The Yolo County GPS Subsidence Network

Recommendations and Continued Monitoring

(Photo: Larry Hatch, City of Woodland, at station HERSHEY)

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Executive Summary

In July and August, 2002, the first re-observation of the Yolo County GPS subsidence network was accomplished. The intent of the survey, following recommendations made after the initial 1999 survey, was to determine the amount of subsidence over the intervening three years. Again, the City of Davis served as the lead agency for the project. Participating agencies were the same as those in 1999. The U.S. Corps of Engineers did not participate in the 2002 project. A complete list of agencies and personnel is included in **Appendix C**.

The most significant area of subsidence occurred near the cities of Davis and Zamora, and in the north and western portion of the county. Subsidence in the vicinity of Davis was about five centimeters (two inches) and in the vicinity of Zamora about seven centimeters (almost three inches). A complete station-by-station listing of subsidence is included in **Appendix B**. A listing of all station coordinates and elevations is included in **Appendix A**.

Seven additional Yolo County stations were added to the 2002 survey. The stations are in the southern portion of the county. These stations had been observed in 1997 as part of a cooperative GPS survey of the Sacramento/San Joaquin Delta, but a decision was made to leave them out of the 1999 survey. A project map depicting all local stations is found in **Appendix D.** Also in Appendix D is a contour map indicating subsidence trends in the county.

The City of Sacramento, through the National Geodetic Survey, asked to cooperate in the Yolo County project. Eight stations in the vicinity of Sacramento were incorporated into the project. The results of these stations are also included in Appendix A. The primary interest of the city was horizontal coordinates: however, their stations were observed to obtain high-accuracy vertical values.

There was a series of ten recommendations in the 1999 report (The Yolo County Subsidence Network: Recommendations for Future Monitoring, Frame and D'Onofrio, 1999). A complete listing of these recommendations and comments is included in Section IV of this report. A review of the results of the 2002 survey and a comparison with the results of the 1999 effort suggests two additional recommendations. These are:

Recommendation 11. Incorporate measurements to relate the two DWR extensometers (at Zamora and Conaway Ranch) and the Yolo County Subsidence network.

Recommendation 12. Seek cooperation with the County of Solano to determine the magnitude and extent of the subsidence in the vicinity of Davis.

These recommendations are further discussed in this report in Section V.

I. INTRODUCTION

This report outlines the results of the 2002 Yolo County Subsidence network observations and compares them to the results of the 1999 network survey. It includes a listing of the recommendations made in 1999 with updated comments. It also includes two new recommendations and the rationale behind them. Detailed information about the origins of the project can be found in the 1999 report: The Yolo County Subsidence Network: Recommendations for Future Monitoring, Frame and D'Onofrio, 1999.

As with the 1999 survey, the 2002 survey was accomplished with observation personnel and GPS equipment from participating public agencies and the University of California, Davis. Personnel and equipment were supplied by the California Department of Transportation and the U.S. Bureau of Reclamation. Personnel were supplied by the Yolo County Planning & Public Works Department, City of Davis Public Works Department, City of Woodland Public Works Department and the California Department of Water Resources. Equipment was supplied by the Department of Geology, University of California, Davis and the California Department of Water Resources. The City of Sacramento also participated by providing personnel and equipment for observing the stations in the city.

II. BACKGROUND

In 1999 the first GPS observations were obtained for the Yolo County Subsidence network stations. The small portion of the county south of Interstate Highway 80 was not included in the survey although seven stations there had been observed as part of the 1997 Sacramento/San Joaquin Delta GPS project. These seven stations were included in the 2002 re-observation of the Yolo County Subsidence Network.

The results of the 1999 GPS observations corroborated subsidence observations previously made by means of other technologies in certain areas of the county. Several stations included in the network indicated subsidence when compared to previous terrestrial elevation data. The most significant was station DUFOUR which indicated subsidence of about 1.4 meters (greater than four feet) from its last known published elevation in 1967. Between the 1999 and 2002 surveys stations along the I-5 corridor and vicinity, from Dunnigan to Woodland, exhibited subsidence. Subsidence was also noted along the Highway 113 corridor and vicinity, from Woodland to Davis. Subsidence in these areas from pre-1999 terrestrial and GPS surveys was also noted.

The utility and accuracy of the GPS technology for monitoring subsidence was demonstrated shortly after completion of the 1999 survey when Andregg, Inc. surveyors performed terrestrial level ties between four station pairs in the network. The terrestrial observations and GPS results agreed to within about one centimeter or better in all

instances. GPS observations are significantly more cost effective than conventional terrestrial leveling.

Results of the 1999 survey accompanied by a project map, station descriptions and the series of recommendations may be found at the web site dedicated to the project. The web site address is: www.yarn.org/subsidence/about.html.

The NGS web site has a complete listing of all station data with additional values and metadata. The data can be obtained at the web site address: www.ngs.noaa.gov/cgi-bin/ds_project.prl. Enter the GPS project identifier, **GPS1790,** to obtain data for all stations used in the Yolo County project.

III. PROJECT ISSUES

All but one station in the original 1999 network were recovered in good condition and still suitable for GPS observations. Station PHILLIPS was found to be unsuitable for continued GPS monitoring due to the growth of trees in the vicinity. A new station, VINCOR, was established nearby. A terrestrial level tie was accomplished between stations PHILLIPS and VINCOR so the continuity of subsidence records history would remain intact. (See **Recommendation 3.**) The Yolo County Planning & Public Works Department requested the addition of a station at the Yolo County Airport. An existing monument was located on the airport and was added to the network as station YCAP. Please note that network stations already exist at the Davis and Woodland airports.

The seven additional stations added to the network in the southern portion of the county had been observed in 1997. The procedures employed in the 1997 survey were the same as those employed in the Yolo County project; thus direct measures of potential subsidence were determined over the five year period between observations. These stations indicated relative stability (no subsidence).

Two of the eight stations added to the project at the request of the City of Sacramento indicated significant subsidence. Station J 1414 subsided five centimeters (two inches) since its 1994 GPS observation. Station RIEGO RM 4 subsided six centimeters (about 2 ½ inches) since its 1994 GPS observation. These two stations were part of the California Department of Transportation HPGN Densification network. Note, however, that the 1994 observations were not conducted according to the same height modernization specifications as were the observations made in 2002.

All other activities associated with the 2002 network re-observation were routine.

IV. 1999 RECOMMENDATIONS AND UPDATED COMMENTS

The original ten recommendations from the 1999 report are included here with updated comments, as appropriate. Two new recommendations are suggested in the following section (**V. NEW RECOMMENDATIONS**).

Recommendation 1. Inform public and private agencies involved in construction, utilities management, public works and related activities in the county about the network and the location of all stations. Information about the project's web site should be included in this information.

There have been numerous indications that the network stations and their related coordinates and elevations are being regularly used. The land surveying community, in particular, relies heavily upon the network stations for positioning activities.

Recommendation 2. Task a single county entity with visiting each monument in the network annually to assess the integrity of the individual monuments. Any discrepancies in monument description or condition should be brought to the attention of interested county parties and to the National Geodetic Survey (NGS). Follow proper reports for reporting such discrepancies.

It is unclear if any agency has accepted this responsibility. This has not yet been a problem since all but one station in the network were recovered in 2002 in good condition and suitable for GPS observations. The only station found unsuitable was station PHILLIPS, which is still in good condition but is under tree canopy. That makes it unsuitable for GPS observations since clear access to the GPS satellites has been compromised. The recommendation is still valid and should be followed.

Recommendation 3. Identify stations in imminent danger of destruction and replace them in advance, following National Geodetic Survey guidelines. (A copy of these guidelines may be obtained from the NGS California State Geodetic Advisor, Marti Ikehara - marti_ikehara@dot.ca.gov.) A station destroyed before replacement represents a permanent break in the subsidence history of that station.

Although station PHILLIPS has been rendered unsuitable for GPS observations the physical station has not been disturbed. After the new station VINCOR was established about 20 meters from station Phillips, Frame Surveying & Mapping performed a terrestrial level tie between the two stations. This helps to retain the subsidence history at the site. The potential for station destruction increases over time, especially as development encroaches in the vicinity if the stations.

Note: The cost of these first three recommendations is relatively minor, less than about two person-weeks of effort per year.

Recommendation 4. Re-observe the entire network in three years (2002). Depending on the results of this re-observation the county can better determine the time period for subsequent re-observations.

This recommendation was accomplished with the re-observation in 2002. We recommend another re-observation in 2005. Subsidence is not uniform over time, but is correlated with groundwater withdrawal. Another re-observation in 2005 should provide further information about subsidence and subsidence patterns, especially in areas of more significant subsidence. The network should be re-observed at about the same time of year as the 1999 and 2002 surveys as some seasonal variation in ground elevation is known to occur. Observations made at a different time of year might compromise the results. The cost of the re-observation should be similar to the cost of the 2002 survey, allowing for inflationary increases.

Recommendation 5. Investigate the benefits of more frequent re-observation of particular areas of the county.

This recommendation was suggested without knowledge of the actual amount of subsidence that might be discovered. A comparison of the 1999 and 2002 surveys indicated a maximum subsidence of about seven centimeters. It is unlikely that this level of subsidence over three years would indicate a need for further re-observations at a lesser time interval. Three-year observations seem to be satisfactory, pending a review of the 2005 proposed re-observation results.

Recommendation 6. Investigate densification of the network in areas of particular interest.

The existing network provides a series of stations at about seven kilometer spacing. These discrete stations may prove unsatisfactory for finer-level understanding of subsidence and subsidence patterns. Differential subsidence over relatively small areas- on the order of one kilometer - have been observed in other subsiding areas in California. The City of Davis has indicated an interest in developing a dense network consisting of one north-south and one east-west transect through the city, intersecting near central Davis. The cost of installing and observing this denser network is estimated at about $37,000. The project would most likely incorporate GPS and terrestrial leveling, and would involve the establishment of additional survey monuments. New monuments suitable for monitoring subsidence add significant costs to a project. The GPS observations would include ties to stability to ensure accurate determinations of subsidence.

Recommendation 7. Provide continuing non-financial support for the Continuously Operating reference Station (CORS) at the University of California, Davis. This site can be of significant value in ongoing subsidence measurement operations.

The UCD CORS site is monitored continuously and can be related to other CORS sites such as those in Fairfield and the Sutter Buttes. These latter two stations have been found

to be stable in the vertical component. Because of the amount of continuous data it is possible to relate the UCD site to the other sites at the sub-centimeter level. At any time the elevation of the UCD site can be determined relative to these other sites. It is the ongoing observations of the UCD site that provides information about the seasonal changes in surface elevation.

Recommendation 8. Investigate the establishment of a CORS site in the north county area.

The California Spatial Reference Center (CSRC) has developed a plan to include a CORS in the north county subject to funding and priorities. A willingness on the part of the county and its cooperating partners to share the cost with CSRC might influence CSRC priorities. Costs were included in the 1999 report. Annual maintenance costs for a CORS site is about $6,000 per year which can be reduced by cooperative efforts.

Recommendation 9. Consider the merits of encouraging the Federal Emergency Management Agency (FEMA) to adopt the results of the project in its flood plain mapping efforts.

The 2002 revision of the FEMA Flood Insurance Rate Map (FIRM) for the City of Woodland was based upon vertical control established by the 1999 subsidence network. The revision includes flood elevation contours published in both NGVD29 (a superseded datum) and NAVD88 (the current national datum and the datum to which the subsidence network is referenced). As future re-observations are accomplished and subsidence in the county becomes more thoroughly documented, FEMA is likely to increase reliance upon the network in its flood plain analysis, and may ultimately convert all Yolo County FIRMs to NAVD88.

Recommendation 10. Investigate other supporting technologies as an adjunct to the GPS Subsidence Network within Yolo County.

The 1999 report suggested investigating Synthetic Aperture Radar (SAR) and Light Detection and Radar (LIDAR) technologies for providing a denser look at subsidence and subsidence patterns in the county. It now appears that LIDAR is a significantly more expensive technology. But perhaps more importantly, the accuracies of LIDAR are at about the 15 centimeter level. Given the level of subsidence disclosed by the 2002 subsidence, it appears that this technology offers no significant benefits.

There is perhaps a better chance for use of SAR technology, however, this technology does not work as well in agricultural areas. It is based upon change detection over time, which requires land areas that do not change over time. Agricultural areas change with the conditions of the ground (level versus furrows) and agricultural growth. For example, SAR cannot distinguish between a barren field and one with a full growth of crops and would give a false interpretation of ground surface change under those conditions. There is some potential for SAR, but it would probably cost about $15,000 for a test project, with no guarantee that the results would be beneficial.

V. 2002 ADDITIONAL RECOMMENDATIONS

After the results of the project had been determined a meeting was held with the staff of the California Department of Water Resources responsible for maintaining the two extensometers in the county. The extensometers are in the vicinity of Zamora and on the Conaway Ranch. Network station ZAMX, near the Zamora extensometer, reflected subsidence of seven centimeters. Station EX-1, near the Conaway Ranch extensometer, subsided only two centimeters. In each case the extensometer records indicated subsidence about one-half that of the GPS measurements.

The extensometers are significantly more responsive to ground level fluctuation on an almost daily basis. GPS measurements, on the other hand, are obtained over a several day period and meaned to a common date. The extensometer fluctuations do not account for the difference between the two types of measurements. Conversations with representatives at the U.S. Geological Survey indicate that extensometers, even those established to a depth of as much as 1,000 feet, may not truly reflect the full amount of ground subsidence. We believe that each of the technologies provides accurate measurements, but that GPS more accurately measures total ground subsidence.

Recommendation 11. Incorporate measurements to relate the two DWR extensometers (at Zamora and Conaway Ranch) and the Yolo County Subsidence network.

As a result of these results and our discussions with DWR, we believe that more direct measurements between the two extensometers and their respective nearby network stations be taken at the time of the GPS measurements. Since GPS observations are made over a several-day period a series of these measurements may be desirable. GPS accuracy is mostly a function of the length of time the GPS satellite constellation is tracked. Observation time at network stations ZAMX and EX-1 might be extended to provide a greater level of accuracy. This could provide sub-centimeter results for the two stations and allow a more accurate measurement of the differences between the technologies.

The cost for these additional observations is estimated at about $6,000.

Recommendation 12. Seek cooperation with the County of Solano to determine the magnitude and extent of the subsidence in the vicinity of Davis.

A review of the subsidence contour map in Appendix D indicates significant subsidence in the vicinity of Davis. The extent of the subsidence is unknown south of Davis since this area is in Solano County and is not part of the Yolo County network. There are several existing stations in Solano County that are part of earlier GPS surveys, specifically the Sacramento/San Joaquin Delta projects. These stations could be added at an additional cost of about $2,000. This assumes Solano County would be willing and able to provide personnel and equipment to occupy these stations. Alternatively, DWR

might be willing to underwrite this extension of the Yolo project, since these stations are part of the Delta network.

VI. CONCLUSION

The completion of the 2002 Yolo County GPS subsidence project provides the first modern review of subsidence in the county. The comparison of the 1999 and 2002 projects indicates areas of the county that, when related to older terrestrial surveys, continue to exhibit subsidence. Most of the county experienced some subsidence. The Interstate Highway 5 corridor from Dunnigan to Woodland and the Highway 113 corridor from Woodland to Davis are affected most by this subsidence. Another pocket of subsidence is in the northwestern portion of the project area. The largest subsidence between the two GPS surveys is in the vicinity of Zamora which subsided seven centimeters. The 2002 results are included in Appendix A and the elevation differences (subsidence = negative, uplift = positive) between the two surveys are included in Appendix B. Continued monitoring of the network is recommended. Continued monitoring of the primary factor causing subsidence, groundwater withdrawal, is also recommended.

It should be noted that the horizontal coordinates (latitude and longitude) also changed for all stations in the network. The county is in the area of horizontal motion caused by being located in the zone affected by the North American and Pacific tectonic plates. All stations in the project move northwesterly a few centimeters per year with minor variation in movement among the stations.

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Appendix A: Final Station List and Coordinates

(Includes City of Sacramento stations)

(Photo: Station CHURCH in the City of Woodland)

Appendix A: Final Station List and Coordinates

STATION DESIGNATION	FINAL ADJUSTED LATITUDE (epoch 2002.53)	FINAL ADJUSTED LONGITUDE (epoch 2002.53)	FINAL ADJUSTED NAVD88 Orthometric HEIGHT, meters (2002 elevations)	PID
169	38 44 12.69568N	121 57 15.85660W	52.50	JS2170
ABUT	38 38 05.70584N	121 57 06.70255W	53.01	AI5050
ALHAMBRA	38 33 31.09757N	121 42 26.68762W	12.97	AI5051
ANDREW	38 23 12.17743N	121 38 18.71969W	3.68	AE9864
B 849	38 32 01.29090N	121 58 15.18331W	39.68	JS2151
BIRD	38 50 54.73498N	122 02 37.47696W	94.11	AI5052
BRIDGE	38 42 41.39518N	122 02 50.18340W	64.20	AI5053
CALDWELL	38 27 33.51280N	121 39 24.21307W	5.42	AE9863
CANAL	38 37 02.05407N	121 51 30.11560W	29.79	AI5054
CASTRO AZ MK RESET	38 33 50.77536N	121 38 37.80288W	5.27	JS4556
CHURCH	38 39 48.00509N	121 48 09.05752W	24.12	AI5055
CODY	38 47 30.59722N	121 46 29.01978W	12.75	AI5056
CONAWAY	38 37 05.49414N	121 38 40.42822W	7.71	AI5057
COTTON	38 38 20.24426N	122 02 08.12167W	91.52	AI5058
COURTLAND	38 20 24.75925N	121 33 40.05033W	8.06	JS4311
COY DUMP	38 35 28.05097N	121 41 31.83411W	8.55	AI5059
CVAP 02	38 50 19.76338N	121 50 39.17593W	8.01	AI5060
DAVEPORT	38 31 59.46429N	121 47 14.17621W	19.39	JS4617
DRAIN	38 55 31.04473N	121 54 52.46219W	12.97	AI5061
DUFOUR	38 45 48.09569N	121 50 39.06776W	20.25	JS2238
F 859 RESET	38 47 34.20043N	121 43 36.01698W	14.21	AI5062
FERRY	38 40 32.00674N	121 37 49.18003W	12.13	JS2338
FORD RM 2	38 43 33.23507N	121 43 47.39158W	17.53	AI5046
FREMONT	38 45 52.89327N	121 38 08.00521W	12.56	AI5063
G 1200	38 47 09.87346N	121 14 32.09509W	77.38	JS0755
GAFFNEY	38 24 25.68438N	121 34 56.13556W	1.00	AE9851
GWM 17	38 46 52.25771N	122 02 38.10735W	84.79	JT0105
GWM 32	38 44 21.97065N	122 09 59.02755W	112.58	JT0026
HERSHEY	38 52 28.84718N	121 54 51.96511W	13.97	AI5064
HPGN CA 03 08	38 43 01.99778N	121 48 07.54090W	23.73	JS4668
HPGN D CA 03 BG	38 30 20.00860N	121 34 55.09118W	9.91	AC9219
HPGN D CA 03 DG	38 38 27.43690N	121 45 39.59540W	24.09	AC9223
HPGN D CA 03 EH	38 51 59.61225N	121 32 32.95659W	10.73	JS4847
JIMENO RM 4	38 55 39.86130N	121 50 35.87435W	12.30	AI5047
KEATON	38 42 33.52245N	121 53 11.08244W	35.83	AI5065
LIBRARY	38 40 44.18419N	121 46 28.10008W	19.90	AI5066
MADISON	38 41 00.22740N	121 58 36.36010W	47.00	JS2364
P 1031	38 40 38.14441N	121 42 34.07731W	10.26	JS2344
P 1075	38 50 51.29489N	121 56 00.25761W	14.87	JS2130
VINCOR **(new station)**	38 48 08.11883N	121 59 00.32187W	48.28	DE9127

PLAINFIELD	38 35 05.49717N	121 48 11.62107W	19.96	AI5068
RIVER	38 38 50.46071N	121 34 20.06216W	12.02	AI5069
RUSSELL RANCH 2	38 32 38.06502N	121 52 33.83768W	29.37	AC9893
SM NO 15	38 43 51.60375N	121 37 59.39187W	7.33	AI5070
SUTTER BUTTES CORS POINT	39 12 20.99452N	121 49 14.10152W	645.89	AF9711
SYCAMORE	38 50 19.12265N	121 45 06.38892W	7.66	AI5071
T 1069	38 35 09.99936N	121 58 17.45546W	54.71	JS2157
T 462	38 26 25.99174N	121 30 17.76157W	9.14	JS1556
T 849	38 47 24.93233N	121 54 56.34425W	36.17	JS2177
TYNDALL	38 52 26.17670N	121 49 03.81149W	9.08	AI5072
UCD1 UC DAVIS GEOL 1 CORS ARP	38 32 10.44759N	121 45 04.37720W	31.44	AI4467
WILSON	38 29 41.85081N	121 41 31.51403W	9.60	AE9857
WOODPORT	38 40 17.76114N	121 52 20.38066W	39.74	JS3886
X 200 RESET	38 54 20.73108N	121 58 59.79141W	29.88	JS2144
YOLO CO AP BASE LINE PT 6 **(new station)**	38 34 20.34417N	121 51 18.37282W	29.61	DE9129
Z 585 RESET	38 34 15.79628N	121 31 49.55488W	6.30	JS2248
ZAMX	38 46 45.78460N	121 48 44.62949W	13.03	AI5074
EX-1	38 38 46.40916N	121 40 03.02450W	7.86	AI5073
POTRERO HILL GRM	38 12 09.43671N	121 56 07.33702W	62.1	AJ1919
STOCKTON CORS ARP	37 53 47.04380N	121 16 42.53064W	11.7	AH8914

City of Sacramento Stations

HPGN D CA CSUS	38 33 14.56994N	121 25 23.72262W	13.31	AC9246
J 1414	38 29 47.62917N	121 23 49.73609W	11.84	JS3901
AP STA A2	38 30 18.05576N	121 30 01.31353W	5.01	JS4839
G 1414	38 27 10.89635N	121 22 51.46942W	11.77	JS3899
CNTRL MON LR 208	38 39 18.54189N	121 23 14.17731W	23.39	AC9237
CAPITOL RESERVOIR	38 39 02.32747N	121 30 26.67360W	4.79	DE9128
HPGN D CA 03 AA	38 36 52.10322N	121 30 52.07406W	6.08	AC9226
RIEGO RM 4	38 45 05.18885N	121 29 05.74989W	14.34	AC9218

NOTE: The epoch date for stations STOCKTON CORS ARP (AH8914)and SUTTER BUTTES CORS POINT (AF9711) IS **2002.00**. All other stations are as indicated, 2002.53.

Appendix B: Table of Station Subsidence

(Photo: Don Stackhouse, USBR, at station CVAP 02.)

Appendix B: Station List
A Comparison of 1999 and 2002 Project Results

STATION DESIGNATION	*Published* Orthometric Height, meters (1999 elevations)	*Adjusted* Orthometric Height, meters (2002 elevations)	*Adjusted minus Published* Ortho Height (2002-1999) Subsidence (-) Uplift (+)
169 USGS	52.52	52.50	-0.02
ABUT	53.03	53.01	-0.02
ALHAMBRA	12.99	12.97	-0.02
ANDREW [1]	3.68	3.68	-0.01
B 849	39.68	39.68	0.00
BIRD	94.13	94.11	-0.02
BRIDGE	64.21	64.20	-0.01
CALDWELL [1]	5.42	5.42	0.00
CANAL	29.80	29.79	-0.01
CASTRO AZ RESET	5.27	5.27	0.00
CHURCH	24.13	24.12	-0.01
CODY	12.80	12.75	-0.05
CONAWAY	7.72	7.71	-0.01
COTTON	91.51	91.52	+0.01
COURTLAND [1]	8.06	8.06	0.00
COY DUMP	8.56	8.55	-0.01
CVAP 02 USGS	8.05	8.01	-0.04
DAVEPORT	19.44	19.39	-0.05
DRAIN	12.99	12.97	-0.02
DUFOUR	20.31	20.25	-0.06
F 859 RESET	14.23	14.21	-0.03
FERRY	12.12	12.13	+0.01
FORD RM NO 2	17.55	17.53	-0.03
FREMONT	12.54	12.56	0.02
G 1200	77.38	77.38	0.00
GAFFNEY [1]	0.99	1.00	+0.01
GWM 17 USGS	84.85	84.79	-0.06
GWM 32 USGS	112.58	112.58	0.00
HERSHEY	13.99	13.97	-0.02
HPGN CA 03 08	23.78	23.73	-0.05
HPGN D CA 03 BG [1]	9.91	9.91	0.00
HPGN D CA 03 DG	24.13	24.09	-0.04
HPGN D CA 03 EH	10.75	10.73	-0.02
JIMENO NO 4	12.30	12.30	0.00
KEATON	35.84	35.83	-0.01
LIBRARY	19.93	19.90	-0.03
MADISON	47.03	47.00	-0.03
P 1031	10.26	10.26	0.00
P 1075	14.90	14.87	-0.03
VINCOR (new station) [2]	48.32	48.28	-0.04
PLAINFIELD	19.99	19.96	-0.03
RIVER	12.03	12.02	-0.01

Appendix B: Station List
A Comparison of 1999 and 2002 Project Results

RUSSELL RANCH 2	29.38	29.37	-0.01
SM NO 15	7.30	7.33	+0.03
SUTTER BUTTES CORS POINT	645.89	645.89	0.00
SYCAMORE	7.67	7.66	-0.01
T 1069	54.73	54.71	-0.02
T 462 [1]	9.14	9.14	0.00
T 849	36.20	36.17	-0.03
TYNDALL	9.10	9.08	-0.02
UCD1 UC DAVIS GEOL 1 CORS ARP	31.50	31.44	-0.06
WILSON (1)	9.61	9.60	-0.01
WOODPORT	39.75	39.74	-0.01
X 200 RESET	29.91	29.88	-0.03
YOLO CO AP BASE LINE PT 6 (new station)		29.61	
Z 585 RESET	6.35	6.30	-0.05
ZAMX	13.10	13.03	-0.07
EX-1	7.88	7.86	-0.02

City of Sacramento Stations

HPGN D CA CSUS [1]	13.31	13.31	0.00
J 1414 [1]	11.79	11.84	+0.05
AP STA A2 [1]	5.00	5.01	+0.01
G 1414 [1]	11.75	11.77	+0.02
CNTRL MON LR 208 [1]	23.38	23.39	+0.01
CRES (new station)		4.79	
HPGN D CA 03 AA [1]	6.09	6.08	-0.01
RIEGO RM 4 [1]	14.40	14.34	-0.06

[1] These stations were observed as part of the 1997 Sacramento/San Joaquin Delta project.

[2] Station VINCOR is a replacement for nearby station PHILLIPS, which was not suitable for GPS observations in 2002 due to tree growth. The 1999 height and "adjusted minus published" values shown are theoretical and were determined from a leveling tie made to PHILLIPS in 2002.

Appendix C: Personnel Listing

C-1: Agency Personnel

C-2: Observation Personnel

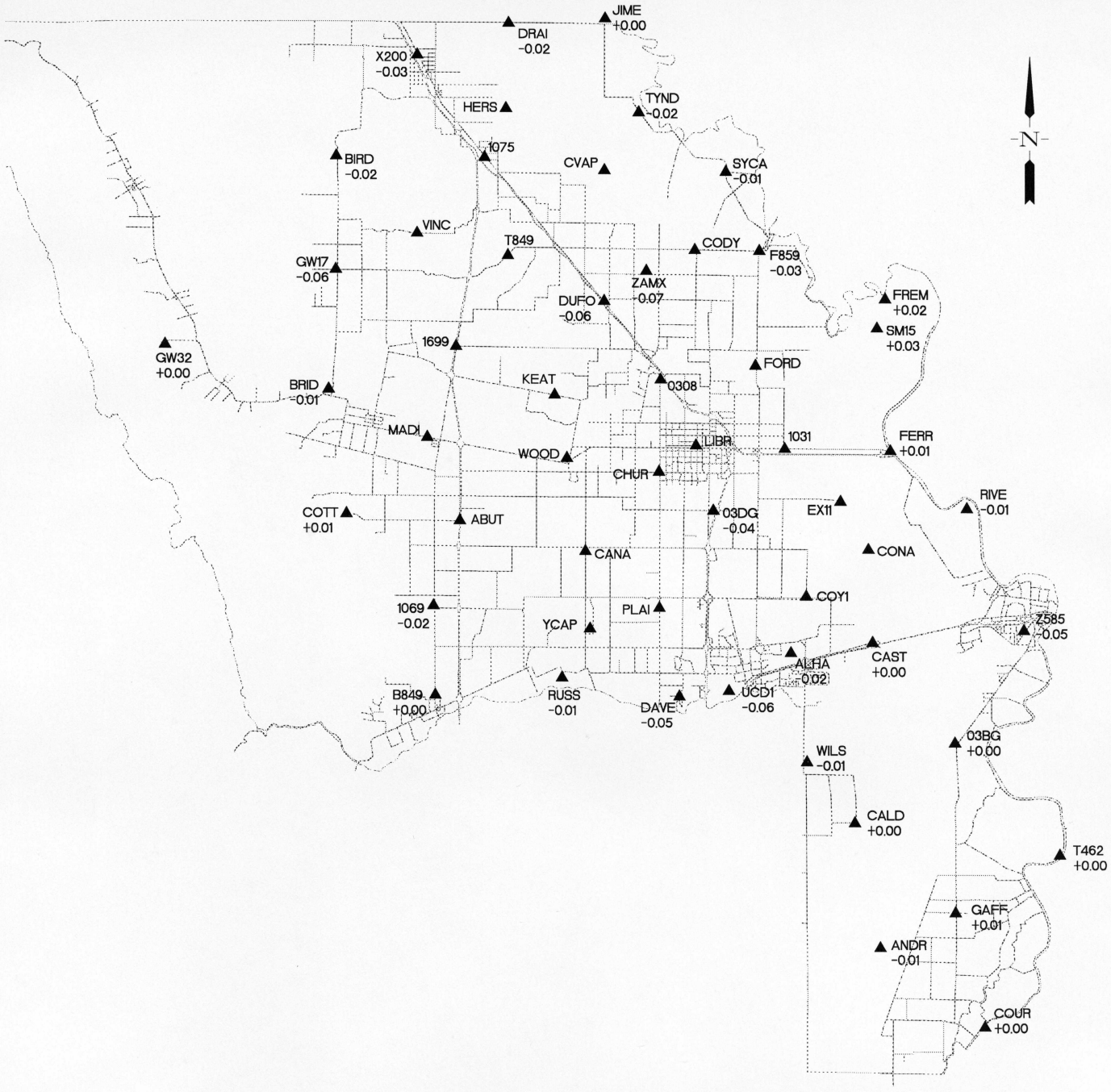
(Photo: GPS Equipment at station ZAMX at the Zamora extensometer)

Appendix C-1: Agency Personnel

Personnel	Agency
Jacques DeBra	Utilities Program Specialist Planning and Public Works Department City of Davis
John Fielden	Hydrogeologist California Department of Water Resources, Sacramento
Christy Barton	Asst. General Manager Yolo County Flood Control and Water Conservation District, Woodland
Ken Misner	County Surveyor Yolo County Planning & Public Works Department, Woodland
Ron Scott	City of Woodland
John Adam	California Department of Transportation North Region, Marysville
Terri Reaves	Surveys & Photogrammetry U.S. Bureau of Reclamation, Sacramento
Louise Kellogg	Associate Professor Department of Geology University of California, Davis
Deborah Braver	Water Resource Association of Yolo County, Woodland
Marti Ikehara	National Geodetic Survey, Sacramento
Jim Frame	Frame Surveying & Mapping, Davis
Don D'Onofrio	Geodetic Consultant, Carmichael

Appendix C-2: Yolo County Observing Personnel

Personnel	Agency
Ken Misner	Yolo County Planning & Public Works Department
Ron Scott	City of Woodland
Larry Hatch	City of Woodland
Marie Graham	City of Davis
Ingdean "Indy" Yan	California Department of Water Resources
Isela Ortiz	California Department of Water Resources
Sal Batmanghilich	California Department of Water Resources
Don Stackhouse	U.S. Bureau of Reclamation
Robert Keller	U.S. Bureau of Reclamation
Ireck Hernandez	California Department of Transportation
Tim Dowell	California Department of Transportation
Jim Frame	Frame Surveying & Mapping
Don D'Onofrio	Geodetic Consultant

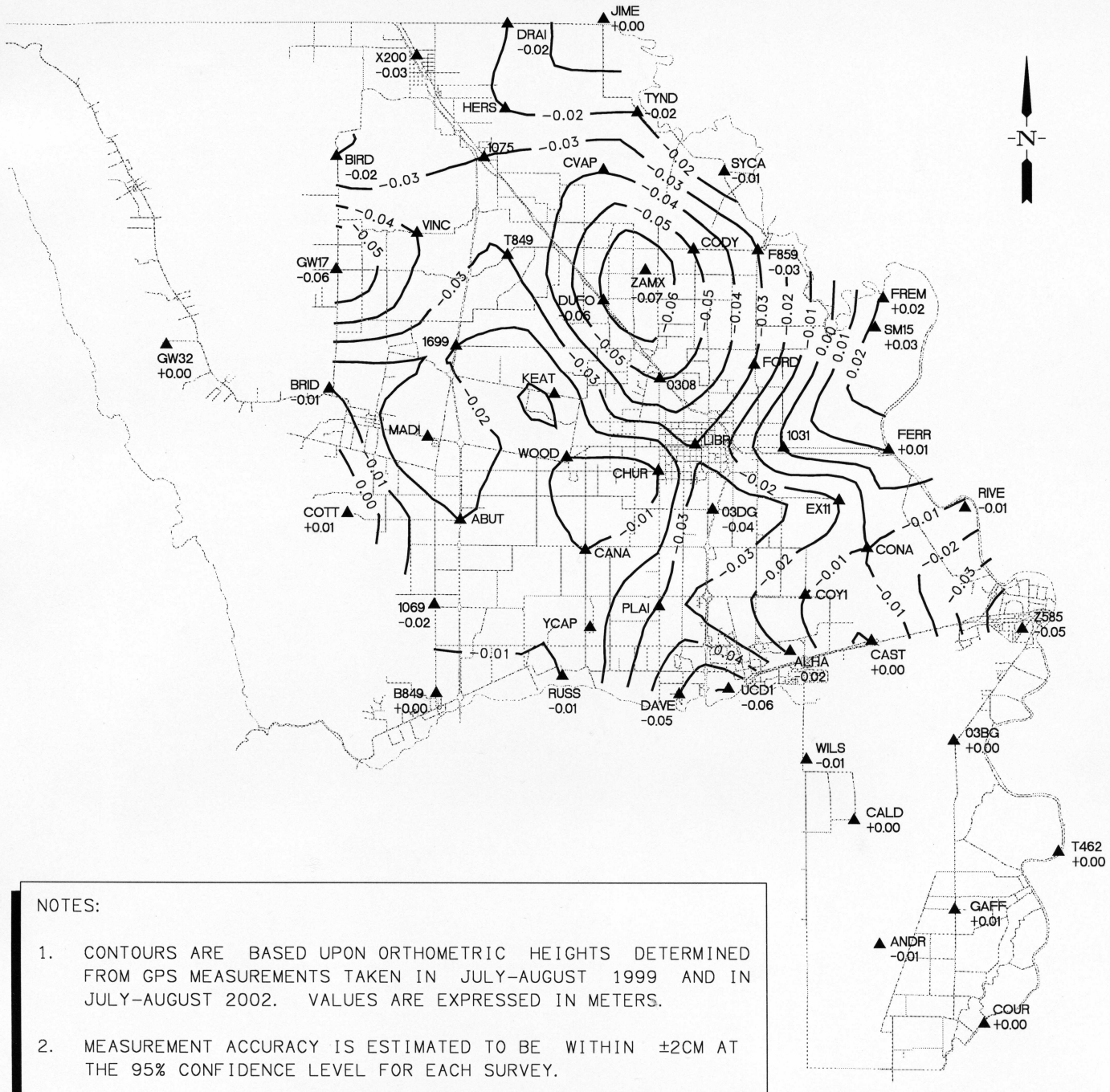


FRAME SURVEYING & MAPPING
609 A Street
Davis, CA 95616
(530) 756-8584 (TEL)
(530) 756-8201 (FAX)

1280-039C

YOLO SUBSIDENCE NETWORK

1999 - 2002 SUBSIDENCE CONTOURS
YOLO COUNTY, CALIFORNIA
FEBRUARY, 2003 SCALE: 1"= 10KM



NOTES:

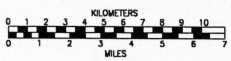
1. CONTOURS ARE BASED UPON ORTHOMETRIC HEIGHTS DETERMINED FROM GPS MEASUREMENTS TAKEN IN JULY-AUGUST 1999 AND IN JULY-AUGUST 2002. VALUES ARE EXPRESSED IN METERS.

2. MEASUREMENT ACCURACY IS ESTIMATED TO BE WITHIN ±2CM AT THE 95% CONFIDENCE LEVEL FOR EACH SURVEY.

3. THE COMBINATION OF MEASUREMENT ERROR AND THE AVAILABILITY OF ONLY TWO DATA POINTS AT EACH STATION MAY RESULT IN UNRELIABLE SUBSIDENCE RATE CALCULATIONS.

4. CONTOUR LOCATIONS ARE APPROXIMATE DUE TO THE SPARSE DISTRIBUTION OF THE DATA POINTS.

5. STATIONS IN THE SOUTHEASTERN PORTION OF THE COUNTY WERE NOT OBSERVED IN 1999. SUBSIDENCE INFORMATION FOR THESE STATIONS IS BASED UPON 1997 OBSERVATIONS.



LICENSE EXPIRES
SEPTEMBER 30, 2004

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