SALINE WATERS AND THEIR DISTRIBUTION
IN GUJARAT

Water not only serves as a vital substance for human existence but also plays an important role in advancing civilization. Owing to the rapid growth in world economy and civilization, the need for the development of water resources has become more urgent than ever before. Many government and private organizations have already taken positive actions to cope with this situation. UNESCO has scheduled an 'International Hydrological Decade' since 1965 for promoting and co-ordinating long term international co-operation programme in hydrology. The most recent definition of hydrology considers it a science dealing with the properties, distribution, and circulation of water; specifically the study of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere, particularly with respect to evaporation and precipitation.
Waters may be classified according to their origin. The various classes are Meteoric waters, Juvenile waters, Rejuvenated waters and Connate waters.

Meteoric water is derived from the atmosphere. It constitutes the major part of atmospheric surface and sub-surface water which has accumulated during precipitation on the surface of the globe during geologic time.

Juvenile water is new water. It constitutes an addition to the water supply of globe and is classified according to the origin as magmatic, volcanic and cosmic water.

**Magmatic water:** Magma is molten rock occurring at depth and consists of a mutual solution of melted rock forming minerals and the gases, most important being water vapour. Water driven out of magma during its crystallization is called magmatic water.

**Volcanic water:** It is furnished by surface lava flows. It has been shown that throughout molten lava, oxygen and hydrogen are uniting to form water and that this action is an important source of volcanic heat.
Cosmic water: This water comes from space with meteorites, no quantitative estimate has been made about the amount of cosmic waters coming to our globe every year.

Rejuvenated water: This is the water returned to earth by geologic processes of compaction and metamorphism. When compaction takes place, the water filling the pore space in clay sediments is released and forced out in the aquifers.

Connate water: The openings and interstices of all sedimentary rocks deposited beneath the ocean were originally filled with salt water. After the rocks have been lifted above the sea, fresh water has slowly been driven out and replaced by the salt water. Exploration of oil-fields has shown that bodies of sea water are preserved in anticlines and under barriers which prevents excess of sweet water descending from the ground surface. Connate water, therefore, exists as pockets of stegnant water, especially in structures which hold oil and gas and which have not been flushed out with fresh water.
THE PROBLEM OF THE STUDY OF GROUND WATER RESOURCES

The problem of water resources has many facets to be studied. Extensive work has been carried out and is in progress in many parts of the world. Starting from the understanding of the rainfall characteristics, run off and recharge of aquifers and the utilization of waters for drinking, agriculture and industry, all the above aspects again can be sub-divided in order to obtain specific information for a specific problem. Only to understand the varied character of the rock, the following aspects have been described. The problem of rainfall, run off, evaporation and transpiration has been studied by Davis and Sampson(14), Saville(54), Folse(19), Lee(39), and many other workers.

The problem of flood characteristic has been studied by Jarvis(29), Veatch(62) et al., The problem of drought condition arising in semi-arid area has also received attention and has been critically studied by Buswell(7), Condra(10), Hoyt(28), Thornthwaite(60), Metzler(40, 41).
In addition to such natural aspects, a continuous study of river flow characteristics is also a common feature of many laboratories. A mention may be made of study by Cleary(9), Krause(35), Newcome(46), Karnaukhov(31), While Mezosi and Donath(42) investigated the dissolved and floating material of Tisza and Maros.

The problem of geochemical classification(11, 22, 48, 59, 63) and irrigation classification (5, 6, 13, 16, 17, 18, 21, 30, 34, 43, 52, 56, 61, 64) has also been continuously studied.

The influence of sea water intrusion in coastal region is of great significance, as many water resources become useless due to such an effect. Studies of sea water intrusion and methods to stop them have been carried out by Baumann(3), Laverty et al.,(38) Banks and co-workers(2).

The need for making more water available is growing more acute, day by day, and therefore problem of conservation on of water (4, 27, 53, 57, 58), the problem of artificial rain-fall (36), the problem of finding out the quantity of underground water using radioactive isotope content (8, 32, 37), the problem
of reclamation of used waters (41, 47), the problem of artificial recharge of aquifers (23, 44, 55, 58) and the problem of obtaining fresh water from sea water (1, 12, 15, 20, 24, 25, 26, 33, 45, 50, 51, 65) have been continuously studied for many years by now.

In many parts of India, the monsoons are irregular and they frequently fail to pour any rain water, hence many towns and villages have to depend on underground water supplies. In Northern India, huge reservoirs of underground water are found in the wide Gangatic-Brahmputra plains. Similarly, the successful organization of important river valley projects has aided in solving the problem of irrigation water in some parts of the country. However, the problem of water will grow more and more acute in arid-regions like Rajasthan and a semi-arid region like Gujarat, with the installation of new industrial projects.

Thus, the climatic variation is very wide, ranging from arid areas of Kutch (and North Gujarat) to humid areas of South Gujarat. The arid climate is an important factor for concentration of salts in ground waters and also in soils. A second factor of equal importance is the geographical location of the state of Gujarat, which has a sea boundary encircling the
area on its Western side. There is possibility of fresh sea-water intrusion, making waters saline, in coastal areas.

A third factor is the inter-mixing of salt-dome waters in oil-field areas, with fresh waters of upper aquifers, when the withdrawal rate is very high.

Map 4.1 shows the salinity levels of ground waters for different regions in Gujarat. The geochemical types have been indicated in Table 4.1.
<table>
<thead>
<tr>
<th>Tract Tract</th>
<th>Average E.C. EC x 10^6 at 25°C</th>
<th>Average salinity (calculated) ppm</th>
<th>Salinity range EC x 10^6</th>
<th>Main geochemical type</th>
<th>Average depth of wells (tube wells)</th>
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<tr>
<td>A1 Bhuj-Nakhatrana-Lakhpat</td>
<td>2506</td>
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<td>1.5 - 11.0</td>
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<tr>
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<td>1800</td>
<td>0.80 - 2.8 3.0 - 9.6</td>
<td>Na-Ca/Mg-Cl-HCO3</td>
<td>48'</td>
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<tr>
<td>A3 Gochnath-Radhanpur-Santalpur</td>
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<td>1900</td>
<td>1.0 - 4.4</td>
<td>Na-Mg/Ca-Cl-HCO3</td>
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<tr>
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<td>953</td>
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<td>A4 Mehsana-Visnagar-Kheralu</td>
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### TABLE 4.1 (Contd....)

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<th>Salinity range EC x 10⁶</th>
<th>Main geochemical type</th>
<th>Average depth of wells (and Tube wells)</th>
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<td>A₄-A₈</td>
<td>Mehsana-Harij-Samia-Becharaji</td>
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<td>Jamnagar-Dhrol-Jodia</td>
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<tr>
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<td>Na-Mg/Ca-HCO₃-CI</td>
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<td>Tract No.</td>
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<td>Salinity range</td>
<td>Main geochemical type</td>
<td>Average depth of Wells (and Tube wells)</td>
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<td>Salinity range (EC x 10^6)</td>
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<td>Tract No.</td>
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<td>Average depth of wells (and Tube wells)</td>
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TABLE 4.1 (Contd....)

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<th>Tract No.</th>
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<th>Main geochemical type</th>
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<td>C₄</td>
<td>Broach-Ankleshwar-Panoli</td>
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</tbody>
</table>
Salinity of ground waters in North Gujarat which includes the tracts $A_1$ to $A_5$ is decidedly very high, ranging from (600) ppm., in Himatnagar-Modasa-Bayad tract, and gradually reaching a level of (2300) ppm., in Mehsana-Harij-Sami area. The arid regions of Bhuj-Gadhasisa-Mandvi, Bhuj-Nakhatrana-Lakhpat, Bhuj-Bhachau-Adesar have a high salinity of the order of (1600 to 1800) ppm., the geochemical type of waters is Na-Ca/Mg-Cl-SO which is close to the sea-water type.

The parts of North Gujarat on the Eastern side of river Sabarmati, namely Himatnagar-Idar-Khedbrahma (700) ppm., Himatnagar-Modasa-Bayad (600) ppm., Himatnagar-Prantij (600) ppm., and Mehsana-Vijapur (600) ppm., are receiving their recharge from river Sabarmati and hence the geochemical type Na-Ca/Mg-HCO$_3$ -Cl can be explained, but in Palanpur-Deesa-Dhanera (800) ppm., Mehsana-Kalol (1900) ppm., Mehsana-Visnagar-Kheralu (1200) ppm., and Mehsana-Sidhpur (1100) ppm., with major geochemical type Na-Mg-Cl-HCO$_3$, which is a gradual change from low salinity to high salinity and from the geochemical type Na-Ca/Mg-HCO$_3$-Cl to Na-Mg-Cl-HCO$_3$. 
Existence of $\text{HCO}_3^-$ in large proportion may be explained on consideration of availability of oil-fields near Mehsana and Kalol.

Thus an important stratification based on low salinity due to fresh recharge from river and continuously increasing salinity as we go East to West is met with in Semi-arid region of North Gujarat.

The middle region of Gujarat as covered within B₁ to B₆ incorporates the area touching the sea coast near Mithapur and Jamnagar, the hilly tracts of Saurashtra near Chotila, the semi-arid plains of Saurashtra including the lake Nal, the coastal salines near Dholera, the oil-field areas near Sanand and Navagam, and the hilly plains including the forests in Eastern region of Godhra-Limkheda-Dahod, thus many geographical, climatic and local problems influence the nature of ground waters. The high salinity (1600) ppm., in Mithapur-Dwarka-Kalyanpur, Ahmedabad-Bavla-Dholka (2000) ppm., Dholka-Dhandhuka-Dholera (8800) ppm., Ahmedabad-Sanand-Viramgam (2000) ppm., belong to the geochemical type $\text{Na-Mg-Cl-SO}_4^-$, can be explained as due to fresh sea-water intrusion in the case of Mithapur-Dwarka tract, while the geological land locked salts in the other three areas.
In Ahmedabad-Aslali-Bareja (1600) ppm., Ahmedabad-Sanand-Viramgam (2000) ppm., Vadgam-Cambay-Dhuvaran (3500) ppm., Navagam-Mehmadabad (1900) ppm., the high salinity and the geochemical type Na-Mg-Cl-HCO₃ may be explained as due to intermixing of underground saline waters of the salt domes in these oil-field areas. The waters in Godhra-Dahod (500) ppm., and Godhra-Shivarajpur (700) ppm., are fresh, as there is no source of salinity in these rocky area. Salinity of Baroda-Dabhoi-Chandod (1500) ppm., can be explained due to mixing of oil-field waters with the upper ground waters.

The areas between C₁ - C₅ also has many geographical and climatic factors affecting the ground water, e.g., sea-coast is very close to Surat, Broach Veraval, Bhavnagar. The most fresh water is met with in Kotdapitha-Babra-Chawand (400) ppm., in Amreli district of Saurashtra, which has no source of salinity. Waters in Bhavnagar-Valbhipur-Patna have a high salinity (1600) ppm., with the geochemical type Na-Ca-Cl-HCO₃, is due to availability of salts in the form of leachate from the rocky terrane of Saurashtra as such Valbhipur-Patna area is the drainage basin of Saurashtra.
In Veraval-Sasan (700) ppm., Junagadh-Keshod-Veraval (400) ppm., the waters are fresh belonging to Na-Ca/Mg-HCO$_3$-Cl type. Similarly waters in middle of Saurashtra, Rajkot-Gondal-Jetpur, Gondal-Atkot-Jasadan, Jetpur-Dhoraji-Upleta have a salinity lower than (700) ppm., and belong to Na-Mg-HCO$_3$-Cl type; the source of bicarbonate being the interaction of rain water with the rocks of this volcanic hilly area. Waters in Broach-Ankleshwar-Panoli (1600) ppm., Broach-Ankleshwar-Hansot (2700) ppm., Surat-Kim-Kosamba (2400) ppm., with a geochemical type of Na-Mg-C1-HCO$_3$ or Na-Mg-HC0$_3$-Cl. This is due to the fact that these areas have rich oil-fields near Ankleshwar and Kim. The salinity of Surat-Dumas (2100) ppm., Broach-Jambusar-Kavi (1700) ppm., can be explained due to closeness of the sea near Dumas and Kavi. The low salinity of Surat-Bardoli-Valod (900) ppm., and Broach-Zagadia-Rajpipla (1000) ppm., is due to influence of local rivulets and no other source of salinity.

The narrowest strip of South Gujarat incorporated in $D_1$ has also a very wide variation in salinity, the salinity is lowest in Navsari-Vansda-Dang area (850) ppm., while the high salinity (1900) ppm., in Navsari-Navsari-Dandi area and (2400) ppm., in Bulsar-Gandevi-
Navsari area seek an explanation from the nearness of the sea at Bulsar and Dandi.

Thus the effect of closeness of sea, old sea water intrusion, availability of oil-field in area, lower topography of a drainage basin, the arid climate and recharge from the river water are the factors governing the salinity of waters, of area under study.
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