Technical Note
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Rainfall Estimation at S-44 Site

(January 2nd, 3rd, and 17th, 1999 Events)

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by

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INTRODUCTION

The purpose of this communication is to reconstruct rainfall data at rain gage site S-44 (North Palm Beach) on the 2^{nd}, the 3^{rd}, and the 17^{th} of January of 1999 (unusually high rainfall events). The gage is believed to have malfunctioned on the 2^{nd} and 3^{rd} of January after recording a too high value, 32.53 inches. This value was revised later to 19.54 inches based on field comparison with a manual gage. Also, rainfall value recorded on the 17^{th} is believed to be too high (4.51 inches) compared to the surrounding gages and S-44 outflow. Flow, rainfall, and groundwater level data measured at nearby stations have been used to estimate the questionable rainfall data at S-44. The estimation is performed by two independent methods; statistical data analysis and water budget computation. The two methods show consistent results. This document is divided into four sections: 1) Brief description of C-17 Basin, 2) Available data used for the estimation, 3) Statistical data analysis, and 4) Water budget computation.

S-44 STATION AND THE C-17 BASIN

The C-17 basin is located in the northeastern part of Palm Beach County with an area of approximately 33 square miles (Figure1). The S-44 structure is located at Longitude and Latitude of 80° 04' 54'' 26° 49' 00'' respectively; and Easting and Northing of 955672, and 903634 feet respectively. Rainfall is the only source of water supply to this basin while C-17 is the only project canal. The C-17 canal and its only water control structure S-44 provide flood protection, drainage, and salt water intrusion prevention for the C-17 basin. Water flows Northward in the C-17 and is discharged to the Intracoastal Waterway through S-44 structure (Figure 1). For more information on C -17 basin, the reader is referred to the Eastern Palm Beach County Basin Atlas (Cooper and Lane, 1988).

AVAILABLE DATA

Data used for this study are daily discharge flow at S-44 structure and groundwater levels at nearby locations for the entire period of record. In addition, daily rainfall data at nearby stations including that at S-44 structure for the months of January/1999 were selected for the analysis. Information about these data is presented in Table 1. Data Locations are depicted in Figure 1. The use of these data to estimate rainfall at S-44 site is presented in the remaining two sections.

Table 1. Information pertaining to the stations used for the estimation in this study.

STATION	AGCY	TYPE	UNITS	STAT	STRT	END	DBKEY	LAT	LONG	X, feet	Y, feet
S44_R	**WMD**	**RAIN**	**Inches**	**SUM**	**1991**	**1999**	**16674**	**264900**	**800454**	**955672**	**903634**
S44_S	WMD	FLOW	CFS	MEAN	1985	1999	06795	264900	800454	955672	903634
PB-809_G	USGS	WELL	Ft., NGVD	MAX	1975	1999	02669	264124	800537	952104	857562
PB-561_G	USGS	WELL	Ft., NGVD	MAX	1973	1999	02694	264231	801204	916959	864092
PB-109_G	USGS	WELL	Ft., NGVD	MAX	1950	1992	02785	264842	801148	918173	901562
JUPITER_R	WMD	RAIN	Inches	SUM	1976	1998	05888	265623	800603	949103	948322
PLANT IN_R	WPBC	RAIN	Inches	SUM	1944	1999	05966	264254	800344	962287	866724
SIRG	WMD	RAIN	Inches	SUM	1994	1999	15730	265426	801130	919583	936308
C18W_R	WMD	RAIN	Inches	SUM	1992	1999	16603	265219	801442	902277	923377
WPB AIRP_R	WMD	RAIN	Inches	SUM	1991	1999	16610	264041	800635	946873	853183
S46_R	WMD	RAIN	Inches	SUM	1993	1999	16673	265603	800830	935812	946210
WPBFS_R	WMD	RAIN	Inches	SUM	1997	1999	GA832	264122	801105	922335	857199
Haverhill & Earnest	WPB.W. W.T.P	RAIN	Inches	SUM	1999	1999	N/A	264424	800706	943963	875619

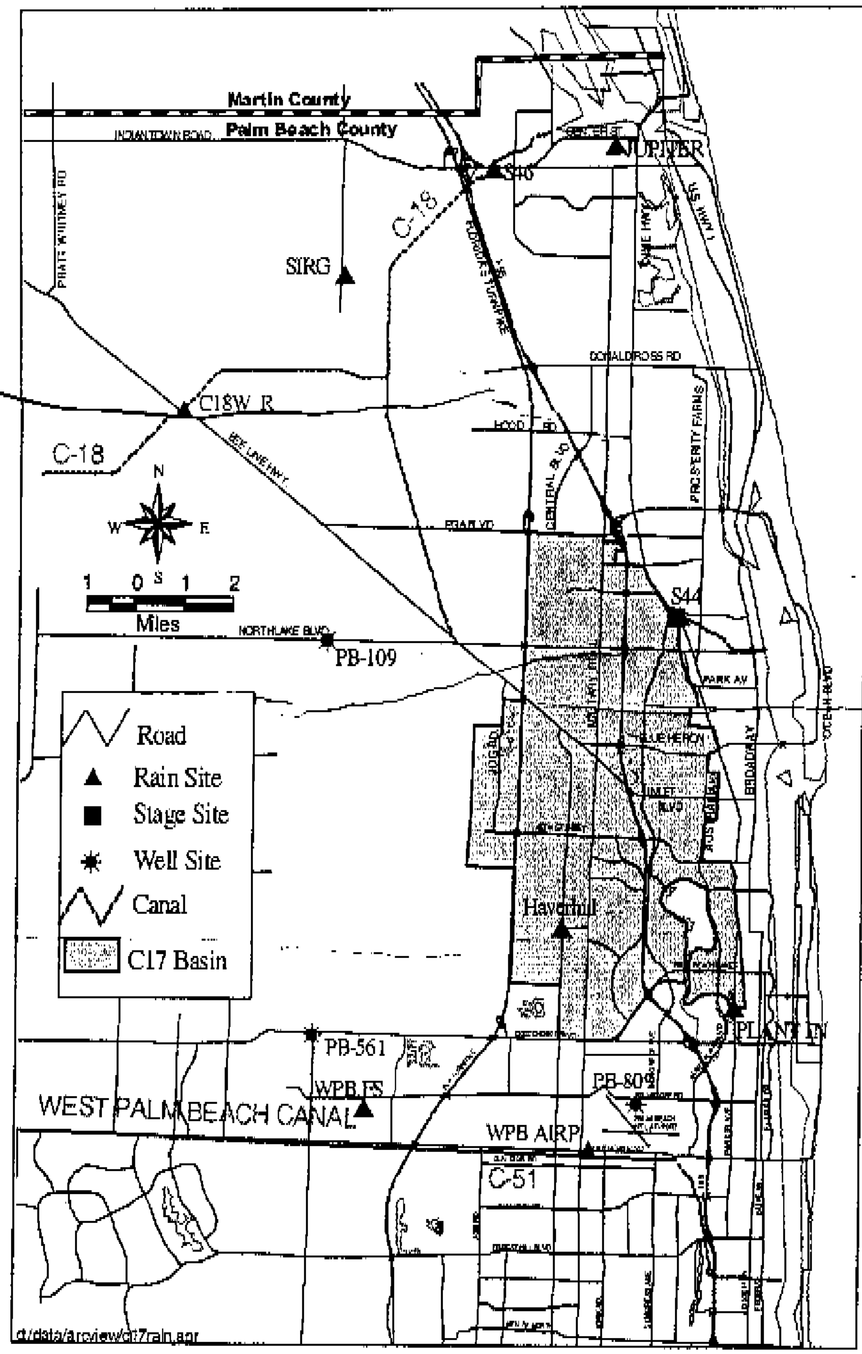

Figure 1. C17 Basin and the nearby stations used for this analysis.

STATISTICAL ANALYSIS

In this section, rainfall at S-44 is expressed in-terms-of:

1) Nearby rainfall data using the Reciprocal Square Distance Interpolation (RSDI),
2) Flow data at S-44 using correlation and regression analysis, and
3) Nearby Groundwater level data using correlation and regression analysis.

The purpose of this exercise is to:

1) Investigate the applicability of each method in providing consistent rainfall estimation with the hydrologic conditions reported on these days;
2) Provide a useful check if any other source of information is made available (e.g., radar data);
3) Benefit the subsequent water budget computation.

Rainfall estimation using neighbor stations.

The average distance between S-44 and the nearest eight stations is about 9.3 miles with the nearest station (PLANT IN) located 7 miles to the southeast. Given the nature of such a local rainfall storm, these stations are not near enough to provide a realistic representation for this storm. Using the Reciprocal Square Distance Interpolation, RSDI, Method (Tabios and Salas, 1985, Abtew et. al., 1993), and the nearest eight rainfall stations, the estimated rainfall on the 2nd, the 3rd, and 17th of January of 1999 are: 4.6, 1.5, and 1.8 inches. The estimates on the 2nd and 3rd are not consistent with other sources of information such as reported flooding, radar data, and flow discharge at S-44 structure. However, the January/17th estimate is consistent with that based on the Rainfall-Flow analysis. It was concluded that the January 2nd and 3rd events at S-44 can not be estimated using the surrounding rain gages.

Rainfall-Flow Correlation and Regression

Correlation and linear regression analysis was conducted between S-44 daily rainfall (inches) and daily flow (cfs) data for several minimum rainfall "cut-off" values. Table 2 shows the results of this analysis. Rainfall data with minimum cut-off value of 1.0-inch shows the highest correlation (0.75). Table 3 shows the regression coefficients, the observed flow and the estimated rainfall on the 2nd, 3rd, and 17th of January of 1999.

Table 2. S-44 Rainfall-Flow Correlation and Regression results.

cut-off (inches)	Correlation	Lag (days)	Number of observations	Regression	
				a	b
0.5	0.724	0	296	0.25	0.00471
1.0	0.749	0	134	0.49	0.00506
1.5	0.749	0	65	0.70	0.00521
2.0	0.704	0	42	0.79	0.00509

Table 3. Observed flow and estimated rainfall at S-44 based on Rainfall-Flow Analysis.

Date	Flow (CFS)	Rainfall (inches)	NOTES
01/02/99	1902.5	10.12	Rainfall (inches) = 0.49+0.00506*Flow (cfs)
01/03/99	1132.96	6.22	Regression coefficients are estimated based on 1 inch
01/17/99	267.23	1.85	minimum rainfall cut-off value, and 134 data points.

Rainfall-Groundwater level Correlation

Three groundwater level stations (PB-809_G, PB-561_G, and PB-109_G) were used for this analysis. The distance of these stations to S-44 are 8.75, 10.50, and 7.11 miles respectively. A Correlation analysis between a three-day moving sum of S-44 rainfall and the corresponding water level change within this window shows that station PB-109_G is highly correlated with S-44 rainfall data while the other two stations are poorly correlated. Table 4 presents the correlation and regression analysis results for "PB-109_G" for several minimum cut-off values of three-day rainfall.

Table 4. Rainfall-Groundwater level Correlation and Regression results.

cut-off (inches)	Correlation	Lag (days)	Number of observations	Regression	
				a	b
1.0	0.83	0	63	1.04	6.89
1.5	0.89	0	31	1.39	7.11
2.0	0.92	0	15	1.69	7.05
2.5	0.93	0	10	1.84	6.97

Table 4 indicates a robust correlation structure between water levels at station "PB-109_G" and three-day rainfall sum at S-44. Unfortunately, water level data are not available beyond May/1992 at this station. Therefore, a direct estimation of rainfall using the PB-109_G station is not possible. However, this rainfall-water level relationship is useful for the water budget computation. Based on 1-inch minimum rainfall cut-off value, this relationship is given as follows:

$$\rho_t = 1.04 + 6.89 * \Delta w_t$$

where:

ρ_t= rainfall sum, in inches, in a three-day period up to "t" day.

Δw_t = Water level change, in feet, within the same period.

WATER BUDGET ANALYSIS

As mentioned earlier, rainfall is the only source of water supply to the C17 basin. Based on S-44 daily flow data (Figure 2), it is noticed that the January 2nd storm effect on the S-44 flow lasts up to the 15th of January. Therefore, the water budget analysis was considered for the period between the 2nd to the 15th of January (14 days) within the C-17 basin. The water budget components are:

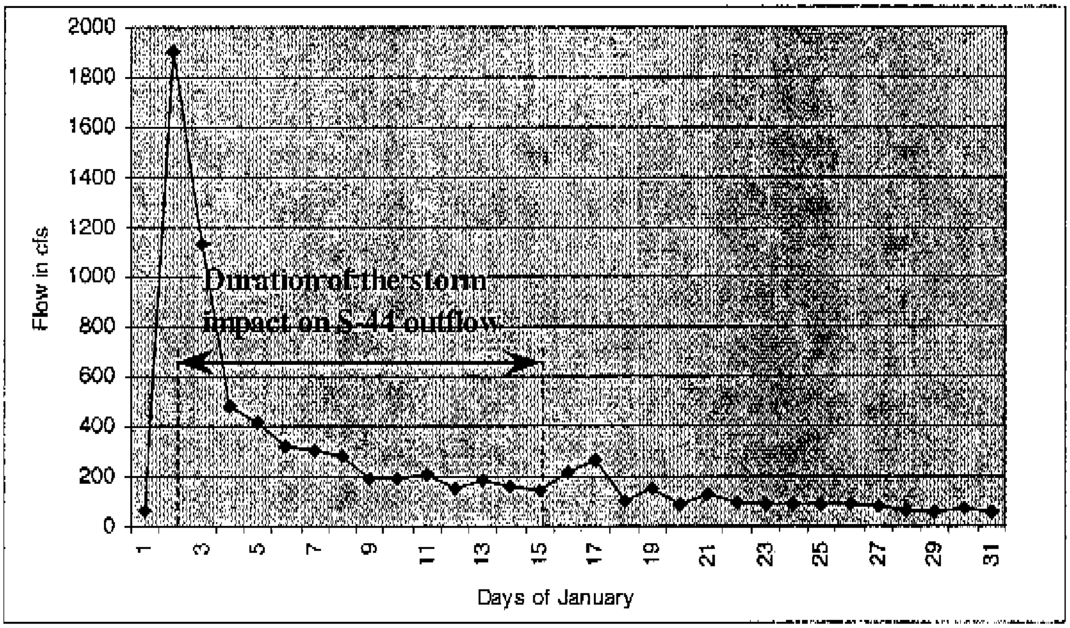

Figure 2. S-44 Outflow during January.

Rainfall

Rainfall accumulated over the period of January 5th to the 15th was 0.71 inch.
Rainfall accumulated over the budget period = rainfall of January (2, 3, and 4) + 0.71

$$= \rho_4 + 0.71$$

Evapotranspiration (ET)

Based on evapotranspiration study at the Everglades Nutrient Removal Project (Abtew, 1996), January daily ET is 0.1 inch. Therefore, the ET over the budget period is estimated as:

ET = 0.1*14= 1.4 inches.

S-44 outflow

S-44 discharge volume = 12075 ac-ft.,
equivalent depth in inches = discharge volume/(total area in acre)*12
= 12075/(33*640)*12= 6.86 inches.

Change in storage

$\delta = \Delta w_t * 12 * n_e$
$= (\rho_t - 1.04)/6.89 * 12 * n_e$, where:
ρ_t= rainfall sum in a three-day period up to "t" day.

δ = Change in subsurface storage in inches.
n_e = Effective porosity; dominant soil type is Basinger and Myakka fine sand. An average value for the effective porosity for sandy soils is 0.32 inch (Marsily, 1986).

Water Budget Computation

The general mass balance equation is:

IN-OUT = Change in the storage.

Where:

IN = Rainfall depth accumulated during this period;
OUT = Evapotranspiration, and equivalent depth due to S-44 outflow;
Change in storage = Depth of water causing volume change in surface and subsurface storage.

Given the above components, effective porosity of 0.32, and assuming no significant change in surface storage between the beginning and end of the water budget analysis period.;

$\rho_4 + 0.71 - (1.4 + 6.86) = \delta = (\rho_4 - 1.04)/6.89 * 12 * n_e$
$0.44 * \rho_4 = 6.97$
$\rho_4 = 15.84$ inches.

Since rainfall on January/4th is 0; the rainfall sum for the 2nd and the 3rd of January is 15.84 inches.

Based on the rain-flow computation, rainfall on the 2nd and 3rd is 10.13 and 6.23 inches respectively. Using the same proportions; rainfall, based on water level correlation, is 9.81 and 6.03 inches on the 2nd; and 3rd respectively.

CONCLUSION

In this study, the estimation of questionable rainfall data at S-44 was carried out using statistical and water budget analyses. In the statistical data analysis, three sources of data were used (nearby rainfall data, S-44 flow data, and nearby groundwater level data). Estimation provided by the RSDI method using rainfall data from surrounding gages is inconsistent with the hydrologic conditions and radar data reported in that area on January 2nd and 3rd. However, such an estimate on the 17th is consistent with that estimated by the rainfall-flow analysis. The rainfall-flow analysis and the water budget analysis provided consistent estimates. Using the available information and the results of these analyses, average estimated rainfall on January 2nd, 3rd, and 17th are 10, 6, and 1.8 inches respectively.

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