Do-It-Yourself, Real-Time, Low Cost Environmental Monitoring Solutions

PRESENTATION – Mar 6, 2017

http://EnviroDIY.org

Presenters
Stroud Water Research Center
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Project Team
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Funding Provided By:
What is the **EnviroDIY Program**?

- A diverse community of people interested in environmental monitoring technologies and solutions that are open-source.
- Stroud Water Research Center focuses on working with and building Arduino-based hardware/software technologies.

[https://www.arduino.cc/](https://www.arduino.cc/)

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**WHAT IS ARDUINO?**

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects.

Learn more about Arduino

**ARDUINO BOARD**

Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

Discover the official Arduino boards

**ARDUINO SOFTWARE**

You can tell your Arduino what to do by writing code in the Arduino programming language and using the Arduino development environment.

Download the Arduino Software
EnviroDIY™ is Presented by Stroud™ Water Research Center

The founding members of EnviroDIY are all scientists and educators of Stroud Water Research Center, an independent not-for-profit organization that seeks to advance knowledge and stewardship of freshwater systems through global research, education, and restoration.

Since 1967, Stroud Center scientists and educators have been focused on one thing — fresh water.

While our research concentrates on streams and rivers — including how they function as a whole and the complex web of life that inhabits them — there’s a much larger story behind our efforts. The health of these freshwater ecosystems is our first line of defense in preserving clean water — and clean water is essential to all life.

Only through knowing how healthy streams and rivers work, and what happens when they become polluted, can we determine how to protect and preserve this vital resource. Learn more at www.stroudcenter.org

EnviroDIY: A Community of Enthusiasts Sharing Do-It-Yourself Ideas for Environmental Science and Monitoring

Our vision is that sharing of ideas and experiences by the EnviroDIY community will result in open-source hardware and software solutions for observing our environment that are low cost, easy to learn, and easy to use, which will lead to an explosion of high-quality real-time data that
Stroud Center EnviroDIY Workshops and Monitoring Programs

• General and Open to All
  – EnviroDIY.org website to share ideas and learn
  – Electronics (Stroud Center’s Mayfly Microprocessor and Datalogger Board and Kit) – limited stock on Amazon.com
  – Disseminating Stroud Center knowledge on building, deploying, using monitoring technologies and methods

• Targeted Workshops
  – Workshops hosted by local organizations lead by Stroud Center with funding support from William Penn Foundation, PA DEP, and US EPA
  – PA, NJ, DE, MD, VA, GA, MN, SD, ND

• Targeted Monitoring
  – Grants to Stroud Center to provide assistance to watershed organizations
Good monitoring requires rationale, takes time, has risks, costs $$, and needs commitment (points to keep in mind)

Intro to the EnviroDIY workshop

Monitoring our water resources
  - What are some national perceptions for low-cost water quality monitoring needs?
  - Traditional water quality monitoring
  - How can we help?

Introduction to “maker” revolution and open source hardware and EnviroDIY approach

Our metrics for success and why we are doing these workshops
Low-Cost, Near Real-Time Water Quality Monitoring

• Although “low-cost”, can be risky to lose equipment, and requires TIME/HUMAN RESOURCES
  – Should not be just for monitoring sake – encourage inquiry-based monitoring!

• Should not sacrifice data quality (obviously cost/benefit choices are made that impacts DQ)
  – Precision, accuracy, dependability

• WQ monitoring should be accessible to “well trained” general public (i.e., not rocket science – but does demand a bit of technological savvy)
10 Q’s for Planning & Designing Your Monitoring Program

1. Why?
2. Who?
3. How?
4. What?
5. How?
6. What?
7. Where?
8. When?
9. How?
10. How?
10 Q’s for Planning & Designing Your Monitoring Program

1. **Why** is the monitoring taking place?
2. **Who** will use the monitoring data?
3. How will the data be used?
4. **What** parameters or conditions will be monitored?
5. How good do the monitoring data need to be?
6. What methods should be used?
7. **Where** are the monitoring sites?
8. **When** will monitoring occur?
9. How will monitoring data be managed and presented?
10. How will the program ensure that data are credible?
Risks for Deploying Real-Time Sensors in Aquatic Environments

1. Deploying electronics in water, hmmm?
   - Weathering, corrosion/moisture
   - Bio-fouling
   - Flowing water, flooding, wet-dry cycles

2. People
   - Public or private property?
   - Vandalism
   - Curiosity

3. Plants and animals
   - Some critters love to chew
   - Some plants grow a “mile a minute”

4. Security
   - Not just about your stuff!
   - Local, state, fed authorities & roads/bridges/etc...

The EnviroDIY Workshop

Hardware Components and Sensors → Programing with Open Source Software → Building Monitoring Stations → Strategies for Deployment

Quality Assurance and Control → Online System for Data Capture and Visualization → Data Management, Analysis, and Interpretation

Quality Control
Quality Assurance

STROUD
WATER RESEARCH CENTER
50 YEARS 1967
• Desire/need for continuous real-time monitoring
  – Rationale is diverse…e.g., pollution monitoring, temporally rich data to detect short term events, need for monitoring real-time conditions, detecting change due to actions (restoration)...

• Need for low-cost solutions, so we can monitor more places with limited budgets

• Need for greater data transparency

• Technological complexity is becoming more simplified

• National survey....
LOW COST WATER QUALITY MONITORING NATIONAL SURVEY

LOW COST WATER QUALITY MONITORING NATIONAL SURVEY

Background

- 2015: Pisces Foundation & Intel Corporation project leaders agree to sponsor a survey of selected groups doing water resource monitoring to better understand gaps between their current and desired:
  - Water monitoring practices
  - Reporting
  - Information sharing technologies

- Goal was to empower citizens to protect their water through information gained or managed with the use of low cost technologies

- National Steering Committee of non-profit, business, academic and government experts guided survey development & distribution
Survey Audience Profile

- Key Characteristics:
  - 130 respondents—all but 3 in U.S.
  - Very knowledgeable—50% monitoring program leads & 78% were either staff, volunteers, or had strong program knowledge
  - Several respondents represented their regional/national staff network
  - Geographically broad representation—42 states
  - Mostly non-profits (72%) & govt. (16%) respondents
  - 50% answered a watershed was their service area
LOW COST WATER QUALITY MONITORING
NATIONAL SURVEY – KEY FINDINGS

- 84% of respondents believe widespread availability of low-cost equipment could affect major improvements in water quality

- **Top 4 perceived needs for low-cost monitoring equipment:**
  - target problem areas
  - use as a screening tool for advanced/expert level monitoring/investigation
  - report pollution incidents
  - As part of monitoring & verification protocols for nutrient trading programs, BMPs, restoration projects, etc.

- **Top 4 parameters for low-cost (under $100) monitoring improvements:**
  - nutrients (N and P forms)
  - bacteria (fecal coliform, E. coli, etc.)
  - dissolved oxygen
  - turbidity
LOW COST WATER QUALITY MONITORING NATIONAL SURVEY — KEY FINDINGS

- Top 4 most desired features in new equipment:
  - equipment durability
  - in-field data entry
  - remote sensing & data loggers
  - automatic metadata capture

- 78% of respondents lack knowledge of beneficial low-cost data access & sharing technologies that could benefit their program

- Top 4 perceived needs for low-cost (less than $50) data access and sharing technologies:
  - quality and reliability of the data
  - low unit cost of the data
  - sharing of water quality information with environmental advocates
  - sharing of water quality information with local government officials
The Future of Water Protection

• Informed citizenry is key to protecting watersheds, but ...
  • It is challenging to assemble data that provides a complete picture of water quality across our stream and rivers...dozens of federal, state, municipal, academic and volunteer sources

• Volunteers monitoring is a stepping stone to protection and advocacy

• “Crowd-sourcing” monitoring with volunteers will be required to better monitor water resources

• In addition, increasing the frequency, spatial extent, and access to data are key
Traditional Water Quality Monitoring

Point measurements

Grab Samples for Lab Analysis

Visual Observations of Potential Chemical Pollution

Co-locate with USGS?

Automated Sampling? $$$

Buy Logger? $$

Traditional Water Quality Monitoring
Rain starts at 2:00pm
Stream out of bank at 3:30 pm
NOAA Climate Reference Network Station at SWRC
Citizen Captured Real-Time Data Example – Weather Underground
Stroud Water Research Center KPAAVOND5

Forecast for Avondale, PA  >  39.860 - 75.781  >  372 ft

Current Conditions  Station reported 3 seconds ago

40.1°F

Feels Like 40.1°F

Dew Point: 35°F  UV: 0.0
Humidity: 82%  Solar: 0 W/m²
Precip Rate: 0 in/hr  Soil Moisture: --
Precip Accum: 0.01 in  Soil Temp: --
Pressure: 29.6 in  Leaf Wetness: --

0.9 mph

Wind from W
Gusts 9.0 mph

7:17 AM  5:13 PM

Waning Crescent | 8% illuminated
Turbidity + TSS w/ Sensor
Continuous & Real-Time Hydrological Data from USGS
Continuous & Real-Time Hydrological Data from USGS

USGS 01478245 White Clay Creek near Strickersville, PA

--- Provisional Data Subject to Revision ---
Why so little real-time water quality monitoring?

Implementation of environmental sensing networks is currently limited by:

- High cost of sensors and data logging hardware
- Inadequate systems for data communication
- Minimal data management infrastructure
- Risks (mentioned earlier)
Sensor Networks: Cost vs. Coverage

• Campbell Scientific data-loggers & radios

CR1000 Measurement & Control Datalogger $1400

AM16/32B 16 or 32 Channel Relay Multiplexer $500

RF430 spread spectrum radio $600

Total = $2500
EnviroDIY Mayfly Data Logger Board

Hardware Version 0.3

- microUSB port
- Power switch
- MicroSD/SPI connector
- User-defined pushbutton
- MicroSD socket (horizontal)
- 20-pin header for analog pins and 2 UART ports
- Auxiliary 16-bit, 4-channel Analog-to-Digital Converter
- Bee Module Socket (Xbee/WiFi/Cell)
- FTDI programming port
- Solar panel connector & charging circuitry
- Red & Green LEDs
- LiPo battery connectors
- DS321 Real Time Clock with battery backup
- 20-pin header for digital pins
- Grove digital ports
- I²C port
- 5V boost converter
Sensor Networks: Cost vs. Coverage

- Open-source data-loggers & radios

EnviroDIY Mayfly Microprocessor & Datalogger: $60

Accessories (vary depending on need): $30-90

Solar Panel: $10-35

Cell Phone or Radio Modules: $30-60

Total = $140-$220
What is an EnviroDIY Sensor Station?

• Whatever you want it to be!
  – Stroud Center and Partners have recommendations and working options...but
  – As we all know technological advancement is fast and results in challenges
    • Hardware changes (obsolete), software updates, changing cellular communication protocols, etc...

• Open source data logger is at the core of our sensor stations, coupled to commercially available sensors
What Sensors Are Available?

• Top recommendations for stream monitoring
  – Pressure transducer (water depth) with temperature
  – CTD (Decagon) – Conductivity, temperature, depth
  – Turbidity sensor (Campbell Sci.) = $$
  – Ultrasonic range finder (water depth) – using in very shallow streams

• Other sensors/instruments Stroud Center has utilized
  – Dissolved oxygen, soil moisture, tipping bucket rain gauge, redox probes, light sensors (PAR), ...
  – some examples
Example Sensor Options

• Bare-wire commercial sensors
  Decagon, Sensorex, Vaisala, Keller America, Apogee, Campbell

  Soil moisture, conductivity, redox, CO\textsubscript{2}, water depth, oxygen, turbidity, CTD
EnviroDIY Mayfly Logger and Sensor Station

Campbell Turbidity

Decagon CTD
Sunlight and Temperature Data directly over a small stream - forest versus meadow

Photosynthetic Active Radiation (PAR μE/m²)

Stream Temperature (°C)
Data Capture/Visualization Examples

- Dreamhosters.com
  http://swrcsensors.dreamhosters.com/

- EnviroDIY Water Quality Data Portal (Beta version)
  http://data.envirodiy.org/

- End vision – embedded in WikiWatershed.org in Model My Watershed
  http://wikiwatershed.org/
  https://app.wikiwatershed.org/#
<table>
<thead>
<tr>
<th>Device ID</th>
<th>Location/Description</th>
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<tr>
<td>SL031: WCC19</td>
<td>Turbidity/CTD</td>
</tr>
<tr>
<td>SL041: WCC40</td>
<td>Turbidity/CTD/Oxygen</td>
</tr>
<tr>
<td>SL066: WCD1139</td>
<td>Flow/Stage</td>
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<tr>
<td>SL032: WCC300</td>
<td>Turbidity/CTD</td>
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<tr>
<td>SL044: WCC720</td>
<td>Turbidity/CTD/PAR</td>
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<tr>
<td>SL043: WCD700</td>
<td>Turbidity/CTD/PAR</td>
</tr>
<tr>
<td>SL025: WCC Ag field</td>
<td>Soil Moisture</td>
</tr>
<tr>
<td>SL053: SWRC</td>
<td>Rain</td>
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<td>SL050: Schuylkill Center, Philadelphia</td>
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<td>SL034: Chestertown, MD</td>
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<td>SL042: Thouon</td>
<td>Turbidity/CTD</td>
</tr>
<tr>
<td>SL038: Thouon</td>
<td>Rain Gauge</td>
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</table>
Wireless Real-Time Data Online Visualizations
Online Data Capture/Visualization

EnviroDIY Water Quality Data Portal
Near Real-Time Data Sharing for the EnviroDIY Community

How it works

1. [Icon: Laptop]
2. [Icon: Wi-Fi]
3. [Icon: Cloud with Up Arrow]
Online Data Capture/Visualization
WikiWatershed.org is presented by Stroud™ Water Research Center. The Stroud Center seeks to advance knowledge and stewardship of freshwater systems through global research, education, and watershed restoration.

Explore the WikiWatershed Toolkit

**Model My Watershed**
Analyze real geo-data, model storms, and compare conservation or development scenarios in a watershed. 
*Learn more*

- **Launch the App**

**Model Micro Site Runoff**
Explore how land use and soil determine runoff for the Site Storm Model package of Model My Watershed. 
*Learn more*

- **Launch the App**

**EnviroDIY™**
Join a community of do-it-yourself enthusiasts sharing open-source ideas for environmental science and monitoring.
*Visit EnviroDIY*

**Monitor**

**Leaf Pack Network**

Welcome to Stroud Water Research Center 50 Years 1967
WikiWatershed’s Model My Watershed
WikiWatershed’s Model My Watershed
The EnviroDIY Vision
Do-It-Yourself Environmental Science & Monitoring

1. Crowd-source development by DIY Enviro-Sensing community results in ...
2. Open-source hardware & software solutions that are low cost, easy to learn and easy to use, leading to ...
3. An explosion of high-quality real-time data that transforms the practice of resource management, watershed protection and environmental science.
WELCOME TO ENVIRODIY™!

We’re a community of enthusiasts sharing do-it-yourself ideas for environmental science and monitoring. This is the place to showcase your gadgets, share your ideas, ask and answer questions, and network with interest groups. Find out how to get started.

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Do-It-Yourself Environmental Science & Monitoring

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Stroud Water Research...
http://envirodiy.org/
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Repositories
People 6
Teams 0
Projects 0
Settings

Search repositories...
Type: All
Language: All

New

EnviroDIY_Mayfly_Logger
Sketches and documentation for Arduino-compatible EnviroDIY
Mayfly data logger

Arduino
1
1
Updated 6 days ago

Top languages
C++
Arduino

Libraries
Arduino libraries used with the Mayfly board

C++
Updated 14 days ago

Arduino_boards

Updated on Oct 18
EnviroDIY Mayfly Data Logger Board, Arduino Compatible
by Stroud Water Research Center
Be the first to review this item

Price: $60.00

In Stock.
Sold by Stroud Water Research Center and Fulfilled by Amazon.

• Fully programmable microprocessor board, compatible with the Arduino IDE software.
• ARM Cortex-M3 32-bit processor.
• Real 32-bit clock.

Roll over image to zoom in

EnviroDIY Mayfly Data Logger Arduino Compatible Board and Starter Kit
by Stroud Water Research Center
Be the first to review this item

Price: $90.00

In Stock.
Sold by Stroud Water Research Center and Fulfilled by Amazon.

• EnviroDIY Mayfly Data Logger Board plus accessories to get you started.
• Includes waterproof enclosure with clear lid and 0.5Watt solar panel.
• Custom microSD connector board plugs into Mayfly for easy access to the memory card.
• 4GB microSD card and adapter included.
• Also includes 1-micron microUSB cable for programming the Mayfly, and 2 Grove cables.

Roll over image to zoom in
Soup-to-nuts

- Technology, software coding, maintenance, supplemental measurements, data management, data analysis, physical/chemical monitoring topics
- Examples…next couple of slides
I have a sensor station - what do I do now?

• Maintenance
  – Check your sensor station online, daily? Or nearly every day!
    • Battery data, sensor data (look for outliers/weird readings)
  – Visit your sensor station regularly
    • Plan for at least every 2-3 weeks
    • Need to be adaptable
      – In advance of large storm? Immediately after storm?
      – SAFETY FIRST
• Clean sensors
  – Remove accumulated debris around sensor/cables
  – Gently wipe turbidity sensor window
  – Ensure conductivity cell/water exchange not plugged
I have a sensor station - what do I do now?

• **Maintenance**
  – Take “reference” measurements
    • Record water-level from staff gauge
    • Measure conductivity with calibrated meter
    • Measure water temperature with meter
  – Reference check conductivity sensor with standards
    • Typically, 1413 $\mu$S/cm standard
  – RECORD ALL MEASUREMENTS AND OTHER OBSERVATIONS IN NOTEBOOK
    • DATE, TIME, PERSON
    • Make a copy back up of your notebook
  – Clean solar panel
  – Make sure no spiders/ants or infestation in box
  – Check wires for damage, check in-stream mounting system
  – Photos
I have a sensor station - what do I do now?

• Supplemental measurements
  – Channel cross-sectional area (Stroud Center)
  – Physical habitat survey (forthcoming) (Stroud Center)
  – Measuring discharge at various stage levels
    • This is also a type of x-sectional measure
  – Collecting water “grab” samples at various stage levels for:
    • Total suspended solids
    • Major ions and/or nutrients
  – Developing rating curves to predict
    • Discharge from stage
    • TSS from turbidity
    • Chloride from specific conductivity
Deploying any monitoring device has maintenance needs –
  – regular check ups, trouble shooting, and problem solving

How do you know your data are accurate and precise?
  – Check standards, calibrations, replacement?

Data interpretation and analysis
  – You should/must? Have rationale and think through your questions – why are you monitoring?
Data Management Teaser

• Curating your data
  – Database? Excel?
  – Back up your data
  – Correcting and annotating your data
  – Linking field observation to your data

• Time-series data management
  – Clocks, dates, time zones, daylight savings time
Why/how is Stroud Center Doing this?

- To support sound freshwater research, restoration, and monitoring
- Improve data acquisition, transparency, interpretation that leads to development of new knowledge and problem solving
- Help citizen scientists learn and collect useful information
- How?...a couple of grants...
Supporting Citizen Science within the Delaware River Watershed Initiative Cluster Teams

M.J. Ehrhart, D.B. Arscott, J.K. Jackson

Project to encourage and support expanded capacity and higher-quality citizen-science monitoring and volunteer participation in the DRWI
Overview of DRWI

• William Penn Foundation (WPF) Delaware River Watershed Initiative (DRWI) project overview – [http://www.drwi.net/downloads](http://www.drwi.net/downloads)
  – 50 leading conservation organizations in Delaware River basin
  – Goal: “watersheds that provide high quality and sufficient water quantity for healthy ecosystems and human communities”

• More Clean Water
Overview of DRWI

• Ongoing projects by organizations
• DWRI emphasis on “establishing and maintaining an expansive monitoring program to assess whether this work is effective at protecting and/or restoring water quality”
  – 8 focus areas for the work—“clusters”
    • Restoration, protection, and hybrid
  – Cluster member organizations aligned toward shared goals
  – Measurable outcomes
  – ANSD lead monitoring initiative
  – Workshops to support citizen science efforts toward these goals
Greening STEM technologies: A model for advancing do-it-yourself (DIY) environmental sensing networks to support citizen science and primary and secondary education

Dave Arscott, Tara Muenz, Shannon Hicks, Steve Kerlin
Stroud Water Research Center, Avondale PA

Anthony Aufdenkampe
LimnoTech, Minneapolis MN

Julie Vastine
ALLARM, Dickinson College, Carlisle PA

U.S. EPA Model Education Grant Program
EPA Grant Partners

- Alliance for Aquatic Resource Monitoring [ALLARM] –
- White Clay Creek Watershed Association (PA, DE)
- Delaware Riverkeeper (NY, NJ, PA geography)
- Groundwork Anacostia River DC (D.C. and MD geography)
- Georgia River Network (Athens, GA)
- Georgia Adopt-A-Stream (Atlanta, GA)
- Smithsonian Conservation Biology Institute (Front Royal, VA)
- Red River Basin International Water Institute (ND, SD, MN)
- Collegium Charter School (Exton, PA)
- Downingtown STEM Academy (Downingtown, PA)
- Green Woods Charter School (Philadelphia, PA)
- Wilmington Pilot School (Wilmington, DE)
- Avon Grove Charter School (Avondale, PA)

DIY Monitoring Workshop
(2016-2018)

Delaware  Georgia  Minnesota
Maryland  New York  North Dakota
New Jersey  Pennsylvania  Virginia

- span across 5 EPA regions (2,3,4,5,8)
What is C-SAW?

The Consortium for Scientific Assistance to Watersheds (C-SAW) is a team of specialists who provide FREE organizational and scientific technical assistance to Pennsylvania-based watershed and conservation organizations.

C-SAW does not conduct watershed monitoring or assessments. Instead, C-SAW helps watershed organizations do a better job with their own monitoring and assessments.

C-SAW can help your group:

- Learn how to assess watershed health
- Identify solutions
- Develop monitoring programs, protection plans, and restoration projects

C-SAW assistance is provided at no cost to qualified applicants!

Assistance is made possible by a Pennsylvania DEP Growing Greener Grant awarded to Pocono Northeast Resource Conservation & Development Council and its six partner institutions located throughout Pennsylvania. Learn more...
United States Geological Survey

As the nation’s largest water, earth, and biological science and civilian mapping agency, the United States Geological Survey (USGS) collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. USGS carries out large-scale, multi-disciplinary investigations and provides impartial scientific information to resource managers, planners, and other customers.

Visit the USGS website

Administrative Assistance Provider

Pocono Northeast Resource Conservation & Development Council

The Pocono Northeast Resource Conservation & Development Council (PNERCD) is a community resource providing expertise in resource management and development throughout a ten county area of Northeastern Pennsylvania. Council members represent numerous interests and disciplines, including agriculture, forestry, environment, education, wildlife management, mine reclamation, recreation and economic development.

Visit the PNERCD website
Contribute to EnviroDIY!

EnviroDIY.org is community-built
We encourage you to help us build it!

• Learn and Share at http://envirodiy.org/
• Contribute at https://github.com/EnviroDIY