Integration of Total Station and GIS for Feature Mapping and Geoid Modeling

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1. Introduction

Global Navigation Satellite Systems (GNSS) have transformed how we navigate and gather location-based data in a variety of applications. Total Station, ArcGIS Pro, and QGIS are indispensable tools that complement Global Navigation Satellite Systems (GNSS) in various ways, enhancing the efficiency and accuracy of location-based data collection, analysis, and mapping. Total Station, a precision surveying instrument, provides precise measurements of angles, distances, and elevations, serving as a crucial tool for capturing spatial data on the ground. ArcGIS Pro and QGIS, on the other hand, are powerful Geographic Information System (GIS) software that enables spatial analysis, visualization, and mapping of the collected data. By integrating Total Station measurements with GNSS data within these software platforms, users can create detailed and accurate maps, perform spatial analysis, and derive valuable insights for a wide range of applications, including urban planning, infrastructure development, environmental management, and more. This synergy between Total Station, ArcGIS Pro, QGIS, and GNSS technology revolutionizes how location-based data is gathered, analyzed, and utilized in various industries and sectors.

2. Objectives

To perform feature mapping using Total Station and develop a geoid model with the provided dataset.

3. Methodology

We utilized Total Station for field surveys and QGIS/ArcGIS Pro for spatial analysis and mapping in this survey. Various exercises demonstrate their combined functionality.

3.1 Total Station

A total station is a precision surveying instrument widely used in the fields of civil engineering, construction, land surveying, and mapping. It combines the functionality of a theodolite for measuring angles and a distance meter (EDM) for measuring distances electronically. Total stations are essential tools for capturing precise measurements of angles, distances, and elevations, allowing surveyors to accurately map out and analyze land features, construct buildings and infrastructure, and perform various surveying tasks with high levels of accuracy and efficiency. These instruments are equipped with electronic displays, keypads, and onboard software for data collection, calculation, and storage, making them indispensable tools for modern surveying professionals.

Setting Up the Total Station:

1. **Set Up the Tripod**: Place the tripod firmly on stable ground, ensuring that the legs are spread evenly and securely locked in place.

2. **Level the Tripod**: Adjust the tripod legs to ensure that the tripod is level using a bubble level attached to the tripod head.
3. **Position Above Control Point**: Position the tripod directly above the control point by aligning it visually or using a plumb bob.
4. **Attach the Total Station**: Mount the total station securely on the tripod head and tighten the locking screws to ensure stability.
5. **Electronic Leveling**: Use the built-in electronic level of the total station to ensure it is accurately leveled. Adjust the leveling screws until the bubble level is centered, ensuring the error is less than 9 seconds.
6. **Verify Crosshair Alignment**: Verify that the crosshair of the total station aligns precisely with the control point's coordinates obtained from an auto level or other surveying equipment.

Taking Readings:

1. **Create a New Job File**: Initialize the total station by creating a new job file and saving it with a descriptive name for the survey area.
2. **Station Setup**: Input the control point's name, instrument height (typically 1.27m), and its coordinates (Northing, Easting, and Elevation) obtained from previous GNSS receiver measurements.
3. **Set Temporary Point as Backsight**: Designate a temporary point near the control point as the backsight reference for the total station.
4. **Measure Topography**: Using the total station's vertical and horizontal angle measurement capabilities, use VX and S series mode, start measuring the topographic features of the survey area.
5. **Set Backsight Height**: Set the backsight height to 1.5m, which typically corresponds to the height of the prism fixed on the bipod.
6. **Take Backsight Reading**: Begin by taking a backsight reading to establish a reference point for subsequent measurements.
7. **Feature Mapping**: Proceed with mapping various features by recording their readings (horizontal angles, distances, and vertical angles) as observed through the total station giving various code names.

3.2 ArcGIS

Generating Contour and map Feature using ArcGIS.

3.2.1 Contour Map: Digitization of point data to features

Digitizing point data in QGIS is a fundamental GIS task with diverse applications ranging from data visualization and analysis to field data collection and historical research. It is a powerful tool for understanding and exploring spatial relationships within a geographic context.
Add coordinate system

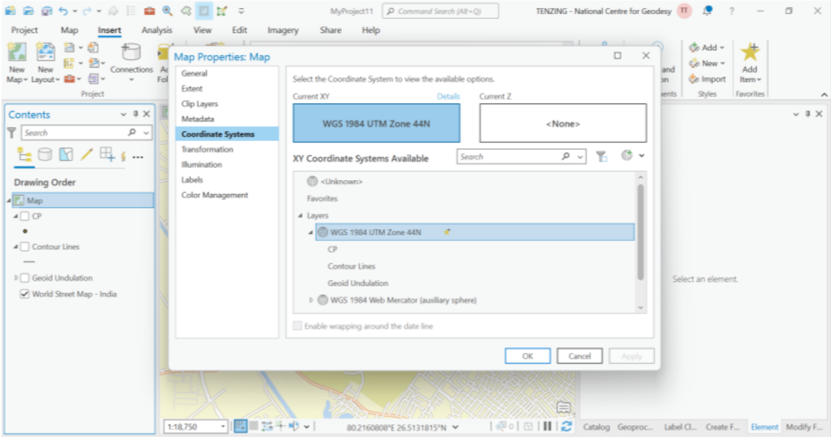


Figure 1: Adding the coordinate system

Add Delimited text file

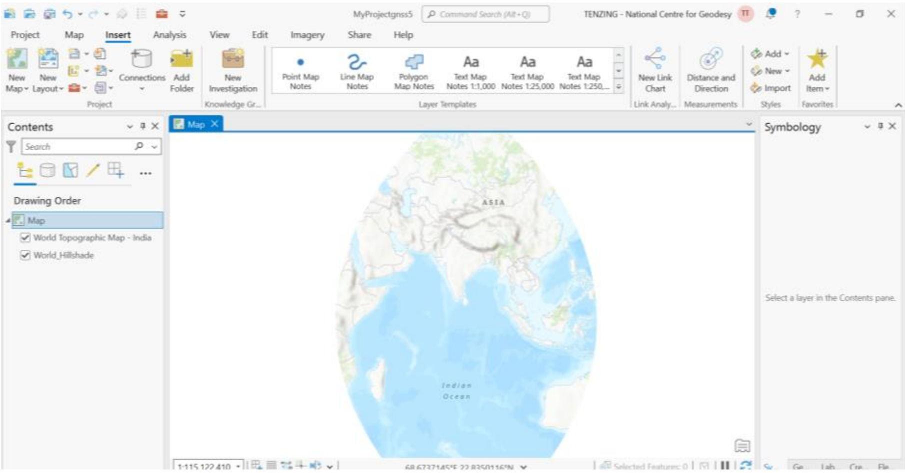


Figure 2: ArcGIS interface left side showing delimited text layer

Add the.CSV file

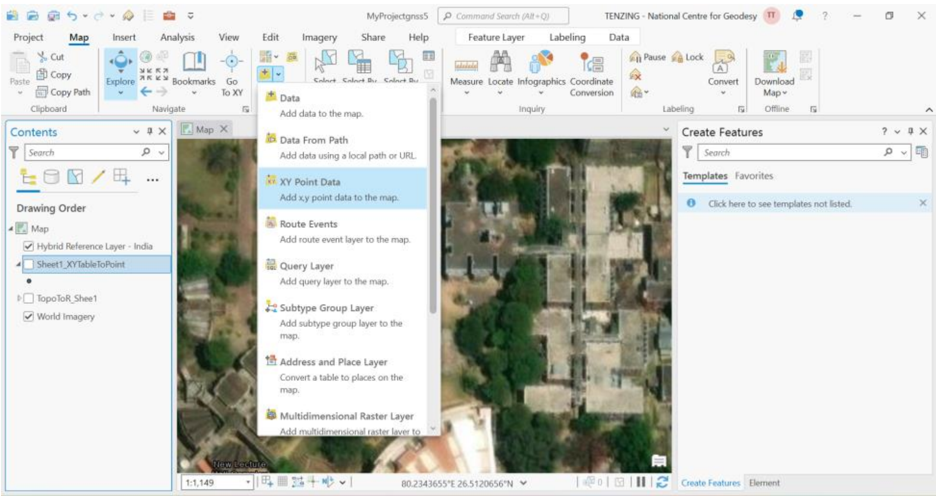


Figure 3: Adding XY point data

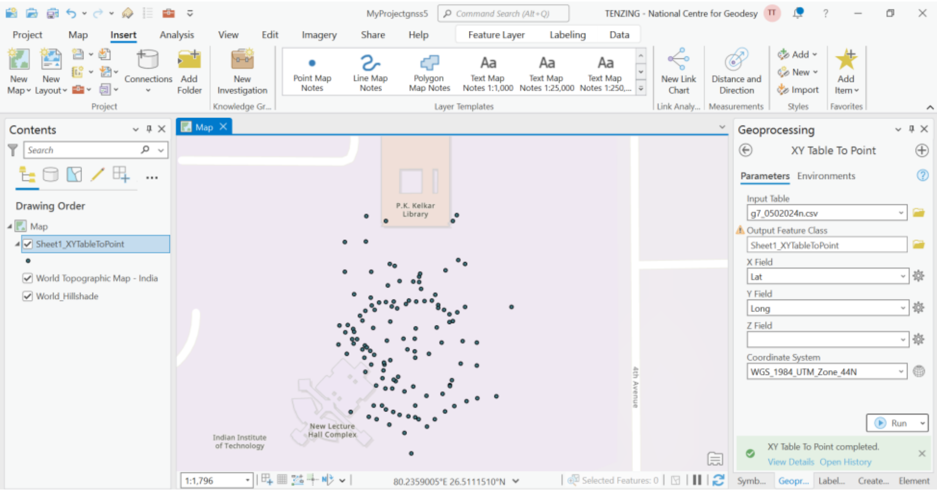


Figure 4: point data generated

Add Base Map "Quick map services"

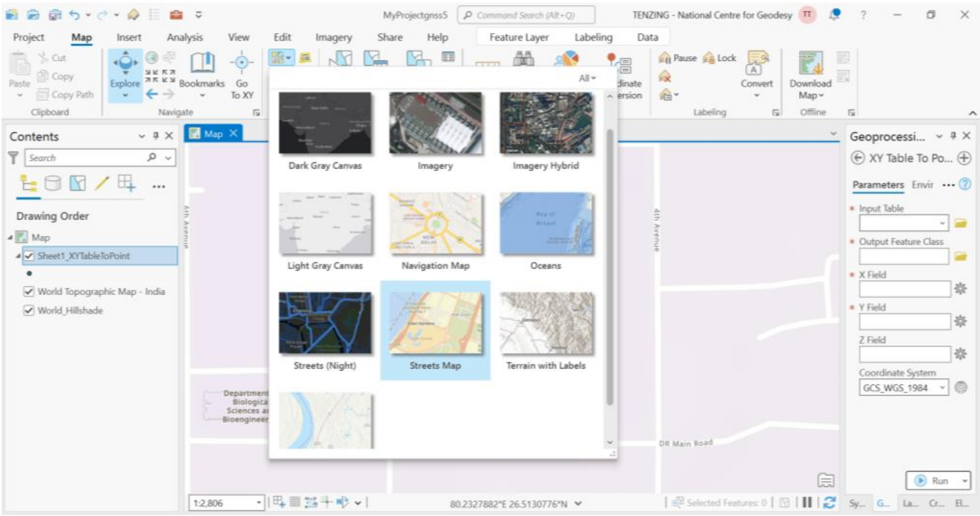


Figure 5: Adding Base Map satellite imagery

Check for correct geographical location

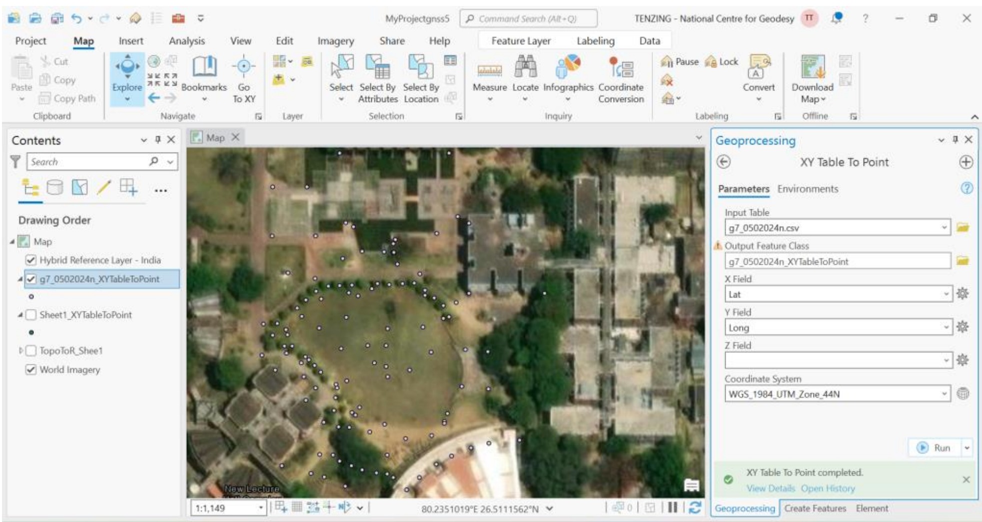


Figure 6: desplaying the georeferenced points on base map

Interpolating topo to raster to generate DEM

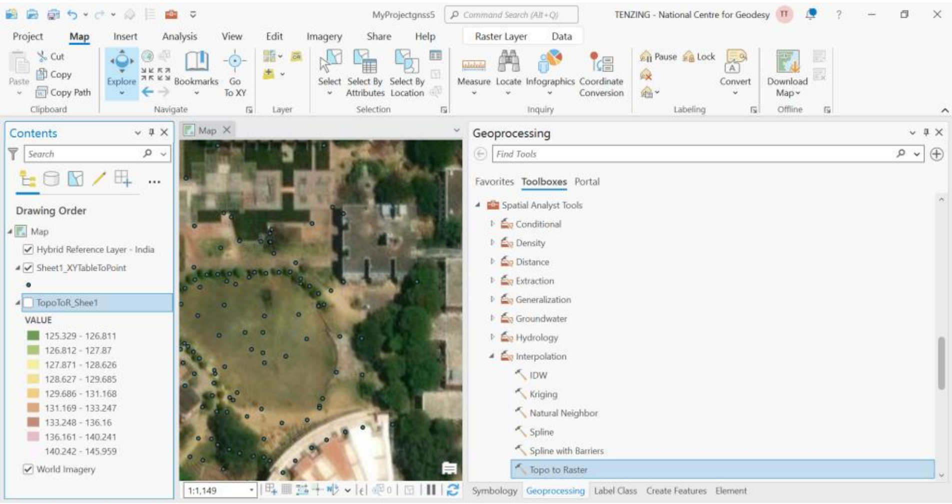


Figure 7: Topo to raster interpolation

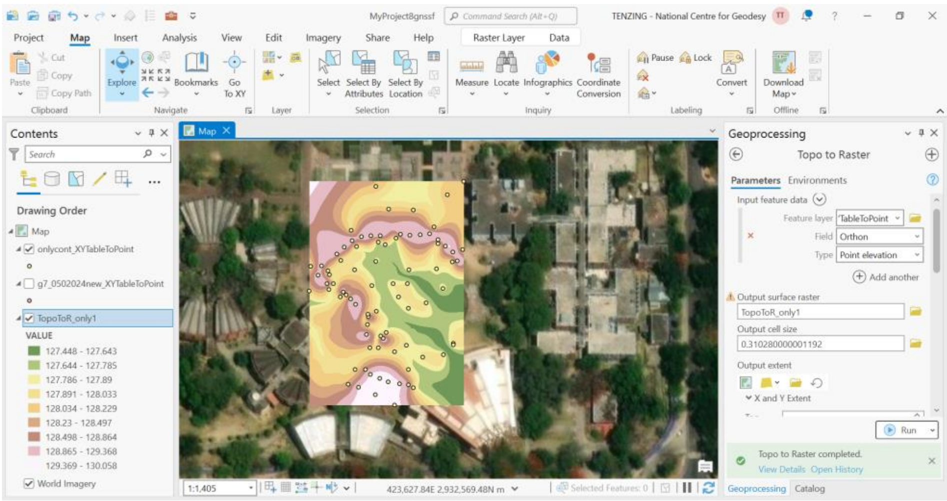


Figure 8: Displaying DEM

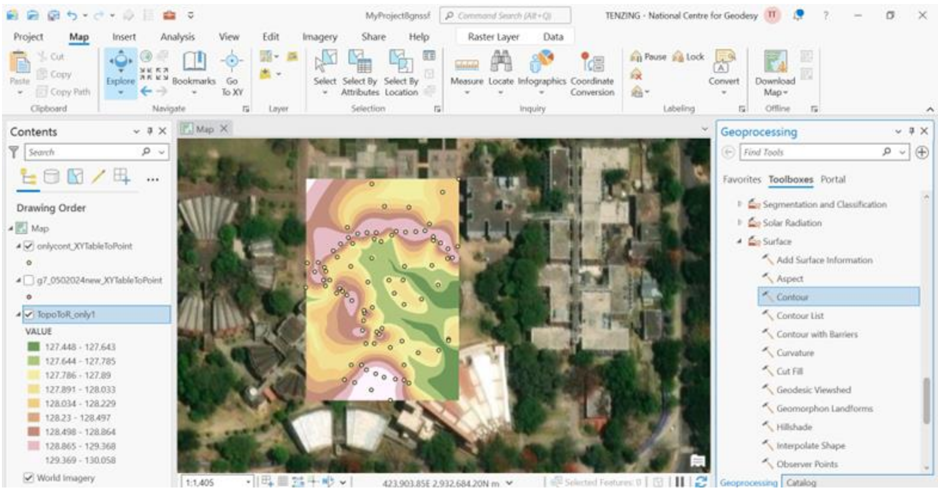


Figure 9: Interface showing toolboxes for contour

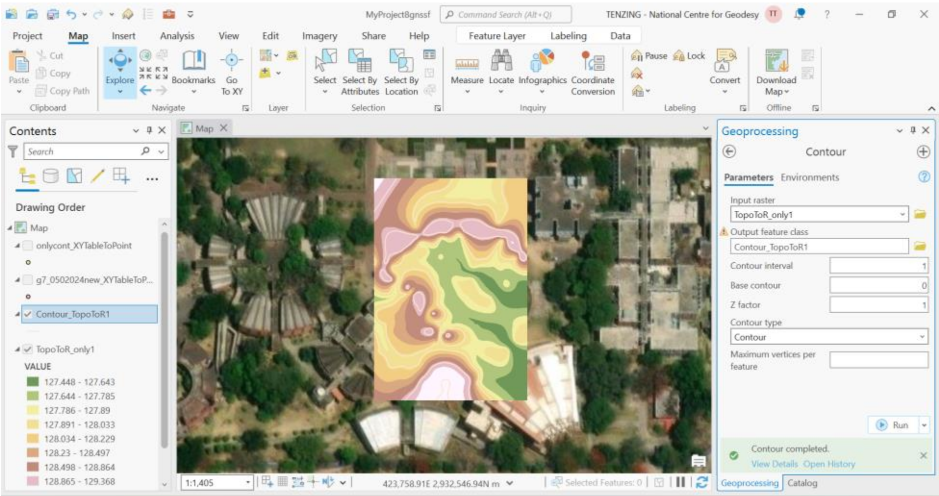


Figure 10: Contour Map generated

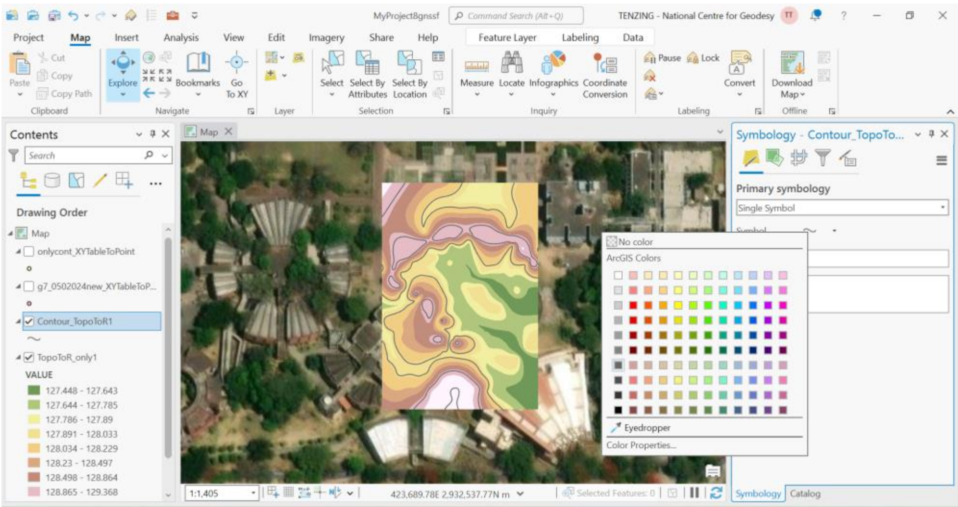


Figure 11: Contour generated

Use Symbology for displaying various colours, width etc.

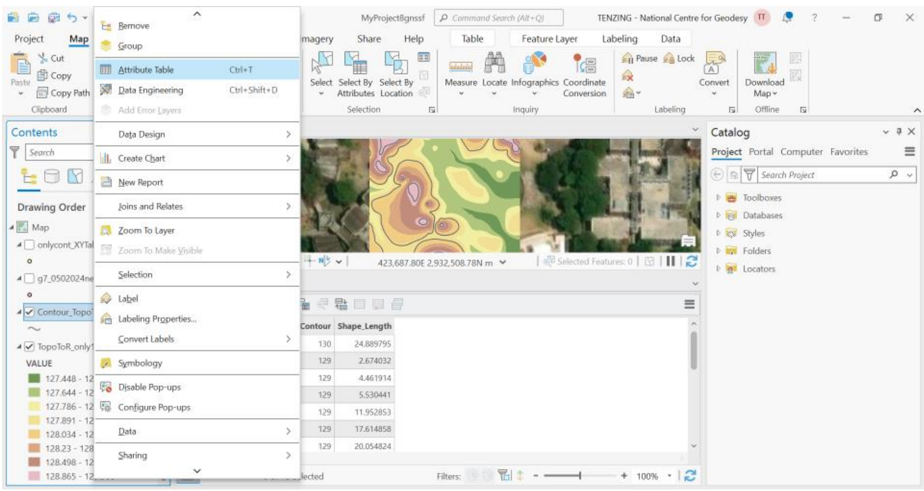


Figure 12: Symbology

Attributes table Showing various datas

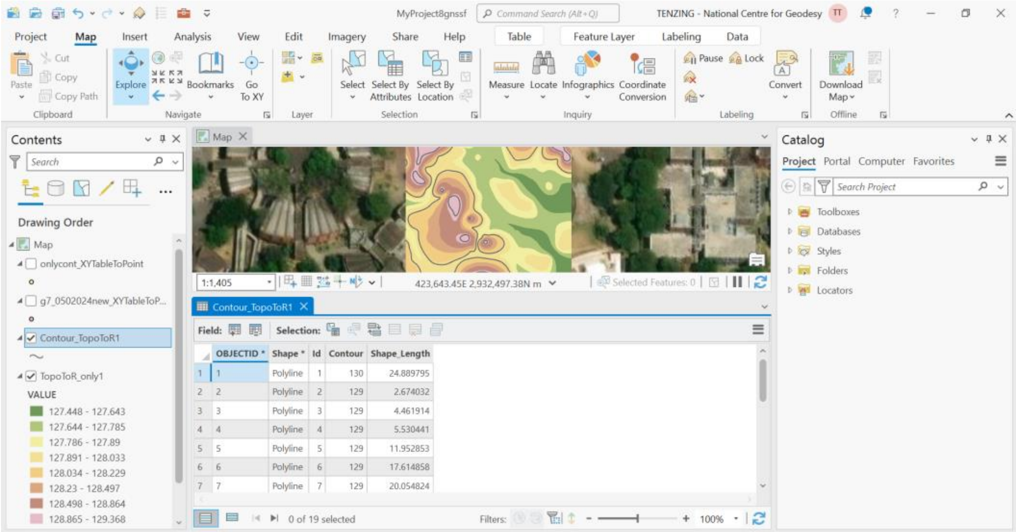


Figure 13: Attributes table

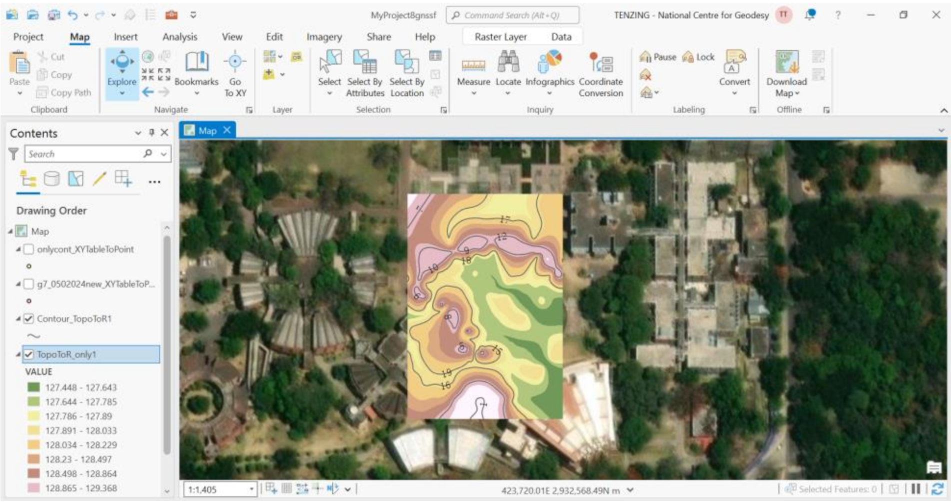


Figure 14: Labelling the generated Contour

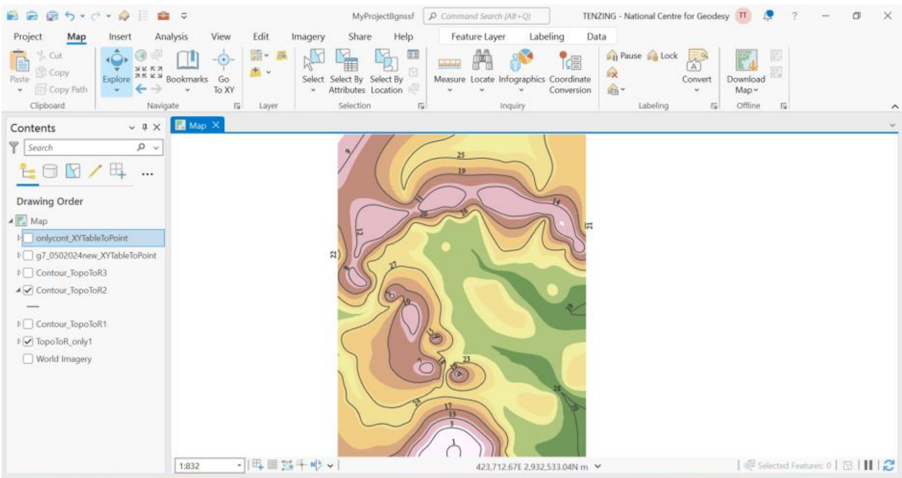


Figure 15: Adding the Labels in contour

3.2.2 Feature Map

Creating various feature class like lines, polygons and point .shp files

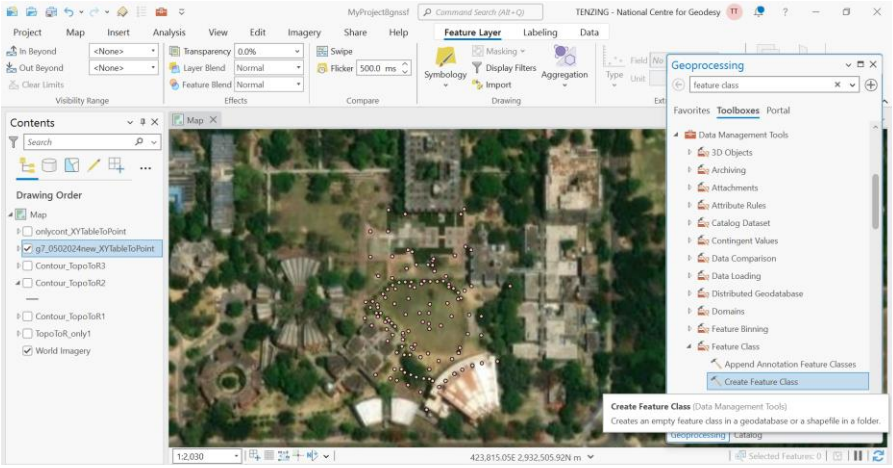


Figure 16: Use the code/name property to view different features individually

Digitization, is the process of converting features into a digital format, it is one way to create data in GIS environment.

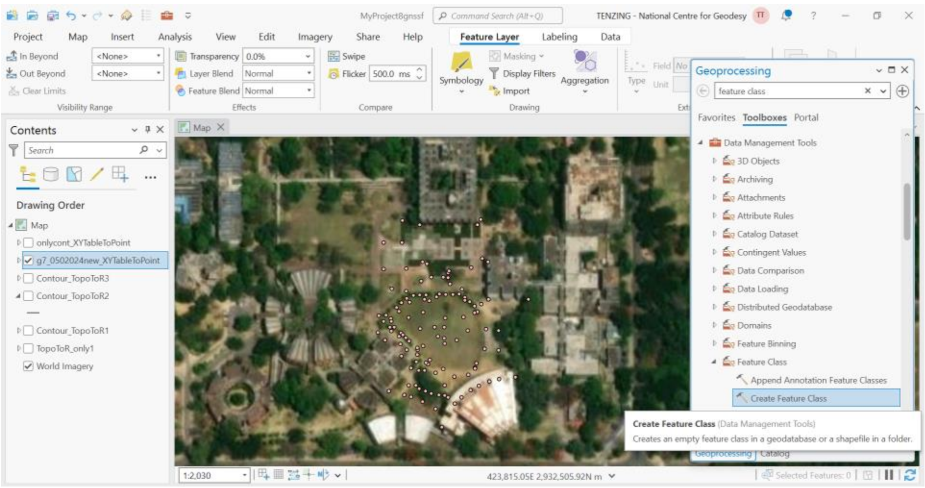


Figure 16: Digitizing toolbar

Once various points, lines, polygon .shp file. Start plotting the map.

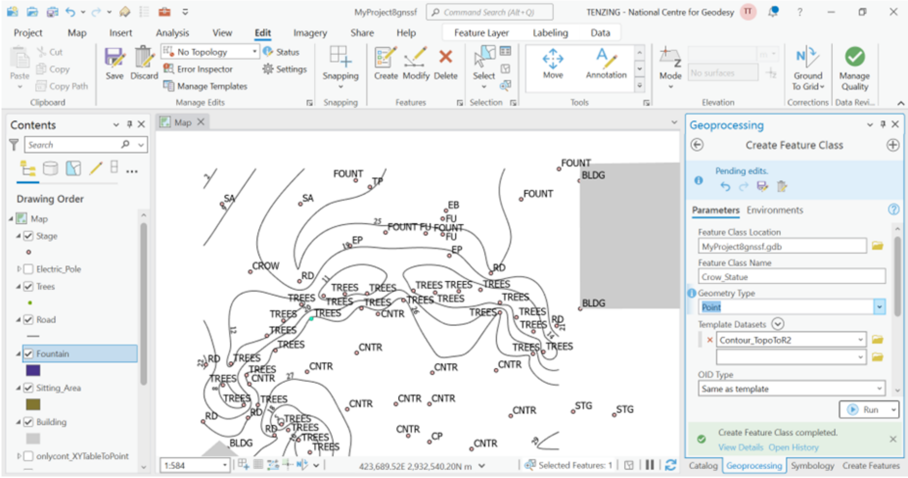


Figure 17: Labels showing various feature codes

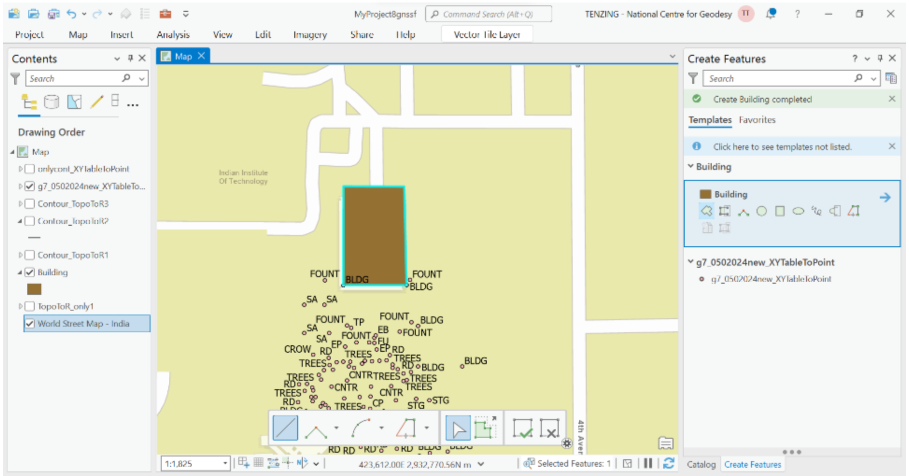


Figure 18: Mapping the area uing the point datas

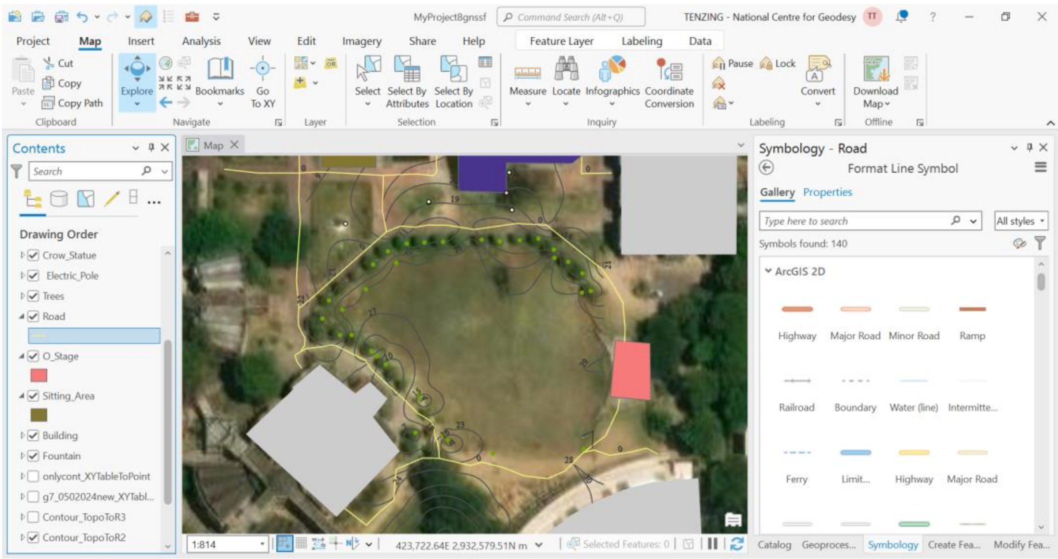


Figure 19: uings symbology to modify the shp files with different colours

Using Buffer tool

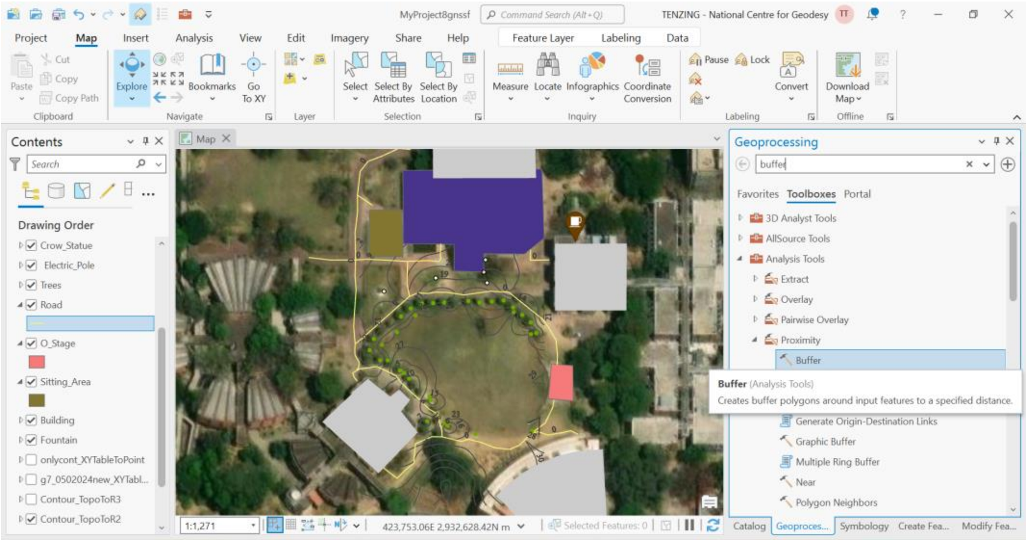


Figure 20: Using Buffer tool on Digitized road to generate smooth road features without sharp edges

Dissolve all features

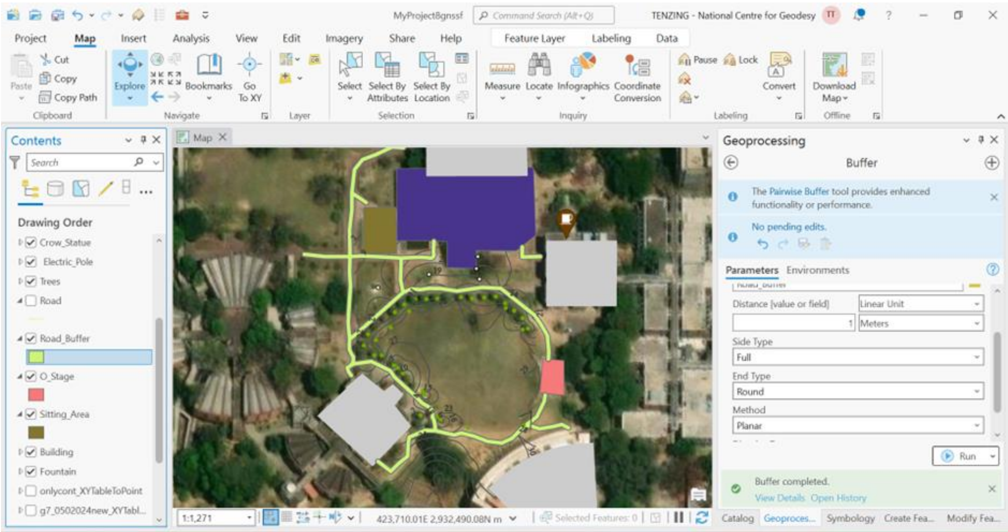


Figure 21: Buffered road of 2m

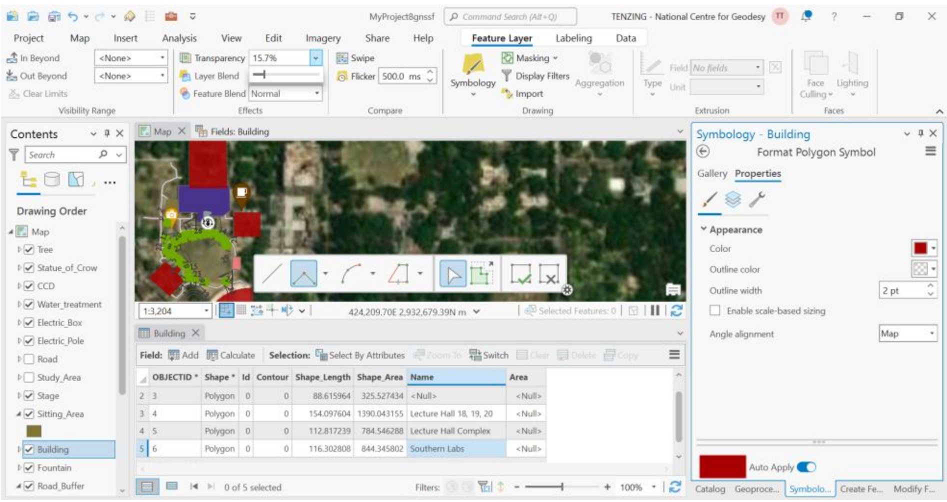


Figure 22: Add in various labels

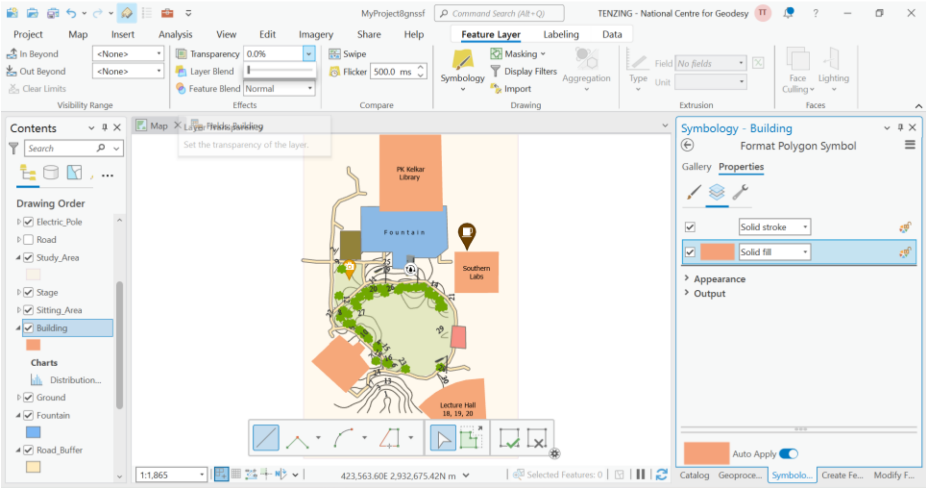


Figure 23: Layer transparency

Map Layout:

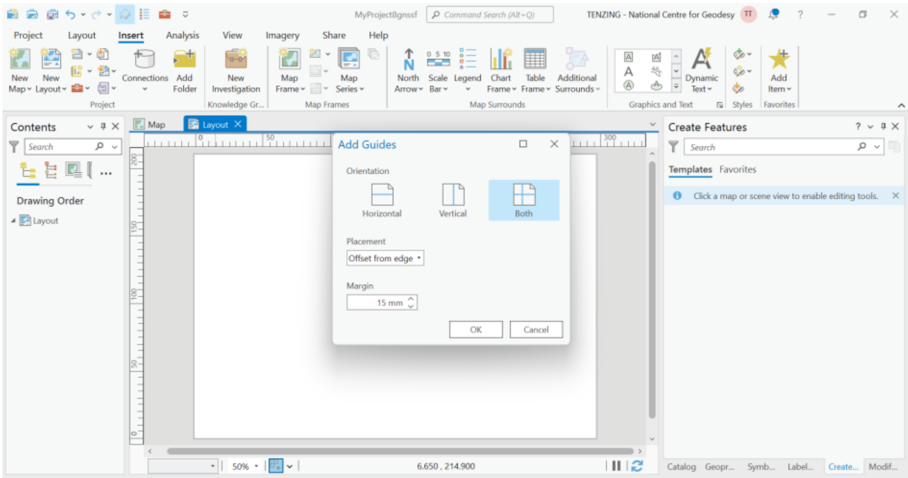


Figure 24: Add Guides

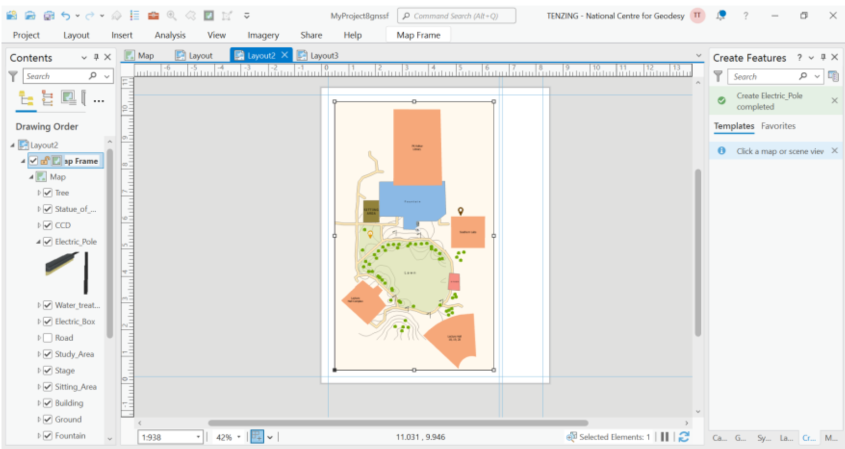


Figure 25: adding margins

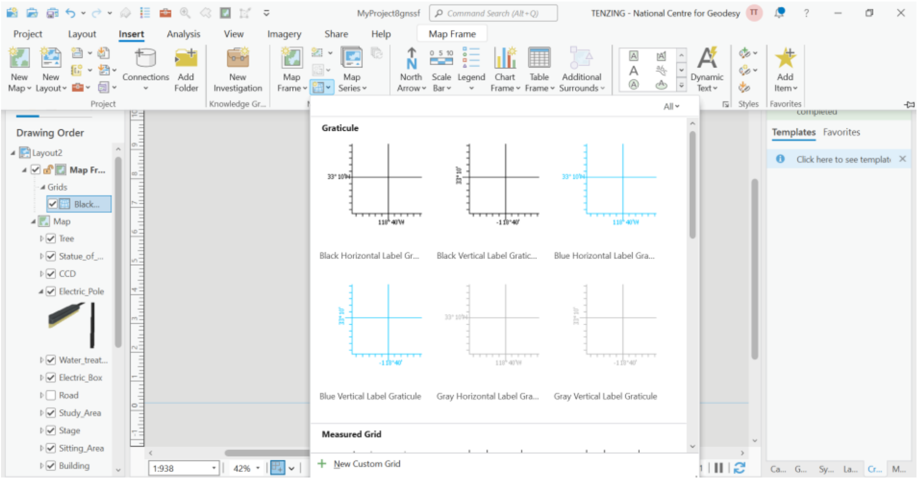


Figure 26: Add Grids

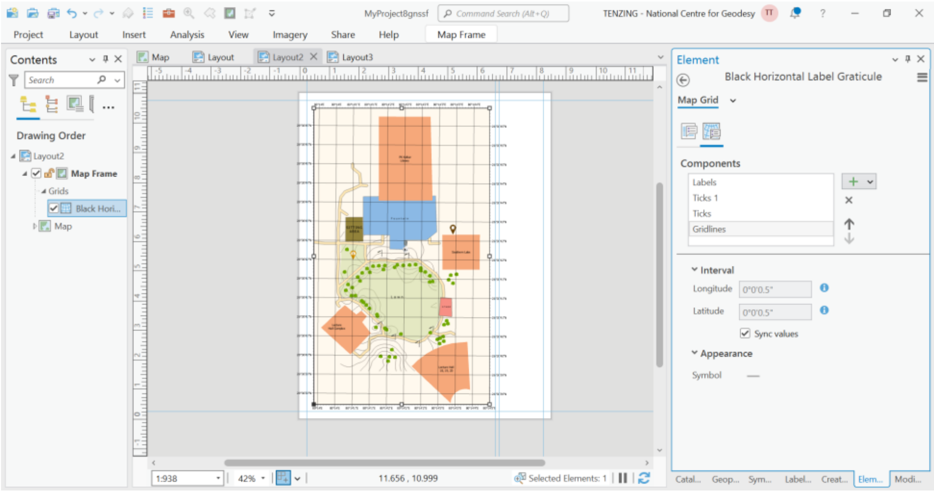


Figure 27: Added Grids

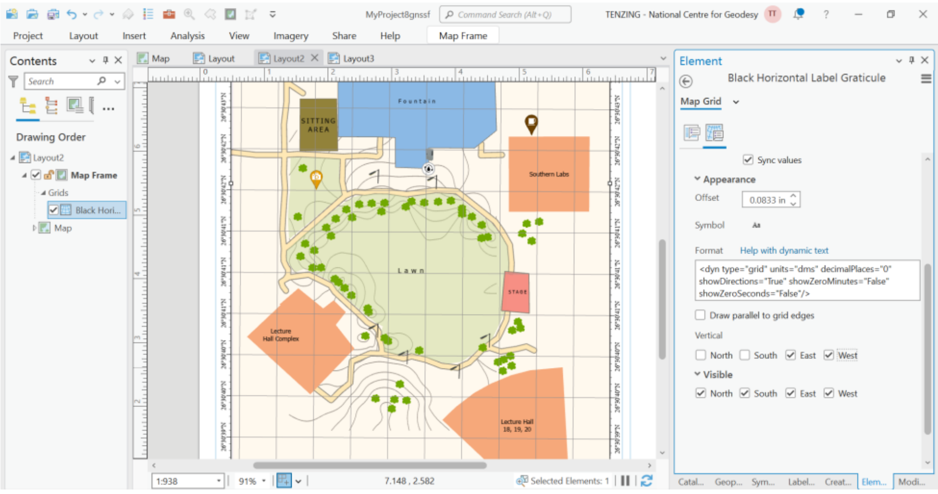


Figure 28: Arrange Grid Orientation

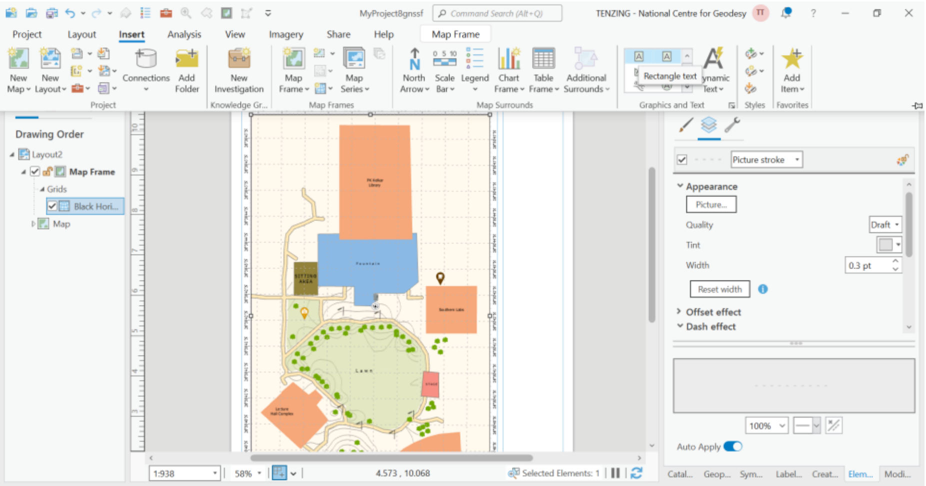


Figure 29: Showing Grids as dash lines

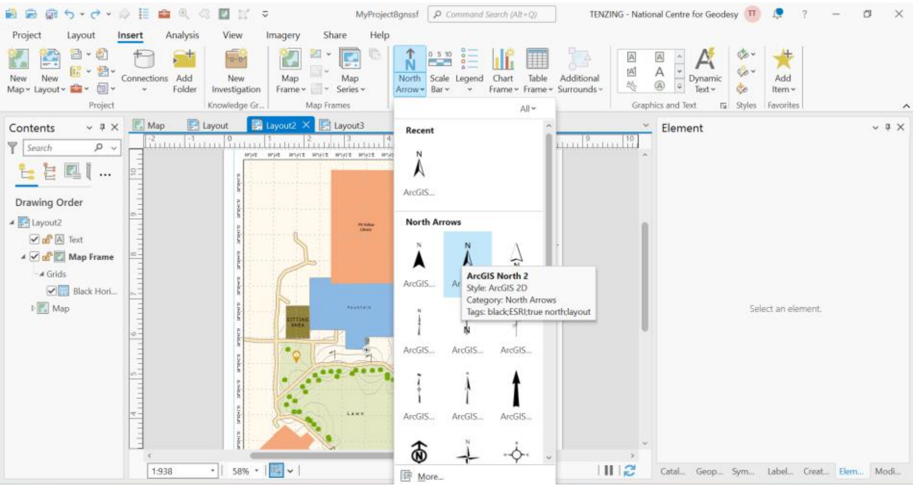


Figure 30: shoiwng North Arrow

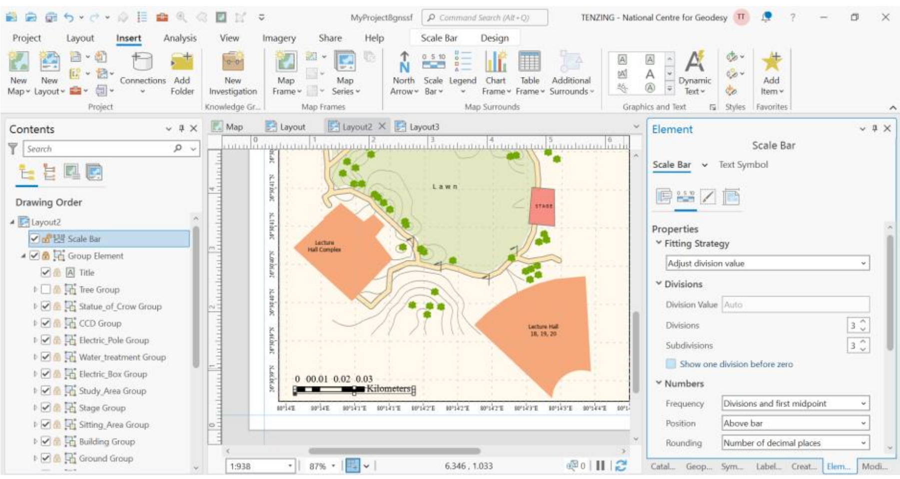


Figure 31: Adding scale

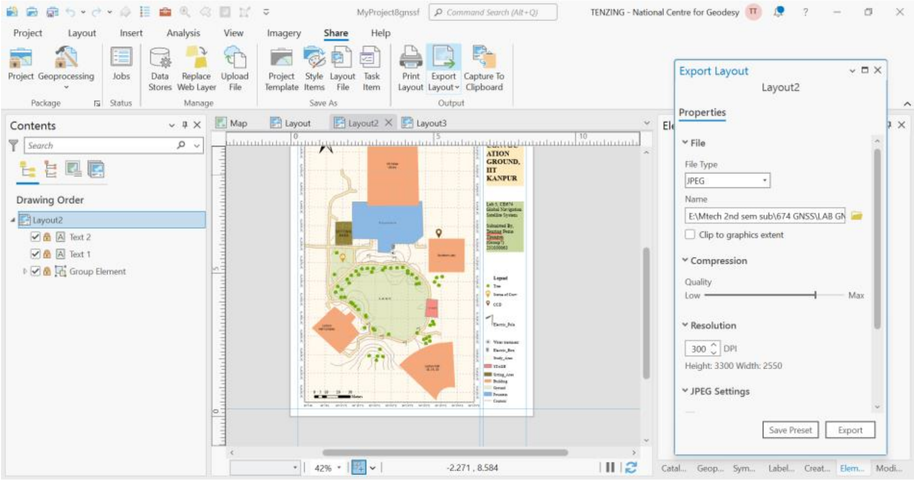


Figure 32: Exporting Map Layout

3.2.3 Geoid Modelling: Generating Geoid Undulation Maps Using ArcGIS for EGM08 and WGS84 Model

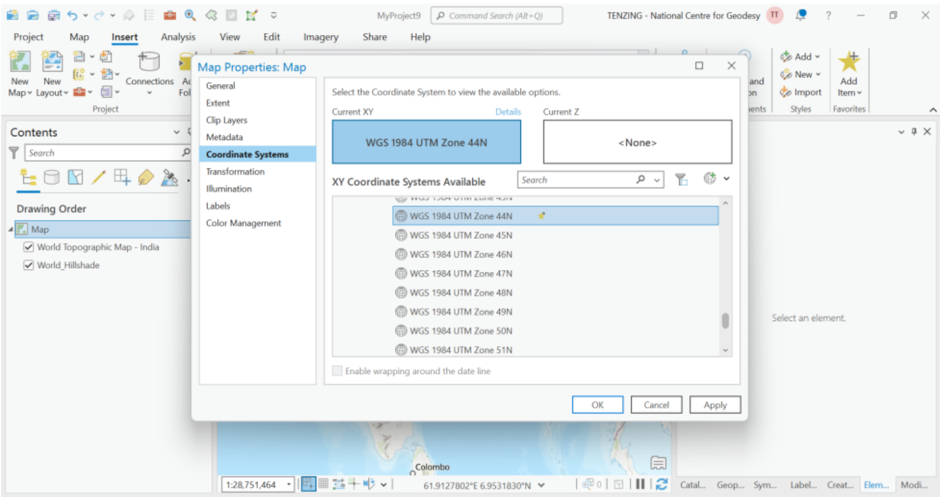


Figure 33: adding the coordinate system

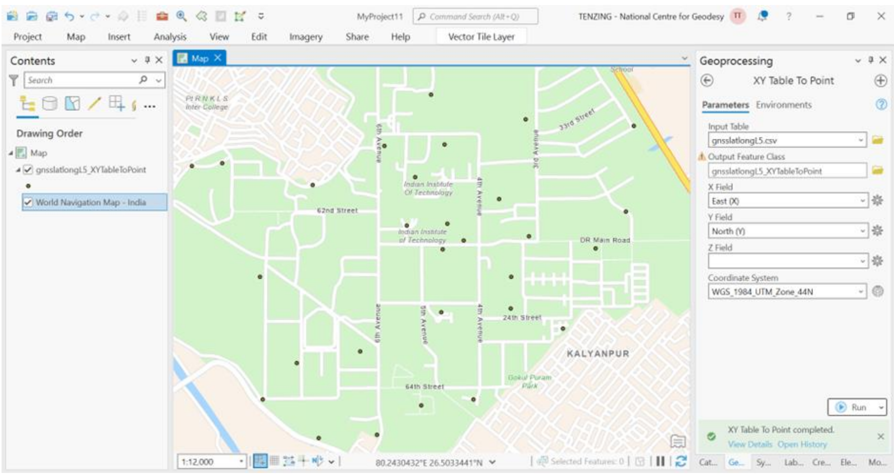


Figure 34: Showing the added point datas

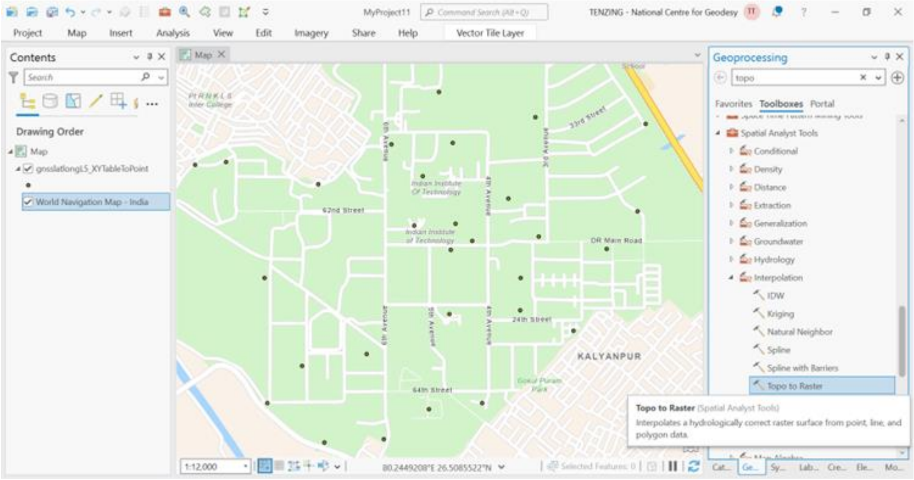


Figure 35: generated contours after Geoprocessing Topo to raster

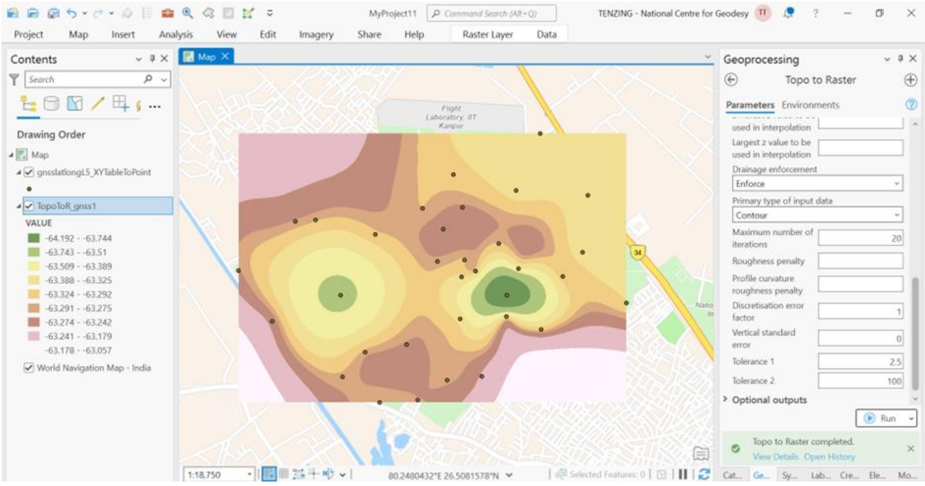


Figure 36: contour values shown as the right

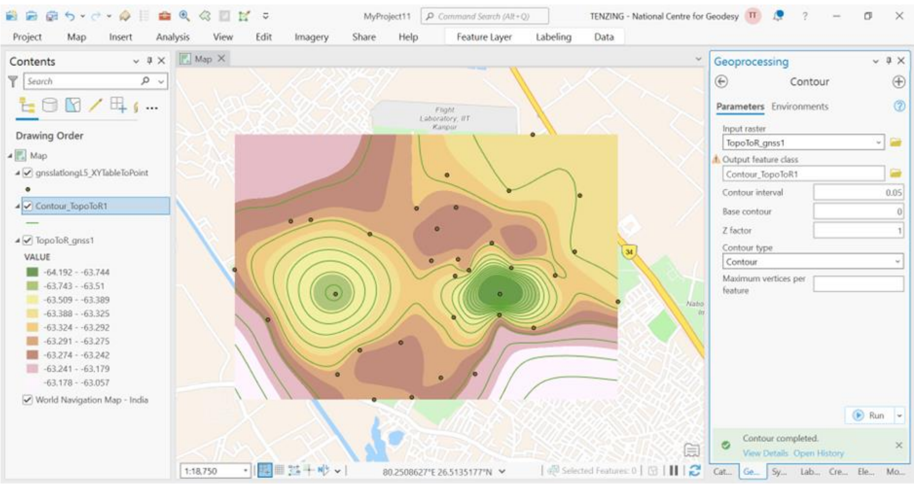


Figure 37: Contour Map generated

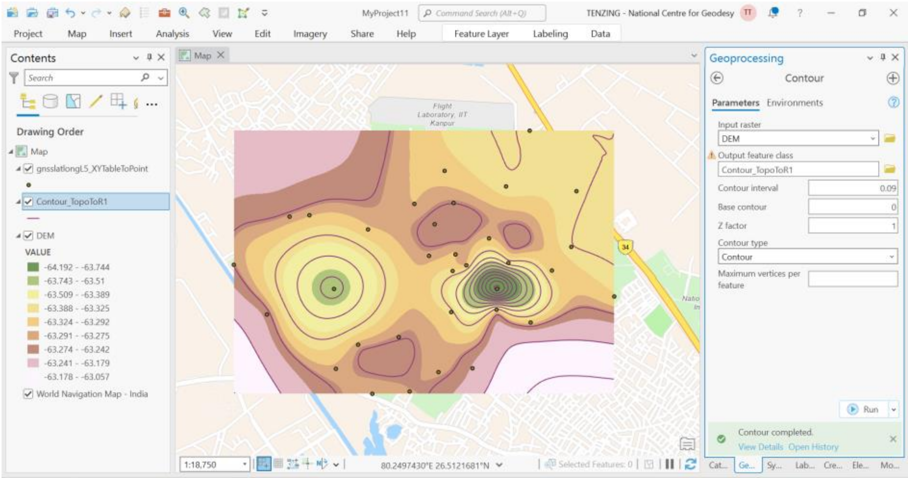


Figure 38: Contour Map generated with 0.09 contour interval

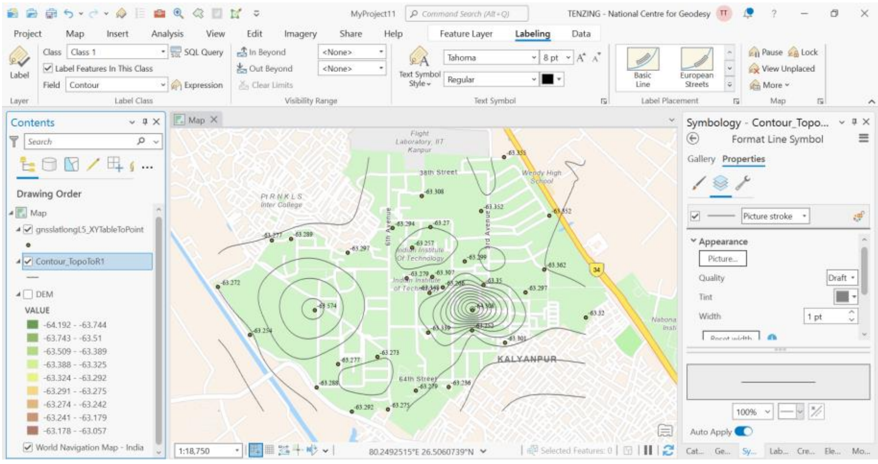


Figure 38: Contour Map shown above OSM of IIT Kanpur

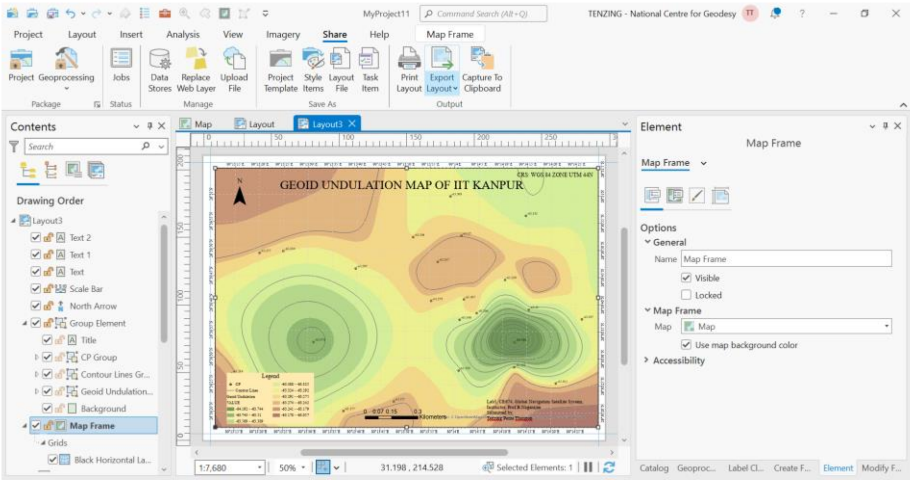


Figure 39: Contour Map Layout of Geoid Undulation using CRS:WGS 84 UTM 44N Model

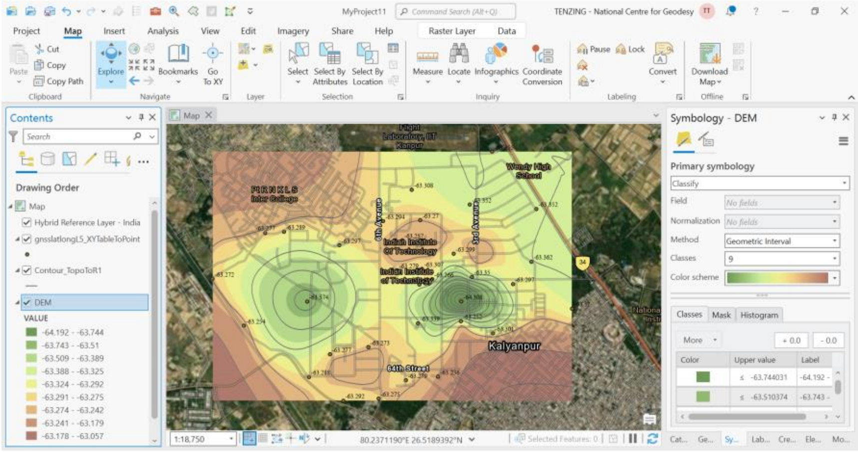


Figure 40: Generated Geoid Undulation Map on Satellite Imagery of IIT Kanpur

Using ICGEM to get the Geoid Undulation Using EGM 2008 Model

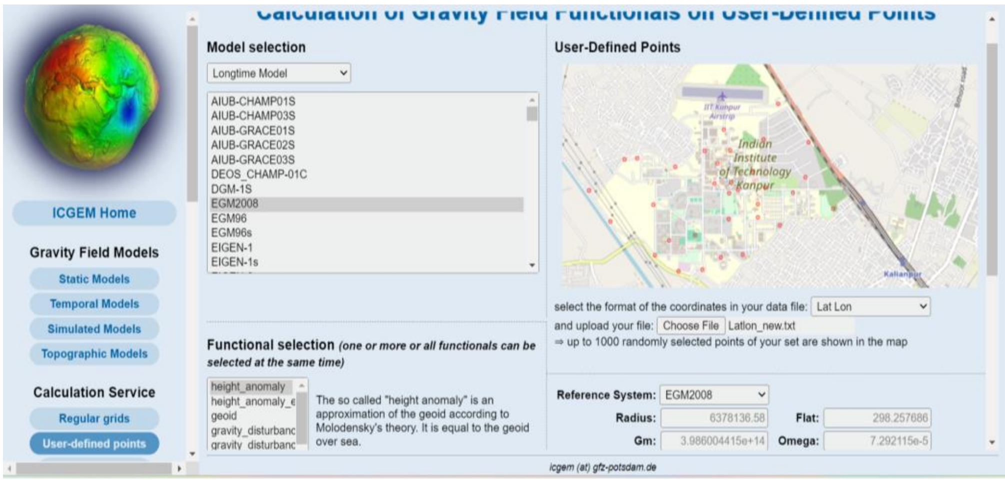


Figure 41: ICGEM used to generate height anomaly by EGM 2008 model

Geoid model computed using EGM 2008

IDW to raster

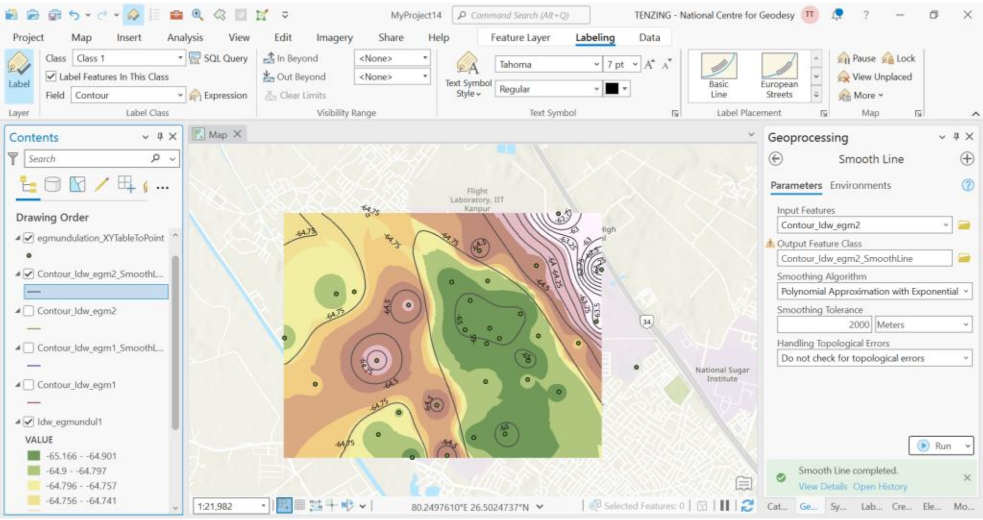
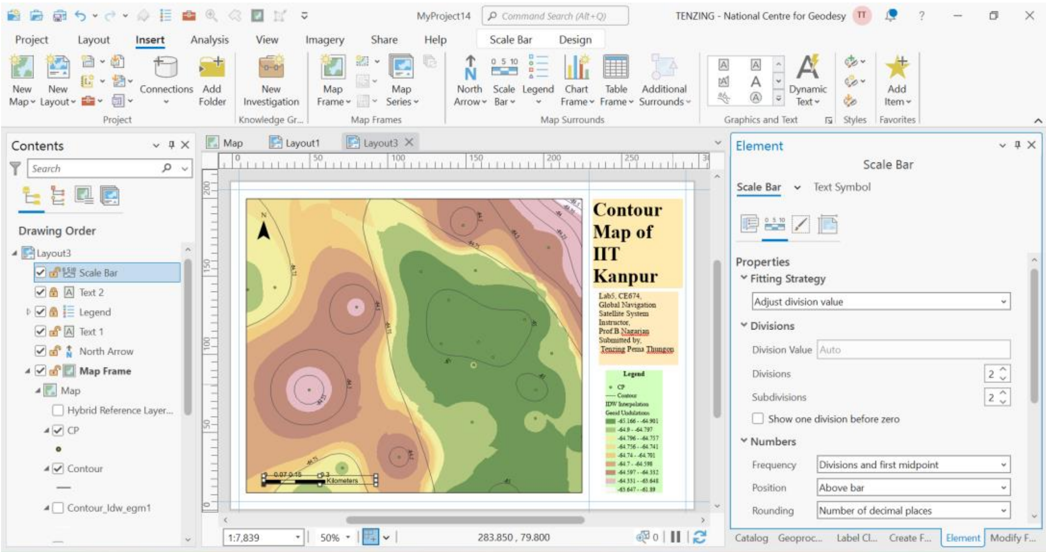


Figure 42: IDW interpolation used to generate Geoid Model with Contour interval of 0.25

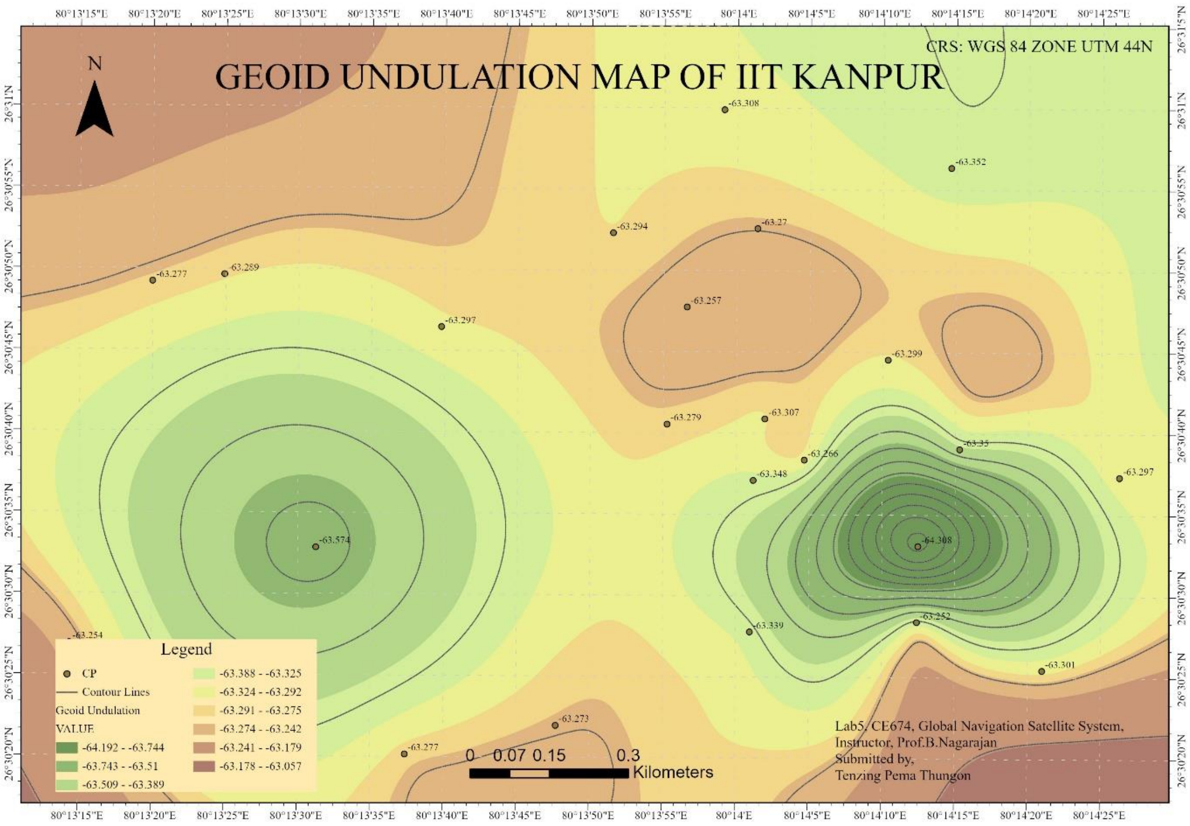


43: Contour Map Layout of Geoid Undulation using CRS: EGM08 Model

In a contour map, a contour interval is the difference in elevation between two adjacent contour lines. It essentially represents the vertical distance between each "step" in the terrain. The smaller the contour interval, the more closely spaced the contour lines are, indicating more detailed variations in elevation. Conversely, a larger contour interval means the contour lines are farther apart, representing less detailed terrain changes. The difference in contour intervals between the geoid undulations generated using WGS 84 UTM 44N (0.09 meters) and EGM 2008 (0.25 meters) indicates the level of detail captured in each model.

WGS 84 UTM 44N with 0.09 meter interval: This model captures geoid undulations with higher detail. It means that there are more contour lines on the map, representing smaller changes in elevation (every 9 centimeters). This is suitable for areas with complex terrain or requiring precise elevation information. EGM 2008 with 0.25 meter interval: This model captures geoid undulations with less detail. It has fewer contour lines, representing larger changes in elevation (every 25 centimeters).

Maps Generated:



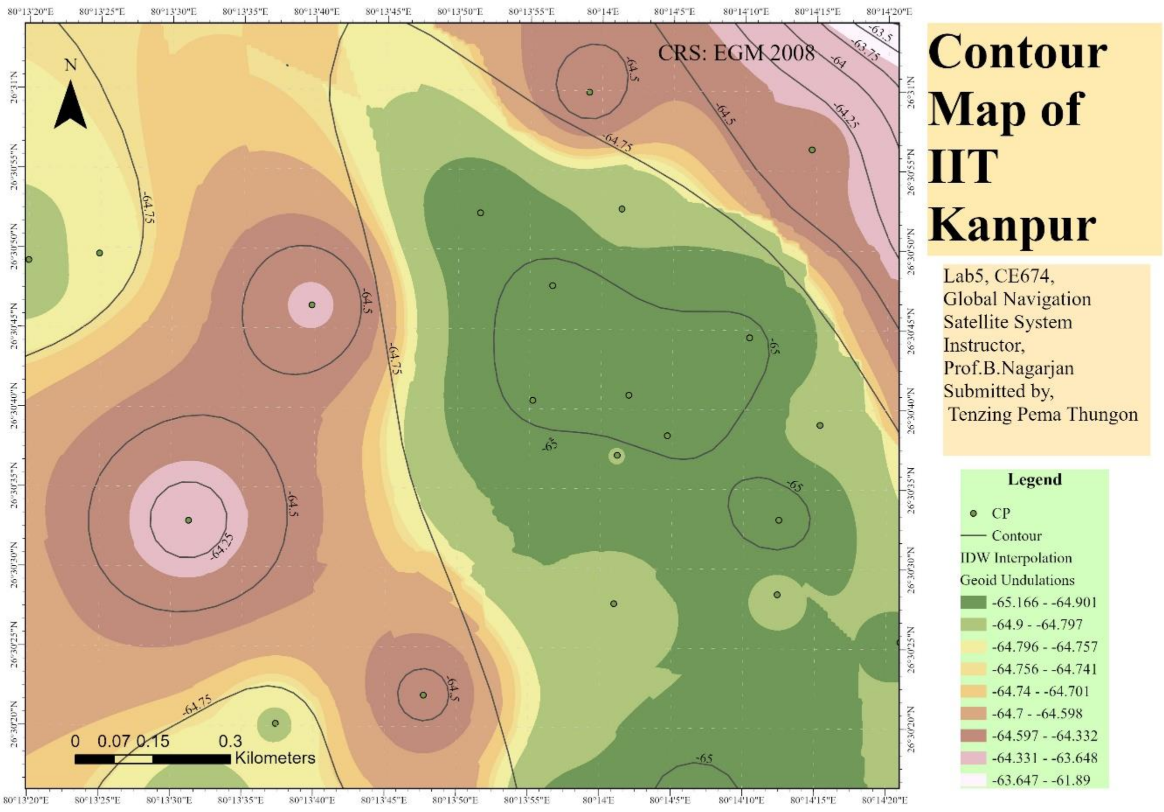


Figure 44: Geoid Undulation Map of IIT Kanpur Generated Using EGM 2008

Figure 45: Feature Map Generated

Listing down the coordinates along with their precision of CP10 that was used in setting Total Station

Table 1 : coordinates along with their precision (Static mode)

Points	Easting (Meter)	Northing (Meter)	H. Prec. (Meter)	V. Prec. (Meter)
P10-CP	423661.245	2932540.889	0.005	0.008
P10	423648.273	2932596.255	0.004	0.006

Table 2 : Coordinates along with their precision (RTK mode)

Points	Easting (Meter)	Northing (Meter)	Elevation
Cp-10	423894.765	2932651.789	65.896

Table 2: Coordinates and the respective Geoid Undulations in WGS 84 and EGM2008

S. No.	N	E	Elep.Height	Reduced Level	Geoid (WGS84) Undulation	Geoid (EGM2008) Undulation
1	26.516636	80.23308	64.12	127.428	-63.308	-64.421
2	26.513784	80.223586	64.464	127.753	-63.289	-64.772
3	26.513664	80.222217	64.56	127.837	-63.277	-64.858
4	26.510606	80.218318	64.506	127.778	-63.272	-64.815
5	26.504092	80.225509	64.512	127.8	-63.288	-64.842
6	26.502527	80.22807	64.628	127.92	-63.292	-64.962
7	26.519209	80.239042	62.183	125.538	-63.355	-62.514
8	26.510849	80.237586	64.511	127.861	-63.35	-64.863
9	26.514606	80.233722	64.584	127.854	-63.27	-64.852
10	26.511357	80.233876	64.729	128.036	-63.307	-65.043
11	26.514521	80.230974	64.682	127.976	-63.294	-64.989
12	26.51126	80.232014	64.752	128.031	-63.279	-65.038
13	26.510657	80.234625	64.795	128.061	-63.266	-65.061
14	26.512371	80.236214	64.77	128.069	-63.299	-65.073

15	26.513261	80.232383	64.921	128.178	-63.257	-65.167
16	26.515657	80.237403	64.061	127.413	-63.352	-64.394
17	26.515408	80.242343	61.546	124.898	-63.352	-61.889
18	26.511883	80.241989	62.912	126.274	-63.362	-63.272
19	26.510374	80.240628	64.432	127.729	-63.297	-64.739
20	26.50707	80.239165	64.598	127.899	-63.301	-64.914
21	26.507889	80.236779	64.613	127.865	-63.252	-64.873
22	26.509189	80.2368	63.746	128.054	-64.308	-65.079
23	26.504155	80.235115	64.798	128.034	-63.236	-65.064
24	26.503899	80.232724	64.676	127.955	-63.279	-64.973
25	26.507716	80.233605	64.487	127.826	-63.339	-64.836
26	26.510306	80.233659	64.531	127.879	-63.348	-64.892
27	26.512901	80.227716	63.965	127.262	-63.297	-64.29
28	26.50913	80.225346	63.543	127.117	-63.574	-64.152
29	26.505598	80.227052	64.499	127.776	-63.277	-64.805
30	26.506102	80.22992	64.14	127.413	-63.273	-64.455
31	26.507482	80.220664	64.416	127.67	-63.254	-64.707
32	26.502676	80.230708	64.094	127.369	-63.275	-64.364
33	26.508764	80.245033	63.898	127.218	-63.32	-64.421

Explaining the need for orienting TS before taking the first reading:

1. Establishing Reference Direction: Orienting the TS sets a reference direction, typically aligned with true north or a known survey reference. This reference direction provides consistency in measurements and ensures that subsequent readings are taken relative to a common reference frame. Without proper orientation, readings may be misaligned, leading to errors in data interpretation and analysis.
2. Ensuring Proper Alignment: Proper orientation ensures that the line of sight of the TS is aligned correctly with the desired survey points or features. This alignment is crucial for accurately measuring angles and distances to the target points. Misalignment between the instrument and the target can lead to measurement errors and inaccuracies in the collected data.

3. Facilitating Traverse Surveys: In traverse surveys, where a series of connected survey lines are measured sequentially, orienting the TS at the starting point allows surveyors to establish the initial azimuth or bearing for subsequent measurements. This initial orientation forms the basis for the entire traverse, ensuring that subsequent measurements are consistently referenced to the starting direction.
4. Enhancing Survey Efficiency: By orienting the TS before starting data collection, surveyors can streamline the measurement process and reduce the likelihood of errors or discrepancies in the collected data. A properly oriented TS enables efficient and accurate data acquisition, saving time and resources during field surveys.

What is plottable error in the map? Explain how you decided scale of your map.

It is considered to be a pencil dot on the map which is approximately equal to 0.25 mm in measurement It is the smallest dimension of a feature that can be represented on a map. Plottable error determines the scale of the map. Plottable error plays a crucial role in determining the scale of the map. The scale of the map is chosen such that features larger than the plottable error are accurately represented and measurable, while features smaller than the plottable error may not be adequately depicted or may be lost in the map's representation.

- For the feature map with a scale of 0:5:10:20:30 meters, this means that each unit on the map represents a distance of 5 meters. For example, if a road is represented as 20 units long on the map, its actual length in the real world would be 20 units multiplied by 5 meters, which is 100 meters. This scale is suitable for mapping features that are relatively large and require a moderate level of detail. Our geoid undulation scales represent the range of elevation variations our map captures 0-0.07-.15 -0.3 kilometers: This signifies that the map displays elevation differences varying from 0 meters to 300 meters.
- Similarly, the geoid undulation scale represents the ratio of distances on the map to the corresponding geoid undulation values on the ground.
  For instance, if the scale is 1:0.15, it means that one unit on the map represents 0.15 units of geoid undulation on the ground.
  In your example, with a scale of 0-.07-0.15-0.3 kilometers, it indicates that each unit on the map represents a geoid undulation value of 0.15 kilometers (or 150 meters).
  This scale is suitable for representing variations in geoid undulation over larger distances, such as regional or continental scales.

Several factors influence choosing a map scale:
Purpose of the map: Different purposes like terrain navigation, city planning, or regional overview require different levels of detail.
Area covered: Smaller areas allow larger scales for more detail, while larger areas might need smaller scales for better overview.

The importance of Geoid Modelling:

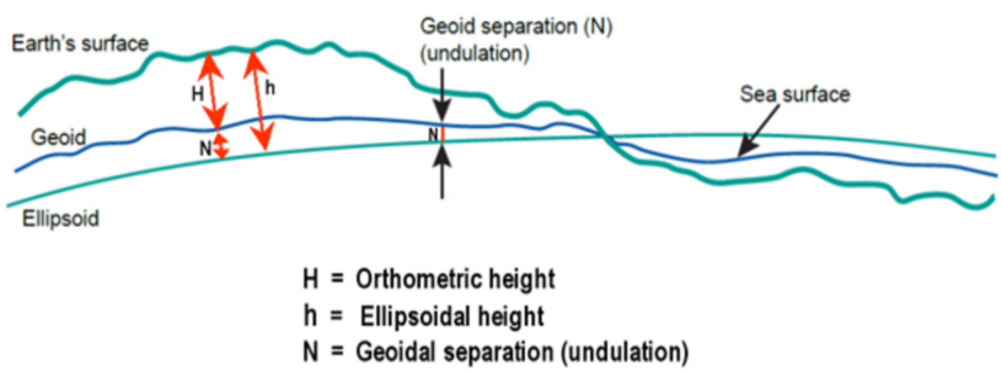
Geoid modeling plays a crucial role in various scientific and engineering applications, primarily related to surveying, mapping, and geodesy. Some key importance of geoid modeling includes:

1. **Height Reference System**: The geoid serves as a reference surface for measuring heights and elevations on Earth. It provides a consistent and accurate framework for defining elevation data used in various applications such as construction, urban planning, and infrastructure development.

2. **Global Positioning Systems (GPS)**: Geoid models are essential for accurate positioning using GPS and other satellite navigation systems. By incorporating geoid undulation values into GPS measurements, users can obtain more precise positioning information, particularly in areas with significant variations in the Earth's gravitational field.
3. **Orthometric Height Determination**: Geoid modeling enables the conversion of ellipsoidal heights (obtained from satellite-based positioning systems) to orthometric heights (heights above mean sea level). This conversion is essential for applications such as hydrology, aviation, and environmental monitoring, where elevations relative to sea level are required.
4. **Gravity Field Studies**: Geoid modeling contributes to the study of Earth's gravity field and its variations. By analyzing geoid undulation data, scientists can gain insights into the Earth's internal structure, mass distribution, and geophysical processes such as tectonic movements and crustal deformation.
5. **Geophysical Exploration**: Geoid models are used in geophysical exploration techniques such as gravity surveys and satellite gravimetry. These methods help identify subsurface geological features, mineral deposits, and hydrocarbon reservoirs by measuring variations in the Earth's gravitational field.
6. **Sea Level Rise and Climate Change**: Geoid modeling plays a crucial role in monitoring sea level rise and assessing the impact of climate change on coastal regions. By accurately measuring variations in sea level relative to the geoid, scientists can track changes over time and predict future sea level trends.
7. **Geodetic Datums and Coordinate Systems**: Geoid models are fundamental for defining geodetic datums and coordinate systems used in mapping and geospatial applications. They provide the foundation for aligning geographic data and ensuring consistency in spatial referencing across different datasets and mapping projects.

Overall, geoid modeling is essential for understanding the Earth's shape, gravity field, and spatial variations, enabling precise positioning, elevation determination, and geospatial analysis in diverse scientific, engineering, and environmental applications.

These are the significance of Geoid Undulation:



Source: Knippers, 2010

Geoid undulation represents the deviation of the geoid (a hypothetical surface of constant gravitational potential) from the reference ellipsoid (a mathematically defined shape approximating the Earth's surface). The significance of geoid undulation lies in its role as a fundamental component in various scientific, engineering, and geospatial applications. Geoid undulation serves as a crucial component in defining vertical datums, which are reference surfaces used to measure elevations and heights on Earth. By incorporating geoid undulation values into measurements, such as GPS-derived ellipsoidal heights, users can convert these heights to orthometric heights (elevations above a reference geoid), providing a consistent vertical reference framework for mapping, surveying, and engineering projects. It contributes to the accurate determination of elevation values, particularly in regions with significant variations in the Earth's gravitational field. By accounting for the local gravity anomalies captured by the geoid undulation, elevation measurements become more precise and reliable, ensuring consistency in geospatial data analysis and interpretation. It plays a crucial role in oceanography, hydrography, and maritime navigation. is essential for precise geodetic surveying, mapping, and geospatial analysis. It provides corrections to ellipsoidal heights, ensuring consistency between geodetic measurements and real-world elevations.

Geoid undulation data are used to create accurate topographic maps, digital elevation models (DEMs), and geographic information systems (GIS) datasets, supporting various applications in land management, urban planning, and environmental monitoring. Overall, geoid undulation is significant for its role in defining vertical datums, ensuring elevation determination accuracy, supporting hydrographic and oceanographic applications, facilitating geophysical studies, and enabling precise geodetic surveying and mapping.

Comparing our local Geoid Model with the EGM08 model:

Comparing the local Geoid Model based on WGS 84 UTM 44N with the EGM08 model involves examining the differences in geoid undulation values obtained from each model for the same geographic area.

Here's how we can compare them:

WGS 84 Geoid Undulation:

- Range: -63.236 to -64.308 meters
- Mean: -63.311 meters

EGM08 Geoid Undulation:

- Range: -61.889 to -65.167 meters
- Mean: -64.436 meters

WGS 84 is a reference ellipsoid that approximates the Earth's shape, while EGM 2008 is a global gravity model that accounts for the Earth's actual gravitational field. As a result, the two models will have slightly different definitions of "sea level," which can lead to differences in geoid undulation values.

The range of geoid undulation values indicates the spread or variability of the data. The EGM08 model has a wider range (-61.889 to -65.167 meters) compared to the WGS 84 model (-63.236 to -64.308 meters), suggesting that the EGM08 model captures a broader range of elevation variations.

The mean geoid undulation value provides a measure of central tendency for the data. The mean geoid undulation value for the EGM08 model (-64.436 meters) is slightly lower than that of the WGS 84 model (-63.311 meters), indicating that, on average, the EGM08 model predicts lower geoid undulations compared to the WGS 84 model.

while both models provide geoid undulation data, the EGM08 model is likely to offer higher accuracy and better representation of the Earth's actual gravitational field due to its global coverage and higher resolution. However, the choice of model depends on the specific requirements of the application and the level of accuracy needed for the analysis.

4. Results and Discussions

- ICGEM was used to access global gravity field models for geoid undulation estimation.
- A map layout was created in QGIS and ArcGIS, including grids and map properties.
- EGM 2008, a precise geoid model, was highlighted for accurate geoid undulation.
- Readings were taken using the Total Station to map out topographic features of the survey area, recording horizontal angles, distances, and vertical angles.
- ArcGIS was used to generate contour maps and feature maps based on the collected data, showcasing detailed topographic features and contours of the survey area.
- Geoid undulation maps were generated using ArcGIS for both the WGS 84 and EGM08 models

5. Conclusion

The lab successfully demonstrated the use of Total Station and ArcGIS for feature mapping and geoid modeling. Total Station proved to be crucial for capturing precise measurements, while ArcGIS facilitated the visualization and analysis of spatial data. The comparison between the WGS 84 and EGM08 geoid models underscored the importance of selecting the appropriate model based on specific application requirements. Overall, the lab provided valuable insights into surveying, mapping, and geoid modeling processes, contributing to enhanced understanding and application of geospatial analysis techniques.

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