Cooperative Extension

ARIZONA project WET WATER EDUCATION TODAY

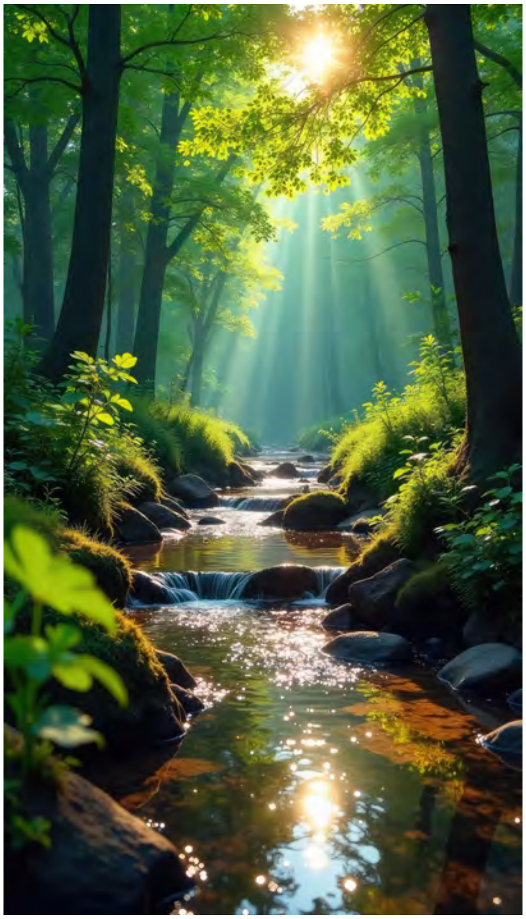
Planting for a Rainy Day Student Handbook

ARIZONA DEPARTMENT of WATER RESOURCES EST. 1980

CITY OF TUCSON

TUCSON WATER

Lesson 1 Background: Adaptations



Many of the human behaviors and engineering feats that help us conserve water and stay cool we learned from desert plants and animals that have practiced water conservation for thousands of years. In fact, these adaptations to arid environments are embedded in their genetic code and have evolved and been passed down from generation to generation. In many parts of Arizona, plants and animals have adapted to hot, dry conditions.

Although water is one of the most common substances on Earth, it is not distributed equally across the planet. Water in the air and soil as well as temperature are the most important environmental factors in determining the amount and type of vegetation in an area. Temperatures in Arizona vary depending on elevation. In the high plateau and mountainous regions of the state, summer temperatures average about 82 degrees (Fahrenheit) in the day and 50 degrees at night. At lower elevations, high temperatures are common during the summer months and average over 100 degrees. Throughout the state, temperatures vary greatly between day and night. The daily minimum and maximum temperatures can vary by 30 or 40 degrees.

Statewide, Arizona averages just thirteen inches of rain per year, with generally more precipitation at higher elevations, and less at lower elevations (e.g., twenty-one inches average annual precipitation in Payson vs. three inches in Yuma). There is very little surface water in Arizona—rivers and streams make up less than five percent of the state's surface area. **Riparian areas** occur along streams and rivers and around springs, ponds, lakes, and reservoirs. Examples include floodplains, stream banks, and lake-shores. More than 80 percent of the animal species in Arizona rely on riparian habitats for survival.

The place where a species lives is called its **habitat**. A habitat contains the food, water, and shelter that a plant or animal requires for survival. For simplicity, biologists, ecologists, and land managers often generalize habitats by associating them with types of vegetation or ecosystems. This makes it easier to understand where plants and animals live without having to know the exact needs of each species.

Because of variations in temperature, rainfall, altitude, and geography, Arizona has many different ecosystems that support different biotic communities, or groups of organisms. The plants, animals, fungi, microorganisms, etc. that live together and interact in a particular place make up a **community**. A community together with its physical environment (the soils, rock formations, water features, etc.) make up an **ecosystem**. Arizona's major ecosystems are: desert scrub, desert grasslands, chaparral, woodlands, pine forests, montane forests, sub-alpine forests, and riparian. These ecosystems are used to describe the habitats of plants and animals in this activity (see Pages # 8 &9 in Student Handbook for descriptions of these ecosystems).

Lesson 1 Background: Adaptations

Arizona is among the top five U.S. states for **biodiversity**. This means that Arizona has many different living organisms that have adapted to live in its diverse habitats and ecosystems. There are more than four thousand different species of plants and animals that live in Arizona! Arizona's plants and animals have adopted various strategies to survive in environments that often have little water and high daytime temperatures. They find ways to avoid and dissipate heat, and to obtain and conserve water.

Plants and animals that have evolved with other organisms and have adapted to a specific place are called **native species**. Native species have evolved to live in the ecosystems of Arizona over thousands of years. **Nonnative species** are those that have been introduced or transported to a new environment that they did not evolve in. Some nonnatives do not have the mechanisms to survive in a new place. For example, a mangrove tree from the Everglades in Florida cannot survive the aridity in Arizona.

Native Species

Gila Monster

Big Horn Sheep

Desert Tortoise

Greater Roadrunner

Saguaro Cactus

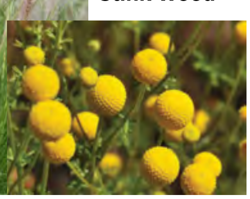
Other nonnatives have adaptations that help them to out-compete native species. An example is Tamarisk, or salt cedar, a phreatophyte from the Middle East and the Mediterranean that was planted in the western United States to help control erosion along stream banks. A **phreatophyte** is a deep-rooted plant that obtains its water from the water table or layer of soil just above it. Tamarisk have long taproots, but they also have shallow roots that allow them to utilize water near the soil surface. Tamarisk's ability to survive periods of drought, as well as tolerate saline soils, gives it a competitive advantage over native riparian plants in many desert riparian areas (especially those that don't experience natural flood events regularly). When Tamarisk becomes dominant in an area, it can reduce habitat for certain species of wildlife (and other plants) that have evolved in relationship with other native species.

Fountain Grass

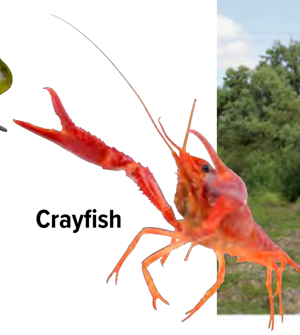
Nonnative Species

Tamarisk

Stink Weed



Bull Frog



Crayfish

Lesson 1 Background: Adaptations

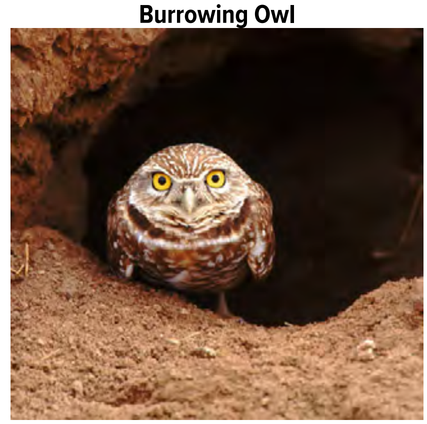
Animal Adaptations

One of the advantages that animals have over plants, when it comes to coping with environmental conditions, is that they are mobile. Some animals, like the big brown bat, live in the deserts in the wintertime and move to cooler areas in the summer to escape the extreme heat and dryness in the desert valleys. Other animals, such as the round-tailed ground squirrel, go into their burrows and **estivate** in the heat of the summer. **Estivation** is like hibernation, except it occurs in the hot dry summer instead of the cold wet winter. Desert toads, such as the Couch's Spadefoot, also estivate, burrowing underground during the dry part of the year and awakening when the first summer thunderstorms come.

Antelope Squirrel

Spadefoot Toad

Burrowing Owl



Another strategy that animals use to avoid the heat of the day is to sleep underground in their burrows or in the shade and then to come out and be active at dusk or dawn (**crepuscular** activity) or at night (**nocturnal** activity). Mule deer, Gila monsters, javelina, and many birds are crepuscular. Bats, foxes, skunks, rodents, and snakes are primarily nocturnal.

Some animals, such as brine shrimp and fairy shrimp, survive dry spells as eggs when the water evaporates. When the water returns, the eggs hatch and the shrimp grow and mature and lay new eggs before their habitat dries up again.

Animals have developed ways to dissipate the desert heat. Many desert animals are light-colored, which helps them to stay cooler by not absorbing as much of the sun's heat. Light-colored scales, feathers, and fur also serve as camouflage and protect against predators.

Big Brown Bat

Rattlesnake

Skunk

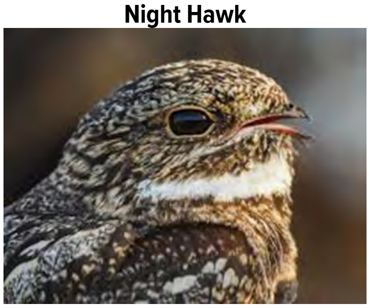
Ringtail Cat

Lesson 1 Background: Adaptations

Coyote

Using **evaporation** is an effective way to cool down in the desert. Perspiration is one method; the skin gives off water either as a vapor by simple evaporation from the skin or as sweat. When humans get too hot, we sweat and the moisture evaporates off of our bodies to help us cool down. Coyotes can pant to stay cool. The air moving in and out of a coyote's lungs evaporates moisture on its tongue and in its mouth, which helps to lower its body temperature. Owls and nighthawks stay cool by opening their mouths and moving their throats in an action similar to panting. Some desert animals, such as the jackrabbit, have long appendages that help to cool them. A jackrabbit's ears can be five to eight inches long! The blood vessels in their ears are close to the surface, which helps dissipate heat.

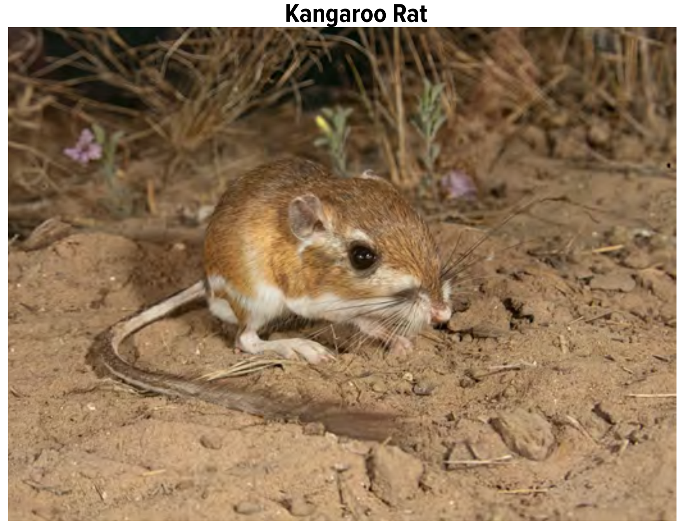
Night Hawk



Jack Rabbit

Because water is so scarce, desert animals have developed ways to obtain and retain water. Most desert animals get their water from the food they eat. Insects, birds, and animals all obtain essential water from the flowers, fruits, seeds, stems, leaves, and roots of plants. Kangaroo rats use water more efficiently than most other mammals. They are able to metabolize all the moisture they need from the dry seeds they eat. Kangaroo rats also have special organs in their noses that help to capture moisture from their breath so it isn't lost when they exhale, and specialized kidneys that concentrate their urine to retain water within their systems. Some scavengers and predators, such as turkey vultures and owls, also can get all the moisture they need from their food.

Kangaroo Rat



Turkey Vulture

Lesson 1 Background: Adaptations

Thick, fleshy, and waxy leaves or stems can help plants store water.

Plant Adaptations

Arizona plants have also adapted in interesting ways to the desert heat and aridity. Some plants have shallow roots to soak up lots of rainwater quickly, while others have long taproots to draw water from deep in the ground (and some have both!). Many desert plants begin to grow in the shade of larger plants, or "nurse" plants, because they can't survive the full sun when they are young. Saguaro cacti often germinate in the shade of nurse plants.

Xerophytes are plants that have adapted to arid environments by developing physical structures that help them to survive extreme heat and water deprivation. Sagebrush, saltbush, creosote bush, palo verde, agave, and cacti are all examples of xerophytes. Cacti are some of the most drought-tolerant plants on Earth. Their shallow root systems can soak up lots of water quickly when it rains, and they can store enough water in their stems to meet their needs for over a year. Cacti reduce the amount of water lost to the environment through **transpiration** by having spines instead of leaves and thick waxy skin (transpiration occurs when water vapor in a plant is lost to the atmosphere through pores in its leaves, called stomata). They also utilize a specialized metabolic system (Crassulacean Acid Metabolism or CAM) that allows them to keep their stomata closed during the day, opening them at night for the exchange of carbon dioxide and oxygen that allows the plant to complete its cycles of photosynthesis and respiration.

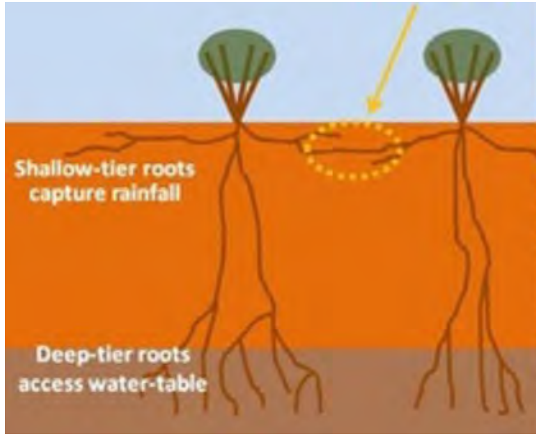
Other xerophytes have adapted by reducing or eliminating their leaves to reduce the amount of water lost through the leaves. They often have green bark like the palo verde tree to enhance photosynthesis. Sagebrush leaves have silvery hairs that reflect sunlight and keep the leaf surfaces cooler.

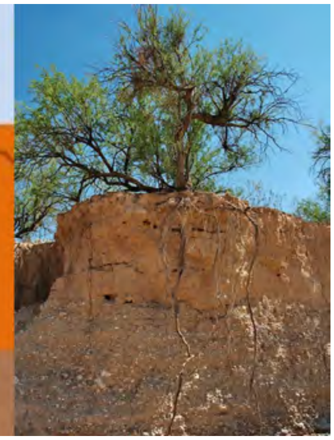
Small, waxy, hairy leaves, or spines help reduce water loss through evaporation.

Lesson 1 Background: Adaptations

Plant Adaptations Continued

Phreatophytes, such as mesquite, grow extremely long roots to tap into water deep beneath the surface. Mesquite trees have the deepest roots of any native desert plant and can reach down eighty feet. Both mesquite trees and creosote bushes have deep taproots that allow them to draw up deeper ground water and shallow radial roots that absorb rainwater from near the surface.





Desert **perennials** survive by becoming dormant when it is hot and dry and then rejuvenating when it rains. Ocotillo will appear to be dead until it rains, and then they spring to life, growing new leaves within a couple of weeks. When the weather becomes hot and dry again, the ocotillo loses its leaves and goes dormant again until the next rainfall. It can repeat this cycle as many as five times a year. The desert lily is a bulb that can store food and moisture underground for years before it comes out of dormancy.

Ephemeral plants germinate when it rains and can complete their entire life cycle in a few weeks or months. There are hundreds of species of ephemerals that have adapted to life in the desert. Examples include lupine, desert sand verbena, and Mojave aster. They grow, flower, and produce seeds in just a few weeks. The seeds can remain viable in the soil for years, waiting for just the right wet spring conditions to germinate.

Arizona Biomes

Arizona's major biomes are desert scrub, desert grasslands, chaparral, woodlands, montane forests, subalpine forests, and riparian. As you travel up in elevation, biomes transition in a relatively predictable pattern that is generalized below. (See the Arizona Game and Fish Web site for a helpful diagram and photos: http://explore.azgfd.gov/Default.aspx?tabid=54).

Desert Scrub

Desert scrub occurs at lower elevations ranging from around 100 feet in the southern part of the state to 5,000 feet in the northern part of the state. Desert scrub is characterized by different shrubs and cacti in each of Arizona's three deserts. In the Sonoran Desert, it is characterized by mesquite, acacia, and saguaro; in the Mojave Desert, it is characterized by creosote and Mojave yucca; and in the Great Basin desert, it is characterized by sagebrush, black brush, and fourwing salt bush.


Kerry Schwartz

Looking from Coronado National Memorial towards the Mule Mountains across desert scrub.

Desert Grasslands

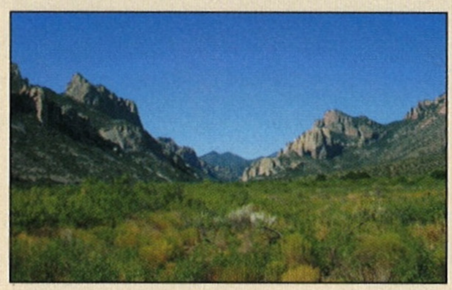
Grasslands occur at elevations of 3,500 to 5,500 feet. They are natural open areas, dominated by a mixture of perennial and annual grasses. Grasslands can form large expanses of open fields or be broken by scatterings of shrubs or trees.


Kerry Schwartz

Desert grasslands near Tombstone.

Chaparral

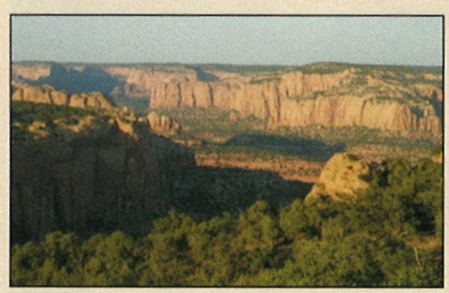
Chaparral can be found from 3,500 to 6,000 feet. Chaparral refers to dense stands of shrubs (and/or small trees) made up of a mixture of species. Some of the more common plants of the chaparral complex include scrub oak, mountain mahogany, and manzanita. Central Arizona has some of the most extensive areas of chaparral in the southwestern United States.


Kerry Schwartz

Chaparral in Cave Creek Canyon.

Woodlands

Open woodlands of small trees are often found at elevations of 4,500 to 6,500 feet. In the northern part of the state (Colorado Plateau and Great Basin), piñon and juniper trees are the characteristic plant species. A variety of shrubs, grasses, and other plants grow within piñon/juniper woodlands. In the southeastern part of the state, woodlands are dominated by evergreen oaks, junipers, and Mexican piñon.


Justin Howe

Piñon/juniper woodland in Navajo National Monument.

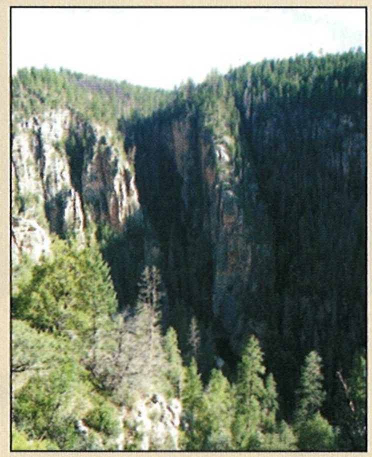
Montane Conifer Forests

Mixed conifer and ponderosa pine forests (together called Montane Forests) are the dominant forests of the higher elevations in Arizona. They can be found from 5,000 to 8,000 feet or higher. Ponderosa pine forests are generally found at lower elevations than are mixed conifer. Ponderosa pine forests include smaller trees and shrubs like Gambel's oak, Arizona white oak, juniper, mountain mahogany, sumac, and manzanita.

Mixed conifer forests are dominated by Douglas fir, white fir, and southwestern white pine; aspen is also common. These forests are usually most fully developed between about 8,000 to 9,500 feet in elevation. They typically have well-developed understories with some of the same species as are found in ponderosa pine forests.

Kerry Schwartz

Ponderosa pine forest near Flagstaff.



Wade Albrecht

Mixed conifer forest along West Clear Creek.

Subalpine Conifer Forests

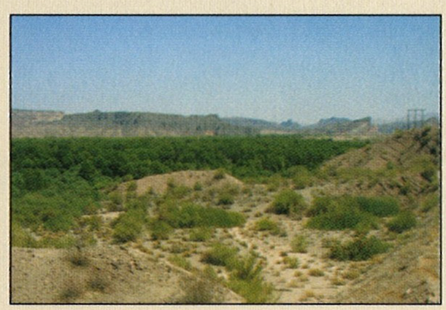
Often referred to as spruce-fir forests, subalpine conifer forests are found at about 9,000 to 11,500 feet (tree line). The primary species are subalpine fir and Engelmann spruce. These forests are cold and moist. Limber pine, bristlecone pine, and aspen also grow here. Understory plants include common juniper, bush honeysuckle, elderberry, and thimbleberry. At tree line, the forest transitions to tundra with low-lying shrubs and plants. Alpine tundra is only found in a few places in Arizona, such as the top of Mount Humphreys.

Kerry Schwartz

Subalpine conifer forest along the East Fork of the Black River.

Riparian

Riparian vegetation is found at all elevations along streams, rivers, washes, and other watercourses and consists mostly of broad-leaved trees and shrubs with grasses, sedges, wildflowers, and annual plants. Some of the larger trees found in a riparian area form a woodland. These large trees often include cottonwoods, sycamores, walnuts, boxelders, ashes, and alders. Willows, mesquite, tamarisk (a non-native invasive plant), and other small trees and shrubs make up an important understory component in riparian areas.



Justin Howe

Riparian area along the Bill Williams River.

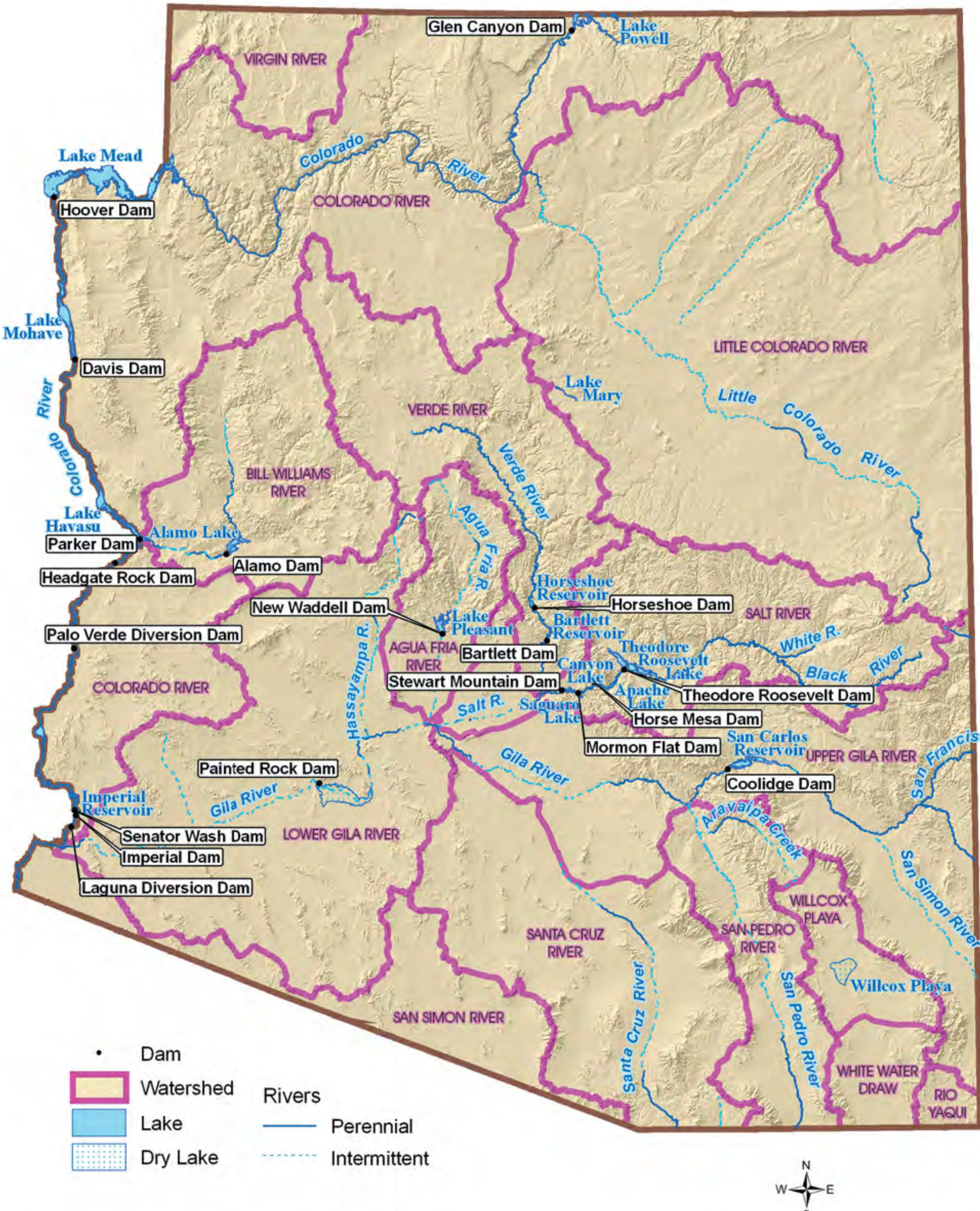
Lesson 1 Maps:

Arizona Reference Map

Data from Arizona State Land Department

Lesson 1 Maps:

Rivers and Watersheds



Watershed boundaries from Arizona Department of Water Resources & other data from Arizona State Land Department

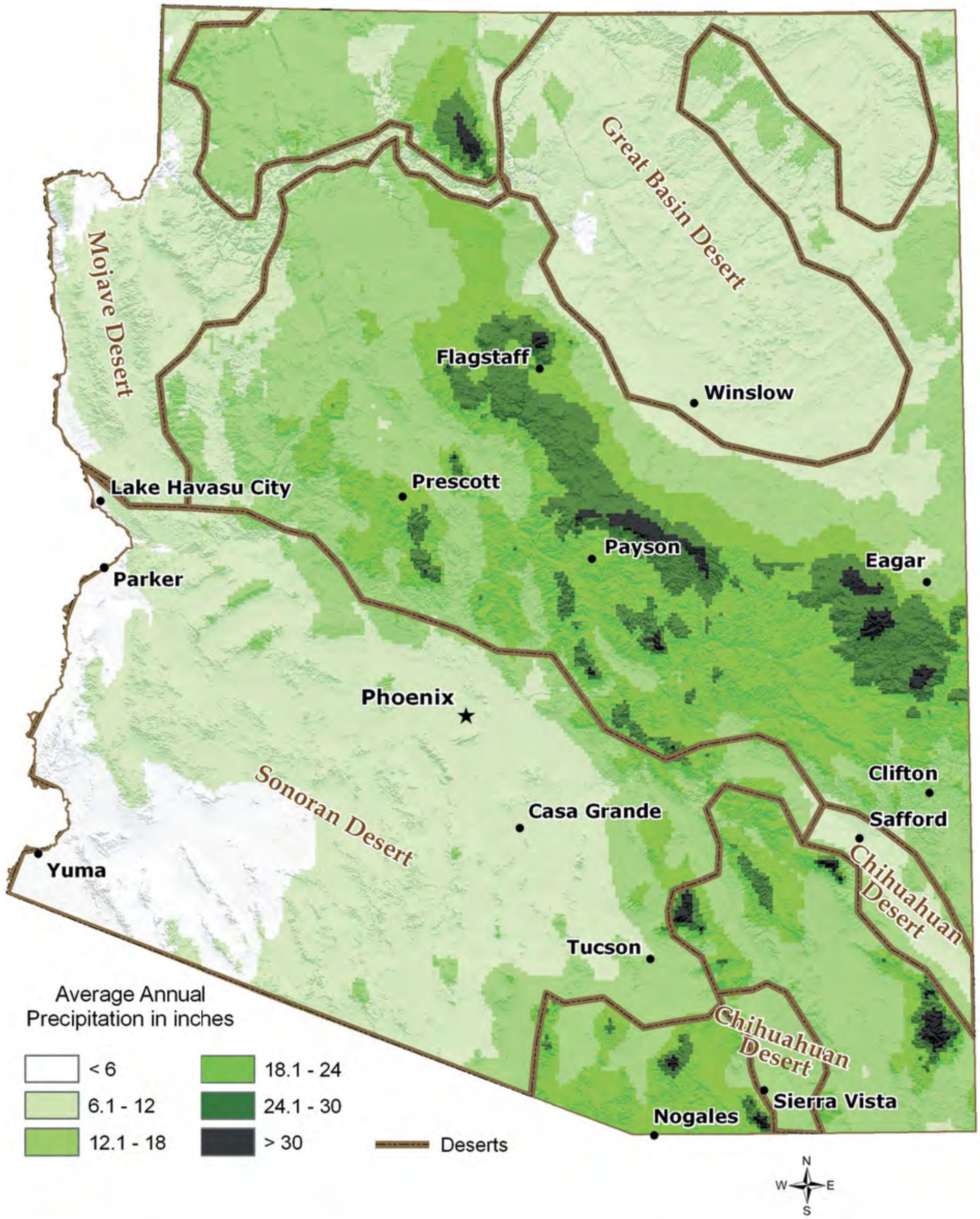
Lesson 1 Maps:

Physiographic Provinces

Physiographic province data from U.S. Geological Survey
Other data from Arizona State Land Department

Lesson 1 Maps:

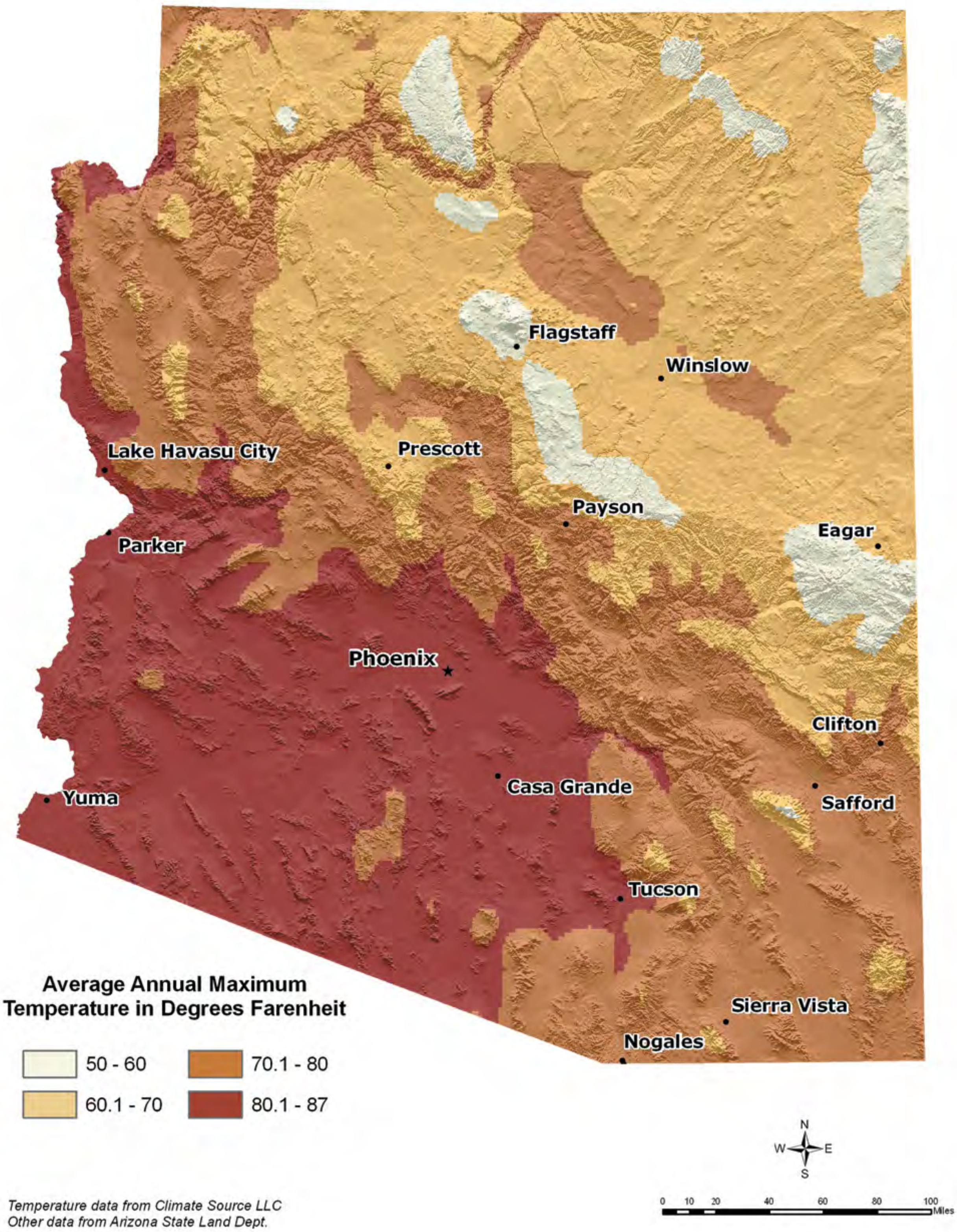
Average Annual Precipitation



Precipitation data from Climate Source LLC & desert regions from Arizona-Sonora Desert Museum

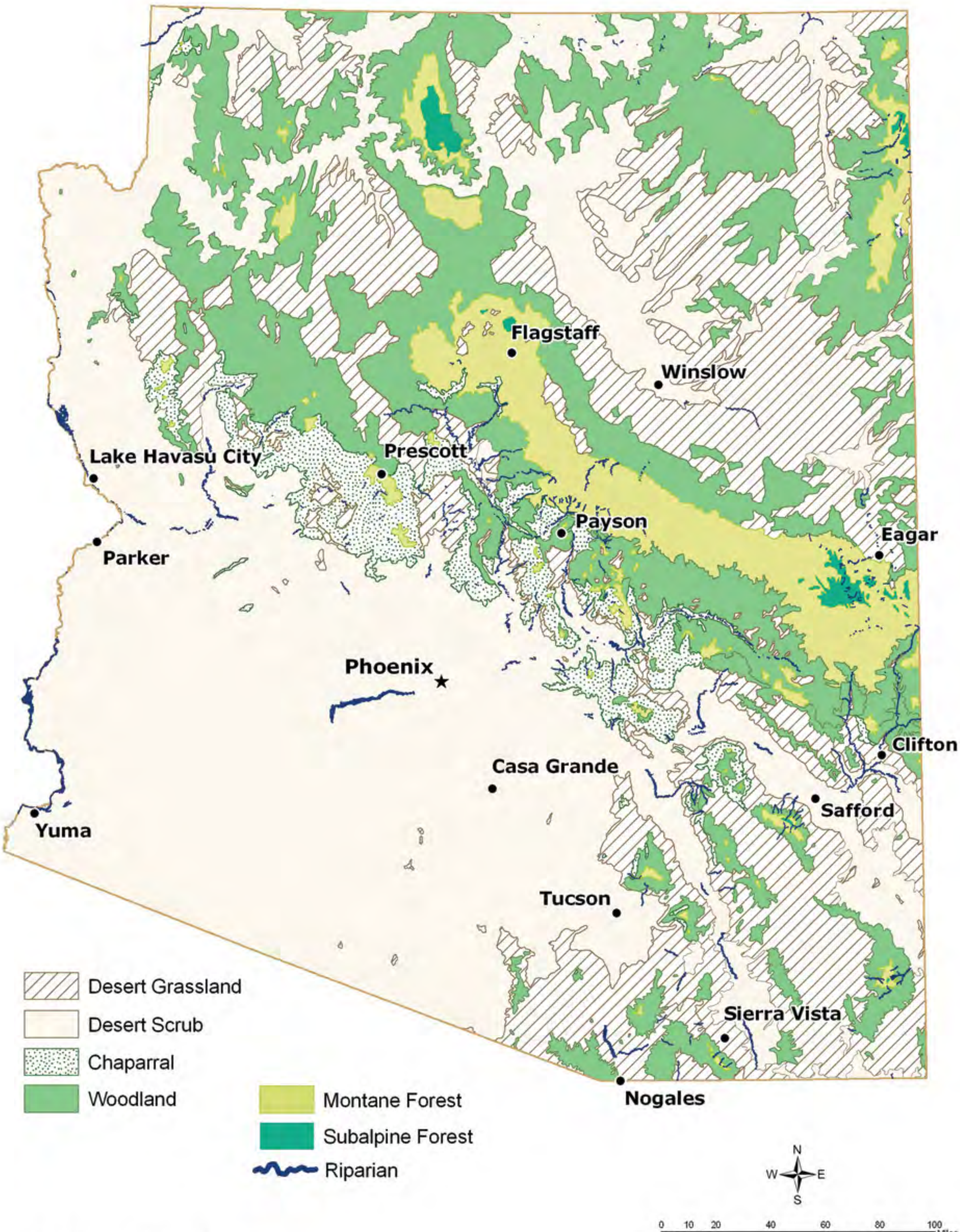
Lesson 1 Maps:

Average Annual Maximum Temperature



Lesson 1 Maps:

Vegetation Coverage



Data from Arizona State Land Department

Lesson 2 Background:

Background
In the hot and dry climates found in much of Arizona, outdoor water use for landscaping can consume tremendous amounts of water. Typically 60–90 percent of all water use by single-family residences is for landscape irrigation, and most of this is used to water turf grass. Choosing landscaping that requires less water can conserve significant amounts of water, as well as requiring less time to maintain. **Water-efficient landscapes** center around the efficient use of rainwater and the use of plants that are adapted for arid conditions. **Native species** that evolved in the local environment and are accustomed to its climate are ideal. Landscaping techniques that conserve water, control temperatures, and store available rainfall are now being applied in many areas of the state.

Native Plants
Using native plants not only conserves water, but also helps maintain healthy ecosystems by providing the food and shelter that other native species (insects, butterflies, birds, wildlife, etc.) require. Incorporating **plant guilds**—associations of plants that benefit each other and enrich the entire habitat—is important, as the various species provide "services" to each other.

For example, mesquite trees' roots harbor colonies of bacteria that fix nitrogen from the atmosphere (convert it into nitrate that is then available for plants' use). When the mesquite trees' nitrogen-rich leaves decompose in the soil, they release the nitrate, enriching the soil for other plants. The mesquite provide favorable habitat and carbon for the bacteria, and the bacteria provide surplus nitrate to the plants. Including legume plants (such as mesquite) that can enrich the nitrogen levels of the soil enhances the health of other plants and eliminates the need for chemical fertilizers.

Mulch
Mulch is material like pine needles, leaves, wood shavings, bark, gravel, or rock that helps hold moisture in the soil and controls erosion. Using mulch around plants conserves water by reducing evaporation, cools the soil surface, and makes the spaces between plants more attractive than bare soil

Temperature Control
Controlling the temperature surrounding a building will reduce the amount of water needed for landscaping. Careful placement of shade trees and shade structures will provide cooling for plantings, for outdoor eating areas, and for the building itself. Keep in mind that the building itself will provide shade, but the shaded area will shift as the sun moves across the sky.

The angle and position of the sun in relationship to the building changes with the season as well as the time of day. The hottest part of a building is on the northwest side in the summer, during the afternoon. Heating in the winter begins in the morning on the southeast side of the building.

Lesson 2 Background:

Rainwater Harvesting

Another important aspect of water-efficient landscaping is the efficient use of rainwater. Arizona's native farming cultures have been masters at this for centuries. Since Arizona's rainfall is sporadic in its timing and amount, techniques for utilizing rainwater as efficiently as possible have been vital to human survival in the past, and remain valuable today.

The main principle of efficient rainwater use is to prevent the water from running off the land surface before it has a chance to soak in and **percolate** deeply into the soil. This can be done in a number of ways: by building **check-dams** in small washes where water tends to flow rapidly, by building **swales** on gradual slopes to slow water flow, and by planting vegetation in low areas where water tends to pool. Arizona's monsoon thunderstorms are often characterized by very heavy, localized rainfall that lasts a short period of time. This type of rainfall can result in major **runoff** and **erosion**, especially in areas where the natural topography and vegetation have been altered.

Another key element to consider is the effect that **permeable** and **impermeable** surfaces have on rainwater runoff. Permeable surfaces, such as sand and soil, allow water to percolate through them, which slows the flow of runoff. Impermeable surfaces, such as roofs and streets, produce the maximum volume and rate of runoff. Capturing and storing the rainwater that runs off your roof can be an excellent way to conserve water.

Rainwater harvesting systems can be as simple as having roof gutters that direct water into a **bermed** landscape holding area. In this model, rainwater is used immediately and is not stored in a holding tank. In a more complex system, a **cistern** or rain barrel is used to store rainwater for future use. This is useful in Arizona because most of the precipitation falls during the winter wet season or summer monsoon season, and there are long periods of very little moisture in between. Having rainwater storage capacity can help provide a more predictable supply. Note: rainwater storage systems need to be covered to prevent mosquito larvae and should be labeled as non-potable water.

Two simple rainwater harvesting systems use bermed soil and drainage ditches to direct water from roof to planted areas.

This complex rainwater harvesting system uses gutters and downspouts to direct rainwater from the roof into a storage cistern (rain water barrel). The storage cistern has a hose attached which leads to a drip irrigation system for watering plants.

ARIZONA project WET
WATER EDUCATION TODAY

Rubric For Smart Landscape Design - Group Name:

Criteria: **Scale of 0-10** (Perfect score 40)	**Effective means of storing and channeling water for beneficial use** (rain barrels, swales, etc.).	**Effective means of temperature control** (shade trees, permeable surfaces, etc.).	**Effective use of native, drought-tolerant plants** (nonnative plant use should be justified).	**Attractive and efficient landscape** (variety of plants of different sizes, colors, textures, etc.).
Fully Met: 9-10				
Partially Met: 7-8				
Half Met: 5-6				
Did not meet: 0-4				

Total Score:

Rubric For Smart Landscape Design - Group Name:

Criteria: **Scale of 0-10**	**Effective means of storing and channeling water for beneficial use** (rain barrels, swales, etc.).	**Effective means of temperature control** (shade trees, permeable surfaces, etc.).	**Effective use of native, drought-tolerant plants** (nonnative plant use should be justified).	**Attractive and efficient landscape** (variety of plants of different sizes, colors, textures, etc.).
Fully Met: 9-10				
Partially Met: 7-8				
Half Met: 5-6				
Did not meet: 0-4				

Total Score:

Effective Water Usage

Store and Channel Water for Beneficial Use

Create berms & swales to slow, spread out and to keep water where we need it.

Use rain gutters & rain barrels to capture water for later use.

Cool it Down

Create Shade

- Cools neighborhoods and promotes recreation.
- Use permeable surfaces.
- Helps mitigate urban heat island effect.

Native & Drought-tolerant Plants



Thick, fleshy, waxy leaves or stems can help plants store more water.



Small and hairy leaves and spines reduce loss of water through evaporation.





Habitat for Wildlife

Native plants provide many homes and food for animals.










Attractive & Efficient Landscape






Before & After Photos








Storm to Shade

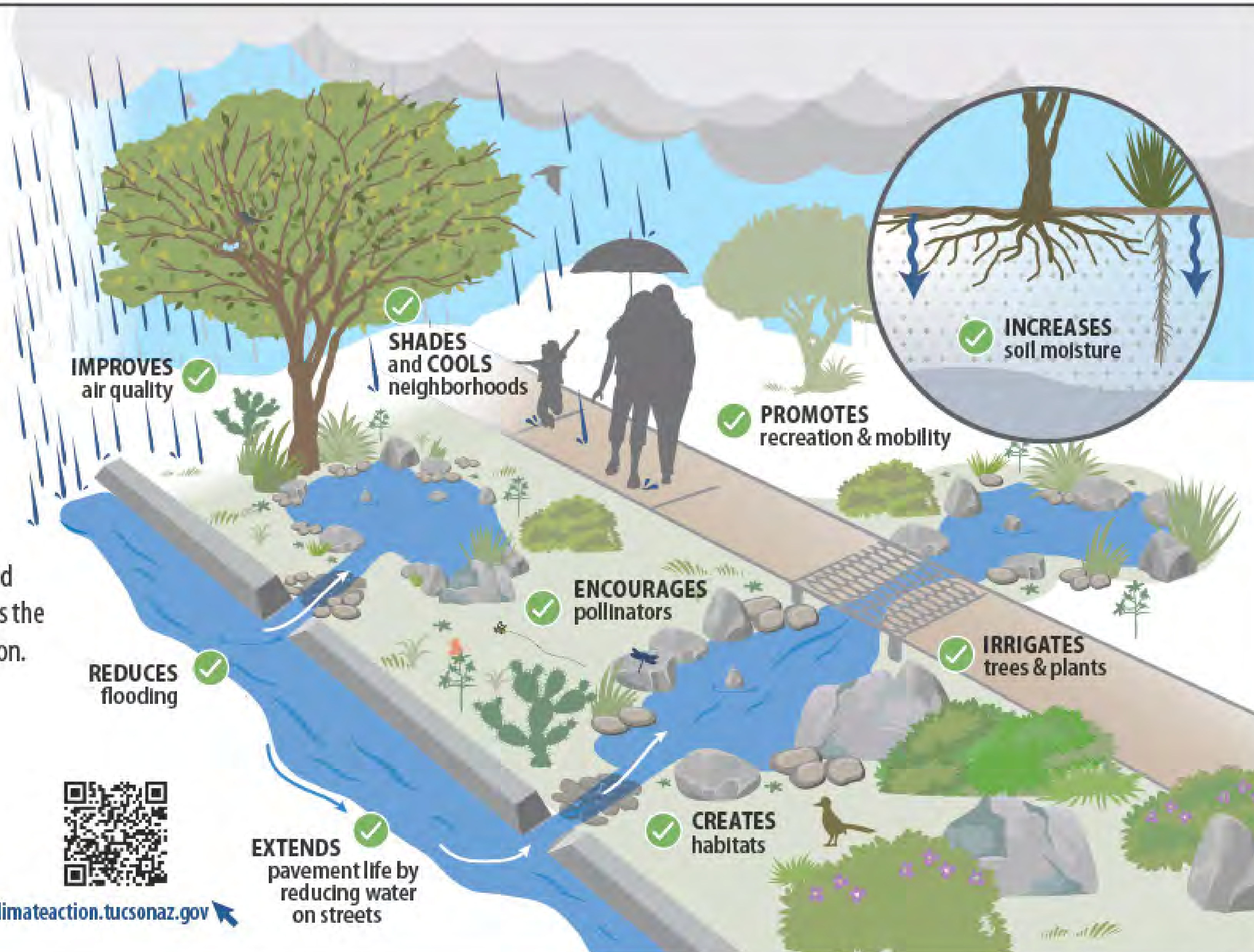
City of Tucson
Green Stormwater
Infrastructure Program

What is GSI?

Green Stormwater Infrastructure (GSI) directs stormwater runoff from streets, parking lots, and rooftops into landscaped areas where it infiltrates the soil to support vegetation.

Find GSI at

- ✓ Parks
- ✓ Greenways
- ✓ Neighborhood streets
- ✓ Bike boulevards
- ✓ Public parking lots
- ✓ Traffic circles



climateaction.tucsonaz.gov

REV 6.13.22

“Watershed Tour” of Your School Grounds

1. Focus on the area around the building at first.

- Look for places where water drains off the roof, and follow the paths water would take, noticing where it leaves the school grounds. Where are high and low areas?
- Does the rainwater get used to water landscaping, or does it get directed off the school grounds as quickly as possible?
- Are there design features in the parking lots where water can flow into low, vegetated areas or is it curbed? Is most of the ground surface permeable or impermeable to water?

2. After you have explored the rainwater drainage patterns of your school grounds and identified high and low areas, areas of high runoff, and areas where water can soak in, now brainstorm ways to keep the water on the grounds where it can be used to water landscaping and recharge the ground water.

- How could the rainwater be stored so that it can be used when needed?
- Ask them to think about where they would place rainwater holding tanks, and how they would get the water from the tanks to the landscaping.
- How big would the tanks need to be? Calculating the size of holding tanks will be practiced in Part II of this activity.
- Can they think of ways to restore more natural topography to the school grounds to keep water from running off?
- Are there places where concrete and asphalt could be replaced with more permeable surfaces such as sand or gravel to allow more water to soak into the ground?

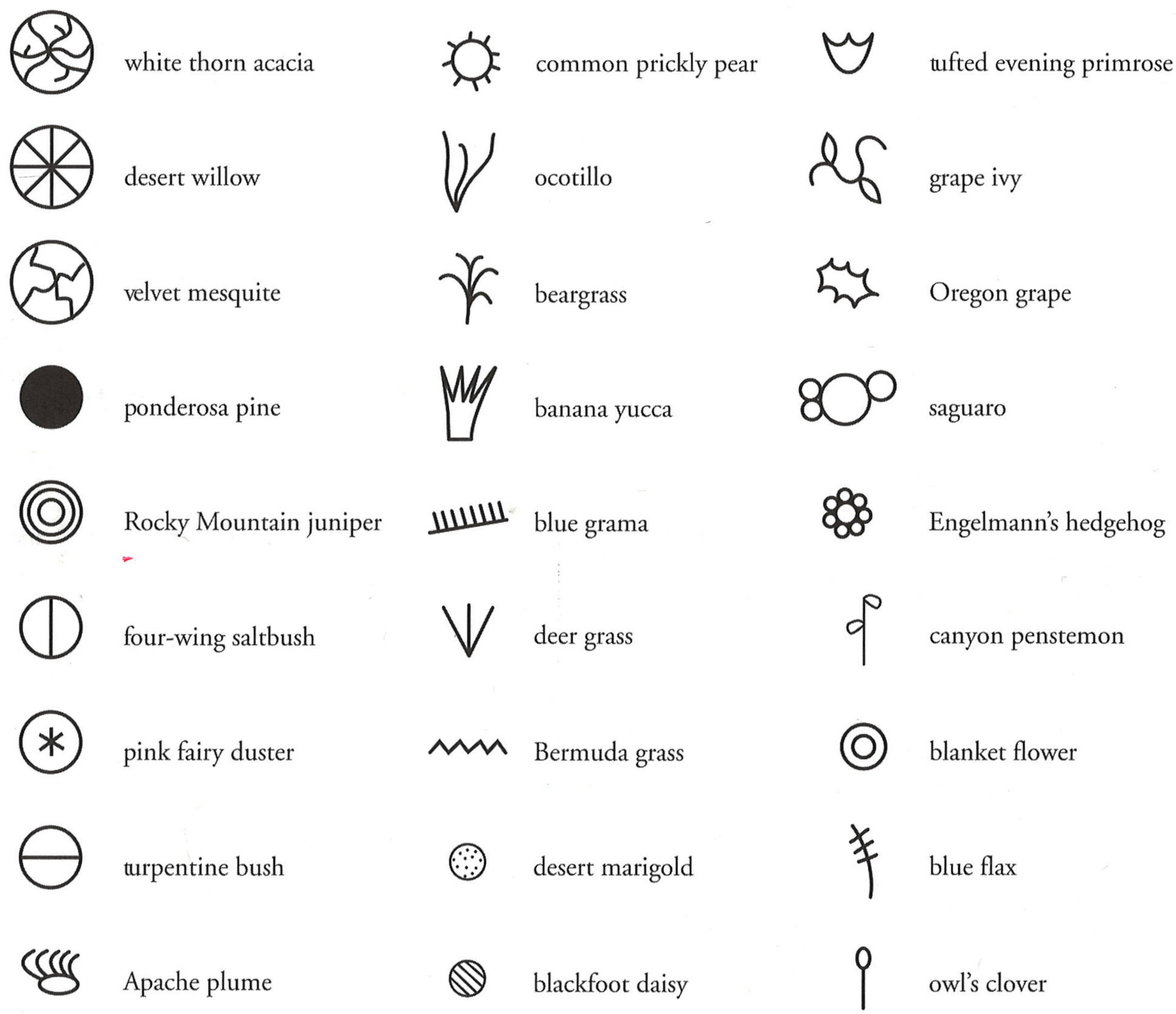
3. Now ask focus on the vegetation.

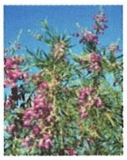
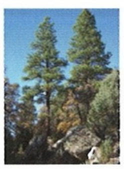
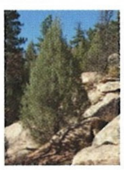
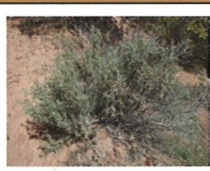
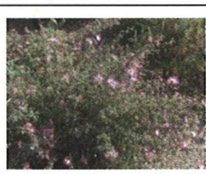
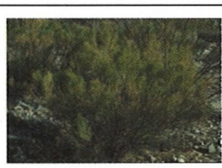
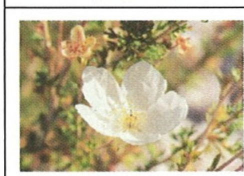
- How many different species of plants do they notice? Are there trees, shrubs, cacti, etc? How much of the grounds is covered with turf grass? Are the places that have grass used for play areas and eating areas or are they just to be looked at?
- Have the students look at the photos of native plants in their packets. Do they see any of the native plants that are included in their packets growing on the school grounds?
- Ask them to think about where they would incorporate native species in the landscaping and whether or not the turf grass (which uses high volumes of water) is necessary in all the places it is currently growing. Replacing turf grass with native vegetation (in decorative areas) or artificial turf (in playing areas) can conserve a lot of water.

Native Plants for Water-Efficient Landscapes

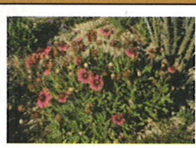
Choose from the following list of native plants as you design your school's landscaping. Use the icons shown beside the plants' names to represent them on your design layout in the suggested color. ***Note:*** perennial plants are those that continue to grow year after year, while annual plants die every year and sprout again from seeds.

Look at the **Physiographic Provinces Map** to find your location and choose plants from the list below that are found in your area (see column 2).



TREES—dark green						
Photograph[14]	**Name**	**Area of Arizona**	**Cold Tolerance**	**Sun Preference**	**Water Requirements**	**Special Features**
	white thorn acacia	Basin and Range	to 5˚	full sun	very low	Yellow puffball flowers. Attracts birds.
	desert willow	all areas	to 0˚	full sun	low	White, pink, purple flowers attract hummingbirds.
	velvet mesquite	Basin and Range	to 0˚	full sun	very low	Pale yellow flowers. Excellent for wildlife.
	ponderosa pine	Colorado Plateau Mogollon Rim	below 0˚	full or partial sun	moderate	Excellent for squirrels and birds.
	Rocky Mountain juniper	Colorado Plateau Mogollon Rim	below 0˚	full or partial sun	low	Seeds attract birds.
SHRUBS—purple						
	four-wing saltbush	all areas	to 0˚	full sun	very low	Excellent for wildlife.
	pink fairy duster	Basin and Range	to 5˚	full sun	very low	Pink powder-puff flowers attract hummingbirds.
	turpentine bush	Mogollon Rim Basin and Range	to 5˚	full sun	very low	Yellow flowers. Seeds attract birds.
	Apache plume	all areas	below 0˚	full or partial sun	very low	White flowers. Attracts wildlife.

Photograph[14]	Name	Area of Arizona	Cold Tolerance	Sun Preference	Water Requirements	Special Features
GROUNDCOVERS AND VINES—blue						
	white evening primrose	Mogollon Rim Basin and Range	to 10˚	full or partial sun	low to moderate	Low groundcover with large white to pink flowers.
	grape ivy	Basin and Range	to 20˚	full sun or shade	low	Vine.
	Oregon grape	Colorado Plateau Mogollon Rim	below 0˚	partial sun or shade	low to moderate	Yellow flowers, blue/purple berries.
Cacti—brown						
	saguaro	Basin and Range	to 18˚	full sun	very low	Red fruits attract birds.
	Engelmann's hedgehog	all areas	to 10˚	full sun	very low	Vivid pink flowers.
	common prickly pear	all areas	to 0˚	full to partial sun	very low	Yellow flowers.
SUCCULENTS—orange						
	ocotillo	Basin and Range	to 10˚	full sun	very low	Red flowers attract hummingbirds
	beargrass	all areas	to 0˚	full to partial sun	very low	Evergreen.
	banana yucca	all areas	to 0˚	full sun	very low	Showy flower stalk.

Photograph[14]	Name	Area of Arizona	Cold Tolerance	Sun Preference	Water Requirements	Special Features
GRASSES—light green						
	blue grama	all areas	to 0˚	full to partial sun	moderate	Good for natural-looking meadows.
	deer grass	all areas	to 0˚	full or partial sun	low	Grows in bunches. Decorative.
	Bermuda grass (NOT native to the Southwest US.)	all areas	to 0˚	full sun	Low in winter, high in summer.	Turf grass; use for lawns or play areas.
PERENNIAL WILDFLOWERS—red						
	desert marigold	all areas	to 10˚	full sun	low	Yellow flowers, blooms for a long time.
	blackfoot daisy	all areas	to 0˚	full to partial sun	low	White and yellow flowers, spreads.
	canyon penstemon	all areas	to 0˚	full to partial sun	low	Rose-colored flowers attract hummingbirds.
ANNUAL WILDFLOWERS—yellow						
	blanket flower	all areas	dies in winter	full sun	low	Red and yellow flowers.
	blue flax	all areas	dies in winter	partial sun	low	Blue flowers. Reseeds itself easily.
	owl's clover	Basin and Range	dies in winter	full to partial sun	low	Rose-pink flower spikes.

14. *Credits for the photographs in this table are as follows: All photos courtesy of the University of Arizona Water Resources Research Center (Desert Landscaping CD) except: pink fairy duster (Ursula Schuch, University of Arizona Plant Sciences Dept.); beargrass (Toni Moore, Master Gardener, Pima County); banana yucca, creosote bush, Engelmann's hedgehog (Kerry Schwartz); grape ivy (Sandra Rode); and four-wing saltbush, Oregon grape, Bermuda grass, prickly pear, blue grama, ponderosa, juniper (Lissa Howe).*

Rainwater Harvesting Calculations

Directions:

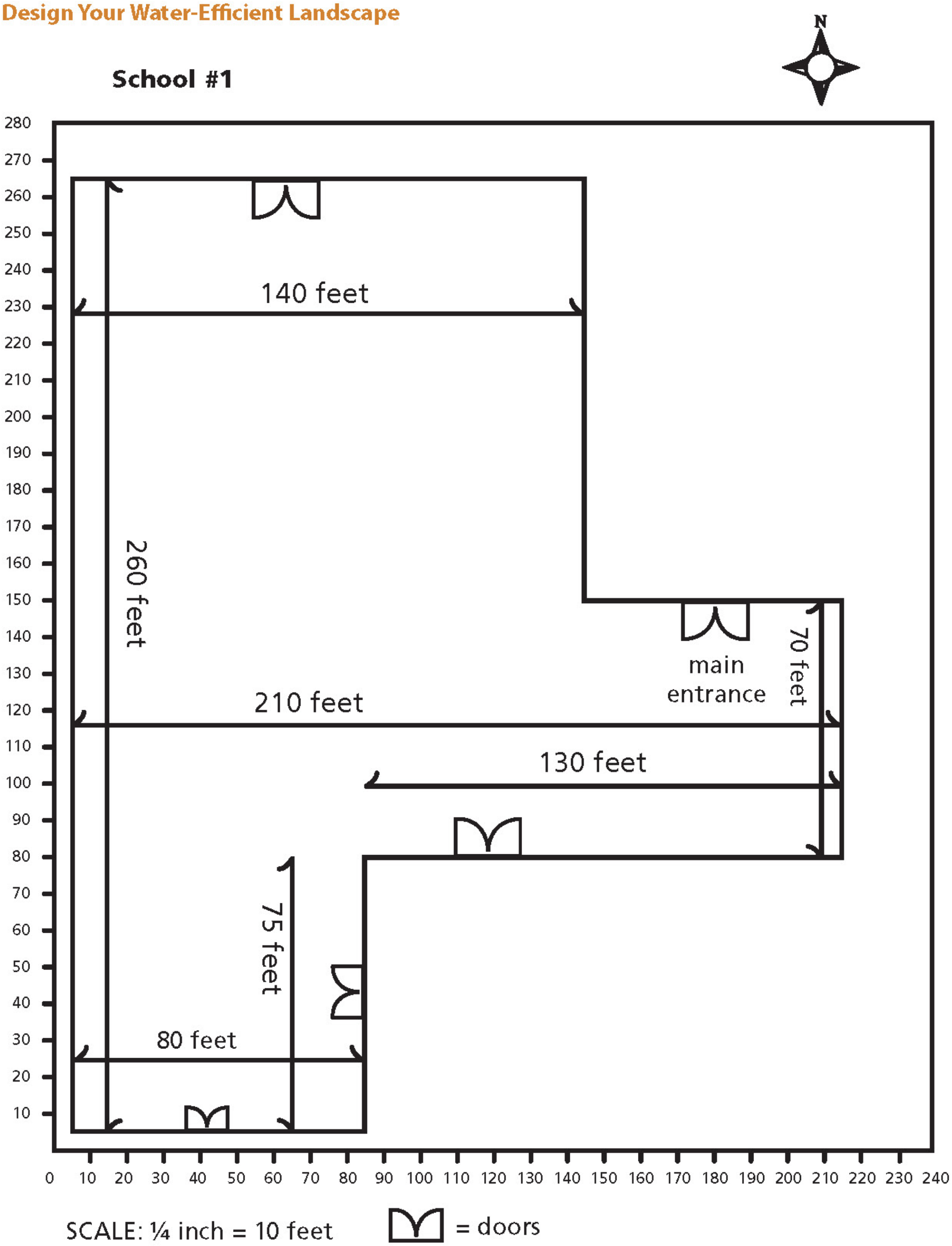
1. Choose a school aerial view from the three shown on pages 136, 137, and 138. Trace the outline you've chosen onto two additional sheets of white paper so you have three views to draw on.

2. Use the measurements for length and width to calculate the amount of square footage for the roof (LENGTH x WIDTH of a rectangle = square feet).

3. Use the chart below to calculate how much water can be harvested from the roof. You will need to refer to the table for average monthly rainfall for your community (provided by your teacher) to fill in column A. If your community is not included in the table, use the numbers for the city in the table that is nearest to you.

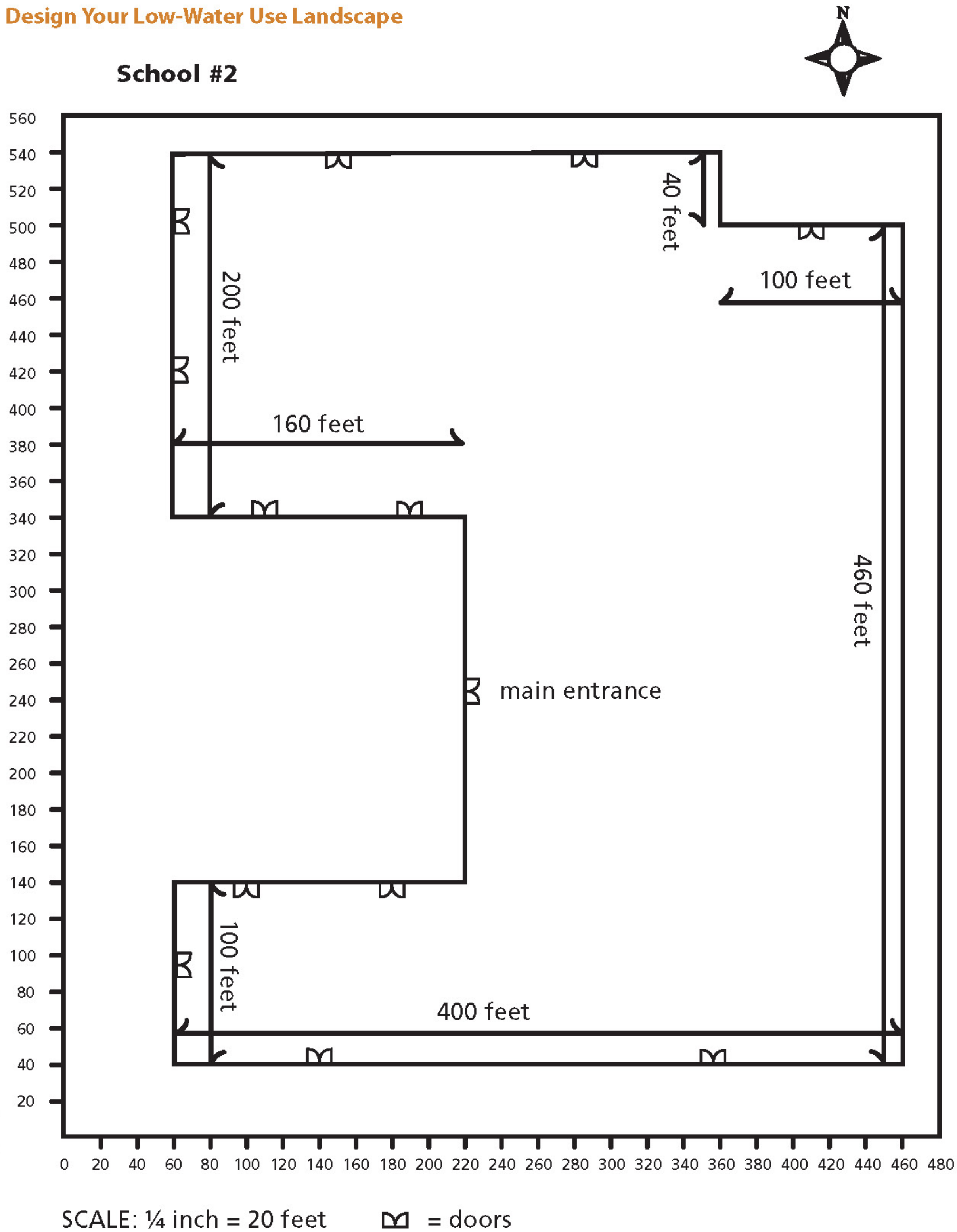
How Much Water Can Be Harvested From Your School's Roof?						
	A	**B**	**C**	**D**	**E**	**F**
For each month of the year, follow the instructions to fill in its row.	Enter the amount of rainfall for each month for your city.	Multiply the number in column A by .623 to convert inches to gallons per square foot.	Enter the square feet for the roof you chose.	Multiply column B by column C. This is the maximum gallons of rainfall per month.	Multiply column D by the given "runoff coefficient." This represents how much of the rain that falls on the roof will run off (95%). Enter your answer in column F.	This is the total gallons of water that can be harvested each month (the remainder may be lost to evaporation).
January					.95	
February					.95	
March					.95	
April					.95	
May					.95	
June					.95	
July					.95	
August					.95	
September					.95	
October					.95	
November					.95	
December					.95	
TOTALS					.95	

Design Your Water-Efficient Landscape



Artist: Rachel Ivanyi, © Project WET

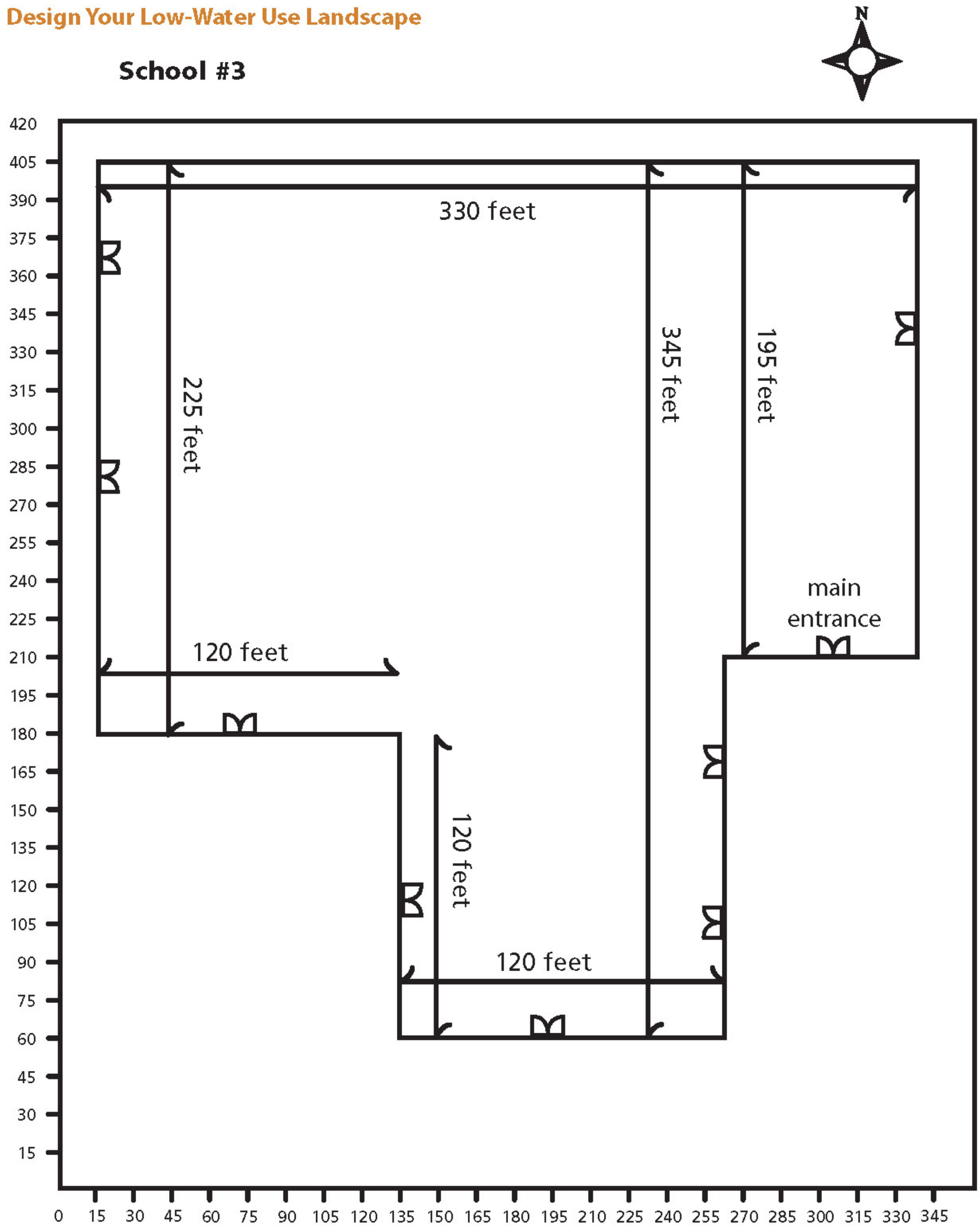
Design Your Low-Water Use Landscape



Artist: Rachel Ivanyi, © Project WET

Design Your Low-Water Use Landscape

School #3



Artist: Rachel Ivanyi, © Project WET

SCALE: ¼ inch = 15 feet = doors

Arizona Climate Data

Inches of Average Monthly Rainfall for Arizona Cities and Towns
(Precipitation Normal for Period 1971–2000, National Weather Service)

	Bullhead City	Casa Grande	Chandler	Douglas	Flagstaff	Gila Bend	Holbrook	Kingman
Jan	0.95	0.77	1.10	0.75	2.18	0.62	0.71	1.23
Feb	0.99	0.83	0.99	0.64	2.56	0.87	0.66	1.10
Mar	0.93	0.99	0.94	0.46	2.62	0.72	0.72	1.31
Apr	0.17	0.28	0.32	0.20	1.29	0.20	0.37	0.47
May	0.08	0.19	0.17	0.33	0.80	0.15	0.38	0.31
June	0.01	0.10	0.15	0.63	0.43	0.04	0.20	0.19
July	0.29	0.80	0.50	3.14	2.40	0.76	1.17	0.98
Aug	0.68	1.97	0.62	2.88	2.89	1.20	1.51	1.41
Sep	0.44	0.82	0.53	1.63	2.12	0.53	1.18	0.66
Oct	0.37	0.77	0.84	1.30	1.93	0.52	1.07	0.81
Nov	0.41	0.74	0.67	0.74	1.86	0.56	0.66	0.71
Dec	0.52	0.96	0.76	1.06	1.83	0.84	0.57	0.82
Annual	5.84	9.22	7.59	13.76	22.91	7.01	9.20	10.00

Inches of Average Monthly Rainfall for Arizona Cities and Towns
(Precipitation Normal for Period 1971–2000, National Weather Service)

	Marana	Mesa	Nogales	Page	Parker	Payson	Phoenix	Pinetop
Jan	1.09	1.01	1.31	0.61	0.87	2.33	0.83	2.00
Feb	1.25	0.99	1.09	0.48	0.70	2.34	0.77	1.90
Mar	0.79	1.19	1.00	0.66	0.65	2.68	1.07	1.63
Apr	0.46	0.33	0.49	0.50	0.17	1.15	0.25	0.88
May	0.17	0.17	0.32	0.40	0.09	0.66	0.16	0.83
June	0.14	0.06	0.54	0.14	0.02	0.37	0.09	0.72
July	1.38	0.89	4.27	0.58	0.27	2.42	0.99	2.82
Aug	2.17	1.14	4.24	0.69	0.61	2.97	0.94	3.72
Sep	0.55	0.89	1.68	0.66	0.57	1.81	0.75	2.59
Oct	0.73	0.81	1.84	0.99	0.32	1.89	0.79	1.84
Nov	0.44	0.77	0.78	0.56	0.33	1.70	0.73	1.74
Dec	1.15	0.98	1.47	0.48	0.57	1.75	0.92	1.93
Annual	10.31	9.23	19.03	6.75	5.17	22.07	8.29	22.6

Inches of Average Monthly Rainfall for Arizona Cities and Towns (Precipitation Normal for Period 1971–2000, National Weather Service)

	Prescott	Safford	Scottsdale	Sierra Vista	Springerville	Tempe	Tuba City	Tucson
Jan	1.58	0.74	1.01	1.19	0.50	1.01	0.55	0.99
Feb	1.87	0.78	1.06	0.65	0.50	1.04	0.52	0.88
Mar	1.91	0.61	0.96	0.44	0.49	1.15	0.59	0.81
Apr	0.76	0.22	0.35	0.36	0.27	0.25	0.27	0.28
May	0.64	0.27	0.17	0.26	0.45	0.21	0.32	0.24
June	0.40	0.31	0.11	0.38	0.53	0.07	0.17	0.24
July	2.87	1.45	0.99	3.01	2.52	0.89	0.66	2.07
Aug	3.28	1.72	1.05	3.85	3.11	1.20	0.69	2.30
Sep	2.07	1.12	0.87	1.29	1.49	0.86	0.98	1.45
Oct	1.28	1.10	0.97	1.16	1.08	0.85	0.85	1.21
Nov	1.25	0.56	0.88	0.45	0.57	0.80	0.43	0.67
Dec	1.28	0.91	0.99	0.98	0.48	1.03	0.32	1.03
Annual	19.19	9.79	9.41	14.02	11.99	9.36	6.35	12.17

Inches of Average Monthly Rainfall for Arizona Cities and Towns (Precipitation Normal for Period 1971–2000, National Weather Service)

	Willcox	Williams	Yuma
Jan	1.11	2.08	0.38
Feb	0.95	2.37	0.28
Mar	0.68	2.32	0.27
Apr	0.25	1.00	0.09
May	0.35	0.80	0.05
June	0.40	0.48	0.02
July	2.36	2.54	0.23
Aug	2.59	3.01	0.61
Sep	1.27	1.73	0.26
Oct	1.36	1.77	0.26
Nov	0.73	1.75	0.14
Dec	1.30	1.52	0.42
Annual	13.35	21.37	3.01

Inches of Average Monthly Evapotranspiration for Arizona Cities and Towns
(Etos (Standardized Ref. Evapotranspiration); Yuma, Bullhead, Tucson, Phoenix computed by AZMET; Nogales, Prescott, Kingman, Williams, Payson estimated using Yitayew*; Flagstaff computed from local weather data.)

	Bullhead City	Casa Grande	Chandler	Douglas	Flagstaff	Gila Bend	Holbrook	Kingman
Jan	2.92	2.31	2.38	3.16	1.61	2.66	1.48	2.82
Feb	3.48	3.16	2.87	3.58	1.74	3.26	2.15	3.37
Mar	5.68	5.17	4.66	5.07	2.85	4.75	3.27	4.40
Apr	7.56	7.24	6.38	6.68	4.24	6.99	4.83	6.03
May	9.78	9.55	8.71	8.67	5.79	9.24	6.87	7.87
June	9.97	10.28	9.39	9.72	7.09	10.18	8.09	9.40
July	9.24	10.00	9.02	8.10	6.46	9.78	8.10	9.56
Aug	8.35	8.75	8.28	7.31	5.63	8.76	7.20	8.44
Sep	6.63	7.00	6.60	6.58	4.64	6.95	5.81	6.89
Oct	5.33	5.18	4.59	5.41	3.21	5.40	4.06	4.96
Nov	3.67	3.00	2.75	3.64	2.13	3.36	2.34	3.53
Dec	3.30	2.14	2.24	2.82	1.74	2.48	1.48	2.48
Annual	75.91	73.78	67.87	70.74	47.13	73.81	55.69	69.74

Inches of Average Monthly Evapotranspiration for Arizona Cities and Towns
(Etos (Standardized Ref. Evapotranspiration); Yuma, Bullhead, Tucson, Phoenix computed by AZMET; Nogales, Prescott, Kingman, Williams, Payson estimated using Yitayew*; Flagstaff computed from local weather data.)

	Marana	Mesa	Nogales	Page	Parker	Payson	Phoenix	Pinetop
Jan	3.16	2.38	3.16	1.58	2.83	2.04	2.38	1.58
Feb	3.72	2.87	3.68	2.25	3.51	2.35	2.87	1.95
Mar	5.70	4.66	4.62	3.73	5.69	3.16	4.66	2.82
Apr	7.44	6.38	6.25	5.81	8.07	4.73	6.38	4.19
May	9.72	8.71	8.10	8.10	10.34	6.64	8.71	5.63
June	10.59	9.39	9.07	9.72	11.12	8.21	9.39	6.47
July	9.53	9.02	7.98	9.45	10.85	7.87	9.02	6.08
Aug	8.26	8.28	7.31	8.44	9.59	6.53	8.28	5.07
Sep	7.28	6.60	6.47	6.58	7.70	5.70	6.60	4.40
Oct	5.94	4.59	5.30	4.51	5.81	3.95	4.59	3.61
Nov	3.97	2.75	3.53	2.45	3.64	2.66	2.75	2.34
Dec	2.79	2.24	2.71	1.48	2.26	1.92	2.24	1.47
Annual	78.10	67.87	68.19	64.10	81.41	55.77	67.87	45.59

Inches of Average Monthly Evapotranspiration for Arizona Cities and Towns
(Etos (Standardized Ref. Evapotranspiration); Yuma, Bullhead, Tucson, Phoenix computed by AZMET; Nogales, Prescott, Kingman, Williams, Payson estimated using Yitayew*; Flagstaff computed from local weather data.)

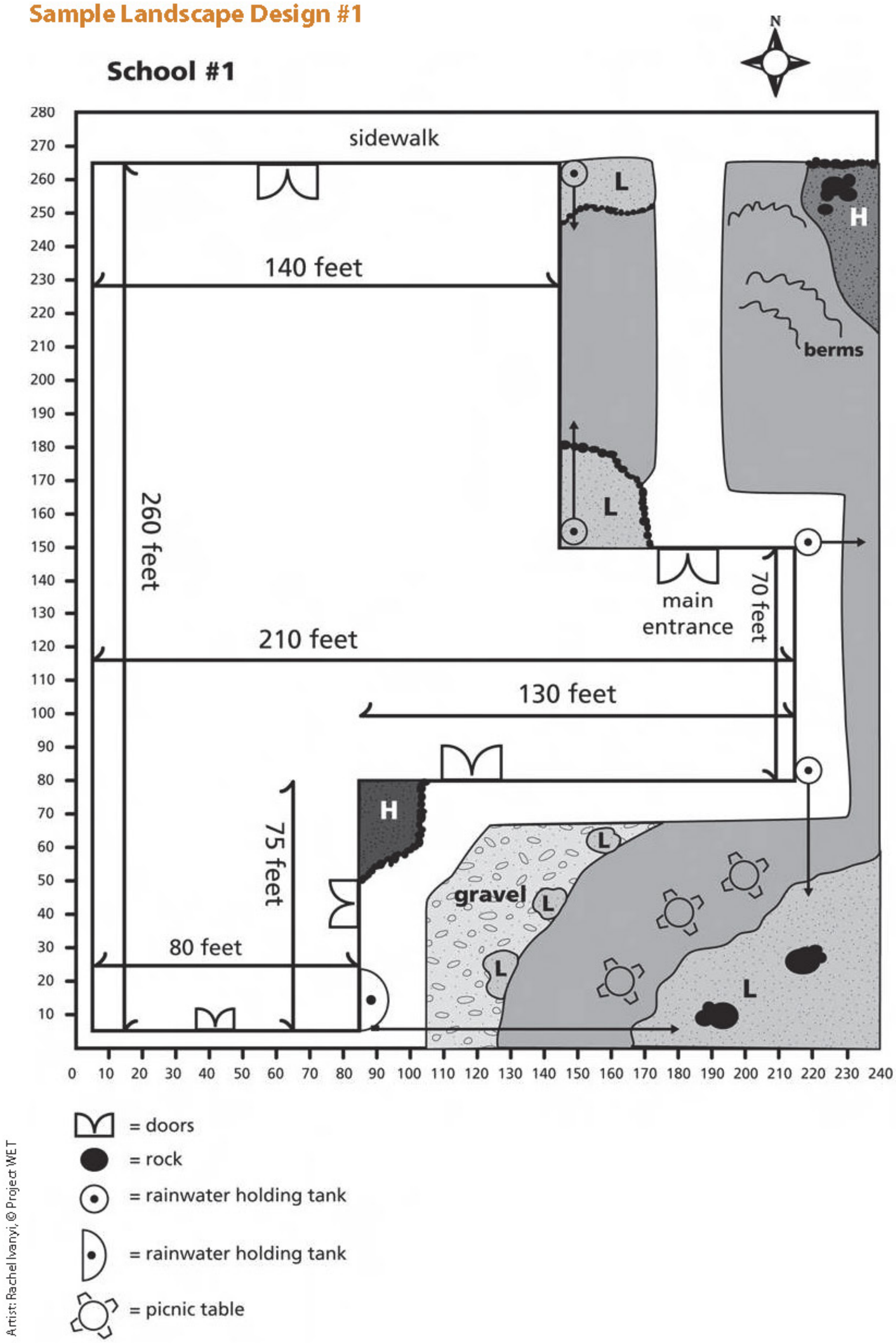
	Prescott	Safford	Scottsdale	Sierra Vista	Springerville	Tempe	Tuba City	Tucson
Jan	1.89	2.69	2.38	2.80	1.48	2.38	1.36	2.52
Feb	2.86	3.41	2.87	3.21	1.95	2.87	1.95	3.19
Mar	3.73	5.48	4.66	4.60	2.82	4.66	3.27	5.07
Apr	5.38	7.52	6.38	6.21	4.07	6.38	4.62	6.82
May	6.08	9.63	8.71	7.97	5.29	8.71	6.98	8.61
June	9.07	10.31	9.39	9.04	6.46	9.39	8.42	9.59
July	8.67	9.18	9.02	7.74	6.08	9.02	8.10	8.95
Aug	6.98	7.42	8.28	7.07	5.52	8.28	7.31	7.75
Sep	6.68	6.35	6.60	6.21	4.40	6.60	6.03	6.68
Oct	4.51	6.08	4.59	4.37	3.61	4.59	4.06	4.96
Nov	2.99	3.24	2.75	3.17	2.01	2.75	2.23	3.02
Dec	2.15	2.38	2.24	2.58	1.36	2.24	1.25	2.16
Annual	60.99	73.69	67.87	64.97	45.07	67.87	55.58	69.32

Inches of Average Monthly Evapotranspiration for Arizona Cities and Towns
(Etos (Standardized Ref. Evapotranspiration); Yuma, Bullhead, Tucson, Phoenix computed by AZMET; Nogales, Prescott, Kingman, Williams, Payson estimated using Yitayew*; Flagstaff computed from local weather data.)

	Willcox	Williams	Yuma
Jan	2.45	1.36	3.27
Feb	3.04	1.65	3.79
Mar	4.96	2.82	5.67
Apr	6.66	4.07	7.24
May	8.26	5.3	9.16
June	9.23	7.12	10.21
July	8.35	6.75	10.50
Aug	6.94	5.63	9.67
Sep	5.99	4.94	7.92
Oct	4.77	3.61	5.87
Nov	3.09	2.00	3.80
Dec	2.19	1.70	3.10
Annual	65.93	46.96	80.20

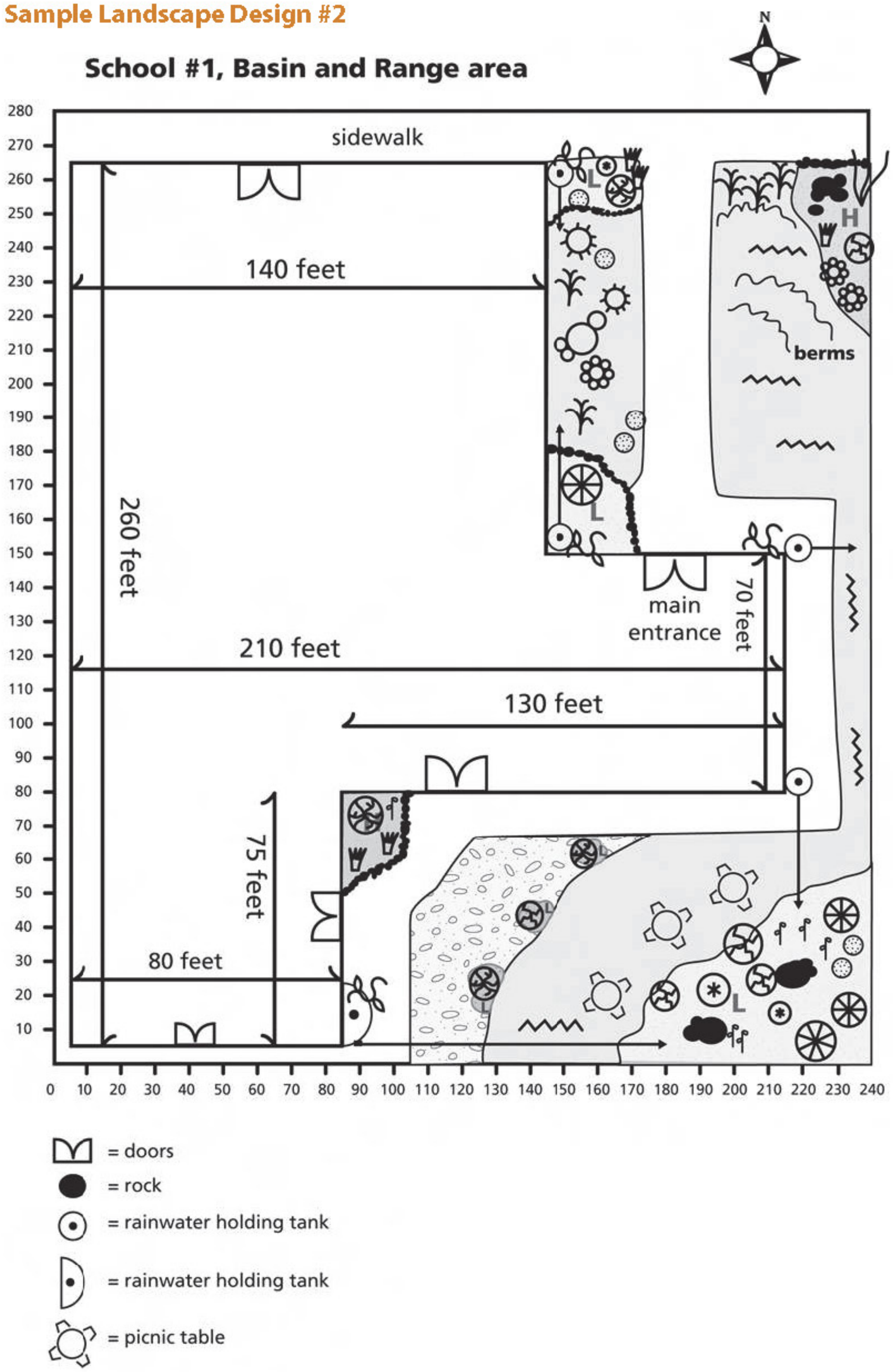
Yitayew, M. 1990. Reference Evapotranspiration Estimates for Arizona. Tech. l Bull. 266. Agr.Exp.Stn.Col. of Agr. Univ. of Arizona.

Sample Landscape Design #1



This sketch includes the sidewalks, gravel areas, rainwater harvesting system, high and low areas, berms, picnic tables, rocks, and everything else in the landscape besides plants (see Sample #2 for plants).

Sample Landscape Design #2



This sketch includes the sidewalks, gravel areas, rainwater harvesting system, high and low areas, berms, picnic tables, rocks, and ***plants****.*

Artist: Rachel Ivanyi, © Project WET

Steps for Designing Your Water-Efficient Landscape

I. Your Rainwater Harvesting System

Envision an area of land on one side of your school building. Where are the high points and where are the low points? What areas are level? Follow the directions on this page to design your rainwater harvesting system for the school of your choice (make all drawings on pages 136, 137, or 138).

1. Keep all drawing within the box that represents the edge of the school grounds.
2. Indicate high points with a plus sign. Use a red pencil.
3. Indicate low points with a minus sign. Use a blue pencil.
4. Indicate level areas by lightly shading them. Use a yellow pencil.
5. Draw the street that the school is located on, sidewalks and walkways, and other non-vegetated areas (playing courts, sand or gravel areas, etc.). Draw rocks and boulders in landscaped areas. Use a black pen.
6. Design your rainwater capturing system. Think about:
   - Where does the water drain off the roof?
   - Do you want to direct the water into holding tanks or into natural holding areas?
   - If the water runs directly off of the roof, how will you capture it and direct it onto plants?
   - Are there places where you want to construct berms to slow the flow of runoff?
   - If you are using a holding tank with a hose attached, how will you design your watering system to get water to plants?
7. Draw roof drains, rainwater holding tanks, watering systems, berms, and other features of your rainwater system (using symbols and a key to them) onto the layout of your choice. Use a black pen.

Steps for Designing Your Water-Efficient Landscape, continued

II. Choosing Native Plants for Your Landscaping

1. Start with a new copy of the school outline. This time you will design your landscaped areas and add plants to make the grounds attractive and shaded.
2. Choose from the list of native plants on pages 141–143. These plants have evolved in the arid Southwest and are good choices for landscaping that uses minimal water. *The only plant on the list that is not native is Bermuda grass, which is a turf grass.* Think carefully about how much turf you need since it uses the most water (73 gal. per square foot on average, compared with 17 gal. per square foot on average for native desert landscaping).
3. Color-code each type of plant from the chart (for example, use green for all trees, purple for shrubs, brown for cacti, and so on).
4. Use the icons shown beside the plants' names to represent them on your design layout.
5. Think about the low and high areas. Locate plants that need water regularly in low areas.
6. As you design your landscaping, plan for natural cooling of the building.
7. You can use the same plant species more than once in your design. Think about what will look beautiful, considering the colors the flowers will be when blooming, what heights the plants will be, what places in your school yard have the most shade and sun, etc.

III. Make a key for your landscaping design to tell which colors and symbols are used for which types of plants, etc. Write a paragraph or more describing your landscape design.