Regional curves relating bankfull channel geometry and discharge to drainage area

USGS Kentucky and Pennsylvania Water Science Centers

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U.S. Department of the Interior
U.S. Geological Survey

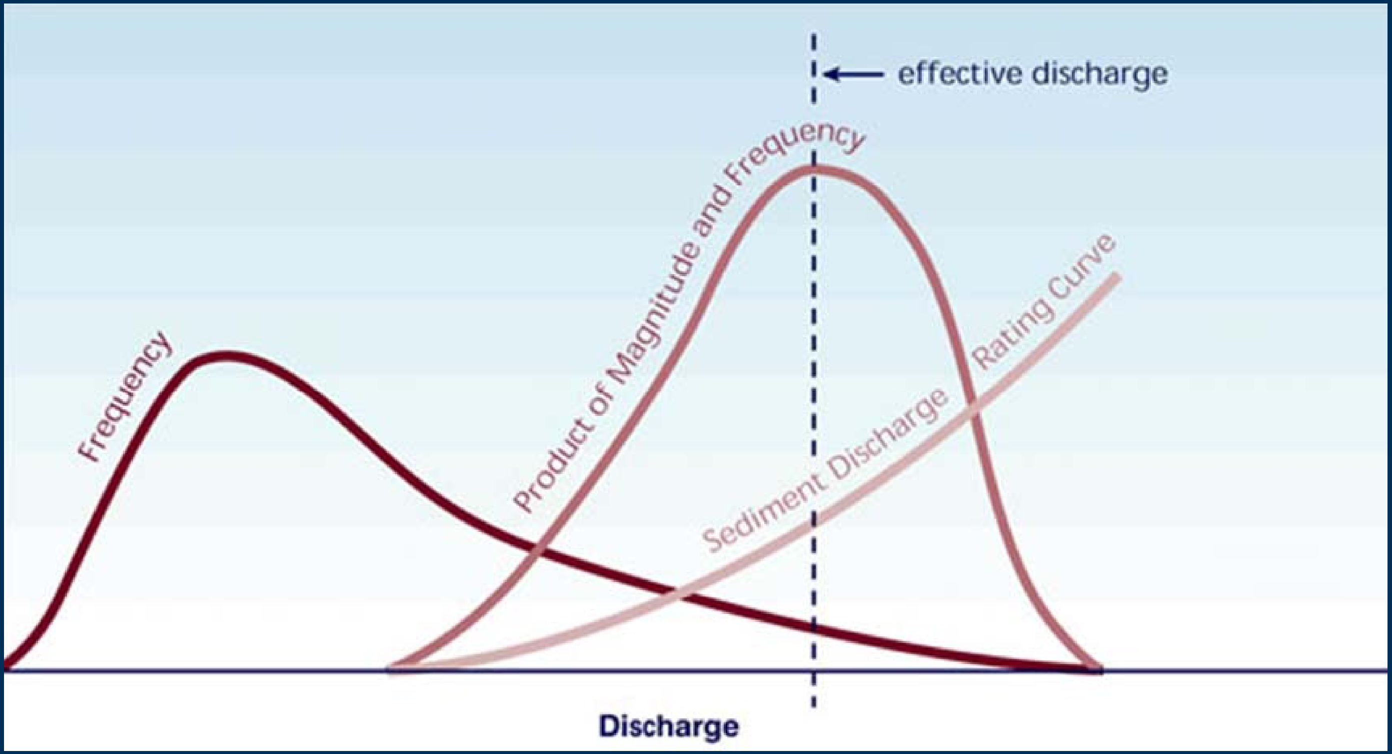
Introduction to Regional Curves

- Regressions relating <u>bankfull</u> channel characteristics to drainage area.
- Provide *estimates* of bankfull discharge and channel geometry at ungaged sites
- Used for validating the selection of the bankfull channel as determined in the field

USGS

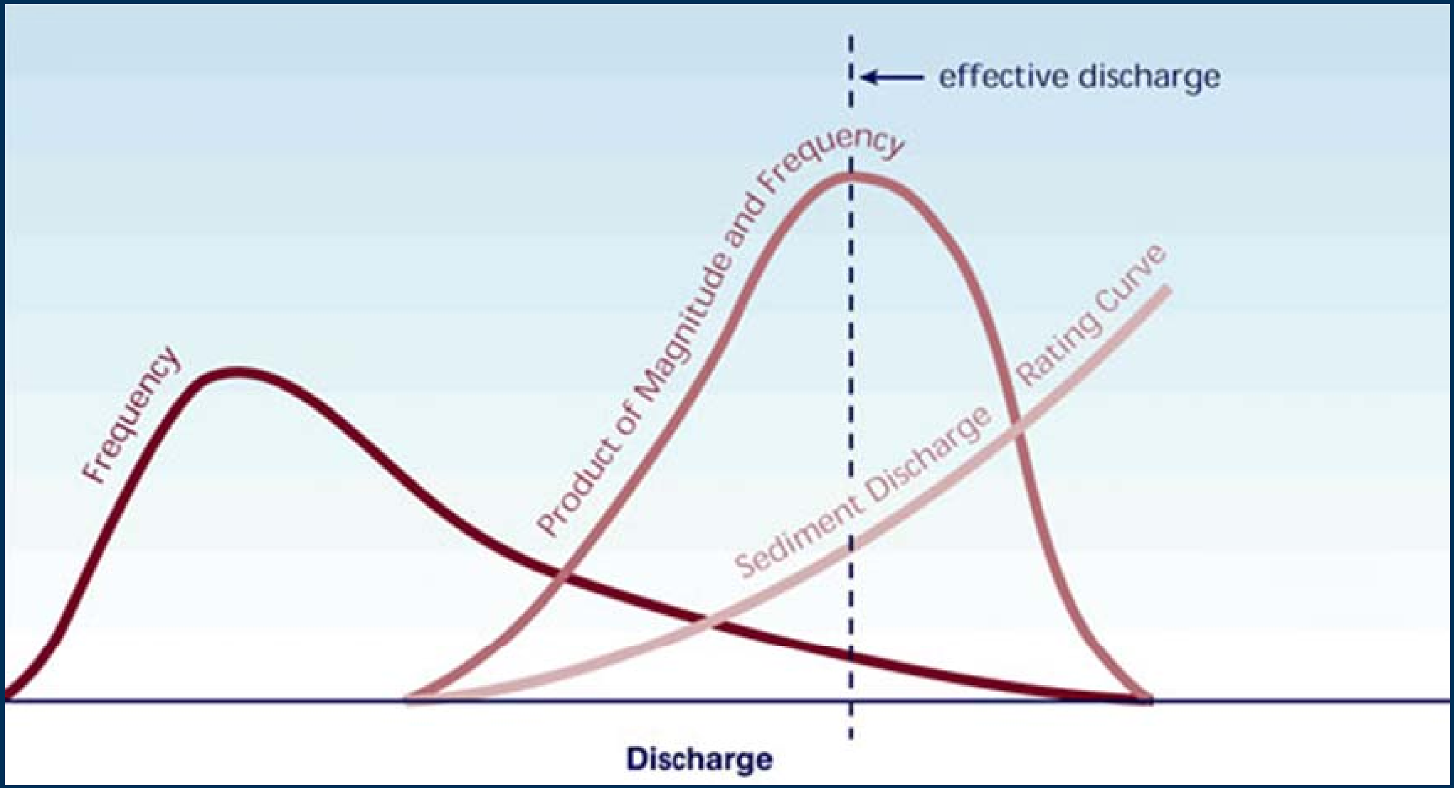
What are the bankfull discharge and the bankfull channel?

"There must be some flow of intermediate size, large enough to be effective in causing change, but sufficiently frequent that the product of its frequency and effectiveness would be greater than that of any other size of flow event. (Wolman & Miller, 1960)



USGS

This system is not necessarily stationary and the inputs can be dynamic – changes to inputs will cause channel evolution as the system seeks to stabilize under the new regime (mining impacts for example).



USGS

Definition of “stable”

Rosgen (1996) defined “stable” as a stream that “has the ability to maintain over time, its dimension, pattern, and profile in such a manner that it is neither aggrading nor degrading and is able to transport, <u>without adverse consequence</u>, the flows and detritus of its watershed”.

A stable stream is considered to be in “dynamic equilibrium” or “graded”.

USGS

In terms of stability, resource managers are generally dealing with relative rates of change and the ability of the local ecosystem to adjust without adverse effects (as noted by Rosgen and with respect to spatial scale as per Schumm and Lichty, 1965). Basically, stability goes as follows:

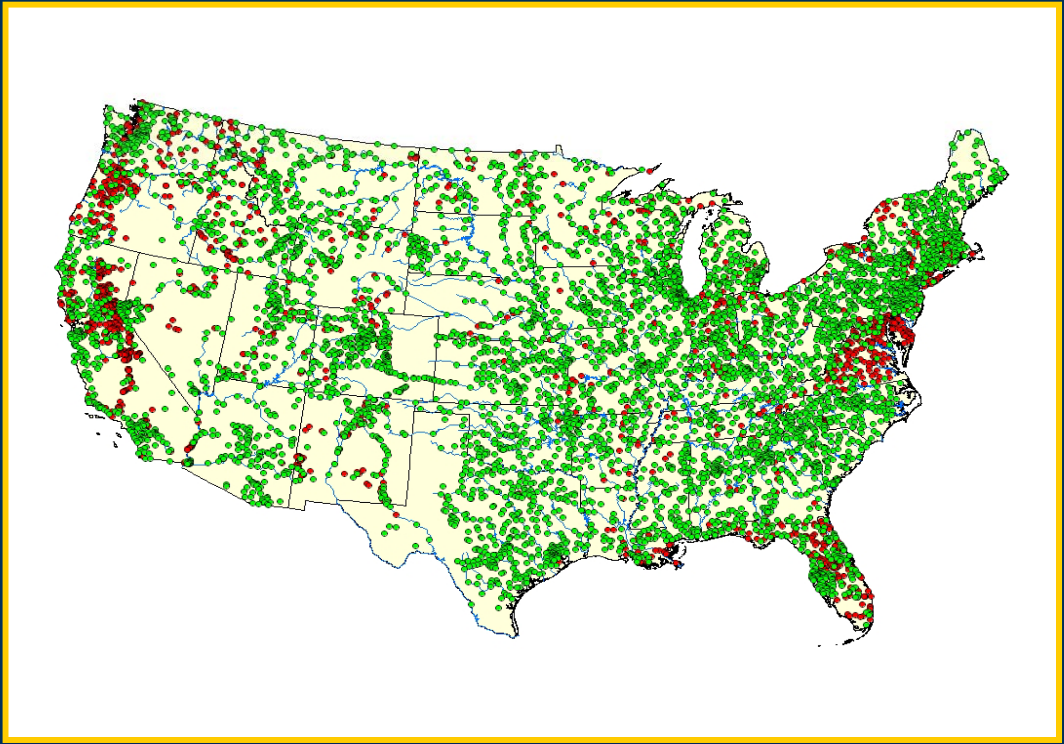
Long time period = progressive loss of energy and mass (basin)
Moderate time period = self-regulation, dynamic equilibrium (subwatershed)
Short time period = steady state (reach)

USGS streamflow-gaging stations provide data to quantify channel stability (when coupled with basic site observations) and generally serve as the backbone of regional curves.

USGS

USGS stream gages are required to develop regional curves - they provide critical data and insight.

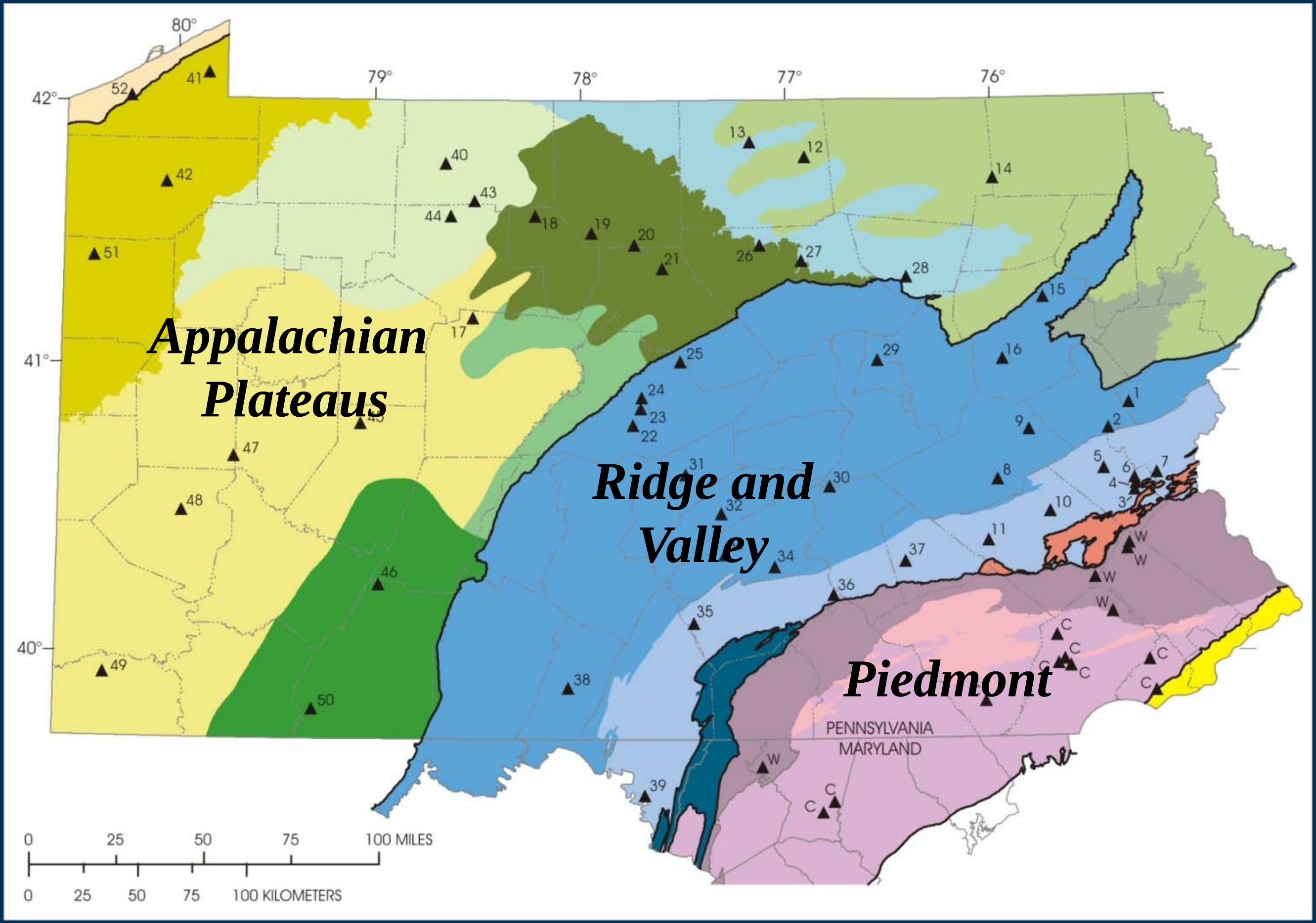
Gage sites become your data points, so the more the better. You can fill in with un-gaged sites, but these sites should be limited.



There are over 7,800 USGS streamflow-gaging stations nationally

USGS

Selection of streamflow-gaging stations for PA study



For geomorphic study, many USGS gages can fall out as you filter them by selection criteria – we used only 66 out of the 350+ gages in the region.

Basic USGS stream gage – measures stage. To compute flow, a rating curve must be established.

USGS

Streamflow is measured over a range of stages to develop the rating curve

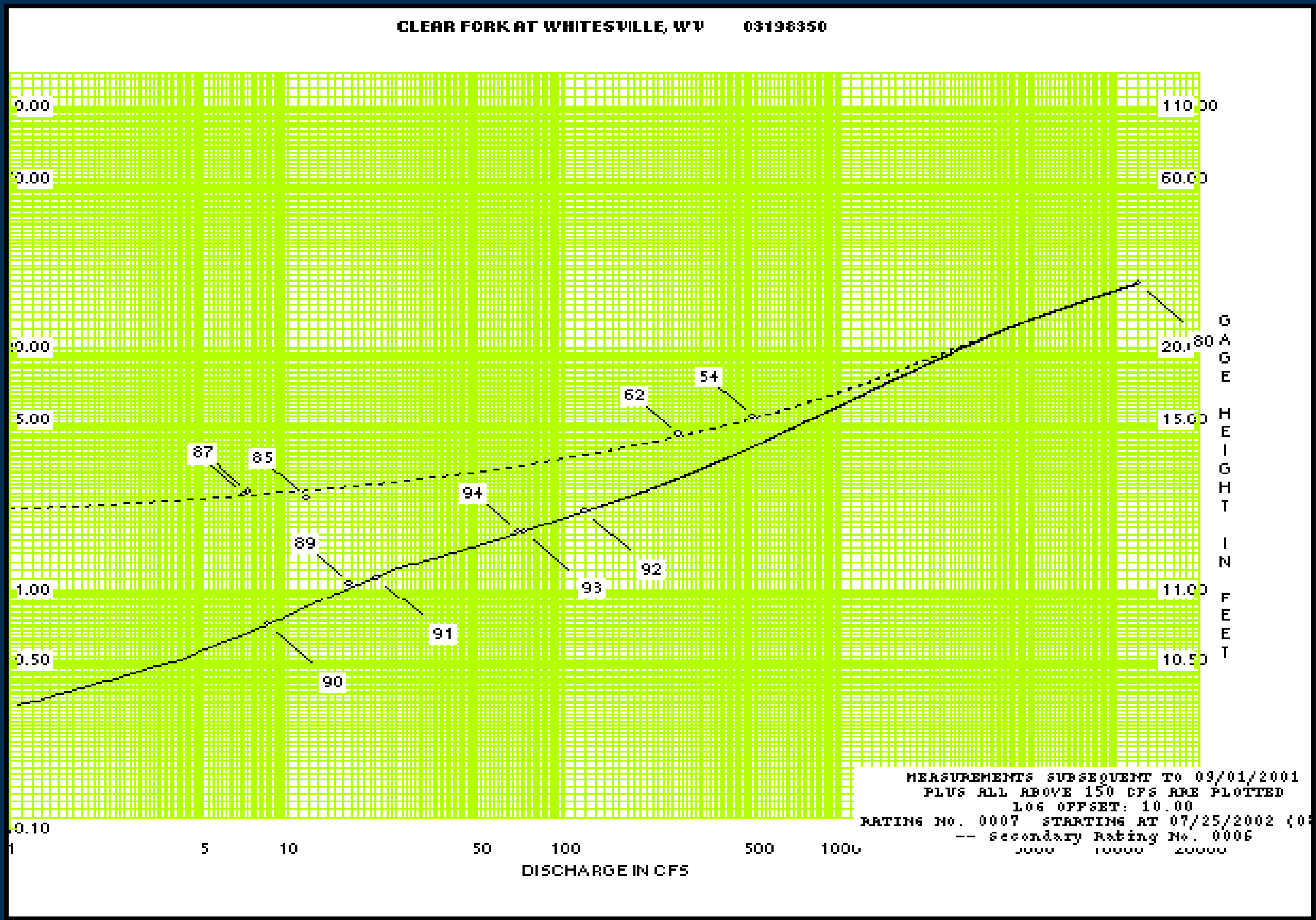
Wading (in a glide)

Flood flow (at a bridge)

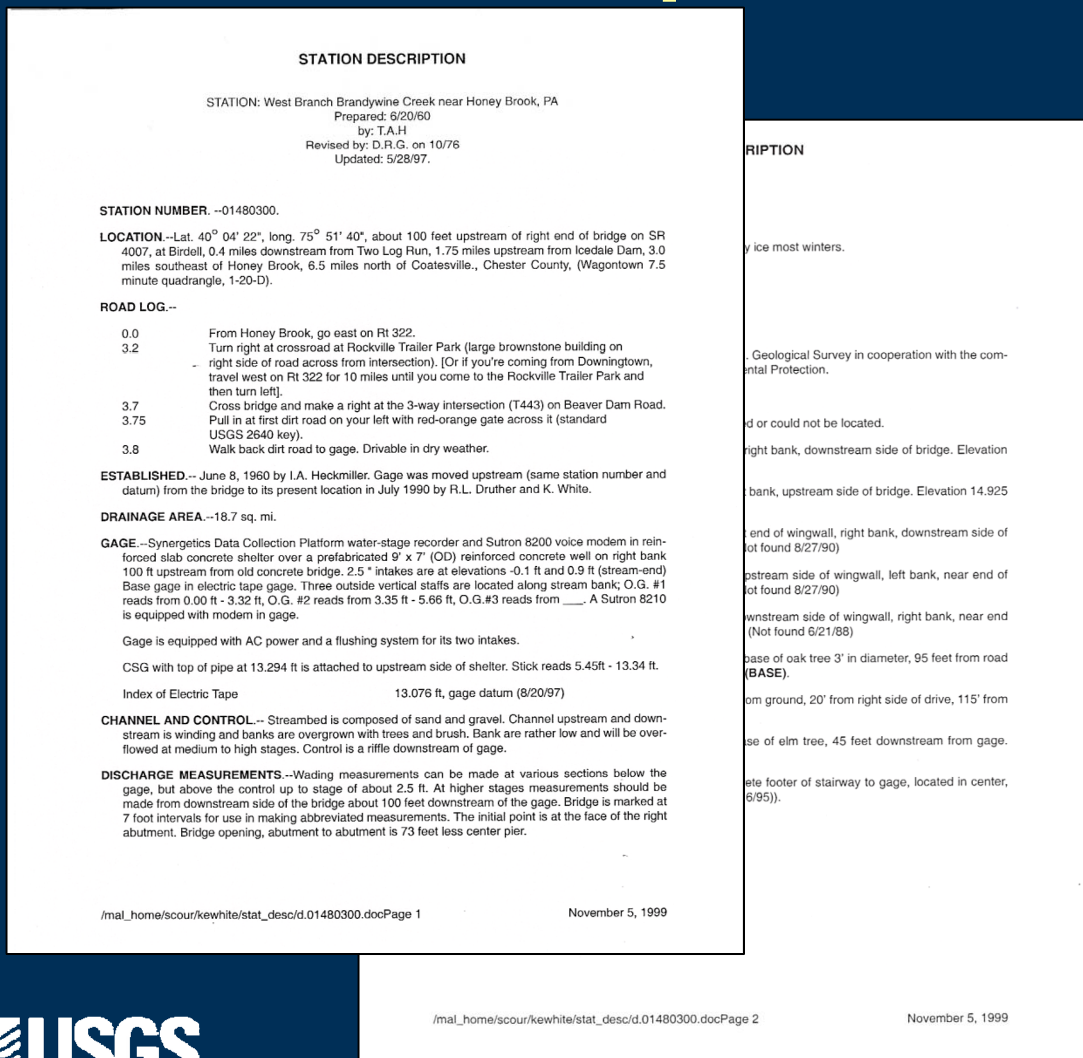
Note – regional curves are developed in natural riffles, so channel geometry from USGS measurements should not be used directly to create regional curves.

Stage / discharge rating curve

Notice the control shifted (scoured) at this gage and a new rating had to be established (rating #7) – ratings are good indicators of relative site "stability"



USGS also provides: Station Descriptions



STATION DESCRIPTION

STATION: West Branch Brandywine Creek near Honey Brook, PA
Prepared: 6/20/60
by: T.A.H
Revised by: D.R.G. on 10/76
Updated: 5/28/97.

STATION NUMBER. --01480300.

LOCATION.--Lat. 40° 04' 22", long. 75° 51' 40", about 100 feet upstream of right end of bridge on SR 4007, at Birdell, 0.4 miles downstream from Two Log Run, 1.75 miles upstream from Icedale Dam, 3.0 miles southeast of Honey Brook, 6.5 miles north of Coatesville., Chester County, (Wagontown 7.5 minute quadrangle, 1-20-D).

ROAD LOG.--

0.0	From Honey Brook, go east on Rt 322.
3.2	Turn right at crossroad at Rockville Trailer Park (large brownstone building on right side of road across from intersection). [Or if you're coming from Downingtown, travel west on Rt 322 for 10 miles until you come to the Rockville Trailer Park and then turn left].
3.7	Cross bridge and make a right at the 3-way intersection (T443) on Beaver Dam Road.
3.75	Pull in at first dirt road on your left with red-orange gate across it (standard USGS 2640 key).
3.8	Walk back dirt road to gage. Drivable in dry weather.

ESTABLISHED.-- June 8, 1960 by I.A. Heckmiller. Gage was moved upstream (same station number and datum) from the bridge to its present location in July 1990 by R.L. Druther and K. White.

DRAINAGE AREA.--18.7 sq. mi.

GAGE.--Synergetics Data Collection Platform water-stage recorder and Sutron 8200 voice modem in reinforced slab concrete shelter over a prefabricated 9' x 7' (OD) reinforced concrete well on right bank 100 ft upstream from old concrete bridge. 2.5 " intakes are at elevations -0.1 ft and 0.9 ft (stream-end) Base gage in electric tape gage. Three outside vertical staffs are located along stream bank; O.G. #1 reads from 0.00 ft - 3.32 ft, O.G. #2 reads from 3.35 ft - 5.66 ft, O.G.#3 reads from ___. A Sutron 8210 is equipped with modem in gage.

Gage is equipped with AC power and a flushing system for its two intakes.

CSG with top of pipe at 13.294 ft is attached to upstream side of shelter. Stick reads 5.45ft - 13.34 ft.

Index of Electric Tape 13.076 ft, gage datum (8/20/97)

CHANNEL AND CONTROL.-- Streambed is composed of sand and gravel. Channel upstream and downstream is winding and banks are overgrown with trees and brush. Bank are rather low and will be overflowed at medium to high stages. Control is a riffle downstream of gage.

DISCHARGE MEASUREMENTS.--Wading measurements can be made at various sections below the gage, but above the control up to stage of about 2.5 ft. At higher stages measurements should be made from downstream side of the bridge about 100 feet downstream of the gage. Bridge is marked at 7 foot intervals for use in making abbreviated measurements. The initial point is at the face of the right abutment. Bridge opening, abutment to abutment is 73 feet less center pier.

/mal_home/scour/kewhite/stat_desc/d.01480300.docPage 1 November 5, 1999

RIPTION

y ice most winters.

. Geological Survey in cooperation with the com-
ntal Protection.

d or could not be located.

ight bank, downstream side of bridge. Elevation

bank, upstream side of bridge. Elevation 14.925

end of wingwall, right bank, downstream side of
ot found 8/27/90)

pstream side of wingwall, left bank, near end of
ot found 8/27/90)

wnstream side of wingwall, right bank, near end
(Not found 6/21/88)

base of oak tree 3' in diameter, 95 feet from road
(BASE).

om ground, 20' from right side of drive, 115' from

se of elm tree, 45 feet downstream from gage.

ete footer of stairway to gage, located in center,
6/95)).

/mal_home/scour/kewhite/stat_desc/d.01480300.docPage 2 November 5, 1999

Tells you:

where the gage is located

if there are any controls, diversions, or regulation

where the reference marks are (to tie surveys into gage datum)

and much more.

USGS

Rating Tables

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PAGE 2
EXPANDED RATING TABLE
TYPE: LOG
01480300
DATE PROCESSED: 03-22-2002 @ 12:30 BY kewhite
West Branch Brandywine Creek near Honey Brook, PA
DD: 3 TYPE: 001 RATING NO: 20.0
OFFSET: .70 BREAK,OFFSET: (4.60,1.00)
START DATE/TIME: 03-22-1999 (0515)
revision of upper end for 1972 peak

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
4.40	258.6	260.0	261.4	262.8	264.2	265.6	267.0	268.4	269.8	271.2	14.00
4.50	272.6	274.1	275.5	276.9	278.3	279.8	281.2	282.7	284.1	285.5	14.40
4.60	287.0*	288.4	289.9	291.3	292.7	294.2	295.6	297.0	298.5	299.9	14.40
4.70	301.4	302.9	304.3	305.8	307.2	308.7	310.2	311.7	313.1	314.6	14.70
4.80	316.1	317.6	319.1	320.6	322.1	323.6	325.1	326.6	328.1	329.6	15.00
4.90	331.1	332.6	334.2	335.7	337.2	338.7	340.3	341.8	343.4	344.9	15.30
5.00	346.4	348.0	349.5	351.1	352.7	354.2	355.8	357.4	358.9	360.5	15.70
5.10	362.1	363.7	365.2	366.8	368.4	370.0	371.6	373.2	374.8	376.4	15.90
5.20	378.0*	380.1	382.2	384.3	386.4	388.5	390.6	392.7	394.8	397.0	21.10
5.30	399.1	401.2	403.4	405.5	407.7	409.9	412.1	414.2	416.4	418.6	21.70
5.40	420.8	423.0	425.3	427.5	429.7	431.9	434.2	436.4	438.7	441.0	22.40
5.50	443.2	445.5	447.8	450.1	452.4	454.7	457.0	459.3	461.6	463.9	23.10
5.60	466.3	468.6	471.0	473.3	475.7	478.1	480.4	482.8	485.2	487.6	23.70
5.70	490.0*	492.8	495.7	498.6	501.5	504.3	507.2	510.2	513.1	516.0	29.00
5.80	519.0	521.9	524.9	527.9	530.8	533.8	536.8	539.9	542.9	545.9	30.00
5.90	549.0	552.0	555.1	558.2	561.3	564.4	567.5	570.6	573.8	576.9	31.10
6.00	580.1	583.3	586.4	589.6	592.8	596.0	599.3	602.5	605.7	609.0	32.20
6.10	612.3	615.6	618.8	622.1	625.5	628.8	632.1	635.5	638.8	642.2	33.30
6.20	645.6	649.0	652.4	655.8	659.2	662.6	666.1	669.6	673.0	676.5	34.40
6.30	680.0*	684.1	688.3	692.5	696.7	700.9	705.2	709.4	713.7	718.0	42.30
6.40	722.3	726.6	731.0	735.3	739.7	744.1	748.5	752.9	757.4	761.9	44.10
6.50	766.4	770.9	775.4	779.9	784.5	789.1	793.7	798.3	802.9	807.6	45.80
6.60	812.2	816.9	821.6	826.4	831.1	835.9	840.7	845.5	850.3	855.1	47.80
6.70	860.0*	864.9	869.8	874.7	879.6	884.5	889.5	894.5	899.5	904.5	49.60
6.80	909.6	914.6	919.7	924.8	929.9	935.1	940.2	945.4	950.6	955.8	51.40
6.90	961.0	966.3	971.6	976.9	982.2	987.5	992.9	998.3	1004	1009	54.00
7.00	1015	1020	1025	1031	1036	1042	1048	1053	1059	1064	55.00
7.10	1070*	1075	1081	1086	1091	1097	1102	1107	1113	1118	54.00
7.20	1124	1129	1135	1140	1146	1151	1157	1162	1168	1174	55.00
7.30	1179	1185	1191	1196	1202	1208	1214	1219	1225	1231	58.00
7.40	1237	1243	1248	1254	1260	1266	1272	1278	1284	1290	59.00
7.50	1296	1302	1308	1314	1320	1326	1332	1339	1345	1351	61.00
7.60	1357	1363	1369	1376	1382	1388	1395	1401	1407	1414	63.00
7.70	1420*	1426	1432	1438	1444	1450	1456	1462	1468	1474	60.00
7.80	1480*	1486	1492	1498	1504	1510	1516	1522	1528	1534	60.00
7.90	1540*	1546	1552	1558	1564	1570	1576	1582	1588	1594	60.00
8.00	1600*	1606	1612	1618	1624	1630	1636	1642	1648	1654	60.00

Tells you:

What the flow is at any given stage - including the bankfull stage.

Peak Flow Analyses (Bulletin 17B)

1960-00

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.0894	0.2837	0.284
BULL.17B ESTIMATE	0.0	1.0000	3.0894	0.2837	0.400

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	291.7	271.7	272.0	200.8	382.9
0.9900	326.3	308.3	308.1	229.6	422.4
0.9500	454.0	443.2	440.4	339.7	565.9
0.9000	549.6	543.8	538.8	424.8	672.1
0.8000	702.7	703.9	695.3	563.5	842.7
0.5000	1176.0	1191.0	1176.0	989.9	1394.0
0.2000	2094.0	2106.0	2124.0	1749.0	2603.0
0.1000	2904.0	2888.0	2991.0	2362.0	3792.0
0.0400	4197.0	4099.0	4438.0	3280.0	5853.0
0.0200	5383.0	5180.0	5839.0	4079.0	7878.0
0.0100	6784.0	6426.0	7581.0	4988.0	10400.0
0.0050	8436.0	7862.0	9763.0	6022.0	13530.0
0.0020	11080.0	10090.0	13500.0	7611.0	18800.0
0.6667	897.8	(1.50-year flood)			
0.4292	1318.5	(2.33-year flood)			

1

Station - 01480300 WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, P
2001 JUN 7 16:21:34

I N P U T   D A T A   L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1960	1870.0		1981	418.0	
1961	810.0		1982	1270.0	
1962	810.0		1983	705.0	
1963	810.0		1984	3650.0	
1964	1180.0		1985	1890.0	
1965	1130.0		1986	546.0	
1966	1080.0		1987	3300.0	
1967	990.0		1988	2920.0	
1968	704.0		1989	1290.0	
1969	1150.0		1990	817.0	
1970	673.0		1991	511.0	
1971	1820.0		1992	400.0	
1972	3660.0		1993	681.0	
1973	2550.0		1994	746.0	
1974	848.0		1995	657.0	
1975	2300.0		1996	3800.0	
1976	1090.0		1997	2960.0	
1977	830.0		1998	709.0	
1978	2760.0		1999	2950.0	
1979	2410.0		2000	1790.0	
1980	731.0				

Tells you:

The recurrence interval of any flow - including the bankfull discharge

Most researchers place the bankfull flow at a recurrence interval of ~1 to ~2 years

Requires 10 years (minimum) of continuous data at the gage to develop

USGS

Standard Form 9-207s

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                 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
                                    SUMMARY OF DISCHARGE MEASUREMENT DATA
01480300                                                                        DATE PROCESSED:  5-Nov-1999 07:19
WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, PA

****************************************************************************************************************
MEAS # /  DATE  /  PARTY  /   WIDTH / AREA / VELOC /  IN GH / OS GH /  DISCH 1/ QCODE 1  / DISCH 2/ QCODE 2  /   RAT / %DIFF / SHIFT
          TIME        # SEC / CHG (FT) / CHG (HR) / RTD / AIR TEMP / WTR TEMP / BF /
****************************************************************************************************************

  162  1975/03/19  kxk       302     481    2.20     7.17               1060  MEASURED                          11.0     0.0   +0.23
                     26     -0.39      1.1      F                                   CONTROL: SUBMERGED   MEAS TYPE: BRG CRANE

  163  1975/04/01  k        21.0    16.3    1.61     1.61               26.2 MEASURED                          11.0    -0.4   -0.05
                     24     0.00       0.5      F                 5.0               CONTROL:             MEAS TYPE: WADING
                     REMARKS: shifting sand; measured wading 30 ft downstream

  164  1975/05/01  zk       21.0    39.2    2.51     2.68               98.5 MEASURED                          11.0    -0.9
                     31     +0.05      0.8      F                11.0               CONTROL: CLEAR       MEAS TYPE: WADING
                     REMARKS: clear; measured wading 15 ft downstream

  165  1975/06/03  k        19.0    16.0    2.13     1.67               34.1 MEASURED                          11.0    +5.4
                     29     +0.01      0.6      G                18.0               CONTROL: CLEAR       MEAS TYPE: WADING
                     REMARKS: clear; measured wading 40 ft downstream

  166  1975/06/12  cz       67.0     188    2.17     5.36                408  MEASURED                          11.0    -3.3
                     24     -0.08      0.6      F                                   CONTROL:             MEAS TYPE: BRG CRANE
                     REMARKS: bankfull; measured 10 ft downstream bridge

  167  1975/06/12  cz       66.0     180    1.97     5.19                354  MEASURED                          11.0    +0.1   -0.17
                     19     -0.09      0.5      F                                   CONTROL:             MEAS TYPE: BRG CRANE
                     REMARKS: bankfull; measured 15 ft downstream bridge

  168  1975/06/12  cz       67.0     171    1.87     5.01                320  MEASURED                          11.0     0.0   -0.21
                     18     -0.06      0.4      F                                   CONTROL:             MEAS TYPE: BRG CRANE
                     REMARKS: bankfull; measured 10 ft downstream bridge

  169  1975/07/10  d        19.0    12.8    1.68     1.45               21.4 MEASURED                          11.0    +4.3
                     33     0.00       0.5      G                                   CONTROL: CLEAR       MEAS TYPE: WADING
                     REMARKS: clear; measured wading 40 ft downstream

  170  1975/08/14  c        17.4    12.0    1.68     1.43               20.2 MEASURED                          11.0    +3.6
                     28     0.00       0.5      G                22.0               CONTROL: CLEAR       MEAS TYPE: WADING
                     REMARKS: clear; measured wading 20 ft downstream

  171  1975/09/19  c        17.0    11.7    1.63     1.41               19.1 MEASURED                          11.0    +2.7
                     32     -0.01      0.6      G                15.0               CONTROL: CLEAR       MEAS TYPE: WADING
                     REMARKS: clear; measured wading 20 ft downstream

  172  1975/09/24  cg       67.0     141    1.94     4.59                273  MEASURED                          11.0    -5.4
                     24     +0.09      0.6      F                                   CONTROL: CLEAR       MEAS TYPE: BRG CRANE
                     REMARKS: clear, flooded; measured at gage from bridge

  173  1975/10/09  c        16.5    11.9    1.55     1.42               18.5 MEASURED                          11.0    -2.6
                     28     0.00       0.5      G                15.5               CONTROL: CLEAR       MEAS TYPE:
                     REMARKS: clear; H.W.M 5.69; measured 15 ft below gage

  174  1975/11/13  c        35.0    72.9    2.08     3.66                151  MEASURED                          11.0     0.0   -0.35
                     24     -0.13      0.6      F                14.0               CONTROL:             MEAS TYPE: WADING
                     REMARKS: channel flooded; mag. = 5.61; measured wading 30  ft downstream
```

Tells you:

Rough channel geometry (area, width, depth)

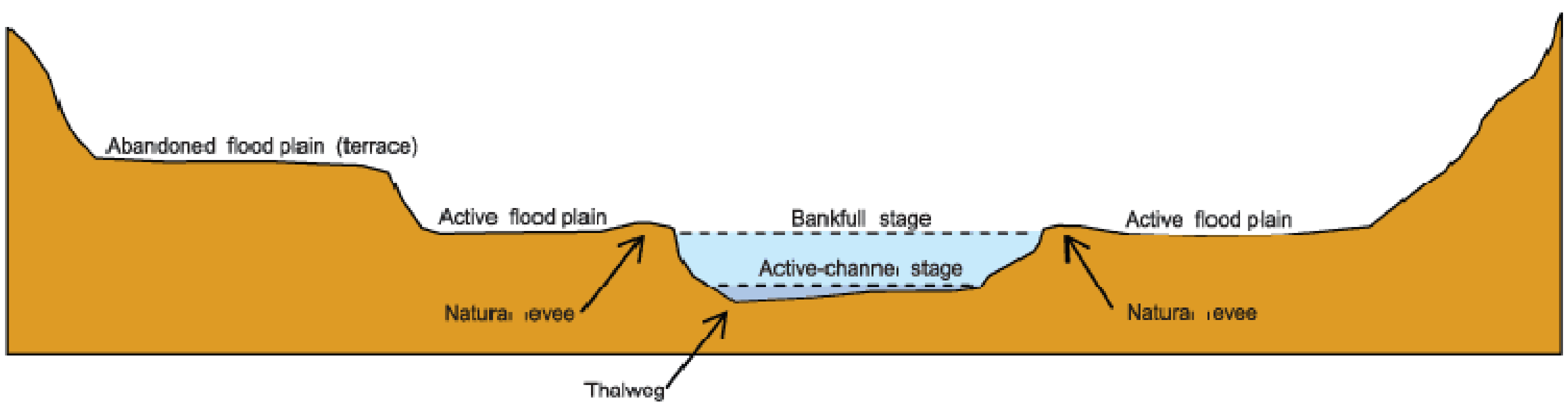
Can help validate the roughness coefficient (Manning's "n") used to estimate discharge at surveyed cross-sections.

USGS

Field data for regional curves can be collected once gage data is obtained and reviewed.

The top of the bankfull channel is identified and two cross-section surveys in riffle sections then provide accurate bankfull-channel geometries and an estimate of bankfull discharge.

While surveying, commonly observed geomorphic features are: …



Common errors include mistaking a lower terrace or active-channel features for bankfull – this is why you need USGS gage data as confirmation (for example, Bulletin 17B estimates).

USGS

From Sherwood and Huitger (2005)

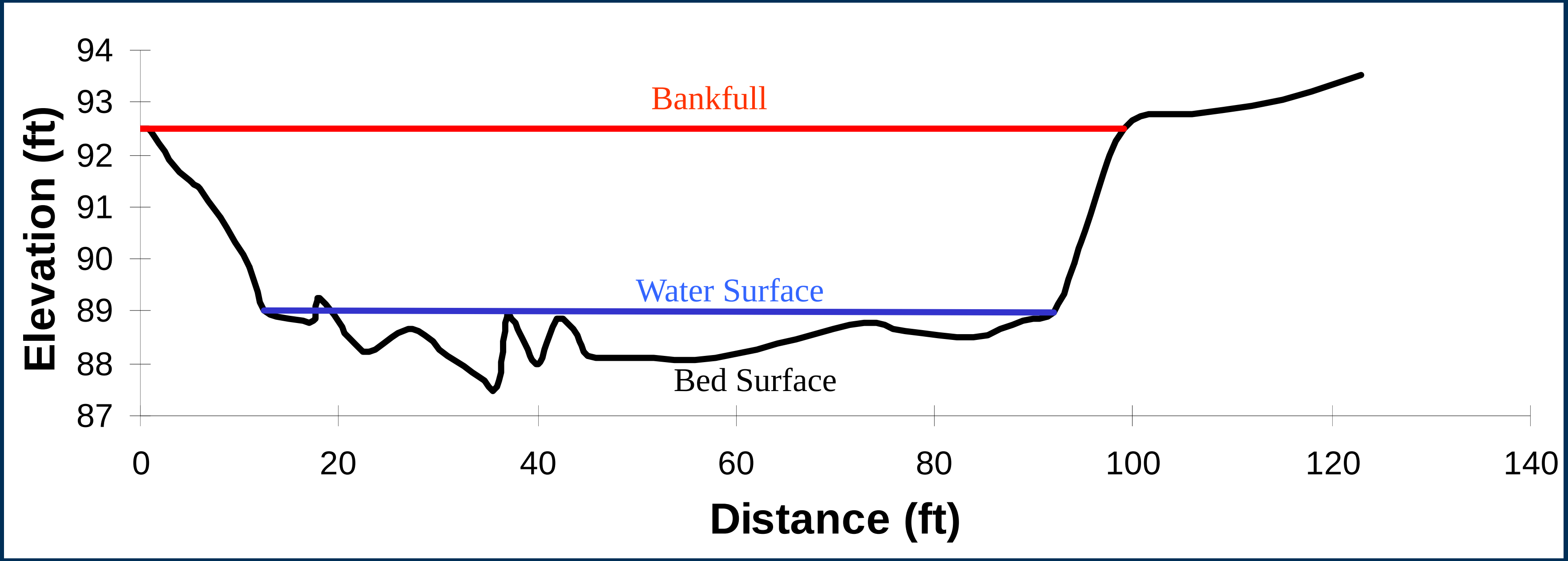
Commonly used bankfull indicators are …

- ***changes in slope of the bank***
- ***height of depositional features***
- ***changes in bank vegetation***
- ***change in the particle size of bank material***
- ***undercuts in the bank***
- ***stain lines***
- ***highest elevation below which no fine debris is evident***

USGS

Determination of bankfull channel geometry and flow

Cross-sectional survey

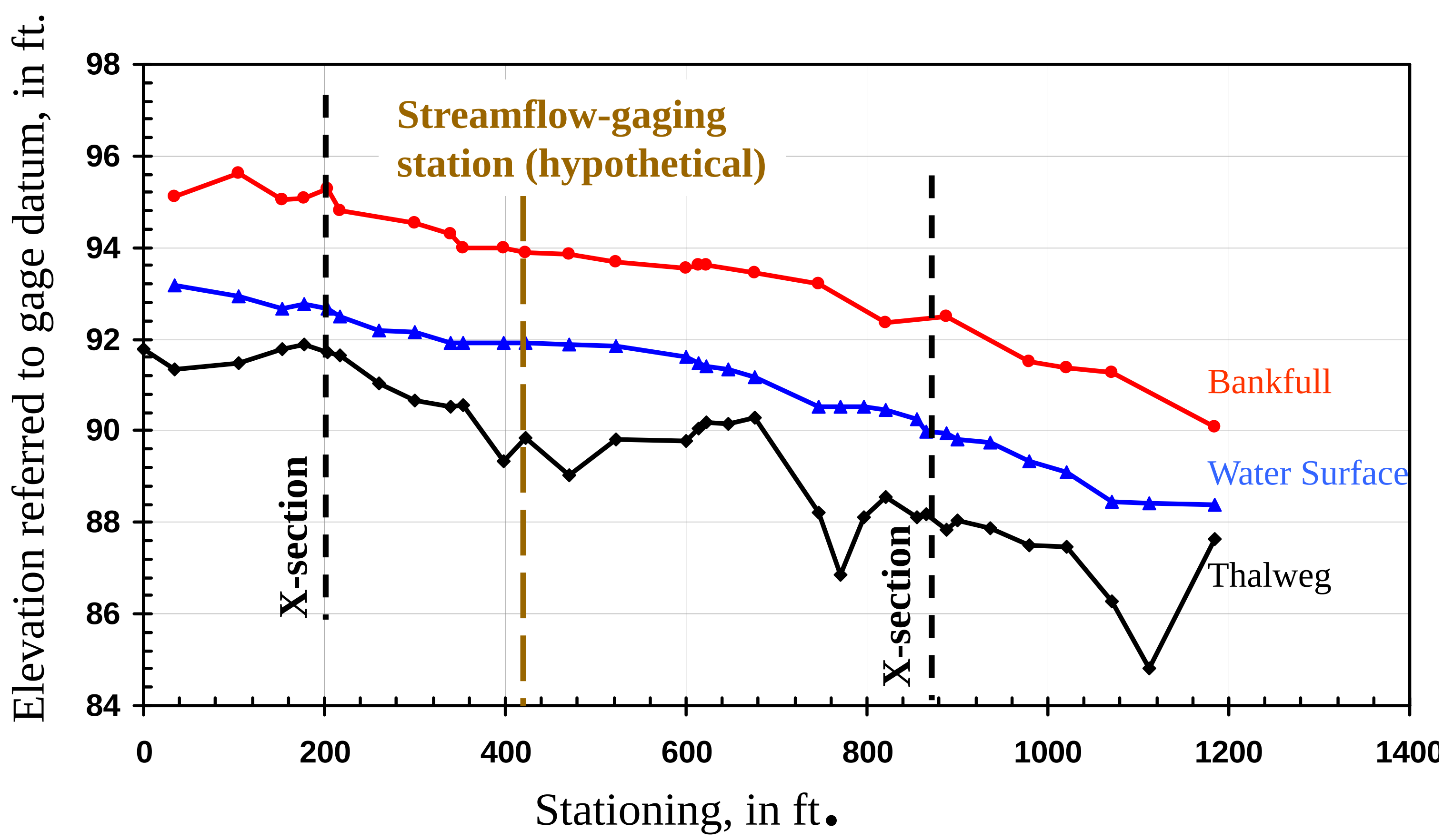


Bankfull discharge, area, width, and mean depth are determined from the cross-sectional surveys

USGS

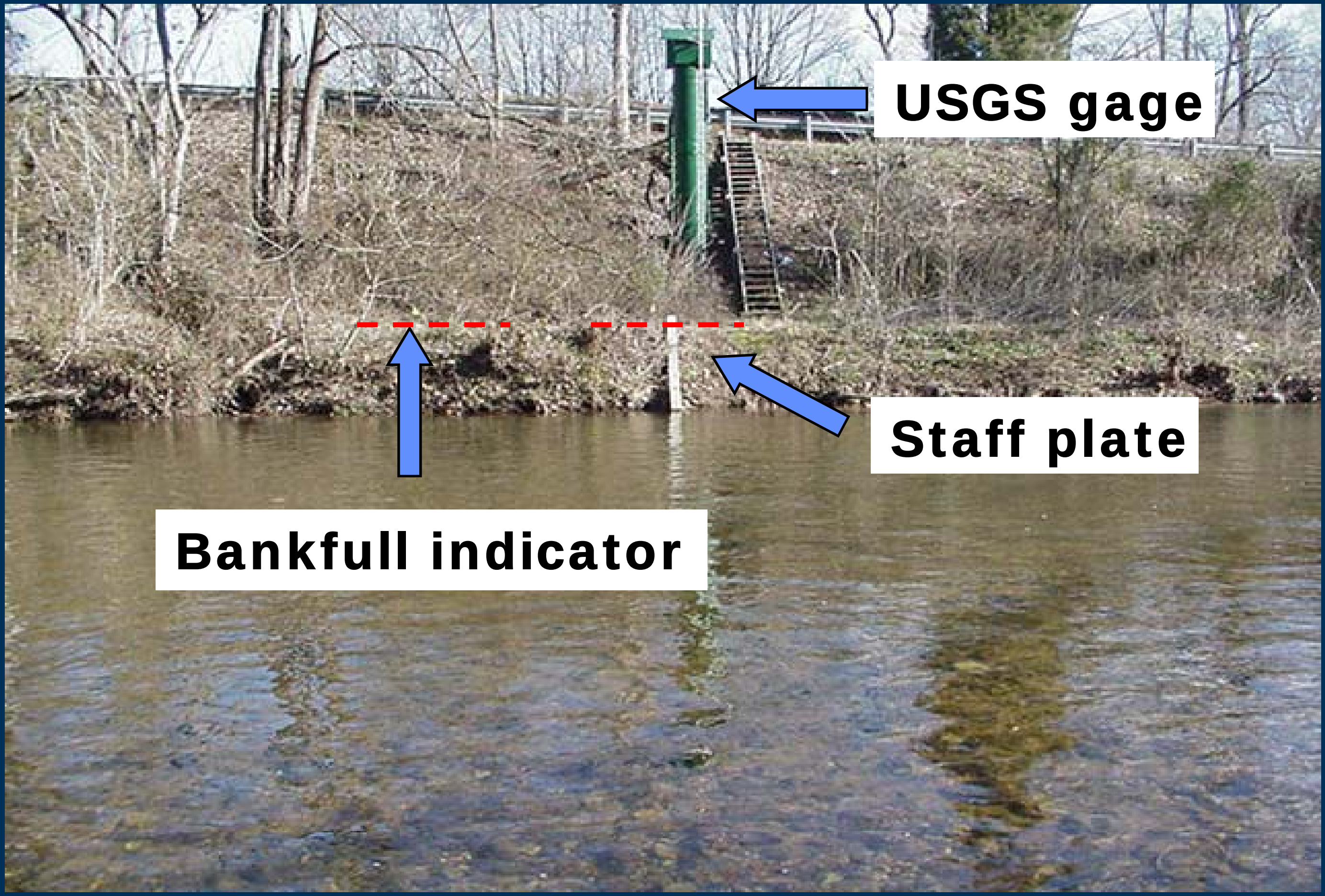
Determination of bankfull stage

Longitudinal-profile survey



Relates each cross section to the gage and determines a bankfull slope.

Note how the surveyed bankfull feature is extended through the gage to validate and determine discharge and recurrence interval



The first data point on the regional curve!

Cross-reference No. C7

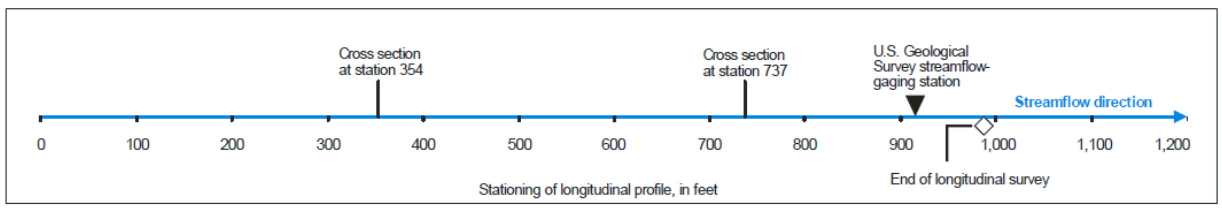
View looking upstream at the reach of West Branch Brandywine Creek near Honey Brook containing cross section at station 354, May 31, 2001.

Cross-sectional data at station 354	
Bankfull cross-sectional area (ft^2)	123
Bankfull width (ft)	51.9
Bankfull mean depth (ft)	2.36
D50 (mm)	8.9
D84 (mm)	54.3

View looking upstream at the reach of West Branch Brandywine Creek near Honey Brook containing cross section at station 737, May 31, 2001.

Cross-sectional data at station 737	
Bankfull cross-sectional area (ft^2)	135
Bankfull width (ft)	62.8
Bankfull mean depth (ft)	2.15
D50 (mm)	5.8
D84 (mm)	16

West Branch Brandywine Creek near Honey Brook, Pa., Station 01480300

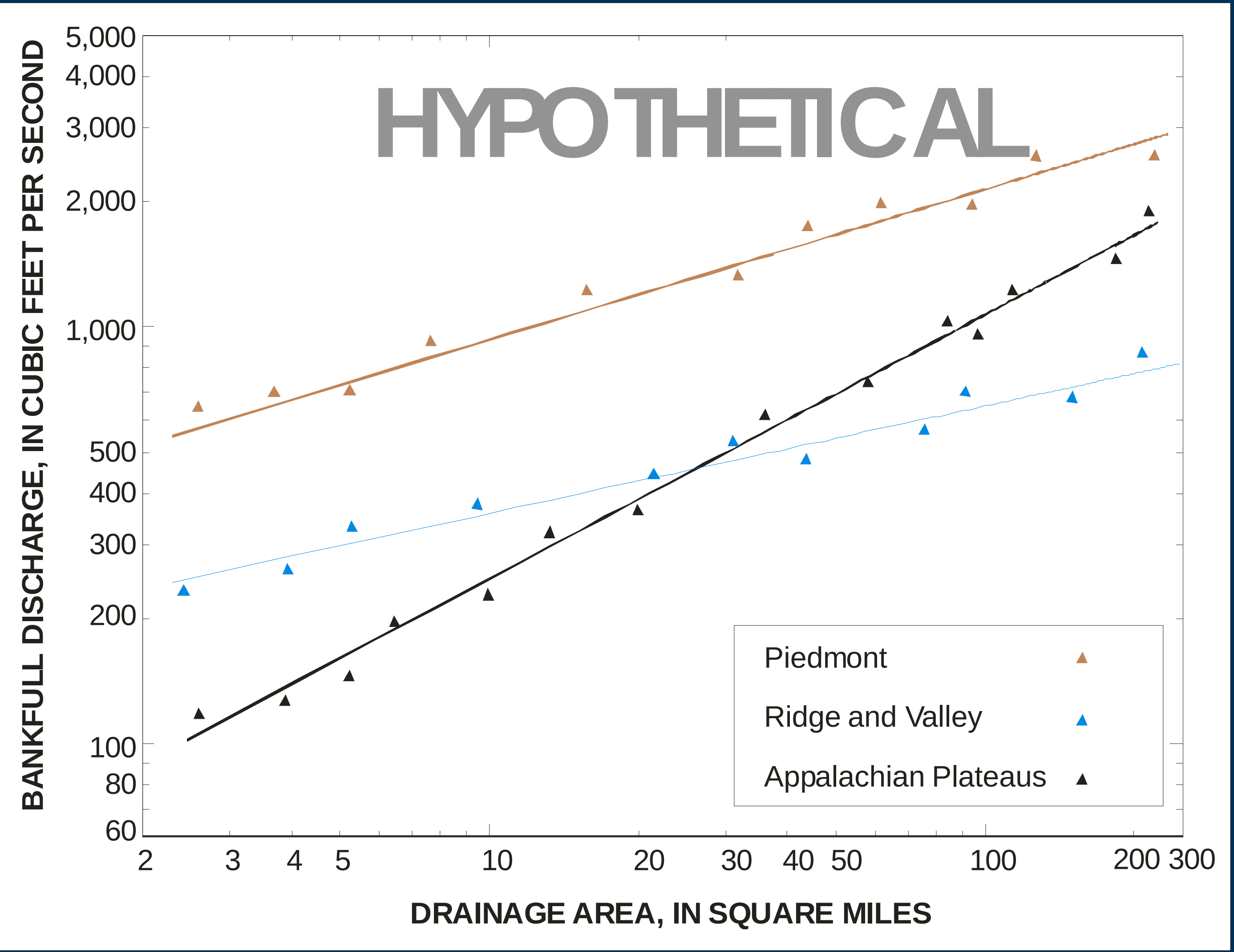


Values from the two cross sections are averaged and a mass-balance check is performed as a QA/QC check (flows estimated at the cross sections should closely match those measured at the gage).

As USGS developed curves in PA, two objectives were addressed:

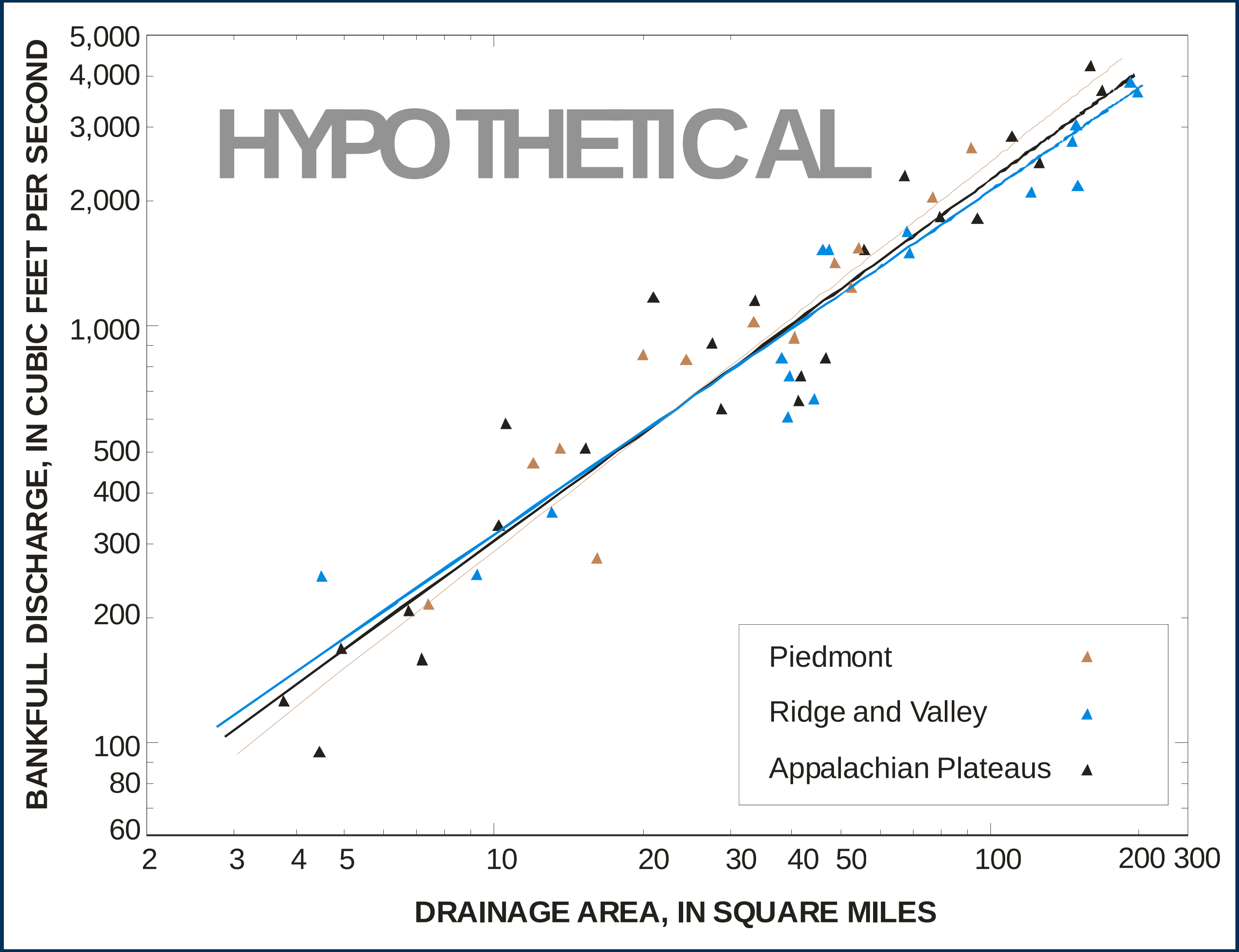
- Are regional curves truly different between physiographic provinces?
- Can multiple-regression models provide better estimates of bankfull characteristics?

Different Slopes and/or intercepts = different regions (typically expected at the time)



USGS

Slopes and/or intercepts are the same = all regions are the same



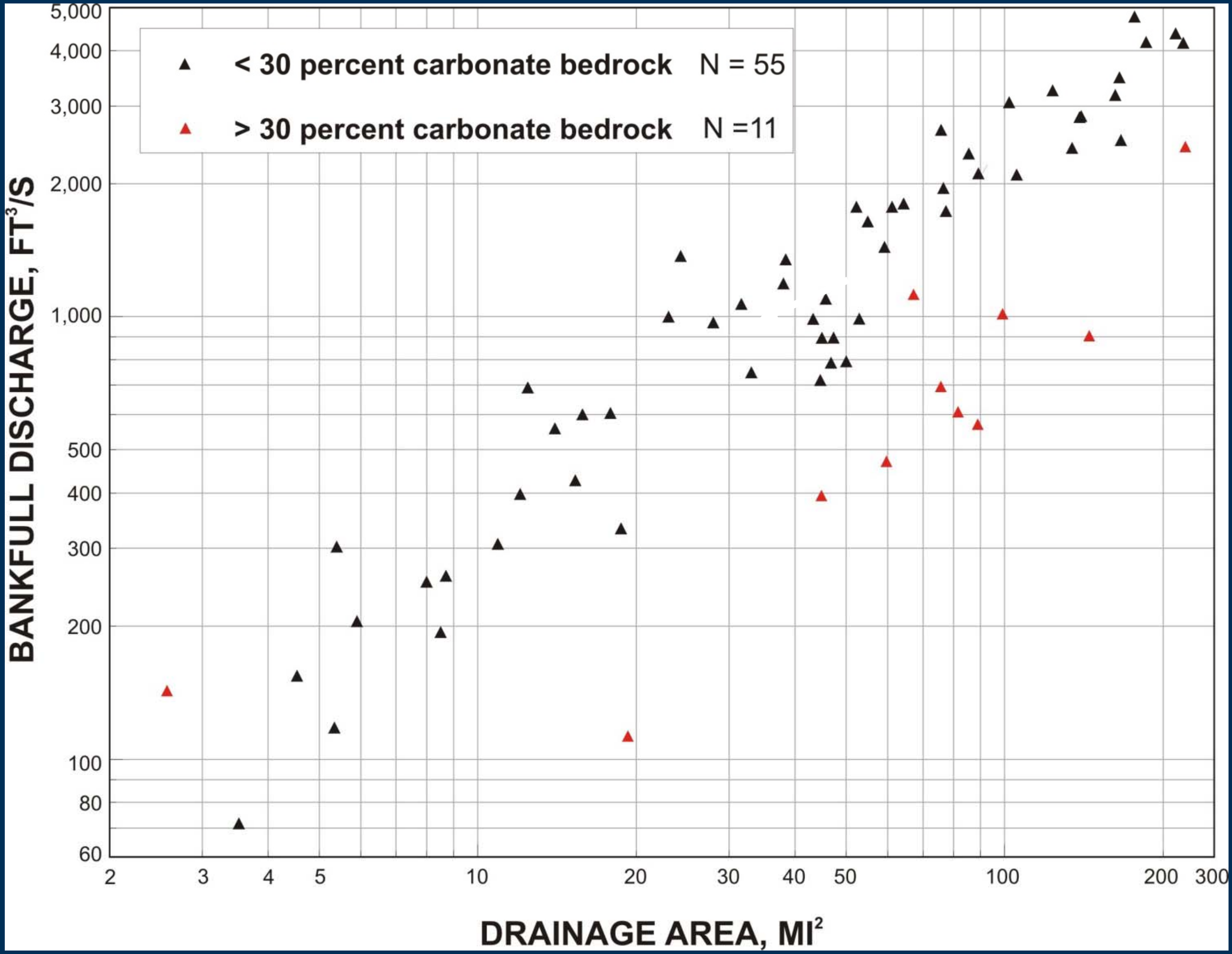
USGS

Were Regional Curves Different by Province in the Pennsylvania study?

Regional curves developed for each province had the same slope and intercept (all p-values < 0.05) - Data was therefore combined across all provinces as bankfull characteristics were similar (however, there were some outliers).

Relation between bankfull discharge and drainage area (66 gages)

Notice this does not say "karst"



Multiple Regression Models to Estimate Bankfull Characteristics

Explanatory Variables Tested:

- **Drainage area**
- **Percent of watershed area underlain by carbonate bedrock (not karst features).**
- Percent of watershed area having glacial deposition
- Other variables tested but dropped due to collinearity (% forest, etc.).

USGS

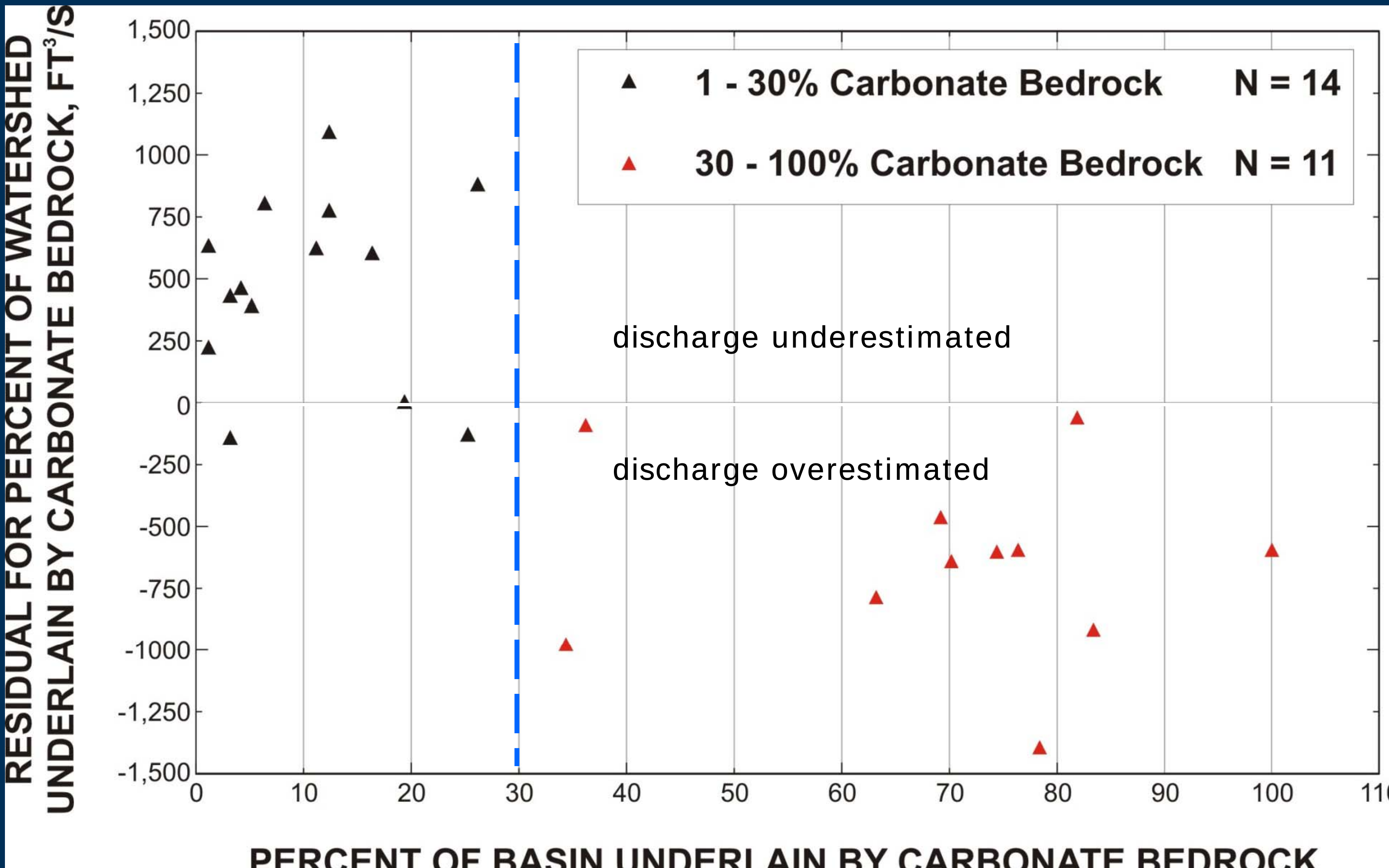
Bold variables DID explain significant variability in the models, other variables did not.

Results of Multiple Regression Models

- More variability was explained by this approach (using both drainage area and % carbonate rock), but the slope coefficient on the carbonate term in the multiple-regression model was negative. As a result, negative flows and areas were estimated for small basins with large amounts of carbonate bedrock.
- This was a major shortcoming of the model that made it unfeasible for use in regional curve development (especially for the person standing at the side of a stream trying to figure out why the discharge is negative).
- So… the multiple regression may not be good for estimation purposes but it still can provide insight on how to handle the carbonate watersheds.

USGS

Relation between Residuals and Percent of Basin Underlain by Carbonate Bedrock

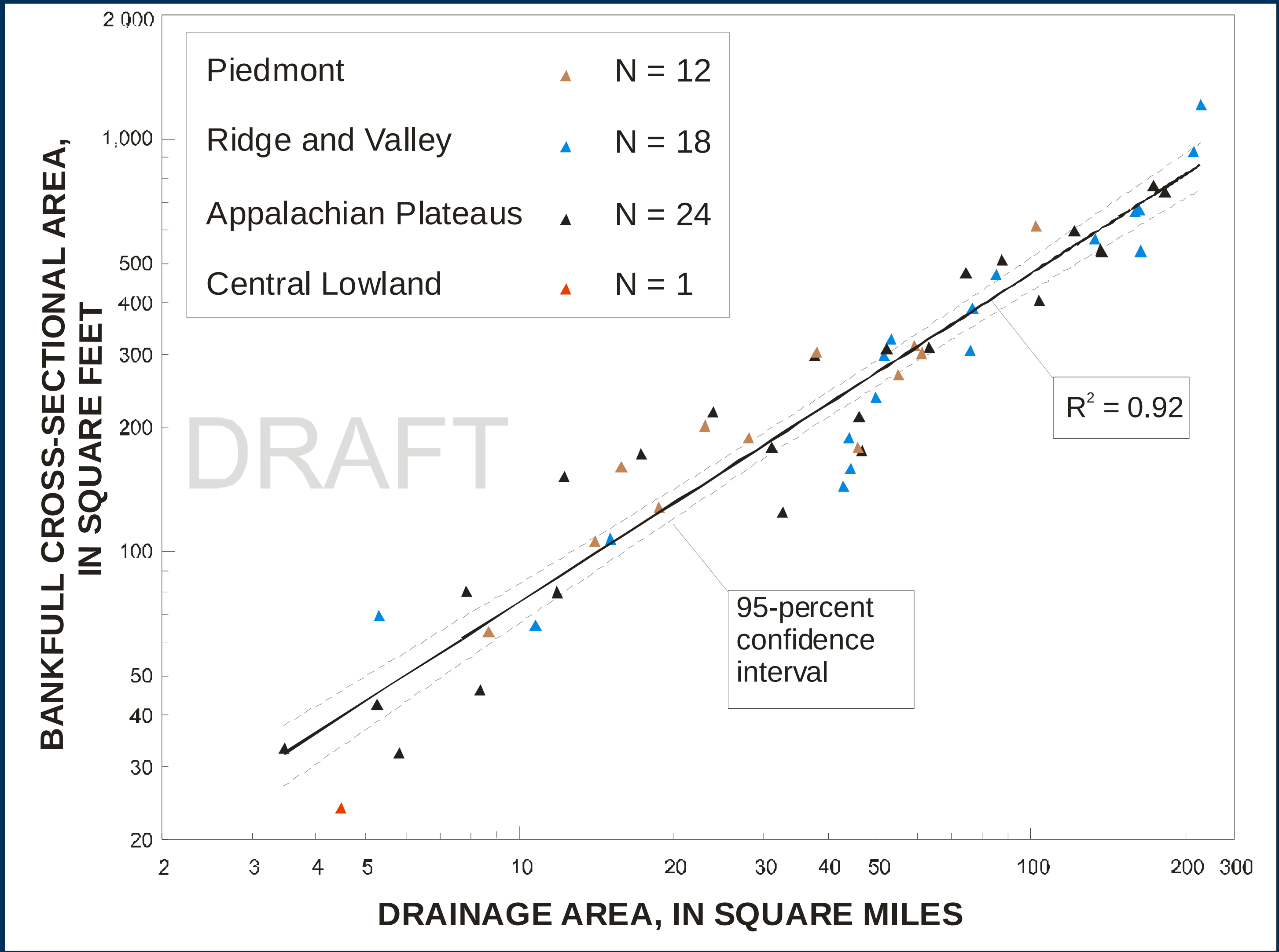


Regional Curves Developed for ...

- Watersheds underlain by less than or equal to 30 % carbonate bedrock (noncarbonate).
- Watersheds underlain by greater than 30% carbonate bedrock (carbonate).

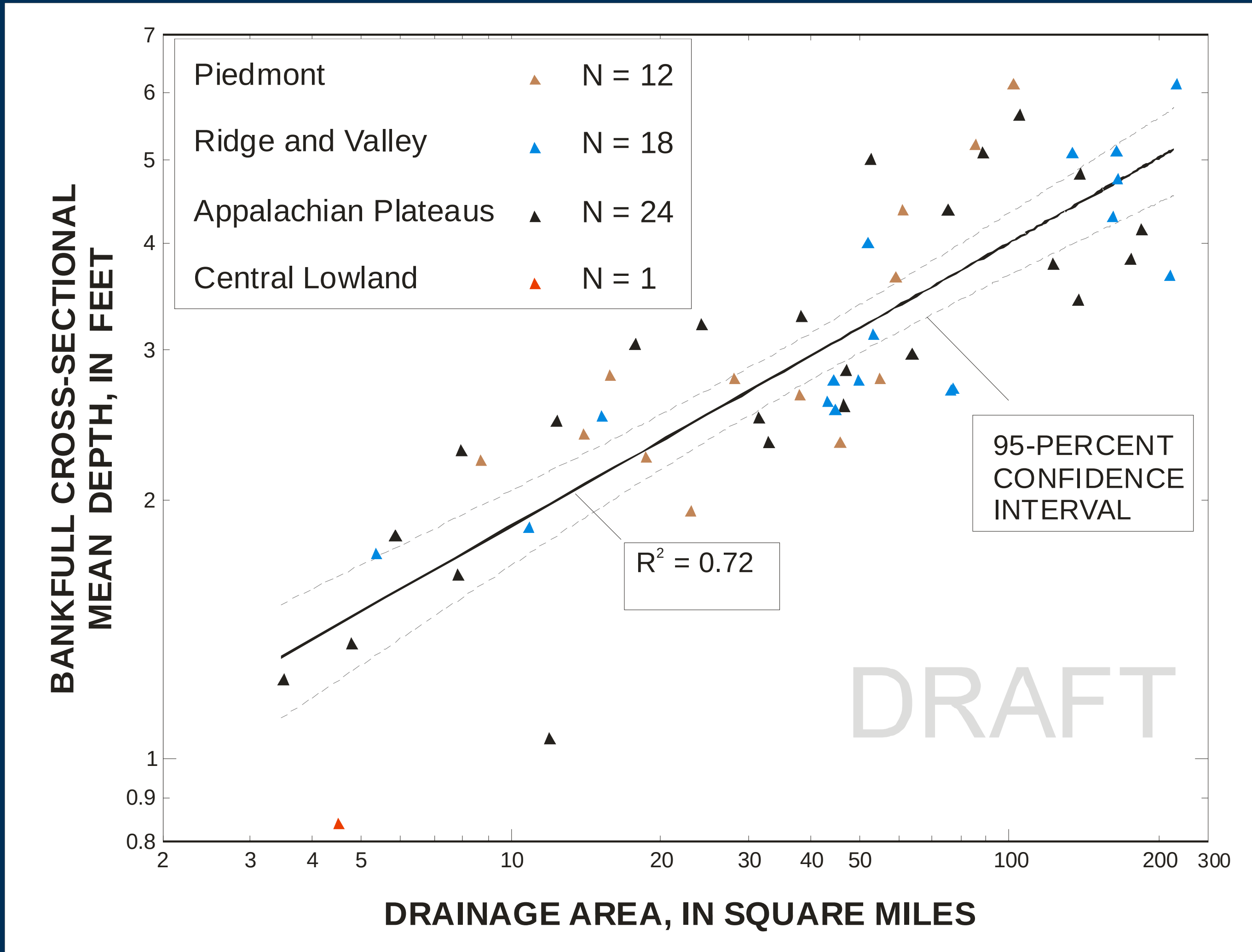
USGS

Noncarbonate Regional Curves



USGS

Noncarbonate Regional Curves



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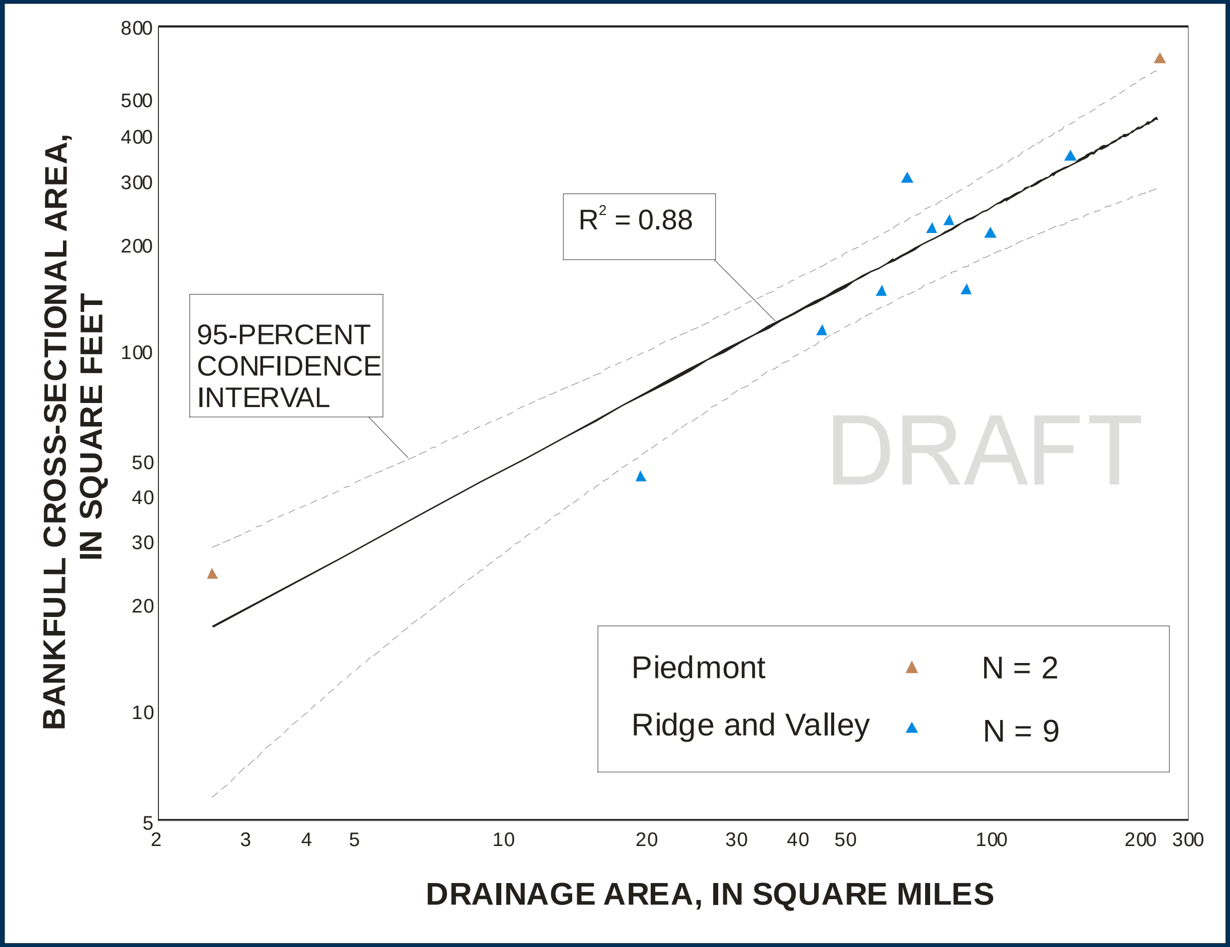
Carbonate Regional Curves



These are definitely unique regional curves, but these are statistically weak!!!

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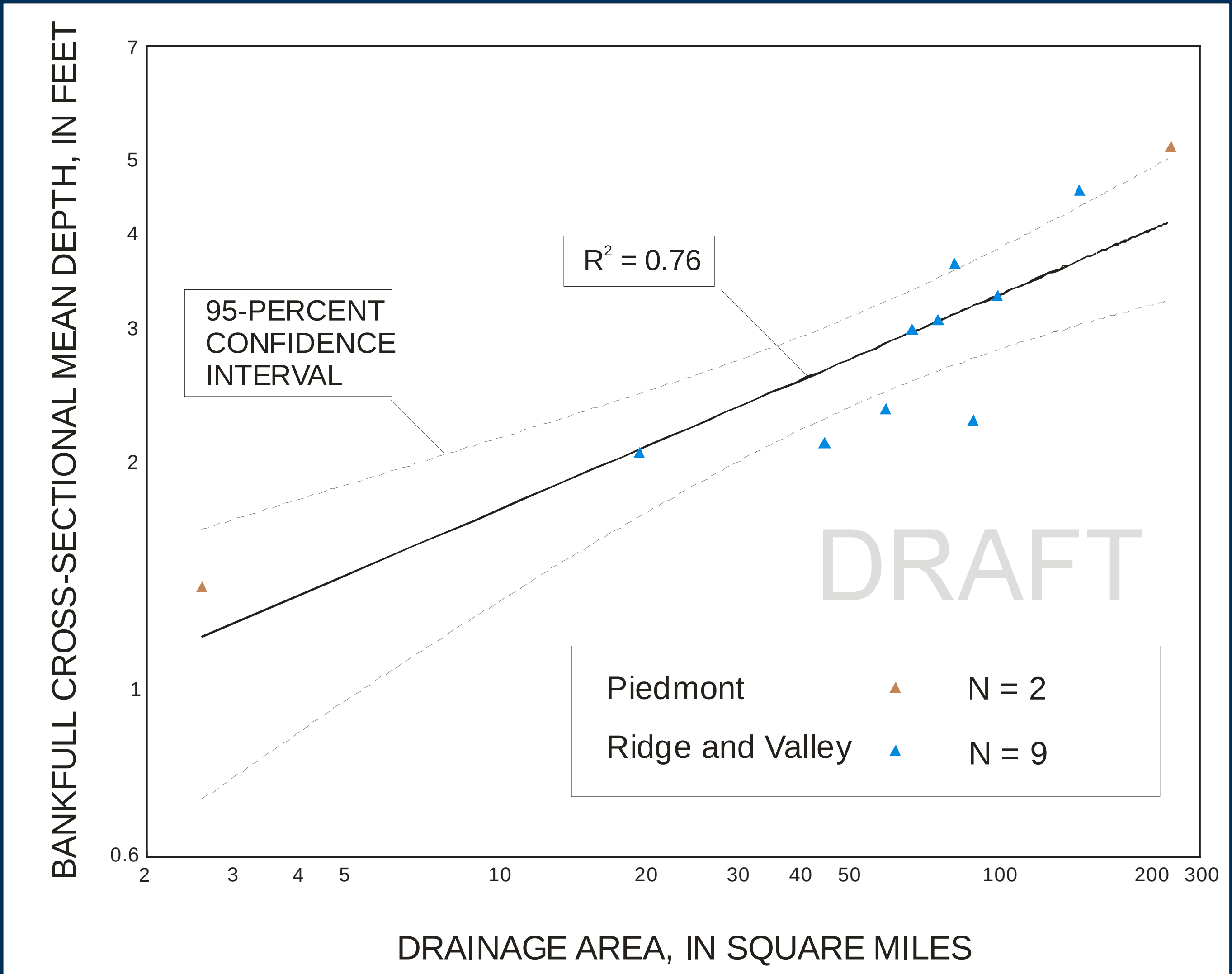
Carbonate Regional Curves



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Three Regression Pathologies

All graphs below have the same R^2

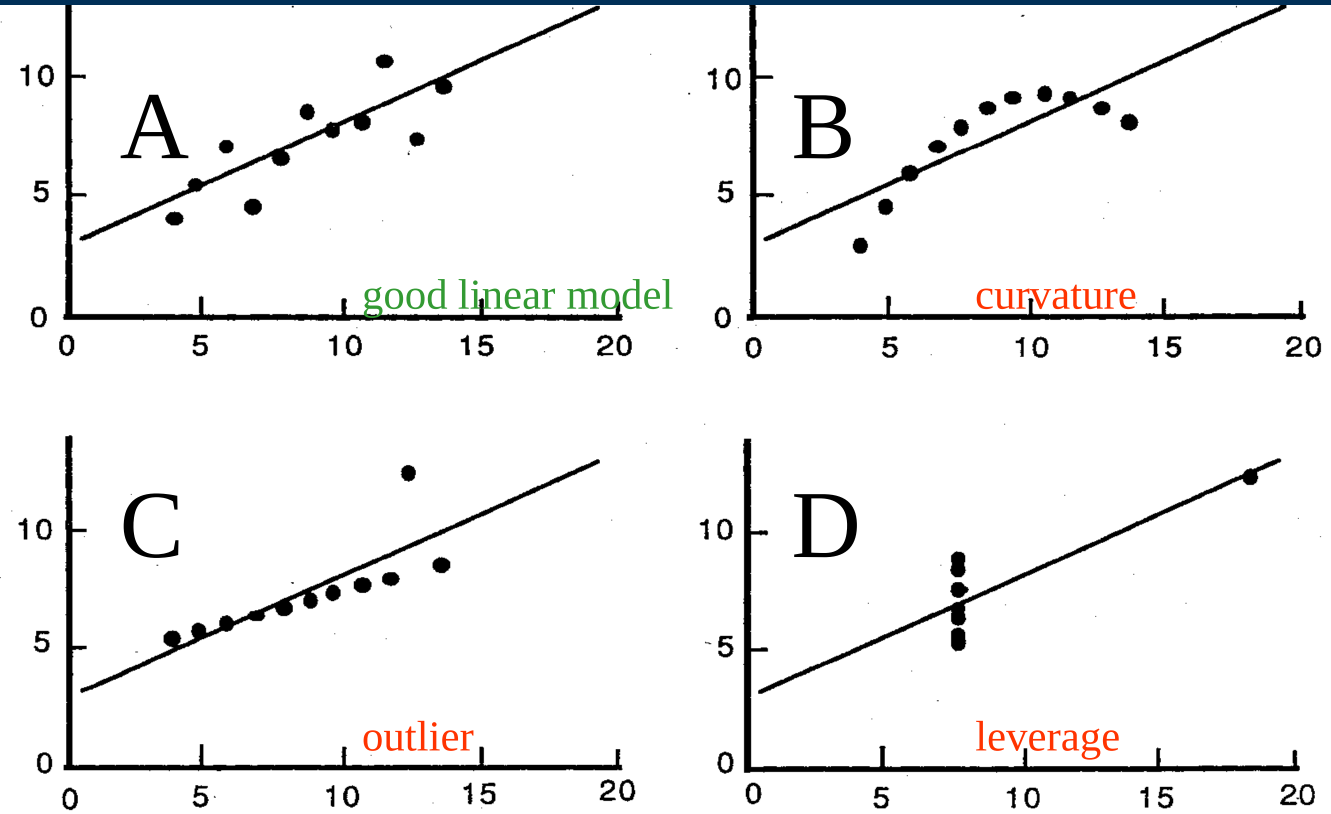

Figure 9.18 Four key pathologies in regression (after Anscombe, 1973).

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Helsel & Hirsch, 1992

Diagnostic Stats for Regional Curves

Bankfull Response Variable	N		R^2		Cook's Distance (Max)[1]		Residual Stnd. Error (log units)	
Log_{10}(bf area)	55	11[2]	0.92	0.88	0.20	7.8	0.11	0.15
Log_{10}(bf Q)	55	11	.92	.73	.27	8.4	.12	.21
Log_{10}(bf width)	55	11	.81	.81	.25	2.4	.10	.12
Log_{10}(bf depth)	55	11	.72	.76	.28	3.6	.10	.09

USGS

[1]Critical value of Cook's Distance is approximately 2.2
[2]Blue = statistic for carbonate setting

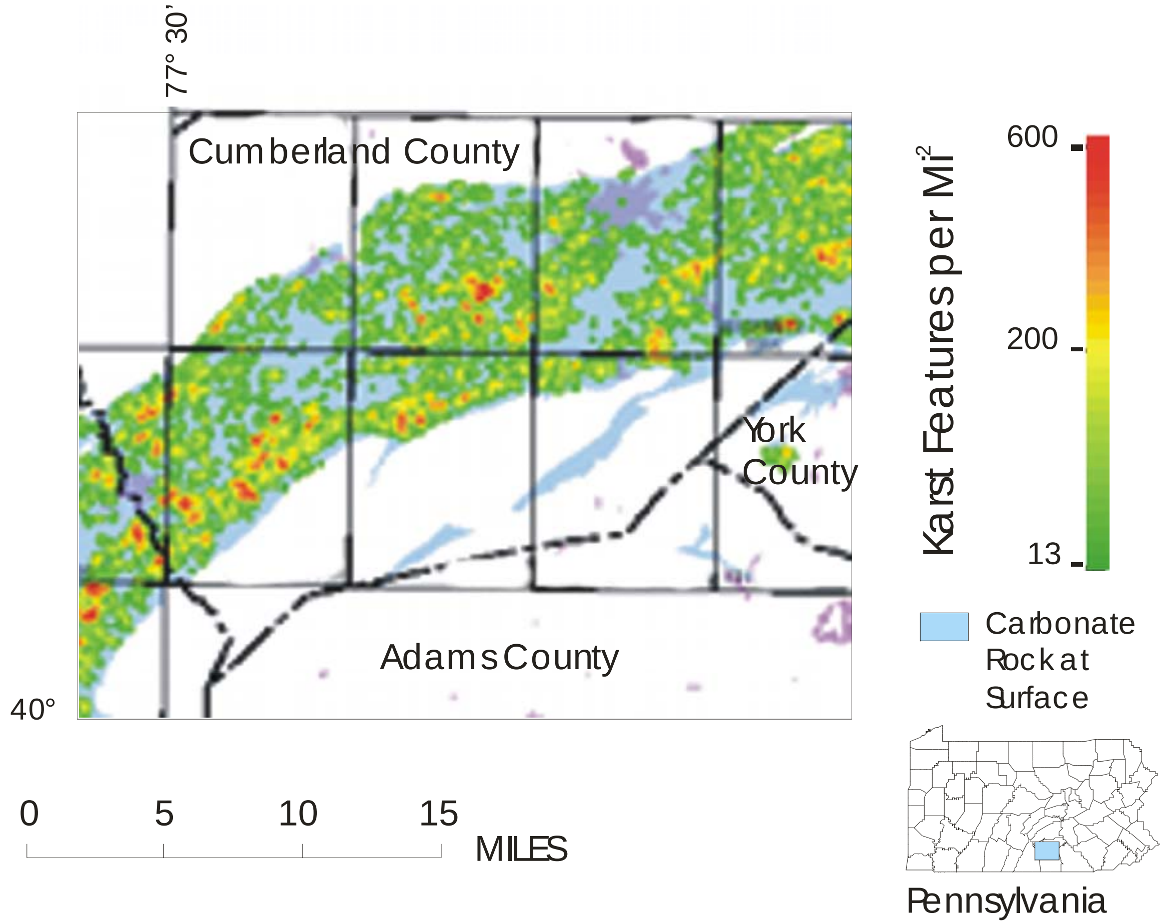
Curves for the Carbonate Setting are Weaker than the NonCarbonate Curves Because…

- Drainage area alone can’t explain variability due to karst development.
- Nonuniformity of karst in regional carbonate bedrock.
- There are fewer streamflow-gaging stations.

USGS

Karst Features are not Uniformly Distributed

Karst overlaps physiographic provinces and does not occur in all carbonate areas.



Map adapted from Kochanov and Reese, PADCNR, (2003)

Iron Run - shale

Iron Run – carbonate (karst)

Spring Creek

(Iron Run as it emerges at a geologic contact with a resistant carbonate formation)

Limitations and Application of Regional Curves

- **Regional Curves generally apply only to the study area unless validation occurs to support the contrary.**
- **Regional Curves only apply to watersheds with characteristics (land use, etc.) that are consistent with station-selection criteria.**
- **Application of Regional curves for carbonate settings should be accompanied by rigorous site-specific field data collection.**
- **Regional Curves should not be used as the sole tool for computation of bankfull channel dimensions. A <u>REFERENCE REACH</u> is required for this process.**

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The reference reach is ...

- **A stable reach of stream that meets the criteria described earlier (Rosgen, 1996).**

- **Reference reaches serve as "templates" for bankfull pattern, profile, and dimension that are then "transferred" to a disturbed project reach located in a similar hydrologic setting.**

- **Regional curves are used to help identify and validate the bankfull characteristics on reference reaches.**

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Designers of restoration projects assume that a stream reach modeled after a stable reference reach of the same stream type will convey streamflow and sediment as effectively as the reference reach.

The reference reach must then equate to the probable stable form of the project reach’s stream type under the present hydrology and sediment regime (as described in Rosgen, 1996) (establish a post-mining reference reach?).

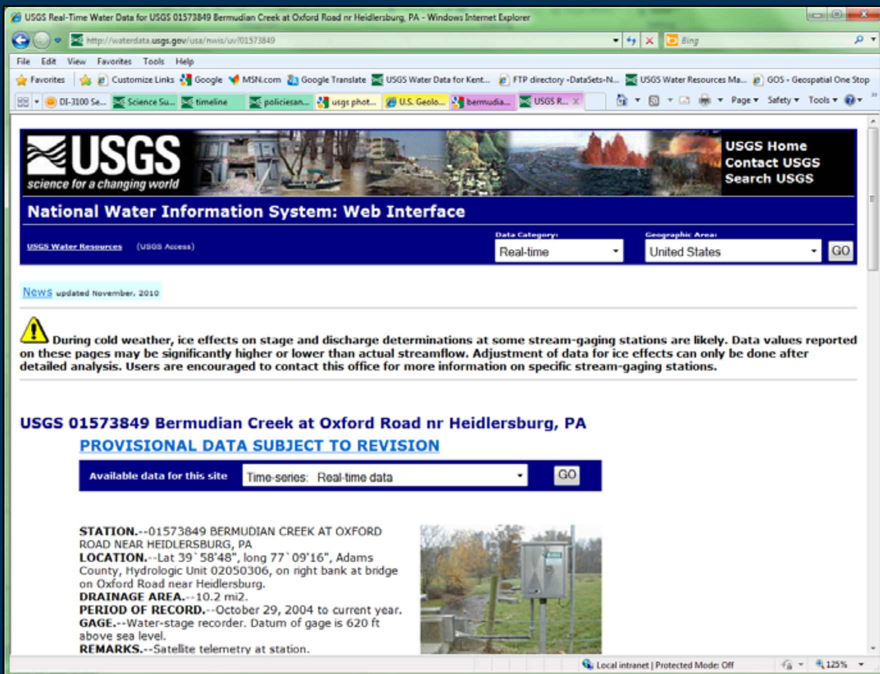
Reference reaches must also be chosen carefully as variability can exist even within the reference reach itself.

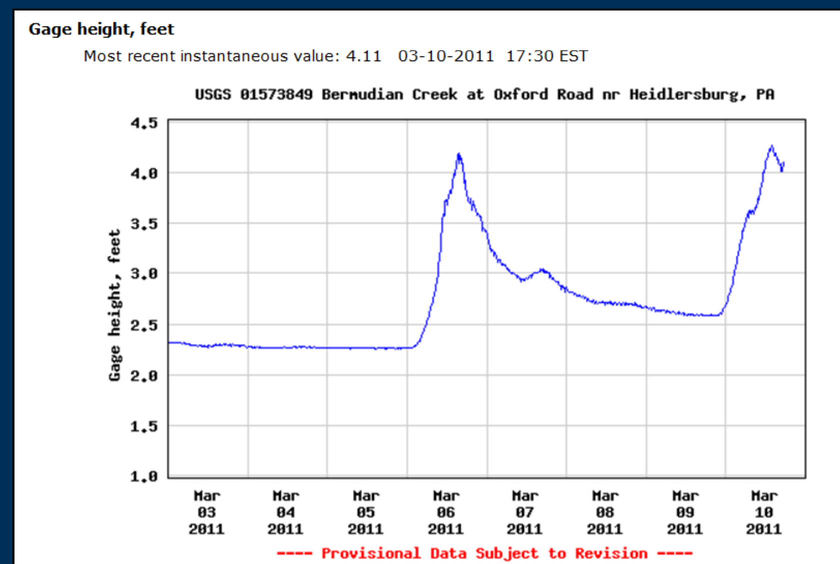
USGS

Bermudian Creek reference reach (PA) downstream

Bermudian Creek reference reach (PA) upstream

Bermudian Creek reference reach
Dedicated streamflow-gaging station





Intensive annual surveys (for several years) to confirm stability

USGS

Where can I find regional curves?

Many places - you need to do a bit of homework!

- **NRCS -** **http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/index.html**
- **Private industry -** **http://www.wildlandhydrology.com/html/references_.html**
- **EPA -** **http://water.epa.gov/lawsregs/guidance/wetlands/wetlandsmitigation_index.cfm#training**
- **USGS (search for "regional curve") -** **http://pubs.er.usgs.gov/**
- **Also check with local universities and state agencies -**

USGS

END