APPENDIX M

DEVELOPMENT OF THE TOPOGRAPHY DATA FOR THE SFWMM V5.5

MEMORANDUM

TO: Ken Tarboton, Supervising Engineer, HSM

FROM: Matthew Hinton, Senior Geographer, TRT

DATE: November 21, 2001

SUBJECT: Topo2000 Elevation Update (SFWMM2000)

The combined TRT/HSM topography evaluation team has completed the review of new elevation datasets to update the South Florida Water Management Model (SFWMM). In conjunction with this memo, you are receiving an electronic document which contains complete details of the process of arriving at the new elevation values. Also, a new statdta file for elevation (AEL) is included. A total of 671 cells received new values.

Of the 671 new values, 570 of the 671 (35 percent) were within .5 feet of SFWMMV3.7 value, and 653 of the 671 (97 percent) were within 1 foot of SFWMMV3.7 value. The largest difference was -1.64 feet.

This dataset will be referred to as the NOVEMBER2001 values.

cc: J Obeysekera

K Saari

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C Neidrauer

D Vogler, USACE

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INTRODUCTION

The combined Technology Resource Team (TRT) and Hydrologic Systems Modeling (HSM) topography evaluation team has completed the review of new elevation datasets to update the South Florida Water Management Model (SFWMM). In conjunction with this memo, you are receiving a new statdta file containing updated elevation values for the SFWMM (**Figure 1**). The purpose of this memo is to document the process used to create this new information. A total of 671 cells in the SFWMM received new elevation values (**Figure 2**).

After considering existing documentation, spatial location, and quality of several new topography datasets identified by the RECOVER (Restoration, Coordination, and Verification) Model Refinement Team, five datasets were selected for incorporation into this update (**Figure 3**). Additionally, it was decided to uniformly lower the elevation of the Everglades Agricultural Area (EAA) based on a uniform subsidence rate. The EAA has several factors which cause rapid subsidence, most importantly aerobic microbiological decomposition (oxidation). Measured rates of subsidence (Shih et al., 1997) were used to determine a rate of subsidence in the EAA for the last decade. The Holeyland and Rotenberger Water Management areas were excluded from this subsidence adjustment.

The new datasets are:

1. *High-Accuracy Elevation Data collection from the United States Geological Survey (USGS) retrieved from their website at http://sofia.usgs.gov/exchange/desmond/desmondelev.html in October 2001.* This data consists of elevation values on a regular grid of 400 meters, throughout the Everglades National Park (ENP) and portions of southern Miami-Dade County. The western limits of the ENP have not been collected/finalized. The data was collected in the North American Datum 1983 (1990) NAD83(90) horizontal datum and the North American Vertical Datum 1988 (NAVD88) vertical datum. The stated vertical accuracy is 0.5 feet.
2. *LIDAR (Light Detection and Ranging) elevation data collected for Water Conservation Area (WCA) 3A, north of Interstate 75 (I-75).* This data was contracted by the USGS to EarthData International, Inc., and acquired for SFWMD by Ken Rutchey. The data collection was flown in May 1999. At that time, the area was experiencing a drought, so the water table was very low. In addition, the area had caught fire and burned, so the bare surface was highly exposed. This created very good conditions for LIDAR collection in South Florida. The raw data was resampled to 5-meter pixels and was then processed by the contractor, using proprietary algorithms, to represent bare-surface elevation. The stated vertical accuracy is 15 centimeters.
3. *The Rotenberger Wildlife Management Area Survey, 1999.* This survey was conducted by Lindahl, Browning, Ferrari, and Hell-

strom, Inc. Using Global Positioning Survey (GPS) technology and airboats, six east-west cross-sections were traversed, with elevations collected at approximately .25 mile spacing. The reported vertical accuracy of this data is .2 feet.

4. *The Stormwater Treatment Areas (STAs) 1990s.* These elevations were compiled by the Everglades Construction Project (ECP) and are based upon the best available data. The only data available are mean elevations for the STA cells.

5. *The 8.5 Square-Mile Area Survey, 1986.* This area was surveyed by Aero-metric Corporation under contract to the United States Army Corps of Engineers (USACE), from January to April 1986. Elevations were collected on a 300-foot grid using conventional methods. The purpose of the survey was to produce cross-sections for hydrologic modeling. The vertical accuracy is reported to be .1 meter, or ~ 4 inches.

Other sources of data that were not used fell into two categories: not within the model domain, or not appropriate to natural surface elevation modeling. The first category is clear, examples of the second category are as follows:

- *The LIDAR data collected by the USACE along and to the east of the levee separating the urban area of South Florida from the Everglades.* This data covered a relatively small area in comparison to the voluminous amount of data it contained. Also, it was not collected with regional-scale hydrology in mind, which seeks to represent the elevation of the natural terrain as opposed to man-made features such as roads and levees. Consequently, this data was not incorporated into the current elevation update.
- *The Truck Survey and the Airboat Survey conducted as part of the USGS High-Accuracy Elevation Data Collection.* These surveys were conducted differently from the more comprehensive Helicopter Survey (which represents the bulk of the collection). The documentation on these sets is sparse, and they were conducted in the urban portion of Miami-Dade County. An analysis of the data shows that the Truck Survey in particular did not target natural ground elevation specifically. For these reasons, the datasets were excluded.

PROCESSING STEPS BY TRT

The High-Accuracy Elevation Data (2001) collection was created using GPS technology in conjunction with numerous vehicles, including helicopter, truck, and airboat platforms. The portions of this dataset east of the levee were excluded. The eastern area was collected primarily by airboat and truck platform, while the helicopter technique was used almost exclusively west of the levee (**Figure 4**). After examining the data, we decided that the data east of the levee was inconsistent with other data sources and would not be used. The data west of the levee was determined to be of good quality because it was consistent with existing knowledge and used a logical and defensible collection technique, albeit new, and unusual.

The processing of this dataset involved the following:

- Projecting the horizontal data from Universal Transverse Mercator (UTM) to Geographic (Lat-Long) using the Arc/Info 'project' command (VERTCON 2.0 requires Lat-Long coordinates).
- Converting the vertical datum from NAVD88 to National Geodetic Vertical Datum 1929 (NGVD29) using the VERTCON 2.0 program provided by the National Geodetic Survey (NGS) (**Appendix C**).
- Projecting to Florida State-Plane East feet using Arc/Info
- Masking out the roads and canals using the SFWMD major canals coverage buffered 50 feet, and the ETAK major roads (1994) buffered by 50 feet. The ETAK roads were chosen because of the higher locational accuracy of the linework. The SFWMD has newer road coverages which I consider better in attribution.
- Aggregating the remaining data to the SFWMM cells by averaging the points that fell within each cell. The process produced an average of 61 points per cell, ranging from 9 to 98 points with a standard deviation of 9. The SFWMM cells containing relatively few points were located on the fringe of the model and were excluded from the final values provided.
- Calculating and removing outlier data points per SFWMM cell based on a value being ~2 standard deviations from the mean value for the cell. These values are man-made features or localized features not representative of natural ground elevation.
- Updating 356 cells in the SFWMM (**Figure 5**).

The WCA-3A LIDAR Data (1999) was masked to exclude areas outside of the natural internal portion of WCA-3 north of I-75. An analysis of the data showed some abnormal variance in the data moving north-south, but the HSM team determined that for regional-scale modeling, this variance would be aggregated out of the data. In the majority of SFWMM cells, over 400,000 points of LIDAR elevation data were aggregated to one value (**Figure 6**).

The processing of this dataset involved the following:

- Masking out the roads and canals using the SFWMD major canals coverage buffered 50 feet, and the ETAK major roads buffered by 100 feet, except for I-75 which was buffered 150 feet. The final mask eliminated all data outside of the internal buffer distance, although some data points had been collected outside of the conservation area.

- Aggregating the data to 100-meter pixels from the original 5-meter pixels that were received.
- Projecting the data from UTM to Geographic (Lat-Long) projection.
- Converting the vertical datum from NAVD88 to NGVD29 using the VERTCON 2.0 program released by the National Geodetic Survey (**Appendix C**).
- Projecting the horizontal data from Geographic to Florida State-Plane East feet using the Arc/Info 'project' command.
- Converting the elevation from meters to feet (meters * 3.2808).
- Aggregating the remaining data per SFWMM cell by averaging the values that fell within each cell. The process produced an average of 730 points per cell, ranging from 23 to 1,055 points with a standard deviation of 371. Some SFWMM cells along the fringe of the dataset were excluded from the final values provided.
- Calculating and removing outlier data points per SFWMM cell based on a value being ~2 standard deviations from the mean value for the cell. These values are man-made features or localized features not representative of natural ground elevation. For the WCA-3A LIDAR, a manual approach was taken to retain "patches" of outlier points that could represent a large-scale natural feature. Only points which were randomly spaced were removed.
- Updating 68 cells in the SFWMM (**Figure 7**).

The EAA was determined to be subsiding at a long-term average rate of between 1 and 1.2 inches per year (Ingebritsen et al., 1999). These rates of subsidence have been corroborated by Stephens and Johnson (1951), Shih et al. (1979), and Stephens et al. (1984). In the previous revision of elevation data for the SFWMM, a rate of .1 foot per year was applied to the 1960 USACE 1-foot contour map data for 28 years (1960-1988) to achieve what became the 1990 updated SFWMM topography (Gove, 1993). According to Shih et al. (1997) subsidence since 1978 has occurred at an average rate of .57 inches per year. Measured rates ranged from .31 to .77 inches per year. In spite of the limited area from which subsidence measurements were taken, and the lack of a clear pattern of subsidence, the average rate of .57 inches per year was applied to all EAA cells (123 SFWMM cells) for ten years (1990-2000) to arrive at a current elevation value (**Figure 8**). Note that the Holeyland and Rotenberger Wildlife Management areas were excluded from this update. Both of these areas are managed differently from the rest of the EAA and each other (Smith, 2001). Both areas were surveyed with conventional methods in 1992 by the Florida Game and Freshwater Fish Commission (FWC) and updated in the SFWMM.

For the Rotenberger Wildlife Management Area Survey (1999), Lehar Brion (HSM) updated the corresponding SFWMM cells based on the surveyed data and a weighting mechanism he manually devised (Brion, 2001). TRT applied the new values to the appropriate cells. Thirteen SFWMM cells were updated.

The STA elevations were drawn from design dots and/or construction plans. The current information available consists of mean elevations for the cells of each STA, provided by Tracey Piccone, ECP. TRT used the coverage sorbnd_1000 from /vol/pcovs83/publands/sorbnd, and STA levee coverages from \\DROUGHT\oprgis\gisdata83\stas\data, to create a coverage representing the STAs. The mean elevations were then applied to the appropriate STA cells. TRT created a weighted average elevation per SFWMM cell using the elevations from the STA cells and SFWMM V3.7 elevations for portions of SFWMM cells not covered by an STA. Seventeen cells in the SFWMM were updated.

For the 8.5 Square Mile Area Survey (1999), remaining elevations were averaged for one SFWMM cell, Rowco 1826. Elevation points collected along the L-31 Levee were manually removed. These values were approximately 6 feet higher than the rest of the data (55 of 1,371 data points removed).

Figure 9 displays the final proposed elevations for the SFWMM.

COMMENT ON VERTCON 2.0

The VERTCON 2.0 Vertical Datum Conversion (NGVD29/NAVD88) program was developed by the NGS for converting vertical datums, and is not recommended for use in South Florida. This is due to the lack of control points used in the NGVD29 datum. A test of the VERTCON program against measured elevation differences between the two datums for selected locations showed that VERTCON returned values generally within 1/10 of a foot from measured differences. The NGS is working on the creation of a new model for converting between these datums in South Florida, but is not expected to be completed until 2003 (**Appendix C**).

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Gove, C., December 22, 1993, SFWMD Memorandum to Cal Neidrauer, SFWMM Topography: Data Sources for the Everglades Agricultural Area (EAA) and Water Conservation Areas (WCAs).

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Shih, S.F., B. Glaz, and R.E. Barnes, Jr., 1997, *Subsidence Lines Revisited in the Everglades Agricultural Area, 1997*. University of Florida Bulletin (Tech) 902. Gainsville.

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Stephens, J. C., and Johnson L., 1951, Subsidence of Organic Soils in the Upper Everglades Region of Florida. In: *The Soil Science Society of Florida, Proceedings Volume XI*, p. 191-237.

FIGURES

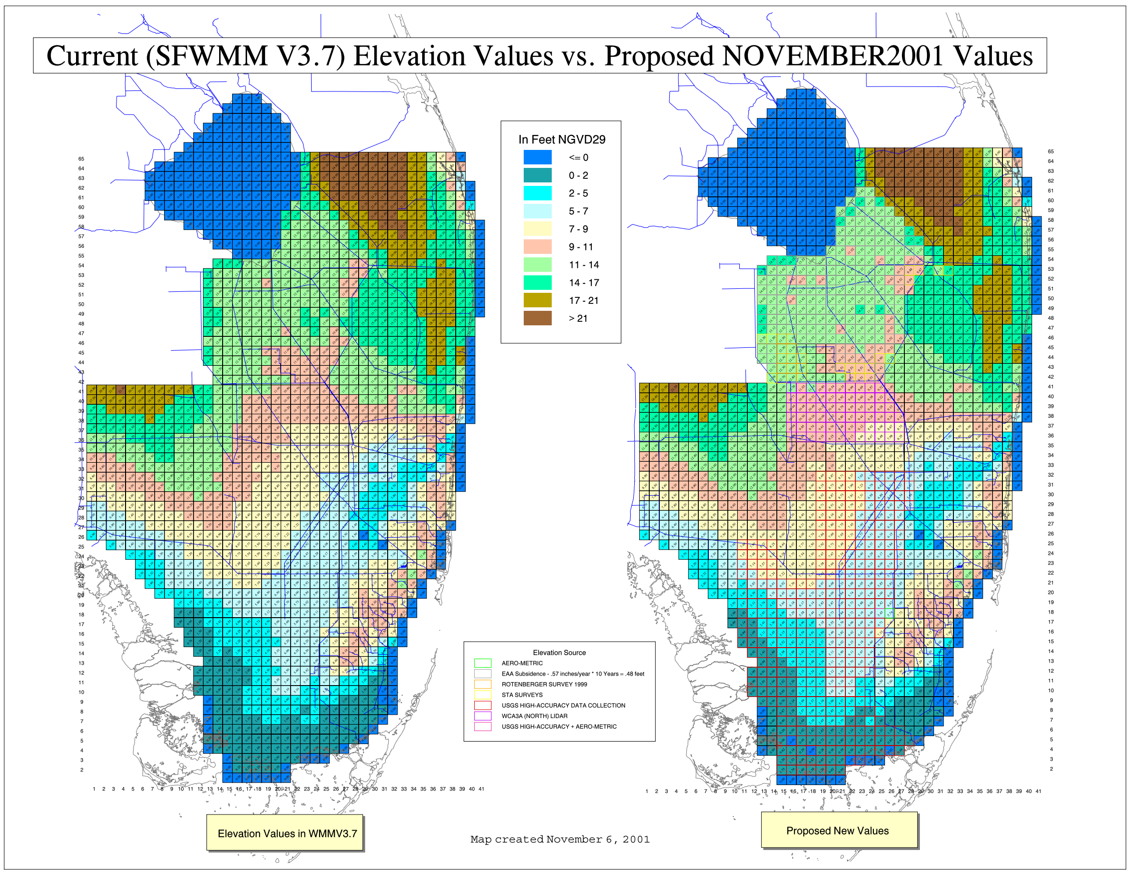

Figure 1. Current (SFWMM V3.7) Elevation Values and Proposed NOVEMBER2001 Values.

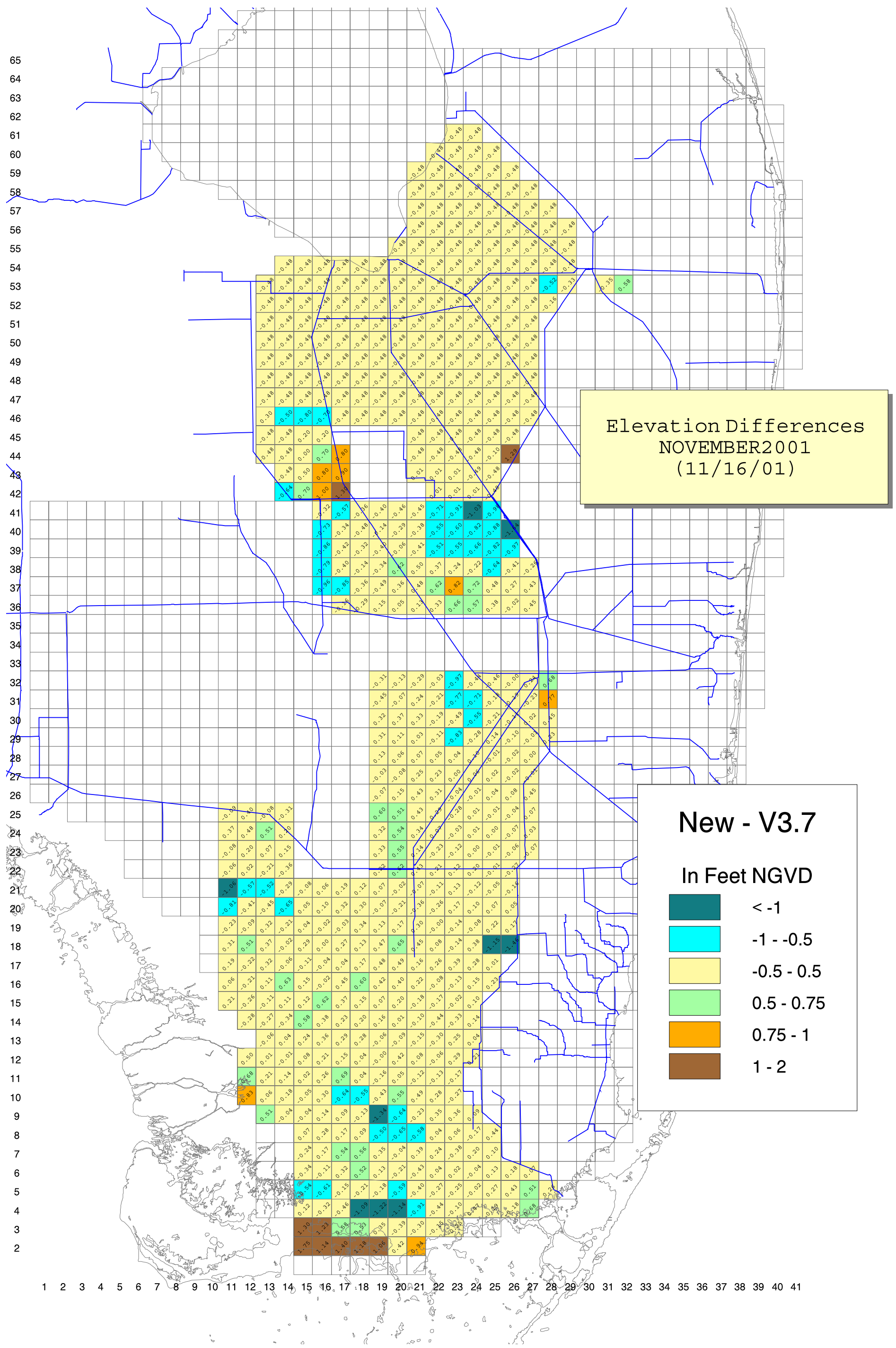

Figure 2. Draft Elevation Differences - NOVEMBER2001.

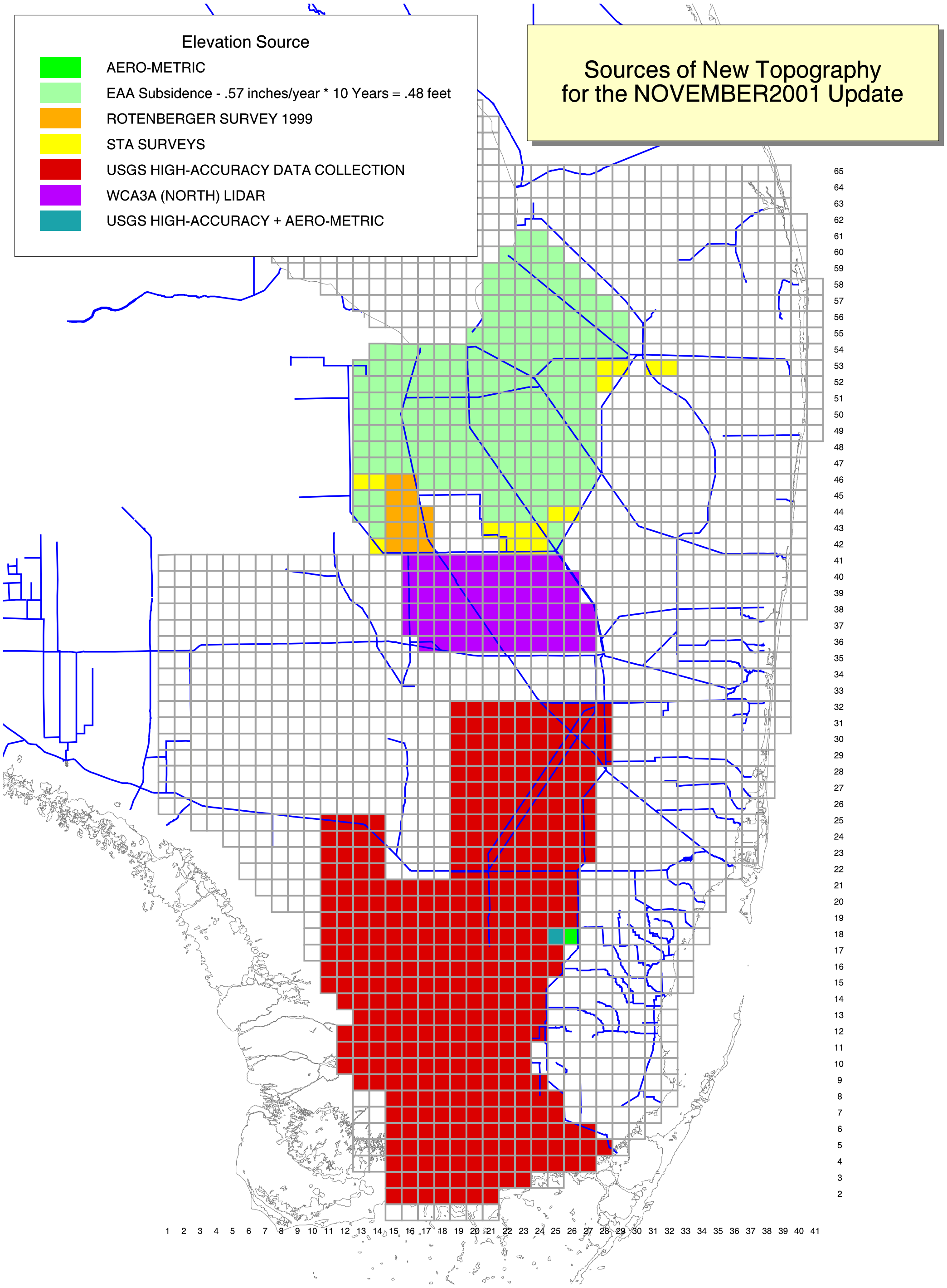

Figure 3. Sources of New Topography for the NOVEMBER2001 Update.

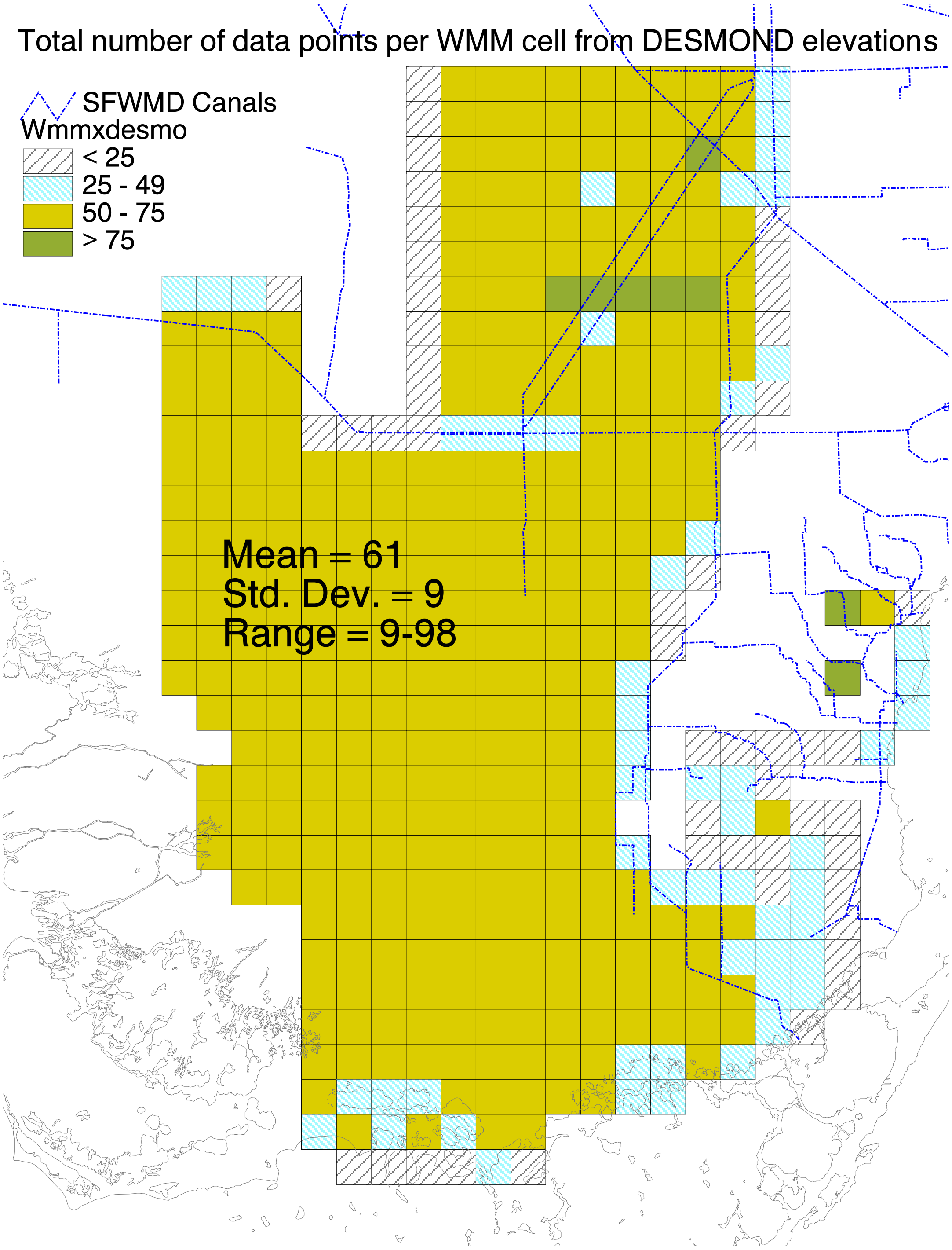

Figure 4. Total Number of Data Points per SFWMM Cell for the High-Accuracy Data Collection.

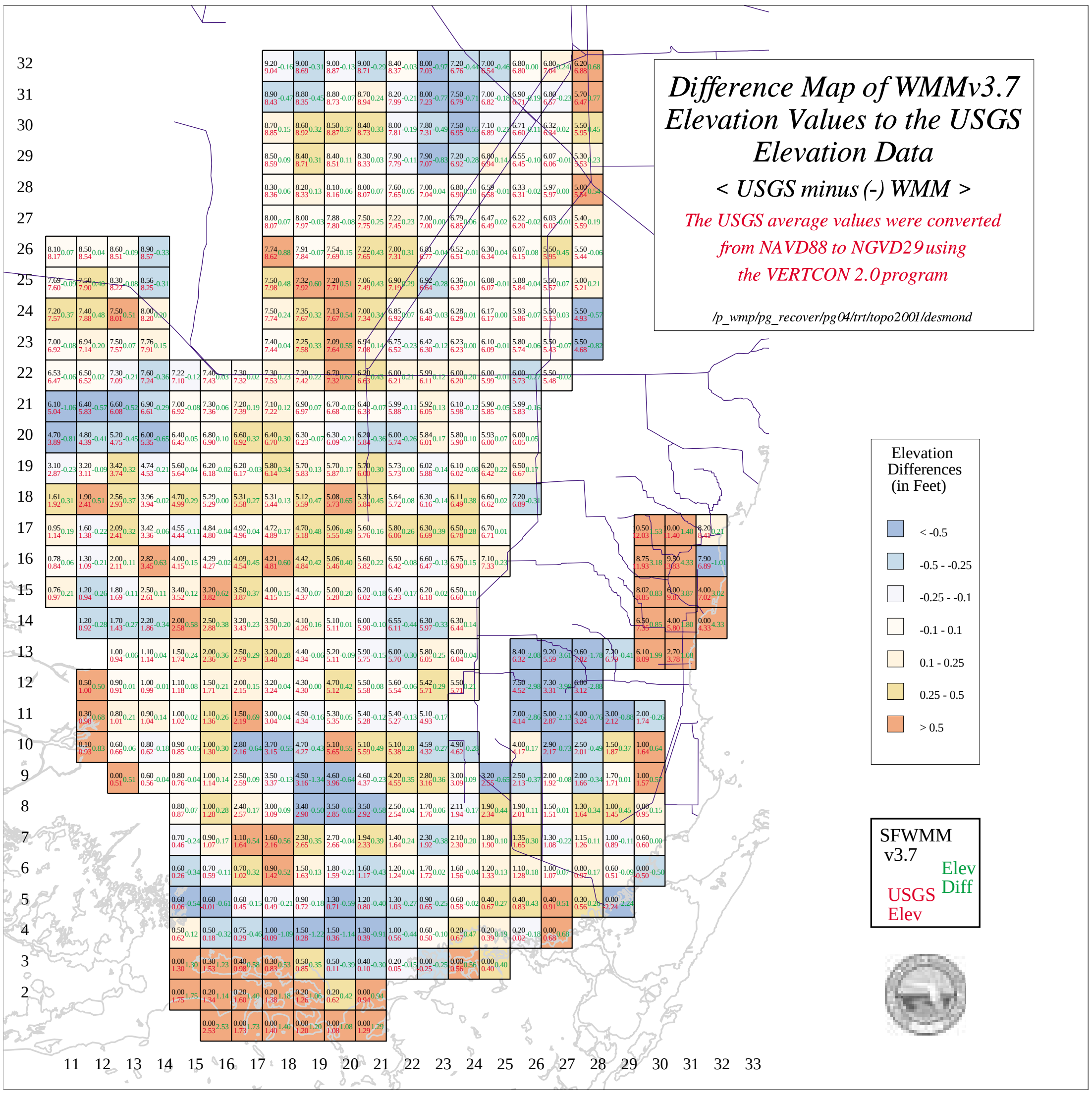

Figure 5. Difference Map of SFWMM V3.7 Elevation Values to the High-Accuracy Data Collection.

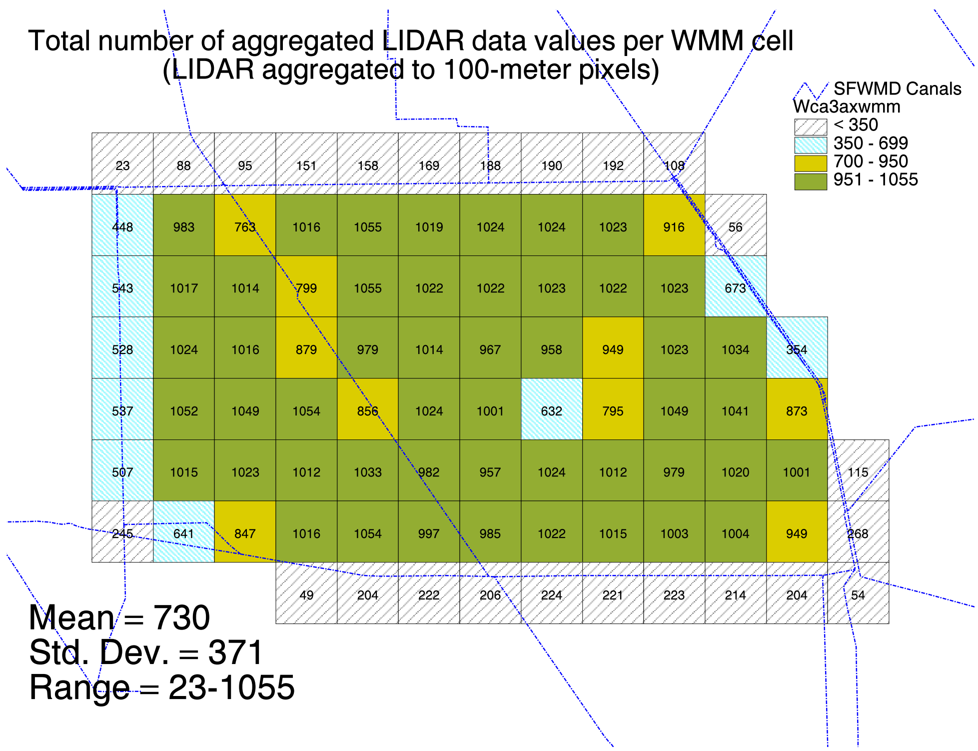

Figure 6. Total Number of Data Points per SFWMM Cell for the USGS LIDAR Data.

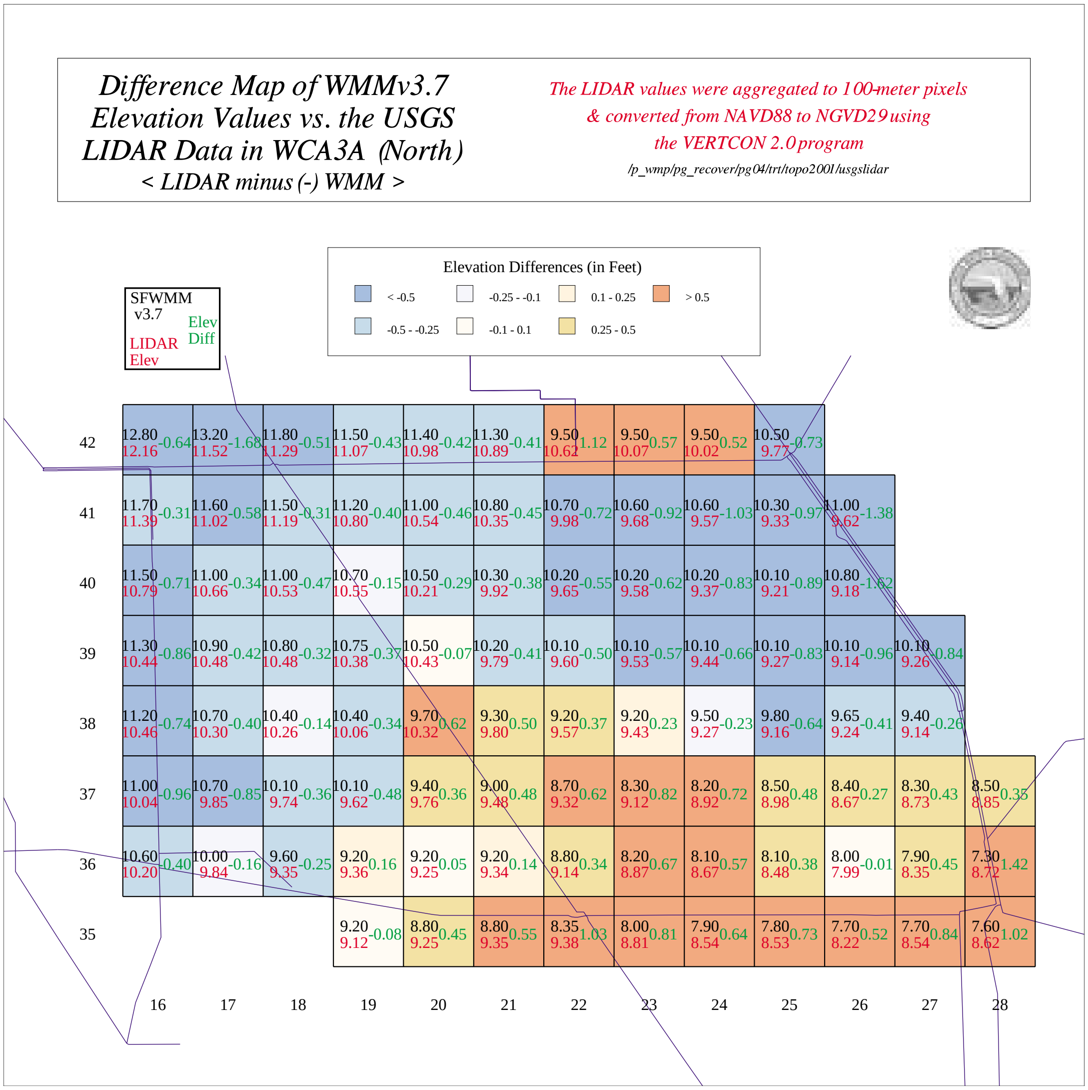

Figure 7. Difference Map of SFWMM V3.7 Elevation Values to the USGS LIDAR Data in WCA-3A (North).

Location of Transects,
from 'Subsidence Lines Revisited in the EAA, 1997'

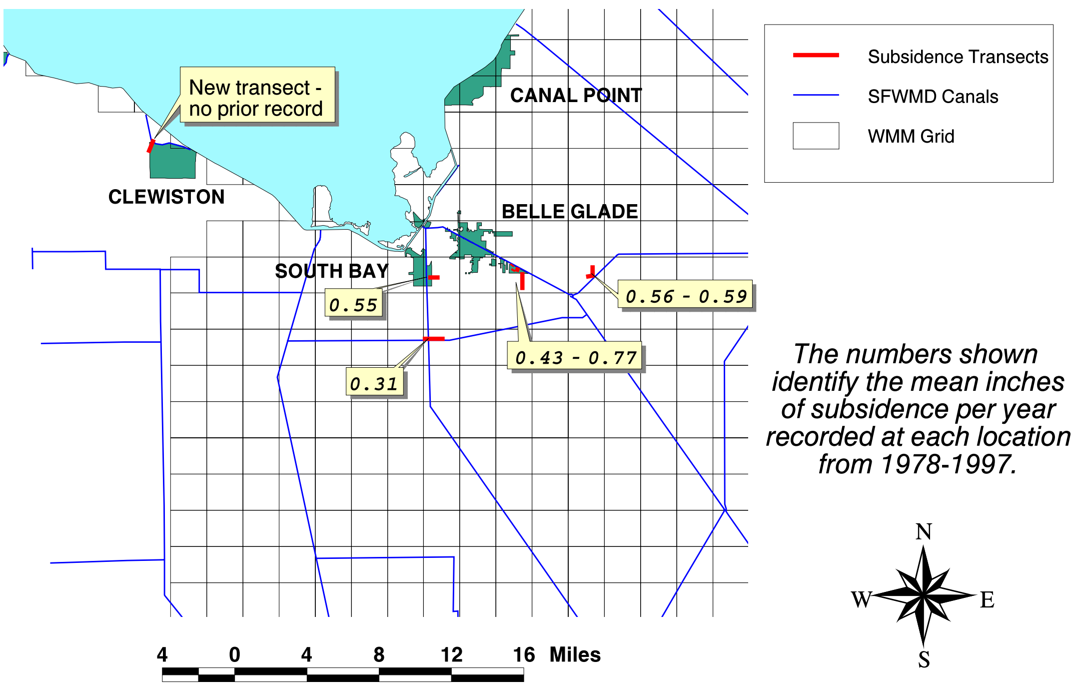

Figure 8. Location of Transects of Measured Subsidence in the EAA (Shih et. al., 1997).

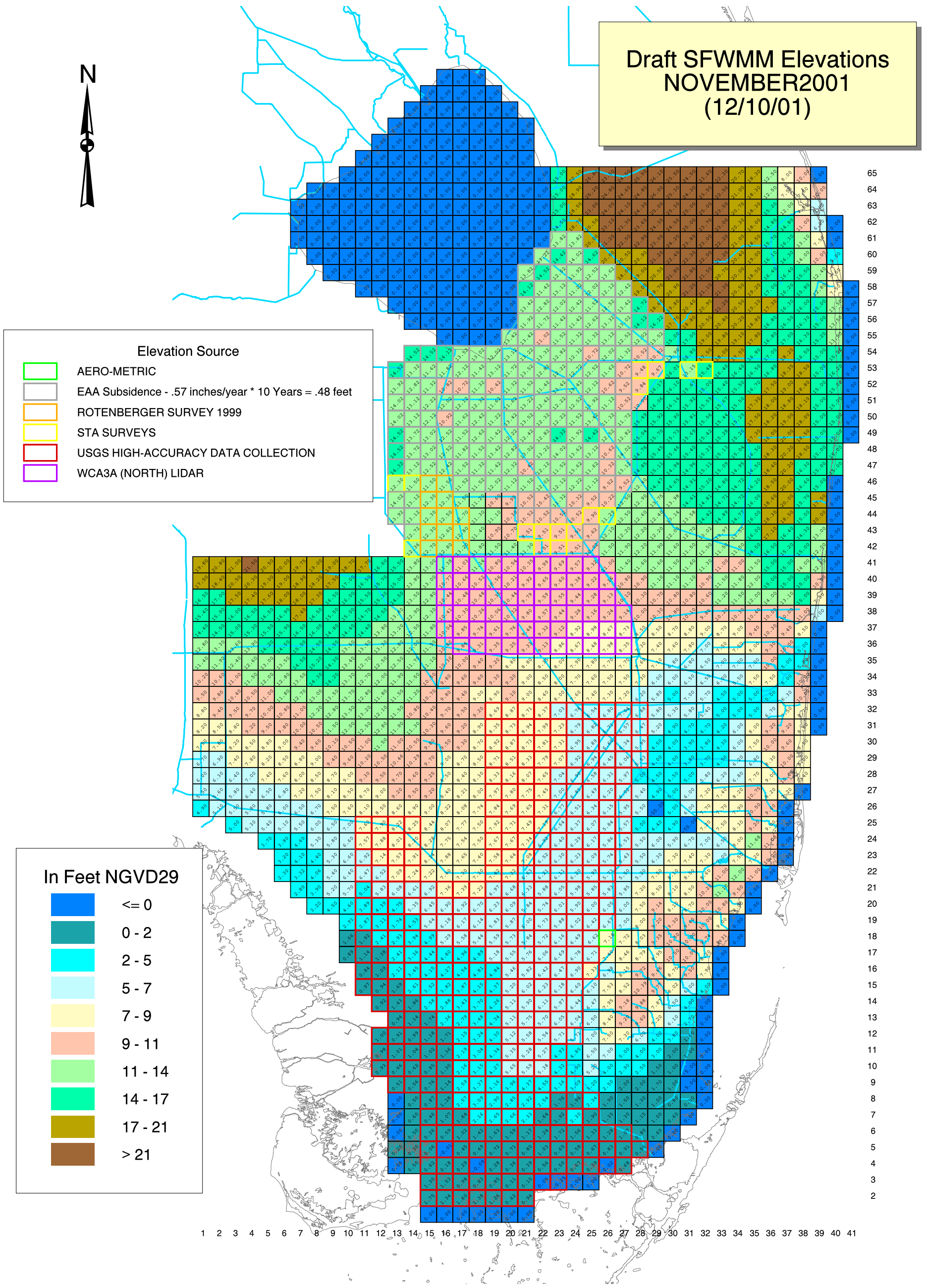

Figure 9. Draft SFWMM Values - NOVEMBER2001.

APPENDIX A - REFERENCES

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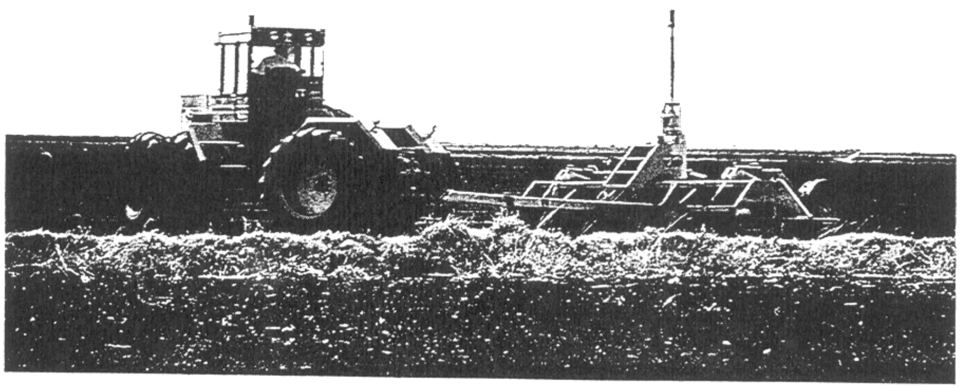
Subsidence Lines Revisited in the Everglades Agricultural Area, 1997

S. F. Shih, B. Glaz, and R. E. Barnes, Jr.



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Subsidence Lines Revisited in the Everglades Agricultural Area, 1997

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INTRODUCTION

Drainage projects in the Everglades beginning in the early 1900s along with water control projects that began in the 1950s have set the boundaries of the Everglades Agricultural Area (EAA) (Figure 1). With approximately 700,000 acres of organic soils, the EAA provides 22% of the total sugar produced in the United States (Lord and Suarez, 1997). This area also produces much of the nation's winter vegetables such as sweet corn, celery, radishes, and leaf crops, in addition to some rice and turf. In 1989, EAA agriculture accounted for more than $750 million and 20,000 full-time jobs (Snyder and Davidson, 1994).

The organic soils of the Everglades, once drained, subside due to several causes: loss of buoyancy, peat shrinkage, fires, wind erosion, and most importantly, aerobic microbiological decomposition (oxidation). The rate of subsidence has averaged historically about 1 inch per year. However, the rate of subsidence is related directly to the depth of the water table: the deeper the water table, the more rapid the rate of subsidence (Stephens and Johnson, 1951). To establish a well-known, one-location measurement of subsidence, a post was established in 1924 from the bedrock to ground level at what is now the Everglades Research and Education Center (EREC) of the University of Florida-Institute of Food and Agricultural Sciences (IFAS) at Belle Glade. In 1997, the post was exposed approximately 5.5 ft above ground level.

Evidence suggests that controlling subsidence and phosphorus discharge are complementary objectives. When subsidence was causing the loss of 1 inch of soil per year, Morris (1975) estimated that oxidation caused the release of 78 lb phosphorus per acre per year, or 400% of the average rate of fertilizer phosphorus applied to sugarcane in the EAA (Sanchez, 1990). As stated above, Stephens and Johnson (1951) reported that maintaining higher water tables would help control subsidence. Similarly, many of the best management practices developed in the EAA to reduce phosphorus discharge are based on storing water on the farms rather than pumping it out to public canals (Izuno and Capone, 1995). Also, plants that yield well and take up higher levels of phosphorus would help reduce EAA phosphorus discharge. Shih and Rosen (1985) and Shih (1989) found that celery, lettuce, and sweet corn all had higher levels of phosphorus uptake at higher water tables, further evidence that controlling both subsidence and phosphorus discharge are complementary objectives.

The purposes of this study were to: 1) survey the current depths of organic soils in the EAA, and 2) update documented survey transects and survey results of soil depth, and ground elevation.

SUBSIDENCE SURVEY LINE HISTORY

As described in Shih et. al. (1978), the first subsidence transect was established in 1913. In the 1930s, additional transects were added to make a total of fifteen. Eleven of these transects, located in five different sites, were re-surveyed about every five years until 1978. The general land uses at these transect lines were categorized as virgin vegetation, pasture, field crops, winter vegetables, and sugarcane. A brief description of each survey transect follows. All land uses described up to 1978 were from Stephens and Johnson (1951) and Shih et. al. (1979). The soils on these transects are classified as Everglades peats and Okeelanta peaty mucks as described by Stephens and Johnson (1951).

<u>**Transect #1:**</u> Transect #1 is located at the EREC of the University of Florida-IFAS at Belle Glade (Palm Beach County, Sections 3 and 10, Township 44 South, Range 37 East). It has four

subsidence lines which were established in 1938, 1934, 1932 and 1938 and identified as transects 1a, 1b, 1c, and 1d, respectively. All four transects were on Everglades peat. Soil scientists have further classified Everglades peat into Terra Ceia, Pahokee, Lauderhill, and Dania mucks. The only difference among these soils is depth to bedrock with Terra Ceia being the deepest, and with depth declining in order to Pahokee, Lauderhill, and finally to Dania, the most shallow (McCollum et. al., 1976). A new transect, still named 1a, was established in 1997 and started 150 ft southward from the end of the original line 1a. The land use of the newly established transect 1a is the same as the original transect 1a. About 14 years before transect 1a was established, the land to which it corresponds was planted to St. Augustine grass. It has remained as St. Augustine grass since then. The new transect was established because soil had been added to the original line 1a since 1978. The land on transect 1b was used to grow winter vegetables from 1934 to 1978 and primarily field crops and winter vegetables since 1978. The land on transect 1c had virgin growth (sawgrass and elders) until 1944, then field crops and winter vegetables until 1978, and primarily sugarcane and some winter vegetables since 1978. The land on transect 1d had virgin growth (primarily sawgrass and elders) until 1950 and field crops and winter vegetables from 1950 to 1959. In 1959, transect 1d was converted to pasture and remained so until 1978. Since 1978, the land on transect 1d has had primarily sugarcane and some winter vegetables.

Transect #2: Transect #2, established in 1913, is located north of the Bolles Canal at Okeelanta (Palm Beach County, Section 36, Township 44 South, Range 36 East). The soil on transect 2 is classified as an Everglades peaty muck. This land's use alternated between fallow and winter vegetable crops before 1942 when pumps were installed. From 1942 through 1953 it had sporadic plantings of winter vegetables, pasture from 1953 to 1965, and primarily sugarcane since 1965.

Transect #3: Transect #3, established in 1913, is located southeast of the city of South Bay near the one mile post on the North New River Canal (Palm Beach County, Section 13, Township 44 South, Range 36 East). The soil on transect 3 is classified as an Everglades peaty muck. It has been used to grow primarily sugarcane and some winter vegetables since 1927 when pumps were installed.

Transect #4: Transect #4, consisting of four segments, is located at Haney Wedgworth (Palm Beach County, Sections 5 and 8, Township 44 South, Range 38 East) and has been surveyed since 1938. The soil is classified as Everglades peat. This transect consists of four segments designated as 4a, 4b, 4c, and 4d. The land on transect 4a had virgin sawgrass before 1938, field crops and winter vegetables from 1938 to 1941, pasture from 1941 to 1962, field crops from 1962 to 1966, and primarily sugarcane since 1966. The land on transect 4b had sawgrass until 1937, winter vegetables from 1937 to 1950, pasture from 1950 to 1978, and primarily sugarcane since 1978. The land on transect 4c was used to grow field crops and winter vegetables from 1938 to 1941, pasture from 1941 to 1966, and primarily sugarcane since 1966. The land on transect 4d was used to grow winter vegetables from 1937 to 1965, field crops from 1965 to 1973, and primarily sugarcane since 1973.

Transect #5: Transect #5, established in 1935, is located at Liberty Point in Hendry County (Section 30, Township 42 south, Range 34 East). The soil is classified as Everglades peat. The land on transect 5 has been used primarily to grow sugarcane since 1935. A new transect 5 was established in 1997 near Clewiston in Hendry County (Section 8, Township 43 south, Range 34 east). Due to differences in elevation between the new and old transect 5 lines, estimates of rate of subsidence since 1978 did not include this transect.

SURVEY PROCEDURES

The investigation of soil subsidence lines was a cooperative project of the Center for Remote Sensing (CRS) at the Agricultural and Biological Engineering Department, IFAS, University of Florida; USDA-ARS Sugarcane Field Station at Canal Point, Florida; and the South Florida Water Management District (SFWMD) at West Palm Beach, Florida. Permanent benchmarks were established for these transects by the Survey and Mapping Division, Construction and Land Management Department, SFWMD. The benchmarks used in this survey are listed in Appendix 1. The locations of the soil transect lines are shown in Appendix 2. The surveying interval was 50 ft for all transects except for 1a and 1b which had intervals of 25 ft. The number of measurements and intervals of surveyed points are listed in Table 1. The horizontal positioning of the transects was established using the Global Positioning System and the marking with flags of surveyed points. The ground surface elevation along each transect was measured using conventional survey procedures. The depth of organic soil was measured at each flagged point by probing to bedrock with solid steel probes and rules. Bedrock elevation was calculated as the difference between ground elevation and depth of soil. Benchmark locations and surveyed points for each soil subsidence transect line are depicted in Appendix 3.

RESULTS AND CONCLUSIONS

The mean, maximum, and minimum value of ground surface and bedrock elevations are listed in Table 2. The standard deviations of bedrock elevations were considerably larger than the standard deviations of the ground elevations. This concurs with the general knowledge that bedrock elevations in the EAA are irregular which could cause increasing problems for water management systems as the organic soils subside. The depth of soil remaining in 1997 at each of the eleven subsidence transects is listed in Table 3. The average soil depth was 3.02 ft.

Table 4 shows the subsidence rate at each transect in 1978 (except transect 5) as reported by Shih et. al. (1979) and the subsidence rates since 1978 measured in this study. In 1978, the mean subsidence rate was 0.93 inches per year. Since 1978, the mean subsidence rate has dropped substantially to 0.56 inches per year. This lower rate of subsidence is probably due to several factors: 1) After Shih (1979a, b) and Shih et. al. (1981) promoted the land-forming program in 1977 as a method of maintaining higher water tables without crop damage thereby protecting more of the organic soil from losses by oxidation, the land forming with laser planes has been practiced extensively in the EAA. Thus, this reduction of subsidence rate could be due in part to having a better water management system after the land-forming program was implemented. 2) Water tables are higher on farms than previously experienced because: a) In addition to the land-forming program providing a better high water-table management system, sugarcane (Shih et. al., 1977; Gascho and Shih, 1979; Shih and Gascho, 1980; Shih, 1984, 1988a, 1988b), vegetables (Shih and Rahi, 1984, 1985; Shih and Rosen, 1985; Shih, 1985, 1987, 1989), field crops (Shih, 1986), and pasture (Shih and Snyder, 1985) could be grown with higher water tables than was the common farm practice in the Everglades. b) Farmers are holding more water on their farms as part of their best management practices to reduce phosphorus content of EAA drainage water. c) Recent changes in basin water management restrict the amount of water that can be pumped from farm canals to public canals. d) As soils subside, there is less room in the soil profile so with each succeeding year the same amount of water creates continually higher water tables. 3) Sugarcane has become the predominant land use in the EAA and oxidation of organic soils planted with sugarcane has been measured as 70-75% less than that measured with other EAA crops (Stephens and Johnson, 1951). Shih et. al. (1982) verified part of this reduction when they reported that subsidence under sugarcane compared to other crops would be expected to be about 16% less due to lower soil temperatures probably caused by the sugarcane cover. 4) Perhaps much of the remaining organic material does not oxidize as readily as that which already oxidized. 5) As oxidation continues, the percentage of mineral matter increases. However, this is probably not yet having a major impact on the rate of subsidence because many of the soils in the EAA still contain more than 85% organic matter.

Glaz (1995) suggested a research approach that aimed to sustain agriculture in the EAA by controlling subsidence. In that report, it was assumed that subsidence rates in the EAA were still at about 1 inch per year. Glaz (1995) predicted that farmer adoption of successful short-term research would lead to a reduced subsidence rate of about 0.33 inches per year. The already reduced subsidence rate of 0.57 inches per year, achieved without any benefit of the research proposed by Glaz (1995), suggests that further short-term reductions in the rate of subsidence, without economic losses, are feasible if a research program were to focus on this issue.

Figure 2 shows the box and whiskers plot for the soil transects. The box displays the lower and upper quartiles (the 25th and 75th percentiles) and the medium (50th percentile) of the soil remaining. Lines extended from the ends of the box were the 5th and the 95th percentiles. Transect line 3 at South Bay and transect 4 near Six-Mile-Bend had the deepest soils of the five surveyed locations.

The results of the surveying of bedrock and ground surface elevation along each transect line were plotted on Figure 3 through 13 for each transect. The discontinued parts of the bedrock and ground surface elevation of those 11 figures illustrated that the data were not available within the field (i.e., either crossing levee, road, or ditch). As these figures show, the bedrock elevations varied considerably more than the surface elevations. Soil depths, ground elevations, and bedrock elevations are listed in Appendix 4.

RECOMMENDATIONS FOR FUTURE STUDIES

The present survey results showed that the average subsidence rate in the past 19 years was 0.57 inch/yr (Table 2), which was much less than historical studies showed, namely, 1 inch/yr as reported previously by Stephens and Johnson (1951) and 0.93 inch/yr as reported by Shih et. al. (1978). The lower subsidence rate means that farmers have saved 8 inches of soil in the past 19 years. The causes of this lower subsidence rate should be investigated further. In the meantime, the historical subsidence rate and land use for each subsidence line should be revisited to further our understanding of subsidence.

There was a 40-mile-long transect across the EAA designated as A-A line in Figure 1. This A-A line was established in 1912 and re-surveyed in 1940. This line is very important for monitoring the subsidence rate of the EAA. Unfortunately, this line has not been surveyed since 1940. Stephens and Johnson (1951) used mainly the A-A line subsidence rate between 1912 and 1940 (i.e., 1 inch/year) to predict the thickness of EAA organic soils that would remain in the year 2000.

Further monitoring of subsidence should

have three areas of emphasis. All information on historical subsidence rates, water management schemes, land leveling, and land uses from the eleven subsidence lines should be reviewed. Secondly, the A-A transect line which runs across the EAA should be surveyed. Finally, a program should be developed that plans to perform monitoring of all subsidence lines at least every 5 years.

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The authors wish to thank Messrs. E. Ebanks, F. Gustafson, J. Burke, and Ms. C. Chennell of the South Florida Water Management District; and Messrs. C. H. Tan, O. Lanni, J. Craig, C. H. Juan, and L. W. Chang of the University of Florida for their assistance in this study.

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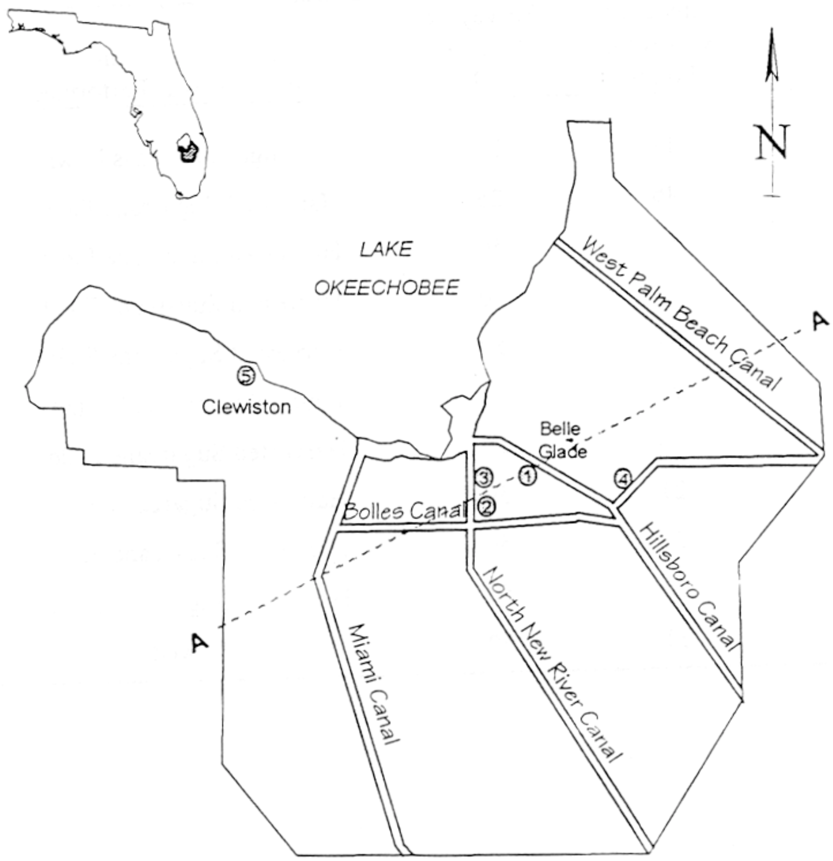


① Transects at Belle Glade Agr. Res. And Edu. Center (4 sections)

② Transect at 280 ft north of the Bolles Canal

③ Transect at North New River Canal and Highway 27

④ Transects at north of Highway 80 between Six and Nine Mile Bend (4 sections)

⑤ Newly established transect at north-east of Clewiston

Figure 1. Established soil subsidence transects in the Everglades Agricultural Area.

Table 1. Number of surveying points, surveying point interval, and land use when surveying was performed in 1997 for each subsidence transect.

Transect	Number of Surveying Points	Surveying Interval (ft)	Land Use When Surveying Was Performed
1a	11	25	St. Augustine Grass Lawn
1b	46	25	Harvested Sugarcane Field
1c	52	50	Harvested Sugarcane Field
1d	51	50	Harvested Sugarcane Field
2	68	50	Harvested Sugarcane Field
3	72	50	Young Sugarcane (2 ft tall)
4a	20	50	Harvested Sugarcane Field
4b	21	50	Harvested Sugarcane Field
4c	21	50	Harvested Sugarcane Field
4d	20	50	Harvested Sugarcane Field
5	31	50	Newly Plowed Field

Table 2. Mean, standard deviation, maximum, and minimum value of ground and bedrock elevation for each subsidence transect in the year 1997.

Transect	Ground Elevation				Bedrock Elevation			
	Mean	Std.	Max.	Min.	Mean	Std.	Max.	Min.
	ft.							
1a	10.44	0.20	10.90	10.20	8.34	0.30	8.68	7.74
1b	10.02	0.23	10.40	9.70	8.26	0.61	9.13	6.72
1c	10.12	0.33	10.80	9.60	7.91	0.53	8.72	6.62
1d	9.89	0.19	10.20	9.50	7.97	0.52	8.70	6.47
2	9.75	0.27	10.50	9.00	8.13	0.50	9.00	6.98
3	11.77	0.47	12.30	10.80	7.93	0.53	8.77	7.00
4a	10.18	0.13	10.50	9.90	5.94	0.26	6.37	5.53
4b	10.26	0.16	10.80	10.10	6.37	0.70	7.70	5.47
4c	10.09	0.12	10.30	9.90	5.84	0.38	6.30	4.90
4d	10.21	0.14	10.50	10.00	5.85	0.50	6.73	5.10
5†	15.92	0.14	16.20	15.60	14.11	0.78	15.28	12.53
Mean	10.79	0.22	11.22	10.39	7.87	0.51	8.67	6.82
Std.	1.70	0.10	1.67	1.70	2.22	0.15	2.33	1.99
C.V.	15.76	45.45	14.26	16.36	28.21	29.41	26.87	29.18

† A new observation transect was established in 1997.

Table 3. Organic soil remaining at the 11 transects surveyed in 1997.

Transect	1997 Organic Soil Remaining (ft)			
	Mean	Std.	Max.	Min.
1a	2.10	0.27	2.46	1.63
1b	1.73	0.54	3.17	1.00
1c	2.21	0.46	4.08	1.50
1d	1.92	0.57	3.33	1.08
2	1.62	0.41	2.50	0.42
3	3.84	0.76	5.00+†	2.42
4a	4.25	0.27	4.75	3.83
4b	3.89	0.69	4.83	2.50
4c	4.24	0.38	5.00+†	3.83
4d	4.36	0.53	5.00+†	3.54
5	1.81	0.75	3.17	0.75
Mean	2.91	0.51	3.94	2.05
Std.	1.12	0.17	0.98	1.20
C.V.	38.49	33.33	24.87	58.05

† Soil depth exceeded the probe limit.

Table 4. Subsidence rates and soil elevations in the Everglades Agricultural Area in 1978 and 1997.

Transect	Subsidence Rate 1973-1978† (in/year)	Soil Elevation in 1978 (in)	Soil Elevation in 1997 (in)	Subsidence Rate 1978-1997 (in/year)
1a	0.83	139.96	125.28	0.77
1b	0.97	128.43	120.24	0.43
1c	1.03	135.87	121.44	0.76
1d	1.20	130.47	118.68	0.62
2	1.04	122.87	117.00	0.31
3	0.61	151.69	141.24	0.55
4a	1.01	132.72	122.16	0.56
4b	0.75	134.37	123.12	0.59
4c	0.99	131.97	121.08	0.57
4d	0.84	133.54	122.52	0.58
Mean	0.93	134.19	123.28	0.57

† From Shih et al., 1978.

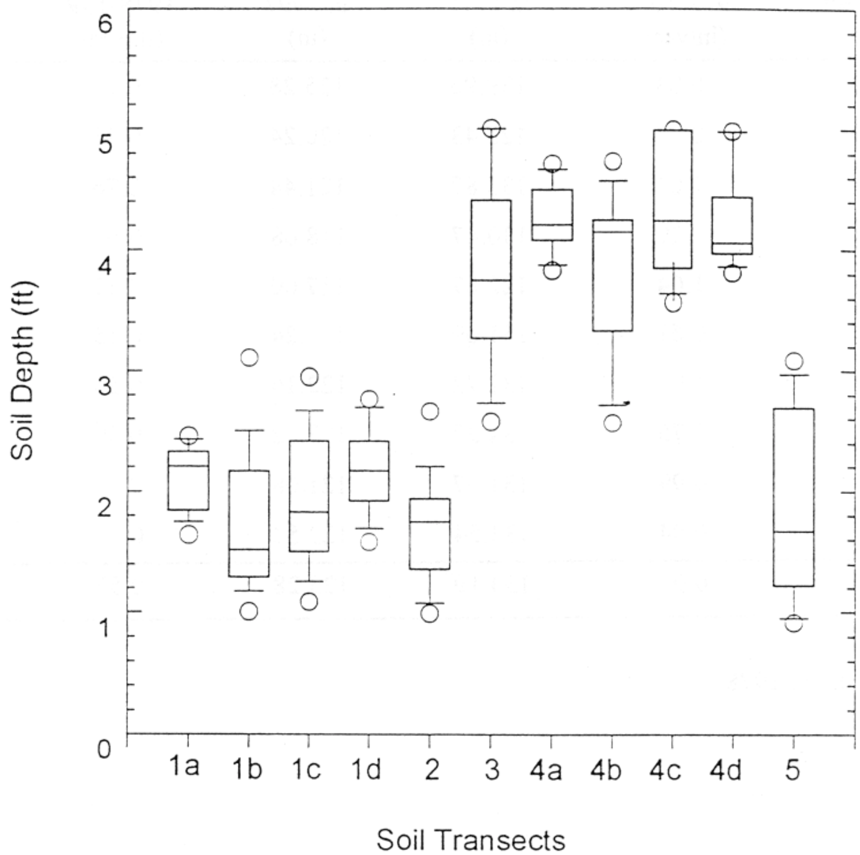


Figure 2. Box and whisker plot for the soil transects. The box displays the lower and upper quartiles (the 25th percentile and the 75th percentile) and the medium. Lines extended from the ends of the box are the 5th and the 95th percentiles. Outliers (circles) are the minimum and the maximum values for each soil transect.

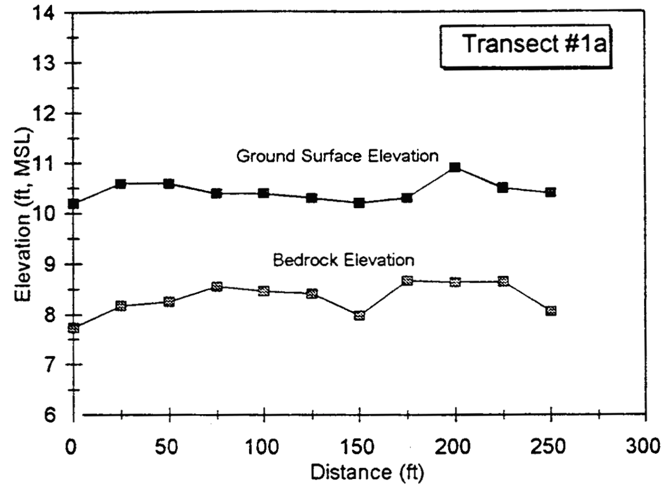


Figure 3. Ground-surface and bedrock elevations of transect #1a in 1997.

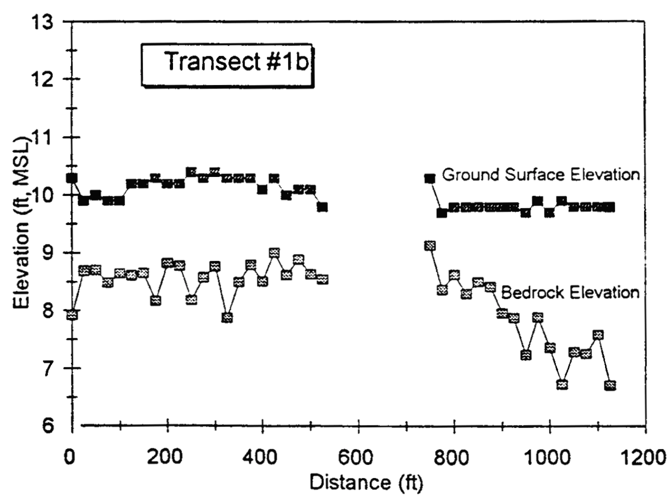


Figure 4. Ground-surface and bedrock elevations of transect #1b in 1997

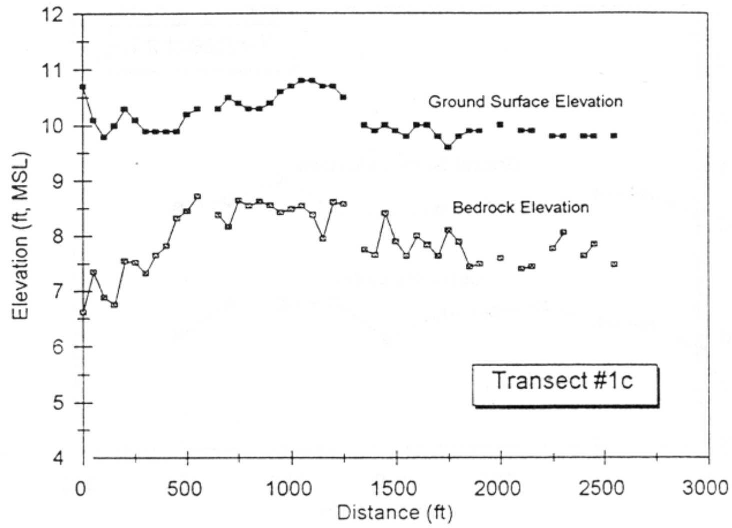


Figure 5. Ground-surface and bedrock elevations of transect #1c in 1997.

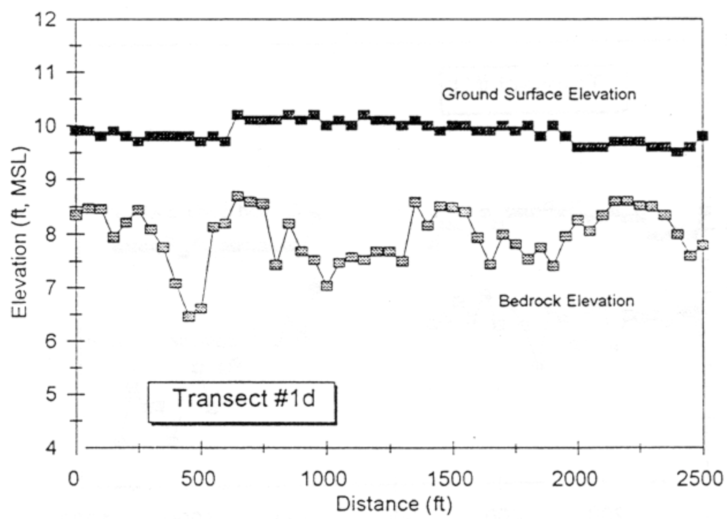


Figure 6. Ground-surface and bedrock elevations of transect #1d in 1997.

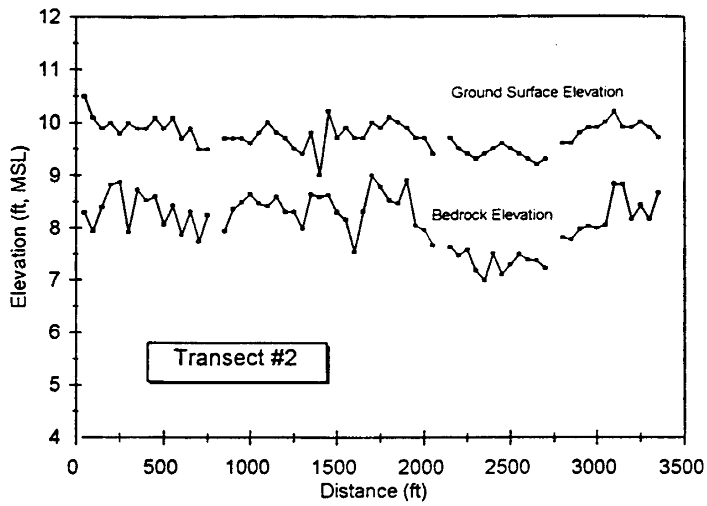


Figure 7. Ground-surface and bedrock elevations of transect #2 in 1997.

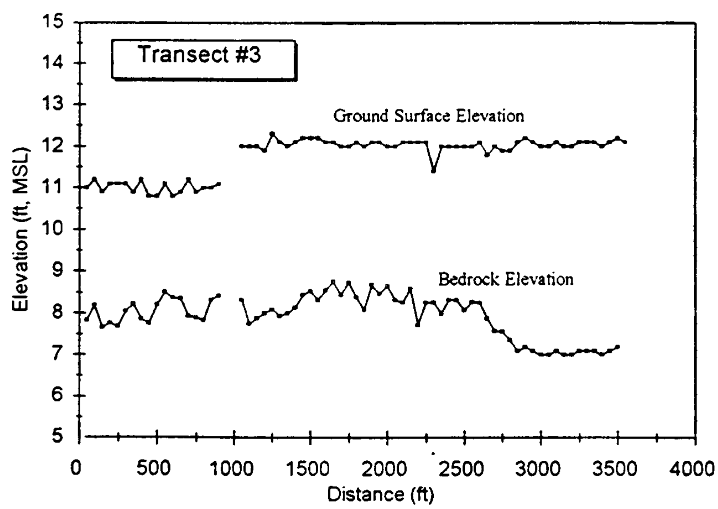


Figure 8. Ground-surface and bedrock elevations of transect #3 in 1997.

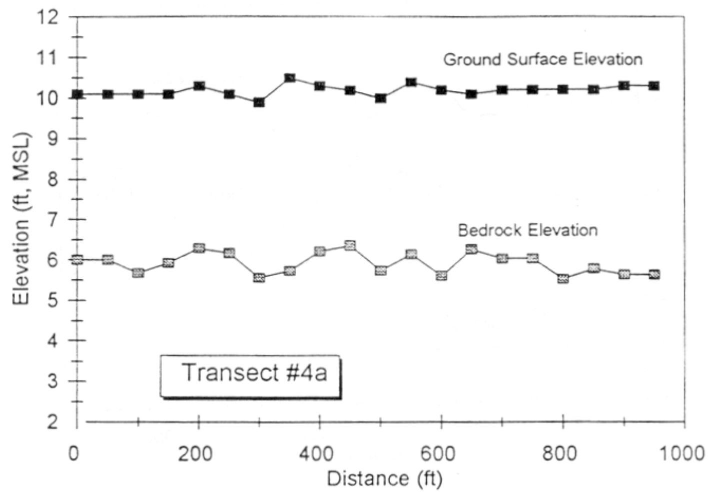


Figure 9. Ground-surface and bedrock elevations of transect #4a in 1997.

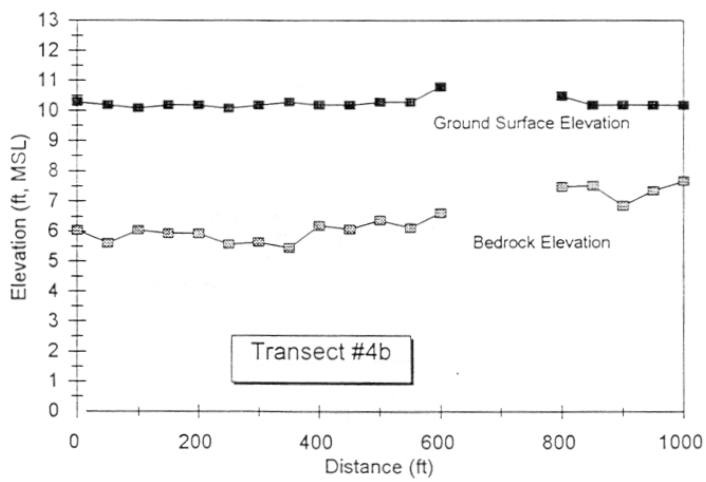


Figure 10. Ground-surface and bedrock elevations of transect #4b in 1997.

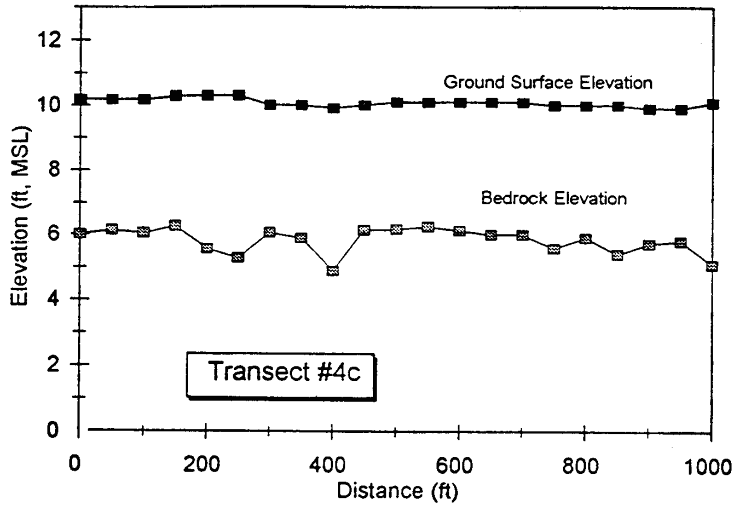


Figure 11. Ground-surface and bedrock elevations of transect #4c in 1997.

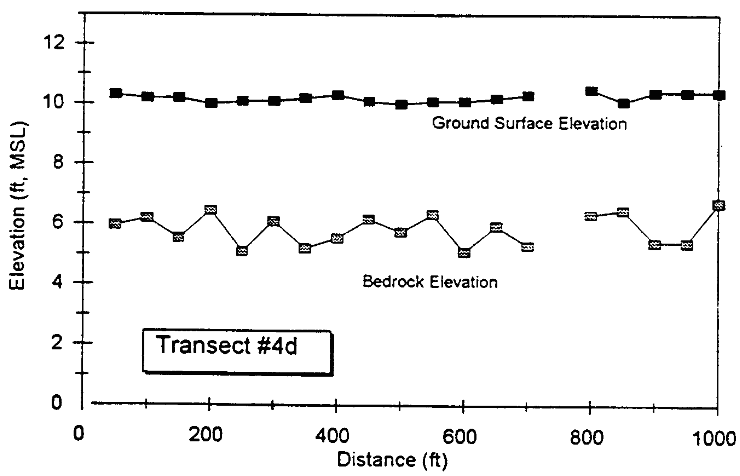


Figure 12. Ground-surface and bedrock elevations of transect #4d in 1997.

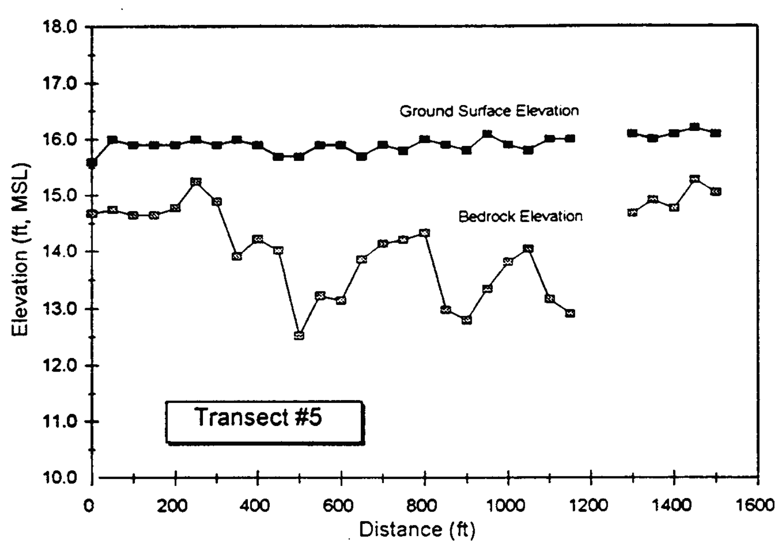


Figure 13. Ground-surface and bedrock elevations of transect #5 in 1997.

Appendix 1 The benchmarks used in the 1997 soil subsidence study.

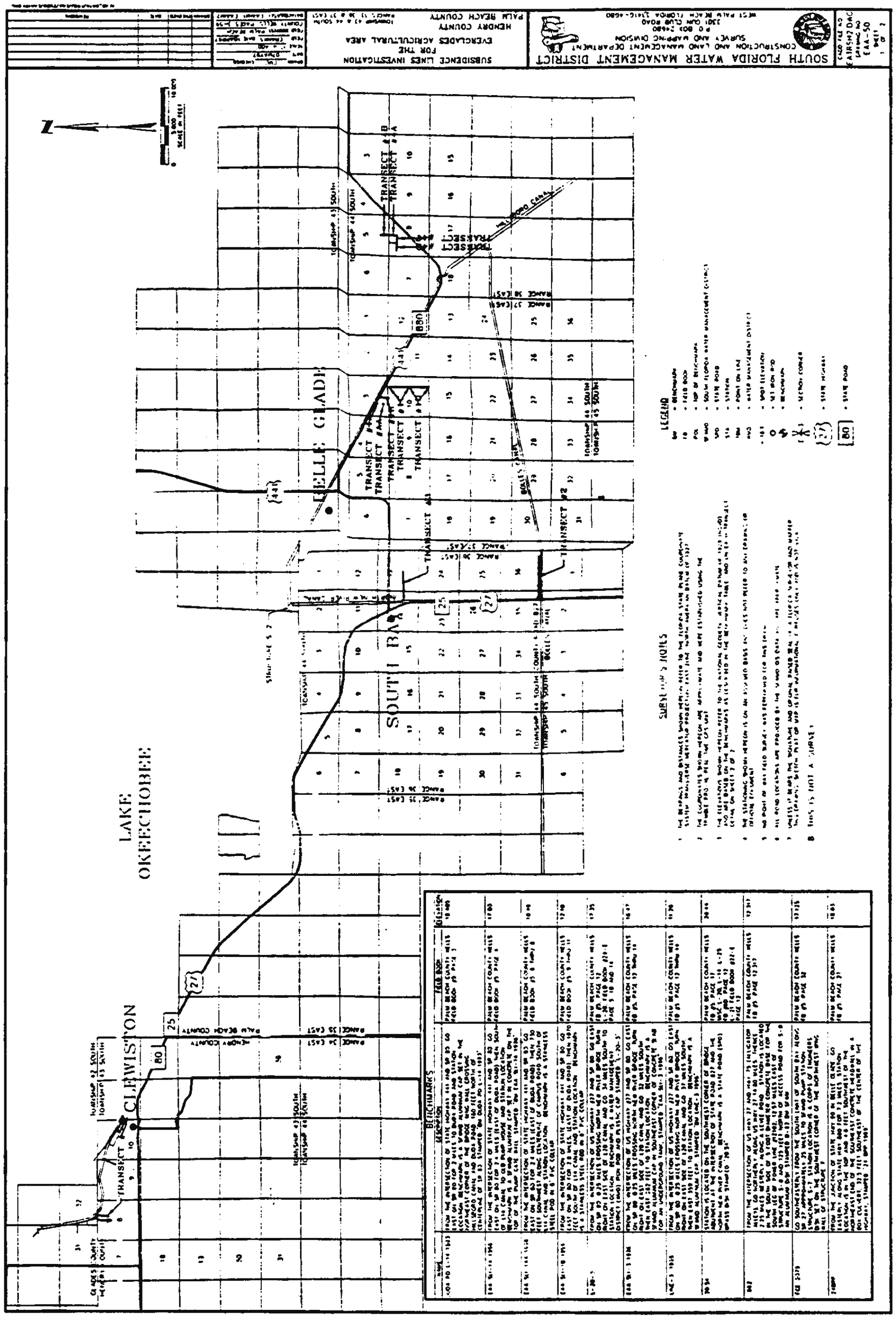
Name	Benchmarks Description	UTM Northing	UTM Easting	Elevation (ft)
DUDA RD L-14 1993	From the intersection of US HWY 441 and SR 880, go east on SR 880 for 2 miles to Duda RD and station location. Benchmark is a SFWMD aluminum cap set in the northeast corner of the bridge wing wall crossing Hillsboro Canal and Duda road, 160 ft north of centerline of SR 880, stamped "BM DUDA RD L-14 1993"			18.405
EAA SLI-1A 1996	From the intersection of US HWY 441 and SR 880, go east on SR 880 for approximately 2.4 miles to the University of Florida EREC old pump house and station location. Benchmark is a SFWMD aluminum cap set in concrete on the top of the pump gate wall, stamped "BM EAA SLI-1A 1996"	848463	619769	17.80
EAA SLI-AA 1996	From the intersection of US HWY 441 and SR 880, go east on SR 880 for approximately 2.4 miles to the University of Florida EREC old pump, then 730 feet southwest along centerline of campus road and station location. Benchmark is a stainless steel rod in 6" PVC collar.	847880	619797	10.46
LINE 1A 0+00	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-1A 0+00"	848682	619891	
LINE 1A 2+50	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-1A 2+50"	848463	619769	
LINE AA 0+00	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-AA 0+00"	847880	619797	
LINE AA 2+50	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-AA 2+50"	847660	619677	
EAA SLI-1B 1996	From the intersection of US HWY 441 and SR 880, go east on SR 880 for 2.8 miles, then 1070 feet south to station location. Benchmark is a stainless steel rod in 6" PVC collar.	847067	620589	12.10

Appendix 1 (continued). The benchmarks used in the 1997 soil subsidence study.

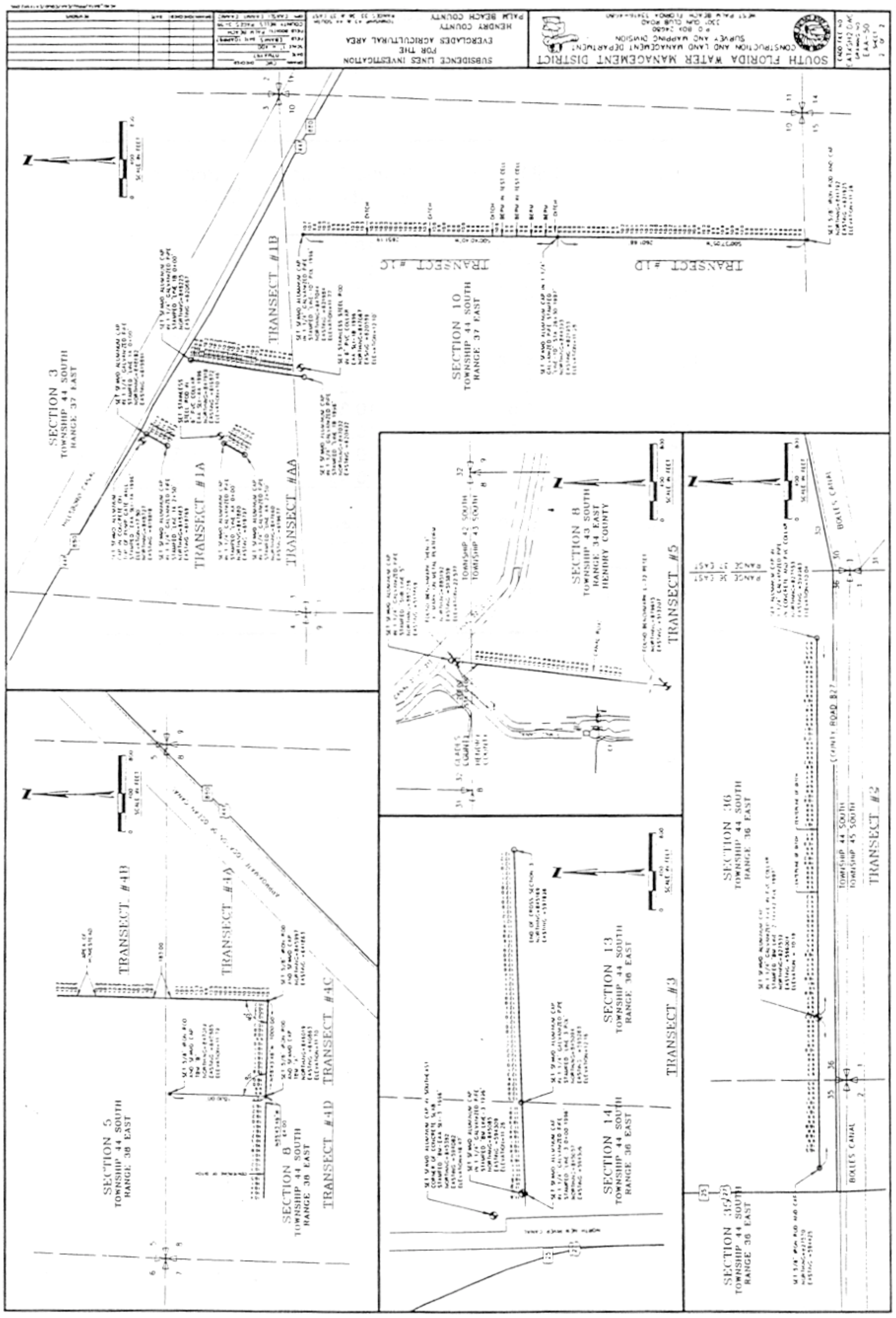
Name	Benchmarks Description	UTM Northing	UTM Easting	Elevation (ft)
LINE 1B 0+00	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE 1B 0+00"	848225	620667	
LINE 1B 1996	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE 1B 1996"	847032	620492	
LINE-1D POL 1996	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-1D POL 1996"	847044	621984	11.77
LINE-1D STA 26+30 1997	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-1D STA 26+30 1997"	844393	621953	11.28
	5/8" iron rod and cap	841792	621925	11.28
BM LINE-2 14+42 POL 1997	SFWMD aluminum cap in 1 1/4" galvanized pipe in PVC collar stamped "BM LINE-2 14+42 POL 1997"	827539	596004	10.19
	5/8" iron rod and cap	827530	594425	
	Stainless steel rod in 1 1/4" galvanized pipe in concrete and PVC collar	827553	599963	10.04
L-20-3	From the intersection of US HWY 27 and SR 80, go east on SR 80, 0.25 miles crossing north new river bridge, turn right on east side of L20 canal and go 0.34 miles south to station location. Benchmark is a SFWMD iron rod and plastic cap.			17.35
EAA SLI-3 1996	From the intersection of US HWY 27and SR 80, go east on SR 80, 0.25 miles crossing north new river bridge, turn right on east side of L20 canal and go 0.32 miles south, then east 262 feet to station location. Benchmark is a SFWMD aluminum cap in southeast corner of concrete slab for an underground tank, stamped "EAA SLI-3 1996".	845382	594082	16.47

Appendix 1 (continued). The benchmarks used in the 1997 soil subsidence study.

Name	Benchmarks Description	UTM Northing	UTM Easting	Elevation (ft)
LINE-3, 1996	From the intersection of US HWY 27 and SR 80, go east on SR 80, 0.25 miles crossing north new river bridge, turn right on east side of L20 canal and go 0.37 miles south, then east 358 feet to station location. Benchmark is a 1 1/4" iron pipe in concrete with a SFWMD aluminum cap, stamped "BM LINE-3 1996"	845085	594309	11.26
LINE-3 0+00 1996	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-3 0+00 1996"	845057	594036	
LINE 3 POL	SFWMD aluminum cap in 1 1/4" galvanized pipe stamped "LINE-3 POL"	845094	595263	12.16
	End of cross section 3	845169	597896	
SRD BRASS DISC	Station is located on the southeast corner of bridge abutment at the intersection of state road 827 and the north new river canal. Benchmark is a state road department (SRD) brass disk stamped "20.54"			20.44
TBM "B"	5/8" iron rod and SFWMD cap TBM "B"	847019	640885	11.79
TBM "A"	5/8" iron rod and SFWMD cap TBM "A"	846019	640863	11.70
	5/8" iron rod and SFWMD cap	845997	641863	
24BRP	From the junction of SR 80 and SR 880 in Belle Glade go easterly along SR 880 for 7.2 miles. Station location is in the top and 4.6 feet southwest of the northeast end of the southeast concrete headwall in a box culvert, 32.5 feet southeast of the center of the highway, stamped "24.5 BRP, 1969"			18.03



Appendix 2. Locations of the soil transect lines.



Appendix 3. Benchmark locations and surveyed points for each soil subsidence transect line.

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 1a).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	2.46	10.20	7.74
25	2.42	10.60	8.18
50	2.33	10.60	8.27
75	1.83	10.40	8.57
100	1.92	10.40	8.48
125	1.88	10.30	8.43
150	2.21	10.20	7.99
175	1.63	10.30	8.68
200	2.25	10.90	8.65
225	1.83	10.50	8.67
250	2.33	10.40	8.07
Mean	2.10	10.44	8.43
Standard Dev.	0.27	0.20	0.30
Maximum	2.46	10.90	8.68
Minimum	1.63	10.20	7.74

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 1b).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	2.38	10.30	7.93
25	1.21	9.90	8.69
50	1.29	10.00	8.71
75	1.42	9.90	8.48
100	1.25	9.90	8.65
125	1.58	10.20	8.62
150	1.54	10.20	8.66
175	2.13	10.30	8.18
200	1.38	10.20	8.83
225	1.42	10.20	8.78
250	2.21	10.40	8.19
275	1.71	10.30	8.59
300	1.63	10.40	8.78
325	2.42	10.30	7.88
350	1.79	10.30	8.51
375	1.50	10.30	8.80
400	1.58	10.10	8.52
425	1.29	10.30	9.01
450	1.38	10.00	8.63
475	1.21	10.10	8.89
500	1.46	10.10	8.64
525	1.25	9.80	8.55
600	—	—	—
625	—	—	—
650	—	—	—
700	1.00	—	—
725	1.29	—	—
750	1.17	10.30	9.13
775	1.33	9.70	8.37
800	1.17	9.80	8.63
825	1.50	9.80	8.30
850	1.29	9.80	8.51
875	1.38	9.80	8.43
900	1.83	9.80	7.97
925	1.92	9.80	7.88
950	2.46	9.70	7.24
975	2.00	9.90	7.90
1000	2.33	9.70	7.37
1025	3.17	9.90	6.73
1050	2.50	9.80	7.30
1075	2.54	9.80	7.26
1100	2.21	9.80	7.59
1125	3.08	9.80	6.72
Mean	1.73	10.02	8.26
Standard Dev.	0.54	0.23	0.61
Maximum	3.17	10.40	9.13
Minimum	1.00	9.70	6.72

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 1c).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	—	10.70	6.62
50	2.75	10.10	7.35
100	2.92	9.80	6.88
150	3.25	10.00	6.75
200	2.75	10.30	7.55
250	2.58	10.10	7.52
300	2.58	9.90	7.32
350	2.25	9.90	7.65
400	2.08	9.90	7.82
450	1.58	9.90	8.32
500	1.75	10.20	8.45
550	1.58	10.30	8.72
600	—	—	—
650	1.92	10.30	8.38
700	2.33	10.50	8.17
750	1.75	10.40	8.65
800	1.75	10.30	8.55
850	1.67	10.30	8.63
900	1.83	10.40	8.57
950	2.17	10.60	8.43
1000	2.21	10.70	8.49
1050	2.25	10.80	8.55
1100	2.42	10.80	8.38
1150	2.75	10.70	7.95
1200	2.08	10.70	8.62
1250	1.92	10.50	8.58
1300	—	—	—
1350	2.25	10.00	7.75
1400	2.25	9.90	7.65
1450	1.58	10.00	8.42
1500	2.00	9.90	7.90
1550	2.17	9.80	7.63
1600	2.00	10.00	8.00
1650	2.17	10.00	7.83
1700	2.17	9.80	7.63
1750	1.50	9.60	8.10
1800	1.92	9.80	7.88
1850	2.46	9.90	7.44
1900	2.42	9.90	7.48
1950	—	—	—
2000	2.42	10.00	7.58
2050	2.17	—	—
2100	2.50	9.90	7.40
2150	2.46	9.90	7.44

Appendix 4 (continued) Soil depth, ground elevation, and bedrock elevation data (transect line 1c).

2200	1.79	—	—
2250	2.04	9.80	7.76
2300	1.75	9.80	8.05
2350	2.00	—	—
2400	2.17	9.80	7.63
2450	1.96	9.80	7.84
2500	2.50	—	—
2550	2.33	9.80	7.47
Mean	2.17	10.12	7.91
Standard Dev.	0.38	0.33	0.53
Maximum	3.25	10.80	8.72
Minimum	1.50	9.60	6.62

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 1d).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation	Bedrock Elevation
0	1.54	9.90	8.36
50	1.42	9.90	8.48
100	1.33	9.80	8.47
150	1.96	9.90	7.94
200	1.58	9.80	8.22
250	1.25	9.70	8.45
300	1.71	9.80	8.09
350	2.04	9.80	7.76
400	2.71	9.80	7.09
450	3.33	9.80	6.47
500	3.08	9.70	6.62
550	1.67	9.80	8.13
600	1.50	9.70	8.20
650	1.50	10.20	8.70
700	1.50	10.10	8.60
750	1.54	10.10	8.56
800	2.67	10.10	7.43
850	2.00	10.20	8.20
900	2.42	10.10	7.68
950	2.67	10.20	7.53
1000	2.96	10.00	7.04
1050	2.63	10.10	7.48
1100	2.42	10.00	7.58
1150	2.67	10.20	7.53
1200	2.42	10.10	7.68
1250	2.42	10.10	7.68
1300	2.50	10.00	7.50
1350	1.50	10.10	8.60
1400	1.83	10.00	8.17
1450	1.38	9.90	8.53
1500	1.50	10.00	8.50
1550	1.58	10.00	8.42
1600	1.96	9.90	7.94
1650	2.46	9.90	7.44
1700	2.00	10.00	8.00
1750	2.08	9.90	7.82
1800	2.46	10.00	7.54
1850	2.04	9.80	7.76
1900	2.58	10.00	7.42
1950	1.83	9.80	7.97
2000	1.33	9.60	8.27
2050	1.54	9.60	8.06
2100	1.25	9.60	8.35
2150	1.08	9.70	8.62
2200	1.08	9.70	8.62

Appendix 4 (continued) Soil depth, ground elevation, and bedrock elevation data (transect line 1d).

2250	1.17	9.70	8.53
2300	1.08	9.60	8.52
2350	1.25	9.60	8.35
2400	1.50	9.50	8.00
2450	2.00	9.60	7.60
2500	2.00	9.80	7.80
Mean	1.92	9.89	7.97
Standard Dev.	0.57	0.19	0.52
Maximum	3.33	10.20	8.70
Minimum	1.08	9.50	6.47

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 2).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	—	—	—
50	2.21	10.50	8.29
100	2.17	10.10	7.93
150	1.50	9.90	8.40
200	1.17	10.00	8.83
250	0.92	9.80	8.88
300	2.08	10.00	7.92
350	1.17	9.90	8.73
400	1.38	9.90	8.53
450	1.50	10.10	8.60
500	1.83	9.90	8.07
550	1.67	10.10	8.43
600	1.83	9.70	7.87
650	1.58	9.90	8.32
700	1.75	9.50	7.75
750	1.25	9.50	8.25
800	—	—	—
850	1.75	9.70	7.95
900	1.33	9.70	8.37
950	1.21	9.70	8.49
1000	0.96	9.60	8.64
1050	1.33	9.80	8.47
1100	1.58	10.00	8.42
1150	1.21	9.80	8.59
1200	3.04	9.70	8.30
1250	3.50	9.50	8.30
1300	1.42	9.40	7.98
1350	1.17	9.80	8.63
1400	0.42	9.00	8.58
1450	1.58	10.20	8.62
1500	1.42	9.70	8.28
1550	1.75	9.90	8.15
1600	2.17	9.70	7.53
1650	3.04	9.70	8.30
1700	1.00	10.00	9.00
1750	1.13	9.90	8.78
1800	1.58	10.10	8.52
1850	1.54	10.00	8.46
1900	1.00	9.90	8.90
1950	1.67	9.70	8.03
2000	1.75	9.70	7.95
2050	1.75	9.40	7.65

Appendix 4 (continued) Soil depth, ground elevation, and bedrock elevation data (transect line 2).

2100	—	—	—
2150	2.08	9.70	7.62
2200	2.04	9.50	7.46
2250	1.83	9.40	7.57
2300	2.13	9.30	7.18
2350	2.42	9.40	6.98
2400	2.00	9.50	7.50
2450	2.50	9.60	7.10
2500	2.21	9.50	7.29
2550	1.92	9.40	7.48
2600	1.92	9.30	7.38
2650	1.83	9.20	7.37
2700	2.08	9.30	7.22
2750	—	—	—
2800	1.79	9.60	7.81
2850	1.83	9.60	7.77
2900	1.83	9.80	7.97
2950	1.88	9.90	8.03
3000	1.92	9.90	7.98
3050	1.96	10.00	8.04
3100	1.38	10.20	8.83
3150	1.08	9.90	8.82
3200	1.75	9.90	8.15
3250	1.58	10.00	8.42
3300	1.75	9.90	8.15
3350	1.04	9.70	8.66
Mean	1.70	9.75	8.13
Standard Dev.	0.52	0.27	0.50
Maximum	3.50	10.50	9.00
Minimum	0.42	9.00	6.98

Appendix 4 (continued) Soil depth, ground elevation, and bedrock elevation data (transect line 3).

2050	3.67	12.00	8.33
2100	3.83	12.10	8.27
2150	3.50	12.10	8.60
2200	4.38	12.10	7.73
2250	3.83	12.10	8.27
2300	3.13	11.40	8.28
2350	4.00	12.00	8.00
2400	3.67	12.00	8.33
2450	3.67	12.00	8.33
2500	3.92	12.00	8.08
2550	3.71	12.00	8.29
2600	3.83	12.10	8.27
2650	3.92	11.80	7.88
2700	4.42	12.00	7.58
2750	4.33	11.90	7.57
2800	4.54	11.90	7.36
2850	5.00	12.10	7.10
2900	5.00	12.20	7.20
2950	5.00	12.10	7.10
3000	5.00	12.00	7.00
3050	5.00	12.00	7.00
3100	5.00	12.10	7.10
3150	5.00	12.00	7.00
3200	5.00	12.00	7.00
3250	5.00	12.10	7.10
3300	5.00	12.10	7.10
3350	5.00	12.10	7.10
3400	5.00	12.00	7.00
3450	5.00	12.10	7.10
3500	5.00	12.20	7.20
3550	—	12.10	—
Mean	3.87	11.77	7.93
Standard Dev.	0.78	0.47	0.53
Maximum	5.00	12.30	8.77
Minimum	2.42	10.80	7.00

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 4a).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	4.08	10.10	6.02
50	4.08	10.10	6.02
100	4.42	10.10	5.68
150	4.17	10.10	5.93
200	4.00	10.30	6.30
250	3.92	10.10	6.18
300	4.33	9.90	5.57
350	4.75	10.50	5.75
400	4.08	10.30	6.22
450	3.83	10.20	6.37
500	4.25	10.00	5.75
550	4.25	10.40	6.15
600	4.58	10.20	5.62
650	3.83	10.10	6.27
700	4.17	10.20	6.03
750	4.17	10.20	6.03
800	4.67	10.20	5.53
850	4.42	10.20	5.78
900	4.67	10.30	5.63
950	4.67	10.30	5.63
1000	—	—	—
Mean	4.25	10.18	5.94
Standard Dev.	0.27	0.13	0.26
Maximum	4.75	10.50	6.37
Minimum	3.83	9.90	5.53

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 4b).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	4.25	10.30	6.05
50	4.58	10.20	5.62
100	4.04	10.10	6.06
150	4.25	10.20	5.95
200	4.25	10.20	5.95
250	4.50	10.10	5.60
300	4.54	10.20	5.66
350	4.83	10.30	5.47
400	4.00	10.20	6.20
450	4.13	10.20	6.08
500	3.92	10.30	6.38
550	4.17	10.30	6.13
600	4.17	10.80	6.63
650	—	—	—
700	—	—	—
750	—	—	—
800	3.00	10.50	7.50
850	2.67	10.20	7.53
900	3.33	10.20	6.87
950	2.83	10.20	7.37
1000	2.50	10.20	7.70
Mean	3.89	10.26	6.37
Standard Dev.	0.69	0.16	0.70
Maximum	4.83	10.80	7.70
Minimum	2.50	10.10	5.47

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 4c).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	4.17	10.20	6.03
50	4.04	10.20	6.16
100	4.13	10.20	6.08
150	4.00	10.30	6.30
200	4.71	10.30	5.59
250	5.00	10.30	5.30
300	3.92	10.00	6.08
350	4.08	10.00	5.92
400	5.00	9.90	4.90
450	3.83	10.00	6.17
500	3.92	10.10	6.18
550	3.83	10.10	6.27
600	3.96	10.10	6.14
650	4.08	10.10	6.02
700	4.08	10.10	6.02
750	4.42	10.00	5.58
800	4.08	10.00	5.92
850	4.58	10.00	5.42
900	4.17	9.90	5.73
950	4.08	9.90	5.82
1000	5.00	10.10	5.10
Mean	4.24	10.09	5.84
Standard Dev.	0.38	0.12	0.38
Maximum	5.00	10.30	6.30
Minimum	3.83	9.90	4.90

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 4d).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
50	4.33	10.30	5.97
100	4.00	10.20	6.20
150	4.67	10.20	5.53
200	3.54	10.00	6.46
250	5.00	10.10	5.10
300	4.00	10.10	6.10
350	5.00	10.20	5.20
400	4.75	10.30	5.55
450	3.92	10.10	6.18
500	4.25	10.00	5.75
550	3.75	10.10	6.35
600	5.00	10.10	5.10
650	4.25	10.20	5.95
700	5.00	10.30	5.30
750	—	—	—
800	4.17	10.50	6.33
850	3.63	10.10	6.48
900	5.00	10.40	5.40
950	5.00	10.40	5.40
1000	3.67	10.40	6.73
Mean	4.36	10.21	5.85
Standard Dev.	0.53	0.14	0.50
Maximum	5.00	10.50	6.73
Minimum	3.54	10.00	5.10

Appendix 4 Soil depth, ground elevation, and bedrock elevation data (transect line 5).

Distance (ft)	Soil Depth (ft)	Ground Surface Elevation (ft)	Bedrock Elevation (ft)
0	0.92	15.60	14.68
50	1.25	16.00	14.75
100	1.25	15.90	14.65
150	1.25	15.90	14.65
200	1.13	15.90	14.78
250	0.75	16.00	15.25
300	1.00	15.90	14.90
350	2.08	16.00	13.92
400	1.67	15.90	14.23
450	1.67	15.70	14.03
500	3.17	15.70	12.53
550	2.67	15.90	13.23
600	2.75	15.90	13.15
650	1.83	15.70	13.87
700	1.75	15.90	14.15
750	1.58	15.80	14.22
800	1.67	16.00	14.33
850	2.92	15.90	12.98
900	3.00	15.80	12.80
950	2.75	16.10	13.35
1000	2.08	15.90	13.82
1050	1.75	15.80	14.05
1100	2.83	16.00	13.17
1150	3.08	16.00	12.92
1200	—	—	—
1250	—	—	—
1300	1.42	16.10	14.78
1350	1.08	16.00	14.92
1400	1.33	16.10	14.87
1450	0.92	16.20	15.38
1500	1.04	16.10	15.16
Mean	1.81	15.92	14.11
Standard Dev.	0.75	0.14	0.78
Maximum	3.17	16.20	15.28
Minimum	0.75	15.60	12.53

BETSY LINDSAY, INC.

SURVEYING AND MAPPING

SURVEYORS REPORT
ROTENBERGER GPS CROSS SECTIONS

PORTIONS OF SECTIONS 27 THROUGH 30 AND 31 THROUGH 35, TWP 46 S,
PORTIONS OF SECTIONS 2 THROUGH 11 AND 14 THROUGH 36, TWP 47 S.

CONTROL

ALL HORIZONTAL AND VERTICAL CONTROL FURNISHED BY LBF&H, REFERENCE FIELD BOOKS ROTENBERGER 1 AND ROTENBERGER 2.

EQUIPMENT:

TRIMBLE 4400 WITH TRIM MARK II RADIOS; ONE BASE STATION AND ONE ROVER; SOKKIA SET5W.

HORIZONTAL CONTROL POINTS USED:

124, 123, 17, 127, 126, 125, 131, 130, 129, 12, 11, 128

BENCH MARKS USED:

R1-4-9, R1-8-9, R1-8-14, R1-8-42, R1-8-133, R1-8-134, R1-8-67, R2-3-41, R2-3-42, R2-3-57, R2-3-54, R1-4-9, R2-3-27, R2-3-28, R2-3-26, R1-8-108, R1-8-109, R1-8-133, R1-8-134, R1-2-1, R2-3-17

JOB SUMMARY:

October 26, 1999; A review of the site and control points was conducted. An attempt to set up for GPS site calibration was made. Due to hardware problems the calibration was aborted.

October 27, 1999; On site at 9:00 AM. Equipment set up at 9:45 AM. The base was set up on control point 126 (stored as pnt 19) and a here was performed to acquire GPS coordinate values for the base location. An elevation was estimated for point 126 based on near benchmarks. A one-point calibration was performed paring point 126 with GPS point 226. Shoot point 125 as GPS point 225. Add the pair to the calibration. Shoot Bench Mark 2-3-54 as GPS point 501 and BM 2-3-41 as GPS point 500. Store point 400 as the grid value of 400 and 401 as the grid value of point 501, substituting the elevations from the LBF&H bench run. Add the pairs 400-500 and 501-401 as vertical restraining components. The calibration illustrated a 24-foot horizontal residual and there was not enough data to achieve vertical residuals. In an effort to utilize the airboat and its driver during daylight hours we began the first cross section. The section was started at a point approximately fifty feet easterly of the edge of water at the base of the westerly berm on the line computed by LBF&H. Data points were collected with a 10.54 high rod with an L1/L2 antenna with a ground plane attached employing a nine second observation generating three measurements restrained to 0.06 feet vertical accuracy at approximately 1320 foot stations along the LBF&H line. Seven to nine satellites were available the entire session. A depth of water was measured at each shot. The elevation of water was shot at the west berm using GPS and with a Sokkia Set5w at the beginning of the run. Due to dense vegetation west of the east berm, the east berm could not be reached by the airboat. A horizontal and vertical check shot could not be obtained. At four in the afternoon the Airboat went home for the day. The GPS Crew spent three more hours acquiring shots on control on the west berm. There was not enough daylight to shoot control on the east berm. The pair for point 125 was removed from the calibration and additional horizontal control was put in. The horizontal residuals came down to 0.20 feet and a level of confidence was gained. Due to the absence of vertical constraining GPS points on the east berm vertical residuals could not be computed. (see ROTEN DC FILE ATTACHED FOR MORE SPECIFIC INFORMATION) Note that the water depth ranged from 9 to 16 inches deep along transect one. The vegetation consisted of mostly saw grass and primrose. A house was located along the line and the approximate southwest corner of the property was shot. Wax myrtals and Brazilian pepper were located near the East berm.

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Note: The environment of flat water and saw grass introduces a possibility of multipath. A high rod with a ground plan was used to restrict the multipath.

All control points were shot with 120 seconds of data averaged to six measurements. Topo shots were shot with 9 seconds of data averaged to six measurements. Check shots on benchmarks were shot with 9 seconds of data averaged to three measurements.

October 29, 1999; On site at 9:00 AM. Set base up at GPS point 218 (being control point 127 of point 18). Performed redundant measurements on horizontal and vertical control. Collected data along the second and third transect line set up by LBF&H . Accessed the east berm at the end of transect three from the airboat and hit two benchmarks and a horizontal control point. At the end of the airboat day. Additional control points were hit on the West Berm and the East Berm. Vertical residuals could be obtained. The water elevation was shot at the west berm utilizing a Sokkia Set5w. The elevation of the water had changed from the previous day. The Southeast corner of the site has large pumps that move water out of the area. The Water elevation is not a constant. This surveyor does not have enough data to determine the rate of change.

November 1, 1999; On site at 8:00 AM. Set base up at GPS point 218. (being control point 127 of point 18). Performed redundant measurements on horizontal and vertical control. Collected data along the fourth and fifth transect line set up by LBF&H . We were unable to access the east 1.5 miles of the transect four due to dense wax myrtle trees. Accessed the east berm at the end of transect five from the air boat to cross section the berm and hit two bench marks and a horizontal control point. At the end of the airboat day additional control points were hit on the West Berm and the East Berm. A cross section the berm at lines one and two were done utilizing a Sokkia Set5w. The vegetation consisted of mostly saw grass cattail and primrose. Wax myrtle was heavy for the east 1.5 miles.

November 3, 1999; On site at 8:00 AM. Set base up at GPS point 211. (being control point 11). Performed redundant measurements on horizontal and vertical control. Collected data along the east 1.5 miles of the fourth and sixth transect line set up by LBF&H . Accessed the east berm at the end of transect five from the air boat to cross section the berm and hit two bench marks and a horizontal control point. At the end of the airboat day additional control points were hit on the West Berm and the East Berm. A cross section of the East berm at lines three, four and six were done utilizing a Sokkia Set5w. The depth of water ranged from nine inches to 35 inches deep. There was quite a bit of open water on these transect with large quantities of waterfowl.

November 9, 1999; Based on analysis of the data an anomaly has occurred with the first day's cross-section. A constant error of 41 feet is observed. An additional trip to site is required to support the hypothesis. Arrive at the site at 8:00 AM. Set base up at GPS point 276. (being control point 126). Performed redundant measurements on horizontal and vertical control. Reshot cross section of the West berm and the east berm. Reshot points along the transect in the swamp. During the shots on the east berm we experienced extremely poor satellite configurations with low satellite coverage. Based on the data collected Points 600 through 630 were lowered 41 feet and points 837 through 842 were lowered 0.9 feet.

VERTICAL ACCURACY

Based on a review of the final set of data the vertical accuracy of 50 percent of the data points is plus or minus 0.10 feet with 50 percent of the data points having a vertical accuracy of plus or minus 0.20.

I hereby certify to LINDAHL, BROWNING, FERRARI & HELLSTROM, INC. that this document is a true and correct report of the field work done for LBF&H at the Rotenberger Tract.

Elizabeth A. Lindsay, P.L.S.
Florida Registration No. 4724
Licensed Business No. 6852

11/30/99
Date

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RES 16-14-03

MEMORANDUM

TO: Cal Neidrauer, Supv. Professional, Lower East Coast Planning Division

THROUGH: Ken Ammon, Supv. Professional, Lower East Coast Planning Division

FROM: Charles Gove, Staff Civil Engineer, Lower East Coast Planning Division

DATE: December 22, 1993

SUBJECT: SFWMM Topography: Data Sources for the Everglades Agricultural Area (EAA) and Water Conservation Areas (WCAs)

This memorandum is in response to the request for comparison and review of the South Florida Water Management Model (SFWMM) topographic data with published topography. The purpose of this memorandum is to 1) identify, to the extent possible, the source(s) of the current land surface elevation data in the SFWMM and 2) confirm that the most recent source of published topographic data is being used. The following discussion is arranged by geographic region: i) EAA; ii) WCA 1; iii) WCAs 2A and 2B; iv) WCAs 3A and 3B; and v) Big Cypress Basin. A Conclusions and Recommendations section summarizes the discussion with future options for SFWMM topographic data.

Correlation of SFWMM land surface elevations with south Florida topographic maps, is accomplished by generating a one-foot contour interval map from the SFWMM topographic data (Thomas Lo); Figure 1. Comparison of Figure 1 (SFWMM topography) to the most likely published source of topographic information (one-foot contours created from Soil Conservation Service, Everglades area south of Lake Okeechobee) is accomplished with Figure 2 (EAA), Figure 3 (WCAs 1, 2A, and 2B), and Figure 4 WCAs 3A and 3B; and Big Cypress Basin.

Everglades Agricultural Area:
It is recalled (M. Guardo) that the SFWMM EAA topographic data set used in the 1991 recalibration was produced by projecting a rate of soil subsidence onto a topographic contour map and extrapolating land surface elevations (± 0.1 ft) for each model cell. Unfortunately, explicit documentation identifying the base map, rate of subsidence, and duration of subsidence has not yet been located.

Under the assumption of a subsidence rate of 0.1 ft/year applied to the 1960 COE one-foot contour map for twenty-eight years (1960-1988), comparison of the EAA topography in Figure 1 with Figure 2 shows similar patterns offset by approximately three feet. Although total verification of the SFWMM EAA topographic data source is not possible, the extreme similarity in pattern between the Figures 1 and 2 strongly suggest identical data sources.

The 0.1 ft/year subsidence rate is affirmed on page 16 under conclusions of *"1988 Subsidence Study of the Everglades Agricultural Area"* (U.S. Department of Agriculture, Soil Conservation Service, Palm Beach Soil and Water Conservation District/South Florida Water Management District): an average subsidence rate of 1.2 inches per year was shown in the four year period from 1984 to 1988. This confirms the approximate 1 inch per year subsidence rate that has been predicted for the organic soils in the EAA.

Water Conservation Area 1:
Following the 1991 SFWMM recalibration, the topographic data for the model cells pertaining to WCA 1 have been revised in accordance with the topographic information in *"An Evaluation of Refuge Habitats and Relationship to Water Quality, Quantity, and Hydroperiod"*, John R. Richardson et al., November 1990

Water Conservation Areas 2A and 2B:
It is recalled (R. Santee) that the SFWMM WCAs topographic data set was created by overlaying a one-foot contour map and extrapolating land surface elevations (± 0.1 ft) for each model cell. Unfortunately, explicit documentation identifying the contour map is not available.

Comparison of the WCA 2A and 2B topography in Figure 1 with Figure 3 shows similar contour patterns. Although total verification of the SFWMM WCA 2A and 2B topographic data source is not possible, the extreme similarity in pattern between the Figures 1 and 3 strongly suggest identical data sources.

Water Conservation Areas 3A and 3B:
It is recalled (R. Santee) that the SFWMM WCAs topographic data set was created by overlaying a one-foot contour map and extrapolating land surface elevations (± 0.1 ft) for each model cell. Unfortunately, explicit documentation identifying the contour map is not available.

Comparison of the WCAs 3A and 3B topography in Figure 1 with Figure 4 shows similar contour patterns. Although total verification of the SFWMM WCAs 2A and 2B topographic data source is not possible, the extreme similarity in pattern between the Figures 1 and 4 strongly suggest identical data sources.

Compilation of land surface elevations from the DBHydro stations located in WCA 3 provides fourteen spot elevations for comparison with the SFWMM topographic dataset for WCA 3. Figure 5 is a plot of the spot elevations and the corresponding SFWMM cell topography. Figure 5 is a plot of the SFWMM WCA 3 topography assigned to the corresponding model cells. Comparison of DBHydro and SFWMM data demonstrates a high correlation between the values. Spot elevations equal SFWMM cell values at most sites and where differences occur, an adjacent cell value equals the elevation.

Big Cypress Basin:
Comparison of the Big Cypress Basin topography in Figure 1 with Figure 4 shows similar contour patterns. Although total verification of the Big Cypress Basin topographic data source is not possible, the extreme similarity in pattern between the Figures 1 and 4 strongly suggest identical data sources.

Conclusions and Recommendations:
The preceding discussion concludes that the SFWMM topographic dataset for the EAA, WCAs 2A, 2B, 3A and 3B, and Big Cypress Basin were most-likely created from the 1960 COE one-foot contour map, which is based on data collected in the mid 1950s. SFWMM EAA topography is a projection of these mid 1950s measurements adjusted in accordance with published subsidence rates. SFWMM WCA 1 topography is based on *"An Evaluation of Refuge Habitats and Relationship to Water Quality, Quantity, and Hydroperiod"*, November 1990. SFWMM topography for WCAs 2A, 2B, 3A and 3B, and Big Cypress Basin appears to have been generated directly from the 1960 COE one-foot contour map. Comparison of WCA 3A cell

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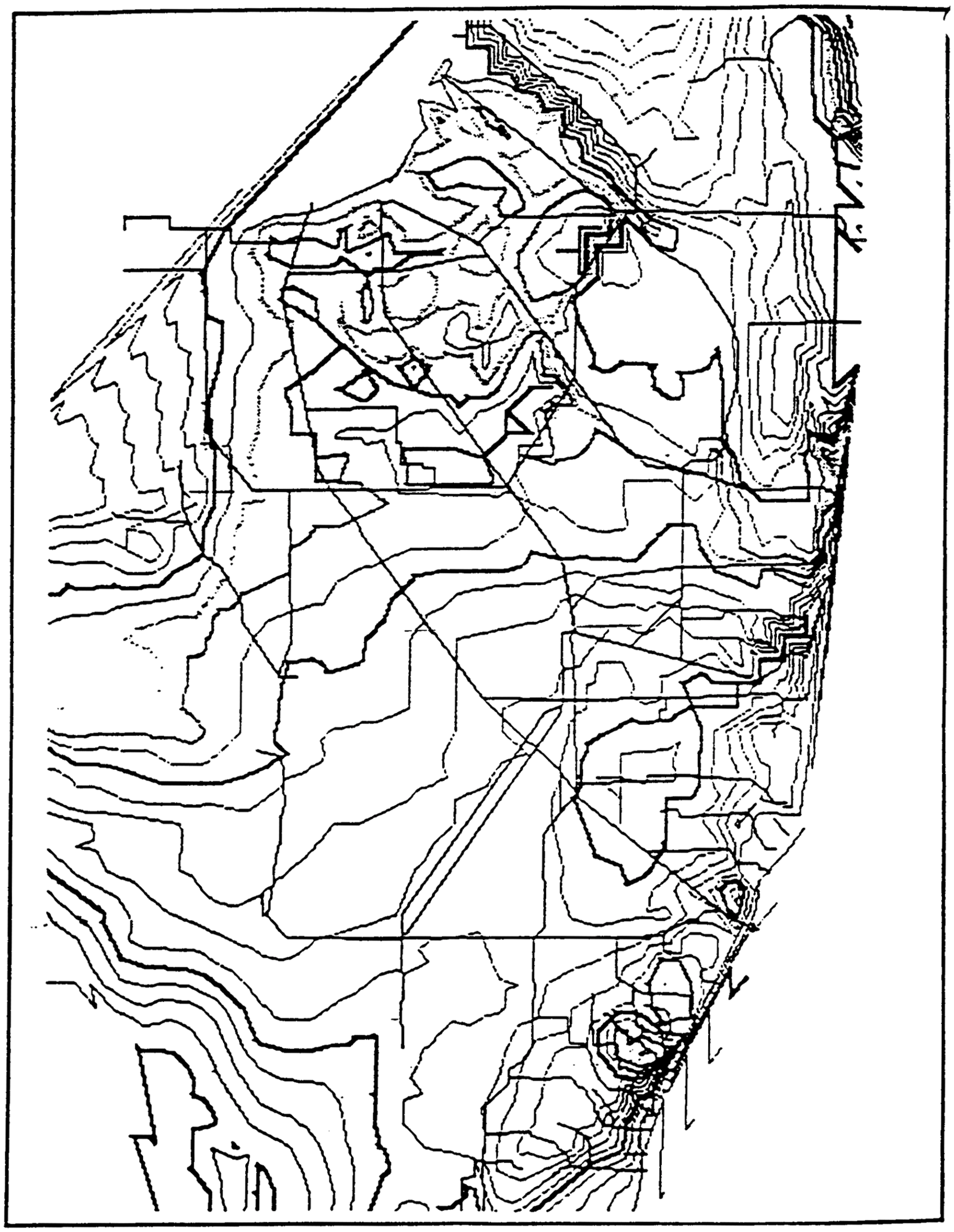
values with fourteen land surface elevations (DBHydro and *Review of th Regulation Schedule for WCA 3A"*, COE, October 1980) affirms the SFWMM topography dataset. Thus, it is concluded that the existing SFWMM topographic dataset appropriately reflects current available topographic information and modification of the dataset should be on the basis of future regional topographic surveys (e.g. WCA 1: *"An Evaluation of Refuge Habitats and Relationship to Water Quality, Quantity, and Hydroperiod"*, November 1990).

CAG/pac
Attachments

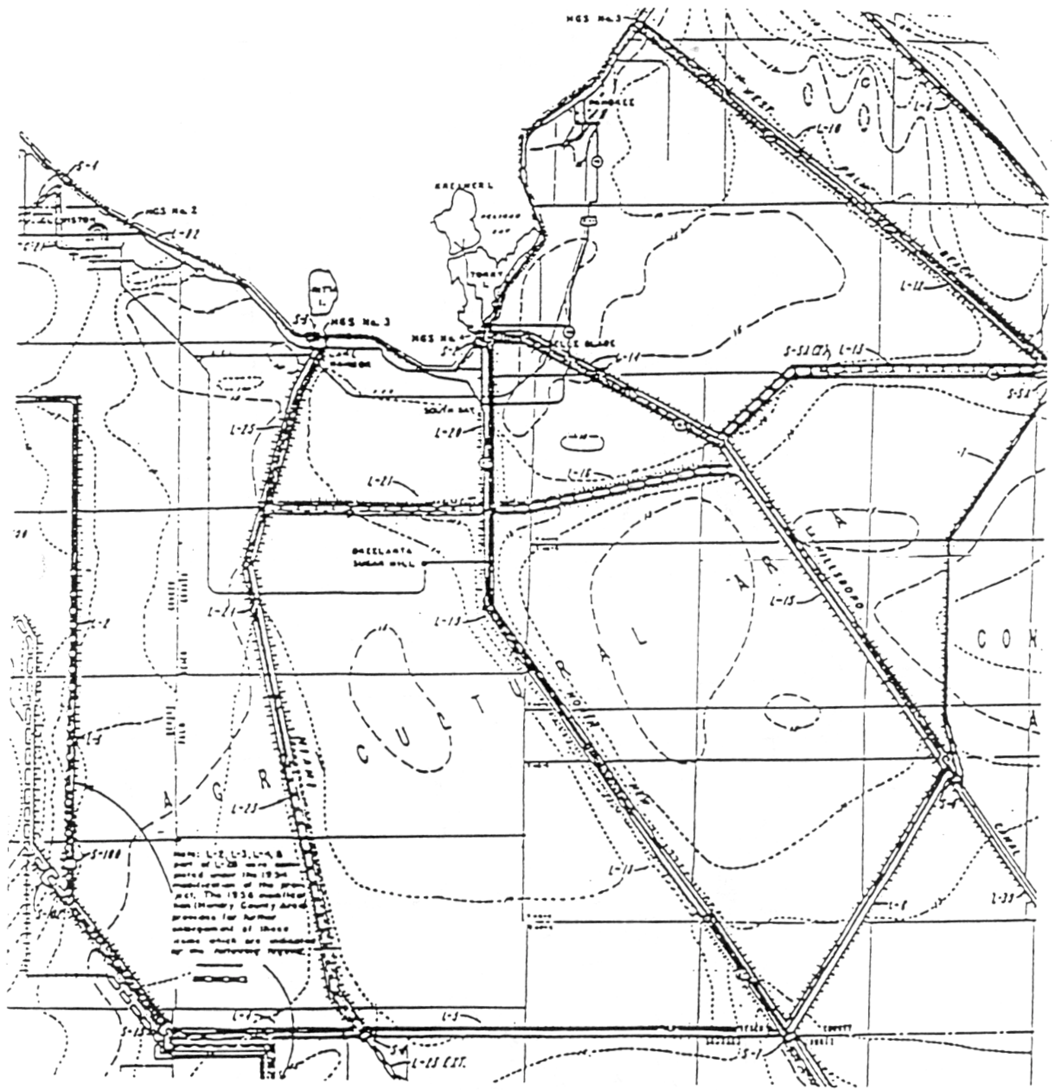
c: Lehar Brion w/att., LECP
Vince Katilius w/att., LMD
Thomas Lo w/att., LECP
Larry Pearson w/att., LECP
Ray Santee w/att., LECP
Tom Teets w/att., LECP
Sharon Trost w/att., PLW

Figure 1: SFWMM One Foot Contours



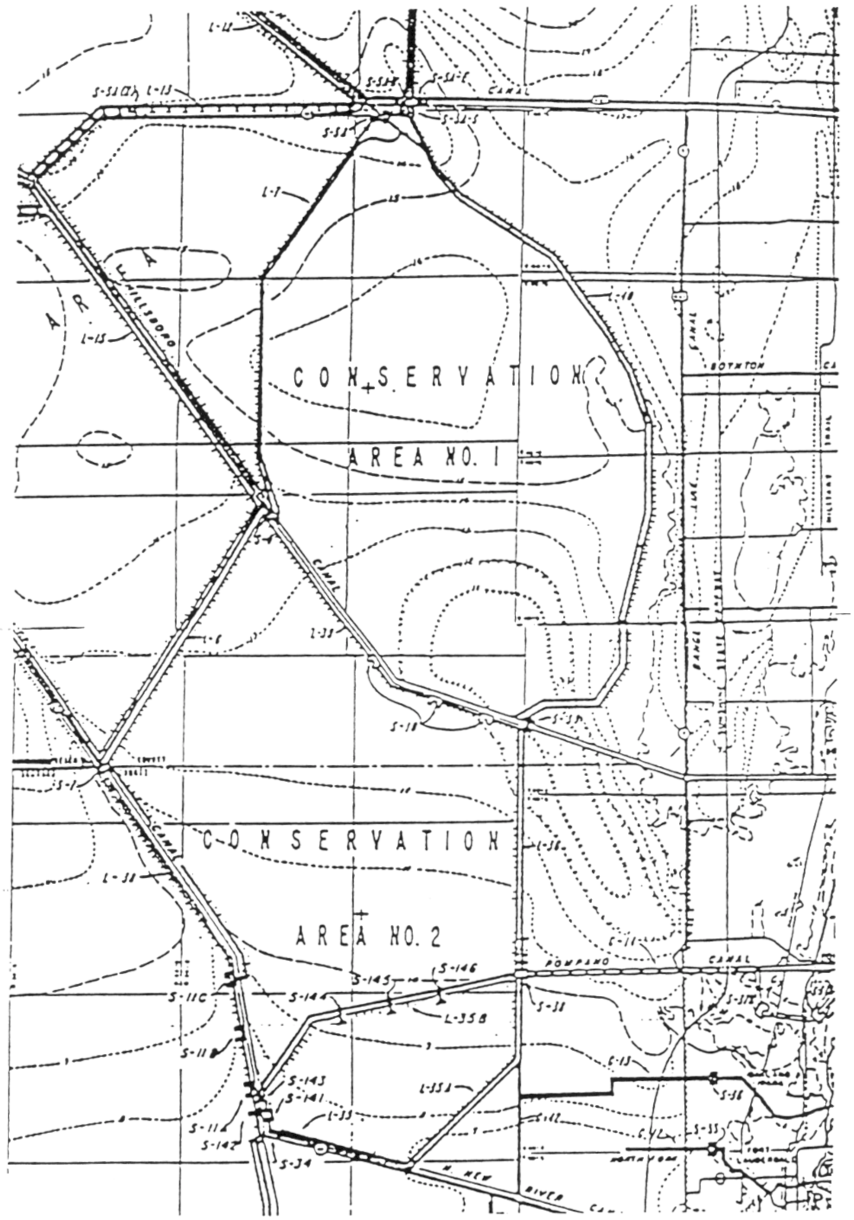
Source: South Florida Water Management Model Topographic data (Thomas Lo)

Figure 2: Everglades Agricultural Area One foot Contou



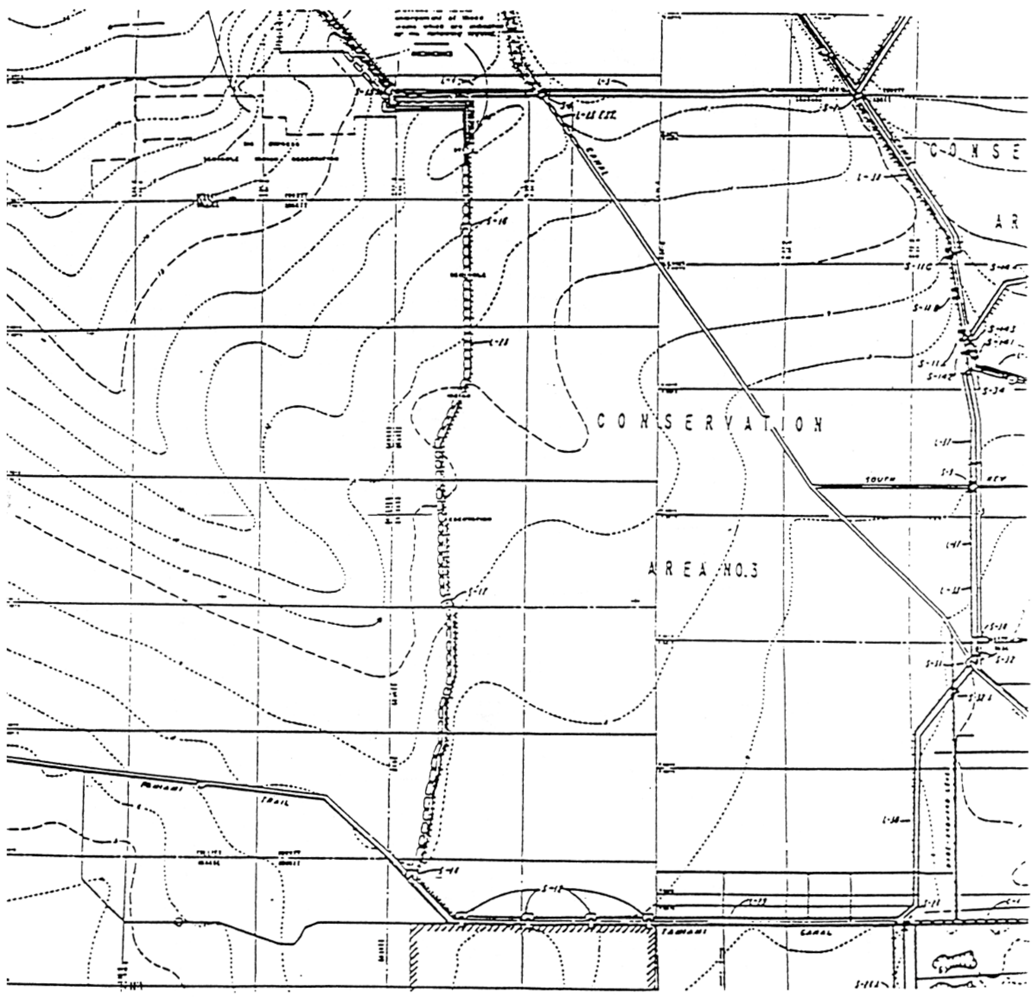
Source: Central and Southern Florida Comprehensive Plan
Corps of Engineers, Jacksonville, Florida Revised June 1960
File No. 400 - 25,255 - 1.3 (F.C.D. File No. FO - 24)

Figure 3: Water Conservation Areas 1, 2A, 2B One Foot Contours



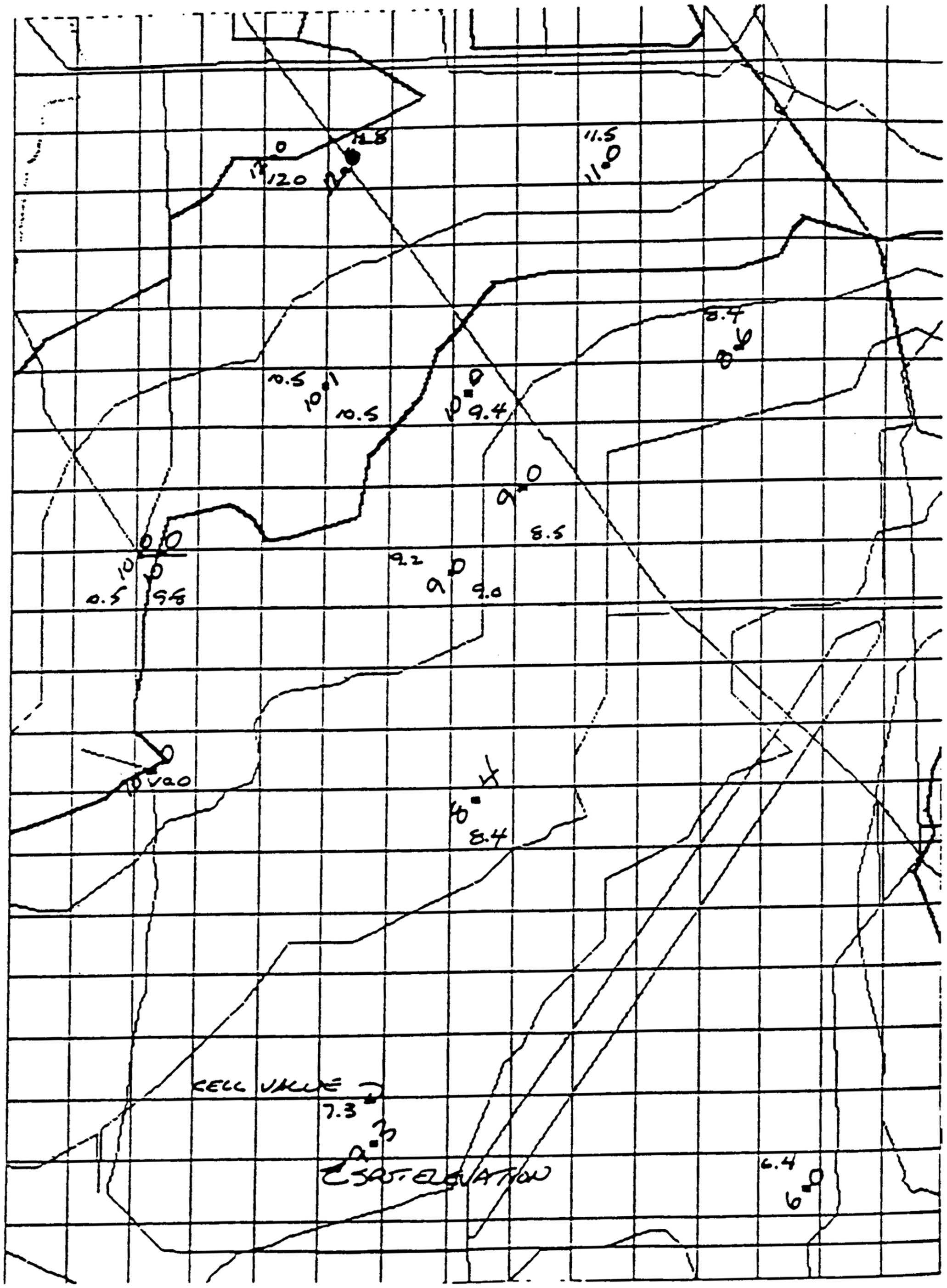
Source: Central and Southern Florida Comprehensive Plan
Corps of Engineers, Jacksonville, Florida Revised June 1960
File No. 400 - 25,255 - 1.3 (F.C.D. File No. FO - 24)

Figure 4: Water Conservation Area 3A, 3B
Big Cypress Basin Contours



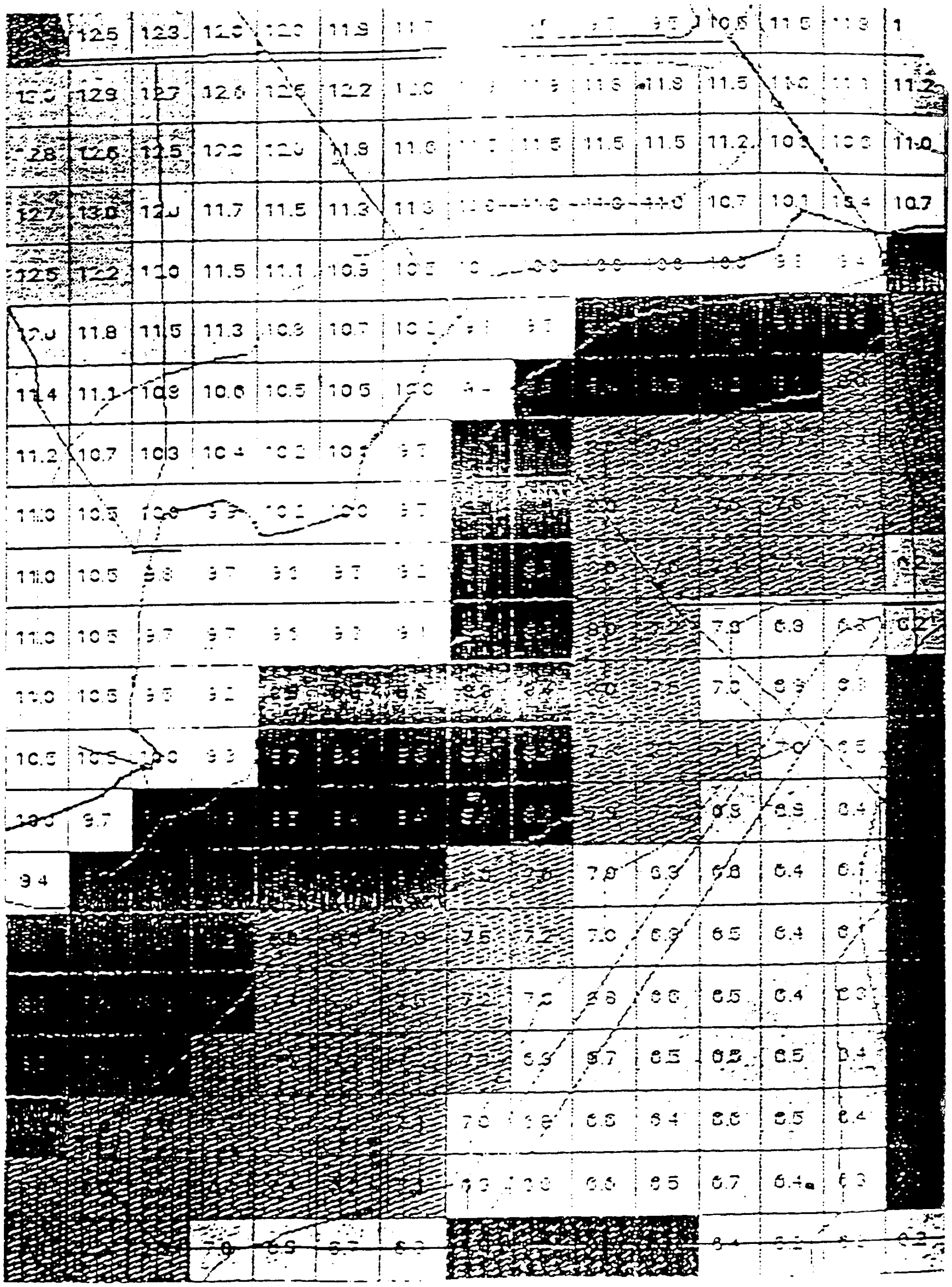
Source: Central and Southern Florida Comprehensive Plan
Corps of Engineers, Jacksonville, Florida Revised June 1960
File No. 400 - 25,255 - 1.3 (F.C.D. File No. FO - 24)

Figure 5: Water Conservation Area 3A and 3B Elevations



Source(s): South Florida Water Management Model / DBhydro

Figure 6: WCA 3 -- SF... ...ell Topographic Valu...



Source: South Florida Water Man...

lbfh LINDAHL, BROWNING, FERRARI & HELLSTROM, INC.
CONSULTING ENGINEERS, SURVEYORS & MAPPERS

**REPORT OF TOPOGRAPHIC SURVEY
OF A PORTION OF LANDS LYING IN
SECTIONS 21, 22, 26-35, TOWNSHIP 46 SOUTH, RANGE 35 EAST;
SECTIONS 2-11, 14-36, TOWNSHIP 47 SOUTH, RANGE 35 EAST;
SECTIONS 1-6, TOWNSHIP 48 SOUTH, RANGE 35 EAST;
AND SECTION 6, TOWNSHIP 48 SOUTH, RANGE 36 EAST;
PALM BEACH COUNTY, FLORIDA**
December 2, 1999

Topographic Survey: Map titled: "Rotenberger Tract, drawing no. 99246S01, project no. 99-0256, sheets 1 of 4 through 4 of 4, last revision dated November 19, 1999.

Project Site: The Rotenberger Tract is an existing, active reservoir lying within approximately 52 land sections in the southwest corner of Palm Beach County, Florida.

Project Scope: A Topographic Survey of the site was prepared consisting of 6 East-West cross-sections. Elevations, typically, were collected at approximate ¼ mile intervals. Due to the existing impracticable terrain and size of the site, conventional leveling techniques were not a realistic option for all of the data collection. Travel across the site was accomplished using an airboat. Ground and water elevations were collected using Trimble series 4300 GPS receivers and automatic levels.

1) **Note Concerning Horizontal Control:** Horizontal datum is the Florida State Plane Coordinate System, Transverse Mercator Projection, East Zone, North American Datum of 1983, adjustment of 1990 (NAD 83/90). Horizontal control for this project was established utilizing the public document "98 Adjustment Western Palm Beach County GPS Control Survey" published values of the following points: "Corner 1970", "FCE 3596", "Course", "Lease" and the Palm Beach County published values for the National Geodetic Survey's (NGS) point: "FLGPS 65 1989".

2) **Note Concerning Vertical Control:** Vertical controls for this project is based on the National Geodetic Vertical Datum (N.G.V.D.) of 1929 and was established utilizing the South Florida Water Management District's (SFWMD) published values for the following benchmarks: SFWMD's benchmark "G350B", "G344C", "G349B" and "B49". Level loops totaling 22.69 miles were ran with all of the raw (unadjusted) closures exceeded the minimum closure requirements as set forth by the current applicable Minimum Technical Standards. Intermediate checks were made to Florida Corp of Engineer (FCE) benchmarks "FCE 3599 1973", "FCE 3601 1973", "FCE 3602 1973" and "FCE 3605 1973". Each of the FCE benchmarks consistently field-checked 0.30' lower than the FCE published elevation and as such the FCE benchmarks were not taken into consideration during the level loop adjustment(s). See the following "To Reach Description" for bench mark location and description:

3550 S.W. CORPORATE PARKWAY • PALM CITY, FLORIDA 34990 • (561) 286-3883 • FAX (561) 286-3925
http://www.lbfh.com • e-mail: info@lbfh.com
PALM CITY WEST PALM BEACH FORT PIERCE OKEECHOBEE

REPORT OF TOPOGRAPHIC SURVEY
Page 2
December 2, 1999

Topographic Survey: Map titled: "Rotenberger Tract, drawing no. 99246S01, project no. 99-0256, sheets 1 of 4 through 4 of 4, last revision dated November 19, 1999.

3) **Note Concerning Vertical Control:** (To Reach Descriptions)

A. Bench Mark "G350B", located 1.13± miles South of the northwest corner of the Rotenberger Tract perimeter dike. Benchmark is on structure G-350B, which lies on the West bank of a canal West of the Rotenberger perimeter dike. Mark is a SFWMD aluminum cap set in the top of the North end of the East concrete headwall of the G-350B structure. Cap is stamped: "BM G350B 1999". Published elevation: 14.159.

B. Bench Mark G344C, located 0.72± miles South of the northwest corner of the Rotenberger Tract perimeter dike. Benchmark is on structure G-344C, which lies West bank of the S.T.A. (Stormwater Treatment Area) 5 dike which lies just West of the Rotenberger perimeter dike. Mark is a SFWMD aluminum cap set in the top of the South end of the West concrete headwall of the structure. Cap is stamped: "BM 344C 1999". Published elevation: 20.543.

C. Bench Mark G349B, located at approximately the northwest corner of the Rotenberger Tract perimeter dike. Benchmark is on structure G-349B, which lies in the discharge canal West of the Rotenberger perimeter dike. Mark is a SFWMD aluminum cap set in the top of the East end of the South concrete headwall of the structure. Cap is stamped: "BM G349B 1999". Published elevation: 14.094.

D. Bench Mark "B49" is located at the southeast corner of the Rotenberger Tract. Benchmark is on the East retaining wall at Pump Station No. 8. Mark is a SFWMD brass disc set in concrete, approximately 23 feet North of the South end of the wall. Cap is stamped: "B-49 BM SFWMD". Published elevation: 23.37.

4) **Note Concerning Topographic Procedures and Elevation Accuracy:** See attached Surveyor's Report prepared by L.B.F.H.'s sub-consultant, Betsy Lindsay, Inc., LB #6852, titled: "Surveyors Report Rotenberger GPS Cross Sections", sheets 1 and 2 of 2, dated November 30, 1999, for specific information.

5) **Project Specific Information**: See attached Topographic Survey drawing, sheet 1 of 4, for overall site configuration and general notes.

Prepared For: South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

John A. Wilson, PSM #5157
Lindahl, Browning, Ferrari & Hellstrom, Inc., LB #959
3550 S.W. Corporate Parkway
Palm City, Florida 34990

Neither the map nor report are full and complete without the other. This survey map and report is not valid without the signature and original raised seal of a Florida licensed surveyor and mapper.

p:\99-0246\w\report of boundary survey.doc

APPENDIX B - OUTLIER IDENTIFICATION METHODOLOGY

Outliers were idenitified in the USGS High-Accuracy data and the WCA-3A LIDAR data using the following formula for each SFWMM cell:

1. Find mean (MU) and standard deviation (SD) of all data points
2. Find the first quartile (Q1) using the following formula

   Q1 = MU + SD * (-0.6745)
3. Find third quartile (Q3) using the following formula:

   Q3 = MU + SD * (+0.6745)
4. Find the Inter Quartile Range (IQR):

   IQR = Q3 – Q1
5. Find the lower threshold for identifying outliers:

   LT = Q1 – 1.5*IQR
6. Find the upper threshold for identifying outliers:

   UT = Q3 + 1.5*IQR
7. Flag all values smaller than LT
8. Flag all values larger than UT
9. Do this for all SFWMM cells with USGS (approx. 64 points per cell) and LIDAR (approx. 1,024 per cell) data.

<u>Example:</u>
For Cell R17C11:

MU = 1.33; SD = 0.23; Q1 = 1.17; Q3 = 1.49; IQR = 0.32; LT = 0.69; UT = 1.81

Any data-point having a value larger than 1.81 or smaller than 0.69 would be considered an outlier.

As stated, all outliers were removed from the High-Accuracy Data collection, while only the outliers in the WCA-3A LIDAR that were determined to be random and not part of a "patch" were removed. The map identifying these patches is included in the hard copy deliverable of this memo to Ken Tarboton.

APPENDIX C - VERTCON ATTACHMENT

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README file   18-aug-94   RJF/dgm

PURPOSE:  Program VERTCON computes the modeled difference in orthometric
          height between the North American Vertical Datum of 1988 (NAVD 88)
          and the National Geodetic Vertical Datum of 1929 (NGVD 29) for a
          given location specified by latitude and longitude.

A partial list of contents of the floppies are:

   VERTCON.EXE    VERTical datum CONversion program
                  (compiled from VERTCON.FOR, a FORTRAN source code)

   VERTCONE.94    VERTCON datum transformation grid file;  eastern USA
                  (non-readable, i.e., binary, file)

   VERTCONC.94    VERTCON datum transformation grid file;  central USA
                  (non-readable, i.e., binary, file)

   VERTCONW.94    VERTCON datum transformation grid file;  western USA
                  (non-readable, i.e., binary, file)

   README.TXT     User’s instruction file

A number of sample output and batch files are included as examples, in
addition to some utility routines described later in this document.

To install:
   1) Make sure the original diskettes are write-protected!
   2) Make a subdirectory on hard disk;
        for example:  mkdir NGVDCONV
   3) Go into subdirectory;
        for example:  cd NGVDCONV
   4) Copy the diskettes into the subdirectory; for example:
                      copy B:*.* *.* /v
   5) Put the original diskettes in a safe place!

To execute:
   Type     VERTCON           and follow the prompts.

To terminate:
   VERTCON computations can be stopped at any time by the Control-C
   (i.e., <ctrl-c>) key combination.  Interactive processing
   can also be terminated by entering 0. (i.e., zero WITH DECIMAL POINT)

BUT PLEASE DON’T START YET;  KEEP READING THIS DOCUMENT.

How program VERTCON works:
   The software and three files of datum transformation grids for the
conterminous United States (CONUS) are provided on the diskettes.  VERTCON
returns the orthometric height difference between NAVD 88 and NGVD 29 at the
geodetic position specified by the user.  VERTCON interpolates the datum
transformation at a point from the appropriate grid in your subdirectory.
```

Data Input:

The user can key in latitude and longitude on a point-by-point basis or can create an input file using a text editor. Several file formats are provided, including the internal bench mark file record format of the Vertical Network Branch, NGS. These formats are detailed in a "Help" menu option which appears when the input filename is specified.

Most horizontal positions of the bench marks used to generate VERTCON were scaled from USGS topographic maps. The estimated uncertainty of the scaled positions, 6", is greater than the differences between NAD 27 and NAD 83. Therefore, the latitude and longitude provided to VERTCON can be on either the NAD 27 or NAD 83 datum.

Data Output:

Results are collected into an output file. The default name of this file is
VERTCON.OUT, but the user can choose any legal filename. (A word of advice: don’t use misleading extensions such as .EXE, .BAT, etc.). The format of the output file is linked to the format of the input file to maintain consistency.

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------------------------>  THE SENSE OF THE SIGNS  <-------------------------
```

The grids contain a model of (NAVD 88 - NGVD 29) height differences.

```
                  ---------------------------------
                 | from    NGVD 29  ---->   NAVD 88 |
                  ---------------------------------
```

If a NAVD 88 height is desired when a NGVD 29 height is given,
ADD the model value ALGEBRAICALLY to the NGVD 29 height.

FORMULA: height (NAVD 88) = height (NGVD 29) + correction

Examples:

1. the NGVD 29 height is 65.532 meters (215 feet) at

```
 35  10  35.0  latitude
110  40  10.0  longitude
```

after keying this position to VERTCON the returned
(NAVD 88 - NGVD 29) datum shift (correction) value is

+ 0.019 meter

```
 -----                            -----------------
| ADD | this value ALGEBRAICALLY | keep the + sign | to the NGVD 29 height:
 -----                            -----------------
```

```
                                    65.532
                                  + 0.019
                                 ---------
      the NAVD 88 height is       65.551  meters


  2.  the NGVD 29 height is 117.348 meters (385 feet) at

                         36  10  35.0  latitude
                        078  40  10.0  longitude

      after keying this position to VERTCON the returned
      (NAVD 88 - NGVD 29) datum shift (correction) value is

                         - 0.267 meter

    -----                             -----------------
   | ADD | this value ALGEBRAICALLY | keep the - sign | to the NGVD 29 height:
    -----                             -----------------

                                   117.348
                                 -  0.267
                                 ---------
      the NAVD 88 height is      117.081  meters

     -    -    -    -    -    -    -    -    -    -    -   -   -   -    -


                     ----------------------------------
                    | from    NAVD 88  ---->   NGVD 29 |
                     ----------------------------------


  If a NGVD 29 height is desired when a NAVD 88 height is given,
       SUBTRACT the model value ALGEBRAICALLY from the NAVD 88 height.


        FORMULA:   height (NGVD 29) =  height (NAVD 88) - correction


Examples:

  1.  the NAVD 88 height is 65.551 meters (215.062 feet) at

                         35  10  35.0  latitude
                        110  40  10.0  longitude

      after keying this position to VERTCON the returned
      (NAVD 88 - NGVD 29) datum shift (correction) value is

                         + 0.019 meter

  --------                            -----------------
```

```
 |SUBTRACT| this value ALGEBRAICALLY | flip the + sign | to the NGVD 29
height:
  --------                            -----------------

                                  65.551
                                 - 0.019
                                ---------
       the NGVD 29 height is      65.532  meters


  2.  the NAVD 88 height is 117.081 meters (384.124 feet) at

                         36  10  35.0  latitude
                        078  40  10.0  longitude

       after keying this position to VERTCON the returned
       (NAVD 88 - NGVD 29) datum shift (correction) value is

                         - 0.267 meter

  --------                            -----------------
 |SUBTRACT| this value ALGEBRAICALLY | flip the - sign | to the NGVD 29
height:
  --------                            -----------------

                                 117.081
                                +  0.267
                                ---------
       the NGVD 29 height is     117.348  meters


     -    -    -    -    -    -    -    -    -    -    -   -   -   -    -
```

The VERTCON 2.0 Model

The VERTCON 2.0 model was computed on May 5, 1994 using 381,833 datum difference values. A key part of the computation procedure was the development of the predictable, physical components of the differences between the NAVD 88 and NGVD 29 datums. This included models of refraction effects on geodetic leveling, and gravity and elevation influences on the new NAVD 88 datum. Tests of the predictive capability of the physical model show a 2.0 cm RMS agreement at our 381,833 data points. For this reason, the VERTCON 2.0 model can be considered accurate at the 2 cm (one sigma) level. Since 381,833 data values were used to develop the corrections to the physical model, VERTCON 2.0 will display even better overall accuracy than that displayed by the uncorrected physical model. This higher accuracy will be particularly noticable in the eastern United States.

Using VERTCON 2.0

It should be emphasized that VERTCON 2.0 is a datum transformation model, and can not maintain the full vertical control accuracy of geodetic leveling. Ideally, one should process level data using the latest reduction software and adjust it to established NAVD 88 control. However, VERTCON 2.0 accuracy is suitable for a variety of mapping and charting purposes.

The VERTCON 2.0 model expresses datum differences between NAVD 88 and NGVD 29 due to removal of distortions in the level data, as well as due to the physical differences in the height systems. In some rare cases, these local NGVD 29 distortions could be 20 cm or more. If both ends of your old vertical survey were tied to one of these "problem" lines, then the datum difference of the problem line is appropriate to use to transform the survey data. If both ends of a vertical survey are tied to "undistorted lines", then it is appropriate to use a slightly distant point to compute the transformation, no matter how close your survey data may approach a given problem line. The possible presense of a problem NGVD 29 line in the vicinity of your survey will become evident if dramatically different datum transformation values are computed within a small area.

It must also be emphasized that VERTCON 2.0 is not to be considered reliable beyond the boundaries of the lower 48 United States. The VERTCON program will interpolate values in Canada, Mexico, or in the ocean, due to the grid structure of the model. Those values do not contain important model components present in the conterminous U.S. model. Future versions of VERTCON may be extended into neighboring countries.

The Defense Mapping Agency:

The Defense Mapping Agency (DMA) has been of immense help in this endeavor. DMA has provided a major portion of the NGS land gravity data set. DMA has also been instrumental in the creation of the various 30" elevation grids in existence. Although the work of the DMA generally precludes public recognition, their cooperation in this work is gratefully acknowledged.

Other Programs:

The datum shift grids and VERTCON software are provided on standard disc operating system (DOS) controlled (IBM-compatible) personal computers (PC). In support of other computer systems, the following utility software is included:

CONVASCI -- copy unformatted (binary) grid files into ASCII files for transfer to other systems

CONVBIN -- will restore the ASCII files into binary grid files on the new system.

Other Future Plans:

A continuing development effort is underway to improve VERTCON results. NGVD 29 normal orthometric heights are being analyzed for localized monument and/or crustal motion effects, for inconsistent adjustments, and other effects.

Computed height differences which are significantly influenced by such effects will be flagged and rated for reliability in future versions.

For More Information

For Products Available From the National Geodetic Survey:

National Geodetic Information Center
N/CG174, SSMC3-9450
National Geodetic Survey, NOAA
1315 East-West Highway
Silver Spring, MD 20910-3282
Telephone: 301-713-3242

For Information on VERTCON 2.0, and Future Research:

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N/CG13, SSMC3-8752
Telephone: 301-713-3191
Fax: 301-713-4324

A special word of thanks goes to our colleague, Sandford R. Holdahl, who has recently retired. Sandy made the first predictions of the vertical datum differences in 1983, and is a co-author of the VERTCON 2.0 model.

README file 18-aug-94 RJF/dgm