CITY GEOID MODELLING FOR GREATER CHENNAI CORPORATION (GCC) USING GEOMETRIC METHOD

(GI5811 - PROJECT II)

PROJECT II REPORT

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in partial fulfilment for the award of the degree of

BACHELOR OF ENGINEERING IN

GEOINFORMATICS

INSTITUTE OF REMOTE SENSING

DEPARTMENT OF CIVIL ENGINEERING

ANNA UNIVERSITY, CHENNAI

APRIL 2025

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Introduction

The accurate determination of elevation is a critical component in urban planning, infrastructure development, flood management, and geospatial analysis. In this context, geoid modelling plays a vital role by providing a reference surface that approximates mean sea level, allowing for the transformation of ellipsoidal heights obtained from GNSS systems into orthometric heights used in engineering and construction. This study focuses on Geoid Modelling for the Greater Chennai Corporation (GCC) using the Geometric Method, one of the widely used techniques for geoid estimation at the local or city level. The geometric method primarily involves the comparison of GNSS-derived ellipsoidal heights with known orthometric heights obtained from levelling. The difference between these two sets of heights allows for the computation of geoid undulations (N), which can then be used to develop a local geoid model. Greater Chennai Corporation, being a densely populated and rapidly urbanizing metropolitan area, requires high-precision geospatial data for various developmental activities. A refined local geoid model can significantly enhance the vertical accuracy of GNSS-based surveys and ensure consistent elevation data across the city. The objective of this project is to generate a reliable and high-resolution city geoid model for GCC using the geometric method. This involves the integration of GNSS survey data and existing benchmark data, the computation of geoid undulations, and the creation of a continuous geoid surface over the study area.

1.2 NEED FOR THE STUDY

Accurate elevation data is essential for urban planning, infrastructure development, and flood management, especially in a low-lying coastal city like Chennai. GNSS provides ellipsoidal heights, which must be converted to orthometric heights using a geoid model. However, global models like EGM96 and EGM2008 lack the precision needed at the city scale. Hence, there is a need to develop a localized geoid model for the Greater Chennai Corporation using the geometric method. This method, which compares GNSS-derived ellipsoidal heights with levelled orthometric heights, allows for accurate determination of geoid undulations. The resulting geoid model will enhance the reliability of elevation data, supporting various engineering and planning applications across the city.

1.3 OBJECTIVES OF STUDY

- To identify optimal locations for Ground Control Points (GCPs) for conducting GPS survey and levelling.
- To measure ellipsoidal coordinates for the GCPs using GNSS observation.
- To collect orthometric heights (H) for the measured GCPs through levelling observation.
- To develop the geoid model for the study area and validate it with Survey of India observations.

CHAPTER 2

LITERATURE REVIEW

2.1GENERAL

Review of Literatures gives an idea about the methodology that needs to be adopted to accomplish the objectives of the project. A number of literatures pertaining to wetland and its influencing zones have been studied.

2.2 STUDY ON GEOID MODELLING

Farsat Heeto Abdulrahman, Determination of the local geoid model in Duhok Region, University of Duhok Campus as a Case study.

The primary aim of this project is to determine a local geoid model for a part of the Duhok region, utilizing known orthometric heights through GPS/levelling techniques. This is essential for converting ellipsoidal heights obtained via GNSS into orthometric heights, which are more applicable in surveying. The study assesses the precision performance of two Earth gravitational models (EGM1996 and EGM2008) in the Duhok area. The models were adjusted based on root mean square errors calculated from the differences between geoid heights derived from GPS/levelling and the EGMs. A significant aspect of the methodology involves the use of the Kriging interpolation method to create a local geoid model based on the GPS/levelling data collected at 54 points. The results indicated that a mean accuracy of geoidal heights at the level of 0.08 m is achievable, with EGM96 demonstrating greater precision than EGM08 by 14 mm in the study area. The project also includes recommendations for future work, such as employing advanced surveying techniques, including the use of unmanned aerial vehicles (UAVs) for low-altitude measurements, and integrating gravity field measurements with height measurements to enhance precision.

B. Kyamulesire, Eteje S.O., P.D. Oluyori. Establishment of local geometric geoid model for Busoga, Uganda.

The project focuses on establishing a local geoid model for Busoga, Uganda, which is essential for accurate geoid height and orthometric height computations used in engineering constructions. This is particularly important as global geopotential models do not fit local areas effectively. The study utilized a total of 26 points, with 20 points dedicated to developing the model and 6 points reserved for testing. GNSS observations were collected using Trimble GNSS dual-frequency receivers, and the data was processed with Bernese and Spectra Precision Survey Office software to obtain coordinates and ellipsoidal heights. The project applied the Least Squares Adjustment technique to determine the fit of the geoid models, specifically comparing Bicubic and Multiquadric models. The accuracy of these models was evaluated using the Root Mean Squares Error (RMSE) index. Results indicated that the Multiquadric geoid model was more suitable for the study area, achieving an accuracy of 0.067m, which is beneficial for applications such as engineering feasibility studies, GIS topographic mapping, and oceanographic projects. Additionally, a Microsoft Excel program was developed to facilitate the application of the model in the study area, enhancing its usability for local engineering and construction projects.

Mohammed Anwar Jassim and Mohanad Mohsen Yousef, Generation of a Local Geoid Model Based on Iraqi Local Datum Karbala 1979, Journal of Civil Engineering and Architecture.

The project focuses on generating a Local Geoid Model (LGM) using the Iraqi local datum Karbala 1979, which was established by the Polish State Enterprise for Geodesy and Cartography (GEOKART).The primary aim is to determine local geoid undulation, which is typically derived from gravity observations. However, this research utilizes a geometrical approach to relate global and local datums. The study involved GNSS observations using the DGPS technique, covering approximately 97 selected points across the Erbil city municipality, which was divided into four parts for analysis. The results indicated that the local geoid undulation ranged from a maximum of 13.871 m to a minimum of 12.093 m within the study area. The accuracy of the generated LGM was estimated to be -0.076 m, which reflects the overall uncertainty across the experimental area. This research is significant as it provides a method for transforming geodetic (ellipsoidal) heights into local orthometric heights, which are essential for understanding elevation above national vertical datums like Mean Sea Level (MSL).

Norberto Alcantar-Elizondo, Ramon Victorino Garcia-Lopez, Xochitl Guadalupe Torres-Carillo, Guadalupe Esteban Vazquez Becerra. Combining Global Geopotential Models, Digital Elevation Models, and GNSS/Levelling for Precise Local Geoid Determination in Some Mexico Urban Areas: Case Study., ISPRS International Journal of Geo-Information.

The project focuses on improving geoid undulation values in urban areas of Mexico by utilizing high-resolution Global Geopotential Models (GGM) in conjunction with Digital Elevation Models (DEM) and GNSS/levelling data. The methodology involves the use of a Residual Terrain Model (RTM) to account for the effects of topographic masses on the geoid. This is achieved through a spherical approach for mass discretization and numerical integration techniques. The study aims to eliminate commission errors associated with GGMs by employing independent geoid undulation values derived from GNSS/levelling stations. A polynomial regression model is used to generate a corrector surface that addresses these errors, as well as any inconsistencies in the data. The research was applied to five urban areas in Mexico, which have established geodetic networks of GNSS/levelling points, ranging from 166 to 811 stations. The project also evaluates two GGMs, EGM2008 with EGM2008 showing better agreement with GNSS/levelling stations, indicating a significant improvement in geoid determination accuracy.

R Y Hussain., Derivation of Earth Geoid Model for Mosul City in Iraq., IOP Conference Series: Materials Science and Engineering.

The project focuses on developing a local Earth Geoid Model (EGM) for Mosul City, Iraq, to provide accurate elevations without relying on traditional surveying methods. This is particularly important due to the high costs and lengthy measurement times associated with conventional surveying techniques. The study involved selecting a hundred control points from the topographic map of the study area. Various interpolation methods were applied using the ArcGIS environment to derive multiple geoid models. The interpolation methods tested included Kriging, Inverse Distance Weighted (IDW), Trend, Natural Neighbour, Spline, and Topo to Raster. Statistical analysis was conducted to determine the effectiveness of each interpolation method, with the results indicating that Kriging interpolation yielded the best performance, showing the lowest root mean square error (RMSE) and standard deviation. Specifically, Kriging had an RMSE of 2.654 m and a standard deviation of 2.226 m, making it the preferred method for this study. The project also highlighted the challenges faced in Iraq regarding the lack of precise geoid specifications, insufficient gravity data, and difficulties in obtaining orthometric height information. Despite these challenges, advancements in satellite positioning and internet data have improved the availability of Digital Elevation Models (DEMs), emphasizing the need for a local geoid model.

Eteje, S. O., Ono, M. N. And Oduyebo, O. F., Practical Local Geoid Model Determination for Mean Sea Level Heights of Surveys and Stable Building Projects. Department of Surveying and Geoinformatics.

The project focuses on determining a local geoid model for Evboriaria, Benin City, using the geometric method, which combines GPS and levelling techniques. This model is essential for calculating mean sea level heights, which are critical for various engineering and construction projects. A total of fifty points were established to create the geoid model, and ten additional points were used for interpolation purposes. The geoid heights were calculated by finding the difference between observed orthometric heights and ellipsoidal heights, ensuring accuracy in the height measurements used in engineering projects. The project emphasizes the importance of using a properly defined geoid model to avoid potential issues in engineering designs, such as unexpected water flow or inconsistent lake surface heights. This is crucial for ensuring the stability and reliability of construction projects. The study also highlights the advantages of using GPS observations for determining orthometric heights, especially when a local geoid model is available. This method is recommended over traditional levelling techniques due to its accuracy, cost-effectiveness, and speed.

Yehia H. Miky, Reda Yaagoubi, Ahmed El Shoun., Study of the Potential of a Local Geoid Model for Extracting the Orthometric Heights from GPS Measurements in Topographic Works., Civil and Environmental Research.

The project focuses on the determination of orthometric heights, which are essential for various engineering and topographic projects. Traditional methods of obtaining these heights through levelling are often time-consuming and costly. The research investigates the use of local geoid models as an alternative method to derive orthometric heights from GPS measurements. This approach aims to provide similar accuracy to traditional levelling methods while reducing the time and costs involved in fieldwork. The study emphasizes the importance of accurately determining geoid undulation, which is the difference between ellipsoidal heights and orthometric heights. This is crucial for transforming GPS-derived ellipsoidal heights into orthometric heights. The methodology proposed in the paper includes generating local geoid models tailored to specific areas, which can enhance the precision of height measurements. The results from applying this methodology in Jeddah, Saudi Arabia, indicate that the differences in undulation values between the local geoid model and traditional levelling techniques are minimal, confirming the effectiveness of the local geoid model. The conclusion drawn from the study suggests that creating a local geoid model is a viable method for obtaining orthometric heights, provided that the study area is well-covered with reference points to ensure accuracy.

Mouhamadou Moustapha Macke Ndour, Papa Matar Sylla, Babacar Faye, Moussa Macke Ndour., Modelling a Local Geoid: Application in Thies, Senegal. International Journal of Geosciences, 2024.

The project aims to produce a geoid model for the city of Thies, Senegal, which is essential for various applications in geodesy, hydrography, and engineering that require accurate height determination linked to the geoid. Traditional methods of obtaining elevations, such as direct levelling, are noted to be slow, time-consuming, and expensive. This project seeks to overcome these limitations by utilizing space techniques and creating a precision geoid model compatible with GNSS (Global Navigation Satellite System) methods. The study combines multi-source data, including direct precision levelling and GNSS levelling in static mode, to cover the study area effectively. Reference points from established networks like RRS04 and NGAO53 are used to enhance the accuracy of the model. Gravimetric measurements are also conducted using a smartphone application, which allows for the collection of data necessary for refining the geoid model. The model is calculated using the Spherical Radial Basis Function (SRBF) method, and the results show an accuracy of less than 2 cm, indicating that the new model is more accurate than existing local models.

CHAPTER 3

3.1 DATA USED

- GCP points obtained from Chennai Metropolitan Development Corporation (CMDA).

3.2 INSTRUMENTS USED

- R12 GPS Receiver.
- Tripod.
- Prism pole.

3.3 SOFTWARE USED

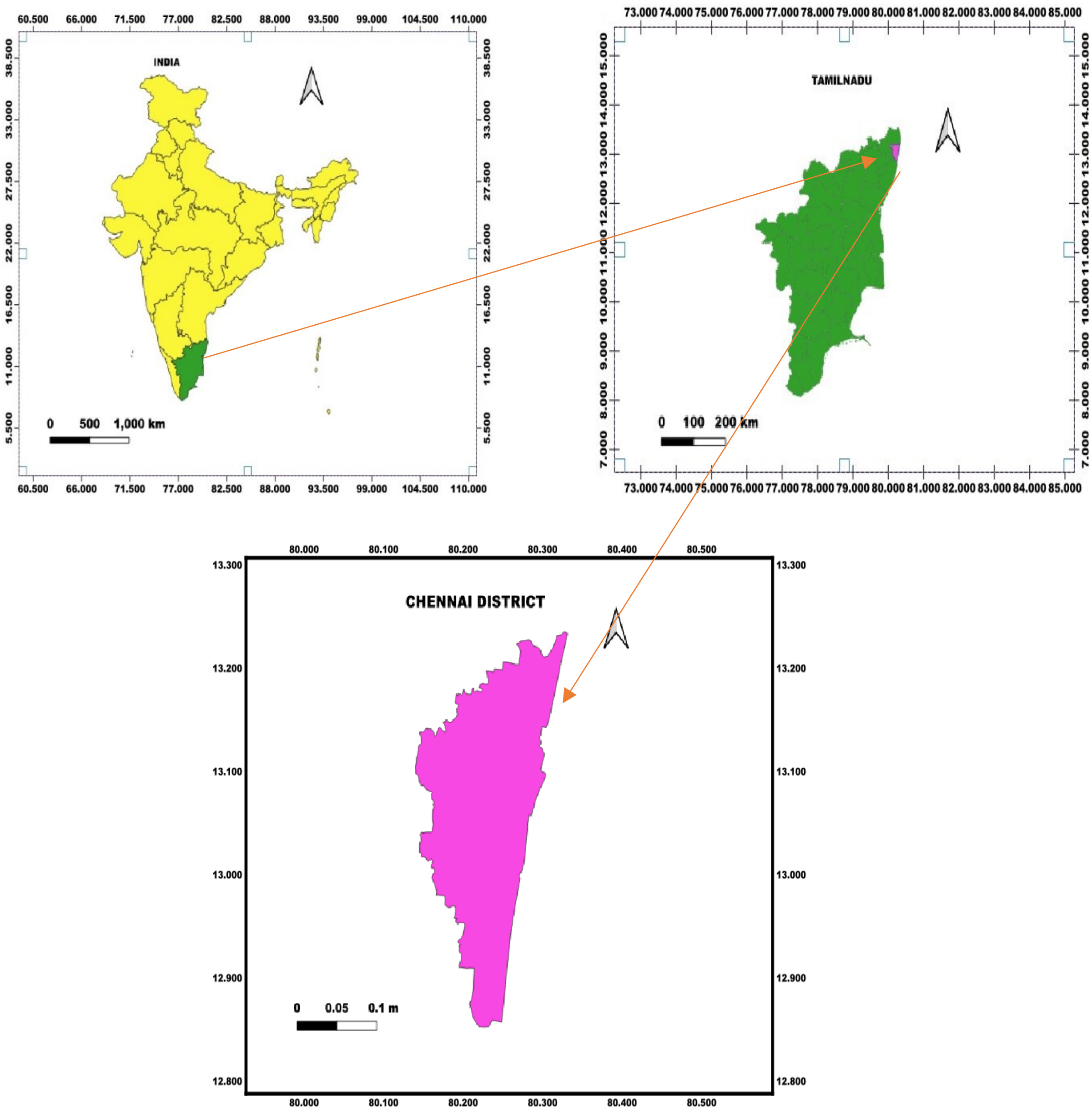
- ArcGIS
- QGIS
- Google Earth Explorer
- Open Street maps

CHAPTER 4

STUDY AREA

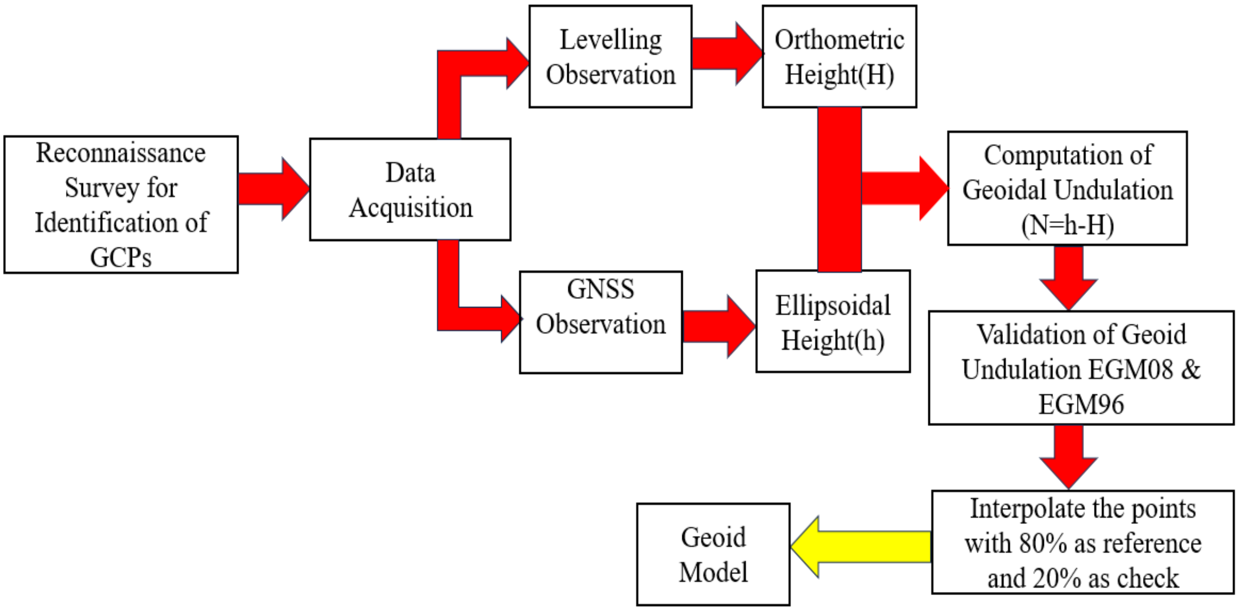
3.1 GENERAL

- Chennai the area of 426 km^2, Latitude 13°05′24.00″ North, Longitude 80°16′12.00″ East.
- The average elevation of 6.7 m (22 ft) and highest point at 60 m (200 ft).



CHAPTER 5

METHODOLOGY



LEVELLING OBSERVATIONS

Levelling observation is a fundamental surveying technique used to determine precise differences in elevation between points on the Earth's surface. In the context of geoid modelling, levelling is crucial for obtaining **orthometric heights (H)**, which are referenced to the mean sea level. These heights are measured using **spirit levelling**, a method known for its high accuracy over short distances. During the project, levelling was carried out at selected Ground Control Points (GCPs) across the Greater Chennai Corporation area. These orthometric heights, when compared with the ellipsoidal heights obtained from GNSS observations, allow for the computation of geoid undulations ($N = h - H$). This accurate height data forms the foundation for developing a reliable local geoid model.

GNSS OBSERVATIONS

GNSS (Global Navigation Satellite System) observation is a modern geodetic technique used to determine precise **ellipsoidal coordinates**, including latitude, longitude, and height above the reference ellipsoid. In this project, GNSS observations were conducted at selected **Ground Control Points (GCPs)** across the Greater Chennai Corporation area to obtain **ellipsoidal heights (h)**. High-precision GNSS receivers were used to collect satellite signals and compute three-dimensional positions. These ellipsoidal heights are essential for geoid modelling, as they are compared with orthometric heights obtained through levelling to calculate **geoid undulations ($N = h - H$)**. GNSS provides a fast, efficient, and accurate method for capturing elevation data over large areas, making it an integral part of the geometric method for local geoid model development.

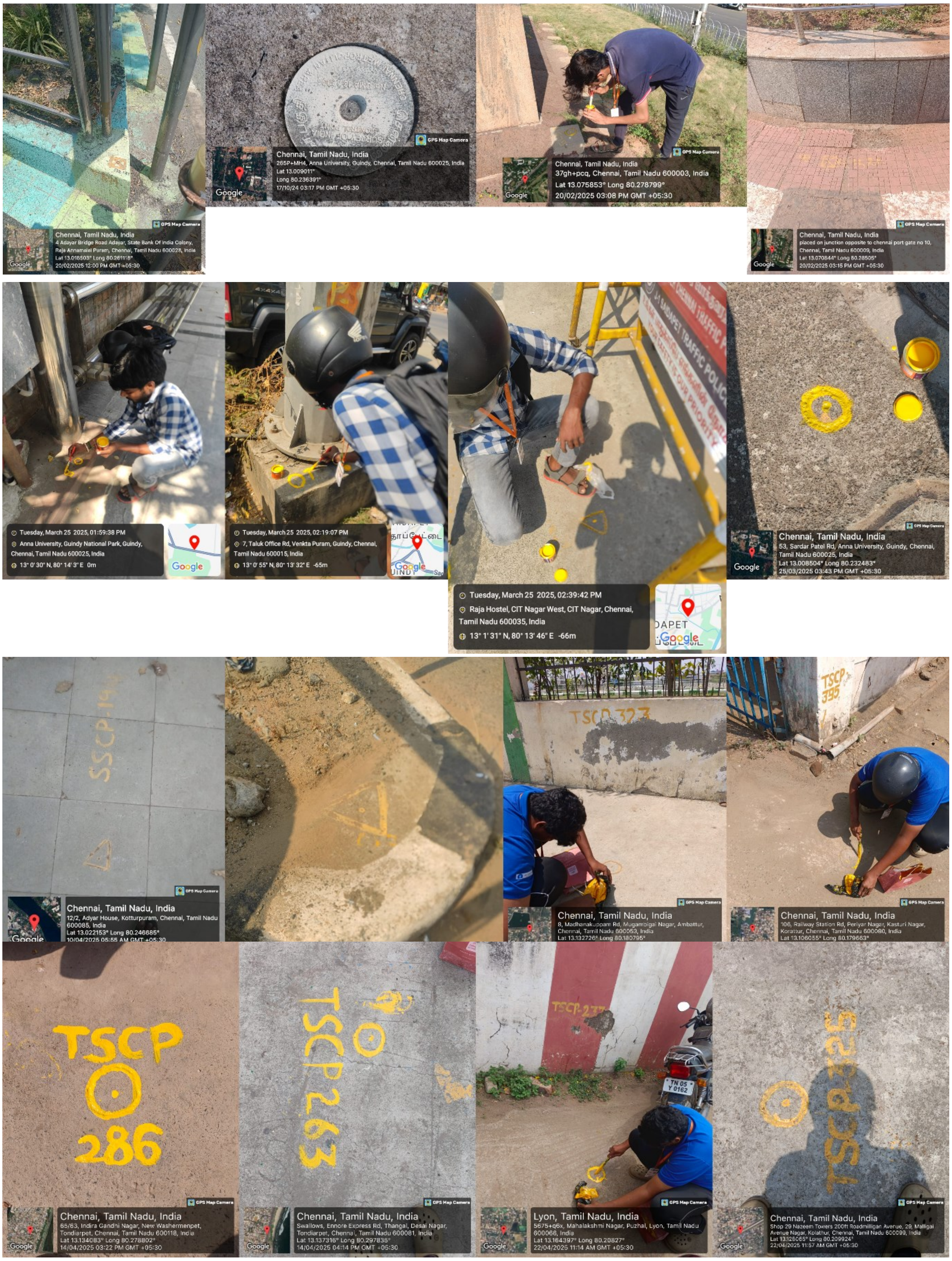
ArcGIS SOFTWARE:

ArcGIS is a powerful geographic information system (GIS) software developed by Esri that allows users to create, manage, analyse, and visualize spatial data. Widely used in fields such as urban planning, environmental science, transportation, and public safety, ArcGIS enables users to make informed decisions based on geographic information. The software offers a comprehensive suite of tools for mapping, spatial analysis, 3D modelling, and geodatabase management. With both desktop and cloud-based solutions, including ArcGIS Pro and ArcGIS Online, it supports collaboration and sharing of geospatial data across various platforms. ArcGIS plays a key role in helping organizations understand patterns, relationships, and trends through the power of maps and spatial data.

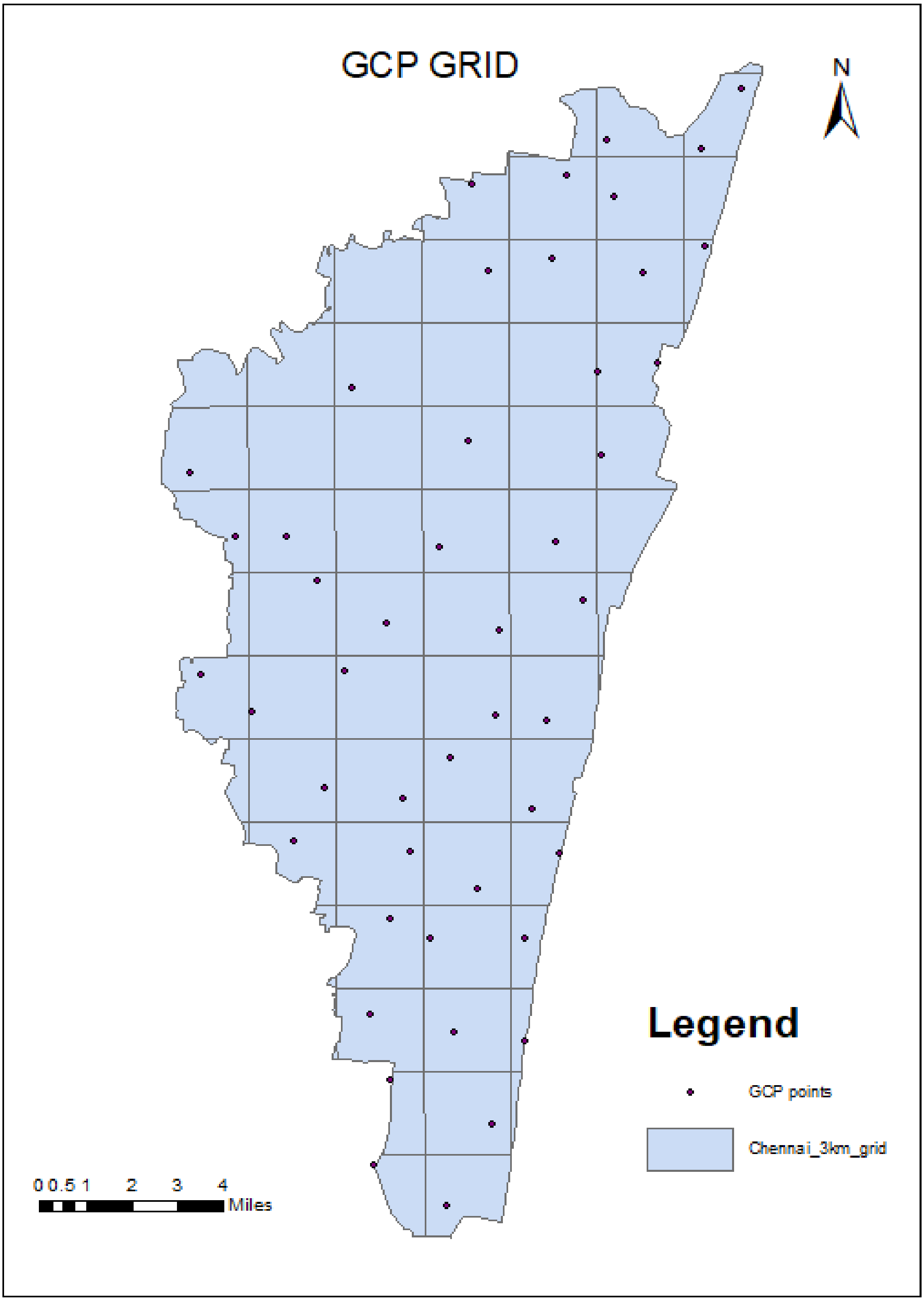
CHAPTER 6

RESULT AND DISCUSSIONS

FOUND GCP POINTS

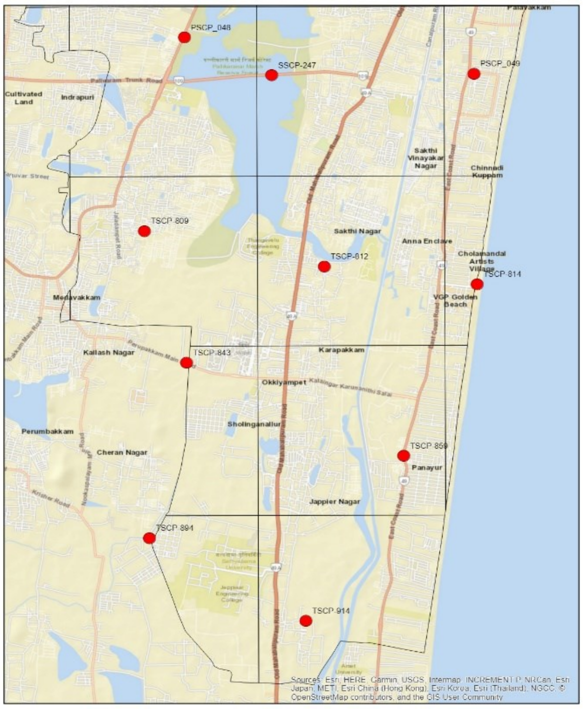


GCP POINTS ALONG WITH GRIDS



GCP POINTS ROUTE MAP

Day 1



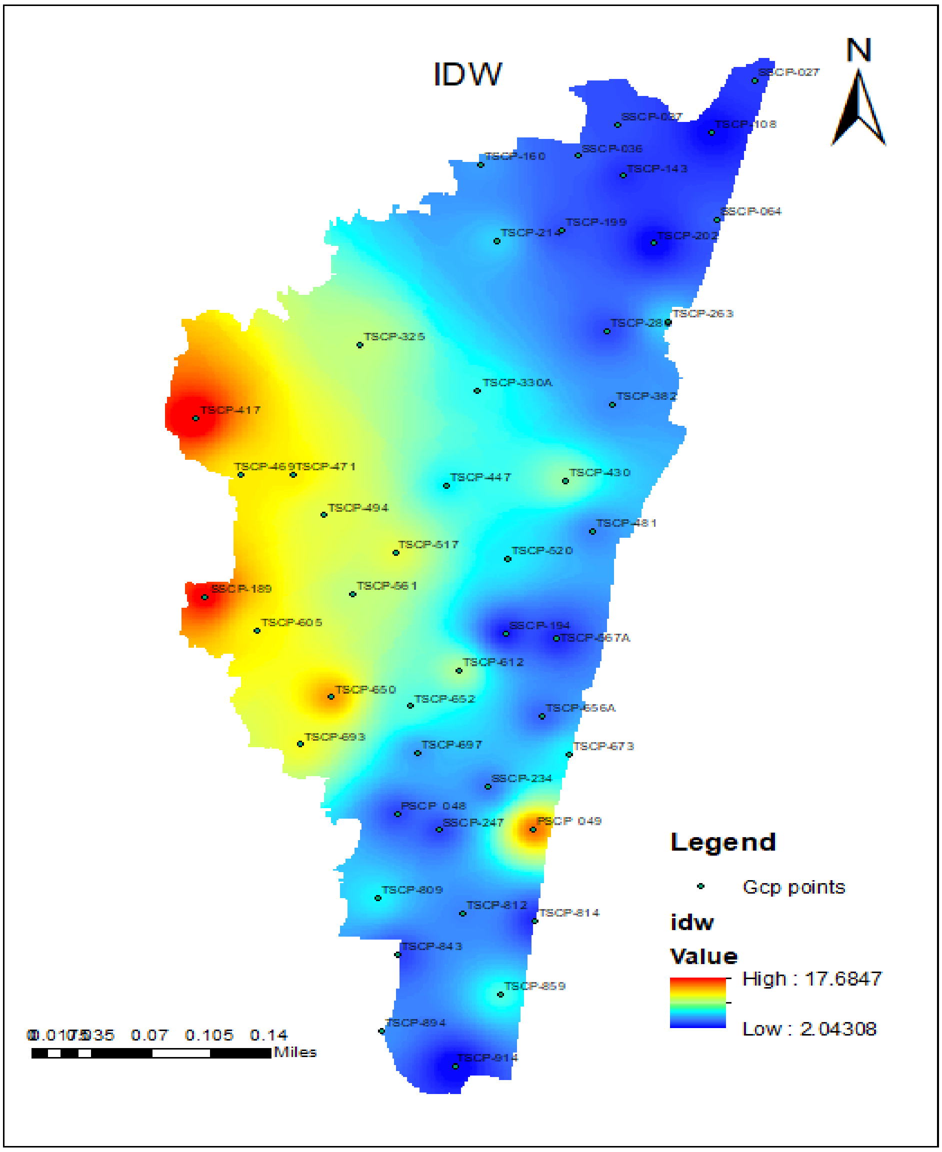
Day 2

Day 3

INTERPOLATED GCP ALONG WITH MSL VALUES

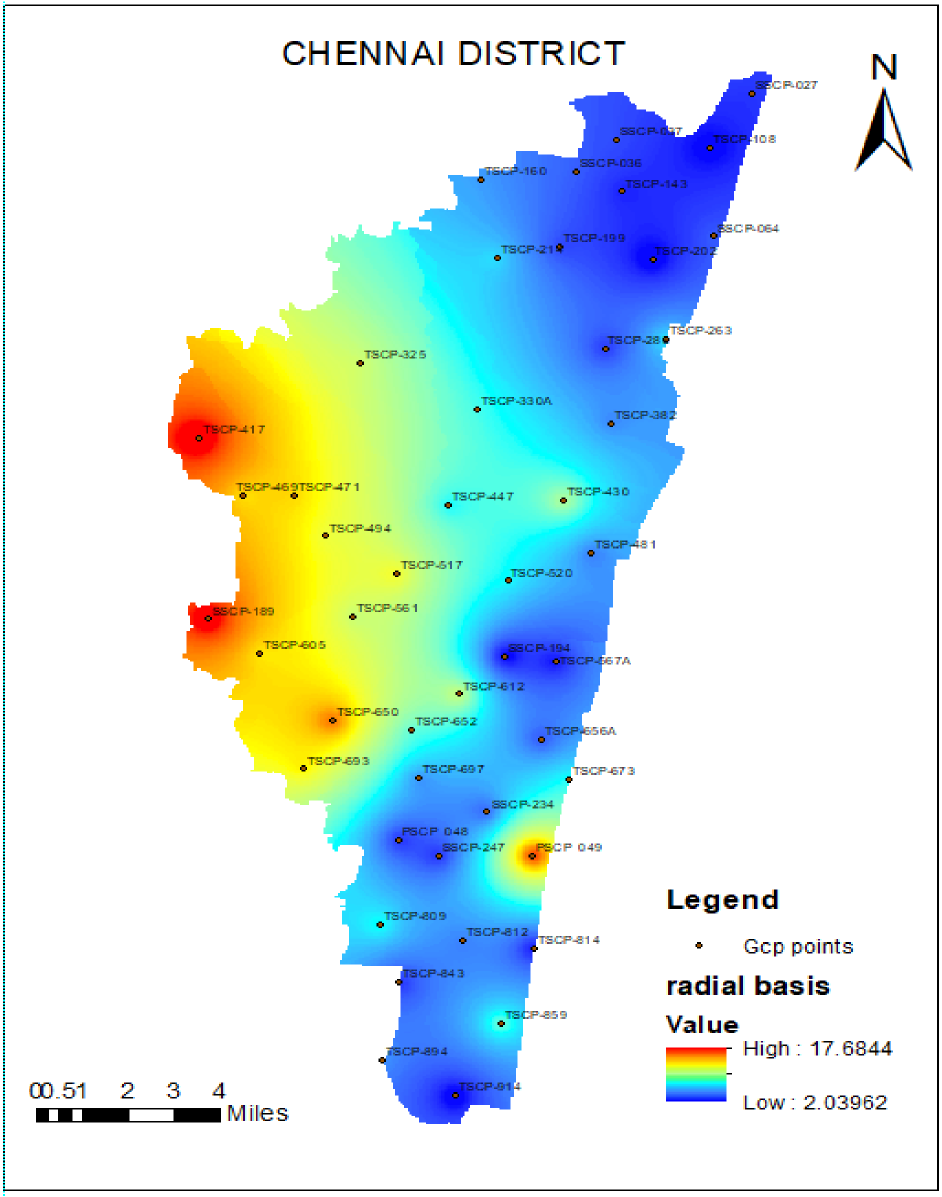
IDW (Inverse distance weighted)

Inverse Distance Weighting (IDW) is a simple and commonly used interpolation technique in geographic information systems (GIS). It estimates unknown values at specific locations based on known values from nearby points. The method assumes that points closer to the prediction location have more influence than those farther away, giving them higher weights in the calculation. IDW is useful for creating smooth surfaces from scattered data, such as rainfall, temperature, or elevation, especially when the data points are evenly distributed.



Radial Basis

Radial Basis Function (RBF) interpolation is a method used in GIS to estimate unknown values based on the distances from known data points. It uses mathematical functions, typically Gaussian or multiquadric, that decrease with distance to create a smooth surface. RBF is effective in handling irregularly spaced data and can produce very smooth and accurate interpolations. This technique is commonly used in surface modelling where precision and smooth transitions between data points are important.



CHAPTER 7

CONCLUSION

The geoid model developed using the geometric method has successfully demonstrated the accuracy and reliability of deriving geoid heights from the difference between GNSS-derived ellipsoidal heights and orthometric heights obtained from levelling. This method offers a practical and efficient approach, especially in regions with limited gravity data. The resulting geoid model provides a valuable reference surface for converting GNSS heights to mean sea level, improving the precision of elevation data for various geospatial and engineering applications. Overall, the geometric method proves to be a viable technique for local geoid determination, supporting enhanced positioning and mapping accuracy.

CHAPTER 8

REFERENCES

Featherstone, W.E., Kirby, J.F., Kearsley, A.H.W., Gilliland, J.R., Johnston, G.M., Steed, J., Forsberg, R., & Sideris, M.G. (2001). The AUSGeoid98 geoid model for Australia: Data treatment, computations and comparisons with GPS-levelling data. *Survey Review*, 36(283), 38–55.

Heiskanen, W.A., & Moritz, H. (1967). *Physical Geodesy*. W.H. Freeman and Company.

Hirt, C., & Seeber, G. (2008). High-resolution local gravity field modelling by combining gravity, astrogeodetic and digital terrain data. *Journal of Geodesy*, 82(4), 231–248.

Leick, A., Rapoport, L., & Tatarnikov, D. (2015). *GPS Satellite Surveying* (4th ed.). Wiley.

Marti, U. (2004). High-resolution local gravity field modelling using digital terrain data. *Geophysical Research Abstracts*, 6, 06190.

Moritz, H. (1980). *Advanced Physical Geodesy*. Wichmann Verlag.

Sánchez, L., & Sideris, M.G. (2017). Vertical datum unification for the International Height Reference System (IHRS). *Geophysical Journal International*, 209(3), 1739–1752.

Seeber, G. (2003). *Satellite Geodesy: Foundations, Methods, and Applications* (2nd ed.). Walter de Gruyter.

Sideris, M.G. (1990). A new approach for the combined solution of geoid and gravity anomaly. *Bulletin Géodésique*, 64(2), 125–133.

Smith, D.A., & Roman, D.R. (2001). GEOID99: Improvements to the US national geoid model. *Surveying and Land Information Systems*, 61(3), 133–152.

Vaníček, P., Kleusberg, A., Martinec, Z., Harrie, R., & Harrie, L. (1996). Compilation of a precise regional geoid. *Journal of Geodesy*, 70(3), 176–189.

Zumberge, J.F., Heflin, M.B., Jefferson, D.C., Watkins, M.M., & Webb, F.H. (1997). Precise point positioning for the efficient and robust analysis of GPS data from large networks. *Journal of Geophysical Research: Solid Earth*, 102(B3), 5005–5017.