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USE OF A HURRICANE STORM-SURGE FORECAST MODEL FOR SOUTHEAST LOUISIANA

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FOREWORD

The potential for a catastrophic hurricane disaster in Southeast Louisiana is well recognized. It is because of this threat that the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service developed a local storm surge forecast model for extreme Southeast Louisiana and a small portion of South Mississippi. This paper is intended to prepare the user for proper interpretation of the model output and suggest a number of ways it may be used. It is deliberately limited in technicality since many of the users of the model results may have a limited scientific background.

INTRODUCTION

This local storm-surge forecast model, referred to as SLOSH, estimates the Sea, Lake and Overland Surges from Hurricanes (Jelesnianski and Chen, 1979). The substance of SLOSH is a set of mathematical equations which represents those laws of physics that describe the motion of water over a surface, in this case the complex topography of extreme Southeast Louisiana and a small portion of South Mississippi. The equations are simplified and written in a special computer language. One of NOAA's National Weather Service computers is used to solve these equations for each particular set of hurricane conditions. A catalog of results for 54 selected hypothetical hurricanes is available from NOAA's New Orleans Area Weather Service Forecast Office at 1120 Old Spanish Trail, Slidell, Louisiana 70458.

For a valuable analysis derived earlier from the model output it is suggested that users study the results presented in Hurricane Surge Potentials Over Southeast Louisiana as Revealed by a Storm-Surge Forecast Model: A Preliminary Study (Crawford, 1979). Crawford used data from several past hurricanes including Betsy (1965) and Camille (1969) to test the SLOSH Storm-Surge Forecast Model. The estimated maximum water levels and time histories were in good agreement with the historical observations. He also presented the storm surge potentials for a variety of hypothetical hurricanes.

Forecasters at NOAA's New Orleans Area Weather Service Forecast Office in Slidell, Louisiana used the SLOSH Model in real-time operations for hurricanes Babe in 1978, and Bob and Frederic in 1979. The forecasts were reasonably accurate. As a result the model was useful for preparing official hurricane statements and for briefing local officials.

In the future, local, state and federal planners may wish to utilize the results of this model for a variety of purposes. Storm surge damage may be mitigated by the wise use of zoning and building codes that are based in part on the results of the model output. The location and elevation of roadways used for evacuation could be determined more effectively through the use of these results. Evacuation procedures can be developed more objectively. During real-time hurricane emergencies evacuation may be carried out more safely and effectively. The catalog may also be used by forecasters as a source of back-up information in the event of computer or communication failure.

In order to aid users of the SLOSH Model, this paper was prepared to provide a set of instructions in the proper use of the model output. It may be used to interpret either the results presented in the catalog or the output obtained from individual model runs.

DESCRIPTION OF MODEL OUTPUT AND INPUT

The SLOSH Model estimates the highest water level above mean sea level (msl) from hurricane storm surges in extreme Southeast Louisiana and a small portion of South Mississippi. This data is printed on a 46 x 37 point grid mesh spaced at 4 statute mile intervals (See Figure 1). The time history of the rise and fall of the surge is also estimated by SLOSH for the following ten locations: Mandeville, West End, Midlake, Frenier, Irish Bayou, Rigolets-US 90, Rigolets-Outlet, Chef Menteur Pass, Shell Beach and Biloxi (See Figure 2).

The meteorological data used to drive the model includes the following:

1. Initial water level for Lake Pontchartrain and Southeast Louisiana and Mississippi coastal waters in feet above mean sea level.

2. Initial meteorological conditions that define the hurricane's location in latitude and longitude, intensity as determined by mean environmental pressure less the central pressure in millibars (mb), and the storm radius as defined by the distance in statute miles from the storm center to the ring of maximum winds.

3. Position of the storm center and meteorological data at 6 hour intervals out to 24 hours.

INTERPRETATION OF SLOSH FORECASTS

Proper interpretation of the model output <u>must</u> consider a number of factors.

1. The estimates of surge heights are only as good as the forecast data that drives the model. Using historical data the heights are usually accurate within a range of plus or minus 20% when compared to observed values (Crawford, 1979). Therefore, the model results are reasonably good for long range planning activities. However, during real-time hurricane operations most of the data-input is forecast information and subject to error. Such errors induce a further reduction of accuracy of the output during real-time operations. This is exemplified later in this report when a comparison of similar storms on parallel paths spaced at 20 mile intervals is presented.

2. Topographic features input into the model were derived from historical data which may not be entirely current. This data was taken from Storm Evacuation Maps prepared by the National Ocean Survey and topographic charts of the U.S. Geological Survey. Levee heights were obtained from the U.S. Army Corps of Engineers.

3. The rather coarse grid mesh of 4 statute miles is a limiting factor in the model's resolution because the complex terrain, levee, roadway and other features cannot be described in detail.

4. The model does not take into account astronomical tidal effects, rainfall or wind generated waves which may over-top levees or other geographical features. These must be accounted for when evaluating the estimates of surge heights.

5. The elevation of topographical features must be considered when estimating the depth of the water at a point since the surge heights are relative to mean sea level. In addition, these estimates represent an average water height in the 4 statute mile grid square. Therefore, to estimate the water height above land, consideration must be given to water heights predicted in surrounding grid squares. Also, the elevation of the location under consideration must be subtracted from the model estimate.

6. One of the most important points to note is that the model output is predicted on the premise that the various levee systems and elevated roadways will remain structurally sound.

DESCRIPTION OF STORMS CONSIDERED

An infinite variety of storm intensities, sizes and movements may be considered. Practical considerations dictated a need to limit the number of hypothetical hurricanes to 54. Some of the considerations used in determining the sample characteristics and number include limited manpower, Gulf of Mexico hurricane history, population density and distribution, and topographic features.

Eighteen storm tracks were selected (See Figure 3). Three storm intensities were selected to correspond to the Saffir Simpson Scale (SSS) 1, 3 and 5 (Saffir 1977). These storm tracks were designed to provide output useful for evaluating storm surge potentials in Orleans and surrounding parishes of extreme southeast Louisiana. SSS-1 is typified by a central pressure of 970 mb at landfall and is similar in intensity to Hurricane Bob of 1979. SSS-3 corresponds to about 940 mb, similar to Betsy in 1965 and SSS-5, a 910 mb storm, is typified by Hurricane Camille in 1969.

In order to simplify the project, each storm was assumed to move on a straight line path at 12 mph and had a radius of maximum winds of 20 nautical miles. The initial water heights selected for SSS-1 & 3 storms were 2 ft msl in Lake Pontchartrain and 1 ft msl for the coastal waters of Southeast Louisiana. For SSS-5 storms these water heights were 4 ft msl and 2 ft msl respectively. These figures are representative of Gulf of Mexico hurricanes. In evaluating the catalog of results in this report these simplifications must be carefully considered.

USE OF THE MODEL OUTPUT

In order to use the model output it will be necessary to obtain a copy of the SLOSH Catalog of Results. The catalog includes a set of overlays and forms which may be used to aid the user in interpreting the model output. The legend for the catalog is shown on page vi.

Highest Storm Surge. The printout of highest surges is the most useful output of the model. However, when evaluating the height of predicted flooding, attention must be focused on the topographic height of the area of interest and features such as levees, roadways, waterways, spoil areas, etc. In some cases these features may block the movement of water, while in other cases they may accelerate it. As a result, more or less flooding may occur at any one point of interest than indicated by the estimated highest surge. Remember that this height represents the mean highest water level in a 4 statute mile square block.

We can assess the storm surge potential from any of the hypothetical hurricanes by aligning the geographic and/or block overlays contained in the catalog over the data printout labeled "Surface Envelope of Highest Surges...etc". The geographic overlay includes topographic height contours, and also includes the demarcation of other useful features. This is used to help the user locate cities, roads, levees, natural boundaries, etc. The block overlay includes parish boundaries & selected grid blocks.

In order to evaluate the potential level of flooding in a particular region, for example a parish, use Form SP-1 (SLOSH, Pontchartrain 1). Blank copies are included in the appendix and catalog. Examples 1 and 2 illustrate a completed SP-1. Here is a step-by-step procedure.

1. Align the block overlay over the printout of highest surges for storm track 3, path A, level 1.

2. Select the grid point you wish to consider. Enter the number of the row (located along left side of printout) and the column (top of printout) in the blanks for block identification number at the top of Form SP-1.

3. Mark the block surrounding the grid point under consideration on the overlay with a pencil. This will aid in identifying the block as you complete the form.

4. Enter the figure for the highest surge shown on the printout. Repeat this procedure for each storm until all 54 blocks in Form SP-1 have been completed.

5. Repeat the above steps for as many locations as needed until enough data is available for the geographical area in which you are interested.

Remember, the values entered in Form SP-1 represent the height above mean sea level estimated by the model. The actual depth of water at a point may be estimated by interpolating between the values on the printout of highest storm surges and subtracting the elevation of the land at that point.

It is easy to evaluate the information that is presented in the completed table. Note from the geographic overlay that the grid point in Example 1 lies along the open coast near Southwest Pass. This particular location would receive the highest surges from hurricanes along paths 7C and 6A. Both of these paths pass very close to the grid point and are from the southeast. This result appears to be logical. However, the situation becomes a little more complicated when an inland grid point is considered since features such as roads, levees and variation in natural elevations increase the complexity of topography.

In Example 2, Form SP-1 has been completed for Row-40, Column 8. This location is near Port Sulphur on the west side of the Mississippi River. As you can see by examining the table, this particular point is harder to evaluate. Note that if we examine each storm intensity separately we find that for a SSS-1 hurricane the highest surge is associated with path 3N. The next to highest for the SSS-1 was for path 5A. If this is repeated for each level of storm intensity it may be determined that the highest surges for SSS-1 & 3 storms occur when the path is from the south-southwest. For SSS-5 storms the highest surge occurs when the hurricane approaches from the southeast. The reason for this could be the fact that SSS-5 storms approaching from the southeast may produce storm surges which over-top the levee. In order to more fully understand the storm surge characteristics, surrounding grid points would also have to be evaluated.

A major pitfall of the procedure outlined above occurs in the case when a levee crosses a block. Figure 4 illustrates such a case. The model "sees" the levee along the vertical and horizontal lines which define the block. In Figure 4 the series of "L's" demonstrates where the model "sees" the levee. The actual position of the levee is shown by the heavy dotted line. In this case, for example, it cannot be assumed that the average water level on both sides of the levee is 13.0 ft msl as indicated in Figure 4. The average water level in a_1 and a_2 may be different and must be manually estimated as follows.

1. Estimate the mean level of the topographic surface areas in a_1 and a_2 from the height contours on the geographic overlay. In this case let's assume a_1 is in Lake Pontchartrain and averages -10 ft msl. We'll also assume a_2 is over normally dry land and averages +5 ft msl. The area of the entire block is represented by the letter A.

2. Estimate the area of A, a_1 and a_2 in ft^2. Recalling that the area of a square is simply the square of the length of its side and that the area for a triangle is one half its base times its height, we may proceed.

$A = \ell^2 = (4\ mi)^2 = 16\ mi^2$

$A = (16\ mi^2) \times (5280\ \frac{ft}{mi})^2 = 446{,}054{,}400\ ft^2$

$A \simeq 4.46 \times 10^8\ ft^2$

$a_2 = \frac{1}{2} \times b \times h = \frac{1}{2} \times 3 \times 4\ mi^2 = 6\ mi^2$

$a_2 = (6\ mi^2) \times (5280\ \frac{ft}{mi})^2 = 167{,}270{,}400\ ft^2$

$a_2 \simeq 1.67 \times 10^8\ ft^2$

$a_1 \simeq A - a_2 \simeq (4.46 - 1.67) \times 10^8\ ft^2$

$a_1 \simeq 2.79 \times 10^8\ ft^2$

3. Estimate the volume v_1 represented under a_1. This is simply the product of a_1 and the average depth d_1 of the water under a_1. Since the water level in a_1 must reach at least 14 ft msl before water spills into a_2, we may assume the height of the water in a_1 will be roughly 14 ft msl, which is the height of the levee. Therefore d_1 may be roughly estimated as the sum of the height of the levee and the mean depth below msl of the lake bottom.

$v_1 = a_1 \times d_1 \simeq (2.79 \times 10^8\ ft^2) \times (14\ ft + 10\ ft)$

$v_1 \simeq (2.79 \times 10^8) \times (24)\ ft^3$

$v_1 \simeq 6.696 \times 10^9\ ft^3$

4. Estimate the total volume V represented under area A, based on the average figure of 13.0 ft msl maximum storm surge height. This average figure is only correct for this compututational purpose. V may be estimated by adding v_1 and v_2. Letting d_1' and d_2' represent the average depths under both a_1 and a_2 we may proceed.

$V = v_1 + v_2 = a_1\ d_1' + a_2\ d_2'$

$V \simeq (2.79 \times 10^8\ ft^2) \times (13\ ft + 10\ ft) + (1.67 \times 10^8\ ft^2) \times (13\ ft - 5\ ft)$

$V \simeq 64.17 \times 10^8\ ft^3 + 13.36 \times 10^8\ ft^3$

$V \simeq 77.53 \times 10^8\ ft^3 \simeq 7.753 \times 10^9\ ft^3$

5. Subtract the volume v_1 computed in step #3 from V to obtain v_2.

$$v_2 = V - v_1 \simeq 7.753 \times 10^9 \text{ ft}^3 - 6.696 \times 10^9 \text{ ft}^3$$

$$v_2 \simeq 1.057 \times 10^9 \text{ ft}^3$$

6. Now to find the actual average water depth above ground level (agl) under area a_2 simply divide v_2 by a_2 .

$$d_2 = \frac{v_2}{a_2} \simeq \frac{1.057 \times 10^9 \text{ ft}^3}{1.67 \times 10^8 \text{ ft}}$$

$$d_2 \simeq 6 \text{ ft agl}$$

Time histories of Surge at Selected Locations. For each hurricane simulated in a model run a time history of the estimated surge is computed for the following ten locations: Mandeville, West End, Midlake, Frenier, Irish Bayou, Rigolets-US 90, Rigolets Outlet, Chef Menteur Pass, Shell Beach and Biloxi.

As noted in "Description of Model Output and Input" time and location must be input into each model run at intervals of 6 hours. This implies both direction and speed of movement. The time intervals are in 6 hour increments labeled T00, T06, T12, T18 and T24. The input data is selected such that at T12 the storm is forecast to be nearest grid point 0,0 (downtown New Orleans). Data for T24 is the final input to the run. You will notice that the model automatically runs an additional 3 hours after T24 and begins 9 hours prior to T00. Therefore, the total output available is for 36 hours. These time extensions are built into the model to allow it to have sufficient time to develop representative surge heights.

The time histories of surge heights are printed in 30 minute increments on the left hand side of the time history printout (Figure 2). In the catalog date and time are arbitrary in each run since these are only simulated hurricanes. A simple means of evaluating the time histories is to plot the height of the surge versus time. Figure 5 illustrates cases of hurricanes of different intensities that move along the same path. This storm path is 4A and the storm strengths SSS-1, 3 and 5. Note from the graph that the highest surge occurs about 4 to 9 hours after the storm makes its closest approach to downtown New Orleans. At that time the storm is centered northeast of Mandeville. The lowest water level occurs when the storm is close to downtown New Orleans, at T12 - T15. The highest surge occurs with the more intense storm, the SSS-5. The time interval between lowest and highest water levels is shorter for the more intense storms.

Figure 6 illustrates the case of storms of the same intensity along 3 parallel paths. This example demonstrates how a storm track difference of a few miles east to west can affect the surge time history at a particular location. Paths 4A and 4N produce nearly identical results while 4C indicates a much higher surge which occurs about 4 hours earlier than in the 4A and 4N cases.

Each user may wish to select several of the 10 locations in order to evaluate the time history of storm surges in a particular area of interest. By interpolating between points you may construct an approximate time history graph at locations other than one of the 10 locations on the printout. Graph Forms SP-2 are available in the appendix.

In addition the model may be specially programmed to obtain time histories at any grid point desired. The catalog does not contain this additional information because it would be too voluminous.

The time histories are especially useful for evacuation planning. Time histories may be graphed at points where evacuation routes are at their lowest elevations. These graphs may be used to determine estimates of when the route will be closed by flooding from the storm surge.

Surge Height Field at 2 Hour Increments. The complete data set for a model run includes output of the surge height field at 2 hour increments. Unfortunately this part of the data set is also too voluminous to include in the SLOSH Catalog of Results. However, complete copies of the entire model output for all 54 runs which includes this information are available at the New Orleans Area Weather Service Forecast Office in Slidell, Louisiana.

The data contained in the output of the surge height field may be used to estimate when significant flooding may occur with any particular storm in any of the grid blocks. Form SP-3 shown in the appendix has been prepared to facilitate the use of this output. A completed sample is also shown in the Appendix (Example 3).

CONCLUDING REMARKS

There may be many other means by which the SLOSH Model output can be presented and analyzed. Those described in this paper represent a few that were developed at the New Orleans Area Weather Service Forecast Office. In addition, the 54 cases available in the SLOSH Catalog are only a fraction of those that may be run. Individual communities may have a need for a few "worst cases" storms that are not included in the catalog.

NOAA's National Weather Service Techniques Development Laboratory recently modified the SLOSH Model to use a finer grid mesh than the version presented in this paper. The output from the finer mesh model will provide much greater resolution for the user and probably a small increase in accuracy.

Finally, NOAA National Weather Service strongly urges those government and industry officials responsible for hurricane safety to increase their efforts to diminish the effects of a potentially catastrophic hurricane disaster in the Greater New Orleans Area. The results of the SLOSH Model should provide valuable information that may be used in achieving this goal.

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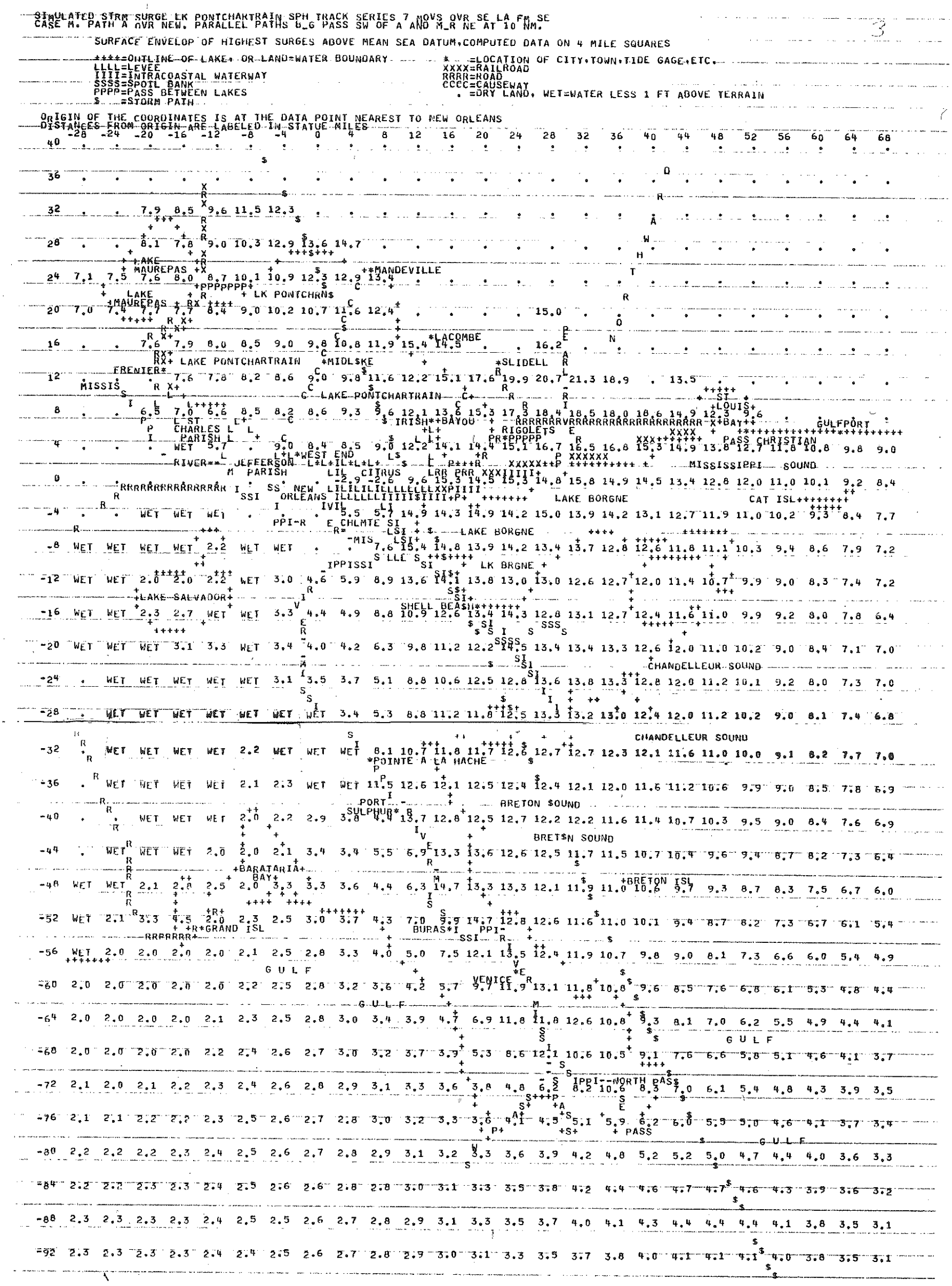


FIGURE 1

Example of SLOSH Model estimates of highest hurricane surges above mean sea level on a four statute mile grid.

SIMULATED STRM SURGE LK PONTCHARTRAIN SPH TRACK SERIES 7 MOVS OVR SE LA FM SE
CASE N. PATH A OVR NEW. PARALLEL PATHS B-G PASS SW OF A AND M-R NE AT 10 NM.
TIME HISTORIES OF SURGES AT SELECTED GAGES OR GRID POINTS

HOUR DAY MTH YEAR	MANDEVELLE WEST END 11.5,32.0	9.5,27.0	MIDLAKE 10.3,29.7	SEABROOK BR I BAYOU 11, 27	RGLETS-US90,-OUTLET 14, 28	CF MNTUR PS SHELL B 15, 27	17, 26	14, 26	15, 23	BILOXI 29, 27
0500 25 SEP 1978	COMPUTATIONS BEGIN									
	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
0530	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
0600 25 SEP 1978	2.00	2.00	2.00	2.01	2.00	2.00	1.99	2.00	2.00	0.99
	1.99	2.01	2.00	2.01	2.00	2.00	1.99	2.00	2.01	0.99
0630	1.99	2.01	2.00	2.01	2.00	2.00	1.99	2.00	2.02	0.98
	1.98	2.02	2.00	2.02	2.00	2.00	1.98	2.00	2.02	0.97
	1.97	2.03	2.00	2.03	2.00	2.01	1.97	1.99	2.03	0.96
0700 25 SEP 1978	1.96	2.04	2.00	2.04	1.99	2.01	1.96	1.99	2.05	0.95
	1.94	2.06	2.00	2.05	1.99	2.01	1.95	1.99	2.06	0.93
0730	1.93	2.07	2.00	2.05	1.99	2.01	1.96	1.99	2.06	0.91
	1.91	2.09	2.00	2.07	1.99	2.01	1.94	1.99	2.08	0.89
	1.89	2.11	2.00	2.09	1.98	2.01	1.93	1.98	2.11	0.86
0800 25 SEP 1978	1.87	2.13	2.00	2.10	1.98	2.01	1.91	1.98	2.14	0.83
	1.85	2.15	2.00	2.12	1.97	2.01	1.90	1.98	2.17	0.80
	1.83	2.17	2.00	2.13	1.97	2.01	1.89	1.97	2.19	0.76
0830	1.81	2.19	2.00	2.14	1.96	2.01	1.88	1.97	2.23	0.73
	1.78	2.20	2.00	2.15	1.96	2.01	1.87	1.96	2.26	0.70
	1.76	2.22	2.00	2.16	1.95	2.01	1.87	1.96	2.29	0.67
0900 25 SEP 1978	1.74	2.24	2.00	2.17	1.95	2.01	1.86	1.96	2.31	0.64
	1.73	2.25	2.00	2.18	1.94	2.01	1.86	1.96	2.34	0.61
	1.71	2.26	2.00	2.18	1.94	2.00	1.86	1.95	2.37	0.58
0930	1.72	2.24	2.00	2.17	1.95	2.00	1.91	1.97	2.30	0.58
	1.71	2.25	2.00	2.19	1.95	2.00	1.90	1.97	2.33	0.54
	1.69	2.26	2.00	2.20	1.94	2.00	1.88	1.97	2.37	0.51
1000 25 SEP 1978	1.68	2.27	2.00	2.21	1.94	2.00	1.87	1.97	2.41	0.47
	1.68	2.28	2.00	2.21	1.93	2.00	1.87	1.97	2.44	0.44
	1.67	2.28	2.00	2.21	1.93	2.00	1.86	1.97	2.47	0.42
1030	1.67	2.29	2.00	2.21	1.93	1.99	1.86	1.97	2.50	0.40
	1.66	2.30	2.00	2.21	1.92	1.99	1.86	1.97	2.53	0.39
	1.66	2.30	2.00	2.22	1.92	1.99	1.87	1.97	2.55	0.38
1100 25 SEP 1978	1.65	2.31	2.00	2.22	1.92	1.99	1.87	1.97	2.58	0.38
	1.65	2.31	2.00	2.22	1.92	1.99	1.87	1.98	2.60	0.37
	1.64	2.31	2.00	2.23	1.92	1.99	1.87	1.98	2.62	0.37
1130	1.67	2.28	2.00	2.20	1.93	1.98	1.93	2.02	2.52	0.48
	1.66	2.30	2.00	2.22	1.92	1.98	1.92	2.03	2.56	0.46
	1.64	2.31	2.00	2.23	1.92	1.98	1.90	2.03	2.60	0.44
1200 25 SEP 1978	1.63	2.32	2.00	2.24	1.91	1.98	1.89	2.03	2.64	0.42
	1.62	2.34	2.00	2.25	1.91	1.98	1.88	2.03	2.68	0.41
	1.61	2.34	2.00	2.25	1.91	1.98	1.87	2.04	2.72	0.40
1230	1.60	2.36	2.01	2.26	1.90	1.98	1.87	2.04	2.75	0.39
	1.59	2.37	2.01	2.26	1.90	1.98	1.87	2.04	2.78	0.39
	1.58	2.38	2.01	2.27	1.90	1.98	1.87	2.05	2.82	0.39
1300 25 SEP 1978	1.57	2.39	2.00	2.28	1.89	1.98	1.87	2.05	2.85	0.39
	1.56	2.39	2.00	2.29	1.89	1.97	1.87	2.06	2.88	0.39
	1.55	2.40	2.00	2.29	1.89	1.97	1.87	2.06	2.91	0.40
1330	1.50	2.36	2.01	2.26	1.91	1.98	1.94	2.10	2.79	0.58
	1.56	2.38	2.01	2.28	1.90	1.98	1.93	2.11	2.84	0.56
	1.54	2.40	2.00	2.30	1.89	1.98	1.91	2.11	2.89	0.53
1400 25 SEP 1978	1.53	2.42	2.00	2.32	1.89	1.98	1.89	2.11	2.95	0.51
	1.51	2.43	2.00	2.32	1.88	1.98	1.88	2.12	3.00	0.49
	1.50	2.45	2.01	2.33	1.87	1.98	1.87	2.12	3.05	0.48
1430	1.48	2.46	2.01	2.34	1.87	1.97	1.86	2.12	3.09	0.47
	1.47	2.48	2.01	2.35	1.86	1.97	1.86	2.13	3.14	0.46
	1.45	2.49	2.01	2.36	1.86	1.97	1.85	2.14	3.18	0.46
1500 25 SEP 1978	1.44	2.50	2.01	2.37	1.86	1.97	1.85	2.14	3.23	0.47
	1.43	2.51	2.00	2.37	1.85	1.96	1.85	2.15	3.27	0.47
	1.41	2.52	2.01	2.38	1.85	1.96	1.85	2.16	3.31	0.48
1530	1.45	2.48	2.01	2.35	1.89	1.99	1.97	2.19	3.18	0.72
	1.43	2.50	2.01	2.38	1.88	1.99	1.94	2.20	3.25	0.70
	1.40	2.53	2.01	2.40	1.87	1.99	1.92	2.20	3.32	0.67
1600 25 SEP 1978	1.38	2.56	2.01	2.42	1.86	1.99	1.90	2.21	3.39	0.64
	1.36	2.58	2.01	2.44	1.85	1.99	1.88	2.21	3.46	0.62
	1.34	2.60	2.01	2.45	1.84	1.98	1.87	2.22	3.53	0.61
1630	1.32	2.62	2.01	2.46	1.83	1.98	1.86	2.23	3.60	0.61
	1.30	2.64	2.02	2.48	1.83	1.97	1.85	2.24	3.66	0.61
	1.27	2.66	2.01	2.49	1.82	1.97	1.85	2.25	3.73	0.62
1700 25 SEP 1978	1.25	2.68	2.01	2.51	1.81	1.96	1.84	2.26	3.80	0.63
	1.23	2.70	2.01	2.52	1.81	1.96	1.84	2.28	3.87	0.65
	1.21	2.72	2.01	2.54	1.80	1.95	1.84	2.29	3.94	0.67
1730	1.26	2.66	2.02	2.49	1.88	2.02	2.05	2.35	3.79	1.02
	1.23	2.70	2.02	2.53	1.87	2.02	2.00	2.34	3.90	1.00
	1.19	2.75	2.02	2.58	1.85	2.02	1.97	2.35	4.01	0.97
1800 25 SEP 1978	1.15	2.79	2.01	2.61	1.83	2.02	1.94	2.36	4.12	0.94
	1.12	2.82	2.02	2.64	1.81	2.01	1.92	2.38	4.23	0.92
	1.09	2.85	2.02	2.66	1.80	2.00	1.91	2.39	4.34	0.91
1830	1.06	2.89	2.03	2.68	1.78	1.99	1.89	2.41	4.45	0.91
	1.02	2.93	2.03	2.71	1.77	1.98	1.88	2.43	4.57	0.92
	0.98	2.96	2.03	2.74	1.76	1.97	1.87	2.46	4.69	0.93
1900 25 SEP 1978	0.94	3.00	2.03	2.77	1.75	1.97	1.87	2.48	4.82	0.96
	0.91	3.03	2.03	2.79	1.74	1.96	1.67	2.51	4.94	1.00
	0.87	3.07	2.03	2.82	1.73	1.95	1.88	2.54	5.07	1.05
1930	0.94	2.99	2.04	2.75	1.88	2.10	2.21	2.59	4.87	1.60
	0.88	3.06	2.04	2.83	1.85	2.09	2.17	2.61	5.07	1.59
	0.81	3.14	2.04	2.91	1.82	2.08	2.13	2.63	5.28	1.59
2000 25 SEP 1978	0.75	3.20	2.04	2.97	1.79	2.07	2.11	2.67	5.49	1.60
	0.70	3.26	2.04	3.02	1.75	2.06	2.11	2.71	5.70	1.63
	0.65	3.32	2.05	3.06	1.72	2.04	2.11	2.75	5.92	1.68
2030	0.59	3.39	2.07	3.11	1.70	2.02	2.13	2.80	6.14	1.76
	0.52	3.46	2.07	3.16	1.68	2.00	2.15	2.86	6.38	1.89
	0.45	3.53	2.07	3.22	1.66	2.04	2.13	2.92	6.62	2.06
2100 25 SEP 1978	0.38	3.60	2.07	3.27	1.64	2.02	2.21	3.00	6.87	2.30
	0.31	3.66	2.07	3.33	1.63	2.11	2.20	3.08	7.12	2.59
	0.25	3.73	2.08	3.39	1.63	2.13	2.30	3.10	7.39	2.93
2130	0.34	3.62	2.09	3.27	1.96	2.70	2.78	3.31	7.12	3.95
	0.23	3.75	2.10	3.42	1.97	2.74	2.85	3.41	7.51	4.17
	0.12	3.88	2.11	3.57	1.99	2.80	2.91	3.53	7.94	4.36
2200 25 SEP 1978	0.02	4.00	2.11	3.69	2.00	2.90	2.99	3.69	8.37	4.56
	-0.08	4.11	2.12	3.79	2.03	2.97	3.15	3.88	8.81	4.80
	-0.18	4.22	2.14	3.89	2.06	3.15	3.25	4.12	9.28	5.08
2230	-0.30	4.35	2.17	4.00	2.11	3.29	3.46	4.40	9.76	5.39
	-0.42	4.49	2.19	4.11	2.18	3.53	3.69	4.73	10.18	5.69
	-0.55	4.63	2.20	4.23	2.29	3.92	3.99	5.12	10.52	5.97
2300 25 SEP 1978	-0.68	4.76	2.22	4.36	2.46	4.38	4.54	5.60	10.99	6.24
	-0.82	4.90	2.23	4.50	2.70	5.06	5.21	6.18	11.66	6.50
	-0.96	5.05	2.26	4.65	3.04	5.85	6.05	6.88	12.33	6.75
2330	-0.83	4.93	2.29	4.43	3.52	6.92	7.67	7.69	12.06	6.72
	-1.04	5.19	2.32	4.77	4.11	8.14	8.32	8.58	12.24	6.99
	-1.26	5.47	2.36	5.10	4.88	9.06	9.21	9.64	12.17	7.22
0000 26 SEP 1978	-1.47	5.73	2.40	5.37	5.78	9.87	9.92	10.93	12.06	7.40
	-1.68	5.96	2.47	5.61	6.72	10.37	10.54	12.48	12.13	7.51
	-1.90	6.22	2.59	5.87	7.60	10.85	11.00	14.07	12.48	7.56
0030	-2.13	6.50	2.73	6.17	8.35	11.47	11.61	15.16	12.86	7.57
	-2.37	6.80	2.89	6.48	8.96	12.29	12.38	15.30	13.05	7.55
	-2.62	7.10	3.06	6.81	9.63	13.06	13.08	14.87	13.07	7.51
0100 26 SEP 1978	-2.86	7.39	3.25	7.12	10.30	13.56	13.61	14.51	13.17	7.46
	-3.08	7.67	3.48	7.41	10.81	13.88	13.97	14.50	13.45	7.41
	-3.28	7.95	3.76	7.65	11.01	14.16	14.27	14.72	13.74	7.36
0130	-2.80	7.84	3.90	6.91	9.99	14.40	14.57	14.59	13.21	7.05
	-3.01	8.19	4.23	7.33	10.55	14.21	14.33	14.62	13.13	7.05
	-3.16	8.49	4.56	7.67	11.50	13.99	14.12	14.35	12.84	7.02
0200 26 SEP 1978	-3.21	8.66	4.90	7.85	12.35	14.02	14.04	13.88	12.51	6.94
	-3.11	8.70	5.28	7.92	12.79	14.12	14.21	13.68	12.28	6.82
	-2.85	8.65	5.68	7.98	12.84	14.27	14.36	13.46	12.16	6.68
0230	-2.42	8.56	6.08	8.09	12.76	14.31	14.47	13.23	12.04	6.51
	-1.80	8.44	6.44	8.23	12.72	14.35	14.38	13.27	11.77	6.35
	-0.95	8.28	6.72	8.35	12.76	14.22	14.41	13.56	11.21	6.19
0300 26 SEP 1978	0.16	8.10	6.94	8.38	12.85	14.19	14.39	13.28	10.48	6.04
	1.54	7.90	7.13	8.29	13.14	14.17	14.31	12.84	9.83	5.90
	3.14	7.70	7.34	8.09	13.49	14.07	14.18	12.66	9.39	5.76
0330	5.34	7.49	7.61	8.24	13.62	13.87	14.02	12.13	9.03	5.74
	6.85	7.32	7.90	8.17	13.61	13.72	13.76	11.88	8.78	5.62
	8.14	7.15	8.19	8.08	13.41	13.50	13.36	11.63	8.40	5.51
0400 26 SEP 1978	9.17	6.97	8.46	7.89	13.16	13.09	12.96	11.38	8.15	5.39
	9.93	6.78	8.68	7.65	12.97	12.65	12.61	11.12	7.97	5.29
	10.52	6.61	8.07	7.45	12.88	12.38	12.28	10.87	7.76	5.18
0430	11.05	6.51	9.03	7.39	12.85	12.16	12.07	10.67	7.20	5.08
	11.57	6.51	9.15	7.53	12.78	12.02	11.86	10.55	7.75	5.01
	12.04	6.62	9.24	7.78	12.58	11.78	11.71	10.48	7.84	4.96
0500 26 SEP 1978	12.46	6.77	9.29	7.99	12.25	11.62	11.42	10.43	7.86	4.91
	12.79	6.90	9.33	8.07	11.88	11.33	11.23	10.36	7.86	4.85
	13.05	6.98	9.40	8.00	11.54	11.09	10.99	10.26	7.85	4.79
0530	12.84	7.24	9.49	8.19	11.30	10.87	10.76	10.25	8.15	4.66
	13.08	7.23	9.53	8.08	11.10	10.63	10.55	10.18	8.17	4.66
	13.22	7.25	9.52	8.04	10.89	10.40	10.34	10.13	8.21	4.65
0600 26 SEP 1978	13.18							10.06	8.25	4.64
	13.01							9.97	8.27	4.62
	12.76							9.84	8.24	4.59
0630	12.49							9.71	8.19	4.55
	12.20							9.60	8.12	4.50
	11.88							9.47	8.06	4.44
0700 26 SEP 1978	11.55							9.35	8.01	4.37
	11.23							9.22	7.97	4.29
	10.95							9.11	7.92	4.21
0730	10.79							9.02	8.09	3.84
	10.54							8.94	8.05	3.78
	10.33							8.88	8.01	3.72
	10.17							8.81	7.96	3.65
	10.04							8.73	7.90	3.58
	9.94							8.66	7.84	3.51

FIGURE 2

Example of a portion of SLOSH Model time histories of hurricane surges at 10 selected locations.

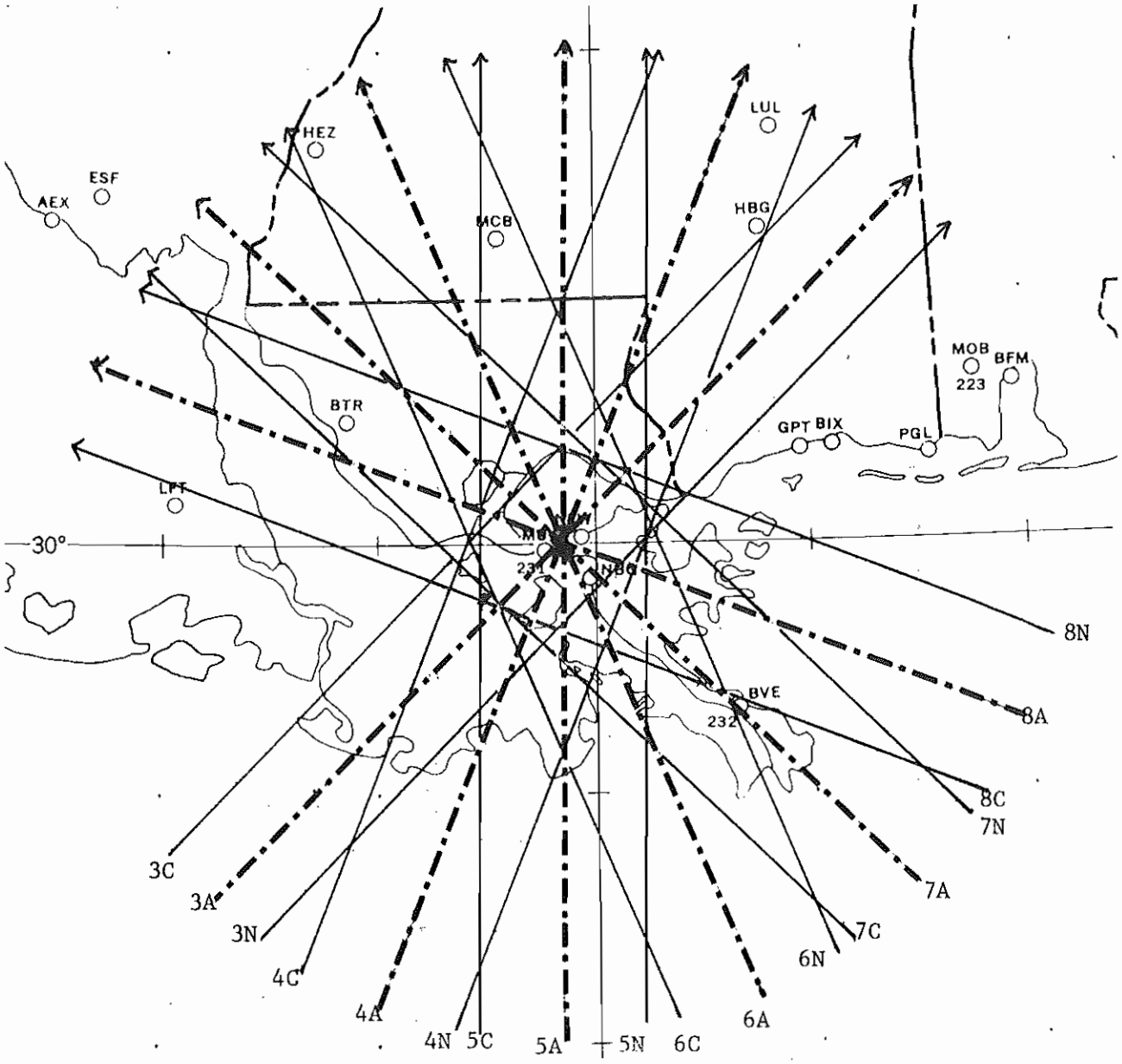


FIGURE 3

18 simulated hurricane tracks.

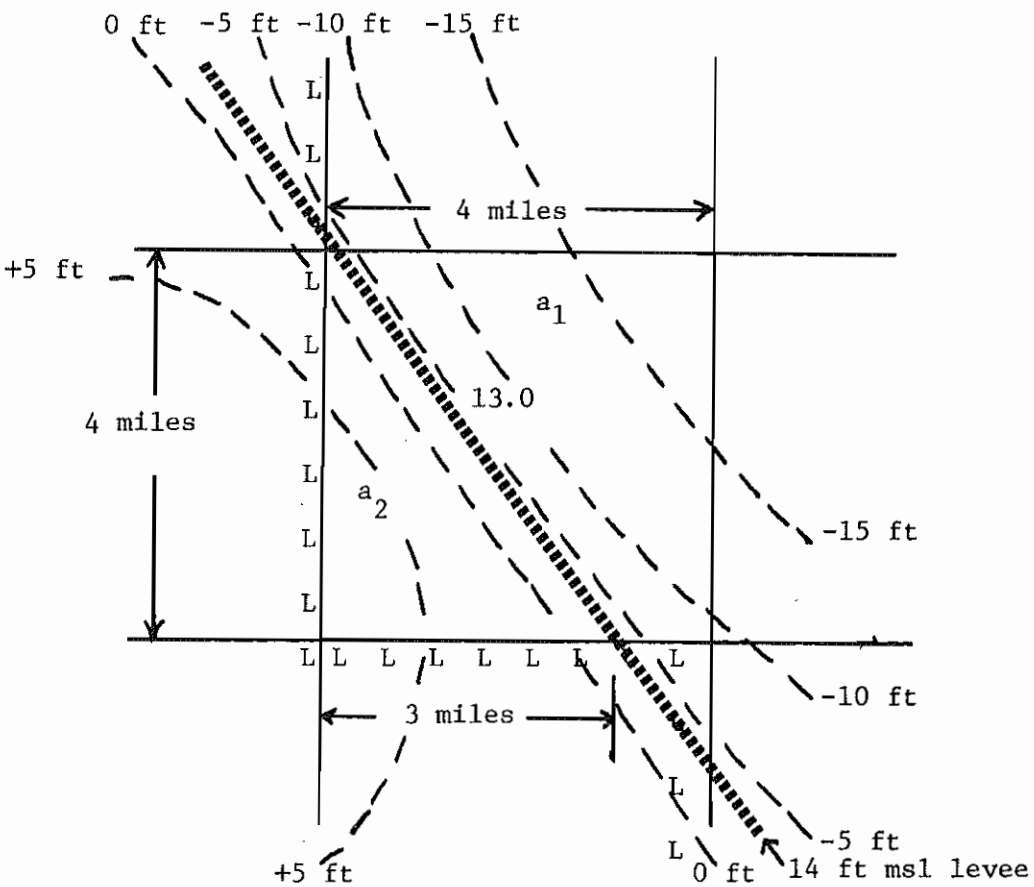


FIGURE 4

Case where a levee crosses a block under consideration.

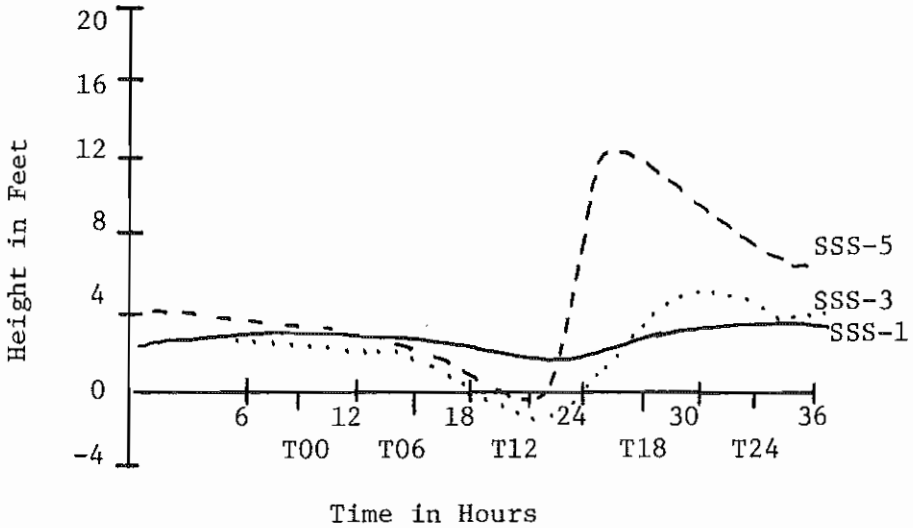


FIGURE 5

Time history of surge for path 4a, SSS1, 2 and 3.

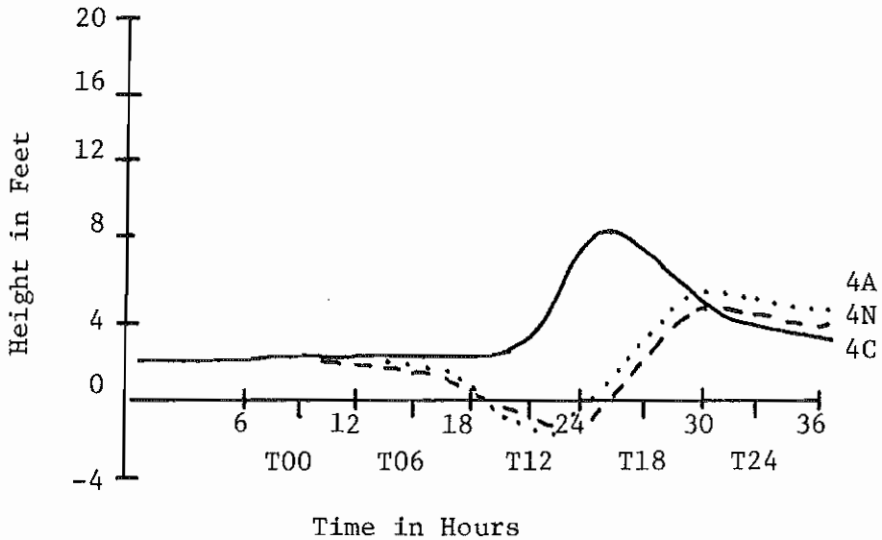


FIGURE 6

Time history of surge for SSS-3, paths 4A, 4C and 4N.

Block Identification No. Row -72 Col 24 Form SP-1			
Storm Path	High Surge Level 1	High Surge Level 3	High Surge Level 5
3 A	2.6	3.1	4.4
C	2.4	2.7	3.9
N	3.1	3.9	5.4
4 A	3.0	3.7	5.2
C	2.6	3.1	4.4
N	3.8	4.9	7.0
5 A	3.9	5.3	7.2
C	3.0	3.7	5.3
N	5.3	7.4	10.3
6 A	5.8	8.1	10.8
C	4.3	6.1	8.6
N	4.1	5.6	7.9
7 A	4.4	5.6	8.0
C	5.6	8.1	11.1
N	2.9	3.4	5.6
8 A	2.8	4.4	4.9
C	4.1	5.7	7.8
N	2.3	2.5	3.6

EXAMPLE 1

Cc ·ted Form SP-1 for block number Row -72,
Cc 24.

Block Identification No. Row-40 Col 8 Form SP-1			
Storm Path	High Surge Level 1	High Surge Level 3	High Surge Level 5
3 A	5.8	11.0	14.8
C	3.5	6.8	10.5
N	9.8	15.9	17.5
4 A	7.6	13.0	15.6
C	4.1	7.7	11.2
N	8.9	14.9	17.8
5 A	9.6	15.5	17.8
C	5.2	9.2	13.7
N	WET	8.6	18.8
6 A	5.8	14.0	18.7
C	WET	12.3	17.7
N	7.4	13.6	16.7
7 A	WET	10.7	19.0
C	6.3	14.4	18.8
N	WET	WET	6.8
8 A	WET	8.1	10.5
C	3.6	14.9	20.0
N	WET	WET	6.8

EXAMPLE 2

Completed Form SP-1 for block number Row -40
Column 8.

	SW 40	W 70	SW 40	W 40												
				SE 130	S 40	SE 200	W 50	W 50								
S 40				SE 200	SE 200											
S 40	SE 220		SE 180													
		SW 40								SE 220				W 50		
		SW 40										W 50		S 40		
		SW 40	SE 200	SE 200									S 40	S 40	SW 40	
W 50	W 50	W 90		W 50									S 40	S 40	SE 220	
W 50	W 50	W 50	W 50	W 50						SW 40	SE 220	SE 200				
W 50	SW 40	SW 40	SW 40	SW 40	W 50			SW 40	SW 40							
SW 40	S 40	SE 200	SW 40		SW 40	SW 40			SW 40	SE 220					SE 220	
SE 200	SE 200				SW 40	SW 40	S 70	S 70	S 70	S 40	SE 200			SE 220	SE 220	
SE 220	SE 220			SE 220	SE 220	SW 40	S 70	S 70	S 70	SE 110	SE 110	S 50	SE 220	SE 200	SE 200	
SE 220	SE 220	SE 220	SE 220	SE 220	S 40	S 40	S 90	S 70	S 70	SE 110	SE 150	SE 180	SE 180	SE 220	SE 200	SE 200
W 50	SE 220	SE 220	SE 220	SE 200	S 50	S 40	SE 110	SE 110	S 70	S 90	S 90	SE 220	SE 200	SE 220	SE 220	
SW 40	SE 200	SE 200	SE 200	SE 180	S 50	S 50	SW 40	SE 200	SE 200	SE 220	SE 220	SE 220	SE 220	SE 220		
SW 40	SE 180	SE 180	SE 180	SE 180	SE 220	S 50	S 50	S 50	SE 220	SE 220						
SW 40	SE 150	S 110	S 110	SE 150	SE 220	SE 200	S 70	S 50	SE 220	SE 220						
SW 40	S 50	S 90	SE 220	SE 220			SE 220	S 70	S 70	SE 220						
S 50	SE 220	SE 220	SE 220				SE 180	SE 220	SE 220	SE 220	SE 180					
SE 220	SE 220	SE 220					SE 180	SE 220	SE 220	SE 220	SE 180	SE 180				
SE 220	SE 220	SE 220							SE 180	SE 220	SE 220	SE 180	SE 180			
SE 220										SE 180	SE 220	S 90	SE 220			
											SE 220	SE 130	SE 220	SE 220		
												SE 180	SE 180	SE 220	SE 180	SE 180
												SE 180	SE 180	SE 220	SE 180	SE 180
													SE 220	SE 220	SE 220	SE 200	SE 220
															SE 220	SE 220	

EXAMPLE 3

Storm Path 7D SSS Level 3

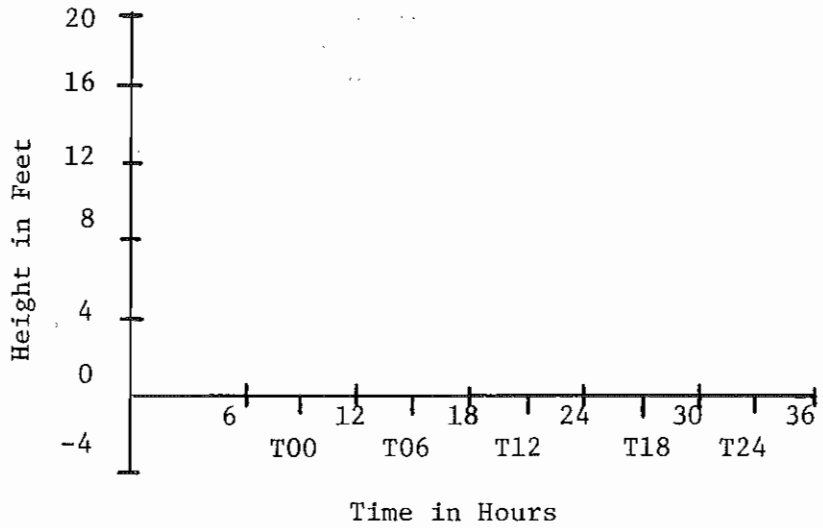
Direction and distance of storm center from downtown New Orleans, when grid area first gets wet (water less than 1 foot).

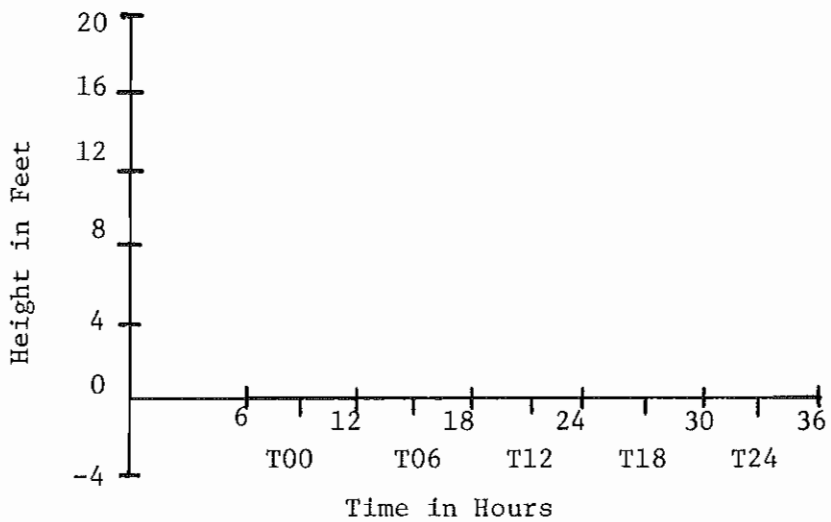
FORM SF -3

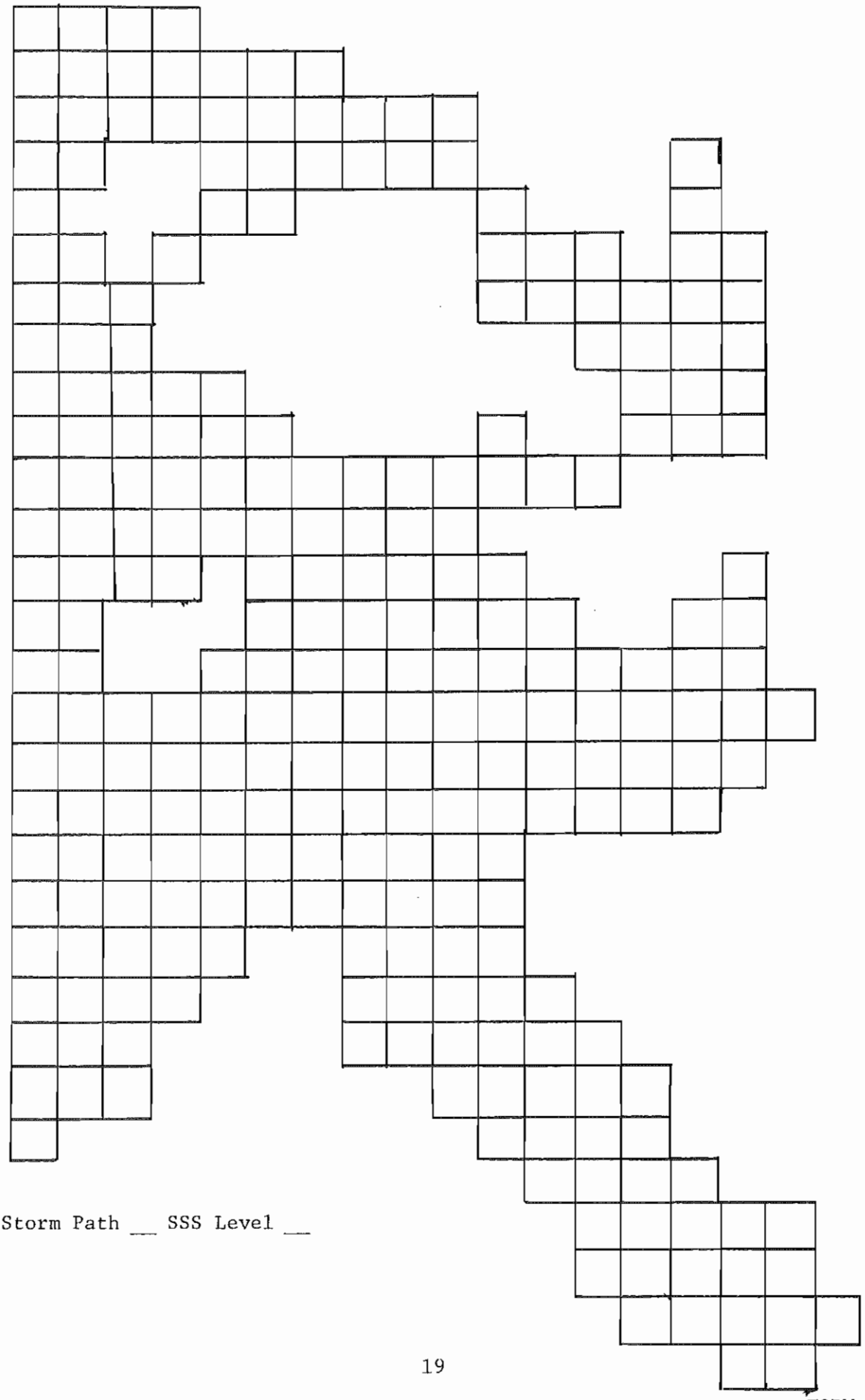
Block Identification No. Row Col			
Storm Path	High Surge Level 1	High Surge Level 3	High Surge Level 5

Block Identification No. Row Col			
Storm Path	High Surge Level 1	High Surge Level 3	High Surge Level 5

Form SP-1


20
16
12
8
4
0
-4
Height in Feet
6
12
18
24
30
36
T00
T06
T12
T18
T24
Time in Hours


20
16
12
8
4
0
-4
Height in Feet
6
12
18
24
30
36
T00
T06
T12
T18
T24
Time in Hours



Storm Path ___ SSS Level ___

FORM SP-3