A NATIONAL SUITABILITY DATASET FOR INFILTRATION–BASED SUSTAINABLE DRAINAGE SYSTEMS

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Abstract

The Floods and Water Management Act 2010, includes the provision for sustainable drainage systems (SuDS) which aim, in part, to reduce flooding and improve water quality. Infiltration-to-the-ground is a key SuDS component that can provide effective and practical opportunities for the attenuation of surface water, however systems must complement ground conditions to ensure effective drainage, stability of ground and protection against groundwater quality deterioration. This paper reports on the development of a national suitability GIS dataset that provides subsurface information that may be useful for the planning and design of effective infiltration-based SuDS, whilst also highlighting those circumstances where infiltration may cause unintended negative consequences including flooding or severe ground instability. The dataset focuses on four key themes: a) severe constraints that preclude infiltration-systems; b) subsurface drainage properties; c) vulnerability of groundwater from infiltration water and d) presence of geological hazards triggered by infiltration. The dataset is populated with a wealth of subsurface data, derived by the British Geological Survey (BGS), enabling rapid assessment of subsurface conditions.

Keywords
Sustainable drainage, infiltration, subsurface, soakaway, infiltration trench, infiltration basin

1. Introduction

Infiltration-based sustainable drainage systems (SuDS) use the water storage capacity of the subsurface to effectively attenuate surface water at source. Systems such as soakaways, permeable paving and infiltration trenches and basins facilitate the infiltration of water into the subsurface. However their effectiveness is dependent upon the suitability of the system design in conjunction with the properties of the subsurface. In particular, the subsurface suitability should be considered with regards to drainage, ground stability and contaminant attenuation, to ensure that systems will function effectively.

Sustainable drainage has become topical in recent years as a result of flooding caused by the inability of traditional pipe-drainage networks to transmit stormwater to watercourses in modern urban environments. Widespread flooding during summer 2007 prompted a review of storm water management in the UK and this identified that surface water was one of the primary causes of flooding [1]. The magnitude of the events was attributed to surface sealing (via pavements and buildings) and high intensity rainfall, both of which resulted in flows that overwhelmed the drainage network. Climate predictions suggest that such events are not isolated occurrences and that high intensity summer storms will become more commonplace [2]. The recommendations of the Pitt review [1] led to the enactment of the Floods and Water Management Act 2010 [3] which includes the provision for the implementation of SuDS. These aim to naturalise surface water flow rates at source; improve water quality, and increase the amenity and biodiversity of the drainage network. A number of SuDS techniques have been described [4], including rainwater re-use, storage with subsequent discharge to watercourses, and infiltration. The subject of this paper is infiltration-to-the-ground, a technique which is given priority over other drainage types in the current building regulations [5].

Infiltration-based SuDS are commonly considered applicable to only freely draining sites where focused recharge is possible through soakaways. However, they are also appropriate in less permeable deposits provided that: the design enables infiltration over a large surface area (e.g. permeable pavements), or sufficient water storage capacity is provided (e.g. infiltration basins). Examples of systems appropriate to a range of geological environments are shown in Figure 1.

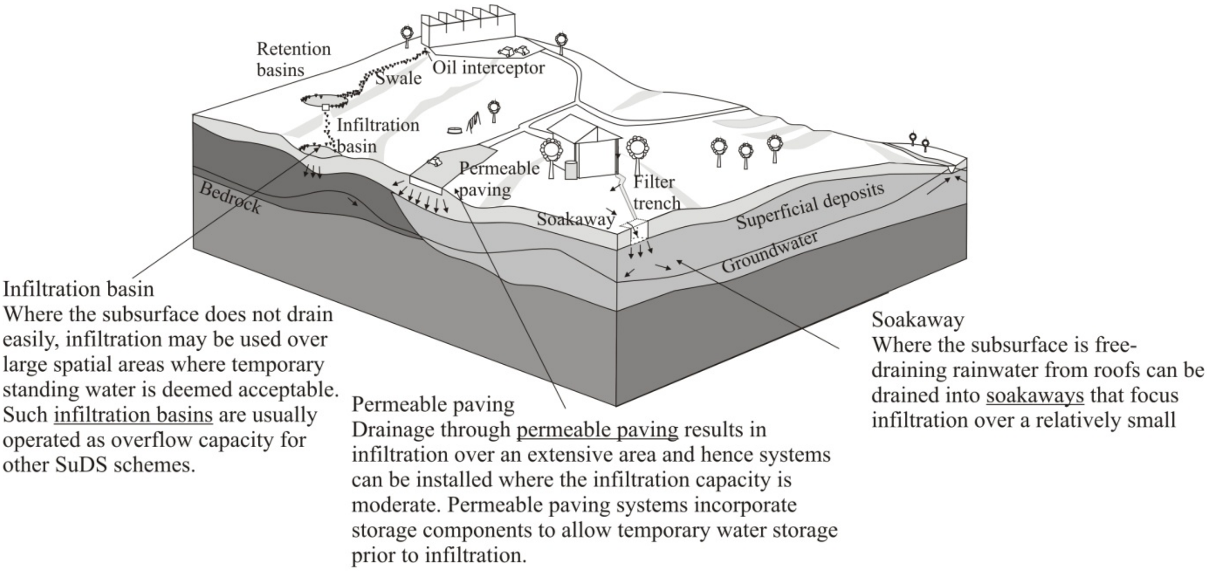

Figure 1. Examples of three infiltration systems that are suitable for installation in different geological conditions

When considering which type of infiltration system is most appropriate, a number of factors must be taken into account, including the potential for drainage, ground instability and impacts to groundwater quality (further details are shown in Table 1). In addition, it is important to note that there are a number of rare, but significant subsurface conditions that may be adversely affected by infiltration leading to unintended negative consequences including flooding or severe ground instability. For example, focused infiltration may impact both: rocks that are susceptible to dissolution, landslide and collapse, and groundwater levels that may rise and emerge at the surface.

Table 1. Subsurface factors to consider for the suitability of the ground for infiltration-based SuDS

Drainage	Permeability of soils, superficial deposits and bedrock (where applicable), unsaturated zone thickness, perched water tables, local receptors, potential for groundwater flooding
Ground instability	Soluble rocks, landslides, compressible deposits, running sands, collapsible ground, shrink-swell clays, mining hazards
Protection of groundwater quality	Quality of surface water, mobilisation of surface/subsurface pollutants, presence of artificial ground, Environment Agency source protection zones

This paper introduces a proposed methodology for a UK national dataset that will provide data necessary to enable preliminary decision-making on the suitability of the ground for the installation of infiltration-based SuDS. The dataset is intended for use by planners, local authorities, developers, consultants and SuDS Approval Bodies to facilitate the selection of appropriate systems and to communicate the opportunities for infiltration, as well as to provide a framework that will guide decision-making.

2. Methodology

2.1 Data sources

The proposed methodology draws on fifteen national datasets typically at 1: 50 000 scale. All datasets are held or are being developed by the British Geological Survey. The details of the datasets are listed in Figure 2.

Table 2 Datasets incorporated within the proposed methodology for assessing ground suitability for infiltration SuDS. Datasets have a scale of 1:50 000 and have full UK coverage

Dataset (type)	Details
Superficial permeability (vector)	Provides a qualitative classification of estimated rates of vertical movement of water from the ground surface through unsaturated superficial deposits [6]
Bedrock permeability (vector)	Provides a qualitative classification of estimated rates of vertical movement of water from the ground surface through unsaturated bedrock [6]
Superficial thickness (raster)	Demonstrates the variation in thickness of superficial deposits across Great Britain [7]
Depth to water table (raster)	SuDS-specific dataset to estimate depth to water table is under development
Groundwater flooding susceptibility (raster)	Identifies areas where geological conditions could enable the groundwater level to be become very shallow or emerge at the surface [8]
Geological indicators of flooding (vector)	Identifies areas that are covered by superficial deposits that are susceptible to fluvial flooding. Derived from BGS geological maps [9]
Soluble rocks (vector)	Identifies the potential for the presence of deposits that may dissolve or collapse into dissolution cavities when water is infiltrated, resulting in subsidence. Derived from BGS GeoSure dataset [10, 11]
Landslides (vector)	Identifies the potential for the presence of deposits that may landslide when water is infiltrated. Derived from BGS GeoSure dataset [11]
Collapsible ground (vector)	Identifies the potential for the presence of deposits that may collapse when water is infiltrated. Derived from BGS GeoSure dataset [11]
Compressible ground (vector)	Identifies the potential for the presence of deposits that may compress when water is infiltrated. Derived from BGS GeoSure dataset [11]
Swelling clays (vector)	Identifies the potential for the presence of clays that may swell when water is infiltrated. Derived from BGS GeoSure dataset [11]
Running sands (vector)	Identifies the potential for the presence of sands that may 'run' when water is infiltrated. Derived from BGS GeoSure dataset [11]
Mining hazards (vector)	Identifies the potential for the presence of shallow mines that may collapse when water is infiltrated. Derived from BGS GeoSure dataset
Artificial ground (vector)	BGS Geological maps
Unsaturated zone predominant flow mechanism (vector)	Provides a qualitative classification of the predominant flow mechanism in superficial and bedrock deposits. Derived from BGS geological maps and hydrogeological data [6]

2.2 Geographical Information System (GIS) Approach

The proposed GIS approach was developed to: (a) guide the user through the relevant subsurface considerations; (b) provide data necessary for site-specific decision-making; (c) provide a spatial overview of infiltration-suitability over wide spatial areas, and (d) communicate opportunities for a wide variety of infiltration-based SuDS techniques (for example those featured in Figure 1).

The GIS methodology comprises four distinct parts organised in a sequence that guides the user through the decision-making process (Figure 2). **Part 1** highlights those areas where infiltration-based SuDS are unsuitable.

These include areas where the subsurface may be impacted by a significant potential for factors including: the dissolution of rock, leading to ground collapse; rocks that could lead to landslide; ground or shallow mines that could collapse and groundwater flooding. Areas covered by greater than 1 m of artificial ground, which is of unknown composition, are also highlighted as unsuitable for infiltration. **Part 2** considers the extent to which the subsurface will drain by providing an estimate of the depth to water table and the permeability of underlying superficial deposits and/or bedrock. We assume that all areas not highlighted in Part 1 will be suitable for infiltration to some extent, provided that the SuDS design is compatible with the subsurface conditions. **Part 3** considers the potential for ground instability that may not preclude the installation of infiltration systems, but should be considered during the design phase. Finally, **Part 4** provides an indicator of whether pollutants are likely to be attenuated in the subsurface by considering the flow mechanism through the unsaturated zone (fracture vs. intergranular flow).

For site-specific applications, data stored within the underlying GIS layers will provide the user with a site-specific dataset within the accuracy constraints of the 1:50,000 scale dataset [12]. This will enable preliminary decisions on the suitability of the ground at individual sites.

For assessment of the ground suitability over more extensive spatial areas, three summary GIS layers were developed: (a) the potential for drainage (including those areas that are unsuitable for infiltration); (b) the potential for ground instability, and (c) the potential for attenuation of surface water-derived contaminants within the unsaturated zone. To create these summary layers, the underlying data was scored to represent the suitability for infiltration (from 1 to 4), following which, maximum score values from the areal units were aggregated. Scores of one to three were assigned where minimal, moderate or considerable design constraints respectively, would be anticipated. Minimal design constraints would be expected in a free-draining site where instability problems were absent and the pollutant attenuation potential was maximised; in these areas a wide variety of infiltration systems are likely to be appropriate. Conversely, considerable design constraints may represent a site on low permeability deposits where the groundwater level was high or, stability or pollutant attenuation concerns were present; the suitability in such areas depends on an appropriate design. A score of four was assigned to represent areas unsuitable for infiltration. For vector datasets, scores were assigned to each polygon. For raster datasets, scores were assigned to grid squares, which were then attributed as per above.

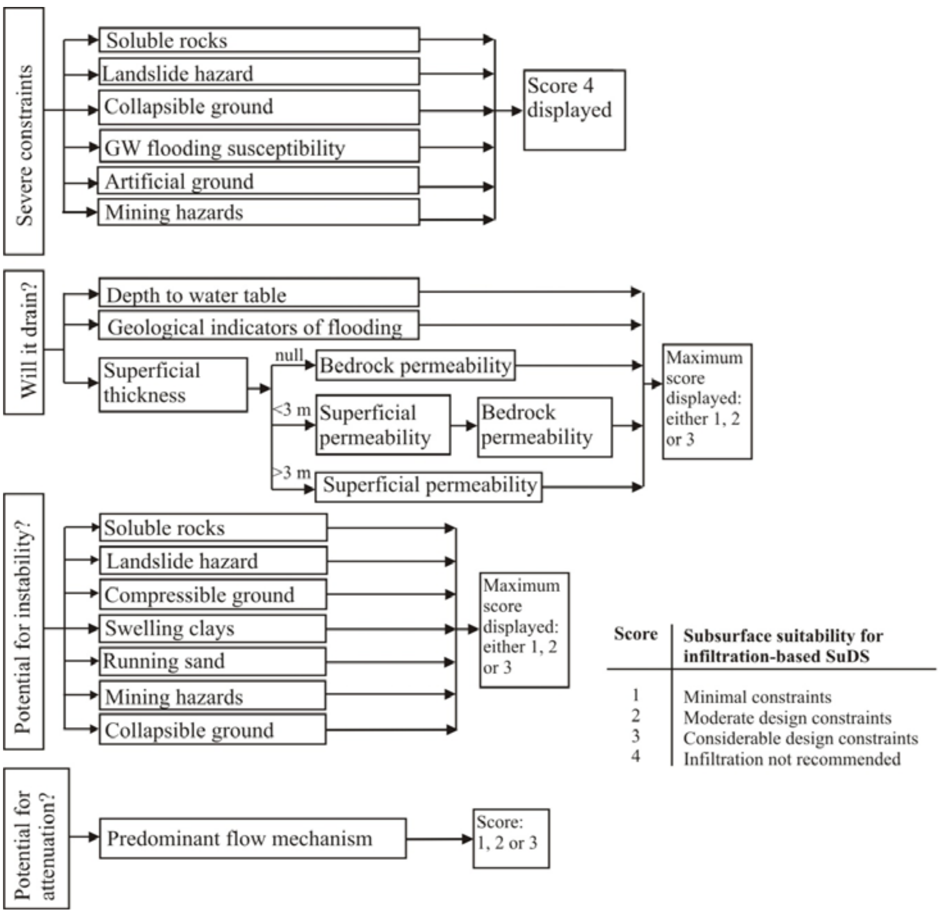

Figure 2. Schematic representation of infiltration suitability methodology

3. Application

Application of the proposed methodology in the Thames Catchment (Figure 3) highlights the opportunities for the installation of infiltration-based SuDS within the study area. To explain how the site-specific data may be used to determine subsurface suitability, three case study locations (shown in Figure 3) are examined.

Location 1: is unsuitable for infiltration because the area is potentially susceptible to groundwater flooding. Groundwater flooding occurs when a rise in groundwater level causes water to emerge at the surface. Infiltration in such areas is not recommended because the infiltration system may become inundated, reducing the unsaturated zone thickness, which is important for pollutant attenuation. In addition, further infiltration may exacerbate groundwater level rise. Other SuDS such as water retention in ponds or rainwater harvesting and re-use could be considered at this site.

Location 2: is likely to be suitable for the installation of an infiltration system. The area is likely to be free-draining as a result of the underlying, permeable Bagshot Formation bedrock, which comprises sands with gravel beds, and a relatively thick unsaturated zone, likely to be over 5 m. The area is affected by the presence of sand that is likely to 'run' if a void is present or excavated; advice should be sought during the design phase to ensure that this hazard is managed. The area is likely to have a good pollutant attenuation potential because the predominant flow mechanism within the unsaturated zone is intergranular which maximises both the infiltration residence time and contact with particle surfaces, encouraging attenuating processes. Nevertheless, the source and quality of the surface water should always be considered. The drainage and pollutant attenuation potential of the subsurface suggests that a soakaway may be appropriate providing that the running sand hazard is managed.

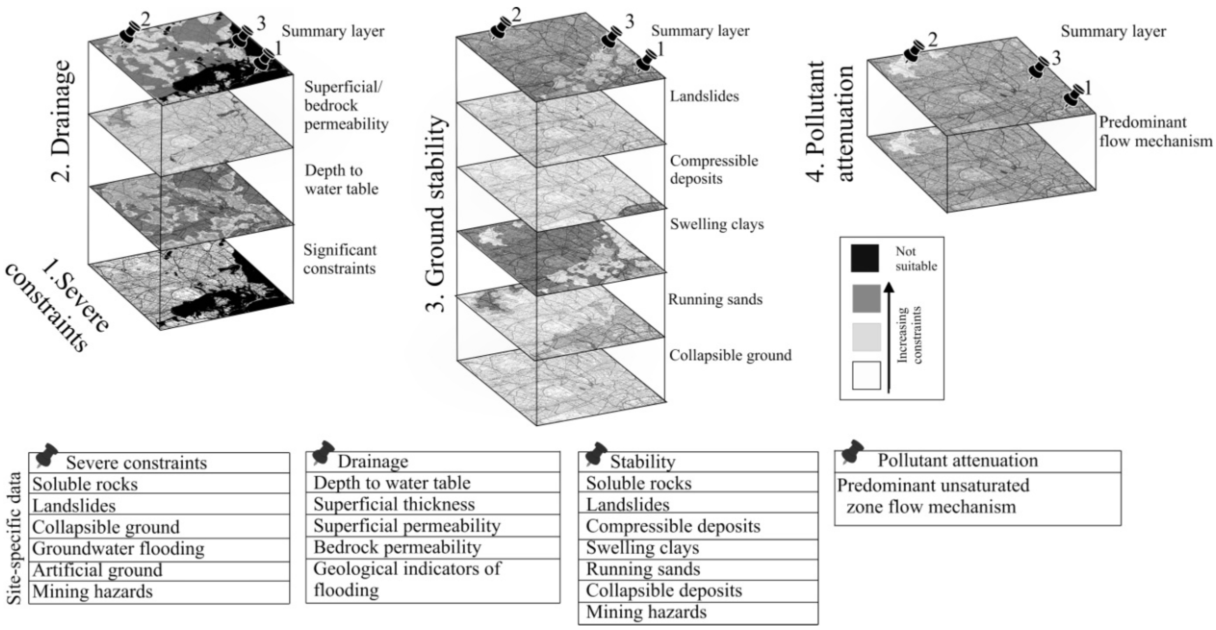

Figure 3. Summary of pilot study in the Thames Catchment showing both underlying and summary data layers for: (a) the potential for drainage (including those areas that are unsuitable for infiltration); (b) the potential for ground instability, and (c) the potential for attenuation of surface water-derived contaminants within the unsaturated zone.

Location 3: is likely to be suitable for the installation of an infiltration system. The area is underlain by superficial deposits, comprising sand and gravel of the Boyn Hill Gravel Member. This deposit is moderately free-draining and has an estimated thickness of greater than 3 m. If the thickness of this deposit was less than 3 m, the permeability of the bedrock would also have been considered. The unsaturated zone is expected to be over 5 m thick and hence is likely to provide a sufficient unsaturated thickness for pollutant attenuation processes, whilst also ensuring that there is space to accommodate any temporary rise in groundwater level (a groundwater recharge mound) resulting from infiltration. The area is potentially affected by the presence of sand that is likely to 'run' if a void is present or excavated; advice should be sought during the design phase to ensure that this hazard is managed. Within 50 m of the site, swelling clays are present that may expand when water is added. The area is likely to have a moderate pollutant attenuation potential because both intergranular and fracture flow are important within the unsaturated zone. Whilst intergranular flow provides good attenuation, flow through fractures is rapid, allowing only minimal interaction with particle surfaces. The quality of the surface water should be considered and pre-treatment stages for improving the water quality should be considered. The drainage potential at this site suggests that a soakaway may be appropriate. However if soakaway tests show marginal suitability, permeable pavements or an infiltration basin may be considered providing that the running sand and swelling clay hazards are managed and that the water quality is considered.

4. Conclusions

The use of the geological subsurface to accept stormwater has the potential to provide effective and low cost opportunities for drainage. However the efficacy of systems depends upon the degree to which they complement the ground conditions with regards to drainage, stability and the protection of groundwater quality. To maximise the potential for infiltration, planners, approval bodies and developers will require access to data that will enable them to make preliminary decisions on the suitability of the subsurface for infiltration. The methodology proposed, addresses this shortfall by not only providing a framework for assessing ground suitability, but also by providing the data therein required. For any UK location, the dataset can identify: (a) where infiltration is not recommended; (b) the drainage potential; (c) ground stability considerations; and (d) the likely potential for attenuation in the unsaturated zone. The proposed dataset is intended as a screening tool which will guide SuDS planning and subsequent infiltration testing; it is not intended to be used without further ground investigation.

5. REFERENCES

[1] M. Pitt, "Pitt Review: Learning lessons from the 2007 floods," ed: HM Government, 2008.

[2] G. Jenkins, *et al.*, "UK Climate Projections: Briefing report," Met Office Hadley Centre, , Exeter, UK. 2009.

[3] HMSO, "Floods and Water Management Act, Chapter 29," ed: HM Government, Her Majesty's Stationery Office, 2010.

[4] B. Woods-Ballard, *et al.*, "The SUDS Manual," Ciria RP697 2007.

[5] HMSO, "The building regulations 2000: Approved document H - Drainage and waste disposal," ed: Office of the Deputy Prime Minister, 2002.

[6] M. Lewis, *et al.*, "Guide to permeability indices," British Geological Survey CR/06/160N, 2006.

[7] R. Lawley and M. Bajo-Garcia, "The national superficial deposit thickness model (version 5)." British Geological Survey OR/09/049, 2009.

[8] D. Macdonald, *et al.*, "Improving the understanding of the risk from groundwater flooding in the UK," presented at the FLOODrisk 2008, European Conference on Flood Risk Management Oxford, UK, 2008.

[9] K. Booth and K. Linley, "Geological indicators of flooding: user guidance notes," British Geological Survey OR/10/012, 2010.

[10] A. Farrant and A. Cooper, "Karst geohazards in the UK: the use of digital data for hazard management," *Quarterly Journal of Engineering Geology and Hydrogeology*, vol. 41, pp. 339-356, 2008.

[11] J. Walsby, "GeoSure: A bridge between geology and decision makers," in *Communicating Environmental Geoscience*, D. Liverman, *et al.*, Eds., ed London: Geological Society of London, 2008, pp. 81-87.

[12] A. Smith, "Digital geological map of Great Britain, information notes," British Geological Survey, Nottingham2011.