

Recommendation for: Defining Channel Conveyance in Harris County (Revised 09/12/2002)

Goal: To understand the original definition of channel conveyance as presented in the original Flood Hazard Study for Harris County and to simplify the determination of channel conveyance in a manner which is consistent with that original definition. The manner in which channel conveyance is applied under current methodology may be askew of the original definition.

A secondary goal is to achieve some consistency in the calculation of TC and R values when DLU moves from 17% to 18%. Under current methodology, the transition from 17% to 18% is a transition of a subarea from an undeveloped condition to a partially developed condition. Because of the discontinuity between the equations for these two conditions, calculated TC and R values actually increase, resulting in lower peak discharges for the higher level of development.

[Admittedly, these two issues could be addressed separately. However, since channel conveyance and urban development work together to define TC and R values, it seemed appropriate to combine these two issues into a single issue paper.]

Recommended Procedure: A description of channel conveyance and a possible recommended procedure for defining it follows.

1. The original definition in the “Hydrology for Harris County” seminar notebook is that “the conveyance of a channel [is] interpreted as the capability of the channel to carry runoff in an area of uniform high velocity.”¹ As examples, the seminar notebook gives the following:

“...an improved channel capable of carrying the flood flow within its banks would be conveying all its flow at a relatively uniform high velocity and is assumed to have full (100 percent conveyance). An unimproved channel carrying one-third of its flood flow within its banks and two-thirds of its flow at a slower velocity in its overbanks is assumed to have a reduce conveyance of 30 percent...By definition, an undeveloped watershed with an unimproved channel would have 100 percent conveyance at the limits of the natural 100-year flood plain.”²

However, this definition appears to be a bit confusing. Therefore, it is recommended that channel conveyance be defined *as a measure of how well channel improvements keep pace with development within a given subarea*. [Perhaps a better name for “channel conveyance” would be “conveyance capacity.”] This alternate definition would appear to be consistent with the original intent of the variable and the examples provided.³

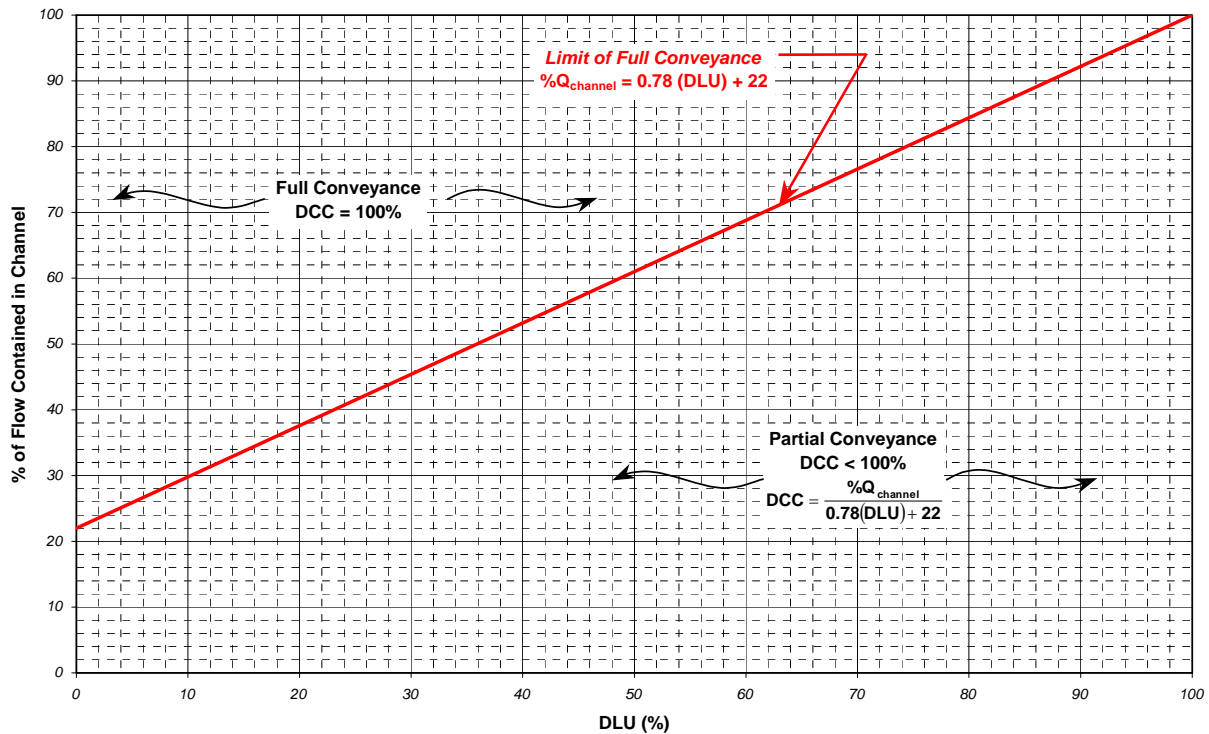
2. Percent channel conveyance could be determined from Figure 1 which provides a simplification of graphs previously used in the seminar notebook.

¹ Harris County Flood Control District, “Hydrology for Harris County,” March 3, 1988, page C-9.

² Ibid.

³ This definition seems to be implied in the seminar notebook (see page C-11).

Figure 1: Estimate of Full Conveyance



3. Enter the x-axis of the graph in Figure 1 with a given percent urban development to determine the percent channel flow which represents full conveyance. For example, a subarea which is 50% developed will produce a full conveyance value of 61% of the flow within the channel.
4. Determine the percent of flow which is contained within the channel. For the example cited, assume that the actual percentage of flow contained within the channel is 52%.
5. Determine the percent channel conveyance by dividing the percentage of flow in the channel for full conveyance percentage by the actual percentage of flow in the channel. For the example, the percent channel conveyance would be equal to 52% divided by 61%, which equals 85%. For values of DCC which exceed 100% (i.e., the channel is more than adequate to provide full conveyance), set DCC equal to 100%.

Additionally, it is recommended that to avoid the discontinuity in the use of undeveloped and partially developed equations for calculating TC and R values, the following procedure should be used.

1. As in the current methodology, TC+R is defined with the following equation:

$$TC + R = C \left(\frac{L}{\sqrt{S}} \right)^{0.706}$$

2. For values of DLU satisfying the following equation, $C = 7.25$ (from the equation for undeveloped conditions):

$$DLU < 11344(DCC)^{-1.4049}$$

3. For values of DLU not satisfying the above equation, C is defined by the following equation (from the seminar notebook):

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

It is noted that the only difference between the methodology described immediately above and the methodology currently in use is the introduction of a new minimum boundary condition for DLU.

Assumptions: The following two assumptions are associated with this procedure.

- A natural channel is capable of carrying 22% of the 100-year flow within the banks. This assumption is based on a secondary assumption that a 2-year event produces a bank-full condition. Lacking any backup data from the original methodology, it was assumed that the 2-year and 100-year flows could be defined by regional equations. Since the question of what percent of flow in the channel should be considered full conveyance in an undeveloped subarea needed to be addressed to develop Figure 1, it was assumed that if the regional equations for rural conditions were used, natural channel full conveyance condition could be estimated by dividing Q_2 by Q_{100} .
- High values of DLU accompanied by low values of DCC combine to define a channel system within a subarea which functions similar to an unimproved stream. In other words, for a given subarea, the value of TC+R would be the same whether DLU = 10% and DCC = 100%, or DLU = 100% and DCC = 20%. This would seem reasonable since the methodology associated with determining the values of TC dictates that TC is a function of DLU. Therefore, while TC+R remains the same, TC would decrease with increased DLU and R would increase (accounting for the flood plain storage due to a lack of capacity in the channel).

Testing Procedure: To develop Figure 1, it was first necessary (as stated under the assumptions) to define the channel capacity for a natural stream with no development in the area draining to it. To do this, USGS regression equations for Texas Region 2 which represent rural conditions were used.⁴ Since average annual flow is considered to be equivalent to a 2.33-year flood,⁵ it was assumed that a 2-year flow would be representative of a bank-full condition. Therefore, to define full conveyance at a DLU value of 0%, the following equations were used for areas ranging from one to four square miles and for channel slopes ranging from five to 20 feet per mile:

$$Q_2 = 216(A)^{0.574} (S)^{0.125}$$

$$Q_{100} = 628(A)^{0.694} (S)^{0.261}$$

The percent channel flow representing full conveyance in an undeveloped subarea was then determined by averaging the value of Q_2 divided by Q_{100} for various combinations of drainage area and channel slope. The average percent channel flow for the 100-year event was determined to be about 22%.

Since two points relating DLU to percent channel flow for full conveyance could now be plotted (22% Q_{channel} at 0% DLU and 100% Q_{channel} at 100% DLU), Figure 1 was constructed using a straight-line approximation between the two points. [Due to a lack of information, it is not clear whether a straight-line approximation accurately reflects reality, but it is assumed for the purpose of this recommendation.]

To develop the limiting equation for DLU (i.e., $DLU < 11344(DCC)^{-1.4049}$), it was first necessary to determine why the discontinuity in TC and R occurs between DLU = 17% and DLU = 18%. To determine this, the coefficient (C) was plotted for varying values of DLU and DCC = 100%. For these conditions, it was noted that at DLU equal to

⁴ Jennings, M.E., W.O. Thomas, Jr., and H.C. Riggs, *Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993*, Water Resources Investigation Report 94-4002, U.S. Geological Survey, Reston, VA, 1994, page 151.

⁵ Chow, V.T. (editor-in-chief), *Handbook of Applied Hydrology*, McGraw-Hill, New York, 1964, page 25-6.

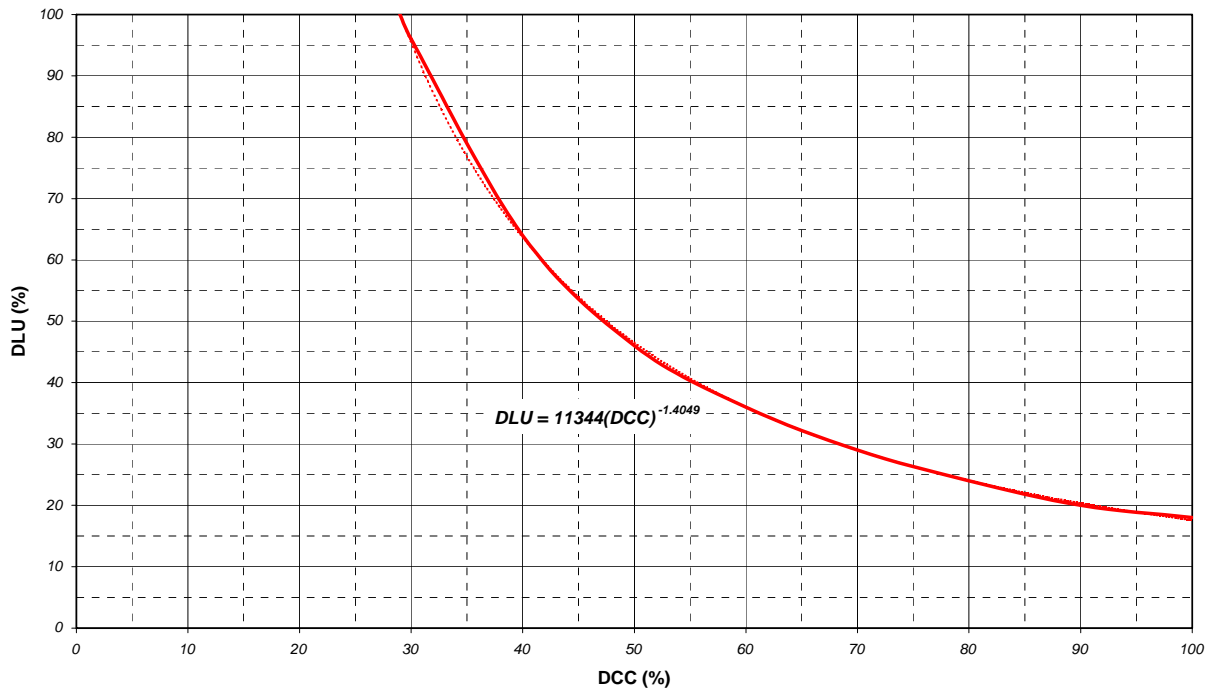
about 17%, C was equal about 7.25; for greater values of DLU, C decreased. However, when DCC was changed to 90%, it was found that C increased to about 7.8 at DLU equal to 18%. This increase translates to an increase in TC+R values, which then translates to an increase in TC and R values when DLU increases from 17% to 18%, reducing peak discharges.

The seminar notebook states the following with regard to the coefficient C:

“...it [is] assumed that undeveloped watersheds respond with full conveyance and any watershed exhibiting less than 18 percent development would be considered as an undeveloped watershed (i.e., C = 7.25).”⁶

Based on that statement, it was assumed that C should not exceed 7.25 under any condition. Therefore, C was plotted against DLU for various values of DCC to determine where C = 7.25 intersects the C vs. DLU curve. From this information, an additional plot (see Figure 2) was made of DLU vs. DCC for all values in which C = 7.25. Finally, a line was fitted for the final plot which was defined by the equation noted above. The net result of this procedure development is that C will not exceed 7.25 for any combination of DLU and DCC. In other words, under this procedure TC+R will not exceed the value for an undeveloped watershed

Figure 2: Urban Development vs. Channel Conveyance
C=7.25



In order to evaluate these procedures, tests were undertaken to compare the values of DCC determined under the new definition with the original methodology developed for the hydrology seminar and the Flood Hazard Study. Additionally, tests were conducted (independent of the DCC methodology) which compared the values of TC and R values for various ranges of DLU and DCC using the original methodology and the revised methodology. These latter tests were performed to ensure consistency between DLU values of 17% and 18%.

⁶ Harris County Flood Control District, “Hydrology for Harris County,” March 3, 1988, page C-11.

Test Results: In the first evaluation, it is noted that the revised determination of DCC caused increases in the value of DCC, which in turn will produce lower values of TC+R, and subsequently, higher discharges. Table 1 compares the values of DCC using the two different methodologies.

Table 1: Comparison of DCC Determination Methods

Subbasin Data			HCFC Method			Revised Method			
A (acres)	DLU (%)	S (ft/mi)	Q100-full (cfs)	Qch (cfs)	DCC (%)	Q100-est (cfs)	Qch (cfs)	Qch (%)	DCC (%)
300	100	9	900	300	33	900	300	33	33
400	75	7	900	1000	100	900	1000	100	100
500	50	5	810	800	99	810	800	99	100
600	25	3	600	300	50	600	300	50	100
700	0	1	410	1000	100	410	1000	100	100
800	100	9	1910	800	42	1910	800	42	42
900	75	7	1670	300	18	1670	300	18	22
1000	50	5	1350	1000	74	1350	1000	74	100
2000	25	3	1420	800	56	1420	800	56	100
3000	0	1	1120	300	27	1120	300	27	100

In the second evaluation, it was determined that the new methodology does provide consistency on either side of the critical 18% DLU. Table 2 presents a comparison of TC and R values for each methodology. The various conditions shown in this table represent a subarea undergoing development without channel improvements.

Table 2: Comparison of TC and R Methods

Subarea Parameters											HCFC Methodology			Revised Methodology		
Area (sq.mi.)	Area (acres)	L (mi)	Lca (mi)	S (ft/mi)	So (ft/mi)	DLU (%)	DCC (%)	DCI (%)	DPP (%)	RTIMP (%)	TC+R (hours)	TC (hours)	R (hours)	TC+R (hours)	TC (hours)	R (hours)
2.12	1358	2.69	1.40	6.2	10	0	90.00	0	0	0.00	7.66	1.34	6.32	7.66	1.34	6.32
2.12	1358	2.69	1.40	6.2	10	10	80.00	0	0	3.50	7.66	1.31	6.35	7.66	1.31	6.35
2.12	1358	2.69	1.40	6.2	10	20	80.00	0	0	7.00	8.60	1.29	7.31	7.66	1.29	6.37
2.12	1358	2.69	1.40	6.2	10	30	80.00	0	0	10.50	6.53	1.26	5.27	6.53	1.26	5.27
2.12	1358	2.69	1.40	6.2	10	40	80.00	0	0	14.00	5.37	1.24	4.14	5.37	1.24	4.14
2.12	1358	2.69	1.40	6.2	10	50	70.00	0	0	17.50	5.25	1.21	5.25	5.25	1.21	4.04
2.12	1358	2.69	1.40	6.2	10	60	70.00	0	0	21.00	4.64	1.19	3.46	4.64	1.19	3.46
2.12	1358	2.69	1.40	6.2	10	70	70.00	0	0	24.50	4.18	1.16	3.02	4.18	1.16	3.02
2.12	1358	2.69	1.40	6.2	10	80	70.00	0	0	28.00	3.82	1.14	2.68	3.82	1.14	2.68
2.12	1358	2.69	1.40	6.2	10	90	70.00	0	0	31.50	3.53	1.11	2.42	3.53	1.11	2.42
2.12	1358	2.69	1.40	6.2	10	100	70.00	0	0	35.00	3.28	1.09	2.20	3.28	1.09	2.20

Final Notes: Additional consideration should be given to these procedures by the TSARP Hydrology Committee. While the redefinition of DCC may not be desirable due to the impacts to discharges, the change to the coefficient C appears to resolve the issue of discontinuity in TC and R methodology. Therefore, it is recommended that the change in C be pursued even if the modified definition of DCC is not.

Committee Resolution: Use the traditional approach, except for the recommendation regarding resolution of the 18% discontinuity. It was requested that the traditional approach be restated here for use by the TSARP hydrology teams. The following is based on the process for defining DCC values described in “Hydrology for Harris County” (March 3, 1988) and the Flood Hazard Study (1984).

Perhaps the two most important statements regarding the determination of percent channel conveyance (DCC) are the following:

- a) “The conveyance of a channel [is] interpreted to be the capability of the channel to carry runoff in an area of uniform high velocity,” and
- b) “Conveyance [is] measured by examining HEC-2 runs on the channel and determining the percent of flow conveyed by the channel for a flow approximating the 100-year discharge that would be anticipated if the channel had full conveyance” [emphasis added].

This leads to the necessity of defining channel capacity and “full conveyance.” To do this, the following steps should be taken:

1. Full conveyance is determined from the curves in Exhibits C-4 through C-8 of *Hydrology for Harris County*. Using the drainage area, percent development, and channel slope of the subarea in question, determine the discharge equivalent to full conveyance. Since some of the drainage areas defined by the TSARP study may be smaller than 300 acres, it is recommended that full conveyance for those areas be extrapolated from the curves.
2. From a storage-outflow model, determine the average amount of flow between the channel banks at individual cross sections for a total flow equal to the full conveyance discharge from Step #1.
3. Divide the flow between the channel banks from Step #2 by the full conveyance discharge and multiply by 100 to determine percent channel conveyance, DCC. Round DCC to the nearest 10%.

If no hydraulic model exists for the channel in a given subarea, the capacity of the channel can be determined by use of the normal depth equation for a typical channel section. DCC is then defined by the channel capacity divided by the full conveyance discharge. Most subareas will fall under this condition.

By definition (or by convention) an undeveloped watershed has a percent channel conveyance equal to 100%.

Further Developments:

The committee further determined that it would be appropriate to define DCC based on frequencies other than simply the 100-year event. Therefore, research was continued to determine a valid and yet simple approach to DCC for the 2-, 5-, 10-, 25-, 50-, 250-, and 500-year events.

In performing analyses with HEC-HMS to estimate the relative difference between the 2-year and 100-year discharge and the 10-year and 100-year discharge for three networked systems (i.e., upper White Oak Bayou, upper Brays Bayou, and upper Cypress Creek), it was determined that the differences were fairly consistent with the differences in rainfall (i.e., the 2-year peak discharge was about 33% of the 100-year peak discharge and the 2-year rainfall was 33% of the 100-year rainfall; the 10-year comparison was similar at 58%). Therefore, rather than creating a whole new set of full conveyance curves for the various frequencies (35 graphs in all), it is recommended that the 100-year curves be utilized and that a factor be multiplied to the 100-year full conveyance values to arrive at values for each respective flood frequency. The following factors based on 24-hour rainfall for all three regions are recommended:

Recurrence Interval	Full Conveyance Factor
2-year	0.33
5-year	0.47
10-year	0.58
25-year	0.73
50-year	0.86
100-year	1.00
250-year	1.23
500-year	1.43

The following is an example of how to apply this procedure:

1. Suppose a channel has been found to have a capacity of 900 cfs. The channel slope is 3 ft/mile and the area draining to the channel is 1.56 square miles (1000 acres) and is 50% developed. From Exhibit C-5 of *Hydrology for Harris County*, a 100-year full conveyance discharge of about 1240 cfs is read.

2. Multiplying the 100-year full conveyance discharge by the factors above, the full conveyance discharges for the remaining.

Recurrence Interval	Full Conveyance Discharge (cfs)
2-year	413
5-year	582
10-year	714
25-year	902
50-year	1062
100-year	1240
250-year	1522
500-year	1775

3. By dividing the capacity of the channel (900 cfs) by the full conveyance discharge, the value of DCC can be obtained. Obviously, if the capacity exceeds the full conveyance discharge, DCC = 100%. As stated previously, DCC should be rounded to the nearest 10%.

Recurrence Interval	Calculated DCC	Rounded DCC
2-year	100%	100%
5-year	100%	100%
10-year	100%	100%
25-year	100%	100%
50-year	85%	80%
100-year	73%	70%
250-year	59%	60%
500-year	51%	50%

Final Developments:

After further investigation and discussion regarding the changing of DCC with various recurrence intervals, it was determined that it is probably more appropriate to define DCC for the 100-year event only and use this value for other recurrence intervals. This additional investigation was derived from question asked by the study teams regarding what frequency to use when calibrating to an observed storm. It is possible that an engineer could estimate the recurrence interval from the rainfall. However, the main concern is that although increasing DCC for higher frequency events seems intuitive, the procedure may be deviating from the original optimization used to develop this parameter. The "Hydrology for Harris County" seminar notebook indicates that this optimization was based on the analysis of eleven stream gages (and assuming the same ratio of storms analyzed to gages analyzed for the overall methodology development, this would indicate that 22 storms were analyzed). While it is highly unlikely that all storms analyzed were of a 100-year magnitude (in all likelihood, they were less), the 100-year frequency was nonetheless assigned to the parameter. Considering all of this along with the calibration question, it would seem that this procedure of varying DCC with recurrence interval may be adding a labor intensive step to the hydrology which would produce results which are more precise, but have no greater level of reliability/accuracy than currently exists with the current methodology of calculating DCC based on the 100-year return interval alone. In fact, it is possible that the reliability/accuracy may decline (this is an unknown). Therefore, it is recommended that the old procedure of using DCC based on 100-year alone be used.

Additionally, one other question has arisen regarding the calculation of DCC. There may be situations in which the channel slope exceeds 9 feet/mile. In these cases, how should the full conveyance be derived? The following is a recommended procedure:

1. Using Exhibits C-4 through C-8, determine the full conveyance discharges for slopes of 7 ft/mi and 9 ft/mi for the drainage area of interest and the corresponding level of development.
2. Construct a log-log plot of channel slope vs. full conveyance discharge using the two determined flows.
3. Extrapolate a line from these two points to the channel slope of interest.
4. Read the full conveyance discharge for the given channel slope.

If slopes exceed 15 feet per mile, it is recommended that the study team discuss it with the TSARP Hydrology Committee to avoid extrapolation of data too far beyond the data set.