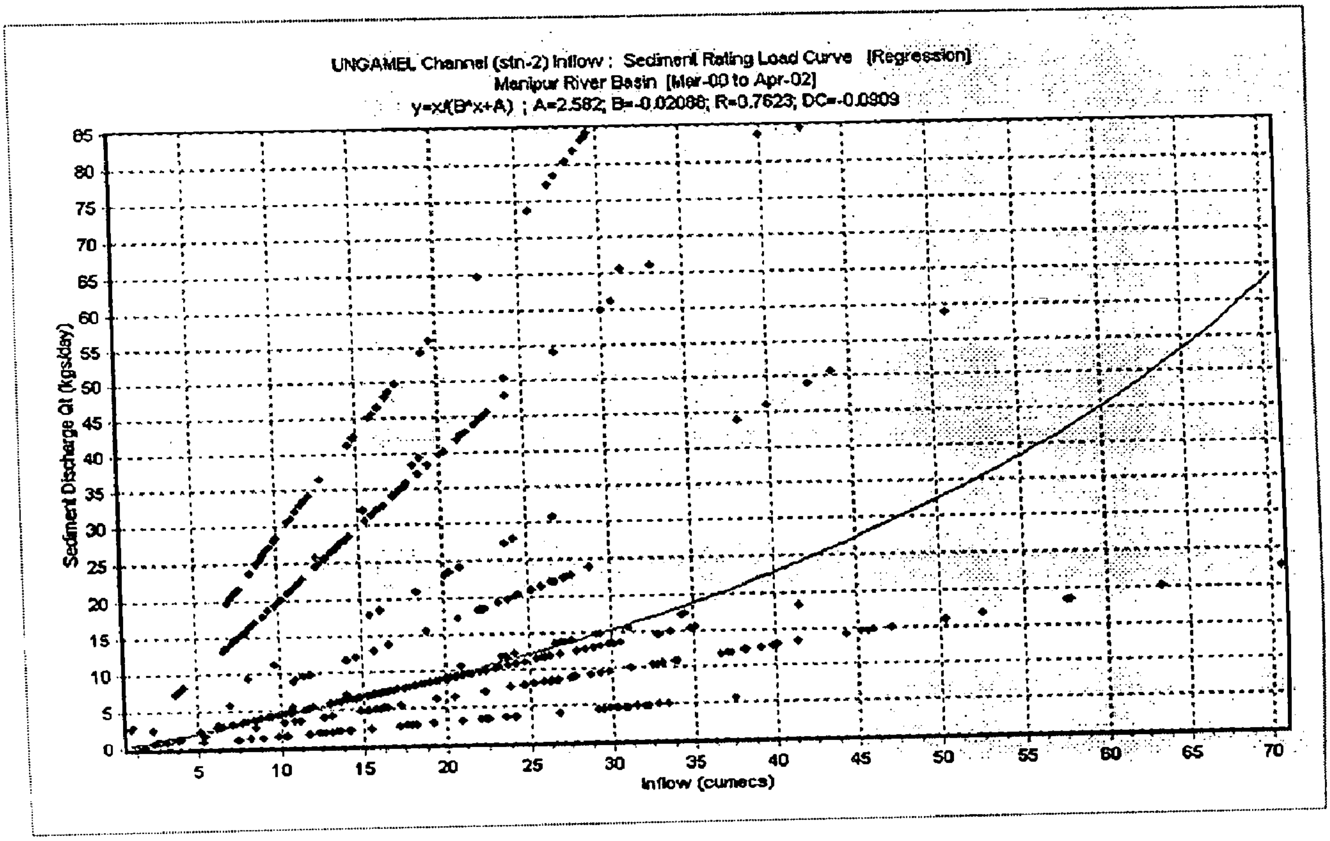
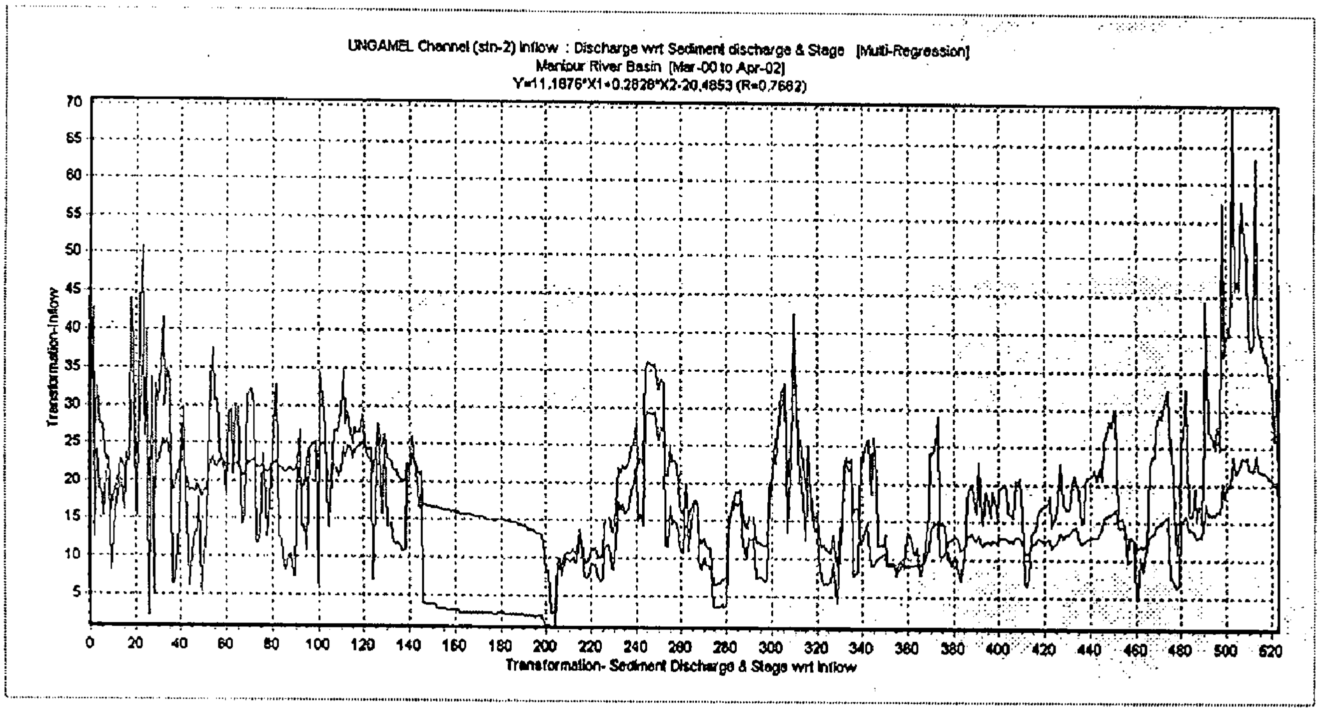
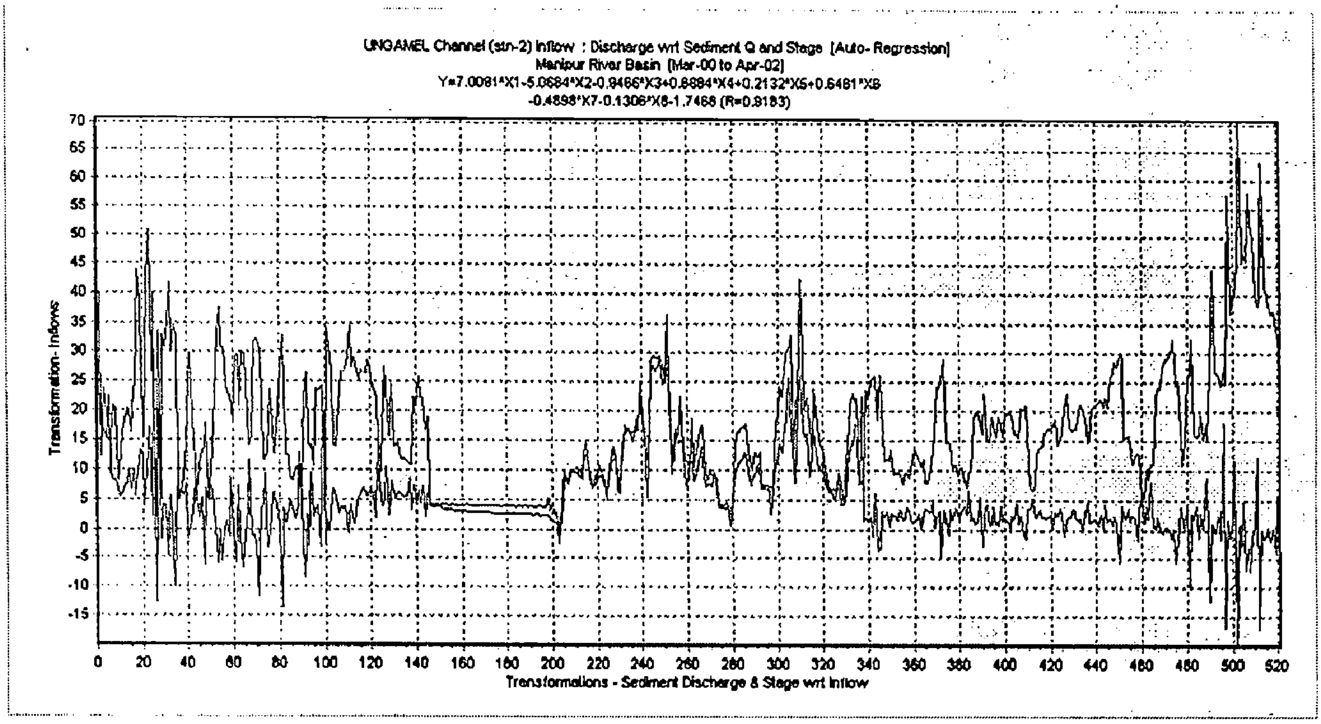


(b)

FIG 4.7-16 Multi-Linear and Auto Regression Models – Ungamel (stn-2) Inflow

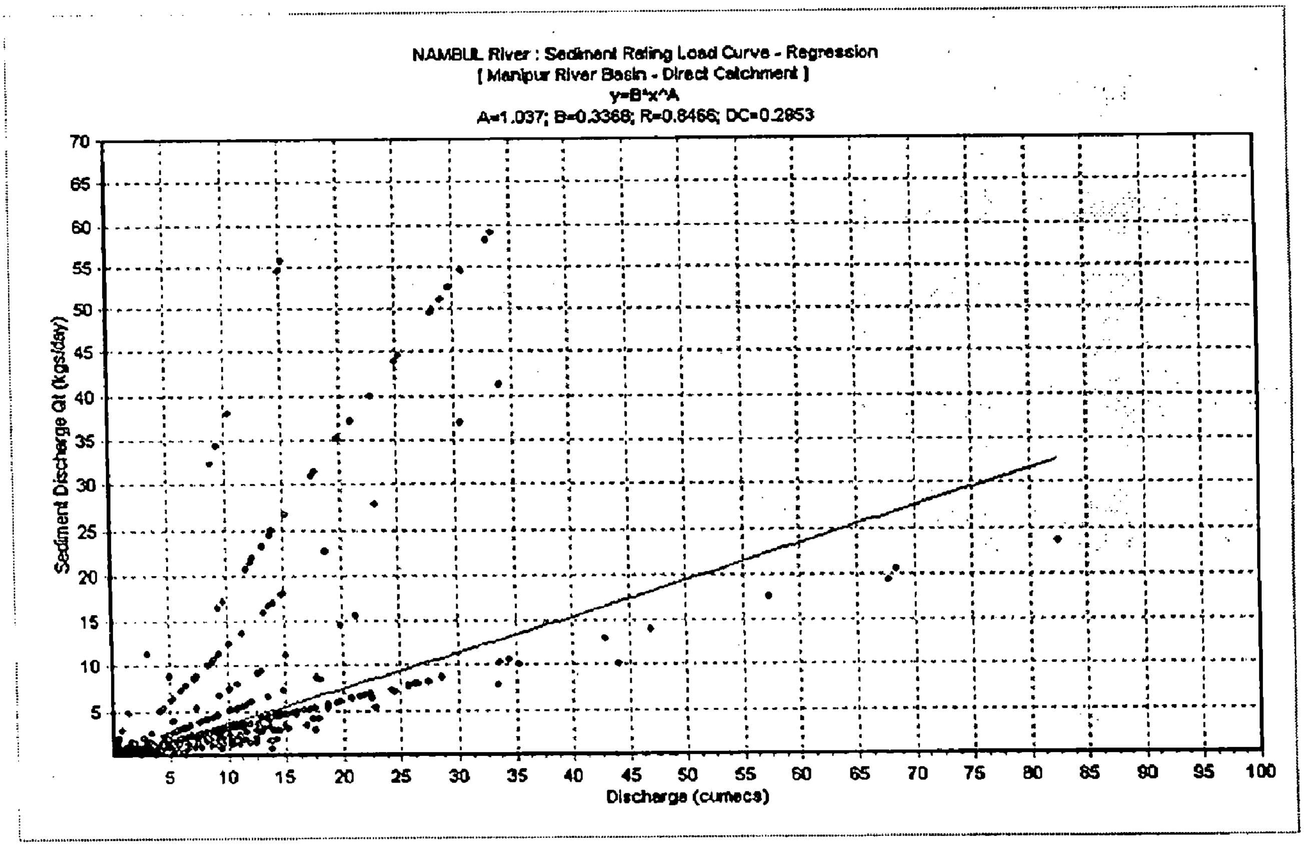


(a)

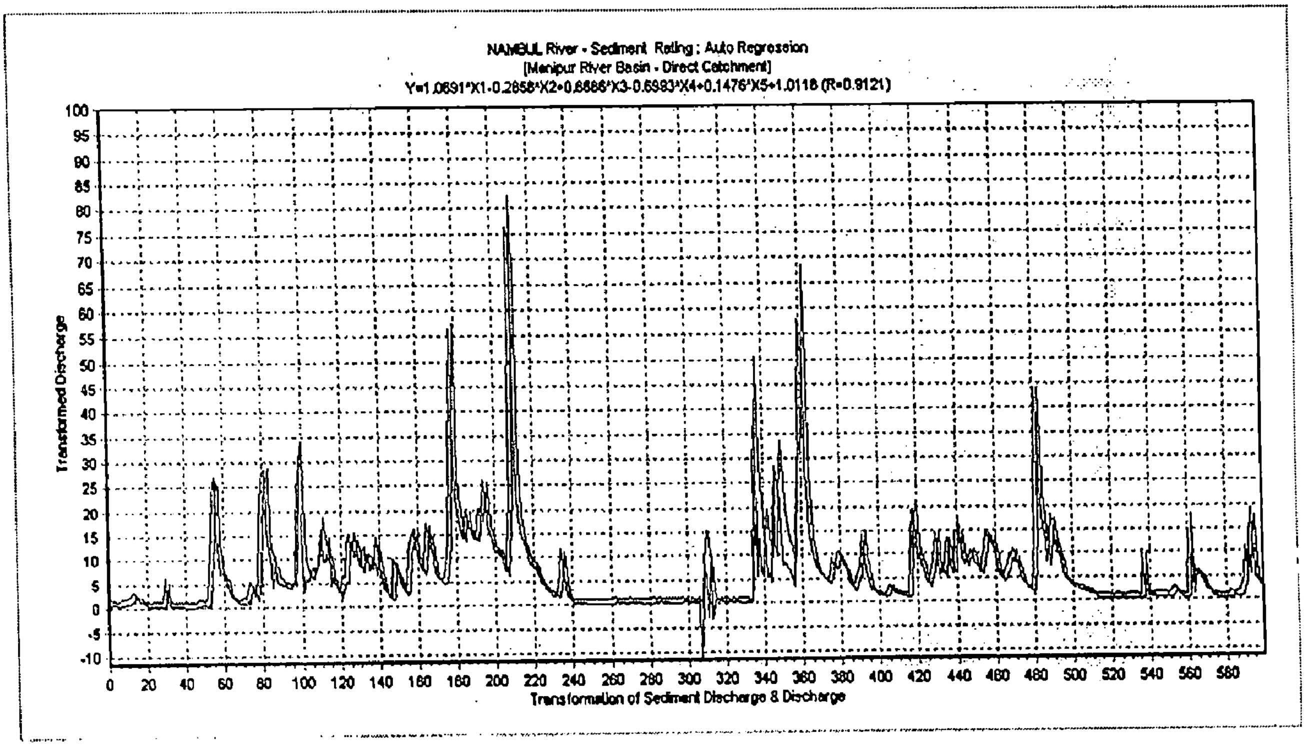


(b)

FIG : 4.7-17 Sediment Discharge Rating and Auto regression –Nambul River [MRB]

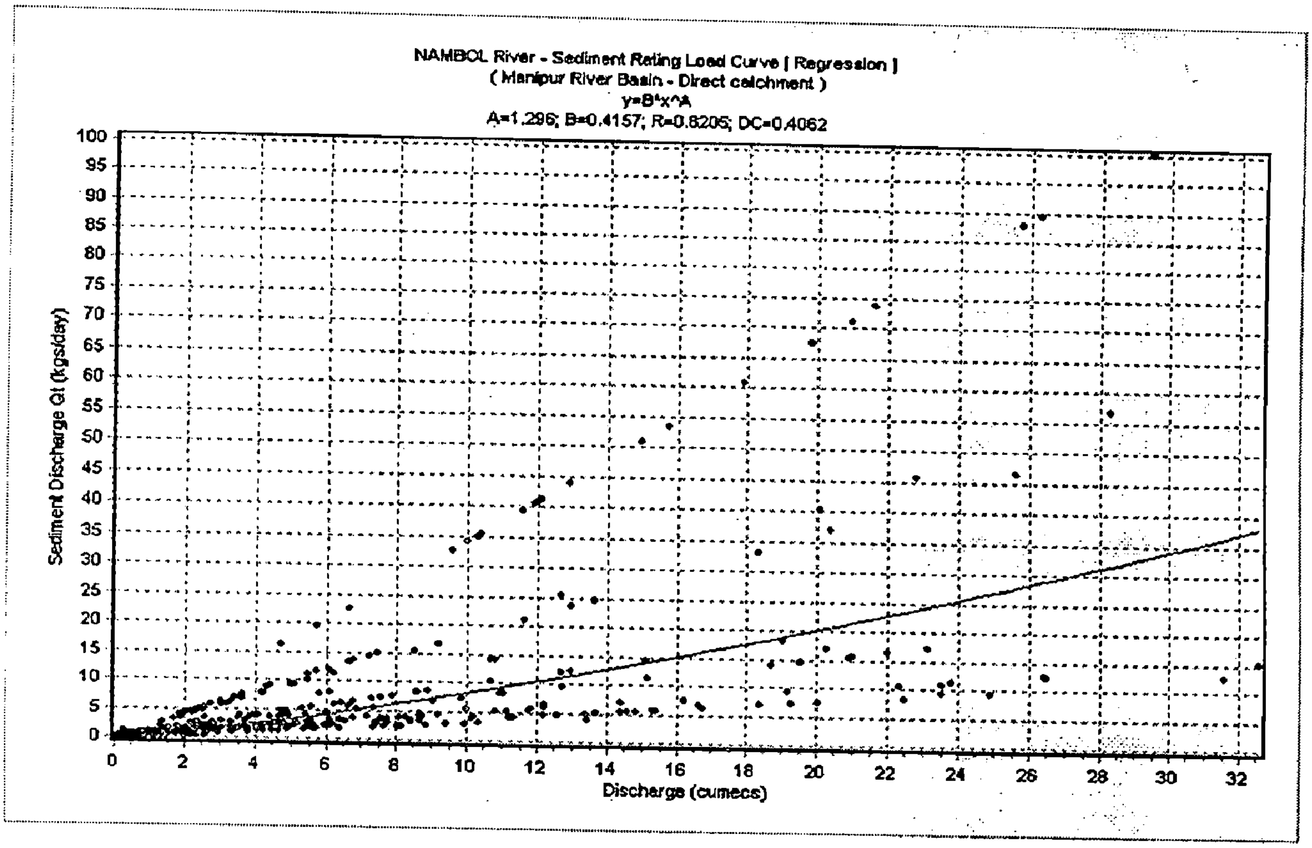


(a)

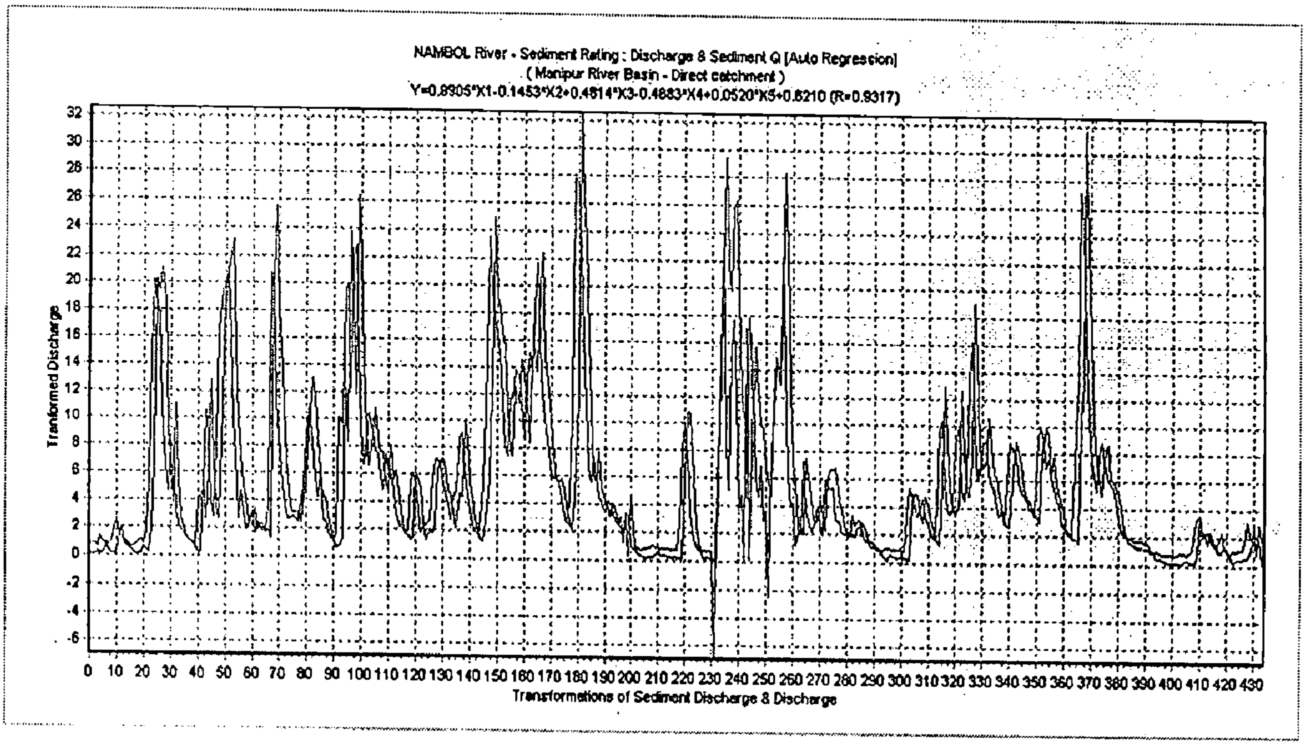


(b)

FIG : 4.7-18 Sediment Discharge Rating and Auto regression –Nambol River [MRB]



(a)



(b)

FIG 4.8-1 Effective Discharge of Nambul River [MRB]

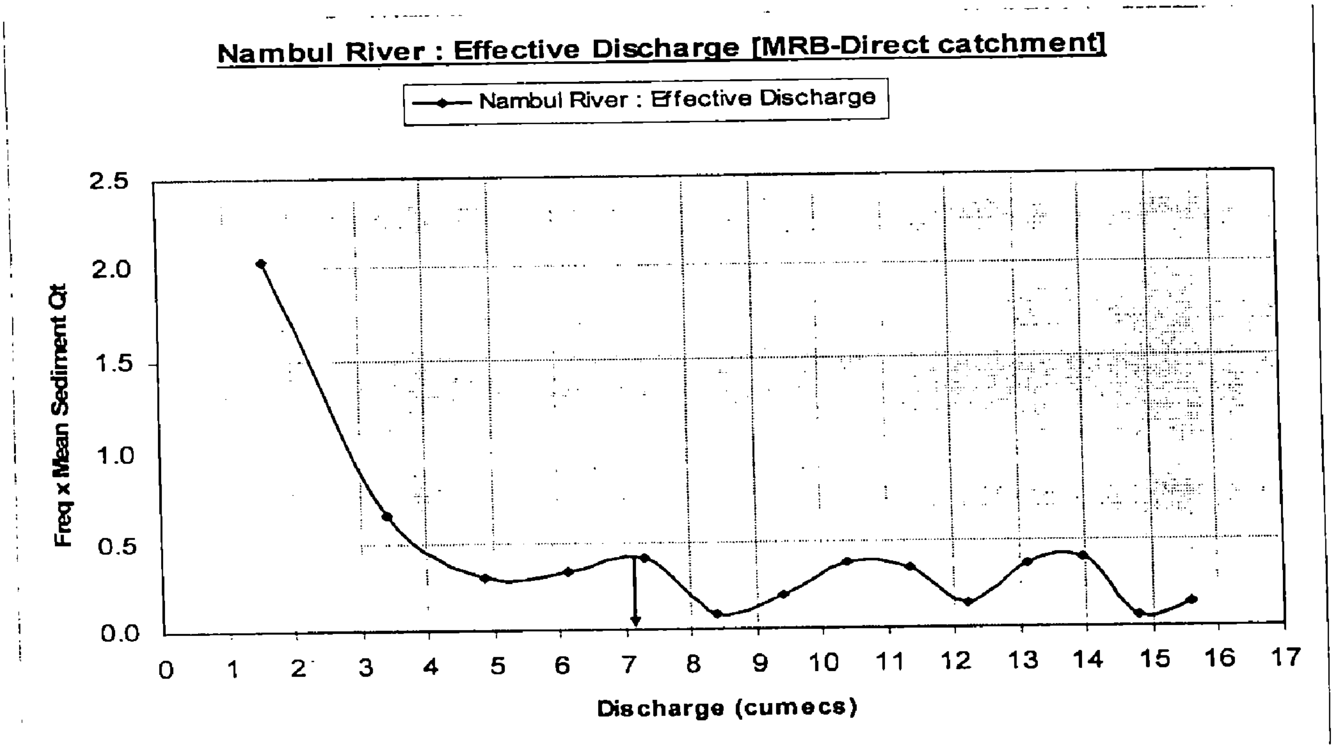


FIG 4.8-2 Effective Discharge of Nambol River [MRB]

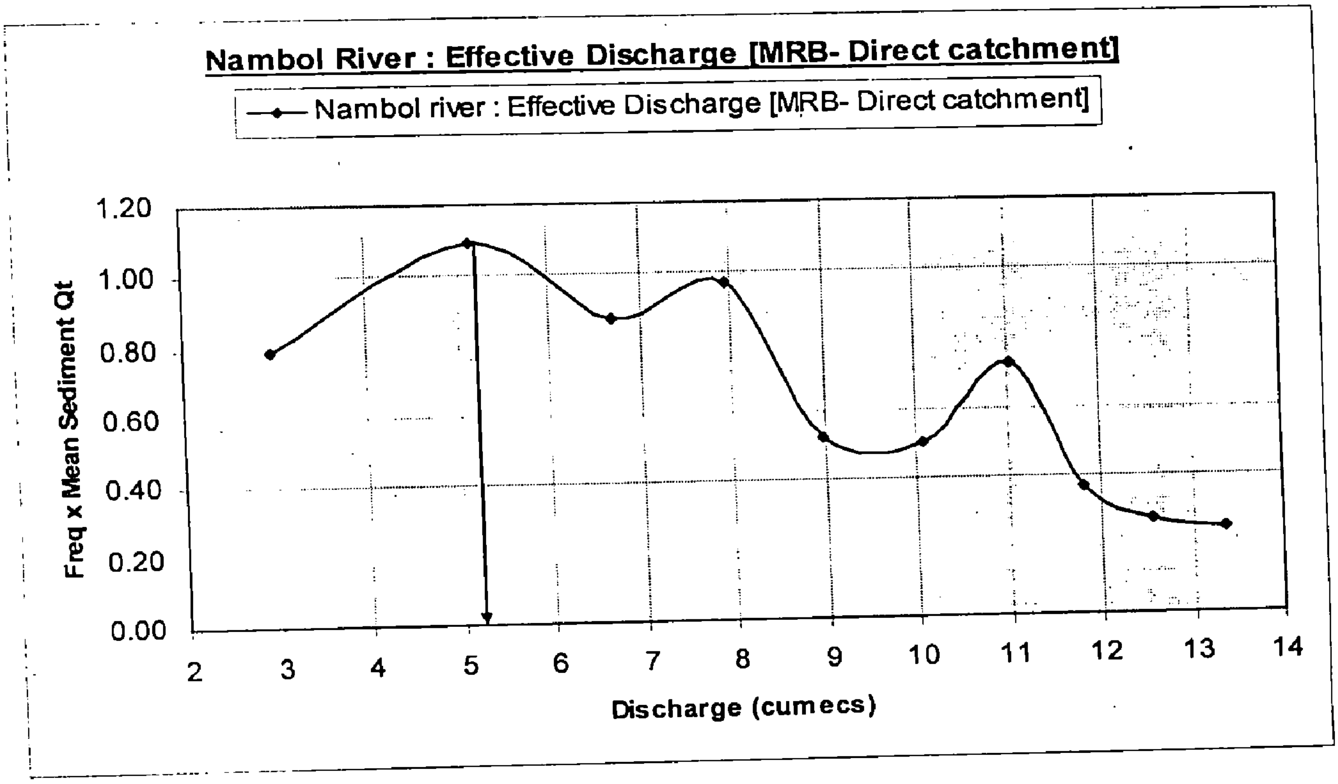


FIG 4.8-3 Effective Discharge of Khordak channel – INFLOWs @ stn-2 [MRB]

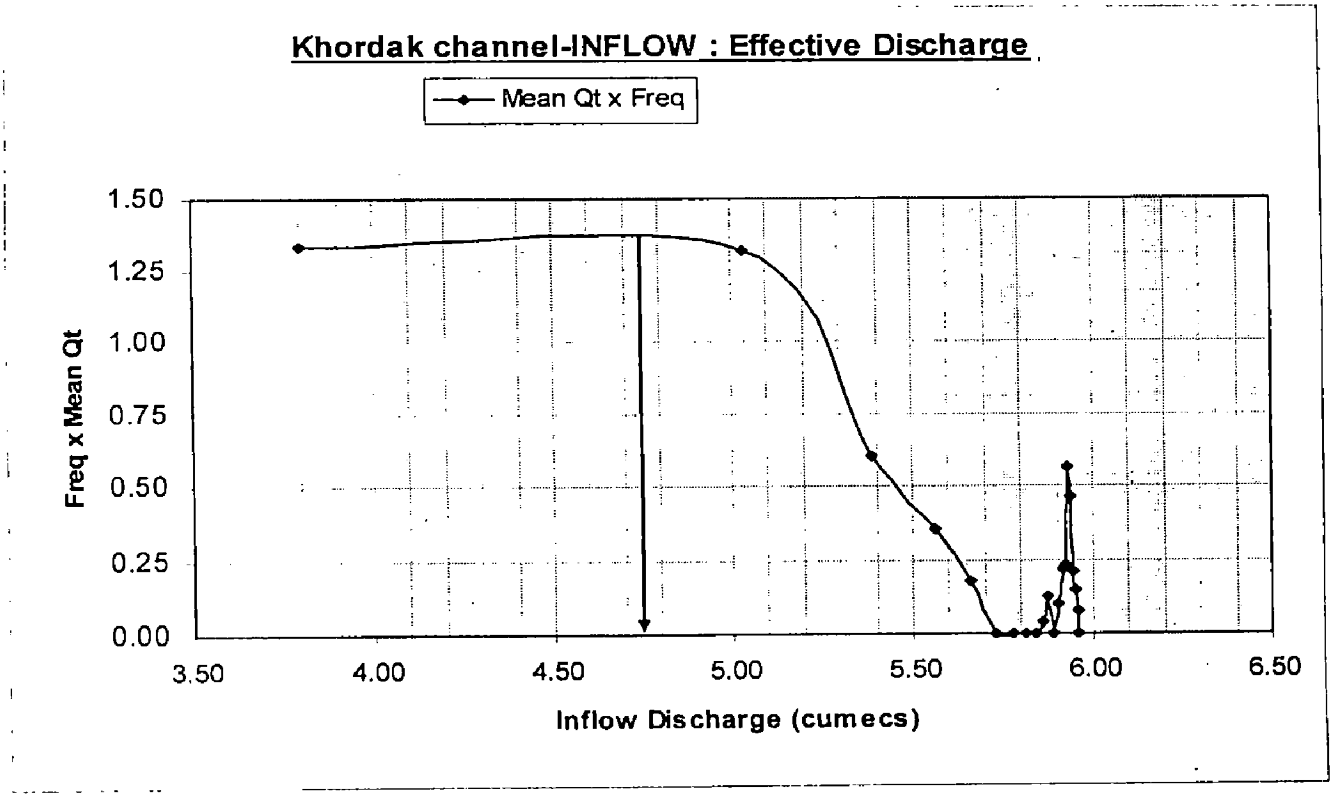


FIG 4.8-4 Effective Discharge of Khordak channel – OUTFLOWs @ stn-1 [MRB]

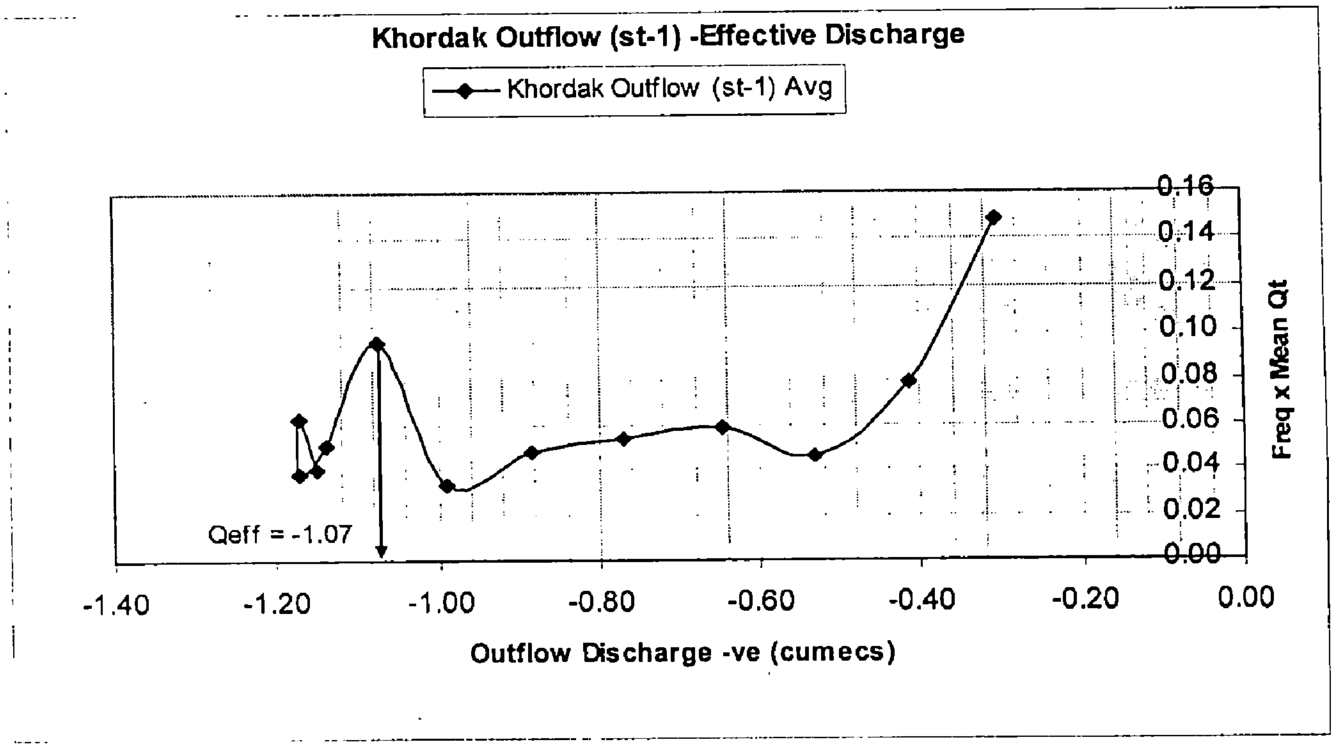


FIG 4.8-5 Effective Discharge of Ungamel channel – INFLOWs @ stn-2 [MRB]

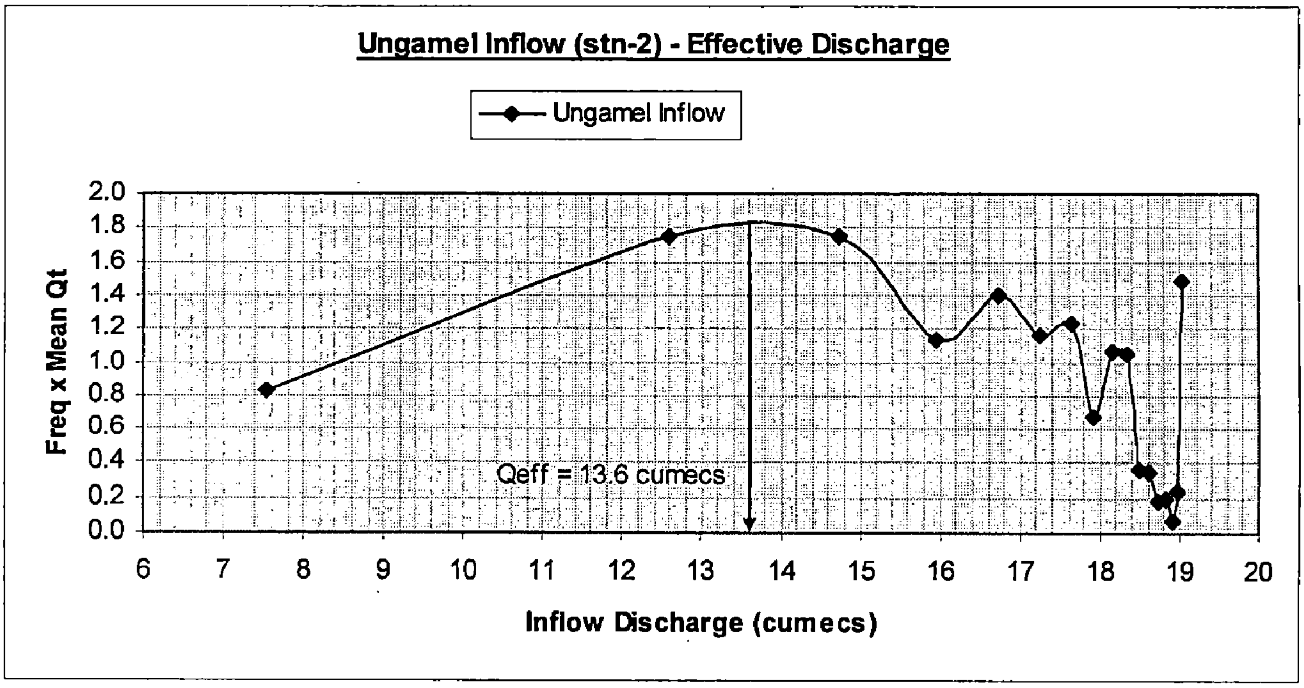
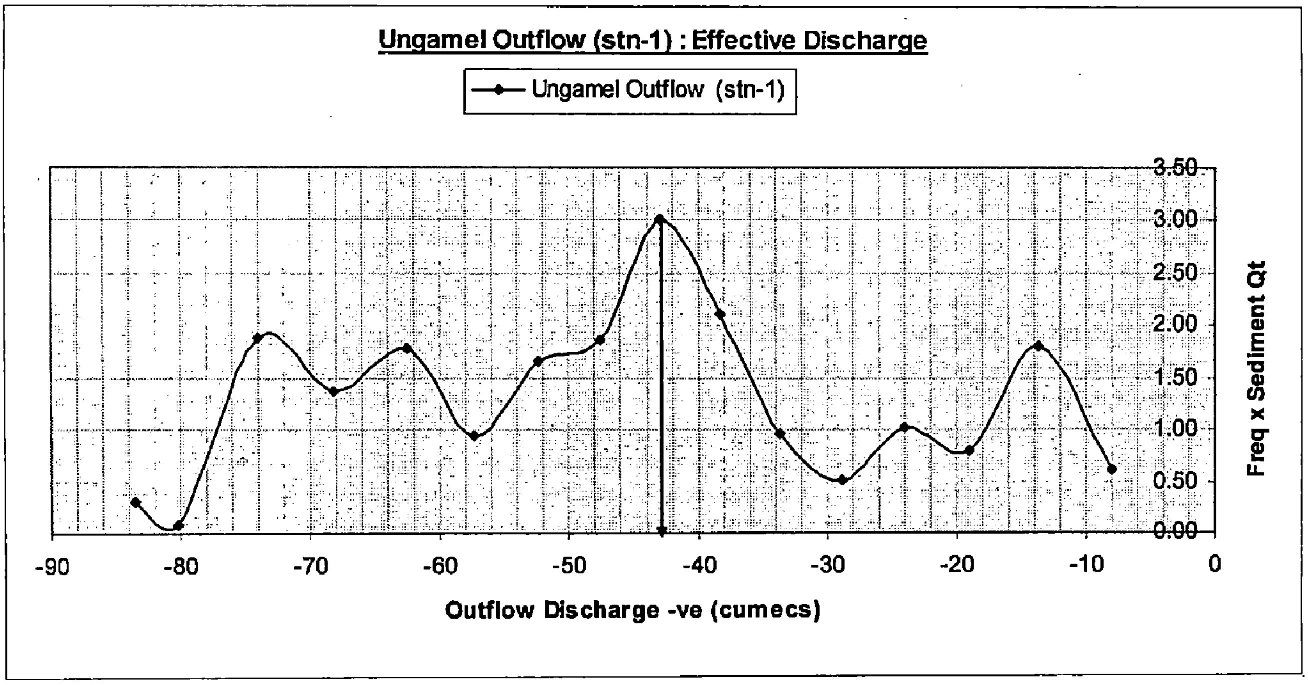


FIG 4.8-6 Effective Discharge of Ungamel channel – OUTFLOWs @ stn-1 [MRB]



4.3.5 WATER LEVEL REGIME CORRELATIONS :

To understand the hydro-regime and the respective effects on the G-Q and Q_t –Q relations of the particular river, water levels (reduced levels at defined benchmarks according to bed levels) between the Loktak lake and the Imphal / Manipur river are processed with the tools deployed above. This analysis is much in relation to the "study of backflow" in the Manipur River Basin.

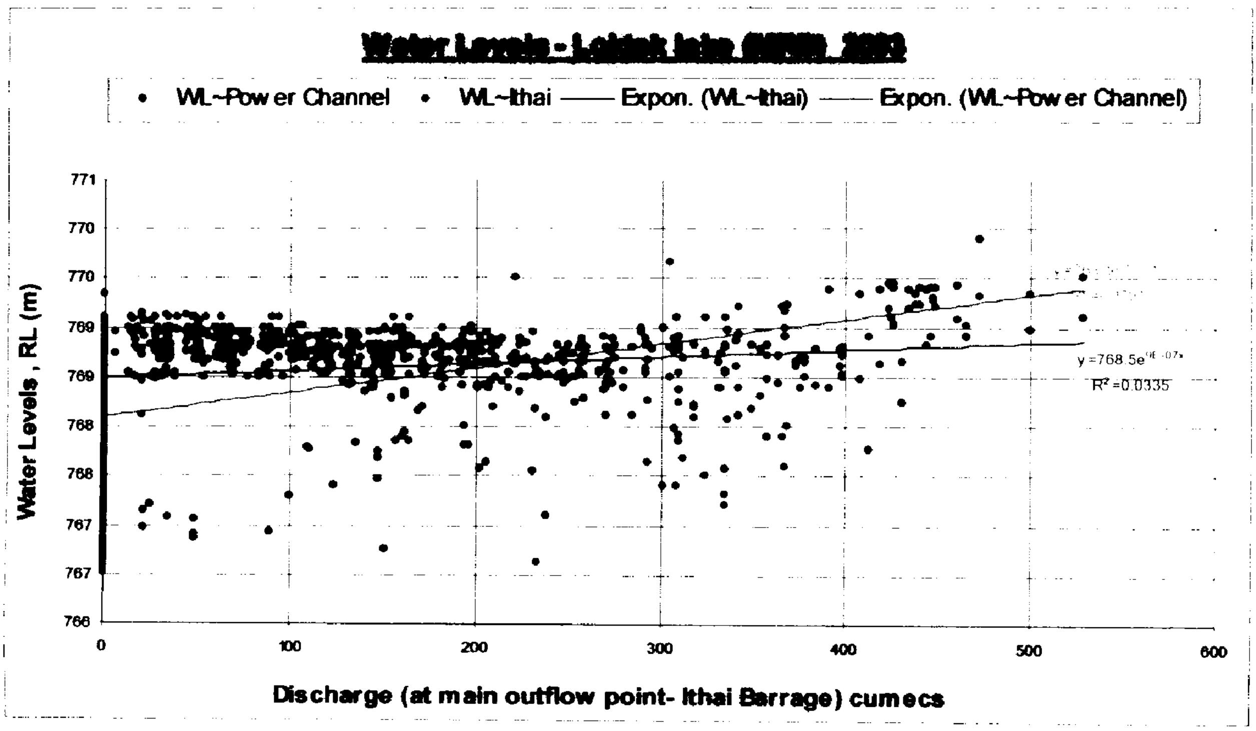
The Lake bed level is marked at 764.00 m above MSL and the Manipur river bed level at 762.00 m above MSL at the station of consideration. Also relative correlations at static locations within the lake are worked out for the levels at the following two sites :

1) in the western portion near the intake of the Loktak project- Power channel ,
2) at the main outflow point of the Lake – Ithai Barrage,

for the three conditions : (a) barrage gates partially or fully open, (b) gates fully closed, and (c) combined conditions of gate positions.

The correlation values are found to be very less within the lake body itself. A comparison with that at the main river is also presented in Figs 4.9 below.

FIG 4.9 Water Level Comparison for Combined Gate conditions



4.4 BACKFLOW OR BI-DIRECTIONAL FLOW ANALYSIS

A preliminary step is taken up to access the 'backflow' or 'bi-directional' flows that are taking place in the two interlink channels – Khordak and Ungamel. The description and few statistics on the phenomena were discussed in preceding sections. It is noted that though the Khordak channel has larger channel capacity , Ungamel channel carries more discharge. The channel stages vary only within 0.5 to 2.0 m water depth in case of Khordak and 1.0 to 3.0 m in case of Ungamel channel.

An important base convention in the analysis is that **positive (+ve)** sign is assigned to **backflow (inflow)** discharges and **negative (-ve)** sign to the **oriented (outflow)** discharges. The signs are adopted on the basis of 'water feeding and abstracting' configurations. It is to be noted that the term "Inflow" has been generally used for the "Backflows". **Station No-1** is assigned at the section at the **meeting point with the Imphal / Manipur River** and **Station No-2** is assigned at the **Loktak lake confluence reach** , for both Khordak and Ungamel channels.

The hydraulic transients and open channel flow concepts are applied to evaluate the 'specific energy' and 'Froude Number' of the flow on daily records of measured velocity and stage. Sub-critical flow persists in most of the period in both the channels.

A Froude number varies from 0.01 to 0.20 in the backflow direction and nearly touches the critical value of 1.0 (range 0.10 – 0.971) during outflow in the station assigned [stn-1] i.e. the confluence point with Imphal / Manipur river in the basin. The specific energy is found to be higher in the backflow than in the outflow cases. This probably indicates the '*initiation of flow*' in the *reverse* direction in Khordak channel.

In the case of Ungamel channel, the Froude No ranges from 0.005 to 0.450 in the backflow direction to 0.004 to 0.670 in the outflow direction, as worked out in the main outflow point (assigned stn-1) of the bain. The specific energy is slightly higher in some periods in the backflow than the outflow direction.Tables regarding the above deductions are given in Appendix.

4.5 DEVELOPMENT AND APPLICATION OF 'HEC-6' MODEL

4.5.1 BASIS OF HEC - 6 FRAMEWORK

General

HEC-6 model is a The HEC-6 code (USAEHEC 1993) is a one-dimensional movable-bed sediment model. It was formulated around Einstein's basic concepts of sediment transport; however, it is designed for the nonequilibrium case. Developed by William A. Thomas at the Hydrologic Engineering Centre, Water Resources Support centers, U.S. Army Corps of Engineers and it is the sixth in the HEC Series of Programs. Based on the sediment transport theory, this program is designed to anlayse scour and deposition by modeling the interaction between the water sediment mixture', sediment material forming the stream's boundary and the hydraulics of flow. This numerical based approach makes it ideal for application to the study of sedimentation in situations like the study of sedimentation in situations like shallow reservoirs, downstream reaches of dams or in natural rivers requiring treatment of the entire movable boundary problem because both scour and deposition and involved and hence complicated unlike the case of sedimentation in deep reservoirs where it an be safely assumed that there is no entrainment of material once it is the stream to transport sediment & its deposition, armoring and the destruction of the armor layer. In general, the program can be used to determine both the volume and location of the sediment deposits.

Equations of flow : The equations for conservation of energy and water mass are simplified by eliminating the time derivative from the motion equation which leaves the gradually varied steady flow equation. It is solved using the standard step method for water-surface profiles.

A brief background is provided in the Appendices.

4.5.2 DATA REQUIREMENTS & INPUT

The basic input data required for sedimentation analysis by HEC-6 model can be grouped into four categories as below. ***It is to be noted that the program requires all data in FPS Units.***

(i) Geometric Data

Geometry of the physical system is represented by cross sections, specified by coordinate points (stations and elevations), and the distance between cross sections. Hydraulic roughness is measured by Manning's n-values and can vary from cross section to cross section. At each cross section n-values may vary vertically and horizontally. The program raises or lowers cross-section elevations to reflect deposition or scour and thus generates data during the course of its execution.

(ii) Sediment Data

The sediment data consist of inflowing sediment load data, gradation of material in the stream bed and information about fluid properties and sediment properties. The inflowing sediment load is related to water discharge by a rating table at the upstream end of the model.

Sediment mixtures are classified by grain size using the American Geophysical union scale. The program accommodates clay (upto 0.004 mm), four classess of silt (0.004 – 0.0625 mm), five classes of sand (very fine sand 0.0625 mm to very course sand 0.2 mm) and five classes of gravel (very fine gravel 0.2mm to very coarse gravel 0.64mm).Sediment transport capacity is calculated at each cross section by using hydraulic data obtained during the calculation of water surface profiles (eg. width, depth, energy slope and velocity of flow) and the gradation of bed material for that cross section.

Various grain sizes adopted for the simulation study are as given in Table 3.2.2. The variations in the sediment load discharge with the flow is calibrated from the Sediment Discharge Rating Curves and entered to the model input.

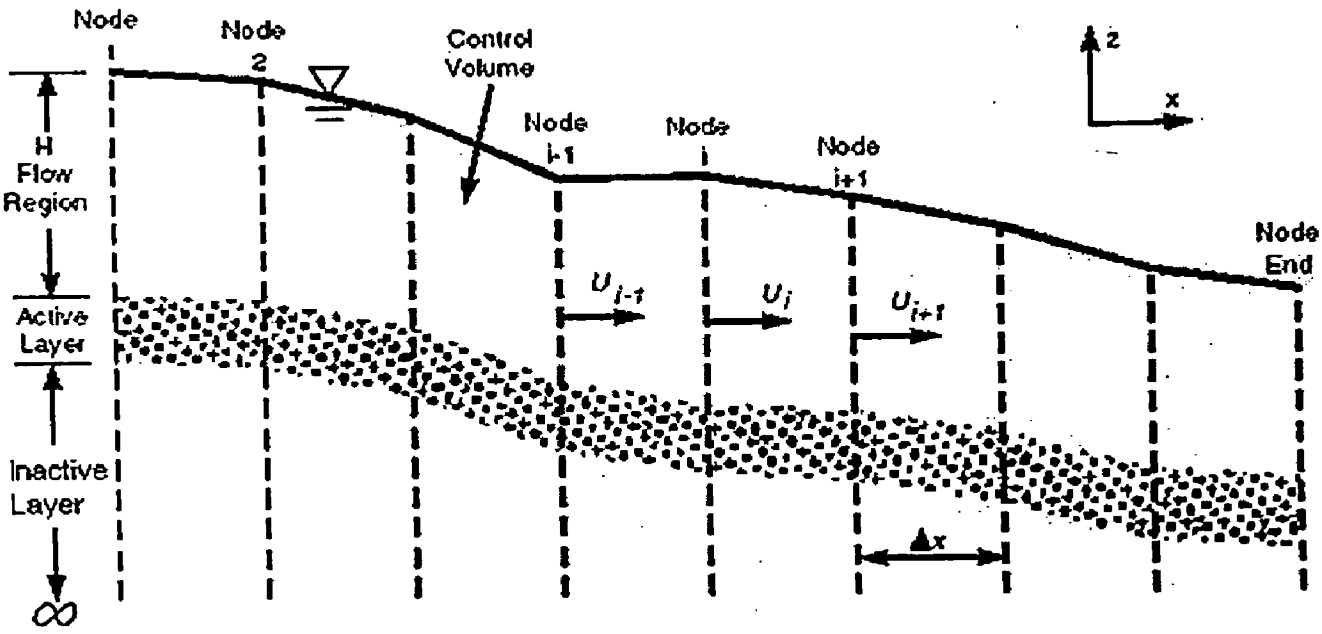
(iii) Hydrologic Data

The hydrologic data consist of water discharges, temperatures and flow durations, the water discharge hydrograph is approximated by a sequence of steady inflow discharges each of which occurs for a specified numbers of days. Water surface profiles are calculated by using the standard step method to solve the energy equation. Friction loss is calculated by Maning's Equation, and expansion and contraction losses will be included if the representative loss coefficients are specified.

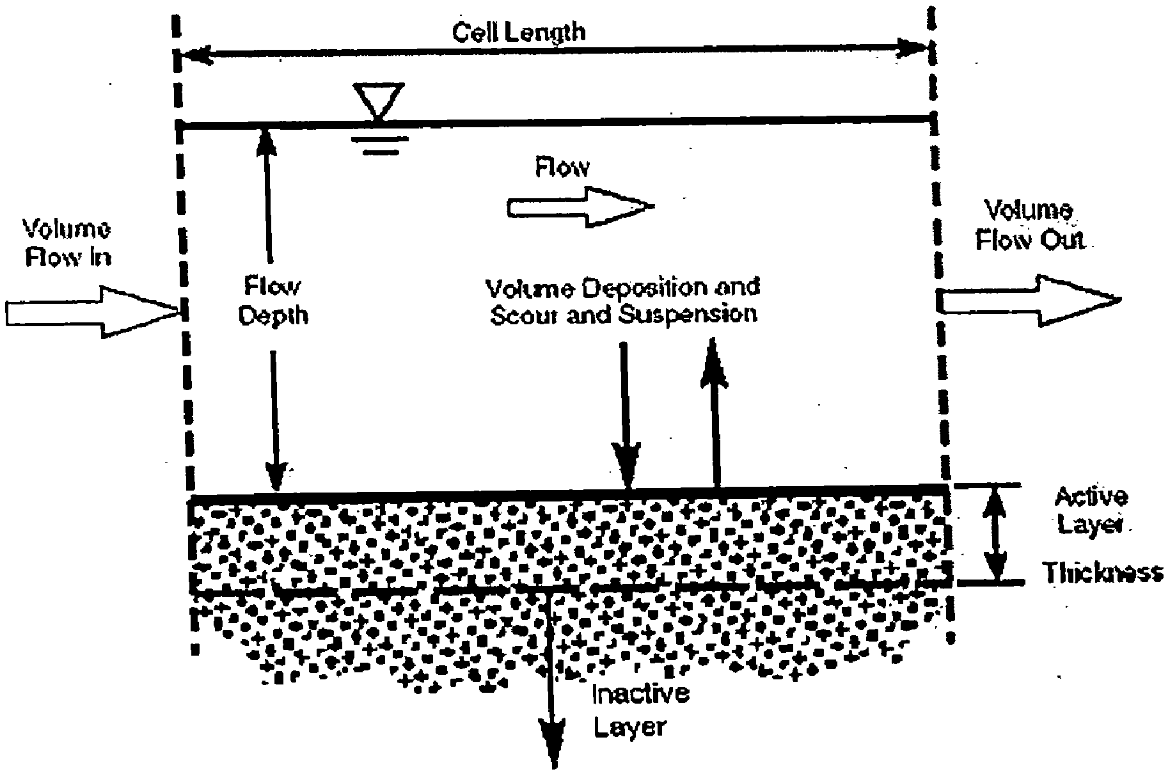
The daily discharges at the site for the period March-2000 to April-2002 are used to obtain a Discharge frequency hydrographs and the gauges respective. The present analysis has been done to estimate the sediment transport rates and the changes in bed levels over that period.

(iv) Operating Rule Data

The operating rule is the functional relationship between the starting water surface elevation and time. It controls the water surface elevation at the downstream end of the study area. This can be a rating curve or a single elevation. It can be changed at any water discharge.The conservation of energy, conservation of water, and conservation of sediment equations are solved under a *Numerical integration scheme* using an explicit, finite difference computation procedure. Figure 4.10 shows a definition sketch. Hydraulic computations begin at the downstream boundary and proceed cross section by cross section to the upstream boundary. Sediment movement computations begin at the upstream boundary and proceed section by section to the downstream boundary. At each section at the beginning of a computational time step, the volume of sediment in the bed that is available for exchange with the water column is determined.



A domain of the HEC-6 Model



Description of the Active layer

FIG 4.10 Domain of the HEC-6 Model

4.5.3 PROGRAM ORGANISATION

The HEC-6 program in its present form has been organized into seven modules. The various modules function together as subprograms where data is transferred in "Labelled Common" or in "Call Linkage". The functional flowchart of the program is shown in Fig. 4.12.

The total water inflow into Loktak Lake averages to 1687 Mcum (2000-01) and the total outflow to 1217 Mcum. The annual average sediment input into the lake has been estimated to 650,000 MT. Two of the major rivers in the basin (viz., Nambul and Nambol) and other non-perennial streams directly fall into the lake and grouped under 'Direct catchment rivers'.In this Model, the two main recurrent flowing rivers have been adopted. The main drainage river- Imphal / Manipur river which by-passes the Lake is discretized to the Model with the two interlinking channels – Khordak and Ungamel. Three other major rivers which are tributaries of the Imphal river and fall into the the 'Indirect catchment rivers', are integrated into the Imphal river formulation as tributaries with their mean flows. The Khuga river, though a major tributary is not taken into the Model as the simulation is set at a cross-section upstream of Ithai (the confluence point and main outlet of the basin).

Backflow or Bi-Directional Flow Idealization and Framing

A special framework to model the 'Backflow' (Inflow) and Outflow , in the frame as bi-directional flow within the same channel is devised. In both the cases of the two channels – Khordak and Ungamel , the **base station is the Imphal river confluence in the outflow convention** and **Loktak confluence in the backflow or inflow convention.** The cross-sections remain the same , accept for the order depending on the base station (the cross section data input is reversed when simulating for outflow to that used in the inflow along the same channel). Station G-Q and Q_t –Q boundary values are applied under the same sediment distribution.

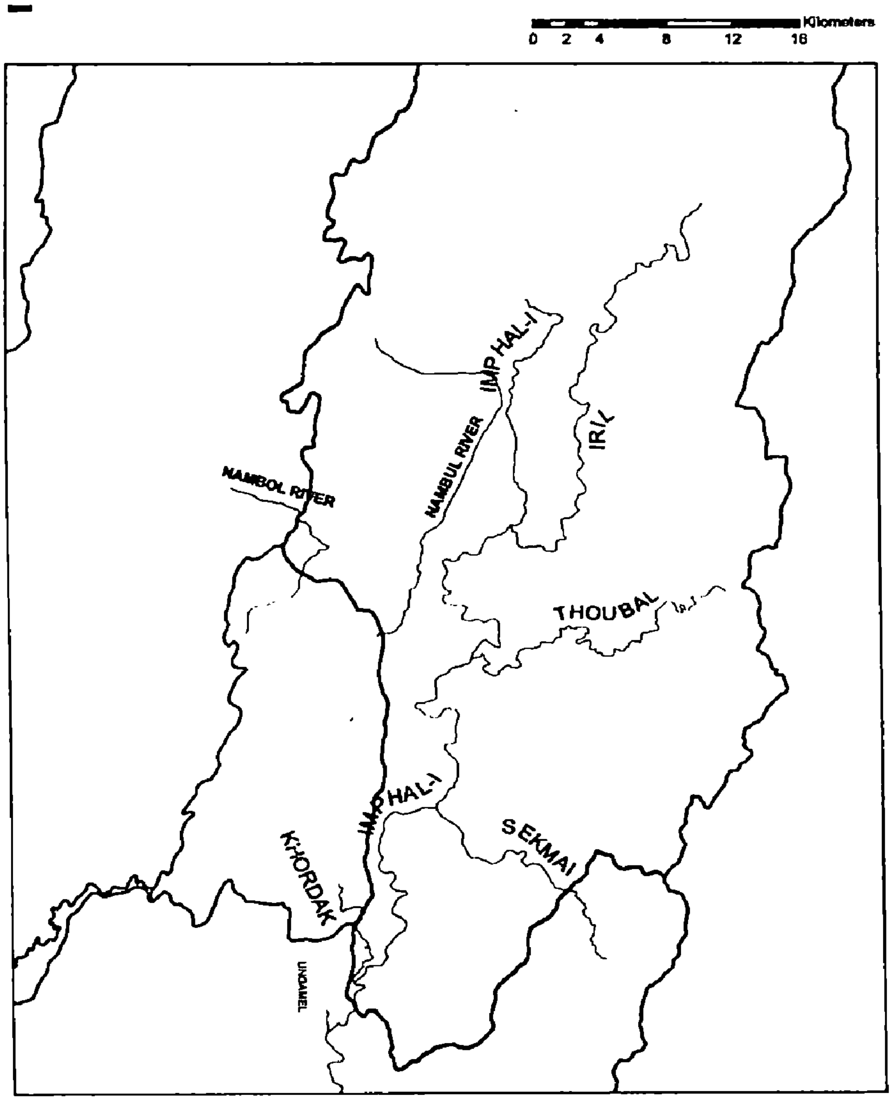


FIG 4. 11

Application of Framework of the Rivers under study in the HEC-6 Model : (i) Imphal river with tributaries Iril, Thoubal and Sekmai, (ii) Nambul and Nambol Rivers in direct catchment, and (iii) Interlink channels – Khordak and Ungamel

Manning's Roughness Coefficient

Based on the observed discharges, constituent material of river channel and vegetation present in the flow path of the stream (referred Chow,1973 and French, 1985), a value of Manning's rugosity coefficient equal to 0.04 for the Left and Right of Banks (LOB and ROB) , and 0.033 for the Middle channel section has been adopted generally for all the cross-sections during the study. A comparison by varying the coefficients is also done.

Boundary Conditions

Besides the hydrologic data, sediment data and roughness coefficients, other bound values accorded is the depth of sediment bed control volume (adopted as 10.0 ft throughout) and the water temperature. The sensitivity of the variation in water temperature (^{0}F) over the sediment transport rates and water surface is also simulated as presented in the result summary tables . A water temperature of 12 ^{0}C (53.6 ^{0}F) as per field data is adopted.

The HEC-6 program was conducted on a WINDOWS\system32\cmd.exe Program menu operating platform and respective simulations carried out for the period as specified above. Filenames (limiting to 8 characters) were used specifying the river name and other details.

Results

The result outputs are displayed in a tabulated figurative format under the same filename as the Input filename (.DAT file) as .OUT file extension.The result outputs are given in the Appendix.

The discussion of the results are presented in the next chapter.

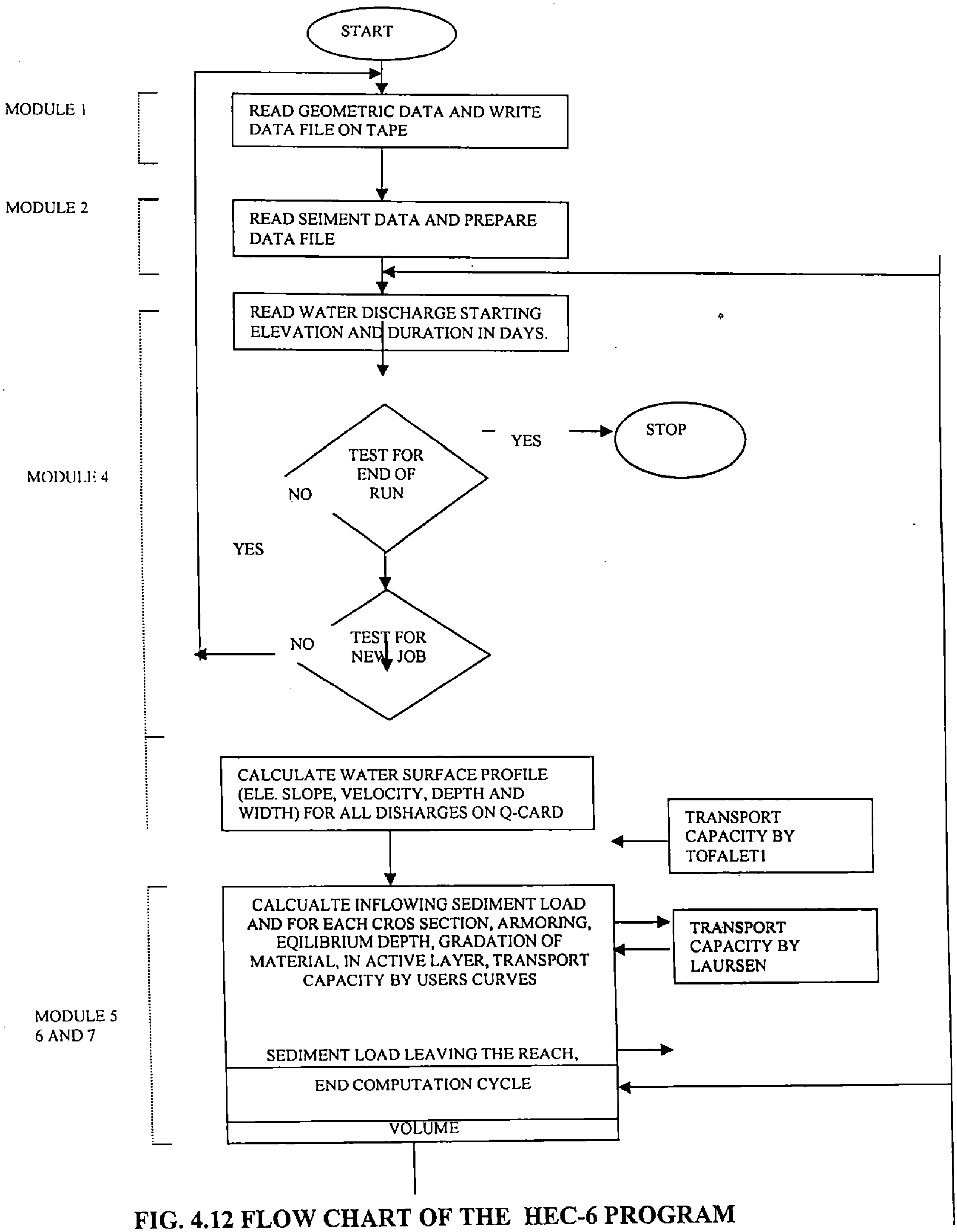


FIG. 4.12 FLOW CHART OF THE HEC-6 PROGRAM

CHAPTER 5

MODEL RESULTS AND DISCUSSIONS

The extensive application of HEC-6 models under the boundary conditions derived from various regression, multi-regression and auto-regression techniques of flow conditions and sediment transport characteristics, along with Effective Discharge, Mean Discharge,etc input values for the major rivers (viz., Imphal / Manipur River, Nambul River , Nambol River , etc) show that there is slight deposition in the the river bed at the cross-sections of consideration. Though there are indications of bed scour for various discharge values, this effect may be attributed to the meanders and loops that most of the rivers traverses. HEC-6 Programs do not model the meander and loops.Also the effects of an upstream Barrage of the main Imphal river may be rooted to have degraded the stream bed. One important note is that as described earlier , the Imphal River does not fall directly in the Loktak Lake . A water level regime relation in the form of multi-variate transformations of the hydraulic factors at the main outflow point of the lake (in Imphal/Manipur River) , between the Lake and at river levels were compared. The estimation of effective and mean discharges of floods that requires long term records (which are found to be unreliable after flood frequency analysis from 1923 in Imphal river has been carried out) , is ascertained by correlating the annual run-off volume and the measurable morphological characteristics of the river, as done using GIS methodology using satellite image data (1998, 2003 & 2005) along with topographic map (G.S.I. , 1966). As most of the other prominent streams (tributaries) are almost unguaged or very little information available , only their annual mean streamflows are accounted as tributary discharge values (QT) in the HEC-6 Model formulations. The other minor streams (from the western hills Loktak sub-basin) characterizing notable sediment yield are evaluated of the mean sediment load and transport values from comparative ratings (ref. appendix) and scattered , as most them are perennial and flows actively only for isolated periods during the flood / rainy months .

The interlink two natural channels – Khordak and Ungamel , which is hypotheticated to regime the Lake and main river fluvial hydrosystem , are formulated to attain , what may be described as a "quasi-equilibria" in the basin. As considerations of **alternate** 'Downstream' and 'Upstream' boundary values with respect to its direction of flow- as 'Inflow / Backflow' and 'Outflow' (from Loktak Lake) in the HEC-6 models indicate that , the *scour* in *particular* sections and *deposition* in *other subsequent* sections of consideration in an Inflow- bound formulation is reverted during the Outflow-bound formulation of the same sections and channel (i.e., there is deposition in the particular sections and scour in the other subsequent sections with respect to that stated earlier). Though, this dynamic fluvial state is more or less regulated by the gate operations of Ithai barrage, the water level profile comparisons and regressive trends plots (presented in the preceeding chapters) near the barrage site and the upstream considered points of Loktak Lake , does not seem to much transient this bed level equilibrium (as the gates almost follow a cycle- they are mostly closed in the dry or lean season and open partially or fully in the flood / monsoon season). This may be the reason why the longitudinal sections of these two interlink channels almost show a flat or mild bed slope.

It is seen that in most of the results derived that , "Silt" as a whole (bounded separately as Very Fine , Fine , Medium and Coarse silt as in the HEC-6 sediment data input) predominates the fluvial transport regime in the river basin. Sand transport is seen to be significant at the downstream bound sections of the rivers in the model results. The records regarding coarser material as gravel, cobbles and boulders are not included in the model as though they play an important role in the mountain head reaches, their parameter in the 'Sediment distribution or gradation' as derived from from the sediment samples and analysis have not been ascertained.

The limitation of One-Dimensional confinement of the HEC-6 program as well as the fixation of the boundary between consecutive cross sections remaining fixed for the study may be the reason that variations in the bed are much prominent when more Channel geometry- Cross sections are defined (as the case with Khordak). The entire movable bed part of the cross section is moved vertically up and down.

The Summary results of the Program are given in Tables 5.1 to 5.3.

TABLE NO 5.1
MAIN DRAINAGE RIVER (MRB)-HEC-6 MOBILE BED MODEL RESULT SUMMARY

River : Imphal River-11/Manipur river
(Tributaries: Iril, Thoubal and Sekmai Rivers)
Station: 1 (Arong) Temp: 53.6^{0}F Manning Coeff: LOB & ROB-0.04, MID-0.033

Sl. No	Notation File for HEC-6	Effective Discharge Valve	Hydraulic Radius	Trap Efficiency			Sediment Transport Rate			Bed Change	Water Surface	Sediment Discharge
				Clay	Silt	Sand	Clay	Silt	Sand			
		Qc	R	%	%	%	Tons/day			ft	ft	Tons/day
1.	IMRIVM	3326.0	8.863	0.03	0.44	1.00	2162	11317	9	0.00	2536.30	13487.01
2.	IMRIVMIN	4590.9	10.482	0.00	-0.11	0.99	2223	22469	53	0.00	2536.90	24744.56
Temp: 53.6^{0}F Manning Coeff: LOB & ROB-0.045, MID-0.035												
3.	IMRIVMC	3326.00	9.021	0.02	0.39	1.00	2170	12449	11	0.00	2536.30	14629.62
Temp: 64.4^{0}F Manning Coeff: LOB & ROB-0.04, MID-0.033												
4.	IMRIVMT2	3326.00	8.863	0.03	0.49	1.00	2144	10371	9.0	0.00	2536.30	12523.65
Without Tributaries Temp: 53.6^{0}F Manning Coeff: LOB & ROB-0.04, MID-0.033												
5.	IMRIVNOT	3326.00	15.325	-0.21	-9.92	1.00	6636	547-950	54	0.00	2536.30	554640.19

Table no 5.2

BI-DIRECTIONAL FLOW ANALYSIS (HEC-6 MOBILE BED MODEL RESULT SUMMARY)

River: - Khordak Channel

Station: 1 Temp: 58.6^{0}F Manning Coeff: LOB & ROB-0.040 MID-0.033

Flow: - Inflow (Backflow)

A-1

Sl. No	Notation File for HEC-6	Effective Discharge Valve	Hydraulic Radius	Trap Efficiency			Sediment Transport Rate			Bed Change	Water Surface	Sediment Discharge
				Clay	Silt	Sand	Clay	Silt	Sand			
		cfs	ft	%	%	%	Tons/day			ft	ft	Tons/day
1.	KHRDKI	169.51	3.539	0	0	0.34	54	493	73	-0.02	2513.48	620.26
2.	KHRDKI 2	209.06	6.225	-0.07	-4.53	-1.07	66	3089	259	-0.34	2517.41	3413.39

Flow: - Outflow (A-2)

Station:2 Temp: - 58.6^{0}F Manning Coeff: LOB & ROB-0.040 , Middle-0.033

3.	KHRDK0	37.79	2.695	0.32	0.79	1.00	207	465	0	0.01	2516.43	671.39
4.	KHRDK0 2	10.59	2.372	0.51	0.99	1.00	9	2	0	0.00	2518.67	11.49

River: - Ungamel Channel

Flow: - Inflow (B-1)

Station: -1 Temp: - 58.6^{0}F Manning Coeff: LOB & ROB-0.040, Middle-0.033

5.	Ungamel1	480.280	4.973	0.00	0.08	1.00	485	4091	1.0	0.01	2522.52	4576.72
6.	Ungamel2	670.980	5.214	0.00	0.00	1.00	713	6524	6.0	0.00	2522.82	7243.02

Flow: -Outflow (B-2)

Station: -2 Temp: - 58.6^{0}F Manning Coeff: LOB & ROB-0.040, Middle-0.033

7.	Ungamel0	1518.53	6.623	0.00	0.00	0.90	2978	272-92	591	0.00	2522.62	30860.97
8.	Ungamel0 2	2577.97	5.892	-0.02	-1.11	-1.61	5491	1040-63	288-66	-5.86	2521.66	138420.31

Table No 5.3a
Direct Catchment Rivers (MRB)-HEC-6 MOBILE BED MODEL RESULT SUMMARY

River: - Nambul River (C-1)
Station: - 1(Hiyanthang) Temp: - 53.6^{0}F Manning Coeff ROB/LOB-0.04, MID-0.033

Sl. No	Notation File for HEC-6	Effective Discharge Valve	Hydraulic Radius	Trap Efficiency			Sediment Transport Rate			Bed Change	Water Surface	Sediment Discharge
				Clay	Silt	Sand	Clay	Silt	Sand			
		Qc	R	%	%	%	Tons/day			ft	ft	Tons/day
1.	NAMBUL 1	252.50	4.997	-0.08	-5.22	-14.57	230	12101	6784	-2.30	2538.79	19115.83
2.	NAMBUL2	483.81	5.903	-0.06	-3.61	-9.31	440	17553	8792	-2.95	2540.09	26786.14
Manning Coeff: - ROB/LOB-0.045, MID-0.035												
3.	NAMBUL 3	252.50	4.227	-0.08	-5.22	-15.14	230	12101	7029	-2.33	2538.79	19361.11
Temp: -64.4^0 F Manning Coeff: - ROB/LOB-0.04, MID-0.033												
4.	NAMBUL 4	252.80	4.997	-0.08	-5.22	-14.16	230	12101	6607	-2.27	2538.79	18938.18

Table No 5.3b

River: - Nambol River (D-1)
Station: - (Nambol) Temp: - 53.6^0 F Manning's Coeff : LOB/ROB-0.04,MID-0.033

Sl. No	Notation File for HEC-6	Effective Discharge Valve	Hydraulic Radius	Trap Efficiency			Sediment Transport Rate			Bed Change	Water Surface	Sediment Discharge
				Clay	Silt	Sand	Clay	Silt	Sand			
		Qc	R	%	%	%	Tons/day			ft	ft	Tons/day
1.	NAMBOL 1	183.640	3.497	0.00	-0.02	0.96	289	2699	25	0.00	2541.67	3012.51
2.	NAMBOL2	388.46	4.304	0.00	-0.03	0.88	763	7168	182	-0.02	2542.85	8112.91
Manning Coeff: - ROB/LOB-0.045, MID-0.035												
3.	NAMBOL 3	183.640	3.571	0.00	-0.02	0.95	289	2699	29	0.00	2541.67	3016.14
Temp: -64.1^0 F Manning Coeff: - ROB/LOB-0.04, MID-0.033												
4.	NAMBOL 4	388.46	4.304	0.00	-0.03	0.89	763	7183	170	-0.02	2542.85	8115.91

CHAPTER 6

CONCLUSIONS

From the defined set of numerical based model analyses , the following conclusions are drawn :

- The Sediment transport rates are in parity with the measured observed data. Though variations in the Discharge boundary values in the model input as in case of the Imphal / Manipur river are less affected.

- The increase of water temperature decreases the sediment transport rate and trap efficiency in case of silt and clay .The total sediment transport rate is marginally found to go down.

- The increase in the roughness coefficients is also found to increase the sediment transport rates and trap efficiency , but a fall in the trap efficiency of Silt is found .

- The frequency in 'effective discharges/flows' is scale dependent (in particularly, the main Imphal river which drains the maximum basin area).

- The net sediment inflow as considering the main stem rivers (viz., Nambul, Nambol, Imphal) has a frequency of exceedance (evaluated to 35.24 % on a day threshold) then the net sediment outflow through the interlink natural channels- Khordak and Ungamel. The minor streams flowing into the lake , as experiencing perennial flows only in the flood season are statisicated with mean and total flows and sediment discharges (appendix).

- No bed change is observed in case of the main Imphal river in the one day simulation. But, there are changes at the upstream sections. A peculiar bed alignment and re-alignment is seen to be one of the effects of the 'backflow' or bi-directional flows in the two interlink channels. A scour in the bed in the Inflow (backflow) is seen to be deposited in the Outflow in the same channel course and section (ref. Khordak KHRDKI and KHRDKO in table 5.2).

- The various Sensitivity tests carried out to check the variance and reliability of data used , shows that the sediment concentrations recorded in the major rivers , are yet to account for large rapid changes as generally occurring in the flood periods. For instance, a concentration of as low as 4 ppm observed in Imphal River in Feb 2000 doesn't coherent the flow values in the same period. So , the use of multi-variate transformation of the hydraulic parameters as stage, discharge flow and sediment discharge , is found to be a viable method in parametrising the observed datasets.

- The special study emphasizing 'backflow or bi-directional flow' regards a highly transient hydraulic variable in the stage, flow , velocity , channel geometry, etc. In the study , only an Auto-regression transformation of the discharge values with respect to the other flow properties stands to attain a realistic model to polynomials as high as to the order 6 of the flow behaviour (as seen in a correlation value of 0.9790 in Khordak channel (stn-2) Inflow). Whether , it is the Lake level at one potential point or the level in the Imphal / Manipur River at the other potential point, the flow in both directions genre a mutual deposition and scour in its bed profile as formulated by the HEC-6 program.

On the whole, it can be inferred that the numerical based model of the fluvial basin system quantifies the sediment transport values and factors affecting the processes to satisfactory extents , taking into account the long memory of the Manipur River Basin sediment system. Parallel equations transcended on correlations , may be adopted as the 'forcing functions' in measuring related system-response parameters in future studies, though more detailed studies based on accurate and indiscriminate temporal data may be required for strategic decisions on the Basin planning and development .

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APPENDIX - I

OUTPUTS OF HEC-6 MODEL

```
**************************************************   ***********************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *    * U.S. ARMY CORPS OF ENGINEERS *
*    Version: 4.1.0                              *    * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE:  IMRIVM.DAT                        *    * 609 SECOND STREET              *
* OUTPUT FILE: IMRIVM.OUT                        *    * DAVIS, CALIFORNIA 95616-4687   *
* RUN DATE: 06 JUN 06   RUN TIME: 20:14:15       *    * (916) 756-1104                 *
**************************************************   ***********************************

X   X XXXXXXX  XXXXX       XXXXX
X   X X      X     X     X     X
X   X X      X           X
XXXXXXX XXXX    X      XXXXX XXXXXX
X   X X      X           X     X
X   X X      X     X     X     X
X   X XXXXXXX  XXXXX       XXXXX

**********************************************************************
* MAXIMUM LIMITS FOR THIS VERSION ARE:                               *
*     10  Stream Segments (Main Stem + Tributaries)                  *
*    150  Cross Sections                                             *
*    100  Elevation/Station Points per Cross Section                 *
*     20  Grain Sizes                                                *
*     10  Control Points                                             *
**********************************************************************
```

T1 FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
T2 # MOBILE BED HEC-6 MODEL #
T3 # TRIBUTARIES [QT] - SEKMAI,THOUBAL & IRIL Rivers respectively-MEAN FLOWS

N values... Left Channel Right Contraction Expansion
.0400 .0330 .0400 1.1000 .7000

SECTION NO. 1.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

LOCAL INFLOW POINT 1 occurs upstream from Section No. 1.000

SECTION NO. 2.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

LOCAL INFLOW POINT 2 occurs upstream from Section No. 2.000

SECTION NO. 3.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

LOCAL INFLOW POINT 3 occurs upstream from Section No. 3.000

SECTION NO. 4.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 4
NO. OF INPUT DATA MESSAGES = 0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK = 4
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK= 1
END OF GEOMETRIC DATA

==
===========================

```
T4    Imphal/Manipur River (Section - II )    ** Movable bed **
T5    LOAD CURVE FROM GAUGE DATA.
T6    BED GRADATIONS FROM FIELD SAMPLES
T7    Use full range of Sands and gravel
T8    SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

   FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
   MOBILE BED HEC-6 MODEL #
   TRIBUTARIES [QT] - SEKMAI,THOUBAL & IRIL Rivers respectively-MEAN FLOWS

---------------------------------------------
SEDIMENT PROPERITES AND PARAMETERS

    SPI   IBG   MNQ    SPGF    ACGR    NFALL   IBSHER
I1   5.    0     1    1.000   32.174     2       1
---------------------------------------------
CLAY IS PRESENT.

   MTCL  SPGC    PUCD     UWCL     CCCD
I2   2   2.650   78.000   30.000   16.000


 DEPOSITION COEFFICIENTS BY LAYER
             DEPOSITION
             THRESHOLD
              SHEAR
         LAYER    STRESS
          NO.     lb/sq.ft

 ACTIVE LAYER  1      .0200
INACTIVE LAYER  2      .0200

 EROSION COEFFICIENTS BY LAYER
           PARTICLE  MASS      MASS      SLOPE OF   SLOPE OF
           EROSION   EROSION   EROSION   PARTICLE   MASS
           SHEAR     SHEAR     RATE      EROSION    EROSION
       LAYER STRESS  STRESS              LINE=ER1   LINE=ER2
        NO   lb/sq.ft  lb/sq.ft.  lb/sf/hr  1/hr     1/hr

 ACTIVE LAYER  1      .0500     .1000    1.5000   30.0000   20.0000
INACTIVE LAYER  2      .1250     .2300    2.0000   19.0476   10.0000
---------------------------------------------
SILT IS PRESENT

    MTCL  IASL  LASL   SGSL   PUSDLB   UWSDLB   CCSDLB
I3   2     1     4    2.650   82.000   65.000    5.700

 DEPOSITION COEFFICIENTS BY LAYER
             DEPOSITION
             THRESHOLD
              SHEAR
         LAYER    STRESS
          NO.     lb/sq.ft

 ACTIVE LAYER  1      .0200
INACTIVE LAYER  2      .0200
```

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY..............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	1954.00	4879.00	6815.00	8400.00	9784.00	12183.0	14751.0	15687.0
LF CLAY	2215.89	10545.4	18642.1	26624.8	34531.8	50185.2	69536.8	77226.0
LF SILT1	7269.19	34594.2	61155.3	87342.4	113281.	164632.	228115.	253339.
LF SILT2	4756.05	22634.1	40012.4	57146.0	74117.1	107715.	149250.	165753.
LF SILT3	4458.80	21219.5	37511.6	53574.3	69484.8	100982.	139922.	155394.
LF SILT4	3783.22	18004.4	31828.0	45457.0	58956.8	85682.1	118721.	131849.
LF VFS	2080.77	9902.43	17505.4	25001.4	32426.2	47125.2	65296.8	72517.1
LF FS	1297.10	6172.94	10912.5	15585.3	20213.8	29376.7	40704.5	45205.4
LF MS	621.529	2957.87	5228.89	7467.94	9685.76	14076.3	19504.2	21660.9
LF CS	540.460	2572.06	4546.86	6493.86	8422.40	12240.3	16960.2	18835.6
TOTAL	27023.0	128603.	227343.	324693.	421120.	612015.	848010.	941780.

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH (ft)	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
1.000	.000	279.100	2540.500	2513.200	2541.000	.000	.000
2.000	93359.000	287.100	2559.000	2520.400	2560.000	93359.000	17.682

```
    30526.000
3.000          257.400  2559.000  2527.700  2561.000  123885.000     23.463
    110109.000
4.000          376.200  2568.900  2536.000  2571.400  233994.000     44.317
```

BED MATERIAL GRADATION

```
---------------------
 SECNO   SAE  DMAX  DXPI   XPI  TOTAL     BED MATERIAL FRACTIONS
         (ft)  (ft)        BED        per grain size
--------------------------------------------------------------------------------
  1.000 1.000  .003  .003 1.000 1.000|  CLAY   .001 | VF SAND  .238 |
                               | VF SILT  .001 | F  SAND  .185 |
                               | F  SILT  .023 | M  SAND  .025 |
                               | M  SILT  .238 | C  SAND  .058 |
                               | C  SILT  .230 |

  2.000 1.000  .003  .003 1.000 1.000|  CLAY   .001 | VF SAND  .238 |
                               | VF SILT  .001 | F  SAND  .185 |
                               | F  SILT  .023 | M  SAND  .025 |
                               | M  SILT  .238 | C  SAND  .058 |
                               | C  SILT  .230 |

  3.000 1.000  .003  .003 1.000 1.000|  CLAY   .001 | VF SAND  .238 |
                               | VF SILT  .001 | F  SAND  .185 |
                               | F  SILT  .023 | M  SAND  .025 |
                               | M  SILT  .238 | C  SAND  .058 |
                               | C  SILT  .230 |

  4.000 1.000  .003  .003 1.000 1.000|  CLAY   .001 | VF SAND  .238 |
                               | VF SILT  .001 | F  SAND  .185 |
                               | F  SILT  .023 | M  SAND  .025 |
                               | M  SILT  .238 | C  SAND  .058 |
                               | C  SILT  .230 |
```

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	46679.500	281.767	10.000	.131527E+09	.487138E+07
2.000	61942.500	282.651	10.000	.175081E+09	.648448E+07
3.000	70317.500	290.553	10.000	.204310E+09	.756703E+07
4.000	55054.500	336.600	10.000	.185313E+09	.686346E+07

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

```
==========================================================================
==========
```

$HYD
BEGIN COMPUTATIONS.

```
==========================================================================
```

TIME STEP # 1
* BB PROFILE 1 = Effective Stream Flow of Imphal / Manipur River

FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
3326.000	62.00	2536.300

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

.100 2540.500	9.800 2541.100	29.500 2540.300	36.100 2539.500	47.600 2539.600
54.800 2539.000	57.700 2535.200	59.400 2530.900	67.300 2527.800	71.200 2526.800
75.800 2524.100	82.300 2521.800	88.900 2521.200	95.500 2519.600	102.000 2514.700
108.600 2513.200	115.200 2513.500	128.300 2513.600	134.800 2513.800	141.400 2514.200
154.500 2514.200	161.100 2515.200	167.600 2515.500	174.200 2516.600	180.800 2517.800
187.300 2516.600	193.900 2519.500	200.500 2525.100	213.600 2529.500	222.100 2534.900
230.000 2539.400	236.500 2539.600	256.200 2539.800	262.800 2541.500	275.900 2541.800
279.200 2541.000				

**** 3326.000 2536.300 2536.322 .022 1.000 167.697 2519.780 .000 1.201 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	769645.341	.000
	AREA	.00	2770.28	.00
	HYD RADIUS	.0000	15.3247	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	.0000	.0000	.0000
D/S SECTION...	AREA	.00	.00	.00
	HYD RADIUS	.000	.000	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	1.000	279.100	.000000000	2906831.45

--- LOCAL INFLOW POINT # 1 is upstream of Section No. 1.000 ---

	DISCHARGE (cfs)	TEMPERATURE (deg F)
Local Inflow:	254.810	.00
Total:	3071.190	67.14

SECTION NO. 2.000

Cross Section Geometry (STA,ELEV)

.100 2559.000	13.100 2559.300	18.000 2552.800	27.900 2554.100	35.100 2554.100
42.700 2551.700	48.100 2547.500	55.800 2544.500	62.700 2540.900	65.600 2539.700
70.500 2537.900	75.000 2534.400	81.600 2530.700	85.500 2527.800	90.700 2523.400
97.200 2521.200	100.000 2520.400	103.800 2520.600	103.900 2520.900	107.100 2521.400

110.400 2521.600	116.900 2522.200	120.200 2521.500	123.500 2521.600	126.800 2521.700
130.100 2521.700	133.300 2522.000	136.600 2522.400	139.900 2524.100	144.800 2526.000
148.100 2527.600	157.900 2531.800	167.800 2535.900	180.900 2541.200	185.500 2543.600
189.100 2550.100	198.000 2552.500	201.900 2554.700	224.900 2555.400	242.800 2555.500
259.200 2555.700	277.400 2556.500	282.000 2558.000	287.200 2560.000	

```
**** 3071.190 2539.555 2539.637   .082   1.000  110.806 2527.499   .000  2.299   .000
                          FLOW DISTRIBUTION (%) =    .000 100.000   .000

   REACH PROPERTIES BY STRIP          1          2          3
         INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE       .000 299494.471       .000
              AREA         .00    1335.84       .00
           HYD RADIUS       .0000    11.1095     .0000
 REACH...      Manning's N      .0400     .0330     .0400
              SQRT(L)   305.5471  305.5471  305.5471
 D/S SECTION...       AREA        .00    2770.28       .00
           HYD RADIUS        .000     15.325      .000


   SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD       2.000     287.100     .000000000        3869397.01

--- LOCAL INFLOW POINT #  2 is upstream of Section No.      2.000 ---
               DISCHARGE   TEMPERATURE
                 (cfs)      (deg F)
        Local Inflow:    840.870        .00
            Total:    2230.320       92.46

SECTION NO.     3.000
```

Cross Section Geometry (STA,ELEV)

.100 2559.000	3.300 2557.700	6.600 2556.400	13.100 2555.900	19.700 2555.300
27.600 2554.700	28.900 2553.900	32.800 2553.800	39.400 2553.500	45.900 2553.300
48.600 2553.200	55.800 2553.600	62.300 2553.300	67.300 2552.800	72.200 2552.500
78.700 2552.600	85.300 2551.900	88.600 2552.100	91.900 2551.400	94.500 2549.700
100.400 2545.400	107.000 2542.000	114.800 2538.600	118.100 2537.300	121.400 2535.700
126.300 2534.100	133.200 2532.200	139.400 2530.600	144.400 2529.500	149.300 2528.500
152.600 2528.800	155.800 2528.500	159.100 2528.400	162.400 2528.200	165.700 2527.900
169.000 2527.700	172.200 2528.300	175.500 2528.800	178.800 2530.300	180.400 2531.500
185.400 2534.100	190.900 2537.400	195.500 2541.300	198.800 2542.400	205.100 2544.100
208.300 2548.000	215.900 2547.700	218.200 2553.800	223.100 2554.400	228.000 2554.900
234.600 2556.100	241.100 2556.800	244.400 2557.400	249.300 2558.700	254.300 2560.800
257.500 2561.000				

```
**** 2230.320 2542.387 2542.488   .101   1.000   92.545 2532.914   .000  2.544   .000
                          FLOW DISTRIBUTION (%) =    .000 100.000   .000

   REACH PROPERTIES BY STRIP          1          2          3
         INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE       .000 169080.694       .000
              AREA         .00     876.77       .00
           HYD RADIUS       .0000     8.8625     .0000
 REACH...      Manning's N      .0400     .0330     .0400
              SQRT(L)   174.7169  174.7169  174.7169
 D/S SECTION...       AREA        .00    1335.84       .00
           HYD RADIUS        .000     11.109      .000
```

```
   SECTION NO  BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      3.000    257.400     .000000000       4515370.34

--- LOCAL INFLOW POINT #  3 is upstream of Section No.      3.000 ---
              DISCHARGE   TEMPERATURE
                (cfs)     (deg F)
     Local Inflow:   1602.800      .00
          Total:     627.520     328.61

SECTION NO.    4.000

Cross Section Geometry (STA,ELEV)
    .100 2568.900     7.500 2564.500    14.800 2564.000    59.100 2563.700    95.100 2564.000
 137.100 2564.400   140.400 2560.600   148.600 2557.900   181.400 2556.700   195.500 2553.700
 201.100 2553.000   208.300 2547.100   217.200 2544.400   221.500 2540.700   228.000 2537.000
 230.300 2536.200   236.200 2536.000   239.500 2536.000   246.100 2536.700   249.300 2536.700
 255.900 2540.700   298.200 2547.500   307.100 2552.100   316.900 2557.700   333.300 2559.100
 356.300 2561.600   376.300 2571.400

****   627.520 2546.237 2546.271   .034   1.000   79.214 2540.857   .000  1.472   .000
                              FLOW DISTRIBUTION (%) =    .000 100.000   .000

   REACH PROPERTIES BY STRIP         1          2          3
        INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE       .000  56858.062       .000
             AREA          .00     426.19        .00
        HYD RADIUS       .0000     5.0995      .0000
 REACH...     Manning's N      .0400     .0330      .0400
          SQRT(L)     331.8268   331.8268   331.8268
 D/S SECTION...      AREA        .00     876.77        .00
        HYD RADIUS        .000      8.863       .000


    SECTION NO  BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
 OLD      4.000    376.200     .000000000       4095538.15
 ** Q BELOW TABLE **                                                    **INLOAD**
 **WATER DISCHARGE, WATER-SEDIMENT LOAD TABLE ENDPOINT**       627.52        1954.00
2215.886000

 ------------------------------------------
 FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
     ACCUMULATED TIME (yrs)....     .003
     FLOW DURATION (days)......    1.000

 UPSTREAM BOUNDARY CONDITIONS
 -----------------------------------------------------------------
 Stream Segment # 1     |  DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
 Section No.    4.000 |    (cfs)    | (tons/day)  |  (deg F)
 -----------------------------------------------------------------
           INFLOW |      627.52 |     27023.00 |     328.61
 ** Q ABOVE TABLE **                                                    **INLOAD**
 **WATER DISCHARGE, WATER-SEDIMENT LOAD TABLE ENDPOINT**       1602.80          1.00
 1.000000

 Upstream of SECTION NO.    3.000 is...
 LOCAL INFLOW POINT # 3 |  DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
                   |    (cfs)    | (tons/day)  |  (deg F)
 -----------------------------------------------------------------
     MAINSTEM  INFLOW |      627.52 |     27023.00 |     328.61
```

LOCAL INFLOW | 1602.80 | 9.00 | .00

TOTAL | 2230.32 | 27032.00 | 92.46
** Q ABOVE TABLE ** **INLOAD**
WATER DISCHARGE, WATER-SEDIMENT LOAD TABLE ENDPOINT 840.87 1.00
1.000000

Upstream of SECTION NO. 2.000 is...
LOCAL INFLOW POINT # 2 | DISCHARGE | SEDIMENT LOAD | TEMPERATURE
| (cfs) | (tons/day) | (deg F)

MAINSTEM INFLOW | 2230.32 | 27032.00 | 92.46
LOCAL INFLOW | 840.87 | 9.00 | .00

TOTAL | 3071.19 | 27041.00 | 67.14
** Q ABOVE TABLE ** **INLOAD**
WATER DISCHARGE, WATER-SEDIMENT LOAD TABLE ENDPOINT 254.81 1.00
1.000000

Upstream of SECTION NO. 1.000 is...
LOCAL INFLOW POINT # 1 | DISCHARGE | SEDIMENT LOAD | TEMPERATURE
| (cfs) | (tons/day) | (deg F)

MAINSTEM INFLOW | 3071.19 | 27041.00 | 67.14
LOCAL INFLOW | 254.81 | 9.00 | .00

TOTAL | 3326.00 | 27050.00 | 62.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME DAYS	ENTRY POINT *	CLAY INFLOW	OUTFLOW	TRAP EFF *	SILT INFLOW	OUTFLOW	TRAP EFF *	SAND INFLOW	OUTFLOW	TRAP EFF *
1.00	4.000 *	3.39		*	14.32		*	2.24		*
	3.000 *	.00		*	.00		*	.00		*
	2.000 *	.00		*	.00		*	.00		*
	1.000 *	.00		*	.00		*	.00		*
TOTAL=	1.000 *	3.40	3.29	.03 *	14.32	7.47	.48 *	2.25	.00	1.00 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	2215.89	VERY FINE SAND....	2080.77
VERY FINE SILT....	7269.19	FINE SAND.........	1297.10
FINE SILT.........	4756.05	MEDIUM SAND.......	621.53
MEDIUM SILT.......	4458.80	COARSE SAND.......	540.46
COARSE SILT.......	3783.22		

TOTAL = 27023.00

SEDIMENT OUTFLOW from the Downstream Boundary

IMRIVM

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	2147.92	VERY FINE SAND....	5.95
VERY FINE SILT....	6351.25	FINE SAND.........	2.10
FINE SILT.........	2846.60	MEDIUM SAND.......	.24
MEDIUM SILT.......	1008.77	COARSE SAND.......	.56
COARSE SILT.......	363.69		

TOTAL = 12727.09

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
4.000	.10	2546.24	2536.10	628.	2144.	9810.	10.
3.000	.00	2542.39	2527.70	2230.	2145.	9814.	72.
2.000	.00	2539.56	2520.40	3071.	2147.	10566.	127.
1.000	.00	2536.30	2513.20	3326.	2148.	10570.	9.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 20

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
*****************************************************   **************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *   * U.S. ARMY CORPS OF
ENGINEERS *
*    Version: 4.1.0                    *   * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE: IMRIVNOT.DAT             *   * 609 SECOND STREET             *
* OUTPUT FILE: IMRIVNOT.OUT            *   * DAVIS, CALIFORNIA 95616-4687  *
* RUN DATE: 06 JUN 06  RUN TIME: 20:44:03  *   * (916) 756-1104            *
*****************************************************   **************************************

          X   X XXXXXXX  XXXXX      XXXXX
          X   X X     X   X     X   X
          X   X X     X         X
          XXXXXXX XXXX   X     XXXXX XXXXXX
          X   X X     X         X  X
          X   X X     X   X     X   X
          X   X XXXXXXX  XXXXX      XXXXX

     ************************************************************************
     * MAXIMUM LIMITS FOR THIS VERSION ARE:                                 *
     *   10  Stream Segments (Main Stem + Tributaries)          *
     *  150  Cross Sections                           *
     *  100  Elevation/Station Points per Cross Section        *
     *   20  Grain Sizes                          *
     *   10  Control Points                          *
     ************************************************************************
```

T1 FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
T2 # MOBILE BED HEC-6 MODEL #
T3 # TRIBUTARIES Neglected

N values...	Left	Channel	Right	Contraction	Expansion
	.0400	.0330	.0400	1.1000	.7000

SECTION NO. 1.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 2.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 3.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 4.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 4
NO. OF INPUT DATA MESSAGES = 0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK = 4
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK= 1
END OF GEOMETRIC DATA

==

T4 Imphal/Manipur River (Section - II) ** Movable bed **
T5 LOAD CURVE FROM GAUGE DATA.
T6 BED GRADATIONS FROM FIELD SAMPLES

T7 Use full range of Sands and gravel
T8 SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
MOBILE BED HEC-6 MODEL #
TRIBUTARIES Neglected

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

	LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER	1	.0200
INACTIVE LAYER	2	.0200

EROSION COEFFICIENTS BY LAYER

	LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER	1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER	2	.1250	.2300	2.0000	19.0476	10.0000

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

	LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER	1	.0200
INACTIVE LAYER	2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER	PARTICLE EROSION SHEAR STRESS	MASS EROSION SHEAR STRESS	MASS EROSION RATE	SLOPE OF PARTICLE EROSION LINE=ER1	SLOPE OF MASS EROSION LINE=ER2

NO	lb/sq.ft	lb/sq.ft.	lb/sf/hr	1/hr	1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
14	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY..............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
15	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	1954.00	4879.00	6815.00	8400.00	9784.00	12183.0	14751.0	15687.0
LF CLAY	2215.89	10545.4	18642.1	26624.8	34531.8	50185.2	69536.8	77226.0
LF SILT1	7269.19	34594.2	61155.3	87342.4	113281.	164632.	228115.	253339.
LF SILT2	4756.05	22634.1	40012.4	57146.0	74117.1	107715.	149250.	165753.
LF SILT3	4458.80	21219.5	37511.6	53574.3	69484.8	100982.	139922.	155394.
LF SILT4	3783.22	18004.4	31828.0	45457.0	58956.8	85682.1	118721.	131849.
LF VFS	2080.77	9902.43	17505.4	25001.4	32426.2	47125.2	65296.8	72517.1
LF FS	1297.10	6172.94	10912.5	15585.3	20213.8	29376.7	40704.5	45205.4
LF MS	621.529	2957.87	5228.89	7467.94	9685.76	14076.3	19504.2	21660.9
LF CS	540.460	2572.06	4546.86	6493.86	8422.40	12240.3	16960.2	18835.6
TOTAL	27023.0	128603.	227343.	324693.	421120.	612015.	848010.	941780.

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS REACH MOVABLE INITIAL BED-ELEVATIONS ACCUMULATED CHANNEL DISTANCE
SECTION LENGTH BED LEFT SIDE THALWEG RIGHT SIDE FROM DOWNSTREAM
NO. (ft) WIDTH (ft) (ft) (ft) (ft) (miles)

	.000						
1.000		279.100	2540.500	2513.200	2541.000	.000	.000
	93359.000						
2.000		287.100	2559.000	2520.400	2560.000	93359.000	17.682
	30526.000						
3.000		257.400	2559.000	2527.700	2561.000	123885.000	23.463
	110109.000						
4.000		376.200	2568.900	2536.000	2571.400	233994.000	44.317

BED MATERIAL GRADATION

```
----------------------
  SECNO   SAE  DMAX  DXPI   XPI  TOTAL     BED MATERIAL FRACTIONS
          (ft)  (ft)        BED         per grain size
-------------------------------------------------------------------------------
  1.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                          | VF SILT  .001 | F SAND  .185 |
                          | F SILT  .023 | M SAND  .025 |
                          | M SILT  .238 | C SAND  .058 |
                          | C SILT  .230 |

  2.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                          | VF SILT  .001 | F SAND  .185 |
                          | F SILT  .023 | M SAND  .025 |
                          | M SILT  .238 | C SAND  .058 |
                          | C SILT  .230 |

  3.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                          | VF SILT  .001 | F SAND  .185 |
                          | F SILT  .023 | M SAND  .025 |
                          | M SILT  .238 | C SAND  .058 |
                          | C SILT  .230 |

  4.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                          | VF SILT  .001 | F SAND  .185 |
                          | F SILT  .023 | M SAND  .025 |
                          | M SILT  .238 | C SAND  .058 |
                          | C SILT  .230 |
```

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	46679.500	281.767	10.000	.131527E+09	.487138E+07
2.000	61942.500	282.651	10.000	.175081E+09	.648448E+07
3.000	70317.500	290.553	10.000	.204310E+09	.756703E+07
4.000	55054.500	336.600	10.000	.185313E+09	.686346E+07

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

==

$HYD
BEGIN COMPUTATIONS.

==

TIME STEP # 1
* BB PROFILE 1 = Effective Stream Flow of Imphal / Manipur River

- -

FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)

ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE	TEMPERATURE	WATER SURFACE
(cfs)	(deg F)	(ft)
3326.000	62.00	2536.300

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

.100 2540.500	9.800 2541.100	29.500 2540.300	36.100 2539.500	47.600 2539.600
54.800 2539.000	57.700 2535.200	59.400 2530.900	67.300 2527.800	71.200 2526.800
75.800 2524.100	82.300 2521.800	88.900 2521.200	95.500 2519.600	102.000 2514.700
108.600 2513.200	115.200 2513.500	128.300 2513.600	134.800 2513.800	141.400 2514.200
154.500 2514.200	161.100 2515.200	167.600 2515.500	174.200 2516.600	180.800 2517.800
187.300 2516.600	193.900 2519.500	200.500 2525.100	213.600 2529.500	222.100 2534.900
230.000 2539.400	236.500 2539.600	256.200 2539.800	262.800 2541.500	275.900 2541.800
279.200 2541.000				

**** 3326.000 2536.300 2536.322 .022 1.000 167.697 2519.780 .000 1.201 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	769645.341	.000
	AREA	.00	2770.28	.00
	HYD RADIUS	.0000	15.3247	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	.0000	.0000	.0000
D/S SECTION...	AREA	.00	.00	.00
	HYD RADIUS	.000	.000	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	1.000	279.100	.000000000	2906831.45

SECTION NO. 2.000

Cross Section Geometry (STA,ELEV)

.100 2559.000	13.100 2559.300	18.000 2552.800	27.900 2554.100	35.100 2554.100
42.700 2551.700	48.100 2547.500	55.800 2544.500	62.700 2540.900	65.600 2539.700
70.500 2537.900	75.000 2534.400	81.600 2530.700	85.500 2527.800	90.700 2523.400
97.200 2521.200	100.000 2520.400	103.800 2520.600	103.900 2520.900	107.100 2521.400
110.400 2521.600	116.900 2522.200	120.200 2521.500	123.500 2521.600	126.800 2521.700
130.100 2521.700	133.300 2522.000	136.600 2522.400	139.900 2524.100	144.800 2526.000
148.100 2527.600	157.900 2531.800	167.800 2535.900	180.900 2541.200	185.500 2543.600
189.100 2550.100	198.000 2552.500	201.900 2554.700	224.900 2555.400	242.800 2555.500
259.200 2555.700	277.400 2556.500	282.000 2558.000	287.200 2560.000	

**** 3326.000 2539.992 2540.082 .090 1.000 113.023 2527.733 .000 2.400 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	314150.724	.000
	AREA	.00	1385.55	.00

HYD RADIUS .0000 11.2984 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 305.5471 305.5471 305.5471
D/S SECTION... AREA .00 2770.28 .00
HYD RADIUS .000 15.325 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 2.000 287.100 .000000000 3869397.01
SECTION NO. 3.000

Cross Section Geometry (STA,ELEV)

.100 2559.000	3.300 2557.700	6.600 2556.400	13.100 2555.900	19.700 2555.300
27.600 2554.700	28.900 2553.900	32.800 2553.800	39.400 2553.500	45.900 2553.300
48.600 2553.200	55.800 2553.600	62.300 2553.300	67.300 2552.800	72.200 2552.500
78.700 2552.600	85.300 2551.900	88.600 2552.100	91.900 2551.400	94.500 2549.700
100.400 2545.400	107.000 2542.000	114.800 2538.600	118.100 2537.300	121.400 2535.700
126.300 2534.100	133.200 2532.200	139.400 2530.600	144.400 2529.500	149.300 2528.500
152.600 2528.800	155.800 2528.500	159.100 2528.400	162.400 2528.200	165.700 2527.900
169.000 2527.700	172.200 2528.300	175.500 2528.800	178.800 2530.300	180.400 2531.500
185.400 2534.100	190.900 2537.400	195.500 2541.300	198.800 2542.400	205.100 2544.100
208.300 2548.000	215.900 2547.700	218.200 2553.800	223.100 2554.400	228.000 2554.900
234.600 2556.100	241.100 2556.800	244.400 2557.400	249.300 2558.700	254.300 2560.800
257.500 2561.000				

**** 3326.000 2544.612 2544.755 .143 1.000 103.585 2534.037 .000 3.036 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 226966.209 .000
AREA .00 1095.38 .00
HYD RADIUS .0000 9.8705 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 174.7169 174.7169 174.7169
D/S SECTION... AREA .00 1385.55 .00
HYD RADIUS .000 11.298 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 3.000 257.400 .000000000 4515370.34
SECTION NO. 4.000

Cross Section Geometry (STA,ELEV)

.100 2568.900	7.500 2564.500	14.800 2564.000	59.100 2563.700	95.100 2564.000
137.100 2564.400	140.400 2560.600	148.600 2557.900	181.400 2556.700	195.500 2553.700
201.100 2553.000	208.300 2547.100	217.200 2544.400	221.500 2540.700	228.000 2537.000
230.300 2536.200	236.200 2536.000	239.500 2536.000	246.100 2536.700	249.300 2536.700
255.900 2540.700	298.200 2547.500	307.100 2552.100	316.900 2557.700	333.300 2559.100
356.300 2561.600	376.300 2571.400			

**** 3326.000 2558.429 2558.481 .053 1.000 179.038 2548.323 .000 1.838 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 367540.937 .000
AREA .00 1809.36 .00
HYD RADIUS .0000 9.5811 .0000

IMRIVNOT

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REACH...      Manning's N     .0400     .0330     .0400
            SQRT(L)    331.8268   331.8268   331.8268
D/S SECTION...     AREA        .00    1095.38      .00
         HYD RADIUS       .000      9.870      .000
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  SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      4.000    376.200     .000000000        4095538.15
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FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).... .003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 4.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	3326.00	66919.03	62.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF IMPHAL/MANIPUR RIVER (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME DAYS	ENTRY POINT *	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF *	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF *	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF *
1.00	4.000 *	8.40		*	35.45		*	5.55		*
TOTAL=	1.000 *	8.40	10.16	-.21 *	35.45	387.05	-9.92 *	5.55	.03	1.00 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	5487.36	VERY FINE SAND....	5152.77
VERY FINE SILT....	18001.22	FINE SAND.........	3212.11
FINE SILT.........	11777.75	MEDIUM SAND.......	1539.14
MEDIUM SILT.......	11041.64	COARSE SAND.......	1338.38
COARSE SILT.......	9368.66		

TOTAL = 66919.03

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	6636.32	VERY FINE SAND....	38.03
VERY FINE SILT....	19150.18	FINE SAND.........	11.34
FINE SILT.........	42468.65	MEDIUM SAND.......	1.25
MEDIUM SILT.......	244091.15	COARSE SAND.......	2.89
COARSE SILT.......	242239.92		

TOTAL = 554639.70

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
4.000	.00	2558.43	2536.00	3326.	5503.	59413.	370.
3.000	-1.37	2544.61	2526.33	3326.	6634.	546412.	612.
2.000	-.01	2539.99	2520.39	3326.	6636.	547950.	1406.
1.000	.00	2536.30	2513.20	3326.	6636.	547950.	54.

$$END

0 DATA ERRORS DETECTED.

WARNING: SILT+CLAY CONCENTRATIONS IN EXCESS OF 50000. PPM WERE DETECTED 2 TIMES.
MUDFLOW CONCENTRATIONS (SILT+CLAY IN EXCESS OF 800000. PPM) WERE DETECTED 0 TIMES.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 20

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
****************************************************  ************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *    * U.S. ARMY CORPS OF
ENGINEERS  *
*    Version: 4.1.0                  *    * HYDROLOGIC ENGINEERING CENTER  *
* INPUT FILE:  KHRDKI.DAT                  *    * 609 SECOND STREET          *
* OUTPUT FILE: KHRDKI.OUT                  *    * DAVIS, CALIFORNIA 95616-4687  *
* RUN DATE: 03 JUN 06    RUN TIME: 23:49:03     *    * (916) 756-1104            *
****************************************************  ************************************

          X    X XXXXXXX  XXXXX       XXXXX
          X    X X      X    X      X    X
          X    X X      X          X
          XXXXXXX XXXX    X       XXXXX  XXXXXX
          X    X X      X          X    X
          X    X X      X    X      X    X
          X    X XXXXXXX  XXXXX       XXXXX

     **********************************************************************
     * MAXIMUM LIMITS FOR THIS VERSION ARE:                               *
     *     10  Stream Segments (Main Stem + Tributaries)              *
     *    150  Cross Sections                                 *
     *    100  Elevation/Station Points per Cross Section           *
     *     20  Grain Sizes                                   *
     *     10  Control Points                                 *
     **********************************************************************

T1    FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)
T2    # Moblie Bed HEC-6 Model #
T3    # Inflow Point-(1) to Loktak lake - Cross Sections & Data(2000-02)

N values...  Left   Channel   Right   Contraction   Expansion
             .0400   .0330   .0400    1.1000        .7000

SECTION NO.    1.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    2.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    3.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    4.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    5.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    6.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  6
NO. OF INPUT DATA MESSAGES =   0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =   6
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA
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T4 Khordak Channel (INFLOW to Loktak Lake) ** Movable bed **
T5 LOAD CURVE FROM GAUGE DATA.
T6 BED GRADATIONS FROM FIELD SAMPLES
T7 Use full range of Sands and gravel
T8 SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)
Moblie Bed HEC-6 Model #
Inflow Point-(1) to Loktak lake - Cross Sections & Data(2000-02)

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY..............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	134.000	178.000	190.000	196.000	200.000	208.000	209.000	210.000
LF CLAY	46.5760	55.5960	57.8920	58.9580	59.6140	60.8440	61.0900	61.3360
LF SILT1	152.792	182.382	189.914	193.411	195.563	199.598	200.405	201.212
LF SILT2	99.9680	119.328	124.256	126.544	127.952	130.592	131.120	131.648
LF SILT3	93.7200	111.870	116.490	118.635	119.955	122.430	122.925	123.420
LF SILT4	79.5200	94.9200	98.8400	100.660	101.780	103.880	104.300	104.720
LF VFS	43.7360	52.2060	54.3620	55.3630	55.9790	57.1340	57.3650	57.5960
LF FS	27.2640	32.5440	33.8880	34.5120	34.8960	35.6160	35.7600	35.9040
LF MS	13.0640	15.5940	16.2380	16.5370	16.7210	17.0660	17.1350	17.2040
LF CS	11.3600	13.5600	14.1200	14.3800	14.5400	14.8400	14.9000	14.9600
TOTAL	568.000	678.000	706.000	719.000	727.000	742.000	745.000	748.000

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH (ft)	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
1.000	.000	134.400	2526.100	2513.500	2524.500	.000	.000
2.000	11155.000	147.500	2526.000	2515.500	2522.400	11155.000	2.113

```
    10335.000
 3.000          157.400  2526.100  2513.600  2524.600   21490.000     4.070
    8694.000
 4.000          196.700  2526.400  2515.000  2528.100   30184.000     5.717
    5906.000
 5.000          170.500  2526.200  2516.900  2525.200   36090.000     6.835
    7874.000
 6.000           98.300  2526.100  2512.100  2523.100   43964.000     8.327
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BED MATERIAL GRADATION

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  SECNO  SAE  DMAX  DXPI  XPI  TOTAL     BED MATERIAL FRACTIONS
          (ft)  (ft)      BED        per grain size
---------------------------------------------------------------------------
  1.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|

  2.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|

  3.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|

  4.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|

  5.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|

  6.000 1.000  .003  .003 1.000 1.000|  CLAY  .001|VF SAND  .238|
                                |VF SILT  .001|F SAND  .185|
                                |F SILT  .023|M SAND  .025|
                                |M SILT  .238|C SAND  .058|
                                |C SILT  .230|
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BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)

```
| SECTION | LENGTH  | WIDTH  | DEPTH  |      V O L U M E      |
| NUMBER  |  (ft)   |  (ft)  |  (ft)  |  (cu.ft)  |  (cu.yd)  |
----------------------------------------------------------------
|  1.000| 5577.500|  138.767|  10.000|.773971E+07|286656.    |
```

2.000	10745.000	146.820	10.000	.157759E+08	584291.
3.000	9514.500	161.593	10.000	.153748E+08	569435.
4.000	7300.000	185.366	10.000	.135317E+08	501176.
5.000	6890.000	160.491	10.000	.110578E+08	409550.
6.000	3937.000	122.367	10.000	.481758E+07	178429.

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

==
==========

$HYD
BEGIN COMPUTATIONS.

==
==========

TIME STEP # 1
* BB PROFILE I Routed Stream INFLOW I VE (Average) of Khordak Channel

- -

FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE	TEMPERATURE	WATER SURFACE
(cfs)	(deg F)	(ft)
169.510	53.60	2517.490

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

.100 2526.100	6.600 2526.400	11.500 2526.000	16.400 2524.700	19.700 2523.900
29.500 2523.800	39.400 2523.700	42.700 2523.100	45.900 2522.000	49.200 2520.300
52.500 2518.100	55.800 2516.900	59.100 2515.800	62.300 2514.600	65.600 2513.800
68.900 2513.500	72.200 2513.600	75.500 2513.800	78.700 2514.300	82.000 2515.200
85.300 2516.300	88.600 2518.800	92.800 2522.000	96.800 2524.400	101.700 2524.500
108.300 2524.100	124.700 2523.800	128.900 2525.500	132.900 2525.500	134.500 2524.500

**** 169.510 2517.490 2517.549 .059 1.000 32.693 2514.819 .000 1.941 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

		1	2	3
REACH PROPERTIES BY STRIP				
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	7369.047	.000
	AREA	.00	87.33	.00
	HYD RADIUS	.0000	2.5650	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	.0000	.0000	.0000
D/S SECTION...	AREA	.00	.00	.00
	HYD RADIUS	.000	.000	.000

```
   SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      1.000    134.400     .000000000       171052.244
SECTION NO.    2.000

 Cross Section Geometry (STA,ELEV)
    .100 2526.000     6.600 2526.100     13.100 2525.800     19.700 2524.400     23.000 2523.600
  36.100 2523.300    42.700 2524.100     52.500 2524.300     62.300 2524.300     68.900 2524.500
  72.200 2523.300    72.300 2522.000     75.500 2518.800     78.700 2517.000     82.000 2516.300
  85.300 2516.100    88.600 2515.800     91.900 2515.900     95.100 2515.900     98.400 2515.600
 101.700 2515.500   105.000 2515.900    108.300 2516.200    111.500 2517.100    114.800 2519.200
 116.500 2522.000   118.100 2524.700    128.000 2524.700    144.400 2526.500    147.600 2522.400

****  169.510 2520.144 2520.164  .020  1.000  41.192 2516.517  .000  1.134  .000
                         FLOW DISTRIBUTION (%) =    .000 100.000   .000

   REACH PROPERTIES BY STRIP        1        2        3
         INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE      .000  15292.478      .000
            AREA        .00     149.44       .00
         HYD RADIUS       .0000    3.4259     .0000
 REACH...      Manning's N     .0400    .0330     .0400
           SQRT(L)   105.6172  105.6172  105.6172
 D/S SECTION...      AREA        .00     87.33       .00
         HYD RADIUS       .000     2.565      .000


   SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      2.000    147.500     .000000000       348655.769
SECTION NO.    3.000

 Cross Section Geometry (STA,ELEV)
    .100 2526.100     6.600 2526.400     11.500 2526.100     16.400 2524.900     23.000 2524.600
  29.500 2525.100    36.100 2525.600     42.700 2525.100     44.300 2524.000     49.200 2522.000
  52.500 2520.500    55.800 2518.900     59.100 2516.900     62.300 2514.900     65.600 2514.300
  68.900 2513.900    72.200 2513.600     75.500 2514.000     78.700 2515.200     82.000 2515.800
  85.300 2517.200    88.600 2518.400     91.900 2522.000     95.100 2524.100    100.100 2524.900
 105.000 2524.900   111.500 2524.800    118.100 2524.800    131.200 2524.800    137.800 2524.500
 144.400 2524.100   147.600 2524.500    157.500 2524.600

****  169.510 2520.985 2520.997  .012  1.000  39.521 2516.201  .000  .897  .000
                         FLOW DISTRIBUTION (%) =    .000 100.000   .000

   REACH PROPERTIES BY STRIP        1        2        3
         INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE      .000  22793.388      .000
            AREA        .00     189.04       .00
         HYD RADIUS       .0000    4.3816     .0000
 REACH...      Manning's N     .0400    .0330     .0400
           SQRT(L)   101.6612  101.6612  101.6612
 D/S SECTION...      AREA        .00    149.44       .00
         HYD RADIUS       .000     3.426      .000


   SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      3.000    157.400     .000000000       339791.237
SECTION NO.    4.000

 Cross Section Geometry (STA,ELEV)
    .100 2526.400     3.300 2526.400      8.200 2526.100     11.500 2525.300     16.400 2525.000
```

23.000	2525.400	32.800	2525.400	49.200	2525.400	65.600	2525.200	78.700	2525.597
78.800	2525.600	95.100	2525.200	98.400	2525.000	101.700	2524.500	103.300	2522.000
105.000	2519.100	108.300	2517.300	111.500	2515.900	114.800	2515.200	118.100	2515.000
121.400	2515.100	124.700	2515.200	128.000	2515.300	131.200	2515.700	134.500	2516.900
137.800	2518.900	141.700	2522.000	144.400	2523.900	147.600	2524.700	150.900	2525.000
157.500	2524.700	164.000	2524.500	170.600	2524.700	193.600	2525.800	196.800	2528.100

**** 169.510 2521.472 2521.486 .013 1.000 37.468 2516.557 .000 .920 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	22439.597	.000
	AREA	.00	184.16	.00
	HYD RADIUS	.0000	4.4510	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	93.2416	93.2416	93.2416
D/S SECTION...	AREA	.00	189.04	.00
	HYD RADIUS	.000	4.382	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	4.000	196.700	.000000000	299059.726

SECTION NO. 5.000

Cross Section Geometry (STA,ELEV)

.100	2526.200	6.600	2526.000	9.800	2526.200	13.100	2525.400	19.700	2524.800
26.200	2524.000	37.400	2525.400	41.000	2526.800	45.900	2525.300	49.200	2525.200
52.500	2526.200	59.100	2525.900	65.600	2525.200	72.200	2524.800	78.700	2524.000
82.000	2522.000	85.300	2519.400	88.600	2518.000	91.900	2518.200	95.100	2517.800
98.400	2518.000	101.700	2517.900	105.000	2517.800	108.300	2517.400	111.500	2517.400
114.800	2516.900	118.100	2516.900	121.400	2517.400	124.700	2518.500	128.900	2522.000
131.200	2523.300	131.300	2525.000	137.800	2525.100	144.400	2525.000	150.900	2524.500
157.500	2525.000	164.000	2525.200	170.600	2525.200				

**** 169.510 2521.882 2521.897 .015 1.000 46.592 2518.139 .000 .972 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	18238.883	.000
	AREA	.00	174.40	.00
	HYD RADIUS	.0000	3.5393	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	76.8505	76.8505	76.8505
D/S SECTION...	AREA	.00	184.16	.00
	HYD RADIUS	.000	4.451	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	5.000	170.500	.000000000	244384.900

SECTION NO. 6.000

Cross Section Geometry (STA,ELEV)

.100	2526.100	6.600	2526.000	13.100	2526.400	16.400	2525.300	19.700	2525.600
26.200	2525.500	29.500	2525.600	32.800	2525.300	37.700	2524.800	37.800	2521.900
38.500	2520.500	42.000	2518.100	45.900	2515.200	49.200	2513.900	55.800	2512.700
62.300	2512.100	68.900	2513.400	72.200	2514.800	75.500	2515.500	78.700	2517.300
82.000	2518.900	85.300	2519.700	89.900	2521.900	91.900	2523.200	95.100	2523.500

98.400 2523.100

**** 169.510 2522.112 2522.116 .004 1.000 52.429 2515.705 .000 .505 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	49035.905	.000
	AREA	.00	335.94	.00
	HYD RADIUS	.0000	5.8361	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	88.7356	88.7356	88.7356
D/S SECTION...	AREA	.00	174.40	.00
	HYD RADIUS	.000	3.539	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	6.000	98.300	.000000000	106471.307

FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).... .003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 6.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	169.51	657.65	53.60

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF KHORDAK Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME DAYS	ENTRY POINT	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF
1.00	6.000	.08			.35			.05		
TOTAL=	1.000	.08	.08	.00	.35	.35	.00	.05	.04	.34

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	53.93	VERY FINE SAND....	50.64
VERY FINE SILT....	176.91	FINE SAND.........	31.57
FINE SILT.........	115.75	MEDIUM SAND.......	15.13
MEDIUM SILT.......	108.51	COARSE SAND.......	13.15
COARSE SILT.......	92.07		

TOTAL = 657.65

SEDIMENT OUTFLOW from the Downstream Boundary

KHRDKI

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY..............	53.87	VERY FINE SAND....	43.66
VERY FINE SILT....	174.18	FINE SAND.........	23.90
FINE SILT.........	112.74	MEDIUM SAND.......	2.10
MEDIUM SILT.......	128.67	COARSE SAND.......	3.37
COARSE SILT.......	77.78		

TOTAL = 620.26

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
6.000	.02	2522.11	2512.12	170.	54.	435.	0.
5.000	.00	2521.88	2516.90	170.	54.	401.	0.
4.000	.00	2521.47	2515.00	170.	54.	401.	1.
3.000	.00	2520.98	2513.60	170.	54.	401.	1.
2.000	.00	2520.14	2515.50	170.	54.	401.	9.
1.000	-.02	2517.49	2513.48	170.	54.	493.	73.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 30

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
**************************************************   ************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *    * U.S. ARMY CORPS OF
ENGINEERS *
*    Version: 4.1.0                 *   * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE: KHRDKO.DAT                 *   * 609 SECOND STREET          *
* OUTPUT FILE: KHRDKO.OUT                *   * DAVIS, CALIFORNIA 95616-4687 *
* RUN DATE: 03 JUN 06   RUN TIME: 01:08:16   *   * (916) 756-1104         *
**************************************************   ************************************

     X   X XXXXXXX  XXXXX       XXXXX
     X   X X      X   X      X   X
     X   X X      X         X
     XXXXXXX XXXX   X      XXXXX XXXXXX
     X   X X      X         X   X
     X   X X      X   X      X   X
     X   X XXXXXXX  XXXXX       XXXXX

   *****************************************************************
   * MAXIMUM LIMITS FOR THIS VERSION ARE:                          *
   *    10 Stream Segments (Main Stem + Tributaries)               *
   *   150 Cross Sections                                          *
   *   100 Elevation/Station Points per Cross Section              *
   *    20 Grain Sizes                                             *
   *    10 Control Points                                          *
   *****************************************************************
```

T1 FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)
T2 # Moblie Bed HEC-6 Model #
T3 # Outflow Point-(1) from Loktak lake - Cross Sections & Data(2000-02)

N values...	Left	Channel	Right	Contraction	Expansion
	.0400	.0330	.0400	1.1000	.7000

SECTION NO. 1.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 2.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 3.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 4.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 5.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO. 6.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 6
NO. OF INPUT DATA MESSAGES = 0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK = 6
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK= 1
END OF GEOMETRIC DATA

==

T4 Khordak Channel (OUTFLOW from Loktak Lake) ** Movable bed **
T5 LOAD CURVE FROM GAUGE DATA.
T6 BED GRADATIONS FROM FIELD SAMPLES
T7 Use full range of Sands and gravel
T8 SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)
Moblie Bed HEC-6 Model #
Outflow Point-(1) from Loktak lake - Cross Sections & Data(2000-02)

- -

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

- -

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

- -

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

- -

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY.............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND........	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

- -

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

- -

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	11.0000	15.0000	19.0000	27.0000	31.0000	38.0000	40.0000	41.0000
LF CLAY	19.4340	36.5720	64.4520	141.286	181.712	241.654	258.136	265.762
LF SILT1	63.7530	119.974	211.434	463.487	596.104	792.743	846.812	871.829
LF SILT2	41.7120	78.4960	138.336	303.248	390.016	518.672	554.048	570.416
LF SILT3	39.1050	73.5900	129.690	284.295	365.640	486.255	519.420	534.765
LF SILT4	33.1800	62.4400	110.040	241.220	310.240	412.580	440.720	453.740
LF VFS	18.2490	34.3420	60.5220	132.671	170.632	226.919	242.396	249.557
LF FS	11.3760	21.4080	37.7280	82.7040	106.368	141.456	151.104	155.568
LF MS	5.45100	10.2580	18.0780	39.6290	50.9680	67.7810	72.4040	74.5430
LF CS	4.74000	8.92000	15.7200	34.4600	44.3200	58.9400	62.9600	64.8200
TOTAL	237.000	446.000	786.000	1723.00	2216.00	2947.00	3148.00	3241.00

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS REACH MOVABLE INITIAL BED-ELEVATIONS ACCUMULATED CHANNEL DISTANCE
SECTION LENGTH BED LEFT SIDE THALWEG RIGHT SIDE FROM DOWNSTREAM
NO. (ft) WIDTH (ft) (ft) (ft) (ft) (miles)

.000
1.000 98.300 2526.100 2512.100 2523.100 .000 .000
7874.000
2.000 170.500 2526.200 2516.900 2525.200 7874.000 1.491

5906.000						
3.000	196.700	2526.400	2515.000	2528.100	13780.000	2.610
8694.000						
4.000	157.400	2526.100	2513.600	2524.600	22474.000	4.256
10335.000						
5.000	147.500	2526.000	2515.500	2522.400	32809.000	6.214
11155.000						
6.000	134.400	2526.100	2513.500	2524.500	43964.000	8.327

BED MATERIAL GRADATION

SECNO	SAE (ft)	DMAX (ft)	DXPI BED	XPI	TOTAL per grain size	BED MATERIAL FRACTIONS	
1.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	
2.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	
3.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	
4.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	
5.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	
6.000	1.000	.003	.003	1.000	1.000	CLAY .001	VF SAND .238
						VF SILT .001	F SAND .185
						F SILT .023	M SAND .025
						M SILT .238	C SAND .058
						C SILT .230	

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	3937.000	122.367	10.000	.481758E+07	178429.

2.000	6890.000	160.491	10.000	.110578E+08	409550.
3.000	7300.000	185.366	10.000	.135317E+08	501176.
4.000	9514.500	161.593	10.000	.153748E+08	569435.
5.000	10745.000	146.820	10.000	.157759E+08	584291.
6.000	5577.500	138.767	10.000	.773971E+07	286656.

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

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$HYD
BEGIN COMPUTATIONS.

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TIME STEP # 1
* BB PROFILE 1 - Routed Stream OUTFLOW -VE (Average) of Khordak Channel

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FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
37.790	53.60	2516.430

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

.100	2526.100	6.600	2526.000	13.100	2526.400	16.400	2525.300	19.700	2525.600
26.200	2525.500	29.500	2525.600	32.800	2525.300	37.700	2524.800	37.800	2521.900
38.500	2520.500	42.000	2518.100	45.900	2515.200	49.200	2513.900	55.800	2512.700
62.300	2512.100	68.900	2513.400	72.200	2514.800	75.500	2515.500	78.700	2517.300
82.000	2518.900	85.300	2519.700	89.900	2521.900	91.900	2523.200	95.100	2523.500
98.400	2523.100								

**** 37.790 2516.430 2516.433 .003 1.000 32.907 2513.663 .000 .415 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	7840.334	.000
	AREA	.00	91.04	.00
	HYD RADIUS	.0000	2.6446	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	.0000	.0000	.0000
D/S SECTION...	AREA	.00	.00	.00
	HYD RADIUS	.000	.000	.000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 1.000 98.300 .000000000 106471.307
SECTION NO. 2.000

Cross Section Geometry (STA,ELEV)

.100 2526.200	6.600 2526.000	9.800 2526.200	13.100 2525.400	19.700 2524.800
26.200 2524.000	37.400 2525.400	41.000 2526.800	45.900 2525.300	49.200 2525.200
52.500 2526.200	59.100 2525.900	65.600 2525.200	72.200 2524.800	78.700 2524.000
82.000 2522.000	85.300 2519.400	88.600 2518.000	91.900 2518.200	95.100 2517.800
98.400 2518.000	101.700 2517.900	105.000 2517.800	108.300 2517.400	111.500 2517.400
114.800 2516.900	118.100 2516.900	121.400 2517.400	124.700 2518.500	128.900 2522.000
131.200 2523.300	131.300 2525.000	137.800 2525.100	144.400 2525.000	150.900 2524.500
157.500 2525.000	164.000 2525.200	170.600 2525.200		

** SUPERCRITICAL ** Using Critical Water Surface +
SECTION NO. 2.000 TIME = 1.000 DAYS.

TRIAL NO.	TRIAL WS	COMPUTED WS	CRITICAL WS
0.	2517.759	2517.444	
1.	2517.840	2517.464	2517.790

**** 37.790 2517.840 2518.054 .213 1.000 20.048 2517.332 .000 3.704 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U S SECTION... CONVEYANCE .000 291.108 .000
AREA .00 10.20 .00
HYD RADIUS .0000 .5045 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 88.7356 88.7356 88.7356
D/S SECTION... AREA .00 91.04 .00
HYD RADIUS .000 2.645 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 2.000 170.500 .000000000 244384.900
SECTION NO. 3.000

Cross Section Geometry (STA,ELEV)

.100 2526.400	3.300 2526.400	8.200 2526.100	11.500 2525.300	16.400 2525.000
23.000 2525.400	32.800 2525.400	49.200 2525.400	65.600 2525.200	78.700 2525.597
78.800 2525.600	95.100 2525.200	98.400 2525.000	101.700 2524.500	103.300 2522.000
105.000 2519.100	108.300 2517.300	111.500 2515.900	114.800 2515.200	118.100 2515.000
121.400 2515.100	124.700 2515.200	128.000 2515.300	131.200 2515.700	134.500 2516.900
137.800 2518.900	141.700 2522.000	144.400 2523.900	147.600 2524.700	150.900 2525.000
157.500 2524.700	164.000 2524.500	170.600 2524.700	193.600 2525.800	196.800 2528.100

**** 37.790 2518.892 2518.895 .003 1.000 32.417 2516.022 .000 .406 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 8197.313 .000
AREA .00 93.04 .00
HYD RADIUS .0000 2.7369 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 76.8505 76.8505 76.8505
D/S SECTION... AREA .00 10.20 .00
HYD RADIUS .000 .504 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 3.000 196.700 .000000000 299059.726
SECTION NO. 4.000

Cross Section Geometry (STA,ELEV)

.100 2526.100	6.600 2526.400	11.500 2526.100	16.400 2524.900	23.000 2524.600
29.500 2525.100	36.100 2525.600	42.700 2525.100	44.300 2524.000	49.200 2522.000
52.500 2520.500	55.800 2518.900	59.100 2516.900	62.300 2514.900	65.600 2514.300
68.900 2513.900	72.200 2513.600	75.500 2514.000	78.700 2515.200	82.000 2515.800
85.300 2517.200	88.600 2518.400	91.900 2522.000	95.100 2524.100	100.100 2524.900
105.000 2524.900	111.500 2524.800	118.100 2524.800	131.200 2524.800	137.800 2524.500
144.400 2524.100	147.600 2524.500	157.500 2524.600		

**** 37.790 2519.021 2519.023 .002 1.000 33.589 2515.535 .000 .323 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 11599.070 .000
AREA .00 117.11 .00
HYD RADIUS .0000 3.2621 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 93.2416 93.2416 93.2416
D/S SECTION... AREA .00 93.04 .00
HYD RADIUS .000 2.737 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 4.000 157.400 .000000000 339791.237
SECTION NO. 5.000

Cross Section Geometry (STA,ELEV)

.100 2526.000	6.600 2526.100	13.100 2525.800	19.700 2524.400	23.000 2523.600
36.100 2523.300	42.700 2524.100	52.500 2524.300	62.300 2524.300	68.900 2524.500
72.200 2523.300	72.300 2522.000	75.500 2518.800	78.700 2517.000	82.000 2516.300
85.300 2516.100	88.600 2515.800	91.900 2515.900	95.100 2515.900	98.400 2515.600
101.700 2515.500	105.000 2515.900	108.300 2516.200	111.500 2517.100	114.800 2519.200
116.500 2522.000	118.100 2524.700	128.000 2524.700	144.400 2526.500	147.600 2522.400

**** 37.790 2519.152 2519.154 .002 1.000 39.633 2516.355 .000 .341 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 9668.016 .000
AREA .00 110.86 .00
HYD RADIUS .0000 2.6951 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 101.6612 101.6612 101.6612
D/S SECTION... AREA .00 117.11 .00
HYD RADIUS .000 3.262 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 5.000 147.500 .000000000 348655.769
SECTION NO. 6.000

Cross Section Geometry (STA,ELEV)

.100 2526.100	6.600 2526.400	11.500 2526.000	16.400 2524.700	19.700 2523.900
29.500 2523.800	39.400 2523.700	42.700 2523.100	45.900 2522.000	49.200 2520.300
52.500 2518.100	55.800 2516.900	59.100 2515.800	62.300 2514.600	65.600 2513.800
68.900 2513.500	72.200 2513.600	75.500 2513.800	78.700 2514.300	82.000 2515.200
85.300 2516.300	88.600 2518.800	92.800 2522.000	96.800 2524.400	101.700 2524.500
108.300 2524.100	124.700 2523.800	128.900 2525.500	132.900 2525.500	134.500 2524.500

**** 37.790 2519.249 2519.250 .001 1.000 38.537 2515.305 .000 .249 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP		1	2	3
	INEFF FLOW EL	-99999.000	-99999.000	-99999.000
U/S SECTION...	CONVEYANCE	.000	16406.259	.000
	AREA	.00	152.01	.00
	HYD RADIUS	.0000	3.7106	.0000
REACH...	Manning's N	.0400	.0330	.0400
	SQRT(L)	105.6172	105.6172	105.6172
D/S SECTION...	AREA	.00	110.86	.00
	HYD RADIUS	.000	2.695	.000

	SECTION NO	BED WIDTH	ACTIVE LAYER(tons)	INACTIVE LAYER(tons)
OLD	6.000	134.400	.000000000	171052.244

FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).... .003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 6.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	37.79	2924.22	53.60

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF KHORDAK Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME DAYS	ENTRY POINT *	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF *	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF *	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF *
1.00	6.000 *	.37		*	1.55		*	.24		*
TOTAL=	1.000 *	.37	.32	.14 *	1.55	.33	.79 *	.24	.00	1.00 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	239.79	VERY FINE SAND....	225.17
VERY FINE SILT....	786.62	FINE SAND.........	140.36

FINE SILT.........	514.66	MEDIUM SAND.......	67.26
MEDIUM SILT.......	482.50	COARSE SAND.......	58.48
COARSE SILT.......	409.39		

TOTAL = 2924.22

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	206.60	VERY FINE SAND....	.00
VERY FINE SILT....	421.69	FINE SAND.........	.01
FINE SILT.........	43.05	MEDIUM SAND.......	.00
MEDIUM SILT.......	.03	COARSE SAND.......	.00
COARSE SILT.......	.00		

TOTAL = 671.39

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
6.000	.21	2519.25	2513.71	38.	232.	1055.	0.
5.000	.03	2519.15	2515.53	38.	219.	648.	0.
4.000	.02	2519.02	2513.62	38.	209.	492.	0.
3.000	.00	2518.89	2515.00	38.	208.	480.	0.
2.000	.00	2517.84	2516.90	38.	208.	480.	5.
1.000	.01	2516.43	2512.11	38.	207.	465.	0.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 30

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
****************************************************   ************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *    * U.S. ARMY CORPS OF ENGINEERS *
*    Version: 4.1.0                             *    * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE:  UNGAMELI.DAT                     *    * 609 SECOND STREET             *
* OUTPUT FILE: UNGAMELI.OUT                     *    * DAVIS, CALIFORNIA 95616-4687  *
* RUN DATE: 02 JUN 06    RUN TIME: 02:24:12     *    * (916) 756-1104                *
****************************************************   ************************************

      X    X XXXXXXX  XXXXX       XXXXX
      X    X X        X    X    X     X
      X    X X        X         X
      XXXXXXX XXXX    X     XXXXX XXXXXX
      X    X X        X         X     X
      X    X X        X    X    X     X
      X    X XXXXXXX  XXXXX       XXXXX

  ******************************************************************
  * MAXIMUM LIMITS FOR THIS VERSION ARE:                           *
  *      10  Stream Segments (Main Stem + Tributaries)             *
  *     150  Cross Sections                                        *
  *     100  Elevation/Station Points per Cross Section            *
  *      20  Grain Sizes                                           *
  *      10  Control Points                                        *
  ******************************************************************

T1    FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)
T2   // Moblie Bed HEC-6 Model //
T3   # Inflow Point-(1) Loktak Lake - Cross Sections & Data (2000-02)

N values... Left   Channel   Right   Contraction   Expansion
        .0400    .0330    .0400     1.1000      .7000

SECTION NO.    1.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

SECTION NO.    2.000
...DEPTH of the Bed Sediment Control Volume =   10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  2
NO. OF INPUT DATA MESSAGES =   0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  2
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=   1
END OF GEOMETRIC DATA


==============================================================================================
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T4    Ungamel Channel (INFLOW to Loktak Lake)     ** Movable bed **
T5    LOAD CURVE FROM GAUGE DATA.
T6    BED GRADATIONS FROM FIELD SAMPLES
T7    Use full range of Sands and gravel
T8    SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

     FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)
     Moblie Bed HEC-6 Model #
     Inflow Point-(1) Loktak Lake - Cross Sections & Data (2000-02)
```

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY.............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	267.000	445.000	564.000	609.000	641.000	658.000	665.000	672.000
LF CLAY	255.348	445.588	581.954	636.648	675.598	696.180	704.954	714.712
LF SILT1	837.666	1461.75	1909.09	2088.52	2216.29	2283.81	2312.59	2344.60
LF SILT2	548.064	956.384	1249.07	1366.46	1450.06	1494.24	1513.07	1534.02
LF SILT3	513.810	896.610	1171.01	1281.06	1359.44	1400.85	1418.51	1438.14
LF SILT4	435.960	760.760	993.580	1086.96	1153.46	1188.60	1203.58	1220.24
LF VFS	239.778	418.418	546.469	597.828	634.403	653.730	661.969	671.132
LF FS	149.472	260.832	340.656	372.672	395.472	407.520	412.656	418.368
LF MS	71.6220	124.982	163.231	178.572	189.497	195.270	197.731	200.468
LF CS	62.2800	108.680	141.940	155.280	164.780	169.800	171.940	174.320
TOTAL	3114.00	5434.00	7097.00	7764.00	8239.00	8490.00	8597.00	8716.00

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH (ft)	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (miles)
1.000	.000	182.300	2529.800	2515.200	2531.300	.000 .000
2.000	4921.000	150.800	2526.300	2513.700	2527.400	4921.000 .932

BED MATERIAL GRADATION

SECNO	SAE (ft)	DMAX (ft)	DXPI	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size			
1.000	1.000	.003	.003	1.000	1.000	CLAY	.001	VF SAND	.238
						VF SILT	.001	F SAND	.185
						F SILT	.023	M SAND	.025
						M SILT	.238	C SAND	.058
						C SILT	.230		

```
2.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                        | VF SILT  .001 | F  SAND  .185 |
                        | F  SILT  .023 | M  SAND  .025 |
                        | M  SILT  .238 | C  SAND  .058 |
                        | C  SILT  .230 |
```

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	(cu.yd)
1.000	2460.500	171.800	10.000	.422714E+07	156561.
2.000	2460.500	161.300	10.000	.396879E+07	146992.

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

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$HYD
BEGIN COMPUTATIONS.

==

TIME STEP # 1
* BB PROFILE 1 = Routed Stream INFLOW +ve (Effective) of Ungamel Channel

- -

FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

```
          DISCHARGE  TEMPERATURE  WATER SURFACE
            (cfs)      (deg F)      (ft)
           480.280      53.60     2522.520
```

```
**** DISCHARGE   WATER   ENERGY  VELOCITY  ALPHA   TOP    AVG    AVG VEL (by subsection)
      (CFS)     SURFACE   LINE    HEAD             WIDTH   BED     1    2    3
```

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

```
   .100 2529.800     .101 2529.800    11.800 2528.700    19.400 2522.500    22.300 2522.500
 25.100 2521.600   32.500 2520.300    40.800 2516.700    46.900 2516.800    55.100 2516.100
 64.000 2515.500   66.800 2515.200    73.500 2515.400    80.400 2515.500    90.900 2516.000
 95.500 2516.200  105.300 2516.700   114.800 2517.200   129.300 2520.300   136.500 2523.400
147.100 2527.200  159.400 2529.900   167.600 2530.800   172.600 2531.500   182.400 2531.300
```

```
****   480.280 2522.520 2522.531  .011  1.000 115.081 2517.465  .000  .826  .000
                        FLOW DISTRIBUTION (%) =  .000 100.000  .000
```

REACH PROPERTIES BY STRIP 1 2 3

INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 76326.046 .000
AREA .00 581.78 .00
HYD RADIUS .0000 4.9730 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 1.0000 .0000 .0000
D/S SECTION... AREA .00 .00 .00
HYD RADIUS .000 .000 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 1.000 182.300 .000000000 93422.3032
SECTION NO. 2.000

Cross Section Geometry (STA,ELEV)

.100 2526.300	9.800 2526.600	19.700 2525.200	26.200 2522.900	29.500 2520.100
32.800 2517.400	37.700 2514.100	45.900 2513.700	55.800 2514.600	65.600 2514.700
75.500 2514.900	85.300 2515.100	91.900 2515.100	98.400 2515.300	105.000 2516.600
111.500 2520.100	112.500 2525.600	121.400 2526.900	128.000 2527.400	150.900 2527.400

**** 480.280 2522.670 2522.680 .010 1.000 85.557 2515.493 .000 .782 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 98209.622 .000
AREA .00 614.06 .00
HYD RADIUS .0000 6.6936 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 70.1498 70.1498 70.1498
D/S SECTION... AREA .00 581.78 .00
HYD RADIUS .000 4.973 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 2.000 150.800 .000000000 87712.5582

FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs).... .003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 2.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	480.28	5921.76	53.60

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF UNGAMEL Channel # INFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME ENTRY * CLAY * SILT * SAND *
DAYS POINT * INFLOW OUTFLOW TRAP EFF * INFLOW OUTFLOW TRAP EFF *
INFLOW OUTFLOW TRAP EFF *
1.00 2.000 * .74 * 3.14 * .49 *

TOTAL= 1.000 * .74 .74 .00 * 3.14 2.89 .08 * .49 .00 1.00 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY..............	485.58	VERY FINE SAND....	455.98
VERY FINE SILT....	1592.95	FINE SAND.........	284.24
FINE SILT.........	1042.23	MEDIUM SAND.......	136.20
MEDIUM SILT.......	977.09	COARSE SAND.......	118.44
COARSE SILT.......	829.05		

TOTAL = 5921.76

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY..............	484.90	VERY FINE SAND....	.43
VERY FINE SILT....	1584.07	FINE SAND.........	.13
FINE SILT.........	1019.28	MEDIUM SAND.......	.01
MEDIUM SILT.......	894.74	COARSE SAND.......	.00
COARSE SILT.......	593.16		

TOTAL = 4576.72

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
2.000	.12	2522.67	2513.82	480.	485.	4210.	1.
1.000	.01	2522.52	2515.21	480.	485.	4091.	1.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 10

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
***************************************************  ************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *   * U.S. ARMY CORPS OF
ENGINEERS  *
*    Version: 4.1.0                    *   * HYDROLOGIC ENGINEERING CENTER  *
* INPUT FILE:  UNGAMELO.DAT            *   * 609 SECOND STREET              *
* OUTPUT FILE: UNGAMELO.OUT            *   * DAVIS, CALIFORNIA 95616-4687   *
* RUN DATE: 02 JUN 06   RUN TIME: 03:31:00   *   * (916) 756-1104           *
***************************************************  ************************************

         X    X XXXXXXX  XXXXX       XXXXX
         X    X X     X    X      X    X
         X    X X     X          X
         XXXXXXX XXXX    X       XXXXX XXXXXX
         X    X X     X          X    X
         X    X X     X    X      X    X
         X    X XXXXXXX  XXXXX       XXXXX

    *******************************************************************
    * MAXIMUM LIMITS FOR THIS VERSION ARE:                            *
    *     10  Stream Segments (Main Stem + Tributaries)               *
    *    150  Cross Sections                                          *
    *    100  Elevation/Station Points per Cross Section              *
    *     20  Grain Sizes                                             *
    *     10  Control Points                                          *
    *******************************************************************
```

T1   FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR RIVER BASIN)
T2   # Moblie Bed HEC-6 Model #
T3   # Outflow Point-(1)near Ithai Barrage - Cross Sections & Data(2000-02)

```
N values...  Left   Channel   Right   Contraction   Expansion
          .0400   .0330   .0400     1.1000      .7000
```

SECTION NO.   1.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

SECTION NO.   2.000
...DEPTH of the Bed Sediment Control Volume = 10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT= 2
NO. OF INPUT DATA MESSAGES = 0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK = 2
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK= 1
END OF GEOMETRIC DATA

==
============================

T4   Ungamel Channel (OUTFLOW from Loktak Lake)   ** Movable bed **
T5   LOAD CURVE FROM GAUGE DATA.
T6   BED GRADATIONS FROM FIELD SAMPLES
T7   Use full range of Sands and gravel
T8   SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR RIVER BASIN)
Moblie Bed HEC-6 Model #
Outflow Point-(1)near Ithai Barrage - Cross Sections & Data(2000-02)

- -

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

- -

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

- -

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

- -

SANDS - BOULDERS ARE PRESENT

UNGAMELO

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
14	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY.............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	283.000	481.000	847.000	1186.00	1350.00	1515.00	1852.00	2612.00
LF CLAY	324.310	597.534	1299.45	2108.96	2534.95	2969.30	3850.39	5468.09
LF SILT1	1063.90	1960.20	4262.84	6918.41	8315.87	9740.76	12631.2	17938.0
LF SILT2	696.080	1282.51	2789.07	4526.54	5440.86	6373.14	8264.26	11736.4
LF SILT3	652.575	1202.36	2614.76	4243.64	5100.81	5974.82	7747.74	11002.9
LF SILT4	553.700	1020.18	2218.58	3600.66	4327.96	5069.54	6573.84	9335.76
LF VFS	304.535	561.099	1220.22	1980.36	2380.38	2788.25	3615.61	5134.67
LF FS	189.840	349.776	760.656	1234.51	1483.87	1738.13	2253.89	3200.83
LF MS	90.9650	167.601	364.481	591.537	711.022	832.853	1079.99	1533.73
LF CS	79.1000	145.740	316.940	514.380	618.280	724.220	939.120	1333.68
TOTAL	3955.00	7287.00	15847.0	25719.0	30914.0	36211.0	46956.0	66684.0

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS REACH MOVABLE INITIAL BED-ELEVATIONS ACCUMULATED CHANNEL
DISTANCE
SECTION LENGTH BED LEFT SIDE THALWEG RIGHT SIDE FROM DOWNSTREAM
NO. (ft) WIDTH (ft) (ft) (ft) (ft) (miles)

.000
1.000 150.800 2526.300 2513.700 2527.400 .000 .000
4921.000
2.000 182.300 2529.800 2515.200 2531.300 4921.000 .932

BED MATERIAL GRADATION

SECNO SAE DMAX DXPI XPI TOTAL BED MATERIAL FRACTIONS
(ft) (ft) BED per grain size

SECNO	SAE	DMAX	DXPI	XPI	TOTAL BED				
1.000	1.000	.003	.003	1.000	1.000	CLAY	.001	VF SAND	.238
						VF SILT	.001	F SAND	.185
						F SILT	.023	M SAND	.025
						M SILT	.238	C SAND	.058
						C SILT	.230		

```
2.000 1.000  .003  .003 1.000 1.000|  CLAY  .001 | VF SAND  .238 |
                         | VF SILT  .001 | F  SAND  .185 |
                         | F  SILT  .023 | M  SAND  .025 |
                         | M  SILT  .238 | C  SAND  .058 |
                         | C  SILT  .230 |


BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT #  1: FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR
RIVER BASIN)
| SECTION |  LENGTH  |  WIDTH   | DEPTH  |      V O L U M E       |
| NUMBER  |   (ft)   |   (ft)   |  (ft)  |   (cu.ft)  |  (cu.yd)  |
--------------------------------------------------------------------------
|   1.000 |  2460.500 |  161.300 |  10.000 | .396879E+07 | 146992.   |
|   2.000 |  2460.500 |  171.800 |  10.000 | .422714E+07 | 156561.   |

NO. OF INPUT DATA MESSAGES=   0
END OF SEDIMENT DATA


==============================================================================
==========

$HYD
BEGIN COMPUTATIONS.


==============================================================================
==========
TIME STEP #      1
*  BB  PROFILE 1 = Routed Stream OUTFLOW -VE (Effective) of Ungamel Channel

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs)..........      .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO.  1 at Control Point #  1 ---
                  DISCHARGE   TEMPERATURE  WATER SURFACE
                    (cfs)      (deg F)       (ft)
                   1518.530      53.60      2522.620

**** DISCHARGE    WATER    ENERGY  VELOCITY  ALPHA    TOP     AVG      AVG VEL (by
subsection)
     .(CFS)    SURFACE   LINE    HEAD          WIDTH    BED      1     2     3

SECTION NO.     1.000

 Cross Section Geometry (STA,ELEV)
      .100 2526.300      9.800 2526.600     19.700 2525.200     26.200 2522.900     29.500 2520.100
    32.800 2517.400     37.700 2514.100     45.900 2513.700     55.800 2514.600     65.600 2514.700
    75.500 2514.900     85.300 2515.100     91.900 2515.100     98.400 2515.300    105.000 2516.600
   111.500 2520.100    112.500 2525.600    121.400 2526.900    128.000 2527.400    150.900 2527.400

****   1518.530 2522.620 2522.718   .098   1.000   85.428 2515.527   .000  2.506   .000
                                 FLOW DISTRIBUTION (%) =    .000 100.000    .000

    REACH PROPERTIES BY STRIP          1          2          3
          INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
```

UNGAMELO

```
U/S SECTION...  CONVEYANCE      .000  96227.673      .000
           AREA        .00    605.95      .00
        HYD RADIUS      .0000    6.6227     .0000
REACH...      Manning's N     .0400     .0330     .0400
         SQRT(L)      .0000     .0000     .0000
D/S SECTION...        AREA        .00       .00       .00
        HYD RADIUS       .000      .000      .000
```

```
   SECTION NO  BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      1.000    150.800    .000000000       87712.5582
SECTION NO.    2.000
```

Cross Section Geometry (STA,ELEV)

```
   .100 2529.800     .101 2529.800    11.800 2528.700    19.400 2522.500    22.300 2522.500
 25.100 2521.600   32.500 2520.300    40.800 2516.700    46.900 2516.800    55.100 2516.100
 64.000 2515.500   66.800 2515.200    73.500 2515.400    80.400 2515.500    90.900 2516.000
 95.500 2516.200  105.300 2516.700   114.800 2517.200   129.300 2520.300   136.500 2523.400
147.100 2527.200  159.400 2529.900   167.600 2530.800   172.600 2531.500   182.400 2531.300

****  1518.530 2523.743 2523.811   .068   1.000  119.578 2517.679   .000  2.094   .000
                          FLOW DISTRIBUTION (%) =    .000 100.000   .000

  REACH PROPERTIES BY STRIP          1          2          3
       INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
U/S SECTION...  CONVEYANCE      .000 107049.055      .000
           AREA        .00    725.14      .00
        HYD RADIUS      .0000    5.9359     .0000
REACH...      Manning's N     .0400     .0330     .0400
         SQRT(L)     70.1498   70.1498   70.1498
D/S SECTION...        AREA        .00    605.95      .00
        HYD RADIUS       .000     6.623      .000
```

```
   SECTION NO  BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      2.000    182.300    .000000000       93422.3032
```

FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED TIME (yrs)....   .003
FLOW DURATION (days)......   1.000

UPSTREAM BOUNDARY CONDITIONS

```
---------------------------------------------------------------------
Stream Segment # 1    |  DISCHARGE  | SEDIMENT LOAD | TEMPERATURE
Section No.   2.000 |   (cfs)    | (tons/day)  |  (deg F)
---------------------------------------------------------------------
        INFLOW |    1518.53 |    36320.19 |    53.60
```

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF UNGAMEL Channel # OUTFLOWS (MANIPUR RIVER BASIN)
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

```
*****************************************************************************************
***********************
  TIME     ENTRY *         CLAY          *          SILT          *          SAND          *
  DAYS      POINT *  INFLOW  OUTFLOW  TRAP EFF *  INFLOW  OUTFLOW  TRAP EFF *
INFLOW  OUTFLOW  TRAP EFF *
  1.00     2.000 *   4.56               *   19.24               *   3.01               *
```

TOTAL= 1.000 * 4.56 4.56 .00 * 19.24 19.28 .00 * 3.01 .29 .90 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	2978.26	VERY FINE SAND....	2796.65
VERY FINE SILT....	9770.13	FINE SAND.........	1743.37
FINE SILT.........	6392.35	MEDIUM SAND.......	835.36
MEDIUM SILT.......	5992.83	COARSE SAND.......	726.40
COARSE SILT.......	5084.83		

TOTAL = 36320.19

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY.............	2978.35	VERY FINE SAND....	417.04
VERY FINE SILT....	9770.22	FINE SAND.........	124.85
FINE SILT.........	6394.76	MEDIUM SAND.......	27.03
MEDIUM SILT.......	6017.79	COARSE SAND.......	22.00
COARSE SILT.......	5108.94		

TOTAL = 30860.97

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
2.000	.42	2523.74	2515.62	1519.	2978.	27268.	653.
1.000	.00	2522.62	2513.70	1519.	2978.	27292.	591.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 10

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
************************************************     **********************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *   * U.S. ARMY CORPS OF ENGINEERS  *
*     Version: 4.1.0                            *   * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE: NAMBUL1.DAT                       *   * 609 SECOND STREET             *
* OUTPUT FILE: NAMBUL1.OUT                      *   * DAVIS, CALIFORNIA 95616-4687  *
* RUN DATE: 04 JUN 06   RUN TIME: 12:04:28      *   * (916) 756-1104                *
************************************************     **********************************

     X   X XXXXXXX  XXXXX      XXXXX
     X   X X     X   X     X   X
     X   X X     X        X
     XXXXXXX XXXX   X     XXXXX XXXXXX
     X   X X     X        X   X
     X   X X     X   X     X   X
     X   X XXXXXXX  XXXXX      XXXXX

  ****************************************************************
  * MAXIMUM LIMITS FOR THIS VERSION ARE:                         *
  *     10 Stream Segments (Main Stem + Tributaries)             *
  *    150 Cross Sections                                        *
  *    100 Elevation/Station Points per Cross Section            *
  *     20 Grain Sizes                                           *
  *     10 Control Points                                        *
  ****************************************************************

T1    FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang
T2    # Moblie Bed HEC-6 Model(1) for Effective Discharge 7.15 cumecs #
T3    # Direct Catchment Flow to Loktak lake - Cross Sections & Data(2000-02)

N values... Left  Channel  Right  Contraction  Expansion
           .0400   .0330   .0400     1.1000     .7000

SECTION NO.   1.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

SECTION NO.   2.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

SECTION NO.   3.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

SECTION NO.   4.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  4
NO. OF INPUT DATA MESSAGES =  0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  4
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=  1
END OF GEOMETRIC DATA

==========================================================================================
==============================

T4    Nambul River (Direct flow to Loktak Lake)    ** Movable bed **
T5    LOAD CURVE FROM GAUGE DATA.
T6    BED GRADATIONS FROM FIELD SAMPLES
```

T7 Use full range of Sands and gravel
T8 SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]

FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang
Moblie Bed HEC-6 Model(1) for Effective Discharge 7.15 cumecs #
Direct Catchment Flow to Loktak lake - Cross Sections & Data(2000-02)

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

PARTICLE MASS MASS SLOPE OF SLOPE OF
EROSION EROSION EROSION PARTICLE MASS
SHEAR SHEAR RATE EROSION EROSION
LAYER STRESS STRESS LINE=ER1 LINE=ER2

```
        NO   lb/sq.ft  lb/sq.ft.  lb/sf/hr  1/hr    1/hr

 ACTIVE LAYER 1      .0500    .1000   1.5000  30.0000   20.0000
INACTIVE LAYER 2      .1250    .2300    2.0000  19.0476   10.0000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 SANDS - BOULDERS ARE PRESENT

     MTC   IASA  LASA   SPGS    GSF   BSAE    PSI   UWDLB
I4    4     1     4   2.650   .667   .500  30.000  93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)
-----------------------------------------------------------------
   CLAY..............   .003 | VERY FINE SAND....  .088
   VERY FINE SILT....   .006 | FINE SAND.........  .177
   FINE SILT.........   .011 | MEDIUM SAND.......  .354
   MEDIUM SILT.......   .023 | COARSE SAND.......  .707
   COARSE SILT.......   .045 |
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED
     DBI    DBN    XID    XIN    XIU    UBI    UBN    JSL
I5  .500   .500   .250   .500   .250   .000  1.000    1
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #  1
       LOAD BY GRAIN SIZE CLASS (tons/day)
```

LQ	57.0000	120.000	172.000	216.000	257.000	367.000	463.000	493.000
LF CLAY	47.8880	98.4820	142.188	180.974	216.562	312.420	397.700	424.514
LF SILT1	157.096	323.069	466.446	593.683	710.429	1024.89	1304.65	1392.61
LF SILT2	102.784	211.376	305.184	388.432	464.816	670.560	853.600	911.152
LF SILT3	96.3600	198.165	286.110	364.155	435.765	628.650	800.250	854.205
LF SILT4	81.7600	168.140	242.760	308.980	369.740	533.400	679.000	724.780
LF VFS	44.9680	92.4770	133.518	169.939	203.357	293.370	373.450	398.629
LF FS	28.0320	57.6480	83.2320	105.936	126.768	182.880	232.800	248.496
LF MS	13.4320	27.6230	39.8820	50.7610	60.7430	87.6300	111.550	119.071
LF CS	11.6800	24.0200	34.6800	44.1400	52.8200	76.2000	97.0000	103.540
TOTAL	584.000	1201.00	1734.00	2207.00	2641.00	3810.00	4850.00	5177.00

```
 REACH GEOMETRY FOR STREAM SEGMENT  1
 ----------------------------------
  CROSS     REACH   MOVABLE    INITIAL BED-ELEVATIONS     ACCUMULATED CHANNEL
DISTANCE
  SECTION    LENGTH    BED   LEFT SIDE  THALWEG  RIGHT SIDE      FROM DOWNSTREAM
   NO.      (ft)   WIDTH     (ft)     (ft)     (ft)        (ft)     (miles)
 ------------------------------------------------------------------------------

          .000
   1.000          207.200  2554.900  2535.900  2554.500      .000       .000
       7382.000
   2.000          188.500  2554.400  2535.200  2553.100   7382.000      1.398
       6234.000
   3.000          178.700  2554.000  2533.600  2552.800  13616.000      2.579
      10170.000
   4.000          190.200  2552.400  2533.200  2552.800  23786.000      4.505

 BED MATERIAL GRADATION
```

```
----------------------
   SECNO   SAE  DMAX  DXPI   XPI  TOTAL      BED MATERIAL FRACTIONS
           (ft)  (ft)        BED          per grain size
---------------------------------------------------------------------------------
   1.000 1.000  .003  .003 1.000 1.000|  CLAY  .001 | VF SAND  .238 |
                                 | VF SILT  .001 | F SAND  .185 |
                                 | F SILT  .023 | M SAND  .025 |
                                 | M SILT  .238 | C SAND  .058 |
                                 | C SILT  .230 |

   2.000 1.000  .003  .003 1.000 1.000|  CLAY  .001 | VF SAND  .238 |
                                 | VF SILT  .001 | F SAND  .185 |
                                 | F SILT  .023 | M SAND  .025 |
                                 | M SILT  .238 | C SAND  .058 |
                                 | C SILT  .230 |

   3.000 1.000  .003  .003 1.000 1.000|  CLAY  .001 | VF SAND  .238 |
                                 | VF SILT  .001 | F SAND  .185 |
                                 | F SILT  .023 | M SAND  .025 |
                                 | M SILT  .238 | C SAND  .058 |
                                 | C SILT  .230 |

   4.000 1.000  .003  .003 1.000 1.000|  CLAY  .001 | VF SAND  .238 |
                                 | VF SILT  .001 | F SAND  .185 |
                                 | F SILT  .023 | M SAND  .025 |
                                 | M SILT  .238 | C SAND  .058 |
                                 | C SILT  .230 |
```

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	3691.000	200.967	10.000	.741768E+07	274729.
2.000	6808.000	190.384	10.000	.129613E+08	480049.
3.000	8202.000	182.318	10.000	.149537E+08	553842.
4.000	5085.000	186.367	10.000	.947675E+07	350991.

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

===

$HYD
BEGIN COMPUTATIONS.

===

TIME STEP # 1
* BB PROFILE 1 = Effective Streamflow (Qe1) of NAMBUL River MRB-Direct

- -

FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang

ACCUMULATED TIME (yrs)......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
252.500	53.60	2538.790

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

```
 .100 2554.900     9.800 2554.700    19.700 2554.700    29.500 2554.600    42.700 2554.500
 55.800 2554.300   68.900 2552.000    80.500 2548.000    87.900 2545.500    92.800 2544.200
 98.800 2542.200  106.000 2540.100   110.600 2538.300   116.100 2538.000   124.000 2537.300
128.300 2535.900  133.900 2536.000   138.100 2536.100   144.400 2538.700   154.500 2540.600
162.400 2544.000  168.000 2545.700   175.500 2549.500   186.300 2554.000   198.500 2554.400
207.300 2554.500
```

```
**** 252.500 2538.790 2539.080 .290 1.000 35.531 2537.145 .000 4.321 .000
              FLOW DISTRIBUTION (%) = .000 100.000 .000
```

```
    REACH PROPERTIES BY STRIP        1           2           3
          INEFF FLOW  EL  -99999.000  -99999.000  -99999.000
U/S SECTION...  CONVEYANCE      .000    3607.528        .000
             AREA        .00       58.44       .00
          HYD RADIUS       .0000      1.6050      .0000
REACH...      Manning's N      .0400      .0330      .0400
            SQRT(L)      .0000      .0000      .0000
D/S SECTION...      AREA       .00        .00        .00
          HYD RADIUS        .000       .000       .000
```

```
    SECTION NO  BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD      1.000    207.200     .000000000          163935.162
SECTION NO.    2.000
```

Cross Section Geometry (STA,ELEV)

```
 .100 2554.400     9.800 2553.200    19.700 2553.200    29.500 2553.200    39.400 2553.100
 49.200 2553.100   59.100 2553.100    68.900 2552.500    75.500 2549.300    82.300 2545.900
 88.900 2544.200   94.200 2542.700    97.400 2541.700   107.300 2538.500   115.200 2537.300
120.100 2535.500  127.300 2535.200   130.500 2535.500   136.800 2535.800   146.700 2538.700
149.900 2541.700  154.200 2545.000   159.100 2548.300   164.000 2550.800   170.600 2552.800
182.100 2553.100  188.600 2553.100
```

```
**** 252.500 2541.792 2541.810 .019 1.000 53.036 2537.434 .000 1.093 .000
              FLOW DISTRIBUTION (%) = .000 100.000 .000
```

```
    REACH PROPERTIES BY STRIP        1           2           3
          INEFF FLOW  EL  -99999.000  -99999.000  -99999.000
U/S SECTION...  CONVEYANCE      .000   26892.745        .000
             AREA        .00      231.12       .00
          HYD RADIUS       .0000      4.1538      .0000
REACH...      Manning's N      .0400      .0330      .0400
            SQRT(L)    85.9186    85.9186    85.9186
D/S SECTION...      AREA       .00       58.44       .00
          HYD RADIUS        .000      1.605       .000
```

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 2.000 188.500 .000000000 286453.162
SECTION NO. 3.000

Cross Section Geometry (STA,ELEV)

.100 2554.000	12.800 2552.500	22.600 2552.100	32.500 2551.900	42.300 2551.600
52.200 2551.400	62.000 2551.100	70.500 2548.900	75.800 2546.000	83.300 2542.700
89.200 2539.700	96.800 2537.600	103.300 2534.600	116.800 2533.600	122.400 2535.900
128.000 2542.800	132.900 2546.600	141.100 2546.900	149.300 2551.200	157.500 2551.500
170.600 2551.900	178.800 2552.800			

**** 252.500 2542.255 2542.272 .017 1.000 43.363 2536.673 .000 1.043 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 31857.691 .000
AREA .00 242.04 .00
HYD RADIUS .0000 4.9974 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 78.9557 78.9557 78.9557
D/S SECTION... AREA .00 231.12 .00
HYD RADIUS .000 4.154 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 3.000 178.700 .000000000 330486.189
SECTION NO. 4.000

Cross Section Geometry (STA,ELEV)

.100 2552.400	6.600 2552.400	13.100 2552.400	19.700 2552.200	21.300 2551.800
23.000 2551.300	26.200 2549.800	27.900 2549.200	29.500 2548.400	31.200 2547.400
32.800 2546.700	36.100 2545.200	39.000 2544.000	42.700 2541.200	45.900 2540.000
49.200 2538.800	52.500 2538.600	55.800 2539.100	59.100 2538.500	65.600 2535.100
68.900 2534.300	72.200 2533.200	75.500 2533.500	78.700 2533.800	82.000 2535.800
83.700 2536.800	85.300 2537.500	86.900 2538.600	88.600 2540.000	91.900 2540.900
96.800 2542.000	106.600 2543.400	114.800 2545.200	124.700 2546.200	136.200 2546.900
141.100 2547.400	152.600 2548.000	162.400 2550.800	170.600 2551.800	185.400 2552.700
190.300 2552.800				

**** 252.500 2542.822 2542.833 .011 1.000 62.137 2538.077 .000 .856 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 35838.748 .000
AREA .00 294.83 .00
HYD RADIUS .0000 4.4352 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 100.8464 100.8464 100.8464
D/S SECTION... AREA .00 242.04 .00
HYD RADIUS .000 4.997 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 4.000 190.200 .000000000 209441.739

FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang
ACCUMULATED TIME (yrs).... .003
FLOW DURATION (days)...... 1.000

UPSTREAM BOUNDARY CONDITIONS

Stream Segment # 1 Section No. 4.000	DISCHARGE (cfs)	SEDIMENT LOAD (tons/day)	TEMPERATURE (deg F)
INFLOW	252.50	2593.25	53.60

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
FLUVIAL ANALYSIS OF NAMBUL River (MANIPUR RIVER BASIN) stn-Hiyanthang
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

****

TIME DAYS	ENTRY POINT *	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF *	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF *	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF *
1.00	4.000 *	.33		*	1.37		*	.22		*
TOTAL=	1.000 *	.33	.35	-.08 *	1.37	8.55	-5.22 *	.22	3.35	-14.57 *

****

TABLE SB-1: SEDIMENT LOAD PASSING THE BOUNDARIES OF STREAM SEGMENT # 1

SEDIMENT INFLOW at the Upstream Boundary:

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY..............	212.65	VERY FINE SAND....	199.68
VERY FINE SILT....	697.58	FINE SAND.........	124.48
FINE SILT.........	456.41	MEDIUM SAND.......	59.64
MEDIUM SILT.......	427.89	COARSE SAND.......	51.86
COARSE SILT.......	363.05		

TOTAL = 2593.25

SEDIMENT OUTFLOW from the Downstream Boundary

GRAIN SIZE	LOAD (tons/day)	GRAIN SIZE	LOAD (tons/day)
CLAY..............	230.39	VERY FINE SAND....	4917.92
VERY FINE SILT....	715.32	FINE SAND.........	1631.11
FINE SILT.........	930.27	MEDIUM SAND.......	102.04
MEDIUM SILT.......	5344.35	COARSE SAND.......	133.14
COARSE SILT.......	5111.30		

TOTAL = 19115.83

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
4.000	.03	2542.82	2533.23	253.	213.	1945.	1.
3.000	.00	2542.25	2533.60	253.	213.	1945.	2.
2.000	-.01	2541.79	2535.19	253.	213.	2014.	52.
1.000	-2.30	2538.79	2533.60	253.	230.	12101.	6784.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 20

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

```
**************************************************   ***********************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS *   * U.S. ARMY CORPS OF ENGINEERS *
*    Version: 4.1.0                             *   * HYDROLOGIC ENGINEERING CENTER *
* INPUT FILE:  NAMBOL1.DAT                      *   * 609 SECOND STREET             *
* OUTPUT FILE: NAMBOL1.OUT                      *   * DAVIS, CALIFORNIA 95616-4687  *
* RUN DATE: 05 JUN 06   RUN TIME: 14:21:52      *   * (916) 756-1104                *
**************************************************   ***********************************

      X    X XXXXXXX  XXXXX       XXXXX
      X    X X       X     X     X     X
      X    X X       X           X
      XXXXXXX XXXX   X     XXXXX XXXXXX
      X    X X       X           X     X
      X    X X       X     X     X     X
      X    X XXXXXXX  XXXXX       XXXXX

   **********************************************************************
   * MAXIMUM LIMITS FOR THIS VERSION ARE:                                *
   *    10  Stream Segments (Main Stem + Tributaries)                    *
   *   150  Cross Sections                                               *
   *   100  Elevation/Station Points per Cross Section                   *
   *    20  Grain Sizes                                                  *
   *    10  Control Points                                               *
   **********************************************************************

T1    FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis
T2    # Moblie Bed HEC-6 Model (1) Effective Discharge - 5.20 cumecs
T3    # Direct Catchment Flow to Loktak lake - Cross Sections & Data(2000-02)

N values... Left  Channel  Right  Contraction  Expansion
           .0400   .0330   .0400     1.1000      .7000

SECTION NO.    1.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

SECTION NO.    2.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

SECTION NO.    3.000
...DEPTH of the Bed Sediment Control Volume =  10.00 ft.

NO. OF CROSS SECTIONS IN STREAM SEGMENT=  3
NO. OF INPUT DATA MESSAGES =  0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  3
TOTAL NO. OF STREAM SEGMENTS IN THE NETWORK=  1
END OF GEOMETRIC DATA


==================================================================================================================


T4    NambOl River (Direct flow to Loktak Lake)    ** Movable bed **
T5    LOAD CURVE FROM GAUGE DATA.
T6    BED GRADATIONS FROM FIELD SAMPLES
T7    Use full range of Sands and gravel
T8    SEDIMENT TRANSPORT BY Yang's STREAM POWER [YANG 1973]
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FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis Moblic Bed HEC-6 Model (1) Effective Discharge - 5.20 cumecs
Direct Catchment Flow to Loktak lake - Cross Sections & Data(2000-02)

SEDIMENT PROPERITES AND PARAMETERS

	SPI	IBG	MNQ	SPGF	ACGR	NFALL	IBSHER
I1	5.	0	1	1.000	32.174	2	1

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000
INACTIVE LAYER 2	.1250	.2300	2.0000	19.0476	10.0000

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS lb/sq.ft
ACTIVE LAYER 1	.0200
INACTIVE LAYER 2	.0200

EROSION COEFFICIENTS BY LAYER

LAYER NO	PARTICLE EROSION SHEAR STRESS lb/sq.ft	MASS EROSION SHEAR STRESS lb/sq.ft.	MASS EROSION RATE lb/sf/hr	SLOPE OF PARTICLE EROSION LINE=ER1 1/hr	SLOPE OF MASS EROSION LINE=ER2 1/hr
ACTIVE LAYER 1	.0500	.1000	1.5000	30.0000	20.0000

INACTIVE LAYER 2 .1250 .2300 2.0000 19.0476 10.0000

SANDS - BOULDERS ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	4	2.650	.667	.500	30.000	93.000

USING TRANSPORT CAPACITY RELATIONSHIP # 4, YANG
GRAIN SIZES UTILIZED (mean diameter - mm)

CLAY..............	.003	VERY FINE SAND....	.088
VERY FINE SILT....	.006	FINE SAND.........	.177
FINE SILT.........	.011	MEDIUM SAND.......	.354
MEDIUM SILT.......	.023	COARSE SAND.......	.707
COARSE SILT.......	.045		

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED

	DBI	DBN	XID	XIN	XIU	UBI	UBN	JSL
I5	.500	.500	.250	.500	.250	.000	1.000	1

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (tons/day)

LQ	104.000	182.000	236.000	280.000	318.000	356.000	417.000	443.000
LF CLAY	138.498	285.196	400.242	499.790	587.858	680.026	836.974	904.542
LF SILT1	454.341	935.582	1312.99	1639.56	1928.46	2230.82	2745.68	2967.34
LF SILT2	297.264	612.128	859.056	1072.72	1261.74	1459.57	1796.43	1941.46
LF SILT3	278.685	573.870	805.365	1005.68	1182.89	1368.34	1684.15	1820.11
LF SILT4	236.460	486.920	683.340	853.300	1003.66	1161.02	1428.98	1544.34
LF VFS	130.053	267.806	375.837	469.315	552.013	638.561	785.939	849.387
LF FS	81.0720	166.944	234.288	292.560	344.112	398.064	489.936	529.488
LF MS	38.8470	79.9940	112.263	140.185	164.887	190.739	234.761	253.713
LF CS	33.7800	69.5600	97.6200	121.900	143.380	165.860	204.140	220.620
TOTAL	1689.00	3478.00	4881.00	6095.00	7169.00	8293.00	10207.0	11031.0

REACH GEOMETRY FOR STREAM SEGMENT 1

CROSS SECTION NO.	REACH LENGTH (ft)	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE (ft)	THALWEG (ft)	RIGHT SIDE (ft)	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM (ft)	(miles)
1.000	.000	107.700	2551.700	2536.100	2552.200	.000	.000
2.000	7545.000	97.800	2552.500	2537.500	2552.200	7545.000	1.429
3.000	10499.000	93.100	2552.500	2537.100	2552.800	18044.000	3.417

BED MATERIAL GRADATION

SECNO	SAE (ft)	DMAX (ft)	DXPI	XPI	TOTAL BED	BED MATERIAL FRACTIONS per grain size			
1.000	1.000	.003	.003	1.000	1.000	CLAY	.001	VF SAND	.238

NAMBOLI

```
                    | VF SILT  .001 | F SAND  .185 |
                    | F SILT  .023 | M SAND  .025 |
                    | M SILT  .238 | C SAND  .058 |
                    | C SILT  .230 |

 2.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                    | VF SILT  .001 | F SAND  .185 |
                    | F SILT  .023 | M SAND  .025 |
                    | M SILT  .238 | C SAND  .058 |
                    | C SILT  .230 |

 3.000 1.000  .003  .003 1.000 1.000 |  CLAY  .001 | VF SAND  .238 |
                    | VF SILT  .001 | F SAND  .185 |
                    | F SILT  .023 | M SAND  .025 |
                    | M SILT  .238 | C SAND  .058 |
                    | C SILT  .230 |
```

BED SEDIMENT CONTROL VOLUMES

STREAM SEGMENT # 1: FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis

SECTION NUMBER	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	VOLUME (cu.ft)	VOLUME (cu.yd)
1.000	3772.500	104.400	10.000	.393849E+07	145870.
2.000	9022.000	98.268	10.000	.886577E+07	328362.
3.000	5249.500	94.667	10.000	.496953E+07	184057.

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

==

$HYD
BEGIN COMPUTATIONS.

==

TIME STEP # 1
* BB PROFILE 1 = Effective Streamflow (Qe1) of NAMBOL River

- -

FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis
ACCUMULATED TIME (yrs).......... .000

--- Downstream Boundary Condition Data for STREAM SEGMENT NO. 1 at Control Point # 1 ---

DISCHARGE (cfs)	TEMPERATURE (deg F)	WATER SURFACE (ft)
183.640	53.60	2541.670

**** DISCHARGE WATER ENERGY VELOCITY ALPHA TOP AVG AVG VEL (by subsection)
(CFS) SURFACE LINE HEAD WIDTH BED 1 2 3

SECTION NO. 1.000

Cross Section Geometry (STA,ELEV)

.100 2551.700	5.200 2551.300	10.300 2550.900	15.100 2549.500	18.200 2548.900
22.300 2548.100	27.100 2546.300	28.500 2544.900	32.600 2542.100	34.400 2540.300
37.600 2538.500	38.900 2537.100	41.800 2536.100	45.600 2536.500	46.800 2536.500
48.900 2536.700	50.500 2537.000	54.600 2537.600	60.200 2538.100	66.400 2539.900
72.500 2541.100	77.900 2544.300	84.600 2547.000	91.000 2549.800	98.400 2550.400
103.300 2551.900	107.800 2552.200			

**** 183.640 2541.670 2541.698 .028 1.000 40.432 2538.302 .000 1.349 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 13244.552 .000
AREA .00 136.18 .00
HYD RADIUS .0000 3.1742 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) .0000 .0000 .0000
D/S SECTION... AREA .00 .00 .00
HYD RADIUS .000 .000 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 1.000 107.700 .000000000 87042.9874
SECTION NO. 2.000

Cross Section Geometry (STA,ELEV)

.100 2552.500	3.300 2552.000	9.800 2551.700	13.100 2549.200	13.800 2548.900
18.400 2548.400	26.600 2544.000	28.200 2543.500	29.900 2542.100	31.800 2540.300
36.400 2538.500	38.100 2537.600	44.300 2537.500	46.800 2537.900	48.400 2539.700
52.000 2540.100	54.500 2541.400	56.100 2544.400	61.000 2546.200	66.400 2546.500
80.100 2546.900	84.800 2547.800	86.300 2548.600	91.900 2550.600	97.899 2552.200
97.900 2552.200				

**** 183.640 2543.333 2543.377 .044 1.000 27.131 2539.312 .000 1.683 .000
FLOW DISTRIBUTION (%) = .000 100.000 .000

REACH PROPERTIES BY STRIP 1 2 3
INEFF FLOW EL -99999.000 -99999.000 -99999.000
U/S SECTION... CONVEYANCE .000 11317.541 .000
AREA .00 109.09 .00
HYD RADIUS .0000 3.4970 .0000
REACH... Manning's N .0400 .0330 .0400
SQRT(L) 86.8620 86.8620 86.8620
D/S SECTION... AREA .00 136.18 .00
HYD RADIUS .000 3.174 .000

SECTION NO BED WIDTH ACTIVE LAYER(tons) INACTIVE LAYER(tons)
OLD 2.000 97.800 .000000000 195938.745
SECTION NO. 3.000

Cross Section Geometry (STA,ELEV)

.100 2552.500	.101 2552.500	4.900 2551.200	17.400 2550.900	23.600 2550.100
27.900 2548.500	33.100 2546.300	35.400 2543.700	40.000 2539.400	44.300 2537.900
48.200 2537.400	51.200 2537.100	54.800 2537.100	57.100 2539.800	59.400 2540.900
60.400 2542.100	65.600 2542.600	68.900 2543.900	77.100 2550.000	85.300 2550.200
93.199 2552.800	93.200 2552.800			

```
****   183.640 2544.870 2544.888  .018  1.000  35.864 2540.140  .000  1.083  .000
                              FLOW DISTRIBUTION (%) =  .000 100.000  .000

   REACH PROPERTIES BY STRIP        1         2         3
        INEFF FLOW  EL  -99999.000 -99999.000 -99999.000
 U/S SECTION...  CONVEYANCE       .000  19669.603     .000
             AREA        .00     169.62      .00
          HYD RADIUS      .0000     4.1324     .0000
 REACH...       Manning's N     .0400      .0330      .0400
            SQRT(L)    102.4646   102.4646   102.4646
 D/S SECTION...        AREA       .00     109.09      .00
          HYD RADIUS      .000      3.497      .000


    SECTION NO   BED WIDTH  ACTIVE LAYER(tons)  INACTIVE LAYER(tons)
OLD       3.000      93.100     .000000000        109829.515

------------------------------------------------
FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis
    ACCUMULATED TIME (yrs)....      .003
    FLOW DURATION (days)......     1.000

UPSTREAM BOUNDARY CONDITIONS
------------------------------------------------------------------
Stream Segment # 1    |  DISCHARGE   | SEDIMENT LOAD | TEMPERATURE
Section No.    3.000 |   (cfs)    | (tons/day)   |  (deg F)
------------------------------------------------------------------
          INFLOW |       183.64 |     3518.93 |      53.60

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
      FLUVIAL ANALYSIS OF NAMBOL River (MANIPUR RIVER BASIN) stn-Nambol vis
      ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

*******************************************************************************************
***********************
   TIME     ENTRY *         CLAY          *         SILT         *         SAND          *
   DAYS      POINT *  INFLOW  OUTFLOW  TRAP EFF *  INFLOW  OUTFLOW  TRAP EFF *
INFLOW   OUTFLOW  TRAP EFF *
   1.00     3.000 *     .44                *    1.86                 *     .29                *
  TOTAL=    1.000 *     .44      .44     .00 *   1.86    1.91    -.02 *    .29     .01     .96 *

*******************************************************************************************
***********************

TABLE SB-1:  SEDIMENT LOAD PASSING THE  BOUNDARIES OF STREAM SEGMENT #  1
------------------------------------------------------------------------------
  SEDIMENT INFLOW at the Upstream Boundary:
    GRAIN SIZE      LOAD (tons/day) |   GRAIN SIZE     LOAD (tons/day)
  ----------------------------------------------------------------------
   CLAY.............      288.55  | VERY FINE SAND....       270.96
   VERY FINE SILT....       946.59  | FINE SAND.........        168.91
   FINE SILT.........       619.33  | MEDIUM SAND.......        80.94
   MEDIUM SILT.......        580.62  | COARSE SAND.......         70.38
   COARSE SILT.......        492.65  |
                     -------------               -------------
                                  TOTAL =      3518.93
  SEDIMENT OUTFLOW from the Downstream Boundary
    GRAIN SIZE      LOAD (tons/day) |   GRAIN SIZE     LOAD (tons/day)
```

CLAY.............	288.66	VERY FINE SAND....	19.01
VERY FINE SILT....	946.70	FINE SAND.........	5.02
FINE SILT.........	622.11	MEDIUM SAND.......	.42
MEDIUM SILT.......	609.45	COARSE SAND.......	.67
COARSE SILT.......	520.49		

TOTAL = 3012.51

TABLE SB-2: STATUS OF THE BED PROFILE AT TIME = 1.000 DAYS

SECTION NUMBER	BED CHANGE (ft)	WS ELEV (ft)	THALWEG (ft)	Q (cfs)	TRANSPORT RATE (tons/day) CLAY	SILT	SAND
3.000	.07	2544.87	2537.17	184.	289.	2657.	12.
2.000	.00	2543.33	2537.50	184.	289.	2685.	21.
1.000	.00	2541.67	2536.10	184.	289.	2699.	25.

$$END

0 DATA ERRORS DETECTED.

TOTAL NO. OF TIME STEPS READ = 1
TOTAL NO. OF WS PROFILES = 1
ITERATIONS IN EXNER EQ = 15

COMPUTATIONS COMPLETED
RUN TIME = 0 HOURS, 0 MINUTES & .00 SECONDS

APPENDIX - II

OTHER RESULTS AND REVIEWS

Calculated Sediment load Discharge-
Direct Catchment Rivers (MANIPUR RIVER BASIN)

Year period: 2000-2002

Sl. No.	**River/Stream**	**Total sediment load (tones)**
1.	Nambul River	77668.83
2.	Nambol River	92965.82
3.	Thogjaorok Stream	83678.48
4.	Awang Khujairok Stream	5762.26
5.	Marakhong	5380.25
6.	Potsangbam	86844.73

SUMMARY OF BED FORM CONFIGURATION AFFECTING ALLUVIAL CHANNEL ROUGHNESS (ASCE, 1966) AND CORRESPONDING REGIME CLASSIFICATION (SIMONS AND RICHARDSON, 1971)

Bed form	Ripples
Size of features	Wave length less than approximately 0.3m height less than approximately 0.03m
Shape of features	Roughly triangular in profile with gentle, slightly convex upstream slopes and down-stream slopes nearly equal to the angle of repose, generally short crested and three dimensional
Comments: behaviour and occurrence	Move downstream with velocity much less than flow velocity, generally do not occur in sediments coarser than about 0.6mm
Regime classification	Regime – Lower Approximate Froude No. 0.14-0.37 Approximate n value 0.018-0.03

Bed form	Bars
Size of features	Lengths comparable to channel width, heights comparable to mean flow depth

Shape of features	Profile similar to ripples, plan form variable
Commcnts: bcahviour and occurrence	Four types of bars are distinguished: point, alternating, transverse and tributary. Ripples may occur on upstream slopes.
Regime classification	Regime – Approximate Froude No. – Approximate n value -
Bed form	Dunes
Size of features	Wavelengths and heights greater than bars
Shape of features	Similar to ripples
Comments: behaviour and occurrence	Upstream slopes of dunes may be covered with ripples, dunes migrate downstream in manner similar to ripples.
Regime classification	Regime – Lower Approximate Froude No.0.28-0.65 Approximate n value – 0.02-0.04
Bed form	Transition
Size of features	Vary widely
Shape of features	Vary widely
Comments: behaviour And occurrence	Heterogeneous array of bed forms, primarily low amplitude ripples and dunes interspersed with flat regions

The ASCE classification of bed forms covers all kinds from ripples to antidunes without sub-classification in respect of ripples and dunes. A more detailed classification was attempted by Davis (3). He defined the 3 characteristics of dunes i.e. shape, size and spacing in terms of geometric parameters.

Pre-Defined Curve fit Equations in Neural Power tool :
(x any y being the variables, the others as constants)

1: $y = a \cdot x + b$	13: $y = b \cdot e^{a \cdot x}$	25: $y = \frac{(\ln(x))^2}{(b \cdot (\ln(x))^2 + a)}$
2: $y = a \cdot x^2 + b$	14: $y = a \cdot e^x + b$	26: $y = \frac{1}{a \cdot (\ln(x))^2 + b}$
3: $y = a \cdot x^3 + b$	15: $y = a \cdot e^{-x} + b$	27: $y = \frac{\ln(x)}{b \cdot \ln(x) + a}$
4: $y = \frac{a}{x} + b$	16: $y = a \cdot \ln(x) + b$	28 $y = b_0 + b_1 \cdot x + b_2 \cdot x^2$
5: $y = \frac{a}{x^2} + b$	17: $y = \frac{1}{a \cdot \ln(x) + b}$	29: $y = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3$
6: $y = \frac{a}{x^3} + b$	18: $y = \frac{a}{\ln(x)} + b$	30: $y = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + b_4 \cdot x^4$
7: $y = \frac{a}{x^4} + b$	19: $y = \frac{a}{(\ln(x))^2} + b$	31: $y = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + b_4 \cdot x^4 + b_5 \cdot x^5$
8: $y = \frac{a}{\sqrt{x}} + b$	20: $y = \frac{a}{(\ln(x))^3} + b$	32: $y = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + b_4 \cdot x^4 + b_5 \cdot x^5 + b_6 \cdot x^6$
9: $y = \frac{1}{a \cdot x + b}$	21: $y = \frac{a}{(\ln(x))^4} + b$	33: $y = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + b_4 \cdot x^4 + b_5 \cdot x^5 + b_6 \cdot x^6 + b_7 \cdot x^7$
10: $y = \frac{1}{(a \cdot x + b)^2}$	22: $y = \frac{a}{(\ln(x))^5} + b$	
11: $y = \frac{x}{b \cdot x + a}$	23: $y = a \cdot (\ln(x))^2 + b$	
12: $y = b \cdot x^a$	24: $y = a \cdot (\ln(x))^3 + b$	

INITIAL UNIT WEIGHTS OF SEDIMENTS (γ_0)

Sl No.	Size(mm)	Unit weight(γ_0)(KN/ m^3)
1.	0.0012	7.55
2.	0.005	9.45
3.	0.01	10.20
4.	0.05	11.60
5.	0.10	12.60
6.	0.25	14.00
7.	0.50	15.00
8.	1.00	15.50
9.	2.0-4.0	16.00
10.	4.0-8.0	17.20
11.	8.0-16.0	18.20
12.	16.0-32.0	19.00
13.	32.0-64.0	20.00
14.	64.0-128	21.6
15.	128-256	22.00

SEDIMENT SAMPLING :

PUNJAB-TYPE BOTTLE SAMPLER:

Various types of samplers have been developed in India and other countries of the world with a view to complying with most of the requirements.

In CWC, (Adopted by LDA) by the Punjab Irrigation Research Institute of India is in use for sampling in shallow stream (Fig. .9.1). It consists of a small necked bottle held in a frame which is attached co-axially to the end of a pipe. The bottle is opened ad closed manually by means of a hand lever at the top and a rod inside the pipe connected to bottle stopper. The efficiency of the water sampler is about 65-70% but it is widely used for its simplicity in application. Besides bottle samplers, in some of the sites other samplers like point integrating sampler viz., USP-61 and depth integrating sampler such as USD-49 are also used in CWC. The bottle-type sampler cannot be used efficiently for depth greater than 5 metres and velocity greater than 3 metres per second due to practical difficulties.

It is very difficult to keep the sampler at 0.6 depth in a vertical position due to high velocity of flow. The bottle-type sampler causes turbulence in flow and hence filling rates are different for different depths and it is unsuitable for sampling very near to the bed. Further, the existence of initial pressure difference between inside and outside of the bottle results in anon-representative character of the sediment samples. This effect increases as the depth increases. The disturbances due to the change in the direction of flow and vertical filling may also cause an error of unknown magnitude. During high floods, it is not possible to collect the sample at 0.6 depth ad hence surface collection is made.

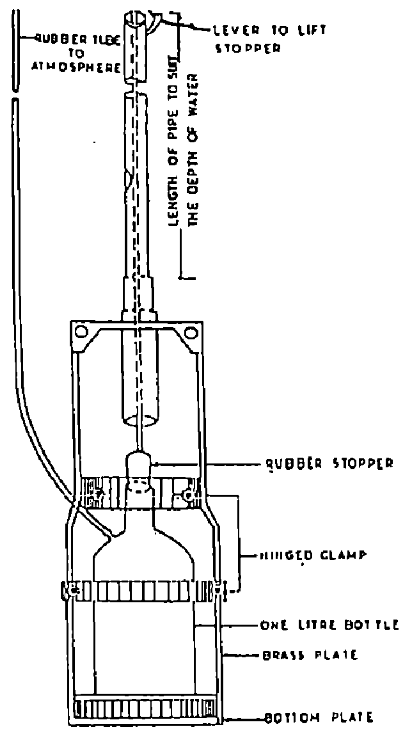

FIG. PUNJAB BOTTLE-TYPE SAMPLER

HEC-6 REVIEW AND APPLICATIONS :

Sediment Transport Equations :

From the calculated velocities, depths and water surface slopes, sediment concentrations at each cross-section may be calculated. The behaviour of sediments depends upon, amongst other things, sediment size. For sediments of sand size and larger (approximately D 0.06 mm) the movement of the sediment depends only on the hydraulic conditions. AS the sediment size decreases the speed with which the sediment concentration reacts to changes in flow conditions diminishes and so for the smaller silt fractions the sediment size decreases the speed with which the sediment concentration depends not only upon the instantaneous local hydraulic conditions, but also the previous history of the flow. For the purposes of the calculation of the sediment transport, therefore, the sediment is divided into two size ranges. Te finer size range, with sediment diameters less than 0.06 mm, consists of material whose transport is usually independent of local conditions and depends chiefly upon the supply. The coarser size range, with sediment diameters larger than 0.06 mm contain sand material whose transport is determined by the local hydraulic conditions. Each of the sediment size ranges is sub-divided 30 that the transport of sand and silt, with different representative particle sizes, can be considered independently.

Once the transport rtes for each size range have been calculated these are added together to obtain the total sediment transport rate at each cross-section. Since sediment is neither lost nor gained, differences between the volume of the sediment passing adjacent cross-sections must lead to the deposition or erosion of sediment on or from the bed. Since the volume of sediment passing each section is determined, the change in bed level can be calculated. Mathematically this conservation of sediment is described by the equation,

$$B\frac{\partial z}{\partial t}+\frac{\partial G}{\partial x}=0$$

Sand Transport

The transport of the sand size at each cross-section is calculated using the Ackers and White sediment transport theory (1973). In tests on an extensive set of field and data this theory produced the most satisfactory predictions of sediment transport (White, Milli and Crabbe, 1973).

The Ackers equations center on several non-dimensional quantities, each of which have a distinct physical significance but incorporate coefficients determined from empirical data.

The sediment mobility F_{gr} is defined to be,

$$F_{gr}=\frac{V^{H}n}{[gD(s-4)]^{1/2}}\left[\frac{V}{(32)1/2\log(lod/D)}\right]^{1-n}$$

where:

n is the Ackers-white transition exponent

The concentration is given by :

$$X = G_{gr} \frac{SD}{d}\left(\frac{v}{v^{*}}\right)^{n} .PXX.\ SPROP$$

where:

$$G_{gr} = C\left[\frac{F_{gr}}{a} - 1\right]^{m}$$

c = Ackers-white parameter

a = Value of F_{gr} at initial motion

m = Ackers – White parameter

PXX= the proportion that sand of diameter D is of the total sand present on the bed

SPROF = the proportion of the bed material which is mobile

The parameters n, A, m and C are functions of the dimensionless particle size D_{gr} defined by,

$$D_{gr} = D\left[\frac{g(G-1)}{\nu^{2}}\right]^{1/3}$$

For coarse sediments ($D_{gr} > 60$)

N = 0.0

A = 0.170

M = 1.50

C = 0.025

And for transitional sizes ($60 > D_{gr} > 1$)

$N = 1.0 - 0.56 \log_{10} D_{gr}$

$$A\frac{0.23}{(D_{gr})^{1/2}}+0.14$$

$$m=\frac{9.66}{D_{gr}}+1.34$$

$$\log C = 2.86 \log D_{gr} - (\log D_{gr})^2 - 3.53$$

Silt Transport

The finer silt fractions are convicted by the flow, but, if the conditions allow, some of the material settles out of suspension onto the ned. The rate of settling is dependent upon the fall velocity. The fall velocity is dependent upon the sediment diameter and varies with the concentration and also with the flow conditions.
If the shear – stress is above a given thereshold then it is assumed that the trubulence geerated is sufficient to maintain all the material in suspension but as the shear stress reduces the fall velocity tends towards the Stillwater value. Hydraulics Research experience has shown that deposition does not take place for shear velocities in excess of 0.01 m/s. Thus the following equation for single-particle fall velocity was uses.

$W = 0$ for $v_* > 0.01$ m/s

$$w_c\frac{(1-v_H)}{0.01}$$ for $v_H \leq 0.01$ m/s

Concentration also affects the fall velocity and it was assumed that w_c is given by,

$$w_c=\frac{w_o}{1+1.56c^{1/3}}$$

where

w_c is a fall velocity I a mixture of concentration C and w_o is a single particle, still-water

fall velocity.

If the shear stress exceeds a certain critical value then material is picked up from the bed. The rate at which it is removed from the bed into suspension depends upon the amount by which the shear stress exceeds the critical value. Thus the re-erosion, at high flows, of sediment previously deposited at low flows may be modeled.

The calculation of the silt concentrations requires cross-sections more closely spaced than for the flow calculations so extra cross-sections are interpolated between those used for the flow calculations. The calculated silt concentrations are then used to determine the transport rate of the silt fractions at each cross-section.

TABLE
Bed Load Correction Table

Suspended Load Concentration	Stream bed material	Texture of Suspended Material	% of Bed Load in Terms of Measured Suspended Load
Less than 1000	Sand	Similar to bed of stream	25 to 150
Less than 1000	Compacted clay, gravel cobbles, boulders	Small amount of sand	5 to 12
1000-7500	Sand	Similar to bed stream	10 to 35
1000-7500	Compacted clay, gravel cobbles, boulders	25% of sand of less	5 to 12
Greater than 7500	Sand	Similar to bed stream	2 to 8
Greater than 7500	Compacted clay, gravel cobbles, boulders	25% sand or less	5 to 15
Any concentration	Clay & silt unconsolidated	Silt & clay	Less than 2