Tutorial:

Making Digital Topographical Maps

Alecos Demetriades

International Union of Geological Sciences

Commission on Global Geochemical Baselines

Tutorial Publication

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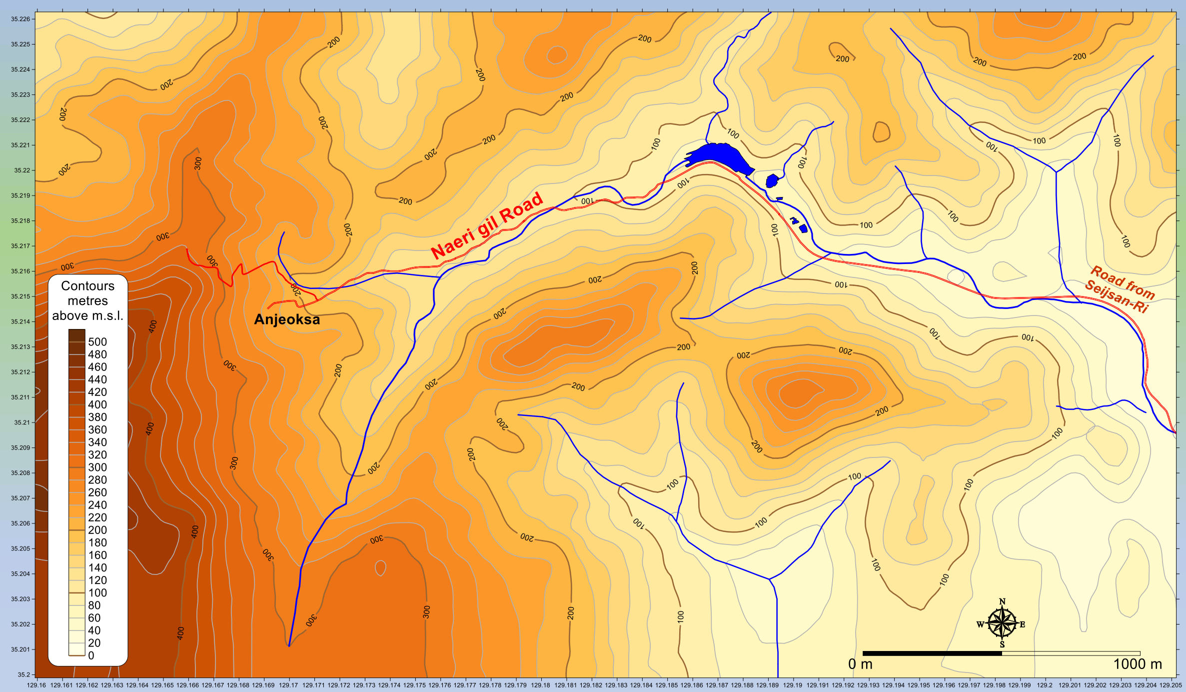

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"Global Geochemical Baselines"
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Front cover image: Topographical map, Nae-Ri area, N.E. of Busan, Republic of Korea.
Plotted by Alecos Demetriades with Golden Software's Surfer™

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37 International Geological Congress, Busan, Republic of Korea
Workshop "*International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network*", 30-31 August 2024
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Tutorial:

Making Digital Topographical Maps

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Abstract

Making a topographical map in the digital age is a straightforward process. You only need a personal or laptop computer, internet access, and a Geographical Information System software. This tutorial utilises three fundamental software packages: (i) Google Earth Pro, (ii) GPS Visualizer, and (iii) Golden Software's Surfer™. The longitude and latitude of digitised points along traverses are extracted from Google Earth Pro. Depending on the required details, a larger Google Earth image is digitised along traverses, which can be in any direction. The file with the longitude (x) and latitude (y) of point data is then copied online into GPS Visualizer, which uses data from different digital elevation models (DEM) to assign the optimum altitude or topographical height (z) in metres (or feet) of the digitised points along the traverses. The topographical data (x, y, z) exported from GPS Visualizer are plotted with Surfer™ or similar mapping software packages, and a digital topographical map of an area is made. This tutorial provides detailed instructions on plotting and annotating an area's topographical map with modern digital tools.

Keywords: Google Earth; Digitisation; GPS Visualizer; Geographical Information System; Surfer

Requirements: For those interested in making topographical maps using modern technological tools, Google Earth Pro (https://www.google.com/earth/about/versions/), GPS Visualizer (https://www.gpsvisualizer.com/), and Golden Software's Surfer™ are indispensable. The best part is that Google Earth Pro is free and can be downloaded from the provided hyperlink. GPS Visualizer is also free and can be used online. As for Surfer™, a fully functional version can be downloaded from the company's website at https://www.goldensoftware.com/products/surfer/. Additionally, Golden Software offers new users a 14-day free trial, making these powerful tools accessible to all.

Golden Software offers generously discounted licenses for students and educators who use the software in their courses. Academic staff and students are encouraged to learn more by visiting https://www.goldensoftware.com/solutions/education. This support and encouragement ensure that students and educators have the resources to learn and effectively teach digital topographical map-making.

Note: This tutorial exercise was designed for the workshop organised at the 37th International Geological Congress in Busan (South Korea) on August 30th and 31st, 2024. The workshop was titled "*International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network*," which is the title of the Manual of Standard Methods that the Commission on Global Geochemical Baselines published in 2022.

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1. Introduction

"*Surveying may be described as the art of making measurements upon the earth's surface for the purpose of producing a map, plan, or estimate of an area. Levelling is combined with surveying when the project requires that the variations in the surface shall be delineated by contour lines, or shown in a vertical section, or used in the calculation of a volume content.*

Surveying may thus be defined as making measurements in the horizontal plane, and levelling as making measurements in the vertical plane" (Higgins, 1974, p.ix).

It is apparent from the above concise description of '*surveying*' and '*levelling*' that producing a contoured topography of a project area was a painstaking procedure requiring considerable fieldwork and hand computations in the office by the surveyor.

With the advent of Landsat imagery and the availability of global high-resolution elevation data sets and models, a digital topographical map of a study/work area is relatively easy to make. What is needed is access to the Internet where the necessary tools are freely provided, *i.e.*,

- Google Earth Pro (https://www.google.com/earth/about/versions/), and
- GPS Visualizer (https://www.gpsvisualizer.com/).

You must first download and install Google Earth Pro on your computer. The GPS Visualizer is used online.

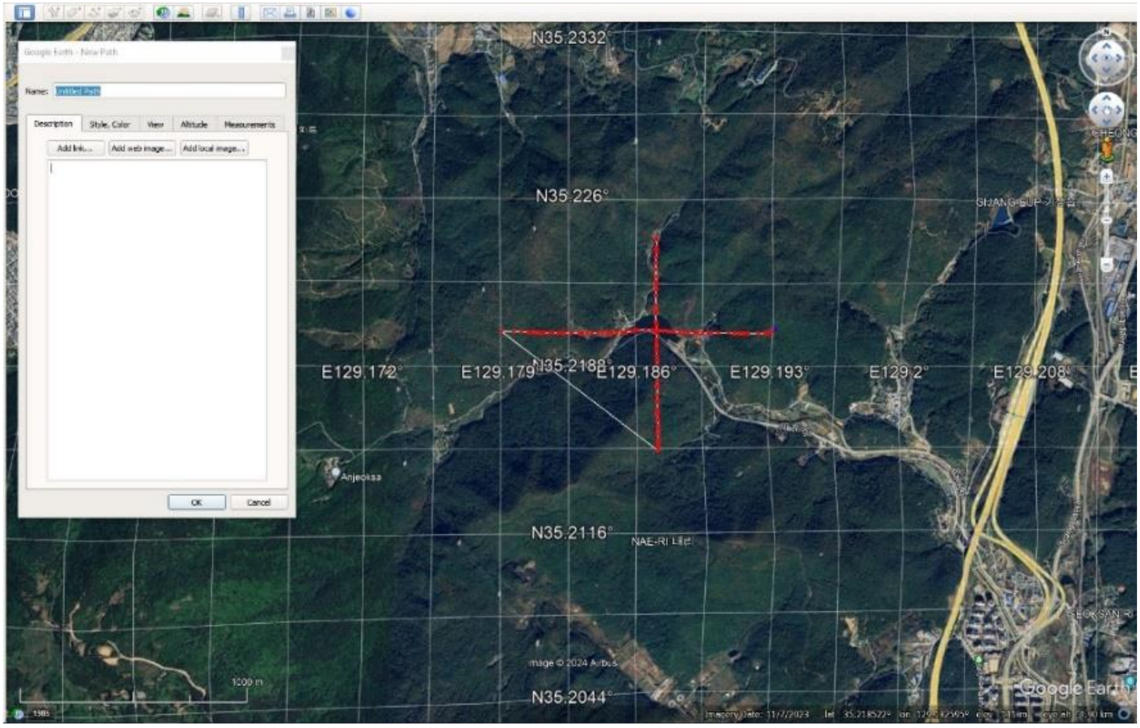
The topographical data, *i.e.*, point coordinates (x, y, z), exported from GPS Visualizer are plotted with a Geographical Information System software, such as Golden Software's Surfer™ or similar mapping software packages.

A crucial decision to be made is the scale of the Google Earth image for extracting the point coordinates. It is strongly recommended that the point coordinates be extracted from a larger-scale Google Earth image than the scale of the field topographical map that will be made. Figure 1 shows the comparison of the Google Earth image mapping scales.

Another critical variable is the density of digitised points. The density of digitised points depends on the moving speed of the mouse over the Google Earth image. A slow mouse movement achieves a greater density of digitised points.

The steps that should be followed are described below.

(a)



(b)

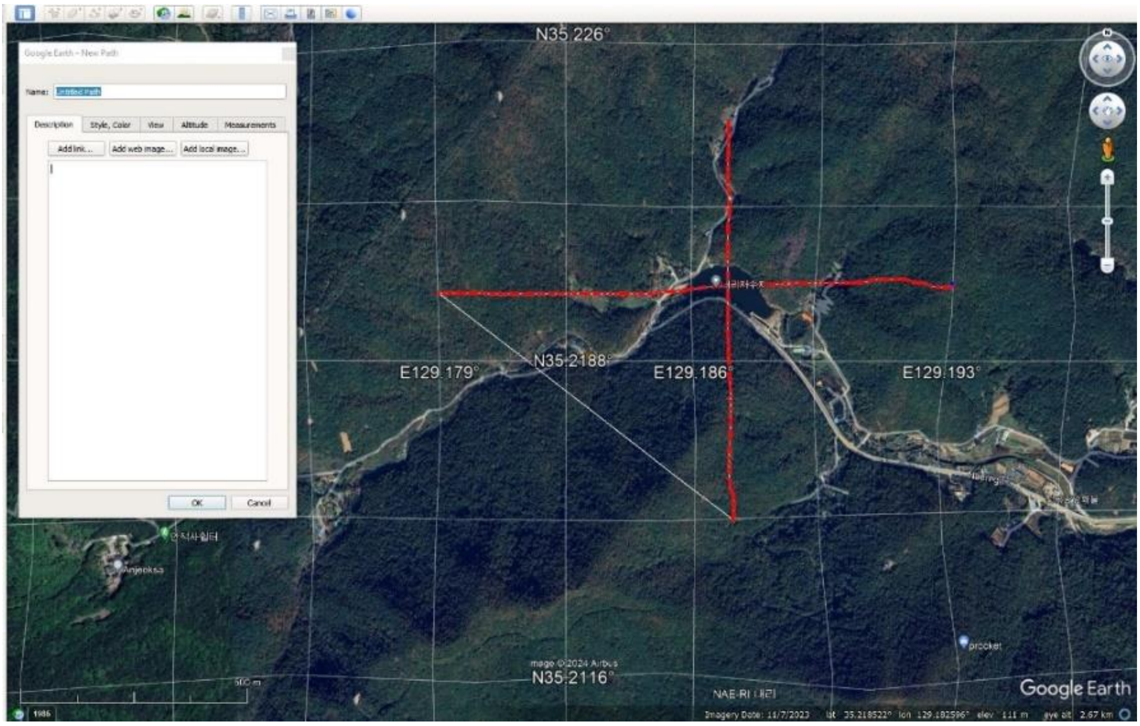


Figure 1. Google Earth images at different scales: (a) 1000 m and (b) 500 m. It is evident that image (b) shows the features of the lake in greater detail, and the density of digitised points along the two traverses is greater.

2. Google Earth files

The following procedure is followed:

1. Open Google Earth Pro.
2. Mark the work area for making a digital topographical map. In this case, the Busan (Republic of Korea) field training workshop area is marked with a yellow line using the Google Earth '*Add Polygon*' tool (Fig. 2).

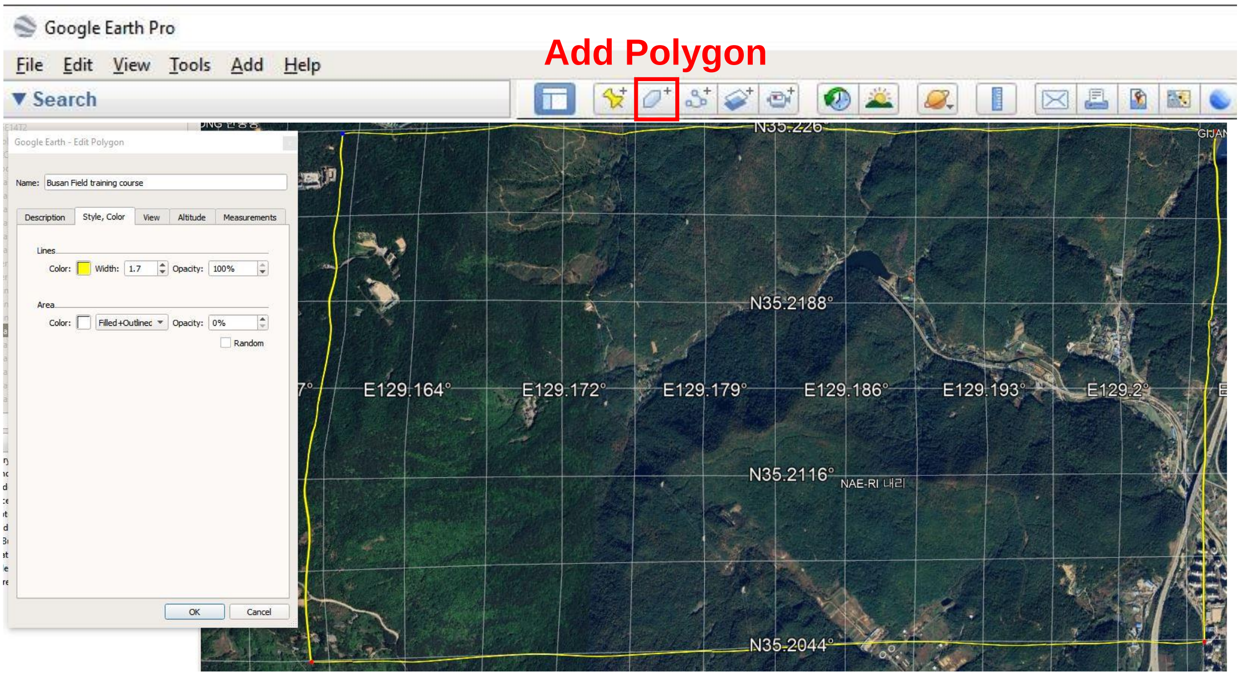


Figure 2. Google Earth Pro image showing the field training area marked with a yellow line with the 'Add Polygon' tool (indicated with a red rectangle). On the left side is the Google Earth - Edit Polygon dropdown window with the parameters used, and the file's name 'Busan Field training course'.

3. Use the Google Earth '*Add Path*' tool to mark the digital x and y point coordinates path (Fig. 3).

Figure 3. The Google Earth 'Add Path' tool (indicated with a red rectangle) marks the points along a digital path or traverse.

4. The Google Earth '*Add Path*' tool is used by moving slowly and steadily the mouse to mark the points along a path (or traverse), as shown by the red colour dot section (Fig. 4). It is important to keep pressing the left mouse button, and the movement to be slow to achieve a greater density of digitised points along each path or traverse. To save the digitised section, add its '*Name*', *i.e.*, '*Busan_1*', and press '*OK*' with the left mouse button. Upon saving the digitised section, the paths (or traverses) on the Google Earth image are shown in white colour lines (Fig. 5).
5. The Google Earth '*Add Path*' tool is selected again, and points within the remaining area are digitised. This is a painstaking procedure, *i.e.*, the hand gets tired by continuously pressing the left mouse button and moving the mouse slowly within the study area. As shown in Figure 6, the whole area has been covered by repeated runs to fill in many gaps. The digitised points of the second run are saved (Fig. 6). The gaps in non-digitised areas can be seen.

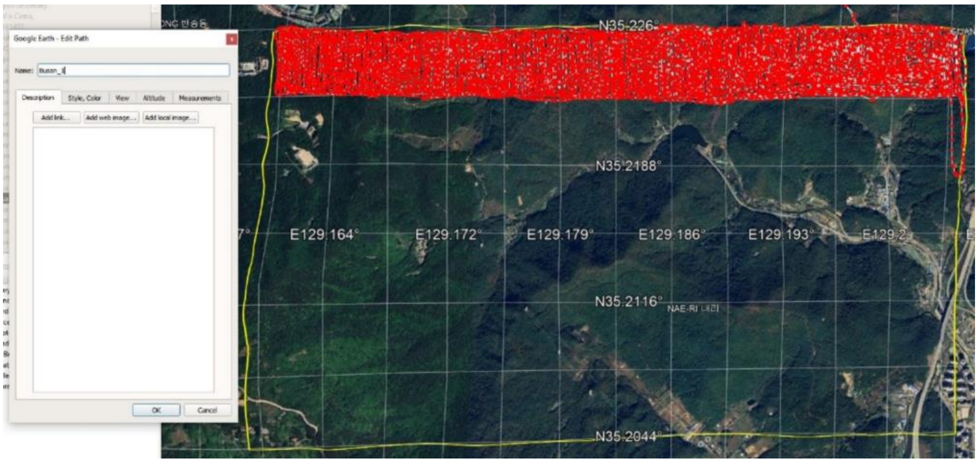


Figure 4. The northern part of the image was digitised using Google Earth's 'Add Path' tool. As can be seen by the very closed red dots, the mouse was moved slowly to achieve a dense network of digitised points along traverses.

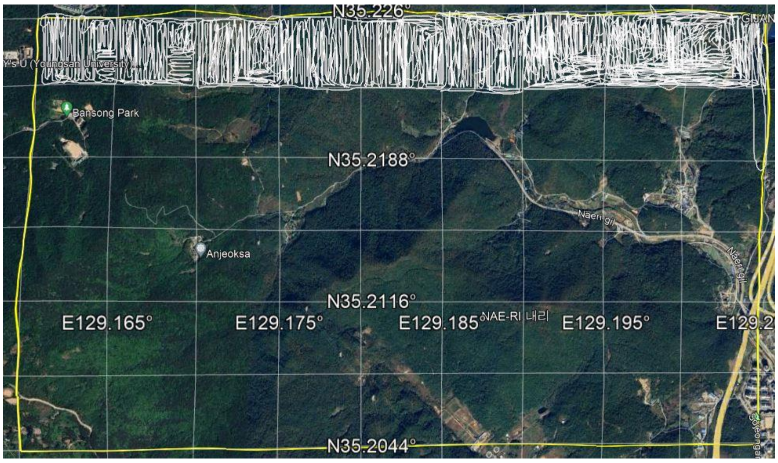


Figure 5. White lines on the Google Earth image show the saved digitised section. In a detailed study of the digitised section, it is apparent that there are gaps between traverses and other runs are needed to fill in the gaps.

6. The Google Earth '*Add Path*' tool is repeatedly selected, and the digitised points along traverses in any direction are saved in different *.kml files until the whole area is covered (Figs. 6 to 9).

Figure 6. Google Earth image showing the field training course area with the digitised points along traverses. Note that there are gaps between traverses, and other runs are needed to fill in the gaps.

Figure 7. Google Earth image shows the saved digitised points along traverses within the field training course area. Note the gaps between traverses that need to be filled-in.

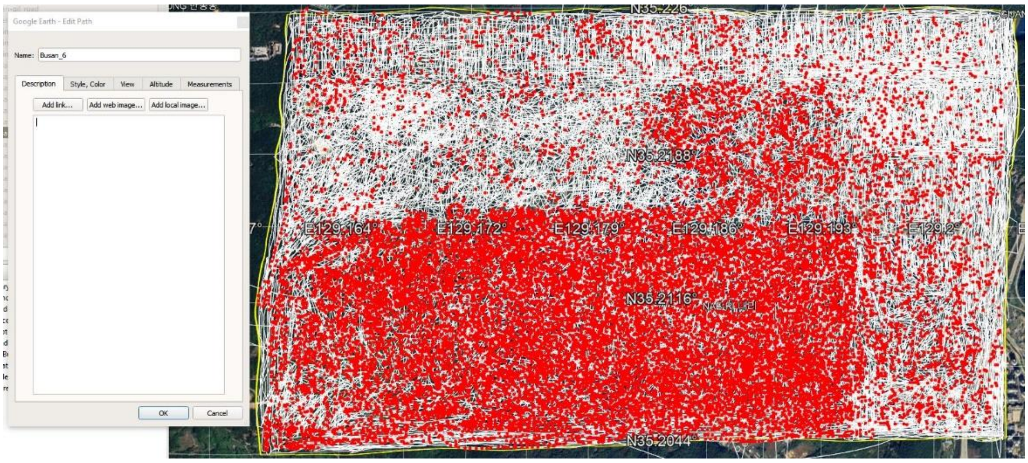


Figure 8. Google Earth image showing the filling in of gaps between traverses.

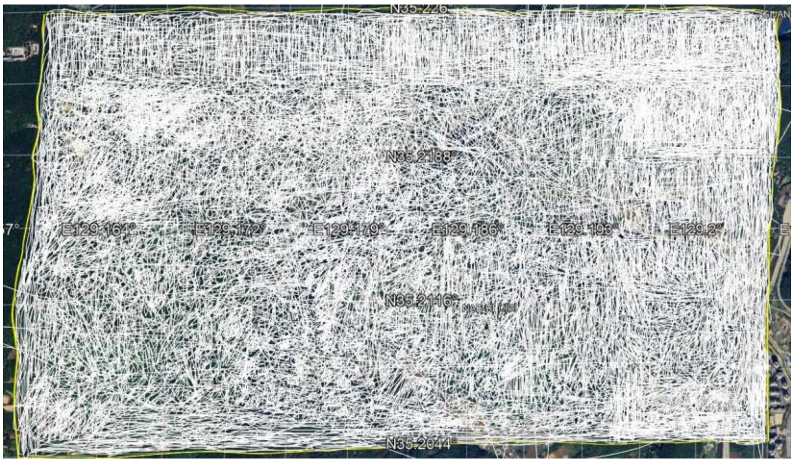


Figure 9. The final Google Earth image shows the completed digitisation of the field training course area.

2.1. Cleaning Google Earth files

Figure 10 shows a few digitised lines outside the Busan field training course area. These few lines do not affect the final result because of the density of digitised lines within the study area. However, a demanding critic will recommend their removal. Hence, the procedure for cleaning the digitised lines shall be demonstrated.

Figure 10. This Google Earth image shows that a few digitised lines are outside the boundaries of the Busan field training course area.

The first file, 'Busan_1' has a short, digitised line in the north-eastern part (Fig. 11), which is outside the boundaries of the field training course area. Also, another line along the eastern border but within the study area can be kept.

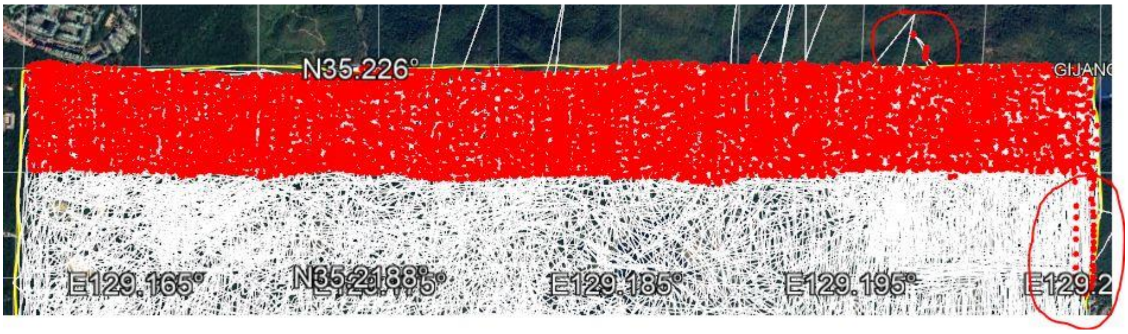
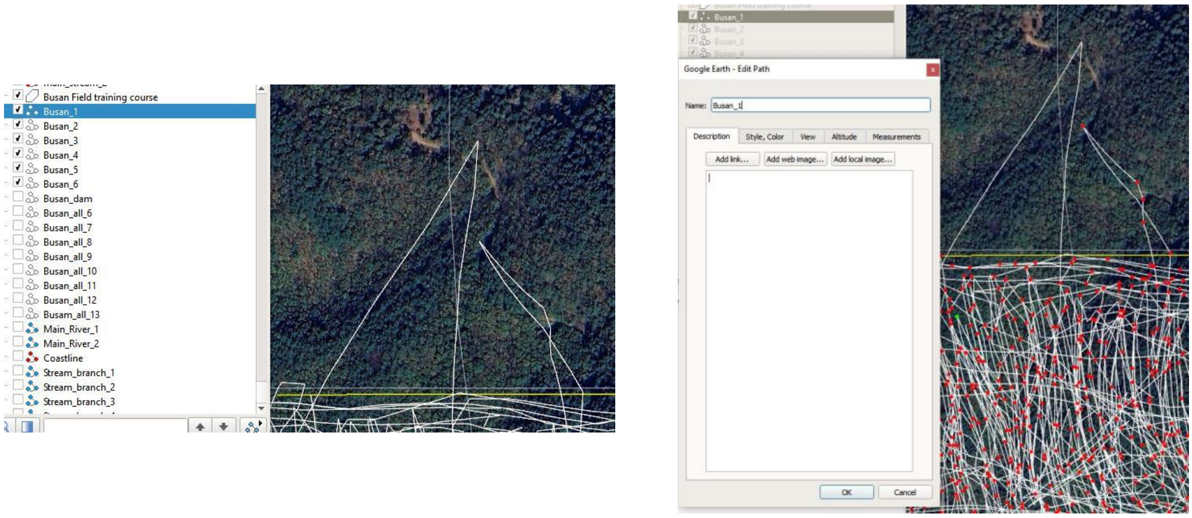


Figure 11. This Google Earth image shows that a few digitised lines (marked with a red circle) are outside the boundaries of the Busan field training course area.

The procedure for deleting the points is described below:

- Enlarge the Google Earth image so that the digitised points of '*Busan_1*' can be seen clearly (Fig. 12a).
- Select the digitised line of 'Busan_1' with a left mouse click, and with a right click, a small dropdown window appears, and then select '*Properties*'. Figure 12b shows the result with 4 points outside the study area.
- Select each point in turn by clicking on it with the left mouse button – the colour changes from a red to a green dot. After selection, click the right mouse button to delete the point. The neighbouring point becomes blue, and by successive right-clicking of the mouse, the outside points are deleted in consecutive order (or use the keyboard's '*Delete*' button, which is a much easier and practical procedure).
- Upon completion, press the '*OK*' button of the Properties drop-down window.
- Repeat this procedure to clean the other digitised files.

Figure 13 shows the final clean digitised Google Earth image.



(a) (b)

Figure 12. This Google Earth image of 'Busan_1' shows (i) a white digitised line outside the boundaries of the field training course area, and (ii) after selecting 'Properties' four points are outside the boundaries.

Figure 13. Final clean digitised Google Earth image of the Busan field training course area.

2.2. Exporting digitised points to kml files

Select in turn from Google Earth files '*Busan_1*', '*Busan_2*', '*Busan_3*', '*Busan_4*', '*Busan_5*' and '*Busan_6*' and save them in a dedicated directory as *.kml files. The procedure for saving each file, after selecting it, is as follows:

- Select 'Busan_1' and right-click the mouse.
- Select from the small drop-down window '*Save Place As …*'.
- Select the folder to save the file.

- The file name is already taken from Google Earth, and '*Save as type:*' should be selected (the choice is between *.kmz and *.kml). Choose '*kml (*.kml)*', and select 'Save' with a left mouse click.
- Repeat the same procedure with the other files, *i.e.*, '*Busan_2*', '*Busan_3*', '*Busan_4*', '*Busan_5*' and '*Busan_6*'.

3. GPS Visualizer

GPS Visualizer (https://www.gpsvisualizer.com/) is used online to extract the height above the mean sea level of the digitised (x, y) points along traverses on Google Earth.

Go to the main page of the GPS Visualizer at https://www.gpsvisualizer.com/ (Fig. 14). Select from the top ribbon '*CONVERT A FILE*' and the conversion page is displayed (see Fig. 15).

There are three choices for the output format, *i.e.*, Plain text, GPX (GPS Exchange Format file, which is simply a text file with geographical information such as waypoints, tracks, and routes saved in it), and Google Earth KML. In our case, select '*Plain text*' as the format of the output file. As there are six *.kml files, click with the left mouse button 'Show more file boxes' (Fig. 16).

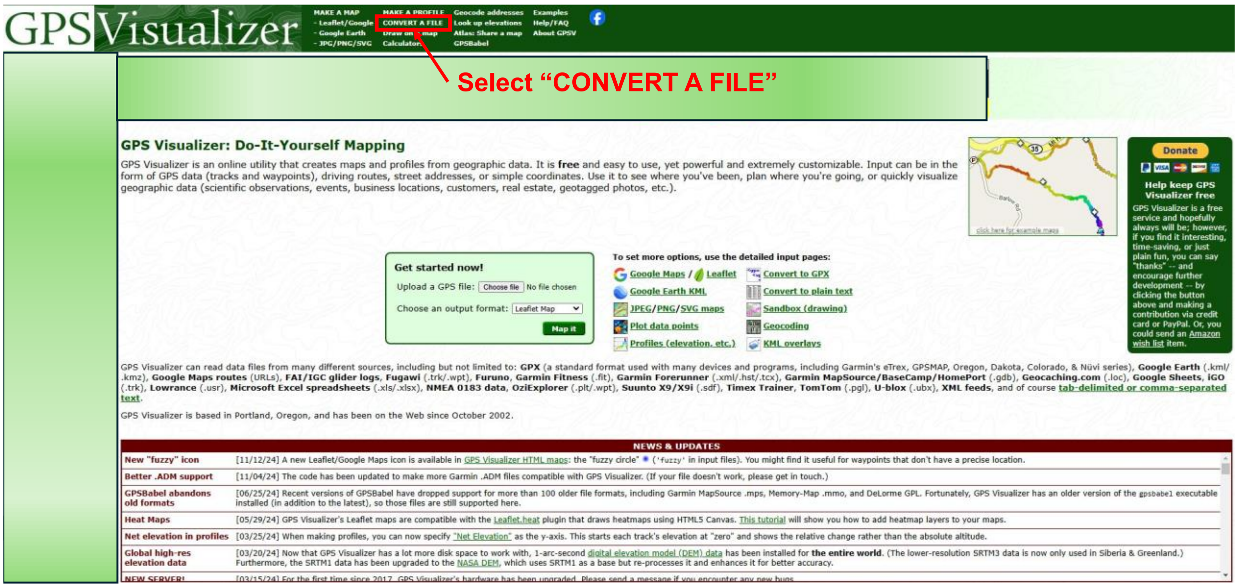


Figure 14. The front web page of GPS Vizualizer. On the top ribbon, the option 'CONVERT A FILE' is marked with a red square, and is indicated by a red arrow.

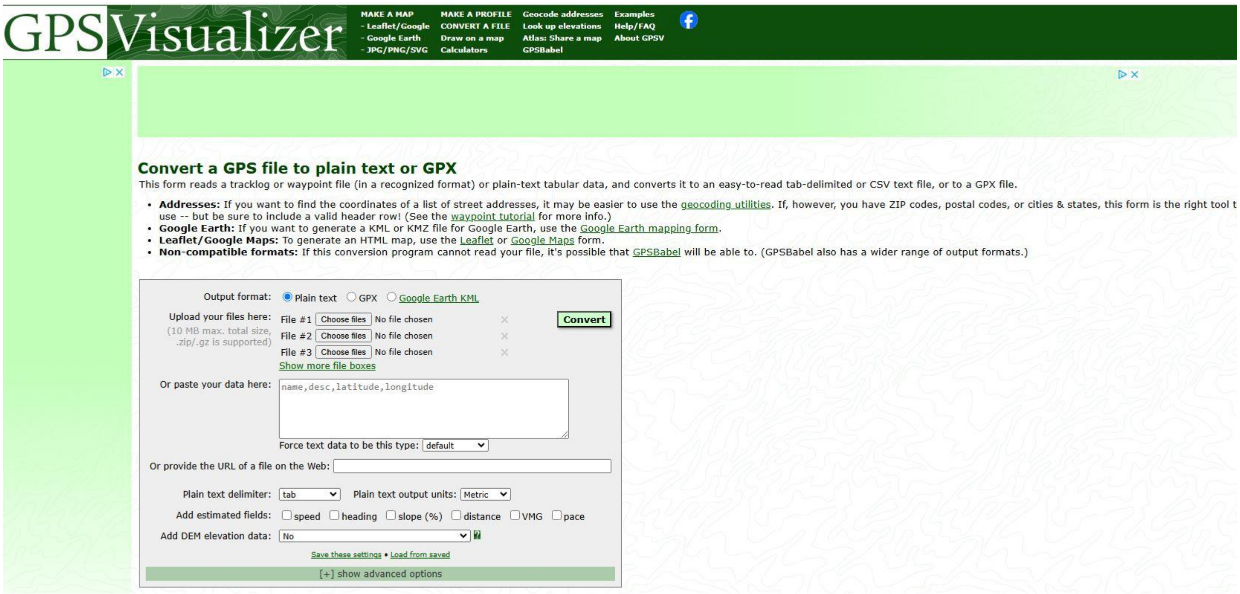


Figure 15. Web page of GPS Vizualizer's 'Convert a GPS file to plain text or GPX'.

- The six *.kml files (Busan_1 to *_6) are selected in turn (Fig. 16).
- For '*Plain text delimiter*', select '*comma*' (*i.e.*, comma-separated values file, CSV).
- For '*Add DEM elevation data*' there are eight options, *i.e.*,
  - No;
  - best available source;
  - USGS NED1 (30 m res., North America);
  - USGS NED2 (60 m res., Alaska only);
  - ODP1 (30 m res., northern/western Europe);
  - NASA1/SRTM1 (30 m res., worldwide);
  - NASA SRTM3 (90 m res., worldwide), and
  - ASTER (30 m res., limited availability).
- Select '*best available source*' (this is the option used for this tutorial, and it produced satisfactory results. However, if you have the time, you can try other worldwide options).
- Click with the left mouse button '***Convert***', and the conversion procedure begins.

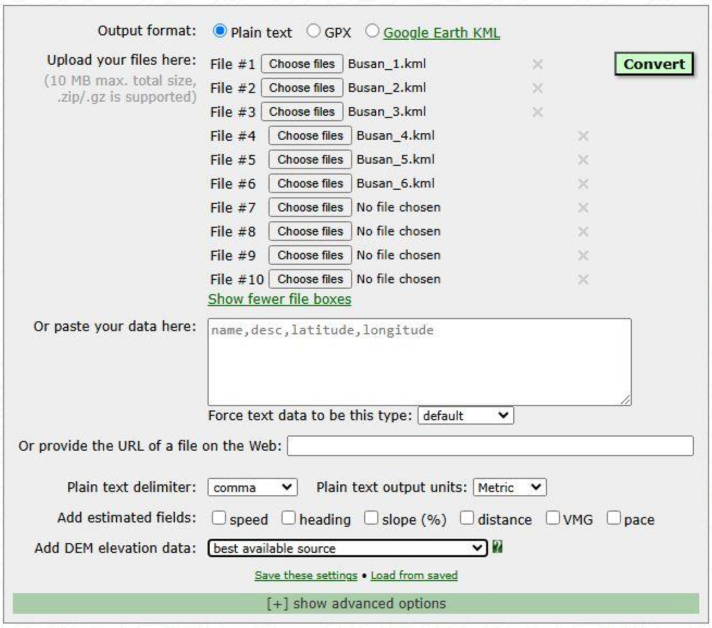


*Figure 16. Insertion of Busan *.kml files and selections in GPS Vizualizer's 'Convert a GPS file to Plain text or GPX' web page.*

- Download the indicated ‘*20240701135227-13046-data.csv*’ file in Figure 17, and place it in your work directory.
- Rename the file to ‘*Busan_field-course_area.csv*’.

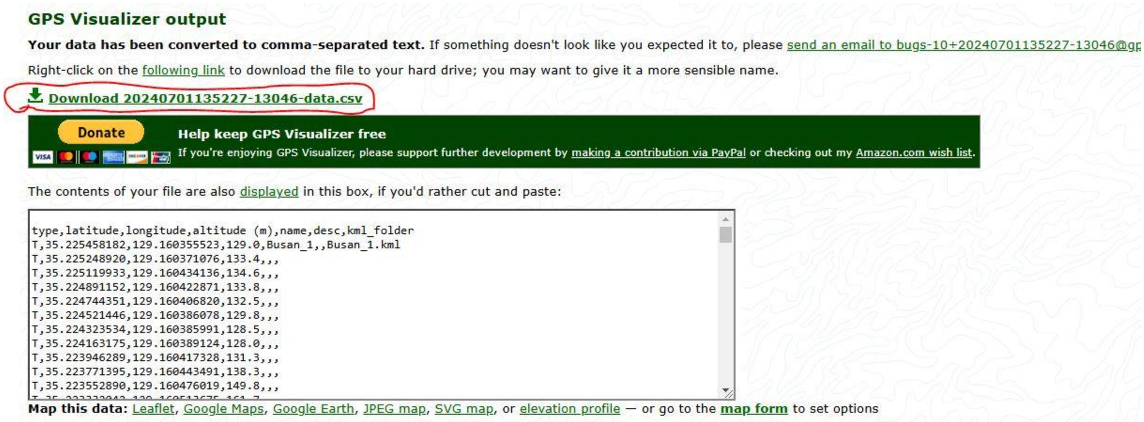


*Figure 17. GPS Visualizer output web page. The *.csv file to be downloaded is indicated with a red-coloured girdle.*

3.1. Opening *.csv file in Microsoft Excel®

- Open the ‘*Busan_field-course_area.csv*’ file in Microsoft Excel® by selecting, after opening, the ‘*Data*’ page, ‘*From Text/CSV*’ (Fig. 18) – alternatively the file can be opened in Surfer’s worksheet (see Section 3.2). Figure 19a shows the top part of the Excel®, and Figure 19b is the section between ‘*Busan_1*’ and ‘*Busan_2*’ files. These gaps exist between the data entry files. Hence, the Microsoft Excel® worksheet needs to be edited by deleting:
  - (i) the gaps between files,
  - (ii) the whole Excel® columns A, E, F and G with ‘type’ (‘T’ entries), ‘Busan-1’, ‘desc’ and ‘Busan_1.kml’, respectively, and
- Transferring the ‘*longitude*’ data in column A, and
- Finally, save the file with the name ‘*Busan_field_course_area.xlsx*’. It is noted that in total 61,238 points were digitised over an area of approximately 8.376 km^2, *i.e.*, 7311 points/km^2.

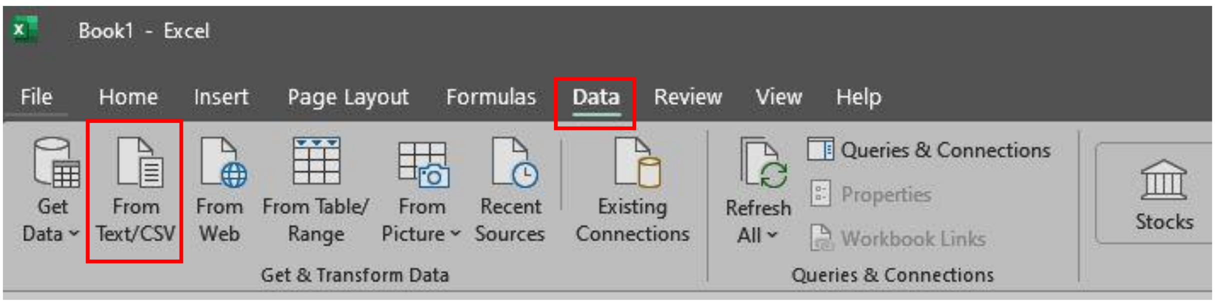
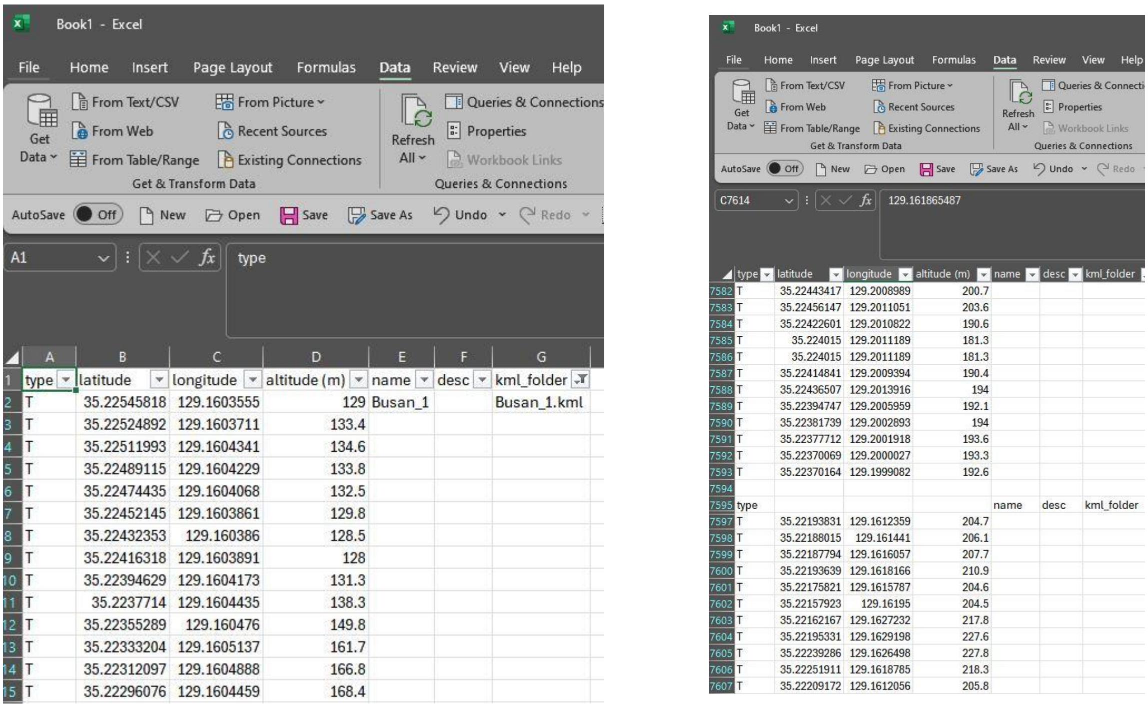


Figure 18. Microsoft Excel® ‘Data’ page for opening the ‘Busan_field-course_area.csv’. The option ‘From Text/CSV’ is selected and then the ‘Busan_field-course_area.csv’ file.



(a) (b)

*Figure 19. (a) Top lines of the 'Busan_field-course_area.csv' in Excel®, and (b) the gaps between the six *.csv files.*

3.2. Opening *.csv file in Golden Software's Surfer™

- Open Surfer™.
- In the inset '*Welcome to Surfer*' select '*New Worksheet*' with a left mouse click (Fig. 20).
- Use the '*Open Data*' command to open the '*Busan_field-course_area.csv*' file (Fig. 21). For editing the worksheet file, the same procedure as described in Section §3.1 should be followed.
- The final file can be saved in a Microsoft Excel® format.

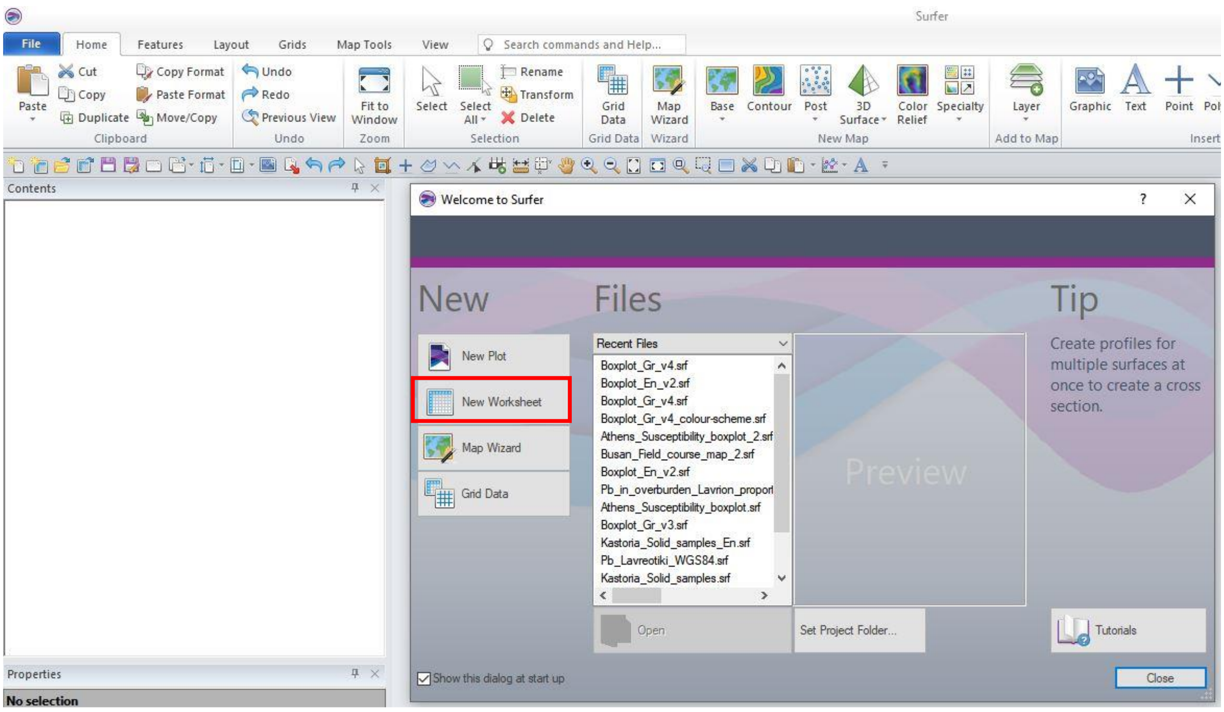


Figure 20. Golden Software's Welcome to Surfer™ page. The 'New Worksheet' option is selected with a left mouse click.

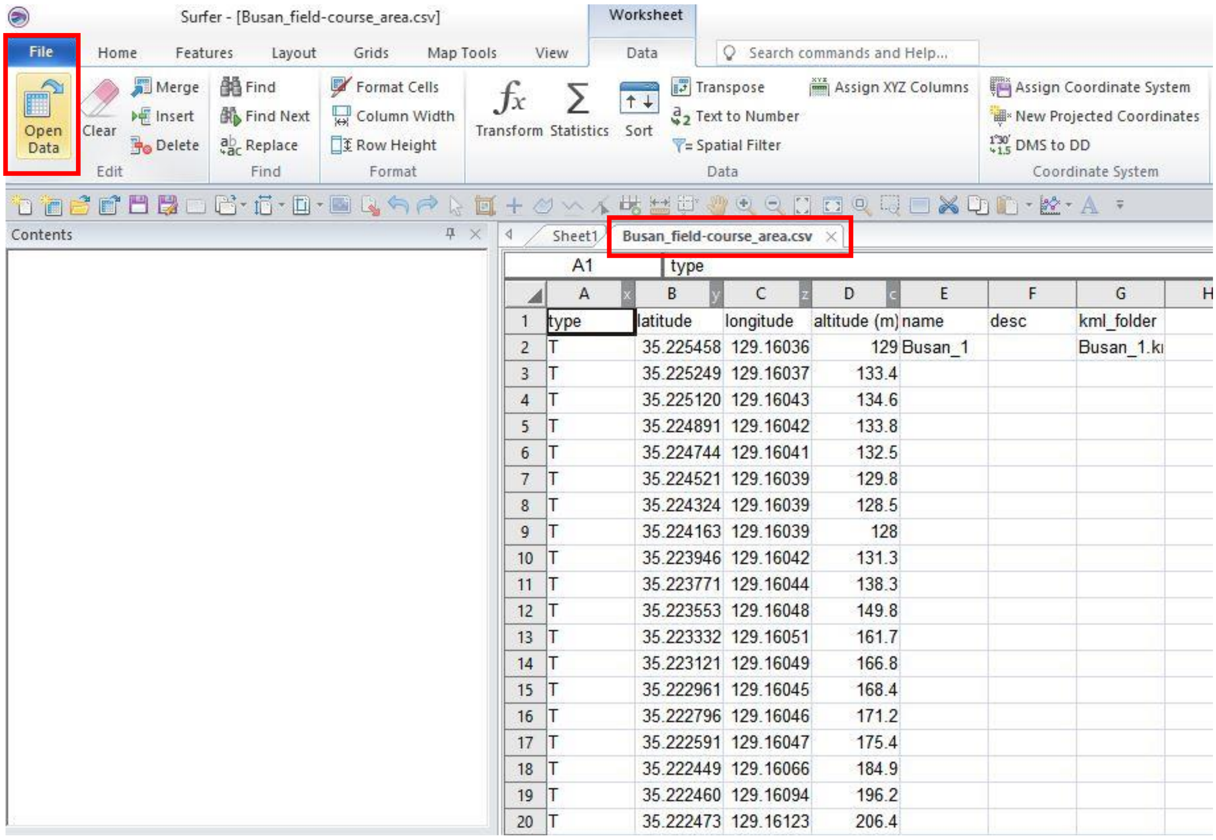


Figure 21. Worksheet page in Golden Software's Surfer™. The 'Busan_field-course_area.csv' file is opened by a left mouse click on the 'Open Data' command (marked with red colour rectangles).

4. Plotting a topographical map with Golden Software's Surfer™

The steps for plotting the topographical map of an area, in this case the Busan field training course area, are:

- Open Surfer™.
- **Grid data:** Select from the Home page commands '*Grid Data*' with a left mouse click (Fig. 22).
- **Gridding method options and data input:** The 'Grid Data' dialogue displays the 'Gridding Method' options, the 'Data Type' choices, and the '*Dataset 1*' to be used (Fig. 23).
- **Gridding method:** The preferred '*Gridding Method*' is '*Kriging*', and the selected '*XYZ*' '*Data Type*' is kept. The '*Browse*' command is used with a left mouse click and the data file '*Busan_field_course_area.xlsx*' is selected (Fig. 24).
- **Kriging parameters:** By clicking with the left mouse button '*Next*', the '*Grid Data – Kriging - Variogram's*' screen appears (Fig. 25). The coloured circle shows the experimental linear variogram surface, depicting the spatial continuity of the height (note that patterns in the NE quadrant are duplicated in the SW quadrant, and patterns in the NW quadrant are duplicated in the SE quadrant; the Distance versus Variogram graph displays the linear Kriging model ('*blue line*'); the '*red dots*' and '*red line*' represent the estimated values at different lag distances, and the red line connects the estimated values. The table on the right-hand side shows different linear kriging parameters.
- **Kriging options:** By clicking with the left mouse button '*Next*' the '*Grid Data – Kriging – Options*' screen appears (Fig. 26). Keep all the selected default parameters, and with a left mouse click on '*Next*'.

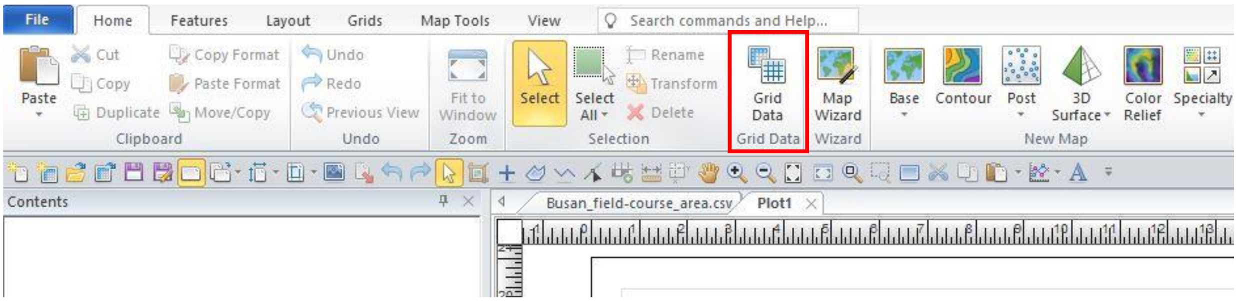


Figure 22. Surfer's Home page commands. The 'Grid Data' option (marked with a red colour rectangle) is selected by a left mouse click.

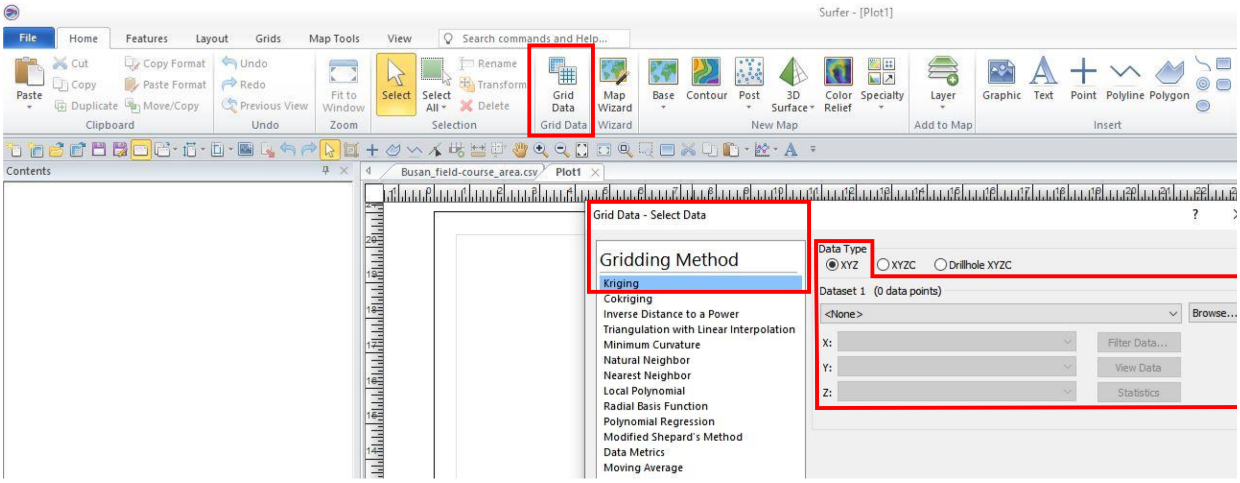


Figure 23. Surfer's 'Grid Data' drop-down window shows the 'Gridding Method', 'Data Type' and 'Dataset 1' options (marked with red rectangles).

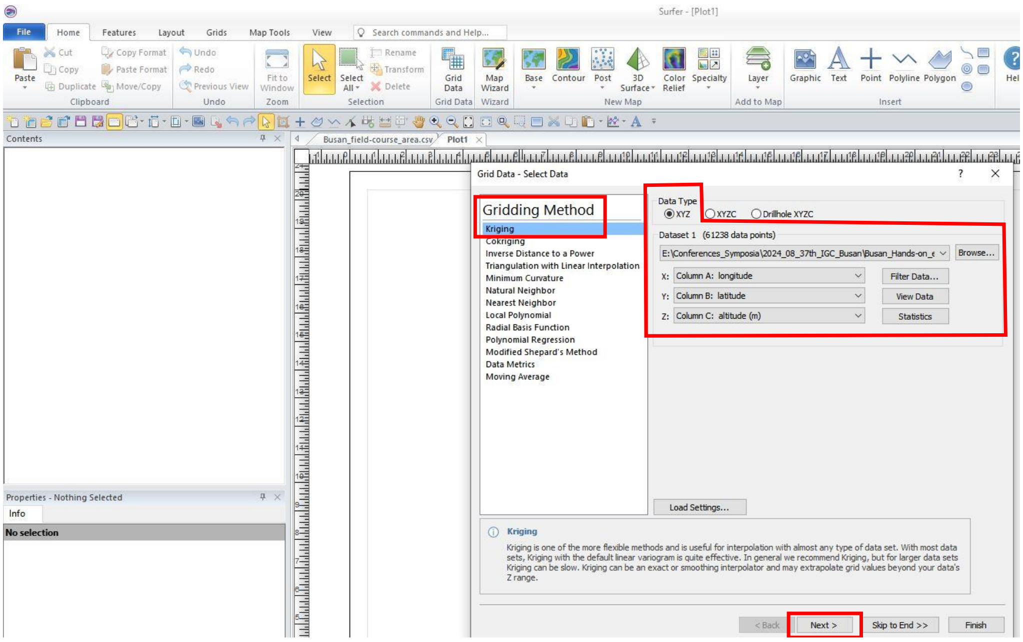


Figure 24. Surfer's 'Grid Data' drop-down window shows the final selections of the 'Gridding Method' (Kriging), and 'Data Type' (XYZ), and the imported data file where the X: Column A, Y: Column B, and Z: Column C are represented by longitude, latitude and altitude (m), respectively.

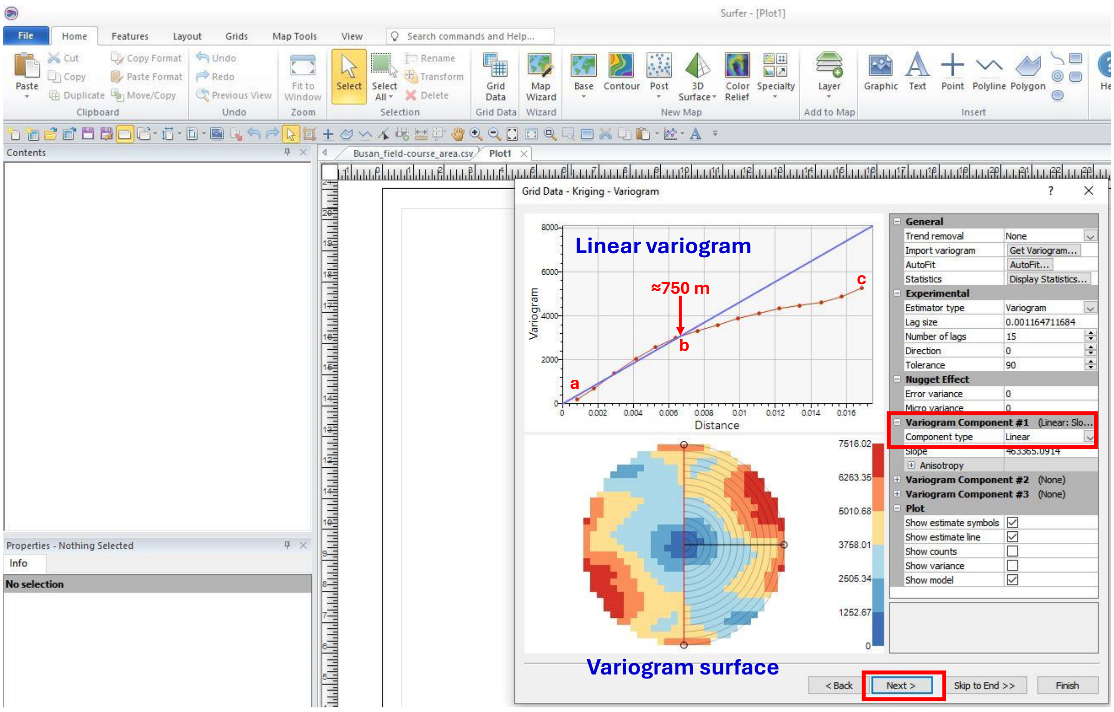


Figure 25. Surfer's 'Grid Data – Kriging – Variogram' page shows (a) the variogram surface (colour circle with legend); (b) an x-y graph of Distance versus the Variogram estimated values, and (c) a table with different parameters. The 'blue line' of the x-y graph represents the linear Kriging model; the 'red dots' and 'red line' show the estimated values at different lag distances. The red line of estimated Kriging values consists of two approximately linear segments, i.e., (i) a to b and (ii) b to c. The a-b linear section is of interest because it provides the maximum range of the search window for extrapolation, which should not exceed 0.0068 degrees (≈750 m).

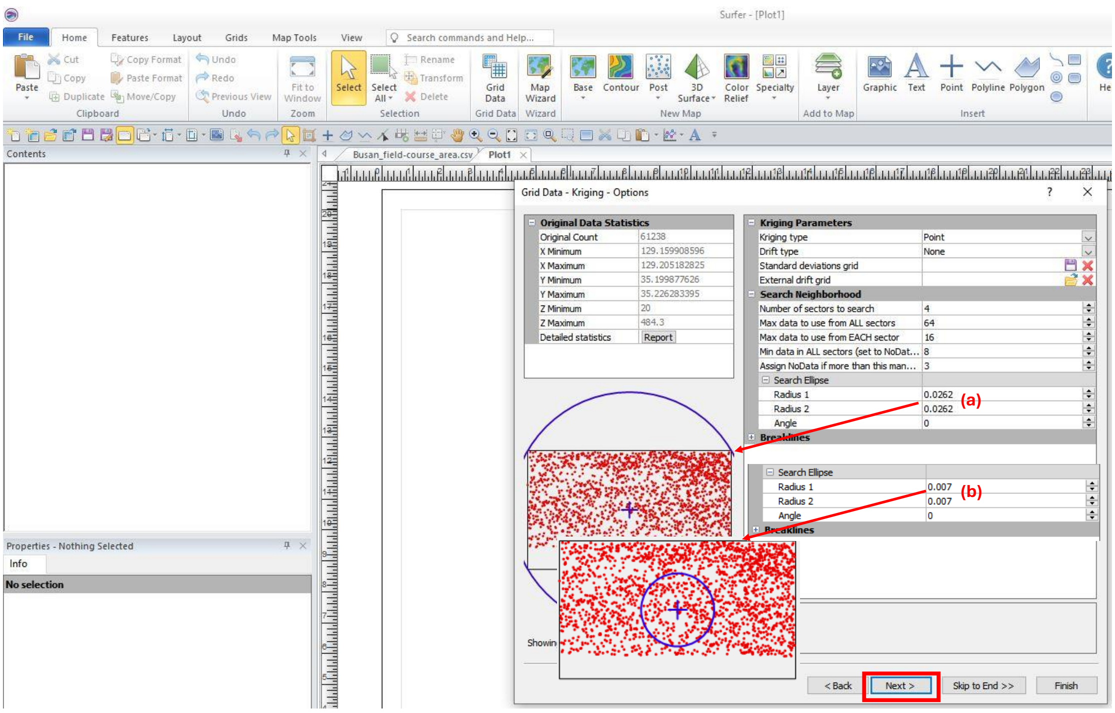


Figure 26. Surfer's 'Grid Data – Kriging – Options'. Change (a) default values of Radius 1 and 2 to (b) values extracted from the linear variogram, i.e., 0.007, and then click 'Next'.

- **Cross Validation:** The '*Grid Data – Kriging – Cross Validation*' screen appears (Fig. 27). Of interest is the Table with '*Measured*', '*Estimated*' and '*Error*' values. The '*Measured*' values represent the actual height in metres extracted for each digitised point by the GPS Visualizer. The '*Estimated*' values are the calculated results using the Kriging equations, and as can be seen, they are remarkably close to the actual measured heights, as shown in the column with the small '*Error*' values. The cross-validation graph of '*Estimated*' versus '*Measured*' values shows a perfect linear fit.
- **Results output:** By clicking with the left mouse button '*Next*' (Fig. 27) the '*Grid Data – Kriging – Output*' screen appears (Fig. 28). The '*X and Y Direction*' boxes show the minimum and maximum coordinates of the study area, the spacing of estimated values, and the *'# of Nodes*' of the X and Y directions, 100 and 59 nodes, respectively. As a detailed topographical map is required the number of nodes is doubled in both directions, *i.e.*, 200 and 118, respectively. Click '*Finish*' with the left mouse button, and the contour line map appears (Fig. 29).

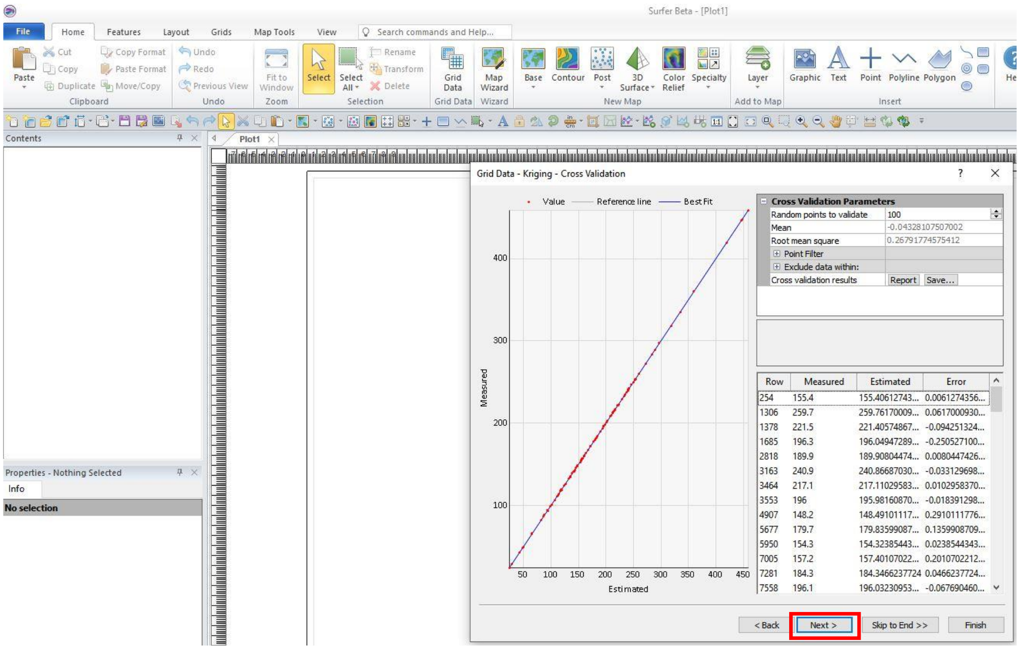


Figure 27. Surfer's 'Grid Data – Kriging – Cross Validation' shows a perfect linear correlation between the Estimated and Measured values.

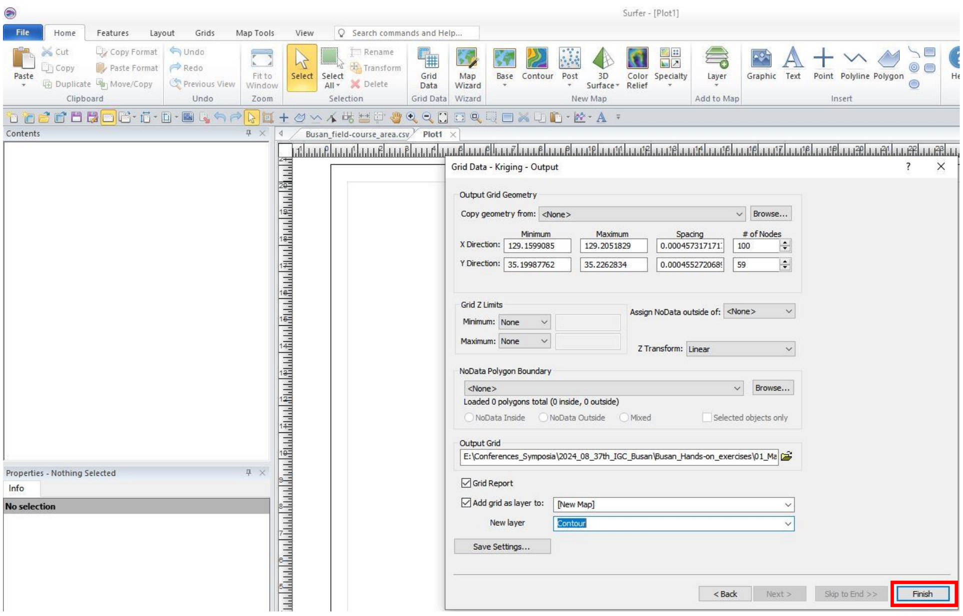


Figure 28. Surfer's 'Grid Data – Kriging – Output' Options page.

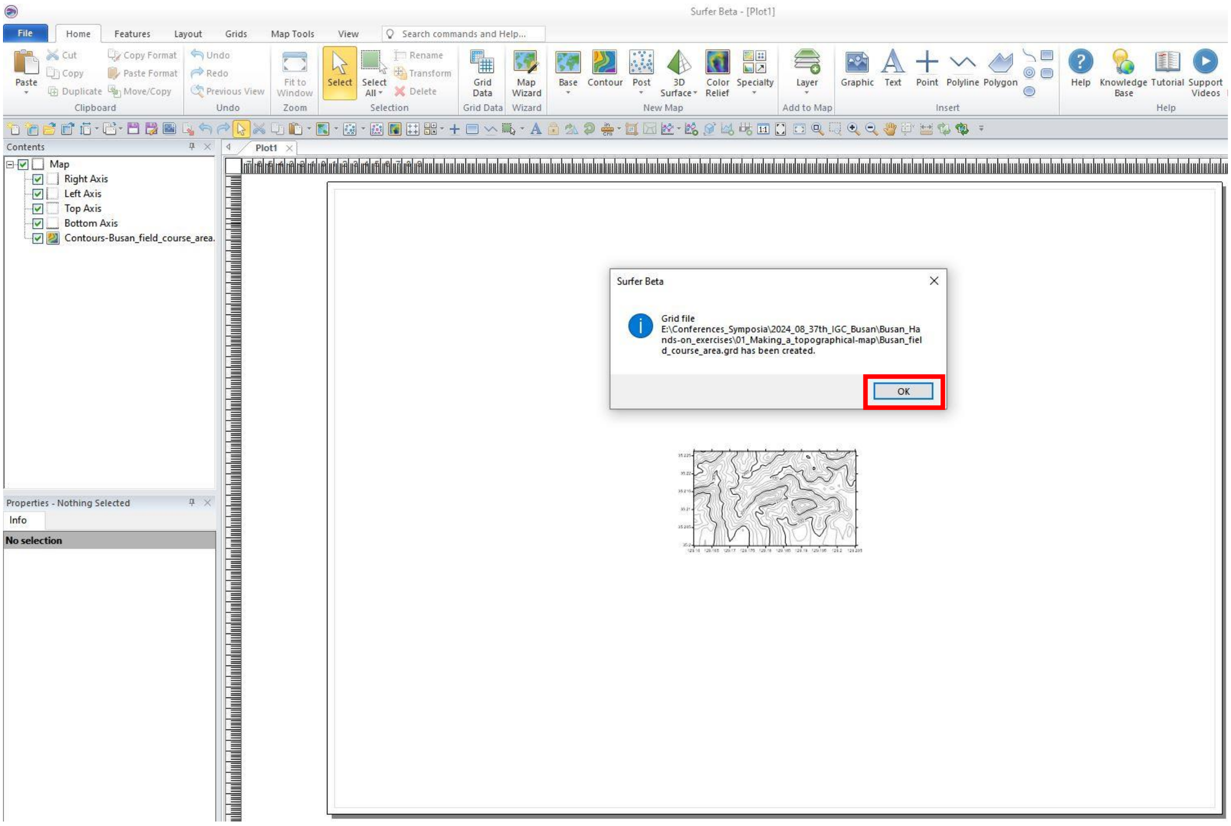


Figure 29. The contoured map is displayed. Click 'OK' to complete the procedure.

- **Assign coordinate system:** Select the '*Contours-Busan_field_course_area.grd*' file, and in the '*Properties*' window, select the '*Coordinate System*' option (Fig. 30). Click with the left mouse button '*Set*' and The '*Assign Coordinate System*' window appears, and the '*Geographic (lat/lon)*' option is selected. Scroll down the different systems until the '*World Geodetic System 1984*' is reached, and after selecting it, click '*OK*' with the left mouse button (Fig. 31). Repeat the procedure and assign the WGS1984 coordinates to the Map.
- **Change the map scale:** Presently the map is displayed on a page of A1 size (84.1 x 59.4 cm) in a landscape mode. Change the default value of length at 15.24 cm (Fig. 32) to 70 cm (Fig. 33), and the map covers almost the whole A1 size page.
  Note for units: Depending on the user's system locale, the plot document may be displayed in inches; the units can be changed by clicking '**Layout | Display | Units | Centimeters**' command to change the units from inches to centimetres.
  Note for paper size: The A1 size page may not be the user's default page size. If it is not, it can be changed by clicking on '**Layout | Page Setup | Size**' command.

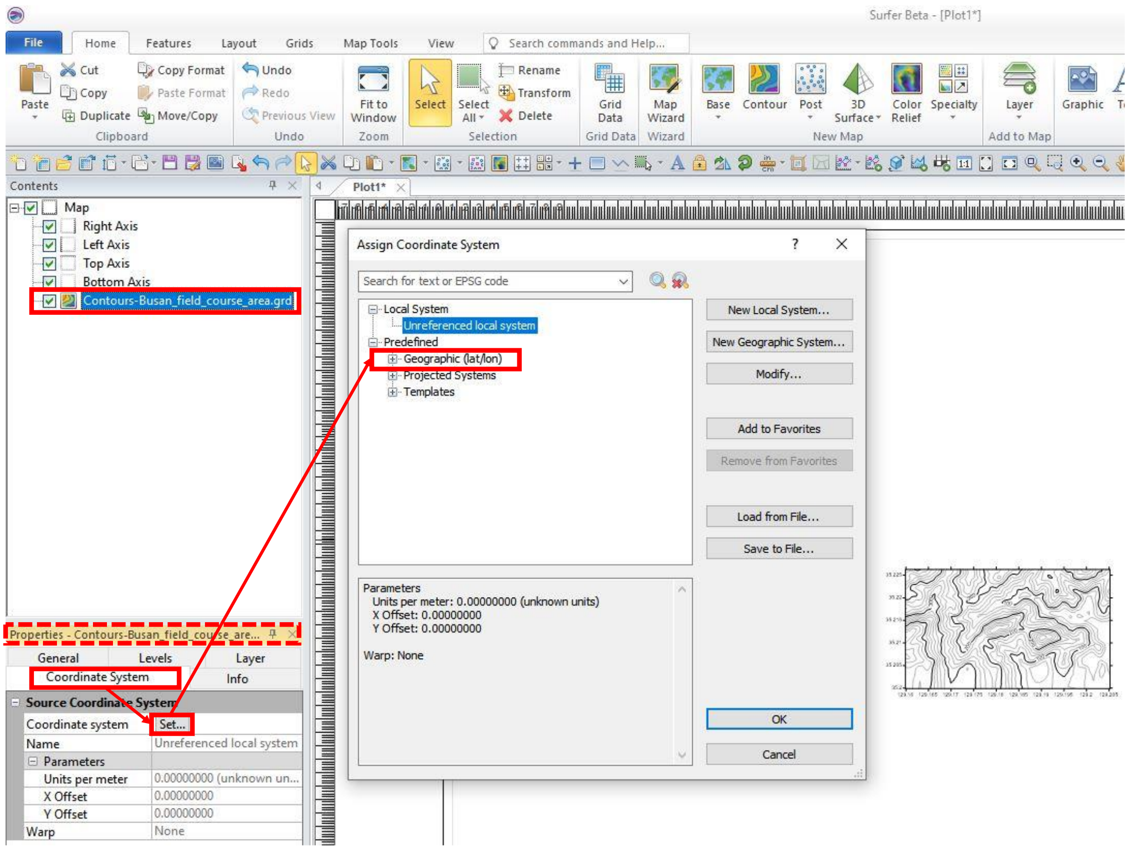


*Figure 30. Defining map coordinates by choosing first the *.grd file, and by selecting in the Properties window the option 'Coordinate System' the 'Assign Coordinate System' window appears, and 'Geographic (lat/lon)' is selected.*

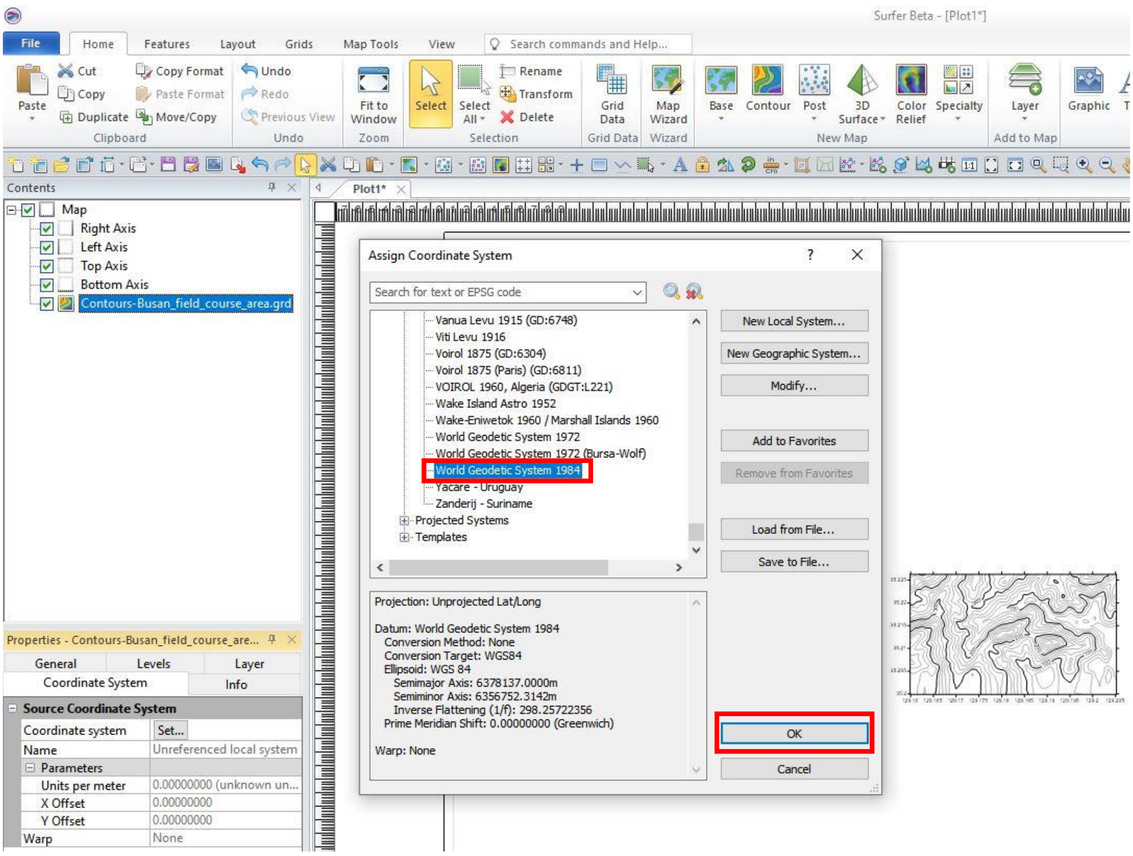


Figure 31. Assign the 'World Geodetic System 1984' coordinate system to the map, and click 'OK' with a left mouse click.

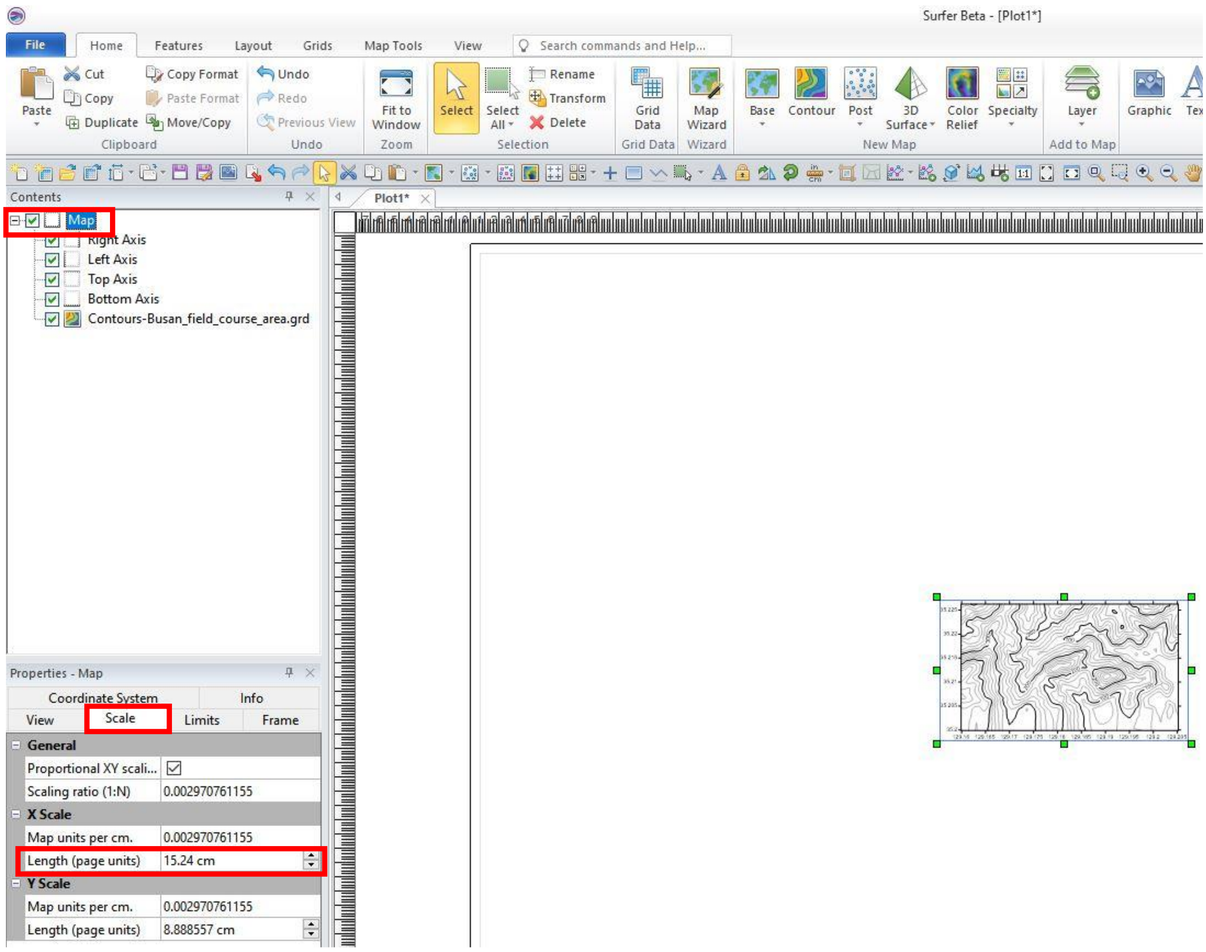


Figure 32. Select 'Map' and in the 'Properties – Map' window, choose 'Scale' and change the Length of the X scale from 15.24 cm to 70 cm.

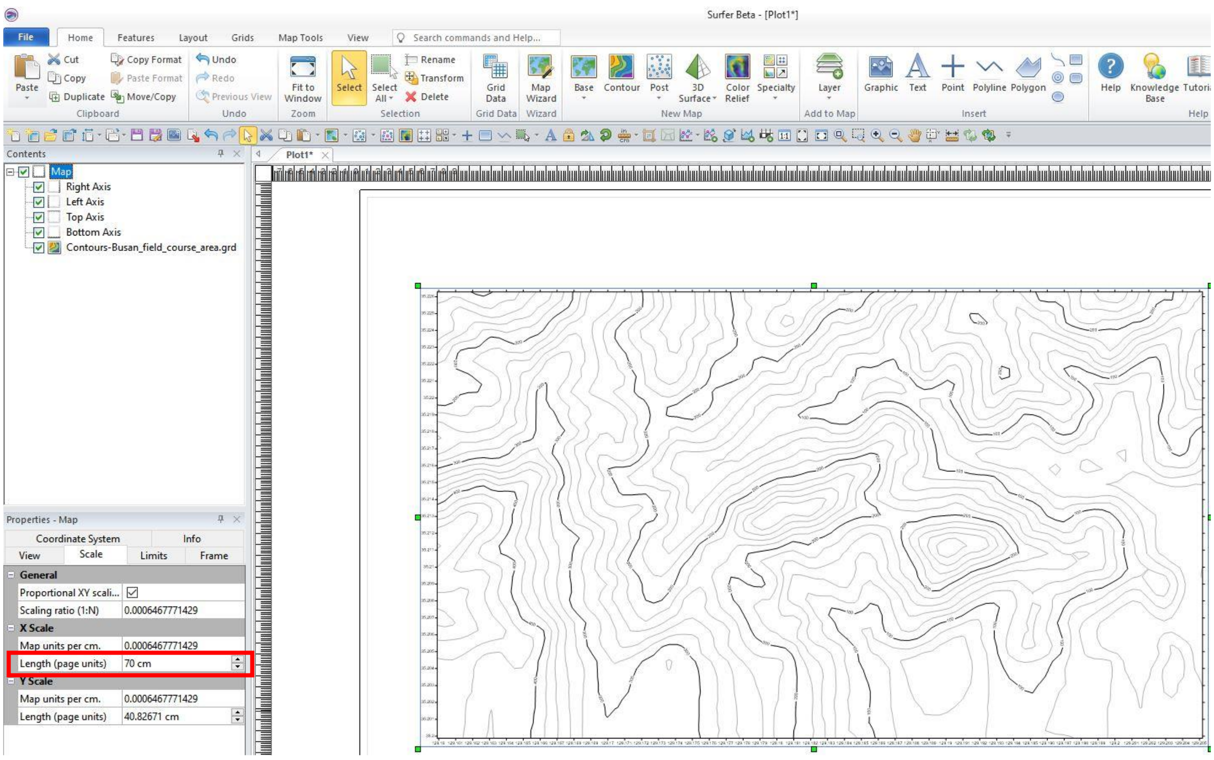


Figure 33. New map scale with X-Scale length at 70 cm.

- **Change the Filled Contours colours of the map:** In the '*Contents*' side window, select the grid file (*.grd), *i.e.*, '*Contours-Busan_field_course_area.grd*'. In the '*Properties*' window at the bottom, select '*Levels*' and go to '*Filled Contours | Fill colors*'. Scroll down the list of colours until you find the '*Yellow-Brown*' palette. Select it with a left mouse click, and at once, the filled contour map colours are changed (Fig. 34). Of course, you can use any other palette. In my opinion, this particular palette is the most appropriate for a contoured topographical map.
- **Fit to Window:** To see the map in full screen within the limits of the software and your computer's screen, select '*View*' from the main menu and click the '*Fit to Window*' command with the left mouse button (Fig. 35).
- **Changing map properties:**
  - Select in '*Map*' the grid file '*Contours-Busan_field-course_area.grd*' and in '*Properties*' choose '*General*' (Fig. 36a), and in '*Smoothing*' tick with a left mouse click 'v' (the dropdown option) and select '*Medium*' (you will observe that the contours are smoothed).
  - Select '*Levels*' and carry out the following changes (Fig. 36b): (i) under '*General*' keep the '*Levelling Method*' Simple; '*Minimum Contour*' & '*Maximum Contour*' 0 & 500 m, respectively; (ii) tick the '*Color scale*' box with a left mouse click, and it directly appears on the right side of the map; (iii) the colour and thickness of the lines of '*Major Contours*' is changed to Brown and the '*Width*' to 0.08 cm; (iv) the colour and thickness of the lines of '*Minor Contours*' is changed to 30% Black & the '*Width*' to 0.05 cm, and (v) The '*Labels | Font properties*' is changed to 14 points.
- **Changing Colour Scale properties:** First select '*Color Scale*' (Fig. 37) and under '*General Properties*' make the following changes (i) the '*Width*' to 1 cm and the '*Height*' to 20 cm (Fig. 37a); (ii) enter the '*Title text*' – "Contours above m.s.l." (mean sea level) and '*Position*' it on '*Top*' of the legend (Fig. 37b), and (iii) going to the '*Labels*' option change the font size to 20 points (Fig. 37c). <u>Question</u>: Is the Colour Scale Title text "*Contours above m.s.l. correct*?"
- **Additional topographical map features:** The Google Earth '*Add Path*' tool can be used to digitise other map features, *for example*, the mainstream/tributaries, reservoir, irrigation ponds, and roads (Fig. 38). Each feature digitised in Google Earth is saved in a *.kml file format, which Surfer™ supports. These features are strongly recommended to be digitised on a large-scale Google Earth image.
- **Importing *.kml files of topographical and other features to Surfer™:** When importing the *.kml files in Surfer™ using the '*Base*' command, two different warning windows appear consecutively (Fig. 39), which are ignored since we do not want to '*adjust the map limits*'. Hence, in both cases, '*OK*' is clicked with the left mouse button, and the four *.kml files of the mainstream and tributaries are, in turn, inserted in Surfer™ (Fig. 40).
- **Transferring the imported *.kml files into the main contoured map:** When transferring the *.kml files into Surfer™, a small window appears with the warning that the imported base file exceeds the current map limits (Fig. 41). This warning is ignored, and with the left mouse button '*No*' is clicked, and directly the '*Mainstream*' is inserted over the contoured topographical map.
  <u>Note for importing KML or base files</u>: As you become more proficient, you can save a few clicks by importing the KML or base files directly into the main contour map by using the 'Map Tools | Add to Map | Base' command and selecting the KML or base file.
- **Changing the properties of the imported *.kml base files:** The Main Stream's *.kml file is selected first, and in the '*Properties*' window, select '*General*' and change the colour of the line from *black* to *blue* and the width of the '*Mainstream*' to 0.1 cm (Fig. 42). In turn, the '*Tributary*' *.kml files are selected and the line colour is changed from *black* to *blue*, and width to 0.08 cm.
- **Correction and addition of topographical features in Surfer™:** Digitisation of streams on the Google Earth image in forested areas is not easy, and it was expected that the drainage might need modification and additions when the detailed topography was plotted. Figure 43 shows that sections a, b and c should be modified, and new streams digitised in areas d, e, f, g and h.
- **Reshaping Main stream in Surfer™:** Select the polygon within the base layer first, and then Select the polyline of the '*Main Stream.kml*' and click the '*Features*' & '*Reshape*' command, and

all the digitised points appear (Fig. 44). For carrying precisely this procedure it is strongly recommended that the '*Zoom Rectangle*' is used, which can be accessed from the '*View | Rectangle*' command or from the '*Quick Access Toolbar*', if it has been transferred there, or the other option is to use the keyboard command '*CTRL+R*' to enter the zoom rectangle mode (see enlarged inset of section (a) in Fig. 44). Proceed by selecting the points that need changing with a left mouse click; the colour of each selected point changes to green, and it can be moved with the left mouse button. When reshaping the polyline of the '*Main Stream*', it can be seen that it extends outside the map limits (Fig. 44d) and justifies the warning that was earlier ignored (Fig. 39). These points that are outside the map limits can be deleted by selecting the endpoint with a left mouse click and pressing the keyboard '*Delete*' button until all outside points are deleted. Press the '*Enter & Esc*' keyboard buttons to return to normal view.

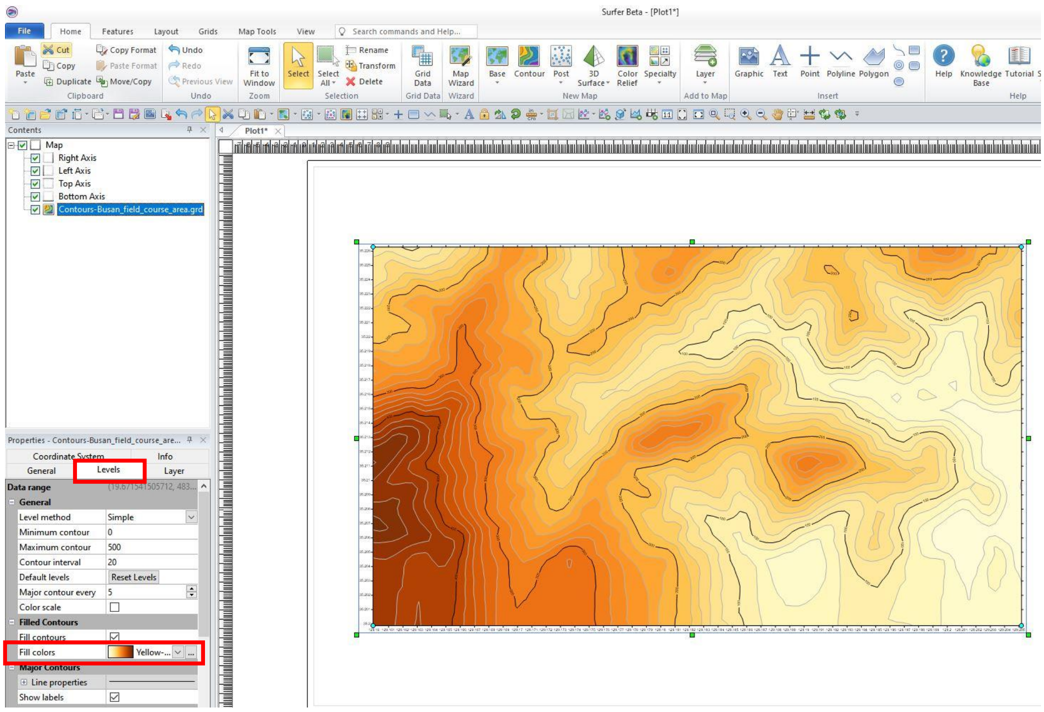


Figure 34. Changing the colour scheme of the filled contours by selecting 'Levels' and scrolling down the 'Fill colors' palettes until 'Yellow-Brown' is reached, and with a left mouse click is selected; the map is directly coloured with shades from pale yellow (low relief) to dark brown (high relief).

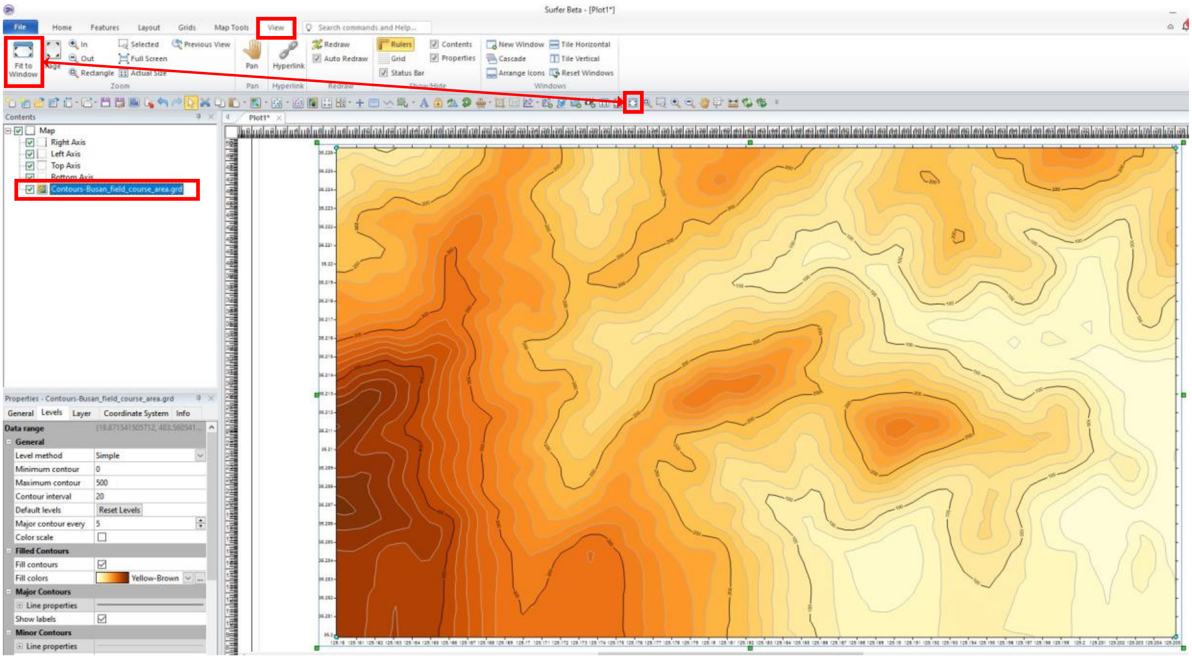


Figure 35. Use the 'Fit to Window' command under the 'View' page options. The 'Fit to Window' command or the smaller option in the 'Quick Access Toolbar' can be used.

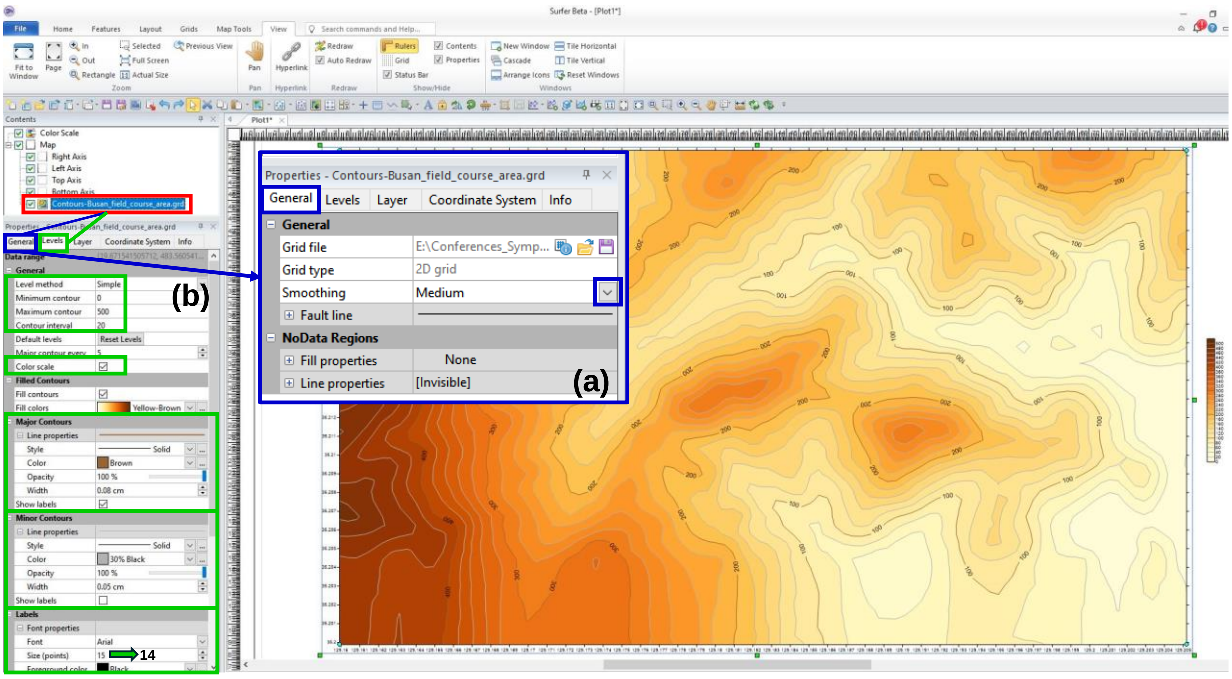


Figure 36. Changing map properties by selecting 'Contours-Busan_field-course_area.grd' (marked with a red rectangle): (a) under 'General Properties' select 'Medium' 'Smoothing' of contour lines, and (b) under 'Levels', make all indicated changes as described in the text.

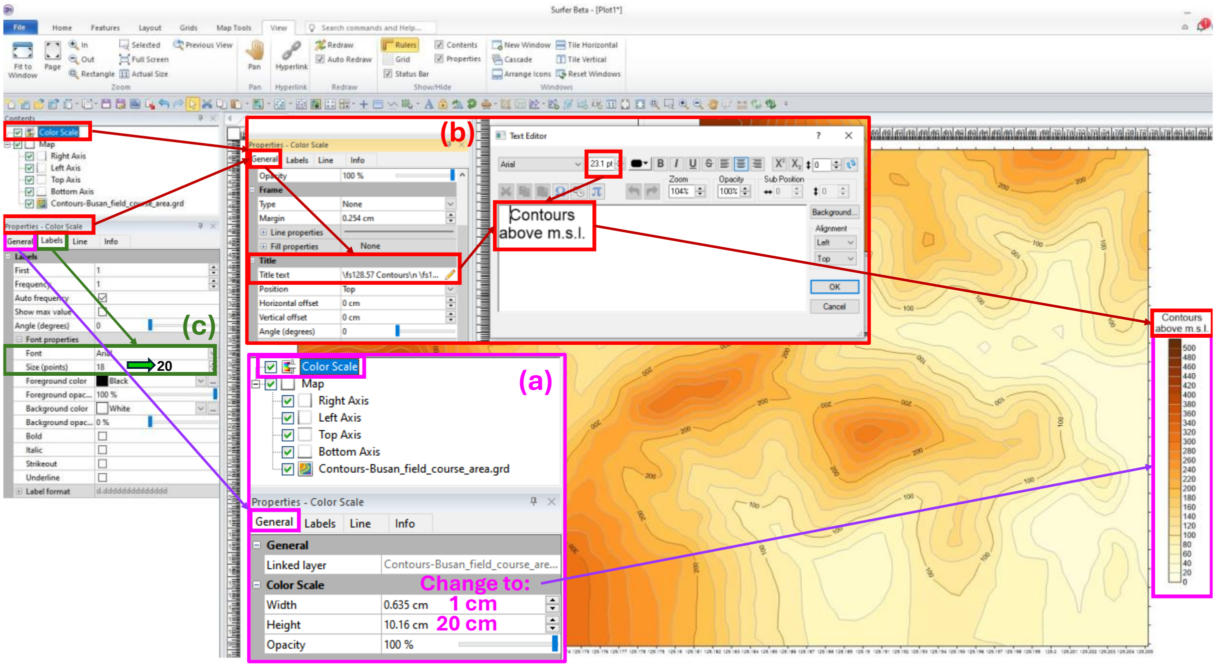


Figure 37. Changing the properties of the Colour Scale (the different commands/options are marked with different colour rectangles and arrows): (a) Inset shows the default value changes to the width (1 cm) and height (20 cm); (b) Inset displays the entry of the Legend title 'Contours above m.s.l.' (mean sea level) and (c) the Font size from 12 (default size) to 20 points.

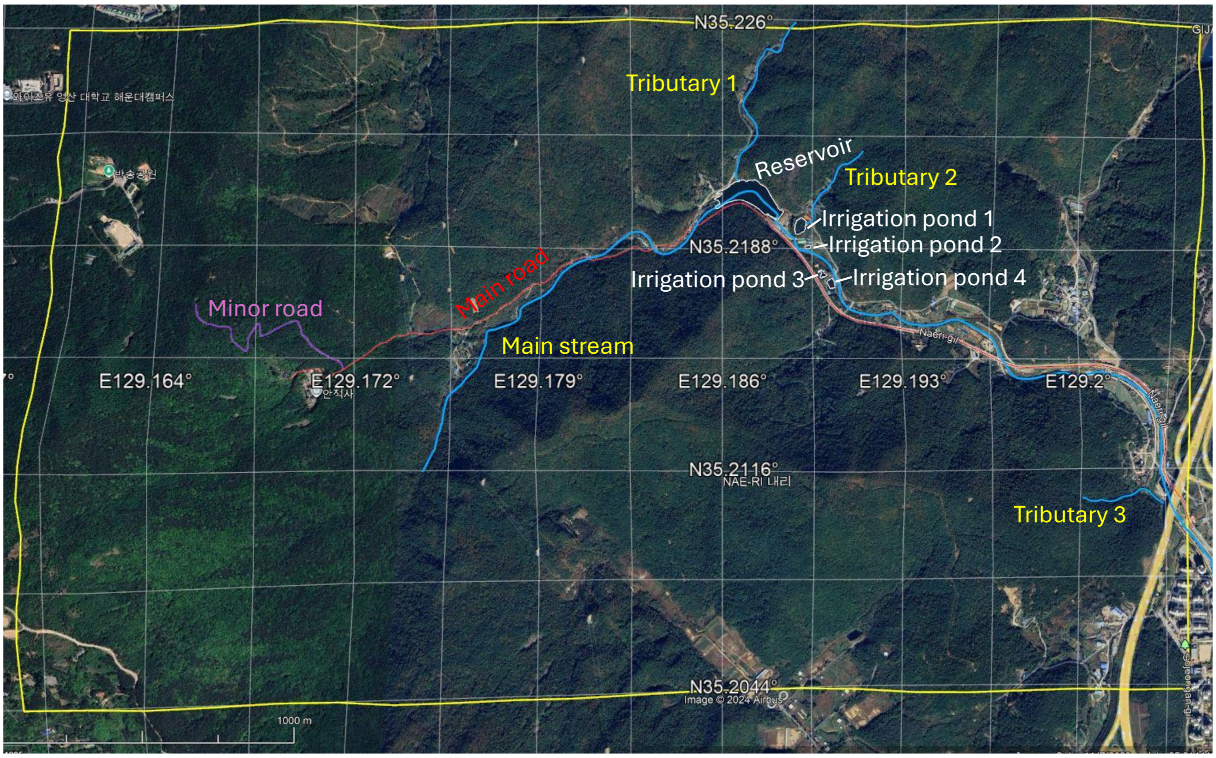


Figure 38. Features digitised in Google Earth using the 'Add path' tool.

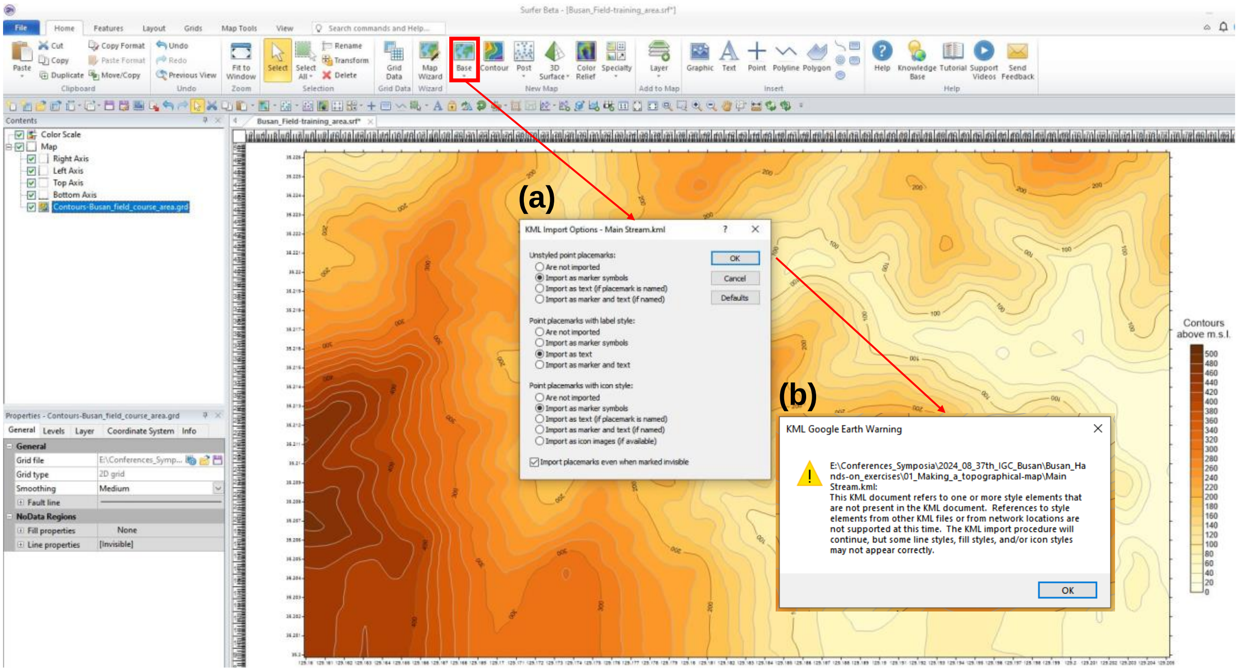


*Figure 39. By using the 'Base' command (marked with a red rectangle), the different *.kml files are inserted, and the following two small windows appear (a) 'KML Import Options -', and (b) 'KML Google Earth Warning'. In both cases, 'OK' is clicked with the left mouse button, and the *.kml file is imported (see Fig. 40).*

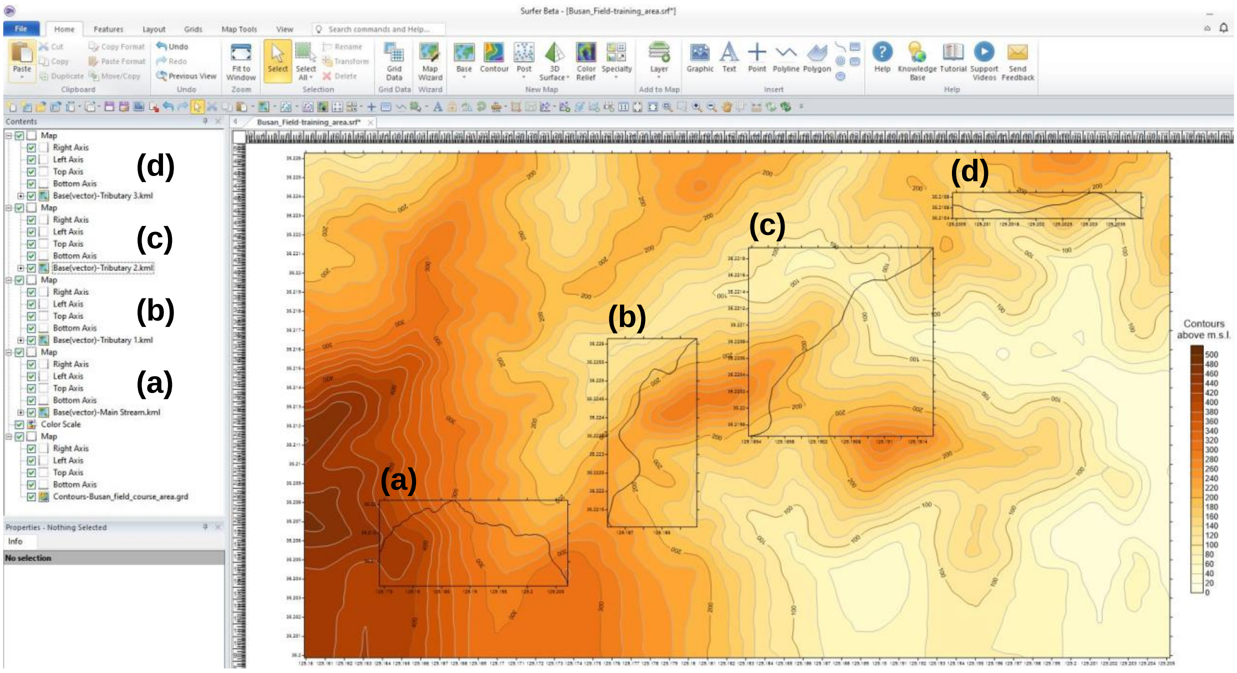


*Figure 40. Four *.kml files are imported using the 'Base' command. On the left-hand side in the 'Contents' window, the names of each map file can be seen (a to d), and their linear features are superimposed on the coloured topographical map.*

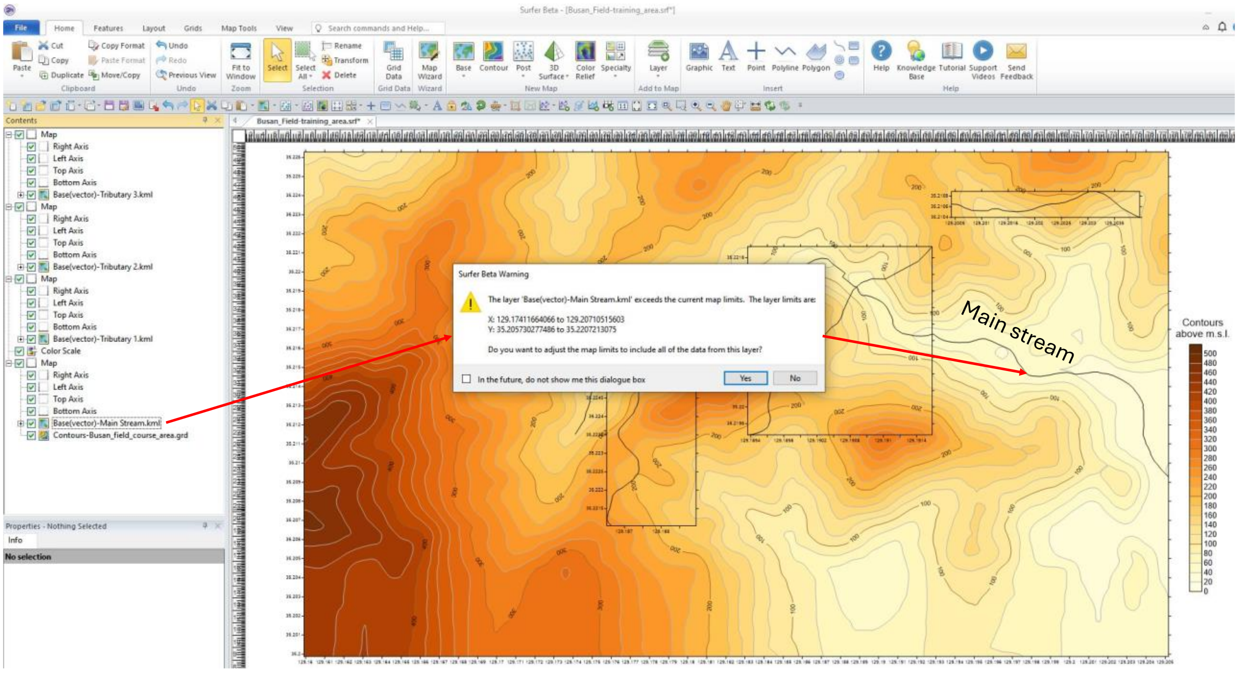


*Figure 41. When moving each *.kml file into the main map composition, a warning appears, which is ignored by clicking the 'No' button with the left mouse because the map limits should not be changed.*

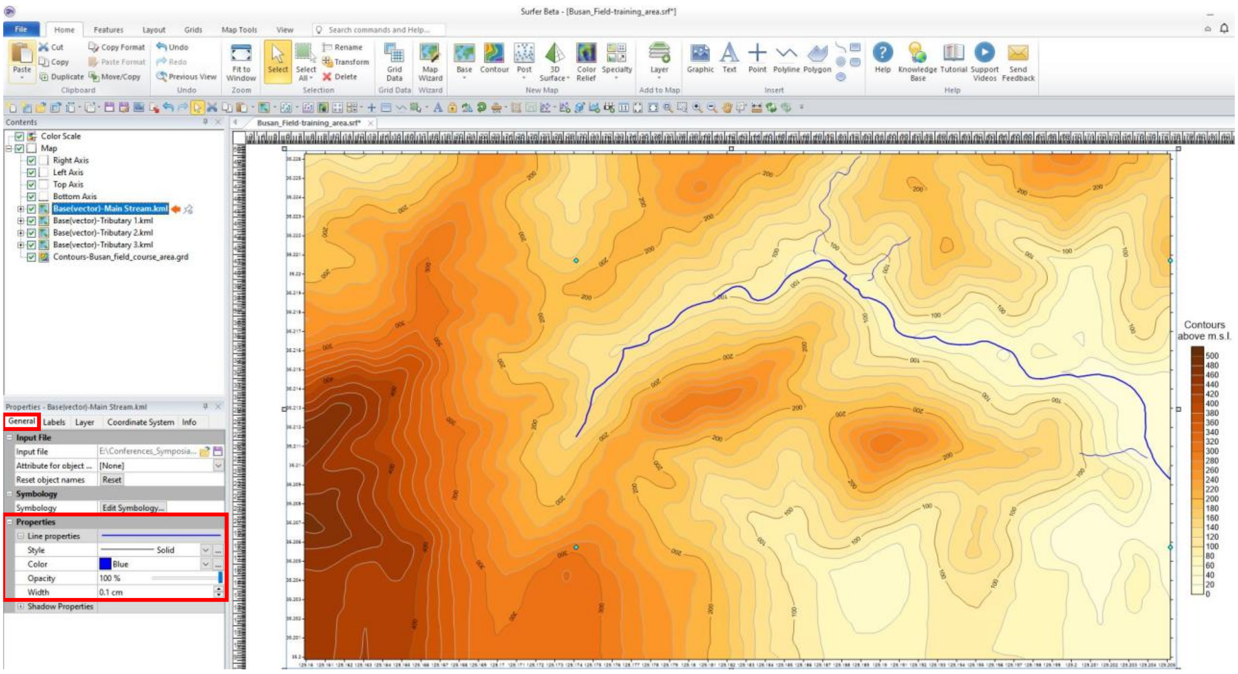


Figure 42. The colour of the four streams is changed from black to blue for better visibility and to represent water bodies. This is done by selecting each stream in turn and using the 'General Properties' option. The width of the streams is changed to 0.1 cm and 0.08 cm for the Main Stream and the three Tributaries, respectively, to depict their size and importance accurately.

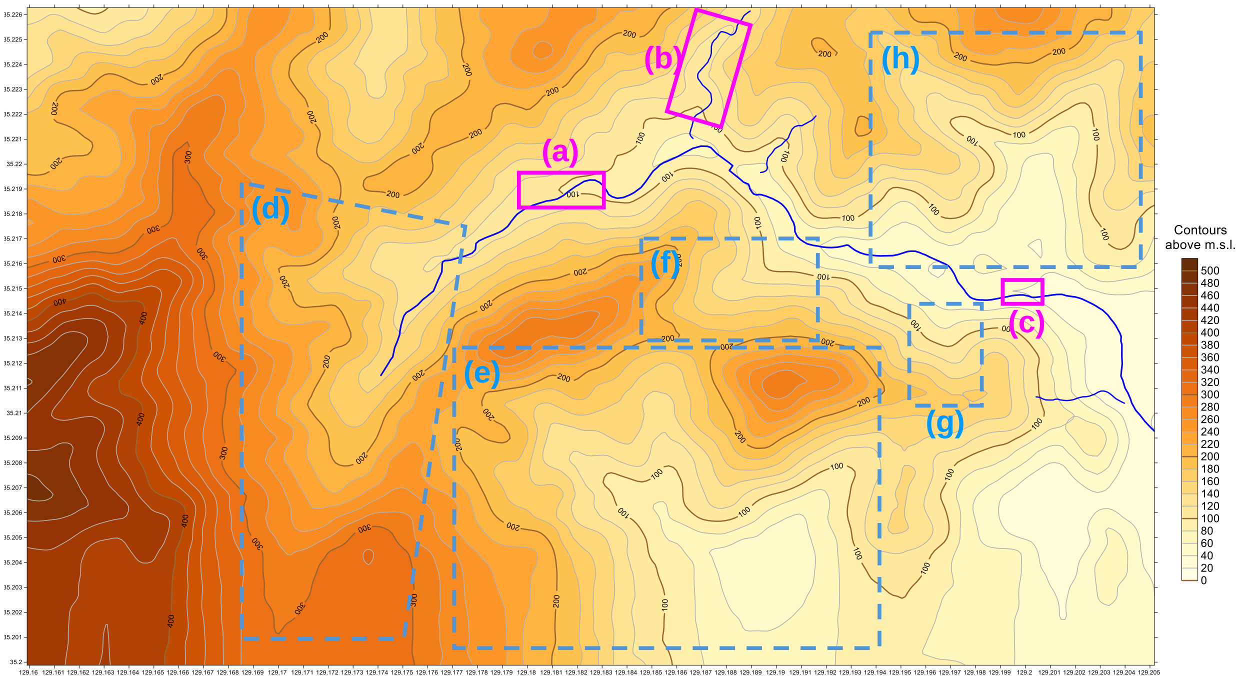


*Figure 43. The imported *.kml files of the streams digitised in Google Earth need reshaping to fit the plotted contour lines (i.e., a, b, c). The areas marked with pale blue dashed lines (d, e, f, g) show missing streams, which should be digitised in Surfer™.*

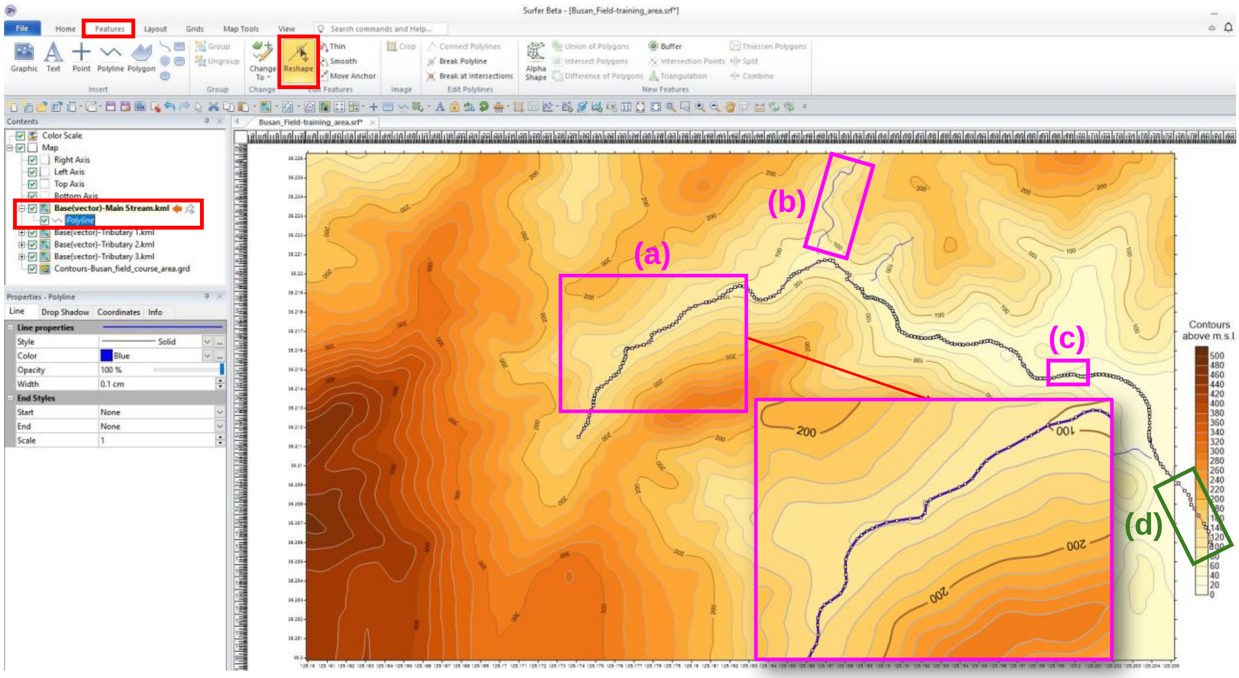


*Figure 44. Reshaping the imported *.kml shapes of the streams that were digitised in Google Earth. The inset shows the enlarged segment of the stream (a) that aids the reshaping of the line according to the contour lines; (c) is another section that has been reshaped; (b) was subsequently reshaped; (d) shows the points of the Main stream that are outside the map limits and are deleted.*

- **Digitisation of new streams in Surfer™:** The new streams in areas d, e, f, g and h (Fig. 43) can be digitised with the command '*Digitize*', which is in '*Map Tools*' or on the '*Quick Access Toolbar*' if it has been transferred there (Fig. 45). The procedure for digitising features in Surfer™ is as follows:
  - Select '*Map*'.

– Rectangle (‘*View* | *Rectangle*’) command to focus on the part of the map where the feature to be digitised is located (in this case, the stream within the rectangle (f) in Figure 43).
– To guide the digitisation process of a linear feature such as that of a stream, it is recommended to draw a line by using the command ‘*Home* | *Polyline*’ (Fig. 46i) or click on its image if it has been transferred on the ‘*Quick Access Toolbar’*; the drawn polyline is shown in Figure 46(ii) in cyan colour so that the digitised red crosses to be visible.
– Using the ‘*Digitize*’ command and with successive left mouse button clicks on the polyline, the course of the stream is digitised and is displayed in Figure 46(iii), *i.e.*, the points on the polyline are marked with small red crosses (+), and the list of digitised points is tabulated in Figure 46(iv), where the x, y, z coordinates of each point can be seen, and
– The digitised coordinates of each point are saved in Golden Software’s *.bln file format as ‘*Stream_1.bln*’; the same procedure is used for digitising the other streams.
– All digitised streams and roads are inserted in the map composition using the ‘*Base*’ command.
Note for importing base files: As you become more proficient, you can save a few clicks by importing the base files directly into the main contour map by using the ‘**Map Tools | Add to Map | Base**’ command and selecting the base file.
– The road's name, ‘Naeri gil,’ is written using Surfer™’s ‘*Text Editor*’ (‘*Home* | *Text*’; Fig. 47).

- **Insertion of the *.kml files of reservoir and irrigation ponds in Surfer™:** Using the ‘*Base*’ command the water ‘*Reservoir.kml*’ is imported in Surfer™, and a small window appears with the ‘*KML Import Options*’ ticked; it is essential to change in the second group (called ‘*Point placements with label style’*) the selection ‘*Import as text*’ to ‘*Import as marker symbols*’ (in fact, in the three groups of options the same option ‘*Import as marker symbols*’ should be selected – Fig. 48a), click ‘*OK*’ with left mouse button, and a second small window appears with a ‘*KML Google Earth Warning*’ (Fig. 48b), which is ignored, and again ‘*OK*’ is clicked, and the outline of the reservoir is inserted over the map composition. The ‘*Base(vector)-Reservoir.kml*’ layer is a polyline, which must be changed to ‘*Polygon*’ to fill the shape with blue colour; select with a mouse right button click the polyline (Fig. 48c) of the ‘*Reservoir.kml’* and the window with different commands appears, select ‘*Change to*’ and in the emerging smaller command window ‘*Polygon*’ is chosen (Fig. 48d).
- The next action is to colour blue the water reservoir by selecting with a left mouse click the ‘*Polygon*’, and in the ‘*Properties – Polygon*’ window, select ‘*Fill*’ properties (Fig. 49); in the option ‘*Foreground color*’ click with the left mouse button the option ‘v’ and select ‘*Blue*’ from the colour palette, and the reservoir polygon is coloured blue.
- Figure 50 shows the first version of the almost final map composition and the corrected ‘*Color Scale title*’: *Contours in metres above m.s.l.* (Contours in metres above mean sea level).

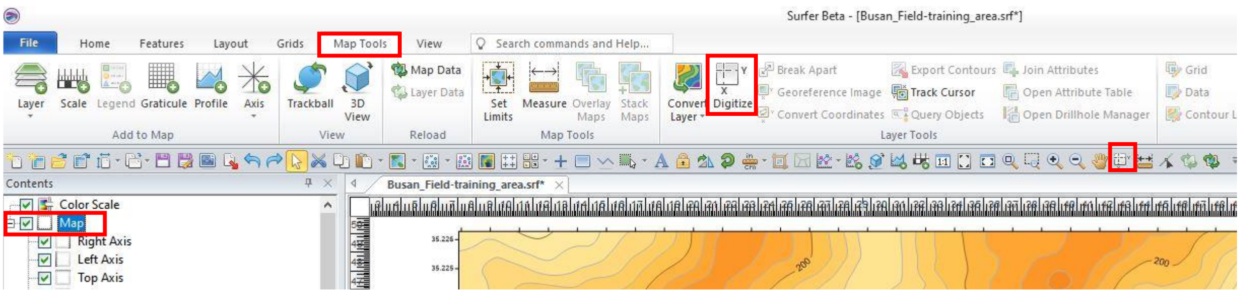


Figure 45. Digitise command in Map Tools and Quick Access Toolbar.

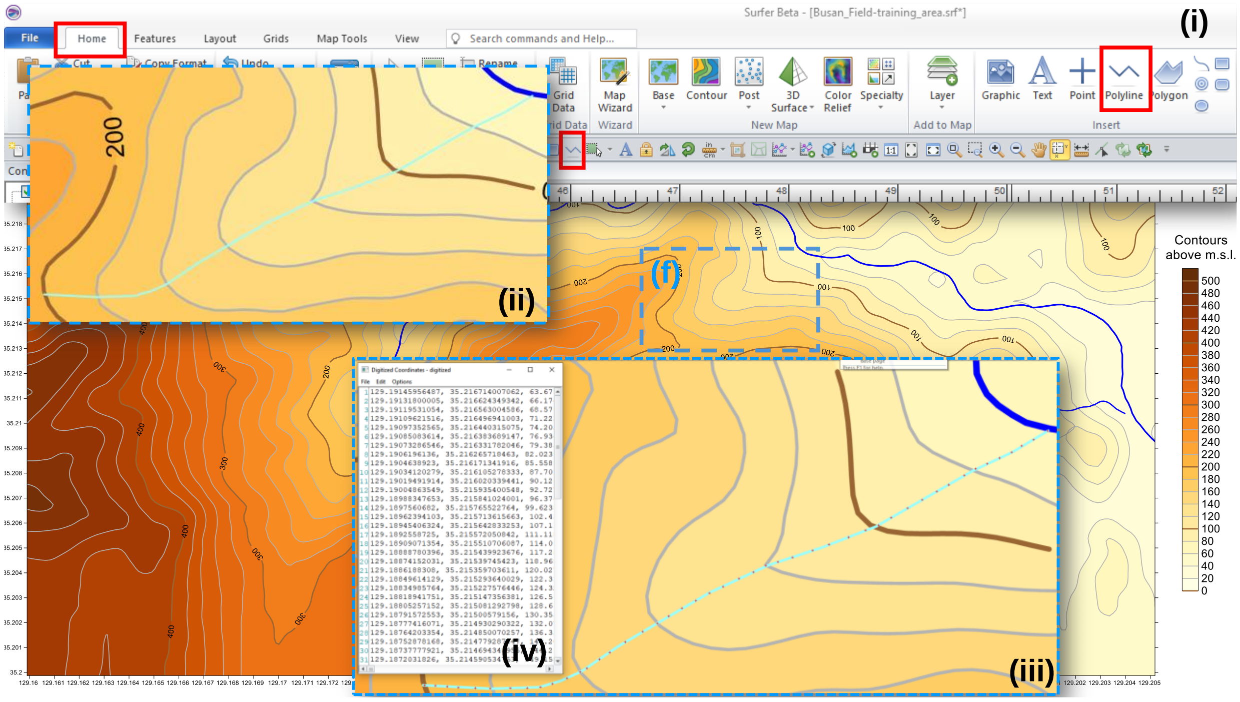


Figure 46. To digitise the stream as shown by the contour lines in (f) a polyline is first drawn by selecting (i) the 'Polyline' command and is displayed on inset (ii); afterwards is digitised using the 'Digitize' command (see Fig. 45) as shown in (iii) with the digitised points represented by small red crosses (+); the x-y-z coordinates of each point are tabulated in (iv).

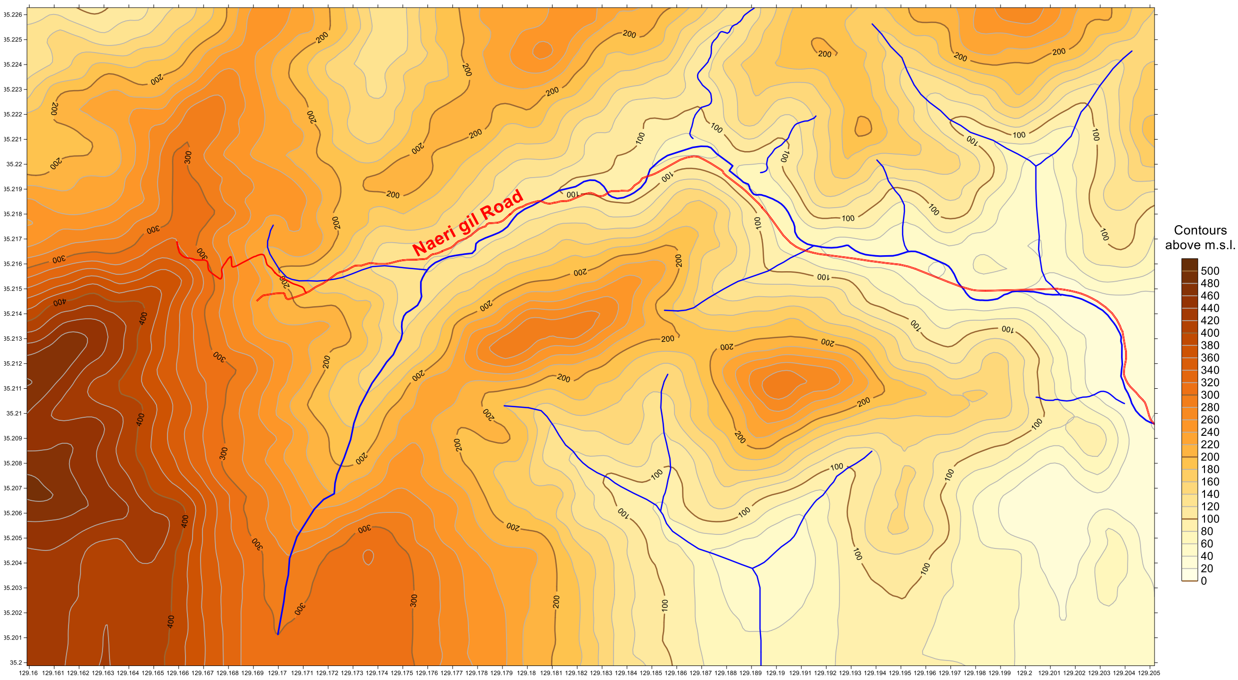


Figure 47. Map composition with the hitherto digitised features (see text for description).

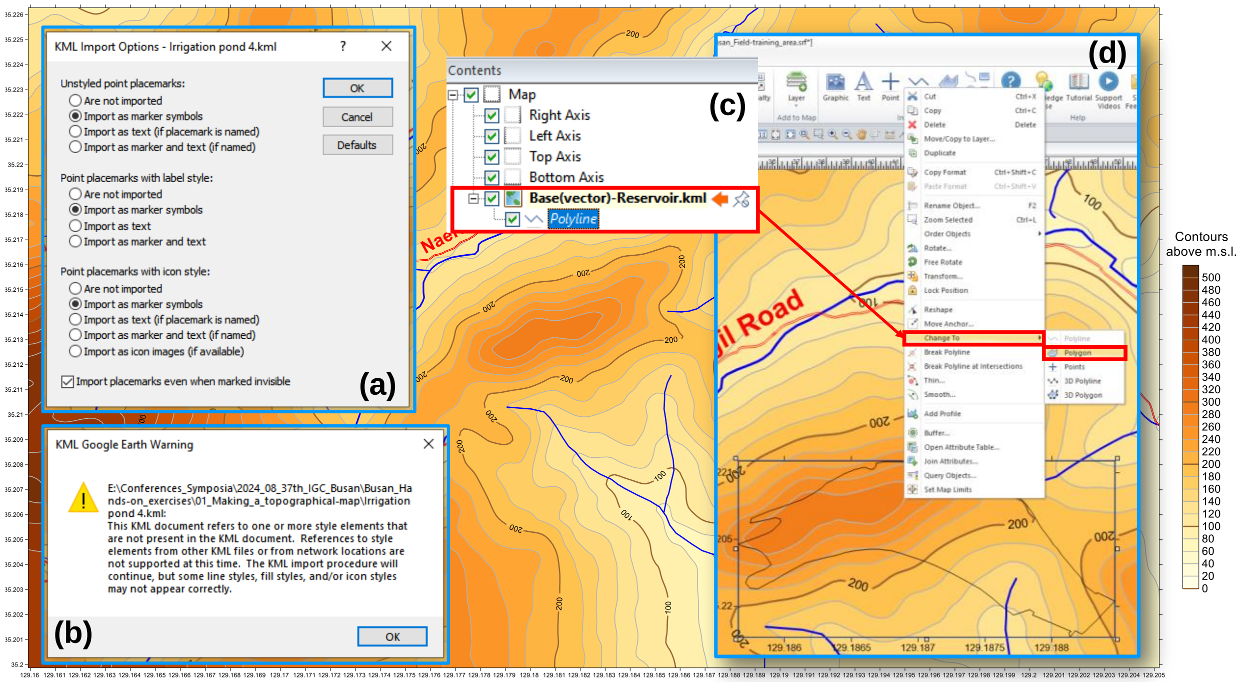


Figure 48. Insertion of reservoir in the map composition by clicking on the 'Base' command with a left mouse click, and selecting the 'Reservoir.kml' file. The first warning screen (a) refers to the 'KML Import Options', which, in all three groups, the 'Import as marker symbols' should be selected with a left mouse button click; (b) the second warning screen is accepted with a left mouse button click; (c) the 'Polyline' is selected, and with a right mouse click the long screen in (d) appears, and the option 'Change to' is selected, a small screen appears, and 'Polygon' is clicked with the left mouse button.

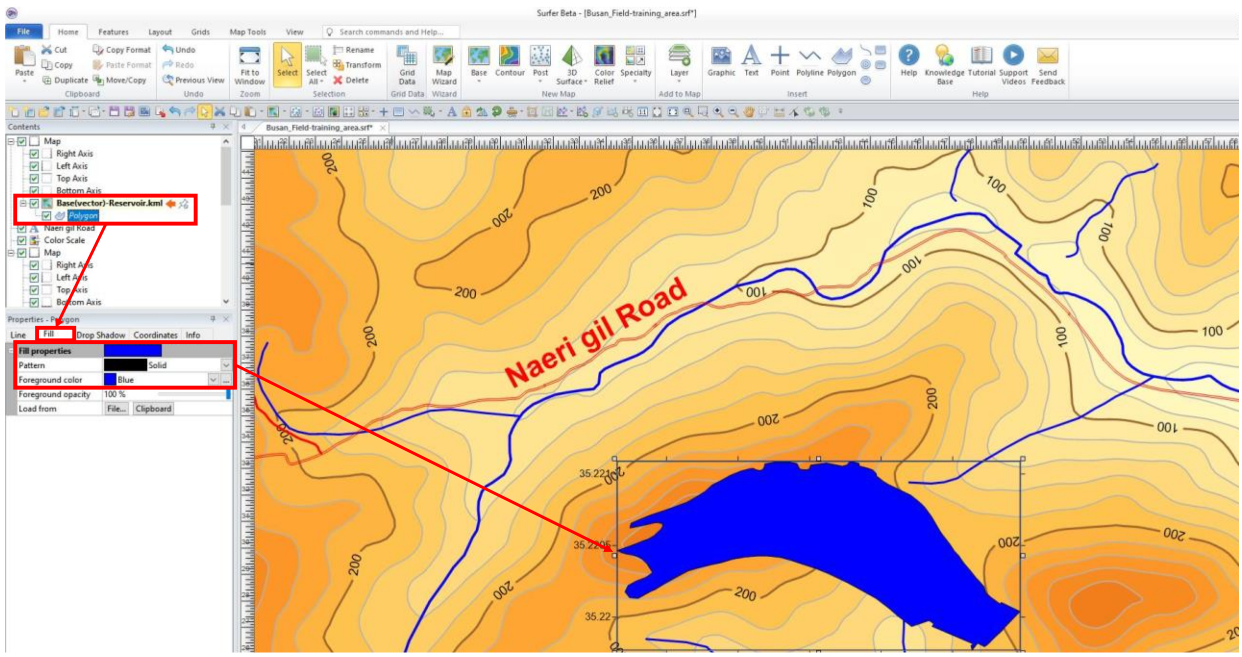


Figure 49. Colour the reservoir by selecting the 'Polygon' and, in the 'Properties' window ', Blue' is chosen as the 'Foreground colour'.

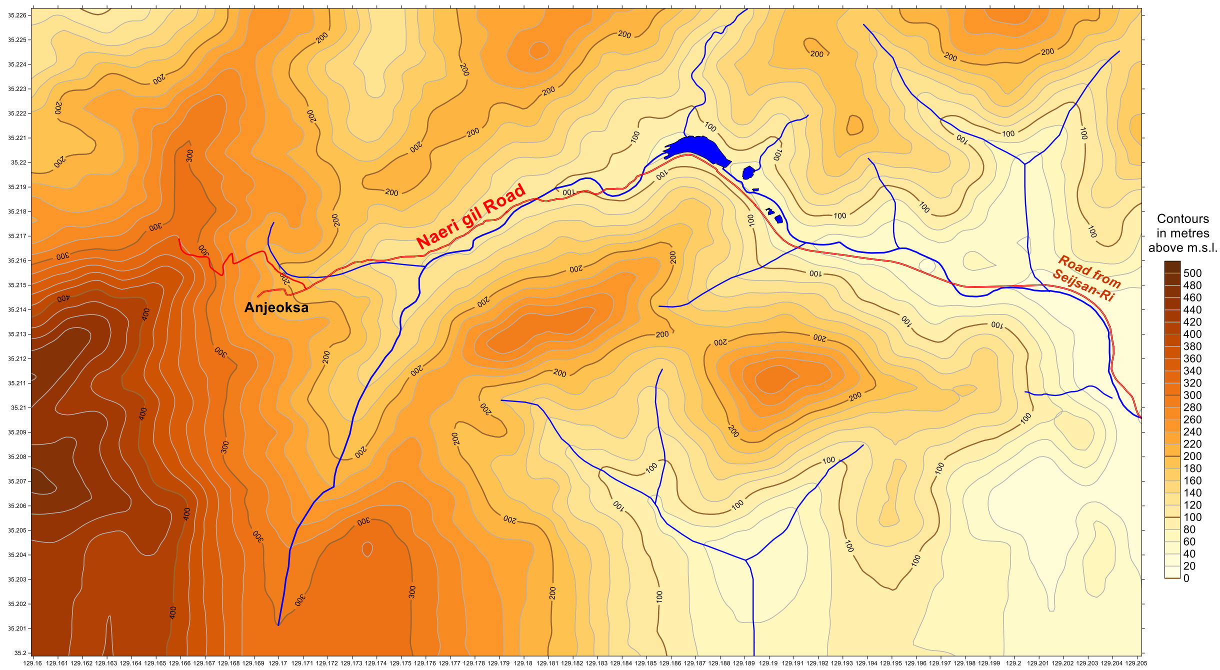


Figure 50. Semi-final topographical map composition. Note correction of colour scale label.

- **Adding the map scale:** To add the map scale, select the '*Map*' composition and '*Map Tools*' with left mouse clicks, and from the tools, select '*Scale*' (or if this option has been transferred to the '*Quick Access Toolbar*', click on the '*Scale*' option). The scale bar with default features is placed below the map (Fig. 51) and in decimal degrees, which must be converted to metres (see below).
- **Conversion of map scale from decimal degrees to metres:** Instructions for this conversion are given by Golden Software, and the files are in sub-directory '*Map_Scale_conversion*', and their source is at: https://support.goldensoftware.com/hc/en-us/articles/226662348-Change-units-of-the-map-scale-bar-in-Surfer?source=search. As stated in the Golden Software instructions, the easiest way to change the scale bar units is by changing the coordinate system of the map to a linear system (*e.g.*, Universal Transverse Mercator, UTM). In this case, the aim is to keep the latitude/longitude values on the map for direct correlation with the Google Earth image, and Golden Software provides a procedure. The Microsoft Excel® file '*Busan_ScaleConversion.xlsx'* calculates the equivalent distance in metres *(see also the Sub-directory 'Map_Scale_conversion').* The steps are the following:
  - Open the Microsoft Excel® file '*Busan_ScaleConversion.xlsx*', where you will see the required parameters, *i.e.*, '*yMin*' and '*yMax*', which should be extracted from the Surfer™ Busan map file.
  - Select '*Map*' in Surfer™ and, go to the small '*Properties – Map*' window, and select '*Limits*' (Fig. 52a) where you can see the '*yMin*' and '*yMax*' values, which are copied to the corresponding cells of the Excel® worksheet.
  - Enter the value of '*1000*' in the Excel® cell of the '*Distance of one cycle (Label increment)*' (Fig. 52b). Automatically, the '*Cycle Spacing*' values for different distance measures are calculated. We are interested in the '*Cycle Spacing*' value for '*Meters*'.
  - Select '*Map Scale*' with a left mouse click, and the '*Properties | Map Scale*' is displayed (Fig. 53a). Enter in the '*Cycle spacing*' the calculated value for metres, *i.e.*, 0.01099490972 (Fig. 53b). The map scale intervals change automatically to multiples of 0.01099490972 (Fig. 53c).
  - Select with a left mouse click '*Labels*' in the '*Properties – Map Scale*' window (Fig. 54a); (b) remove the tick from the '*Match increment*', and the '*Label increment*' value of

- 0.01099490972 is shown; (c) replace it with the value of 1000, and (d) the map scale changes to multiples of 1000 metres.
- Figure 55 shows that the map scale has been changed to 1000 m intervals.
- Select the '*General*' option of the '*Properties – Map Scale*' and (i) change the '*Number of Cycles*' from 4 to 1; (ii) tick '*Show subdivisions*' and (iii) change the '*Number of subdivisions*' from 4 to 2 (Fig. 56a); then select (iv) '*Labels* | *Font properties*' and change the '*Size (points)*' from 12 to 26 points, and in the '*Labels* | *Label format*' type '*m*' in the '*Suffix*' (Fig. 56b). To have a space between the scale numbers '0' & '1000' and 'm', *i.e.*, '0 m' & '1000 m', you need to place the cursor at the beginning of the '*Suffix*' option and tap one time the '*Space bar*' and afterwards type '*m*'.
- Finally, select '*Home* | *Point*' and under '*Properties – Point* | *Symbol* | *Symbol set*' choose '*GSI North Arrows*' & select '*(Symbol 15)*', and change its '*Size*' to 3 cm. Lastly, move the map scale and north symbol to the bottom left corner of the map (Fig. 57).

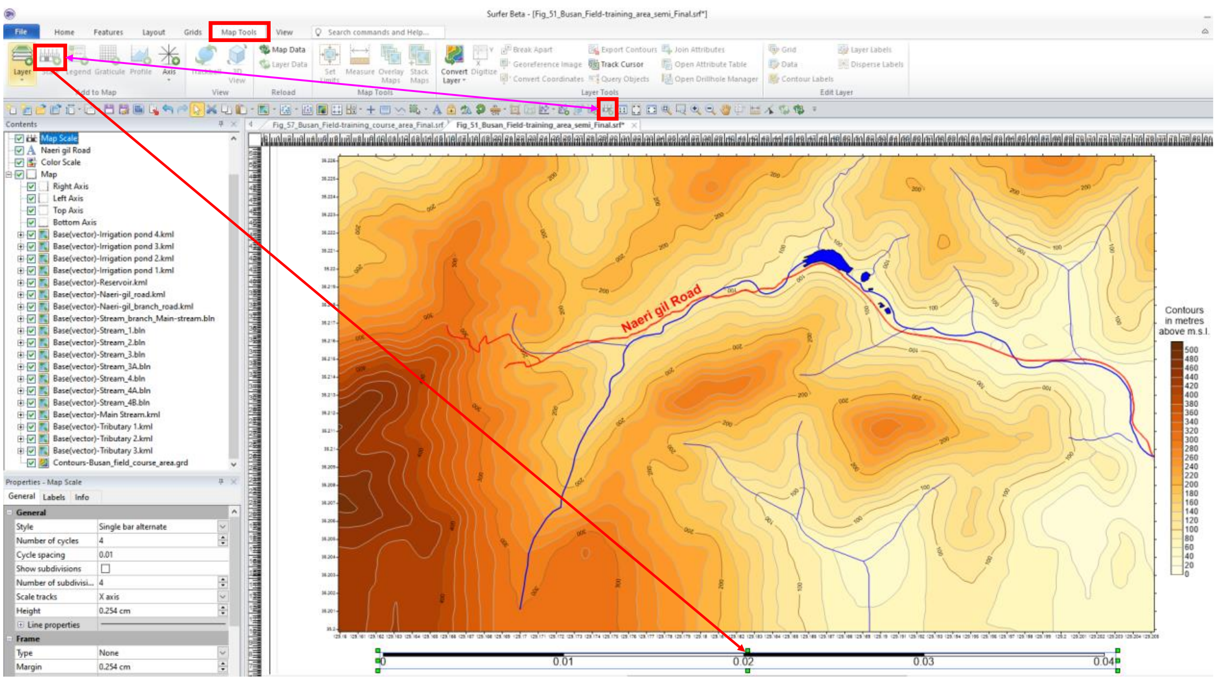


Figure 51. Map scale was added at the bottom of the map composition. Note that it is in decimal degrees.

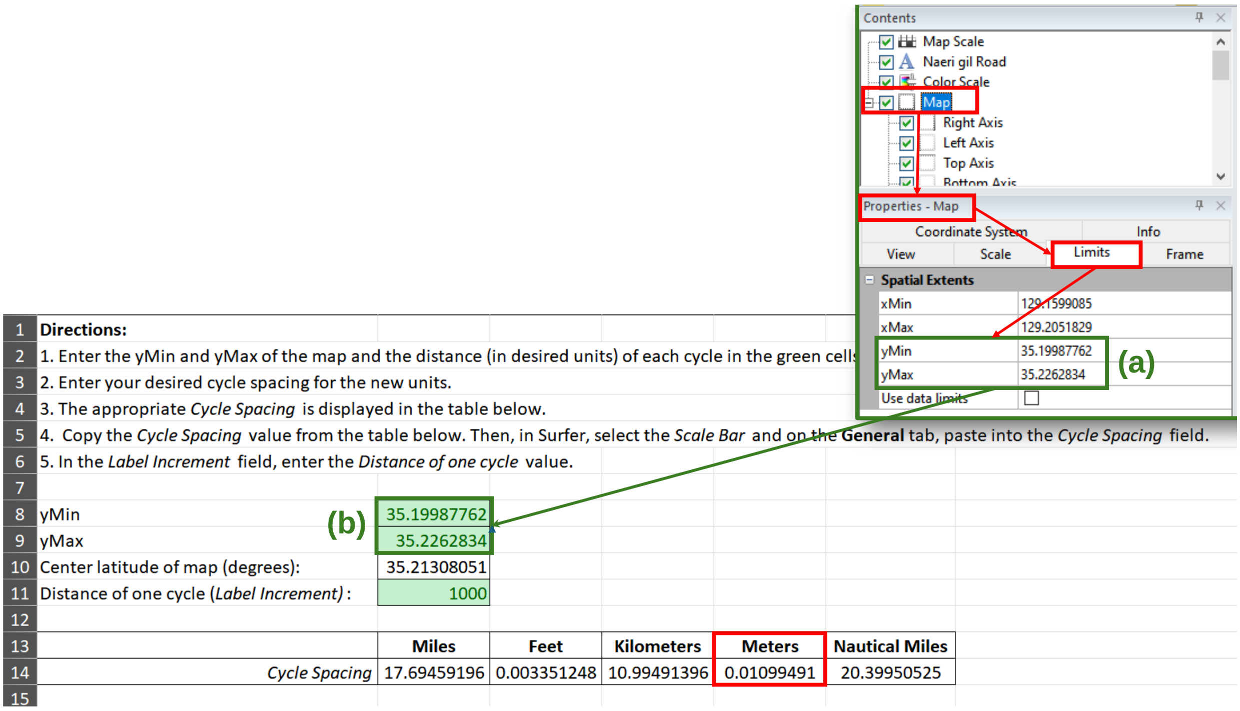


*Figure 52. (a) The values of 'yMin' and 'yMax' from the Surfer™ map properties window are copied in the corresponding (b) **green-coloured shaded cells** of '**yMin**' and '**yMax**' of Microsoft Excel®; the value of '**1000**' is entered in cell of the 'Distance of one cycle (Label increment). The corresponding 'Cycle Spacing' values for different distance measures are automatically calculated, and the value of the 'Meters' is selected for copying (see Fig. 53a).*

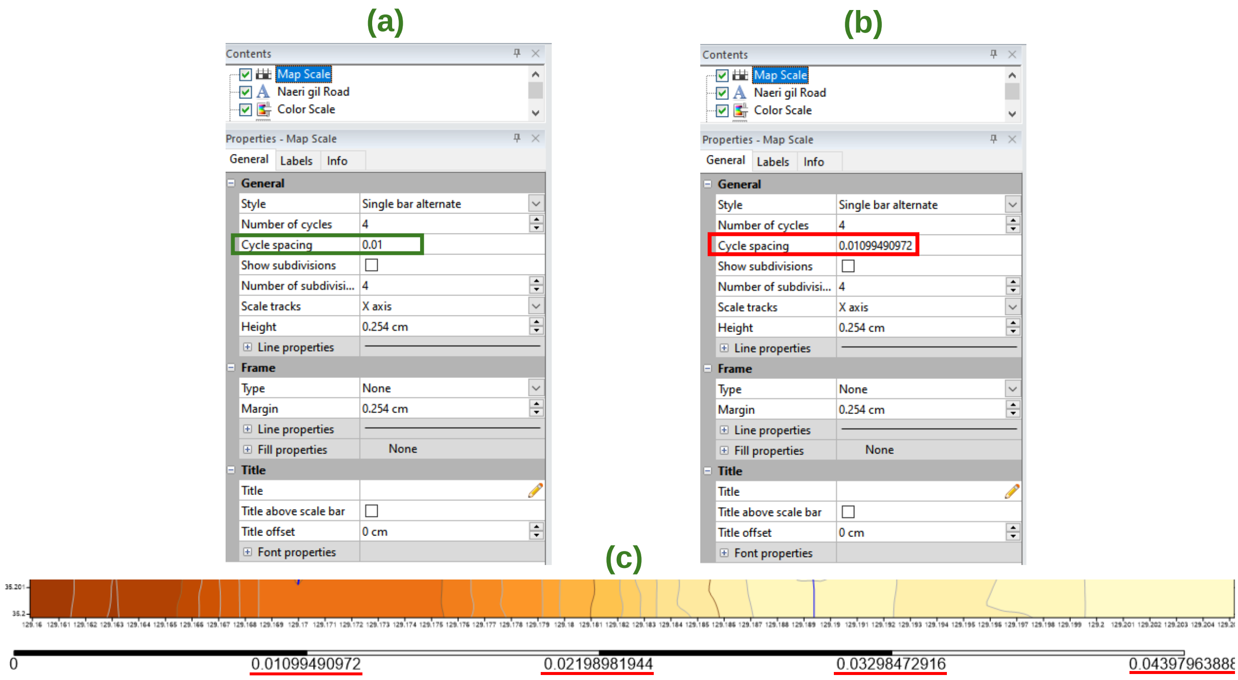


Figure 53. (a) The 'Cycle spacing' value of 0.01 is changed to 0.01099490972 in (b), and automatically, the intervals in the map scale (c) are changed to multiples of 0.01099490972.

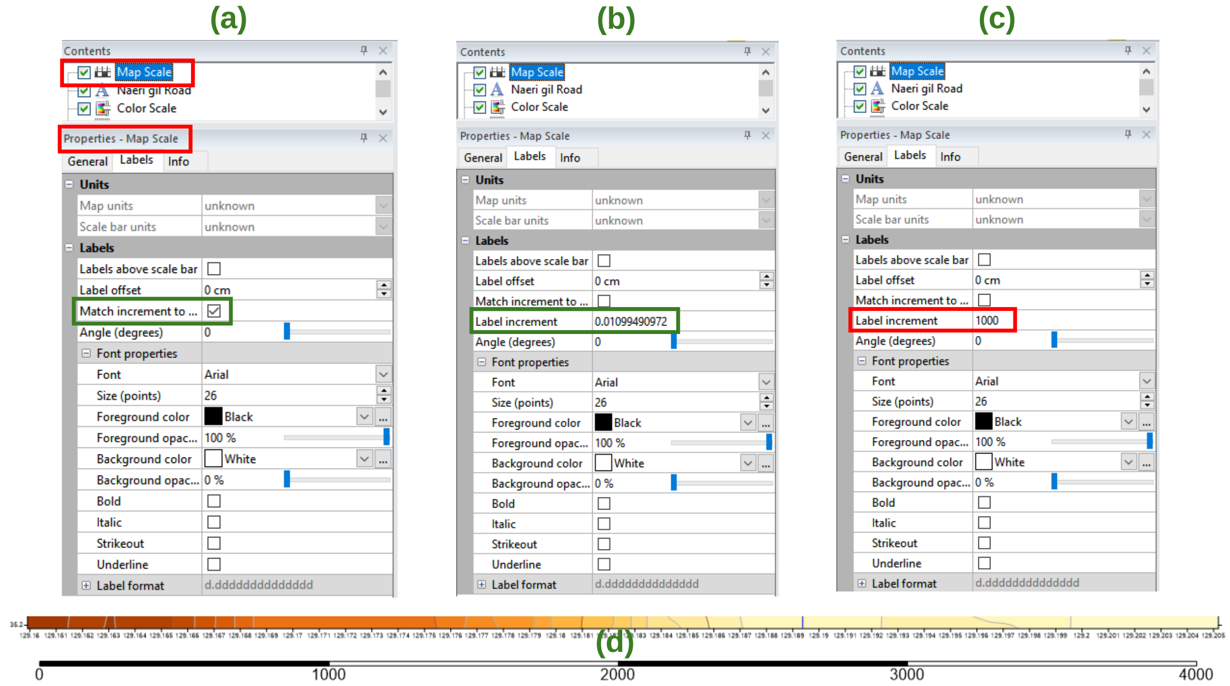


Figure 54. In the 'Labels' option of the 'Properties – Map Scale' window, remove (a) the tick from 'Match increment to ...'; (b) the 'Cycle spacing' of 0.01099490972 is the 'Label increment' value, which is replaced by the 'Label increment' value of '1000' (c), and (d) the map scale is changed to metre intervals.

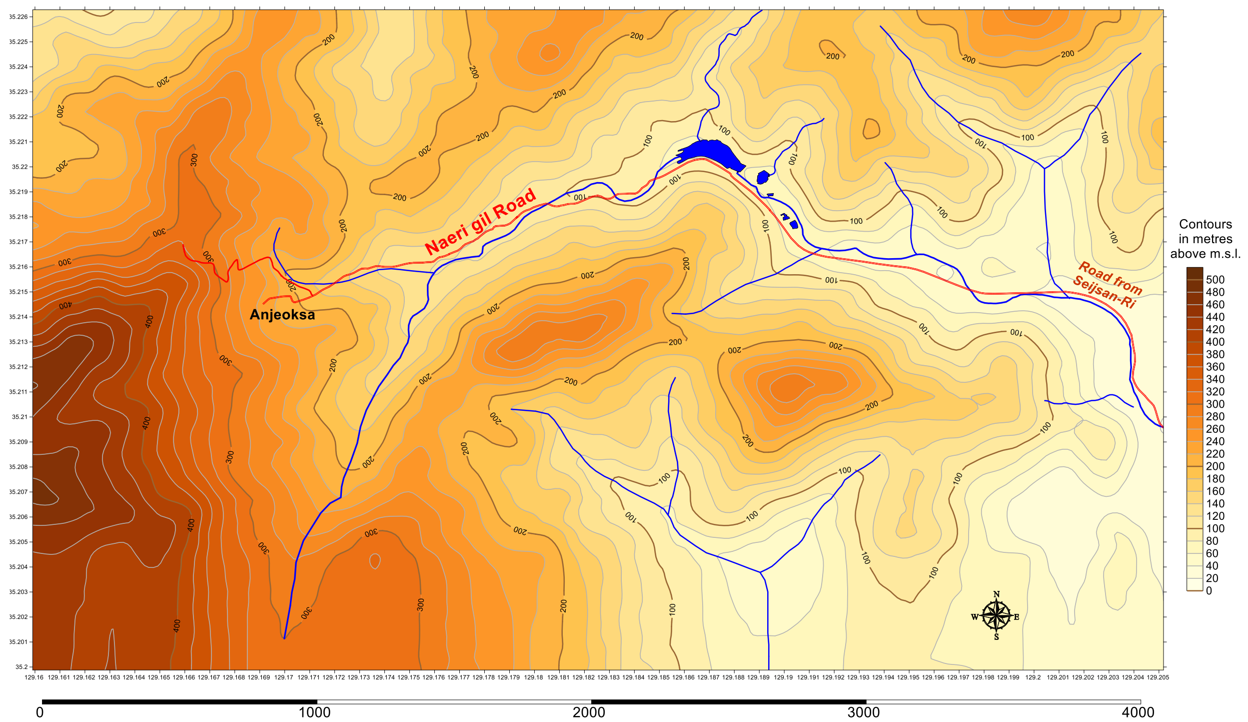


Figure 55. The map scale is changed to 1000-metre intervals (compared with the map in Figure 51).

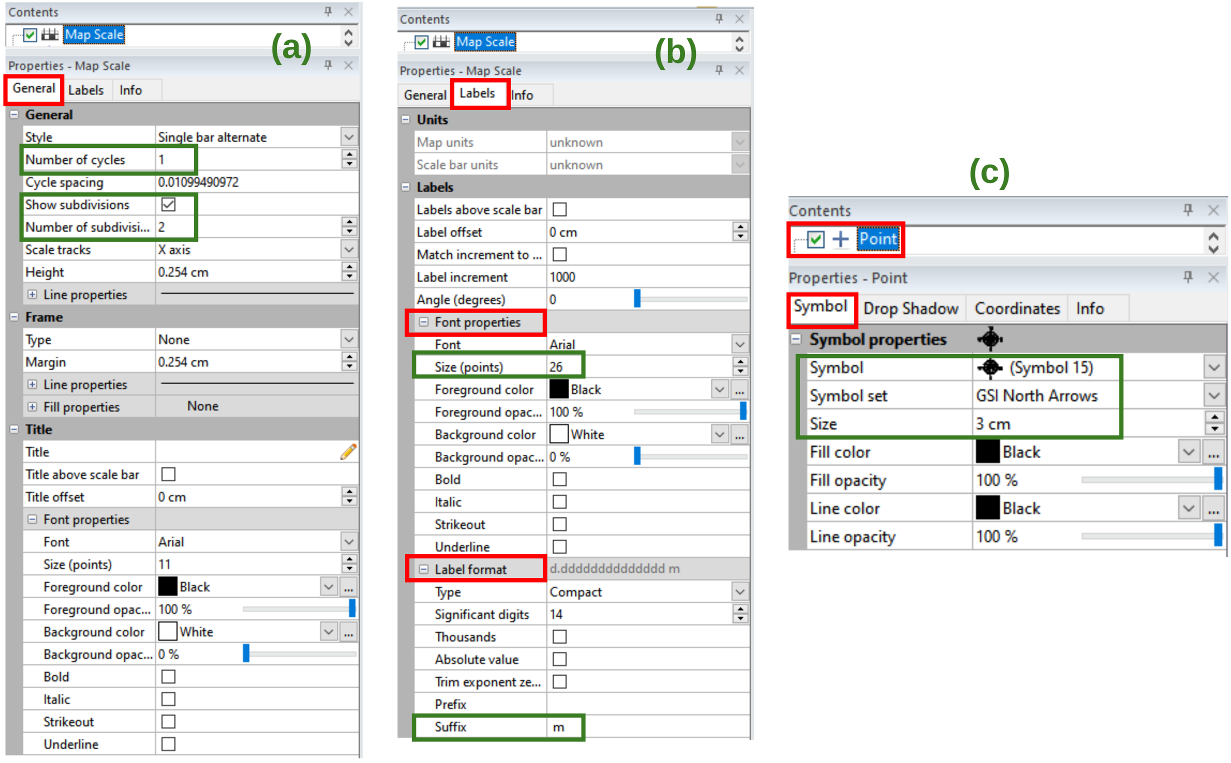


Figure 56. (a) In the 'General' options and the 'Properties - Map Scale', the 'Number of cycles' is changed from 4 to 1 and 'Number of subdivisions' to 2; (b) in the 'Labels' screen, go to 'Font size' and change to 26 points, and in the 'Label format' and to 'Suffix' enter ' m' (the metres symbol with one space in front), and (c) the North Arrow is added by introducing 'Point' and then selecting Symbol 15, and changing its 'Size' to 3 cm.

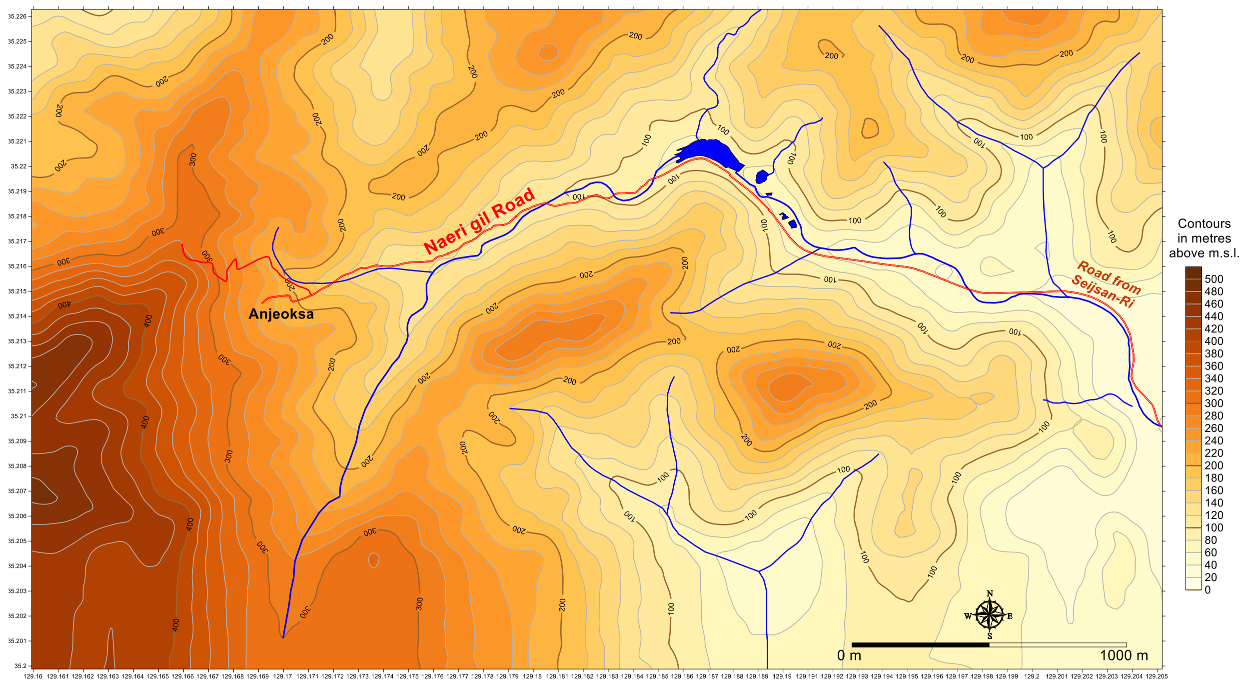


Figure 57. Final map composition of Busan field course area (South Korea). The 2-cycle map scale is placed at the bottom right-hand corner of the map, and the North symbol is positioned at its centre.

Acknowledgements

The workshop entitled "*International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network*" was held on the 30th and 31st of August 2024 during the 37th International Geological Conference in Busan (South Korea). It was co-sponsored by the International Union of Geological Sciences and the Association of Applied Geochemists, and both organisations are thanked for their generosity. The assistance of Golden Software's staff is acknowledged, and special thanks are extended to Drew Dudley (Senior Business Development Manager) and Brittney Ferrari (Customer Support), and especially Drew's help on the map scale. Further, Drew Dudley and the Golden Software management are thanked for the *free, gratis* renewal of my personal annual Surfer™ licence. Finally, Rachel VanOsdol (Customer Success Engineer, Golden Software Support) is thanked for reviewing the instructions text and her constructive comments, which improved the technical quality of this tutorial.

Supplementary material

The following files are included in the Tutorial file "Making_a_topographical-map.zip":

Busan_1.kml Busan_2.kml Busan_3.kml Busan_4.kml Busan_5.kml Busan_6.kml Busan_field-course_area.csv Busan_field_course_area.xlsx Busan_field_course_area_Final.srf Busan_field_map_Drew-Dudley.srf Busan_ScaleConversion.xls Contours-Busan_field_course_area.grd Irrigation pond 1.kml Irrigation pond 2.kml Irrigation pond 3.kml Irrigation pond 4.kml Main Stream.kml Naeri-gil_branch_road.kml Naeri-gil_road.kml Reservoir.kml	Stream_1.bln Stream_2.bln Stream_3.bln Stream_3A.bln Stream_4.bln Stream_4A.bln Stream_4B.bln Stream_branch_Main-stream.bln Tributary 1.kml Tributary 2.kml Tributary 3.kml Sub-directory: Map_Scale_conversion • Change units of the map scale bar in Surfer – Golden Software Support.pdf • ScaleConversion.xlsx • ScaleCoordinates.srf Sub-directory: Surveying_book • Ghilani_&_Wolf_2012_Elementary_Surveying_13th_ed-libre.pdf

References

Higgins, A.L., 1974. Elementary surveying. Third Edition with notes on metrication and metric equipment – Revised and Enlarged by Leroy Arthur Beaufoy. Longman, London, 197 pp.

Bibliography

Note: All hyperlinks were checked on the 19th of February 2025.

Ghilani, C.D. & Wolf, P.R., 2012. Instruction's Manual to Accompany Elementary Surveying – An Introduction to Geomatics. Pearson Education, Inc., Upper Saddle River, New Jersey, U.S.A., 271 pp.; https://cdn.prexams.com/10981/Solutions_-_Elementary_Surveying_13th_ed-libre.pdf.

Tutorial videos can be found on Golden Software's web page at: https://www.goldensoftware.com/support/webinars/, *e.g.*,

"*Bring your data to life with Google Earth and Surfer*" (https://youtu.be/MBbM3tQe5II?si=OiccLvk4qj_F2GIW)
"*Gridding on the Go: Managing Field Data with Surfer*" (https://youtu.be/KIPalgZDaIw?si=k03_VqUvQluV1Lfw).

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Making a topographical map in the digital age is a straightforward process. You only need a personal or laptop computer, internet access, and a Geographical Information System software. This tutorial utilises three fundamental software packages:

(i) Google Earth Pro,

(ii) GPS Visualizer, and

(iii) Golden Software's Surfer™.

The longitude and latitude of digitised points along traverses are extracted from Google Earth Pro. Depending on the required details, a larger Google Earth image is digitised along traverses, which can be in any direction. The file with the longitude (x) and latitude (y) of point data is then copied online into GPS Visualizer, which uses data from different digital elevation models (DEM) to assign the optimum altitude or topographical height (z) in metres (or feet) of the digitised points along the traverses. The topographical data (x, y, z) exported from GPS Visualizer are plotted with Surfer™ or similar mapping software packages, and a digital topographical map of an area is made. This tutorial provides detailed instructions on plotting and annotating an area's topographical map with modern digital tools.

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