ENVIRONMENT MANAGEMENT OF A RIVER IN MYANMAR

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
CONSERVATION OF RIVERS AND LAKES

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this "**ENVIRONMENT MANAGEMENT OF A RIVER IN MYANMAR** "in partial fulfillment of the requirement for the award of the degree of Master of Technology in **CONSERVATION OF RIVERS AND LAKES**, Submitted in the **Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee** is an authentic record of my work carried out during the period from July 2011 to June 2012 under the guidance and supervision of **Dr. Sunil Kumar Singal, Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee.**

I also declare that I have not submitted the matter in this dissertation for award of any other degree or diploma.

Date: June 11 , 2012
Place: Roorkee

(Kyaw Naing Oo)

CERTIFICATE

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

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ABSTRACT

The Chindwin river is one of the most useful and important rivers in Myanmar. Chindwin River is the largest tributary of the Ayeyarwady River. Chindwin River has a mountainous forested terrain with the only exception of its lowest Southern part which is a vast plain. The highest mountains are in the West and North of the basin where they reach 10,000 feet and more. From East the water-shed passes a mountain chain of 3000-5000 feet high. The source of the river, which in its upper reaches before entering the Hukawng valley, bears the name of TanaiHka, flows at the height of about 7000 feet, then within the distance of 80 miles it goes down to the height of 700 feet and enters the Hukawng valley. There, it receives several tributaries, gets the name of Chindwin and on the whole of its flow of 620 miles down to its confluence with the Ayeyarwady.In its upper reaches the Chindwin river has the gradient around 0.0003and in the down reaches it is around 0.00005.The river flows in a narrow valley crossing a number of vast plains and forms several defiles. Some of its tributaries include Uyu, Mu and Myittha Rivers. Some important urban centers on its banks include Hkamti, Htamanthi, Homalin, Mawlaik, Kalawa, Kalaymyo, Mingin and Monywa.

Chindwin River is being used as water transport for communication between the area of the basin and the central part of the country. The numbers of passengers transported annually are around 100,000 and cargo including timber – 200,000 tons. Economically, the Chindwin river basin is poorly developed, but if possess a variety of natural resources i.e. coal, copper, ore, oil, timber, gold, jade etc.

Considering importance of this river, an attempt has been made for detailed study on its environment management. The water and wastewater samples were collected and analyzed for evaluating the physical, chemical and biological parameters in the laboratory of Directorate of Water Resources and Improvement of River Systems department and Yangon Technology University. The data taken from the field as well as the data collected from Directorate of Water Resources and Improvement of River Systems department were used to compute the National Sanitation Foundation Water Quality Index (NSFWQI), which is mostly applicable

parameter in WHO and India. The result of the NSFWQI of Chindwin River indicates that its water quality is Medium-Good over the stretch considered. Thus Chindwin River water can be safely used not only domestic but also water supplied and agricultural lands in all year round.

The other problems found with from environment point of view are bank erosion and sediment deposition. The length of the Chindwin River is about 1100 km.Among them, 816 km length can only be utilized for water transport from Hkamti to Confluence. Water transport is the cheapest and greatest in Myanmar. Myanmar has three seasons namely summer, rainy and cold seasons. Therefore, all the rivers in Myanmar experience large variation in discharge. Normally, more discharge observed from Mid-May to Mid-November. The water level difference in Chindwin River is at least 10 m to 13m. The Chindwin Catchment area has observed less water volume and more sediment deposit year by year due to the Environmental Impact. The average sediment load in Chindwin River is 131 million tons per year. These sediments create sand bars and a lead to the change of river morphology and affect the water transport.

Based on data collected, measurements and analysis carried out in the environment management plan of the Chindwin Rive from Hkamti to confluence (816 km), it has been found that 37 sites have problems of bank erosion and sedimentation. Maintenance by means of rive training works in these 37 locations are proposed between Hkamti and confluence to improve the navigation channel of Chindwin river.

River training structures are proposed for improvement of navigable channel, stability inland water post, achieve adequate depths for maximum loading capacity of the vessels, prevention of river bank erosion. The details of these structures with cost estimates are presented in the study. It has been estimated that with a cost of Rs. 13.02 millions for a stretch of 125 km Chindwin river conservation plan can be executed.

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ABBREVIATIONS AND NOTATIONS

AHEC	Alternate Hydro Energy Centre
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
cuft	Cubic Feet
DMH	Department of Meteorology and Hydrology
DO	Dissolved Oxygen
DWIR	Directorate of Water Resources and improvement of River Systems
GOI	Government of India
IITR	Indian Institute of Technology Roorkee
km	kilometer
lpcd	Liters per capita per day
mg/l	milligram per liter
mlw	mean low water
MLD	Million Liter per Day
MSL	Mean Sea Level
NSFWQI	National Sanitation Foundation Water Quality Index
Rs	Rupees
sqft	Square Feet
sqm	Square meter
sqkm	Square kilometer
WD	Waterways Department
WHO	World Health Organization

CHAPTER – 1

RIVERS IN MYANMAR

1.1 LOCATION AND AREA

The Union of Myanmar, a tropical country in Continental South East Asia, is geographically situated between latitudes 09° 32' to 28° 31' North and longitudes 92° 10' to 101° 11' East (See fig 1.1). Myanmar is bordered on the North and Northeast by the People's Republic of China, on the East and Southeast by the Lao People's Democratic Republic and the Kingdom of Thailand, on the South by the Andaman Sea and the Bay of Bengal and on the West by the People's Republic of Bangladesh and the Republic of India. Myanmar is administratively divided into seven states and seven divisions (See fig 1.2).

The country has a total land area of 676,577 km^2 stretching for 936 km from East to West at the maximum width and 2,051 km from North to South. The length of contiguous frontier is 6,129 km and coastline from the mouth of the Naaf River to Kawthaung is approximately 2,229 km.

Fig 1.1 Location Map of Myanmar

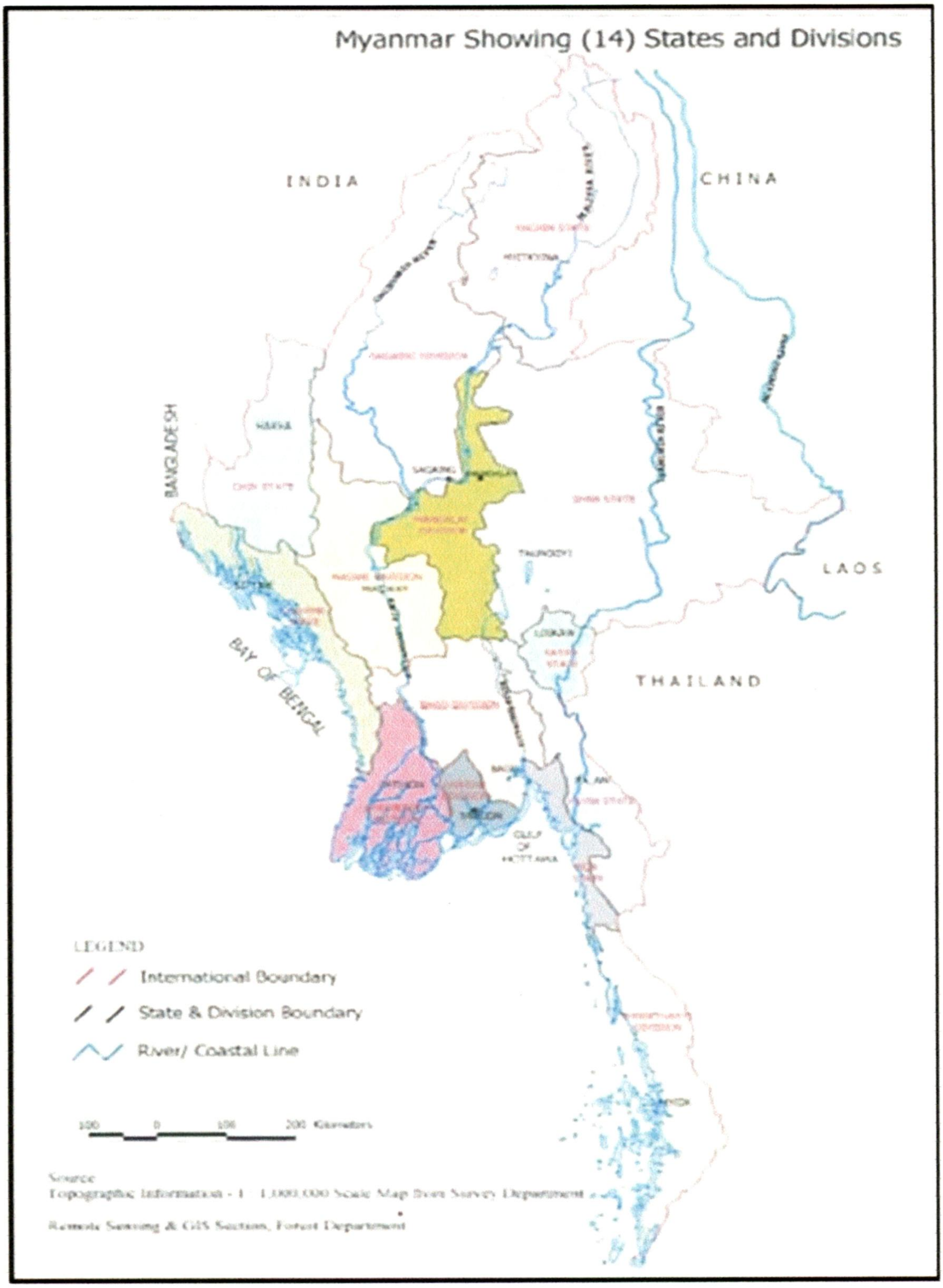


Fig 1.2 States and Divisions Map of Myanmar

1.2. POPULATION

The total population of Myanmar in 2012 was 60.0 million, of which around 67 percent lived in rural areas. With a population density of 70 inhabitants/km^2, Myanmar is well below the density level of other countries in South and Southeast Asia. The annual population growth rate during the period 1999-2009 was around 0.7 percent.

Access to improved drinking water sources in 2008 was 71 percent (75 and 69 percent for the urban and rural population respectively). Access to improved sanitation reached 81 percent (86 and 79 percent for the urban and rural population respectively).

1.3. TOPOGRAPHY

The topography of Myanmar is generally low lying in the coastal and deltaic regions, rising to about 6,000 meters in the rugged North of the country. Topographically, the country can be roughly divided into three main parts, namely the Western hills region, the Central valley region, and the Eastern hilly region.

In the Western hilly region, the Western mountain ranges (Yomas), which serve as a wall that separates Myanmar from India, has a link with the Himalayan range in the North. The KhakaboRazi with the highest peak of about 5,881 m and Sarameti which is 3,826 m high are situated in the Northern most part of the Western mountain ranges. In the Western portion, the Rakhine mountain ranges and Chin hills have undulating hills with altitudes over 914 m above mean sea level.

The Central valley region consists of the broadest part of the Ayeyawady, Sittaung and Chindwin valleys. In this region lies the low range of the BagoYomas with elevation of about 300 m and some small mountain ranges such as Zeebyu, Min-wun, Hman-kin and Gangaw. The central core of the country, which falls within the rain shadow area, is relatively flat, constituting the Central Dry Zone.

The Eastern hills' region is the Shan Plateau having an average elevation of about 914 m to 1,219 m above sea-level. Unlike the plain, the plateau has high mountain ranges and the Thanlwin River flows through the Shan Plateau to the northern Taninthayi coastal strip. Some other rivers, namely Shweli, Myitnge, Zawgyi and Pan-laung have also their sources at the Shan Plateau and flow into the Ayeyawady River.

1.4. GEOLOGY AND SOILS

1.4.1. Geology

Geomorphologically as well as tectonically, Myanmar can be sub-divided into four provinces which are North-South tending linear belts. These are, from East to West:

Geomorphic Provinces	Tectonic Provinces
1. Eastern Highland	1. Shan-Tanintharyi Block
2. Central Lowland	2. Central Cenozioc Block
3. Western Ranges	3. Western Fold Belt
4. Rakhine Coastal Plain	4. Rakhine Coastal Belt

As the geomorphic features are mere reflections of the underlying rock types and structures, the geomorphic provinces and tectonic provinces generally coincide to each other respectively. The four provinces differ from one another not only in physiography, but also in lithology, geological structures and geological ages.

1.4.1.1 Tectonic provinces

(i) Shan-Taninthayi Block-consolidates the Shan Plateau, eastern Kachin ranges and Taninthayi ranges. The presence of Precambrian orthogneisses and low grade metasedimentary rocks (ChaungMagyi Group), Paleozoic and Mesozoic carbonates, clastics, and igneous rocks enable this province to remain as a highland, locally with Karst topography in the limestone areas.

(ii) Central Cenozoic Belt – is relatively low-lying Central Belt drained by the Ayeyawady, Chindwin and Sittaung rivers. Locally, hills ridges and small mountain ranges are present, especially in the northern part. As the name implies, it is mainly constituted with Cenozoic sedimentary rocks consisting of sandstones, shales and clays. Mesozoic clastics and Cretaceous limestones occur only in the northern part. The Central Volcanic line (CVL) has divided this province into two parts since about Miocene Epoch.

(iii) Western Fold Belt – covers the RakhineYomas, Chin Hills and Naga Hills. It consists of a thick Mesozoic and Eocene flysch sequence, locally with bedded chert (radiolarite) and green-stone. The Western Range which is also known as Indo-Burrnan range arose as the result of folding, overthrusting and uplifting during the Early Himalayan orogeny at the close of Ecoeen.

(iv) Rakhine Coastal Belt – occupies Rakhine coastal plain. It is the southern continuation of the Assam Basin in the north eastern India where a thick Tertiary succession is also present. The Minbu and Assam basins are fairly similar not only in stratigraphy and lithology but also in the occurrence of oil and gas, especially in the Oligocene and Miocene formations.

1.4.2. Soils

A number of academicians from agriculture, forestry, geology and geography have reported the soils observed in various parts of the country in their own ways. In 1965, Myanmar soil scientists from Land Use Bureau conducted soil surveys in cooperation with Russian soil scientists and prepared the first Schematic Soil Map of Myanmar showing 24 major soil types, based on the system of soil classification used by the International Soil Science Society and FAO/UNESCO. About 106 major soil types are recognized worldwide.

1.4.2.1 Classification of soils

Soils can be classified into zonal soils, intrazonal soils and azonal soils.

(i) Zonal soils – are classified generally based on climate and grouped into four zones, namely Tropical Wet Zone, Tropical Dry Zone, Subtropical Zone and Temperate High Mountain Zone.

Soils of Tropical Wet Zone include red-brown forest soils, yellow-brown forest soils and lateritic soils and laterites.

Soils of Tropical Dry Zone include cinnamon soils, red-brown savanna soils, dark compact savanna soils, Solonetz (alkaline) soils, Solonchak (Saline) soils and primitive gravelly soils of savanna.

Soils of Subtropical Zone include red earths and yellow earths. Soils of Temperate high mountain zone include brown mountain-forest soils, mountain-meadow Alpine soils and mountain sod soils.

(ii) Intrazonal soils – grouped the complex of the meadow, swampy and alluvial soils of river valleys and lowlands. This group includes alluvial soils, swampy soils and various meadow soils (alluvial, gley, alkaline, saline, swampy and swampy carbonate soils).

(iii) Azonal soils – are youthful due to hardness of parent material, rapid rate of erosion or deposition and insufficient length of time. Such soils are saline mud, silt, alluvium, gravelly soils, turfy primitive soils and turfy carbonate soils.

1.4.2.2 Distribution of soils

Red-brown forest soils developed under tropical evergreen forests and wet tropical monsoon forests mostly at altitudes between 300 m and 1,300 m above sea level. These soils have the average humus content of 2% and the pHvalue is between 5.5 and 6.5. Such soils are generally found in the area between East-West trending the Ayeyawady River and northeast southwest trending the Shweli River.

Red-brown forest soils, together with mountain red brown forest soils, primitive crushed stone soils are found in Taninthayi, Southern Mon-Kayin, RakhineYoma and south-western Chin areas.

Yellow-brown forest soils are widespread under wet tropical monsoon forests at altitudes between 100 and 450 m above sea-level. The humus content is on average between 2 and 4%. The pH value is between 4.5 and 6.5 and the water holding capacity is 30-35%. Such soils occur in hilly areas between the Chindwin and Ayeyawady Rivers, in lower hills of the BagoYomas, RakhineYomas and TaninthayiYomas. At higher altitudes, these soils are replaced by Yellow-brown mountain forest soils. They are suitable for forest plantation. Lateritic soils and laterites are found at altitude below 100m above sea-level. The humus content is 1.5 to 3% and pH value is between 4 and 5. These soils occur in Taninthayi, Mon, Kayin, Southern Bago mountain ranges and southern Rakhine mountain ranges areas. Such soils are suitable for rubber plantation, fruit trees and horticulture.

Light Cinnamon soils occur along the belt surrounding the Dry Zone and dark Cinnamon soils develop- at relatively wet sites. Humus content varies between 1% in light cinnamon to 3-5% in dark cinnamon. The pH value is between 5.5 and 6.5. These soils are suitable for agriculture when properly irrigated.

Red-brown savanna soils are typical soils of the Dry Zone and cover the central part of Myanmar. The humus contents are below 2% and nitrogen and available phosphorus contents are also low. The pH varies from 6.5 to 8 and it may reach 9 in extreme cases. These soils are suitable for dry farming but soil erosion is the main problem.

Dark compact savanna soils are mostly found in flat, even terrain and alluvial in the dry zone of central Myanmar. The pH value is ranging from 6 to 8.5 and humus content is only about 1%. Saline and alkaline should be checked and remedied. Suitable irrigation is essential for successful utilization of the land.

Gravelly soils of savanna are also found in the Dry Zone of central Myanmar. They consist of stone fragments with small residues of humus and such soils are not suited for agriculture. Only indigenous species such as Than, Dahat, Thanakha, etc. should be planted.

Red earths occur at altitudes around 1000 m. above sea-level and mountain red earths are found at relatively higher altitudes. These soils cover the area from eastern Mandalay division, eastern Kayin, Kayah to, large parts of Shan Plateau. The humus content is between 2 and 4% in the light red earths and may be up to 8% in dark red earths. The pH value is between 6 and 7. Such soils are suitable for diversified agriculture.

Yellow earths soils occur on level surfaces or slopes at lower altitudes on the Shan limestone plateau. They are less suited for agriculture when compared to red earths. Mountain Sod soils are found in Mount Popa area and best suited for forestry purposes. Meadow soils are the best soils for paddy cultivation in Myanmar.

1.5 CLIMATE

Most of Myanmar belongs to the tropical region. It is characterized by a tropical monsoon climate with three well-defined seasons: summer, rainy season and cool season. Summer months are from March to Mid-May; the rain falls from Mid-May to the end of October and the cool season starts in November up to the end of February. Due to widely differing topographical situations of the country, its climate conditions also differ widely from one place to another.

1.5.1 Annual Rainfall

Annual rainfall and intra-annual distribution of rainfall in costal and deltaic regions is generally as high as 5,000 mm whereas it is only about 600 mm in the Dry Zone. Fig 1.3 shows mean annual rainfall in Myanmar.

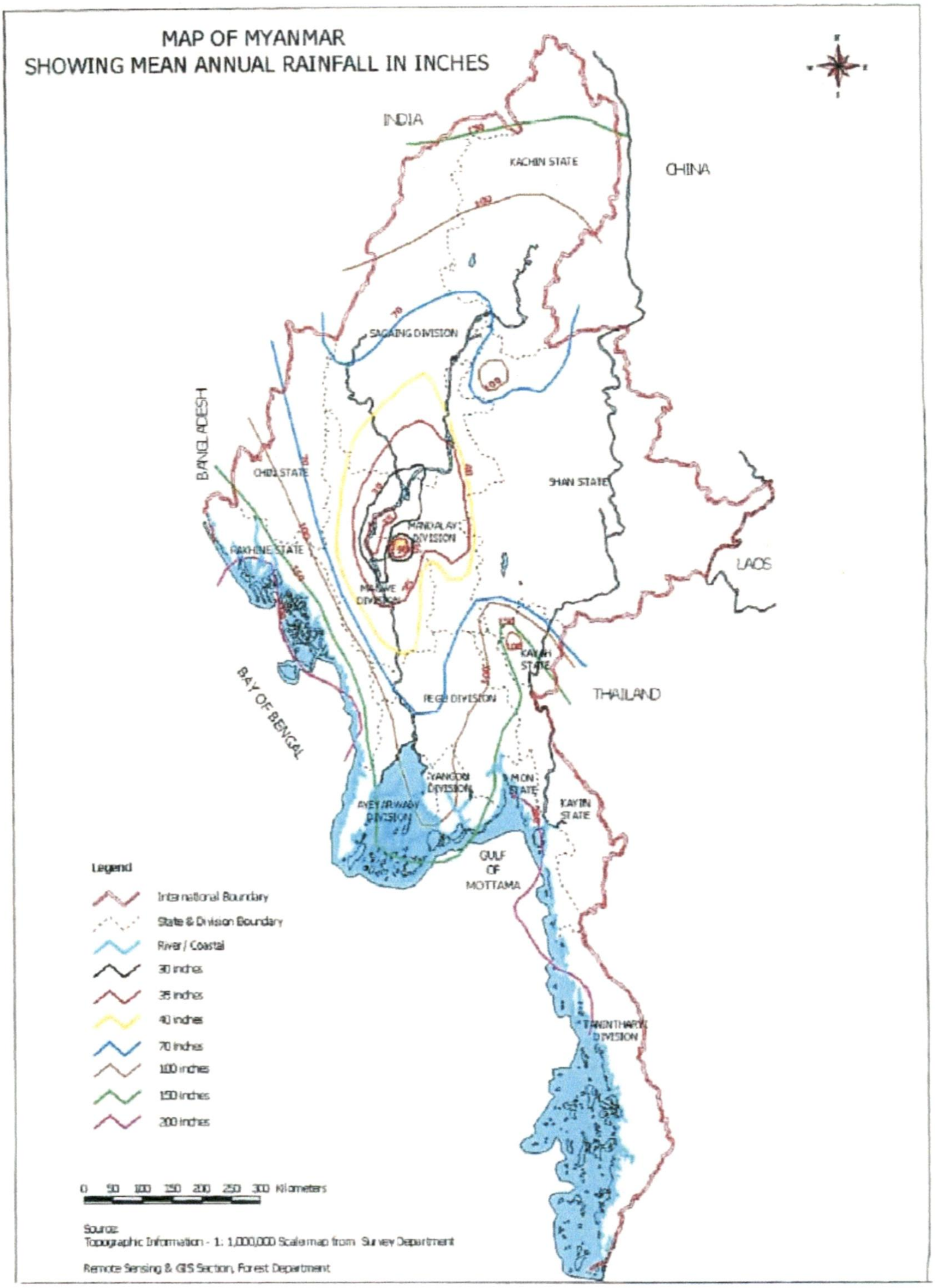


Fig 1.3 Mean Annual Rainfall Map of Myanmar

The average annual rainfall of some meteorological stations during the last two decades is shown in Table 1.1.

Table 1.1: Annual Rainfall at Selected Stations

Station	State Division	Annual Rainfall	
		in mm	in inches
(a) Coastal and deltaic region			
- Thantwe	Rakhine State	5500	217
- Dawei	Taninthayi Division	5300	209
- Mawlamyine	Mon State	4800	189
- Hpa-an	Kayin State	4000	157
- Bago	Bago Division	3100	122
- Pathein	Ayeyawady Division	2700	106
- Yangon	Yangon Division	2700	106
(b) Hilly and mountainous areas			
- Myitkyina	Kachin State	2300	91
- Hakha	Chin State	1800	71
- Taunggyi	Shan State	1600	63
- Loikaw	Kayah State	1000	39
(c) Dry Zone Area			
- Magway	Magway Division	800	31
- Monywa	Sagaing Division	700	28
- Nyaung-Oo	Mandalay Division	600	24

Source: Statistical Yearbook 2009, Central Statistical Organization

1.5.2 Temperature and Humidity

Temperature also varies from one place to another depending on location and elevation. During the summer months, March and April, the average highest temperature in Central Myanmar is generally above 43° C while it is about 36° C in Northern Myanmar and 29° C on Shan Plateau. Average temperature and humidity monitored at the stations in the states and divisions are given in Table 1.2.

According to the recorded data of the temperature during the last two decades, the average temperature varies from 21° C to 34° C in summer and from 11° C to 23° C in the cool season. The mean relative humidity ranges between 58 and 79%.

Table 1.2: Average Temperature and Humidity

Station	State Division	Temperature (Deg.C)		Mean Relativ[e] Humidity (%[)]
		Mean Max.	Mean Min.	
Myitkyina	Kachin State	29	19	77
Loikaw	Kayah State	29	16	71
Hpa-an	Kayin State	33	23	77
Hakha	Chin State	21	11	74
Monywa	Sagaing Division	34	22	68
Dawei	Taninthayi Division	32	22	79
Bago	Bago Division	33	22	77
Magway	Magway Division	34	20	66
Naung-Oo	Mandalay Division	34	22	58
Mawlamyine	Mon State	32	22	75
Thantwe	Rakhine State	32	20	78
Yangon	Yangon Division	33	22	75
Taunggyi	Shan State	25	14	69
Pathein	Ayeyawady Division	32	23	78

Source: Statistical Yearbook 2009, Central Statistical Organization

1.6. BIODIVERSITY

In Myanmar, conservation of biological resources primarily wildlife, wild plants and pristine forests has traditionally been prioritized at the national level. Diverse forest ecosystems in Myanmar are homing nearly 300 mammal species, 360 reptiles and 1,000 bird species. There are also more than 1,200 species of butterfly of which six are identified as rare species even at the global level. Myanmar is also known to have about 7,000 plant species, of which 1,071 are endemic. Recorded number of vegetative species in the natural forests of Myanmar has reached 1,347 species of big trees, 741 species of small trees, 96 species of bamboos, 1,696 species of shrubs, 36 species of rattans and 841 species of orchids.

1.7 WATER RESOURCES IN MYANMAR

Myanmar is a country endowed with abundant water resources. The catchment area of Myanmar's ten principal river basins comprises about 737800 km^2. Potential water resources volume is about 1082 km^3 for surface water and 495 cubic km for groundwater. As well constitute national water resources annually. As an agro-base country of Myanmar, water utilization for agricultural sector stands for 90% while industry and domestic use is only about 10% of the total water use. The total utilization of the nation's water resources is only about 5 percent of the potential. It is clear that the physical potential for further development of water resources in Myanmar is quite substantial. However with the increase of population and enhanced need for water for economic activities there is increasing pressure on use of surface water and extraction of groundwater. Control and management of surface water and groundwater is therefore important for sustainable development of the country in future.

Table 1.3: Potential Water Resources in Myanmar

S. No.	River basin	Catchment Area (km^2)	Inflow (km^3)
1	Chindwin	115300	141.22
2	Ayeyarwady (Upper)	193300	227.80
3	Ayeyarwady(lower)	95600	85.75
4	Sittoung	34400	41.93
5	Rivers in Rakhaing State	58300	139.17
6	River in Thanintharyi Division	40600	130.86
7	Thanlwin (in Myanmar)	158000	257.79
8	Mekong (in Myanmar)	28600	17.62
9	Belin River and other rivulets	8400	31.15
10	Bago River	5300	8.01
Total		**737800**	**1081.3**

Table 1.4: Potential Groundwater in Myanmar

S. No.	River basin	Catchment Area (km^2)	Inflow(km^3)
1	Chindwin	115300	57.58
2	Ayeyarwady (Upper)	193300	92.60
3	Ayeyarwady(lower)	95600	153.25
4	Sittoung	48100	28.40
5	Rivers in Rakhaing State	58300	41.77
6	River in Thanintharyi Division	40600	39.28
7	Thanlwin (in Myanmar)	158000	74.78
8	Mekong (in Myanmar)	28600	7.05
Total		**737800**	**494.71**

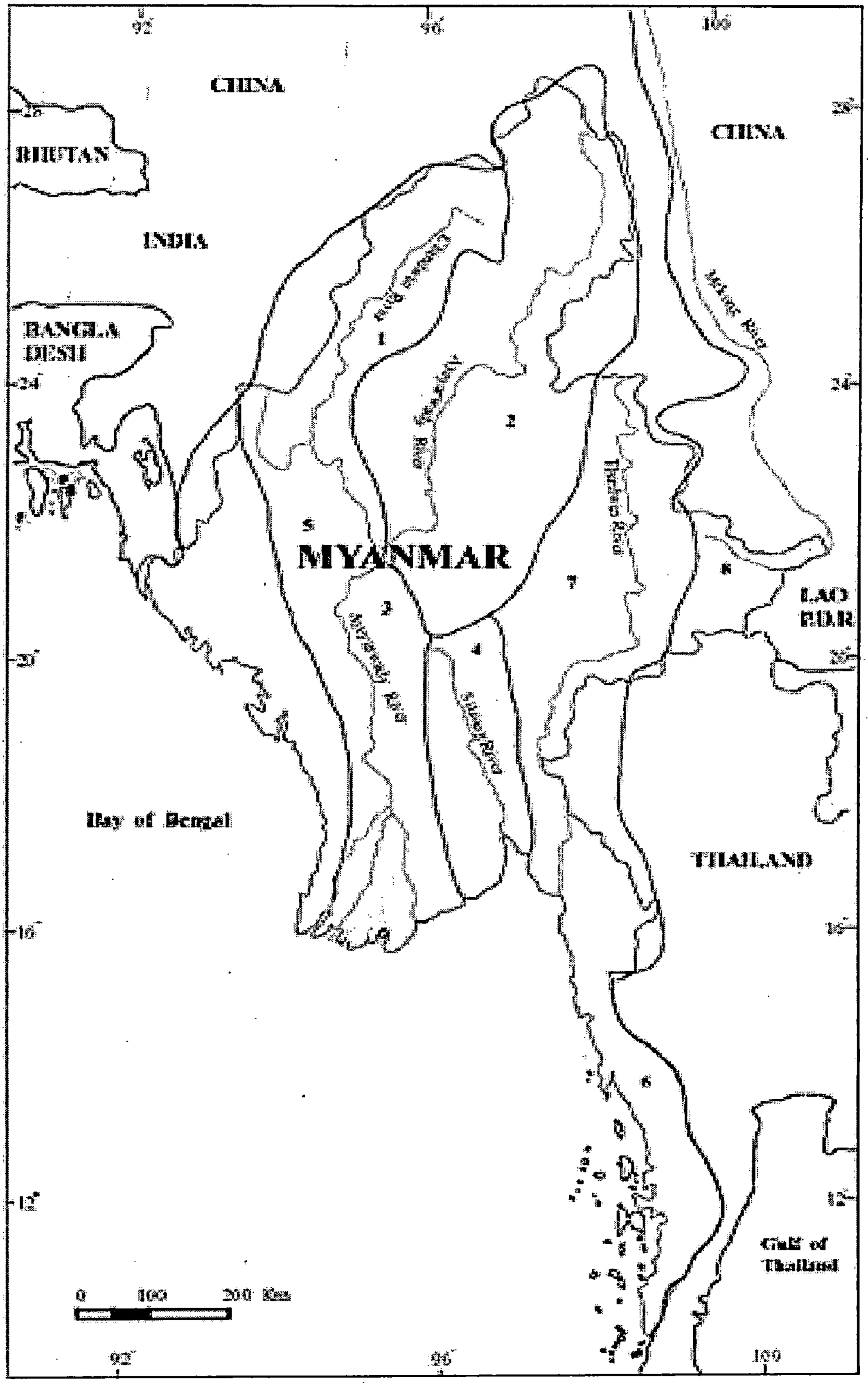


Fig 1.4 Map of Myanmar River Basin

1.8 RIVER SYSTEMS IN MYANMAR

Myanmar is well endowed with natural river resources; of which Ayeyarwady, Chindwin, Sittaung, ThanLwin, Kaladan, Leimyo, Mayu, Attaram, Gyaing are the major rivers and numerous small rivers. In the lower region of Myanmar the delta is crossed with many rivers and creeks.

The North South direction of the mountain ranges of Myanmar is reflected in course of river valleys running from North to South divided each other by mountain ranges and the plateau.

1.8.1 Ayeyarwady River System

Ayeyarwady river system includes the Ayeyarwady river, the Chindwin river, their tributaries and connecting canals draining nearly 415000 square kilometers, covering 55 percent of the area of Myanmar. Ayeyarwady river and Chindwin river are the principal arteries of inland navigation in Myanmar. This river system traverses Myanmar most fertile lands and forms the main highways of commerce.

1.8.1.1 Ayeyarwady river

Ayeyarwady river, Myanmar lifeline is the most important river and has always been the backbone of the country. The Ayeyarwady which means Elephant River, is listed a twelfth greatest river of the world in term of annual flow. It is also remarkable that the river may be classed among the fastest eroding large river of the world.

The source of Ayeyarwady lies in the hill country North of Myitkyina. The Ayeyarwady is formed by the junction of two streams, the NamiHka and the Mali Hka. The Eastern stream, the NamiHka, lays claim to being the main branch, through the Western, the Mali Hka, Join about 45 kilometer above Myitkyina. The NamiHka rises in the Languela glacier in about latitude 29^0North, on the mountain range which separates Putao from Tibet. Then the Ayeyarwady river runs through the central part of country and flows into Bay of Bengal after forming a huge delta. Ayeyarwady river is some 2000 kilometer long and is for about 75 percent (1534 kilometer) navigable. A straight line distance is over 1230 kilometer.

The course of river can be divided into three sections : the upper Ayeyarwady, the lower Ayeyarwady and the delta : in descending order of ages. Three important defiles are located in the section of upper Ayeyarwady while the remaining two defiles are in the lower Ayeyarwady section. The Shan plateau region is built of Archaean, Palaeozoic and Mesozoic rocks and is distinctly marked off from the Central Tertiary region on the West; there is often a drop more than 600 meter from the edge of the plateau to the neighboring alluvial plain of the Ayeyarwady river. The geological features of lower Ayeyarwady section and the delta were formed during the Quaternary, Tertiary and Cretaceous Periods. The area is tropical with heavy rainfall; consequently the rock formation in mountains and hills are completely weathered and severely eroded. The plains basically have old alluvial deposits and new alluvium is found only at the river side.

The rainfall of river system regime depends largely one geographic orientation. Annual rainfall distributions due to the geographic orientation are state below:

Geographic Orientation	**Annual Rainfall (Millimeter)**
Upper Ayeyarwady	4064 – 762
Lower Ayeyarwady	2032 – 762
Delta	3048 - 2032

It is determined by use of the Thiessen Net Work, average annual rainfall of Ayeyarwady river system are obtained 1740 millimeter up to Pyay and 1792 millimeter up to Yangon. The rainy season starts from the middle of May to the middle of October, and most of the annual rainfall is concentrated in this season. Upper Ayeyarwady section belongs to the main reception basin as it comprises 75 percent of total catchment area and 84 percent of river water resources. On the other hand, annual evaporation amount of the Ayeyarwady river is roughly estimated as 18.2 million cubic meters or 4,000 million gallons.

The current velocity varies not only with the season but also with the locality. Except for two defiles : First &Second : in the upper river section, current velocities impose no constraint to navigation. In general the current velocities between Yangon and Bhamo can be taken as:

	Average	**Maximum**
Low Water Seasons	0.89 meter/second	1.78 meter/second
High Water Season	1.78 meter/second	2.70 meter/second

Maximum current velocities range from 3.5 meter per second to 4.5 meter per second. These high velocities are very local and occur only during a limited period. High flow velocities occur in the Twante Canal during ebb; are slightly less than 3.5 meter per second.

The most distinctive feature of Ayeyarwady river is remarkable difference of water surface level between in wet season and in dry season. The maximum difference between high and low water level is in the range of 7.0 meters to 13.5 meters depending on circumstances. It shows the large fluctuation in water surface elevation. As a result, large seasonal variations in water discharge are characteristics of the river system. Ratio of daily maximum discharge to daily minimum discharge is also high. River system begins to rise following the onset of the monsoon in May or June and attain maximum flow in August or September. In October or November, river system falls rapidly until December.

Afterward recedes slowly during the dry period of the year, to reach its lowest level in late April or early May, just before the onset of monsoon. Ayeyarwady river possesses a relatively large base flow. It is notable that melting snow of northern hill ranges usually produces short during fluctuations in March/April.

Large amount of sediment load and concentration of the Ayeyarwady River are important factors that affect river morphology and river environment. Suspended sediment samples are taken by the Department of Meteorology and Hydrology at some major riverine stations along the river system and develops the relationships between daily mean water discharges and daily mean sediment discharges. Examination of relationships shows that, like water discharge, the suspended sediment discharge varies greatly throughout the year. Gordon's estimate (1868) of suspended sediment transport at Pyay is 236 million tons or 150 million cubicmetrs. HASKONING'S estimate (1987) of suspended sediment transport at Pyay is 278 million tons or 175 million cubicmeters. Since records on bed material transport are not available, it is estimated on the basis of hydraulic and sediment transport computation. Haskoning consultants selected 1973 as a typical year and bed material transport estimate was prepared for Pyay Station. In the lower Ayeyarwady section, so called perennial streams are located. Flows are short-lived and are present in the streams only duration period of intense rainfall. These perennial streams discharge quite a large amount of sediment into main river, the Ayeyarwady. Annual sediment inflow discharge by perennial streams is roughly estimated as 120 million tons or 75 million cubicmeters. As a result from short duration surveys indicates that high sediment load in Yaw Chaung than in the Ayeyarwady river below the confluence with Yaw Chaung. Haskoning consultants remark on perennial streams that sediment inflow itself does not belong to morphologic phenomenon of the river. It is the difference in sediment inflow and sediment discharge capacity of the river, so that the extent of disturbances by perennial streams is very difficult to qualify.

1.8.1.2 Ayeyarwady delta

It is considered that some 300000 years ago, the mouth of Ayeyarwady river was still situated near Pyay. The maximum rate of advance of the deltaic formation is estimated at 5 kilometer to 6 kilometer in 100 years which is equivalent to some 10 square kilometer annually. The whole delta is bordered by mangroves and mud flats in the South where the building of the delta continues at a fast rate. An important factor in the delta building process is the action of waves generated by the South – West monsoon. The sediments are moving to the East where the strong ebb currents of the Yangon river and farther away, that of the Sittoung river carry the sediments farther offshore. In this way the comparatively low rate of growth of the delta front configuration can be explained. At present delta coast line is 438 kilometer long.

Near Hinthada, Ayeyarwady river enters its delta, which forms an irregular triangle, having its apex about 225 kilometer from the sea, and with a curved base facing the sea. The sides of the triangle are formed by RakhineYoma on the West and BagoYoma on the East; the greatest width is about 240 kilometer at the arched base of the triangle. At about latitude of the Hinthada, the BagoYoma and the RakhineYoma approach comparatively close to one another, being only 130 kilometer apart; Southwards they diverge again, leaving the broad stretch of the delta through which the waters of the Ayeyarwady find their ways to the sea through countless channels.

Ayeyarwady delta which is one of the rice granaries of Myanmar and offers the typical example of humid tropical zone delta in an early stage of hydraulic and agricultural development. It lies from North Latitude 15^0 40' to $17^0$5' and from East Longitude $94^0$20' to $96^0$01'; covering an area of about 35000 square kilometer. Ayeyarwady delta stretches from its apex near Hinthada, being subtended on 80 degree arc between the Yangon river (Hlaing river) and Pathein river or Ngawun river. This region is widely interspersed with numerous creeks, most of which are navigable all the year round. Total navigable waterways in the Ayeyarwady delta alone are about 2400 kilometer. Delta area is entirely different from the main river Ayeyarwady as regards to river transportation. It is obviously low land and flat terrain and inundation can happen in many areas in the rainy season; that results the formation of swampy lands.

As mentioned earlier, the area downstream from Kyangin is a vast delta formed by the Ayeyarwady, whose course there has not yet been stabilized. Here the Ayeyarwady river empties itself into the Andaman sea through nine large distributaries: from West to East : Pathein, Thetkethaung, Ywe, Pyamalaw, Ayeyarwady, Bogale, Pyapon, Toe and Yangon rivers. The deltaic area slopes gently from the apex to seaward with an average slope of about 5×10^{-5}. Average elevation of the plain area is 12 meter and ground elevation at Hinthada is about 11.5 meter above mean seas level. When the water level in the Ayeyarwady river, Myitmake river and Pathein river rises, inundation occurs in those basins of the area whose elevation is more than half of the plain area with elevation below 15 meter. The inundation lasts three months : from June to August every year : and the water reaches about 0.5 meter deep and 3.0 meter at its deepest. In the coastal zone about 5200 square kilometer are below high spring tide level and are subject to flooding with more or less salin water. This is likely to occur in September/October when the river floods recede South – Westerly winds cause some piling up of the sea above the level of the high spring tides.

Well known and useful estuaries are located in this region. Most waterways are natural water courses. The exception is the Twante canal, which shortening the **connexion** between Yangon and Western part of the delta. The rivers and creeks of the delta remain convenient means of transport for a large volume of rice and consumer goods and passenger travel. Major limiting factor in navigation is insufficient depth. Other factors that impair navigation are arising from limited bend radia/narrow width of natural low water channel and occasionally high velocities and swift currents. Apart from these constraints; one obstacle to navigation: especially in the deltaic rivers: is due to the densely and quickly growth of water – hyacinth (Bayda). As an example, waterways along the Daga river is usually blocked up to the Bayda plants.

The tide in Myanmar is diurnal. The tidal variation shows a distinct pattern of spring and neap tides. Tidal predictions made by Myanma Navy indicate that the flood tide is about 5 hours in duration while the ebb is about 7 hours long. The delta of Ayeyarwady river is a complex area and subject to both tide and fresh water discharges. The increasing fresh water discharge has an effect in delta although not as strongly marked as in upper reach of the Ayeyarwady river. It is cleared that the water level of deltaic rivers varies by the influence of tide changes. Further inland tides are smaller.

The Ayeyarwady and the Pathein are tidal rivers up to Hinthada, and the Myitmaka river is tidal up to around Tharrawaddy. The difference between high and low water level is about 2.0 meter at Pathein, 110 kilometer from sea. At Yangon, 32 kilometer from sea, the difference is about 5.6 meter. At low tide, river side stretches turn into muddy field. The tidal ranges of the Ayeyarwady delta are the highest of all deltaic areas in the humid tropical zone.

The tidal currents in the estuaries and between the shoals in the coastal waters can be quite strong. In the entrance of the Pathein estuary velocities of 0.75 meter per second to 1.5 meter per second occur whereas the combined effect of ebb current and river flood discharge may increase velocities up to 3.0 meter per second. The tidal range in Yangon port area is about 5.8 meter and 2.5 meter at spring and neap tide respectively; spring tides are accompanied by current of upto 3.0 meter per second. Inundation of the Myitmaka river has been caused not only floodings from its own catchment area but also by over flooding from the Ayeyarwady river.

The drainage area of Myitmaka – Hlaing – Yangon river system is estimated to be around 7000 square kilometer. Mean discharge in monsoon is about 6000 cubicmeter per second and peak upland discharge of 9000 cubicmeter per second for the Yangon river at Kemmendine some 35 kilometer from sea. Based on the size and character of the drainage area, the annual sediment transport has been estimated at 37 million tons for Yangon river.

1.8.1.3 Chindwin River

The great tributary of the Irrawaddy, the Chindwin, is about 1,158 km (750 miles) long, and drains the western region. The Chindwin River is the largest tributary of the Irrawaddy River. It flows entirely within Burma and is known as "Ning-thi" to the Manipuris. The Chindwin rises in the Kumon Range in northern Burma, and flows northwest through the Hukawang Valley, then south along the Indian border and then southeast to the Irrawaddy River at Myingyan.

The Chindwin is navigable for some 500 miles (816km) from its confluence with the Irrawaddy below Mandalay to the confluence with the Uyu River, its chief tributary. The Chindwin is served by regular river-going vessels up to the town of Homalin. Much of Chindwin's course lies in the within mountain ranges and forests.

Due to the difficulty of access, much of the un-navigable river area remains unspoiled. The government of Myanmar recently created a very large (2,500 square mile) sanctuary for the endangered tiger within the Hukawng Valley. Teak forests within the drainage area have been a valuable resource since ancient times. The Hukawng Valley is known for its abundance of Burmese amber. Along the river, there are also deposits of jade, but the best jade is found in the region around the headwaters of the Uyu river.

1.8.1.4 Tributaries of Chindwin River

The **Uyu River** is a river in Northern Myanmar. It is a major tributary of the River. Its source lies in the Hukawng Valley of Kachin State, and it takes a Southwesterly course through a fertile and well irrigated valley. It enters the Chindwin on the left bank at Homalin in Sagaing Division.

Mu River is a river in upper central Myanmar and a tributary of the country's chief river the **Ayeyarwady.** It drains the Kabaw valley and part of the Dry Zone between the Ayeyarwady to the East and its largest tributary Chindwin River to the West, flows directly North to South for about 275 km (171 mi) and enters the Ayeyarwady West of Sagaing near Myinmu.

Its catchment area above the Kaboweir is 12,355 Sqkm (4,826 sqmiles). River flow and rainfall are both seasonal and erratic, at its lowest from January to April, rising sharply during May and June, and high from August to October. Because the Mu lies within the Dry Zone in the rainshadow of RakhineYoma, it receives scanty summer monsoon rainfall with a total flow of 350 mm.

Myittha River is a river of Western Myanmar. It originates in the Chin Hills and flows into the Chindwin River just below the town of Kalawa.

1.8.2 Thanlwin River System

The Thanlwin, known as Salween until 1989, is one of the major rivers in Southeast Asia. It originates in the tangular range of the Tibettan plateau, drains the total basin area of about 320000 square kilometer. The Thanlwin river flows along the stretch of 2410 kilometer before it drains into the Gulf of Martaban or Moattama near Mawlamyine. Within the upper stretch of the river in Yannan Province of China, the river flows into the deep gorges with rugged and steep mountains. The width of the river basin is just about 20 kilometer at some places in Yannan Province. Starting from the Myanmar and China border, the Thanlwin river runs through Shan state and Kayah state, along the Myanmar – Thai border and then Kayin state before flowing into the Andaman sea. The Thaungyin or Nam Moei river, a tributary, runs towards Northwest and enters the Thanlwin river. The Thaungyin river flows on the Myanmar and Thailand border from its origin to the confluence point with the Thanlwin river. Apart from the Thaungyin river, several major tributaries join into the main river Thanlwin within the Myanma territory. The downstream about 110 of the Thanlwin river is located in an alluvial plain where meanderings and alternated channel exits.

Thanlwin river basin is shared by three countries of the total drainage area, 56 percent in China, 39 percent in Myanmar and only 5 percent in Thailand of the entire length of 2410 kilometer, the upper most portion of 1370 kilometer to the Myanmar and China border flows through the Yunnan Province of China. The midstream portion is entirely in Myanmar. Only a small portion along lower reaches is in Thailand. The main stream of Thanlwin river constitutes the Myanmar and Thai border for a stretch of 120 kilometer. The lower most portion is again entirely within Myanma territory. The average width of the basin is calculated at 133 kilometer to make the length-width ratio of 18.3. Only a few major river in the world has length-width ratio as high as this.

The annual precipitation of the Thanlwin river basin ranges widely from around 1200 millimeter in the midstream area up to over 2000 millimeter in the upstream and downstream areas. The long and narrow catchment tends to make flood peaks higher and travel time of flood water from the upstream longer. Overall runoff ratio is low partly due to the existence of rainfall distribution within the year. Another factor for the low runoff ratio may be relatively undisturbed upper catchment area.

Reflecting this, assumption of low sediment yields, typically at 0.22 millimeter per year or 286 ton per square kilometer at 1.30 ton per cubicmeter. Maximum difference between high water surface level and low water surface level at Hpa-an is about 8.40 meter. The average annual discharge at the Ban Mae Puaguuging station in Thailand with the catchment area of 295270 square kilometer is 3880 cubicmeter per second and specific discharge is 0.013 cubicmeter per second per kilometer. At Hpa-an, with the same catchment area to the Ban Mae Pua gauging station, the maximum daily mean discharge in high water season is about 17700 cubicmeter per second.

For hundreds of kilometers from its source, the Thanlwin river channel has been swift, narrow and turbulent. As a result, except in its lower courses approaching its mouth, the Thanlwin river is unfit for general navigation, but is used for floating down the logs and plying of country boats in some considerable reaches. Throughout the most of its length in Myanmar, numerous large tributaries enter by steep channels or sizable cascades. Consequently, the energy potentials of the tributaries are very large.

Within Myanmar, the Thanlwin river is navigable from Shwegyun to Mawlamyine, a distance of 67 kilometer. The Donthami river, the Gyaing river and the Attaran river: the principal navigable tributaries enter the Thanlwin river between Shwegyun and Mawlamyine, and thus becomes a part of Thanlwin traffic pattern.

The Donthami river enters the Thanlwin river from the West 24 kilometer above Mawlamyine. This tributary follows a very tortuous route and is tidal up to some 128 kilometer above its mouth. Barges and 33 meter launches can reach Dayinzeik of 51 kilometer and very high tide can get to I-He of 96 kilometer. From I - He small launches can go upstream as far as Thlaingkayan of 128 kilometer.

The Gyaing river has its headwaters in Thailand and flows Westward to join the Thanlwin river from the East about 6 kilometer above Mawlamyine. It is navigable for a distance of 88 kilometer. The Gyaing is a broad river, much obstructed by bars islands, and its tidal throughout its length to Kyondo.

The Attaran river runs from South to North in Mon state. The Attaran river and its tributary, the Zami river joins the Thanlwin river just to the East of Mawlamyine and the tidal effect extends to Kya-in-seikkyi. It is navigable for a distance of 117 kilometer from Kya-in-seikkyi to Mawlamyine. Large launches run to Kya-in-seikkyi all the year round.

The Thanlwin river splits at Mawlamyine into two channels, both flowing to the Andaman Sea. The Darebauk River, Westerly channel is used for local traffic only. The Southerly channel : the Mawlamyine river and Bilugyun channel : is the principal artery of travel for both local and sea going commerce. The bed of the Mawlamying river is of alluvial type, thus the navigation channel both in the bay and river section is subject to constant change. The part of the channel east of the entrance is threatened by the encroaching sand banks and the channel has already moved a few hundred meters to the South in this area. The currents are strong: 1 to 2 meter per second caused by the tidal difference, but area more one directional, although not always in the direction of the channel. The remainder of the channel to reach Mawlamyine port is also subject to shifting sand banks and currents. It appears that most of the time sufficient depth can be found. However, the hazards occur when sharp bends have to be negotiated.

The port of Mawlamyine has a 30 kilometer long approach channel. Due to the considerable tidal difference and extensive back waters, strong currents up and down this channel occur. These currents carry silt and sand, and cause constantly shifting shoals. At present the design profile of the channel is 4.25 meter deep, by 300 meter wide at the bottom with slopes of one to fifteen. The mean river level at Mawlamyine is highest in September 2.90 meter + C.D and lowest in March 1.40 meter + C.D. Mean high water spring MHWS is 4.12 + C.D. and mean high water neap MHWN is 2.44 + C.D.

Table 1.5: Major Tributaries of Thanlwin River

Tributary	Enter from	Drainage Area (Sq. Km)	Annual Output (Million Cubic Meter)
Donthami	West Side	2823	6414
Yunzalin	West Side	2927	7401
Nam Pawn	West Side	18881	20106
Nam Teng	West Side	15229	17392
Nam Peng	West Side	12665	15419
Attaran	East Side	5698	14432
Gyaing	East Side	9531	23930
Nam Hsim	East Side	5128	5427
Nam Hka	East Side	10308	10978
Nam Ting	East Side	8961	10978

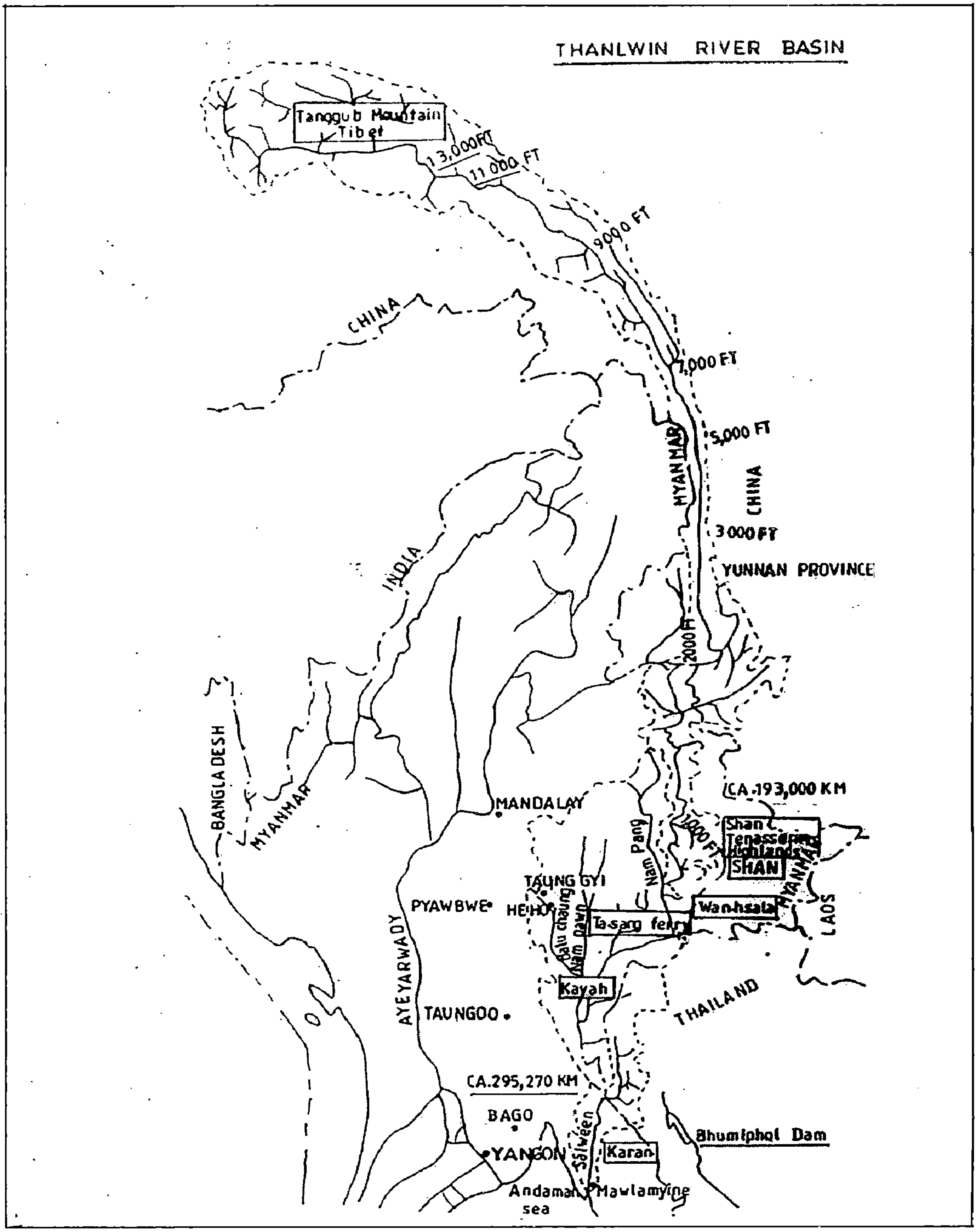


Fig 1.5Thanlwin River Basin

1.8.3 The Sittoung River System

The Sittoung river is the fourth largest river of Myanmar with the entire length of about 420 kilometer. It originates near Yamethin, North Latitude $20^0 15'$ and discharges into the Gulf of Moattama, about 96 kilometer East of Yangon. The source of Sittoung river is at 460 meter above mean sea level. This river parallels the Ayeyarwady river in its Southward flow. It has a valley length of about 320 kilometer and width of 64 kilometer to 80 kilometer. The Sittoung depression is bounded by the Shan plateau in the East and by the BagoYoma in the West. At the boundary between the BagoYoma range with the Sittoung depression, the existence of a tectonic fault trending North-South direction is suggested as the marginal fault of the BagoYoma. This fault can be traced from Bago to Mandalay according to the Geological Map of Myanmar. However the Sittoungriver lies within the area of high agricultural use.

The fan deposit from BagoYoma is projected to the flood plain of the Sittoung river, resulting in steeper land slope. Consequently, its tributaries carry large amount of sediments. The low lying flood plain along the Sittoungriver lower than 10 meter in elevation, is accompanied by numerous oxbow lakes and swamps covered by the back swamp and lucustrine deposits. Left bank of the Sittoungriver is occupied by the Eastern edge of the Shan plateau, which is mainly composed of Masozoic hard granitic rocks, offering good sources of sand and gravel. On the other hand, the water level of Sittoungriver normally rises rapidly in June and reaching its peak in August. In this stage the back water of Sittoungriver goes up into its tributaries especially in middle and lower catchment areas, resulting in long duration of inundation in those areas.

The Sittoung river is formed by three streams: Paunglaungchaung, Sinthechaung and Ngalikechaung: of different sources. The source of Paunglaungchaung lies in the Shan plateau whereas the Sinthechaung and the Ngalikechaung have their headwaters in BagoYoma. Then the Sittoung river flows Southwards between Shan Yoma and BagoYoma, and empties into Gulf of Moattama. Numerous large tributaries having good sustained flows enter the main river Sittoung from both East and West side. Several of these tributaries have sufficient outputs and heads to be considered for irrigation and hydroelectric power. Along its stretch considerable tributaries which join the Sittoung river are: Pyonechaung, Thaukyegyutchaung, Kyaukgyichaung and Shwegyinchaung from the East bank and; Swachaung, Kabaungchaung, Pyuchaung and Yenwechaung from the West bank: respectively.

It is only for a short distance that the Sittoungriver can be considered navigable for commercial vessels. The entrance of the Sittoung river, beginning at the town of Sittoung and continuing to the head of the Gulf of Moattama: a distance of about 80 kilometer: is bell – shaped, uncharted, and is entered only occasionally by local crafts. The Sittoung river below the Bago-Sittoung canal is dangerous to navigation by numerous sand banks in the delta by a tide bore.

The Bago-Sittoung canal, constructed primarily for navigational purposes to connect Bago river with the Sittoung river in the endeavor to avoid the adverse conditions on the lower reach of Sittoungriver. The canal leaves the Bago river at Tawa and continue for 61 kilometer to enter the Sittoung river at Myitkyo. The average depth of the canal is about 2.3 meter.

Although the entrance of the Sittoung river is troublesome due to a bore, this area is bypassed by Bago- Sittoung canal bringing small country boats from the Sittoung river into the Yangon river. Above the Bago- Sittoung canal the Sittoung river is navigable to 10 kilometer above toungoo : a distance of 250 kilometer : by crafts drawing 1.37 meter, during the rains from mid-July to mid-October, however, beyond Madauk : a distance of 40 kilometer : the navigable channel presents difficulties to other than serangs accustomed to the waters. Most of the tributaries of the Sittoungriver navigable to country boats only a few kilometer from their mouths during the rains.

The whole drainage area of the Sittoung river is 34395 square kilometer and annual output is about 41900 million cubic meter. River basin annual rainfall ranges from 760 millimeter in upstream area up to around 3800 millimeter in its mouth. The maximum difference between high water level and low water level is in the range of 5.5 meter to 8.5 meter. The Sittoung river is tidal to about 16 kilometer above its junction with the Bago- Sittoung canal and is subject to tidal bore up to this 16 kilometer limit. The bore occurs daily between September and May. Between June and August there is no bore.

As stated earlier, the tributaries of the Sittoungriver carry a large amount of sediment, but sediment related data are very scantily available. Sir Alexander Gibb (1976) estimated the annual sediment transport of Sittoungriver at 35 million tons. According to the Irrigation Department practice, Pyinmana irrigation project located along the BagoYoma has adopted the sediment volume of 1000 cubic meter per square kilometer per year. Referring to the Hydrologic Annual (1990) published by the Department of Meteorology and Hydrology, annual sediment runoffs of the Sittoungriver at Toungoo gauging station is 12363410 tons and Shwegyingchaung at Shwegyin station is 2079193 tons respectively.

Table1.6: Some Facts about Sittoung River Gauge Stations

Particular	Unit	Yeni	Toungoo	Madauk
Latitude (North)	Deg: Min	18 : 54	18 : 55	17 : 55
Longitude (East)	Deg : Min	96 : 23	96 : 28	96 : 51
Station Elevation	Meter	68.765	44.282	10.801
Drainage Area	Sq. Km	11083	14660	26758
Zero of Gauge	Meter	59.2	37.0	0 (ARB)
Danger Level	Centimeter		600	1070
Max : Water Level	Centimeter	1065 (85)	725 (73)	1178 (90)
Min : Water Level	Centimeter	503 (85)	80 (72)	320 (69)
Max : Daily Mean Discharge	CMS		1623 (73)	4102 (90)
Min : Daily mean Discharge	CMS		6 (72)	10 (69)

* CMS : Cubic meter per Second

* (85) : Year 1985

Table 1.7: Monthly Mean Run-Off of the Yenwe Chaung at Myogyaung (Cubicmeter Per Second)

Month	Run – off in cubic meter per second
January	2.6
February	1.6
March	1.6
April	1.0
May	8.9
June	42.0
July	83.1
August	92.3
September	65.3
October	32.3
November	12.8
December	5.0
Annual	29.0

(1) YenweChaung is one of the major tributaries of Sittoung river.

(2) 90% of annual run – off concentrates in the monsoon season during June to October.

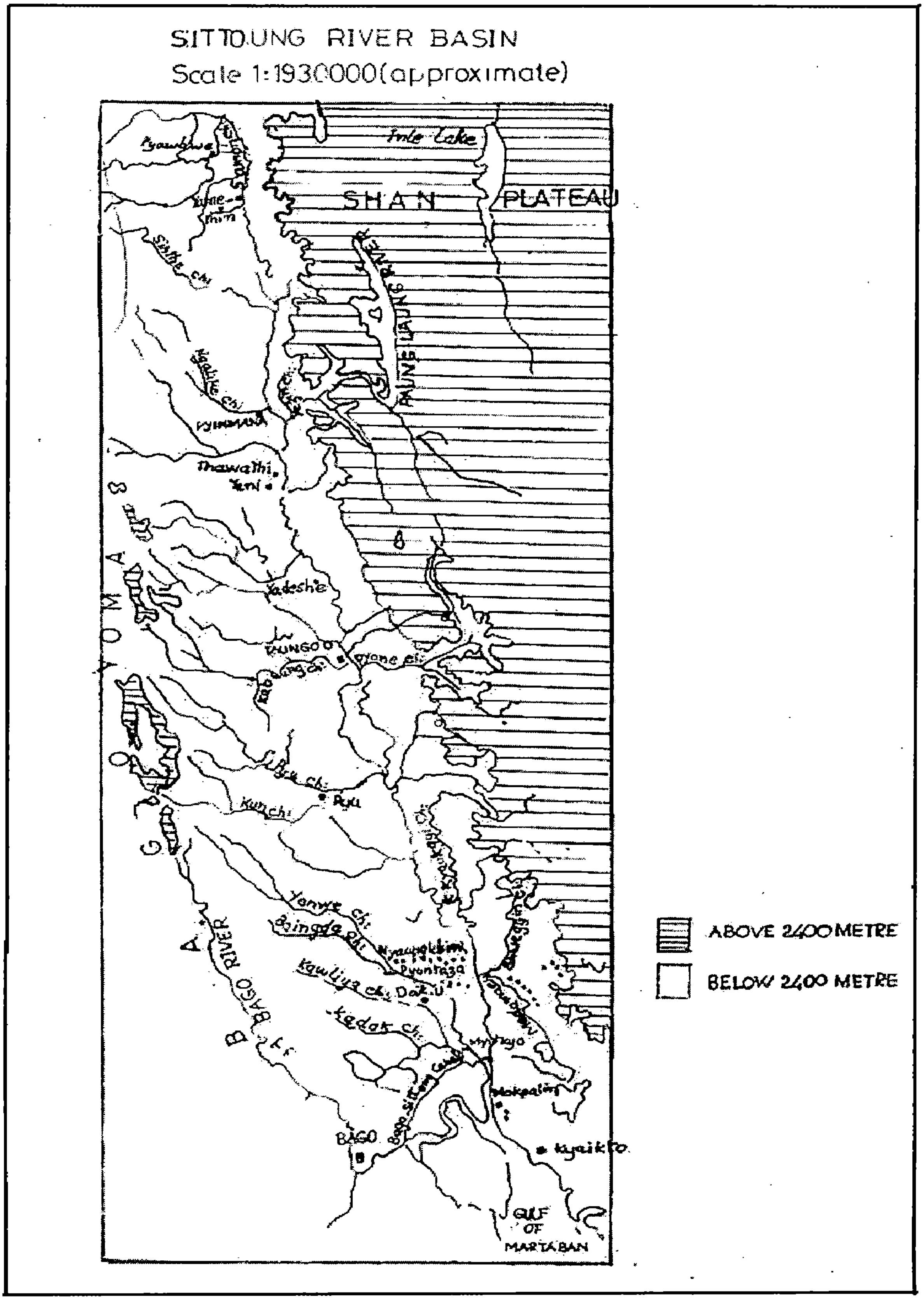


Fig 1.6 Sittoung River basin

Table 1.8: Flood Frequency Analysis (Yenwe Chaung)

Probability of Recurrence (Year)	Peak Flood Run – off (Cubic meter Per Second)
1000	3470
500	3300
200	3100
100	2800
50	2500
20	2100
10	1750

1.8.4 The Rakhine river system

The narrow coastal strip of Rakhine is one of the physical divisions of Myanmar. Rakhine coastline belongs to the length of about 713 kilometer. West of the Ayeyarwady valley lie the coastal mountains extending from low foot hills near Pathein (North Latitude 16^0) to the Indian border (North Latitude 21^0). The foot hills, termed RakhineYoma, increase steadily toward the North culminating in 3054 meter high Mount Victoria. North of this peak there is a continuous range of mountains, 2440 meter to 2740 meter in height, terminating in the rugged Chin Hills. These coastal mountains are heavily watered. The principal towns are along or near the sea coast, where many islands are formed with navigable waterways along either side of these islands.

The Kaladan, the Leimyo and the Mayu are principal rivers on the West slope of RakhineYoma discharge directly into the Bay of Bengal. These major rivers and other rivers with their tributaries constitute the river system of Rakhine State, separated from the Ayeyarwady river by RakhineYoma. Most of the Rakhine rivers are navigable. Navigation is depending upon the tide favourable especially in their tributaries. On the Southern route from Sittwe, river transport voyages are mixed with coastal and creek routes. Navigation in the Northern part of Rakhine is entirely along rivers. Traditionally, riverine transport has been the most important means of transportation in Rakhine State. Judging from the topographical conditions and development of land transportation, riverine transport will continue to be the most important means of transportation for Rakhine State.

The Kaladan river system is one of the largest river systems of Myanmar and separated by RakhineYoma from the Ayeyarwady river system. This river system is in conjunction with the Mayu, An, Taungup and Thandwe rivers, and the chain of coastal islands between the mouths of the Kaladan and Thandwe rivers. The Kaladan river rises in the Lushai Hills, and flows through Chin State to enter the Bay of Bengal near Sittwe.It is about 650 kilometer long whereas the length of 257 kilometer in Myanma territory and flows for the greater length through rugged country creating a turbulent stream. The Kaladan is formidable river in the rains, especially in its lower reaches. In the rainy season the surface water level of Kaladan river often rises very rapidly. The Kaladan river is navigable from Sittwe to Paletwa, a distance of 176 kilometer. Sailing upstream from Sittwe, the water depth for navigation is in excess of 2.7 meter for the first 147 kilometer, greater than 1.35 meter for the next 24 kilometer and less than 1.35 meter for the remainder.

The tidal effect is felt as far upstream as Paletwa, a distance of about 160 kilometer from the sea. Coming downstream, the width of the river varies from about 0.8 kilometer at Paletwa to over **8.0** kilometer in the Sittwe harbor. From Paletwa the valley gradually opens up, but it is not until the neighborhood of Kyauktaw: about 96 kilometer above Sittwe: that the paddy lands begin. From Kyauktaw to a point that opposite Myochaung, or from about kilometer 96 to 60 on the Kaladan river, the valley is served also Yanwa or Thayechaung with interconnecting creeks and canals which are navigated by country boats. Entering the Kaladan river from the East about 8 kilometer downstream from the Yanwa, is Yan chaung, which navigable to Kyeyabin about 48 kilometer above the mouth. About 32 kilometer above Sittwe, The Yo river enters the Kaladan river from the West. This tributary is navigable by launches as far upstream as Kanzauk, about 56 kilometer above mouth. The delta area of the Kaladan river is a maze of waterways and basic mode of travel is by boat.

The Leimyo river has its headwaters in Mount Victoria and flows into the Bay of Bengal near the town of Myebon. The Kywegi river, entering the Kaladan river from the East opposite Sittwe, is in reality a part of the Leimyo river. The Leimyo river is navigable from Sittwe to Pan Myaung, a distance of 96 kilometer with a water depth in excess of 2.7 meter for the first 50 kilometer and less than **1.35** meter for the last 8 kilometer. From the Kaladan river to Leimyo river, as far upstream as *Yanwa*chaung, lies an area of nearly 2590 square kilometers of paddy lands, with all rivers on the East interconnected with an extremely complicated system of waterways and chaungs, which are navigated by country boats within the tide influence.

The Mayu river is the Westernmost river wholly in Myanmar whereas the Naaf river is the boundary river with Bangladesh. With its headwaters in

Bangladesh/Assam the Mayu river flows into the Bay of Bengal near Sittwe. It is about 160 kilometer long and is navigable from Buthidaung to sea, a distance of 128 kilometer. The first 109 kilometer provides a water depth in excess of 2.7 meter and the remainder more than 1.35 meter. From the sea, the entrance to the Mayu river is much congested by sand and mud flats and these, plus the coastal exposure, necessitate riverine transport to use an interconnecting systems of waterways between the Kaladan river and Mayu river via Mingan creek, Sabata creek, Mozi river and Laungzin creek.

The Kalabon river system enters the Kaladan river from the East about 24 kilometer upstream of Sittwe. The Kalabon river is name given to the lower reaches of a complicated network of waterways, most of which are navigable.

Table 1.9: Rakhine Rivers

River	Length (Km)	Elevation at Source (M)	Drainage Area (Sq.Km)	Annual Output (Million CBM)
Leimyo	270	1676	10127	25039
Kaladan	650	2438	22611	53779
Mayu	155	610	5115	11348

(M) Meter

(CBM) Cubic meter

Table 1.10: Major Gauging Stations of Kaladan River

Particular	Unit	Paletwa	Kyauktaw
Latitude (North)	Deg : Min	21 : 18	20 : 51
Longitude (East)	Deg : Min	92 : 51	92 : 58
Station Elevation	Meter	55.00	3.00
Drainage Area	Sq. Km	19631	17604
Zero of Gauge	Meter	0 (ARB)	0 (ARB)
Max : Water Level	Centimeter	2255 (1989)	677 (1989)
Min : Water Level	Centimeter	202 (1988)	126 (1988)

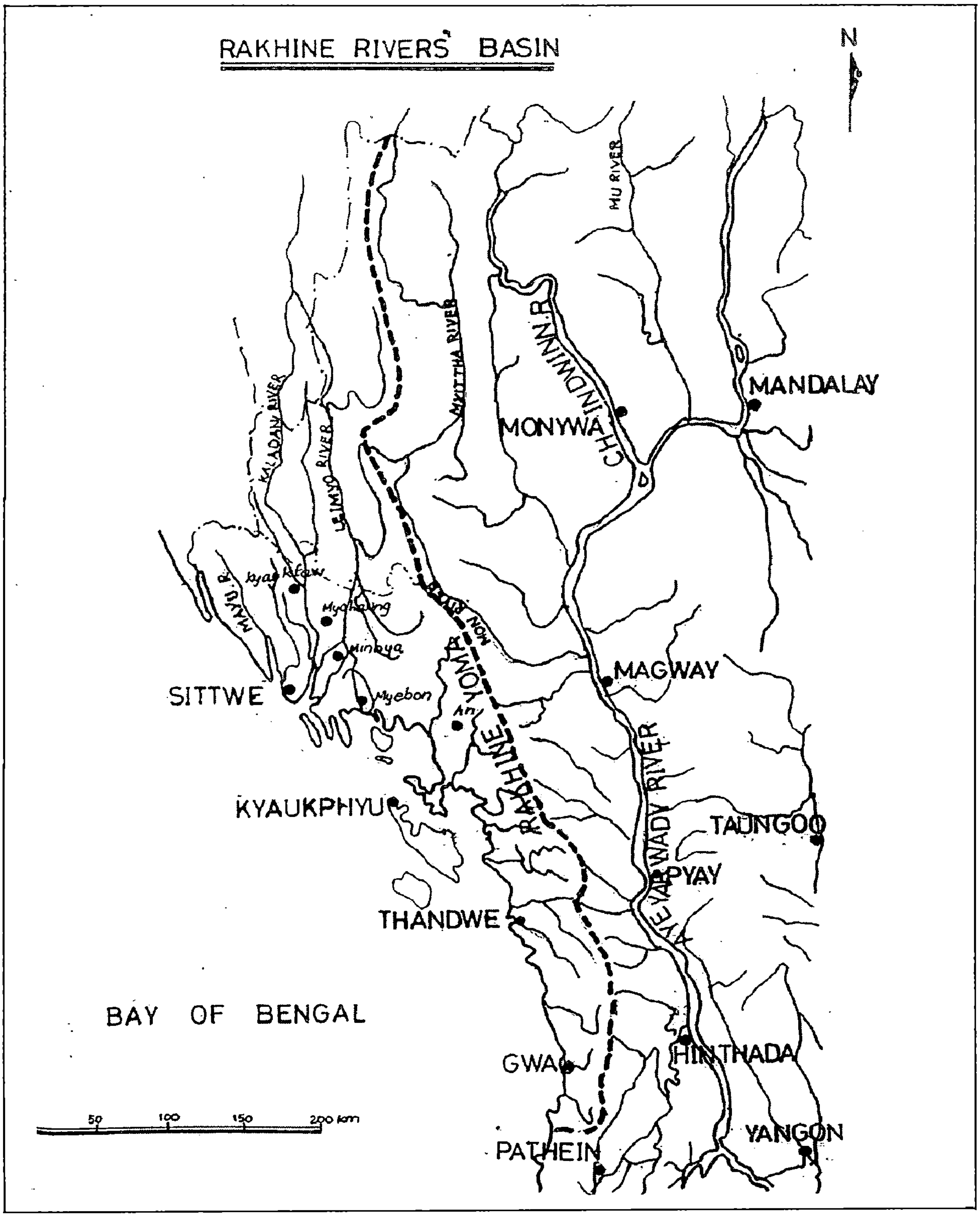


Fig 1.7 Rakhine River Basin

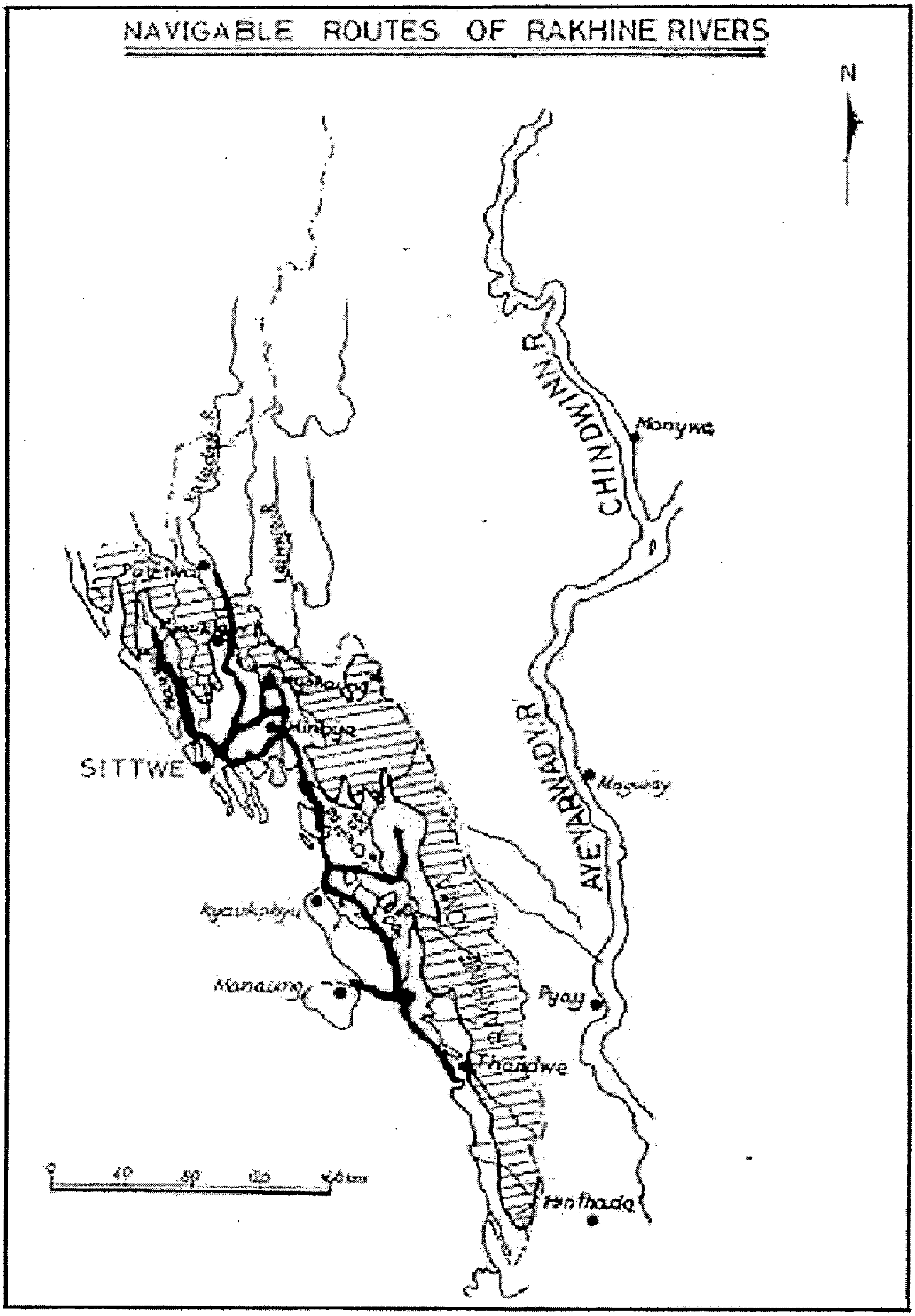


Fig 1.8 Navigable Routes of Rakhine Rivers

Fig 1.9 River Map of Myanmar

1.9 NAVIGABLE LENGTH

Most of Myanmar Rivers are navigable. The rivers and their tributaries offer over 8000 most kilometers commercial navigable waterways and other thousands of kilometers used by country boats for the principal mode of travel and transport. The most heavily used part of extensive waterways system is the Ayeyarwady River and its delta. The navigability lengths of inland water ways is summarized in the following.

River Navigable length (km)

(a)	The Ayeyarwady	1534
(b)	The Chindwin	730
(c)	The Ayeyarwady delta	2404
(d)	The Thanlwin and Mon state rivers	380
(e)	The Rakhine state rivers	1602
(f)	The Mekong (within Myanmar territory)	265
	Total	**6915**

1.9.1 Deterioration of Rivers

Rivers are being faced with deterioration by artificial activities and natural processes. Braided channels, insufficient water depth in low water season, dangerous flood / serious erosion in wet season and large sediment transport are the symptoms of deterioration. Some are visible symptoms and some are hydrological features.

1.9.2 Constraints to Inland Navigation

The constraints to inland navigation are insufficient depths, narrow channel width, sharpness of bends, high velocities. The major constaint is identified as insufficient depth during the low water season. Due to the insufficient least Available Depth (LAD) of low water season, vessel draft plying along the Ayeyarwady and Chindwin rivers are limited by the draught restriction issued by the **Directorate of Water Resources And Improvement of River Systems** (DWIR) annually from 15 November to 15 May. Draught Restriction is the one of the rules junder the inland Stream vessels Act (ISV) relating to safety of vessel plying along the inland waterways system.

Stretch Ayeyarwady & Chindwin	Restricted Draught
Henzada-Pyay (172 km)	1.7 meter
Pyay-Mandalay (522 km)	1.5 meter
Mandalay-Katha (290 km)	1.2 meter
Katha-Bhamo (130 km)	1.1 meter
Sinbo-Myitkyina (134 km)	0.8 meter
Mouth of Chindwin-Monywa(85 km)	0.9 meter
Monywa - Kalewa (234 km)	1.0 meter
Kalewa - Homalin (300 km)	0.9 meter
Homalin - Hkamti (300 km)	0.8 meter

Apart from the insufficient depth, the hazards for navigation are sang, wrecks and rock out crops. The less pronouncing constraints are sharp bend, and high current velocity at some places.

1.9.3 Role of Inland water Transportation in Myanmar

All modes of transport can be operated in Myanmar and due to the geographical formation of the country, majority of the access are running North to South and parallel to each other. Among the various modes of transportations, inland water transport is mode that has special advantages. For the transport of bulk cargoes, barges and river boats have the advantages of large capacity, high productively and low fuel consumption. The physical size and weight of large and heavy cargo units transported by waterways is virtually unlimited.

1.9.4 The River Improvement Works

Major responsibility of Directorate of Water Resources and Improvement of River Systems (DWIR) is for the infrastructure development of inland water transport in Myanmar, undertaking the following tasks, which support that specific objective:

(a) River Engineering Work

(b) Dredging work

(c) Navigation Aids operation.

1.9.5 River Engineering Works

To improve the rivers in terms of Least Available Depth, access channel to port facilities and erosion control measures, DWIR uses the following types of structures which are inexpensive in cost, workable in local conditions with local material and labours, and satisfactory in effectiveness. DWIR has implemented river engineering work with an emphasis to solve the constraints along the Myanma Rivers especially on Ayeyarwaddy and Chindwin rivers by construction of wooden pile, open groynes, rock filled groynes, sand filled stone groynes, stone groyens, bandall and stone spurs.

1.10 SELECTION OF RIVER FOR STUDY

Myanmar has the four main rivers. These are Ayeyarwaddy, Chindwin, Sittoung and Thanlwin rivers. Among them, the Chindwin River is selected due to the following reasons.

1. Chindwin River is the most important river in North-West of Myanmar.
2. Waterway Transportation is more useful transportation than any other transportation in North-West of Myanmar.
3. Chindwin River water can be used for domestic as well as water supply for agricultural lands round the year.
4. Chindwin is also used as water transport for communication between the area of the basin and the central part of the country. The numbers of passengers transported annually are 100,000 and cargo including timber – 200,000 tons.
5. Economically, the Chindwin river basin is poorly developed, but if possess a variety of natural resources i.e. coal, copper, ore, oil, timber, gold, jade etc.

There are problems associated with the water quality, bank erosion etc. which need to be studied is detailed to arrive at comprehensive environment management of this river. This considered for study.

REVIEW OF LITERATURE

2.1 THE CHINDWIN RIVER BASIN

The Chindwin River is the largest tributary of the Ayeyarwady River. It flows entirely within Myanmar and is known as "Ning-thi" to the Manipuris. The Chindwin is navigable for some 500 miles (816 km) from its confluence with the Ayeyarwady below Mandalay to the confluence with the Uyu River, its chief tributary. Along the river, there are also deposits of jade, but the best jade is found in the region around the headwaters of the Uyu River. The study carried out by DWIR (1966-1990) report for Daily Maximum and Minimum Water Level Difference (meter) Chindwin River System is given in table 2.1.

Table 2.1: Daily Maximum and Minimum Water Level Difference (meter) Chindwin River System

Calendar Year	Mawlaik	Kalawa	Monywa
1966	14.5	17.3	9.4
1967	11.6	14.0	8.2
1968	11.3	15.8	9.0
1969	13.0	14.7	9.0
1970	13.0	14.5	9.1
1971	12.2	14.0	9.2
1972	10.6	13.0	8.0
1973	13.8	16.2	9.3
1974	12.8	16.2	8.5
1975	11.3	13.9	8.3
1976	14.5	16.6	8.5
1977	12.1	16.1	8.7
1978	11.8	14.3	8.2
1979	12.9	15.4	9.1
1980	13.3	16.6	9.1
1981	11.0	12.9	7.5
1982	13.3	16.0	9.1

Calendar Year	Mawlaik	Kalawa	Monywa
1983	12.5	18.8	8.7
1984	13.3	17.7	9.2
1985	11.9	14.8	8.9
1986	10.2	13.2	8.2
1987	12.0	15.1	8.8
1988	13.3	16.8	9.3
1989	13.1	16.0	8.7
1990	11.6	15.3	8.2

The Study carried out by DWIR (1966-1990) report: for Ratio of Daily Maximum Discharge to Daily Minimum Discharge (Chindwin River System) is given in table 2.2.

Table 2.2: Ratio of Daily Maximum Discharge to Daily Minimum Discharge (Chindwin River System)

Year	Mawlaik	Kalawa	Monywa
1966	283	50	42
1967	86	32	27
1968	201	37	32
1969	194	36	38
1970	300	37	40
1971	198	31	42
1972	69	26	25
1973	145	46	43
1974	70	37	30
1975	72	30	29
1976	57	36	30
1977	41	39	29
1978	48	33	28
1979	83	39	40
1980	77	39	34
1981	61	22	22

Year	Mawlaik	Kalawa	Monywa
1982	218	36	36
1983	108	29	33
1984	105	47	39
1985	51	34	36
1986	42	32	31
1987	61	38	31
1988	102	45	34
1989	59	38	32
1990	30	37	23
RMAX	27215	25492	24259
RMIN	66	441	518

1. Sediment Transport of Chindwin River

The Chindwin River carries a considerable amount of silt suspended matter. The volume of silt in Chindwin River sharply decreases further upstream from its confluence with Uyu river. Considerable portion of silt forms in the lower reaches due to soil wash out and bank erosion. Gordon's estimate (1868) of annual suspended sediment transport at the mouth of the Chindwin river is about 112 million tons. According to the Chiber of 1909-1910, the silt suspended volume being estimated at 100 tons per year for the Chindwin River. HASKONING's estimate (1987) of annual suspended sediment transport at Thamanthi on the Chindwin river is 50 million tons. Like AyeyarwadyRiver, the Chindwin is also fast reacting river. But the fall velocity of the representative grain size, D_{50}, on the lower reach of the Chindwin River is 6.0 centimeter per second, whereas the fall velocity of the AyeyarwadyRiver is approximately 3.5 centimeter per second. This indicates that the current velocity on the lower Chindwin river needs to be higher than on the Ayeyarwady river in order to transport its bed material. [5]

2. Water Quality Parameters in Myanmar Rivers

The permissible values of different water quality parameters in Myanmar Rivers are as follows:

Nitrate content	- (0 – 0.38) mg/l
Iron content	- (1.53 – 2.73) mg/l
Chloride content	- (0 – 250) mg/l
Hardness	- (0 – 165) mg/l
Fluoride	- (0.7 – 1.15) mg/l
Ammonia	- (0 – 0.83 mg/l NH3)
Dissolved Oxygen	- (3.22 – 8.2) mg/l
Salinity intrusion	- (0.3 – 0.5) mg/l [6]

3. Study carried out by DWIR Chindwin river Report; Maximum and Minimum water level difference (centimeter) at Hkamti Station [15]

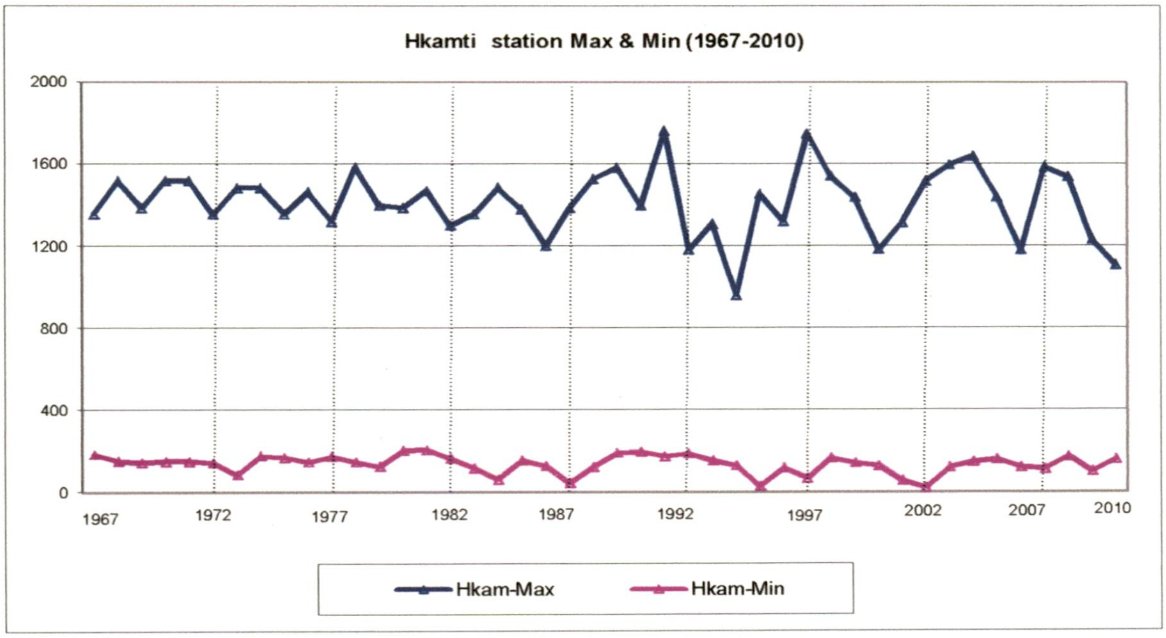


Fig 2.1 Maximum and Minimum Water Level at Hkamti (1967-2010)

4. Study carried out by DWIR Chindwin river Report; Maximum and Minimum water level difference (centimeter) at Homalin Station [16]

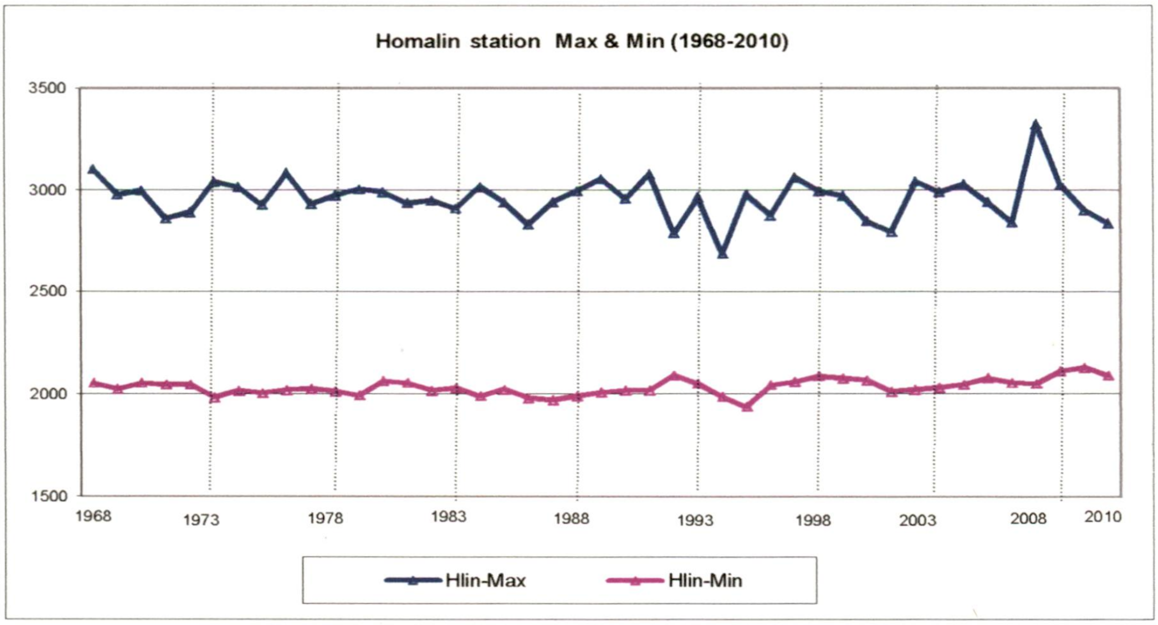


Fig 2.2 Maximum and Minimum Water Level at Homalin (1968-2010)

5. Study carried out by DWIR Chindwin river Report; Maximum and Minimum water level difference (centimeter) at Mawliak Station [17]

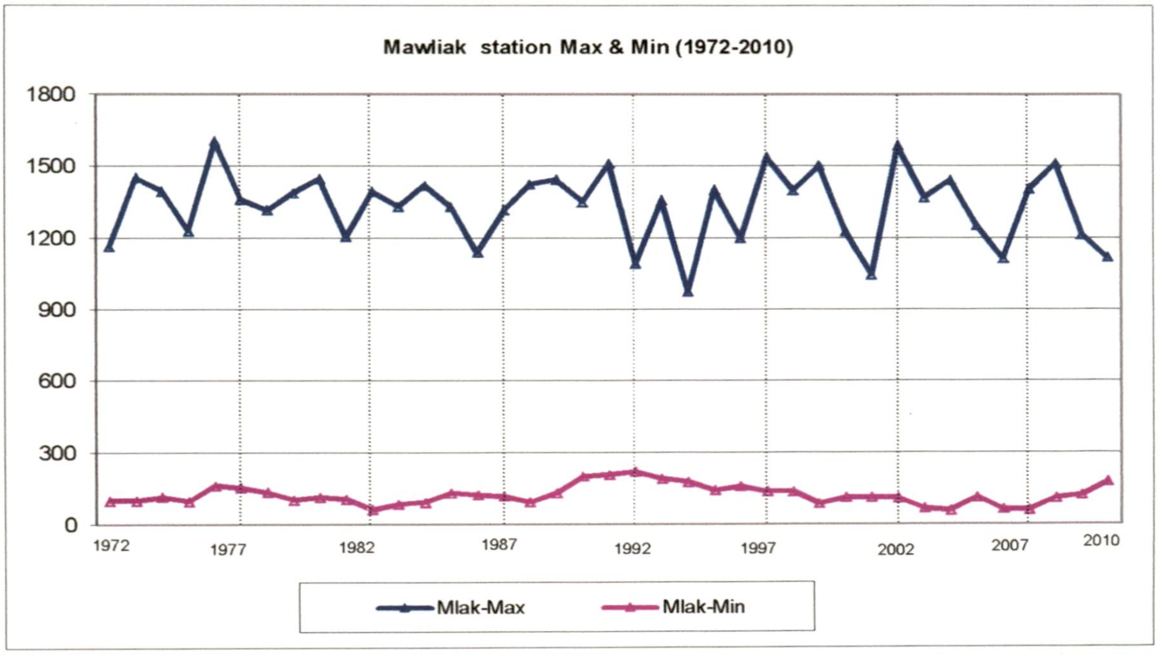


Fig 2.3 Maximum and Minimum Water Level at Mawliak (1972-2010)

6. Study carried out by DWIR Chindwin river Report; Maximum and Minimum water level difference (centimeter) at Kalewa Station [18]

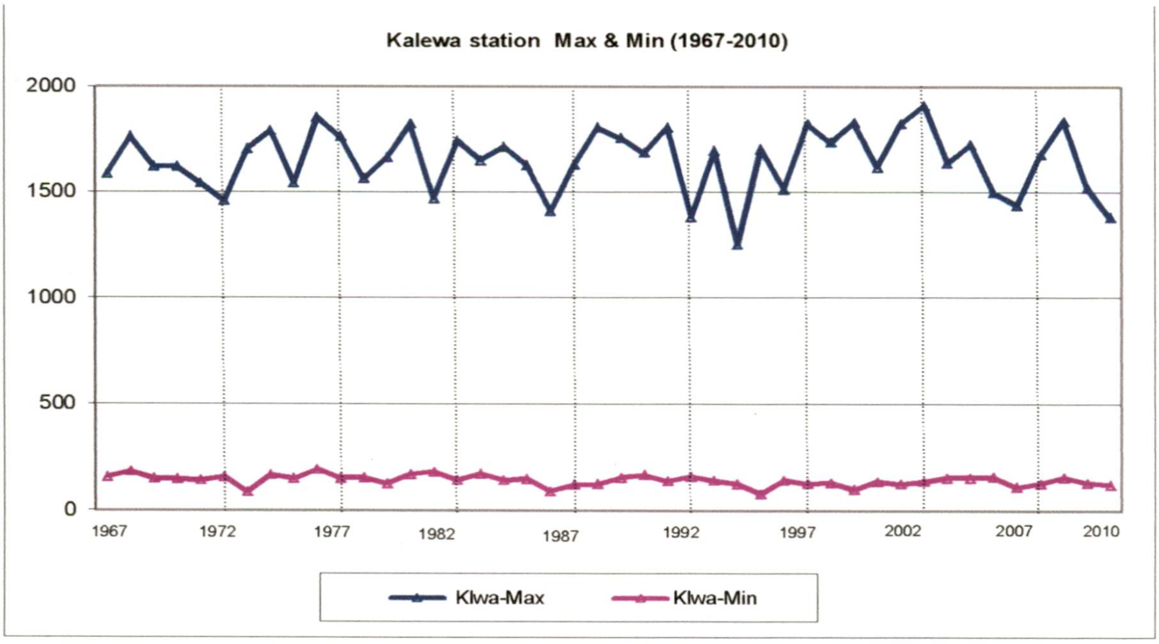


Fig 2.4 Maximum and Minimum Water Level at kalewa (1967-2010)

7. Study carried out by DWIR Chindwin river Report; Maximum and Minimum water level difference (centimeter) at Monywa Station [19]

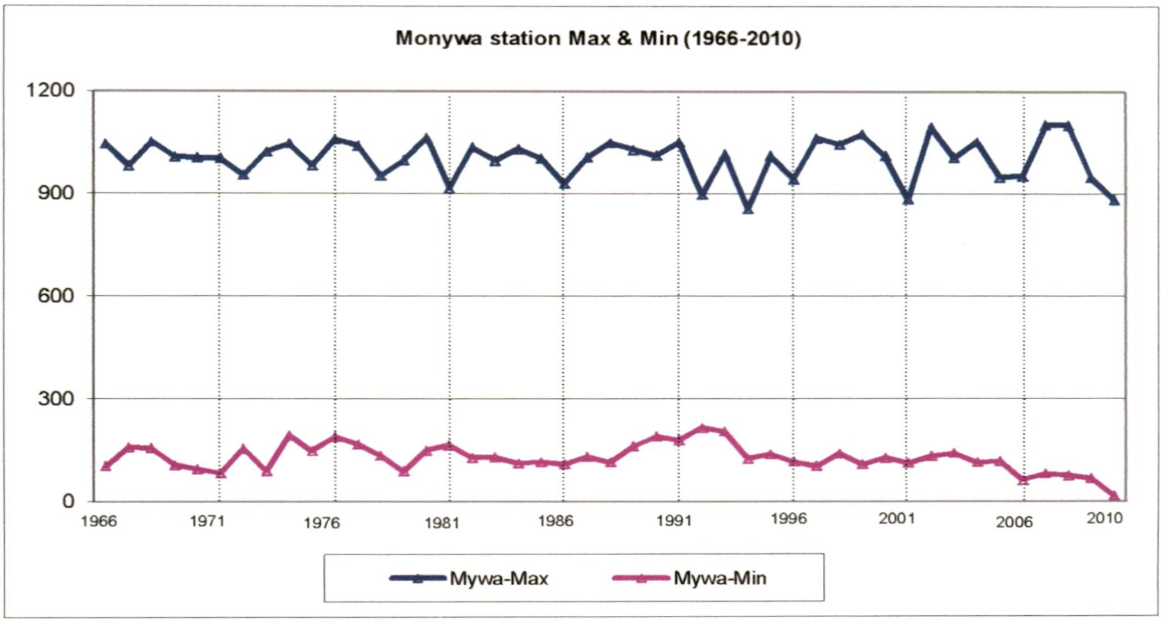


Fig 2.5 Maximum and Minimum water level at Monwya (1966-2010)

8. Study carried out by DWIR Chindwin River Report Water Level at **Monywa** Station [3]

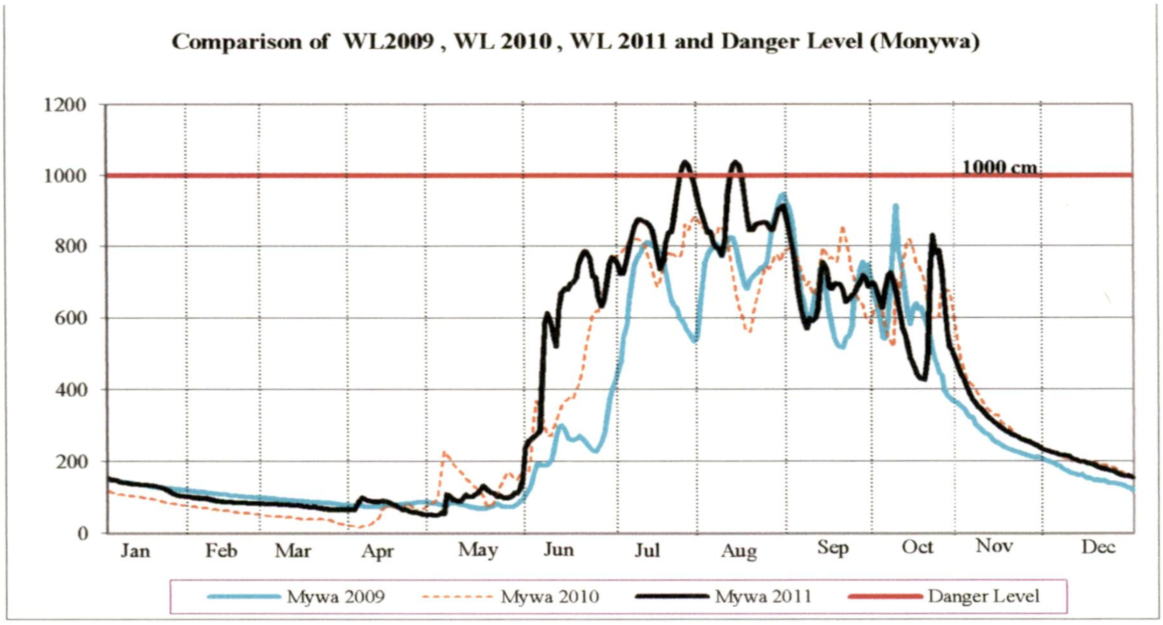


Fig 2.6 Comparison of Water Level at Monwya Station (2009, 2010, 2011)

9. Study carried out by DWIR Chindwin River Report; Water Level at **Kalewa** Station

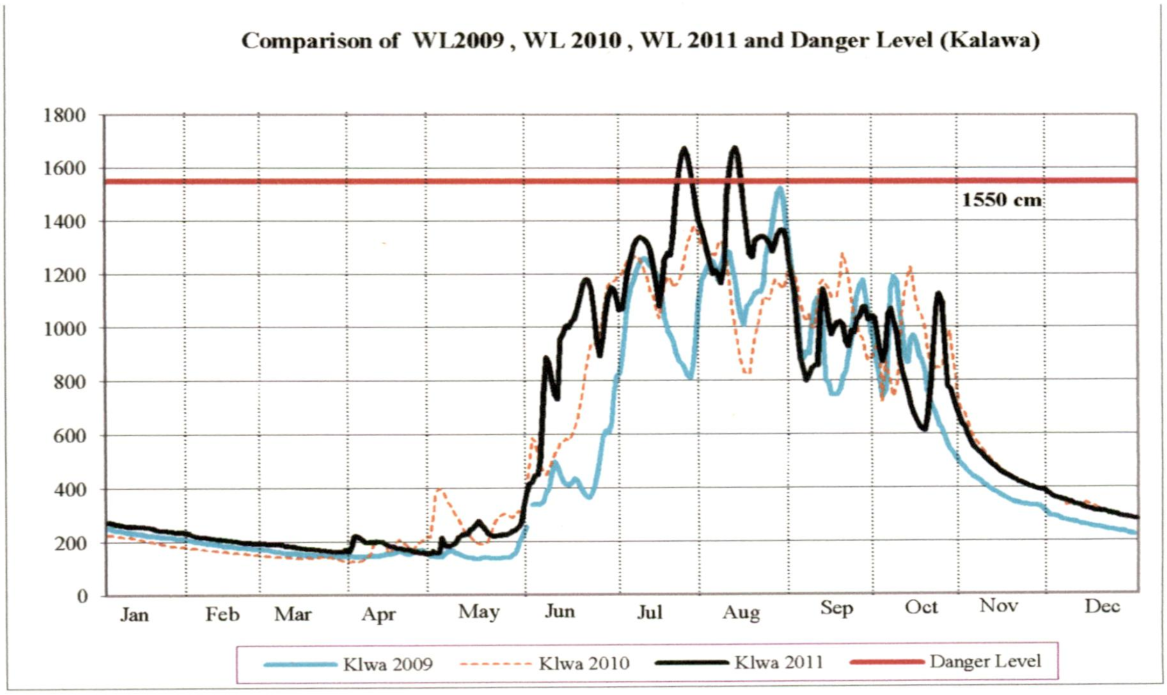


Fig 2.7 Comparison of Water Level at Kalewa Station (2009, 2010, 2011)

10. Study carried out by DWIR Chindwin River Report; Water Level at **Mawlaik** Station

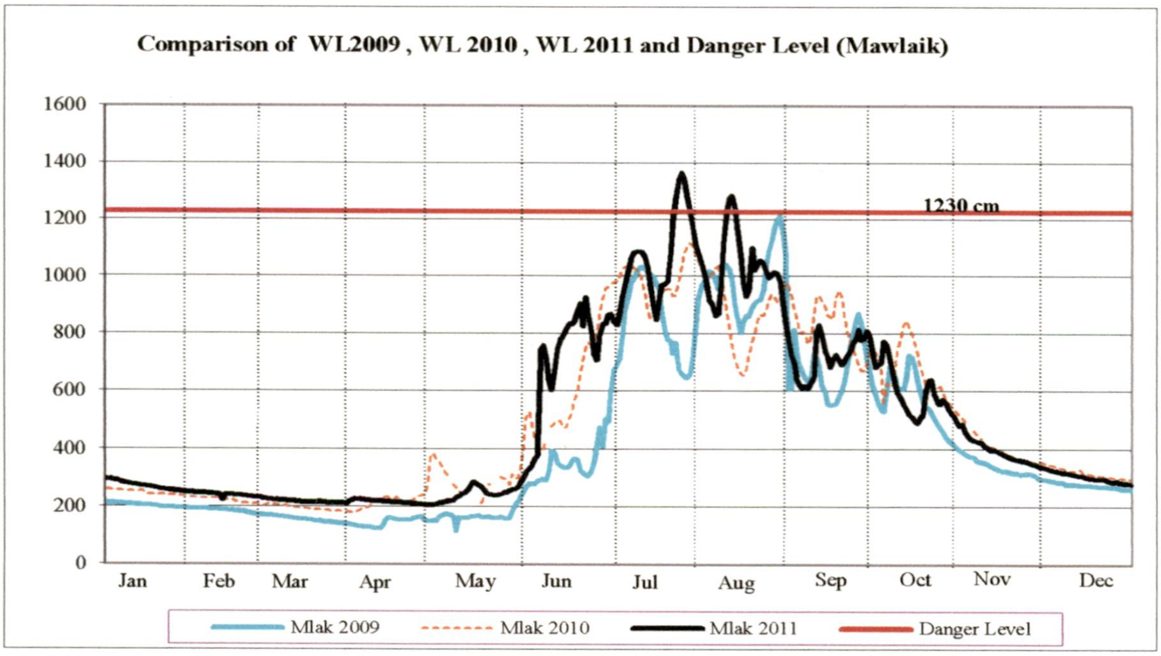


Fig 2.8 Comparison of Water Level at Mawliak Station (2009, 2010, 2011)

11. Study carried out by DWIR Budget Report; **Waterway Development Works &Protection of Bank Erosion Works along the Chindwin River [20]**

Table 2.3: Chindwin River Budget (Myitsone-Monywa) 2000-2011

Particular	Budget Year	Waterway Development Works		Protection of Bank Erosion Works		Total Cost (Million Kyat)
		Quantity	Cost	Quantity	Cost	
Myitsone-Monywa	2000-01	5	10.0			**10.0**
	2001-02	2	10.0			**10.0**
	2002-03	1	5.0			**5.0**
	2003-04	1	15.0			**15.0**
	2004-05	2	20.0			**20.0**
	2005-06	2	17.0			**17.0**
	2006-07	1	19.75			**19.75**
	2007-08	3	53.3			**53.3**
	2008-09	1	24.3			**24.3**
	2009-10	1	11.45	4	28.481	**39.931**
	2010-11	1	8.10	1	10.0	**18.10**
	Total	**20**	**193.90**	**5**	**38.481**	**232.381**

Note 1$ = 820 kyat

Table 2.4: Chindwin River Budget (Monywa-Mawliak) 2000-2011

Particular	Budget Year	Waterway Development Works		Protection of Bank Erosion Works		Total Cost (Million Kyat)
		Quantity	Cost	Quantity	Cost	
Monywa-Mawliak	2000-01	2	5.0			**5.0**
	2001-02	2	5.0			**5.0**
	2002-03	1	5.0			**5.0**
	2003-04	1	10.0	2	20.0	**30.0**
	2004-05	2	20.0	2	20.0	**40.0**
	2005-06	1	27.0	1	22.225	**49.23**
	2006-07	3	30.0			**30.0**
	2007-08	11	174.639			**174.639**
	2008-09	8	117.0			**117.0**
	2009-10	11	90.905			**90.91**
	2010-11	15	124.66	1	10.50	**135.16**
	Total	**57**	**609.204**	**6**	**72.725**	**681.929**

Note 1$ = 820 kyat

Table 2.5: Chindwin River Budget (Mawliak-Hkamti) 2000-2011

Particular	Budget Year	Waterway Development Works		Protection of Bank Erosion Works		Total Cost (Million Kyat)
		Quantity	Cost	Quantity	Cost	
Mawliak-Hkamti	2000-01	1	5.0			**5.00**
	2001-02	1	5.0			**5.00**
	2002-03	1	5.0			**5.00**
	2003-04	1	10.0			**10.00**
	2004-05	1	20.0			**20.00**
	2005-06	1	27.0			**27.00**
	2006-07	1	14.5			**14.5**
	2007-08	1	3.57			**3.57**
	2008-09	1	22.9	1	32.5	**55.40**
	2009-10	2	50.392	1	28.958	**79.350**
	2010-11	1	26.0	1	58.2	**84.20**
	Total	**12**	**189.362**	**3**	**119.658**	**309.02**

Note 1$ = 820 kyat

12. Department of Meteorology and Hydrology Report: **Flood Record in Chindwin River, Myanmar (since1966) [35]**

Table 2.6: Flood Record in Chindwin River, Myanmar (since1966)

Station	Danger Level(cm)	Max. WL (cm)	Flood Duration	Above DL (m)	Year
Chindwin					
Homalin	2900	3107	18 Days 6 Hrs	2.07	1968
Mawlaik	1230	1608	15 Days 12 Hrs	3.78	1976
Hkamti	1360	1771	18 Days 06 Hrs	4.11	1991
Kalewa	1550	1920	10 Days 12 Hrs	3.70	2002
Monywa	1000	1099	9 days 6 Hrs	0.99	2002

13. **Department of hydrology Report: Floods in Myanmar with loss and damage data (1997-2007) due to Chindwin River**

Table 2.7: Floods in Myanmar with loss and damage data (1997-2007) due to Chindwin River

Location	Date	No. of Affected Village Tracts and Villages	No. of Affective House Holds	No. of Affected Families	Affected Population	Death Toll	Loss (x100000 kyat)
Homalin, Sagaing Division	08/07/97	5 villages in 2 wards	9,916	9,950	59,594	-	99 (9,000 USD)
Homalin, Sagaing Division	25/09/97	63 villages	3,867	3,867	28,399	-	238 (21,636 USD
Mawlaik, Sagaing Division	13/07/97	16 villages	3,622	3,622	21,897	-	-
Monywa, Sagaing Division	18/08/02	-	9,178	9,460	48,746	-	2,535 (213,909 USI
Kani, Sagaing Division	19/08/02	-	2,042	2,207	12,048	-	2,447 (222,454 USI
Hkamti Sagaing Division	03/07/03	-	1,230	1,536	8,131	-	-
Sagaing Division	11/09/06	6 villages near Yaymyetgyi Lake	770	791	5,372	-	-

14. River environmental management requires a basin-wide understanding of the interactions between river, environment and human infrastructure, including the interactions between ecology, hydrology, water quality, climate, flooding and drinking water supply, waste water inputs and waste water treatment. **[21]**

15. The Bagmati Basin currently faces a number of serious environmental and ecological challenges. Urbanization and industrialization of the Basin headwaters at Kathmandu contributed to water quality deterioration with regional consequences on the aquatic ecosystem and on the health of the downstream sub-basin's user groups. Increasing population pressure on the fragile mountain slopes has also resulted in the rapid degradation of the natural resources. As a consequence, deforestation, soil erosion, landslides, siltation etc. are occurring in the upper and middle sections whereas sedimentation and flooding is frequent in the lower stretches of the watershed. This synergetic effect is of concern for the sustainable use of the resources and infrastructures. **The mitigation measures for erosion control and sediment transport** at the Bagmati Barrage and Kulekhani Hydroelectric Power Reservoir include:

Short term measure

- Physical intervention

Long term measures

- Land stabilization and erosion control;
- Conservation of forest resources;
- Reforestation of degraded forest;
- discouraging conversion of forest into agricultural land; and
- discouraging traditional agriculture practice on sloping or unleveled surfaces

The mitigation measures for river pollution include:

- setting of effluent standards;
- setting of ambient river quality standard;
- construction of wastewater treatment plants in the Kathmandu Valley;
- on-site sanitation;
- effective solid waste management;
- ban on river bed sand mining in the upper Bagmati sub-basin; and

- increase assimilative capacity of the river in the upper Bagmati sub-basin. **[22]**

16. Hydrology is a primary control on the ecological quality of river systems, through its influence on flow, channel geomorphology, water quality and habitat availability. Scottish rivers are widely perceived to be of high ecological quality, with abundant flow volumes and high water quality. However, historical and current river flow regulations, and land use change have altered the physical and chemical characteristics of Scottish rivers, with adverse consequences for aquatic biota. Baseline hydrological, geomorphological and water quality conditions in Scottish rivers are thus summarised. The impacts of river regulation and land use change on the hydrology, geomorphology and water quality of Scottish rivers are then discussed. Consequences of these changes for aquatic habitat are examined, with particular reference to the economically significant salmonid species (*Salmosalar* and *Salmotrutta*). Policy and management issues relating to the future ecological quality of Scottish rivers are reviewed. These include the impacts of climate change on ecological quality, the calculation and implementation of ecologically acceptable flows, and river restoration and best management practices within integrated catchment planning. **[23]**

17. Flooding is occurs in Myanmar on an almost annual basis. Floods generally occur during the Southwest monsoon, between the months of June to October. These floods cause appreciable damage to livestock, agricultural crops, roads, bridges and buildings. Flood hazard maps can reduce the flood damage to great extent. However, the techniques for preparation of flood risk maps are still under development, especially in developing countries. The purpose of this study was to develop the technique for preparation of flood hazard maps using data available for a typical river reach. In this paper, flood hazard mapping for the lower part of Chindwin basin of Myanmar has been presented. For this purpose daily stage and discharge data of six gauging stations and topographic maps at a scale of 1: 63,360 scales have been utilized. The preparation of flood risk maps included the following steps:

(i) Computation of different return period flood discharges and stages at six locations using Pooled frequency analysis,

(ii) Digitization of topographical data and preparation of digital elevation model using ArcGIS,

(iii) Simulation of flood flows of different return periods using HEC-RAS, and

(iv) Preparation of flood risk maps integrating the results of (ii) and (iii). **[24]**

18. Emergent vegetation development, wave extinction and soil erosion are strongly interrelated processes in exposed riparian zones. The above-ground parts of the vegetation reduce wave energy, while the below-ground parts strengthen the soil. On the other hand, vegetation development may be restricted as a result of wave stress. Interactions between waves, soil erosion, and emergent vegetation were studied during three consecutive years. Sections on two types of sediment, sand and silty sand, in a wave tank. Erosion of the banks occurred due to down slope transport of sediment. Soil erosion patterns closely reflected the patterns of standing waves over the horizontal part of the bank. Emergent vegetation influenced the erosive impact of waves by both sediment reinforcement and wave attenuation. A smaller amount of net erosion was measured in the wave-exposed sections covered by vegetation than in the unplanted sections. **[25]**

19. Embankment failure and riverbank erosion are common problem in Bangladesh. Almost every year earthen embankments and riverbanks are facing problems like erosion, breaching or retirements. Among many reasons the major causes are considered due to the use of geotechnically unstable materials, improper method of construction, seepage and sliding. In this study the problem is considered geotechnical point of view where the geotechnical properties of failed Jamuna river embankment material and Padma riverbank material were investigated. Moreover, stability analysis technique of embankment has been reviewed through a case study of Manu river embankment. **[26]**

20. Bank erosion induced by alluvial river channel migration often causes problems of encroachment upon valuable farm land, downstream channel deposition and degradation water quality. In populated areas, it could cause

fatalities and property damage if banks collapse abruptly, compromising the integrity of residential buildings and civil facilities. Bank erosion study is in general a very complex problem because it involves multi-processes such as bank surface erosion, bank toe erosion and bank material mechanic failure, etc. Each of these processes is related to several parameters: sediment size distribution, bank material cohesion, slope, homogeneity, consolidation, soil moisture and ground water level, as well as bank height; and the bank erosion rate is also related to the strength of the flow in the river indicated by the flow shear stress, water depth, and channel curvature.[27]

21. The groynes are defined as a structure that was installed at the front of bank or revetment to protect bank or levee against erosion by controlling the flow direction and velocities. It is same in the case of Korea and the definition is approximately same, water and regulation or control. In Korea and Japan, a groyne is classified as when it is placed in a cross direction against flow direction, and as when it is paralleled with flow. In English -speaking countries, a system of protruding structures established in a cross way against flow is 'dikes'; a serial structure paralleled with flow is 'retards' separately. For more information, 'dikes' is sometimes called 'groins(or groynes)', 'jetties', 'deflectors', 'spurs', 'wing dams', but called 'hard points' as a protruded distance would be short. However, in case of European countries, commonly groynes are called groins but dikes can mean in some cases. In addition, also 'retards' are called 'longitudinal dikes', 'parallel dikes', 'jetties', 'guide banks', and 'training walls'.Flow velocity measurement for the groyne zone flow area was carried out by Rajaratnam and Nwachukwu (1983). They measured the flow velocity with two different groyne lengths, divided into $-1 \le x/b \le 6$ and $0 \le y/b \le 3$ (x: length of the river, y; vertical distance from the bank, b; length of the groyne). However, only two types of groynes were not analyzed with respect to the characteristics of the recirculation zone along various lengths of the groyne and the permeability. Tingsanchali and Maheswaran (1990) carried out a numerical analysis of the recirculation zone of a downstream groyne and suggested the main characteristics of the local flow field around the groyne, but adopted only the impermeability groyne and did not concern itself with the downstream flow separation area and the

influence of the groyne on the flow center line. In the latest study carried out by Ettema and Muste (2004), the influence of the downstream recirculation zone of an impermeable groyne and its deposition influence on the flow center line were analyzed, but did not deal with permeable groynes.

Former study about the space of groynes is suggesting that "the space of groynes may have to be maximized to properly protect the bank" and its space (L), length of groyne (l) and its non-dimensional value (L/l) are suggested. Acheson (1968) suggested the space of L/l = 2 ~ 4 for the angle of curvature, it was failed to support precise standard for the relationship between the space of groynes, groyne permeability and cannel curvature. Fenwick (1969) classified the space of groynes along the purpose of installation, for example, L/l = 2 ~ 2.5 for flow control and L/l = 3 for bank protection purpose. Richardson and Simons (1974) suggested L/l = 1.5 ~ 2.0 and L/l = 3 ~ 6 along the condition of installation, for instance, 4 ~ 6 for the straight line or curved groyne with large radius and 3 ~ 4 for curved groyne with small radius. Jansen and others (1979) suggested the space of groyne into Energy equation based on irrigation experiment result.

$$S = C_d d^{1.33} / 2gn^2$$

Experimental energy loss coefficient C_d herein was shown to 0.6. This equation shows a big space and Kinori and Mevorach (1984) suggested to apply this value as an upper limit.

Copeland (1983) suggested no less than L/l = 3 using the length of groyne erosion for bank protection purpose. FHWA (1985) suggested to consider the length, angle, permeability and curvature of curved river of groyne, which was generally ranged in L/l = 1 ~ 6, for the purpose of groyne installation and its protection. The result of research of FHWA expressed the length of river bank protected by each groyne into flow extension angle which indicates the angle from the groyne-tip to the line of bank which ends the recirculation zone. 17 degree for extension angle was suggested for impermeable groyne and extension angle was increasing along the permeability in permeable groyne.

These researches above are the experimental results along the installation purpose(bank protection, flow control, etc), they are, however, failed to suggest the data for the flow characteristics(increasing speed of flow in river zone, vortex phenomenon in groyne zone) at river and groyne zone along the space of groynes.

Recently, the purpose of constructing groynes has greatly diversified with increasing attention to its environmental (ecological) aspects, such as making it serve as a recirculation zone by flow separation in the downstream of the groyne and scour holes by local scour, which can be utilized as diverse underwater habitats and shelters for fish in the event of flood. Klingeman et al(1984) suggested the possibility that scour holes around a groyne could contribute to improving the underwater ecosystem regardless of safety concerns, and Knight and Cooper(1991) also argued that "groyne provide habitats such as swampy land and generally has more advantages as ecological environment than any other known bank-protective structures". Shields et al (1995) argued that the important advantages for enhance aquatic habitat in unstable stream is related to scour holes. The majority of scour-related experiments to date mainly focus on establishing an estimation formula for the maximum scour depth. Recently, more attention has been increasingly paid to those studies working on the scour field. Recently, Thompson (2002) conducted experiment with two differently sized but identically designed scours, argued that at a water level higher than the bank at full stage, a bigger groyne that can naturally make diverse forms of big and deep bogs are more advantageous from the ecological point of view. However, studies on existing groyne areas are lacking.

In **Switzerland**, usually groyne is applied to the river regulation, and groynes considering river environment are established in Thru River in Zürich state. ThurRiver is one of the main rivers managed by Zürich state. Thur River originating from Mount.Santis has about 1,700 m^2 basin and it is close-to-nature comparatively. In the course of nature, concave and convex bankline was created by establishing the series of groynes at almost straightened channel and created bar in groynes downstream created habitats for protected birds, where is restored nature-friendly conditions. Previous model experiments were not practiced, but a groyne was established as an experiment in field. Design engineers were not sure because it was very venturous to construct, but at this moment the stability and effect of a groyne are verified from three-time floods in the past.

In **Japan** early technique of groyne is used for river training works, the history of river training works using groynes is found in a reference in the early of 17 century. Particularly methods of construction for groynes were developed and improved for 30 years since 1920. Therefore the theory for groynes was elaborate, and various methods of construction were developed and applied. For 4 years 1949 to 1953, the construction of groynes was operated to repair damages on a riverbank at 39 sites in 184 ～ 120 km section of Tone River. The bankline created by groynes established in Tone River (121 ～120 km section) and Ibi River (9 ～10 km section) respectively. However, after this period techniques for groynes stagnates and application of groynes reduced, but groynes were constructed to take an action only for maintenance or disaster. The change of measures for attack point in downstream of Tone River. Groynes reduced since 1960's and were not constructed after 1970's. The use of Groynes was replaced to Footing techniques using concrete block. This is a trend not only in Tone River but also most of all rivers in Japan, and groynes for bank protection are not used any more. **[28]**

22. River bank erosion occurs both naturally and through human impact. Rivers and streams are dynamic systems as they are constantly changing. The natural process of riverbank erosion can produce favorable outcomes such as the formation of productive floodplains and alluvial terraces. Even stable rivers have some amount of erosion occurring, however, unstable rivers and the erosion taking place on those banks are a cause for concern. River bank erosion is a perennial problem in Bangladesh causing loss of lands and livelihood along major rivers. Structural and non-structural interventions are needed to prevent potential loss of land and livelihoods. Riverbank erosion is possible at any riverbank site. Past records of erosion or lack of erosion are not good indicators of the potential for future erosion at any particular site. Records of riverbank erosion are not kept but past aerial photographs may give an indication of past erosion. Long serving staff will have knowledge of some historical erosion sites.[29]

23. Bank protection is needed where there is the risk of erosion of the bank and where this erosion would cause economic or environmental loss. If there is sufficient space available, it may be possible to reduce the need for bank protection by re-profiling the bank to a flatter slope to reduce velocities and encourage good vegetation growth. Even if bank protection is still required, it may be less severe if a flatter slope can be achieved, or may only be required below normal water level. Where it is needed, erosion protection for a bank can range from a good grass cover to heavy concrete slabs, but is broadly categorized as 'hard' or 'soft'. Soft bank protection is generally considered to be vegetation of various types, whereas hard bank protection consists of concrete block work, riprap or similar. This is not a universally accepted definition as, in some parts of the country, riprap is termed 'soft' (because it is locally sourced and more natural than concrete), with 'hard' being reserved for the likes of piling and solid concrete walls.

Retaining walls are required to protect and enhance the shoreline. This is usually the case when severe erosion has taken place or where building foundations have been built too close to the water and are threatened by shoreline erosion .A retaining wall is basically a vertical structure that is implemented to hold back a slope and prevent further shoreline erosion. The use of sheet steel or cement in retaining walls is the common building material, but produces a sterile, vertical, flat-faced structure, which is of little use for fish or other aquatic organisms.

Furthermore, retaining walls tend to deflect energy rather than dissipate it, which usually results in erosion problems elsewhere. Thus, the use of vertical retaining walls for shoreline stabilization is not encouraged and generally not approved .However, where vertical retaining walls are the only option, they are more stable if stone riprap is placed at the foot of the wall to prevent erosive forces from cutting under the wall and the stone riprap should be placed to form a 45-degree angle to the wall.

Gabion walls and baskets involves the placement of baseball to football-sized rocks into closed wire cages and then placing these structures along the shoreline .Gabion baskets are an effective and relatively inexpensive type of shoreline stabilization, they are easily transported and installed, can be purchased in various sizes to accommodate the project, and little maintenance is required after installation .Unfortunately, the durability of these baskets is questionable when they are exposed to the elements and can pose a serious health risk to uneducated people using an area where these have been installed .Other associated problems with gabion baskets include the ability to find the appropriate gabion rock for the project, and this type of method is limited to intermittent flows and small drainage areas .Lastly, the fish habitat provided by gabion baskets is marginal and the use of this type of technique for shoreline stabilization is generally not encouraged anymore

Geotextile tube technology continues to evolve as a versatile construction alternative for both shoreline protection and restoration applications. This concept is basically a horizontally lying geotextile tube that is deployed near the shoreline and then filled with soil or debris to reduce wave action and erosion. This type of method is utilized in coastal protection, river construction, erosion management, and in foundation engineering. Most projects rely on sand-filled geotextile tubes as a main structural component, but some include a geotextile armour layer to increase durability and aesthetics of a restoration project. Geotextile tubes, when uncovered, are susceptible to debris damage and this is why many projects include the armourlayer.Furthermore, a woven, vinyl-coated, polyester fabric has been used in many projects to act as the armour layer because it is superior to woven polypropylene and doesn't t have the negative aesthetic disadvantage. One interesting aspect of this stabilization method is the ability to use biodegradable materials in the construction of the geotextile tube and armour layer. The tube casing is designed to degrade over a period of years, adding biomass to the fill material and the tube produces natural vegetation and adapts to the surrounding environment. This technique is growing rapidly in restoration and shoreline stabilization projects and has many beneficial uses in wetland restoration and river & estuary shoreline protection due to the fact it utilizes hard and soft engineering techniques.**[30]**

24. Sediment transport is a direct function of water movement. During transport in a water body, sediment particles become separated into three categories: suspended material which includes silt + clay + sand; the coarser, relatively inactive bed load and the saltation load.

Suspended load comprises sand + silt + clay-sized particles that are held in suspension because of the turbulence of the water. The suspended load is further divided into the wash load which is generally considered to be the silt + clay-sized material (< 62 μm in particle diameter) and is often referred to as "fine-grained sediment". The wash load is mainly controlled by the supply of this material (usually by means of erosion) to the river. The amount of sand (>62 μm in particle size) in the suspended load is directly proportional to the turbulence and mainly originates from erosion of the bed and banks of the river. In many rivers, suspended sediment (i.e. the mineral fraction) forms most of the transported load.

Bed load is stony material, such as gravel and cobbles that moves by rolling along the bed of a river because it is too heavy to be lifted into suspension by the current of the river. Bed load is especially important during periods of extremely high discharge and in landscapes of large topographical relief, where the river gradient is steep (such as in mountains). It is rarely important in low-lying areas. Measurement of bed load is extremely difficult. Most bed load movement occurs during periods of high discharge on steep gradients when the water level is high and the flow is extremely turbulent. Such conditions also cause problems when making field measurements. Despite many years of experimentation, sediment-monitoring agencies have so far been unable to devise a standard sampler that can be used without elaborate field calibration or that can be used under a wide range of bed load conditions. Even with calibration, the measurement error can be very large because of the inherent hydraulic characteristics of the samplers and the immense difficulty with representative sampling of the range of sizes of particles in transit as bed load in many rivers. Unless bed load is likely to be a major engineering concern (as in the filling of reservoirs), agencies should not attempt to measure it as part of a routine sediment-monitoring programme. Where engineering works demand knowledge of bed load, agencies must acquire the specialized expertise that is essential to develop realistic field programmes and to understand the errors associated with bed load measurement.

Saltation load is a term used by sedimentologists to describe material that is transitional between bed load and suspended load. Saltation means "bouncing" and refers to particles that are light enough to be picked off the river bed by turbulence but too heavy to remain in suspension and, therefore, sink back to the river bed. Saltation load is never measured in operational hydrology. [31]

Gaps found in the Literature Review

It is observed that there has been no scientific study carried out for comprehensive environment management of the Chindwin River in the past. The measurement on water quality, sedimentation etc are available only in selected reaches and works have been undertaken in the past as per requirements. Thus there is requirement of detailed study on its environmental management plan.

Objectives

Based on the above literature review and gaps found in earlier studies, the objectives of the present study are as follows:

1. Study on water quality of Chindwin river.
2. Study on catchment characteristics of the river.
3. Study on sedimentation and bank erosion.
4. Study on water depth for navigation purpose.
5. Preparation of comprehensive environment management plan of Chindwin river including design / remedial measures along with cost estimate.

Methodology

To achieve above objectives, following methodology shall be adopted:

1. Collection of data on water quality parameters of the river from various offices.
2. Collection of water samples from the selected reaches.
3. Analysis of water samples for water quality parameters.
4. Computation of NSFW QI based on collected as well as analyzed water quality parameters for assessment of water quality.
5. Collection of data on discharge, L-section, X-section of the river.
6. Analysis for finding problem stretches of river related to bank erosion and sedimentation.
7. Design / proposal for river training measures to check bank erosion and sedimentation.
8. Cost estimates of proposed remedial measure.

THE CHINDWIN RIVER

3.1 PROFILE OF CHINDWIN RIVER

Chindwin River is the largest and most important tributary of the Ayeyarwady river. The Chindwin runs into the Ayeyarwady River above Pakokku by several mouths. The Chindwin river with its tributaries is practically the only possible way of communication within the basin, and it also communicates the basin with the main economically developed areas of the country. Upper reach of the river before entering the Hukaung valley is known as the Tanai Hka. After entering the Hukaung valley, it receives several tributaries and bears the name of Chindwin.

The source of the Chindwin River is situated on North Latitude 25^0 40' and East Longitude 97^0 00'. The Chindwin basin is continuous to that of upper Ayeyarwady in the East and North – East; and to the Brahmaputra basin in the West and North – West. The basin of the river is, in general a mountainous forested terrain with the only exception of its lowest Southern part which is a vast plain. The whole basin is equal to some 124320 square kilometer in area. The highest mountains are to be found to the West and the North of the basin where they reach 3000 meter or more. From the East the watershed passes a mountain chain of 700 meter to 1500 meter high. The basin is constituted mainly by tertiary continental sediments. Among them more frequently found are sandstones of different hardness, less frequent are clay with gypsecus veins, shales and limestones.

As mentioned earlier, the Chindwin river runs between mountainous ridge and only below Kalewa it comes out to the flat plain. The river channel is tortuous. The banks are high and rocky. The bank line in many places is uneven. The main tributaries of the Tanai Hka within the valley are Tarung Hka and Tawang Hka. Both of them run into Tanai Hka from the Northern right bank. On leaving the Hukaung valley, the Chindwin river changes its course and runs to South. Upto 840 kilometer length it runs in the defile abundant in rapids and small waterfalls. Ongoing out of the defile the Chindwin river receives one of its tributaries – Nampuk Hka. The valley of the river in this place gets wider and width of the river also increases. Major tributaries of which the Chindwin river receives are: Namtaleik chaung and Thamanthi, UYu river 6 kilometer below Homalin, UYu river 48 kilometer above

Mawlaik and the most largest tributary Myittha river at Kalawa. The valley of the river gradually gets expended, but on the background of such expansion there take place an abrupt contraction of channel in certain place. A typical example is Shwezaye: the clam, broad passage of the river across open country is interrupted by a barrier of cliff of volcanic ash, through which the river cuts a narrow channel, only about 120 meter in breath.

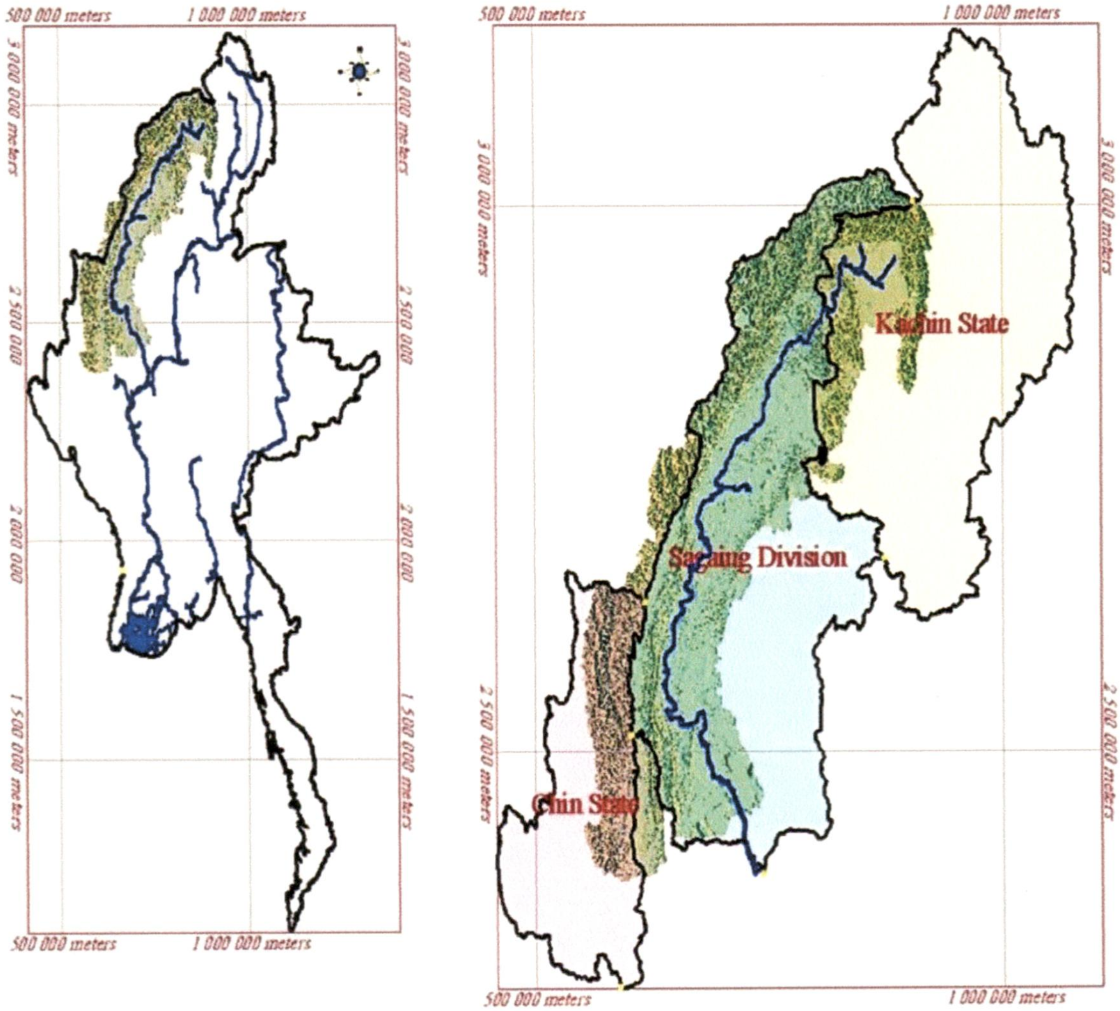
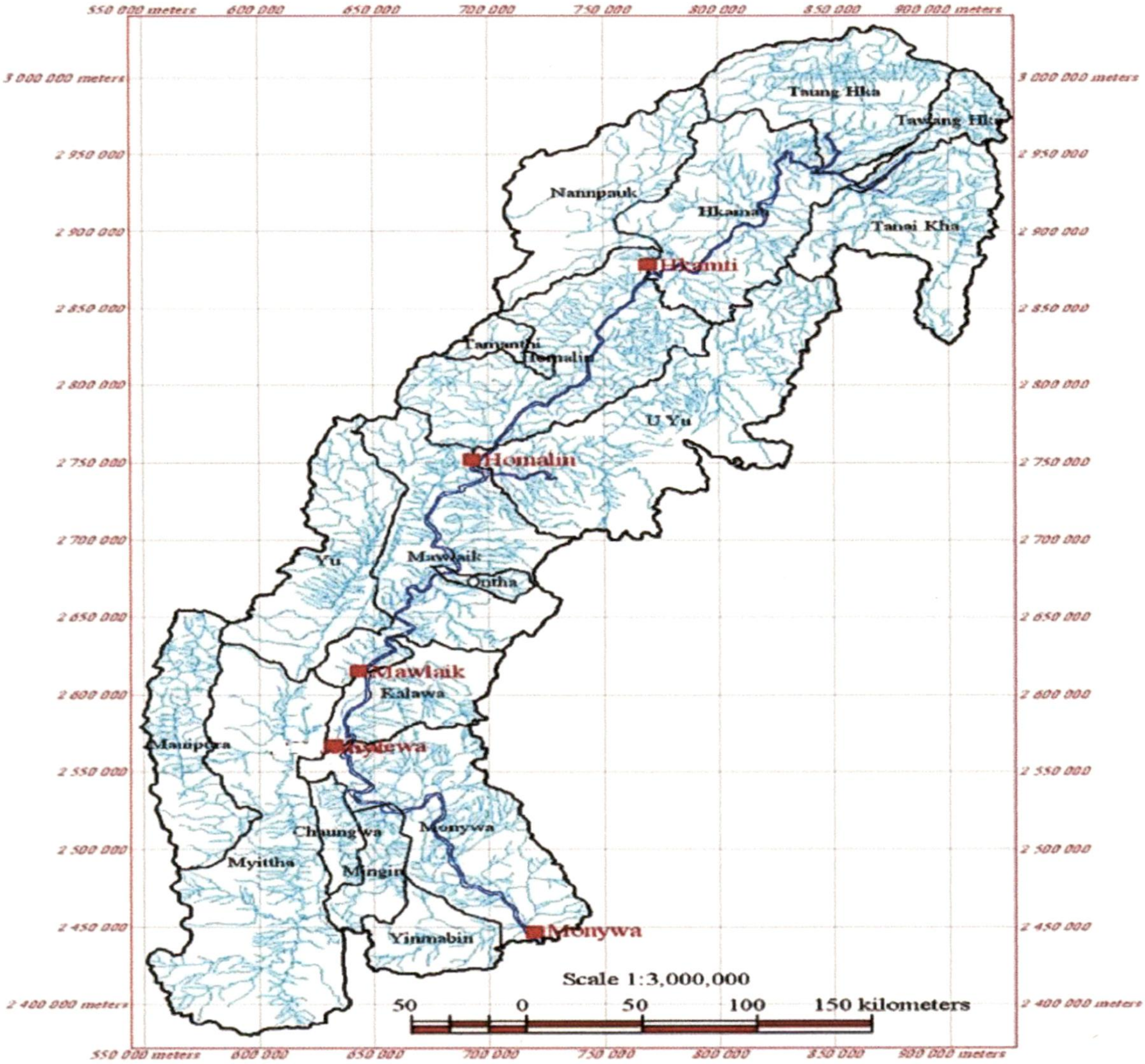


Figure 3.1: Chindwin River Basin



Soruce : Quarter inch Topographic Map (Reprinted in 1964)
Prepared by : RS & GIS Section.
Sclae : 1 : 253,440 250 ft Contour Interval
Planning & Statistics Division Forest Department

Figure 3.2 : Location Map of Observation Stations of Chindwin Basin

The river bed is rocky and is covered with alluvial deposits of various thickness. In its upper reaches the Chindwin river has the gradient around 0.0003 and in the down reaches it is around 0.00005. Rocky islands and spits can often be found in the channel. The river bed and sides in the lower stretch of Chindwin are mostly constituted by soft, easily eroded rocks. The width of the river is not stable and varies from 180 – 200 meter to 3000 meter. On this stretch of the river, the channel is highly branched and abounds in sandy island and spits. The Chindwin river becomes braided below Monywa.

Approximately 1100 kilometer long Chindwin River is navigable from Hkamti to confluence with the Ayeyarwady river over a distance of 816 kilometer. The upper portion of the river to Hukaung valley is not navigable mainly on account of the rapids. According to the climatic conditions it is possible to arrange navigation on the Chindwin river all the year round. However, due to considerable current velocities during the monsoon period and shallow depths in low water season, the navigation is confined. A large number of snags and great amount of silt are brought into the Chindwin river by its tributaries. The Uyu and the Myittha rivers are main suppliers of slit and snags.

It should be noted that Chindwin river basin is narrow and this specifies fast coming of rain waters to the main channel of the river and forming of high maximum discharge. The rainfall records the average run-off of the Chindwin for several years was estimated at 76 million acre/feet, the annual run-off variation ratio being 0.30 at the mouth and 0.50 at the upper reaches. The runoff is formed mainly in the upper part of the basin with the average precipitation of 3650 millimeter per year. Lower course precipitation is only 810 millimeter per annum. Average basin rainfall at Monywa is calculated as 2370 millimeter. Floods raise the water level in the river from 8 meter to 17 meter as compared to the low water level.

Tanai Hka River, before bearing the name of Chindwin, flows on the height of about 2150 meter to 215 meter within the distance of only 130 millimeter and enter the Hukaung valley. It is clear that the current velocity is too high in this river stretch. Apart from the Tanai Hka river stretch, Chindwin river is navigable without imposing the constraint due to current velocity except for few places in the river reaches. The velocity regime in contraction during high peaks of flood is extremely complicated. For example, a large whirlpool is formed near the left bank at the entrance to the Shwezayae defile. In the defile itself there takes place a cross current circulation of the flow. The velocities in this place at maximum current velocity up to 3.67 meter per second.

The Chindwin River carries a considerable amount of silt suspended matter. The volume of silt in the Chindwin river sharply decreases further upstream from its confluence with Uyu river. Considerable portion of silt forms in the lower reaches due to soil wash out and bank erosion. Based on the size of drainage area, transport of annual suspended sediment and annual bed material transport have been estimated at 131 million tons and 28.6 million tons receptively at the mouth of Chindwin river.

The fall velocity of the representative grain size, D_{50}, on the lower reach of the Chindwin river is 6.0 centimeter per second, whereas the fall velocity of the Ayeyarwady river is approximately 3.5 centimeter per second. This indicates that the current velocity on the lower Chindwin river needs to be higher than on the Ayeyarwady river in order to transport its bed material.

At present the Chindwin is being used as water transport for communication between the areas of the basin and the central part of the country. The number of passengers transported annually is equal to 100,000 and cargo including timber - 200,000 tons. Economically the basin is poorly developed, although it possesses a variety of natural resources –coal, copper, ore, oil, timber, etc.

3.2 Navigation for Water Transportation

3.2.1 Hkamti – Homalin Stretch

The Hkamti – Homalin Stretch of the river is characterized by numerous abrupt bends, rocky cusps of the shore line which stipulate the formation of strong cross-current velocities and whirl-pools. In two places at the villages of Kado and Limpha the channel is divided by rocky islands into branches .There are many sandy and rocky spits. The river breadth changes approximately from 300 to 2000 feet. The minimum discharges may be estimated at 2800 – 3500 cusecs. The depths along the fairwater during low water season fall to 2-8.5 feet on some shoals. Due to the depths the shoals set limits for navigation.During high water period the navigation on this reach gets complicated by high current velocities coming to 9-10 feet per sec.

3.2.2 Homalin – Kalawa Stretch

The Homalin – Kalawa Stretch of the river has a wider but also tortuous channel. The width of the river ranges from 1000 to 4000 feet. The minimum discharges below the Uyu come to 5990-6650 cusecs. The depths along the fairwater are comparatively stable and decrease on certain shallows to 2.5 feet. The Homalin shallow situated in the area of the Uyu River junction and spread over some 10-12 miles long is most difficult. This complicated shallow in the form of a scattering is likely to have been formed as a result of large expansion of the channel and super-saturation of the flow by the Uyu River silt. Below this reach there are a few shoals in the area of the villages, Natset, Taungdoot, Yaphin, Mokpha and Matu.

3.2.3 Kalawa – Mouth Stretch

The Kalawa – Mouth stretch of the river is most difficult for navigation, especially in the mouth reach below Monywa. The channel from Kalawa to Shwezaye for a distance of 130 miles is meandering and comparatively wide. During high water season strong velocities and whirlpools can be found in the contraction below Kalawa and at the villages of Thibaw-Kabyit where there is a rocky island in the channel, and rocky reefs along the left side being a result of the erosion of the rocky bank. There is an abrupt contraction of less than 700 feet wide at the village of Shwezaye. At high discharges whirlpools are formed above it. The velocities in the contraction itself are likely to reach 12 feet per second and more.

Below Shwezaye for a distance of 70 miles the channel presents a continuous chain of contractions and expansions. The width of the channel in places amounts to 10,000 feet. The fair-water is extremely tortuous and shifting. Its position changes every year and some years – several time per annum. The navigable channel is highly congested with rocky obstacles and snags. The intensive erosion of the banks is going on in this stretch of the river. As a result of that a few towns and villages situated along the bank were shifted. The areas of the towns of Alon, Sadon, Amyint and the mouth are the most difficult passages on this stretch of the river. Full improvement of the channel will be required to stabilize the fairwater on this stretch.

Table 3.1: Average Annual Rainfall Chindwin River Basin

Station	Occupied Area (Sq.Km)	% of Station Occupied Basin Area to whole	Station Annual	Basin Annual
Mindat	3210	2.91	1575.2	45.8
Gangaw	9993	9.06	1286.9	116.6
Monywa	4789	4.34	806.3	35.0
Falam	4401	3.99	1573.0	62.8
Kalewa	8000	7.26	1637.1	118.9
Mawlaik	14394	13.05	1726.0	225.2
Pinlebu	4789	4.34	1502.2	65.2
Homalin	23171	21.04	2173.7	456.7
Hkamti	37539	34.04	3651.3	1242.9
Total	**110286**	**100.00**		**2369.1**

* Rainfall Unit in Millimeter.

Table 3.2: Minimum Depths of Chindwin River

River/ Stretch	Limited Draught (Meter)	Location (Km)*	JAN.	FEB.	MAR.	APR	MAY	NOV	DEC
			Depth in Month (Meter)						
Homalin-Kalewa	0.9	364	1.2	1.1	1.1	1.4	1.5	3.0	2.3
Kalewa-Monywa	1.0	203	1.2	1.2	1.2	1.2	1.5	1.5	1.3
Monywa-Confluence	0.9	87	1.2	1.2	1.2	1.4	1.4	1.7	1.4

Chindwin Kilometerage from confluence of Chindwinn and Ayeyarwady

Table 3.3: Recession Characteristics (RC) of Lowest Water Level

State	RC	Oct/ Nov.	Nov/ Dec	Dec/ Jan	Jan/ Feb	Feb/ Mar	Mar/ Apr	Apr/ May
Mawlaik	r	0.79	0.85	0.96	0.93	0.92	0.90	0.83
	a	29.21	64.84	-8.61	-24.92	-3.66	11.80	15.79
	b	0.573	0.490	0.828	0.983	0.914	0.933	1.117
Kalewa	r	0.68	0.89	0.91	0.71	0.78	0.91	0.85
	a	71.179	87.524	46.150	17.457	39.982	61.773	21.475
	b	0.517	0.491	0.639	0.793	0.650	1.396	1.027
Monywa	r	0.68	0.89	0.91	0.71	0.78	0.91	0.85
	a	71.179	87.524	46.15	17.457	39.982	-61.77	21.475
	b	0.514	0.491	0.639	0.739	0.650	1.396	1.027

* Regression Equation: $Y = a + bX$ r: Correlation coefficient

Y : Lowest W.L. of coming month X : Lowest W.L. of present month

Table 3.4: Hydraulic Geometrical Relations (Chindwin River System)

Station	Velocity vs. Discharge $V = kQ^m$		
	k	m	r^3
Hkamti	0.056	0.374	0.991
Tamanthi	0.026	0.460	0.996
Homalin	0.024	0.454	0.991
Pyaungpyin	0.008	0.576	0.996
Mawlaik	0.381	0.134	0.927
Kalewa	0.016	0.522	0.993
Monywa	0.005	0.612	0.999

Table 3.5: Rating Curves (Chindwin River System)

Stations H_x	H_Y	A	B	C	SE	t_l
Mawkaik	Monywa	-0.225	1.201	_ 0.035	0.309	2
Kalewa	Monywa	-0.085	0.925	_0.020	0.232	2
Monywa	Nyaung U	0.541	0.959	0.013	0.600	3

General form of rating curve: $H_Y = A + B.\ H_X + C.H^2$

SE = Standard error of estimate (M)
H_x and H_y in meter (M).
t_l = Timelag in day (s)

Table 3.6: Rating Curves (Chindwin)

River/Station	(F or M)	A	B	C	*SE
Hkamti	M	-776.9	413.0	46.2	249.5
Thamanthi	M	-63.7	-27.7	53.4	161.2
Homalin	M	69450.6	-6903.9	172.5	165.7
Mawlaik	M	-80.6	222.1	92.0	107.3
Kalewa	F	365.1	25.8	67.1	
Kalewa	M	1030.1	-258.4	86.7	363.3
Monywa*	M	2186.1	-1394.0	325.5	1179.0
Monywa**	F	402.9	18.9	120.7	

(1) F Rating curves based on analysis of field data and M Rating curves as provided by Department of Meteorology and Hydrology
(2) General equation is Q = A + B.H + C. H **2.
(3) *SE : Standard error of estimate (Cubic meter per second)
(4) Monywa* : For low after Monywa** : For high water

Table 3.7: Annual – Runoff

Gauging Station	Drainage Area (sq.km)	Annual Runoff in (10^6 m^3)		
		Minimum	Mean	Maximum
Mawlaik	69339	79005	123700	155540
Kalewa	72848	84321	132666	174827
Monywa	110350	103821	155624	207238

Table 3.8: Bed Material Grain Size Distribution Along the Chindwin (Mawlaik – Confluence)

Sample No.	Location [km]	D_{10} [um]	D_{15} [um]	D_{50} [um]	D_{85} [um]	D_{90} [um]
1	380	203	243	438	658	779
2	374	95	138	221	376	384
3	370	154	167	251	385	391
4	360	39	70	301	2,192	3,435
5	350	251	324	519	790	845
6	330	225	300	812	2,783	2,662
7	330	191	284	558	933	1,082
8	320	282	392	542	720	879
9	300	210	257	460	692	776
10	290	180	202	322	364	655
11	270	188	208	296	458	303
12	260	80	154	532	2,457	3,528
13	260	736	957	2.768	5,992	6,453
14	250	102	134	210	371	379
15	228	336	434	604	936	1032
16	223	190	211	287	415	445
17	220	157	175	679	2,012	2,243
18	210	37	50	218	526	570
19	190	151	161	242	380	384
20	180	204	247	448	593	693
21	170	25	40	100	467	520
22	160	334	437	844	3,288	4,312
23	150	186	203	277	403	413
24	143	216	263	483	3,874	7,240
25	142	197	225	433	558	598
26	139	216	305	785	6,177	6,947
27	135	82	96	203	470	542
28	130	158	200	477	830	1,037
29	110	17	96	650	3,042	3,746
30	90	196	222	317	521	561
31	90	205	243	427	682	783
32	64	231	298	697	3,705	4,780
33	20	193	214	283	404	414
34	30	183	199	273	399	408
35	40	86	158	284	526	595
36	50	164	182	281	460	545
37	50	164	177	255	383	386
38	60	159	170	248	380	383
39	70	191	211	278	397	404
40	80	210	298	866	3,396	4,177
STATISTICAL CHARACTERISTICS						
Mean		192	234	477	1,274	1,583
Stand. Deviation		115	148	422	1,517	1,964
Coeff. of Variation		0.6	0.6	0.9	1.2	1.2

Table 3.9: Channel Geometry Derived From Measured Cross-Section Chindwin River

Cross Section No.	Location (km)	Width (m)	Depth (m)	Area (m)	Width/Depth Ratio (-)
1	10	680	390	2,100	220
2	20	620	2.42	1,503	256
3	30	405	1.17	473	346
4	40	370	4.54	1,680	81
5	50	135	2.19	295	62
6	60	410	1.50	615	273
7	70	230	3.47	798	66
8	80	505	1.48	747	341
9	90	670	2.17	1,454	309
10	100	515	4.70	2,418	110
11	110	340	5.73	1,948	59
12	120	480	6.92	3,320	69
13	130	240	12.98	3,114	18
14	135	600	2.36	1,417	254
15	139	640	1.78	1,138	360
16	140	345	2.16	744	160
17	143	575	1.78	1,022	323
18	148	405	2.86	1,160	142
19	150	700	2.10	1,473	333
20	160	590	2.03	1,200	291
21	170	510	4.41	2,247	116
22	180	470	3.41	1,603	138
23	190	195	3.18	621	61
24	200	440	2.59	1,138	170
25	205	593	2.72	1,612	218
26	210	208	5.88	1,224	35
27	220	525	1.85	970	284
28	226.5	380	2.05	779	185
29	227.5	710	1.63	1,157	436
30	230	338	7.77	2,625	44
31	240	470	3.06	1,437	154
32	250	390	3.48	1,359	112
33	260	725	2.23	1,614	325
34	270	500	2.16	1,082	231
35	280	555	4.37	2,428	127
36	290	305	2.65	808	115
37	300	425	1.93	819	220
38	310	245	5.63	1,380	44
39	320	620	1.67	1,034	371
40	330	465	2.09	974	222
41	340	515	3.51	1,809	147
42	360	420	5.52	2,205	76
43	370	345	5.23	1,805	66
44	374	325	2.74	892	119
45	380	375	4.07	1,528	92

CHINDWIN RIVER WATER QUALITY ANALYSIS

4.1 INTRODUCTION

Earth, the Water planet is the only one in our solar system presently characterized and shaped by abundant liquid water a necessity for life. This vital resource makes up 60 percent of the human body. A person can live no more than 4 to 5 days without water, and we rely on it for drinking, cooking, bathing, washing clothes, growing food, recreation, industry, and mining, as well as generation of electric power. Like the air we breathe, water is essential to our daily life.

Water is a major factor in shaping our landscape. Through the processes of erosion and sediment transport, water forms many surface features such as valleys, flood plains, deltas, and beaches. Water also forms subsurface features such as caves. Natural wonders such as the Grand Canyon were, and are being, carved by water. Streams from upland areas carried much of the sand that is located on ocean beaches. Water is a renewable resource.

However, it is not always available when or where it is needed, and it may not be of suitable quality for intended uses. Although we commonly take for granted that clean and abundant water is as close as the nearest faucet, water resources can be depleted or contaminated with pollutants. Having too much water (floods) or not having enough (droughts) may have serious consequences for people, wildlife, and their habitats. Providing sufficient quantities of good quality water is a major factor in creating the life style we enjoy in the Myanmar.

4.1.1 Why Water is Important

Water is essential to life. It is part of the physiological process of nutrition and waste removal from cells of all living things. It is one of the controlling factors for biodiversity and the distribution of Earth's varied ecosystems, communities of animals, plants, and bacteria and their interrelated physical and chemical environments.

In terrestrial ecosystems, organisms have adapted to large variations in water availability. Water use by organisms in desert ecosystems is vastly different from those in forest ecosystems. For example, some seeds lie dormant for years in arid climates waiting to be awakened by a rare precipitation event. In contrast, a large oak tree in a temperate climate returns about 4,000 gallons of water a year to the atmosphere.

Through the process of transpiration, plants give off moisture largely through their leaves.

Aquatic ecosystems, such as wet- lands, streams, and lakes, are especially sensitive to changes in water quality and quantity. These ecosystems receive sediment, nutrients, and toxic substances that are produced or used within their watershed - the land area that drains water to a stream, river, lake or ocean. As a result, an aquatic ecosystem is indicative of the conditions of the terrestrial habitat in its watershed.

Wetland ecosystems provide habitat to a great variety of birds, plants and animals. These transitional areas between dry and wet habitats help reduce floods and abate water pollution. They also support many recreational activities and commercial fisheries and provide a number of other important functions.

Nearly every activity that occurs on land ultimately affects groundwater or sur face waters. Water plays a major role in shaping the land surface of the Earth.

Canyons, flood plains, terraces, underground and in the atmosphere. Most of the water on Earth, (approximately 97.5 percent) is salt water located mostly in the oceans, and only 2.5 percent is fresh water. The fresh water available for our water needs is less than 1 percent of Earth's supply. The problem is that fresh water is not evenly distributed on Earth. Some desert areas, like Kuwait, have very limited fresh water resources, whereas rain forest areas, such as in Papua New Guinea, can have as much as 30 feet of rainfall in a year! Approximately 88 percent of the Earth's fresh water is frozen in polar ice caps and glaciers, making it unavailable for use of the remaining fresh water supply, most is groundwater.

The uneven distribution of water resources has been an important control on human habitation and development throughout history. Societies have struggled to control water resources, human migrations have been made to obtain water resources, and litigation is commonly used to resolve conflicting water needs.

4.1.2 River Water Pollution

A river is defined as a large natural stream of water emptying into an ocean, lake, or other body of water and usually fed along its course by converging tributaries. Rivers and streams drain water that falls in upland areas. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world.

A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic) are concentrated along the rivers. Industries and cities have historically been located along rivers because the rivers provide transportation and have traditionally been a convenient place to discharge waste. Agricultural activities have tended to be concentrated near rivers, because river floodplains are exceptionally fertile due to the many nutrients that are deposited in the soil when the river overflows.

4.1.3 Sources of Pollution

Farmers put fertilizers and pesticides on their crops so that they grow better. But these fertilizers and pesticides can be washed through the soil by rain, to end up in rivers. If large amounts of fertilizers or farm waste drain into a river the concentration of nitrate and phosphate in the water increases considerably. Algae use these substances to grow and multiply rapidly turning the water green. This massive growth of algae, called eutrophication, leads to pollution. When the algae die they are broken down by the action of the bacteria which quickly multiply, using up all the oxygen in the water which leads to the death of many animals.

Chemical waste products from industrial processes are sometimes accidentally discharged into rivers. Examples of such pollutants include cyanide, zinc, lead, copper, cadmium and mercury. These substances may enter the water in such high concentrations that fish and other animals are killed immediately. Sometimes the pollutants enter a food chain and accumulate until they reach toxic levels, eventually killing birds, fish and mammals.

Factories use water from rivers to power machinery or to cool down machinery. Dirty water containing chemicals is put back in the river. Water used for cooling is warmer than the river itself. Raising the temperature of the water lowers the level of dissolved oxygen and upsets the balance of life in the water. People are sometimes careless and throw rubbish directly into rivers.

4.1.4 River Water Quality & Environmental Factors

River water quality is highly variable by nature due to environmental conditio ns such as basin lithology, vegetation and climate. In small watersheds spatial variations extend over orders of magnitude for most major elements and nutrients, while this variability is an order of magnitude lower for major basins. Standard river water for use as reference is therefore not applicable. As a consequence natural waters can possibly be unfit for various human uses, even including drinking. There are three major natural sources of dissolved and soluble matter carried by rivers: the atmospheric inputs of material, the degradation of terrestrial Organic matter and the weathering of surface rocks. These substances generally transit through soil and porous rocks and finally reach the rivers. On their way, they are affected by numerous processes such as recycling in terrestrial biota, recycling and storage in soils, exchange between dissolved and particulate matter, loss of volatile substances to the atmosphere, production and degradation of aquatic plants within rivers and lakes etc. As a result of these multiple sources and pathways, the concentrations of elements and compounds found in rivers depend on physical factors (climate, relief), chemical factors (solubility of minerals) and biological factors (uptake by vegetation, degradation by bacteria). The most important environmental factors controlling river chemistry are:

Occurrence of highly soluble (halite, gypsum) or easily weathered (calcite, dolom ite, pyrite, olivine) minerals

Distance to the marine environment which controls the exponential decrease of ocean aerosols input to land (Na^+, Cl^-, SO^-, and Mg^{2+}).

Aridity (precipitation/runoff ratio) which determines the concentration of dissolved substances resulting from the two previous processes. Terrestrial primary productivity which governs the release of nutrients (C, N, Si, K).

Ambient temperature which controls, together with biological soil activity, the weathering reaction kinetics.

Uplift rates (tectonism, relief) Stream quality of unpolluted waters (basins without any direct pollution sources such as dwellings, roads, farming, mining etc).

4.2 Chindwin River Water Quality Analysis

4.2.1 Discharge Data

Discharge is also very important in case of water quality because if discharge is high then the water quality is bad but if discharge is low then the water quality is good. For example : in Moon-soon period i.e. from June to October the water quality of the Chindwin river is bad but in the Non-monsoon period the water quality of Chindwin river is good.

Three gauge discharge sites data namely Kalawa, Mawliak and Monywa were collected for analysis of the water quality change effect. The data collected are shown in Table 4.1, 4.2 and 4.3 respectively.

The discharge at **Kalawa** station has been calculated by using the following equation.

$$Q = A + B*H + C*H*H$$

Where,

A = 365, B = 25.8, C = 67.1

Q is discharge (m^3/s), H = Water Level (m)

Table 4.1: Discharge at Kalawa Station

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
1-Jan	272	932	2.24	760	2.51	853
2-Jan	271	928	2.24	760	2.5	849
3-Jan	269	920	2.24	760	2.47	838
4-Jan	266	909	2.23	756	2.44	828
5-Jan	264	901	2.2	747	2.42	821
6-Jan	262	893	2.2	747	2.41	817
7-Jan	261	890	2.19	743	2.39	810
8-Jan	258	878	2.18	740	2.37	803
9-Jan	257	875	2.17	737	2.35	796
10-Jan	257	875	2.15	731	2.33	789
11-Jan	257	875	2.15	731	2.31	783
12-Jan	256	871	2.08	709	2.3	779
13-Jan	256	871	2.08	709	2.29	776
14-Jan	255	867	2.04	697	2.27	769
15-Jan	254	864	2.03	694	2.25	763
16-Jan	252	856	2.01	688	2.23	756
17-Jan	250	849	1.99	682	2.22	753
18-Jan	247	838	1.97	676	2.21	750
19-Jan	243	824	1.95	671	2.2	747
20-Jan	242	821	1.92	662	2.19	743
21-Jan	241	817	1.89	654	2.17	737
22-Jan	241	817	1.87	648	2.16	734
23-Jan	240	814	1.85	642	2.16	734
24-Jan	240	814	1.84	640	2.15	731
25-Jan	235	796	1.83	637	2.14	728
26-Jan	235	796	1.82	634	2.12	721
27-Jan	235	796	1.81	632	2.11	718
28-Jan	234	793	1.8	629	2.1	715
29-Jan	233	789	1.79	626	2.08	709
30-Jan	229	776	1.77	621	2.06	703
31-Jan	225	763	1.76	618	2.05	700
1-Feb	221	750	1.75	616	2.02	691

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
2-Feb	218	740	1.74	613	2	685
3-Feb	216	734	1.72	608	1.99	682
4-Feb	215	731	1.71	605	1.97	676
5-Feb	215	731	1.7	603	1.95	671
6-Feb	213	724	1.69	600	1.93	665
7-Feb	212	721	1.67	595	1.92	662
8-Feb	210	715	1.66	593	1.9	656
9-Feb	209	712	1.64	588	1.89	654
10-Feb	209	712	1.63	585	1.87	648
11-Feb	207	706	1.62	583	1.84	640
12-Feb	207	706	1.61	581	1.83	637
13-Feb	205	700	1.59	576	1.82	634
14-Feb	203	694	1.58	573	1.82	634
15-Feb	201	688	1.57	571	1.79	626
16-Feb	201	688	1.57	571	1.78	624
17-Feb	199	682	1.55	566	1.76	618
18-Feb	197	676	1.54	564	1.75	616
19-Feb	195	671	1.54	564	1.75	616
20-Feb	195	671	1.53	562	1.74	613
21-Feb	194	668	1.52	559	1.73	611
22-Feb	193	665	1.51	557	1.72	608
23-Feb	192	662	1.5	555	1.71	605
24-Feb	192	662	1.49	553	1.71	605
25-Feb	192	662	1.48	550	1.71	605
26-Feb	192	662	1.47	548	1.69	600
27-Feb	191	659	1.46	546	1.68	598
28-Feb	191	659	1.45	544	1.66	593
29-Feb	191	659	1.44	541	1.64	588
1-Mar	190	656	1.44	541	1.63	585
2-Mar	189	654	1.44	541	1.62	583
3-Mar	187	648	1.43	539	1.6	578
4-Mar	184	640	1.43	539	1.58	573
5-Mar	182	634	1.41	535	1.56	569
6-Mar	181	632	1.4	533	1.55	566
7-Mar	180	629	1.39	531	1.54	564
8-Mar	177	621	1.39	531	1.54	564
9-Mar	175	616	1.39	531	1.52	559
10-Mar	174	613	1.39	531	1.52	559
11-Mar	173	611	1.4	533	1.51	557
12-Mar	172	608	1.4	533	1.51	557
13-Mar	172	608	1.39	531	1.5	555
14-Mar	171	605	1.39	531	1.5	555

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
15-Mar	170	603	1.42	537	1.49	553
16-Mar	169	600	1.44	541	1.49	553
17-Mar	167	595	1.44	541	1.48	550
18-Mar	166	593	1.42	537	1.48	550
19-Mar	164	588	1.41	535	1.47	548
20-Mar	164	588	1.4	533	1.47	548
21-Mar	163	585	1.37	526	1.46	546
22-Mar	163	585	1.36	524	1.46	546
23-Mar	163	585	1.32	516	1.46	546
24-Mar	162	583	1.29	510	1.45	544
25-Mar	170	603	1.27	506	1.45	544
26-Mar	163	585	1.26	504	1.45	544
27-Mar	184	640	1.24	500	1.45	544
28-Mar	220	747	1.24	500	1.44	541
29-Mar	220	747	1.24	500	1.44	541
30-Mar	216	734	1.28	508	1.44	541
31-Mar	208	709	1.29	510	1.44	541
1-Apr	199	682	1.38	528	1.44	541
2-Apr	197	676	1.44	541	1.45	544
3-Apr	197	676	1.6	578	1.47	548
4-Apr	197	676	2	685	1.46	546
5-Apr	202	691	1.99	682	1.46	546
6-Apr	200	685	1.98	679	1.47	548
7-Apr	200	685	1.97	676	1.51	557
8-Apr	193	665	1.95	671	1.53	562
9-Apr	188	651	1.63	585	1.53	562
10-Apr	184	640	1.63	585	1.54	564
11-Apr	180	629	1.89	654	1.57	571
12-Apr	176	618	2	685	1.62	583
13-Apr	173	611	2.08	709	1.62	583
14-Apr	173	611	1.98	679	1.62	583
15-Apr	170	603	1.92	662	1.58	573
16-Apr	170	603	1.8	629	1.52	559
17-Apr	168	598	1.68	598	1.54	564
18-Apr	165	590	1.72	608	1.62	583
19-Apr	159	576	1.87	648	1.66	593
20-Apr	159	576	1.94	668	1.67	595
21-Apr	158	573	2.04	697	1.68	598
22-Apr	157	571	2.1	715	1.63	585
23-Apr	156	569	2.2	747	1.56	569
24-Apr	155	566	2.18	740	1.48	550
25-Apr	167	595	2.92	1013	1.45	544

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
26-Apr	158	573	3.86	1464	1.44	541
27-Apr	163	585	4	1542	1.44	541
28-Apr	216	734	3.92	1497	1.43	539
29-Apr	193	665	3.8	1432	1.54	564
30-Apr	184	640	3.54	1297	1.62	583
1-May	186	645	3.37	1214	1.66	593
2-May	189	654	3.19	1130	1.66	593
3-May	197	676	3.02	1055	1.58	573
4-May	218	740	2.86	988	1.54	564
5-May	225	763	2.59	882	1.5	555
6-May	228	773	2.42	821	1.45	544
7-May	228	773	2.3	779	1.41	535
8-May	244	828	2.23	756	1.38	528
9-May	252	856	2.08	709	1.38	528
10-May	264	901	1.98	679	1.34	520
11-May	278	955	1.94	668	1.33	518
12-May	264	901	1.9	656	1.38	528
13-May	250	849	1.92	662	1.4	533
14-May	236	800	1.96	673	1.39	531
15-May	228	773	2.2	747	1.38	528
16-May	223	756	2.49	845	1.37	526
17-May	221	750	2.82	971	1.37	526
18-May	223	756	2.88	996	1.36	524
19-May	224	760	2.99	1042	1.38	528
20-May	226	766	3.04	1064	1.39	531
21-May	228	773	3.02	1055	1.39	531
22-May	233	789	2.94	1021	1.41	535
23-May	240	814	2.9	1004	1.5	555
24-May	244	828	3	1046	1.58	573
25-May	256	871	3.16	1117	1.92	662
26-May	272	932	3.1	1090	2.12	721
27-May	332	1190	3.18	1126	2.34	793
28-May	380	1432	3.88	1475	2.56	871
29-May	416	1634	4.8	2035	0	365
30-May	424	1681	5.88	2837	3.4	1228
31-May	448	1827	5.76	2740	3.38	1219
1-Jun	448	1827	5.26	2357	3.38	1219
2-Jun	512	2256	4.88	2089	3.42	1238
3-Jun	764	4479	4.6	1904	3.5	1277
4-Jun	888	5885	4.52	1853	3.86	1464
5-Jun	870	5668	4.71	1975	4	1542
6-Jun	810	4977	5	2172	4.54	1865

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
7-Jun	750	4333	5.3	2387	5	2172
8-Jun	732	4149	5.4	2461	4.8	2035
9-Jun	956	6744	5.7	2692	4.5	1840
10-Jun	978	7035	5.7	2692	4.28	1705
11-Jun	1008	7443	5.86	2820	4.16	1634
12-Jun	1000	7333	5.8	2772	4.12	1610
13-Jun	1024	7665	5.96	2902	4.2	1657
14-Jun	1030	7749	6.21	3113	4.38	1765
15-Jun	1068	8294	6.6	3458	4.3	1717
16-Jun	1112	8949	7.04	3872	4.06	1576
17-Jun	1159	9678	7.62	4458	3.88	1475
18-Jun	1181	10029	8.4	5316	3.74	1400
19-Jun	1181	10029	8.98	6008	3.64	1348
20-Jun	1145	9457	9.4	6537	3.76	1411
21-Jun	1060	8178	9.42	6562	4.06	1576
22-Jun	960	6797	9.36	6485	4.5	1840
23-Jun	894	5959	9.74	6982	5.24	2343
24-Jun	956	6744	10.37	7848	5.88	2837
25-Jun	1044	7948	10.97	8723	6.16	3070
26-Jun	1112	8949	11.6	9693	6.06	2986
27-Jun	1149	9520	11.7	9852	6.42	3296
28-Jun	1144	9442	11.72	9884	7.62	4458
29-Jun	1108	8889	11.86	10109	8.18	5066
30-Jun	1066	8265	11.91	10190	8.3	5202
1-Jul	1070	8323	12.06	10436	8.94	5959
2-Jul	1149	9520	12.3	10834	10.1	7471
3-Jul	1213	10551	12.52	11206	10.95	8693
4-Jul	1254	11240	12.65	11429	11.48	9504
5-Jul	1306	12147	12.63	11395	11.78	9980
6-Jul	1328	12541	12.71	11533	12.13	10551
7-Jul	1339	12741	12.61	11360	12.39	10985
8-Jul	1338	12723	12.43	11053	12.54	11240
9-Jul	1329	12559	12.13	10551	12.62	11377
10-Jul	1315	12307	11.79	9996	12.51	11189
11-Jul	1289	11846	11.39	9364	12.34	10901
12-Jul	1232	10868	11.26	9163	12.26	10767
13-Jul	1156	9630	10.69	8309	12.04	10403
14-Jul	1080	8470	10.35	7820	11.78	9980
15-Jul	1150	9536	10.9	8618	11.18	9041
16-Jul	1252	11206	11.58	9662	10.4	7891
17-Jul	1279	11672	11.92	10207	9.9	7197
18-Jul	1270	11515	11.82	10045	9.72	6955

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
19-Jul	1349	12924	11.6	9693	9.48	6640
20-Jul	1492	15687	11.6	9693	9.08	6132
21-Jul	1586	17653	11.72	9884	8.76	5740
22-Jul	1649	19036	12.09	10485	8.68	5645
23-Jul	1673	19578	12.53	11223	8.45	5374
24-Jul	1652	19104	13.12	12254	8.25	5145
25-Jul	1595	17847	13.46	12869	8.14	5021
26-Jul	1526	16384	13.76	13425	8.68	5645
27-Jul	1461	15065	13.83	13556	9.64	6849
28-Jul	1406	13992	13.52	12979	10.93	8663
29-Jul	1371	13331	13.16	12325	11.79	9996
30-Jul	1328	12541	13.04	12111	12.03	10386
31-Jul	1289	11846	12.94	11934	12.26	10767
1-Aug	1249	11155	12.86	11794	12.44	11070
2-Aug	1202	10370	12.78	11654	12.5	11172
3-Aug	1214	10567	12.74	11585	12.21	10684
4-Aug	1197	10288	13.14	12290	11.8	10013
5-Aug	1167	9804	13.26	12505	12.26	10767
6-Aug	1230	10834	13.17	12343	12.76	11619
7-Aug	1502	15890	12.51	11189	12.89	11846
8-Aug	1590	17739	11.66	9789	12.84	11759
9-Aug	1657	19216	10.7	8323	12.39	10985
10-Aug	1676	19646	9.92	7224	11.68	9820
11-Aug	1640	18835	9.24	6332	10.95	8693
12-Aug	1555	16991	8.74	5716	10.42	7919
13-Aug	1461	15065	8.38	5293	10.1	7471
14-Aug	1346	12869	8.26	5156	10.8	8470
15-Aug	1277	11637	8.28	5179	10.92	8648
16-Aug	1263	11395	9.06	6107	11.1	8919
17-Aug	1330	12578	9.7	6929	11.28	9194
18-Aug	1337	12705	10.2	7609	11.37	9333
19-Aug	1340	12759	10.65	8251	11.36	9317
20-Aug	1342	12796	11.15	8995	11.7	9852
21-Aug	1337	12705	11.09	8904	12.73	11567
22-Aug	1314	12290	11.05	8843	13.37	12705
23-Aug	1284	11759	11.44	9442	13.76	13425
24-Aug	1314	12290	11.81	10029	14.51	14867
25-Aug	1349	12924	11.75	9932	15.06	15972
26-Aug	1367	13257	11.56	9630	15.24	16343
27-Aug	1366	13238	11.46	9473	14.84	15525
28-Aug	1335	12668	11.79	9996	13.94	13764
29-Aug	1252	11206	12.15	10584	13.2	12397

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
30-Aug	1178	9980	12.24	10734	12.14	10567
31-Aug	1126	9163	11.99	10321	10.97	8723
1-Sep	980	7062	11.53	9583	10.44	7948
2-Sep	883	5825	10.95	8693	9.24	6332
3-Sep	837	5282	10.48	8005	8.86	5861
4-Sep	800	4866	10.3	7749	9.1	6156
5-Sep	820	5088	10.49	8019	9.02	6057
6-Sep	846	5386	10.02	7360	10.1	7471
7-Sep	859	5538	10	7333	10.92	8648
8-Sep	855	5491	10.66	8265	11.12	8949
9-Sep	1058	8149	11.66	9789	10.92	8648
10-Sep	1145	9457	11.79	9996	10	7333
11-Sep	1107	8873	11.67	9804	8.07	4943
12-Sep	1016	7554	11.48	9504	7.9	4757
13-Sep	972	6955	11.15	8995	7.5	4333
14-Sep	1000	7333	11.15	8995	7.5	4333
15-Sep	1018	7581	11.15	8995	7.48	4312
16-Sep	1022	7637	11.95	10255	7.7	4542
17-Sep	1010	7471	12.81	11706	8.16	5044
18-Sep	950	6666	12.52	11206	8.36	5270
19-Sep	928	6383	11.99	10321	8.9	5910
20-Sep	989	7183	11.1	8919	9.64	6849
21-Sep	980	7062	10.45	7962	10.58	8149
22-Sep	1030	7749	10.06	7415	11.22	9102
23-Sep	1040	7891	9.75	6995	11.6	9693
24-Sep	1075	8397	9.6	6797	11.79	9996
25-Sep	1078	8441	9.08	6132	11.3	9225
26-Sep	1028	7721	8.78	5764	10.6	8178
27-Sep	1043	7934	8.8	5788	9.86	7143
28-Sep	1040	7891	9.08	6132	9.5	6666
29-Sep	990	7197	9.36	6485	8.66	5621
30-Sep	918	6257	9.46	6614	8.04	4910
1-Oct	870	5668	7.2	4029	7.42	4251
2-Oct	920	6282	8.76	5740	7.62	4458
3-Oct	1050	8034	8.3	5202	9.14	6206
4-Oct	1070	8323	7.92	4778	11.52	9567
5-Oct	1023	7651	7.42	4251	11.94	10239
6-Oct	978	7035	7.8	4649	11.76	9948
7-Oct	890	5910	9	6032	10.8	8470
8-Oct	836	5270	10.57	8135	10	7333
9-Oct	798	4844	11.3	9225	9	6032
10-Oct	760	4437	11.97	10288	8.7	5668

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
11-Oct	710	3931	12.28	10800	9.6	6797
12-Oct	680	3643	11.68	9820	9.72	6955
13-Oct	654	3404	11.08	8889	9.48	6640
14-Oct	630	3191	10.56	8120	8.94	5959
15-Oct	619	3096	10.47	7991	8.8	5788
16-Oct	614	3053	10.08	7443	8.35	5259
17-Oct	668	3532	9.28	6383	7.62	4458
18-Oct	796	4822	8.63	5585	7.26	4089
19-Oct	936	6485	8.4	5316	6.98	3814
20-Oct	1078	8441	8.52	5456	6.69	3541
21-Oct	1126	9163	8.5	5432	6.37	3252
22-Oct	1098	8738	8.5	5432	6.2	3104
23-Oct	940	6537	9.18	6257	5.95	2894
24-Oct	780	4649	9.6	6797	5.64	2645
25-Oct	772	4563	9.88	7170	5.46	2506
26-Oct	736	4190	8.8	5788	5.3	2387
27-Oct	701	3843	8.02	4888	5.16	2285
28-Oct	672	3569	7.2	4029	5	2172
29-Oct	641	3287	6.9	3738	4.88	2089
30-Oct	630	3191	6.78	3625	4.74	1995
31-Oct	600	2936	6.48	3350	4.62	1917
1-Nov	579	2764	6.18	3087	4.53	1859
2-Nov	559	2606	5.96	2902	4.44	1802
3-Nov	547	2514	5.8	2772	4.38	1765
4-Nov	535	2424	5.64	2645	4.32	1729
5-Nov	527	2365	5.5	2537	4.22	1669
6-Nov	516	2285	5.38	2446	4.14	1622
7-Nov	504	2200	5.22	2328	4.06	1576
8-Nov	495	2137	5.1	2242	3.98	1531
9-Nov	484	2062	4.98	2158	3.91	1492
10-Nov	478	2022	4.88	2089	3.86	1464
11-Nov	467	1949	4.78	2022	3.79	1427
12-Nov	458	1891	4.7	1969	3.72	1390
13-Nov	450	1840	4.62	1917	3.66	1358
14-Nov	446	1815	4.54	1865	3.6	1328
15-Nov	442	1790	4.48	1827	3.54	1297
16-Nov	435	1747	4.4	1778	3.48	1267
17-Nov	430	1717	4.3	1717	3.45	1253
18-Nov	423	1675	4.26	1693	3.43	1243
19-Nov	419	1651	4.16	1634	3.4	1228
20-Nov	413	1616	4.12	1610	3.37	1214
21-Nov	409	1593	4.06	1576	3.36	1209

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
22-Nov	404	1565	4	1542	3.35	1205
23-Nov	401	1548	3.97	1525	3.33	1195
24-Nov	398	1531	3.94	1508	3.33	1195
25-Nov	395	1514	3.93	1503	3.32	1190
26-Nov	393	1503	3.93	1503	3.29	1176
27-Nov	390	1486	3.93	1503	3.19	1130
28-Nov	384	1454	3.87	1470	3.08	1081
29-Nov	376	1411	3.8	1432	2.98	1038
30-Nov	368	1369	3.72	1390	2.93	1017
1-Dec	363	1343	3.65	1353	2.93	1017
2-Dec	359	1323	3.61	1333	2.91	1008
3-Dec	357	1312	3.56	1307	2.85	984
4-Dec	354	1297	3.5	1277	2.81	967
5-Dec	351	1282	3.34	1200	2.78	955
6-Dec	346	1258	3.4	1228	2.76	947
7-Dec	343	1243	3.35	1205	2.74	940
8-Dec	337	1214	3.31	1186	2.72	932
9-Dec	334	1200	3.3	1181	2.69	920
10-Dec	331	1186	3.29	1176	2.65	905
11-Dec	327	1167	3.4	1228	2.62	893
12-Dec	323	1148	3.43	1243	2.6	886
13-Dec	320	1135	3.38	1219	2.58	878
14-Dec	317	1121	3.35	1205	2.56	871
15-Dec	314	1108	3.31	1186	2.52	856
16-Dec	312	1099	3.22	1144	2.51	853
17-Dec	310	1090	3.19	1130	2.5	849
18-Dec	309	1085	3.16	1117	2.49	845
19-Dec	308	1081	3.11	1094	2.45	831
20-Dec	305	1068	3.07	1077	2.43	824
21-Dec	301	1051	3.02	1055	2.41	817
22-Dec	299	1042	2.96	1029	2.41	817
23-Dec	297	1034	2.91	1008	2.4	814
24-Dec	292	1013	2.88	996	2.37	803
25-Dec	290	1004	2.87	992	2.34	793
26-Dec	289	1000	2.84	980	2.34	793
27-Dec	287	992	2.81	967	2.3	779
28-Dec	285	984	2.78	955	2.28	773
29-Dec	283	976	2.78	955	2.26	766
30-Dec	282	971	2.77	951	2.53	860

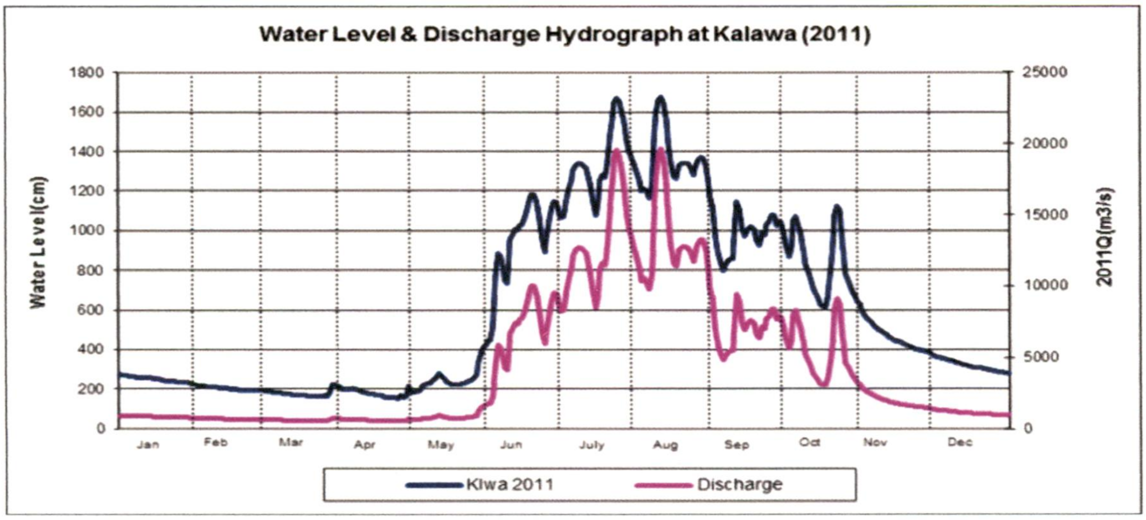


Fig 4.1Water Level & Discharge Hydrograph at Kalawa 2011

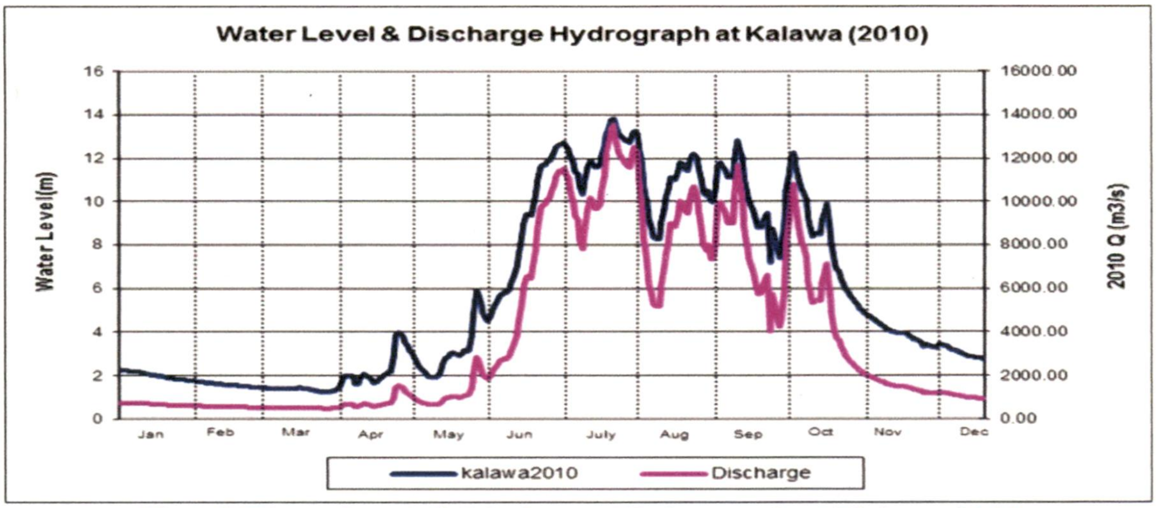


Fig 4.2 Water Level & Discharge Hydrograph at Kalawa 2010

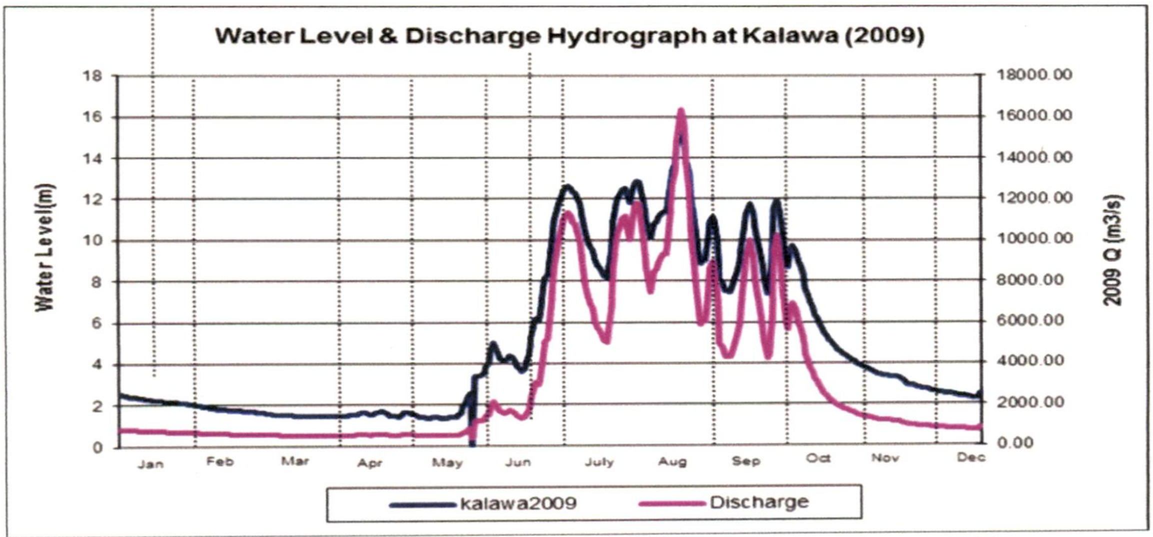


Fig 4.3 Water Level & Discharge Hydrograph at Kalawa 2009

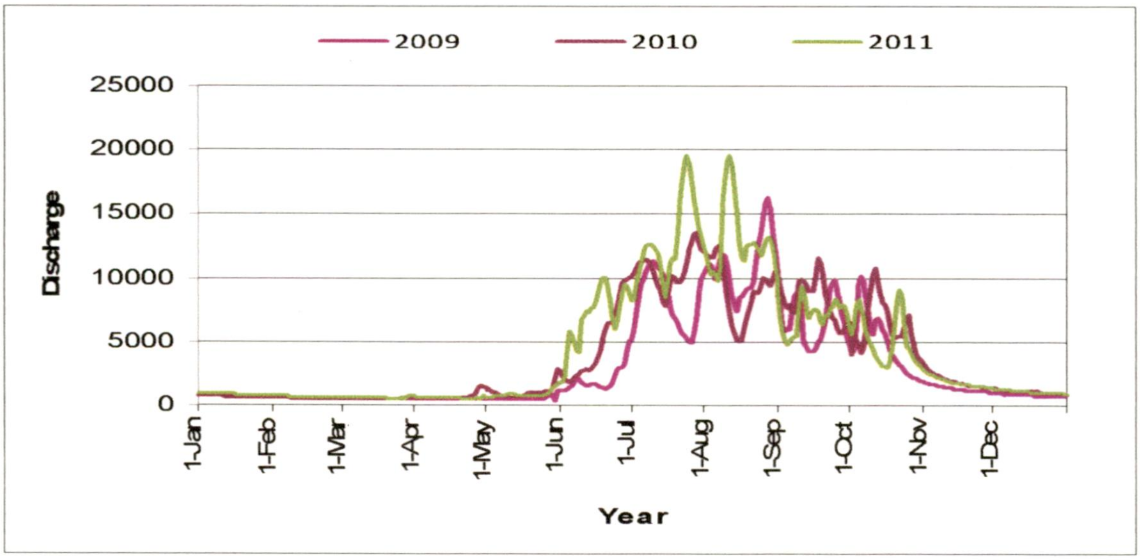


Fig 4.4 Water Level & Discharge Hydrograph at Kalawa 2011, 2010, 2009

From Kalawa station discharge data we can see that the discharge is varies yearly. In year 2009, the discharge is between 14000 – 16000 m^3/sec. In year 2010, the discharge is between 12000 – 14000 m^3/sec. In year 2011, the discharge is between 15000 – 19000 m^3/sec. The variation in discharge very much affects the water quality of Chindwin River at Kalawa.

The discharge at **Mawliak** Station has been calculated by using the following equation

Q = A + B*H + C*H*H

Where,

Q is discharge (m^3/s),

H = Water Level (m).

And value of A = -80.6, B = 222, C = 92.

Table 4.2: Discharge at Mawliak Station

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
1-Jan	296	1383	2.6	1119	2.16	828
2-Jan	295	1375	2.6	1119	2.14	816
3-Jan	294	1368	2.58	1105	2.13	810
4-Jan	291	1345	2.58	1105	2.12	804
5-Jan	291	1345	2.58	1105	2.11	798

Date	2011		2010		2009	
	Water Level (cm)	**Discharge (m^3/s)**	**Water Level (m)**	**Discharge (m^3/s)**	**Water Level (m)**	**Discharge (m^3/s)**
6-Jan	287	1315	2.56	1091	2.1	792
7-Jan	285	1300	2.56	1091	2.1	792
8-Jan	282	1277	2.55	1084	2.09	785
9-Jan	279	1255	2.54	1077	2.09	785
10-Jan	277	1241	2.54	1077	2.08	779
11-Jan	276	1233	2.54	1077	2.07	773
12-Jan	275	1226	2.53	1070	2.07	773
13-Jan	273	1211	2.53	1070	2.06	767
14-Jan	272	1204	2.53	1070	2.05	761
15-Jan	271	1197	2.46	1023	2.05	761
16-Jan	270	1190	2.44	1009	2.05	761
17-Jan	268	1175	2.44	1009	2.04	755
18-Jan	266	1161	2.44	1009	2.03	749
19-Jan	264	1147	2.43	1002	2.02	743
20-Jan	262	1133	2.43	1002	2	732
21-Jan	261	1126	2.43	1002	1.99	726
22-Jan	260	1119	2.4	982	1.98	720
23-Jan	258	1105	2.4	982	1.98	720
24-Jan	256	1091	2.4	982	1.98	720
25-Jan	255	1084	2.4	982	1.97	714
26-Jan	254	1077	2.38	969	1.96	708
27-Jan	253	1070	2.38	969	1.96	708
28-Jan	252	1063	2.36	956	1.95	702
29-Jan	251	1056	2.36	956	1.95	702
30-Jan	250	1050	2.34	943	1.95	702
31-Jan	250	1050	2.34	943	1.94	697
1-Feb	249	1043	2.32	930	1.94	697
2-Feb	248	1036	2.32	930	1.94	697
3-Feb	248	1036	2.3	917	1.93	691
4-Feb	247	1029	2.3	917	1.93	691
5-Feb	247	1029	2.3	917	1.93	691
6-Feb	246	1023	2.3	917	1.93	691
7-Feb	245	1016	2.3	917	1.92	685
8-Feb	245	1016	2.3	917	1.91	679
9-Feb	244	1009	2.3	917	1.91	679
10-Feb	243	1002	2.3	917	1.91	679
11-Feb	224	879	2.3	917	1.9	674
12-Feb	243	1002	2.24	879	1.89	668
13-Feb	242	996	2.23	872	1.89	668
14-Feb	241	989	2.23	872	1.88	662
15-Feb	240	982	2.23	872	1.87	656
16-Feb	239	976	2.18	841	1.85	645
17-Feb	238	969	2.16	828	1.84	640
18-Feb	238	969	2.15	822	1.83	634

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharg (m^3/s)
19-Feb	237	963	2.14	816	1.82	628
20-Feb	236	956	2.14	816	1.81	623
21-Feb	235	949	2.12	804	1.78	606
22-Feb	234	943	2.11	798	1.76	595
23-Feb	233	936	2.1	792	1.74	584
24-Feb	232	930	2.08	779	1.73	579
25-Feb	232	930	2.06	767	1.72	574
26-Feb	229	910	2.05	761	1.72	574
27-Feb	227	898	2.1	792	1.71	568
28-Feb	226	891	2.14	816	1.73	579
29-Feb	225	885	2.1	792	1.7	563
1-Mar	224	879	2.08	779	1.68	552
2-Mar	223	872	2.06	767	1.68	552
3-Mar	222	866	2.05	761	1.66	542
4-Mar	222	866	2.04	755	1.65	536
5-Mar	221	860	2.04	755	1.64	531
6-Mar	220	853	2	732	1.64	531
7-Mar	219	847	1.98	720	1.62	521
8-Mar	219	847	1.97	714	1.6	510
9-Mar	218	841	1.96	708	1.59	505
10-Mar	217	835	1.96	708	1.58	500
11-Mar	216	828	1.95	702	1.57	495
12-Mar	216	828	1.94	697	1.56	490
13-Mar	216	828	1.93	691	1.55	485
14-Mar	215	822	1.92	685	1.54	480
15-Mar	215	822	1.91	679	1.53	475
16-Mar	217	835	1.9	674	1.51	465
17-Mar	218	841	1.91	679	1.5	460
18-Mar	216	828	1.91	679	1.48	450
19-Mar	215	822	1.89	668	1.47	445
20-Mar	214	816	1.88	662	1.46	440
21-Mar	213	810	1.86	651	1.46	440
22-Mar	214	816	1.85	645	1.44	430
23-Mar	213	810	1.84	640	1.44	430
24-Mar	212	804	1.84	640	1.42	420
25-Mar	216	828	1.83	634	1.41	415
26-Mar	211	798	1.82	628	1.4	411
27-Mar	220	853	1.82	628	1.4	411
28-Mar	223	872	1.8	617	1.38	401
29-Mar	228	904	1.8	617	1.36	392
30-Mar	226	891	1.85	645	1.34	382
31-Mar	228	904	1.9	674	1.32	373
1-Apr	224	879	1.95	702	1.32	373
2-Apr	223	872	1.95	702	1.3	364

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
3-Apr	222	866	2	732	1.29	359
4-Apr	221	860	2.08	779	1.28	354
5-Apr	220	853	2.12	804	1.27	350
6-Apr	220	853	2.2	853	1.25	341
7-Apr	219	847	2.26	891	1.24	336
8-Apr	219	847	2.3	917	1.36	392
9-Apr	218	841	2.34	943	1.54	480
10-Apr	218	841	2.34	943	1.64	531
11-Apr	217	835	2.28	904	1.62	521
12-Apr	216	828	2.27	898	1.6	510
13-Apr	216	828	2.34	943	1.56	490
14-Apr	215	822	2.28	904	1.54	480
15-Apr	215	822	2.16	828	1.54	480
16-Apr	214	816	2.08	779	1.54	480
17-Apr	213	810	2.1	792	1.54	480
18-Apr	212	804	2.22	866	1.58	500
19-Apr	211	798	2.26	891	1.62	521
20-Apr	210	792	2.36	956	1.64	531
21-Apr	209	785	2.36	956	1.66	542
22-Apr	208	779	2.42	996	1.66	542
23-Apr	207	773	2.4	982	1.54	480
24-Apr	206	767	2.7	1190	1.52	470
25-Apr	206	767	3.8	2092	1.51	465
26-Apr	207	773	3.84	2129	1.5	460
27-Apr	209	785	3.66	1965	1.5	460
28-Apr	212	804	3.62	1929	1.66	542
29-Apr	215	822	3.38	1721	1.7	563
30-Apr	218	841	3.22	1588	1.74	584
1-May	220	853	3.1	1492	1.76	595
2-May	222	866	0	-81	1.72	574
3-May	224	879	2.8	1263	1.67	547
4-May	232	930	2.7	1190	1.16	301
5-May	236	956	2.56	1091	1.64	531
6-May	244	1009	2.48	1036	1.62	521
7-May	248	1036	0	-81	1.61	515
8-May	256	1091	0	-81	1.61	515
9-May	272	1204	2.28	904	1.65	536
10-May	286	1307	0	-81	1.66	542
11-May	284	1292	2.2	853	1.68	552
12-May	276	1233	0	-81	1.7	563
13-May	272	1204	2.14	816	1.66	542
14-May	258	1105	2.4	982	1.64	531
15-May	248	1036	2.6	1119	1.66	542
16-May	244	1009	2.8	1263	1.66	542

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharg (m^3/s)
17-May	242	996	0	-81	1.62	521
18-May	238	969	3	1414	1.62	521
19-May	242	996	0	-81	1.62	521
20-May	244	1009	3.04	1445	1.66	542
21-May	250	1050	2.96	1383	1.62	521
22-May	250	1050	2.96	1383	1.6	510
23-May	256	1091	2.78	1248	1.62	521
24-May	260	1119	3.14	1524	1.84	640
25-May	262	1133	3	1414	2.1	792
26-May	270	1190	3	1414	2.2	853
27-May	286	1307	3.44	1772	2.36	956
28-May	302	1429	4	2280	2.52	1063
29-May	320	1572	5.1	3445	2.68	1175
30-May	334	1688	5.3	3681	2.82	1277
31-May	346	1789	4.84	3150	2.8	1263
1-Jun	368	1983	4.34	2616	2.8	1263
2-Jun	378	2073	4.25	2525	2.9	1337
3-Jun	747	6712	0	-81	2.94	1368
4-Jun	760	6921	4	2280	2.94	1368
5-Jun	716	6226	4.32	2596	2.92	1352
6-Jun	640	5109	0	-81	3.28	1638
7-Jun	604	4617	4.78	3083	3.94	2223
8-Jun	676	5625	4.92	3239	3.9	2185
9-Jun	748	6728	5	3330	3.52	1841
10-Jun	780	7249	5	3330	3.44	1772
11-Jun	790	7416	4.78	3083	3.4	1738
12-Jun	816	7858	4.76	3061	3.36	1704
13-Jun	832	8136	5.06	3399	3.4	1738
14-Jun	832	8136	5.22	3586	3.6	1911
15-Jun	844	8347	5.68	4149	3.68	1983
16-Jun	880	8998	6	4564	3.66	1965
17-Jun	906	9483	6.64	5450	3.28	1638
18-Jun	826	8031	7.04	6043	3.2	1572
19-Jun	928	9903	7.5	6760	3.12	1508
20-Jun	872	8852	7.7	7084	3.08	1476
21-Jun	802	7618	7.64	6986	3.28	1638
22-Jun	728	6412	7.72	7117	3.6	1911
23-Jun	708	6103	8.1	7755	4.1	2377
24-Jun	794	7483	8.68	8779	4.78	3083
25-Jun	836	8206	9.24	9826	4.08	2357
26-Jun	836	8206	9.6	10530	5.06	3399
27-Jun	868	8779	9.64	10610	4.94	3262
28-Jun	870	8815	9.74	10810	5.96	4511
29-Jun	846	8383	9.82	10972	6.74	5596

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
30-Jun	830	8101	9.84	11013	6.94	5892
1-Jul	874	8888	10	11340	7.1	6134
2-Jul	930	9942	10.24	11841	7.86	7349
3-Jul	976	10851	10.36	12095	8.8	8998
4-Jul	1018	11715	10.32	12010	9.34	10019
5-Jul	1062	12654	10.34	12052	9.86	11054
6-Jul	1084	13137	10.34	12052	9.92	11176
7-Jul	1088	13226	10.26	11883	10.14	11631
8-Jul	1086	13182	10.12	11589	10.32	12010
9-Jul	1086	13182	9.84	11013	10.36	12095
10-Jul	1070	12829	9.44	10214	10.28	11925
11-Jul	1034	12052	8.9	9183	10.2	11757
12-Jul	970	10730	8.56	8562	10.12	11589
13-Jul	900	9370	8.54	8526	10	11340
14-Jul	848	8419	8.84	9072	9.78	10891
15-Jul	916	9673	9.18	9711	9.6	10530
16-Jul	970	10730	9.48	10293	8.8	8998
17-Jul	976	10851	9.56	10451	8.16	7858
18-Jul	984	11013	9.58	10491	7.82	7282
19-Jul	1076	12961	9.58	10491	7.76	7183
20-Jul	1200	15833	9.34	10019	7.32	6475
21-Jul	1276	17733	9.36	10058	7.7	7084
22-Jul	1342	19469	9.88	11094	6.76	5625
23-Jul	1365	20093	10.28	11925	6.66	5479
24-Jul	1340	19415	10.84	13137	6.56	5335
25-Jul	1280	17836	11.04	13584	6.48	5222
26-Jul	1226	16471	11.2	13947	6.66	5479
27-Jul	1168	15064	11.12	13765	7.24	6350
28-Jul	1112	13765	10.78	13005	8.22	7961
29-Jul	1084	13137	10.6	12611	9.26	9865
30-Jul	1046	12308	10.34	12052	9.72	10770
31-Jul	1012	11589	10.2	11757	9.84	11013
1-Aug	968	10690	10.12	11589	9.96	11258
2-Aug	920	9750	10.04	11423	10.2	11757
3-Aug	904	9446	10.12	11589	10.16	11673
4-Aug	862	8670	10.32	12010	9.86	11054
5-Aug	870	8815	10.4	12180	9.6	10530
6-Aug	964	10610	10.1	11548	10.04	11423
7-Aug	1126	14085	9.52	10372	10.32	12010
8-Aug	1230	16570	8.86	9109	10.42	12223
9-Aug	1276	17733	8.16	7858	10.28	11925
10-Aug	1284	17939	7.6	6921	9.88	11094
11-Aug	1244	16920	7.16	6226	9.08	9521
12-Aug	1166	15017	6.88	5802	8.56	8562

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m³/s)	Water Level (m)	Discharge (m³/s)	Water Level (m)	Discharg (m³/s)
13-Aug	1068	12785	6.64	5450	8.04	7652
14-Aug	978	10891	6.56	5335	8.44	8347
15-Aug	932	9981	6.76	5625	8.66	8742
16-Aug	956	10451	7.24	6350	8.64	8706
17-Aug	1102	13539	7.7	7084	8.92	9221
18-Aug	1024	11841	8.06	7686	9.08	9521
19-Aug	1046	12308	8.5	8454	9.16	9673
20-Aug	1056	12524	8.7	8815	9.2	9750
21-Aug	1048	12351	8.66	8742	9.54	10411
22-Aug	1020	11757	8.8	8998	10.34	12052
23-Aug	996	11258	9.2	9750	10.94	13360
24-Aug	1006	11464	9.4	10136	11.28	14131
25-Aug	1016	11673	9.34	10019	11.68	15064
26-Aug	1012	11589	9.14	9635	12.04	15930
27-Aug	984	11013	9.2	9750	12.14	16175
28-Aug	920	9750	9.56	10451	11.74	15207
29-Aug	844	8347	9.82	10972	10.9	13271
30-Aug	776	7183	9.72	10770	6.09	4684
31-Aug	728	6412	9.4	10136	6.09	4684
1-Sep	700	5982	8.96	9295	8.16	7858
2-Sep	646	5193	8.64	8706	7.38	6569
3-Sep	624	4888	8.08	7720	6.92	5862
4-Sep	610	4698	8.1	7755	6.64	5450
5-Sep	620	4833	8	7584	6.48	5222
6-Sep	610	4698	7.66	7019	6.38	5081
7-Sep	628	4943	7.84	7315	6.38	5081
8-Sep	650	5250	8.68	8779	7.32	6475
9-Sep	812	7789	9.34	10019	7.22	6319
10-Sep	830	8101	9.36	10058	6.88	5802
11-Sep	796	7517	9.2	9750	6.24	4888
12-Sep	740	6601	9	9370	6	4564
13-Sep	720	6288	8.68	8779	5.6	4048
14-Sep	684	5743	8.64	8706	5.54	3973
15-Sep	710	6134	8.54	8526	5.56	3998
16-Sep	728	6412	9.32	9981	5.58	4023
17-Sep	710	6134	9.56	10451	5.86	4380
18-Sep	692	5862	9.32	9981	6	4564
19-Sep	708	6103	8.64	8706	6.36	5053
20-Sep	726	6381	8.12	7789	6.94	5892
21-Sep	742	6633	7.76	7183	7.56	6857
22-Sep	768	7052	7.48	6728	8.04	7652
23-Sep	784	7315	7.28	6412	8.48	8419
24-Sep	816	7858	7	5982	8.74	8888
25-Sep	780	7249	6.76	5625	8.4	8277

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
26-Sep	786	7349	6.74	5596	7.76	7183
27-Sep	812	7789	7	5982	7.16	6226
28-Sep	790	7416	7.3	6443	6.7	5537
29-Sep	740	6601	7.48	6728	6.26	4915
30-Sep	684	5743	7.38	6569	5.94	4485
1-Oct	692	5862	7.18	6257	5.64	4099
2-Oct	700	5982	6.9	5832	5.4	3801
3-Oct	774	7150	5.65	4111	5.32	3705
4-Oct	760	6921	6.3	4970	6.06	4644
5-Oct	716	6226	6.2	4833	6.9	5832
6-Oct	668	5508	6.2	4833	6.78	5654
7-Oct	628	4943	6.8	5684	6.5	5250
8-Oct	596	4511	7.5	6760	6.08	4671
9-Oct	576	4251	7.9	7416	6.1	4698
10-Oct	556	3998	8.36	8206	6.1	4698
11-Oct	540	3801	8.5	8454	6.5	5250
12-Oct	524	3609	8.28	8066	7.28	6412
13-Oct	512	3468	8	7584	7.2	6288
14-Oct	500	3330	7.7	7084	6.82	5713
15-Oct	490	3217	7.38	6569	6.38	5081
16-Oct	508	3422	6.9	5832	6.04	4617
17-Oct	520	3562	6.58	5364	5.7	4174
18-Oct	610	4698	6.28	4943	5.44	3850
19-Oct	636	5053	6.16	4779	5.44	3850
20-Oct	642	5137	6.14	4751	5.28	3657
21-Oct	592	4459	6.06	4644	5.1	3445
22-Oct	564	4099	6.16	4779	4.9	3217
23-Oct	556	3998	6.2	4833	4.76	3061
24-Oct	572	4200	6.02	4591	4.62	2909
25-Oct	564	4099	5.8	4302	4.48	2761
26-Oct	542	3826	5.66	4124	4.36	2637
27-Oct	526	3633	5.5	3924	4.26	2535
28-Oct	512	3468	5.38	3777	4.18	2455
29-Oct	496	3284	5.3	3681	4.08	2357
30-Oct	482	3127	5.2	3562	4	2280
31-Oct	486	3172	5.1	3445	3.92	2204
1-Nov	458	2866	4.94	3262	3.86	2147
2-Nov	448	2761	0	-81	3.8	2092
3-Nov	436	2637	0	-81	3.74	2037
4-Nov	432	2596	4.66	2952	3.74	2037
5-Nov	428	2555	4.54	2824	3.62	1929
6-Nov	424	2515	4.44	2719	3.6	1911
7-Nov	424	2515	4.38	2657	3.58	1894
8-Nov	412	2396	0	-81	3.54	1859

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharg (m^3/s)
9-Nov	404	2318	0	-81	3.5	1824
10-Nov	398	2261	4.12	2396	3.44	1772
11-Nov	396	2242	4.08	2357	3.4	1738
12-Nov	396	2242	4.03	2309	3.36	1704
13-Nov	390	2185	3.98	2261	3.32	1671
14-Nov	385	2138	3.93	2213	3.28	1638
15-Nov	380	2092	3.88	2166	3.26	1621
16-Nov	376	2055	3.84	2129	3.24	1605
17-Nov	372	2019	3.8	2092	3.22	1588
18-Nov	368	1983	3.76	2055	3.18	1556
19-Nov	366	1965	3.72	2019	3.18	1556
20-Nov	364	1947	3.68	1983	3.18	1556
21-Nov	362	1929	3.65	1956	3.15	1532
22-Nov	360	1911	3.63	1938	3.16	1540
23-Nov	358	1894	3.6	1911	3.17	1548
24-Nov	352	1841	3.58	1894	3.18	1556
25-Nov	349	1815	3.57	1885	3.14	1524
26-Nov	346	1789	3.54	1859	3.1	1492
27-Nov	342	1755	3.59	1902	3.02	1429
28-Nov	340	1738	3.58	1894	3	1414
29-Nov	337	1713	3.54	1859	2.98	1398
30-Nov	336	1704	3.51	1832	2.96	1383
1-Dec	332	1671	3.49	1815	2.94	1368
2-Dec	330	1654	3.46	1789	2.9	1337
3-Dec	326	1621	3.44	1772	2.9	1337
4-Dec	324	1605	3.4	1738	2.86	1307
5-Dec	320	1572	3.38	1721	2.86	1307
6-Dec	318	1556	3.35	1696	2.86	1307
7-Dec	318	1556	3.3	1654	2.8	1263
8-Dec	317	1548	3.24	1605	2.8	1263
9-Dec	314	1524	3.24	1605	2.8	1263
10-Dec	312	1508	3.24	1605	2.8	1263
11-Dec	310	1492	3.32	1671	2.78	1248
12-Dec	308	1476	3.32	1671	2.78	1248
13-Dec	307	1468	3.21	1580	2.76	1233
14-Dec	304	1445	3.2	1572	2.76	1233
15-Dec	302	1429	3.16	1540	2.76	1233
16-Dec	300	1414	3.14	1524	2.76	1233
17-Dec	300	1414	3.13	1516	2.74	1219
18-Dec	298	1398	3.12	1508	2.74	1219
19-Dec	296	1383	3.1	1492	2.72	1204
20-Dec	296	1383	3.08	1476	2.72	1204
21-Dec	296	1383	3.06	1460	2.72	1204
22-Dec	292	1352	3.06	1460	2.72	1204

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
23-Dec	289	1330	3.05	1453	2.7	1190
24-Dec	287	1315	3.04	1445	2.68	1175
25-Dec	290	1337	3.03	1437	2.68	1175
26-Dec	284	1292	3.02	1429	2.67	1168
27-Dec	283	1285	3.01	1421	2.63	1140
28-Dec	282	1277	3	1414	2.64	1147
29-Dec	281	1270	2.99	1406	2.62	1133
30-Dec	280	1263	2.97	1391	2.62	1133

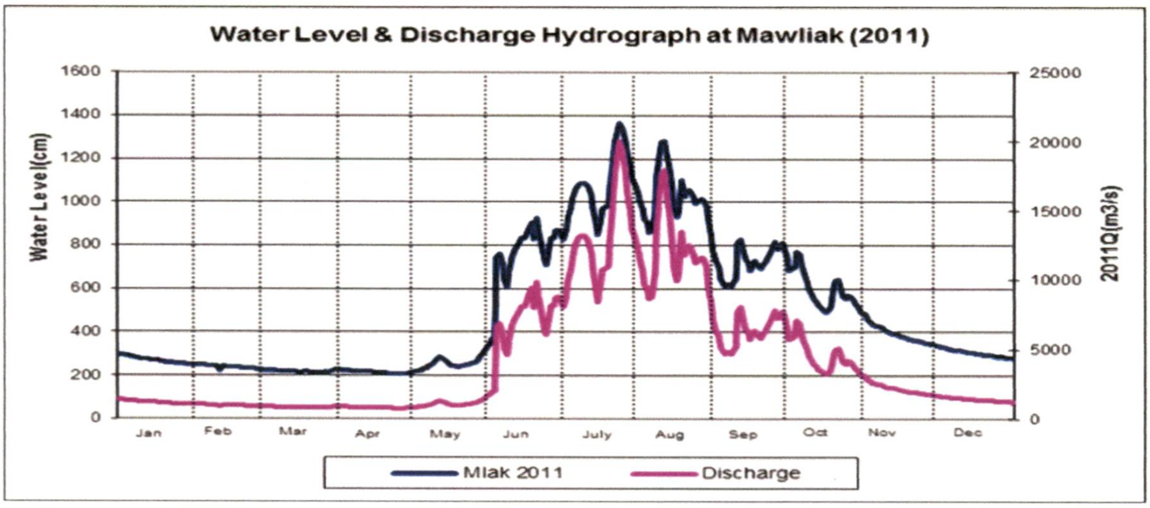


Fig 4.5 Water Level & Discharge Hydrograph at Mawliak 2011

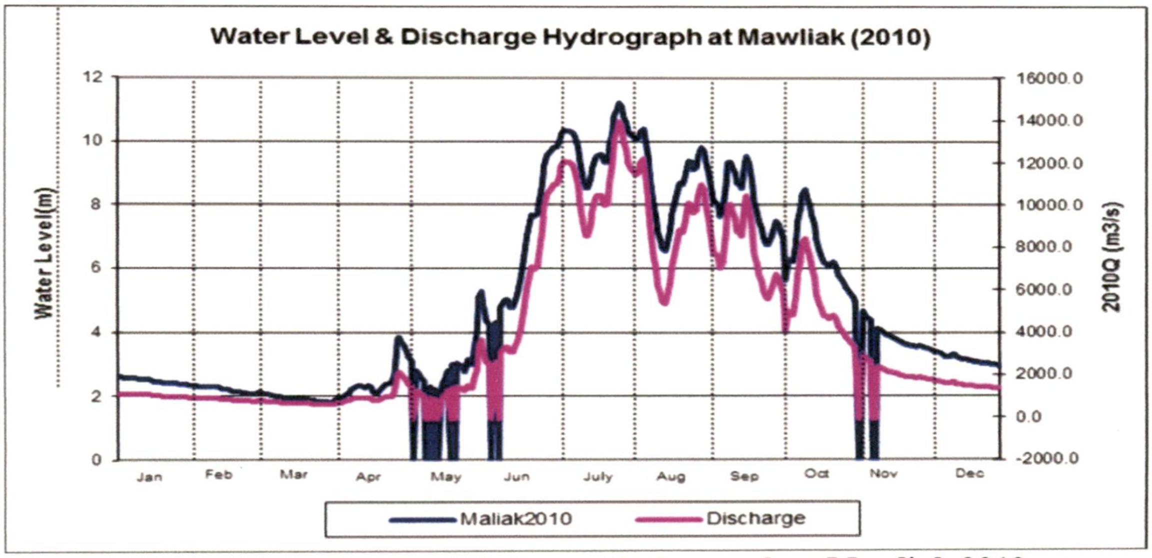


Fig 4.6 Water Level & Discharge Hydrograph at Mawliak 2010

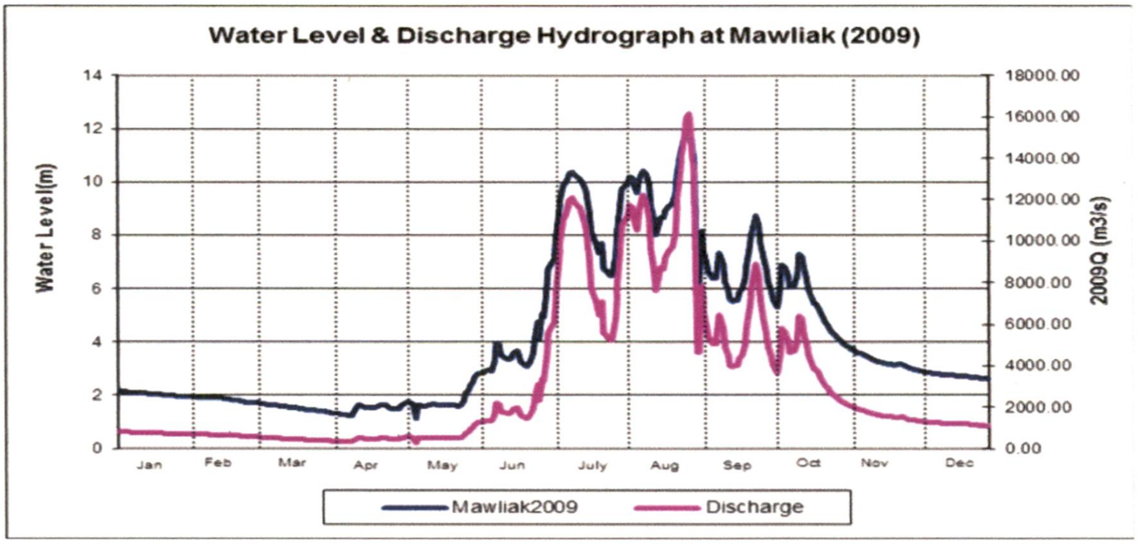


Fig 4.7 Water Level & Discharge Hydrograph at Mawliak 2009

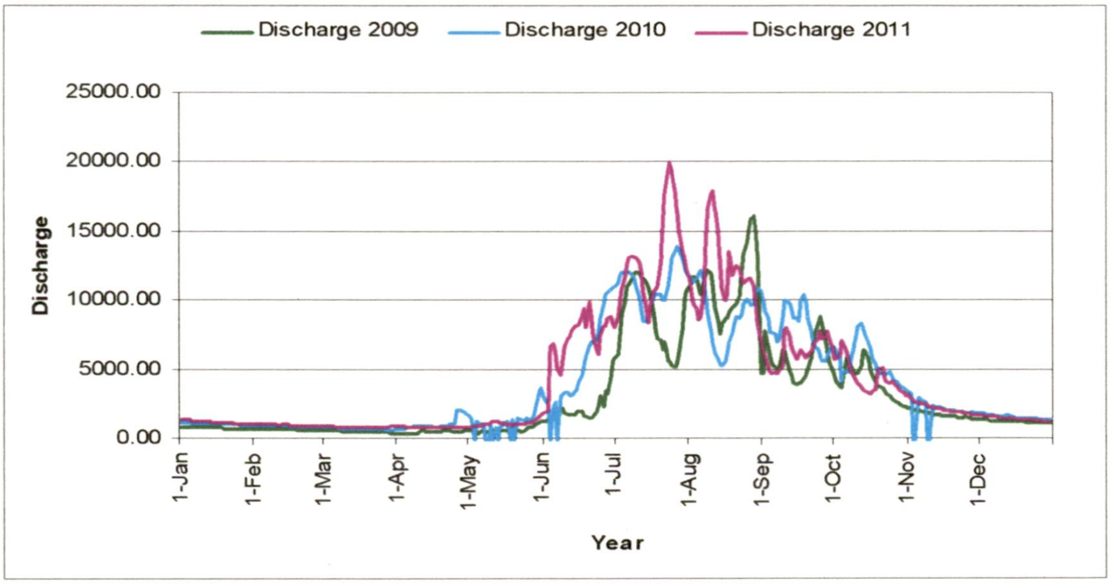


Fig 4.8 Water Level & Discharge Hydrograph at Mawliak 2011, 2010, 2009

From Mawliak station discharge data we can see that the discharge is varies yearly. In year 2009, the discharge is between 12000 – 16000 m^3/sec. In year 2010, the discharge is between 12000 – 14000 m^3/sec. In year 2011, the discharge is between 15000 – 20000 m^3/sec. The variation in discharge very much affects the water quality of Chindwin River at Mawliak.

The discharge at **Monwya** Station has been calculated by using the following equation

Q = A + B*H + C*H*H

Where

Q is discharge (m^3/s),

H = Water Level (m).

And value of A = 2186, B = -1394, C = 326.

Table 4.3: Discharge at Monwya Station

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
1-Jan	153	815	1.19	988	1.5	827
2-Jan	150	827	1.16	1007	1.49	832
3-Jan	148	836	1.13	1027	1.48	836
4-Jan	146	845	1.11	1040	1.46	845
5-Jan	144	854	1.09	1053	1.45	849
6-Jan	142	863	1.08	1060	1.44	854
7-Jan	140	872	1.06	1074	1.42	863
8-Jan	139	877	1.05	1081	1.41	868
9-Jan	138	882	1.04	1088	1.4	872
10-Jan	137	887	1.03	1096	1.39	877
11-Jan	137	887	1.02	1103	1.37	887
12-Jan	137	887	1.01	1110	1.36	892
13-Jan	135	897	1	1118	1.35	897
14-Jan	135	897	0.99	1125	1.34	903
15-Jan	134	903	0.97	1140	1.33	908
16-Jan	133	908	0.96	1148	1.32	913
17-Jan	133	908	0.95	1156	1.3	924
18-Jan	131	919	0.93	1171	1.29	930
19-Jan	130	924	0.91	1187	1.28	935
20-Jan	127	941	0.89	1203	1.27	941
21-Jan	124	958	0.87	1220	1.26	946
22-Jan	119	988	0.85	1236	1.25	952
23-Jan	115	1013	0.83	1253	1.24	958
24-Jan	111	1040	0.82	1262	1.24	958
25-Jan	107	1067	0.81	1271	1.23	964
26-Jan	105	1081	0.8	1279	1.23	964
27-Jan	104	1088	0.79	1288	1.21	976
28-Jan	103	1096	0.78	1297	1.2	982
29-Jan	102	1103	0.77	1306	1.2	982
30-Jan	101	1110	0.76	1315	1.19	988
31-Jan	100	1118	0.75	1324	1.18	994

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
1-Feb	99	1125	0.74	1333	1.17	1001
2-Feb	98	1133	0.73	1342	1.16	1007
3-Feb	97	1140	0.72	1351	1.15	1013
4-Feb	97	1140	0.71	1360	1.15	1013
5-Feb	96	1148	0.7	1370	1.14	1020
6-Feb	95	1156	0.69	1379	1.13	1027
7-Feb	93	1171	0.68	1389	1.12	1033
8-Feb	90	1195	0.67	1398	1.1	1047
9-Feb	89	1203	0.66	1408	1.1	1047
10-Feb	88	1211	0.65	1418	1.09	1053
11-Feb	88	1211	0.64	1427	1.09	1053
12-Feb	87	1220	0.63	1437	1.08	1060
13-Feb	86	1228	0.62	1447	1.07	1067
14-Feb	86	1228	0.61	1457	1.06	1074
15-Feb	85	1236	0.6	1467	1.06	1074
16-Feb	85	1236	0.59	1477	1.05	1081
17-Feb	85	1236	0.59	1477	1.04	1088
18-Feb	84	1245	0.58	1487	1.03	1096
19-Feb	84	1245	0.57	1497	1.02	1103
20-Feb	83	1253	0.57	1497	1.02	1103
21-Feb	83	1253	0.56	1508	1.01	1110
22-Feb	82	1262	0.55	1518	1	1118
23-Feb	82	1262	0.54	1528	1	1118
24-Feb	82	1262	0.52	1549	0.99	1125
25-Feb	82	1262	0.51	1560	0.98	1133
26-Feb	81	1271	0.5	1570	0.98	1133
27-Feb	81	1271	0.49	1581	0.97	1140
28-Feb	81	1271	0.48	1592	0.96	1148
29-Feb	81	1271	0.47	1603	0.96	1148
1-Mar	81	1271	0.46	1614	0.95	1156
2-Mar	80	1279	0.46	1614	0.94	1163
3-Mar	80	1279	0.46	1614	0.94	1163
4-Mar	79	1288	0.45	1625	0.93	1171
5-Mar	79	1288	0.45	1625	0.92	1179
6-Mar	78	1297	0.44	1636	0.92	1179
7-Mar	78	1297	0.43	1647	0.91	1187
8-Mar	77	1306	0.42	1658	0.9	1195
9-Mar	77	1306	0.41	1669	0.9	1195
10-Mar	76	1315	0.4	1681	0.89	1203
11-Mar	75	1324	0.4	1681	0.88	1211
12-Mar	74	1333	0.39	1692	0.88	1211
13-Mar	73	1342	0.4	1681	0.87	1220
14-Mar	72	1351	0.4	1681	0.87	1220
15-Mar	72	1351	0.39	1692	0.86	1228

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
16-Mar	71	1360	0.4	1681	0.86	1228
17-Mar	69	1379	0.4	1681	0.85	1236
18-Mar	68	1389	0.39	1692	0.85	1236
19-Mar	67	1398	0.38	1703	0.84	1245
20-Mar	66	1408	0.36	1726	0.84	1245
21-Mar	66	1408	0.33	1762	0.83	1253
22-Mar	66	1408	0.29	1809	0.82	1262
23-Mar	66	1408	0.27	1833	0.81	1271
24-Mar	66	1408	0.26	1846	0.8	1279
25-Mar	66	1408	0.24	1870	0.79	1288
26-Mar	66	1408	0.22	1895	0.79	1288
27-Mar	65	1418	0.21	1908	0.78	1297
28-Mar	65	1418	0.2	1920	0.78	1297
29-Mar	80	1279	0.19	1933	0.77	1306
30-Mar	92	1179	0.18	1946	0.77	1306
31-Mar	100	1118	0.21	1908	0.77	1306
1-Apr	95	1156	0.2	1920	0.75	1324
2-Apr	91	1187	0.23	1883	0.75	1324
3-Apr	89	1203	0.26	1846	0.75	1324
4-Apr	88	1211	0.31	1785	0.75	1324
5-Apr	88	1211	0.38	1703	0.76	1315
6-Apr	88	1211	0.47	1603	0.75	1324
7-Apr	90	1195	0.67	1398	0.76	1315
8-Apr	89	1203	0.73	1342	0.77	1306
9-Apr	88	1211	0.77	1306	0.78	1297
10-Apr	85	1236	0.76	1315	0.78	1297
11-Apr	81	1271	0.75	1324	0.79	1288
12-Apr	79	1288	0.73	1342	0.8	1279
13-Apr	73	1342	0.71	1360	0.81	1271
14-Apr	68	1389	0.7	1370	0.81	1271
15-Apr	66	1408	0.77	1306	0.82	1262
16-Apr	66	1408	0.84	1245	0.83	1253
17-Apr	60	1467	0.79	1288	0.83	1253
18-Apr	58	1487	0.72	1351	0.85	1236
19-Apr	59	1477	0.73	1342	0.86	1228
20-Apr	57	1497	0.57	1497	0.86	1228
21-Apr	55	1518	0.62	1447	0.87	1220
22-Apr	52	1549	0.71	1360	0.87	1220
23-Apr	52	1549	0.77	1306	0.88	1211
24-Apr	52	1549	0.81	1271	0.87	1220
25-Apr	51	1560	0.87	1220	0.85	1236
26-Apr	50	1570	0.9	1195	0.83	1253
27-Apr	51	1560	1.05	1081	0.82	1262
28-Apr	58	1487	1.69	760	0.8	1279

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
29-Apr	56	1508	2.29	701	0.79	1288
30-Apr	108	1060	2.21	695	0.81	1271
1-May	107	1067	2.13	694	0.83	1253
2-May	95	1156	1.99	701	0.85	1236
3-May	94	1163	1.89	714	0.86	1228
4-May	90	1195	1.8	732	0.83	1253
5-May	89	1203	1.72	751	0.81	1271
6-May	102	1103	1.63	779	0.79	1288
7-May	109	1053	1.54	811	0.77	1306
8-May	102	1103	1.46	845	0.76	1315
9-May	101	1110	1.39	877	0.73	1342
10-May	107	1067	1.32	913	0.72	1351
11-May	114	1020	1.24	958	0.7	1370
12-May	122	970	1.18	994	0.69	1379
13-May	133	908	1.06	1074	0.69	1379
14-May	128	935	0.82	1262	0.71	1360
15-May	119	988	0.72	1351	0.74	1333
16-May	112	1033	0.81	1271	0.74	1333
17-May	112	1033	0.91	1187	0.81	1271
18-May	102	1103	1.04	1088	0.83	1253
19-May	105	1081	1.3	924	0.79	1288
20-May	100	1118	1.46	845	0.75	1324
21-May	99	1125	1.64	775	0.76	1315
22-May	100	1118	1.73	749	0.75	1324
23-May	103	1096	1.65	772	0.75	1324
24-May	114	1020	1.54	811	0.77	1306
25-May	113	1027	1.51	823	0.83	1253
26-May	125	952	1.64	775	0.89	1203
27-May	150	827	1.76	741	0.94	1163
28-May	238	712	1.66	769	1.09	1053
29-May	259	759	1.7	757	1.2	982
30-May	264	775	2.23	696	1.37	887
31-May	269	792	3.17	1038	1.65	772
1-Jun	276	818	3.71	1495	1.93	708
2-Jun	286	862	3.48	1277	1.93	708
3-Jun	450	2504	3.2	1058	1.9	713
4-Jun	587	5219	2.94	901	1.9	713
5-Jun	613	5872	2.72	803	1.94	707
6-Jun	583	5122	2.72	803	2.08	695
7-Jun	553	4431	2.97	917	2.35	708
8-Jun	522	3779	3.18	1045	2.7	795
9-Jun	625	6188	3.39	1201	2.99	928
10-Jun	670	7458	3.56	1349	3.02	945
11-Jun	683	7849	3.7	1484	2.9	881

Date	2011		2010		2009	
	Water Level (cm)	**Discharge (m^3/s)**	**Water Level (m)**	**Discharge (m^3/s)**	**Water Level (m)**	**Discharge (m^3/s)**
12-Jun	678	7697	3.75	1536	2.7	795
13-Jun	694	8189	3.81	1600	2.62	768
14-Jun	698	8314	3.76	1546	2.6	762
15-Jun	712	8762	4.03	1855	2.65	778
16-Jun	749	10006	4.18	2046	2.72	803
17-Jun	771	10787	4.45	2429	2.68	788
18-Jun	785	11301	4.82	3029	2.6	762
19-Jun	785	11301	5.34	4024	2.5	735
20-Jun	767	10643	5.79	5027	2.4	715
21-Jun	715	8859	6.11	5820	2.31	703
22-Jun	715	8859	6.19	6029	2.3	702
23-Jun	661	7194	6.19	6029	2.4	715
24-Jun	633	6405	6.38	6542	2.58	756
25-Jun	653	6963	6.85	7910	2.84	852
26-Jun	700	8378	7.19	8990	3.32	1146
27-Jun	750	10040	7.57	10286	3.77	1557
28-Jun	769	10715	7.67	10643	4.04	1867
29-Jun	764	10535	7.68	10679	4.31	2224
30-Jun	747	9936	7.76	10969	4.57	2614
1-Jul	723	9122	7.8	11116	4.78	2960
2-Jul	725	9189	7.89	11450	5.48	4322
3-Jul	766	10607	8	11866	5.84	5147
4-Jul	800	11866	8.13	12367	6.57	7078
5-Jul	827	12920	8.21	12681	7.14	8827
6-Jul	857	14146	8.18	12563	7.5	10040
7-Jul	874	14867	8.23	12761	7.68	10679
8-Jul	876	14953	8.17	12524	7.82	11190
9-Jul	873	14824	8.11	12290	8.01	11904
10-Jul	869	14653	7.93	11601	8.1	12251
11-Jul	863	14398	7.68	10679	8.12	12328
12-Jul	847	13731	7.4	9695	8.05	12058
13-Jul	817	12524	7.06	8569	7.98	11790
14-Jul	773	10860	6.87	7972	7.93	11601
15-Jul	736	9558	7.05	8537	7.81	11153
16-Jul	757	10286	7.46	9901	7.62	10464
17-Jul	810	12251	7.62	10464	7.28	9289
18-Jul	837	13322	7.81	11153	6.85	7910
19-Jul	840	13444	7.79	11080	6.5	6877
20-Jul	881	15169	7.77	11006	6.37	6514
21-Jul	946	18128	7.71	10787	6.25	6188
22-Jul	995	20541	7.71	10787	6	5540
23-Jul	1024	22043	7.89	11450	5.9	5292
24-Jul	1039	22841	8.64	14440	5.73	4886
25-Jul	1030	22360	8.46	13689	5.6	4587

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
26-Jul	1006	21104	8.68	14610	5.5	4365
27-Jul	980	19786	8.82	15212	5.36	4066
28-Jul	948	18224	8.84	15300	5.46	4279
29-Jul	915	16683	8.71	14738	6.19	6029
30-Jul	885	15343	8.54	14021	7.03	8473
31-Jul	861	14314	8.56	14104	7.58	10322
1-Aug	837	13322	8.5	13854	7.75	10933
2-Aug	842	13525	8.41	13485	7.9	11488
3-Aug	805	12058	8.33	13160	8.03	11981
4-Aug	797	11752	8.31	13080	8.06	12096
5-Aug	792	11563	8.56	14104	7.9	11488
6-Aug	774	10896	8.54	14021	7.72	10824
7-Aug	817	12524	8.47	13731	7.92	11563
8-Aug	950	18319	8.1	12251	8.19	12603
9-Aug	1000	20796	7.67	10643	8.26	12880
10-Aug	1030	22360	7.16	8892	8.24	12800
11-Aug	1039	22841	6.68	7399	7.99	11828
12-Aug	1030	22360	6.31	6350	7.59	10357
13-Aug	996	20592	6.1	5795	7.24	9155
14-Aug	944	18033	5.75	4932	6.92	8127
15-Aug	883	15256	5.64	4678	6.83	7849
16-Aug	844	13607	5.62	4633	7.08	8633
17-Aug	847	13731	6.12	5846	7.16	8892
18-Aug	862	14356	6.46	6764	7.24	9155
19-Aug	863	14398	6.74	7577	7.33	9457
20-Aug	865	14483	7.06	8569	7.41	9729
21-Aug	867	14568	7.36	9558	7.44	9832
22-Aug	865	14483	7.44	9832	7.59	10357
23-Aug	852	13937	7.37	9592	8.09	12212
24-Aug	845	13648	7.56	10251	8.62	14356
25-Aug	872	14781	7.77	11006	8.88	15474
26-Aug	904	16185	7.74	10896	9.2	16912
27-Aug	909	16410	7.59	10357	9.43	17986
28-Aug	914	16637	7.9	11488	9.49	18272
29-Aug	881	15169	7.88	11413	9.3	17374
30-Aug	832	13120	7.97	11752	9.08	16365
31-Aug	792	11563	8.02	11943	8.73	14824
1-Sep	751	10075	7.86	11339	7.94	11638
2-Sep	679	7728	7.64	10535	7.3	9356
3-Sep	624	6162	7.39	9661	6.72	7517
4-Sep	589	5268	7.1	8697	6.45	6736
5-Sep	570	4816	6.93	8158	5.94	5391
6-Sep	600	5540	7.02	8441	6.05	5667
7-Sep	590	5292	6.75	7607	6.18	6003

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
8-Sep	600	5540	6.65	7310	6.76	7637
9-Sep	623	6135	6.97	8283	6.21	6082
10-Sep	720	9023	7.56	10251	7.38	9627
11-Sep	754	10181	7.96	11714	7.21	9056
12-Sep	737	9592	7.8	11116	6.68	7399
13-Sep	687	7972	7.65	10571	6.19	6029
14-Sep	680	7758	7.71	10787	5.75	4932
15-Sep	695	8220	7.64	10535	5.45	4257
16-Sep	695	8220	7.56	10251	5.26	3859
17-Sep	692	8127	8.07	12135	5.2	3739
18-Sep	679	7728	8.61	14314	5.18	3699
19-Sep	645	6736	8.28	12960	5.46	4279
20-Sep	652	6934	7.93	11601	5.5	4365
21-Sep	664	7281	7.35	9525	5.77	4980
22-Sep	668	7399	7.1	8697	6.67	7369
23-Sep	685	7910	6.64	7281	6.93	8158
24-Sep	697	8283	6.46	6764	7.32	9423
25-Sep	718	8957	6.38	6542	7.57	10286
26-Sep	713	8794	6.08	5743	7.27	9255
27-Sep	687	7972	5.92	5341	7.5	10040
28-Sep	694	8189	5.85	5171	7.06	8569
29-Sep	698	8314	6.19	6029	6.71	7488
30-Sep	675	7607	6.34	6432	6.4	6597
1-Oct	647	6793	6.36	6487	6.02	5590
2-Oct	627	6242	6.23	6135	5.48	4322
3-Oct	677	7667	5.8	5051	5.44	4235
4-Oct	719	8990	5.47	4300	6	5540
5-Oct	725	9189	5.33	4003	7.09	8665
6-Oct	698	8314	5.2	3739	8.1	12251
7-Oct	670	7458	7.12	8762	9.17	16774
8-Oct	630	6323	6.66	7340	7.87	11376
9-Oct	572	4862	7.4	9695	7.38	9627
10-Oct	552	4409	7.74	10896	6.78	7697
11-Oct	522	3779	8.18	12563	6.19	6029
12-Oct	489	3153	8.19	12603	5.83	5122
13-Oct	466	2758	7.92	11563	6.28	6269
14-Oct	445	2429	7.56	10251	6.4	6597
15-Oct	435	2281	7.5	10040	6.25	6188
16-Oct	430	2210	7.29	9322	6.3	6323
17-Oct	429	2196	7.05	8537	6.03	5616
18-Oct	495	3261	6.45	6736	5.71	4839
19-Oct	735	9525	6.02	5590	5.4	4150
20-Oct	830	13040	6.01	5565	5.12	3582
21-Oct	781	11153	6	5540	4.8	2994

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
22-Oct	787	11376	6.03	5616	4.48	2474
23-Oct	737	9592	6.76	7637	4.42	2384
24-Oct	657	7078	6.75	7607	4.01	1830
25-Oct	565	4701	6.75	7607	3.89	1689
26-Oct	520	3739	6.77	7667	3.8	1589
27-Oct	505	3447	6.3	6323	3.72	1505
28-Oct	485	3082	5.72	4862	3.68	1464
29-Oct	462	2693	5.29	3921	3.64	1425
30-Oct	442	2384	4.86	3099	3.56	1349
31-Oct	427	2169	4.53	2551	3.47	1268
1-Nov	407	1904	4.32	2239	3.35	1169
2-Nov	389	1689	4.22	2100	3.25	1094
3-Nov	374	1526	4.15	2007	3.24	1087
4-Nov	362	1405	4	1818	3.04	956
5-Nov	353	1321	3.88	1678	2.98	923
6-Nov	347	1268	3.76	1546	2.91	886
7-Nov	339	1201	3.65	1434	2.83	848
8-Nov	330	1131	3.53	1321	2.78	826
9-Nov	322	1072	3.42	1226	2.72	803
10-Nov	314	1018	3.37	1185	2.64	775
11-Nov	307	974	3.3	1131	2.57	753
12-Nov	303	951	3.32	1146	2.53	743
13-Nov	296	912	3.12	1005	2.48	731
14-Nov	290	881	3.07	974	2.43	721
15-Nov	285	857	3.03	951	2.4	715
16-Nov	281	839	2.99	928	2.36	709
17-Nov	276	818	2.9	881	2.33	705
18-Nov	273	806	2.76	818	2.3	702
19-Nov	270	795	2.68	788	2.28	700
20-Nov	265	778	2.65	778	2.26	698
21-Nov	260	762	2.6	762	2.23	696
22-Nov	258	756	2.57	753	2.2	695
23-Nov	255	748	2.53	743	2.18	694
24-Nov	252	740	2.47	729	2.16	694
25-Nov	248	731	2.45	725	2.13	694
26-Nov	245	725	2.4	715	2.13	694
27-Nov	239	714	2.36	709	2.12	694
28-Nov	235	708	2.33	705	2.08	695
29-Nov	232	704	2.3	702	2.05	696
30-Nov	229	701	2.28	700	2.02	698
1-Dec	226	698	2.25	697	1.98	702
2-Dec	224	697	2.22	696	1.96	704
3-Dec	222	696	2.2	695	1.92	710
4-Dec	220	695	2.17	694	1.88	716

Date	2011		2010		2009	
	Water Level (cm)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)
5-Dec	218	694	2.14	694	1.82	727
6-Dec	217	694	2.11	694	1.78	736
7-Dec	215	694	2.08	695	1.74	746
8-Dec	210	694	2.04	697	1.7	757
9-Dec	207	695	2.02	698	1.67	766
10-Dec	204	697	2.01	699	1.65	772
11-Dec	201	699	1.99	701	1.62	782
12-Dec	199	701	2.03	698	1.66	769
13-Dec	198	702	2.02	698	1.58	796
14-Dec	195	706	2.01	699	1.56	804
15-Dec	193	708	2	700	1.54	811
16-Dec	191	711	1.99	701	1.51	823
17-Dec	189	714	1.97	703	1.49	832
18-Dec	185	721	1.96	704	1.48	836
19-Dec	181	729	1.94	707	1.47	840
20-Dec	179	734	1.91	711	1.46	845
21-Dec	177	738	1.9	713	1.43	858
22-Dec	175	743	1.87	718	1.4	872
23-Dec	172	751	1.85	721	1.39	877
24-Dec	169	760	1.82	727	1.39	877
25-Dec	165	772	1.77	738	1.38	882
26-Dec	163	779	1.72	751	1.36	892
27-Dec	161	785	1.68	763	1.34	903
28-Dec	159	793	1.64	775	1.3	924
29-Dec	158	796	1.6	789	1.27	941
30-Dec	156	804	1.56	804	1.23	964

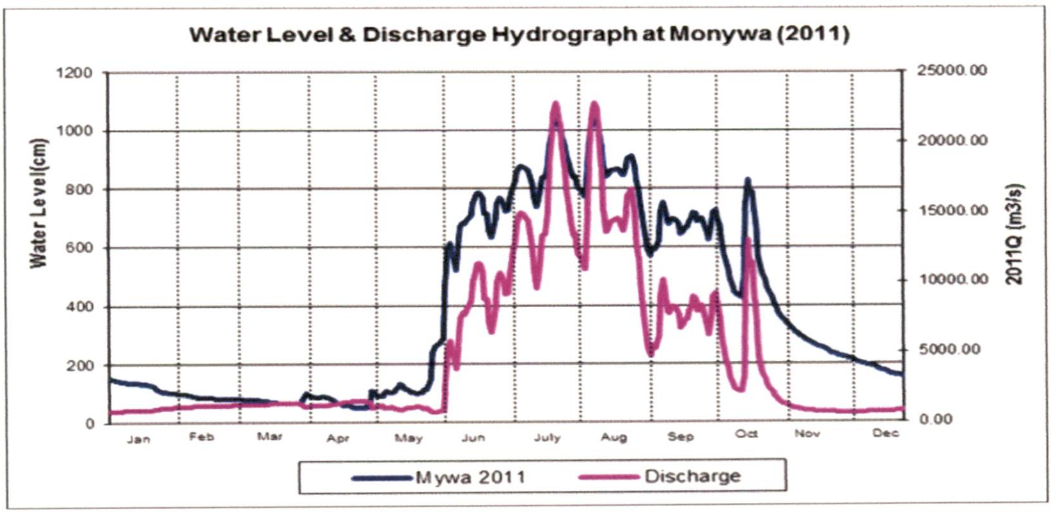


Fig 4.9 Water Level & Discharge Hydrograph at Monywa 2011

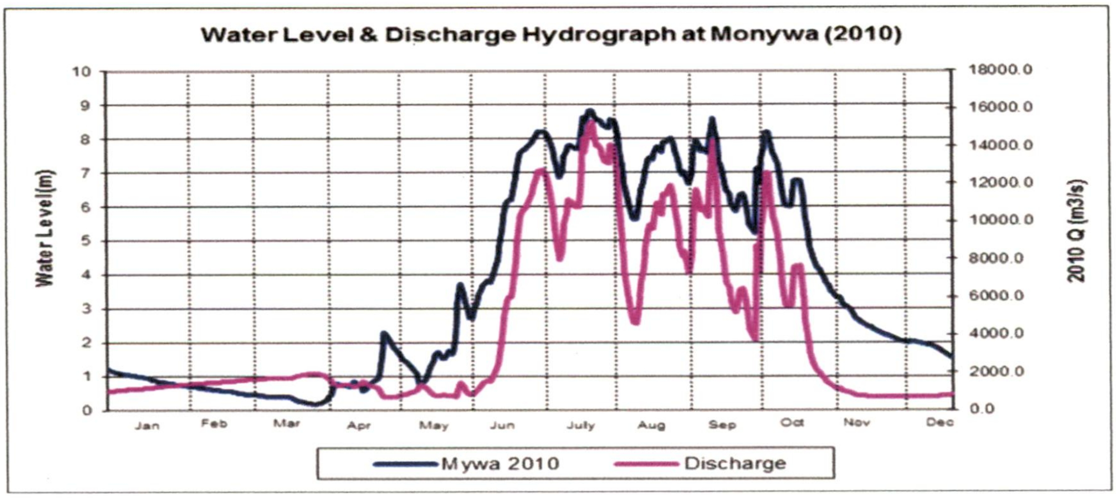


Fig 4.10 Water Level & Discharge Hydrograph at Monwya 2010

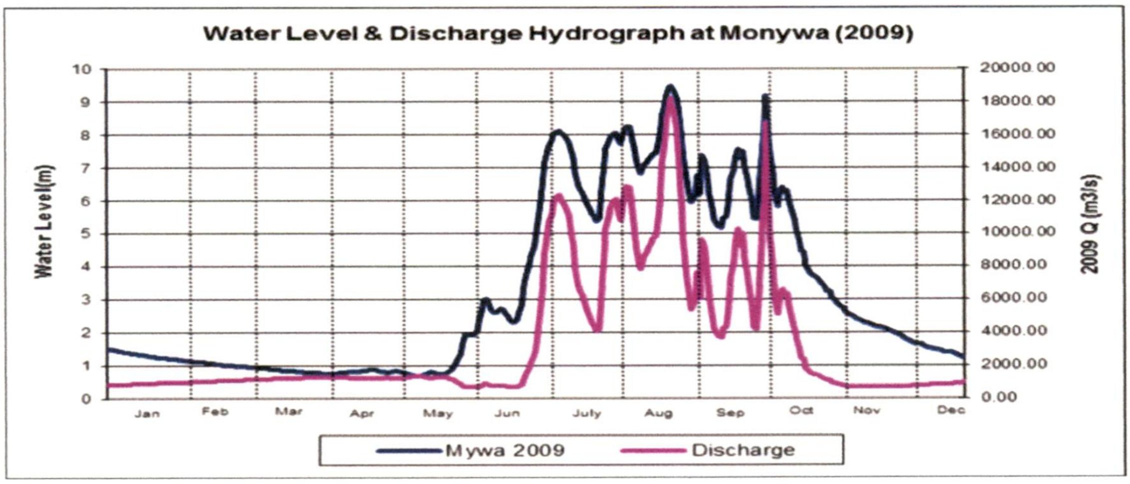


Fig 4.11 Water Level & Discharge Hydrograph at Monwya 2009

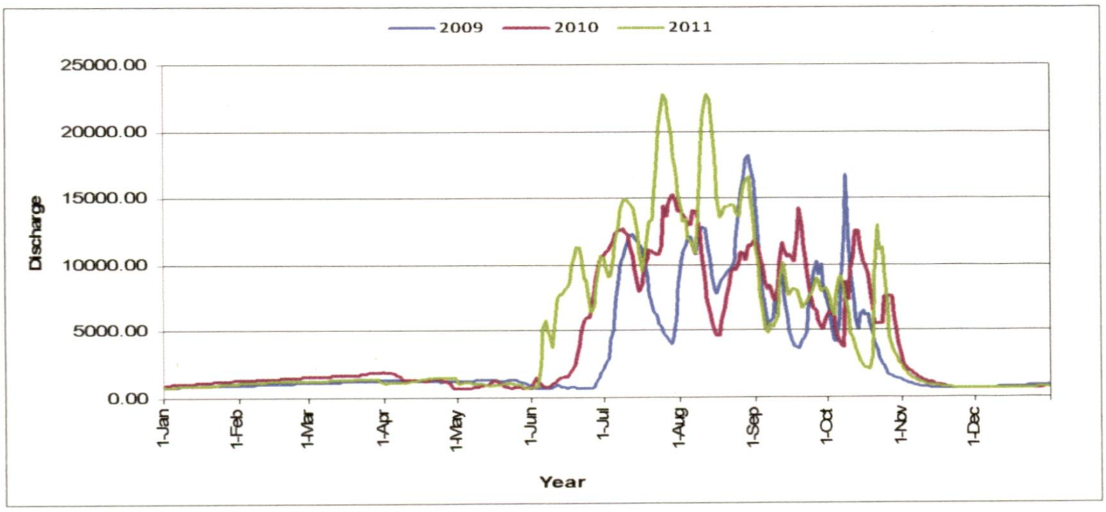


Fig 4.12 Water Level & Discharge Hydrograph at Monwya 2011, 2010, 2009

From Monywa station discharge data we can see that the discharge is varies yearly. In year 2009, the discharge is between 16000 – 18000 m^3/sec. In year 2010, the discharge is between 12000 – 15000 m^3/sec. In year 2011, the discharge is between 17000 – 22000m^3/sec. The variation in discharge very much affects the water quality of Chindwin River at Monywa.

4.2.2 Sewage/Waste Water Management

The big amount of waste water can cause the changes of the river water quality. The higher value of the Biological parameters (BOD, COD, DO) the worse of the river water quality. Wastewater from the Towns has not taken disposes into the river directly.

4.2.2.1 Monywa Township Wastewater Estimate

Monywa is city in central Myanmar, the fourth largest city and situated on the Eastern bank of the Chindwin River. Monywa serves as a major trade center for India and Myanmar through KalayMyo road and Chindwin River. Monywa is a major Centre for trade and commerce and for agricultural produce from the surrounding Chindwin Valley, especially beans, orange, pulses and jaggery (palm sugar).

Population in Monywa = 217511

Water supply daily = 135 lpcd

Average sewage discharge = $0.8 \times 135 \times 217511$

= 23.49 MLD.

Table 4.4: Sewage Parameters from Monywa Township

Sample	Outlet-1	Outlet-2	Outlet-3
pH	8.0	7.9	7.6
Iron	Trace	2.5	Trace
Total Solid	2586	1188	2068
Alkalinity	760	380	1080
Total Hardness	270	196	440
Chloride	354.4	510.4	148.8
Manganese	Nil	0.03	Nil
Copper	Nil	Nil	0.15
Sulphate	0.1795	0.1463	0.1243
Arsenic	<0.01	<0.01	Nil
Nitrite	Nil	Nil	0.15
BOD	42	28.8	72
COD	201.6	70.4	224
Dissolved Oxygen	Nil	Nil	Nil

4.2.3 Management of Exploring of Mining

The Chindwin River has many natural resources i.e. gold, jade. Most of the persons who living along the Chindwin river have taken the exploring of gold, jade. The exploring of mining can cause the changes of the river water quality. The Government of the country controls the exploring of mining by using "Conservation of Water Resources and River Law".

No person shall:

(a) Dispose of engine oil, chemical, poisonous material and other materials which may cause environmental damage, or dispose of explosives from the bank or from a vessel which is plying, vessel which has berthed, anchored, stranded or sunk.

(b) Catch aquatic creatures within river-creek boundary, bank boundary or waterfront boundary with poisonous materials or explosives.

(c) Dispose of disposal soil and other materials from panning for gold, gold mineral dredging or resource production in the river and creek, into the river and creek or into the water outlet gully which can flow into the river and creek.

4.2.4 Measurement of Chindwin River Water Quality Parameters

4.2.4.1 Equipment and Parameters

Paqua Lab water quality test photometer was used for testing eleven elements including in river water. Eleven elements are Iron, Chloride, Chlorine, Alkalinity, Total Hardness, Ammonia, Nitrate, Nitrite, Fluoride, Turbidity and pH .These elements were tested out and compared to WHO drinking water standard.

4.2.4.2 Sampling and Testing Method

Water samples were taken from the surface and 0.6 x depth at the deepest point by using water sampler along cross section of each and every station. The water samples taken were tested just after sampling.

4.2.4.3 Sample Collection Period

Sample Collection Period was done in low water season (dry season). i.e. end of February to beginning of March.

4.2.4.4 River Water Quality Parameters

The Chindwin river water quality monitoring is most essential aspect of restoring the water quality. One of the main objectives of the river water quality monitoring is to assess the suitability of river water for drinking purposes, irrigation, outdoor bathing and Propagation of wildlife, fisheries. The physical and chemical quality of river water is important in deciding its suitability for drinking purposes. As such the suitability of river water for potable uses with regard to its chemical quality has to be deciphered and defined on the basis of the some vital characteristics of the water.River water quality is very important for aspect in Myanmar. The physic-chemical parameters like pH, Chloride, Fluoride, Iron, Nitrate and Total hardness are main constituents defining the quality of river water in surface water. Actually every river stretch has a distinct water use as some is used for irrigation, other for mass bathing and still others for drinking. The best use classification is essential, for maintaining the quality of river water of the particular stretch.

Table 4.5: Water Quality Parameters in Chindwin River (2010) MARCH

S. No.	Town / Place	Latitude	longitude	Laboratory Observations									
				Iron (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Fluoride (mg/l)	Turbidity (NTU)	pH
	WHO (standard value)			**0.3**	**250**	**20-200**	**150-500**	**0.5**	**10.0 (N)**	**50 (N)**	**1.5**	**5**	**6.5-8.5**
1	Chindwin Wa	21° 28'09.44	95° 16' 41.5	0.3	194	107	47	0.39	0.15	10	1.55	35	7.2
2	Thitthe	21°32'20.04	95°15'17.74	0.49	94	187	185	0.15	0.1	35	0.4	130	7.3
3	Chitthu	21°37'12.13	95°15'38.02	1.1	250	235	165	1.1	0.12	45	0.5	180	7.2
4	Yezagyo	21° 38'28.02	95°14'51.8	0.995	335	267	165	0.33	0.18	45	1.5	160	7.1
5	Prima	22°15'30.2	95°10'23.4	0.945	355	235	130	0.61	0.14	50	0.4	180	7.3
6	Monywa	22°06'43.58	95°07'20.76	0.85	78	180	137	0	0.1	50	0.05	200	7.4
7	AinTaw	22°18'24.22	95°03'30.12	0.925	0.63	230	220	0.23	0.17	55	0.2	180	7.4
8	Shwesaya	22°20'22.16	94°59'21.65	1.015	410	225	145	1.1	0.18	60	1.2	150	7.5
9	Ye Butalin	22°20'49.01	94°59'05.58	1.03	162	230	155	0.16	0.17	50	0.25	180	7.8
10	Kani	22°26'44.57	94°50'23.88	0.89	176	220	130	0.11	0.22	70	0.3	140	7.5
11	Mingin	22°54'19.66	94° 30'00.25	0.77	122	202	145	0.16	0.16	45	1.5	140	7.4
12	Kalewa	23°11'55.85	94°18'29.3	0.9	112	202	145	0.16	0.12	40	0.05	140	7.3
13	Mawlaik	23°37'25.04	94°23'15.22	0.03	232	110	102	0.16	0.17	60	0.25	190	7.3
14	Pantha	23°50'00.10	94°32'02.41	1.02	133	220	210	0.16	0.14	70	0.55	190	7.4
15	Sitaung	24°09'49.95	94°35'33.41	0.89	188	220	145	0.87	0.22	60	1.15	200	7.7
16	Phaungpyin	24°16'10.93	94°48'41.06	0.47	171	215	130	0.2	0.094	85	0.2	150	8.3
17	Homalin	24°51'43.92	94°54'34.06	0.025	232	130	34	0	0.55	10	0.55	12.5	7.1

Table 4.6: Calculation of NSFW Quality Index in Chindwin River 2010

S. No.	Elements / Towns	pH		Turbidity		Nitrate		NSFW Q Index	
		Data	Q-Value	Data	Q-Value	Data	Q-Value		
1	Chindwin Wa	7.5	93	35	49	0.15	97	**82**	**Good**
2	Thitthe	7.5	93	130	5	0.1	97	**70**	**Good**
3	Chitthu	7.3	93	180	5	0.12	97	**70**	**Good**
4	Yesagyo	7.5	93	160	5	0.18	97	**70**	**Good**
5	Prima	7.3	93	180	5	0.14	97	**70**	**Good**
6	Monywa	7.4	93	200	5	0.1	97	**70**	**Good**
7	AinTaw	7.4	93	180	5	0.17	97	**70**	**Good**
8	Shwesayae	7.5	93	150	5	0.18	97	**70**	**Good**
9	Ye Butalin	7.8	90	180	5	0.17	97	**69**	**Medium**
10	Kani	7.5	93	140	5	0.22	97	**70**	**Good**
11	Mingin	7.4	93	140	5	0.16	97	**70**	**Good**
12	Kalewa	7.3	93	140	5	0.12	97	**70**	**Good**
13	Mawlaik	7.3	93	190	5	0.17	97	**70**	**Good**
14	Pantha	7.4	93	190	5	0.14	97	**70**	**Good**
15	Sitaung	7.7	91	200	5	0.22	96	**69**	**Medium**
16	Phaung Pyin	8.3	73	150	5	0.94	97	**63**	**Medium**
17	Homalin	7.1	90	12.5	71	0.55	97	**87**	**Good**

Table 4.7: Water Quality Parameters in Chindwin River (2010) APRIL

S. No.	Town / Place	Latitude	longitude	Laboratory Observations									
				Iron (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Fluoride (mg/l)	Turbidity (NTU)	pH
	WHO (standard value)			**0.3**	**250**	**20-200**	**150-500**	**0.5**	**10.0 (N)**	**50 (N)**	**1.5**	**5**	**6.5-8.5**
1	Chindwin Wa	21° 28'09.44	95° 16' 41.5	0.3	300	125	38	0.55	0.18	5	1.1	35	7.5
2	Thitthe	21°32'20.04	95°15'17.74	0.49	171	108	108	1.0	0.1	35	0.35	130	7.5
3	Chitthu	21°37'12.13	95°15'38.02	1.1	225	230	175	0.44	0.15	45	1.45	175	7.3
4	Yezagyo	21° 38'28.02	95°14'51.8	0.995	315	245	137	1.0	0.27	50	1.45	190	7.2
5	Prima	22°15'30.2	95°10'23.4	0.945	270	214	175	1.0	0.14	40	0.55	180	7.5
6	Monywa	22°06'43.58	95°07'20.76	0.85	300	175	145	0.55	0.12	45	0.35	200	7.4
7	AinTaw	22°18'24.22	95°03'30.12	0.925	1.39	214	130	0.34	0.13	50	0.35	150	7.3
8	Shwesaya	22°20'22.16	94°59'21.65	1.015	260	220	137	0.55	0.19	50	1.4	160	7.7
9	Ye Butalin	22°20'49.01	94°59'05.58	1.03	450	202	155	0.66	0.23	45	0.55	180	7.9
10	Kani	22°26'44.57	94°50'23.88	0.89	300	202	145	1.0	0.22	45	0.35	120	7.4
11	Mingin	22°54'19.66	94° 30'00.25	0.77	149	193	122	1.0	0.1	40	0.35	140	7.3
12	Kalewa	23°11'55.85	94°18'29.3	0.9	500	202	175	0.19	0.15	40	1.5	120	7.5
13	Mawlaik	23°37'25.04	94°23'15.22	0.03	100	202	70	1.0	0.024	60	0.5	150	7.6
14	Pantha	23°50'00.10	94°32'02.41	1.02	205	197	155	0.15	0.2	65	0.5	200	7.3
15	Sitaung	24°09'49.95	94°35'33.41	0.89	211	267	155	1.0	0.21	60	0.3	180	7.5
16	Phaungpyin	24°16'10.93	94°48'41.06	0.47	121	387	122	0.34	0.11	48	0.1	170	7.6
17	Homalin	24°51'43.92	94°54'34.06	0.025	64	125	38	0.45	0.59	0	0.05	20	7.4

Table 4.8: Water Quality Parameters in Chindwin River (2011) MARCH

S. No.	Town / Place	Latitude	Longitude	Laboratory Observations									
				Iron (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Fluoride (mg/l)	Turbidity (NTU)	pH
	WHO (standard value)			0.3	250	20-200	150-500	0.5	10.0 (N)	50 (N)	1.5	5	6.5-8.5
1	Chindwin Wa	21° 28'09.44	95° 16' 41.5	0.57	46	125	60	0	0.25	0	0.25	90	7.3
2	Thitthe	21°32'20.04	95°15'17.74	1.48	58	197	175	0.06	0.23	10	1.55	300	7.7
3	Chitthu	21°37'12.13	95°15'38.02	0.58	74	214	155	0.11	0.17	0	1.06	180	7.1
4	Yezagyo	21° 38'28.02	95°14'51.8	0.95	166	220	155	0.02	0.22	10	0.25	170	7.4
5	Prima	22°15'30.2	95°10'23.4	0.74	54	214	130	0	0.23	5	1.45	250	7.2
6	Monywa	22°06'43.58	95°07'20.76	1.08	380	225	175	0.01	0.35	15	0.35	180	7.1
7	AinTaw	22°18'24.22	95°03'30.12	1.07	122	202	137	0	0.1	10	1.5	200	8.0
8	Shwesaya	22°20'22.16	94°59'21.65	0.63	50	187	56	0	0.18	10	1.5	220	7.6
9	Ye Butalin	22°20'49.01	94°59'05.58	1.7	38	255	220	0.07	0.9	15	1.3	260	7.9
10	Kani	22°26'44.57	94°50'23.88	1.32	380	220	165	0.02	0.23	10	1.45	190	7.9
11	Kalewa	23°11'55.85	94°18'29.3	1.3	335	220	195	0.1	0.53	15	0	240	7.1
12	Mawlaik	23°37'25.04	94°23'15.22	1.04	188	202	145	0.05	0.6	10	1.1	200	7.1
13	Sitaung	24°09'49.95	94°35'33.41	0.95	122	197	185	0.03	0.28	10	0.25	220	7.6
14	Phaung Pyin	24°16'10.93	94°48'41.06	1.37	68	180	145	0.12	0.3	10	1.3	200	8.1
15	Lower UyuRiver (Chindwin)	24°48'30.43	94°56'22.74	0.37	152	80	52	0	0.75	0	1.15	230	8.8
16	Lower Uyu river (Chindwin + Uyu)	24°49'39.18	94°56'35.01	0.32	48	115	70	0	0.5	10	0	110	8.9
17	Lower Uyu river	24°49'47.01	94°56'39.8	2.86	80	245	390	0.13	0.65	20	0	420	8.9
18	Homalin	24°51'43.92	94°54'34.06	0.25	206	140	34	0.01	0.4	0	1.5	25	7.8

Table 4.9: Calculation of NSFW Quality Index in Chindwin River 2011(March)

S. No.	Elements / Towns	pH		Turbidity		Nitrate		NSFW Index	
		Data	Q Value	Data	Q Value	Data	Q Value		
1	Chindwin Wa	7.3	93	90	22	0.25	97	**75**	**Go**
2	Thitthe	7.7	91	300	5	0.23	95	**69**	**Med**
3	Chitthu	7.1	90	180	5	0.17	96	**69**	**Med**
4	Yesagyo	7.4	93	170	5	0.22	97	**70**	**Go**
5	Prima	7.2	92	250	5	0.23	96	**69**	**Med**
6	Monywa	7.1	90	180	5	0.35	97	**69**	**Med**
7	AinTaw	8.0	84	200	5	0.1	96	**66**	**Med**
8	Shwesayae	7.6	.92	220	5	0.18	96	**69**	**Med**
9	Ye Butalin	7.9	87	260	5	0.9	96	**67**	**Med**
10	Kani	7.9	87	190	5	0.23	96	**67**	**Med**
11	Kalewa	7.1	90	240	5	0.53	97	**69**	**Med**
12	Mawlaik	7.1	90	200	5	0.6	96	**69**	**Med**
13	Sitaung	7.6	92	220	5	0.28	97	**70**	**Go**
14	Phaung Pyin	8.1	80	200	5	0.3	96	**65**	**Med**
15	Lower Uyu River (Chindwin)	8.8	56	190	5	0.75	96	**56**	**Med**
16	Lower Uyu River (Chindwin + Uyu)	8.9	52	110	5	0.5	97	**55**	**Med**
17	Lower Uyu River	8.9	52	420	5	0.65	97	**55**	**Med**
18	Homalin	7.8	90	12.5	71	0.4	95	**86**	**Go**

Table 4.10: Water Quality Parameters in Chindwin River (2011) APRIL

S. No.	Town / Place	Latitude	longitude	Laboratory Observations									
				Iron (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Fluoride (mg/l)	Turbidity (NTU)	pH
	WHO (standard value)			**0.3**	**250**	**20-200**	**150-500**	**0.5**	**10.0 (N)**	**50 (N)**	**1.5**	**5**	**6.5-8.5**
1	Chindwin Wa	21° 28'09.44	95° 16' 41.5	0.69	137	130	75	0.03	0.33	0	1.4	80	7.2
2	Thitthe	21°32'20.04	95°15'17.74	1.48	133	235	185	0.04	0.28	10	0.5	190	7.6
3	Chitthu	21°37'12.13	95°15'38.02	2.2	250	202	210	0.07	0.28	0	1.55	180	7.3
4	Yezagyo	21° 38'28.02	95°14'51.8	0.76	72	214	137	0.19	0.19	10	1.5	180	7.6
5	Prima	22°15'30.2	95°10'23.4	0.86	129	202	155	0	0.21	5	0.5	200	7.3
6	Monywa	22°06'43.58	95°07'20.76	1.09	260	202	155	0	0.24	10	0.55	190	7.2
7	AinTaw	22°18'24.22	95°03'30.12	0.94	90	208	185	0	0.38	5	1.35	200	7.9
8	Shwesaya	22°20'22.16	94°59'21.65	1.39	110	290	155	0.01	0.22	5	0.4	220	7.3
9	Ye Butalin	22°20'49.01	94°59'05.58	1.47	450	208	130	0.05	0.21	5	1.35	270	7.8
10	Kani	22°26'44.57	94°50'23.88	0.52	166	193	195	0	0.18	15	0.2	190	7.2
11	Kalewa	23°11'55.85	94°18'29.3	1.32	450	220	145	0.1	0.95	10	1.2	240	7.2
12	Mawlaik	23°37'25.04	94°23'15.22	1.13	285	208	155	0.07	0.23	10	1.45	210	7.1
13	Sitaung	24°09'49.95	94°35'33.41	0.62	50	197	137	0	0.2	10	0.4	220	7.5
14	Phaung pyin	24°16'10.93	94°48'41.06	1.15	25	165	130	0.02	0.27	10	0.25	200	7.9
15	Lower UyuRiver (Chindwin)	24°48'30.43	94°56'22.74	0.42	22	85	38	0	0.25	0	0	5	8.9
16	Lower Uyu river (Chindwin + Uyu)	24°49'39.18	94°56'35.01	0.54	16	130	75	0.07	0.21	5	1.1	120	8.9
17	Lower Uyu river	24°49'47.01	94°56'39.8	3	66	323	500	0.2	0.5	25	0.05	420	8.7
18	Homalin	24°51'43.92	94°54'34.06	0.71	23	80	52	0	0.28	0	1.35	21	7.5

Table 4.11: Chindwin River Water Quality 2012

S. No.	Town/Place	Latitude	Longitude	Laboratory Observations													
				pH	Iron (mg/l)	Chloride (mg/l)	Alkalinity (mg/l)	Total Hardness (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)	Turbidity (NTU)	Fluoride (mg/l)	Temp °C	Dissolved Oxygen (mg/l)	BOD (mg/l)	COD (mg/l)
	WHO (Normal Value)			6.5-8.5	0.3	250	20-200	150-500	0.5	50(N)	10.0(N)	5	1.5		5.0		
1	Homalin	24°51'43.92	94°54'34.06	8	0.295	148	145	0	0	10	0.42	50	0.35	26.3	7.57	-	-
2	Mawliak	23°37'25.04	94°23'15.22	8.6	1.93	158	245	210	0.15	320	0.8	140	0	26.8	7.98	-	-
3	Upper Kalawa	23°11'55.85	94°18'29.3	8.8	2.07	285	235	195	0.02	400	0.55	250	0.25	25.3	6.131	-	-
4	Lower kalawa	23°11'49.45	94°19'19.6	8.6	1.735	410	260	390	0.19	435	0.55	400	1.1	26.3	5.96	-	-
5	Upper Mingin	22°54'19.66	94°30'00.25	8.9	1.745	500	267	210	0.12	140	0.7	320	1.15	26.6	7.23	-	-
6	Lower Mingin	22°52'38.48	94°32'39.05	8.2	1.57	335	252	185	0.18	180	0.4	300	1.06	26	7.86	-	-
7	Upper Kani	22°26'44.57	94°50'23.88	8.2	4.63	270	273	195	0.12	180	0.75	300	0.25	25.9	11.49	-	-
8	Lower Kani	22°26'04.76	94°52'45.1	8.3	1.9	500	267	300	0.23	210	0.58	200	0.25	25.9	9.17	-	-
9	Upper Shwesaye	22°20'22.16	94°59'21.65	8.1	1.74	450	225	95	0.07	435	0.58	300	0.05	25.3	8.43	1.06	2.44
10	Lower Shwesaye	22°20'09.38	94°59'58.18	8.2	1.45	500	208	102	0.06	75	0.35	200	0.55	25.8	14.75	0.74	1.98
11	Monywa	22°06'43.58	95°07'20.76	8.1	1.1	510	225	99	0.05	80	0.34	195	0.56	25.9	14.5	0.14	0.3

Table 4.12: Calculation of NSF Water Quality Index in Chindwin River 2012

S. No	Station / Elements	Homalin		Mawliak		Upper Kalawa		Lower Kalawa		Upper Mingin		Lower Mingin		Upper Kani		Lower Kani		Upper Shwesayae		Lower Shwesayae		Monywa	
		Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value	Data	Q Value
1	pH	8.0	84	8.6	63	8.8	56	8.6	63	8.9	52	8.2	77	8.2	77	8.3	73	8.1	80	8.2	77	8.1	80
2	Turbidity	50	39	140	5	250	5	400	5	320	5	300	5	300	5	200	5	300	5	200	5	195	5
3	Temperature	26.3	93	26.8	93	25.3	92	26.3	92	26.6	92	26	92	25.9	91	25.9	91	25.3	91	25.8	91	25.9	91
4	Dissolved Oxygen	7.57	98	7.98	99	6.13	81	5.96	81	7.23	96	7.86	99	11.49	50	9.17	93	8.43	99	14.75	50	14.5	50
5	BOD	-	-	-	-													1.06	94	0.74	97	0.14	99
6	Nitrate	0.42	97	0.8	96	0.55	96	0.55	96	0.34	96	0.4	97	0.75	96	0.58	96	0.58	96	0.35	97	0.34	97
7	**NSFW Q Index**	**86 Good**		**77 Good**		**70 Good**		**71 Good**		**74 Good**		**80 Good**		**65 Medium**		**77 Good**		**82 Good**		**70 Good**		**59 Medium**	

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Table 4.13: Comparison of NSFW Quality Index

S. No.	Station	2010	2011	2012
1	Homalin	87	86	86
2	Mawliak	70	69	77
3	Kalawa	70	69	70
4	Mingin	70	70	80
5	Kani	70	67	77
6	Shwesaye	70	69	82
7	Monywa	70	69	59

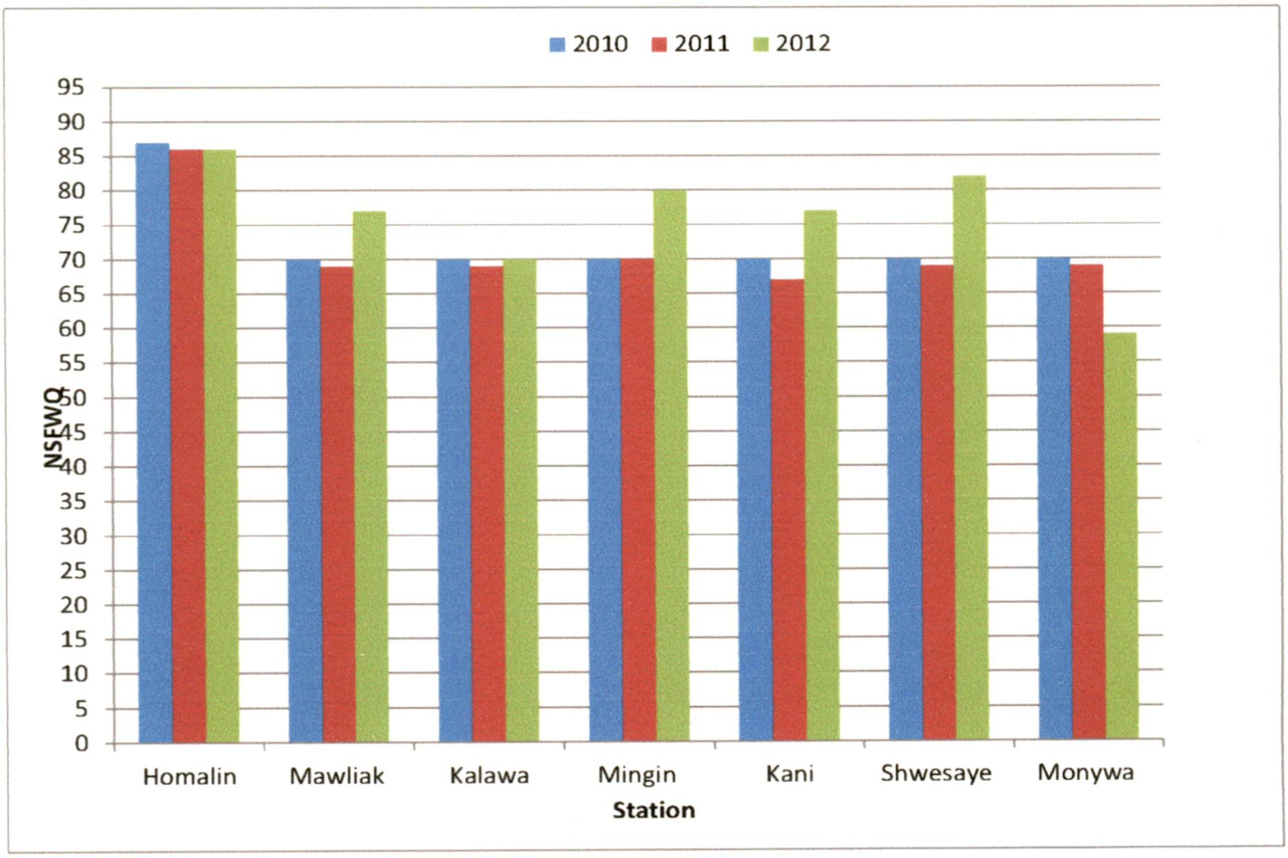


Fig 4.13 Comparison of NSFW Quality Index 2010, 2011, 2012

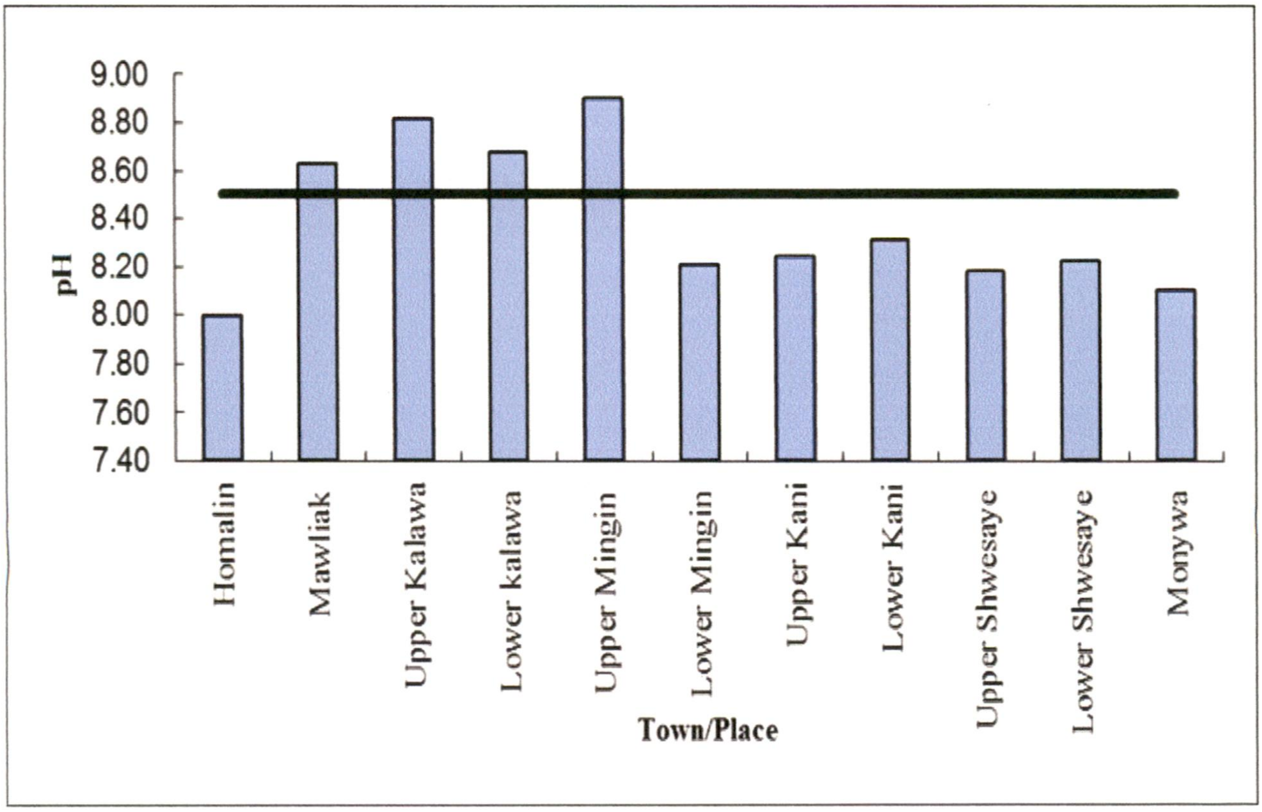


Fig. 4.14

4.2.4.5 pH

WHO (World Health Organization) have recommended a desirable limit of 6.5 – 8.5 of pH in drinking water.

High values of pH greater than 8.5 are observed at Mawliak, Upper & lower kalewa and upper Mingin as shown in fig.4.14. pH is related to a variety of other parameters, it is not possible to determine whether pH has a direct relationship with human health. Insofar as pH affects the unit processes in water treatment that contribute to the removal of viruses, bacteria and other harmful organisms, it could be argued that pH has an indirect effect on health. The destruction of viruses by the high pH levels encountered in water softening by the lime/soda ash process could also be considered beneficial.

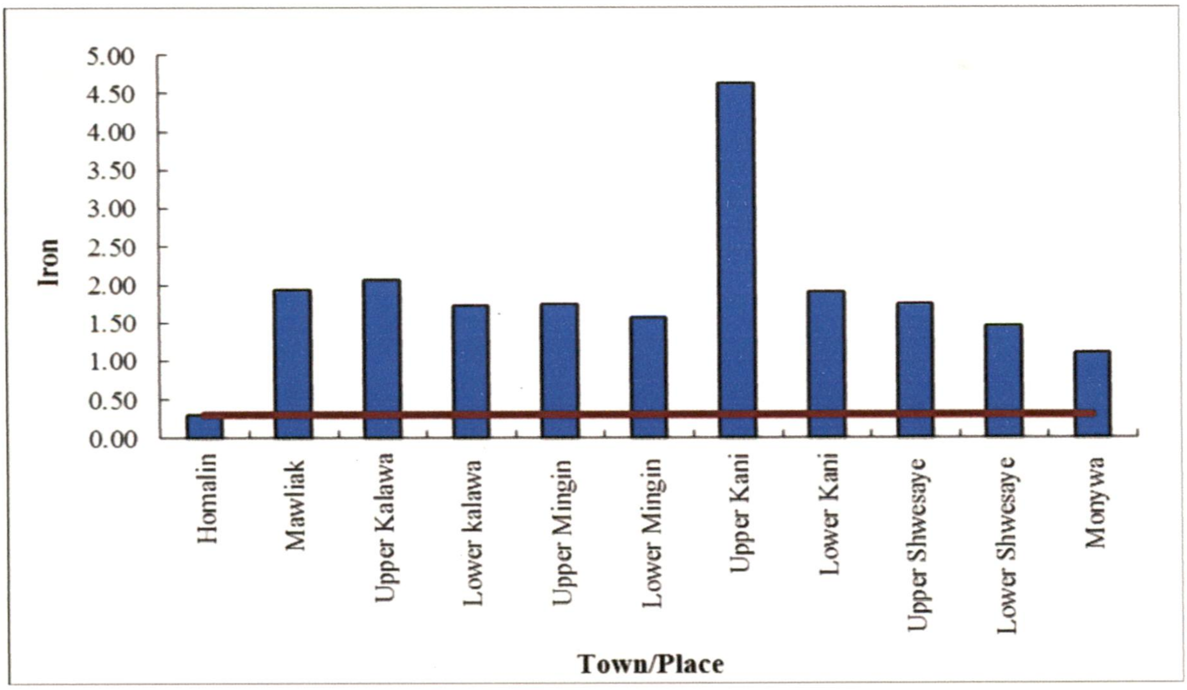


Fig. 4.15

4.2.4.6 Iron

WHO (World Health Organization) have recommended a desirable limit of 0.3mg/l of Iron in drinking water.

High values of Iron greater than 0.3mg/l are observed at all the stations except Homalin station as shown in fig.4.15.Iron is an essential nutrient in animal and plant metabolism. It is not normally considered a toxic substance. However: its presence at elevated levels can cause aesthetic problems on ornamental plants, buildings and structures, and its accumulation on irrigation equipment can lead to clogged emitters.

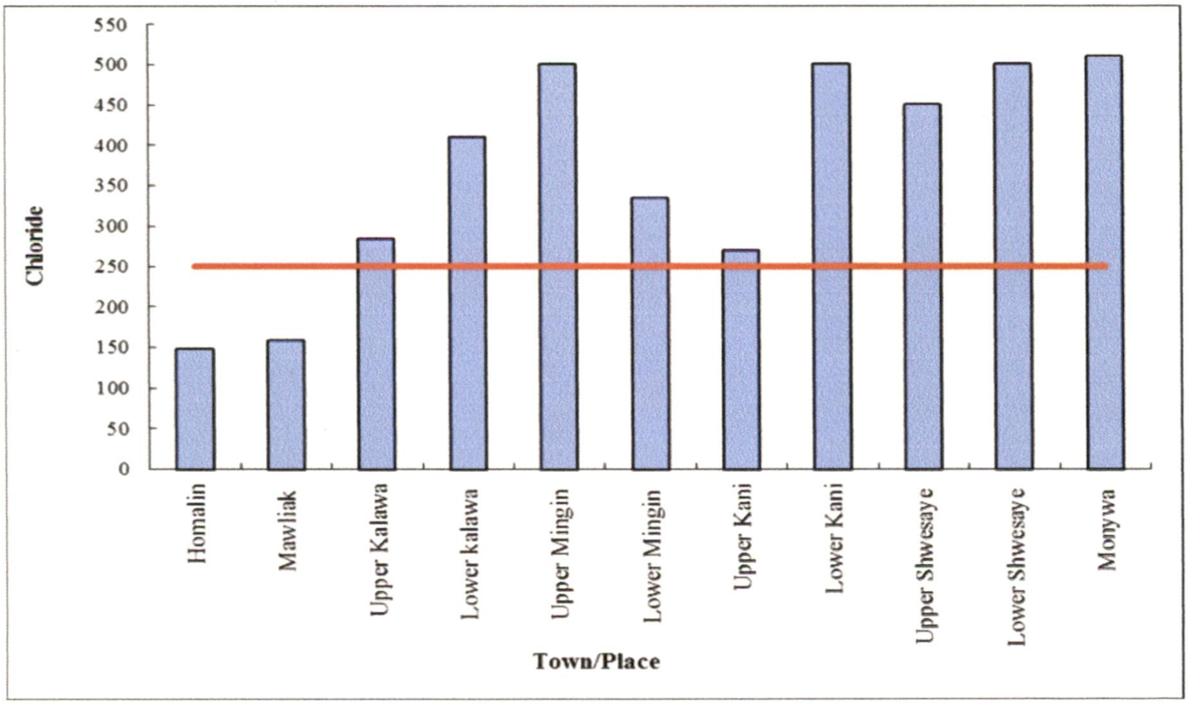


Fig. 4.16

4.2.4.7 Chloride

WHO (World Health Organization) have recommended a standard value of 250mg/l of chloride in drinking water.

High values of Chloride greater than 250mg/l are observed at all the stations except Homalin and Mawliak as shown in fig.4.16.Chloride is the most abundant anion in the human body and is essential to normal electrolyte balance of body fluids. For adults, a daily dietary intake of about 9 mg of chloride per kilogram of body weight is considered essential for good health. Chlorides in water are more of a taste than a health concern, although high concentrations may be harmful to people with heart or kidney problems.

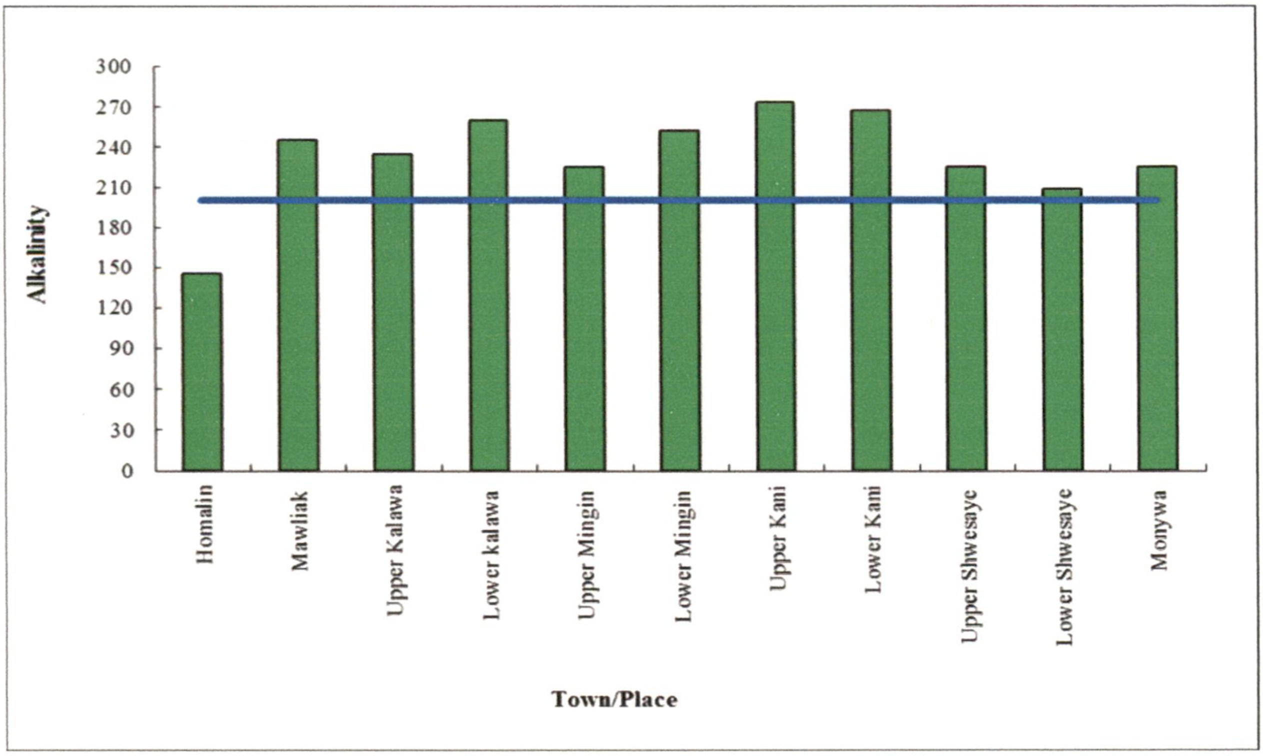


Fig. 4.17

4.2.4.8 Alkalinity

Water alkalinity is determined by the levels in the water of bicarbonates and carbonates as shown in fig.4.17; bicarbonates are normally the most Important Factor in irrigation water. Alkalinity is important for fish and aquatic life because it protects against rapid pH changes. Hard water can cause several problems for consumers including decreased life of house hold plumbing and water using appliances, decreased efficiency of water heaters and white chalky deposits on items such as plumbing, tubs, sinks and pots and pans.

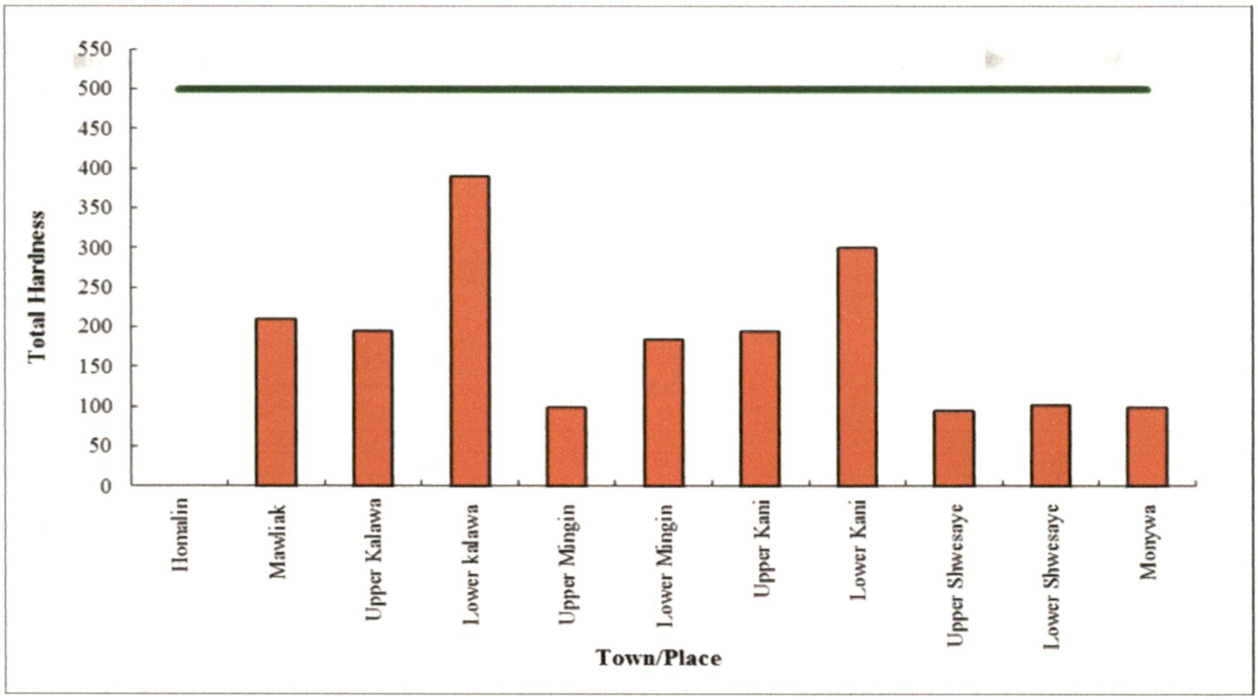


Fig. 4.18

4.2.4.9 Total hardness

WHO (World Health Organization) have recommended a desirable limit of 150-500mg/l of total hardness in drinking water.

The hardness of water depends mainly on the presence of dissolved calcium and magnesium salts. Public acceptability of the degree of hardness of water may vary considerably from one community to another, depending on local conditions. The taste threshold for the calcium ion is in the range 100-300 mg/l depending on the associated anion, and the taste threshold for magnesium is probably less than that for calcium. In some instances, water hardness in excess of 500 mg/l is tolerated by consumers. Other divalent ions such as zinc etc also contribute to hardness.

Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/l may cause scale deposition in the distribution system and will result in excessive soap consumption and subsequent "scum" formation. On heating, hard waters form deposits of calcium carbonate scale. Soft water, with a hardness of less than 100 mg/I, may, on the other hand, have a low buffer capacity and so be more corrosive for water pipes.

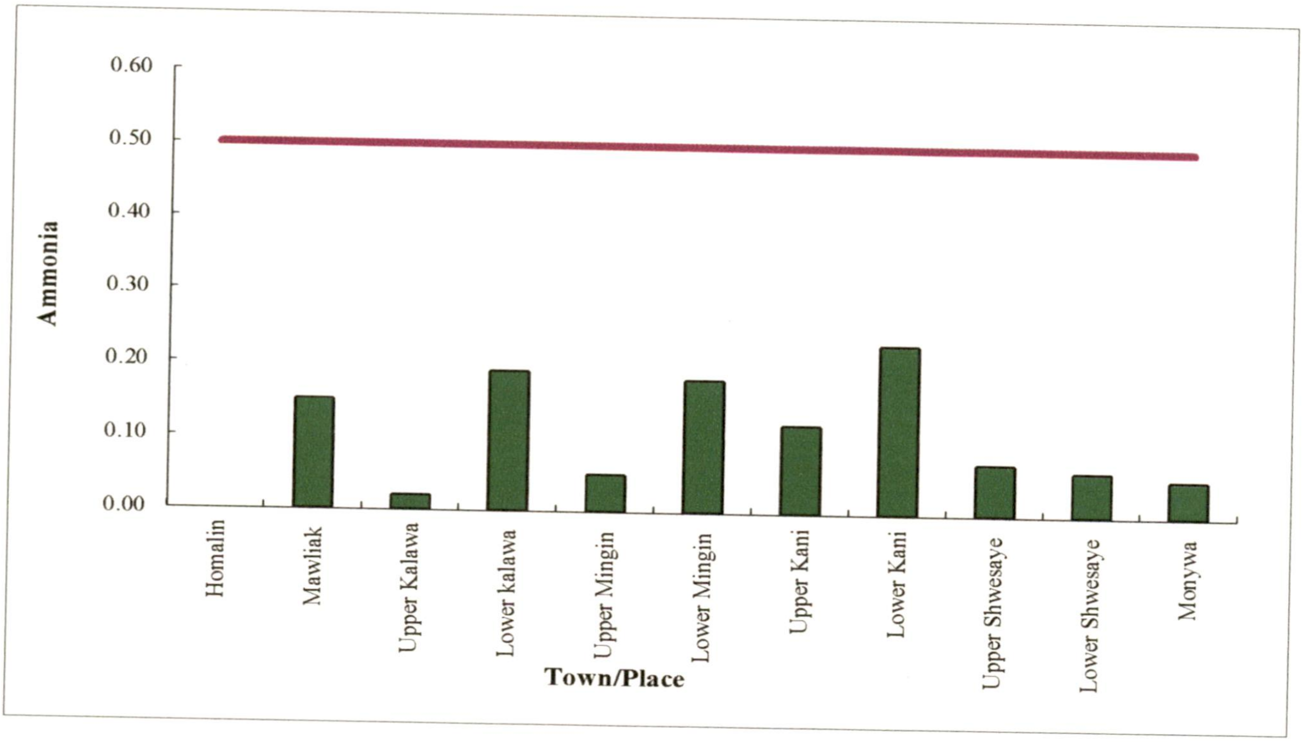


Fig. 4.19

4.2.4.10 Ammonia

WHO (World Health Organization) have recommended a standard value of 0.5mg/l of ammonia in drinking water.

Excess ammonia may affect hatching and growth rate of fishes. Toxic concentrations of ammonia in humans may causes loss of equilibrium convulsions, coma and death. The data is inadequate to determine water can result in human cancer. Methemogloninemia, a form of anemia, can result from the reaction of nitrite with hemoglobin in the blood. When this occurs, the ability of the blood to carry oxygen to the body's tissues is decreased. In infants, this condition is called "blue baby" syndrome.

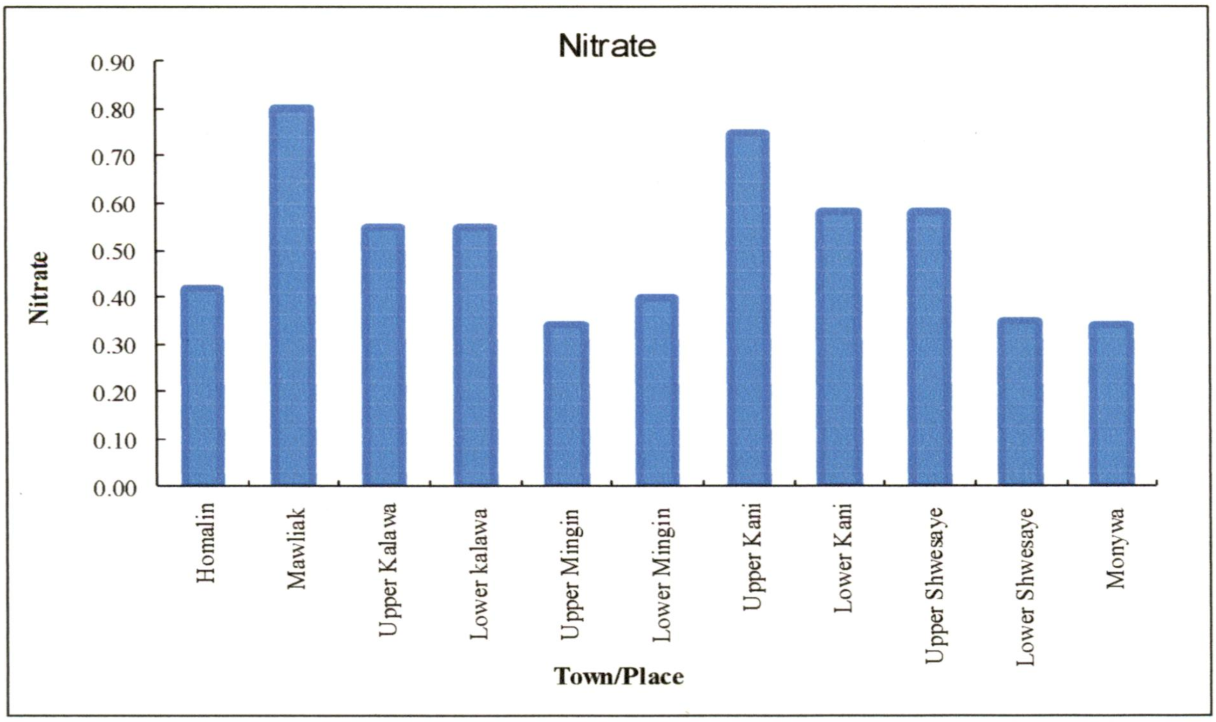


Fig. 4.20

4.2.4.11 Nitrate

WHO has recommended standard for drinking water the maximum desirable limit of Nitrate concentration in 10mg/l as nitrate N (45 mg/l as Nitrate NO_3).

Nitrate is a normal dietary component. A typical adult ingests around 75 mg/day, mostly from the natural nitrate content of vegetables, particularly beets, celery, lettuce, and spinach. Nitrate is converted to nitrite in the body, and nitrite oxidizes Fe2þ in blood hemoglobin to Fe3þ, rendering the blood unable to transport oxygen, a condition called methemoglobinemia. Infants are much more sensitive than adults to this problem because of their small total blood supply.

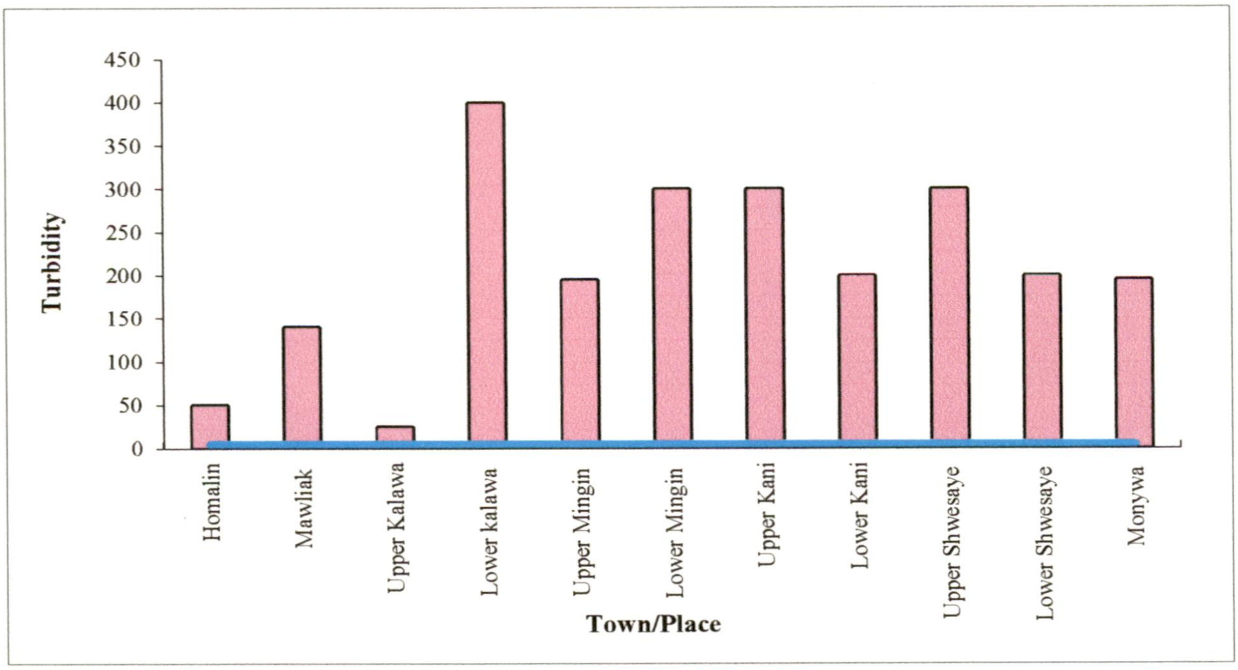


Fig. 4.21

4.2.4.12 Turbidity

WHO (World Health Organization) have recommended a standard value of 5 NTU of turbidity in drinking water.

High values of turbidity greater than 5NTU are observed at all the stations as shown in fig.4.21.Turbidity is the condition resulting from suspended solids in the water, including silts, clays, industrial wastes, sewage and plankton. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels and may harm fish and their larvae.

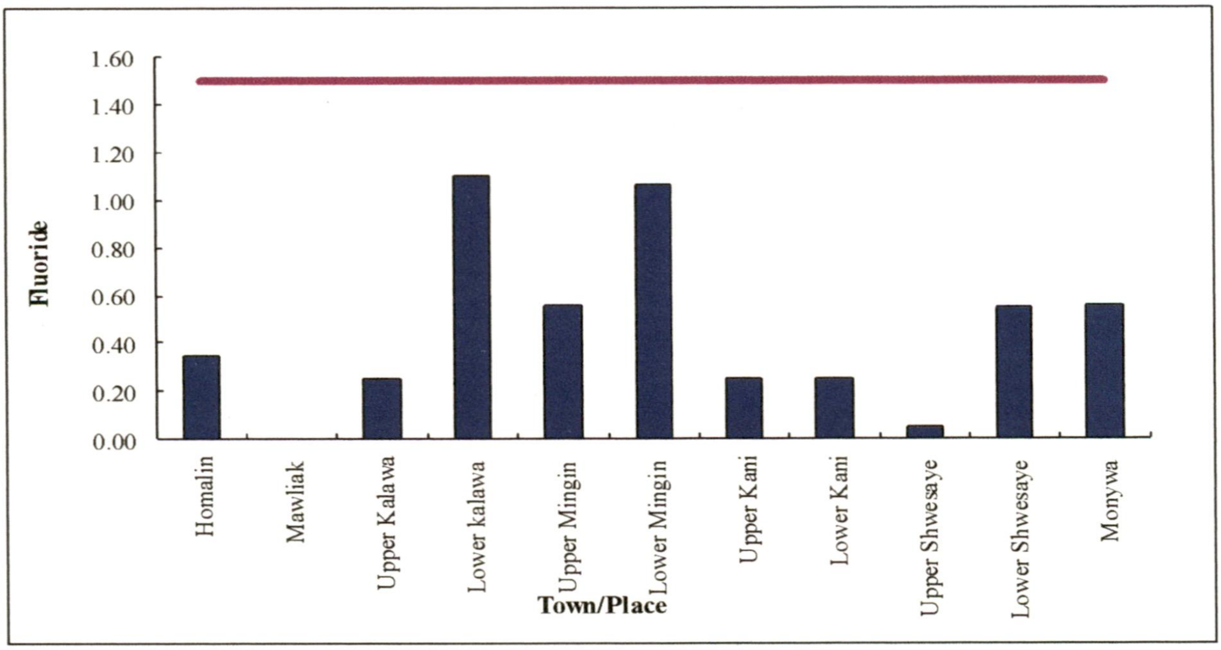


Fig. 4.22

4.2.4.13 Fluoride

WHO has recommended an upper desirable limit of 1.0 mg/l of F as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/l of F in case no alternative source of water is available. River/ ground Water having fluoride concentration of more than 1.5 mg/l are not suitable for drinking purposes. Too much fluoride can cause enamel fluorosis, a discoloration or mottling of the permanent teeth.

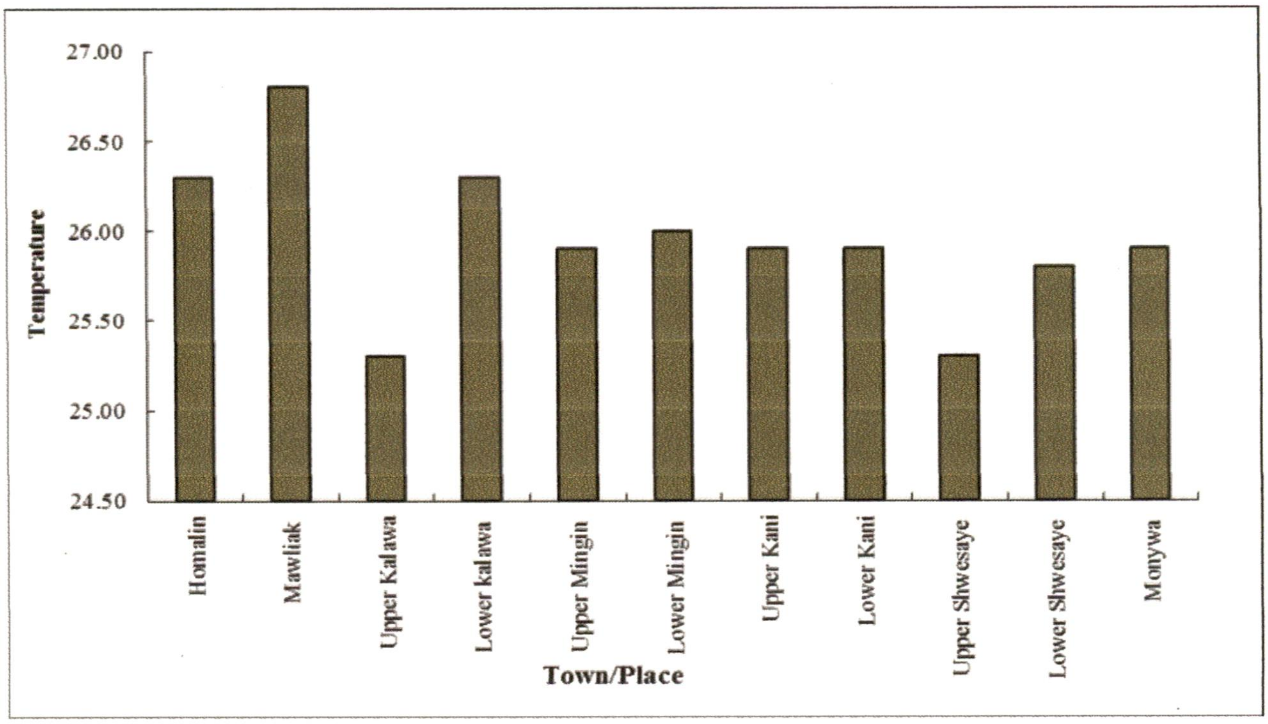


Fig. 4.23

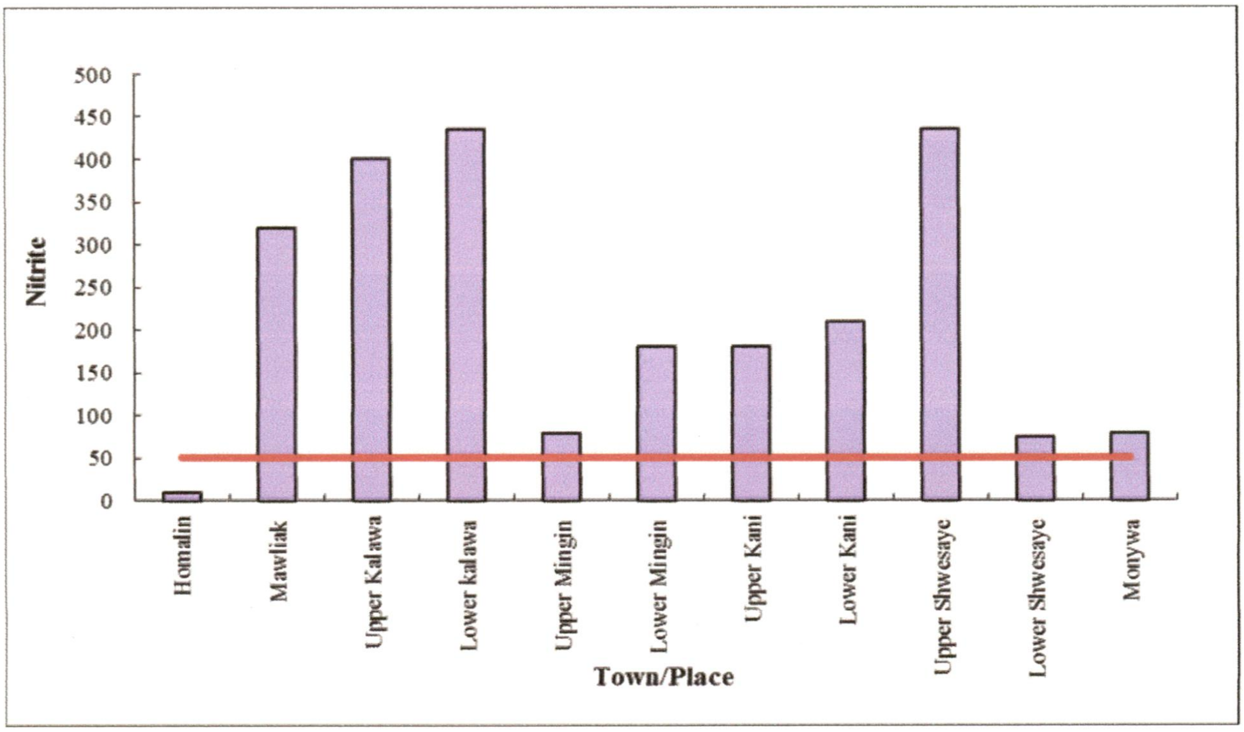


Fig. 4.24

4.2.4.14 Dissolved Oxygen

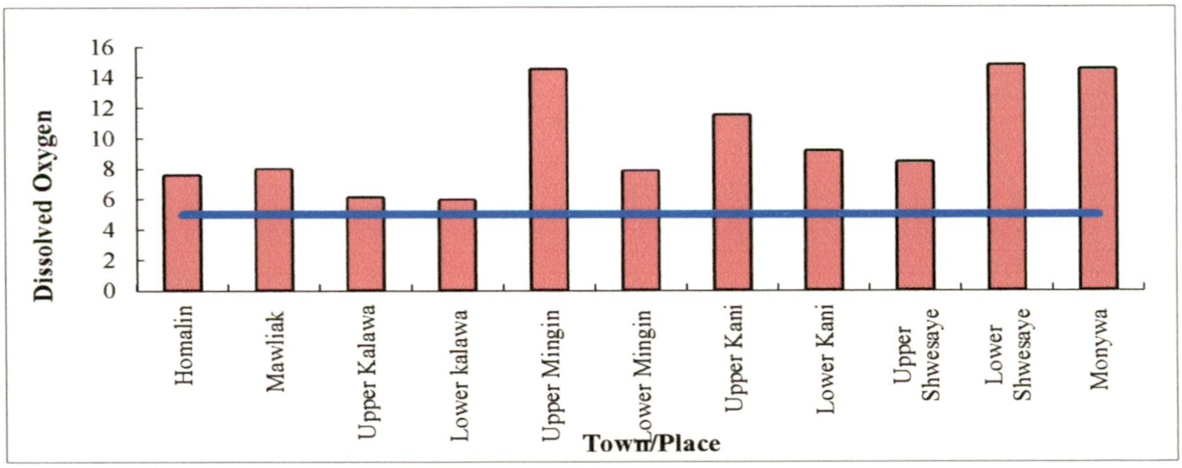


Fig. 4.25

WHO has recommended 5.0 mg/l concentration of dissolved oxygen for outdoor bathing. Water having below 5.0 mg/l DO concentration is not suitable for outdoor bathing in river. High values of Dissolved oxygen greater than 5.0mg/l are observed at all the stations as shown in fig.4.25.

DO is required to maintain the health of aquatic ecosystems. Oxygen is produced by photosynthesis, but is also used by plants, animals, and microorganisms that live in water. DO is crucial for the survival of fish and most other aquatic life forms. It oxidizes many sources of objectionable tastes and odors. Oxygen becomes dissolved in surface waters by diffusion from the atmosphere and from aquatic–plant photosynthesis. On average, most oxygen dissolves into water from the atmosphere; only a little net DO is produced by aquatic–plant photosynthesis. Although water plants produce oxygen during the day, they consume oxygen at night as an energy source. When they die and decay, dead plant matter serves as an energy source for microbes, which consume additional oxygen. The net change in DO is small during the life cycle of aquatic plants. Oxygen makes up 21% of all gases in air. Only a fraction of a percentage of atmospheric oxygen, however, dissolves in water. Oxygen dissolves in water through diffusion from the atmosphere and is facilitated by wind-mixing. This transfers oxygen to the water, especially in shallow aquatic systems that are not strongly stratified. Colder water can hold more DO than warm water as the solubility of oxygen is greater in colder water than in warm water. At the same time, cold temperatures reduce respiration rates in microorganisms that use DO. Phytoplankton and submersed aquatic macrophytes in the photic zone of lakes infuse oxygen into the water during the day during photosynthesis. Absence of photosynthesis, and respiration by these organisms and others, reduces oxygen concentration in the water at night.

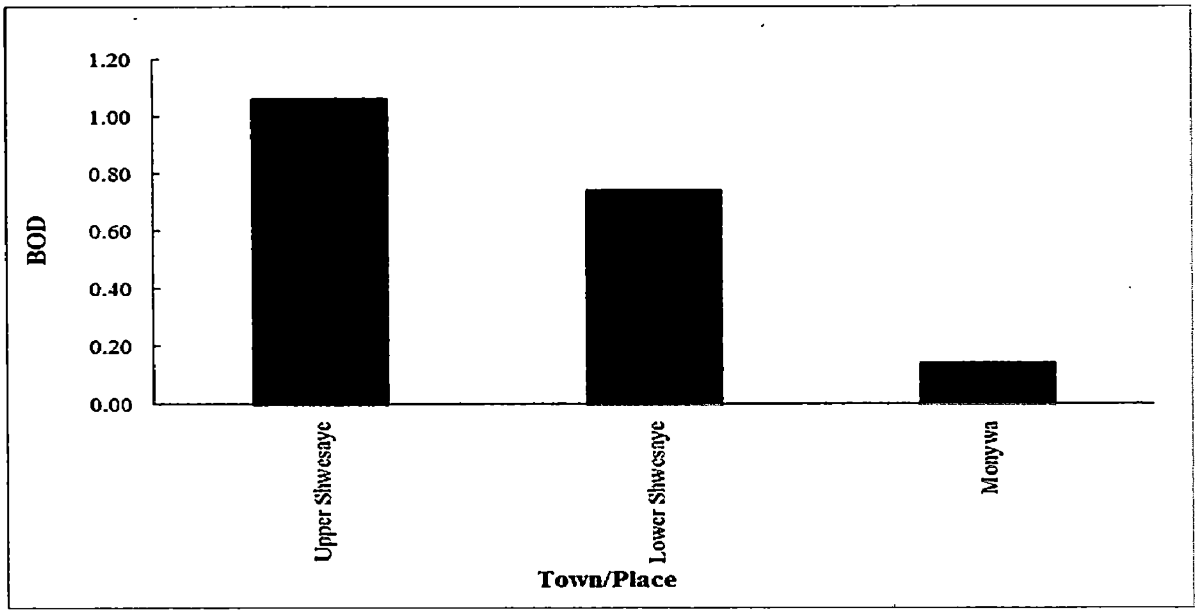


Fig. 4.26

4.2.4.15 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria, and energy is derived from its oxidation. BOD is an indicator of the potential for a water body to become depleted in oxygen and possibly become anaerobic because of biodegradation.

The BOD test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream-pollution – control activities. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water. The BOD test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matter present in a waste, under conditions as similar as possible to those that occur in nature.

Oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matter present in a waste, under conditions as similar as possible to those that occur in nature.

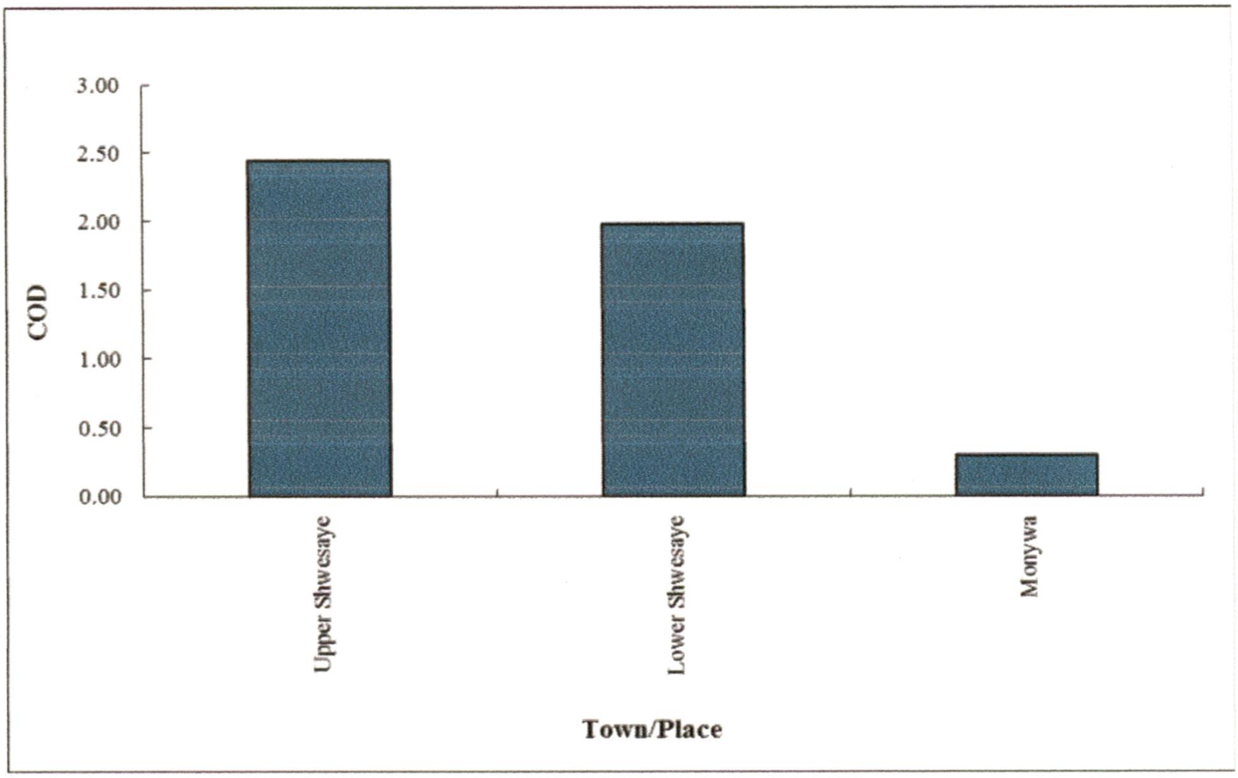


Fig. 4.27

4.3 CONCLUSION

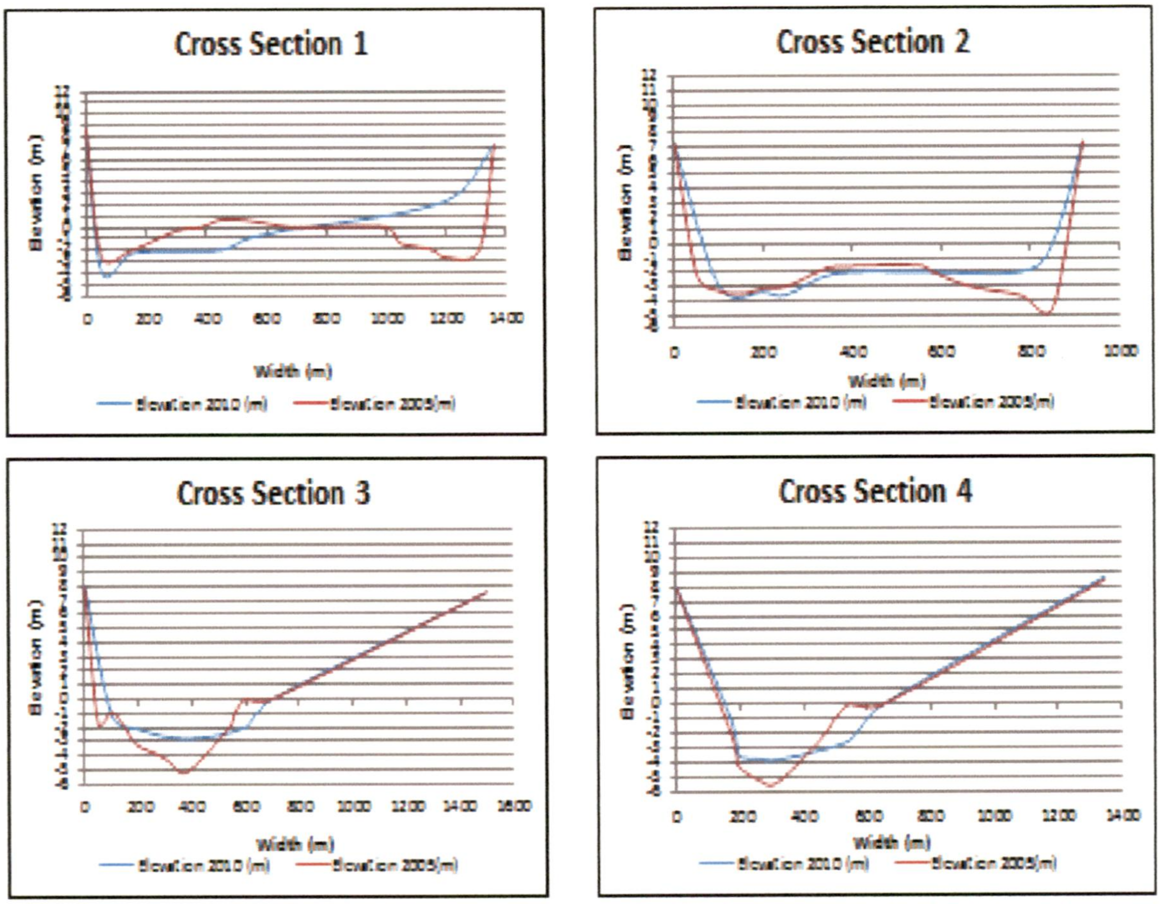
Iron and Turbidity are increased from year 2010 to 2012.However Chloride, Total Hardness, Ammonia and Nitrite are decreased. Nitrate, Alkalinity, Fluoride and pH do not change so much. It is not enough to say that the water quality of Chindwin River become better or worse from only three years data but the result of the National Sanitation Foundation Water Quality Index (NSFWQI) of Chindwin River indicates that its water quality is Medium-Good over the stretch considered. Thus, the Chindwin River water can be safely used not only domestic but also water supplied and agricultural lands in all year round.

ASSESSMENT OF SEDIMENTATION AND BED EROSION OF CHINDWIN RIVER

5.1 STUDY AREA

There are 12 km river stretch encompassing 12 no. of different cross section consideration for the present study encloses a 12 km river stretch of Monywa encompassing 12 no. 12 cross sections for the year 2005 and 2010 have been shown in Fig 5.1. One can easily figure out the significant variations in width as well as bed configuration in general. Widths of the channel vary ranging from 0.85 km to 1.56 km. In an average width is around 1 km in the study reach.

Comparing of Chindwin river channel 2005 and 2010



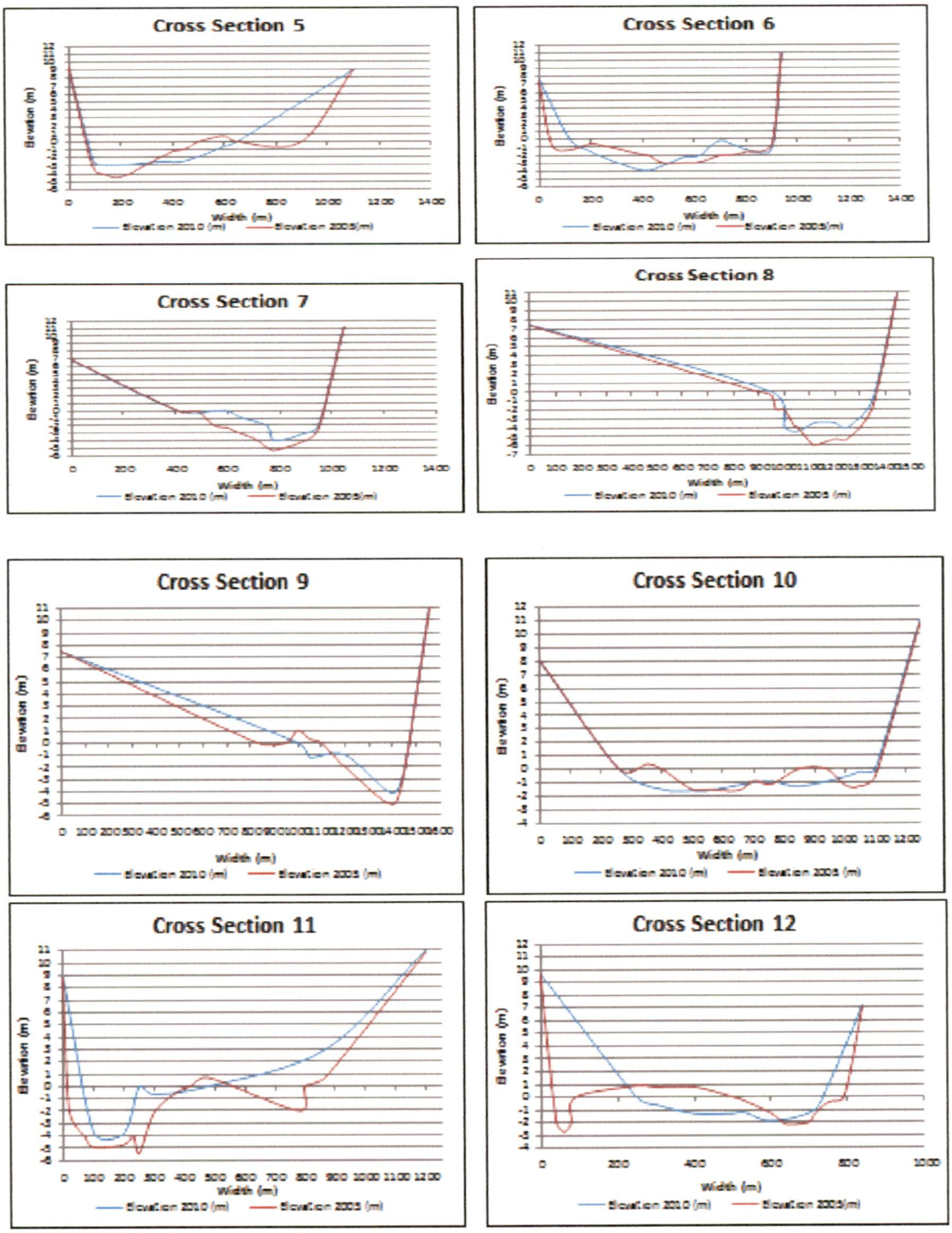


Fig 5.1: Observed profile of cross-section in Year 2005 and 2010

The Chindwin River is one of the rivers which are well under the observation of different stake holders. The sediment discharges and flood discharges at certain locations have not been continuingly recorded and the river cross sections surveyed.

Still, the limitation in the human capacity, instrumentation, the ambience of the measurement and the risk involved, the actual data acquisition often remain off-set by errors. The importance of the information that could be derived from the analysis of the data is very high in the design, management and future risk and hazard strategies.

Taking in to account the situation as described above, the present study is a formative attempt to implement a flow sedimentation model HEC-RAS for the study reach. The algorithms established by the researchers / modelers in the various literatures advocate success of sedimentation model application depends on the size of the data covering wide patterns of phenomena. More the data sets better is the results' reliability. In the assessment of the available data, data sorting, data generation supporting further analysis, modeling and deriving inferences HEC-RAS has been known to be robust. As the technique is a data driven model requiring gamut of data patterns representing the actual phenomena to accommodate all the possibilities within the patterns of independent and dependent variables.

The study has been carried out on the following data sets and the area.

a) Study Stretch of the river channel 12 km.

b) Number of the river cross sections 12 no.

c) Hydrological Data 2005 and 2010.

5.2 DATA SOURCES AND DATA TYPES

5.2.1 Hydrographic Data

Morpho-metric data: the reduced levels of the river cross-sections of post – monsoon period for the year 2005 and 2010 have been collected in respect of river cross-sections from map of Monywa Water Way.

5.2.2 Discharge and Stage Data

Discharge and stage data of the Chindwin collected for various cross-sections from Meteorology and Hydrology Department in Myanmar have constituted main data resource to the model implementation. The length of data record was 2005 and 2010.

5.2.3 Sediment Data

Sediment data obtained from the daily suspended sediment data in respect of Monywa station for the year 2005 and 2010 and daily discharge (cumecs) and daily suspended sediment for all the year 2005 and 2010 have been used in the study.

Characteristics sediment particle size distribution at the cross-sections was collected from Meteorology and Hydrology Department in Myanmar.

5.2.4 Pre-Processing of Hydro Graphic Data

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, Stream flow Hydrographs, etc needs to adequately represented from the observed field data.

5.2.5 Sediment Transport Analysis

A sediment model requires a geometry file, a quasi-unsteady flow file, a sediment file and a sediment analysis plan file.

5.3 DATA REQUIREMENTS AND INPUT

The basic input data required for sedimentation analysis by HEC-RAS model can be grouped into four categories as below.

5.3.1 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.

5.3.1.1 The River System Schematic

The river system schematic is required for any geometric data set within the HEC-RAS system. The schematic defines how the various river reaches are connected, as well as establishing a naming convention for referencing all the other data. The river system schematic is developed by drawing and connecting the various reaches of the system within the geometric data editor. It is required to develop the river system schematic before any other data can be entered.

Each river reach on the schematic is given a unique identifier. As other data are entered, the data are referenced to a specific reach of the schematic. For example, each cross section must have a "River", "Reach" and "River Station" identifier. The river and reach identifiers defines which reach the cross section lives in, while the river station identifier defines where that cross section is located within the reach, with respect to other cross sections for that reach.

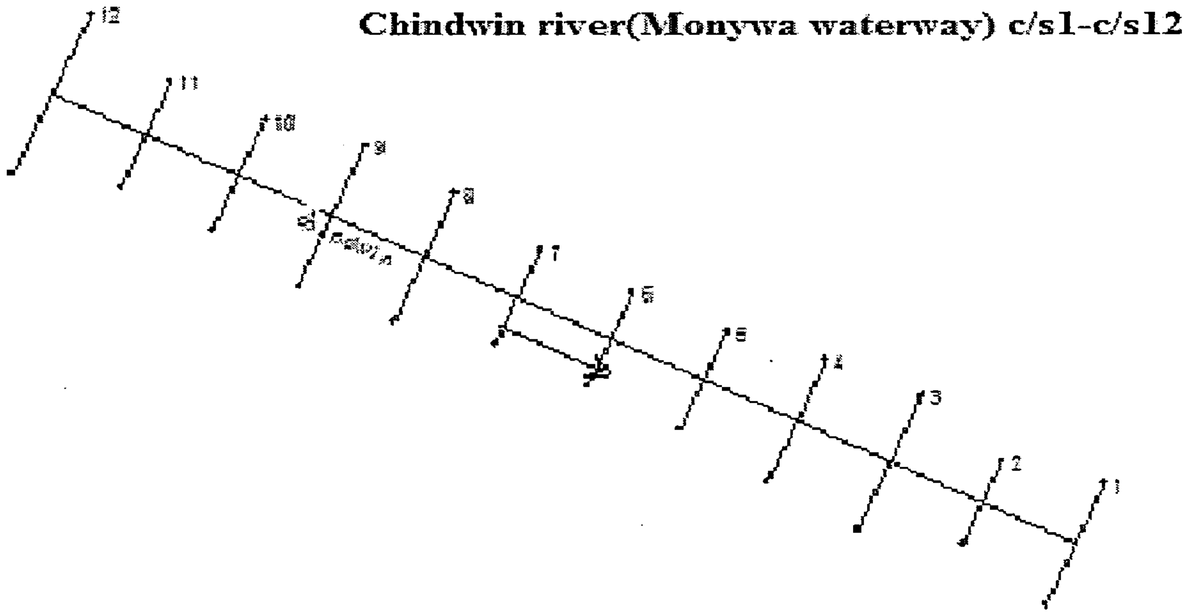


Fig 5.2: Schematic Plot of the Study Reach of Chindwin River Module

The connectivity of reaches is very important in order for the model to understand how the computations should proceed from one reach to the next. It is required to draw each reach from upstream to downstream, in what is considered to be the positive flow direction.

5.3.1.2 Cross section geometry

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross sections) and the measured distances between them (reach lengths). Cross sections are located at intervals along a stream to characterize the flow carrying capability of the stream and its adjacent floodplain. They should extend across the entire floodplain and should be perpendicular to the anticipated flow lines. Occasionally it is necessary to layout cross-sections in a curved or dog-leg alignment to meet this requirement. Every effort should be made to obtain cross sections that accurately represent the stream and floodplain geometry.

Cross sections are required at representative locations throughout a stream reach and at locations where changes occur in discharge, slope, or roughness, at locations where levees begin or end and at bridges or control structures such as weirs.

Where abrupt changes occur, several cross sections should be used to describe the change regardless of the distance. Cross section spacing is also a function of stream size, slope, and the uniformity of cross section shape. In general, large uniform rivers of flat slope normally require the fewest number of cross sections per km.

The purpose of the study also affects spacing of cross sections. For instance, navigation studies on large relatively flat streams may require closely spaced (e.g., 200 feet) cross sections to analyze the effect of local conditions on low flow depths, whereas cross sections for sedimentation studies, to determine deposition in reservoirs, may be spaced at intervals on the order of km.

Each cross section in an HEC-RAS data set is identified by a River, Reach, and River Station lable. The cross section is described by entering the station and elevation (X-Y data) from left to right, with respect to looking in the downstream direction. The River Station identifier may correspond to stationing along the channel, mile points, or any fictitious numbering system. The numbering system must be consistent, in that the program assumes that higher numbers are upstream and lower numbers are downstream.

Each data point in the cross section is given a station number corresponding to the horizontal distance from a starting point on the left. Up to 500 data points may be used to describe each cross section. Cross section data are traditionally defined looking in the downstream direction. The program considers the left side of the stream to have the lowest station numbers and the right side to have the highest. Cross section data are allowed to have negative stationing values. Stationing must be entered from left to right in increasing order. However, more than one point can have the same stationing value. The left and right stations separating the main channel from the over bank areas must be specified on the cross section data editor. End points of a cross section that are too low (below the computed water surface elevation) will automatically be extended vertically and a note indicating that the cross section had to be extended will show up in the output for that section. The program adds additional wetted perimeter for any water that comes into contact with the extended walls.

Other data that are required for each cross section consist of: downstream reach lengths; roughness coefficients; and contraction and expansion coefficients. Numerous program options are available to allow easily adding or modifying cross section data.

5.3.1.3 Reach lengths

The measured distance between cross sections is referred to as reach lengths. The reach lengths for the left over bank, right over bank and channel are specified on the cross section data editor. Channel reach lengths are typically measured along the thalweg. Over bank reach lengths should be measured along the anticipated path of the center of mass of the over bank flow. Often, these three lengths will be of similar value. There are, however, conditions where they will differ significantly, such as at river bends, or where the channel meanders and the over banks are straight. Where the distances between cross sections for channel and over banks are different, a discharge – weighted reach length is determined based on the discharges in the main channel and left and right over bank segments of the reach. In the selected reach of Chindwin all three lengths were taken similar values.

5.3.1.4 Energy loss coefficients

Several types of loss coefficients are utilized by the program to evaluate energy losses: (1) Manning's n values or equivalent roughness "k" values for friction loss, (2) contraction and expansion coefficients to evaluate transition (shock) losses.

Manning's n: Selection of an appropriate value of Manning's n is very significant to the accuracy of the computed water surface profiles. The value of Manning's is highly variable and depends on a number of factor including: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal changes; temperature; and suspended material and bed load. There is a difference in Manning's n between fixed and movable bed situations. Fixed bed n's are values which do not depend on the characteristics of the movable boundary, movable bed n's are values which may depends on the rate of sediment transport and, hence, the discharge.

5.3.1.5 Selection of contraction and expansion coefficients

Information for contraction and expansion losses is sparser than that for n values. King and Brater (1963) give values of 0.5 and 1.0 respectively for a sudden change in area accompanied by sharp comers, and values of 0.05 and 0.10 for the most efficient transitions. Design values of 0.1 and 0.2 are suggested. They cite Hinds (1928) as their reference. Values often cited by the Corps of Engineers (HEC, 1990a) are 0.1 and 0.3, contraction and expansion respectively, for gradual transitions. So in the present study, contraction and expansion coefficient are by default taken as 0.1 and 0.30.

5.3.2 Hydrologic Data

The hydrologic data consist of water discharges, temperatures and flow durations. The 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 Manning'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 2005 and 2010 are used to obtain a discharge frequency hydrographs and the gauges respective

5.3.3 Quasi-unsteady Flow Data

Current sediment capabilities in HEC-RAS are based on quasi-unsteady hydraulics. The quasi-unsteady approach approximates a flow hydrograph by a series of steady flow profiles associated with corresponding flow durations. Boundary conditions were flow series (flow hydrograph) at upstream boundary.

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 behavior.

5.3.4 Sediment Data

The sediment data consist of inflowing sediment load data, gradation of material in the stream bed and information about 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 caly (up to 0.004 mm), four classes of silt (0.004 – 0.0625 mm), five classes of sand (very fine sand 0.0625 mm the very course sand 0.2 mm) and five classes of gravel (very fine gravel 0.2 mm to very coarse gravel 0.64 mm). Sediment transport capacity is calculated at each cross section by using hydraulic data obtained during the calculation of water surface profiles and the gradation of bed material for that cross section.

The variations are the sediment load discharge with the flow is calibrated from the Sediment Discharge Rating Curves and entered to the model input.

Each cross-section must have an associated bed gradation. Possession of data in regard to bed material for all cross section couldn't be done. But character of bed material within the study reach can presumed to be similar in nature so far sediment transport is concerned.

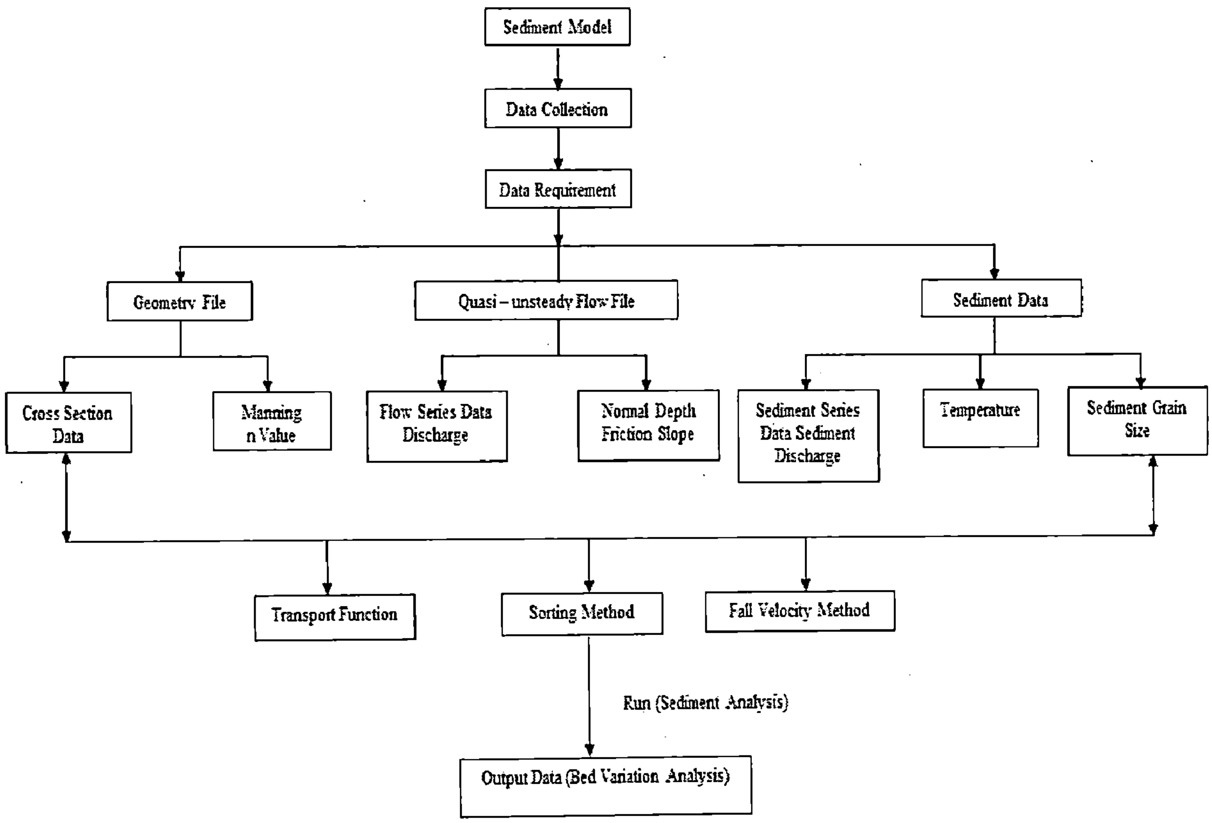
5.3.4.1 Sediment boundary conditions

For sediment transport analysis sediment boundary conditions must be applied. Usually boundary conditions are applied at extreme u/s and d/s cross sections.

Besides the hydrologic data, sediment data and roughness coefficients, other bound values accorded are the depth of sediment bed control volume (adopted as 5.0 meter wherever necessary) and the water temperature.

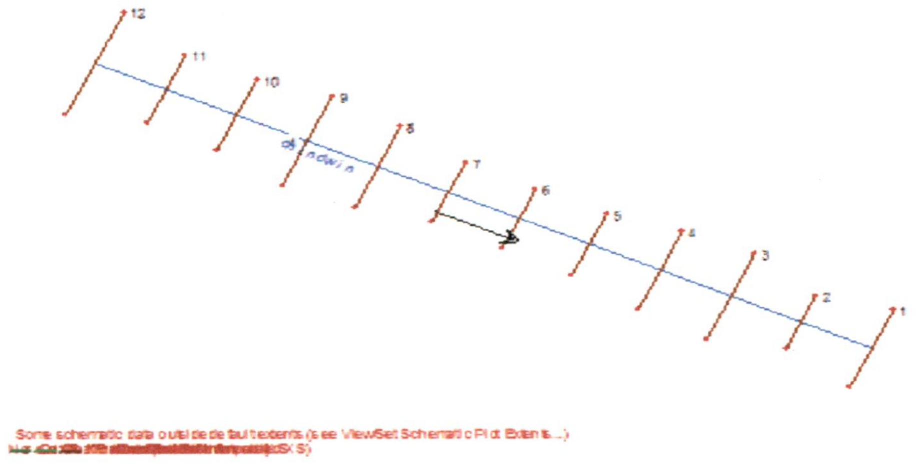
5.4 PROGRAM ORGANIZATION

The HEC-RAS program in its present form has been organized into major module. Module runs with various sub-programs where data have been transferred for specific output generation. The functional flowchart of the program is shown



5.5 RESULTS AND DISCUSSIONS

CHINDWIN RIVER 2005 PROFILE



WATER PROFILE

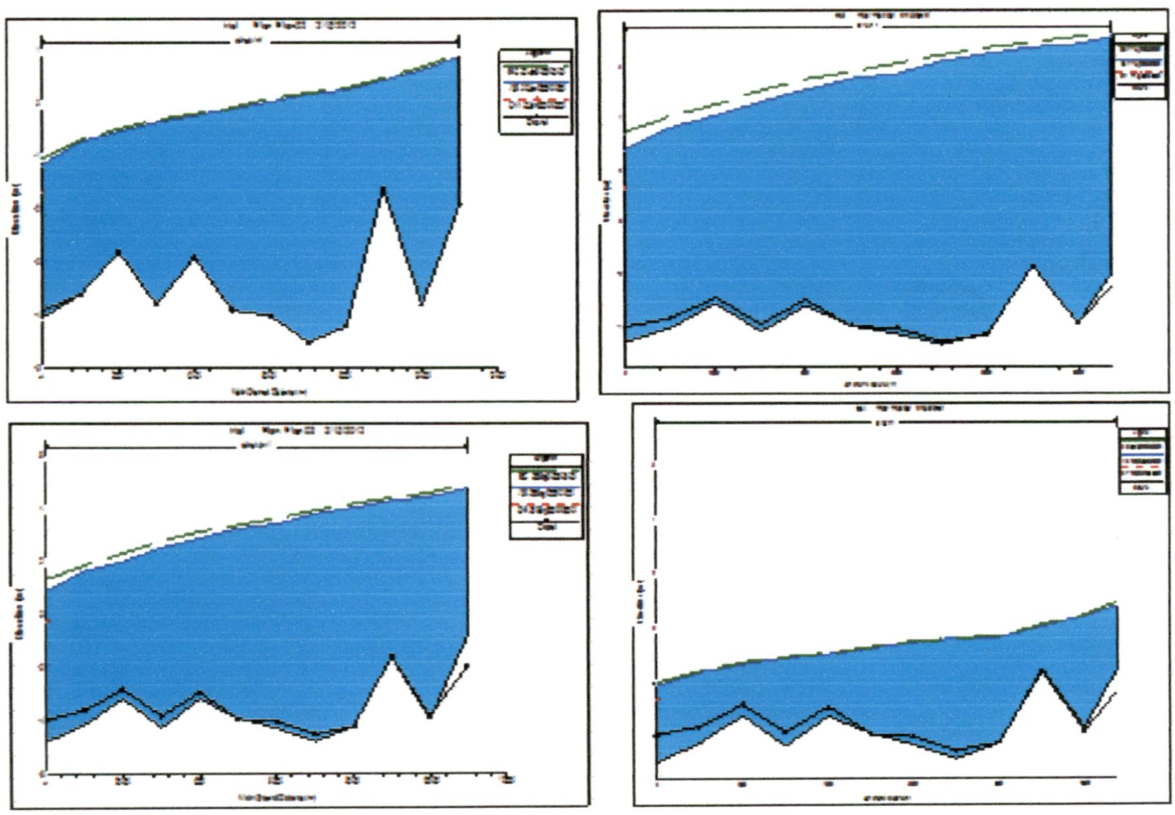
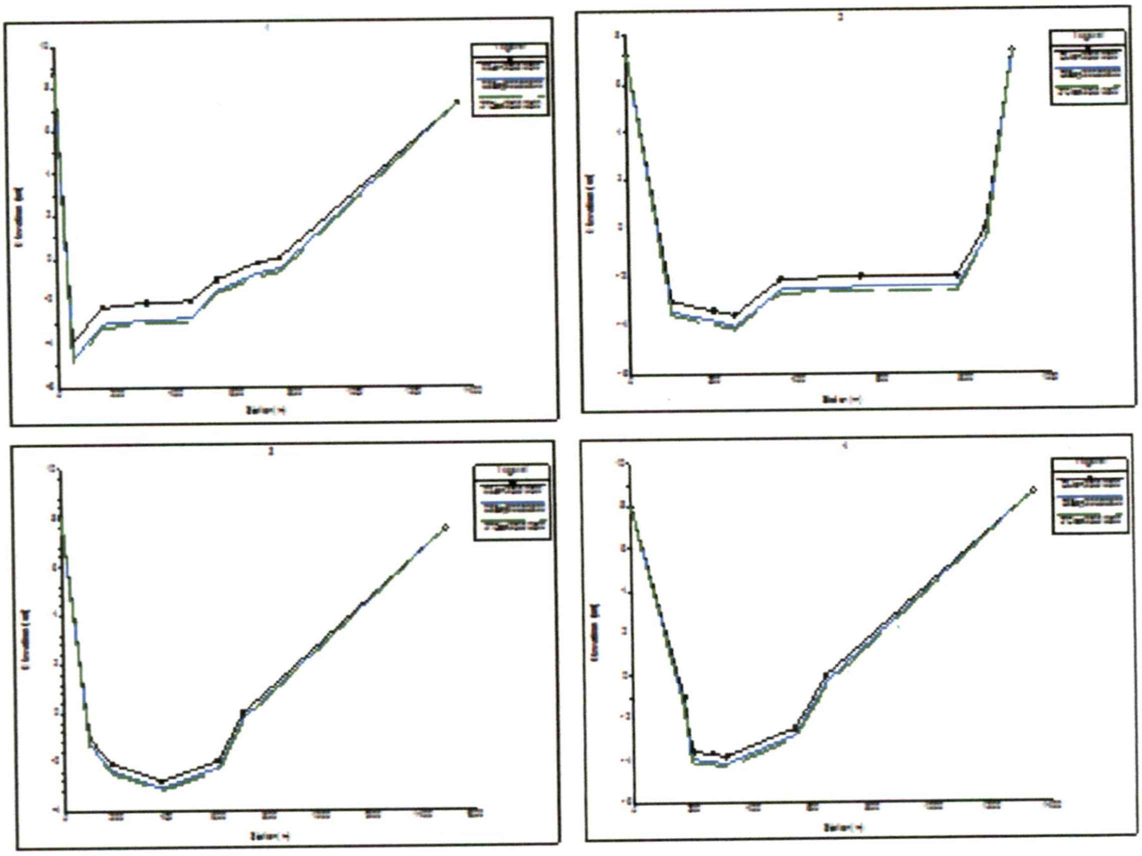


Fig 5.3 Water profile 2005

In above water profile, Bed level change can be seen about 0.3 m in July. In September bed level changes occurred about 0.5 m to 0.8m and about 0.5 to 1 m in December at c/s 1 to c/s 9.

SEDIMENT CROSS-SECTION BED CHANGE

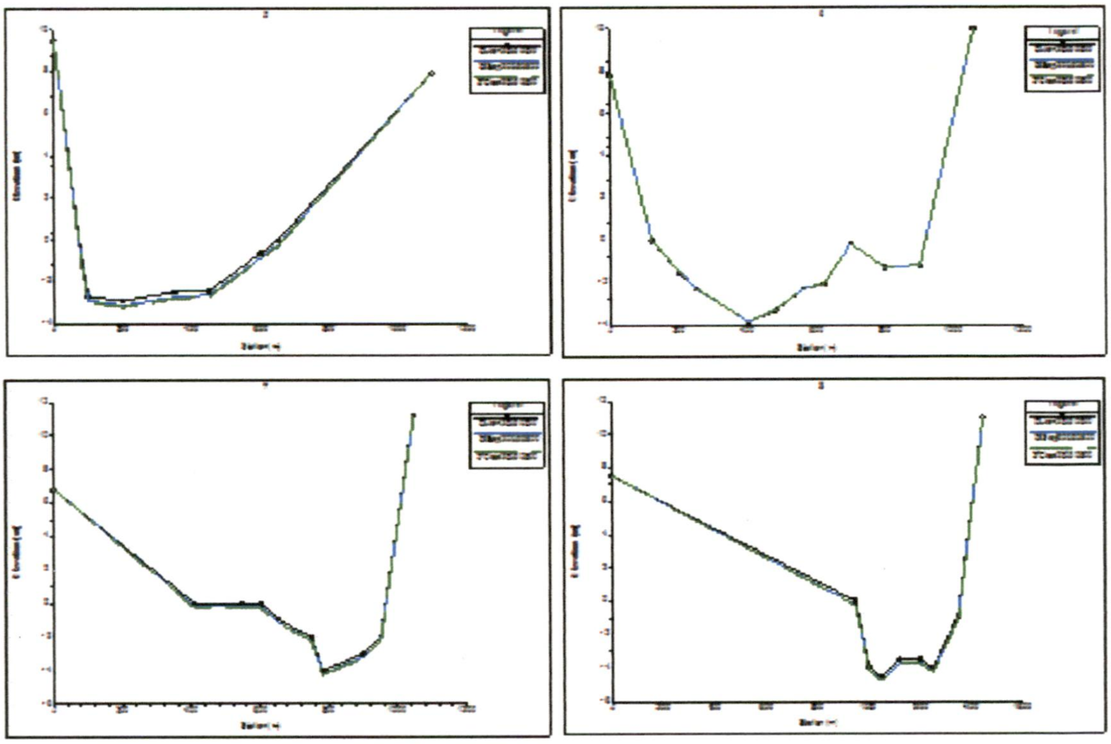


In c/s-1 Bed Erosion observed range 0.5 m to 1m between 50 m and 1200 m.

In c/s-2 Bed Erosion observed range 0.5 m to 1m between100 m and 870 m.

In c/s-3 Bed Erosion observed about 0.4m between 100 m and 600 m.

In c/s-4 Bed Erosion observed about 0.5 m between 200 m and 650 m.



In c/s-5 Bed Erosion observed about 0.4m between 100 m and 700 m.

In c/s-6 Bed level changes cann't be found clearly.

In c/s-7 Bed Erosion observed about 0.3 m between 450 m and 1000 m.

In c/s-8 Bed Erosion observed about 0.2 m between 1000 m and 1400 m.

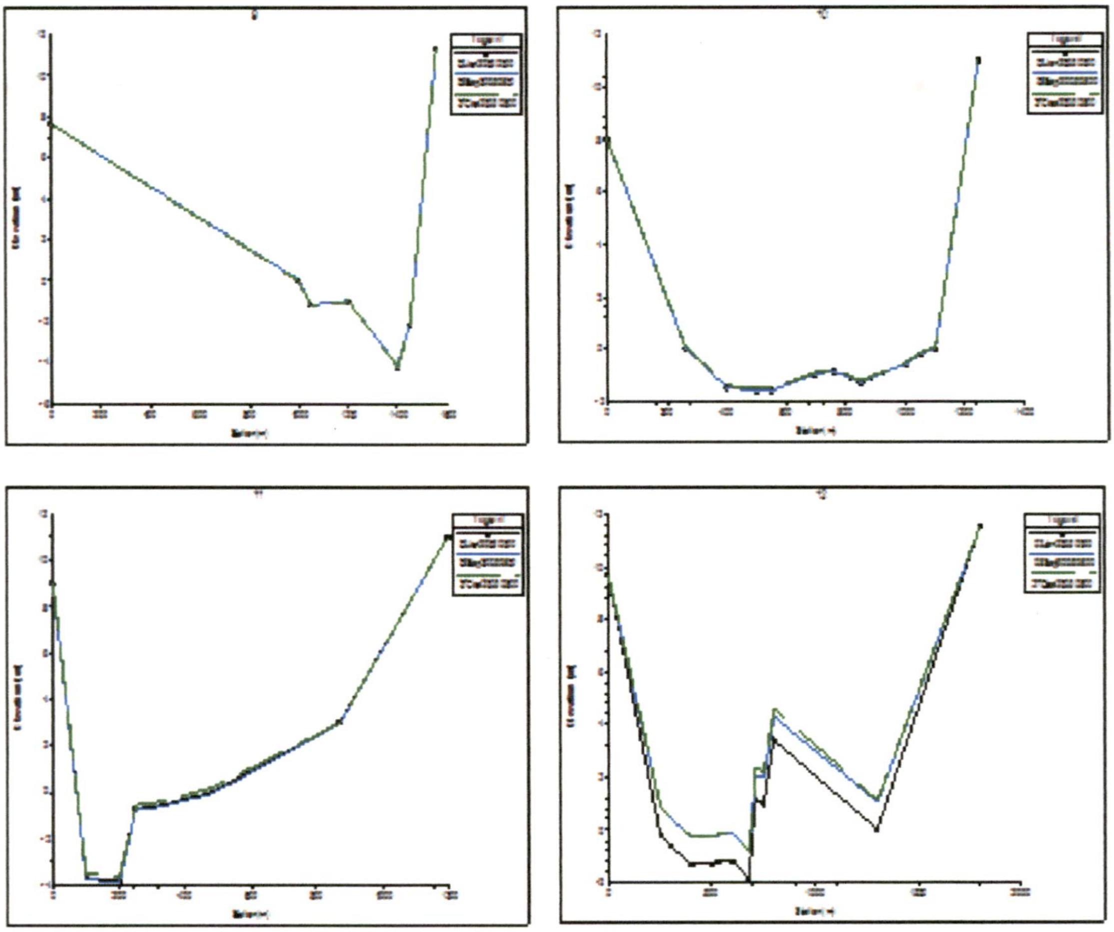


Fig 5.4 Sediment Cross-section bed changes 2005

In c/s-9 Bed level changes cann't be found clearly.

In c/s-10 Sedimentation occurred about 0.1 m between 250 m and 1150 m.

In c/s-11 Sedimentation occurred about 0.3 m between 100 m and 600 m.

In c/s-12 Sedimentation occurred range 1 m to 1.3 m between 250 m and 1500 m.

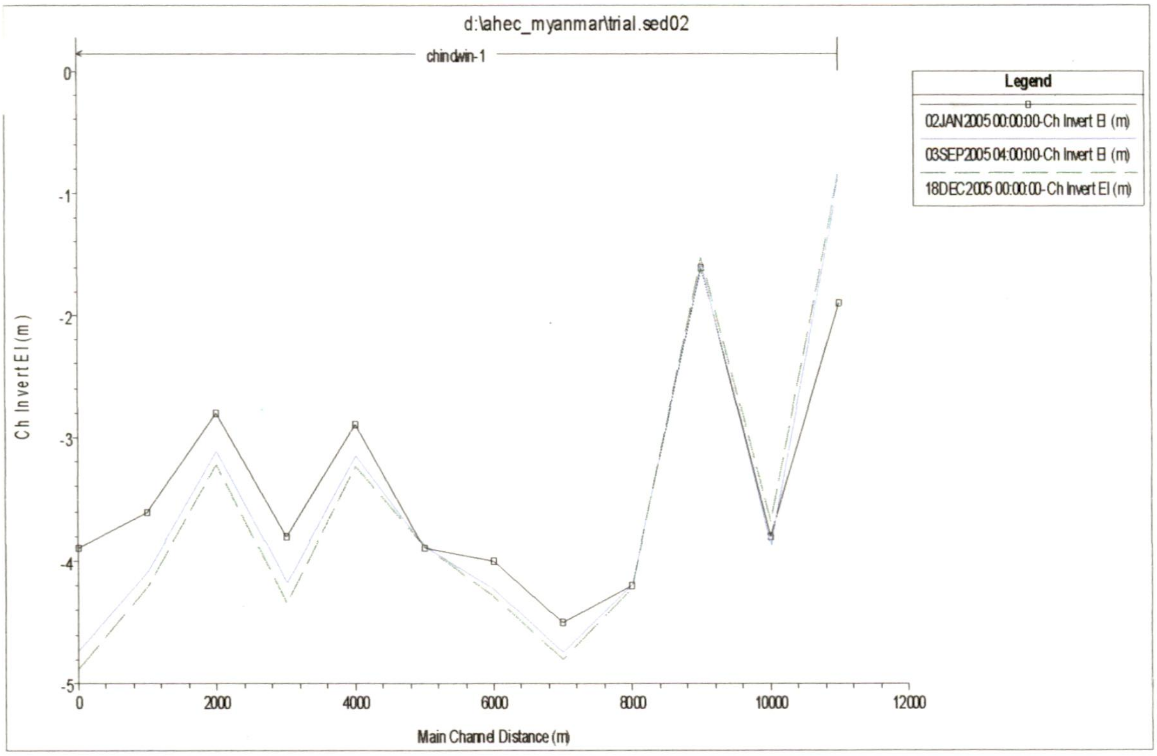


Fig 5.5 Sediment Spatial plot 2005

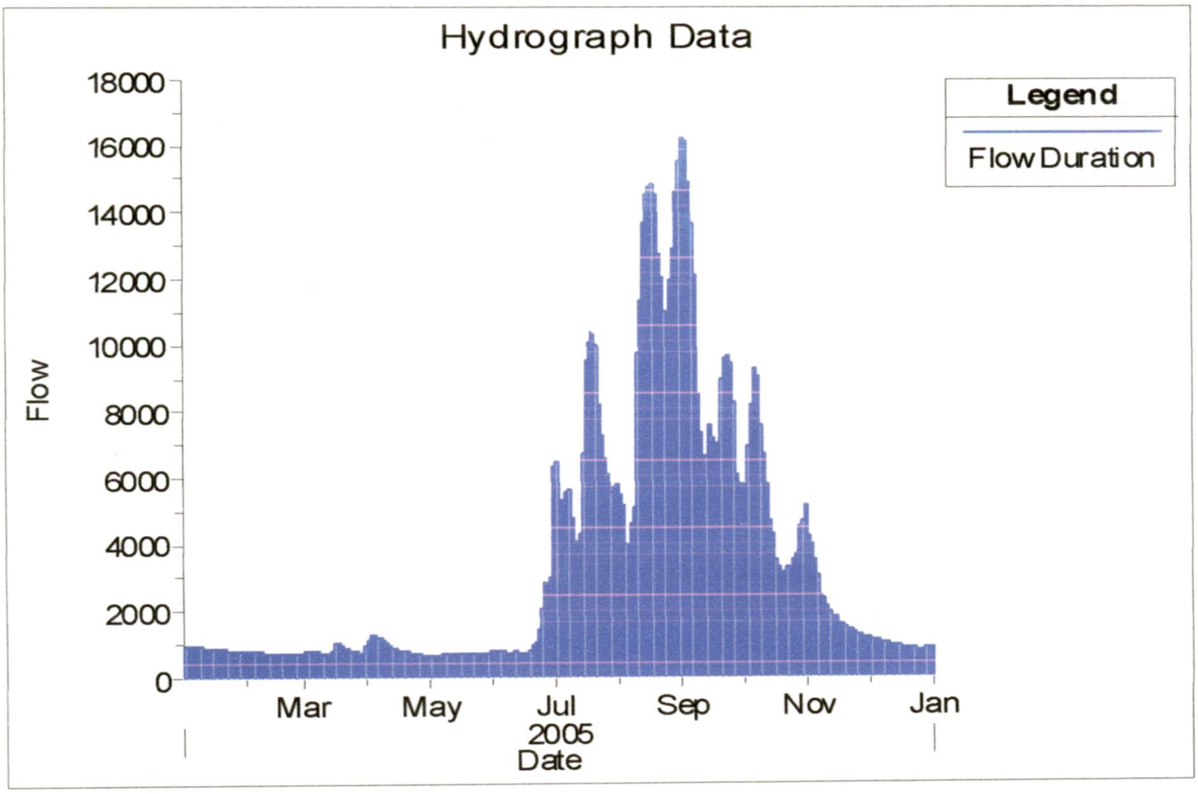


Fig 5.6 Discharge Hydrograph 2005

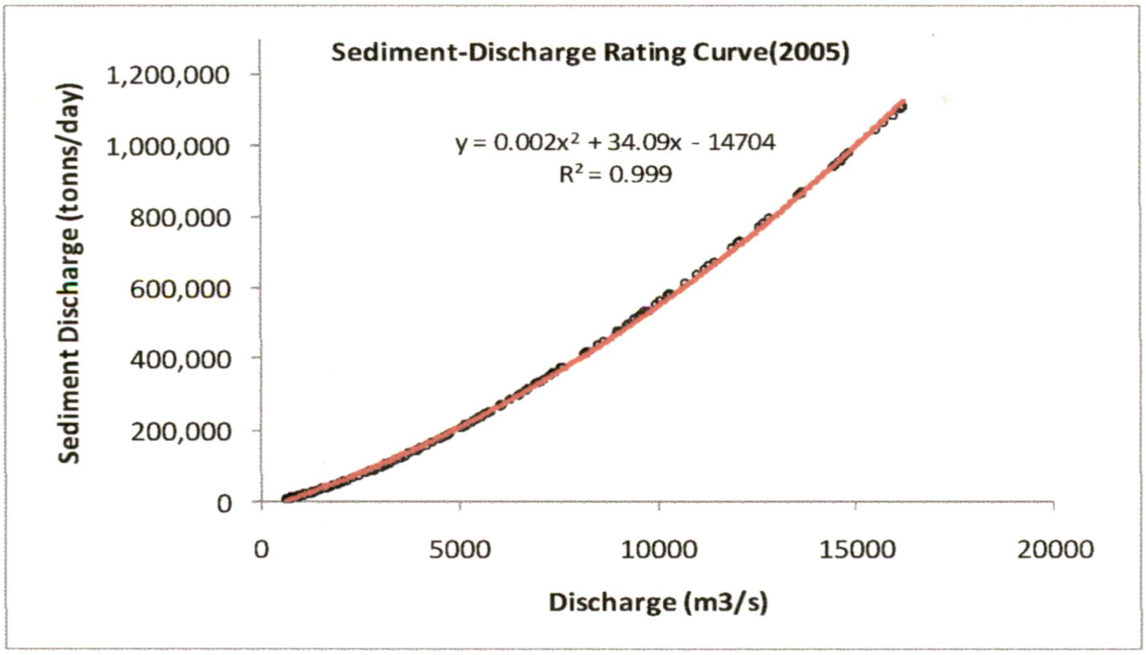


Fig 5.7 Sediment Discharge-Discharge Hydrograph 2005

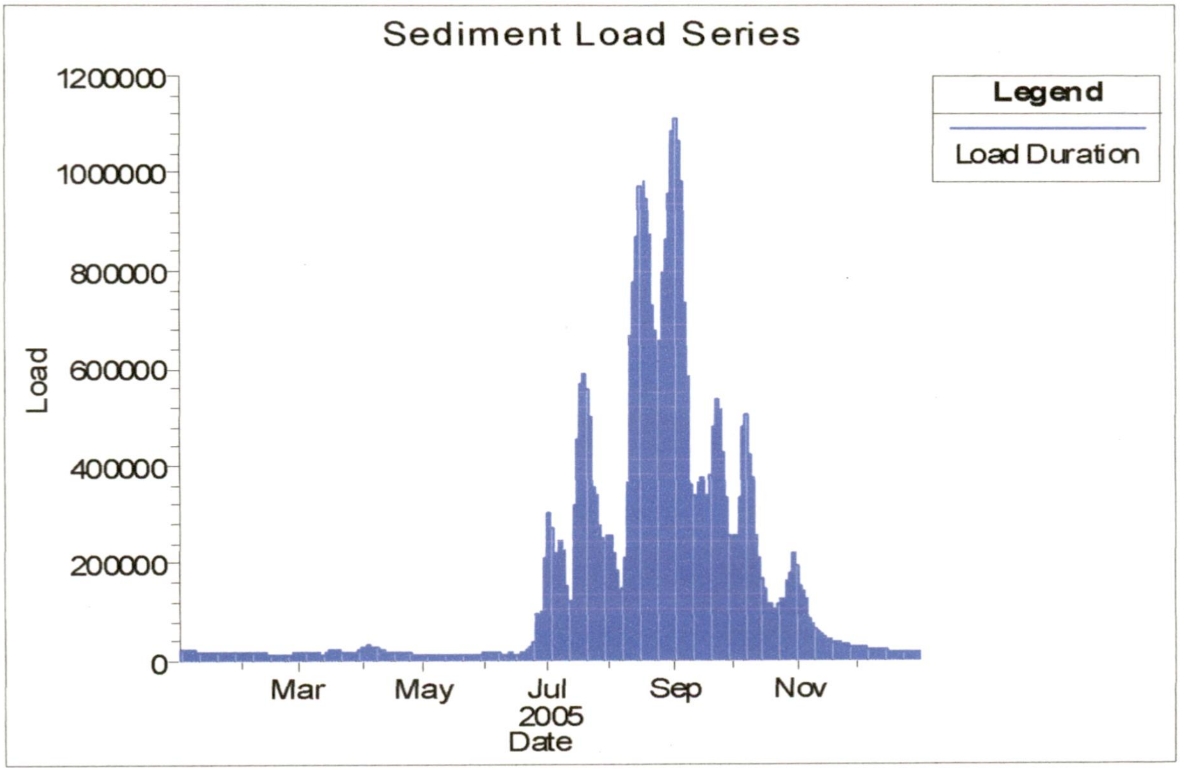


Fig 5.8 Sediment Discharge Hydrograph 2005

Table 5.1 Profile Output 2005 Data

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: chindwin Reach: 1 Profile:

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
1	12	01Apr2005 0800	1183.00	-1.86	1.16		1.21	0.000280	1.02	1163.21	751.59	0.26
1	11	01Apr2005 0800	1183.00	-3.80	0.88		0.95	0.000248	1.13	1049.73	531.04	0.26
1	10	01Apr2005 0800	1183.00	-1.60	0.71		0.74	0.000159	0.81	1463.26	872.59	0.20
1	9	01Apr2005 0800	1183.00	-4.19	0.51		0.57	0.000187	1.03	1149.77	539.26	0.22
1	8	01Apr2005 0800	1183.00	-4.50	0.43		0.46	0.000065	0.80	1487.84	464.97	0.14
1	7	01Apr2005 0800	1183.00	-4.01	0.25		0.32	0.000369	1.23	959.58	572.12	0.30
1	6	01Apr2005 0800	1183.00	-3.90	0.12		0.14	0.000093	0.71	1658.63	800.59	0.16
1	5	01Apr2005 0800	1183.00	-2.90	-0.04		0.01	0.000182	1.00	1188.52	574.24	0.22
1	4	01Apr2005 0800	1183.00	-3.84	-0.17		-0.13	0.000113	0.92	1283.83	488.68	0.18
1	3	01Apr2005 0800	1183.00	-2.84	-0.37		-0.31	0.000295	1.14	1038.73	589.15	0.27
1	2	01Apr2005 0800	1183.00	-3.63	-0.57		-0.53	0.000169	0.87	1354.67	754.29	0.21
1	1	01Apr2005 0800	1183.00	-4.09	-1.04	-1.64	-0.88	0.000998	1.75	674.15	498.80	0.48

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: chindwin Reach: 1 Profile: 06

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
1	12	06Sep2005 0800	12090.00	-0.80	6.38		6.58	0.000269	1.95	6187.32	1459.72	0.30
1	11	06Sep2005 0800	12090.00	-3.90	6.04		6.30	0.000264	2.28	5298.17	974.65	0.31
1	10	06Sep2005 0800	12090.00	-1.59	5.91		6.08	0.000150	1.83	6613.86	1112.41	0.24
1	9	06Sep2005 0800	12090.00	-4.20	5.65		5.87	0.000279	2.10	5769.59	1257.54	0.31
1	8	06Sep2005 0800	12090.00	-4.75	5.37		5.60	0.000261	2.13	5666.37	1143.07	0.31
1	7	06Sep2005 0800	12090.00	-4.25	4.92		5.28	0.000389	2.65	4556.14	893.63	0.38
1	6	06Sep2005 0800	12090.00	-3.89	4.73		4.97	0.000200	2.13	5667.01	937.53	0.28
1	5	06Sep2005 0800	12090.00	-3.18	4.32		4.68	0.000379	2.67	4531.61	864.86	0.37
1	4	06Sep2005 0800	12090.00	-4.23	3.87		4.27	0.000459	2.77	4360.22	906.46	0.40
1	3	06Sep2005 0800	12090.00	-3.14	3.32		3.74	0.000606	2.88	4201.77	1018.50	0.45
1	2	06Sep2005 0800	12090.00	-4.12	2.89		3.26	0.000365	2.67	4529.01	840.17	0.37
1	1	06Sep2005 0800	12090.00	-4.76	2.05	0.70	2.66	0.001000	3.47	3487.36	930.27	0.57

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: chindwin Reach: 1 Profile: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	16Oct2005 0800	3508.00	-0.58	3.00		3.23	0.000993	2.13	1649.59	911.78	0.50
1	11	16Oct2005 0800	3508.00	-3.84	2.54		2.68	0.000325	1.63	2151.67	765.71	0.31
1	10	16Oct2005 0800	3508.00	-1.56	2.37		2.45	0.000151	1.19	2945.51	948.20	0.22
1	9	16Oct2005 0800	3508.00	-4.23	2.11		2.24	0.000296	1.59	2212.48	765.87	0.30
1	8	16Oct2005 0800	3508.00	-4.80	1.91		2.01	0.000169	1.39	2519.32	694.67	0.23
1	7	16Oct2005 0800	3508.00	-4.28	1.60		1.76	0.000364	1.77	1979.45	677.89	0.33
1	6	16Oct2005 0800	3508.00	-3.89	1.42		1.50	0.000168	1.29	2717.20	838.97	0.23
1	5	16Oct2005 0800	3508.00	-3.23	1.14		1.28	0.000280	1.65	2131.28	669.16	0.29
1	4	16Oct2005 0800	3508.00	-4.32	0.88		1.01	0.000256	1.65	2131.40	625.74	0.28
1	3	16Oct2005 0800	3508.00	-3.20	0.46		0.65	0.000523	1.95	1799.01	700.45	0.39
1	2	16Oct2005 0800	3508.00	-4.18	0.17		0.28	0.000250	1.49	2356.78	791.10	0.28
1	1	16Oct2005 0800	3508.00	-4.89	-0.46	-1.44	-0.18	0.001001	2.32	1509.34	734.05	0.52

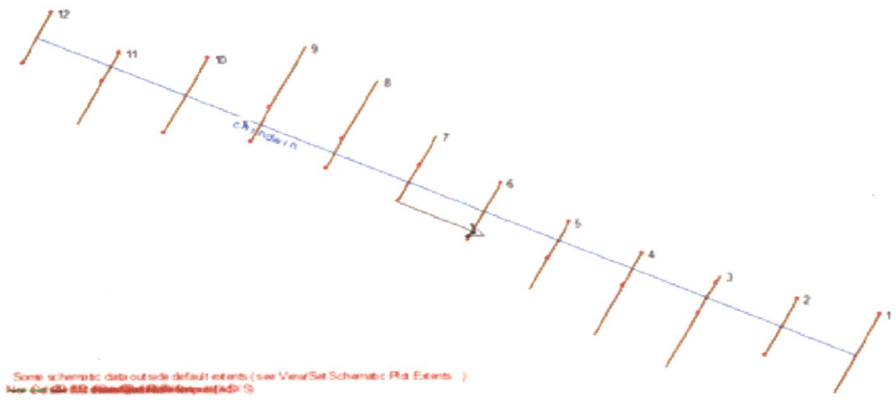
Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: chindwin Reach: 1 Profile: 2

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	27Dec2005 0800	811.00	-0.87	0.89		1.06	0.001639	1.83	443.77	448.23	0.59
1	11	27Dec2005 0800	811.00	-3.67	0.38		0.45	0.000294	1.09	741.40	445.99	0.27
1	10	27Dec2005 0800	811.00	-1.53	0.02		0.07	0.000484	0.99	815.33	822.28	0.32
1	9	27Dec2005 0800	811.00	-4.22	-0.38		-0.32	0.000313	1.11	730.55	450.42	0.28
1	8	27Dec2005 0800	811.00	-4.80	-0.45		-0.43	0.000046	0.65	1243.95	404.40	0.12
1	7	27Dec2005 0800	811.00	-4.29	-0.58		-0.52	0.000238	1.14	713.90	346.40	0.25
1	6	27Dec2005 0800	811.00	-3.89	-0.78		-0.74	0.000198	0.83	979.94	665.12	0.22
1	5	27Dec2005 0800	811.00	-3.23	-1.01		-0.96	0.000234	0.96	842.29	516.34	0.24
1	4	27Dec2005 0800	811.00	-4.34	-1.13		-1.10	0.000091	0.76	1066.98	458.96	0.16
1	3	27Dec2005 0800	811.00	-3.22	-1.35		-1.28	0.000489	1.17	693.29	551.95	0.33
1	2	27Dec2005 0800	811.00	-4.21	-1.64		-1.61	0.000216	0.82	990.93	731.23	0.22
1	1	27Dec2005 0800	811.00	-4.89	-2.14	-2.63	-2.02	0.001000	1.55	524.19	469.10	0.47

CHINDWIN RIVER PROFILE (2010)



Water Profile

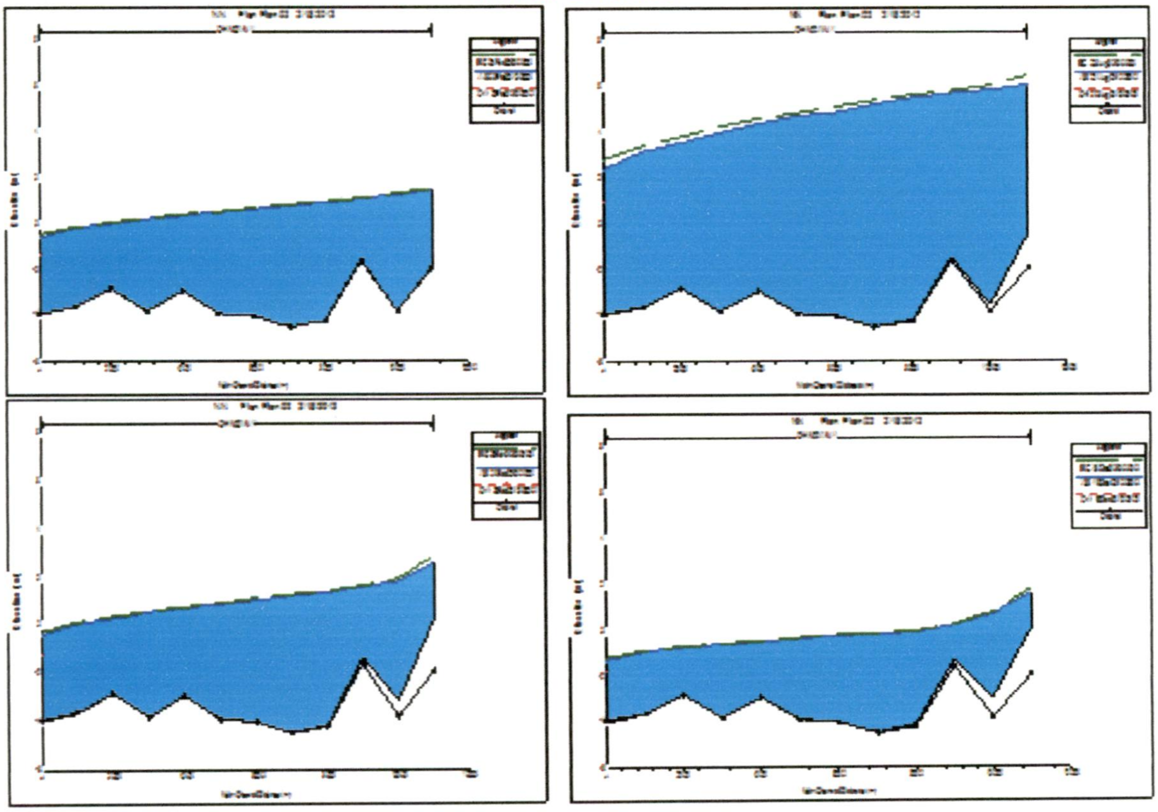
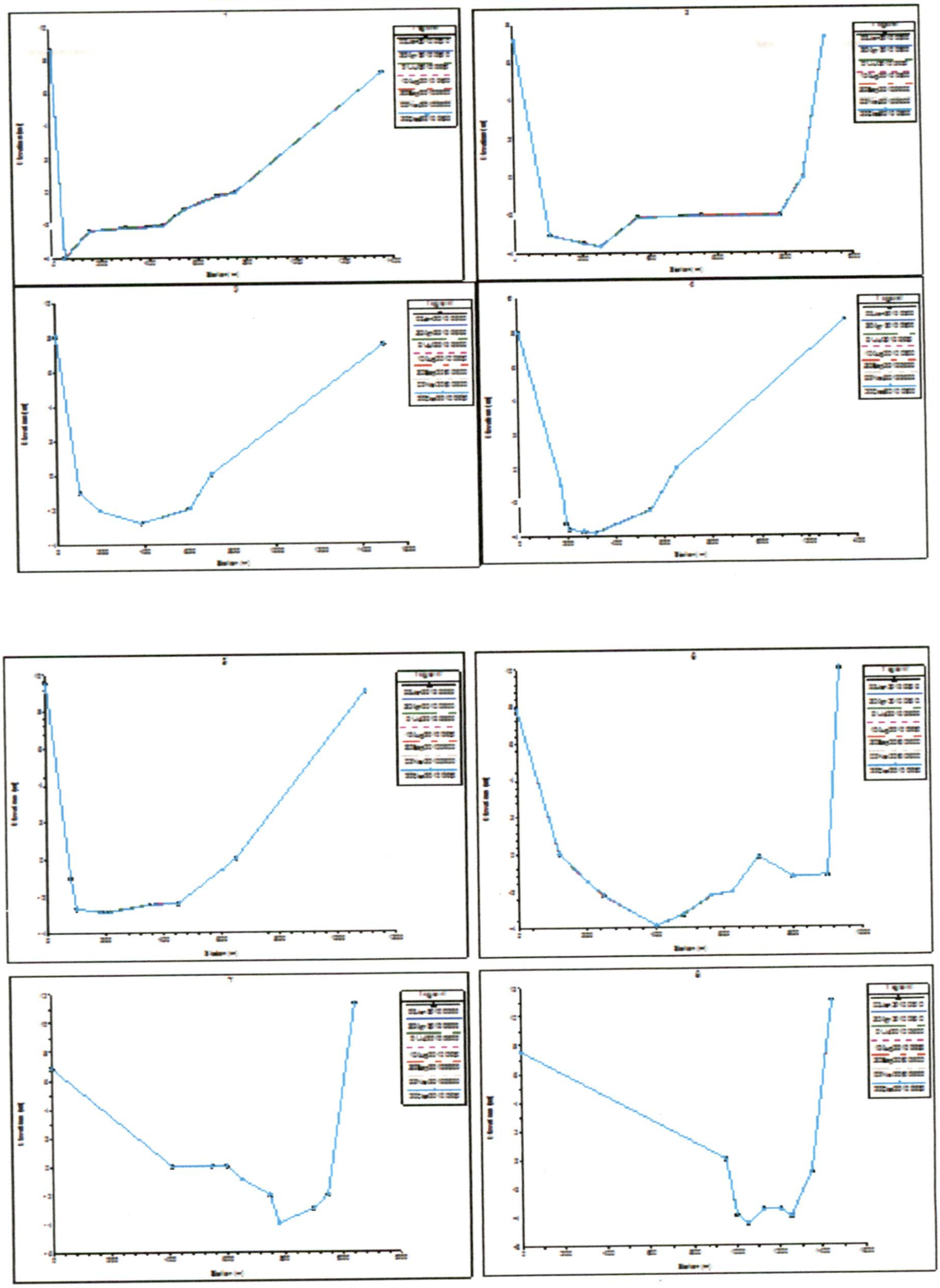


Fig 5.9 Water Profile 2010

In above water profile, Bed level change can't be found in July clearly..In September bed level changes occurred about 0.5 m to 1m in December at c/s 11 to c/s 12.

SEDIMENT CROSS-SECTION BED CHANGE



In c/s-1 to c/s 8 Bed level changes cann't be found clearly.

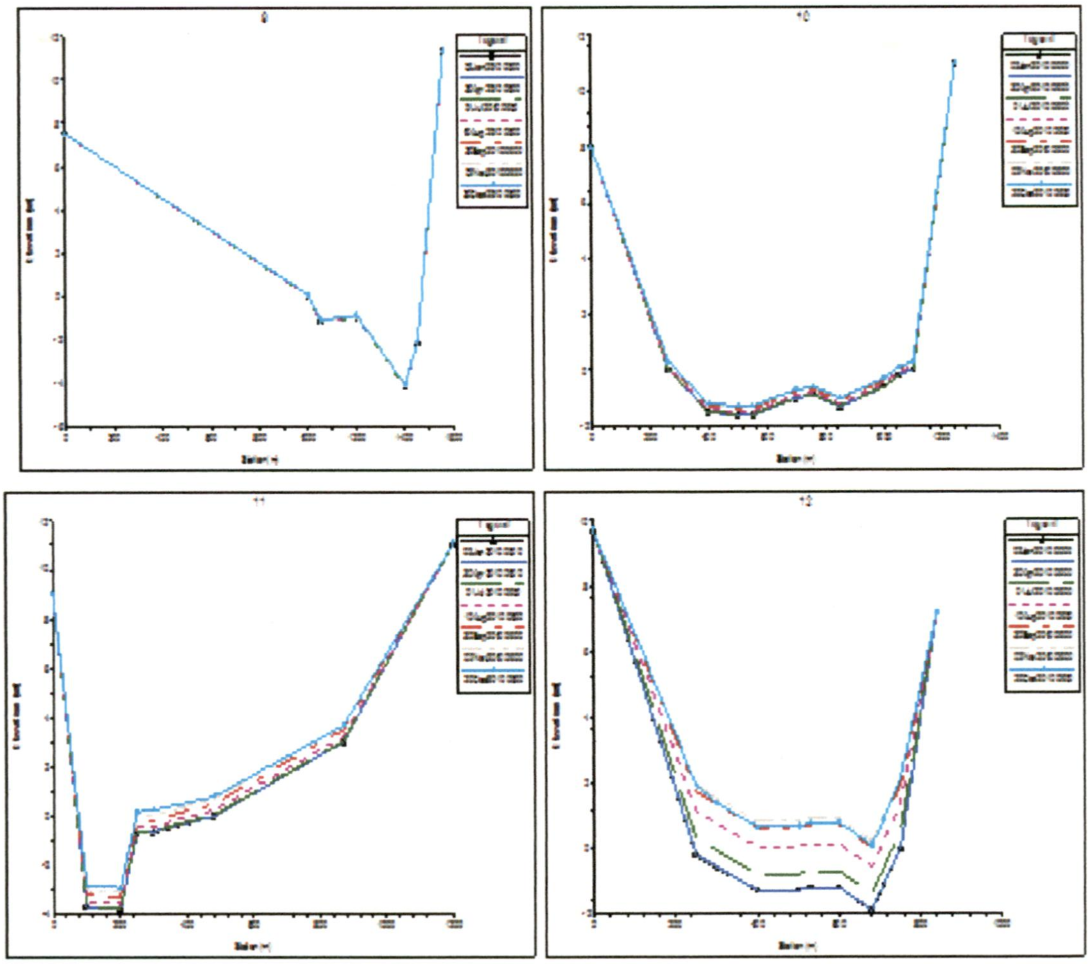


Fig 5.10 Sediment Cross-section bed changes 2010

In c/s-9 Bed level changes cann't be found clearly.

In c/s-10 Sedimentation occurred about 0.5 m between 250 m and 1110 m.

In c/s-11 Sedimentation occurred about 1.5 m between 50 m and 500 m.

In c/s-12 Sedimentation occurred range 1 m to 3 m between 50 m and 800 m.

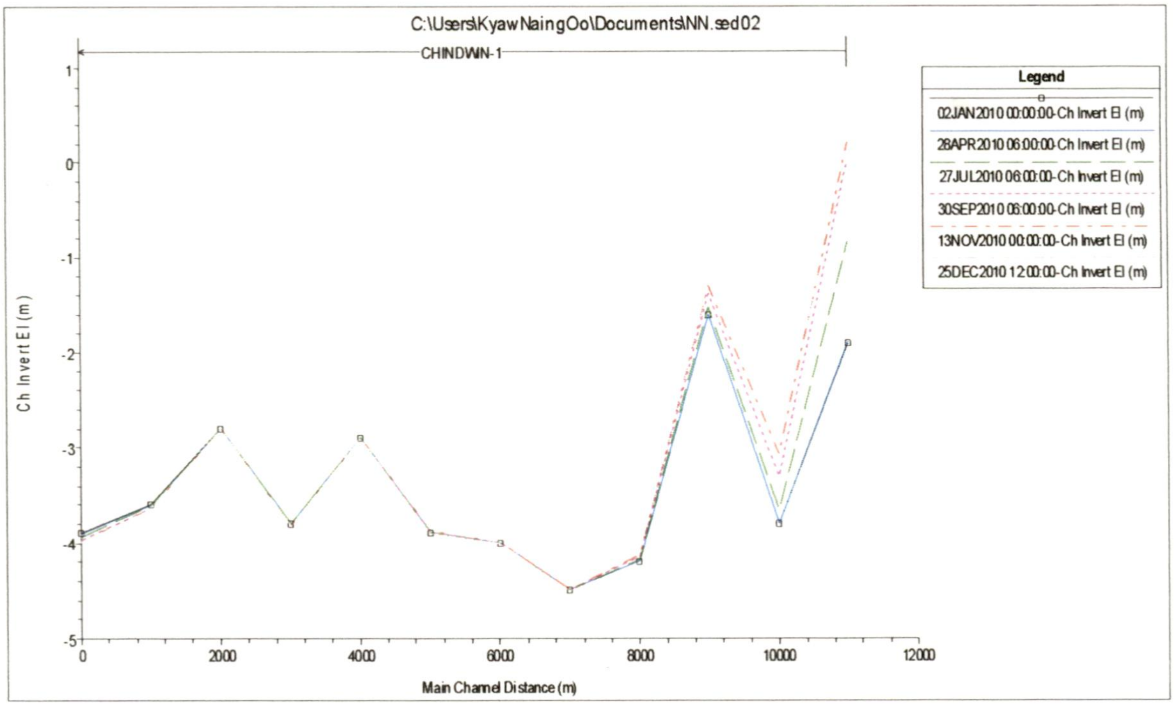


Fig 5.11 Sediment Spatial plot 2010

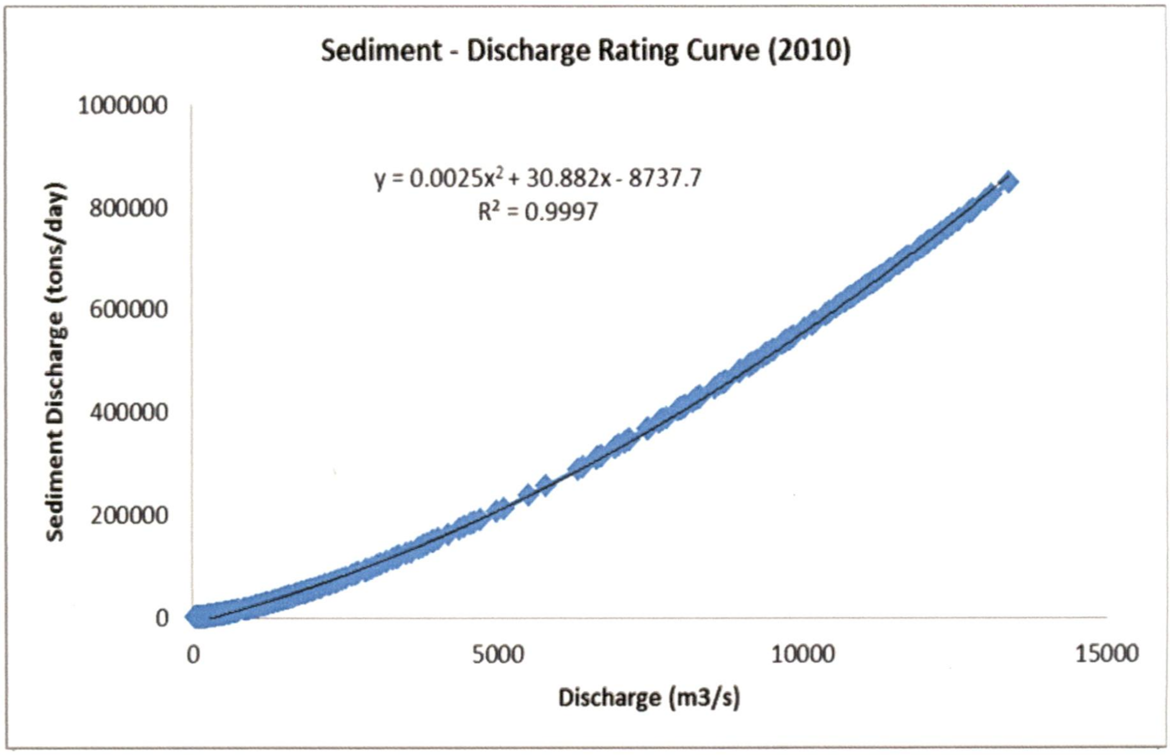


Fig 5.12 Sediment Discharge-Discharge Hydrograph 2010

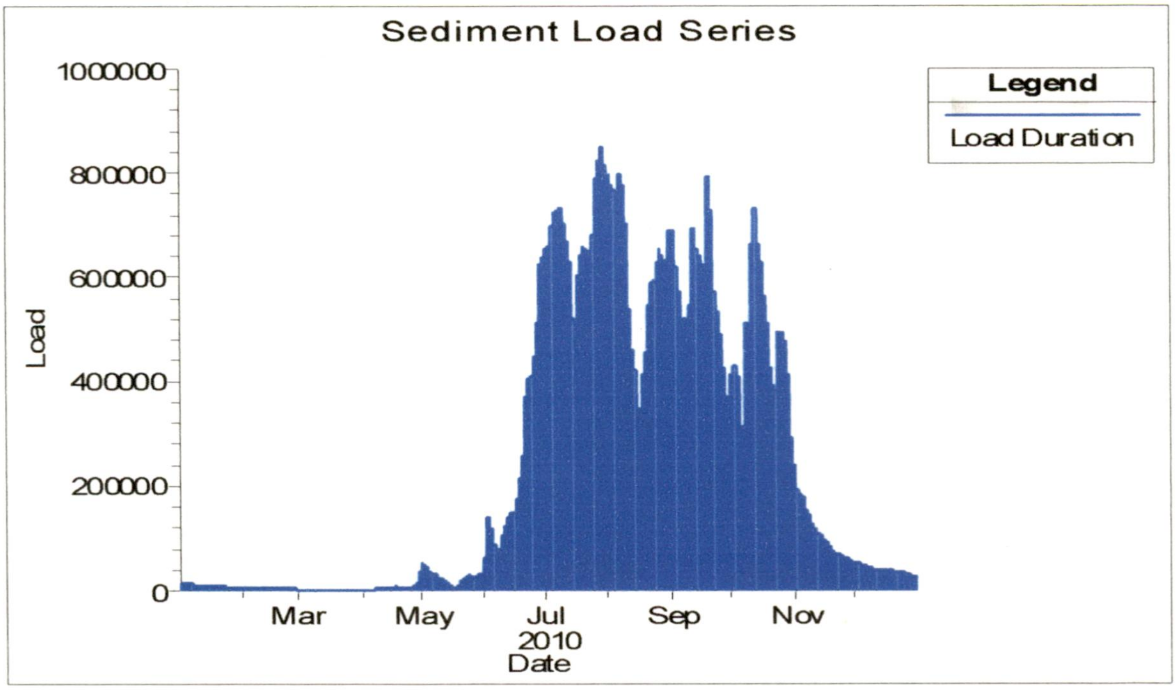


Fig 5.13 Sediment Discharge Hydrograph 2010

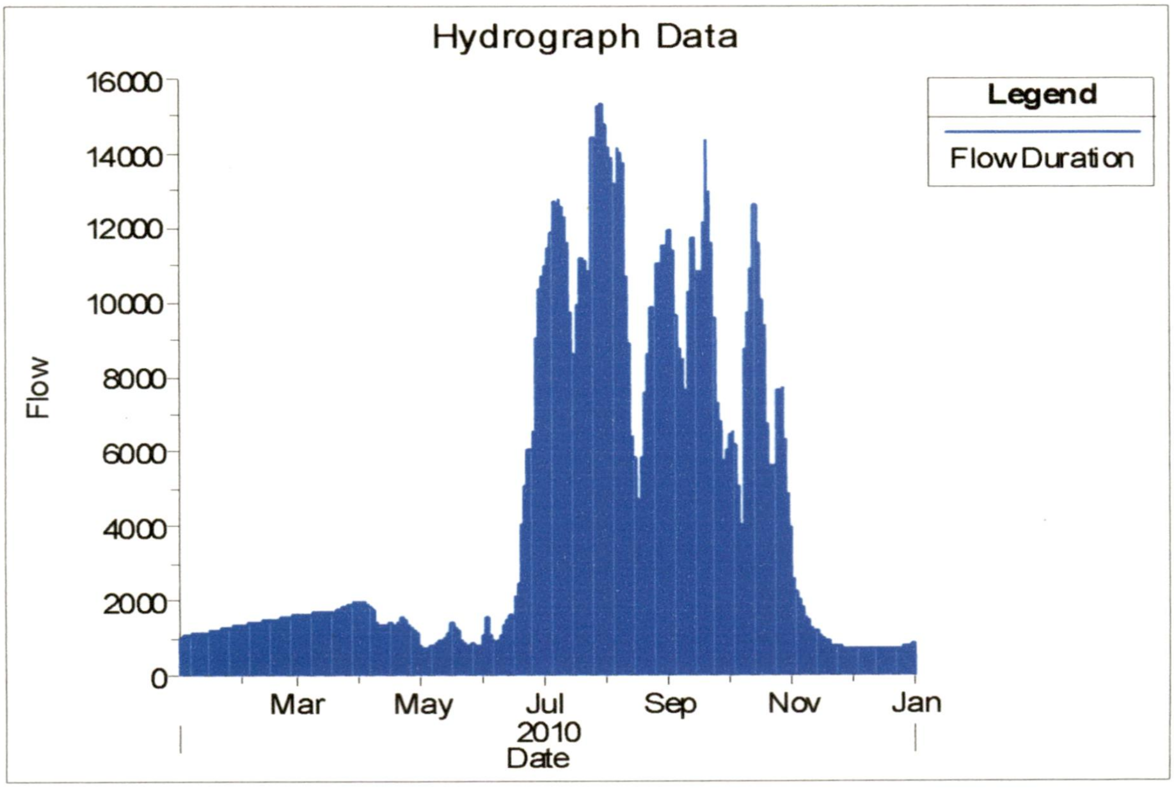


Fig 5.14 Discharge Hydrograph 2010

Table 5.2 Profile Output 2010 Data

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: CHINDWIN Reach: 1 Profile

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	01Apr2010 0900	1907.70	-1.89	2.01		2.08	0.000194	1.16	1644.20	580.65	0.22
1	11	01Apr2010 0900	1907.70	-3.80	1.78		1.85	0.000261	1.21	1577.21	654.08	0.25
1	10	01Apr2010 0900	1907.70	-1.60	1.64		1.67	0.000117	0.83	2294.83	915.51	0.17
1	9	01Apr2010 0900	1907.70	-4.20	1.46		1.52	0.000201	1.10	1726.70	674.09	0.22
1	8	01Apr2010 0900	1907.70	-4.50	1.32		1.37	0.000109	0.97	1960.80	586.26	0.17
1	7	01Apr2010 0900	1907.70	-4.00	1.11		1.20	0.000310	1.29	1476.04	630.52	0.27
1	6	01Apr2010 0900	1907.70	-3.90	0.99		1.03	0.000091	0.81	2346.47	803.11	0.15
1	5	01Apr2010 0900	1907.70	-2.90	0.83		0.90	0.000187	1.11	1712.90	625.71	0.21
1	4	01Apr2010 0900	1907.70	-3.80	0.66		0.72	0.000165	1.12	1705.09	565.07	0.21
1	3	01Apr2010 0900	1907.70	-2.80	0.42		0.50	0.000309	1.27	1503.79	660.10	0.27
1	2	01Apr2010 0900	1907.70	-3.60	0.22		0.27	0.000164	0.98	1946.89	783.73	0.20
1	1	01Apr2010 0900	1907.70	-3.91	-0.25	-1.09	-0.08	0.001000	1.83	1042.49	636.48	0.46

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: CHINDWIN Reach: 1 Profile: 0

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	06Sep2010 0900	8157.80	-0.21	5.56		5.97	0.000697	2.85	2863.87	686.99	0.45
1	11	06Sep2010 0900	8157.80	-3.45	5.28		5.47	0.000295	1.96	4172.14	923.30	0.29
1	10	06Sep2010 0900	8157.80	-1.44	5.15		5.26	0.000132	1.45	5639.57	1074.60	0.20
1	9	06Sep2010 0900	8157.80	-4.16	4.94		5.08	0.000236	1.67	4895.07	1164.71	0.26
1	8	06Sep2010 0900	8157.80	-4.49	4.69		4.84	0.000233	1.74	4695.77	1040.76	0.26
1	7	06Sep2010 0900	8157.80	-4.00	4.33		4.56	0.000343	2.12	3854.68	848.82	0.32
1	6	06Sep2010 0900	8157.80	-3.89	4.18		4.31	0.000148	1.63	4992.60	863.38	0.22
1	5	06Sep2010 0900	8157.80	-2.91	3.87		4.10	0.000310	2.10	3882.74	800.85	0.30
1	4	06Sep2010 0900	8157.80	-3.81	3.51		3.75	0.000385	2.19	3729.20	851.21	0.33
1	3	06Sep2010 0900	8157.80	-2.80	3.07		3.32	0.000485	2.22	3669.14	972.03	0.37
1	2	06Sep2010 0900	8157.80	-3.63	2.72		2.93	0.000300	2.05	3983.14	832.38	0.30
1	1	06Sep2010 0900	8157.80	-3.96	1.99	0.65	2.41	0.001000	2.85	2857.71	895.68	0.51

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: CHINDWIN Reach: 1 Profile:

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	16Oct2010 0900	10040.50	0.13	6.26		6.78	0.000817	3.20	3141.76	714.49	0.49
1	11	16Oct2010 0900	10040.50	-3.21	5.96		6.20	0.000336	2.18	4600.88	951.02	0.32
1	10	16Oct2010 0900	10040.50	-1.35	5.83		5.96	0.000145	1.60	6283.92	1104.93	0.21
1	9	16Oct2010 0900	10040.50	-4.14	5.61		5.77	0.000240	1.76	5694.97	1259.82	0.26
1	8	16Oct2010 0900	10040.50	-4.49	5.35		5.53	0.000246	1.86	5410.46	1129.91	0.27
1	7	16Oct2010 0900	10040.50	-4.00	4.96		5.22	0.000356	2.28	4403.37	891.62	0.33
1	6	16Oct2010 0900	10040.50	-3.89	4.79		4.96	0.000163	1.82	5526.69	875.07	0.23
1	5	16Oct2010 0900	10040.50	-2.91	4.45		4.72	0.000337	2.30	4361.44	834.52	0.32
1	4	16Oct2010 0900	10040.50	-3.82	4.06		4.35	0.000420	2.38	4218.33	906.80	0.35
1	3	16Oct2010 0900	10040.50	-2.81	3.60		3.89	0.000507	2.39	4203.22	1034.49	0.38
1	2	16Oct2010 0900	10040.50	-3.64	3.21		3.48	0.000329	2.28	4407.13	842.03	0.32
1	1	16Oct2010 0900	10040.50	-3.99	2.45	0.99	2.92	0.001000	3.05	3296.41	937.15	0.52

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 02 River: CHINDWIN Reach: 1 Profile:

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	27Dec2010 0900	751.40	0.05	1.68		1.84	0.002128	1.79	419.15	465.30	0.60
1	11	27Dec2010 0900	751.40	-2.91	0.76		0.84	0.000557	1.26	595.26	409.23	0.33
1	10	27Dec2010 0900	751.40	-1.29	0.28		0.32	0.000459	0.89	839.80	836.29	0.29
1	9	27Dec2010 0900	751.40	-4.12	0.00		0.04	0.000195	0.88	857.52	464.44	0.21
1	8	27Dec2010 0900	751.40	-4.49	-0.07		-0.05	0.000044	0.59	1270.05	405.88	0.11
1	7	27Dec2010 0900	751.40	-4.00	-0.19		-0.14	0.000212	1.00	749.79	353.16	0.22
1	6	27Dec2010 0900	751.40	-3.89	-0.29		-0.28	0.000088	0.57	1321.13	752.58	0.14
1	5	27Dec2010 0900	751.40	-2.91	-0.42		-0.39	0.000154	0.77	978.70	539.86	0.18
1	4	27Dec2010 0900	751.40	-3.82	-0.53		-0.51	0.000084	0.68	1107.83	466.82	0.14
1	3	27Dec2010 0900	751.40	-2.81	-0.69		-0.65	0.000276	0.90	838.33	569.60	0.24
1	2	27Dec2010 0900	751.40	-3.64	-0.86		-0.84	0.000138	0.65	1148.53	742.58	0.17
1	1	27Dec2010 0900	751.40	-3.99	-1.24	-1.79	-1.14	0.001001	1.40	535.54	487.35	0.43

The sedimentation and Erosion assessment of 12 km long stretch of Chindwin River of Monywa water way carried out. It is found that in 2005 and 2010, the maximum sediment loads were about 1000000 tons/day and 900000 tons/day.

In 2005 year, the maximum velocity is found as 3.47 m/s at c/s 1.Bed Erosion indicates about 1m to 2m erosion at c/s (1) to c/s 9. Sedimentation indicates about 0.5 m to 1m deposit at c/s 10 to c/s 12. In 2010 year, the maximum velocity is found as 3.2 m/s at c/s 12. Bed erosion indicates only about 0.2 m from c/s 1 to c/s 9. Sedimentation occurs 1.5 m to 3 m deposit from c/s 10 to c/s 12.

IMPROVEMENT OF NAVIGABLE CHANNEL & PROTECTION FOR BANK EROSION

INTRODUCTION

Rivers and streams are dynamic entities with boundaries, such as bed and banks, which are subject to erosion and deposition. Artificial channels are often constructed using erodible materials such as existing ground or compacted earth fill. In both cases there is a need for works to stabilize the bed and banks so that the channel does not migrate and cause damage to adjacent infrastructure

There are three main situations where protection to the bed and banks of a channel is necessary.

- In the vicinity of structures, such as bridges, sluices, locks and weirs, where flow velocities and turbulence are often higher, and erosion of the channel could threaten the safety or integrity of the structure.
- Along a channel where the natural material of the bed and banks could be subject to erosion, and where such erosion is unacceptable, for example, where the river or canal runs close to a road or other type of infrastructure.
- In a navigation canal where the currents and turbulence caused by ships could erode the bed and banks. These conditions are predominantly encountered on major inland waterways in locations where large vessels dock or manoeuvre.

6.1 EROSION PROCESSES

Erosion processes are essentially induced by high water velocity, high turbulence and high shear stress. The nature and origin of bank material as well as the processes affecting surface erosion of unprotected banks are key considerations in the selection and the design of river training works.

River bank erosion is a perennial problem in Myanmar, causing loss of lands and livelihood along major rivers. Structural and non-structural interventions are needed to prevent potential loss of land and livelihoods.

River training works are constructed to constrain the river, eg to ensure navigability or to avoid excessive erosion, which consequently restricts the progression of natural changes that occur as a result of the erosion and deposition of sediment. All river training works achieve their objective by protecting erodible material in the bed and banks from the effects of high current velocities and turbulent flow.

Revetments provide a direct form of erosion protection to a riverbank. An alternative indirect method consists of spur-dikes or groynes, and hard points that deflect the erosive flow away from the bank.

6.2 RIVER BANK EROSION CONTROL METHODOLOGIES

(I) Direct Method

(II) Indirect Method

6.2.1 Revetments

The most common form of river training structure is the **revetment** or **bank protection** .It is composed of a layer of erosion-resistant material that covers the erodible material of the river banks, and sometimes also the bed of the river. Various materials may be used for this purpose, including grouts and geotextiles. This manual focuses on armourstone - based solutions. The choice of the most suitable material should be made at an early stage in the project. Armourstone can be directly placed onto the bank or bed to be protected However, it is generally good practice to place it on an under layer that provides a transition between the coarse armourstone of the cover layer and the fine erodible material of the foundation. The under layer may be made of crushed rock or gravel that prevents sub soils from being eroded through the voids of the protection. Geotextiles may be used as a part of the filtering system, either with or instead of the granular filter .The under layer reduces both the risk of the foundation material being washed through the armour layer and of the cover layer punching into the subsoil.

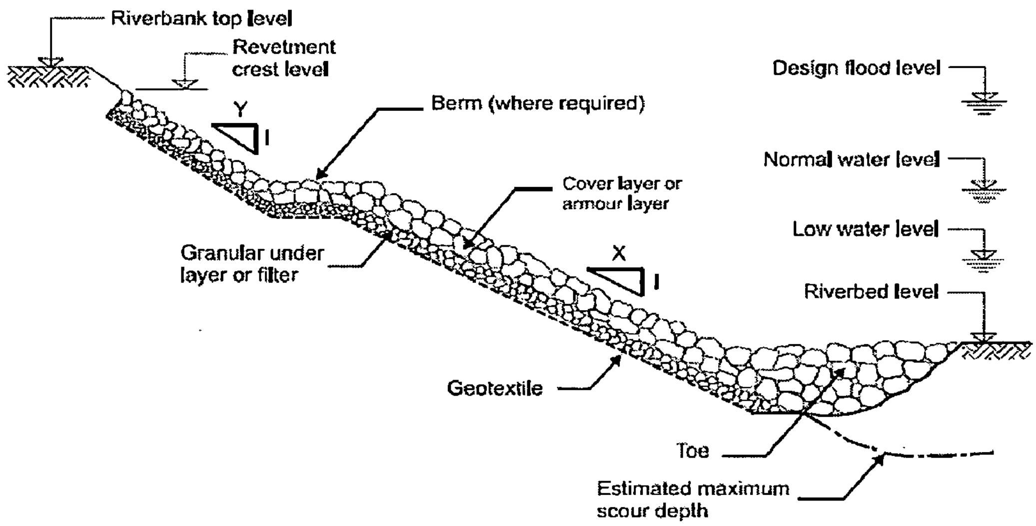


Fig 6.1: Components of a Typical Armourstone Revetment

The level of the revetment toe is determined in relation to the maximum scour expected after completion of the works. A retaining element for the toe such as a sheet pile wall may also be used.

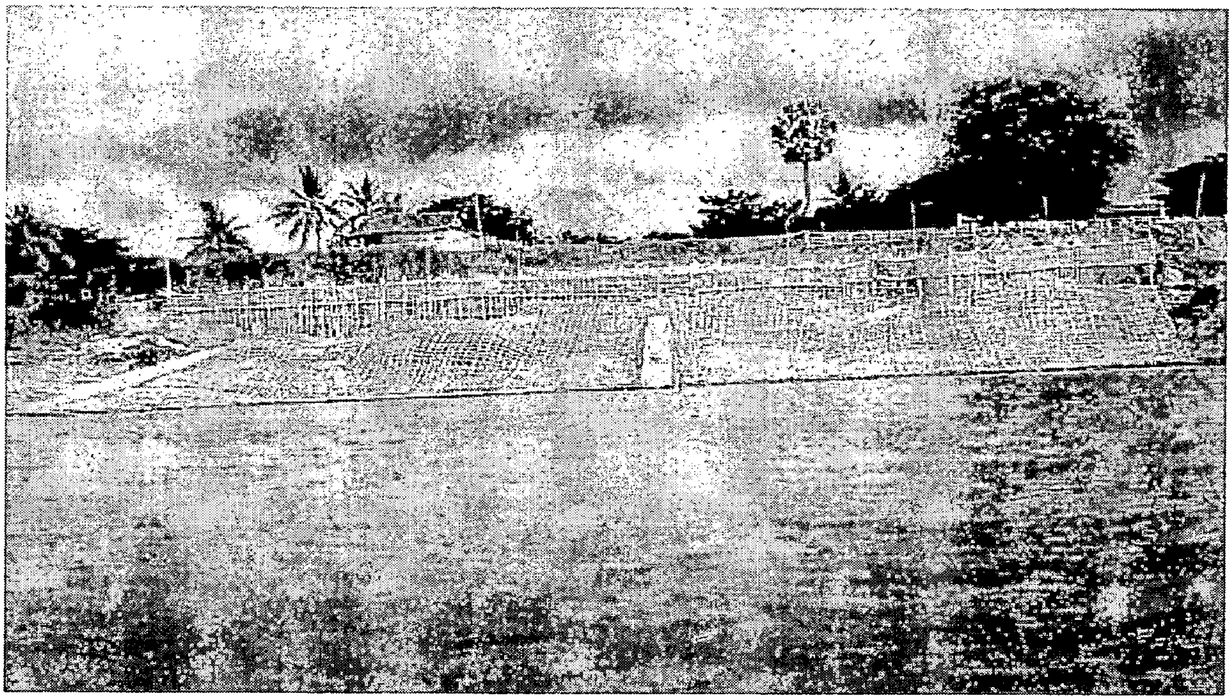
Revetments are suitable in many situations where the riverbank is to be protected in its existing position, with little work needed to reform or re-shape the bank line or profile. With any revetment work there will, of course, be the need for straightening of the bank line and profile to allow the construction of the revetment to appropriate lines and levels. However, if major realignment of the bank is required it will be necessary to consider the following options:

- If the provision of a continuous revetment on the existing line of riverbank is too expensive, the option of using hard points may be considered.
- In situations where it is necessary to reinstate the river bank before protecting it, for example to reclaim lost land, a revetment may be selected as a principal solution.
- However, if reinstatement is too expensive, but it is important to re-align the bank, for navigation reasons for example, the alternative of using spur-dikes should be considered.

6.2.2 Willow Mattress or Riparian Vegetation

Riparian vegetation helps to protect River bank from erosion. The roots of vegetation reinforce the soil in the same way that steel rods reinforce concrete. Fine roots are more important in this process than thick roots. Root reinforcement by riparian vegetation is usually the most important safeguard against bank collapse. Riparian vegetation also uses much of the water present in River bank and improves the drainage of River bank soils. Banks often collapse when saturated with water, so riparian vegetation, by helping to use that water, reduces the risk of sudden collapse. Vegetation also absorbs the erosive force of flows, preventing that force from being applied to the bank. It also reduces the extremes of temperature and moisture variation that can loosen sediment from the banks through swelling and shrinking of the soil.

Riverbank vegetation plays an extremely important role in protecting the "health" of river systems, particularly as habitat for aquatic organisms. Riverbank vegetation stabilizes bank sediments to reduce erosion, and provides a buffer between the river and the rest of the catchments to reduce the amount of sediment and nutrients entering the river. Native riverbank vegetation also provides important habitat for animals living on the bank and in the water.



6.3 TYPES OF RIVER TRAINING STRUCTURES

The focuses on river training works implemented on the middle and lower reaches of rivers characterized by mild slopes, i.e. slopes smaller than 1:1000, current velocities, U, generally in the range of 0.5 to 0.3 (m/s) and never greater than 5 m/s, and alluvial soils with grain sieve sizes, D (mm), in the range of 0.01 to 20 mm.

6.3.1 Spur Dikes

6.3.1.1 Design methodology

These structures are used in river training as contraction works to establish normal channel width; to direct the axis of flow; to promote scour and sediment deposition where required; and to trap bedload to build up new banks. Although less effective than training walls in rivers carrying small bedloads and in channels having steep gradients and swift currents, they are often more economical than longitudinal works since material is required to protect the bank.

The general practice in design and construction of spur dikes has been to place the crest of each dike in a system at about the same elevation with respect to a low-water profile and position most of the dikes in a system generally normal (perpendicular) to flow.

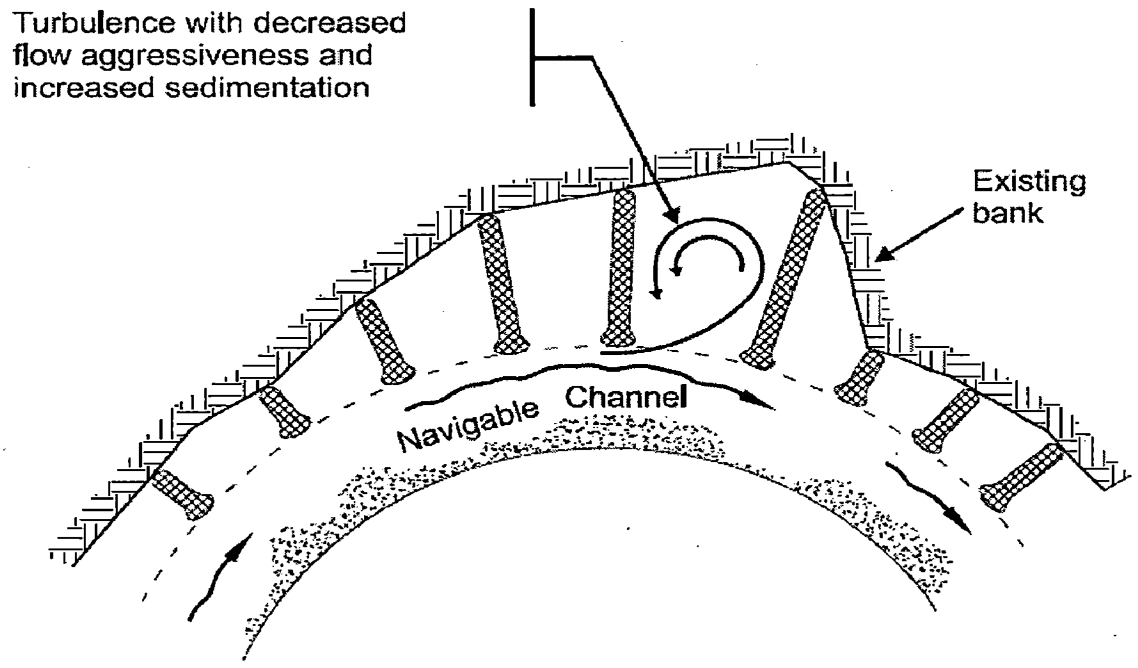


Fig 6.2 Plan View of a System of Spur-Dikes Constructed to Control and Stabilize the Erosion of the Outer Bend

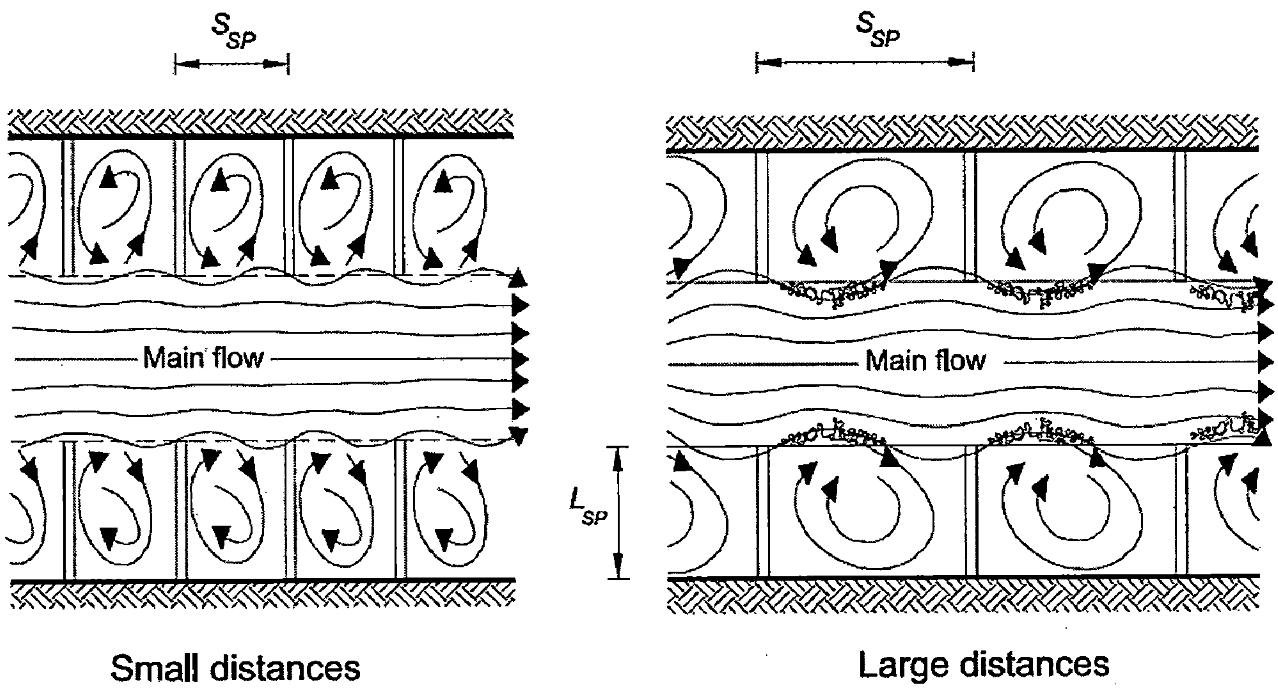


Fig 6.3 Illustration of a System of Spur-Dikes with Definitions of Length and Spacing of the Individual Dikes with Respect to the River Width.

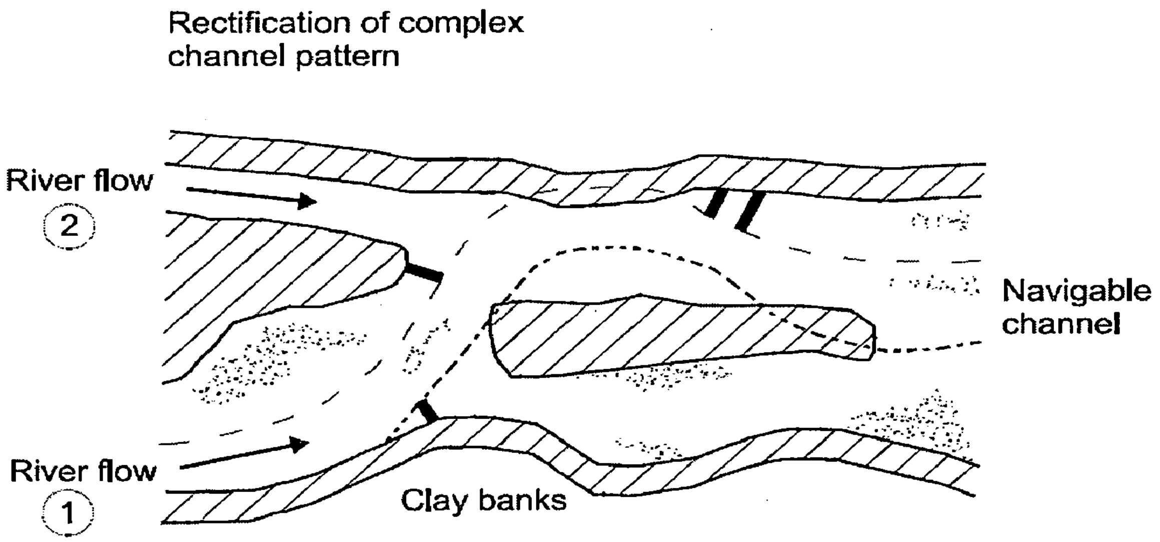


Fig 6.4: Illustration of Individual Spur-Dikes used for Rectification of a Complex Channel Pattern

Spur-dikes are suited to navigable rivers, where they can be used to define the navigable channel. They are more likely to be used on wide, shallow rivers than narrow deep channels. They are also more common on steeper, gravel bed rivers than on slower flowing channels. Effectively designed spur-dikes encourage sediment deposition between the spurs and consequently the re-establishment of an eroded bank line, Spur-dikes may be not be appropriate for rivers where the variation in water level, from low flow to flood conditions, is very large.

WES evaluated dike performance and released the results. Some parameters considered in the development of the rating system were as follows:

Controlling Depth - The least channel depth available along the thalweg in the reach is referred to mean low water, and indicates the maximum draft of a tow which could navigate the reach. Controlling depth would be a measure of the effectiveness of the dike in producing the channel depths required. Measurement of increase in controlling depth in feet below that existing without the structures.

Channel Alignment – The alignment of the sailing line in which would have to be followed by a tow having a draft equal to the controlling depth, indicating the degree of maneuvering required to navigate the reach. The alignment a channel could be such that long tows (1200 ft and longer) could negotiate the turns required. Value of 3.0 for excellent, 2.5 for good, 1.5 for fair, and none for poor.

Dredging – Amount of material to be removed to provide project depth along a reasonably good channel alignment. The amount of dredging required to produce the required channel dimensions is not necessarily indicated by the controlling depth. The amount of reduction in dredging index (1,00 cu yd per foot channel width) required to produce a channel of project depth based on that required without the structures.

Maximum Scour – Maximum scour usually occurs at the channel end of dikes. It provides an indication of a dike's obstruction of flow; head loss at the dike, reinforcement needed near the ends, and maintenance requirements. Value obtained when elevation when elevation of the dike, in feet mlw, is divided by the depth of scour referred to mlw. Scour is related to the elevation of the dike in this rating system to prevent low dikes, which normal produce less scour from being given a rating of such value that it might offset other more serious deficiencies.

Deposition Below Dikes – An indication of the effectiveness and permanency of the structure is provided by the deposition below the dikes. It is probably more important with permeable type dikes which depend on the material deposited behind them for the degree of contraction provided. The effective height of rock dikes could be increased by deposition sufficient to promote the growth of willows. Deposition is based on average of the maximum elevation below each dike related to the average elevation of the dikes, and may be given

$$\text{Deposition} = \frac{\text{Average elevation of maximum deposition below each dike in feet mlw;}}{\text{Sum of average elevation of each dike divided by number of dikes}}$$

Dike Elevation – Dike elevation is an indication of the amount of rock required for construction per unit length. Because of side slope, the rate of increase in rock required is greater than the rate of increase in height of dike. Channel Cross-Sectional Area and Dike Elevation – The cross-sectional area as affected by the dikes and the elevation of the dikes are not considered in the rating system. In this study, the cross section was not changed except as affected by differences in dike elevation. Dike elevation will tentatively be considered as a description of the dike system and an indication of relative cost. To provide an indication of the relative cost, the average elevation of a dike system is considered as

$$\text{Average Elevation of dike system} = \frac{\text{Sum of average elevation of each dike times length of dike}}{\text{Total length of all dikes in system}}$$

Channel Cross-Sectional Area – The degree of contraction effected by the dikes could be expected to have an effect on the performance of the dyke system. This would ordinarily determine the length and position of dikes rather than type of dike structures. In streams not fully canalized, the change in cross-sectional area caused by the construction of dikes would not necessarily be an indication of the degree of contraction produced by dike. In such cases, current directions and velocities in the reach before the installation of the dikes would provide a better indication of the probable effects of the dikes on flow, since dikes placed in slack water or low-velocity areas would not be as effective in higher velocity currents. Also, it must be considered that the degree of contradiction would change with river stages. See section on Dike elevation above.

6.3.2 Groynes

Groynes are defined as a structure that was installed at the front of bank or revetment to protect bank or levee against erosion by controlling the flow direction and velocities.

Groynes are the hydraulic structures that have functions of protecting bank erosion and maintaining water level by deflecting flow direction. In Europe, Japan, USA and others, the groynes have long been used as a measure of water training. Although the usage of groynes are reduced as the development of direct methods for bank erosion protection like as concrete revetment, the groynes are continuously installed to control the flow for navigation and improve the channel alignment. Recently groynes attract attention again because the natural bank form made by groynes is very beneficial to river ecosystem. In developing ages the social needs for river environment is insufficient. And groynes did not attract the attention because of the convenience of concrete revetment. However, the value of groynes as a bank protection technique with the consideration of river environment have been revaluating recently. And various types of groynes have been installed as a pilot project.

Groynes or spurs are constructed transverse to the river flow extending from the bank into the river. This form of river training works perform one or more functions such as training the river along the desired course to reduce the concentration of flow at the point of attack, creating a slack flow for silting up the area in the vicinity and protecting the bank by keeping the flow away from it.

6.3.2.1 Purposes of Installation

The main purposes of installation are divided into flow control and bank protection. In detail purpose it can be changed as the goals of river work and characteristics of river in each country. The purposes in functional side that defined in typical guidelines of Myanmar are as follow;

· Protection of existing bank line
· Improvement of flow direction
· Flow constriction
· Security of enough depth of river for navigation
· Increasing hydraulic conveyance of river and reducing flood risk
· Increasing flow velocity to prevent sedimentary deposit
· Prevention of river bank erosion
· Maintenance and modification of plane configuration of river
· Security of regular depth of water and stabilization of river flow
· Prevent of bank erosion and failure as high water level

6.3.2.2 Functions of Groyne

(i) Prevention of river bank erosion
(ii) Control of flow
(iii) Improvement of ecological environment and scenery
(iv) Security of stability of nature-friendly river

(i) Prevention of river bank erosion

The main object of installation of groyne in rivers is to prevent the breaking of a bank caused by sediment erosion as a flood. In particular, a strong flow in a bight of a river causes sediment in environs to move, which brings out problems related to erosion.

Effects of a bank protection by installation of groyne depend on main factors of groyne, which are hydraulic characteristics (the water level, velocity, flow of main stream, and change of thalweg etc), topographic features of river (the bight of river). Also, effects depend on design factors, which are the length, interval degree and arrangement of groyne. For instance, as the length of groyne increases the range of a bank protected extends. However, at the same time as the velocity of a main channel and head of groyne changes considerably, it would have dangerousness causing serious local scours around structures. In addition, the installation of groyne series causes recirculation flow between groynes. In this area it is very important to design a groyne with proper intervals for security of a bank as a strong reverse flow causing erosion of bank can occur according to intervals of groyne.

(ii) Flow Control

There are two main effects controlling flow, expected by installation of a bank. The first effect is that an existing thalweg can be led to other direction, so the direction of flow would be controlled. Then another is as the strong velocity of a river bank in a bight can be reduced, a flow would be delayed. These effects controlling flow cause a flow to concentrate affect maintenance of the depth of water for navigation and reduce the velocity of a river bank. As a result, a river bank would be protected.

(iii) Improvement of ecological environment and scenery

A Groyne is a protection technique which can protect a bank and improve scenery in environs at the same. In particular, as the velocity in a groyne field would be reduced enough compare to a main stream. According to this phenomenon, not only various habitats but also a refuge as a flood for fishes and microorganisms are provided. In short groynes contribute to create ecological environments.

(iv) Security of stability of nature-friendly river

US Army Corps Engineering emphasizes it is important to consider the scenery, quality of water and ecological affects including physical affects as protection measures against a bank erosion is designed. Recently nature-friendly materials such as a wood are used for river training works, and revetments using vegetation are used widely for the stability of bank. However, these nature-friendly materials are weaker than existing materials like concrete, and even they are not verified enough with constructive cases. So a groyne is disadvantageous in aspect of stability. At this moment, although mixed materials like block with vegetation are used it is required to verify actual constructive cases and stability enough. Therefore, constructions with these nature-friendly river techniques need to secure the stability by proper protection techniques.

6.3.2.3 Classification of Groynes

Groynes or spurs are classified according to (i) the method and materials of construction (ii) the height of spur with respect to water level (iii) function to be performed and (iv) special types which include the following:

These are

(i) Permeable or impermeable

(ii) Submerged or non-submerged

(iii) Attracting, deflecting repelling and sedimenting and

(iv) T-shaped, hockey (or Burma) type, kinked type, etc.

(i) Impermeable Groyne

Impermeable spurs do not permit appreciable flow through them whereas permeable ones permit restricted flow through them. Impermeable spurs may be constructed of a core of sand or sand and gravel or soil as available in the river bed and protected on the sides and top by a strong armour of stone pitching or concrete blocks. They are also constructed of balli crates packed with stone inside a wire screen or rubble masonry. While the section has to be designed according to the materials used and the velocity of flow the head of the spur has to have special protection.

Fig 6.5 Impermeable Groyne

(ii) Permeable Groyne

Permeable spurs usually consist of timber stakes or piles driven for depths slightly below the anticipated deepest scour and joined together to form a framework by other timber pieces and the space in between filled up with brush wood or branches of trees. The toe of the spur would be protected by a mattress of stones or other material. As the permeable spurs slow down the current, silt deposition is induced. These spurs, being temporary in nature, are susceptible to damage by floating debris. In bouldery or gravelly beds, the spurs would have to be put up by weighing down timber beams at the base by stones or concrete blocks and the other parts of the frame would then be tied to the beams at the base.

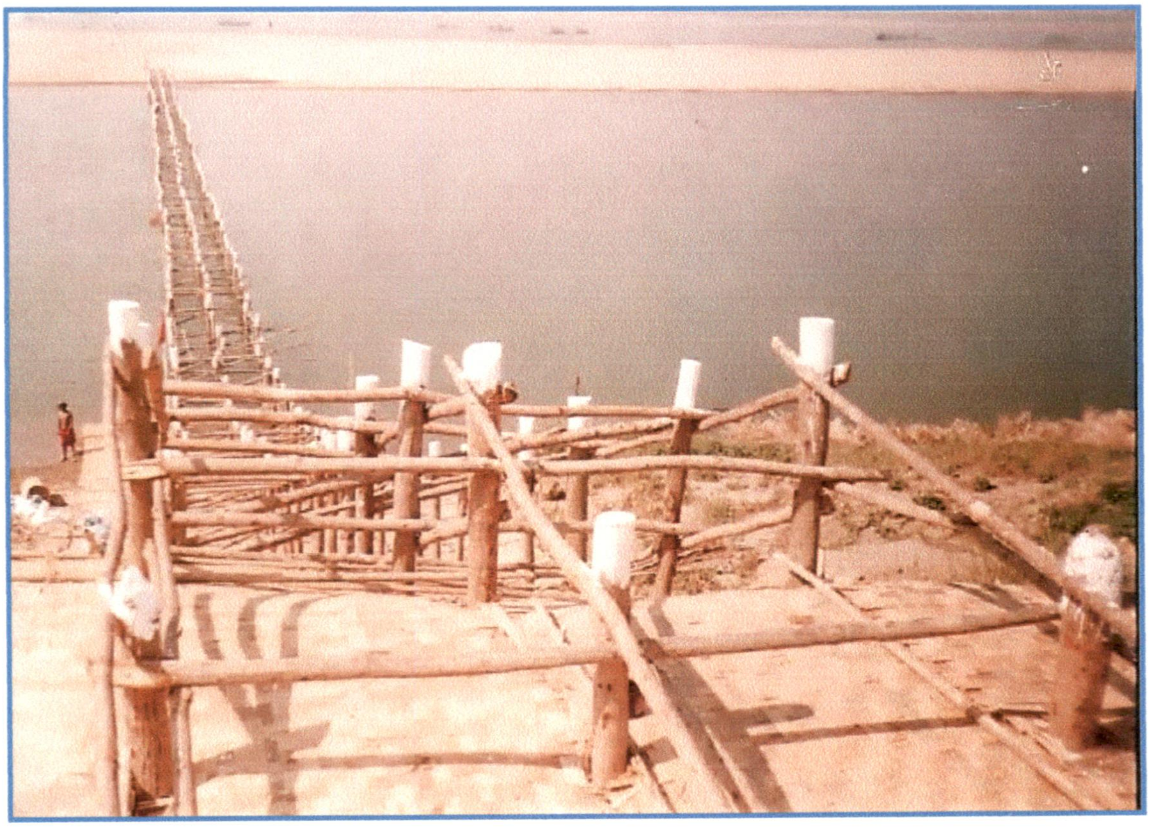
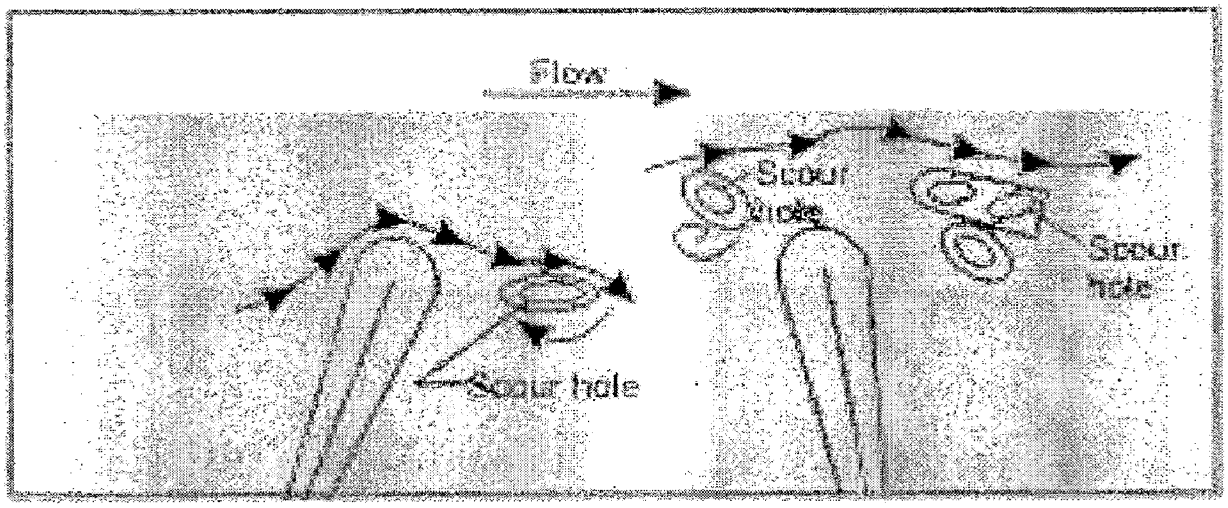
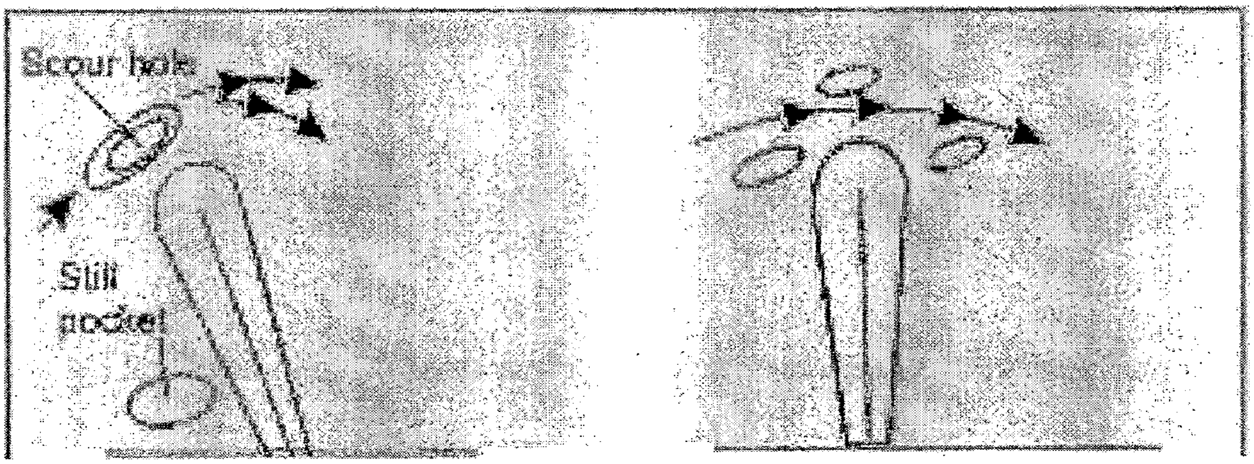


Fig 6.6 Permeable Groyne

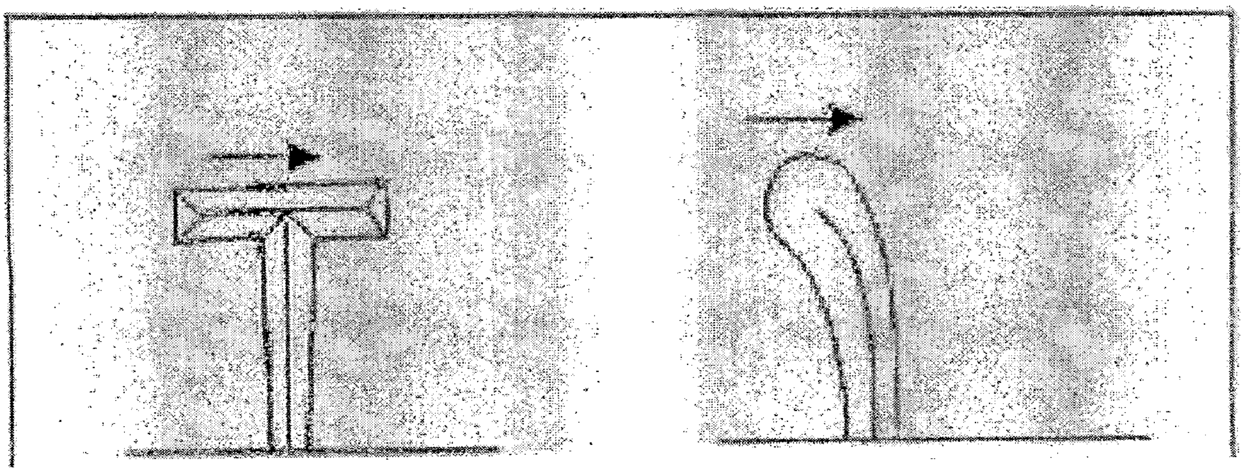
The different types of Groyne are shown in Figure



Attracting Groyne **Deflecting Groyne**



Reflecting Groyne **Sedimenting Groyne**



T-Headed Groyne **Hockey Groyne**

Fig 6.7 Different type of Groynes

6.3.2.4 Layout of groynes

Groynes are much more effective when constructed in series as they create a pool of nearly still water between them which resists the current and gradually accumulates silt forming a permanent bank line in course of time. The repelling spurs are constructed with an inclination upstream which varies from 10 to 30 to the line normal to the bank. In the T-shaped groynes, a greater length of the cross groyne projects upstream and a smaller portion downstream of the main groyne.

6.3.2.5 Length of Groynes

The length of groynes depends upon the position of the original bank line and the designed normal line of the trained river channel. In easily erodible rivers, too long groynes are liable to damage and failure. Hence, it would be better to construct shorter ones in the beginning and extend them gradually as silting between them proceeds. Shorter and temporary spurs constructed between long ones are helpful in inducing silt deposition.

6.3.2.6 Spacing of Groynes

Each groyne can protect only a certain length and so the primary factor governing the spacing between adjacent groynes is their lengths. Generally, a spacing of 2 to 2.5 times the length of groynes at convex banks and equal to the length at concave banks is adopted. Attempts to economise in cost by adopting wider spacings with a view to insert intermediate groynes at a later date may not give the desired results as the training of river would not be satisfactory and maintenance may pose problems and extra expenditure. T-shaped groynes are generally placed 800 m apart with the T-heads on a regular curved or straight line.

6.3.2.7 Design of groynes

The design of groynes or spurs include the fixation of top width, free board, side slopes, size of stone for pitching, thickness of pitching, filter and launching apron.

6.3.2.8 Top width of groyne

The top width of the spur is kept as 3 to 6 m at formation level.

6.3.2.9 Free board

The top level of the spur is to be worked out by giving a free board of 1 to 1.5 m above the highest flood level for 1 in 500 year flood or the anticipated highest flood level upstream of the spur, whichever is more.

6.3.2.10 Side slopes

The slopes of the upstream shank and nose is generally kept not steeper than 2:1 the downstream slope varies from 1.5 : 1 to 2:1.

6.3.2.11 Size of stone for pitching

The sloping surface of the guide bund on the water side has to withstand erosive action of flow. This is achieved by pitching the slope manually with stones. For average velocities up to 2 m/sec, burnt clay brick on edge can be used as pitching material. For an average velocity upto 3.5 m/sec, pitching of stone weighing from 40 to 70 kg (0.3 to 0.4 m in diameter) and for higher velocities, cement concrete blocks of depth equal to the thickness of pitching can be used. On the rear side, turfing of the slope is normally found to be adequate.

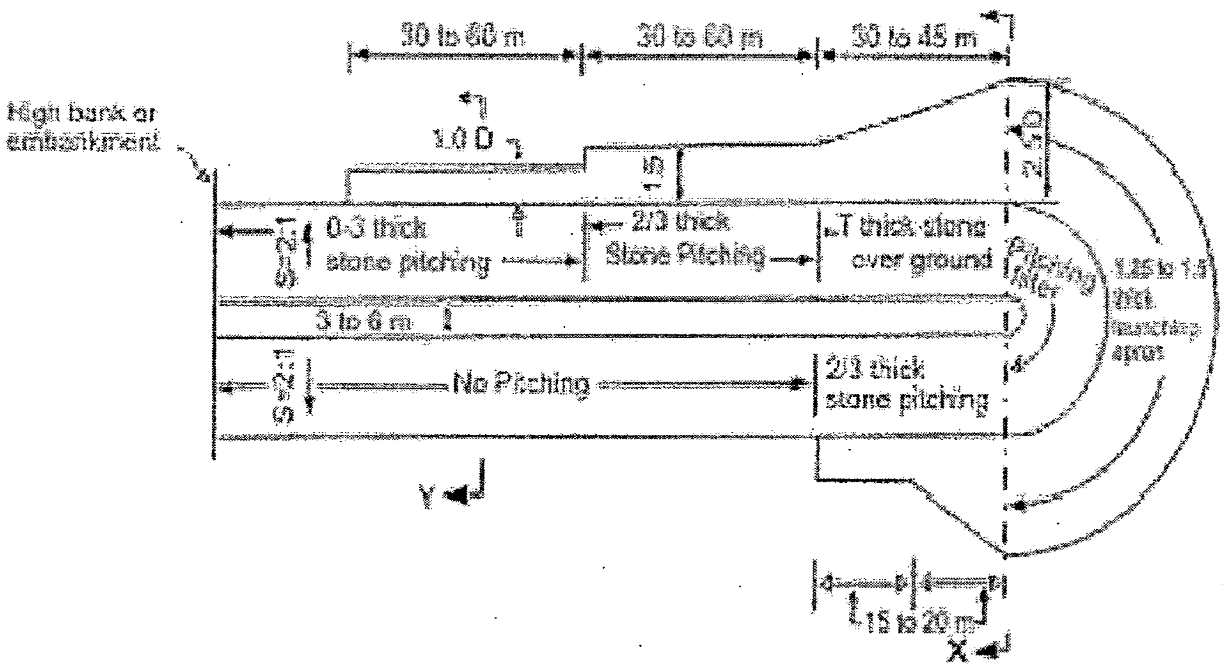
6.3.2.12 Thickness of pitching

The thickness of pitching for spurs may be determined from the formula $\mathbf{T = 0.06\ Q^{1/3}}$ Where Q is the design discharge in cumecs. The thickness of stone need not be provided the same through-out the entire length of the spur. It can be progressively reduced from the nose.

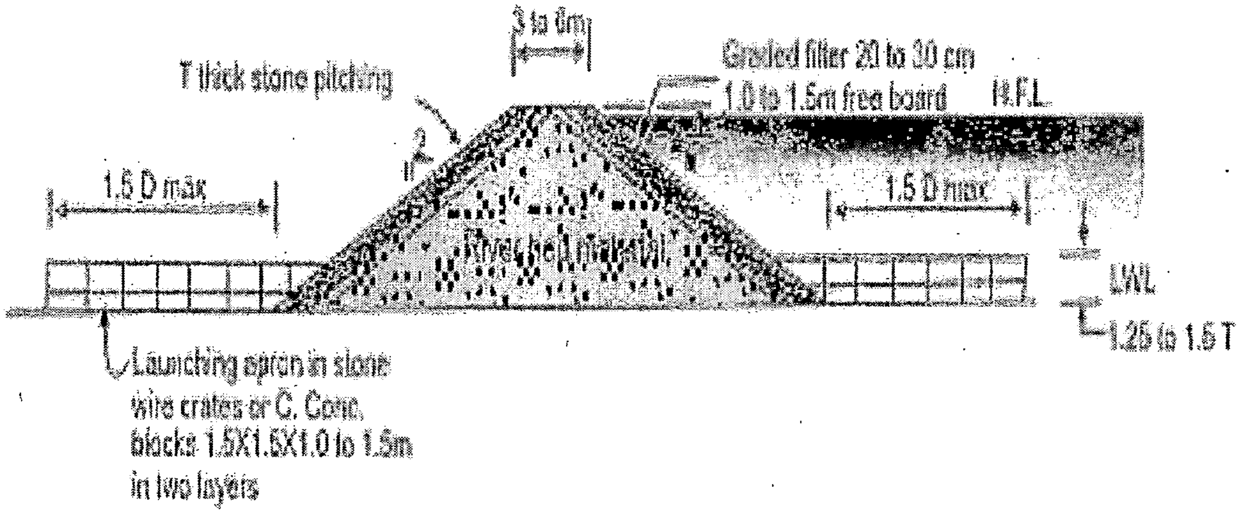
6.3.2.13 Provision of filters

Provision of filter satisfying the filter criteria has to be made below the pitching at nose and on the upstream face for a length of 30 to 4 m for the next 30 to 45m from the nose. The thickness of the same may be 20 to 30cm. The thickness of filter for the next 30 to 45m on the upstream face may be reduced to about 15 cm and beyond that, it can be omitted.

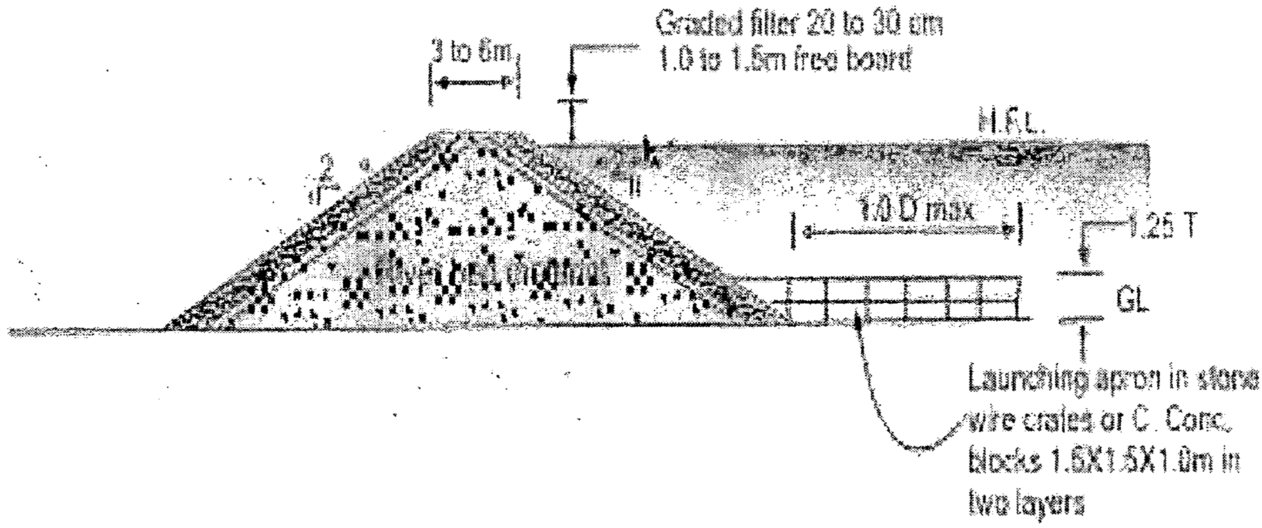
A typical layout of a spur is shown is Figure.



Plan view



Enlarged Section X-X



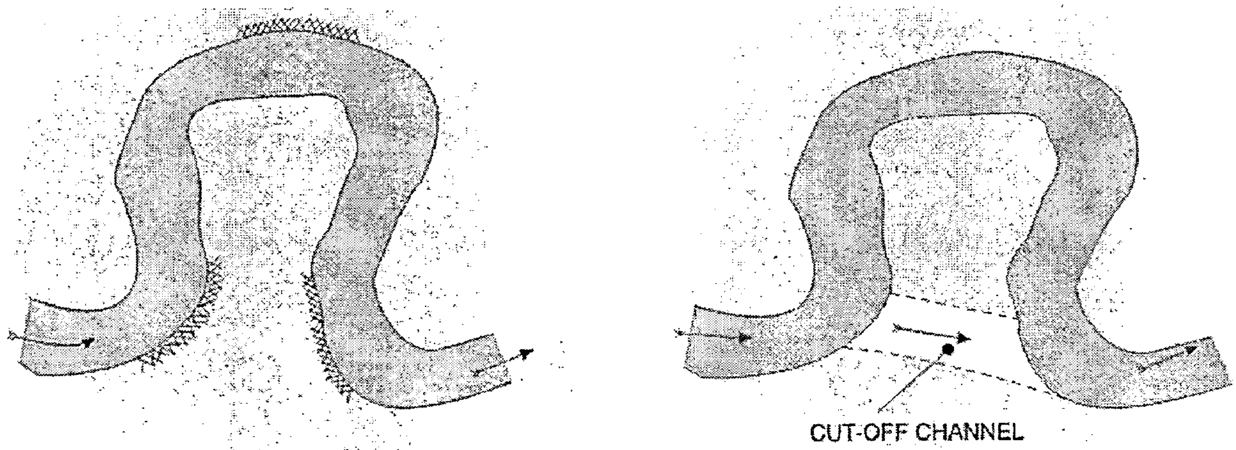
Enlarged Section Y-Y

Fig 6.8 Typical Layout and Section of Groyne

6.4 CUT-OFFS

Cut-offs as river training works are to be carefully planned and executed in meandering rivers. The cut-off is artificially induced with a pilot channel to divert the river from a curved flow which may be endangering valuable land or property or to straighten its approach to a work or for any other purpose. As the cut-off shortens the length of the river, it is likely to cause disturbance of regime upstream and downstream till readjustment is made. A pilot cut spreads out the period of readjustment and makes the process gradual. Model tests come in handy in finalizing this form of river training works wherever needed.

A typical instance of a cutoff is shown in Figure.



(a) (b)

Fig 6.9 (a) Meandering River with possible threat back erosion (b)An Engineered Cut-off channel

6.5 In 2011-2012 year, the Chindwin River Management for improvement of navigable channel and protection for bank erosion

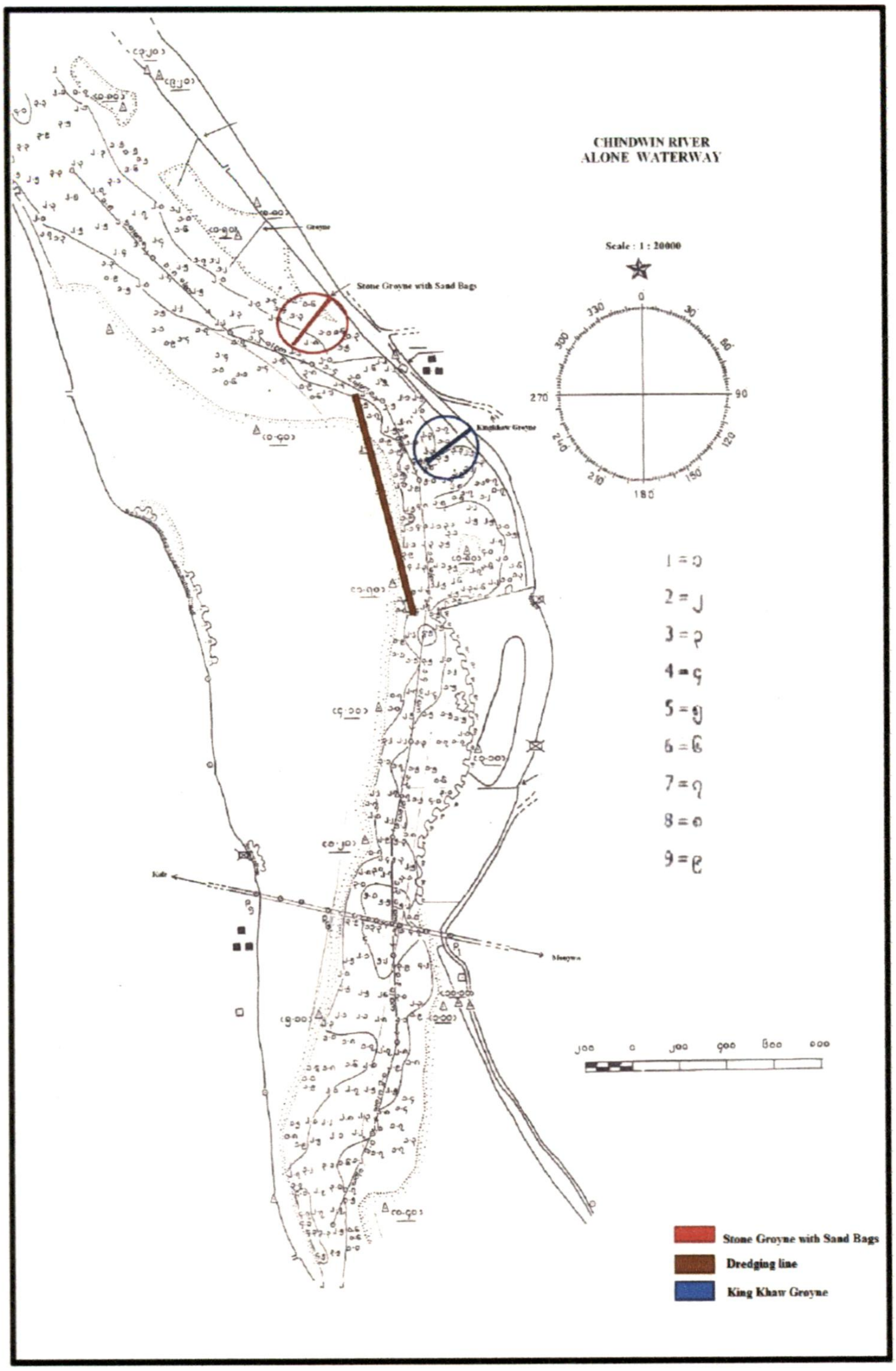


Fig 6.10 Map of Alone waterway

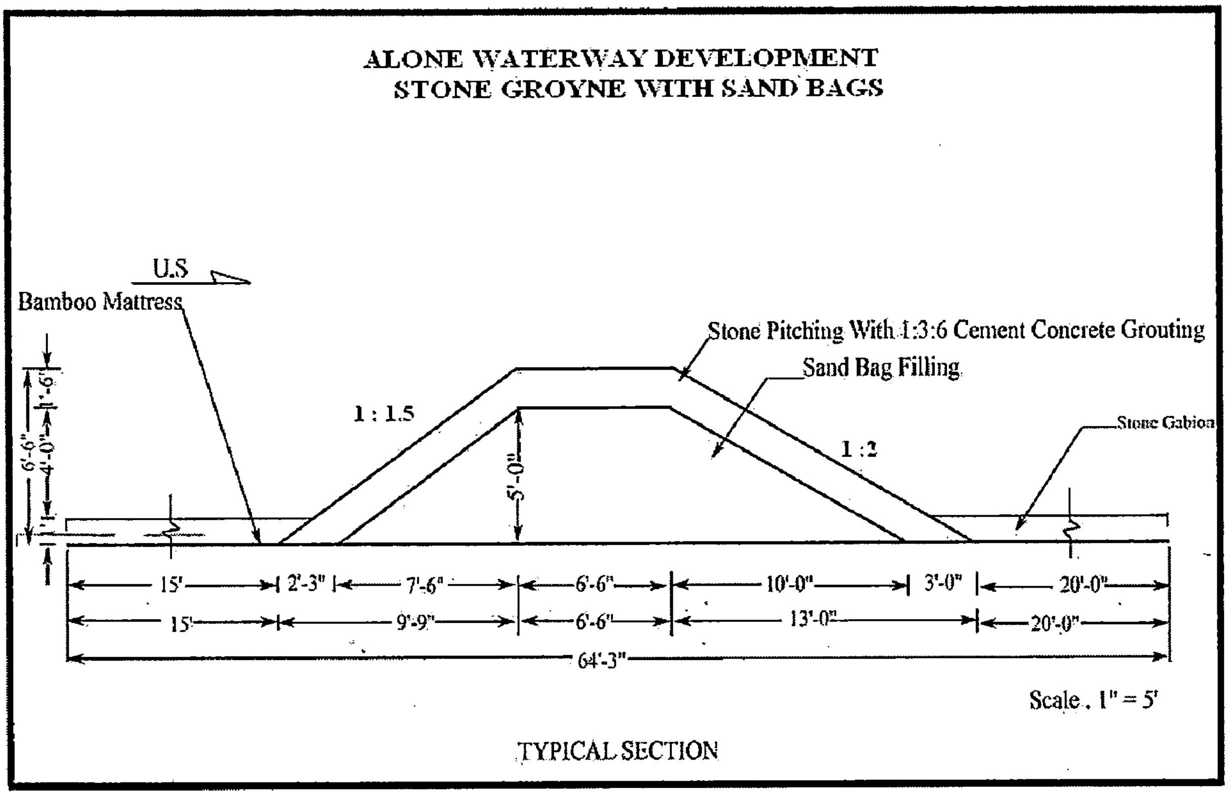


Fig 6.11 Cross-section of Structure at Alone waterway

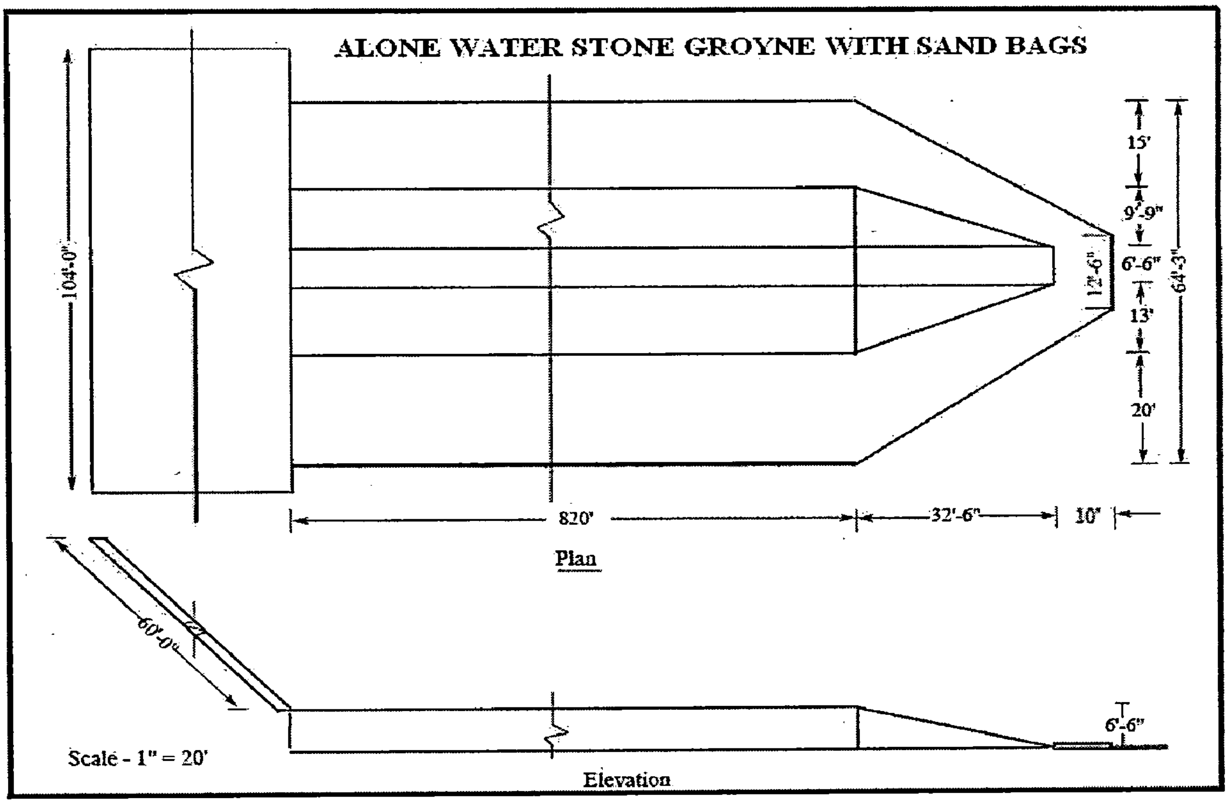


Fig 6.12 Plan & Elevation of Structure at Alone waterway

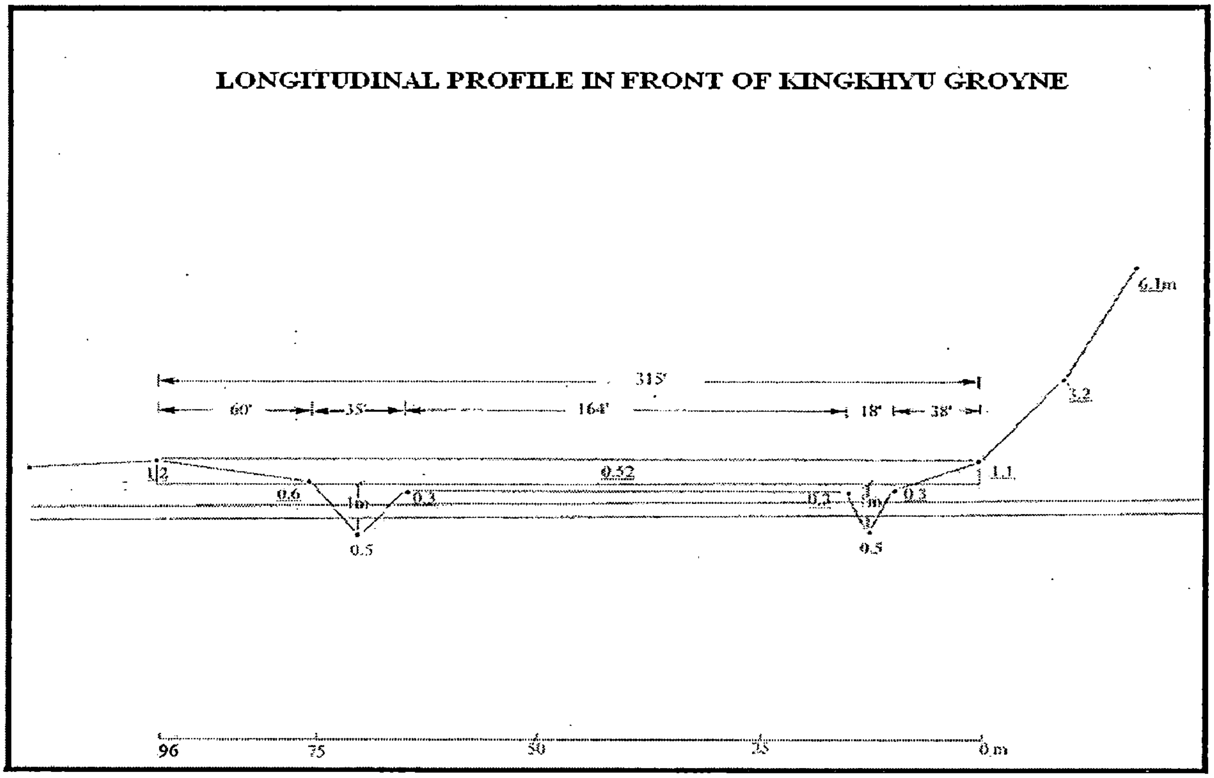


Fig 6.13 longitudinal profile in front of Structure at Alone waterway

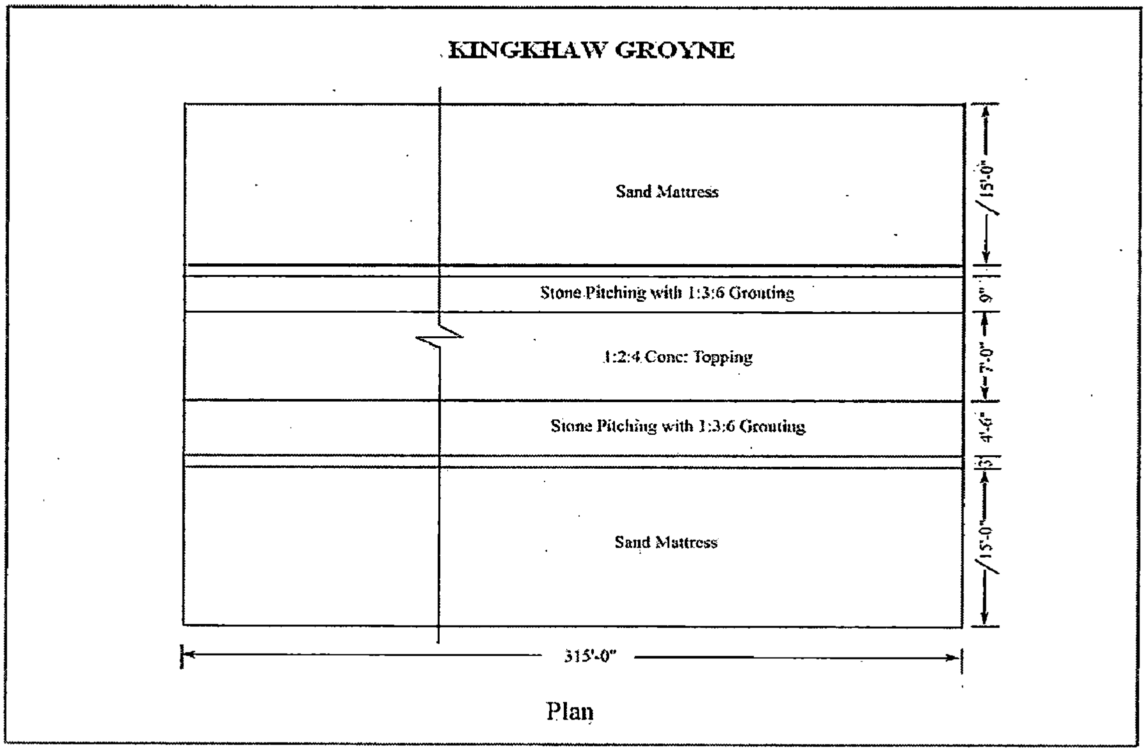


Fig 6.14 Plan View of Structure at Alone waterway

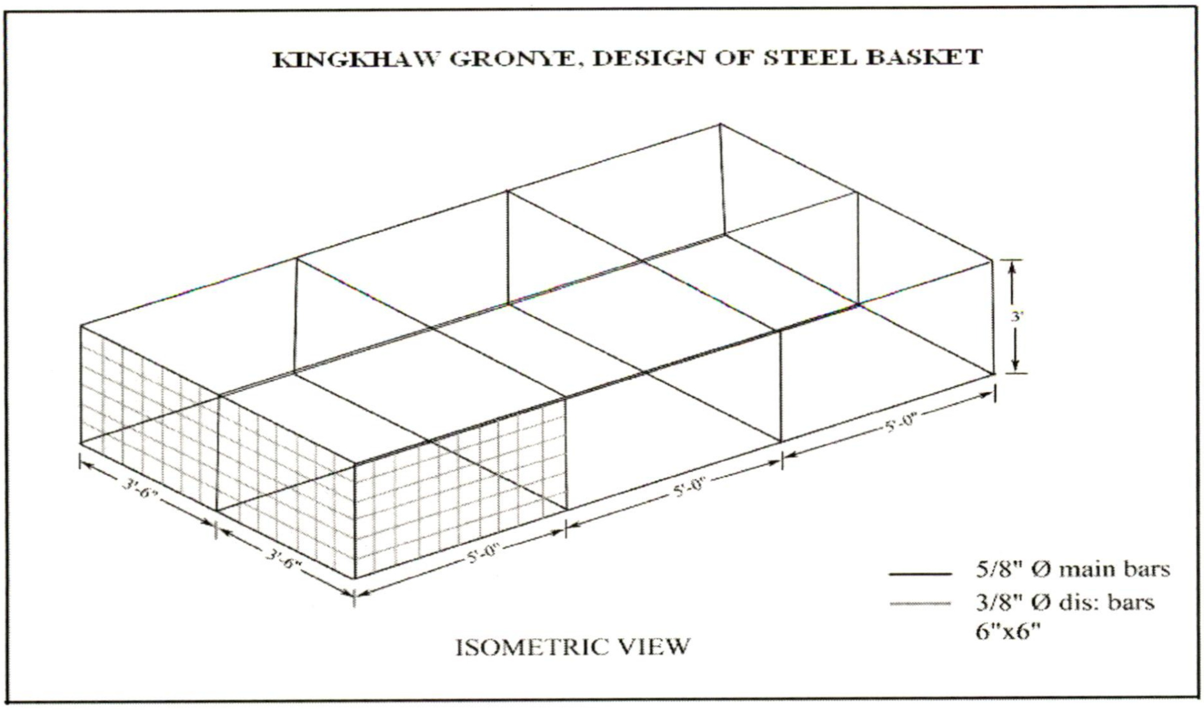


Fig 6.15 Design of steel basket at Alone waterway

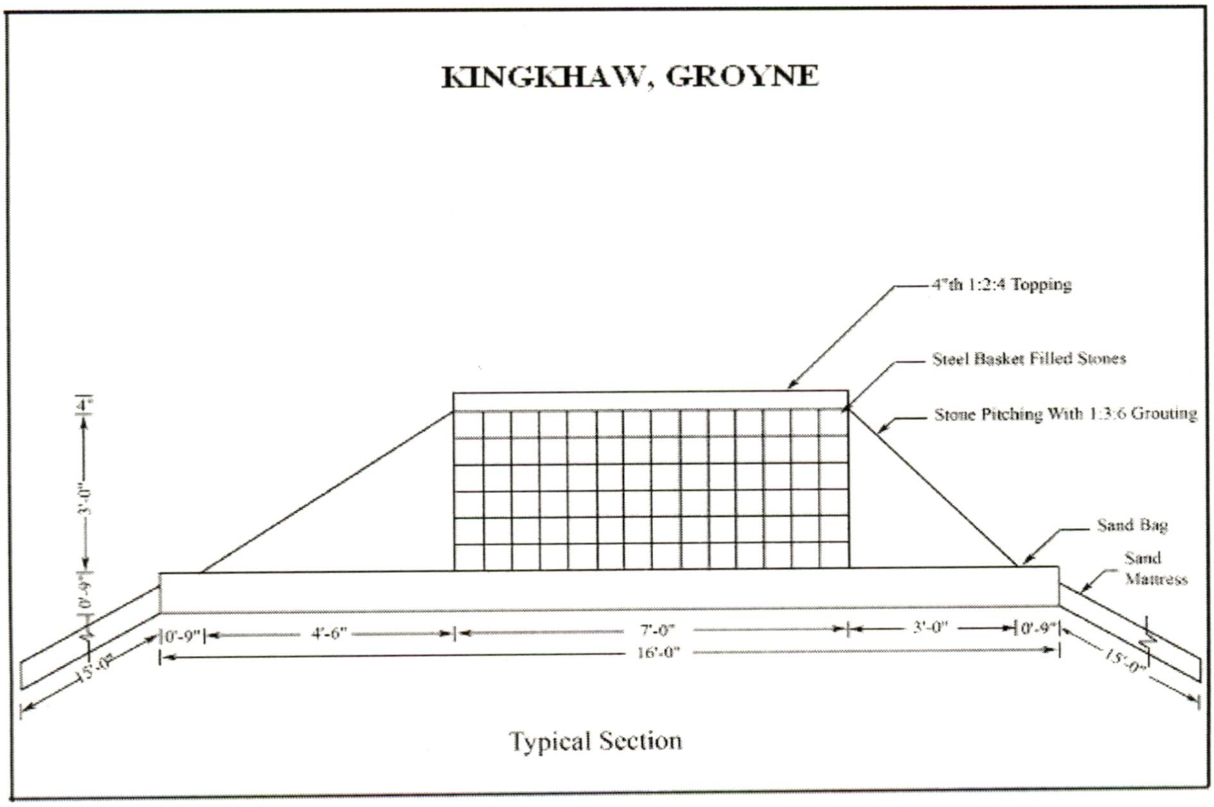


Fig 6.16 Cross-section of Structure at Alone waterway

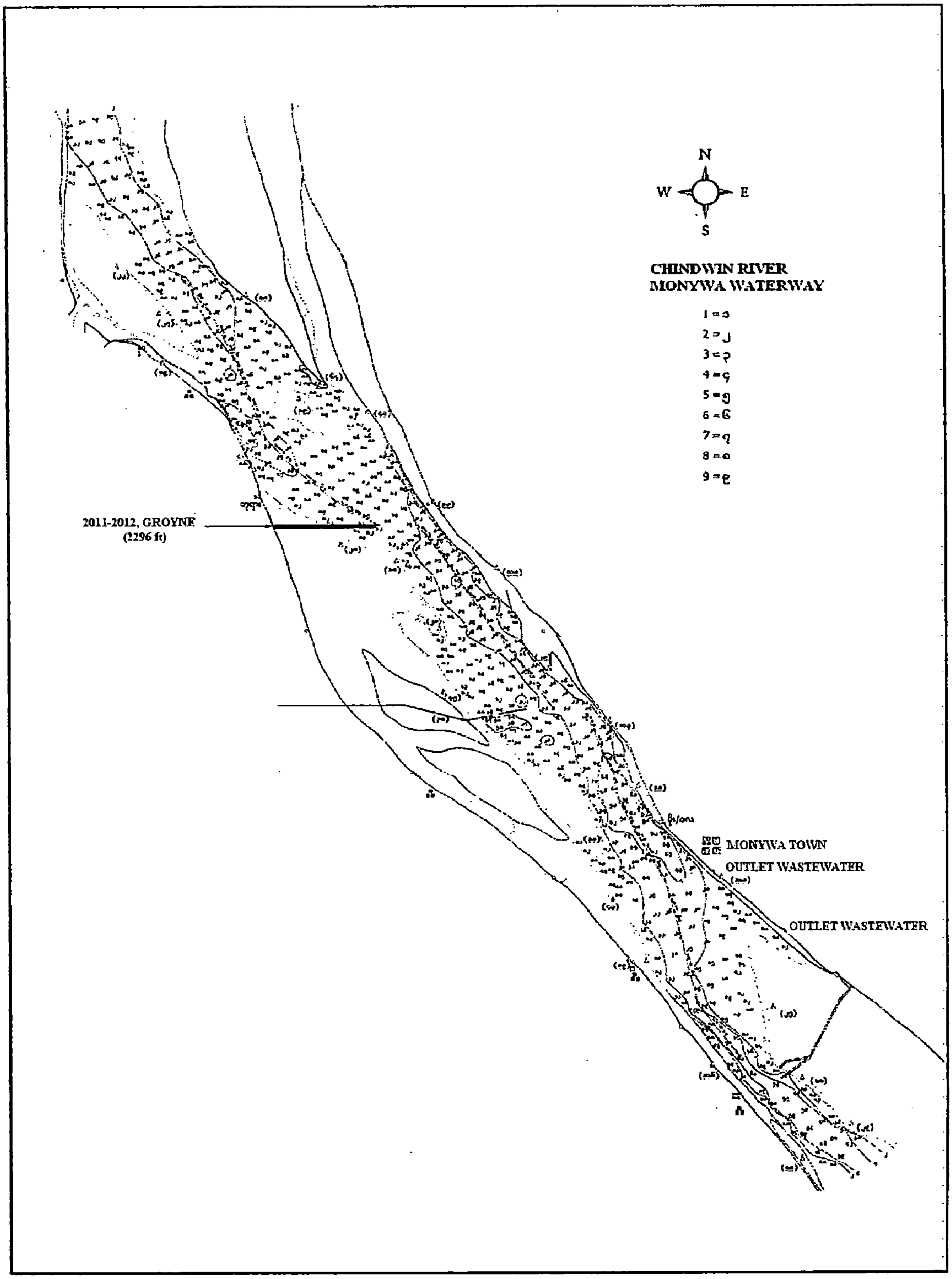


Fig 6.17 Map Of Monywa Waterway

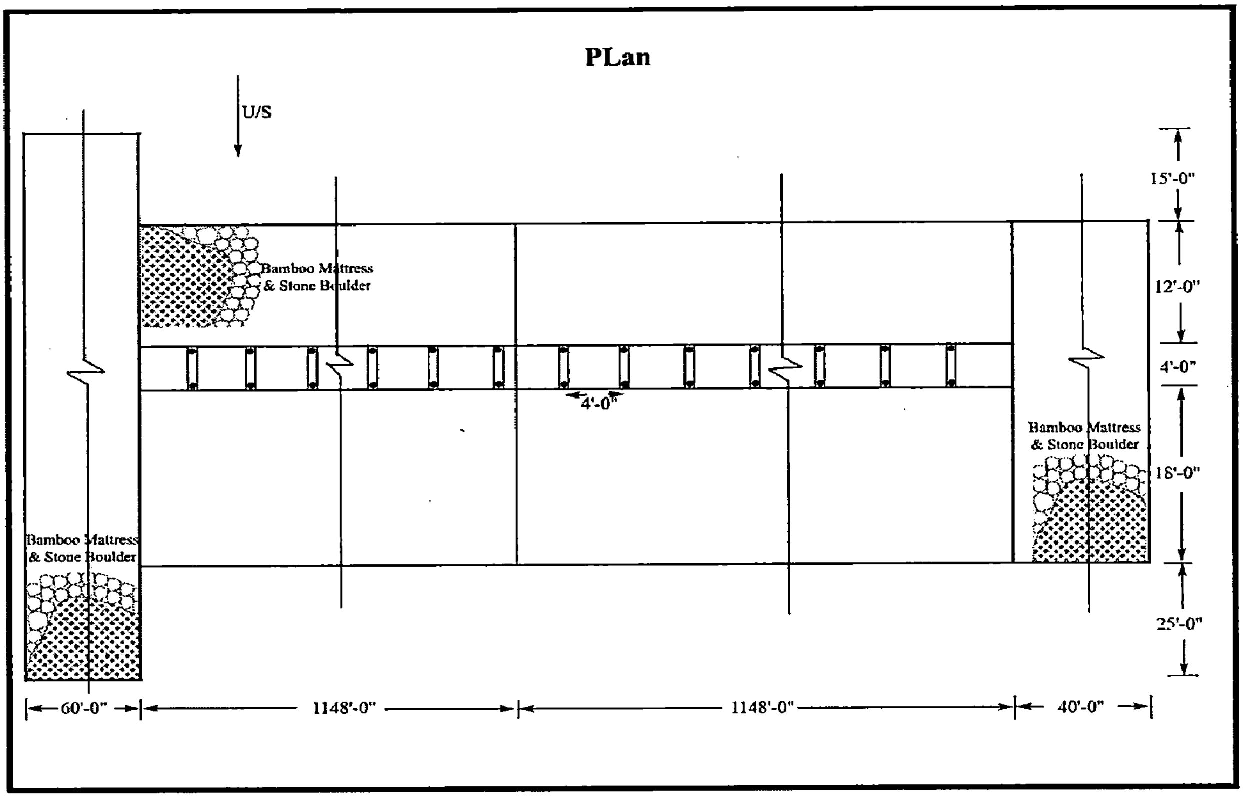


Fig 6.18 Plan View of Structure at Monwya waterway

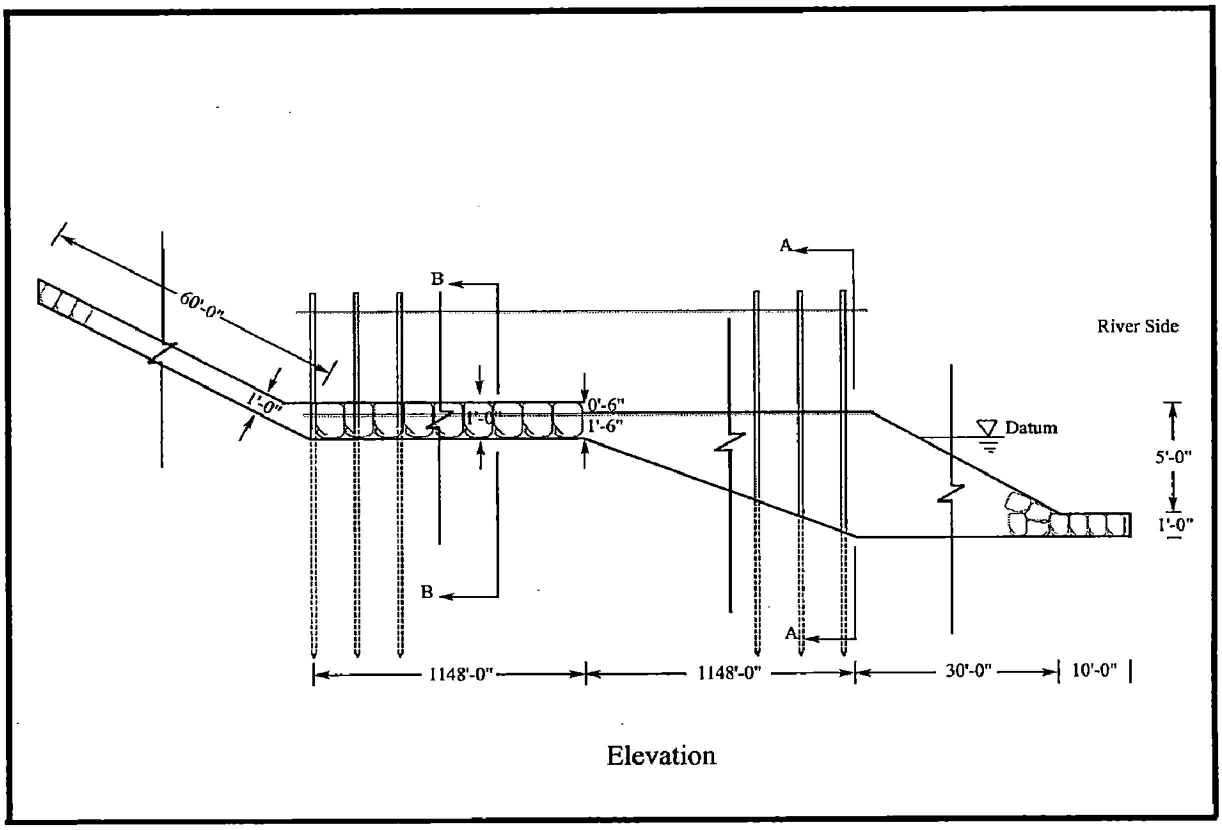


Fig 6.19 Elevation of Structure at Monwya waterway

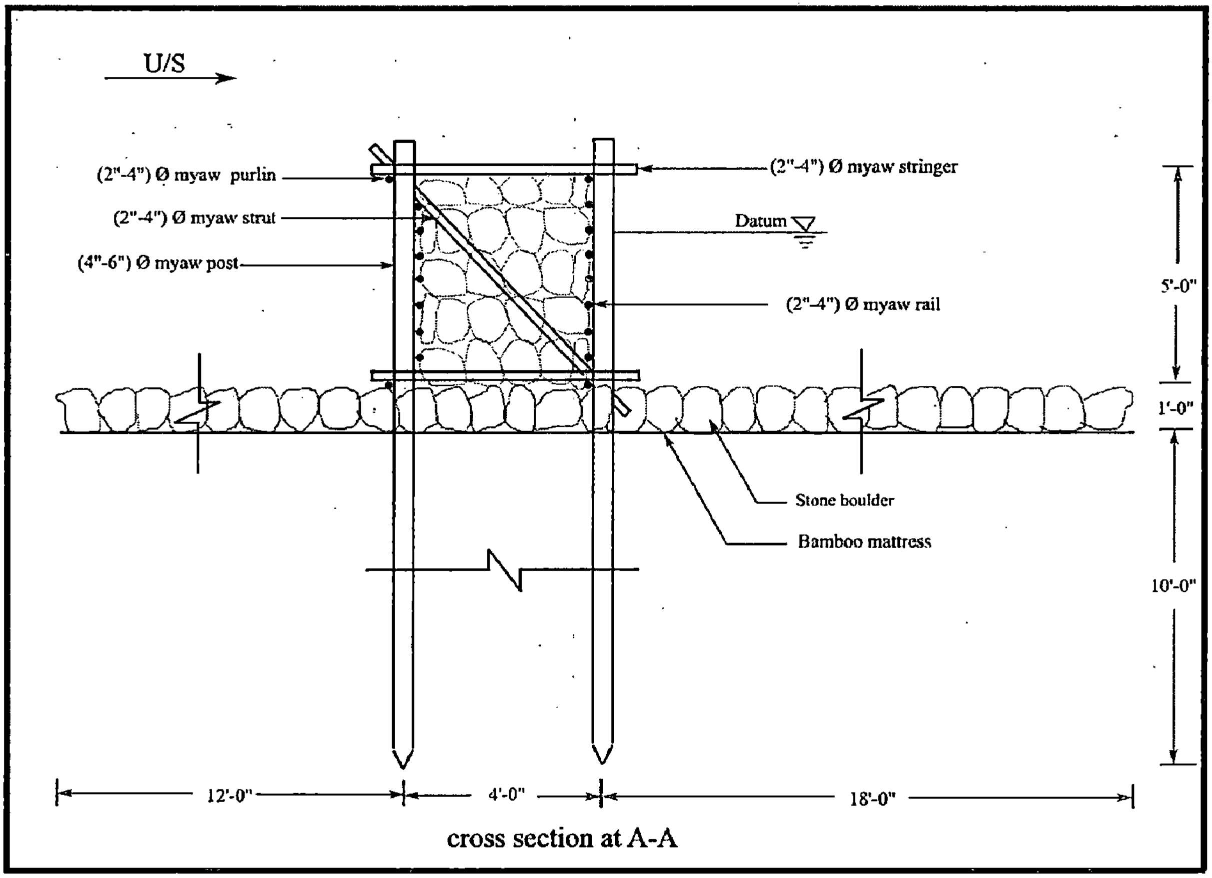


Fig 6.20 Cross-section A-A of Structure at Monywa waterway

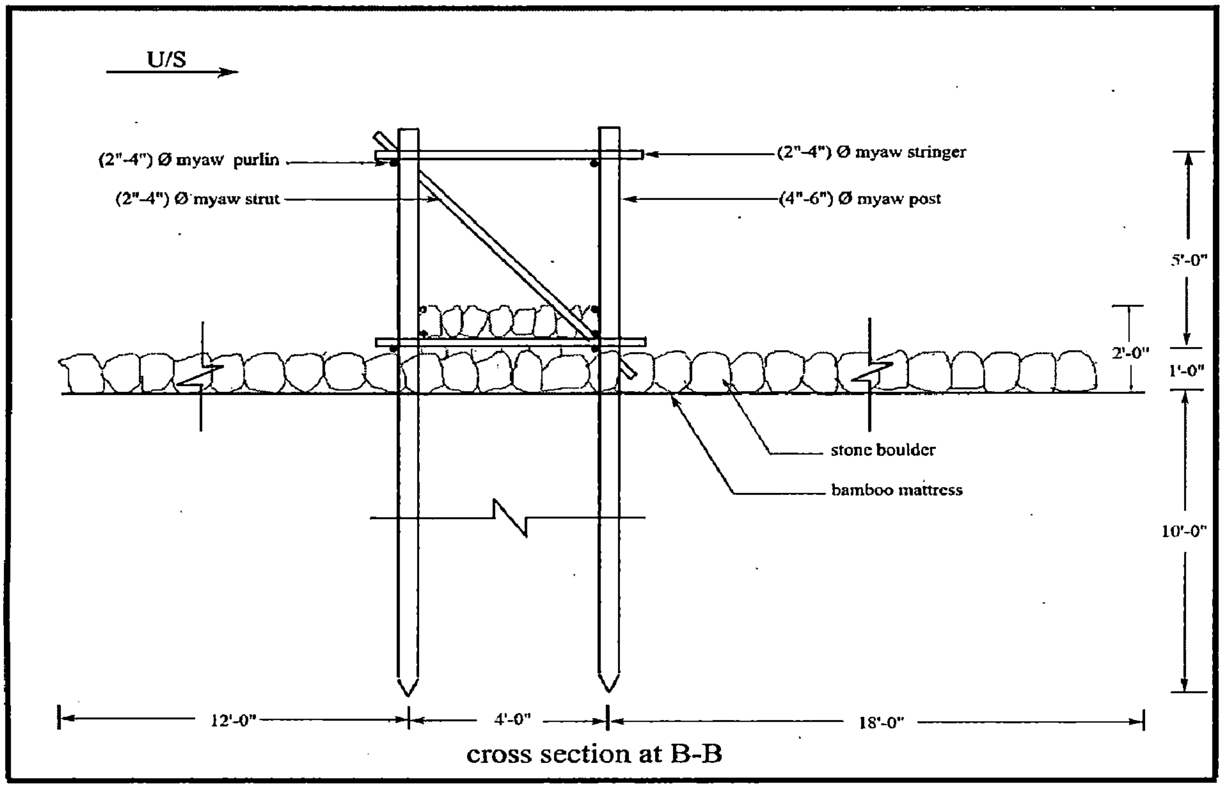


Fig 6.21 Cross-section B-B of Structure at Monywa waterway

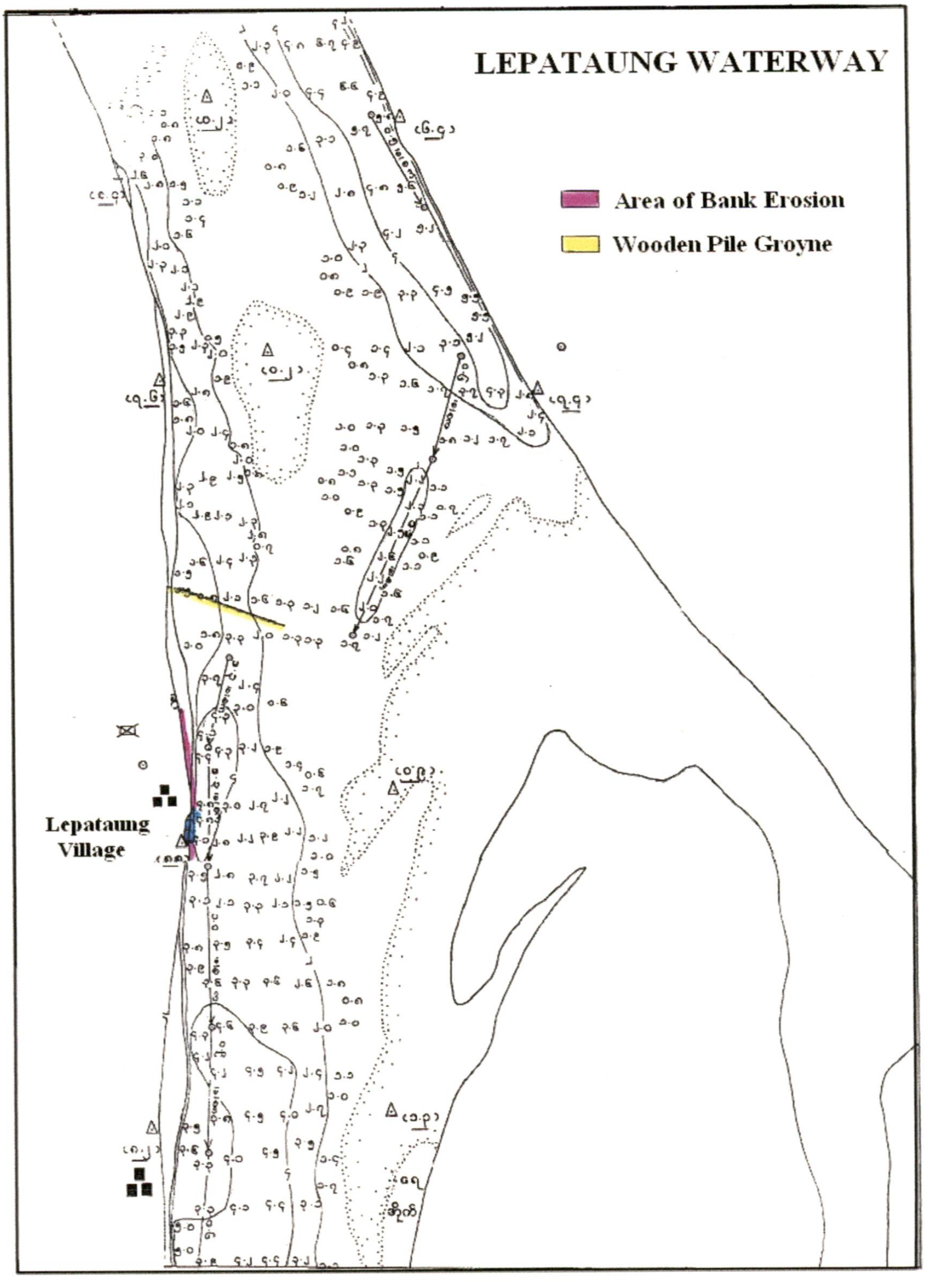


Fig 6.22 Map of Lepataung Waterway

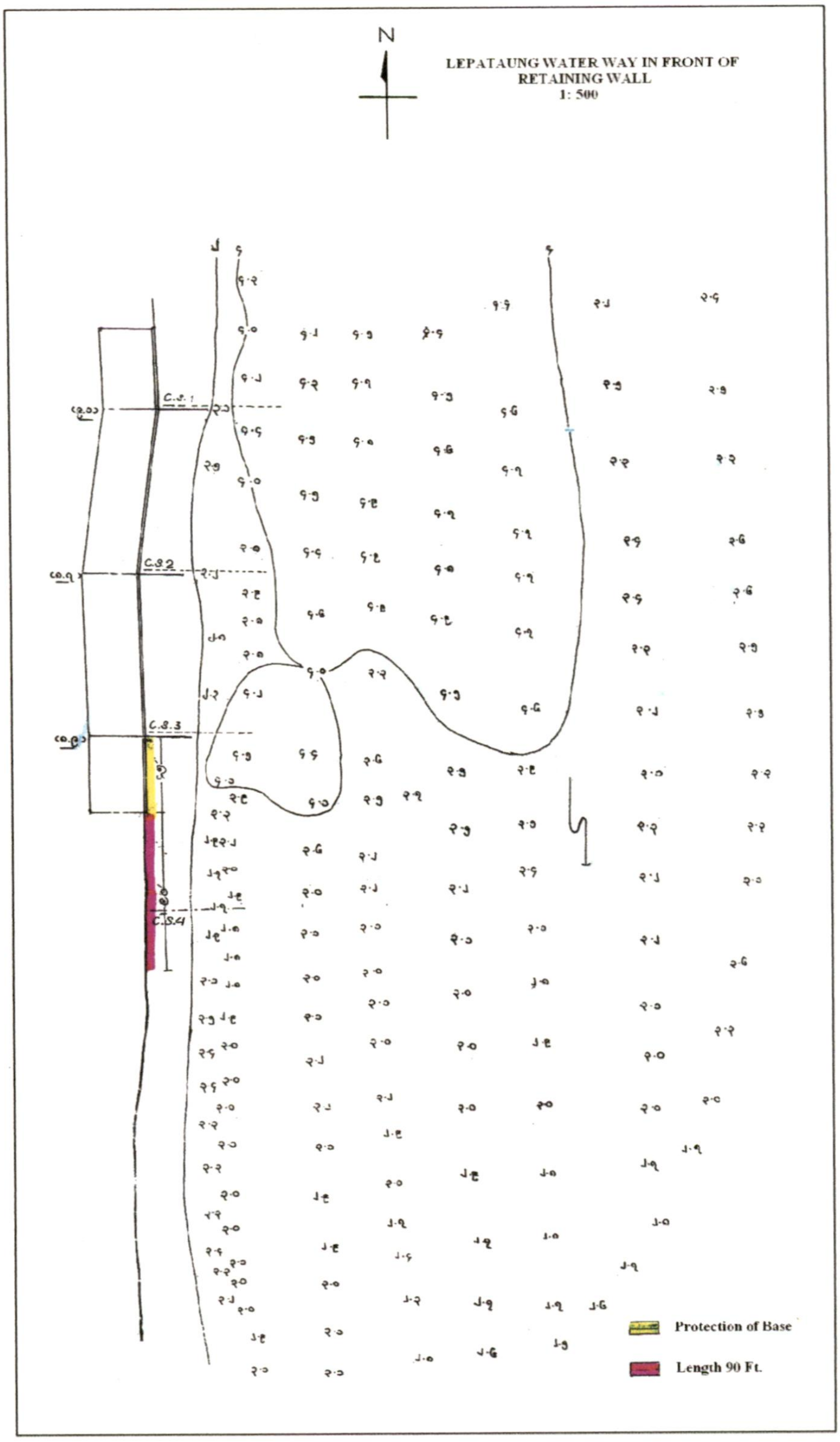


Fig 6.23 Map of Lepataung Waterway in front of Structure

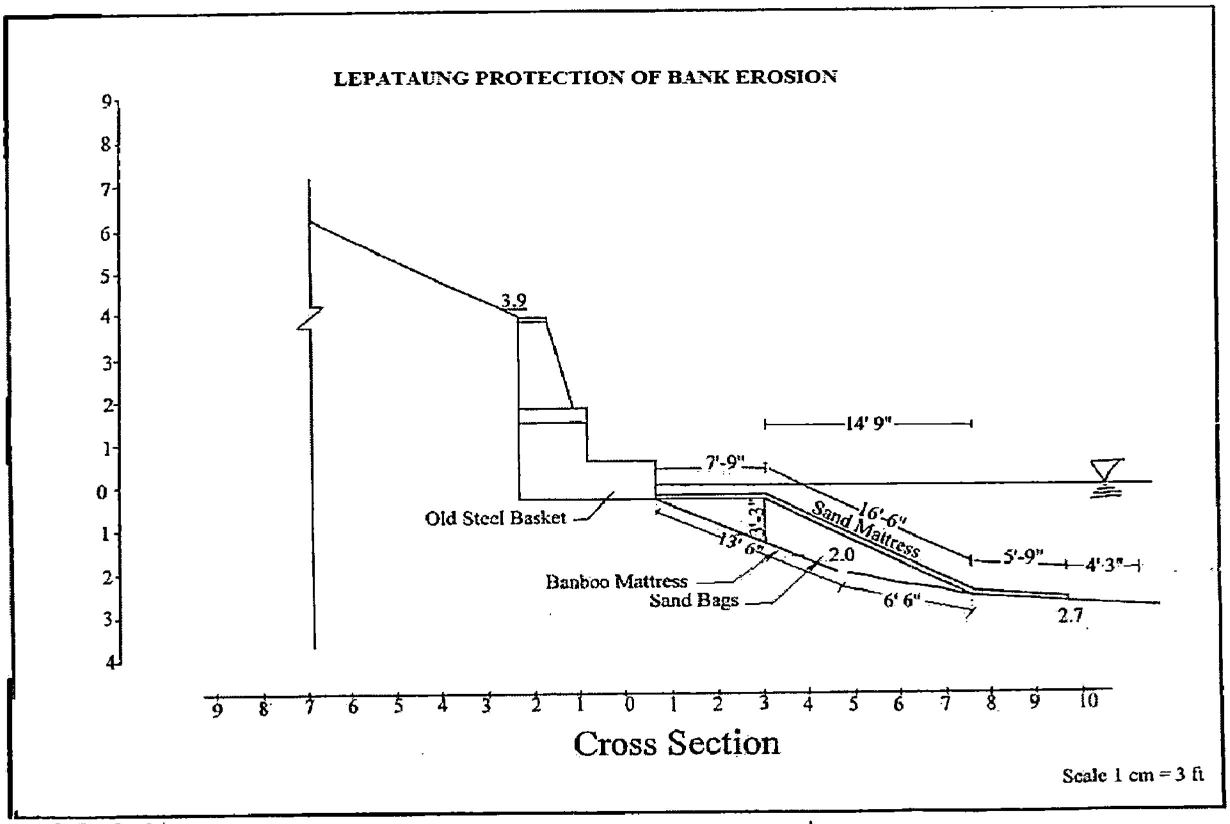


Fig 6.24 Cross-Section of in front of Structure(55ft) at Lepataung waterway

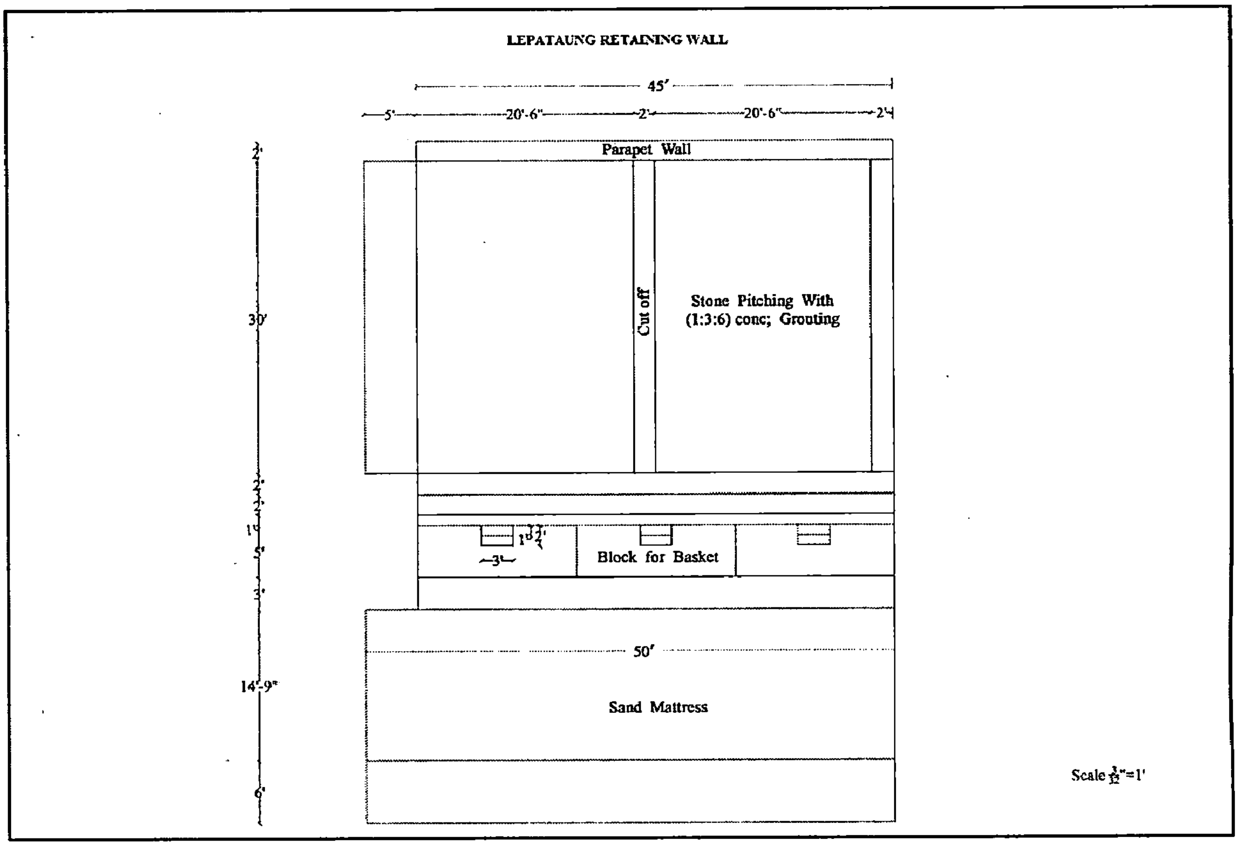


Fig 6.25 Plan View of Structure at Lepataung waterway

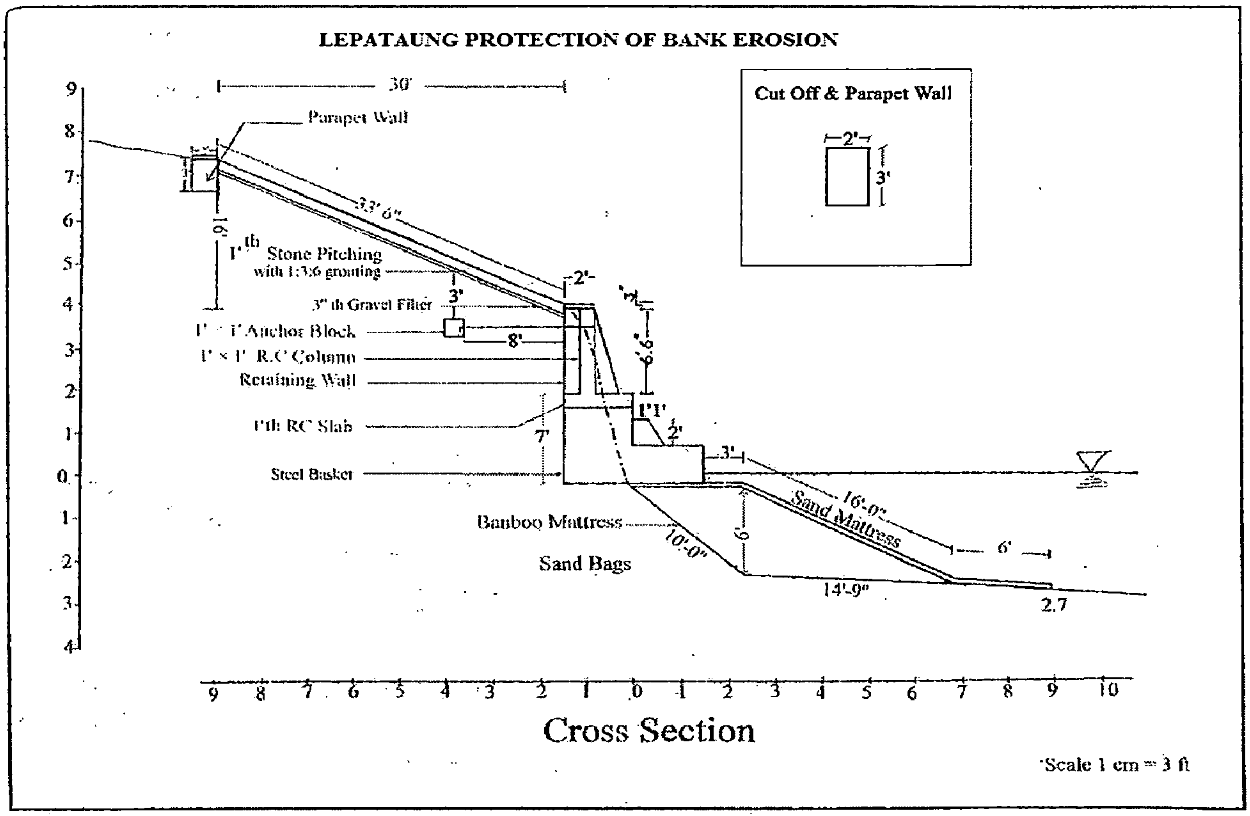


Fig 6.26 Cross-Section in front of Structure(45ft) at Lepataung waterway

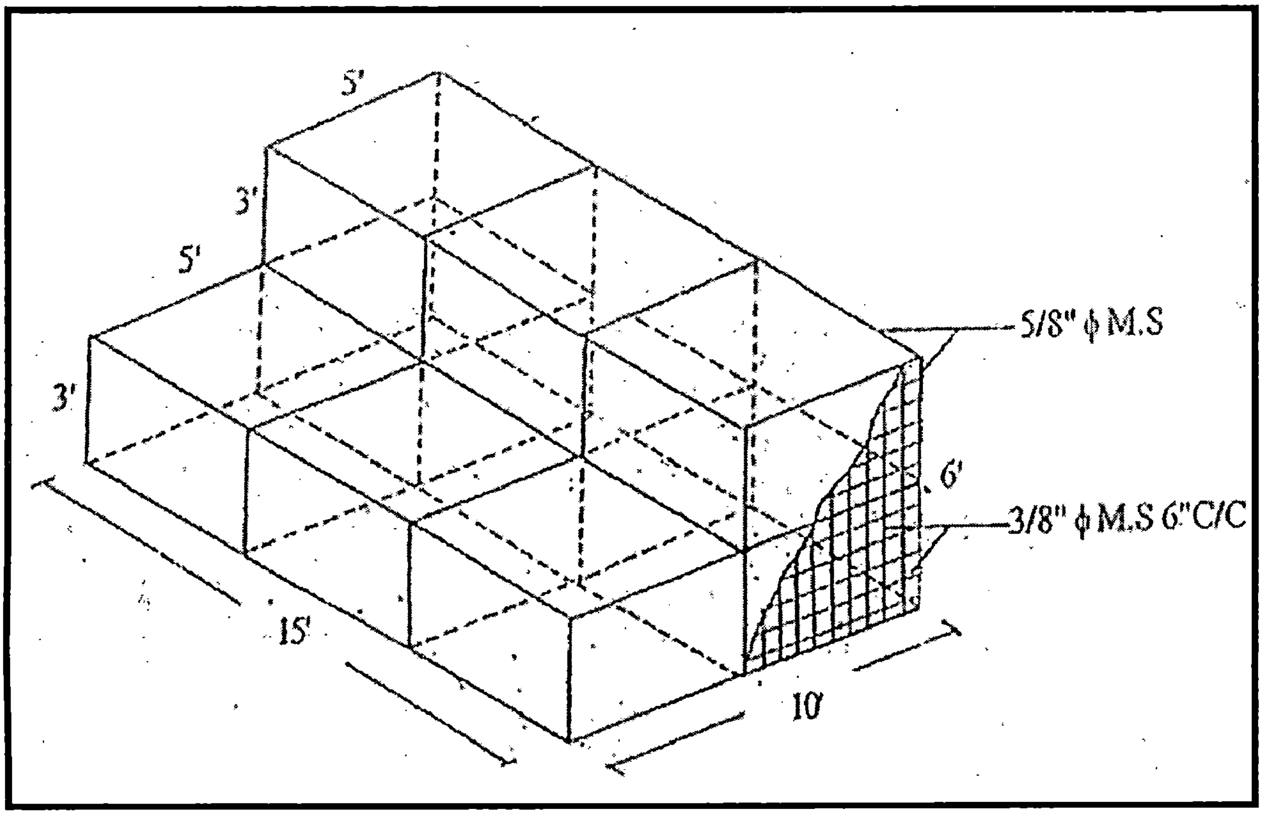


Fig.6.27 Design Of Steel Basket

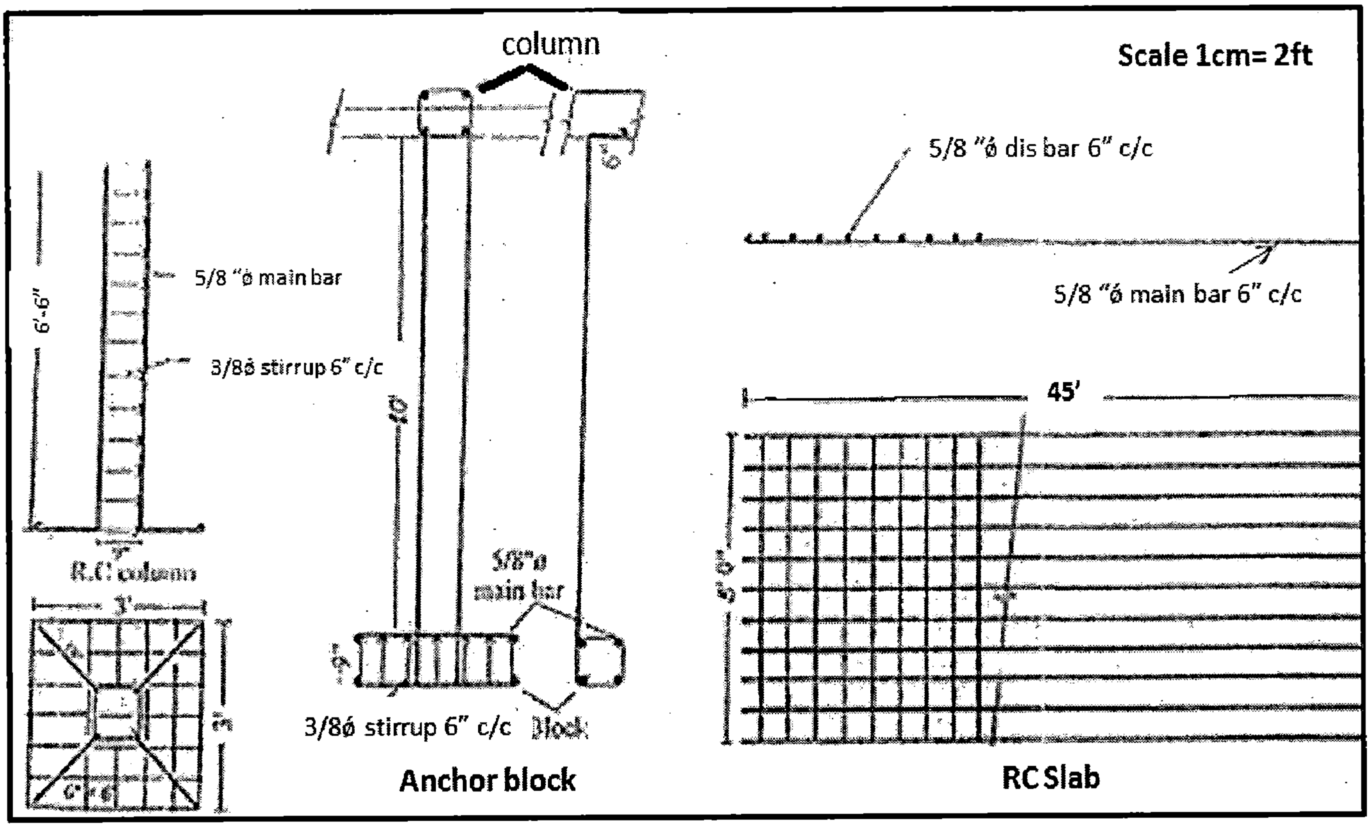


Fig 6.28 Design of Steel structures

COST ESTIMATE FOR MANAGEMENT OF THE CHINDWIN RIVER

7.1 Development of the Chindwin River: To Improve the Alone Waterway Stone Boulder Groyne with Sand Bags (250 meter)

7.1.1 Bill of Quantity (From Fig 6.10 to Fig 6.12)

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amount (KYAT)
I.	MATERIALS					
1.	Bamboo Mattress	69638	sq.ft.	150	1 sq.ft.	10445700
2.	Bamboo	2422	No.	400	1 Nos.	968800
3.	Pi Nan Bag	46893	Bag	150	1 Bag	7033950
4.	Pi Nan String	469	lb	650	1 – lb	304850
5.	Pin Bag	200	Nos.	100	1- Nos.	20000
6.	Stone Boulder (9"-12")	858.1	Sud	28500	1- Sud	24455850
7.	Cement	441	Bags	7300	1- Bag	3219300
8.	Sand	16.4	Sud	12000	1- Sud	196800
9.	Stone Chips	32.9	Sud	25000	1- Sud	822500
						47467750
II.	LABOUR COST					
1.	Head Mason	1501.2	Nos.	3000	1- Nos.	4503600
2.	Worker	5832.1	Nos.	2000	1- Nos.	11664200
						16167800
III.	TRANSPORT CHARGES					
1.	Bamboo Mattress (10000/ per Nos.)	7	Nos.	6000	1- Nos.	42000
2.	Bamboo (350 / per Nos.)	7	Nos.	6000	1 - Nos.	42000
3.	Pi Nan Bags	3	Nos.	10000	1 - Nos.	30000
4.	Cement (100 per Nos.)	4	Nos.	10000	1 - Nos.	40000
						154000
IV.	MATERIAL (UP/DOWN) COST					
1	Bamboo Mattress	69638	sq.ft.	2 × 1.5	1 sq.ft.	208914
2.	Bamboo	2422	Nos.	2 × 5	1 - Nos.	24220
3.	Pinan Bags (pack)	469	Pack	2 × 15	1- pack	14070
4.	Cement	441	Bag	2 × 60	1- Bag	52920
						300124
V.	HIRE COST					
1.	Motor Boat	45	Day	25000	1-day	1125000
						1125000
VI.	CONTINGENCES (1%)					636355
						636355
					Total	65851029
					Say	**65850000**

(Kyats 65.85 Million)

Development of the Chindwin River
To Improve the Alone Waterway
Stone Boulder Groyne with Sand Bags (250 meter)

7.1.2 Details of Measurement

S. No.	Particular	No.	Measurement L	B	H	Deduction	Content	Total of Each
1	Bamboo Mattress Work							
	- Groyne Body	1	820'	64'- 3"			52685	
	- Groyne Root	1	60'	104'			6240	
	- Groyne Head	1 × ½	(12'-6"+64'-3") × 42'- 6"				1630.9	
							60555.9	60555 sq.
2.	Groyne Body with Sand Bags Work	1 × ½	820'(6'-6" + 24') × 5'				62525	62525 cu.
3.	Stone Boulder Works							
	- Groyne Body	1 × ½	820' (6'-6"+29'-3") × 6'-6"				95273.75	
	- Deduction for Sand Bags					62525		
	- Groyne Head;							
	- Upstream Pyramid	⅓ × ½	32'- 6" × 9' – 9" × 6' – 6"				343.28	
	- Middle triangular Prism	½	32'- 6" × 6' – 6" × 6' – 6"				686.56	
	- D/S Pyramid	⅓ × ½	32'- 6" × 13'× 6' – 6"				457.7	
						62525	96761.29	34236
4.	Stone Boulder Work in Gabion							
	- U/s Gabion	1	820'	15'	1'		12300	
	- D/s Gabion	1	820'	20'	1'		16400	
	- Groyne Root	1	60'	104'	1'- 6"		9360	
	- Groyne Head	1 × ½	(12'-6"+64'-3") (42'-6") ×1				1630.9	
	- Deduction for Head	1 × ½	(6'-6" +29'-3") 32'-6" × 1			580.9		39110
5.	1 : 3 : 6 Cement Concrete Grouting in Surface Groyne work							
	- Groyne Body (11.7'+6.5'+14.5')	1	820'	32.7'	0-6"		13407	
	- Groyne Head							
	- U/s Triangle	1 × ½	11.7'	33.1'	0-6"		96.8	
	- D/s Triangle	1 × ½	14.5'	33.1'	0-6"		119.9	
	- Middle rectangular $\sqrt{(32'-6")^2+(6'-6")2}$ = 33.1	1	33.1'	6'-6"	0-6"		107.5	
							13731.2	
	25% of Volume						3432.8	3432
6	Transport Charges							
7	Material (Up/Down) Charges							
8	Hire Cost							
9	Contingencies							

7.2 Development of the Chindwin River

To Improve of Alone Waterway

Dredging Work

7.2.1 Detail of Measurement

S. No.	Particular	No.	Measurement			Deduction	Content	Total o Each
			L	B	H			
1	Dredging Work (58970) m^3	1	942	$\left(\frac{29.2+25}{2}\right)$	2.1		53609	
	10% contingencies						5360.9	
							58969.9	
						Say	58970 m^3	

Development of the Chindwin River
To Improve of Alone Waterway
Dredging Work

7.2.2 Bill of Quantity

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amount (KYAT)
I.	MATERIALS					
1.	Diesel Oil	6812	Gallon	3000	1-gallon	20436000
2.	Engine Oil	65	Gallon	10000	1-gallon	650000
3.	Hydraulic Oil	10	Gallon	14000	1-gallon	140000
4.	Black Oil	279	Gallon	1600	1-gallon	446400
						21672400
II.	HELPER BOAT FOR SUPPORTING OF MAIN BOAT					
-	Diesel Oil	196	Gallon	3000	1-gallon	588000
III.	TRANSPORT CHARGES					
-	MPPE to Monywa Office	5	Nos.	50000	1- Nos.	250000
-	Monywa Office to Site	5	Nos.	50000	1 - Nos.	250000
						500000
IV.	CONTINGENCES (1%)					239600
					Total	23000000

(Kyats 23 Million)

7.3 Development of Chindwin River: To Improve the Alone Waterway
Steel Basket Groyne with Sand Bags (315 ft.)

7.3.1 Bill of Quantity (Fig 6.10, 6.13 to Fig 6.16)

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amou (KYA
I.	**MATERIALS**					
1.	Steel ⅝"φ	1.93	Tons	820000	1-Tons	158
2.	Steel ⅜"φ	3.299	Tons	800000	1-Tons	263
3.	Binding Wire	34.8	lb	700	1-lb	2
4.	Solder Pack	20	Pack	7000	1-Pack	14
5.	Stone Boulder (9" ~ 12")	126.8	Sud	28500	1-Sud	361
6.	Cement	184.5	Bag	7300	1-Bag	134
7.	Sand	5.2	Sud	12000	1-Sud	6
8.	Stone Chips	10.3	Sud	25000	1-Sud	25
9.	Tarpaulin Clothes	1312.5	Yard	1800	1-Yd	236
10.	String For Sand Mattress	42	Viss	5000	1-Viss	21
11.	Pi Nan Bag	2835	Bag	150	1-Bag	42
12.	Pi Nan String	28.3	Ib	650	1-lb	1
13.	Pin	37	Nos.	100	1- No.	[illegible]
						1268
II.	**LABOUR COST**					
1.	Head Mason	214.2	Nos.	3000	1 - Nos.	64
2.	Steel Worker	149.4	Nos.	3000	1 - Nos.	44
3.	Special Worker	129.9	Nos.	3000	1 - Nos.	38
4.	Worker	579.3	Nos.	2500	1 - Nos.	144
5.	Helper Worker	679.4	Nos.	2000	1 - Nos.	135
						428
III.	**MATERIAL (Up/Down) CHARGES**					
1	Steel	5.229	Ton	2 × 2500	1-Ton	2
2	Cement	184.5	Bag	2 × 60	1-Bag	2
3	Pi Nan Bag Pack	28	Packs	2 × 15	1-Pack	
4	Sand Mattress	52.5	Packs	2 × 15	1-Nos.	
						5
IV.	**HIRE COST**					7
1	Motor Boat (1)	9	Day	25000	1-day	22
2	Electricity Machine	12.5	Day	25000	1-day	31
3	Solder Machine	12.5	day	15000	1-day	18
						72
V.	**TRANSPORT CHARGES**					
1.	Steel	2	Nos.	10000	1-Nos.	2
2	Cement	2	Nos.	10000	1-Nos.	2
3.	Pi Nan Bag, Tar purlin and other material	1	Nos.	10000	1-Nos.	1
						5
VI.	**CONTINGENCIES (1%)**					17
					Total	1797
					Say	1795

(Kyats 17.95 Million)

Development of Chindwin River
To Improve the Alone Waterway
Steel Basket Groyne with Sand Bags (315 ft.)

7.3.2 Details of Measurement

S. No.	Particular	No.	Measurement L	Measurement B	Measurement H	Deduction	Content	Total of Each
1	Surface Groyne with Sand Bags Works	1	315'	16'	0 – 9"		3780	3780 ft^3
2.	Steel Basket Work with $\frac{5}{8}$"ϕ Main Bar							
	- Horizontal length (Long)	6	15' – 6"				93	
	- Horizontal length (Short)	8	7' – 6"				60	
	- Vertical	10	3' – 6"				35	
							188	
	$\frac{3}{8}$"ϕ dis :bar							
	- Side 15'	2×5	15' – 6"				155	
	- Side 3'	2×27	3' – 6"				189	
	- Top 7'	2×5	7' – 6"				75	
	- Top 3'	2×12	3' – 6"				84	
	- Bottom 15'	12	15' – 6"				186	
	- Bottom 7'	27	7' – 6"				202.5	
							891.5	
	For 21 Steel Basket							
	$\frac{5}{8}$"ϕ Main Bars	3948					1.838 Tons	
	$\frac{3}{8}$"ϕ Dis : Bars	18721.5						
	Total (4.98) Tons						3.142 Tons	
3	Stone Boulder Put into the Steel Basket Work	21	15'	7'	3'		6615	6615 ft^3
4	Stone Boulder Work in Both side of Steel Basket							
	U/S	1×½	315	3	3		1417.5	
	D/S	1×½	315	4' – 6"	3		2126.25	
							3543.75	3543 ft^3
5	1:2:4 Concrete Work in Top of the Steel Basket (4")	1	315	7	0' – 4"		735	735 ft^3
6	1:3:6 Cement Concrete Grouting Work in Both sides of Stone Boulder (6")	1 1	315 315	4.24' 5.4'	0' – 6" 0' – 6"		667.8 850.5	
	25% volume of work						1518.3	379 ft^3
7	Sand Mattress Work in Both Side of Groyne (Gabion) $9450 \div 180 = 52.5$	2	315	15'			9450	52.5 Nos.
8	Transport Charges							
9	Hire Charges							
10	Materials (up/down) Charges							
11	Contingencies							

7.4 Development of the Chindwin River (Monywa Waterway)
Wooden Pile Groyne with Stone Boulder (2296 ft.)

7.4.1 Bill of Quantity (Fig 6.17 to Fig 6.21)

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amount (KYAT)
I.	**REQUIRED MATERIALS**					
1.	Wooden Pile (4" to 6")	1502	Nos.	4500	1 Nos	67590(
2.	Wooden Pile (3" to 4")	2456	Nos.	2500	1 Nos	61400(
3.	Bamboo	3354	Nos.	400	1 Nos	13416(
4.	Bamboo Mattress	96443	Sq.ft.	150	1 sq.ft.	144664:
5.	Nail	150.2	Viss	1900	1-Viss	2853!
6.	Stone Boulder (9" to 12")	1115.2	Sud	28500	1-Sud	3178320
						607756:
II.	**LABOUR COST**					
1.	Head Mason	2027.6	1 Nos	3000	1-day	60828(
2.	Blacksmith	5601.1	1 Nos	2000	1-day	1120220
3.	Wooden Pile (4" to 6") (Up /down charges)	1502	1 Nos	80	1 Nos.	1201(
4.	Wooden Pile (3" to 4") (Up/down charges)	2456	Nos.	50	1 Nos.	1228(
5.	Bamboo (Up/down)	3354	Nos.	20	1 Nos.	670!
6.	Bamboo Mattress (Up/down)	96443	Sq.ft.	1.5	1 sq.ft	1446(
7.	Stone Boulder (Up/down)	1115.2	Sud	3400	1-sud	37916!
						215313!
III.	**TRANSPORT CHARGES**					
(i)	**(Shop → Harbour)**					
1.	Wooden Pile (4" to 6") (130/per Nos.)	12	Nos.	10000	1- Nos.	1200(
2.	Wooden Pile (3" to 4") (150/ Nos)	16	Nos.	10000	1 - Nos.	1600(
3.	Bamboo Mattress (10000 sq.ft/nos)	9	Nos.	10000	1 - Nos.	900(
4.	Bamboo (250/nos)	9	Nos.	10000	1 - Nos.	900(
(ii)	**(Harbour → Site)**					
5.	Wooden Pile (4" to 6")	1502	Nos.	130	1 - Nos.	1952(
6.	Wooden Pile (3" to 4")	2456	Nos.	80	1 - Nos.	1964!
7.	Bamboo Mattress	96443	sq.ft.	2	1 sq.ft.	1928!
8.	Bamboo	3354	Nos.	30	1 - Nos.	10062
9.	Stone Boulder	1115.2	Sud	4000	1 - Sud	446080
						56060⁴
IV.	**HIRE COST**					
1	Motor Boat (1 Boat)	50	Day	25000	1 – day	125000
						125000
V.	**CONTINGENCES (2%)**					16461⁴
						16461⁴
					Total	9080920
					Say	**9080000**

(Kyats 90.8 Million)

Development of the Chindwin River (Monywa Waterway)
Wooden Pile Groyne with Stone Boulder (2296 ft.)

7.4.2 Detail of Measurement

S. No.	Particular	No.	Measurement L	Measurement B	Measurement H	Deduction	Content	Total of Each
1	Wooden Pile Post Work (2 ways)							
	Body Groyne	2	$\left[\frac{2296'}{4'}+1\right]$				1150	
	Added Wooden Pile for Protection of main Groyne	2	$\left[\frac{2296'}{15'}+1\right]$				308	
							1458	1458 Nos.
2.	Wooden Pile Strut Work							
	Longitudinal	2 × 2	2296'				9184	
	Cross	2	$\left[\frac{2296'}{4'}+1\right]\times 5'-6"$				6325	
	Strut	1	$\left[\frac{2296'}{4'}+1\right]\times 7'-0$				4025	
	To Fill Stone Boulder (in water)	2 × 7	1148				16072	
	To Fill Stone Boulder (on land)	2 × 2	1148				4592	
							40198	40198 Ft.
	Nail (Groyne)	10	$\left[\frac{2296'}{4'}+1\right]\times\frac{1}{80}\times 1.1$				79	
	Nail (To Fill Stone) (in water)	2 × 7	$\left[\frac{1148'}{4'}+1\right]\times\frac{1}{80}\times 1.1$				55.4	
	(on land)	2 × 2	$\left[\frac{1148'}{4'}+1\right]\times\frac{1}{80}\times 1.1$				15.8	
							150.2	150.2 viss
3	Bamboo Mattress Work							
	Body Groyne	1	2296'	34'			78064	
	Groyne Root	1	60'	74'			4440	
	Groyne Head	1	40'	34'			1360	
							83864	83864 sq.ft.
4	Stone Boulder Work							
	Body Groyne							
	- On Land	1	1148'	4'-0"	2'-0"		9184	
	- In Water	½	1148'	4'	(1'-6"+6'-0")		17220	
	Gabion	1	(2296+40')	30'	1'-0		70080	
	Groyne Head	½	30'	4'-0	(6'+1')		420	
	Groyne Head Gabion	1	10'-0	4'-0	1'-0		40	
	Groyne Root	1	60'-0	74'-0	1'-0		4440	
							101384	101384 ft^3
5	Material (up/down) charge							
6	Transport Charges							
7	Hire Charges							
8	Contingencies							

7.5 Protection for Lepataung Village Bank Erosion in Front of Steel Basket Retaining Wall (55 ft)

7.5.1 Bill of Quantity (Fig 6.22 to Fig 6.24)

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amount (KYAT)
I.	**MATERIALS**					
1.	Bamboo Mattress	2071	sq.ft.	150	1sq.ft.	31065
2.	Bamboo	72	Nos.	400	1 Nos.	2880
3.	Pi Nan Bag	1507	Bag	150	1 Bag	22605
4.	Pi Nan String	15	lb	650	1- lb	975
5.	Pin	20	Nos.	100	1 - Nos.	200
6.	Tarpaulin Clothes	225	Yard	1800	1-Yd	40500
7.	String for Sand Mattress	7.2	Viss	5000	1-Viss	3600
						101825
II.	**LABOUR COST**					
1.	Special Worker	18	Nos.	3000	1 - Nos.	5400
2.	Worker	72	Nos.	2500	1 - Nos.	18000
3.	Helper Worker	115.4	Nos.	2000	1 - Nos.	23080
						46480
III.	**HIRE COST**					
1.	Motor Boat (1)	5	Day	25000	1-day	12500
IV.	**CONTINGENCIES (5%)**					7415
	Transport + Up/down					
					Total	**168220**
					Say	1680000

(Kyats 1.68 Million)

Protection for Lepataung Village Bank Erosion
In Front of Steel Basket Retaining Wall (55 ft.)

7.5.2 Details of Measurement

S. No.	Particular	No.	Measurement			Deduction	Content	Tc I
			L	B	H			
1	Base Bamboo Mattress Work	1	55'	32 - 9"			1801.25	18
2.	Base level adjust with sand bags							
	Portion (1)	$1\times\frac{1}{2}$	55'	3'– 3"	7' – 9"		692.6	
	Portion (2)	$1\times\frac{1}{2}$	55'	3'– 3"	14' – 9"		1318.2	
3.	Sand Mattress Work above Sand Bag Surface $1650\div(15'\times12')=9.1$	1	55'	30'–0			1650	16
4.	Hire Cost							
5.	Contingencies							

7.6 Protection for Lepataung Village Bank Erosion

Retaining Wall Base with Steel Basket (45') ft

7.6.1 Bill of Quantity (Fig 6.25 to Fig 6.28)

S. No.	Particular	Quantity	Unit	Rate (KYAT)	Per	Amount (KYAT)
I.	**MATERIALS**					
1.	Cement	205	Bag	7300	1 Bag	14965
2.	Stone Boulder (9"~12")	64.9	Sud	25000	1 sud	16225
3.	Sand	6.9	Sud	12000	1 sud	828
4.	Stone Chips	8.75	Sud	25000	1 sud	2187
5.	Binding Wire	21.3	lb	750	1- lb	159
6.	Wooden	34.35	ft^3	8000	1-ft^3	2748
7.	Nail	8.4	lb	700	1-lb	58
8.	Solder Pack	4.8	Pack	7000	1 Pack	336
9.	Steel $\frac{5}{8}$"ϕ	1.063	Ton	820000	1 Ton	8716
10.	Steel $\frac{3}{8}$"ϕ	0.8795	Ton	800000	1 Ton	7036
11.	Tarpaulin Clothes	200	Yard	1800	1 Yd	3600
12.	String	6.4	Viss	5000	1 Viss	320
13.	Bamboo Mattress	1796	sq.ft.	150	1 sq.ft	2694
14.	Bamboo	62	Nos	400	1- Nos.	248
15.	Pi Nan Bag	2559	Bag	150	1 Bag	3838
16.	Pi Nan String	25.5	lb	650	1- lb	165
17.	Pin	34	Nos	100	1- Nos.	34
						641609
II.	**LABOUR COST**					
1.	Head Mason	218.8	Nos.	3000	1- Nos.	6564
2.	Carpenter	11	Nos.	3000	1- Nos.	330
3.	Steel Worker	45.5	Nos.	3000	1- Nos.	1365
4.	Solder Worker	6	Nos.	3000	1- Nos.	180
5.	Special Worker	19	Nos.	3000	1- Nos.	570
6.	Worker	102.4	Nos.	2500	1- Nos.	2560
7.	Helper Worker	540.2	Nos.	2000	1- Nos.	10804
						22373
III.	**HIRE COST**					
1.	Electricity Machine	3	Day	25000	1- day	750
2.	Solder Machine	3	Day	15000	1- day	450
						1200
IV.	**TRANSPORT CHARGES**					
1	Steel	1	Nos.	31500	1-Nos.	315
2.	Cement	205	Bag	390	1-Bag	799
3.	Tarpualin Clothes and other Materials	1	Nos.	25000	1-Nos.	250
						1364
V.	**MATERIAL (UP/DOWN) CHARGE**					
1	Steel (shop→Harbour →Site)	1.9425	Ton	3×2500	1-Ton	145
2.	Cement	205	Bag	2×100	1-Bag	410
						555
VI.	**CONTINGENCIES (1%)**					865
					Total	90519
					Say	**90500**

(Kyats 9.05 Million)

Protection for Leptaung Village Bank Erosion
Retaining Wall Base with Steel Basket (45') ft

7.6.2 Details of Measurement

S. No.	Particular	No.	Measurement L	Measurement B	Measurement H	Deduction	Content	Total Eac
			L	B	H			
1	Base Bamboo Mattress Work	1	50	31' – 3"			1526.5	1562..
2.	Base Level adjust with sand Bags							
	Portion (1)	1 × ½	50'	6' – 0	8' – 0		1200	
	Portion (1)	1 × ½	50'	6' – 0	14' – 9		2215.5	341
3	Sand Mattress Work above the Surface of Sand Bags	1	48	30' – 0			1440	1440
4	Steel Basket Work							
	⅝"ϕ (H, long)	8	15' – 6"				124	
	⅝"ϕ (H, Cross)	8	10' – 6"				84	
	⅝"ϕ (H, cross)	4	5' – 6"				22	
	⅝"ϕ (U, 2 step)	8	6' – 6"				52	
	⅝"ϕ (U, 1 step)	4	3' – 6"				14	
							296	2
	For (3) Baskets (0.413 Tons)	3	296				888	8
	⅜"ϕ (H, long)	18+20	15' – 6"				589	
	⅜"ϕ (H, Cross)	10+27	10' – 6"				388.5	
	⅜"ϕ (H, Cross)	10	5' – 6"				55	
	⅜"ϕ (V, 2 Step)	9×5	6' – 6"				292.5	
	⅜"ϕ (V, 1 Step)	9×8	3' – 6"				252	
							1577	1
	For (3) Steel Baskets (0.79 Tons)	3	1577				4731	4
5	Earth Excavation Work							
	- Base Steel Basket	1	45'	½' × 5'	13' – 6"		1518.75	
	- Anchor Line	4	8'	$\frac{3.5'+1'}{2}$	1'		72	
	- Anchor Block	4	3'	1'	4'		48	
	- Parapet Wall	1	45'	2'	3'		270	
		1	41'	1' – 3"	33' – 6"		1716.875	
	- Cut-Off Line	2	2'	33' – 6"	3'		402	
							4027.6	402
6	Stone Boulder Work (3) Steel Basket							
	1st Step	1×3	15'	10'	3'		1350	
	2nd Step	1×3	15'	5'	3'		675	
							2025	20
7	1:2:4 R.C For Form Work							
	Slab (L)	1×2	45'	1' – 0"			90	
	Slab (B)	1×2	5'	1' – 0			10	
	Column	4×4	1'	6' – 6"			104	
							204	20

S. No.	Particular	No.	Measurement L	B	H	Deduction	Content	Total of Each
8	Steel work for 1:2:4 RC							
	- Slab (L) $\frac{5}{8}"\phi$	11	45' – 6"				500.5	
	- Slab (B) $\frac{5}{8}"\phi$	91	5' – 6"				500.5	
	Column							
	- $\frac{5}{8}"\phi$ Main Bar	4×4	(6' – 6" + 1' – 6"+6")				136	
	- $\frac{3}{8}"\phi$ Stirrup Bar	4×13	(36" + 6")				182	
	Anchor Line $\frac{5}{8}"\phi$	4×2	(10' – 9" + 6" + 6")				94	
	Anchor Block $\frac{5}{8}"\phi$	4×4	(3' + 3" + 3")				56	
	Anchor Block Stirrup $\frac{3}{8}"\phi$ $\frac{5}{8}"\phi$ =1287' (0.6 tons) $\frac{3}{8}"\phi$ = 280 (0.047 tons) Total = 0.647 Tons	4×7	(36" + 3" + 3")				98	
9.	1:2:4 RC Concrete Work							
	Slab	1	45'	5'	1'		225	
	Column	4	1'	1'	6' – 6"		26	
	Anchor Block	4	3'	1'	1'		12	
							263	263 ft
10.	Stone Boulder Work for 1:3 Cement Motor							
	- Retaining Wall	1	45'	$\frac{4'+2'}{2}$	6' – 6"		877.5	
	- Deduction for column	4	1'	1'	6' – 6"	26		
	- Cut Off Line	2	33' – 6"	2'	3'		402	
	- Parapet Wall	1	45'	2'	3'		270	
	- Steel Block for Supporting Steel Basket	3	$\frac{1'+2'}{2}$	3'	2'		27	
						26	1576.5	1550.5 ft
11.	Form Work for 1:3:6 CC Topping							
	- Retaining Wall	1×2	47'		0' – 3"		23.5	
	- Parapet Wall	1×2	47'		0' – 3"		23.5	
	- Cut Off Wall	2×2	33' – 6"		0' – 3"		33.5	
							80.5	80.5 sq.ft
12.	1:3:6 Topping Work							
	- Retaining Wall	1	45'	2'	0' – 3"		22.5	
	- Parapet Wall	1	45'	2'	0' – 3"		22.5	
	- Cut Off Wall	1×2	33' – 6"	2'	0' – 3"		33.5	
							78.5	78.5 ft
13.	Stone Chip Woke above Surface of Retaining Wall for Protection of Water	1	41	33' – 6"	0' – 3"		34.3.375	343.375 ft
14.	Stone Boulder Work above Surface of							
	- Retaining Wall	1	45'	33' – 6"	1'		1507.5	
	- Deduction for Cut Off	1×2	2'	33' – 6"	1'	134		

S. No.	Particular	No.	Measurement			Deduction	Content	Total of Each
			L	B	H			
								1373.5
15.	1:3:6 Grouting Work							
		1	41'	33' – 6"	0 – 6"		686.75	
	25% of vol ≈ 171.7 ft^3							171.7
16.	Stone Boulder Work in Gabion	1	5'	33' – 6"	2'		335	
								335
17.	Transport Charges							
18.	Hire Charges							
19.	Materials (up/down) Charges							
20.	Contingencies							

FINALIZATION OF ENVIRONMENT MANAGEMENT OF CHINDWIN RIVER

8.1 DIRECTORATEOF WATER RESOURCES AND IMPROVEMENT OF RIVER SYSTEMS (DWIR)

Waterways Department (WD) was established on Oct 1st, 1972 under the Ministry of Transport and Communications. The responsibility is to identify, mark, maintain and improve the navigation channel of major rivers of Myanmar. In 1999, WD is reorganized to Directorate of Water Resources and Improvement of River Systems with the following **objectives**.

(1) To improve the navigation channel and to stabilize the inland water ports.

(2) To protect the bank erosion of rivers.

(3) To cooperate with each other is demarcation of danger water level.

(4) To utilize the river waters for domestic and agriculture for all year round.

(5) To protect border rivers.

(6) To observe the long-term existence of cross river bridges by the river engineering points of views.

(7) To manage the prevention of river water pollution.

(8) To achieve adequate depths for maximum loading capacity of the vessels.

It reveals that major responsibility of DWIR is for the infrastructure development of Inland water transport and river water resources of the country. DWIR undertakes its objectives not only direct support activities such as river training works, dredging works, and navigation aids operation but also by draught restrictions issues for the navigable waterways.

8.1.1 FUNCTIONS OFDWIR

8.1.1.1 Hydrographic Survey Section

- Channel surveying and mapping
- Surveying and technical suggestions for waterways of the cross river bridges
- To provide technical suggestions from river engineering points of views at construction of cross river bridges.

8.1.1.2 River Engineering Section

□ Construction of river training structures to achieve adequate water depth

□ River bank protections

□ River training and bank stabilization for the long term existence of the cross river bridges.

□ Bank protection of Border Rivers.

□ To utilize the river water for agriculture all the year round.

8.1.1.3 Dredging Section

□ Dredging in river constraints

□ Bend cutting for improvement of waterways and erosion protection

□ Dredging to improve approach channel for pump irrigation

□ Dredging for new navigation channel

8.1.1.4 Navigation Section

□ Provision of navigation aids.

□ Promulgation of navigation warning

□ Snag removing

□ Monitoring and marking of approach channels for the cross river bridges according to seasonal changes.

□ Administration of Twantay canal navigation.

8.1.1.5 Hydrological Research and Planning Department

□ Establish the data banks to support the river training works.

□ Forecast the Least Available Depth along the inland rivers

□ Execute research works for the river training projects.

□ Monitor the environmental impact by the changes of water quantity and quality

□ Develop the yearly, monthly and daily water level hydrographic envelopes

8.1.2 River Training Work

Since 1972, DWIR involves river training works in major navigable rivers. To improve the rivers in term of Least Available Depth, DWIR uses the types of structures which are inexpensive in cost, workable in local conditions with local material and labors, and satisfactory in effectiveness.

Different types of river protection structures mentioned below are investigated for Master Plan.

- Rock groynes
- Wooden pile groynes
- Steel cable groynes
- Sand fill dams
- Protective mattresses with vegetation
- weirs
- multi-purpose dam

For engineering reasons, those structures considered as suitable for the master plan are listed below

- Rock groynes

- Wooden pile groynes
- Steel cable groynes

8.2 "CONSERVATION OF WATER RESOURCES AND RIVER LAW" IN MYANMAR

8.2.1 Duties of the Directorate

The duties of the Directorate are as follows:

(a) Carrying out so as not to cause moving of urban ports and to keep the waterways good and for perpetual use;

(b) Making arrangements and carrying out to prevent erosion of towns and villages due to changes of river and creek course;

(c) Making arrangements and carrying out so as not to adversely affect the environment in and, around river and creek;

(d) Determining dangerous water levels for towns; in so determining, cooperating with relevant government departments and organizations;

(e) Giving necessary assistance to the relevant government departments and organizations when co-coordinating to utilize river water as drinking water, for domestic use and for agricultural use the whole year round;

(f) Protecting and maintaining the waterways of border rivers so as not to lose State-owned land, and making arrangements thereof;

(g) Submitting report to the Ministry of Transport with recommendations after surveying and inspecting the waterways of river and creek for long term durability of bridges spanning rivers;

(h) Prescribing terms and conditions to prevent water pollution, and supervising thereof;

(i) Carrying out to deepen river courses and to increase cargo tonnage of vessels;

(j) Carrying out works of technology related to hydro-technology, dredging and disposal of waste, required in the rivers to prevent silting up of rivers and creeks;

(k) Removing and clearing objects obstructing watercourse of rivers and creeks;

(1) Removing vessels berthed, anchored, grounded or sunken causing obstruction or danger to plying vessels at urban and rural ports and narrow rivers-creeks and waterways;

(m) prohibiting anchorage of vessels at sites where there are underwater electric power cable connection, telecom cable connection, gas pipeline, water pipeline or underwater tunnel, and removing vessels anchored within the distance prohibited;

(n) Collecting navigation pilot charge, harboring charge and other charges and fees relating to conservation of rivers and creeks;

(o) Carrying out other functions and duties assigned by the Ministry;

(p) Submitting a report on performance of its duties to the Ministry.

8.2.2 The Powers of the Directorate are as follows:

(a) granting permission after examining the application for permission to carry out the construction of switchback, dockyard, wet dockyard and water-tight dockyard, building of jetty and landing stage and vessel landing by drainage in the river-creek boundary, bank boundary and waterfront boundary:

(b) permitting, after scrutiny, to pile sand, shingle and other heavy substances within the bank boundary and waterfront boundary;

(c) issuing recommendation to the relevant government department and organization in respect of application for construction of buildings and bridges in the river-creek boundary, bank boundary and waterfront boundary;

(d) determining of waterway grade, issuing information on opening and closing of waterway and warning on the use of waterway from time to time;

(e) determining the size of vessel and number of barges to ply along each waterway, and determining of draught:

(f) choosing site in the river for the inland vessels to dock, demarcating of port boundary, and opening and closing thereof;

(g) issuing recommendation to the relevant government department and organization after scrutiny as to whether or not the waterways of the rivers-creeks can be affected adversely, on the application to grant permit for business of sand suction, sand dredging, sand excavating, rivers shingle suction, panning for gold, gold mineral dredging or extracting resources in river-creek boundary, bank boundary and waterfront boundary;

(h) issuing notifications prescribing terms and conditions in accordance with the guidance of the Ministry in respect of the navigation of vessels in rivers and creeks for conservation of water resources, rivers and creeks.

7. The Directorate may, if necessary, delegate its functions and duties to the State or Divisional Offices, Sub-State or Sub-Divisional Offices and Sub-Regional Offices subordinate to it.

8.2.3 PROHIBITIONS

8. No person shall:
   (a) Carry out any act or channel shifting with the aim to ruin the water resources and rivers and creeks.
   (b) cause the wastage of water resource wilfully.

9. No person shall destroy, cause damage or cause collision of vessel with the river training structure either wholly or partly.

10. No person shall anchor the vessels where vessels are prohibited from anchoring in the rivers and creeks.

11. No person shall:
   (a) dispose of engine oil, chemical, poisonous material and other materials which may cause environmental damage, or dispose of explosives from the bank or from a vessel which is plying, vessel which has berthed, anchored, stranded or sunk.
   (b) catch aquatic creatures within river-creek boundary, bank boundary or waterfront boundary with poisonous materials or explosive.
   (c) dispose of disposal soil and other materials from panning for gold, gold mineral dredging or resource production in the river and creek, into the river and creek or into the water outlet gully which can flow into the river and creek.

12. No person shall carry out growing of garden, digging, filling, silt trapping, closing pond, dyke building or erecting spur in the river-creek boundary, bank boundary and waterfront boundary without the permission of the relevant government department and organization.

13. No person shall carry out sand suction, sand dredging, sand excavating, river shingle suction, panning for gold, gold material dredging or resource production for commercial purpose in the river-creek boundary, bank boundary and waterfront boundary without the recommendation of the Directorate.

14. No person shall carry out sand suction, sand dredging, sand excavating, river shingle suction, panning for gold, gold mineral dredging or resource production from the sandbank maintained for prescribed river training work, prohibited place in the river and creek or the watercourse.

15. No person shall carry out the construction of switchback, dockyard, wet dockyard, water-tight dockyard, building of jetty, pier, landing stage or vessel landing by drainage in the river-creek boundary, bank boundary and waterfront boundary without the permission of the Directorate.

16. No one shall:

(a) ply a vessel which is not in conformity with stipulations regarding the size, horse power and number of flat in the river-creek.

(b) ply a vessel which is not in conformity with the prescribed draught in the river-creek.

17. No one shall, without abiding by the signal for the vessels to halt and wait by the responsible person as river training work, surveying work, dredging work, navigation work or obstruction clearance work is being carried out, ply the vessel passing through.

18. No one shall drive loading goods above the loaded draught or ply outside the demarcation channel.

19. No one shall dispose of any substance into the river-creek that may cause damage to waterway or change of watercourse from the bank or vessel which is plying, vessel which has berthed, anchored, stranded or sunk.

20. No one shall:

(a) cast the fishing net, lay net, drift net, set up net which may cause silting or blocking of the watercourse in river-creek.

(b) cause collision of the vessel with piles of bridges spanning the river.

21. No one shall:

(a) build lavatories unsuitable to the urban and rural community lifestyle in the bank area and waterfront area.

(b) drill well or pond or dig earth without the permission of the Directorate.

22. No one shall, without the permission of the directorate, pile sand, shingle and other heavy materials for business purposes in the bank area and waterfront area.

23. No one shall:

(a) without the permission of the Ministry of Transport, salvage the sunken vessel for business purposes.

(b) without the permission of Directorate build structures and bridges in river-creek boundary, bank boundary and waterfront boundary.

(c) destroy or cause to destroy or remove the navigation symbols, mile posts or navigation marks without the permission of the Directorate.

24. No one shall:

(a) violate the conditions relating to navigation of vessels in rivers and creeks prescribed by the Directorate for conservation of water resources, rivers and creeks.

(b) violate the conditions prescribed by the Directorate so as not to cause water pollution and change of watercourse in rivers and creeks.

8.2.4 PENALTIES

25. Whoever violates any of the prohibitions contained in sections 8, 9, 15 or section 23 may, on conviction, be punished with imprisonment for a term not exceeding 3 years or with fine not exceeding kyats 50,000 or with both.

26. whoever violates any of the prohibitions contained in sections, 10, 11, 12, 13 or section 14 may, on conviction, be punished with imprisonment for a term not exceeding 2 years or with fine not exceeding kyats 30,000 or with both.

27. Whoever violates any of the prohibitions contained in sections 16, 17, 18, 19, 20, 21, 22 or section 24 may, on conviction, be punished with imprisonment for a term not exceeding 1 year or with fine not exceeding kyats 10,000 or with both.

28. Whoever has, no conviction, been punished under sections 25, 26 or section 27 and if there is any loss and damage by his act, he shall be punished with fine for the relevant offence and shall also be ordered to pay the value of the loss and damage as compensation. If the said compensation is not paid, it shall be recovered as fine under section 386 of the Code of Criminal Procedure.

29. Whoever attempts or conspires or abets in the commission of an offence under this Law shall be punished with the punishment provide for such offence in this Law.

8.3 SNAGS REMOVING WORKS

Snags are very dangerous for water transportation. A large number of snags and great amount of silt are brought into the Chindwin River by its tributaries. The annual volume of work with regard to the channel clearing from snags which is done at present chiefly in the middle and in the upper course of the Chindwin river amounts to 100 tons. The annual cost of the fairwater clearing work is 10, 000, 00 kyats. Snags removing works should be taken for water transportation yearly.

Fig 8.1 Snags Removing Work

8.4 FINALIZATION MANAGEMENTPLAN OF THE CHINDWIN RIVER

Chindwin River is the most important river in North-West of Myanmar. The length of the Chindwin River is 1100 km.Among them, 816 km length can be utilized water transport from Hkamti to Confluence. Water transport is the cheapest and greatest in Myanmar. Myanmar has three seasons namely summer, rainy and cold seasons. Therefore, all the rivers in Myanmar experience large variation in discharge. Normally, more discharge observed from Mid-May to Mid-November. The water level difference in Chindwin River is at least 10 m to 13m.

The Chindwin Catchment area has observed less water volume and more sediment deposit due to the Environmental Impact. The average sediment load is 131 million tons. The sediment deposit load flow from upstream to downstream, water transport is limited due to Morphology changes. Thus, the Chindwin river is occurred as follow events:

(i) Braided channels

(ii) Insufficient water depth in low water season

(iii) Large sediment transport

(iv) Instability of water flow direction

These events can be solved by using of River training Structures. These structures should be taken according to the following the Chindwin master plan.

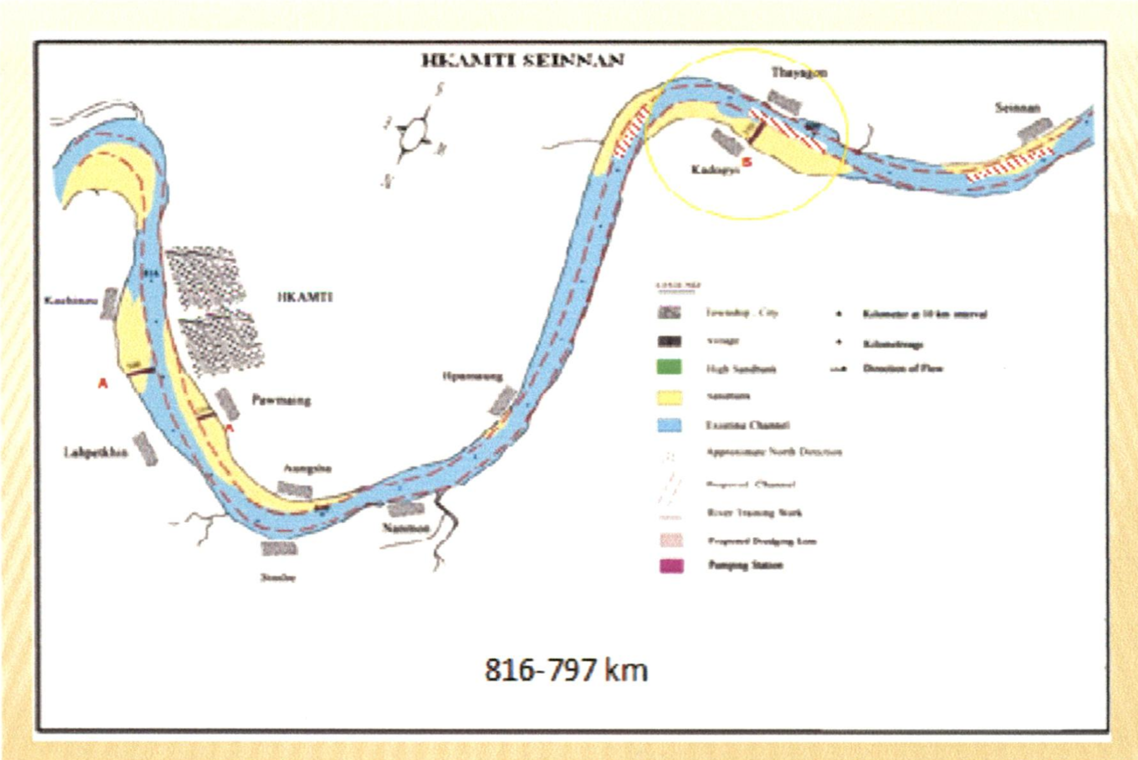


Fig 8.2Hkamti-Seinnan (816-797) km

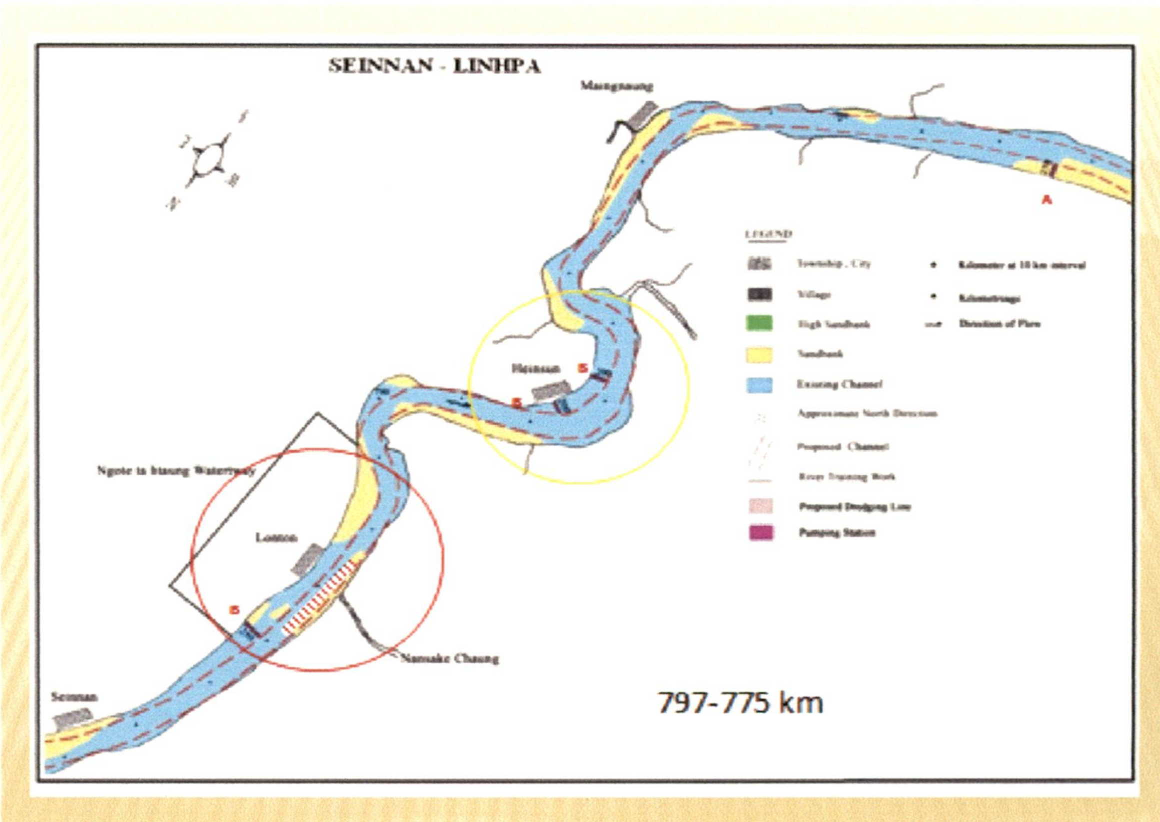


Fig 8.3 Seinnan-Linhpa (797-775) km

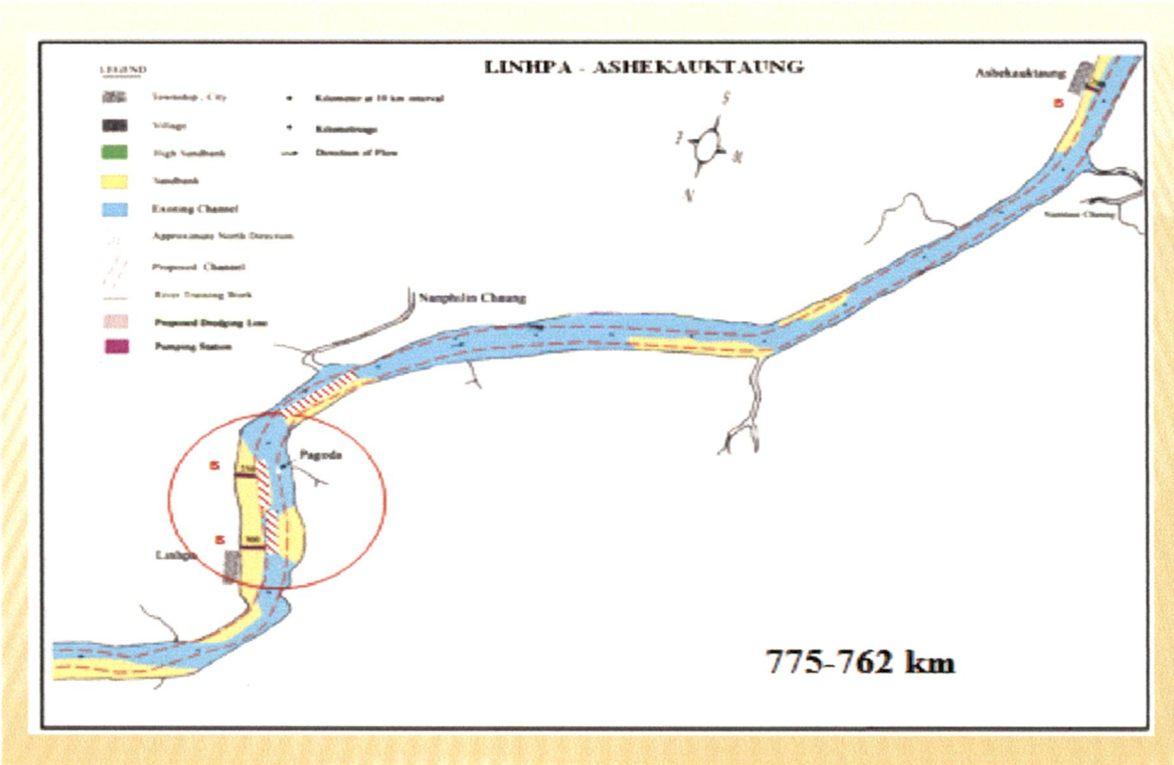


Fig 8.4 Linhpa-Ashekauktaung (775-762) km

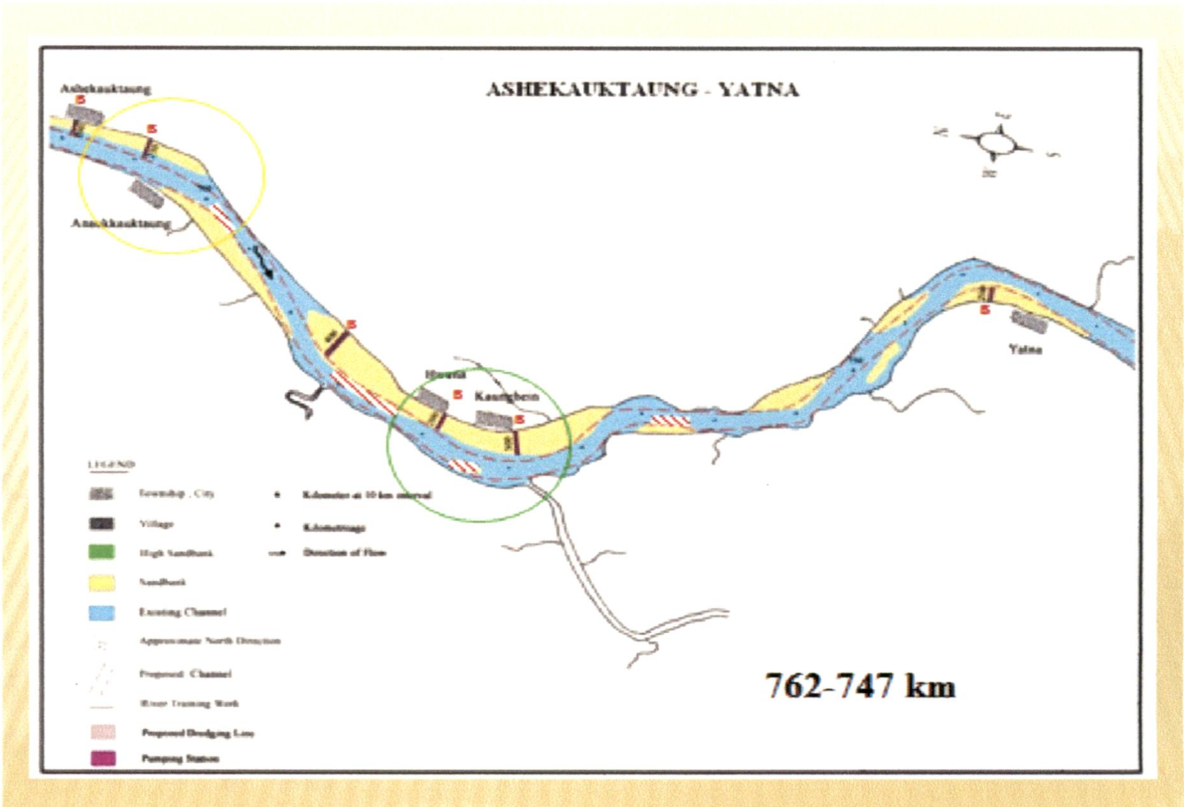


Fig 8.5Ashekauktaung-Yatna (762-747) km

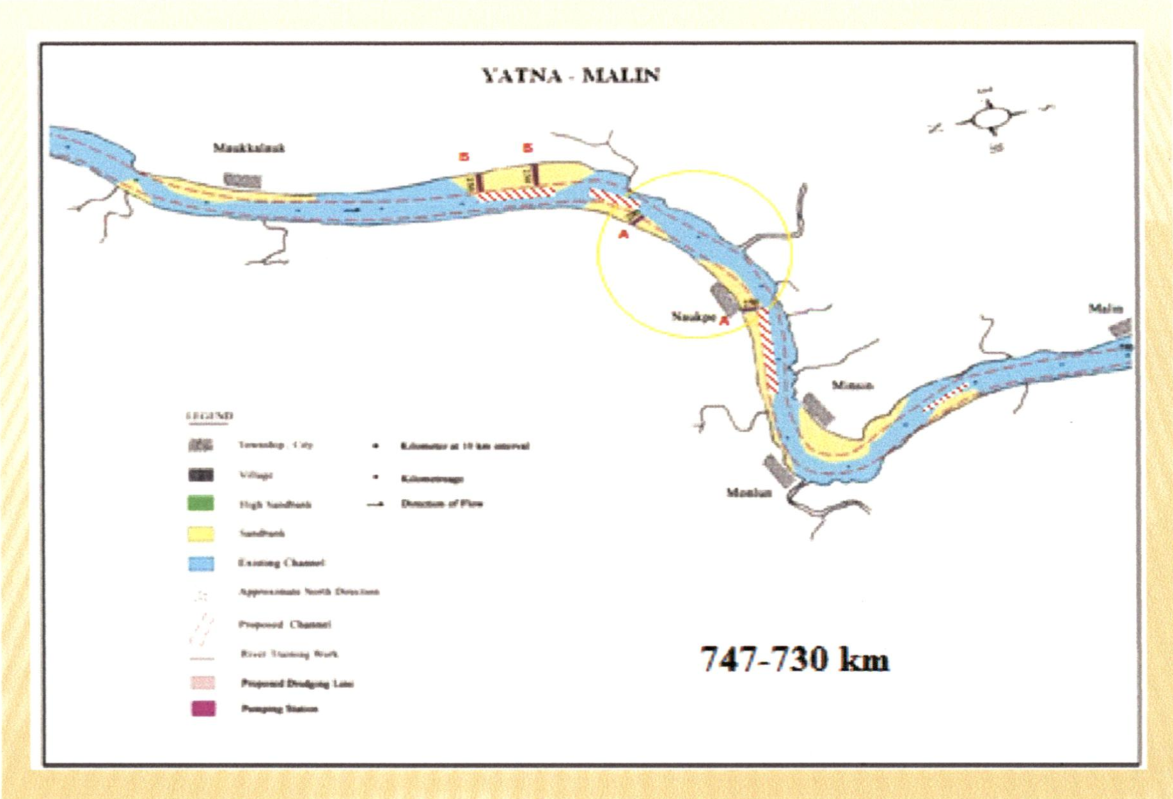


Fig 8.6 Yatna-Malin (747-730) km

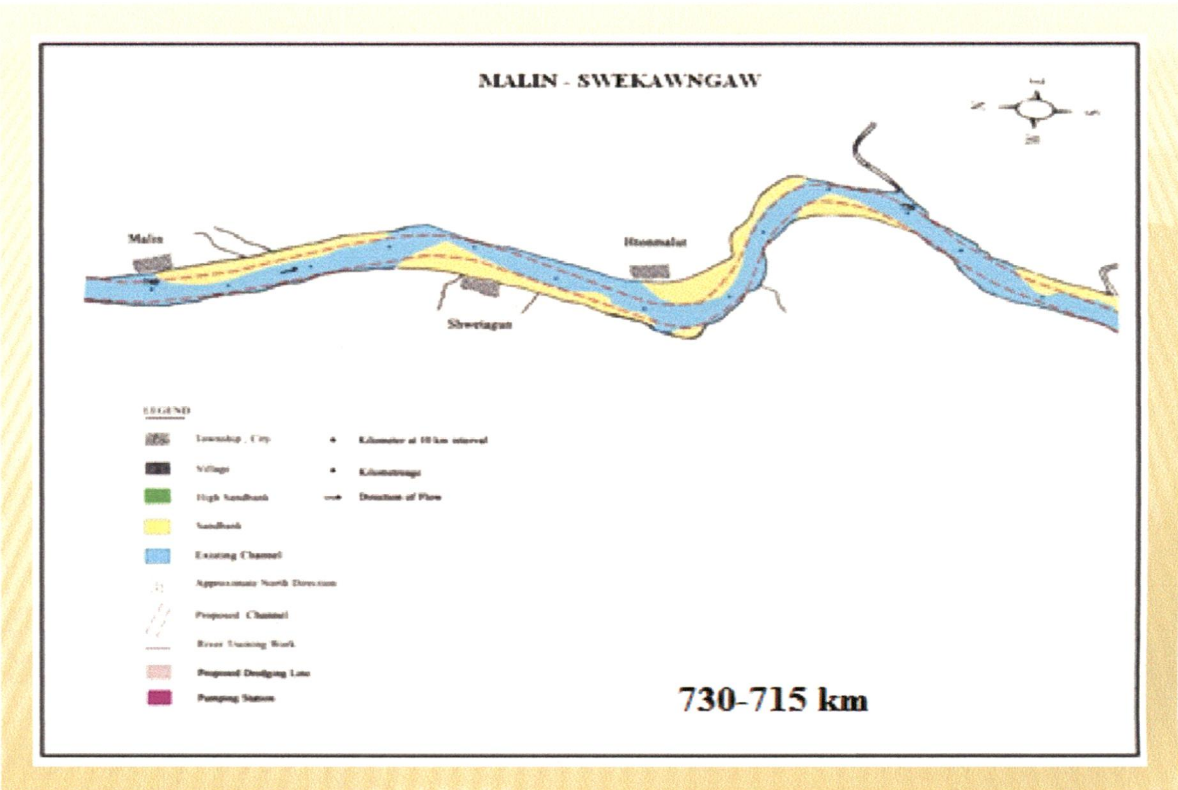


Fig 8.7 Malin-Swekawngaw (730-715) km

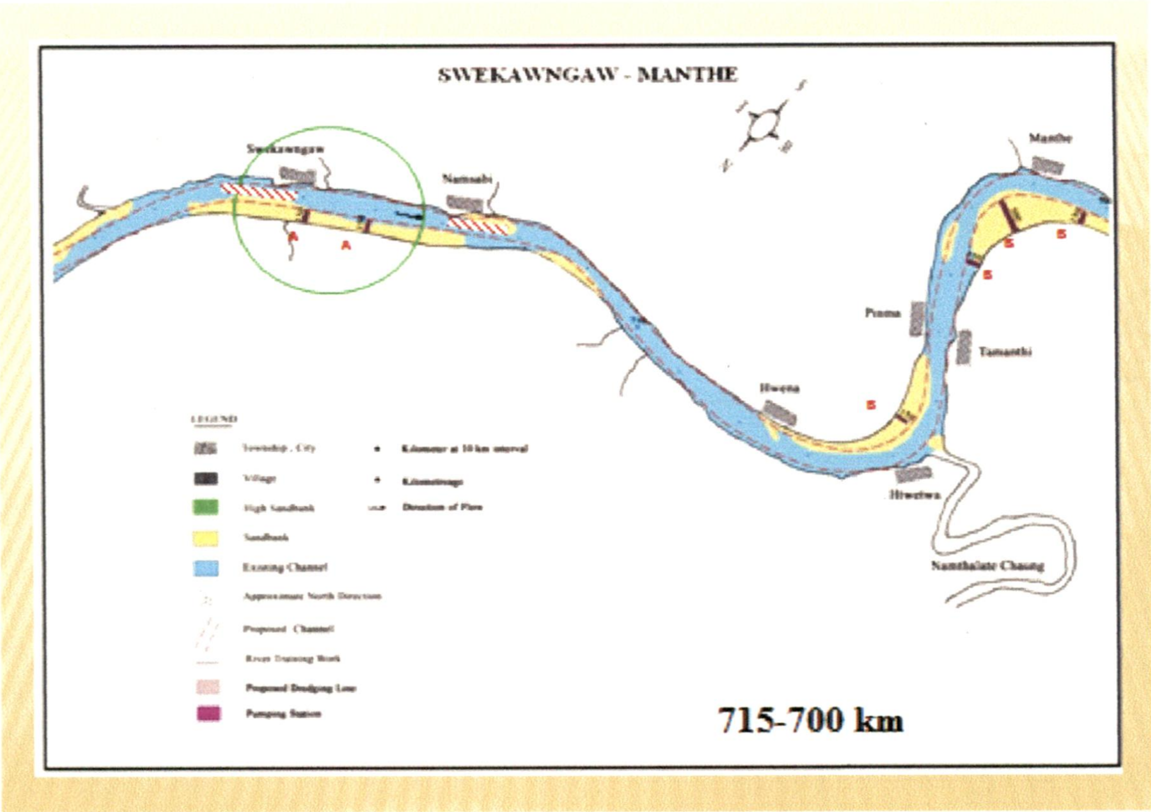


Fig 8.8 Swekawngaw-Manthe (715-700) km

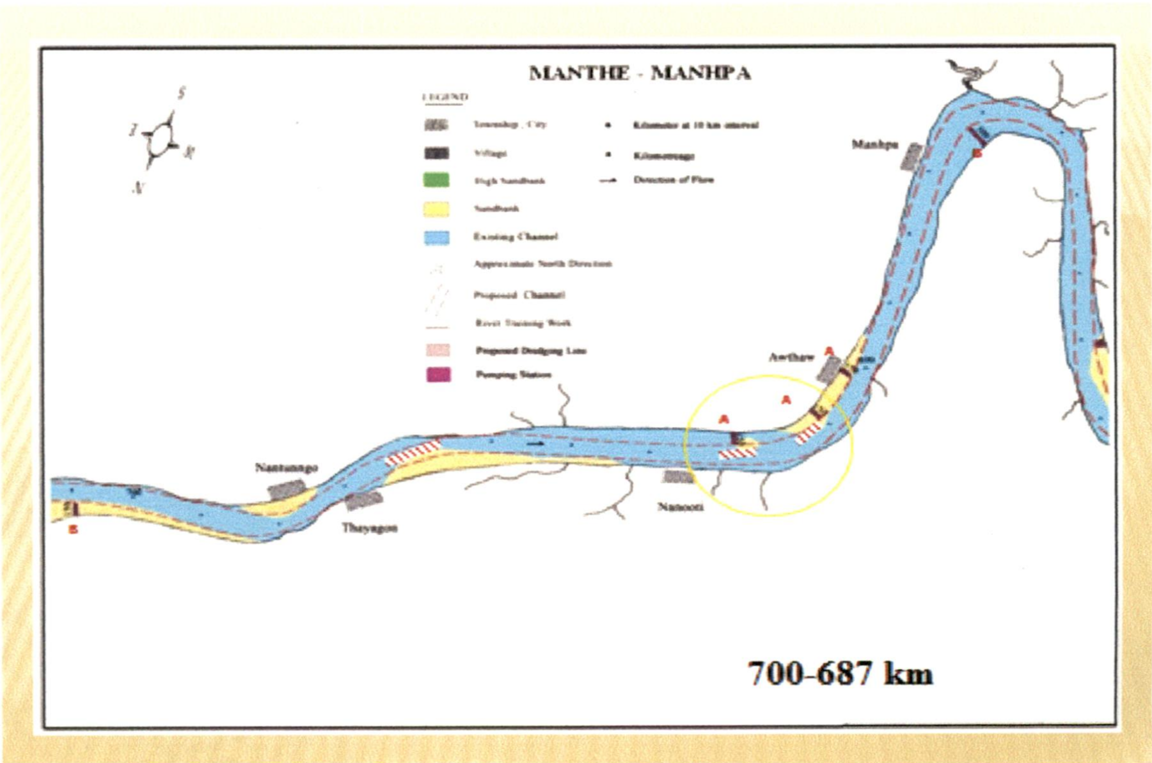


Fig 8.9 Manthe-Manhpa (700-687) km

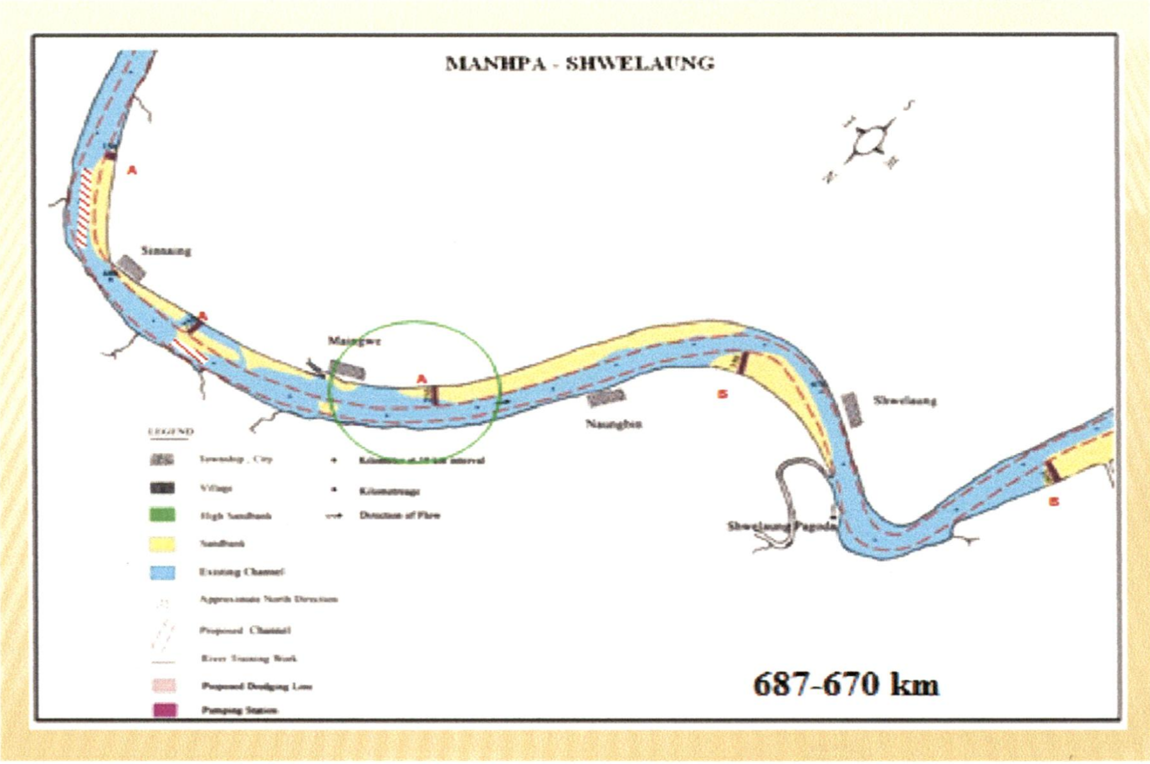


Fig 8.10 Manhpa-Shwelaung (687-670) km

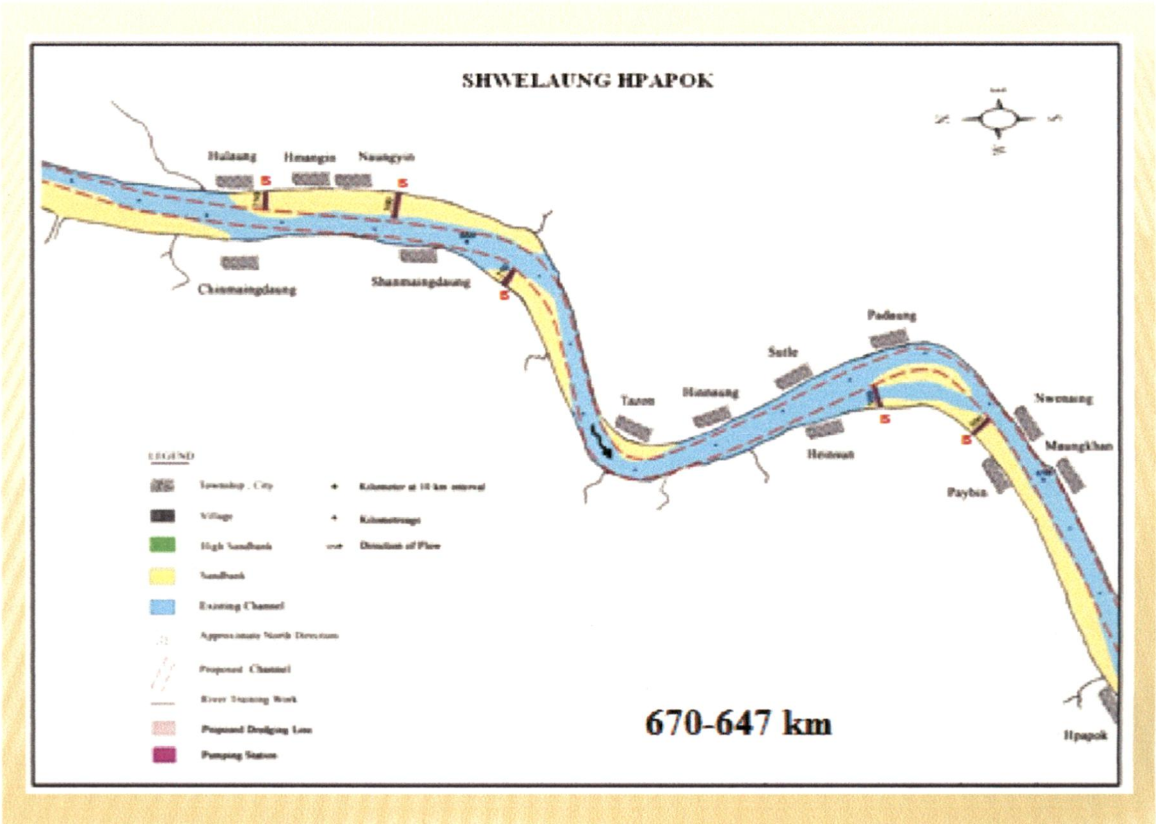


Fig 8.11 Shwelaung-Hpapok (670-647) km

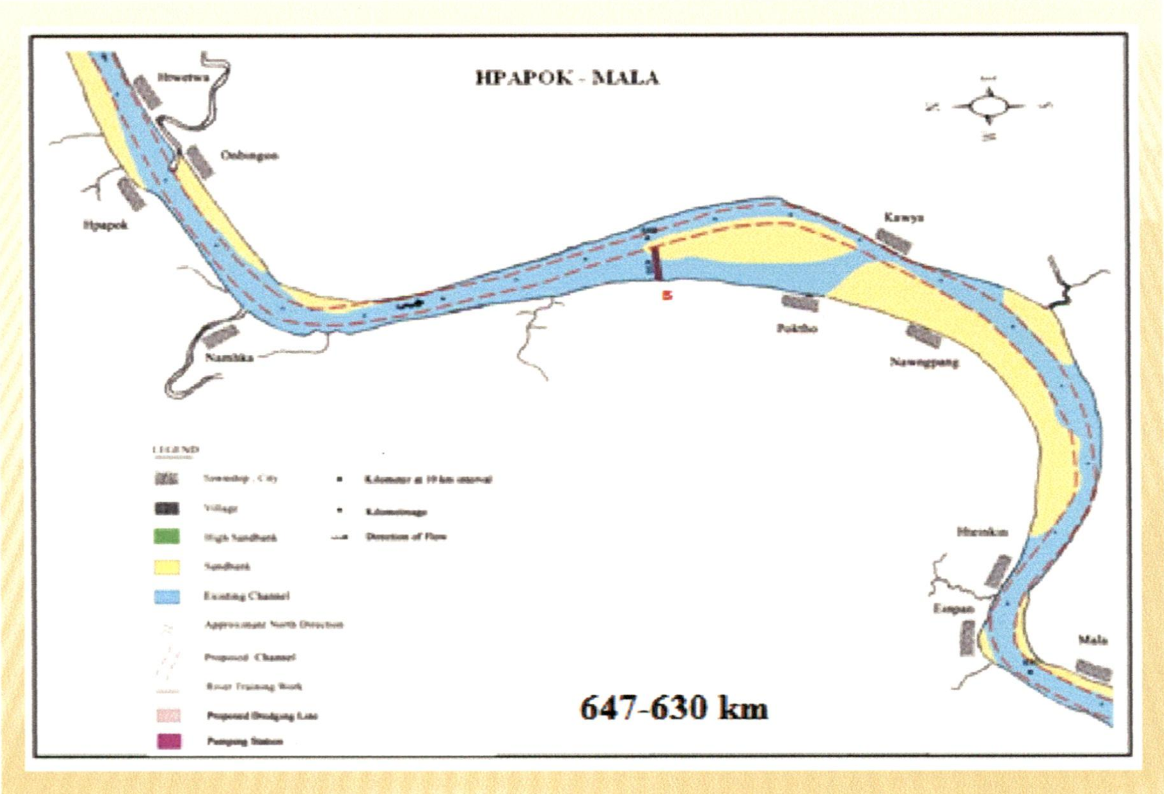


Fig 8.12 Hpapok-Mala (647-630) km

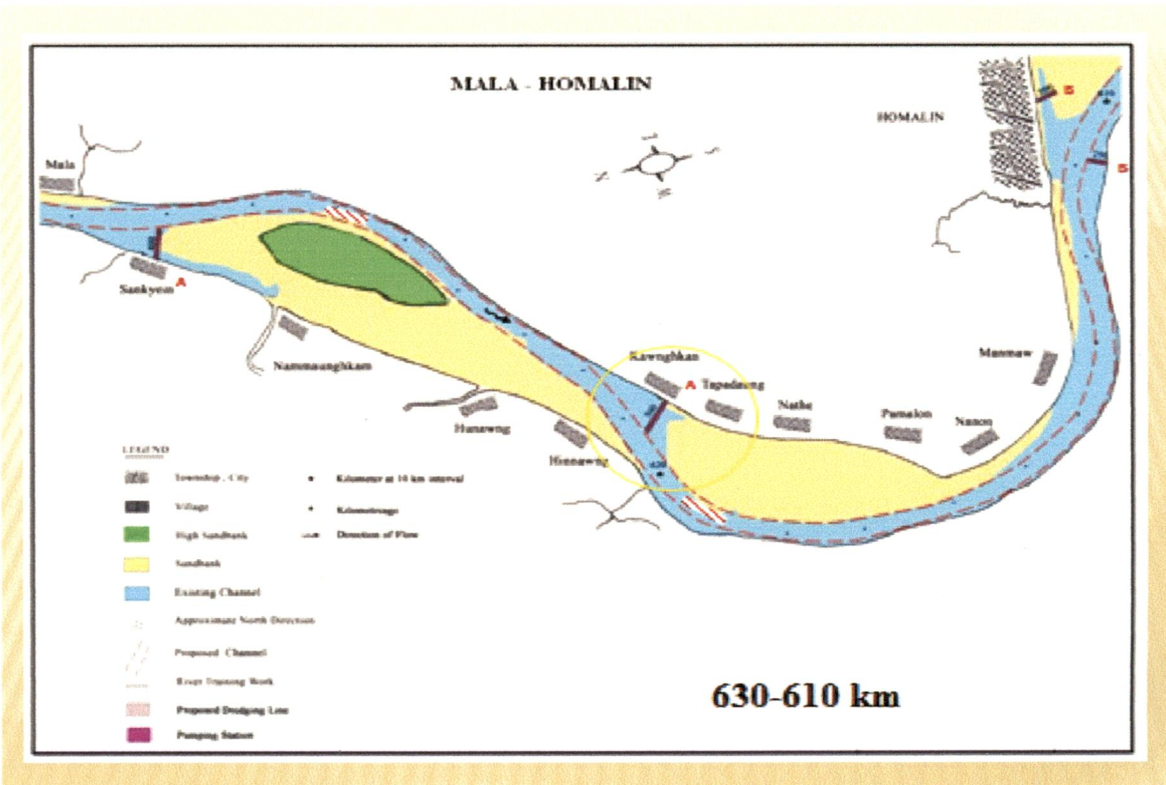


Fig 8.13 Mala-Homalin (630-610) km

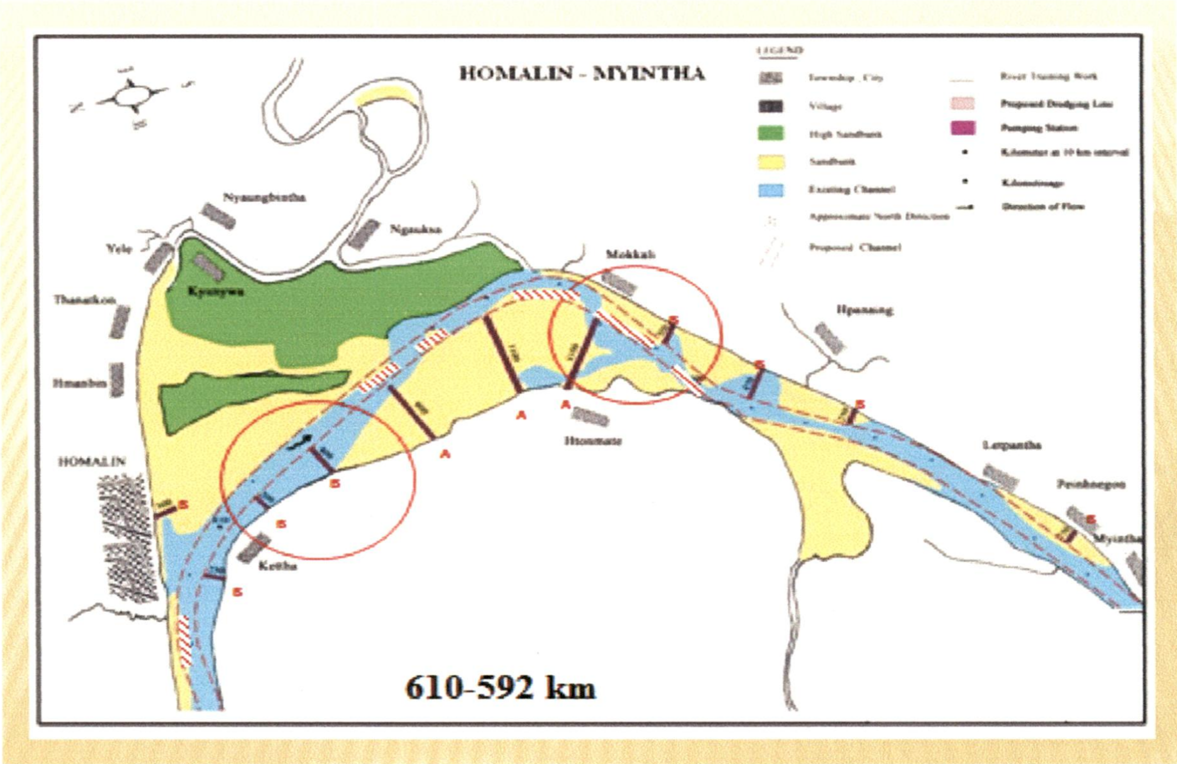


Fig 8.14 Homalin-Myintha (610-592) km

Fig 8.15 Myintha-Laungmin (592-573) km

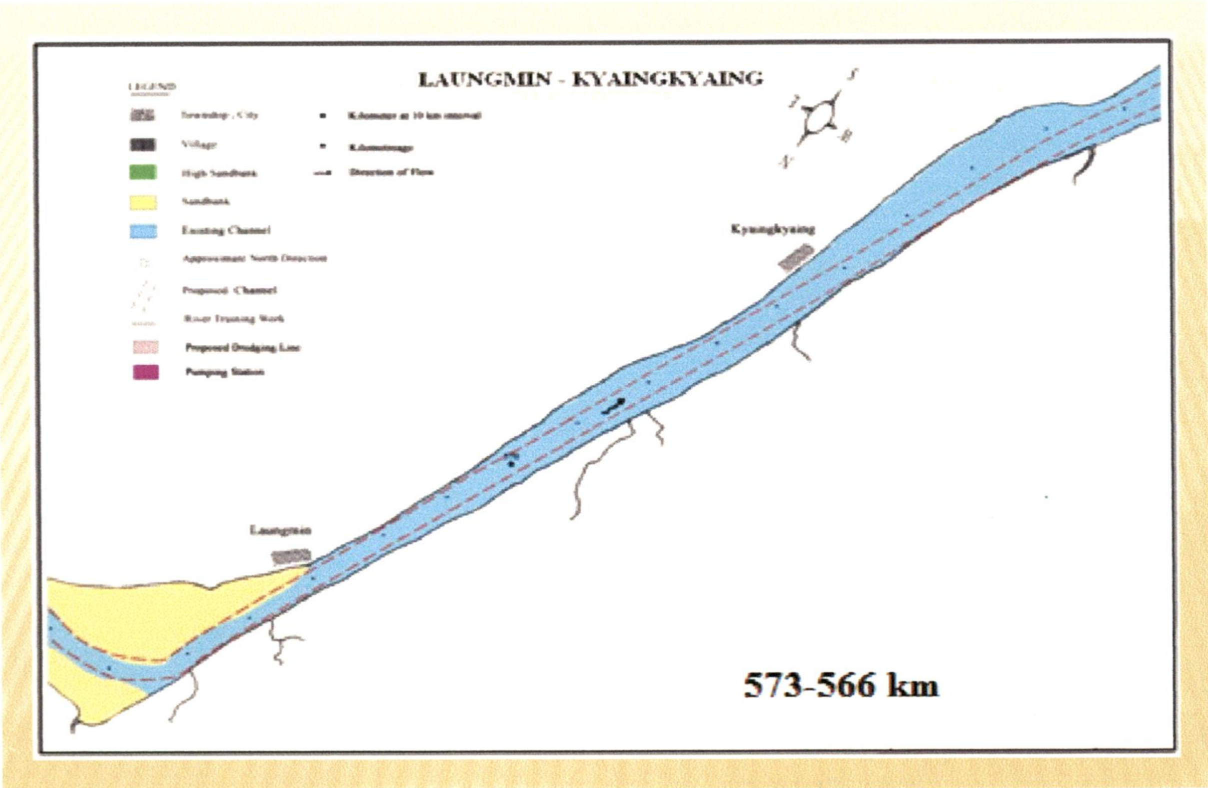


Fig 8.16 Laungmin-Kyaingkyaing (573-566) km

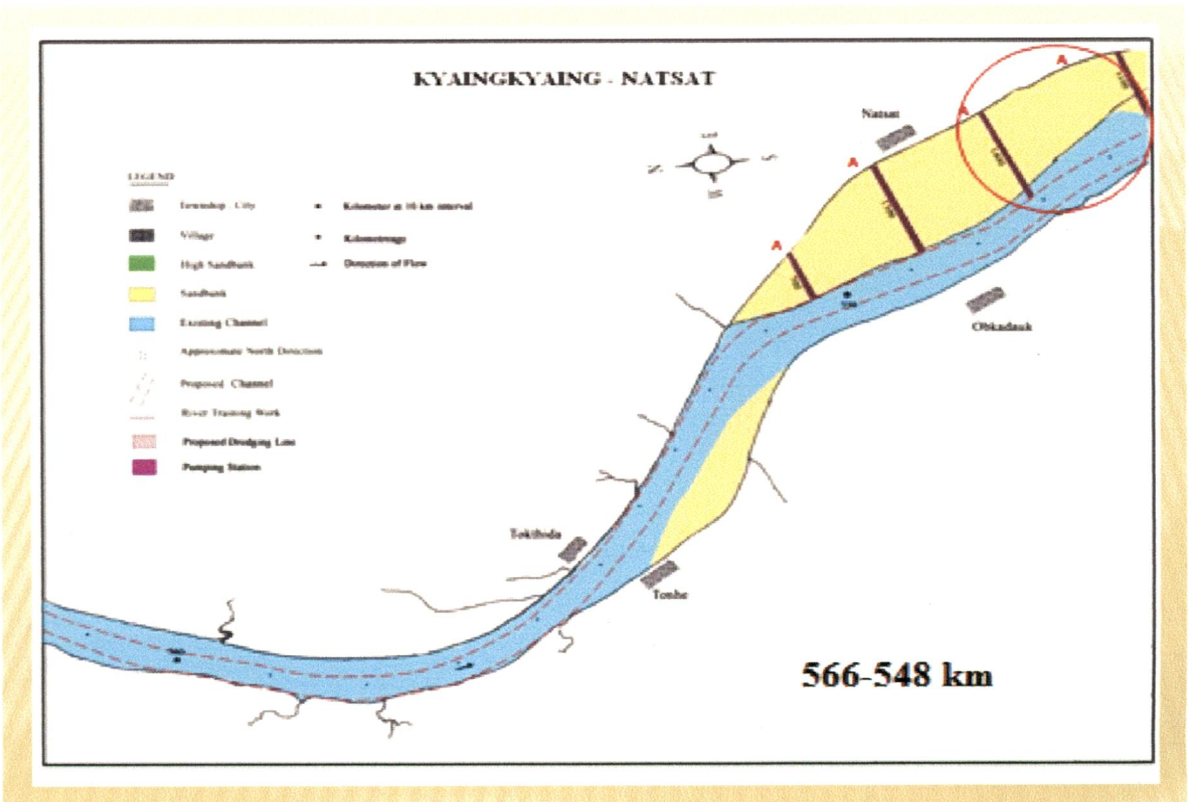


Fig 8.17 Kyaingkyaing-Natsat (566-548) km

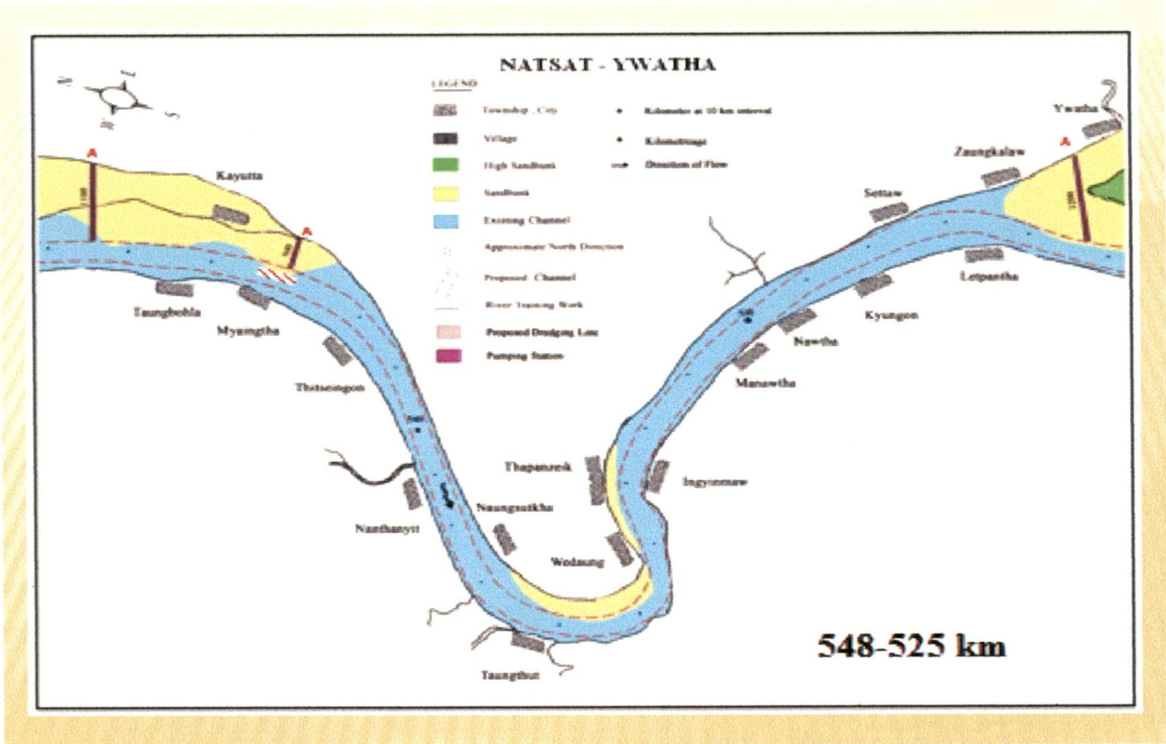


Fig 8.18 Natsat-Ywatha (548-525) km

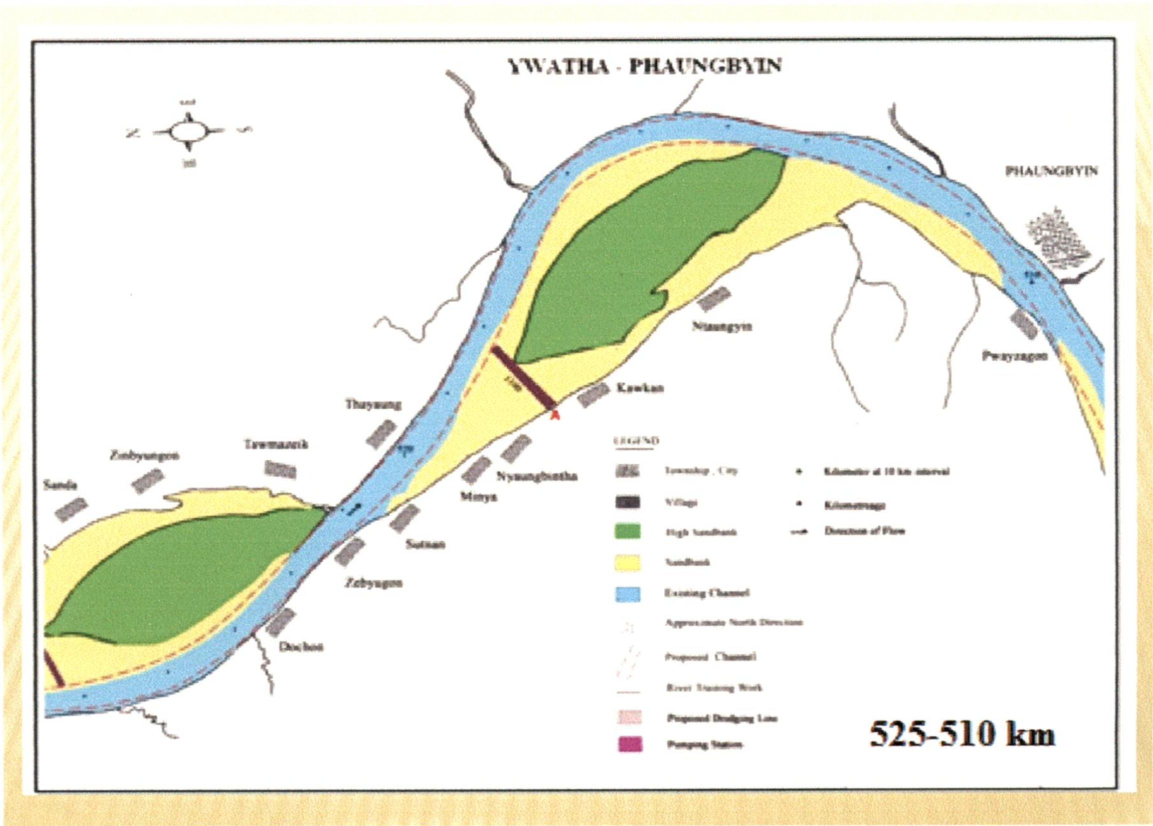


Fig 8.19 Ywatha-Phaungbyin (525-510) km

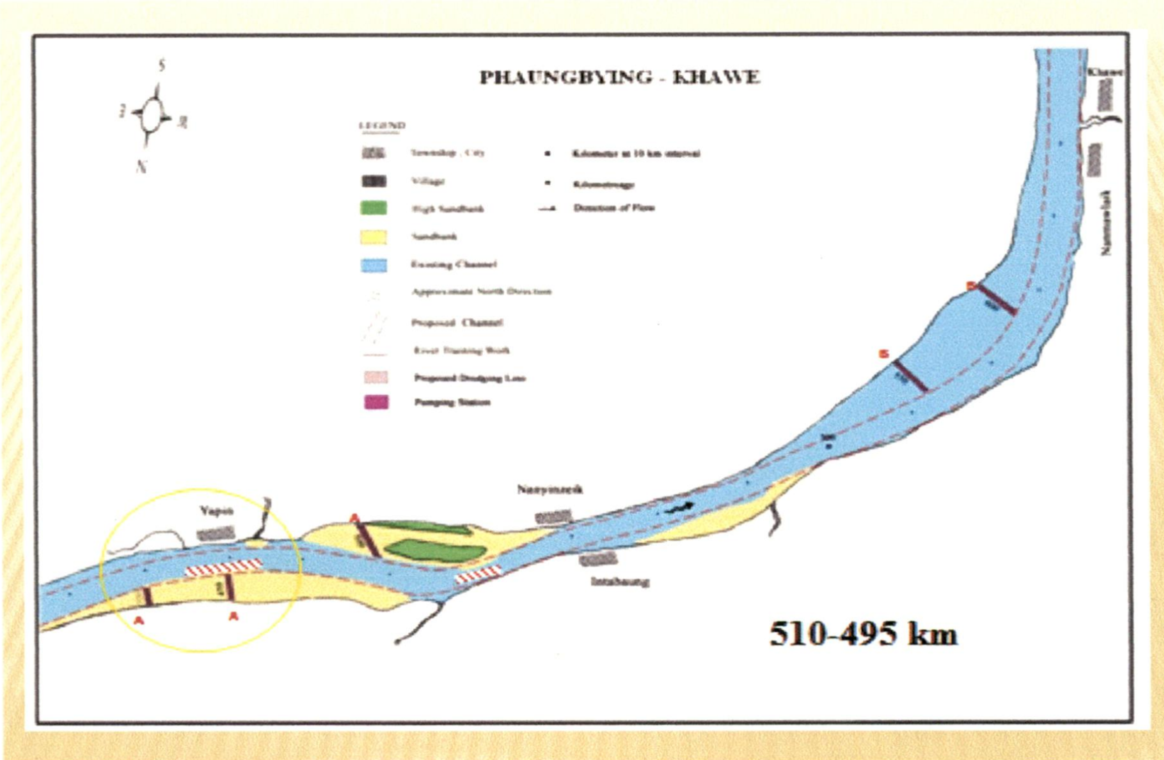


Fig 8.20 Phaungbyin-Khawe (510-495) km

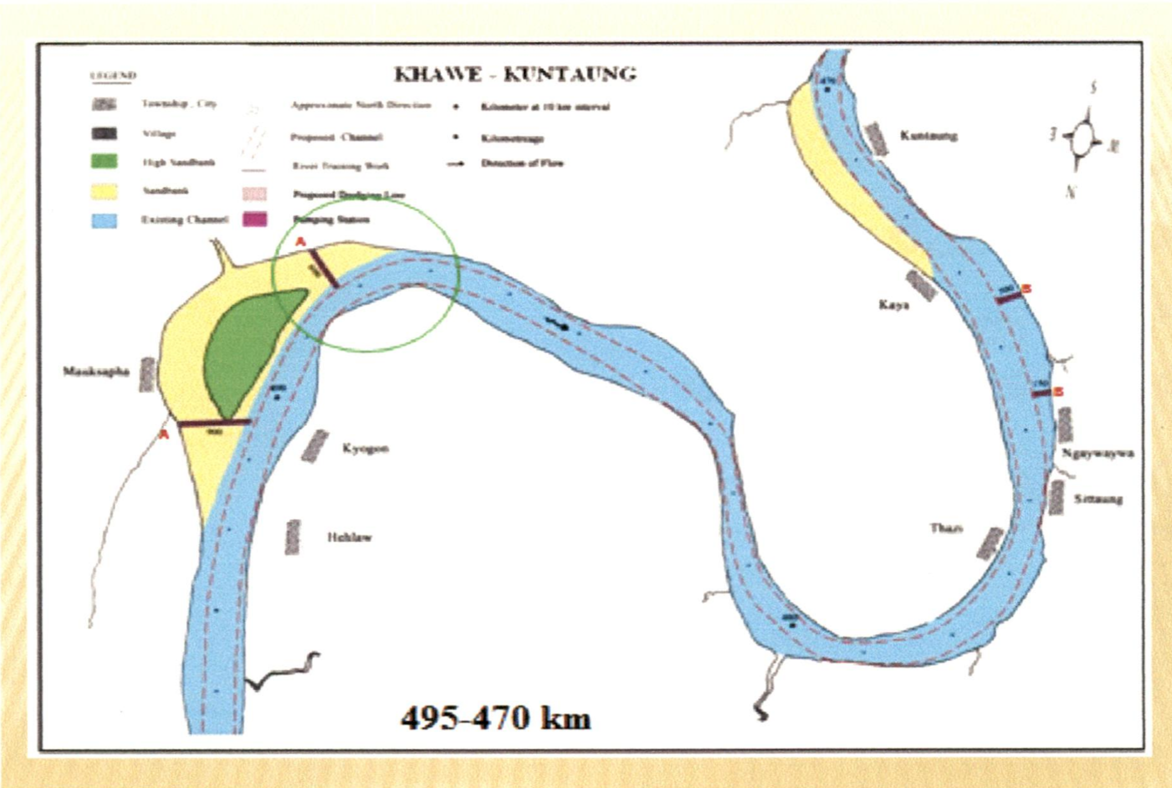


Fig 8.21 Khawe-Kuntaung (495-470) km

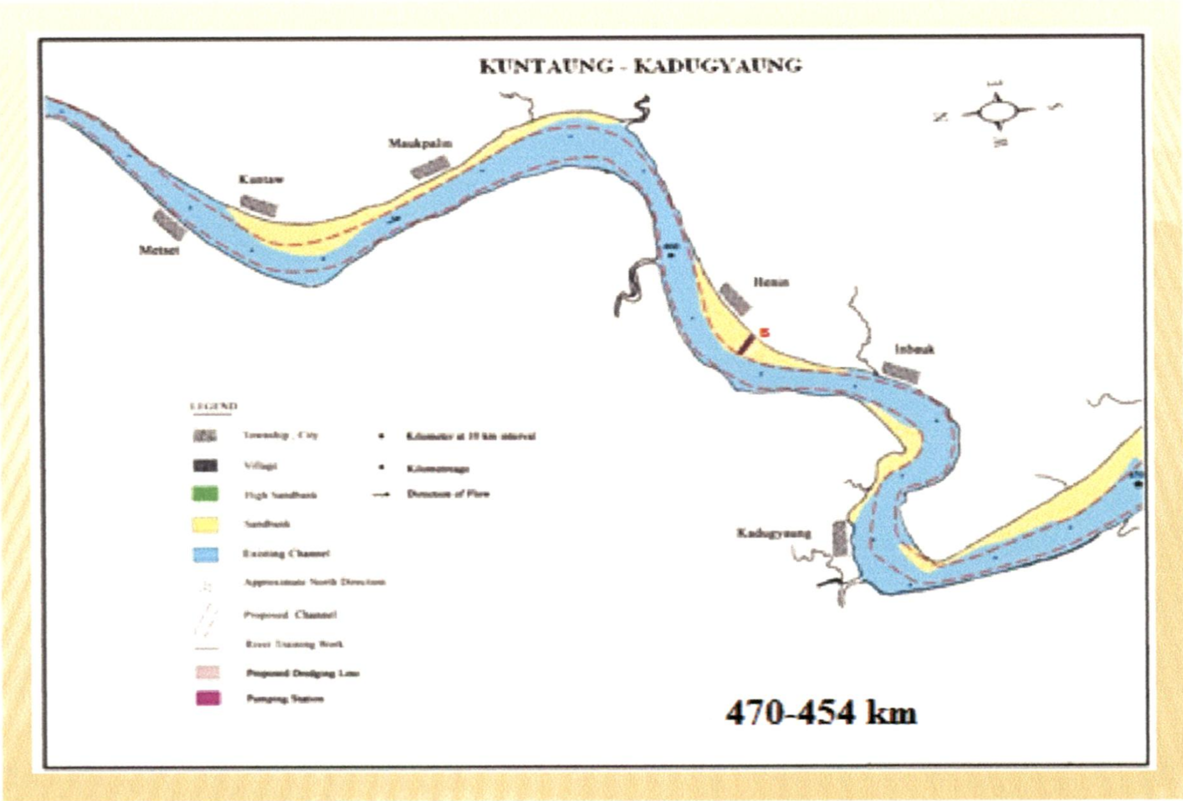


Fig 8.22 Kuntaung-Kadugyaung (470-454) km

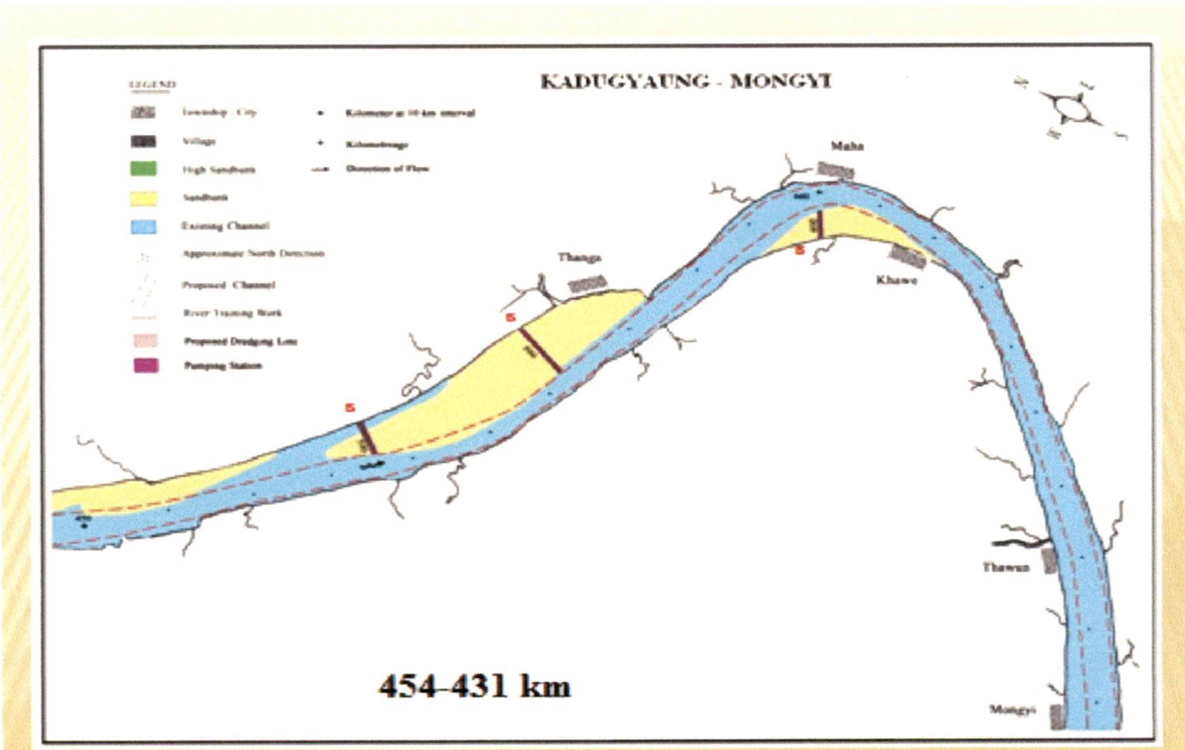


Fig 8.23 Kadugyaung-Mongyi (454-431) km

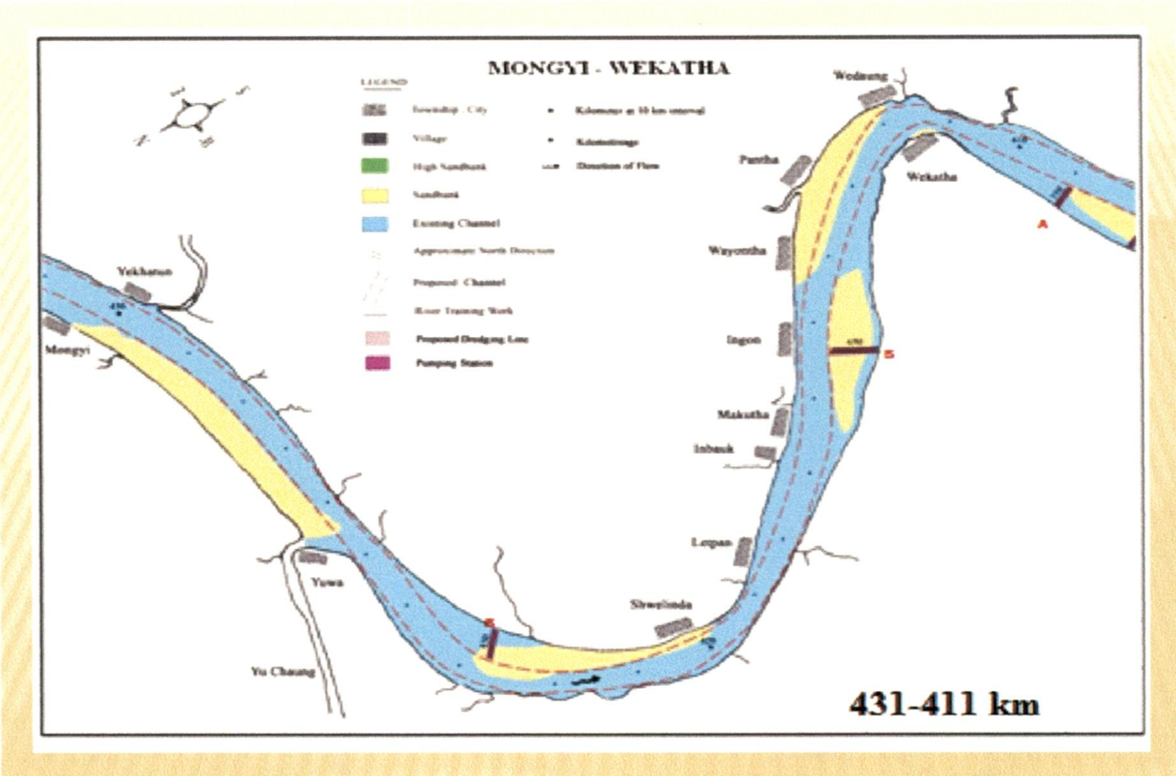


Fig 8.24 Mongyi-Wekatha (431-411) km

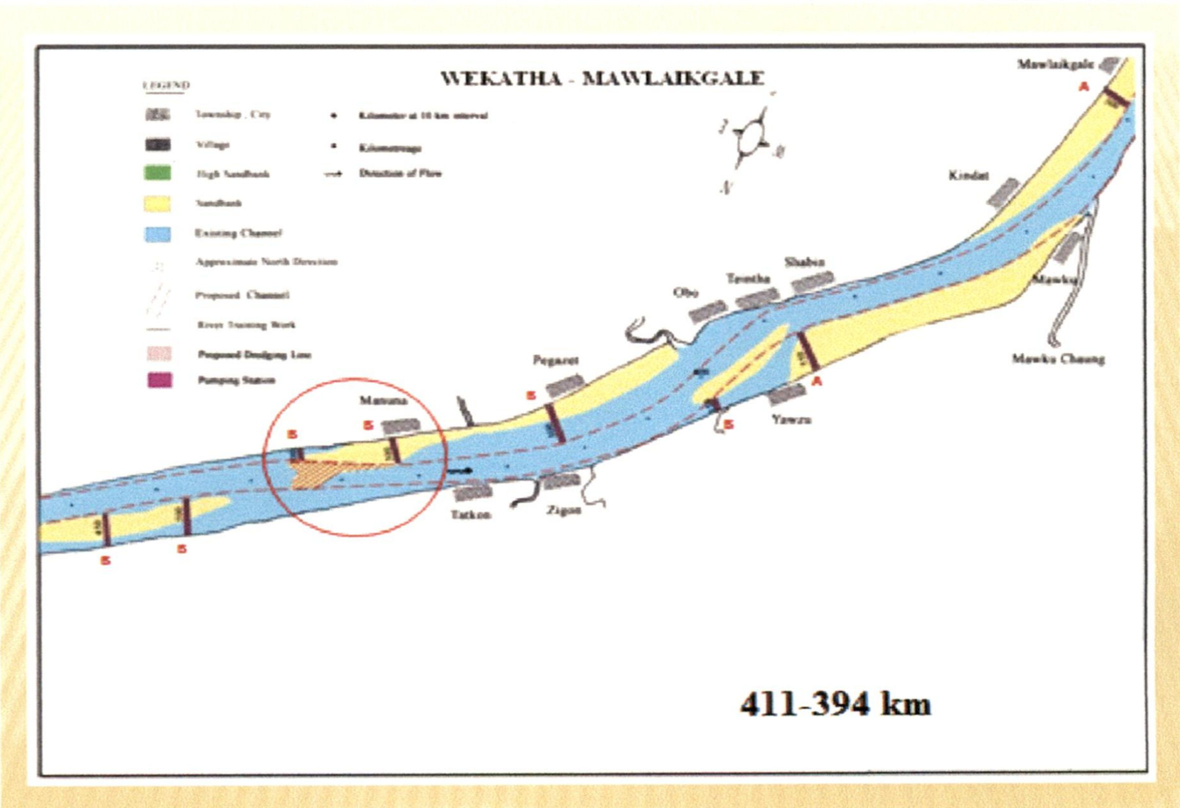


Fig 8.25 Wekatha-Mawlaikgale (411-394) km

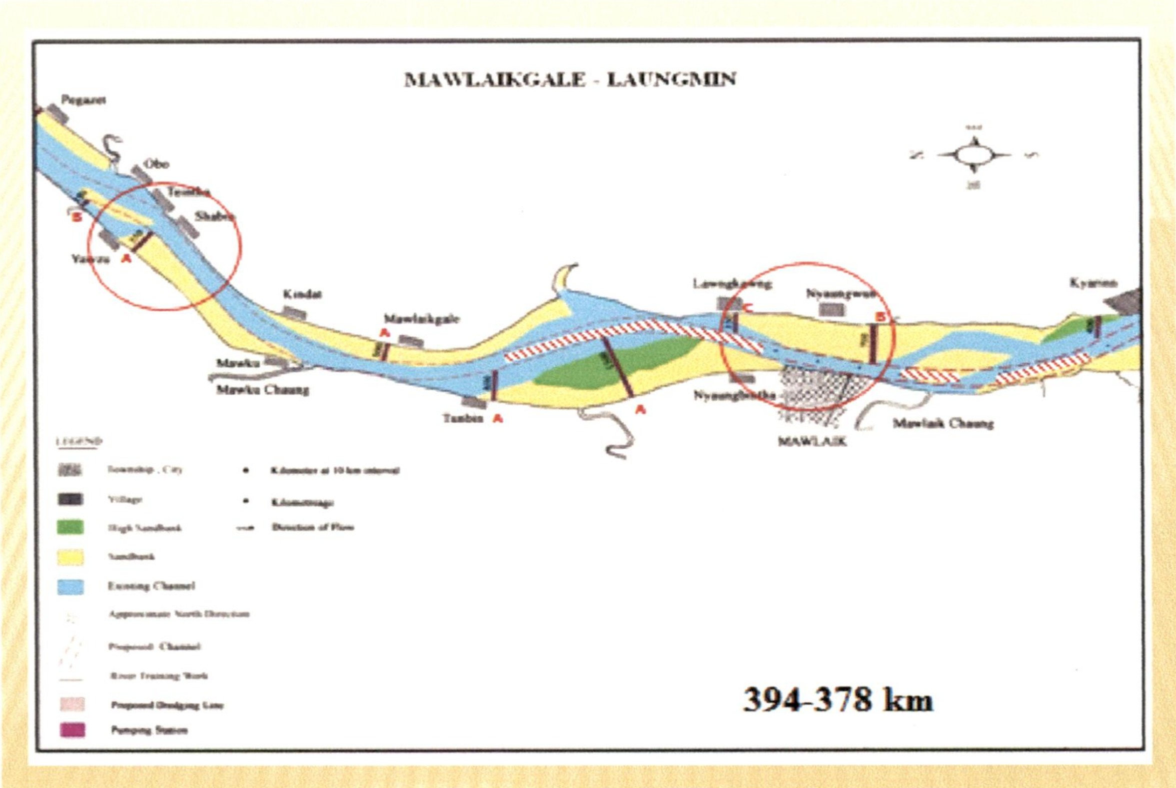


Fig 8.26 Mawlaikgale-Laungmin (394-378) km

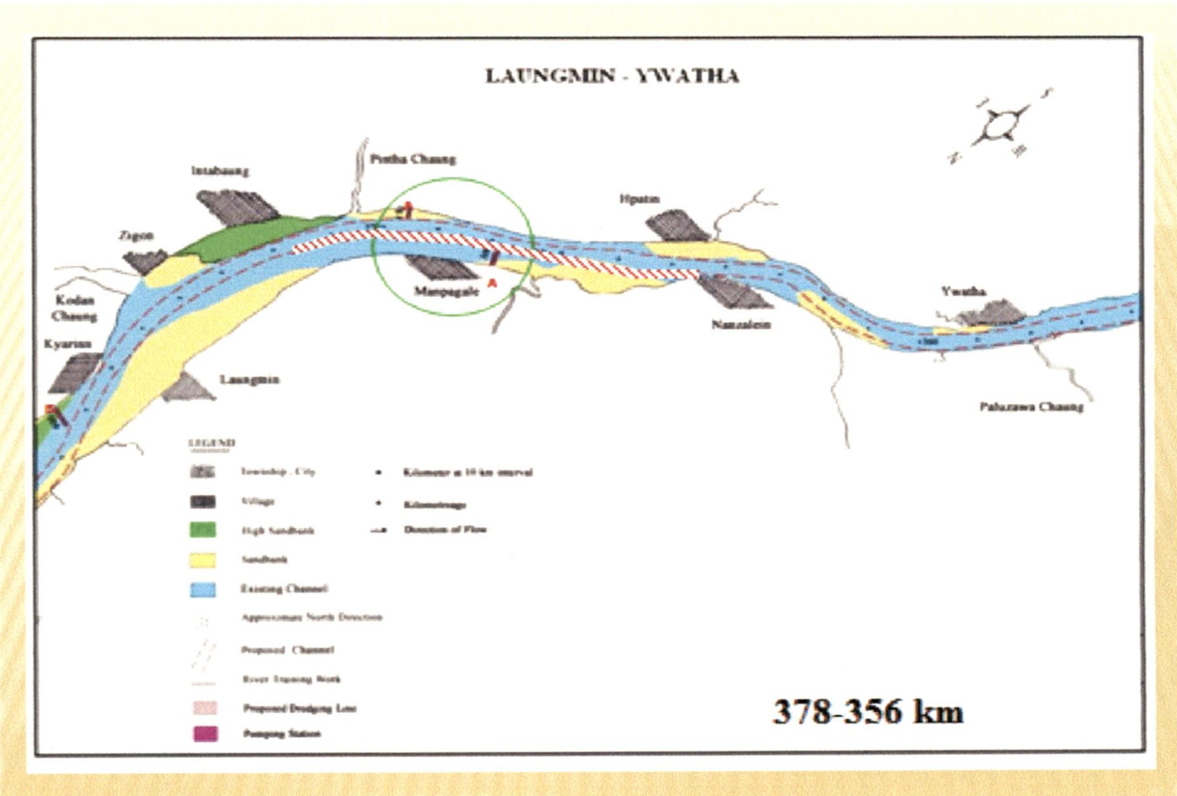


Fig 8.27 Laungmin-Ywatha (378-356) km

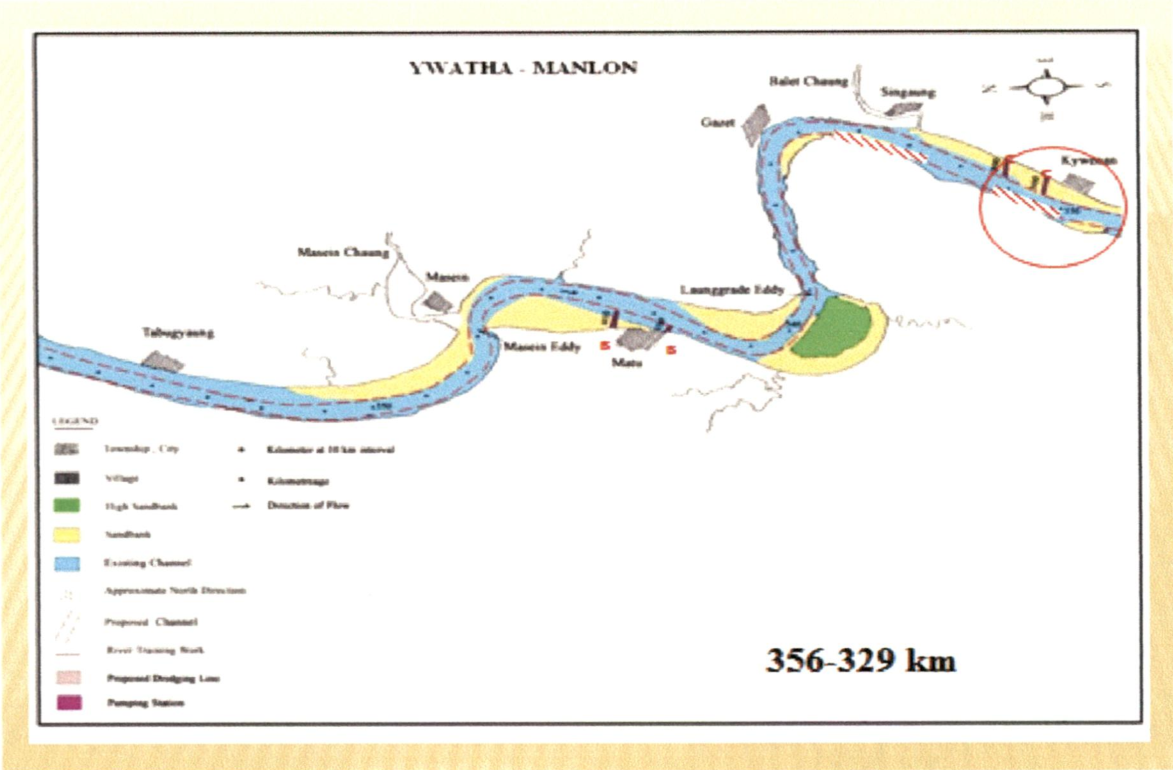


Fig 8.28 Ywatha-Manlon (356-329) km

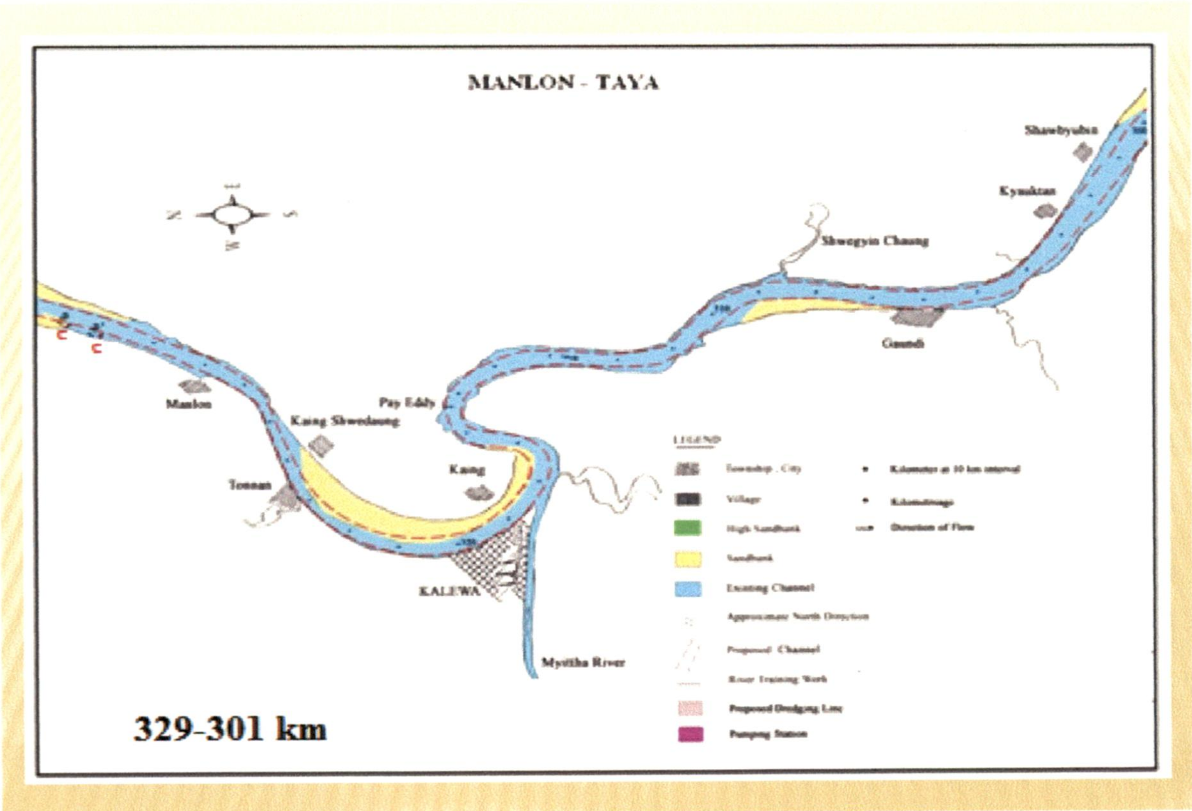


Fig 8.29 Manlon-Taya (329-301) km

Fig 8.30 Taya-Uyinma (301-266) km

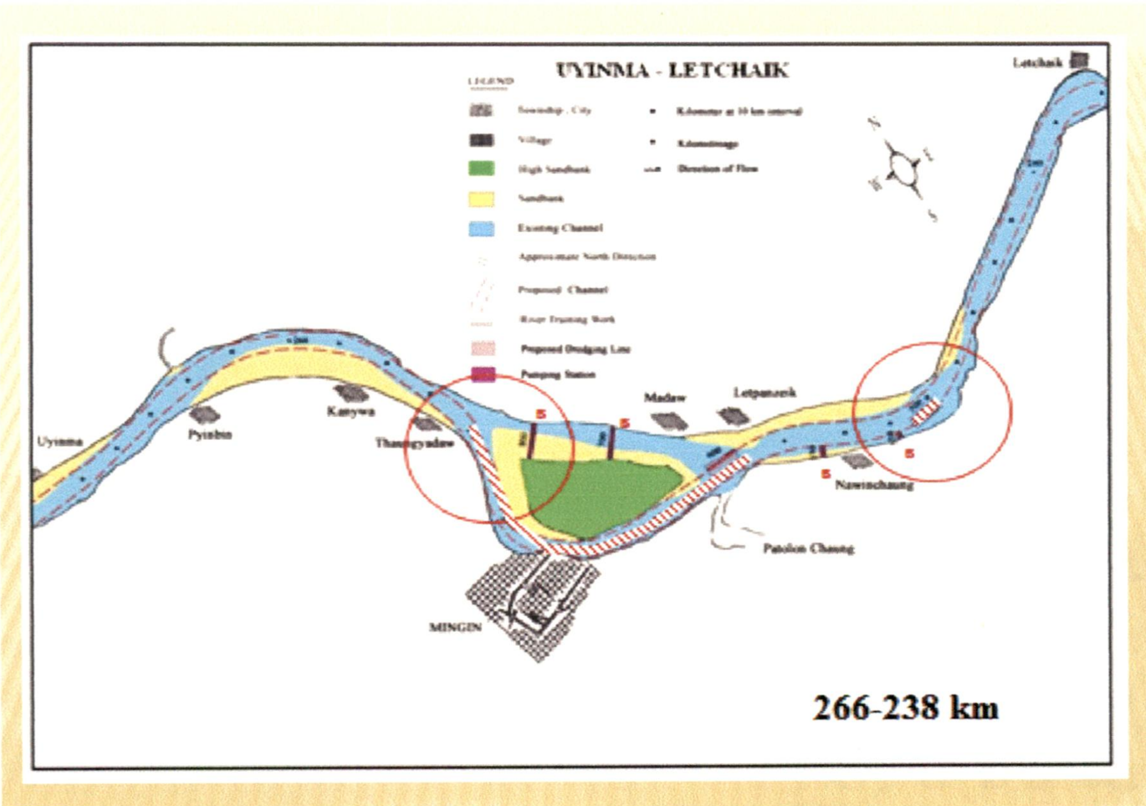


Fig 8.31 Uyinma-Letchaik (266-238) km

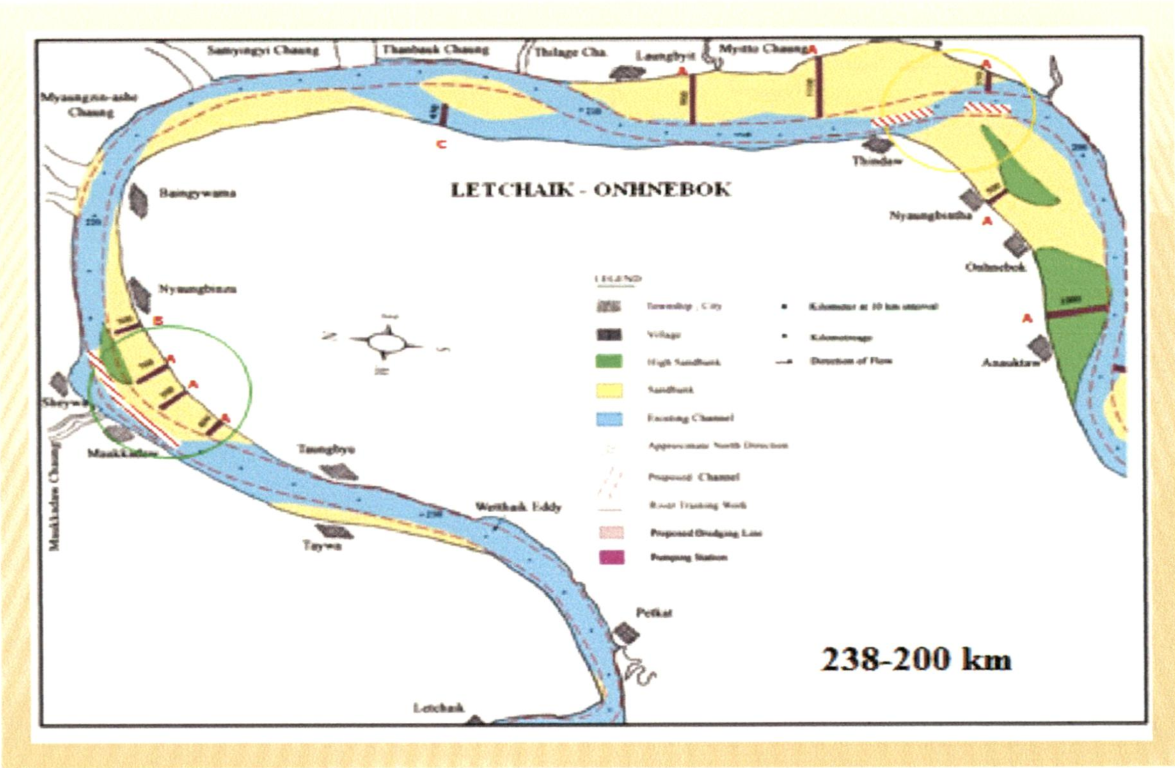


Fig 8.32 Letchaik-Onhnebok (238-200) km

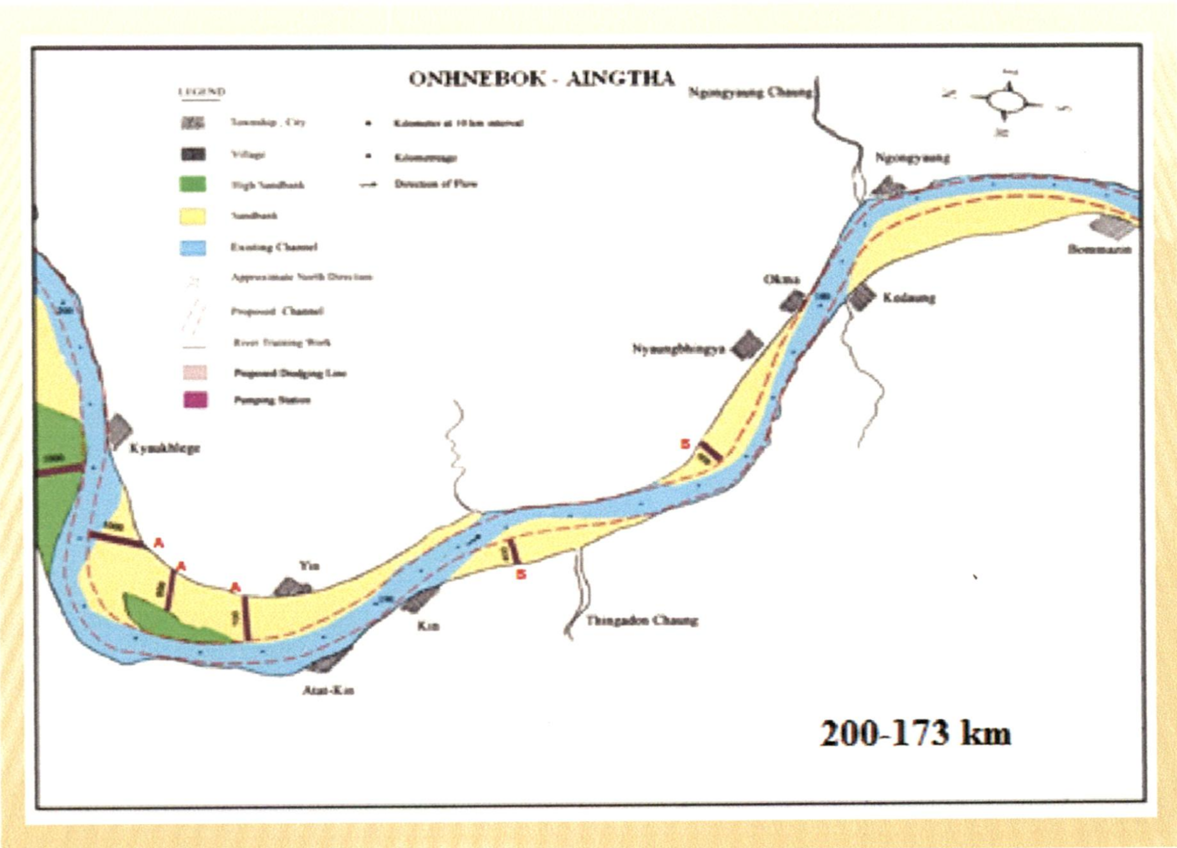


Fig 8.33 Onhnebok-Aingtha (200-173) km

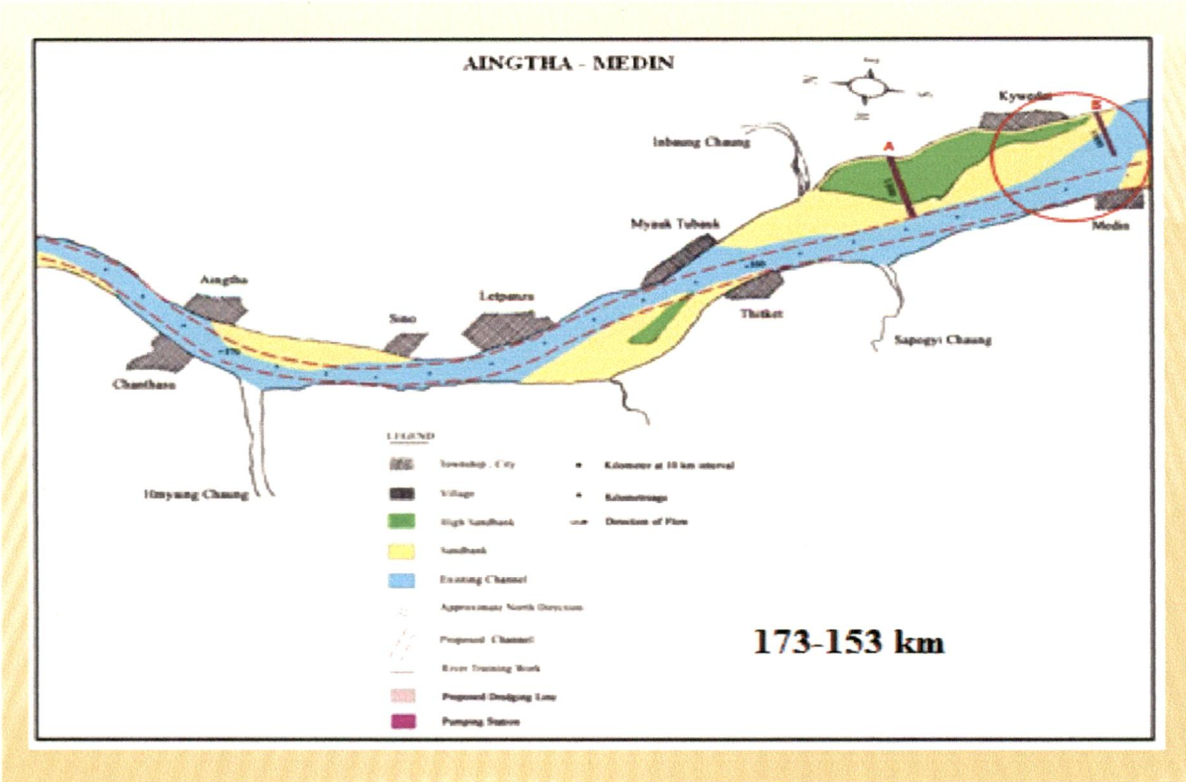


Fig 8.34 Aingtha-Medin (173-153) km

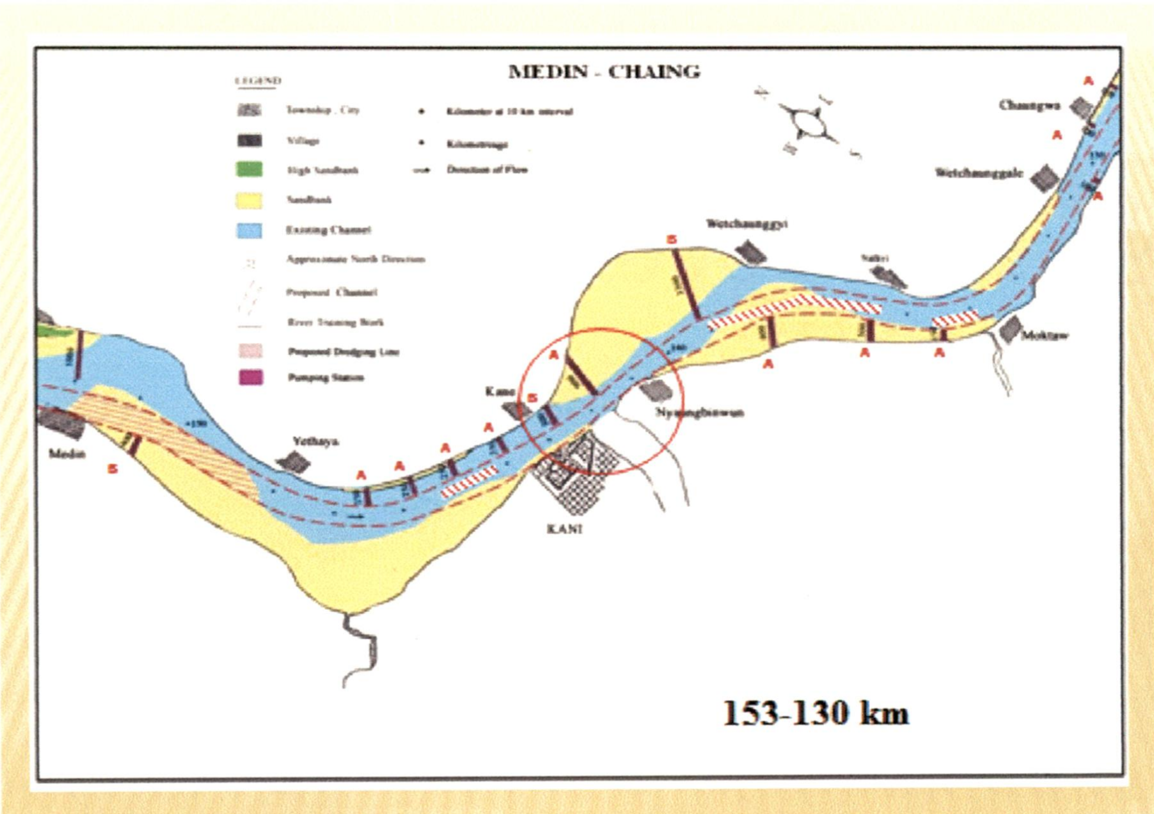


Fig 8.35 Medin-Chaing (153-130) km

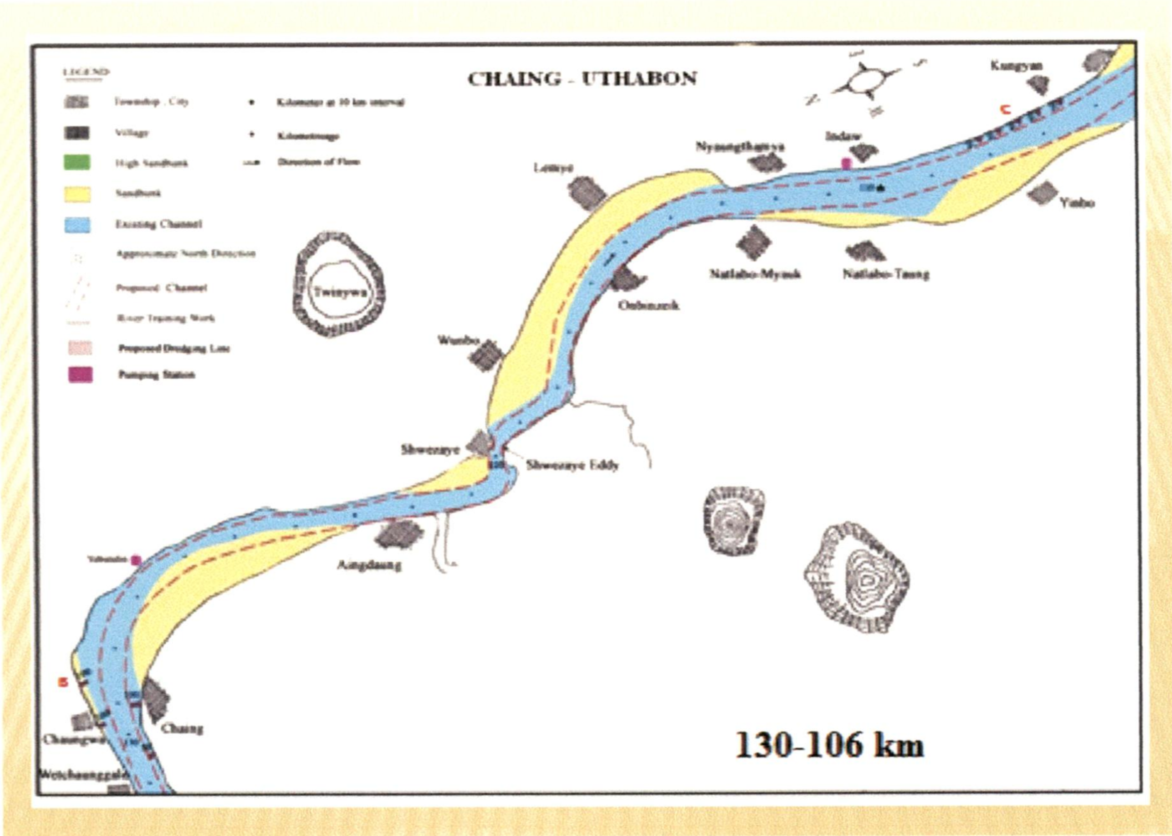


Fig 8.36 Chaing-Uthabon (130-106) km

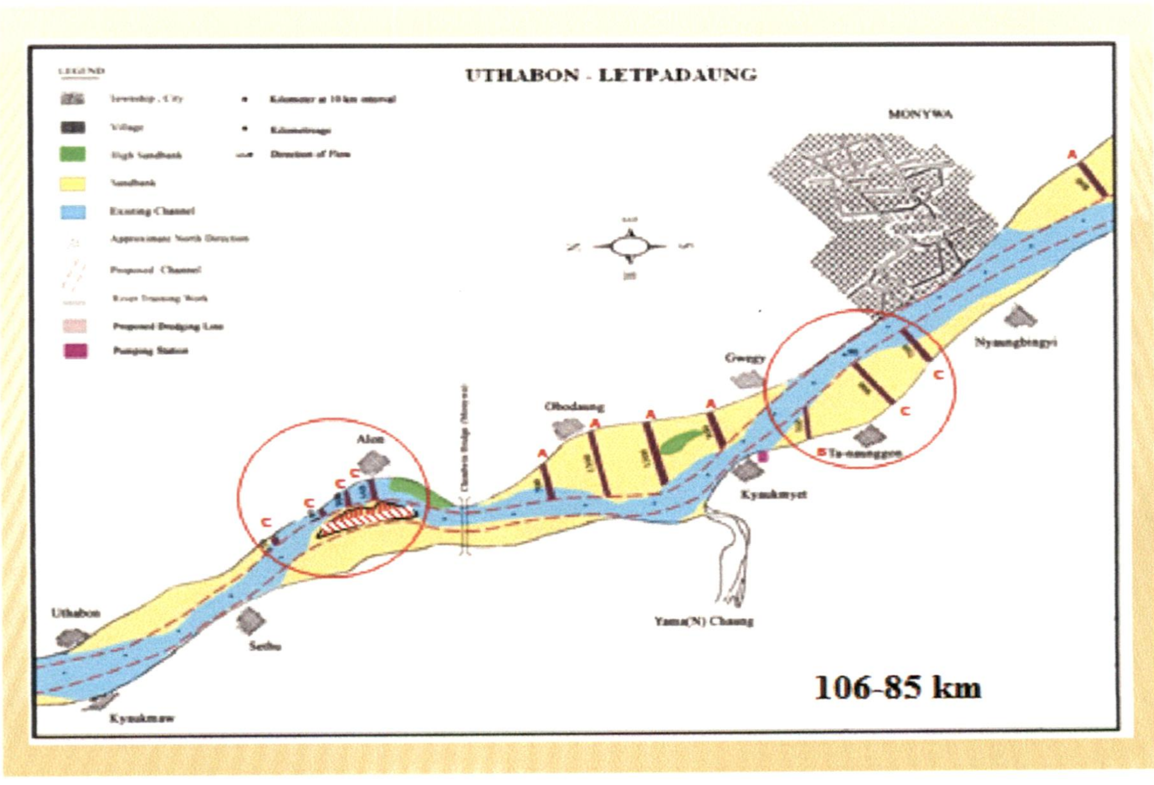


Fig 8.37 Uthabon-letpadaung (106-85) km

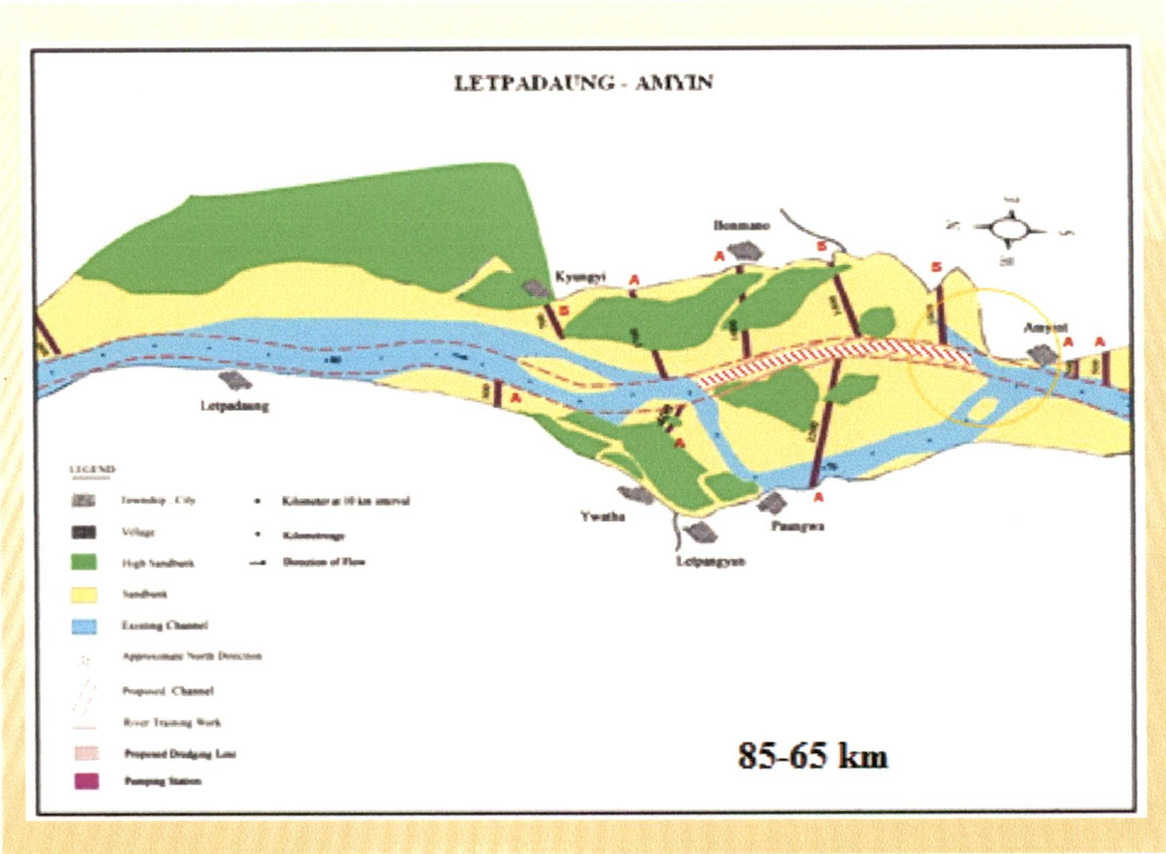


Fig 8.38 letpadaung-Amyin (85-65) km

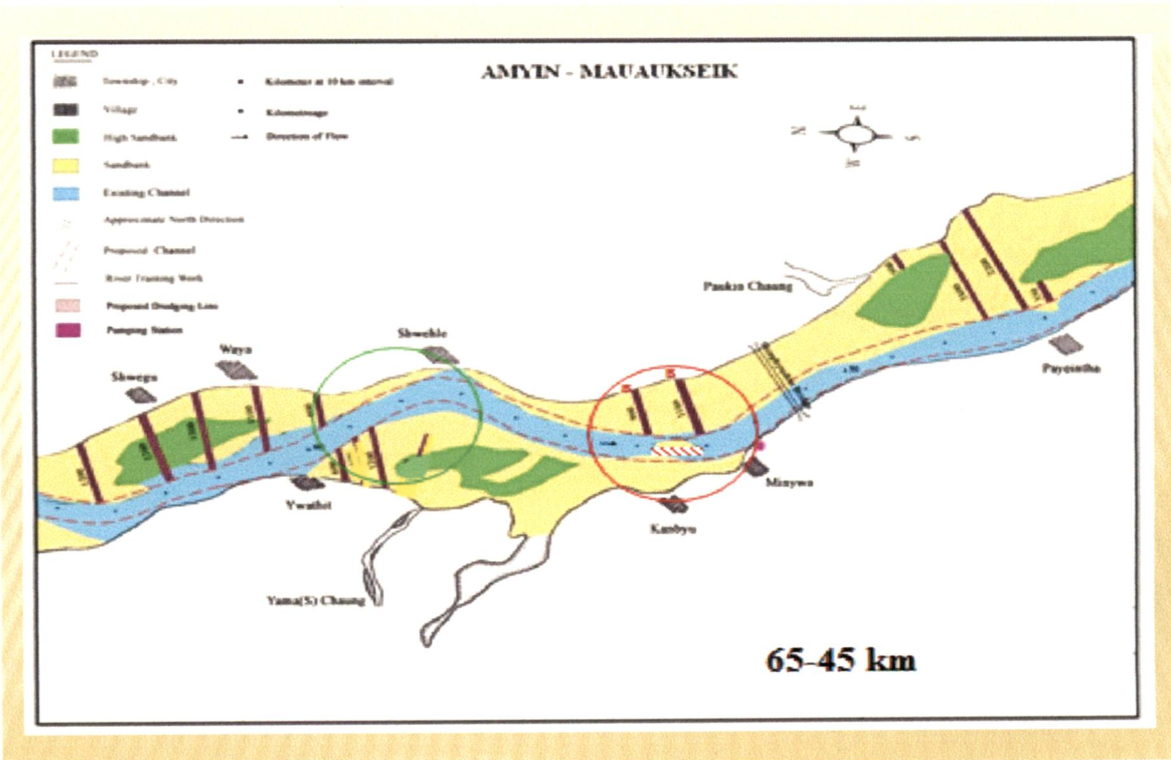


Fig 8.39 Amyin-Mauaukseik (65-45) km

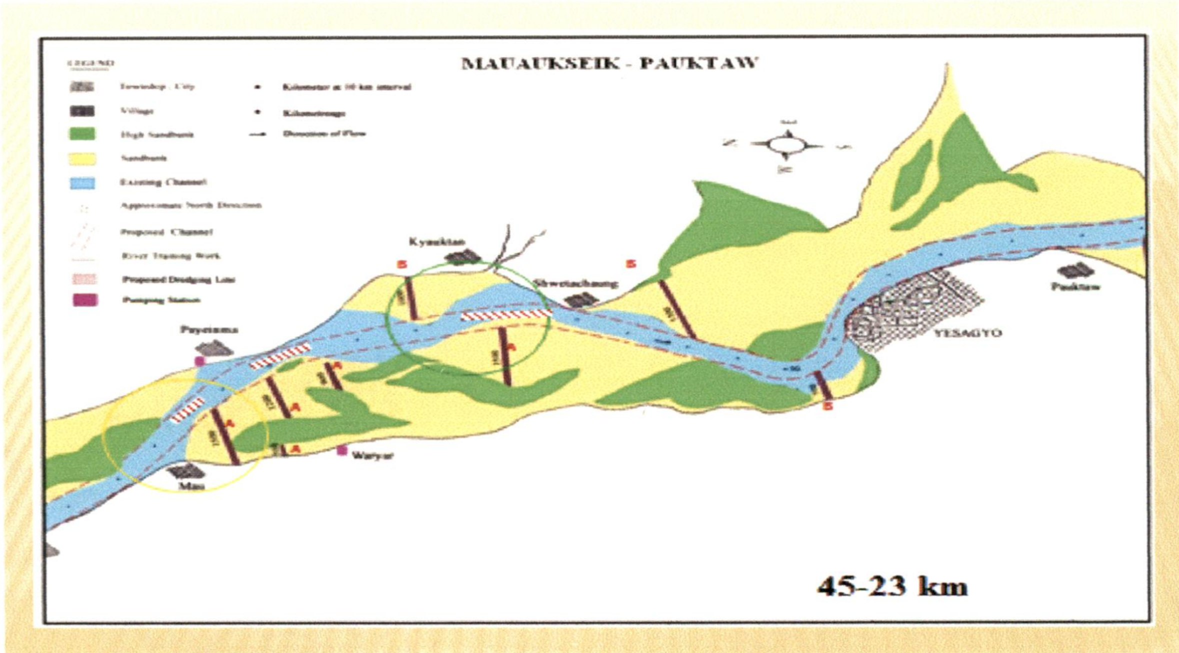


Fig 8.40 Mauaukseik-Pauktaw (45-23) km

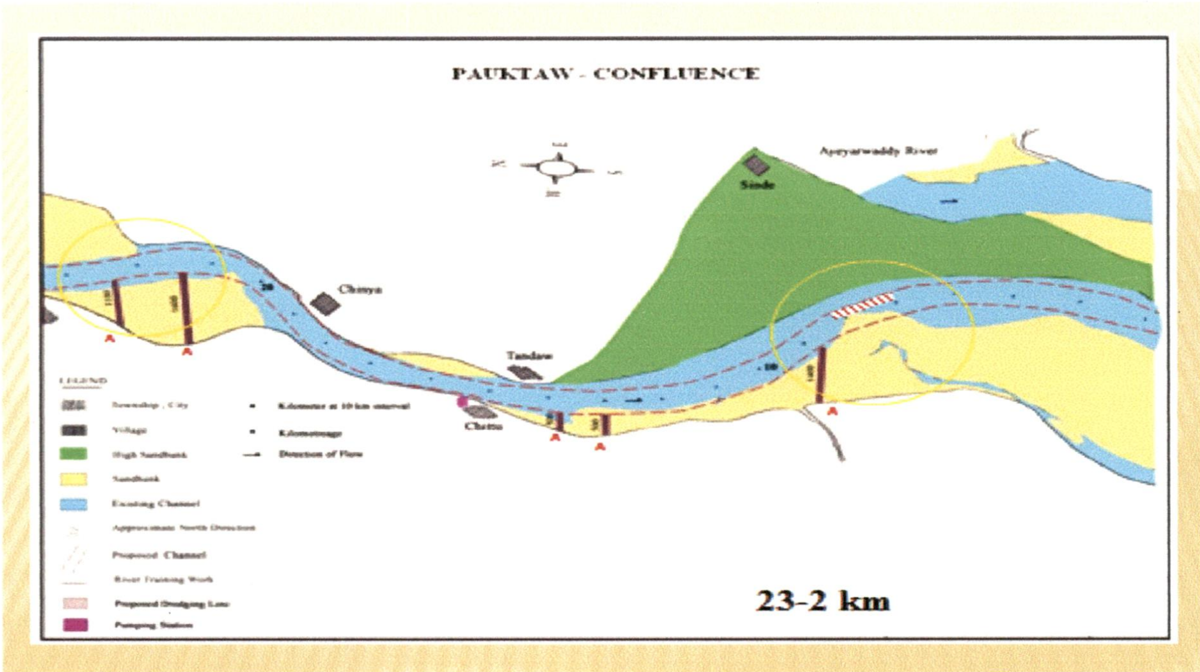


Fig 8.41 Pauktaw-Confluence (23-2) km

Measured and analyzed the finalization management plan of the Chindwin river from Khamti to confluence, it is found that 37 sites occur constraint problem.Maintenance by means of river training works in these 37 locations are also needed between Khamti and confluence to improve the navigation channel of Chindwin river.The total estimate cost of improvement for navigable channel in these 37 constraint is found as kyats 12329.35 million (Rs770.58 million).

CONCLUSIONS AND RECOMMENDATIONS

Based on the study carried out for environment management of Chindwin River, following conclusions are drawn.

1. The River water quality assessment of 650 km long stretch of Chindwin River from Confluence to Homalin was carried out. The National Sanitation Foundation Water Quality Index computed from the data measured and analyzed in March 2012 as well as 2010 and 2011 data (collected). It has been found that in Homalin, Mawliak, Kalawa and Kani Towns, the river water quality is good.

2. Water samples from Monwya waterway (city) were used to compute the National Sanitation Foundation Water Quality Index (NSFWQI).The results of the NSFWQI of Monywa waterway indicate that its water quality is Medium. This is due to the large industrial zone and sediments deposited.

3. It has been found that Iron and Turbidity are increased from year 2010 to 2012.However; Chloride, Total Hardness, Ammonia and Nitrite are decreased. Nitrate, Alkalinity, Fluoride and pH do not change significantly. It is not enough to say that the water quality of Chindwin River become better or worse from only three years data but the result of the National Sanitation Foundation Water Quality Index (NSFWQI) of Chindwin River indicates that its water quality is Medium-Good over the stretch considered. Therefore, the Chindwin River water can be safely used for domestic as well as agricultural lands.

4. The sedimentation and Erosion assessment of 12 km long stretch of Chindwin River of Monywa water way carried out. It is found that in years 2005 and 2010, the maximum sediment loads were about 1000000 tons/day and 900000 tons/day. From the study of different cross section in the selected reach following was observed:

(i) In year2005, Bed Erosion indicates about 1m to 2m erosion at c/s (1) to c/s 9.

(ii) Sedimentation indicates about 0.5 m to 1m deposit at c/s 10 to c/s 12.

(iii) In year 2010 Bed erosion indicates only about 0.2 m from c/s 1 to c/s 9.

(iv) Sedimentation occurs 1.5 m to 2 m deposit from c/s 10 to c/s 12.

5. The Chindwin Catchment area has observed less water volume and more sediment deposit year by year due to the Environmental Impact. The average sediment load is 131 million tons per year. These sediments create sand bars and leads to the change of river morphology.

6. Morphology changes can be checked by using River training structures. Improvement of navigable channel, stable inland water post, achieve adequate depths for maximum loading capacity of the vessels, and prevention of river bank erosion.

7. For Environment Management of Chindwin River, the cost of improvement for navigable channel and bank protection measure have been computed and found to be 208.33 million kyats (Rs 13.02 million)for a stretched of 125 km.

RECOMMENDATIONS

Future Works for Environment Management of the Chindwin River

- Sewage Treatment Plant should be established at Monywa City for treating the diverted sewage.
- Control of the exploring and dredging of gold mining along the Chindwin River.
- Measure and analyze of River water quality parameters two times in a year.
- River training structures should be taken according to the management plan of the Chindwin River.
- Apply the "Conservation of Water Resources and River Law". It will be very effective tool for the environment management of the Chindwin River.

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