ESCUELA COLOMBIANA DE INGENIERÍA JULIO GARAVITO

South América, Colombia, Bogotá.

# NON - VEGETATED STANDARD BIORETENTION STRUCTURE HYDRODYNAMIC SOIL CHARACTERIZATION FOR PONDING - LAYER OPTIMUM THICKNESS DETERMINATION WITH A DISTINCTIVE URBAN - REGION RAINFALL EVENT IN BOGOTA

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# Where is Bogotá Colombia?

# CONTENTS

# Rainstorm Characterization in Bogota City

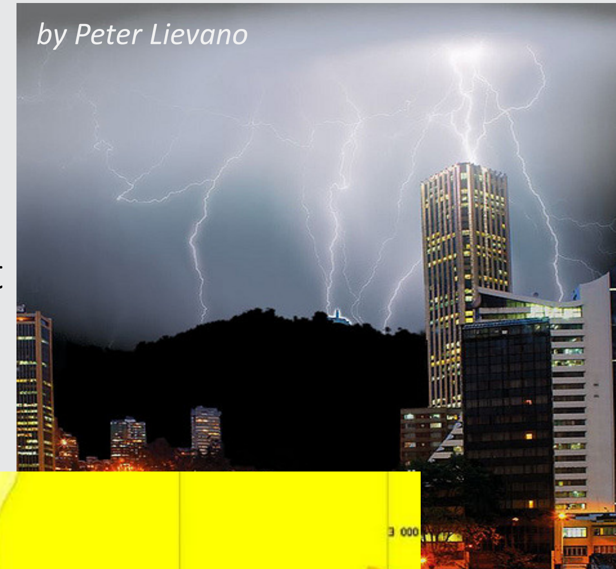
Escuela Colombiana de Ingeniería Julio Garavito

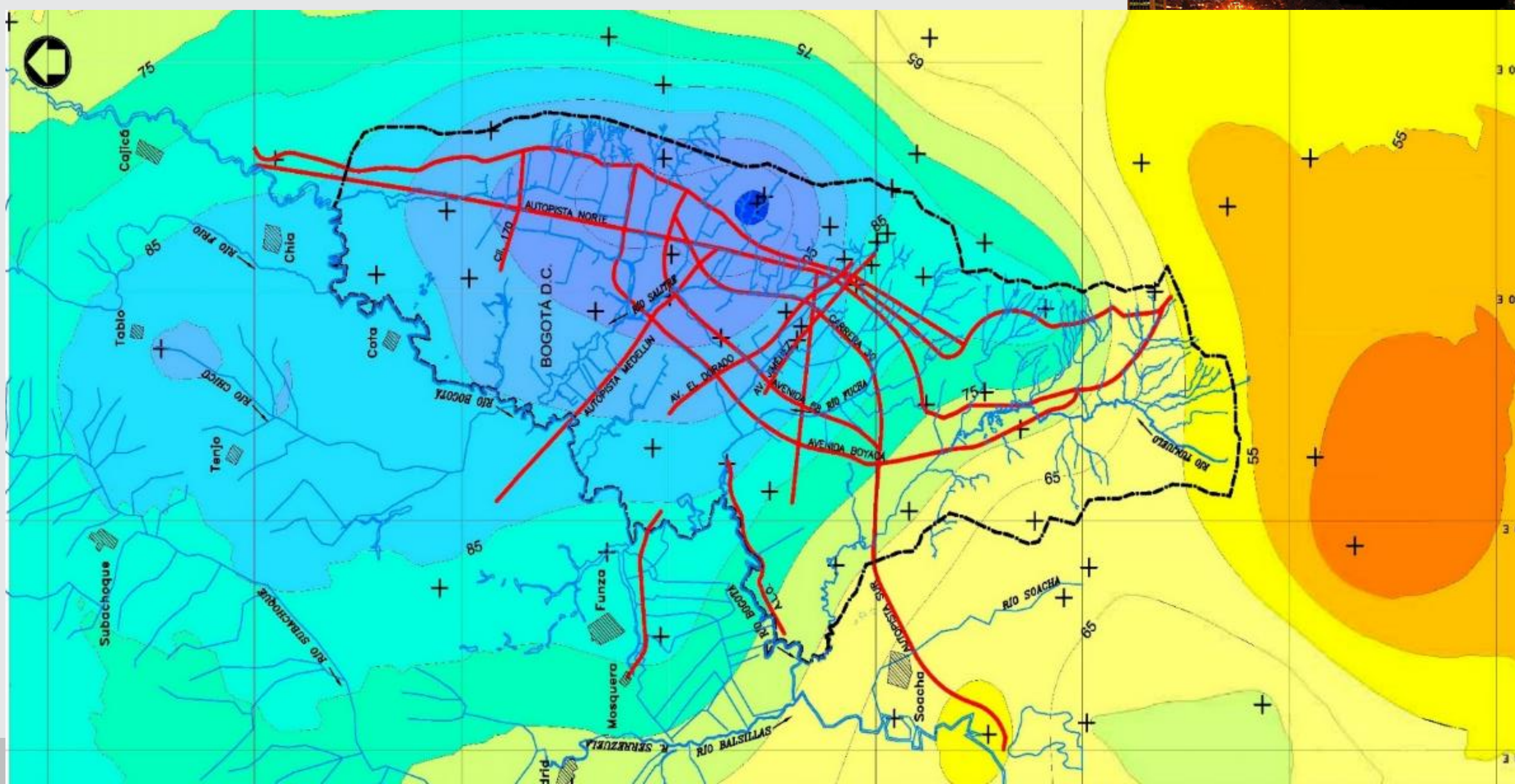
Bimodal rainfall pattern

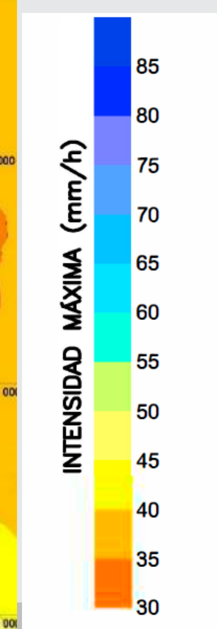
- April and May, has characteristic values from 69 mm in the west to 142 mm in the north of the city (montly average precipitation).

- October and November, rain values from 70 mm in the West to 126 mm in the north can occur.

- Elliptical pattern



# Susceptibility Facing Flooding in Bogota

Generally these areas in Bogota, in winter seasons are highly susceptible of flooding by overflows, ponding and landslides, as a consequence of drainage obstructions, water currents diversion or saturation of some sewerage systems.

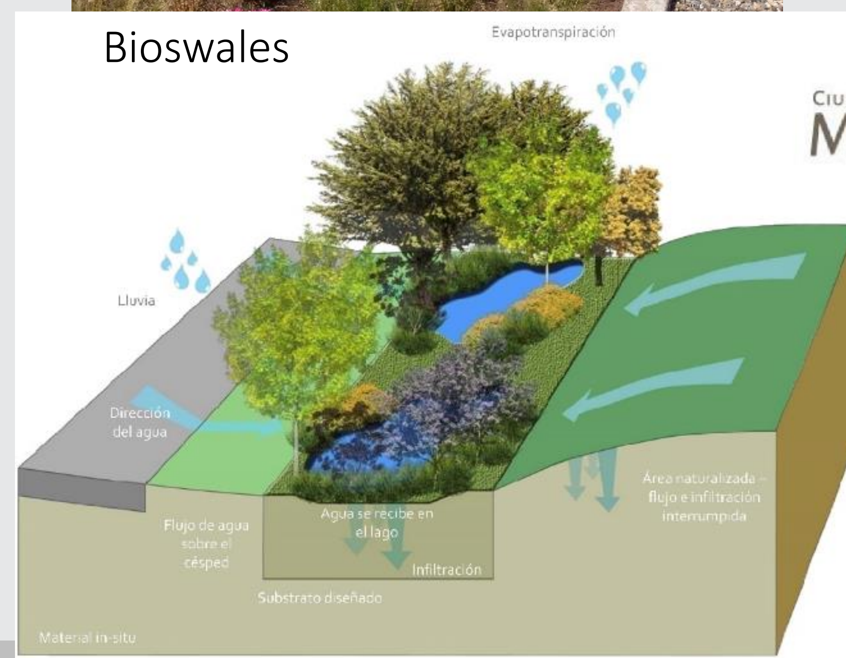

Bogotá:
Population: 8 million Hab.
Urban Area: 384 $Km^2$
Population Density: 13500 hab/$Km^2$.

# Applied BMP Solutions in Bogota

## Permeable Surfaces

## Rain Gardens

## Bioswales



# Objectives – Present Investigation

1. Identification of the components of a Bioretention structure to apply in the city of Bogota.
2. Selection of dimensions and/or requirements of soil, aggregates and membranes which compose the proposed Bioretention structure.

Methodology :

- To build and size an experimental prototype
- To develop the suitable instrumentation to make automatic data capturing in the experimental pilot, in real time, with a user friendly interface and display.
- Using the Hydrus 1D inverse solution:
  - Determine the hydrodynamic properties of the technosol (without vegetation)
  - Establish the suitable layer thickness for the storage layer and its application for a typical rainfall event in the urban zone of Bogota city.

# Methodology and Materials

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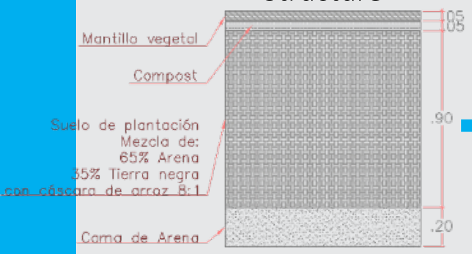
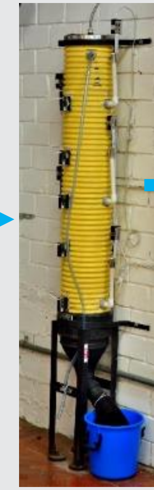
Proposed Bioretention Structure



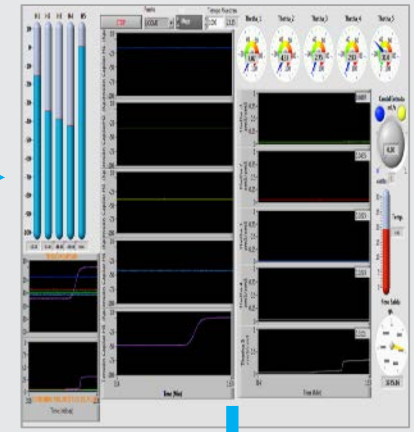

Soil Selection and Design

Physical Characterization of Soils

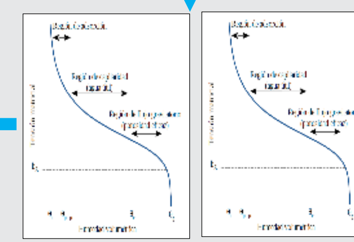
Experimental Pilot



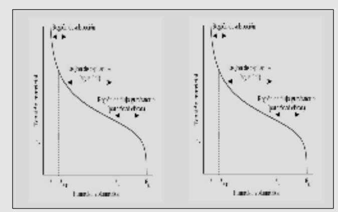
Instrumentation and Automatic Data Capture



Soil Retention Curves



Hydrus 1D Inverse Model. Parameter Estimation, Grey Box Technique

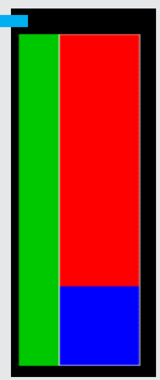


Inverse Model Results

$$k_1, \alpha_1, n_1, \; m,_1 \;\; i_1$$

$$k_2, \alpha_2, n_2, \; m,_2 \;\; i_2$$

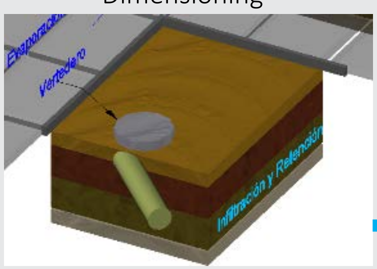
New Direct Model



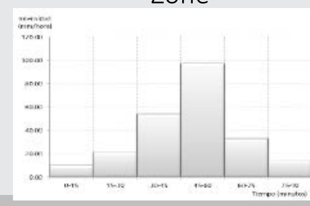
Suitable Retention Volume Estimation

**Desing Criteria: Retention Time And Retention Volume**

Final Bioretention Structure Dimensioning




Rainfall Event for the Study Zone



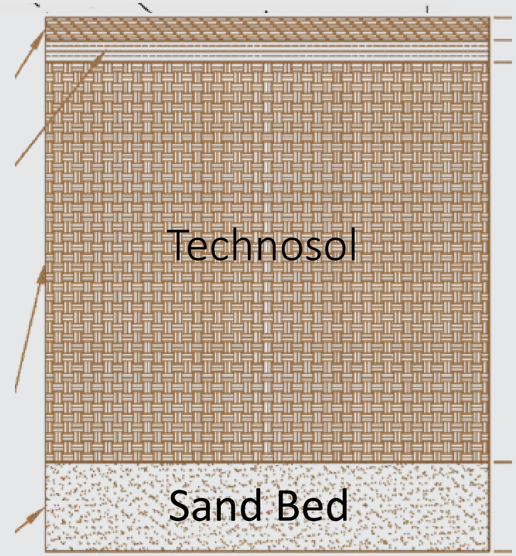
Direct Model with Hyetograph

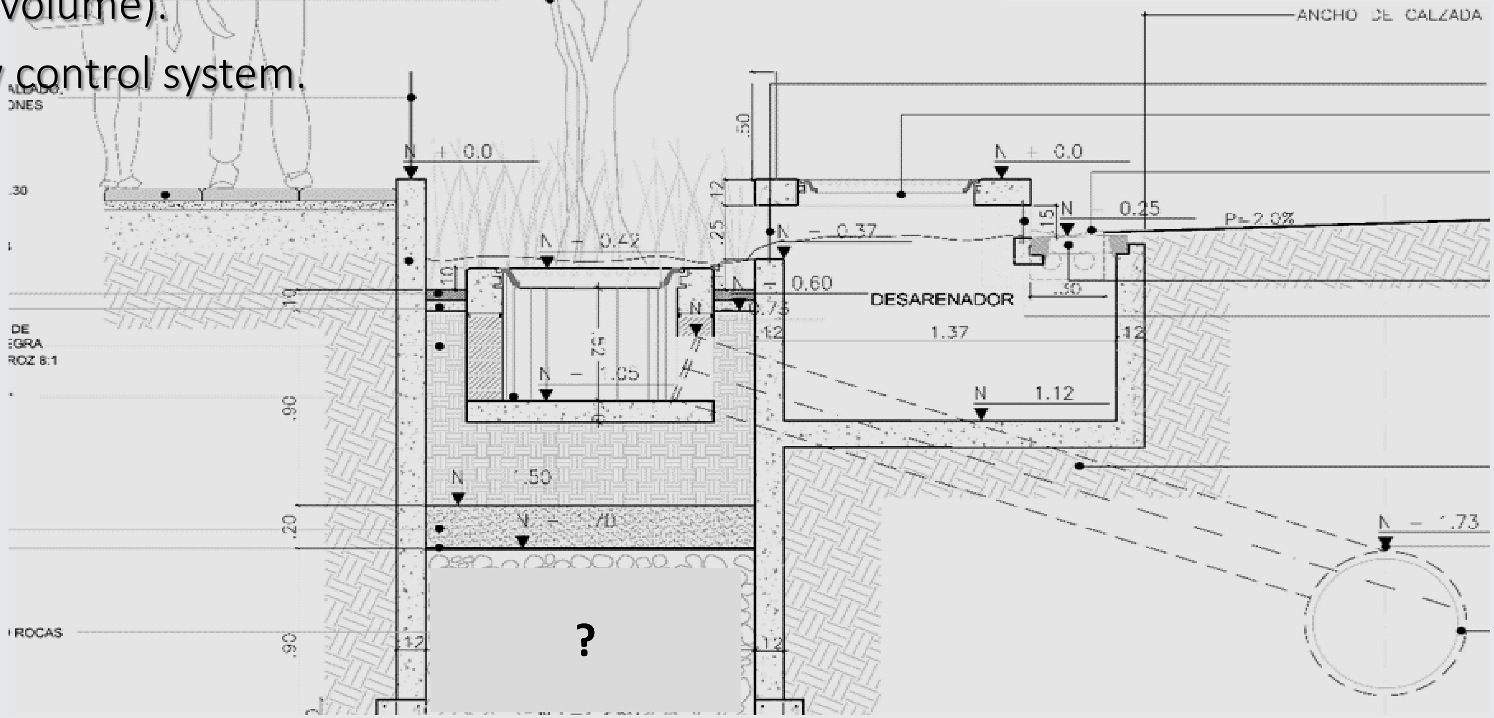
**vGM model**

**Out=?** Analysis Result

# Proposed Bioretention Structure

- Inlet flow control,
- Pretreatment,
- Surface flooding area.
- Superficial organic layer
- Vegetal layer.
- Vegetation support layer (Technosol).
- Sand bed.
- Gravel composed sub-drainage system (retaining volume).
- Overflow control system.



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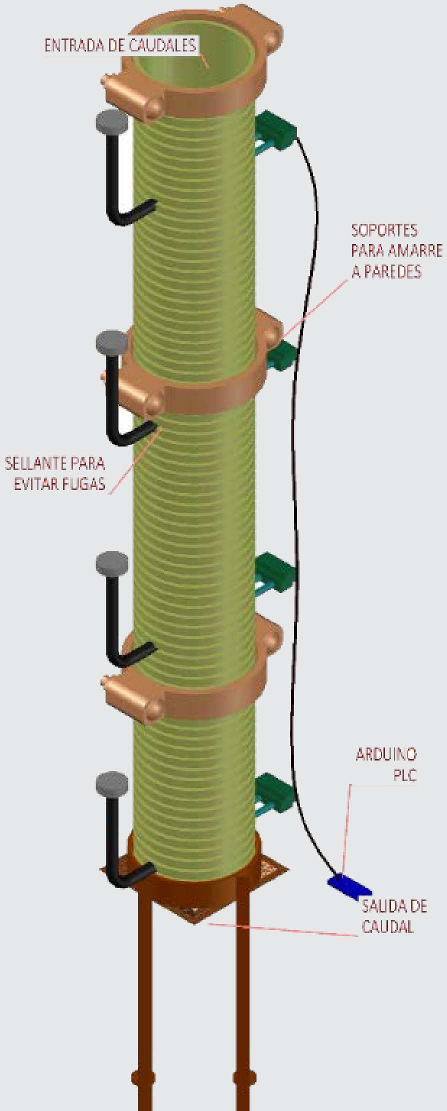
# EXPERIMENTAL PILOT: SOIL COLUMN




Spray Nozzle

System with Pumping, Recirculation and Constant Level Tank

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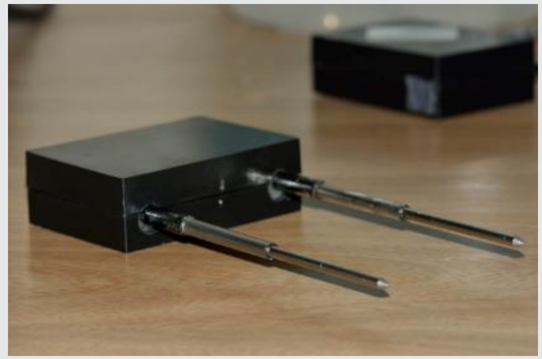
# INSTRUMENTATION

## Tensometers

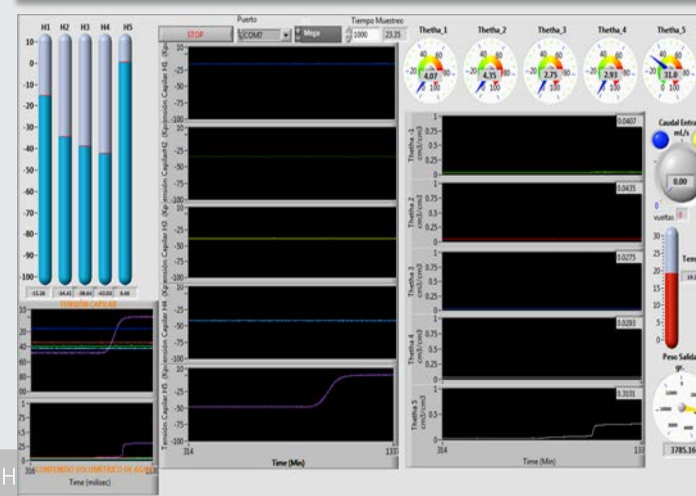
## Hygrometer



## Inlet Flow Measurement

## Thermometer

## AUTOMATIC DATA CAPTURE SYSTEM



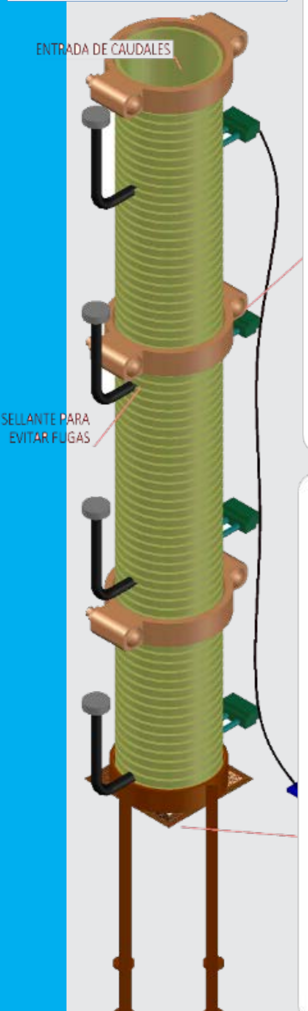
## Arduino Mega PLC

## Outlet Flow Measurement

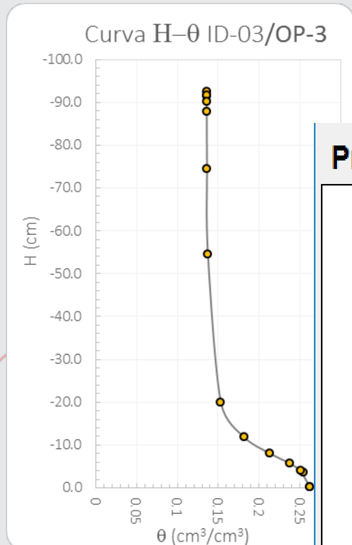
# RESULTS: Inverse Model, Soil Hydrodynamic Calibration

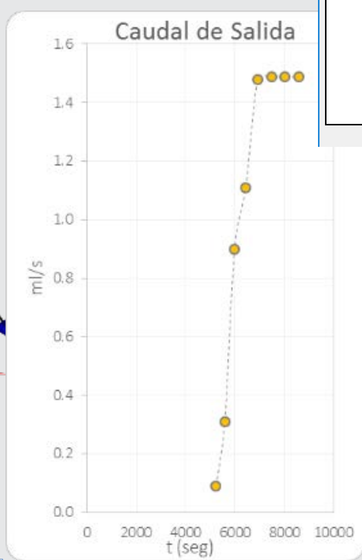
Capillary barrier formation between both layers was observed.

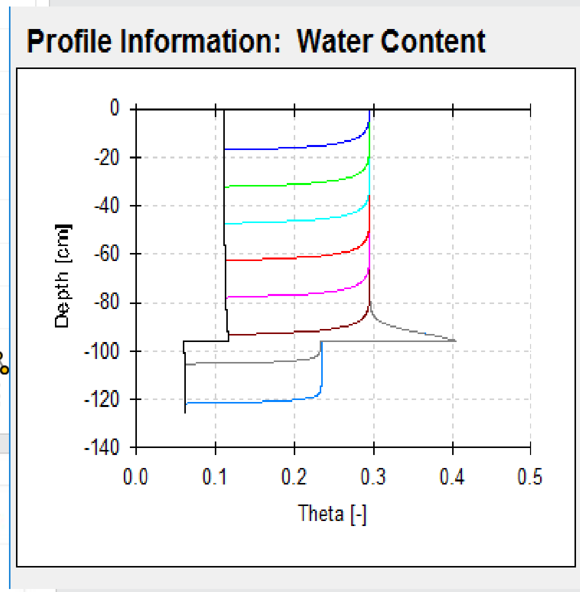
Constant Flux

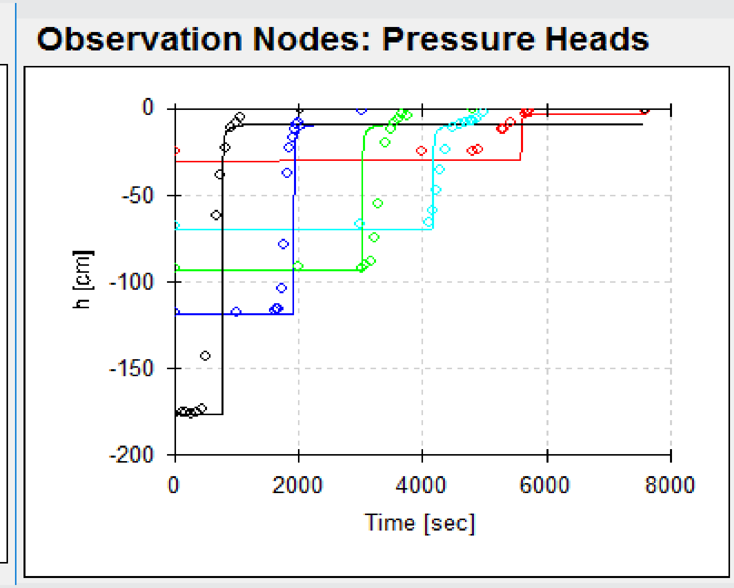



Free Drainage



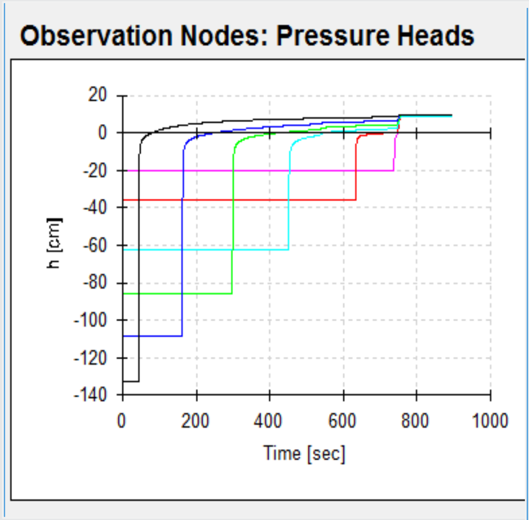



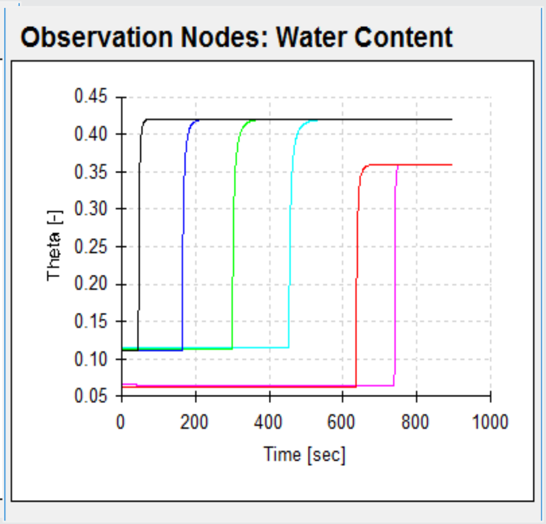

- A high value for n indicates that the soil has great content of sand; that the characteristic flow is not so diffuse and it is close to a piston-kind flow.

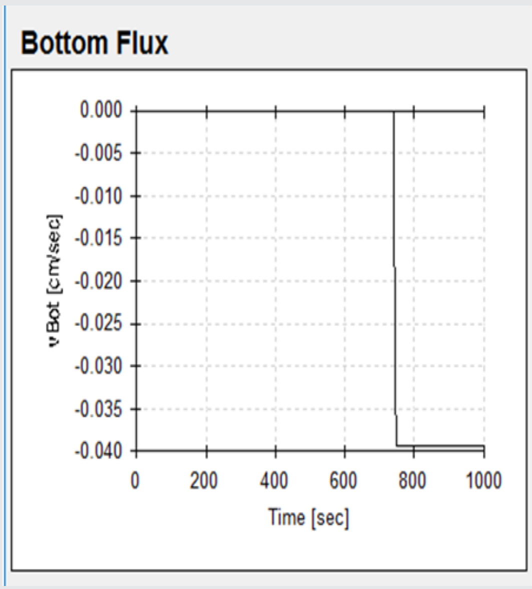
- The low correlation between the n, ks and α parameters indicates that the soils are well distinguished and that there is no dependency between them.

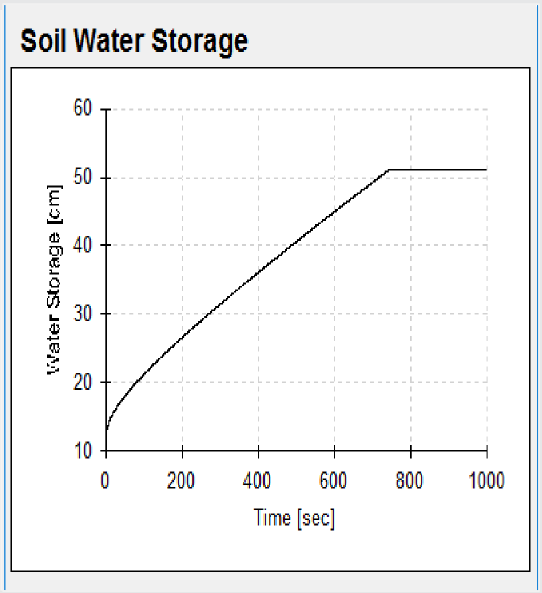
# RESULTS: Direct Model, Storage Layer Sizing






The pressure varies until it rises a pressure head of 10 cm.

Outlet flow => the retention time is approximately 12.3 minutes

Soil storage for a given event, depends on the resident moisture value of the preceding event: the maximum storage is 511 mm.

Rock Layer: The rock layer thickness was made up of rocks used to make cyclopean concrete. (Total Porosity 60%)

A thickness of 0.8 to 1.0 m is recommended.

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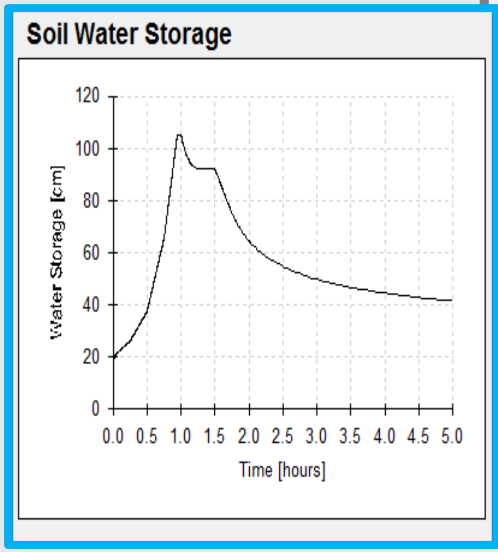
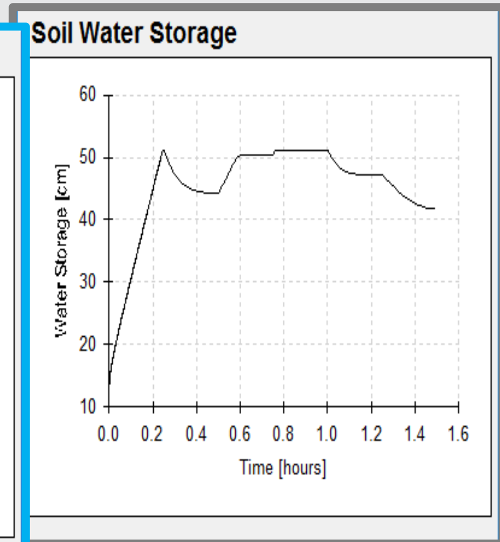
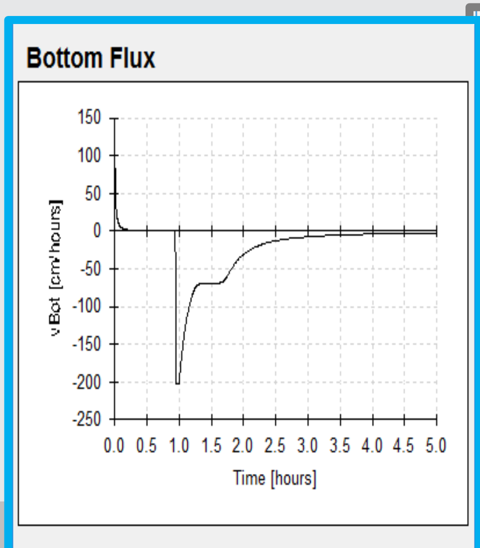
# RESULTS: Application Example with Inlet Rain

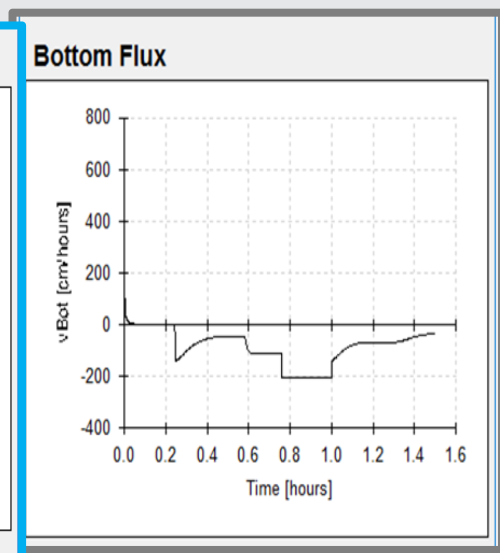


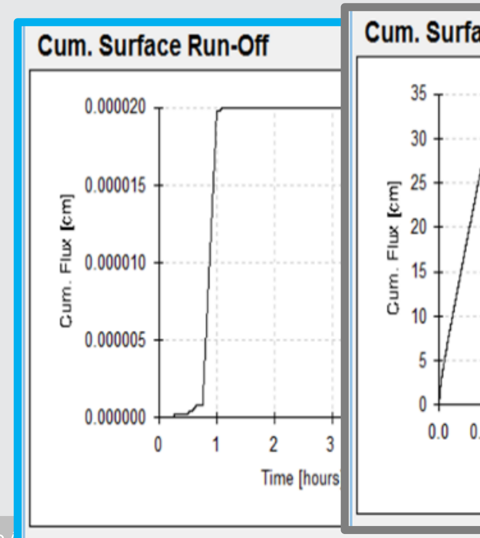



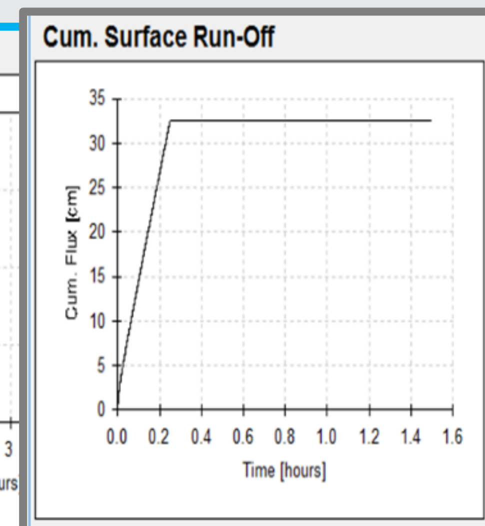

The storage capacity enhances when there is a retention layer.

The discharge in the bottom shows that when there is a retention layer, the water moves easily until it is settled in the mentioned layer



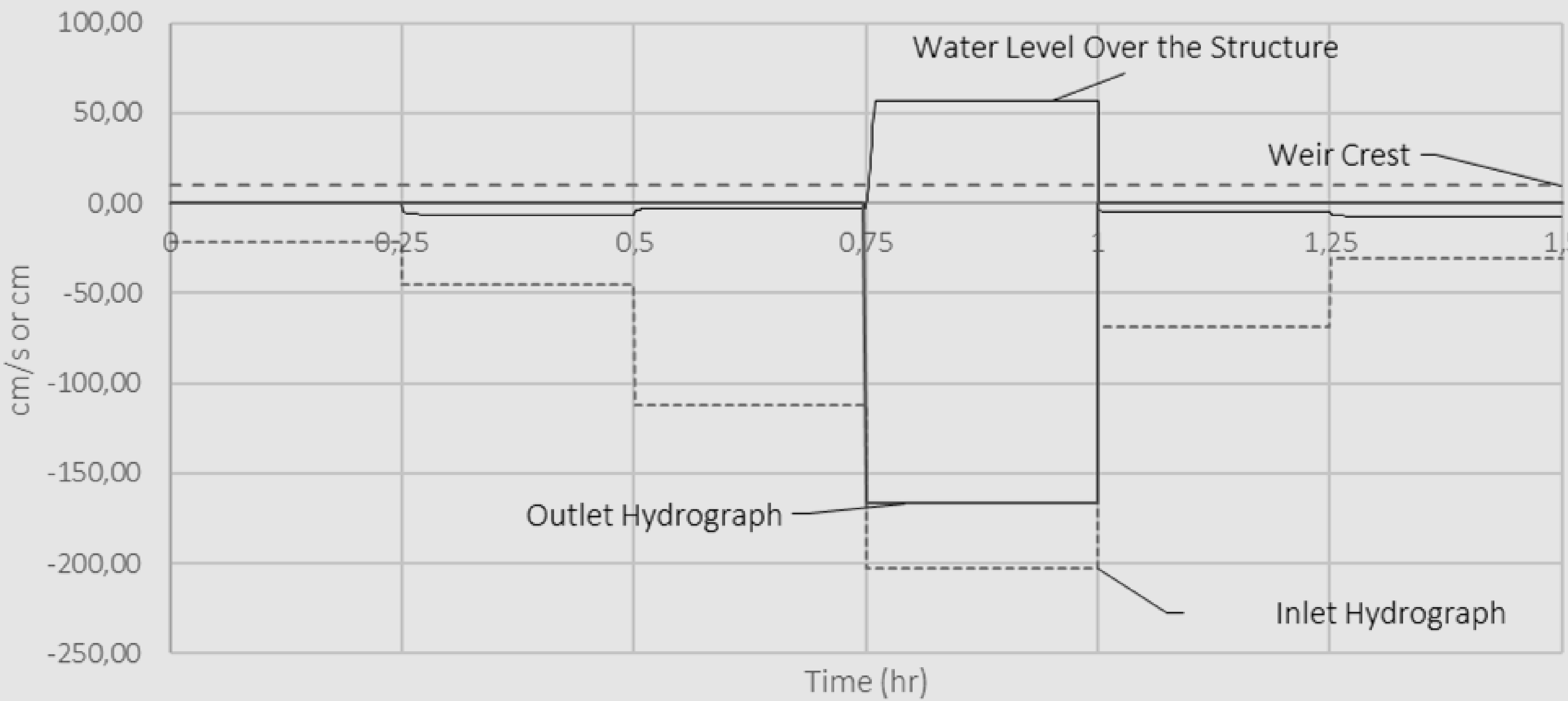



# RESULTS: Application Example with Inlet Rain

Inlet Hydrograph vs. Water Storage Over the Structure




This schema shows that at first, all the inlet flow in the soil is controlled by infiltration. Once the spillway elevation (weir crest) is reached and the excess goes out of the system, the small increases of flow are retained in the structure and stored in the soil.

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# CONCLUSIONS

In general:

- Numeric Modelling + Soil Physical Tests + Soil Column Experimenting → were sufficient and very adequate in the bioretention system design.
- Hydrus 1D Developed model: it could be demonstrated the importance of the water storage in bioretention systems as its dimensioning coming from different boundary conditions.

BMP Structure/Technosol proposed design for Bogota:

- It is recommended to make a rock layer, with porosity of 60%, of about 0.8 to 1.0 m depth.

- The structure reduces the runoff peak.

Exerimental Pilot:

- Good model adjustment (RMSE = 0.72).
- Uncertainty in the measure of $\theta$ close to the soil saturation
- Possible soil densification thoughout some tests soil (the Surface reduced its level in 5 cm in some tests).

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# Further Investigation

- Construction of a pilot, scale 1:1, to incorporate diverse native plants of Bogota city, aiming to make physical-chemical analysis (chemical retention) and influence on the water cycle.

- Study and characterization of the plants that are part of standard bioretention structures in Bogota.

- Applied phytoremediation in the proposed standard bioretention system, using vascular native plants of the savannah region of Bogota, in the removal of heavy metals and motor oil that come from urban roadways.

# More Information

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