HydroGEN

# Impactful engagement through games: Examples and experiences from a successful outreach collaboration

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PRINCETON UNIVERSITY

Integrated GroundWater Modeling Center

HydroFrame

# The Partnership:

# IGWMC and the Watershed Institute

The Integrated GroundWater Modeling Center (IGWMC) is a research center housed within the Civil and Environmental Engineering Department at Princeton University.

The researchers and students of the IGWMC focus on using field observations, hydrological models, and emerging technologies like machine learning to address important water and climate related issues.

The researchers and students working in this center also support a mission to develop and promote education and outreach in our community. Much of our outreach focuses on providing fun, social, hands-on activities that are gamified for maximum impact.

The IGWMC has an ongoing partnership with the Watershed Institute, an organization in Pennington, New Jersey, that supports a wealth of community focused education, advocacy, and stewardship initiatives.

Through the Watershed Institute's Watershed Academy program for high school students, researchers, and students from IGWMC were given the opportunity to host a week-long educational camp, focused on water and climate.

## Water and Climate Academy

During this week, high school students attending engaged with scientists, engineers, graduate students, and undergraduate students to learn about and engage with water and climate topics.

We will discuss a collection of gamified activities that have been developed and used for these events along with the impactful experiences had by all.

# The Games and Activities

*Click a circle to learn more*

Choose Your Own Water "Adventure"

DIY Soil Permeameter

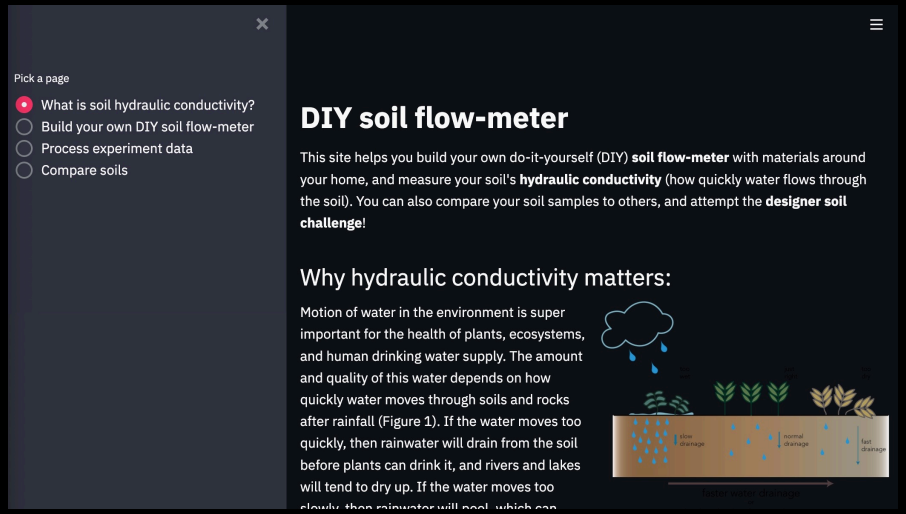
ParFlow Sandtank: Agrosystem

Machine Learning: Sandtank-ML

Machine Learning: Training Card Game

Hydrology: Water Balance

# Engineering Design:
# DIY Soil Permeameter




This online application helps you build your own soil permeameter with materials around your home, then measure the hydraulic conductivity (how quickly water flows through the soil) of your own soil sample.

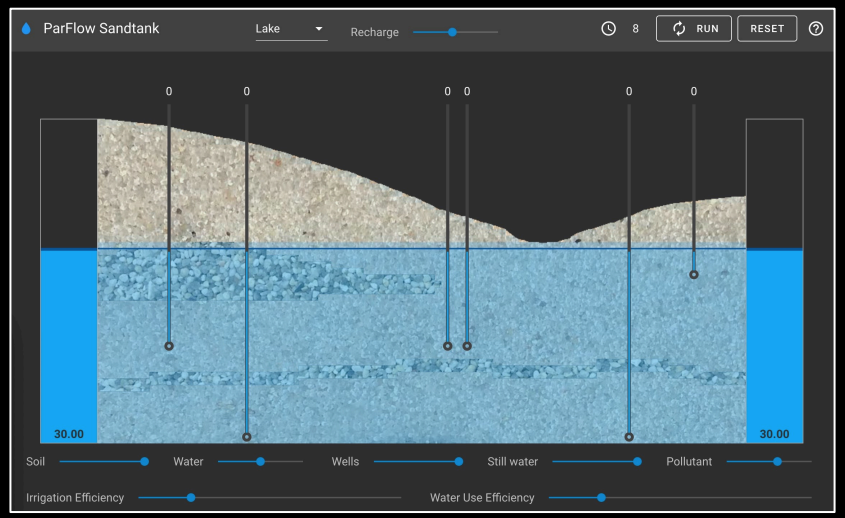
You can also compare your soil samples to others and attempt the designer soil challenge!

Try DIY Permeameter

# ParFlow Sandtank: Agrosystem

An online gamified tool that lets users interactively simulate and visualize groundwater movement through a virtual slice of the subsurface. Users can adjust groundwater levels, change subsurface properties, pump groundwater, and add pollutants then watch the system respond in real time.

The ParFlow Sandtank was developed to mimic the capabilities of physical groundwater models and overcome inherent limitations.

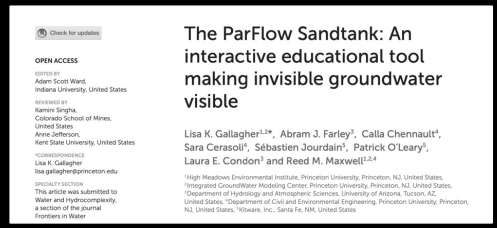



Try ParFlow Sandtank Agrosystem

Please also find a user manual and other resources at: hydroframe.org/groundwater-education-tools/

The Agrosystem is an advanced ParFlow Sandtank template with enhanced capabilities to explore topics like climate change and sustainable agriculture practices.

Publication:



The ParFlow Sandtank: An interactive educational tool making invisible groundwater visible

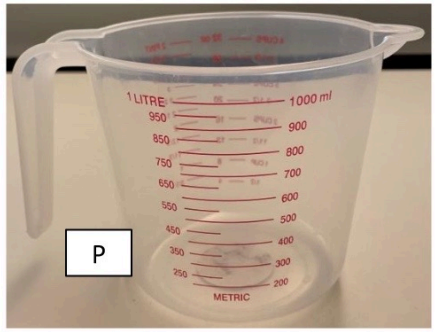
Lisa K. Gallagher[1,2*], Abram J. Farley[2], Calla Chennault[4], Sara Cerasoli[4], Sébastien Jourdain[5], Patrick O'Leary[5], Laura E. Condon[3] and Reed M. Maxwell[1,2,4]

# Hydrology:
# Water Balance

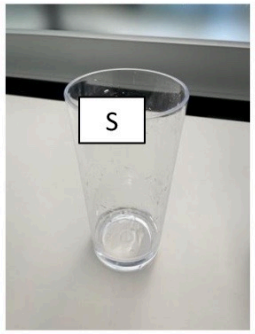
**WATER BALANCE ACTIVITY**

$$S_{day1} - S_{day2} = P_{day1} - ET_{day1} - R_{day1}$$

(S=storage, P=precipitation, ET=evapotranspiration, R=runoff)








An activity using basic materials to actively teach the components of the water balance—gamify this activity by challenging students to write their own scenarios that could lead to various water balance conditions with respect to storage, precipitation, evapotranspiration, and runoff or buy, sell, and trade various components to reach a desired outcome.

# Machine Learning: Training Card Game

This game was developed to teach students about the importance and dynamics of data quantity in the ML model training process.

Training cards have four input variables and one output variable, water table depth.

Input

| | |
|---|---|
| Soil Hydraulic Conductivity | Medium |
| Total Annual Precipitation | High |
| Average Annual Temperature | Medium |
| Ground Slope | Medium |

Output

| | |
|---|---|
| Water Table Depth | High |

| | |
|---|---|
| Soil Hydraulic Conductivity | Low |
| Total Annual Precipitation | Low |
| Average Annual Temperature | High |
| Ground Slope | Medium |

Output

| | |
|---|---|
| Water Table Depth | Low |

Each card represents a site with a certain set of characteristics, represented by input variables. We want to predict the water table depth at these sites using patterns we learn from our training data.

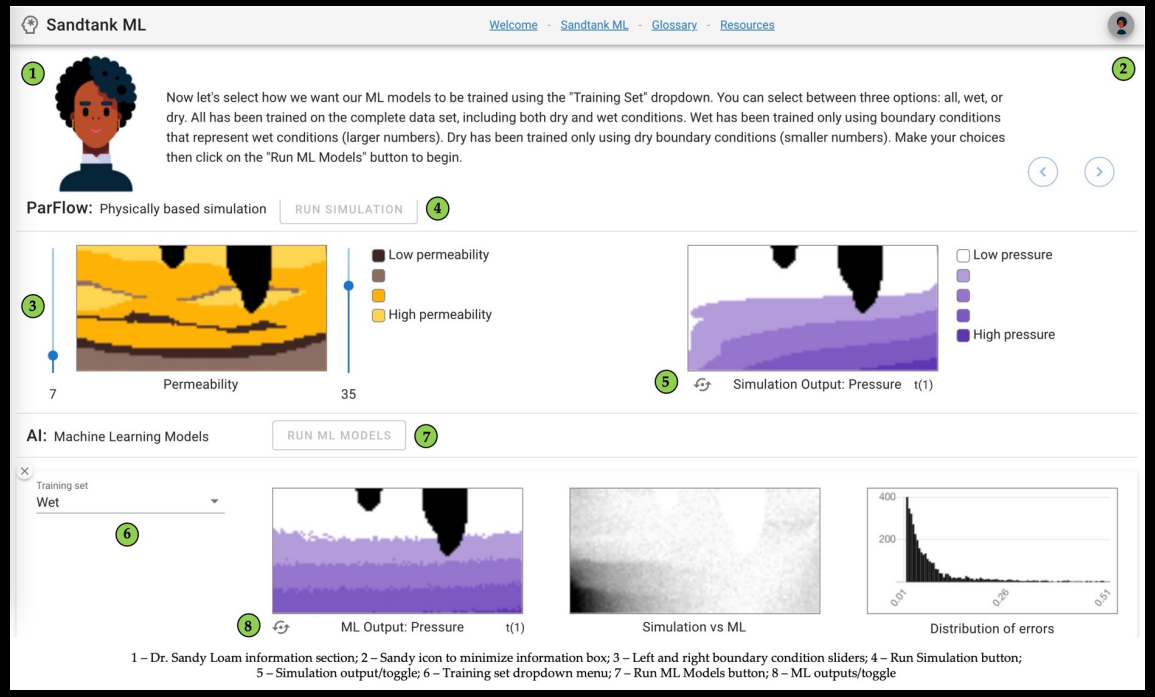
Input variables can either be 'Low', 'Medium', or 'High'. For example, a 'Low' value for Total Annual Precipitation would indicate that this site does not experience much annual rainfall.

The output variable, water table depth, can only be 'Low' or 'High'. For our testing cards, the output variable will be blank so you can make your predictions!

The game was played in 3 rounds:
Round 1: 4 training cards and 4 testing cards
Round 2: 6 training cards and 4 testing cards
Round 3: 10 training cards and 4 testing cards

# Machine Learning: Sandtank-ML

Dr. Sandy Loam guides you through the application




Sandtank-ML allows users to run various ML models and manipulate training sets and other components to explore how particular decisions impact model accuracy. The goal of the application is to help users gain an understanding of basic ML approaches and processes, while building confidence in ML as a tool that can be used to understand and address real world environmental issues.

## Gamifying Sandtank-ML

Competition to build the best and worst performing ML models

Try Sandtank-ML

Publication:


water
MDPI
Article
Sandtank-ML: An Educational Tool at the Interface of Hydrology and Machine Learning
Lisa K. Gallagher, Jill M. Williams, Drew Lazzeri, Calla Chennault, Sebastien Jourdain, Patrick O'Leary, Laura E. Condon and Reed M. Maxwell

# Choose Your Own Adventure: Clean, Safe Water

## Start Here

Picture this: You're the sole income earner in your family of 6 living in the Dharavi slums of Mumbai, India. It is the 4th of August - the peak of the annual rainy season, and the water filtration system you had bought from your house has stopped working. Having it fixed is not an option right now, your salary isn't due for a week and the warranty ran out years ago. Your family depends on you to find a way to get them water to drink and cook food with. Are you ready to make the decisions and face the opportunity costs that millions in the developing world currently have to?

For some co[illegible], Mumbai is the financial capital c[illegible]d. Yet, Dharavi is amongst Asia's largest and most densely populated slums. With no centralised access to drinking water, people here rely on either mini water filtration systems, or purchase bottled water from corner stores. Monsoons here are devastating, with upwards of 90 inches of rainfall a year - that's 2x most parts of New Jersey. Poor infrastructure means overwhelmed sewers, waterclogged roads, and leaking ceilings. It is time to decide what to do:

**Drink water straight from the tap**

**Go to the market to buy bottled water**

**Head to the neighborhood groundwater pump**

A 2009 study in Lancet found that waterborne diseases like cholera take more than 3.4 million lives per year. Tap water in the slums of Mumbai is particularly notorious for being contaminated with Hepatitis A, Cholera, and Diarrheahea causing germs. Chances are, your family will soon become symptomatic for one of these.

8 hours later, everyone seems to have a stomach bug, and you realised you need to to try one of the other options. This time, you need to pick up medicine when you leave the house as well - you're worse off than when we started. ADD 6 HOURS & 400 rupees.

**Go to the market to buy bottled water and medicines**

**Head to the neighborhood groundwater pump for water and medicines**

You leave the house on fo[illegible]ad to the market.

You notice that the otherwise 10 minute walk is going to take you atleast 30 minutes - you're going to have to wade through waterclogged roads that rise up to your waist. Maybe taking a rickshaw is wiser?

**Hail a rickshaw**

**Keep walking**

Water and Climate Academy students connected with undergrad intern in Mumbai to learn about a completely different perspective and outlook on daily water needs

Walk through activity, making decisions that affect your ability to access clean, safe water for you and your family

Storyline based on real lived experiences from student's community in Mumbai

Gamified by limiting time or money or competing for the least amount of money or time spent to get clean, safe water

Real value of this gamified lesson is expanding students' understanding of water availability and accessibility worldwide, not just in the US or their community

# Thank you for stopping by!

# Please reach out with any questions or to connect

Abstract

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**THANKS TO ALL THE IGWMC STUDENTS AND RESEARCHERS FOR SHARING THEIR TIME AND EXPERTISE!**

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