DEVELOPMENT OF AN INTEGRATED CATCHMENT PLANNING SYSTEM FOR THE URBAN ENVIRONMENT

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ABSTRACT

This paper describes the progress made in developing a methodology for undertaking land use and water management planning within urban catchments. This work forms a major part of a new EU-funded LIFE Environment demonstration project, SMURF (**S**ustainable **M**anagement of **U**rban **R**ivers and **F**loodplains). The SMURF project aims to demonstrate how the principles of river basin planning, contained in the Water Framework Directive (WFD), can be applied to highly modified and degraded catchments, using the River Tame in the West Midlands, UK as an example. The paper will describe the rationale behind the system development, which is required to accommodate a range of different users. Some of the applications that the system will be used for within the Tame catchment are outlined; these include flood risk, water quality, groundwater and ecology. As well as being used to implement elements of the WFD relating to urban planning up to 2015, the system will be used in the planning of two small-scale projects, aimed at producing significant improvements. Already, discussions over the development of the system have facilitated an improved dialogue between the three major stakeholders.

Keywords : Catchment planning; flooding; GIS; urban catchments; Water Framework Directive; water quality

BACKGROUND

A large part of the current global debate on water availabilty and use is concerned with the urban environment, where typically populations are expected to rise, with consequent increases in water demand, effluent volumes to dispose of, and development pressures to accommodate the needs of the rising populace. With such pressures, the river and floodplain environment tends to become degraded, with development taking place right up to the river's edge, for both domestic and industrial needs. In addition the rivers become merely carriers of floodwater and pollution, and are often heavily engineered with uniform shape, brick or concrete lined, and with many culverts to accommodate the above ground infrastructure. In such circumstances, the river and floodplain is severely degraded, supporting very poor ecology and with low amenity value.

Given the above, it not surprising that there is considerable research underway in Europe and elsewhere, looking at the options for better and sustainable management of water within cities (see for example, *http://citynet.unife.it/*). Another research focus is on the rehabilitation of urban rivers and floodplains, to improve their ecological status and general amenity value (see *http://www.urbem.net/*). Both these areas of research have been given added impetus in Europe, by the adoption of the Water Framework Directive (WFD) in December 2000. This legislation will require all Member States to achieve 'good ecological status' or 'good ecological potential' (if the water body is significantly altered in character by human activity) by 2015.

One example of a project that is testing and developing techniques and tools for achieving the objectives of the WFD is SMURF (**S**ustainable **M**anagement of **U**rban **R**ivers and **F**loodplains). This is an EU LIFE Environment demonstration project that runs from August 2002 until July 2005, and is centred on the upper River Tame catchment in the West Midlands, England. It is being led by the Environment Agency (EA), in partnership with Birmingham City Council, HR Wallingford, Severn Trent Water, Staatliches Umweltamt Herten (Germany), and the University of Birmingham and King's College London. The Partners therefore include the key players in the management of the catchment, from both a land use and water perspective, namely the environmental regulator, the local planning authority and the water and wastewater undertaker.

In addition to providing an opportunity to trial the practical application of the Agency's emerging plans and policies for the WFD, SMURF will develop and change the way that land use and water management is carried out within urban floodplains. In this latter connection it is benefiting from the extensive research carried out in the Tame, under the URGENT thematic programme (Urban Regeneration and the Environment) (Webster et al., 2001). This was an NERC-funded programme (see also *http://urgent.nerc.ac.uk/*), which considered the use and management of contaminated urban aquifers, biodiversity of urban habitats, and the modelling of urban corridors. There is therefore a wealth of knowledge and data that can be assimilated within the overall planning system that is being developed under the SMURF project.

The project objectives will be achieved through an integrated package of specific tasks:

- Development and dissemination of a methodology for urban water management, including demonstration of new modelling techniques, that are transferable to EU and Candidate Country planning authorities and water managers with responsibility for implementing the WFD

- Extensive citizen consultation to define the local requirements/objectives for the future management of the river system and to demonstrate the approach used
- Development of a land-use planning model using the latest GIS techniques
- Physical demonstrations to test the full application of the model through small-scale structural modifications to improve water quality and quantity issues.

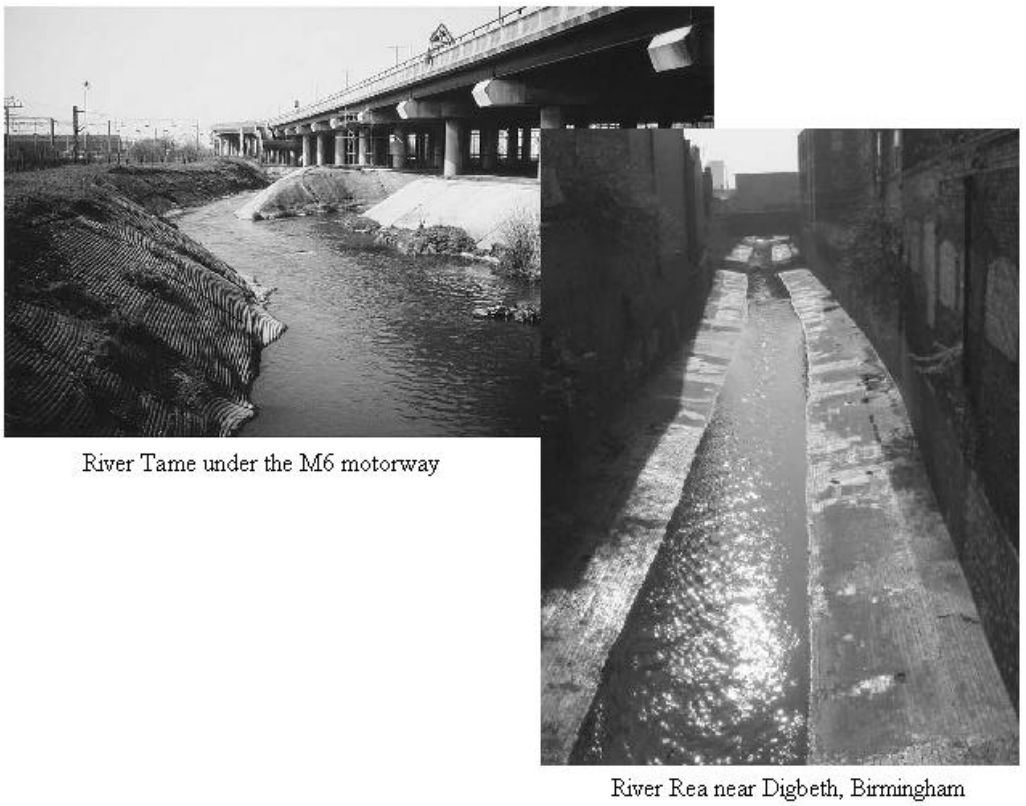
As part of the Common Implementation Strategy (CIS) for the WFD, a set of guidance documents has been produced to assist Member States. One of these deals with the identification and designation of heavily modified and artificial water bodies (CIS Working Group 2.2, 2002). From initial work, it would appear that most of the upper Tame watercourses would be designated as heavily modified (see Figure 1). This reflects the extensive modification of the channel form, to accommodate both flooding and the industrial urbanisation that has been experienced in the catchment since the late 18th century. One of the uses of the SMURF planning model will be to assist in designing sustainable improvements to the modified morphology, as well as determining suitable standards for the 'good ecological potential'.

THE STUDY AREA

The upper Tame catchment forms one of the headwaters of the River Trent basin (Figure 2), which in turn is part of the Humber river basin district; one of the 10 river basin districts in England and Wales that have been identified for reporting of the WFD (DEFRA, 2002). The upper Tame is unusual in that it lies within the West Midlands conurbation, and encompasses Birmingham, the second largest city in the UK. Typically, such large urban areas, such as London or Paris, are found in the lower part of the catchment, rather than the headwaters. Some 73% of the catchment is urban/industrial and is home to 1.8m people. Another distinguishing feature is that the majority of the water used in the catchment is imported from elsewhere.

The Tame catchment has suffered from significant structural modifications and pollution associated with 200 years of mining, industrialisation and urban development. The principal industries of engineering, metal finishing and other manufacturing still form the main economic activity,

Figure 1. Example of watercourses in the upper Tame



River Tame under the M6 motorway

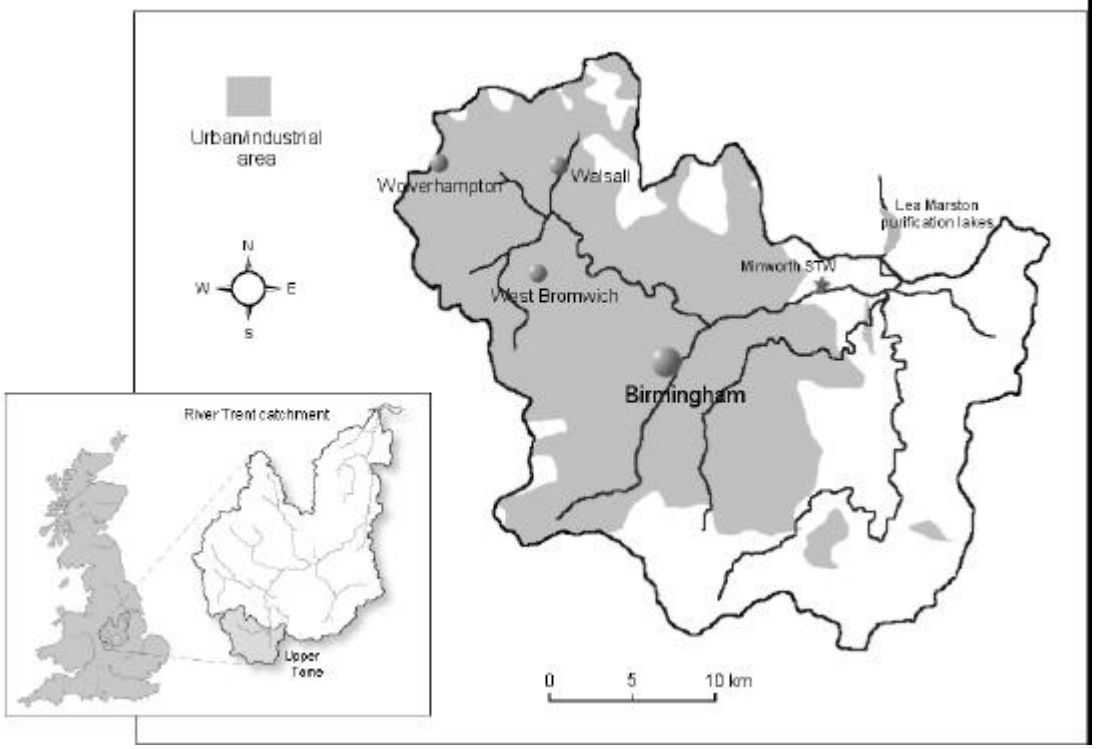
River Rea near Digbeth, Birmingham

although there has been a steady industrial decline since the 1980s. This has given rise to substantial land use changes and has left some 6000 ha of contaminated land. The environmental pressure of this 'development and decline' has significantly altered the hydrological nature of the area, affecting both surface and groundwater. The sewage treatment works at Minworth is the biggest inland treatment works in Europe, processing all the foul sewage collected across the catchment.

In spite of significant investment in the wastewater systems over the past 13 years, river water quality across the catchment is among the poorest in the country, with some 75% in the poor or very poor categories. This compares to 30% of rivers in

London and 24% in Manchester. There is also evidence of an increasing incidence of storm events, which puts significant pressure on the urban drainage infrastructure, increasing the occurrence of flooding and foul sewer overflows. This in turn leads to the flushing of pollutants into the watercourses during storm events, and the mobilisation of contaminated sediments in both the sewers and the rivers. As a result there is poor ecology and riparian habitats and frequent fish kills. This illustrates the profound challenges that SMURF needs to address within the catchment if the objectives of the WFD are to be realised.

Figure 2. Location and main features of the upper Tame catchment



THE PROJECT CHALLENGE

Whatever the final form of the SMURF system, its principal aim will be to bridge the gap between land use planning on the one hand, and the catchment management functions undertaken by the EA (and other competent authorities across Europe), both now and in the future. These latter activities include compliance assessment of chemical and biological quality, flood defence, waste management licensing and control. The system will therefore have two main aims. Firstly, to display land use and other catchment-wide information alongside the existing datasets that the EA are using on a routine basis (e.g. water quality archive). Secondly, to develop tools that can determine how planning decisions could impact on the riverine environment, and particularly the achievement of the WFD objectives.

In meeting these broad objectives, the SMURF system has to overcome several challenges. Firstly, all the Partner organisations have their own, very different GIS and database systems. The new system has therefore to be independent of these, both in terms of the system architecture and the data that it holds, since the Partners agreed that access to live databases was to be avoided. The SMURF system will therefore hold an agreed subset of the existing data, covering only the data that are required for catchment planning and achievement of WFD objectives. Also, because it is a planning system, a consistent and 'fixed' dataset should be used, but which is updated on a regular basis, say annually. A second consideration is the different Partner needs. In the case of the City Council, they are primarily concerned with developing planning guidance and procedures and using these to inform what planning developments should be allowed within the city. They have agreed that they would benefit from additional information to include within their assessment of constraints and opportunities. For example, they do not have ready access to information on river water quality, which could be an important consideration when creating new riverside developments. At the simplest level, therefore, SMURF will generate new GIS layers, either from existing or modelled data, which can be imported into Partners' systems.

In the case of the EA and Severn Trent Water, they use an existing set of modelling tools for answering a range of 'what-if' scenarios. These include issues such as how will changing a discharge consent improve river water quality, or where should investment be directed to improve the operation of the sewer system. The SMURF software needs to make use of these detailed and complex model approaches, but in a novel and more comprehensive way. Options that are being considered for the SMURF system, include incorporating the model results as part of the SMURF database, so that they can be accessed against selected development options. Alternatively, there could be an off-line link, such that a user option generates an instruction for the model(s) to be run, and the results then fed back into the system for assessment. In any event, there would appear to be a need for a simpler, overall catchment model that can be applied at any scale and which

would provide the main route for simulating the many what-if scenarios. This would need to incorporate the underlying elements from the existing models, and as a minimum should simulate quality and quantity aspects. In deriving such a model, it may be possible to simplify and combine existing models.

Another important, and innovative, aspect of the SMURF project will be the involvement of stakeholders, including citizens. A variety of techniques will be used to involve local communities in the future planning of the catchment, and to engender a greater ownership of the river environment. In terms of the development of the new planning system, the key stakeholder considerations will be:

- What data should be stored in the system?
- What planning options or what-if scenarios should be tested?
- What improvements would they like to see in the catchment?
- What results would they like to see, and how should they be presented? (E.g. available on project web site, CD, computer in Council offices).

Meetings will be held with the various stakeholders, to present the proposed system methodology and the reasoning behind it, and to then discuss the above questions. In this way, the views of other users of the river and floodplain can be taken on board at an early stage; a clear requirement of the WFD.

A final issue in the development of the integrated system is the time and resources available within the project programme. To produce a new-generation catchment planning system, which addresses all user requirements and has undergone rigorous testing, would require several years to develop. Such a timescale is not possible within the overall SMURF project. Work on developing the draft system methodology has taken place between November 2002 and April 2003, with the methodology presented and discussed at a workshop on the 25th April. A revised version of the methodology will be posted on the SMURF web site during June for further comment (see *http://www.smurf-project.info/*). Actual work on the development of the system, including data acquisition, model calibration etc. only started in February this year. As the draft system has to be presented at a subsequent workshop in January 2004, and available on CD for distribution, there is therefore only some 10/11 months for development. The system therefore will have to rely on utilising existing modelling systems and approaches, but combining them with state-of-the-art GIS/database/modelling techniques in a new and innovative way. For example, we believe that the bringing together of river modelling with land use, social issues and ecological condition within one planning system will be the first time that this has been attempted. In the same way, the co-operative working between the planning authority, environmental regulator and water company, with improved liaison with a range of stakeholders, including academic institutions, will also be a first.

OUTLINE OF PROPOSED SMURF SYSTEM

At the time of writing (May 2003), the development of the SMURF system and associated software is at an early stage, and it is currently only possible to provide an outline of the design and proposed functionality. In general terms the system will bring together the essential data for catchment planning into a single information store, which will be managed by a new software tool. The software tool will allow the information store to be queried to provide answers to a range of what-if questions related to planning that the catchment manager may wish to investigate. Outputs of the what-if analyses will be provided in the form of GIS layers, which will display the data in geographical forms appropriate to the stakeholders in the project. The software tool will also be able to interface with models representing processes within the catchment to support the what-if analysis where necessary. As noted earlier, this will be achieved by either utilising existing model results, or by 'instigating' a new model simulation to represent the new planning scenarios. In effect then, the SMURF system can be considered in terms of three main elements. These are the data stores, both existing and the SMURF information store; existing and new catchment models; and the new SMURF software tool.

Data stores

The data required for the SMURF system is extensive, and includes a wide range of GIS, monitoring data and model outputs. Examples include physical data on the catchment, flow, level and water quality sampling data, habitat data, information on amenity value, sewer records, land use data, and planning information. The data generally falls into two categories – GIS data and time-series data. The GIS data is readily imported into the internal SMURF data store, either directly or through conversion into a common format such as ArcView shape files. Time-series data are currently held in a range of different databases by the partner organisations and will be brought into SMURF via CSV (comma separated variable) import.

Catchment models

A range of models exists that cover different areas and processes within the Tame catchment. For example, there are highly detailed InfoWorks models covering the hydraulics of the main river and sewer systems. However, these models are effectively independent and interactions between the river and sewer system are in the main neglected. The Environment Agency uses the SIMCAT water quality model fairly extensively for discharge consent setting, whilst Severn Trent Water uses WRc's SIMPOL3 model to represent water quality in the river system. This latter model includes the effect of point discharges, CSOs and diffuse pollution upon the receiving river water quality. A major challenge for the SMURF project is to bring together these models and/or their outputs in a way that supports the overall aims of the project. The creation of a more general and simplified catchment model, possibly based on InfoWorks, will allow for an initial assessment of planning options, before the more detailed models are utilised. In addition, it is proposed that some form of decision

support system will be developed, that will link a variety of planning options with their anticipated outcomes. This will utilise rule-based modelling, and will therefore provide an alternative means of assessing proposed developments, particularly where a numerical modelling solution is not appropriate or possible. Again, this approach will make use of current practices in Europe.

The SMURF software

The SMURF software will form the main software output from the SMURF project. The software will incorporate an internal data store, into which the range of data outlined above will be imported. Via a user-friendly front-end, the user will be able to interrogate and display these data in ways that are appropriate for catchment management. In designing the data store and output formats, the developing GIS guidance from the WFD CIS will be utilised wherever possible (CIS Working Group GIS, 2002).

The software will also include a network description of the catchment, which will identify how the various components of the drainage system are connected together. The network description (or "flow map") will allow the drainage path from any point in the catchment to be determined. The user would then be able to identify downstream impacts of any change in the catchment. As an example, the Tame catchment includes both surface drainage systems, which drain directly to the rivers, and combined drainage systems which drain into the foul sewer network and from there into sewage treatment works. Developments in the catchment, which are spatially very close, can have potentially very different impacts depending on which drainage system is impacted.

EXAMPLE APPLICATIONS

Although 'real' examples from the SMURF system cannot be presented at this time, there is a range of potential example applications that have been derived from discussions with users.

At the simplest level there will be an improved 'data manager and display', which will allow disparate data to be displayed together for the first time. For example, biological data for one or more years could be plotted against the river quality and flow, to allow for improved understanding of the functioning of the catchment. The impact of CSO discharges or new land developments on the river environment will be easier to identify. This basic functionality does not exist currently in any of the partner systems within the UK, nor probably across much of Europe.

Achievement of current and future river objectives is normally made on a reach basis, and colour-coded maps are normally produced on a regular basis showing the compliance. Again, the guidance on "Reporting" from the WFD CIS will be consulted to ensure the SMURF system conforms to the emerging requirements. The SMURF system will be used to investigate the reasons for non-compliance, and to test various options to rectify this. Such options could include improved discharge consents, changes to the channel morphology, additional aeration of the flow or use of retention areas to trap sediment and other pollutants. Figure 3 presents an example of a colour-coded river network, displaying the results of a theoretical model test of a planning scenario.

The 'flow path' tool has already been mentioned. This will allow the impact of any land use change to be tracked to the downstream parts of the catchment. So the site of a new development, or an area of contaminated land, can be related to the sections of the river that will be affected. This will allow for more informed planning decisions, and to identify 'hot spots' within the catchment, where tighter planning controls may be needed or where intervention would be most effective.

Finally, the SMURF system will be used to test a range of small-scale modifications or improvements to the catchment, to identify two sites where prototype structures will be constructed during 2004. These structures will be designed to demonstrate significant improvements to the river environment, and will be informed by the views of the public, in addition to undergoing detailed environmental assessment and planning approvals. The system will therefore provide a means of communicating such designs to a range of stakeholders, and ensuring that all aspects are covered, such as social impacts and cost, as well as engineering design and environmental impacts.

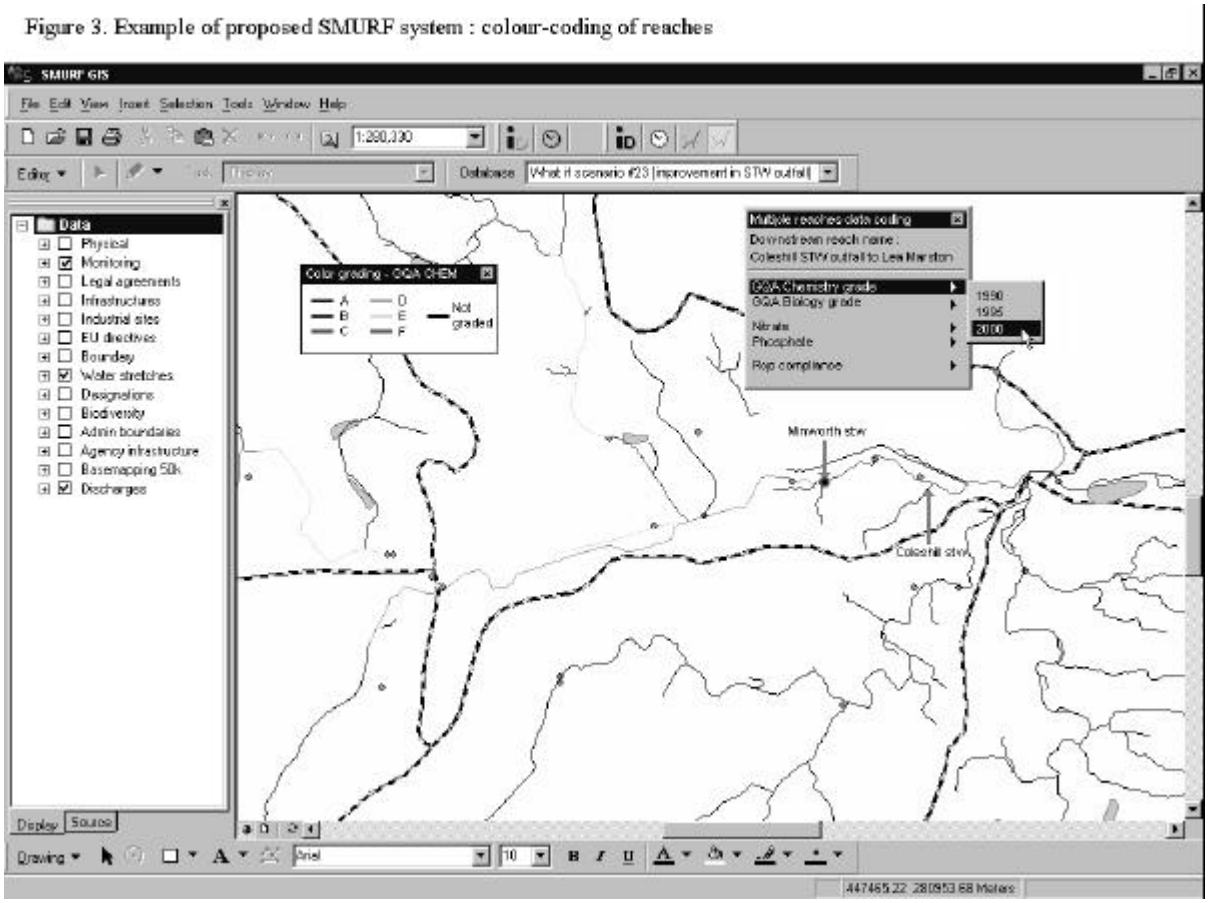
CONCLUSIONS

Although the development of the integrated catchment planning system is at an early stage, a draft methodology has been produced and discussed with both the Partners and a range of stakeholders. Meetings have been held with key users, to identify requirements from such an integrated planning system, and further meetings are planned over the coming months with other stakeholders to discuss their needs. Already, some project successes can be claimed. The bringing together of different interest groups, each with their own needs, has produced not only a clear desire to make the project a success, but also to bring real improvements to the catchment by closer collaboration. Similarly, the sharing of data and tools has been accepted as the only way forward in improving decision-making and dialogue. There has already been significant engagement with other interested parties, and this will be continued over the coming year, particularly involving local citizens – a key part of the overall SMURF project.

Although the current proposed methodology has been described as ambitious, the Partners are keen to ensure that a usable system is produced, albeit one that is a demonstration rather than general purpose product software. This will address specific functional requirements, that can be applied over the coming decade, but which can be readily developed as

requirements change. The successful application of the 'Whole Catchment Management' approach will therefore be an important demonstration output of the whole SMURF project.

Figure 3. Example of proposed SMURF system : colour-coding of reaches



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