

**INTRODUCTION**

## 1

## INTRODUCTION

Water is vital to life and development in all parts of the world. Although water is very important key element for all activities related to life, it is scarce (Subramanya, 1994). To assess the total water storage on the Earth reliably is a complicated problem because water is so very dynamic. It is constantly changing from liquid to solid or gaseous phase and back again. Current estimates are that the Earth's hydrosphere contains a huge amount of water about 1386 million cubic kilometers. However, 97.5 % of these amounts are saline waters and only 2.5 % is fresh water. The greater portion of this fresh water (68.7 %) is in the form of ice and permanent snow cover in the Antarctic, the arctic, and in the mountainous regions. Next, 29.9 % exists as fresh ground waters. Only 0.26 % of the total amount of fresh waters on the Earth is concentrated in lakes, reservoirs and rivers systems where they are most easily accessible for our economic needs and absolutely vital for ecosystems (Patel and Shah, 2008). Dividing the water resources of a region into surface water and ground water is often artificial or questionable. The surface runoff, in certain cases contributes to the groundwater or in yet-some other cases ground water emerges at the ground surface becoming surface flow. The above considerations apply not only to water quantum of the region, but also to water quality. Contaminated surface water may easily reach and pollute ground water (Dalwadi, 1998). Surface water sources are limited in nature. Ground water is a precious and the most widely distributed resource of the earth. It is the largest source of fresh water on the planet excluding the polar icecaps and glaciers. It gets its annual replenishment from the meteoric precipitation (Raghunath, 1997). Ground water systems are dynamic in nature and adjust continually to short term and long term changes in climate, ground water withdrawal and land use (Mohapatra et al., 2006). India is endowed with substantial water resources. The basic source of water is precipitation (Water Technology Centre, IARI, 1983).

There is tremendous increase in the Global water usage in different sectors like agricultural, industrial and domestic. However there is considerable variety how these resources are used in different parts of the World. The availability of fresh water is going

to be the most pressing problem over the coming decades. Water in India is not only a usable commodity but a very sentimental and religious value is attached to it, spiritual cultures of India have mushroomed on the banks of various holy rivers, abundance and greenery of India had attracted many invaders. Increasing demand and decreasing availability of fresh water is bound to result in water scarcity in near future. It is now widely accepted that the solution to the water scarcity lies only in efficient use of available water by good water management. The river runoff is one of the main sources of fresh water which meets various water demands. Though it is continuous and renewable by the hydrological cycle, river runoff represents the dynamic component of the total water resources, in contrast to the less mobile volumes of water contained in lakes and groundwater reservoirs.

### 1.1 Rivers of Gujarat

Gujarat popularly known as the “Garden State of India” is noted for the fertility of its soils and prosperity of its agricultural class. Gujarat is a land of rivers. Its land is fertile. Its agriculturists are diligent and resourceful (Directorate of Information, GOG, 1960).

The state of Gujarat is located on the northwestern shores of India, lying between N 20° 01' and 24° 07' latitudes and E 68° 10' and 74° 28' longitudes; covering a land area of 1, 95, 984 sq.km. The agricultural area of the state is 95, 000 sq.km. It has a coastline of 1663 km, which is the longest amongst all the states of the country and is 21.3% of the total Indian coastline of 7517 km. The coastline of Gujarat has two indentations, the Gulfs of Khambhat and Kachchh (Sen Gupta, 2000).

On the basis of geographical features, the Gujarat state is composed of four regions, viz. (i) North Gujarat region (ii) Central and South Gujarat (iii) Saurashtra peninsular region and (iv) Kachchh region. (Mistry, 1988). These zones have been characterized by their typical land forms and coastline. The present geomorphic configuration of the state is the result of the sub aerial geological processes that have given rise to a variety of erosion and depositional landforms.

From the water resources consideration the Gujarat state can be divided into four major physiographic regions. The Rivers of Gujarat are represented in figure 1.1. There are 185 river basins which can be distributed region wise as shown in table 1.1.

Table 1.1 Region Wise River Basins of Gujarat

Region	Nos. of River Basins
North Gujarat	05
Central and South Gujarat	12
Saurashtra	71
Kachchh	97
Total	185

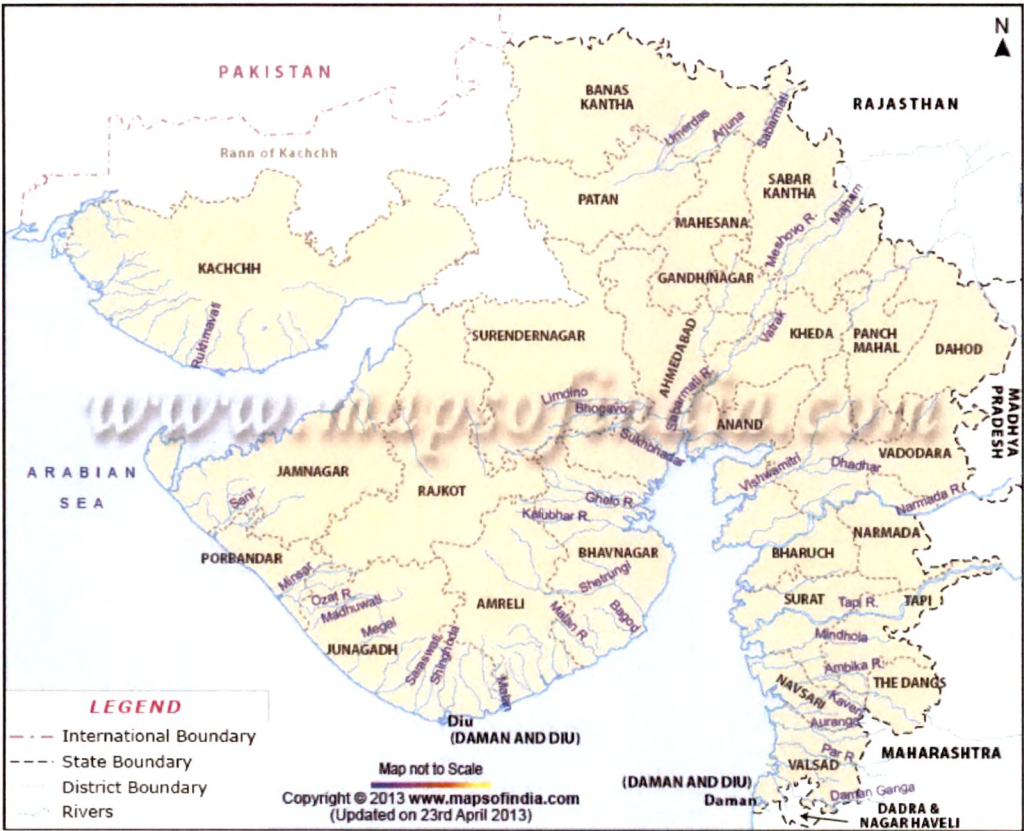


Figure 1.1 Gujarat River Map

Due to centrally elevated ridges in the Saurashtra and Kachchh regions, the rivers originate from central uplands. They are small, flashy and flow radially towards the Arabian Sea, Gulf of Khambhat, Gulf of Kachchh and Rann areas. In contrast to this, most of the rivers of Gujarat region are major rivers, viz., Banas, Sabarmati, Mahi, Narmada, Tapi and Damanganga which originate from the hilly regions in the adjoining states (Mistry, 1988).

Except Narmada, Tapi and Mahi rivers, all other rivers in the eastern part of the state, originate on the western slopes of the eastern hills. They flow in the direction almost at right angle to the boundary i.e. towards southwest (Sabarmati and Mahi rivers) in the northeastern part, towards almost West (Narmada, Tapi and Dhadhar) in the central region and towards Northwest (Kolak, Par, Ambica, etc.) in the southern part. Most of the rivers in the alluvial plain meander with very wide courses whereas those in rocky tracts have deep and narrow courses. Out of 185 river basins of Gujarat State only four basins i.e. Narmada, Mahi, Tapi and Damanganga have surplus water. Tapi, Narmada, Mahi and Sabarmati are the main perennial rivers of Gujarat. They are meeting Arabian Sea in Gulf of Khambhat.

## **1.2 Estuaries**

Estuaries have been used for time immemorial. Estuaries are very important even though their area is only a small proportion of the world's surface. Because of their fertile waters, sheltered anchorages and the navigational access they provide to a broad hinterland. Estuaries have been the main centers of man's development (Dyer, 1979).

Historically estuaries in their upper ends have been used as sources of water in cities and industries and some times in the fields. The main uses of estuaries are for transportation, navigation harbors, national security, commercial, industrial sites, scientific research, natural beauty, fishing, cooling water and waste disposal. Waste disposal has started ever since man has started inhabiting the banks of the estuaries. The estuary with the beaches serves as great recreational and tourism spots-jolly boat-riding also. Estuaries are some of the most productive ecosystems in the world. They constitute a very complex environment with widely varying ecological conditions (Calcutta Metropolitan Development Authority, 1972). Most of the large cities in the world are located on them.

### **1.2.1 The Estuary Definitions**

Estuaries around the world vary greatly in their characteristics and it is not easy to define one with absolute precision. Definitions of estuaries are very broad and include almost any body of water which joins the ocean at the coast. Estuaries are those bodies of water which are connected to the ocean at one end and fed by sources of fresh water as the water body's boundaries extend landward (Thatcher and Harleman, 1972).

An estuary is the tidal mouth of a river. In other words an estuary is the area in which mouth of a river meets the ocean. This unique environment mixes the fresh water of the river with salt water of the sea. The effects of the tides are typically strong in an estuary. The mouth of a river is the area in which the river enters a larger body of water.

Bowden has defined an estuary as “a partially enclosed body of water which has an influx of fresh water at one end and which is in free communication with the sea at the opposite end.”

An estuary can also be defined as a body of water in which river water mixes with and measurably dilutes sea water. It has also been described as the wide mouth of a river or arm of the sea where the tide meets the river currents, or flows and ebbs (Reid, 1961).

### **1.3 Sea Water Intrusion Problem in Coastal Aquifers**

Due to increasing concentration of human settlement, agricultural development and economic activities, the shortage of fresh ground water for domestic, agricultural, and industrial purposes become more striking in these coastal zones (Parekh, 2009).

A sea water hydraulic gradient exists in the aquifer and excess fresh water from inland area flows to the ocean. Under the natural conditions a state of equilibrium is maintained when fresh water flows at a steady rate into the ocean. With reduction of fresh water flow and increased demand for groundwater, if the water table or piezometric surface is lowered below the potential of the adjacent sea water, the sea water moves inland. The process is known as sea water intrusion.

In some areas, water withdrawals are so high, relative to supply that surface water supplies are shrinking and ground water reserves are being depleted faster than they can be replenished by precipitation. Agriculture is by far the biggest user of water accounting for over 70 percent of water (Mohapatra et al., 2006).

### 1.3.1 Abrupt Interface Approach

More than 50 years ago two investigators (Ghyben and Herzberg), working independently along the European coast. They found that salt water occurred underground, not at sea level but at a depth below sea level of about 40 times the height of the fresh water above sea level. The equation derived to explain the phenomenon is generally referred to as the Ghyben-Herzberg relation after its originators (Todd, 1995). In this relationship the fresh water and saline water are considered to be immiscible fluids. An abrupt interface between fresh water and saline water regions is assumed to exist. This sharp interface approximation is valid where transition zone from fresh water to salt water is relatively limited in comparison with aquifer dimensions. This approximation, together with the equilibrium of pressure on the interface and Dupuit assumption of homogeneous horizontal flow, leads to an approximate solution of sea water intrusion problem. In fact both fluids are miscible and the sharp interface approach is not realistic when the width of the transition zone is considerable (Dalwadi, 1998).

### 1.3.2 Hydrodynamic Dispersion Approach

Under field conditions a brackish transition zone of finite thickness separates the two fluids. This zone develops from dispersion by flow of the fresh water plus unsteady displacements of the interface by external influences such as tides, recharge and pumping of wells. In general, greatest thicknesses of transition zones are found in highly permeable coastal aquifers subject to heavy pumping (Todd, 1995). Dispersion of the interface is the phenomenon that the fresh water-salt water interface is not sharp, but is represented by a narrower or wider transition zone in which the amount of total solids increases more or less rapidly from the landward to the seaward side. Calculations can be made for lines of equal total solids, say 1,500 or 2,000 ppm and this can be assumed as the interface (Raghunath, 1987).

### 1.3.3 Sea Water Intrusion Problem in Coastal Aquifer Overlain by an Estuary

The ever increasing demand of fresh water for various uses is a sufficient motivation for the exploration of additional sources of surface and subsurface water resources. In surface water resources in a coastal region the fresh water abstraction from the surface flow as rivers disturbs the equilibrium of fresh and salt water in the estuary.

In many coastal areas, the groundwater gets contaminated not only from sea to which one face of the aquifer connected but also from the tidal water of the overlain estuary. In normal condition, the dynamic equilibrium prevails between fresh water and salt water of these two surface and subsurface water systems. The impoundments sited on the estuary reaches will create imbalance in both surface and groundwater regimes. Coastal aquifer is in contact with saline water from the sea on one side. Changing discharge of fresh water towards the sea from the land ward side and infiltration from the estuary/recharge from the rain/water body into the coastal aquifer creates complex problem. This necessitates a detailed study about the sea water intrusion into the aquifer (Dalwadi, 1998).

#### **1.4 Purpose of Artificial Recharge Structures in Estuarine Area**

Artificial recharge is necessary to save water in times of water surplus, for use in times of water shortage. Limited natural rainfall recharge and increased water usage calls for conservation as well as augmentation by artificial recharge. Varieties of methods have been developed to recharge the groundwater (Mohapatra et al., 2006). Tidal water from Sea entering the river mouth imparts salinity to the river aquifers that are being tapped for water supply purposes. The discharge from radial collector well depends on static water level in river bed aquifer and induced recharge from nearby channel. Hence the presence of channel with sufficient water level increases the discharge from radial collector well. In non-monsoon season the water level in river is low. The construction of weir increases the water level in the vicinity of radial collector well and thus improves the flow.

Construction of a low weir on river estuary serves two purposes:

- 1) To provide a standing pool of water over radial collector wells.
- 2) To provide a surface barrier to prevent tidal water from entering collector well areas and also to provide a subsurface barrier to prevent subsurface saline water from entering radial collector well area.

#### **1.5 Scope and Objectives of the Study**

The present study is related to region of Mahi estuarine area which is laying in three districts of Gujarat namely Vadodara, Anand and Bharuch. The Mahi River is one of the major west flowing rivers and flowing through central Gujarat and meeting Arabian Sea



in the Gulf of Khambhat near Kavi. Vadodara Mahanagar Seva Sadan and many industries near Vadodara are taking water from Mahi River for potable and industrial uses by constructing radial collector wells. The outflow of Mahi River in to the sea is being decreased due to construction of structures like Bajaj sagar, Kadana, Panam dams and Wanakbori weir. The tidal effect of sea in the estuary has increased the sea water intrusion in the land ward side.

The groundwater has been contaminated over the period and the quality of the ground water is continuously deteriorating due to the increasing rate of withdrawal and the aquifer having not been recharged at the same rate on account of erratic rainfall pattern in Mahi estuarine area.

The Mahi River is a tidal river. Mahi estuary joins the Arabian Sea at the northern part of the Gulf of Khambhat. The estuary is strongly influenced by the hydro dynamics of the Gulf of Khambhat. The limit for the daily tidal zone of Mahi estuary is up to the horse shoe bend downstream of Mahammadpura, 50 km upstream from the mouth. Sea water intrusion normally occurred up to Mahammadpura. The sill near Mahammadpura acts as a barrier between tidal flow and river discharge during the dry season. Further intrusion of sea water was obstructed by the sill at Mahammadpura. The tides were observed to cross the sill only during the high spring tides in summer and influenced the river segment up to Vasad on such occasions, the salinity of water increases and chloride concentration as high as 600-1000 mg/l has been reported at Vasad. The industries are, therefore, required to suspend operation on these days (NEERI and NIO, 1975). The fresh water regime of the river is limited to a few kilometers distance downstream below Vasad. Beyond this limit the water remains brackish throughout the dry weather conditions. The water is not suitable for drinking or agriculture.

The Gulf of Khambhat experiences semi-diurnal tides of high amplitude up to 10 m. The Mahi experiences a semi-diurnal tide. i. e. high waters occur daily twice at intervals averaging 12 to 12.4 hours.

Here an attempt is done to investigate the artificial recharge in the study area with salinity control cum artificial recharge structures.

Following are the objectives of the study:

1. Groundwater fluctuations study in Mahi estuarine area by using Groundwater Modeling System.
2. To study water quality and impacts of weir on artificial groundwater recharge.

## **1.6 Closure**

A detailed literature review is described in chapter two. The study area is described in chapter three. Data collection and methodology are discussed in chapter four. Model simulation and regression analysis of water quality data are described in chapter five and six. Finally the results are discussed in chapter seven. Finally conclusions are listed in chapter eight.