# Performance Analysis of an Innovative Stormwater Management Infiltration System with Implications for Land Management Practices

2022 Association of Conservation Engineers

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Infiltronics Environmental LLC

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# Overview

- The evolving stormwater landscape
- The stormwater management device
- Lab work
- Test sites
- Data collection
- Site 1 Specifics
- Data analysis
- Modeling
- Conclusions and Next Steps
- Device applications

# The Evolving Stormwater Landscape

- Stormwater management is important in developed and conservation-focused areas
- For developed areas, as more and more is learned about stormwater and the management methods for stormwater, changes are made in practice and regulation
  - For example:
    - Short-comings of basins
    - Benefits of retaining water onsite
      - Water Quality Volumes and infiltration requirements
  - New management methods are required
    - Stormwater Redistribution and Infiltration Device
- Similarly, in conservation areas the need and principles still apply, independent of the regulatory framework
  - Erosion mitigation
  - Water quality concerns
  - Wetland preservation/enhancement
  - Aquatic life preservation/enhancement

# Origins of the Device

- Developed throughout the course of general work in and understanding of hydraulics, hydrology, and stormwater management
- Not based on a particular research project
- Provisional patent by the University of Missouri
- Intellectual property released by MU to Kathleen Trauth
- Patent received by Kathleen Trauth for the theoretical device

# Stormwater Management Device

- The device is a system of tubular structures, composed of aggregate-filled geotextile segments
  - No piping withing the device, only for “feeding” the system
- It produces 3D flow, dictated by differences in hydraulic conductivities, due to differences in aggregate sizes and the configuration of the aggregate segments
  - Dictate how the water flows around a site
  - Slow it down, spread it out, soak it in
- It is installed shallowly below ground and works to maximize redistribution and infiltration of stormwater runoff
- A system of multiple devices placed throughout the landscape helps redistribute the stormwater around the site to avoid water “mounding” in one area, helping to maximize infiltration

# Stormwater Management Device

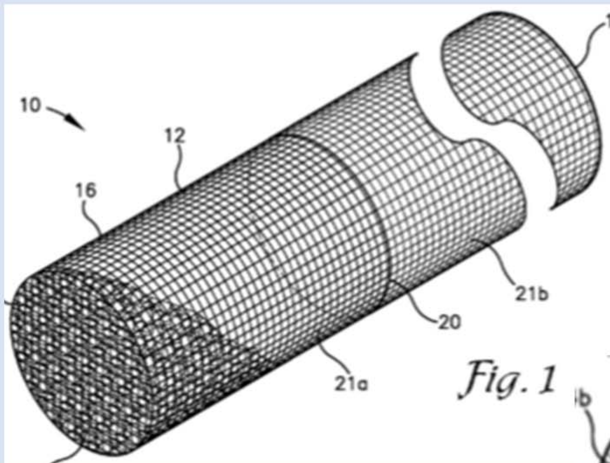


Fig. 1

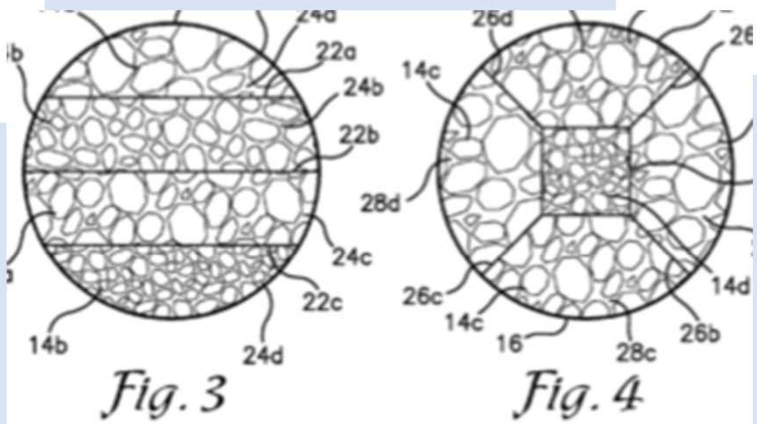
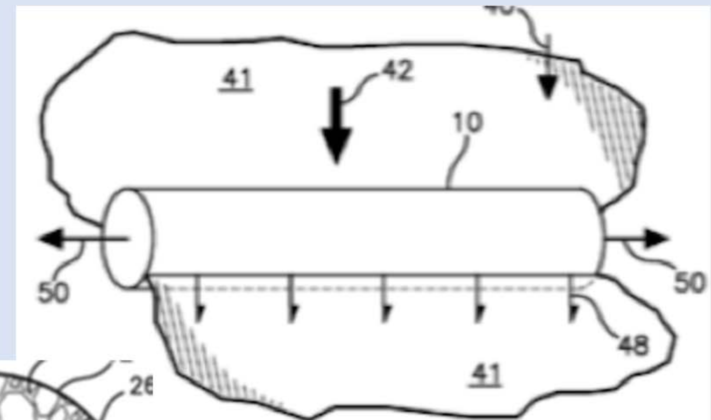


Fig. 3
Fig. 4



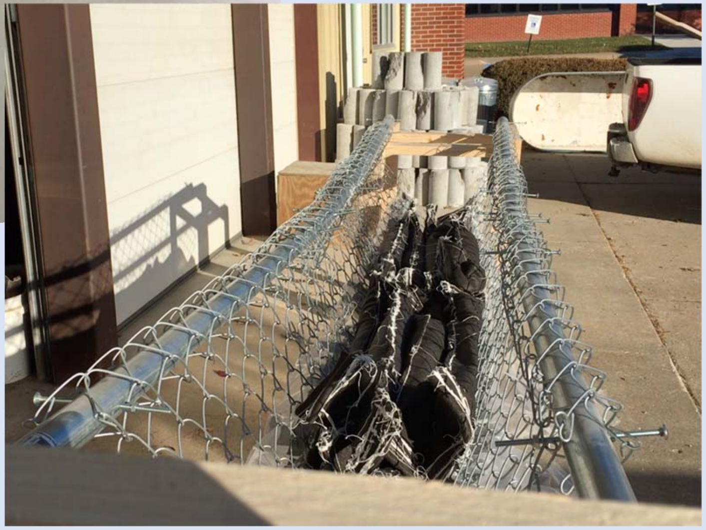
# Stormwater Management Device

# Stormwater Management Device

- Mix and configurations will vary
- Design based on:
  - Soil characteristics
  - Site slope
  - Impervious cover
  - Rainfall
  - Site layout
  - Applicable regulations

# Theory to Lab to Field

- Theoretical patent
- Lab work
  - Device construction
  - 3D flow
  - Continuation of flow
- Field sites
  - 3D flow
  - Continuation of flow
  - Soil interactions
  - Real world conditions



# Site 1:

- Fr. Tolton Regional Catholic High School  (Columbia, MO)
- 2018 (extended 2020)
- Concentrated flow

# Site 2:

- Rock Bridge Memorial State Park (Columbia, MO)
- 2019
- Overland Flow

# Site 3:

- Rock Bridge Memorial State Park (Columbia, MO)
- 2019
- Continuous and concentrated flow

# Site 4:

- Shaw Nature Reserve (Grey Summit, MO)
- 2021
- Overland flow that concentrates in a drainage ditch

# Site 5:

- Residential site (Pittsburgh, PA)
- 2022
- Overland Flow

# Data Collection

- Soil moisture sensors are located around the installations
  - Placed three-dimensionally
  - Allows for flow around the installations to be "seen"
- Ultrasonic level sensors have been installed at Site 1
  - Allows for volumetric analysis

# Site 1:

- Fr. Tolton Regional Catholic High School (Columbia, MO)
- 2018 (ext. 2020)
- Concentrated flow

# Site 1: Soil

- Site is an urban soil on a 25% slope
- Subsoil:
  - Filled in 6” lifts, compacted to 4-5”, lifted to meet design specifications.
  - Fat Clays, ~45% of matrix
  - Glacial Till
  - LEP approximately 8%
- Topsoil
  - Topped with 8-10” topsoil
  - Seeded with Tall Fescue
- Some root penetration into subsoil, with roots splaying along horizonal lift contacts

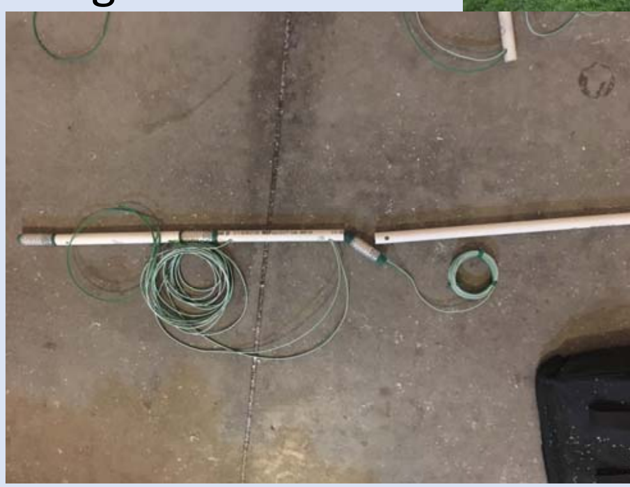
# Site 1: Installation

# Site 1: Installation

- Excavation
  - 2’ wide x 1.5’ deep
- Alignment
  - 25’ @ 3% slope
  - 25’ @ 4.5% slope
- Device placement
  - 3’ segments
  - 3 layers with 4 units a layer
  - 1 sand layer with 2 layers of 1” clean gravel on top

# Site 1: Data Collection

- Sensors Placement
  - Vertical: 12”, 24”, 36”
  - Transverse: 2.5’, 5’
  - Longitudinal: 8.3’, 16.6’, 26.5’
  - Upslope: 12’ longitudinal & -1.5’



# Site 1: Finished Installation

# Site 1: Extension

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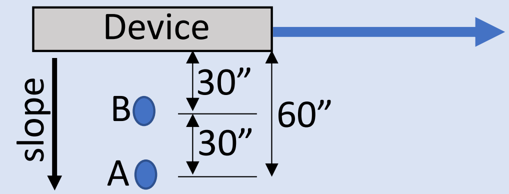
# Site 1: Extension

- Sensors have been added along the two extension sites in the same configuration as the original installation
- Additional downhill sensors have been added to the entire installation
- To better track how much water is entering the system and to allow for volume calibration of the device:
  - New sedimentation basins have been installed and will have ultrasonic level sensors placed above them to quantify the discharge each side (3% slope and 4.5% slope) of the installation is receiving

# Site 1: Extension

# Data Analysis: Basic Comparison




| | | | | | | | A 36” | A 24” | A 12” | B 36” | B 24” | B 12” |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/6/2018 7:19 | 1538828340 | T223 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 22 | 12 |
| 10/6/2018 8:19 | 1538831940 | T224 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 23 | 12 |
| 10/6/2018 9:19 | 1538835540 | T225 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 23 | 12 |
| 10/6/2018 10:19 | 1538839140 | T226 | 0.03 | 15 | 5 | 0.18 | 239 | 239 | 3 | 4 | 23 | 13 |
| 10/6/2018 11:19 | 1538842740 | T227 | 0.02 | 10 | 0 | 0.12 | 239 | 239 | 3 | 4 | 24 | 13 |
| 10/6/2018 12:19 | 1538846340 | T228 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 24 | 13 |
| 10/6/2018 13:19 | 1538849940 | T229 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 24 | 13 |
| 10/6/2018 14:19 | 1538853540 | T230 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 25 | 13 |
| 10/6/2018 15:19 | 1538857140 | T231 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 4 | 25 | 14 |
| 10/6/2018 16:19 | 1538860740 | T232 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 26 | 14 |
| 10/6/2018 17:19 | 1538864340 | T233 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 26 | 14 |
| 10/6/2018 18:19 | 1538867940 | T234 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 26 | 15 |
| 10/6/2018 19:19 | 1538871540 | T235 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 27 | 15 |
| 10/6/2018 20:19 | 1538875140 | T236 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | [illegible] | 27 | 15 |
| 10/6/2018 21:19 | 1538878740 | T237 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 28 | 15 |
| 10/6/2018 22:19 | 1538882340 | T238 | 0 | 0 | 0 | 0 | 239 | 239 | 3 | 5 | 28 | 16 |
| 10/6/2018 23:19 | 1538885940 | T239 | 0.07 | 35 | 25 | 0.42 | 239 | 239 | 3 | 5 | 29 | 12 |
| 10/7/2018 0:19 | 1538889540 | T240 | 0.15 | 75 | 65 | 0.9 | 239 | 239 | 2 | 6 | 28 | 3 |
| 10/7/2018 1:19 | 1538893140 | T241 | 0 | 0 | 0 | 0 | 239 | 10 | [illegible] | [illegible] | 7 | 6 |
| 10/7/2018 2:19 | 1538896740 | T242 | 0.02 | 10 | 0 | 0.12 | 239 | 10 | 2 | 4 | 7 | 6 |
| 10/7/2018 3:19 | 1538900340 | T243 | 0.02 | 10 | 0 | 0.12 | 239 | 10 | 2 | 4 | 6 | 5 |
| 10/7/2018 4:19 | [illegible] | T244 | 0 | 0 | 0 | 0 | 239 | 10 | 2 | 4 | 5 | 5 |
| 10/7/2018 5:19 | 1538907540 | T245 | 0 | 0 | 0 | 0 | 239 | 11 | 2 | 4 | 5 | 5 |
| 10/7/2018 6:19 | 1538911140 | T246 | 0 | 0 | 0 | 0 | 239 | 11 | 2 | 4 | [illegible] | 5 |
| 10/7/2018 7:19 | 1538914740 | T247 | 0 | 0 | 0 | 0 | 239 | 11 | 2 | 4 | 5 | [illegible] |
| 10/7/2018 8:19 | 1538918340 | T248 | 0 | 0 | 0 | 0 | 239 | 11 | 2 | 4 | 5 | 5 |
| 10/7/2018 9:19 | 1538921940 | T249 | 0 | 0 | 0 | 0 | 239 | 12 | 2 | 4 | 5 | 5 |
| 10/7/2018 10:19 | 1538925540 | T250 | 0 | 0 | 0 | 0 | 239 | 12 | 2 | 4 | 5 | 5 |
| 10/7/2018 11:19 | 1538929140 | T251 | 0 | 0 | 0 | 0 | 239 | 3 | 2 | 4 | 5 | 5 |
| 10/7/2018 12:19 | 1538932740 | T252 | 0 | 0 | 0 | 0 | 239 | 4 | 2 | 5 | 5 | 5 |
| 10/7/2018 13:19 | 1538936340 | T253 | 0 | 0 | 0 | 0 | 239 | 5 | 2 | 5 | 5 | 5 |
| 10/7/2018 14:19 | 1538939940 | T254 | 1.27 | 635 | 625 | 7.62 | 5 | 4 | [illegible] | [illegible] | 5 | 5 |
| 10/7/2018 15:19 | 1538943540 | T255 | 0.07 | 35 | 25 | 0.42 | 6 | 5 | 2 | 9 | [illegible] | [illegible] |
| 10/7/2018 16:19 | 1538947140 | T256 | 0.03 | 15 | 5 | 0.18 | 4 | 3 | 2 | 10 | 7 | 8 |
| 10/7/2018 17:19 | 1538950740 | T257 | 0.05 | 25 | 15 | 0.3 | 6 | 3 | 2 | 10 | 8 | 6 |
| 10/7/2018 18:19 | 1538954340 | T258 | 0.16 | 80 | 70 | 0.96 | 6 | 3 | 2 | 9 | 8 | [illegible] |
| 10/7/2018 19:19 | 1538957940 | T259 | 0.02 | 10 | 0 | 0.12 | 6 | 3 | 2 | 9 | 7 | 5 |
| 10/7/2018 20:19 | 1538961540 | T260 | 0.18 | 90 | 80 | 1.08 | 7 | 2 | 2 | 9 | 6 | 5 |
| 10/7/2018 21:19 | 1538965140 | T261 | 1.73 | 865 | 855 | 10.4 | 8 | 3 | 3 | 10 | 5 | 5 |
| 10/7/2018 22:19 | 1538968740 | T262 | 0.11 | 55 | 45 | 0.66 | 9 | 2 | 3 | 11 | 5 | 4 |

12” sensor is wet, no storm response

12” sensor is moist, then wets during first hour

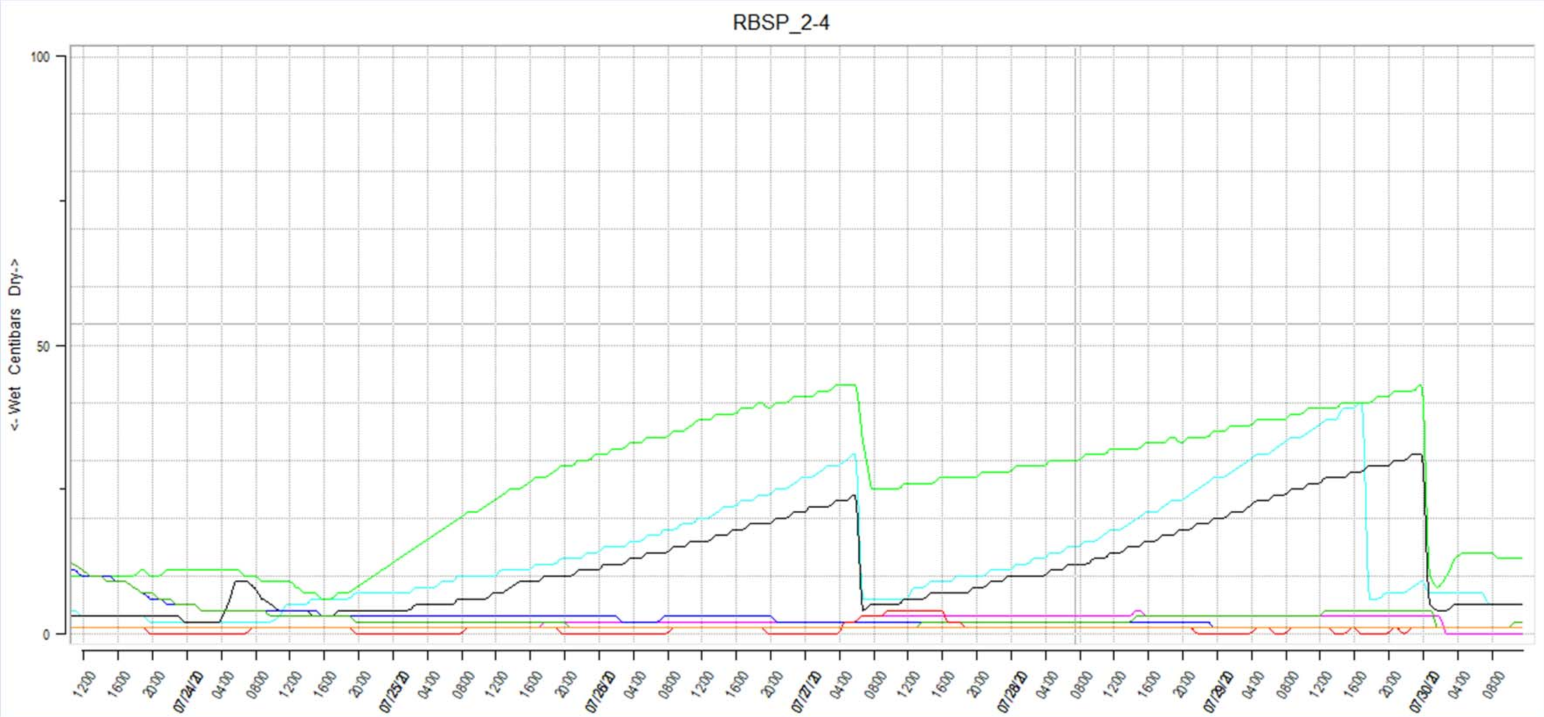
24” sensors are moist, then wet during second hour

36” sensor is moist, and stays moist, with no response

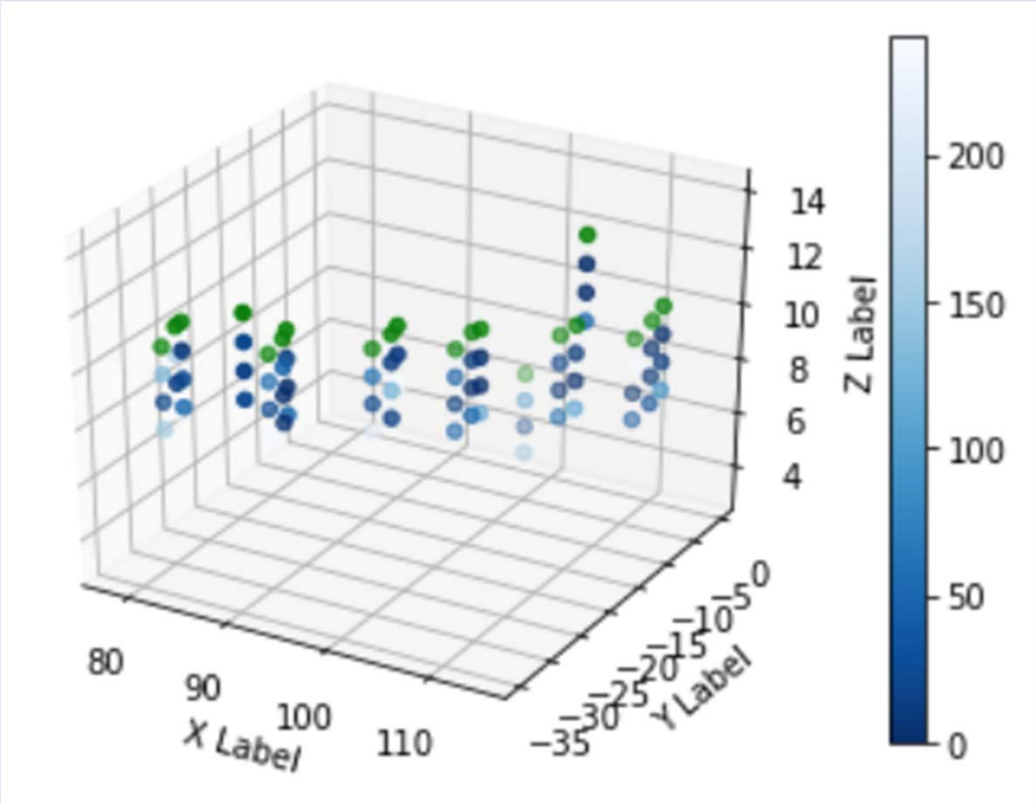
36” sensor is dry, wets 15 hours later

36” sensor is moist, draining

# Data Analysis: Graphical

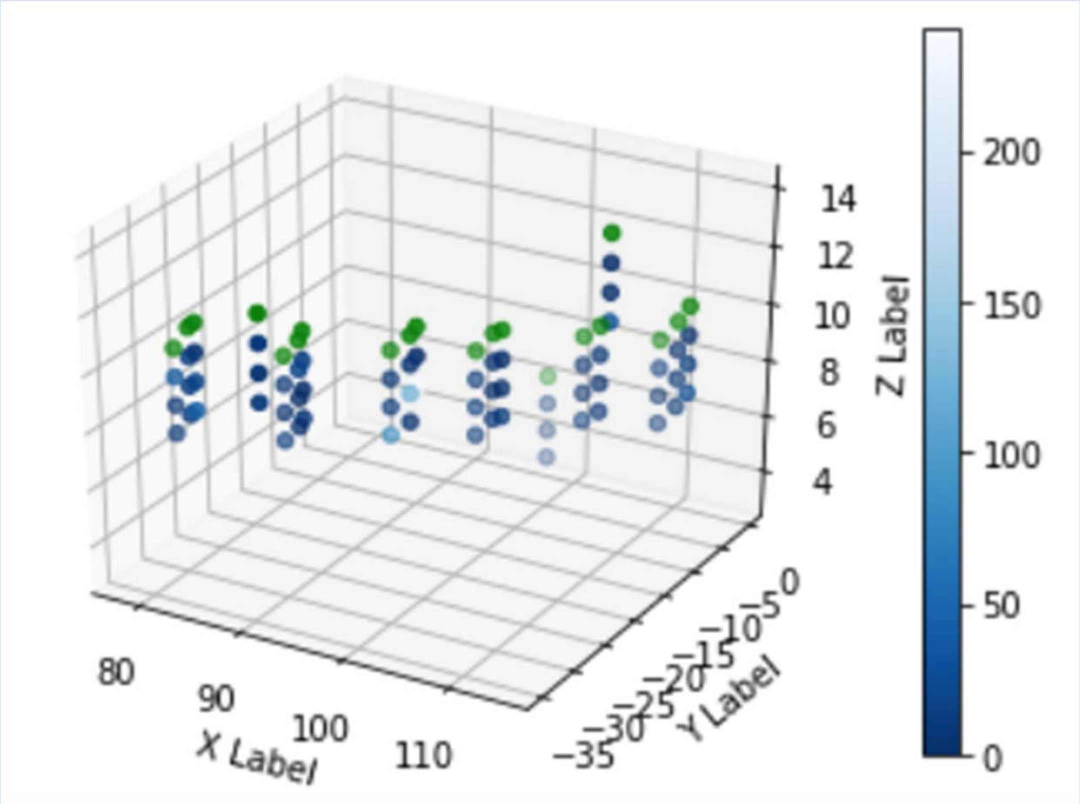


# Data Analysis: Soil Moisture




*9/20/21 15:52*

# Data Analysis: Soil Moisture




*9/21/21 4:52*

# Data Analysis: Soil Observation

# Data Analysis: Soil Observation

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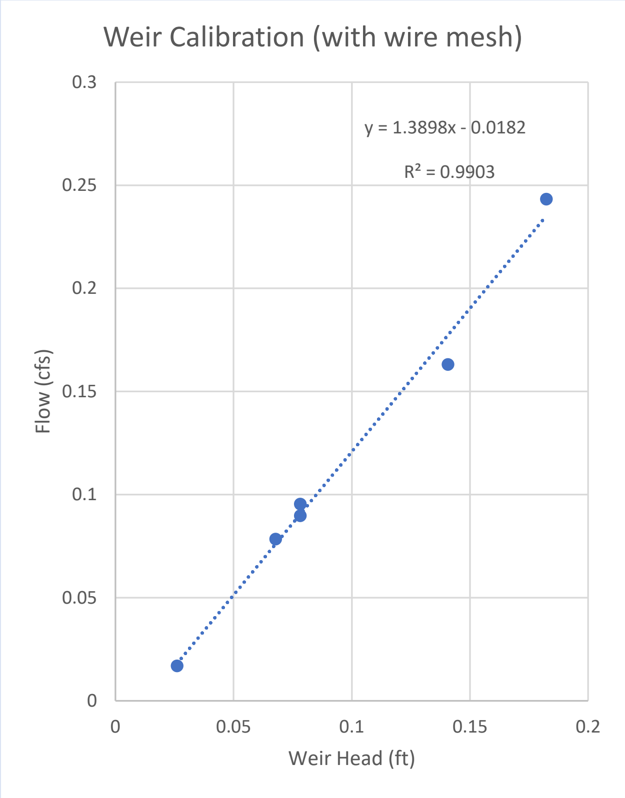
# Data Analysis: Soil Observation

# Data Analysis: Weir Calibration

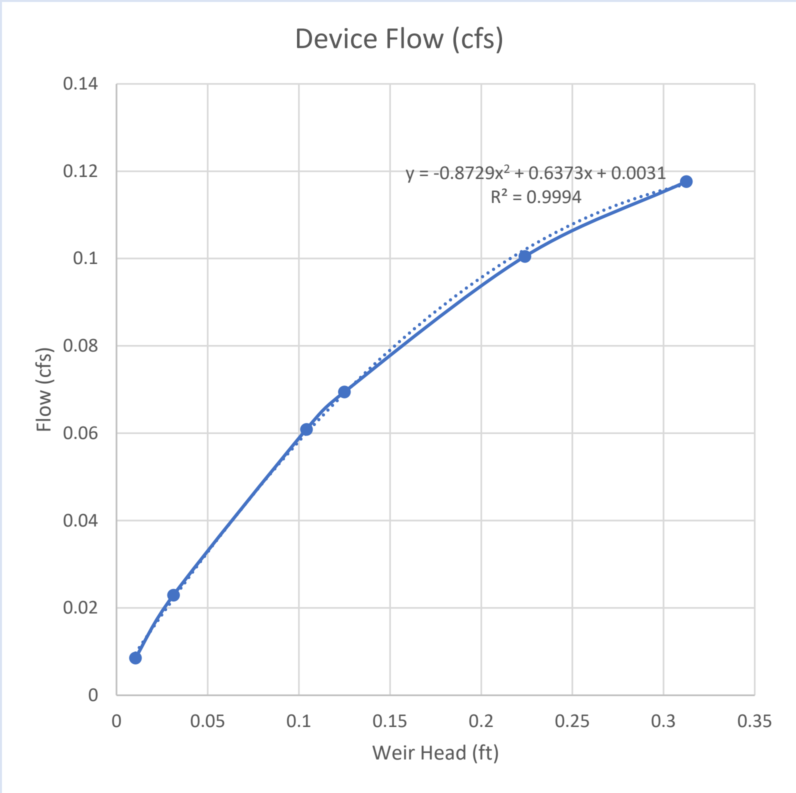
| | | | | |
|---|---|---|---|---|
| | | Middle | Height | |
| | | height | above | Flow rate |
| Pumps | Flow rate (gpm) | (in) | weir (ft) | (ft3/s) |
| Lg pump | 35.22504892 | 11.875 | 0.0677083 | 0.0784814 |
| 2 Lg pumps | 73.23180568 | 12.75 | 0.140625 | 0.1631605 |
| 3 Lg pumps | 109.2318057 | 13.25 | 0.1822917 | 0.2433685 |
| Lg pump + Lg fountain | 40.3000461 | 12 | 0.078125 | 0.0897885 |
| Lg fountain + Sm fountain | 7.617370062 | 11.375 | 0.0260417 | 0.0169715 |
| Lg pump + Lg fountain + Sm fountain | 42.84241899 | 12 | 0.078125 | 0.0954529 |
| | | | | |
| Height of weir from inside (middle height) | | | | |
| 11.0625 | | | | |

Q=0.9589y^1.37



# Data Analysis: Device Calibration

| Device Flow Calibration | | | | | |
|---|---|---|---|---|---|
| | | Height | Weir | Height | Device |
| Pump | Inflow | above weir | flow | above weir | flow |
| | (cfs) | (ft) | (cfs) | (ft) | (cfs) |
| Orange hose | 0.00982704 | 0.0104 | 0.00184123 | 0.0104 | 0.00855877 |
| Fountain | 0.02268335 | 0.03125 | 0.00831224 | 0.03125 | 0.02293776 |
| Lg pump #1 | 0.08639415 | 0.10417 | 0.04325943 | 0.10417 | 0.06091057 |
| Lg pump #1 + Fountain | 0.1090775 | 0.125 | 0.05553158 | 0.125 | 0.06946842 |
| Lg pumps #1 + #2 | 0.17704551 | 0.223958 | 0.12345297 | 0.223958 | 0.10050503 |
| Lg pumps #1 + #2 + #3 | 0.27587293 | 0.3125 | 0.19485782 | 0.3125 | 0.11764218 |



# Data Analysis: In-situ Performance

| Label | Minute | Rain Gage Events (tips) | Rain (in) | Rainfall Intensity (in/hr) | Runoff Vol (ft^3) | 310 Level (in) | Water Elevation (ft) | Weir Head (ft) | Weir Flow (ft^3/s) | Weir Volume (ft^3) | Device Flow (ft^3) | Device Volume (ft^3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Weir Crest (ft) | | 1 | | | | |
| | | | | | | | Basin Area | | 2 | | | |
| | | | | | | | | Device Invert (ft) | | 0.67 | | |
| 2021-09-20T22:31:00 | 1 | 3 | 0.03 | 1.8 | 15 | | | | | | | |
| 2021-09-20T22:32:00 | 2 | 4 | 0.04 | 2.4 | 20 | | | | | | | |
| 2021-09-20T22:33:00 | 3 | 5 | 0.05 | 3 | 25 | 6.647637 | 0.55397 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T22:34:00 | 4 | 5 | 0.05 | 3 | 25 | 13.16831 | 1.09736 | 0.097359 | 0.0394319 | 2.3659132 | 0.056873 | 3.412367 |
| 2021-09-20T22:35:00 | 5 | 5 | 0.05 | 3 | 25 | 14.20079 | 1.1834 | 0.183399 | 0.0938917 | 5.6335014 | 0.09062 | 5.437201 |
| 2021-09-20T22:36:00 | 6 | 5 | 0.05 | 3 | 25 | 15.01477 | 1.25123 | 0.25123 | 0.1445015 | 8.6700881 | 0.108115 | 6.486873 |

# Data Analysis: In-situ Performance

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Weir Crest (ft) | | 1 | | | | |
| | | | | | | | Basin Area | | 2 | | | |
| | | | | | | | | Device Invert (ft) | | 0.67 | | |
| Label | Minute | Rain Gage Events (tips) | Rain (in) | Rainfall Intensity (in/hr) | Runoff Vol (ft^3) | 310 Level (in) | Water Elevation (ft) | Weir Head (ft) | Weir Flow (ft^3/s) | Weir Volume (ft^3) | Device Flow (ft^3) | Device Volume (ft^3) |
| 2021-09-20T22:55:00 | 25 | 0 | 0 | 0 | 0 | 10.82677 | 0.90223 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T22:56:00 | 26 | 0 | 0 | 0 | 0 | 10.44685 | 0.87057 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T22:57:00 | 27 | 0 | 0 | 0 | 0 | 10.0689 | 0.83907 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T22:58:00 | 28 | 1 | 0.01 | 0.6 | 5 | 9.711615 | 0.8093 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T22:59:00 | 29 | 0 | 0 | 0 | 0 | 9.437009 | 0.78642 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:00:00 | 30 | 0 | 0 | 0 | 0 | 9.206693 | 0.76722 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:01:00 | 31 | 1 | 0.01 | 0.6 | 5 | 9.015749 | 0.75131 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:02:00 | 32 | 0 | 0 | 0 | 0 | 9.021653 | 0.7518 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:03:00 | 33 | 0 | 0 | 0 | 0 | 9.448819 | 0.7874 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:04:00 | 34 | 0 | 0 | 0 | 0 | 10.2874 | 0.85728 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:05:00 | 35 | 1 | 0.01 | 0.6 | 5 | 11.25492 | 0.93791 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:06:00 | 36 | | 0 | 0 | 0 | 11.99508 | 0.99959 | 0 | 0 | 0 | 0 | 0 |
| 2021-09-20T23:07:00 | 37 | | 0 | 0 | 0 | 12.12402 | 1.01033 | 0.010335 | 0.0018254 | 0.1095256 | 0.009593 | 0.575586 |
| 2021-09-20T23:08:00 | 38 | | 0 | 0 | 0 | 12.12303 | 1.01025 | 0.010253 | 0.0018056 | 0.1083344 | 0.009542 | 0.572533 |
| 2021-09-20T23:09:00 | 39 | | 0 | 0 | 0 | 12.09843 | 1.0082 | 0.008202 | 0.00133 | 0.0798007 | 0.008269 | 0.496111 |

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| Label | Minute | Rain Gage Events (tips) | Rain (in) | Rainfall Intensity (in/hr) | Runoff Vol (ft^3) | 310 Level (in) | Water Elevation (ft) | Weir Head (ft) | Weir Flow (ft^3/s) | Weir Volume (ft^3) | Device Flow (ft^3) | Device Volume (ft^3) |
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| | | | | | | Weir Crest (ft) | | 1 | | | | |
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| | | | | | | | | Device Invert (ft) | | 0.67 | | |
| 2021-09-21T00:07:00 | 97 | | 0 | 0 | 0 | 12.25886 | 1.02157 | 0.021572 | 0.0050026 | 0.3001548 | 0.016441 | 0.986486 |
| 2021-09-21T00:08:00 | 98 | | 0 | 0 | 0 | 12.23032 | 1.01919 | 0.019193 | 0.0042626 | 0.2557571 | 0.01501 | 0.900606 |
| 2021-09-21T00:09:00 | 99 | 1 | 0.01 | 0.6 | 5 | 12.18701 | 1.01558 | 0.015584 | 0.0032044 | 0.1922626 | 0.01282 | 0.769181 |
| 2021-09-21T00:10:00 | 100 | 1 | 0.01 | 0.6 | 5 | 12.18996 | 1.01583 | 0.01583 | 0.0032739 | 0.1964325 | 0.01297 | 0.778183 |
| 2021-09-21T00:11:00 | 101 | | 0 | 0 | 0 | 12.18996 | 1.01583 | 0.01583 | 0.0032739 | 0.1964325 | 0.01297 | 0.778183 |
| 2021-09-21T00:12:00 | 102 | 1 | 0.01 | 0.6 | 5 | 12.36122 | 1.0301 | 0.030102 | 0.0078966 | 0.4737966 | 0.021493 | 1.289568 |
| 2021-09-21T00:13:00 | 103 | | 0 | 0 | 0 | 12.42913 | 1.03576 | 0.035761 | 0.0099988 | 0.5999253 | 0.024774 | 1.486454 |
| 2021-09-21T00:14:00 | 104 | 1 | 0.01 | 0.6 | 5 | 12.37303 | 1.03109 | 0.031086 | 0.0082526 | 0.4951537 | 0.022068 | 1.324058 |
| 2021-09-21T00:15:00 | 105 | 1 | 0.01 | 0.6 | 5 | 12.32579 | 1.02715 | 0.027149 | 0.0068551 | 0.4113082 | 0.019759 | 1.18552 |
| 2021-09-21T00:16:00 | 106 | 1 | 0.01 | 0.6 | 5 | 12.42717 | 1.0356 | 0.035597 | 0.009936 | 0.5961593 | 0.02468 | 1.480795 |
| 2021-09-21T00:17:00 | 107 | 3 | 0.03 | 1.8 | 15 | 12.64961 | 1.05413 | 0.054134 | 0.0176452 | 1.0587117 | 0.035042 | 2.102492 |

# Data Analysis: In-situ Performance

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Weir Crest (ft) | | 1 | | | | |
| | | | | | | Basin Area | | 2 | | | |
| | | | | | | | Device Invert (ft) | | 0.67 | | |
| Minute | Rain Gage Events (tips) | Rain (in) | Rainfall Intensity (in/hr) | Runoff Vol (ft^3) | 310 Level (in) | Water Elevation (ft) | Weir Head (ft) | Weir Flow (ft^3/s) | Weir Volume (ft^3) | Device Flow (ft^3) | Device Volume (ft^3) |
| | 136 | | | | | | | | 318.54215 | | 267.8294 |
| Total Rain (in) | | 1.36 | | 680 | | | | | | | |

# Data Analysis: Soil Moisture Movement

- We look for trends
  - Soil discontinuities
  - Surface impacts
  - Foreign bodies in the soil (i.e.: silt fence from construction)
- In general, for all storms, more saturation occurs at the end of the installation
- During drought and when there are long durations between storms
  - The middle and bottom sensors were drying, but not as much as the top sensor
  - Wetter soil at the end of the installation
- Upper sensors:
  - May experience surface impacts
    - Occasional wetting up for sensors near the overflow weir, from overflow
  - Often experience draining
  - May be located above the flow, and miss impacts from the flow
  - Limited capillary action, but some does occur
    - Particularly with big events

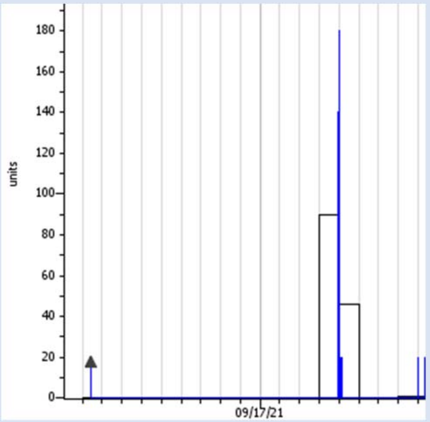
# Data Analysis: Soil Moisture Movement

| A1.3-3-5 | A1.2-3-6 | A1.1-3-7 |
|---|---|---|
| 21 | 8 | 22 |
| 21 | 8 | 22 |
| 21 | 8 | 23 |

9/20/2021 6:52:00 PM-8:52 PM
No recent rainfall
Stack A1 located 8.33' longitudinal and 2.5' downslope transverse (close to basin)

| G1.3-16-1 | G1.2-16-2 | G1.1-16-3 |
|---|---|---|
| 11 | 0 | 24 |
| 11 | 0 | 24 |
| 11 | 0 | 25 |

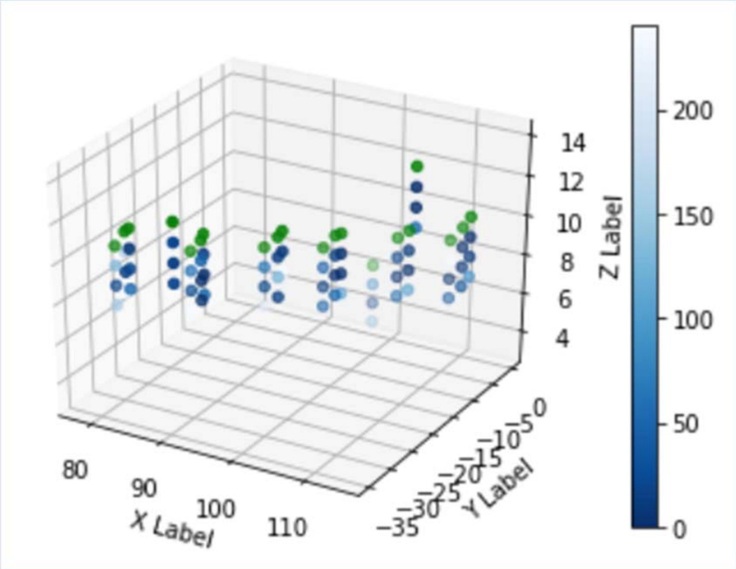
9/20/2021 6:52:00 PM-8:52 PM
No recent rainfall
Stack G1 located 50' longitudinal and 2.5' downslope transverse (close to end)



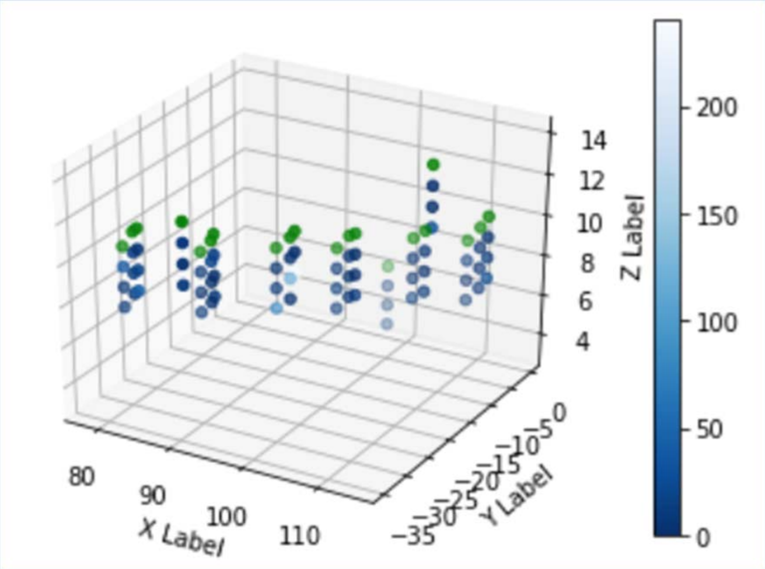
# Data Analysis: Soil Moisture Movement

- Intense Storms
  - Water moves longitudinally towards the end and then moves to fill the rest of the device installation, towards the basin
  - Water is then pushed into the surrounding soil in all directions
  - In general, for all storms, more saturation occurs at the end of the installation
  - Some capillary action

# Data Analysis: Soil Moisture

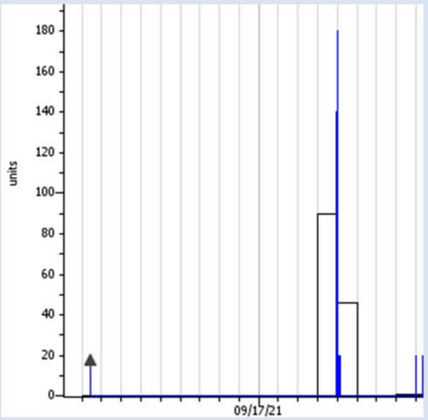



*9/20/21 15:52*




*9/21/21 4:52*

# Data Analysis: Soil Moisture Movement




Moisture increase is seen with both stacks at the same time, but after the initial increase the stack closer to the basin (A3) sees a slower moistening trajectory than the stack closer to the end (G3).
Also, stack at the end has higher overall saturation, even before the rain event

| A3.3-12-7 | A3.2-12-8 | A3.1-3-1 |
|---|---|---|
| 15 | 120 | 239 |
| 15 | 122 | 239 |
| 15 | 122 | 239 |
| 15 | 122 | 239 |
| 3 | 12 | 8 |
| 3 | 12 | 6 |
| 3 | 11 | 7 |
| 3 | 11 | 8 |
| 3 | 11 | 8 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 11 | 9 |
| 3 | 10 | 9 |
| 3 | 10 | 9 |
| 3 | 10 | 9 |
| 3 | 10 | 10 |
| 3 | 10 | 10 |
| 3 | 10 | 10 |

9/20/21 6:52 PM-9/21/22 4:52 PM
Stack A3 located 8.33' longitudinal and 10' downslope transverse

Rain event begins

Rain event ends

Potential surface impact from weir overflow

Drying begins

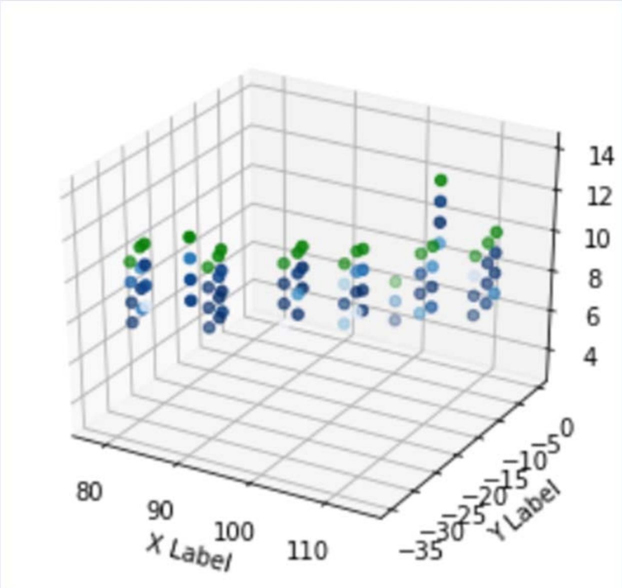
| G3.3-16-7 | G3.2-16-8 | G3.1-15-7 |
|---|---|---|
| 0 | 16 | 101 |
| 0 | 16 | 101 |
| 0 | 16 | 101 |
| 0 | 16 | 101 |
| 0 | 1 | 10 |
| 0 | 1 | 22 |
| 0 | 1 | 28 |
| 0 | 1 | 27 |
| 0 | 1 | 25 |
| 0 | 1 | 23 |
| 0 | 1 | 23 |
| 0 | 1 | 23 |
| 0 | 1 | 23 |
| 0 | 1 | 19 |
| 0 | 1 | 16 |
| 0 | 1 | 15 |
| 0 | 1 | 14 |
| 0 | 1 | 13 |
| 0 | 1 | 13 |
| 0 | 1 | 12 |
| 0 | 1 | 12 |
| 0 | 1 | 12 |

9/20/21 6:52 PM-9/21/22 4:52 PM
Stack G3 located 50'' longitudinal and 10' downslope transverse

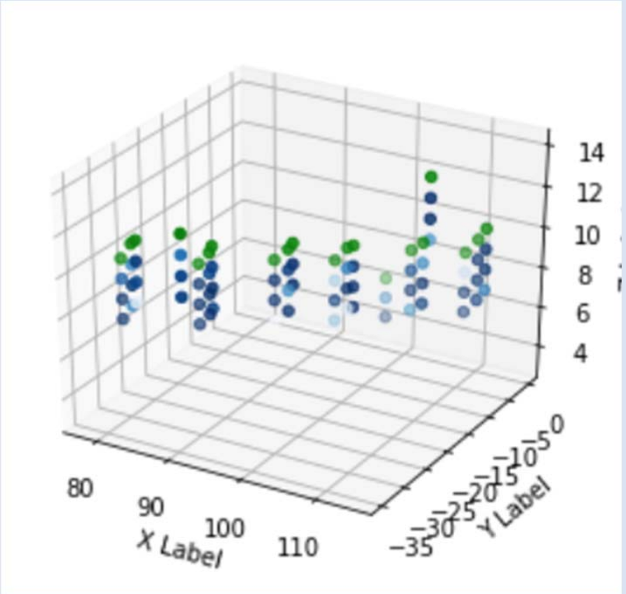
# Data Analysis: Soil Moisture Movement

- Gentle Storms
  - As seen in the device calibration testing
    - 5gpm/2:40
  - Only see saturation at the end

# Data Analysis: Device Calibration




*7/8/22 16:30*




*7/9/22 4:30*

# Data Analysis: Soil Moisture Movement

- Filling event occurred in the soil moisture record between 7/8/2022 5:30:00 PM and 7/8/2022 8:30:00 PM

| A2.3-3-2 | A2.2-3-3 | A2.1-3-4 |
|---|---|---|
| 6 | 86 | 211 |
| 6 | 86 | 212 |
| 6 | 86 | 211 |
| 6 | 86 | 211 |
| 6 | 87 | 212 |
| 6 | 86 | 212 |
| 6 | 87 | 212 |
| 6 | 87 | 213 |
| 6 | 87 | 214 |
| 6 | 88 | 215 |
| 6 | 88 | 215 |

Filling event begins

7/8/2022 4:30:00 PM-7/9/2022 2:30:00 AM
Stack A2 located 8.33' longitudinal and 5' downslope transverse

Even while water is entering the system, A2 continues to dry, while G2 maintains it's saturation, with some draining of the lowest sensor

Filling event begins

| G2.3-16-4 | G2.2-16-5 | G2.1-16-6 |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 0 |
| 0 | 0 | 0 |
| 0 | 0 | 0 |
| 1 | 0 | 0 |
| 1 | 0 | 0 |
| 1 | 0 | 0 |
| 1 | 0 | 0 |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 2 | 0 | 0 |

7/8/2022 4:30:00 PM-7/9/2022 2:30:00 AM
Stack G2 located 50' longitudinal and 5' downslope transverse

# Data Analysis: Soil Moisture Movement

- If the location of the site at Tolton was not in compacted clay lifts and on a constructed slope the soil moisture analysis demonstrates potential to contribute to baseflow-water getting into the subsurface
- In intense storms the installation is able to handle more water, due to an increased head, an important feature with storm intensity increasing
- Consistently high moisture content in deeper (2’ and 3’ down) soil around the installation could support native species with deeper roots and potentially soil conditions conducive to wetland vegetation

# Modeling: Green-Ampt

- Infiltrates all precipitation until surface saturation
- Decreasing rate of infiltration after surface saturation
- Reaching saturated hydraulic conductivity

- Based on precipitation on the landscape
- No consideration of a head driving the infiltration

# Modeling: Darcy Flow

- Head per flow length
- Multiples of saturated hydraulic conductivity
- Cross-sectional area of flow

# Modeling: Hydraulic Conductivities

- Sand is the bottom layer of the device
  - Lower hydraulic conductivity than other aggregates
- Retains water longer, maintaining saturation
- Saturation facilitates the flow to be more like Darcy than Green-Ampt
- Initial wetting to get through Green-Ampt phase, and then saturated sand helps maintain Darcy flow, maximizing infiltration

# Effective Hydraulic Conductivity

- Volume infiltrated through device for the 5.5-hr storm with level sensor measurements: 276.7 $ft^3$
- Performed a Darcy flow calculation
  - 17 individual 3-ft segments
  - Variable head along length of installation
  - Area: bottom and sides of installation trench
  - Summed infiltrated volumes over time
- Unknowns
  - Length of saturated zone
  - Hydraulic conductivity

# Effective Hydraulic Conductivity

- Soil scientist estimated hydraulic conductivity of in situ soil as 0.00008
- Volume infiltrated through device for the 5.5-hr storm with level sensor measurements: 276.7 $ft^3$
- Producing at least an order of magnitude increase in the hydraulic conductivity of the soil

| Saturated Length (ft) | Hydraulic Conductivity (ft/sec) | Volume ($ft^3$) |
|---|---|---|
| 4 | 0.001 | 278.1 |
| 5 | 0.00125 | 278.1 |
| 6 | 0.0015 | 278.1 |
| 7 | 0.0017 | 270.1 |
| 8 | 0.002 | 278.1 |

# Conclusions and Next Steps

- Results show water is getting into the system
- This is demonstrated by multiple means of assessment
- With a stronger understanding of the processes involved, work on a design tool can begin

# Device Application

- Developed Areas:
  - Regulations
    - Onsite retention
    - Retrofit or additions on small urban sites
    - Infiltration
    - Reduce flow to combined sewer systems
  - Reduce basin size
  - Stand-alone or as a part of a treatment train
  - Mitigate erosion issues
- Conservation Areas:
  - Mitigate erosion issues
  - Reduce overland pollutant transport
  - Preserve or enhance wetlands
  - Promote infiltration to support baseflow for aquatic life

# Find out more

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