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SEAWATER INTRUSION

ANALYSIS OF SEAWATER INTRUSION IN COASTAL AQUIFER

Mrunali H. Parmar[1], Rahil M. Goswami[2], Dhavalsinh R. Vaghela[3], Devangi N. Patel[4], Ishani Upadhyay[5]

[1]Final Year Student at Civil Dept., Shankersinh Vaghela Bapu Institute of Technology.
[2]Final Year Student at Civil Dept., Shankersinh Vaghela Bapu Institute of Technology.
[3]Final Year Student at Civil Dept., Shankersinh Vaghela Bapu Institute of Technology.
[4]Final Year Student at Civil Dept., Shankersinh Vaghela Bapu Institute of Technology.
[5]Assistant Prof. at Civil Dept., Shankersinh Vaghela Bapu Institute of Technology.

Abstract : *"Saltwater Intrusion is the migration of saltwater into a freshwater aquifer." It occurs when there is a reduction in the freshwater head and flow at the sea water interface. This commonly occurs when there is over pumping or insufficient groundwater recharge of an aquifer in the coastal zone. It can be prevent by artificial ground water recharge.*

Keywords *: Sea water intrusion , Coastal area , Fresh water aquifer , Artificial Ground water recharge , Transition zone.*

I. INTRODUCTION

Saltwater intrusion is the movement of saline water into a freshwater aquifer. Where the source of this saline water is marine water, this process is known as seawater intrusion.

Seawater intruding in a coastal aquifer mixes with fresh groundwater, creating a water body in which the mass density varies continuously, according to the continuously varying concentration of salt in the water and, typically, rapidly over a narrow transition zone.

It also affect the density of ground water and its flow. Hence it is necessary to prevent it. There are many methods of prevention and detect the sea water intrusion.

Sea water intrusion causes many problems for crop, affected water is also not suitable for drinking , domestic and industrial purpose. Effect of sea water intrusion pollute the fresh ground water.

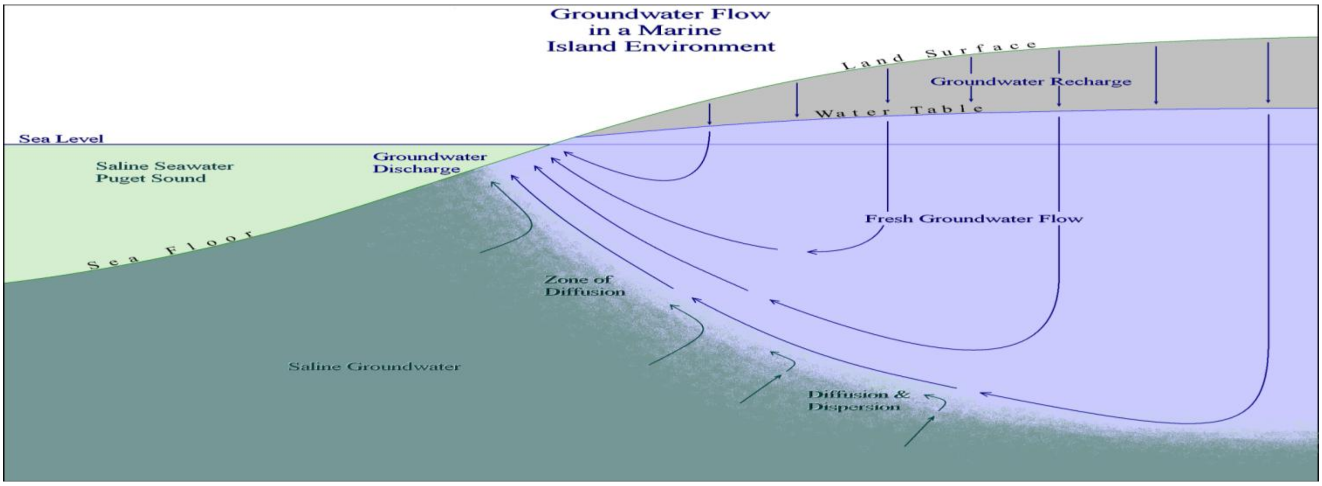

Figure 1. Flow of seawater towards the freshwater aquifer due to groundwater discharge

II. ILL EFFECTS OF SEAWATER INTRUSION

A. Ill effect on crop:

The using of intrusion affected ground water in irrigation purpose causes worst effect on crops. Thus, crop products failed. Also the use of fertilisers and chemicals are increased for the crop products which also effects badly on people.

Figure 2. Ill effect of seawater intrusion on crop

B. Effect on structure:

Salt present in ground water due to effect of seawater intrusion, foundation of structure affected by salt which corrode the structural member like walls, column, etc. It also spoil the good look of structure.

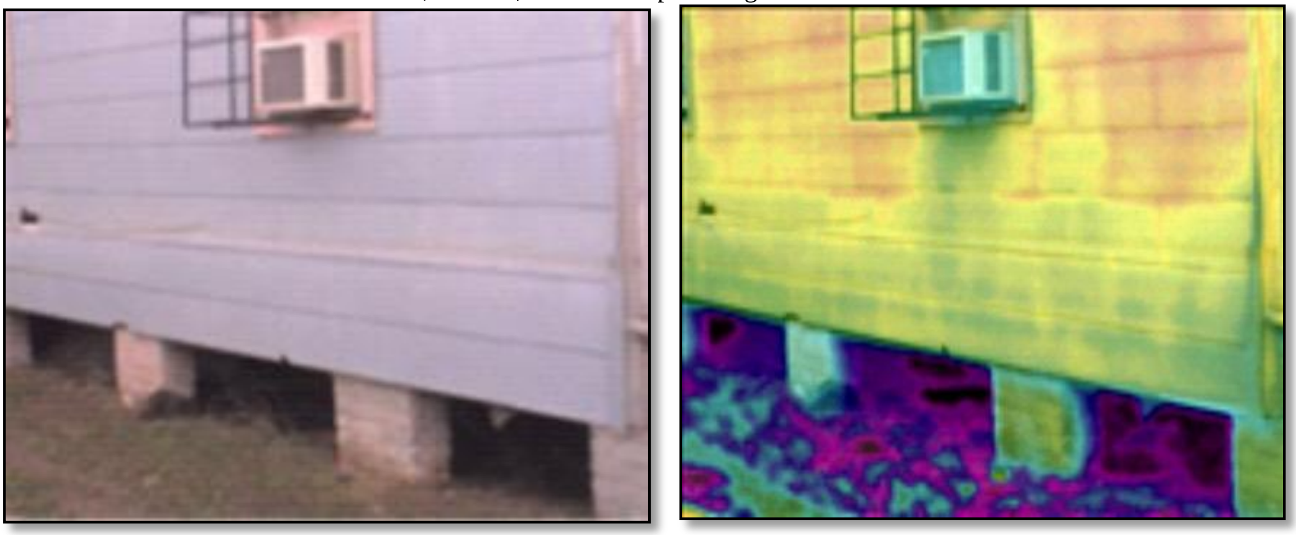

Figure 3. Ill effect of seawater intrusion on structure

C. Effect on pipes lying underground :

Pipes laying below ground mostly come in contact of water present in ground, if there is presenc of salt in ground water may corrose that pipes and also effects economy due to repalcement of the pipes.

Figure 4. Ill effect of seawater intrusion on pipes laying below ground

D. Effect on fresh ground water:

Flow of saline water into the fresh water aquifer occurs due to density difference between them. Amount of minerals in fresh water is increase due to intrusion of seawater. This may pollute the fresh ground water aquifer and its water can't be used for any domestic, agricultural, industrial, structural or any daily life usage due to access of minerals contents.

Figure 5. Ill effect of seawater intrusion on fresh water

III. THE OBJECTIVES OF ANALYSIS OF SEAWATER INTRUSION

- To find out the intensity of sea water intrusion in selected coastal area.
- To reduce the problem of sea water intrusion of selected coastal area.
- To solve the problem of access of minerals in domestic water.
- To prevent sea water migration toward the fresh water aquifer.
- To reduce worst effect on crop due to effect of sea water intrusion.
- To reduce the pollution of ground water.
- To prevent groundwater from intrusion, hence it may be useful for domestic, industrial, irrigation and any other purposes, without any harmful effects.
- To prevent structures existing near by the sea coast areas, from ill effects from salt present in soil in contact with the foundation, which may corrode the surface of structural members like plinth, column, wall etc. and spoil outer look of the structure.

IV. BASIC DEFINITIONS

A. **Aquifer:**

An aquifer is an underground layer of water bearing permeable rock, rock fractures or unconsolidated materials from which groundwater can be extracted using water well.

B. **Confined aquifer:**

Confined aquifer are those in which an impermeable dirt/rock layer exists that prevents water from seeping into the aquifer from the ground surface locate directly above.

C. **Unconfined aquifer:**

Unconfined aquifer are those into which water seeps from the ground surface directly above the aquifer.

D. **Water table**:

water table is the level below which the ground is saturated with water.

E. **Equipotential Line:**

Equipotential in mathematics and physics refers to a region in space where every point in it is at the same potential.

F. **Groundwater discharge:**

Groundwater discharge is the volumetric flow rate of groundwater through an aquifer.

G. **Transition zone:**

Transition zone is the narrow line at which saltwater and freshwater meets below the ground water.

IV. NECESSITY OF ANALYSIS OF SEAWATER INTRUSION

A. Sea water intrusion affects many fields of regular life of people:

Due to effect of seawater intrusion in water of well which effected water consumed by villagers, causes pain in joints and stone as well as kidney problems.

B. Saving Crops:

For save the crops from the effect of salt present in ground water due to effect of intrusion. We can save crops from the worst effect of intrusion by studying the intensity of intrusion.

C. Reduce the use of fertilizer and chemicals during the growth period of crops :

As per survey it deduct that due to seawater intrusion effect use of fertilizer and chemicals in the growth of crop, are increase and hence its increase in economy and also health of people.

D. Reduce ill-effect on structure:

To prevent damaging structure due to effect of salt present in the ground water, which is in contact with foundation, which also affect other structural members.

E. To know about the amount of salinity in ground water :

By the study of seawater intrusion we come to know about the presence of salts in the fresh ground water aquifer also we can measure intensity of dissolved salt content by using sensors.

V. METHODS FOR ANALYSIS OF SEAWATER INTRUSION[4]

Methods of analysis of sea water intrusion are as below. A broad classification is there based on different models and techniques used for analysis, but there are mainly three methods of analysis are there, which are as shown below:

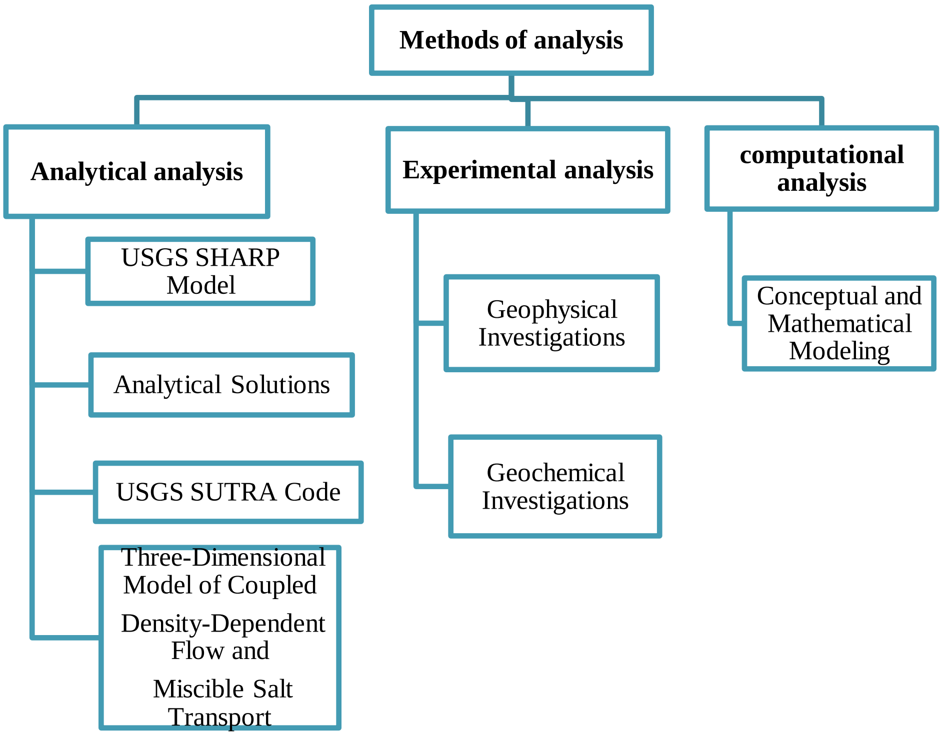

Figure : 6 Basic Classification of Methods of Analysis of Seawater Intrusion.

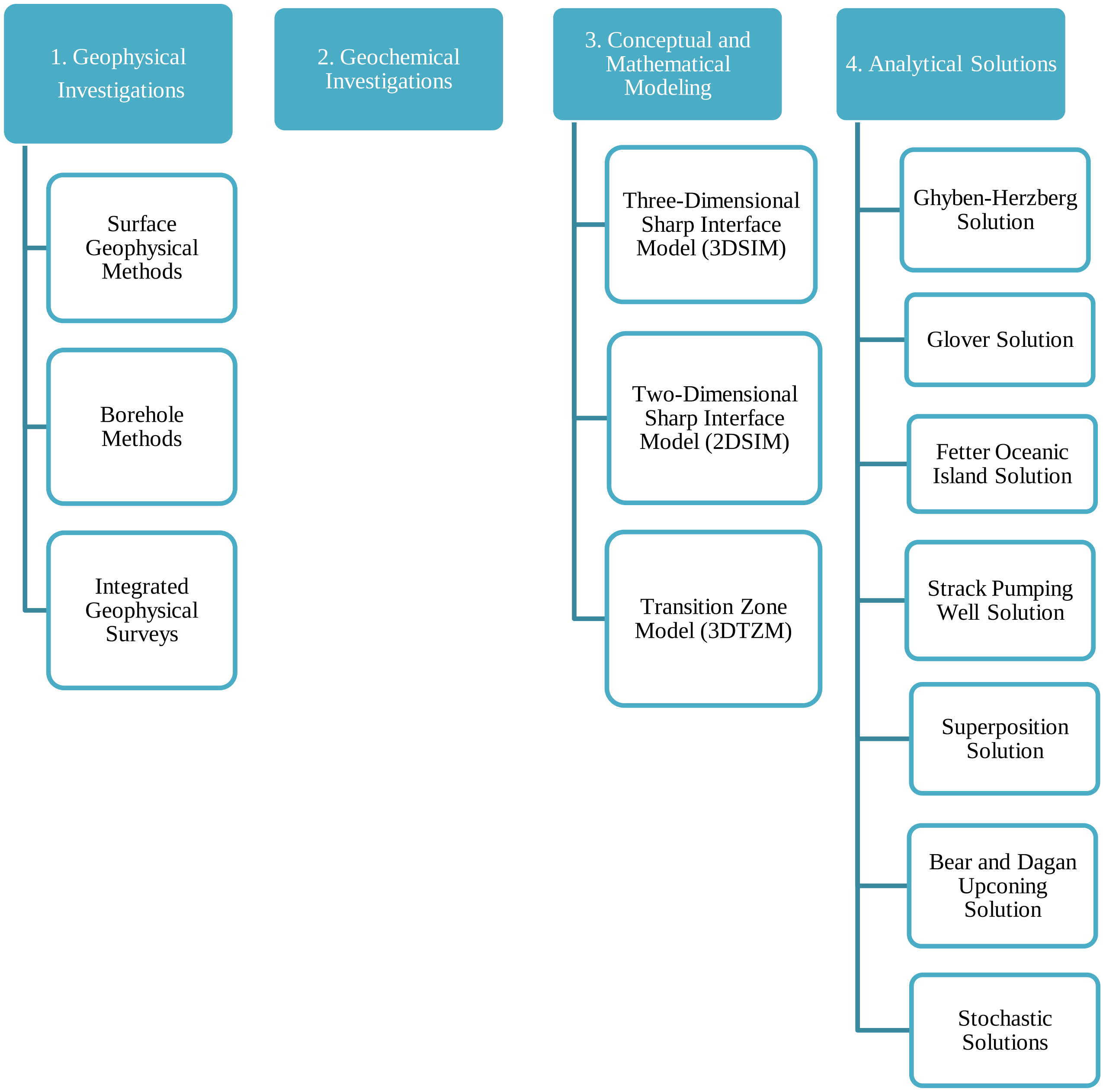

Figure : 7(a) Secondary Classification of Methods of Analysis of Seawater Intrusion.

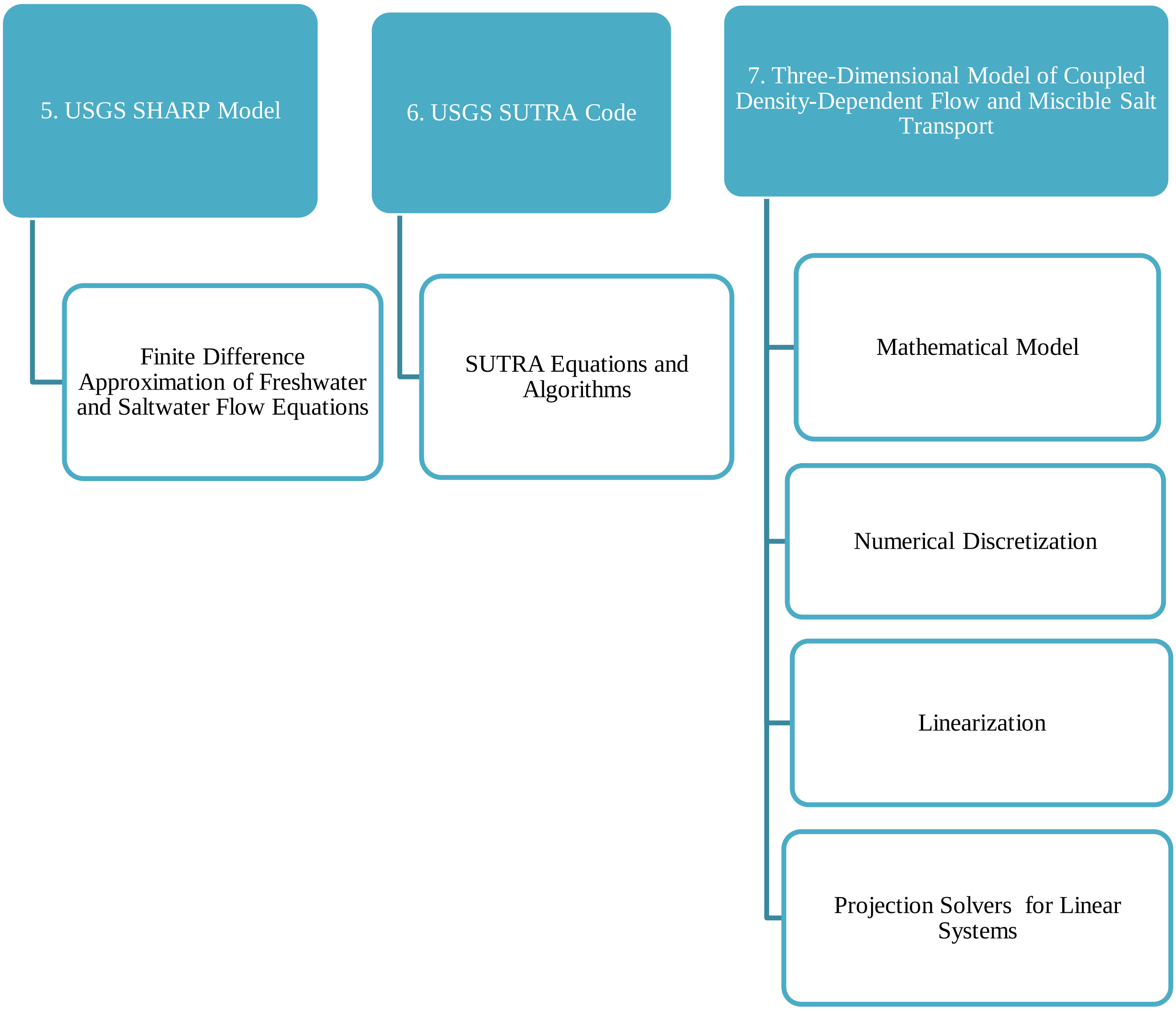

Figure : 7(b) Secondary Classification of Methods of Analysis of Seawater Intrusion.

From all above methods we adopted Ghyben-Herzberg Solution of analysis for analyze the problem of seawater intrusion in coastal area of Gopnath-Bhavnagar, Gujarat. By using this method for analysis we can determinate the depth of transition zone near the coastal area. By determining the depth of transition zone we can conclude about the possible solutions and remedial measures of the problem of seawater intrusion.

A. Ghyben-Herzberg Solution:[5]

More than a century ago Badon-Ghyben [1888] and later Herzberg [1901] independently found that saltwater occurred underground, not at sea level as expected for static water bodies, but at a depth below sea level of about forty times the freshwater head above sea level. This relation, known as Ghyben-Herzberg relation, has been widely used.

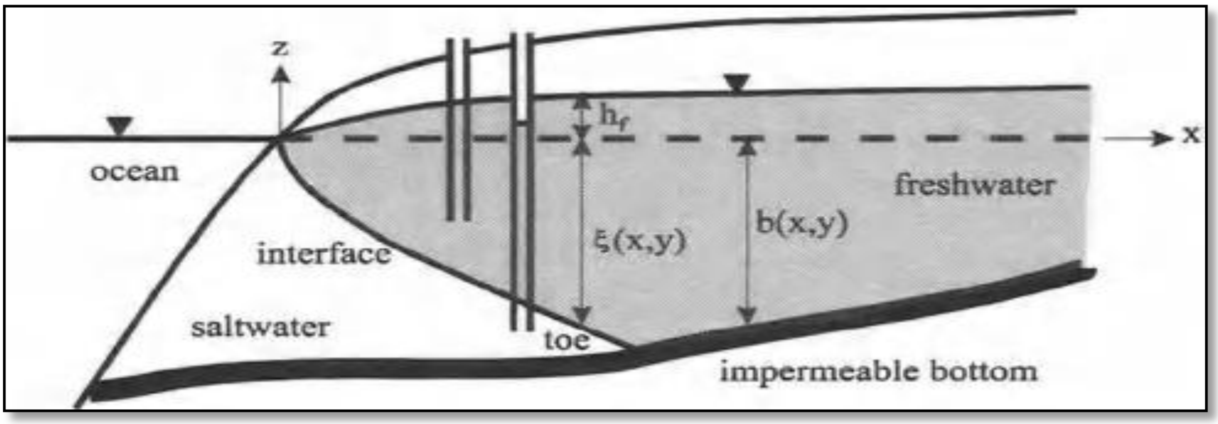

Figure: 8 Saltwater-freshwater interface

We define the piezometric head in the saltwater zone and freshwater zone respectively as;

$$h_s = \frac{p}{\rho_s \cdot g} + z \qquad (4.1)$$

$$h_f = \frac{p}{\rho_f \cdot g} + z \qquad (4.2)$$

Where; p= pore pressure
ρ_s = Saltwater density
ρ_f = Freshwater density
g = gravity acceleration

As understood by Muskat [1937] in the form of oil/water interface and later by Hubbert [1940] the dynamic equilibrium requires that the pressure p be continuous across the saltwater/freshwater interface.

The pressure can be eliminated between equations 4.1 and 4.2 to give the condition;

$$\rho_f \cdot h_f = \rho_s \cdot h_s + (\rho_s - \rho_f)\xi \qquad (4.3)$$

In which; $\xi = \xi(x, y) = -z$; the depth of interface below the datum (Figure4.1)

In solving a boundary value problem involving a freshwater zone and a saltwater zone, Eq. 4.3 is a condition that must be satisfied at the interface.

For aquifers that are relatively shallow such that flow lines are nearly horizontal, it is customary to invoke the Dupuit assumption [Bear, 1979] which assumes that $h_s$and$h_f$does not change in the vertical direction z. Equation 6.3 is no longer restricted to head measured at the interface and can be written as;

$$\xi = \frac{\rho_f}{\rho_s - \rho_f} h_f - \frac{\rho_s}{\rho_s - \rho_f} h_s \qquad (4.4)$$

This offers the opportunity of predicting the interface depth $\xi$from water level in observation wells. Referring to Figure 4.1, if two wells are located near to each other, but one is deep enough to be opensin the saltwater region and the other shallow enough to be in the freshwater region, then $h_s$and $h_f$can be observed at the same location. Equation 4.4, as suggested by Lusczynski [1961] provides a better estimate of ξas compared to the Ghyben-Herzberg relation to be introduced below. However, despite the advantage, this method is less practical as it requires extra wells that penetrate deeper into the saltwater region. This requires the rough knowledge of interface location for the proper placement of well screen, and higher cost.

Ghyben and Herzberg made the further assumption that the saltwater is stagnant. The pressure in the saltwater region becomes hydrostatic, $\boldsymbol{p = -\rho_s \cdot g \cdot z}$ with the datum shown in Figure 4.1, the saltwater head is zero and Eq. 4.4 reduces to;

$$\xi = \frac{\rho_f}{\rho_s - \rho_f} h_f \approx 40 h_f \qquad (4.5)$$

In the above and throughout the chapter we adopt these values ρ_f = 1000 kg/m³ and ρ_s=as per data for different time period of the year (different for every calculation). Equation 4.5 is known as the Ghyben-Herzberg relation. The prediction of interface location requires only the water level in freshwater wells.

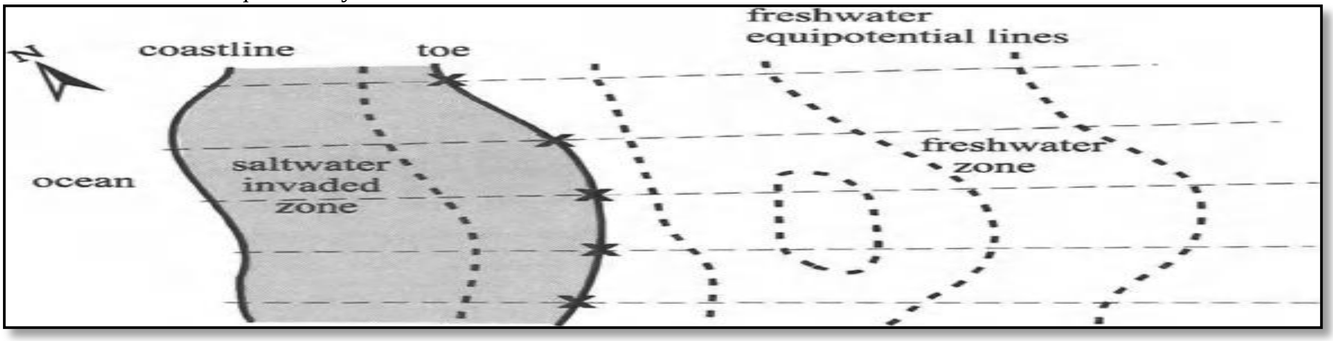

Figure: 9 Tracking saltwater toe location by Ghyben-Herzberg relation

With the Ghyben-Herzberg relation, it is possible to map the saltwater-freshwater interface using the following steps in a field investigation:

1. A network of shallow wells is deployed for observation of water table height.

2. Contour lines showing the freshwater head h_f are drawn using an interpolation technique, such as kriging.

3. The interface depth ξ (x, y) is represented by the same set of contour lines, but with amplified contour values according to Eq.4.5.

4. The location of aquifer bottom *b(x, y)* (Figure 4.1) is found from geological maps.

5. The intersection of the two surfaces ξ (x, y) and *b(x, y)* is sought, which represents the saltwater toe location. Instead of finding the intersection in a three-dimensional space, it might be more efficient to find it in a number of two-dimensional vertical sections cut along lines perpendicular to the coast and connect these points together, see Figure 4.2
The above procedure is applicable for confined as well as unconfined aquifers.

VI. POSSIBLE OUTCOME

To deduct the place where the effect of sea water intrusion is observed and to solve the problems due to sea water intrusion. By solving the problem of sea water intrusion we can prevent the entry of sea water into the fresh aquifers and make It useful for various domestic purpose, for drinking, for industrial use and also for irrigation purpose. We can also use sensors to deduct the presence of saline water below ground where fresh water is exist.

By using Ghyben Herzberg Solution we can denote contour line of depth of transition zone. We also can be denote contour lines for intensity of seawater intrusion in transition zone.

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