Briefing Paper

The Impact of River and Groundwater Abstraction

- River flows are a critical factor for the creation and maintenance of river and floodplain morphology and their associated fauna, flora and ecosystem services.
- Extensive and comprehensive evidence exists showing the damaging impacts of artificially low flow regimes on fish, invertebrates, plants and river morphology.
- Current management strategies are not enforcing the precautionary principle.
- Urgent action is required to remove damaging abstraction licences.

Water is essential for all life forms. It makes up approximately 60 to 70%, by weight of all humans and is vital for all. It is essential for photosynthesis and controls biodiversity distribution on the planet. Globally, water covers approximately 71% of the earth surface, yet 97% is saline water in the oceans. Of the 3% of freshwater, about 69% is trapped in icecaps, 30% in groundwater and only 1% is readily available in surface waters such as rivers and lakes (Gleick, 1996). The demand for freshwater to support both human and environmental needs can therefore result in conflicts.

River flow is the result of the conversion of rainfall into run-off, measured in units of volume / time and often referred to as discharge. This conversion from precipitation to run-off is hugely variable across different landscapes and climatic zones. The interaction of discharge/flow with the shape of a river channel results in variable water velocity patterns. Rivers do not have single, uniformed flows. Instead, river flows vary through time in response to changing rainfall, mediated by underlying geology: more porous rocks allow greater storage of water in aquifers (underground or groundwater reserves) and lead to smoother, more damped flow patterns through time. In-channel habitat, including seasonal structure such as submerged vegetation, can also give rise to significant variability of water velocity within a reach of river, which may be significant for maintaining habitat diversity and biodiversity including different life stages within individual species (for example fish eggs, fry, juveniles and adults).

The timing and intensity of high and low flow events can have important effects on aquatic biodiversity (Poff *et al*. 1997; Brown and Ford, 2002). Human activities, such as the direct removal of water from rivers and aquifers (abstraction), and impoundment (construction of dams for various purposes); have greatly modified the natural flow regimes of many rivers (Ward and Stanford, 1983, 1995; Poff *et al*., 1997). It is estimated, for example, that approximately 60% of the world's rivers have been diverted, and many of the rivers, including the Colorado, Murray and Yellow, no longer reach the sea (Naiman *et al*., 2002). In-channel and riparian habitat management may also simplify flow variability.

Human water management activities are threatening our freshwater systems (Giles *et al*., 1991; Wood and Petts, 1994). Abstraction (also called withdrawals in the US) is the permanent or temporary removal of water from rivers, canals, lakes, reservoirs or aquifers. Data from 2005 showed 57,757 megalitres of water per day was abstracted from surface and ground waters in England and Wales, of which approximately 52% was used in electricity production and 30% in public water supply. The remaining amount was utilised by agriculture, fish farming, mineral washing and other industries (Defra Abstraction Statistics, 2005). Although some of this water is returned to the river, it is often not in the same place as the discharge point, and the quality of returned water will often have declined.

The restoration and preservation of native stream biota requires the rehabilitation of natural flow regimes (Stanford *et al*., 1996; Poff *et al*., 1997). Yet, it is predicted that, by 2025, 40% of the world's population will be facing water poverty (Naiman *et al*., 2002). This is likely to be significantly affected by climate change. The challenge is how we balance these needs.

Potential Impacts of Water Abstraction

Hydrological variability within rivers and streams is widely recognised as one of the primary factors influencing the distribution of aquatic flora and fauna (Townsend *et al*., 1997). The biological communities living in flowing water conditions are adapted to natural flow regimes combined with natural channel morphology, for example via their body shape, metabolism and feeding behaviours (Statzner *et al*., 1988). Hence, unnaturally low flows and altered flow regimes caused by water abstraction can have damaging impacts on river systems and their associated biota (Wright and Berrie, 1987; Giles *et al*., 1991; Wood and Petts, 1994: McKay and King, 2006).

Over-abstraction of river systems can cause:

- *Hydrological and hydraulic changes.* Velocity is a significant factor affecting the distribution and assemblage of stream invertebrates (Statzner *et al*., 1988), by influencing their respiration, feeding biology and behavioural characteristics (Petts, 2008). A reduction in discharge alters the width, depths, velocity patterns and shear stresses within the river channel (Armitage and Petts, 1992). This can modify the distribution and availability of in-stream habitat, which can have detrimental effects on invertebrates and fish populations (Wood *et al*., 1999). Altered flow regimes have also been linked to invasion of non-native species (Baltz and Moyle, 1993; Brown and Moyle, 1997: Brown and Ford, 2002).
- *Temperature changes.* Artificially low flows may increase water temperatures by increasing the area of air-water interface per unit volume of water (Webb *et al*., 2003). Increases in water temperature will affect the river fauna and flora (Richardson *et al*., 1994). Temperature has a direct effect on metabolic processes, while increased temperature raises biochemical reaction rates and can cause wide fluctuations in dissolved oxygen levels. Temperatures over 22℃ will have serious negative effects on salmonids (Elliott, 1994), with rising temperatures imposing increasing stress up to this level.
- *Water quality changes*. An artificial reduction in flow reduces dilution of effluent which is returned to rivers (Armitage and Petts, 1992), increasing the concentration of pollutants already within and newly entering the watercourse.
- *Sediment deposition.* Periodic high flows (spates or freshets) are important for maintaining in-stream habitats by flushing fine sediment out of the system (Reiser *et al*., 1989; Old and Acreman 2006). The highest flows also play a role in maintaining channel carrying capacity and structure. Similarly, artificially low flows can result in fine sediment being deposited in the channel. This can clog interstitial spaces in the substrate, thus reducing available fish spawning habitat (Carling and McCahon, 1987; Crisp, 1989) and invertebrate refugia (Wood and Armitage, 1999; Milan *et al*., 2000).
- *Shifts in invertebrate assemblages* (Armitage, *1987*). For example, reduced abundance of filter-feeding invertebrates and a reduction of stoneflies and heptageniid mayflies, which favour clean stones and well-oxygenated water (Extence *et al*., 1999), and an increase in taxa associated with low velocity including chironomids and molluscs (Jowett and Duncan, 1990). Some macroinvertebrates are able to survive short episodes of low flow, providing adequate refugia are available. However, prolonged artificially low flow conditions can lead to invertebrate mortality (Armitage and Petts, 1992) or replacement by more tolerant groups of invertebrate. The Salmon and Trout Association (S&TA) River Fly Life Abundance survey data from 2002 correlates low flow with decreasing fly abundance (Hayes, 2007).
- *Reduced growth of aquatic flora* (Franklin *et al*., 2008; Wilby *et al*., 1998; Herne and Armitage, *1997).* Low flows can inhibit the growth of certain aquatic plants, such as *Ranunculus*. Reduced *Ranunculus* growth can have significant knock-on effects for invertebrates, fish and river structure.
- *Change in fish communities*, with species requiring higher oxygen concentrations (frequently salmonids) being replaced by more generalist species.
- *Disruption to migratory passages.* Low flows can impede the migration of salmonids and other migratory fishes and limit the distribution of spawning fish (Strevens, 1999; Environmental Agency, 2004; Old and Acreman, 2006). The upper reaches of river catchments are often very important for

juvenile salmonid production; however, these areas may not be accessible to upstream migrating fish at low flows.

- *Reduced connectivity with floodplains and riparian margins.* Functioning floodplains have a major influence on in-channel processes, for example by providing inputs of nutrients and refugia and breeding habitat, essential to the life cycles of many riverine species (Bunn and Arthington, 2002).
- *Reduced fisheries production* which may jeopardise angling participation, resulting in the loss of social and economic benefits to local communities (Willis and Garrod, 1999) and onward investment in river management and conservation projects.

Measuring the Impact

These mechanisms of impact are reasonably well known and the science of Environmental Flows is developing rapidly (Acreman and Dunbar, 2004). However, it can still be very difficult to precisely diagnose the ecological impacts of low flows in any particular situation. There are several reasons for this, but particularly important are:

- The availability of sufficient hydrological data, both on historical flows and current water use extractions. (For many abstractions, only licensed volumes are known);
- The availability of sufficient ecological data, as variability in natural systems is often high even without human impacts. Furthermore, introductions and stocking can confound hydroecological relationships;
- The complexity of the environmental interrelationships and the presence of multiple stressors such as historical channel modification and water quality impacts. Rivers are commonly subject to, and will respond to and integrate, multiple stresses. Determining the impacts arising from an individual stressor (such as abstraction) alone can be difficult, and may also overlook synergistic effects (such as the impacts of pollution exacerbated by declining dilution).
- Where there is a requirement to seek proof of impact beyond all reasonable doubt before taking action (a common condition of many strands of statute law) runs the risk that protection will only be provided when the damage to the environment is already too serious, subject to strong vested interests and possibly beyond redemption. Rejection of all evidence of impact with less than very high levels of statistical significance is inappropriate.

Some of the most acute problems with over-abstraction have been found in chalk stream systems, where naturally up to 95% of the flow is derived from underground aquifers (Owen, 1991). The catchments of chalk streams provide underground reservoirs of generally high quality groundwater which can be abstracted for public supply. Under natural conditions, classic chalk rivers have buffered flows due to groundwater interactions (Berrie, 1992), creating one of the most productive riverine habitats, particularly for salmonid fisheries ((Mann, 1971; Mantle and Mantle, 1992; Bowes *et al.*, 2005). Low flow periods, which are artificially lower for longer, can change the physical and biological attributes of these waterbodies. Abstraction for public water supply and industry has dramatically reduced the flow in many chalk streams and, in some cases, completely dried up sections of these important rivers, particularly during dry summers when public demand is at its highest (National Rivers Authority, 1993). This also has an economic impact to local communities, resulting from the inability to fish, enjoy river views due to encroaching vegetation or undergo other recreational activities (Willis and Garrod, 1999).

Current Management

The Environmental Agency is responsible for regulating water systems and abstraction licenses in England and Wales. The duties of the Agency and its predecessor bodies date back to the Water Resources Act 1963, which required the regulation of water abstraction to balance the needs of water users with those of the environment. Historically, this was undertaken and updated on a piecemeal basis, informed by local precedents and "rules of thumb". An example of this is the use of "hands off flows", when abstraction had to cease or be significantly reduced if a specific low flow criteria was reached.

In May 1997, the Government held a Water Summit involving a range of key stakeholders to review the Water Resources Act abstraction licensing system. This resulted in the 1999 publication of 'Taking Water

Responsibly', which announced changes to the water abstraction licensing system in England and Wales. The legislative changes were realised in the Water Act 2003, which included (Defra, 2008):

- Time limits for all new abstraction licences;
- The facility to revoke abstraction licences causing serious environmental damage without compensation;
- Greater flexibility to raise or lower licensing thresholds;
- Deregulation of small and environmentally-insignificant abstractions;
- Licensing extended to abstractors of significant quantities presently outside the licensing system; and
- Conversion of water company drought plans and water resource management plans to statutory status.

Non-legislative changes include;

Catchment Abstraction Management Strategies (CAMS)
CAMS were developed as a response to the requirements of 'Taking Water Responsibly' and to provide a consistent mechanism for managing water use through catchment planning and licensing. The Resource Assessment and Management (RAM) framework within CAMS provides information on water availability at a catchment scale (Dunbar *et al*., 2004). This assessment is based on the requirements of river ecosystems and other water users. CAMS were designed to provide the information necessary for the review of existing time-limited licences and for the assessment of new time-limited licenses.

The first formal cycle of CAMS commenced in 2001 and concluded in March 2008, after which there was a review of the first cycle of the CAMS process: the *Managing Water Abstraction Interim update* (Environment Agency, 2008). With the implementation of the Water Framework Directive, CAMS will no longer be produced on their own cyclical programme, but will feed into the WFD River Basin Planning process. Research undertaken to set abstraction limits to achieve 'Good Ecological Status' under WFD (Acreman *et al*., 2008a) has now been included within revisions to the RAM framework. Appropriate managed flow releases from reservoirs have been investigated (Acreman *et al*., 2008b) but it has proved difficult to define simple rules, as each reservoir and river system is unique. Site-specific studies are usually required.

Restoring Sustainable Abstraction (RSA) Programme
The RSA Programme was set up by the Environmental Agency in 1999 to identify sites which may be at risk from abstraction, and to prioritise how to resolve the conflicts in these areas. These included sites classified under the European Habitats Directive [and Birds] and designated as Sites of Specific Scientific Interest (SSSI). The RSA programme is a successor to the Alleviation of Low Flows (ALF) programme established during the 1990s to target 40 rivers believed to be suffering most because of artificially low flows. An ongoing review is taking place (Environment Agency, 2008) to identify environmental damage still occurring as a result of abstraction, focusing on sites designated under the Habitats and Birds Directives.

Since April 2004, all new abstraction licenses must incorporate a time limit, specifying start and expiry dates. The Environment Agency has the power, under existing legalisation, to vary or revoke abstraction licenses causing environmental damage. However, in many circumstances, such as permanent licences, this requires compensation to be paid to the licence holder. With most existing abstraction licenses being permanent (Environment Agency, 2005), the need for compensation is preventing progress to remove the damaging abstractions. For example, eight years of consultation on how to alleviate over-abstraction of the Rivers Brennand and Whitendale in the upper Ribble catchment, which results in important salmonid spawning and nursery areas being reduced to pools in the drier months, has ended in no changes to the current abstraction licences because no funds are available to compensate water companies for taking less water. Serious equity issues are raised by the support of private benefits (on the basis of over-abstraction) through costs incurred by the wider public (people's enjoyment of aquatic ecosystems and the many societal benefits they provide).

There is also concern over the effectiveness of the CAMS process in aquifer-fed catchments such as the Bourne Rivulet, where the Environment Agency is still allowing high levels of winter abstraction in the Test and Itchen CAMS. This is deemed acceptable because of high seasonal rainfall, but continuing abstraction during these winter months is jeopardising replenishment of the aquifer, with potential to impact the ecology of the Bourne Rivulet, especially in the spring and summer.

Despite the conservation of aquatic biodiversity and ecosystem health being embedded in current policies, there seems to be little political will to prioritise it. Environmental protection tends to favour small-scale site protection or rehabilitation, poorly connected if at all to the ecological health of the wider catchment. However, structural river restoration will provide very little long-lasting environmental benefit if other key stressors on the system are not removed, including the integrity of the catchment as a whole. The conservation of running water systems requires the restoration of the underlying processes that support the biota. Restoring natural flow regimes is fundamental to improving aquatic habitats, and increasing biodiversity. Restoring flow regimes should not be considered in isolation, but linked with water quality and morphology targets. Restoring flow regimes should also be considered alongside climate change, in order the help manage anthropogenic demand and improve environmental resilience. This is essential not merely for the health of salmonid populations and ecosystems, but for the many and diverse benefits that people derive from catchments.

Action Required

The S&TA believes that WFD compliance will be compromised if further action is not taken to address damaging abstractions through altering their licenses. This could lead to the EU initiating legal infraction proceedings against the UK Government.

The S&TA calls for:

- An urgent review of the CAMS process to: 1) make allowances for inadequacies in historical flow data in assessing future flows and water availability; 2) take full account of the necessary dilution requirements needed to reduce the impact of consented discharges and diffuse pollution; and 3) to enforce the Precautionary Principle where limited data exist.
- The Government to quantify the effectiveness of the Restoring Sustainable Abstraction (RSA) Programme and revise on the basis of lessons learned.
- Action to make all existing licences time-limited, and to remove the requirement to provide compensation to the licence holder if the abstraction is causing environmental damage.
- Sufficient funding for monitoring, so that the impacts of abstraction can be separated from other stressors to provide clear evidence of the environmental damage caused by abstractions, and to fund research to distinguish human impacts on flow regimes from the effects of climate change.

Conclusions

River flows are a critical factor in the creation and maintenance of in-river morphology, riparian zones and floodplains, and create habitat for their fauna and flora. Flows help sustain water quality by flushing nutrients, containments and sediments (thus protecting spawning gravels) from the fluvial system. The magnitude, timing, frequency and duration of high and low flow events are critical to all elements of the river biota. Increasing human populations and escalating demand on freshwater resources, coupled with mounting concerns about environmental change, raise the need to protect, maintain and restore natural riverine flows. Over-abstraction can be destructive to resident river flora and fauna, including organisms with migratory lifecycles. It can also degrade the many benefits the people derive from river ecosystems.

Action is required now to create more natural running water systems in order to improve ecosystem health and provide resilience to climate change. Precautionary decisions must be made now to prevent future ecological damage, as comprehensive scientific evidence is available now to show the damage which may be caused by artificially low flow. This evidence can and should not be ignored.

Acknowledgements
Thanks for the expertise and guidance from Professor Geoff Petts (University of Westminster), Dr Mike Dunbar (Centre of Ecology and Hydrology) and Dr Mark Everard (Visiting Research Fellow, University of the West of England).

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