SOIL ROBUSTERS

ROBUST is a 5 year project investigating the Regeneration of Brownfield Land Using Sustainable Technologies and involves a group of five researchers at Durham University in North East England.

The North East of England has many outstanding features, but the decline of traditional industries has also left it with a legacy of post industrial landscapes and brownfield land. Brownfield land is previously developed land as opposed to greenfield land which, apart from for agricultural purposes, has never been previously developed. The North East's much publicised renaissance has seen many brownfield sites redeveloped and returned to productive use, but smaller, less valuable sites aren't generally as appealing to developers and may miss out on such treatment.

Key to the project is an investigation into the potential for using waste materials to provide a cheaper, safe means to remediate low-level contamination in particular. Metal Oxides, such as Manganese and Iron Oxides in the form of clean mine tailings or water treatment sludge, are one waste type with particular promise. Previous research at Durham University has shown that Manganese Oxides are capable of both oxidising organic molecules and immobilising metals.

For more information and to catch up on the project, visit www.robustdurham.org.uk

ROBUST *www.robustdurham.org.uk* Durham University

ROBUST

Three areas of study are being focused on in the ROBUST project: the **geotechnical** and **geochemical** properties of contaminated soil with the addition of waste minerals and the **computational modelling** of both these aspects.

The geotechnical properties under investigation are primarily the soil strength and permeability, and the impact of additives on these characteristics.

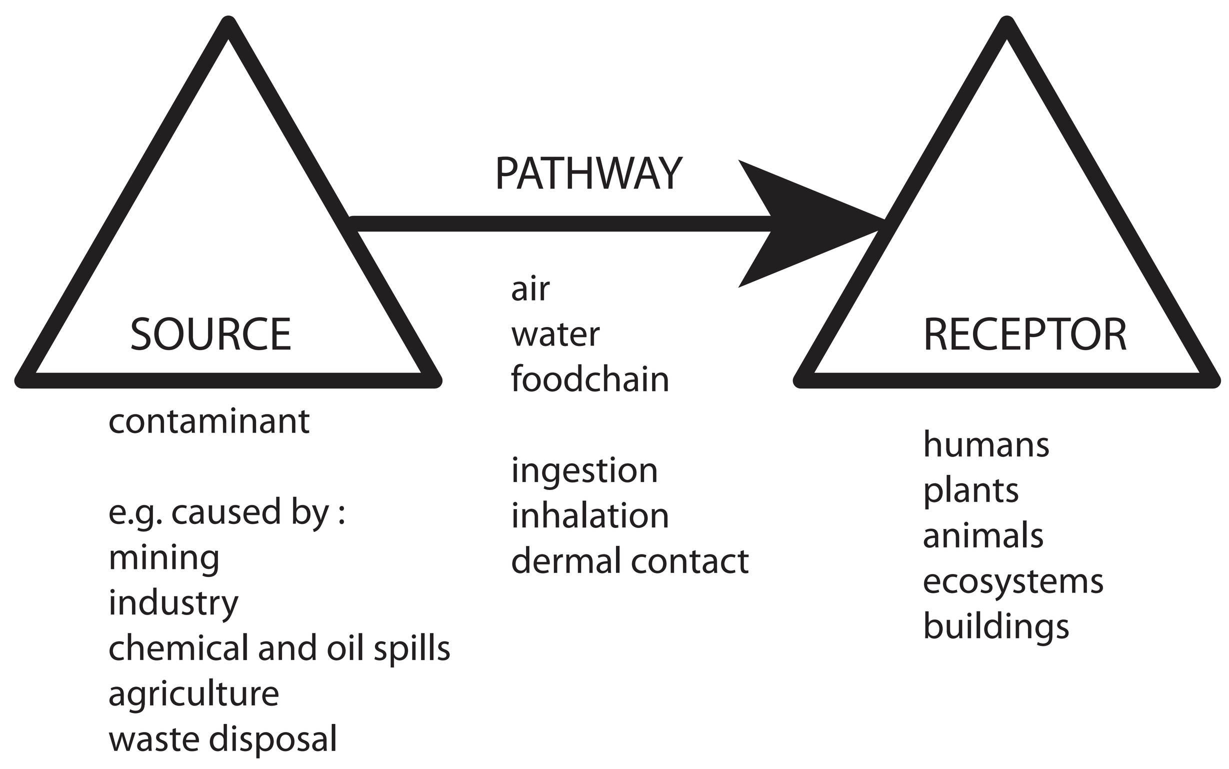
Environmental geochemistry investigations are exploring how sources of waste minerals help to breakdown contaminants that might be found in the ground, such as oils and toxic compounds. This involves looking into the chemical reactions that happen between the mineral and the contaminant within the complex soil system.

A computational model will use results from the geotechnical and geochemical studies to create a method for long term predictions of contaminant movement.

Contaminated Land

Contaminated land is land that contains substances in or under the ground which have the potential of causing significant harm to the environment and health.

Fundamental to assessing the risk posed by contaminated land is the **pollutant linkage model**.



Not all contaminated land causes a problem. Sources of pollution may exist, but there must be a pathway via which the contaminant can reach the receptor for there to be a risk of causing harm.

The amount and type of contaminant involved will determine its effect on the environment and on human health. What happens to the contaminant in the ground depends on the properties of the contaminant and the soil, the rate of rainfall and the activity of the soil organisms.

SPOSH, the 'significant possibility of significant harm', is a concept meant to help define whether land should be determined as contaminated under the current legislation (Part 2A of the 1990 Environmental Protection Act).

There are lots of remediation techniques available to treat contaminated land. These include:
● Bioremediation - using microbes to clean up unwanted substances;
● Phytoremediation - using plants to mop up contaminants;
● Oxidation - using chemicals to break down contaminants;
● 'Dig and dump' - simply removing the contaminated soil to a place where it is less of an issue.

A major problem with most clean-up strategies is their high cost. ROBUST is trying to find cheap, sustainable alternative technologies so that more land can be remediated and brought back into beneficial use.

What is soil?

Soil is a complex, living, dynamic and bio-diverse system that:

● Supports plant growth, and hence everything above it in the food chain;
● Acts as a sink for carbon dioxide from the atmosphere, helping to improve water and air quality.

Soil is formed from parent material i.e. rocks and deposits, which are weathered over time and acted on by physical, chemical and biological processes to form the mineral component of the soil. When vegetation dies and falls to the ground, micro-organisms help to digest this vegetation and other living material to form the main source of organic matter in the soil. The organic matter in soil provides the carbon source and the minerals provide the nutrients to help plants grow.

Factors such as the shape of the landscape, climate, and time all play an important role in creating a soil. A soil is composed of gravels, sands, silts, clays, organic matter, microbes, water and air. Variable conditions around the world lead to the formation of different soil types. This is what makes soil an incredibly diverse and complex system.

Minerals such as manganese oxide are naturally present in soil, along with iron and aluminium oxides. They can be found as very small particles in soil and sediment, as coatings on other minerals and in larger clumps of soil, called aggregates.

Soil Health

Soil 'health' is a measure of the soil quality, particularly the biological component, which includes the microbes and fungi that live in the soil. These play an important role in the formation of organic matter which gives the soil its structure and also in helping to breakdown unwanted compounds into useful energy.

Sand

Sand is variable in constituents but is primarily composed of silicon dioxide (SiO_2), otherwise known as silica or quartz, and is a granular material that can be felt to be coarse when rubbed between the fingers.

Particle size ranges from 0.06 mm to 2 mm in diameter, at which point the grains are classed as gravel. Any smaller than 0.06 mm in diameter and the grains are harder to distinguish by feel as a coarse material.

The colour of sand can vary depending upon impurities in the silicon dioxide crystal lattice and also of any other mineral grains or fragments that may be present within the particle size range. This can be observed on different beaches around the world, for example the black beaches in Hawaii formed from lava.

Silt

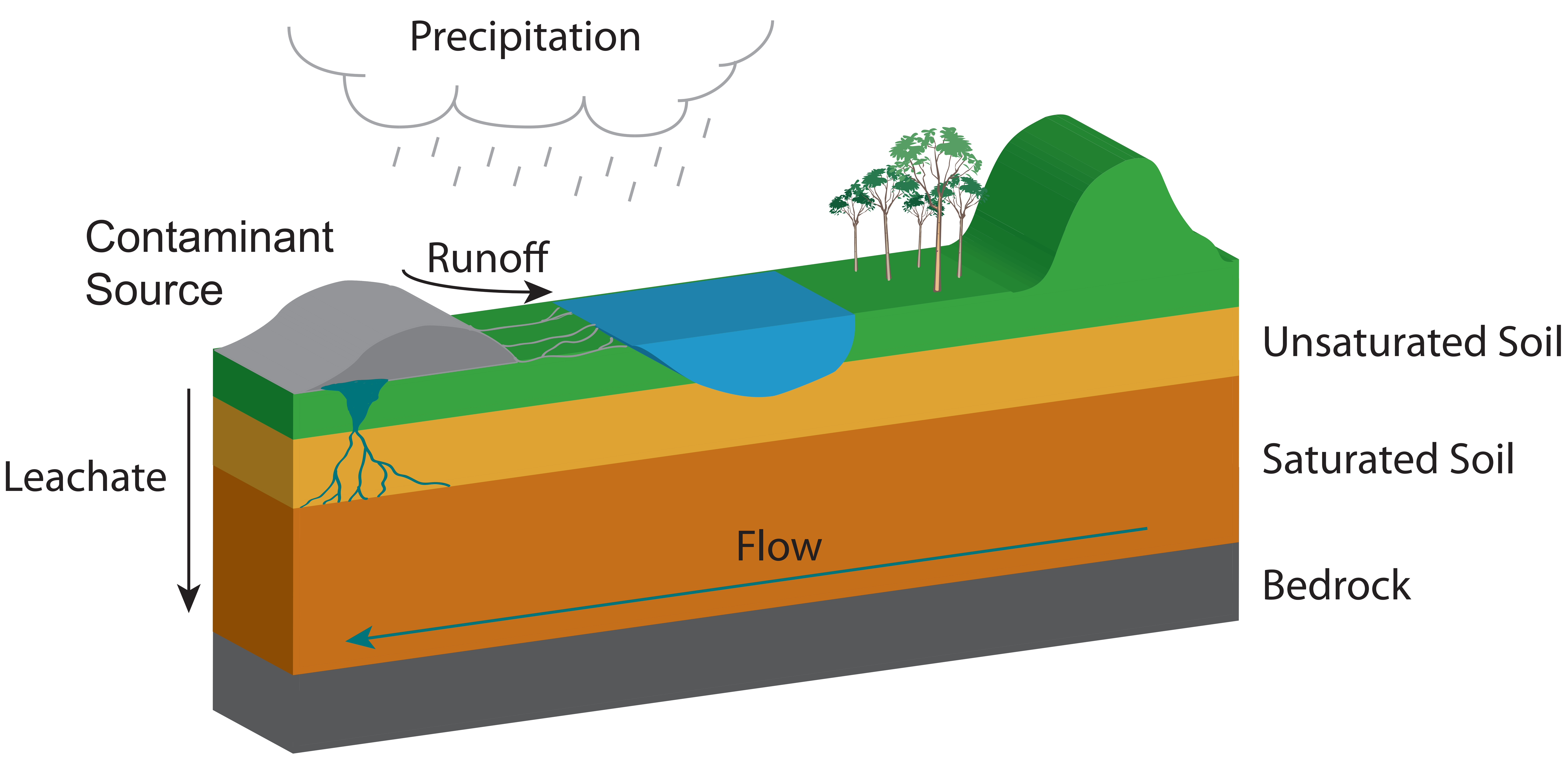
Silt is primarily composed of quartz and some feldspar, with a particles size ranging from 0.002 mm to 0.2 mm in diameter.

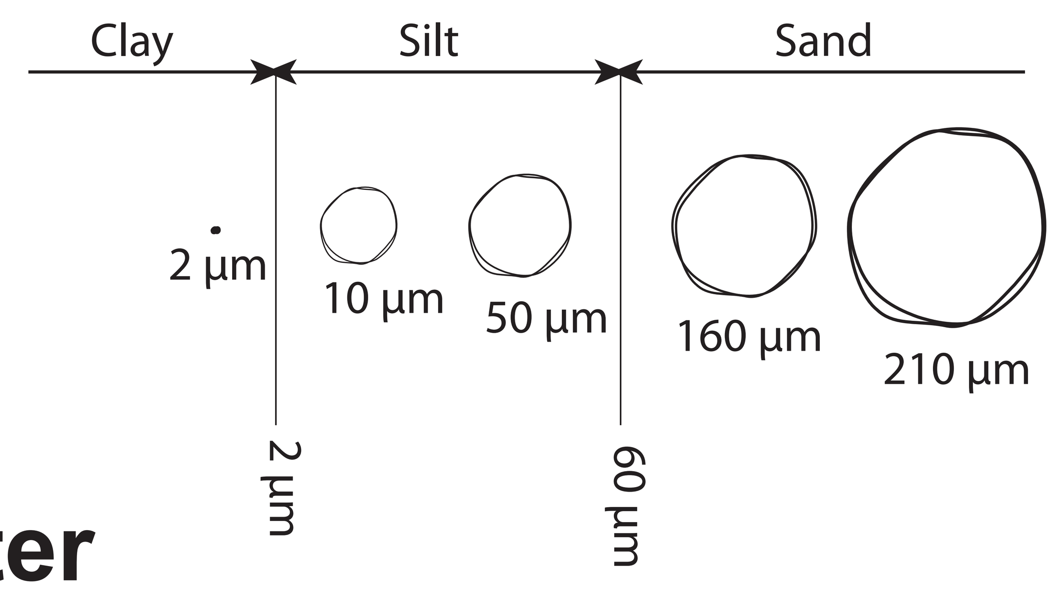
Quartz is weathered and broken down into smaller particles through weaknesses in the crystal lattice. The feldspar minerals, the most common geological mineral group on Earth's surface, may be weathered from igneous or sedimentary rocks. Feldspar minerals are composed of sodium, potassium or calcium held within a crystal lattice of silicon dioxide (SiO_2) and aluminium dioxide (AlO_2). The resultant weathered silt particles are rounded, fairly uniform in shape and may be transported with ease in water. The overall feel of silt particles rubbed between the fingers is that of flour.

Clay

Clay differs from sand and silt substantially. Instead of rotund particles, clays are typically composed of layers (or plates) containing alternating sheets of silica $[SiO_2]$ and either gibbsite $[Al_2(OH)_6]$ or brucite $[Mg_3(OH)_6]$. Common examples include kaolin, otherwise known as China clay, with a two-sheet structure comprising of silica and gibbsite; and montmorillonites, otherwise known as smectites, with a gibbsite sheet sandwiched between two sheets of silica.

Formation of kaolin occurs through the weathering of basic feldspar containing rocks where feldspars are more unstable and structurally weaker than the harder quartz containing rocks. Montmorillonites on the other hand are formed through the weathering of volcanic ash. In terms of size, the platelets of different clays may vary between 0.1 μm to 4 μm in length and 0.001 μm to 2 μm in thickness.





Water

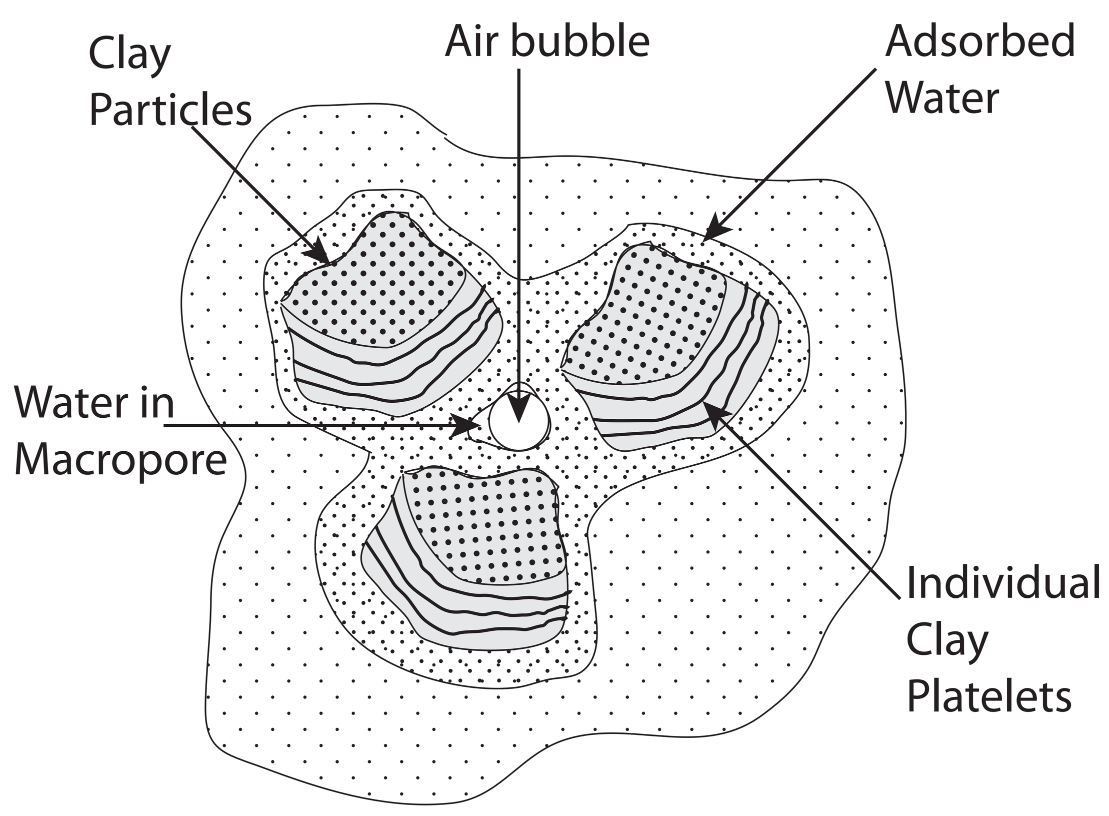
Water is one of, if not 'the', most complex material known to man. It exhibits a range of properties that can be quite bewildering at times and is on occasion, referred to as the universal solvent. Within soils the ability of water to dissolve almost any substance is incredibly important for chemical and physical changes. These changes on a molecular level affect the strength of a soil and its ability to transmit water from pore to pore on a larger scale.

Saturated Soil

If all the voids between soil particles are filled with water the soil is described as being in saturated conditions. What this means is all loads taken by the soil are divided between those transmitted through the skeleton of the soil and those countered by the buoyancy of the soil particles. Just like steel ships float, the uplift on soil particles is equal to the weight of the water displaced. In unsaturated conditions this is quite a different story.

Unsaturated Soil

Soils that contain air and water in the voids are classed as unsaturated soils. They behave differently to saturated soils, far more than just removing the buoyancy term from the equation. This is due to how the water sits in the voids between particles. The water doesn't just do 'nothing', it adds strength to the soil by connecting the soil particles with a 'liquid bridge'. The liquid bridge gives strength through the surface tension of water, the more bridges you have the greater then strength. The number of liquid bridges within a soil therefore depends primarily on how much water you have and the void size distribution i.e. for a well graded soil, the lower the water content, the more liquid bridges are formed hence a greater suction holding the soil in place. A good example of unsaturated soil is sand castles; these stand up and maintain their shape only because of the water and air present in the voids.



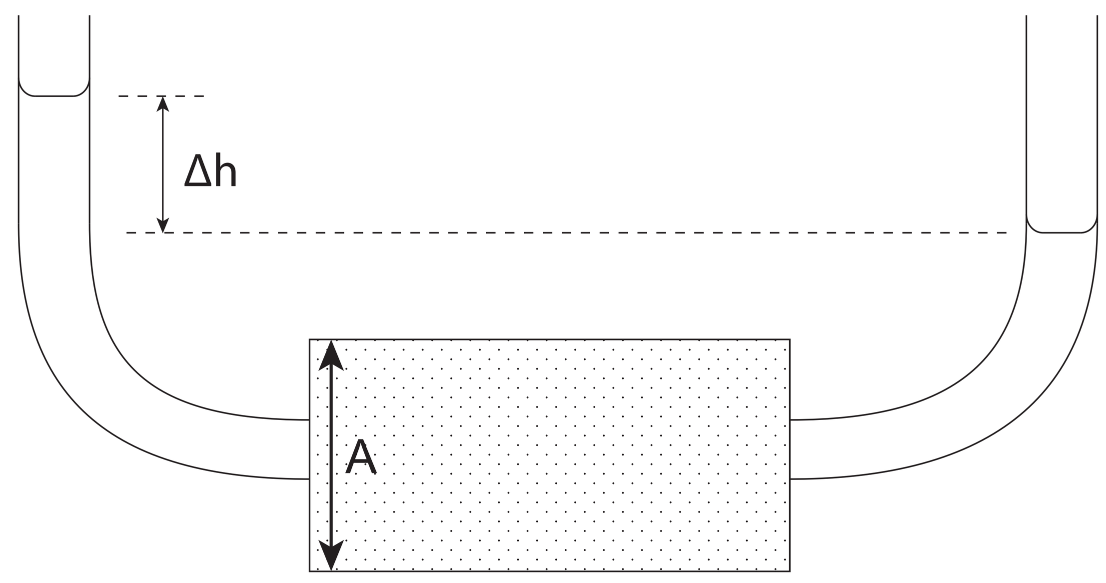
Computational Modelling

It is important to be able to predict the movement of contaminants through a brownfield site to be able to assess and predict the risks posed by those contaminants.

The transport of contaminants is driven by the flow of water through the soil and so to understand contaminant transport we need to understand water flow.

It is not practical to map the pore spaces in a soil and describe water flow on a pore scale. Instead water flow through soil is described on the macroscopic scale. This means that the average properties of the soil on a scale much larger than any of the pore spaces are determined and it is assumed that these properties do not alter throughout the soil.

Darcy's Law, as determined by Henry Darcy in 1856, states that the flow rate of water through a saturated soil is proportional to the differences in pressure within the soil. The proportionality is dependent upon the soil type and is captured by a parameter called the hydraulic conductivity. Soils with larger pore spaces tend to have higher hydraulic conductivities. Water will flow faster through a sandy soil than a clayey soil.



In unsaturated soils the situation becomes slightly more complicated as water flow is also driven by gravity and the hydraulic conductivity of a soil is dependent upon how much water is in the soil. Assuming air pressure in the soil is constant water flow through soil can be described by Richards' equation. Richards' equation is very similar to Darcy's Law. Water flow is still driven by pressure differences but is also driven by gravity.

Contaminants can be transported by one of two methods, diffusion and advection. Advection is the movement of contaminants by the movement of the water they are dissolved in. Diffusion is caused by the random movement of contaminant particles. The particles constantly move about in random directions. The net result of these movements is to spread contaminants out so that concentrations are equal everywhere.

Solving these different equations to predict water and contaminant movement often require large numbers of calculations and so is done by computers.