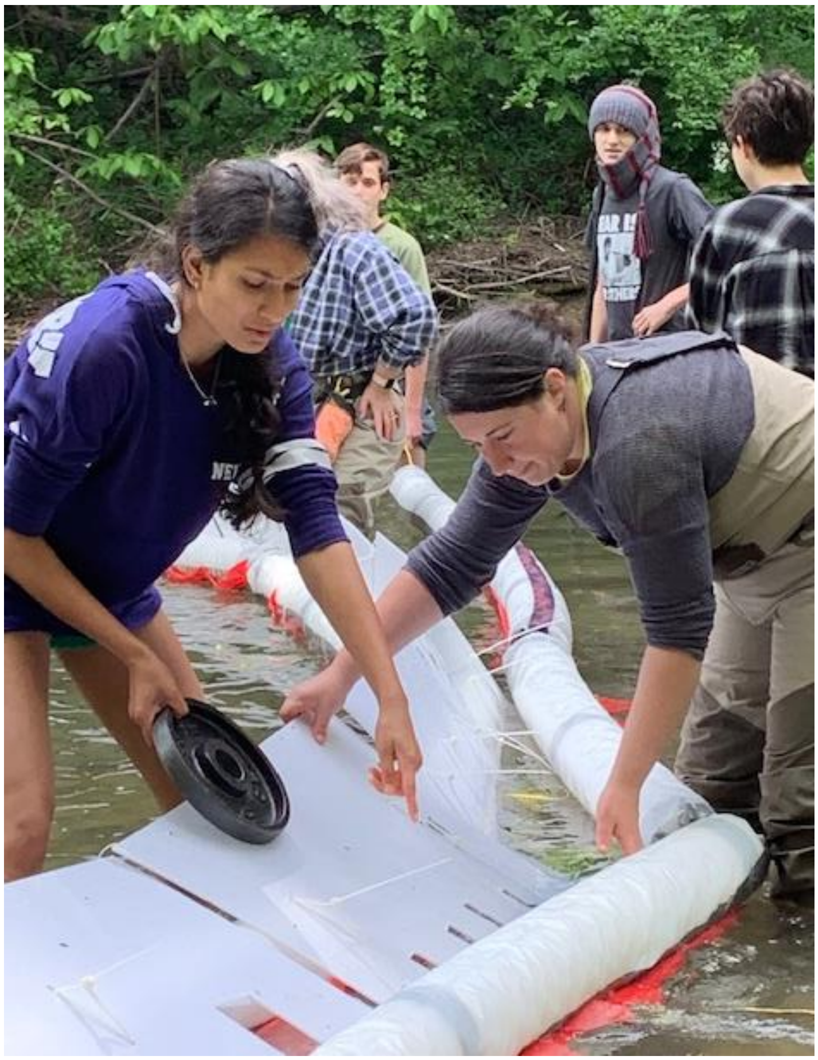
POLLUTION SOLUTION

How can we design and build a floating device that keeps plastic from entering our oceans?

A project-based learning (PBL) module for high school classrooms



Clean Valley Council

Funded through the Competitive Grant Program from the Virginia Department of Environmental Quality

NOVEMBER 2019

Contents

Each year, our organization connects over 15,000 students to environmental science through hands-on lessons taking place in our community. We have witnessed the way that interactive learning can lead to an "aha moment" - that beautiful realization that our individual role is making the world a less polluted place, that moment when the creative energy hums.

This project-based learning (PBL) tool is meant to trigger that moment, and to connect science with real world challenges and solutions. Trash in our waterways poses threats to all the aquatic life forms in the steams – not only where it lands, but all the way downstream to the ocean. Our volunteer teams clean up over 100 tons of trash each year, and together we want to find better ways to "catch it" before it leaves our community. We are reaching out to the students for new and innovate ways to do just that...

Have fun researching, discovering, and designing new solutions to this pollution!

Mary Ann
Executive Director
Clean Valley Council
maryann@cleanvalley.org

About This Project

Content

This module teaches students about environmental issues through a **research and development** (R&D) process. In the research phase, students learn about the impact of pollution (particularly plastic) on water quality and aquatic ecosystems. Students investigate watersheds of various scales. They learn how human impact threatens natural resources through urbanization, population growth and pollution.

Students apply this knowledge to the development phase of the project in which they design and build a pollution solution. Students use engineering thinking and processes to refine their model. If time allows, students build their prototype and travel to a local stream to test their prototype's effectiveness in capturing simulated debris (e.g. rubber duckies). The project concludes with a community presentation.

Instructional Approach

This module is designed to be flexible. Teach it as a self-contained project-based learning (PBL) unit. Alternately, select activities from the module that support your teaching needs. Use the **Project Overview** and **Teaching Tips** section to guide your decisions.

The project uses a student-centered instructional approach adapted from PBL Works, a leading non-profit national resource for project-based learning. In its entirety, the project also meets the expectations of a high quality meaningful watershed educational experience (MWEE), as mandated by the Virginia Department of Education. It supports, as well, attainment of Virginia's 21st Century Success Skills (The 5 C's). In other words, this unit need not be an "add-on" to what you are already teaching. Use it as a tool in your toolkit: a high-quality method of instruction.

Virginia Standards of Learning

This project aligns with a variety of science-based SOLs, as well as supporting SOLs in language arts and mathematics.

- **Earth Science**
  ES.1 & 2 (scientific investigation)
  ES.8 e, f (watersheds and human impact)

- **Biology**
  BIO.8 (human impact on ecosystems)

- **Environmental Science** (Guidelines)
  Scientific Skills & Processes, including engineering design (I), The Physical World (II), The Living World (III), Resources (IV), Human Impact (V)

- **Environmental Science AP**
  The Living World, Earth Systems and Resources, Population, Land and Water Use, Pollution

Pedagogical Alignments

PBL Works "Gold Standard" Essential Project Elements	As expressed in the Pollution Solution project . . .
Challenging Problem or Question	Students tackle a real-life design/build challenge: *Can we design and build an economical device that removes litter from our stream or, that prevents plastic from entering our ocean?*
Sustained Inquiry	Students pursue a series of supporting questions and activities as part of the project. This teacher-facilitated pathway guides students to first understand the pollution problem (its causes & effects). They then address that problem via an engineered solution.
Authenticity	Students address an urgent problem that impacts wildlife and humans. Students work authentically, using engineering processes.
Student Voice & Choice	Students design and model inventions of their own creation. They themselves vote which prototype to build as a class.
Reflection	Students reflect on content, process, and product throughout this project. Lesson plans include formative and summative reflection.
Critique & Revision	Students (teams) receive and share feedback about each other's designs. They use critique to refine their prototypes.
Public Product	Students build and test their invention in a local waterway. Students present their work to community stakeholders.

The 5 C's	As expressed in this project . . .
Creativity	Students invent novel solutions to the litter catcher challenge.
Collaboration	Students work together in research, design, and build teams. They confer with outside experts about their design.
Communication	Students share ideas within teams and between teams. They communicate with outside experts during the project.
Critical Thinking	Students devise—and revise—their litter catcher prototypes using design criteria, outside feedback, and test trials.
Citizenship	Students actualize environmental stewardship by participating in a litter clean-up, and by creating their pollution-solution invention.

POLLUTION SOLUTION, Part 1: Researching the Problem

5-10, 60-min. sessions (1-2 weeks) including field investigations

Project Milestone	Key Student Question(s)	Activities	Products & Assessment
1. Project Launch Goal: Meet the challenge *1 – 2 sessions, 60 – 90 min. total*	Driving Question: **Can we invent and build an economical device that keeps plastic out of the ocean?** • What do we know/need to know to meet this challenge?	Entry Event, see suggestions p. 7 *Sticky-storm*: Class creates and sorts a collection of stickies to develop guiding research questions, see p. 8	Organized class list of key questions
2. Classroom Research Goal: Understand the global situation *Several sessions, 60 – 240 min. total*	**How is plastic pollution impacting our oceans?** • What's causing the plastic pollution? • How does this plastic pollution affect wildlife and people? • How bad is the problem?	1. Class reviews/discusses video clips. 2. Class participates in Enviroscape Model or other watershed simulation activity. (*Oceans to Watersheds*, CVC program) 3. Class participates in understanding the chemical makeup/and breakdown of different plastics (*World Drowning in Plastic,* CVC program)	Teacher-designed worksheet(s) or quiz
	What are people doing to tackle plastic litter and pollution?	The class interviews outside experts and/or forms student research teams	Individual or team worksheet or powerpoint presentation
3. Field Research Goal: Understand the local situation *60 – 240 min, including field session*	**How are our local streams contributing to the problem?** • Where is one stream's pathway to the ocean in our community? • What kinds of litter enter this pathway? Optional: How healthy is our stream? (biotic/abiotic testing)	1. Class plans and implements a data-rich field investigation (litter pick-up, sort, weigh-in) at proposed project launch site. 2. Students note details of the test site pertinent to their upcoming design phase. 3. Students analyze data, make conclusions via class discussion and/or lab report.	Individual data sheets and lab reports Individual or group powerpoint slides describing site and/or litter investigation results

POLLUTION SOLUTION, Part 2: Designing a Solution

5-10, 60-min. sessions, (1.5 - 2 weeks) plus all-day Build Day and Test Day

Project Milestone	Key Student Question(s)	Activities	Products & Assessment
4. Develop Prototypes Goal: Design devices *3 – 5 sessions, 180 – 300 min.*	**What will our invention look like?** • What are our design criteria? • What materials can we use? **How can we improve our design?** • How can we present our idea to others? • How can we give and receive constructive feedback? • What criteria will we use for selecting the class prototype?	1. Class develops common criteria. 2. Teams sketch their designs 3. Teams make small prototype models. 4. Teams create their slides and/ or poster. 5. Peers and experts provide feedback and teams revise plans. 6. Class develops team work plan for build day.	Class-developed design criteria Team designs & prototypes Prototype rubric (team) Team and/or individual feedback for another team
5. Build Device Goal: Build prototype *½ - 1 full day*	**How can we work together effectively to complete our build?**	Class constructs their selected prototype.	Class (and/or team) work plan Class-developed teamwork rubric
6. Field Test Device *Goal:* *Try it out!* *1 field session (60 – 120 min.)*	**How will we measure the effectiveness of our design?**	Class tests prototype and gathers data to measure its effectiveness.	Data sheet and/or report
7. Public Presentation *Goal: Sharing and Recognition* *2 – 4 sessions, 90 – 240 min.*	**What shall we share about our project with the greater community? How shall we do it?**	Team create different components of the presentation, then present per their plan.	Individual reflection with prompts about the problem, the project, and the solution.

Teaching Tips

Milestone 1: Project Launch

Overview:
Students meet the challenge in a compelling way. In a teacher-facilitated process, they then generate questions that guide their learning about plastic pollution. This session sets the stage for **Part I of the R&D process: Research.**

Materials:

- stacks of post-it stickies
- watershed maps (Google Earth)
- *optional:* bag of (cleaned) litter including plastic

Notes:
1. Kick-off this Project Challenge with an Entry Event that is memorable and meaningful to your students. Use your creativity, but a few options:

- Empty a bag of cleaned plastic bottles, straws, drink cans, etc. on a student desk (or litter the entire classroom with the debris). Do we want litter in our school habitat? Of course not, and neither do marine animals. What's the problem with marine debris? Encourage student sharing of what they already know. Does everyone agree it's a problem? What can we, as science students in this classroom, do about this problem?

- Jumpstart the conversation by showing video clips of the Great Pacific Garbage path and other ocean gyres. What is the source of this plastic? How is it harming ecosystems? How are people tackling the problem? How can we help with this effort where we live?

- Show photos of marine animals emmeshed in plastic and litter. It will be distressing but direct the conversation to address causes and remediations. Then introduce the **R&D Pollution Solution Challenge**.

2. Orient students to the **Project Challenge**.

   a. Post the driving question in the classroom.
   b. Explain the culminating product (building and testing the device for a local waterway).
   c. Provide a sense of the project length.
   d. Inform students that they will be working as scientists and as engineers in an **R&D** (research and development) process to complete this project.

3. Create with students a road map of "what we need to know" research questions.

a. Inform students they will have a role (with you) in identifying questions they need answered in order to be informed and successful inventors. These questions will serve as a road map for the **research phase** of the project.

b. Ask students in pairs or small groups to generate at least 5 good questions that would help the class understand more about plastic pollution in our waterways and oceans. Students should write each of their questions on a separate sticky.

c. Collect and read aloud all the stickies and/or have groups read. Sort the question stickies by similar category on the board.

d. Note major areas of interest then add yours, as linked to your curricular goals.

e. Condense all the questions into a few major supporting questions for this phase of the project. Retain these questions on the board, as guide for future research & lessons.

Milestone 2: Classroom Research

Overview:
Students learn more about the problem of marine pollution through research. This phase is ideal for teaching content subject matter. Maximize its utility by Identifying vocabulary and concepts you want students to master; design research tasks and products accordingly. Consider a quiz or test after this component of the project.

Materials:

- Video Clips: Mr. Trash Wheel; https://www.youtube.com/watch?v=XLPSmKLg8hc
- *Optional:* enviroscape or other interactive watershed model
- *optional: A World Drowning in Plastics* (CVC program).

Notes:
1. Review with students the major supporting questions for this project phase. Then show how what they do in class relates to answering those questions. Go light or deep, depending on your students and course needs. A sampler of options:

- Content stations: have teams rotate, answering worksheet. Or use jigsaw method: one team becomes experts in one topic, then disperse to share their expertise with others.
- Video clips, textbooks, on-line research in tandem with an individual or team graphic organizer or worksheet
- Guest expert(s): panel, Q&A, or lecture; live or online/Skype
- Role play or watershed simulation. Does your school or natural resource agency have access to the Enviroscape watershed model? Simpler build-it yourself variations can be found online.
- *A World Drowning in Plastics* (CVC program). Gain a better understanding of what makes up plastics, how it is created and its pro/cons to sustainability

2. Let your summative assessment do double duty by having students create small, finished products, some of which the class can later assemble as part of the class public presentation. The same process can also be used to synthesize findings from the **Field Research** phase.

Examples (created by individuals or teams):
- Tri-fold display with paragraphs each answering one of your class's supporting questions
- Powerpoint slides providing the same.

Milestone 3: Field Research

Overview:
Students travel to your identified outdoor test site to gather data about type and amount of litter near and in the target stream. They also investigate features of the test site (land and water) that will influence design and build decisions.

Extension: Students investigate health of the stream through abiotic and/or biotic testing. Students look for opportunities to protect the streams such as riparian buffers. Students do a clean up while they are on-site.

Materials:
Classroom:
- Google satellite view of outdoor test site and surrounding landscape.

Field:
- *Litter Investigation*: Safety gear (gloves, etc.), trash bags, first-aid kits, portable scale, clipboards, data sheets, pencils, cameras, portable dry erase board (optional)

- *Site Investigation I* (site assessment): 10 m. tape, stopwatches & oranges (for measuring velocity, see next page 2b.), wading boots (optional), maps or paper for drawing maps, clipboards, pencils, cameras

- *Site investigation II* (stream-monitoring): abiotic and biotic testing supplies, boots, nets, tarps, clipboards, lab sheets, pencils

Notes:
1. Prior to the Field Day:

When students arrive on the site, they should be fully prepared. They should know what they will be doing, as well as why, how, where, and when. They should be versed in all routines including what happens if they are off-task or acting unsafely. You should feel comfortable and knowledgeable about the site and have all the help and materials you need for a successful day.

a. Recruit one or more resource partners to join your class on site, to add a real-world career component as well as to help with activities and data gathering.

b. Select your public access test site with care. Criteria include: distance from school; parking; access to shelter and restrooms; width, depth, and flow rate of waterway (narrow, shallow and slow is best); presence of litter, overall safety of site. NOTE: Water levels change daily, be sure to have 1-2 back up locations. Check test sites the night before to select the best location.

c. Outline outdoor behavior expectations with students (stay with buddy or group in designated area, no throwing rocks, no wading unless sanctioned, stay on task, etc.).

d. Designate individual/team roles and expectations.

e. Review with students: safety protocol, data gathering tasks, purposes, data charts, tools, and methods.

2. During the Field Day:

a. Litter Investigation:
While maintaining safety protocols, have students work in small teams to collect debris and litter from the investigation site (you determine the area). Then have students sort and weigh (or count) litter by type. Record on data sheet. Consider framing the activity as an investigative question requiring data-gathering. For example, what percent of debris is plastic heading to the ocean? Bag and discard the collected refuse properly.

b. Site Investigation:
Remind students this location will be the test site for their device. Have student teams map the area, measure key components, calculate velocity (if water levels and flow rates are safe), and note other significant features (where/how will they attach their device?).
Velocity: measure and mark out 10 meters along stream. Step in stream and release orange at start point. Time the orange's passage to the 10 m. mark. Velocity = sec/meter.

3. After the Field Day:

Debrief in class about both elements of the investigation. Reflect on findings and impressions. Also reflect on the investigation and teamwork processes: what went well and what would they do differently next time based on their experience?

Use the field experience to tie together concepts explored in Part One of the **Pollution Solution** project. Products from Part One can include charts, maps, paragraphs, lab reports, or powerpoint slides, some of which the class can later use as part of the final presentation. Revisit the "road map" questions from Day One to point out how student research in the class and in the field has helped answer those questions.

Milestone 4: Develop Prototypes

Overview:
Students move into **Part II of the R&D process**: **Development**. Teams now create and refine their inventions for removing litter from their waterway. First, the class develops common design criteria. As teams they then design and model prototypes that meet their criteria. Later in the process, teams create a poster about their design for peer and community critique and subsequent revision. Note: the prototype can be the final project product if time is short.

Materials:
- Graph paper, lightweight cardboard, scissors, duct tape, glue guns
- Poster (chart) paper and markers
- Data and maps from site investigation

Notes:
1. Develop **a common design criteria** for the devices: ask students to create criteria on individual stickies, then share and sort responses. Determine and post the key design criteria. *Examples:*
- Function: Must catch x percent of floating debric (represented in this project by released rubber duckies, (see p. 13) during the field test. Must not harm living things or pollute the water. Must accommodate fluctuations in stream volume and velocity.
- Form: Must be easy to transport, assemble, install (including attachment strategy) and remove. Must be built with basic materials with people of basic skills in less than x hours.

2. Form student teams of 3 – 4 "engineers" to design their device. Teams must design their prototype aligned with the criteria, construct a paper model, and prepare a powerpoint.

3. Facilitate a feedback session for student designs. Students can share their ideas to peers and invited guests (such as local municipal engineers/staff) through powerpoint presentations. Alternately, students can print and post the 2-3 main design pages for a Gallery Walk. In a Gallery Walk, each team places its poster pages on wall for others to walk by, examine, and leave constructive comments on stickies they attach to the poster. Charge teams to revise or even combine their designs based on the feedback.

4. Have class select one prototype for the class build using a decision-making protocol.

5. Create a class work plan together:
- break down construction and other project tasks into component parts
- create a plan for concurrent assemblage stations that support these tasks
- outline a timeline that identifies the sequence of these tasks
- identify materials needed
- assign students to teams, tasks, and individual jobs

6. Create a teamwork rubric with student input that allows self- and teacher assessment of their teamwork contributions during the upcoming "Build Day."

Milestone 5: Build The Device

Overview:
Full-size student prototype should be designed to be constructed in a day or less, but plan for several hours of work. Assign students to specific cooperative work teams and stations and/or rotate through stations, depending on your project. Sample sequence:

9:00– 9:30 a.m.: Review project goal, work plan (team and individual roles) and safety
9:30 a.m. – noon: Work in stations to construct components, assemble, and decorate
12:30 – 1:15 p.m.: lunch
1:15 – 2:00 p.m. Final efforts, clean-up, reflect & brief for Test Day (plus what to wear).

Materials:

- Student-created Teamwork Rubric (assessment tool)
- Construction supplies, tools, and safety equipment (see resources)
- Camera for documentation

Milestone 6: Field Test The Device

The Test Day is the culmination of your project. Have fun, and make it successful!

Preparation:

1. Test-Site: Double-check your test site (stream) the day before the field day: is this a safe environment for the students? Is that water level and velocity appropriate for project success? Is there easy access to the test site? Do you have permission (if needed) for its use?

2. Students: Ensure students are dressed appropriately (water shoes, shorts, change of clothes) and understand the process and safety expectations for the day.

3. Supplies: Bring everything you need and set up stations for the final on-site assembly and site attachment. Bring materials for the 25 – 50 object debris simulation (a collection of rubber duckies or empty water bottles with caps) and sufficient catch nets to prevent any escapes.

Process:

1. Lead students and their device into the stream.

2. Designate roles for back-up catchers with nets, ensuring no debris flows beyond the test-site.

3. Release the "test debris" upstream of the device in such a way to ensure no lost debris.

4. Document by photo or video the effectiveness of the device in catching the debris.

5. Reflect and celebrate your success and take a group photo! Then "Leave No Trace."

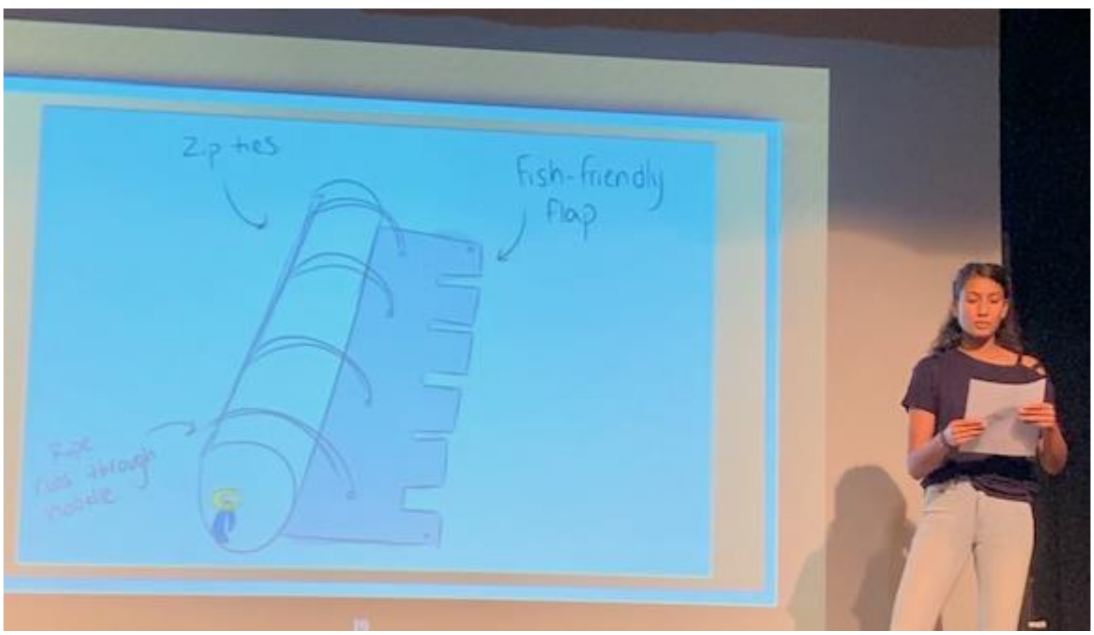
Milestone 7. Public Presentation

Overview:
Students present results of their project to a community panel; includes Q&A.

Notes:
Presenting publicly connects students and their topic to the community. Form a panel of school officials, other students, and/or community members. Decide scope of the project and its purpose (informative? persuasive?) and work with students toward that end. Students may want to create a final powerpoint for this presentation, taking turns presenting the steps.

Use artifacts and products already created during the project as part of the presentation and/or display. Add new material (data charts, photos, reports) from the Field Test Day.

As possible, give each student a job on presentation day. *Examples:* Greeters, Display/Caption Makers, Welcome/MC, Presenters, Q&A responders, Hospitality, etc. Take photos & share!
The presentation is the culminating event, but needs not be assessed itself if you have assessed individual and team components along the way. Enjoy and celebrate!



POLLUTION SOLUTION: Character Education in Action

Caring…for our rivers and each other
Responsibility…for our actions
Creativity…for solving problems and find the best solutions

Thank You, Teachers!

Additional Resources

1. FREE resources from Clean Valley Council

Clean Valley Council is a resource for all teachers. Classes are free where we have contracts. Contact us to see if your community is under contract or if you'd like us to reach out to municipal leaders to create a cooperative agreement. Some free supplemental tools are on our website at www.cleanvalley.org

2. Suggested Project Toolkit for Build Day ($300 - $500 range):

Toolbox on wheels
Power Drill and Misc. Bits

Misc. Small Tools:

- Rubber Mallet
- Standard Hammer
- Phillips/Straight Screw Drivers
- Needle Nose Pliers
- Snippers
- Utility Knife
- Utility Saw

Design-specific supplies:

- Wire Ties - multiple lengths
- Rope
- Heavy Duty scissors
- Duct Tape
- Spring Clips
- Small Level
- Safety Glasses/Vests/Gloves
- Extension Cord

3. Community Partners

a. Natural Resource Agencies

State-funded agencies in your area may have staff such as rangers, watershed educators, or classroom specialists able to help your project at no or low cost. Many offices with educational outreach may also have gear to lend including an Enviroscape model, posters, lesson kits, and more.

- Your local Virginia Soil and Water Conservation Board and local water authorities
- Local 4-H agent (Virginia Extension Office)
- Nearby state parks

b. Municipal Agencies

Local offices may also have pro bono staff, resource, and insight to share. You may need to coordinate your field test with one or more of these offices.

- Municipal stormwater managers and engineers; municipal solid waste/recycling managers
- Parks and Recreation departments
- Water Authority engineers and outreach staff

4. Other Helpful Resources (free)

a. Project-Based Learning materials from PBL Works: *A treasure trove of free materials, templates, lessons, rubrics, and blogs. Website: http://pblworks.org*

b. Chesapeake Bay & Meaningful Watershed Education Experiences (MWEE) Activities & Guide
Free education-related Bay material, including the new MWEE 101 Guide (1 credit course you can complete on-line). The Pollution Solution can easily be framed as a MWEE, a Virginia mandate at the elementary, middle, and high school levels. Website: http://baybackpack.com

c. Community-Action and Problem-Solving Resources from Earth Force:
Free educator guides and lessons supporting student voice and choice, empowered decision-making processes, environmental civic action, and more. Website: http://earthforceresources.org