# Appendix 15
# Computational Methodology

## Introduction

This Appendix describes the process used by the risk team to determine the final loss exceedence values in the risk analysis. The process involved the following steps:

1. The data collected as described in the previous appendices was input to a spreadsheet program developed by the risk team entitled “Flood Risk Analysis for Tropical Storm Environments” (FoRTE). This program implemented the risk methodology discussed in Appendix 9.

2. Input data included: system descriptions, hurricane hydrographs, fragility relationships, rainfall and consequence information.

3. The system descriptions input to FoRTE were developed for the two Hurricane Protection Systems (HPS) under investigation (Pre-Katrina and June 2007).

4. Hurricane hydrographs were developed (as described in Appendix 8) for the two HPS based on the changes made in levee or wall heights and any other changes that could alter the hydrology and hydraulics of the HPS.

5. Fragility relationships in the two HPS were also tailored to model the changes in the engineering characteristics caused by modifications to levees and walls.

6. Rainfall volumes were input for each storm.

7. Pumping was modeled for the “no pumping”, “50% pumping” and “100% pumping” scenarios by modifying the rainfall volumes by the amount of water that could be evacuated by the pumps in each subbasin.

8. FoRTE was run for each of the 152 storms for the following conditions:

    a. Pre-Katrina with no pumping
    b. Pre- Katrina with 50% pumping
    c. Pre-Katrina with 100% pumping

d. June 2007 with no pumping
e. June 2007 with 50% pumping
f. June 2007 with 100% pumping

9. The FoRTE results for each set of runs were aggregated into a single elevation-exceedence curve using a separate program developed for that purpose. At this stage, only the 76 storms with frequencies were aggregated.

10. The 2%, 1% and .2% elevations were selected from the elevation-exceedence curves for each subbasin.

11. Wave runup and overtopping water volumes were calculated for each storm. This volume was examined to determine the impact on total water volume in the subbasin. An adjustment was made to the subbasin elevations where appropriate to account for the additional water volume.

12. Elevations within the subbasins basin were examined to determine if they were consistent with the interconnectivity between the subbasins. Elevations used in map preparation were adjusted in a few cases to account for interconnectivity between subbasins that could not be represented in the simple drainage model used in FoRTE.

## Flood Risk Analysis for Tropical Storm Environments (FoRTE)

FoRTE provides the analytical engine underlying the Interagency Performance Evaluation Task Force (IPET) study of the risks associated with the New Orleans hurricane protection system. FoRTE was designed to be accessible on most personal computers by leveraging the common Microsoft Excel interface. The FoRTE analyses were done using Microsoft Excel XP and 2007.

## General Overview and User Interface

The standard FoRTE user interface is shown in Figure 15-1 with inputs labeled and described in Table 1. In general, execution of the FoRTE tool requires the following three steps:

1. **Input system definition:** this step defines the stage-storage relationships for the subbasins, conditions for interflow between adjacent subbasins, reach, transition, and feature definitions, and storm data.

2. **Specify analysis parameters:** this step specifies the parameters for analysis, to include uncertainty inputs, stratification inputs, and the hydrograph start time.

3. **Specify output options:** this step chooses the output and calculation options.

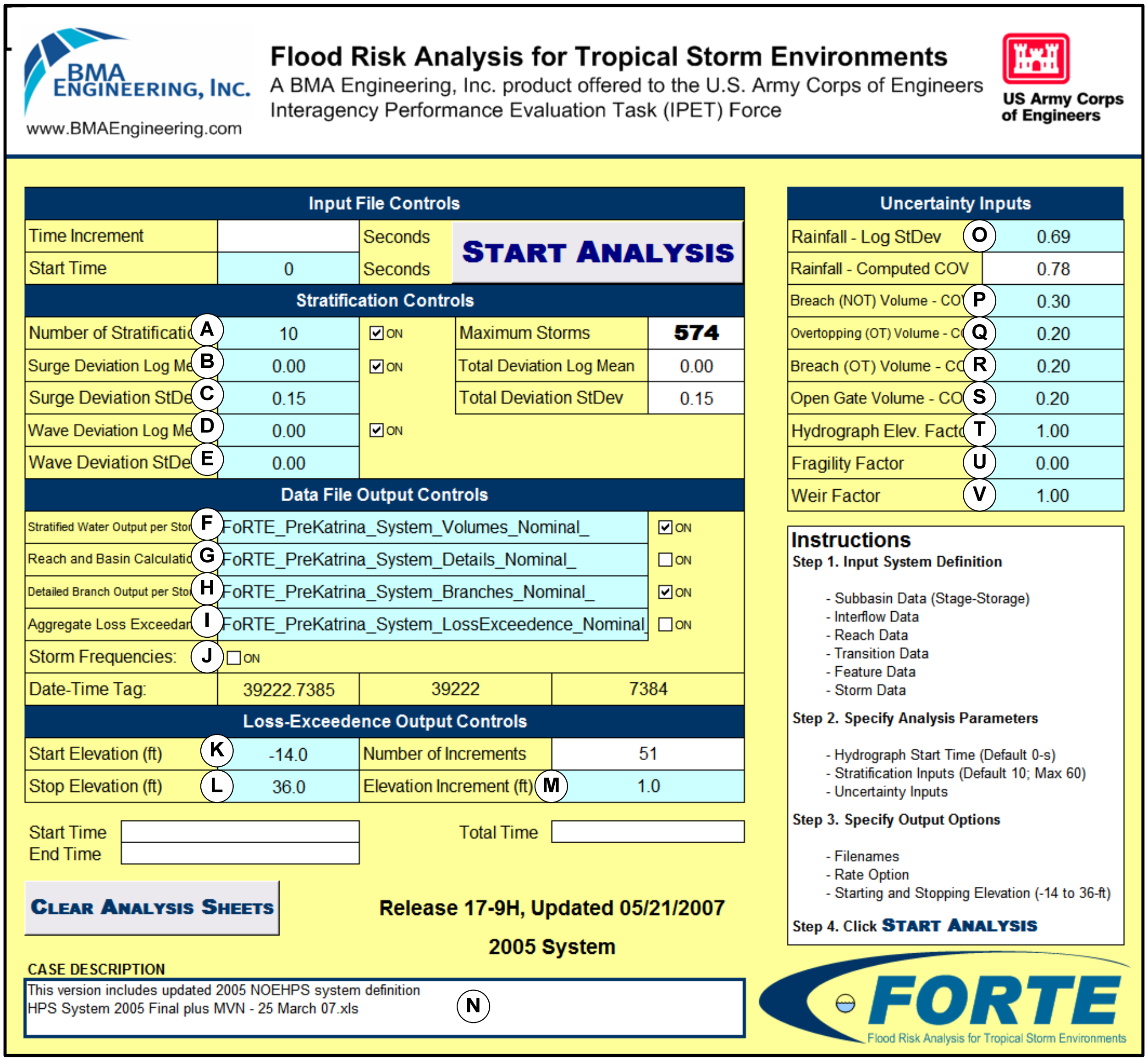



Figure 15-1. FoRTE User Interface

| Table 15-1. Description of FoRTE Inputs | |
|---|---|
| **Item** | **Description** |
| A | Number of evenly-spaced stratifications of the distribution on surges and waves. The check box to the right of this input field turns stratifications on (checked) and off (unchecked). An unchecked box sets the default number of stratifications to 1 regardless of the value entered in this cell. |
| B | Log-mean on the uncertainty distribution for surge height. The check box to the right of this input field toggles the consideration of uncertainty in surge height, where on (checked) accounts for uncertainty, and off (unchecked) assumes no uncertainty. |
| C | Log-standard deviation on the uncertainty distribution for surge height. This field is ignored if the check box in item B is set to off. |
| D | Log-mean on the uncertainty distribution for wave height. The check box to the right of this input field toggles the consideration of uncertainty in wave height, where on (checked) accounts for uncertainty, and off (unchecked) assumes no uncertainty. |
| E | Log-standard deviation on the uncertainty distribution for wave height. This field is ignored if the check box in item D is set to off. |
| F | Prefix for the output file containing surge heights and water volumes for each stratification. The check box to the right of this input field determines whether this type of output file will be generated by the FoRTE system (on is checked, and off is unchecked). |
| G | Prefix for the output files containing detailed calculations for each stratification. A separate file is generated for each stratification. The check box to the right of this input field determines whether this type of output file will be generated by the FoRTE system (on is checked, and off is unchecked). |
| H | Prefix for the output file containing detailed branch output per storm. This file is required for use with the FoRTE storm aggregator tool. The check box to the right of this input field determines whether this type of output file will be generated by the FoRTE system (on is checked, and off is unchecked). |
| I | Prefix for the output file containing the aggregate loss exceedence curves for each subbasin based on the number of storms studies in a given run. The check box to the right of this input field determines whether results will be aggregated to produce loss-exceedence curves, and whether this type of output file will be generated by the FoRTE system (on is checked, and off is unchecked). |
| J | This box turns on storm frequencies. Checked means that frequencies will be used as described in the storm frequencies sheet. Unchecked means that the rate is set to one. This latter option is the one needed for aggregating results using the FoRTE storm aggregator tool. |
| K | The starting elevation for generating loss exceedence curves. This input field is ignored if the check box in item I is unchecked. |
| L | The ending elevation for generating loss curves. This input field is ignored if the check box in item I is unchecked. |
| M | The elevation increment for generating loss exceedence curves. This input field is ignored if the check box in item I is unchecked. |
| N | This is a notes field used to describe the case and system under study. |
| O | Log standard deviation on the rainfall. This value assumes that rainfall is a lognomally distributed random variable with a log mean of 1. |
| P | Coefficient of variation on the volume of water due to breach for non-overtopping breach failures. This uncertainty is due to uncertainty in the Weir coefficient used for calculating water volume. |
| Q | Coefficient of variation on the volume of water due to overtopping. This uncertainty is due to uncertainty in the Weir coefficient used for calculating water volume. |
| R | Coefficient of variation on the volume of water due to breach for overtopping breach failures. This uncertainty is due to uncertainty in the Weir coefficient used for calculating water volume. |
| S | Coefficient of variation on the volume of water due to open closures and gates. This uncertainty is due to uncertainty in the Weir coefficient used for calculating water volume. |
| T | This is a modification factor used to adjust the height of the hydrographs. This factor is used for epistemic uncertainty analysis. The default value of one corresponds to no adjustment of the hydrographs. |
| U | This is a modification factor used to adjust the position of the fragility curve along the x-axis. This value shifts the entire fragility curve along the x-axis. This factor is used for epistemic uncertainty analysis. The default value of zero corresponds to no shift in the fragility curve, |
| V | This is a modification factor used to adjust the value of the Weir coefficients used for calculating volume. This factor is used for epistemic uncertainty analysis. The default value of one corresponds to no adjustment to the Weir coefficients. |

## System Definition

The definition of the hurricane protection system spans several spreadsheets as described in the following sections. In particular, the definition of the hurricane protection system includes the following elements:

- High-level basin information that includes the name of the basin and number of associated subbasins; and
- Stage-storage relationships for each subbasin that specifies the volume of water held in a subbasin as a function of water elevation; and
- Interflow mapping matrix that specifies the elevation at which a subbasin would begin to overflow into an adjacent subbasin; and
- Reach, transition, and feature data that includes heights, widths, materials, probability of gate open for closures, fragility curve for reaches and transitions, and mapping to associated reaches (for transitions and closures), subbasins, and basins.

### Basin Information

Basic high-level basin information is provided in the “Basin Data” worksheet of the FoRTE tool. An annotated snapshot of the “Basin Data” worksheet is provided in Figure 15-2. The “Basin Data” worksheet stores the following information:

- Name of basin
- Number of subbasins associated with a basin
- Prefix for mapping subbasins and lower-level features to basins

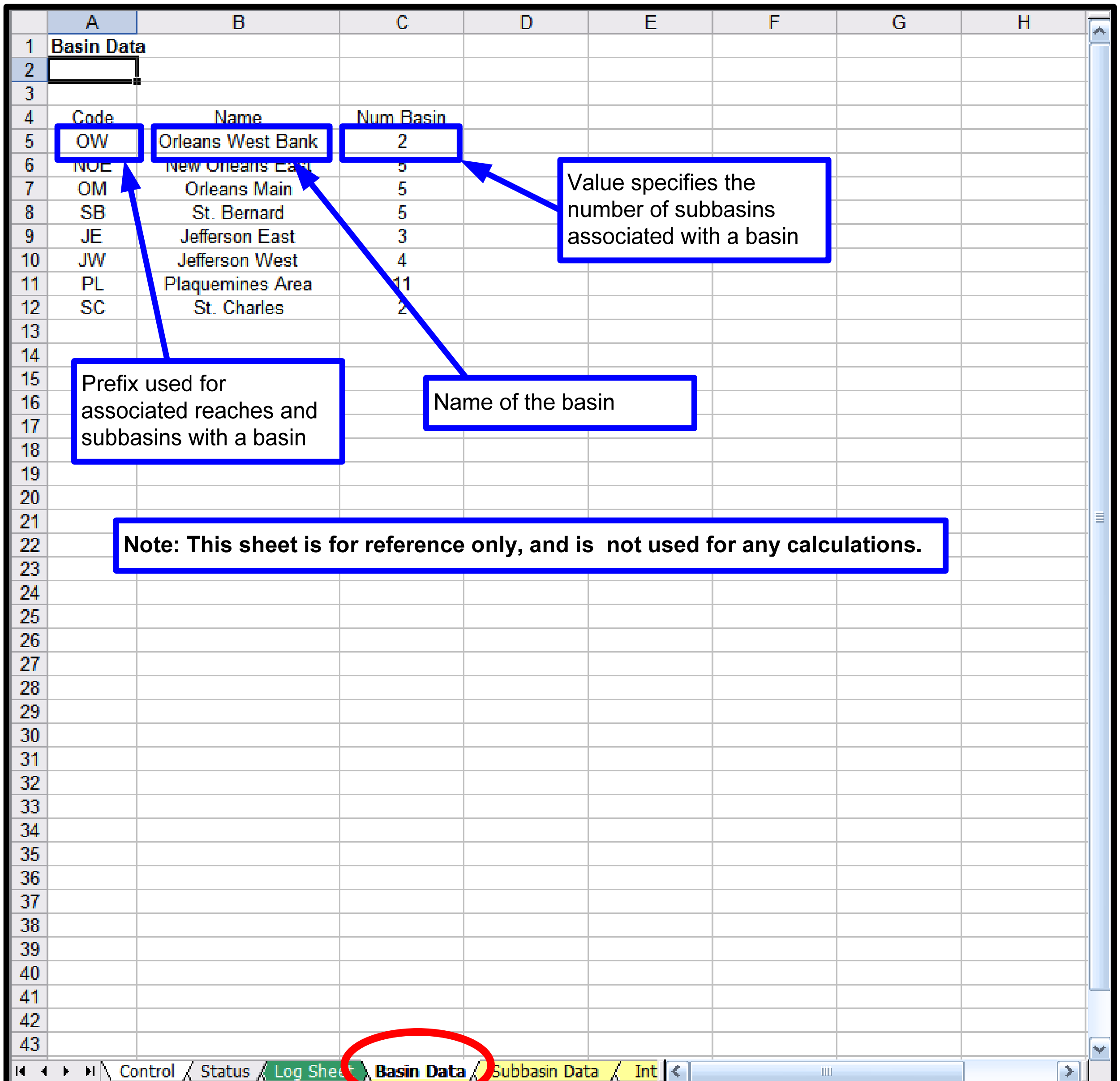
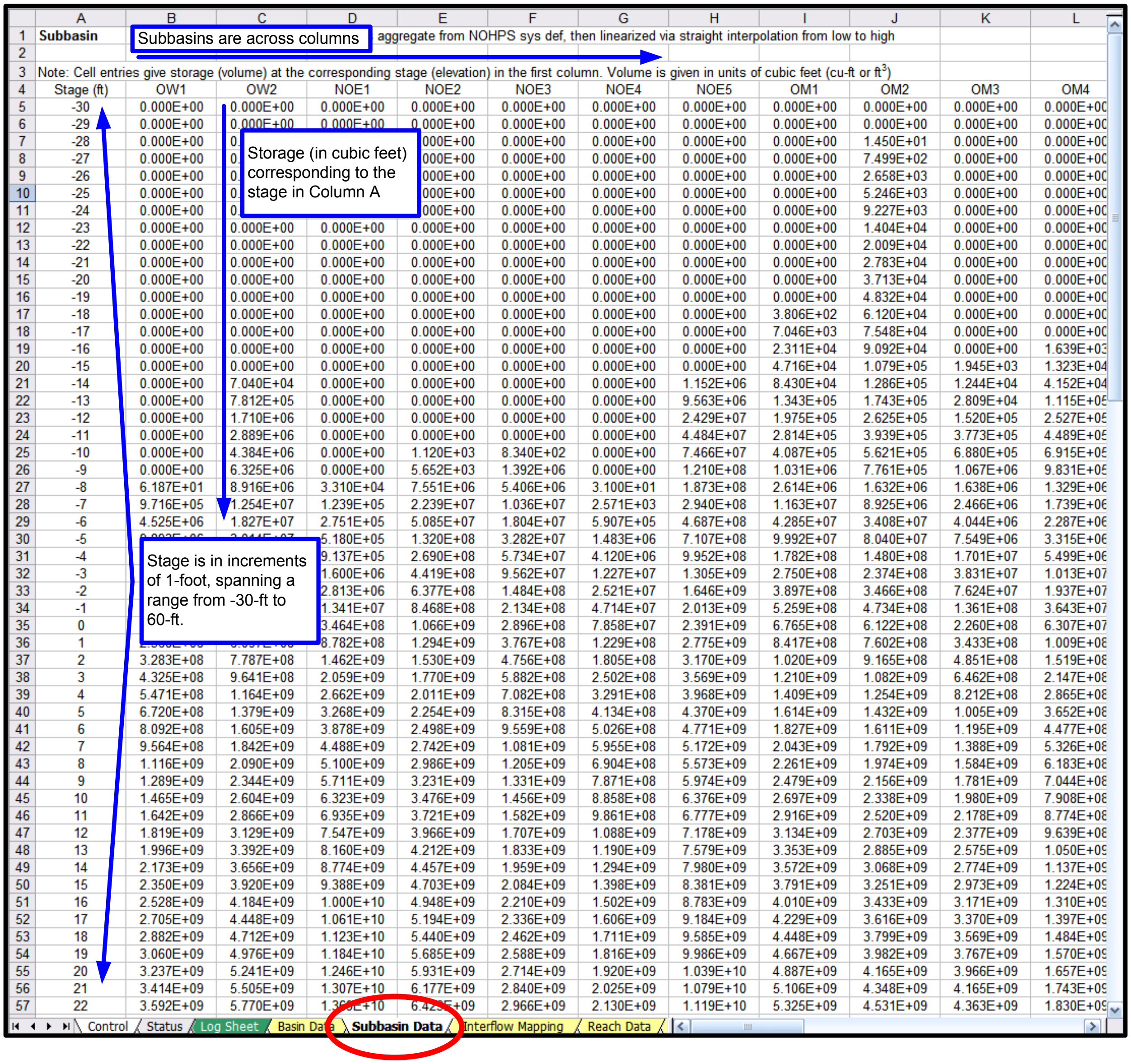



Figure 15-2. Worksheet showing count of subbasins in each basin.

### Subbasin Stage-Storage Relationships

The stage-storage relationships for each of the subbasins is provided in the "Subbasin Data" worksheet. An annotated snapshot of the "Subbasin Data" worksheet is provided in Figure 15-3. The "Subbasin Data" worksheet stores the following information:

- Water elevations or stage (in feet) for which a corresponding water volume or storage is assigned
- Corresponding water volumes at that stage (in cubic feet) for each subbasin



| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Subbasin | … aggregate from NOHPS sys def, then linearized via straight interpolation from low to high | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | Note: Cell entries give storage (volume) at the corresponding stage (elevation) in the first column. Volume is given in units of cubic feet (cu-ft or ft$^3$) | | | | | | | | | | | |
| 4 | Stage (ft) | OW1 | OW2 | NOE1 | NOE2 | NOE3 | NOE4 | NOE5 | OM1 | OM2 | OM3 | OM4 |
| 5 | -30 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 6 | -29 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| 7 | -28 | 0.000E+00 | [illegible] | [illegible] | [illegible] | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.450E+01 | 0.000E+00 | 0.000E+00 |
| 8 | -27 | 0.000E+00 | [illegible] | [illegible] | [illegible] | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 7.499E+02 | 0.000E+00 | 0.000E+00 |
| 9 | -26 | 0.000E+00 | [illegible] | [illegible] | [illegible] | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 2.658E+03 | 0.000E+00 | 0.000E+00 |
| 10 | -25 | 0.000E+00 | [illegible] | [illegible] | [illegible] | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 5.246E+03 | 0.000E+00 | 0.000E+00 |
| 11 | -24 | 0.000E+00 | [illegible] | [illegible] | [illegible] | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 9.227E+03 | 0.000E+00 | 0.000E+00 |
| 12 | -23 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.404E+04 | 0.000E+00 | 0.000E+00 |
| 13 | -22 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 2.009E+04 | 0.000E+00 | 0.000E+00 |
| 14 | -21 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 2.783E+04 | 0.000E+00 | 0.000E+00 |
| 15 | -20 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 3.713E+04 | 0.000E+00 | 0.000E+00 |
| 16 | -19 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 4.832E+04 | 0.000E+00 | 0.000E+00 |
| 17 | -18 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 3.806E+02 | 6.120E+04 | 0.000E+00 | 0.000E+00 |
| 18 | -17 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 7.046E+03 | 7.548E+04 | 0.000E+00 | 0.000E+00 |
| 19 | -16 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 2.311E+04 | 9.092E+04 | 0.000E+00 | 1.639E+03 |
| 20 | -15 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 4.716E+04 | 1.079E+05 | 1.945E+03 | 1.323E+04 |
| 21 | -14 | 0.000E+00 | 7.040E+04 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 1.152E+06 | 8.430E+04 | 1.286E+05 | 1.244E+04 | 4.152E+04 |
| 22 | -13 | 0.000E+00 | 7.812E+05 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 9.563E+06 | 1.343E+05 | 1.743E+05 | 2.809E+04 | 1.115E+05 |
| 23 | -12 | 0.000E+00 | 1.710E+06 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 2.429E+07 | 1.975E+05 | 2.625E+05 | 1.520E+05 | 2.527E+05 |
| 24 | -11 | 0.000E+00 | 2.889E+06 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 4.484E+07 | 2.814E+05 | 3.939E+05 | 3.773E+05 | 4.489E+05 |
| 25 | -10 | 0.000E+00 | 4.384E+06 | 0.000E+00 | 1.120E+03 | 8.340E+02 | 0.000E+00 | 7.466E+07 | 4.087E+05 | 5.621E+05 | 6.880E+05 | 6.915E+05 |
| 26 | -9 | 0.000E+00 | 6.325E+06 | 0.000E+00 | 5.652E+03 | 1.392E+06 | 0.000E+00 | 1.210E+08 | 1.031E+06 | 7.761E+05 | 1.067E+06 | 9.831E+05 |
| 27 | -8 | 6.187E+01 | 8.916E+06 | 3.310E+04 | 7.551E+06 | 5.406E+06 | 3.100E+01 | 1.873E+08 | 2.614E+06 | 1.632E+06 | 1.638E+06 | 1.329E+06 |
| 28 | -7 | 9.716E+05 | 1.254E+07 | 1.239E+05 | 2.239E+07 | 1.036E+07 | 2.571E+03 | 2.940E+08 | 1.163E+07 | 8.925E+06 | 2.466E+06 | 1.739E+06 |
| 29 | -6 | 4.525E+06 | 1.827E+07 | 2.751E+05 | 5.085E+07 | 1.804E+07 | 5.907E+05 | 4.687E+08 | 4.285E+07 | 3.408E+07 | 4.044E+06 | 2.287E+06 |
| 30 | -5 | [illegible] | [illegible] | 5.180E+05 | 1.320E+08 | 3.282E+07 | 1.483E+06 | 7.107E+08 | 9.992E+07 | 8.040E+07 | 7.549E+06 | 3.315E+06 |
| 31 | -4 | [illegible] | [illegible] | 9.137E+05 | 2.690E+08 | 5.734E+07 | 4.120E+06 | 9.952E+08 | 1.782E+08 | 1.480E+08 | 1.701E+07 | 5.499E+06 |
| 32 | -3 | [illegible] | [illegible] | 1.600E+06 | 4.419E+08 | 9.562E+07 | 1.227E+07 | 1.305E+09 | 2.750E+08 | 2.374E+08 | 3.831E+07 | 1.013E+07 |
| 33 | -2 | [illegible] | [illegible] | 2.813E+06 | 6.377E+08 | 1.484E+08 | 2.521E+07 | 1.646E+09 | 3.897E+08 | 3.466E+08 | 7.624E+07 | 1.937E+07 |
| 34 | -1 | [illegible] | [illegible] | 1.341E+07 | 8.468E+08 | 2.134E+08 | 4.714E+07 | 2.013E+09 | 5.259E+08 | 4.734E+08 | 1.361E+08 | 3.643E+07 |
| 35 | 0 | [illegible] | [illegible] | 3.464E+08 | 1.066E+09 | 2.896E+08 | 7.858E+07 | 2.391E+09 | 6.765E+08 | 6.122E+08 | 2.260E+08 | 6.307E+07 |
| 36 | 1 | [illegible] | [illegible] | 8.782E+08 | 1.294E+09 | 3.767E+08 | 1.229E+08 | 2.775E+09 | 8.417E+08 | 7.602E+08 | 3.433E+08 | 1.009E+08 |
| 37 | 2 | 3.283E+08 | 7.787E+08 | 1.462E+09 | 1.530E+09 | 4.756E+08 | 1.805E+08 | 3.170E+09 | 1.020E+09 | 9.165E+08 | 4.851E+08 | 1.519E+08 |
| 38 | 3 | 4.325E+08 | 9.641E+08 | 2.059E+09 | 1.770E+09 | 5.882E+08 | 2.502E+08 | 3.569E+09 | 1.210E+09 | 1.082E+09 | 6.462E+08 | 2.147E+08 |
| 39 | 4 | 5.471E+08 | 1.164E+09 | 2.662E+09 | 2.011E+09 | 7.082E+08 | 3.291E+08 | 3.968E+09 | 1.409E+09 | 1.254E+09 | 8.212E+08 | 2.865E+08 |
| 40 | 5 | 6.720E+08 | 1.379E+09 | 3.268E+09 | 2.254E+09 | 8.315E+08 | 4.134E+08 | 4.370E+09 | 1.614E+09 | 1.432E+09 | 1.005E+09 | 3.652E+08 |
| 41 | 6 | 8.092E+08 | 1.605E+09 | 3.878E+09 | 2.498E+09 | 9.559E+08 | 5.026E+08 | 4.771E+09 | 1.827E+09 | 1.611E+09 | 1.195E+09 | 4.477E+08 |
| 42 | 7 | 9.564E+08 | 1.842E+09 | 4.488E+09 | 2.742E+09 | 1.081E+09 | 5.955E+08 | 5.172E+09 | 2.043E+09 | 1.792E+09 | 1.388E+09 | 5.326E+08 |
| 43 | 8 | 1.116E+09 | 2.090E+09 | 5.100E+09 | 2.986E+09 | 1.205E+09 | 6.904E+08 | 5.573E+09 | 2.261E+09 | 1.974E+09 | 1.584E+09 | 6.183E+08 |
| 44 | 9 | 1.289E+09 | 2.344E+09 | 5.711E+09 | 3.231E+09 | 1.331E+09 | 7.871E+08 | 5.974E+09 | 2.479E+09 | 2.156E+09 | 1.781E+09 | 7.044E+08 |
| 45 | 10 | 1.465E+09 | 2.604E+09 | 6.323E+09 | 3.476E+09 | 1.456E+09 | 8.858E+08 | 6.376E+09 | 2.697E+09 | 2.338E+09 | 1.980E+09 | 7.908E+08 |
| 46 | 11 | 1.642E+09 | 2.866E+09 | 6.935E+09 | 3.721E+09 | 1.582E+09 | 9.861E+08 | 6.777E+09 | 2.916E+09 | 2.520E+09 | 2.178E+09 | 8.774E+08 |
| 47 | 12 | 1.819E+09 | 3.129E+09 | 7.547E+09 | 3.966E+09 | 1.707E+09 | 1.088E+09 | 7.178E+09 | 3.134E+09 | 2.703E+09 | 2.377E+09 | 9.639E+08 |
| 48 | 13 | 1.996E+09 | 3.392E+09 | 8.160E+09 | 4.212E+09 | 1.833E+09 | 1.190E+09 | 7.579E+09 | 3.353E+09 | 2.885E+09 | 2.575E+09 | 1.050E+09 |
| 49 | 14 | 2.173E+09 | 3.656E+09 | 8.774E+09 | 4.457E+09 | 1.959E+09 | 1.294E+09 | 7.980E+09 | 3.572E+09 | 3.068E+09 | 2.774E+09 | 1.137E+09 |
| 50 | 15 | 2.350E+09 | 3.920E+09 | 9.388E+09 | 4.703E+09 | 2.084E+09 | 1.398E+09 | 8.381E+09 | 3.791E+09 | 3.251E+09 | 2.973E+09 | 1.224E+09 |
| 51 | 16 | 2.528E+09 | 4.184E+09 | 1.000E+10 | 4.948E+09 | 2.210E+09 | 1.502E+09 | 8.783E+09 | 4.010E+09 | 3.433E+09 | 3.171E+09 | 1.310E+09 |
| 52 | 17 | 2.705E+09 | 4.448E+09 | 1.061E+10 | 5.194E+09 | 2.336E+09 | 1.606E+09 | 9.184E+09 | 4.229E+09 | 3.616E+09 | 3.370E+09 | 1.397E+09 |
| 53 | 18 | 2.882E+09 | 4.712E+09 | 1.123E+10 | 5.440E+09 | 2.462E+09 | 1.711E+09 | 9.585E+09 | 4.448E+09 | 3.799E+09 | 3.569E+09 | 1.484E+09 |
| 54 | 19 | 3.060E+09 | 4.976E+09 | 1.184E+10 | 5.685E+09 | 2.588E+09 | 1.816E+09 | 9.986E+09 | 4.667E+09 | 3.982E+09 | 3.767E+09 | 1.570E+09 |
| 55 | 20 | 3.237E+09 | 5.241E+09 | 1.246E+10 | 5.931E+09 | 2.714E+09 | 1.920E+09 | 1.039E+10 | 4.887E+09 | 4.165E+09 | 3.966E+09 | 1.657E+09 |
| 56 | 21 | 3.414E+09 | 5.505E+09 | 1.307E+10 | 6.177E+09 | 2.840E+09 | 2.025E+09 | 1.079E+10 | 5.106E+09 | 4.348E+09 | 4.165E+09 | 1.743E+09 |
| 57 | 22 | 3.592E+09 | 5.770E+09 | [illegible] | [illegible] | 2.966E+09 | 2.130E+09 | 1.119E+10 | 5.325E+09 | 4.531E+09 | 4.363E+09 | 1.830E+09 |



Figure 15-3. Data input sheet for subbasin stage-storage relationships.

## Interflow Mapping

The interflow relationships for each subbasin are provided in the “Interflow Mapping” worksheet. An annotated snapshot of the “Interflow Mapping” worksheet is provided in Figure 15-4. The “Interflow Mapping” worksheet stores the water elevation at which a subbasin (noted in a row) begins to overflow into an adjacent subbasin (noted in a column).

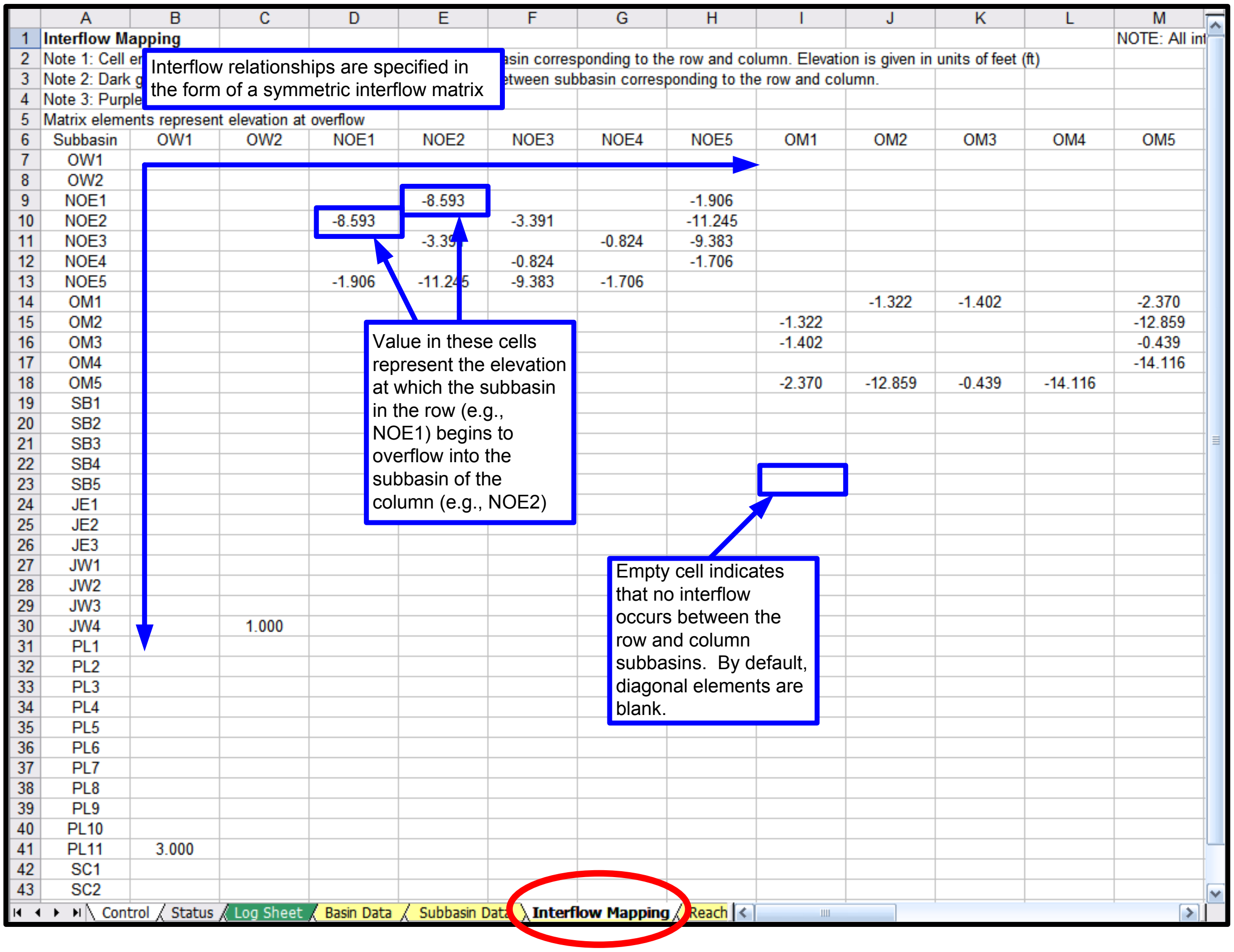
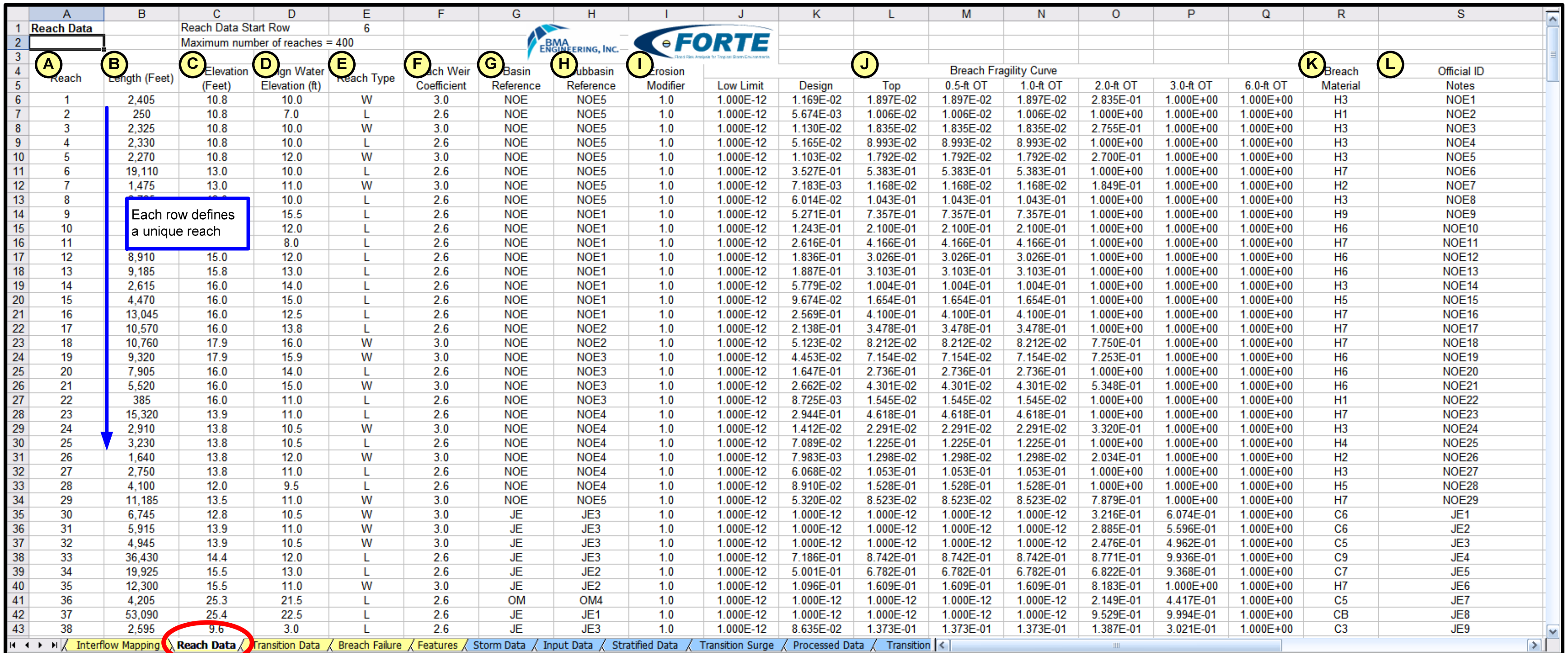



Figure 15-4. Subbasin interflow matrix.

## Reach Definition

Data that defines the reaches comprising the hurricane protection system is provided in the "Reach Data" worksheet. An annotated snapshot of the "Reach Data" worksheet is provided in Figure 15-5. Descriptions of the inputs to the "Reach Data" worksheet are provided in Table 15-2.





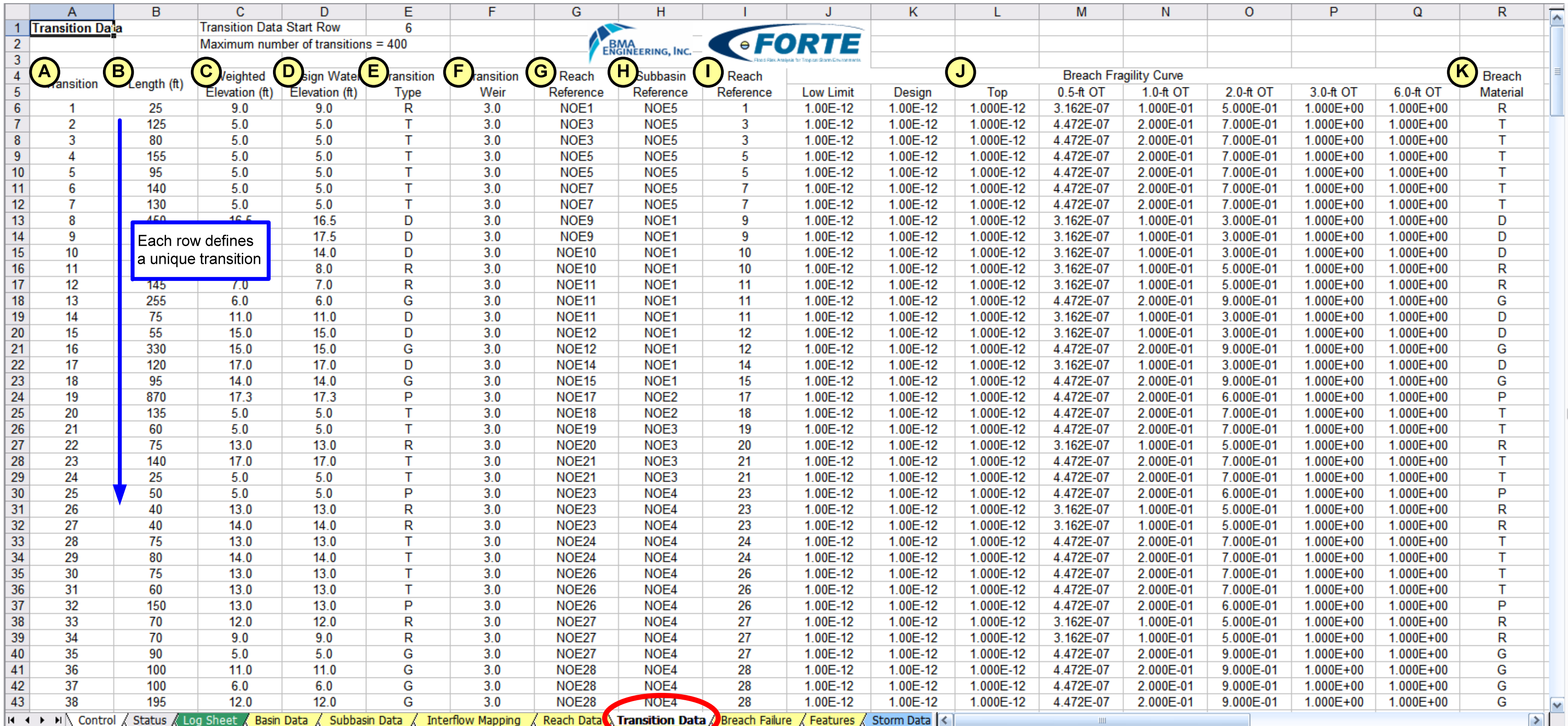
| | (A) Reach | (B) ength (Feet) | (C) Elevation (Feet) | (D) gn Water Elevation (ft) | (E) each Type | (F) ach Weir Coefficient | (G) Basin Reference | (H) ubbasin Reference | (I) rosion Modifier | Breach Fragility Curve (J) Low Limit | Design | Top | 0.5-ft OT | 1.0-ft OT | 2.0-ft OT | 3.0-ft OT | 6.0-ft OT | (K) Breach Material | (L) Official ID Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 2,405 | 10.8 | 10.0 | W | 3.0 | NOE | NOE5 | 1.0 | 1.000E-12 | 1.169E-02 | 1.897E-02 | 1.897E-02 | 1.897E-02 | 2.835E-01 | 1.000E+00 | 1.000E+00 | H3 | NOE1 |
| 7 | 2 | 250 | 10.8 | 7.0 | L | 2.6 | NOE | NOE5 | 1.0 | 1.000E-12 | 5.674E-03 | 1.006E-02 | 1.006E-02 | 1.006E-02 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H1 | NOE2 |
| 8 | 3 | 2,325 | 10.8 | 10.0 | W | 3.0 | NOE | NOE5 | 1.0 | 1.000E-12 | 1.130E-02 | 1.835E-02 | 1.835E-02 | 1.835E-02 | 2.755E-01 | 1.000E+00 | 1.000E+00 | H3 | NOE3 |
| 9 | 4 | 2,330 | 10.8 | 10.0 | L | 2.6 | NOE | NOE5 | 1.0 | 1.000E-12 | 5.165E-02 | 8.993E-02 | 8.993E-02 | 8.993E-02 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H3 | NOE4 |
| 10 | 5 | 2,270 | 10.8 | 12.0 | W | 3.0 | NOE | NOE5 | 1.0 | 1.000E-12 | 1.103E-02 | 1.792E-02 | 1.792E-02 | 1.792E-02 | 2.700E-01 | 1.000E+00 | 1.000E+00 | H3 | NOE5 |
| 11 | 6 | 19,110 | 13.0 | 10.0 | L | 2.6 | NOE | NOE5 | 1.0 | 1.000E-12 | 3.527E-01 | 5.383E-01 | 5.383E-01 | 5.383E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H7 | NOE6 |
| 12 | 7 | 1,475 | 13.0 | 11.0 | W | 3.0 | NOE | NOE5 | 1.0 | 1.000E-12 | 7.183E-03 | 1.168E-02 | 1.168E-02 | 1.168E-02 | 1.849E-01 | 1.000E+00 | 1.000E+00 | H2 | NOE7 |
| 13 | 8 | [illegible] | [illegible] | 10.0 | L | 2.6 | NOE | NOE5 | 1.0 | 1.000E-12 | 6.014E-02 | 1.043E-01 | 1.043E-01 | 1.043E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H3 | NOE8 |
| 14 | 9 | [illegible] | [illegible] | 15.5 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 5.271E-01 | 7.357E-01 | 7.357E-01 | 7.357E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H9 | NOE9 |
| 15 | 10 | [illegible] | [illegible] | 12.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 1.243E-01 | 2.100E-01 | 2.100E-01 | 2.100E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H6 | NOE10 |
| 16 | 11 | [illegible] | [illegible] | 8.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 2.616E-01 | 4.166E-01 | 4.166E-01 | 4.166E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H7 | NOE11 |
| 17 | 12 | 8,910 | 15.0 | 12.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 1.836E-01 | 3.026E-01 | 3.026E-01 | 3.026E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H6 | NOE12 |
| 18 | 13 | 9,185 | 15.8 | 13.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 1.887E-01 | 3.103E-01 | 3.103E-01 | 3.103E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H6 | NOE13 |
| 19 | 14 | 2,615 | 16.0 | 14.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 5.779E-02 | 1.004E-01 | 1.004E-01 | 1.004E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H3 | NOE14 |
| 20 | 15 | 4,470 | 16.0 | 15.0 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 9.674E-02 | 1.654E-01 | 1.654E-01 | 1.654E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H5 | NOE15 |
| 21 | 16 | 13,045 | 16.0 | 12.5 | L | 2.6 | NOE | NOE1 | 1.0 | 1.000E-12 | 2.569E-01 | 4.100E-01 | 4.100E-01 | 4.100E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H7 | NOE16 |
| 22 | 17 | 10,570 | 16.0 | 13.8 | L | 2.6 | NOE | NOE2 | 1.0 | 1.000E-12 | 2.138E-01 | 3.478E-01 | 3.478E-01 | 3.478E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H7 | NOE17 |
| 23 | 18 | 10,760 | 17.9 | 16.0 | W | 3.0 | NOE | NOE2 | 1.0 | 1.000E-12 | 5.123E-02 | 8.212E-02 | 8.212E-02 | 8.212E-02 | 7.750E-01 | 1.000E+00 | 1.000E+00 | H7 | NOE18 |
| 24 | 19 | 9,320 | 17.9 | 15.9 | W | 3.0 | NOE | NOE3 | 1.0 | 1.000E-12 | 4.453E-02 | 7.154E-02 | 7.154E-02 | 7.154E-02 | 7.253E-01 | 1.000E+00 | 1.000E+00 | H6 | NOE19 |
| 25 | 20 | 7,905 | 16.0 | 14.0 | L | 2.6 | NOE | NOE3 | 1.0 | 1.000E-12 | 1.647E-01 | 2.736E-01 | 2.736E-01 | 2.736E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H6 | NOE20 |
| 26 | 21 | 5,520 | 16.0 | 15.0 | W | 3.0 | NOE | NOE3 | 1.0 | 1.000E-12 | 2.662E-02 | 4.301E-02 | 4.301E-02 | 4.301E-02 | 5.348E-01 | 1.000E+00 | 1.000E+00 | H6 | NOE21 |
| 27 | 22 | 385 | 16.0 | 11.0 | L | 2.6 | NOE | NOE3 | 1.0 | 1.000E-12 | 8.725E-03 | 1.545E-02 | 1.545E-02 | 1.545E-02 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H1 | NOE22 |
| 28 | 23 | 15,320 | 13.9 | 11.0 | L | 2.6 | NOE | NOE4 | 1.0 | 1.000E-12 | 2.944E-01 | 4.618E-01 | 4.618E-01 | 4.618E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H7 | NOE23 |
| 29 | 24 | 2,910 | 13.8 | 10.5 | W | 3.0 | NOE | NOE4 | 1.0 | 1.000E-12 | 1.412E-02 | 2.291E-02 | 2.291E-02 | 2.291E-02 | 3.320E-01 | 1.000E+00 | 1.000E+00 | H3 | NOE24 |
| 30 | 25 | 3,230 | 13.8 | 10.5 | L | 2.6 | NOE | NOE4 | 1.0 | 1.000E-12 | 7.089E-02 | 1.225E-01 | 1.225E-01 | 1.225E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H4 | NOE25 |
| 31 | 26 | 1,640 | 13.8 | 12.0 | W | 3.0 | NOE | NOE4 | 1.0 | 1.000E-12 | 7.983E-03 | 1.298E-02 | 1.298E-02 | 1.298E-02 | 2.034E-01 | 1.000E+00 | 1.000E+00 | H2 | NOE26 |
| 32 | 27 | 2,750 | 13.8 | 11.0 | L | 2.6 | NOE | NOE4 | 1.0 | 1.000E-12 | 6.068E-02 | 1.053E-01 | 1.053E-01 | 1.053E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H3 | NOE27 |
| 33 | 28 | 4,100 | 12.0 | 9.5 | L | 2.6 | NOE | NOE4 | 1.0 | 1.000E-12 | 8.910E-02 | 1.528E-01 | 1.528E-01 | 1.528E-01 | 1.000E+00 | 1.000E+00 | 1.000E+00 | H5 | NOE28 |
| 34 | 29 | 11,185 | 13.5 | 11.0 | W | 3.0 | NOE | NOE5 | 1.0 | 1.000E-12 | 5.320E-02 | 8.523E-02 | 8.523E-02 | 8.523E-02 | 7.879E-01 | 1.000E+00 | 1.000E+00 | H7 | NOE29 |
| 35 | 30 | 6,745 | 12.8 | 10.5 | W | 3.0 | JE | JE3 | 1.0 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 3.216E-01 | 6.074E-01 | 1.000E+00 | C6 | JE1 |
| 36 | 31 | 5,915 | 13.9 | 11.0 | W | 3.0 | JE | JE3 | 1.0 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 2.885E-01 | 5.596E-01 | 1.000E+00 | C6 | JE2 |
| 37 | 32 | 4,945 | 13.9 | 10.5 | W | 3.0 | JE | JE3 | 1.0 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 2.476E-01 | 4.962E-01 | 1.000E+00 | C5 | JE3 |
| 38 | 33 | 36,430 | 14.4 | 12.0 | L | 2.6 | JE | JE3 | 1.0 | 1.000E-12 | 7.186E-01 | 8.742E-01 | 8.742E-01 | 8.742E-01 | 8.771E-01 | 9.936E-01 | 1.000E+00 | C9 | JE4 |
| 39 | 34 | 19,925 | 15.5 | 13.0 | L | 2.6 | JE | JE2 | 1.0 | 1.000E-12 | 5.001E-01 | 6.782E-01 | 6.782E-01 | 6.782E-01 | 6.822E-01 | 9.368E-01 | 1.000E+00 | C7 | JE5 |
| 40 | 35 | 12,300 | 15.5 | 11.0 | W | 3.0 | JE | JE2 | 1.0 | 1.000E-12 | 1.096E-01 | 1.609E-01 | 1.609E-01 | 1.609E-01 | 8.183E-01 | 1.000E+00 | 1.000E+00 | H7 | JE6 |
| 41 | 36 | 4,205 | 25.3 | 21.5 | L | 2.6 | OM | OM4 | 1.0 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 2.149E-01 | 4.417E-01 | 1.000E+00 | C5 | JE7 |
| 42 | 37 | 53,090 | 25.4 | 22.5 | L | 2.6 | JE | JE1 | 1.0 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 1.000E-12 | 9.529E-01 | 9.994E-01 | 1.000E+00 | CB | JE8 |
| 43 | 38 | 2,595 | 9.6 | 3.0 | L | 2.6 | JE | JE3 | 1.0 | 1.000E-12 | 8.635E-02 | 1.373E-01 | 1.373E-01 | 1.373E-01 | 1.387E-01 | 3.021E-01 | 1.000E+00 | C3 | JE9 |

Figure 15-5. Reach definition worksheet.

| Table 15-2. Description of Reach Data inputs | |
|---|---|
| **Item** | **Description** |
| A | Reach ID. Each reach is assigned a unique integer ID corresponding to the IDs used to define hydrograph data. |
| B | Length of the reach section measured in feet. |
| C | Nominal top elevation of the reach section measured in feet. This is the value used to calculate the volume of water due to reach overtopping. |
| D | Nominal design elevation of the reach section measured in feet. This value is used for specifying failure probabilities on the fragility curve. |
| E | Reach type. "W" corresponds to "Wall" and "L" corresponds to "Levee." This value is used to determine the appropriate Weir coefficient. |
| F | Reach Weir coefficient. A nominal value of 2.6 is used for levees, and a nominal value of 3.0 is used for walls. |
| G | This is the ID of the associated basin containing the reach. |
| H | This is the ID of the associated subbasin containing the reach. |
| I | Erosion modifier. **This value is not currently used for any calculations.** |
| J | Breach fragility curve that specifies the probability of failure of the reach as a function of peak water elevation. The low limit corresponds to an elevation of 0-feet. The high-limit corresponds to an elevation of 6-feet above the nominal top elevation of the reach. Data points specified in between include probability of reach failure at the design and top elevations, and 0.5-feet, 1.0-feet, 2.0-feet, and 3.0-feet above the nominal top elevation of the reach. See Appendix 10 for further information. |
| K | Breach material specifies the composition of the reach as a two-character ID. The first character corresponds to the material composition (e.g., "H" for "hydraulic fill") and the second character corresponds to the length class (e.g., "5" for "4000-4999 feet"). This ID is used to determine the breach depth and breach width for use in calculating water volumes due to failure. |
| L | This is the official reach ID as specified by the IPET team. The first set of characters corresponds to the associated basin, and the number is a unique ID for reaches in that basin. |

## Transition Data

Data that defines the transitions within the hurricane protection system is provided in the "Transition Data" worksheet. An annotated snapshot of the "Transition Data" worksheet is provided in Figure 15-6. Descriptions of the inputs to the "Transition Data" worksheet are provided in Table 15-3.




Transition Data

Transition Data Start Row 6

Maximum number of transitions = 400

| Row | (A) Transition | (B) Length (ft) | (C) Weighted Elevation (ft) | (D) Design Water Elevation (ft) | (E) Transition Type | (F) Transition Weir | (G) Reach Reference | (H) Subbasin Reference | (I) Reach Reference | (J) Breach Fragility Curve: Low Limit | Design | Top | 0.5-ft OT | 1.0-ft OT | 2.0-ft OT | 3.0-ft OT | 6.0-ft OT | (K) Breach Material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 25 | 9.0 | 9.0 | R | 3.0 | NOE1 | NOE5 | 1 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 7 | 2 | 125 | 5.0 | 5.0 | T | 3.0 | NOE3 | NOE5 | 3 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 8 | 3 | 80 | 5.0 | 5.0 | T | 3.0 | NOE3 | NOE5 | 3 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 9 | 4 | 155 | 5.0 | 5.0 | T | 3.0 | NOE5 | NOE5 | 5 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 10 | 5 | 95 | 5.0 | 5.0 | T | 3.0 | NOE5 | NOE5 | 5 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 11 | 6 | 140 | 5.0 | 5.0 | T | 3.0 | NOE7 | NOE5 | 7 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 12 | 7 | 130 | 5.0 | 5.0 | T | 3.0 | NOE7 | NOE5 | 7 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 13 | 8 | [illegible] | 16.5 | 16.5 | D | 3.0 | NOE9 | NOE1 | 9 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 14 | 9 | [illegible] | [illegible] | 17.5 | D | 3.0 | NOE9 | NOE1 | 9 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 15 | 10 | [illegible] | [illegible] | 14.0 | D | 3.0 | NOE10 | NOE1 | 10 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 16 | 11 | [illegible] | [illegible] | 8.0 | R | 3.0 | NOE10 | NOE1 | 10 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 17 | 12 | 145 | 7.0 | 7.0 | R | 3.0 | NOE11 | NOE1 | 11 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 18 | 13 | 255 | 6.0 | 6.0 | G | 3.0 | NOE11 | NOE1 | 11 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 19 | 14 | 75 | 11.0 | 11.0 | D | 3.0 | NOE11 | NOE1 | 11 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 20 | 15 | 55 | 15.0 | 15.0 | D | 3.0 | NOE12 | NOE1 | 12 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 21 | 16 | 330 | 15.0 | 15.0 | G | 3.0 | NOE12 | NOE1 | 12 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 22 | 17 | 120 | 17.0 | 17.0 | D | 3.0 | NOE14 | NOE1 | 14 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 3.000E-01 | 1.000E+00 | 1.000E+00 | D |
| 23 | 18 | 95 | 14.0 | 14.0 | G | 3.0 | NOE15 | NOE1 | 15 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 24 | 19 | 870 | 17.3 | 17.3 | P | 3.0 | NOE17 | NOE2 | 17 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 6.000E-01 | 1.000E+00 | 1.000E+00 | P |
| 25 | 20 | 135 | 5.0 | 5.0 | T | 3.0 | NOE18 | NOE2 | 18 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 26 | 21 | 60 | 5.0 | 5.0 | T | 3.0 | NOE19 | NOE3 | 19 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 27 | 22 | 75 | 13.0 | 13.0 | R | 3.0 | NOE20 | NOE3 | 20 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 28 | 23 | 140 | 17.0 | 17.0 | T | 3.0 | NOE21 | NOE3 | 21 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 29 | 24 | 25 | 5.0 | 5.0 | T | 3.0 | NOE21 | NOE3 | 21 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 30 | 25 | 50 | 5.0 | 5.0 | P | 3.0 | NOE23 | NOE4 | 23 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 6.000E-01 | 1.000E+00 | 1.000E+00 | P |
| 31 | 26 | 40 | 13.0 | 13.0 | R | 3.0 | NOE23 | NOE4 | 23 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 32 | 27 | 40 | 14.0 | 14.0 | R | 3.0 | NOE23 | NOE4 | 23 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 33 | 28 | 75 | 13.0 | 13.0 | T | 3.0 | NOE24 | NOE4 | 24 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 34 | 29 | 80 | 14.0 | 14.0 | T | 3.0 | NOE24 | NOE4 | 24 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 35 | 30 | 75 | 13.0 | 13.0 | T | 3.0 | NOE26 | NOE4 | 26 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 36 | 31 | 60 | 13.0 | 13.0 | T | 3.0 | NOE26 | NOE4 | 26 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 7.000E-01 | 1.000E+00 | 1.000E+00 | T |
| 37 | 32 | 150 | 13.0 | 13.0 | P | 3.0 | NOE26 | NOE4 | 26 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 6.000E-01 | 1.000E+00 | 1.000E+00 | P |
| 38 | 33 | 70 | 12.0 | 12.0 | R | 3.0 | NOE27 | NOE4 | 27 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 39 | 34 | 70 | 9.0 | 9.0 | R | 3.0 | NOE27 | NOE4 | 27 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 3.162E-07 | 1.000E-01 | 5.000E-01 | 1.000E+00 | 1.000E+00 | R |
| 40 | 35 | 90 | 5.0 | 5.0 | G | 3.0 | NOE27 | NOE4 | 27 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 41 | 36 | 100 | 11.0 | 11.0 | G | 3.0 | NOE28 | NOE4 | 28 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 42 | 37 | 100 | 6.0 | 6.0 | G | 3.0 | NOE28 | NOE4 | 28 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |
| 43 | 38 | 195 | 12.0 | 12.0 | G | 3.0 | NOE28 | NOE4 | 28 | 1.00E-12 | 1.00E-12 | 1.000E-12 | 4.472E-07 | 2.000E-01 | 9.000E-01 | 1.000E+00 | 1.000E+00 | G |

Figure 15-6. Transition definition worksheet.

| Table 15-3. Description of Transition Data inputs | |
|---|---|
| **Item** | **Description** |
| A | Transition ID. Each transition is assigned a unique integer ID. |
| B | Length of the transition section measured in feet. |
| C | Nominal top elevation of the transition section measured in feet. This value is used for specifying failure probabilities on the fragility curve. |
| D | Nominal design elevation of the transition section measured in feet. This value is used for specifying failure probabilities on the fragility curve. |
| E | Reach type. "R" corresponds to "Ramp," "T" corresponds to "Wall-levee," "D" corresponds to "Drainage Structure," "P" corresponds to "Pumping Stations," "G" corresponds to "Gates," and "U" corresponds to "Unknown." This value is used to determine the appropriate breach parameters. |
| F | Reach weir coefficient. A default value of 2.0 is used for all transitions. |
| G | This is the IPET ID of the reach containing the transition. This ID is used to map to the appropriate hydrograph. |
| H | This is the ID of the associated subbasin containing the transition. |
| I | This is the FoRTE ID of the reach containing the transition. |
| J | Breach fragility curve that specifies the probability of failure as a function of peak water elevation. The low limit corresponds to an elevation of 0-feet. The high-limit corresponds to an elevation of 6-feet above the nominal top elevation of the reach. Data points specified in between include probability of breach failure at the design and top elevations, and 0.5-feet, 1.0-feet, 2.0-feet, and 3.0-feet above the nominal top elevation of the reach. |
| K | Transition material is equivalent to reach type in item E above. |

## Breach Failure

Data that define the width and depth of a breach within the hurricane protection system are provided in the "Breach Data" worksheet of the FoRTE tool. An annotated snapshot of the "Breach Data" worksheet is provided in Figure 15-7. Descriptions of the inputs to the "Breach Data" worksheet are provided in Table 15-4 and further description of the breaching model is provided in Appendix 9, Table 9-5.

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Breach Failure Data | | | | | | | | | |
| 4 | | | Overtopping | | | | | | Not Overtopping | |
| 5 | Material | Symbol | 0 to 1ft | | 1ft to 3ft | | >3 ft | | | |
| 6 | | | Depth (ft) | Width (ft) | Depth (ft) | Width (ft) | Depth (ft) | Width (ft) | Depth | Width |
| 7 | Hydraulic Fill, <1000 ft | H1 | 0 | 0 | 9 | 400 | 18 | 430 | 18 | 500 |
| 8 | Hydraulic Fill, 1001 ft | H2 | 0 | 0 | 9 | 400.4 | 18 | 430 | 18 | 500 |
| 9 | Hydraulic Fill, 2000 ft | H3 | 0 | 0 | 9 | 800 | 18 | 800 | 18 | 500 |
| 10 | Hydraulic Fill, 3000 ft | H4 | 0 | 0 | 9 | 1200 | 18 | 1200 | 18 | 500 |
| 11 | Hydraulic Fill, 4000 ft | H5 | 0 | 0 | 9 | 1600 | 18 | 1600 | 18 | 600 |
| 12 | Hydraulic Fill, 5000 ft | H6 | 0 | 0 | 9 | 2000 | 18 | 2000 | 18 | 750 |
| 13 | Hydraulic Fill, 10000 ft | H7 | 0 | 0 | 9 | 4000 | 18 | 4000 | 18 | 1500 |
| 14 | Hydraulic Fill, 20000 ft | H8 | 0 | 0 | 9 | 8000 | 18 | 8000 | 18 | 3000 |
| 15 | Hydraulic Fill, 30000 ft | H9 | 0 | 0 | 9 | 12000 | 18 | 12000 | 18 | 4500 |
| 16 | Hydraulic Fill, 40000 ft | HA | 0 | 0 | 9 | 16000 | 18 | 16000 | 18 | 6000 |
| 17 | Hydraulic Fill, 50000 ft | HB | 0 | 0 | 9 | 20000 | 18 | 20000 | 18 | 7500 |
| 18 | Clay, <1000 ft | C1 | 0 | 0 | 3 | 135 | 13 | 135 | 13 | 500 |
| 19 | Clay, 1001 ft | C2 | 0 | 0 | 3 | 135 | 13 | 135 | 13 | 500 |
| 20 | Clay, 2000 ft | C3 | 0 | 0 | 3 | 200 | 13 | 200 | 13 | 500 |
| 21 | Clay, 3000 ft | C4 | 0 | 0 | 3 | 300 | 13 | 300 | 13 | 500 |
| 22 | Clay, 4000 ft | C5 | 0 | 0 | 3 | 400 | 13 | 400 | 13 | 500 |
| 23 | Clay, 5000 ft | C6 | 0 | 0 | 3 | 500 | 13 | 500 | 13 | 500 |
| 24 | Clay, 10000 ft | C7 | 0 | 0 | 3 | 1000 | 13 | 1000 | 13 | 1000 |
| 25 | Clay, 20000 ft | C8 | 0 | 0 | 3 | 2000 | 13 | 2000 | 13 | 2000 |
| 26 | Clay, 30000 ft | C9 | 0 | 0 | 3 | 3000 | 13 | 3000 | 13 | 3000 |
| 27 | Clay, 40000 ft | CA | 0 | 0 | 3 | 4000 | 13 | 4000 | 13 | 4000 |
| 28 | Clay, 50000 ft | CB | 0 | 0 | 3 | 5000 | 13 | 5000 | 13 | 5000 |
| 29 | Unknown (Average), <1 | U1 | 0 | 0 | 6 | 290 | 17 | 315 | 17 | 500 |
| 30 | Unknown (Average), 10 | U2 | 0 | 0 | 6 | 300.3 | 17 | 315 | 17 | 500 |
| 31 | Unknown (Average), 20 | U3 | 0 | 0 | 6 | 600 | 17 | 600 | 17 | 500 |
| 32 | Unknown (Average), 30 | U4 | 0 | 0 | 6 | 900 | 17 | 900 | 17 | 500 |
| 33 | Unknown (Average), 40 | U5 | 0 | 0 | 6 | 1200 | 17 | 1200 | 17 | 500 |
| 34 | Unknown (Average), 50 | U6 | 0 | 0 | 6 | 1500 | 17 | 1500 | 17 | 625 |
| 35 | Unknown (Average), 10 | U7 | 0 | 0 | 6 | 3000 | 17 | 3000 | 17 | 1250 |
| 36 | Unknown (Average), 20 | U8 | 0 | 0 | 6 | 6000 | 17 | 6000 | 17 | 2500 |
| 37 | Unknown (Average), 30 | U9 | 0 | 0 | 6 | 9000 | 17 | 9000 | 17 | 3750 |
| 38 | Unknown (Average), 40 | UA | 0 | 0 | 6 | 12000 | 17 | 12000 | 17 | 5000 |
| 39 | Unknown (Average), 50 | UB | 0 | 0 | 6 | 15000 | 17 | 15000 | 17 | 6250 |
| 40 | Wall, <1000 ft | W1 | 0 | 0 | 0 | 0 | 17 | 315 | 17 | 500 |
| 41 | Wall, 1001 ft | W2 | 0 | 0 | 0 | 0 | 17 | 315 | 17 | 500 |
| 42 | Wall, 2000 ft | W3 | 0 | 0 | 0 | 0 | 17 | 315 | 17 | 500 |
| 43 | Wall, 3000 ft | W4 | 0 | 0 | 0 | 0 | 17 | 315 | 17 | 500 |
| 44 | Wall, 4000 ft | W5 | 0 | 0 | 0 | 0 | 17 | 400 | 17 | 500 |
| 45 | Wall, 5000 ft | W6 | 0 | 0 | 0 | 0 | 17 | 500 | 17 | 500 |
| 46 | Wall, 10000 ft | W7 | 0 | 0 | 0 | 0 | 17 | 1000 | 17 | 750 |
| 47 | Wall, 20000 ft | W8 | 0 | 0 | 0 | 0 | 17 | 2000 | 17 | 1500 |
| 48 | Wall, 30000 ft | W9 | 0 | 0 | 0 | 0 | 17 | 3000 | 17 | 2250 |
| 49 | Wall, 40000 ft | WA | 0 | 0 | 0 | 0 | 17 | 4000 | 17 | 3000 |
| 50 | Wall, 50000 ft | WB | 0 | 0 | 0 | 0 | 17 | 5000 | 17 | 3750 |
| 51 | Wall-Levee | T | 3 | 50 | 3 | 50 | 3 | 50 | 0 | 0 |
| 52 | Drainage Structures | D | 5.5 | 65 | 5.5 | 65 | 5.5 | 65 | 0 | 0 |
| 53 | Pump Stations | P | 5 | 100 | 5 | 100 | 5 | 100 | 0 | 0 |
| 54 | Ramps | R | 3 | Full Breach | 3 | Full Breach | 3 | Full Breach | 0 | 0 |
| 55 | Gates | G | 5 | 25 | 5 | 25 | 5 | 25 | 0 | 0 |
| 56 | Unknown | U | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Reach Data / Transition Data / Breach Failure / Features / Storm Data / Input Data

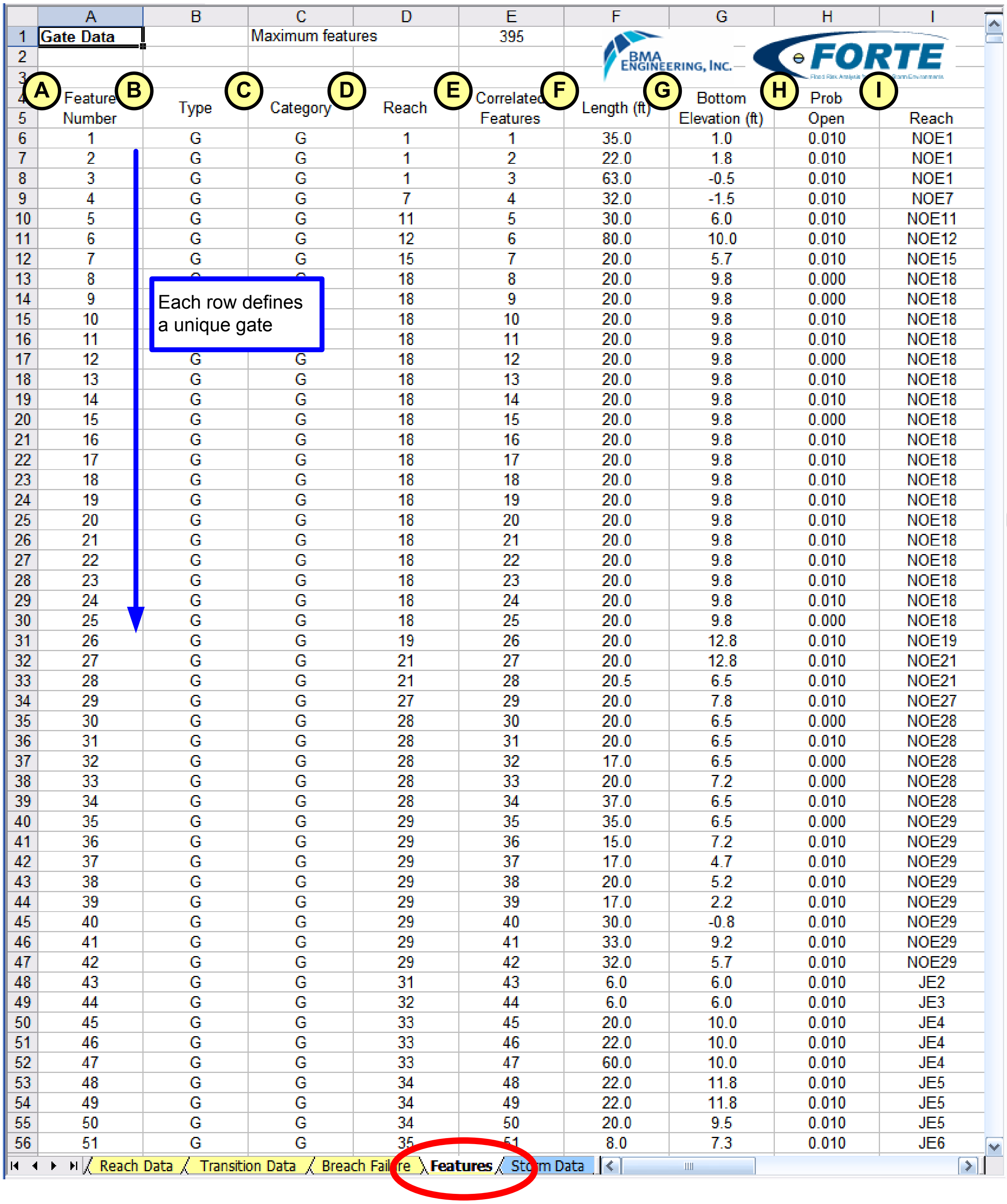
Figure 15-7. Breach data definition worksheet.

**Table 15-4. Description of Breach Data inputs**

| Item | Description |
|---|---|
| A | Material and length description. |
| B | Symbol used for associating different breach materials and lengths to system levees and transitions |
| C | Breach depths measured from the top of reach or transition (in feet) and breach widths (in feet) for several overtopping conditions: (1) 0 to 1-ft overtopping, (2) 1 to 3-ft overtopping, and (3) > 3-ft overtopping. |
| D | Breach depths measured from the top of reach or transition (in feet) and breach widths (in feet) for non-overtopping conditions. Note that these inputs do not apply to transitions. |

### Features

Data that define the closures within the hurricane protection system are provided in the "Features" worksheet. An annotated snapshot of the "Features" worksheet is provided in Figure 15-8. Descriptions of the inputs to the "Features" worksheet are provided in Table 15-5.



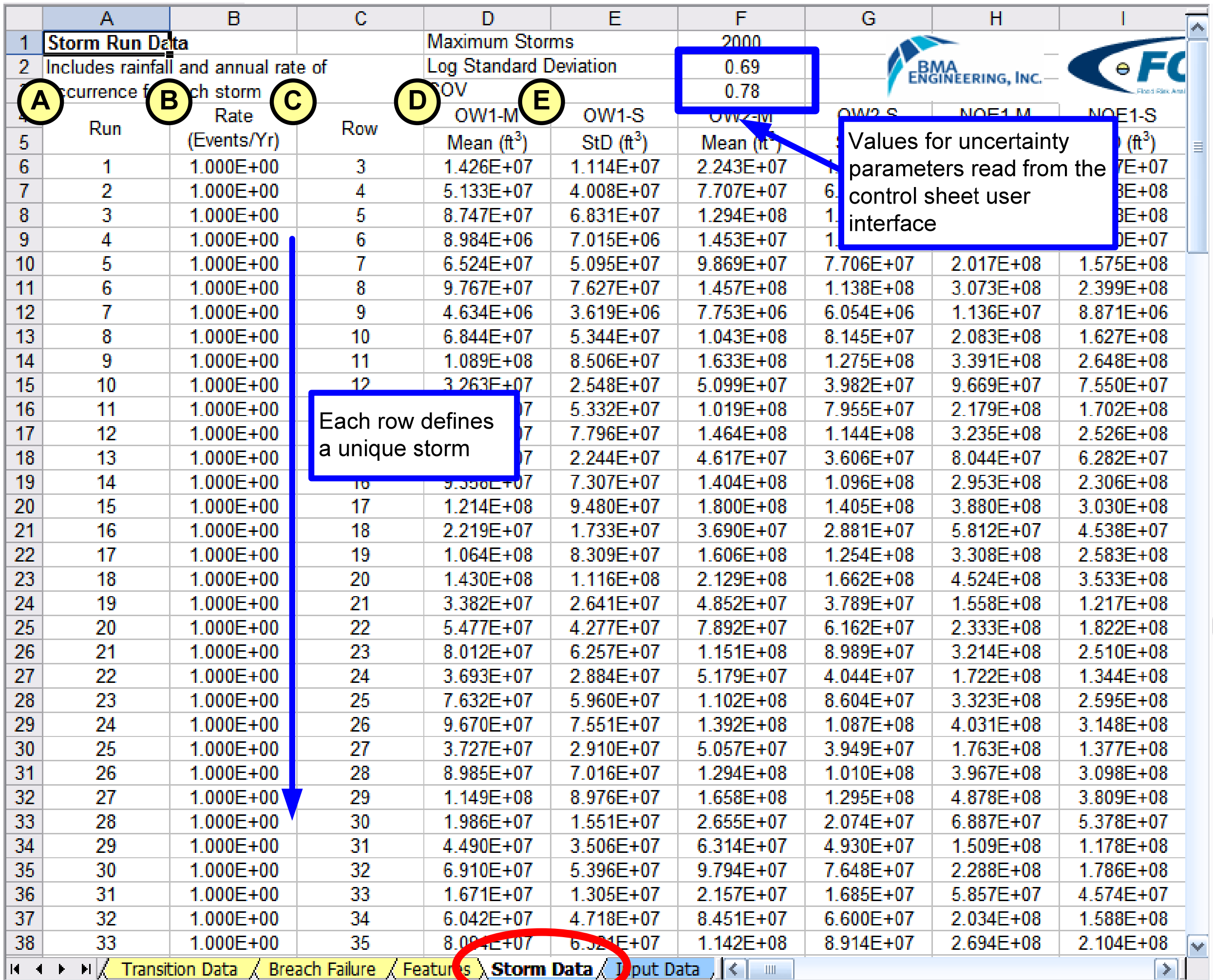

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Gate Data | | Maximum features | | 395 | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4–5 | Feature Number | Type | Category | Reach | Correlated Features | Length (ft) | Bottom Elevation (ft) | Prob Open | Reach |
| 6 | 1 | G | G | 1 | 1 | 35.0 | 1.0 | 0.010 | NOE1 |
| 7 | 2 | G | G | 1 | 2 | 22.0 | 1.8 | 0.010 | NOE1 |
| 8 | 3 | G | G | 1 | 3 | 63.0 | -0.5 | 0.010 | NOE1 |
| 9 | 4 | G | G | 7 | 4 | 32.0 | -1.5 | 0.010 | NOE7 |
| 10 | 5 | G | G | 11 | 5 | 30.0 | 6.0 | 0.010 | NOE11 |
| 11 | 6 | G | G | 12 | 6 | 80.0 | 10.0 | 0.010 | NOE12 |
| 12 | 7 | G | G | 15 | 7 | 20.0 | 5.7 | 0.010 | NOE15 |
| 13 | 8 | | | 18 | 8 | 20.0 | 9.8 | 0.000 | NOE18 |
| 14 | 9 | | | 18 | 9 | 20.0 | 9.8 | 0.000 | NOE18 |
| 15 | 10 | | | 18 | 10 | 20.0 | 9.8 | 0.010 | NOE18 |
| 16 | 11 | | | 18 | 11 | 20.0 | 9.8 | 0.010 | NOE18 |
| 17 | 12 | G | G | 18 | 12 | 20.0 | 9.8 | 0.000 | NOE18 |
| 18 | 13 | G | G | 18 | 13 | 20.0 | 9.8 | 0.010 | NOE18 |
| 19 | 14 | G | G | 18 | 14 | 20.0 | 9.8 | 0.010 | NOE18 |
| 20 | 15 | G | G | 18 | 15 | 20.0 | 9.8 | 0.000 | NOE18 |
| 21 | 16 | G | G | 18 | 16 | 20.0 | 9.8 | 0.010 | NOE18 |
| 22 | 17 | G | G | 18 | 17 | 20.0 | 9.8 | 0.010 | NOE18 |
| 23 | 18 | G | G | 18 | 18 | 20.0 | 9.8 | 0.010 | NOE18 |
| 24 | 19 | G | G | 18 | 19 | 20.0 | 9.8 | 0.010 | NOE18 |
| 25 | 20 | G | G | 18 | 20 | 20.0 | 9.8 | 0.010 | NOE18 |
| 26 | 21 | G | G | 18 | 21 | 20.0 | 9.8 | 0.010 | NOE18 |
| 27 | 22 | G | G | 18 | 22 | 20.0 | 9.8 | 0.010 | NOE18 |
| 28 | 23 | G | G | 18 | 23 | 20.0 | 9.8 | 0.010 | NOE18 |
| 29 | 24 | G | G | 18 | 24 | 20.0 | 9.8 | 0.010 | NOE18 |
| 30 | 25 | G | G | 18 | 25 | 20.0 | 9.8 | 0.000 | NOE18 |
| 31 | 26 | G | G | 19 | 26 | 20.0 | 12.8 | 0.010 | NOE19 |
| 32 | 27 | G | G | 21 | 27 | 20.0 | 12.8 | 0.010 | NOE21 |
| 33 | 28 | G | G | 21 | 28 | 20.5 | 6.5 | 0.010 | NOE21 |
| 34 | 29 | G | G | 27 | 29 | 20.0 | 7.8 | 0.010 | NOE27 |
| 35 | 30 | G | G | 28 | 30 | 20.0 | 6.5 | 0.000 | NOE28 |
| 36 | 31 | G | G | 28 | 31 | 20.0 | 6.5 | 0.010 | NOE28 |
| 37 | 32 | G | G | 28 | 32 | 17.0 | 6.5 | 0.000 | NOE28 |
| 38 | 33 | G | G | 28 | 33 | 20.0 | 7.2 | 0.000 | NOE28 |
| 39 | 34 | G | G | 28 | 34 | 37.0 | 6.5 | 0.010 | NOE28 |
| 40 | 35 | G | G | 29 | 35 | 35.0 | 6.5 | 0.000 | NOE29 |
| 41 | 36 | G | G | 29 | 36 | 15.0 | 7.2 | 0.010 | NOE29 |
| 42 | 37 | G | G | 29 | 37 | 17.0 | 4.7 | 0.010 | NOE29 |
| 43 | 38 | G | G | 29 | 38 | 20.0 | 5.2 | 0.010 | NOE29 |
| 44 | 39 | G | G | 29 | 39 | 17.0 | 2.2 | 0.010 | NOE29 |
| 45 | 40 | G | G | 29 | 40 | 30.0 | -0.8 | 0.010 | NOE29 |
| 46 | 41 | G | G | 29 | 41 | 33.0 | 9.2 | 0.010 | NOE29 |
| 47 | 42 | G | G | 29 | 42 | 32.0 | 5.7 | 0.010 | NOE29 |
| 48 | 43 | G | G | 31 | 43 | 6.0 | 6.0 | 0.010 | JE2 |
| 49 | 44 | G | G | 32 | 44 | 6.0 | 6.0 | 0.010 | JE3 |
| 50 | 45 | G | G | 33 | 45 | 20.0 | 10.0 | 0.010 | JE4 |
| 51 | 46 | G | G | 33 | 46 | 22.0 | 10.0 | 0.010 | JE4 |
| 52 | 47 | G | G | 33 | 47 | 60.0 | 10.0 | 0.010 | JE4 |
| 53 | 48 | G | G | 34 | 48 | 22.0 | 11.8 | 0.010 | JE5 |
| 54 | 49 | G | G | 34 | 49 | 22.0 | 11.8 | 0.010 | JE5 |
| 55 | 50 | G | G | 34 | 50 | 20.0 | 9.5 | 0.010 | JE5 |
| 56 | 51 | G | G | 35 | 51 | 8.0 | 7.3 | 0.010 | JE6 |

Figure 15-8. Feature (closure) data definition worksheet.

| Table 15-5. Description of Feature Data inputs | |
|---|---|
| **Item** | **Description** |
| A | Feature ID. Each closure is assigned a unique feature ID. |
| B | Type of feature. Options are “G” for “Gate” and “R” for “Ramp.” |
| C | Feature category. The only option is “G” for “Gate.” This field is not used for ay calculations. |
| D | ID of associated reach. This value is used to map the gates to the corresponding reaches. |
| E | IDs of correlated features used for determining probability of open among a set of related features. |
| F | Length of closure opening when open (in feet). This value is used with the Weir formula to determine volume of water passing through the gate when left open. |
| G | Bottom elevation of closure when open (in feet). This value is used with the Weir formula to determine volume of water passing through the gate when left open. |
| H | Probability that the gate will be left open during a storm. |
| I | Associated IPET reach ID. |

## Storm Data

Data that define the storm parameters (not including hydrographs) affecting the hurricane protection system are provided in the “Storm Data” worksheet of the FoRTE tool. An annotated snapshot of the “Storm Data” worksheet is provided in Figure 15-9. Descriptions of the inputs to the “Storm Data” worksheet are provided in Table 15-6.



| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Storm Run Data | | | Maximum Storms | | 2000 | | | |
| 2 | Includes rainfall and annual rate of | | | Log Standard Deviation | | 0.69 | | | |
| 3 | occurrence for each storm | | | COV | | 0.78 | | | |
| 4 | Run | Rate | Row | OW1-M | OW1-S | OW2-M | OW2-S | NOE1-M | NOE1-S |
| 5 | | (Events/Yr) | | Mean ($ft^3$) | StD ($ft^3$) | Mean ($ft^3$) | [illegible] | [illegible] | [illegible] ($ft^3$) |
| 6 | 1 | 1.000E+00 | 3 | 1.426E+07 | 1.114E+07 | 2.243E+07 | [illegible] | [illegible] | [illegible] |
| 7 | 2 | 1.000E+00 | 4 | 5.133E+07 | 4.008E+07 | 7.707E+07 | [illegible] | [illegible] | [illegible] |
| 8 | 3 | 1.000E+00 | 5 | 8.747E+07 | 6.831E+07 | 1.294E+08 | [illegible] | [illegible] | [illegible] |
| 9 | 4 | 1.000E+00 | 6 | 8.984E+06 | 7.015E+06 | 1.453E+07 | [illegible] | [illegible] | [illegible] |
| 10 | 5 | 1.000E+00 | 7 | 6.524E+07 | 5.095E+07 | 9.869E+07 | 7.706E+07 | 2.017E+08 | 1.575E+08 |
| 11 | 6 | 1.000E+00 | 8 | 9.767E+07 | 7.627E+07 | 1.457E+08 | 1.138E+08 | 3.073E+08 | 2.399E+08 |
| 12 | 7 | 1.000E+00 | 9 | 4.634E+06 | 3.619E+06 | 7.753E+06 | 6.054E+06 | 1.136E+07 | 8.871E+06 |
| 13 | 8 | 1.000E+00 | 10 | 6.844E+07 | 5.344E+07 | 1.043E+08 | 8.145E+07 | 2.083E+08 | 1.627E+08 |
| 14 | 9 | 1.000E+00 | 11 | 1.089E+08 | 8.506E+07 | 1.633E+08 | 1.275E+08 | 3.391E+08 | 2.648E+08 |
| 15 | 10 | 1.000E+00 | 12 | 3.263E+07 | 2.548E+07 | 5.099E+07 | 3.982E+07 | 9.669E+07 | 7.550E+07 |
| 16 | 11 | 1.000E+00 | [illegible] | [illegible] | 5.332E+07 | 1.019E+08 | 7.955E+07 | 2.179E+08 | 1.702E+08 |
| 17 | 12 | 1.000E+00 | [illegible] | [illegible] | 7.796E+07 | 1.464E+08 | 1.144E+08 | 3.235E+08 | 2.526E+08 |
| 18 | 13 | 1.000E+00 | [illegible] | [illegible] | 2.244E+07 | 4.617E+07 | 3.606E+07 | 8.044E+07 | 6.282E+07 |
| 19 | 14 | 1.000E+00 | [illegible] | [illegible] | 7.307E+07 | 1.404E+08 | 1.096E+08 | 2.953E+08 | 2.306E+08 |
| 20 | 15 | 1.000E+00 | 17 | 1.214E+08 | 9.480E+07 | 1.800E+08 | 1.405E+08 | 3.880E+08 | 3.030E+08 |
| 21 | 16 | 1.000E+00 | 18 | 2.219E+07 | 1.733E+07 | 3.690E+07 | 2.881E+07 | 5.812E+07 | 4.538E+07 |
| 22 | 17 | 1.000E+00 | 19 | 1.064E+08 | 8.309E+07 | 1.606E+08 | 1.254E+08 | 3.308E+08 | 2.583E+08 |
| 23 | 18 | 1.000E+00 | 20 | 1.430E+08 | 1.116E+08 | 2.129E+08 | 1.662E+08 | 4.524E+08 | 3.533E+08 |
| 24 | 19 | 1.000E+00 | 21 | 3.382E+07 | 2.641E+07 | 4.852E+07 | 3.789E+07 | 1.558E+08 | 1.217E+08 |
| 25 | 20 | 1.000E+00 | 22 | 5.477E+07 | 4.277E+07 | 7.892E+07 | 6.162E+07 | 2.333E+08 | 1.822E+08 |
| 26 | 21 | 1.000E+00 | 23 | 8.012E+07 | 6.257E+07 | 1.151E+08 | 8.989E+07 | 3.214E+08 | 2.510E+08 |
| 27 | 22 | 1.000E+00 | 24 | 3.693E+07 | 2.884E+07 | 5.179E+07 | 4.044E+07 | 1.722E+08 | 1.344E+08 |
| 28 | 23 | 1.000E+00 | 25 | 7.632E+07 | 5.960E+07 | 1.102E+08 | 8.604E+07 | 3.323E+08 | 2.595E+08 |
| 29 | 24 | 1.000E+00 | 26 | 9.670E+07 | 7.551E+07 | 1.392E+08 | 1.087E+08 | 4.031E+08 | 3.148E+08 |
| 30 | 25 | 1.000E+00 | 27 | 3.727E+07 | 2.910E+07 | 5.057E+07 | 3.949E+07 | 1.763E+08 | 1.377E+08 |
| 31 | 26 | 1.000E+00 | 28 | 8.985E+07 | 7.016E+07 | 1.294E+08 | 1.010E+08 | 3.967E+08 | 3.098E+08 |
| 32 | 27 | 1.000E+00 | 29 | 1.149E+08 | 8.976E+07 | 1.658E+08 | 1.295E+08 | 4.878E+08 | 3.809E+08 |
| 33 | 28 | 1.000E+00 | 30 | 1.986E+07 | 1.551E+07 | 2.655E+07 | 2.074E+07 | 6.887E+07 | 5.378E+07 |
| 34 | 29 | 1.000E+00 | 31 | 4.490E+07 | 3.506E+07 | 6.314E+07 | 4.930E+07 | 1.509E+08 | 1.178E+08 |
| 35 | 30 | 1.000E+00 | 32 | 6.910E+07 | 5.396E+07 | 9.794E+07 | 7.648E+07 | 2.288E+08 | 1.786E+08 |
| 36 | 31 | 1.000E+00 | 33 | 1.671E+07 | 1.305E+07 | 2.157E+07 | 1.685E+07 | 5.857E+07 | 4.574E+07 |
| 37 | 32 | 1.000E+00 | 34 | 6.042E+07 | 4.718E+07 | 8.451E+07 | 6.600E+07 | 2.034E+08 | 1.588E+08 |
| 38 | 33 | 1.000E+00 | 35 | [illegible] | [illegible] | 1.142E+08 | 8.914E+07 | 2.694E+08 | 2.104E+08 |



Figure 15-9. Storm data definition worksheet.

| Table 15-6. Description of Storm Data inputs | |
|---|---|
| **Item** | **Description** |
| A | Run ID. This is the ID of the storm. This value is used to map storm parameters to input hydrographs. |
| B | Storm recurrence rate in events per year. By default this value is set to 1 to accommodate offline aggregation using the FoRTE Storm Aggregator. |
| C | Row ID. This is not a user defined input. |
| D | Mean volume of water due to precipitation for each storm. This column is repeated for each subbasin. |
| E | Standard deviation of water volume due to precipitation for each storm. This value is calculated for each storm and subbasin by multiplying the Rainfall COV by the mean precipitation water volume. |

## Hydrograph Processing and Calculation Worksheets

FoRTE performs calculations on hydrograph data as illustrated in Figure 15-10.

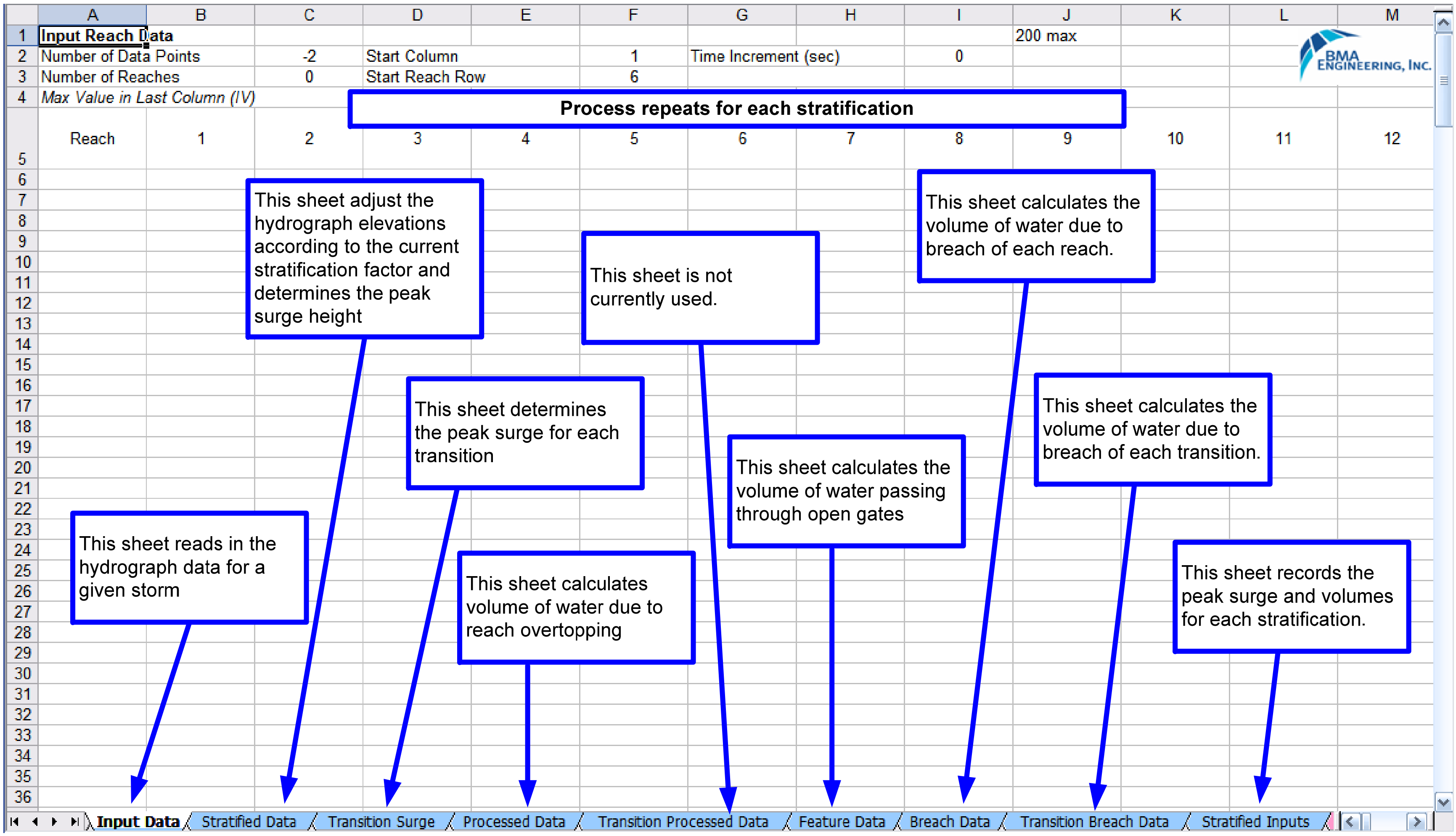



Figure 15-10. Hydrograph processing and calculation worksheets.

In particular, FoRTE begins by reading a hydrograph file for a given storm into the "Input Data" worksheet. Then, for each stratification, FoRTE does the following:

1. FoRTE applies a stratification factor to the hydrograph surge heights according to the current stratification and determines the peak surge for each reach ("Stratified Data" worksheet)

2. The peak surge is determined for each transition ("Transition Surge" worksheet)

3. The volume of water due to overtopping of each reach is calculated ("Processed Data" worksheet)

4. The volume of water passing through open gates is calculated ("Feature Data" worksheet")

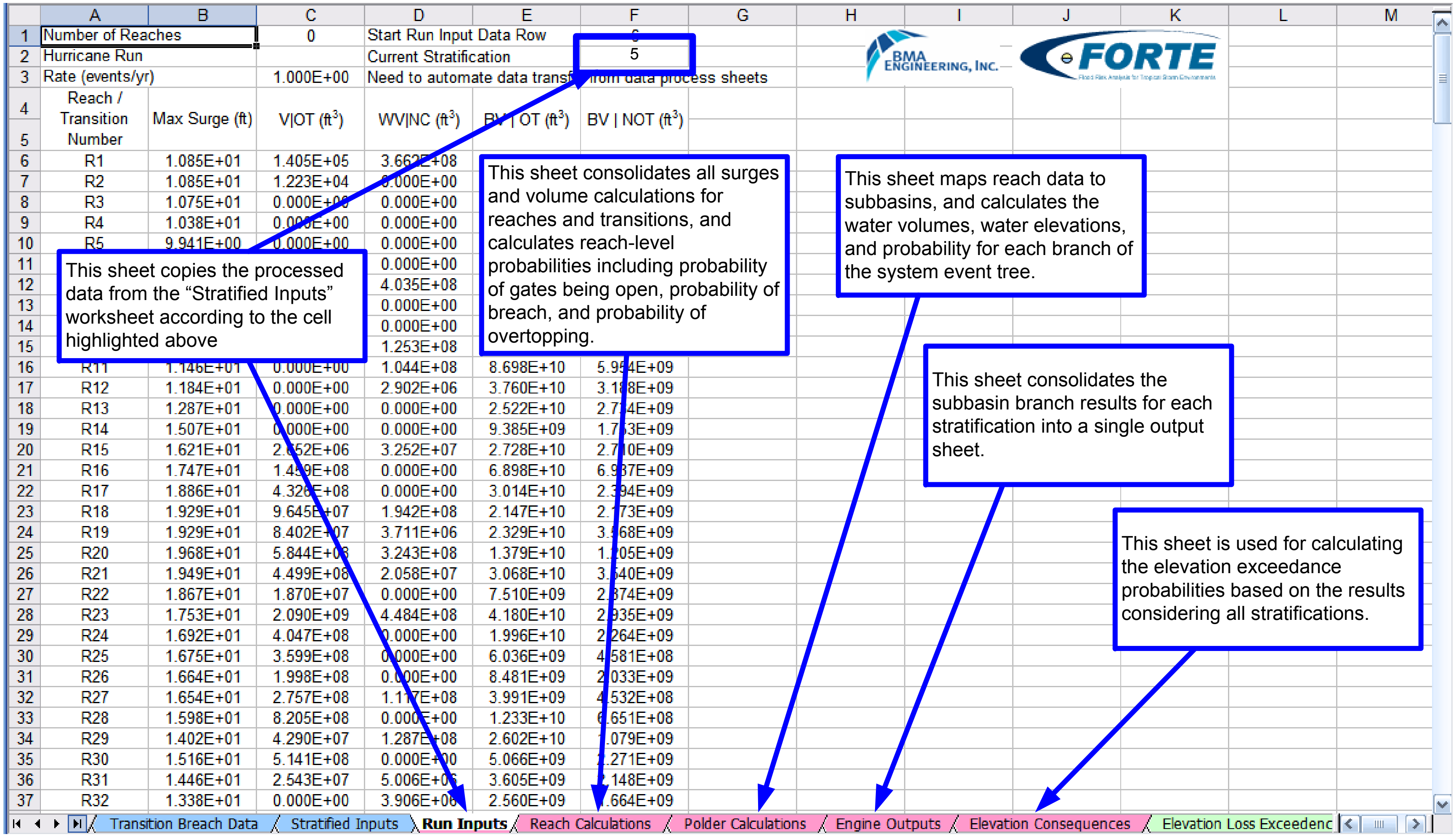
5. The volume of water due to breach of each reach and transition is calculated ("Breach Data" and "Transition Breach Data" worksheets)

6. The surge and volume data is then accumulated and stored in the "Stratified Inputs" worksheet.

If the option to output "Stratified Water Output per Storm" is selected, the FoRTE tool will output the "Stratified Inputs" sheet according to the filename specified on the control sheet user interface.

## Branch Calculations and Analysis Results Worksheets

Following the hydrograph processing and calculation phase, the program processes the information for each stratification in turn to determine reach probabilities, and subbasin water volumes, elevations, and probabilities (or rates) for each branch of the system event tree. The sheets are described in Figure 15-11. If "Detailed Branch Output per Storm" is desired, the FoRTE will output the "Elevation Consequences" sheet according to the filename specified on the control sheet user interface.



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Number of Reaches | | 0 | Start Run Input Data Row | | 6 |
| 2 | Hurricane Run | | | Current Stratification | | 5 |
| 3 | Rate (events/yr) | | 1.000E+00 | Need to automate data transfer from data process sheets | | |
| 4–5 | Reach / Transition Number | Max Surge (ft) | V\|OT (ft³) | WV\|NC (ft³) | BV \| OT (ft³) | BV \| NOT (ft³) |
| 6 | R1 | 1.085E+01 | 1.405E+05 | 3.662E+08 | | |
| 7 | R2 | 1.085E+01 | 1.223E+04 | 0.000E+00 | | |
| 8 | R3 | 1.075E+01 | 0.000E+00 | 0.000E+00 | | |
| 9 | R4 | 1.038E+01 | 0.000E+00 | 0.000E+00 | | |
| 10 | R5 | 9.941E+00 | 0.000E+00 | 0.000E+00 | | |
| 11 | | | | 0.000E+00 | | |
| 12 | | | | 4.035E+08 | | |
| 13 | | | | 0.000E+00 | | |
| 14 | | | | 0.000E+00 | | |
| 15 | | | | 1.253E+08 | | |
| 16 | R11 | 1.146E+01 | 0.000E+00 | 1.044E+08 | 8.698E+10 | 5.954E+09 |
| 17 | R12 | 1.184E+01 | 0.000E+00 | 2.902E+06 | 3.760E+10 | 3.188E+09 |
| 18 | R13 | 1.287E+01 | 0.000E+00 | 0.000E+00 | 2.522E+10 | 2.714E+09 |
| 19 | R14 | 1.507E+01 | 0.000E+00 | 0.000E+00 | 9.385E+09 | 1.753E+09 |
| 20 | R15 | 1.621E+01 | 2.652E+06 | 3.252E+07 | 2.728E+10 | 2.710E+09 |
| 21 | R16 | 1.747E+01 | 1.459E+08 | 0.000E+00 | 6.898E+10 | 6.937E+09 |
| 22 | R17 | 1.886E+01 | 4.326E+08 | 0.000E+00 | 3.014E+10 | 2.394E+09 |
| 23 | R18 | 1.929E+01 | 9.645E+07 | 1.942E+08 | 2.147E+10 | 2.173E+09 |
| 24 | R19 | 1.929E+01 | 8.402E+07 | 3.711E+06 | 2.329E+10 | 3.568E+09 |
| 25 | R20 | 1.968E+01 | 5.844E+08 | 3.243E+08 | 1.379E+10 | 1.205E+09 |
| 26 | R21 | 1.949E+01 | 4.499E+08 | 2.058E+07 | 3.068E+10 | 3.540E+09 |
| 27 | R22 | 1.867E+01 | 1.870E+07 | 0.000E+00 | 7.510E+09 | 2.874E+09 |
| 28 | R23 | 1.753E+01 | 2.090E+09 | 4.484E+08 | 4.180E+10 | 2.935E+09 |
| 29 | R24 | 1.692E+01 | 4.047E+08 | 0.000E+00 | 1.996E+10 | 2.264E+09 |
| 30 | R25 | 1.675E+01 | 3.599E+08 | 0.000E+00 | 6.036E+09 | 4.581E+08 |
| 31 | R26 | 1.664E+01 | 1.998E+08 | 0.000E+00 | 8.481E+09 | 2.033E+09 |
| 32 | R27 | 1.654E+01 | 2.757E+08 | 1.117E+08 | 3.991E+09 | 4.532E+08 |
| 33 | R28 | 1.598E+01 | 8.205E+08 | 0.000E+00 | 1.233E+10 | 6.651E+08 |
| 34 | R29 | 1.402E+01 | 4.290E+07 | 1.287E+08 | 2.602E+10 | 1.079E+09 |
| 35 | R30 | 1.516E+01 | 5.141E+08 | 0.000E+00 | 5.066E+09 | 1.271E+09 |
| 36 | R31 | 1.446E+01 | 2.543E+07 | 5.006E+06 | 3.605E+09 | 1.148E+09 |
| 37 | R32 | 1.338E+01 | 0.000E+00 | 3.906E+06 | 2.560E+09 | 1.664E+09 |



Figure 15-11. Branch calculations and results worksheets.

## Pumping Calculations

The total volume entering a subbasin was calculated for each branch of the event tree by summing volumes of water due to overtopping, breaching, and closure structures, as well as the water volume from rainfall and wave runup minus the effect of pumping. The pumping system in New Orleans was designed to remove rainfall from tropical storms up to about a 10-year event and not specifically designed to handle larger water volumes from breaching or overtopping. This was demonstrated during Katrina when very few pumps operated throughout the storm. Most pump stations were abandoned early in the storm and lost power during the event and in some cases water flowed back through the stations causing additional flooding. Since Katrina, pump stations have been upgraded with safe houses for operators, back flow suppressors and power upgrades, however, many stations are still antiquated and the system does not have the capacity to evacuate large volumes of water during catastrophic event.

The effect of pumping on subbasin inflow water volumes was approximated by subtracting a portion of the rainfall that was equal to three assumed pumping conditions. In order to approximate the range of pumping reliability and efficiency, the conditions modeled were "no pumping", "50% pumping" and "100% pumping". These conditions were selected to show how pumping can be a factor in the depth of flooding. They are intended to provide a relative comparison between the flooding expected without pumps and that with pumping and do not reflect any actual prediction of pumping capability. In fact, it is highly unlikely that any pumping system comprised of hundreds of aging pumps could ever achieve 100% of its nameplate capacity.

The IPET Drainage and Pumping Team developed a detailed model of the interior drainage system and the pumping system. The HEC-RAS model was able to show how water was distributed through the subbasins by breaching and overtopping during Katrina, and was able to show predictions of water levels if breaching had not occurred. The model is described in Volume 6 of the IPET report. The level of detail in that model could not be reproduced for the full range of hurricanes studied in the risk analysis so a simplified approximation was developed. The pumping model developed for the risk analysis looks only at volumes of water evacuated by a single pump in each subbasin that has the capacity of all the individual pumps in the subbasin. The drainage system that transports water throughout the subbasin to the pump stations is not modeled. The water volume that could be pumped within a particular subbasin was estimated by taking the capacity of the individual pump stations and multiplying it by the duration of the intense portion of the rainfall for each storm. These volumes were then summed for all the stations within a subbasin. This volume was considered to be the 100-percent pumping capacity of the subbasin and was subtracted from the rainfall from each storm, up to the total estimated rainfall volume. Volumes were also determined for 50-percent pump station capacity and no pump station capacity. An example of these calculations is presented in Table 15-7. The net volumes shown in this table were determined for each storm and input into the FoRTE model as replacements for the rainfall for the three pumping conditions and the two HPS scenarios.

**Table 15-7**
**Pumping Volume Calculation Example**

| Storm No. | Subbasin A | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | Rainfall Mean ($ft^3$) | Runoff Factor | Runoff volume from rain (cf) | Pumping Capacity (cfs) | Rainfall duration (hr) | Net volume (cf) w/100% pump capacity | Net volume (cf) w/50% pump capacity | Net volume (cf) w/0% pump capacity |
| 1 | 6.604E+07 | 0.82 | 5.415E+07 | 11597 | 8.00 | 0.00E+00 | 0.00E+00 | 5.42E+07 |
| 2 | 2.001E+08 | 0.82 | 1.641E+08 | 11597 | 12.00 | 0.00E+00 | 0.00E+00 | 1.64E+08 |
| 3 | 3.230E+08 | 0.82 | 2.648E+08 | 11597 | 12.00 | 0.00E+00 | 1.43E+07 | 2.65E+08 |
| 4 | 4.614E+07 | 0.82 | 3.783E+07 | 11597 | 8.00 | 0.00E+00 | 0.00E+00 | 3.78E+07 |
| 5 | 2.612E+08 | 0.82 | 2.142E+08 | 11597 | 12.00 | 0.00E+00 | 0.00E+00 | 2.14E+08 |
| 6 | 3.714E+08 | 0.82 | 3.046E+08 | 11597 | 12.00 | 0.00E+00 | 5.41E+07 | 3.05E+08 |
| 7 | 2.695E+07 | 0.82 | 2.210E+07 | 11597 | 8.00 | 0.00E+00 | 0.00E+00 | 2.21E+07 |
| 8 | 2.815E+08 | 0.82 | 2.309E+08 | 11597 | 12.00 | 0.00E+00 | 0.00E+00 | 2.31E+08 |
| 9 | 4.221E+08 | 0.82 | 3.461E+08 | 11597 | 12.00 | 0.00E+00 | 9.56E+07 | 3.46E+08 |

**Computations**
Column 1 = Mean rainfall associated with the hurricane
Column 3 = Column 1 * Column 2 = Volume of water expected to runoff during the storm
Column 5 = Duration of rainfall expected for the hurricane
Column 6: If Column 4 * (Column 5 * 60 Minutes * 60 seconds (or 100% pumping capacity volume)) is greater than the rainfall volume (Column 3), a zero is entered. Otherwise the net value of rainfall minus pump capacity is entered.
Column 7 = Column 6 except that 0.50* pumping volume is used
Column 8 = Column 3

## Performing a FoRTE Analysis

To perform a FoRTE analysis, perform the following steps:

1. Enter the appropriate system definition, including subbasin stage storage and interflow relationships, reach data, transition data, breach failure data, and feature data, as was described in the previous sections.

2. Specify analysis parameters and output file options on the control sheet as specified in the “General Overview and User Interface” section of this document (Table 15-1).

3. Click on the “Start Analysis” button. When prompted, browse to the directory where the hydrographs reside and select the input hydrographs. The hydrographs must be in data files ending with a *.dat. extension for calculations. The program accommodates selecting as many as 256 data files for batch processing. FoRTE will output files to the same directory containing the hydrographs.

4. To produce a single loss-exceedence rate curve by consolidating the results from multiple storms, a separate program entitled Storm Aggregator (Figure 15-12) was used as follows:

   a. Load “FoRTE Storm Aggregator”

b. Input the storms frequencies on the “Storm Data” worksheet, making sure that the frequencies are for the appropriate storm numbers.

c. Click on the “Click Here to Build Loss Exceedence Curves from…” button and select the output data files corresponding to the storms to be aggregated.

d. When complete, the results will available on the “Elevation Loss Exceedence” worksheet.

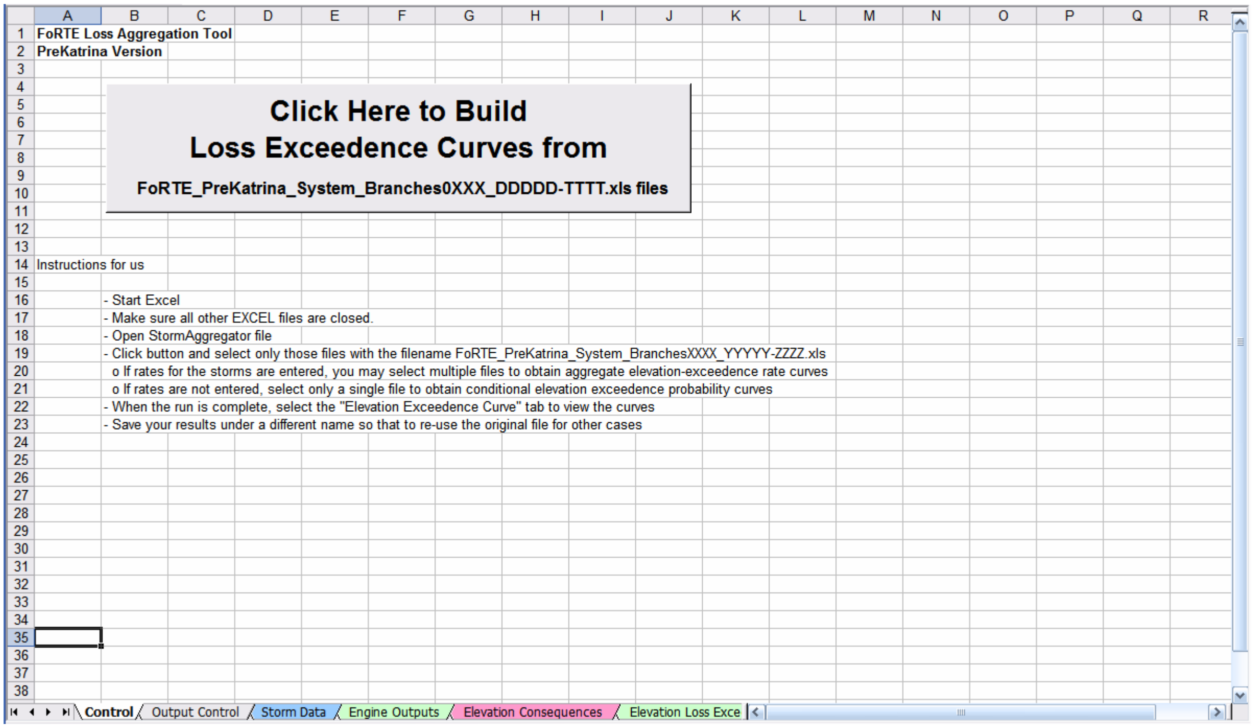



Figure 15-12. Screenshot of the FoRTE Storm Aggregator tool.

# Wave Runup Calculations

The hurricane hydrographs used in the FoRTE model do not include wave runup and therefore do not include overtopping water volumes that enter the HPS due to waves. Water volumes due to wave runup were calculated in a spreadsheet outside of the FoRTE model and added to the subbasins where appropriate. The additional loads on levees and walls was addressed in the fragility curves for the affected areas.

## Run-up water volume entering polders

The average wave overtopping over levees and walls is calculated according to Van der Meer (2002) and utilized an algorithm developed by the New Orleans District.

**For levee sections** the run-up overflow specific discharge was calculated by,

$$\frac{q}{\sqrt{gH_{m0}^3}} = \frac{0.067}{\sqrt{\tan\alpha}}\gamma_b\xi_0 \exp\left(-4.75\frac{R_c}{H_{m0}}\frac{1}{\xi_0\gamma_b\gamma_f\gamma_\beta\gamma_v}\right) \tag{15-1}$$

The maximum for this discharge is,

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.2\exp\left(-2.6\frac{R_c}{H_{m0}}\frac{1}{\gamma_f\gamma_\beta}\right) \tag{15-2}$$

in which:

$q$ = overtopping rate [cfs per ft]
$g$ = gravitational acceleration [= 32.18 ft/s$^2$]
$H_{m0}$ = significant wave height at toe of the structure [ft]
$\xi_0$ = surf similarity parameter [-]
$\alpha$ = slope [-]
$A_{rc}$ = free crest height above still water line [ft]
$\gamma$ = influence factors for presence of beam (b), friction (f), wave incidence ($\beta$), vertical wall (v)

The "maximum" discharge value calculated from Eq. 15-2 gives values consistent with Figure 15-1 below, was used in the spreadsheet. Equation 15-1 can give values almost 10 times larger, and this did not seem reasonable. To obtain total storm volumes per reach, the specific discharge was multiplied by 30 minutes (i.e., 30 x 60 seconds) for each hydrograph time increment and the time increments were summed for the hydrograph. The total was multiplied by the reach length in feet to determine the volume of water added to the subbasin by runup and overtopping. The coefficients 4.75 and 2.6 in Eq. (1) are means. The standard deviations of these coefficients are 0.5 and 0.35, respectively, and normally distributed. This equation is valid for $\xi_0 < 5$, where $\xi_0$ is defined by equation 15-3, and slopes steeper than 1:8. This appears to hold for the conditions in New Orleans. See Van der Meer for other conditions.

The surf similarity parameter $\xi_0$ is,

$$\xi_0 = \frac{\tan\alpha}{\sqrt{s_0}} \quad \textit{with} \quad s_0 = \frac{2\pi H_{m0}}{g\left(T_{m-1,0}\right)^2} \tag{15-3}$$

in which:

$s_0$ = wave steepness [-]
$T_{m-1,0}$ = mean period [s]

The parameter values used in the calculations are: slope $\alpha = 1/4$, a berm factor $\gamma_b = 0.7$ and $\gamma_f = \gamma_\beta = \gamma_v = 1$.

*Figure 21:*
*wave overtopping data with mean and 5% under and upper exceedance limits and indication of application area; breaking waves*

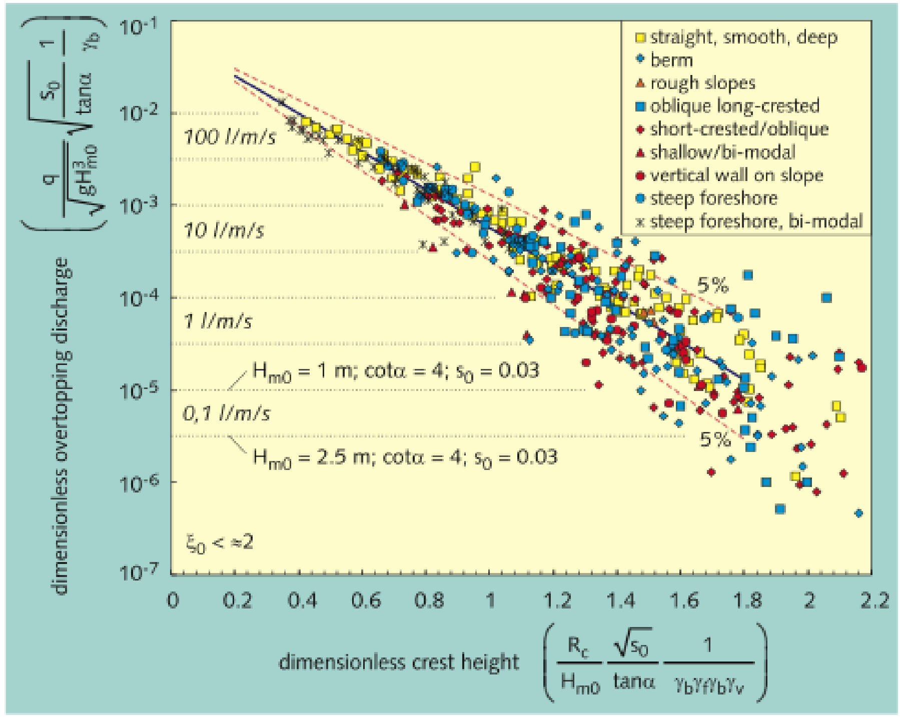



Figure 15-1. Figure and caption from Van der Meer (2002)

**For Floodwall Sections**

The average wave overtopping over floodwalls according to USACE ERDC-CHL (2006) is calculated as,

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.082 \exp\left(-3.0 \frac{R_c}{H_{m0}} \frac{1}{\gamma_\beta \gamma_s}\right)$$

in which:

$q$ = overtopping rate [cfs per ft]
$H_{m0}$ = significant wave height at toe of the structure [ft]
$R_c$ = free crest height above still water line [ft]
$\gamma$ = influence factors for wave incidence ($\beta$) and type of geometry (s)

The coefficient 3.0 is the mean value. The standard deviation of this coefficient is 0.26. No information is given about the error distribution, but a normal distribution has been assumed in design studies conducted by the New Orleans District. The influence factors are: $\gamma_s = 1$ and $\gamma_\beta = 0.83$ for plain impermeable floodwalls with perpendicular wave attack of short-crested waves. These settings have been applied in the 100-year design study for the New Orleans District.

### Wave information

Wave information by storm and reach has been provided numerically by the New Orleans District in the form of two spreadsheets, one for significant wave height and one for mean period. For both levees and floodwalls, the average wave overtopping can be computed using the still water level from ADCIRC and the wave information from STWAVE. The mean wave period $T_{m-1,0}$ is derived directly from the STWAVE results at 600 ft in front of the levees/floodwalls. The significant wave height at the toe of the structure ($H_{m0}$) is also derived from the STWAVE results, but is adapted because of depth-limited breaking in front the structure. The significant wave height based on the STWAVE results is limited to the maximum significant wave height according to:

$$H_{m0,\max} = \gamma\left(\zeta - z_{toe}\right)$$

in which:

$\gamma$ = breaker parameter [-]
$\zeta$ = still water level [ft]
$z_{toe}$ = bottom level at toe of structure [ft]

The breaker parameter is set at $\gamma = 0.4$ in the design study. The bed level at the toe of most of the structures is assumed to be at $z_{toe} = 0$ ft. The standard deviation for the significant wave height is assumed to be 10% of the value based on STWAVE (or after reduction due to depth-limited breaking according to Eq. (5)). The error in the wave period is set at 20% of the STWAVE result. The error is assumed to normally distributed. Both errors are based on expert judgement due to lack of field data.

### Overtopping

For several of the extreme storm some reaches are directly overtopped, that is, the still water level (SWL) is higher than the top of levee. In these cases the same weir equation calculation that is used in FORTE was applied.

$$q = 3.33LH^{3/2}$$

in which,

$L$ = the reach length

$H$ = the height of overtopping in feet.

The same uncertainties in the weir coefficient 3.33 were assumed to apply as in FORTE.

## Determination of Subbasin Flooding Elevations

The risk model makes basic calculations of volumes of water entering each subbasin for each of the 76 storms used to characterize the hazard and converts the volumes to elevations using the stage-storage curves for each subbasin. The result for each storm is an elevation-exceedence curve. The results for all of the individual subbasins are combined into a single elevation-exceedence curve using the storm aggregator described in Figure 15-12.

Once the aggregated elevation-exceedence curve was developed for each scenario, the additional volume of water entering the subbasins by wave overtopping was examined to determine the estimated impact on water depths in the subbasin. Elevations were increased where appropriate to account for wave overtopping.

The analysis process in FoRTE includes a step (for each storm) to consider the interflow between adjacent subbasins based on the elevations of the geographic features that separate them. Note that this is based only on topography and physical structures and does not include the internal drainage systems that often connect the adjacent basins. It was not deemed practical to model internal drainage at this level for the planning level risk assessment. The elevation-exceedence results of the FoRTE runs were examined to select the .2, .1 and .02 frequency elevations for each scenario. In cases where the elevation corresponding to the frequency required interpolation, the interpolated elevation was recorded and rounded to the nearest foot after all adjustments were made for wave overtopping.

We found it necessary in a few cases to smooth out the subbasin elevations for the final elevations used in map preparation. This smoothing was done to make the elevations more consistent across an individual basin and was based on feedback from local entities and consideration of the additional interconnectivity of the subbasins not represented in the simple drainage model used for the storm-to-storm re-distribution of water. There was no smoothing done for 50 of 500 year flood elevation data. Smoothing was done for Orleans and Jefferson Parishes for the 100 year flood elevations only for both the Pre-K and Current HPS scenarios.

## References

Van der Meer, J. W. (2002). Technical report — Wave Run-up and Wave Overtopping at Dikes. Prepared for: Road & Hydraulic Engineering Institute under auspices of the Technical Advisory Committee on Flood Defense, The Netherlands.

USACE ERDC-CHL (2006). *Coastal Engineering Manual, Fundamentals of Design*, Part VI, Chapter 5. EM 1120-2-1100.