Title of Geographical Study	Word count (Max 3000)
CARRON WATER RIVER STUDY	3105

Title of Geographical Issue	Word count (Max 1800)
MICROPLASTICS IN OUR OCEANS	1885

For centre completion

☑ In ticking this box it is confirmed that any potential child welfare concerns arising from the content of the materials enclosed are being or have been addressed.

For SQA Use Only

Geography Advanced Higher Assignment

Skills, knowledge and understanding	Marks Available	Marks Awarded
Folio Section A: Geographical Study		
A. Justify choice of topic	4	
B. Plan and carry out research	10	
C. Evaluate research techniques and reliability of data	8	
D. Demonstrate a detailed knowledge and understanding	8	
E. Use a wide range of appropriate techniques	10	
F. Analyse information to identify and explain relationships	12	
G. Reach reasoned conclusion(s)	8	
Total for Section A	60	
Folio Section B: Geographical Issue		
A. Justify choice of issue	4	
B. Undertake wider background reading	8	
C. Summarise a wide range of view points	10	
D. Critically evaluate each viewpoint	10	
E. Reach a reasoned conclusion	8	
Total for Section B	40	

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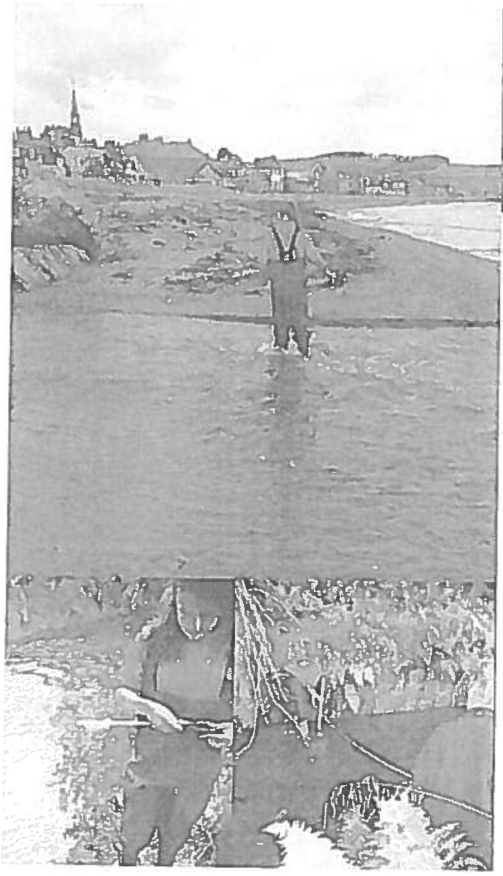

CARRON WATER RIVER STUDY

Advanced Higher Geography Project

Word count: 3,105

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Introduction

The aim of this study is to investigate sites along Carron Water from source to sea (Appendix 1), in terms of channel characteristics and to analyse the bedload with a view to understanding maturity and transport, from geological origin. Parameters used include channel width and depth, current velocity and bedload type, size and roundness.

Carron Water flows 15km from its headwaters in Fetteresso Forest, on the eastern edge of the Grampians, to its mouth in Stonehaven, on the North Sea coast of Aberdeenshire. The source lies in excess of 260m above sea-level. The predominant direction of flow is east-north-east.

Most of Carron Water's catchment lies in the Stonehaven Group, comprising mainly sandstone with subordinate conglomerate and siltstone (Appendix 2); its source lies in the Highland Border Complex. The two provinces are separated by the Highland Boundary Fault, one the largest and most significant crustal dislocations in Britain.

Stonehaven, a coastal town lying approximately 25km south of Aberdeen in North East Scotland, has a history of inundation by Carron Water. On an approximately decadal periodicity, the damage which it has caused has made headlines, including: "Residents evacuated after flooding on Stonehaven waterfront"; "Stonehaven families left devastated as homes are flooded just days before Christmas". The notorious Carron Water is subject of an on-going alleviation programme to reduce the frequency and impact of flooding. Following a 2012 tidal surge in which almost £2million worth of damage was caused, Aberdeenshire Council have spent £300,000 on drainage, ensuring a rapid run-off from the lowest lying area, which is most susceptible due to its proximity to the river mouth. £16million is in place for the ongoing projects, including maintenance; channel and bridge modifications; upstream storage (allowing the creation of wetlands) and direct defences, such as high walls.

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Research questions

1. Do channel width and depth increase as the distance from the source increases in accordance with the Bradshaw model (Figure 1)?
2. Does velocity increase as the distance from the source increases in accordance with the Bradshaw model?
3. Does bedload roundness increase and longest axis decrease as the distance from the source increases in accordance with the Bradshaw model?
4. Does geology influence the river and does bedload rock type reflect both local geology and become increasingly mixed downstream, as more rock types are eroded and transported by the river channel?

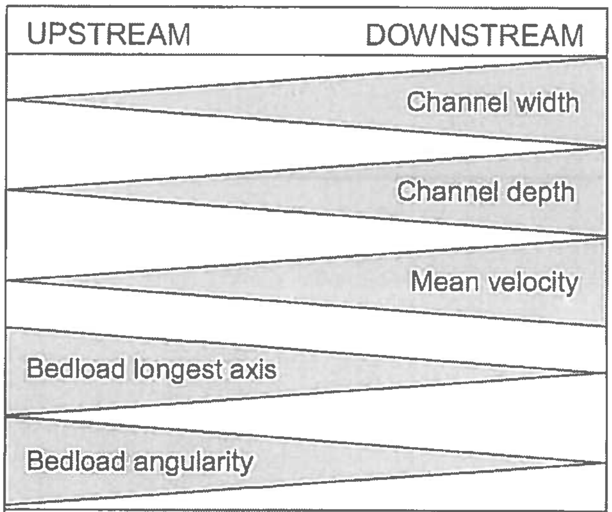

Figure 1: Bradshaw Model.

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Methodology

Site selection in the river system was undertaken by examining a map of the Stonehaven area. Sample sites were provisionally chosen based on systematic spacing with modifications for accessibility and safety. Permission was obtained from landowners. Fieldwork was undertaken on 21-22/10/15 with maximum daytime temperatures at Stonehaven varying from 21°C - 14°C. Both days were sunny with little rainfall.

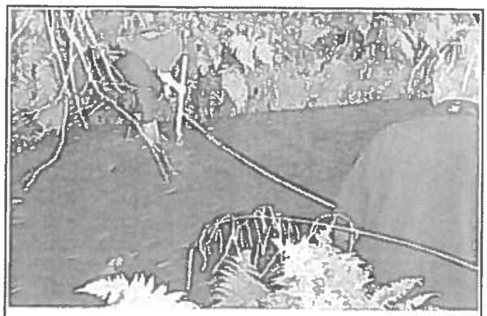

Figure 2: Measuring the depth with a meter stick, after having recorded the channel depth.

At each site the following parameters were collated:

Channel width was measured by extending a tape measure orthogonal to the channel axis, at about 10cm above the water level.
Channel depth was recorded at every decile of the width. At each decile, a metre ruler w

as placed vertically on the bed of the river and the depth recorded (Figure 2).
Rock type was defined on comparison to photographs of local rock types (Figure 3). Samples were taken from immediately below the ruler, when measuring depth. **Longest-axis** was measured by placing callipers along the longest axis of each specimen, previously selected for rock type identification, and reading the value. **Bedload roundness**, using the same rocks, was defined by comparison with Power's Index (Figure 4).

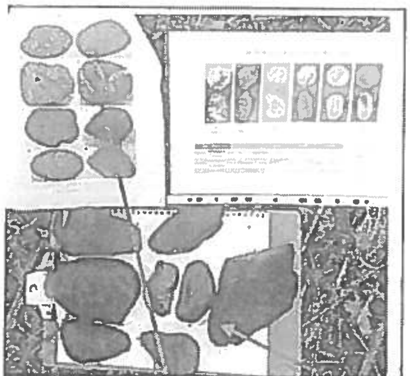

Figure 3: Selected rocks and identification sheet.

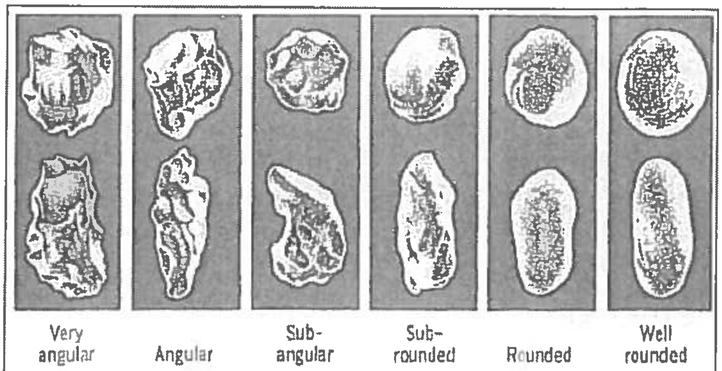

Figure 4: Power's Index. (earthstudies.co.uk)

Channel velocity was measured at river left, middle and right and time recorded for the floating orange to travel 5m was recorded (Figure 5).

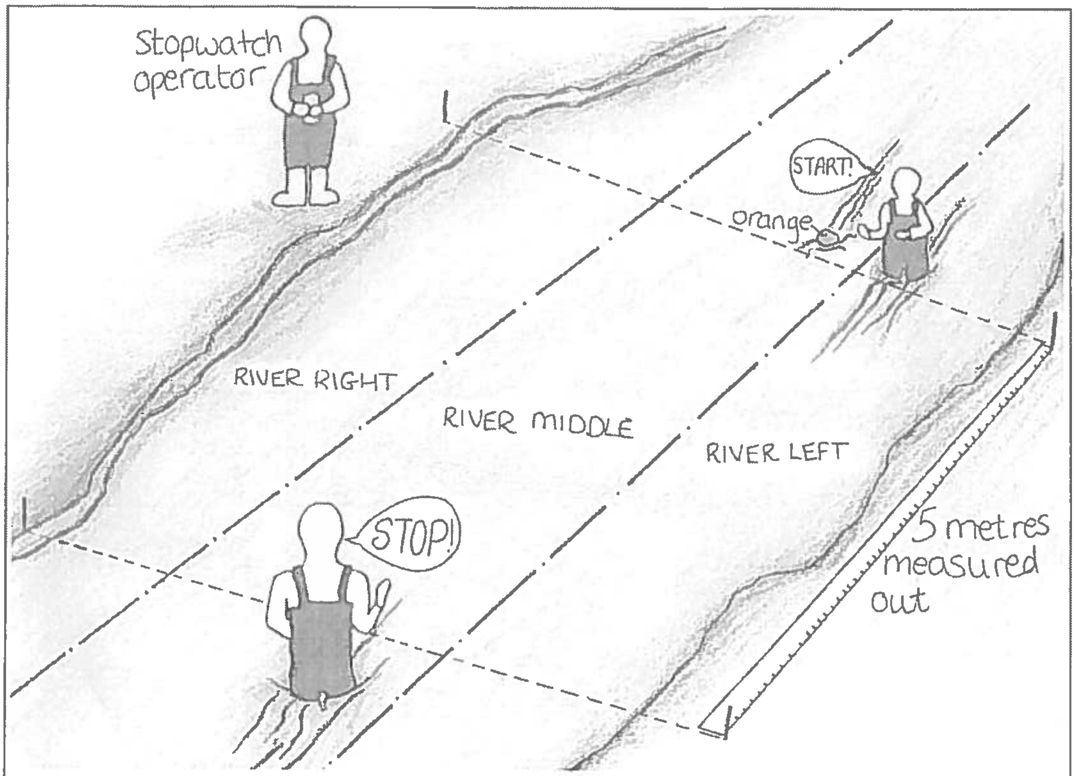

Figure 5: Diagrammatic representation of river velocity being recorded.

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Analysis

Research question 1: Do channel width and depth increase as the distance from the source increases in accordance with the Bradshaw model (Figure 1)?

Width and depth are displayed as cross sectional diagrams to show progression, development and anomalies.

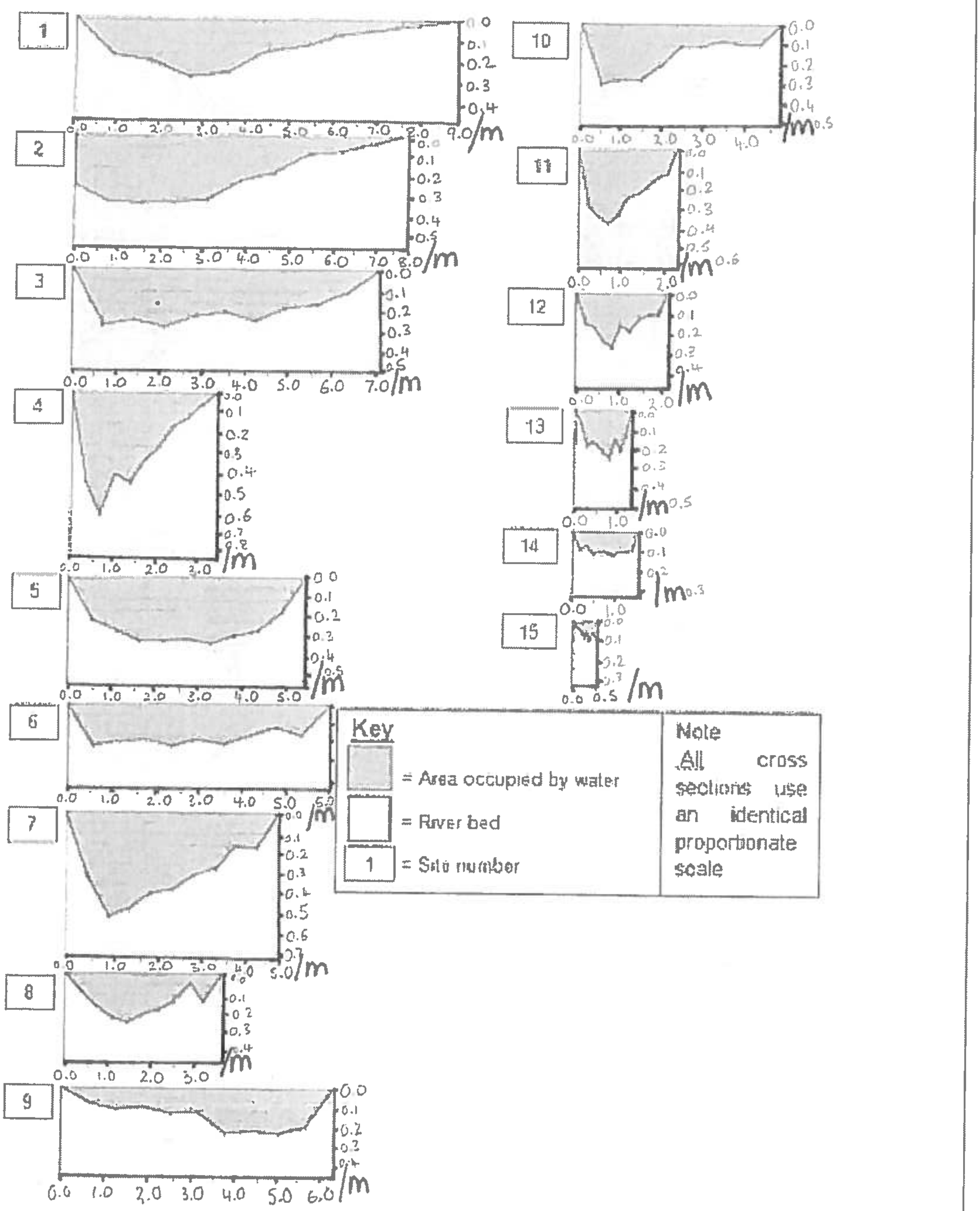

Figure 6: Channel width and depth processed data.

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Figure 7: Narrowing of channel, due to railway bridge construction.

Channel width shows close to linear-broadening, from source to river mouth, in accordance with Bradshaw's model (Figure 1). This is particularly prominent from the source at site 15 to 9. Site 10 is particularly deep towards the left (deepest point 0.29m), due to construction of a railway bridge narrowing the channel (Figure 7). This forces water to cut downwards instead of laterally, deepening the channel by hydraulic action. From site 8 to 1, at the river mouth, this relationship largely continues with minor fluctuation – channel widths at sites 8 and 4 are less than anticipated (3.82m and 3.58m respectively).

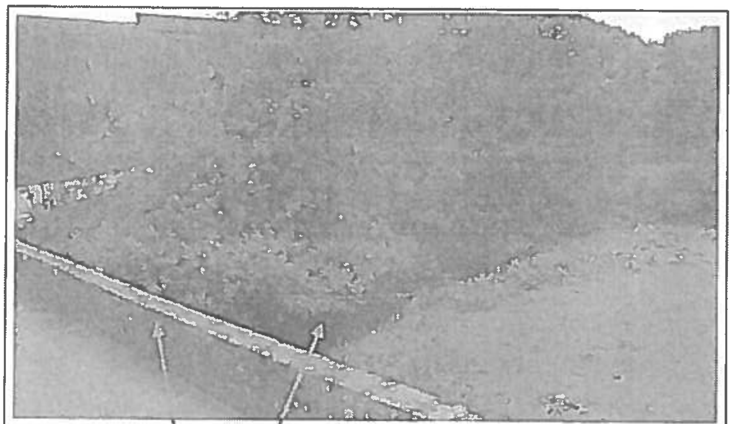


Figure 8: Site 4's channel narrowing to accommodate bridge construction.

Site 4, adjacent to Kirkton of Fetteresso Bridge, is artificially narrowed to accommodate the bridge (Figure 8).

Site 8 has lower velocity than expected ($0.44ms^{-1}$), with many "angular" rocks present, showing the river may not have the erosive power to cut a wide channel (Figure 9). Local deepening at sites 4 and 8 correlates with decreased channel width. Channel depth shows a less well-defined pattern from source to sea, with greatest depths recorded in the middle course, at sites 4 and 7. Deepening at site 7 could be explained by the confluence of the Burn of Graham and Burn of Baulks (Figure 21), approximately 100metres upstream, adding erosive potential to enable the local deepening (Figure 10).

Figure 9: Site 8 is the site of a meander. River left is the outside bend (river cliff at 0.24m deep) and river right is a shallow river beach (0.09m deep) with larger rocks comprising the channel bed. A cliff is an area of erosion where erosive power has caused undercutting. The slower flowing water cannot carry rocks and deposists them, forming a river beach.

(getrevising.co.uk)

5/9

Figure 10: Deeping at site 7 with the bottom of the channel not being visible. Maximum channel depth increases to 0.50m, the deepest point recorded in the entire river course.

Generally, channel width increases as the distance from the source increases, in accordance with the Bradshaw model (Figure 1). There are some anomalies, contradicting the model, but human activity accounts for these.

5/10

Research question 2: Does velocity increase as the distance from the source increases in accordance with the Bradshaw model (Figure 1)?

Mean velocity is displayed as a line graph, and linear mean indicates the overall correlation, which may have otherwise been ambiguous.

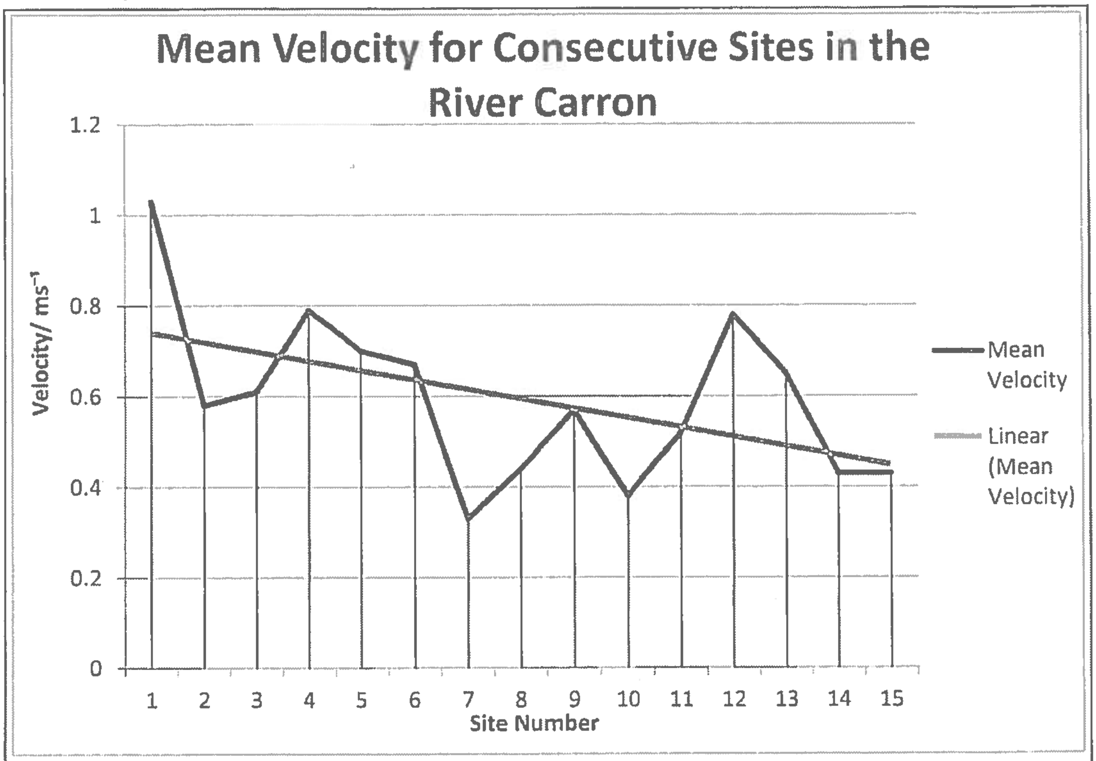


Figure 11: Velocity processed data.

Sites 10, 7 and 2 are extreme outliers, in terms of anomalously low velocity (0.38 ms^{-1}, 0.33ms^{-1} and 0.58ms^{-1} respectively). In contrast, the velocities recorded at sites 13, 12 and 4 (0.65ms^{-1}, 0.78ms^{-1} and 0.79ms^{-1}) are greater than anticipated. Despite bridge construction, site 10 sees a substantial increase in channel width, in comparison with sites upstream of this location – the channel is almost twice the width of adjacent site 11. The increased wetted perimeter, and thereby friction from the channel margin, may explain the decrease in velocity. Furthermore, the gradient at site 10 is relatively low (Figure 13) - possibly a further factor in the low velocity recorded, as gravity cannot act as strongly upon the movement of water. Similar issues are apparent with regard to site 7, wetted perimeter increases and

Figure 12: Ford - data collected upstream of ford.

there is a small change in gradient. Site 7 lies just upstream of a ford, meaning the velocity was slowed as water interacted with the concrete barrier (Figure 12). Furthermore, at site 7, an increase in median longest-axis of bedload is evident (12.0cm), from which an increase in channel friction can be postulated.

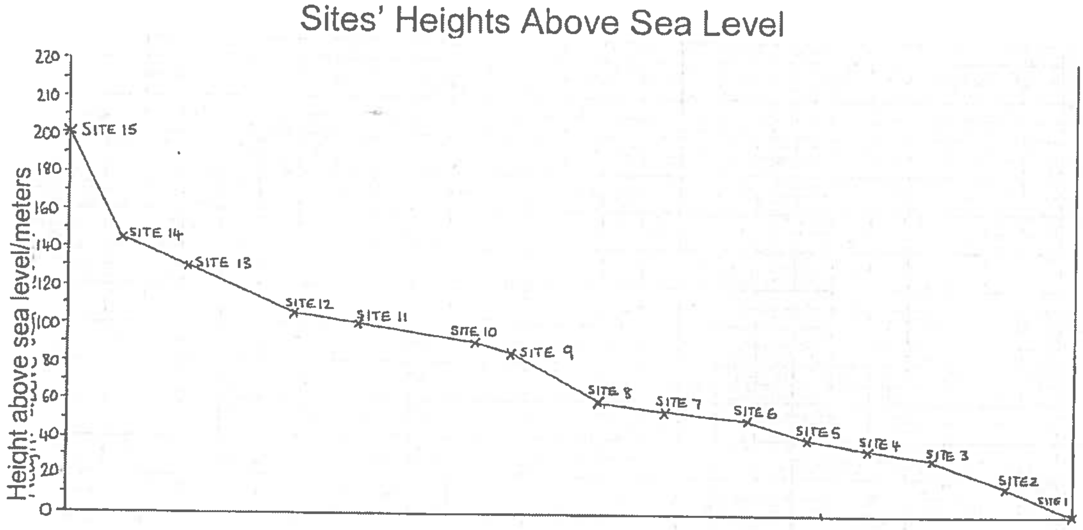


Figure 13: Cross sectional diagram correlating site number to height above sea level.

The anomalously low velocity recorded at site 2 may be linked to the partial-canalisation of this section which may have interfered with the natural system (Figure 14).

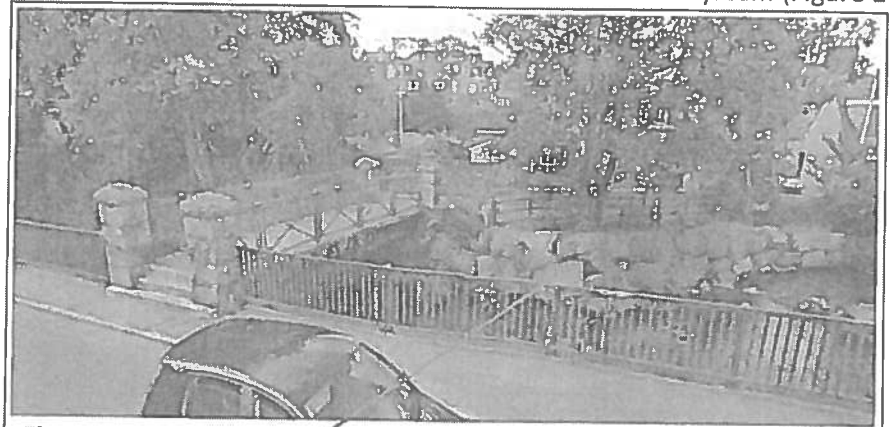


Figure 14: Artificial canalisation of channel, using boulders and cement.

At sites 12 and 13, channel velocity is above the mean. Relative to adjacent sites, no significant steepening of gradient, decrease in wetted perimeter or reduction in the median long-axis of bedload is apparent.

As shown by the linear mean line, there is a negative correlation between increasing site number and velocity, and therefore fits the Bradshaw model.

5|12

Research question 3: Does bedload roundness increase and longest axis decrease as the distance from the source increases in accordance with the Bradshaw model (Figure 1)? The number of rocks gathered at each site was not constant, therefore a proportionate bar charts were constructed to allow valid comparison.

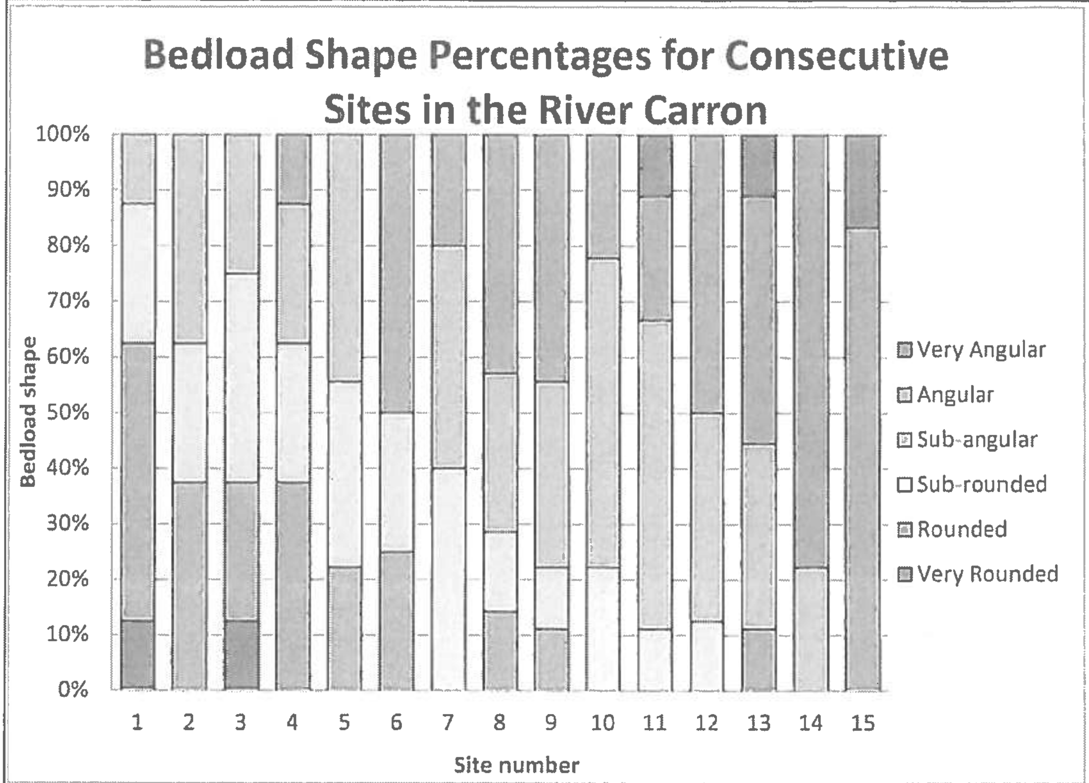


Figure 15: Bedload shape processed data.

Figure 15 shows a marked, gradual and persistent trend for increased roundness and corresponding decrease in angularity passing from source to river mouth.
This accords well with the Bradshaw model and suggests the developing maturity of bedload as abrasion and attrition within the channel progressively reduce the angularity of material.

5/13

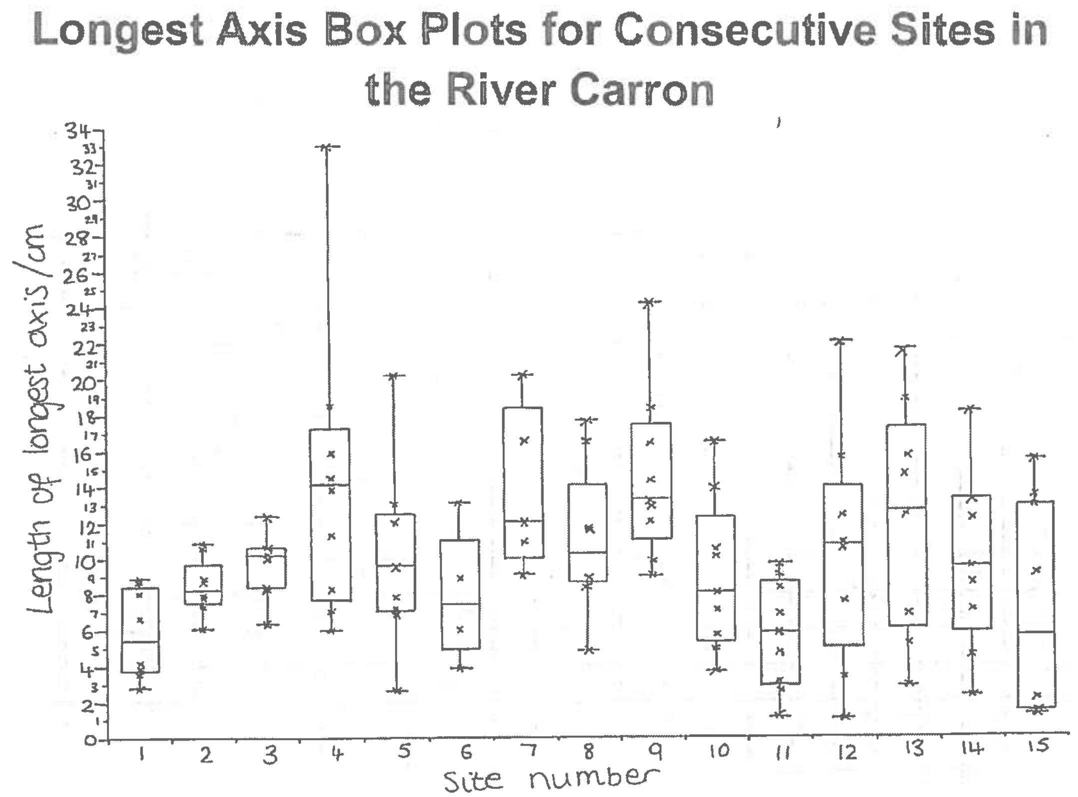


Figure 16: Bedload longest axis processed data.

Figure 17: Bedload comprising large boulders covered in moss which could not be extracted and analysed.

Site 15 has a median of 5.6cm; Q1 is 12.9cm; Q3 is 12.9cm and the lowest value collated is 1.2cm. Site 15 to 13 also has an increase in all values. The majority of rocks collected in site 13 are angular; the river does not have the erosive power to round particles. From site 9 to 6, there would be an overall decrease in longest axis, however site 7 bucks the trend - 7 has the slowest velocity recorded for the entire course, meaning the slow current cannot bring about attrition and particle size therefore remains high. Site 6 has rocks of lesser longest-axis because the bedload mainly comprised boulders which could not be extracted; only 4 rocks could be collected (Figure 17). Site 4 has one large rock, measuring 33.0cm, dramatically increasing the range to 27cm. This anomalously large specimen may be very locally derived with exposure to attrition for only a short period of time.

5/14

In order to discern whether geology has an influence on longest-axis, rock type of the 2 of longest axis for each site showed that although schists comprise only 23% of the rocks gathered in the study (Figure 18), a disproportionately higher 30% of the rocks of longest-axis are schists (Figure 19). In contrast, sandstone comprise 62% of the total number of rocks collected, yet only 21% of the rocks of longest axis are sandstone. Only 5 granite rocks were measured: 3 of these comprised rocks of greatest longest-axis, which had a disproportionally higher value of 49% (Figure 19).

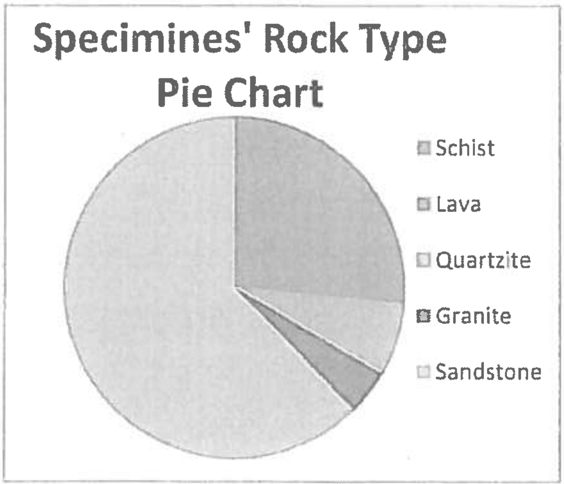


Figure 18: Total number of rocks collated into pie chart form and represented by different colours.

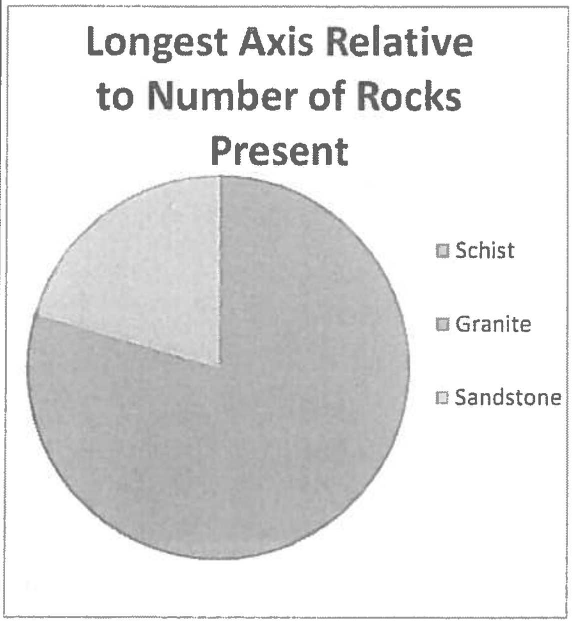


Figure 19: 2 rocks of longest axis for each site comprising a pie chart, relative to their occurrence.

Input from tributaries might help explain some of the local increases in longest-axis with material being locally-sourced and less abraded, having not travelled down the full river system. For two such sites: 9 and 7, the confluences with tributaries are apparent immediately upstream – site 9 with the Burn of Elfhill (Figure 20) and site 7 with the burns of Graham and Baulks Figure 21).

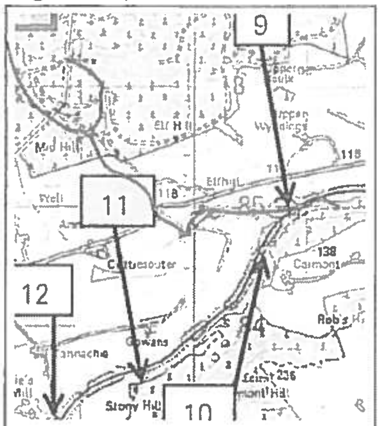


Figure 20: Burn of Elfhill contributory highlighted in red.

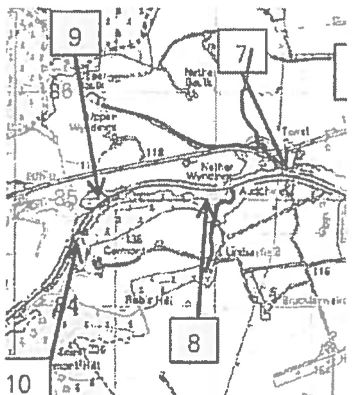
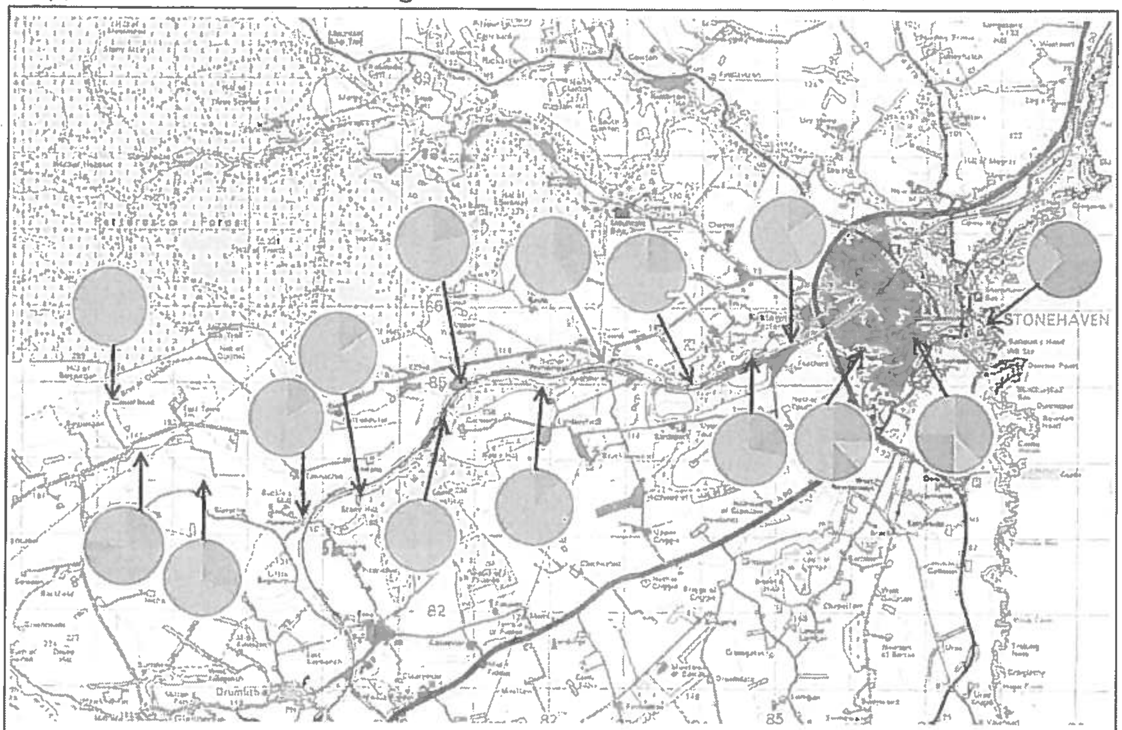


Figure 21: Pink stream is Burn of Graham; purple stream is Burn of Baulks.

5/15

Research question 4: Does geology influence the river and does bedload rock type reflect both local geology and become increasingly mixed downstream, as more rock types are eroded and transported by the river channel?

Bedload rock type is displayed as a series of pie charts (superimposed upon a site location map) since the number of rocks gathered at each site was not constant.



Key: Schist Lava Quartzite Granite Sandstone

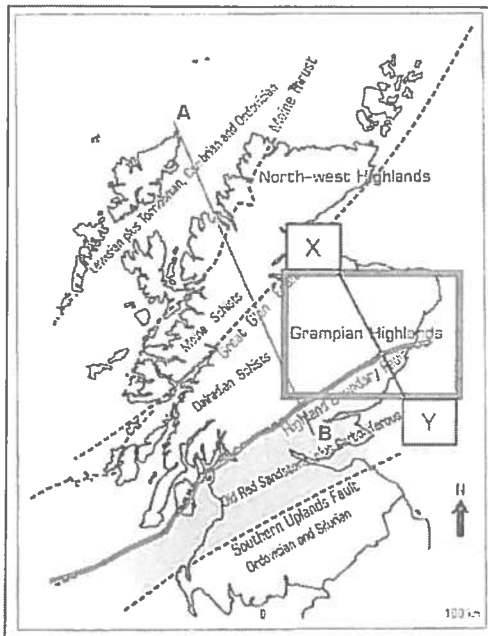
Figure 22: Rock type processed data.

Four rock types originate from north of the Highland Boundary Fault: schist, quartzite, granite and lava – older geological terrain. The metamorphic Dalradian Super Group (Figure 23) contains both schist and quartzite and with igneous granite intrusions also shown. Igneous lava is considered to be part of the Highland Border Complex, adjacent to the fault. In contrast, the sedimentary sandstone (Old Red Sandstone) is derived from south of the Highland Boundary fault, where the majority of the river's drainage basin lies. This change in geology is marked by different topography; the softer sandstones form the low ground with the more resistant metamorphic and igneous rocks forming the high ground and watershed.

Carron Water drains predominantly the Old Red Sandstone and the dominance of this rock type in selected bedload reflects this. Tributaries which are intersecting the Highland Boundary Fault incorporate more exotic rocks from the Dalradian Super Group and its associated granites, reducing the proportion of sandstone rocks present. The older, harder material (north of the fault) may be remaining intact, as the local, softer sandstones disintegrate through attrition.

An example of granite, originally brought about by intrusions, is shown near the source, at site 14, with 11% occurrence. In addition to this, selected bedload is 22% sandstone and 67% schist. A significant anomaly is site 15: this sits in Dalradian Super Group terrain, yet it is 100% sandstone. This may be explained by glacial or fluvioglacial processes of distribution and deposition, during the Pleistocene, which began approximately 2.6 million years ago and ended 11.7 thousand years ago.

The rock types present become increasingly diverse with river maturity. This is seen at site 2: 37% schist, 13% quartzite, 25% granite, 25% sandstone; site 1: 25% schist, 37% lava, 25% quartzite, 13% granite. This reflects immediate geology and transportation by tributaries lying north of the Highland Boundary Fault.



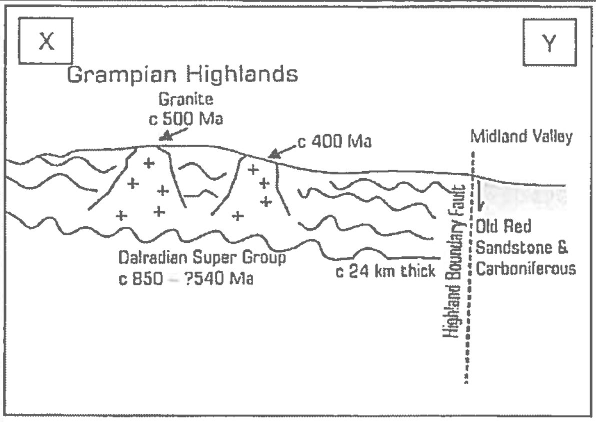


Figure 23: Highland Boundary Fault in relation to Scotland. Blue line highlights the location of the Highland Boundary Fault, perpendicular to the X-Y cross sectional diagram. *'The Geology of Britain, An Introduction'.*

Appendix 2 shows the course of Carron Water across sandstones; subordinate conglomerates and siltstones. The source of Carron Water lies in the high ground, north of the drainage basin, where a number of tributaries have their headwaters.

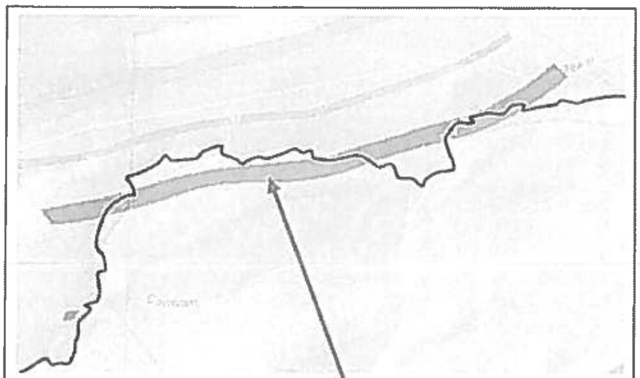


Figure 24: Course of Carron Water marked by the black line, with the red section of rock being a siltstone and sandstone.

An example of a local geological alteration is found in a gorge section of the river, between 804845 and 813851 (between sites 10 and 9), however no outcrop is visible on the steep, vegetated slopes surrounding the river. Siltstone (a thin, finer-grained and potentially softer rock than that of sandstone) may have comprised the centre of the gorge channel, with sides of sandstone.

5/17

Because sandstone is somewhat harder and more resistant, siltstone could have preferentially eroded downwards, resulting in the formation of this steep-sided gorge which controls the course of the river (Figure 25).
Geology therefore does have an influence on the course of the River Carron, at both regional and local scales.

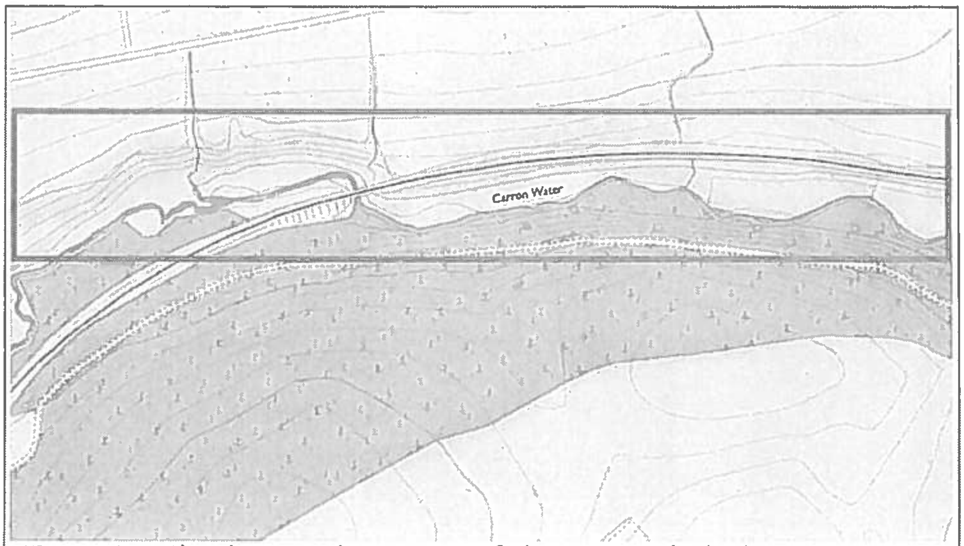


Figure 25: Closely spaced contours of the gorge which the River Carron flows through.

5/18

Conclusion

The River Carron generally fits the Bradshaw model in all parameters (Figure 1).

Channel width shows fairly linear broadening, with anomalies which can be accounted for by both human and natural causes. Over time, the channel may be subject to further alteration, due to Stonehaven's reoccurring flooding issues, which have the potential to carve entirely new channels, as a meander (site 8) may be cut through, resulting in the formation of an oxbow lake where the existing river was.

The line of mean velocity (Figure 11) does not obviously show a negative correlation between increasing site number and decreasing velocity. This relationship is clearly expressed by the linear mean velocity, however. The anomalies for this go hand-in-hand with anomalies of other parameters measured and are therefore accounted for.

Bedload shape fits the Bradshaw Model almost perfectly – bedload becomes increasingly angular with increasing site number. The same conclusion cannot be postulated for the box plots of longest axis (Figure 17) – a much more random pattern is shown, however some areas of increasing longest axis in accordance with increasing site number exist.

Bedload rock type generally matches expectations, with the majority of sites having a large portion of sandstone. There are some significant anomalies, however, which did not match the bedrock geology shown in Figure 2, and these could be explained by glacial deposition or tributaries from the northern side of the Highland Boundary Fault joining as confluences to the Carron Water.

Geology was found to have an influence on the course of the Carron Water, but not for the entirety. The gorge section of river was carved due to the presence of siltstone.

5/19

Evaluation

Systematic sampling yields both advantages and disadvantages. Advantages include that selection of sites was more straight-forward than random sampling, and therefore a good coverage of the River Carron was investigated, throughout the 15 sites selected. Contrastingly, inaccessibility due to private land, dense vegetation, livestock and river stretches of deep water skewed efforts to maintain as regular spacing as possible. Areas of the gorge were inaccessible, due to the slope gradient, and data from this geologically significant area of interest could not be collated.

Possible limitations, when gathering data in the river, may have confounded results. When measuring channel depth, a soft river bed (such as sand) caused the meter stick to sink deeper than the surface of the bed, yielding values too deep. A strong current in sites of turbulence bent the ruler to a bow shape, increasing depth values. To therefore reduce resistance, the narrow meter stick's edge should have faced upstream. When floating the orange downstream, it began to sink below the water surface, because it became saturated with water, resulting in a gain in mass, and this may have affected the velocity. This is because the current could not transport it the speed it might have, had the orange not been fresh at each site. Human error resulted in a delayed reaction time when operating the stopwatch for the orange travelling 5 metres. To reduce this error, a mean of the three measurements for each site (river left, right, middle) was used. The use of subjective charts, such as Power's Index, is subjective – to reduce differing opinion, the same person analysed all rock samples. To avoid the bias of rock selection, a rock was chosen wherever the meter stick landed, when measuring the depth at the 10 intervals. Some rock identification posed difficulty, as the specimens were covered in moss. To make sure rock type identification was sound, a geological hammer could have been used to expose a fresh face of the rock.

5/20

Appendices

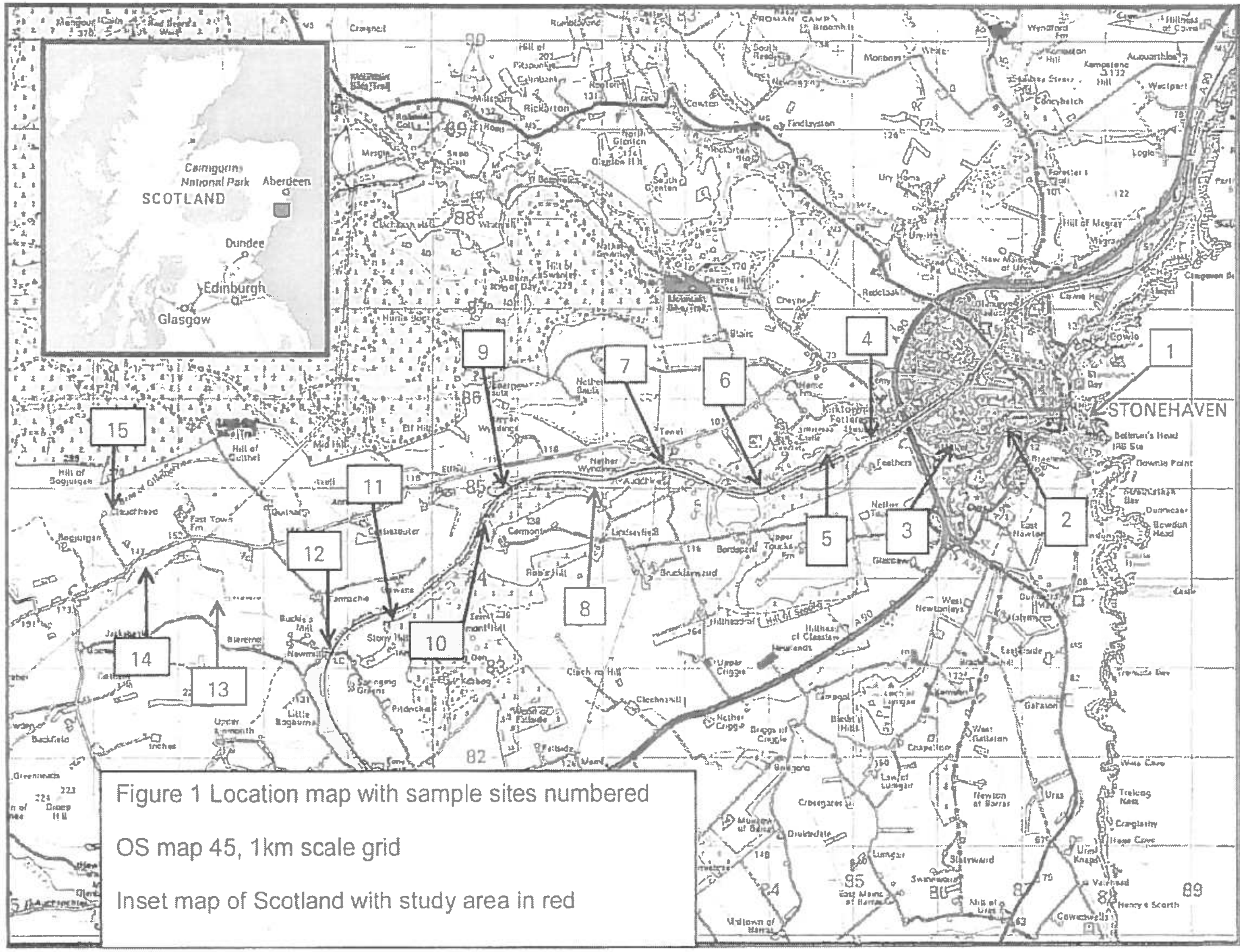


Figure 1 Location map with sample sites numbered

OS map 45, 1km scale grid

Inset map of Scotland with study area in red

Key

= site number

1 = GR 877 857
2 = GR 869 856
3 = GR 861 854
4 = GR 853 855
5 = GR 845 853
6 = GR 838 849
7 = GR 827 853
8 = GR 818 849
9 = GR 807 848
10 = GR 805 846
11 = GR 794 836
12 = GR 787 833
13 = GR 774 837
14 = GR 765 841
15 = GR 762 847

Appendix 1: Site map.

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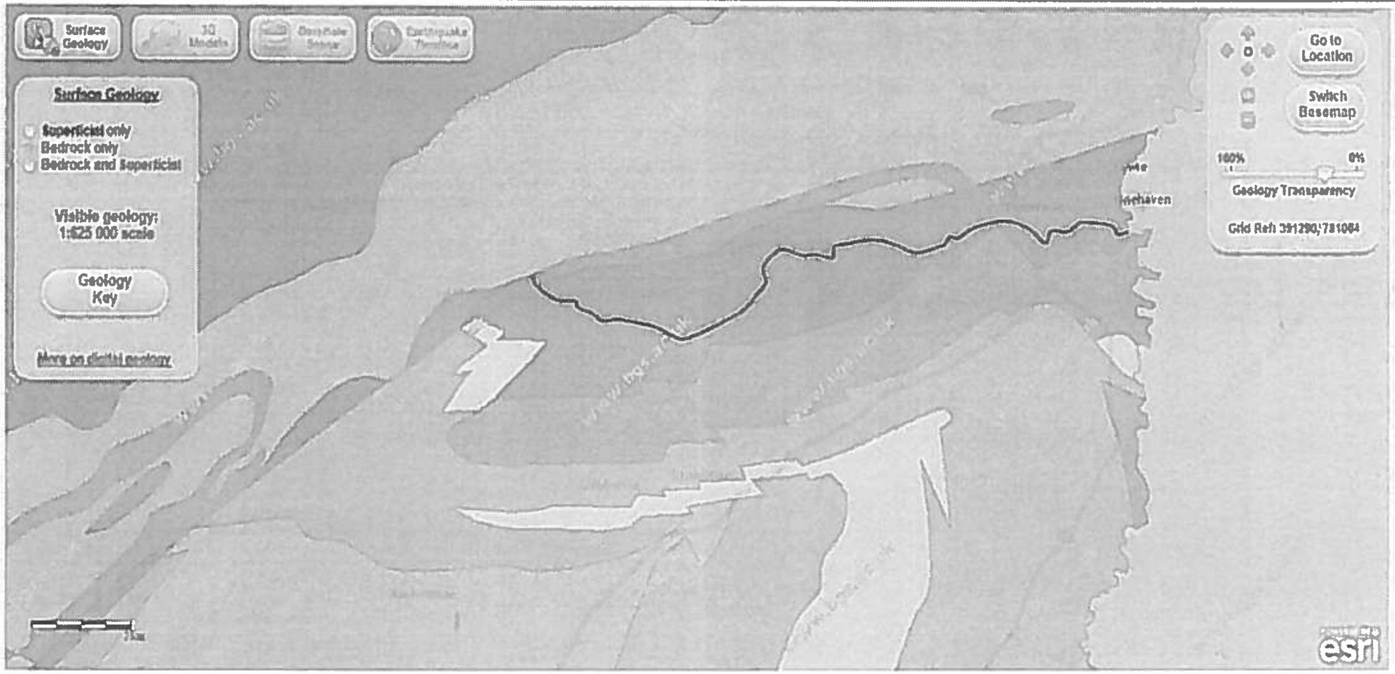

Appendix 2: geological map showing bedload type.

Key

- ARBUTHNOTT-GARVOCK GROUP - SANDSTONE WITH SUBORDINATE CONGLOMERATE, SILTSTONE AND MUDSTONE
- DUNNOTTAR-CRAWTON GROUP - SANDSTONE AND CONGLOMERATE, INTERBEDDED
- UNNAMED IGNEOUS INTRUSION, LATE SILURIAN TO EARLY DEVONIAN - FELSIC-ROCK
- STONEHAVEN GROUP - SANDSTONE WITH SUBORDINATE CONGLOMERATE AND SILTSTONE
- UNNAMED EXTRUSIVE ROCKS, SILURIAN TO DEVONIAN - MAFIC LAVA AND MAFIC TUFF
- UNNAMED IGNEOUS INTRUSION, ORDOVICIAN TO SILURIAN - FELSIC-ROCK
- HIGHLAND BORDER COMPLEX - SERPENTINITE, METABASALT, METALIMESTONE AND PSAMMITE
- SOUTHERN HIGHLAND GROUP - PELITE
- SOUTHERN HIGHLAND GROUP - PSAMMITE AND PELITE
- CARRON WATER

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