FLO-2D (V. 2009, Pro) Technical Guidance for Hydrologic and Hydraulic modeling in Unincorporated Pima County, Arizona

Version: DRAFT

This version of the guidance document *has not* been adopted by the Pima County Board of Supervisors. Effective this date, it is to be implemented in its draft form and utilized on a case-by-case basis.

Purpose: To provide guidance for and standards regarding floodplain modeling using the FLO-2D (versions 2009, Pro) software package, with the intent of improving the consistency of modeling results generated by Pima County Regional Flood Control District (District) staff and modeling submitted to the County by qualified applicants.

The following guidance document is provided as **Amendment A – FLO-2D** to the District's Technical Policy, TECH-033: *Criteria for Two Dimensional Modeling*.

Background: FLO-2D is a proprietary computer software program that conducts two-dimensional rainfall-runoff models. Two-dimensional models like FLO-2D provide an analytical environment suitable for mapping distributary flow conditions common to the southern Arizona terrain. FLO-2D (versions 2009, Pro) is FEMA approved to support hydrologic and hydraulic analyses in Pima County, Arizona.

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Director

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Technical Guidance

1. **Application**
   a. Written justification for the use of a FLO-2D model to support a hydrologic and/or hydraulic analysis submittal to the District shall be provided.
   b. It is recommended to discuss the use of FLO-2D with the District prior to conducting any significant modeling efforts.

2. **Verification**
   a. To verify the accuracy of the FLO-2D modeling results, the District may request the submittal of additional information. Data requests may include, but are not limited to comparisons to other modeling processes and/or observed data sets, including:
      i. Gauge data
      ii. NextRAD data
      iii. Regression equations
      iv. Volumetric comparisons
      v. HEC-HMS , HEC-RAS
      vi. Aerial photography
      vii. TR-55 travel time

3. **Grid Element Size (ft.)**
   a. Grid size should be a function of the purpose of the model. The following provides guidelines for selecting the appropriate grid size.
      i. <u>If possible</u>, grid element size should be equal to or greater than twice the average DTM point spacing.
      ii. For hydraulic modeling, the grid size shall be no greater than 30 ft.
      iii. For hydrologic modeling, the grid size area (square-feet) should be no greater than one-tenth of the peak discharge (cfs) being modeled.
      iv. In order to properly simulate travel times through well-defined or visible (sand bed) channels and linear features (street) for accurate hydrologic modeling, the modeling effort should maximize the faithful reproduction of the channel/street geometry. Where two or more grids fit within the bottom of the channel or street, no 1-D channel/street segments are required. However, where geometry of street/visible channels cannot be faithfully simulated with the grid, then inclusion of 1-D channel/street segments is recommended, or application of other methods to correct the overland flow times for the slower velocity due to the poor reproduction of channel geometry.
   b. Written documentation stating the origin and specifics of the DTM data used for modeling shall be provided. In particular, provide at a minimum the date the elevation data was collected, the vertical and horizontal datum that was used to collect the data, the method of collection, and a statement of both horizontal and vertical accuracy and average sampling size.
   c. The District recommends that the applicant pursue and receive approval of grid size selection prior to initiating substantial modeling efforts.

4. CONT.DAT

a. SIMULT (Simulation Time, hours)
   i. Simulation time shall be set to capture the maximum depth condition for all grid cells.
   ii. Simulation time should, at minimum, extend into the receding limb of the hydrograph being modeled.

b. TOUT (Output Time Interval, hours)
   i. The output time interval shall be set small enough -for the model to construct accurate output hydrographs.

c. AMANN (Manning's n Coefficient Increment)
   i. The AMANN parameter should be turned off (set to -99). Written justification is required for AMANN values not set to -99 (see SHALLOWN guidance).

d. FROUDL (Limiting Froude Number)
   i. A global Limiting Froude Number should be used, typically within the range of 0.90-0.95.
   ii. For grid cells with steep slopes or smooth, armored surfaces where supercritical flow may occur, FROUDL may be set at 1.2 or higher.
   iii. FROUDL may be spatially variable.
   iv. For Limiting Froude Number for Channels (FROUDC) and for Streets (STRFNO), see CHAN.DAT and STREET.DAT, respectively.
   v. Review of the ROUGH.OUT and TIME.OUT output files is recommended to aid verification of proper roughness selections against resulting Froude numbers.

e. SHALLOWN (Shallow Manning's n Coefficient)
   i. SHALLOWN should be not be used unless written justification is provided that demonstrates roughness varies by depth.
   ii. The SHALLOWN parameter is not used when AMANN is turned off (set to -99).
   iii. The SHALLOWN parameter may be set to a value between 0 and 0.2 for watersheds that are predominately natural when it is determined that roughness varies by depth.
   iv. Unless otherwise justified, the SHALLOWN parameter should not be used for highly urbanized watersheds when unreasonably low velocities occur over smooth impervious surfaces compared to normal depth calculations.

5. TOLER.DAT

a. TOLGLOBAL (Surface Detention, ft)
   i. The TOLGLOBAL parameter should be set to 0.004 ft (0.05 in) for rainfall-runoff modeling.
   ii. The TOLGLOBAL parameter may be spatially variable, implementing the TOLSPATIAL.DAT file.
   iii. A written description of the TOLGLOBAL parameter used in the model shall be provided. Justification shall be provided when the TOL parameter is not set to the default value of 0.004 ft (0.05 in), and/or when spatially variable.

b. DEPTOL (Tolerance Value for Percent Change in Flow Depth)
   i. The DEPTOL parameter shall be set to zero (turned off).
   ii. Written justification shall be provided when the DEPTOL parameter is not set to zero.
c. WAVEMAX (Numerical Stability Coefficient, maximum value)
   i. WAVEMAX shall be set to the default value of 0.
   ii. Written justification shall be provided when the WAVEMAX parameter is not set to zero.
d. COURANT (Numerical Stability Coefficient)
   i. COURANT should be set to the default value of 0.6.
   ii. If the model is stable, increase COURANT by increments of 0.1, to a maximum of 0.8, to decrease model runtime. If the model is unstable, reduce COURANT by increments of 0.1, to a minimum of 0.3, until model stability is reached.

6. INFIL.DAT

a. INFMETHOD (Infiltration Method)
   i. Hydrologic modeling shall employ the SCS Curve Number Method, consistent with Technical Policy TECH-018: *Acceptable Model Parameterization for Determining Peak Discharges*.
b. SCSN(N) (Spatially Variable SCS Curve Number)
   i. The Curve Number shall be spatially variable to match soil, vegetation, and land use conditions specific to the individual grid cells. Impervious surfaces providing flood storage (i.e. roads, parking lots) should be simulated with a modified curve number.
c. ABSTSCS (Initial Abstraction, inches)
   i. ABSTSCS shall be set to zero, which will trigger F2D to automatically calculate the initial abstraction per the SCS method.

7. ARF.DAT

a. ARF (Area Reduction Factors)
   i. For hydrologic models, ARF values should be used to simulate impervious surfaces that do not provide flood storage (i.e. buildings with roofs). ARF values for individual grid cells shall be consistent with *Table D-3: Summary of Approximate Impervious Cover Percentages for Various Land Development Types*, from Pima County's current PC-Hydro User Guide.
b. WRF (Width Reduction Factor)
   i. Any use of the WRF parameter shall include a written justification.

8. RAIN.DAT

a. Application (-)
   i. For a hydrologic-only model, the RAIN.DAT file shall be used.
   ii. For a hydraulic-only model, the RAIN.DAT file shall not be used.
   iii. For a hydrologic-hydraulic mixed model, the RAIN.DAT file shall be used.
b. IRAINBUILDING
   i. When using ARF.DAT to simulate the impervious cover of buildings' roofs,

        1. IRAINBUILDING shall be set to zero (0) if the roofs convey stormwater directly to the storm drain system, through which it is eliminated as runoff.
        2. IRAINBUILDING shall be set to one (1) if the roofs convey stormwater to the ground and contributes to runoff.
        3. A written statement shall be provided regarding the setting of IRAINBUILDING.

c. RTT (Rainfall Depth, Total, inches)
    i. The total rainfall depth shall be consistent with Technical Policy TECH-010: *Rainfall Input for Hydrologic Modeling*.

d. RAINABS (Rainfall interception and abstraction, inches)
    i. RAINABS shall be set to zero. Infiltration of rainfall shall be modeled with INFIL.DAT.
    ii. A written justification shall be provided when the interception and abstraction of rainfall is being modeled.

e. R_TIME(I) (Rainfall Time, hours)
    i. The rainfall distribution shall be consistent with Technical Policy TECH-018: *Acceptable Model Parameterization for Determining Peak Discharge*, and equivalent to any inflow hydrographs (see INFLOW.DAT) within the model.

f. R_DISTR(I) (Rainfall Depth, cumulative percentage)
    i. See "R_TIME(I)" above.

g. RAINARF(I) (Rainfall Depth Area Reduction)
    i. Rainfall depth may be spatially variable, while maintaining consistency with Technical Policies TECH-010: *Rainfall Input for Hydrologic Modeling* and TECH-033: *Criteria for Two-Dimensional Modeling*.
    ii. RAINARF, a value between 0 and 1, is multiplied against the total rainfall depth, RTT, to calculate and assign the reduced rainfall depth to the coordinating grid cells, IRGRID(I).

9. MANNINGS_N.DAT

a. FP(I,J) (Manning's n Roughness Coefficient)
    i. The Manning's n roughness coefficient shall be spatially variable to match the surface roughness conditions specific to the individual grid cells.
    ii. Table 1 (below), Table 1 in the *FLO-2D Reference Manual*, and Table 8.1 of the *Standards Manual for Drainage Design and Floodplain Management* provide suggested Manning's n values for various land use conditions:

Table 1: Suggested Manning's n roughness coefficients for specific land use conditions

n	*Land Use*
0.020	*Streets, Concrete Channels*
0.025	*Open Space, Lawn*
0.030	*Right of way (clear area beside pavement)*
0.035	*Commercial*
0.035	*Earth channels, constructed*
0.035	*Roadside swale*
0.040	*Office, Retail*
0.045	*Open Space, Light to Medium Brush*
0.055	*Retail, Warehousing*
0.055	*Natural Vegetated Channels*
0.065	*Manufacture, Salvage*
0.065	*Open Space, dense and Densely Vegetated Natural Channels*
0.065	*Residential*
0.070	*Industrial*
0.100	*Agriculture*
0.100	*Detention Basin*

iii. Manning's n roughness coefficients obtained from other sources shall be identified and supported with a written justification.

10. INFLOW.DAT

a. IHOURDAILY (Inflow Hydrograph Time Unit)
   i. The time unit for inflow hydrographs shall be hourly (IHOURDAILY set to 0).
b. KHIN(I) (Grid Elements with Inflow Hydrograph)
   i. An inflow hydrograph should be evenly divided among the adjacent grid cells that represent an estimated top-width of the main-channel at the location of the inflow hydrograph. A normal depth calculation of the peak discharge at the location of the inflow hydrograph may be requested.
   ii. If multiple models occur in series (upstream to downstream), the outflow hydrograph of the upstream model shall equal the inflow hydrograph of the downstream model.
   iii. All inflow hydrographs shall be generated from the same rainfall distribution. For a hydrologic-hydraulic mixed model, the rainfall distribution used to generate the inflow hydrographs shall equal the rainfall distribution of RAIN.DAT.

11. OUTFLOW.DAT

a. NODDC(I) (Grid Elements with Outflow)
   i. To avoid boundary condition influence, outflow elements should be placed a minimum of five (5) grid cells downstream of the area of interest.
   ii. Grid cells assigned as outflow nodes should not be assigned other cell node functions, including but not limited to ARF/WRF nodes, hydraulic structure nodes, inflow nodes, and levee nodes.

12. FPXSEC.DAT

a. NODX(N,J) (Grid Elements of Cross Section)
   i. Discharge recording cross sections should be placed throughout the model at points of interest. Cross sections should be aligned perpendicular to the direction of the expected flow.

b. IFLO(N) (Direction of Expected Flow)
   i. The general direction of expected flow should be assigned to the cross section with a positive integer, corresponding to one of the eight cardinal directions, to account for flow occurring in the neighboring directions:
      1. North
      2. East
      3. South
      4. West
      5. Northeast
      6. Southeast
      7. Southwest
      8. Northwest

   ii. Written justification shall be provided if discharge in a specific single direction, obtained by using a negative integer, is collected at a discharge recording cross section.

13. CHAN.DAT

a. A written justification shall be provided for any use of the CHAN.DAT input file.

14. STREET.DAT

a. A written justification shall be provided for any use of the STREET.DAT input file.

15. LEVEE.DAT

a. A written justification shall be provided for any use of the LEVEE.DAT input file.