A LOOK INSIDE OUR STORMWATER SYSTEM

STORMWATER 101

Large storms can pour a lot of water on our communities in a short period of time. That poses a serious challenge for towns and cities. Some stormwater soaks into the ground, but the rest runs across roofs, roads, parking lots, sidewalks, and other hard surfaces that don't absorb water. The job of municipal stormwater systems is to funnel this stormwater from our streets and neighborhoods to local waterways to prevent flooding and at the same time protect waterways from pollution in stormwater.

This book explores these key questions: When it rains, or when snow melts, where does the water go? How can we prevent flooding in homes, schools, and roads? And how do we stop stormwater from carrying pollutants into rivers and streams?

WHY MANAGING STORMWATER MATTERS

FLOODING

Flooding occurs when there is more water than the ground can absorb or storm drains and streams can safely carry. When storm drains are blocked by leaves or debris, the system becomes overwhelmed. Engineers, field crews, and educators work daily to prevent flooding and keep communities safe. Even well-designed systems can fail if drains are clogged. Everyone is responsible for picking up litter and clearing leaves to prevent stormwater problems.

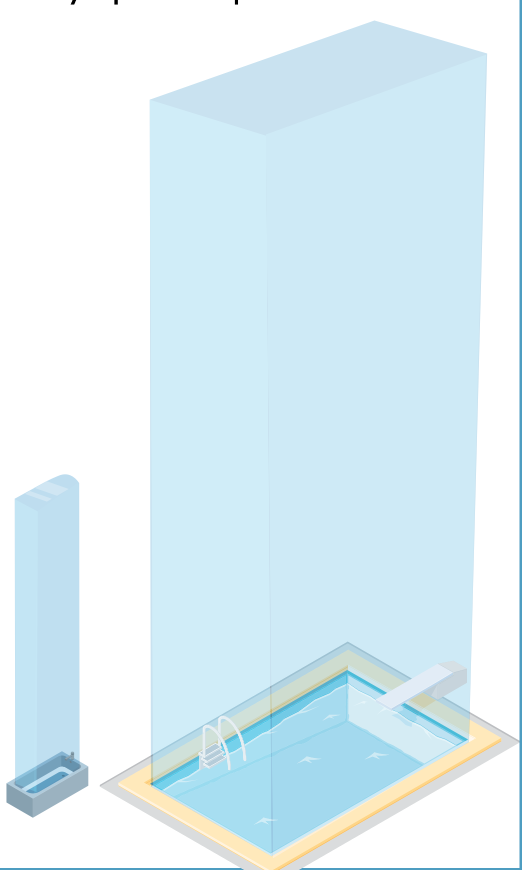
POLLUTION

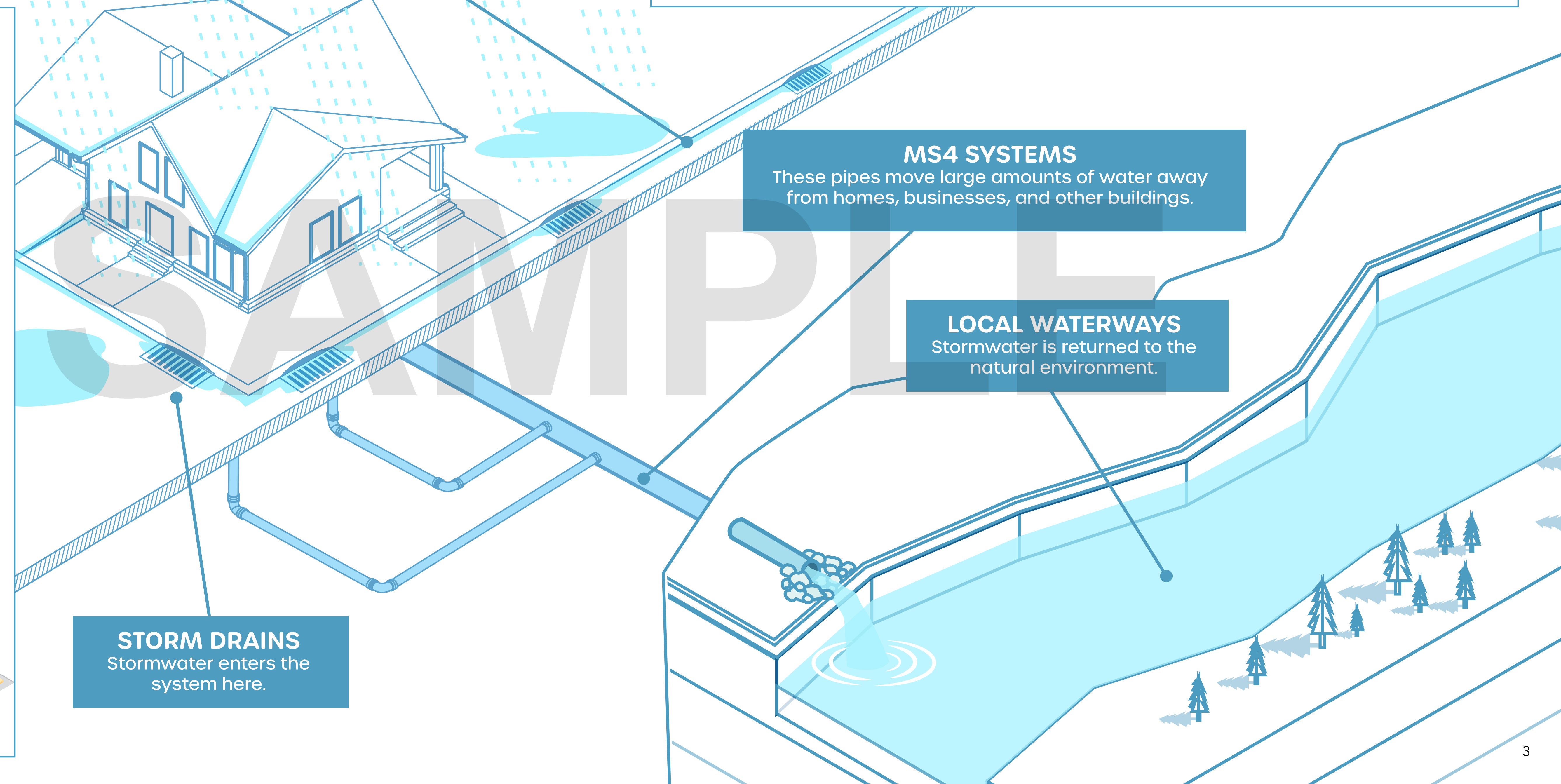
When rainwater runs off roofs and streets, it can wash away oil from cars, fertilizer from lawns, pet waste, litter, and loose soil. All of that can end up in creeks, lakes, and rivers. Polluted runoff can cloud the water and damage habitats. It can also threaten drinking water sources and make swimming, paddling, and fishing less safe and enjoyable. Monitoring and preventing pollution are important parts of stormwater professionals' jobs. We all play an important role. Picking up pet waste, cleaning up spills, and making sure pollutants don't end up in storm drains help keep our waterways clean.

PICTURE IT!

One inch of rain on a 1,000 square foot roof is about 623 gallons of water. That's nearly a dozen bathtubs of water.

Over 1 square mile, that same inch of rain adds up to approximately 17.4 million gallons, enough to fill 26 Olympic-size pools!





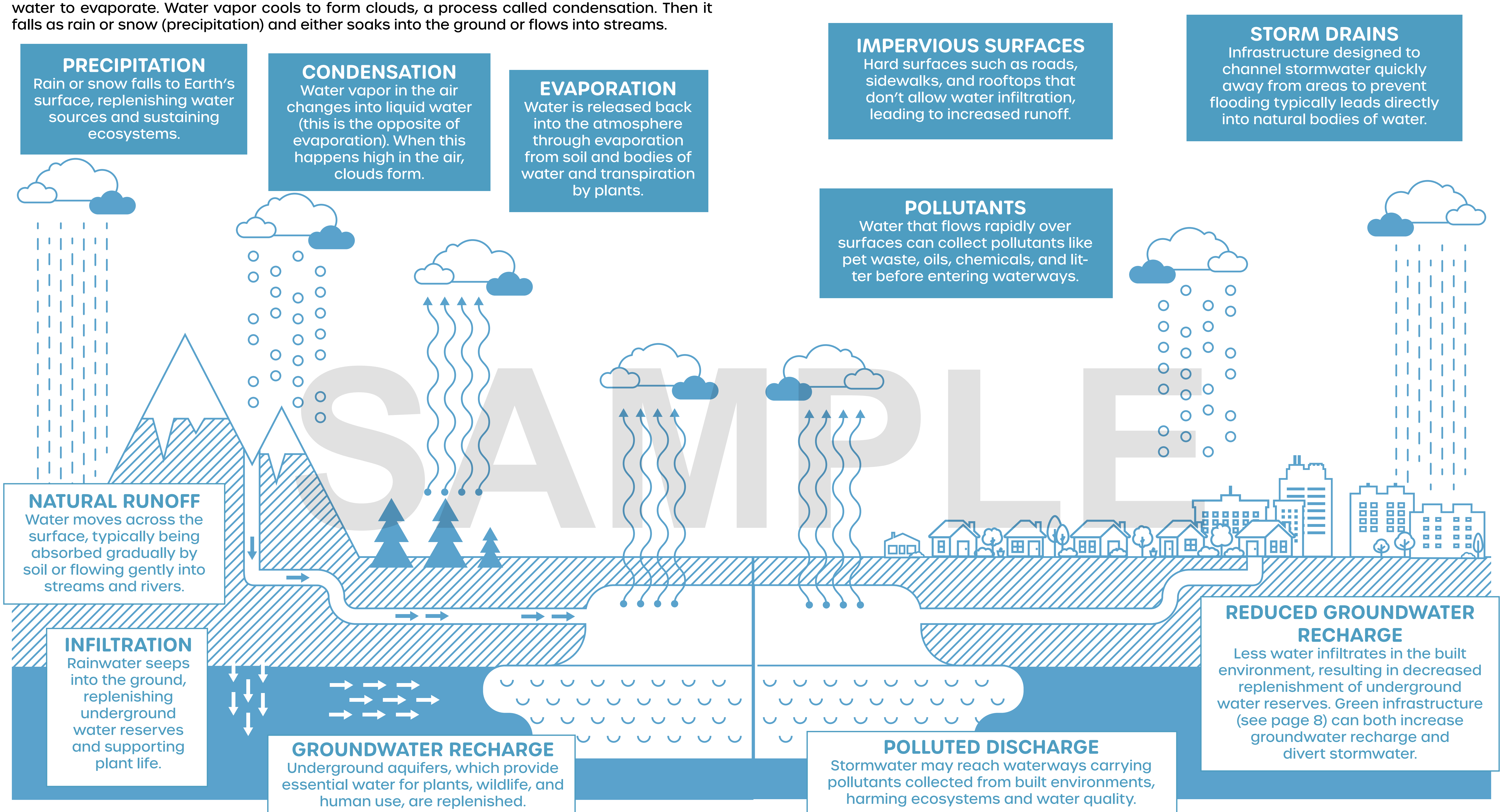
THE WATER CYCLE

THE NATURAL WATER CYCLE

The water cycle is nature's never-ending loop for water. The sun warms lakes and oceans, causing water to evaporate. Water vapor cools to form clouds, a process called condensation. Then it falls as rain or snow (precipitation) and either soaks into the ground or flows into streams.

BUILT ENVIRONMENTS

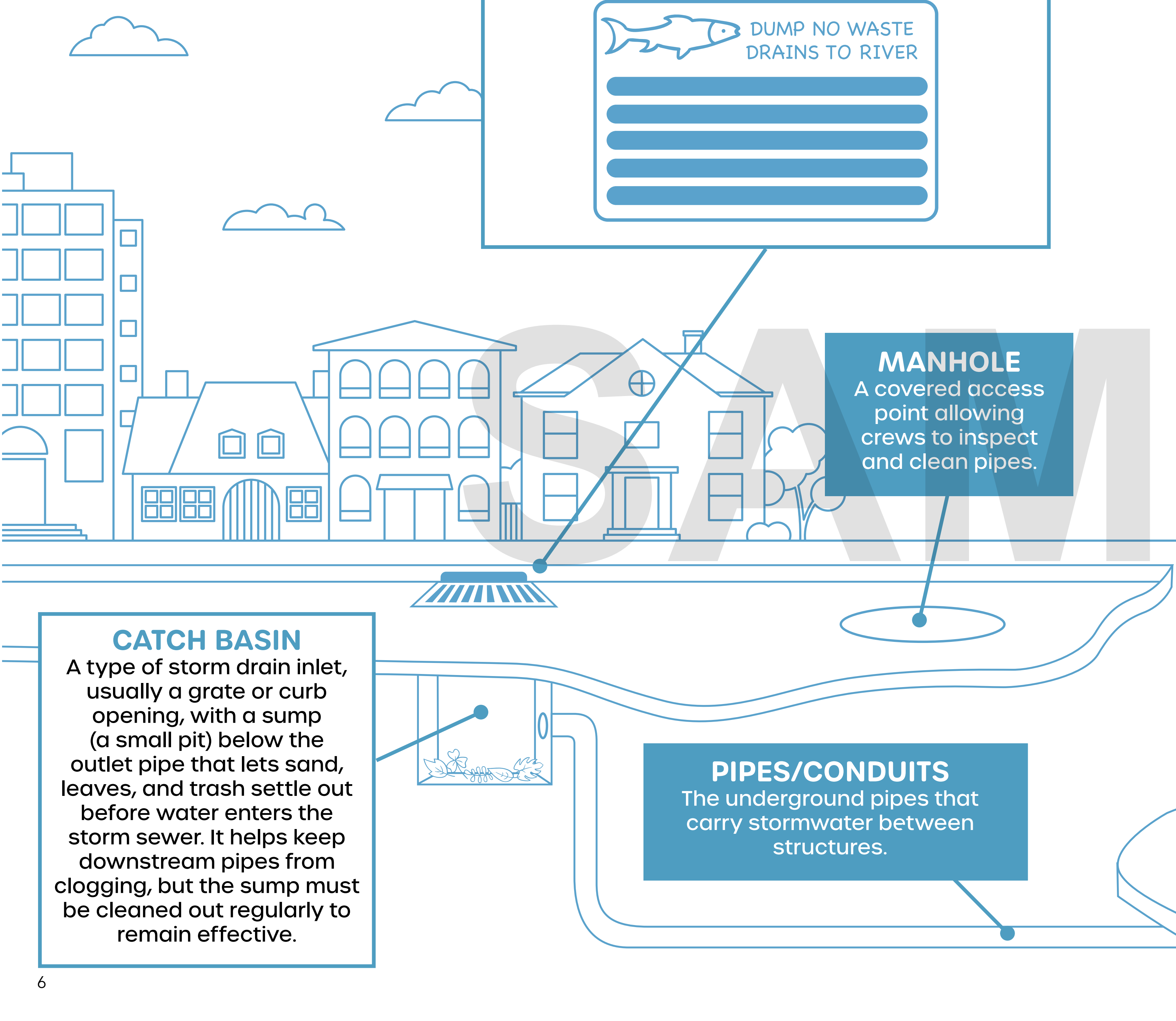
The natural water cycle is altered, redirected, and challenged in many ways by the built environment. Hard surfaces like pavement, roofs, and roads speed up runoff, which can produce flooding and pollution. Storm drains that carry water to local waterways can become overwhelmed if too much water comes down too quickly.



MS4 SYSTEMS

HOW THEY'RE DESIGNED & HOW THEY WORK

For most cities and towns, a municipal separate storm sewer system (MS4) is the system of pipes that move stormwater from streets and yards to local creeks, rivers, or lakes. It is separate from the sanitary sewer (the pipes that carry wastewater from sinks and toilets). The MS4's job is to reduce flooding and protect water quality by moving water safely and keeping pollutants out. Think of it as roads for water. Storm drains collect it, pipes carry it, and outfalls release it to streams.



STORM DRAIN/INLET

The opening in a curb or street where water enters the system. These lead to local waterways.

MANHOLE

A covered access point allowing crews to inspect and clean pipes.

CATCH BASIN

A type of storm drain inlet, usually a grate or curb opening, with a sump (a small pit) below the outlet pipe that lets sand, leaves, and trash settle out before water enters the storm sewer. It helps keep downstream pipes from clogging, but the sump must be cleaned out regularly to remain effective.

PIPES/CONDUITS

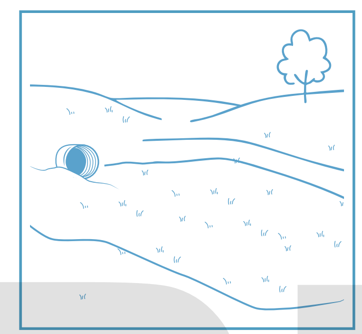
The underground pipes that carry stormwater between structures.

HOW AN MS4 MOVES RAIN

1. **COLLECT.** Water flows into storm drains on streets and parking lots.
2. **CONVEY.** Water travels through pipes or ditches to downstream areas.
3. **FILTER.** Sumps, forebays, and separators grab sediment, oils, and trash. It's important to note that these tools filter out only some pollutants. To prevent polluting waterways, we need to keep pollutants from entering the stormwater system in the first place.
4. **STORE/CONTROL.** Detention/retention basins hold water, which flattens the flood peak, and release it slowly through small openings.
5. **DISCHARGE.** Water exits at an outfall to the waterway. Some outfalls will have a riprap apron to protect the bank.
6. **MAINTAIN.** Crews sweep streets, vacuum inlets, jet pipes, and run checks to keep water clean and systems working.

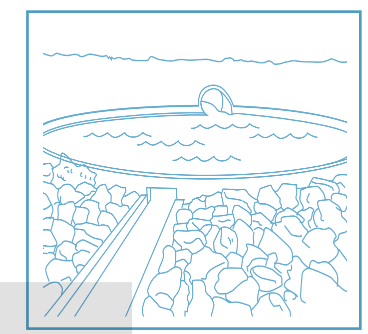
OUTFALL

This is where stormwater leaves the system and enters local waterways. Sometimes it flows directly into a stream or river, but stormwater systems can also use different outfall designs to filter pollutants or control how much water enters the waterway:



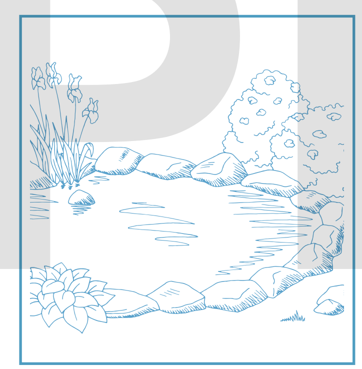
DETENTION BASIN

A (usually) dry basin that holds water during storms and releases it slowly to prevent flooding.



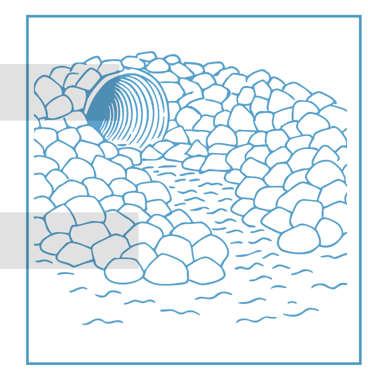
FOREBAY

A small, shallow area at the inlet to a pond/basin that catches sediment and trash first.



RETENTION BASIN

A pond that keeps a permanent pool of water and also holds extra water during storms.



RIPRAP APRON

A layer of rocks placed at the end of a pipe, culvert, or spillway where fast water comes out. It spreads and slows the flow to prevent erosion of the soil or streambed.

GREEN INFRASTRUCTURE

MS4 systems made of concrete, metal, and other building materials are called gray infrastructure. A second, colorful toolbox is green infrastructure. These tools are centered on plants and soils that soak, slow, and store stormwater before it reaches local waterways.

Another benefit is that they help recharge groundwater. Groundwater is the water stored in aquifers, which are the pores and cracks of soil and rock underground. This recharge keeps streams flowing between storms, often with cooler, cleaner water that supports fish and other aquatic life. It also strengthens local water supplies and helps trees and landscapes during dry spells.

MS4 SYSTEMS AND GREEN INFRASTRUCTURE: BETTER TOGETHER

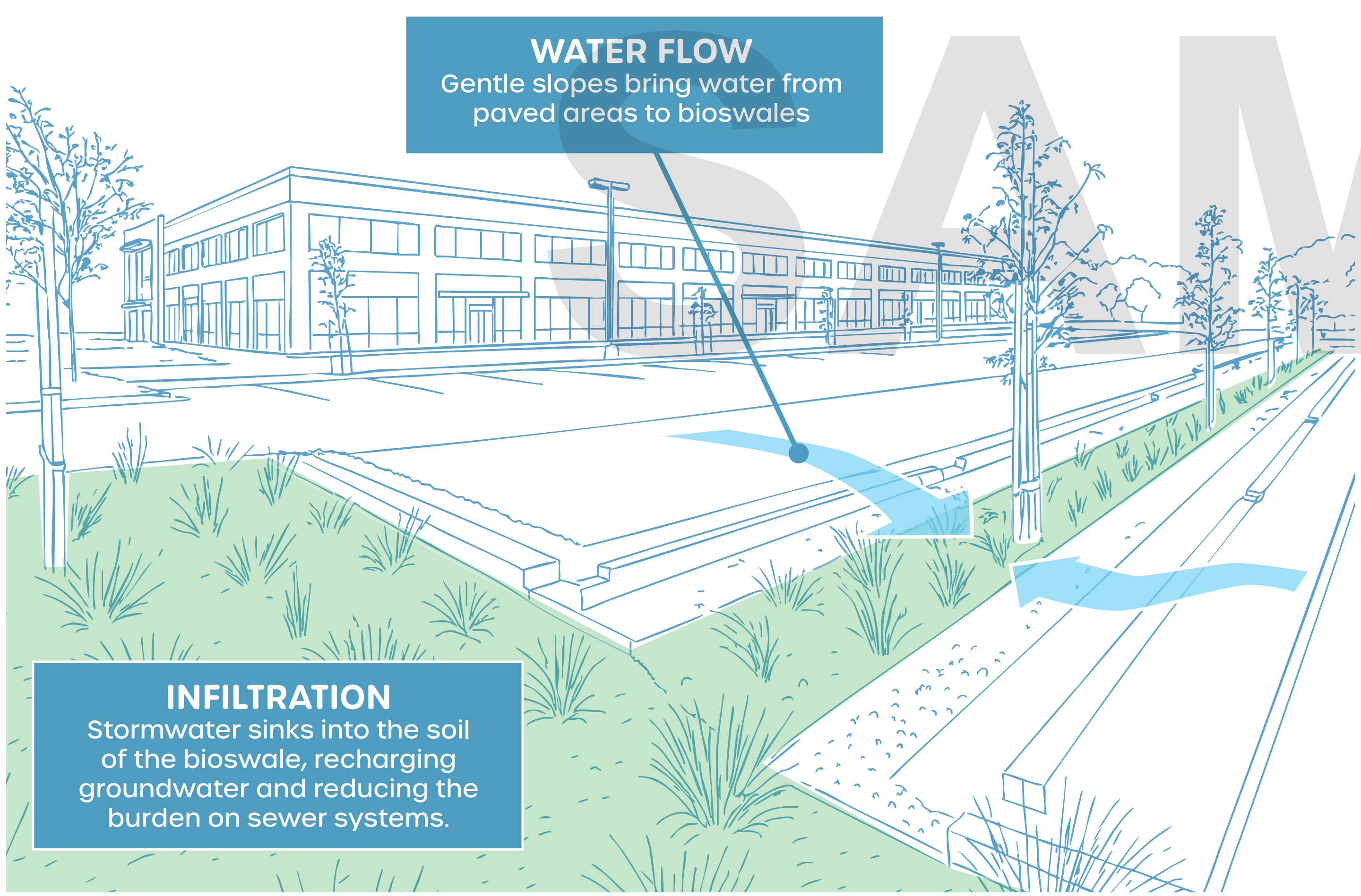
Stormwater planning works best when green and gray infrastructure work together, with green infrastructure to reduce volume and pollution being layered with gray infrastructure to safely move the remaining stormwater.

BIOSWALE/VEGETATED SWALE

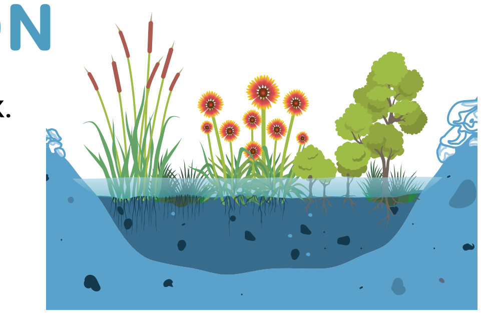
WHAT: A gently sloped, vegetated channel (often with check dams).

WHY: To slow water so sediment drops out, spread flow so it soaks in, and cut erosion.

WHERE: Along lot edges, medians, and road shoulders.



RAIN GARDEN/BIORETENTION

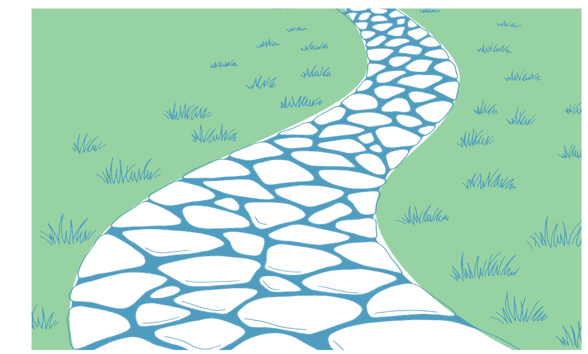


WHAT: A shallow, planted basin with a well-draining soil mix.

WHY: To filter and infiltrate runoff, reduce volume and peak flow, and recharge groundwater.

WHERE: Near downspouts, in yards, along sidewalks, by parking lots.

PERMEABLE PAVEMENT

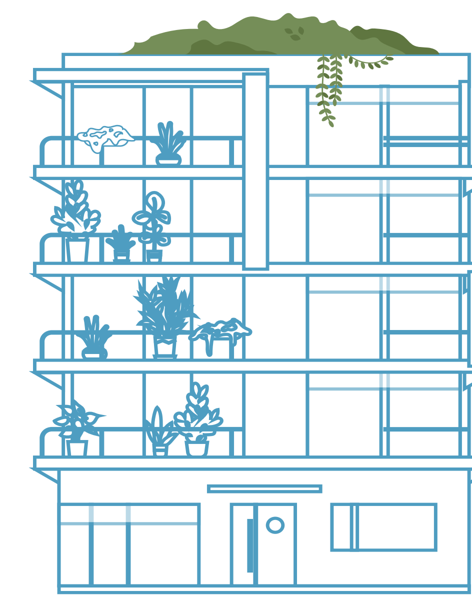


WHAT: Pavers or porous asphalt over a washed stone basin with voids.

WHY: To store water in the basin, infiltrate it, and reduce runoff volume and peak flow.

WHERE: Sidewalks, plazas, low-traffic parking.

GREEN ROOF



WHAT: Thin layers of soil and hardy plants on a roof.

WHY: To reduce roof runoff and cool buildings as stormwater soaks into the soil and growing plants.

WHERE: Schools, libraries, offices and other buildings.

STREET TREES/TREE TRENCHES

WHAT: Trees in sidewalk strips and bioretention boxes

WHY: To intercept rain on leaves and bark, open soil with roots, shade and cool streets, and support infiltration

WHERE: Sidewalk strips, courtyards, parking-lot islands

DESIGNING & MAINTAINING A STORMWATER SYSTEM

To protect people and property from flooding and to protect waterways, cities use a blend of green infrastructure (rain gardens, swales, trees, permeable pavement) and gray infrastructure (curbs, inlets, pipes, culverts, basins). Good design plans for today's storms *and* tomorrow's. The many professionals in the stormwater field deploy their expertise to protect people, property, and waterways. These engineers, planners, scientists, lab technicians, educators, and maintainance and public workers all work together to design, build, and maintain stormwater systems.

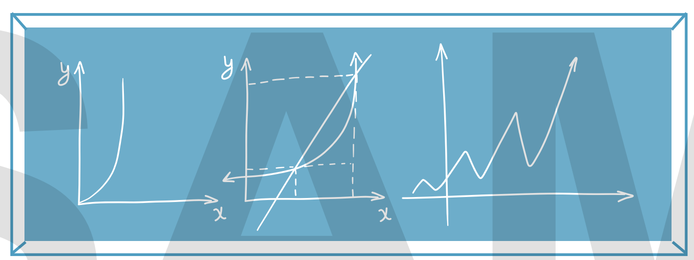
HOW ENGINEERS DESIGN

1. KNOW THE PLACE

Stormwater engineers map the drainage area, taking into account soil types, slopes, elevations, and land use; observe current patterns of water movement; and consider how any new systems might affect them.

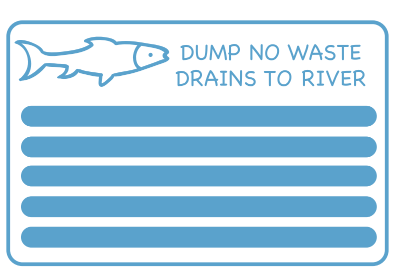
2. ESTIMATE RUNOFF

How much water does the system need to be able to remove? How much stormwater does the area get in an average year? How much would it get from an especially large storm? For small areas, engineers often use a formula called the rational method. For bigger watersheds, many use the NRCS curve number method, which you'll learn more about when you turn the page.



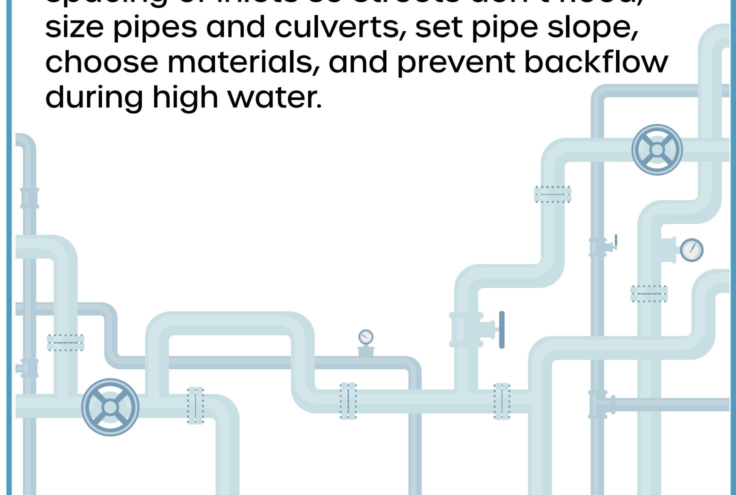
3. DESIGN FOR PEOPLE & CREWS

Cities and towns post clear signs (like "Only Rain Down the Drain"). They also design stormwater systems to handle water flow and maintenance needs. This can include fenced or shallow ponds where appropriate, along with maintenance access for vacuum trucks and mowers. Communities also plan for life-cycle costs, redundancy, and future upgrades.



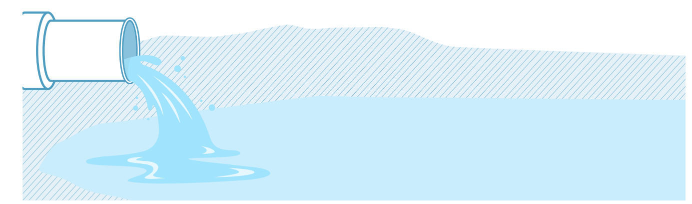
4. SIZE INLETS AND PIPES

Engineers choose the number and spacing of inlets so streets don't flood, size pipes and culverts, set pipe slope, choose materials, and prevent backflow during high water.



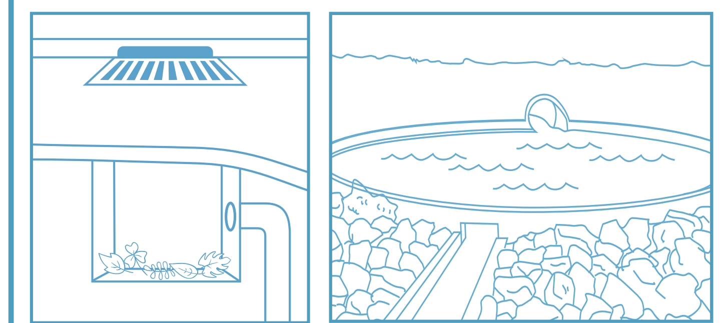
5. PLAN STORAGE AND RELEASE

Stormwater systems often use detention and retention to manage heavy rain. Both approaches store water temporarily so it doesn't rush downstream all at once, helping reduce peak flows (the fastest, highest surges in storms). Detention basins hold stormwater for a short time and then release it slowly through an outlet or control structure. Retention basins keep some water on-site for longer periods.



6. PROTECT WATER QUALITY

Stormwater workers remove trash, pollution, and debris that gets into the system and use catch basins, forebays, sumps, or hydrodynamic separators to trap sediment, trash, and oils. Often these are sized to treat the first inch or so of rain—because that's where most pollution rides along.



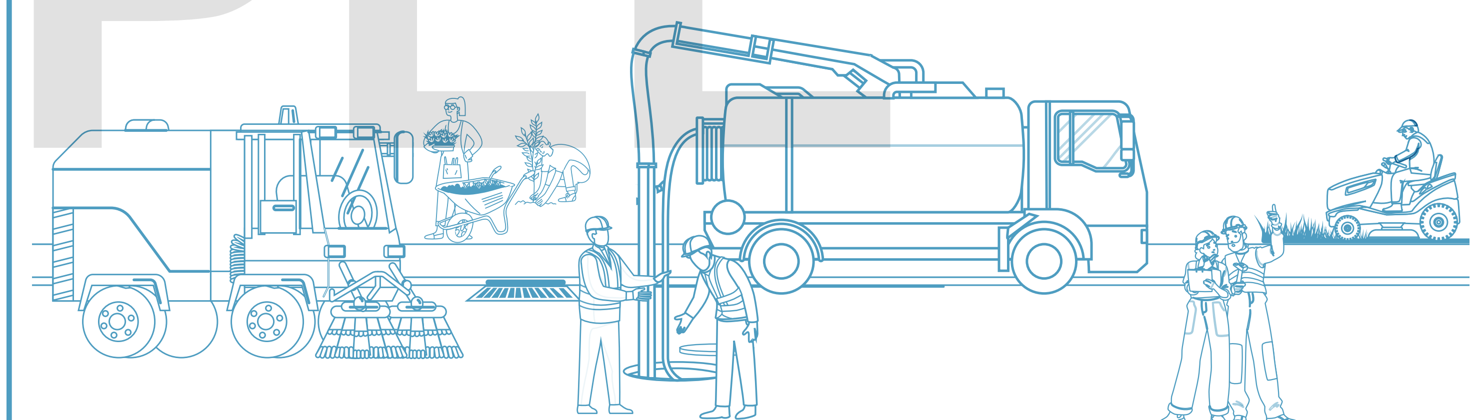
HOW CREWS MAINTAIN THE SYSTEM

It takes a lot of work to keep a stormwater system running smoothly. Here are some of the things workers do:

STREETS & INLETS: Sweep streets, vacuum catch basins, clean grates before storms, fix broken frames/lids

PIPES & CULVERTS: Inspect pipes using remote video systems, remove blockages with high-pressure jets of water, repair joints, and check for cross-connections

BASINS & OUTLETS: Mow/inspect embankments, clear trash racks, clean orifices/weirs, dredge forebays when sediment builds up, check riprap for erosion



GREEN INFRASTRUCTURE: Weed, mulch, replant, remove litter, vacuum permeable pavements, maintain check dams in swales

WATER QUALITY & MONITORING: Sample outfalls, trace and remove illicit discharges (soap, oil, mop water), store salt under cover, calibrate spreaders for smart salting

RECORD & REPORT: Log work, post public updates, host a stormwater hotline to report pollution

CALCULATING PEAK FLOW

City planners use a set of standard equations to calculate how much stormwater to expect in a given area and how to build infrastructure to prevent it from causing floods. Here are the most common calculations:

Rational method: a simple formula to estimate the peak runoff from small drainage areas using rainfall intensity, area, and the type of land

NRCS curve number method: a formula that estimates the total runoff volume from rainfall using soil type, land use, and ground-cover conditions

Hydrologic and hydraulic models: computer-based tools that simulate how water flows and behaves in complex watersheds and storm systems

YOU DO THE MATH: THE RATIONAL METHOD

The rational method is a way to calculate peak flow from drainage areas that are smaller than 200 acres. Peak flow is how much water is rushing off the land at the storm's most intense moment. It measures the speed of the water in cubic feet per second (cfs). It is used most for housing developments, parking lots, or similar small community and commercial areas. The rational method gets its name from its being a reasonable estimate of how much water will run off during a storm.

HOW DOES THE RATIONAL METHOD WORK?

The rational method looks at how much of the rain turns into runoff, how hard the rain is falling, and how big of an area is being investigated to calculate a peak flow estimate.

THE FORMULA

Q is the peak flow in cubic feet per second (cfs).

C is the runoff coefficient. C is how much rain turns into run-off, considering what the ground is made of, pavement, grass, mud, etc.

i is the rainfall intensity in inches per hour (in/hr). It is the measure of how hard it's raining during the storm.

$$Q = C_f \times C \times i \times A \times 1.008$$

C_f (read "C sub-F") is the runoff coefficient adjustment factor. This factor adjusts for how big or small the storm is. On some surfaces, like mud, the ground becomes so soaked that it can't hold more water, so more rain becomes runoff. On other surfaces, like concrete, the ground stays the same throughout the storm.

A is the drainage area in acres (ac).

1.008 is the conversion factor when A is in acres and I is in in/hr.

TRY IT OUT!

Complete the problems below using the rational method formula. The first one is done for you already. You can find the values for C and C_f by referencing Table 1 and Table 2*.

TABLE 1: RUNOFF COEFFICIENTS FOR THE RATIONAL METHOD

	FLAT	ROLLING	HILLY
Pavement & roofs	0.90	0.90	0.90
Heavy industrial areas	0.60	0.80	0.90
Earth shoulders	0.50	0.50	0.50
Drives & walks	0.75	0.80	0.85
Gravel pavement	0.85	0.85	0.85
City business areas	0.80	0.85	0.85
City parks	0.10	0.15	0.25
Apartment dwelling areas	0.50	0.60	0.70

Runoff coefficient tables come from studies that measure how much rain turns into runoff in different locations and on different surfaces. This will help you find C.

TABLE 2: RUNOFF COEFFICIENT ADJUSTMENT FACTORS

RECURRENCE INTERVAL	RUNOFF COEFFICIENT ADJUSTMENT FACTOR
10 years or less	1.0
25 years	1.1
50 years	1.2
100 years	1.25

The runoff coefficient adjustment factors are also read from a table and come from hydrologic studies and stormwater design guidelines. This will help you find C_f.

1. A heavy industrial complex is located on flat land with a drainage area of 12 acres. What is the peak runoff for a 25-year storm whose rainfall intensity is 4.0 in/hr?

Use: $Q = C_f \times C \times i \times A \times 1.008$

Read the runoff coefficient from Table 1:

look up heavy industrial with flat terrain to find a coefficient of $C = 0.60$.

The recurrence interval is every 25 years.

Read the value from Table 2 where $C_f = 1.1$.

The rainfall intensity, i, is given in the problem as 4.0 in/hr.

The drainage area, A, is given in the problem as A = 12 ac.

$Q = 1.1 \times 0.60 \times 4.0 \times 12 \times 1.008 = 31.93344$ cfs

$Q \approx 31.93$ cfs

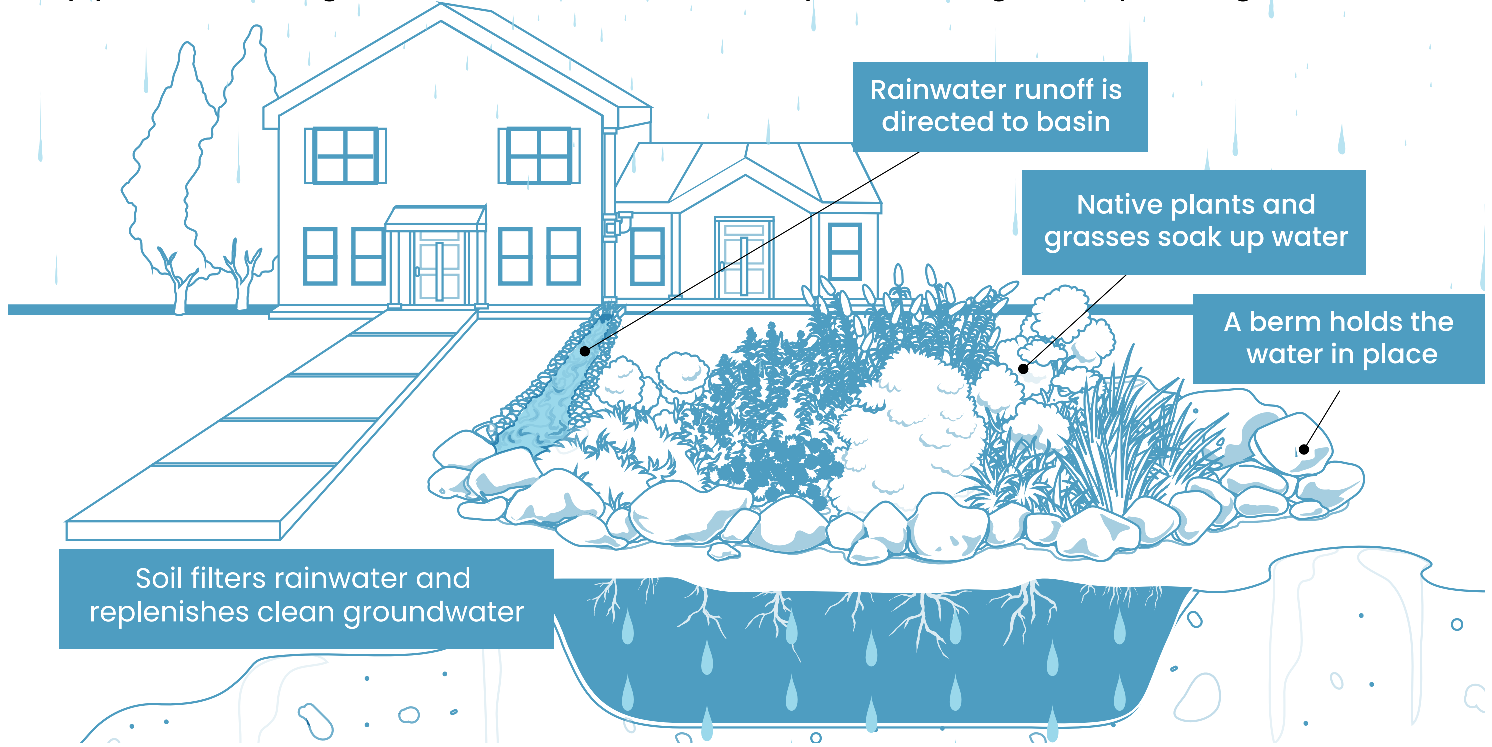
2. A city park is in a hilly area that covers 40 acres. The city wants to estimate the runoff for a 50-year storm with a rainfall intensity of 5.0 in/hr. What is it?

Source: Oregon Department of Transportation Hydraulic Manual

DESIGN A RAIN GARDEN

WHAT IS A RAIN GARDEN?

Rain gardens collect rainwater from roofs, driveways, and sidewalks. They are a beautiful way to help prevent flooding, filter stormwater, reduce mosquito breeding, and replenish groundwater.

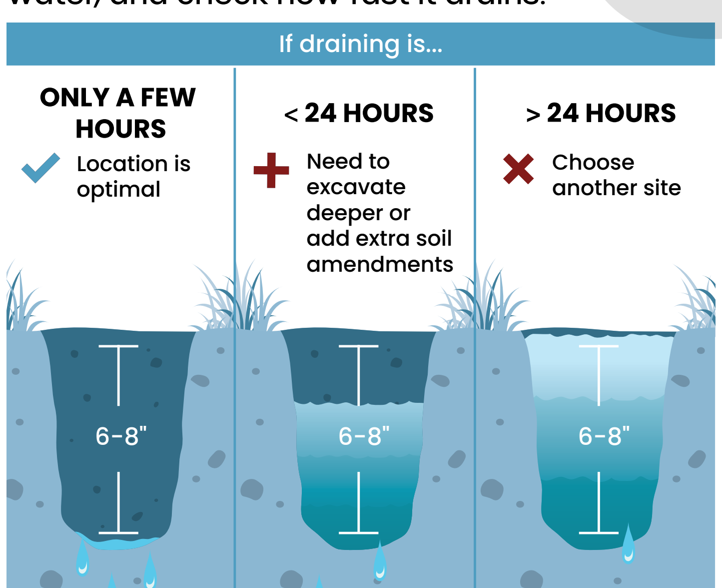


STEPS TO BUILD A RAIN GARDEN

Pick your spot: Choose an area where water naturally flows or collects in your yard, like the bottom of a slope or a low-lying area. Be sure to avoid septic systems, wells, tree roots, and electric and gas lines. Always call 811 before you dig.

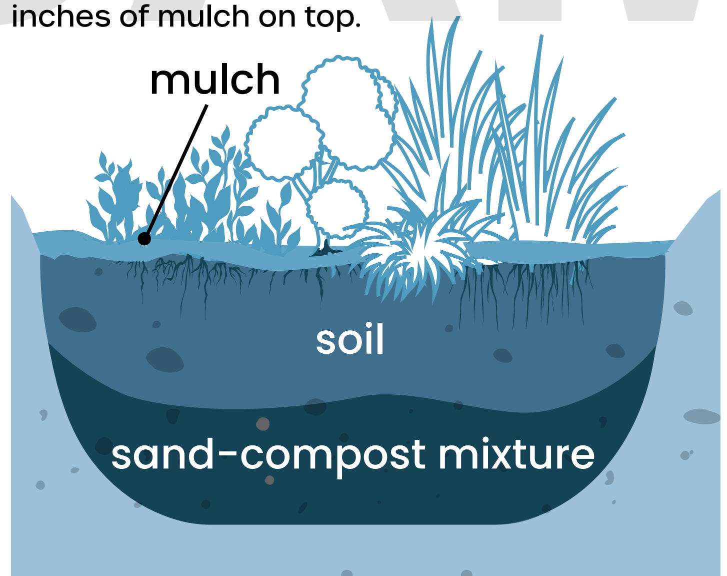
DO A SOIL DRAINAGE TEST:

Dig a hole 6–8 inches deep, fill the hole with water, and check how fast it drains.



BUILD THE LAYERS:

Add 6–8 inches of sand and compost mixture and then 6–8 inches of soil. Finish with 2–3 inches of mulch on top.

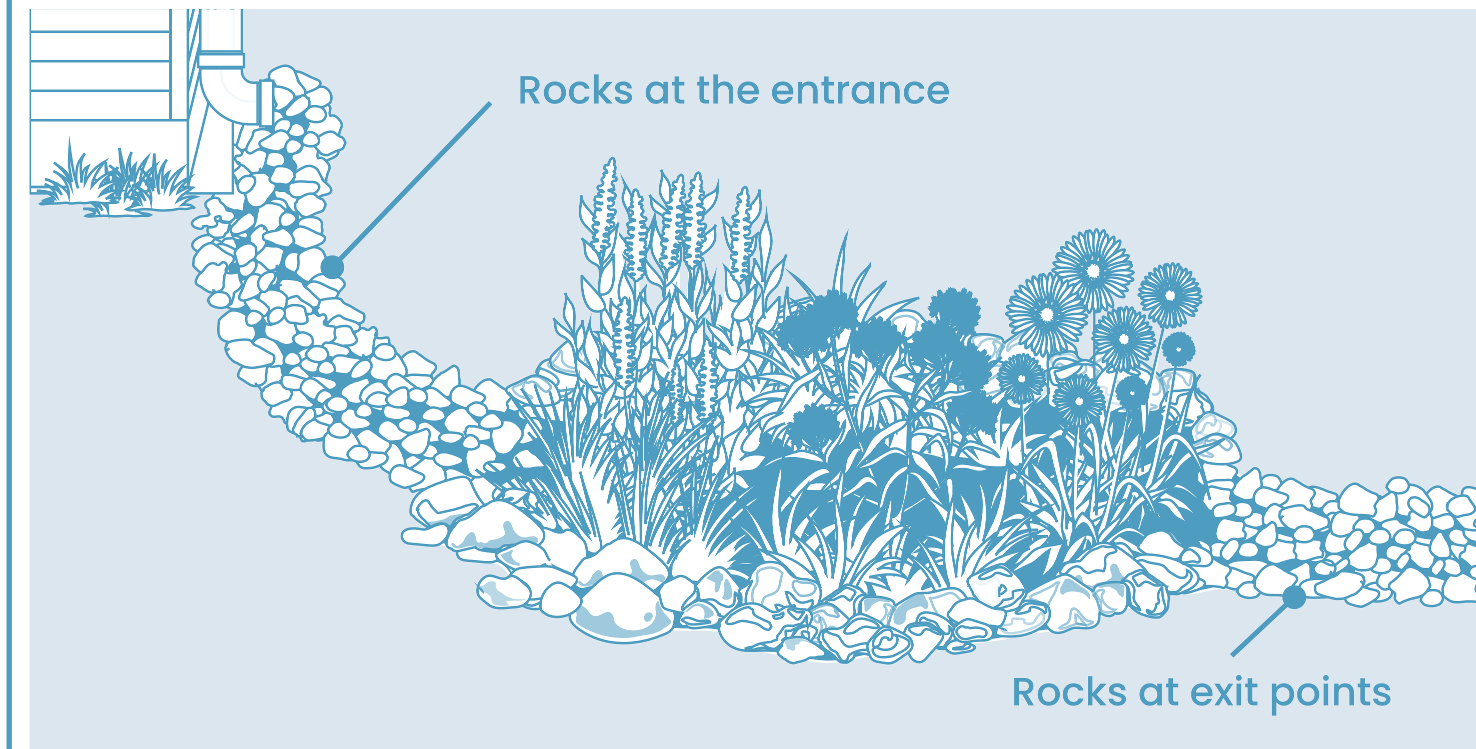


CHOOSE PLANTS:

The best plants for a rain garden are a mix of shrubs, grasses, and short plants that can tolerate both wet and drought conditions.

DIRECT THE WATER TO THE GARDEN:

Choose how to get more of the water to your garden by using downspouts; pipes; shallow, grassy ditches; and rocks.



CALCULATE THE SIZE OF A RAIN GARDEN

Your garden should be about 10% of the area of the surfaces it collects water from.

For example: *For a 1,000 ft² roof, your rain garden needs to be 100 ft² because 1,000 x 0.10=100.*

YOU TRY IT!

1. A new driveway measures 400 square feet, and a sidewalk 100 more square feet. What size should the rain garden be to collect the runoff from both areas?

2. A school roof measures 2,400 square feet. The school wants to build a rain garden that will collect water from half the roof. How big should the rain garden be?

STORM DRAIN SIGNS MATTER

Storm drains don't lead to a treatment plant; they carry water (and whatever's in it) straight to creeks, rivers, and lakes. Signs remind people that dumping soap, paint, oil, or litter pollutes waterways and can cause clogs and flooding. Clear signage is one of the simplest, most effective outreach tools a city has.

WHAT MAKES A GREAT SIGN?

SIMPLE. VISIBLE. LOCAL.

The best storm drain signs use just a few words and a strong icon that people can read at a glance.

- Message: 3–6 words max, action-oriented (e.g., "Drains to River—No Dumping")
- Icon: A single symbol that "reads" fast (fish, wave, raindrop, river, turtle, water drop + slash over trash)
- Contrast: Light text on dark background or vice versa; large type; avoid thin fonts
- Location: Near curb inlets, catch basins, and along sidewalks where people rinse, wash, or sweep
- Durability: Weather-safe materials (paint stencil, epoxy medallion, outdoor vinyl) and nontoxic paints and adhesives

MESSAGING THAT WORKS

Stormwater is a complex subject to capture in 3–6 words. But it's important to get the message across quickly and clearly. When designing a sign, there are a few common slogans to start from:

- Only Rain Down the Drain
- Drains to River—No Dumping
- Keep It Clean for (Creek Name)
- Storm Drain = Stream. Keep It Clean.
- Protect Our Fish & Turtles—No Litter
- Your Street • Our River

EXAMPLES

DRAW YOUR OWN STORM-DRAIN SIGN!

Challenge (six words or fewer):
Write a clear message that would stop someone from letting pollution reach your local waterway.

1) Pick your message:

____

____

2) Choose ONE icon and sketch it BIG: (raindrop, fish, turtle, river, or your idea)

3) Make it local—name the waterway you want to protect:

"Drains to ______________________ Creek/River/Lake"

4) Draw it here:

CAREERS IN STORMWATER

Every storm is a real-world test. Stormwater pros prevent floods, protect streams, and turn city blocks into greener, safer places. If you like science, building, maps, or community projects, there's a path for you.

CAREER PATHS (WHAT THEY DO DAY-TO-DAY)

1) DESIGN & ENGINEERING

Titles: Stormwater engineer, civil engineer (water resources), green-infrastructure designer.

What: Size pipes and basins, design rain gardens/bioretention, run flow models, write plans and specs, visit sites during construction.

Where: Consulting firms, city/county engineering, state DOTs.

Path: HS math/physics, college degrees in civil/environmental engineering or landscape architecture, internships, EIT/FE exam on the way to PE (engineer licensure).

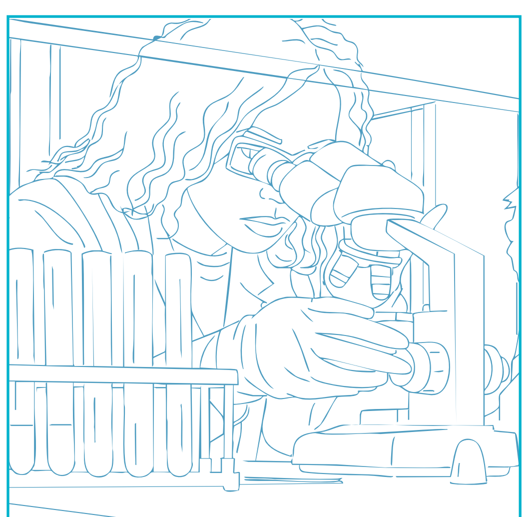
2) FIELD & OPERATIONS

Titles: Stormwater maintenance technician, crew leader, CCTV/jetting operator.

What: Clean inlets, inspect pipes/outfalls, maintain basins and swales, vacuum permeable pavement, respond to flooding.

Where: Public works departments, contractors, campus facilities.

Path: Skilled trades or community college programs; safety training (traffic control, confined spaces); CDL is a plus. Some states have certification exams for stormwater field and operations roles.



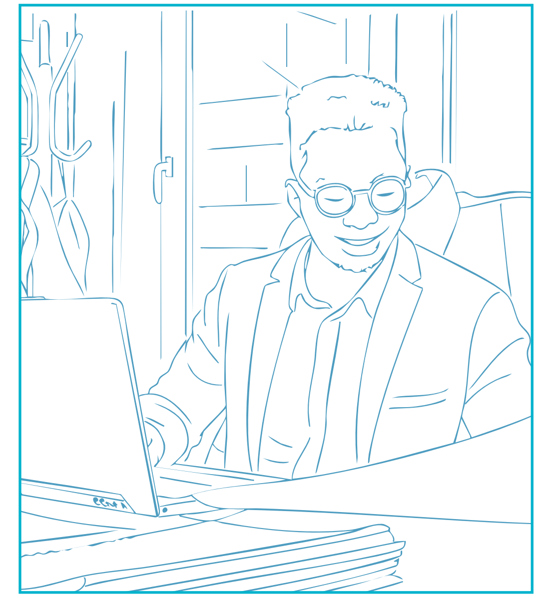
3) WATER QUALITY & LAB

Titles: Environmental technician, water quality specialist, laboratory analyst.

What: Collect samples after storms, test for bacteria/nutrients/metals/chloride, keep chain-of-custody and QA/QC records, report results.

Where: Municipal labs, consulting labs, health departments.

Path: HS chemistry/biology, 2- or 4-year college degrees in environmental science/tech, lab methods certifications are helpful.



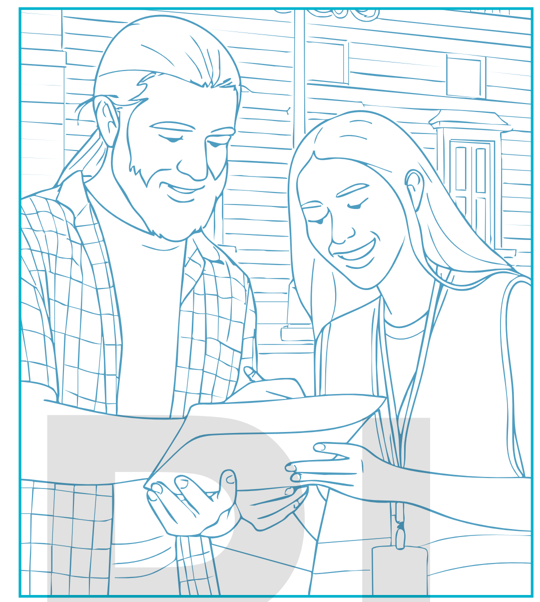
4) DATA, MAPPING & MODELING

Titles: GIS analyst, asset management tech, hydrologic modeler.

What: Map pipes and BMPs, manage maintenance data, build dashboards, analyze watersheds, create flood maps.

Where: Cities, utilities, consulting firms, regional planning agencies.

Path: GIS courses/certificates; programming/data (Excel, Python/R) is a plus.



5) EDUCATION, OUTREACH & POLICY

Titles: MS4 program coordinator, public education specialist, watershed planner.

What: Run "Only Rain Down the Drain" campaigns, organize cleanups/Adopt-a-Drain, write permits/reports, coordinate with schools and neighborhoods.

Where: City stormwater programs, nonprofits, regional watershed groups.

Path: Communications, environmental studies, planning or public policy; volunteer and program experience matter.

SKILLS THAT TRANSFER ACROSS ROLES

- Problem solving with numbers (unit conversions, $Q = C \cdot i \cdot A$, basic geometry)
- Observation and note-taking (field logs, photos, maps)
- Tools and tech (hand tools, GPS/GIS, spreadsheets, basic coding)
- Communication (short emails, drawings/diagrams, talking to the public)

GET STARTED NOW

- Take: algebra, geometry, physics, environmental science, computer apps/GIS if available
- Join/try: science club, robotics, Envirothon, scouting conservation projects
- Volunteer: stream cleanups, rain-garden installs, storm-drain marking

RESOURCES

SOAK UP THE RAIN
WWW.EPA.GOV/SOAKUPTHERAIN

POLLUTED RUNOFF: NONPOINT SOURCE POLLUTION
WWW.EPA.GOV/NPS/RESOURCES-STUDENTS-AND-EDUCATORS-ABOUT-NONPOINT-SOURCE-NPS-POLLUTION

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
WWW.EPA.GOV/NPDES

ANSWER KEY

CALCULATING PEAK FLOW

USE: $Q = C_F \times C \times I \times A \times 1.008$

RUNOFF COEFFICIENT ADJUSTMENT FACTOR (C_F) = 1.2

RUNOFF COEFFICIENT (C) FROM TABLE 1: 0.25

THE RAINFALL INTENSITY (I) = 5.0

THE DRAINAGE AREA (A) = 40

$Q = 1.2 \times 0.25 \times 5.0 \times 40 \times 1.008 = 60.48$

$Q \approx 60.48$

CALCULATE THE SIZE OF A RAIN GARDEN

QUESTION 1

(400 + 100) X 0.10 = 50 SQ. FT

QUESTION 2

2400 X 0.10 = 240 SQ. FT