CHAPTER 1

INTRODUCTION

1 INTRODUCTION

General

It is well accepted fact that the land and water are the two most precious natural resources. Water supports all forms of life on this earth. It plays a vital role in agricultural and industrial development which sustains human life. Rainfall is the only source of fresh water which available as (i) soil moisture, (ii) stored water in surface storage like reservoirs, tanks, ponds, temple tanks, and in open wells, (iii) groundwater in sub-surface, (iv) sea water, (v) waste water like sewage and effluent.

There is a lot of pressure on the land due to the increasing population from the agricultural, industrial and housing sectors. On the other hand, the land is subjected to soil erosion and land degradation problem, due to rain or wind action and faulty cultivation practices resulting in loss of top soil, which is the place where all nutrients are available. Depending upon the rainfall, its intensities and frequencies, an area becomes drought prone or flood affected.

Hence the conservation, development and management of the land and water resources, which ensures the physical, chemical and biological health of soil profile, are of prime importance. In a predominantly agricultural system, the objective of improving the productivity, profitability and prosperity of the farmers and achieving agricultural development on an ecologically sustainable basis can be attained only when conservation, development and management of the land and water resources are assured. It is of great concern that the world will be facing scarcity of water and it has been predicted by deep thinkers and social workers that the third world war will be because of water rights as well as its quantity. Present scenario of water and different statistical numbers provide greater concentration on diverse alarming numbers of water scarcity at different places in the world, the predicted levels and quantity criteria available from different resources either perennial and seasonal or temporary. Now the emphasis is also given for different soil as well as water conservation measures. As land and water are the major natural resources which demands different methods to conserve it as well as to rehabilitate their resources too.

Present Situation on the Earth

Since older time human inhabitance has always remained more close to the rivers and that's why from the study of various developed and progressive cities of the world even today. But after the development as well as change of various revolutionary machines, mechanism, materials, methods and modifications, in giving rise to pollution level, which in still dominating and also disturbing the natural cycles. Due to human's unthoughtful and selfish thinking, various disasters and calamities are happening throughout the world.

In many developing countries, natural disasters, such as cyclones, floods, landslides, drought, volcanic eruptions and earthquakes, are recurring quite frequently. The Indian subcontinent is the one among the world's most disaster prone areas, whose 54% of land is vulnerable to Earthquakes, 8% of land vulnerable to Cyclones, 5% of land vulnerable to Floods.

It is well-known that above said natural calamities are inter-connected with environmental characteristics like precipitation and its intensity, temperature, pressure variation, wind velocities, etc. With catchment characteristics like slope, soil type, vegetation, etc. Thus, an imaginary cyclic structure in the form of "disaster cycle" appears in one's mind and disaster becomes calamity when it affects lives and properties.

It is so called natural calamities affects considerably to developed countries, while these affect severely to developing countries. As India is a developing country, in recent time it is observed & proved that instead of recovering from the calamities, it is high time to think about the mitigating of them, as prevention is always better than cure. Each and every structural measure consists expenditure or investment of more and more colossal nature of financial funds, snatched out from the pocket of common man in developing country. The time has arrived not only to give emphasis to non–structural measures but to adopt them also with considering each and every characteristics causing disaster, i.e. Catchment characteristics, environmental characteristics, etc., while fighting against these natural calamities.

One of the serious, harmful and most recurring disastrous phenomena, especially recurrent event in India, is nothing but the flood. By definition, a flood may be defined as an overflow coming from some river or from some other body of water. A river may get flooded due to excessive rainfall or excessive melting of snow or due to some other form of ice obstruction in the form of jams. Whenever the water overflows the banks of the river, the river is said to be flooded. In fact, the banks of the stream may vary in height throughout its course and hence, there is no definite stage at which the whole river is about to overflow. However, on important rivers, arbitrary representative warning and danger levels are generally assigned at important locations, and are called flood stages. Apart from the overflow of rivers, the floods may be caused by the failure of some dam, with a sudden release of huge amounts of water, causing considerable damage to life and property.

From the above description, it is very interesting to know that engineers today believe that every dam should be constructed for particular purpose as well as to save the downstream side against the vulnerable effects of flood and its critical and adverse effects against the worst possible cases and situations. Thus, the dam can be taken as one of the important measure to fight against flood and during flood the release decisions in terms of quantity as well carrying capacity of the downstream river or channel have pulled more concentration and attention of scientists and researchers.

Floods are recurrent phenomena in India from time immemorial. Every year few or the other parts of the country are affected by the floods of different magnitude. Different regions of the country have different climates and rainfall patterns and as such it is also experienced that when part of the country is experiencing devastating floods, there is another part of the country at the same time which is in grips of severe drought. Out of the total rainfall of India, about 75% of it is received during the four moths (June to September) due to the South-West monsoon, which is non-uniformly distributed in space as well. India is covered by a large number of river systems. The rivers of Northern and Central zone are prone to frequent floods during the South-West monsoon season, particularly in the month of July, August and September. In the Brahmaputra river basin, floods have often been experienced as early as in late May, while in southern rivers floods continue till November. However, the heavy and intense rainfall is not the only factor contributing to floods. The other causes of flood are inadequate capacity within riverbanks to contain high flows and silting of riverbeds, landslides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, cyclones, snowmelt and glacial outbursts, and dam break flow. With the flood plains which has resulted in more serious nature of damage over the year. The National Flood commission (1980) has reported that out of 40 million hector flood prone area, about 15.8 million ha area has been provided with reasonable degree of protection so far.

There are considerable increases in the occurrence of floods and flood-related damage globally since and during 2006, the flood events accounted for nearly 55% of all disasters registered and approx 72.5% of total economic losses world ride flooding is considered as the world's most costly type of natural disaster in farms of both human causalities and property damage. The annual disaster review indicates that the flood occurrence has increased almost 10 fold during the last 45 years, from just 20 events in 1960, 190 events in 2005 these extreme flood events have caused major damage to property, agricultural produce, industrial production, communication networks, and infrastructure, mainly in the downstream parts of catchment. There area, floods are posing a great concern and challenge to design engineers, insurance industries, policy makers and to the Government as a whole.

In India, about 40 million ha of land is flood prone, which is about 12% of the total geographical area (328 million ha) of the country. The flooding occurs typically during the monsoon season (July-Sept.), caused by the formation of heavy tropical storms, ever decreasing channel capacity due to encroachments on river beds, and sometime due to high tide back water effects from the sea, The Indian sub-continent in general, and the western peninsula in particular, experienced heavy floods during 8^{th} to 11^{th} August 2006 that cause great damage to personal and property.

Surat has been blessed by the flow of Tapi however it has also suffered a catastrophy because of floods in Tapi since historic time. There have been several flood events known to us since late 19^{th} century; which has done great damage to this city. The most severe event was the flood of 2006.

During the flood 2006, overtopping of Tapi River embankments resulted in great damages in different areas like Fulpada, Chhapra-Bhata, Amroli-Uttran, Jahangirpura-Rander, Katargam, Ved-Dabholi, Rander-Adajan etc. covering major important areas of main city including outskirts. In addition to overtopping, back water effect of tide influenced the flood water level and added to the severity of the disaster. This flood caused damages on flood embankment and retaining wall at many places. It also resulted in losses of municipal properties like Roads, equipments, material, street lights, infrastructures, furniture-assets, records in addition to buildings. The flood also resulted in total losses of Indian Rupees 21000 Crores in the year 2006.

This flood event of 2006 was signified concern on flood protection and control as such as frequent event causes extensive damage to public property, infrastructure, agriculture, trade, industries, wages etc. along with loss to private properties and business establishments in general. Keeping in view the serious concern of revised Ukai dam reservoir operation for flood protection & control, it feels the research in that direction for minimization of Tapi river flood impacts –Surat (Gujarat) is of vital importance. Here, an attempt has been made to study the reservoir water level, the dam spillage event and downstream release decision of Ukai Dam, for Surat City of Gujarat state, India. But, before addressing the concern on Ukai dam, the brief introduction has been given, beginning with definition related to flood.

1.1 Flood

Flood is a relatively high stages in a river, markedly higher than the usual, also the inundation of low land which may result (Accordingly to ICID). Dr. Gilbert White stated the facts that: "Floods are acts of Nature; but flood losses are largely acts of man". Flood control starts from "top of hill and ends until single drop of rain stop". Flood Plain means any land susceptible to being inundated by water from any source. Low-lying area along a river, stream, or coast subject to flooding. Area along a river, stream, or coast subject to flooding by the 1% chance flood (100 years) which established the Base Flood Elevation (BFE). Floodway means a Channel of a river or other water course and adjacent land that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

The rivers in India can be broadly divided into the following four regions for a study of flood problem: (a) Brahmaputra River region, (b) Ganga River region, (c) North-West Rivers region, and (d) Central India and Deccan Rivers region.

Central India and Deccan Rivers region

Important rivers in this region are the Narmada, the Tapi, the Mahanadi, the Godavari, the Krishna and the Cauvery. These rivers have mostly well defined stable course. They have adequate capacity within the natural banks to carry the flood discharge except in their lower reaches and in the delta, where the average bed slope is very flat. The lower reaches of the important rivers on the East Coast have been embanked.

This region covers all the Southern States namely Andhra Pradesh, Chhattisgarh, Karnataka, Tamil Nadu, Kerala, Orissa, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have very serious problems except for some of the rivers of Orissa (the Brahmani, the Baitarni, and the Subarnarekha). The delta areas and discharge of rainwater/ heavy rain problems in the wake of cyclonic storms. The Tapi and the Narmada are occasionally in high floods affecting areas in the lower reaches of Gujarat. In Orissa, damage due to floods is caused by the Mahanadi, the Brahmani and the Baitarani, which have a common delta.

Flooding is the only major natural hazard in India which occurs with an unfailing regularity. Some of the most unusual and unprecedented floods have been recorded on different rivers of the subcontinent in the most recent decades. The 1986 flood on the Godavari River, with a peak discharge of about 99,300 m^{3}/s (Nageswara Rao, 2001), is the largest flood on record in the entire Indian subcontinent till date. The recent literature on monsoon floods is dominated by studies on the spatiotemporal aspects of floods, research focused on the impact of monsoon floods on the fluvial systems and remote sensing and GIS-based research that have gained considerable momentum in the last few years.

1.2 Flood Hazard Mapping

Over the review period, work has continued on mapping of the flood-prone areas in India. Several agencies, such as the Central Water Commission – CWC (Flood Atlas of India), the Building Materials and Technology Promotion Council – BMTPC (Vulnerability Atlas of India), and the National Atlas and Thematic Mapping Organization – NATMO (Natural Hazard Map of India), have been involved in the flood-hazard mapping. These and other studies indicate that the areas that are frequently vulnerable to flooding in the country are:

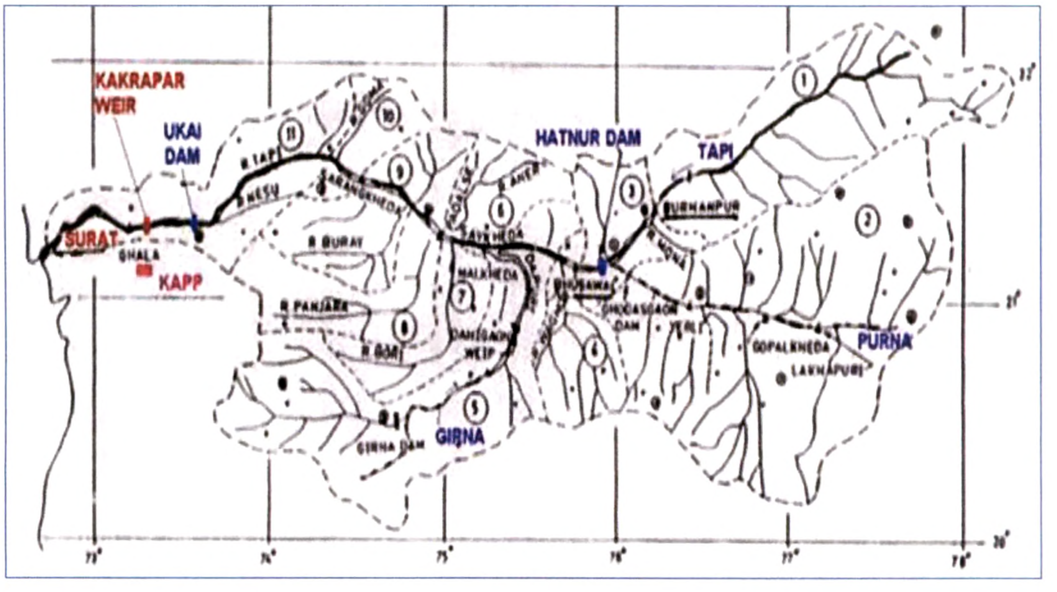
1. Sub-Himalayan region and the Ganga plains.
2. Brahmaputra Valley
3. Punjab Plains
4. Mahanadi-Godavari-Krishna-Kaveri Delta Plains
5. Lower Narmada- Tapi- Mahi Valleys

1.3 Tapi River Basin

1.3.1 Tapi River

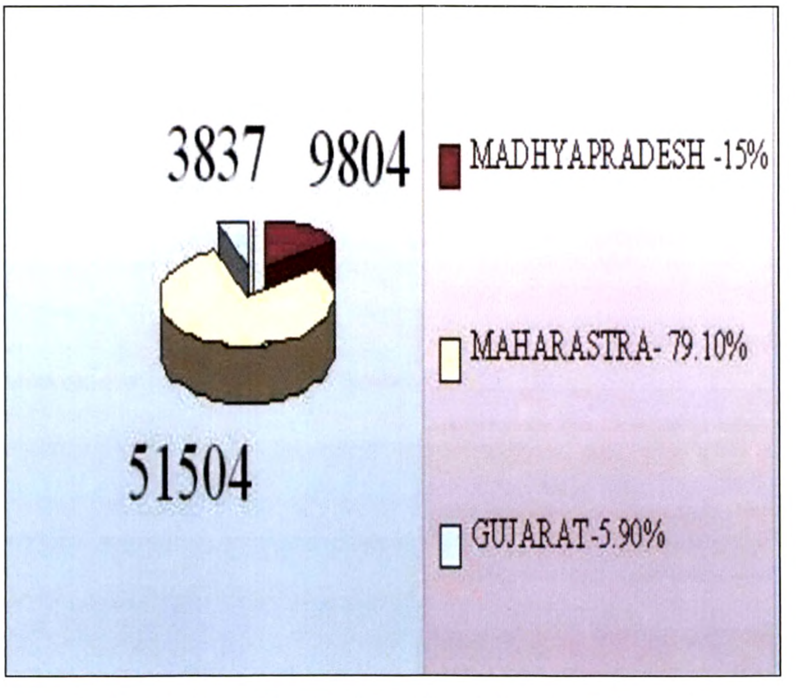
River Tapi is the second largest west-flowing river of India as shown in Plate.No.1.3. Tapi River immerges at Mulati in Betul District of Madhya Pradesh. The river has a total length of 720 km out of which 208 km lies in the Madhya Pradesh, 323 km in the Maharashtra and 189 km in Gujarat as shown in Pie Chart.No.1.1. It ultimately meets the Arabian Sea approximately 19.2 km west of Surat in Gujarat. Tapi River has meandering shape while passing through Surat city. Graph.1.5. shows important role of Purna and Girna tributaries in Catchment area of Tapi River. The river has four district reaches during its course, ultimately meets the Arabian Sea in the Gulf of Cambay approximately 19-2 km west of Surat. In the initial reach of 150 miles (240 km) the river flows through area covered with dense forest of Madhya Pradesh. The river then emerges into a narrow plain, which starts widening out at Burhanpur. In this reach the river has an average bed slope of 1 in 460.The River after gradually widening out near Burhanpur leaves Madhya Pradesh and enters

Maharashtra. It is swelled by several of its large tributaries on both the sides in Maharashtra. The river has high banks and rocky outcrops in the bed below Bhusawal.



(Source: Surat Irrigation Circle)

Plate.1.1 Map of Tapi basin along with Major and Minor Dams for Flood Control



Pie Chart.1.1 Distribution of Tapi Catchment (Sq. Km.)

The length of the river in this section is about 180 miles (288 km). The bed gradients in this reach are of the order of 1 in 1900.In the third section, i.e. between mile 330 (528 km) and mile 380 (608 km) the river enters the hilly country covered with thick forest. Here the hills on the north bank are fairly close to the river whereas the hills on the south bank gradually recede away. In this reach, the river has more or less a uniform section with bed-width of 1000 to 1100 ft. and steep banks. The average slope of the river in this reach is about 1 in 1760.In this last downstream of Ukai, the river enters the flat and fertile lands of Gujarat. The river has low banks and many rapids and falls beyond Kakrapar, where it flows past the town Mandvi and Kathor. Low banks beyond Kakrapar which causes periodic overflow resulting in extensive flood damages. The deltaic conditions are formed many times with increasing zone of flood damages. Between Kakrapar and Piparia, the river drops by about 90 ft. (27.43 m) in length of 16 mile (25.6 km). The river bed is fairly flat beyond Piparia. The river joins the Arabian Sea after flowing past Bodhan, Kathor and Surat.

1.3.2 Basin Physiography

Tapi is the second largest westside draining interstate river basin, which covers large area in the state of Maharashtra besides areas in the States of Madhya Pradesh and Gujarat. The Tapi basin in the Northern most basin of the Deccan Plateau and is situated between North Latitude 22° to 20° East longitudes 72° to 78° approximately. The Saputara range forms its Northern boundary whereas the Ajanta and Satmala hills from its Southern extremity. Mahadeo hills form its Eastern boundary. The basin finds its outlet in an Arabian Sea in the West. Surrounded on the three sides by the hilly ranges, the Tapi along with its tributaries more or less flows over plains of Vidarbha, Khandesh and Gujarat.

1.3.3 River System

The Tapi River rises near Multai in Betul District at an elevation of 752 m. above M.S.L. The total length of this West flowing river from its origin to its outfall into the sea is 724 km. For the first 282 km., the river flows in Madhya Pradesh, out of which 54 km. from the common boundary with Maharashtra State. It flows for 228 km. in Maharashtra before entering Gujarat. Traversing a length of 214 Km. in Gujarat, the Tapi joins Arabian Sea in Gulf of Cambay after flowing past the Surat City. The river receives tidal influence for a length of about 25 km. upstream from mouth. The Tapi receives several tributaries on both banks. There are 14 major tributaries having a length more than 50 km. On the Right Bank 4 tributaries namely, the Vaki, the Gomal, the Arunavati and the Aner join the Tapi. On the left bank, 10 important tributaries namely the Nesu, the Arunavati, the Buray, the

Panjhra, the Bori, the Gima, the Vaghur, the Purna, the Mona and the Sipna drian into the main channel. The drainage system on the left bank of the Tapi is therefore, more extensive as compared to the right bank area. The Purna and the Gima, the two important left bank tributaries together account for nearly 45 percent of the total catchment area of the Tapi. The Purna is one of the principal drains through three districts of Vidarbha namely Amravati, Akota and Buldana. The Gima another Major tributary rises in the Western Ghats and drains Nasik and Jalgaon district of Maharashtra. The Tapi basin has been divided into 5 (five) Sub basins.

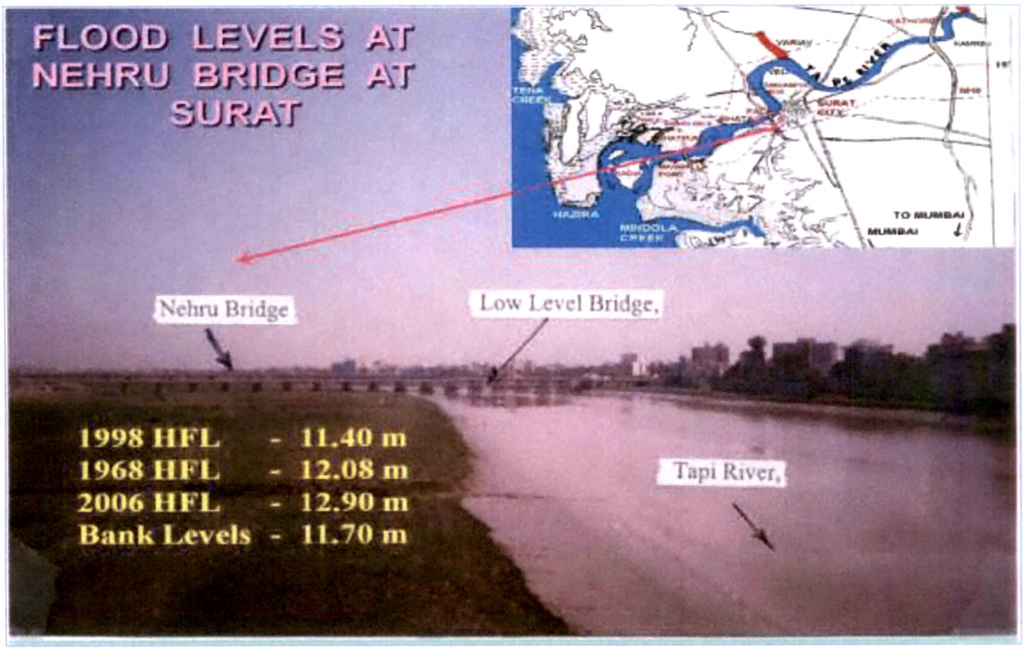
1.3.4 Important Tributaries

The important tributaries of the river; (i) Purna, (ii) Waghur, (iii) Girna, (iv) Bori, (v) Anar, (vi) Panjara, (vii) Buray, (viii) Arunawati and (ix) Gomai. The basin area of all these tributaries lies outside of the Gujarat State. Their respective details are shown in below Table.No.1.4.

Table.1.1 Tapi River-Important Tributaries

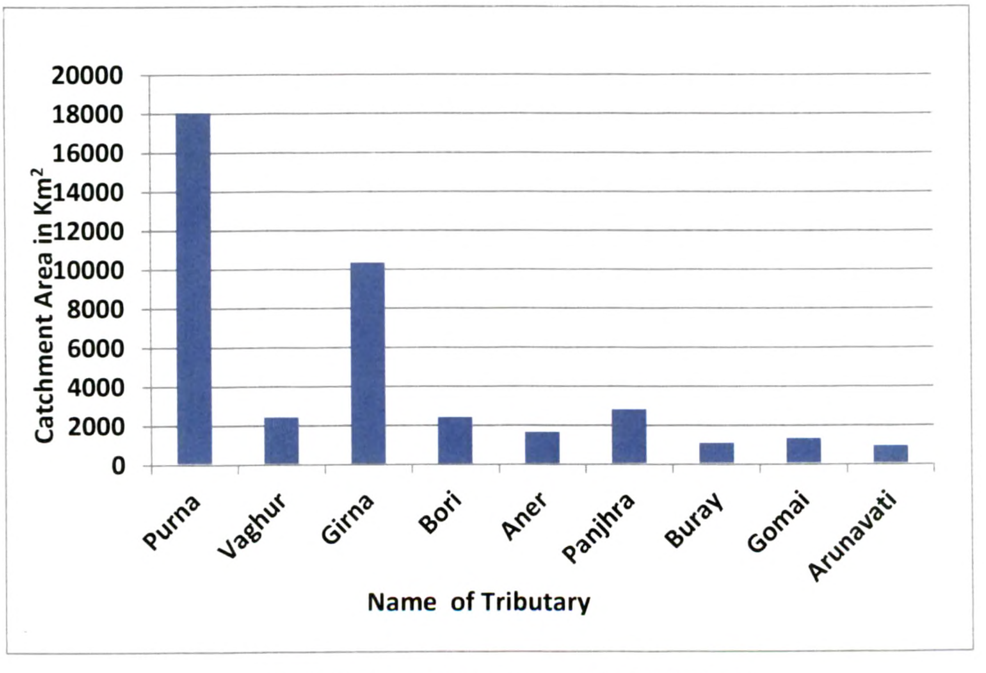
Sr. No.	Name of Tributary	Length in		Catchment Area of tributary in		Name of village at confluence of tributary with Tapi	River length up to confluence from origin	
		Mile	Km	$Mile^2$	Km^2		Mile	Km
1	Purna	215.00	344.00	6949.00	17998.00	Edalabad	176.00	281.00
2	Vaghur	67.00	107.20	939.00	2432.00	Shanked	195.00	312.00
3	Girna	188.00	300.80	4000.00	10360.00	Kathora	222.00	355.00
4	Bori	22.00	35.20	938.00	2429.00	Bahara	241.00	385.00
5	Aner	70.00	112.00	640.00	1658.00	Piloda	242.00	387.20
6	Panjhra	96.00	153.60	1083.00	2805.00	Vadhola	250.00	400.00
7	Buray	65.00	104.00	415.00	1075.00	Sindhkheda	265.00	424.00
8	Gomai	48.00	76.80	506.00	1311.00	Korat	300.00	480.00
9	Arunavati	33.13	53.00	361.00	935.00	NA	NA	NA

(Source: Surat Irrigation Circle)



(Source: Surat Irrigation Circle)

Plate.1.2 Flood Level mark at Nehru Bridge –Surat city for the year 1998, 1968 & 2006



Graph.1.1 Catchment Areas of Tapi Tributaries

1.3.5 Rainfall

The storm in the Tapi catchment is caused by the depressions originating from the Bay of Bengal. The monsoon generally breaks out during the third week of June. There are heavy rain storms only in lower catchment from the middle of August to the end of September. About 90 per cent of the rainfall precipitates during the monsoon period extending from June to October. The floods are generally caused by the storms travelling roughly from east to west. Since the river also travels from east to west, synchronization of storms with flood waves increases the flood intensity. The special characteristic of this catchment is that the heavy rain storms occur from middle of August to end of September. Practically all the heavy floods in the river have been during this period only. There exists a good network of the rain gauge stations in the catchment area. There are about 80 well distributed rain gauge stations installed in the Tapi basin above Kathor. The available rainfall records for the period over 69 years (i.e. from 1891 to 1959) were taken for the hydrological studies of the Tapi basin. The mean rainfall during the monsoon period was worked out by taking the arithmetical average of all the rain gauge station in the catchment area. During project planning the weighted mean rainfall during the monsoon period was worked out by Thiessen's polygon method. The average value worked out is 29.84 inch (758 mm) whereas the maximum rainfall of 46.01 inches (1168 mm) in 1944 and the minimum rainfall of 10.11 inches (257 mm) in 1899. The average Monsoon rainfall of last 10 years including 1998 in the Tapi Basin is 897 mm. Average Rainfall of Upper Tapi upto Hathnur (excluding Purna) is about 1013 mm. and for Purna sub basin 746 mm. and for Middle Tapi and Lower Tapi is 749 mm. and 1214 mm. respectively. Although the Monsoon withdraws during the first week of October, about 5 to 7 % of the Monsoon rainfall is received during this month and hence has been included in the monsoon months.

1.4 The Ukai Multipurpose Project

The Gujarat government does the development of the lower Tapi in two stages. The Kakrapar weir and its canal system having estimated cost of Rs.18 crores form the first stage. This project was commissioned in the year 1954 and the canal system provided seasonal irrigation facilities 2, 27,530 ha, from the runoff of the river. The second stage is the Ukai multipurpose project with estimated cost of Rs.136 crores. The dam is located across the river Tapi about 29 km upstream of the Kakrapar weir. A barrier is constructed across Tapi River in form of an Ukai dam, water gets stored on upstream side of the dam, forming a pool of water called as Ukai dam reservoir. The quality of water stored in such a reservoir is not much different from that of a natural lake. The water so stored in a given reservoir during rainy season can be easily used almost throughout the year, till the time of arrival of the next rainy season, to refill the emptying reservoir again.

Tapi river reservoir planned and constructed to serve not only one purpose but various purposes together is called as Ukai Multipurpose Reservoir. The purposes of the project are listed below:

(1) Irrigation

(2) Power generation

(3) Partial flood control

(4) Fisheries development

Ukai is the largest multipurpose project under taken by the state and only next to Narmada project, so far as benefits are concerned. Ukai forms the terminal reservoir harnessing nearly half the water of the Tapi River. The Ukai dam work were geared up in a big way from 1966 onwards and essentially completed in 1972. Late Prime Minister Smt.Indira Gandhi on 29th Jan. 1972 performed opening ceremony. Nowadays, Ukai project site may be developed as a one of the best tourist resorts by taking advantage of esthetic views and water storage of reservoir along with green forest covered land escape around it, 112 km long Ukai reservoir is surrounded by pleasant green and blue hills with dense deciduous forest creating beautiful scenery. Ukai is a multipurpose reservoir and is designed to cope with projected floods of 49470 m^3/s (17.47 lac cusecs) and probable maximum flood of 59880 m^3/s (21.16 lac cusecs). The provided spillway has a capacity of 16.34 lac cusecs. The Ukai Multipurpose project forms the terminal reservoir on the Tapi River harnessing nearly half of the river flow for benefits of irrigation, hydropower generation and other facilities. The Ukai dam, located about 29-km upstream of the Kakrapar Weir was originally cleared by the Planning Commission in 1961, and essentially completed in 1972. The catchment area up to the dam site is 62225 Sq.km, about 83% of which lies in the State of Maharashtra, 15.5% in M.P. The drainage area within the Gujarat State is only about 1.5%. Salient features of Ukai dam listed below.

1.4.1 Salient Features of Ukai Dam

A. Location of Dam

• State	Gujarat
• District	Surat

• Taluka	Fort Songadh
• River	Tapi
• Village	Ukai
• Latitude	21° 15′ N
• Longitude	73° 35′ E

B. Hydrology

C. • Catchdrologment Area

(a) At Ukai	62225 Sq. Km.	(24025 Sq.mile)
(b) At Kakrapar	62308 Sq. Km.	(24057 Sq.mile)
(c) At Kathor Bridge	63823 Sq. Km.	(24642 Sq.mile)
(d) At Surat	64100 Sq. Km.	(24749 Sq.mile)
• Mean annual rainfall in the water shed	785 mm	
• Maximum annual rainfall in the watershed	1191 mm	
• Minimum annual rainfall	270 mm	
• Mean annual runoff at the dam site	17220 Mm^3	(14 Maft.)
• Observed maximum flood at dam (Aug.1968)	42470 m^3/s	(15 lac cusecs)
• Observed maximum dry weather flow	0.03813×16^6	
• (a) Design floods	49490 m^3/s	(17.48 lac cusecs)
(b) Probable floods	59920 m^3/s	(21.16 lac cusecs)
• Max. Regulated outflow from the reservoir	24100 m3/s	(8.50 lac cusecs)
• Mean annual rainfall in the command		
• North of Tapi River	889 mm to 1145 mm	

• South of Tapi River	1524 mm to 2032 mm
• 11. 75% Dependable Annual Yield	12750 MCM (9.18 Maft.)

D. Reservoir

• Gross storage capacity at FRL.	8511 MCM (6.90 Maft.)
• Dead storage below R.L. 82.296 m	1142 MCM (0.926 Maft.)
• Live storage	7369 MCM (5.974 Maft.)
• Full Reservoir Level	105.156m (345 ft)
• Water spread at R.L. 105.156 m	60095 ha.
• (a) Cultivated land submerged	30350 ha.
(b) Other land submerged	7485 ha.
(c) Forest land submerged	22260 ha.
• Village affected by submerged	170 no.
• High Flood Level (HFL)	106.99 m (351 ft.)
• Length of Reservoir	112 km (70 miles)

E. Dam

• Length of dam	
(a) Length of masonry section incl. spillway	868.83 m
(b) Length of earth dam section	4057.96 m
Total Length	4926.79 m
• Maximum height of main dam	
(a) Earth dam above river bed	68.58 m
(b) Masonry dam above deepest foundation	80.772 m
• Total earth work	23240×10^6 m^3

• Total quantity of stripping	4950×10^3 m^3
• Total quantity of masonry concrete	1484×10^3 m^3
• Top of dam	111.252 m
• Road width of spillway	6.706 m

F. Spillway

• Crest level of spillway	91.135 m
• Length of spillway	425.195 m
• Top of Crest level	105.461 m
• Type of gates	Radial
• Size of Gates	15.545 m X 14.783 m (51×46ft)
• No. Gates	22 Gates
• Discharging Capacity from all 22 gates	
(i) At FRL - 345 ft	13.37 lac cusecs (37,859cumecs)
(ii) At HFL – 351 ft	16.34 lac cusecs (46,269cumecs)

G. Power section (Hydro)

• Size of penstock	4 No.s, 7.01 m Dia
• Installation of 4 units of 75 MW each	300 M.W.
• Generation at 35 load factor	193 M.W.
• Annual energy (Units)	670×10^6 K.WH

H. Canal Bed Power House

• Size of penstock	3.96 m × 2.05 m
• Installation of 2 units of 2.5 MW each	5 M.W.
• Type of hoist	Hydraulic hoist

• Discharge through each unit	550 cusecs

I. **Irrigation Requirement**

• Direct Ukai Left Main Canal	0.59 Maft.
• Kakrapar Left and Right Bank Main Canal	2.62 Maft.
Total	3.21 Maft.

1.4.2. Ukai Dam Reservoir

The reservoir up to its FRL of 345.0 ft (105.15 m.) has a live storage capacity of 7369 MCM with a water spread of about 600 sq.km and maximum length of about 112 km. The reservoir is expected to attain a maximum level of (MWL) 351.0 ft (106.99 m) while passing the Probable Maximum Flood (PMF) of 60,000 Cusecs.

1.4.3 Dam and Spillway

The Ukai dam is a composite dam with a maximum height of about 80.7 m above its deepest foundation. The total length of dam is 4927 m. of which, 4058 m is earth dam of zoned fill type. Masonry gravity dam, including the 425 m long spillway and the power dam occupies the remaining length. The spillway, located in the left bank of the river, is provided with 22 radial crest gates of 51 x 48.5 ft (15.55 m x 14.78 m) size. The maximum discharge capacity of the spillway at MWL is 46,270 Cumec (16.34 lac cusec). The corresponding capacity at FRL is 37,860 Cumec (13.37 lac Cusec). All the radial gates are operated by electric motors supplemented by manual operation.

1.4.4 Power Facilities

The dam toe powerhouse located on the left side of the spillway is equipped with 4 units of 75 MW each, and generally operates as a peaking station. The Canal head powerhouse has 2 units of 2.5 MW each, to provide incidental power generation through irrigation withdrawals into the Ukai Left Bank Canal. The water released from the dam toe powerhouse is picked up at the Kakrapar Weir, for firming up the irrigation in the Kakrapar system.

1.4.5 Project Benefits

The estimated 75% dependable yield at the Ukai dam site is 11,350 MCM (9.2 MAF). The Gujarat State is allotted 3947 MCM of the water, making its share as 34.80%, which is made available through storages at the Ukai Dam site. The storage extends;

- Irrigation to 1, 52,000 ha. Under the Ukai left and right bank canals
- Firming up irrigation in 2, 27,000 ha. Under the Kakrapar canal system and
- Generation a maximum of 300 MW of hydropower for 8 to 10 hours in a day to meet the peak demands.

Ukai Reservoir Project also affords a partial flood control benefit to downstream areas and the Surat City, a highly industrialized city of Gujarat. For the purpose of flood protection and flood moderation, a reservoir operation schedule was prepared by CWC, New Delhi, for the monsoon months in 1975. By partial flood moderation, Ukai Reservoir affords protection against heavy floods to an area of about 827 Sq.km. Later on, by constructing flood embankments on both the banks of the river Tapi between Kathor and Surat provides protection to an additional area of 230 Sq.km. Thus, the Ukai Reservoir and the flood embankments together provide protection to area of 1057 Sq.km. with the result that about 2 million people residing in rural areas and Surat City are protected from floods. The floods embankments are designed for a uniform river discharge of 24,070 Cumec (8.5 lacs Cusec) based on the assumption that the maximum regulated outflow from the Ukai Reservoir would be of that order. The embankments are, however, stated to be safe up to a discharge of about 28,317 Cumec (10.0 lac Cusec) with some encroachment of the free board. Besides these direct benefits, Ukai reservoir is also used for fisheries development. Area development through tree plantation at and around Ukai reservoir is under progress.

1.5 Flood situation in Surat city

Subsequent to construction of Ukai dam large urban developments have taken place along Tapi river banks Singanpur and Hazira. The Government of Gujarat (GOG) has developed an industrial zone at Hazira along RELIANCE, NTPC, HPCL, GAIL, ESSAR, KRIBHCO and L & T have established their plants in this area, The natural ground levels in this zone about 4.0 m to 5.0 and some urban development projects and industries have adopted the finished ground levels as low as 5.50m with the moderation of flood at Ukai reservoir, no major floods were experienced at Surat and Hazira till 1994,During

1994,1998 and 2006 floods of the order of 14870 m^3/s (5.25 lac cfs), 19820 m^3/s(7.00 lac cfs) and 28315 m^3/s (9.10 lac cfs) were experienced shown in table no-1 and 2 large portion of Surat area was inundated along with large scale flooding at Bhata, Bharatpur, Surat and surrounding area, there were heavy damages of industrial and urban properties costing 21000 crores in 4 days.

The Lower Tapi Basin (LTB) receives an average annual rainfall of 1376 mm, and these heavy downpours result in devastating floods and water logging downstream. The LTB contains the Ukai and Kakrapar reservoirs and part of the flow is diverted for irrigation from Kakrapar weirs. The major crops grown are cotton and maize, followed by soybean. The prevailing land use is mixed forest, agricultural land, rural and urban settlements. The topography in LTB comprises narrow v drainage valleys and gently sloping ground.

The Surat city is usually affected by two types of flood: (i) Tapi River flood (ii) Khadi flood. Tapi river flood occur due to heavy inflow of rainfall in LTB while Khadi flood due to heavy rainfall in city and high tide effect of sea, The main reasons for flooding in LTB are the heavy rainfall and discharge due to high water levels from major control point Ukai Dam. Therefore the flood problems of the river system are inundation due to overflowing of the banks, in adequate drainage capacity of the river, congestion at point of condense, and an excessive silt load factor.

It is estimated that a single flood event In the lower Tapi basin, a river stretch between the Ukai dam and Arabian sea, during 7-14 August-2006 resulted in 300 people being killed and approx Rs. 21,000 crore (US $ 4.5 billion) of property damage-human life came to a stand-still for almost two weeks in Surat. The inflow increase sharply from about 50000 cusecs in second half of 5th August to about 10.6 lac cusecs in the second half of 7th August 2006. This increase was indeed sharp occurred over a period of 48 hours only. The flooding of Surat city and other downstream areas due to sudden release of water high outflow over a long period, from the Ukai dam. The out flow could have been reduced with proper operation of the dam, thus avoiding the flood.

This was no act of nature but a situation wholly created by the fact that for as long as 24 hours after the inflow in the Ukai reservoir started increasing sharply, no major releases of water were initiated from the dam and water level in the reservoir was raised up to 340ft. It was this long delay in releasing water from reservoir that created a situation where large quantities of water had to be subsequently released at high rate of 8-9 lac cusecs, causing great havoc in Surat and downstream areas. Strong indications say that faulty urban planning, few storm water drains, encroachment on traditional water bodies and improper operation of upstream dam aggravated Surat floods situation.

The nation has paid huge costs in creating these reservoir capacities and negligence of the dam operators is leading to disastrous consequences which are entirely avoidable.

Surat is highly developed thickly populated cosmopolitan character city with fall of various activities going on day and night. Any natural calamity which causes loss of lives, properly and infrastructure along with effects on industrial processes going on has serious impact on economy of the state. Therefore, it becomes highly necessary that flood events are studied and analyzed properly in order to propose adequate flood control policies & protection measures in time to come. Many research organizations like Central Water Commission (CWC), Gujarat Engineering Research Institute (GERI), Central Water Power and Research Station (CWPRS), Central Design Organization (CDO), are already involved in study of flood phenomena of Tapi River. It appears to be of vital importance to initiate studies as an extension in lights of finding of such studies, using modern computer, model & software technology. Objective is to develop an "Optimization Process" to minimize the Tapi river flood impacts – Surat (Gujarat).

1.6 Impacts of Past Floods in Surat city.

1.6.1 Damages and Losses due to Flood -Aug' 2006

1.6.1.1 Damages on Flood Embankment and retaining wall

During the flood event 2006, overtopping of Chhapara bhata, Variav, Jahangir pura-Rander, Katargam-Ved-Dabholi, Adajan, Siganpure Weir Left Bank (u/s & d/s), Right Bank at Rander, Tunki, Bharimata, Jahangirpura ,Hari Om ashram, Narayan nagar, Hanuman tekri, Borwada, Judgesbunglow, Amroli were observed.

1.6.1.2 SMC Losses

Municipal Properties within Surat Municipal Corporation area Building & Civil Work, Roads, Equipment/ Material, Street light, Infrastructure, Furniture/ Assets, Records, Vehicles Total Losses found in Lacs Rs. 12541.67.

1.6.1.3 Other Losses

- Extensive damage to public property and Infrastructure.
- Extensive damage to agriculture.
- Loss of man days, and major losses to trade, industries & commerce.
- Loss of wages for wage earners in Surat and Hazira twin cities.

• Damage to private property - houses, hutments and business establishment.

1.6.1.4 Estimated cost of Damages in Lacs

Particulars	Short Term	Long Term	Total
K'par L.B.C.	20.22	27.69	47.91
K'par R.B.C.	600.00	279.00	879.00
Ukai R.B.C.	52.00	69.00	121.00
Drainage Sy.	680.00	820.00	1500.00
Tapi Flood	1100.00	28000.00	29100.00

1.6.2 Disaster Management of Tapi river flood '2006 - Surat

1.6.2.1 Organizations in the Field of Flood Management

• State Flood Control Departments

• Central Water Commission

• Ganga Flood Control Commission

• Brahmaputra Board.

Measures help greatly in mitigation of distress and provide immediate relief to the population.

1.6.2.2 Flood Areas of Operation at Surat during Flood 2006

Chowk Bazar, Anand-Mahalroad, Tadwadi, Palanpur Patia, Rander road, Umra, Piplod, Singanpure, Katargam, Amroli, Kadarsha ni nal, Ved, Karada, Variav, Chhaprabhata, Kosad, Hazira road, Bhatha, Pal, Rudarpura, Bombay colony, Hidayat nagat, Bombay colony, Rabia manzil.

1.6.3 Relief and Rescue

1.6.3.1 Documentation

• Reported Human Deaths: 155 nos.

• Compensations Paid: Rs. 7.60 Lacs

• Cash doles paid: Rs. 561 lacs

• House-hold aid: Rs. 1643 lacs (No. of families – 1, 40,804)

• No. of Survey teams: 1164

• No. of Payment centers: 200

Post flood immediate actions taken by defence and SMC Shown in Table.No.1.5.

Table.1.2 Post Flood Immediate Actions

Date	Rescue		Relief				Water Tanker	
	Defense forces	SMC	Food (no. of packets)	Water (bottle)	Milk (liters)	Medical Aid	No. of Trips	Quantity in Lit.
Total	11964	13867	1951852	545400	75000	274657	3844	34596000

1.6.3.2 Environment Engineering Works and Restoration Services

Solid waste disposed: 2.39 lacks Metric ton, Water Supply, Drainage, Electricity Torrent, Street Light, Domestic and Industrial Gas Supply restored within 96 hours.

1.6.3.3 Earth Moving Equipment Deployed

JCB/Loader: 179, Dumber/Tipper: 893, Tractors: 256, Manpower Deployed: 8227nos.

1.6.3.4 Flood Protection Works

Flood protection works is carried out for short and long term basis for newly construction as well as strengthening of existing earthen embankment scheme by SMC and SIC of costing 776 crores. Earthen embankments are protected by pitching as well as retaining wall sometimes combination of both. Typical earth dam section revised by brick masonry retaining wall. Construction of Sluice regulator on small Khadies / Kotar carried out from Kathor to Hazira.

1.7 Causes of Tapi River Flood – 2006

- Heavy precipitation and continuous downpour in lower Tapi basin.
- Unexpected outflow from Ukai (amounting 9 lacs cusecs for almost 24 Hours).

- Due to Slums encroachment from 43,185 nos. of hutments identified on right and left side of Tapi River near Vivekananda and Nehru Bridge by SMC, which resulted reduction in waterway.
- 1.9 m afflux due to Singanpur weir construction extends up to Kathor for 4 Lac Cusecs.
- Non completion of newly earthen embankment construction and strengthening and rising of existing works.
- Siltation due to geology and tide. Island created by silting between Vivekanand and Sardar Bridge, d/s of Singanpure weir.
- Tide effect at the time of flood period.
- Other construction activities near banks of Tapi development of industries in Hazira area.
- Reduction in capacity of Tapi River at Surat from 8 lacs cusec to 4 lacs.

1.8 Research Study Area and Objectives

1.8.1 Ukai dam

Ukai is the largest multipurpose Project undertaken by the State. It is next to Narmada Project, so far as benefits are concerned. Ukai forms the terminal reservoir harnessing nearly half the water of the Tapi. Development of Tapi River Valley 2nd stage Ukai reservoir project in the year 1972.

1.8.2 Surat City

Area of City: 334.23 Sq.km. total population: 28, 77,241(census 2001), total 7 nos. zone shown in Plate 1.6. Average Rainfall: 1894 mm, major rivers: Tapi, major dams: Ukai, Kakrapar. Major flood disaster started from the year 1959,1968,1978,1979, 1994, 1998 and 2006 causing heavy loss of human, property, industries, dwelling etc. in Surat city.

1.8.3 Research Study Area

River Tapi flows through the city and meets the Arabian Sea at about 16 km from Surat. Surat is 90 km in downstream of Ukai Dam over river Tapi. Five main and several minor creeks pass through the city and meet river Mindhola in south of Surat. Schematic diagram of Tapi creek channel network as shown in Plate.No.1.7 reflects its connectivity, bifurcation and interconnections.

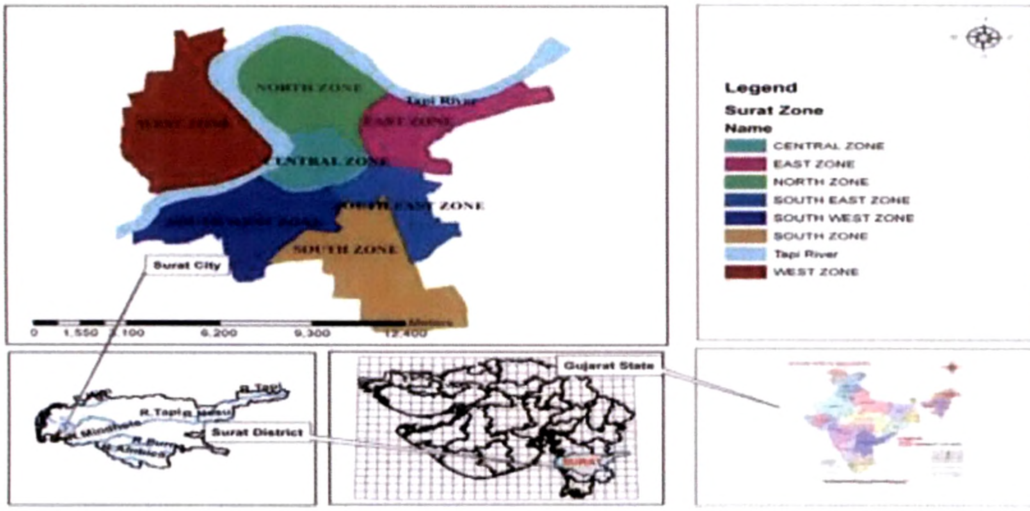
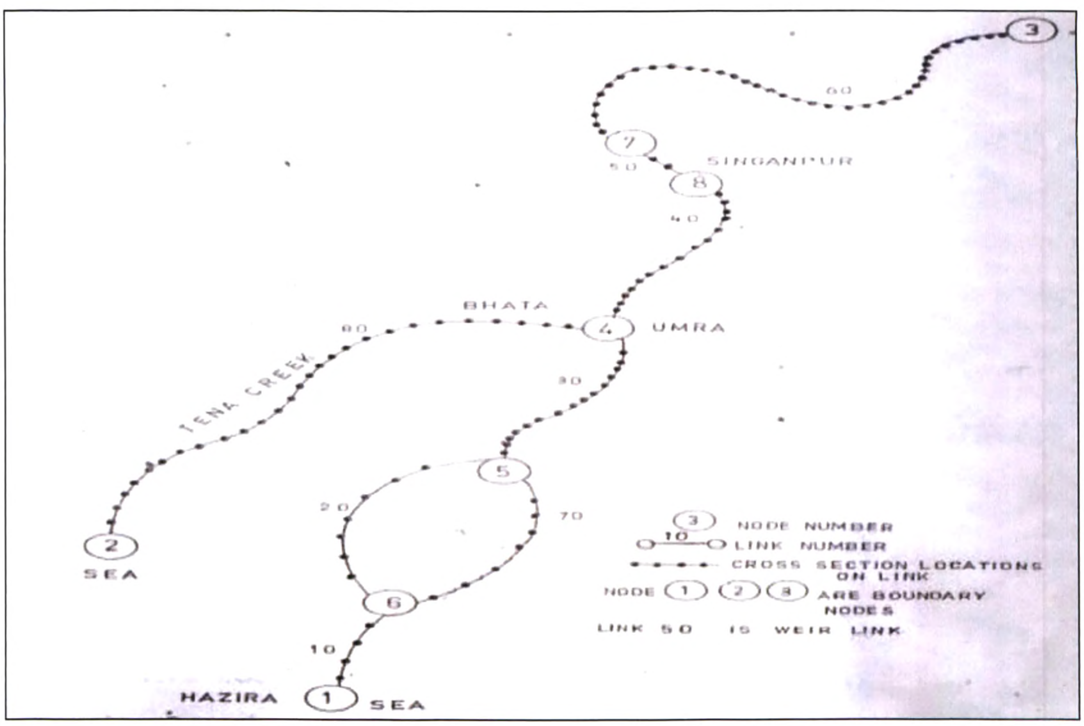


Plate.1.3 Location Map of Study Area

(Source: Surat Irrigation Circle)



(Source: Surat Irrigation Circle)

Plate.1.4 Schematic Diagram of Tapi Creek Channel Network

Study area of Surat city Cartosat –1 (image data) fore and after a scene of town mentioned in below Table.No.1.6.

Table.1.3 Information of Fore and After Scenes

Sr. No.	Fore Image	After Image
1	Satellite ID=Cartosat-I	Sat. ID=Cartosat-I
2	Date of Pass: 20th March 2012	Date of Pass: 20th March 2012
3	Sensor= PAN_AFT	Sensor = PAN_FORE
4	Path = 0511	Path = 0511
5	Row = 0299	Row = 0299
6	Resolution Along = 2.5 m	Resolution Along 2.5 m
7	Resolution Across = 2.5 m	Resolution Across = 2.5 m
8	No. of Scans = 12000	No. of Scans = 12000
9	No. of Pixels = 12000	No. of Pixels = 12000

(Source: NRSC, Hyderabad)

1.8.4 Research Objectives

Followings are the objective of present research work.

- To suggest a revised reservoir gate operation schedule for Ukai Dam after 1998 and 2006 flooding events.
- To prepare an appropriate model which shows the flood water surface profile for Tapi River in each flood frequency and different scenario of flood, while passing through Surat City and meets Arabian Sea.
- Determination of actual Tapi River flood carrying capacity along with development of Surat.
- Prepare a Flood Forecasting Based on Real time Operation program.
- Flood frequency probability and flood routing analysis, Diversion of Tapi river flood study.

- Recommend probable/optimal solutions to minimize the Tapi River flood impacts- Surat (Gujarat).

1.9 Necessity of Present Study

As stated earlier Surat is one of the most important cities of Gujarat. It is a locus of trade and economical activities along with varieties of industries starting from Cotton industry, Diamond industry, Sugar industry to Petrochemical industries located in or around nearby area. By the proximity to Metro City of Mumbai has increased economic and industrial activities in multifold.

In view of above scenario, it is observed that Surat is a highly developed, thickly populated cosmopolitan character city with full of various activities going on day and night. Any natural calamity which causes loss of lives to property & infrastructure along with effects on industrial processes going on has serious impact on economy of the state. So, it becomes highly necessary that past flood events must be studied and analyzed properly in order to propose adequate flood control & protection measures in time to come.

Many research organizations like Central Water Commission (CWC), Gujarat Engineering Research Institute (GERI), Central Water Power and Research Station (CWPRS), is already involved in study of flood phenomena of Tapi River. It appears to be of vital importance to initiate studies as an extension in lights of finding of such studies, using historical data, modern computer, model and software technology which can minimize Tapi river flood impacts-Surat (Gujarat).

1.10 Methodology Adopted

1. Development of simulation model to simulate reservoir operation using monthly available historical inflow. Month end storage and canal releases obtained from simulation. Month end storage overlaid oval a simulation period. Ultimately, calculation of rule level and flood absorption volume for revised Ukai Dam reservoir operation.
2. Studying river behavior, tidal effect, historical flood impact, and rain fall contribution in flood. Calibration and validation of ARIMA-1D Mathematical model by comparing observed past flood water levels.
3. Preparation of river cross section with respect to caring capacity while river flow through Surat city.

4. Preparation of excel program for flood Forecasting Based on Real Time Reservoir Operation (FBRO).
5. Determination of peak flood frequency probability by California method.
6. Preparation of flood risk and flood hazard map for whole Surat city by using Cartosat data image and software (MicroDEM for Image Processing and DEM processing/Eshayal Smart for GIS Map Window 4.5 for Stereo Data Processing and Watershed Delineation).
7. Interpretation and compilation of all results of analysis for optimal solutions for minimization of Tapi River flood impacts – Surat.