Lecture Notes

FLUVIAL GEOMORPHOLOGY: ITS BASIS, HISTORY AND METHODS (Part-I)

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1.1 Introduction

Rivers are the arteries of the landscape, integrating the impacts of change in atmospheric and terrestrial systems and delivering these to the coast. En-route geomorphological processes create dynamic and diverse habitats, both in-stream and in riparian and floodplain environments (Petts and Amoros, 1996). The dynamics of channel change have led to conflict with human resource development with the outcome that many river and riparian environments have been significantly modified and damaged (Brookes & Shields, 1996, Sear *et al*, 2000). Responses to change in driving variables (runoff regime and sediment loads) have become dampened or prevented through river maintenance (Sear *et al*, 1995), while in other circumstances, landuse and land management changes, coupled to more efficient drainage networks may have increased system sensitivity to environmental change (Robinson, 1990; Newson & Leeks, 1987). Nevertheless, increasing focus on the importance of the physical habitats created by geomorphological processes, and concerns raised by recent flooding have served to highlight the importance of geomorphological processes in creating and sustaining biodiversity and flood conveyance. Thus, the recent EU Water Framework Directive (European Commission, 2000) makes 'hydromorphic condition' (the physical outcome of the inter-relationship between flow regime and the channel perimeter) a central parameter in spatial and temporal assessment of compliance with regulations. In England and Wales, the introduction of Catchment Flood Management Plans (Evans *et al*, 2002) forces the attention of the most powerful river management function (Flood Defence) to evaluate channel properties and changes as a basis for sustainable asset management. Monitoring change in the geomorphology of the river environment is, therefore (and belatedly), becoming an important measure both of river management practice and system resilience to external environmental change (Raven *et al* 1998, Newson and Sear 1998). Fluvial geomorphology is a key to understanding long-term river and floodplain processes of change; it is making an increasing contribution to environmental management of river basins and at the coast.

1.2 What is Geomorphology and what is it not?

Geomorphology is a natural or Earth Science that draws its roots from Geology, Hydraulic Engineering and Physics. It differs from other natural sciences in that its focus is on the study of the processes of production, movement and storage of sediment within the landscape and on the characterisation of the features these processes produce. In its widest definition, Geomorphology encompasses the study of glacial, coastal, slope, wind and fluvial processes of sediment movement across the surface of the Earth. However, for the purposes of this Guidebook, we shall be focussing on the movement of sediment within river catchments, and principally within the river channel and floodplain; or in other words, Fluvial Geomorphology.

Fluvial Geomorphology is**: "***the study of sediment sources, fluxes and storage within the river catchment and channel over short, medium and longer timescales and of the resultant channel and floodplain morphology"* (Newson and Sear 1993*)*.

It is a specialist subject that usually requires outside contractors to supply the necessary levels of expertise. From the outset it is important to make clear that like any science, a broad understanding of principles only gets you so far, and a little knowledge can be a very dangerous thing. Reading this guidebook will not make you a professional geomorphologist, but it will permit you to understand what

fluvial geomorphology is and is not and help you to understand what type of contribution it can make to a range of river management issues. Fluvial geomorphology draws on inputs from hydraulics, ecology and geology. It provides an explanation for the creation and dynamics of the physical habitat concerns of ecology/biology and nature conservation while providing explanations for the channel maintenance and channel instability concerns of flood protection.

The term "morphology" is also used in UK river management. Morphology refers to the description of the features and form of the river channel (and increasingly the floodplain). Morphology has significance to conservation and flood protection interests through its links to physical habitat and conveyance respectively. Descriptions of channel morphology on their own, do not provide information on the processes of sediment transfer and channel adjustment; to do this requires additional interpretation. For example, an input to channel design that talks about "morphology" refers only to the description of features and river channel shape; it does not mean that the channel will have been designed with regard to sediment transport and channel stability.

With the advent of the EC Water Framework Directive (European Commission 2000) comes another term "Hydromorphology". The Hydromorphology of a river channel includes consideration of:

1) the extent of modification to the flow regime
2) the extent to which water flow, sediment transport and the migration of biota are impacted by artificial barriers
3) the extent to which the morphology of the river channel has been modified, including constraints to the free movement of a river across it's floodplain.

Process and form information exists within the broad defining elements and clearly Fluvial Geomorphology will be central both to the definition of hydromorphology, and to the design and implementation of emerging Pan-European monitoring methods (Raven *et al* 2002, Newson 2002).

1.3 Expertise and expectation in consulting geomorphologists

For the river manager, an important question is what skills come with what training and experience in geomorphology. For many river management problems, the geomorphologist needs to have 1) a good understanding of the processes of sediment transport and channel adjustment and how these are modified by changes in catchment processes or modification to the channel, and 2) good field experience of interpreting river and floodplain geomorphology. At present, no formal industry accreditation currently exists for geomorphologists such as the Chartered status available to Civil Engineers and Landscape Architects. Instead, fluvial geomorphology is generally taught as part of an Undergraduate or Masters degree in Geography (Physical Geography) or Environmental Science. There is no training in geomorphology within existing taught courses in Civil Engineering or Biology. Industry training in applied fluvial geomorphology for river management is available within the Environment Agency, though tends to be organised at the Area level. This situation places river managers in a difficult position when attempting to identify the appropriate level of expertise for a particular task. Table 1.1 provides guidance for assessing the level of expertise that can be expected for a given qualification and experience. The daily rates for the different levels of experience & training should fall within normal commercial ranges (e.g. £100 - £800 per diem).

Table 1.1 Guidance on the expected capability for different levels of training and experience in applied fluvial geomorphology.

Experience of Consultant	Expected Capabilities
Specialist fluvial geomorphologist (Ph.D) with extensive field experience and track record of working with river management agencies.	Able to provide science-based but practical solutions to most river management issues, clearly and in terms understandable to non-specialists. Could be used on more complex projects and as specialists at public enquiries.
Specialist fluvial geomorphologist (Ph.D) with no or limited field experience and no/limited experience of working with river management agencies.	Sound on principles of fluvial geomorphology, but will have a steep learning curve on practical issues of river management. Advice on complex issues would be sound, and could be used as a specialist at public enquiry.
First degree in Geography / E.S. with Masters training in fluvial geomorphology/river management. No/limited field experience. No/limited experience of working with river management agencies.	Will understand more complex issues and should be able to identify potential causes of most problems. Limited experience of providing solutions. Best working alongside experienced practitioners.
Trained non-specialist with field experience and experience of working with river management agencies. (e.g. GeoRHS/RHS Geomorph. bolt-on surveyor).	Can identify potential problems, and suggest solutions in straightforward cases. Able to make reliable decisions as to whether more specialised advice is required.
Un-trained non-specialist with field experience of working with river management agencies (e.g. RHS surveyor).	Able to recognise basic morphological features, with limited ability to interpret their significance or judge the need for specialised advice.
Undergraduate trained Geographer/Environmental Scientist.	Able to recognise basic morphological features and identify potential problems, but would have a steep learning curve on practical issues. Best working alongside experienced practitioners.

1.4 What is the contribution of Fluvial Geomorphology to river management?

"It should be possible to persuade decision-makers that incorporating historical or empirical (field based) geomorphic information into river management strategies is at least as valuable as basing decisions on precise, yet fallible mechanistic models", (Rhoads and Thorn 1996). Since the early 1990's, applied fluvial geomorphology has risen up the operational and policy agendas of river management authorities (Sear *et al*. 1995, Brookes & Shields 1996). It is now firmly established within the river management policy and practice of Government and non-Government Agencies within Europe, North America, South Africa, Australia and New Zealand, where it is seen as vital and necessary for sustainable river channel and catchment management. The upsurge in the application of geomorphology has been driven by the recognition of the cost, both financial and environmental of ignoring natural system processes and structure in river channel management. More slowly, a sense has emerged that geomorphology also brings direct benefits rather than simply reducing costs; its role in achieving sustainable channel management is a case in point. Figure 1.1 provides a simple framework for assessing whether or not a proposed or existing river management practice requires any knowledge of geomorphology in order to improve its performance or sustainability. Geomorphology needs to be considered in river management practice/policy if the answers to any of the following questions are YES:

1) Has / Will the Proposal / Work alter the river discharge or sediment load?
2) Has / Will the Proposal / Work alter the river channel or floodplain morphology or dimensions?
3) Has / Will the Proposal / Work alter the channel boundary materials?

If the answer to more than one question is YES then it is likely that the functioning of the geomorphology of the river system will be significantly impacted and some form of assessment will be required.

Figure 1.1 When to Consider Geomorphology in River Management

At its core, the fundamental philosophy of applied fluvial geomorphology, is to understand, through good interdisciplinary science, the causes of river management problems arising from river channel sediment transport processes, and to consider the implications of any proposed activity to address the problem on the local and regional sediment system. In concept this simplifies to answering the following three questions:

1) How is the problem linked to the catchment sediment system?

2) What are the local geomorphological factors that contribute to the problem?

3) What is the impact of any proposed / existing solutions on channel geomorphology (which includes physical habitat and sediment transfer processes)?

This concept is not alien to river management. The clearest analogy is in flood protection. A flooding problem may be viewed at two scales. Firstly, the localised problem of the flooding itself, the cause of which may be a low point in a flood embankment. Secondly, the flooding problem may be viewed in terms of the wider catchment processes that generate the flood, such as changes in the infiltration capacity of the land surface and the efficiency of flood routing through the river network. The solution to this problem may be tackled locally (e.g. raising the flood embankment) or holistically (e.g. creating upstream flood storage areas, improving urban runoff management). The former is time efficient the latter is sustainable. The same approach applies to problems arising from processes of fluvial sediment transport only that here, river managers are only just beginning to appreciate that you need additional specialist input to identify the cause of the problem – Fluvial Geomorphology. Similarly when designing river rehabilitation projects or flood alleviation works, the river manager is used to considering the effects on water conveyance (usually applied through 1-D hydraulic modelling of a proposal), but rarely considers the effects on sediment conveyance.

A review of the scientific literature and R&D reports highlights the following major problems facing the river environment and river management bodies in the UK that would benefit from the application of fluvial geomorphology:

1. Problems of excessive levels of fine sediments or pollutant/toxin association with fine sediments (including metaliferous mine waste);
2. Channel instability – river maintenance, habitat change (pool infilling), loss or gain of conveyance, land/infrastructure loss or damage;
3. Design and strategic planning of river rehabilitation, flood channels, and river maintenance and flood protection programmes;
4. Mitigation through restoration of the legacy of past river management where this has led to (currently) unacceptable damage to the river environment.

Some of the above relate to relatively local problems arising from sediment transport through a reach, but others clearly have a wider catchment basis. Fluvial geomorphology links these scales, and when working alongside other relevant disciplines can make meaningful and significant contributions to the improvement of river system management.

Not all river management issues require the input of geomorphological advice, however those that influence the conveyance of sediment, or the modification of channel features and form, most likely require some level of input. Common or typical river management problems that benefit from understanding the fluvial geomorphology of the river system include:

1) Sedimentation of river beds, in particular spawning gravels;
2) Contamination of floodplain soils through overbank sedimentation and floodplain evolution;
3) Influence of channel adjustment on flood conveyance;
4) Bank erosion management;
5) Desilting/shoal removal arising from deposition of sediments that increase flood frequency;
6) Rehabilitation of rivers and floodplains for habitat improvement;
7) Design of environmentally acceptable flood / drainage channels;
8) Strategic assessment of catchment issues including Catchment Flood Management Planning, cSAC monitoring and designation, designation of conservation status;
9) Environmental Impact Assessment.

The forgoing lists, make clear that fluvial geomorphology contributes naturally to issues of flood defence and conservation. This is a strong asset, since its application can help rationalise the issues surrounding channel maintenance or rehabilitation by focusing on the implications of proposed operations on river channel form and stability. Since river channel form encompasses attributes of both physical habitat and channel stability, the use of fluvial geomorphology is pivotal to planning projects that are sustainable. Table 1.2 sets out some of the main generic procedures undertaken in support of river management in the UK, together with their main National and European Policy drivers. The geomorphological input to these management procedures is given in broad terms. What is clear is that how any proposed work / policy may impact the form, function and sediment system of a river channel and surrounding catchment should be among the issues considered.

1.5 Costs and Benefits of using fluvial geomorphology in river management

Previous NRA and EA Research & Development has revealed that problems associated with erosion and deposition in England & Wales are more extensive and expensive than previously thought (EA 1998). Yet little specific cost information is available at a national level. At the same time the number of projects that have used river geomorphology is increasing. A review of over 40 projects in which geomorphology has been used reveals the following benefits of using fluvial geomorphology:

1. Geomorphological approaches differ from existing conservation-led approaches, in providing a clear link between catchment processes and management and the management of river processes;
2. In a strategic role, fluvial geomorphology may be used to predict the outcome of operations for inclusion in Environmental Assessment procedures and the planning of improvements in river morphology and habitats;
3. In a proactive role, fluvial geomorphology may be used as a decision support tool for managing Flood Defence capital and maintenance programmes; providing reasons for the preservation or restoration of morphological features and creating designs for channels that seek to minimise or accommodate erosion and deposition over short, medium and longer-terms;
4. In a regulatory role, geomorphology is used to assess and consider Land Drainage consents and planning applications in terms of the likely impacts of proposals on morphological change and sediment load;
5. In a reactive role, geomorphology may be used to assess the cause of channel changes, and provide practical guidance directly applicable to a wide range of functional users;
6. The outcome of incorporating geomorphological approaches is always beneficial to the river environment and those seeking to manage them.

Before moving further into the detail of geomorphology as a science and source of useful information and assistance to the decision making of river management, it is important to emphasise that rivers (particularly mountain streams and those rivers conveying gravel loads in steeper areas of the country), often behave quite unpredictably during flooding. Thus just like other disciplines associated with rivers, whilst in general it may be possible to explain or even predict how a river and reach function, there will always be "surprises". These should not be seen as failures of the science, but rather, as that great engineer Sir Isembard Kingdom Brunel realised on the collapse of his first railway bridge on the Great Western Line, such occurrences are in fact the greatest opportunity to learn (Sear, et al., 2010)!

References

Sear, D. A., Newson, M. D. & Thorne, C. R., 2010. *Guidebook of Applied Fluvial Geomorphology.* 1st ed. London: Thomas Telford.