Recommendation for:
Applying Calibration Data
(Revised 11/04/2002)

Goal: To utilize historical rainfall and hydrograph data to create a model which replicates conditions during various storms.

Recommended Procedure: It is recommended that the following steps be adopted as the method for developing a hydrologic calibration model for analyzing historical storm events.

1. **Gather All Rainfall and Hydrograph Data:** Rainfall data may be in the form of radar data or gage data. If radar data is used, it should be calibrated to ground data. There are several companies which do this, each using different methods to provide a calibrated radar product. Calibrated radar data will tend to be more accurate because of its ability to better define rainfall spatially than a traditional gage network. Hydrograph data may either be defined as stage vs. time or flow vs. time. Hydrograph data must be converted to a flow vs. time format before it is input into HEC-HMS.

2. **Format Rainfall Data:** The rainfall data must first be distributed evenly through time (i.e., 15-minute, 30-minute, or 1-hour increments, etc.). Then, depending on the type of rainfall data available, one of the following procedures is recommended.

   - If calibrated radar data is available, overlay the radar grid onto the subarea map for the watershed. For each subarea, the grid cells in that subarea for each time step in the radar can be averaged since they are evenly distributed (generally, 4km x 4km or 1km by 1km). Weighted averaging can be used for those grid cells lying on the subarea boundary. Weighting should be based on an estimated percentage of the grid cell lying within the subarea. This method will provide a weighted average hyetograph for the subarea in question.

   - If gage data is to be used, as much recording and non-recording information that is available should be used. A Theissen polygon network (or other similar process) should be constructed to determine the average rainfall over each subarea. This rainfall total should then be applied to the pattern from the nearest recording gage. Patterns from recording gages should <u>not</u> be averaged or weighted as this will tend to dampen rainfall peaks.

3. **Format Hydrographs:** If the hydrograph data available is in the form of stage vs. time, this data must be converted to flow vs. time using a rating curve either provided by an outside source (such as the USGS, if the data came from a USGS gage) or a hydraulic model (such as a storage vs. outflow model) at the location of the gage. Then, the hydrograph data must be distributed evenly through time (i.e., 15-minute, 30-minute, or 1-hour increments, etc.). Once it has been formatted, the appropriate location of the observed hydrograph must be identified for comparison to the calculated hydrograph. This would preferably occur at a node, but may occur at the last junction prior to a downstream tributary entering the system. Considerable judgment should be used in identifying this point.

4. **Add Data to HEC-HMS:** Gage data may be input into HEC-HMS as precipitation or discharge gage data either manually or brought into HEC-HMS using DSS. A DSS file may be created by setting up the gage data in a HEC-1 model format and writing the data to DSS (using the ZW record).

5. **Initial Run:** After all gage information has been incorporated into HEC-HMS and assigned to the appropriate locations, the model should be run without any adjustments. Comparisons should be made to the peak discharge, hydrograph volume, hydrograph shape, and peak time. Ideal goals would be for the peak discharge and hydrograph volume to be within 10% of observed values (within 5% if possible). Be aware that baseflow in the observed data may skew the volume significantly. In this case, it may be appropriate to add a constant baseflow to the model to account for this during calibration. It may be that

hydrogaph shape is a better indicator of how well the volume matches observed data. Judgment should be used to determine whether the hydrograph shape and timing are adequate.

6. **Verify Parameters:** If the initial HEC-HMS run does not compare favorably, review the input parameters to ensure that the model adequately represents existing field conditions (e.g., Are there any assumptions that may be invalid? Are there input errors in cross sections or structures in the storage model which do not reflect field observations and may have significant hydraulic effects? Are structures such as reservoirs and detention facilities adequately modeled? Are there routing reaches in which the number of routing steps is so high as a result of low velocities that it acts as a linear reservoir and would be better modeled using a routing step of one? Are there potential overflow areas not accounted for in the hydrologic model?). Changing such parameters could cause drastic differences in hydrograph comparisons.

7. **Optimize Initial Loss:** If input parameters appear to be valid or if adjustment to these parameters still does not create a good match between calculated and observed data, the initial loss in the Green & Ampt method should be calibrated. Adjustment of the initial loss would appear to be the most appropriate modification since soil saturation prior to a large storm event may vary. This can either be done manually or using the optimization routine in HEC-HMS. It is recommended that the initial loss parameters be calibrated in the downstream direction (i.e., calibrate the losses for the subareas upstream of the upstream-most stream gage first, then calibrate the losses for the subareas between the upstream-most gage and the next downstream gage, and so on allowing for different initial losses upstream of each respective gage).

8. **Review Storage Data:** If adjusting the initial loss parameters does not produce reasonable results, it is recommended that the hydraulic model used to develop reach routing data be reviewed to determine inconsistencies. Of particular note are the possibilities that ineffective flow areas are inadequately defined, alternative routines for structure modeling could be used to more adequately reflect head losses, and/or Manning's "n" values may be adjusted based on field observations. Residential subdivisions along the streams may have cedar fences (typical to the Houston area) which may impede flow considerably in the overbanks.

9. **Storm Conditions:** If calibration is still inconsistent with observed data, look for features which may or may not have been present during the observed storm event which are or are not represented in the hydrologic/hydraulic models. These may include bridges or control structures which have been constructed or removed since the storm in question, development which has occurred between the date of the model and the date of the storm, and detention facilities or channel modifications which have been constructed.

If these procedures are followed and the calculated results still vary considerably from observed conditions, the problem should be discussed with the TSARP hydrology committee to define a resolution. Once the decision that the hydrologic model for the storm in question has adequately replicated observed data, the peak discharges may be incorporated into the hydraulic model for the stream. The calculated energy grade elevation should match measured high water marks within three feet (within one foot is preferable). The calculated energy grade is recommended in Harris County over the calculated water surface elevation for comparison due to the low velocity heads expected in areas where high water marks are usually measured (e.g., in the wide shallow overbanks typical of Harris County drainage systems, within subdivisions, against bridge abutments or bridge decks, etc.).

For ungaged streams, it is not possible to calibrate discharges due to the lack of observed data (however, if high water marks are available, it may be possible to calibrate water surface elevations). Since the original Flood Hazard Study for Harris County used observed data to derive the standard hydrologic methodology for Harris County, it would appear that additional validation of flows on ungaged streams is unnecessary. However, for drainage areas less than 300 acres, the site runoff curves from the *Hydrology for Harris County* seminar may be used to verify the general reasonableness of the discharges for those drainage basins.

Assumptions: Rainfall and hydrograph data provided to study teams represent a reasonable estimate of observed data. For ungaged watersheds, significant differences can occur between site runoff curves and standard hydrologic modeling methodology because the site runoff curves assume there is no defined outfall channel while the standard methods assume a channel system which is effective in conveying anticipated flood flows.[1]

Testing Procedure: Testing to be performed by study teams. This process has worked well for Dodson & Associates in the past.

Test Results: Testing to be performed by study teams. Past studies have yielded fairly reasonable results.

Final Notes: None.

Committee Resolution: This procedure appeared to be reasonable to the committee. Further information was requested on how to consider and continue calibration to a flood frequency analysis.

Once the calibration to observed storm events has been completed, it will be necessary to compare modeled results to a flood frequency analysis (which can be performed with HEC-FFA or PEAKFQ). A flood frequency analysis may be performed on a gage with a period of record which has as little as 10 years of record. Following the completion of the flood frequency analysis, the calibrated HEC-HMS model should be run with the various frequency-based rainfalls. Discharge vs. frequency should then be compared to the flood frequency analysis. Discharges from the HEC-HMS model should fall within the 16% and 84% confidence limits (68% confidence interval; plus or minus one standard deviation) established by the flood frequency analysis results. If they do not, it may be reasonable to adjust the initial loss rates to a value which is an average of the initial loss values calculated in the calibration analysis. If this still does not provide a reasonable comparison to the flood frequency analysis, other inconsistencies between the gage data and the model data should be investigated. The following are a few example questions which might be investigated:

- Are there areas of significant ponding within the watershed which may affect the timing of hydrographs? If so, it may be appropriate to introduce ponding factors into the calculation of Clark's unitgraph parameters (TC & R).

- Does gage-calibrated radar adequately reflect rainfall over the watershed? If not, it may be reasonable to

    1. Use the radar for a "spatial footprint" of the rainfall (i.e. to represent storm patterns over various subareas), but adjust the storm totals based on either an isohyetal map or a Theissen polygon analysis. Or,

    2. Use an isohyetal map or Theissen polygon analysis to assign rainfall patterns and totals from nearby gages (based on the closest rainfall gage to the subarea).

- Has significant development occurred upstream of the gage throughout the gage's period of record (typical of stream gages in Harris County which have long periods of record)? If so, perhaps it is necessary to adjust past discharges to bring them to the present for a reanalysis of the flood frequency. By using USGS regional equations for Urban Houston[2] and varying the percent urban development for various years and various frequency flood events, an average percent increase in discharges as a result of urbanization could be estimated. The percent urban development through time can be estimated for several watersheds from information in another USGS report.[3]

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[1] Harris County Flood Control District, "Hydrology for Harris County," March 3, 1988, page C-14.

[2] Liscum, F. and B.C. Massey, *Technique for Estimating the Magnitude and Frequency of Floods in the Houston, Texas, Metropolitan Area*, U.S. Geological Survey, Water Resources Investigation Report 80-17.

[3] Liscum, Fred; D.W. Brown; and Mark C. Kasmarek; *Summary of Surface-Water Hydrologic Data for the Houston, Metropolitan Area, Texas, Water Years 1964-89*, U.S. Geological Survey, Open-File Report 96-250.

- Have significant channel modifications taken place during the period of record? If so, perhaps the period of record prior to the construction of such channel improvements should be omitted from the flood frequency analysis.

- Are there historical storms which were not directly measured which are well beyond reasonable extrapolation for the gage's rating curve? If so, the resulting discharge could be too high or too low and may affect the flood frequency analysis. A decision must be made whether or not to use this data point in the flood frequency analysis, or whether or not to use the gage data at all.

- Are there upstream structures such as reservoirs, bridges, or other potential storage areas (e.g., the Englewood Railroad Yard on Hunting Bayou upstream of the I-610 gage), which dramatically affect the stage vs. discharge relationship at the gage? If so, the HEC-HMS model may not be adequately taking these storage areas into account.