

IMTECO Ltd: Modelling the Hydrological Impact of Infrastructure Near Bog Pool Systems

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Context & Motivation Peatlands with **dense bog pool systems** are highly sensitive ecosystems. Infrastructure (e.g. wind farms, access tracks, buried cables) is usually prohibited in these zones — but even construction near the pools can affect their delicate **hydrology**. Impacts include drainage “shadows”, altered connectivity between pools, or changes in hydroperiod (pool water duration and levels).

Currently, there is **no standard tool** for ecologists or regulators to quantify these risks or to define *evidence-based buffer zones*, as is done for other sensitive habitats like GWDTEs (Groundwater-Dependent Terrestrial Ecosystems).

This challenge should also be considered in the context of current **NatureScot peatland guidance**, which sets the regulatory framework for assessing impacts on peatland and carbon-rich soils in development management. The guidance includes structured templates and checklists (see NatureScot peatland guidance website) that practitioners must follow when evaluating direct and indirect impacts, defining buffer zones, and identifying mitigation requirements. A PDF copy of the guidance is also available here: [NatureScot Guidance PDF](#). NatureScot also provide a structured site visit template to guide assessments. This includes criteria such as peat depth, vegetation type, surface pattern, drainage condition, and presence of Sphagnum-rich ridges. Sites are classified according to whether they are raised, montane, or blanket bogs, with combinations of criteria indicating potential national interest and informing mitigation or buffer requirements.

The Challenge How can we **develop or adapt a hydrological modelling tool** that allows users (especially non-modellers like ecologists) to assess:

At a more fundamental level, the scientific challenge is to understand why bog pool systems form in the first place—only with this understanding can we begin to model their behaviour under disturbance.

From a broader perspective, bog pool systems are not just hydrological features but also geomechanical systems. The pools and ridges emerge from complex feedbacks between water flow, peat deformation, growth and decay, and long-term surface stability. Infrastructure loading can change pore pressures, compaction, and settlement, which then alter water levels and connectivity. Thus, flow-based modelling must be coupled with geomechanical and ecohydrological understanding to capture the full dynamics.

- How infrastructure might influence nearby **bog pool dynamics**.

- What buffer zones are necessary to minimise hydrological disruption.
- How to communicate these risks clearly to regulators and developers.

The tool should be:

- Scientifically credible.
- Flexible enough to incorporate field data.
- Simple enough to be used in practical consultancy settings.

Realistic Outcome for the Workshop This is a complex and not yet fully understood problem. A fully working model cannot be built in two days, so the aim of this group is to identify what is known, what remains uncertain, and to frame a roadmap for future work. The immediate outcome is not a model but a shared roadmap aligned with policy frameworks. Participants should aim to connect the scientific and modelling perspectives with the NatureScot templates, so outputs can help practitioners interpret results directly within regulatory assessments.

The group may also wish to highlight where geomechanics, ecohydrology, and long-term feedbacks need to be integrated with simpler hydrological tools, so that Irene’s vision of a practitioner-oriented model remains grounded in the deeper physical processes.

In particular, the group will:

- Identify key physical processes and modelling options
- Review what tools already exist (and their limitations)
- Discuss the **data requirements** and simplifications needed for consultants
- Propose a **roadmap** for developing a prototype tool, e.g. in Python/R or an interface for an existing model (like DigiBog or HEC-RAS)

The result would be a shared vision and technical outline that could seed a collaborative research or innovation project.

The group should also reflect on how any proposed approaches could align with, or help simplify, the assessment process outlined in the NatureScot Assessment Template and related guidance, to ensure outputs are directly relevant to regulatory practice.

Modelling Approaches (for discussion) Below is a categorisation of possible modelling approaches, adapted from current research and industry practice. These should be discussed in terms of feasibility, input requirements, and applicability to bog pool systems.

1. Physically-Based Distributed Flow Models (2D/3D)

Examples: **MIKE SHE**, **HydroGeoSphere**, **MODFLOW** (with UZF/SFR/LAK), **COMSOL**

- Simulate: water-table response to tracks/foundations, pool water levels, GW–SW (groundwater–surface water) exchange, culvert placement
 - Inputs:
 - High-resolution LiDAR digital elevation model (DEM)
 - Peat layer stratigraphy and hydraulic properties (K, van Genuchten curves)
 - Drainage layout, rainfall/evaporation data
 - Logger data for calibration
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2. Surface Flow & Barrier Routing Models

Examples: **HEC-RAS 2D**, **TELEMAC-2D**

- Simulate: how roads, tracks, or berms act as **barriers**, causing ponding or fragmentation between pools
 - Inputs:
 - Sub-metre DEM
 - Roughness maps (e.g. open water vs. Sphagnum mats)
 - Rainfall hyetographs
 - Water-level data from pool loggers
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3. Catchment-Scale Conceptual Screening Models

Examples: **TOPMODEL**, **HBV**, **GR4J** (with peat-specific parameters)

- Simulate: broader **seasonal drawdown risks**, “what-if” scenarios of cumulative impact
 - Inputs:
 - Rainfall and evapotranspiration time series
 - Simplified soil and land cover types
 - Outflow measurements or dipwell data
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4. Peatland-Specific Eco-Hydrological Models

Example: **DigiBog**

- Simulate: long-term interaction between **peat growth** and **hydrology**, particularly pool-ridge feedback
- Inputs:
 - Microtopography
 - Peat decomposition and productivity parameters
 - Historic water-table records
- Notes: DigiBog also includes a standalone hydrology module (*DigiBog_Hydro*)

More info: <https://www.peatmothership.org/digibog>

5. Graph-Based & Cellular Automata Models (from LiDAR)

- Simulate: how **microtopography** and barriers affect **connectivity** between pools
- Can model thresholds for hydrological fragmentation and loss of function
- Inputs:
 - High-resolution DEM
 - Seasonal pool extents
 - Mapped pool network

6. Water Quality & Export Models

Examples: **SWAT+**, **HYPE** (peat-parameterised)

- Simulate: how construction corridors affect **DOC (dissolved organic carbon)** or sediment exports
- Inputs:
 - Soil carbon maps, surface runoff patterns
 - Event-based water sampling of DOC and turbidity

Explanation of Key Terms

- **van Genuchten curves**: Describe how water is retained in soil/peat at different tensions — needed for accurate modelling of flow through porous media
- **GW–SW exchange**: The bidirectional flow between groundwater and surface water (like pools)

- **Hyetograph:** Graph of rainfall intensity over time
 - **Hydroperiod:** Duration and frequency of pool inundation
 - **Acrotelm/Catotelm:** The upper active and lower anoxic peat layers in bogs
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Final Aim

- Clarify the fundamental scientific questions around bog pool formation and dynamics

The aim of this group is not to develop a working model immediately, but to outline:

- A **recommendation** for model type and structure
- A minimum data standard for ecological assessments
- Possible avenues for future development (student projects, grant proposals, open-source collaboration)