Hydropedology

The science of hydropedology – linking soil morphology with hydrological processes

An exciting new branch of science, hydropedology, offers exciting research opportunities in South Africa. Article by Johan van Tol, Pieter le Roux and Simon Lorentz.

Hydropedology is the relatively new, interdisciplinary research field which focuses on the interactive relationship between soils and water. Soil physical properties, such as the hydraulic conductivity and porosity, have an important impact on the occurrence and rates of hydrological processes. In turn, hydrological processes play an important role on the formation of soil morphological properties such as colour, mottles, macropores and carbonate accumulations.

Accurate mapping and the interpretation of these soil morphological properties can thus be used to conceptualise and characterise hydrological processes, including water flow paths, storage mechanisms and the connectivity between different flow paths. Most of these hydrological mechanisms and processes are very difficult to observe (let alone measure!) in the field because they are dynamic in nature with strong temporal and spatial variation.

Nevertheless, soil morphological properties are not dynamic in nature and their spatial variation is not random – making soil properties the ideal vehicle for predicting and conceptualising hydrological processes. One of the major contributions of hydropedology is the ability to conceptualise hydrological processes spatially i.e. not only one dimensional mechanisms, but a more holistic understanding of the hydrological functioning of landscapes (catchments or hillslopes).

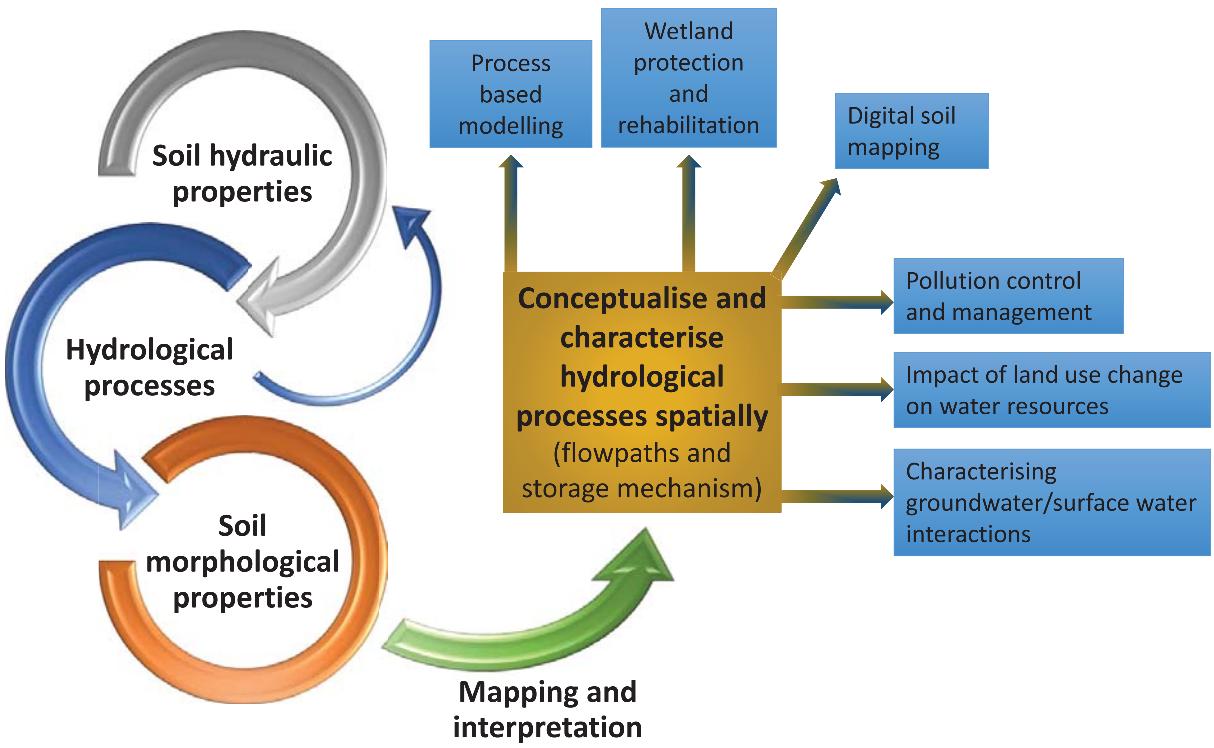

Figure 1: Hydropedology and some of the applications of hydropedological surveys.

Hydropedological information is used in process based landscape water resource management. This includes, for example:

- configuration and parameterisation of distributed hydrological models;
- effective wetland delineation, protection and rehabilitation;
- understanding and controlling the fate of pollution in the subsurface;
- determining the impact of land use change (e.g. open pit mining) on water resources and
- characterising groundwater/surface-water interactions, including the important mechanism of low-flow generation.

In general, hydropedological information assists with effective water resource management, as required by the National Water Act through improved understanding and characterisation of hydrological processes.

Hydropedological behaviour of soil types

The hydropedological behaviour of different soils can differ significantly. For example in Figure 2a, the red colours of the top and subsoils of are typically associated with freely drained soils. Vertical flow into, through and out of the profile are the dominant hydrological pathway. These soils are termed ***recharge soils***, as they are likely to recharge groundwater, or lower lying positions in the regolith, via the bedrock.

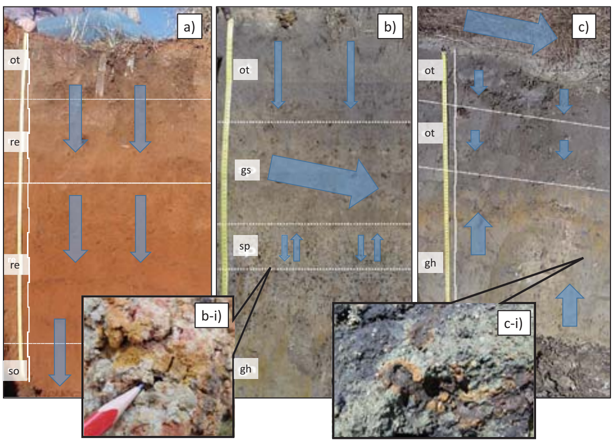

Figure 2: Different hydropedological soil types a) recharge soil, b) interflow soil and c) responsive soil.

In the second example (Figure 2b), lateral flow is likely to be dominant. These soils are termed ***interflow soils***. Lateral flow occurs due to differences in the conductivity of horizons. In Figure 2b the 'sp' is restricting downward movement and lateral flow occurs at the A/B horizon interface. The lighter colour of the 'gs' horizon is further support that lateral flow dominates. Lateral flow frequently occurs on soil/bedrock interfaces due to the permeability of the rock. Mottles (red, yellow and grey colours) in the 'sp' horizon (magnified in Figure 2b-i) is the result of a fluctuating water table.

In Figure 2c the grey colours of the 'gh' horizon and the dark colours of the topsoil horizon are indications that this profile is saturated for long periods of time. Because these soils are close to saturation, especially during peak rainy seasons, additional rainfall is unlikely to infiltrate the soils but will flow as overland flow (or surface runoff) downslope. These soils are termed ***responsive soils*** due to their rapid response to rain events. The same type of response can be expected on very shallow soils i.e. a small amount of rain can saturate the soil and additional rain will drain away as overland flow.

Hydropedology of hillsopes

For effective water resource management it is important to gain a holistic understanding of hydrological processes. Figure 3 presents a typical example of the hydropedological response of a hillslope. In the recharge zone, the dominant flow direction is vertical through the soil and into the fractured rock, from where it can recharge groundwater levels or downslope positions in the hillslope soils. Lateral flow at the A/B horizon interface or soil/bedrock interface dominate in the interflow zone. The responsive zone is fed by lateral flowing water from the interflow zone as well as via the bedrock from the recharge zone.

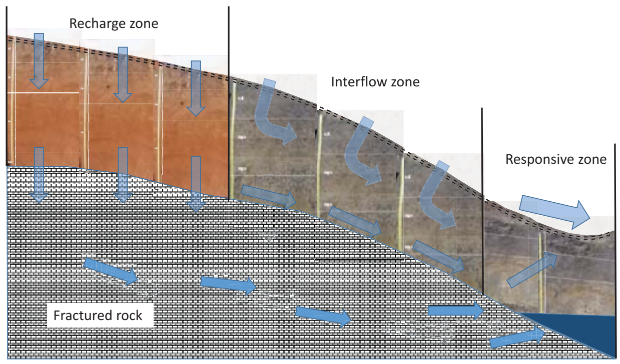

Figure 3: Typical example of hydrological flowpaths on different hydropedological soil types- hillslope hydropedological behaviour.

Although Figure 3 represents an oversimplification of a fraction of the complex hydrological cycle, the application of this information can make important contributions to effective management. Four scenarios are presented to support this statement.

1. Pollution: The fate of pollution will differ depending whether it was spilled on recharge, interflow or responsive soils. A spill on recharge soils is likely to end up in the groundwater or might arrive in the stream several months after the spill *via* flow through the fractured rock. Pollutants spilled on interflow zones will migrate downslope through the soil. Because this downslope migration will be in contact with the soil, and hence abundance of micro-organisms. It is possible that it may be transformed into non-toxic forms (depending on the pollutant). If a pollutant is spilled on the responsive zone it may travel quickly and unaltered to streams and other surface water bodies.

2. Conserving wetlands: Hydropedological information can aid in identifying the sources of water in order to preserve wetlands. If the recharge zone is the major source of water to the wetland i.e. the recharge zone is the hydrological

driver of the wetland, care should be taken to restrict surface sealing (paving) of the recharge zone. If the wetland's water comes from an interflow zone, care should be taken to prevent obstruction of subsurface lateral flowpaths.

3. Hydrological modelling: Hydropedological information can assist in the correct configuration of distributed hydrological models. In many landscapes different landscape elements (or Hydrological Response Units – HRU's) are not connected in a simple cascading downslope way to one another. There might be areas which are disconnected from the stream or groundwater stores. In addition, deep infiltration from recharge soils at the crest of a hillslope, may re-appear as lateral flow water further down the slope. Hydropedological information can thus be used to ensure that the model configuration properly reflects the hydrological processes. This can be critical in simulating low flows, where vegetation may have access to near-surface water and thus limit contributions to streamflow.

4. Land-use change: Hydropedological information can support the understanding of the impact of land-use change on water resources. If, for example, the interflow zone is urbanised it may result in a build-up of water against foundations and the generation of return flow to the surface and overland flow which may cause erosion. Open pit mining close to responsive zones are likely to result in a draw-down of water levels and drying of wetlands. If such an open-pit intersects lateral flowpaths it will break the connectivity of flowpaths and cut the source of water to wetlands. Although the impact of land-use change cannot always be avoided, hydropedological information might aid in managing and protecting the hydrologic drivers of the ecosystem and thereby minimise negative impacts.

Hydropedological surveys

A hydropedological survey (in the context discussed above) is different from a conventional soil survey in the following aspects:

- Observation depth: the depth of observation in a conventional survey is 1.5 m, whereas the observation depth for the hydropedological survey is the depth to the soil bedrock interface.
- Classification: conventional soil surveys aim to classify soils in accordance with a specific classification system. In hydropedological surveys all morphological properties and all soil horizons are described, recorded and interpreted, with particular emphasis on the ambient and connected soil water environment. This include saprolitic (weathering rock) horizons and horizons which are not necessarily included in the hierarchy of the classification system.
- Observation density: Conventional soil surveys aim to capture the distribution of different soils in a particular landscape. Hydropedological surveys focus on the hydrological response of dominant hillslopes/transects.

Important to note is that hydropedological surveys cannot be used as a surrogate for mapping the agricultural potential (as required during most Environmental Impact Assessments) of an area. Conventional soil surveys (or other existing soil information) can also not always be used to infer the hydropedological response of an area, due to the differences between conventional and hydropedological surveys highlighted above.

Hydropedological surveys do not replace detailed soil physical or hydrometric measurements but rather serves as a vehicle to identify representative sites for such measurements and to extrapolate these measurements to larger areas. Hydropedological surveys are also not a surrogate for hydrological modelling, but can contribute to the efficiency and accuracy of modelling exercises.

In conclusion, hydropedological surveys and the interpretation and application of hydropedological information can be a cost -and time effective approach to conceptualise and characterise hydrological behaviour of landscapes.