

Appendix G

Application: Structural Deformation Reference Network Survey--Dworshak Dam, Idaho (Walla Walla District and Topographic Engineer Center)

G-1. General

High precision GPS control surveys may be performed to establish reference locations for structural deformation monitoring surveys. Accurate reference control in the vicinity of the structure is critical. Absolute NGRS coordinate on monitoring points is of lesser importance. NGRS control may be brought into one of the reference points with GPS. Only the NGRS coordinates of this fixed point are held fixed for all subsequent adjustments in the vicinity of the structure.

G-2. Project Description

This project was conducted in the vicinity of Dworshak Dam, Idaho and was performed to establish permanent reference points in the vicinity of the dam. A diagram of the project is shown in Figure G-1. Baseline data from the NGRS control to one point (Fish Hatchery - 4001) at the project site were collected and other baseline data for baselines between 4001, BIG EDDY (4002), and four points on the Dworshak Dam and Reservoir (4003, 4004, 4005, and 4006) as shown in Figure G-1. Loop closure checks were done for the complete network by using the loop closure routine shown in Figure G-2. The resultant precision for the loop is 0.43 ppm (1:2,300,000).

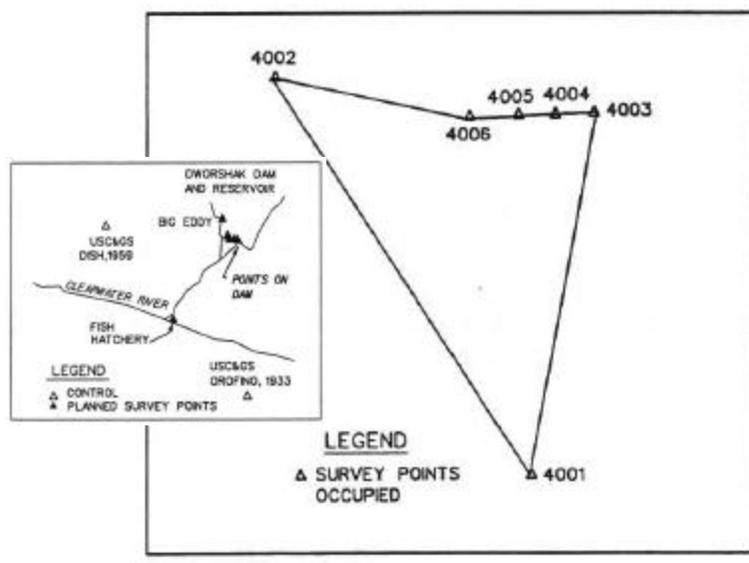


Figure G-1. Dworshak Dam locale and GPS project diagram

G-3. Adjustment

An IOB file for the adjustment based on the formulated baselines was set up. Station USC&GS Dish, 1959, and USC&GS Orofino, 1933, were held fixed to establish NGRS control on Corps of Engineers Station 4001 at the project site. Then, for the next adjustment, 4001 was held fixed to adjust station 4002, 4003, 4004, 4005, and 4006. The resultant adjustment statistics are shown in Figure G-3 (a-h). The 2-D station confidence is on the order of 0.04 m (95%) in the horizontal and ± 0.06 m in the vertical. The largest line accuracy is 36.322 ppm (1:27,000) over a short (62 meter) baseline. This would be acceptable even though a 1:100,00 relative accuracy is required. Due to fixed centering errors, maintaining 1:100,000 relative accuracies over lines less than 200 to 500 meters is unrealistic.

Trimble Loop Closure Utility			
Start Traverse at Station: 4006			
Starting Coords :	46x30'56.88832"GN	116x17'48.33684"GW	489.943
Baseline 1			
File Name:	06053001.FIX		
From Station:	4006	To Station:	4005
Distance Travelled (m):	82.829		
Current Coords :	46x30'55.20552"GN	116x17'46.75486"GW	500.412
Baseline 2			
File Name:	05042993.FIX		
From Station:	4005	To Station:	4004
Distance Travelled (m):	124.262		
Current Coords :	46x30'54.30015"GN	116x17'44.23756"GW	489.809
Baseline 3			
File Name:	04032991.FIX		
From Station:	4004	To Station:	4003
Distance Travelled (m):	214.384		
Current Coords :	46x30'51.68841"GN	116x17'42.38493"GW	497.376
Baseline 4			
File Name:	01032992.FIX		
From Station:	4003	To Station:	4001
Distance Travelled (m):	2872.755		
Current Coords :	46x30'05.98861"GN	116x19'27.67811"GW	308.887
Baseline 5			
File Name:	01023012.FIX		
From Station:	4001	To Station:	4002
Distance Travelled (m):	6122.940		
Current Coords :	46x31'41.46032"GN	116x18'24.06337"GW	490.036
Baseline 6			
File Name:	02063001.FIX		
From Station:	4002	To Station:	4006
Distance Travelled (m):	7695.981		
Current Coords :	46x30'56.88826"GN	116x17'48.33690"GW	489.941
End Traverse at Station: 4006			
Distance Travelled (m):	7695.981	Precision (ppm):	0.43
dx:	-0.001	dy:	0.001
		dz:	-0.003
		dh:	-0.002
Ending Coords :	46x30'56.88826"GN	116x17'48.33690"GW	489.941
Reference Coords:	46x30'56.88832"GN	116x17'48.33684"GW	489.943

Figure G-2. Loop Closure (Dworshak)

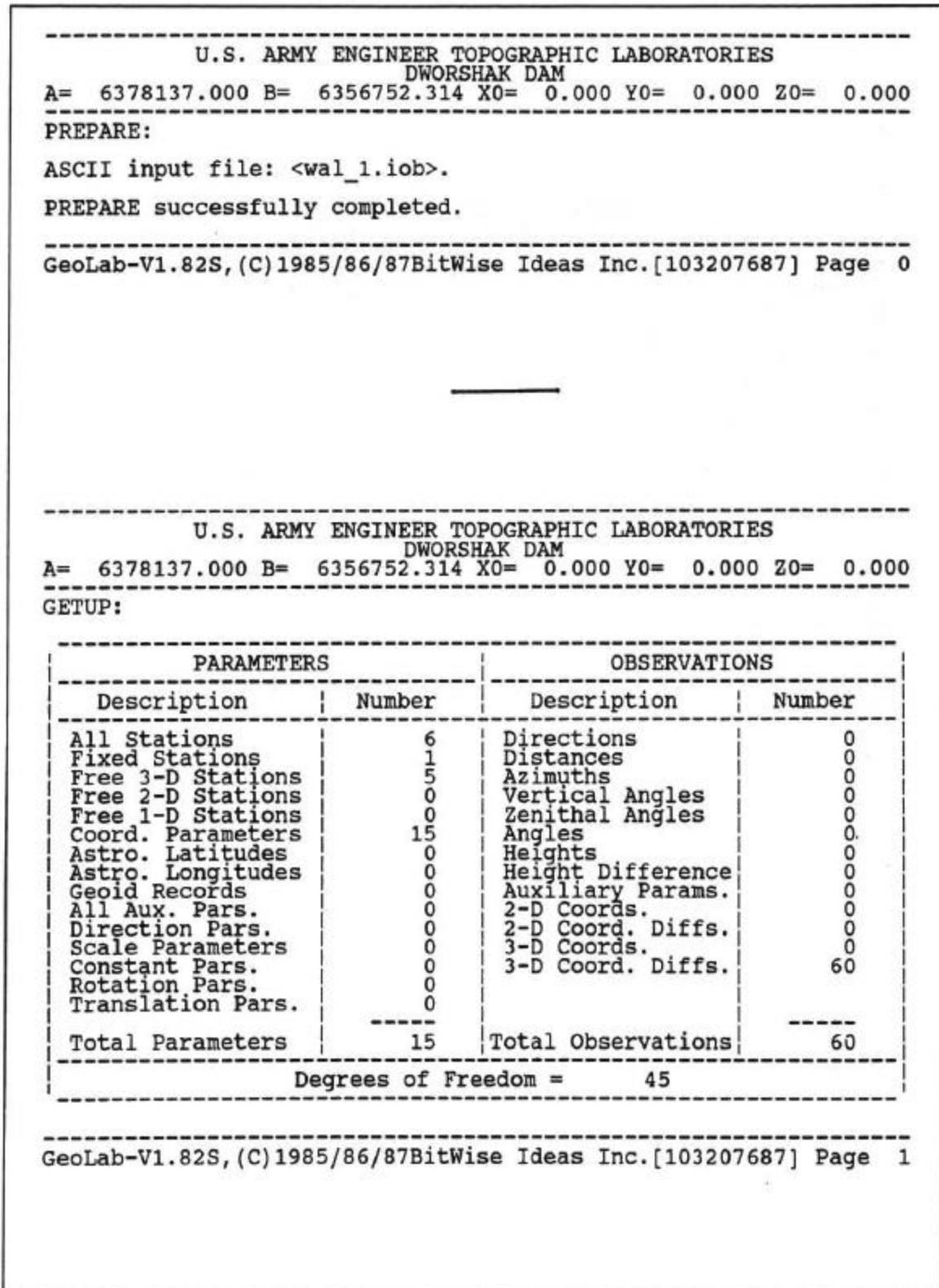


Figure G-3a. GEOLAB adjustment output (Dworshak Dam Reference Network)

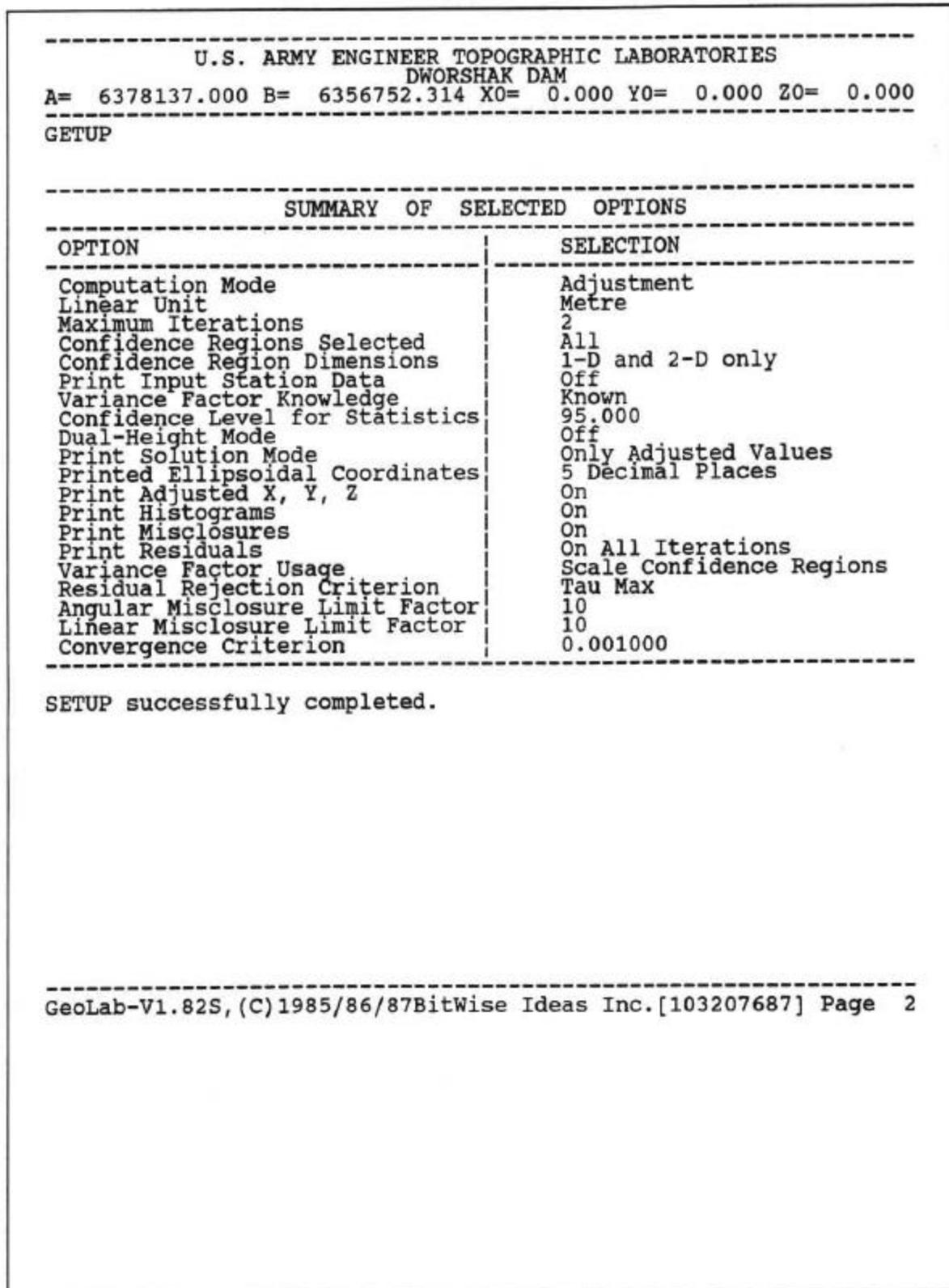


Figure G-3b. GEOLAB adjustment output (Dworshak Dam Reference Network)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES						
DWORSHAK DAM						
A= 6378137.000		B= 6356752.314		X0= 0.000	Y0= 0.000	Z0= 0.000
FORMEQ:						
NOTE 6: Reordering was done.						
AT	TO	OBS	TYPE	OBSERVATION	APPROX. SIG.	MISCLOSURE
4001	4003	3-D	X-Coord Diff	2408.6880	0.0029	22.8708
4001	4003	3-D	Y-Coord Diff	-193.5840	0.0016	25.8258
4001	4003	3-D	Z-Coord Diff	1108.0180	0.0021	-26.6407
4004	4003	3-D	X-Coord Diff	7.1790	0.0007	22.7040
4004	4003	3-D	Y-Coord Diff	-74.6270	0.0003	21.7690
4004	4003	3-D	Z-Coord Diff	-50.0120	0.0006	-25.7900
4001	4004	3-D	X-Coord Diff	2401.5070	0.0055	.1688
4001	4004	3-D	Y-Coord Diff	-118.9530	0.0065	4.0528
4001	4004	3-D	Z-Coord Diff	1158.0230	0.0062	-0.8437
4001	4002	3-D	X-Coord Diff	2108.6340	0.0061	-1.6862
4001	4002	3-D	Y-Coord Diff	1204.4260	0.0079	36.7548
4001	4002	3-D	Z-Coord Diff	2160.2690	0.0067	-27.6797
4001	4003	3-D	X-Coord Diff	2408.6870	0.0055	22.8718
4001	4003	3-D	Y-Coord Diff	-193.5780	0.0072	25.8198
4001	4003	3-D	Z-Coord Diff	1108.0110	0.0062	-26.6337
4001	4005	3-D	X-Coord Diff	2359.1380	0.0047	-0.9472
4001	4005	3-D	Y-Coord Diff	-83.5390	0.0122	5.9208
4001	4005	3-D	Z-Coord Diff	1184.9630	0.0073	-7.2267
4005	4004	3-D	X-Coord Diff	42.3580	0.0008	1.1270
4005	4004	3-D	Y-Coord Diff	-35.4190	0.0015	-1.8630
4005	4004	3-D	Z-Coord Diff	-26.9330	0.0006	6.3760
4001	4002	3-D	X-Coord Diff	2108.6240	0.0045	-1.6762
4001	4002	3-D	Y-Coord Diff	1204.4190	0.0104	36.7618
4001	4002	3-D	Z-Coord Diff	2160.2710	0.0063	-27.6817
4001	4006	3-D	X-Coord Diff	2348.8140	0.0033	32.4128
4001	4006	3-D	Y-Coord Diff	-28.3330	0.0019	24.3928
4001	4006	3-D	Z-Coord Diff	1213.1260	0.0021	-23.8437
4006	4005	3-D	X-Coord Diff	10.3400	0.0008	-33.3760
4006	4005	3-D	Y-Coord Diff	-55.2020	0.0004	-18.4760
4006	4005	3-D	Z-Coord Diff	-28.1650	0.0007	16.6190
4002	4006	3-D	X-Coord Diff	240.1770	0.0031	34.1020
4002	4006	3-D	Y-Coord Diff	-1232.7570	0.0020	-12.3640
4002	4006	3-D	Z-Coord Diff	-947.1440	0.0019	3.8370
4002	4005	3-D	X-Coord Diff	250.5120	0.0027	0.7310
4002	4005	3-D	Y-Coord Diff	-1287.9560	0.0040	-30.8430
4002	4005	3-D	Z-Coord Diff	-975.3050	0.0031	20.4520
4001	4005	3-D	X-Coord Diff	2359.1440	0.0055	-0.9532
4001	4005	3-D	Y-Coord Diff	-83.5400	0.0067	5.9218
4001	4005	3-D	Z-Coord Diff	1184.9690	0.0063	-7.2327
4001	4006	3-D	X-Coord Diff	2348.8070	0.0054	32.4198
4001	4006	3-D	Y-Coord Diff	-28.3370	0.0066	24.3968
4001	4006	3-D	Z-Coord Diff	1213.1310	0.0062	-23.8487
4002	4003	3-D	X-Coord Diff	300.0520	0.0022	24.5590
4002	4003	3-D	Y-Coord Diff	-1398.0030	0.0043	-10.9360

GeoLab-V1.82S, (C) 1985/86/87BitWise Ideas Inc. [103207687] Page 3

Figure G-3c. GEOLAB adjustment output (Dworshak Dam Reference Network)

```

-----
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000
-----
FORMEQ:

```

AT	T0	OBS TYPE	OBSERVATION	APPROX. SIG.	MISCLOSURE
4002	4003	3-D X-Coord Diff	-1052.2550	0.0024	1.0430
4006	4003	3-D X-Coord Diff	59.8780	0.0007	-9.5460
4006	4003	3-D Y-Coord Diff	-165.2500	0.0015	1.4320
4006	4003	3-D Z-Coord Diff	-165.2500	0.0006	-2.7900
4001	4002	3-D X-Coord Diff	2108.6250	0.0045	-1.6772
4001	4002	3-D Y-Coord Diff	1204.4170	0.0104	36.7638
4001	4002	3-D Z-Coord Diff	2160.2740	0.0063	-27.6847
4001	4002	3-D X-Coord Diff	2108.6270	0.0043	-1.6792
4001	4002	3-D Y-Coord Diff	1204.4160	0.0028	36.7648
4001	4002	3-D Z-Coord Diff	2160.2680	0.0029	-27.6787
4001	4002	3-D X-Coord Diff	2108.6320	0.0063	-1.6842
4001	4002	3-D Y-Coord Diff	1204.4280	0.0078	36.7528
4001	4002	3-D Z-Coord Diff	2160.2620	0.0062	-27.6727
4001	4002	3-D X-Coord Diff	2108.6250	0.0045	-1.6772
4001	4002	3-D Y-Coord Diff	1204.4170	0.0101	36.7638
4001	4002	3-D Z-Coord Diff	2160.2780	0.0061	-26.6887

```

FORMEQ successfully completed.
-----
GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 4
-----
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000
-----
SOLVE:
SOLVE successfully completed.
-----
GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 5
-----
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000
-----
FORMEQ:
FORMEQ successfully completed.
-----
GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 6
-----

```

Figure G-3d. GEOLAB adjustment output (Dworshak Dam Reference Network)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES									
DWORSHAK DAM									
A=		6378137.000		B=		6356752.314		X0= 0.000 Y0= 0.000 Z0= 0.000	

SOLVE:									
Adjusted Values (Iteration Count = 2):									
CODE	IDENT.	TYPE	INITIAL			DX	ADJUSTED		
14	4001	LATITUDE	46	30	5.78733	FIXED			
14	2006	LONGITUDE	-116	19	17.36405	FIXED			
14	2006	HEIGHT			312.18200	FIXED			
24	4003	LATITUDE	46	30	51.48677	0.00000	46	30	51.48677
24	4003	LONGITUDE	-116	17	42.07099	0.00000	-116	17	42.07099
24	4003	HEIGHT			500.68216	0.00001			500.68217
24	4004	LATITUDE	46	30	54.09853	0.00000	46	30	54.09853
24	4004	LONGITUDE	-116	17	43.92366	-0.00000	-116	17	43.92366
24	4004	HEIGHT			493.11850	0.00000			493.11851
24	4002	LATITUDE	46	30	41.25876	0.00000	46	31	41.25876
24	4002	LONGITUDE	-116	18	23.74916	-0.00001	-116	18	23.74917
24	4002	HEIGHT			493.34210	0.00003			493.34213
24	4005	LATITUDE	46	30	55.00394	-0.00000	46	30	36.93927
24	4005	LONGITUDE	-116	17	46.44097	-0.00000	-116	17	46.44097
24	4005	HEIGHT			503.72111	0.00000			503.72111
24	4006	LATITUDE	46	30	56.68676	0.00000	46	30	56.68676
24	4006	LONGITUDE	-116	17	48.02294	0.00001	-116	17	48.02294
24	4006	HEIGHT			493.25364	0.00003			493.25367

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 7									

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES									
DWORSHAK DAM									
A=		6378137.000		B=		6356752.314		X0= 0.000 Y0= 0.000 Z0= 0.000	

Adjusted Cartesian Coordinates:									
CODE	IDENT.	X-COORDINATE			Y-COORDINATE			Z-COORDINATE	
24	4003	-1948002.5548			-3942346.3361			4605137.8787	
24	4004	-1948009.7358			-3942271.7102			4605187.8935	
24	4002	-1948302.6080			-3940948.3316			4606190.1331	
24	4005	-1948052.0934			-3942236.2903			4605213.8271	
24	4006	-1948062.4335			-3942181.0887			4605242.9935	
SOLVE successfully completed.									

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 8									

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES									
DWORSHAK DAM									
A=		6378137.000		B=		6356752.314		X0= 0.000 Y0= 0.000 Z0= 0.000	

INVERT:									
INVERT successfully completed.									

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc. [103207687] Page 9									

Figure G-3e. GEOLAB adjustment output (Dworshak Dam Reference Network)

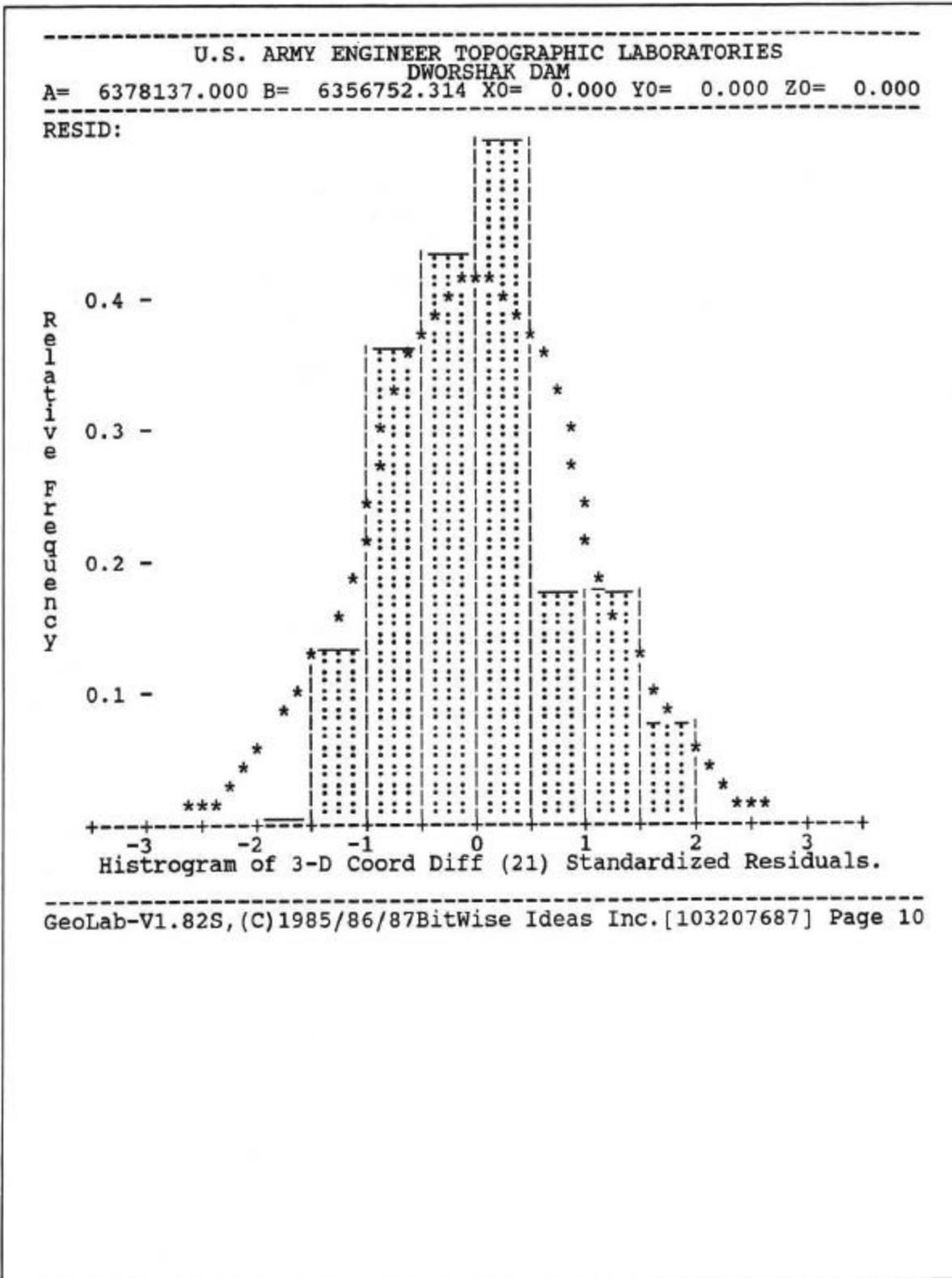


Figure G-3f. GEOLAB adjustment output (Dworshak Dam Reference Network)

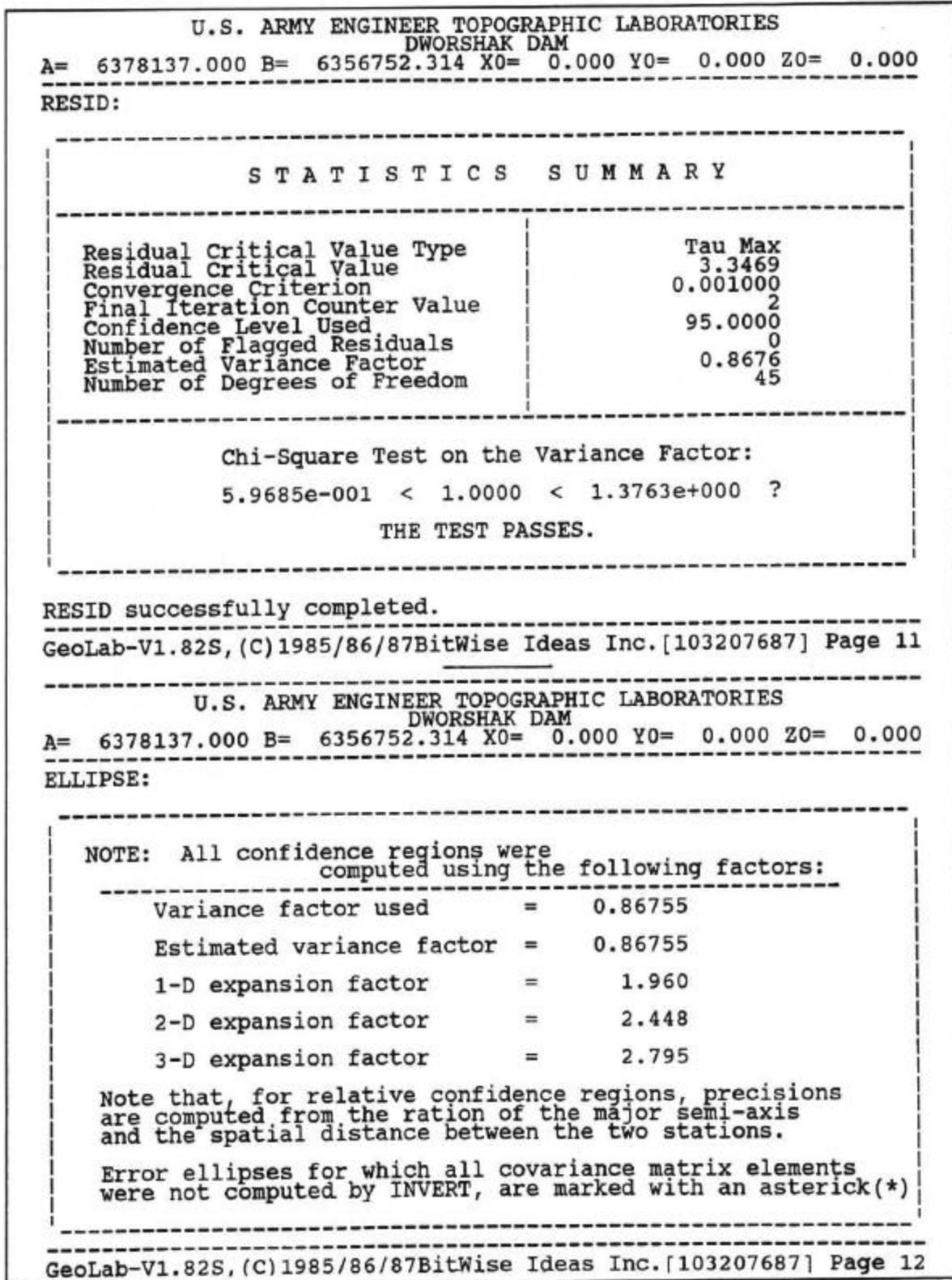


Figure G-3g. GEOLAB adjustment output (Dworshak Dam Reference Network)

```

-----
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000
-----
ELLIPSE:
2-D AND 1-D STATION CONFIDENCE REGIONS ( 95.000 %):
-----
IDENT.      MAJOR SEMI-AXIS  MINOR SEMI-AXIS  AZ(MAJ)  VERTICAL
-----
4003                0.0034          0.0022      76.62    0.0056
4004                0.0036          0.0023      82.71    0.0057
4002                0.0035          0.0026      89.02    0.0061
4005                0.0035          0.0023      82.89    0.0057
4006                0.0035          0.0022      79.03    0.0056
-----

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc.[103207687] Page 13
-----

                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000
-----
ELLIPSE:
2-D and 1-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):
-----
FROM  TO      MAJ.SEMI  MIN.SEMI  AZ(MAJ)  VERT.  SPAT.DIST.  PREC.
-----
4003  4004      0.0023    0.0008    89.79    0.0033    90.1225    25.220PPM
4003  4002      0.0033    0.0026    96.46    0.0057   1775.2993    1.847PPM
4003  4005      0.0025    0.0016   104.89    0.0038   143.1265   17.408PPM
4003  4006      0.0018    0.0014   130.30    0.0027   204.7957    8.998PPM
4004  4002      0.0035    0.0027    97.42    0.0059   1685.7014    2.064PPM
4004  4005      0.0019    0.0014   128.56    0.0027    61.4342   30.745PPM
4004  4006      0.0026    0.0016   102.27    0.0039   118.4286   21.633PPM
4002  4005      0.0033    0.0025    92.33    0.0056   1634.8752    2.019PPM
4002  4006      0.0033    0.0024    85.85    0.0056   1573.0376    2.098PPM
4005  4006      0.0023    0.0009    88.94    0.0033    62.8290   36.322PPM
-----
ELLIPSE successfully completed.
-----

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc.[103207687] Page 14

```

Figure G-3h. GEOLAB adjustment output (Dworshak Dam Reference Network)