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SAND2002-1643
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Printed June 2002

Analysis of Subsidence Data from West Hackberry, LA

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Abstract

Since 1983, ground surface elevation data from the US DOE West Hackberry Strategic Petroleum crude oil storage facility has been routinely collected. The data have been assimilated, analyzed, and presented in terms of absolute elevations, subsidence rate, and estimates of volumetric changes of the storage facility. The information presented impacts operations and maintenance of the facility, and provides important constraints on the interpretation of ongoing structural analyses of the facility.

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Acknowledgements

A thorough understanding of elevation surveying and data quality from which the report benefited was obtained from discussions with Eloy Solis of Jacobik & Associates and Jim McHenry of DynMcDermott. Jim McHenry was also responsible for timely collection of the elevation data presented. This report profited immensely through review comments made by Darrell Munson and Brian Ehgartner.

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Introduction

Herein we report the recent and historical (since 1983) collection, analysis, and presentation of routine elevation measurements (Appendix 1) at the West Hackberry US DOE Strategic Petroleum Reserve (SPR) crude oil storage facility (site). The West Hackberry site is located in southwestern Louisiana in Cameron Parish about 3 miles west of Hackberry, LA. The geology (salt dome, overlying caprock, and sediments which abut the salt dome) has been described and characterized (Whiting, 1980; Magorian et al, 1991). The geologic details are not discussed herein, but were very important in the design and construction of the facility. The geology, together with the cavern size, geometry, depth, and pressure/temperature history will act to prescribe the cavern closure. Cavern closure manifests itself at the surface as subsidence. Although simply stated, cavern closure is a three-dimensional time-dependent phenomenon, owing to creep of the salt mass, in response to the ever-present imbalance of stresses once the cavern is solutioned. The maximum cavern pressure is about 0.85 of the lithostatic pressure at the casing seat (at the top of a cavern). The overlying caprock will displace downward in response to cavern closure. Thus, the thickness, strength, ductility, fault, and fracture characteristics of the caprock will affect the subsidence observed. Subsidence is therefore the surface manifestation of this very complicated engineering of an active geologic system. Rigorous discussion of the relationship between geology and the mechanics of cavern closure is beyond the scope of this report; rather implications and constraints upon this relationship are presented.

A layout of the site with caverns and the DOE property boundary is given in Figure 1. Typically, elevation measurements are made at or near wellheads, at positions on surface structures, and at specifically installed elevation monuments. Elevation measurement locations are shown in ensuing figures with a (+). The number and location of measurement stations can change slightly from one year to the next because all measurement locations are susceptible to site construction, unintentional changes, and loss.

The reference elevation at West Hackberry is an off-site benchmark located a couple of miles from the site. This introduces error in traversing the distance to the site. Since 1988, the leveling surveys have been performed to Second-Order First-Class accuracy, with allowable vertical closure not to exceed approximately 0.02 ft/mile$^{0.5}$. This may amount to less than 0.05 ft for a survey, and that error when incurred, would be reflected in all measurements on the site (i.e., they may all be "high" or "low", which has been observed for some surveys). On the site, there had been a fairly dense array of survey stations, providing reasonably good coverage within the DOE property boundary. The correction for "error" would be approximately the same on all elevation data, because survey loops are short within the DOE property area. During the recent life extension work, over 30 elevation measurement locations were removed, relocated or buried. Some of these may be retrieved to maintain the historic data quality level.

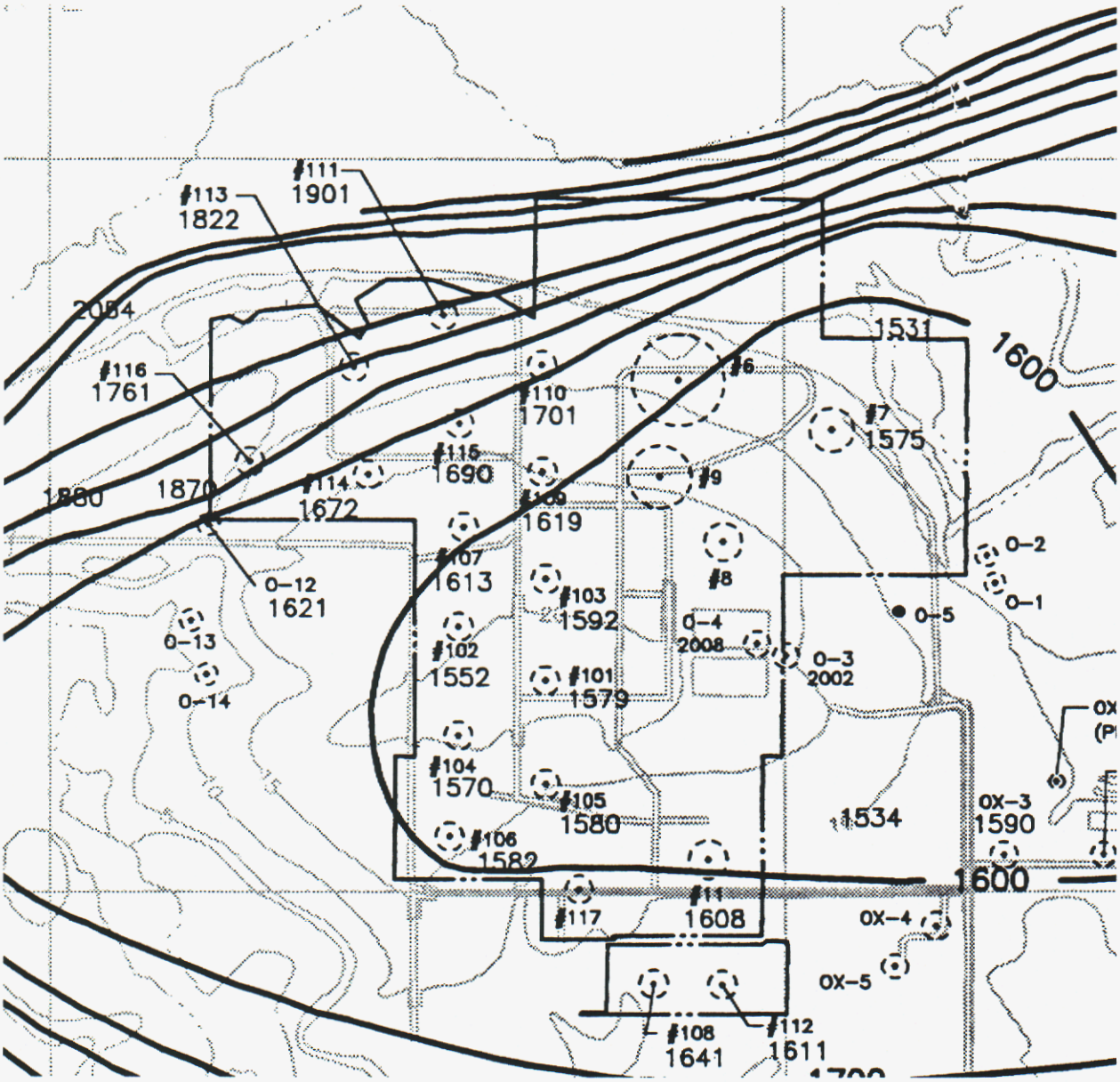

Figure 1. Top of cap rock contour map at West Hackberry (Magorian, et al., 1991).

Analysis

Comments on accuracy and precision of measurements

The accuracy and precision of elevation measurements are important if we are to assign a value to the data and its interpretation and application. This section presents a comparison between two sets of recent elevation measurements completed at different times. One set of measurements was associated with the life extension process, the second, completed a number of months later, was the routine "subsidence" survey.

In early 2001, the elevation survey was completed as part of the life extension process. This survey was extensive, covering the entire site, to permit a topographical map to be developed of the site. This survey used benchmark monuments (datum references) that were set by GPS. However, the x-y coordinate systems used for the two surveys were different. The life extension elevation measurements used the "state" coordinate system, and the subsidence survey used the "local" coordinate system.

In September of 2001, a second elevation survey was completed as part of the routine subsidence measurements. The datum reference was the same reference historically used, a couple of miles from the site. In the following, the two data sets are presented and compared.

Topographic representations of the site using the two data sets are presented in Figures 2 (elevation survey) and 3 (life extension survey). The diagrams are contoured using a 3-D interpolation of the data to develop an elevation surface. Nearest neighbors are used in this interpolation between data points and to extrapolate to extremities of the contoured area. The control on contours within a "map" is shown by the location of (+) symbols, which represent data points.

The subsidence survey data (Figure 2) has many more data points (from the entire survey). The data points common from life extension survey were identified and their elevations were assigned the subsidence survey x-y locations.

Thus, two independent measurements, using two different methods and reference locations were made. In Figure 4, the difference (in ft) between the two surveys is contoured. Only the survey points common to both surveys were used. The difference in the two independent measurements is less than 0.1 ft over about a mile of horizontal distance. This difference is very small, and indicates that each method presents a reasonable degree of accuracy in representing the absolute elevations.

A comparison of the contoured elevations shows significant differences particularly in critical locations where elevations are close to MSL and prone to flooding. For example a large area of the NE portion of the site shows 2 to 4 ft elevations in Figure 2 whereas the same area in Figure 3 is contoured by 4 to 6 ft elevations as visualized by the dark and light blue area. Therefore although specific subsidence stations, common to both surveys,

had similar elevation measurements (to within less than 0.1 ft difference), the resulting mapping of contours (the interpolated areal site elevations) is also sensitive to the number and location of stations.

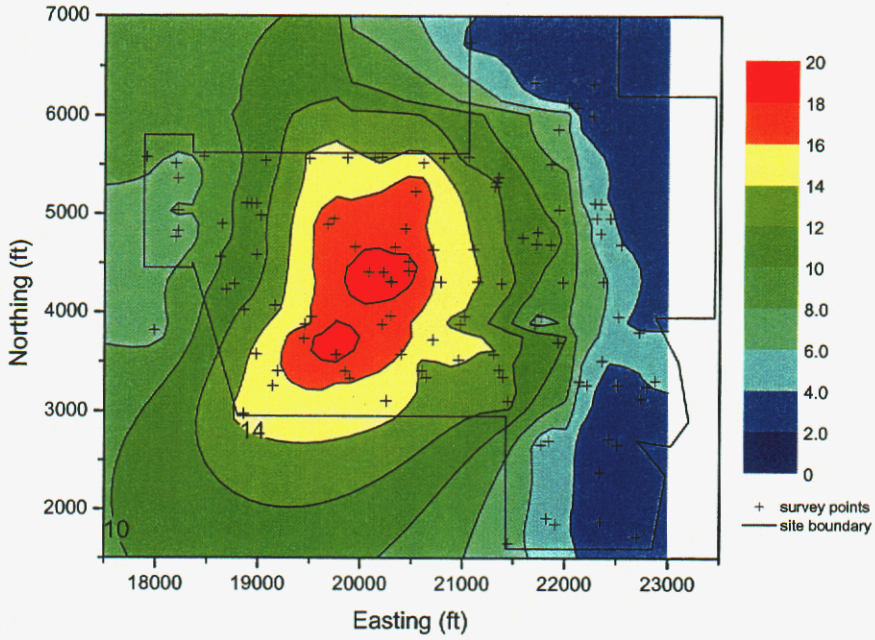

Figure 2. Elevations at West Hackberry (ft), made during subsidence survey.

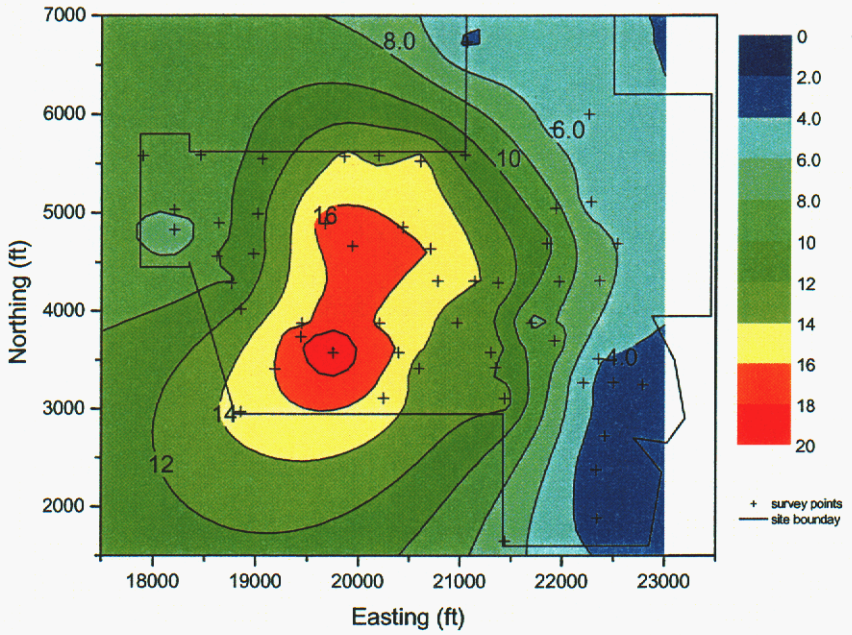

Figure 3. Elevations at West Hackberry (ft), made during life extension survey mapping.

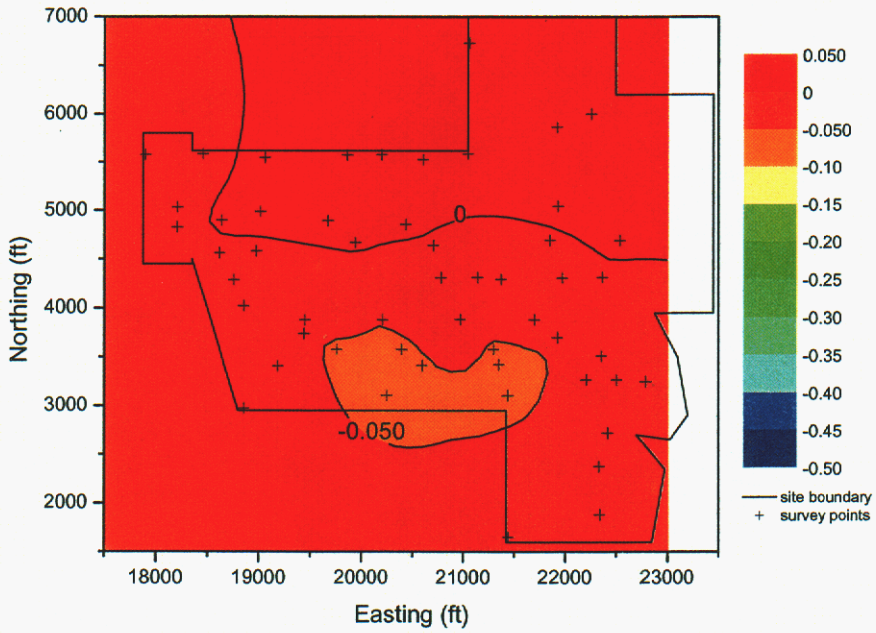

Figure 4. Contour of difference (ft) between the data collected at same stations from two survey methods.

Flood Potential

Flood potential is an important concern at West Hackberry because low-lying regions of the site are susceptible to inundation from Black Lake and/or hurricane storm surges. During life extension at West Hackberry roads were raised, dikes were constructed, and wellheads were repositioned to solve part of the flood potential problems. The elevations today, and those projected for the future, are important to facility operations planning. The models developed to extrapolate historic data into the future are presented in Appendix 2. The elevation contours of these analyses are presented in Figures 5, 6, and 7. The extrapolations, and the maps presented, indicate that subsidence will continue, but at an ever decreasing rate.

Key elevations presented in Figure 5, 6, and 7 are (+) 2.5 feet, the mean elevation of Black Lake which abuts the site on the north, and (+) 4.5 foot contour interval which is considered the hurricane flood level at the site.

There are areas of the site that have susceptibility to inundation based on these analyses. The measures taken during life extension may act to mitigate these potential problems. For example roads have been raised, local dikes have been constructed, and pumps have been installed. The elevations of these "raised" features are not captured in the maps presented because monuments are not yet located in the survey.

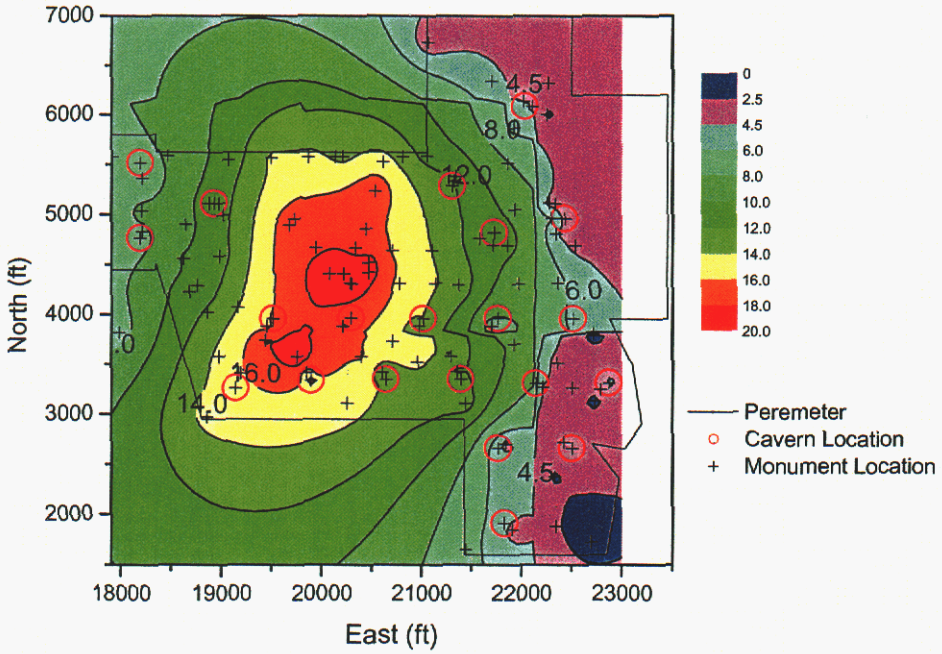

Figure 5. Elevations September 2001, flood potential contours.

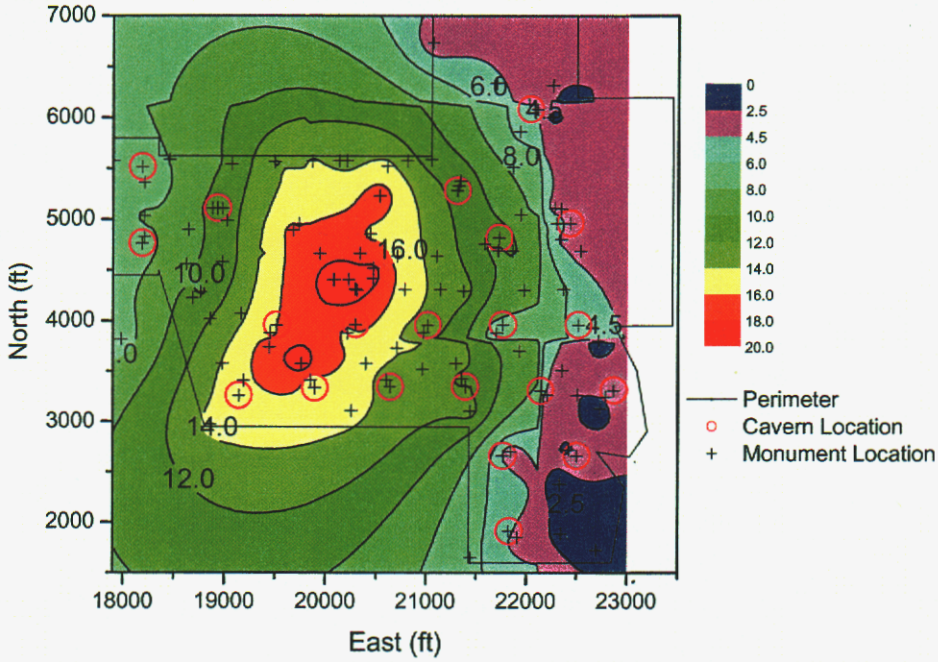

Figure 6. Projected Elevations 2011, flood potential contours.

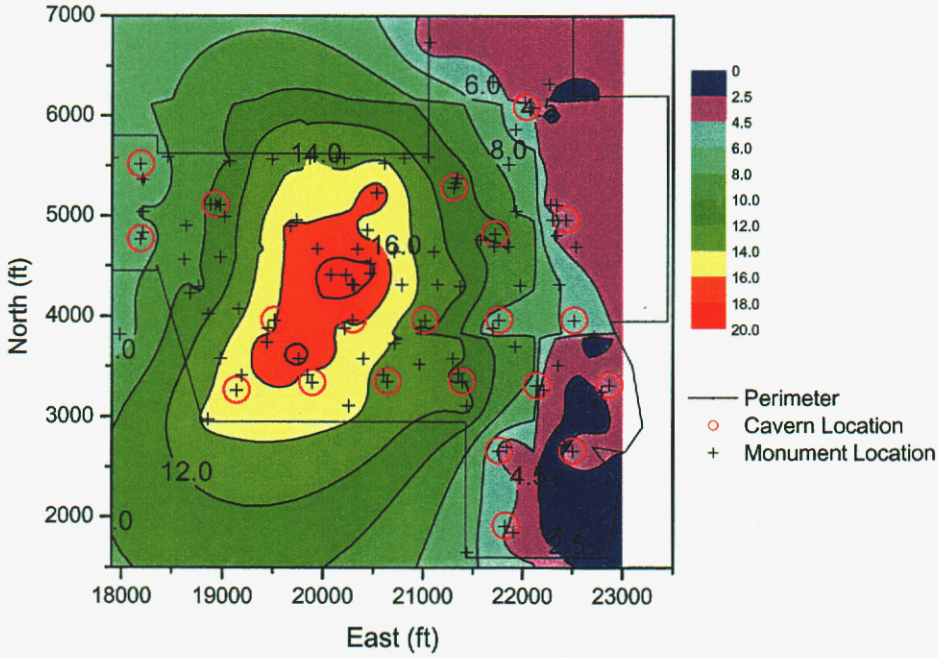

Figure 7. Projected Elevations 2021, flood potential contours.

Subsidence Rates

The subsidence rates are calculated by dividing the vertical displacement measured by the time encompassed for selected time intervals (sometimes encompassing more than one measurement period) and are presented in terms of ft/yr in Figures 6 through 12. The contour interval (.025 ft/yr) and range (0.1 to –0.4 ft/yr) is identical for all figures, facilitating comparison. The diagrams are contoured using a 3-D interpolation of the data to develop a surface similar to that described above.

Generally, subsidence rates (both average and highs) decrease from the early 1980's with maximum rates decreasing from 0.35 ft/yr to 0.2 ft/yr in the late 1980's, and decreasing further to maximum rates of less than 0.1 ft/year in the 1990's. The decrease in subsidence rates has been attributed in part to better cavern operation practices during the past 10-12 years in which higher average operating pressures are maintained, and duration of workovers (with attendant low pressure intervals) has decreased (Woodrum, 2001). (Note: the contour interval is small, .025 ft/yr, causing dense contours in certain areas [c.f. Figures 10 & 12]; the dense contours do not necessarily represent anomalous behavior in these areas).

The subsidence rates at West Hackberry, although low, are the greatest of all of the SPR sites due to the relatively fast creep rate of the salt (Ehgartner, 2001). The thin caprock (300-400 ft), its faulted and fractured nature (c.f. Magorian, et al, 1991), and the additional causes for subsidence at and near the dome (oil and gas production), all contribute to the subsidence rate at this site.

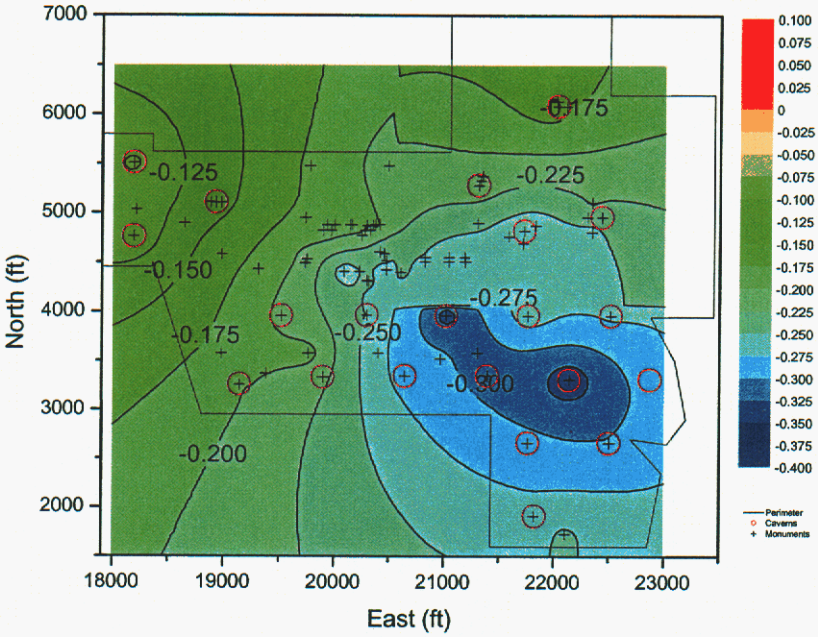

Figure 8. West Hackberry subsidence rates (ft/yr), 1/83-3/85.

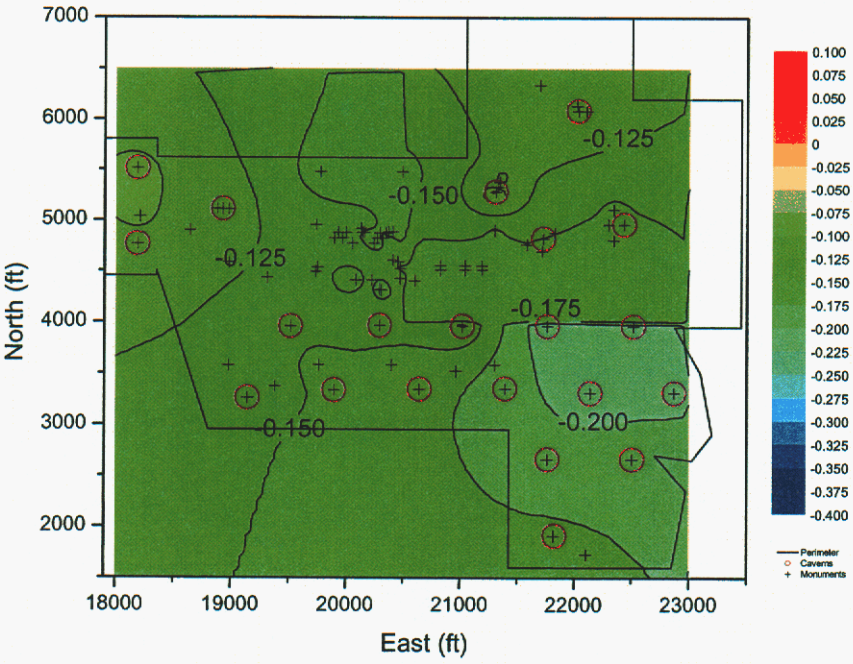

Figure 9. West Hackberry subsidence rates (ft/yr), 9/86-10/88.

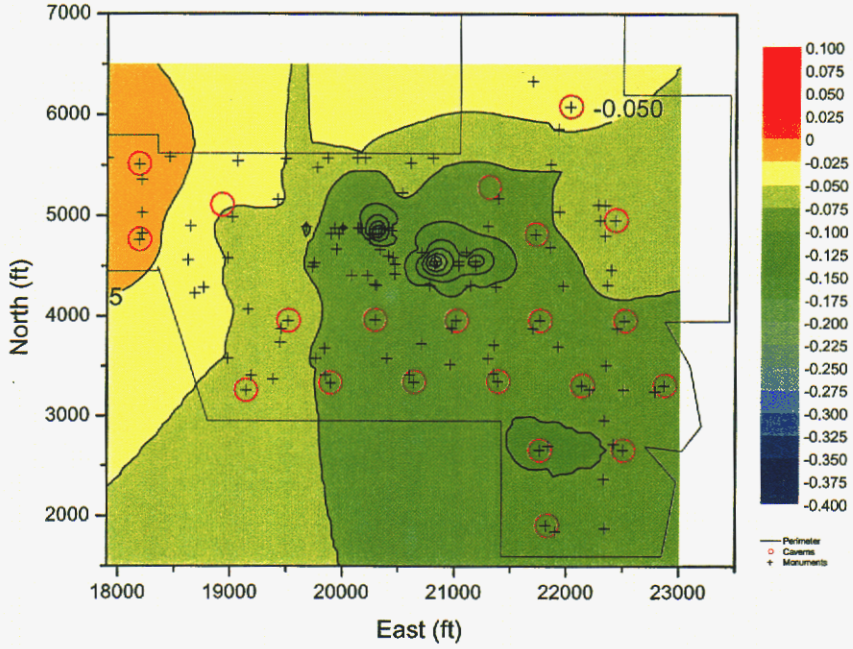

Figure 10. West Hackberry Subsidence Rates (ft/yr), 5/91-1/93.

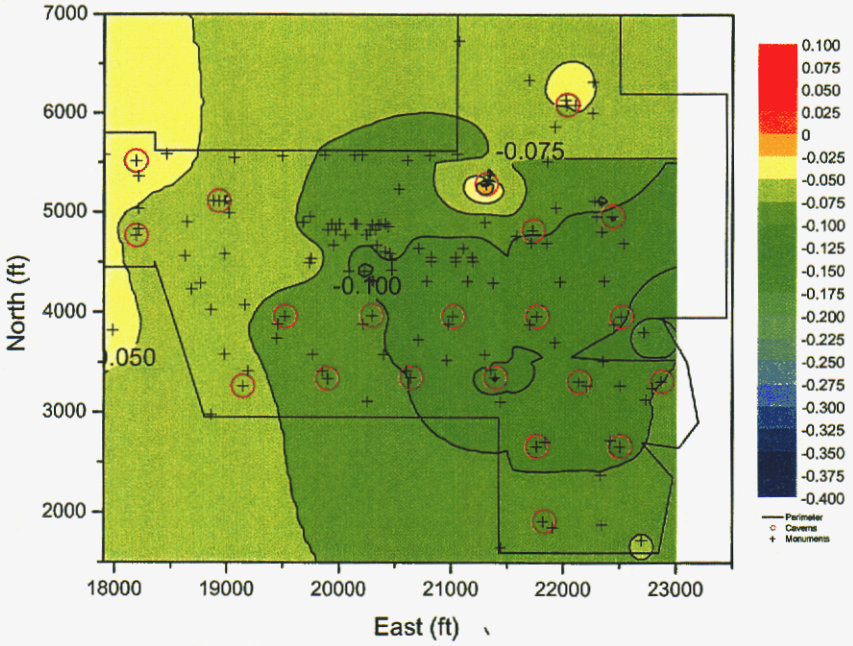

Figure 11. West Hackberry Subsidence Rates (ft/yr), 10/96-11/98.

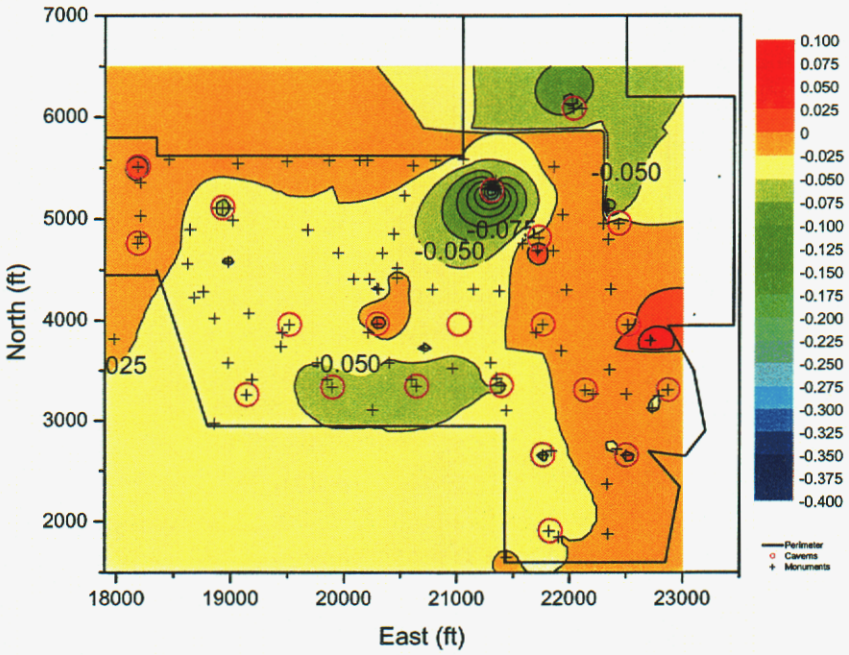

Figure 12. West Hackberry Subsidence Rates (ft/yr), 11/98-9/00.

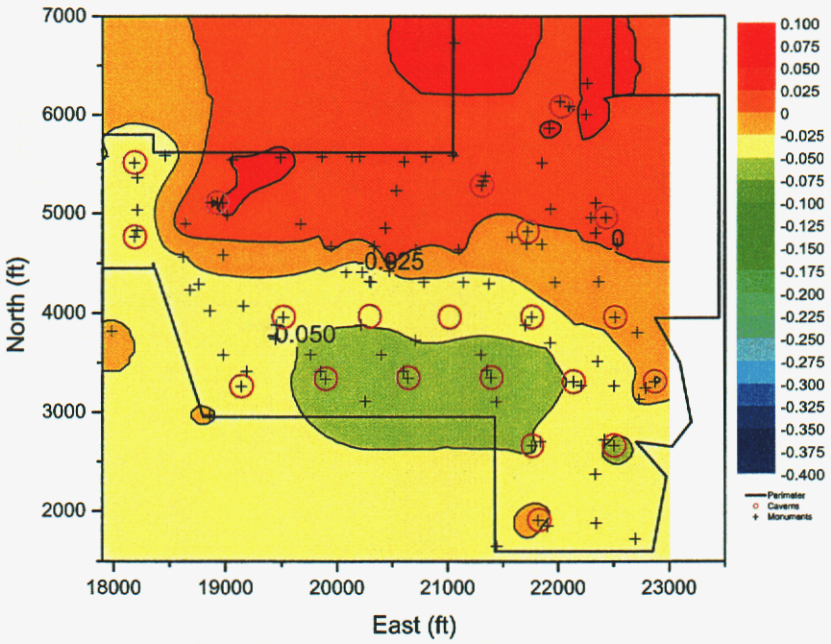

Figure 13. West Hackberry Subsidence Rates (ft/yr), 9/00-9/01.

Volumetric Change Estimates

The volume change for time intervals between measurements was determined by first contouring the vertical displacement per unit area, and then from the known vertical change and the area, the volume calculation was made. The volume change was determined for the map area outlined by the SPR site footprint. This area was chosen in an attempt to standardize the estimation of the closure of the oil storage facility. The area chosen provides an estimate of the total volumetric creep deformation (and allows an estimate of volume loss) into the caverns; other factors may contribute to subsidence at West Hackberry. For example oil production beneath Black Lake and other subsurface deformation associated with nearby industrial underground storage facilities would also lead to subsidence. Also, the subsidence does not translate directly to volume loss because possibly not all of the subsidence due to cavern closure is captured within the site boundaries.

We feel that this measure provides a consistent estimate (probably an underestimate) of the volumetric sum total of cavern closure. The cumulative volume change (Figure 14) is an estimate of the volume loss for the recent history of the facility. This change could be used as a measured constraint for numerical analyses of creep closure of caverns at this facility, and volumetric changes measured within caverns as a result of maintaining appropriate cavern pressures. The volume change could also be correlable to the pressure bleed history of the overall facility. The slope of the volume loss versus time relationship is proportional to the rate of volumetric creep closure of the facility (if pressure was held relatively constant for the entire history). The change in slope of the curve represents a change in closure rate assuming the shape of the subsidence trough is unchanged.

The interval volumetric creep closure rate was calculated as the quotient of the volume change per time interval between measurements (Figure 15). The trend for volumetric closure rate versus time is clearly downward, towards decreasing rates. If the cavern fluid pressures were constant, this decrease in rate would be attributed to transient creep. If the stresses internal to all of the caverns were not constant, this decrease would be attributed to an average change from low internal pressures in caverns to greater internal pressures in caverns. Although the volumetric creep closure rates versus time recorded probably represent a combination of these two causes, the change in operations practices in the early 1990s to maintain high cavern pressures, and minimize workover time periods has generally been cited as the cause for the decrease in close and subsidence rates.

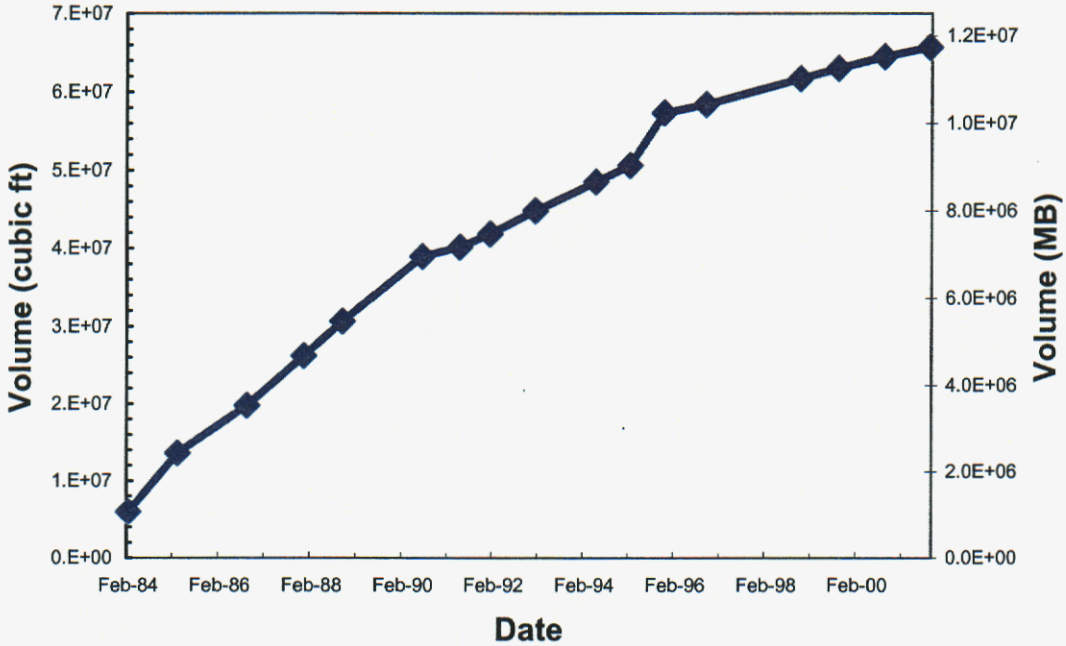

Figure 14. Cumulative storage volume loss.

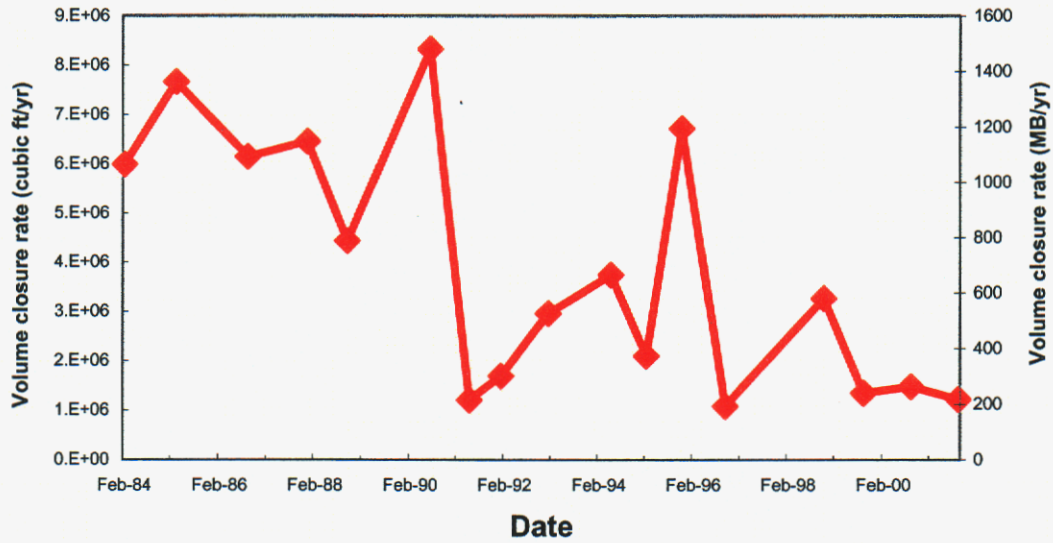

Figure 15. Interval volumetric closure rate versus time.

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Discussion and Conclusions

The elevation data from the US DOE West Hackberry Strategic Petroleum crude oil storage facility have been routinely collected since 1983. The data have been assimilated, analyzed, and presented in terms of absolute elevations, subsidence rate, and estimates of volumetric changes of the storage facility. The information presented shows the impact of operations on subsidence, predicts when additional mitigation against flooding may be needed, and provides important constraints on the interpretation of ongoing structural analyses of the facility.

Subsidence at the West Hackberry site continues, however rates are decreasing as a result of better operation practices. The subsidence rates are the greatest of all SPR sites, and this fact is attributed to geologic and engineering factors at the West Hackberry dome. Some of these factors are beyond the control of the SPR. Those factors within SPR's control (for example cavern operations) are being improved resulting in decreased subsidence.

The historic volumetric changes represent a new means to examine subsidence data. The volumetric changes are presented, and while not rigorously pursued for comparison with numerical analyses results in this report, but recently have been compared to 3-D analyses (Ehgartner and Sobolik, 2002). These changes can also be directly compared to a summed effect of measured cavern changes.

The ground elevations have always been a concern at West Hackberry because of the low elevations and proximity of Black Lake, thus increasing the susceptibility to flooding. The life extension measures recently completed address this issue.

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References

Bauer, S. J. 1997, "Analysis of Subsidence Data for the West Hackberry Site, Louisiana," SAND97-2036, August 1997, Sandia National Laboratories, Albuquerque, NM 87185.

Ehgartner, B.L. 2001. "Ullage Study 2000," memo dated January 18, 2001 to R.E. Myers, DOE/SPR, New Orleans, LA, Sandia National Laboratories, Albuquerque, NM.

Ehgartner, B.L and S. Sobolik. 2002, "3-D Cavern Enlargement Analyses, " SAND2002-0526, March 2002, Sandia National Laboratories, Albuquerque, NM 87185.

Magorian, T. R., J. T. Neal, S. Perkins, Q. J. Xiao, K. O. Byrne. 1991, "Strategic Petroleum Reserve (SPR) Additional Geologic Site Characterization Studies West Hackberry Salt Dome, Louisiana," SAND90-0224, December, 1991, Sandia National Laboratories, Albuquerque, NM 87185.

Whiting, G. H. (editor), 1980, "Strategic Petroleum Reserve (SPR) Geologic Site Characterization Report West Hackberry Salt Dome, Louisiana," SAND80-7131, October, 1980, Sandia National Laboratories, Albuquerque, NM 87185.

Woodrum, S. L. 2001, memo to B. Ehgartner dated April 23, 2001, Sandia National Laboratories, Albuquerque, NM 87185.

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Appendix 1: Historic Elevation (feet) Measurements

			JAN 83	AUG 83	FEB 84	MAR 85	SEP 86	DEC 87	OCT 88	JUL 90	MAY 91	JAN 92	JAN 93	MAY 94	FEB 95	Nov 95	Oct 96	Nov 98	Sept 99	Sep 00	Sep 01
PT #	EAST	NORTH	0	7	13	26	44	59	68	89	99	107	119	135	144	153	164	189	200	211	223
1	4495.5	19729	21.72	21.69	21.57	21.34	21.13	20.81	20.82	20.57	20.47	20.44	20.33	20.18	20.14	20.01	20.00	19.87	destroyed	#N/A	#N/A
2	4535.3	19745	21.74	21.70	21.58	21.36	21.10	20.80	20.83	20.61	20.47	20.44	20.34	20.17	20.15	20.02	20.00	19.87	destroyed	#N/A	#N/A
3	4410.6	20079	22.58	22.54	22.40	22.16	21.80	21.65	21.60	21.29	21.22	21.19	21.09	20.92	20.89	20.73	20.70	20.51	20.52	20.44	20.40
4	4409.9	20223	22.60	22.54	22.42	22.14	21.87	21.62	21.55	21.24	21.15	21.12	21.02	20.85	20.80	20.80	20.77	20.41	20.40	20.35	20.30
5	4318.2	20290	21.52	21.46	21.32	21.05	20.81	20.57	20.45	20.15	20.06	20.03	19.92	19.75	19.71	19.55	19.54	19.36	19.35	19.24	19.20
6	4310.6	20305	21.56	21.50	21.35	21.08	20.84	20.56	20.49	20.17	20.09	20.06	19.95	19.78	19.74	19.56	19.54	19.33	19.33	19.27	19.22
7	4425.1	20470	21.67	21.60	21.47	21.17	20.88	20.64	20.60	20.27	20.16	20.13	20.03	19.84	19.80	19.65	19.61	19.33	19.43	19.34	19.30
8	4521.7	20470	21.62	21.58	21.43	21.16	20.91	20.61	20.57	20.31	20.19	19.94	20.04	19.88	19.86	19.71	19.64	19.43	19.37	19.36	19.38
9	4590.1	20451	21.66	21.61	21.46	21.21	20.91	20.69	20.62	20.36	20.24	20.20	20.11	19.94	19.89	19.75	19.71	19.54	destroyed	#N/A	#N/A
10	4606.0	20410	21.64	21.57	21.44	21.18	20.92	20.66	20.59	20.31	20.21	20.19	20.07	19.90	19.86	19.71	19.65	19.48	destroyed	#N/A	#N/A
11	4885.0	20408	24.24	24.21	24.08	23.84	23.64	23.41	23.31	23.03	22.94	22.89	22.80	22.66	22.61	22.47	22.43	22.23	destroyed	#N/A	#N/A
12	4884.8	20370	24.20	24.17	24.04	23.81	23.62	23.34	23.27	23.05	23.11	22.85	22.78	22.67	22.61	22.49	22.45	22.25	destroyed	#N/A	#N/A
13	4874.1	20349	24.15	24.13	24.00	23.77	23.56	23.30	23.23	22.96	23.07	22.83	22.74	22.59	22.55	22.40	22.37	22.16	destroyed	#N/A	#N/A
14	4823.8	20321	24.17	24.16	24.02	23.79	23.56	23.33	23.25	23.01	23.07	22.84	22.75	22.60	22.55	22.41	22.38	22.18	destroyed	#N/A	#N/A
15	4874.1	20291	24.18	24.16	24.04	23.81	23.60	23.33	23.27	23.04	23.11	22.87	22.78	22.63	22.58	22.44	22.42	22.20	destroyed	#N/A	#N/A
16	4823.7	20271	24.15	24.17	23.99	23.76	23.56	23.33	23.22	22.98	23.07	22.82	22.73	22.57	22.52	22.39	22.36	22.15	destroyed	#N/A	#N/A
17	4772.6	20242	31.54	31.52	31.39	31.15	30.95	30.72	30.60	30.35	30.24	30.21	30.11	29.96	29.92	29.76	29.74	29.55	destroyed	#N/A	#N/A
18	4880.2	20154	31.52	31.50	31.36	31.14	30.95	30.67	30.60	30.38	30.25	30.22	30.12	29.97	29.94	29.79	29.78	29.58	destroyed	#N/A	#N/A
19	4880.1	20138	30.52	30.50	30.37	30.14	29.95	29.69	29.61	30.32	29.26	29.23	29.13	29.00	28.97	28.82	28.79	28.60	destroyed	#N/A	#N/A
20	4772.5	20050	30.51	30.48	30.36	#N/A	29.95	29.68	29.64	29.41	#N/A	29.22	29.13	29.03	28.94	28.84	28.82	28.61	destroyed	#N/A	#N/A
21	4880.0	19996	24.13	24.11	23.97	23.74	23.57	23.30	23.25	22.98	22.90	22.87	22.78	22.64	22.61	22.46	22.44	22.26	destroyed	#N/A	#N/A
22	4823.6	19962	24.06	24.04	23.90	23.66	23.48	23.21	23.17	22.90	22.82	22.78	22.69	22.55	22.52	22.38	22.35	22.17	destroyed	#N/A	#N/A
23	4880.0	19926	24.10	24.08	23.95	23.72	23.54	23.28	23.24	22.98	22.89	22.85	22.76	22.62	22.59	22.44	22.42	22.22	destroyed	#N/A	#N/A
24	4823.6	19892	24.08	24.06	23.92	23.69	23.52	23.22	23.20	22.95	22.84	22.81	22.71	22.58	22.56	22.42	22.39	22.21	destroyed	#N/A	#N/A
25	5480.1	19770	24.59	24.58	24.46	24.24	24.06	23.78	23.69	23.36	23.35	23.31	23.21	23.08	23.06	23.94	22.91	destroyed	destroyed	#N/A	#N/A
26	4920.1	20128	24.66	24.68	#N/A	#N/A	24.05	23.84	23.78	23.57	#N/A	23.87	#N/A	#N/A	#N/A	#N/A	#N/A	area dist.	area dist	#N/A	#N/A
27	5480.3	20489	24.29	24.23	24.11	23.87	23.63	23.33	23.26	22.94	22.87	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	area dist	area dist	#N/A	#N/A
29	4551.8	21183	18.73	18.69	18.54	18.28	17.95	17.68	17.61	17.32	17.47	17.20	17.07	16.90	16.83	16.69	16.64	16.41	destroyed	#N/A	#N/A
31	4550.9	21039	19.08	19.04	18.89	18.62	18.31	18.01	17.97	17.66	17.64	17.47	17.42	17.25	17.19	17.05	17.01	16.77	destroyed	#N/A	#N/A
33	4552.9	20824	18.19	18.13	17.98	17.71	17.43	17.14	17.09	16.82	17.02	16.75	16.54	16.38	16.32	16.18	16.12	15.90	destroyed	#N/A	#N/A
35	4508.9	20823	19.04	18.98	18.84	18.56	18.27	17.98	17.93	17.66	17.75	17.45	17.38	17.21	17.15	17.00	16.96	16.73	destroyed	#N/A	#N/A
37	4508.2	21039	18.70	18.67	18.51	18.25	17.91	17.64	17.58	17.28	17.24	17.18	17.04	16.87	16.80	16.66	16.62	16.38	destroyed	#N/A	#N/A
39	4508.2	21189	18.68	18.64	18.49	18.23	17.91	17.64	17.55	17.26	17.23	17.05	17.00	16.83	16.77	16.62	16.59	16.33	destroyed	#N/A	#N/A
WH6	4959.3	22434	6.00	5.95	5.83	5.63	5.30	5.12	4.98	4.46	4.65	4.64	4.53	4.39	4.35	4.19	4.20	3.91	3.87	3.91	3.93
WH6A	4959.0	22298	8.69	8.66	8.53	8.34	8.00	7.77	7.67	6.45	7.30	7.31	7.20	7.09	7.06	6.88	6.86	6.64	6.61	6.62	6.62
WH6B	5108.6	22343	6.16	6.14	6.01	5.83	5.54	5.33	5.19	4.62	4.87	4.85	4.76	4.65	4.62	4.45	4.43	4.34	4.27	4.12	4.15
WH6C	4805.5	22343	6.28	6.24	6.11	5.90	5.55	5.33	5.19	4.61	4.83	4.82	4.71	4.59	4.54	4.38	4.36	4.13	4.07	4.10	4.11
WH7	6083.9	22031	#N/A	5.88	5.78	5.64	5.46	5.24	5.23	4.70	5.00	4.98	4.93	4.87	4.87	4.73	4.70	4.56	4.50	4.44	#N/A
WH7A	6084.2	22104	#N/A	5.08	4.94	4.87	4.54	4.36	4.32	6.32	6.56	4.09	4.00	3.98	3.98	3.85	3.82	3.79	3.70	3.70	3.73
WH7B	6134.0	22019	#N/A	5.04	4.90	4.89	4.59	4.40	4.37	6.38	6.62	4.16	4.08	4.04	4.02	3.89	3.85	3.84	3.78	3.57	3.59
WH8	5282.3	21308	14.42	14.41	14.29	14.09	13.86	13.85	13.80	15.88	16.10	13.44	13.08	12.97	12.94	12.77	12.74	12.88	12.19	12.20	12.21
WH8A	5329.3	21324	14.04	14.03	13.90	13.71	13.42	13.19	13.15	15.05	15.61	12.79	12.70	12.56	12.54	12.38	12.35	12.16	12.14	11.97	11.99
WH8B	5376.9	21342	14.05	14.07	13.93	13.74	13.48	13.35	13.18	15.07	15.66	12.86	12.76	12.65	12.60	12.45	12.42	12.24	12.19	12.15	12.15
WH9	4819.5	21727	14.70	14.66	14.52	14.29	13.94	13.31	13.61	12.98	13.23	13.15	13.10	11.43	11.37	11.19	11.15	10.95	10.92	12.41	12.42
WH9A	4761.1	21583	#N/A	12.45	12.29	12.08	11.71	12.24	11.38	13.22	13.42	10.96	10.85	10.70	10.67	10.51	10.47	10.26	10.20	10.21	10.19
WH9B	4695.3	21716	#N/A	11.85	11.68	11.48	11.10	11.50	10.75	12.64	12.82	10.33	10.23	10.11	10.08	9.86	9.84	9.59	9.56	9.68	9.66
WH11	5109.3	18925	10.89	10.88	10.80	10.62	10.50	10.37	10.26	12.45	12.37	10.24	9.88	9.91	9.86	9.66	9.68	9.52	9.47	9.30	9.32
WH11A	5107.8	18975	12.16	12.16	12.08	11.89	11.77	11.66	11.54	13.57	13.77	11.25	11.22	11.13	11.11	11.41	11.41	11.34	11.30	11.26	11.30
WH11B	5111.6	18877	13.16	13.16	13.09	12.91	12.79	12.67	12.57	12.37	13.45	12.33	12.21	12.18	12.10	12.00	11.97	11.15	11.12	11.79	11.82
WH101	3965.7	20292	19.75	19.68	19.51	19.26	18.96	18.76	18.65	17.90	18.22	18.16	18.07	17.93	17.82	17.69	17.64	17.44	17.42	17.51	17.28
WH102	3343.5	20641	17.06	#N/A	16.78	16.47	16.16	15.90	15.80	14.98	15.34	15.29	15.18	15.02	14.91	14.78	14.73	14.52	14.47	14.40	14.35
WH103	3959.0	21015	17.12	17.04	16.89	16.58	16.14	16.07	15.91	15.11	15.45	15.41	15.29	15.12	15.04	14.92	14.84	14.61	14.58	#N/A	14.49
WH104	3335.1	19891	18.74	#N/A	18.48	18.27	18.01	17.77	17.69	16.94	17.28	17.23	17.14	16.98	16.89	16.76	16.71	16.54	16.51	16.43	16.36
WH105	3957.9	19515	18.67	18.66	18.49	18.27	18.04	17.81	17.72	17.02	17.35	17.33	17.25	17.14	16.96	16.92	16.89	16.70	16.67	16.62	16.56
WH106	3258.7	19140	#N/A	17.17	17.05	16.77	16.62	16.41	16.29	16.08	15.94	15.92	15.85	15.71	15.63	15.54	15.49	15.33	15.66	15.26	15.22
WH107	3349.6	21390	15.84	15.73	15.50	15.15	14.82	14.54	14.41	13.61	13.96	13.90	13.79	13.62	13.53	13.40	13.48	13.12	13.07	13.01	12.93
WH108	4764.3	18186	8.02	8.01	7.92	7.76	7.71	7.56	7.48	6.87	7.26	7.25	7.25	#N/A	7.08	7.04	7.00	6.91	6.88	6.89	6.84
WH109	3960.3	21765	10.61	10.48	10.27	9.98	9.73	9.40	9.24	9.29	8.78	8.75	8.63	8.47	8.41	8.22	8.19	7.93	8.07	7.90	7.86
WH110	3957.6	22515	7.98	7.91	7.69	7.38	7.11	6.81	6.67	5.89	6.24	6.23	6.10	5.96	5.93	5.73	5.69	5.47	5.40	5.44	5.43
WH111	3308.9	22870	8.08	8.04	7.85	#N/A	7.27	6.94	6.81	6.05	6.39	6.40	6.26	6.12	6.09	5.94	5.89	5.68	5.63	5.67	5.63
WH112	5514.1	18186	#N/A	8.48	8.31	8.14	8.11	7.99	7.92	7.37	7.75	7.74	7.75	7.64	7.60	7.56	7.56	7.44	7.45	7.46	7.42
WH113	2659.8	22502	7.45	7.43	7.17	6.81	6.51	6.28	6.11	5.31	5.66	5.61	5.49	5.37	5.29	#N/A	5.09	4.86	4.84	4.89	4.81
WH114	2659.6	21765	7.37	7.34	7.06	6.71	6.43	6.19	6.02	5.66	5.54	5.49	5.36	5.20	5.14	4.93	4.94	4.70	4.68	4.66	4.60
WH115	3307.4	22139	9.15	9.07	8.87	8.43	8.10	7.79	7.62	6.80	7.13	7.09	6.99	6.82	6.77	6.59	6.54	6.30	6.27	6.28	6.24
WH116	1911.2	21821	#N/A	8.01	7.83	7.49	7.25	7.00	6.88	6.15	6.44	6.39	6.30	6.14	6.08	5.96	5.91	5.74	5.71	5.65	5.65
WH117A	4230.1	18680	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	12.62	12.06	12.34	12.31	12.27	12.14	12.10	12.02	11.98	11.86	11.84	11.80	11.78
			JAN 83	AUG 83	FEB 84	MAR 85	SEP 86	DEC 87	OCT 88	JUL 90	MAY 91	JAN 92	JAN 93	MAY 94	FEB 95	Nov 95	Oct 96	Nov 98	Sept 99	Sep 00	Sep 01
PT #	EAST	NORTH	0	7	13	26	44	59	68	89	99	107	119	135	144	153	164	189	200	211	223
WH117B	4230.0	18680	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	12.67	12.09	12.39	12.36	12.31	12.18	12.15	12.05	12.01	11.89	11.86	11.82	11.79
BM1	4900.0	18641	10.61	10.60	10.53	10.35	10.23	10.03	9.98	9.85	9.76	9.75	9.67	9.58	9.58	9.48	9.45	9.34	9.26	9.28	9.31

WH113	2659.8	22502	7.45	7.43	7.17	6.81	6.51	6.28	6.11	5.31	5.66	5.61	5.49	5.37	5.29	#N/A	5.09	4.86	4.84	4.89	4.81
BM3	4839.9	20600	18.14	18.11	17.98	17.74	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BM4	4400.0	20600	18.83	18.76	18.62	18.35	18.11	17.84	17.74	17.45	#N/A	17.29	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BM5	4900.4	21300	16.16	16.11	15.97	15.75	15.45	15.22	15.11	14.86	14.75	14.73	14.63	14.47	14.44	14.26	14.22	14.01	destroyed	#N/A	#N/A
BM7A	4900.3	22100	7.79	#N/A	7.62	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.34	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BM8	4435.1	19308	17.48	17.45	17.34	17.12	16.94	16.70	16.66	16.41	#N/A	#N/A	#N/A	16.08	16.05	15.93	15.89	destroyed	destroyed	#N/A	#N/A
BM9	4395.0	19798	20.49	#N/A	20.31	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BM11	4583.9	18978	12.40	12.39	12.30	12.09	11.94	11.77	11.68	11.46	11.39	11.38	11.31	11.17	11.16	11.04	11.01	10.87	10.83	10.83	10.81
BM12	3578.6	18978	16.31	16.29	16.19	15.96	15.80	15.60	15.51	15.32	15.20	15.19	15.12	14.98	14.94	14.82	14.77	14.63	14.61	14.55	14.52
BM13	3579.1	19758	23.50	23.45	23.33	23.19	22.94	22.70	22.60	22.30	22.22	22.19	22.09	21.94	21.86	21.73	21.68	21.50	21.47	21.40	21.35
BM14	3579.1	20399	19.05	18.98	18.85	18.55	18.27	18.01	17.92	17.60	17.49	17.45	17.34	17.18	17.09	16.95	16.90	16.70	16.66	16.59	16.53
BM15	3579.1	21300	17.49	17.39	17.25	16.89	16.57	16.33	16.19	15.83	15.73	15.69	15.57	15.39	15.32	15.16	15.10	14.87	14.83	14.78	14.72
SMS1	5035.3	18210	10.11	10.11	10.04	9.88	9.80	9.67	9.60	9.45	9.43	9.42	9.41	9.28	9.26	#N/A	9.18	9.07	9.06	9.06	9.02
SMS2	4955.9	19731	19.08	19.05	18.93	18.70	18.53	18.22	18.23	17.98	17.90	17.90	#N/A	17.64	17.61	17.48	17.44	17.27	destroyed	#N/A	17.18
SMS3	6338.0	21696	3.51	3.54	3.45	#N/A	3.19	3.01	2.98	2.84	2.79	2.79	2.73	2.66	2.66	2.50	2.48	2.36	destroyed	#N/A	2.40
SMS4	4875.7	21830	8.03	8.01	7.88	7.67	7.30	7.10	6.98	6.71	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	not found	not found	#N/A	#N/A
SMS5	1727.0	22103	6.65	6.63	6.47	6.16	5.94	5.66	5.57	5.29	5.19	5.13	#N/A	#N/A	#N/A	#N/A	#N/A	destroyed	destroyed	#N/A	#N/A
SMS6	3521.9	20961	17.08	16.99	16.85	16.54	16.22	15.99	15.86	16.06	15.40	15.36	15.24	15.07	14.98	14.82	14.75	15.53	14.48	14.43	14.39
SMS7	3371.5	19379	21.33	21.28	21.17	20.91	20.73	20.50	20.42	20.22	20.07	20.04	19.97	#N/A	#N/A	#N/A	#N/A	destroyed	destroyed	#N/A	#N/A
P8	NA	NA	#N/A	18.31	18.18	17.98	17.67	17.38	17.38	16.99	17.05	17.02	16.93	16.80	16.77	16.60	16.55	16.38	no access	#N/A	#N/A
P9	NA	NA	#N/A	18.22	18.08	17.83	17.49	17.18	17.14	16.85	16.74	16.71	16.60	16.45	16.40	16.22	16.17	16.02	15.96	#N/A	#N/A
PB1	NA	NA	#N/A	16.69	16.56	16.37	#N/A	15.94	16.11	24.05	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	not found	not found	#N/A	#N/A
P11	NA	NA	#N/A	13.78	13.71	13.54	13.37	13.18	13.14	12.98	12.87	12.86	12.77	12.74	12.66	12.54	12.50	12.37	no access	#N/A	#N/A
1	5577.7	17903	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	9.67	9.67	9.66	9.67	9.56	9.55	9.50	9.48	9.41	9.94	9.40	9.38
2	5361.7	18209	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	5.72	5.67	5.66	5.67	5.54	5.52	5.46	5.45	5.35	5.34	5.34	5.30
3	4829.4	18208	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.60	5.34	5.32	5.32	5.18	5.16	5.09	5.08	4.96	4.95	4.95	4.91
4	4562.1	18619	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	10.91	10.83	10.83	10.77	10.65	10.62	10.53	10.50	10.38	10.37	10.33	10.30
5	4288.8	18760	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	10.02	9.94	9.93	9.86	9.74	9.71	9.60	9.56	9.45	9.42	9.37	9.35
6	4072.2	19158	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.96	13.94	13.87	13.72	13.67	13.56	13.52	13.37	13.35	13.29	13.25
7	3740.7	19442	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.60	19.47	19.44	19.36	19.21	19.14	19.02	18.97	18.81	18.78	18.72	18.67
8	3409.1	19187	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.88	16.73	16.71	16.63	16.48	16.43	16.31	16.27	16.11	16.09	16.04	15.99
9	3879.8	19452	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.56	15.46	15.44	15.35	15.21	15.15	15.01	14.98	14.80	14.77	14.72	14.67
10	3678.9	19837	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	20.17	20.14	20.04	19.88	19.81	19.67	19.63	destroyed	destroyed	#N/A	#N/A
11	3410.6	19847	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.14	15.03	15.00	14.90	14.74	14.67	14.53	14.49	14.30	14.27	14.20	14.15
12	3880.7	20211	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.32	16.19	16.16	15.06	15.91	15.83	15.68	15.64	15.43	15.40	15.33	15.28
13	3414.3	20600	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.14	13.02	12.99	12.87	12.71	12.61	12.48	12.43	12.21	12.18	12.11	12.05
14	3727.1	20710	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.72	15.61	15.56	15.47	15.28	15.19	16.58	16.51	16.29	16.25	14.70	14.65
15	3883.8	20974	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.26	13.13	13.10	12.98	12.81	12.73	12.58	12.53	12.30	12.27	#N/A	12.18
16	3424.9	21352	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	11.96	11.84	11.80	11.68	11.51	11.43	11.28	11.22	10.96	10.95	10.89	10.84
17	3715.1	21354	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	14.85	14.74	14.70	14.59	14.42	14.34	14.17	14.12	destroyed	destroyed	#N/A	#N/A
18	3881.2	21704	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.16	7.05	7.03	6.89	6.74	6.67	6.49	6.46	6.20	6.33	6.17	6.13
19	3700.8	21928	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	10.96	11.05	11.02	10.89	10.73	10.67	10.48	10.44	10.18	10.16	10.16	10.11
20	3881.0	22453	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.84	3.74	3.37	3.60	3.45	3.43	3.23	3.19	2.95	destroyed	#N/A	#N/A
21	3512.5	22356	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.50	4.41	4.39	4.25	4.10	4.06	3.88	3.84	3.59	3.56	3.58	3.54
22	3268.1	22209	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	5.03	4.93	4.90	4.77	4.61	4.57	4.40	4.34	4.11	4.07	4.09	4.04
23	3266.6	22505	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.10	3.99	3.97	3.83	3.69	3.64	3.48	3.43	3.19	3.16	3.17	3.14
24	3247.5	22789	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.98	3.88	3.87	3.73	3.60	3.56	3.40	3.36	3.15	3.09	3.10	3.08
25	2959.1	22340	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.71	2.64	2.61	2.47	2.32	2.29	2.11	2.05	destroyed	destroyed	#N/A	#N/A
26	2720.8	22420	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.37	3.30	3.26	3.13	3.00	2.96	#N/A	2.74	2.53	2.46	2.46	2.43
27	2701.8	21841	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.50	4.40	4.36	4.23	4.08	4.02	3.84	3.80	3.58	3.56	3.52	3.49
28	2376.0	22336	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.06	2.97	2.93	2.81	2.67	2.64	2.47	2.44	2.23	2.18	2.18	2.14
29	1881.9	22343	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	3.33	3.25	3.20	3.09	2.96	2.95	2.79	2.76	2.59	2.54	2.56	2.52
30	1851.5	21906	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.04	3.90	3.86	3.75	3.61	3.57	3.42	3.39	3.21	3.18	3.18	3.15
31	5585.4	18458	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	8.70	8.64	8.64	8.60	8.51	8.50	8.43	8.41	8.32	8.30	8.31	8.26
32	5545.9	19062	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	10.96	10.94	10.94	10.89	10.78	10.79	10.67	10.65	10.54	10.50	10.51	10.54
33	5164.8	19419	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.86	15.81	15.80	15.74	15.66	15.59	15.46	15.44	destroyed	destroyed	#N/A	#N/A
34	4896.7	19674	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	18.42	18.36	18.32	18.24	18.10	18.08	17.94	17.91	17.75	17.72	17.69	17.71
35	4669.7	19943	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	18.13	18.07	18.03	17.94	17.80	17.75	17.61	17.58	17.41	17.36	17.33	17.34
36	4668.4	20336	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	17.63	17.53	17.49	17.40	17.24	17.20	17.05	17.02	16.81	16.78	16.75	16.75
37	4856.6	20439	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.84	16.74	16.70	16.61	16.46	16.41	16.27	16.23	16.04	16.00	15.97	15.98
38	4639.5	20711	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.60	16.47	16.44	16.35	16.18	16.13	15.99	15.95	15.73	destroyed	15.62	15.62
39	4642.0	21103	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.05	14.94	14.91	14.81	14.65	14.59	14.45	14.40	14.17	destroyed	13.97	13.98
40	4294.8	21373	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.47	15.21	15.18	15.06	14.90	14.85	14.67	14.63	14.40	14.35	14.34	14.31
41	4307.0	21974	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	9.67	9.53	9.52	9.40	9.25	9.20	9.02	8.99	8.76	8.70	8.71	8.70
42	4314.8	22367	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.48	7.35	7.34	7.23	7.09	7.05	6.87	6.84	6.60	6.55	6.58	6.58
43	4468.3	22397	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.85	6.73	6.72	6.61	6.48	6.45	6.26	6.24	destroyed	destroyed	#N/A	#N/A
44	5113.2	22281	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.38	4.27	4.26	4.17	4.05	4.03	3.85	3.83	3.63	3.56	4.16	3.61
45	5045.4	21937	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	9.53	9.43	9.41	9.32	9.19	9.15	8.98	8.95	8.74	8.67	8.71	8.73
46	4693.1	21855	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	11.75	11.68	11.66	11.55	11.41	11.37	11.19	11.15	10.94	10.89	10.90	10.89
47	5513.8	21859	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	8.75	8.71	8.69	8.61	8.51	8.49	8.33	8.29	8.10	8.06	8.10	8.12
48	5862.4	21926	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	5.86	5.78	5.78	5.70	5.62	5.60	5.46	5.43	5.26	destroyed	5.26	5.29
49	5174.4	21395	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.07	12.99	12.96	12.86	12.73	12.70	12.53	12.50	destroyed	destroyed	#N/A	#N/A
50	5524.1	20610	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.11	16.05	16.05	15.95	15.82	15.80	15.66	15.62	15.44	15.40	15.42	15.43
			JAN 83	**AUG 83**	**FEB 84**	**MAR 85**	**SEP 86**	**DEC 87**	**OCT 88**	**JUL 90**	**MAY 91**	**JAN 92**	**JAN 93**	**MAY 94**	**FEB 95**	**Nov 95**	**Oct 96**	**Nov 98**	**Sept 99**	**Sep 00**	**Sep 01**
PT #	**EAST**	**NORTH**	**0**	**7**	**13**	**26**	**44**	**59**	**68**	**89**	**99**	**107**	**119**	**135**	**144**	**153**	**164**	**189**	**200**	**211**	**223**
51	5232.4	20536	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.17	19.14	19.13	19.04	18.89	18.85	18.70	18.66	18.46	18.41	18.42	18.43
52	5577.8	20203	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.62	13.58	13.59	13.50	13.37	13.34	13.22	13.20	13.03	13.00	13.02	13.03

53	5573.7	19863	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.44	15.38	15.37	15.29	15.16	14.99	15.03	15.01	14.85	14.83	14.84	14.86
54	5566.0	19492	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.18	15.16	15.15	15.08	14.97	14.96	14.84	14.83	14.71	14.65	14.67	14.70
55	5575.5	20131	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	14.23	14.20	14.20	14.11	13.98	13.96	13.83	13.82	13.65	13.62	13.64	13.65
56	5576.4	20808	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	13.51	13.49	13.49	13.38	13.27	13.25	13.11	13.07	12.89	12.85	12.88	12.89
57	4311.0	20784	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.41	16.13	16.10	15.99	15.82	15.76	15.60	15.56	15.34	15.30	15.27	15.24
58	4312.0	21143	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.12	15.00	14.97	14.85	14.69	14.63	14.66	14.41	14.2	14.15	14.13	14.09
59	4989.1	19018	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	12.08	12.01	12.01	11.91	11.88	11.80	11.70	11.67	11.53	11.47	11.47	11.51
60	3818.3	17981	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.58	6.56	6.49	6.45	6.37	6.35	6.34	6.32
61	4022.8	18856	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	12.61	12.57	12.47	12.42	12.29	12.27	12.22	12.19
62	2972.9	18856	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.57	15.54	15.42	15.38	15	15	15.19	15.16
63	3109.0	20252	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	15.90	15.83	15.68	15.64	15.44	15.41	15.34	15.28
64	3105.9	21439	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	14.69	14.62	14.46	14.40	14.17	14.16	14.09	14.03
65	1651.0	21443	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.07	7.04	6.89	6.87	6.69	6.67	6.66	6.63
66	1722..0	22695	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.00	1.99	1.83	1.82	1.67	destroyed	1.66	1.62
67	3128.9	22732	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.26	2.22	2.05	2.01	1.80	1.73	1.75	1.73
68	3802.4	22716	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.74	1.72	1.53	1.49	1.10	1.20	1.23	1.22
69	4691.5	22538	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.53	4.51	4.32	4.30	4.08	destroyed	3.88	3.88
70	6002.5	22258	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.20	2.19	2.05	2.03	1.89	destroyed	1.69	1.72
71	6320.2	22264	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.81	2.81	2.68	2.65	2.55	destroyed	2.65	2.68
72	6734.6	21066	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.99	2.99	2.89	2.88	2.78	destroyed	2.82	2.86
73	5585.2	21051	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	11.43	11.41	11.25	11.22	11.03	10.97	10.99	11.02

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Appendix 2

Fitting Parameters

The data was fit to a first order exponential decay of the form:

$$Y = Y_0 + A_1 e^{-(x-x_i)/t_1}$$

where Y and Y_0 represent elevation, A_1 is a constant, x and x_i are time, and t_1 is a fitting parameter. This first order exponential decay form was chosen because most of the data appears to fit the same functional form. Mathematically the first order exponential decay fits the data very well. This allowed for creating extrapolated fits for 10 and 20 years, with confidence. The fitting parameter x_0 (x_1 at time = 0) is equal to zero for all predictions.

From the first order exponential decay representations, elevation data was obtained on extrapolated fits for 10 and 20 years to create the prediction representation graphs shown in Figures 6-7.

Pt. I.D.	EAST	NORTH	Y_0	A_1	$t1$
3	20079.1	4410.6	19.74202	2.87231	149.84797
4	20222.5	4409.9	19.63502	2.99702	150.75345
5	20289.5	4318.2	18.49823	3.06038	150.8562
6	20304.8	4310.6	18.44791	3.14441	155.03577
7	20470.1	4425.1	18.49632	3.20183	154.55988
8	20470.2	4521.7	18.58491	3.07981	150.98189
9	20450.8	4590.1	18.68205	3.00885	153.04777
10	20410.1	4606.0	18.50593	3.15735	163.42245
11	20407.9	4885.0	21.09401	3.1864	186.57832
12	20369.8	4884.8	21.07626	3.15326	195.05935
13	20349.0	4874.1	20.76603	3.41641	214.94214
14	20320.8	4823.8	20.72972	3.47515	218.2768
15	20291.0	4874.1	20.66928	3.54325	228.66676
16	20270.6	4823.7	20.62613	3.56426	224.56401
29	21183.4	4551.8	15.08369	3.67136	190.77023
31	21039.0	4550.9	15.8391	3.28566	156.40731
33	20823.8	4552.9	14.44013	3.74795	206.37126
35	20823.4	4508.9	15.45766	3.5947	186.4468
37	21038.9	4508.2	15.37461	3.36799	163.00808
WH6	22433.8	4959.3	3.247	2.8043	142.18125
WH6A	22298.3	4959.0	5.89821	2.84876	148.62064
WH6B	22343.0	5108.6	3.77824	2.46239	121.47126
WH6C	22343.1	4805.5	3.62796	2.73383	120.35291
WH7A	22104.0	6084.2	3.54917	1.63639	93.72551
WH7B	22019.4	6134.0	3.31672	1.78344	138.92187
WH8	21308.0	5282.3	-4.81092	19.2376	1799.0721
WH8A	21324.3	5329.3	11.00549	3.07076	194.77708

Pt. I.D.	EAST	NORTH	Y_0	A_1	$t1$
WH8B	21341.7	5376.9	11.24962	2.86182	183.88606
WH9	21727.0	4819.5	12.03484	2.74328	109.78007
WH9A	21583.4	4761.1	8.89635	3.69718	195.80898
WH9B	21716.1	4695.3	8.65026	3.35283	163.75414
WH11	18925.1	5109.3	5.69426	5.18987	613.22608
WH11A	18974.5	5107.8	11.22465	1.03081	55.23376
WH11B	18876.8	5111.6	11.137	2.06987	184.92787
WH101	20291.5	3965.7	16.83874	2.96348	125.82827
WH102	20640.5	3343.5	13.79919	3.27806	127.28873
WH103	21015.3	3959.0	13.94691	3.22265	126.06728
WH104	19890.7	3335.1	15.78229	2.97231	139.92124
WH105	19515.4	3957.9	16.12045	2.61821	128.53129
WH106	19139.5	3258.7	14.85744	2.4239	128.40879
WH107	21390.2	3349.6	12.52728	3.3358	113.65401
WH108	18186.0	4764.3	6.42984	1.61541	160.31011
WH109	21764.5	3960.3	7.01439	3.58998	150.10115
WH110	22514.5	3957.6	5.00209	3.03555	108.62206
WH111	22870.1	3308.9	5.28308	2.88652	102.63681
WH112	18185.7	5514.1	7.23308	1.23892	118.32109
WH113	22501.6	2659.8	4.44756	3.08597	103.20788
WH114	21764.6	2659.6	3.94607	3.46925	129.98776
WH115	22139.3	3307.4	5.865	3.36864	99.97825
WH116	21820.5	1911.2	5.29786	2.88069	104.43463
WH117A	18680.0	4230.1	11.14724	1.89373	200.45411
WH117B	18680.0	4230.0	10.9799	2.08576	233.6029
BM1	18640.6	4900.0	8.83682	1.81547	1.81547
BM11	18977.7	4583.9	10.22088	2.22893	159.34772
BM12	18977.9	3578.6	13.8012	2.54844	172.71207
BM13	19758.0	3579.1	20.26579	3.28451	196.9941
BM14	20398.6	3579.1	15.66604	3.4192	161.15759
BM15	21300.0	3579.1	13.90895	3.60722	147.87783
SMS1	18209.9	5035.3	8.66521	1.47387	155.25557
SMS2	19731.1	4955.9	16.42777	2.68566	166.74599
SMS6	20960.9	3521.9	13.27439	3.8277	173.4961
SMS7	19379.4	3371.5	18.86268	2.50151	142.52875
2	18208.7	5361.7	4.95423	1.34913	161.86551
4	18619.4	4562.1	9.71026	1.98531	180.02971
5	18759.8	4288.8	8.66149	2.2132	186.17756
7	19441.8	3740.7	17.87592	2.92335	168.99153
8	19187.4	3409.1	15.61236	2.81808	112.16086
9	19451.6	3879.8	14.0695	2.83182	143.80277
11	19846.7	3410.6	13.99577	3.59667	79.23461
12	20210.6	3880.7	13.81899	3.64347	236.75702
13	20600.1	3414.3	11.49418	3.47314	123.74022
14	20709.6	3727.1	13.01053	3.90408	247.54853
15	20973.8	3883.8	9.58228	4.79554	337.58453
16	21351.5	3424.9	8.97667	4.22449	259.88671
18	21704.4	3881.2	5.21271	3.36003	167.3919
19	21927.8	3700.8	9.75215	3.25719	100.99179

Pt. I.D.	EAST	NORTH	Y_0	A_1	$t1$
21	22356.0	3512.5	1.89408	3.77373	248.3987
22	22208.8	3268.1	2.33366	3.85209	254.13994
23	22505.3	3266.6	1.67599	3.60977	227.9758
24	22789.0	3247.5	1.40255	3.62216	266.85948
26	22420.3	2720.8	-0.15618	4.50593	375.62362
27	21841.0	2701.8	2.17269	3.60968	207.78091
28	22335.5	2376.0	1.07307	3.19637	192.20618
29	22343.0	1881.9	1.72551	2.75091	168.38063
30	21906.3	1851.5	2.56524	2.92862	129.51437
31	18457.7	5585.4	7.81375	1.42639	189.56333
32	19062.2	5545.9	9.07722	2.41374	388.2542
34	19673.7	4896.7	17.11813	2.44778	146.65064
35	19942.7	4669.7	16.59501	2.7086	162.59195
36	20335.6	4668.4	16.00235	2.93895	154.23667
37	20438.8	4856.6	15.27798	2.88192	148.73662
38	20710.5	4639.5	14.52465	3.27946	195.98045
39	21103.4	4642.0	9.92001	6.06408	538.87401
40	21373.0	4294.8	12.25182	4.24118	288.61661
41	21974.2	4307.0	8.18458	3.31045	114.54503
42	22366.7	4314.8	6.1543	3.21457	104.19731
44	22280.6	5113.2	2.99163	2.77185	133.99453
45	21936.5	5045.4	6.36357	4.05739	365.38831
46	21854.8	4693.1	10.43479	3.06169	112.29674
47	21859.0	5513.8	7.26751	2.41716	194.34905
48	21925.5	5862.4	5.02887	2.11336	99.4316
50	20609.7	5524.1	13.4253	3.47458	361.11392
51	20535.9	5232.4	18.01009	2.7538	112.55161
52	20203.0	5577.8	12.43634	2.16251	158.25185
53	19862.6	5573.7	14.226	2.08169	166.57793
54	19492.4	5566.0	14.2047	1.8049	155.79944
55	20131.3	5575.5	13.33707	2.22995	105.53873
56	20808.0	5576.4	12.42024	2.30499	130.30633
57	20783.9	4311.0	14.76009	3.70122	105.6479
58	21142.6	4312.0	12.82516	3.52347	211.5901
59	19017.9	4989.1	10.76993	2.09567	195.52746
60	17980.6	3818.3	6.12677	2.04936	91.05314
61	18855.8	4022.8	11.83651	2.65912	108.94403
62	18856.2	2972.9	14.99598	4.12562	68.94936
63	20251.6	3109.0	14.97494	4.94133	80.74633
64	21439.3	3105.9	13.7825	6.69421	68.016
65	21442.5	1651.0	6.51985	8.11907	50.84975
66	22694.9	1722.9	1.55517	9.22117	45.24727
67	22732.0	3128.9	1.58324	10.7026	49.6508
68	22716.2	3802.4	1.09163	24.49229	38.05079
69	22537.5	4691.5	3.57162	6.2969	73.50107
70	22257.8	6002.5	1.50119	5.03672	70.31442
71	22263.9	6320.2	2.52321	0.81026	114.11328
72	21066.0	6734.6	2.79759	10.67976	33.4955
73	21050.9	5585.2	10.89738	13.33389	42.74842

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