

Adjusting the Network

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About this tutorial

In this tutorial, you will adjust the network for a project that contains GNSS, total station, and level data.

Note: If you need additional help at any time you are using the software, press **F1** to display the online help.

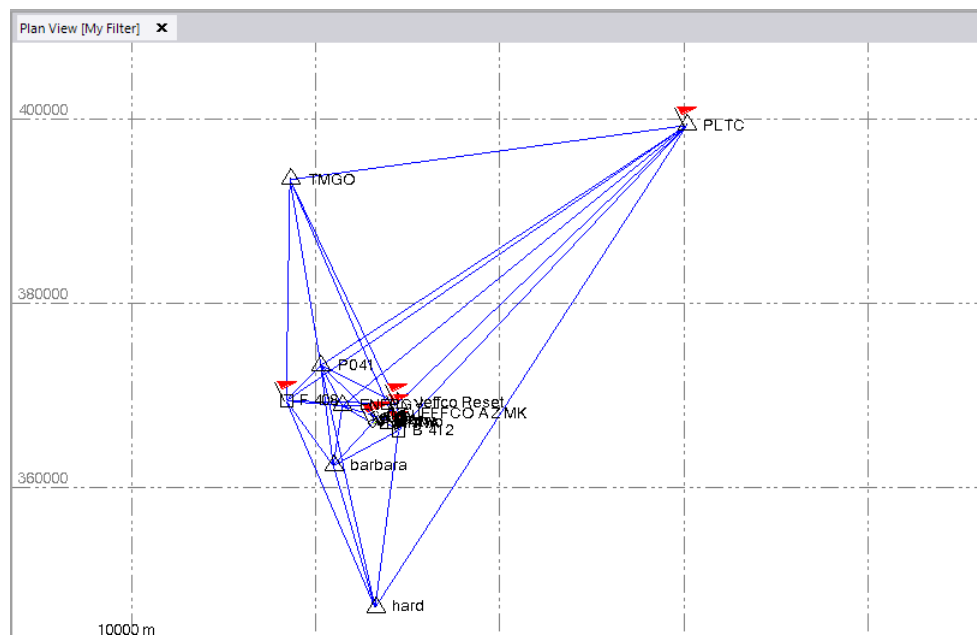
Step 1. Open the project

For this tutorial, you will use the project file *Adjusting the Network.vce*. GNSS, total station, and level data has already been imported into the project, and GNSS baselines have been processed.

Note: The downloaded *AdjustingtheNetwork* folder contains this PDF file, a *Data* folder, and the *Adjusting the Network.vce* project file. You will import data from the *Data* folder later in this tutorial.

1. In SO, select **File > Open**.
2. In the **Open File** dialog, browse to `..\AdjustingtheNetwork\Adjusting the Network.vce` and click **Open**.

The project opens in the **Survey Office** window.

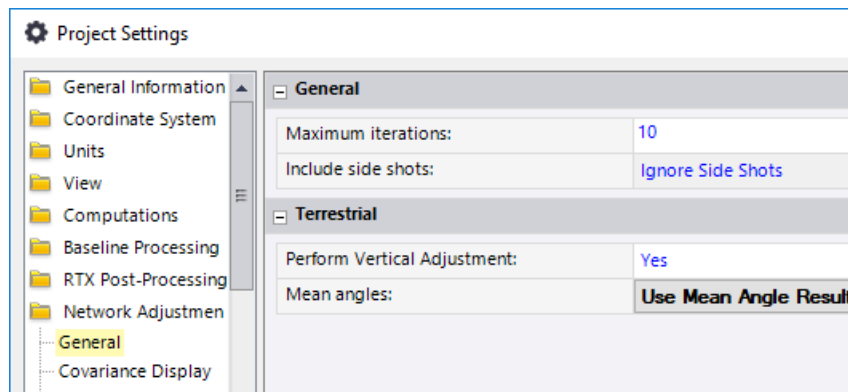


The project file is read-only. You can perform the tutorial steps without saving the project file. However, if you are interrupted while performing the tutorial, you can save it with a new name by selecting **File > Save Project As**. Then, you can re-open the project to continue the tutorial at a later time.

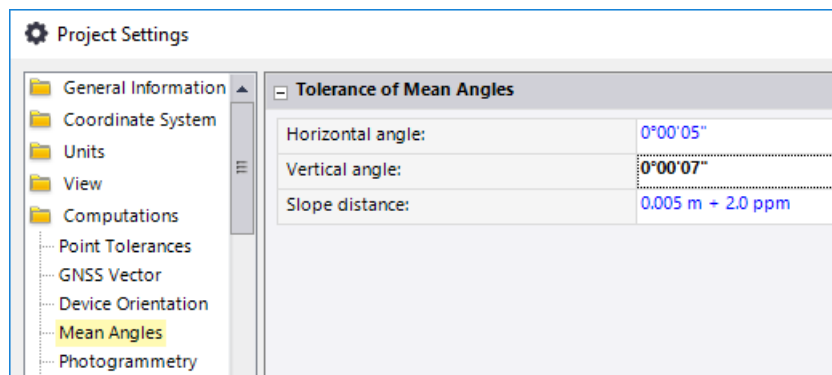
Step 2. Modify project settings

In this step, you will select the sources to use for default standard errors when performing the network adjustment. Then, you will specify default standard errors for total station, leveling, and GNSS data.

1. In the **Quick Access Toolbar** located at the top of the **Survey Office** window, select **Project Settings**.
2. In the navigation (left) pane in the **Project Settings** dialog, select **Network Adjustment > General**. Then, in the **Mean angles** drop-down list, select *Use Mean Angle Results*.

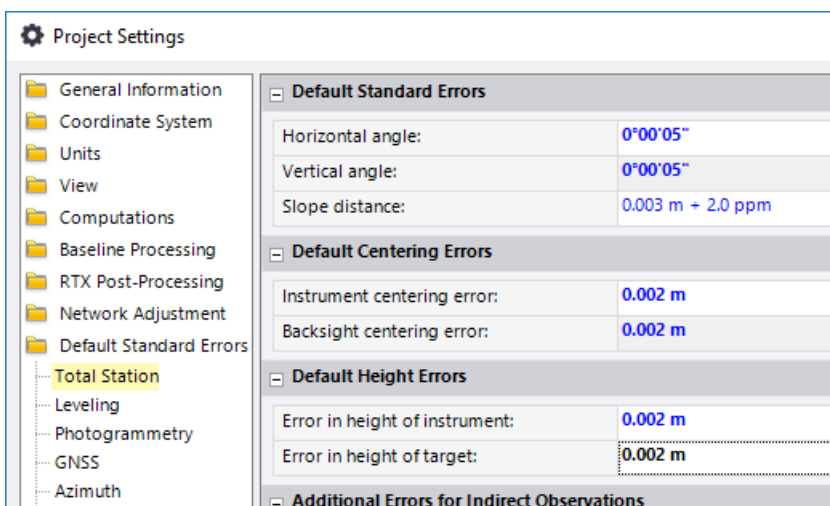


3. In the navigation pane, select **Computations > Mean Angles**. Then change the **Vertical angle** to $0^{\circ}00'07''$.

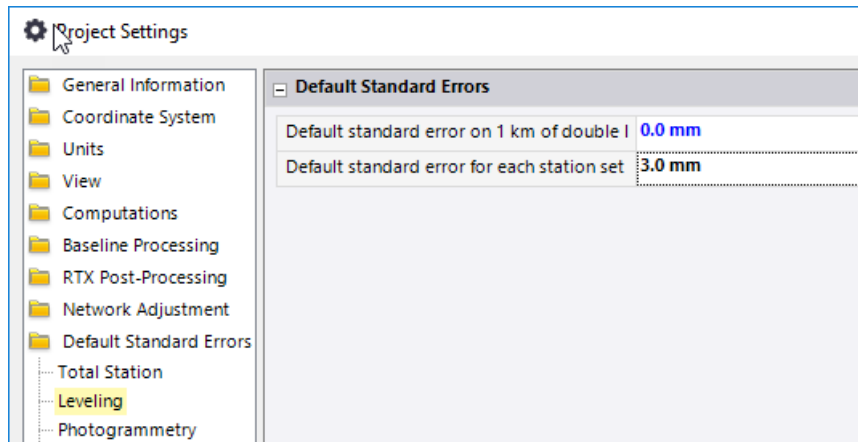


4. In the navigation pane, select **Default Standard Errors**. Then select options as follows:
 - **Total Station:**
 - Source for centering errors: *Project Settings*

- **Leveling:**
 - **Source for standard errors:** *Project Settings*
5. In the navigation pane, select **Default Standard Errors > Total Station**. Then select options as follows:
- **Default Standard Errors:**
 - **Horizontal angle:** *0°00'05"*
 - **Vertical angle:** *0°00'05"*
 - **Default Centering Errors:**
 - **Instrument centering error:** *0.002 m*
 - **Backsight centering error:** *0.002 m*
 - **Default Height Errors:**
 - **Error in height of instrument:** *0.002 m*
 - **Error in height of target:** *0.002 m*

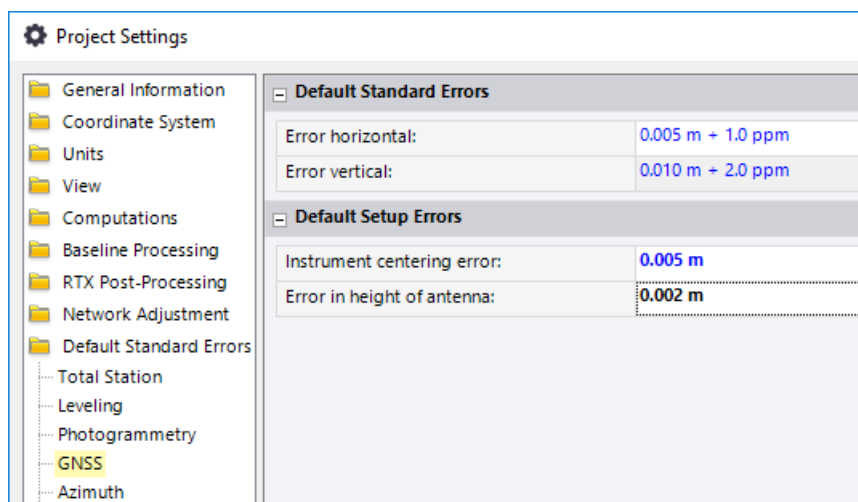


6. In the navigation pane, select **Default Standard Errors > Leveling**. Then select options as follows:
- **Default Standard Errors:**
 - **Default standard error on 1 km of double leveling:** *0.0 mm*
 - **Default standard error for each station setup:** *3.0 mm*



7. In the navigation pane, select **Default Standard Errors > GNSS**. Then select options as follows:

- **Default Setup Errors:**
 - Instrument centering error: *0.005*
 - Error in height of antenna: *0.002*



8. Click **OK** to save your changes and close the **Project Settings** dialog.

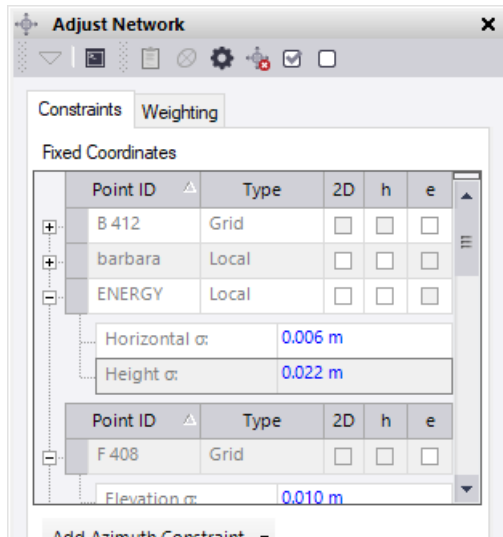
You are now ready to perform a network adjustment. You will do this using a two-step process. First, you will perform a minimally constrained network adjustment. Then, you will perform a constrained network adjustment.

Step 3. Perform a minimally constrained network adjustment

To evaluate the internal consistency of the survey network, you must first perform a minimally constrained network adjustment, which uses the minimum number of constraints required to define the coordinate system.

1. Select **Survey > Network > Adjust Network**.

The **Adjust Network** pane displays. The node for each point that includes standard error estimates is expanded showing the values. You can expand or collapse any point node by using the +/- (plus/minus) button preceding the node.



Notes: The **Constraints** tab includes two major work areas. The upper area includes the **Fixed Coordinates** list, which you will use in this tutorial to fix coordinates for the adjustment. The lower area includes a drop-down list that allows you to select to add azimuth and/or horizontal distance constraints for the adjustment. For this tutorial, you will not be using these constraints. For more information, see "Adjust a Network" in the online Help.

There are 13 control points listed in the **Fixed Coordinates** list on the **Constraints** tab. Ten are the vertical control points from the DiNi level data and the data sheet:

- *B412*
- *barbara*
- *ENERGY*
- *F 408*
- *flange*
- *hard*
- *Jeffco AZ MK*
- *Jeffco Reset*
- *Jeffco Reset*
- *sixtwo*

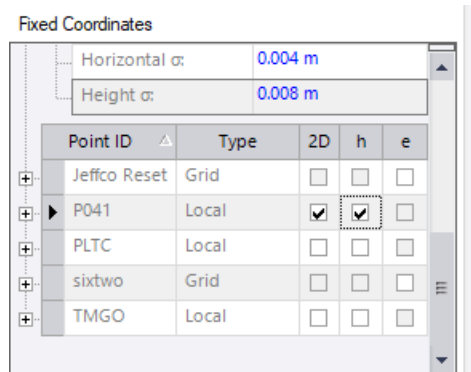
Three are horizontal control points from the CORS (Continuously Operating Reference Stations) data sheet:

- *P041*
- *PLTC*

- **TMGO**

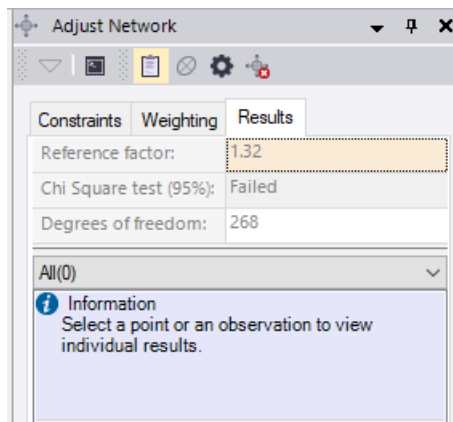
For this project, you will perform a minimally constrained adjustment by holding the station *P041* fixed in **2D** and **h**.

2. In the **Fixed Coordinates** list, select the **2D** and **h** check boxes for *P041*.



3. Click the **Adjust** button.
4. In the **Question** message window asking if you want to resolve project computation errors, click the **Yes** button to continue the network adjustment without resolving the errors.

A summary of the results of the adjustment displays on the **Results** tab in the **Adjust Network** pane.



The **Chi Square** test has *Failed*. This indicates that some vectors may have been flagged as outliers in the adjustment and/or it is necessary to apply a weighting strategy to the processed vectors.

5. In the **Adjust Network** pane toolbar, click the **Network Adjustment Report** icon.
The *Network Adjustment Report* displays in your browser window. To navigate to the various sections of the report, click the links in the navigation pane on the left side of the report, or use your mouse to scroll through the report.
6. Review the report, paying particular attention to the "Observations" sections and the "Histogram of Standardized Residuals" section.

Observations with a standardized residual that fails the Tau criteria are displayed in red. These observations are outliers. In this case, the post-processed vectors *TMGO* --> *PLTC (PV135)* and *filter* --> *5 (PV22)* are flagged as outlier (red text) in the "Adjusted GNSS Observations" section.

Adjusted GNSS Observations				
Observation ID		Observation	A-posteriori Error	Residual
TMGO --> PLTC (PV135)	Az.	82°24'51"	0.017 sec	-0.001 sec
	Δ Ht.	-170.169 m	0.003 m	-0.042 m
	Ellip Dist.	43541.309 m	0.003 m	0.001 m
filter --> 5 (PV22)	Az.	51°23'56"	2.227 sec	-3.511 sec
	Δ Ht.	11.210 m	0.002 m	-0.019 m
	Ellip Dist.	442.723 m	0.002 m	0.011 m
D041 --> PLTC (PV135)	Az.	57°01'25"	0.014 sec	0.001 sec

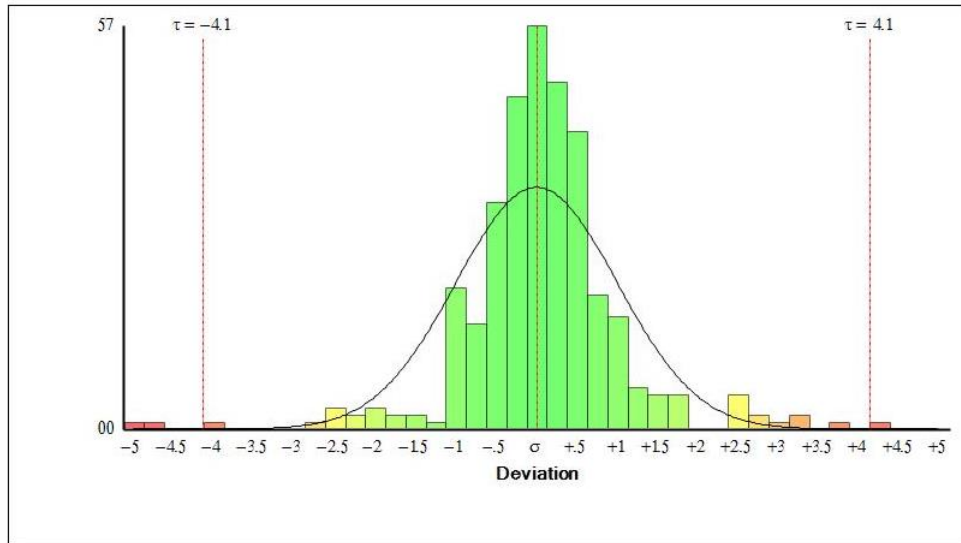
Note: The software automatically assigns a number in parenthesis to each set of observations. The numbers in your report may vary from the numbers shown above.

Since you have a high-level redundancy in the network, you can disable *TMGO* --> *PLTC (PV135)* and *filter* --> *5 (PV22)* as described in the following steps, then readjust the network.

The "Histogram of Standardized Residuals" section provides a quick visual reference showing the distribution of standardized (normalized) adjustment residuals displayed against a normal distribution curve line for comparison. The graph includes two vertical boundary lines representing the critical tau value so you can easily identify the number and distribution of failing observations. Both the critical tau value and the number of failing observations are also displayed as numerical values above the graph.

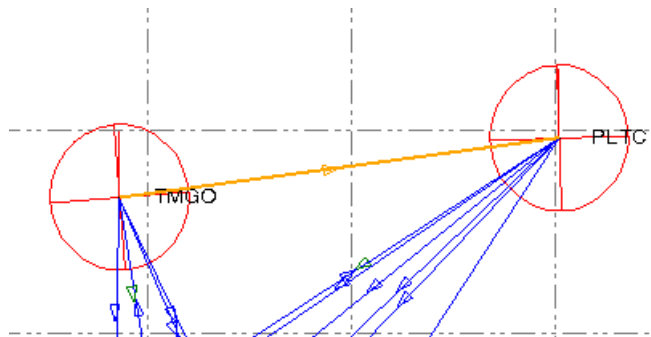
Histogram of Standardized Residuals

Critical Tau Value: 4.1
Observations Failing the Tau Test: 3



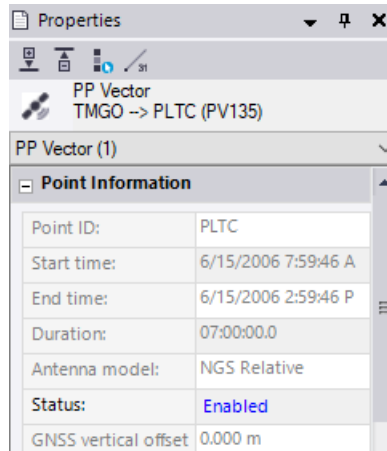
7. In the *Network Adjustment Report*, click the *TMGO --> PLTC (PV135)* link in the "Adjusted GNSS Observations" section.

This selects the vector in the project.



8. In the **Survey Office** window, right-click on the **Plan View** and select **Properties** in the context menu.

The **Properties** pane displays showing the *TMGO --> PLTC (PV135)* vector.



Note: If you click anywhere else in the window before right-clicking on the **Plan View**, the vector will no longer be selected.

- In the **Status** drop-down list, select **Disabled**.

The **Clear Adjustment** message dialog displays asking whether you want to keep or clear the results of the previously performed network adjustment.

- In the **Clear Adjustment** dialog, click the **Clear Adjustment** button.

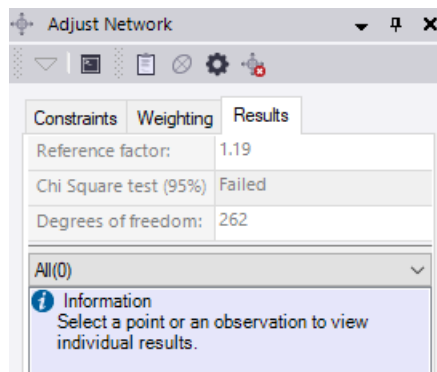
- In the *Network Adjustment Report*, click the *filter --> 5 (PV22)* link in the "Adjusted GNSS Observations" section. Then, in the **Properties** pane for the *filter --> 5 (PV22)* vector, select **Disabled** for the **Status**.

With *TMGO --> PLTC (PV135)* and *filter --> 5 (PV22)* disabled, you can now repeat the network adjustment process.

- On the **Constraints** tab in the **Adjust Network** command pane, click the **Adjust** button to repeat the minimally constrained network adjustment.

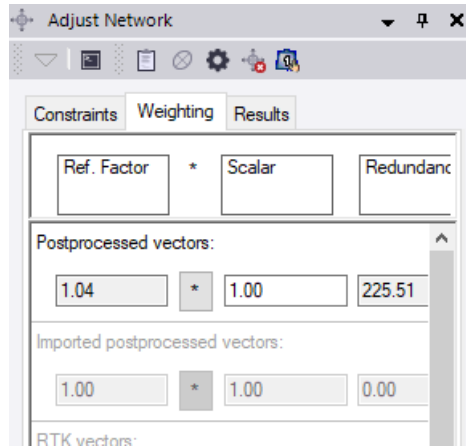
- In the **Question** message window, click the **Yes** button to continue the network adjustment without resolving the errors.

A summary of the results of the adjustment displays on the **Results** tab in the **Adjust Network** pane.



The **Chi Square** test has still failed, so it is necessary to apply a weighting strategy to the processed vectors. Applying a weighting strategy will improve the initial *a priori* error estimates for the observations. (*A priori* errors are estimated errors for observations before a network adjustment is performed.)

14. In the **Adjust Network** pane, select the **Weighting** tab.




The goal in using the **Weighting** tab is to selectively apply a scalar to each of the various observation types and perform adjustments as necessary until the **Reference Factor** displayed for each observation type is within the range of *0.95* to *1.05*. Note that each time you apply a scalar to an observation type and perform an adjustment, the **Reference Factor** for the selected observation type changes and its **Scalar value** changes accordingly. In addition, the **Reference Factor** for other observation types may change as well.

The typical workflow strategy is to apply scalars to observation types whose **Reference Factor** is not within *0.95* and *1.05*. This is done in sequence, starting with the observation type with the highest **Redundancy** and working downward in an iterative way to the observation type with the lowest **Redundancy** until all **Reference Factor** values are within the acceptable range. (The **Redundancy** is *roughly* equivalent to the number of observations of the selected observation type.)

Although the **Postprocessed vectors** observation type has the highest **Redundancy**, you will not apply a scalar to it because its **Reference Factor** is already within the acceptable range.

The observation type with the next highest **Redundancy** is **Vertical angles**, which has a **Reference Factor** that is outside the acceptable range. You will apply a scalar to it.

Note: An alternative workflow strategy may be applied that is based on your confidence level in the observation data. In this workflow, you would apply a scalar to the most "trusted" observation type first, followed by the next most trusted type, and so on (as opposed to basing the sequence on the **Redundancy**). For example, level data is often considered to include the most trusted measurements, followed by static GNSS data, total station data, and RTK data. So you might apply scalars in this sequence, as appropriate, instead of applying scalars based on **Redundancy**. Depending on how familiar you are with the data and the way it was collected, this might be a better workflow option.

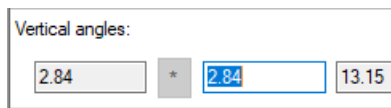
15. In the **Vertical angles** row, click the **Apply scalar** button . Then, click the **Adjust** button and click **Yes** in the **Question** message window.

Before clicking the **Apply scalar** button:



Vertical angles:
<input type="text" value="2.84"/> * <input type="text" value="1.00"/> <input type="text" value="13.15"/>

After clicking the **Apply scalar** button:



Vertical angles:
<input type="text" value="2.84"/> * <input type="text" value="2.84"/> <input type="text" value="13.15"/>

After adjustment:




Vertical angles:
<input type="text" value="1.16"/> * <input type="text" value="2.84"/> <input type="text" value="13.81"/>

The **Reference Factor** for the **Vertical angles** observation type is lower, but it is still outside the acceptable range. You will revisit this observation type in a moment.

Note that the **Reference Factor** for **Postprocessed vectors** (which has the highest **Redundancy**) changed but is still within the acceptable range. If it had changed to a value outside the acceptable range, you would apply a scalar to it and adjust prior to applying a scalar to the next observation type.


The observation type with the next highest **Redundancy** is **Slope distances**. Its **Reference Factor** is outside the acceptable range, so you will apply a scalar.

16. In the **Slope distances** row, click the **Apply scalar** button . Then, click the **Adjust** button and click **Yes** in the **Question** message window.

The **Reference Factor** for the **Slope distances** observation type is now within the acceptable range.

The **Reference Factor** for the other observation types remain unchanged.


You will now re-apply a scalar to the **Vertical angles** observation type to see if the **Reference Factor** has improved.

17. In the **Vertical angles** row, click the **Apply scalar** button . Then, click the **Adjust** button and click **Yes** in the **Question** message window.

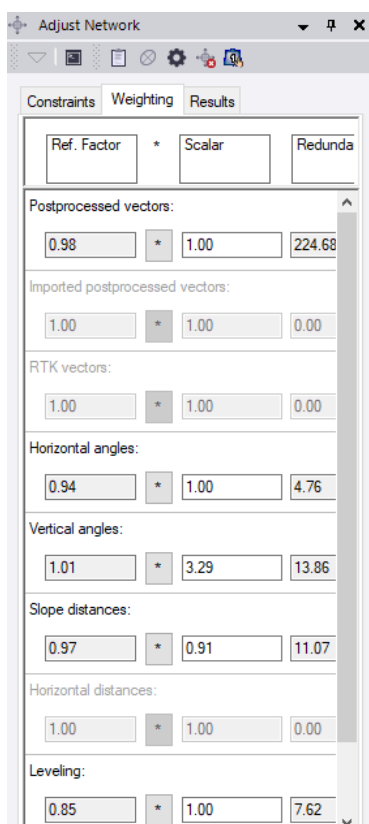
The **Reference Factor** for **Vertical Angles** is now within the acceptable range.

The **Reference Factor** for several of the other observation types changed slightly.

The observation type with the next highest **Redundancy**, and the only observation type whose **Reference Factor** is still outside the acceptable range, is **Leveling**. You will apply a scalar.

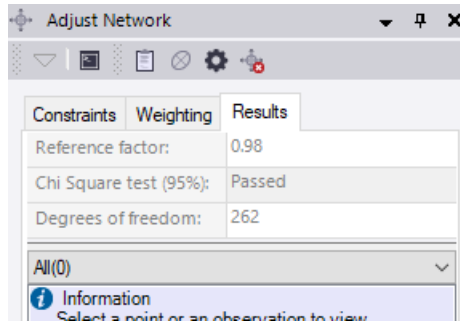
18. In the **Leveling** row, click the **Apply scalar** button . Then, click the **Adjust** button and click **Yes** in the **Question** message window.

The **Reference Factor** for each of the observation types is now within the acceptable range so there is no need to apply additional scalars.



19. Select the **Results** tab.

The **Chi square** test is now *Passed*.



You are ready to perform a constrained network adjustment.

Step 4. Perform a constrained network adjustment

In this step, you will perform a constrained adjustment in which the remaining control points are held (fixed) to the coordinates from the imported data sheets. The objective is to compute adjusted coordinates for the measured points in the survey network, relative to the existing control stations.

The stations in this survey are of mixed survey quality, including:

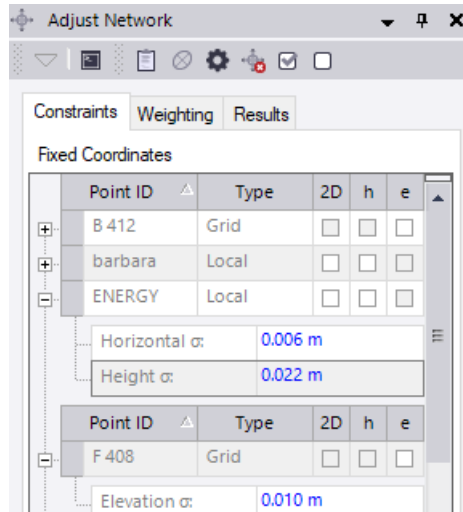
- CORS (Continuously Operating Reference Stations) quality
- Varying qualities from national network reference stations
- Adjusted DINI observation quality

You can assign standard error values to each control point based on its quality, using previously adjusted values from past surveys or error estimates from CORS or national network reference station adjustments. When you assign a standard error to a control point, you enable the network adjustment to adjust the coordinate value of the control point based on the quality of the observations and the other control points.

If you choose not to assign standard error values, a “fixed” value of 0.000001m (micrometer) is assigned to each point regardless of point quality.

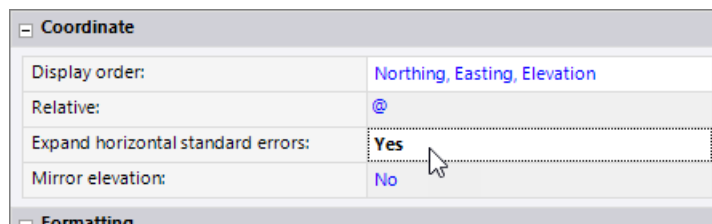
For this tutorial, you will enter “fixed” values for the CORS stations, accuracy estimates from the National Geodetic Survey (NGS) datasheets, along with some assumed values for the lower order control points.

1. In the **Adjust Network** pane, select the **Constraints** tab.

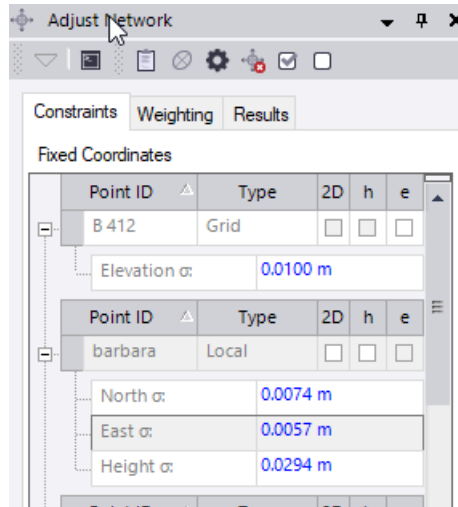


You can expand each control point to enter standard error estimates. For this tutorial, you will enter the North and East values of the estimates. (If available, you can also enter the horizontal values.) However, before doing so, you will need to make some changes to your **Project Settings**.

2. In the **Quick Access Toolbar** located at the top of the **Survey Office** window, select **Project Settings** and do the following:
 - a. Select **Units > Coordinate** and in the **Expand horizontal standard errors** drop-down list select **Yes**.



- b. Select **Units > Distance** and change the **Decimal precision** from *0.123* to *0.1234*.
 - c. Click **OK** to close the **Project Settings** dialog.
3. On the **Constraints** tab in the **Adjust Network** pane, do the following:
 - a. Click the plus symbol to expand *B412*. Then enter *0.01 m* in the **Elevation σ** field.
 - b. Click the plus symbol to expand *barbara*. Then enter:
 - 0.0074 m* in the **North σ** field
 - 0.0057 m* in the **East σ** field
 - 0.0294 m* in the **Height σ** field



Typically, you would enter error estimates for the rest of the points as well. **However, for this tutorial the additional values have already been entered.**

Error estimates entered for a point are used in the adjustment only if you select one or more of the "fix" check boxes for the point, making it a constraint point.

Although, in practice, you would generally take a more incremental approach to the constrained adjustment and add only one control point at a time, for this tutorial you will complete the constrained adjustment in two steps. First, you will constrain the NAD83 local geodetic coordinates for the three horizontal control points. Then, you will add the elevation constraints for the Trimble DiNi control elevation.

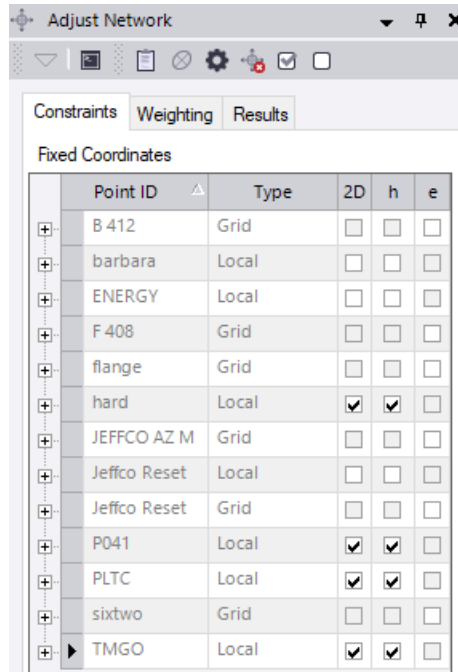
Note the following:

- Local (**2D** and **h**) values refer to NAD83 local geodetic (latitude, longitude, and ellipsoid height) coordinates imported from the data sheets.
- Grid (**e**) values refer to NAVD88 elevations imported from the data sheet or the adjusted digital level files.

For this tutorial, you will constrain points using the local geodetic coordinates. You will add elevation constraints later.

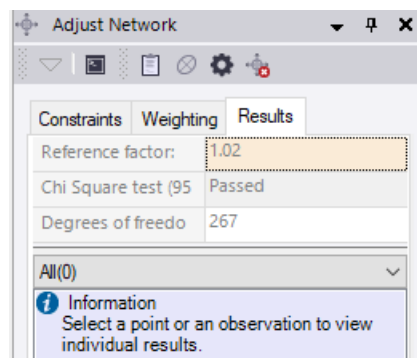
4. Select the constraints for the adjustment by checking the **2D** and **h** checkboxes for the following points:
 - *hard*
 - *P041* (should already be checked)
 - *PLTC*
 - *TMGO*

You might find it easier to first collapse all of the expanded coordinate nodes.



- Click the **Adjust** button and click **Yes** in the **Question** message window to continue the network adjustment without resolving the errors.

The **Results** tab displays.



Typically, you would now review the *Network Adjustment Report*. Based on that review, you might decide to select some other horizontal control points. For this tutorial, you will proceed without selecting other horizontal control points.

Next, you will constrain only the **2D** coordinates for the three horizontal control points. You will also add the benchmark elevations as vertical constraints. In this way, the network is constrained horizontally to the NAD83 local geodetic coordinates and vertically to the NAVD88 benchmark elevations as measured by the DiNi level.

- On the **Constraints** tab, uncheck the **h** checkbox for each of the four local points:
 - hard*
 - P041*

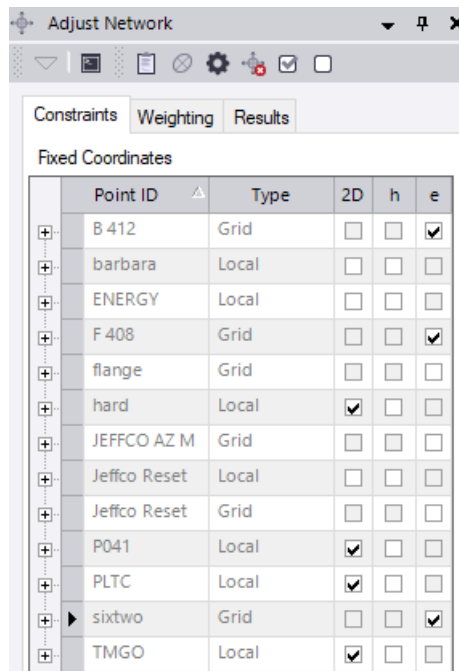
- *PLTC*
- *TMGO*

This removes the ellipsoid height constraints that you added earlier.

7. Check the **e** checkbox for the grid points:

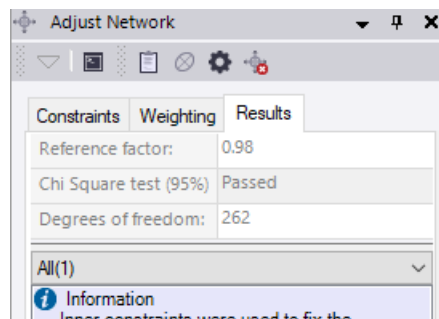
- *B 412*
- *F 408*
- *sixtwo*

This adds the benchmark elevation for the adjustment.

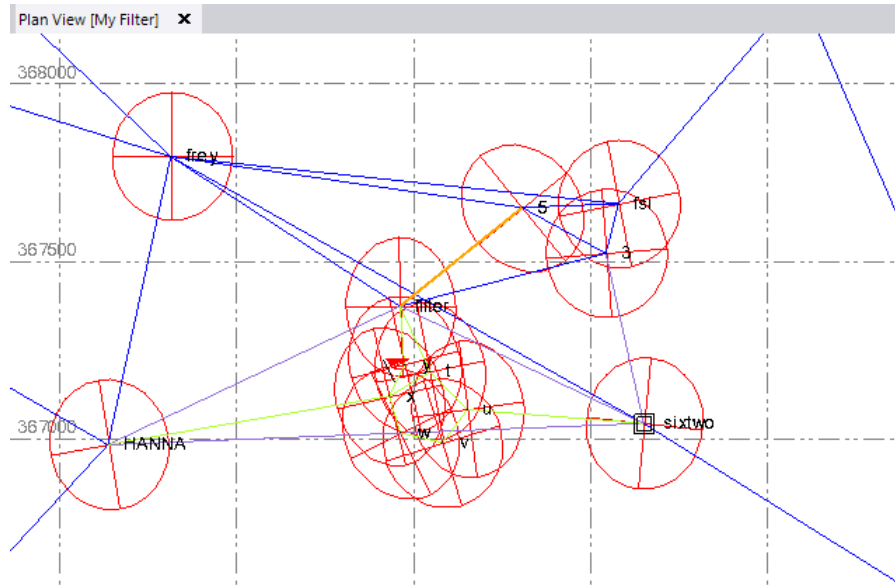


8. Click the **Adjust** button and click **Yes** in the **Question** message window to continue the network adjustment without resolving the errors.

The **Results** tab displays.



9. Click on the **Plan View** and use your mouse wheel to zoom in. Then press the mouse wheel and move the mouse to center the points as shown here. (Alternatively, in the **SO** ribbon, select **Home > View > Zoom In** and **Home > View > Center**.)



The error ellipses are displayed in red.

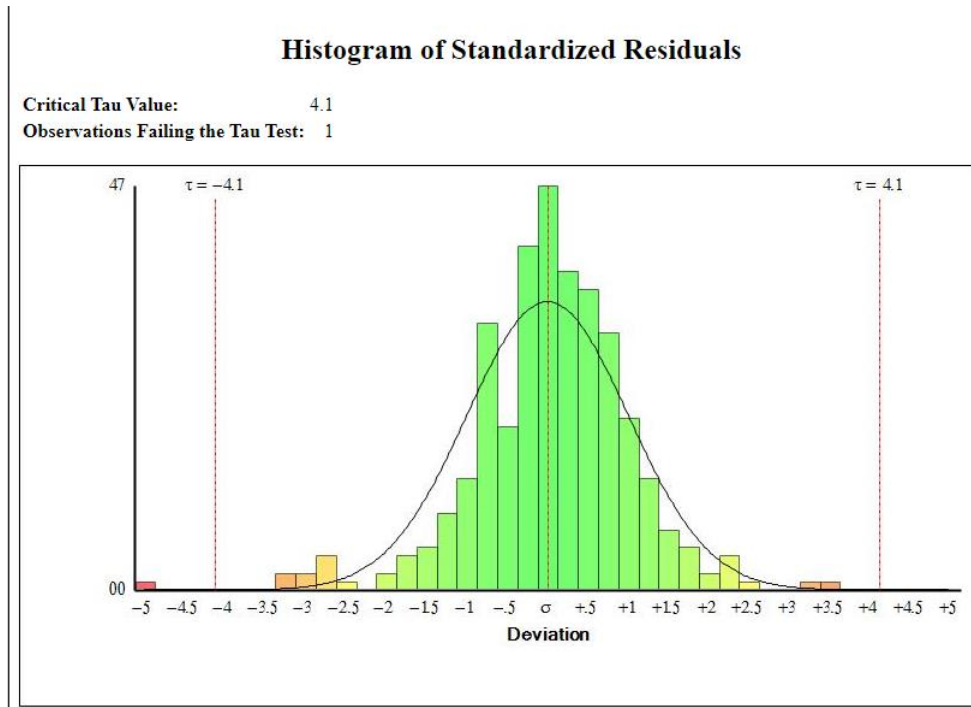
- In the **Adjust Network** pane, click the **Report** icon and view the "Adjusted Grid Coordinates" section of the *Network Adjustment Report*.

This section of the report illustrates which coordinates were held fixed in the adjustment. All coordinates except for control points have estimated errors.

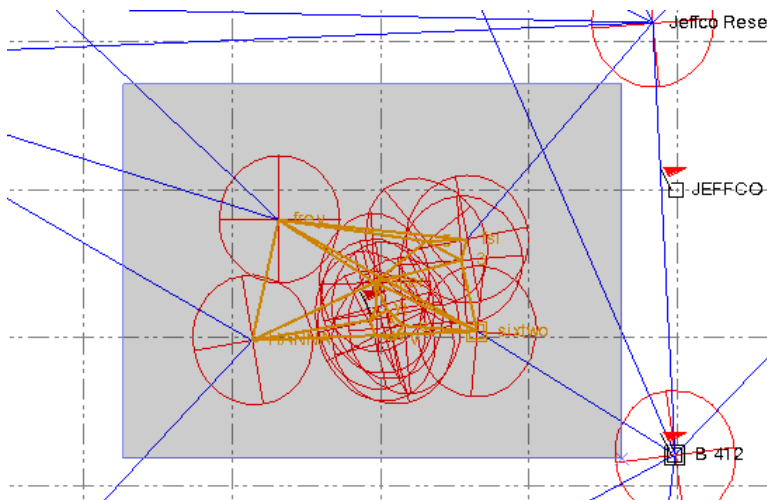
Point ID	Northing (Meter)	Northing Error (Meter)	Easting (Meter)	Easting Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
3	367522.3125	0.0034	947543.0469	0.0033	1667.9250	0.0084	
5	367651.4431	0.0029	947306.4788	0.0032	1673.5892	0.0088	
5b	?	?	?	?	1674.1904	0.0093	
B 412	366213.0316	0.0028	948981.6641	0.0025	1636.1572	?	e
barbara	362388.0203	0.0028	941895.8545	0.0024	1773.1058	0.0466	
ENERGY	368872.9875	0.0025	942874.4579	0.0022	1785.0314	0.0097	
F 408	369416.5122	0.0029	936777.2894	0.0025	1809.3031	?	e
filter	367373.7508	0.0025	946961.6859	0.0021	1662.3475	0.0073	

The **Results** tab in the **Adjust Network** pane displays errors and residuals for one or more selected points, observations, or postprocessed vectors.

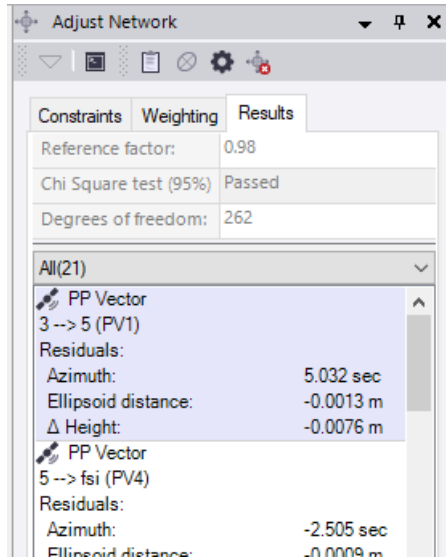
You can also view the "Histogram of Standardized Residuals" section and compare the histogram to the report you generated for the minimally constrained network adjustment earlier in the tutorial.



- In the **Plan View**, select the items you want to view by clicking and dragging to "draw" a box around them.



Your selections display in the **Results** tab.




You are done adjusting the network. Next, you will import additional data into your adjusted project.

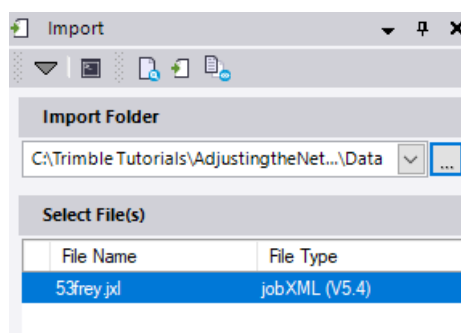
Step 5. Import additional data into the adjusted project

If the additional job data you are importing includes the same point IDs as your adjusted project, you can select to have the new coordinates based on the adjusted coordinate values. In this case, you will import a new data file that includes a traverse from point 5 to point *frey*, points that already exist in your adjusted project.

1. Select **Home > Data Exchange > Import**.

The **Import** pane opens in the right side of the **Survey Office** window.

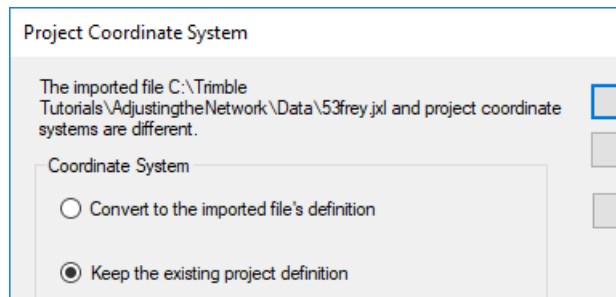
2. In the **Import** pane, click the **Browse** button  and browse to `..\AdjustingtheNetwork\Data` and click **OK**.



3. In the **Select File(s)** list, select *53frey.jxl* and click the **Import** button.

Since the software detects a difference between the coordinate system specified in the project and the coordinate system specified in the imported file, the **Project Coordinate System** message dialog displays.

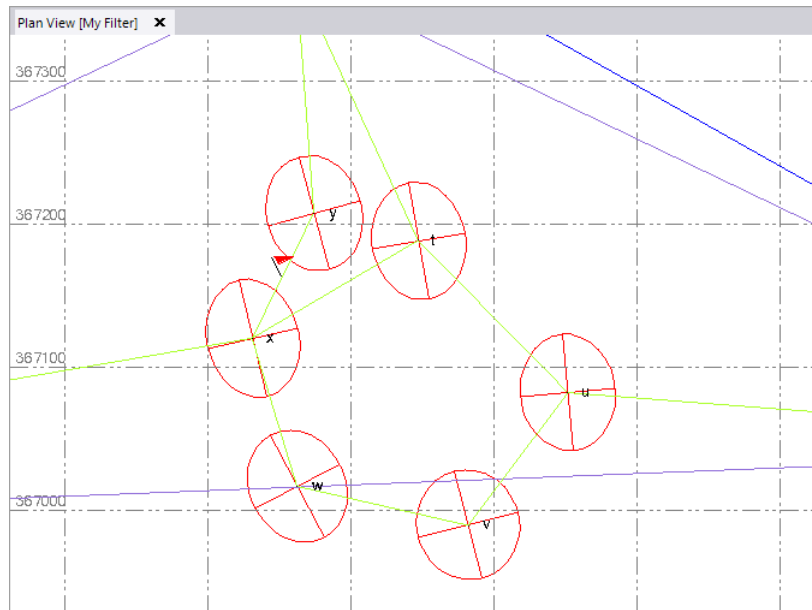
4. Select the **Keep the existing project definition** option in the **Project Coordinate System** message dialog. Then click **OK**.



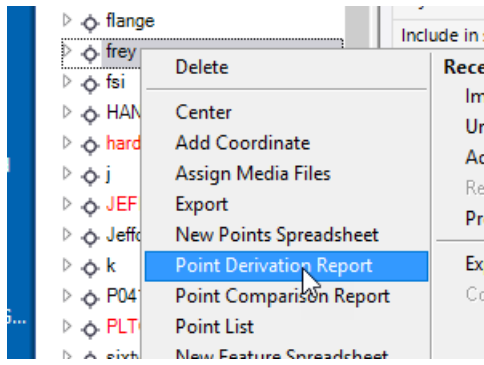
5. In the **Clear Adjustment** dialog, click the **Keep Adjustment** button.

The new data is imported based on the coordinate values of points *5* and *frey* that were calculated in the network adjustment.

Use your mouse wheel to enlarge the view as shown here to see the newly imported traverse.



6. If the **Project Explorer** pane is not already open, select **Home >Data > Project Explorer**. Then, expand the **Points** node, right-click *frey*, and select **Point Derivation Report**.



The *Point Derivation Report* displays in a browser window.

Point Derivations

Resultant Coordinates for point: frey						
Northing		Easting		Elevation		I
367794.8363 m		946313.8009 m		1674.7566 m		1658
Data	Used to calc.	Status	Δ North (Meter)	Δ East (Meter)	Distance (Horiz) (Meter)	Δ Elevation (Meter)
Adjusted (Local)	NEeh	Enabled	0.0000 m	0.0000 m	0.0000 m	0.0000 r
Grid (53frey.jxl)		Enabled	-0.0003 m	0.0145 m	0.0145 m	-0.0207 r
P041 → frey		Enabled	-0.0003 m	-0.0004 m	0.0005 m	-0.0002 r
HANNA → frey		Enabled	-0.0014 m	0.0074 m	0.0075 m	-0.0038 r
ENERGY → frey		Enabled	0.0009 m	0.0017 m	0.0019 m	0.0018 r

The report shows the value where point *frey* was established. In this case, it is the network adjusted value. You can also see the coordinate value from the *53frey.jxl* file import.

This completes the tutorial.