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Evaluation of urban groundwater monitoring requirements and increasing access to subsurface data

STSM Report to COST MC Chair

Management and access to subsurface data – lessons learnt from BSU Hamburg as a case study of best practice

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British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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1. STSM rationale and purpose

Rationale

BGS and BSU Hamburg proposed this STSM based on the ongoing work to rationalise groundwater monitoring data in Hamburg (Germany) and Glasgow (UK). Significant differences exist in the level of urban groundwater monitoring currently conducted in the two cities, and in the amount of groundwater data already available. Hamburg has been dependent on groundwater for public water supply for nearly 100 years, and extensive groundwater datasets stretching back over more than 50 years exist from hundreds of boreholes within the city. In Glasgow, where there has been little use of groundwater, very few groundwater datasets exist, and in the absence of dedicated monitoring networks groundwater data are sourced from disparate regeneration projects and local ground investigations.

This disparity is groundwater monitoring and data availability was highlighted across the COST Action cities, within the NAG-CITY workshop discussions in Odense (January 2013). In cities where there has been a dependence on groundwater for public water supply, or for industry, there are typically extensive groundwater datasets, and excellent monitoring infrastructure – such as in Hamburg. In contrast, in cities where there has been little dependence on the groundwater resource, there are few groundwater data records and a lack of monitoring infrastructure. Issues of urban groundwater flooding, impacts of sustainable urban drainage schemes, alongside the management requirements of the WFD, are now making it essential there is some investment in groundwater monitoring in these cities.

The aim and purpose of this STSM was to look at Hamburg as a best practice example of subsurface data management, and examine how the data are used to support groundwater management. A secondary aim of the STSM was to make a primarily assessment of how applicable the practices in Hamburg are to other COST cities such as Glasgow – where there is little groundwater data, and where there is lack of formal data management of subsurface data between the public and private sectors, making access and re-use of groundwater data for managing the resource very difficult.

Current work in the STSM institutions:

BSU Hamburg, in collaboration with *Hamburg Wasser*, has in the last 5 years undertaken significant work to rationalise groundwater monitoring within Hamburg, to: reduce the number of monitoring points in the city; standardise the monitoring network and data captured; and, to ensure the network provides an appropriate density and frequency of monitoring data to address the key issues.

This rationalisation of urban groundwater monitoring provides a 'Benchmark' example to the COST Action, as to:

1) How other cities can target urban groundwater monitoring, and identify key monitoring data requirements (see STSM 14884 report); and
2) How subsurface data should be managed to support decision making within cities by both the public and private sectors (discussed within this STSM report).

The rationalisation of the groundwater monitoring network undertaken by BSU Hamburg was possible only due to the very effective management of available subsurface data in the city by the BSU Geological Survey and Water Management departments. Having both knowledge of, and ready access to, borehole construction information of all the monitoring points within the city, and the existing time series groundwater monitoring data for these boreholes, was fundamental to being able to characterise the variability of the groundwater resources within the city, and ascertain what spatial and temporal frequency of monitoring was required to manage the groundwater resource effectively.

The applicant of the STSM [*Helen Bonsor*] in *BGS* is currently developing a pilot study within the city of Glasgow, to assess how private sector subsurface data can better captured and used within the city by the public and private sectors to support decision making, urban redevelopment and environmental management. Part of this is particularly looking at how a city wide urban groundwater monitoring network could be developed from existing groundwater monitoring infrastructure and data at individual regeneration and site investigation project. Most of the subsurface data within the city, is generated from private sector site investigations, remediation and regeneration projects, and very little is reported systemically to Glasgow City Council (GCC) or BGS in the absence of any legislative drivers to do so.

Currently in Glasgow there is:

- no legal requirement to submit shallow (<30 m deep) borehole data and information to the BGS, and as a result no centralised database of the available borehole data collected by the private sector work in the city
- No dedicated urban monitoring network for groundwater in the city. In the absence of this infrastructure data are sourced from disparate regeneration projects and local ground investigations
- There has been no historical driver to monitor the urban groundwater resource – it is not used for public water supply or industry. Future requirements of the Water Framework Directive (WFD), together with key issues of urban groundwater flooding and installation of sustainable urban drainage schemes, are only now, making it a priority.

As a result the majority of subsurface data produced is hard to access and rarely re-used by either the private or public sector to inform future decisions. The work being led by GCC and BGS in Glasgow, is aiming to emplace a systematic reporting of private sector data to GCC and BGS; develop a centralised repository of subsurface data generated within the city; and foster a virtuous cycle of data and knowledge exchange between the public and private sector organisations within the city.

Purpose

The purpose of the STSM was to facilitate knowledge exchange between specialists in *BSU Hamburg* and *BGS* so that the subsurface data management practices developed by BSU could be learned and understood as a best practice example within the COST Action. Of particular interest was to gain an understanding of how subsurface data from the private sector is received and managed by BSU Hamburg – this being the primary source of subsurface data and information within some COST Action cities such as Glasgow where there is little official (public sector) borehole data, or public sector monitoring infrastructure. A second key interest was to gain an understanding of how existing groundwater monitoring data within Hamburg had been used by BSU Hamburg to rationalise the urban groundwater monitoring network.

Standardisation and rationalisation of existing subsurface data, and groundwater monitoring are required in nearly all COST cities to meet key current urban redevelopment and groundwater management demands. The lessons learnt from the STSM would, therefore, of benefit to all COST-participants, and not just BGS and BSU Hamburg.

The main aims and purpose of the STSM between the *BGS, BSU Hamburg*, and *Hamburg Wasser* were to:

- Facilitate knowledge exchange between specialists in these organisations
- Using Hamburg as a benchmark case study, identify best practice for reporting, storing, and accessing subsurface data (particularly groundwater monitoring) in a city, so that the data can be used effectively to support decision making, and understand and manage key issues.

  Of key interest were processes of:
  i. Data collection and retrieval
  ii. Data management systems within BSU Hamburg for subsurface and groundwater data
  iii. Use of technology and web-delivery to access the subsurface data and geo-outputs held by BSU Hamburg – both internally in BSU and to external third parties
- Evaluate how a dynamic update of subsurface data and knowledge (with a focus on urban groundwater monitoring data) can be achieved between BSU and data providers, to improve the use and re-use of subsurface data.
- Examine inter-organisational relationships between BSU Hamburg and private sector organisations within the city of Hamburg, and how this facilitates greater impact of data use and subsurface knowledge within the city.

2. Work carried out within the STSM

The STSM involved a 5 day visit of the STSM applicant (Helen Bonsor [BGS]), and Stephanie Bricker (BGS) to BSU Hamburg from 21 to 25 October 2013. Meetings over the week between BGS, BSU Hamburg and Hamburg Wasser, were centred on discussion of methods of subsurface data management in BSU Hamburg, and re-use of the subsurface data by both BSU Hamburg and Hamburg Wasser for groundwater management. The meetings included two meetings within Hamburg Wasser – the public sector company managing the public groundwater supply across Hamburg. This provided an invaluable insight into how: 1) BSU Hamburg data are used by Hamburg Wasser to protect and maintain the public groundwater-supply; and 2) how the collaborative partnership between the two organisations has led to a virtuous cycle of data and knowledge exchange.

The main topics of meetings and discussion held in the week were:

- Collation and validation of drilling data
- Collation and management of official (BSU) and private sector groundwater data
- The Borehole and Groundwater data portals
- Re-use of subsurface and groundwater data
- Collaboration, and knowledge and data exchange between public and private sector organisations

Meeting were led by a series of different specialists within BSU Hamburg, and Hamburg Wasser:

- **Lothar Moosmann, Ingolf Stüven, Dr Renate Taugs (BSU Geological Survey)** – Collation and validation of subsurface data
- **Nikolaus Classen (BSU Water Management unit)** – Collation and management of groundwater data
- **Dr. Jorg Grossman, Dr. Frank Skowronek (Hamburg Wasser), Paul Meyer (Consulaqua), Lothar Moosmann (BSU geological survey)** – Re-use of subsurface and groundwater data
- **Paul Meyer (Consulaqua), Dr. Frank Skowronek (Hamburg Wasser), Lothar Moosmann** – Collaboration and knowledge exchange between BSU and public and private sector organisations in Hamburg.

3. Lessons learnt from BSU Hamburg as a case study of best practice to subsurface data management

3.1 Collation and validation of official (BSU) and private sector subsurface data within BSU – 'Data Lines'

Each federal state within Germany has a common 'Data Line' of: data capture, data reporting and storage, and data classification (e.g. classification of geological units) according to the EU INSPIRE Directive. There has been much work across the federal states in Germany in the last few years (e.g. the E-Earth project) to achieve standardised classifications of subsurface data, so that all borehole data in Germany is standardised to a unified dictionary of geology and borehole coding.

The BSU Hamburg Data Line for borehole data is discussed below. This Data Line has already been adopted as a best practice example by the city of St Petersburg (the partner city of Hamburg), to improve standardisation of urban subsurface data and increase the accessibility and re-use of the data.

BSU Hamburg Borehole Data Line

Data collation:
BSU Hamburg receives borehole data from official (BSU-contracted) boreholes, private boreholes (e.g. ground source heat boreholes, private water supply boreholes) and site investigation work associated with urban regeneration and development. It is a legal requirement that borehole data is submitted to BSU Hamburg for any new borehole drilled, and that standardised lithological and borehole coding is used by contractors and drillers.

For official boreholes the minimum data required to be submitted are:

i. Paper or PDF borehole log and construction information – using a standard template available from BSU website. This is a national standardised borehole log template.

   The minimum information required in the log are: borehole location, address, date of drilling, borehole ID by driller, borehole location (x,y) and depth (z), and lithological descriptions.
ii. Plan of location of BH within the site of interest
iii. Lithology samples
iv. Digital Access Database data sheet, containing required standardised borehole construction information, standardised lithological descriptions (set descriptions are enforced by the Access database) and standardised borehole coding. The Access database sheet, and standardised codings are available from BSU Hamburg website.

For private boreholes the minimum data required to be submitted are:

i. Paper or PDF borehole log and construction information – using a standard national template. Borehole location, address, date of drilling, borehole ID by driller, borehole location (x,y) and depth (z), and lithological descriptions must be reported.
ii. Plan of location of BH within the site of interest

Generally all borehole information is received by BSU through the post; very little is emailed due to the stringent BSU firewalls. Work is ongoing to move towards a web portal delivery system.

If required data are not submitted, BSU request the missing data from the data depositor. Required data are generally always deposited from official boreholes as otherwise the consultancies/contractors are not paid by BSU. However, required data is often not reported from private boreholes, and it takes typically 4-5 telephone calls from BSU to acquire this information. The high cost associated with retrieving missing borehole data is deemed to be cost-effective in the long-term by BSU to have accurate and usable borehole data. BSU also invests time to actively visit consultancies to encourage use of standardised information forms, and submission of all required data.

Data validation:
A BSU 'Data line index number' is assigned to borehole data once it is deposited to the BSU Geological Survey. The data submitted is then validated. Key data required for the borehole data to be useable are checked within the validation.

For all boreholes:

- The grid reference reported on the borehole log is cross-checked to the grid reference on the site plan

For official boreholes:

- The lithological descriptions provided on the paper/PDF borehole log are checked to be consistent to the descriptions given in the digital Access Database sheet.
- The lithological descriptions are checked to be accurate to the lithology borehole samples submitted to BSU.

Inconsistencies in the borehole data are manually corrected by BSU; 1 BSU staff member being dedicated to this full time, along with chasing missing key information. The high cost associated with the validation of borehole data to BSU is deemed to be cost-effective in the long-term to have accurate and standardised borehole data.

The lack of requirement to submit lithological borehole samples from private boreholes means the borehole log descriptions cannot be validated by BSU. As a result, data from private boreholes are flagged in the BSU Oracle Borehole Database as "information boreholes" only.

Data storage: completion of the Borehole Data Line:
Once validated, borehole data are assigned a BSU Hamburg borehole ID number, and the data are stored within the BSU Geological Survey Oracle borehole database. Private and official borehole records are differentiated within the database by flags – "P" for private, or "S" for official. The Borehole Data Line is then completed, and the new data within the Oracle database becomes instantly available within other live-linked data portals internally within the BSU Geological Survey, and externally via the BSU website – see section 3.2 below.

Currently approximately 60% of the borehole data received by the BSU Geological Survey is from official borehole data, with the remaining 40% being from private boreholes. This is changing to become a more equal proportion of public to private borehole data, with the increase in private boreholes being drilled in the city for geothermal energy.

The level of validation performed by BSU Hamburg within the Data Line is unique – validation of borehole log lithological descriptions to borehole samples is only possible in BSU Hamburg due to the relatively small land area under the remit of BSU. In larger federal states, such as Bavaria which covers a large area across southern Germany, this level of validation is not practical.

BSU Hamburg Groundwater Data Line

Groundwater monitoring data is received, validated and stored following a discrete data line to borehole data, and the groundwater data is stored within a separate BSU Oracle database. The groundwater data line and database is managed by the Water Management unit within BSU Hamburg, rather than the Geological Survey – see Figure 1. However, the two data lines are connected, so that the borehole construction information and lithological descriptions for a groundwater borehole are stored within the Borehole Data Line, whilst the groundwater data collected from this borehole are stored within the Groundwater Data Line. If borehole information is updated in either of the databases, the other database is automatically updated; the databases are 'live-linked'.

The Geological Survey and Water Management teams within BSU work closely to ensure the datasets are consistent, and that the datasets are used to develop a consistent conceptualisation of the geological and hydrogeological systems within BSU, as well as coherent spatial datasets and 3D-models. The strength of the collaborative working between the two units is highlighted by the 'hydrostratigraphy' developed by the two departments for the city of Hamburg in the last 10 years, based on an agreed conceptualisation of the geology between the two departments – refer to STSM report 14884). The hydrostratigraphy underpins new derived data products developed by both teams.

BSU Water Management provide a standardised digital reporting form (Excel Spreadsheet or Access Database sheets) for groundwater data to be reported to BSU to enable accurate and automatic data transfer into BSU GW-monitoring Oracle database. Within these standardised forms, a minimum level of BH information, and units of measurements are specified.

Despite implementation of standard data reporting forms, BSU still experience problems of incomplete borehole information, incorrect units, and inconsistency in laboratory nomenclature. 2-3 BSU staff within the Water Management team work almost full-time in sorting out the databank and resolving inconsistencies with data providers. There is, therefore, a large staff and cost investment by BSU to receive and use private groundwater monitoring data within the Official Oracle database. No official cost-benefit analysis has been completed by BSU, but the investment by BSU to use external data to supplement the official groundwater monitoring data is seen as cost-effective; private sector data reduces gaps in spatial coverage; and it is often focused to key contamination issues in the city, which BSU wouldn't be able to afford to monitor in sufficient detail to understand the pollutants and remediate the pollution. External private data also provides an important cross-check on groundwater monitoring data from the official monitoring network.

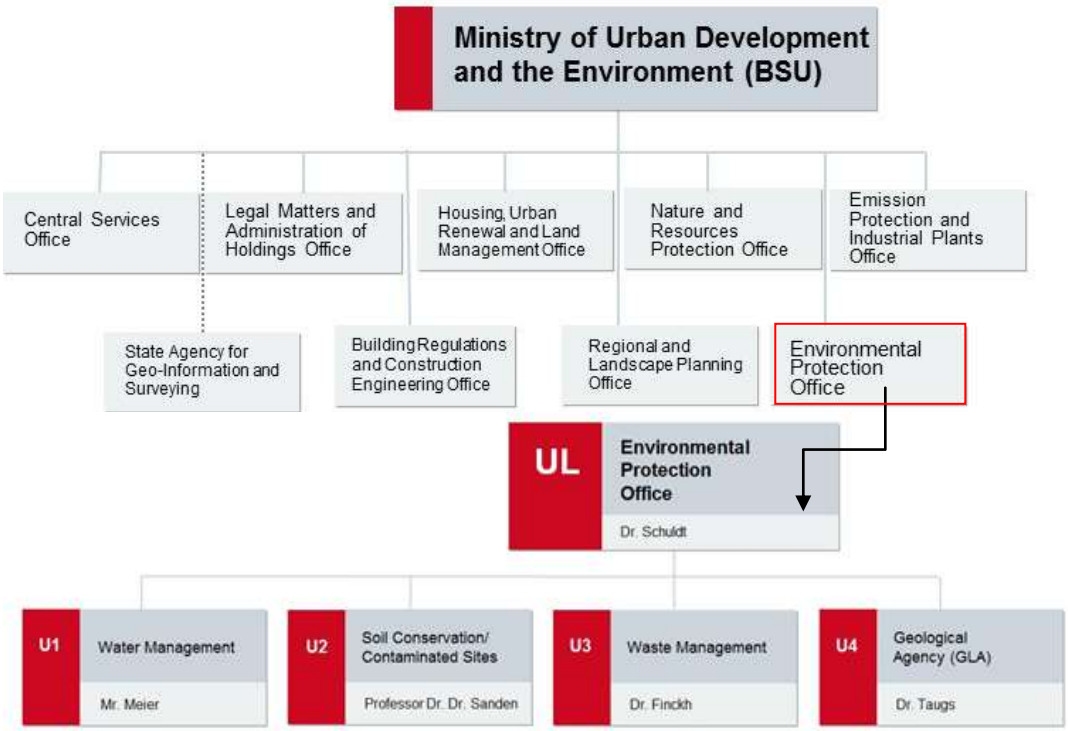

Figure 1 – Schematic representation of the internal organisation of departments within the Ministry of Urban Development and the environment in BSU Hamburg.

Key points:

- **A large cost investment is made by BSU Hamburg in ensuring rigorous validation of all borehole and groundwater data submitted the geological survey and water management teams – this is deemed to be cost effective in the long-term to have a large amount of usable, standardised borehole data available to BSU Hamburg for policy and decision making.**
- **All data received by BSU are validated to ensure data stored by BSU is of a minimum level of accuracy and the data are re-useable.**
- **BSU Hamburg issue standardised templates for borehole and groundwater data to be reported to BSU**

3.2 BSU Hamburg Drilling data portal and GEROVIEW Groundwater data portal – re-accessing data

Borehole and groundwater data received by BSU Hamburg are stored within separate, but linked, Oracle databases. These databases are available, at different levels access, to all internal departments within BSU Hamburg, and to external users, via Data Portals.

Internal access to Borehole and Groundwater data within BSU Hamburg

All borehole and groundwater data contained within the BSU Oracle databases are accessible via a Borehole Data Portal and the groundwater GEROVIEW data portal to internal BSU departments. These portals were developed in 2004 using software which combines contents information management, with maps and a spatial viewing platform. The location of boreholes are pinpointed in the spatial viewing platform, and an identify tool is used to select the data held for that borehole. Borehole data can be searched for by: map sheet area; street address; or borehole co-ordinates. Within the Borehole Data Portal, the identify tool generates a 'data window' for each borehole selected, displaying the written borehole log, a graphical borehole log (with extended lithological descriptions to those given in the written log), and the borehole construction and location information, and purpose of borehole construction. *This information shown within the 'data window' is generated on the fly from the Oracle Borehole database, so if the Oracle Borehole database is updated, the information shown in the Data Portal will instantly update as well*.

The GEROVIEW groundwater data portal displays information held for groundwater monitoring points similarly. Boreholes are flagged in the spatial viewing platform, and indicate whether the point contains groundwater chemistry data, groundwater-level data, or both, and whether the borehole is an official monitoring point or private point. Selecting a borehole point with the 'identify tool' brings up all the information for that point, including plots of the time series groundwater-level data for that borehole. These plots and other information displayed in the portal, are again live-linked to the Oracle database, so that the information displayed within the data portal automatically updates if the Oracle database is amended.

Both private and official borehole data are displayed to BSU users within the data portals, however, a password log-in is required by BSU users to access all the information contained within a private data record.

Write access to the Borehole and Groundwater databases is retained by the Geological Survey, and Water Management units, respectively. Both units can view the indexes of the two databases via the data portals, but the units can only view the complete information contained within the database, for the database to which they have write access. This is the result of a legislative issue, and is circumvented effectively by cross-department requests for data. *However, the fact that all BSU departments can see the index of the complete datasets available in either of the Oracle databases is highly effective in ensuring significant re-use of subsurface data across the departments to support decision making.*

The data contained within the Borehole and Groundwater Oracle databases is also accessible through GIS layers. Different GIS layers are used to display different databases. These GIS layers are not live-linked the Oracles databases, but are updated every 2-3 years with new borehole information.

External access to Borehole and Groundwater data by third parties

Limited access to the Borehole data portal is available from the BSU Hamburg external website (www.hamburg.de/bohrdaten-geologie) – Figure 2.

The spatial viewing platform of the external data portal is identical to that used internally within BSU, with the exception that only official borehole points, monitoring points, and data are shown. Private boreholes are not visible within the external portals, and the data is not available on request. Some official groundwater-monitoring wells and groundwater-abstraction wells (e.g. public water supply abstraction wells) are also not shown to mitigate sabotage. The external data portal remains 'live-linked' to the BSU Oracle databases, so that borehole information displayed on the external portals is generated on the fly from the databases, as it is to internal BSU users.

As well as displaying the information held within the Oracle databases, the external data portals also provide access to the digital scans of geological cross-sections across the city, as well as interpolated maps of geothermal potential at varying depths, and groundwater –level contour maps.

A limited version of the GEORVIEW Groundwater data portal will be made available to external third parties via the BSU external website in the future. Currently, under the EU Transparency Law all routine groundwater-monitoring data has to be made freely and publically available.

Figure 2 – External viewing platform of the BSU Borehole Data portal

Key points:

- **Data portals with spatial viewing platforms, make the data held within the Borehole and Groundwater Oracle databases highly accessible to internal departments of BSU. The portal provide a quick and immediate access to an index of all the available subsurface**

data within BSU databases. Detailed information and raw data from the Oracle databases for areas/points of interest are then available on cross-department request. This gives a high awareness of the potential data available to support decision making to different departments of BSU, and the data portals are a very powerful tool in increasing the accessibility and re-use of subsurface datasets.

- The external version of the Borehole and Groundwater data portals provides a high level of information to the public,which is also the latest version of the data available, and that which the BSU are also using.
- The BSU data portals highlight the worth of a centralised repository of subsurface data in the city, and how it can encourage data and knowledge exchange between private and public sectors.

3.3 Examples of how data are being used to support decision making, and understand and manage key issues within BSU Hamburg

The Geological Survey and Water Management teams within BSU work closely to both manage and develop the Borehole and Groundwater datasets, as consistent and validated datasets, and to develop combined spatial datasets and 3D-models from the datasets. These derived data products are focused to key environmental and redevelopment issues within the city, such as flooding and assessing the potential impacts of sustainable urban drainage schemes. The re-use and impact of the subsurface data is therefore very high. Such effective re-use of the data is only possible due the way in which the data is collated, validated and stored by BSU Hamburg and the strength of working relationship between the Geological Survey and Water Management units to address key issues.

Some examples of how the Borehole and Groundwater databases are used to support decision making within BSU Hamburg are highlighted below.

i. *Development of hydrostratigraphy:*
The Geological Survey and Water Management teams in BSU Hamburg have worked together in the last 10 years to develop a consistent 'hydrostratigraphy' based on the lithological information and hydrogeological data available from the BSU databases and 3D geological model. Units of lithology are classified into a regional hydrostratigraphy coding system developed for Northern Germany; the lithology units being either amalgamated or subdivided based on their hydrogeological properties.

The hydrostratigraphy has formed the basis of groundwater management units defined in the city, and it has been a key tool in rationalising the city's groundwater monitoring network; a higher density of groundwater monitoring points being maintained in the hydrostratigraphy units of greatest hydrogeological variability.

ii. *Update of groundwater monitoring network:*
The groundwater monitoring network in Hamburg has been rationalised by BSU Hamburg in the last 10 years, reducing the number of monitoring points in the network from over 1100 boreholes, to 646 monitoring points. Gaps in the monitoring network are now filled iteratively as new boreholes are constructed and borehole information is reported to the Geological Survey of BSU. Key gaps in the monitoring network are known from the groundwater data portal, and the Geological Survey team report any new borehole information received from one of these areas to the Water Management team, to highlight the availability of a potential new monitoring point. This cross-department communication and collaboration is facilitated by the effective access to the borehole and groundwater datasets in BSU and it leads to an efficient and cost-effective development of the groundwater monitoring network.

iii. *BSU map of Potential Infiltration:*
This is a new map developed in the last year by BSU Water Management team, designed to assist BSU and regulators assess applications for new infiltration drainage schemes. Within Hamburg all new infiltration schemes require approval from BSU, due to the very shallow groundwater-levels within the city. The map is based on the soil material, and depth to water-table, with the legend indicating 'capable depth of infiltration'. The map highlights

that in areas where depth to groundwater is <2.5 metres below the ground surface, installation of infiltration schemes is difficult.

iv. *Groundwater thermal model:*
This model has been developed in the last year, and will play a key role in helping BSU assess applications for new ground source heat boreholes within the city – enabling site specific applications to be placed into regional context of the existing geothermal gradients in the subsurface. The model has been developed within GoCAD and is based on over 100 high confidence borehole data points of groundwater temperature data from the Borehole and Groundwater monitoring databases. The model shows clear spatial and vertical thermal gradients – significantly warmer groundwater temperatures found close to salt domes in the city, and cooler temperatures near to areas of groundwater recharge and inflow. The model can be imported directly into the groundwater flow model and 3D geological model of the city.

v. *3D Geological mode*l:
The Geological Survey department have developed a 3D geological model of the Tertiary geology underlying Hamburg, using GoCAD software. The model primarily uses the coded borehole records in the Oracle Borehole database to extrapolate 3D volumes of the geological units. The model can be imported directly into the BSU and Hamburg Wasser groundwater models. Future work is focused to extending the model to include the more complex, overlying Quaternary geology.

Key points:

- **The accessibility of the Borehole and Groundwater datasets via the Data Portals within BSU means there is a high re-use of the data to support decision making, and assist environmental regulation.**
- **Effective data management means there is high re-use of the subsurface data available, to improve understanding of the subsurface, and to develop derived data products which are targeted to address key urban redevelopment or environmental management issues in the city.**
- **The Borehole and Groundwater datasets have a high impact, as a result of effective data management, and the close collaborative working relationship between different interested departments in BSU.**
- **The accessibility of the subsurface datasets to all BSU departments, and the close working relationships between different BSU departments, means that the data are used consistently by different departments, and coherent and agreed conceptual models of the subsurface are used to support decision making.**

3.4. Inter-organisational relationships between BSU Hamburg and public and private sector organisations within Hamburg: achieving a virtuous cycle of data and knowledge exchange

The Geological Survey and Water Management departments in BSU invest significant time in developing good working relationships with other public sector and private sector organisations involved in either generating or using subsurface and environmental data in the city. Developing strong inter-organisational working relationships has taken many years, but it has been instrumental to:

- Developing comprehensive and standardised Borehole and Groundwater datasets for the city, which have enabled a strong understanding and coherent management of the subsurface by different organisations in the city. The Borehole and Groundwater databases would not be as large, or as useful datasets, to support decision making and improve the understanding of the subsurface in Hamburg, without the inclusion of data from other public and private sector sources.
- Environmental and urban redevelopment decisions are made from the same data and 3D models, across different organisations.
- Fostering a virtuous cycle of data and knowledge exchange between BSU and other public and private sector organisations in the city.

Inter-organisational relationships have been key to not only developing the high quality comprehensive subsurface datasets now available for Hamburg, but also to developing standardised 3D models, which can underpin environmental policy and management decisions by multiple organisations in the city. The key example of this is the collaboration between BSU Hamburg and Hamburg Wasser to develop a standardised regional groundwater flow model for the city and surrounding area.

The groundwater flow model was developed by Hamburg Wasser and its sister company Consulaqua. The main driver to develop the model was the need to define catchment protection areas for the public water-supply abstraction well fields within the deep Tertiary aquifer. The model was also required to improve understanding of the deeper groundwater resource, to support policy and management decisions within BSU. Previously existing regional groundwater models (of which there were 3) had significant differences in designated geological units, aquifer properties and boundary conditions, and it was not possible to use the models together to define catchment protection areas across the region.

The close working relationship and collaboration between Hamburg Wasser and BSU enabled a unified groundwater model to be developed, and now enables a regular update of the groundwater model from new borehole and groundwater data input to the BSU Oracle databases. A virtuous circle of data and knowledge exchange is being achieved the two organisations, which is supporting policy and decision making.

Examples of this virtuous cycle of data and knowledge exchange between BSU and Hamburg Wasser are:

- The groundwater flow model developed by Hamburg Wasser is based directly on the hydro-stratigraphy and 3D geological model developed by BSU Hamburg;
- The geological and hydrogeological interpretations within the model are jointly decided between BSU and Hamburg Wasser.

- The groundwater flow model is updated with new borehole and groundwater data input to the BSU Oracle databases every 1-2 years.
- Both BSU and Hamburg Wasser use the groundwater flow model to support decision making and management of the groundwater resource. Any discrepancies found by either user can, therefore, identified and investigated in collaboration. For example, if observed groundwater-level measurements from the BSU database are found to be significantly different to modelled data, the BSU Geological Survey department cross-checks the borehole information for these points with the data held in the BSU Oracle database. In some cases it has been found that the borehole co-ordinates within the model have been wrong, or depth information incorrect.

The key benefit of this collaborative approach to develop the groundwater model is shown in how the model is used. Hamburg Wasser use the model for its own purposes of monitoring abstraction, and management of catchment zones (Figure 3); whilst BSU use to the model to assess applications for new private abstraction boreholes in a regional context. Decisions by both organisations would normally be based on site-specific or point data, however, the collectively agreed groundwater model provides a standardised regional platform on which decisions can be based. There is the potential for the model to be formally recognised within BSU regulation and environmental management – i.e.new groundwater-abstraction licences would be based on them being validated within the GW model.

Figure 3 – Hamburg Wasser use the regional unified groundwater flow model for monitoring abstraction and establishing regional catchment protection zones around the public supply well-fields. The photograph here show the scale of one of the water abstraction points in one of the 16 well fields in Hamburg for drinking water supply.

Key points:

The Geological Survey and Water Management departments in BSU invest significant time in developing good working relationships with other public sector and private sector organisations

involved in generating or using subsurface and environmental data in the city. Developing strong inter-organisational working relationships has taken many years, but it has been instrumental to:

- **Developing comprehensive and standardised Borehole and Groundwater datasets for the city, which have enabled a strong understanding and coherent management of the subsurface by different organisations in the city.**
- **Environmental and urban redevelopment decisions are made from the same data and 3D models, across different organisations.**
- **Fostering a virtuous cycle of data and knowledge exchange between BSU and other public and private sector organisations in the city.**

4. Applicability of lessons learnt from BSU Hamburg – transfer of best practice

BSU Hamburg provides a benchmark example to COST cities as to how subsurface data should be managed to support decision making within cities by both the public and private sectors.

Key messages from this STSM are:

- The accessibility of the Borehole and Groundwater datasets via the Data Portals within BSU means there is a high re-use of the data to support decision making, and assist environmental regulation.
- The accessibility of the subsurface datasets to all BSU departments, and the close working relationships between different BSU departments, means that the data are used consistently by different departments, and coherent and agreed conceptual models of the subsurface are used to support decision making.
- The strong inter-organisational working relationships developed by BSU with public and private sector organisations has taken many years, but it is instrumental to:
    - Developing comprehensive and standardised Borehole and Groundwater datasets for the city, which have enabled a strong understanding and coherent management of the subsurface by different organisations in the city.
    - Environmental and urban redevelopment decisions are made from the same data and 3D models, across different organisations.
    - Fostering a virtuous cycle of data and knowledge exchange between BSU and other public and private sector organisations in the city.

Standardisation and rationalisation of existing subsurface data, and groundwater monitoring are required in nearly all COST cities to meet key current urban redevelopment and groundwater management demands. The lessons learnt from the STSM are, therefore, of benefit to all COST-participants, and not just BGS and BSU Hamburg.

The feasibility of transferring the subsurface data management practiced in Hamburg to other COST cities is in part dependent on the different legislative frameworks existing in COST cities, and the different remits of geological surveys and city partners.

Data management practices:
The BSU borehole and groundwater datasets are comprehensive of all public and private sector data, due to the legal requirement in Hamburg for all new borehole data to be submitted to the BSU Geological Survey. Developing comprehensive datasets will be more difficult within COST cities which lack a similar legislative framework.

The level of validation which BSU performs to achieve a quality assurance and standardisation of all subsurface data received is also only possible due to the relatively small land area which comes under the remit of BSU.

Putting these factors aside, implementing standardised templates for reporting subsurface data is something all geological surveys or city councils could request – be it on a voluntary basis or as a contractual requirement. The use of standardised templates for data reporting, and specifying a

minimum level of information for each new borehole, has proven to be an effective method of reducing the work needed to collate and manage a comprehensive database of borehole and groundwater data by BSU. Implementation of using standardised data reporting formats is currently being trialled in Glasgow (U.K.) as a contractual requirement of the city council, so that more subsurface data can be captured.

Accessibility and effective re-use of data:
The direct use of the sub-surface data to support decision making by the BSU, and the close working relationships between different departments, gives a strong cohesion as to how the subsurface data are used, and it facilitates the data to be used to high-impact. This is in part stems from the Geological Survey and Water Management teams being embedded within the Government Ministry. The geological survey and water management teams have a direct remit to the ministry to provide subsurface understanding to support city policy and regulation. Such close working relationships are more difficult within the geological surveys which are not directly embedded within government ministries, such as the BGS. However, cross-departmental projects which examine an urban area as a whole, can facilitate better re-use of subsurface data across different disciplines in geological surveys like the BGS. The Clyde Urban Super Project in Glasgow has been very effective at achieving more cohesive use of available subsurface in Glasgow by the BGS.

Developing effective data portals for viewing subsurface datasets is something all geological surveys should aspire to and is something which is directly transferable from Hamburg to other COST cities and geological surveys. The Borehole and Groundwater Data Portals are highly powerful tools both within and outside of BSU for increasing the accessibility and use of the subsurface datasets.

Inter-organisational relationships:
The strong inter-organisational working relationships developed by BSU with public and private sector organisations are instrumental to BSU being able to foster a virtuous cycle of data and knowledge exchange between BSU and other public and private sector organisations in the city. Whilst these inter-organisational relationship are, in part, assisted by the legal framework in Hamburg that requires all consultancies and contractors submit new borehole data to BSU, forcing some measure of collaboration and data exchange between different parties working in the subsurface in Hamburg, the strength and effectiveness of the inter-organisational relationships is largely due to the collaboration by individual key staff in the organisations working in the city. Developing similar inter-organisational relationships, and common use of standard subsurface datasets, is therefore something which all COST cities can aspire to.

The importance of the inter-organisational relationships within Hamburg to how subsurface data are re-used, gave re-assurance that the time being invested by BGS and Glasgow city council to set up a data and knowledge exchange network within Glasgow city (ASK – Accessing Subsurface Knowledge network) is fundamental to the subsurface datasets for the city being used to greatest effect.

5. Future collaboration and outputs

Continued knowledge exchange:
Continued discussions and knowledge exchange on subsurface data management and groundwater monitoring practices will almost certainly follow on from the STSM as work in these areas in both institutions progresses.

A reciprocal knowledge exchange visit is likely between BSU Hamburg and BGS to discuss different 3D geological modelling software available for modelling complex geological deposits – such as the Quaternary deposits in Hamburg. BGS has extensive experience of using the GSI3D modelling software to create 3D models of Quaternary systems and would be able to provide training and knowledge exchange to BSU on its application to the Quaternary geology in Hamburg. This is will be followed up by BSU and BGS in the next few months.

Engagement of wider group of COST participants:
It would be a natural extension to this STSM, to engage a wider group of COST participants to the discussions on subsurface data management, and increasing the re-use and impact of the data. This could be achieved through a possible follow-on COST workshop.

Outputs:
Hamburg provides a best practice example to the COST Action for subsurface data management in urban areas, and how subsurface data and knowledge can inform policy and environmental management – as show-cased by the rationalisation of the groundwater monitoring network by BSU in Hamburg. There is potential for a joint output between BSU and BGS to publish guidelines on how best practice might be applied to other urban areas within the COST Action cities – drawing on the work being done in Glasgow by BGS to apply similar data management procedures within a very different legislative framework, and background of subsurface data availability.

6. Summary

The STSM facilitated an invaluable, focused period of knowledge exchange between BSU and BGS, centred on key issues of subsurface data management, and the application of this data for groundwater management. The knowledge exchange initiated between the two institutions in the STSM is envisaged to be continued, and built upon, as work in both institutions in these work areas progresses.

BSU Hamburg provides a bench mark of subsurface data management to other COST cities, and to how data can used coherently between multiple public and private sector organisations in urban areas to inform policy and decision making in urban redevelopment and environmental management. The lessons learnt within this STSM are of benefit to all COST-participants, and it is hoped the work of the STSM can be built upon to engage a wider group of COST participants and cities into the discussions.

The STSM gave reassurance that work being led by BGS and GCC in Glasgow, to improve the accessibility and re-use of subsurface data in the city, and to develop coherent data and knowledge exchange between different organisations in the city, is following best practice. Visiting BSU Hamburg and Hamburg Wasser also gave a direct insight into the full potential of subsurface datasets to inform urban environmental management if the data are accessible; something to aspire to within the work in Glasgow.

The COST STSM programme provides an unparalleled opportunity to COST participants and cities, to learn from each other and to gain an insight into the different approaches being developed in cities to address common issues. It is only by developing this level of knowledge exchange that the COST group can really assess examples of best practice and examine the applicability of these to the range of COST cities.

7. STSM Host institution approval / sign-off

Report noted with approval.

Hamburg, 19th of November, 2013

Renate Taugs (BSU Hamburg)