Fluvial Geomorphology of Scotland (FLU-GME-SC)

Block Description

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Introduction

A general introduction to British fluvial geomorphology is provided under **Fluvial Geomorphology of England (FLU-GME-EG)**.

Scottish rivers afford a richer variety of process, form and pattern than other UK rivers because of the greater diversity of environments within which they have evolved. This arises because of deeply dissected relief (particularly to be found in the Scottish Highlands), the juxtaposition of reaches from highland, upland and lowland environments, and the marked rainfall gradient across Scotland from west to east. This GCR Block encompasses the specific geomorphic controls that govern the operation of fluvial processes in Scotland, together with the spatial and temporal patterns of the resulting river systems.

In terms of the hydrological setting for Scottish rivers, a marked west–east precipitation gradient exists, with Glen Quoich having a mean annual precipitation >3000 mm but Aberdeenshire, Fife and Berwickshire recording <700 mm. This, when combined with generally low evapotranspiration losses, results in parts of the NW Highlands recording rainfall:runoff ratios >75% and the majority of Scotland recording ratios > 50%. This is in marked contrast to East Anglia where rainfall : runoff ratios can be as low as 25%. This rainfall-controlled pattern of runoff gives the River Tay by far the largest mean flow for any river in Britain, although in terms of drainage area it ranks only third.

Given this pattern of runoff, it might be expected that the largest and most powerful rivers would also be located in the NW Highlands and SW Grampians. But this is not the case because of the extremely asymmetric location of the main east–west watershed in Scotland. This asymmetry has arisen because the most active ice streams during the Pleistocene Epoch operated from an east–west iceshed located close to the present-day watershed. This in turn was inherited from a watershed that developed during the latter part of the Tertiary sub-Era. To the west of the present-day watershed, steep and relatively short icestreams produced a series of deeply incised glaciated valleys often with hanging tributary valleys (e.g. Glen Coe). Following deglaciation, the relatively short river systems in this part of Scotland have merely occupied courses previously excavated by the major icestreams. In contrast, the largest rivers in the Highlands (e.g. River Tay, River Spey and River Dee) flow eastwards from the main watershed and it is only in the Southern Uplands that the watershed between the River Clyde and River Tweed is more symmetrically located.

Another significant legacy of repeated Pleistocene glaciation is the calibre of the bed material, with many of the large rivers of Scotland having gravel beds down to their marine limits (e.g. the Spey, Tay and Tweed). This arises not because such material is continuously transported from source to mouth but because lateral channel migration constantly reworks the Late Quaternary glacial and glaciofluvial deposits adjacent to the valley floors. A further inherited glacial feature is that many of the upper reaches of upland channels are cut directly into bedrock, these occasionally being so confined that they represent the courses of former subglacial meltwater channels (e.g. Corrieshalloch Gorge on the River Droma and Randolph's Leap on the River Findhorn). Such former meltwater channels are a persistent element in the upper reaches of many Highland rivers, producing stepped long profiles in which alluvial reaches occupy a series of basins separated from each other by bedrock sections. The precise pattern of such alternating alluvial and bedrock channels owes much to differential glacial erosion during the Devensian and is exemplified particularly well in the Middle and Lower River Findhorn and the Tay–Tummel–Garry river system.

Another result of selective glacial erosion is the presence of many lochs within river courses. A striking example of this is the Tay drainage system with four lochs > 0.1 km3 in volume. These lochs have a twofold impact in terms of fluvial processes: they serve to dampen flood waves and thus reduce the potential stream power in the lower reaches of major river systems, and they also act as sediment traps. However, not all lochs contained within major river systems owe their origin to glacial scouring; others (e.g. Lochs Insh, Alvie and Morlich within the River Spey drainage system) are former large kettle holes which, on final deglaciation, became incorporated into the present-day drainage system.

A variety of channel types arises from the operation of the major controls and these in turn generate a number of distinctive spatial patterns. A typical Scottish river originating in the Highlands and flowing to the sea will commence as a boulder-bed torrent, often interrupted by bedrock reaches. Such a channel will be relatively stable over short timescales and subject to major episodic adjustment only during rare extreme floods (e.g. the Allt Mor, Glenmore). In addition, many upland channels pass through 'alluvial basins' (glaciated valley floors infilled with alluvium) which are often separated from each other by further bedrock reaches; for example Glen Derry and Abhainn an t-Srath Chuileannaich. Downstream from these initial channel types, the reduction of bed material size and channel slope is often combined with a widening of the valley floor. This typically results in a low-sinuosity wandering gravel river which, depending on local controls, may exhibit both divided and undivided channels of variable sinuosity, for example the Rivers Tulla and Feshie and Dorback Burn. In sediment transport terms such reaches are bedload channels, but the number of competent transport events in any year will vary greatly according to bed material size and the associated entrainment function.

The supply of bed material from tributary valleys and the location of undercut terraces adjacent to the valley floor also controls the degree of channel stability (e.g. on the upper River Findhorn and the upper River Dee). In such reaches the channel is overwhelmingly an alluvial channel reworking its floodplain and only occasionally confined by bedrock reaches and gorge-like sections. Moving further downstream, the channel may be interrupted by a loch which acts as a sediment trap; for example the River Balvag and Loch Lubnaig. However, the channel gradient downstream of the outfall combined with a renewed sediment supply from banks and tributary streams usually ensures that the river continues to display many of the characteristics noted above.

Truly lowland reaches constitute only a relatively small proportion of the total channel length of an idealized large river system in Scotland. This arises because lowland areas are confined to a narrow coastal fringe around the Highlands and Southern Uplands and become extensive only within Central Scotland. In this central belt, in contrast to their upland counterparts, lowland rivers are generally characterized by sand-sized rather than gravel beds. Low channel gradients plus river training along many reaches means that these channels are highly stable and it is only rarely that major reworking of the floodplain occurs (e.g. the River Clyde at Carstairs and the lower Endrick Water). Nevertheless, bedrock controls can still provide dramatic changes in channel type, and gorge-like reaches are locally significant even in the Central Lowlands (e.g. the River Clyde at Falls of Clyde and the River Devon at Rumbling Bridge). The final sections of the major river systems which terminate in the Central Lowlands are the well-known firths or estuaries (e.g. Firth of Tay) which serve as major long-term sediment stores.

Such is the sequence of channel types in an idealized large Scottish river system originating in the Highlands or Southern Uplands and terminating at the coast, but other types of channel exist alongside this idealised model. Three types which are especially important are 'integrated', 'discordant' and 'progressive' channel systems. The integrated system typically occurs in upland areas and comprises a sediment source, a transportational reach and a depositional sink all within a small area of only a few square kilometres. The sediment sources are often areas of deeply dissected till, while the depositional sinks take the form of major alluvial fans. In these integrated drainage systems, the sediment source and the depositional sink are end members of a sequence in which channel morphology and processes rapidly change downstream. There may be abrupt changes in control within this marked downstream change. The concept of an 'integrated' system is therefore scale dependent.

The glacial legacy and recent climatic history of Scotland exercise a strong control on the pattern of downstream fining. Scottish rivers (e.g. the upper River Dee, River Feshie and River Findhorn) do not display classic progressive downstream fining throughout their length. Instead, there is local fining, often within the context of glacially eroded basins that have subsequently been infilled by alluvium and which display a local base-level control (e.g. lower Glen Derry and the Allt Dubhaig). The triggers that induce a local coarsening of bed material downstream are lateral inputs derived either from glacigenic sediments (on or adjacent to the valley floor), or from alluvial fans at the mouth of steep tributary valleys. It is rare that downstream fining develops more than a few kilometres before one or other of these disturbing controls exerts an influence. For similar reasons, the long profiles of Scotland's larger rivers (e.g. the River Tay) do not conform to the familiar concave up model, but instead comprise a series of concave segments, often linked by steeper units where the river flows through a bedrock-controlled section.

In terms of specific types of channel patterns, a rich variety has been identified for Scottish rivers. The traditional distinction between 'braided' and 'meandering' channels is inappropriate for many rivers in Scotland, since a given reach often exhibits both types of pattern simultaneously; or, if studied over a number of years, reveals an alternating development of divided and undivided channels of varying sinuosity.