Soak My World

DRAFT

Purpose:

This activity explores how urbanization alters the timing and volume of storm water runoff. Students learn how this in turn affects the physical structure, the water quality and the aquatic communities in the streams that flow through urban areas. Finally, the lesson explores ways that communities or individuals can prevent these impacts.

Grade level: 7th -12th

Setting: Classroom, Outdoors - (optional field activity)

Duration:
Lab and discussion: 1 hour

Field activity: 1 hour

Curriculum Connections:

- 7th Grade Math: Geometry 7.G6
- Mathematics II: Geometry GMD.3
- Earth Science: Standard 4.2d
- Natural Resource 1: Standard 4.3

Summary:

Students will use simple watershed models to measure runoff from natural and urbanized areas. They will graph the data to create and compare the hydrographs of these two different types of watersheds. Students will also map different areas in their neighborhood, calculate the amount of impervious surface in the area, and determine how this affects the volume of stormwater runoff from a typical rainstorm.

Finally, students will list different types of pollutants that enter the streams from urban areas and learn about possible impacts to the stream. They will also learn about possible methods of reducing these impacts through community or individual actions.

*See additional activities to further explore actual conditions in streams.

Background:

When it rains or snows, where does all the water go? In addition to soaking into the soil or evaporating, some of the water will also flow over the land surface, heading downhill to the nearest stream or ditch. We call this stormwater runoff.

In cities and towns, the water can't soak through the pavement and rooftops like it can into the soil in rural or wildland areas. As a result, cities have much more stormwater runoff than forests and fields do. The water flows off impervious surfaces such as driveways, rooftops, sidewalks, and parking lots, and then collects in gutters or basins which run directly into storm drains. These drains carry the water (as well as oil and other toxic chemicals) directly to your local stream or lake.

As little as 10% impervious land cover in an urban watershed can put streams and lakes at risk. The more impervious cover, the greater the risk.

Soak My World

Classroom Activity: Students will measure and compare runoff from watershed "models."

Materials: For each group of students (3 students/group minimum), provide…

- Stop watch
- Clip board
- Data sheets
- Calculator
- Ruler
- Cookie Sheet modified with a small "spout" at one end.
- Spray bottle (with a fine spray)
- Measuring device (eg. graduated cylinder)
- Funnel
- Felt cut to the same size as the cookie sheet
- Clips or Velcro for attaching felt to cookie sheet
- PVC rack (see instructions on pg. 5)
- Paper towels

Class discussion prior to student activity:

1. **Setting the stage:** This exercise focuses on the precipitation and runoff components of the hydrologic cycle.
   - **Discuss** the different components of the hydrologic cycle (precipitation, infiltration, runoff, evaporation/evapotranspiration, condensation).
   - **Define** runoff as the volume of water moving across the landscape following a storm event (or melting snow event).
   - **Emphasize** that runoff moves across the landscape until it infiltrates into the soil or enters a stream or other waterbody.
   - **Explain** that infiltration is important because it "recharges" our ground water and provides summer base flow (low flows) in streams.

2. Show the students how to set up the rack, cookie sheet, funnel, and collection bottle (see page 5). This is their experimental watershed. Tell the students that the sheet with felt represents a "natural" watershed area, while the bare cookie sheet represents a paved watershed area (100% impervious area). Note that the watershed models have different slopes, which will need to be measured and recorded during the activity.

   Explain to students that they are going to "rain" (using the spray bottles) on both the vegetated and impervious watersheds and will collect runoff data from each.

   Ask the students how they think runoff will vary between a vegetated watershed and a paved watershed.

Soak My World

Student activity:

1. Divide the class into groups of 3-5 students and distribute materials. Have groups set up the rack and cookie sheet.

2. Have students measure and record the rise and run for their "watershed". They will use these measurements to calculate the slope.

3. Explain that students will use the spray bottle to "rain" on the watersheds. They will measure runoff on the vegetated (felt covered) watershed first. Then they will remove the felt, dry off the cookie sheet with paper towels and repeat the experiment on the "paved" watershed.

4. Adjust spray bottles so spray is relatively gentle and will cover as much of the watershed as possible with each spray. Each rain storm will last 2 minutes and students should spray continuously over that time, covering the entire watershed. The students will measure runoff every 10 seconds from the beginning of the rain storm – for 4 minutes total or until the runoff stops entirely.
    - One student will spray the watershed.
    - One student will keep time, calling out 10 second intervals.
    - One student will measure and record the accumulated volume during each volume.
    - If you have more than 3 students / group, have them switch roles for the second set of watershed measurements.

5. Have students determine the runoff discharge (ml / 10 sec) by calculating the difference between accumulated volumes (column D) after each 10 second interval and record in column E.

6. Have students graph the runoff discharge in column E (ml / 10 sec) from the beginning of the rain storm (t=0 sec) until the end of their experiment (t = 240 seconds). These graphs are called storm "hydrographs".

7. For both the vegetated and the impervious watersheds, have the students calculate and fill out the Results Table for the following. Make sure they record the units as well.

    - Slope of their watersheds
    - Length of the rainstorm
    - Time after the storm began until water begins to runoff the cookie sheet.
    - Time when runoff ends.

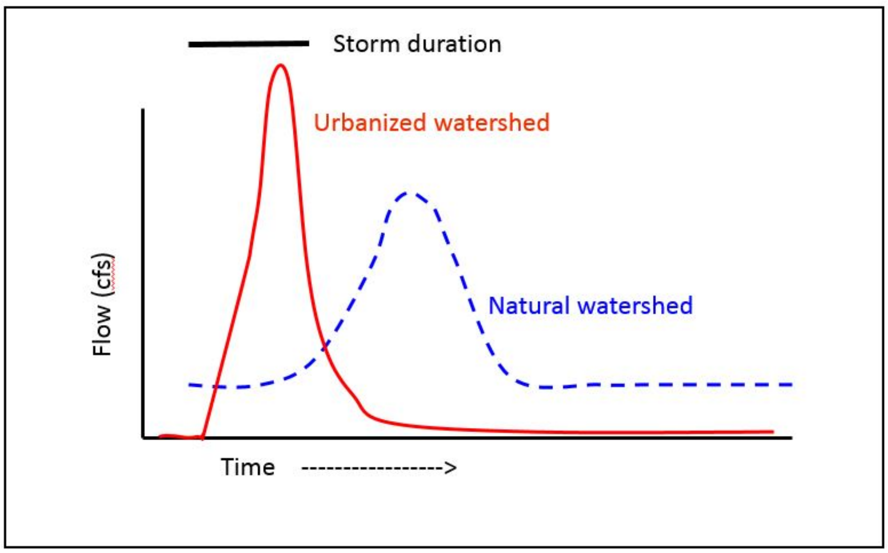
- Time of peak runoff discharge.
- Peak runoff discharge.
- Estimated total volume of runoff. (Have students count each square under the curve. When the graph crosses a square, count it if 50% of more of the square is under the curve).

Extra activities:

- This activity compared 100% vegetated landscapes with 100% paved landscapes. Using smaller strips of felt, students can explore the effectiveness of strips or areas of vegetation in an urban landscape. Graph results for landscapes with different percentages of impervious surface area. Is the vegetation more effective at the bottom or top of the landscape?

Follow up discussion:

To the right is an "idealized" graph of a vegetated (natural) watershed and an impervious (urbanized) watershed. A full-sized version of this graph found on page 11 can be used in your discussion.

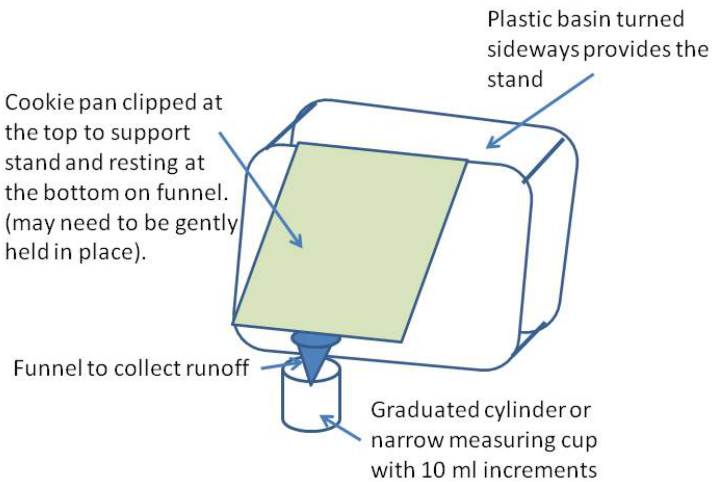


Have students share their results (e.g. tape their graphs and tables on the board to use for the discussion). **Discuss the following with your students.**

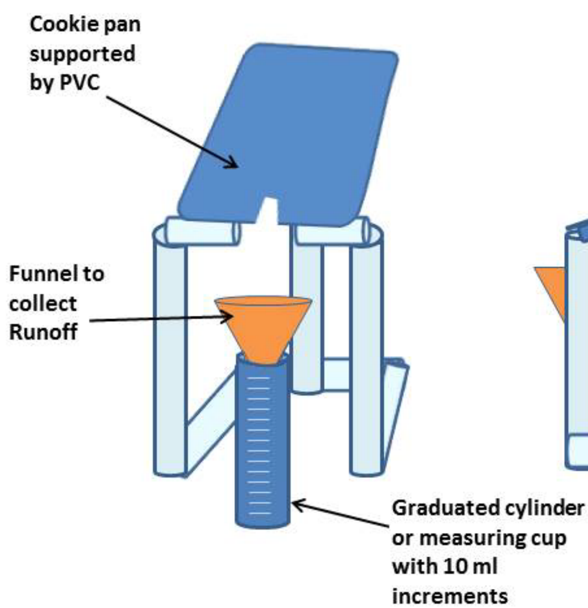
- How did the student graphs differ from the "idealized" graph? Why?
- What effect did "paving" a watershed have on runoff timing and volume?
- What effect did slope have?
- Why was there an earlier runoff and a higher peak flow in the urban watershed?
- Why did baseflow disappear in the urban watershed?
- What are the implications of "paving a watershed" on groundwater levels, stream flows throughout a year?
- How might "paving" a watershed affect movement of pollutants into a stream?
- Explain that water moves more quickly over paved surfaces because there is no longer vegetation and soil to slow it down. Define the terms **impervious** and **pervious** surfaces

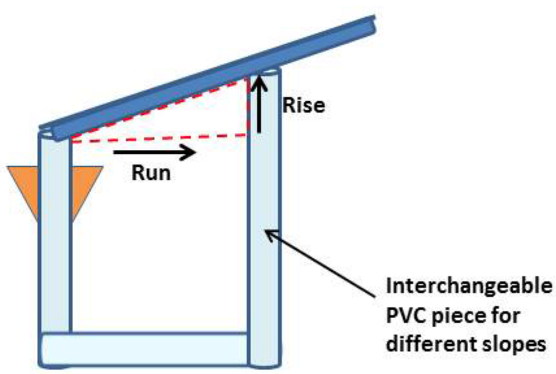
Soak My World

Basin or Tub Method



PVC Stand Method





Soak My World

Optional Field Mapping Activity:

This activity can be done as a homework assignment or in class, and as a group or individual assignment. If multiple groups or students do the exercise, you can compare results for different types of land uses.

Materials:

- Clip board
- Data sheet
- Calculator
- Measuring tape

Student activity:

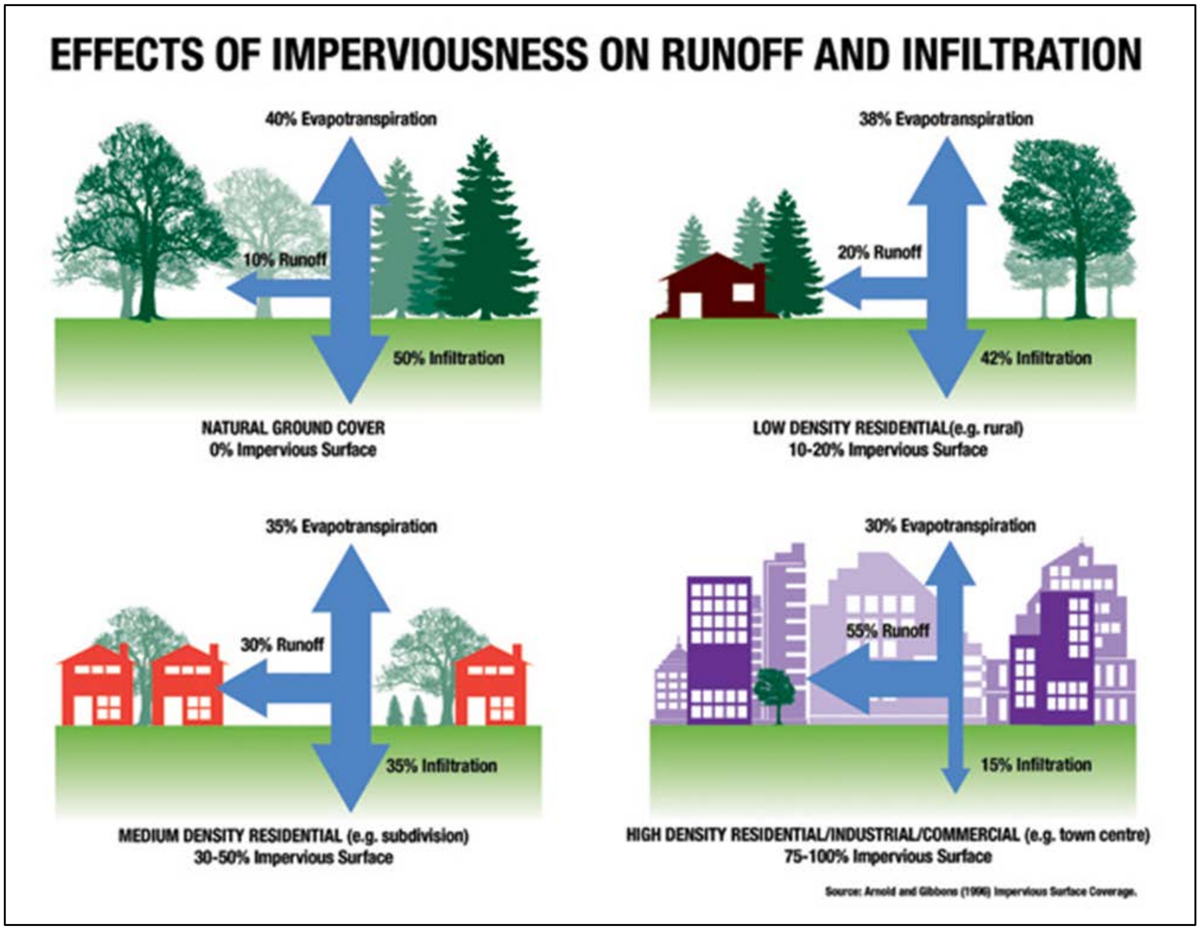
1. Students will measure the total area of the lot size of their choice (eg. part of a park, their home or apartment building lot, the school property, commercial areas).
2. Have students calculate total volume of water that a one inch rain storm would create on this lot. (Total area * 1 inch) Make sure students convert units appropriately!
3. Students will then measure individual areas of impervious surfaces. These will include buildings, driveways, roads and parking lots. Sum up the impervious surfaces and subtract from the total area to determine the area of pervious surfaces.
4. Note any modifications to the lot that would reduce runoff (grassy swales or depressions, detention basins).
5. Have students calculate percent impervious surface areas for their project area.
6. Estimate one value for percent impervious surface by using the graphic on page 6 and the calculated percent impervious surface from step 5. Multiply this percentage by the volume in step 2 to determine the total volume of runoff for this storm.
7. Compare the students' results for different landscapes. Are students surprised at the differences?

Helpful conversions:

1. 1cm = .01 meter
2. 1 inch = 2.54 cm
3. 1 cubic meter = 1000 liters
4. 1 cubic foot = 7.48 gallons

Soak My World

- Figure below summarizes changes with increased imperviousness. Graphic from: Chester L. Arnold Jr. & C. James Gibbons. 2007. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. Journal of the American Planning Association 62:2, 243-258.



Soak My World

Further Discussion:

1. **Summary of changes in urbanized watershed compared to the natural watershed**:
   - Runoff starts sooner because far less water infiltrates into the soil.
   - The peak runoff is much higher and occurs sooner. This increase in peak discharge can cause increased erosion and changes in the stream channel.
   - Greater volume of storm water runoff can alter stream channels and cause flooding.
   - Reduced infiltration reduces subsurface flows to the stream. These flows feed the stream between storms, so streams may dry up completely during parts of the year. This will kill off fish and the macroinvertebrates they feed on.
2. **What types of pollutants are found in stormwater? What are their sources and impacts?**
   - More pollutants will reach streams and other waterbodies.
   - See summary of urban pollutants in table below:

Water Pollutant	Sources	Impacts
Oils and greases	Car leaks, dumping in storm drains	Compounds may include toxic petroleum products. Floating oils can harm aquatic birds and mammals.
Heavy metals	Wearing of brakes, tires, etc.	Teratogenic or carcinogenic.
Antifreeze	Leaks, dumping in storm drains	May be directly toxic. Can deplete oxygen from water.
Polycyclic aromatic hydrocarbons (PAHs)	Byproduct of fossil fuel combustion	Varies with actual compound. May be carcinogenic, mutagenic and teratogenic. Affects fish, other aquatic life and may bioaccumulate.
Plastics	Trash, nets	Can choke or interfere with aquatic organisms. If ingested, interferes with digestion.
Sediment (dirt, sand, clay, rock)	Construction, lawns/gardens, bare lots	Fill up space between cobble in streams, interfering with fish spawning or macroinvertebrate habitat. Carries many other pollutants.
Nitrogen and phosphorus	Fertilizers, pet waste, yard waste	Excess plant growth in streams and lakes decomposes, consuming dissolved oxygen and harming aquatic life. Some algae are toxic to dogs/livestock. Ammonia can be toxic to fish. Nitrates in drinking water may cause blue baby syndrome.
Pesticides / herbicides	Garden/lawn use, household use.	May bioaccumulate and have toxic or sub-lethal affects.
Bacterial / other microscopic organisms	Pet / wild animal waste, failing septic systems	May cause intestinal disease.
Vegetation (leaves, yard clippings)	Yard waste left in ditches, drains, dumped in streams	Decomposition can result in low oxygen concentrations, leading to fish kills or sub-lethal impacts on aquatic life.

Thermal pollution	Runoff over hot pavement and roofs, loss of riparian shade	Many aquatic organisms are sensitive to warm temperatures. Saturation levels of dissolved oxygen are lower in warm water. Some toxins (eg. ammonia) are more toxic in warm water.

3. **What are some ways that the city controls runoff from impervious surfaces?**
   "MS4 communities" (municipal separate storm sewer systems) are required by EPA to obtain an urban stormwater permit and to implement control measures, including:
   - Public education and outreach – target homeowners, businesses, students
   - Public Participation and involvement – storm drain stenciling, citizen monitoring
   - Illegal discharge detection and elimination (seek out illegal dischargers)
   - Construction site stormwater runoff control (straw bales, sediment barriers)
   - Post construction stormwater management in new and re-development (detention or retention basins, permeable parking, greenroofs, stormwater treatment)
   - Pollution prevention/good housekeeping (eg. street cleaning, maintain vehicles, proper salt storage).

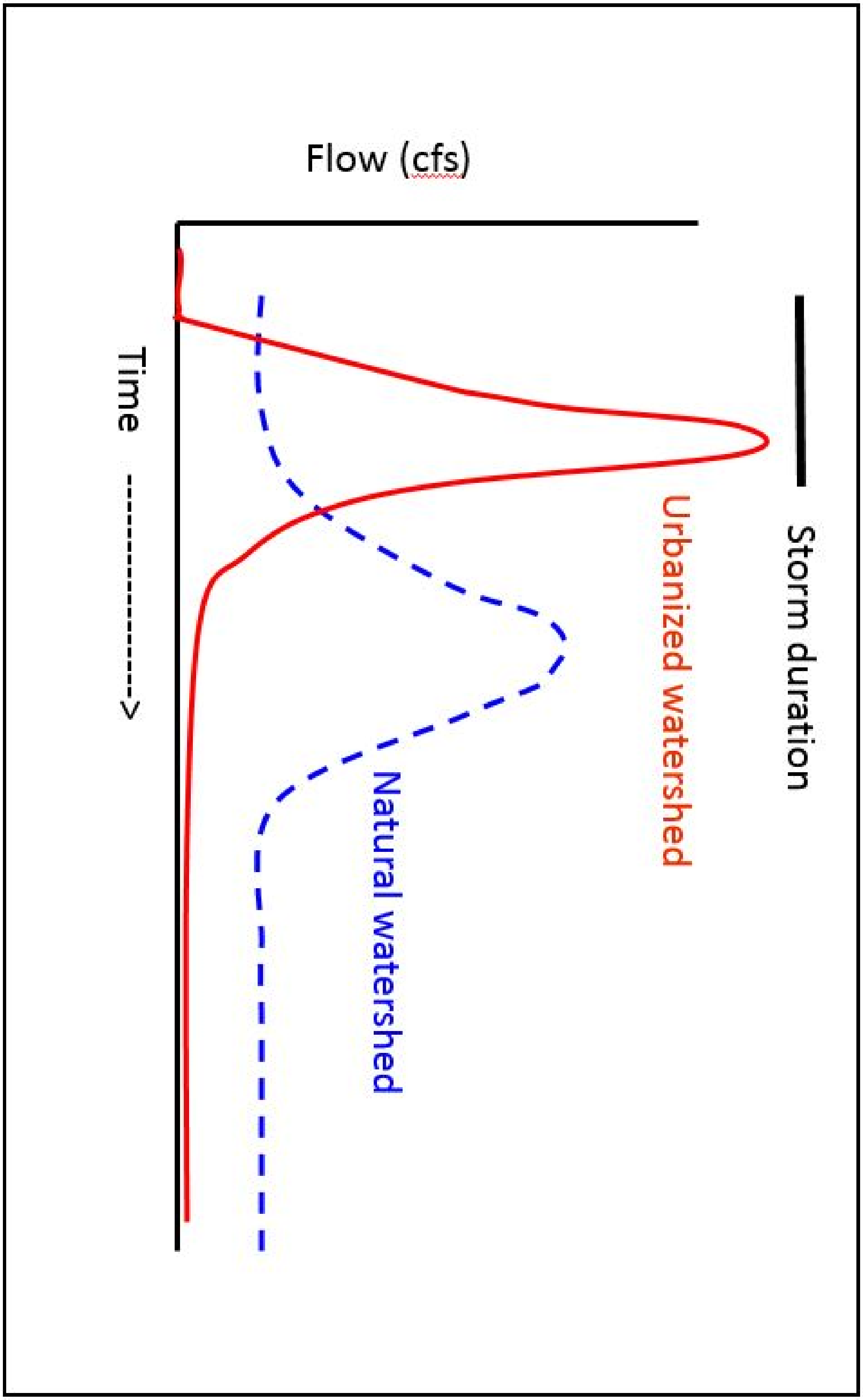
   For more information on urban "best management practices", go to http://extension.usu.edu/waterquality/bmps/ .

4. **How can students or people reduce the pollution on parking lots?**
   - **Pick up garbage**. *Don't be a litter bug. Always dispose of trash in a proper container; not in the water.*
   - **Don't rinse down garages or driveways into the street**. *Wash cars on lawns or at car washes with appropriate water disposal.*
   - **Reduce car traffic.** *Use public transit, car pool, walk or bike.*
   - **Make sure that their family car doesn't leak oil or antifreeze**. *This can wash into the water and be dangerous for fish, birds, and even cats and dogs.*
   - **NEVER put anything down storm drains** *that may pollute downstream water – this includes oils, pesticides, antifreeze, but also pet waste and lawn clippings*.
   - **Participate in community outreach efforts**, *present class research or project findings at public meetings or forums (eg. libraries, city councils), participate in citizen monitoring efforts, stencil or provide signage to protect storm drains.*

5. **Check out other activities and resources in Utah**:
   - See USU Water Quality Extension's website (www.extension.usu.edu/waterquality) for information about educator resources, about water science and watershed protection.
   - **Stream Side Science** contains 12 lesson plans designed around stream science. Most lessons are based on stream monitoring or other exploration. All lessons are aligned

to Utah Core curriculum standards and intended learning outcomes. Visit http://streamsidescience.usu.edu for all of the Stream Side Science lessons.

- Other lessons for K-12 are also available online (http://streamsidescience.usu.edu)
- Teacher training workshops are offered on request.
- Utah Water Watch: Opportunity for schools, families or individuals to collect water quality data that will be included in a statewide database. Tier I collection methods are for educational and screening purposes. Tier II methods require more training and are designed to assist watershed coordinators and the Utah Division of Water Quality in their water quality protection efforts. Visit http://extension.usu.edu/utahwaterwatch


Flow (cfs)
Time
Storm duration
Urbanized watershed
Natural watershed

DATA SHEETS:

Lab exercise:

- **“Natural” watershed runoff**
- **“Urban” watershed runoff**
- **Graphs**
- **Data comparison tables**

Field exercise:

- **Mapping activity field sheet**

Natural Watershed Runoff Data Sheet

Name: ________________________________ **Date:** _______________________

Rise:________________ **Run:** ______________ **Slope (rise/run):** ___________________

A	B	C	D	E
Measured Time		**Conversion to Time in Seconds**	**Measured** Total runoff volume (ml)	**Calculated** Runoff rate (ml/10 sec)
Minutes	Seconds			
0	0	0		
0	10	10		
0	20	20		
0	30	30		
0	40	40		
0	50	50		
1	0	60		
1	10	70		
1	20	80		
1	30	90		
1	40	100		
1	50	110		
2	0	120		
2	10	130		
2	20	140		
2	30	150		
2	40	160		
2	50	170		
3	0	180		
3	10	190		
3	20	200		
3	30	210		
3	40	220		
3	50	230		
4	0	240		

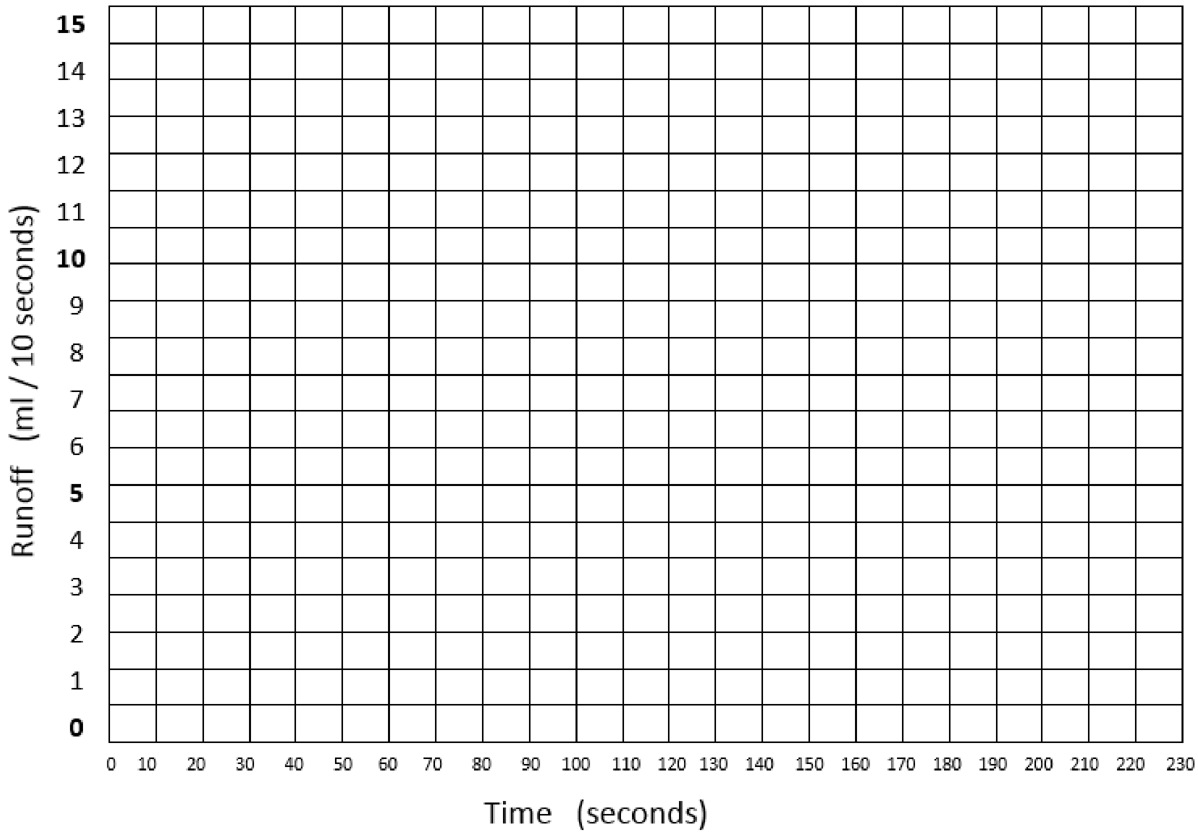
Urban Watershed Runoff Data Sheet

Name: ______________________________ **Date:** _____________________

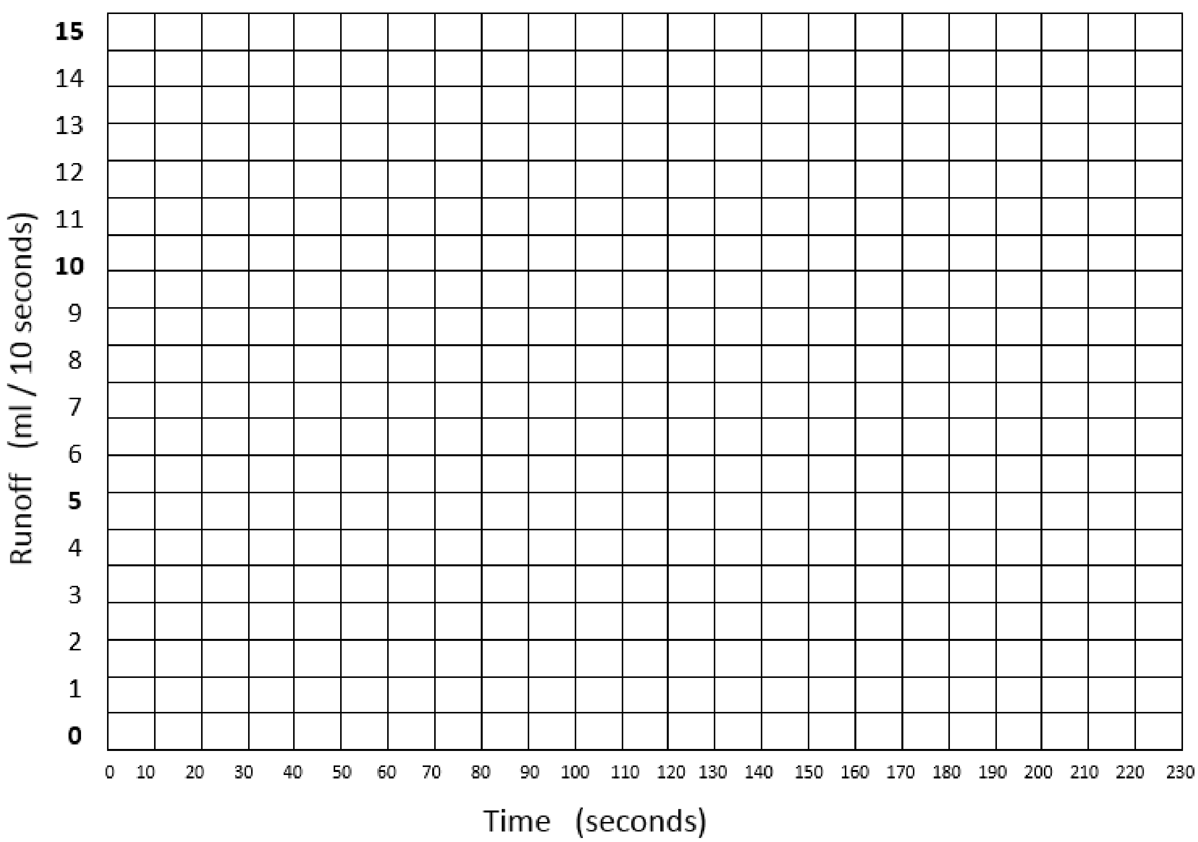
Rise:_______________ **Run:** _____________ **Slope (rise/run):** _________________

A	B	C	D	E
Measured Time		**Conversion to Time in Seconds**	**Measured** Total runoff volume (ml)	**Calculated** Runoff rate (ml/10 sec)
Minutes	Seconds			
0	0	0		
0	10	10		
0	20	20		
0	30	30		
0	40	40		
0	50	50		
1	0	60		
1	10	70		
1	20	80		
1	30	90		
1	40	100		
1	50	110		
2	0	120		
2	10	130		
2	20	140		
2	30	150		
2	40	160		
2	50	170		
3	0	180		
3	10	190		
3	20	200		
3	30	210		
3	40	220		
3	50	230		
4	0	240		

Natural watershed runoff



Urban watershed runoff



Comparison of watersheds

Watershed slope = ____________________

	Natural watershed	Urban watershed	Units
Length of rainstorm			
Time when runoff begins			
Time when runoff ends			
Time of peak runoff discharge			
Peak runoff rate			
Estimated volume to storm runoff			

Notes:

Mapping Activity: Calculated areas and runoff

Names: ____

Date: ________________

Area Description	**Dimensions**	**Impervious Area**	**Pervious area**	
				Impervious + Pervious Area
	TOTAL:			

Total area (impervious + pervious area) = ____________________ (units = ____)

Convert area to square inches: ________________

Total volume of a 1 inch rainfall over this watershed area: _______________

Total impervious area: ________________

Total pervious area: ________________

Percent impervious: ________________

Assumed runoff percentage: ________________

Total runoff: _________________

Use this space to draw your field map.