

Ilston River Study

Introduction

The Ilston River valley is located in West Glamorgan, South Wales. It's source is located close to Swansea Airfield, it then flows through the villages of Ilston and Parkmill before reaching the sea at Threecliff Bay. The valley is unusual in that it is the result of glacial activity, and not carved out of the rock by the River Ilston. The topography here is a result of "surface fluvial erosion by summer meltwater in periglacial environments", as permafrost made the underlying limestone impermeable, causing meltwater to flow as runoff. (The Geological Society, 2012)

As such, the River Ilston is a "misfit stream", defined in Fundamentals of Geomorphology as "streams presently too small to have created the valleys they occupy". (Fundamentals of Geomorphology, Routledge, 2003). The results from this survey were recorded during the autumn of 2015, on Monday 26th October, by twelve undergraduate students from The University of Wales Trinity St David. There were ten data collection Sites along the river, chronologically Site 1 is the closest to the river source, whilst Site 10 is the closest to its estuary. Within each Site, five Points were measured and again these are labelled chronologically, Point 1 being the furthest upstream whilst Point 5 is the furthest downstream.

The overall aim of the study was to examine the changing characteristics of the river Ilston, and within this the main hypotheses being investigated were as follows:

1. The river becomes wider and deeper downstream
2. The cross sectional area of the river increases downstream
3. The river velocity increases on the outside of a meander
4. The highest velocity is to be found in the centre of the river
5. The river velocity decreases downstream
6. The size of the bedload gets smaller downstream
7. The shape of the bedload becomes more rounded downstream
8. The discharge of water in the river increases downstream

Special attention was also paid to the relationship of ecological form and behaviour to the physical setting.

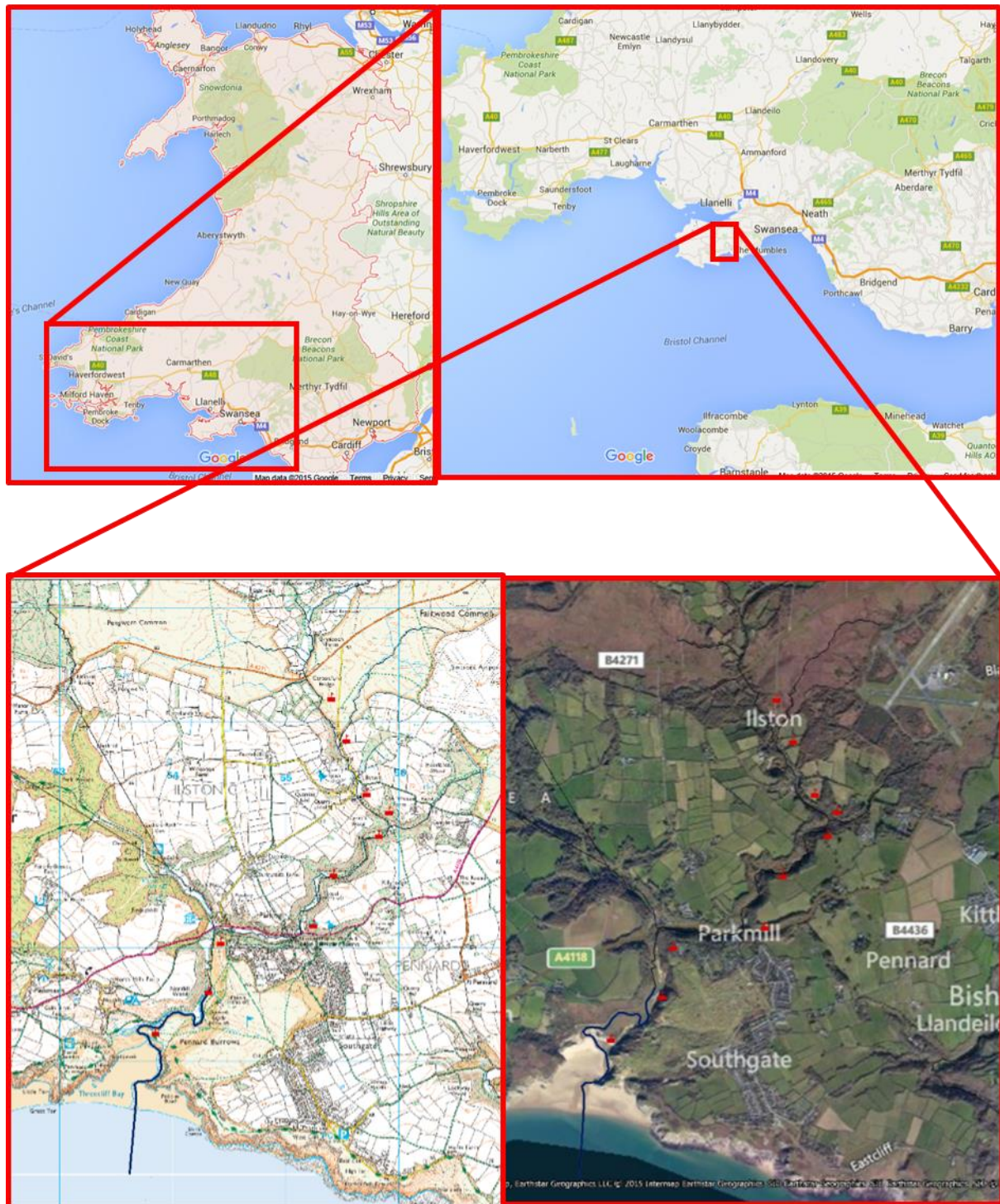
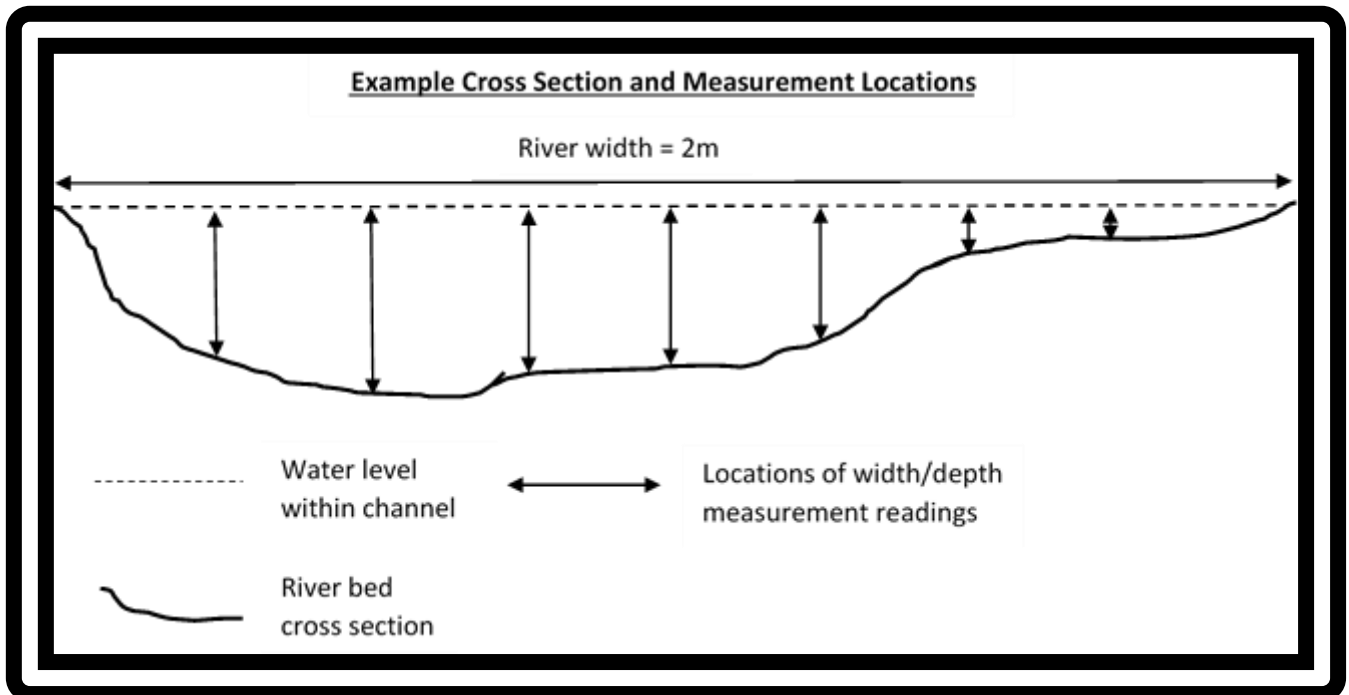


Figure 1: Location of River Ilston within South West Wales, with the ten Study Sites marked as red flags on the lower pictures. (Google Maps, 2015) (Ordnance Survey, 2015)

Methodology

To gather data relevant to hypotheses 1 and 2, the stream was measured from the waters edge to the waters edge at five Points at each of the ten Sites we were studying using a tape measure. The width of the river was then recorded to the nearest centimetre, and the depth of the river was measured from the waters surface to the river bed at 25cm intervals, using a metre rule, along these five cross sections. The depths, in turn, were recorded to the nearest centimetre, from the right

hand bank (facing downstream) to the left hand bank. From this, the average depth and width of each river Site was calculated and plotted as an average cross-section (see Results).



The average cross-sectional area of each river Site was calculated in the following way: starting at the right hand bank, the midpoint between the depth of each 25cm measurement and the one directly to the left of it (looking downstream) was multiplied by the distance between them (25cm, or in some cases 50cm). The sum of these then gave the cross-sectional area in cm^2 for this river point. To convert it to m^2 it was then divided by 10000 (100×100). Once every points cross-sectional area had been calculated, these were then averaged to find the average cross-sectional area for each river Site.

Hypotheses 3 and 4 were examined using a current meter. At five points in each cross-section of river, the velocity was recorded in m/s. The distribution of measurements is shown in the diagram below (left hand bank, top-centre, mid-centre, bottom centre, right hand bank), and the flowmeter was lowered on it's adjustable pole to the relevant position within the streams flow and held still until a reading appeared on the hand-held display.



Flow meter in use at Site 3, photograph taken by Shane Thomas, featuring Julia Iremonger and Abdulla Al-zahid

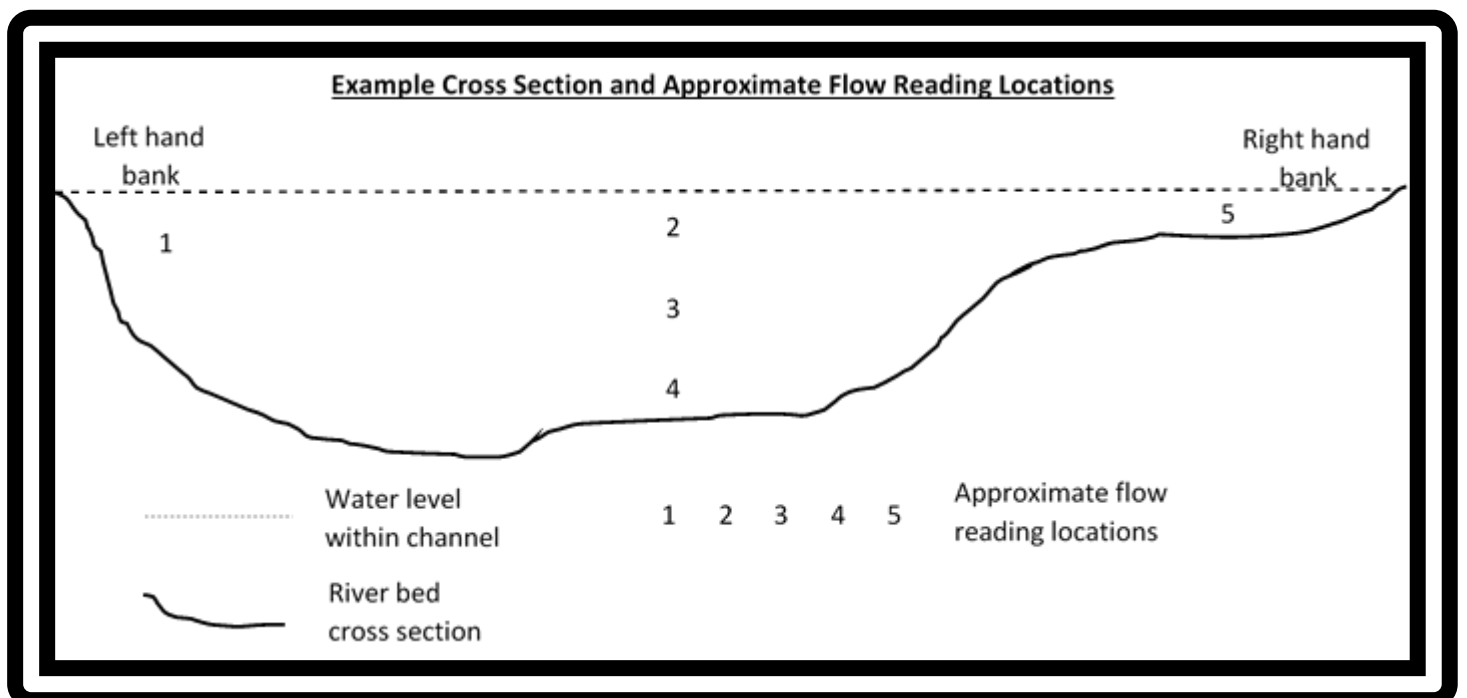
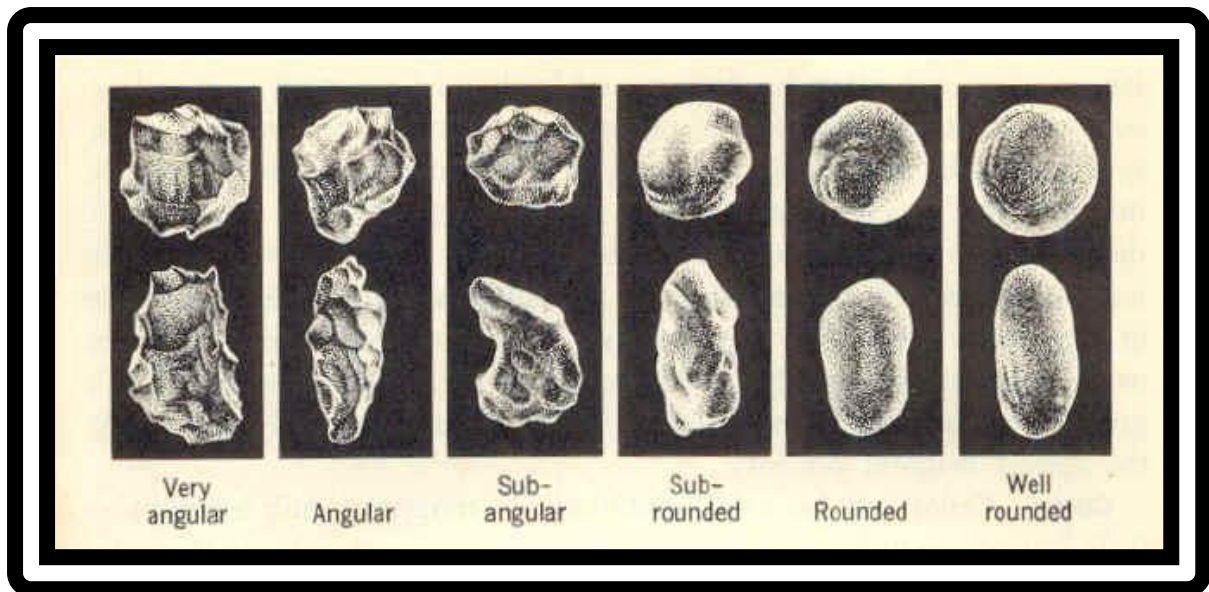


Diagram to demonstrate the relative location of the flow-readings

In addition to this, oranges were used to calculate the velocity. The orange was placed at the start (upstream) of a 10m stretch of river (measured out using a tape measure), and timed to see how

long it took to reach the end using a stop-watch. By dividing the distance the orange travelled by the time it took, a velocity unit in m/s was calculated. This was repeated three times at each site so that an average could be found. By multiplying this average by 0.85 the surface velocity is then converted to stream velocity.

With regards to sediment, hypotheses 6 and 7 were investigated by taking 5 representative samples from each river Site. The long axis of each was measured with a tape measure and recorded to the nearest cm, to give an average sediment size. The roundness was then assessed using Powers table of angularity (shown below) for each sample taken.



Modified after Powers, 1953

Hypothesis 8 was calculated using the data collected above, by multiplying the velocity by the average-cross-sectional area for each Site, giving the river discharge value in m³/s.

Results and Analysis

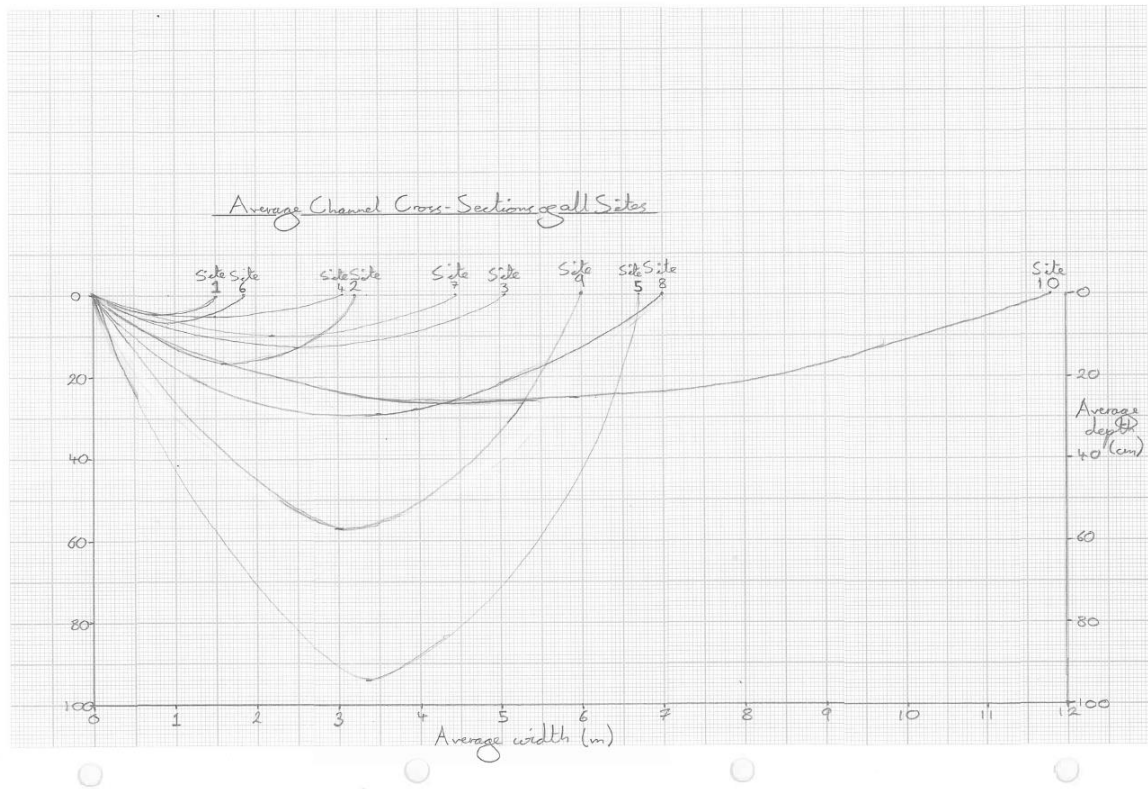
Figures highlighted in yellow are data from a previous year, as the data from this study was either unsuitable or non-existent. Where possible, I have used data from this study, as the conditions from a previous year may have been very different eg. A different time of year or a period of unusually high rainfall. Therefore I hope to illuminate these factors as much as possible by using this years data.

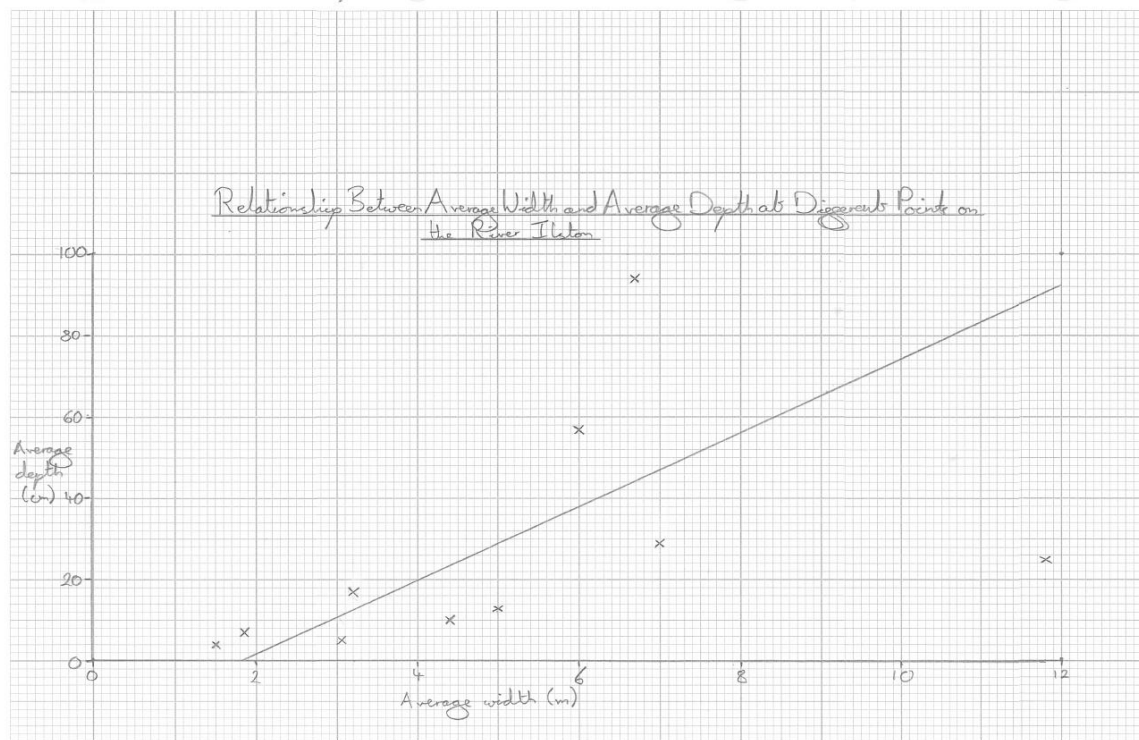
Hypothesis 1: The river becomes wider and deeper downstream.

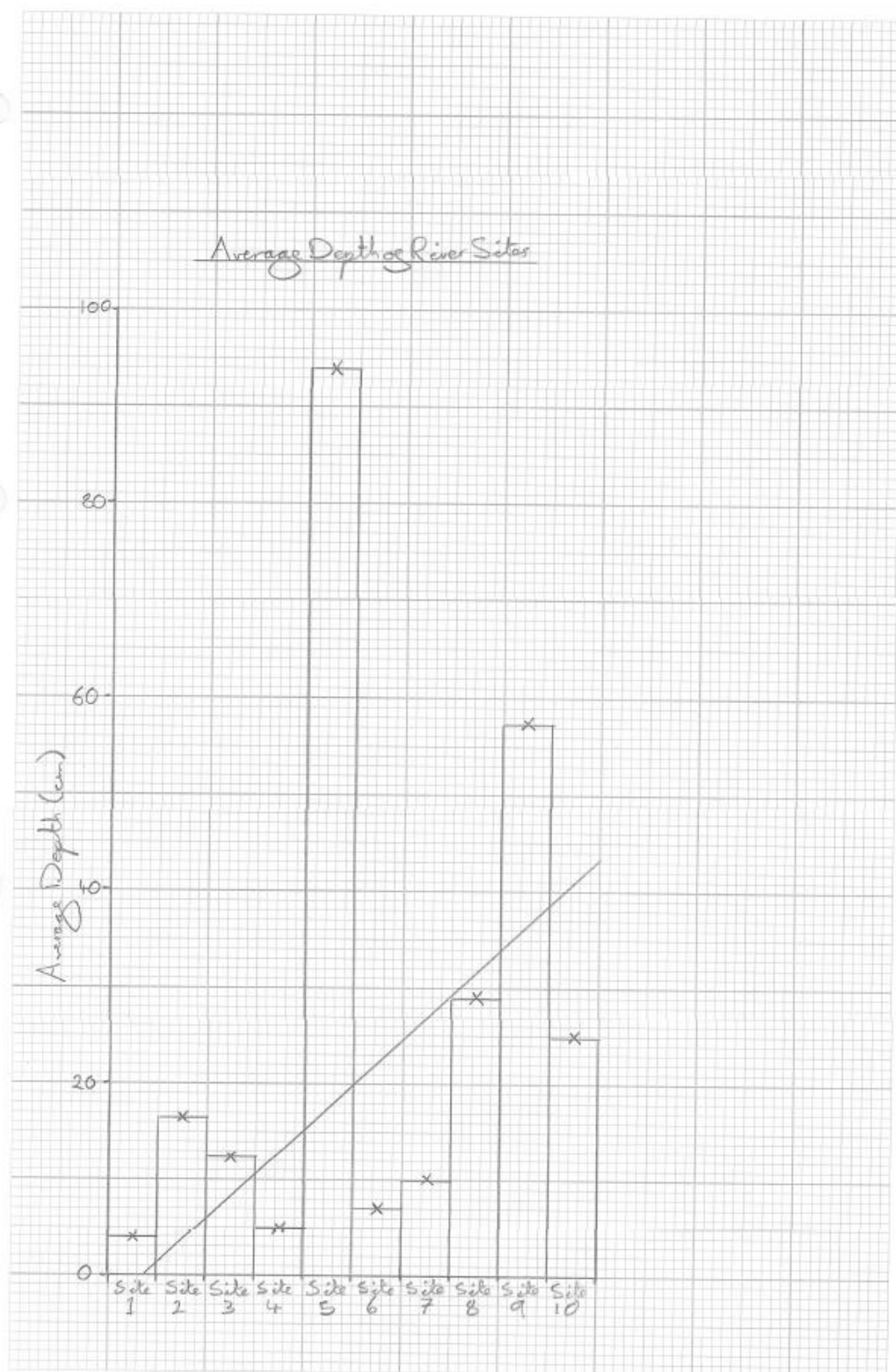
Site	Average width (m)	Average depth (cm)
1	1.5	4.08
2	3.2	16.63
3	5.03	12.69
4	3.04	5
5	6.7	94.29
6	1.86	7.1
7	4.43	9.9
8	7	29.13
9	6	57.31

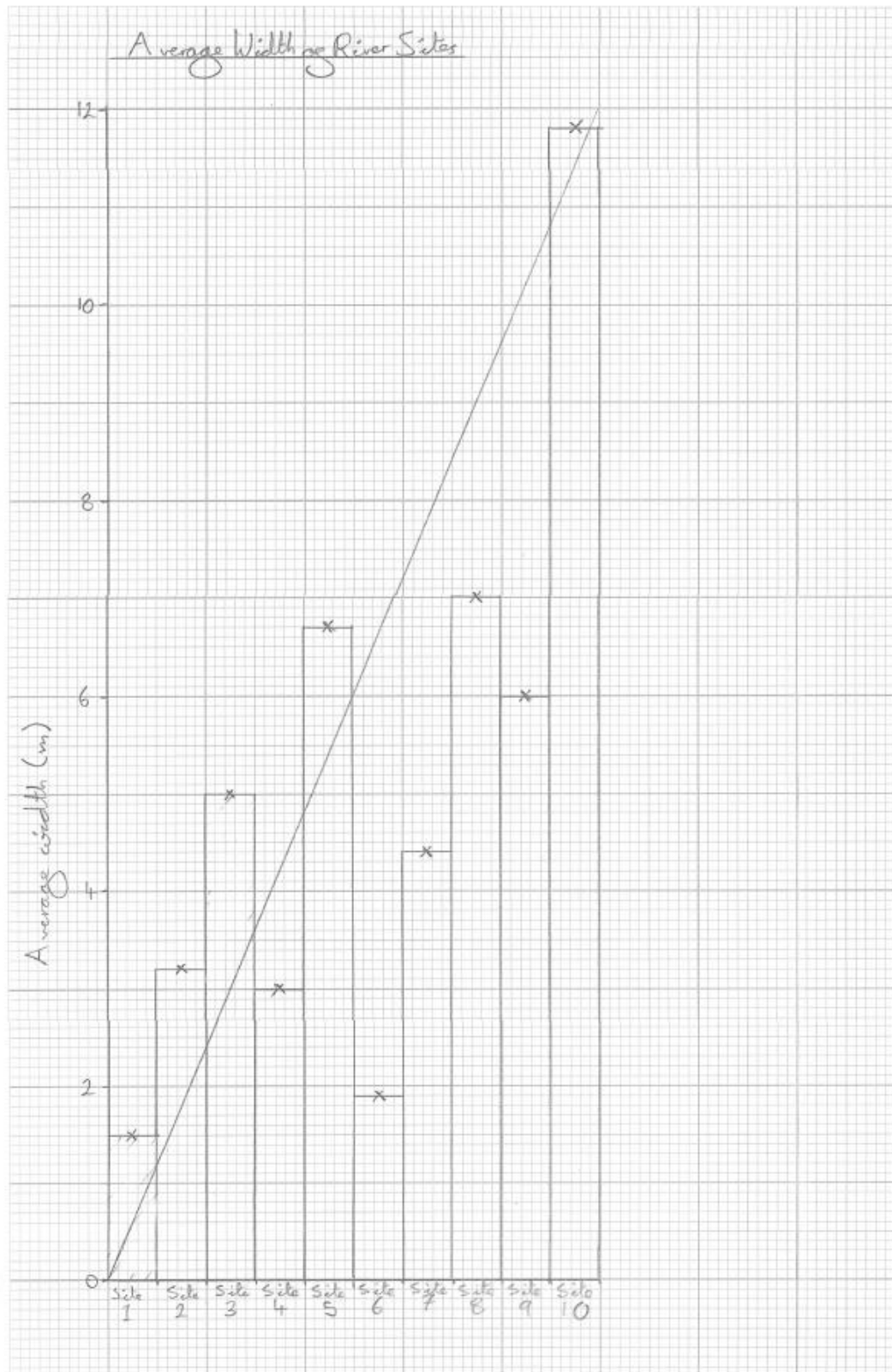
10	11.8	24.8
----	------	------

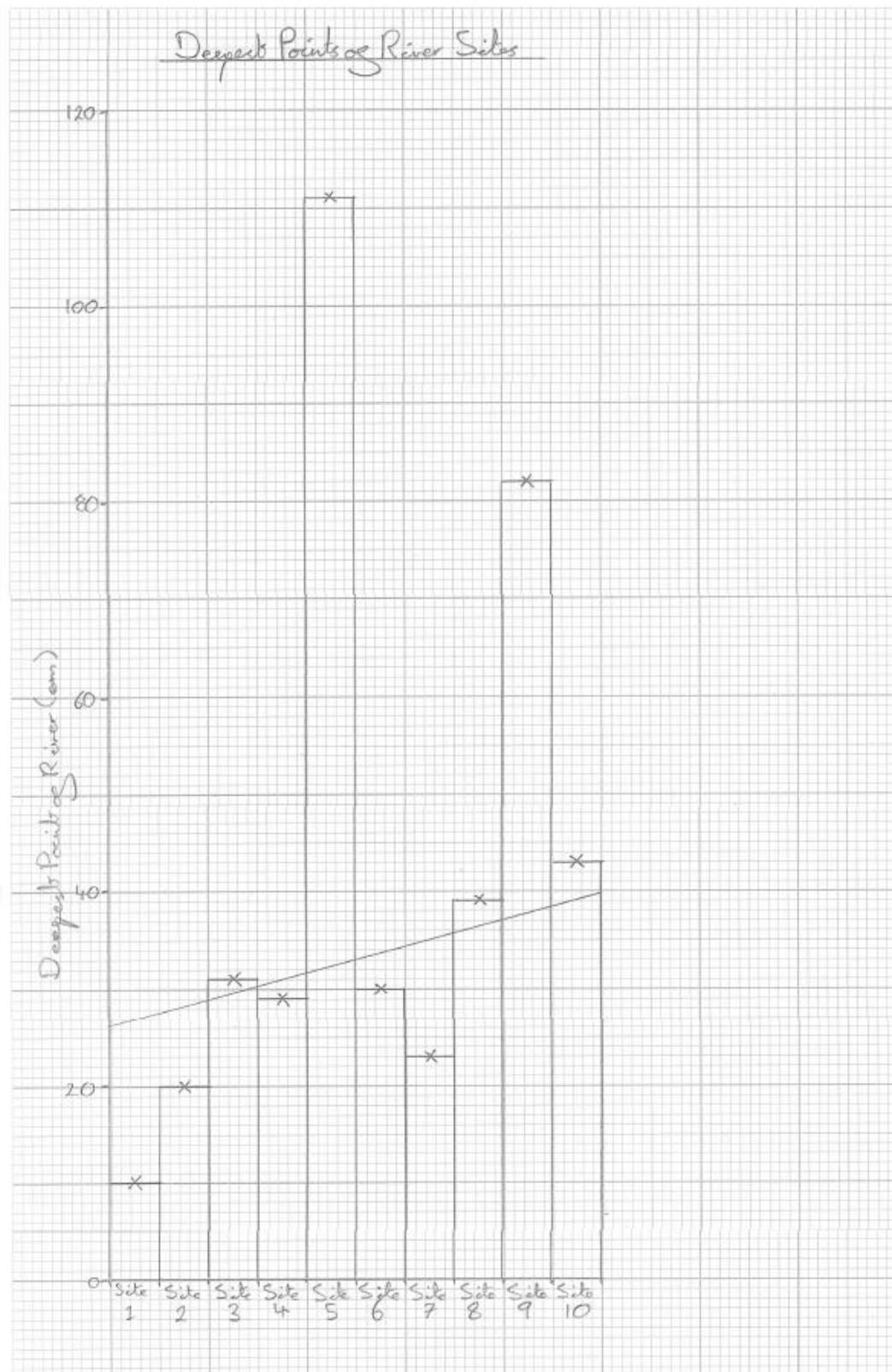
Site	Deepest point of river (cm)	Widest point of river (m)
1	10	1.85
2	20	3.2
3	31	5.5
4	29	3.75
5	111	6.7
6	30	2.05
7	23	4.9
8	39	7
9	82	6
10	43	11.8

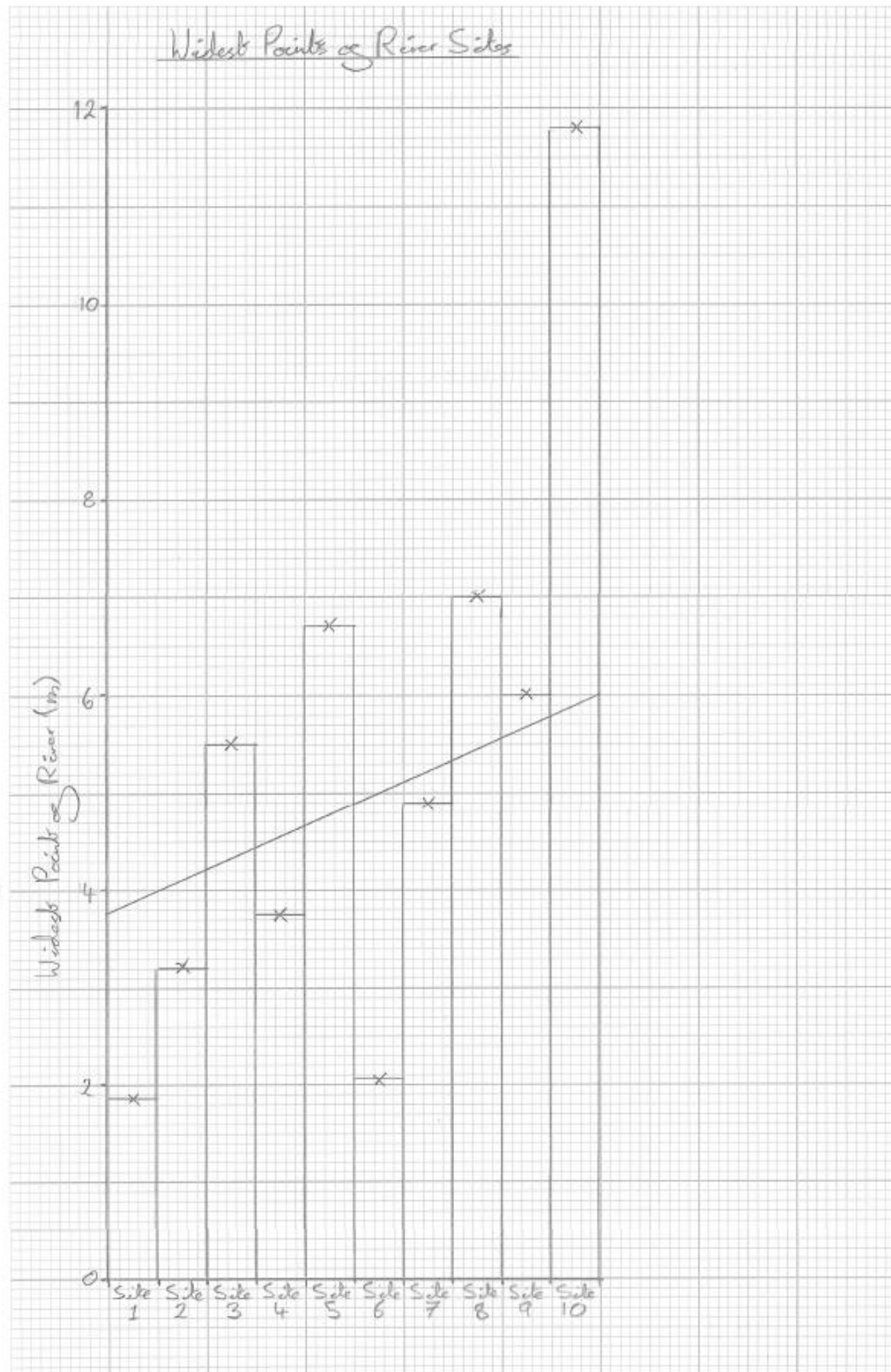










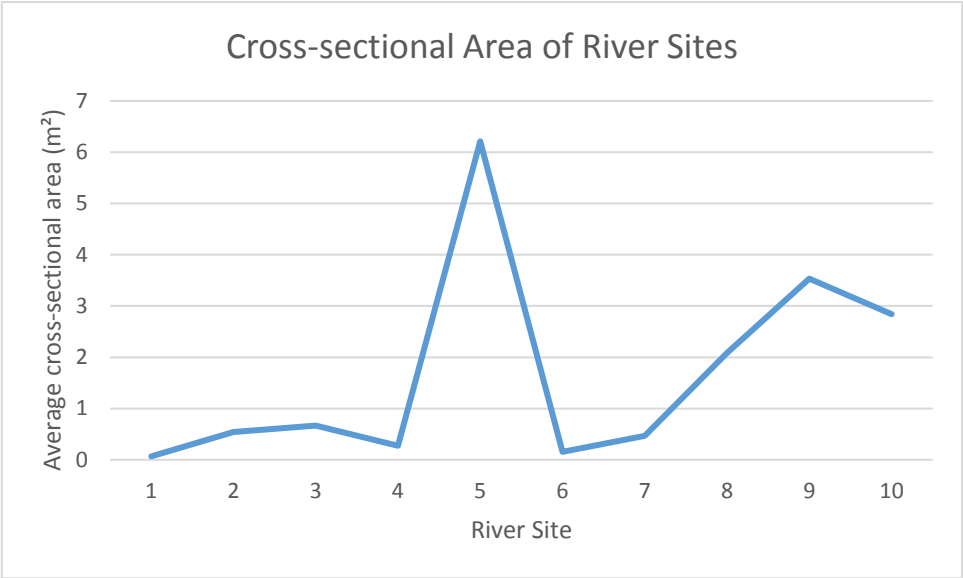


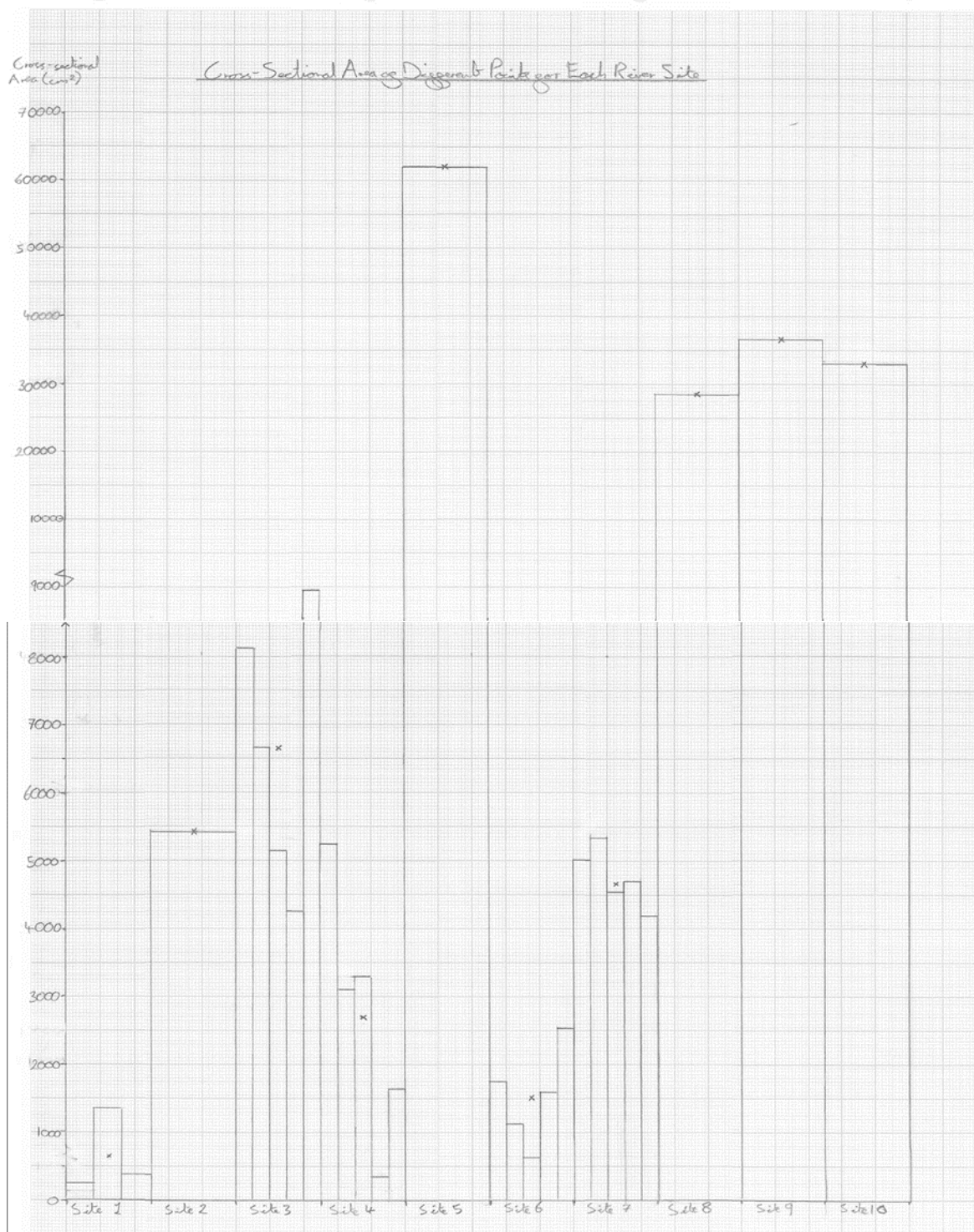
The data suggests that there is correlation between the width and the depth of the river, but this does not follow a strict pattern of both increasing downstream. However, the widest point of the river is the furthest downstream, and the least wide is Site 1, the furthest upstream. The depth of the river does follow a slight trend of increasing downstream, but this is not particularly strong, with a correlation coefficient value of only 0.3. The data for width increasing downstream has a correlation coefficient of 0.4, a low positive correlation.

Hypothesis 2: The cross sectional area of the river increases downstream.

Site	Point	Cross-sectional area (cm²)	Average cross-sectional area (cm²)	Average cross-sectional area (m²)
1	1	287.5	671.7083333	0.067170833
	2	1352.5		
	3	375.125		
2		5435		0.5435
3	1	8130	6656	0.6656
	2	6775		
	3	5175		
	4	4250		
	5	8950		
4	1	5250	2733.95	0.273395
	2	3118.5		
	3	3326.25		
	4	345		
	5	1630		
5		62125		6.2125
6	1	1775	1531	0.1531
	2	1125		
	3	620		
	4	1610		
	5	2525		
7	1	5040	4677.1	0.46771
	2	5347.5		
	3	4568		
	4	4707.5		
	5	3722.5		
8		20875		2.0875
9		35350		3.535
10		28412.5		2.84125

Site	1	2	3	4	5	6	7	8	9	10
Average cross-sectional area (m ²)	0.067171	0.5435	0.6656	0.273395	6.2125	0.1531	0.46771	2.0875	3.535	2.84125





There is no evidence from within each Site that the Points measured have a larger cross-sectional area further downstream, only Site 3 and Site 6 demonstrate this but even so this is not consistent within the other Points measured at these Sites, only the first and last Points. Overall, there is a general trend towards larger cross-sectional areas downstream, but there is a notable exception in Site 5. The Sites with the smallest average cross-sectional area 1, 4, 6 and 7, which are located in the middle section of the river. In support of the hypothesis, Site 1 has by far the smallest cross-sectional

area overall (0.09m² smaller than the second smallest, Site 6). However, Site 5, in the mid-section of the river, has an average cross-sectional area 3.37m² larger than Site 10, the furthest downstream. This has a Spearman's Rank coefficient of 0.3, a weak positive correlation.

The mid-course of the river may have a smaller cross-sectional area due to the river retreating underground, percolating into the underlying limestone and flowing largely as groundwater at these points. (House, 2015)

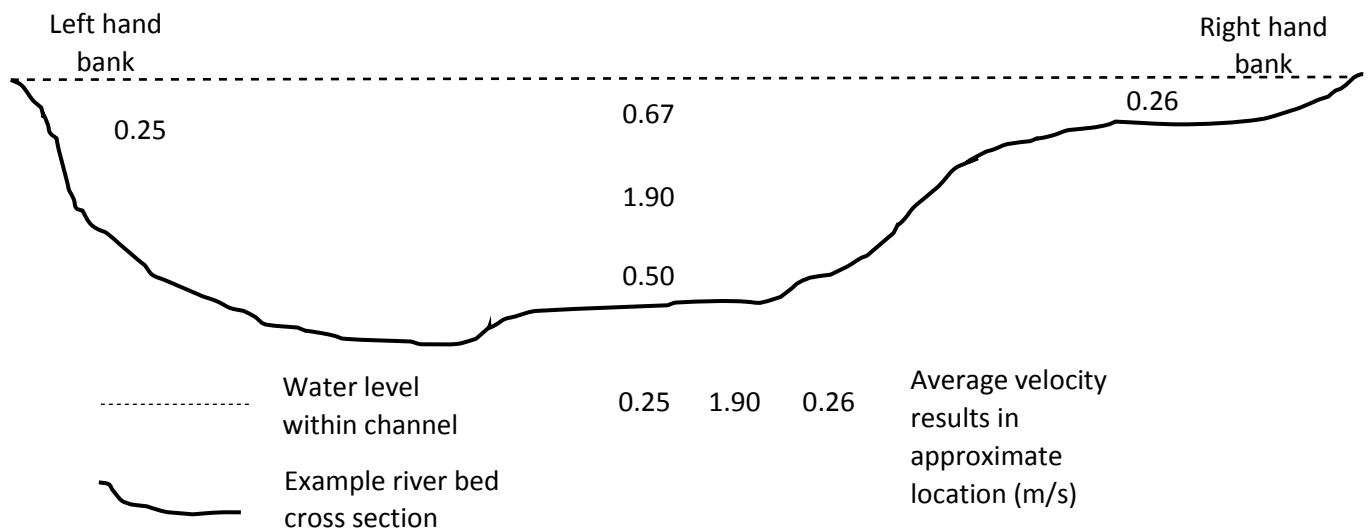
Hypothesis 3: The river velocity increases on the outside of a meander.

No sites with a meander were observed during this study.

Hypothesis 4: The highest velocity is to be found in the centre of the river.

Site	Average velocity at location 1 in the river (m/s)	Average velocity at location 2 in the river (m/s)	Average velocity at location 3 in the river (m/s)	Average velocity at location 4 in the river (m/s)	Average velocity at location 5 in the river (m/s)
1	0.003333333	0.0066667	0	0	0
2	0	3	16	3	0
3	0.45	0.47	0.35	0.3	0.4
4	0	0	0.006	0.002	0
5	0.37	0.55	0.48	0.34	0.4
6	0.244	0.244	0.41	0.196	0.015
7	0.662	1.02	0.476	0.226	1.05
8	0.51	0.58	0.54	0.37	0.4
9	0.22	0.51	0.43	0.26	0.1
10	0.07	0.32	0.33	0.26	0.25
Average	0.252933333	0.6700667	1.9022	0.4954	0.2615

Average Velocity Results in Approximate Locations

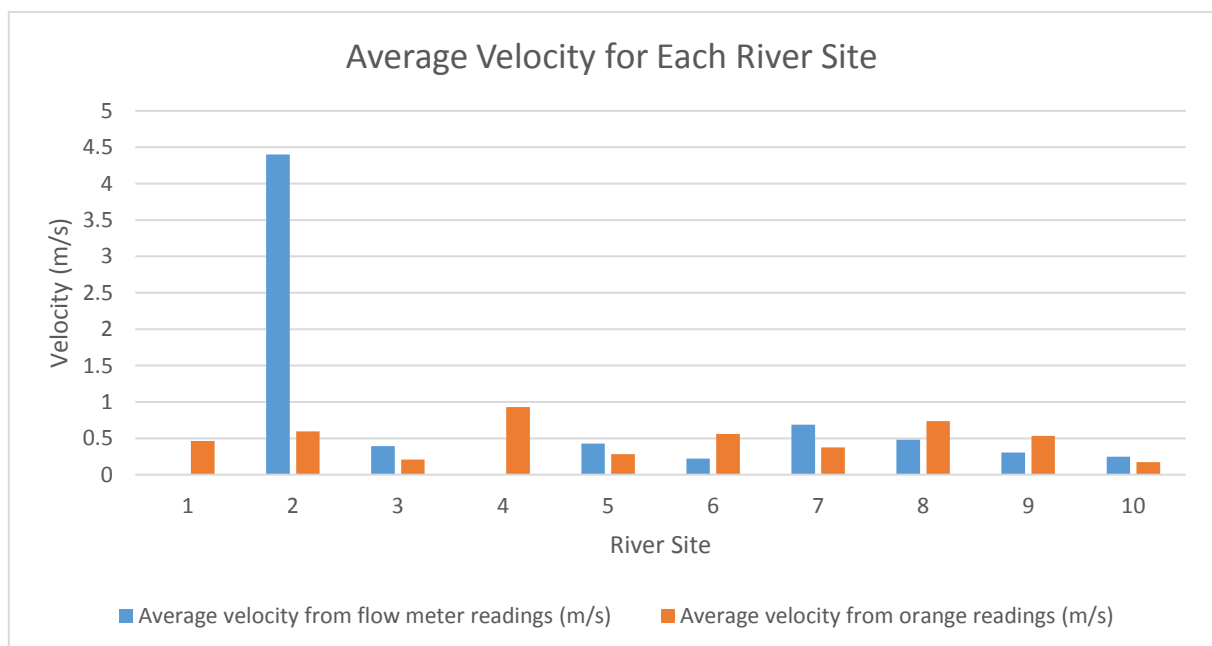


From these results, it appears that the centre of the river does have the highest velocity. This is the case at Sites 2, 4, 6 and 10, and for the averages which represent the river as a whole. However, at over half the Sites (1, 3, 5, 7, 8 and 9) the point of highest velocity was at the surface of the centre of the river. To improve the accuracy of the results for this hypothesis, more readings should be taken at more regular intervals along the streams cross-sections. In many cases, the thalweg is not stationary within the channel and winds from side to side (Huggett, 2003), and so it stands to reason that the point of highest velocity would do the same.

Note: anthropogenic structures such as river channelling have not been taken into account in this study, though these would likely have an effect on the rivers flow. Such structures were present on the River Ilston, particularly in the mid-course of the river.

Hypothesis 5: The river velocity decreases downstream.

Site	1	2	3	4	5	6	7	8	9	10
Average velocity from flow meter readings (m/s)	0.002	4.4	0.394	0.0016	0.428	0.2218	0.6868	0.48	0.304	0.246
Average velocity from orange readings (m/s)	0.462	0.596	0.21	0.928	0.282	0.56	0.373333	0.738	0.534	0.172



The data does not suggest a particularly strong correlation between velocity and the distance downstream. In fact, when looking at the average velocity from the flow meter readings, Site 1, the furthest upstream, has the second lowest velocity, though this area was predominantly marshy without much in the way of a recognisable channel. Therefore, Site 1 could be considered an outlier in this case. The lowest velocity was at Site 4, but here there were fallen trees creating a natural dam and

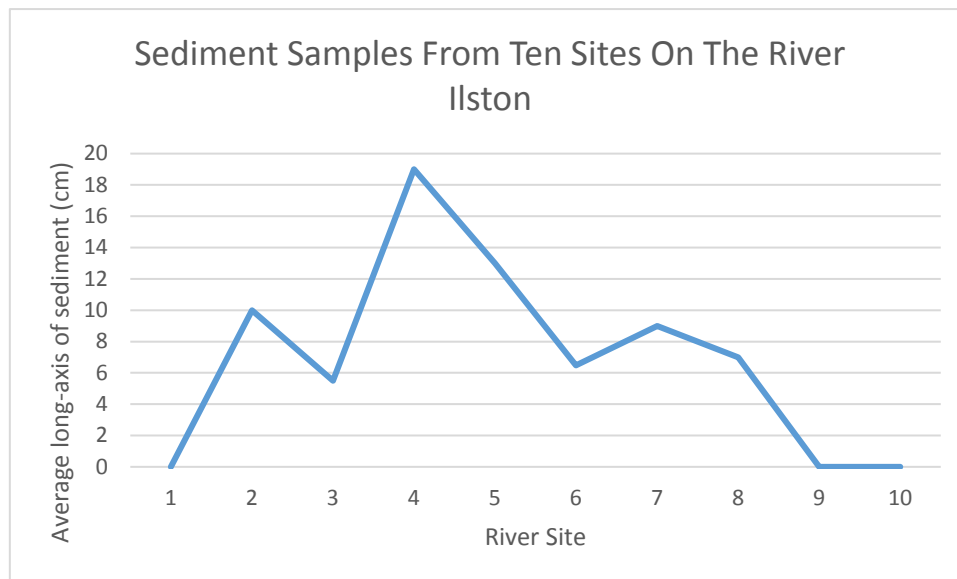
the channel was very stagnant. Perhaps in times of higher rainfall this area would have a flow, but our equipment was able to detect very little. In fact, when we placed an orange here, it did not flow downstream at all but headed approximately 30cm upstream instead, suggesting that this, to, is an outlier. The highest velocity by a considerable amount, using the flow meter data, is Site 2, which has a velocity 4.15m/s greater than that of Site 10. The pattern is true, however, of the last four Sites along the river. On the other hand, the correlation coefficient for this data is 0.2, a low positive correlation where a negative correlation was expected, therefore going against the hypothesis.

When the data collected using the orange method is analysed, there appears to be slightly more of a correlation. The Site with the lowest velocity appears to be Site 10, followed by Site 3. Site 1 has the fourth lowest velocity (which we may again presume to be an outlier). The values for the last three Sites follow a pattern of decreasing velocity downstream, but this is not reflected by the results for the other Sites. With a coefficient value of -0.1, this shows a weak negative correlation.

The velocity of the River Ilston is likely heavily affected by the inconsistency of the channel and groundwater flow. In some parts the river only flows on the surface during periods of high flooding. (House, 2015)

Hypothesis 6: The size of the bedload gets smaller downstream.

Site		1	2	3					4	5	6					7	8	9	10
				1	2	3	4	5			1	2	3	4	5				
Sample 1	Long-axis (cm)	N/A	8	9	5	5	7	8	18	19	8	6	6	5	6	11	6	N/A	N/A
Sample 2	Long-axis (cm)	N/A	7	8	8	5	5	5	37	13	7	4	8	6	5	7	7	N/A	N/A
Sample 3	Long-axis (cm)	N/A	11	4	5	5	5	3	7	10	10	6	5	8	4	7	8	N/A	N/A
Sample 4	Long-axis (cm)	N/A	12	4	5	4	6	4	12	6	9	8	9	5	6	13	4	N/A	N/A
Sample 5	Long-axis (cm)	N/A	13	4	8	5	5	8	21	19	6	7	6	8	7	6	9	N/A	N/A
Average long-axis of sediment (cm)		N/A	10	6	6	5	6	5	19	13	8	6	7	6	6	9	7	N/A	N/A
				5.5							6.48								
Range in sediment size (cm)		N/A	6	5	4	1	2	5	30	13	4	4	5	4	3	7	5	N/A	N/A



This appears to be true in that Sites 9 and 10 have sediment which is too fine to sample using the method described above, and even though this is also the case for Site 1, we may consider this an outlier as the source of the river had not formed a recognisable channel at this point. However, the other points follow no real pattern and have a coefficient value of 0, which is suggestive of no correlation.

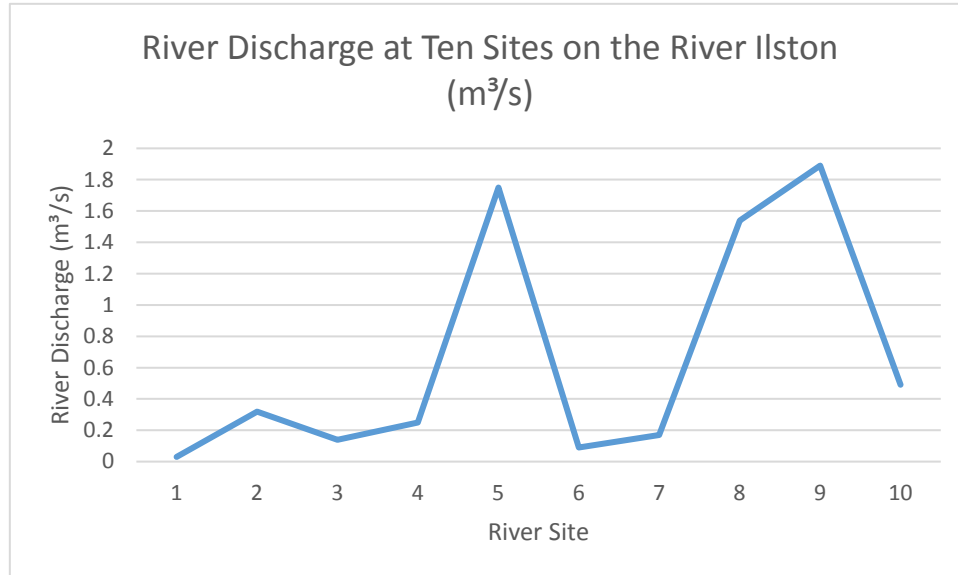
Hypothesis 7: The shape of the bedload becomes more rounded downstream.

Sediment angularity										
Very angular										
Angular										
Sub-angular										
Sub-rounded										
Rounded										
Very rounded										
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10

Sites 1, 9 and 10 had sediment too fine to sample; at Site 1 this was mostly peat whereas Sites 9 and 10 had a bedload of mostly sand and silt. Otherwise, it is true that the only Sites with bedload samples considered to be “very rounded” are 7 and 8, further downstream. On the contrary, Site 4 had the only bedload samples considered to be “very angular”, and though this was in the midcourse of the river, it was not in the upper course as the hypothesis suggests it might.

Hypothesis 8: The discharge of water in the river increases downstream.

Site	1	2	3	4	5	6	7	8	9	10
Discharge (m ³ /s)	0.03	0.32	0.14	0.25	1.75	0.09	0.17	1.54	1.89	0.49



There does appear to be a slight positive correlation here, as Site 9's average discharge is approximately $1.86\text{m}^3/\text{s}$ more than that of Site 1's. Though Site 5 could perhaps be considered an outlier in this case, the other Sites seem to follow more or less the same pattern of increasing river discharge downstream. With a correlation coefficient of 0.4, this is a weak positive correlation.

Note: The velocity values used to calculate the discharge from each Site were the results from the orange technique, rather than the flowmeter readings, as the flowmeters used for fieldwork were temperamental and broke, hence why so much of this data has been discarded and replaced with that from a previous year.

Conclusion

In conclusion, none of the hypotheses were strictly proved or disproved, though a weak positive correlation was identified for Hypotheses 1, 2, 5 (flowmeter data) and 8, which suggests those hypothesis may be correct to some degree (excluding Hypothesis 5, which expected a negative correlation). On the contrary, Hypothesis 5 produced a weak negative correlation (orange data), which also suggests that this hypothesis may be correct. Rivers are known to be affected in a variety of ways by a series of factors, including anthropogenic and climatic (Hooke, 2001). This study could be further improved by repetition over a number of years, and in different seasons, to fully compare how these factors are impacting on the river Ilstons' behaviour and characteristics.

It is also worth considering that the River Ilston is a "misfit stream" and as such behaves differently to conventional rivers, as such the behaviour of this river cannot be assumed to be the same as other rivers. If a control survey was to be set up, then the results of this survey could be compared more fully to establish just how different the River Ilston is from other rivers.

References

Websites:

- The Geological Society of London, 2012 <https://www.geolsoc.org.uk/Education-and-Careers/Resources/Field-Work-Resources/Gower-Field-Guide/Other-sites-of-Geological-Interest>
- Google Maps 2015 <https://maps.google.co.uk/>
- Ordnance Survey 2015 <http://www.riverhabitatsurvey.org/map-open-os/>

Books:

- Fundamentals of Geomorphology, Richard John Huggett, Routledge, London 2003
- Geomorphological Processes and Landscape Change, Britain in the last 1000 years. Edited by David L Higgitt and E Mark Lee. 2001 Blackwell Publishers Ltd. Pp 116-146 Fluvial Processes, Janet M Hooke (2001)

Papers:

- Powers, M. C., Journal of Sedimentary Petrology Vol. 23 (1953)No. 2. (June), Pg 118

Personal Communication:

- Chris House, Monday 26th October 2015

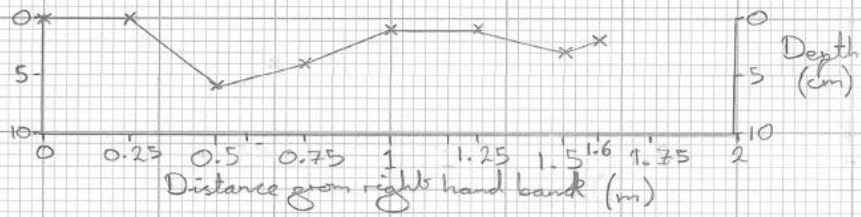
Appendices

Adjusted GPS Co-ordinates for River Sites

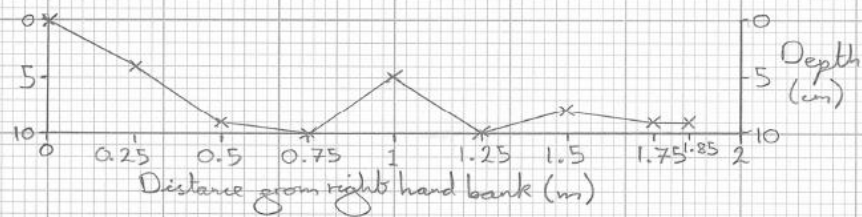
	Adjusted longitude (°)	Adjusted latitude (°)	Data from a previous year long (°)	Data from a previous year lat (°)
Site 1	-4.08431	51.6013	-4.088170	51.600700
Site 2	-4.08661	51.59786	-4.086050	51.597400
Site 3	?	?	-4.083290	51.593200
Site 4	-4.08001	51.59116	-4.080410	51.591800
Site 5	-4.08067	51.59007	-4.081550	51.589900
Site 6	?	?	-4.087280	51.586700
Site 7	-4.09116	51.58277	-4.089670	51.582600
Site 8	-4.103434	51.581220	-4.101350	51.581000
Site 9	-4.10298	51.57814	-4.102770	51.577100
Site 10	N/A	N/A	-4.109350	51.573700

Site 1 Results: River Cross Sections

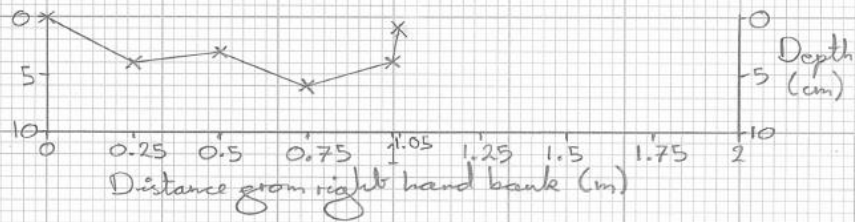
Point 1



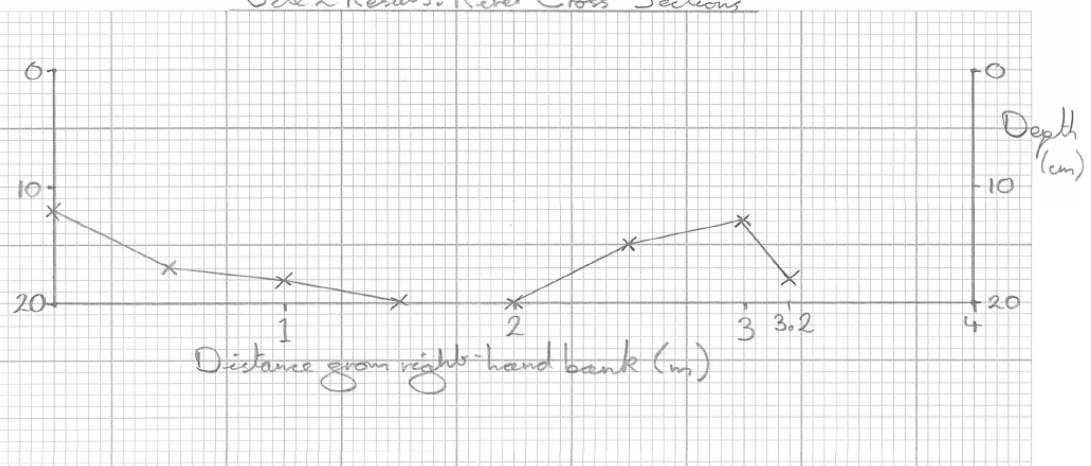
Point 2

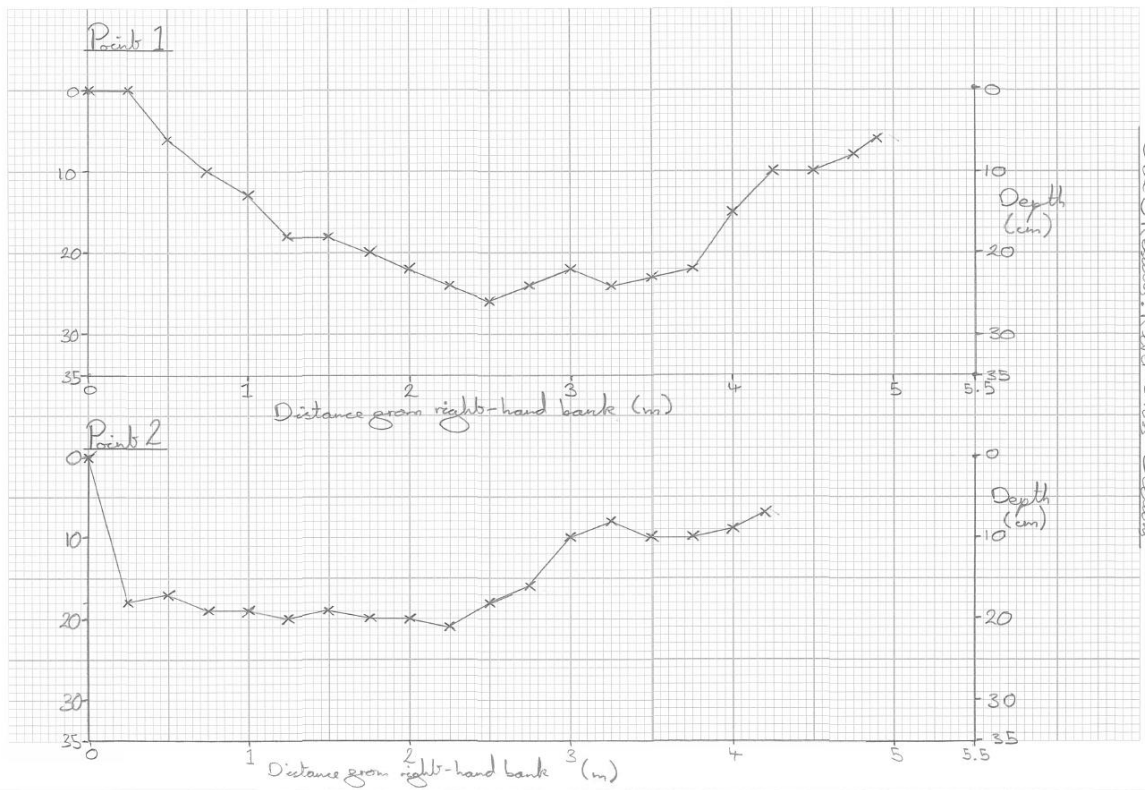


Point 3

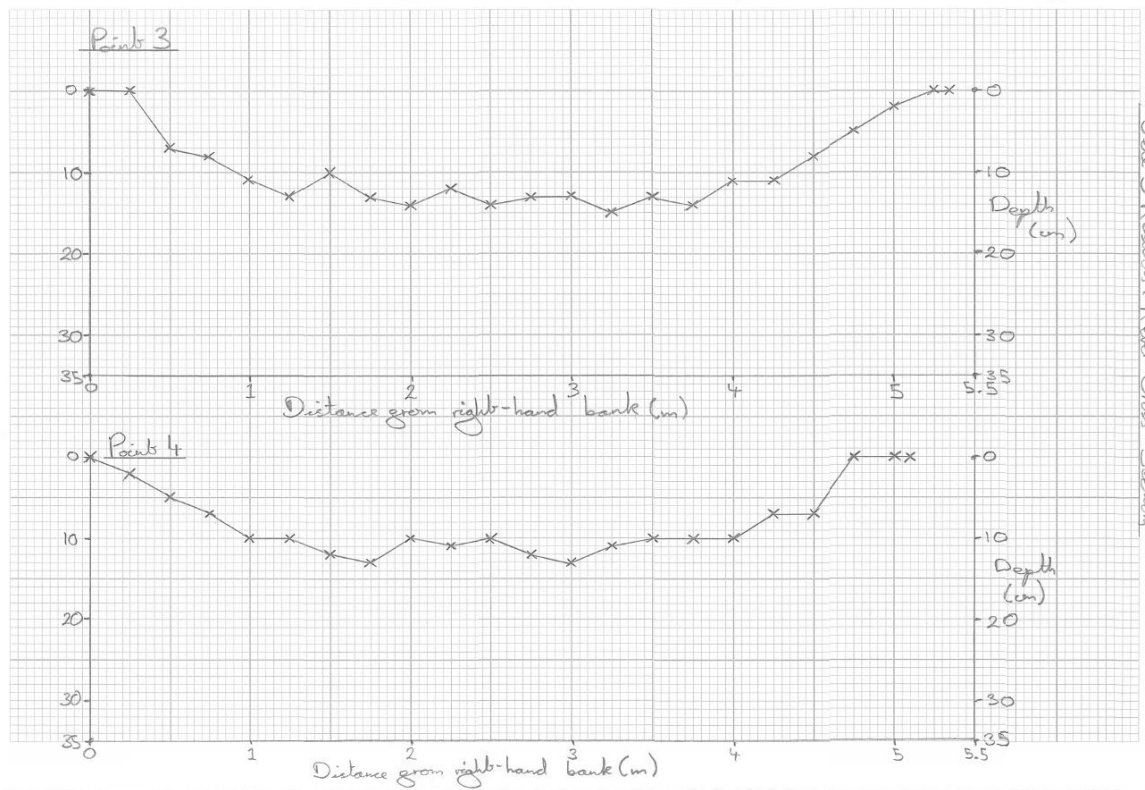


Site 2 Results: River Cross Sections

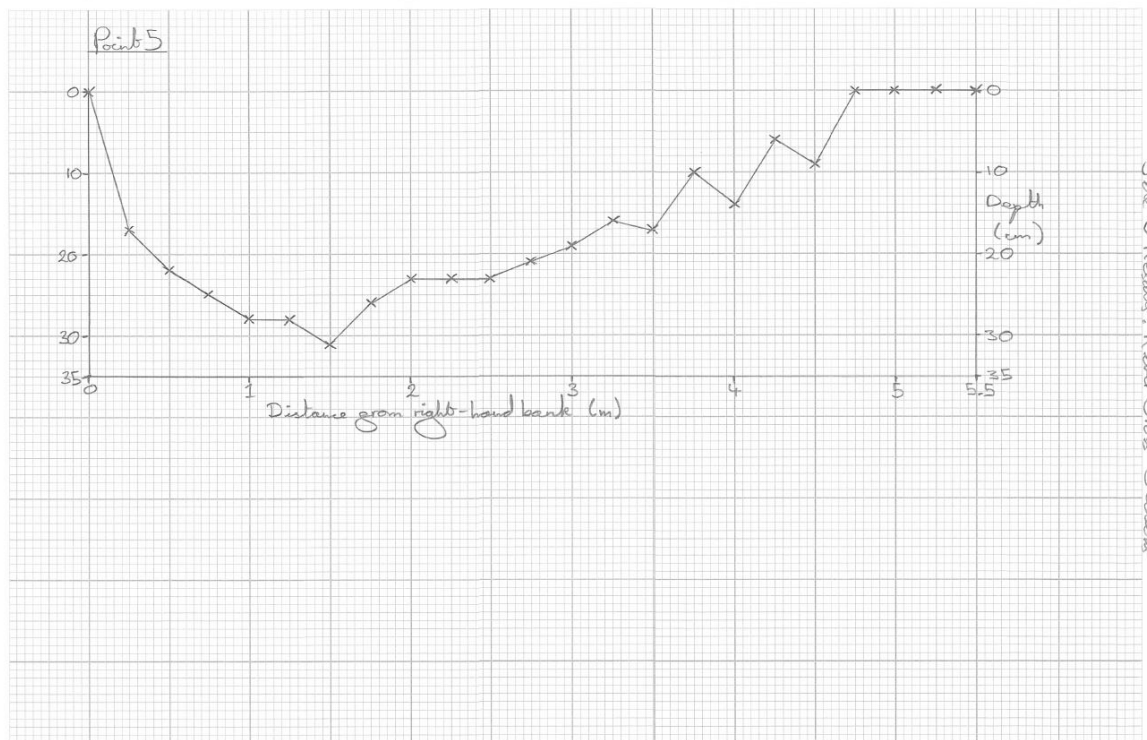




Side 3 Results: River Cross-Section



Side 3 Results: River Cross-Section

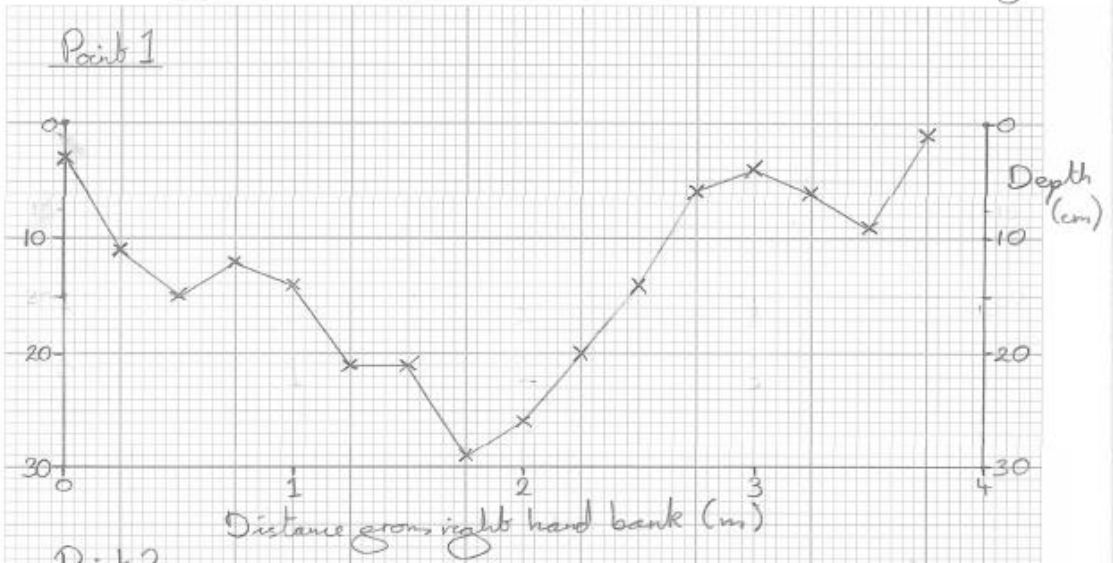


Site 3 Results: River Cross-Sections

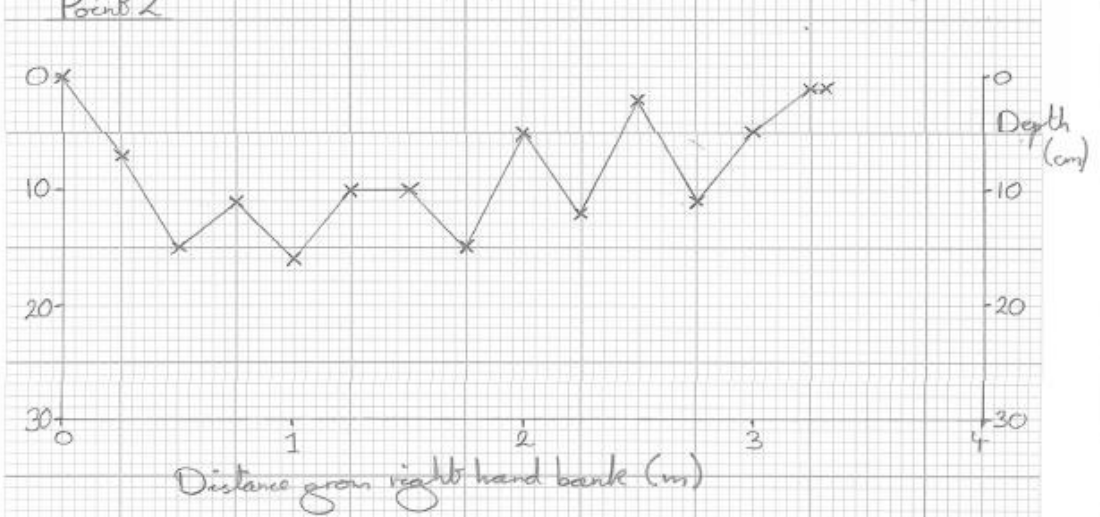
Site 4 Results: River Cross-Section

1 of 2

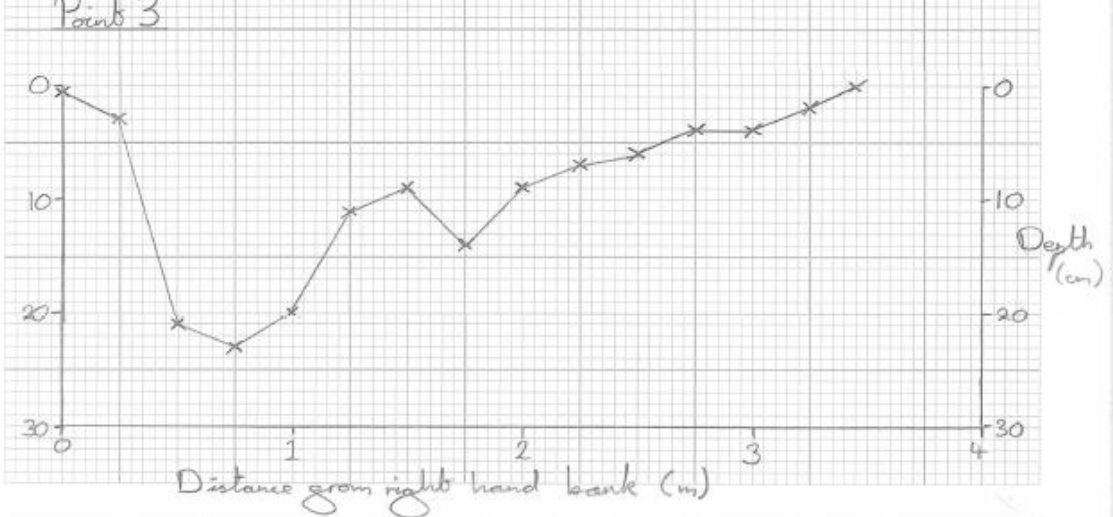
Point 1



Point 2



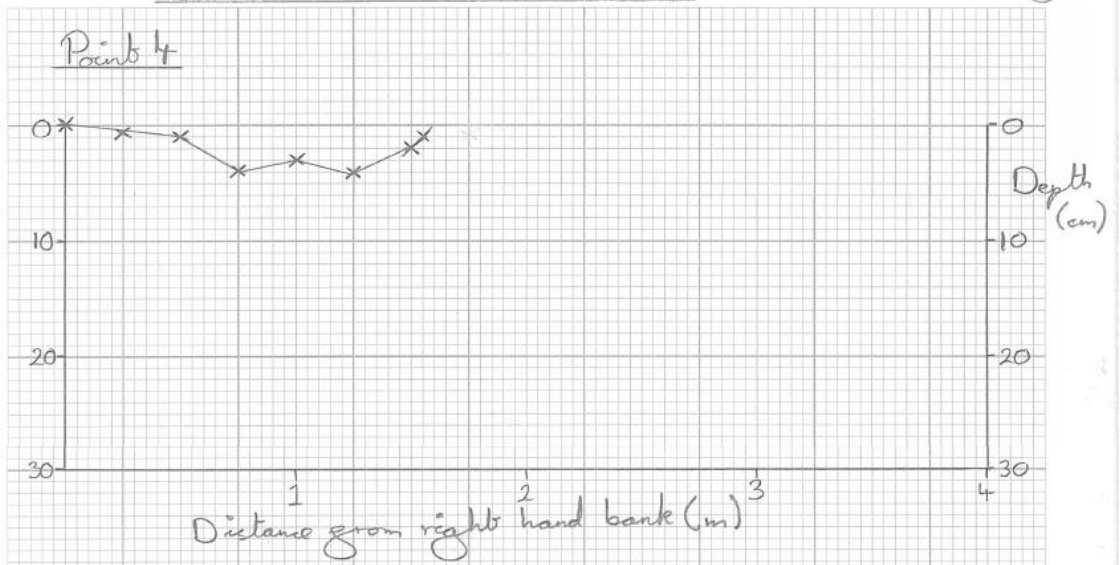
Point 3



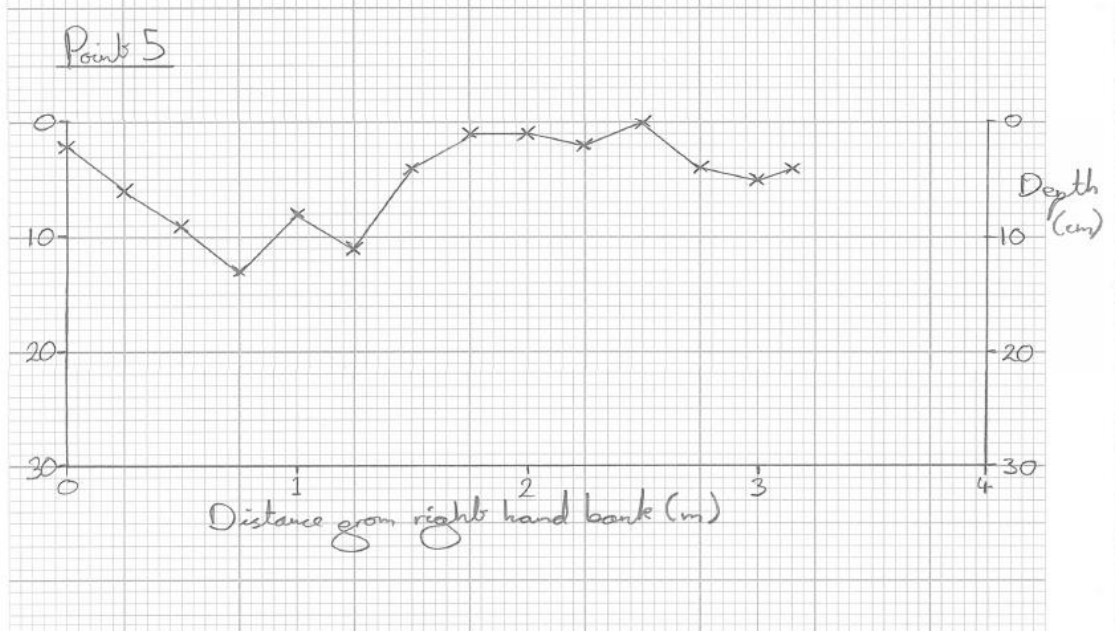
Site 4 Results: River Cross-Sections

2 of 2

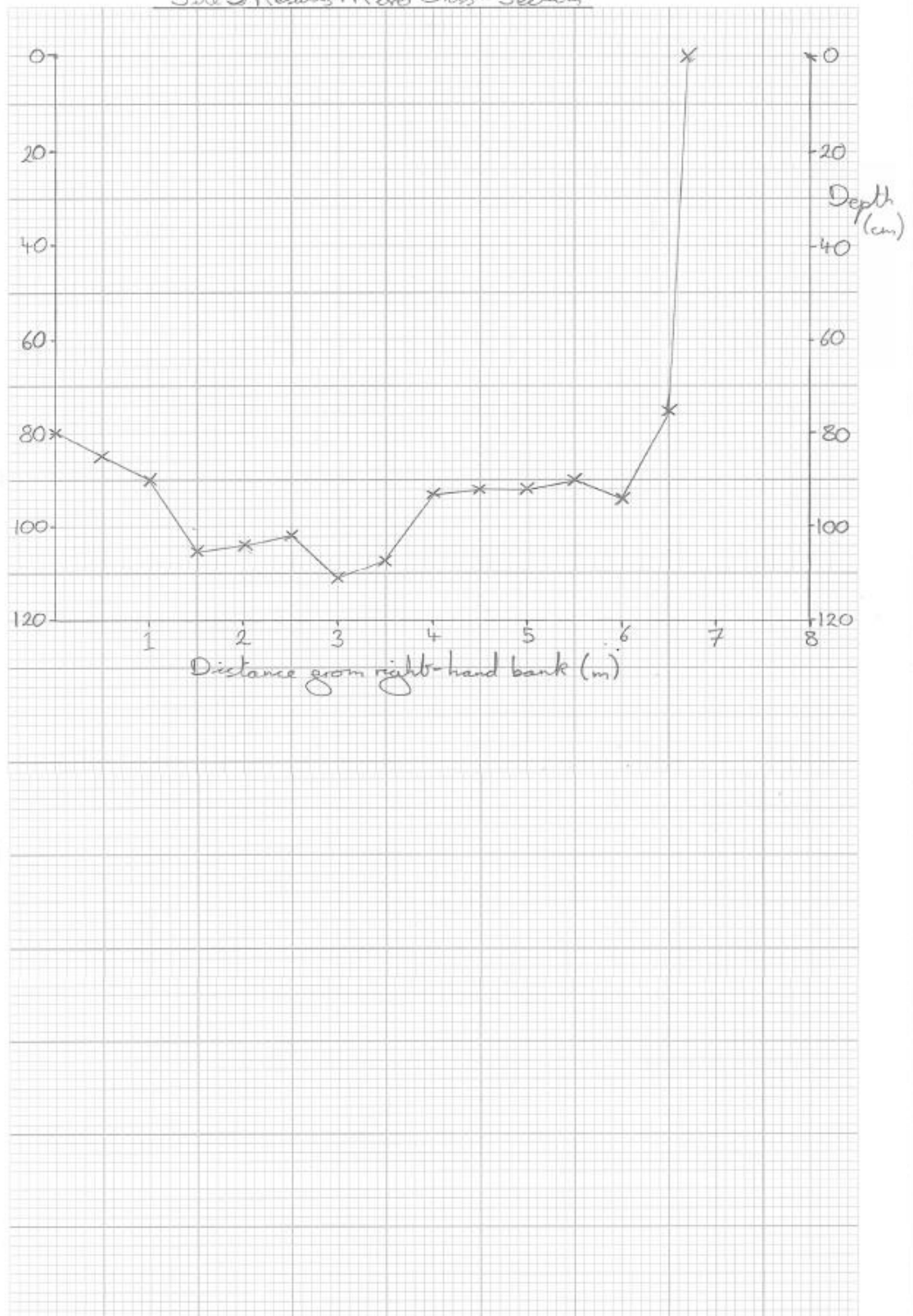
Point 4



Point 5

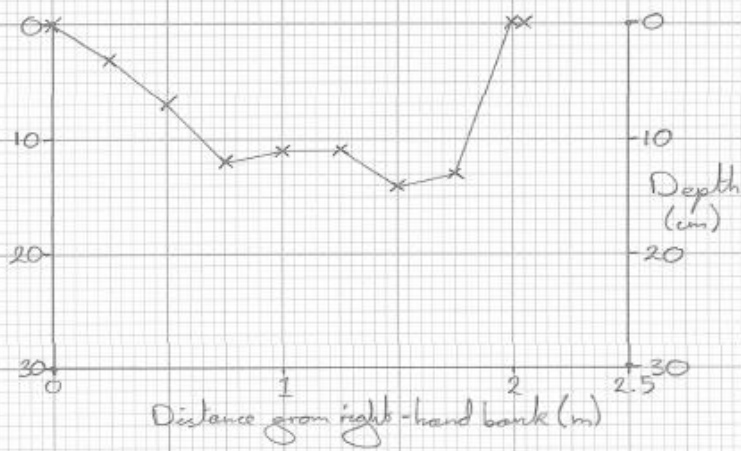


Site 5 Results: River Cross-Sections

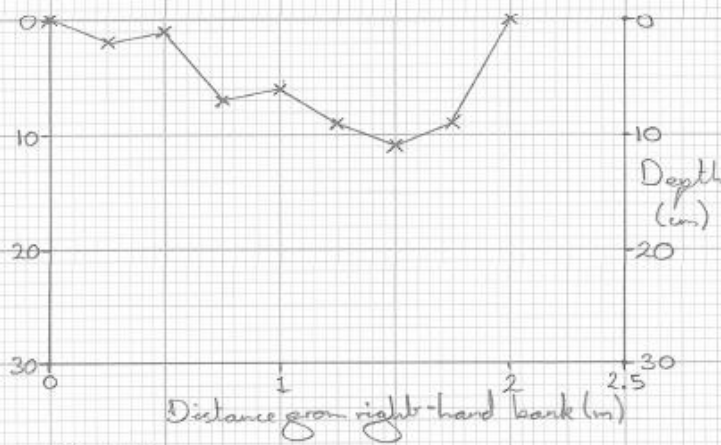


Site 6 Results: River Cross-Sections

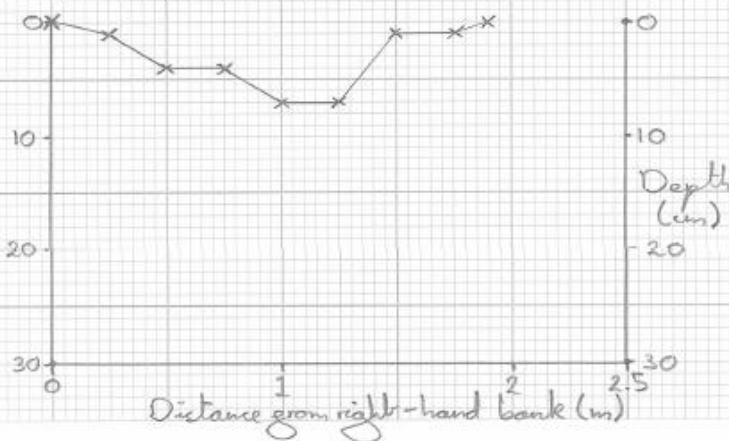
Point 1



Point 2

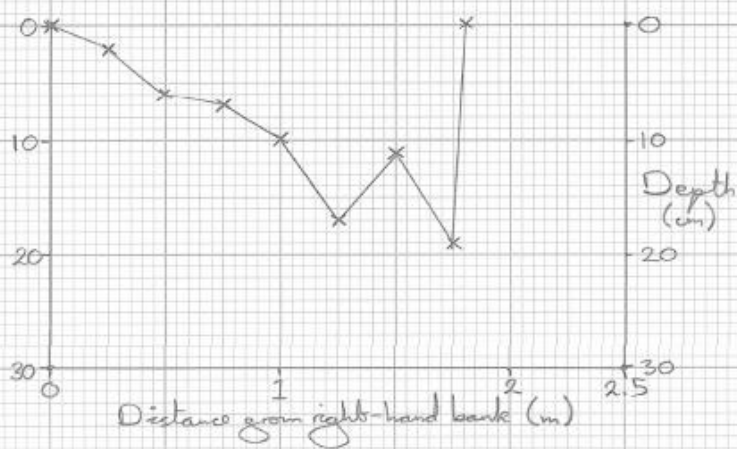


Point 3

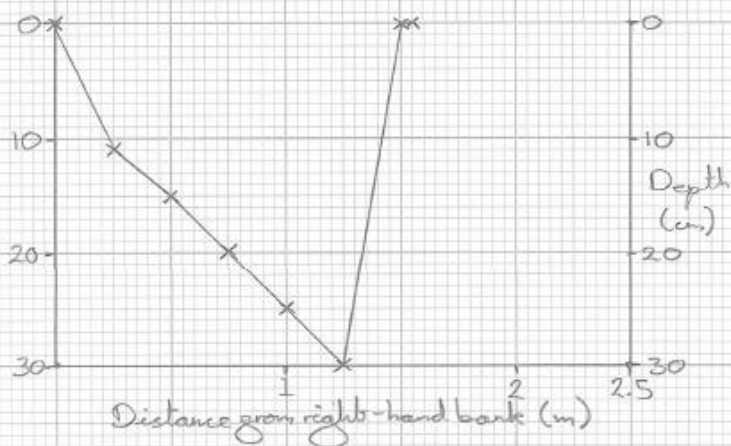


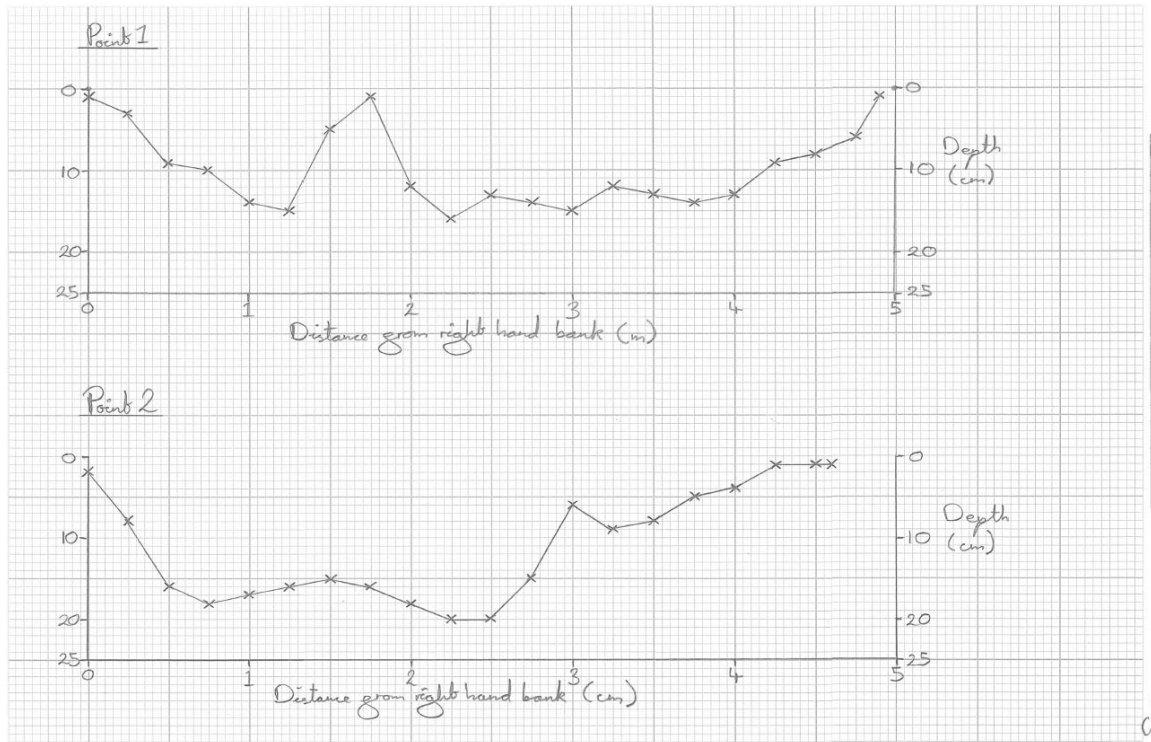
Site 6 Results: River Cross-Sections

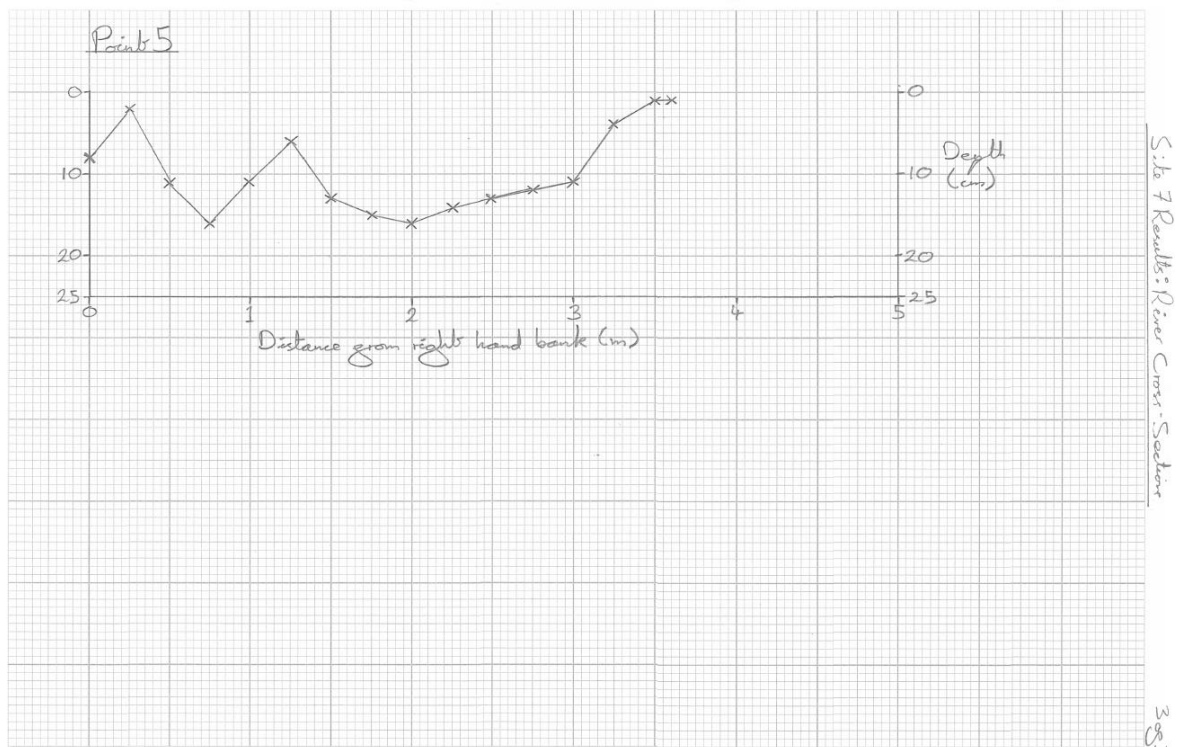
Point 4



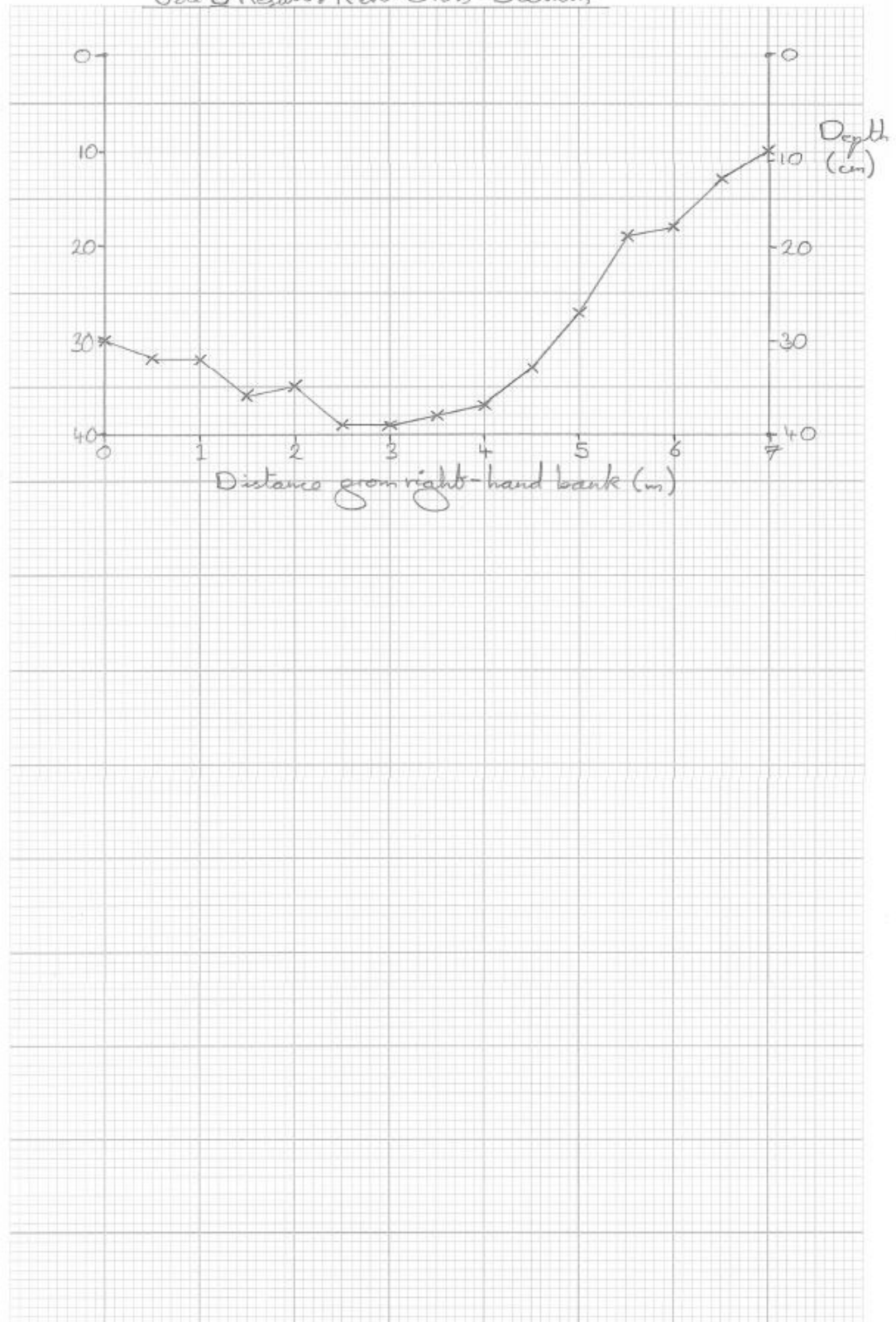
Point 5

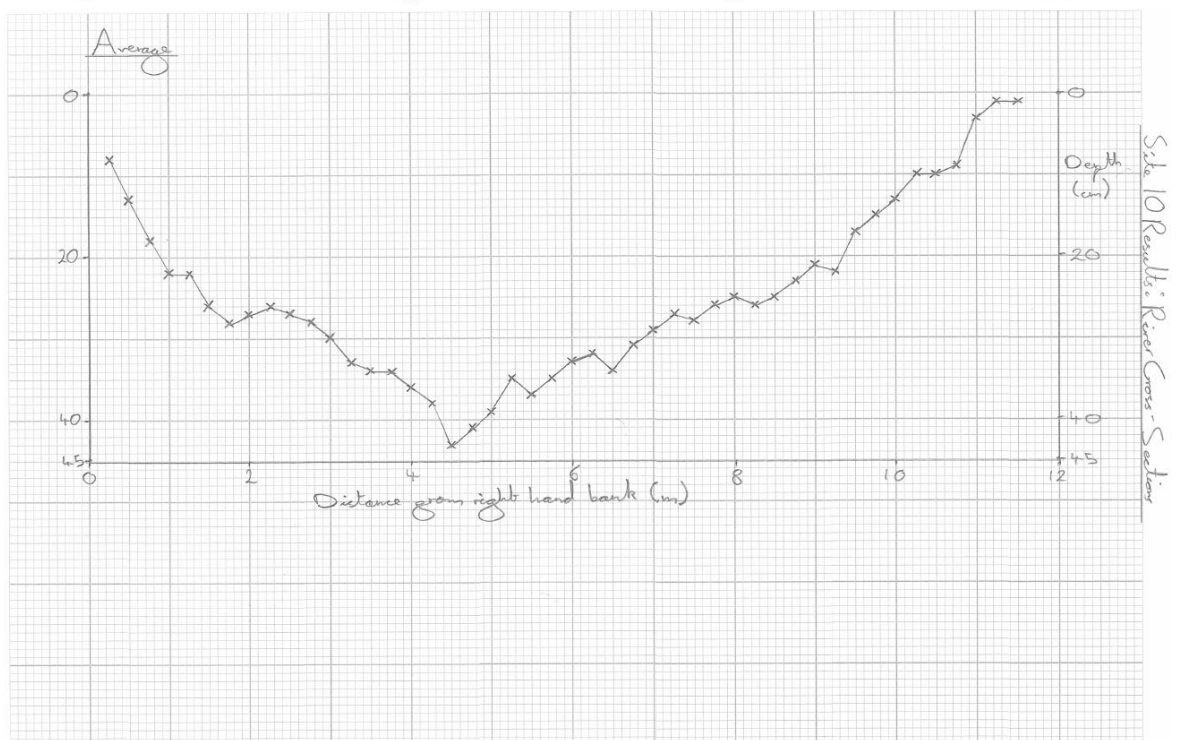
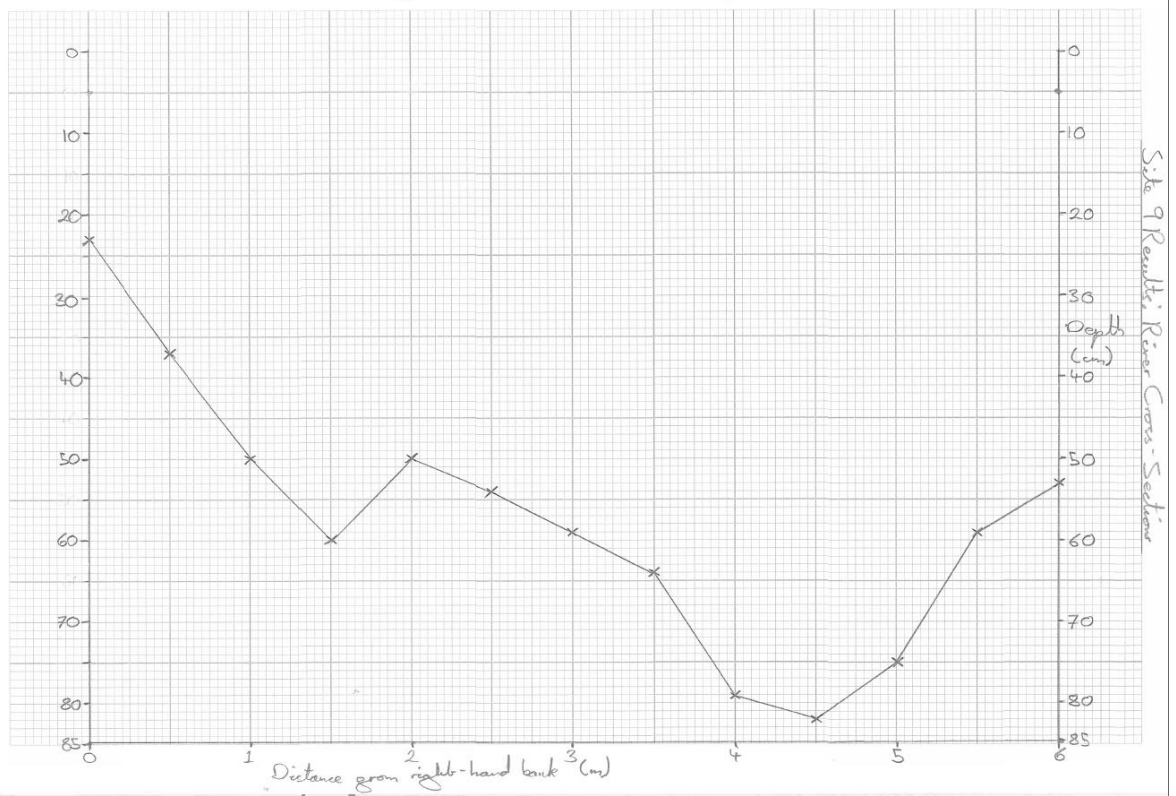






Site 8 Results: River Cross-Sections





Spearman's rank correlation coefficient: River width increases downstream.

Distance down-stream	Rank	Width of river (cm)	Rank	Difference between ranks (d)	d ²
1.1	28	160	25	-3	9
1.2	27	185	23	-4	16
1.3	26	105	28	2	4
2	25	320	18	-7	49
3.1	24	500	8	-16	256
3.2	23	420	13	-10	100
3.3	22	535	6	-16	256
3.4	21	510	7	-14	196
3.5	20	550	5	-15	225
4.1	19	375	14	-5	25
4.2	18	331	17	-1	1
4.3	17	345	16	-1	1
4.4	16	155	26.5	10.5	110.25
4.5	15	315	19	4	16
5	14	670	3	-11	121
6.1	13	205	20	7	49
6.2	12	200	21	9	81
6.3	11	190	22	11	121
6.4	10	180	24	14	196
6.5	9	155	26.5	17.5	306.25
7.1	8	490	9	1	1
7.2	7	460	11	4	16
7.3	6	468	10	4	16
7.4	5	435	12	7	49
7.5	4	360	15	11	121
8	3	700	2	-1	1
9	2	600	4	2	4
10	1	1180	1	0	0
				Sum of d ²	2346.5
				r _s	0.357827039

Spearman's rank correlation coefficient: River depth increases downstream.

Distance down-stream	Rank	Average depth (cm)	Rank	Difference between ranks (d)	d ²
1.1	28	2.125	27	-1	1
1.2	27	7.111111111	21	-6	36
1.3	26	3	25	-1	1
2	25	16.625	5	-20	400
3.1	24	15.28571429	8	-16	256
3.2	23	15.88888889	6	-17	289
3.3	22	9	16	-6	36

3.4	21	7.727272727	20	-1	1
3.5	20	15.56521739	7	-13	169
4.1	19	13.25	9	-10	100
4.2	18	8.4	18	0	0
4.3	17	8.9	17	0	0
4.4	16	1.9375	28	12	144
4.5	15	5	23.5	8.5	72.25
5	14	94.28571429	1	-13	169
6.1	13	7.1	22	9	81
6.2	12	5	23.5	11.5	132.25
6.3	11	2.777777778	26	15	225
6.4	10	8	19	9	81
6.5	9	12.625	10	1	1
7.1	8	9.714285714	13	5	25
7.2	7	10.8	11	4	16
7.3	6	9.3	15	9	81
7.4	5	10.05263158	12	7	49
7.5	4	9.625	14	10	100
8	3	29.13333333	3	0	0
9	2	57.30769231	2	0	0
10	1	24.80434783	4	3	9
				Sum of d ²	2474.5
				r _s	0.322796935

Spearman's rank correlation coefficient: Cross-sectional area increases downstream.

Distance down-stream	Rank	Cross-sectional area (cm ²)	Rank	Difference between ranks (d)	d ²
1.1	28	287.5	28	0	0
1.2	27	1352.5	23	4	16
1.3	26	375.125	26	0	0
2	25	5435	8	17	289
3.1	24	8130	6	18	324
3.2	23	6775	7	16	256
3.3	22	5175	11	11	121
3.4	21	4250	15	6	36
3.5	20	8950	5	15	225
4.1	19	5250	10	9	81
4.2	18	3118.5	18	0	0
4.3	17	3326.25	17	0	0
4.4	16	345	27	-11	121
4.5	15	1630	21	-6	36
5	14	62125	1	13	169
6.1	13	1775	20	-7	49
6.2	12	1125	24	-12	144

6.3	11	620	25	-14	196
6.4	10	1610	22	-12	144
6.5	9	2525	19	-10	100
7.1	8	5040	12	-4	16
7.2	7	5347.5	9	-2	4
7.3	6	4568	14	-8	64
7.4	5	4707.5	13	-8	64
7.5	4	3722.5	16	-12	144
8	3	20875	4	-1	1
9	2	35350	2	0	0
10	1	28412.5	3	-2	4
				Sum of d ²	2604
				r _s	0.287356322

Spearman's rank correlation coefficient: River velocity decreases downstream.

Distance downstream	Rank	Velocity data from orange technique (m/s)	Rank	Difference between ranks (d)	d ²
1.1	48	0.52	24	-24	576
1.2	47	0.41	30	-17	289
1.3	46	0.44	28	-18	324
1.4	45	0.38	32	-13	169
1.5	44	0.56	19.5	-24.5	600.25
2.1	43	0.58	16	-27	729
2.2	42	0.56	19.5	-22.5	506.25
2.3	41	0.54	21.5	-19.5	380.25
2.4	40	0.63	12	-28	784
2.5	39	0.67	11	-28	784
3.1	38	0.23	38.5	0.5	0.25
3.2	37	0.2	43	6	36
3.3	36	0.16	47	11	121
3.4	35	0.22	40.5	5.5	30.25
3.5	34	0.24	37	3	9
4.1	33	0.74	8	-25	625
4.2	32	1.09	1	-31	961
4.3	31	0.96	3	-28	784
4.4	30	1	2	-28	784
4.5	29	0.85	4	-25	625
5.1	28	0.23	38.5	10.5	110.25
5.2	27	0.3	35.5	8.5	72.25
5.3	26	0.33	33.5	7.5	56.25
5.4	25	0.22	40.5	15.5	240.25
5.5	24	0.33	33.5	9.5	90.25

6.1	23	0.51	25	2	4
6.2	22	0.53	23	1	1
6.3	21	0.59	15	-6	36
6.4	20	0.57	17.5	-2.5	6.25
6.5	19	0.6	14	-5	25
7.1	18	0.3	35.5	17.5	306.25
7.2	17	0.39	31	14	196
7.3	16	0.43	29	13	169
8.1	15	0.72	9	-6	36
8.2	14	0.77	5	-9	81
8.3	13	0.69	10	-3	9
8.4	12	0.75	7	-5	25
8.5	11	0.76	6	-5	25
9.1	10	0.49	26	16	256
9.2	9	0.46	27	18	324
9.3	8	0.54	21.5	13.5	182.25
9.4	7	0.61	13	6	36
9.5	6	0.57	17.5	11.5	132.25
10.1	5	0.17	45	40	1600
10.2	4	0.14	48	44	1936
10.3	3	0.17	45	42	1764
10.4	2	0.17	45	43	1849
10.5	1	0.21	42	41	1681
				Sum of d ²	20366.5
				r _s	-0.105433131

Spearman's rank correlation coefficient: River discharge increases downstream

Distance down-stream	Rank	Discharge (m ³ /s)	Rank	Difference between ranks (d)	d ²
1.1	28	0.000132825	28	0	0
1.2	27	0.000624855	24	-3	9
1.3	26	0.000173308	27	1	1
2	25	0.00323926	6	-19	361
3.1	24	0.0017073	13	-11	121
3.2	23	0.00142275	16	-7	49
3.3	22	0.00108675	19	-3	9
3.4	21	0.0008925	22	1	1
3.5	20	0.0018795	11	-9	81
4.1	19	0.004872	5	-14	196
4.2	18	0.002893968	8	-10	100
4.3	17	0.00308676	7	-10	100
4.4	16	0.00032016	26	10	100

4.5	15	0.00151264	15	0	0
5	14	0.01751925	2	-12	144
6.1	13	0.000994	20	7	49
6.2	12	0.00063	23	11	121
6.3	11	0.0003472	25	14	196
6.4	10	0.0009016	21	11	121
6.5	9	0.001414	17	8	64
7.1	8	0.0018816	10	2	4
7.2	7	0.0019964	9	2	4
7.3	6	0.001705387	14	8	64
7.4	5	0.001757467	12	7	49
7.5	4	0.001389733	18	14	196
8	3	0.01540575	3	0	0
9	2	0.0188769	1	-1	1
10	1	0.00488695	4	3	9
				Sum of d ²	2150
				r_s	0.41160372

Spearman's rank correlation coefficient: bedload size increases downstream

Distance down-stream	Rank	Average long-axis of sediment (cm)	Rank	Difference between ranks (d)	d ²
1	18	0	2	-16	256
2	17	10.2	16	-1	1
3.1	16	5.8	8	-8	64
3.2	15	6.1	9	-6	36
3.3	14	4.6	4	-10	100
3.4	13	5.6	7	-6	36
3.5	12	5.4	5	-7	49
4	11	19	18	7	49
5	10	13.4	17	7	49
6.1	9	7.8	14	5	25
6.2	8	6.2	10.5	2.5	6.25
6.3	7	6.7	12	5	25
6.4	6	6.2	10.5	4.5	20.25
6.5	5	5.5	6	1	1
7	4	8.8	15	11	121
8	3	6.8	13	10	100
9	2	0	2	0	0
10	1	0	2	1	1
				Sum of d ²	939.5
				r_s	0.030443756

All Sediment Data for 10 Sites On the River Ilston

VA=Very Angular A=Angular SA=Sub-angular SR=Sub-rounded R=Rounded VR=Very Rounded

Site		1	2	3					4	5	6					7	8	9	10
				1	2	3	4	5			1	2	3	4	5				
Sample 1	Long-axis (cm)	N/A	8	9	5	4.5	7	7.5	18	19	8	6	6	5	5.5	11	6	N/A	N/A
	Angular-ity		R	SR	SR	SR	R	SA	VA	SA	SR	SA	SA	SR	A	SR	R	N/A	N/A
Sample 2	Long-axis (cm)	N/A	7	8	8	4.5	5	5	37	13	7	4	8	6	5	7	7	N/A	N/A
	Angular-ity		SA	SR	SA	SA	SA	SA	VA	SR	SA	R	SA	SR	SA	SR	SR	N/A	N/A
Sample 3	Long-axis (cm)	N/A	11	4	5	5	5	3	7	10	9.5	6	4.5	7.5	4	7	8	N/A	N/A
	Angular-ity		SR	SR	SR	SR	SR	SR	A	A	SR	SA	SA	SR	SA	VR	SA	N/A	N/A
Sample 4	Long-axis (cm)	N/A	12	4	4.5	4	6	3.5	12	6	8.5	8	9	4.5	6	13	4	N/A	N/A
	Angular-ity		SA	SR	SR	SR	SA	SA	A	SR	A	SA	R	A	SA	A	SR	N/A	N/A
Sample 5	Long-axis (cm)	N/A	13	4	8	5	5	8	21	19	6	7	6	8	7	6	9	N/A	N/A
	Angular-ity		SA	SR	SA	SR	SA	R	VA	A	SA	A	SR	SR	SR	A	SR	N/A	N/A
Average long-axis of sediment (cm)		N/A	10.2	5.8	6.1	4.6	5.6	5.4	19	13.4	7.8	6.2	6.7	6.2	5.5	8.8	6.8	N/A	N/A
Range in sediment size (cm)		N/A	6	5	3.5	0.5	2	5	30	13	3.5	4	4.5	3.5	3	7	5	N/A	N/A

Mode sediment angularity	N/A	SA	SR	SR	SR	SA	SA	VA	SR /A	SR /SA	SA	SA	SR	SA	SR /A	SR	N/A	N/A
Range in sediment angularity	N/A	R-SA	SR	SR-SA	SR-SA	R-SA	R-SA	VA-A	SR-A	SR-A	A-R	SA-R	SR-A	A-SR	VR -A	R-SA	N/A	N/A

