DOE/WIPP 06-2293

WIPP
Subsidence Monument Leveling Survey
2005

December 2005

REVIEWED BY _____ DATE 12-1-05
Cognizant Engineer

REVIEWED BY _____ DATE 6 Dec 05
Cognizant Manager

Waste Isolation Pilot Plant

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List of Acronyms

DOE	Department of Energy
DOY	Day of year
FGCS	Federal Geodetic Control Subcommittee
M&TE	Measurement and Test Equipment
NGS	National Geodetic Survey
WTS	Washington TRU Solutions
WIPP	Waste Isolation Pilot Plant

References

Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys, Federal Geodetic Control Committee (now Federal Geodetic Control Subcommittee), [1975] 1980, Reprint.

FGCS Specifications and Procedures to Incorporate Electronic Digital / Bar-Code Leveling Systems, Federal Geodetic Control Subcommittee, ver. 4.0, dated July 15,1994.

WP 09-ES4001, *Subsidence Survey Data Acquisition and Report,* June 2002

Subsidence Monitoring Software Quality Assurance Plan, July 2002

WIPP Subsidence Monument Leveling Surveys 1986-1997, DOE / WIPP 98-2293, June 1998.

WIPP Subsidence Monument Leveling Surveys 1998, DOE / WIPP 99-2293, October 1998.

WIPP Subsidence Monument Leveling Surveys 1999, DOE / WIPP 00-2293, October 1999.

WIPP Subsidence Monument Leveling Surveys 2000, DOE / WIPP 01-2293, October 2000

WIPP Subsidence Monument Leveling Surveys 2001, DOE / WIPP 02-2293, October 2001

WIPP Subsidence Monument Leveling Surveys 2002, DOE / WIPP 03-2293, October 2002

WIPP Subsidence Monument Leveling Surveys 2003, DOE / WIPP 04-2293, October 2003

WIPP Subsidence Monument Leveling Surveys 2004, DOE / WIPP 05-2293, December 2004

1. Introduction

Sections 2 through 7 of this report define the result of the 2005 leveling survey through the subsidence monuments at the WIPP site. Approximately 15 miles of leveling was completed through nine vertical control loops. The 2005 survey includes the determination of elevation on each of the 48 existing subsidence monuments and the WIPP baseline survey, and 14 of the National Geodetic Survey's (NGS) vertical control points. The field observations were completed during September through November of 2005 by personnel from the Washington TRU Solutions (WTS) Surveying Group, Mine Engineering Department. Additional rod personnel were provided by the Geotechnical Engineering Department.

Digital leveling techniques were utilized to achieve better than Second Order Class II loop closures as outlined by the Federal Geodetic Control Subcommittee (FGCS). Because it is important to perform the subsidence survey in exactly the same manner each year, WIPP procedure (WP 09-ES4001) details each step of the survey. Starting with the 2002 survey this procedure has been used to perform the subsidence survey.

Starting with the survey of the year 2001, Loop 1 and redundant survey connections among the various loops were removed from the survey and report. This resulted in a reduction of fieldwork with no loss of accuracy or precision. The redundant connections caused multiple elevations for the same stations. The differences were so slight that they were not used in elevation adjustments for the loops. The redundancy was used to spot gross errors in the field. After several years of surveying these loops it is evident that no gross errors occur that are not also evident in the loop closures.

Finally, Section 8 contains Table F, which summarizes the elevations for all surveys from 1987 through 2005, inclusive. A detailed listing of the 1986 through 1997 surveys is contained in the report, *WIPP Subsidence Monument Leveling Surveys 1986-1997*, DOE/WIPP 98-2293. A reference to the summary reports for each year after 1997 is listed in the reference section of this document.

2. Equipment

The observations were taken with the WILD NA3003 Electronic Digital Level (WIPP M&TE ID# DM0999 and DM1002) manufactured by Leica, and bar coded leveling staffs. The calibration date for DM0999 is valid from March 3, 2005, through March 3, 2007. The calibration for the DM1002 is valid from March 22, 2004, through March 22, 2006. The data were recorded electronically on the Leica GRM10 REC-Module, which plugs directly into the instrument. In addition to the electronic record, a written field log was maintained to record information that is not stored in the electronic record.

3. Office Processing

Each day the data were downloaded from the GRM10 REC-Module to the survey group computer. The original raw data files were maintained intact, and further processing was performed on a copy of the original raw data file.

Listing of the data, and the adjustment of the loops, was completed with the DIGILEV software (version 10.94d) from Leica Canada. The results, as summarized below, were extracted from the output of the DIGILEV software. A Software Quality Assurance Plan was written for the computer programs used in reducing the subsidence survey field notes. DIGILEV was tested, verified and validated. The program was deemed acceptable and is now in the WIPP controlled software list.

4. Methodology

The weather conditions during the observations of the 2005 survey were generally mild with moderate temperatures and light to moderate breezes.

The elevations for the 2005 survey are computed from the adjusted observations based on the elevation of the subsidence monument, S-37 (3,423.874 feet). S-37 is the WIPP monument that is furthest from the influence of the underground excavations, and has been held fixed for all of the subsidence leveling surveys since 1993. The condition of the individual monuments was substantially the same as the previous subsidence survey with three exceptions.

In the 2004 survey, it was noted that the brass cap of monument PT-31 came loose making it unusable and monuments S-17 and S-18 no longer exist due to construction of the new salt storage/disposal pad.

As in previous years, the subsidence survey was divided into nine loops. Each loop generally takes one day to complete. This allows a loop to be completed in one surveying session and results in a lower probability of error.

For visual reference, Figure 1 shows a graphic display of the individual loops, the total survey, and the relationship to the underground excavations.

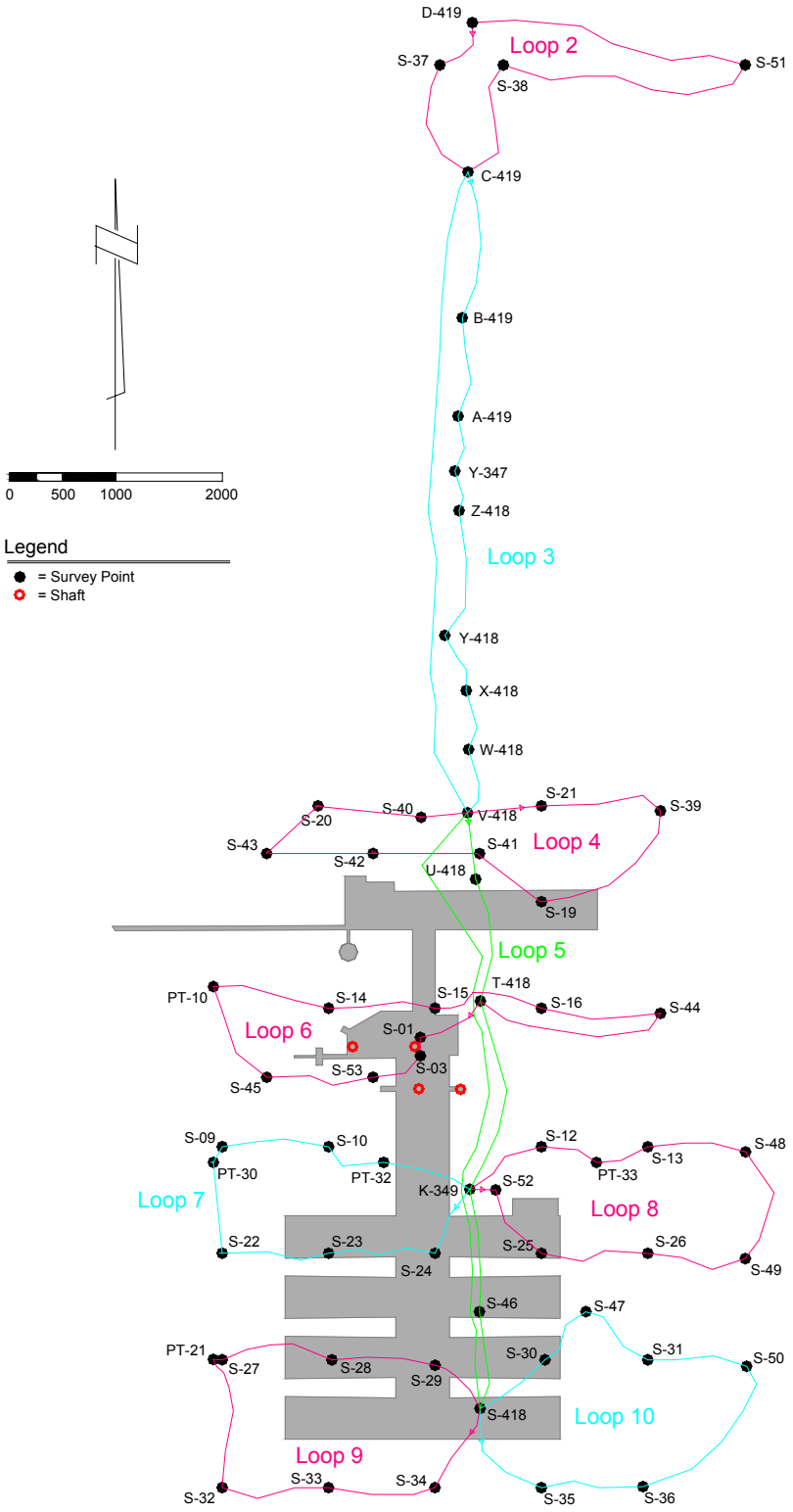

Figure 1. Individual Loops, Total Survey and Underground Excavations

5. General Summary of Results

Table A below describes the nine leveling loops that were measured to obtain the elevations of the subsidence monuments. The table contains the start date of the observations, a loop number, and the points that are contained within the loop.

Table A. Description of 2005 Leveling Loops

Start Date (DOY)	Loop	Points
September 2, 2005 (264)	2	D-419, S-37, C-419, S-38, S-51, D-419
September 23 & 28, 2005 (266 & 271)	3	C-419, B-419, A-419, Y-347, Z-418, Y-418, X-418, W-418, V-418, C-419
October 5, 2005 (278)	4	V-418, S-21, S-39, S-19, S-41, S-42, S-43, S-20, S-40, V-418
October 12, 2005 (285)	5	V-418, U-418, T-418, K-349, S-46, S-418, V-418
November 8, 2005 (312)	6	T-418, S-01, S-03, S-53, S-45, PT-10, S-14, S-15, S-16, S-44, T-418
November 2, 2005 (306)	7	K-349, S-24, S-23, S-22, PT30, S-09, S-10, PT-32, K-349
October 19, 2005 (292)	8	K-349, S-52, S-25, S-26, S-49, S-48, S-13, PT-33, S-12, K-349
October 26, 2005 (299)	9	S-418, S-34, S-33, S-32, PT-21, S-27, S-28, S-29, S-418
October 21, 2005 (294)	10	S-418, S-35, S-36, S-50, S-31, S-47, S-30, S-418

Table B summarizes the results of the leveling loops in terms of vertical closure and accuracy. The requirement for Second Order Class II loop closure accuracy was achieved in all cases.

Table B. Summary of Distance and Accuracy for 2005 Leveling Loops

Loop	Cumulative Distance (ft.)	Vertical Closure (ft.)	Accuracy (ft.√mile)	Allowable Accuracy (ft.√mile)
2	8,497.32	0.0070	0.006	0.042
3	12,764.04	0.0040	0.003	0.051
4	8,428.40	-0.0062	0.005	0.042
5	13,302.52	0.0045	0.003	0.052
6	9,914.56	0.0069	0.005	0.045
7	6,743.13	0.0078	0.007	0.037
8	7,032.78	0.0041	0.004	0.038
9	7,505.01	0.0080	0.007	0.039
10	6,950.17	0.0064	0.006	0.038

5.1 Accuracy Summary by Loop

Table C shows a detailed summary of the observations in the leveling loops for the 2005 survey. All results are shown in feet. The information in the table for each loop includes:

Between each benchmark in the loop:

- The distance leveled between benchmarks along the loop.
- The number of instrument setups between each of the benchmarks.
- The difference in elevation from each benchmark to the next.

For each loop as a whole:

- The cumulative, or total, distance of each loop.
- The vertical closure of the loop.
- The accuracy of leveling.
- Allowable accuracy for each loop.

The accuracy of the leveling is given in terms of feet times the square root of the length of the loop in miles. The actual accuracy of leveling is computed in the DIGILEV software, and is based on the actual vertical closure of the loop. The maximum allowable accuracy is based on the allowable accuracy of a loop as stated in the FGCS specification for digital leveling. The FGCS specification for Second Order Class II loop closure permits a maximum of 8mm$\sqrt{}$Km (8mm times the square root of the length of the loop in Km). This converts to 0.033ft.$\sqrt{}$mile (0.033 feet times the square root of the length of the loop in miles) when stated in English System. All values indicated in this summary are expressed in feet.

Inspection of the following tables shows that in every case the actual accuracy is well below the maximum allowable accuracy for each loop. The column in each table that is labeled “Difference” is the vertical difference from one point to the next. It is important to note that the vertical difference figures have been rounded, and a slight difference may exist in the vertical closure figure from the algebraic sum of the column.

Table C. Detailed Loop Measurements

Loop 2

From	To	Distance	Setups	Difference
D-419	S-37	627.69	4	0.631
S-37	C-419	1,287.89	8	13.789
C-419	S-38	1,463.92	8	-7.906
S-38	S-51	2,347.80	14	7.962
S-51	D-419	2,770.02	16	-14.476
Cumulative Distance:		8,497.32		
Vertical Closure:				0.007
Accuracy of Leveling:				0.006
Allowable Accuracy:				0.042

Loop 3

From	To	Distance	Setups	Difference
C-419	B-419	1,416.31	8	12.185
B-419	A-419	959.27	6	4.894
A-419	Y-347	538.70	4	0.559
Y-347	Z-418	460.48	4	5.807
Z-418	Y-418	1,251.78	8	4.005
Y-418	X-418	585.36	4	-9.120
X-418	W-418	573.28	4	-6.698
W-418	V-418	644.74	6	-12.810
V-418	C-419	6,334.12	36	1.178
Cumulative Distance:		12,764.04		
Vertical Closure:				0.004
Accuracy of Leveling:				0.003
Allowable Accuracy:				0.051

Loop 4

From	To	Distance	Setups	Difference
V-418	S-21	826.25	6	5.456
S-21	S-39	1,151.24	8	-3.796
S-39	S-19	1,457.05	10	-12.037
S-19	S-41	781.43	6	4.774
S-41	S-42	1,026.77	8	-2.638
S-42	S-43	1,009.21	8	-4.445
S-43	S-20	682.56	6	10.545
S-20	S-40	1,034.74	8	0.106
S-40	V-418	459.15	4	2.036
Cumulative Distance:		8,428.40		
Vertical Closure:				-0.006
Accuracy of Leveling:				0.005
Allowable Accuracy:				0.042

Loop 5

From	To	Distance	Setups	Difference
V-418	U-418	656.43	4	-10.233
U-418	T-418	1,191.52	6	-9.384
T-418	K-349	2,660.97	14	-12.763
K-349	S-46	1,165.79	6	-4.360
S-46	S-418	1,045.43	6	1.889
S-418	V-418	6,582.38	40	34.851
Cumulative Distance:		13,302.52		
Vertical Closure:				0.004
Accuracy of Leveling:				0.003
Allowable Accuracy:				0.052

Loop 6

From	To	Distance	Setups	Difference
T-418	S-01	779.51	4	-7.317
S-01	S-03	179.39	2	-0.812
S-03	S-53	557.48	4	-0.072
S-53	S-45	1,160.98	6	-8.246
S-45	PT-10	1,167.82	6	7.248
PT-10	S-14	1,144.87	6	3.638
S-14	S-15	1,002.29	6	1.812
S-15	S-16	1,018.98	6	8.150
S-16	S-44	1,157.27	8	6.824
S-44	T-418	1,745.97	12	-11.225
Cumulative Distance:		9,914.56		
Vertical Closure:				0.007
Accuracy of Leveling:				0.005
Allowable Accuracy:				0.045

Loop 7

From	To	Distance	Setups	Difference
K-349	S-24	949.88	6	-2.129
S-24	S-23	1,025.23	6	-6.150
S-23	S-22	1,034.85	6	-8.106
S-22	PT-30	888.92	6	5.005
PT-30	S-09	177.74	2	1.273
S-09	S-10	1,196.82	8	8.360
S-10	PT-32	543.35	4	1.795
PT-32	K-349	926.34	6	-0.047
Cumulative Distance:		6,743.13		
Vertical Closure:				0.008
Accuracy of Leveling:				0.007
Allowable Accuracy:				0.037

Loop 8

From	To	Distance	Setups	Difference
K-349	S-52	250.39	2	3.367
S-52	S-25	898.33	6	0.314
S-25	S-26	1,013.32	6	12.067
S-26	S-49	931.27	6	12.750
S-49	S-48	1,012.79	6	0.694
S-48	S-13	957.50	6	-11.023
S-13	PT-33	513.74	4	-2.485
PT-33	S-12	543.55	4	-8.177
S-12	K-349	911.89	6	-7.506
Cumulative Distance:		7,032.78		
Vertical Closure:				0.004
Accuracy of Leveling:				0.004
Allowable Accuracy:				0.038

Table C continued on next page…

Table C. Detailed Loop Measurements (continued)

Loop 9				
From	**To**	**Distance**	**Setups**	**Difference**
S-418	S-34	1,113.73	6	-9.599
S-34	S-33	1,016.56	6	-13.025
S-33	S-32	1,086.13	6	-5.585
S-32	PT-21	1,279.80	8	10.436
PT-21	S-27	148.54	2	3.359
S-27	S-28	1,081.46	6	6.074
S-28	S-29	977.42	8	6.667
S-29	S-418	801.37	6	1.673
Cumulative Distance:		7,505.01		
Vertical Closure:				0.008
Accuracy of Leveling:				0.007
Allowable Accuracy:				0.039

Loop 10				
From	**To**	**Distance**	**Setups**	**Difference**
S-418	S-35	1,369.09	8	-1.129
S-35	S-36	977.45	6	9.031
S-36	S-50	1,505.99	8	16.318
S-50	S-31	966.20	6	-13.619
S-31	S-47	739.24	4	-3.121
S-47	S-30	599.83	4	-5.213
S-30	S-418	792.37	6	-2.268
Cumulative Distance:		6,950.17		
Vertical Closure:				0.006
Accuracy of Leveling:				0.006
Allowable Accuracy:				0.038

6. Adjusted Level Loops

Table D is a summary of the adjusted elevations for the nine loops measured in 2005. They have been extracted from the output of the DIGILEV software. These are adjusted elevations within each loop. These final adjusted elevations also appear in Table E.

Table D. Adjusted Elevations by Loop

Loop 2	
D-419	3,423.243
S-37	3,423.874
C-419	3,437.663
S-38	3,429.757
S-51	3,437.720
D-419	3,423.243

Loop 3	
C-419	3,437.663
B-419	3,449.848
A-419	3,454.742
Y-347	3,455.301
Z-418	3,461.108
Y-418	3,465.113
X-418	3,455.993
W-418	3,449.295
V-418	3,436.485
C-419	3,437.663

Loop 4	
V-418	3,436.485
S-21	3,441.941
S-39	3,438.144
S-19	3,426.107
S-41	3,430.882
S-42	3,428.243
S-43	3,423.798
S-20	3,434.343
S-40	3,434.449
V-418	3,436.485

Loop 5	
V-418	3,436.485
U-418	3,426.252
T-418	3,416.868
K-349	3,404.105
S-46	3,399.745
S-418	3,401.634
V-418	3,436.485

Loop 6	
T-418	3,416.868
S-01	3,409.551
S-03	3,408.739
S-53	3,408.667
S-45	3,400.421
PT-10	3,407.669
S-14	3,411.307
S-15	3,413.118
S-16	3,421.268
S-44	3,428.093
T-418	3,416.868

Loop 7	
K-349	3,404.105
S-24	3,401.976
S-23	3,395.826
S-22	3,387.720
PT-30	
S-09	3,393.997
S-10	3,402.357
PT-32	3,404.152
K-349	3,404.105

Loop 8	
K-349	3,404.105
S-52	3,407.473
S-25	3,407.786
S-26	3,419.853
S-49	3,432.603
S-48	3,433.297
S-13	3,422.274
PT-33	3,419.789
S-12	3,411.611
K-349	3,404.105

Loop 9	
S-418	3,401.634
S-34	3,392.035
S-33	3,379.011
S-32	3,373.426
PT-21	3,383.862
S-27	3,387.221
S-28	3,393.294
S-29	3,399.961
S-418	3,401.634

Loop 10	
S-418	3,401.634
S-35	3,400.505
S-36	3,409.536
S-50	3,425.855
S-31	3,412.235
S-47	3,409.114
S-30	3,403.902
S-418	3,401.634

7. Adjusted Elevations (2005)

Table E shows the adjusted elevations for the subsidence monuments and the NGS points contained within the 2005 survey. These elevations are normalized to the monument, S-37. All elevations are shown in feet, and are within the WIPP local coordinate system.

Table E. 2005 Adjusted Elevations

Point	Elevation (ft.)	Point	Elevation (ft.)
S-01	3,409.551	S-42	3,428.243
S-03	3,408.739	S-43	3,423.798
S-09	3,393.997	S-44	3,428.093
S-10	3,402.357	S-45	3,400.421
S-12	3,411.611	S-46	3,399.745
S-13	3,422.274	S-47	3,409.114
S-14	3,411.307	S-48	3,433.297
S-15	3,413.118	S-49	3,432.603
S-16	3,421.268	S-50	3,425.855
S-19	3,426.107	S-51	3,437.720
S-20	3,434.343	S-52	3,407.473
S-21	3,441.941	S-53	3,408.667
S-22	3,387.720		
S-23	3,395.826	PT-10	3,407.669
S-24	3,401.976	PT-21	3,383.862
S-25	3,407.786		
S-26	3,419.853	PT-31	Monument damaged
S-27	3,387.221	PT-32	3,404.152
S-28	3,393.294	PT-33	3,419.789
S-29	3,399.961	S-418	3,401.634
S-30	3,403.902	T-418	3,416.868
S-31	3,412.235	U-418	3,426.252
S-32	3,373.426	V-418	3,436.485
S-33	3,379.011	W-418	3,449.295
S-34	3,392.035	X-418	3,455.993
S-35	3,400.505	Y-347	3,455.301
S-36	3,409.536	Y-418	3,465.113
S-37	3,423.874	Z-418	3,461.108
S-38	3,429.757	A-419	3,454.742
S-39	3,438.144	B-419	3,449.848
S-40	3,434.449	C-419	3,437.663
S-41	3,430.882	D-419	3,423.243
		K-349	3,404.105

8. Comparison of Elevations*

Table F compares the elevations from all of the subsidence leveling surveys from 1987 through 2005. All elevations are shown in feet.

Table F. Comparison of Elevations 1987-2005

	S-01	S-02	S-03	S-09	S-10	S-11	S-12	S-13	S-14
1987	3,409.738	3,408.219	3,408.914	3,394.056	3,402.466	3,406.437	3,411.790	3,422.428	3,411.500
1989	3,409.719	3,411.907	3,408.900	3,394.046	3,402.459	3,406.408	3,411.739	3,422.413	3,411.483
1992	3,409.695	3,411.904	3,408.875	3,394.053	3,402.440	3,406.372	3,411.727	3,422.412	3,411.439
1993	3,409.616	(1) (2)	3,408.797	3,393.969	3,402.365	(3)	3,411.630	3,422.324	3,411.382
1994	3,409.626		3,408.806	3,393.988	3,402.374		3,411.653	3,422.348	3,411.372
1995	3,409.613		3,408.795	3,393.986	3,402.373		3,411.650	3,422.345	3,411.376
1996	3,409.615		3,408.795	3,393.994	3,402.373		3,411.645	3,422.340	3,411.369
1997	3,409.610		3,408.793	3,394.002	3,402.379		3,411.656	3,422.349	3,411.368
1998	3,409.617		3,408.802	3,394.011	3,402.388		3,411.653	3,422.352	3,411.374
1999	3,409.613		3,408.798	3,394.004	3,402.385		3,411.650	3,422.358	3,411.365
2000	3,409.607		3,408.792	3,394.003	3,402.381		3,411.644	3,422.352	3,411.364
2001	3,409.599		3,408.786	3,394.006	3402.378		3,411.636	3,422.350	3,411.361
2002	3,409.595		3,408.783	3,394.012	3,402.381		3,411.637	3,422.354	3,411.357
2003	3,409.583		3,408.771	3,394.007	3,402.372		3,411.629	3,422.307	3,411.351
2004	3,409.575		3,408.762	3,394.006	3,402.373		3,411.630	3,422.310	3,411.329
2005	3,409.551		3,408.739	3,393.997	3,402.357		3,411.611	3,422.274	3,411.307

Note: (1) The subsidence monument, S-02 was relocated in 1989.
(2) The subsidence monument, S-02, no longer exists after the 1992 survey.
(3) The subsidence monument, S-11, no longer exists after the 1992 survey.

	S-15	S-16	S-17	S-18	S-19	S-20	S-21	S-22	S-23
1987	3,413.291	3,421.378	3,422.519	3,425.010	3,426.235	3,434.464	3,442.030	3,387.786	3,395.914
1989	3,413.291	3,421.341	3,422.482	3,424.974	3,426.217	3,434.452	3,442.005	3,387.795	3,395.970
1992	3,413.263	3,421.331	3,422.469	3,424.964	3,426.223	3,434.364	3,441.956	3,387.788	3,396.028
1993	3,413.185	3,421.256	3,422.404	3,424.859	3,426.136	3,434.332	3,441.919	3,387.701	3,395.853
1994	3,413.188	3,421.261	3,422.402	3,424.852	3,426.134	3,434.339	3,441.932	3,387.732	3,395.886
1995	3,413.189	3,421.261	3,422.418	3,424.864	3,426.143	3,434.342	3,441.936	3,387.727	3,395.877
1996	3,413.182	3,421.263	3,422.419	3,424.860	3,426.138	3,434.345	3,441.935	3,387.727	3,395.885
1997	3,413.178	3,421.268	3,422.431	3,424.864	3,426.141	3,434.346	3,441.937	3,387.738	3,395.889
1998	3,413.184	3,421.271	3,422.436	3,424.869	3,426.150	3,434.355	3,441.946	3,387.744	3,395.887
1999	3,413.177	3,421.275	3,422.435	3,424.865	3,426.152	3,434.362	3,441.959	3,387.729	3,395.873
2000	3,413.172	3,421.278	3,422.440	3,424.864	3,426.140	3,434.362	3,441.956	3,387.727	3,395.861
2001	3,413.167	3,421.277	3,422.434	3,424.858	3,426.138	3,434.363	3,441.956	3,387.728	3,395.857
2002	3,413.159	3,421.275	3,422.434	3,424.855	3,426.132	3,434.361	3,441.950	3,387.731	3,395.857
2003	3,413.152	3,421.279	3,422.430	3,424.849	3,426.117	3,434.350	3,441.939	3,387.728	3,395.850
2004	3,413.142	3,421.281	(4)	(5)	3,426.128	3,434.359	3,441.955	3,387.727	3,395.841
2005	3,413.118	3,421.268			3,426.107	3,434.343	3,441.941	3,387.720	3,395.826

Note: (4) The subsidence monument, S-17, no longer exists after the 2003 survey.
(5) The subsidence monument, S-18, no longer exists after the 2003 survey.

Table F continued on next page…

Table F. Comparison of Elevations 1987-2005 (continued)

	S-24	S-25	S-26	S-27	S-28	S-29	S-30	S-31	S-32
1987	3,402.201	3,408.036	3,420.010	3,387.280	3,393.414	3,400.111	3,404.082	3,412.315	3,373.513
1989	3,402.167	3,408.005	3,419.978	3,387.287	3,393.400	3,400.098	3,404.064	3,412.302	3,373.498
1992	3,402.159	3,407.974	3,419.948	3,387.310	3,393.421	3,400.113	3,404.073	3,412.303	3,373.533
1993	3,402.042	3,407.870	3,419.854	3,387.181	3,393.287	3,400.008	3,403.958	3,412.206	3,373.396
1994	3,402.072	3,407.907	3,419.883	3,387.225	3,393.312	3,400.038	3,403.984	3,412.234	3,373.427
1995	3,402.062	3,407.895	3,419.871	3,387.216	3,393.309	3,400.031	3,403.978	3,412.230	3,373.425
1996	3,402.074	3,407.897	3,419.875	3,387.213	3,393.316	3,400.037	3,403.979	3,412.221	3,373.411
1997	3,402.077	3,407.897	3,419.883	3,387.229	3,393.330	3,400.050	3,403.994	3,412.248	3,373.438
1998	3,402.076	3,407.902	3,419.883	3,387.248	3,393.338	3,400.059	3,403.998	3,412.248	3,373.452
1999	3,402.067	3,407.898	3,419.886	3,387.229	3,393.322	3,400.053	3,403.990	3,412.252	3,373.429
2000	3,402.051	3,407.876	3,419.871	3,387.226	3,393.316	3,400.045	3,403.980	3,412.252	3,373.428
2001	3,402.035	3,407.862	3,419.872	3,387.231	3,393.318	3,400.040	3,403.972	3,412.255	3,373.431
2002	3,402.029	3,407.858	3,419.877	3,387.231	3,393.316	3,400.034	3,403.968	3,412.258	3,373.433
2003	3,402.012	3,407.840	3,419.871	3,387.233	3,393.311	3,400.016	3,403.951	3,412.252	3,373.433
2004	3,401.995	3,407.822	3,419.870	3,387.231	3,393.310	3,399.996	3,403.932	3,412.254	3,373.439
2005	3,401.976	3,407.786	3,419.853	3,387.221	3,393.294	3,399.961	3,403.902	3,412.235	3,373.426

	S-33	S-34	S-35	S-36	S-37	S-38	S-39	S-40	S-41
1987	3,379.093	3,392.128	3,400.597	3,409.583					
1989	3,379.073	3,392.137	3,400.583	3,409.584	3,423.888	3,429.736			
1992	3,379.090	3,392.138	3,400.591	3,409.605	3,423.874		3,438.146	3,434.469	3,430.931
1993	3,378.975	3,392.026	3,400.478	3,409.504	3,423.874	3,429.736	3,438.110	3,434.430	3,430.888
1994	3,379.006	3,392.042	3,400.490	3,409.518	3,423.874	3,429.740	3,438.115	3,434.425	3,430.888
1995	3,379.009	3,392.042	3,400.495	3,409.520	3,423.874	3,429.739	3,438.124	3,434.437	3,430.899
1996	3,378.992	3,392.028	3,400.483	3,409.501	3,423.874	3,429.744	3,438.118	3,434.436	3,430.891
1997	3,379.019	3,392.057	3,400.516	3,409.533	3,423.874	3,429.745	3,438.127	3,434.444	3,430.894
1998	3,379.028	3,392.066	3,400.516	3,409.539	3,423.874	3,429.750	3,438.134	3,434.442	3,430.901
1999	3,379.011	3,392.056	3,400.507	3,409.539	3,423.874	3,429.751	3,438.149	3,434.445	3,430.900
2000	3,379.012	3,392.053	3,400.505	3,409.541	3,423.874	3,429.754	3,438.145	3,434.445	3,430.902
2001	3,379.014	3,392.057	3,400.509	3,409.546	3,423.874	3,429.756	3,438.145	3,434.436	3,430.898
2002	3,379.017	3,392.060	3,400.513	3,409.550	3,423.874	3,429.757	3,438.142	3,434.437	3,430.897
2003	3,379.016	3,392.057	3,400.511	3,409.546	3,423.874	3,429.760	3,438.130	3,434.425	3,430.892
2004	3,379.020	3,392.055	3,400.514	3,409.549	3,423.874	3429.761	3,428.152	3,434.449	3,430.900
2005	3,379.011	3,392.035	3,400.505	3,409.536	3,423.874	3,429.757	3,438.144	3,434.449	3,430.882

	S-42	S-43	S-44	S-45	S-46	S-47	S-48	S-49	S-50
1987									
1989									
1992	3,428.279	3,423.849	3,428.146	3,400.501	3,399.946	3,409.236	3,433.308	3,432.635	3,425.868
1993	3,428.230	3,423.813	3,428.070	3,400.406	3,399.837	3,409.133	3,433.238	3,432.572	3,425.809
1994	3,428.228	3,423.820	3,428.066	3,400.419	3,399.865	3,409.163	3,433.264	3,432.596	3,425.830
1995	3,428.238	3,423.826	3,428.071	3,400.424	3,399.856	3,409.158	3,433.258	3,432.588	3,425.830
1996	3,428.238	3,423.823	3,428.078	3,400.423	3,399.856	3,409.157	3,433.256	3,432.585	3,425.816
1997	3,428.249	3,423.815	3,428.084	3,400.428	3,399.877	3,409.181	3,433.274	3,432.600	3,425.846
1998	3,428.252	3,423.822	3,428.086	3,400.440	3,399.876	3,409.178	3,433.276	3,432.598	3,425.838
1999	3,428.255	3,423.825	3,428.091	3,400.435	3,399.866	3,409.176	3,433.289	3,432.611	3,425.851
2000	3,428.254	3,423.820	3,428.095	3,400.434	3,399.842	3,409.168	3,433.288	3,432.606	3,425.854
2001	3,428.247	3,423.818	3,428.094	3,400.433	3,399.824	3,409.163	3,433.290	3,432.606	3,425.858
2002	3,428.246	3,423.815	3,428.097	3,400.435	3,399.818	3,409.160	3,433.297	3,432.613	3,425.863
2003	3,428.236	3,423.805	3,428.090	3,400.430	3,399.790	3,409.147	3,433.294	3,432.610	3,425.857
2004	3,428.254	3,423.814	3,428.105	3,400.440	3,399.770	3,409.149	3,433.311	3,432.620	3,425.876
2005	3,428.243	3,423.798	3,428.093	3,400.421	3,399.745	3,409.114	3,433.297	3,432.603	3,425.855

Table F continued on next page…

Table F. Comparison of Elevations 1987-2005 (continued)

	S-51	S-52	S-53	S-54	PT-10	PT-21	PT-30	PT-31	PT-32
1987									
1989									
1992	3,437.765	3,407.611	3,408.775	3,411.085	3,407.722		3,392.914	3,385.117	3,404.370
1993	3,437.746	3,407.523	3,408.670	(6)	3,407.664	3,383.821	3,392.823	3,385.027	3,404.296
1994	3,437.749	3,407.542	3,408.709		3,407.672	3,383.868	3,392.843	3,385.051	3,404.311
1995	3,437.746	3,407.542	3,408.702		3,407.671	3,383.862	3,392.844	3,385.050	3,404.322
1996	3,437.729	3,407.536	3,408.704		3,407.669	3,383.858	3,392.852	3,385.053	3,404.312
1997	3,437.725	3,407.544	3,408.702		3,407.675	3,383.874	3,392.857	3,385.063	3,404.321
1998	3,437.724	3,407.549	3,408.714		3,407.687	3,383.887	(7)	3,385.067	3,404.322
1999	3,437.729	3,407.544	3,408.709		3,407.689	3,383.868		3,385.053	3,404.315
2000	3,437.729	3,407.531	3,408.704		3,407.685	3,383.868		3,385.053	3,404.306
2001	3,437.731	3,407.522	3,408.701		3,407.687	3,383.874		3,385.053	3,404.259
2002	3,437.733	3,407.521	3,408.700		3,407.688	3,383.871		3,385.057	3,404.250
2003	3,437.731	3,407.507	3,408.690		3,407.685	3,383.874		3,385.054	3,404.234
2004	3,437.730	3,407.501	3,408.686		3,407.685	3,383.874		(8)	3,404.172
2005	3,437.720	3,407.473	3,408.667		3,407.669	3,383.862			3,404.152

Note: (6) The subsidence monument, S-54, no longer exists after the 1992 survey.
(7) The monument, PT-30, has been physically disturbed and was removed from the 1998 survey.
(8) The monument, PT-31, has been physically disturbed and was removed from the 2004 survey.

	PT-33	S-418	T-418	U-418	V-418	W-418	X-418	Y-347	Y-418
1987									
1989									
1992	3,419.939								
1993	3,419.853								
1994	3,419.884								
1995	3,419.869								
1996	3,419.865	3,401.696	3,416.902	3,426.267	3,436.481	3,449.276	3,455.969	3,455.274	3,465.080
1997	3,419.873	3,401.708	3,416.906	3,426.272	3,436.487	3,449.282	3,455.976	3,455.281	3,465.091
1998	3,419.879	3,401.715	3,416.915	3,426.279	3,436.497	3,449.292	3,455.987	3,455.291	3,465.101
1999	3,419.880	3,401.707	3,416.913	3,426.275	3,436.500	3,449.304	3,456.000	3,455.304	3,465.117
2000	3,419.872	3,401.702	3,416.911	3,426.273	3,436.502	3,449.307	3,456.005	3,455.309	3,465.123
2001	3,419.866	3,401.702	3,416.905	3,426.270	3,436.502	3,449.310	3,456.007	3,455.312	3,465.125
2002	3,419.868	3,401.701	3,416.901	3,426.269	3,436.502	3,449.311	3,456.009	3,455.314	3,465.126
2003	3,419.866	3,401.685	3,416.892	3,426.264	3,436.500	3,449.308	3,456.007	3,455.312	3,465.125
2004	3,419.855	3,401.670	3,416.887	3,426.265	3,436.499	3,449.310	3,456.009	3,455.315	3,465.126
2005	3,419.789	3,401.634	3,416.868	3,426.252	3,436.485	3,449.295	3,455.993	3,455.301	3,465.113

Table F continued on next page…

Table F. Comparison of Elevations 1987-2005 (continued)

	Z-418	A-419	B-419	C-419	D-419	K-349			
1987									
1989									
1992									
1993									
1994									
1995									
1996	3,461.073	3,454.714	3,449.825	3,437.633	3,423.234	3,404.152			
1997	3,461.082	3,454.720	3,449.829	3,437.642	3,423.238	3,404.162			
1998	3,461.091	3,454.730	3,449.835	3,437.648	3,423.242	3,404.173			
1999	3,461.105	3,454.744	3,449.848	3,437.657	3,423.247	3,404.169			
2000	3,461.109	3,454.749	3,449.853	3,437.660	3,423.250	3,404.157			
2001	3,461.111	3,454.752	3,449.856	3,437.663	3,423.254	3,404.152			
2002	3,461.113	3,454.754	3,449.857	3,437.665	3,423.256	3,404.150			
2003	3,461.112	3,454.752	3,449.856	3,437.665	3,423.256	3,404.137			
2004	3,461.117	3,454.754	3,449.858	3,437.668	3,423.257	3,404.127			
2005	3,461.108	3,454.742	3,449.848	3,437.663	3,423.243	3,404.105			

[*] The 1986 elevations that appear in all reports prior to the 2001 report are from a report filed by Jerry Williams (3/89), Geoscience Dept. Those elevations were, in turn, taken from the 1987 data, rounded to two decimal places and referenced as 1986. When this was discovered it was decided to remove the 1986 information from all subsequent reports.