

Recommendation for: On-Site Detention Considerations in Harris County Hydrologic Modeling (Revised 08/15/2003; Reformatted 11/26/2003)

Goal: To identify a means of accounting for the effects of on-site detention on hydrograph development for subareas of a watershed-wide hydrologic model. The traditional approach has been to use undeveloped values for time-of-concentration (TC), Clark's storage coefficient (R), and percent impervious (RTIMP in HEC-1) in subareas where on-site detention has been provided. This approach, however, negated the effects of timing and additional runoff from increased development. In an attempt to account for the additional runoff, a recent departure from this approach has been to increase the RTIMP value to reflect the increased development while leaving the TC and R values at existing levels. This increases the volume of runoff, but it also neglects the effects of timing. The net effect of this alteration is a slight increase in peak discharges from the intended result.

Recommended Procedure: It is recommended that the following approach be used as an alternative to the traditional approach defined above.

1. For a given subarea, determine the percent DLU affected by detention by subtracting the DLU for areas with no on-site detention from the total DLU for the entire subarea. For simplicity in the TSARP study, one possibility would be to subtract the DLU from 1984 conditions (approximate year of detention policy adoption) from the DLU for current conditions. For example, if the value of DLU in 1984 was 30% and the current value of DLU is 70%, the percent DLU affected by detention would be 40%.
2. Using Table 1, determine the multipliers for R and TC+R. In the stated example, the adjustment factors are 0.95 and 1.21, respectively.

Table 1: Adjustment Factors for Accounting for On-Site Detention

%DLU Affected by Detention	Adjustment Factors	
	For R	For TC+R
100	1.01	1.33
90	0.99	1.33
80	0.97	1.32
70	0.96	1.29
60	0.95	1.26
50	0.95	1.23
40	0.95	1.21
30	0.95	1.20
20	0.96	1.18
10	0.98	1.13
0	1.00	1.00

3. Multiply the 1984 conditions R and TC+R by the respective adjustment factors. If R(1984) and TC+R(1984) are 3.32 and 4.33, respectively, then R(adjusted) will equal 3.15 and TC+R(adjusted) will equal 5.24.
4. Derive TC(adjusted) from TC+R(adjusted) minus R(adjusted). TC(adjusted) for the example equals 2.09. Therefore, the adjusted TC and R values which account for on-site detention for the given subarea are 2.09 and 3.15, respectively.

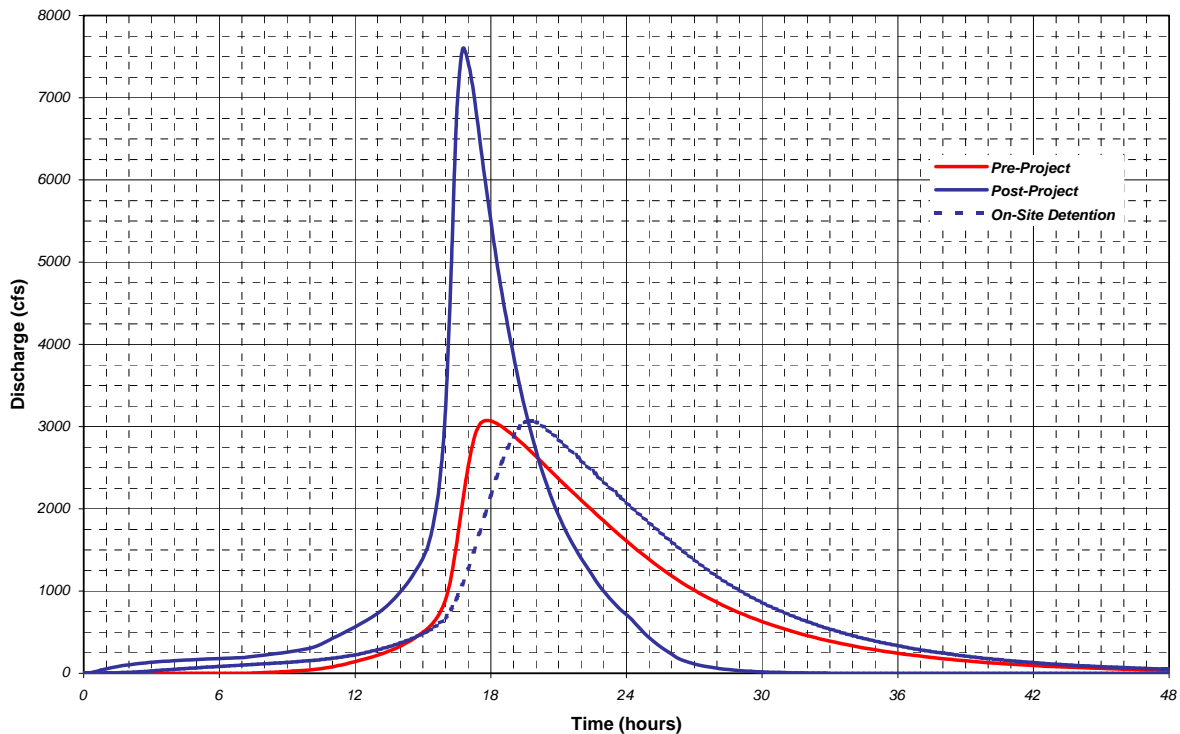
Assumptions: The following assumptions are made regarding this procedure.

- On-site detention is assumed to fully mitigate the effects of increased development.
- Channel conveyance and channel improvements are keeping pace with development.
- In 1984, the Harris County Drainage Criteria Manual was published. It is assumed that this is the year when detention requirements came into effect.
- Areas served by impact fees are assumed to be served by regional detention elsewhere in the watershed, which will be modeled separately.

Testing Procedure: In order to evaluate this alternative, two tests were made. The first test was used to determine the values in Table 1. The second test was to verify the results/usefulness of the procedure.

In the first test, a single subarea was analyzed for various levels of development (DLU for “pre-project” was varied from 0% to 100% and RTIMP was varied appropriately assuming that RTIMP equals 35% of DLU). Each “post-project” condition DLU was set to 100%. Then, the TC and R values for the “post-project” conditions were adjusted until the peak discharges were about equal with the “pre-project” conditions and the hydrograph peak fell on the falling limb of the initial “post-project” conditions hydrograph (see Figure 1). This third hydrograph would then represent the “on-site detention” condition. Plots were then made for TC, R, and TC+R of the ratios of “on-site detention” to “pre-project” conditions for various percents DLU affected by detention.

Figure 1: Typical Hydrograph Comparison



The second test was to examine three subareas in varying degrees of development and to apply the procedure to determine the adequacy of the method described herein. Table 2 provides a description of each subarea.

Table 2: Example TC & R Values for On-Site Detention

Parameter			Existing Subbasin #1	Proposed Subbasin #1	Existing Subbasin #2	Proposed Subbasin #2	Existing Subbasin #3	Proposed Subbasin #3
Drainage Area	A	(mi ²)	2.64	2.64	3.20	3.20	5.32	5.32
Watershed Length	L	(mi)	1.76	1.76	1.94	1.94	2.69	2.69
Length to Centroid	L _{ca}	(mi)	1.01	1.01	0.78	0.78	1.40	1.40
Channel Slope	S	(ft/mi)	6.34	6.34	5.32	5.32	6.20	6.20
Watershed Slope	S ₀	(ft/mi)	10.00	10.00	10.00	10.00	10.00	10.00
Urban Development	DLU	%	20.00	50.00	60.00	100.00	50.00	100.00
Channel Improvement	DCI	%	30.00	50.00	0.00	60.00	50.00	100.00
Average Channel Conveyance	DCC	%	70.00	80.00	40.00	100.00	100.00	100.00
Percent Impervious	RTIMP	%	7.00	17.50	21.00	35.00	17.50	35.00
Percent Ponding	P	%	0.00	0.00	0.00	0.00	0.00	0.00
Watershed Development	WD	%	27.00	50.00	18.00	72.00	50.00	100.00
Percent Impervious	RTIMP	%	7.00	17.50	21.00	35.00	17.50	35.00
Tc + R		Hour	7.19	3.40	6.69	1.95	3.72	2.33
Tc		Hour	0.78	0.64	0.69	0.43	0.92	0.51
R		Hour	6.41	2.75	5.99	1.52	2.80	1.82
On-Site Detention Parameters								
Percent Impervious	RTIMP	%		17.50		35.00		35.00
Tc + R		Hour		8.63		8.09		4.58
Tc		Hour		2.54		2.40		1.92
R		Hour		6.09		5.69		2.66

Test Results: The curves (from the plots in the first test) which define the relationships between TC, R, and TC+R vs. the percent DLU affected by detention are difficult to work with (see Figures 2, 3, and 4); therefore, it was determined that Table 1 would provide adequate information for use in the procedure. This test provided better results when defining TC as TC+R minus R rather than determining it directly. When determining TC and R directly, the sum did not always add to equal TC+R.

Figure 2: TC Multiplier to Account for On-Site Detention

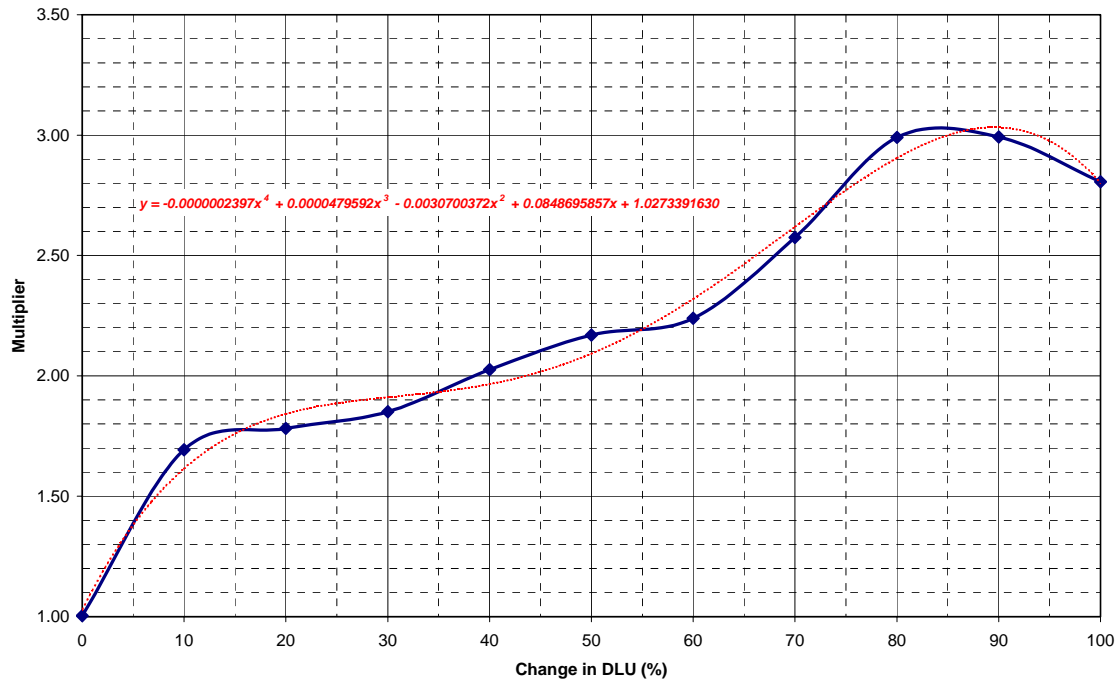


Figure 3: R Multiplier to Account for On-Site Detention

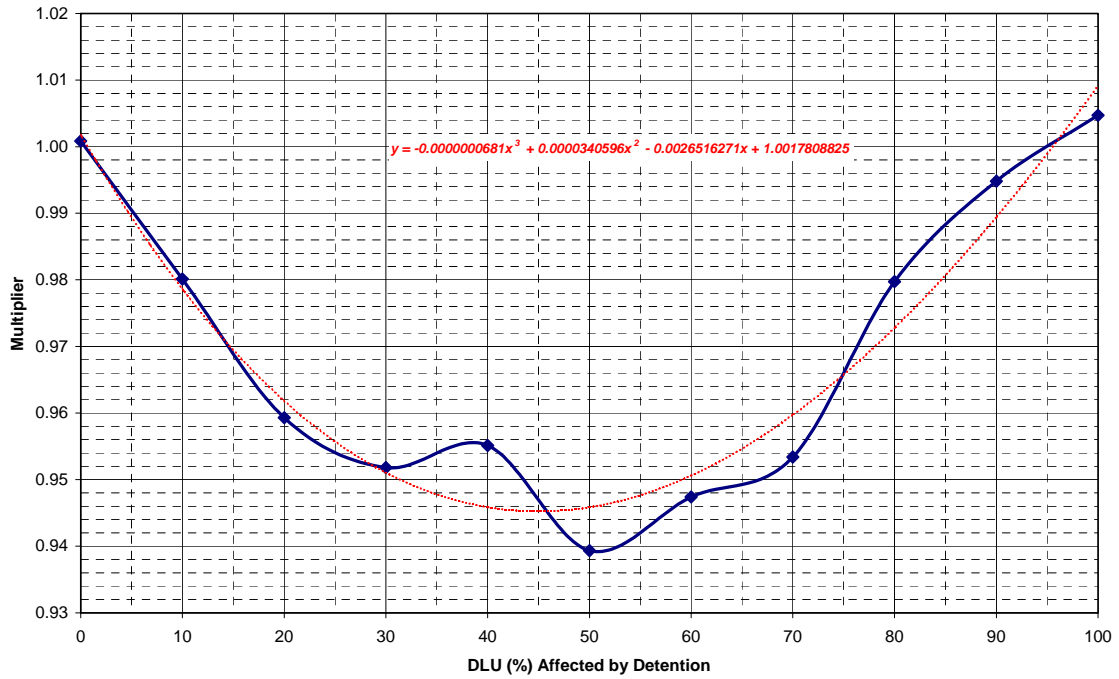
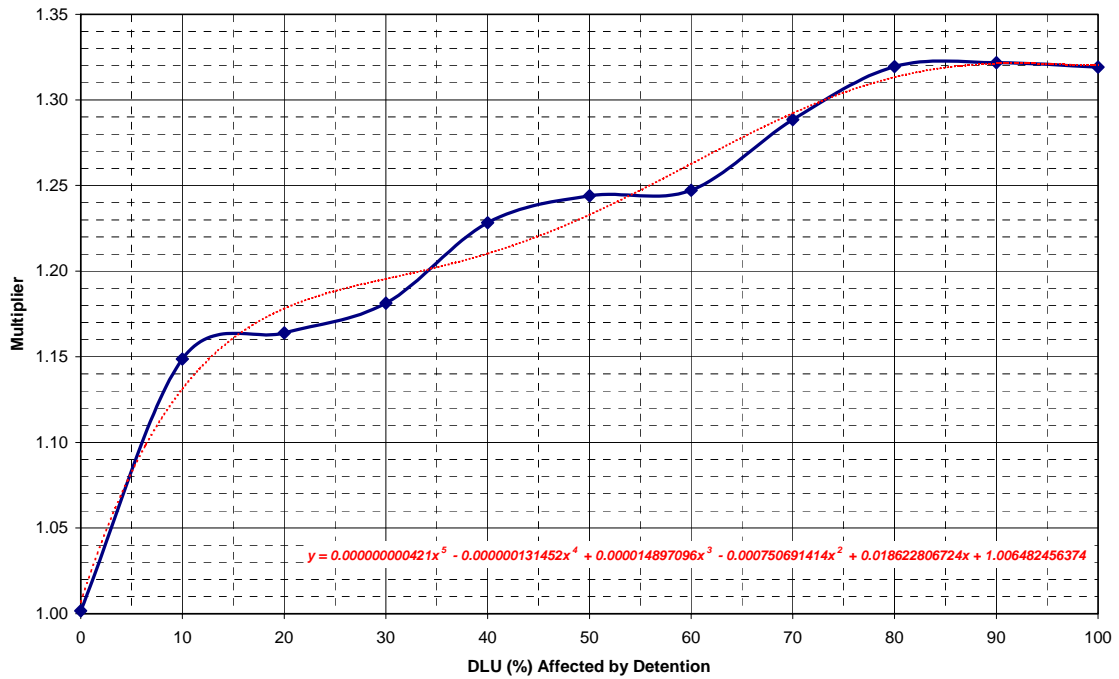


Figure 4: TC+R Multiplier to Account for On-Site Detention



For the second test, the results are indicated on the attached hydrograph plots. As illustrated by these graphs, the recommended approach appears to provide reasonable results to account for both timing and volume increases.

Final Notes: While this approach provides a reasonable means of accounting for on-site detention, it is recognized that there may be deficiencies in the methodology which may cause the model to not accurately reflect the runoff from certain basins where on-site detention is present.

Committee Resolution: Use the method described above. However, instead of 1984 assumed conditions, tracts with on-site detention will be determined directly using GIS data and records search. Therefore, the steps iterated above would read as follows:

1. For a given subarea, determine the percent of urban development which is offset by on-site detention. For example, if the current value of DLU is 70%, but 40% of the total subarea (i.e., 57.14% of the developed area) consists of development with on-site detention, then the percent DLU affected by detention would be 40%.
2. Using Table 1, determine the multipliers for R and TC+R. In the stated example, the adjustment factors are 0.95 and 1.21, respectively.
3. Multiply the R and TC+R for the current value DLU conditions (for the stated example, DLU is 70%) the respective adjustment factors. If R(current) and TC+R(current) are 3.32 and 4.33, respectively, then R(adjusted) will equal 3.15 and TC+R(adjusted) will equal 5.24.
4. Derive TC(adjusted) from TC+R(adjusted) minus R(adjusted). TC(adjusted) for the example equals 2.09. Therefore, the adjusted TC and R values which account for on-site detention for the given subarea are 2.09 and 3.15, respectively.

Further Developments:

The committee requested further clarification on the application sequence of the on-site detention procedure in subbasins where percent ponding (DPP) was also a factor. It would appear from testing the different sequences of application that it is more appropriate to apply the on-site detention procedure first and then to apply the ponding factor afterward. Applying the ponding factor first may result in a TC value which is significantly smaller than the without on-site detention scenario, which would be counter-intuitive. It is noted that in some cases, applying the ponding factor first may result in a negative TC value.

Final Committee Resolution:

The above adjustments to the Clark unit hydrograph parameters (TC and R) were found to not correctly account for on-site detention. Since this discovery, an alternate methodology has been presented and tested by the hydrologic contractors for the TSARP study.

For a basin served by on-site detention, the peak flows would be similar to undeveloped peaks but would occur later in time. Since the equations for TC and R are dependent on DLU,¹ and reducing DLU will generally increase the time of concentration (TC) and increase the storage coefficient (R), adjustments to DLU can be used to replicate the effects of detention. It is recommended that the amount of development served by detention be accounted for in the adjustment to DLU. Therefore, to accommodate this recommendation, the TSARP study has developed a map of on-site detention that the hydrologic contractors have utilized in determining areas served by on-site detention for a given subwatershed. To make the adjustment to DLU, the following equation should be used:

$$DLU_{\text{detention}} = DLU - DET$$

¹ Harris County Flood Control District, "Hydrology for Harris County," March 3, 1988, page C-10.

Where,

$DLU_{detention}$ = the percent urbanization adjusted for on-site detention,

DLU = the percent urbanization unadjusted for on-site detention, and

DET = the percent of the subwatershed served by on-site detention.

As described in the TSARP technical paper entitled *Recommendation for Defining Channel Conveyance in Harris County*, there is a discontinuity between the two “TC+R” equations at 18% development. To avoid this discontinuity and to provide consistency with the definition of conveyance in the original Harris County Flood Insurance Study, the following methodology should be used in adjusting DLU for detention and using it in the TC+R equation.

1. Determine DCC and DLU for current development conditions
2. Calculate $DLU_{minimum} = 11344(DCC)^{-1.4049}$
3. Calculate DET
4. Calculate $DLU_{detention} = DLU - DET$

The criteria below should be used in determining the appropriate value of “C” in the TC+R equation. The equation for C is as follows:

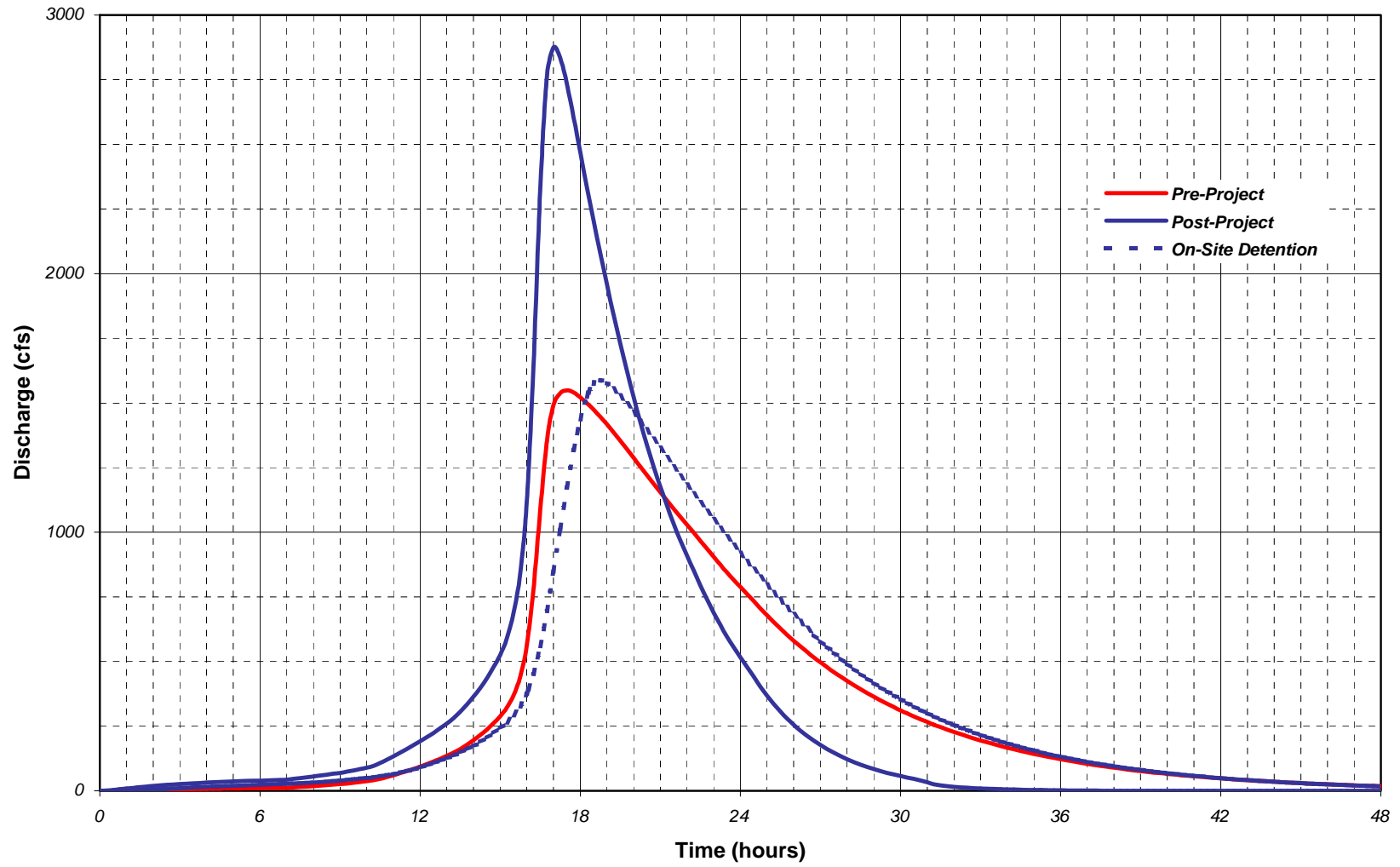
$$C = 4295(DLU_{detention})^{-0.678}(DCC)^{-0.967}$$

- If $DLU < DLU_{minimum}$, then $DLU_{detention} = DLU$
- If $DLU > DLU_{minimum}$, and $DLU_{detention} < DLU_{minimum}$, then $DLU_{detention} = DLU_{minimum}$
- If $DLU_{detention} \geq DLU_{minimum}$, then $DLU_{detention} = DLU - DET$

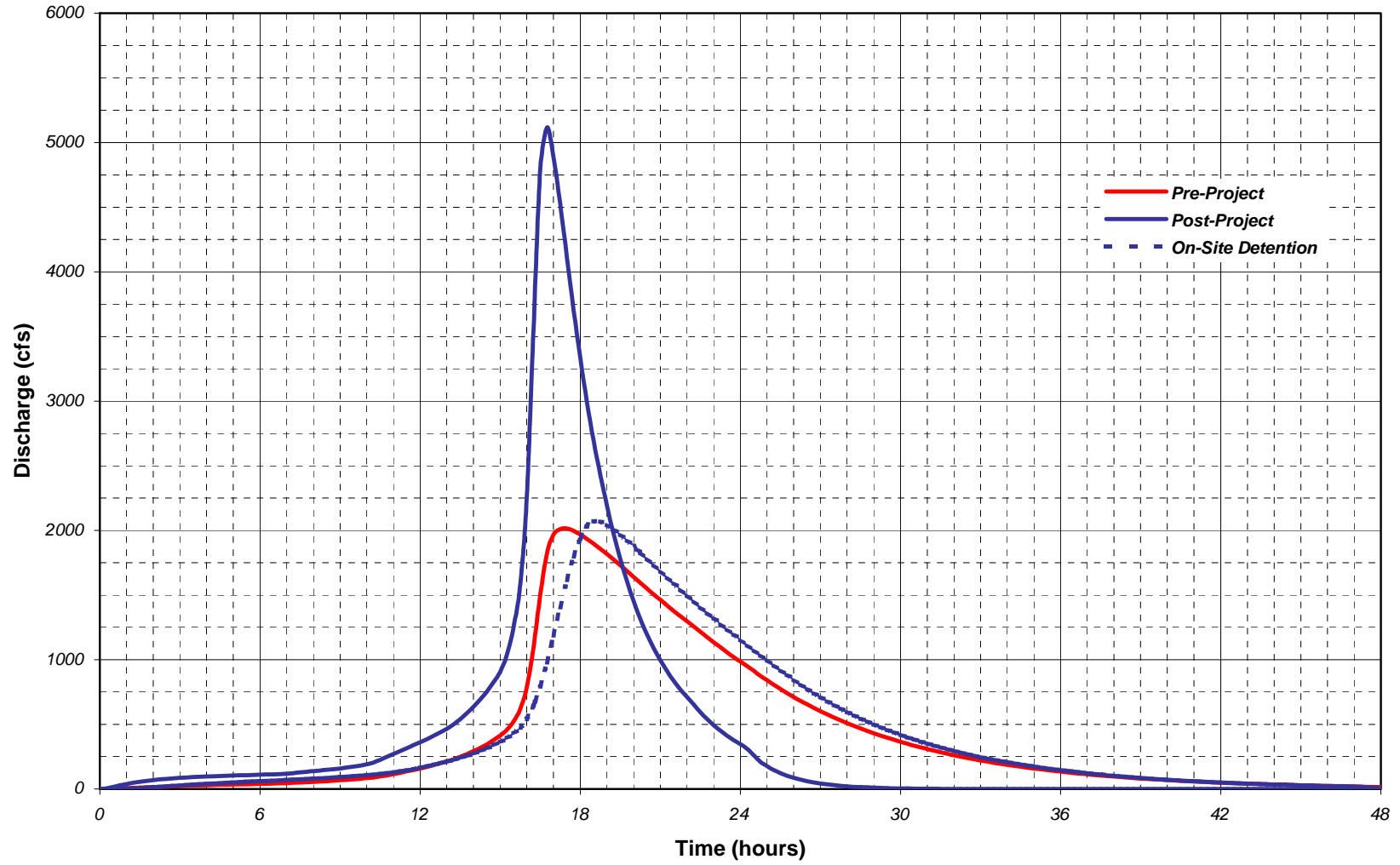
In order to account for increased runoff volume from increased impervious cover, TSARP has acquired land use data and prepared a table of impervious cover presented in the TSARP technical paper entitled *Land Use Categories and Impervious Cover*. The percent impervious (RTIMP) utilized in the hydrologic modeling should not be adjusted for on-site detention (i.e., it should reflect current conditions development levels).

The combined effects of modifying DLU to account for on-site detention while maintaining impervious cover rates in this alternate method produce results that are within the expectations and accuracy of the TSARP Project.

Subbasin #1 Hydrograph Comparison



Subbasin #2 Hydrograph Comparison



Subbasin #3 Hydrograph Comparison

