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Ghat road alignment in Palamalai Hills, Tamil Nadu, India using Ghat Tracer, GPS and GIS

R.Arulmozhi[1] & T.Subramani[©2*]
[1]Tamil Nadu Highways Department, Salem, Tamil Nadu, India
[2]Department of Mining Engineering, CEG, Anna University, Chennai-600025, India
*[Email: geosubramani@annauniv.edu; geosubramani@yahoo.com]

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Present study was conducted while fixing alignment in the study area Palamalai hills from Mulakkadai village in the plains to Kemmampatti village on the top of the hill. In this work survey to form road from Mulakkadai to Kemmampatti was conducted using Ghat Tracer, Total Station and GPS. The elevation of the starting point of the road is 320 m and the hill top is 742 m above mean sea level (MSL). Road alignment in the hilly terrain was fixed using Ghat Tracer with a gradient of 6%. Length of the alignment in the ghat section is 6.30 km with eight hairpin bends. Total station and GPS surveys were conducted along the alignment to get the coordinates. Using the data alignment plans and longitudinal sections were prepared for the proposed road. A digital map was prepared for the study area by digitizing contours, drains, roads, forest boundaries and villages. From the elevation data a digital elevation model (DEM) was prepared using GIS software. GIS was further used for creating alignment plans with 6.00 m buffer to represent the road width. The implications of using these modern technologies in time and cost aspects were discussed in this work.

[**Keywords:** Road alignment in hilly terrain, Ghat tracer survey, GPS and GIS in road alignment, Palamalai hill, South India]

Introduction

Planning of road alignment in hilly terrain is a difficult task when comparing it in plains. Several factors need to be evaluated to choose the best alignment among alternatives in hill roads[1]. Conventional methods are more time consuming and expensive for the extraction of surface profile information required for road alignment[2]. It is perceived that the use of Geographical Information System (GIS) in the task will reduce the difficulties of such work. Using maps alone to determine routes is tedious, time consuming and les accurate. On the other hand, a good model for road planning should incorporate the knowledge of the road engineer and be simple and easy to use[3&4]. During the last decades, a few attempts were made to automate the route planning process using GIS technology. A review of a number of papers suggests that, the planning of hill road using GIS will result in a safer and cost-effective route with lower construction and maintenance costs[5].

The first step involved in hill road planning is tracing various tentative alignments on the ground. This is done by using the ghat tracer instrument or other suitable methods with designated gradient usually between 5% and 7%. The next step is to find out the coordinates and elevations of the path at close intervals using compass and leveling instruments in the olden or the total station. Using this data, plan and profile of various tentative alignments are prepared and studied for their merits and the final one is selected based on safety and economy. Doing total station survey in adverse hilly terrain conditions along all the alternate alignments is tedious and time consuming. Therefore Global Positioning System (GPS) survey is used in the alternate alignments to get the plan and profiles to study them for their merits before selecting the final one. Accuracy of GPS data is sufficient for this purpose. The total station will be used only along the final alignment to take precise data for estimation and construction purposes.

Materials and Methods

The study area Palamalai hill is geographically located within latitude 11° 38’ 00” - 11° 52’ 00” N and longitude 77° 42’ 00” - 77° 48’ 00” E and physically situated in Kolathur panchayat union of Salem district in the State of Tamil Nadu, South India on the banks of the river Cauvery. Proposed road formation is from Mulakkadai a village located on the existing road in the plains to Kemmampatti a remote unconnected village on the top (Fig 1). Palamalai is a isolated hill and its length is 22 km. and width varies between 4 km. and 5 km. Altitude of the hill varies from 320 to 1450 m. According to revenue classification the area is under reserved forest and the vegetative cover is predominantly bushes and small trees. Slope of the hill varies

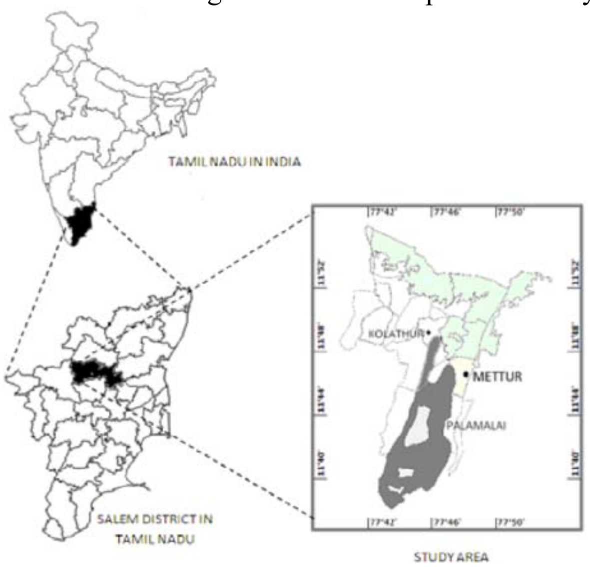


Fig. 1- Study area location map

from 25% to 50%. Meteorologically the area is tropical with average annual rainfall of about 910 mm. Mean temperature of the area is ranging from 32°C to 45°C. The precipitation occurs mainly between July and December. There are relatively flat areas on the top mostly of agricultural lands and the predominant crops are Turmeric, Tamarind, Coconut and Jackfruit.

Field work consists of reconnaissance survey, preliminary survey and final location survey. In this work, we were dealing with reconnaissance and preliminary surveys. During the reconnaissance survey obligatory points to start and end the alignment were identified after studying the terrain features of the study area. Some locations were identified on the foot path as control points to take the alignment along them. Survey of India (SOI) topo sheets of 1:50000 scale and satellite images have been contemplated to finalize the obligatory and control points[8]. Though the information contain in topo maps are slightly older they could be very helpful to read with the remote sensing images[9]. Preliminary survey work has been started to trace the alignment from the top using Ghat tracer instrument. In this work as per Indian Roads Congress guidelines a gradient of 6% is provided as the area comes under steep terrain category[6&10]. Using topo sheets and the terrain features observed during the reconnaissance survey, suitable locations for hairpin bends were selected. Selected flat locations were integrated with the alignment by moving the site suitably to adjust the gradient and length as per code provisions. It is also important to identify the places such as rocks, landslide areas and stream crossings in advance for better planning of alignment survey. During this process, the chainages and identifications were marked over some permanent places. Initially two engineers, two survey assistants, three helpers and around twenty workers for clearing the bushes were engaged to trace the alignment and daily outturn is around 150 to 200 m. Likewise the total alignment length of 6300 m. was traced on the hill by clearing the bushes for three meter width. The methodology of the work is given in Fig. 2.

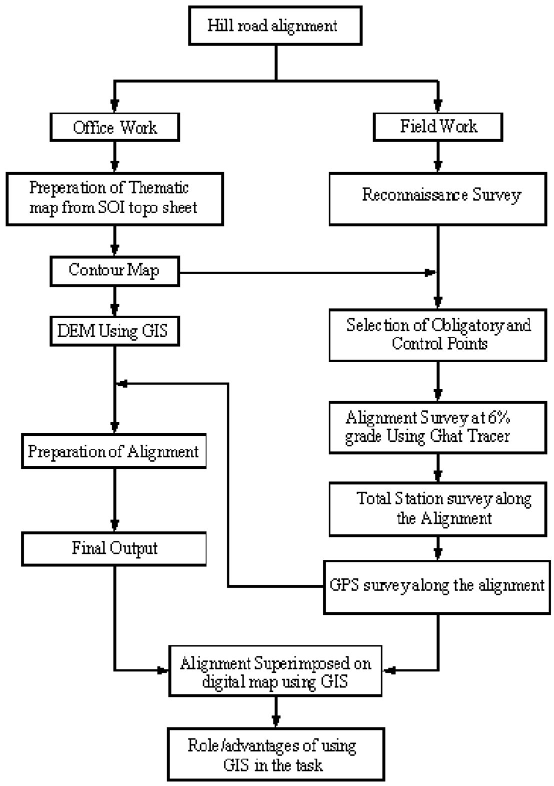


Fig. 2 - Methodology flowchart

Highway alignment in hilly terrain requires to include many factors and often balancing of conflicting features. It is to obtain a best route at a minimum cost, with minimum disturbance to the natural terrain and safety. Conventionally this process include reconnaissance survey, identification of practicable routes, selection of suitable one, preliminary survey of the selected route and location survey and staking of the designed route on the ground. This approach is tedious and may not be feasible when factors such as landslides, geology, soil type, vegetation, cross drainages, and land cover are considered in view of safety and economy. Satellite imageries are good source for evaluation of routes in hilly terrain. GIS and computer techniques are being used since recent times to determine and comparing costs of alternative alignments. With the popularity of GIS it is appropriate to explore opportunities to integrate traditional road design techniques into the GIS [11,12,13&14].

Ghat tracer is a survey instrument used to fix required gradient in the hill with simple operational procedures and extensively used for locating a number of points on a given gradient during preliminary route surveys (Fig. 3). It is also used for measuring grades or angles of slopes[15&16]. Survey with Ghat tracer has to be started

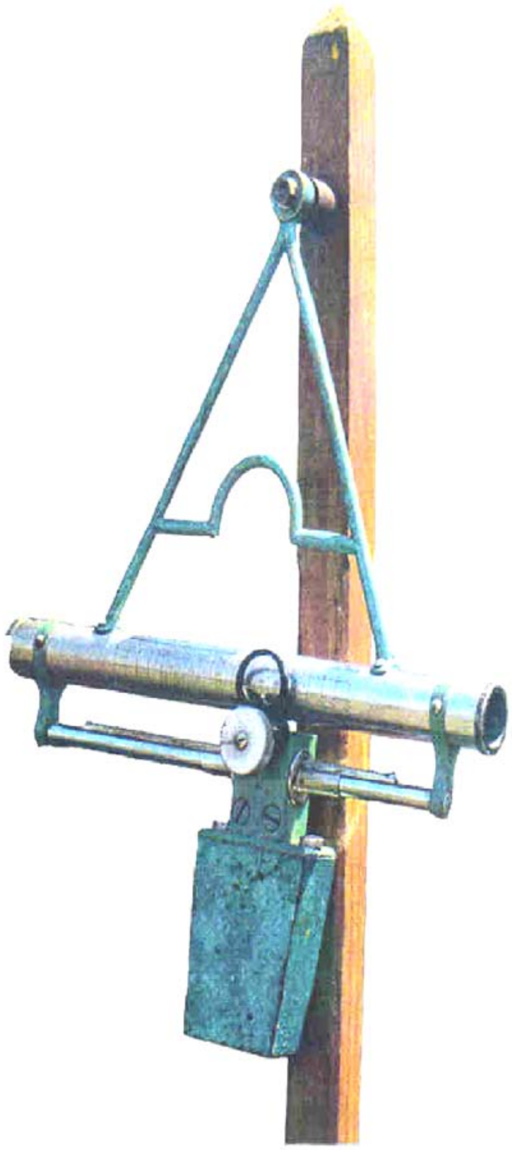


Fig. 3 - Ghat Tracer survey

from the top and continued towards the bottom. In mountainous terrain where very steep slopes are encountered it is sometimes unavoidable to use hairpin bends. Wherever it is required to introduce hairpin bends the survey has to be started from the proposed hairpin point location towards top and join with alignment coming from the top suitably by adjusting the gradient. Likewise the ghat tracer survey has to be done towards the down side from the same location. Hairpin bends are curves with a very small radius continuing in some cases until the direction of the road has changed 180°. When a number of hairpin bends are constructed it is possible to descend a slope where little space for road construction is available. Since, it is not only difficult to construct and maintain but also difficult for traffic to use, they should be avoided if alternative methods are available[17].

Longitudinal and cross sections of the alignment are required to modify the path based on its cutting, filling and geometrics. In view of the above, survey has been conducted to get the coordinates of the alignment using Total Station instrument. Longitudinal coordinates were taken at 10.00 m intervals and cross sections with 2 points on either side at 20.00 m intervals. Where the drainages are met with, extra coordinates were taken at required locations. Since the survey work was taken up in adverse land conditions in hilly terrain, it took lot of time and man power to complete this survey work. It involved immense bush clearance for viewing of the target prism and land leveling for setting up the instrument. While starting the survey the instrument was oriented towards north using compass and survey proceeded from top of the hill to the bottom.

GPS survey could be attributed to both the ease of use as well as reduction in costs and time. It is three dimensional, weather independent, capable of rapid data processing system and less labor intensive. GPS eliminates the need for establishing the control before a survey. The selection of final alignment involves the considerations of length, grade, construction cost and safety. As the final alignment has to be selected from the alternatives, it is essential to get the coordinates of all the paths to decide their suitability. Doing survey with total station along all alternate alignment is tedious, time consuming and expensive. Therefore, GPS survey was conducted along the alternatives as preliminary survey and the data has been utilized to select the final alignment route along which detailed survey using total station has been conducted.

GIS is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information[18]. Practitioners also regard the total GIS as including the operating personnel and the data that go into the system[19]. Spatial features are stored in a coordinate system, which references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. Spatial analytical capabilities of the GIS provide valuable inputs to the highway alignment optimization[20]. One of the many useful things about GIS and software in general is its ability to automate simple and complex tasks[14]. Reconnaissance or pre feasibility study helps to examine the entire area lying between the end points of a road and to identify suitable routes within it[21].

Integrating GPS and GIS

GPS is an excellent data collection tool for creating and maintaining a GIS. It provides accurate positions for point, line, and polygon features. By verifying the location of previously recorded sites, GPS can be used for inspecting, maintaining, and updating GIS data. GPS provides an excellent tool for validating features, updating attributes, and collecting new features. These facilities were used to select the final alignment route from the alternate routes traced using the ghat tracer. The GPS survey data taken from the alternate routes combined together for the selected final alignment route by omitting the data of discarded alignment stretches.

The survey of India contour maps Nos. C43F9 and C43F10 of 1:50,000 scale were used as base maps for the preparation of digital maps of the study area. All the required features for the study such as contour lines, water bodies, forest boundary, existing roads, foot path, habitations and drainages were digitized using AutoCAD software. Alignment plan prepared from the GPS survey data was plotted using the GIS facilities in the software SURFER and the same has been superimposed in the digital map Fig. 4. A digital elevation model has also been created from the digital map.

The term digital elevation model or DEM is frequently used to refer to any digital representation of a earth surface and most often it is used to refer specifically to a raster or regular grid of spot heights[5]. Resolution, or the distance between adjacent grid points, is a critical parameter and the best horizontal resolution commonly available is 30 m, with a vertical resolution of 1 m. Several different methods are used to create DEM using various GIS and other compatible softwares. In this case the DEM of study area has been created using SURFER software. For this purpose, contours, drains and

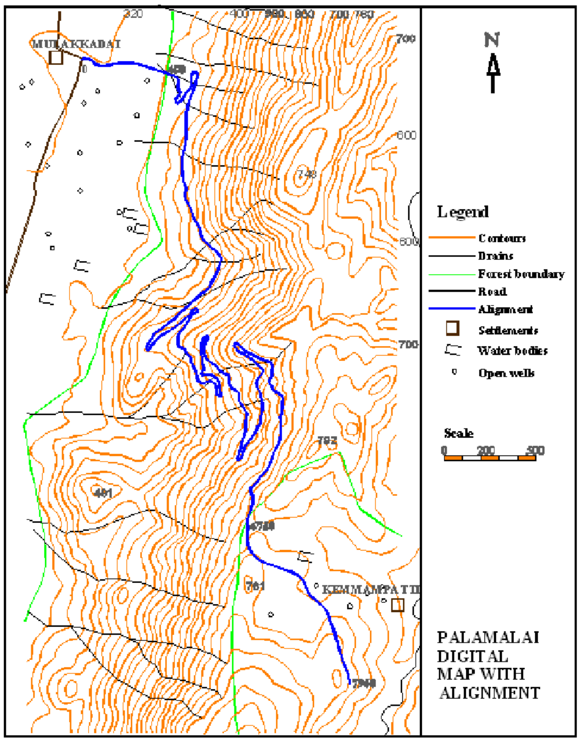


Fig. 4 - Digital topographic map with alignment

boundaries are digitized from the topo sheet and relevant elevations to the contours and georeferences to other features are tagged and the DEM is created (Fig. 5).

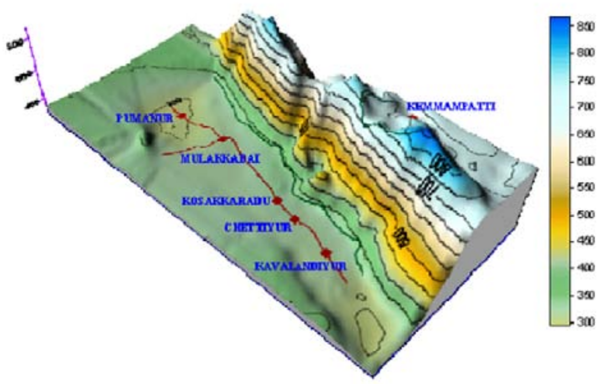


Fig. 5 - Digital Elevation Model of study area

Results and Discussion

As the scope of this work is to study the usefulness of the GPS in the alignment planning work in hilly terrain, certain relevant aspects such as hairpin bends and horizontal alignment components are only looked into for fixing final alignment. Superimposed GPS alignment over topo sheet has been studied elaborately. From the alignment plan the curves, tangents and hairpin

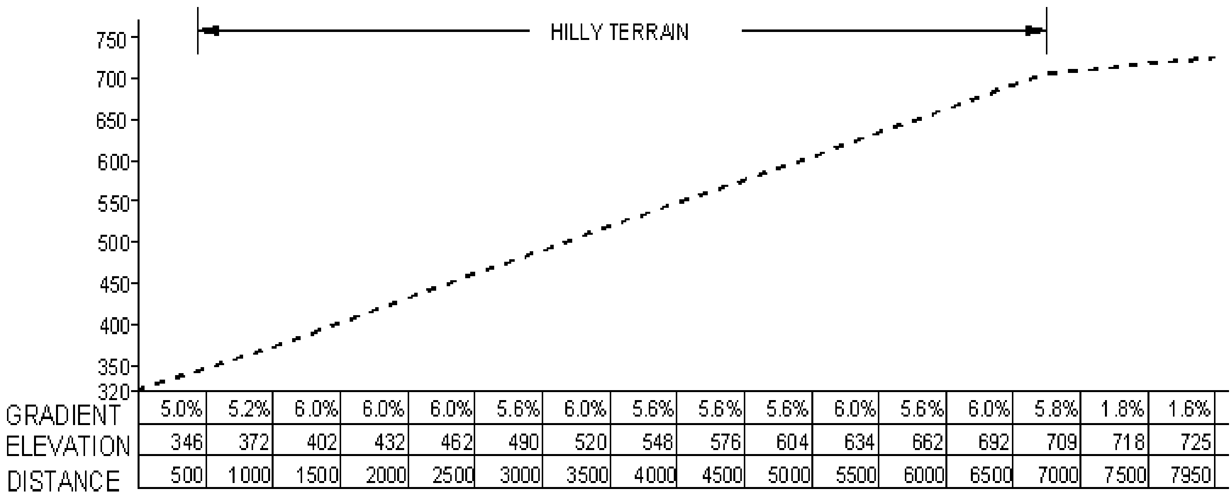


Fig. 6 - Longitudinal Section with gradients

bend locations were mainly focused in the study. Radii of the curves were checked in the digital map to make them standard as per code provisions for design speeds. Each hairpin bend was examined for the correctness of its components such as radius of curvature and gradient of the locations. In some cases the location and the radius was altered and the same was verified in the field for the suitability. Location of the culverts and small bridges were studies in the digital map and DEM[22&23]. The locations are slightly modified to have the approaches and the bridge main to cross the drain in square.

A longitudinal section has been plotted using the GPS data and analyzed for its coordination and integration with the site (Fig. 6). Gradient of the alignment also studied for different sections from the longitudinal section. Its correctness was verified from the topo sheet contours and DEM. Gradient detail for every 500 m is given in table 1. Locations of the cross drainage works also verified in the longitudinal profile. Hairpin bends are critical sections in ghat road alignment. It has to be governed for its special requirements such as allowable grade and curvature. If the location where the hairpin bend lies is not suitable to provide required grade and curvature, the site was shifted to more flat and wider locations. It is also good to keep it in mind, the locations of other nearby hairpin bends proposed in the alignment while doing so. In this alignment there are eight hairpin bends and twenty one cross drainage works.

The alignment plans with a roadway width of 6.00 m for normal stretches and 10.00 m for hair pin bends are presented in Fig. 7(a) to 7(e). Horizontal curves and hairpin bends were designed as per standard provisions in the Indian Road Congress[13]. Alignment plan prepared in the digital map has been buffered in the GIS software to represent the proposed road width.

Table 1 - Gradients of each 500 m

Distance in metre	Level in metre	Block length in metre	Gradient of each block in %	Remarks
0	321	-	-	Branching from exisitng raod at Mulakkadai
440	343	440	5.00	Hilly terrain starts
500	346	60	5.00	Reserved forest
1000	372	500	5.20	Reserved forest
1500	402	500	6.00	Reserved forest
2000	432	500	6.00	Reserved forest
2500	462	500	6.00	Reserved forest
3000	490	500	5.60	Reserved forest
3500	520	500	6.00	Reserved forest
4000	548	500	5.60	Reserved forest
4500	576	500	5.60	Reserved forest
5000	604	500	5.60	Reserved forest
5500	634	500	6.00	Reserved forest
6000	662	500	5.60	Reserved forest
6500	692	500	6.00	Reserved forest
6740	706	240	5.83	Hilly terrain ends
7000	709	260	1.15	Cultivated lands
7500	718	500	1.80	Cultivated lands
7950	725	450	1.56	Alignment ends at Kemmampatti

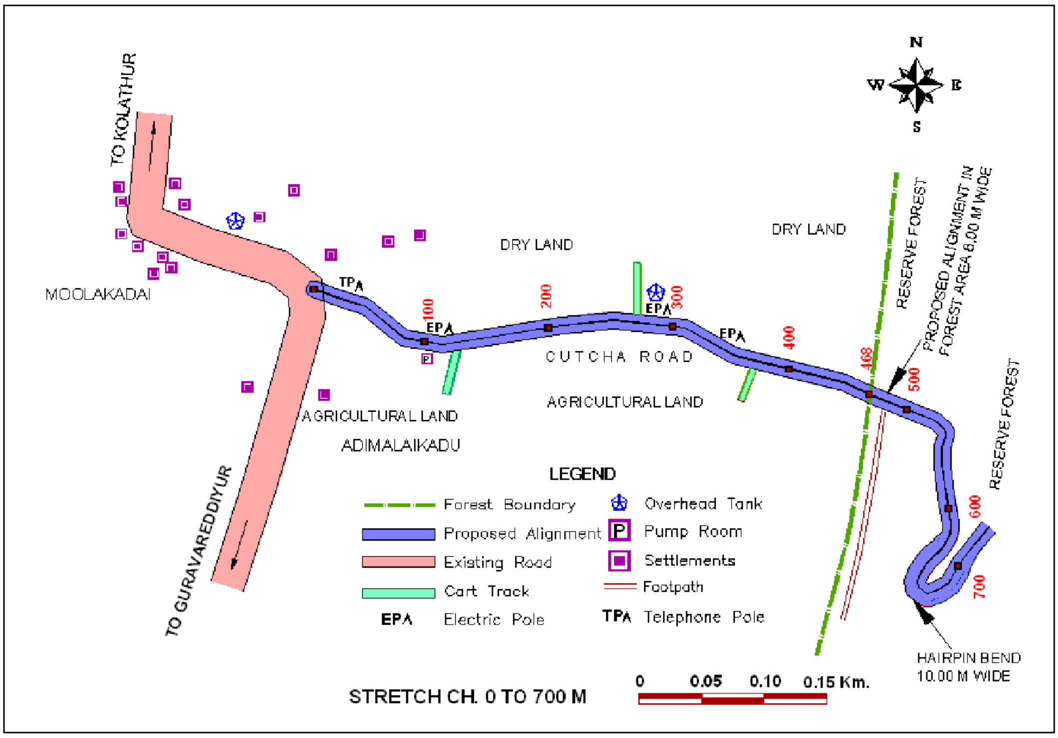
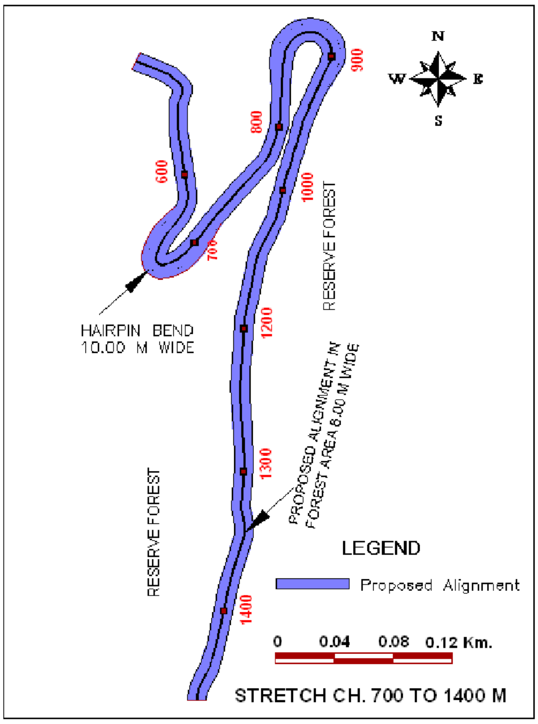


Fig. 7(a) - Alignment plan from 0 m to 700 m



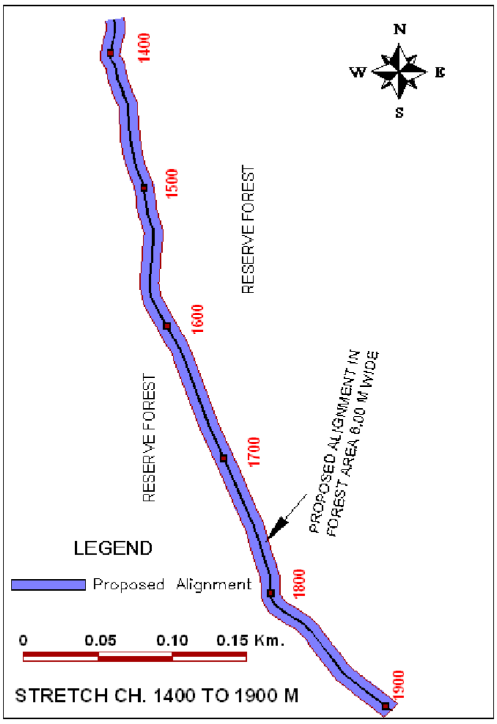


Fig. 7(b) - Alignment plan from 700 m to 1900 m

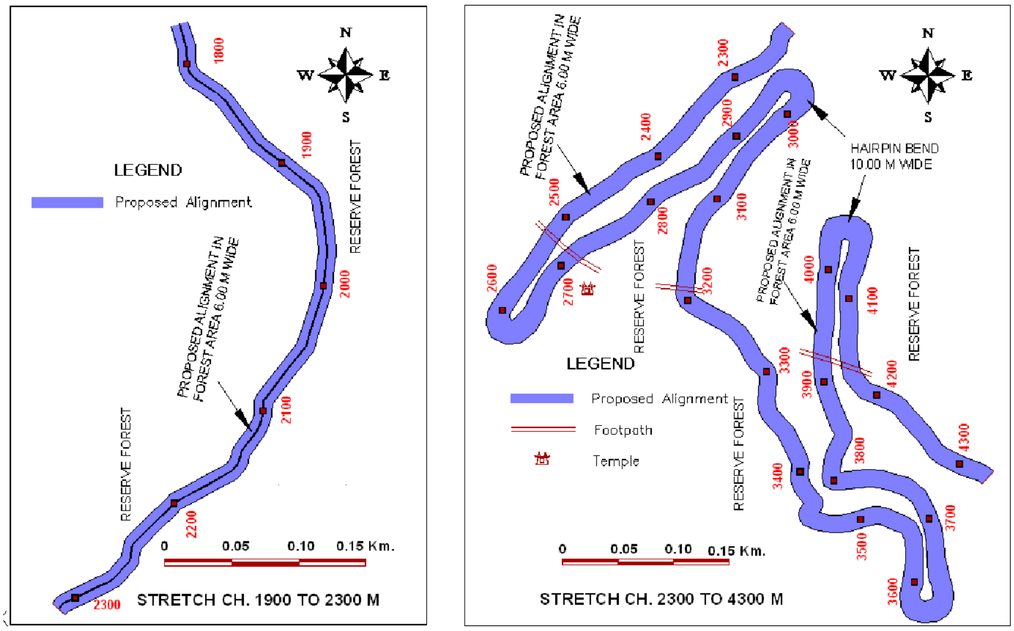


Fig. 7(c) - Alignment plan from 1900 m to 4300 m

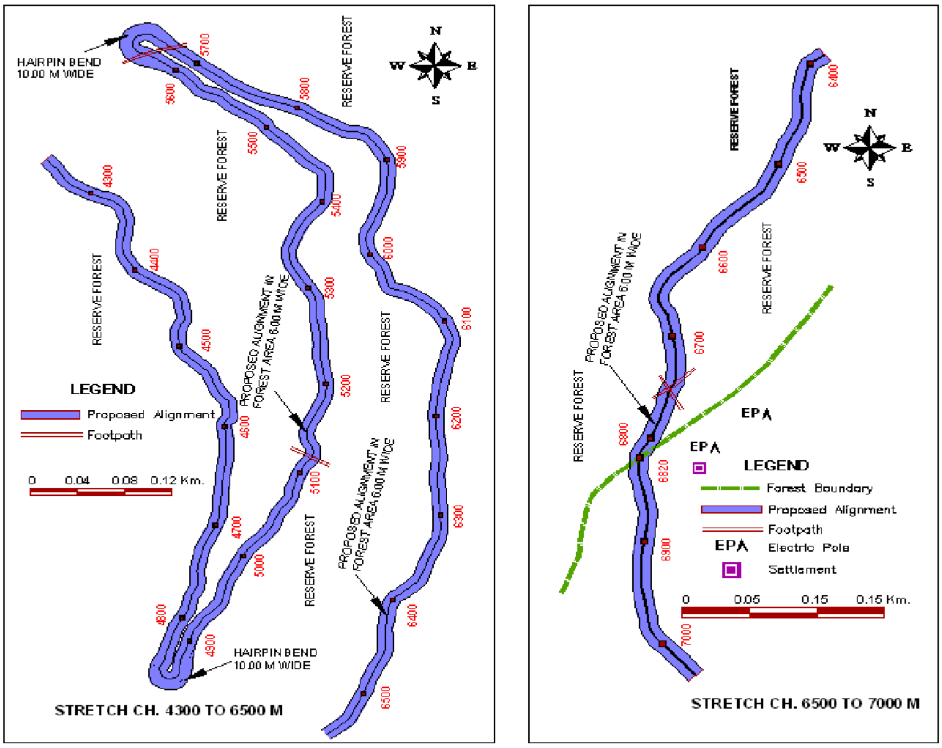


Fig. 7(d) - Alignment plan from 4300 m to 7000 m

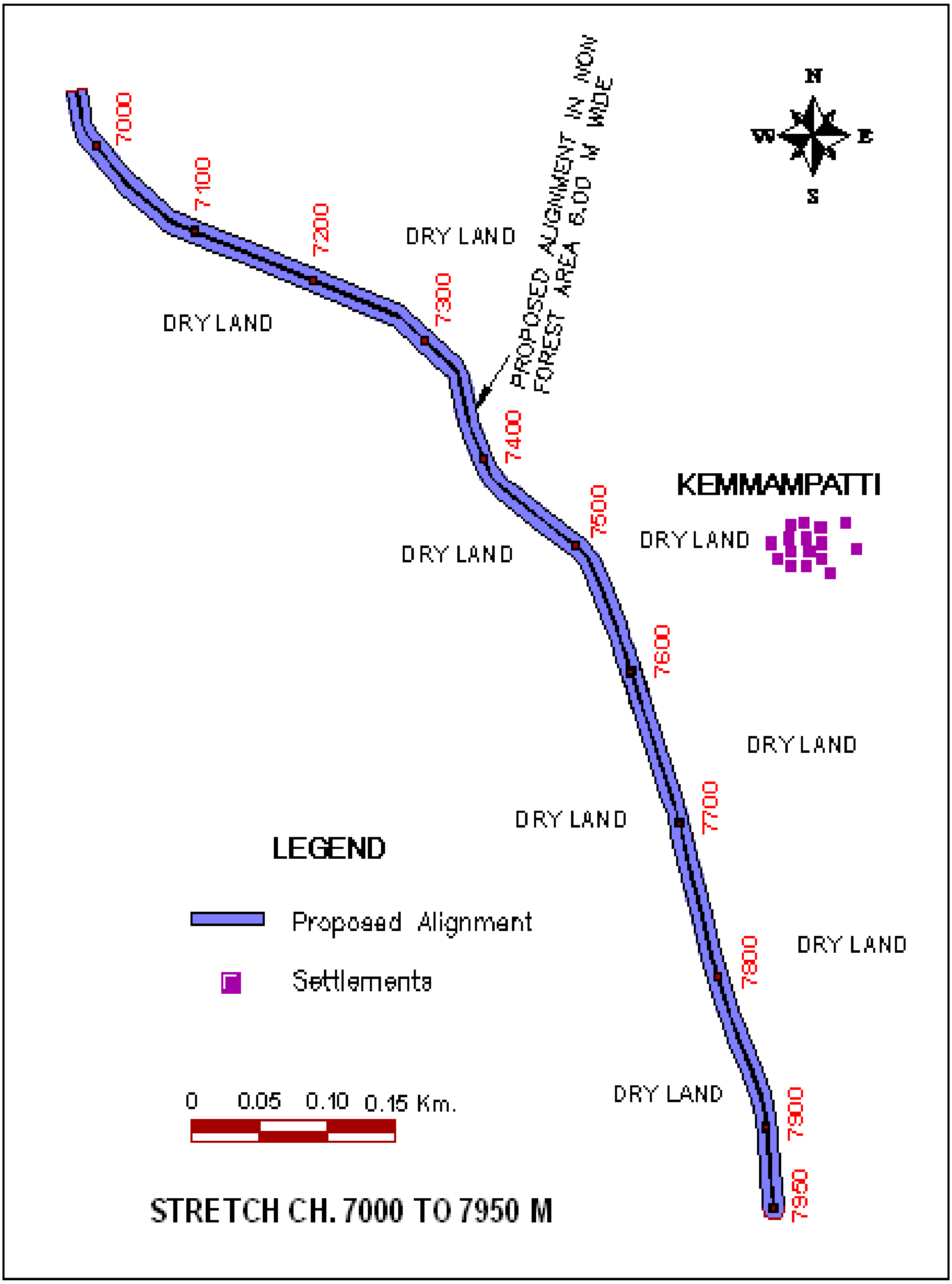


Fig. 7(e) - Alignment plan from 7000 m to 7950 m

The use of GPS in the preliminary survey works helped to reduce the time and resources required to finish the work. It deserves significance when compare it with the conventional methods using compass and levelling instruments for taking bearings, distances and levels or total station for taking coordinates in the place of GPS data. Hence, the GPS survey is found to be a good substitute for fast and economical preliminary survey works. In the GIS part, the techniques are used to prepare the digital map of the study area using AutoCAD software. GIS software has been used to prepare the Digital Elevation Model as detailed supra. Digital map and the DEM are useful in deciding the obligatory points to decide the route and to identify the places to avoid like valleys, steep slopes, rocks, drains and water plains. The facility in the DEM to exaggerate the vertical scale is much useful in deciding the slope and aspect ratio.

Conclusion

GPS combined with GIS techniques have rendered valuable inputs to finalize the alignment in hilly terrain. T. In this study the alignment finalized from Mulakkadai to Kemmampatti is followed the contours of survey of India topo sheet in good order. Same has been checked on the field and found that the alignment is having good agreement with the topography of the terrain. The study has conceptually thrown light on the use of GPS with GIS in the preliminary stage of alignment survey as the data are in digital form and use of computer analysis is simplified. Digital map was useful in the decision making process of preliminary survey stage. Accurate GPS coordinates of known locations are used to bring the digital map accuracy mere close to the actual ground by making corrections, additions and deletions.

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