British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Technical Note: Hyporheic Zone Sampling Procedures

Groundwater Science Programme

Open Report OR/10/048

BRITISH GEOLOGICAL SURVEY

GROUNDWATER SCIENCE PROGRAMME

OPEN REPORT OR/10/048

Technical Note: Hyporheic Zone Sampling Procedures

R Dearden and B Palumbo-Roe

Keywords

Hyporheic zone, sampling, DGT.

Front cover

Rookhope Burn, Stanhope, Northumberland

Bibliographical reference

DEARDEN R AND PALUMBO-ROE B. 2010. Technical Note: Hyporheic Zone Sampling Procedures. *British Geological Survey Open Report*, OR/10/048. 21pp.

Keyworth, Nottingham British Geological Survey 2010

BRITISH GEOLOGICAL SURVEY

The full range of our publications is available from BGS shops at Nottingham, Edinburgh, London and Cardiff (Welsh publications only) see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications, including maps, for consultation.

We publish an annual catalogue of our maps and other publications; this catalogue is available online or from any of the BGS shops.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as basic research projects. It also undertakes programmes of technical aid in geology in developing countries.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

BGS Central Enquiries Desk

Tel 0115 936 3143 Fax 0115 936 3276
email enquiries@bgs.ac.uk

Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG

Tel 0115 936 3241 Fax 0115 936 3488
email sales@bgs.ac.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA

Tel 0131 667 1000 Fax 0131 668 2683
email scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road, London SW7 5BD

Tel 020 7589 4090 Fax 020 7584 8270
Tel 020 7942 5344/45 email bgslondon@bgs.ac.uk

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff CF15 7NE

Tel 029 2052 1962 Fax 029 2052 1963

Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB

Tel 01491 838800 Fax 01491 692345

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

Tel 028 9038 8462 Fax 028 9038 8461

www.bgs.ac.uk/gsni/

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU

Tel 01793 411500 Fax 01793 411501
www.nerc.ac.uk

Website www.bgs.ac.uk
Shop online at www.geologyshop.com

Foreword

This report is the product of a study by the British Geological Survey (BGS) to develop techniques to sample porewaters within river bed sediments.

Acknowledgements

We are grateful for the assistance provided by Dr. Richard Greswell (University of Birmingham) and Humphrey Wallis during the development of the hyporheic zone sampling equipment. We are also grateful to Rosalind Preston who provided help during sampler installation and sampling.

The authors would like to thank the landowner adjacent to the Rookhope Burn sampling site for allowing us to park on this property.

Contents

FIGURES

Summary

This report describes sampling apparatus that we produced as part of the Abandoned Mine Project, under the Groundwater Science programme. The report introduces the concepts of the overall study and identifies the need for sampling apparatus that can be installed within the riverbed. The report describes the development of three types of hyporheic zone sampling apparatus including:

- Hyporheric zone multilevel sampler
- Hyporheic zone DGT (diffusive gradients in thin films) disc sampler
- Hyporhetic zone DGT strip sampler

The report explains the design, installation, monitoring and removal of the devices and discusses their successful implementation at a field site..

1 Introduction

A study of zinc and lead contamination in the Rookhope Catchment in Weardale prompted an investigation of the river and hyporheic zone, defined as the region beneath or aside from the river bed where shallow groundwater mixes with surface water. The primary aim was to collect data on metal concentrations in the surface water and hyporheic zone porewater. This report describes the apparatus that were developed to achieve this aim.

Two types of sample collection methodologies were implemented: a) traditional water sampling that involved collection of water samples for standard laboratory analysis, and b) water sampling by means of *diffusive gradients in thin films* passive samplers (DGT). The use of DGT samplers (supplied by DGT Research Ltd, Lancaster University) was necessitated by the need to monitor accurate, in-situ, trace metal concentrations. The technique is specifically designed to:

- measure in-situ, trace dissolved concentrations of metals, phosphates, sulphides and radionuclides
- avoid sample alteration through the process of handling
- provide an integrated measurement of species concentration throughout the monitoring period (flux)

The DGT device is available in two forms. The first is a DGT disc that is 40 mm diameter and 18 mm high and contains an exposed surface of DGT membrane measuring 19 mm in diameter. The second is a DGT strip sampler that is 200 mm long (240 mm including handle), 50 mm wide and ~6 mm thick and contains a membrane approximately 170 mm long and 2 cm wide. The former is designed to collect bulk samples from water, whilst the second is designed to be installed within a zone of concentration change such that concentration changes with distance (and time) can be observed. Given the size of these sampling devices, purpose-made sampling kit was required to deploy them within the hyporheic zone.

The specification of sampling location requirements included:

(a) collection of hyporheic zone porewater chemistry from multiple depths

(b) deployment of the disc DGT within the hyporheic zone

(c) deployment of the strip DGT within the hyporheic zone

(d) measurement of electrical conductivity, electrode potential (E_h) and pH within the hyporheic zone at multiple depths

(e) measurement of relative water level between the hyporheic zone and river.

In order to fulfil these requirements, three sampling devices were designed, built and tested. The hyporheic zone multilevel sampler was designed to provide samples for specification points (a), (d) and (e). The hyporheic zone DGT disc sampler was designed to meet the needs of (b) and (e). Finally, the hyporheic zone DGT strip sampler was designed to meet the needs of (c).

The sample devices were tested in the Rookhope Burn, Stanhope Moor in Northumberland. This river provided a challenging environment for the installation of such in-situ apparatus because of the pebbly nature of the river bed.

2 Hyporheic Zone Multilevel Sampler

2.1 OVERVIEW

A hyporheic zone multilevel sampler was developed for monitoring porewater within the river bed with regards to both piezometric level and water quality. The samplers were designed to meet the following specification requirements:

- Collection of traditional porewater samples at discrete and multiple depths within the hyporheic zone
- Measurement of the piezometric surface within the hyporheic zone
- Hand-based sampler installation that minimises the disturbance to hyporheic zone sediments and reduces the chances of short circuiting between sampling ports and between the surface water and hyporheic zone porewater.
- Simple and rapid sampler installation and removal
- Rapid and inexpensive sampler construction

2.2 DESIGN AND CONSTRUCTION

The use of hyporheic zone multilevel samplers was originally recorded in an unpublished BGS study of the Smestow Brook, Wolverhampton. Since then, an early design was described in Ellis (2003) and then a more comprehensive account was provided by Rivett et al. (2008). The hyporheic zone multilevel sampler designs in this technical note are based on those described by Rivett et al. (2008).

The hyporheic zone multilevel samplers comprise a 12 mm ID, 16 mm OD, 1200 mm long, HDPE tube, fitted at one end with a machined, stainless steel drive-point that assists penetration of the device into sediments. The drive point, measuring 45 mm in length and 31.5 mm in maximum diameter, screws into a 27 mm diameter, 29 mm long stainless steel, 0.5” British Standard threaded pipe fitting, which attaches to the HDPE tube via a 16 mm compression fitting of 17 mm length. This compression fitting was milled to a diameter of 27 mm. The HDPE tube required milling to an external diameter of ~15.5 mm to enable the compression fitting to be attached. To allow the piezometric surface within the hyporheic zone to be monitored, two 4 mm diameter holes were drilled in opposite sides of the HDPE pipe approximately 1 cm above the stainless steel pipe joint. A piece of nylon screen material (e.g. 45 µm mesh size) measuring approximately 50 mm wide and 100 mm long was wrapped around the base of the HDPE tube to prevent sediments blocking the holes. The screen material was secured using three 2.5 mm wide plastic cable ties, the ends of which were removed. Four discrete depth sampling ports were installed around the central stock of the hyporheic zone multilevel sampler, comprising Teflon tube (1.6 mm ID, 3.2 mm OD) measuring ~200 mm in length and fitted at one end with nylon mesh screen (e.g. 45 µm mesh size) to prevent blockages due to sediment. The screens were 40 mm by 50 mm and were neatly folded over the tube end and then wrapped around and secured using three 1.5 mm wide plastic cable ties. The fastenings of the three cable ties were orientated in the same vertical axis to decrease the bulk of the screen. The first Teflon tube was positioned on the central stock with the screened end positioned a couple of millimetres above the stainless steel pipe joint. The tube was secured using plastic cable ties, ensuring that the fastenings of the cable ties securing the Teflon tube screen were orientated such that the total diameter of the sampler was minimised. The second Teflon tube was installed 100 mm above the first tube. The tube was secured using a plastic cable tie. Further cable ties were then used to secure tubes 1 and 2 around the central stock. The third and fourth Teflon tubes were installed at 100 mm intervals. Further cable ties were positioned around both the central stock and the four sampling tubes, ensuring that all tubes were aligned and did not cross one another. A schematic of the design is shown in Figure 1 and photographs of the final product are shown in Figure 2 and Figure 3. A scale engineering drawing of the drive-point is shown in the Appendix.

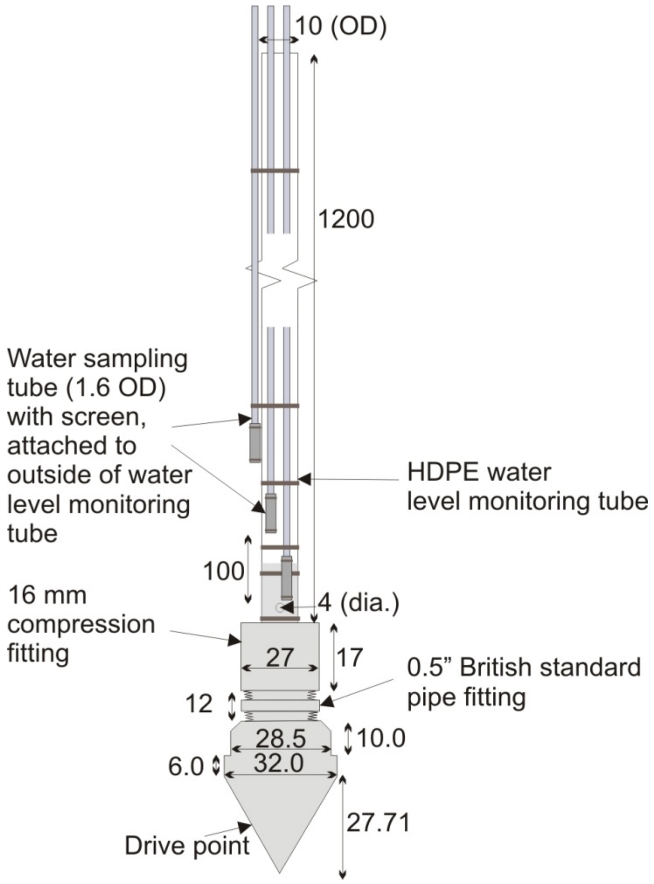

Figure 1 Schematic of hyporheic zone multilevel sampler showing sample with two multilevel ports and central water level monitoring well. Not to scale. All dimensions in mm.

Figure 2 Photograph of hyporheic zone multilevel sampler nose cones and lower, external sampling ports

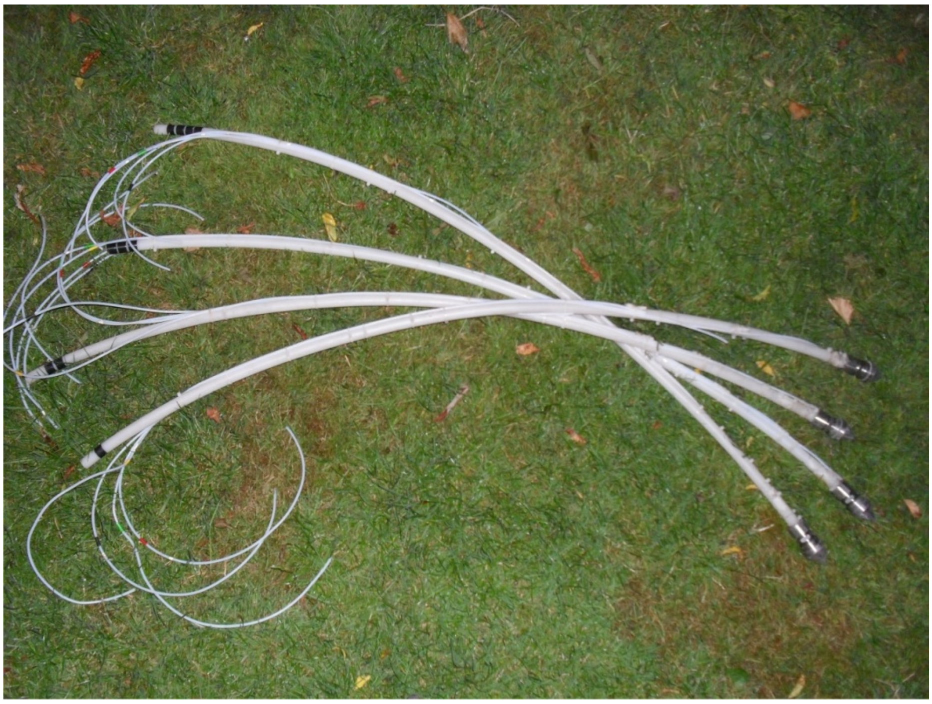

Figure 3 Photograph of hyporheic zone multilevel samplers

2.3 INSTALLATION

Installation of the hyporheic zone sampler into the riverbed is dependent upon the resistance of the riverbed. River beds that are lined with cobbles offer more resistance than those that are sediment lined. Installation of the hyporheic zone sampler into rock (pebbles/cobbles) is likely to cause damage and hence, the resistance of the river bed was tested using hand augers to find a suitable location for installation.

To install the sampler into the hyporheic zone, the device was inserted into a 1500 mm long, metal *driving tube* (ID of 29 mm, OD of 31.5 mm), leaving the 36 mm diameter drive-point protruding from the pipe end. During installation, the *driving tube* rests on the lip of the widest part of the drive-point cone (Figure 4). In order to drive the sampler into the hyporheic zone, two methodologies were trialled. In the first methodology, a sledge hammer was used to apply force to a metal cap placed on the top of the *driving tube.* The metal cap was intended to prevent metal fatigue and deformation, however where hyporheic zone sediments were comprised of cobbles, deformation beneath the metal cap occurred. In the second methodology a sliding sledge hammer was used to apply force to the top of the *drive tube.* The sliding sledge hammer comprised a vertical pole that screwed into a metal housing at the top of the *drive tube*. A large aluminium weight, with a central hole was positioned over the pole, such that it could be slid vertically up and down, providing a downward force when dropped from height. This methodology appeared to damage the *drive tube* less than the sledge hammer approach presumably because the force was applied to the top of the tube more uniformally. A force applied to the top of the *driving tube* causes the sampler to penetrate the sediments, with the force being applied to the drive-point instead of the plastic central stock of the sampler. The samplers were driven into the hyporheic zone to a depth of up to 400 mm below the river bed. The *driving tube* was then removed. In clay-rich sediments the sampler and *drive tube* readily parted leaving the sampler in the ground. In gravel-rich sediments, the sampler tended to lift during removal of the *drive tube* and hence a 10 mm OD, 2 m long rod was placed within the *drive tube* to enable downward pressure to be applied to the sampler whilst the *drive tube* was removed. The installation procedure is shown schematically in Figure 5 and in photographs in Figure 6.

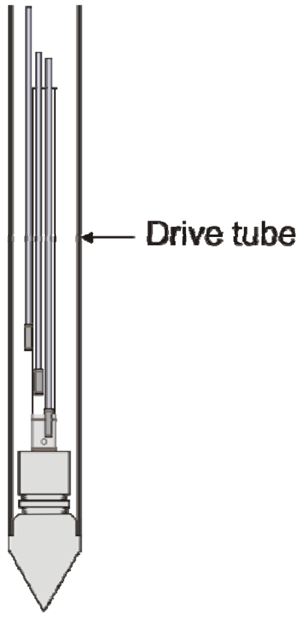

Figure 4 Schematic of hyporheic zone multilevel sampler inserted into drive tube

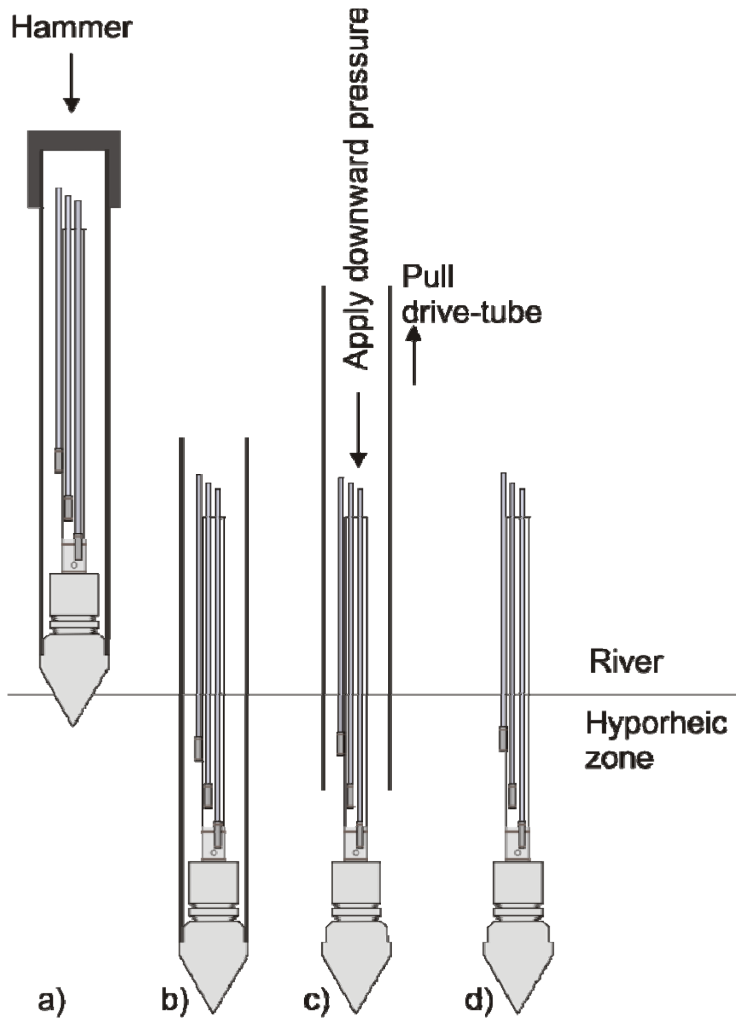

Figure 5 Installation procedure: a) hammer device into ground (preferably with slide hammer); b) in gravelly sediment place rod down drive tube and apply pressure; c) whilst applying pressure to rod, pull drive tube; d) leaving hyporheic zone multilevel sampler in place.

The sampler construction and installation procedure have been designed to reduce disturbance to the hyporheic zone, however given the differential diameter of the drive-point (32 mm) versus the water monitoring tube (16 mm), some disturbance to surrounding sediments is anticipated. During penetration of the hyporheic zone sampler within the drive-tube, the surrounding sediments will be compressed in an outward, radial direction. Following removal of the drive-tube, decompression of the sediments will reduce the volume of the void around the sampler. Decompression in unconsolidated deposits will occur as relatively rapid “fall-in” around the void, although changes in porosity within the disturbed zone around the water monitoring tube may remain. In clay-rich deposits, decompression may result in re-expansion of the clay into the void. In consolidated/unconsolidated layered deposits, the situation may be more complex, with the potential for relatively rapid fall-in of unconsolidated material and slower re-expansion of clay-rich material. This process may cause layers to become misaligned relative to their natural position. Monitoring should be undertaking following a period of stabilisation, e.g. 24 hours. This recovery time likely represents a minimum period for recovery.

Once installed, the installation depth of the sampler is calculated by measuring the stick-up above the river bed. When correctly installed, the hyporheic zone sampler pertrudes above the surface of the water.

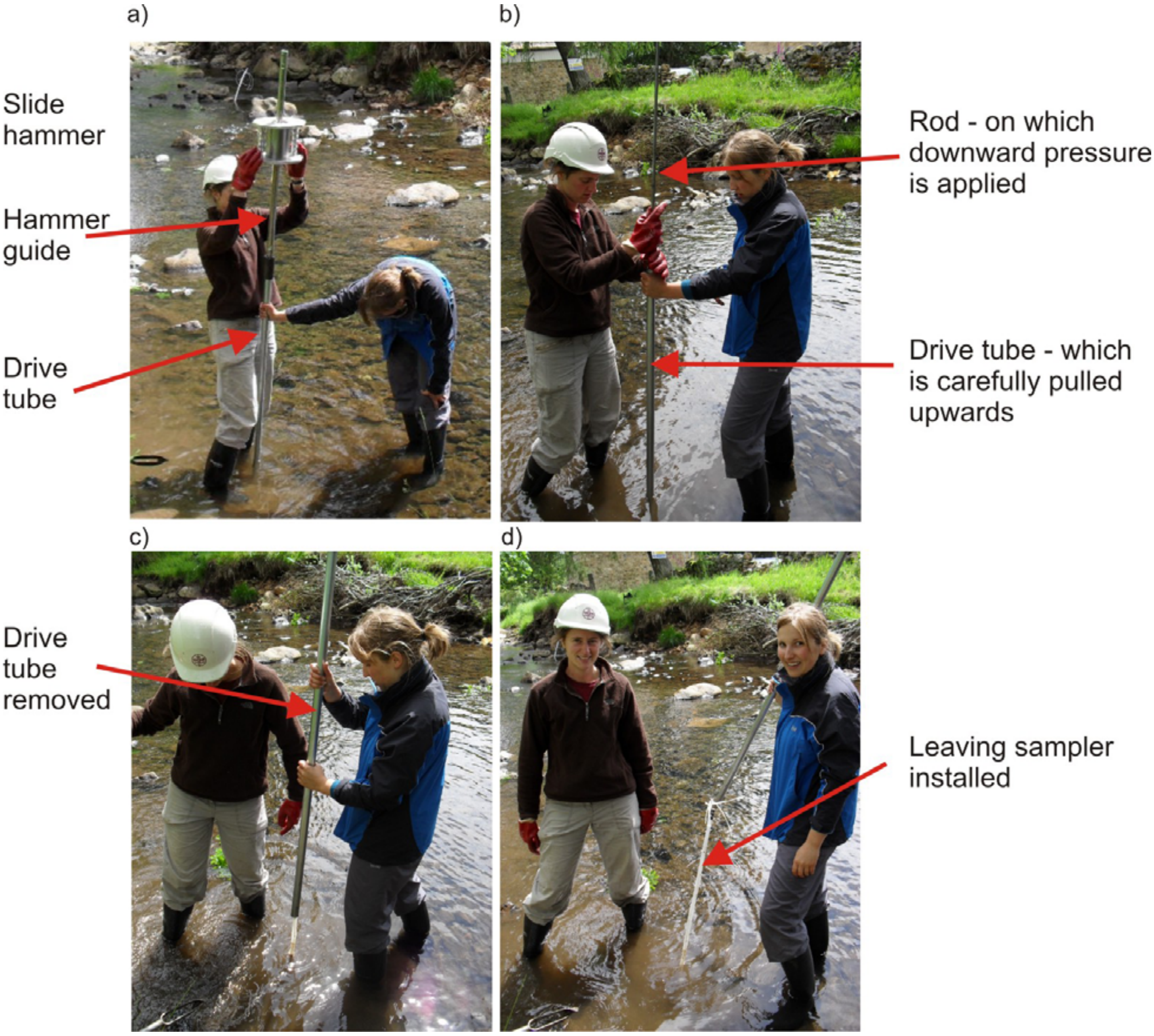

Figure 6 Installation of hyporheic zone multilevel sampler including: a) installation into the river bed; b) disengagement of sampler from the drive tube; c) removal of drive tube, and d) resulting completed installation.

2.4 MONITORING

The piezometric surface within the river bed was monitored before water samples were taken to ensure that the measurement recorded a natural and not artificially pumped water level. The water level in the hyporheic zone was measured relative to the river water level rather than absolutely, which would have required a more permanent datum. A Solinst mini dipper was placed down the central HDPE tube of the hyporheic zone multilevel sampler and the water level was recorded from the top of the tube. To measure the relative river water level from the same datum, an additional HDPE tube of 25 mm diameter, with 4 mm (dia) holes drilled in opposite sides of the lower 10 cm, was held adjacent to the hyporheic zone sampler. This provided a well in which to measure the river water level whilst reducing turbulence in water levels as a result of flowing water.

Porewater samples were drawn from the Teflon tubes using a low flow multichannel peristaltic pump that enabled simultaneous sampling of the four ports at an approximate flow rate of 4 ml/min (Figure 7). The sample tubes were purged before sampling by collecting and discarding 3 times the volume of water present in the sample tube. Samples of ~50 ml were then collected in plastic 50 ml bottles. After all water samples were collected, ports were re-sampled to enable wellhead parameters including pH, E_h, electrical conductivity and temperature to be collected. The Teflon sampling tubes were connected in series to a flow through cell and then to the low flow pump, such that porewaters were pumped through the flow through cell enabling parameters to be measured. A period of equilibration of approximately 10 to 15 minutes was required for the E_h probe to stabilise. Other probes stabilised more rapidly.

Figure 7 Sampling the hyporheic zone multilevel samplers using the multichannel, peristaltic pump

2.5 REMOVAL

The hyporheic zone samplers were removed from the river by applying gentle upward pressure on the plastic HDPE tube. During removal slight damage was incurred to a small number of screens which became twisted and crumpled and hence needed replacement (Figure 8). The original multilevel design (Rivett et al., 2008) was not developed with the intention of removal, because porewater concentrations were monitored temporally. Piezometers were removed in this trial study, but in the long term devices may be left in the riverbed for long periods. Where this is the case, more flexible central tubes should be considered such that the devices lie within the river rather than protrude from the water surface. This will decrease the visibility of the installation to the public, reduce the likelihood of flood debris leading to uprooting and also decrease the likelihood that wildlife will interfere. Where devices are stored beneath the water, small screws inserted into the ends of the multilevel tubes prevent clogging and sedimentation of the narrow diameter sampling tubes. When measuring water levels in the central monitoring well, the tube will need to lifted and the water level allowed to stabilise before measurements are obtained.

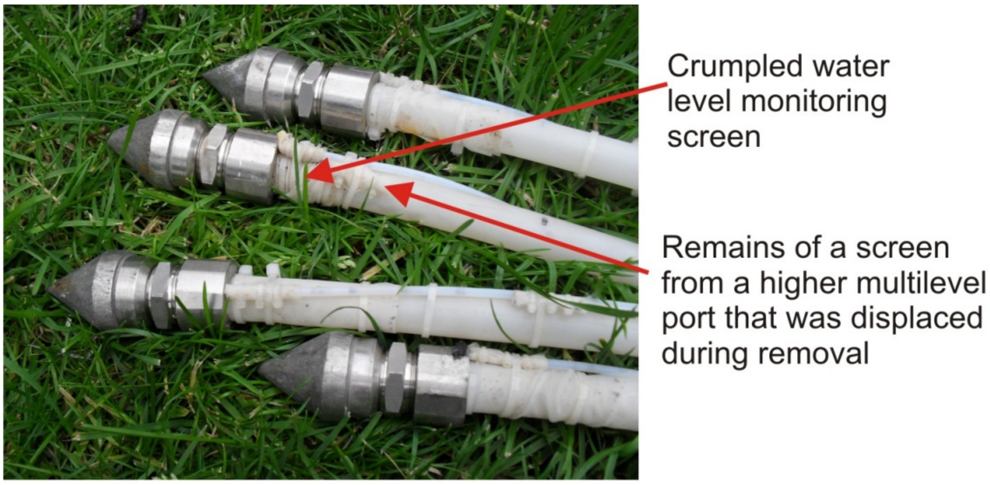

Figure 8 Condition of samplers following removal

2.6 FIELD TRIAL

The hyporheic zone multilevel samplers described in this report were used in the Rookhope Burn, Stanhope Moor, Northumberland to sample hyporheic porewaters. The insertion procedure worked well in fine-grained sediment, however where cobbles were present beneath the surface, penetration was more difficult. As discussed above, deformation of the drive tube should be reduced by using a sliding hammer instead of a sledge hammer. It is also recommended that sampler positions are tested using a hand auger for the presence of cobbles beneath the river bed.

Wellhead parameter and sample analysis results (not shown) suggest that porewater obtained from the bottom multilevel port was significantly different from that obtained from the upper three ports suggesting that short circuiting of water between the surface water and hyporheic zone was minimal at depths of ~300-400 mm below the river bed.

3 Hyporheic Zone DGT disc sampler

3.1 OVERVIEW

A hyporheic zone DGT disc sampler was developed for monitoring porewater within the river bed with regards to both piezometric level and quality. The samplers were designed to meet the following specification requirements:

- Disc-DGT deployment within the hyporheic zone porewater at a single depth within the hyporheic zone
- Measurement of the piezometric surface within the hyporheic zone
- Hand-based sampler installation that minimises the disturbance to hyporheic zone sediments and reduces the chances of short circuiting between the surface water and the hyporheic zone porewater
- Simple and rapid sampler installation and removal
- Rapid and inexpensive sampler construction

This sampler was designed to monitor the porewater at a single depth only, because the diameter of the DGT disc sampler meant that a multilevel system would be too bulky to install in the river bed. If multilevel sampling was required, it is envisaged that a number of hyporheic zone DGT disc samplers could be manufactured and then installed in a cluster to different depths.

3.2 DESIGN AND CONSTRUCTION

The hyporheic zone DGT disc sampler comprises a 45.5 mm ID, 60 mm OD ABS (acrylonite butadiene styrene) plastic tube of 1180 mm length. A PVC drive-point cone of 51 mm length fitted to the end of the tube assists easy installation into river bed sediments. A PVC plastic cap prevents contamination of the water internally from outside debris and provides a surface on which the tube can be hammered into position. To allow hyporheic zone water to enter the sampler, two opposite 6 mm holes were drilled into the tube at a distance of 95 mm above the drive cone point.

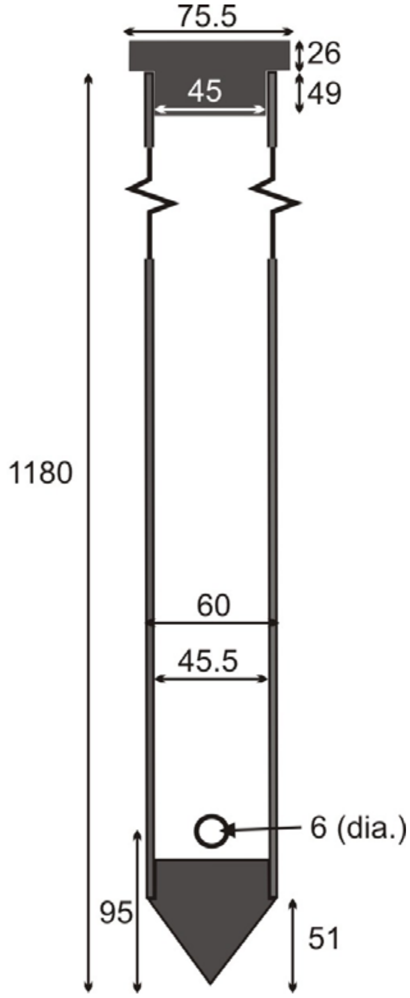

Figure 9 Schematic diagram of DGT disc sampler. Not to scale. Dimensions in mm

3.3 INSTALLATION

Installation of the hyporheic zone DGT disc sampler into the riverbed is dependent upon the resistance of the riverbed. River beds that are lined with cobbles offer more resistance than those that are sediment lined. Installation of the sampler into rock (pebbles/cobbles) is likely to cause damage and hence, the resistance of the river bed was tested using hand augers to find a suitable location for installation.

To install the sampler into the hyporheic zone the device was held vertically with the point facing downwards and the cap in place on the top opening (Figure 10). Blows of the sledge hammer onto the cap drove the device into the river bed. The distance between the river bed and the top of the device was measured to determine the penetration distance into the river.

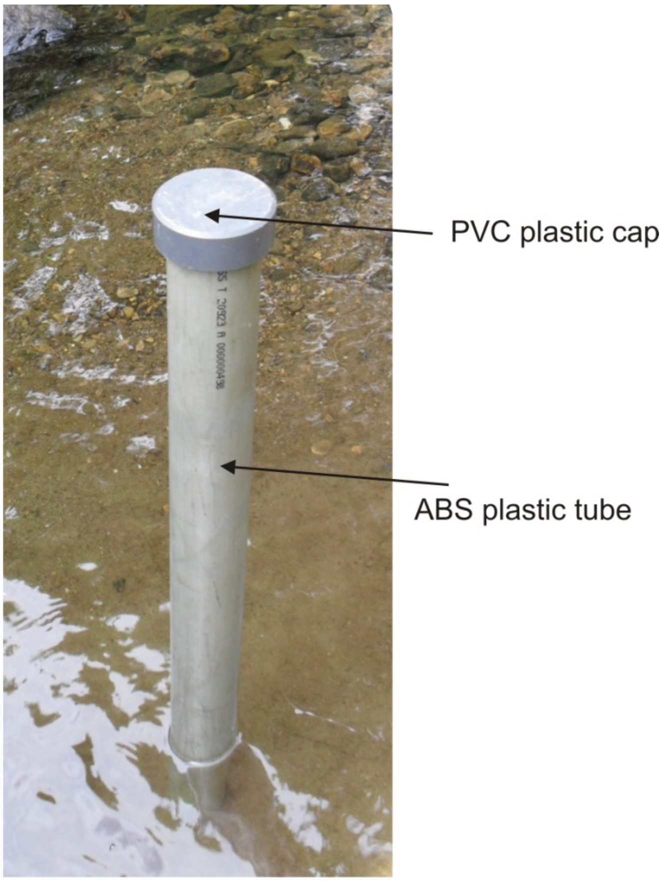

Figure 10 Hyporheic zone disc sampler installed in Rookhope Burn, Stanhope Moor.

3.4 MONITORING

A DGT disc sampler and a weight were attached to a piece of fishing line and lowered to the bottom of the hollow sampler. The line was secured at the top. The DGT discs were left in the device for around 24 hours. At the time of collection, the water level relative to the river level was measured and then the DGT sampler was removed.

3.5 REMOVAL

The hyporheic zone DGT disc sampler was removed from the river by applying gentle upward pressure on the plastic tube.

3.6 FIELD TRIAL

The hyporheic zone DGT disc sampler described in this report was used in the Rookhope Burn, Stanhope Moor, Northumberland to sample hyporheic porewaters via a DGT membrane. The insertion procedure worked well in finer-grained sediment, although could not easily be installed where cobbles were present. The cap was undamaged by sledge hammer blows, although it has been suggested that in colder weather, the cap may split as a result of such force.

4 Hyporheic Zone DGT strip sampler

4.1 OVERVIEW

A methodology to deploy DGT strip samplers into the hyporheic zone was developed for monitoring the porewater composition profile from the river bed to ~200 mm into the hyporheic zone. The methodology was designed to meet the following specification requirements:

- Vertically-orientated, strip-DGT deployment within the hyporheic zone
- Hand-based installation that minimises the damage to the strip-DGT device and minimises disturbance to hyporheic zone sediments to reduce the chance of short circuiting between the surface water and the hyporheic zone porewater
- Simple and rapid installation and removal

4.2 DESIGN AND CONSTRUCTION

The DGT strip sampler was inserted into the hyporheic zone using two devices. The first was a ~500 mm long, ~80 mm wide, ~10 mm thick aluminium plate that when hammered into the hyporheic zone using a sledge hammer, producing a slot within which the strip sampler could be installed. The second device, the DGT protector shield, was designed to protect the membrane window during installation and comprised a ~280 mm long, ~70 mm wide, ~10 mm thick PVC plastic plate that contained an indented inset, in which the DGT strip sampler could be positioned (Figure 11). The concept was that the DGT could be placed within the indent with the membrane window downwards facing towards the plastic, such that the DGT could be installed without damage to the membrane.

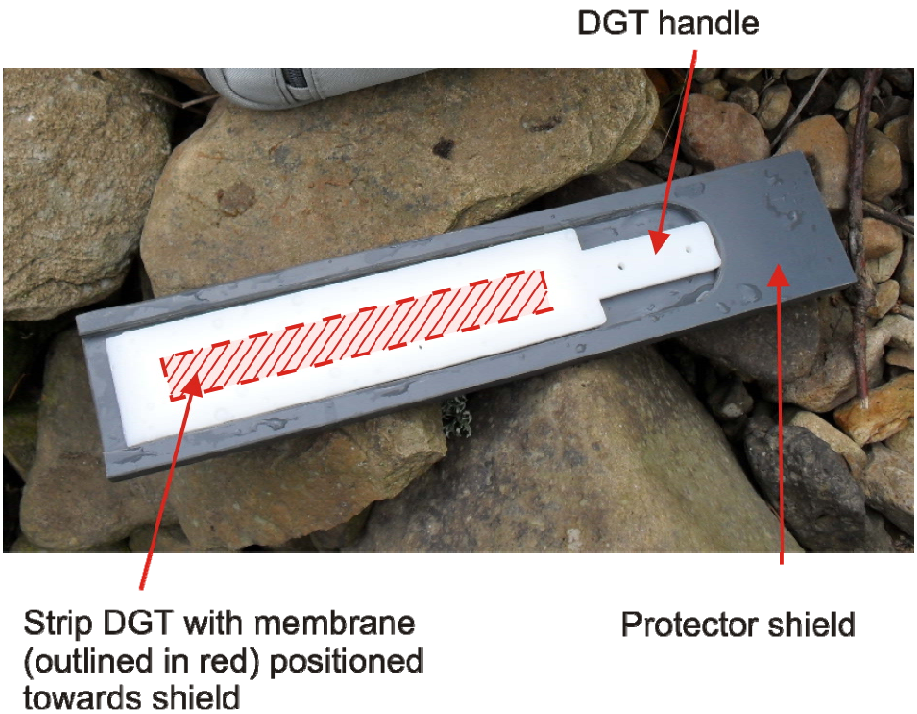

Figure 11 Strip DGT in protector shield

4.3 INSTALLATION

The aluminium plate was hammered into the hyporheic zone to the correct depth. As the plate was removed, the DGT strip sampler protected by the DGT protector shield was immediately and simultaneously inserted. Once inserted to the correct depth, the protector shield was carefully removed leaving the DGT strip sampler within the hyporheic zone (Figure 13). A piece of nylon line was attached to the strip sampler and secured outside of the river.

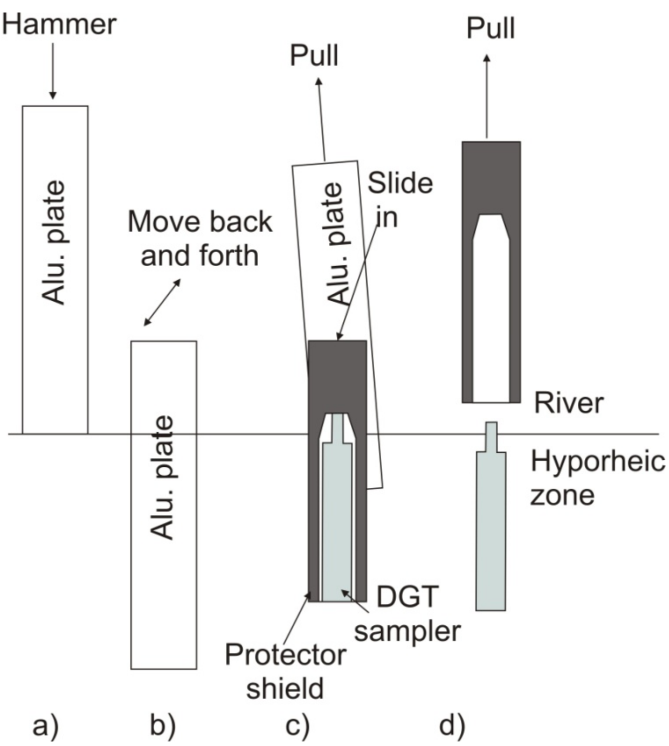

Figure 12 Schematic showing installation of strip DGT using an aluminium plate and DGT protector shield.

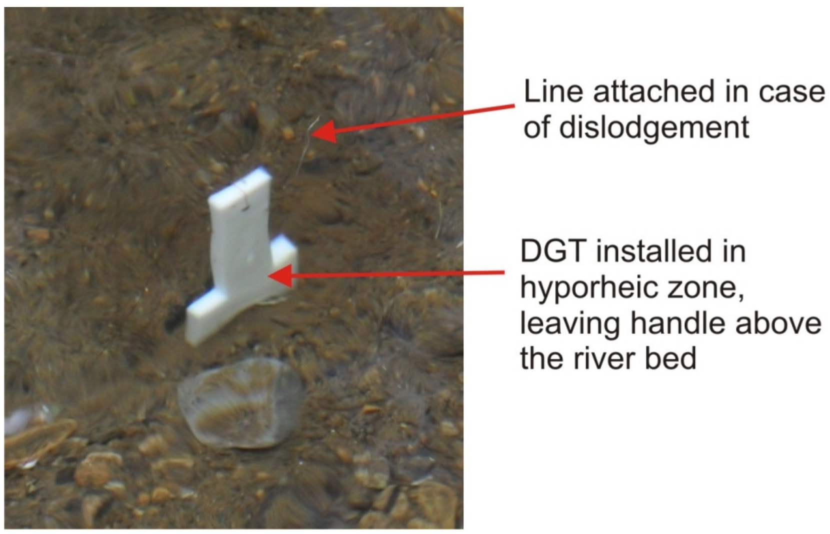

Figure 13 Strip DGT installed within the hyporheic zone

4.4 MONITORING

The DGT strip sampler was left in place for around 24 hours and then carefully removed. During removal, the protector shield was not used.

4.5 FIELD TRIAL

The hyporheic zone DGT strip sampler installation apparatus described in this report was used in the Rookhope Burn, Stanhope Moor, Northumberland to sample hyporheic porewaters. The insertion procedure worked well in the chosen finer-grained sediment, although installation would have been more difficult where cobbles were present. The aluminium plate was slightly bent following blows with the sledge hammer, hence better consideration of river bed sediments or use of a stronger metal place is recommended. Insertion of the DGT strip sampler using the protector shield was largely successful and the DGT membrane remained undamaged during both insertion (when protected) and removal (when unprotected).

5 Conclusions

The three methods discussed were successfully implemented in the Rookhope Burn, Stanhope Moor. This river provides a challenging environment for the installation of in-situ hyporheic zone apparatus, however installation was relative straightforward and the sampling specification was met. It is anticipated that these methodologies would work elsewhere and could be used to sample for a wide range of species.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

ELLIS, P.A. 2003. The impact of urban groundwater upon surface water quality. PhD thesis, University of Birmingham

RIVETT, M.O., Ellis, P.A., Greswell, R.B., Ward, R.S., Roche, R.S., Cleverly, M.G., Walker, C., Conran, D., Fitzgerald, P.J., Willcox, T. and Dowle, J. 2008. Cost-effective mini drive-point piezometers and multilevel samplers for monitoring the hyporheic zone. *Quarterly Journal of Engineering Geology and Hydrogeology* 41, pp 49-60

Appendix 1

Engineering scale drawing of the stainless steel nose cone, discussed in Section 2.2, drawn by H. Wallis, BGS Workshops