

# Minimum Requirements for Documenting Stage-Area & Index-Velocity Ratings

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# OSW Technical Memo 2015.05

## Thanks to:

Molly Wood, Lars Soderqvist,  
Marc Stewart, Mike Rehmel,  
Jeff East, Liz Hittle, Sonny  
Anderson, Victor Levesque



United States Department of the Interior  
U.S. GEOLOGICAL SURVEY  
Reston, Virginia 20192

In Reply Refer To:  
Mail Stop 415

March 6, 2015

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2015.05

**SUBJECT:** Minimum requirements for documenting stage-area and index-velocity ratings for computation of streamflow records using the index velocity method

The purpose of this memo is to specify the documentation required for stage-area and index-velocity ratings when using the index velocity method for computing streamflow records. The index velocity method was documented and described in the Techniques and Methods (T&M) report "Computing Discharge Using the Index Velocity Method" (Levesque and Oberg, 2012). However, the T&M does not specify minimum requirements for the documentation of stage-area and index-velocity ratings. Because much of the development for stage-area and index-velocity ratings presently (2015) takes place outside of the National Water Information System (NWIS), it is therefore necessary to provide guidance for documenting the development and implementation of these ratings.

### Stage-Area Rating Documentation

Methods for acquiring data for stage-area ratings are described in Levesque and Oberg (2012, p29-30). The AreaComp2 software (an updated version of the software described in that report) should be used to create stage-area ratings until equivalent or better capability is provided as a part of the NWIS software. AreaComp2 is available for download at the USGS Hydroacoustics Web pages (<http://hydroacoustics.usgs.gov/>). The cross-section survey data used to develop and validate the rating, the current rating information, and the rating validation must be documented. Additional details, including the suggested location for this information, are specified below.

1. Standard cross-section data. The data used to develop the stage-area rating must be available in the electronic data archive (EDA) so that the stage-area rating can be re-created readily. The data also can be summarized in a rating spreadsheet or other rating analysis tool or software. This includes any files used to create the ratings (for example, the \*.mat or \*.txt outputs from an acoustic Doppler current profiler (ADCP), and any level notes of the banks). An example of such data is shown on p. 31-32 of Levesque and Oberg (2012). The exact geographic location of the standard cross-

# Overview

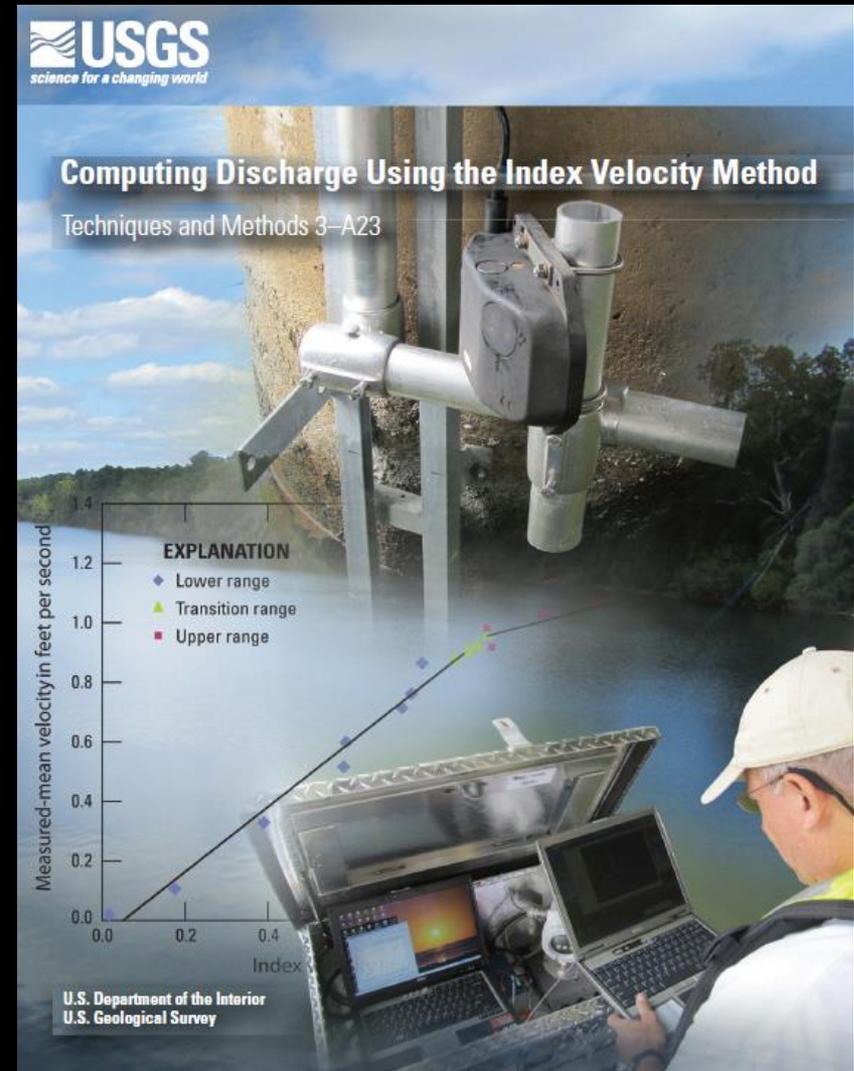
- Motivation
- Considerations
- Stage-area Ratings
- Index-velocity Ratings
- Summary
- Questions and Answers

# Some Terms

- ADVN Acoustic Doppler Velocity Meter
- EDA Electronic Data Archive
- I-V Index Velocity
- S-A Stage-Area
- NWIS National Water Information System
- Averaging Period Time that velocity is measured & averaged to compute a single value for velocity
- Measurement Interval The time between two successive velocity measurements.
- Blanking distance The distance from the transducer face within which no velocity measurements are made

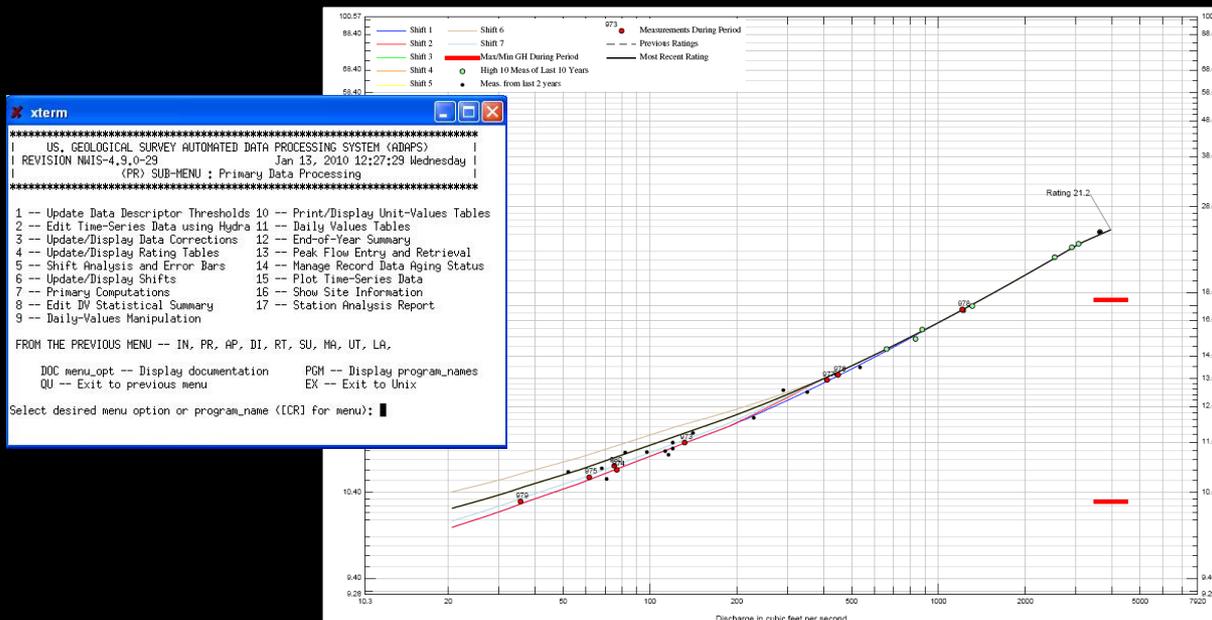
# Motivation: Need for Clear Guidance

- Published T&M in 2012; contains many examples of documentation for both S-A & I-V ratings; including example Station Analyses
- Does NOT explicitly state minimum requirements for rating documentation



# Motivation

- Ratings are NOT created in NWIS; therefore standard NWIS outputs do not provide necessary documents on rating development.
- I-V method is new & therefore no standard protocols

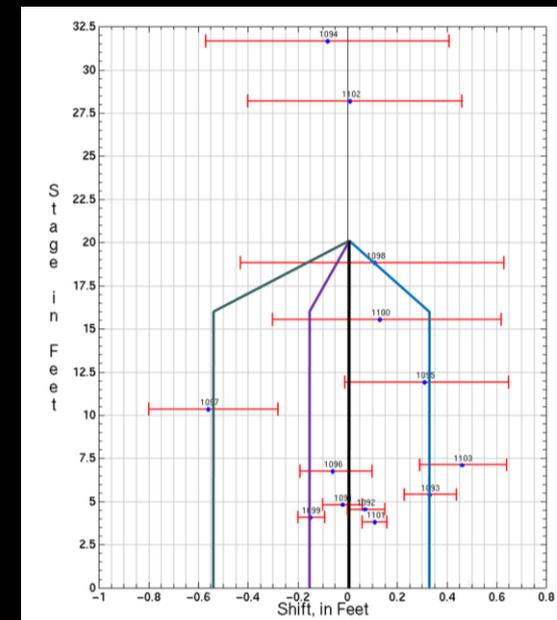


```
xterm
*****
US, GEOLOGICAL SURVEY AUTOMATED DATA PROCESSING SYSTEM (ADAPS)
REVISION NWIS-4.9.0-29 Jan 13, 2010 12:27:29 Wednesday
(PR) SUB-MENU : Primary Data Processing
*****
1 -- Update Data Descriptor Thresholds 10 -- Print/Display Unit-Values Tables
2 -- Edit Time-Series Data using Hydra 11 -- Daily Values Tables
3 -- Update/Display Data Corrections 12 -- End-of-Year Summary
4 -- Update/Display Rating Tables 13 -- Peak Flow Entry and Retrieval
5 -- Shift Analysis and Error Bars 14 -- Manage Record Data Aging Status
6 -- Update/Display Shifts 15 -- Plot Time-Series Data
7 -- Primary Computations 16 -- Show Site Information
8 -- Edit DV Statistical Summary 17 -- Station Analysis Report
9 -- Daily-Values Manipulation

FROM THE PREVIOUS MENU -- IN, PR, AP, DI, RT, SU, MA, UT, LA,

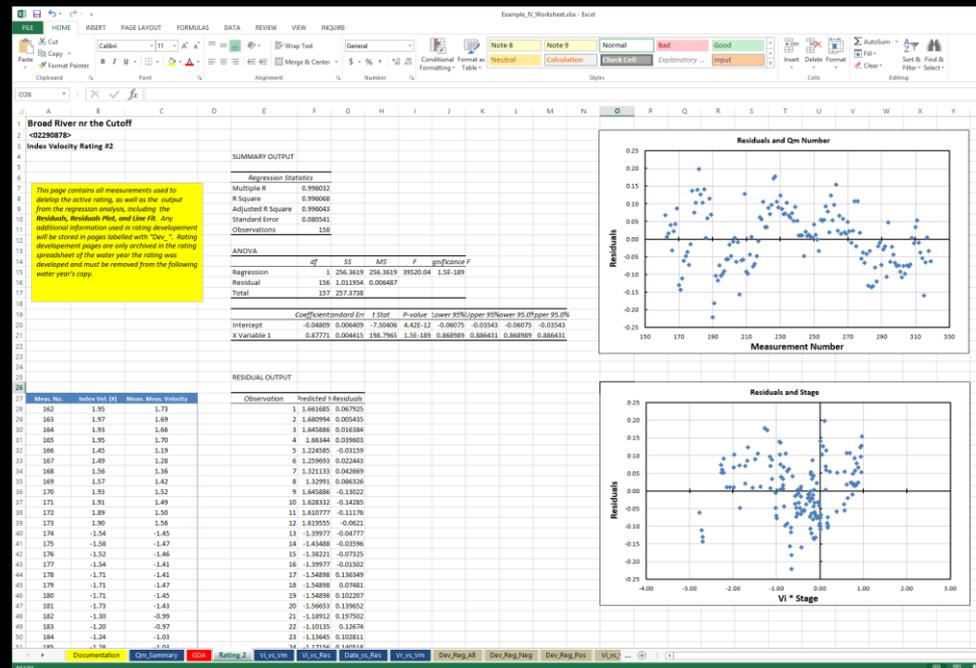
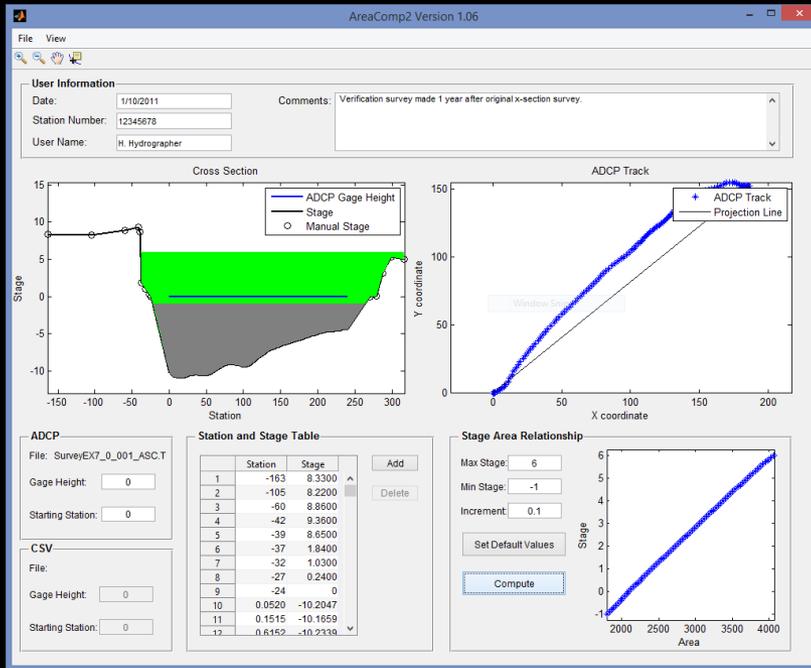
DOC menu_opt -- Display documentation PGM -- Display program_names
QU -- Exit to previous menu EX -- Exit to Unix

Select desired menu option or program_name (CR) for menu: █
```



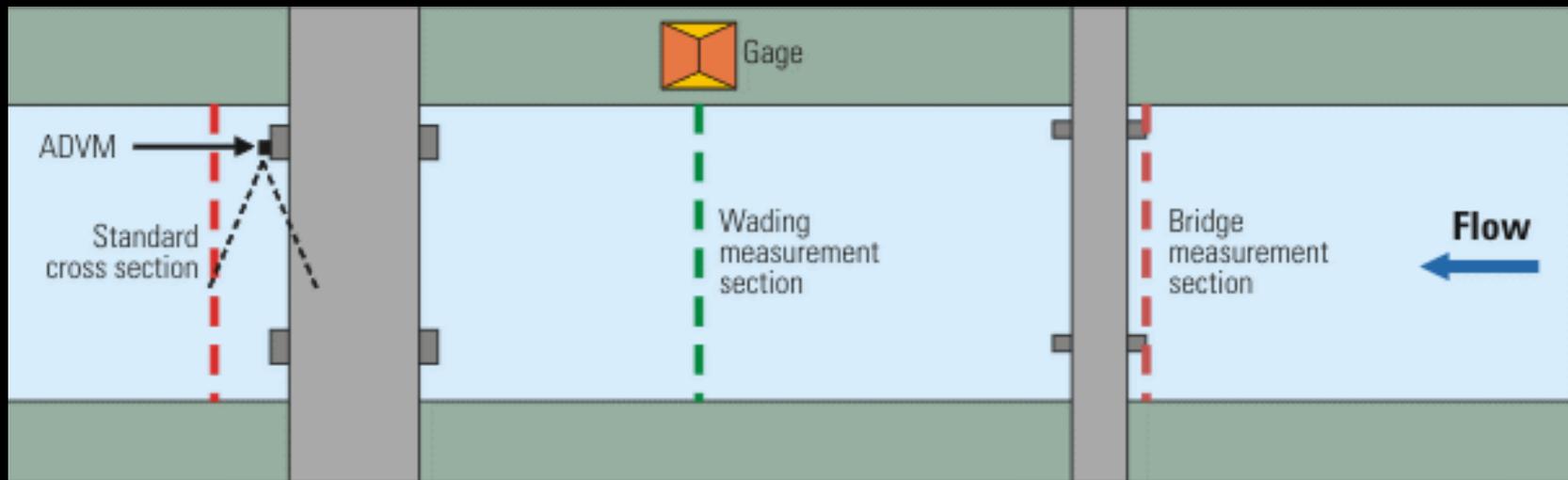
# Motivation

- Ratings are usually created using AreaComp2 and Microsoft Excel or similar tools



# Motivation: Stage-Area Examples

- Location of standard cross-section not in station description or elsewhere
- Standard cross section not used
- Survey notes are not in **EDA**



# Motivation: Index-Velocity Examples

Excel interface showing regression analysis results and residual plots.

**Regression Statistics**

Multiple F	0.999136
R Square	0.998274
Adjusted R Square	0.926845
Standard Error	0.080363
Observations	15

**ANOVA**

	df	SS
Regression	1	52.27958
Residual	14	0.090415
Total	15	52.37

**Coefficient**

	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.031047	0.01146	89.9724	9.58E-21	1.006469	1.055625	1.006469

**RESIDUAL OUTPUT**

Observation	Predicted Y	Residuals	Standard Residuals
1	-1.26819	0.120697	1.554612
2	-1.44347	0.03666	0.472192
3	-1.60843	-0.0554	-0.71358
4	-1.75278	0.015053	0.193888
5	-1.9693	0.037929	0.488538
6	-2.04147	-0.02404	-0.30967
7	-2.06209	-0.20869	-2.68804
8	-2.1652	0.113062	1.456268
9	-2.18582	-0.01462	-0.18828
10	-2.15489	0.06994	0.900847
11	-2.05178	-0.08147	-1.04934
12	-2.02085	0.004559	0.058721
13	-1.7734	0.001912	0.024624
14	-1.7734	0.003881	0.049992
15	-1.39191	0.032748	0.421809

**PROBABILITY OUTPUT**

Percentile	Y
3.333333	-2.27079
10	-2.20044
16.66667	-2.13325
23.33333	-2.08495
30	-2.06552
36.66667	-2.05214
43.33333	-2.01629
50	-1.93137
56.66667	-1.77149
63.33333	-1.76952
70	-1.73773
76.66667	-1.66383
83.33333	-1.40681
90	-1.35916
96.66667	-1.14749

**Normal Probability Plot**

**X Variable 1 Residual Plot**

**X Variable 1 Residual Plot**

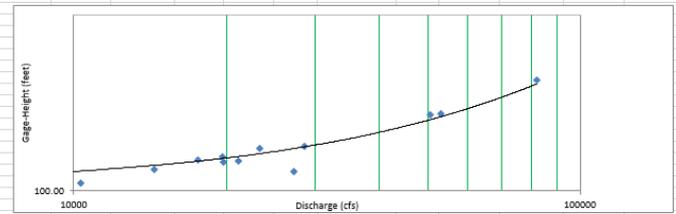
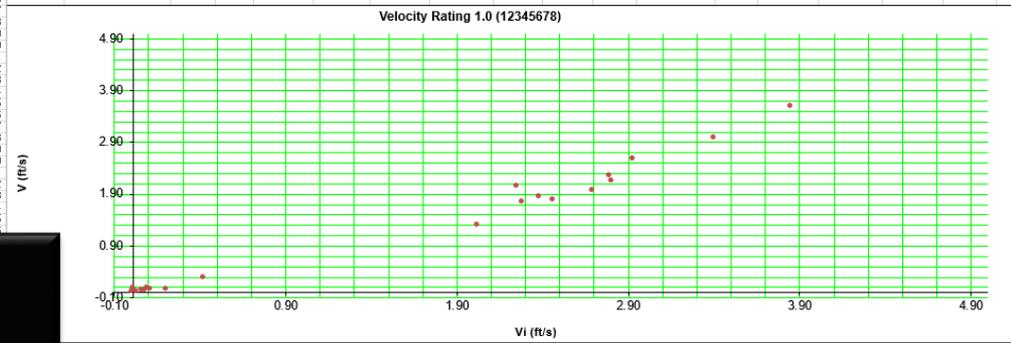
**Annotations:**

- No line fit plot
- Axes not labeled
- Rating not identified

Rating using all measurements    Rating 2 for IV less than 0    Rating 2 for IV greater than 0

# Motivation: I-V Examples

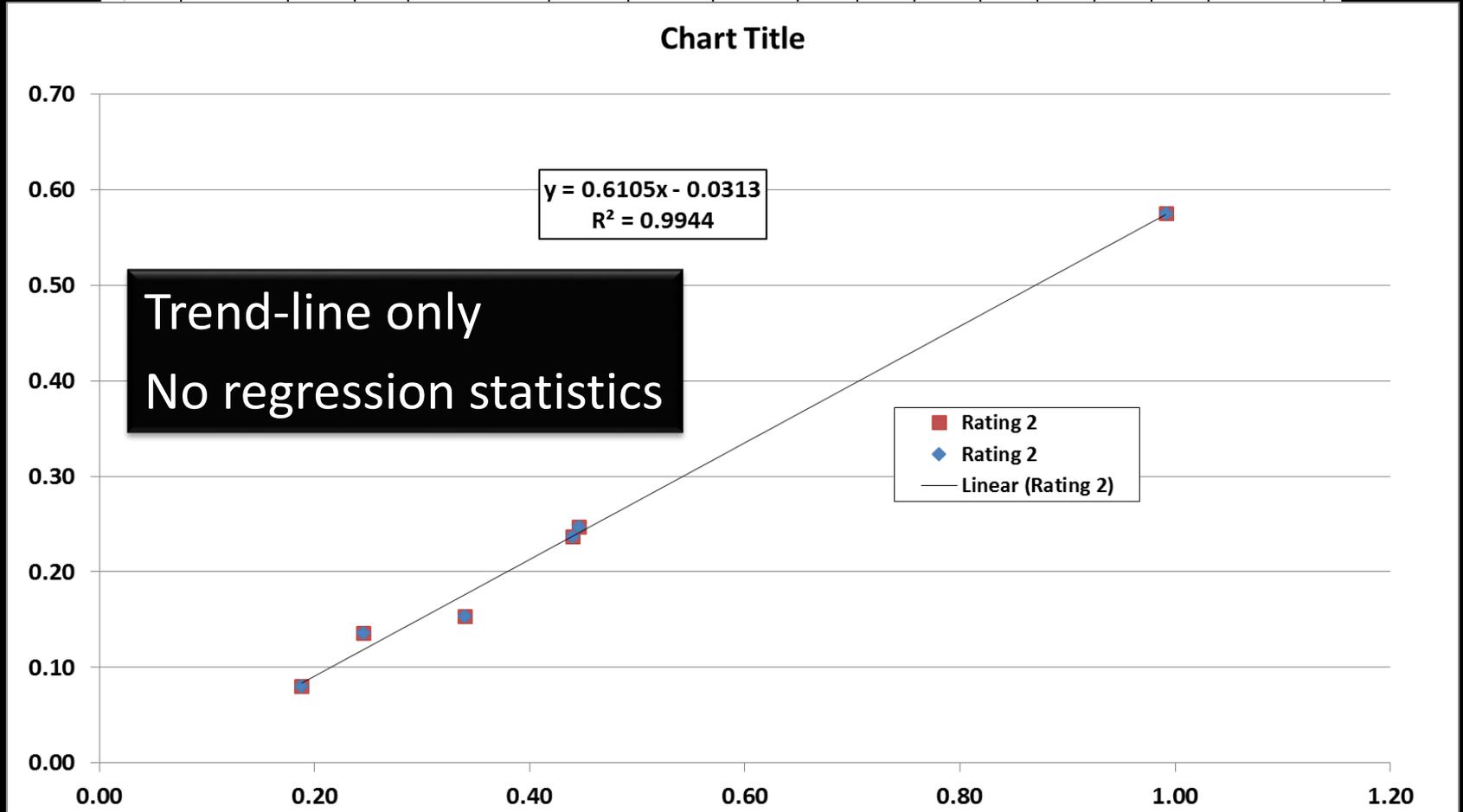
12345678		Stage-Area Rating 1.0															S	T	U
Velocity Rating 1.0																			
MEAS. NO.	DATE	START TIME	END TIME	STAGE	MEAS Q	CHAN. AREA RATING	MEAN CHAN. VEL.	INDEX VEL.	RATED VEL.	CAL. Q	UNSHIFTED % DIFF	SHIFT	SHIFTED RATED VEL.	CAL. SHIFTED Q	SHIFTED % DIFF	MEAS. RATING			
1	7/9/2009	10:40	11:17	101.92	224	5847	0.04	0.03	0.02	142	57.7	0.00	0.02	142	57.7				
2	9/26/2009	9:13	9:23	122.79	53000	17000	3.12												
3	10/8/2009	14:10	14:21	108.09	19800	9149	2.16	2.80	2.27	20750	-4.6	0.00	2.27	20750	-4.6	good	0.0383	0.03	
4	12/9/2009	12:58	13:10	112.13	23300	11300	2.06	2.25	1.82	20594	13.1	0.00	1.82	20594	13.1	fair	2.16	2.80	
5	12/16/2009	11:46	11:50	134.20	82100	23300	3.52									good	2.06	2.25	
6	2/4/2010	10:29	10:41	108.70	17600	9485	1.86	2.38	1.93	18285	-3.7	0.00	1.93	18285	-3.7	good	1.86	2.38	
7	4/7/2010	15:27	15:54	105.98	14400	8019	1.80	2.46	1.99	15979	-9.9	0.00	1.99	15979	-9.9	fair	1.80	2.46	
8	6/8/2010	14:54	15:04	108.42	21100	9331	2.26	2.79	2.26	21087	0.1	0.00	2.26	21087	0.1	good	2.2613	2.79	
9	8/4/2010	14:26	14:37	104.26	9280	7098	1.31	2.02	1.64	11614	-20.1	0.00	1.64	11614	-20.1	good	1.3074	2.02	
10	10/21/2010	8:53	9:28	101.78	338	5772	0.06	0.06	0.06	374	-9.6	0.00	0.06	374	-9.6	poor	0.0586	0.06	
11	1/5/2011	14:27	14:57	102.11	560	5950	0.98	0.09	0.07	434	29.1	0.00	0.07	434	29.1	poor	0.0941	0.09	
12	2/6/2011	17:36	17:47	109.58	19700	9970	1.98	2.69	2.18	21724	-9.3	0.00	2.18	21724	-9.3	good	1.9759	2.69	
13	5/2/2011	15:06	15:14	105.56	27200	7576	3.59	3.85	3.12	23626	15.1	0.00	3.12	23626	15.1	fair	3.5903	3.85	
14	7/6/2011	10:07	10:23	101.73	387	5750	0.07	0.20	0.16	932	-58.5	0.00	0.16	932	-58.5	poor	0.0673	0.2	
15	10/5/2011	14:10	14:20	102.02	10300	5901	1.75	2.28	1.85	10898	-5.5	0.00	1.85	10898	-5.5	fair	1.7455	2.28	
16	2/7/2012	11:56	12:09	102.68	539	6254	0.09	0.01	0.01	51	964.0	0.00	0.01	50.66	964.01	Poor	0.0862	0.01	
17	6/6/2012	10:44	10:57	101.80	126	5783	0.02	0.00	0.00	5	2589.9	0.00	0.00	4.68	2589.88	Poor			
18	8/6/2012	10:22	10:35	101.87	435	5820	0.07	0.11	0.0891	519	-6.1	0.00	0.09	518.56	-6.11	poor			
19	10/11/2012	7:43	7:56	102.23	291	6013	0.05	0.06	0.0486	292	-0.42	0.00	0.05	292.23	-0.42	poor			
20	1/9/2013	16:53	17:06	102.07	1700	5927	0.29	0.42	0.3402	2016	-15.69	0.00	0.34	2016.37	-15.69	poor			
21	2/12/2013	10:57	11:11	122.46	60500	16840	3.00	3.40	2.754	46377	9.9	0.00	2.75	46377.36	8.89	fair			
22	5/6/2013	14:00	14:15	112.49	28500	11020	2.59	2.93	2.3733	26154	9.00	0.00	2.37	26153.77	8.97	fair			
23	7/2/2013	8:03	8:16	102.04	561.00	5910	0.09	0.18	0.15	862	-34.89	0.00	0.15	861.68	-34.89	POOR			
24	12/3/2013	10:05	10:19	105.37	2750.00	7690.00	0.36	1.48	1.20	9219	-70.17	0.00	1.20	9218.77	-70.17	poor			
25	3/3/2014	11:45	12:00	104.24	1040.00	7090.00	0.15	0.29	0.23	1665	-37.55	0.00	0.23	1665.44	-37.55	poor			



No line fit plot  
No residual plots  
No equation for the rating

# Motivation: Index-Velocity Examples

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
2						SonTek			Meas.	rated	rated		Used	Residual		
3		Meas.	Date	Meas.	Stage	Vel.	Rated Area	Rated Area	Vel.	Vel.	Q	%	(Yes)	Velocity	Site Visit	Remarks



# Considerations

- Stage-area and index-velocity ratings are developed OUTSIDE of NWIS; but NWIS used to compute Q
- USGS is transitioning to Aquarius software
- Aquarius software will not include the I-V rating **tool** in the first release. (*1<sup>st</sup> release AQ will handle existing ratings*)
- Assume that AreaComp2 is being used for S-A rating development; though Aquarius may have that capability
- Therefore, policies must be general enough for both the present and the future, but be as specific as possible

# OSW Technical Memo 2015.05

- Stage-Area Rating Documentation
- Index-Velocity Rating Documentation
- Additional Documentation



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#### Stage-Area Rating Documentation

Methods for acquiring data for stage-area ratings are described in Levesque and Oberg (2012, p29-30). The AreaComp2 software (an updated version of the software described in that report) should be used to create stage-area ratings until equivalent or better capability is provided as a part of the NWIS software. AreaComp2 is available for download at the USGS Hydroacoustics Web pages (<http://hydroacoustics.usgs.gov/>). The cross-section survey data used to develop and validate the rating, the current rating information, and the rating validation must be documented. Additional details, including the suggested location for this information, are specified below.

1. Standard cross-section data. The data used to develop the stage-area rating must be available in the electronic data archive (EDA) so that the stage-area rating can be re-created readily. The data also can be summarized in a rating spreadsheet or other rating analysis tool or software. This includes any files used to create the ratings (for example, the \*.mat or \*.txt outputs from an acoustic Doppler current profiler (ADCP), and any level notes of the banks). An example of such data is shown on p. 31-32 of Levesque and Oberg (2012). The exact geographic location of the standard cross-

# S-A Ratings: Standard Cross Section Data

- Data used to develop S-A rating must be available in the **EDA**. ADCP data files (\*.mat or \*.txt files), level notes, etc.
- Data also may be summarized in spreadsheet or some other rating analysis tool
- **Station Description** must contain:
  - Exact geographic location of the standard cross-section
  - Description of the methods used to perform the survey; e.g. level and stadia, ADCP, tagline and soundings

# S-A Ratings: Standard Cross Section Data

Internal Only

Station Description View

Responsible Office

Stage Area rating #2 was created using ADCP transect file xxxxxRiver\_20110803\_005 and generated using AreaComp. **The cross-section is located between RM2 (behind the gage) and a 1.5 inch aluminum pipe pounded directly across the channel from the station (done to allow for easy re-verification of the standard area cross section).** Area rating #2 is used beginning with WY 2011.

Copeland Ave. CR 29-S. Use the ramp at Outdoor Resorts located on the left. Follow the wilderness waterway south to Broad River. Station located on left bank of the Broad River between Broad River Bay and the Cut-off (refer to map insert) in Monroe County, Florida. Local knowledge is recommended to avoid numerous shoals and oyster bars.

**SITE HAZARD ANALYSIS.**--Float plans must be filed with ENP dispatch and Ft Myers USGS office prior to departure. A spot and satellite phone should be carried at all times. Upon return to the dock an "OK" message should be sent with the SPOT and a call to ENP dispatch to end the float plan

2 people are required for motor boat operation (at least one person with MOCC training).

There are no hazards associated with water quality measurements. Chemicals used are potassium chloride.

Be mindful of weather and tides.

\*\*Carry printed copy of ENP Permit at all times.

**DRAINAGE AREA.**--Indeterminate.

**ESTABLISHMENT AND HISTORY.**--February 22, 2001.

History of Gage: Original station built December 12, 1997 by Victor Levesque, Paul Boetcher, and Tim O'Hare out of the Tampa USGS sub-district at a location further upstream between Broad River Bay and ENP campsite, "Camp Lonesome." Station was equipped with a CR-10 data logger, H-310 pressure transducer, 1.5 MHz Up-looking SonTek ADP, MetOne wind anemometer, R.M. Young barometric pressure sensor, and two YSI 600R temperature/conductivity sondes. Water samples for nutrient analysis (nitrogen and phosphorous species) were collected at three cross-river stations with a depth integrated sampler during this time period, along with depth, pH, specific conductance, temperature and D.O. from a Hydrolab sonde. Servicing and computation of record performed by Victor Levesque Paul Boetcher, and Tim O'Hare from initial construction until station responsibilities taken over by Ft. Myers USGS and station was rebuilt and relocated at existing location. Current location established February 22, 2001, by Eduardo Patino, Lars Soderqvist, and Marc Stewart at current location.

Servicing of station and computation of record by Eduardo Patino, Lars Soderqvist and Craig Thompson from initial construction through water year 2007. Servicing of station and computation of record by Amanda Booth began during water year 2008. Servicing of station and computation of record by Travis Knight began during water year 2010.

# S-A Ratings: Rating Information & Output

- **Station Analysis** must clearly state:
  - when the data were acquired,
  - the tool used to develop the rating (e.g., AreaComp2),
  - the NWIS rating number, and
  - the applicable range of dates and stage
  - current S-A rating should be documented IF methods change among surveys
- **EDA** must have:
  - The output of AreaComp2 (or equivalent), which consists of both the stage-area rating table and final cross-section table
  - A saved copy of the AreaComp2 \*.act file

# S-A Ratings: Rating Information & Output

STAGE-AREA RATING.-- For the period, stage-area Rating 1.0 was used. The channel consists of sand, silt and mud with some rock. Both banks are covered with grass and brush. The channel is somewhat diked by Hwy 3 on the right bank and by steeper banks on the Left bank side.

Stage-area rating No. 1, developed using the USGS program AreaComp and cross-section field data collected on Mar. 15, 2010, was used for the period. The standard cross-section extends from the OSS and up the Left bank and over to the right bank to a fence post high upon the Hwy 3 embankment. Elevations from the level set were entered into AreaComp to the nearest .1 ft. After the Excel stage-area rating was made, input points were entered into ADAPS every .5 ft. from 12.00 ft to 39.00 ft. The top of the rating, and the last entry point, was at 39.09 ft. so the 39.5 ft. mark was not entered.

The standard cross-section was checked again on Sep. 14, 2012. No significant change to the channel geometry was seen and Stage-Area Rating 1.0 was continued in use throughout the period. Stage-area check files have been archived. (\\Igswwfs001\SiteData\Surface Water\12415135\Analyses\Other\SA Rating\AreaComp\_Checks\Rating\_1.0\12415135\_20110420\_SACheck.act) Cross-section checks are now on a three year interval as it has been proven stable. Standard x-section checks will be done sooner if the need arises.

# S-A Ratings: Rating Information & Output

- Analyses of the stage-area rating **validation measurements** must be documented in the **Station Analysis**. Must include:
  - brief description of the data acquisition (where, when, and how),
  - comparisons of computed area over the observed range of stages and cross-section shape (see Appendix 5 of T&M).
- **EDA** must contain validation data (ADCP files, survey notes, AreaComp output and \*.act file).
- A plot of the validation cross section data with the prior cross section data for the existing rating is recommended.

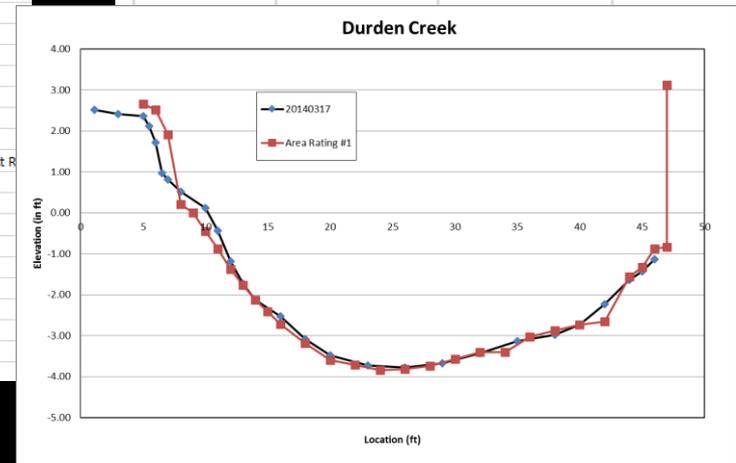
# Stage-Area Ratings – Example Validation

Durden Creek 02293252									
Cross-section location: At ADVM. Transcribed from LES fieldbook.									
Date: 3/27/2014									
Party: L. Soderqvist									
Field Data Collection						Post Processing			
Position	Location (ft)	Time (local)	Tape to WS (ft)	Tape to Land (ft)	Depth (ft)	Tape elevation	WS elevation	Cross-section elevation	
(All elevations in gage datum, in ft)									
land	1.1	10:18		0.9		3.42		2.52	
land	3			1		3.42		2.42	
land	5			1.05		3.42		2.37	
land	5.5	10:19		1.3		3.42		2.12	
land	6			1.7		3.42		1.72	
land	6.5			2.45		3.42		0.97	
land	7			2.6		3.42		0.82	
land	8	10:20		2.9		3.42		0.52	
land	10			3.3		3.42		0.12	
LEW	11	10:21	3.85	3.85	0.0	3.42	-0.43	-0.43	
water	12				0.75		-0.43	-1.18	
water	13				1.3		-0.43	-1.73	
water	14	10:23			1.7		-0.43	-2.13	
water	16				2.1		-0.43	-2.53	
water	18				2.65		-0.43	-3.08	

Stage (NAVD88)	Area Rating #1	Area Verification	% Diff
-3.5	2.4	2.0	-19%
-3	10.5	9.5	-9%
-2.5	22.3	20.9	-6%
-2	36.5	34.6	-5%
-1.5	51.8	49.8	-4%
-1	68.5	66.5	-3%
-0.5	86.5	83.8	-3%
0	105.2	101.5	-4%
0.5	124.6	119.8	-4%
1	144.3	139.2	-4%
1.5	164.1	159.0	-3%
2	184.1	179.1	-3%
2.5	204.3	199.7	-2%

Validation info must be in station analysis

Example show it in Excel



Instructions:	Time	WS	RP
1- String tape across standard cross-section	10:17	-0.44	
2- Make sure the start of the tape (low numbers) are on the LEW	10:27	-0.42	
3- Tape must be tight and level (use long level to adjust)			
4- Perform stage sensor inspection			
5- Collect cross-section data, adding/removing lines as needed			
6- Perform stage sensor inspection			
7- Perform post processing			

# I-V Ratings: Measurement Summary

- **Station Description** must contain current ADVIM configuration information. The following information must be present:

ADVIM acoustic frequency	Mounting info	Location in the water column (gage datum)	Measurement volume beginning & ending distance
Averaging period	Measurement interval	Salinity (tidal sites)	Multi-cell data (number and size of cells, cell-size, blanking distance)

# I-V Ratings: Measurement Summary

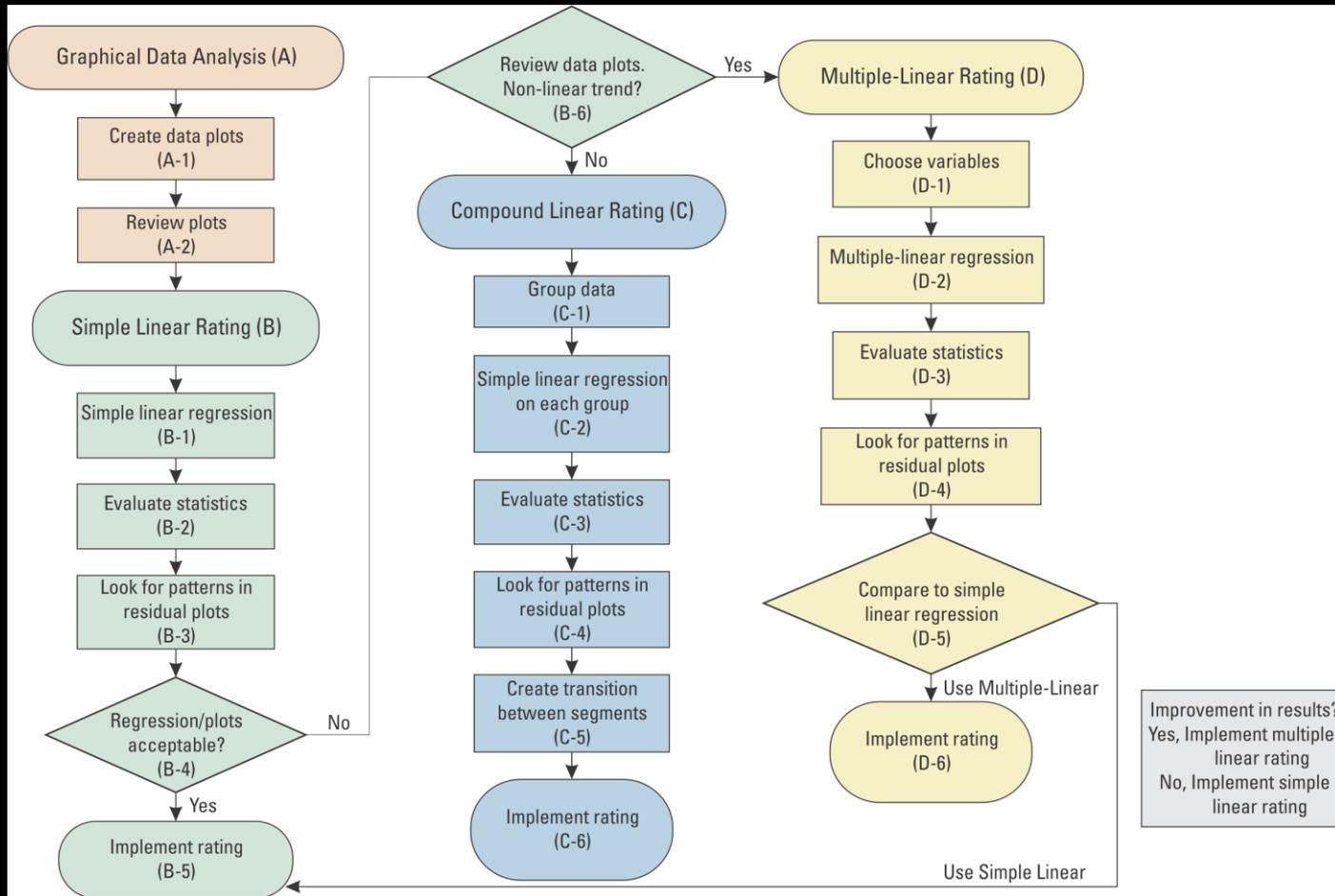
- **EDA** must contain a table (worksheet) of every Qm for the current ADVm configuration

Required Parameters			
Qm number	Qm date	Qm start/end time	Synchronized stage
Measured discharge	Rated area ( $A_{\text{rated}}$ ) for the synch. stage	Synch. index velocity for the Qm time	Measured mean velocity ( $Q/A_{\text{rated}}$ )

Sites with Shifts				
Optimal shift	Applied shift	Shifted velocity	Shifted discharge	% diff. of shifted Q from rating

Optional Parameters				
Rated Q	% diff. of measured Q from the rating	Multi-cell velocity data	Qm rating (G, F, P)	Qm comments

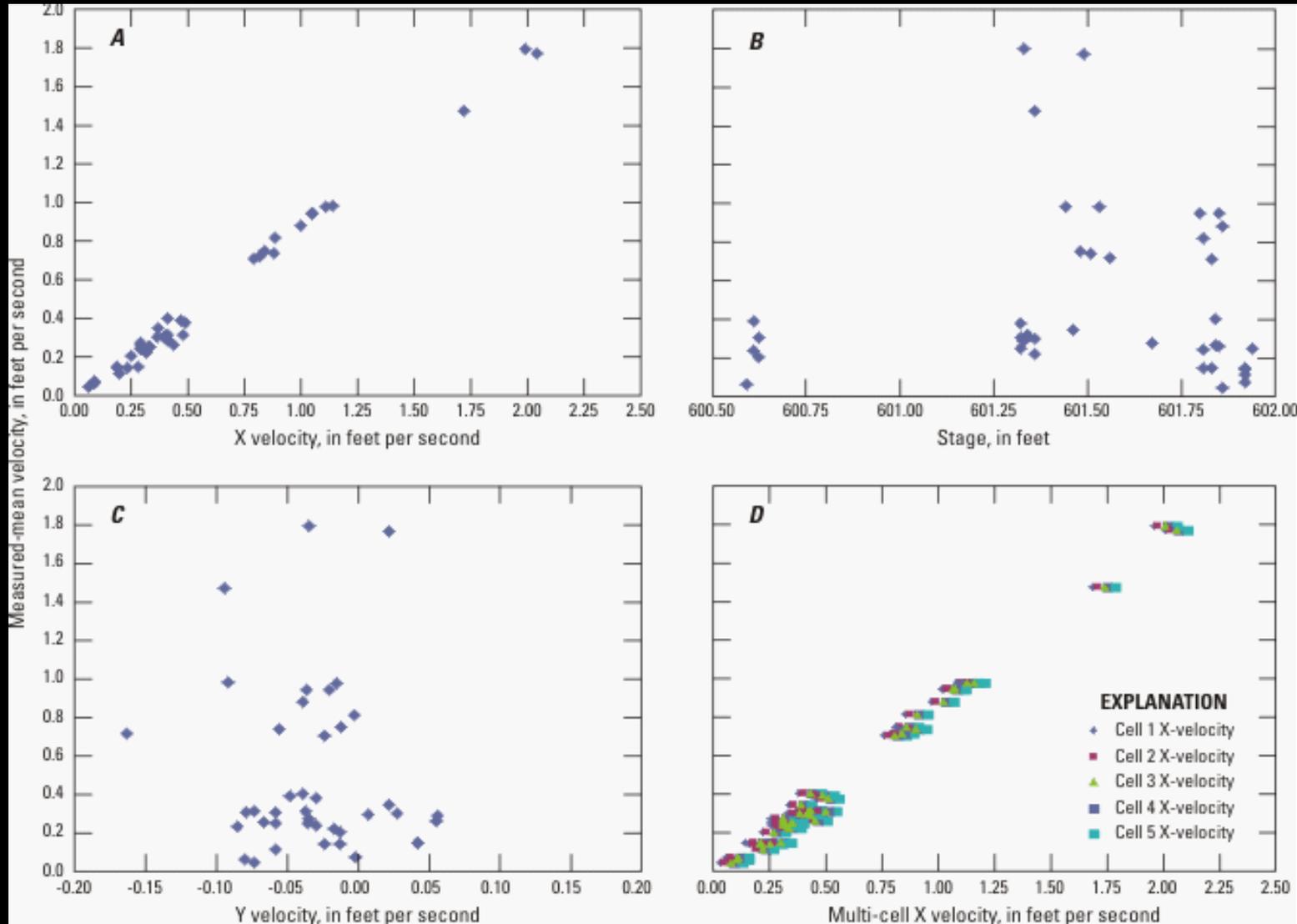
# Steps in I-V Rating Development



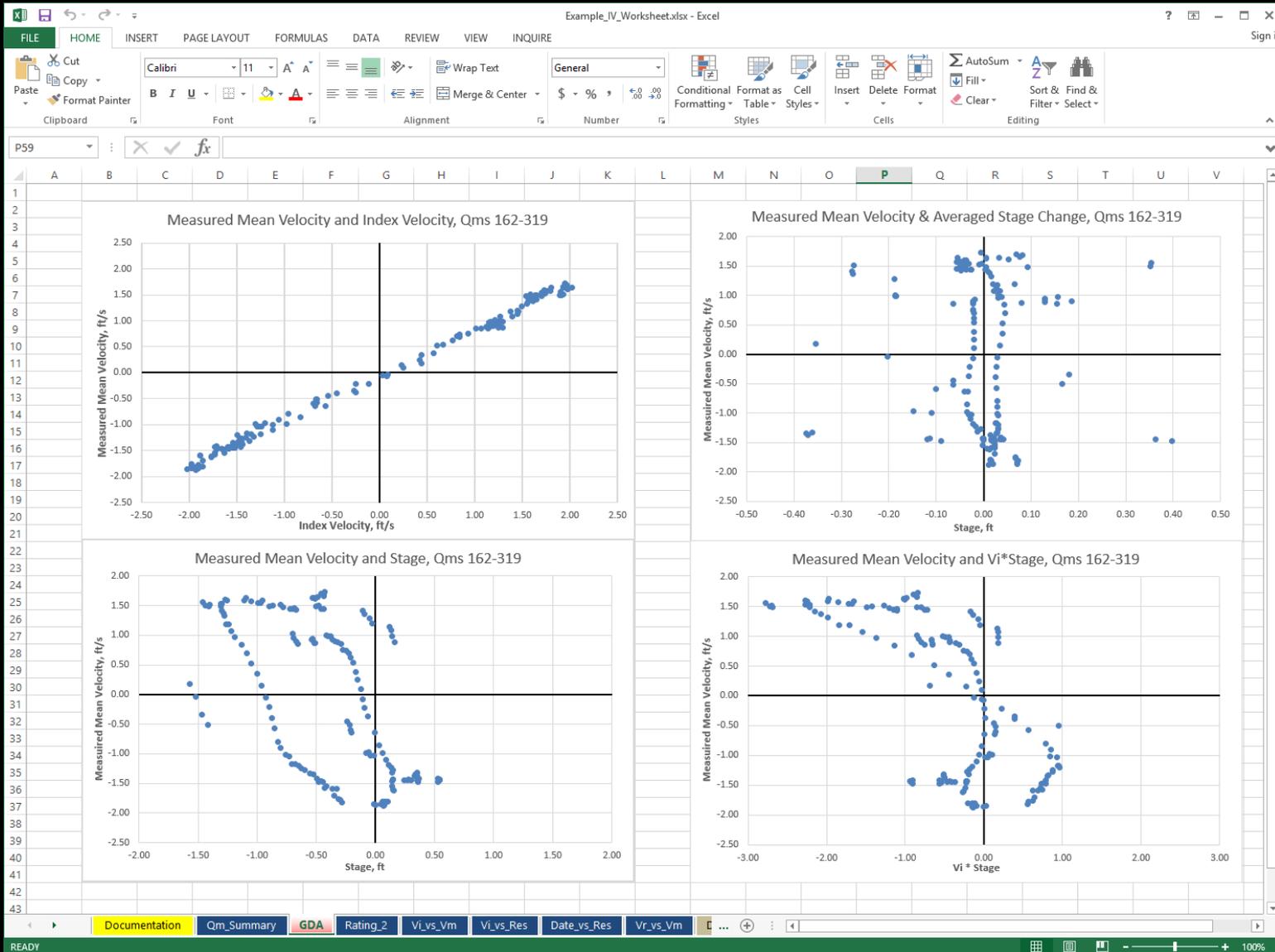
# I-V Ratings: Graphical Data Analysis Results

Documentation for Graphical Data Analysis	Requirements
1. Plot of index velocity (x) and measured mean velocity (y)	Required
2. Plot(s) of multi-cell index velocity data (x) and measured mean velocity (y)	Strongly encouraged
3. Plot of Y-velocity (sidelookers) or Z-velocity (uplookers) component (x) and measured mean velocity (y)	Strongly encouraged
4. Plots of other explanatory variables such as stage (x) and measured mean velocity (y)	Required for multiple linear ratings

# I-V Ratings: Graphical Data Analysis Results



# I-V Ratings: Graphical Data Analysis Results



# I-V Ratings: Regression Analysis Results

- Results for final rating must be stored in **EDA** and clearly identified
  - The regression analysis documentation must contain the regression software output with regression **statistics**, the regression **residuals**, **residual plots**, and **line fit plots**.
  - Required regression statistics: **number of measurements**, the **coefficient of determination** ( $R^2$ ), the **standard error of the estimate**, and the **equation coefficients**, and their associated **p-values**
- Results of any other preliminary regression analyses must be kept in the **EDA**

# I-V Ratings: Regression Analysis Results

## Regression statistics

Multiple R	0.997162
R-square	0.994332
Adjusted R-square	0.994242
Standard error	0.048462
Observations	65

## Simple Linear Regression

## ANOVA

	df	SS	MS	F	Significance F
Regression	1	25.95845	25.95845	11052.69	1.71E-72

## Regression statistics

Multiple R	0.967618
R-square	0.936284
Adjusted R-square	0.929577
Standard error	0.064607
Observations	22

## Multiple Linear Regression

## ANOVA

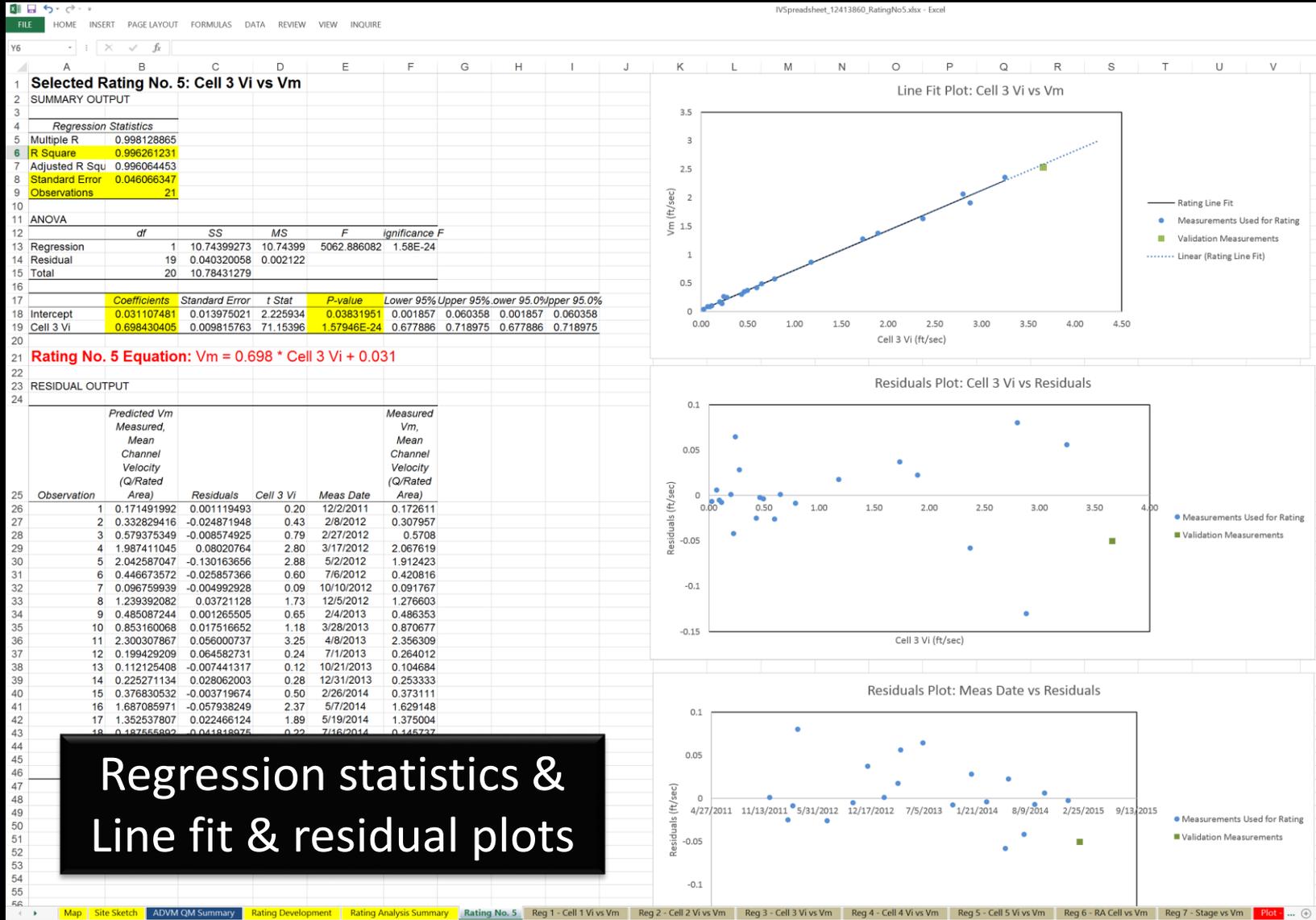
	df	SS	MS	F	Significance F
Regression	2	1.165416	0.582708	139.6	4.37E-12
Residual	19	0.079308	0.004174		
Total	21	1.244724			

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.164684	0.096255	1.710909	0.103376	-0.03678	0.366148
Vi	0.821397	0.071668	11.46108	5.61E-10	0.671393	0.971401
Vi*Stage	-0.1519	0.034217	-4.4394	0.000281	-0.22352	-0.08029

# I-V Ratings: Regression Analysis Results

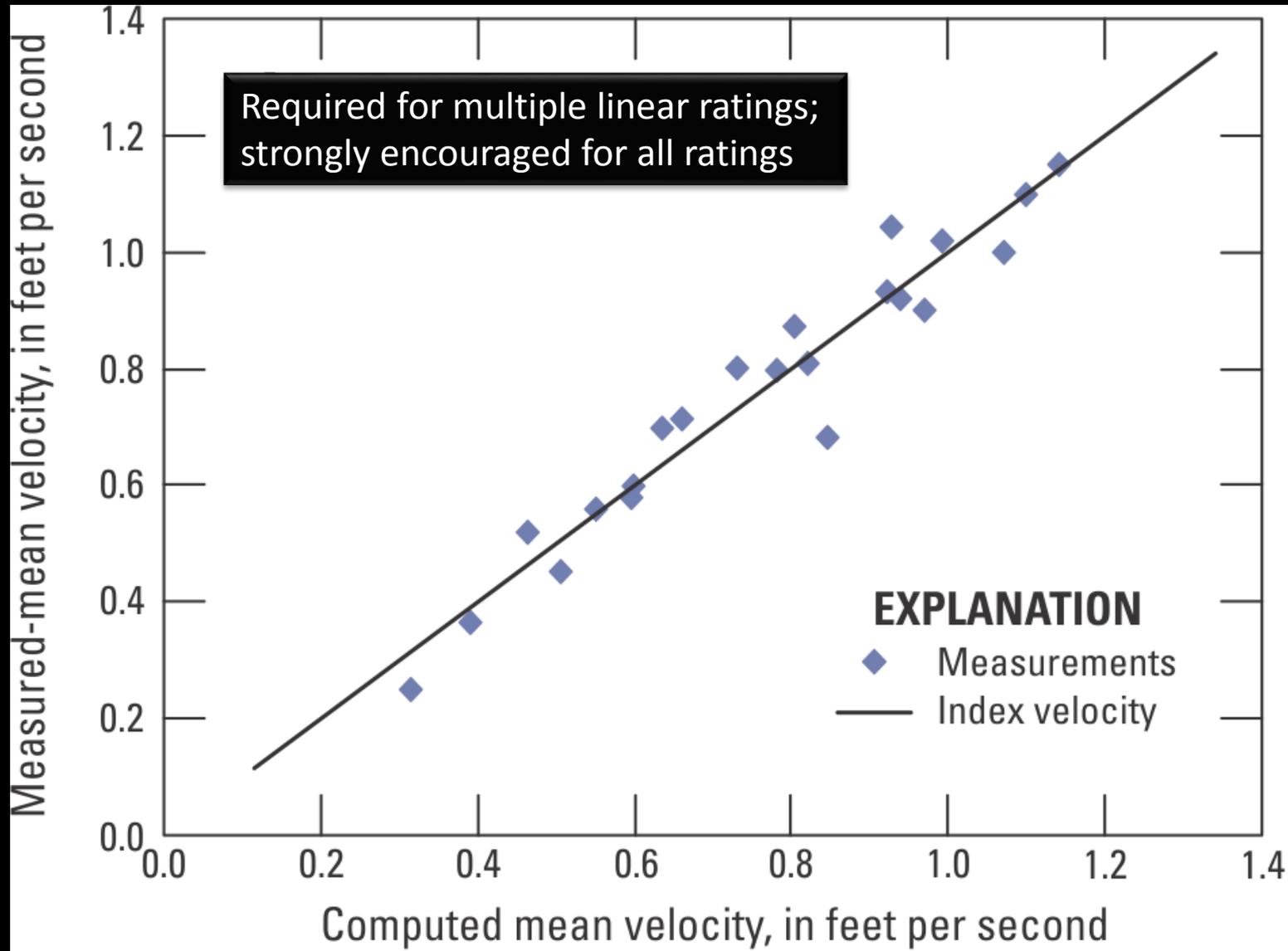
Graphical Documentation for Regression Analysis	Requirements
1. Line fit plot of index velocity (x) and measured mean velocity (y), showing Qms and rating line. (new line fit plot or augmented plot)	Required
2. Plot of rated mean velocity (x) and measured mean velocity (y)	Required for MLR; strongly encouraged for all
3. Plots of index velocity (x) and regression residuals (y)	Required
4. Plots of other explanatory variables such as I-V * stage (x) and regression residuals (y)	Required for MLR
5. Plots of Qm date (x) & regression residuals (y)	Required

# I-V Ratings: Regression Analysis Results



Regression statistics & Line fit & residual plots

# I-V Ratings: Regression Analysis Results



# I-V Ratings: Rating Information & Analysis

- **Station Analysis** MUST contain:
  - The rating number (in NWIS), measurement numbers and range in discharge of measurements used to develop the rating, justification for any measurements excluded from rating development, rating equation(s) or points used to define the rating, and the applicable dates and velocity ranges
  - Rationale for rating and description of rating development process (what variables were investigated, why was this rating chosen)
  - For previously developed rating: information on that rating and the measurements that confirm the rating
  - Justification of shifts

# I-V Ratings: Rating Information & Analysis

INDEX-VELOCITY RATING.-- The channel consists of sand, silt and mud with some rock. Both banks are covered with grass and brush. The channel is somewhat diked by Hwy 3 on the right bank and by steeper banks on the Left bank side.

Index Velocity Rating No.2.0, a linear equation, was started on Jan. 11, 2011 at 22:00 hrs. and has continued in use through this period and into the next. It uses the eight measurements from Rating 1.0 (7-13, 15) and includes eight more that were made this period. (measurements 16-23) The measurements cover a range in stage of 24.36 ft (No. 8) to 32.78 ft.(No. 18) They cover a range of measured discharge of 211 cfs (No. 13) to 18400 cfs (No. 18) The range in velocities during the measurements at the standard cross-section range from .04 ft/sec to 2.67 ft/sec. (Meas. No's. 13 and 15)

The rating equation for Rating 2.0 follows:

$$\text{Rating No. 2: } V = (V_i * 0.889) + 0.009$$

V = mean channel velocity

$V_i$  = velocity Range cell of the ADVN

For the period, IV rating 2.0 was checked with five measurements. (Meas. Nos. 30-34) Measured discharges were between 432 cfs (No.34) and 9,510cfs (No. 32). Percent differences were from - 10.8% with measurement 33 to +4.8% with measurement 31.

New measurements were added to the set of measurements that make up the equation for Rating 2.0. This was done to see if the rating could be improved. No improvements were evident. Rating 2.0 is still valid.

# I-V Ratings: Rating Information & Analysis

	A	B	C	D	E	F	
1	12413860, Coeur d'Alene River near Harrison, ID						
2	Index Velocity Rating						
3	Summary of Rating Analysis						
4	For Development of Rating No:					5	
5							
6							
7	Regression No.	Predictor of Vm	No. of Observations	R <sup>2</sup>	Standard Error	P-Value on Predictor	Remarks
8	1	Cell 1 Vi	21	0.989	0.077	3.10E-20	Concerns with use of Cell 1 - Periodically, debris can pile up on bridge where ADVm is mounted, which may cause undesirable turbulence and high variability in velocities in cell 1. Do not use as index.
9	2	Cell 2 Vi	21	0.996	0.045	1.08E-24	
10	3	Cell 3 Vi	21	0.996	0.046	1.58E-24	Selected as index
11	4	Cell 4 Vi	21	0.997	0.044	7.77E-25	
12	5	Cell 5 Vi	21	0.985	0.091	6.46E-19	Concerns with use of Cell 5 - During some periods of the year (winter), there are insufficient scatterers to reflect signal for accurate velocity measurement in cell 5. Do not use as index.
13	6	Range-Avg Cell	21	0.997	0.042	2.60E-25	Use of the Range-Avg Cell results in the highest R <sup>2</sup> and lowest standard error; however, there are some concerns with use of the range-averaged cell due to concerns noted above for cells 1 and 5. Decided not to use as index.
14	7	Stage	21	0.235	0.659	2.59E-02	Performed regression just to see if there was a linear relation. The relation is technically statistically significant (p<0.05), but it is very weak. Stage is not expected to be a significant contributor given good relations with Vi alone.
15							
16							
17	<b>Conclusion:</b>						
18							
19	Regressions were performed using measurements 227 - 248 (all measurements made since SL orientation was changed). Measurement no. 245 was not used because power was lost to the DCP and ADVm during the measurement. Measurement no. 246 was made immediately after the problem was found and was used in the regressions. Regression results are similar for						
20	cells 2 - 4 -- all had fairly high R <sup>2</sup> , relatively low standard error, and very small p-values which indicate a good linear fit between Vi and measured Vm. Decided to use Cell 3 Vi as the index,						
21	even though it didn't have the absolute "best" regression statistics. This choice was made to avoid any possible problems with wake turbulence near the ADVm and bridge piers due to						
22	variable debris pile-up (see remarks for cell 1) and with obstructions or insufficient scatterers toward the end of the measurement volume (see remarks for cell 5).						
23							

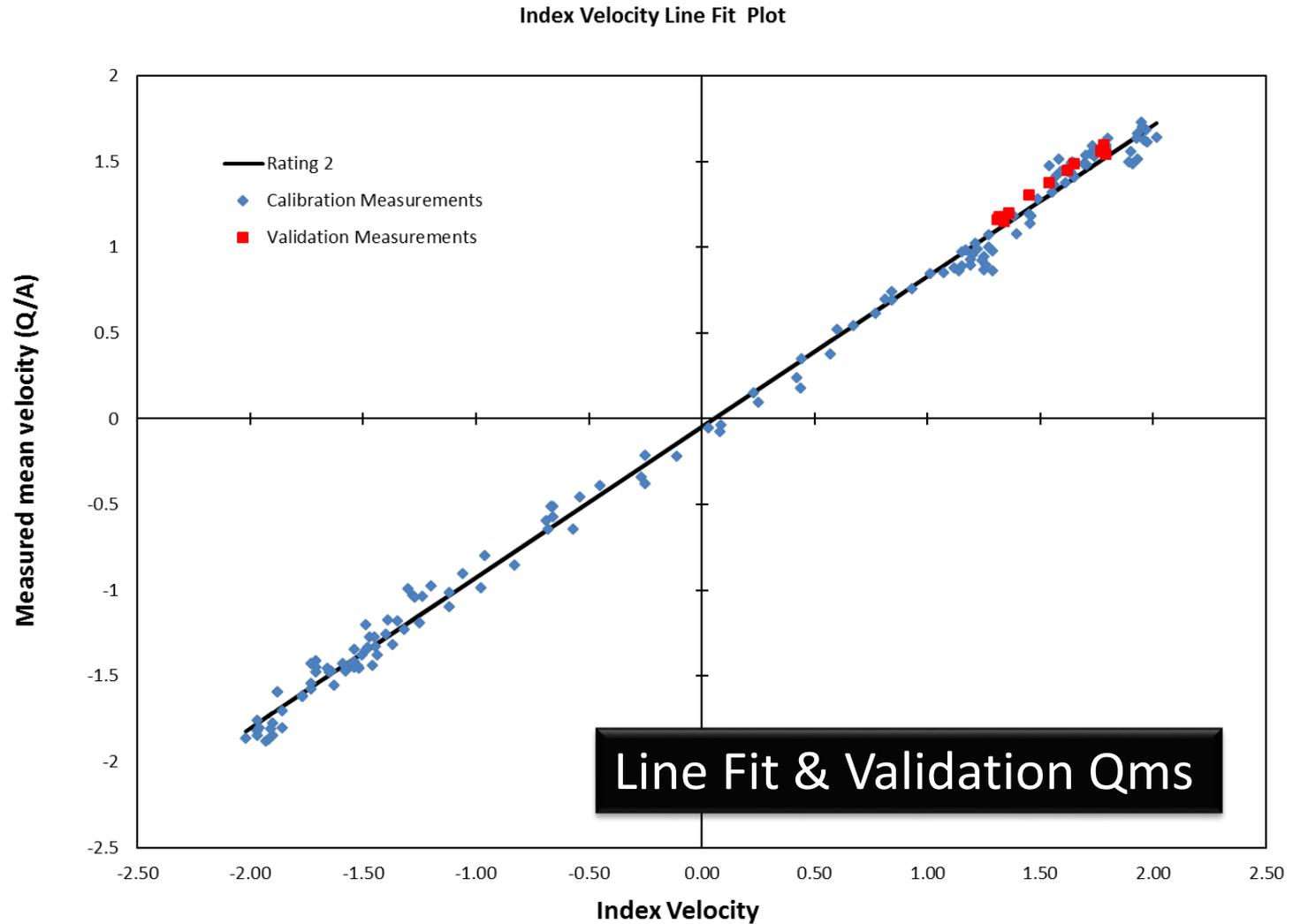
Regression/Rating analysis documented in station analysis

This example also in Excel: nice addition

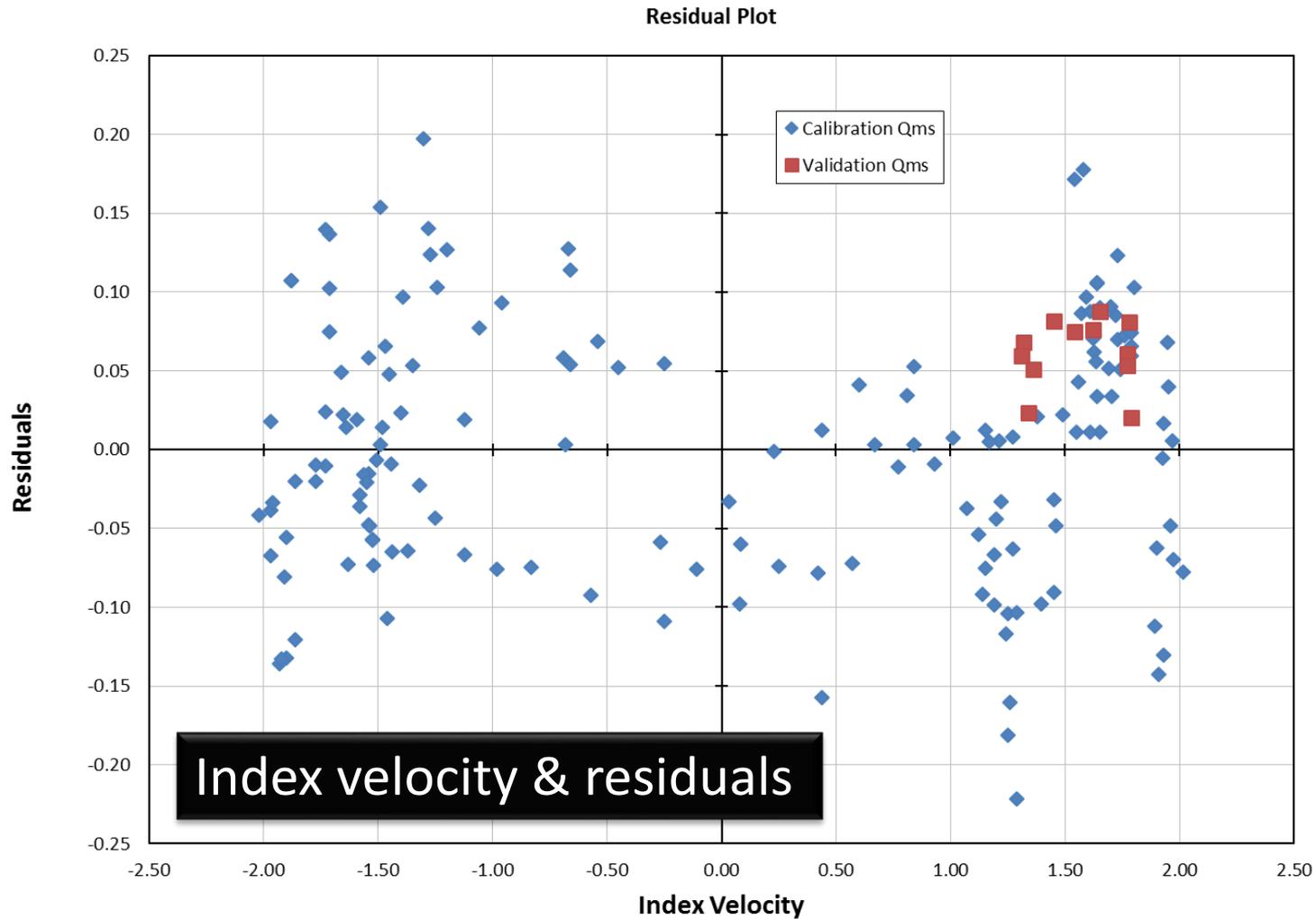
# I-V Ratings: Validation Results

- **EDA** must contain plots generated during Step 3 augmented with rating **validation Qms** as they are made.
  - Qms used to develop the initial rating may be plotted on these graphs using a unique symbol at the discretion of the hydrographer.
  - Use rating validation plots to evaluate rating bias, inherent noise, and to determine whether more complex ratings are needed.
- **Station Analysis** must contain summary of the validation results.

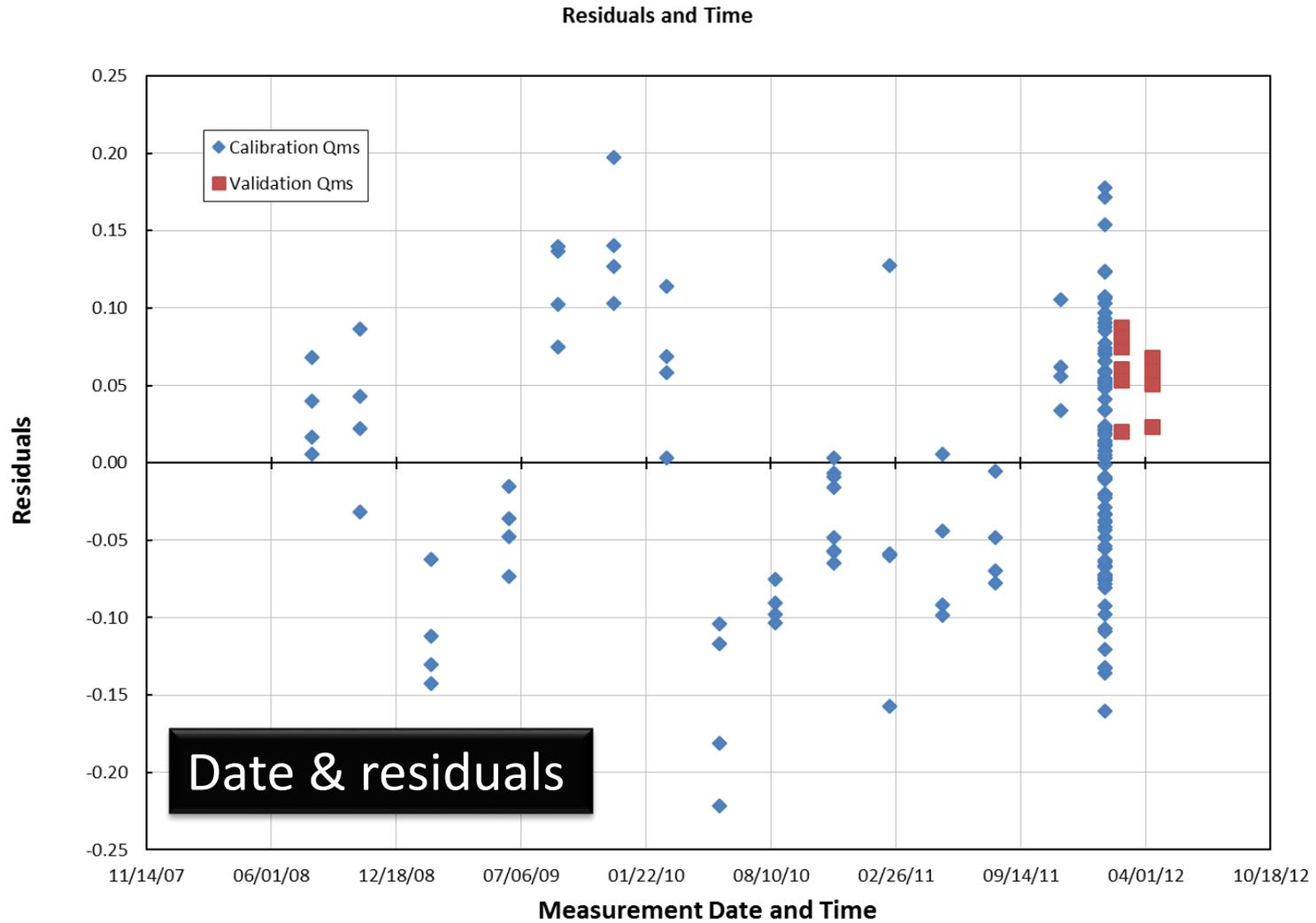
# I-V Ratings: Validation Results



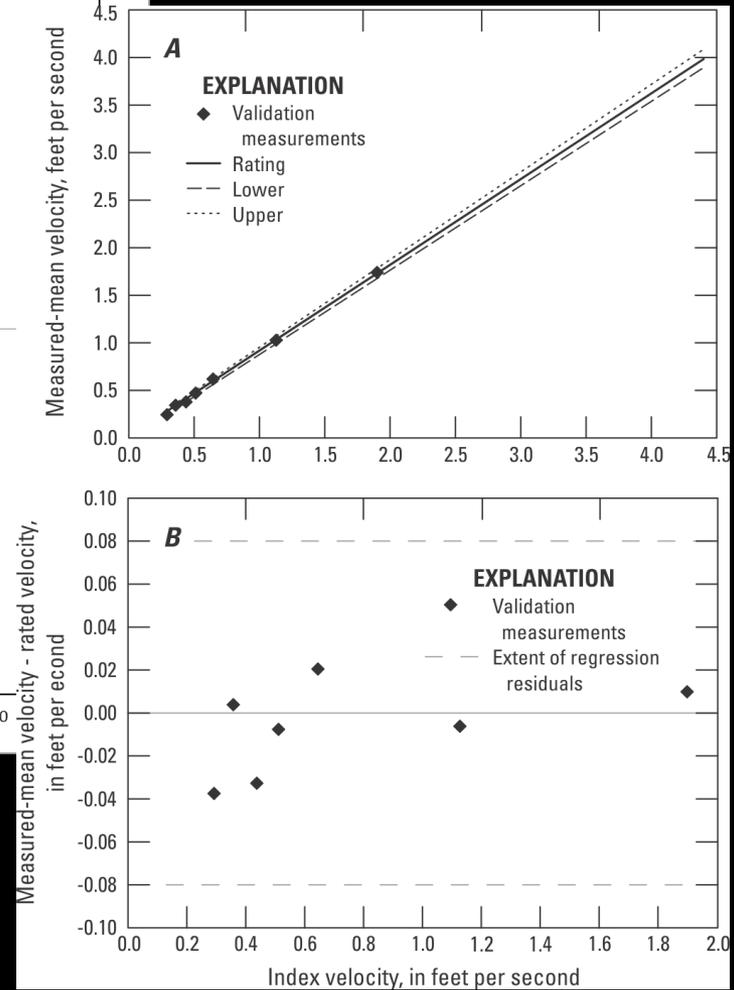
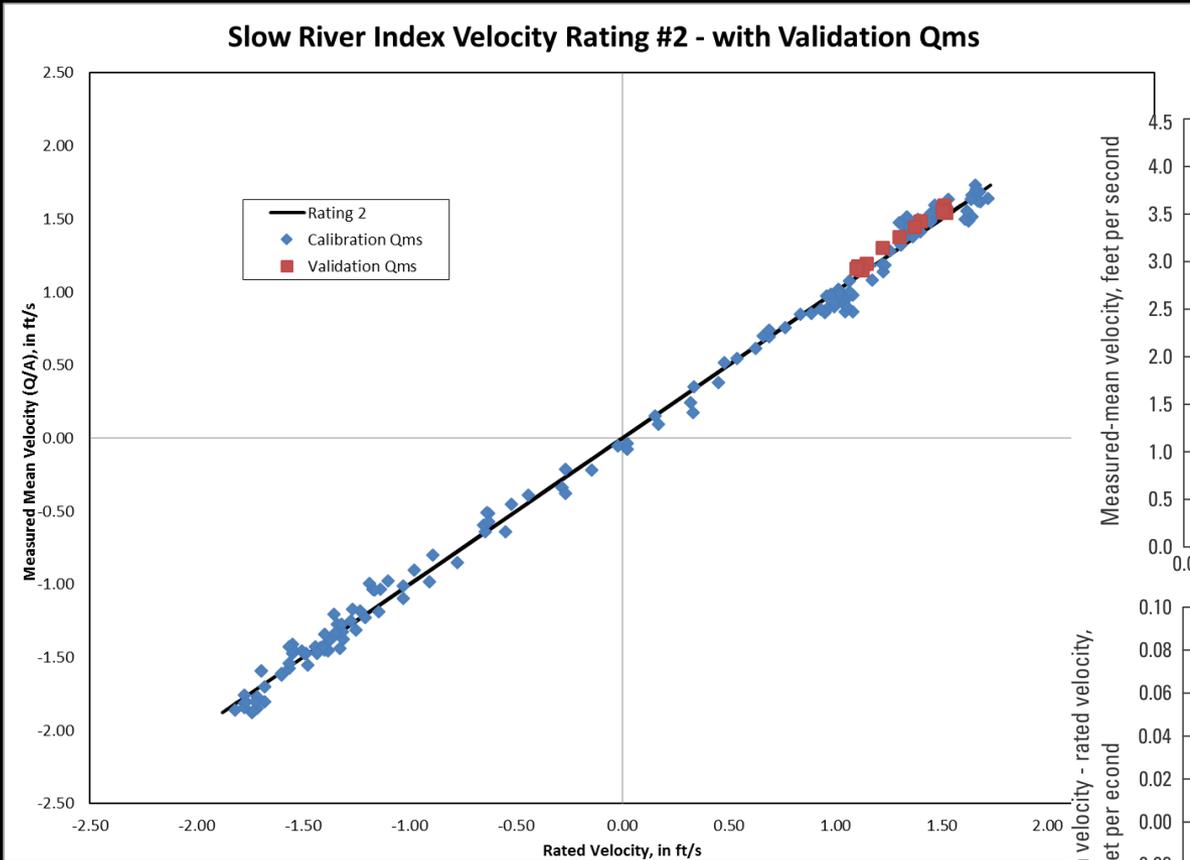
# I-V Ratings: Validation Results



# I-V Ratings: Validation Results



# I-V Ratings: Validation Results



# Index-Velocity Ratings

- Suggested Additional Documentation (store in **EDA**)
  - Photographs of the site including the measurement section(s) and the standard cross section used for the stage-area rating.
  - Ancillary data, such as multi-cell velocity data or any other information that were used in rating development or validation.
  - Hydrograph comparisons or plots with discharge from nearby or similar streamgages, if applicable.

# Summary Table – Stage-Area

## Summary of Minimum Requirements for Documenting Stage-Area Ratings

Stage-Area Rating Documentation	Electronic Data Archive (EDA) or Rating Spreadsheet/Analysis Tool	Station Analysis	Station Description
Standard cross-section field survey data: survey notes, ADCP files, etc.	Required		
Geographic location of standard cross-section	Possible <sup>1</sup>	Possible	Required
Methods and equipment used to survey standard cross-section	Possible	Possible	Required
Methods and equipment used to survey standard cross-section for current stage-area rating in use (if methods vary among surveys)	Possible	Required	
Field survey date and time	Possible	Required	Possible
Software used to develop rating (should be AreaComp2)	Possible	Required	
NWIS rating number, applicable dates, and applicable range of stage	Possible	Required	
AreaComp2 output: stage-area rating table and final cross-section table	Required		
AreaComp2 .act file	Required		
Rating validation analysis: description of survey, comparison of areas, and comparison of cross-section shape	Possible	Required	
Rating validation survey field data: survey notes, ADCP files, etc.	Required		
Rating validation survey AreaComp output and .act files	Required		

<sup>1</sup> The term "Possible" indicates that it is possible for the specified information to be documented in that location, however it also must be documented in the location listed as "Required".

# Summary Table – Index-Velocity

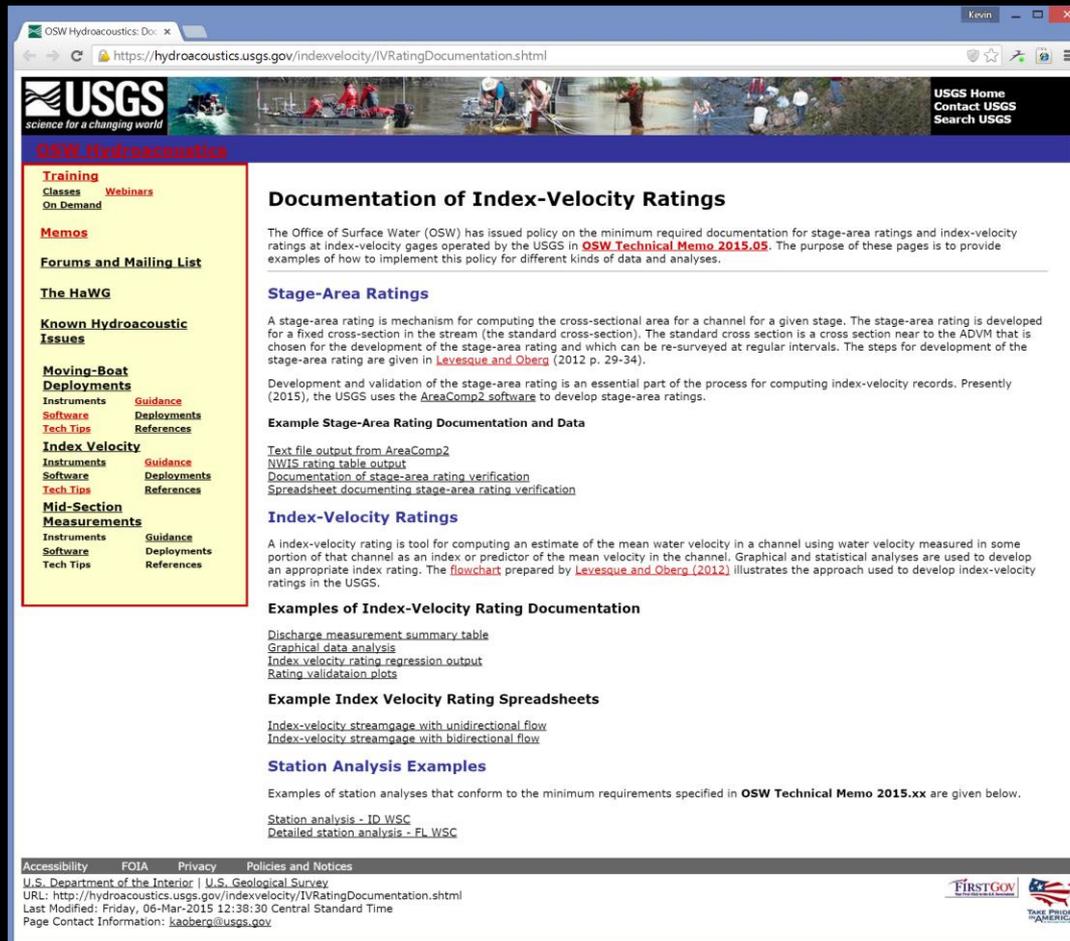
**Summary of Minimum Requirements for Documenting Index-Velocity Ratings**

Index-Velocity Rating Documentation	Electronic Data Archive (EDA) or Rating Spreadsheet/Analysis Tool	Station Analysis	Station Description
ADVM configuration information currently in use: frequency, location in the water column, mounting information, salinity used (only required for coastal sites) measurement volume beginning and ending distance, multi-cell (number and size of cells, blanking distance), averaging period, and measurement interval			Required
Measurement summary: <u>Required fields</u> : measurement number, date, start and stop times, stage, discharge, rated area, index velocity, measured mean velocity, brief justification (comment) for any measurements excluded from rating development, shift calculation and information if applicable; <u>Optional fields</u> : rated discharge, percent difference from rating, multi-cell velocity data, measurement rating, comments	Required		
Documentation for graphical data analysis	Required		
Regression analysis software output: regression statistics, regression residuals	Required		
Graphical documentation for regression analysis: line fit and residuals plots	Required		
NWIS Rating #, summary of measurements used to develop rating (numbers and range of discharge measured), justification for any measurements excluded from rating development, rating equation, applicable dates, and applicable velocity ranges	Possible <sup>1</sup>	Required	
Rationale for selected rating, such as multi-cell analysis and rating type (simple linear, compound, multi-linear), and any applied shifts	Required	Required	
Plots of validation measurements overlain on current line fit (rating) and residuals plots	Required		
Discussion of validation measurements	Possible	Required	

<sup>1</sup>The term "Possible" indicates that it is possible for the specified information to be documented in the rating spreadsheet, however it also must be documented in the location listed as "Required".

# Example Documentation

<http://hydroacoustics.usgs.gov/indexvelocity/IVRatingDocumentation.shtml>



The screenshot shows a web browser window displaying the USGS Hydroacoustics website. The page title is "Documentation of Index-Velocity Ratings". The left sidebar contains a navigation menu with categories like Training, Memos, Forums and Mailing List, The HaWG, Known Hydroacoustic Issues, Moving-Boat Deployments, Index Velocity, Mid-Section Measurements, and Examples of Index-Velocity Rating Documentation. The main content area includes sections for Stage-Area Ratings, Index-Velocity Ratings, and Examples of Index-Velocity Rating Documentation. The footer contains accessibility information, FOIA, Privacy, and Policies and Notices, along with the USGS logo and the "FIRST GOV" logo.

**OSW Hydroacoustics**

**Documentation of Index-Velocity Ratings**

The Office of Surface Water (OSW) has issued policy on the minimum required documentation for stage-area ratings and index-velocity ratings at index-velocity gages operated by the USGS in [OSW Technical Memo 2015.05](#). The purpose of these pages is to provide examples of how to implement this policy for different kinds of data and analyses.

**Stage-Area Ratings**

A stage-area rating is mechanism for computing the cross-sectional area for a channel for a given stage. The stage-area rating is developed for a fixed cross-section in the stream (the standard cross-section). The standard cross section is a cross section near to the ADVN that is chosen for the development of the stage-area rating and which can be re-surveyed at regular intervals. The steps for development of the stage-area rating are given in [Levesque and Oberg \(2012 p. 29-34\)](#).

Development and validation of the stage-area rating is an essential part of the process for computing index-velocity records. Presently (2015), the USGS uses the [AreaComp2 software](#) to develop stage-area ratings.

**Example Stage-Area Rating Documentation and Data**

- [Text file output from AreaComp2](#)
- [NWIS rating table output](#)
- [Documentation of stage-area rating verification](#)
- [Spreadsheet documenting stage-area rating verification](#)

**Index-Velocity Ratings**

An index-velocity rating is tool for computing an estimate of the mean water velocity in a channel using water velocity measured in some portion of that channel as an index or predictor of the mean velocity in the channel. Graphical and statistical analyses are used to develop an appropriate index rating. The [flowchart](#) prepared by [Levesque and Oberg \(2012\)](#) illustrates the approach used to develop index-velocity ratings in the USGS.

**Examples of Index-Velocity Rating Documentation**

- [Discharge measurement summary table](#)
- [Graphical data analysis](#)
- [Index velocity rating regression output](#)
- [Rating validation plots](#)

**Example Index Velocity Rating Spreadsheets**

- [Index-velocity streamgage with unidirectional flow](#)
- [Index-velocity streamgage with bidirectional flow](#)

**Station Analysis Examples**

Examples of station analyses that conform to the minimum requirements specified in [OSW Technical Memo 2015.xx](#) are given below.

- [Station analysis - ID\\_WSC](#)
- [Detailed station analysis - FL\\_WSC](#)

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

URL: <http://hydroacoustics.usgs.gov/indexvelocity/IVRatingDocumentation.shtml>

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# Questions?

