APPENDIX D: THE METHOD USED BY THE STORMWATER HARVESTING SPREADSHEET TO MODIFY A PC-HYDRO HYDROGRAPH TO ACCOUNT FOR STORMWATER HARVESTING

APPENDIX D: THE METHOD USED BY THE STORMWATER HARVESTING SPREADSHEET TO MODIFY A PC-HYDRO HYDROGRAPH TO ACCOUNT FOR STORMWATER HARVESTING

This section presents a method to modify a PC-Hydro hydrograph to account for stormwater harvesting based on the peak reduction factors and volume from Section 3.3.

The "Stormwater Harvesting" spreadsheet is available that performs all of the following modifications to a PC-Hydro hydrograph and provides a hydrograph to represent outflow from a watershed with one or more stormwater harvesting basins that may be distributed within the watershed.

Method:

Generate PC Hydro hydrographs that model the post-development discharge without stormwater harvesting basins for each return period. A PC-Hydro calculation is needed to determine the peak discharge ($Qp_{post\text{-}rp}$), runoff volume ($V_{post\text{-}rp}$), and a hydrograph that approximates this runoff volume for the post-developed condition without stormwater harvesting basins.

1. Use the methods in Sections 3.3 to calculate the stormwater harvesting factor (H_{rp}) and the peak of the post-development hydrograph with stormwater harvesting basins ($Q_{swh\text{-}rp}$) from the volume of the proposed stormwater harvesting basins (V_{bas}), post-developed runoff volume ($V_{post\text{-}rp}$), and the percent of the watershed area flowing to stormwater harvesting (W_A). The spreadsheet will perform the peak discharge reduction calculation when provided with the PC-Hydro peak discharges, runoff volumes, and stormwater harvesting basin volumes.

2. The spreadsheet creates an intermediate hydrograph using the Pima County dimensionless hydrograph (Table G.1) with the reduced peak discharge due to stormwater harvesting ($Q_{swh\text{-}rp}$) and the time to rise from the original PC-Hydro hydrograph (Tr). Stormwater harvesting basins may cause a slight lag in the hydrograph peak depending on the distribution of the basins within the watershed, but quantifying the detention effects of stormwater harvesting would require detailed modeling on a case-by-case basis and the time to rise of the intermediate hydrograph is assumed to remain the same as the original hydrograph for simplification and to reduce analysis time.

   The intermediate hydrograph is created by calculating time (t) and outflow (q) for each point on the hydrograph using the table below based on Table 3.3 from PCDOT&FCD (1987):

Table G.1. Pima County dimensionless hydrograph ordinates.

t/T_r	q/Q_{swh-rp}	t/T_r	q/Q_{swh-rp}
0.00	0.000	1.60	0.545
0.10	0.025	1.70	0.482
0.20	0.087	1.80	0.424
0.30	0.160	1.90	0.372
0.40	0.243	2.00	0.323
0.50	0.346	2.20	0.241
0.60	0.451	2.40	0.179
0.70	0.576	2.60	0.136
0.80	0.738	2.80	0.102
0.90	0.887	3.00	0.078
1.00	1.000	3.40	0.049
1.10	0.924	3.80	0.030
1.20	0.839	4.20	0.020
1.30	0.756	4.60	0.012
1.40	0.678	5.00	0.008
1.50	0.604	7.00	0.000

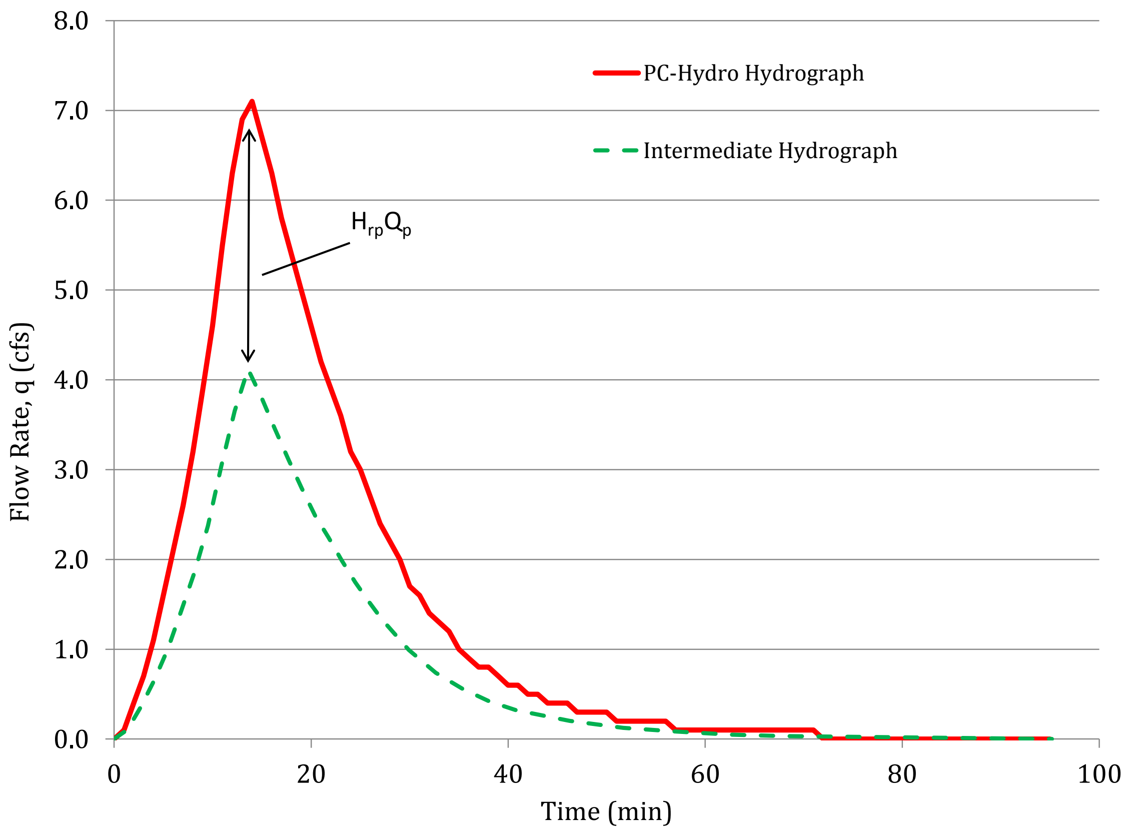

Figure G1. Intermediate hydrograph with peak equal to the reduced peak discharge calculated from Section 3.3.

3. The spreadsheet calculates the ratio of the reduced runoff volume due to stormwater harvesting (V_{swh-rp} from Section 3.3) by the volume of the intermediate hydrograph calculated in step 4 (V_{int}). This ratio is defined here as the "volume factor", which is equal to V_{swh-rp} /V_{int}. The spreadsheet uses the "volume factor" to match the reduced runoff volume when enough of the watershed is diverted to stormwater harvesting basins to utilize the storage capacity of the basins:

a. If the "volume factor" is less than one (this typically occurs when the percent reduction in peak discharge is less than the percent reduction in volume), volume is removed from the intermediate hydrograph in the spreadsheet using the following method:

i. The excess volume of the intermediate hydrograph is calculated by subtracting the reduced runoff volume (V_{swh-rp}) from the intermediate volume (V_{int}).

ii. The front of the intermediate hydrograph is reduced by a volume equal to the amount from step (i) (the capacity of the stormwater harvesting basins) or the volume up to the time step before the reduced peak discharge, whichever is less.

When volume is removed from the front of the hydrograph, the volume of retention is calculated by multiplying the flow rates (q) by the percent of watershed area directed to stormwater harvesting (W_A) and the time step (Figure G.2). The outflow rate at the front of the hydrograph is determined as the percent of directly-connected watershed area ($1 – W_A$) multiplied by the intermediate hydrograph flow rate (q).

The time to peak of this stormwater harvesting hydrograph matches the time to peak of the original PC-Hydro hydrograph because the stormwater harvesting basins are treated as "depression storage" and additional detention effects will vary depending on the distribution of the basins and are not included for simplification.

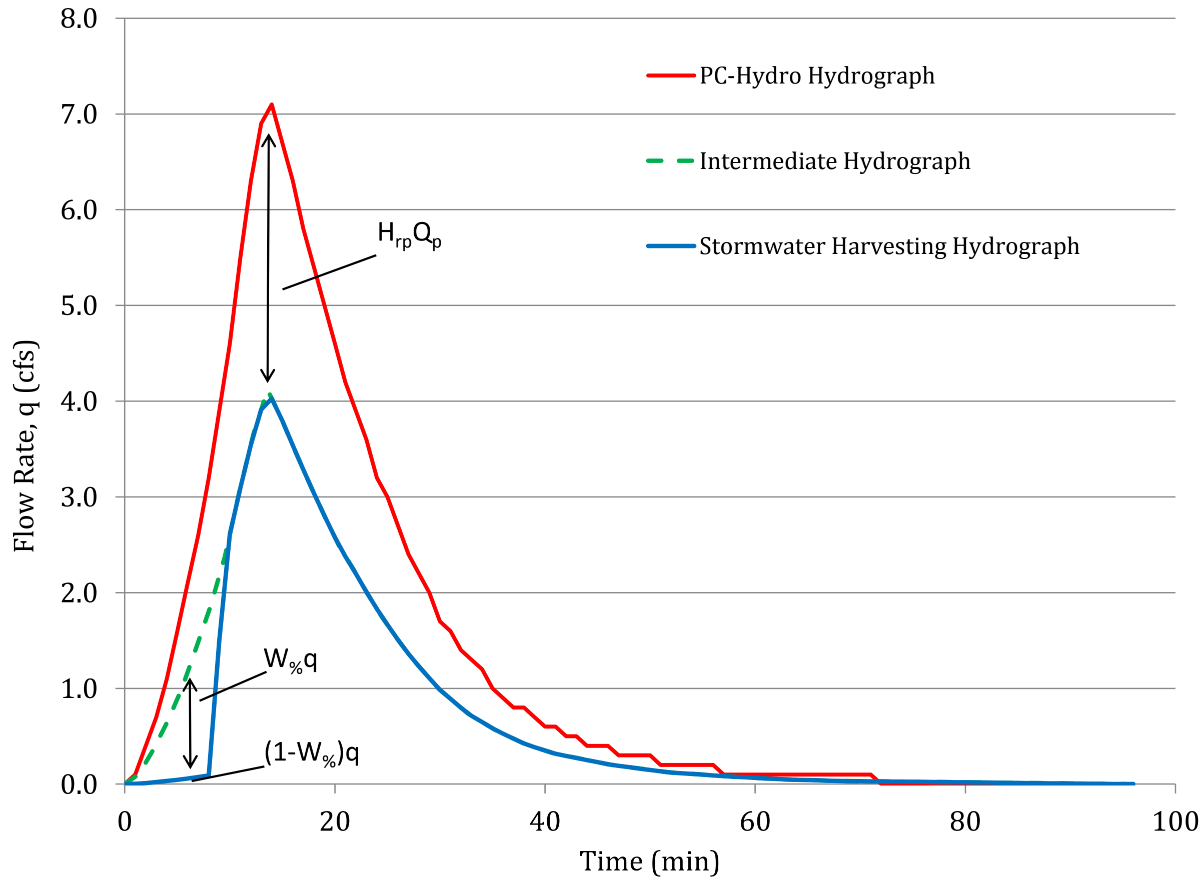

Figure G.2. Stormwater harvesting hydrograph with H_{rp} = 0.436 and W_A = 0.95.

- **b.** If the “volume factor” is slightly greater than one (this may occur in a few cases where the percent reduction in peak discharge is slightly greater than the percent reduction in volume), each time step in the hydrograph (i.e. each ‘t’ in Table G.1 above) is multiplied by the volume factor, and all flow rates from the intermediate hydrograph are left unchanged, so that the hydrograph volume matches the runoff volume after stormwater harvesting (V_{swh-rp}).

4. The stormwater harvesting hydrograph obtained from completing Step 5 using the spreadsheet may be used as the inflow hydrograph to a detention basin or another concentration point.

Appendix G References

PCDOT&FCD, 1987. Stormwater Detention/Retention Manual. Pima County Department of Transportation and Flood Control District, and the City of Tucson Department of Transportation, Tucson, Arizona.