Hydrologic and Hydraulic Studies, what Ingredients am I Getting?

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2015 Road School

BANNING ENGINEERING

Presentation Goals

- Review some of the basic input data for hydrograph methodology. Are we using sound assumptions?
  - Example of modified assumptions for site design.
- Basic review of options for NRCS Type II, NOAA Atlas 14 and Huff rainfall distributions.
  - Show how the use of the different methods and options within the models could affect results?

Statement of Difficulty for Defining Hydrologic Response

In Indiana, watershed hydrologic response varies greatly depending on location. For example, runoff from a watershed in northern Indiana's "lake country" is dramatically different than a watershed in the rolling hills of the southeastern part of the state. These response differences impact assessment of watershed hydrology in many different ways. For example, when using the NRCS unit hydrograph method, the default unit hydrograph shape is typically not adjusted for the type of terrain or for storage in a watershed. Therefore, the engineer must fully understand the limitations of the methodology used for determining a discharge and the implications for properly applying it to the watershed and its location.

In the science of hydrology there are uncertainties and limitations for any method chosen for the estimation of peak discharges and runoff volumes for a watershed. Evaluation of the rainfall-runoff characteristics of a watershed, especially for rare frequency storms, is extremely complex with many interrelated variables, and existing data are typically too sparse and limited to provide the resulting degree of accuracy involved in many other engineering disciplines. When IDNR determines discharges, many different methods are used to estimate peak discharges and runoff volumes. Consequently, experience and engineering judgment are necessary aspects of making a final determination. Good engineering practice rarely includes one method to obtain a "final answer" for a discharge. Instead, challenge the results by applying other methods, running sensitivity analyses, and/or evaluating other similar watersheds where more information may be available.

Many engineers use a hydrologic modeling program, such as HEC-1, HEC-HMS, or Technical Release 20 (TR-20) to determine discharges for a watershed. While these programs can be very complex and require detailed input data, the results only represent a "well worked out opinion," rather than an absolute answer. The results from these widely used models should be carefully evaluated to ascertain if assumptions inherent in the models adequately reflect the particular system being modeled.

Technical Release 55
Urban Hydrology for Small Watersheds

- Time of concentration
  - NRCS Technical Note #4 (1986) recommended 100’ maximum sheet flow for unpaved areas
- Runoff Curve Number (RCN)
  - Much of the work based on agricultural watersheds
  - Disturbed soil profiles (Urban Areas)
    - State of Ohio example
  - Antecedent moisture condition adjustment
    - Typically used mostly for calibrating models, or recreating specific events

Excerpt from TR-55 Regarding Limitations of RCN Development for Urban Watersheds

- The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place. The opposite effect, a greater initial loss, can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must redevelop equation 2-3, figure 2-1, table 2-1, and table 2-2 by using the original rainfall-runoff data to establish new S or CN relationships for each cover and hydrologic soil group.

NRCS Technical Release 55, Urban Hydrology for Small Watersheds, June 1986

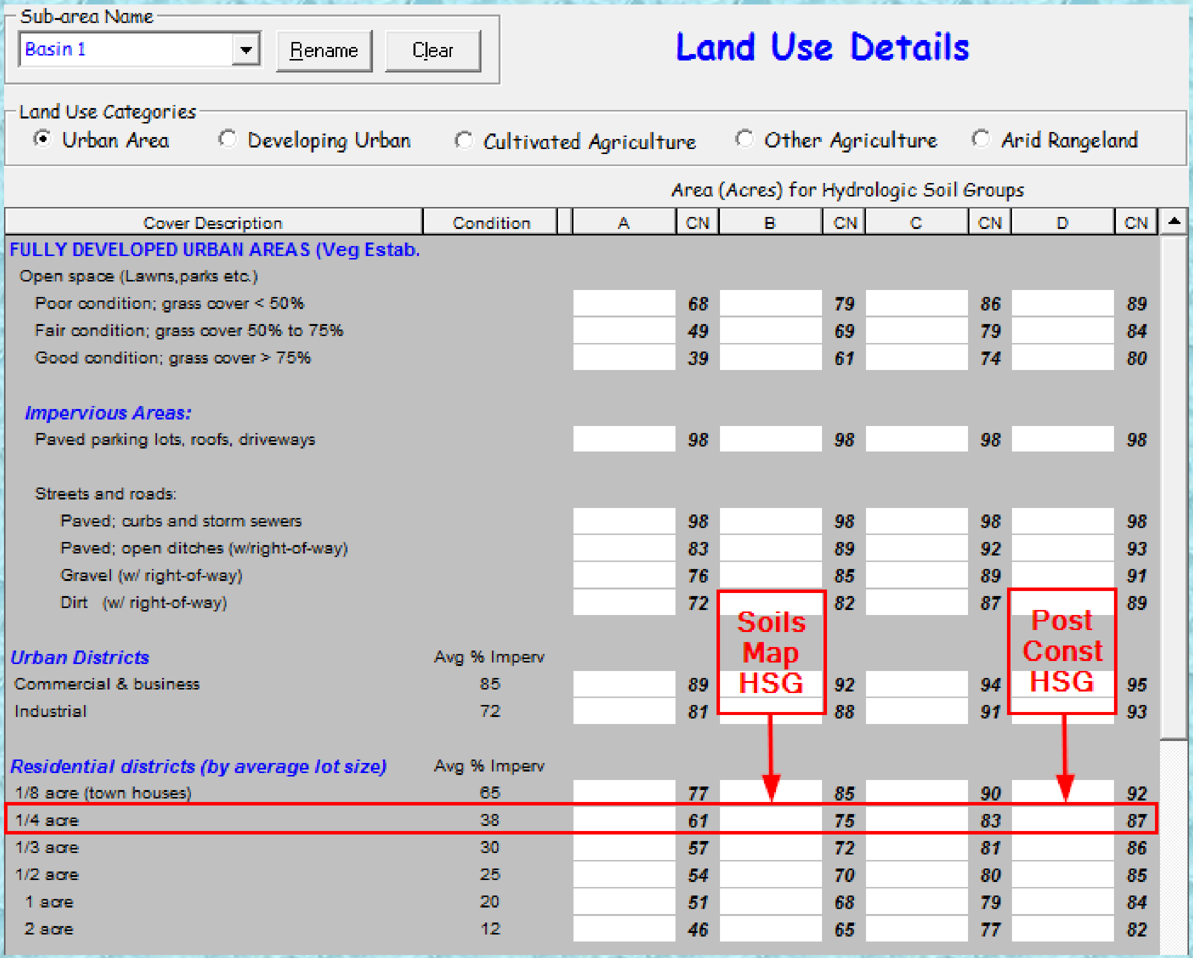
Adjusted Hydrologic Soil Group for Post Construction (State of Ohio)

Soil Map Unit Component	HSG[1]	Post-Const HSG
Aaron	C	D
Abscota Variant (Warren)	A	No Eval.
Adrian	A/D	D
Aetna	B/D	D
Alexandria	C	D
Alford	B	D
Algansee	A/D	D
Algiers	B/D	D
Allegheny	B	C
Allegheny Variant (Belmont, Pike)	B	No Eval.
Allis	D	D
Alvada	B/D	D
Amanda	C	D
Amanda Variant (Licking)	B	No Eval.
Arkport	A	A
Ashton	B	D
Atlas	D	D
Aurand	C/D	D
Ava	C	D
Avonburg	D	D
Barkcamp	A	No Eval.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Barkcamp (CL surface)	A	A
Barkcamp (L surface)	A	B
Beasley	C	No Eval.
Beaucoup	C/D	D
Belmore	B	C
Belpre	C	No Eval.
Bennington	C/D	D
Berks	B	D
Bethesda	C	D
Biglick	D	D
Birkbeck	B	D
Bixler	B	D
Blairton	C	No Eval.
Blakeslee	B/D	D
Blanchester	C/D	D
Blount	C/D	D
Bogart	B/D	D
Bogart Variant (Mahoning)	C	No Eval.
Bonnell	C	D
Bonnie	C/D	D
Bono	C/D	D

Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection * Third Edition 2006 (Appendix 9 *Updated 2012)

Land Use Example



Cover Description	Condition	A	CN	B	CN	C	CN	D	CN
FULLY DEVELOPED URBAN AREAS (Veg Estab.									
Open space (Lawns,parks etc.)									
Poor condition; grass cover < 50%			68		79		86		89
Fair condition; grass cover 50% to 75%			49		69		79		84
Good condition; grass cover > 75%			39		61		74		80
Impervious Areas:									
Paved parking lots, roofs, driveways			98		98		98		98
Streets and roads:									
Paved; curbs and storm sewers			98		98		98		98
Paved; open ditches (w/right-of-way)			83		89		92		93
Gravel (w/ right-of-way)			76		85		89		91
Dirt (w/ right-of-way)			72		82		87		89
Urban Districts	Avg % Imperv								
Commercial & business	85		89		92		94		95
Industrial	72		81		88		91		93
Residential districts (by average lot size)	Avg % Imperv								
1/8 acre (town houses)	65		77		85		90		92
1/4 acre	38		61		75		83		87
1/3 acre	30		57		72		81		86
1/2 acre	25		54		70		80		85
1 acre	20		51		68		79		84
2 acre	12		46		65		77		82

Windows TR-55

HSG Adjustment on Runoff Totals

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$I_a = 0.2S$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - 0.2*(1000/RCN-10))^2}{P + 0.8*(1000/RCN-10)}$$

1.
- 6.5”, 75RCN
  - 3.7” runoff
- 6.5”, 87RCN
  - 5” runoff
- 35% More

2.
- 4.0”, 75RCN
  - 1.7” runoff
- 4.0”, 87RCN
  - 2.6” runoff
- 53% More

3.
- 1.5”, 75RCN
  - 0.2” runoff
- 1.5”, 87RCN
  - 0.5” runoff
- 150% More

Site Design Critical Duration Analysis Example

- Ordinance
  - 100-year proposed must not exceed 10-year existing
- Existing Site
  - 30 Acres row crop ag
- Proposed Site
  - 30 Acre commercial development
- Analysis Performed
  - Huff critical duration
  - Fully meets ordinance
- What happens if we adjust input data?
  - Existing Conditions
    - Double Time of Concentration (27 to 54 minutes)
    - Adjust down RCN within acceptable tolerances (79 to 74)
  - Proposed Conditions
    - Half Time of Concentration (29 to 15 minutes)
    - Adjust up RCN due to disturbed soil profiles (91 to 92 & 77 to 82)

Results

Approved Report

Storm	1-Year		2-Year		10-Year		100-Year	
Duration	Exz	Pro	Exz	Pro	Exz	Pro	Exz	Pro
1-Hour	4.6	1.6	7.5	2.5	17.9	6.0	42.6	14.6
2-Hour	4.7	2.4	6.9	3.5	14.1	7.6	37.9	16.3
3-Hour	4.0	2.7	5.8	3.9	12.9	7.9	34.6	15.9
6-Hour	2.9	2.9	4.3	3.9	10.4	7.2	25.5	13.9
12-Hour	3.1	2.7	4.5	3.6	9.0	6.7	18.6	13.7
24-Hour	3.3	3.1	4.4	4.2	7.9	7.5	14.9	13.6

Adjusted Input

Storm	1-Year		2-Year		10-Year		100-Year	
Duration	Exz	Pro	Exz	Pro	Exz	Pro	Exz	Pro
1-Hour	1.8	2.6	3.5	3.8	10.7	8.3	29.8	18.3
2-Hour	2.9	3.1	4.7	4.4	11.0	8.9	26.3	18.0
3-Hour	2.8	3.2	4.3	4.6	9.3	8.8	22.3	17.0
6-Hour	2.2	3.2	3.2	4.3	6.9	7.7	19.3	14.6
12-Hour	2.2	3.0	3.3	3.9	7.3	7.5	16.4	14.6
24-Hour	2.6	3.5	3.6	4.6	6.9	7.9	13.8	14.1

What Affect Does Modified Input Have?

on approved design

- More frequent events exceed pre-developed conditions
  - Does this lead to more erosion?
  - Does this, over time, start exceeding existing channel capacities 1-2 year events?
- Slight increase in pond elevations
- Likely to engage emergency spillway slightly more often
- No real detriment to site

What would have to be done to meet ordinance requirements

- Significant decrease in outlet pipe
- 33% more storage required
- Larger pond or higher staging of pond
- Less developable area
- Higher flood protection grades
- More analysis would need to be completed to ensure more frequent events do not exceed pre-developed conditions

Comparing Runoff Hydrograph Methods

NOAA Atlas 14

- Numerous temporal distributions (45 possible per Storm Duration)
- Storm Quartiles
  - Which one 1st, 2nd, 3rd, 4th, all?
- Percent probability of temporal distribution
  - 10% through 90% @ 10% intervals
- Numerous storm durations
  - 30 Minute to 24 hour, 315 potential scenarios
- Rainfall depths
  - 90% confidence
  - Upper and Lower Bounds?
- Data server makes information acquisition very easy

Huff

- Storm Quartiles
  - 1st, 2nd, 3rd, 4th
- Huff Curve Ordinates
  - 10% through 90% @ 10% intervals
- (4) Stations
  - Indianapolis
  - Evansville
  - Fort Wayne
  - South Bend
- Numerous storm durations
  - 30 Minute to 24 Hour, 63 potential scenarios
- 9 Rainfall Depth Regions for State
- Bulletin 71 & HERPICC Manual great references

NRCS Type II

- One Hydrograph
- 24 Hour Storm
- Rainfall Depths Standard
- Peaking Factors???
- Easy to find data
- Already incorporated into most H & H software
- Most Conservative Method

How Do Different Methods Compare?

- Sample watershed
  - Smallest area 0.65 Square Miles
  - Largest area 5 Square Miles

1% Synthetic Storm Analysis					
	NOAA 1st Quartile (Temporal Distributions)				
DA (mi^2)	10%	50%	90%	Huff (50%)	NRCS Type II
0.65	680	481	450	435	766
0.89	815	611	555	555	895
1.00	870	671	555	585	933
2.0	1645	1170	1120	1120	1870
2.1	1700	1190	1120	1140	1865
2.93	2055	1440	1330	1375	2100
4.41	2775	1840	1730	1820	2765
4.71	2840	1910	1740	1865	2770
4.97	2890	1970	1740	1865	2770

What does this mean for a Floodplain Analysis of this Reach NOAA Atlas 14 (50% Probability) 1st Quartile -vs- NRCS Type II

- Flowrates
  - NRCS ~50% More
- Base Flood Elevations
  - NRCS averages 0.8’ Higher
- Floodway
  - NRCS averages 25% Wider
- Both are accepted methods for drainage areas over 1 square mile

So what did we see?

- Hydrologic and Hydraulic modeling is not an exact science
  - Input data is EXTREMELY important
    - Know what assumptions are made
    - Are these assumptions reasonable and valid?
    - Consider potential impacts of urban development on RCN
  - Data and tools allow for very complex modeling
  - Be careful how you apply the information available
  - Know your engineer’s or hydrologist’s assumptions
    - If you don’t know, then ask
    - Assumptions can have a significant impact on results

Links for this Discussion

- USDA / NRCS Part 630 NEH (Time of Concentration)
  - http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=27002.wba
- TR-55 Small Watershed Hydrology Win TR-55 User Guide
  - http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042897.pdf
- Ohio DNR Rainwater and Land Development Manual
  - http://soilandwater.ohiodnr.gov/water-conservation/stormwater-management#RAI
- HERPICC Manual
  - http://rebar.ecn.purdue.edu/ltap1/multipleupload/Drainage/2008%20STORMWATER%20DRAINAGE%20MANUAL%20-%20UPDATED.pdf
- Bulletin 71
  - http://www.sws.uiuc.edu/pubdoc/B/ISWSB-71.pdf
- NOAA Atlas 14
  - http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume2.pdf
- IDNR General Guidelines for Hydrologic-Hydraulic Assessment
  - http://www.in.gov/dnr/water/5710.htm

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