CHAPTER 4
HYDROGEOLOGY OF THE MINJUR-PANJETTY AQUIFER SYSTEM

4.1 INTRODUCTION

The geological formation constituting an aquifer has the properties to hold and transmit water in sufficient quantities. The water holding capacity of an aquifer depends on its volume and effective porosity, and the elastic properties of the aquifer skeleton and water. The ability of an aquifer to transmit water depends on the area of flow section, and its porosity and the pore size. The porosity and pore size of an aquifer skeleton in turn are related to the grain size, shape and distribution of the aquifer material and its compaction. These two important properties of an aquifer are known as hydrogeologic parameters or simply the aquifer parameters. The hydrogeologic parameters of an aquifer with its areal extent and thickness form part of the basic data needed for the groundwater resource evaluation and management.

The topography of the MPAS taken up for digital simulation is described. The collection and analysis of the borehole data of the geological formation of the system are explained and the complex nature of the alluvial deposit is described. Based on the borehole data, the different hydrogeologic formations present in the system and their areal extents are delineated. The nature of the different hydrogeologic formations present in the system is described and the hydrogeologic parameters are given.

4.2 THE STUDY AREA

4.2.1 Location and topography

The MPAS is in Tamilnadu, India, situated about 20km northwest of the city of Madras (Figure 1.1). The study area lies between the latitudes 13°13'00"N and 13°25'00"N and between the longitudes 80°07'00"E and 80°20'20"E. It covers an areal extent of 450 square kilometres and is 24km long in east-west direction and 22km wide in north-south direction.
The area is bounded on the eastern side by the Bay of Bengal.

Figure 4.1 shows the altitude of the land surface in the study area. It was constructed using land-surface elevation data from wells and the published topographic map of this region. As seen from Figure 4.1, the land surface slopes in the east-west direction with the contour lines being almost parallel to the north-south direction. The altitude of the area varies almost uniformly from sea level on the eastern end to 16 metres above mean sea level (MSL) on the western end in a distance of 24km. The slope of the area is mild, a condition which gives less opportunity for surface runoff to enter into sea through streams. There are two rivers, Korattaliar and Araniar, flowing in this area. They are shallow in depth and have flows only for a few days in a year during the northeast monsoon period of October, November and December. During the monsoon period, when flow occurs, these rivers contribute to the recharge of the aquifer system.

4.2.2 Geology

The study area is underlain by formations of quaternary, tertiary and cretaceous as well as by the basement complex of crystalline rocks. Gondwana series consisting of a massive pile of lacustrine and fluvial deposits lie over the crystalline rocks. The Gondwana exposure occurs southwest of Cholavaram lake and in the northern side of the study area. The tertiary and quaternary formations lie over the Gondwana formations. These formations outcrop in the north of Araniar and along the southern bank of Korattaliar. The eastern part of the Gondwana series is overlain by deposits known as boulder beds. The wornout and eroded surface of unexposed tertiary and Gondwana rocks are covered by the extensive stretch of alluvium which forms the aquifer in the study area. The laterite and alluvium deposits and the outcrop of the underlying tertiary are shown in Figure 4.2. All the above mentioned formations are underlain by crystalline rocks. The alluvium consists of gravel, fine to coarse sand, clay, sandy clay, silt, clayey silt and silty clay.

Pumping tests that were carried out by the Public Works Department of Tamilnadu state in the deposits of tertiary, laterite and Gondwana (UNDP Report, 1975) indicate very low value of hydraulic
FIG. 4.1 LAND SURFACE ELEVATION OF THE MPAS.
FIG. 4.2 GEOLOGY OF THE MPAS.
conductivity. These deposits exhibit poor hydraulic conductivity because of the presence of shale, mudstone and sandstone with interstices clogged with clay materials. These deposits are considered as impervious base for the alluvial deposits.

4.2.3 Lithology of the alluvial formation

The type of hydrogeological formations present in the alluvial deposits and the thickness and elevation of each formation are determined from the borehole data collected from the following agencies:

(i) The Exploratory Tube-well Organisation (ETO) of the Geological Survey of India and the Public Works Department (PWD) of the Government of Tamilnadu: these two organizations have drilled a number of boreholes in the study area to determine the spatial variation of the thickness of the alluvium and the different hydrogeologic formations present in it.

(ii) The Agricultural Engineering Department of the Government of Tamilnadu: This organisation has drilled a number of boreholes and constructed irrigation wells for the farmers. It maintains a record of the boreholes drilled and the wells constructed. The record gives the location of each borehole (name of the village and the survey number of the field), the depths from ground level to and the soil classifications of the different layers found in the borehole, the diameter and depth of the well, and the static water level and the quality of water.

(iii) The farmers who own wells for irrigation purpose: Some of the farmers who own wells for irrigation have a knowledge of the hydrogeology of the different formations present in the location of the wells and the depths to these formations from the land surface.

As the locations of most of the boreholes are known by village names, a map showing the location of all the villages in the study area is prepared. There are 152 villages in the study area and the number of borehole data analysed is about 830. Some of the villages, especially in
the area east of Minjur and Kattur, have a very few borehole data. The data collected from the various agencies are grouped villagewise and analysed. The analysis shows that the alluvium of the area consists of gravel, fine to coarse sand, silt, clay and mixture of silt and clay of various shades of grey and brown. The data indicate different types of alluvial deposits, intercalated or dovetailed in the form of lenses and pockets. The deposits exhibit a multi-layered formation without uniformity in respect of the number and thickness of the layers and the sequence of arrangement. However, the alluvial deposits can be broadly divided into three formations: the upper formation consisting of silt with a small percentage of clay and sand, referred to as upper aquifer; the intermediate formation consisting of clay and silty clay, referred to as aquitard; and the lower formation consisting of fine to coarse sand and gravel, known as lower aquifer. The upper formation is a water table aquifer and the lower formation is an artesian aquifer.

The borehole data of most of the villages are such that the delineation of the three formations could be done easily. But in some villages the data are so varied and complex, the lithology of each borehole in a village differs much from the others. Such a complex lithology in a village led to approximation in the delineation of the three formations.

Using all the available borehole data of a village, an average thickness for each formation and the relative position of it from the ground level are arrived at. In arriving at these details, the thickness and the elevation of the corresponding formation in the neighbouring villages are taken into consideration. Thus the depths from the ground level to the top and bottom of the aquitard and to the bottom of the lower aquifer in each village are estimated. From the altitude of a village obtained from Figure 4.1, the altitudes of the top and bottom of the aquitard and the bottom of the lower artesian aquifer at the location of the village are computed. Using these data, contours are drawn for the top and bottom surfaces of the aquitard and the bottom surface of the lower aquifer, Figures 4.3, 4.4 and 4.5.

Figure 4.3 shows the altitudes of the surface that separates the upper water table aquifer and the aquitard. The altitude of the surface varies
from 10 metres above MSL near the western boundary to 18.0m below MSL near the eastern boundary. The surface slopes down in the west-east direction.

Figure 4.4 shows the altitudes of the surface that separates the aquitard and the lower artesian aquifer. The altitude of the surface varies from 0.0m above MSL near the south-west region of the study area to 28.0m below MSL near the eastern boundary. The surface dips almost uniformly from west to east.

Figure 4.5 shows the altitudes of the bottom surface of the lower aquifer. The elevation of the surface varies from 10m below MSL near the western boundary to 46.0m below MSL near the eastern boundary. The surface slopes down from west to east.

Figures 4.6 and 4.7 show the spatial variation of the thicknesses of the aquitard and the lower aquifer, respectively. The thickness of the lower aquifer in the Panjetty and Minjur well-fields is more than 14m. The thickness of the aquifer near the coast varies from 18m to 24m. As pointed out earlier, sufficient litholog-data for the eastern part of Minjur and Kattur are not available and the thicknesses of the aquitard and lower aquifer reported here are based on the extrapolation of the available data.

Figure 4.8 shows the section taken along Duranallur village in the west-east direction. The figure shows that all the three formations slope downward in the west-east direction and the thickness of each formation increases towards the east. Figure 4.9 shows the section taken along south-north direction through Pulikulam village and it indicates that the thickness of the lower aquifer reduces to about 3m at the boundaries. Figure 4.7 shows that on the eastern part of the southern and northern boundaries the aquifer thickness is more than 10m.

4.2.4 Nature of the aquifer system

The alluvial deposits of the study area are broadly divided, as stated previously, into three formations: the upper water table aquifer, the intermediate aquitard and the lower artesian aquifer. The upper formation (aquifer) consists mainly of silt with random distribution of clay lenses. The
thickness of the formation varies from 5m in the west to 18m in the east. The hydraulic conductivity of the formation is assumed to be very low for regional flow of water. This assumption is supported by the fact that the abstraction of water from the shallow wells for irrigation is practically negligible. From the hydrogeologic point of view, this formation functions as a reservoir whose water table elevation varies with recharge to and leakage from it. The intermediate formation consists of layers of clay and silt alternately with varying thickness. The net effect of these layers is to retard the vertical flow of water between the upper and lower formations. As a result, the intermediate formation functions as an aquitard. The formation also creates the confined condition for water in the lower aquifer. The lower formation consists of fine to coarse sand and gravel. In some places, the presence of pebbles at the bottom of the formation has been reported. This formation forms a potential aquifer and the abstraction of water for irrigation and industrial use takes place from it. As in most part of the formation the water occurs under confined condition, it is called artesian aquifer. It is underlain by the impervious Gondwana formation.

The lower aquifer is bounded on the eastern side by the Bay of Bengal. The western half of the northern and southern sides of the aquifer are bounded by impervious formation and the rest of them are treated as streamline boundary. The western boundary is fixed arbitrarily to limit the size of the study area and it is bounded by the alluvial deposits that extend towards west from the study area.

4.3 HYDROGEOLOGIC PARAMETERS

The hydrogeologic parameters of an aquifer are hydraulic conductivity and storage coefficient. The capacity of an aquifer to store water depends on the magnitude of the storage coefficient whereas the magnitude of the hydraulic conductivity indicates the ability of an aquifer to transmit water. In formulating a simulation model, the magnitude and spatial variation of these parameters form the important input data. The study area has three distinct formations and therefore, the hydrogeologic parameters of all the three formations are needed for the model formulation.
4.3.1 Hydraulic conductivity

The hydraulic conductivity of an aquifer depends on the properties of water and the aquifer skeleton. The important properties of water that influence hydraulic conductivity are the viscosity and density. These two properties vary with temperature; but the variation of these properties for the expected range of temperature variation in groundwater is insignificant and hence the properties of water are assumed to have little influence on the variation of hydraulic conductivity. The properties of the aquifer skeleton that influence the hydraulic conductivity are the pore size and shape, and the percentage of porosity. These properties in turn depend on the grain size and shape, and its distribution, arrangement and compaction. Though the relationship between the grain size of materials and its distribution and the hydraulic conductivity can be known from laboratory experiments, the hydraulic conductivity of an aquifer is normally determined from tests conducted in the field. Among the field tests, the pumping test is considered to be the more reliable one. As pumping test analysis is an expensive and time consuming procedure, only a few tests are normally carried out in an aquifer. In the absence of pumping tests, the hydraulic conductivity of a formation is estimated using the soil classification and the standard values published in literature. The range of hydraulic conductivity values given by Freeze and Cherry (1979) for different soils in unconsolidated formation is presented in Table 4.1.

<table>
<thead>
<tr>
<th>Unconsolidated deposits</th>
<th>Range of Hydraulic conductivity values in m/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt, Loess</td>
<td>0.00009 - 2.0</td>
</tr>
<tr>
<td>Silty sand</td>
<td>0.009 - 86.</td>
</tr>
<tr>
<td>Clean sand</td>
<td>5. - 864.</td>
</tr>
<tr>
<td>Gravel</td>
<td>86. - 86400.</td>
</tr>
</tbody>
</table>
4.3.2 Storage coefficients

The storage coefficient of an aquifer is defined as the ratio of the volume of water released by an aquifer column of unit cross sectional area for unit decline of the average groundwater head in the column. The storage coefficient of a confined aquifer depends on the elastic properties of water and the aquifer skeleton and it varies normally between 0.005 to 0.0001. In the case of unconfined aquifer, the storage coefficient is the volume of water drained by gravity per unit volume of aquifer. This property is also known as unconfined storage coefficient or specific yield and is related to the effective porosity or drainable porosity which forms a fraction of the porosity of aquifer. The specific yield value for alluvial deposits normally varies from 0.01 to 0.20. The National Bank for Agriculture and Rural Development (NABARD) has recommended the following specific yield values (Table 4.2) for unconsolidated formations in the absence of field test.

TABLE 4.2 : SPECIFIC YIELD VALUES

<table>
<thead>
<tr>
<th>Unconsolidated deposits</th>
<th>Specific yield values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.12 - 0.18</td>
</tr>
<tr>
<td>Valley fills</td>
<td>0.10 - 0.14</td>
</tr>
<tr>
<td>Silt and clay</td>
<td>0.05 - 0.12</td>
</tr>
</tbody>
</table>

4.3.3 Aquifer parameter values

4.3.3.1 Lower artesian aquifer

The lower artesian aquifer was formed by the deposition of the materials carried by the flowing water. In the process of deposition, the coarser particles settle first, followed by the finer particles. In a vertical section, the grain size of the material in an alluvial aquifer increases from top to bottom. Such a distribution of aquifer materials has been reported in the borehole data of the study area. It is expected that the hydraulic conductivity of the formation will increase from top to bottom. In modelling regional flow systems made up of alluvial deposits such variation in hydraulic
conductivity is ignored and an average value is used, unless the variation is appreciable.

The grain size of the aquifer materials formed from the deposition of alluvium varies in the horizontal plane also. In a river course, coarser materials are deposited in the upstream and finer materials in the downstream. In the study area, the borehole data indicate a trend that the grain size of the aquifer material in the lower formation decreases in the flow direction of the rivers. The variation of the hydraulic conductivity caused by the spatial distribution of the size of the aquifer material is considered in modelling an aquifer system.

Figure 4.10 gives the hydraulic conductivity and the confined storage coefficient values of the lower aquifer at different locations, obtained from the UNDP report (1975). The UNDP report indicates that the aquifer parameter values were estimated using the methods of analysis applicable for nonleaky artesian aquifer. As the MPAS is a leaky one, the aquifer parameter values reported here are likely to differ from the true values.

The parameter values based on pumping test are available for the area lying between the two rivers, Figure 4.10. For the areas north of Araniar and east of Kattur and Minjur villages, the parameter values are chosen on the basis of the soil classification reported in the borehole data. The values chosen are: hydraulic conductivity varying from 90m/day to 200m/day and the confined storage coefficient varying from $2.0 \times 10^{-4}$ to $7.5 \times 10^{-4}$.

The analysis of the hydrographs of wells tapping the lower aquifer reveals that the western part of the aquifer changes between confined and unconfined conditions, Figure 1.2. As the change in the condition of the aquifer is to be incorporated in the model, the unconfined storage coefficient of the lower aquifer is needed for the model formulation, but the aquifer has not been tested to ascertain this value. A value of 0.1 is used as the unconfined storage coefficient for the model formulation.
4.3.3.2 Aquitard

The aquitard consists of layers of silt and clay of varying thickness laid alternately. The net effect of these layers, on hydrogeologic point of view, is to retard the vertical flow from the upper water table aquifer to the lower artesian aquifer. It is assumed that this formation permits vertical leakage, but has negligible storage effect. This formation has not been tested to ascertain its vertical hydraulic conductivity. To start with, a uniform value of 0.001m/day is used for the model formulation.

4.3.3.3 Upper water table aquifer

The upper water table formation consists of silt with random distribution of lenses of clay. The hydraulic conductivity of this formation for regional flow is assumed to be negligible. As the formation functions as a reservoir and the annual variation of the water table is of appreciable magnitude, the specific yield of the formation forms an important parameter in the system. The specific yield depends on the type of soil distributed in the formation. Based on the type of soil reported in the borehole data, specific yield values are chosen. The range of values chosen is 0.02 for silty clay to 0.10 for silt.
FIG. 4-3 ELEVATION OF TOP SURFACE OF AQUITARD.
FIG. 4.4 ELEVATION OF TOP SURFACE OF LOWER AQUIFER.
FIG. 4.5 ELEVATION OF BOTTOM SURFACE OF LOWER AQUIFER.
FIG. 4-6 THICKNESS OF AQUITARD
FIG. 4-7 THICKNESS OF LOWER AQUIFER.
FIG. 4-8 SECTION ALONG WEST-EAST DIRECTION.
FIG. 4.9 SECTION ALONG SOUTH-NORTH DIRECTION.
FIG. 4-10 HYDROGEOLOGIC PARAMETERS OF THE LOWER AQUIFER.