Chapter 6

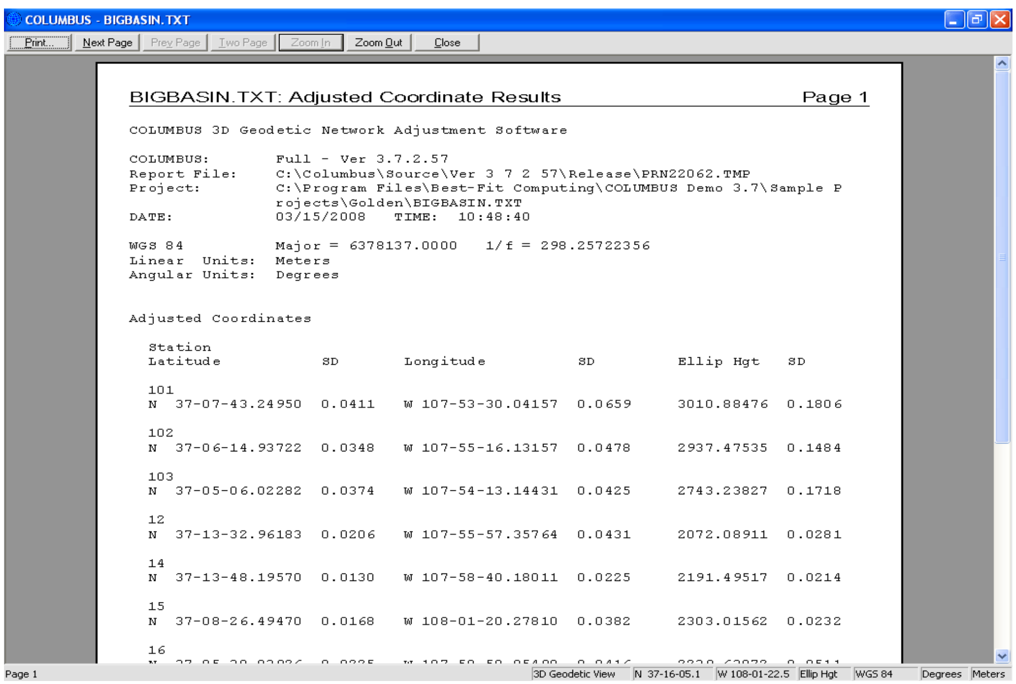
Network Results *(updated September 7, 2009)*

Results Overview

The RESULTS views allows you to examine results from your 1D, 2D or 3D network adjustment or pre-analysis. Refer to the NETWORK chapter of this manual for a discussion on performing network adjustment or network pre-analysis.

Throughout this chapter, we will be referring to results from the 3D Geodetic adjustment of the **BIGBASIN.TXT** network described in the NETWORK chapter. Where appropriate, we will mention how the results views might differ for a 1D Vertical or 2D Geodetic adjustment.

The results from network adjustment or network pre-analysis are displayed within individual views. Several views can be examined simultaneously. To write the results from a view to a report file, invoke the REPORT command or click on the Report toolbar button. COLUMBUS will prompt you for the name of a report file. You can either create a new report file or append to the bottom of an existing file. To print the report directly, invoke the FILE - PRINT or FILE - PRINT PREVIEW command.



You can also automatically generate all applicable reports desired by turning on report generation flags in the OPTIONS - NETWORK OPTIONS - REPORT SETTINGS dialog. All selected reports that are applicable to the network adjustment or pre-analysis (1D vertical, 2D geodetic, 3D State Plane, etc.) will be written into the **Network Processing Summary** view. From here, you can PRINT, use PRINT - PREVIEW or write the results to a report file by invoking the RESULTS - REPORT menu command or toolbar button.

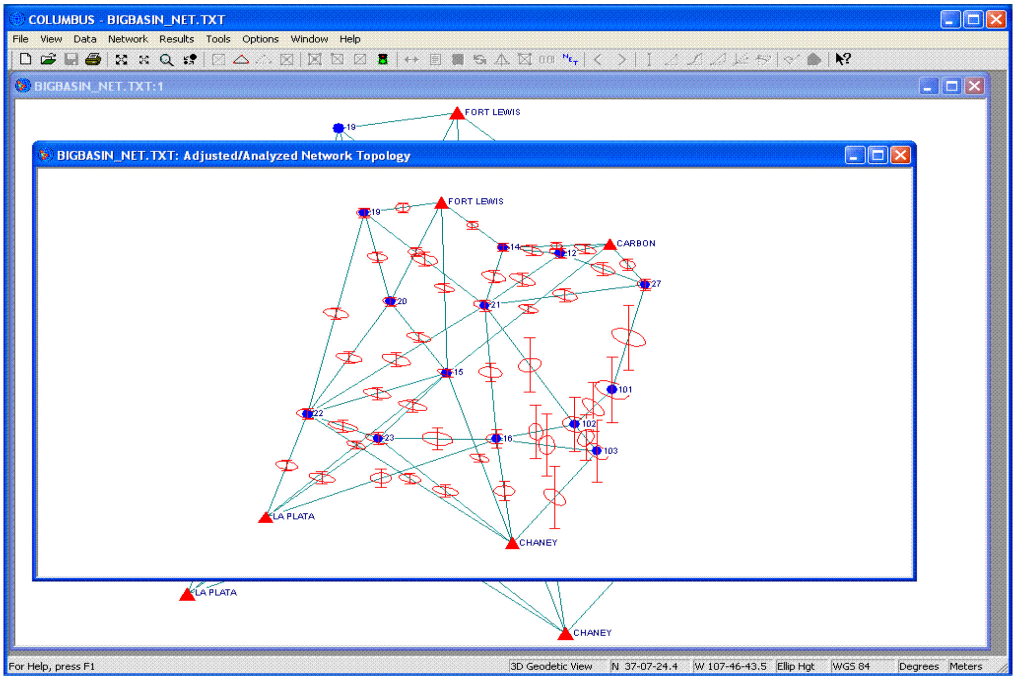
Most report views contain multiple columns of data. You can sort the report view by any column (toggling between ascending and descending order) by simply clicking on a column header. To sort by the absolute value of a numeric column, change the VIEW - SORT BY ABSOLUTE VALUE menu item to a checked state.

You can resize the width of any column by grabbing the applicable column separator with the mouse and moving it left or right. Using this technique, you can hide the contents of a column by simply making that column very narrow. This will enhance your ability to look at only the data in which you are interested.

Any changes to a view column width is remembered by COLUMBUS the next time you display the view. You can always set the column widths back to their default values by selecting the RESTORE DEFAULT WIDTH command from the RESULTS menu or by clicking the Restore Default Width toolbar button. The width, for all columns, is restored for the focused view.

Network View

To bring up a graphical view of the adjusted network, invoke the ADJUSTED NETWORK VIEW menu item. Only those stations and observations included in the adjustment or pre-analysis will be visible. Stations that have been selected to be hidden, will not be shown.



From the Adjusted Network View you can access additional results:

- To examine the adjusted coordinates for a station, double click on the station symbol.
- To examine the error ellipses for any adjusted station or between stations, double click within the applicable error ellipse. For 1D Vertical networks, height error information can be viewed by double clicking within the 1D height bars (they look like a capital letter ’I’ or a sideways ’H’).
- To examine the adjusted observation between any two stations, double click on the line connecting the station pair.

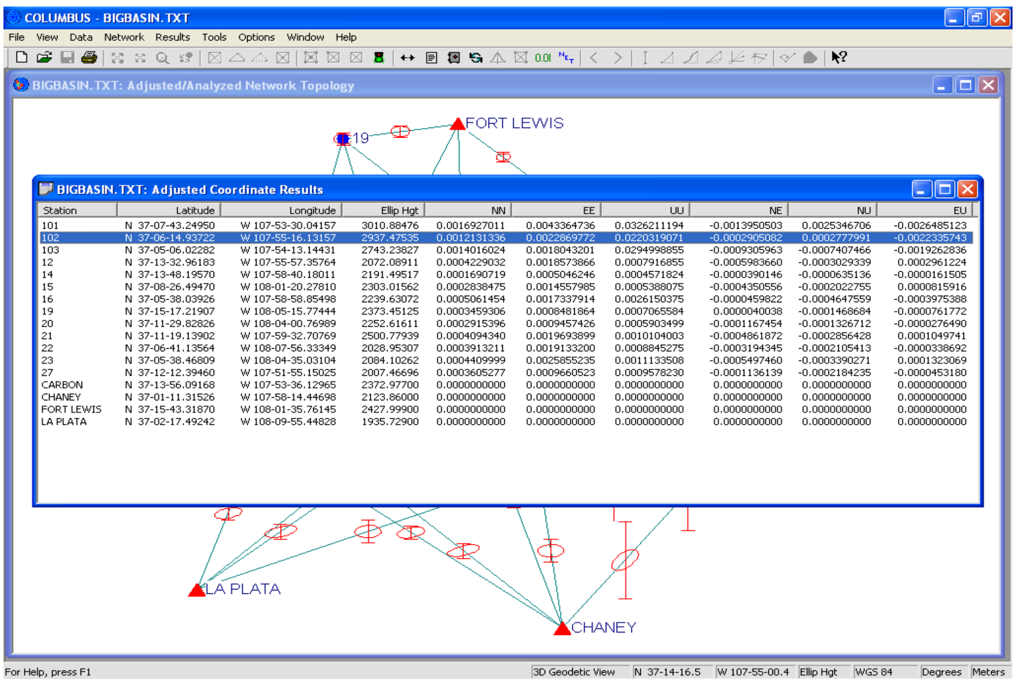
Coordinates

Geodetic Coordinates

Select the COORDINATES - ADJUSTED GEODETIC COORDS command to display the adjusted geodetic coordinates view following a geodetic, State Plane, or UTM adjustment or geodetic pre-analysis.

For each station, the adjusted coordinates and their estimated *a posteriori* covariance matrix (NEU matrix) is displayed. Each station is presented in alphabetical order by default. Click on any column to sort the view by that columns' data.

To switch from viewing the covariance matrix to viewing individual coordinate component standard deviations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button. The latitude, longitude and height standard deviations are the square root of the corresponding covariance diagonal elements.



In the screen above, the adjusted latitude, longitude and height for Station 102 is highlighted.

The adjusted coordinates (latitude, longitude and height) are stored in a temporary area of the project. To Keep these coordinates into the project where other modules have access to them, invoke the KEEP command or the Keep toolbar button. You can Keep some or all of the adjusted station coordinates into the project. For a 3D geodetic adjustment, you will be prompted for the height field you want to change when keeping either orthometric height or ellipsoidal height.

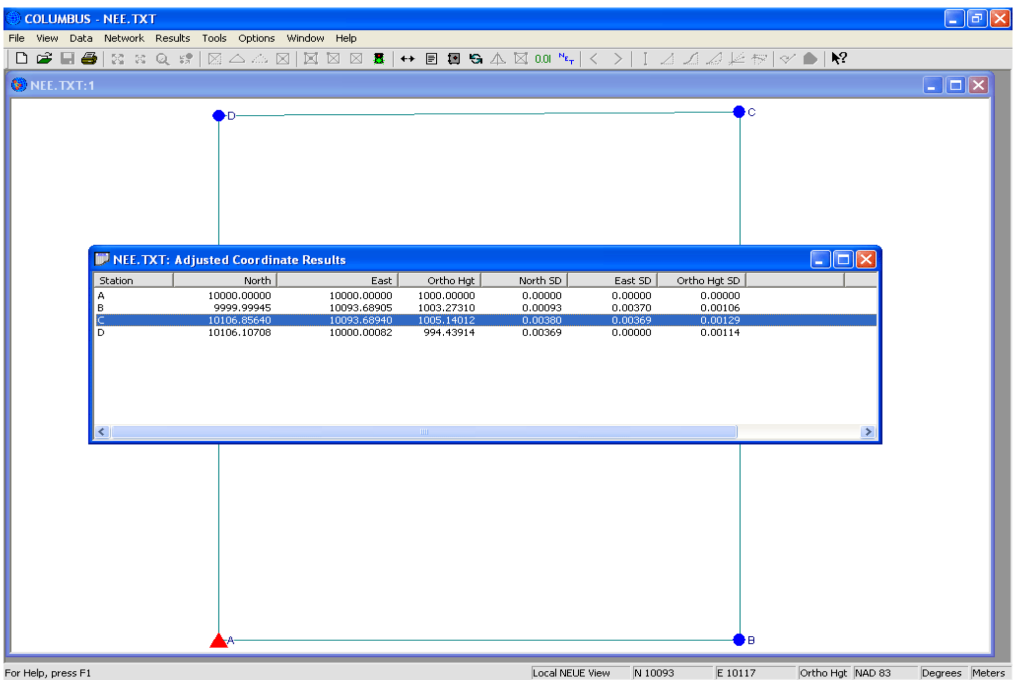
Keeping coordinates into the project does not save them to disk. Once the coordinates have been Kept, they can be stored to disk (for future loading) by returning to the FILE menu and invoking the SAVE or SAVE AS option.

Local NEE Coordinates

Select the COORDINATES - ADJUSTED LOCAL NEE COORDS command to display the adjusted local NEE (or NE if a 2D adjustment) coordinates view following a Local NEE adjustment.

For each station, the adjusted coordinates and their estimated *a posteriori* covariance matrix (NEU matrix) is displayed. Each station is presented in alphabetical order by default. Click on any column to sort the view by that columns' data.

To switch from viewing the covariance matrix to viewing individual coordinate component standard deviations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button. The north, east and orthometric height standard deviations are the square root of the corresponding covariance diagonal elements.



In the screen above, the adjusted north, east and orthometric height for Station C is highlighted (from sample project NEE.TXT).

The adjusted coordinates (north, east and orthometric height) are stored in a temporary area of the project. To Keep these coordinates into the project where other modules have access to them, invoke the KEEP command or the Keep toolbar button. You can Keep some or all of the adjusted station coordinates into the project.

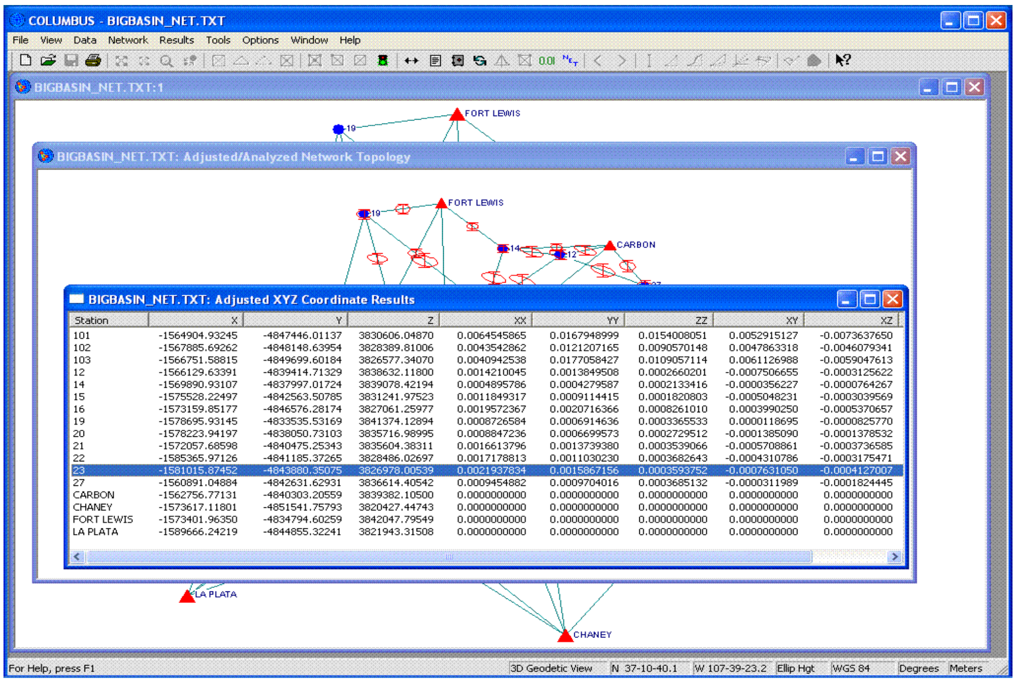
Keeping coordinates into the project does not save them to disk. Once the coordinates have been Kept, they can be stored to disk (for future loading) by returning to the FILE menu and invoking the SAVE or SAVE AS option.

ECEF XYZ Coordinates

Select the COORDINATES - ADJUSTED XYZ COORDS command to display the adjusted ECEF XYZ coordinates view following a 3D Geodetic of 3D ECEF XYZ adjustment.

For each station, the adjusted coordinates and their estimated *a posteriori* covariance matrix (XYZ matrix) is displayed. Each station is presented in alphabetical order by default. Click on any column to sort the view by that columns' data.

To switch from viewing the covariance matrix to viewing individual XYZ component standard deviations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button. The X, Y and Z standard deviations are the square root of the corresponding covariance diagonal elements.



Station	X	Y	Z	XX	YY	ZZ	XY	XZ
101	-1564904.93245	-4847446.01137	3830606.04870	0.0064545865	0.0167948999	0.0154008051	0.0052915127	-0.0073637650
102	-1567885.69262	-4848148.63954	3828389.81006	0.0043542862	0.0121207165	0.0090570148	0.0047863318	-0.0046079341
103	-1566751.58815	-4849699.60184	3826577.34070	0.0040942538	0.0177058427	0.0109057114	0.0061126988	-0.0059047613
12	-1566129.63391	-4839414.71329	3838632.11800	0.0014210045	0.0013849508	0.0002660201	-0.0007506655	-0.0003125622
14	-1569890.93107	-4837997.01724	3839078.42194	0.0004895786	0.0004279587	0.0002133416	-0.0000356227	-0.0000764267
15	-1575528.22497	-4842563.50785	3831241.97523	0.0011849317	0.0009114415	0.0001820803	-0.0005048231	-0.0003039569
16	-1573159.85177	-4846576.28174	3827061.25977	0.0019572367	0.0020716366	0.0008261010	0.0003990250	-0.0005370657
19	-1578695.93145	-4833535.53169	3841374.12894	0.0008726584	0.0006914636	0.0003365533	0.0000118695	-0.0000825770
20	-1578223.94197	-4838050.73103	3835716.98995	0.0008847236	0.0006699573	0.0002729512	-0.0001385090	-0.0001378532
21	-1572057.68598	-4840475.25343	3835604.38311	0.0016613796	0.0013739380	0.0003539066	-0.0005708861	-0.0003736585
22	-1585365.97126	-4841185.37265	3828486.02697	0.0017178813	0.0011030230	0.0003682643	-0.0004310786	-0.0003175471
23	-1581015.87452	-4843880.35075	3826978.00539	0.0021937834	0.0015867156	0.0003593752	-0.0007631050	-0.0004127007
27	-1560891.04884	-4842631.62931	3836614.40542	0.0009454882	0.0009704016	0.0003685132	-0.0000311989	-0.0001824445
CARBON	-1562756.77131	-4840303.20559	3839382.10500	0.0000000000	0.0000000000	0.0000000000	0.0000000000	0.0000000000
CHANEY	-1573617.11801	-4851541.75793	3820427.44743	0.0000000000	0.0000000000	0.0000000000	0.0000000000	0.0000000000
FORT LEWIS	-1573401.96350	-4834794.60259	3842047.79549	0.0000000000	0.0000000000	0.0000000000	0.0000000000	0.0000000000
LA PLATA	-1589666.24219	-4844855.32241	3821943.31508	0.0000000000	0.0000000000	0.0000000000	0.0000000000	0.0000000000

In the screen above, the adjusted ECEF XYZ Station 23 is highlighted.

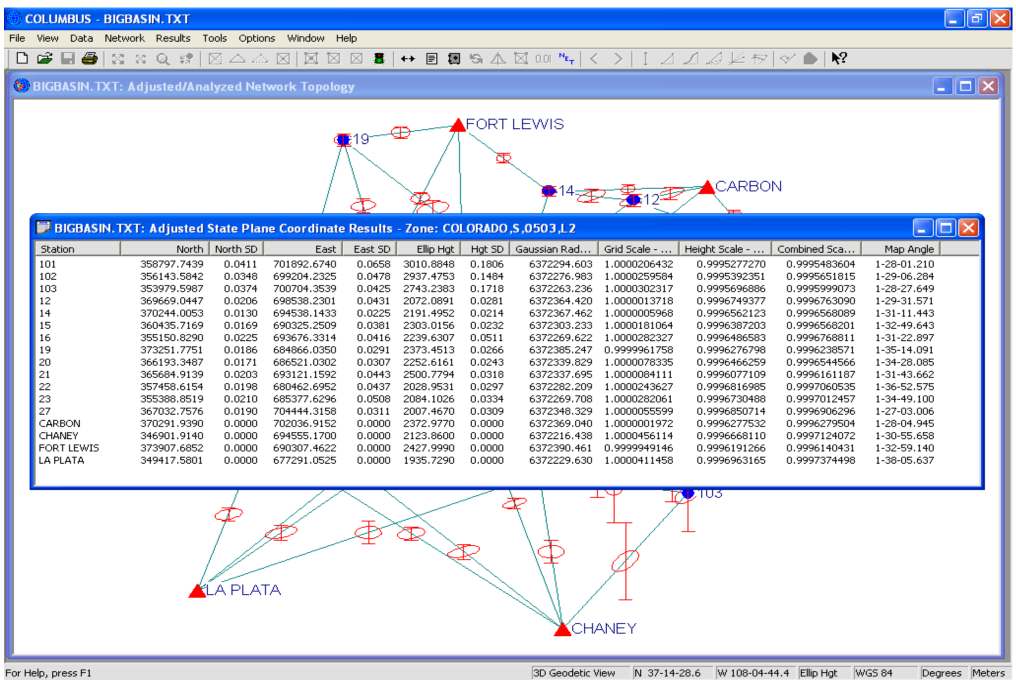
The adjusted coordinates (X, Y and Z) are stored in a temporary area of the project. To Keep these coordinates into the project where other modules have access to them, invoke the KEEP command or the Keep toolbar button. You can Keep some or all of the adjusted station coordinates into the project.

Keeping coordinates into the project does not save them to disk. Once the coordinates have been Kept, they can be stored to disk (for future loading) by returning to the FILE menu and invoking the SAVE or SAVE AS option.

State Plane Coordinates

Select the COORDINATES - ADJUSTED STATE PLANE COORDS command to display the adjusted coordinates in State Plane form (after a geodetic, State Plane or UTM adjustment) .

The State Plane zone is visible in the view title. If the correct zone is not shown, enter the OPTIONS - PROJECTION ZONES - STATE PLANE ZONES list and select the correct zone. The coordinates will immediately be re-calculated. If your zone is not shown in the list, set up a User Defined Zone using one of the first four choices (see OPTIONS chapter of this manual for details). **Modifying the State Plane zone on the fly, as described above, is only possible after a geodetic or UTM adjustment.**



Station	North	North SD	East	East SD	Ellip Hgt	Hgt SD	Gaussian Rad...	Grid Scale - ...	Height Scale - ...	Combined Sca...	Map Angle
101	358797.7439	0.0411	701892.6740	0.0658	3010.8848	0.1806	6372294.603	1.0000206432	0.9995277270	0.9995483604	1-28-01.210
102	356143.5842	0.0348	699204.2325	0.0478	2937.4753	0.1484	6372276.983	1.0000259584	0.9995392351	0.9995651815	1-29-06.284
103	353979.5987	0.0374	700704.3539	0.0425	2743.2383	0.1718	6372263.236	1.0000302317	0.9995696886	0.9995999073	1-28-27.649
12	369669.0447	0.0206	698538.2301	0.0431	2072.0891	0.0281	6372364.420	1.0000013718	0.9996749377	0.9996763090	1-29-31.571
14	370244.0053	0.0130	694538.1433	0.0225	2191.4952	0.0214	6372367.462	1.0000005968	0.9996562123	0.9996568089	1-31-11.443
15	360435.7169	0.0169	690325.2509	0.0381	2303.0156	0.0232	6372303.233	1.0000181064	0.9996387203	0.9996568201	1-32-49.643
16	355150.8290	0.0225	693676.3314	0.0416	2239.6307	0.0511	6372269.622	1.0000282327	0.9996486583	0.9996768811	1-31-22.897
19	373251.7751	0.0186	684866.0350	0.0291	2373.4513	0.0266	6372385.247	0.9999961758	0.9996276798	0.9996238571	1-35-14.091
20	366193.3487	0.0171	686521.0302	0.0307	2252.6161	0.0243	6372339.829	1.0000078335	0.9996466259	0.9996544566	1-34-28.085
21	365684.9139	0.0203	693121.1592	0.0443	2500.7794	0.0318	6372337.695	1.0000084111	0.9996077109	0.9996161187	1-31-43.662
22	357458.6154	0.0198	680462.6952	0.0437	2028.9531	0.0297	6372282.209	1.0000243627	0.9996816985	0.9997060535	1-36-52.575
23	355388.8519	0.0210	685377.6296	0.0508	2084.1026	0.0334	6372269.708	1.0000282061	0.9996730488	0.9997012457	1-34-49.100
27	367032.7576	0.0190	704444.3158	0.0311	2007.4670	0.0309	6372348.329	1.0000055599	0.9996850714	0.9996906296	1-27-03.006
CARBON	370291.9390	0.0000	702036.9152	0.0000	2372.9770	0.0000	6372369.040	1.0000001972	0.9996277532	0.9996279504	1-28-04.945
CHANEY	346901.9140	0.0000	694555.1700	0.0000	2123.8600	0.0000	6372216.438	1.0000456114	0.9996668110	0.9997124072	1-30-55.658
FORT LEWIS	373907.6852	0.0000	690307.4622	0.0000	2427.9990	0.0000	6372390.461	0.9999949146	0.9996191266	0.9996140431	1-32-59.140
LA PLATA	349417.5801	0.0000	677291.0525	0.0000	1935.7290	0.0000	6372229.630	1.0000411458	0.9996963165	0.9997374498	1-38-05.637

For each station, the adjusted grid north, grid east, and height are shown along with their standard deviation. Also shown is the gaussian radius, grid scale factor, height scale factor, combined scale factor, and the grid mapping angle.

The height scale factor and combined scale factor are based on the adjusted ellipsoidal height when the adjustment is based on ellipsoidal height (only applicable for a 3D geodetic adjustment). Otherwise, they are based on the estimated ellipsoidal height (the adjusted orthometric height + the approximate average geoid height shown in the view title).

The height scale factor takes you from the surface (ground) to the ellipsoid. The grid scale factor takes you from the ellipsoid to grid. The combined scale factor takes you from surface (ground) to grid in one calculation (it is simply the grid scale factor * height scale factor).

The average gaussian radius, grid scale factor, height scale factor and combined scale factor are viewable in their respective column label. This information can be useful when creating a custom projection for your project.

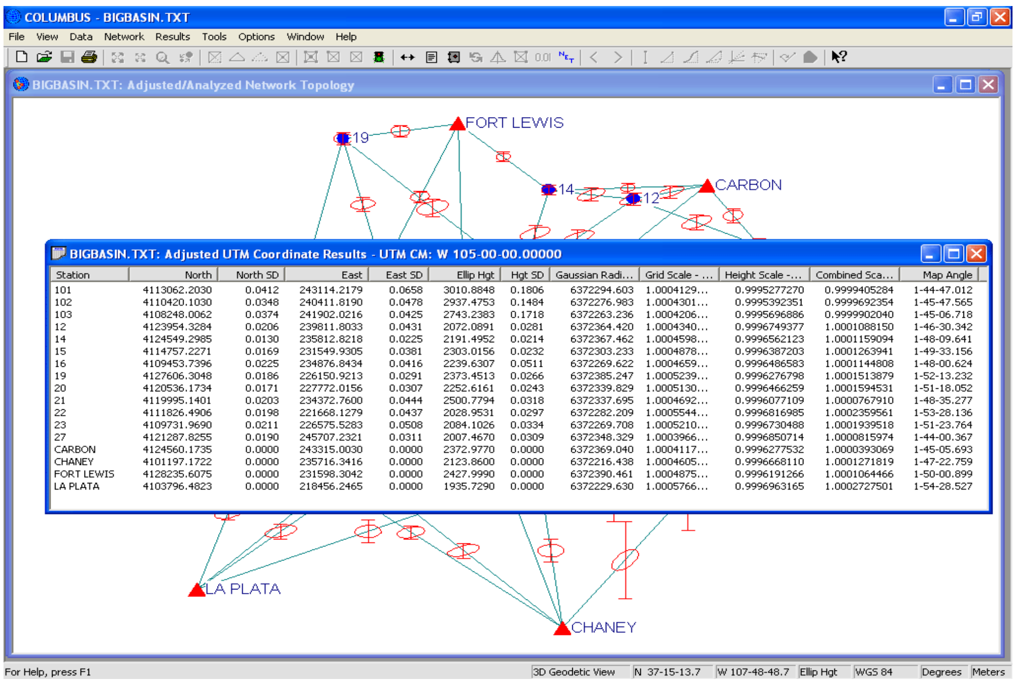
The adjusted State Plane coordinates are stored in a temporary area of the project. To Keep these coordinates into the project where other modules have access to them, invoke the KEEP command or the Keep toolbar button. You can Keep some or all of the adjusted station coordinates into the project.

Keeping coordinates into the project does not save them to disk. Once the coordinates have been Kept, they can be stored to disk (for future loading) by returning to the FILE menu and invoking the SAVE or SAVE AS option.

UTM Coordinates

Select the COORDINATES - ADJUSTED UTM COORDS command to display the adjusted coordinates in UTM form (after a geodetic, State Plane or UTM adjustment) .

The UTM Central Meridian is visible in the view title. If the correct value is not shown, enter the OPTIONS - PROJECTION ZONES - UTM ZONE SETUP dialog and set up the correct value. The coordinates will immediately be re-calculated. **Modifying the UTM Central Meridian on the fly, as described above, is only possible after a geodetic or State Plane adjustment.**



Station	North	North SD	East	East SD	Ellip Hgt	Hgt SD	Gaussian Radi...	Grid Scale - ...	Height Scale -...	Combined Sca...	Map Angle
101	4113062.2030	0.0412	243114.2179	0.0658	3010.8848	0.1806	6372294.603	1.0004129...	0.9995277270	0.9999405284	1-44-47.012
102	4110420.1030	0.0348	240411.8190	0.0478	2937.4753	0.1484	6372276.983	1.0004301...	0.9995392351	0.9999692354	1-45-47.565
103	4108248.0062	0.0374	241902.0216	0.0425	2743.2383	0.1718	6372263.236	1.0004206...	0.9995696886	0.9999902040	1-45-06.718
12	4123954.3284	0.0206	239811.8033	0.0431	2072.0891	0.0281	6372364.420	1.0004340...	0.9996749377	1.0001088150	1-46-30.342
14	4124549.2985	0.0130	235812.8218	0.0225	2191.4952	0.0214	6372367.462	1.0004598...	0.9996562123	1.0001159094	1-48-09.641
15	4114757.2271	0.0169	231549.9305	0.0381	2303.0156	0.0232	6372303.233	1.0004878...	0.9996387203	1.0001263941	1-49-33.156
16	4109453.7396	0.0225	234876.8434	0.0416	2239.6307	0.0511	6372269.622	1.0004659...	0.9996486583	1.0001144808	1-48-00.624
19	4127606.3048	0.0186	226150.9213	0.0291	2373.4513	0.0266	6372385.247	1.0005239...	0.9996276798	1.0001513879	1-52-13.232
20	4120536.1734	0.0171	227772.0156	0.0307	2252.6161	0.0243	6372339.829	1.0005130...	0.9996466259	1.0001594531	1-51-18.052
21	4119995.1401	0.0203	234372.7600	0.0444	2500.7794	0.0318	6372337.695	1.0004692...	0.9996077109	1.0000767910	1-48-35.277
22	4111826.4906	0.0198	221668.1279	0.0437	2028.9531	0.0297	6372282.209	1.0005544...	0.9996816985	1.0002359561	1-53-28.136
23	4109731.9690	0.0211	226575.5283	0.0508	2084.1026	0.0334	6372269.708	1.0005210...	0.9996730488	1.0001939518	1-51-23.764
27	4121287.8255	0.0190	245707.2321	0.0311	2007.4670	0.0309	6372348.329	1.0003966...	0.9996850714	1.0000815974	1-44-00.367
CARBON	4124560.1735	0.0000	243315.0030	0.0000	2372.9770	0.0000	6372369.040	1.0004117...	0.9996277532	1.0000393069	1-45-05.693
CHANEY	4101197.1722	0.0000	235716.3416	0.0000	2123.8600	0.0000	6372216.438	1.0004605...	0.9996668110	1.0001271819	1-47-22.759
FORT LEWIS	4128235.6075	0.0000	231598.3042	0.0000	2427.9990	0.0000	6372390.461	1.0004875...	0.9996191266	1.0001064466	1-50-00.899
LA PLATA	4103796.4823	0.0000	218456.2465	0.0000	1935.7290	0.0000	6372229.630	1.0005766...	0.9996963165	1.0002727501	1-54-28.527

For each station, the adjusted grid north, grid east, and height are shown along with their standard deviation. Also shown is the gaussian radius, grid scale factor, height scale factor, combined scale factor, and the grid mapping angle.

The height scale factor and combined scale factor are based on the adjusted ellipsoidal height when the adjustment is based on ellipsoidal height (only applicable for a 3D geodetic adjustment). Otherwise, they are based on the estimated ellipsoidal height (the adjusted orthometric height + the approximate average geoid height shown in the view title).

The height scale factor takes you from the surface (ground) to the ellipsoid. The grid scale factor takes you from the ellipsoid to grid. The combined scale factor takes you from surface (ground) to grid in one calculation (it is simply the grid scale factor * height scale factor).

The average gaussian radius, grid scale factor, height scale factor and combined scale factor are viewable in their respective column label. This information can be useful when creating a custom projection for your project.

The adjusted UTM coordinates are stored in a temporary area of the project. To Keep these coordinates into the project where other modules have access to them, invoke the KEEP command or the Keep toolbar button. You can Keep some or all of the adjusted station coordinates into the project.

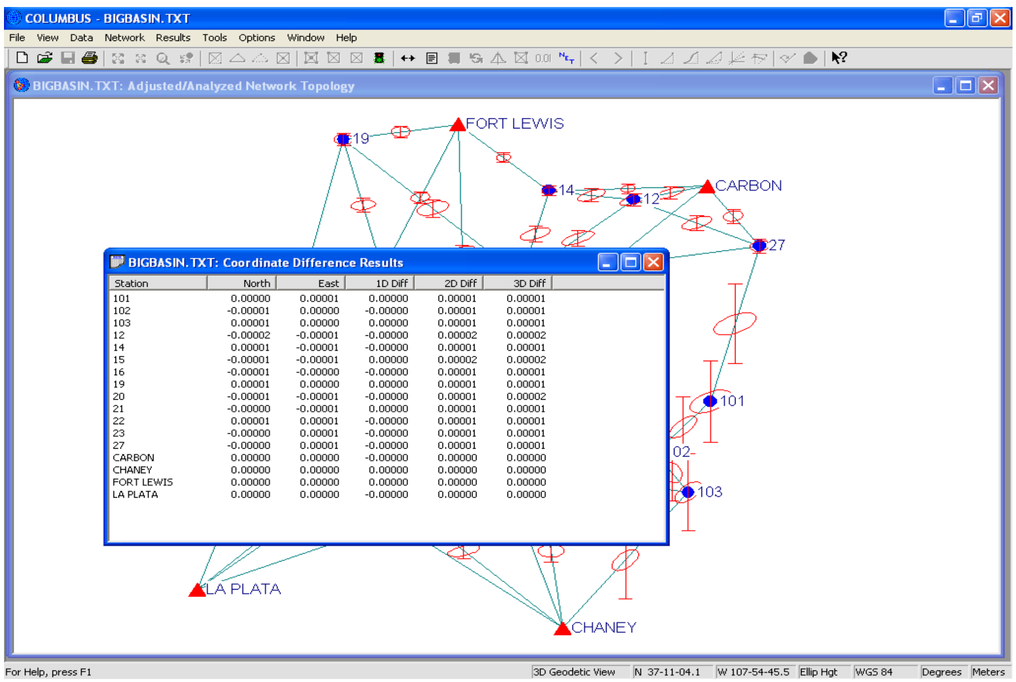
Keeping coordinates into the project does not save them to disk. Once the coordinates have been Kept, they can be stored to disk (for future loading) by returning to the FILE menu and invoking the SAVE or SAVE AS option.

Coordinate Differences

Select the COORDINATES - COORD DIFFERENCES command to display the difference in coordinates (north, east, 1D, 2D, 3D) between the adjusted station position and its current coordinate values in the project. The adjusted coordinates for each station are stored in a temporary area of the project until you perform a Keep. All coordinate differences are presented in the active linear units.

If the coordinates within the project are the same as the adjusted coordinates, each Coordinate Difference will be zero (or very close to zero). This option is useful when you compute several adjustments, each time altering the network slightly. If the results from the current adjustment are Kept into the project, these results can be compared with the results from the next adjustment.

Be sure to invoke this option before Keeping the current adjusted coordinates into the project, otherwise you will get all zeros.

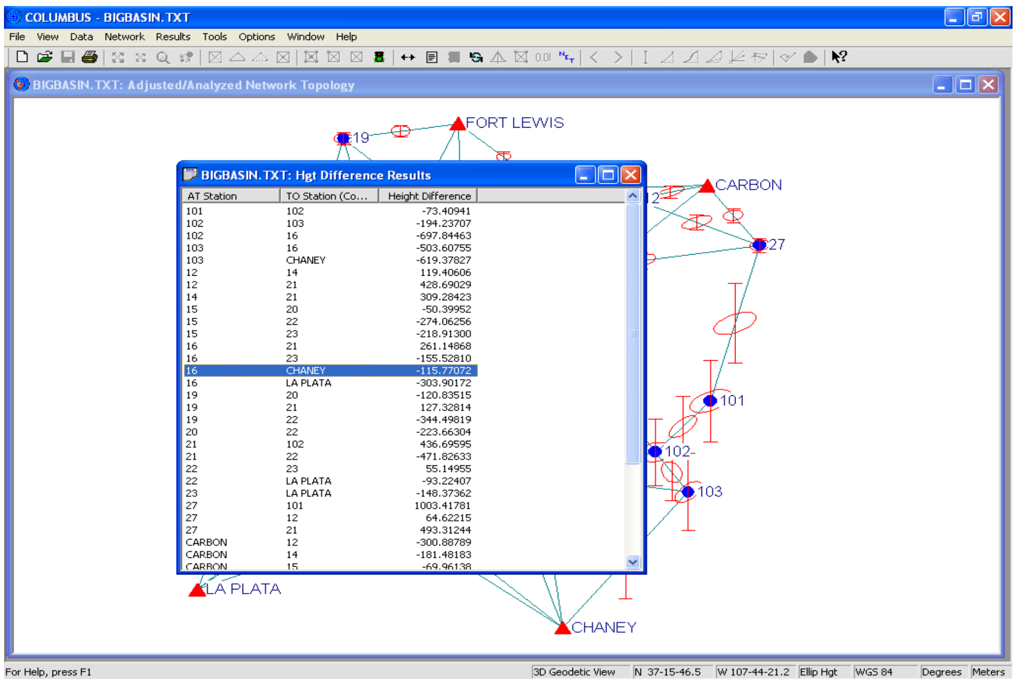


In our example network BIGBASIN.TXT, the coordinates in the ASCII (Text) file are the adjusted coordinates; therefore, all coordinate differences are close to zero.

If you wish to compute the coordinate differences between the adjusted coordinates and the approximate coordinates (computed during adjustment), you must Keep the approximate coordinates into the project before the adjustment finishes (see OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog for instructions on how to view the approximate coordinates computed during adjustment).

1D Height Difference Inverses

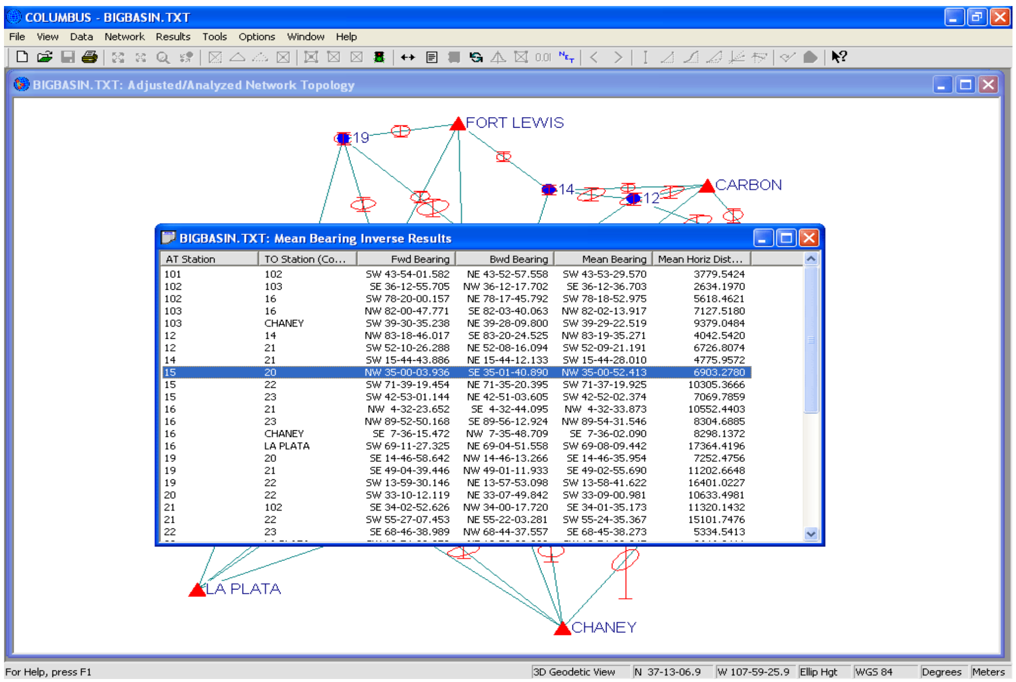
Select the COORDINATES - 1D HGT DIFFERENCE INVERSE command to view the difference in height between each connected station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button. For 3D geodetic networks, the height context (orthometric or ellipsoidal) is dependent on the 3D Geodetic Height setting in the OPTIONS - GLOBAL SETTINGS dialog.



2D Mean Bearing Inverses

Select the COORDINATES - 2D MEAN BEARING INVERSE command to view the Mean Bearing Inverse between each connected station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button.

To compute the mean bearing inverse and mean horizontal distance, the inverse data from the AT station to the TO station is computed and averaged with the inverse data from the TO station to the AT station. The resulting distance is based on the mean height of each station pair.

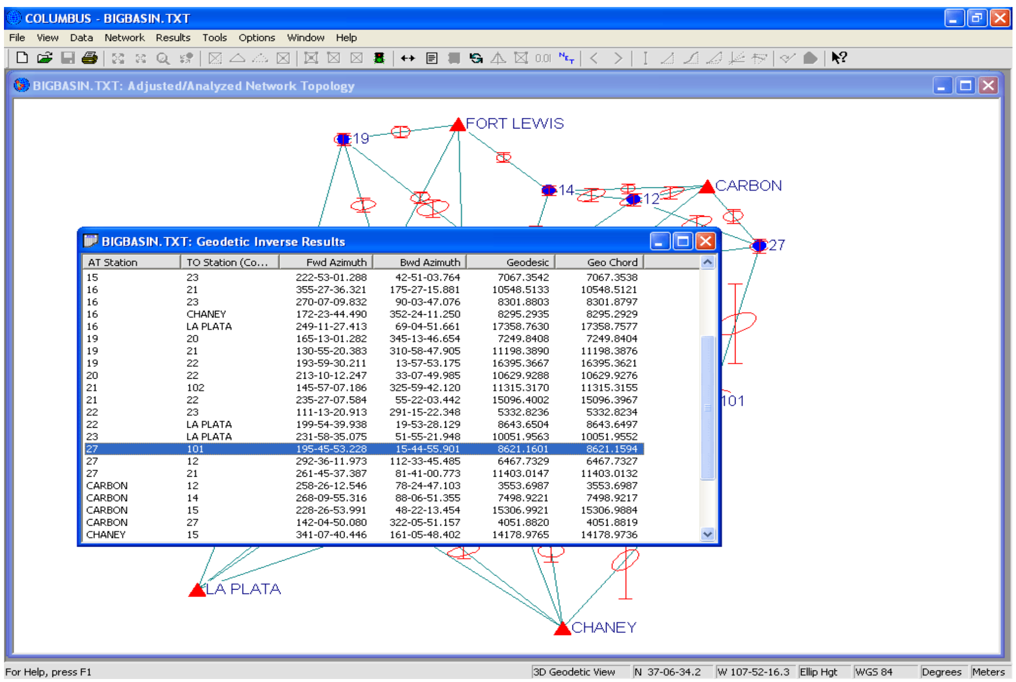


2D Geodetic Inverses

Select the COORDINATES - 2D GEODETIC INVERSE command to view the 2D Geodetic Inverse between each connecting station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The 2D geodetic inverse is computed on the ellipsoidal surface at an ellipsoidal height of zero.

The geodesic is the shortest distance along the ellipsoidal surface between two stations. The geo chord is the shortest distance in 3D space between the two stations. It actually cuts through the ellipsoidal surface and will always be less than or equal to the geodesic distance. Both distances are presented in the active linear units. The geodesic azimuth is the azimuth along the curved geodesic distance.

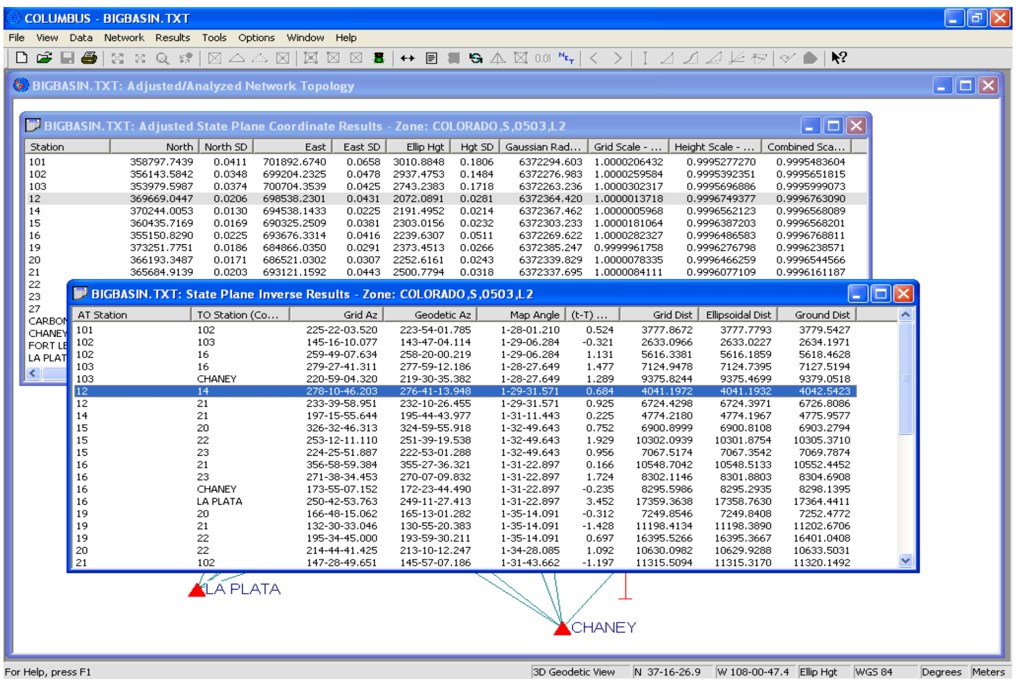


AT Station	TO Station (Co...	Fwd Azimuth	Bwd Azimuth	Geodesic	Geo Chord
15	23	222-53-01.288	42-51-03.764	7067.3542	7067.3538
16	21	355-27-36.321	175-27-15.881	10548.5133	10548.5121
16	23	270-07-09.832	90-03-47.076	8301.8803	8301.8797
16	CHANEY	172-23-44.490	352-24-11.250	8295.2935	8295.2929
16	LA PLATA	249-11-27.413	69-04-51.661	17358.7630	17358.7577
19	20	165-13-01.282	345-13-46.654	7249.8408	7249.8404
19	21	130-55-20.383	310-58-47.905	11198.3890	11198.3876
19	22	193-59-30.211	13-57-53.175	16395.3667	16395.3621
20	22	213-10-12.247	33-07-49.985	10629.9288	10629.9276
21	102	145-57-07.186	325-59-42.120	11315.3170	11315.3155
21	22	235-27-07.584	55-22-03.442	15096.4002	15096.3967
22	23	111-13-20.913	291-15-22.348	5332.8236	5332.8234
22	LA PLATA	199-54-39.938	19-53-28.129	8643.6504	8643.6497
23	LA PLATA	231-58-35.075	51-55-21.948	10051.9563	10051.9552
27	101	195-45-53.228	15-44-55.901	8621.1601	8621.1594
27	12	292-36-11.973	112-33-45.485	6467.7329	6467.7327
27	21	261-45-37.387	81-41-00.773	11403.0147	11403.0132
CARBON	12	258-26-12.546	78-24-47.103	3553.6987	3553.6987
CARBON	14	268-09-55.316	88-06-51.355	7498.9221	7498.9217
CARBON	15	228-26-53.991	48-22-13.454	15306.9921	15306.9884
CARBON	27	142-04-50.080	322-05-51.157	4051.8820	4051.8819
CHANEY	15	341-07-40.446	161-05-48.402	14178.9765	14178.9736

2D State Plane Inverses

Select the COORDINATES - 2D STATE PLANE INVERSE command to view the 2D State Plane Inverses between each connecting station pair in the adjusted network (after a geodetic, State Plane or UTM adjustment). You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The State Plane zone is visible in the view title. If the correct zone is not shown, enter the OPTIONS - PROJECTION ZONES - STATE PLANE ZONES list and select the correct zone. The inverses will immediately be re-calculated. If your zone is not shown in the list, set up a User Defined Zone using one of the first four choices (see OPTIONS chapter of this manual for details). **Modifying the State Plane zone on the fly, as described above, is only possible after a geodetic or UTM adjustment.**



The results for each State Plane inverse include the grid azimuth, geodetic azimuth, mapping angle, (t-T) correction, grid distance, ellipsoidal distance, and the ground distance.

The grid azimuth = geodetic azimuth - mapping angle + (t-T). (t-T) is usually very small (a few angular seconds or less).

The grid distance is the distance along the 2D surface of the projected grid.

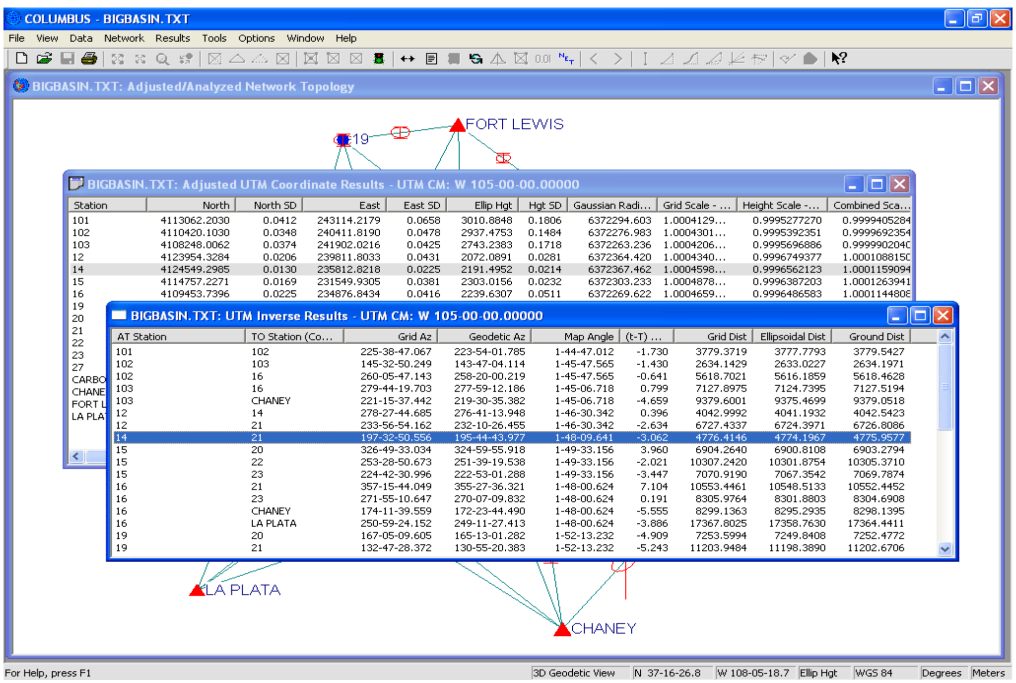
The ellipsoidal distance is the distance on the ellipsoidal surface (ellipsoidal height = 0). It is also called the geodesic.

The ground distance is the distance between the AT and TO station - calculated based on the average adjusted ellipsoidal height for each paired station (only applicable for 3D geodetic adjustment). Otherwise, it is based on the estimated ellipsoidal height (the adjusted orthometric height + the approximate average geoid height shown in the view title).

2D UTM Inverses

Select the COORDINATES - 2D UTM INVERSE command to view the 2D UTM Inverses between each connecting station pair in the adjusted network. (after a geodetic, State Plane or UTM adjustment). You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The UTM Central Meridian is visible in the view title. If the correct value is not shown, enter the OPTIONS - PROJECTION ZONES - UTM ZONE SETUP dialog and set up the correct value. The inverses will immediately be re-calculated. **Modifying the UTM Central Meridian on the fly, as described above, is only possible after a geodetic or State Plane adjustment.**



The results for each UTM inverse include the grid azimuth, geodetic azimuth, mapping angle, (t-T) correction, grid distance, ellipsoidal distance, and the ground distance.

The grid azimuth = geodetic azimuth - mapping angle + (t-T). (t-T) is usually very small (a few angular seconds or less).

The grid distance is the distance along the 2D surface of the projected grid.

The ellipsoidal distance is the distance on the ellipsoidal surface (ellipsoidal height = 0). It is also called the geodesic.

The ground distance is the distance between the AT and TO station - calculated based on the average adjusted ellipsoidal height for each paired station (only applicable for 3D geodetic adjustment). Otherwise, it is based on the estimated ellipsoidal height (the adjusted orthometric height + the approximate average geoid height shown in the view title).

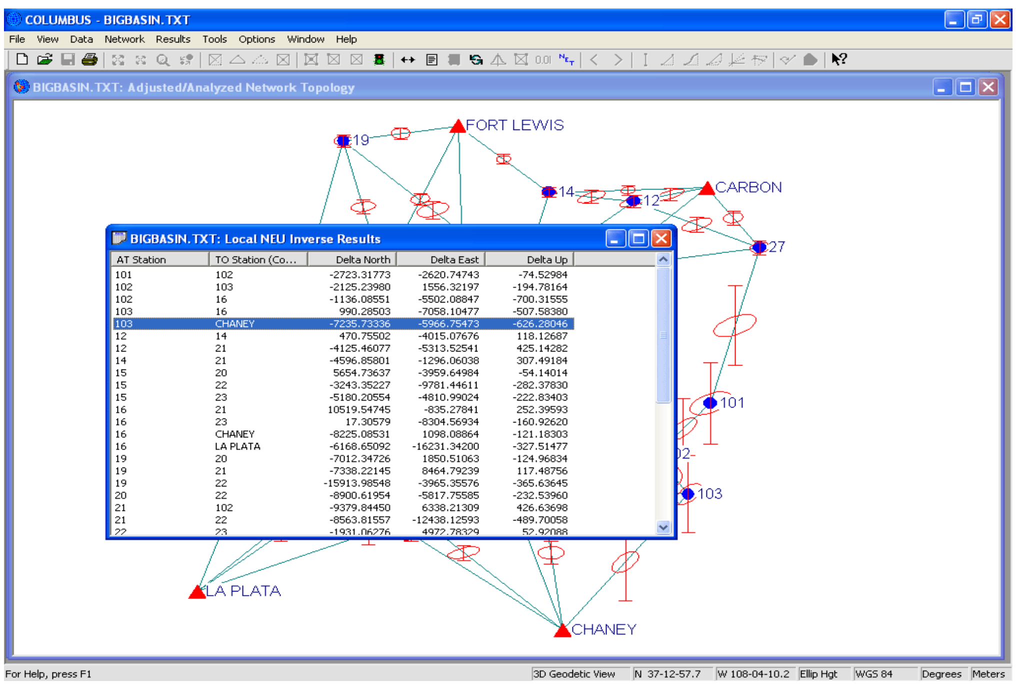
3D Local NEU Inverses

Select the COORDINATES - 3D LOCAL NEU INVERSE command to view the 3D Local Horizon NEU Inverse between each connected station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The 3D Local Horizon NEU inverse is based on a tangent plane surface with its origin at the AT station. This tangent plane forms a Local NEU (North, East and Up) Horizon and is perpendicular to the ellipsoidal normal (which closely approximates the direction of gravity). For a more complete description of this inverse type, please see the TOOLS - COORDINATE GEOMETRY section of this manual.

The chord (slope) distance between the two stations is expressed by the following:

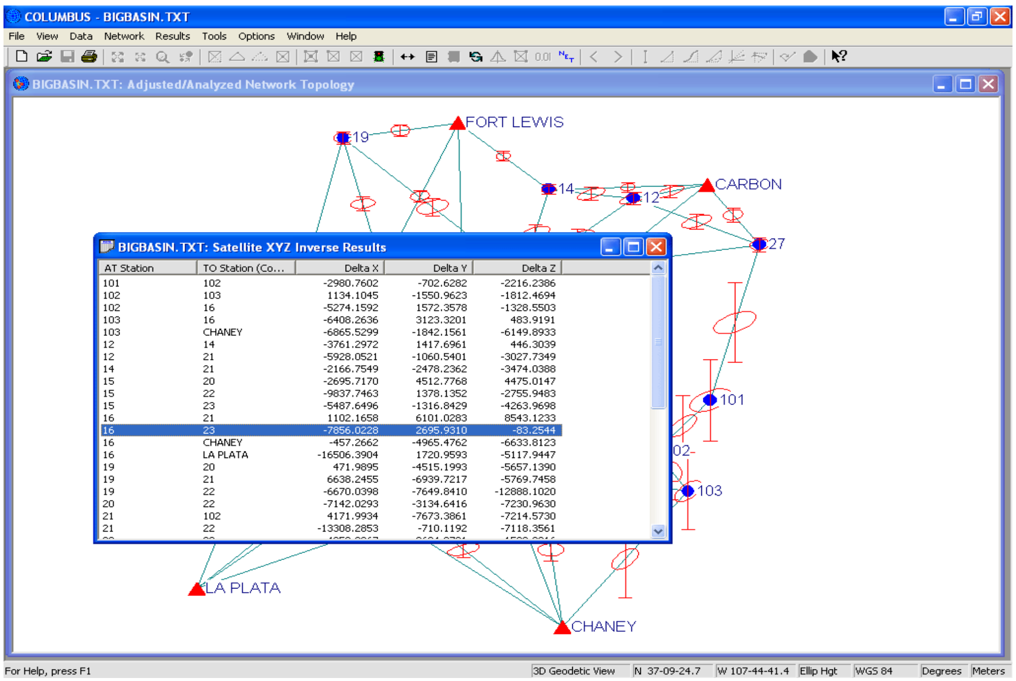
$$chord\ (slope)\ distance\ =\ \sqrt{delta\ north^2 + delta\ east^2 + delta\ up^2}$$



3D Satellite XYZ Inverses

Select the COORDINATES - 3D SATELLITE XYZ INVERSE command to view the GPS type delta X, delta Y, delta Z Inverse between each connected station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The 3D Satellite XYZ inverse (Earth Centered Earth Fixed delta X, Y, Z vector) is analogous to a baseline measured using GPS techniques if the adjustment was performed on the WGS 84 or NAD 83 ellipsoid. Since these are vectors in 3D space, the magnitude of each vector between the AT and TO station is the same in either direction. Only the sign (±) will differ if the AT and TO stations are reversed.



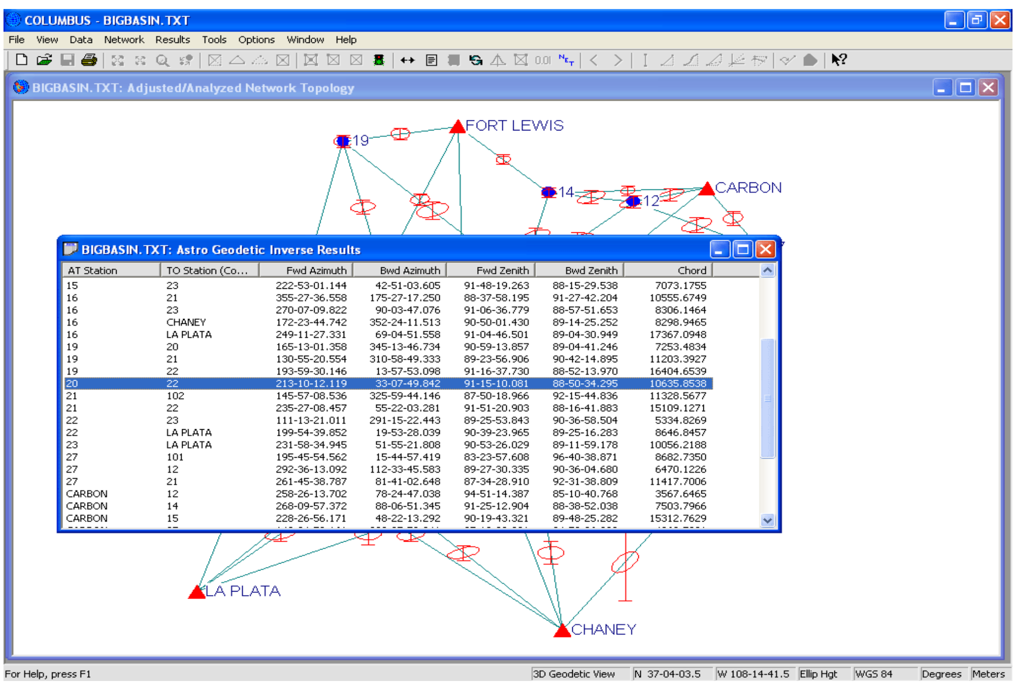
3D Astro Geodetic Inverses

Select the COORDINATES - 3D ASTRO GEODETIC INVERSE command to view the 3D Astro Geodetic Inverse between each connected station pair in the adjusted network. You can also view all station pair combinations by clicking on the Switch Context toolbar button.

The 3D Astro Geodetic inverse computes results as they would be observed in the field (mark-to-mark) on the geoid (for adjustments based on orthometric height). If the adjustment is based on ellipsoidal height and deflections of the vertical are known at each adjusted station, the inverse results are corrected to Astronomic by using the provided deflection data.

NOTE: For 3D adjustments based on orthometric height, disable the usage of deflection of the vertical corrections from within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog (prior to adjustment). These corrections should only be applied when using conventional measurements in a project based on ellipsoidal height.

The forward azimuth and zenith angle are computed in relation to a plane tangent to the Earth's surface at the AT station. Likewise, the backward azimuth and zenith angle are computed in relation to a plane tangent to the Earth's surface at the TO station. The chord distance represents the straight-line distance between the two stations. This is analogous to a slope distance measurement between the stations at monument level (mark-to-mark).



Observations

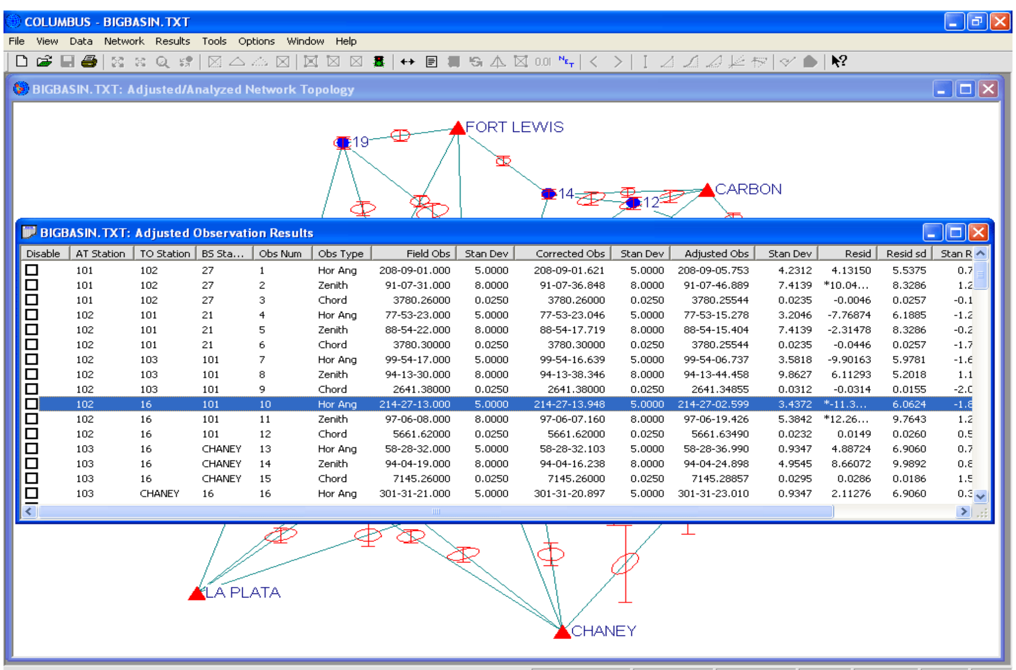
Observations

Select the OBSERVATIONS - ADJUSTED OBSERVATIONS command to view the Adjusted Observations in the adjusted network. Each observation is displayed in alphabetical order according to its AT and TO station names.

For each observation, its measured value, *a priori* standard deviation, corrected value, corrected value standard deviation, adjusted value, adjusted value standard deviation, residual, residual standard deviation, standardized residual, residual *a priori* standard deviation ratio, and redundancy are displayed.

2D Networks: Bearing observations are corrected to true azimuths if the Rotate Bearings switch is enabled in the OPTIONS module. Chord distances are reduced (corrected) to horizontal distances if the zenith angle is provided. Otherwise, the chord distance observations are assumed to be horizontal distances.

3D Networks: Corrected observations apply to terrestrial type observations. They are due to bearing rotations, mark-to-mark reductions, deflection of the vertical corrections, refraction corrections, or scaling corrections. **When a GPS network is adjusted with scale and rotation enabled, corrections are made to the GPS observations during the actual adjustment. These corrections are combined into the Adjusted Observation result, not the Corrected Observation result.**



If the Standardized Residual exceeds the Standardized Residual Rejection Constant, the Standardized Residual value is tagged with an asterisk.

If the Residual/APriori Standard Deviation ratio exceeds the Residual/Apriori Standard Deviation Rejection

Constant, the Residual/Apriori Standard Deviation value is tagged with an asterisk.

If the Residual is greater than the Observation type Residual Rejection Constant, the Residual is tagged with an asterisk.

The observation shown above is a **possible** outlier because it has failed the Residual test.

The redundancy number for each adjusted observation is yet another statistic that may help the user isolate problem areas in the network.

For each adjusted observation in the network, a redundancy number is calculated. The redundancy number ranges from 0 to 1. Observation redundancy numbers are a measure of how close the variance of the residual is to the variance of the observation.

If the redundancy number is close to 1, then the variance of the residual is close to the variance of the observation and the variance of the adjusted observation is close to zero. If the redundancy number is close to zero, then the variance of the residual is close to zero, and the variance of the adjusted observation is close to the variance of the observation.

Intuitively it is expected that the variance of the residuals and the variance of the observations are close. When this is the case, the noise in the residuals equals that of the observations, and the adjusted observations are determined with high precision. The case where redundancy is close to one is preferred. and it is said that the gain on the adjustment is high. If the redundancy is close to zero, one expects the noise in the residuals to be small.

For a more detailed explanation of the use of the redundancy number, see the latest book by Dr. Alfred Leick (other books by Dr. Leick are listed in Appendix D).

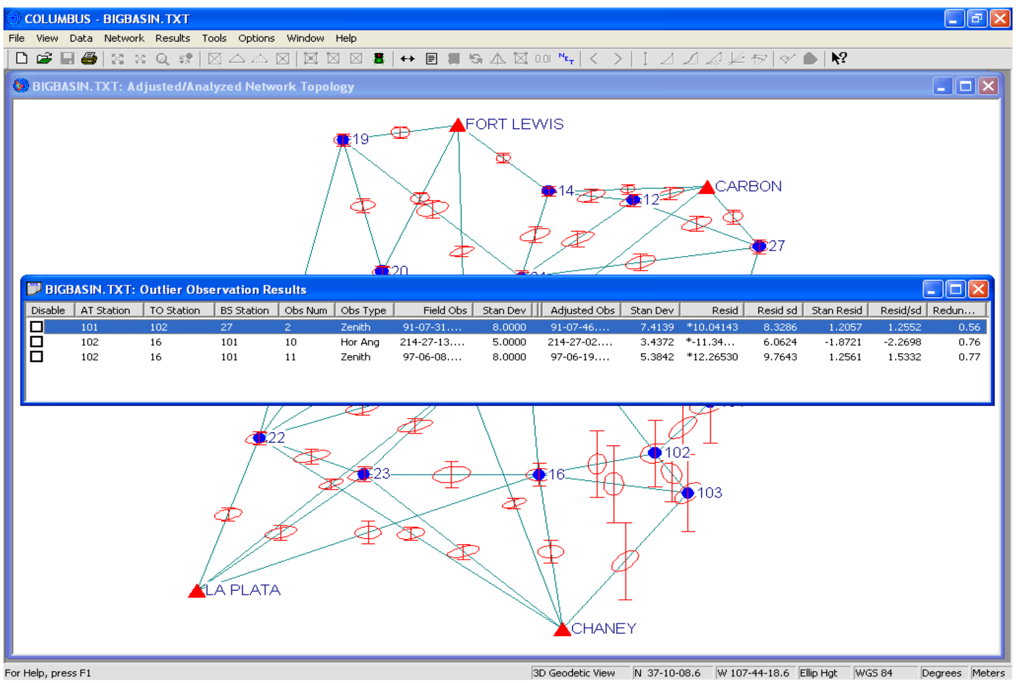
To disable an observation, place a check mark in its Disable check box. The observation will be tagged as not usable within COLUMBUS (for COGO traversing or new adjustments) until the Disable flag is removed.

Outlier Observations

Select the OBSERVATIONS - OUTLIER OBSERVATIONS command to view any detected **possible** outlier observations.

You do not have to search through every observation looking for possible outliers, because this option only displays the flagged observations. When invoked, all observation are scanned to see if any exceed one of the three outlier tests. For more information regarding each test, please see the Outlier Rejection Constants topic in the OPTIONS chapter.

Outliers can be sorted by four methods. If you sort by one of the options other than the AT - TO station name combination, the outliers will be arranged in descending order (from the largest offenders to the smallest offenders). Please see the Outlier Sorting discussion in the OPTIONS chapter of this manual for a more detailed explanation. This is the ’old’ way or sorting in COLUMBUS. **A better way is to simply sort any column you wish, by clicking on the desried column header.**



For our BIGBASIN.TXT network adjustment, there are three possible outliers. The outlier view is identical in appearance and navigation to the Adjusted Observations view. You can disable an observation by placing a check mark in the observation’s Disable column. Disabled observations will not be used in subsequent adjustments.

Deciding what to do with outliers is beyond the scope of this manual. However, many papers have been written about detecting outliers using a variety of techniques.

One of the downsides of a least squares adjustment is its accommodating properties. During the adjustment, all observations are looked at simultaneously and an attempt is made to best fit all observations to the network as a whole. **In some cases, this can result in bad observations causing otherwise good observations to look bad.** In other words, the good observations are adjusted more than they should in order to make the bad observations fit the network better. One of the many challenges facing the outlier detection theorists is minimizing this problem.

With that in mind, **the Standardized Residual test has been recognized as one of the better indicators for removing possible outlier observations.** A commonly accepted methodology is to perform your adjustment repeatedly until all observations flagged by this test have been removed. However, only **one** observation should be removed after each adjustment. The removal of the largest offender could, and often does, result in smaller offenders going away during subsequent adjustments (therefore, they need not be removed). Continue the steps of adjusting, removing the largest offender, adjusting, removing the largest offender - until no more outliers are identified by the Standardized Residual test.

For networks with low redundancy, you may not be able to remove all outlier observations, before reaching a situation in which the degrees of freedom (redundancy) becomes zero.

No Check Observations

Select the OBSERVATIONS - NO CHECK OBSERVATIONS command to view any detected No Check observations. If none are present, this command is disabled. No Check (sometimes called Fly-Lined, Stubbed-Out, or **Sideshot**) observations are those that were not adjusted. They have residuals of zero. An observation with a residual of zero could be an indication of poor network structure or some other inconsistency.

A common reason for No Check observations appearing in networks are Sideshots. Sideshot stations are connected to the network by limited observation data. If there are no redundant measurements into the station, the station is not adjusted. Its computed position has been calculated from the connecting station using the limited observations measured. These observations receive no adjustment, since there is no redundancy.

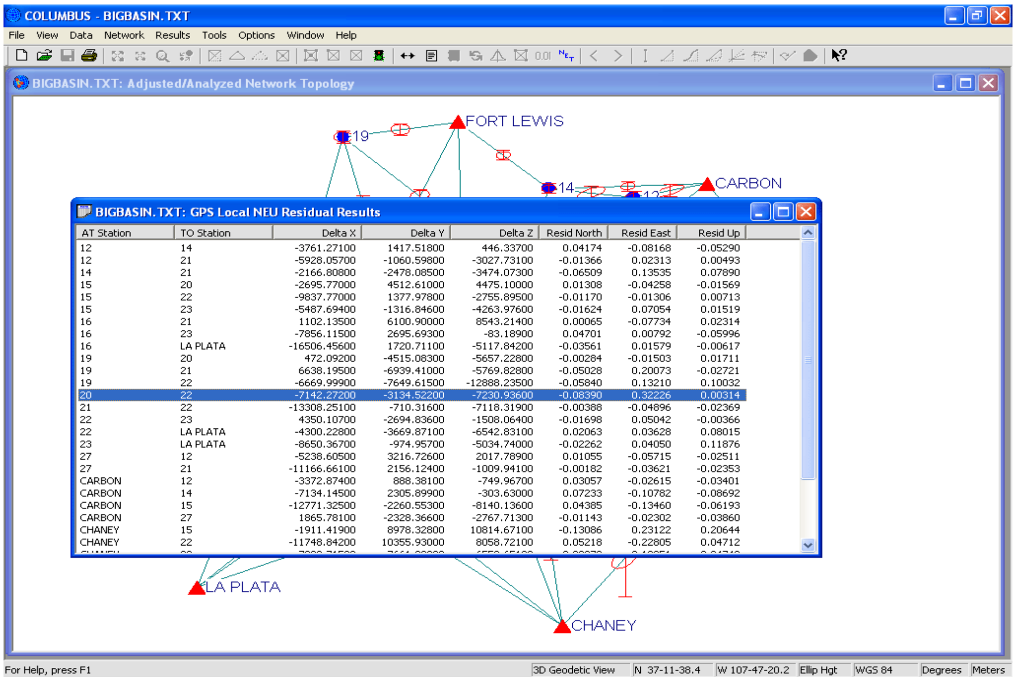
When performing RTK GPS surveys, it is common to end up with dozens of points that are radially laid out from one known station. If these points are not tied in (using RTK or some other measurement method) from another known station, these points will receive no adjustment and hence will be flagged as No Check observations.

For our BIGBASIN.TXT network adjustment, there are no No Check observations. The No Check Observations view is identical in appearance and navigation to the Adjusted Observations view. The observation number in the fifth column of the view can be matched to the observation number in the Select Network Observations list.

If you encounter any No Check observations within your network, check each of the stations connected to these observations. Are the stations Sideshots (i.e., flylined)? Or have you given these observations such a large weight (small standard deviations) that no adjustment is applied to these observations?

GPS Local NEU Residuals

Select the OBSERVATIONS - GPS LOCAL NEU RESIDUALS command to view the adjusted GPS residuals in a Local NEU (North, East, Up) Horizon system. This command is only applicable to 3D networks containing GPS observations.



The Local Horizon NEU residuals help in the detection of receiver centering and height measurement errors over the AT or TO stations. To compute the Local Horizon NEU residual for each baseline, the GPS XYZ residuals are transformed to Local Horizon NEU residuals based on the mean geodetic position for each AT and TO station pair (i.e., at the midpoint of the GPS vector).

The Delta North and East components represent the error in northing and easting of the baseline between the AT and TO stations. The Up component represents the error in the vertical component of the baseline between the two stations.

Residual Distribution

Select the OBSERVATIONS - RESIDUAL DISTRIBUTION command to view the distribution of Standardized Residuals for all observations collectively and for each observation type.

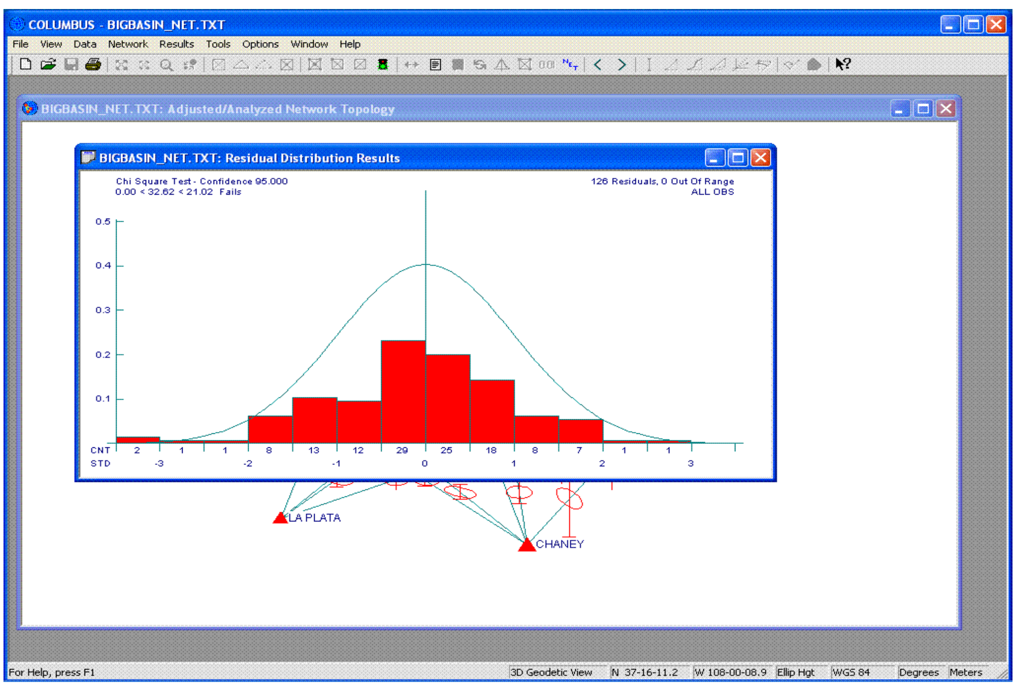
The standardized residual for an observation is simply:

$$\frac{\textit{the adjusted observation residual}}{\textit{the residual standard deviation}}$$

This is a unitless quantity that allows both angular and linear observations to be compared directly.

Probability theory suggests that random errors taken from large samples will tend to be normally distributed about their mean. Graphically, this can be represented by a bell-shaped curve, where the majority of the standardized residuals are expected to be clustered about the midpoint. COLUMBUS presents the histogram, as well as the numerical results from the Chi-squared "**Goodness of Fit**" test.

COLUMBUS looks at all the standardized residuals and groups them into classes about the theoretical mean (zero). Each class spans the range of 0.5 standard deviations. There are seven classes on each side of the mean, for a total of 14. Any standardized residual outside the leftmost or rightmost class is tabulated as out of range.



The figure above represents the histogram of standardized residuals for our 3D Geodetic network, BIGBASIN.TXT. As more observations are added to the network, the distribution will generally approach normality (unless there is a problem in the network). The x-axis of the diagram contains two sets of values:

CNT: The number of actual standardized residuals within each class. Standardized residuals falling greater than 3.5 standard deviations from the mean are not depicted. However, the number out of range are tabulated in the upper right corner of the screen.

STD: The number of standard deviations from the theoretical mean (zero) for each class. Each class represents one-half standard deviation.

The central vertical line of the histogram represents the theoretical mean of the standardized residuals for all observations (zero). Since the x-axis represents the number of standard deviations from this value, the observations with the smallest standardized residuals will fall near this vertical line, while observations with larger standardized residuals will be farther away. Therefore, the closer the histogram approximates the bell-shaped curve, the closer the standardized residuals approach normality.

The Chi-squared Goodness of Fit test is a quantitative measure as to the **fit** of the histogram to the normal distribution. In the figure above, the Chi-square test fails at the 95 percent confidence level. We have found the Chi-square test to be very sensitive (with 14 interval classes). Therefore, the graphical representation of the residual distribution should be considered in combination with the numerical Chi square test results before concluding the residuals are or are not normally distributed. Even if the test fails (misses by some small amount), the residuals may be considered normally distributed if they form a bell-shaped curve.

You may also notice a hashed region in the vertical histogram bars for some observation types. This indicates that the bar would normally be higher than what can be displayed on the screen.

For our example network BIGBASIN.TXT, the Chi-square test has failed, yet the distribution of residuals appear to be normally distributed. If we were to add more measurements to this network, we might expect the distribution to approach better normality.

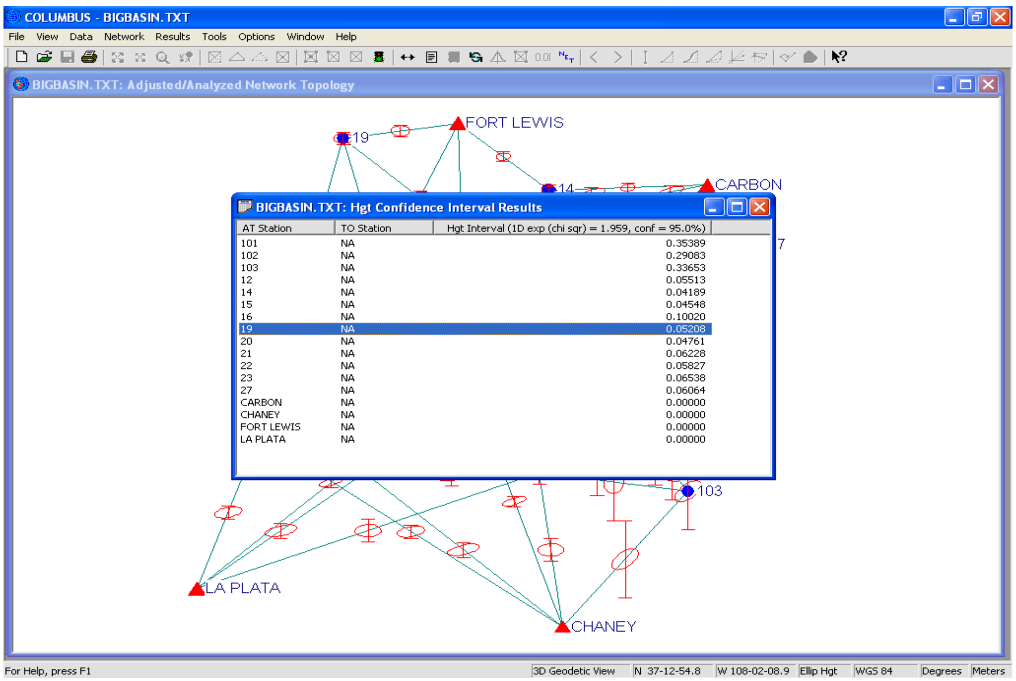
To view each residual distribution histogram, click on the Previous or Next arrow toolbar button. If you display the distribution for the chord distance observations, you will notice that many are to the left of the graph center (negative standardized residuals). **This could be an indicator of some sort of systematic error in the measured chord distances.** For example, the rod person may not be holding (or setting up) the prism at the correct position. Thus most distances were measured too long, resulting in a negative residual after adjustment. A negative residual will yield a negative standardized residual.

Confidence Regions

Height Confidence Intervals

Select the CONFIDENCE REGIONS - HGT CONFIDENCE INTERVALS command to view Height Confidence Interval results at each station and between connect station pairs.

The Height Confidence Interval is an estimate of the precision of the adjusted height (orthometric or ellipsoidal, depending on the network adjustment context), at each station and the relative precision of the height between connected stations.



The station height confidence interval is computed from the *a posteriori* covariance matrix for each station. To compute the relative height confidence interval between connected stations, the *a posteriori* covariance matrix for the AT station, the TO station and the *a posteriori* covariance matrix which correlates the two stations are used. Since the height confidence interval is a one-dimensional result, the 1D expansion factor is used to scale the height confidence interval to the chosen confidence level (in this case, 95%).

To toggle between the station height confidence intervals and the relative connected stations height confidence intervals, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button.

Distance Errors

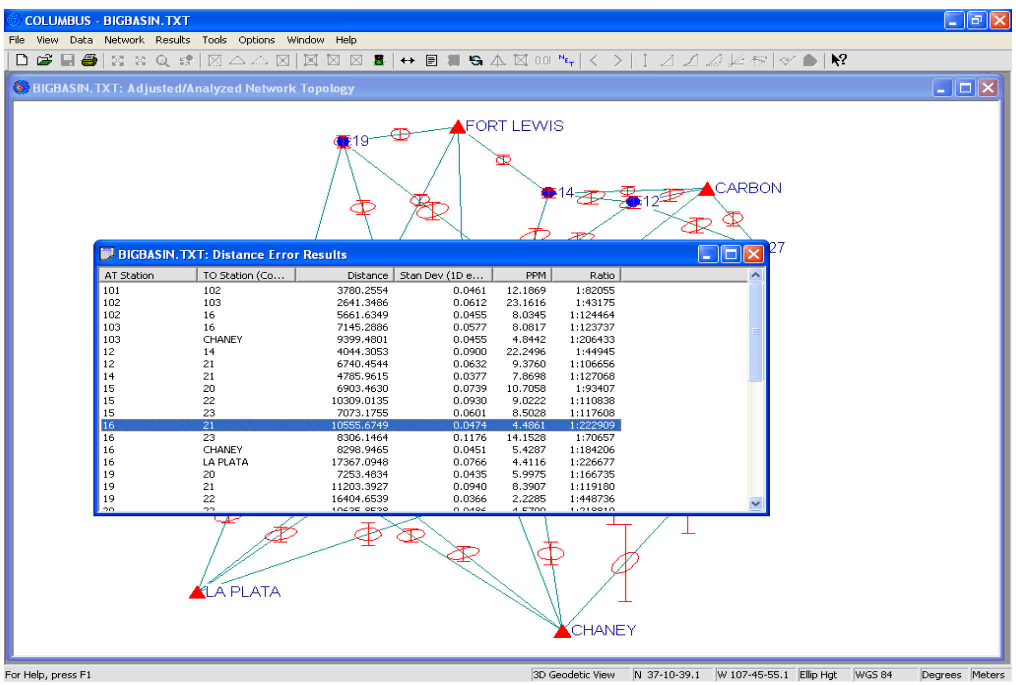
Select the CONFIDENCE REGIONS - DISTANCE ERRORS command to view the distance errors between connected station pairs or all station pairs.

The Distance Error is an estimate of the precision of the adjusted chord (slope) distance between two stations in the network. It can be computed between connected stations or between all station combinations in the network.

The distance error is computed from the *a posteriori* covariance matrix for the AT station, the TO station, and the *a posteriori* covariance matrix which correlates the two stations. Because the distance error is a one-dimensional statistical result, the 1D expansion factor is used to scale the results to the chosen confidence level (in this case, 95%).

Connected Stations

In the screen below, the distance error from Station 16 to Station 21 is highlighted. The standard deviation has been scaled to the 95 percent confidence level by the expansion factor 1.95937 (shown in the Standard Deviation column). The distance represents the adjusted chord distance between the two stations. At the 95 percent confidence level, we expect the true chord distance between these stations to be within the interval 10555.6749 ± 0.0474 Meters.



The PPM and ratio are two separate ways of expressing the precision of the chord distance. PPM is computed from:

$$\frac{scaled\ Stan\ Dev}{Distance} \times 1,000,000.0$$

The ratio is equal to the:

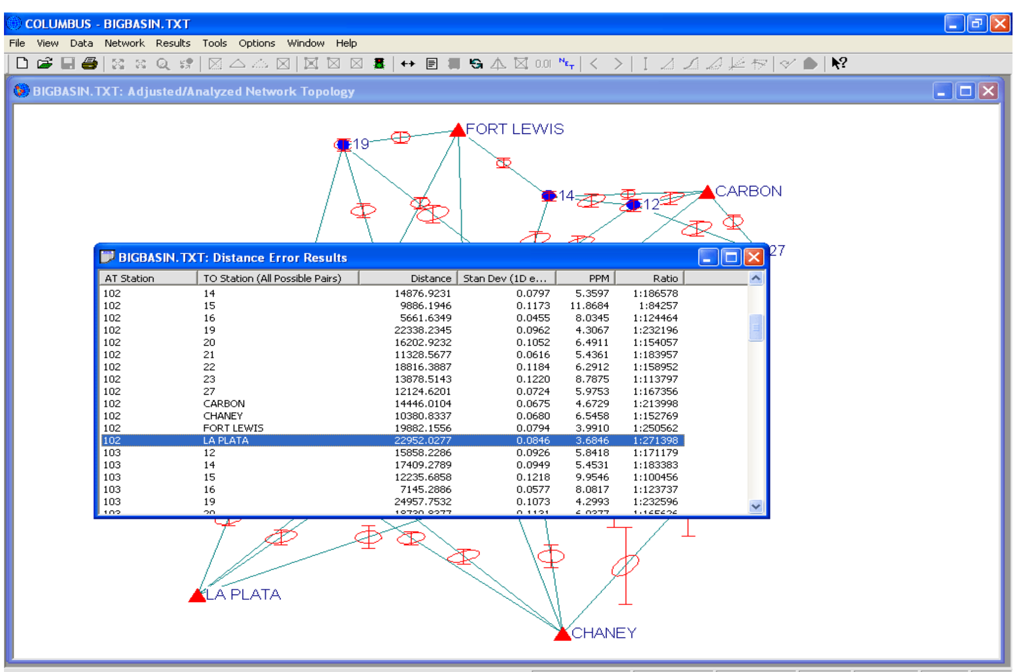
$$\frac{Distance}{scaled\ Stan\ Dev} \quad \text{or} \quad \frac{1,000,000.0}{PPM}$$

As you lower the confidence level from 95 percent to 68 percent (to approximately one sigma), the 1D expansion factor will decrease to 1.0. This will result in the scaled standard deviation decreasing; therefore, the PPM and ratio will appear more optimistic. Raising the confidence level will have the opposite effect.

The results are alphabetically arranged according to the AT and TO station names. Only those station combinations with connecting observations are displayable.

All Possible Pairs

To view/report all station pair combinations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “All Possible Pairs” appears in the "TO Station" column.



In the screen above, the distance error from Station 102 to Station LA PLATA is highlighted. The standard deviation has been scaled to the 95 percent confidence level by the expansion factor 1.95937 (shown in the Standard Deviation column). The distance represents the adjusted chord distance between the two stations. At the 95 percent confidence level we expect the true chord distance between these stations to be within the interval 22952.0277 ±0.0846 Meters.

WARNING: For medium to large networks, the number of combinations can grow very large. In fact, the number of possible combinations can be computed from the number of stations (*n*) in the network, i.e.,

$$\frac{n \times (n-1)}{2}$$

Error Circles

Error Circles are another statistic for evaluating your survey. The statistics below are based on the method used by NGS (National Geodetic Survey). They are closely related to error ellipses; in fact, error circles are partially derived from error ellipses, but they are circles with fixed radius. Their computation is rigorous and follows the theory outlined in the standard literature.

Select the CONFIDENCE REGIONS - ERROR CIRCLES command from the RESULTS menu to view the error circles at each adjusted station and between station pairs.

As with any confidence result offered in COLUMBUS (height errors, distance errors, error circles, error ellipses, error ellipsoids, and ALTA requirements), choose the method that matches the required standards for the survey. For example, one client may demand only Distance Errors, while another may want to see Distance Errors, Error Circles, Error Ellipsoids, and ALTA results.

Chi Square Distribution and Fisher Distribution ('F' Test)

You can examine statistical results using the Chi Sqr test or the 'F' Test (Fisher Distribution) for Error Circles. Select the Toggle Chi Square <--> Fisher Test command from the RESULTS menu to toggle the context of the result types you are currently viewing. For example, when viewing error circles, you can toggle between viewing the error circles scaled using the Chi Square Distribution or the Fisher Distribution ('F' Distribution).

Note: The Fisher Distribution is better for modeling networks with small degrees of freedom than the Chi Square test.

Chi Square Distribution

The Chi Square Distribution is used in sampling statistics to determine the range in which the variance of a population can be expected to occur. It is a function of the:

1. Specified level of probability

2. The computed variance of the sample set

3. The degrees of freedom in the sample

Fisher Distribution

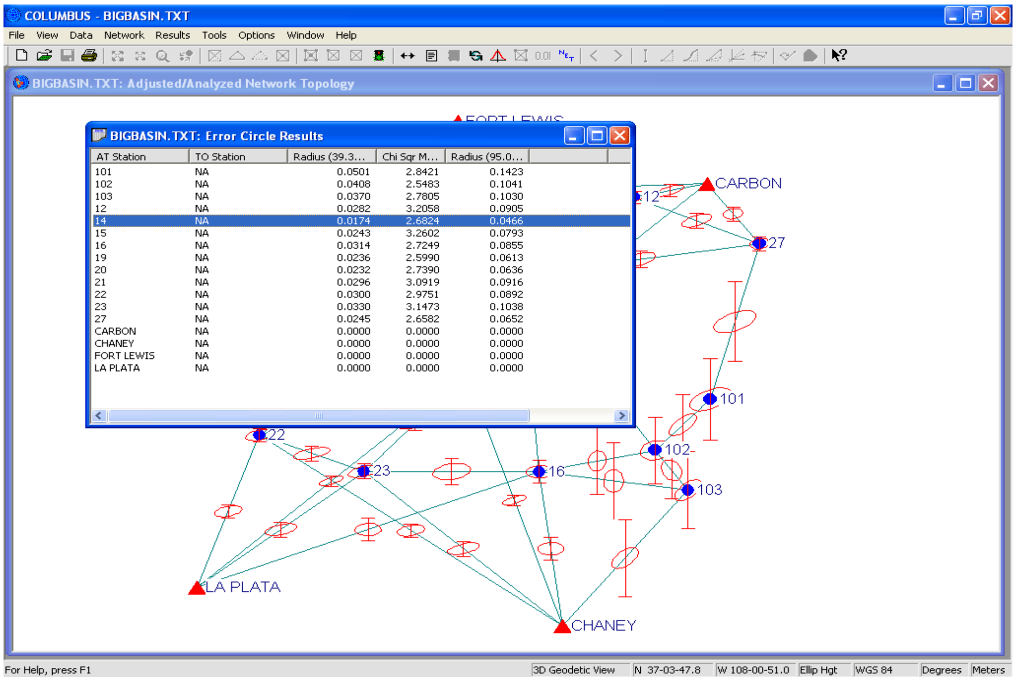
The Fisher Distribution ('F' Distribution) is used when comparing the computed variances from two sample sets. It represents the variance ratios for varying degrees of freedom. The 'F' Distribution is used to model the statistical results for samples containing small degrees of freedom.

Note: As the number of degrees of freedom in a survey approaches infinity, the results from the Fisher' distribution and Chi Square distribution approach the same value.

Stations

This views below allows you to see the error circles for each adjusted station (absolute), the error circles between connected station pairs (relative) and the error circles between all station pairs (relative). The absolute error circle is a measure of the precision between the fixed stations and the adjusted stations. The relative error circle is a measure of the precision between two adjusted stations.

The expansion factor is a value that expands the error circle to a size commensurate with the confidence level. For example, if the confidence level is set to 95% (set in the OPTIONS - GLOBAL SETTINGS dialog), the error circle is expanded by the 95% expansion factor.



The following are reported for both absolute and relative error circles:

- Confidence level
- AT and TO station names
- Radius or error circle at one sigma (for 2D, it is 39.35 percent)
- The Chi Square Multiplier or the “F” Multiplier, depending on context
- Radius at two sigma (approximately 95 percent)

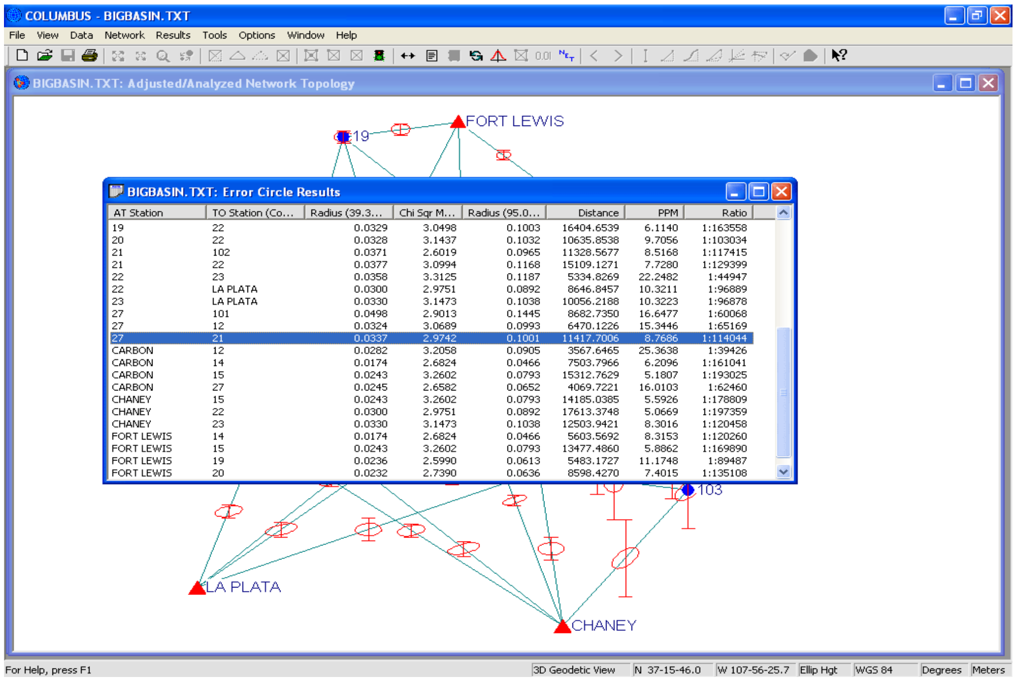
For relative error circles only:

- Distance (the chord distance between the adjusted stations)
- PPM (the relative error circle expressed in parts per million; error circle radius / Distance x 1000000.0.)
- Ratio (PPM expressed in ratio form)

The results are in alphabetical order by station name. Click on the Normal Distribution Curve toolbar symbol or select the TOGGLE CHI SQR<--> FISHER option from the Results menu to change the multiplier. For the ’F’ test, the multiplier is the same for all results. The Chi Square multiplier will vary from one result to another.

Connected Stations

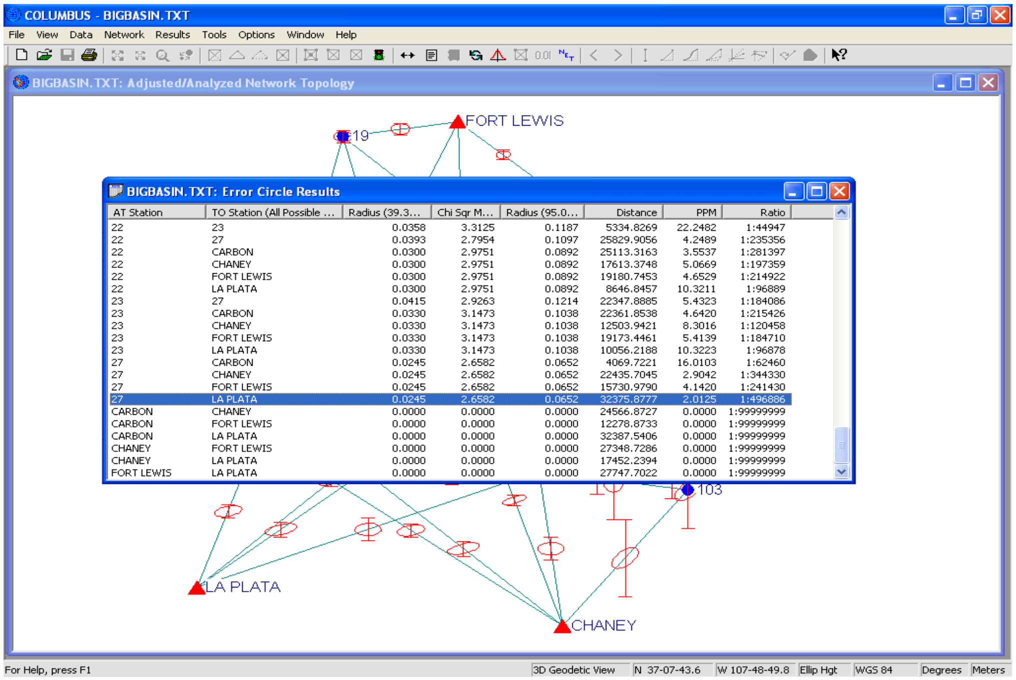
To view/report the connected station pair combinations, select the SWITCH CONTEXT command from the Results menu or click on the Switch Context toolbar button until the words, “Connected Pairs” appears in the view.



AT Station	TO Station (Co...	Radius (39.3...	Chi Sqr M...	Radius (95.0...	Distance	PPM	Ratio
19	22	0.0329	3.0498	0.1003	16404.6539	6.1140	1:163558
20	22	0.0328	3.1437	0.1032	10635.8538	9.7056	1:103034
21	102	0.0371	2.6019	0.0965	11328.5677	8.5168	1:117415
21	22	0.0377	3.0994	0.1168	15109.1271	7.7280	1:129399
22	23	0.0358	3.3125	0.1187	5334.8269	22.2482	1:44947
22	LA PLATA	0.0300	2.9751	0.0892	8646.8457	10.3211	1:96889
23	LA PLATA	0.0330	3.1473	0.1038	10056.2188	10.3223	1:96878
27	101	0.0498	2.9013	0.1445	8682.7350	16.6477	1:60068
27	12	0.0324	3.0689	0.0993	6470.1226	15.3446	1:65169
27	21	0.0337	2.9742	0.1001	11417.7006	8.7686	1:114044
CARBON	12	0.0282	3.2058	0.0905	3567.6465	25.3638	1:39426
CARBON	14	0.0174	2.6824	0.0466	7503.7966	6.2096	1:161041
CARBON	15	0.0243	3.2602	0.0793	15312.7629	5.1807	1:193025
CARBON	27	0.0245	2.6582	0.0652	4069.7221	16.0103	1:62460
CHANEY	15	0.0243	3.2602	0.0793	14185.0385	5.5926	1:178809
CHANEY	22	0.0300	2.9751	0.0892	17613.3748	5.0669	1:197359
CHANEY	23	0.0330	3.1473	0.1038	12503.9421	8.3016	1:120458
FORT LEWIS	14	0.0174	2.6824	0.0466	5603.5692	8.3153	1:120260
FORT LEWIS	15	0.0243	3.2602	0.0793	13477.4860	5.8862	1:169890
FORT LEWIS	19	0.0236	2.5990	0.0613	5483.1727	11.1748	1:89487
FORT LEWIS	20	0.0232	2.7390	0.0636	8598.4270	7.4015	1:135108

All Possible Pairs

To view/report all station pair combinations, select the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “All Possible Pairs” appears in the "TO Station" Column.



WARNING: For large networks, the number of combinations can grow very large. In fact, the number of possible combinations can be computed from the number of stations (*n*) in the network, i.e.,

$$\frac{n \times (n-1)}{2}$$

Error Ellipses

Select the CONFIDENCE REGIONS - ERROR ELLIPSES command from the RESULTS menu to view the error ellipses at each adjusted station and between station pairs.

The error ellipse is an estimate of the precision of the adjusted 2D coordinates (latitude and longitude in this example) at each station, and the relative precision of the 2D coordinates between stations. Error ellipses can be computed for each adjusted station, between connected stations and between all station combinations.

The station error ellipses are computed from the *a posteriori* covariance matrix for each station. To compute the relative error ellipse between stations, the *a posteriori* covariance matrix for the AT station, the TO station and the *a posteriori* covariance matrix which correlates the two stations are used. Because the error ellipse is a two-dimensional statistical result, the 2D expansion factor is used to scale the semi-major and semi-minor axes to the chosen confidence level (in this case, 95%). The 1D expansion factor is used to scale the height component (not relevant to 2D geodetic network adjustments).

Chi Square Distribution and Fisher Distribution (’F’ Test)

You can now examine statistical results using the Chi Sqr test or the 'F' Test (Fisher Distribution) for Error Ellipses. Select the Toggle Chi Square <--> Fisher Test command from the RESULTS menu to toggle the context of the result types you are currently viewing. For example, when viewing error ellipses, you can toggle between viewing the error ellipses scaled using the Chi Square Distribution or the Fisher Distribution ('F' Distribution).

Note: The Fisher Distribution is better for modeling networks with small degrees of freedom than the Chi Sqr test.

Chi Square Distribution

The Chi Square Distribution is used in sampling statistics to determine the range in which the variance of a population can be expected to occur. It is a function of the:

1. Specified level of probability
2. The computed variance of the sample set
3. The degrees of freedom in the sample

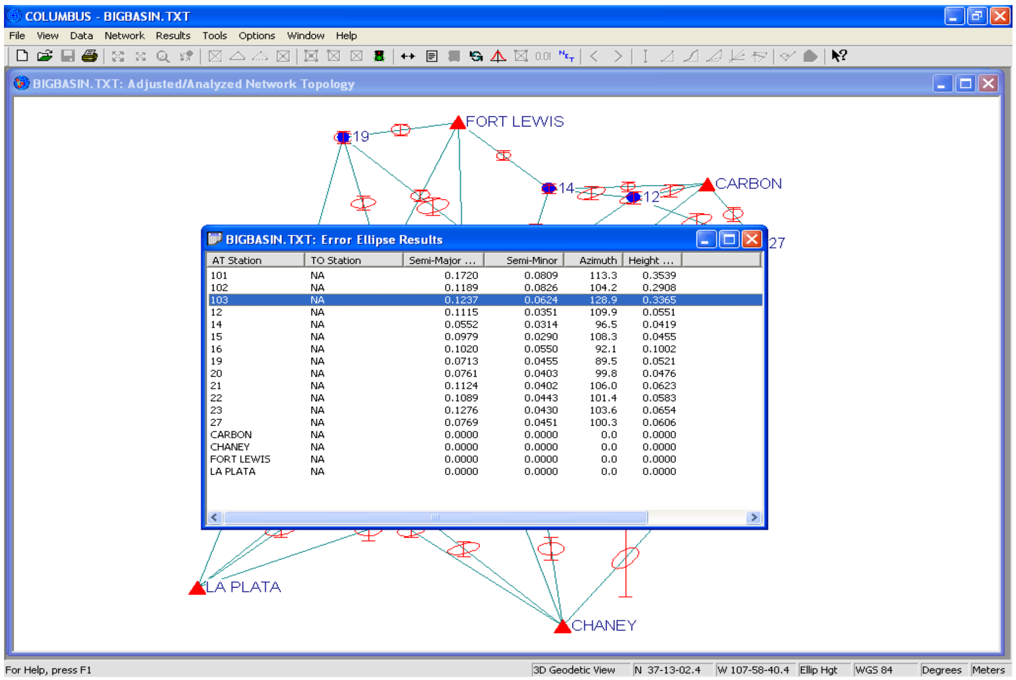
Fisher Distribution

The Fisher Distribution ('F' Distribution) is used when comparing the computed variances from two sample sets. It represents the variance ratios for varying degrees of freedom. The 'F' Distribution is used to model the statistical results for samples containing small degrees of freedom.

Note: As the number of degrees of freedom in a survey approaches infinity, the results from the 'F' distribution and Chi Square distribution approach the same value.

Stations

In the screen below, the 2D error ellipse at Station 103 is highlighted. The semi-major and semi-minor axes have been scaled to the 95 percent confidence region using the 2D expansion factor. The semi-major and semi-minor axes form a local elliptical region around the adjusted station coordinates (latitude and longitude). We expect (with 95% confidence) the true latitude and longitude of Station 103 to fall within this region.

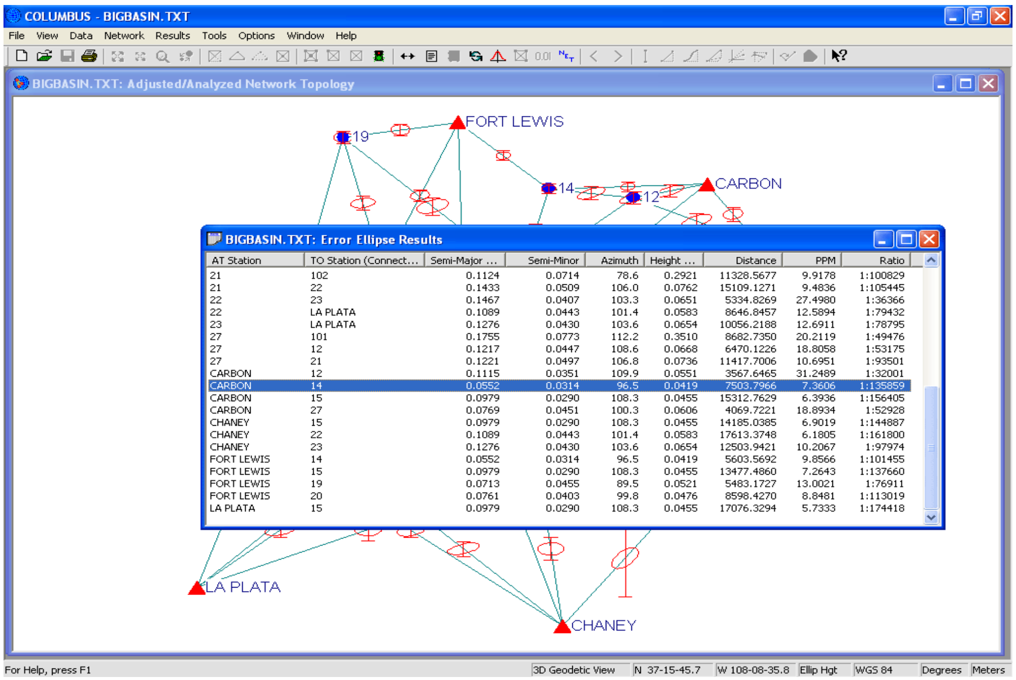


As you lower the confidence level from 95 percent to 68 percent (to approximately one sigma), the 2D expansion factor will decrease. This will result in the semi-major and semi-minor axes to appear more optimistic. Raising the confidence level will have the opposite effect.

The results are in alphabetical order by station name. The semi-major and semi-minor axes are determined by COLUMBUS. The semi-major axes is simply the larger of the two. The azimuth is the orientation from due north to the semi-major axis.

Connected Stations

To view or report the connected station pair combinations, select the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “Connected Pairs” appears in the view.



In the screen above, the relative error ellipse from Station CARBON to Station 14 is highlighted. The semi-major and semi-minor axes have been scaled to the 95 percent confidence region using the 2D expansion factor (i.e., 2.44788 visible in the "Major (2D exp..." column heading). The chord distance is the adjusted chord distance between the two stations. The error ellipse (formed by the semi-major and semi-minor) represents the expected error in 2D (latitude and longitude in this network) between the two adjusted stations.

The PPM and ratio are two ways of expressing the 2D precision between each station. PPM is computed from the:

$$\frac{\textit{scaled semi-major axis}}{\textit{chord distance}} \times 1,000,000.0$$

The ratio is equal to the:

$$\frac{\textit{chord distance}}{\textit{scaled semi-major axis}} \quad \text{or} \quad \frac{1,000,000}{PPM}$$

As you lower the confidence level from 95 percent to 68 percent (to approximately one sigma), the 2D expansion factor will decrease. This will result in the semi-major and semi-minor axes to decrease; therefore, the PPM and ratio will appear more optimistic. Raising the confidence level will have the opposite effect.

All Possible Pairs

To view/report all station pair combinations, select the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “All Possible Pairs” appears in the dialog box.

WARNING: For large networks, the number of combinations can grow very large. In fact, the number of possible combinations can be computed from the number of stations (*n*) in the network, i.e.,

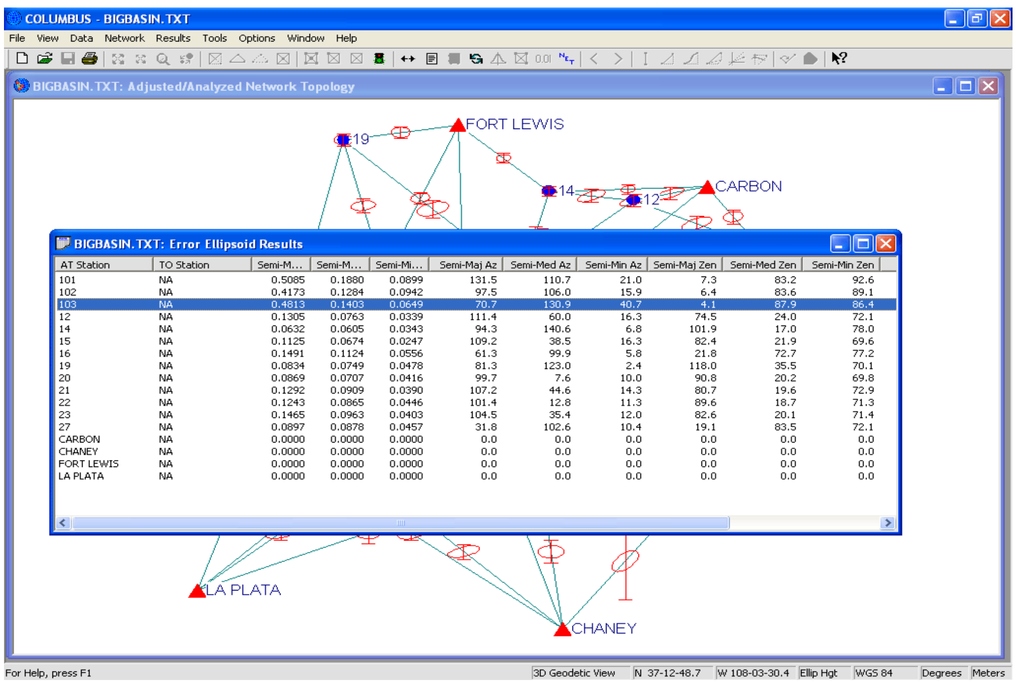
$$\frac{n \times (n-1)}{2}$$

Error Ellipsoids

Select the CONFIDENCE REGIONS - ERROR ELLIPSOIDS command to view the error ellipsoids at each adjusted station and between station pairs.

The error ellipsoid is an estimate of the precision of the adjusted 3D coordinate (latitude, longitude and height in this example) at each station, and the relative precision of the 3D coordinates between stations. Error ellipsoids can be computed for each adjusted station, between connected stations and between all station combinations.

The station error ellipsoids are computed from the *a posteriori* covariance matrix for each station. To compute the relative error ellipsoid between stations, the *a posteriori* covariance matrix for the AT station, the TO station and the *a posteriori* covariance matrix which correlates the two stations are used. Because the error ellipsoid is a three-dimensional statistical result, the 3D expansion factor is used to scale the ellipsoidal axes to the chosen confidence level (in this case 95%).



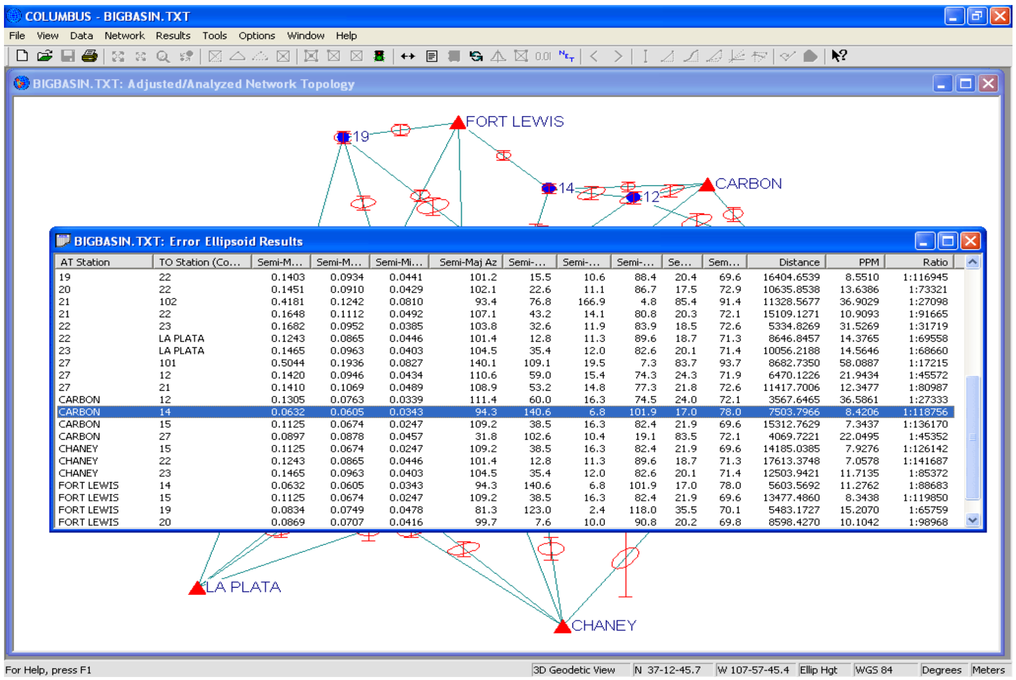
AT Station	TO Station	Semi-M...	Semi-M...	Semi-Mi...	Semi-Maj Az	Semi-Med Az	Semi-Min Az	Semi-Maj Zen	Semi-Med Zen	Semi-Min Zen
101	NA	0.5085	0.1880	0.0899	131.5	110.7	21.0	7.3	83.2	92.6
102	NA	0.4173	0.1284	0.0942	97.5	106.0	15.9	6.4	83.6	89.1
103	NA	0.4813	0.1403	0.0649	70.7	130.9	40.7	4.1	87.9	86.4
12	NA	0.1305	0.0763	0.0339	111.4	60.0	16.3	74.5	24.0	72.1
14	NA	0.0632	0.0605	0.0343	94.3	140.6	6.8	101.9	17.0	78.0
15	NA	0.1125	0.0674	0.0247	109.2	38.5	16.3	82.4	21.9	69.6
16	NA	0.1491	0.1124	0.0556	61.3	99.9	5.8	21.8	72.7	77.2
19	NA	0.0834	0.0749	0.0478	81.3	123.0	2.4	118.0	35.5	70.1
20	NA	0.0869	0.0707	0.0416	99.7	7.6	10.0	90.8	20.2	69.8
21	NA	0.1292	0.0909	0.0390	107.2	44.6	14.3	80.7	19.6	72.9
22	NA	0.1243	0.0865	0.0446	101.4	12.8	11.3	89.6	18.7	71.3
23	NA	0.1465	0.0963	0.0403	104.5	35.4	12.0	82.6	20.1	71.4
27	NA	0.0897	0.0878	0.0457	31.8	102.6	10.4	19.1	83.5	72.1
CARBON	NA	0.0000	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0
CHANEY	NA	0.0000	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0
FORT LEWIS	NA	0.0000	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0
LA PLATA	NA	0.0000	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0

Stations

In the screen above, the error ellipsoid at Station 103 is highlighted. The semi-major, semi-medium and semi-minor axes have been scaled to the 95 percent confidence region using the 3D expansion factor. The semi-major, semi-medium and semi-minor axes form a local ellipsoidal region around the adjusted station (latitude, longitude and height coordinate). We expect (with 95% confidence) the true latitude, longitude and height of Station 103 to fall within this region.

As you lower the confidence level from 95 percent to 68 percent (to approximately one sigma), the 3D expansion factor will decrease. This will result in the semi-major, semi-medium and semi-minor axes to appear more optimistic. Raising the confidence level will have the opposite effect.

The results are in alphabetical order by station name. The semi-major, semi-medium and semi-minor axes are determined by COLUMBUS. The semi-major axes is simply the largest of the three. The azimuth for all semi-axes are their orientation from due north. The zenith angles represent an angle as measured from the zenith.



Connected Stations

To view or report the connected station pair combinations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “Connected Pairs” appears in the view.

In the screen above, the relative error ellipsoid from Station CARBON to Station 14 is highlighted. The semi-major, semi-medium and semi-minor axes have been scaled to the 95 percent confidence region using the 3D expansion factor (i.e., 2.79532, shown in the Major column). The chord distance is the adjusted chord distance between the two stations. The error ellipsoid (formed by the axes) represents the expected error in 3D (latitude, longitude and height) between the two adjusted stations.

The PPM and ratio are two ways of expressing the 3D precision between each station. PPM is computed from the:

$$\frac{scaled\ semi\text{-}major\ axis}{chord\ distance} \times 1,000,000.0$$

The ratio is equal to the:

$$\frac{chord\ distance}{scaled\ semi\text{-}major\ axis} \quad \text{or} \quad \frac{1,000,000}{PPM}$$

As you lower the confidence level from 95 percent to 68 percent (to approximately one sigma), the 3D expansion factor will decrease. This will result in the semi-major, semi-medium and semi-minor axes to decrease; therefore, the PPM and ratio will appear more optimistic. Raising the confidence level will have the opposite effect.

All Possible Pairs

To view/report all station pair combinations, invoke the SWITCH CONTEXT command or click on the Switch Context toolbar button until the words, “All Possible Pairs” appears in the dialog box.

WARNING: For large networks, the number of combinations can grow very large. In fact, the number of possible combinations can be computed from the number of stations (*n*) in the network, i.e.,

$$\frac{n \times (n-1)}{2}$$

ALTA Positional Uncertainty

Select the CONFIDENCE REGIONS - ALTA POSITIONAL UNCERTAINTY command to view ALTA test results between connected station pairs or all station pairs.

ALTA Positional Uncertainty testing is usually based on a minimally constrained (free) network adjustment. Any errors in observations are due to your field work and not due to other control station errors.

The ALTA results in this section are based on a minimally constrained (free) adjustment holding station LA PLATA fixed in 3D. The linear units are shown in U.S. Feet.

COLUMBUS supports two different ALTA/ACSM positional uncertainty tests. The first test (**and the most commonly accepted**) is based on the semi-major axis of the relative error ellipse between station pairs. The second, less commonly used test is based on the distance error between station pairs. See the Error Ellipse and Distance Error based tests earlier in this chapter for more details. Unlike the Distance Error and Error Ellipse tests mentioned earlier, the ALTA test is based on the horizontal distance between station pairs and not the chord (slope) distance.

From within this view, there are four different combination of results:

1. Connected station positional uncertainty based on the semi-major axis of the relative error ellipse.

2. All station pair positional uncertainty based on the semi-major axis of the relative error ellipse.

3. Connected station positional uncertainty based on the distance error.

4. All station pair positional uncertainty based on the distance error.

To toggle between the four different sets of results, invoke the SWITCH CONTEXT command or the equivalent toolbar button.

Within the view, the second column heading from the left indicates either **connected pair** results or **all possible pair** results. The fourth column indicates whether the results are based on the semi-major axis of the relative error ellipse or the distance standard deviation (distance error).

For each test type, the relative error ellipse or distance error is compared against an allowable tolerance threshold. If the relative error ellipse or distance error (depending on the context of 1 - 4 above) is greater than the threshold (ratio of error / threshold > 1.0), the test fails between that station pair. The allowable tolerance threshold is based on a fixed constant + a PPM (parts per million component). Currently the ALTA/ASCM allowable tolerance is 0.070 U.S. feet + 50 ppm. For a distance of 250 U.S. feet, that results in an allowable tolerance of 0.070 U.S. feet + (250 * 50 / 1000000.0) or 0.0825 U.S. feet.

ALTA/ACSM testing can be performed at any confidence level between roughly 1.0 and 99.999 percent. The most commonly acceptable setting is 95%. This value can be changed in the OPTIONS - GLOBAL SETTINGS dialog. As you increase this percentage, more results may fail the test. Within the view, failed tests are shown in a different color in the **ratio** column.

To quickly view a report style format, invoke the FILE - PRINT PREVIEW command. The report is always based on the current combination (1 - 4). Any failed tests are always shown at the top of the test report, but not the view.

The ALTA/ACSM test is based on the horizontal distance between station pairs. The distance shown in the view and reports is the mean horizontal distance between each station pair. The mean horizontal distance is obtained by calculating the mean of the horizontal distance from the AT station to the TO station plus the horizontal distance from the TO station to the AT station. For most small projects, the horizontal distance from the AT station to the TO station and from the TO station to the AT station are essentially the same.

Like all Network Adjustment results, you can automatically create these reports at adjustment time by making the applicable report settings within the OPTIONS - NETWORK OPTIONS - REPORT SETTINGS dialog.

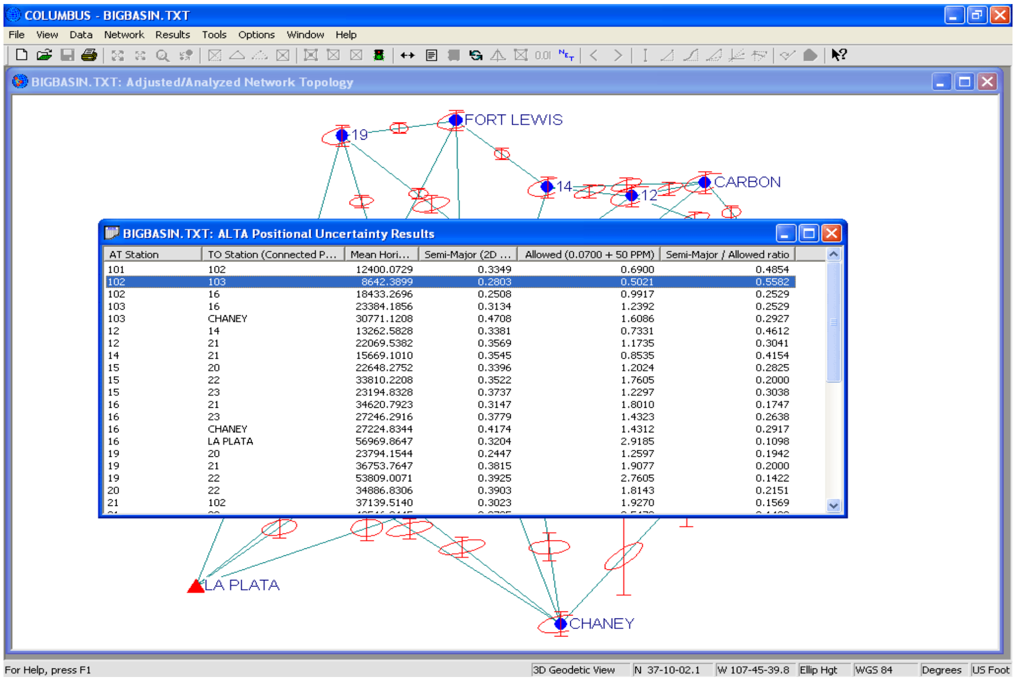
To write all results (for the current test context 1 - 4) to a report file, invoke the REPORT command or click on the Report toolbar button. COLUMBUS will prompt you for the name of a report file. You can create a new report file or append to an existing file.

WARNING: For medium to large networks, the number of all pair combinations can grow very large. In fact, the number of possible combinations can be computed from the number of stations (*n*) in the network:

$$\frac{n \times (n - 1)}{2}$$

Connected Stations (relative error ellipse based)

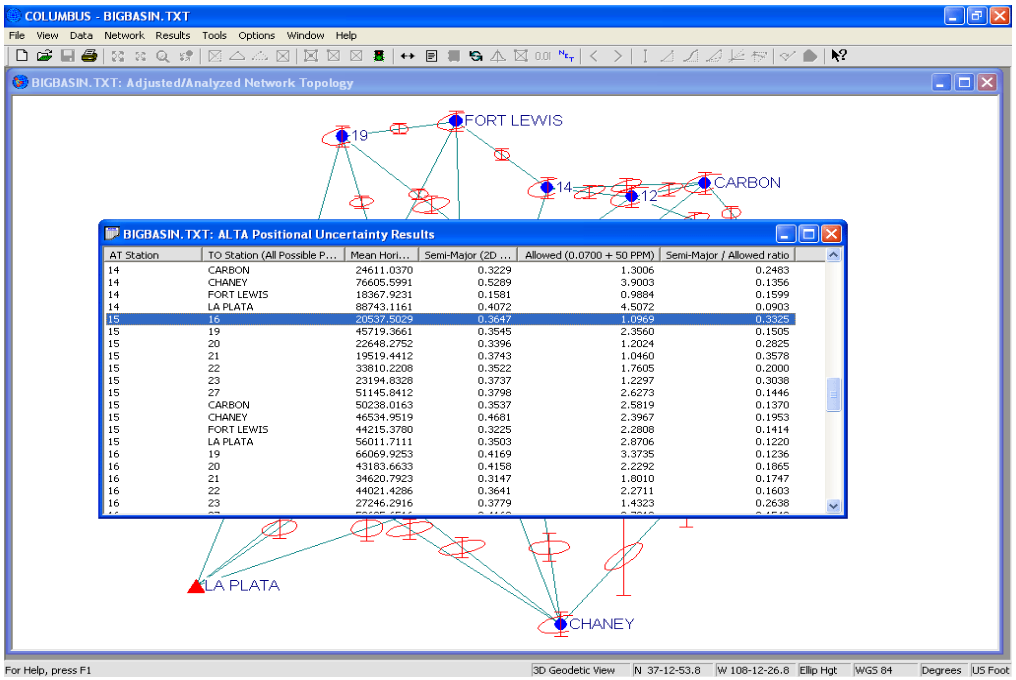
In the screen below, the ALTA/ACSM ratio for the station pair 102 and 103 is 0.5582. The ratio is less than or equal to 1.0 and therefore passes the testing criteria. These ALTA results are based on a minimally constrained (free) adjustment holding station LA PLATA fixed in 3D. The linear units are shown in U.S. Feet.



The results are alphabetically arranged according to the AT and TO station names. Only those station combinations with connecting observations are displayable.

All Possible Pairs (relative error ellipse based)

In the screen below, the ALTA/ACSM ratio for the station pair 15 and 16 is 0.3325. The ratio is less than or equal to 1.0 and therefore passes the testing criteria. These ALTA results are based on a minimally constrained (free) adjustment holding station LA PLATA fixed in 3D. The linear units are shown in U.S. Feet.

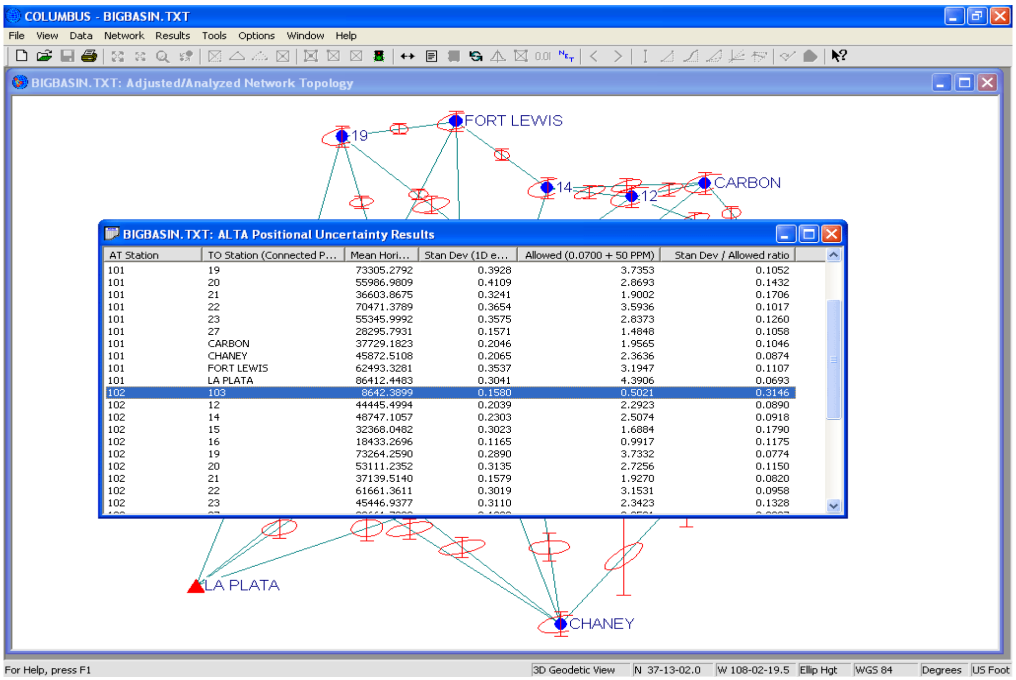


AT Station	TO Station (All Possible P...	Mean Hori...	Semi-Major (2D ...	Allowed (0.0700 + 50 PPM)	Semi-Major / Allowed ratio
14	CARBON	24611.0370	0.3229	1.3006	0.2483
14	CHANEY	76605.5991	0.5289	3.9003	0.1356
14	FORT LEWIS	18367.9231	0.1581	0.9884	0.1599
14	LA PLATA	88743.1161	0.4072	4.5072	0.0903
15	16	20537.5029	0.3647	1.0969	0.3325
15	19	45719.3661	0.3545	2.3560	0.1505
15	20	22648.2752	0.3396	1.2024	0.2825
15	21	19519.4412	0.3743	1.0460	0.3578
15	22	33810.2208	0.3522	1.7605	0.2000
15	23	23194.8328	0.3737	1.2297	0.3038
15	27	51145.8412	0.3798	2.6273	0.1446
15	CARBON	50238.0163	0.3537	2.5819	0.1370
15	CHANEY	46534.9519	0.4681	2.3967	0.1953
15	FORT LEWIS	44215.3780	0.3225	2.2808	0.1414
15	LA PLATA	56011.7111	0.3503	2.8706	0.1220
16	19	66069.9253	0.4169	3.3735	0.1236
16	20	43183.6633	0.4158	2.2292	0.1865
16	21	34620.7923	0.3147	1.8010	0.1747
16	22	44021.4286	0.3641	2.2711	0.1603
16	23	27246.2916	0.3779	1.4323	0.2638

The results are alphabetically arranged according to the AT and TO station names.

Connected Stations (distance error based)

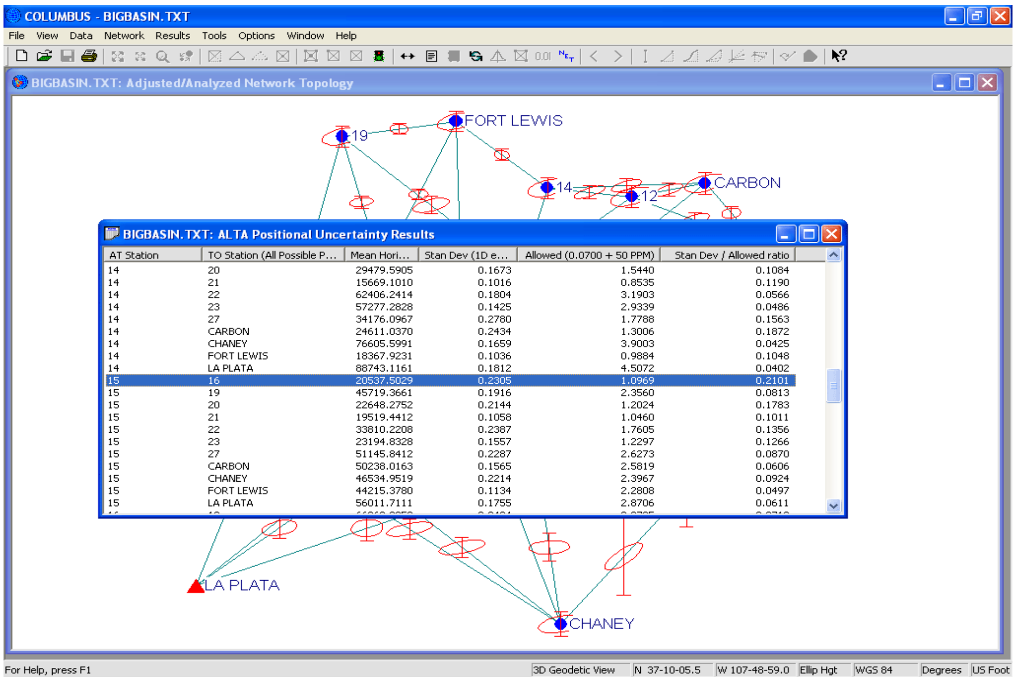
In the screen below, the ALTA/ACSM ratio for the station pair 102 and 103 is 0.3146. The ratio is less than or equal to 1.0 and therefore passes the testing criteria. These ALTA results are based on a minimally constrained (free) adjustment holding station LA PLATA fixed in 3D. The linear units are shown in U.S. Feet.



The results are alphabetically arranged according to the AT and TO station names. Only those station combinations with connecting observations are displayable.

All Possible Pairs (distance error based)

In the screen below, the ALTA/ACSM ratio for the station pair 15 and 16 is 0.2101. The ratio is less than or equal to 1.0 and therefore passes the testing criteria. These ALTA results are based on a minimally constrained (free) adjustment holding station LA PLATA fixed in 3D. The linear units are shown in U.S. Feet.



The results are alphabetically arranged according to the AT and TO station names.

Create Inverse Text File

After performing a network adjustment or pre-analysis, you can save the contents of the final binary inverse file into a readable ASCII (Text) file for further review.

The final inverse file contains most of the statistical raw data from which many of the statistical results are derived. Some advanced users occasionally want to perform additional statistical analyses not supported by COLUMBUS. These users can extract the inverse data from this file and compute additional statistics as needed.

For 2D and 3D networks, the resulting file format consists of one 3 x 3 matrix for each row in the file. Each row represents the inverse data for each station pair. Therefore, each line in the file consists of the following fields:

At Station Name, To Station Name, nn, ne, nu, en, ee, eu, un, ue, uu

Where:

nn = At station north and To station north covariance element.

ne = At station north and To station east covariance element.

nu = At station north and To station up covariance element.

en = At station east and To station north covariance element.

ee = At station east and To station east covariance element.

eu = At station east and To station up covariance element.

un = At station up and To station north covariance element.

ue = At station up and To station east covariance element.

uu = At station up and To station up covariance element.

When the At and To station name are the same, the covariance elements are for that station alone. These data are found on the diagonal 3 x 3 band of the inverse matrix. In this scenario, the 3 x 3 matrix will always be symmetrical.

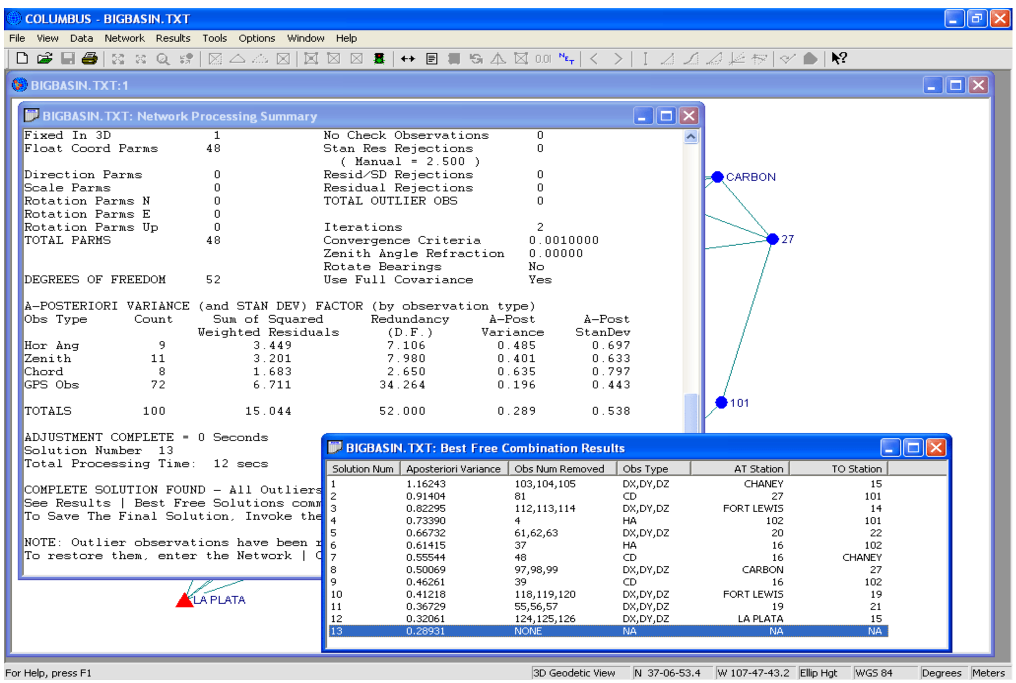
After selecting the file to write the ASCII (Text) inverse data into, COLUMBUS will ask you if you want to scale the raw data by the **A Posteriori Variance** factor. If you select Yes, COLUMBUS will scale each inverse element by the **A Posteriori Variance** factor before writing it to the file. The scaler will also be written on the first line of the resulting file. It will be 1.0 if you elect not to scale.

For 1D networks, only one variance element exists for each station pair. For 2D networks, the up components will always be zero. For 2D and 3D networks, the final inverse file can get quite large for networks containing hundreds of stations.

Best Free Solutions

In the ADJUSTMENT (FREE - ELIMINATE OUTLIERS) section of the NETWORK ADJUSTMENT chapter, an example is given of the usage of the automated outlier detection removal tool in COLUMBUS. To demonstrate the detection of outliers using the BIGBASIN.TXT data set, we changed the Standardized Residual Outlier Rejection constant (found in the OPTIONS - NETWORK OPTIONS - OUTLIER REJECTION CONSTANTS tabbed dialog) to 2.5. We did this to force the creation of some outliers.

After running the tool to identify and remove outliers, we brought up the BEST FREE SOLUTIONS view. The results are shown below. As you can see, COLUMBUS removed one outlier observation at a time (in the case of GPS, the entire baseline was removed if an individual component was found to be an outlier), then resolved the network to find any additional outliers. The largest outlier was removed after each adjustment until no additional outliers were found.



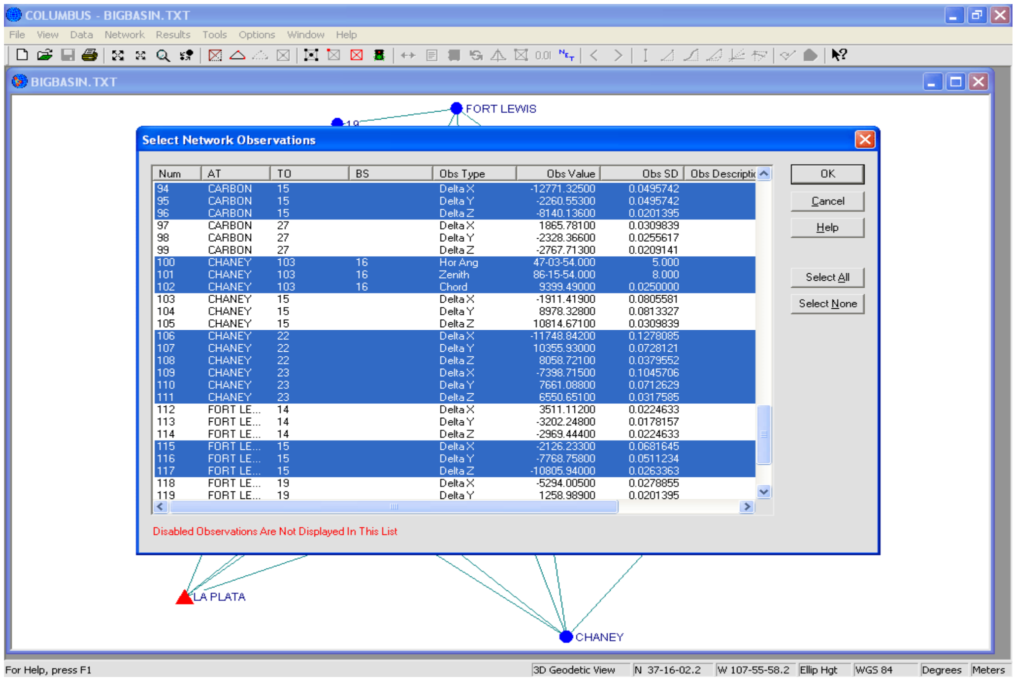
The highlighted row in the screen above represents the final combination, that when solved, resulted in no outliers. The rows above it show the observations that were detected as outliers and then removed before running the next adjustment.

After successfully removing all outlier observation, COLUMBUS allows you to immediately examine all the applicable network adjustment results for the last solution (with all outliers removed).

You can than save the final network configuration with the NETWORK - SAVE NETWORK command or you can proceed to do a constrained adjustment by closing the current adjustment, selecting additional fixed stations and then invoking the NETWORK - ADJUSTMENT command. As long as you do not re-enter the NETWORK - OBSERVATIONS dialog, change a selection, then select **OK -** the observations that have been removed will NOT be included during a new adjustment.

To view the observations that were removed during the automated outlier detection process, enter the

NETWORK - OBSERVATIONS dialog and scroll down to see which observations are now **un-selected**. Selected and unselected observations.

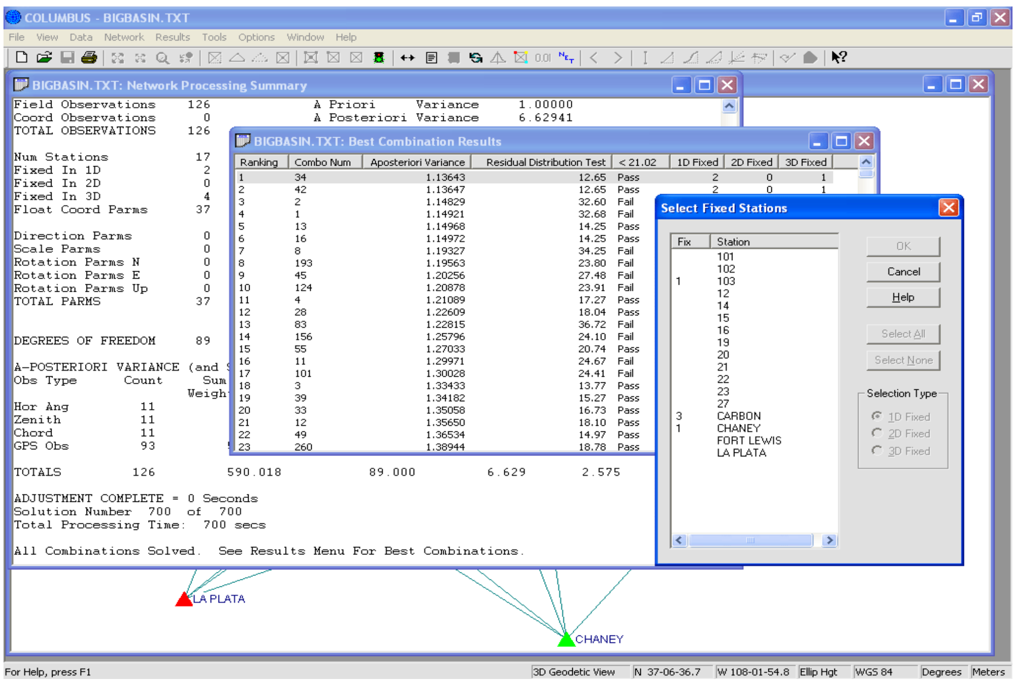


Best Constrained Combinations

After performing a network adjustment using the ADJUSTMENT (FIXED - ALL CASES) option from the NETWORK ADJUSTMENT chapter, the standard adjustment summary window is displayed. To bring up a list of the top solutions (best 20,000 max) invoke the BEST CONSTRAINED COMBOS command from the RESULTS menu.

How Solutions Are Ranked

As COLUMBUS processes each new combination, it keeps track of the top 20,000 (max) solutions for two independent tests: the A Posterior Variance Factor test and the Residual Distribution Test. When processing is complete, these solutions can be displayed and printed. You can then pick which of these solutions to use as your final constrained adjustment. Or you might take a closer look at the top 10 solutions by solving them individually and looking at several other statistical indicators presented by COLUMBUS after the traditional network adjustment process.



The A Posteriori Variance Factor ranking is always performed. **The closer the A Posteriori Variance Factor is to 1.0, the better the ranking for a given solution.** This test does not require a final inverse on each solution, which results in faster processing times for larger networks.

The Residual Distribution Test is optional. It will give you a numeric indicator as to how evenly the Standardized Residuals (for all observations) are distributed about their mean. Since this test requires additional statistical information found within the final inverse for each solution, it will lengthen processing times for large networks when enabled.

For each solution displayed in the screen above, the number of stations that were held fixed in 1D, 2D and 3D is shown. To determine exactly which stations were fixed in 1D, 2D or 3D for a solution, highlight that solution in the view and select from the COMBINATION DETAILS command or click the Combination

Details toolbar button. This will bring up a dialog showing all the station names in the network and highlighting the ones which were the control stations for this solution.

For this example, we show the top-ranked solution. Station Carbon was fixed in 3D. Station Chaney and station 103 were fixed in 1D. To quickly see what stations were fixed for the top 20,000 (max) solutions, you can also go to the Print Preview option from the FILE menu and preview a complete report for all the solutions.