Model Simulation of a field drainage system

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Introduction:

- Mole drainage is used in fine, poorly permeable soils in conjunction with conventional PVC tile drains to improve hydraulic conductivity of the soil matrix and thereby increase infiltration of rainwater to the tile drainage system.
- The capacity of a combined tile/mole systems at various stages in its lifespan is difficult to quantify empirically as the integrity of the system cannot be fully assessed without invasive investigations, and variables such as weather, both current and antecedent, and intensity of agricultural production/traffic and the interactions between these factors impact performance.
- Numerical simulations of such systems would allow for the effect of variations in system design and in the integrity of the mole channel and related fissuring on performance to be quantified in a controlled manner.
- The Finite Element Modelling software package SEEP/W developed by GEO-SLOPE (2012a) and was used in this study

Objectives:

- To establish a legitimate model of an existing combined tile/mole drainage system utilizing data on system geometry, soil physical/hydrological characteristics and assumed boundary conditions, using SEEP/W software.
- To model the performance of this system during a short-term high intensity rainfall event and calibrate it to allow observed performance in the field to be replicated by the model.
- To validate the model and assess the reliability of model outputs relative to observed tile drain discharge data collected over a 3 month period.
- To model the installed system and a range of alternative system designs, including a tile only system and combined mole/tile systems of varying integrity, under a range of rainfall event scenarios to assess their performance.

Materials & Methods:

- The model outlined is based on a drainage system installed on a 2 ha grassland site in Doonbeg, Co. Clare (52°44'N, 09°30'W) comprising tile drains at a depth of 0.9 m and 15 m spacing and mole drains, installed perpendicularly to tile drains at a depth of 0.6 m and spacing of 1.4 m.
- The system was modeled in SEEP/W with a soil profile depth of 1.4 m and 4 soil horizons (Table 1)
- Rainfall rate applied to upper boundary in 15m wide band (catchment of one tile drain)
- **Model calibrated** by varying input parameters to align modelled discharge with observed field discharge during rainfall Event A (156.4 mm over 5 days).
- **Model validated** by assessing its predictive performance during a 3 month period (Event B-October 1st to December 31st 2015)

Table 1. Soil profile, classified as a Humic Groundwater Gley following pedological survey, with soil texture and modeled hydraulic parameters.

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	θr (cm³ cm⁻³)	θs (cm³ cm⁻³)	k_s (m/s)
0-26	21	45	34	0.078	0.390	3.52E-07
26-47	13	49	38	0.077	0.370	1.75E-07
47-75	12	59	29	0.053	0.288	6.73E-08
75-140	23	50	27	0.078	0.441	1.47E-06

Materials & Methods:

- Alternative drainage system designs were then evaluated under both actual and hypothetical rainfall event scenarios (Table 2)

Table 2. (a) Modelled alternative systems and (b) rainfall events

System	Description
1	As installed at field site
2	Tile drains only (without mole drainage)
3	K_s above mole channels decreased to mimic poor installation or deterioration
4	K_s above mole channels increased to mimic improved initial disturbance/fissuring

Events	
A	Actual: 156.4 mm of rainfall over 5 days
B	Actual: 516.0 mm-Oct 1st to Dec. 31st 2015
C	Hypothetical: Fixed Rainfall: 2 mm/hr for 50 hrs
D	Hypothetical: Historical Rainfall: 30 year average rainfall (1185 mm) applied at daily time steps

Results:

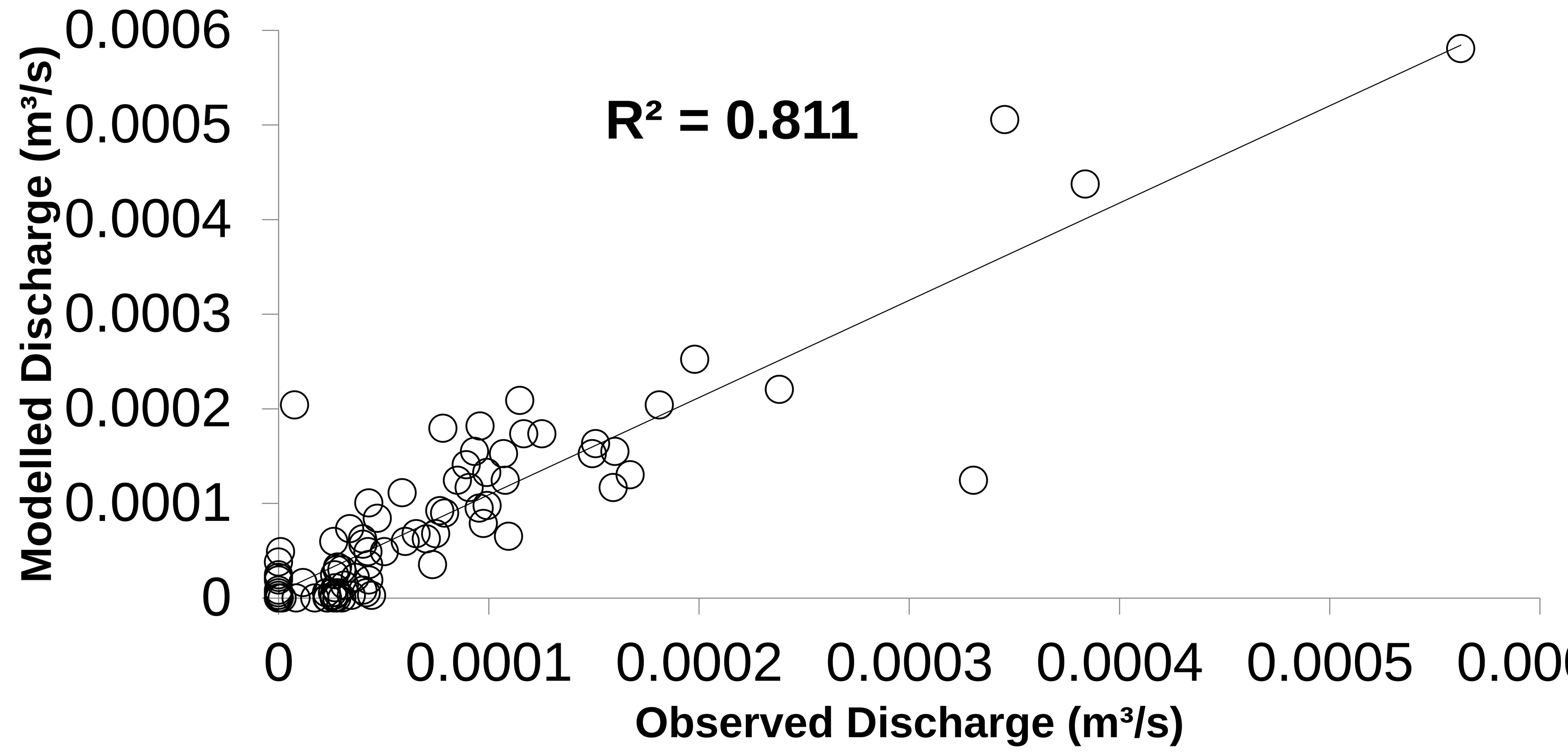

Figure 1. Modeled vs. observed daily tile drain discharge (m³/s) from System 1 during the validation event (Event B). Index of Agreement = 0.94

- System 2 consistently had the lowest average and total discharge, while Systems 1 and 4 were the best performing systems.
- The performance of System 3 was comparable to System 2 during high intensity rainfall Events A and C where its capacity was clearly exceeded, but performed relatively well during lower intensity rainfall Events B and D

Table 3. Modelled performance of drainage systems during rainfall events

		System				
	Event	1	2	3	4	S.E.M.
Average Discharge (m³/s)	A	$4.31 \times 10^{-04}{}_a$	$4.18 \times 10^{-05}{}_c$	$2.15 \times 10^{-04}{}_b$	$4.51 \times 10^{-04}{}_a$	1.49×10^{-05}
	B	$7.62 \times 10^{-05}{}_a$	$3.41 \times 10^{-05}{}_b$	$7.34 \times 10^{-05}{}_a$	$7.62 \times 10^{-05}{}_a$	4.68×10^{-06}
	C	$6.39 \times 10^{-04}{}_a$	$9.77 \times 10^{-05}{}_c$	$4.69 \times 10^{-04}{}_b$	$6.39 \times 10^{-04}{}_a$	1.63×10^{-05}
	D	$5.71 \times 10^{-05}{}_a$	$4.49 \times 10^{-05}{}_b$	$5.70 \times 10^{-05}{}_a$	$5.71 \times 10^{-05}{}_a$	2.58×10^{-07}
Average WT depth (m)	A	0.78_b	0.50_c	0.54_c	0.89_a	0.009
	B	0.88_a	0.36_c	0.73_b	0.90_a	0.016
	C	0.73_b	0.02_c	0.02_c	0.88_a	0.029
	D	0.89_b	0.07_d	0.79_c	0.90_a	0.009

Means having the same subscript letter are not significantly different. Comparisons significant at the 0.05 level.

Conclusions:

- The SEEP/W software was shown to offer reliable predictions of tile drain discharge of a tile/mole drainage system and offers a reliable methodology of assessing design variations of such systems.
- The poor performance of the tile only system showed the limitations of such systems in fine impermeable soils.
- The greater the improvement in soil hydraulic conductivity brought about during mole channel installation the better the system capacity and performance will be.