Hydrology model for educational purposes

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Abstract

Lake Champlain, situated between the border of Vermont, New York State and Québec, is subjected to large sediment and nutrient loadings originating throughout its 8,234-square mile watershed. High phosphorus concentrations can be observed throughout regions of the lake. This has enormous potential to lead increased algae blooms and excessive plant growth, causing harm to the local ecology, aquatic species, as well as limit the overall use of the lake (Lake Champlain Basin Program, 2016). Many of the nutrients that end up in the lake are a product of agricultural activity. The project objective was to create a three dimensional (3D) physical model illustrating watershed processes focused on streambank erosion in the Mad River Basin, Missisquoi Basin and other forested landscapes using an Augmented Reality (AR) Sandbox. This model will be integrated in educational modules at the University of Vermont.

Introduction

In this project, we built an Augmented Reality (AR) Sandbox. We focused on a 3D visualization app to teach concepts related to hydrology and earth sciences. Virtual topography and water features are projected onto sand using a closed loop with the Microsoft Kinect 3D camera, a powerful simulation and visualization software (LINUS), and a data projector.
The sandbox is a flexible educational tool that can be used to explore the importance of water, via lines of inquiry in hydrology, earth science, and environmental studies.

The sandbox is a flexible educational tool that may be used to explore the importance of water movement. Water is a critical resource for all life on earth. The landforms found on the earth's surface were created by a variety of processes such as erosion, tectonics and glaciation. When water flows on the Earth's surface, it travels, converges and diverges based on the shape of landforms. This distribution of water which leads to regions called watersheds plays a key role in the type and distribution of ecosystems around the world (Lake Visualization 3D, 2012).

Key processes represented by Lake Champlain watershed models should include (Dec-Nysdec, 2002):
• Rainfall and runoff
• Erosion and sediment transport
• Pollutant loading (e.g., wash-off pollutants from a land surface).
• Stream flow and sediment transport
• Management practices such as measured loadings and expected water quality impacts, including farming or land-based fertilizer application, structural, or input/output to streams (e.g. wastewater treatment)

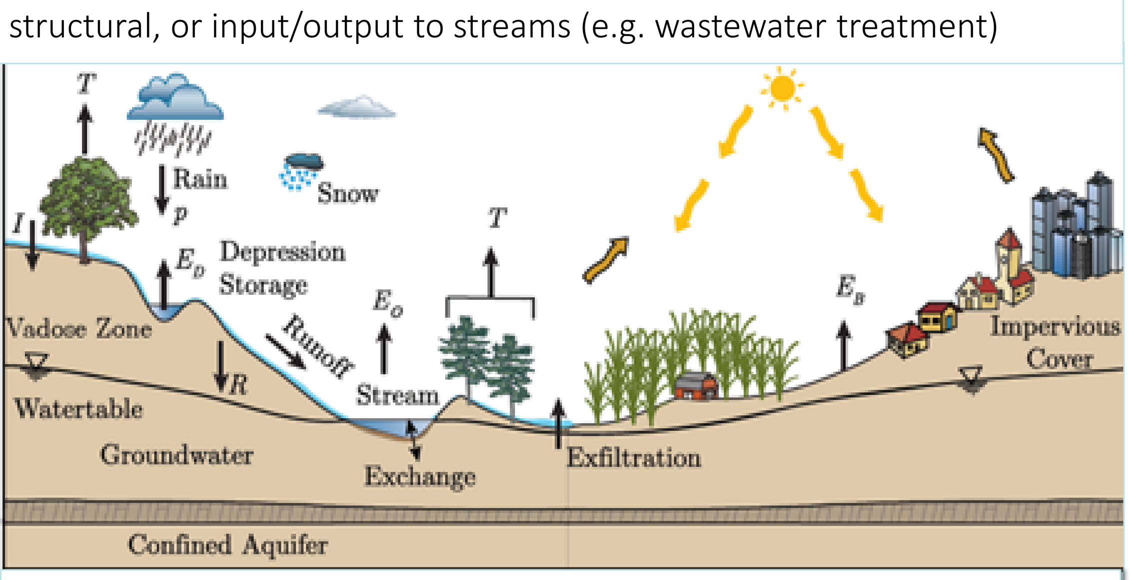

Figure 1. Watershed Processes ("Computational Hydrology and Reactive Transport @ MSU," n.d.)

Sandbox Main Purposes

General
• Defines the shape of the Earth's surface defining watersheds.

Topographic Maps
• Understand the construction of topographic maps and the use of contour lines to show the earth's surface in 3D. Create a 3D model from a topographic map.

Geology
• Understand how the earth's surface changes through natural processes such as erosion and deposition, which are driven by movement of water.

Hydrology
• Understand how liquid water moves on the earth's surface and how its flow relates to land surface elevation and shape.
• Understand the diversity of landforms and water bodies found on the planet.

Q2 Team

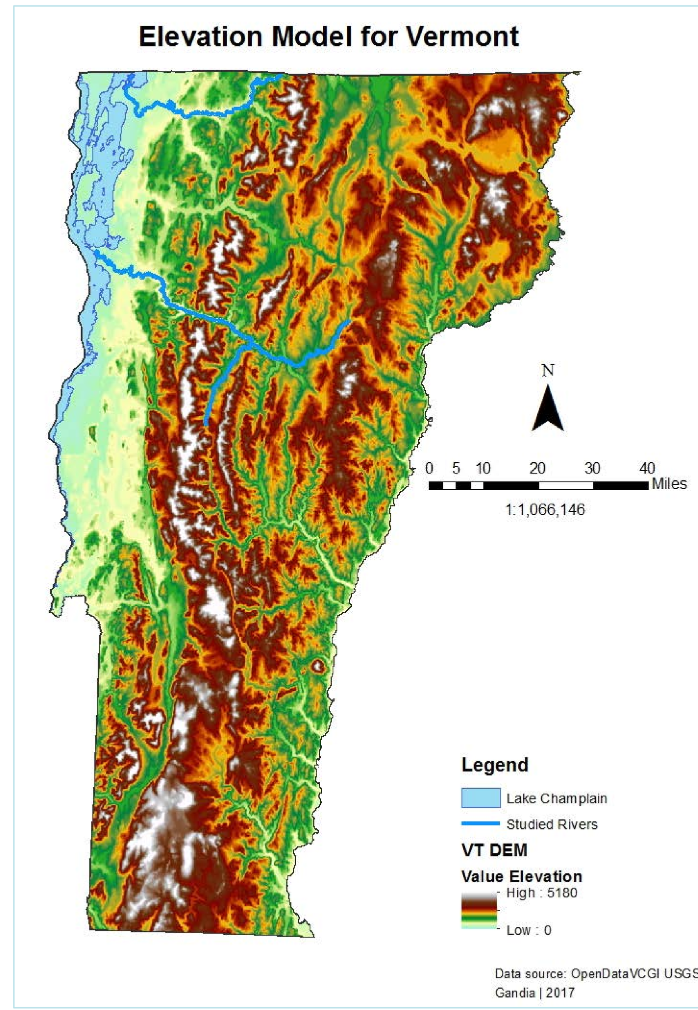

Figure 2: a) Elevation Model using Geographic Information Systems. A Digital Elevation Model (DEM) layer was used to determine the terrain elevation in Vermont. Data Source: Vermont Center for Geographic Information, Inc., U.S. Geological Survey (USGS), EROS Data Center. b) As-built Augmented Reality Sandbox.

Building the Augmented Reality Sandbox requires:
- a computer with a good graphics card, running any version of Linux,
- a Microsoft Kinect 3D camera,
- a digital data projector with a digital video interface, (e.g. HDMI, DVI, or DisplayPort,
- a frame to house the sandbox,
- an overhead mount for the Kinect camera and projector, and
- kinetic sand.

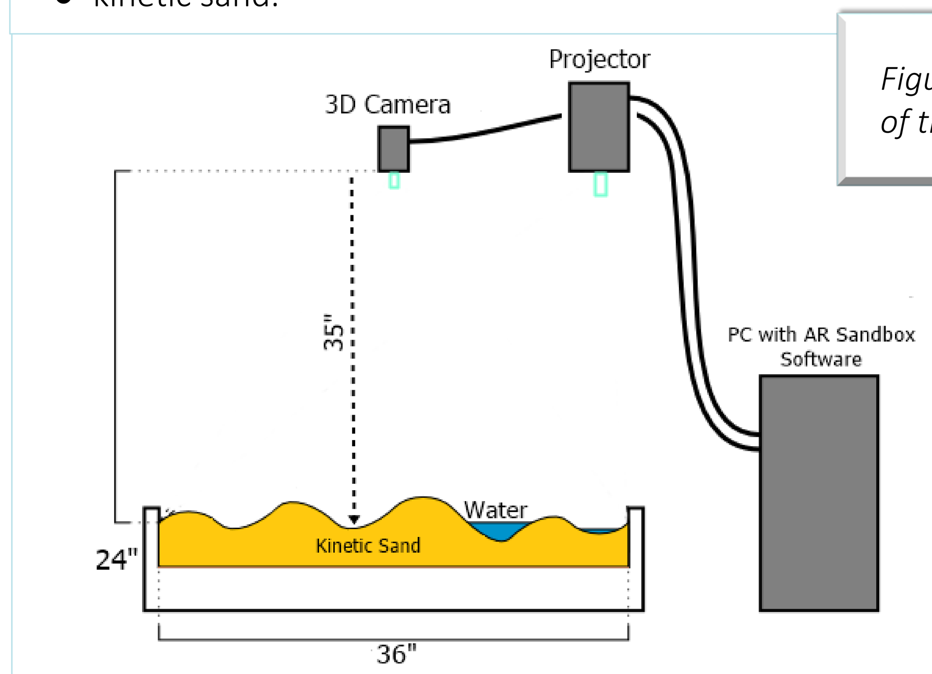

Figure 3: Measurements of the AR sandbox

Creating Kinetic Sand (Standard Operating Procedure)

We opted to make our own kinetic sand in lieu of commercially available kinetic sand. Our experimental design included, two concentrations of *Dimethicone*[1] (Dimethicone 500 and Dimethicone 1,000) and three grain sizes (No. 40, No. 30 and Original play sand), 5 oz. of Clear Glue, liquid starch and ultrafine sand.

Materials used

Samples

Testing Sieve

Grain Size

- Determine the amount of sand using a scale in pounds (lbs)
- Place sand in a sieve shaker to separate relatively uniform fine sand particles
- Place fine sand in a rectangular metal container and dry in an oven @ 130 °C
- Remove sand sample from oven using thermal gloves and cool the sample
- Weigh the empty container.
- Record results (e.g. total sample composition is 98% sand and 2% Dimethicone by weight)
- Determine the amount of Dimethicone needed using the formula:
  Amount of Dimethicone = (Amount of sand)/(0.98×0.02)
- Place an empty volumetric flask (at least 500 mL) on scale and reset scale to zero.
- Add the calculated amount of Dimethicone to the volumetric flask.
- Turn on the fume hood.
- In the fume hood, dissolve the Dimethicone in *Methanol*[2] using a solution ratio of 1:3 and seal the volumetric flask.
- Shake the solution until Dimethicone is completely dissolved and add it to the sand.
- Turn the heavy-duty mixer on (medium-high velocity) and mix for 5 minutes or until all sand is completely wet.
- Transfer the sample from the mixer container to a clean container.
- Label sample container with the contents, date, initials, and hazard identification.
- Lower the fume hood sash.
- Allow sample to air dry inside the fume hood for at least 24 hours.
- Check whether sample is completely dry, otherwise continue drying until the methanol completely evaporates.
- Wipe down lab materials (i.e. containers, whisker, beakers, flasks) with paper towels or cleaning wipes.
- Dispose of contaminated disposable materials (i.e. gloves, paper towels, etc.) in a clear plastic paper bag. (If materials are not contaminated with chemical residues, they can go in regular trash).
- Wash hands thoroughly.

(Procedure by Laura Obregón | Graduate student at University of Vermont)

[1]*Dimethicone* | ((C2H6OSi)n) *also known as polydimethylsiloxane, is a silicon-based polymer. This is used in various products like shampoo, creams, body wash etc.*
[2]*Methanol* | *(CH_3OH) Methanol is a clear, flammable liquid used in the manufacture of ACETIC ACID, in chemical synthesis, antifreeze. In this case it was used as a solvent.*

Kinetic Sand Testing

Seven experiments were designed and tested to determine which is the best kinetic sand for the AR Sandbox.

Samples	Grain size	Solutions
Sample 1	No. 40	Dimethicone 500
Sample 2	No. 40	Dimethicone 1,000
Sample 3	No. 30	Dimethicone 500
Sample 3	No. 30	Dimethicone 1,000
Sample 5	Original play sand	Dimethicone 500
Sample 6	Original play sand	Dimethicone 1,000
Sample 7	Original play sand	Starch and clear glue

We concluded that the best kinetic sand was produced with the fine sand of approximately 0.4 mm particle size with Dimethicone 500 because the consistency of this sample is better for molding the surface. About 167.5 pounds of the optimal kinetic sand was made to fill the sandbox shown in Figure 2.

For Linux installation procedure go to:
https://arsandbox.ucdavis.edu/forums/topic/complete-installation-instructions/

Expected Results

After engaging in an interactive activity with the AR sandbox, visitors will be able to understand the concepts of topography, geology and hydrology. The level of difficulty of the educational modules will vary depending on the grade level and interest of the visitors. Through this project our main goal is to raise awareness about how watershed processes work with sedimentary and chemical processes found in watersheds similar to the Mad River Valley, Missisquoi and Lake Champlain.

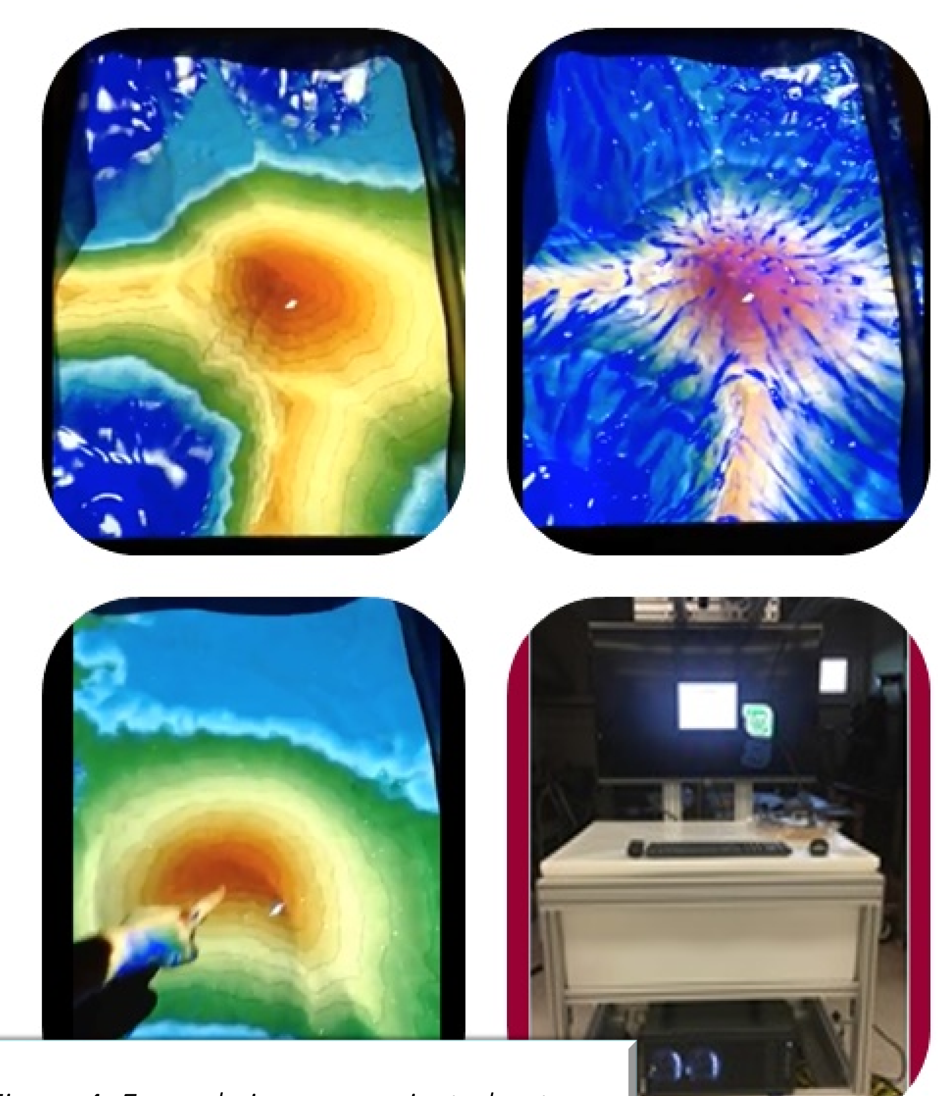

Figure 4: Example images projected onto augmented sandbox

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