APPENDIX E

GEOMORPHIC PROCESS ASSESSMENT

1 INTRODUCTION

Field survey data on extents and rates of bank erosion, areas of sediment deposition and sediment input from tributaries was collected for the surveyed water bodies of the Nith. This information, together with an assessment of the specific stream power (i.e. the capacity of the river to perform geomorphic work), allowed the continuous description of the 'geomorphic process regime' (the relative balance of the supply of sediment to the system and the capacity of the river to transport that supply) and prediction of likely rates of morphological adjustment (including lateral migration and avulsion of the channel). The dominant geomorphic process and degree of channel dynamic behaviour allowed identification of the likely sensitivity of a given reach to engineering or other pressures through a quantitative means, thus enhancing the qualitative MImAS assessment of reach sensitivity. The approach taken is described here.

2 REACH DELINEATION

The surveyed water bodies were subdivided into reaches of approximately a kilometre in length. These formed the units on which further assessment was based. The chosen reach length was determined to be at a spatial scale that allowed appropriate interpretation and resolution of geomorphic variables, while being manageable in terms of the data analysis process.

3 SPECIFIC STREAM POWER ASSESSMENT

Specific stream power is the unit rate at which energy is applied to the bed of a river and is closely related to processes of dynamic channel behaviour (including lateral migration and avulsion of the channel) and sediment transport regime. It is defined as:

$$\omega = \frac{\rho \cdot g \cdot S \cdot Q_{bf}}{w}$$

where ρ is the density of water, g is gravitational acceleration, S is slope (typically indexed to channel bed or water surface slope), Q_{bf} is bankfull discharge (typically indexed to the 2-year return interval flow) and w is bankfull channel width. System-scale analysis of specific stream power provides a quantitative measure of the geomorphic energy regime of the system which, together with sediment input and storage, is an important element of the geomorphic process regime. The mean specific stream power in each reach was calculated from values of specific stream power averaged over 50 m lengths, supplied by SEPA. This had been derived from remotely sensed channel slope and width data and discharge values estimated from the Flood Estimation Handbook.

Spatial variation in specific stream power across the catchment is shown in Figure . Specific stream power shows the expected pattern with the highest values found in the steep upper reaches of several tributaries (including Pennyland Burn, Crichope Linn and Laggan Burn) and a general downstream decrease in specific stream power. Variation within this reflects the distribution of areas of confinement and bedrock control, which tend to be steeper.

4 SEDIMENT INPUT INDEX

The volumetric rate of sediment input to a reach, and the dominant size of this sediment, is important in determining how the energy of the flow (i.e. as indexed by specific stream power) is translated into geomorphic 'work' (i.e. dynamic channel behaviour) and the channel morphology that results. Sources of sediment input include bank erosion and tributaries.

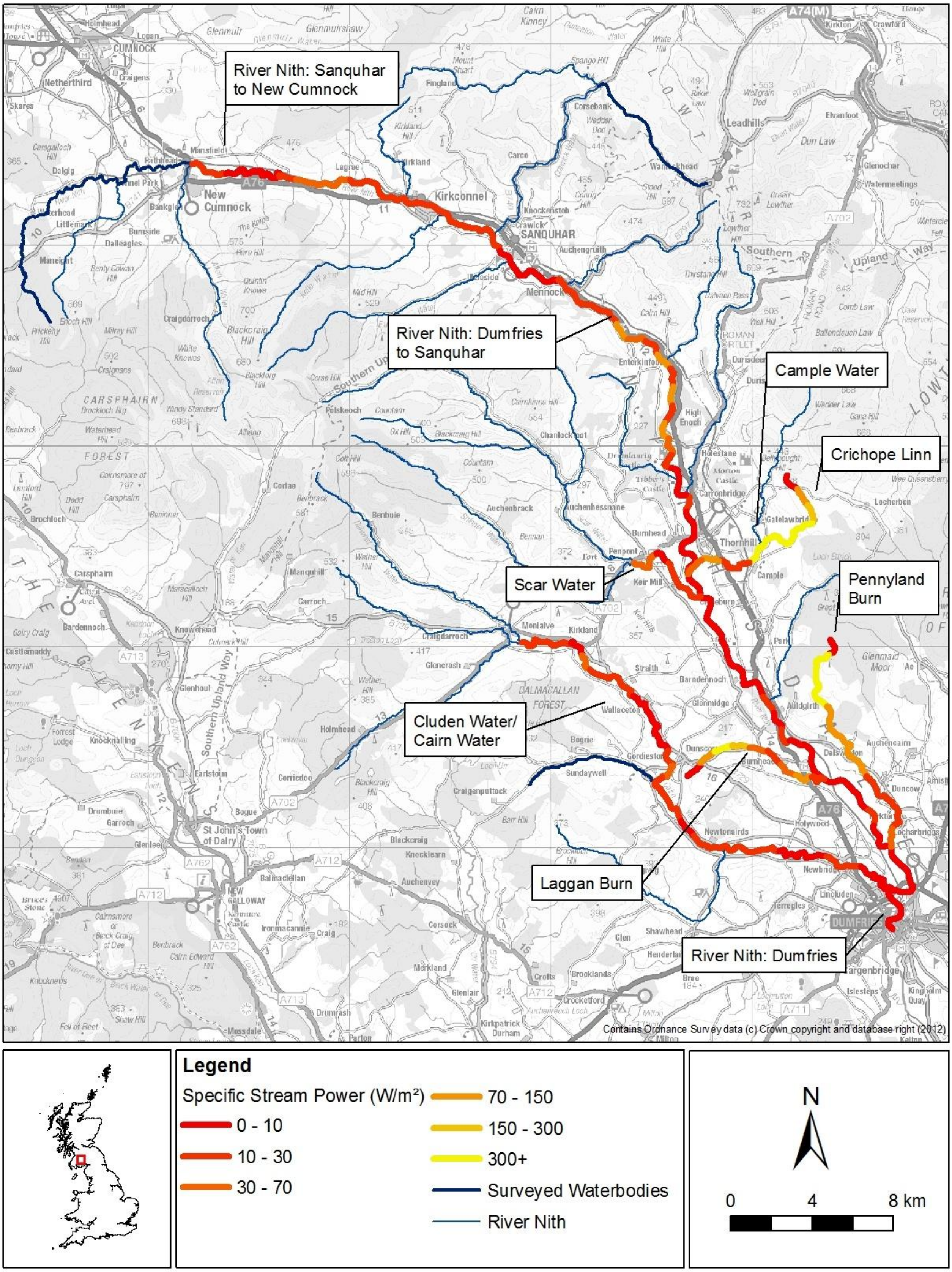
Absolute volumes of sediment input could not be determined with sufficient accuracy, given the constraints on time spent in the field. Therefore, relative levels of sediment input from bank erosion were estimated from the fluvial audit data, using a non-dimensional method of assessment. This allowed reaches to be compared with each other in terms of the level of sediment input. Incidences of bank erosion were given a weighting based on the recorded severity of the erosion and the height of the bank. The weighting was then multiplied by the length of the feature. Sediment inputs from tributaries were scored based on the size of the tributary as recorded in the fluvial audit (minor/moderate/major) and whether any evidence of sediment supply was observed in the field (e.g. confluence bar features).

Scores for bank erosion and tributary input were standardised in relation to each other so that sediment input values were comparable. The total scores for bank erosion and tributary input were then summed for each reach to give a dimensionless index of sediment input. The spatial variation in this variable is shown in Figure . Sediment supply shows a high spatial variability at relatively small spatial scales, with no strong trends apparent at the catchment scale. The highest levels of input are found in the main stem of the Nith downstream of New Cumnock, downstream of Thornhill and just upstream of Dumfries. These are associated with high rates of bank erosion resulting from channel lateral migration and meandering activity. The lowest rates of sediment supply tend to be associated with stable, bedrock-controlled reaches where there is little potential for bank erosion.

5 SEDIMENT STORAGE INDEX

In-channel storage of sediment in provides a further indication of the balance between sediment supply and the transport capacity of the flow and whether the sedimentary processes in the reach are supply-limited or transport-limited.

The approximate area of each alluvial bar feature recorded during the fluvial audit was calculated from the product of its width and length. The total area of alluvial bars in each reach was then calculated and divided by reach length to give an index of sediment storage (in m^2m^{-1}). The spatial variation in this variable is shown in Figure . There is a general trend for reaches with high levels of deposition to coincide with those of low specific stream power, as might be expected, given that specific stream power indicates the capacity for sediment transport. The highest levels of deposition are found in the Nith main stem downstream of Drumlanrig. In addition, the upper Cairn Water, Scar Water and the Nith main stem near Sanquhar show higher rates of sediment deposition and storage.



Notes:

River Nith Restoration

Specific stream power

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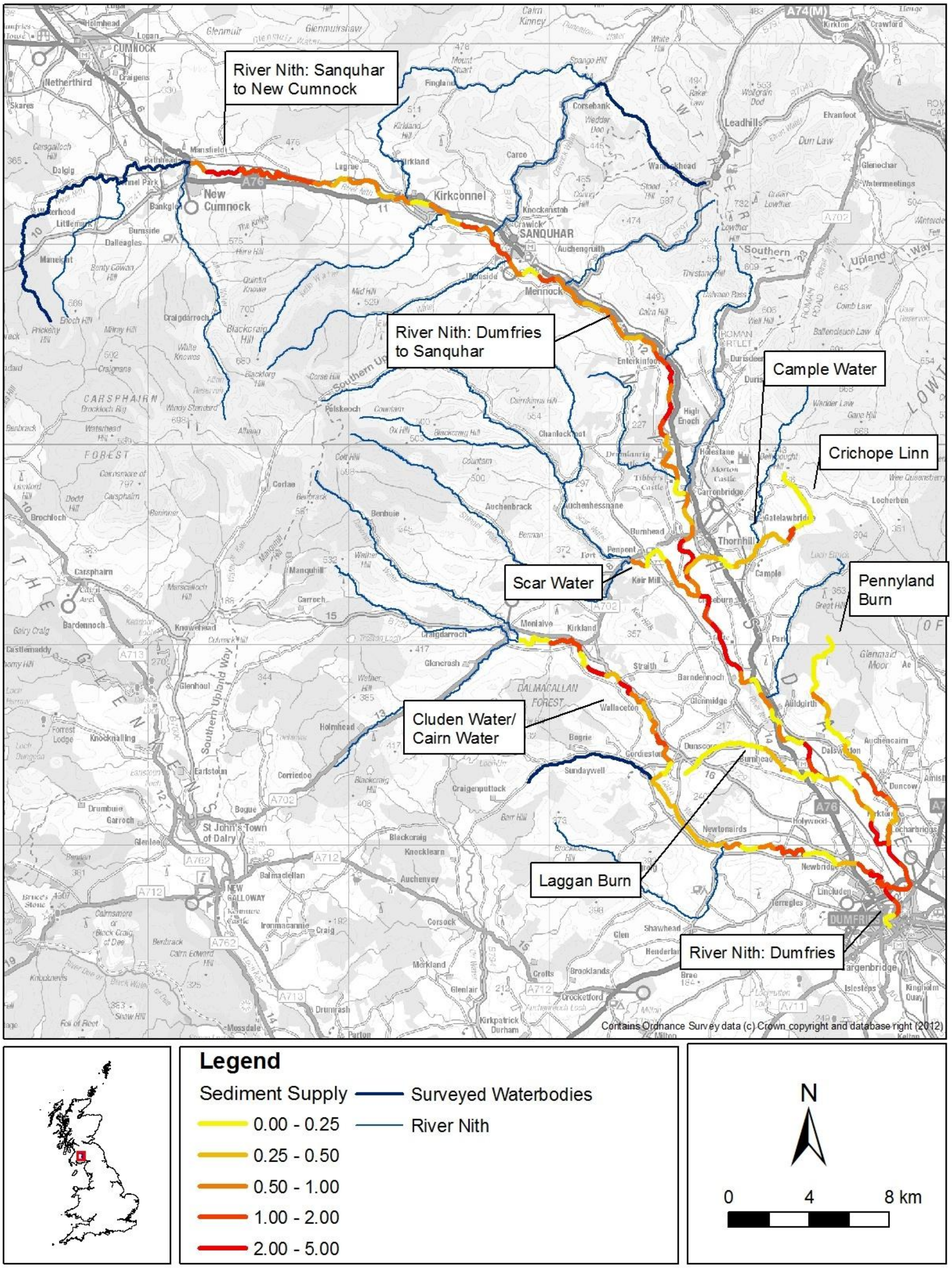
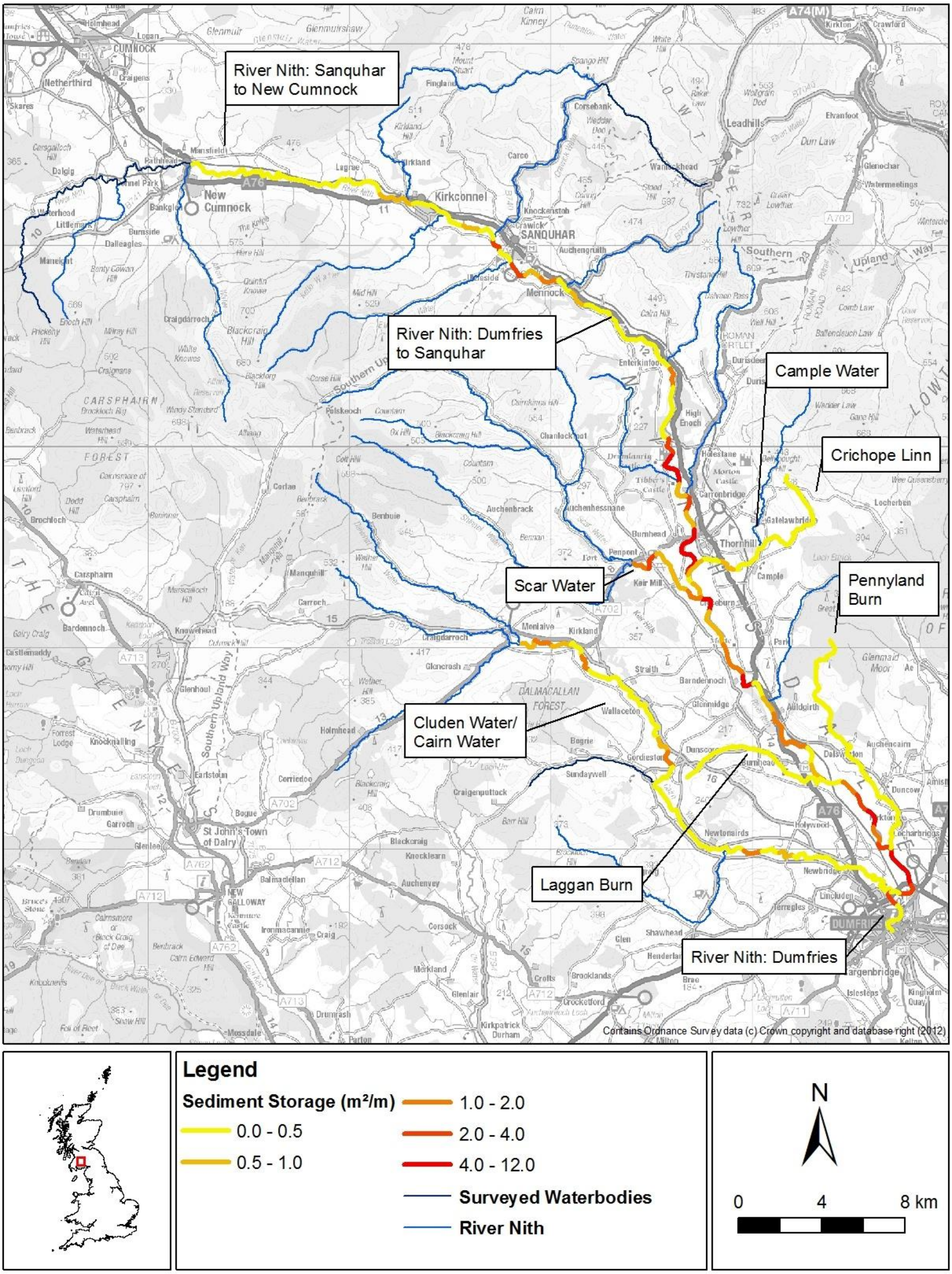
Figure E1



Notes:	cbec eco engineering	*River Nith Restoration*		
		Sediment input index		
		Project No. U13-1007	Created By: GK	**Figure E2**



Notes:

River Nith Restoration

Sediment storage index

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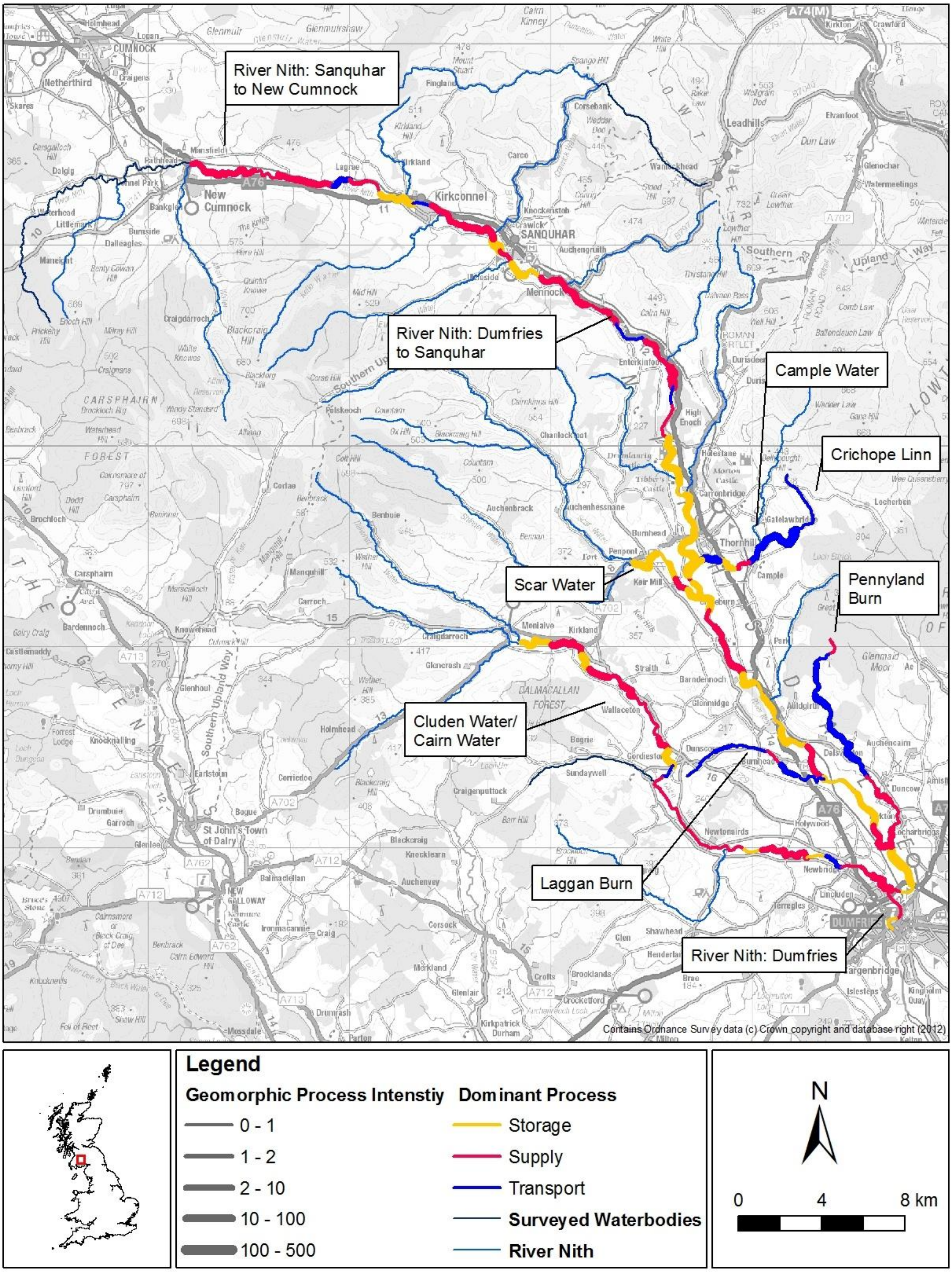
6 GEOMORPHIC PROCESS REGIME

The relationships between sediment input, sediment storage and specific stream power define the dominant geomorphic process in a given reach, whether the reach is a zone of net sediment supply, transfer or storage, and, together with the intensity of these processes, its likely rate of morphological adjustment.

Geomorphic behaviour was simplified to three processes: sediment transport, sediment supply and sediment storage, with the intensity of each process taken to be represented by specific stream power, sediment input index and sediment storage index, respectively. The dominant geomorphic process in each reach was derived from the relative magnitudes of these three values. The values within each index were standardised (to make them comparable with each other) by dividing by the mean index value across all reaches. In each reach the index with the highest normalised value was then taken to indicate the dominant process. The product of standardised specific stream power, standardised sediment input index and standardised sediment storage index (i.e. SSP*SSI*SII) was calculated for each reach, to provide a measure of 'geomorphic process intensity'. This indicates the overall level of geomorphic activity in the reach and was used as an indication of channel dynamic behaviour.

The dominant geomorphic process and the geomorphic process intensity together provide a quantitative description of the nature of geomorphic behaviour across the River Nith system. This is depicted in map form in Figure , which indicates zones of sediment supply, transfer and storage, together with the degree of channel dynamic behaviour or stability (i.e. geomorphic process intensity).

The most dynamic reaches in the system are those with combinations of high values for all three parameters (sediment storage, supply and transport). On the Nith main stem, the areas with the highest process intensity include the reach adjacent to Sanquhar, reaches between Drumlanrig and Thornhill and reaches around the Pennyland Burn confluence (near Dumfries). These are all reaches characterised by high levels of sediment storage and reworking (Figure 6.1 A, B). An area of high process intensity can also be found within the confined section of the Nith main stem near Enterkinfoot. This represents a localised area of sediment storage within a zone of high specific stream power. Reaches towards the upper extents of Pennyland Burn and Crichope Linn tributaries also have high process intensities. These also represent zones of increased sediment storage and reworking between steeper, transport-dominated reaches (Figure 6.1 C, D).



Notes: Geomorphic process intensity indicated by line width	cbec eco engineering	*River Nith Restoration* **Geomorphic process regime**		
		Project No. U13-1007	Created By: GK	**Figure E4**

Figure 6.1 Examples of reaches with high process intensity – A: Nith main stem near Thornhill; B: Nith downstream of Pennyland Burn confluence; C: Pennyland Burn; D: Crichope Linn

7 COMPARISON WITH MIMAS REACH TYPES

The geomorphic process intensity calculated above is taken to represent the degree of channel sensitivity. The values of process intensity for each reach were compared with the reach type classification under MImAS (used as a measure of channel sensitivity in the MImAS calculations) to determine whether spatial patterns of sensitivity were the same (Table).

Table shows that there is little relationship between geomorphic process intensity and MImAS subtypology, except for MImAS type F channels, which have a very low process intensity compared with all other channel types. The geomorphic process intensities associated with MImAS type A, B, C and D channels are very variable within each type, shown by the high standard deviations and ranges.

The dominant geomorphic process relates better to the MImAS subtypologies (Table). MImAS type A (bedrock/cascade) channels tend to be more dominated by sediment supply and transport with lower levels of storage, as might be expected given the typically high stream powers associated with these types of channel. MImAS type B (step pool or plane bed) channels show a very strong tendency to be transport-dominated, with no incidences of storage-dominated reaches. This is consistent with the processes typically associated with these types of channel. MImAS type C and D (plane-riffle, wandering and active meandering) channels tend to be dominated by sediment supply processes, but also have relatively high levels of sediment storage, consistent with the meandering and bar formation tendencies in these channel types. MImAS type F (passive meandering) channels are also dominated by sediment supply (although overall levels of supply are low, as indicated by the low process intensity values).

The poor relationship between MImAS subtypologies and geomorphic process intensity indicates that the two parameters are not providing the same measure of reach sensitivity to morphological pressures. As such it is suggested that the geomorphic process intensity provides a useful additional measure of sensitivity, to be used on top of MImAS, to further support assessment of restoration options.

Table E1 Comparison of MImAS subtypology categories with geomorphic process intensity and dominant geomorphic process

MImAS sub-typology	Geomorphic process intensity				Dominant geomorphic process (% of reaches)		
	mean	*standard deviation*	*median*	*range*	*storage*	*supply*	*transport*
A	40.2	74.4	2.5	262.2	13	46	42
B	25.1	48.8	9.3	262.2	0	28	72
C	16.7	50.4	2.8	425.8	34	40	26
D	15.8	34.5	4.6	262.2	36	49	15
F	0.2	0.4	0.0	1.4	22	54	24
All	18.0	47.7	3.5	425.8	31	43	26