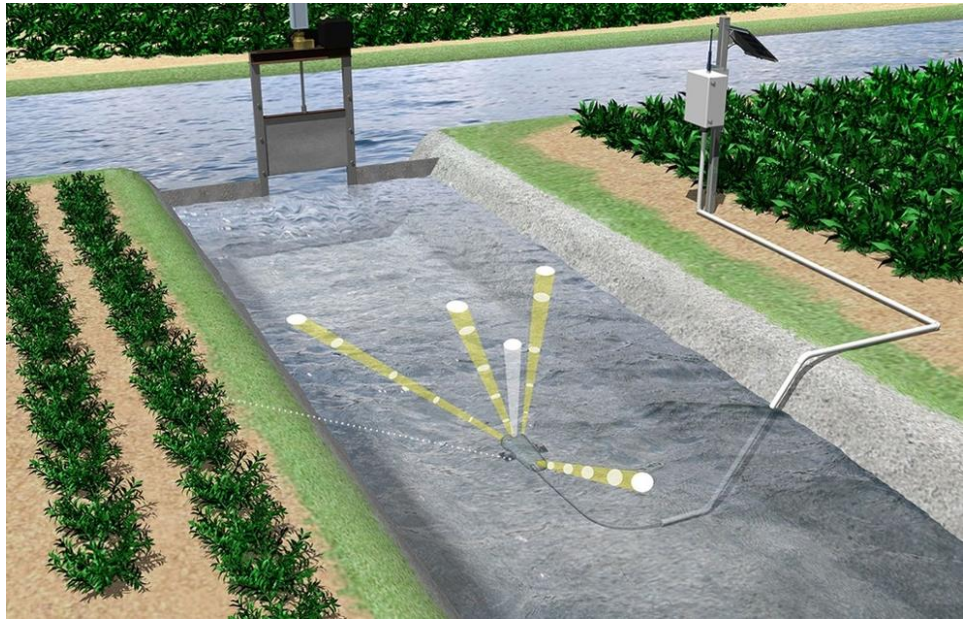
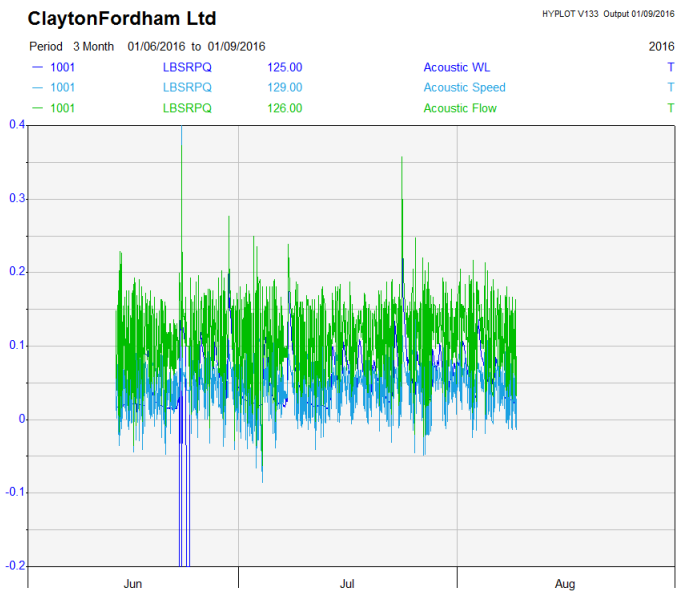
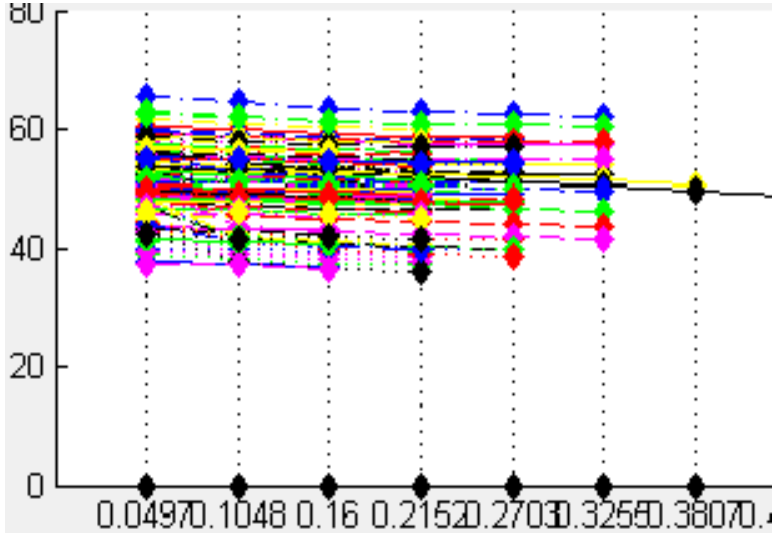
Using acoustic monitoring to determine suspended sediment loads







Ed Clayton

Introduction

- Assessment of an acoustic sensor
- Two month study – first test site
- Comparison against:
  - Laboratory measured TSS & Turbidity
  - In situ TSS/Turbidity sensor

- Can we replace current automated sampling units with these sensors?

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Monitoring of SRP's

- Auckland Plan lists sediment as a contaminant of concern

- Currently some earthworks sites require automated monitoring
  - Adaptive Environmental Monitoring and Management Response Plans
  - Can require manual grab sampling following an event
  - Can include automated monitoring

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Automated site setups

- What is the aim of monitoring?
  - Time series information of water level and flow
  - Volume based discrete sampling of events
  - Telemetered – can text and email alarms if required

- Total sediment yield

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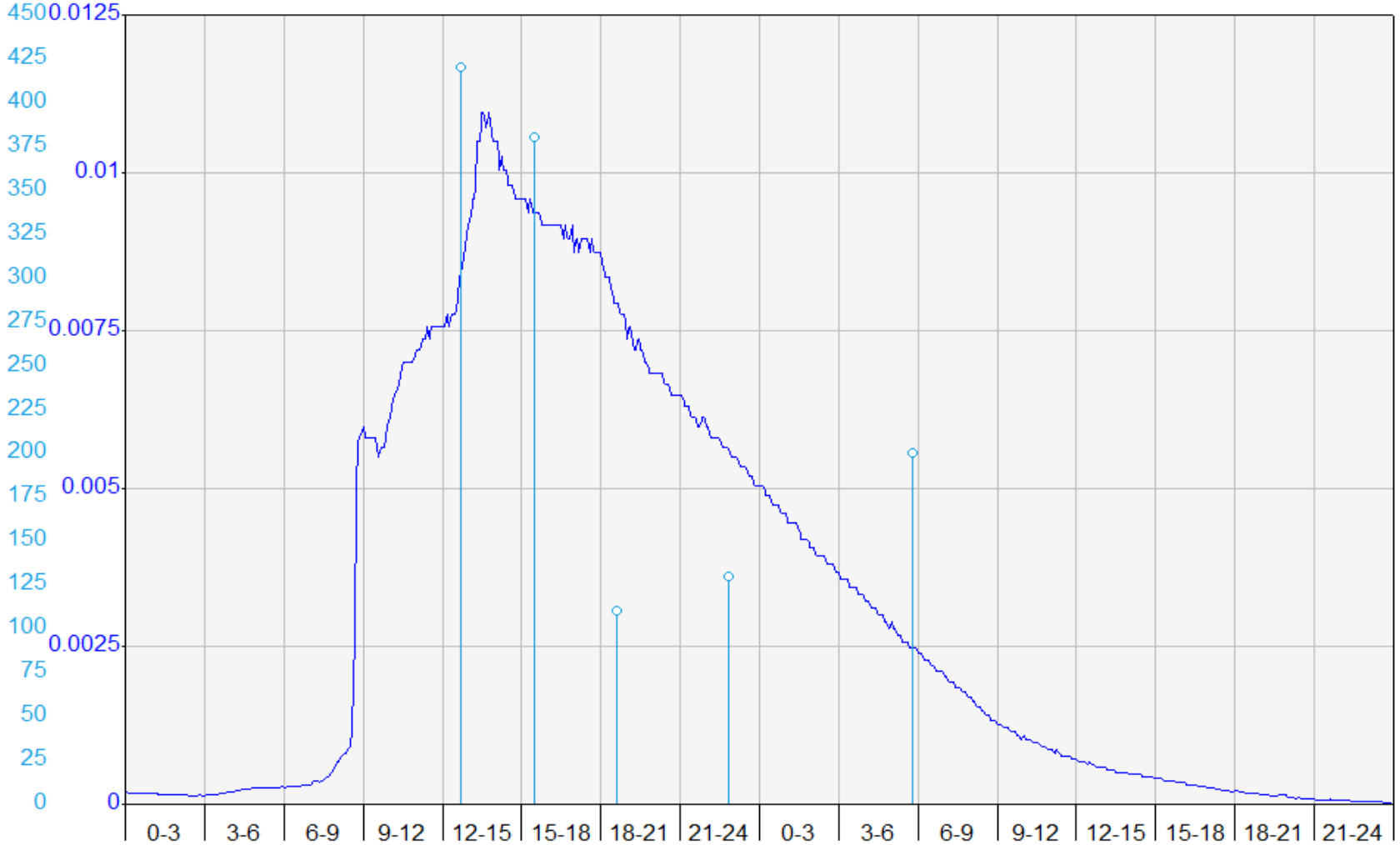
HYPLOT V133 Output 20/07/2016

Period 2 Day 29/06/2016 to 01/07/2016 2016

— 1005	140.00	Discharge (m3/s)	C
-o- 1005	845.00	TSS (mg/l)	C



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Sampler Event Discharge June 29 2016

Event sediment yield:	135	kg
Event total water discharge:	549	m^3
Event peak discharge:	11	l/s

Bottle number	Time_Date	Volume between bottles (m3)	Mean flow between bottles (l/s)	Lab sediment concentration (mg/l)	Bottle mean sediment discharge (g/s)	Time between bottles (s)	Bottle sediment yield (kg)	Accumulated yield(kg)	Flow at point of sample (L/s)
Trigger	00:00_29/06/2016	0	0	0	0	0	0	0	0.19
160707-104-2	12:41_29/06/2016	106.66	2.33	420	0.98	45685	44.80	44.80	8.40
160707-104-3	15:30_29/06/2016	100.07	9.88	380	3.75	10133	38.02	82.82	9.38
160707-104-4	18:38_29/06/2016	99.72	8.87	110	0.98	11237	10.97	93.79	7.94
160707-104-5	22:51_29/06/2016	99.92	6.58	130	0.86	15178	12.99	106.78	5.63
160707-104-6	05:46_30/06/2016	99.53	3.99	200	0.80	24924	19.91	126.69	2.48
Reset*	00:00_01/07/2016	43.61	0.66	0	0.00	65643	8.72	135.41	0.03

***Reset uses previous sample concentration to measure sediment yield**

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Acoustic sensor – Test Site 1

- Sontek IQ - Xylem
  - Utilises 3000khz frequency
  - 5 transducers
  - Measures velocity, water depth, water temperature and associated parameters

- Built to measure flow instantly without needing to create a flow rating

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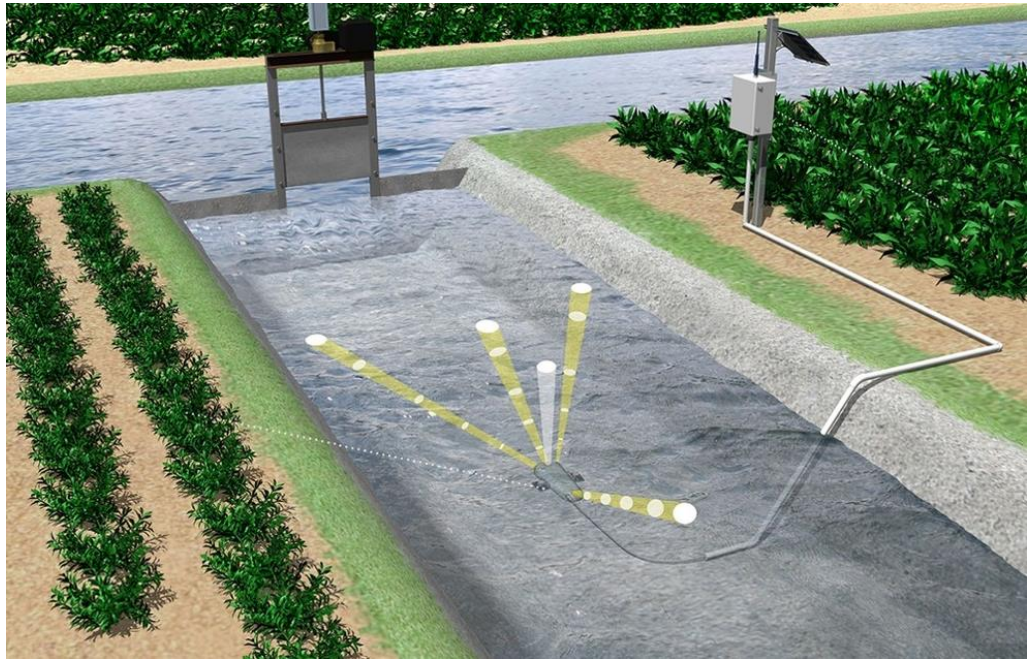
Acoustic sensor

- Can measure the entire cross section of a channel



(www.ekotechnika.cz)

(www.sontek.com)

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Acoustic sensor

- Signal to Noise Ratio (SNR) measures the backscatter (noise) compared to the outgoing signal.
  - Higher SNR = more particles in the water
- Corrected against site samples (from discrete sampling) and measured water temperature
- ‘Sediment Corrected Backscatter’

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Acoustic sensor

- Advantage compared to discrete sampling:
  - Measures the whole cross section – less error due to sampling location
  - Time series – frequency of measurement can be set
  - Real time information
  - Less time required on site and lower cost of laboratory sampling

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Test Site 1: Site deployment

- Sensors:
  - Pressure transducer with temperature
  - Automatic Sampler – volume based sampling
  - Turbidity & TSS sonde
  - Sontek IQ

- Datalogger measuring at 5 minute intervals
- 12 volt solar
- Outfall of two sediment retention ponds plus one DEB

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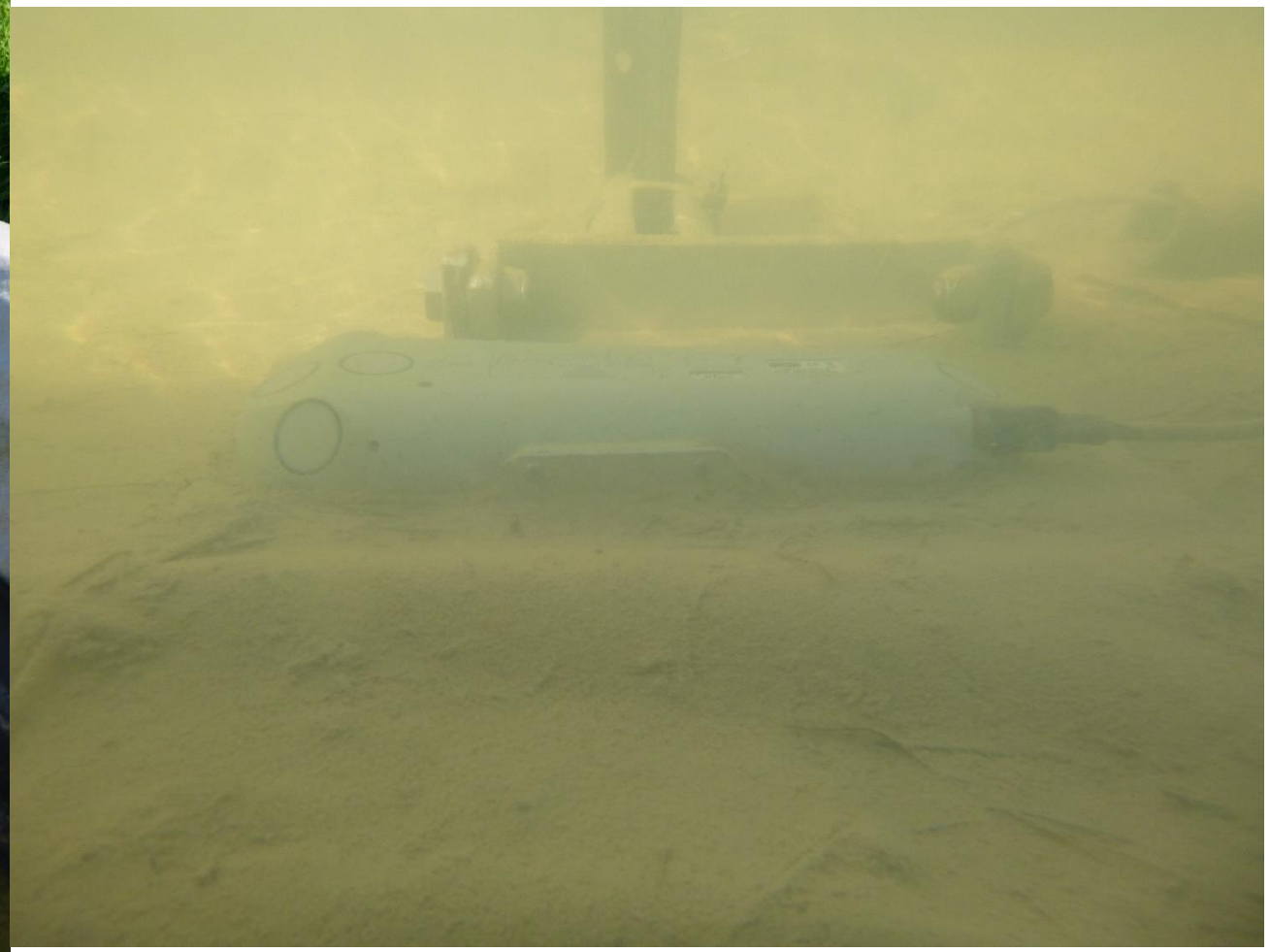

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Test Site 1: Acoustic data

- Poor accuracy when velocity was low
- Better accuracy when levels are around 100mm or higher above v-notch
  - Flow rates of 2< litres per second
  - Higher velocity
- Sediment deposition on sensor

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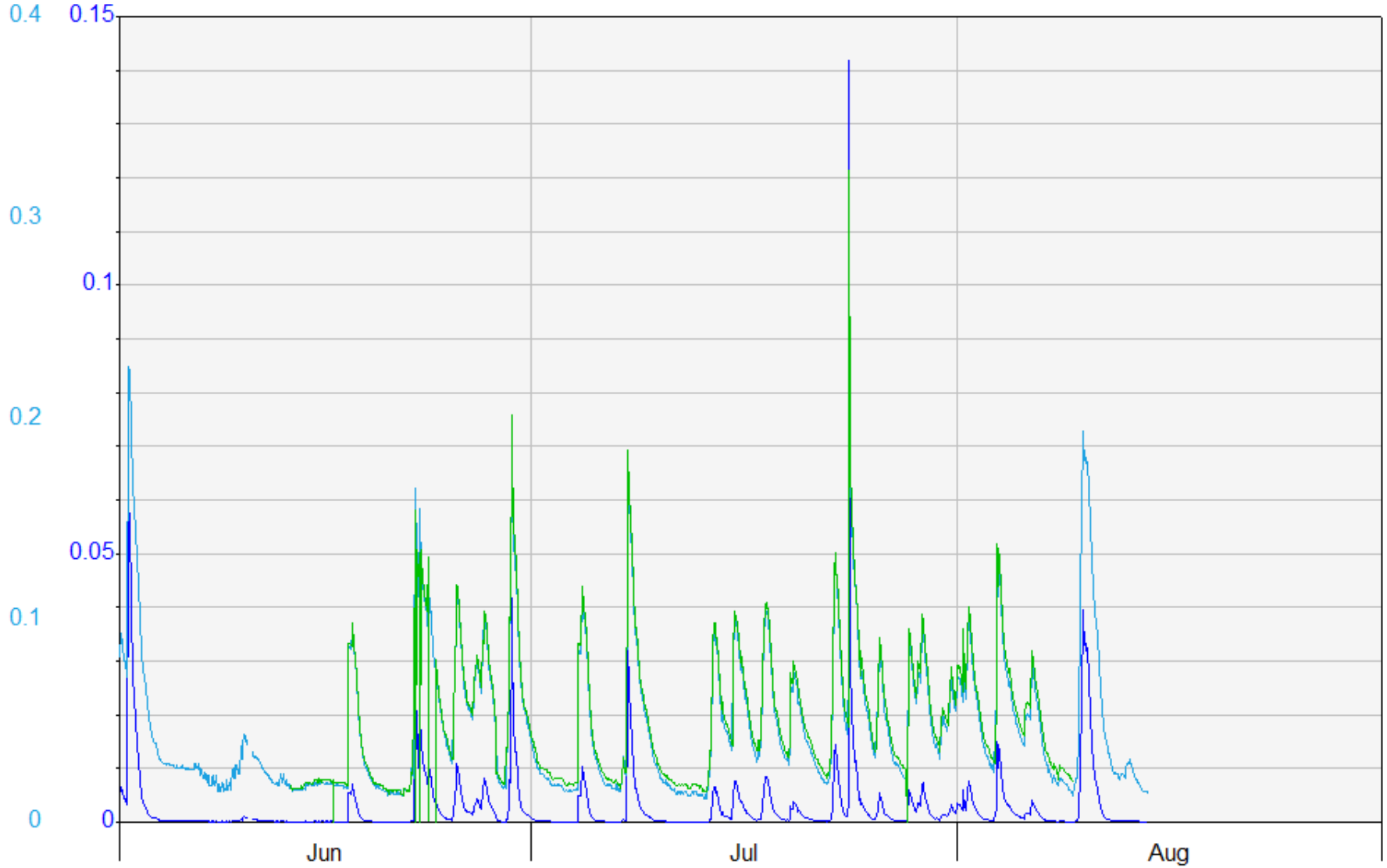
HYPLOT V133 Output 01/09/2016

Period 3 Month 01/06/2016 to 01/09/2016 2016

— 1001	140.00	Discharge (m3/s)	B
— 1001	100.00	Level (m)	B
— 1001	125.00	Acoustic WL	T



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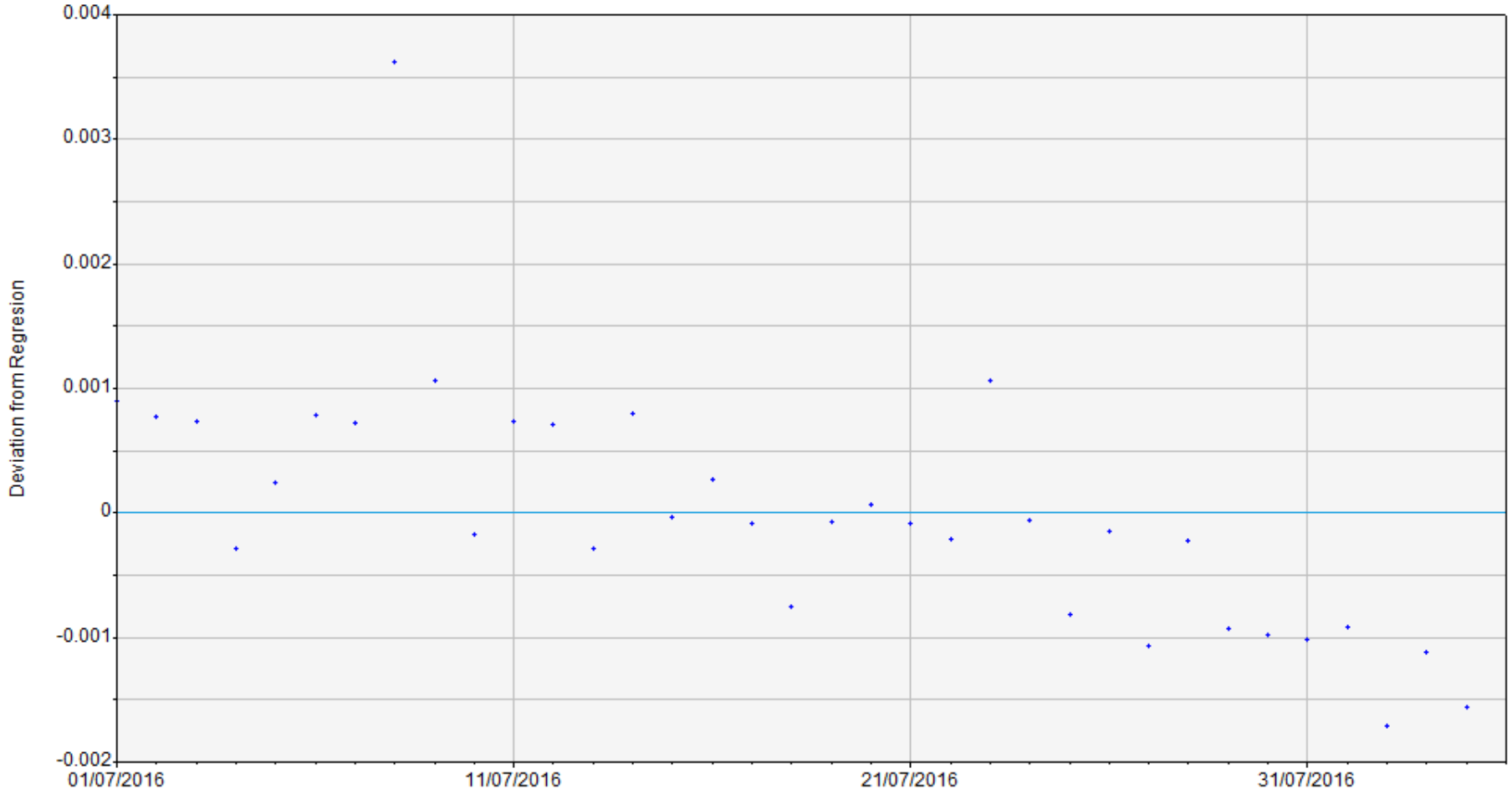
HYPLOTXY V137 Output 01/09/2016

Regression	Transform	Site	DataSource	Type	Variable
X (ind)	(None)	1001	B	Inst.	125.00 Acoustic WL
Y (dep)	(None)	1001	B	Inst.	100.00 Level (m)

Interval	1 Day	Equation	Y = 0.993 * X - 0.004
Start	00:00_01/07/2016	Correlation Coefficient	1.000
End	00:00_05/08/2016	Standard Error of Estimate	0.001
Points	35		



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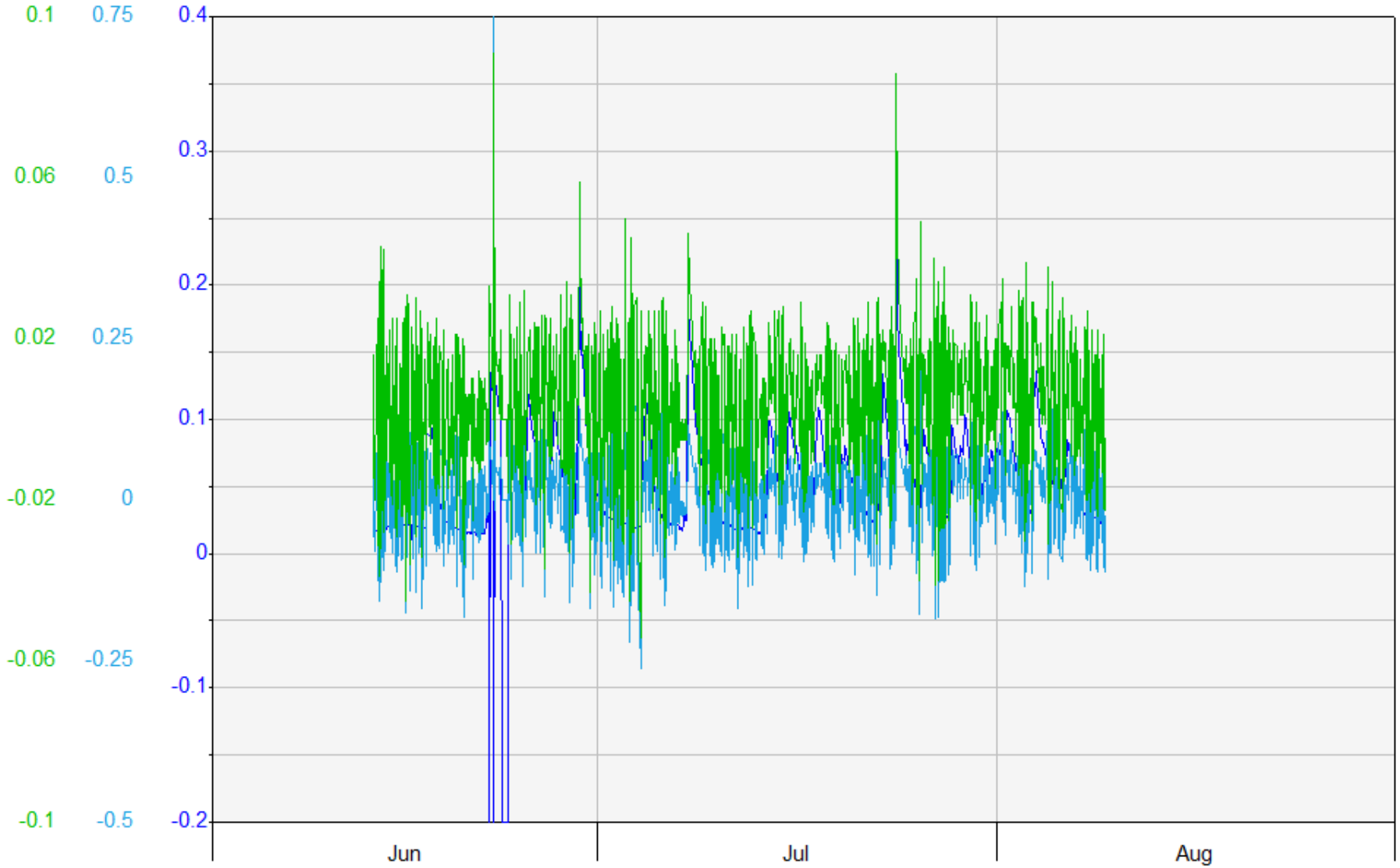
HYPLOT V133 Output 01/09/2016

Period 3 Month 01/06/2016 to 01/09/2016 2016

— 1001	125.00	Acoustic WL	T
— 1001	129.00	Acoustic Speed	T
— 1001	126.00	Acoustic Flow	T



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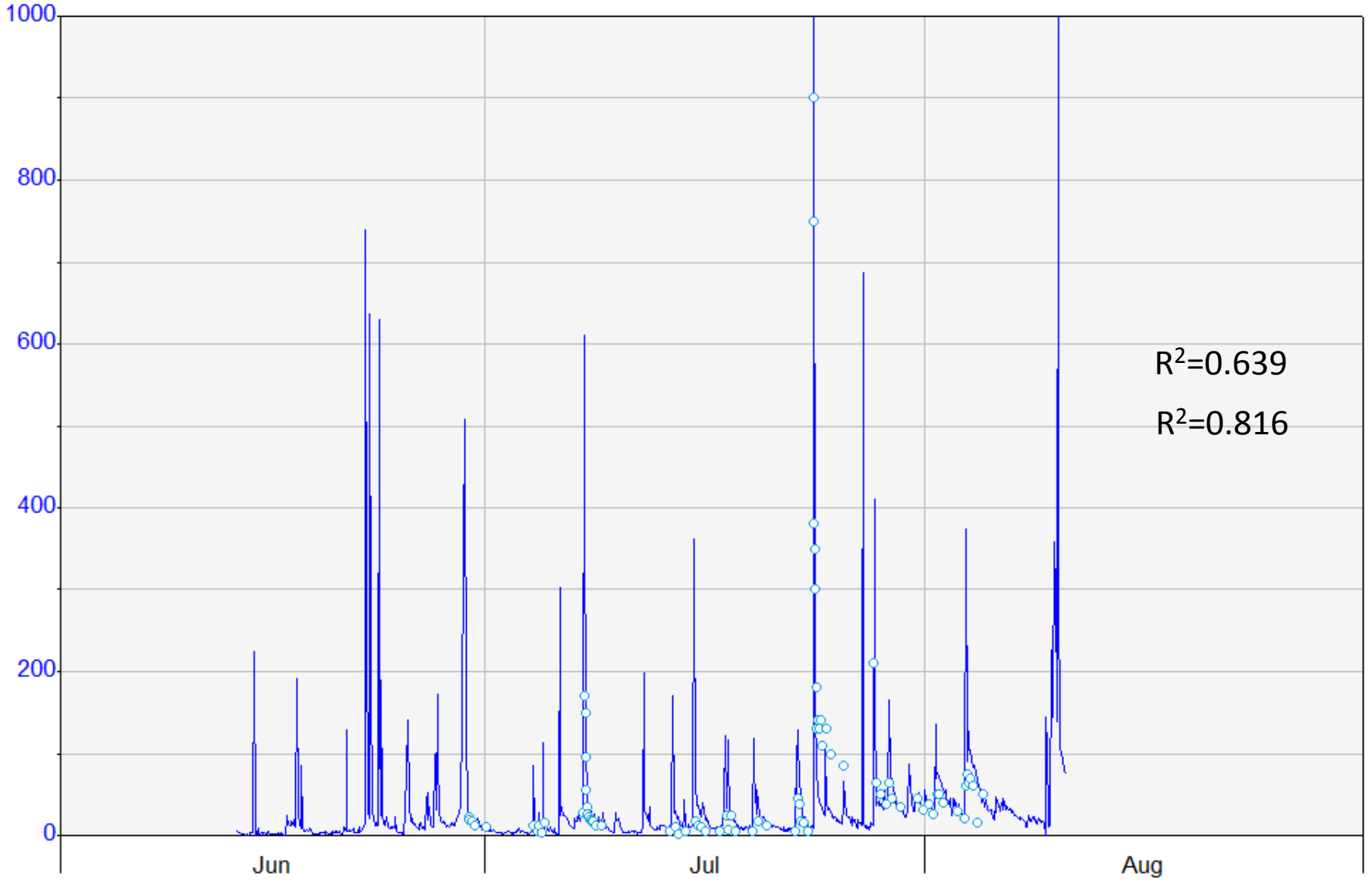
HYPLOT V133 Output 01/09/2016

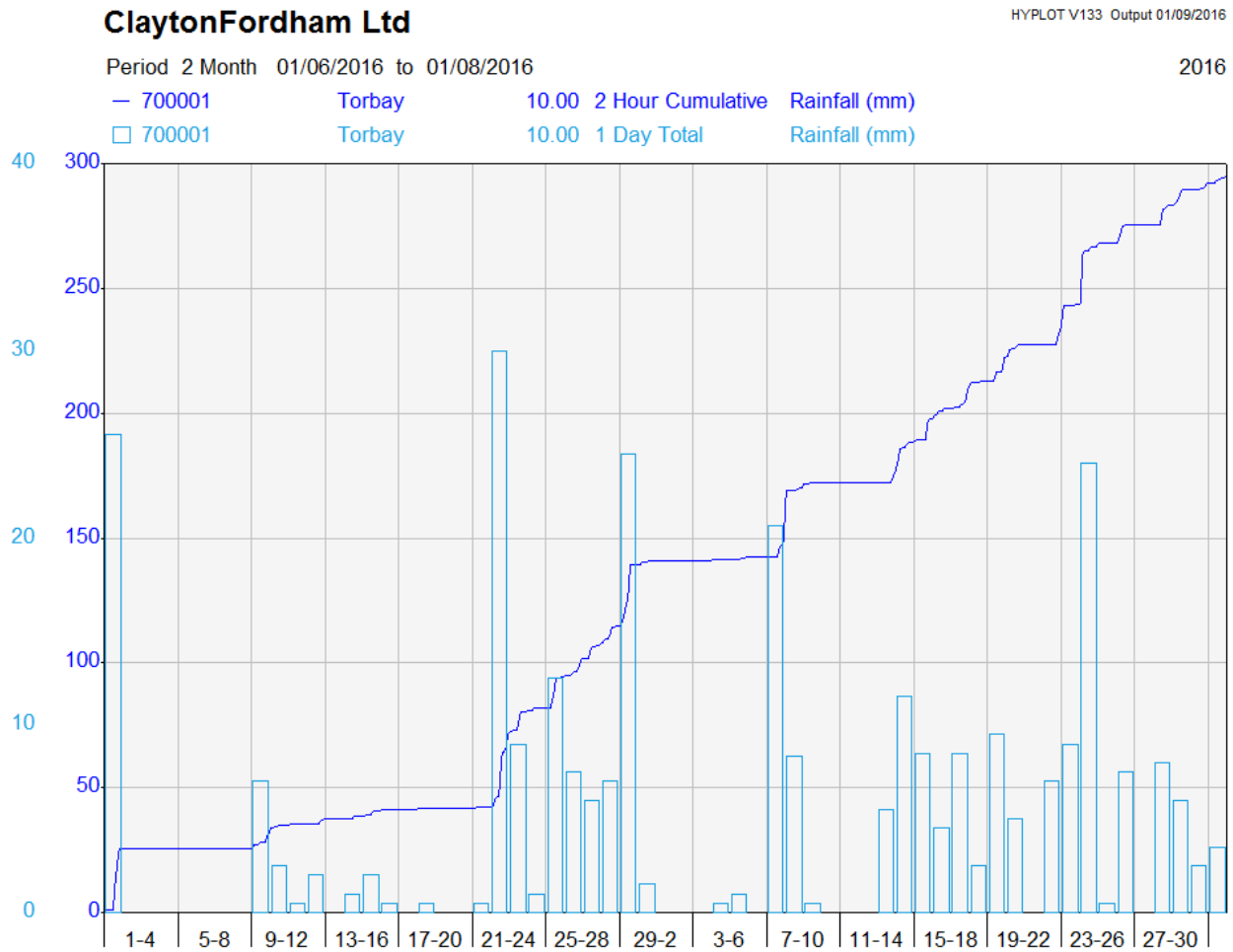
Period 3 Month 01/06/2016 to 01/09/2016 2016

— 1001	810.00	Turbidity (NTU)	B
○ 1001	809.00	Lab Turb	B



Test Site 1: Storm events

- Multiple events during monitoring period
  - 317mm of rain
  - Max one hour intensity 16.25mm
  - Max 24 hour intensity 30.50 mm



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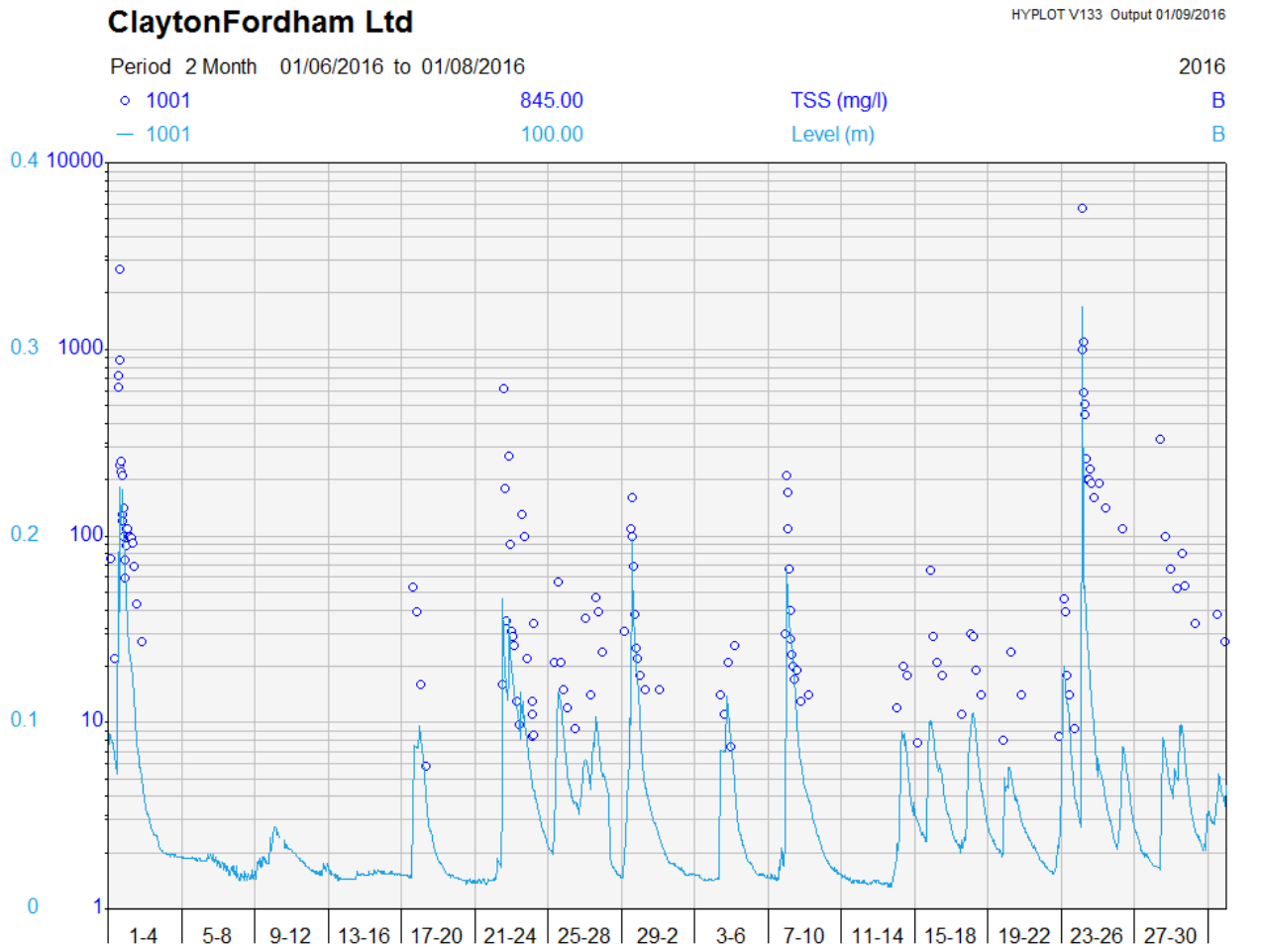
Test Site 1: Storm events

- Total flow: 12,295 m^3
- Peak flow: 141 l/s
- Total sediment yield (from discrete samples): 1,725 kg



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Test Site 1: Processing of acoustic data

- Adjustment of data using water temperature and discrete sediment samples

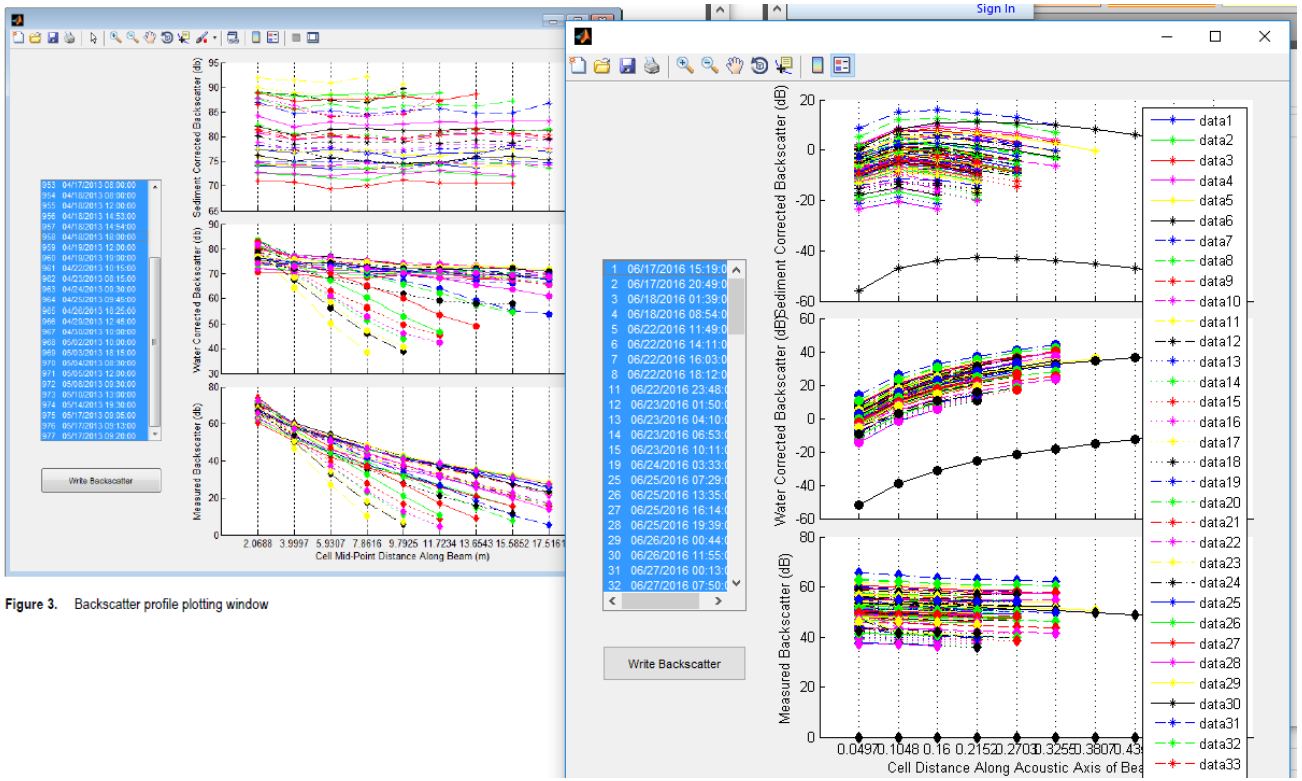

Figure 3. Backscatter profile plotting window

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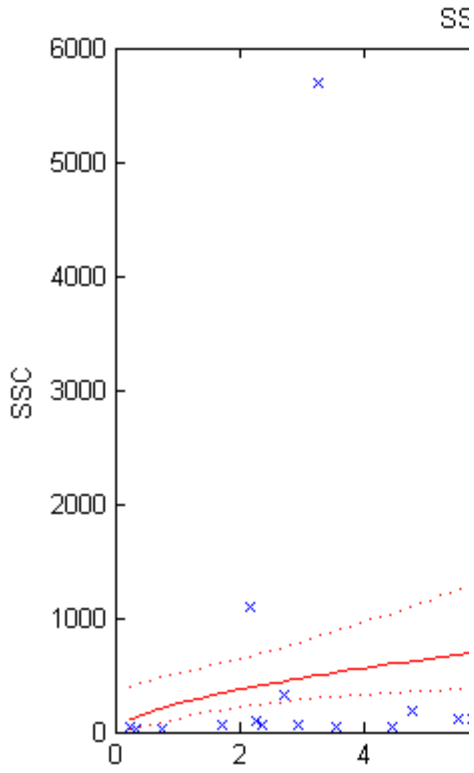
Test Site 1: Processing of acoustic data

- For entire Datas rrected backscatter and observed s



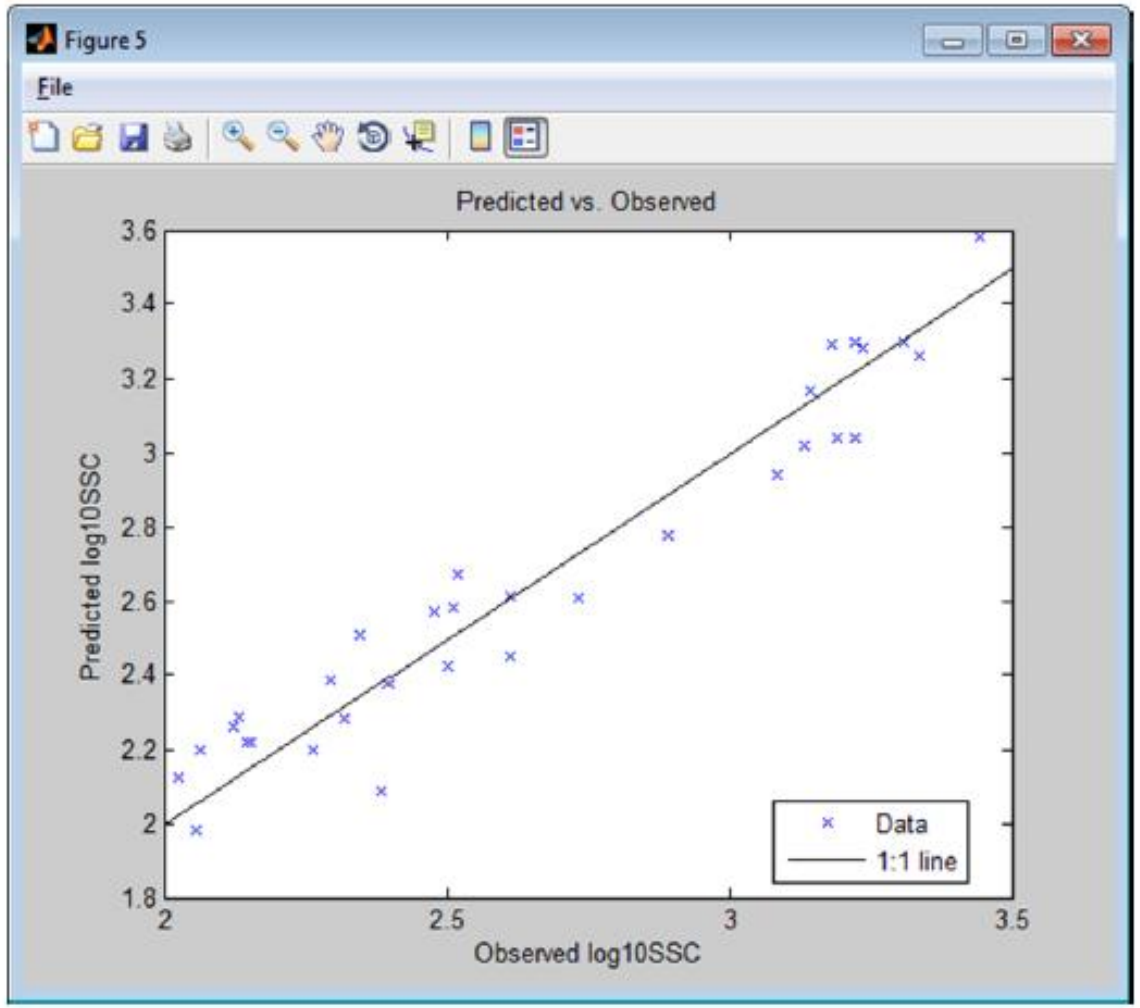
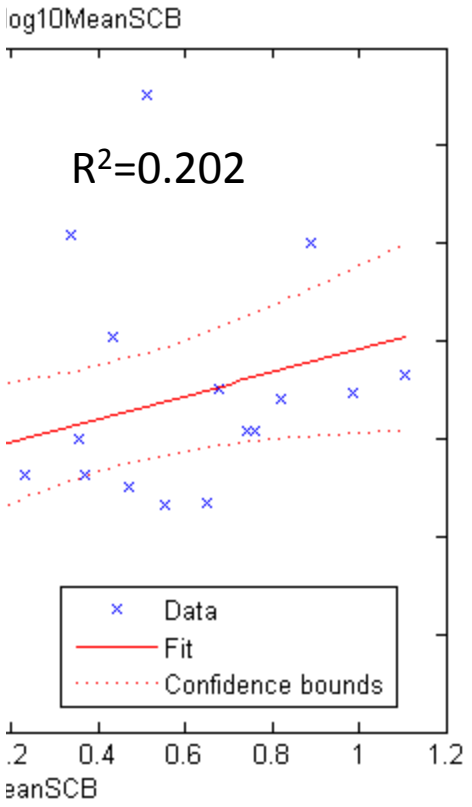


Figure 10. Predicted response variable plotted against observed response variable



Test Site 1: Processing of acoustic data

- For entire Dataset: unable to produce sediment yield due to poor correlation between sediment corrected backscatter and observed sediment concentration

- Dataset broken down into events and investigated further

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Test Site 1: Processing of acoustic data

- Six different periods analysed – range of hydrological characteristics

Test Site 1: Results										
	Date		Number of Samples	Q (m^3s^{-1})			Sediment Yield (kg)	Rainfall		
	Start	End		Average	Peak	Total		10 min intensity	1 hour intensity	Total
DataSet 1	22/06/2016	24/06/2016	19	0.0058	0.027	1509	159	4.25	11.27	40.0
DataSet 2	25/06/2016	27/06/2016	11	0.0038	0.011	1013	28	1.59	2.76	26.0
DataSet 3	29/06/2016	1/07/2016	11	0.0042	0.042	1103	60	3.92	7.17	26.0
DataSet 4	7/07/2016	9/07/2016	13	0.0049	0.034	1285	74	3.00	10.56	29.5
DataSet 5	14/07/2016	23/07/2016	22	0.0024	0.015	2105	46	3.52	6.50	66.0
DataSet 6	24/07/2016	26/07/2016	15	0.0062	0.141	1633	949	6.25	16.25	32.0

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Test Site 1: Processing of acoustic data

- Six different periods analysed – range of hydrological characteristics

Test Site 1: Results												
	Date		Number of Samples	Q (m^3s^{-1})			Sediment Yield (kg)	Rainfall			MeanSCB R^2	
	Start	End		Average	Peak	Total		10 min intensity	1 hour intensity	Total	log10SSC	SSC
DataSet 1	22/06/2016	24/06/2016	19	0.0058	0.027	1509	159	4.25	11.27	40.0	0.283	0.678
DataSet 2	25/06/2016	27/06/2016	11	0.0038	0.011	1013	28	1.59	2.76	26.0	0.569	0.588
DataSet 3	29/06/2016	1/07/2016	11	0.0042	0.042	1103	60	3.92	7.17	26.0	0.887	0.779
DataSet 4	7/07/2016	9/07/2016	13	0.0049	0.034	1285	74	3.00	10.56	29.5	0.945	0.942
DataSet 5	14/07/2016	23/07/2016	22	0.0024	0.015	2105	46	3.52	6.50	66.0	0.406	0.415
DataSet 6	24/07/2016	26/07/2016	15	0.0062	0.141	1633	949	6.25	16.25	32.0	0.806	0.371

- Better correlation achieved when looking at individual events

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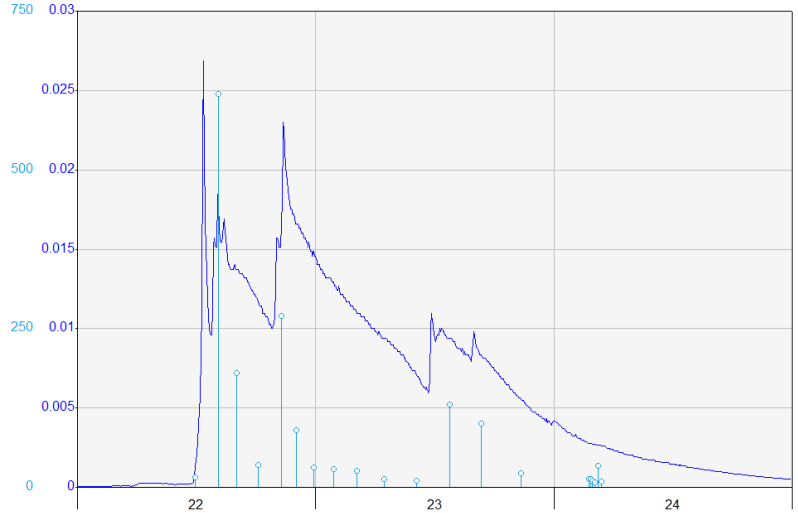
HYPLOT V133 Output 31/10/2016

Period 3 Day 22/06/2016 to 25/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

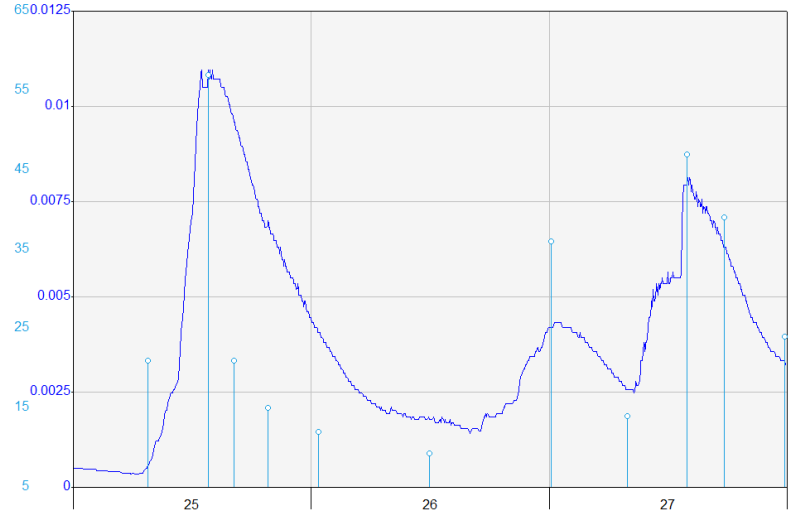


HYPLOT V133 Output 31/10/2016

Period 3 Day 25/06/2016 to 28/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

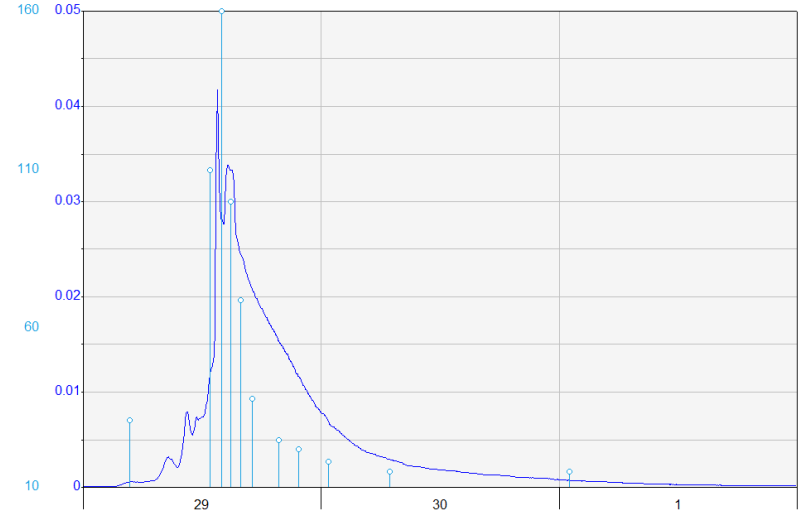


HYPLOT V133 Output 31/10/2016

Period 3 Day 29/06/2016 to 02/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

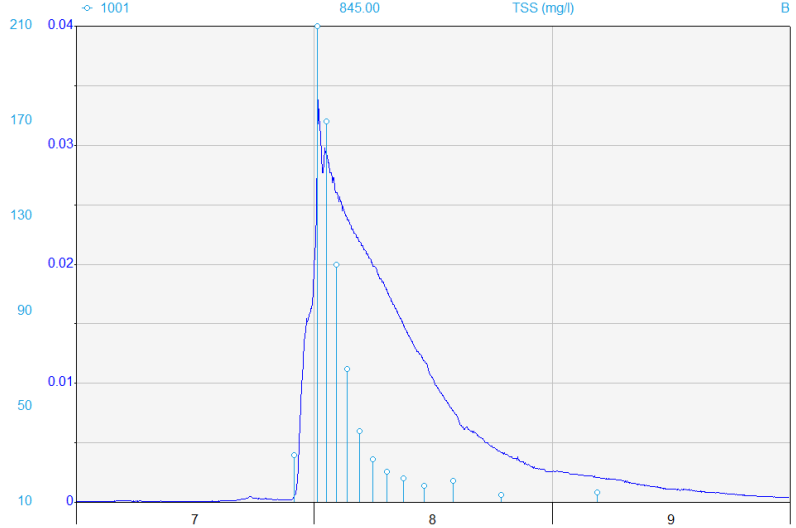


HYPLOT V133 Output 31/10/2016

Period 3 Day 07/07/2016 to 10/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

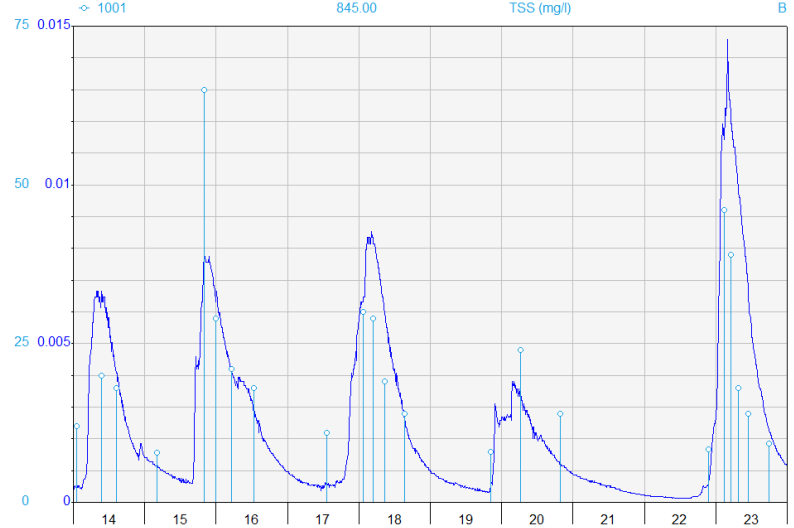


HYPLOT V133 Output 31/10/2016

Period 10 Day 14/07/2016 to 24/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

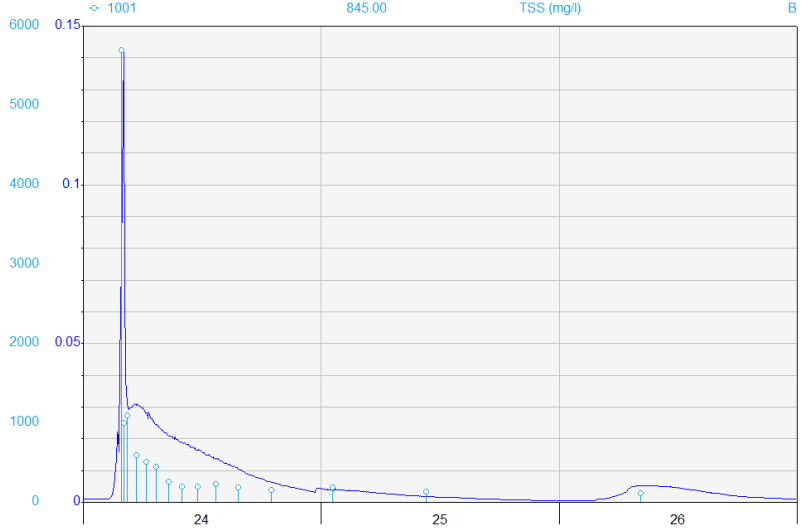


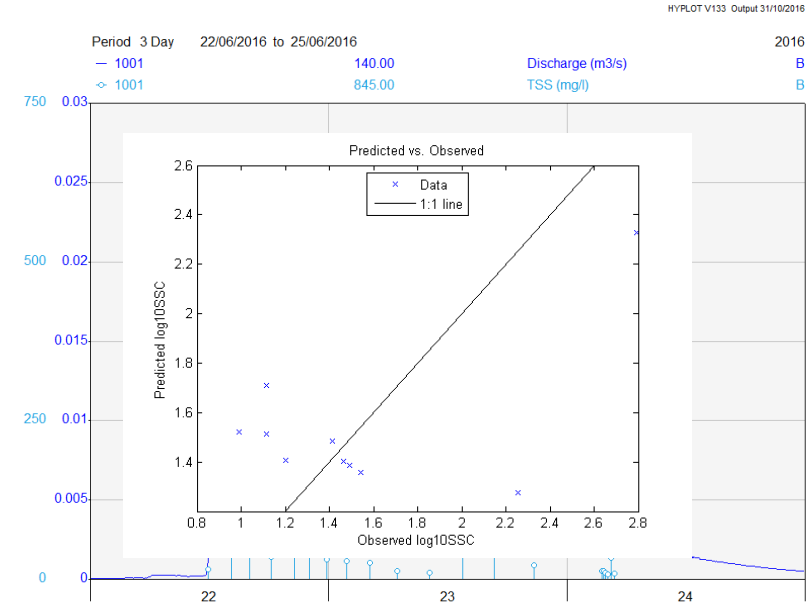
HYPLOT V133 Output 31/10/2016

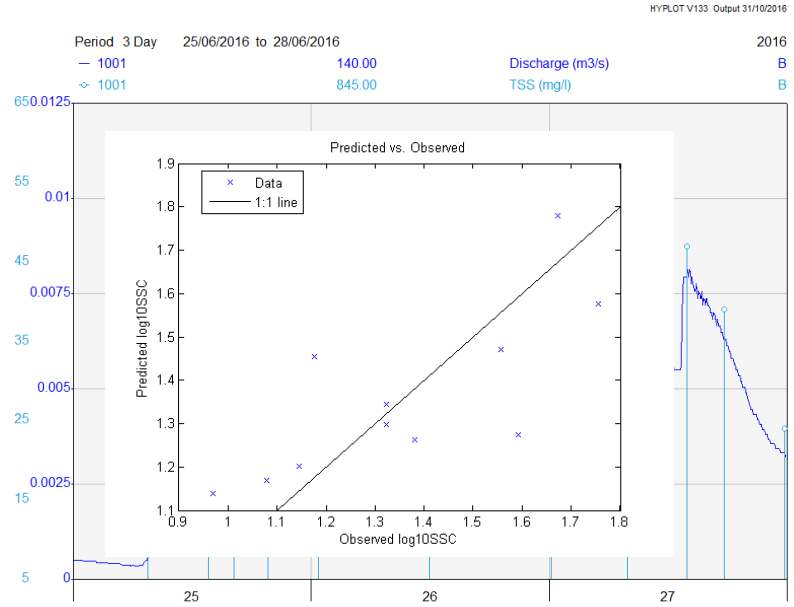
Period 3 Day 24/07/2016 to 27/07/2016 2016

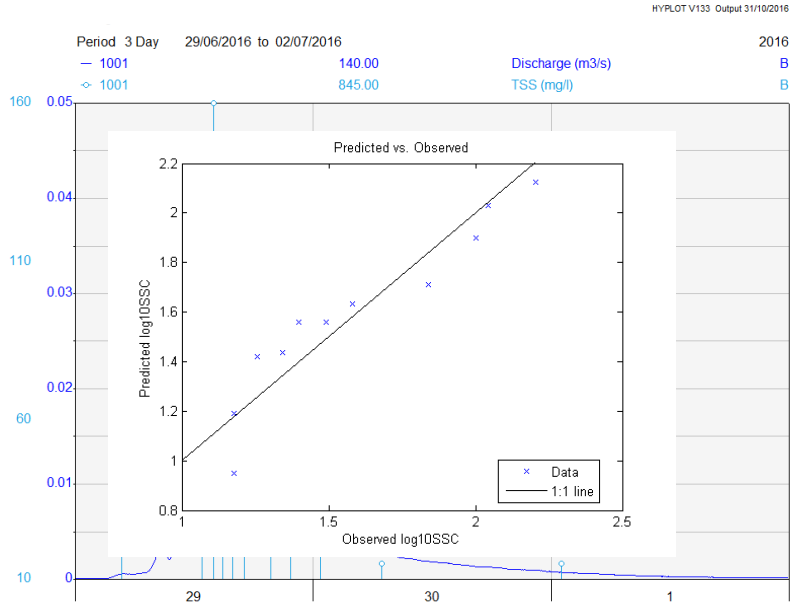
1001 140.00 Discharge (m3/s) B

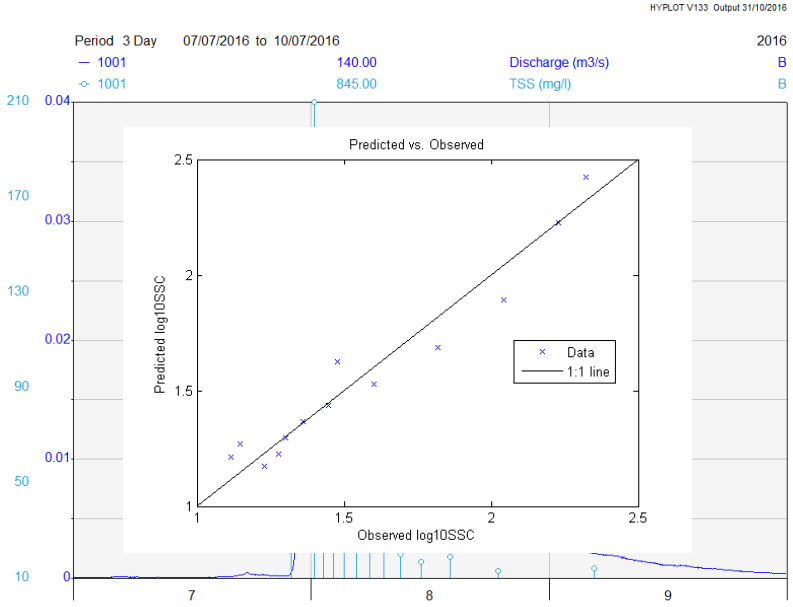
1001 845.00 TSS (mg/l) B

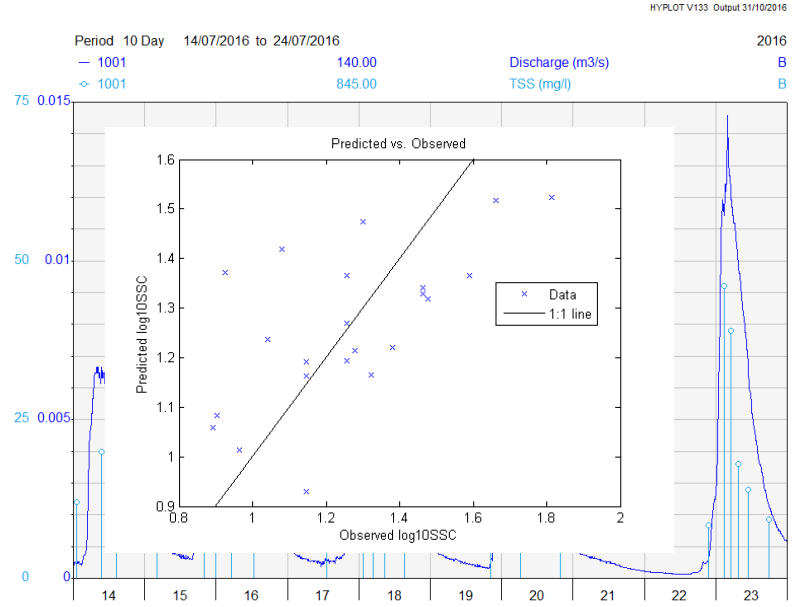


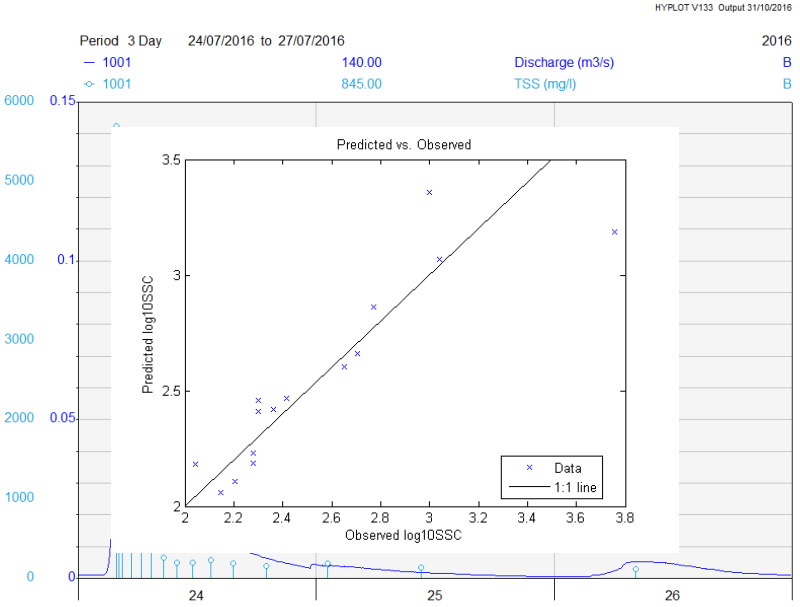

HYPLOT V133 Output 31/10/2016
Period 3 Day 22/06/2016 to 25/06/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC


HYPLOT V133 Output 31/10/2016
Period 3 Day 25/06/2016 to 28/06/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC


HYPLOT V133 Output 31/10/2016
Period 3 Day 29/06/2016 to 02/07/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC


HYPLOT V133 Output 31/10/2016
Period 3 Day 07/07/2016 to 10/07/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC


HYPLOT V133 Output 31/10/2016
Period 10 Day 14/07/2016 to 24/07/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC

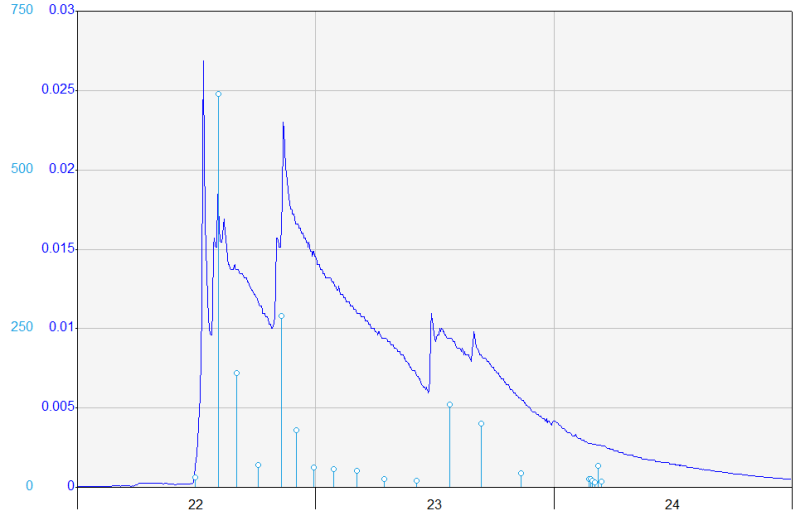

HYPLOT V133 Output 31/10/2016
Period 3 Day 24/07/2016 to 27/07/2016 2016
1001 140.00 Discharge (m3/s) B
1001 845.00 TSS (mg/l) B
Predicted vs. Observed
Data
1:1 line
Predicted log10SSC
Observed log10SSC

HYPLOT V133 Output 31/10/2016

Period 3 Day 22/06/2016 to 25/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

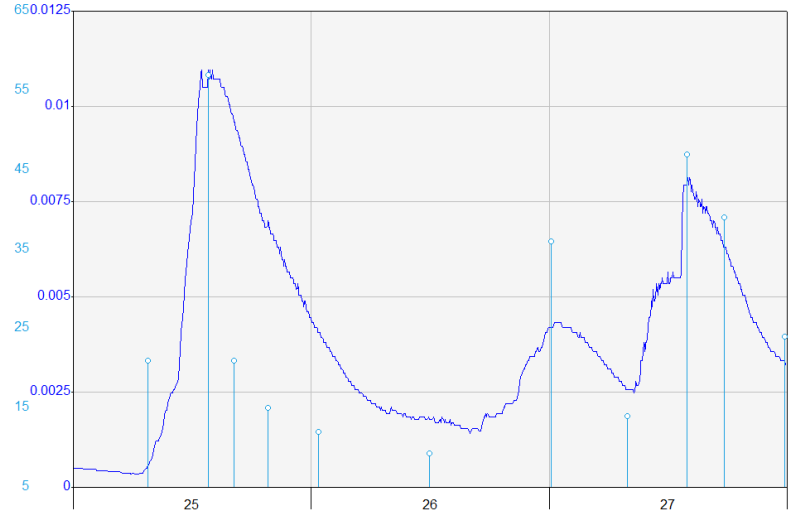


HYPLOT V133 Output 31/10/2016

Period 3 Day 25/06/2016 to 28/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

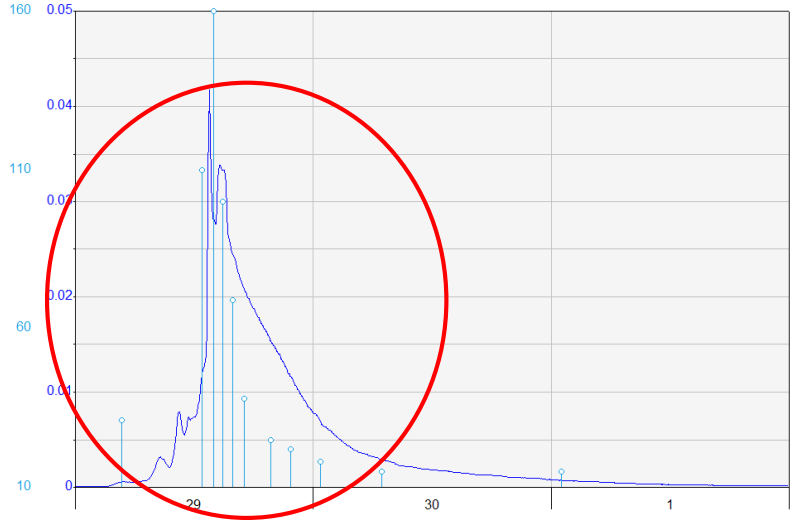


HYPLOT V133 Output 31/10/2016

Period 3 Day 29/06/2016 to 02/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

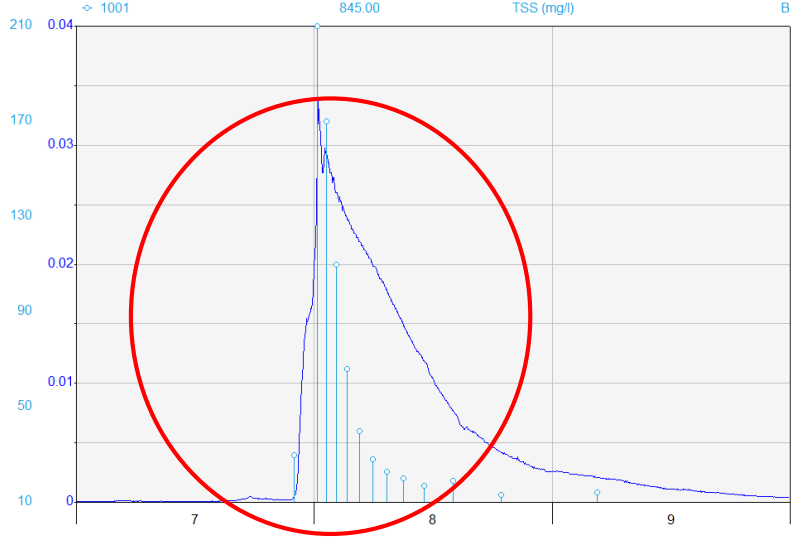


HYPLOT V133 Output 31/10/2016

Period 3 Day 07/07/2016 to 10/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

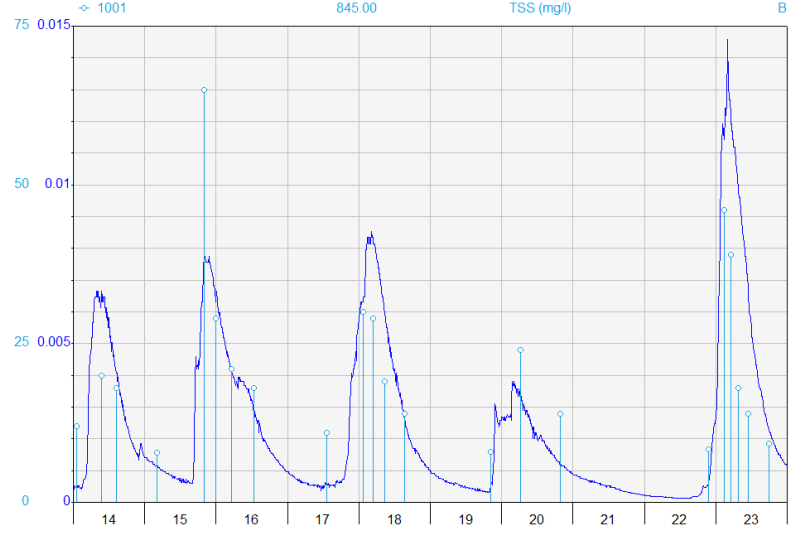


HYPLOT V133 Output 31/10/2016

Period 10 Day 14/07/2016 to 24/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

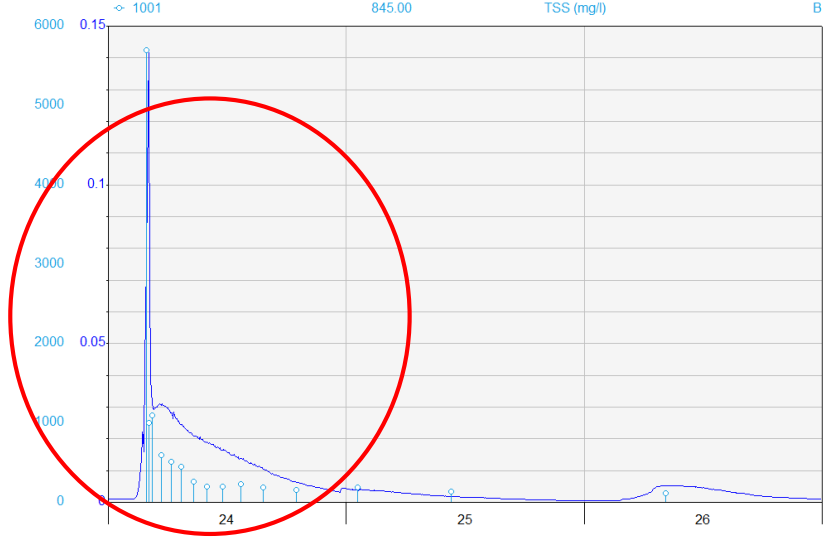


HYPLOT V133 Output 31/10/2016

Period 3 Day 24/07/2016 to 27/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B



Test Site 1: Processing of acoustic data

- Six different periods analysed – range of hydrologic characteristics

Test Site 1: Results												
	Date		Number of Samples	Q (m^3s^{-1})			Sediment Yield (kg)	Rainfall			MeanSCB R^2	
	Start	End		Average	Peak	Total		10 min intensity	1 hour intensity	Total	log10SSC	SSC
DataSet 1	22/06/2016	24/06/2016	19	0.0058	0.027	1509	159	4.25	11.27	40.0	0.283	0.678
DataSet 2	25/06/2016	27/06/2016	11	0.0038	0.011	1013	28	1.59	2.76	26.0	0.569	0.588
DataSet 3	29/06/2016	1/07/2016	11	0.0042	0.042	1103	60	3.92	7.17	26.0	0.887	0.779
DataSet 4	7/07/2016	9/07/2016	13	0.0049	0.034	1285	74	3.00	10.56	29.5	0.945	0.942
DataSet 5	14/07/2016	23/07/2016	22	0.0024	0.015	2105	46	3.52	6.50	66.0	0.406	0.415
DataSet 6	24/07/2016	26/07/2016	15	0.0062	0.141	1633	949	6.25	16.25	32.0	0.806	0.371

- Better correlation achieved when looking at individual events

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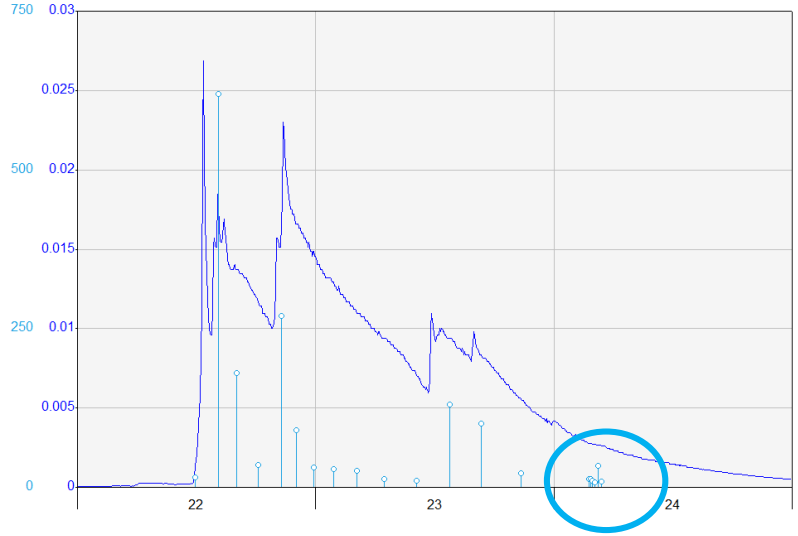
HYPLOT V133 Output 31/10/2016

Period 3 Day 22/06/2016 to 25/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

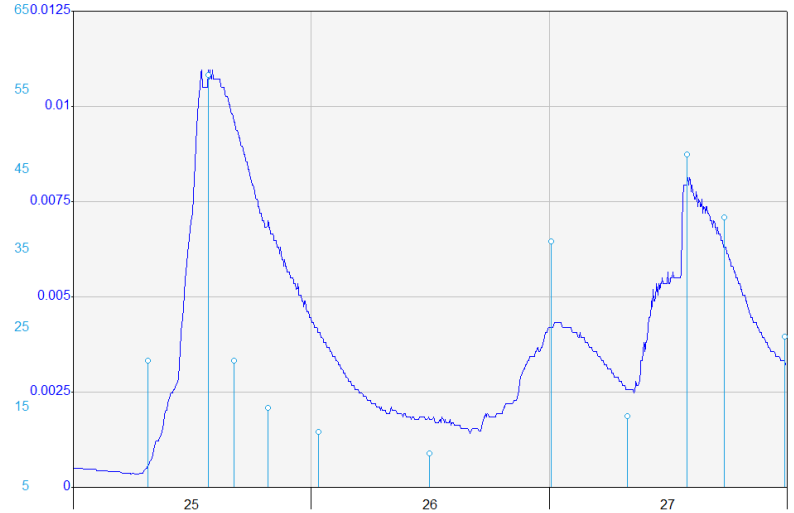


HYPLOT V133 Output 31/10/2016

Period 3 Day 25/06/2016 to 28/06/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

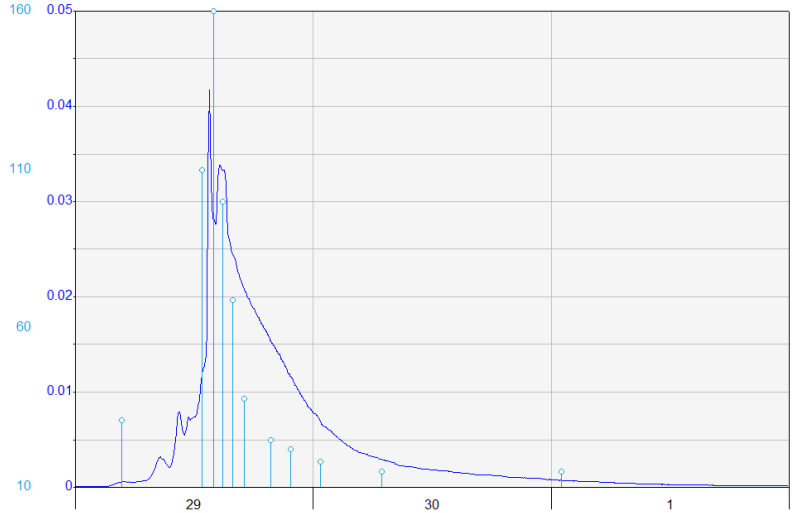


HYPLOT V133 Output 31/10/2016

Period 3 Day 29/06/2016 to 02/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

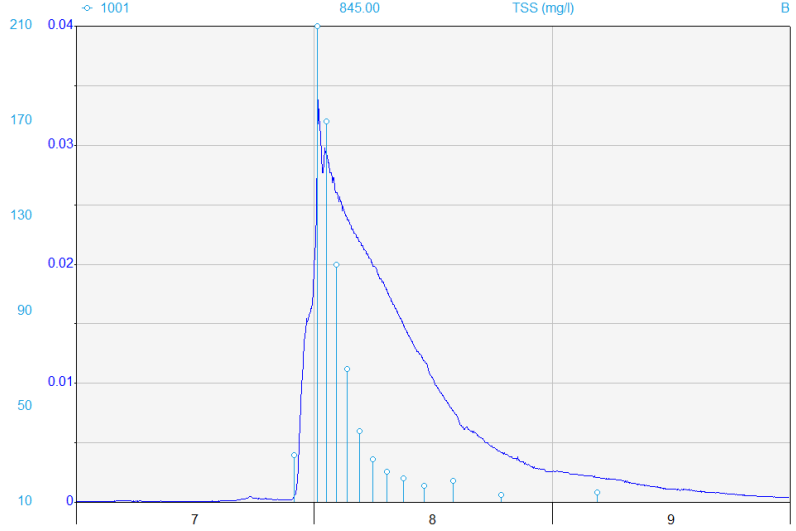


HYPLOT V133 Output 31/10/2016

Period 3 Day 07/07/2016 to 10/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

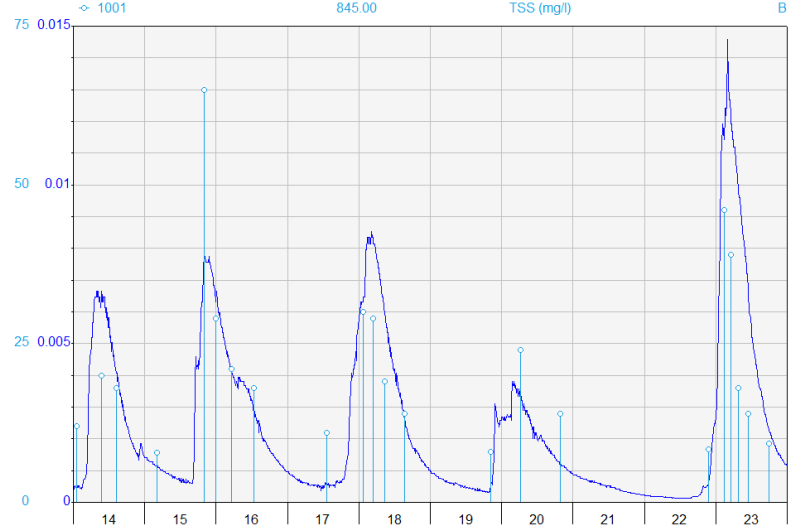


HYPLOT V133 Output 31/10/2016

Period 10 Day 14/07/2016 to 24/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B

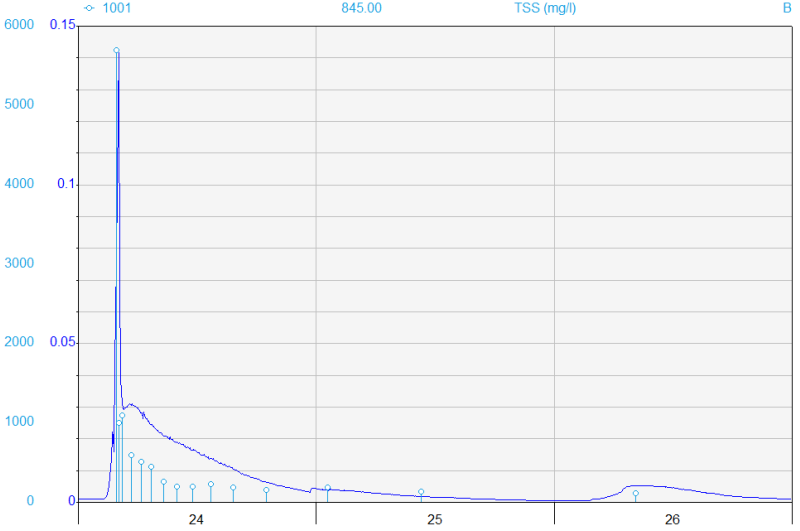


HYPLOT V133 Output 31/10/2016

Period 3 Day 24/07/2016 to 27/07/2016 2016

1001 140.00 Discharge (m3/s) B

1001 845.00 TSS (mg/l) B



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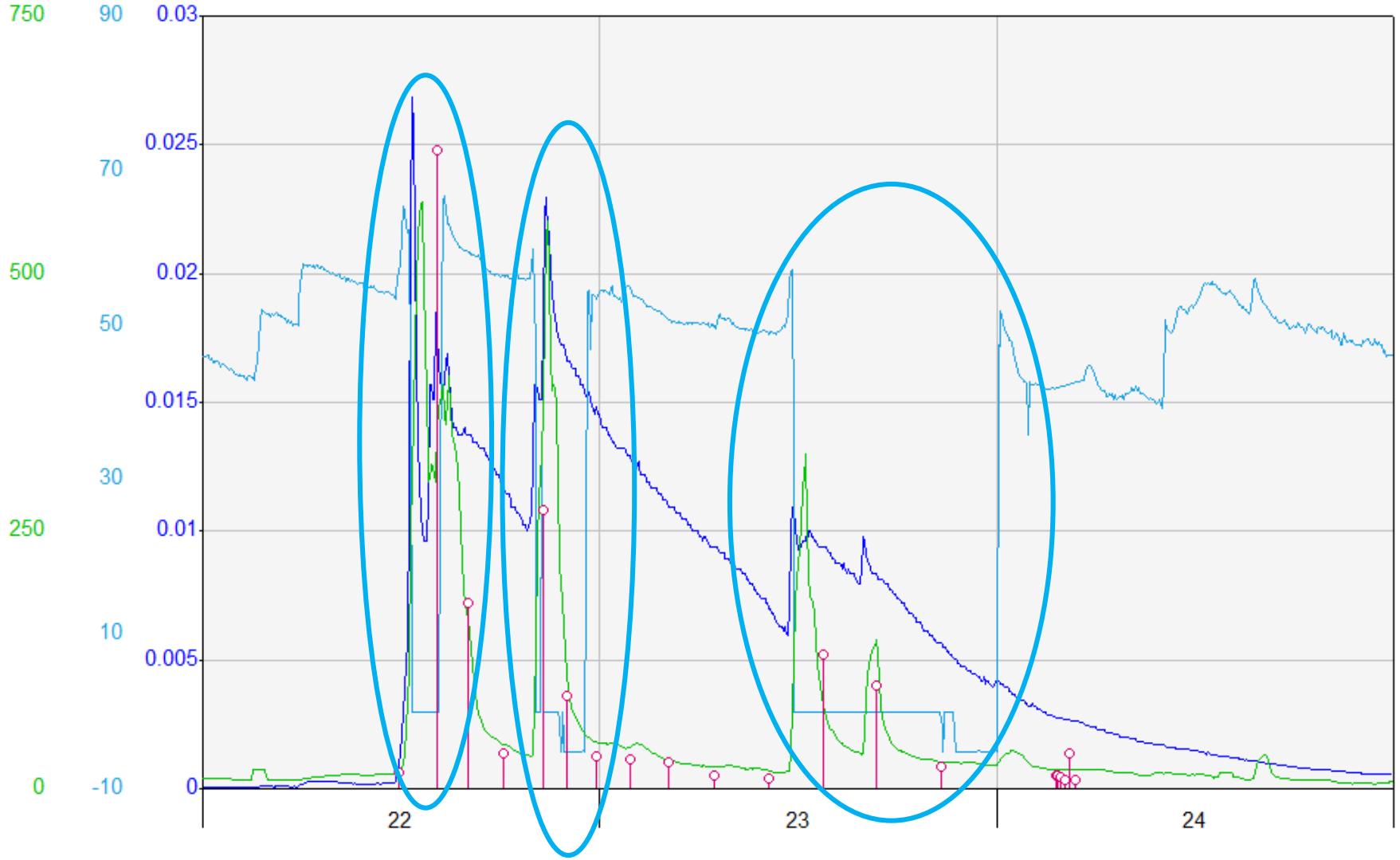
HYPLOT V133 Output 31/10/2016

Period 3 Day 22/06/2016 to 25/06/2016 2016

— 1001	140.00	Discharge (m3/s)		B
— 1001	127.11	Acoustic Sed	SNR Beam 1	C
— 1001	811.00	TSS		B
-o- 1001	845.00	TSS (mg/l)		B



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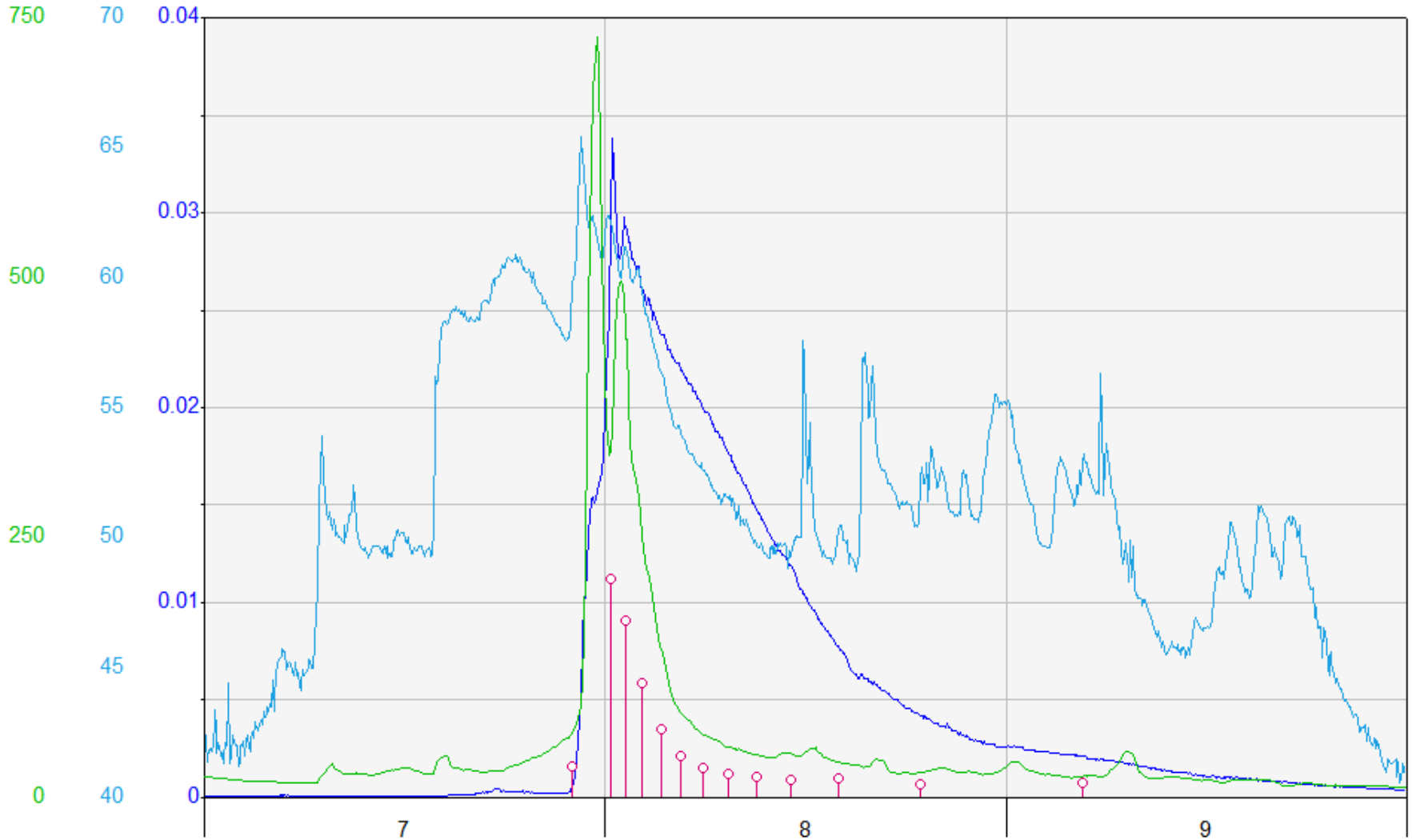
HYPLOT V133 Output 31/10/2016

Period 3 Day 07/07/2016 to 10/07/2016 2016

— 1001	140.00	Discharge (m3/s)		B
— 1001	127.11	Acoustic Sed	SNR Beam 1	C
— 1001	811.00	TSS		B
-o- 1001	845.00	TSS (mg/l)		B



Test Site 1: Particle size analysis

- Large change in particle size
- Difference in flocc rate?

	Number of samples	µm																																					
		0.05	0.06	0.12	0.24	0.49	0.70	0.98	2.00	3.90	7.80	10.00	15.60	31.00	37.00	44.00	53.00	63.00	74.00	88.00	105.00	125.00	149.00	177.00	210.00	250.00	300.00	35.00	420.00	500.00	590.00	710.00	840.00	1000.00	1190.00	1410.00	1680.00	2000.00
Sample 1	10	0	0	0	0	0	0.2	0.41	0.91	1.36	3.27	4.8	7.7	11.02	11.69	12.36	13.13	13.95	14.83	15.89	17.07	18.32	19.69	21.31	23.45	26.56	31.25	36.64	44.9	54.14	63.83	74.66	83.49	90.83	96.01	99.05	99.99	100
		0	0	0	0	0	0.2	0.21	0.5	0.45	1.91	1.53	2.9	3.32	0.67	0.67	0.77	0.82	0.88	1.06	1.18	1.25	1.37	1.62	2.14	3.11	4.69	5.39	8.16	9.34	9.69	10.83	8.83	7.34	5.18	3.04	0.94	0.01
Sample 2	13	0	0	0	0	0.19	0.6	1.08	2.79	4.41	7.3	8.97	11.27	12.82	13.16	13.53	13.98	14.48	15.05	15.79	16.68	17.67	18.74	19.88	21.25	23.17	26.27	30.71	36.9	45.5	55.31	67.19	77.56	86.69	93.45	97.91	99.34	100
		0	0	0	0	0.19	0.41	0.48	1.51	1.82	2.89	1.67	2.3	1.55	0.34	0.37	0.45	0.5	0.57	0.74	0.89	0.99	1.07	1.14	1.37	1.92	3.1	3.94	6.69	8.6	9.81	11.88	10.37	9.13	6.76	4.46	2.03	0.06
Sample 3	13	0	0	0	0	0	0	0	0	0.24	1.04	1.46	2.32	3.86	4.24	4.58	4.89	5.16	5.42	5.8	6.39	7.25	8.41	9.75	11.12	12.34	13.33	14.06	15.37	18.01	22.79	31.66	43.07	57.34	72.23	85.19	95.07	100
		0	0	0	0	0	0	0	0	0.24	0.8	0.42	0.86	1.54	0.38	0.34	0.31	0.27	0.26	0.38	0.59	0.86	1.16	1.34	1.37	1.22	0.99	0.73	1.31	2.64	4.78	8.87	11.41	14.27	14.89	12.96	9.88	4.93
Sample 4	23	0	0	0	0	0.72	2.29	4.13	9.42	13.79	25.78	35.01	49.73	62.04	64.45	66.73	69.12	71.25	73.1	74.89	76.4	77.53	78.33	78.93	79.6	80.68	82.52	84.77	88.15	91.73	94.96	97.83	99.49	100	100	100	100	100
		0	0	0	0	0.72	1.57	1.84	5.29	4.37	11.99	9.23	14.72	12.31	2.41	2.28	2.39	2.13	1.85	1.79	1.51	1.13	0.8	0.6	0.67	1.08	1.84	2.25	3.38	3.58	3.23	2.87	1.66	0.51	0	0	0	0
Sample 5	24	0	0	0	0	0.92	3.12	5.79	13.2	21.3	38.91	49.99	67.82	84.4	87.48	90.08	92.37	93.99	95.11	95.98	96.59	97.03	97.38	97.68	97.98	98.3	98.69	99.06	99.49	99.85	100	100	100	100	100	100	100	100
		0	0	0	0	0.92	2.2	2.67	7.43	8.08	17.61	11.08	17.83	16.58	3.08	2.6	2.29	1.62	1.12	0.87	0.61	0.44	0.35	0.3	0.3	0.32	0.39	0.37	0.43	0.36	0.15	0	0	0	0	0	0	0
		Clay								Silt									Sand																					
																			Very fine				Fine				Medium				Coarse				Very course			

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Test Site 2: Where to from here?

- Correlation between Mean SCB & measured sediment concentration dependant on event characteristics – why?
- Second deployment planned for December – January
- New firmware & software to be released for acoustic sensor
- Deployed in conjunction with a higher frequency sensor
  - Higher frequency = better performance in small water bodies and finer sediments
- Investigate effects of flocculant on acoustic performance?
- Compare correlation between TSS Sonde and Mean SCB?
- Greater flow accuracy required
- Work in progress

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Acknowledgements

- Xylem: Daniel Wagenaar – support with data processing
- Envco: Graham Andrew, Richard Morrow – supply of IQ unit

- Questions?

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