CHAPTER 6

GIS ANALYSIS FOR EXPLORING
SILICA - GRADE SAND DEPOSITS

This chapter presents the results of an exercise that integrates the various thematic maps and collateral information described in the previous chapters.

Since the initial field investigations revealed that the localisation of silica-grade sand deposits are perhaps controlled by the geomorphic factors, fluvial, fluvio-marine processes and the provenance, it was decided to carry out a GIS based analysis of the various factors and arrive at a map showing the potential locations of silica - grade sand.

6.1 INTRODUCTION

A Geographic Information System (GIS) captures, stores, analyzes, manages, and presents data that is linked to geographic location. Data source for a GIS typically include maps and remote sensing system, both of which are capable of producing large volumes of data. The important components of GIS are hardware, software, data, people, training and sound analysis methods for interpreting the results generated by the GIS. GIS has wide range of applications in many field. Some of the applications of GIS are agriculture, business, environment, geology, hydrology, land use, planning, military, risk assessment, site planning, transportation etc. GIS is often classified as being either a raster or vector system. Raster systems are also referred to as grid or
cellular systems and vector system systems are often called polygon systems. A raster system consists of an array of matrix of square cells. In a vector system, the digital representation of line and polygon information generally consists of an ordered sequence of x-y coordinate pairs. These coordinate pairs, when linked together by short, straight lines, produce an approximation of the original line or polygon, It is often generalized that vector systems are more accurate and storage efficient than raster systems. Keeping this in mind, vector GIS techniques have been adopted in this thesis.

6.2 WHY GIS?

The use of GIS in mineral exploration is now widespread, allowing the integration of disparate digital datasets into a single, unified database. Using of geographic information system in mineral exploration, is a favorable way for studying immense amount of data which can reduce budget and time and limit the area for exploration and getting better results. GIS is an ideal partner to image processing systems allowing the rapid manipulation, comparison and interpretation of the various image processing interpreted products with other relevant datasets.

According to Ray (2002) careful consideration must be given in developing the exploration model so that all of the relevant, important aspects of the deposit being sought are represented. Mineral potential map is produced by the compilation of all available data sets within the GIS. The model is also very important in deciding what weights to apply to each of these aspects. In the final analysis, these weights may be arbitrarily applied, with an intimate knowledge of the model and the deposit, ie, which of the factors related to the deposit are most important, ranging down to those of least importance (a knowledge based approach). Another approach, which is not applicable in all situations, is to use a statistical method in order to decide upon weights. The final result is a combination of all of the weighted values,
producing a map which ranks the study area by degrees of perceived prospects. The review of Ray has a great significance as far as exploring the silica sand deposits are concerned. Hence, a knowledge based approach has been adopted in the study to assign the appropriate weights to certain area/factors.

6.3 INTEGRATION IN GIS

The need to include ancillary information (e.g. maps and ground surveys) in the process of interpreting remotely sensed data has long been acknowledged by the remote sensing community. On the other hand, the advantage of using information derived from remotely sensed data to correct, update and maintain cartographic data bases and GIS has been amply demonstrated over the last few years (Burrough 1986; Chang 1998). The various tasks envisaged in integrating remote sensing and creating a data base through GIS is as follows:

a) Collection and preparation of input data.

b) Storing and organizing the data such as:

i. Digitization of point, line and polygon feature coverages.

ii. Editing of different coverages.

c) Topology building and error removal.

d) Defining and assigning attributes to coverage features.

e) Transformation of spatial data to generate information on desired scale.

f) Map composition for plotting coverage features, legends, titles and integration of different coverages.
6.4 SIGNIFICANCE OF EACH THEME IN THE ANALYSIS

Geographic problems often require the analysis of many different factors. For finding the suitable sites of deposition of silica-grade sand, thematic layers like geomorphology, palaeochannel, geology and elevation are to be considered. Each theme has different importance in the context of finding the suitable sites for the localisation of silica-grade sand. Choudhury (1999) states that consideration of relative importance factors often leads to a better representation of the actual ground situation.

6.4.1 Geomorphology

The topography of the area has a better role in the deposition and accumulation of mineral deposits. In this study, emphasis is given to the areas near the coast; hence the studies of the upland were not taken into account. The geomorphic units present in the study area are lagoons, dunes, swales, flood plain, mudflat with / without vegetation, sedimentous uplands, palaeochannels, shallow and deep buried pediments, creek, palaeo creeks etc. The characteristics of geomorphic units has already been listed in Chapter 4. Apart from the above mentioned geomorphic features, the palaeochannels are an important component of the landscape.

6.4.2 Palaeochannel

Climatic changes and neotectonic movements have led to migration and abandonment of several rivers and drainage systems. Some of them are ‘extinct’ because of the continuous deposition of sand and silt on the channels. Identification of palaeochannels is considered important in the study because it is believed that the rivers and streams were responsible for eroding the source rocks, transporting and sorting the fragments, before depositing the resistant and residual silica-sand near the coastal areas.
6.4.3 Geology

From the literature it is clear that the lithology of the source area has a bearing on the mineralogy and purity of sand accumulated in the study area. Citing Hahn (1969) and Kodewijn (1955), Pettijohn (1984) mentions that certainly the source rock play a vital role in determining the character of sand. The author adds that sands supplied by small watersheds of differing bedrock differ from one another. The case study of Rhine River has shown the effect of local bedrock on the composition of the sands in the river. Sands derived from a rhyolitic volcanic terrain will differ from those produced in a region underlain by deep-seated granites and gneisses. The former has a paucity of quartz and feldspar and a super-abundance of rhyolitic rock fragments; whereas the later is primarily quartz and feldspar rich with few or no rock fragments. Studies of modern sedimentary basins show that the mineralogy of sands reflects closely the composition of the source area.

Thus geology has been given due importance in this study. The study is marked by the presence of cretaceous and tertiary rocks like various sandstones, clay and limestone in south eastern portion of study area. The river channels that had once flown through these sedimentary rocks, may have transported and deposited the resistant sand particles. Since sandstones are the major source rock for silica - sand, it has given due importance in this study of silica - grade sand.

6.4.4 Vaanches

These special type of water bodies have already described in Chapter 3. Vaanches play an important role while identifying silica-sand deposits; because most silica - grade sand deposits occur adjacent to these Vaanches. Discussions with the locals and the groundwater geologists
indicate that the fresh/sweet water present in the vaanches is from the silica-sand horizon.

6.4.5 Elevation

The drainages of an area are controlled by the physiography of that area. Hence, elevation has been given due importance in the study of palaeochannels. Section 4.3 describes the elevation in detail.

6.5 OVERLAY ANALYSIS

The tutorial of Arc 9.1 mentions that, overlay analysis is one of the spatial GIS operations that seem to define a GIS. It integrates spatial data with attribute data (attributes are information about each map feature). Overlay analysis does this by combining information from one GIS layer with another GIS layer to derive or infer an attribute for one of the layers. At its simplest, overlay analysis can be a visual operation, but analytical operations require one or more data layers to be joined physically. Results of overlay analysis rely on the spatial accuracy of the GIS layers. If the layers don’t line up well, then the attributes inferred by the overlay may be incorrect. That is, the results are only as good as the GIS data used for the analysis. In addition to overlay analysis, other spatial GIS operations include:

- Query and Analysis, i.e. Retrieval/classification/measurement functions
- Answering analytical questions (distance, location, what's there, etc.)
- Continuity analysis
- Buffering
- Proximity analysis
Weighted overlay is a technique for applying a common scale of values to diverse and dissimilar input to create an integrated analysis (ARC GIS 9.1, tutorial). Weighted Index Overlay Analysis (WIOA) is a simple and straightforward method for a combined analysis of multi-class maps. The efficacy of this method is that the human judgment can be incorporated in the analysis. A weight represents the relative importance of a parameter with respect to the objective.

WIOA method takes into consideration the relative importance of the parameters and the classes belonging to each parameter (Saraf and Choudhury 1998). Topology creation and error removal has to be done prior to the overlay analysis. Topology is used most fundamentally to ensure data quality and allow the geodatabase to more realistically represent geographic features.

In the current study of silica - grade sand the thematic maps are analysed by overlaying and rank and weights are assigned to each category in the theme to model the probable occurrence of silica - sand rich areas. The input layers to the weighted overlay are geomorphology, palaeochannels, geology and elevation. The weighted overlay model is displayed in the Figure 6.1.

![Weighted overlay model](image)

**Figure 6.1** Weighted overlay model
Determination of the weights of each class is the most crucial in integrated analysis, as the output is largely dependent on the assignment of appropriate weight. Considering the probability criteria of the input themes which lead to the deposition of silica - grade sand, weighted indexing has been adopted and shown in Table 6.1.

Table 6.1 Table showing the ranks and weights assigned to various themes and units

<table>
<thead>
<tr>
<th>Theme</th>
<th>Weight</th>
<th>Units</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>20</td>
<td>Charnockite/ Gondwana sandy clay / Boulder beds/ Hornblende-Biotite Gneiss</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lime stone, River</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand stone, Fluvial, Marine</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluvio-marine, Lagoon</td>
<td>4</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>30</td>
<td>Denudational hill, structural hill, Creek, Shallow /Moderate / Deep buried pediment upland, Spit, fresh water tank, Flood plain</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beach, Sand bar, Mangroves, River channel, Shallow / moderately buried pediment coastal</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deep buried pediment coastal, Oxbow lake, Palaeo creek, Sedimentous up land, Mud flat with vegetation, Mud flat without vegetation, Dune, Meander scar</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slack/ Swale, Lagoon</td>
<td>4</td>
</tr>
<tr>
<td>Palaeochannel</td>
<td>35</td>
<td>Upland</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coastline</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Present channel</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coastal plain, Palaeochannel, Buried channel, Vaanch</td>
<td>4</td>
</tr>
<tr>
<td>Elevation map (m))</td>
<td>15</td>
<td>35 – 100, 25 – 35, Above 100</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 – 25</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 – 15</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 – 5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 -10</td>
<td></td>
</tr>
</tbody>
</table>
The contents of Table 6.1 are similar to the contents of the criterion table listed by Nagarajan and Singh (2009), Murukesan (1995), Rajakumar (2006), Mahadevaiah (2006) and Jayaseelan (2006). The deposition and localisation of silica-sand is controlled by various factors. The influences of all factors need not be the same in all the area. Therefore, each parameter is assigned a weight depending on its influence which leads to the accumulation of silica-sand. The different units in each theme are assigned knowledge-based hierarchy of ranking from 1 to 4 on the basis of their significance with reference to their role which leads to the formation of the deposit. In this ranking, 1 denotes poor, 2 denotes moderate, 3 denotes good and 4 denotes very good factors controlling the deposition. In the geomorphology layer, lagoons and mudflats are highly suitable for the occurrence of silica-sand, while upland is not. In the geology layer, suitability values are high for fluvio-marine area and low for the crystalline rock areas. Likewise, all themes have been assigned ranks and weights according to its priority to form a workable sand deposit. Each of the four input themes is then weighted. In this weighted overlay approach, it is estimated that geomorphology has 30 percent influence, elevation has 15 percent influence, palaeochannel has 35 percent and lithology has 20 percent influence on the localisation of silica-sand deposit. Ranks assigned to various sub categories for each theme is multiplied with the weights assigned to the criteria and summed for all the criteria to get composite weight (Murugesan 1995).

\[
\text{Composite Weight} = R1 \times W1 + R2 \times W2 + R3 \times W3 + R4 \times W4
\]

where,

- \(R1 \times W1\) = Rank and weight of Palaeochannel
- \(R2 \times W2\) = Rank and weight of Geology map
- \(R3 \times W3\) = Rank and weight of Geomorphology map
- \(R4 \times W4\) = Rank and weight of Elevation map
6.6 RESULTS OF THE GIS ANALYSIS

When the weighted overlay analysis is run, a map of the overall suitability with respect to occurrence of silica-sand is created (Figures 7.2(a) and 7.2(b)). The most suitable areas are shown in red, moderate suitable areas by green and poor areas by orange. Light green areas in the map represent areas not included in the study (such as the uplands) or areas unsuitable for the localisation of silica-grade sand deposits. These four categories were arrived at by taking into consideration the mean of the score and the standard deviation of score (Table 6.2). Mean ($\mu$) of the resultant map is 189 and the standard deviation ($\sigma$) is 69. Very good prospect zone is assigned the value of 258 and above, which is the addition of standard deviation and mean. Similarly good has given a value in between 258 and 189, moderate as 189 to 120 and poor less than 120. The accuracy of the GIS analysis and their implications is discussed in the next chapter.

Table 6.2 Statistical estimation of zones of silica potential (adopted from Rajakumar 2006)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Value</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu + \sigma$</td>
<td>&gt; 258</td>
<td>Very good potential</td>
</tr>
<tr>
<td>$\mu + \sigma$ to $\mu$</td>
<td>258 to 189</td>
<td>Good</td>
</tr>
<tr>
<td>$\mu$ to $\mu - \sigma$</td>
<td>189 - 120</td>
<td>Moderate</td>
</tr>
<tr>
<td>$&lt; \mu - \sigma$</td>
<td>&lt; 120</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Modifying the suitability values or the influence percentages will produce different results. In the GIS analysis carried out and presented above, the ranks and weights have been assigned to the corresponding themes and units. These values of rank and weight have been assigned based on
preliminary field work, field evidences and certain logic that result due to the understanding of these deposits. The resultant zonation map shows the possible locations of silica-grade sand deposits.

6.7 CONCLUSIONS

This chapter has examined in detail, the factors that control the distribution and grade of silica-grade sand deposits along the northern Tamil Nadu coastal tract. These factors have been depicted in the form of thematic maps such as geologic map, geomorphic map, palaeochannel map and elevation map.

Thus GIS analysis presented the results of an exercise that integrated the various thematic maps which control the transportation and accumulation of silica-grade sand. Analysis in a GIS and preparation of map showing potential zones of silica-grade sand deposits have also described. Assigning appropriate ranks and weights for the theme, explanation of the rationality in assigning the ranks and weights, overlay analysis and generation of a final map has been elaborately presented.

The accuracy of the GIS analysis and their implications is also verified. These values of rank and weight have been assigned based on preliminary field work, field evidences and certain logic that result due to the understanding of these deposits. The resultant zonation map shows the possible locations of silica-grade sand deposits.