Stream Discharge Rating Curves

WHAT Overview
Current Practice
Improvements
Options Available

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What is *"WHAT"* ?

Help that is Available

- **Watershed Modeling:**
  - Daily Base Flow/RunOff Water Balance Models
  - Real-time 5 min. - 1 hr. RunOff Models
  - **Base Flow Correlation with nearby USGS Streams or other Gaged Streams**
  - **Rating Curve Development and Analysis**
  - Cockeysville Aquifer Water Balance Model
  - Rain Event ***"WHAT"*** **CN RunOff Model**

- **Data Analysis:**
  - Using Conductivity to determine % Cockeysville flow into Broad Run
  - Turbidity - TSS: *Sediment Stream Loading Correlation vs. RunOff Intensity*
    Multiple Watershed Generalize Sediment Loading Correlation
  - Linear and non-linear Multi-variable analysis
  - Estimating RunOff sediment using Auto & Tower Samplers

- **Stream Sensor and Sampler Development:**
  - Low cost sensor development: IR / Sonic / Turbidity
  - **Automated Pump Stream Samplers**
  - **Tower Stream Samplers**

In-Stream Samplers

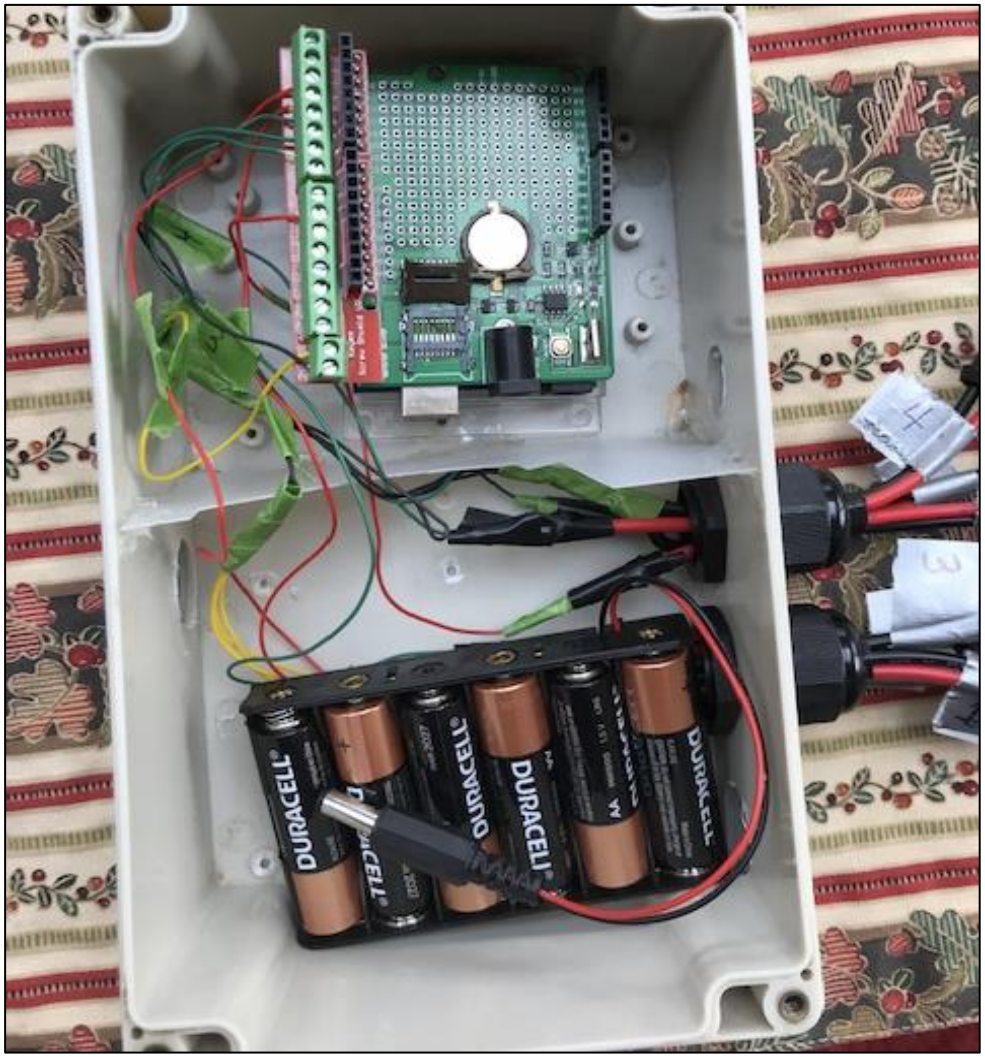
Tower & Auto Pump

In-Stream Samplers

Tower

In-Stream Samplers

Tower Bottle Sensor Recorder



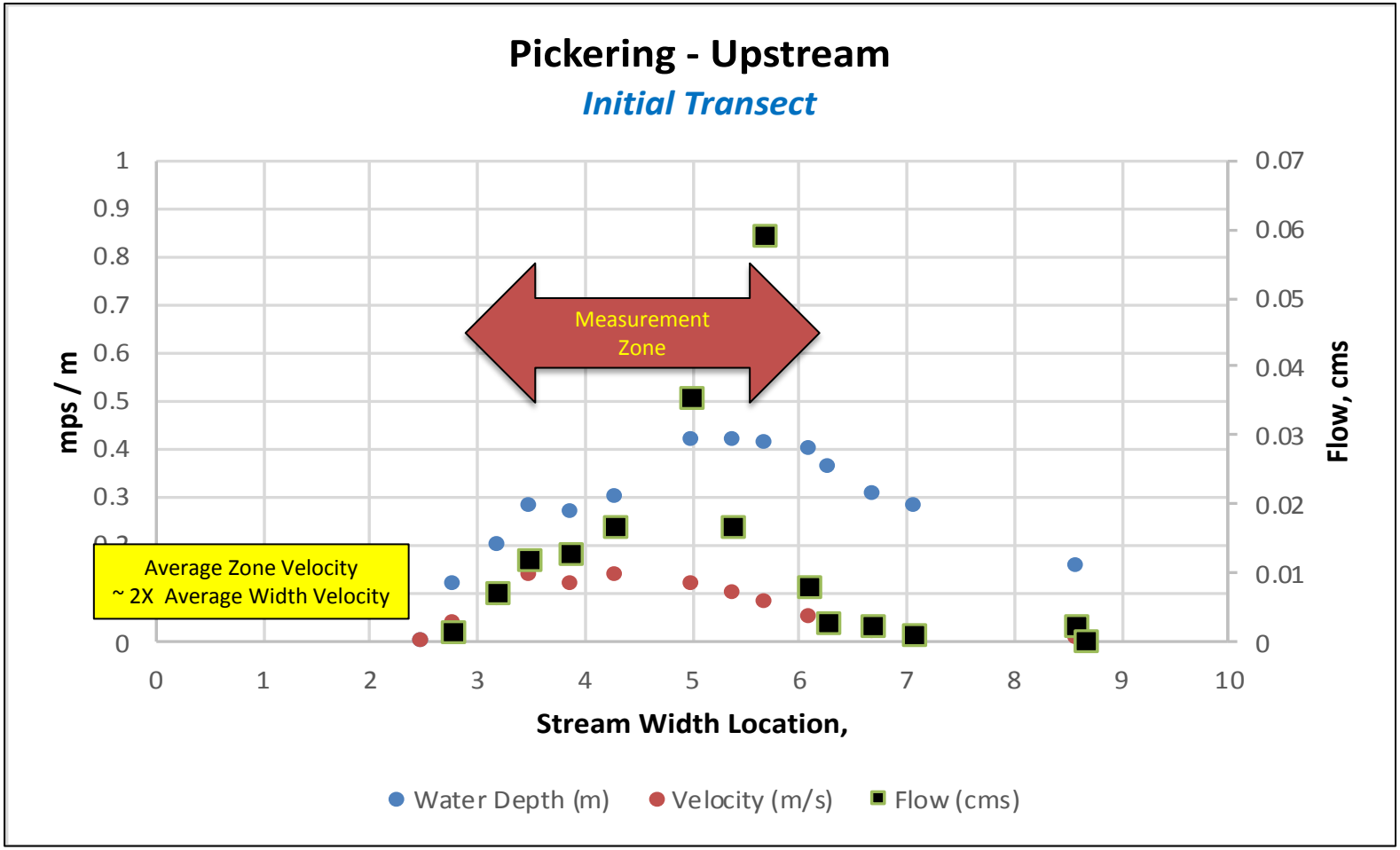
Discharge Rating Curves

Current Practice

- **Field measurements:**
  - ***Direct stream flow transects:***
    - *Generally one or two w/ the sensor teams at Base Flow conditions*
    - *Some groups use instream velocity sensors*
    - *Data is inputted to "Discharge Calculator Worksheet" to generate stream flow*
    - *"Hand Held" meters also used (…is it representative?...how deep?)*
  - ***NBO - Float method:***
    - *Teams toss neutral buoyant object into stream and measure time to travel a set distance*
    - *Generally done near stream main flow center* – ***may not be representative of the average*** ***(High Side Bias)***
    - *Need method to test if data is reasonably accurate/consistent for use*
    - *Cost effective method for teams to gain understanding of their streams/watersheds*
  - ***Timing:***
    - *Prior to and during RunOff Event – difficult for small fast response streams with uneven stream beds.*
  - ***Labor intensive:***
    - *Especially for Stroud to take on across the network*
- **Implications to Sensor Program:**
  - *Stroud manpower tied up when it could be used elsewhere*
  - *Rating curve* ***flow rates are generally overstated*** *- complicates sediment erosion estimates*
  - ***New RO Analysis tools could facilitate user network watershed understanding and compliment existing practice***

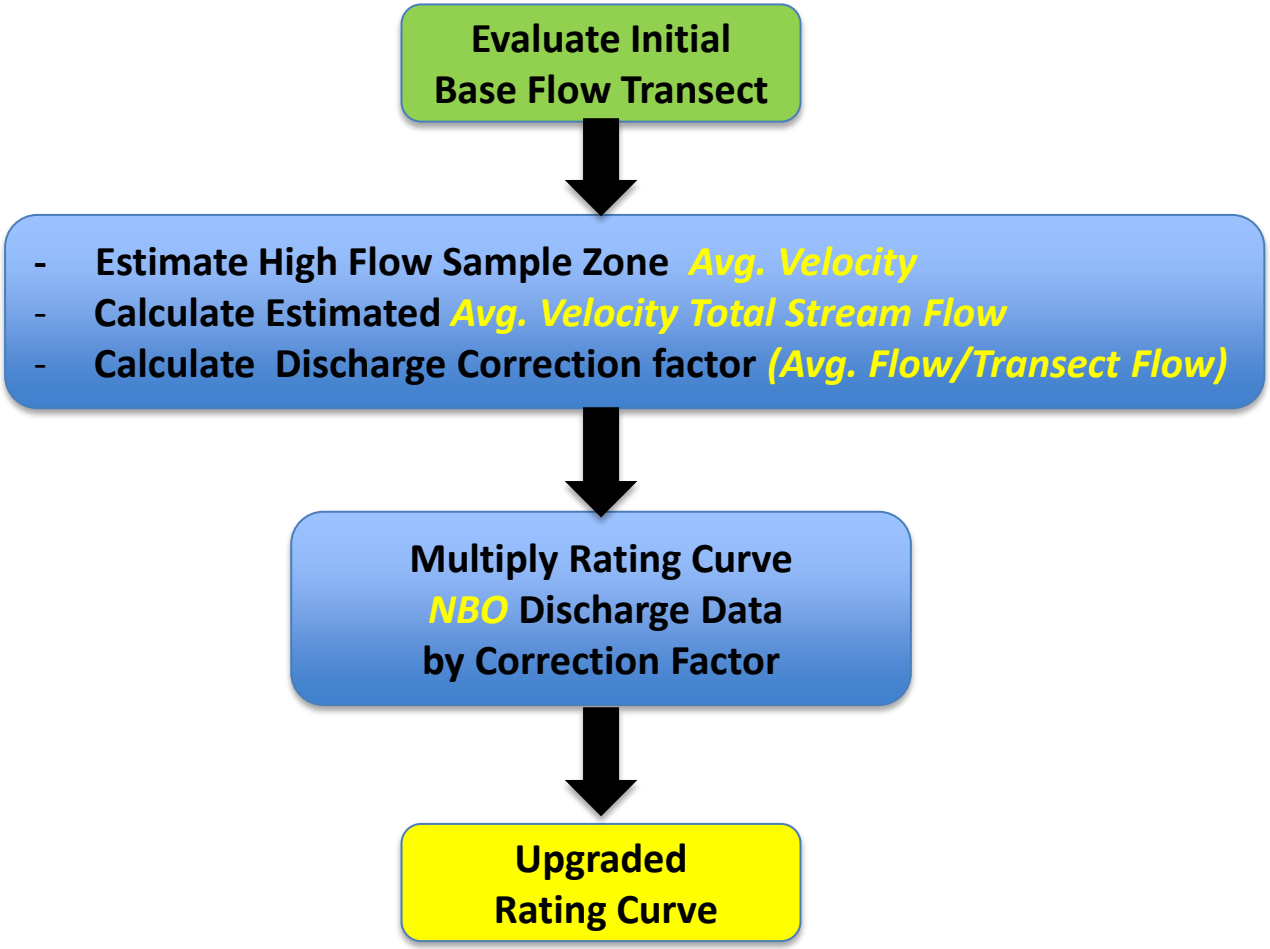
Neutral Buoyant Float Method

Non-representative Velocities



Neutral Buoyant Float Method

Method to Correct NBO Velocities



Float Discharge Correction Factor

Illustration using Pickering - *upstream*

Point	Points of note:	Distance (m)	Water Depth (m)	Velocity (m/s)	NBO Avg Vel. Discharge, cms	Discharge, cms	Comment
1	LEW	2.48	0	0			
2		2.8	0.12	0.04	0.001248	0.0004	
3		3.2	0.2	0.09	0.00832	0.0042	
4		3.5	0.28	0.14	0.00936	0.0083	
5		3.9	0.27	0.12	0.0143	0.0143	Float Measurement Zone
6		4.3	0.3	0.14	0.01482	0.0148	
7		5	0.42	0.12	0.03276	0.0328	
8		5.4	0.42	0.1	0.02184	0.0185	
9		5.7	0.41	0.08	0.016185	0.0112	
10		6.1	0.4	0.05	0.02106	0.0105	
11		6.3	0.36	0.04	0.00988	0.0034	
12		6.7	0.31	0.02	0.01742	0.0040	
13		7.1	0.28	0.01	0.01534	0.0018	
14		8.6	0.16	0.01	0.0429	0.0033	
15	REW	8.7	0	0	0.00104	0.0000	
16							
	Total:				**0.2265**	**0.1275**	

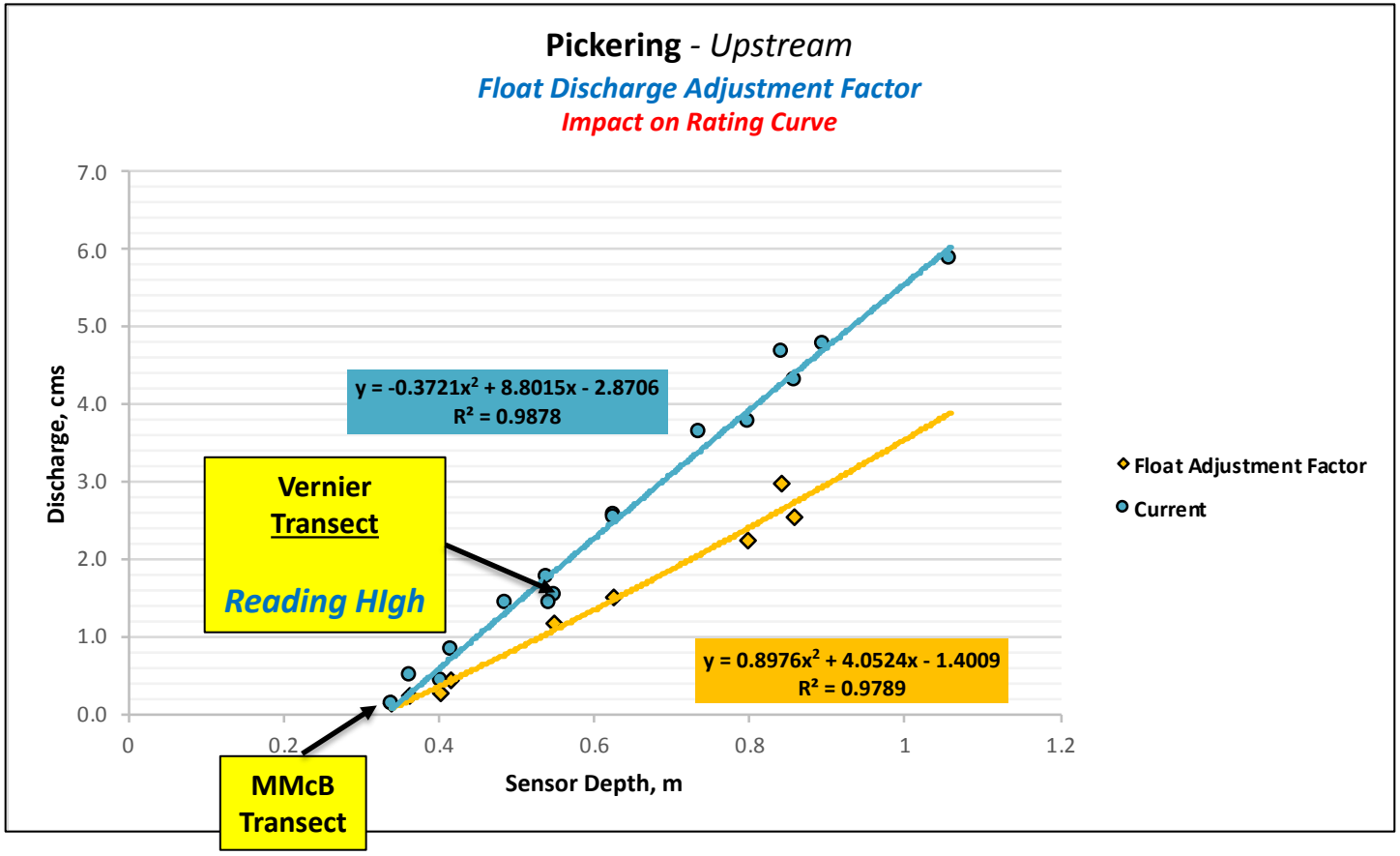
NBO Adjustment Factor

Stream Width, m	6.22
Thalweg Width, m	2.9
Peak Vel, m/s	0.14
75% Peak Vel, m/s	0.105
Total Discharge, cms	0.127
Thalweg Avg. Velocity, m/s	0.130
Thalweg Stream Avg. Discharge, m/s	0.226
NBO Discharge Adjustment	56%

Float Discharge Correction Factor

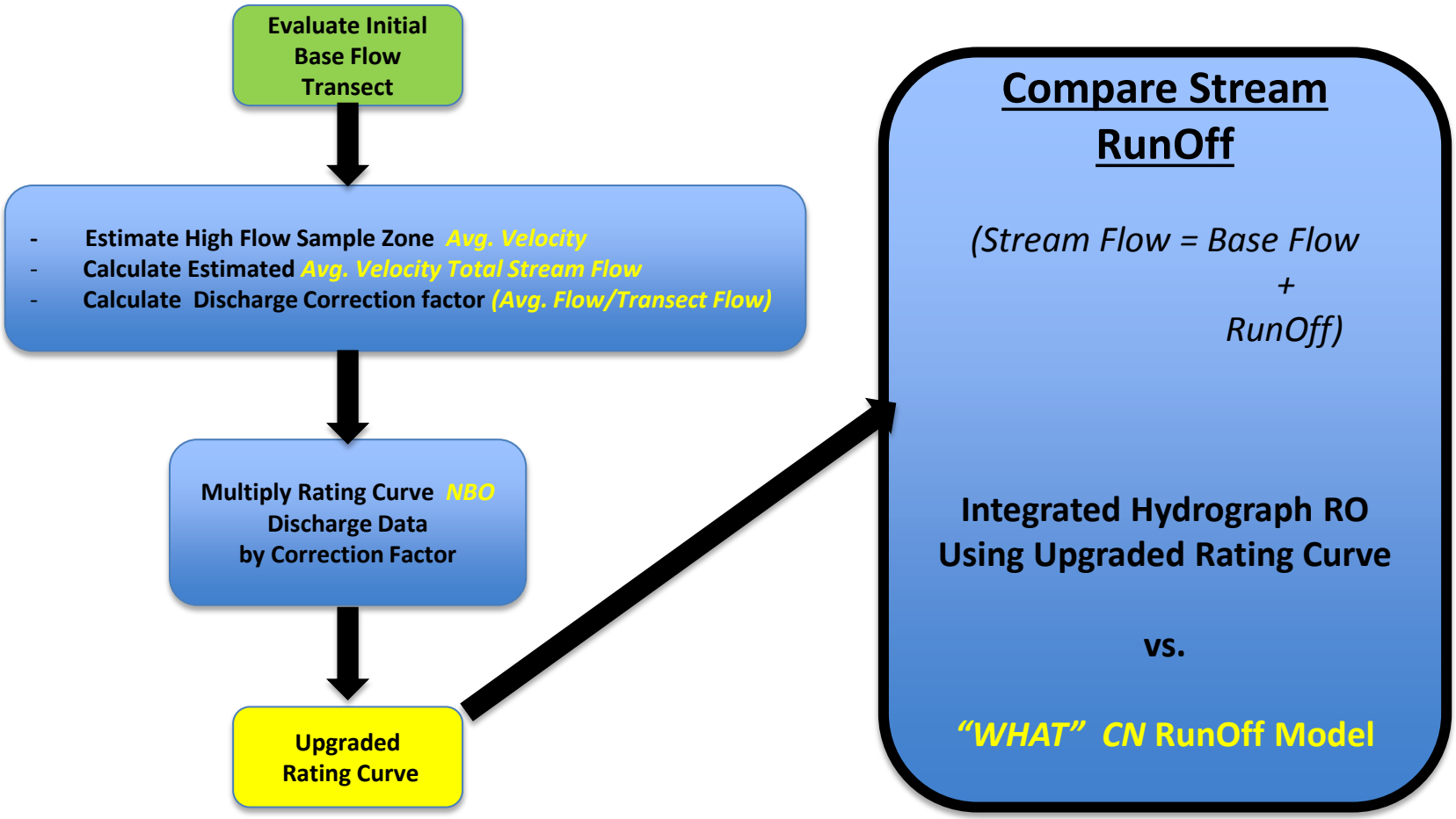
Impact on Rating Curve

Adjust all NBO Data



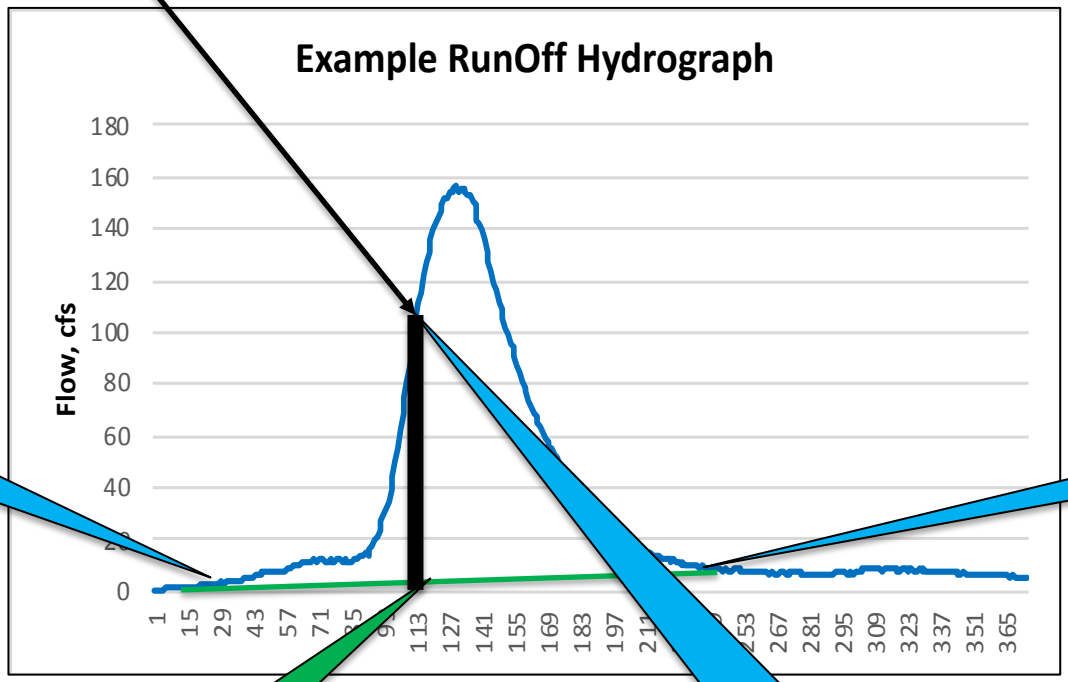
Upgraded Rating Curve

How Accurate is the Curve?



Area = RO = (Discharge Flow – Base Flow) x Time Increment *(cu. Ft)*

RO*(in. rain)* **= Total RO** *(cu. Ft)* **x 12** *(in/ft)* **/ Watershed Area** *(sq. ft)*



Start of Surface RunOff

End of Surface RunOff

Base Flow

Area Under Curve is RunOff

Hydrograph RunOff Integration

Excel Example

Date	Depth, mm							Flow, cms	Flow, cfs	Flow -BF cfs
4/15/18 14:20	260	11.8	407	1.6	0.7	6.8	4.06	0.650	24.3	0.0
4/15/18 14:25	260	11.8	403	1.8	0.8	6.5	4.06	1.000	24.3	0.0
4/15/18 14:30	259.7	11.8	393.3	1.8	0.9	6.5	4.06	1.000	24.1	-0.2
4/15/18 14:35	258.7	11.8	399.3	1.6	0.6	6.5	4.06	1.000	23.6	-0.7
4/15/18 14:40	260	11.7	401	1.8	0.9	6.5	4.06	1.000	24.3	0.0
4/15/18 14:45	260.3	11.7	400.7	1.7	0.8	6.5	4.06	1.000	24.5	0.2
4/15/18 14:50	262.3	11.7	400.7	2	1	6.5	4.06	1.000	25.6	1.3
4/15/18 14:55	261.7	11.7	401.3	2.3	1.4	6.5	4.06	1.000	25.3	1.0
4/15/18 15:00	262.3	11.6	403	2.2	1.2	6.3	4.06	1.000	25.6	1.3
4/18/18 4:45	321	7	361	37.4	39	3	4.03	1.000	59.8	35.4
4/18/18 4:50	323	7	361.3	44.7	46.3	3	4.03	1.000	60.9	36.6
4/18/18 4:55	322.3	7	363.3	45.7	47.9	3	4.03	1.000	60.5	36.2
4/18/18 5:00	322.7	7	364	42.2	43.7	3	4.03	1.000	60.8	36.4
4/18/18 5:05	322	7	365.3	37.2	38.8	2.8	4.03	1.000	60.4	36.0
4/18/18 5:10	322.7	7	360	35.8	37.1	2.8	4.03	1.000	60.8	36.4
4/18/18 5:15	322	6.9	365.7	64.1	66.4	2.8	4.03	1.000	60.4	36.0
4/18/18 5:20	323	6.9	363.3	40.5	42	2.8	4	1.000	60.9	36.6
									SUM	112777
									RO in =	0.44
									Rain =	2.22
									Model RO, in	0.44

Estimating Watershed RunOff

"WHAT" CN RunOff Model

- **Uses "Wikiwatershed" – *"Model My Watershed":***
  - *Land use*
  - *Soil type based upon infiltration rates*
  - *Terrain slope*

- **Incorporated into automated CN RunOff Model:**
  - *Based upon extensive USDA correlations & data*
  - ***Key input data is soil moisture prior to a rain event***
  - ***Highly accurate and simple to use***

  - ***Hourly Rainfall data is very helpful***

"WikiWatershed" - *Model My Watershed*

WHAT CN RunOff Model

Source: Wikiwatershed - Slope and Land Use Profiles

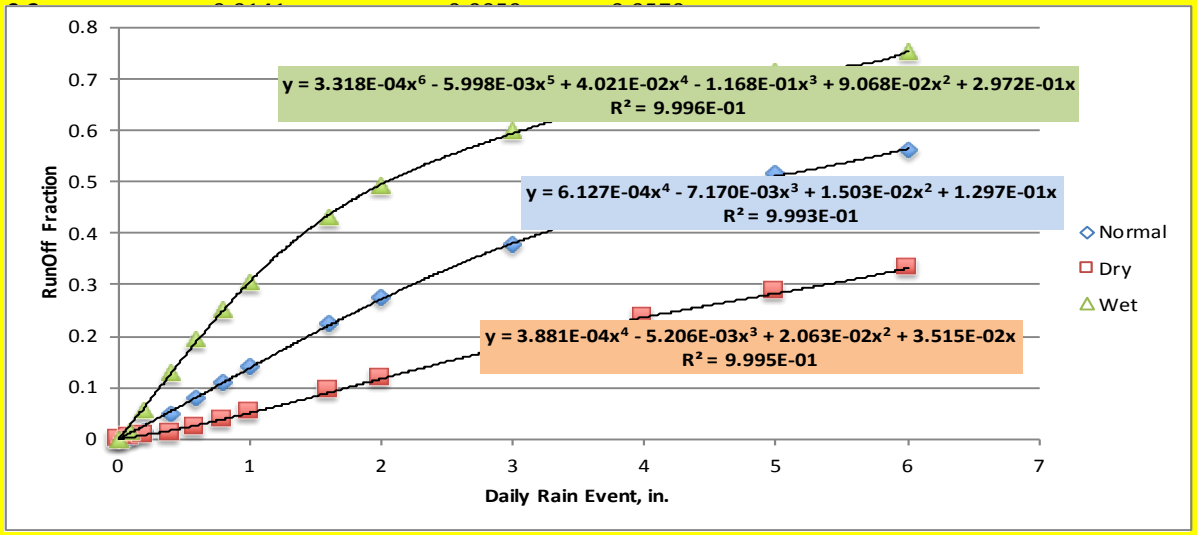
Inflitration Rates, in/hr	Terrain	>0.3	0.15 - 0.3	.05 - 0.15	<.05
infiltration Rates, in/5 min	Slope	0.0250	0.0188	0.0083	0.0042
	6.5%	3.250	3.250	3.250	3.250
		0.0%	59.2%	35.8%	4.9%
Land Use			Soil	Classification	
		A	B	C	D
Open Water	0.0%	100	100	100	100
Impervious RO	0.0%	100	100	100	100
Developed, Open Space	24.0%	55	71	81	87
Developed, Low Intensity	14.5%	84	91	93	96
Developed, Medium Intensity	8.3%	87	92	96	97
Developed, High Intensity	1.0%	91	95	96	97
Barren Land (Rock/Sand/Clay)	0.0%	73	84	91	95
Deciduous Forest	28.7%	33	58	73	80
Evergreen Forest	0.2%	33	58	73	80
Mixed Forest	0.5%	33	58	73	80
Shrub/Scrub	4.6%	3	45	58	65
Grassland/Herbaceous	1.5%	3	66	78	88
Pasture/Hay	14.0%	43	64	76	82
Cultivated Crops	2.2%	65	77	85	89
Woody Wetlands	0.0%	89	89	89	89
Emergent Herbaceous Wetlands	0.4%	83	83	83	83

WHAT CN RunOff Model

Estimating Rain Event RunOff

	Rain from start of event, in	2.22	
	Infilt'n Rate, in/hr.	*0.23463*	
% RunOff	19.90%	8.12%	36.22%
Rain, in.	Normal	Dry	Wet
Soil VMC	0.23	0.15	0.33
0	0	0	0
0.1	0.0041	0.0035	0.0159

Prior to Rain Soil VMC	Estimated % RO	RO In
0.15	8.1%	0.180
0.23	19.9%	0.047
0.33	36.2%	0.029
0.33	**36.2%**	**0.804**



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Discharge Rating Curve Assessment

Application of WHAT CN Model

Is the Rating Curve Accurate?

	Size, sq. mi.
Pickering Creek – *Downstream YMCA:*	33
– *Upstream:*	6.3
Pennypack Creek – *Downstream:*	23.5
Ridley Creek – *Upstream*	8.15
Rocky Run - *Downstream:*	1.6

Discharge Rating Curve Evaluation

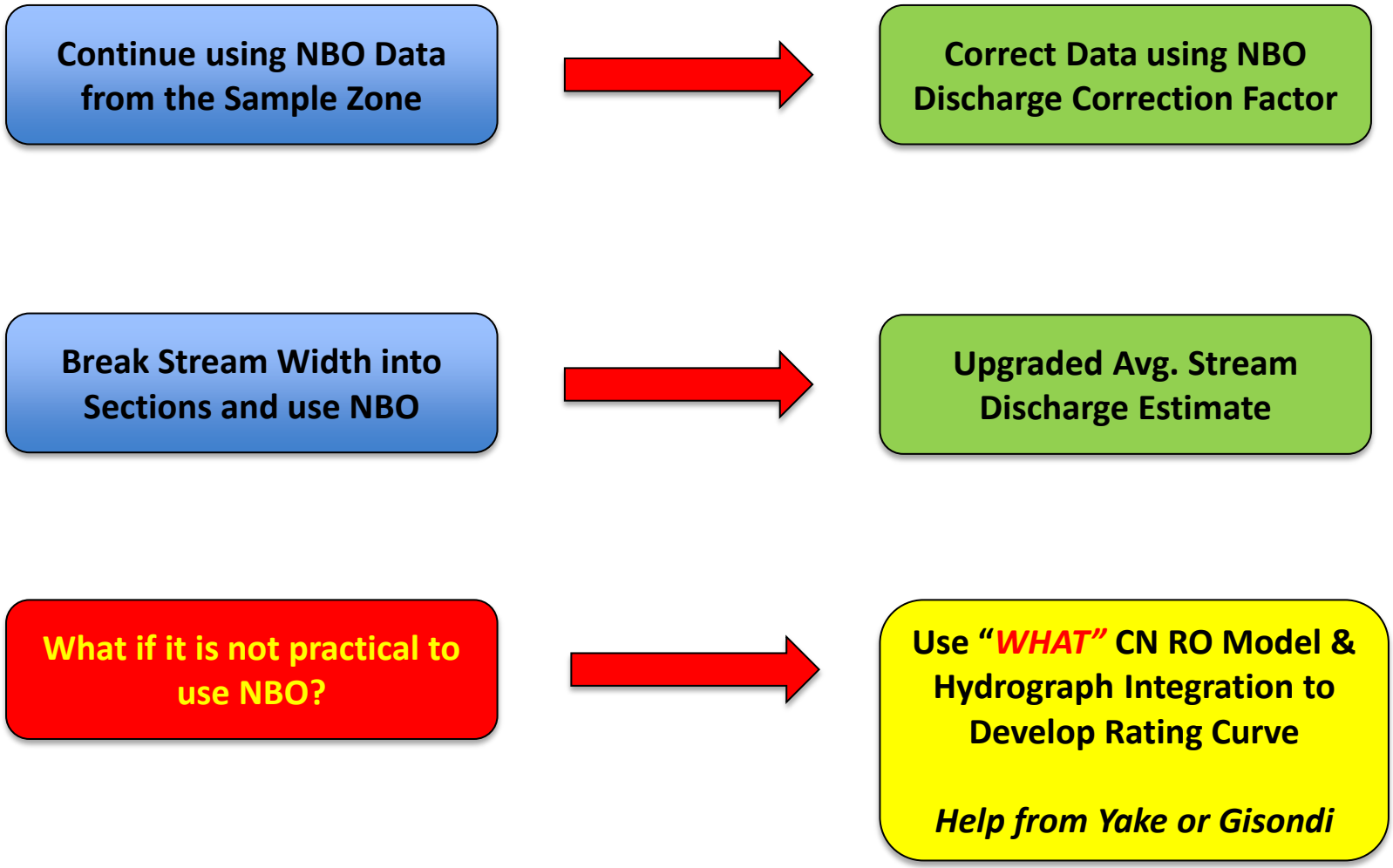
Applying the Float Discharge Correction Factor

(75% of Peak Flow)

Representative Rainfall is Critical

Stream/Location	Date	Rain, in	*WHAT* RO Model RO, in	Hydrograph Integrated RO: Current Discharge RO, in	Hydrograph Integrated RO: Corrected Discharge RO, in.	Correction Factor	Estimated Correction Factor
Pickering - down	4/15-16/18	2.14	0.46	0.84	0.46	65%	72%
	8/31/18	0.88	.06	0.2	0.10		
	10/27/18	1.10	0.16	0.31	0.17		
	11/8/18	0.89	0.14	0.34	0.20		
	11/24-26/18	2.22	0.70	1.34	0.80		
	12/27/18	1.27	0.22	0.37	0.22		
Pickering - up	4/15-16/18	2.14	0.389	0.74	0.40	56%	62%
	8/31/18	0.83	0.077	0.118	0.072		
Pennypack - down	4/15-16/18	2.09	1.08	1.74	1.09	60%	69%
Ridley - up	4/15-16/18	2.16	0.88	0.96	0.90	90%	86%

Options for your Team



Stroud Development of NBO Float Method

Representative Average Stream Velocity

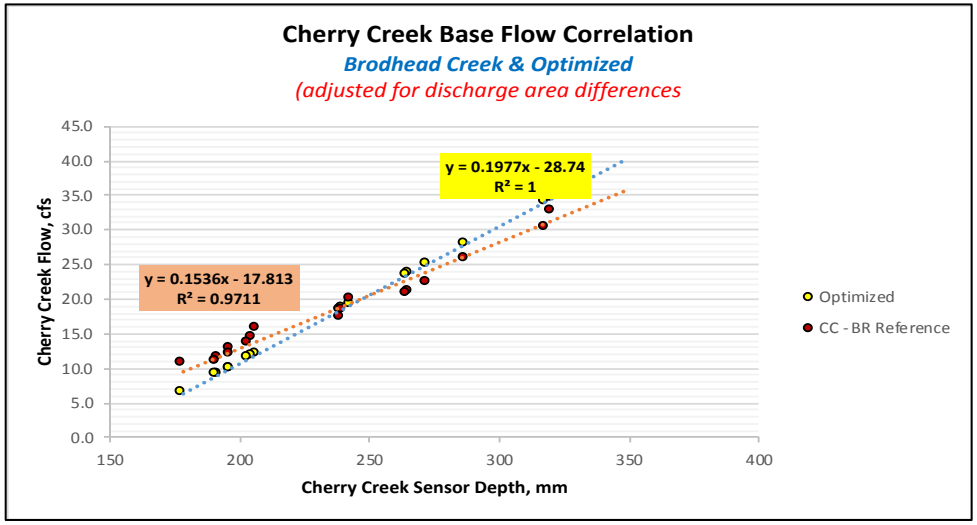
4 Methods Evaluated

NBO Method	Correction
1. Traditional High Flow Zone:	Discharge * NBO Adjust Factor
2. Multiple Zones Across Stream Width (5 x 5)	*Discharge*
3. Distributed Across Stream Width (5 x 1)	*Discharge*
4. Multiple Zones Across Stream Width (3 x 3)	*Discharge * 3/3.5*

Discharge Rating Curve Development

Using "WHAT" CN RunOff Model

Cherry Creek - Pourpoint



Date	Rain, in.	RO, in	Model RO
6/11/18	0.77	**0.119**	**0.128**
6/27/18	1.03	**0.041**	**0.048**
7/17/18	1.16	**0.017**	**0.032**
8/18/18	0.19	**0.014**	**0.006**
8/22/18	0.78	**0.325**	**0.205**
9/20/18	2.34	**1.27**	**1.24**
10/3/18	1.35	**0.487**	**0.537**

NOTE:

Rain Data from Monroe Co. Station
Hourly data for WHAT RO Model is from Scranton or Allentown
Soil Moisture data is average of Stroud and Ithaca, NY.
Stream base flow comparison vs. Brodhead Creek

Support for your Team

Matt Gisondi

Dave Yake

Determining Float Average Adjustment Factor

NBO Thalweg vs. Transect

Point	Points of note:	Distance (m)	Water Depth (m)	Velocity (m/s)	Discharge, cms	Thalwag Avg. Velocity, m/sec	Average Thalwag Discharge, cms		Raw Thalwag Float Vel, m/s	Avg. Discharge, cms	Comment
1	LEW	17.4	0	0							
2		17.7	0.12	0.1	0.0009	0.3225	0.0029		0.3280	0.0030	
3		18.1	0.17	0.47	0.0165	0.3225	0.0187		0.3280	0.0190	Thalwag Zone @ 60% Peak
4		18.35	0.17	0.52	0.0210	0.3225	0.0137		0.3280	0.0139	0.06
5		18.6	0.17	0.46	0.0208	0.3225	0.0137		0.3280	0.0139	Avg =0.3225 m/s
6		18.9	0.19	0.2	0.0178	0.3225	0.0174		0.3280	0.0177	
7		19.2	0.21	0.23	0.0129	0.3225	0.0194		0.3280	0.0197	
8		19.5	0.23	0.2	0.0142	0.3225	0.0213		0.3280	0.0216	
9		19.8	0.22	0.21	0.0138	0.3225	0.0218		0.3280	0.0221	
10		20.1	0.2	0.29	0.0158	0.3225	0.0203		0.3280	0.0207	
11		20.4	0.21	0.21	0.0154	0.3225	0.0198		0.3280	0.0202	
12		20.7	0.2	0.12	0.0101	0.3225	0.0198		0.3280	0.0202	
13		21	0.16	0.1	0.0059	0.3225	0.0174		0.3280	0.0177	
14		21.2	0.14	0.01	0.0016	0.0000	0.0048		0.0000	0.0049	Velocity of effective end point = 0
15	REW	21.35	0	0	0.0001		0.0000		0.0000	0.0000	
16				**Total Discharge, cms**	**0.1670**		**0.2111**			**0.2147**	
17											
18											
19				**Float Adjustment Factor**	**79%**					**79%**	
20											
21											
22											
23											
24				**NBO Adjusted Discharge**						**0.170**	
25				*% of Actual*						*102%*	
26											
27											

All NBO Approaches are Comparable

OK for Teams to Use

Multiple Zones
5 x 5

Point	Points of note:	Distance (m)	Water Depth (m)	Velocity (m/s)	Avg Velocity, m/s)	Discharge w/ Avg Vel.	Comment
1	LEW	17.4	0	0	0		NBO
2		18.1	0.19	0.43	0.411	0.0137	NBO
3		18.6	0.19	0.58	0.411	0.0390	NBO
4		19.1	0.2	0.35	0.411	0.0401	NBO
5		19.7	0.22	0.32	0.411	0.0518	NBO
6		20.6	0.18	0.375	0.411	0.0740	NBO
7	REW	21.35	0	0	0	0.0139	NBO
8				**Float Total Discharge, cms**		**0.232**	
9							
10							
11				**Float Adjustment Factor**		**100%**	already accounted for from Velocity Avg
12				**Depth Adjustment Factor**		**76%**	
13				**Estimated Discharge, cms**		**0.177**	
14				*% Actual*		*106%*	
15							

Distributed
5 x 1

Point	Points of note:	Distance (m)	Water Depth (m)	Velocity (m/s)	Flow Discharge, cms	Comment
1	LEW	17.4	0			
2		18.1	0.19	0.393	0.013	
3		18.6	0.19	0.393	0.037	
4		19.1	0.2	0.393	0.038	
5		19.7	0.22	0.393	0.049	
6		20.6	0.18	0.393	0.071	
7	REW	21.35	0	0.000	0.013	
8			Float Total Discharge, cms		0.222	
9						
10			**Float Adjustment Factor**	**100%**		Velocity is averaged already
11			**Depth Adjustment Factor**	**76%**		
12			Float Avg. Discharge	0.222		
13			**Depth Adjusted Discharge**	**0.169**		
14			*% of Actual*	*101%*		
15						

Angelica Creek – NBO Analysis

Transect Overview

Distributed 3 x 3

Point	Points of note:	Distance (m)	Water Depth (m)	Velocity (m/s)	Thalweg Flow, cms	4 Zone Avg. Velocity Flow, cms	Total Flow, cms	Comment
1	REW	4.1	0	0				
2		4.7	0.28	-0.03		0	-0.0013	
3		5.1	0.43	0.02	0.0109	0.0063	-0.0007	
4		5.5	0.46	0.14	0.0273	0.0158	0.0142	*Recorded as 0.41 on datasheet - seemed too high
5		5.9	0.38	0.19	0.0258	0.0149	0.0277	
6		6.4	0.32	0.13	0.0268	0.0155	0.0280	Peak Velocity = 0.19
7		6.7	0.33	0.11	0.0149	0.0087	0.0117	0.75* Peak Velocity = 0.1425
8		7.2	0.36	0.07	0.0264	0.0153	0.0155	**Avg. Thalweg Velocity**
9		7.7	0.3	0.02	0.0253	0.0146	0.0074	**0.1533**
10		8.3	0.26	0.01	0.0129	0.0149	0.0025	**4 Zone Avg. Velcoity, m/s**
11		8.7	0.24	0.01	0.0000	0.00000	0.0010	**0.0887**
12	LEW	9.4	0	0	0		0.0004	
13								
50								
			Total Discharge =		**0.170**	**0.106**	**0.107**	

NBO Adjustment Factor =	**63%**