Water Strand Pre-Post 2012-2013 – Annotated Assessment

Student Water assessment with detailed written explanations after every question

Written by: Kristin Gunkel (University of Arizona), Beth Covitt (University of Montana), and water strand group

Culturally relevant ecology, learning progressions and environmental literacy

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Water Strand Pre-Post 2012-2013 – Annotated

Please put your initials (not your full name) in the boxes.

First	Middle	Last

Date ________________

LTER Site ____________________

This assessment is designed to identify student level of achievement on the Water Systems Learning Progression. This learning progression describes the range of student accounts (i.e. explanations and predictions) of water and substances in water moving through connected environmental systems (i.e., natural and human-engineered components) across a broad span of grades from upper elementary through high school. The following annotations explain some of the characteristics of student accounts at each level of achievement on the learning progression. Actual student accounts are provided in italics as examples. Example accounts are categorized into levels based on students' ideas. Problematic spelling and grammar may be found in accounts at different levels and are not indicators of performance.

Although this assessment can measure changes in students' accounts from less to more sophisticated on the learning progression, it is not intended to be the basis for evaluation of student performance for a grade. We recommend that classroom teachers use our formative assessment probes and accompanying teacher materials to inform adjustments to instruction according to student performance on the learning progression http://www.pathwaysproject.kbs.msu.edu/?page_id=36

Table 1 on the following page summarizes the Water Systems Learning Progression by levels of achievement and elements of accounts. Summaries for each cluster and items in each cluster are then provided.

Table 1: Water Systems Learning Progression
Characteristics of accounts at each level of achievement

	Elements of Accounts				
Level of Achievement	Structures & systems	Scale	Scientific principles	Representations	Dependency & human agency
Level 4 Qualitative model-based accounts	Provide multiple, detailed, accurate pathways through environmental systems Account for chemical nature of substances during mixing and moving	Atomic-molecular through large landscape	Include driving forces (e.g., gravity, pressure) Include constraining factors (e.g., permeability, topography)	Interpret constraining factors inferred from representations	Identify limitations to human agency or dependence on environmental systems
Level 3 Incomplete school science accounts	Provide multiple pathways through hidden and invisible connections, including human-engineered systems in moderate detail Identify different types of substances in water	Microscopic to landscape scale May refer to smaller particles such as atoms or molecules	Put events in order No driving forces or constraining factors included	Connect representations to three-dimensional physical world Do not infer driving forces or constraining variables	Include human systems as part of environmental systems Do not recognize limitations of either human agency or environmental systems
Level 2 Force-dynamic accounts with mechanisms	Identify familiar and visible connections, including general connections to human systems Water quality is referred to as a function of "good" and "bad" stuff	Broader macroscopic to large-scale focus across familiar and visible dimensions	Identify mechanism Rely on actors or agents Fit particular circumstances	Include limited (e.g., 2 dimensional) connections from representations to the physical world	Portray human systems as operating separately from natural systems but human systems can be impacted by natural systems
Level 1 Force-dynamic accounts	Water is represented only in isolated, visible locations Water quality is referred to as a function of types of water	Limited to macroscopic and immediately visible structures or phenomena	Focus on human structures, actions or needs No mechanisms for phenomena included	No connections from representations to the physical world	Portray humans as sources and movers of water Portray water as serving human needs

Soccer Game Questions

The three items in this cluster are designed to elicit student accounts of water moving through multiple systems, primarily including the soil/groundwater system and the atmospheric system, but also considering possible surface system and biotic system pathways.

Elements of accounts for each level of achievement that are relevant to the items in this cluster are shown in Table 2.

Table 2: Elements of Soccer Game Cluster Items

	Structure & Systems	**Scientific Principles**	**Scale**
Level 4: Model-based accounts	Describe multiple pathways in detail, including hidden and invisible pathways.	Explain how/why the water moves by identifying driving forces and constraining factors.	Describe spaces in which underground soil or groundwater exists at microscopic scale (e.g., pore spaces or cracks)
Level 3: School Science Stories	Describe one and possibly more pathways, including hidden and invisible pathways.	Do not identify drivers or constraints. Generally do not use force-dynamic language.	Scale of description of soil/groundwater in smaller spaces than level 2, although may not have complete description of underground structures
Level 2: Force Dynamic Accounts	Describe visible and familiar structures of systems, but do not yet accurately describe or recognize the structure of hidden or invisible components	Use force-dynamics to explain how or why water moves from one location to another.	Scale of description of soil/groundwater spaces is too large (e.g., underground lakes or layers filled with water only)
Level 1: Human-centered Force Dynamic Accounts	Water is represented only in isolated, visible locations. Only visible structures are described. Water is not traced to invisible or hidden locations. There is a focus on human-made aspects of systems as well.	Invoke people to move or change water. Otherwise, no mechanisms are provided.	Students talk about visible and familiar structures only at a macroscopic scale.

Your soccer game gets canceled at half time due to a massive down pouring of rain. As you run for cover, you notice that there are large puddles forming on the grass-covered playing field, but no puddles forming in the sand covered playground just a few steps away.

1. Why are there puddles on the grass and not on the sand?

Level 4 accounts explain that gravity (driver) pulls the water down into the pore spaces between the grains of sand and soil (process of infiltration), but that the sand is more permeable than the grass (constraint). These accounts may include reference to saturation of the grass, absorption of water onto clay particles, or capillary action in soils.

Infiltration of the water happens more quickly in the sand than the grass due to the sand being more pores. The water move into the space between the sand with the help of gravity, on the playing field water in not able to move as quickly because the space are smaller due to a difference in soil and the organic matter

Level 3 accounts tell a story about what happens (e.g., infiltrates, seeps, percolates) to the water, but is vague about how or why. There may be errors in the details of the story. For example, accounts may state that there is more room for the water in the sand (porosity, not permeability).

There are no puddles in the sandy playground because the sand is loose and the water seeps into the ground.

Level 2 accounts identify actors (e.g. the sand) acting on the water to make the water move. For example, accounts may state that the water is absorbed by the sand, that the sand soaks up the water, or that the ground sucked the water in. There may be impossible or unlikely pathways. Also, accounts sometimes say that the sand is deeper, thicker, or lighter than the grass.

Because the sandy ground suck of all the water.

Level 1 accounts may restate the conditions of the problem. For example, accounts may state that there are no puddles on the playground because it is made of sand. Level 1 accounts may also reference human actions, such as people stepping in puddles.

Because it's sand.

2. Explain what happens to the water that lands on the sandy playground? Be sure to explain how and why.

Level 4 traces water into the sand, groundwater, aquifer, or water table, recognizes gravity as a driving force and permeability as a constraining factor, and describes the size and connectedness of the spaces between particles or the rate at which water moves through these spaces.

The water infiltrates the sandy playground by seeping into the spaces between sand particles. The closer these particles are, the slower water can be absorbed into the ground. If the particles are extremely close (asphault), then it is considered impermeable.

Level 3 tells a school science story about water infiltrating or seeping into the sand, ground, groundwater, aquifer, or water table and names the process that moves water (e.g. infiltration, seeping, percolation), but does not include drivers (gravity) or constraints (permeability).

The rainwater goes underground and becomes groundwater. It gets there by seeping into the ground.

Level 2 accounts use force dynamic language to describe an actor or agent acting on the water to make it move. These accounts may trace the water into the ground, sand, or underground. They sometimes talk about water going under the sand or to the bottom of the sand. They may also reference the water cycle as a mechanism for moving water, refer to groundwater in large, open, underground spaces or layers, explain that the water turns the sand or dirt into mud, or state that the water sinks into the sand.

it gets there well the water has a cycle and the rain water gose down in the ground.

Level 1accounts may state that the water goes into the sand without providing a mechanism (e.g., it went into the ground), that the water disappeared (e.g., the water dried up), or traces the water directly into human structures (e.g., it went into the pipes). Level 1 accounts may also respond to the prompt but not answer the question.

By the pipes.

3. The next week you come back to the soccer field and you notice there is no water on the grassy field. Explain what happened to that water? Be sure to explain how and why.

Level 4 accounts trace water by more than one pathway. For example, these accounts may trace water into the atmosphere via evaporation or into the soil, groundwater, aquifer, or water table via infiltration. These accounts must acknowledge drivers and constraints for at least one of these pathways.
the water either evaporated or infiltrated the soil and is now underground or in vegetation. this is because soil is NOT impermeable and so water can penetrate the surface eventually.
Level 3 accounts tell a school science story about one or more pathways. These stories can give detailed descriptions of ordered sequences of events as water moves along pathways (e.g., evaporates into the air, condenses into clouds, etc.). These stories recognize water in invisible forms or hidden locations. However, these accounts do not acknowledge drivers or constraints along these potential pathways. Thus, unlikely pathways may be included (e.g., runoff is unlikely if the water on the soccer field initially formed puddles) or all pathways may be described as equally possible.

The water on the grassy field infilitrated into the ground and all of the puddles evaporated into the air.

Level 2 accounts use force-dynamic language to describe where water goes. For example, accounts may reference the grass using or sucking up the water, the ground sucking up the water, or the water sinking into the ground. Accounts may trace water into the sky or clouds, but do not recognize water in invisible forms (e.g., water vapor). These accounts may also reference the water cycle as a mechanism (e.g., the water went into the ground because of the water cycle.).

the water maybe dried because the sun hit it which made it dry up and it went into the grass.

Level 1 accounts may state that the water disappeared (e.g., it left, it dried up). Accounts may use the term "evaporate" to mean that the water disappeared, however other contextual clues from other responses may help distinguish if the account reflects more sophisticated use of this term.

It left.

River Map Questions

Items in this cluster assess how students use representations to account for water and substances moving through watersheds. The items primarily focus on surface water systems, although understanding of the constraints of groundwater, atmospheric, and biotic systems is necessary for a complete, scientific account.

The map provided does not include topographic lines or other direct elevation information. However, elevation and topography can be inferred from the shape of the stream network.

Elements of accounts for each level of achievement that are relevant to the items in this cluster are shown in Table 3.

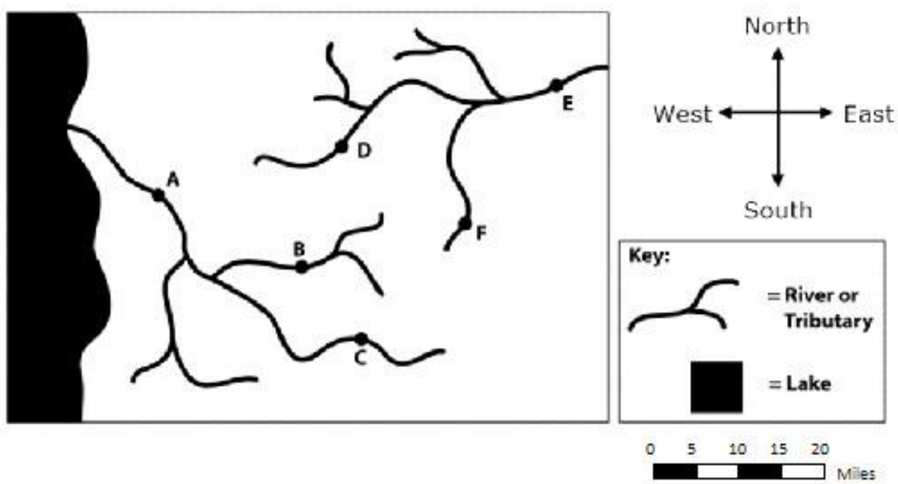


Table 3: Elements Accounts for River Maps Cluster Items

	Structure & Systems	**Scientific Principles**	**Representations**	**Scale**
Level 4: Model-based accounts	Describe structure of watershed systems in detail.	Identify gravity as a driving force and topography as a constraint on direction of water flow.	Interpret constraints from map representations.	Apply scientific principles to the landscape scale.
Level 3: School Science Stories	Describe structure of watershed systems.	Use school rules to determine flow direction without recognizing drivers or constraints or do so with errors. Generally do not use force-dynamic language.	Interpret and describe the direction of water flow based on features of the map.	Recognize and use landscape scale.
Level 2: Force Dynamic Accounts	Identify familiar features of river systems, such as lakes and rivers.	Identify that water has natural tendencies to flow or move. May also identify actors or agents that do things to move water and/or pollution.	Generally read maps as 2D representations of a flat surface (horizontal and not vertical)	Focus on familiar (macroscopic) distances and sizes
Level 1: Human-centered Force Dynamic Accounts	View all water in connected rivers as the same (e.g., polluted).	No mechanisms needed.	Describe lines on the map. Do not connect map to physical landscapes.	Map scale and real world scale may be conflated.

Use the map below to answer questions 4 and 5.

4. Can pollution in the river water at Town B get to Town C?
   (circle one) Yes No

   Explain why or why not.

Level 4 accounts trace water from Town B downhill (due to gravity) to the lake. These accounts explain that water at Town B will not get to Town C because Town C is located upstream from where the tributary from Town B enters the river.

No. Creek B is a tributary to River A. C also is a tributary to A, thus water would have to flow uphill against gravity to move from B to C without some unnatural disturbance.

Level 3 accounts can either trace water into the lake or to Town C. The reasoning given relies on school rules without attention to underlying principles. These rules can result in tracing water in an incorrect direction. Examples of school science rules include
- rivers flow from smaller to bigger bodies of water
- all rivers flow into lakes or oceans

Level 3 accounts may trace water along unlikely pathways because they do not consider constraints. Thus, these accounts may inappropriately trace a pollutant as moving with water through the groundwater or the atmosphere.

No. Because water travels towards an ocean or other large body of water.

Yes. The pollution can travel from point B to point C. It could travel through acid rain or through some groundwater that may lead from point B to point C.

Level 2 accounts may answer yes or no to the first question. They describe water as having natural tendencies to flow, travel, spread, or drift. These accounts use force dynamic language about rivers "needing" to go somewhere or invoke agents such as a current that "make" the water flow in a particular direction. Many level 2 accounts trace water in an eastward direction from bigger to smaller bodies of water or state that the lake pushes the water downstream. Level 2 accounts may invoke wind as pushing the water or refer to the water cycle as a mechanism or agent.

Yes. It can because the water from river b can travel down stream and get into the current and travel down to river c.

Yes. Water goes through the water cycle so water can end up anywhere on the planet no matter where it is.

No because its a different water flow

Level 1 accounts describe the rivers as connected, but do not refer to the water as flowing or moving.

Yes. It could because the river of the points connect.

No. The rivers are seperate from each other.

6. Draw an arrow showing the direction water is flowing away from Town **F**. How do you know the water is flowing this direction?

Level 4 accounts trace water from Town F to Town E, explaining that gravity pulls water downhill and/or describing the topography of the watershed.

Point F is a beginning stream at the top of a hill flowing to another drainage area with other tributaries including D. These both flow downhill toward point E on the other side of the hill from tributaries A,B, and C and the lake.
Tributaries feed into rivers that feed into lakes. All of these flow downhill. If a stream starts, it is usually at the top of a drainage area/ hill/ mountain.

Level 3 accounts describe the direction of the flow of water and use school rules without considering underlying principles to reason about the flow of the water. This may result in errors in direction of water flow. Examples of school rules include
- rivers flow from smaller to bigger bodies of water
- all rivers flow into lakes or oceans

The water in point F is flowing to the right, towards point E because point E is connected to a larger body of water. Smaller bodies of water always flow in to larger bodies of water.
Tributaries always flow in to rivers or larger bodies of water. The water at point F will flow in to the larger body of water, which in this case is the river, or point E.

Level 2 accounts trace water to various locations on the map. They describe water as having natural tendencies to flow, travel, spread, or drift. They may use erroneous reasons/rule such as water flows from bigger bodies to smaller bodies of water. These accounts use force dynamic language about rivers "needing" to go somewhere or invoke agents that "make" the water flow in a particular direction.

The water would be going South because it cant go the other way, the Lake is to strong to let it change.
I know the water is flowing South because the water cant go the oppostie way it just came from. The lake is too strong to let it go another direction.

River f goes up to collid with river e.

The river is going up.

Level 1 accounts describe the rivers as connected. They may trace the water south or state that the water will stop according to characteristics of the drawing rather than the watersheds the drawing represents, such as tracing water down the page or stating that rivers always flow south.

all water is connected
all water is connected

it is flowing into a dead end.
because the map no longer shows the river flowing further.

Substances Questions

The picture below shows part of a school campus with several grassy playing fields near a river. Use the picture to answer questions 6, 7, and 8.

The items in this cluster are designed to elicit student accounts of a) how a substance (in this case fertilizer) can move through surface and groundwater systems with water, b) the nature of matter and substances (in this case, what fertilizer is composed of), and c) how substances in water can impact living systems.

Elements of accounts for each level of achievement that are relevant to the items in this cluster are shown in Table 4. Note that the third item relating to impacts on living systems is, to some extent, beyond the scope of the core water systems learning progression elements that have been developed thus far.

Substances Cluster

Table 4: Elements of Fertilizer Cluster Items

	Structure & Systems	**Scientific Principles**	**Scale**	**Human Dependency & Agency**
Level 4: Model-based accounts	Describe multiple pathways of substances moving with water in detail, including hidden and invisible pathways. Account for chemical nature of substances during mixing and moving.	Explain how and why substances move in water.	Describe substances at atomic-molecular scale. Describe movements of substances at landscape scale.	Identify limitations of human agency or dependence on environmental systems.
Level 3: School Science Stories	Describe one and possibly more pathways of substances moving with water, including hidden and invisible pathways. Identify different types of substances in water.	Tell story of ordered events in which substances move with water. Story does not reference drivers and constraints. May use technical vocabulary in vague ways.	Describe substances at macroscopic scale rather than atomic scale (i.e., do not use chemical substance identifiers).	Include human systems as part of environmental systems.
Level 2: Force Dynamic Accounts	Describe visible and familiar structures of systems. Nature of substances described in terms of familiar objects or evaluative qualities.	Identify force dynamic mechanisms or proximity to explain movement of substances.	Broad macroscopic focus on familiar and visible entities and substances.	Portray human systems as operating separately from natural systems; but human systems can be impacted by natural systems.
Level 1: Human-centered Force Dynamic Accounts	Familiar systems are recognized as separate, unconnected entities. Nature of substances is referred to in terms of types of water.	Invoke people to move substances or change water. Otherwise, no mechanisms are provided.	Mention visible and familiar structures only at a macroscopic scale.	Portray water as serving human needs.

7. A. If the playing fields were treated with fertilizer, do you think that some of the fertilizer could get into the river? (Circle one) YES NO

If you think yes, explain how and why the fertilizer could get into the river. If you think no, explain why fertilizer would not get into the river.

Level 4 accounts trace fertilizer with water along several routes, including surface water and groundwater pathways. These accounts may also identify fertilizer as a soluble substance that is subject to the same drivers and constraints as liquid water for moving through surface and groundwater systems.

if it were to rain the runoff and some infiltrated water will end up in the river and the fertilizer would be carried with it.

Level 3 accounts generally recognize overland (i.e., runoff) transport of fertilizer with water into the river. These accounts may mention rain as a cause for fertilizer moving. Also, level 3 accounts may send fertilizer through the ground, but without mentioning water as a transport mechanism.

Yes. When it starts to rain, the runoff from the water will get into the river.

Yes. It could get into the river by going into the ground by just moving a little downward or forward.

Level 2 accounts describe a force dynamic mechanism to trace fertilizer (e.g., fertilizer can get into the river if it is blown there by wind). Alternatively, level 2 accounts may use proximity reasoning, either indicating that fertilizer will not get into the river because river is too far from field, or that it will get into the river because the field is close by.

Yes because since the soil and river are so close, some of the fertilizer may fall in.

No. I don't think that fertilizer could get into the river because water from rain would already absorb into the soil and fertilizer, which could not travel into rivers.

Yes, because the water will evaporate into the ground and the water cycle will have it in one point go into the lake which the fertilizer will go along.

Level 1 accounts may indicate that the fertilizer won't get into the river because the field and river aren't connected, or might just say that fertilizer can't get into river without an explanation. These accounts may also utilize a human mechanism (e.g., people kick fertilizer into river).

No. The grass is not touching the water.

Yes. because they can accidently through some into the river on accident.

Yes. The fertilizer could spread.

What is in the fertilizer that could get in the river? (In other words, what is fertilizer made of?)

Level 4 accounts identify the chemical make up of what is likely to be a commercially produced fertilizer used by a school (e.g., nitrogen, phosphorus, potassium, possibly calcium and magnesium). Similarly, compounds such as nitrates and phosphates may be mentioned.

Components of the fertilizer that could get into the river include nitrates, nitrites, phosphates and other nitrogen componds that help plants to grow. Some fertilizers also have weed killer components that will kill the 'weeds' (which could be native plant species) but not the grasses they are growing on the field.

Level 3 accounts describe general categories of substances (e.g., chemicals) but also indicate that these substances are nutrients that support plant growth. Alternatively, level 3 accounts may provide a list mixing general substances (e.g., chemicals) with specific substances (e.g., nitrates).

Extra nutrients that make the plants grow faster or in better quality.

Nitrogen, phosphorous, and chemicals. .

Level 2 accounts suggest fertilizer is made of visible objects (e.g., cow poop, manure, compost) or unspecified materials (e.g., chemicals, toxins, pesticides, nutrients). Accounts may use adjectives to describe what's in fertilizer (e.g., dangerous or harmful chemicals).

Chemicals and cow manuer.

Dangerous particles.

Level 1 accounts may conceive of fertilizer as being made of fertilizing stuff (i.e., does not think about distinct materials) or perceptual things (e.g., bad stuff, dirty stuff). Also, these accounts may suggest fertilizer is made of things that fertilizer generally isn't made of (e.g., water, mud, dirt, or grass).

The fertilizer is for the grass.

Bad water.

8. If some of the fertilizer got into the river, how would the fertilizer affect the river water and living things in the river?

Level 4 accounts describe how fertilizer in the river could lead to rapid growth of plants and subsequent disruption of a river ecosystem. Response is generally provided as an accurate account of eutrophication (E.g., algal blooms block sunlight. When they die decomposition by bacteria follows, leading to decline in dissolved oxygen). Accounts may also recognize that amount of fertilizer in river will determine extent of impact.

The aquatic plants are likely to grow more and this can choke waterways physically. This also can result in die off of the plants which would then decompose and the bacteria which are doing the decomposition would use significant amounts of dissolved oxygen from the water. This could have a detrimental effect on aquatic consumers.

Level 3 accounts provide a school science story about what happens to water quality and/or living things. These stories go beyond saying that plants and animals die. Examples include incomplete or problematic descriptions of eutrophication; suggestions that fertilizer in the river could change the pH of water, harming living organisms; or stories identifying marginally related concepts such as biomagnification.

There will be an alge boom.

The fertilizer can affect the bug first and the bug can fall in the water and fish eat bug which affect the fish and fish get eaten by big fish or bird so it can affect more then river animals.

Level 2 accounts provide a force dynamic mechanism for the effect on water quality or living things. For example, fertilizer will…
-kill living plants or animals
-feed the fish
-make the water dirtier
-pollute the water.
These accounts do acknowledge that fertilize mixes with water, rather than making a different kind of water.

It could poison the water and end up killing plants that the fish eat.

it could posibly make the live grow (plant life)

Level 1 accounts may focus on a human-centered story (e.g., fertilizer makes people sick). Alternatively, level 1 accounts may suggest fertilizer does something to water or the river without describing any specific effect on water quality or living things (e.g., destroys the river, ruins the water, makes water into a different type of water like dirty water). Finally, level 1 accounts may suggest fertilizer would not affect the river with no reason or mechanism provided as explanation.

It could get into peoples drinking water and such.

It will mabey make it nastey.

Tree Questions

Like many rivers, the Sturgeon River in northern Michigan has lots of large trees growing along its banks.

The first question in this cluster is designed to elicit students' ideas about what happens to the water that is absorbed by a tree. The question has a specific focus on examining the extent to which students are aware of the process of transpiration. Students often think of trees absorbing, using and/or storing water. In their responses, students often provide places in the tree where water is sent (e.g., leaves, branches, trunk, roots). In addition, some students are aware that trees use water in photosynthesis. However, in reality, more than 90% of water that enters through a tree's roots is transpired back into the atmosphere. Only a very small percentage of water in the tree is used for photosynthesis.

The second question in this cluster is intended to elicit students' ideas about the relationship between trees and water in a nearby river. The question asks students to identify a directional quantitative relationship (i.e., if number of trees goes down, what happens to the amount of water in the river?).

Elements of accounts for each level of achievement that are relevant to the items in this cluster are shown in Table 5.

Table 5: Elements of Tree Cluster Items

	Structure & Systems	**Scientific Principles**	**Scale**
Level 4: Model-based accounts	Describe structure of surface-groundwater-biotic system connections.	Recognize factors that constrain the volume of water in the river and factors that drive and constrain movement of water through trees via transpiration.	Apply scientific principles to the landscape scale and atomic-molecular scale.
Level 3: School Science Stories	Recognize connections among surface, groundwater, and biotic systems.	Tell school science stories about where water goes without reference to drivers or constraints. Generally do not use force-dynamic language.	Recognize and use landscape scale, may also describe microscopic structures.
Level 2: Force Dynamic Accounts	Recognize connections among visible features of rivers and trees.	Mechanisms are force-dynamic, usually with trees as agents that control water pathways.	Focus on familiar distances and sizes.
Level 1: Human-centered Force Dynamic Accounts	No connections recognized among surface, groundwater and biotic systems.	No mechanisms needed.	Focus on human scale.

10. A large tree can pull in 200 gallons of water a day. What happens to the 200 gallons of water that the tree pulls in? Please fill in the table below.

List one place that the water the tree pulls in could go. Explain how it gets there and why it goes there.	How much of the water that the tree uses would go there?
Level 4 accounts trace MOST of the water through trees via transpiration. Matter is conserved (e.g., doesn't get "used up" by tree) and the percentages of water going to different places are reasonable. These accounts may acknowledge that a small percentage of water is used during photosynthesis. Ideally, these accounts would describe matter and processes at the atomic-molecular scale. Level 4 accounts may also indicate that a small volume of water provides structure for the plant (e.g., turgor pressure). Other possible components of a Level 4 account could include identification of drivers such as capillary action and/or water potential differences that result from transpiration. Constraints on transpiration such as temperature and humidity may also be identified. *The water goes into the atmosphere by evapotranspiration. The tree absorbs the water in its roots, and when it has traveled through the tree to the leaves, it goes into the atmoshpere as water vapor. Most.* Level 3 accounts trace water into or through the tree. These accounts tell school science stories about evaporation or transpiration, but do not attribute accurate volumes of water to the transpiration process and/or do not trace water all the way into the atmosphere in a gas state. Level 3 accounts may identify different parts of the tree that store or contain water (e.g., leaves, stems, roots, trunk) and must describe the pathway and/or the process for how water gets there. Level 3 accounts may suggest that water in trees provides structure or rigidity without indicating that the water continues to move through the tree. Level 3 accounts also may put events or places in order (e.g., water moves through roots and stems into leaves). While these accounts may describe water as part of the process of photosynthesis, errors will likely be evident – such as indicating that a large percentage of water is used in photosynthesis. Level 3 accounts may attribute unreasonable volumes of water to a process or pathway. *One places the water goes is to the leaves, and it gets there through absorption threw the roots. From the roots to the leaves it goes through the trunk and out the veins of the trees. Most.* *All the water could go to the leaves to create sugar for the tree's food. Most.* Level 2 accounts describe an incorrect or impossible pathway or otherwise describe structures incorrectly (e.g., water flowing into the leaves from rain, or flowing from roots into soil). These accounts may also identify different parts of the tree that store or contain water (e.g., leaves, stems, roots, trunk) but do not describe how the water gets	All Most Half A little

there. Level 2 accounts generally use force-dynamic descriptions to explain tree's use of water (e.g., trees need water to live, water helps the tree survive, etc.). *The water would be used for it to grow. A little.* *It would go to the trunk because the trunk needs water to stay alive. Most.* *The trunk. Half. The leaves. A little. The roots. Most.* Level 1 accounts do not recognize connections between biotic systems and the water cycle. The response may not answer the question, or it may focus on human-centered concerns or structures. Similarly, people may be identified as primary agents. *Sidewalk, rain* *To the trees stomach so it isnt thirsty. It goes in the trees mouth and through its body until it hits the bladder then the tree pees it out onto the ground and repeats the cycle*	
List a second place that the water the tree pulls in could go. Explain how it gets there and why it goes there. *See text above.*	How much of the water that the tree uses would go there?

11. What would happen to the amount of water in the Sturgeon River if all of the trees died or were cut down? Be sure to explain how this would happen and why.

Level 4 accounts indicate that the level of the water in the river would likely increase because large volumes of water move through trees via transpiration and when the trees are cut down, the water that would have transpired runs off into the river. Accounts may indicate that water moves through trees, not just that the tree uses water. Level 4 accounts may also offer other possible responses such as competing mechanisms (e.g., increased evaporation because tree canopies no longer provide shade). *It would decrease because more sunlight on the river would lead to more evaporation. However, the trees would not be using the river water and losing much of that water to transpiration.* *the water level would greatly increase because the trees are no longer there and preforming the process of transperation.* Level 3 accounts indicate that the water in the river will increase or decrease with a level 3 reason (i.e., school science story, no reference to drivers and/or constraints, not force-dynamic). These accounts may tell a school science story about trees absorbing, using, or taking in water without indicating that the water moves through the tree into the atmosphere via transpiration. Accounts may also mention that more water will evaporate from the river. Some level 3 accounts suggest that removing trees causes flooding because the presence of vegetation decreases runoff.

More water would enter the river because there would be nothing to stop the runoff into the river. The trees stop the flow of water and allow more to soak into the ground for use by the trees and other plants.

I am not sure of this answer at all. The trees use the water to grow taking it up by their roots. If all the trees dies or were cut down, my first instinct is to say that the area would become flooded because there is no where for the excess water to go.

Level 2 accounts indicate a decrease or increase in amount of water or a flood or an overflow of water with a level 2 reason/mechanism. These accounts indicate that there is a connection between trees and runoff. The mechanisms that are offered are force-dynamic in nature (e.g., trees drink, slurp, suck up water, or rivers water the trees or feed the trees, or trees need water for nourishment). Similarly, accounts may indicate that trees use up water or take water from the river. Other ideas sometimes seen in level 2 accounts include that the river will widen because trees control the path of the water or that the river will cease being a river, usually because the banks will fall down. Alternatively, level 2 accounts may indicate a change in water quality as the primary effect.

I believe the water level would rise slightly because the trees and plant life would not be there to suck up and take all the water.

if the trees where cut down or died the water would widen becasue the trees are blocking it from going anywhere

amount of water would decrease. Trees use water as source of food, trees keep the water in place, water will spread over the banks until eventually there is little to no water.

Level 1 accounts do not recognize a connection between biotic systems and the water cycle and/or offer no mechanisms. Responses may not answer the question that was asked, or may focus on human centered concerns or structures or use people as primary agents. Level 1 accounts sometimes focus on good/bad effects.

There would be no more rivers.

It would decrease

It would be bad because then all of the animals would not live

Pie Chart Questions

The items in this cluster address quantitative reasoning about water pathways. The intent is to assess how students reason about how much water (relative) flows along potential pathways in a given situation. Elements of accounts relevant to these items are shown in Table 6.

The pie chart below describes where water goes on your school grounds when it rains.

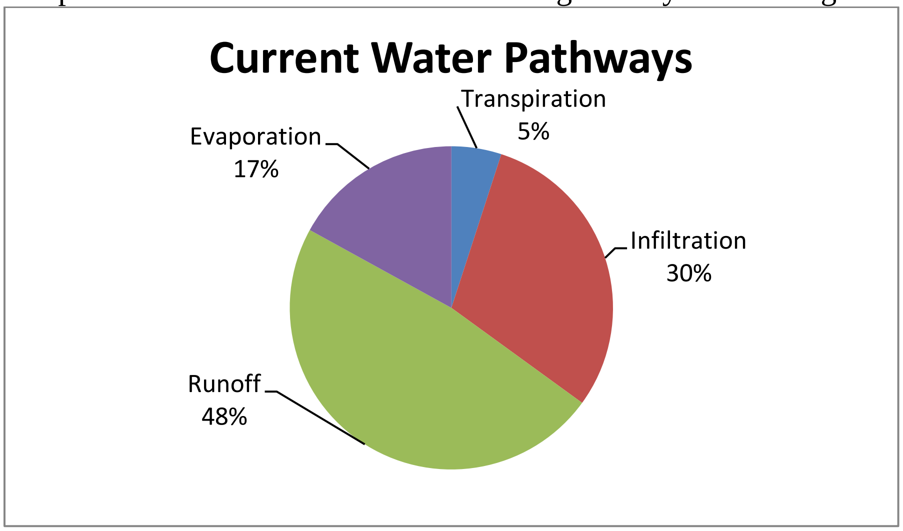
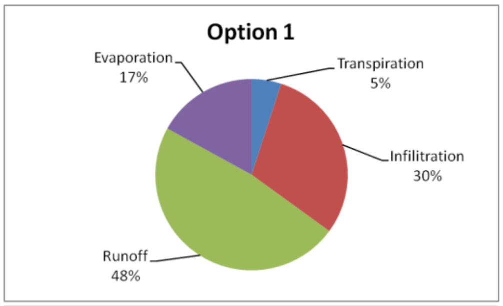


Table 6: Elements of Pie Chart Cluster Items

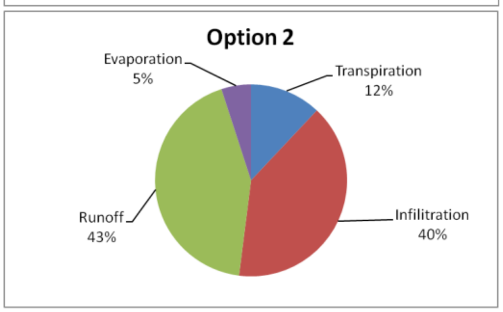
	Structure & Systems	Scientific Principles	Representations
Level 4: Model-based accounts	Describe multiple pathways in detail, including hidden and invisible pathways.	Refer to constraining factors to explain how/why there is a change.	Identify the correct pie chart
Level 3: School Science Stories	Describe one and possibly more pathways, including hidden and invisible pathways.	Describe what happens, but do not identify drivers or constraints. Generally do not use force-dynamic language.	Correct or incorrect pie chart chosen; reasoning suggests constraining factors not considered when choosing pie chart.
Level 2: Force Dynamic Accounts	Describe visible and familiar structures of systems, but do not yet accurately describe or recognize the structure of hidden or invisible components	Use force-dynamic language to explain why there is a change or not.	Correct or incorrect pie chart chosen; reasoning force-dynamic.
Level 1: Human-centered Force Dynamic Accounts	Water is represented only in isolated, visible locations. Do not recognize relative relationship between infiltration and runoff or evaporation and transpiration.	Invoke people to account for changes. Otherwise, no mechanisms are provided.	Do not connect information represented in the pie charts to the situation described.

12. Your school is considering replacing part of the school parking lot with an open space of grass and trees. Before the decision is made to do this, however, the potential impacts of this change on the water budget have to be considered. Which of the pie charts below best fits the result that would be most likely? (Circle the letter next to the chart).

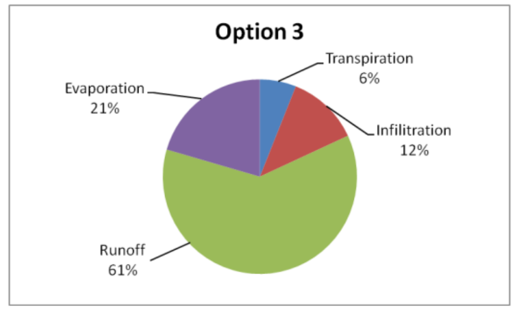
A



B



C



Option B is the desired response. This pie chart shows an increase in infiltration and transpiration and a decrease in runoff and evaporation. Option A shows no change and Option C shows changes opposite from what one would expect.

13. Please explain what happened to the amounts of <u>infiltration</u> and <u>runoff</u>. Include the reasons why.

Level 4 accounts recognize that removing the asphalt parking lot and replacing it with vegetated ground cover will increase the permeability of the surface, thus increasing the infiltration. They also recognize that increasing permeability results in decreased runoff.

Option B (increase infiltration, decrease runoff): Amounts of infiltration will increase and runoff will decrease. Since grass and soil has a higher permeability than concrete, more water will be able to sink into the ground rather than running off to other locations as it does on concrete.

Option B (increase infiltration, decrease runoff): the amounts of infiltration will increase whereas the amounts of runoff will decrease. Infiltration will be easier because the open field and trees is amore permeable surface for the water to infiltrate rather than the asphalt. runoff will decrease because there wont be as much hard surface as before.

Level 3 accounts include options B or C. These accounts describe what happens, but do not explain how or why. These accounts may have errors because they did not account for the constraints. Level 3 accounts may also provide reasons for the change but not describe permeability.

Option B (increase infiltration, decrease runoff): The infiltration of water will increase and the runoff will decrease because the grass and trees will absorb all the water that used to be run-off.

Option B (increase infiltration, decrease runoff): What will happen to the amount of infiltration is it would increase because you have more room for water to go to. The run off would decrease by a little.

Option C (decrease infiltration; increase runoff): The open space will create little less infiltration and will increase the amount of runoff. The more the infiltration decreases, the more the runoff increases.

Level 2 accounts choose options A, B, or C and use force-dynamic language to describe what happens to the water, such as that grass needs more water or that more water will go into watering the grass. Also, there may be confusion between processes.

Option A (no change): During in filtration, the open space filled with grass with probably take in most of the water. So the runoff waters will just go with the flow.

Option B (increase infiltration, decrease runoff): It's going to be more grass. More water is going to go down into the grass and less of it is going to runoff because soil absorbs water. The reason why I say it wouldn't runoff as much is because plants need water to grow so that why I say it would absorb more.

Option C (decrease infiltration; increase runoff): the amount of evaporation will go up cuz the water wont have anywhere to go

Level 1 accounts usually choose option A; they do not recognize that changing the permeability of the surface will change infiltration or runoff. Additionally, level 1 accounts may choose options B or C, but provide a human-centric reason for the noted changes.

Option A (no change): The amount of infiltration and runoff will stay the same.

Option B (increase infiltration, decrease runoff): i think it will be a big problem.

Option C (decrease infiltration; increase runoff): Yes building more open space would be good for oue school but losing parking space would be hard for the poeple that works at our schol because they would have to fnd parking space somewhere else therefore wasting more gas.

15. Please explain what happened to the amounts of evaporation and transpiration. Include the reasons why.

Level 4 accounts recognize that removing the asphalt parking lot and replacing it with vegetated ground cover will increase the permeability of the surface, thus increasing the infiltration. With less water on the surface, evaporation will decrease. However, with an increase in vegetation, more water will transpirate.

They also recognize that increasing permeability results in decreased runoff.

Option B (increase transpiration; decrease evaporation): There will be less evaporation because water will not just sit on a warm, non-permeable surface. Directly related, the amount of transpiration will increase because there are more plants that transpire waste-water.

Level 3 accounts choose options B or C. They describe what happens, but do not explain how or why. Level 3 accounts may also provide reasons for the change but not describe permeability. These accounts may have errors because they did not account for the constraints.

Option B (increase transpiration; decrease evaporation): transpiration will increase and evaporation will decrease b/c it is grass and soil

Option B (increase transpiration; decrease evaporation): If the parking lot is replaced with an open space then the amount of evaporation will decrease because the water will be going into the dirt and to the plants so there will not be as much water out to evaporate. Transpiration will increase beacuase of the ability of the plants to absorb the water from the dirt.

Option C (decrease transpiration; increase evaporation): There would be more evaporation from the plants instead of runoff from the concrete.

Level 2 accounts choose options A, B, or C and use force-dynamic language to describe what happens to the water, such as that grass needs more water or that more water will go into watering the grass. Also, there may be confusion between processes.

Option A (no change): The evaporation will increase because of all the water that is trying to be absorbed. And the transpiration will decrease.

Option B (increase transpiration; decrease evaporation): It would evaporate less because there would be more water being used by the grass.

Option C (decrease transpiration; increase evaporation): the open space would make the water evaporate more and then the transpiration would go up

Level 1 accounts usually choose option A; they do not recognize that changing the permeability of the surface will change infiltration or runoff. Additionally, level 1 accounts may choose options B or C, but provide a human-centric reason for the noted changes.

Option A (no change): itwould be the green cuzz its the biggest

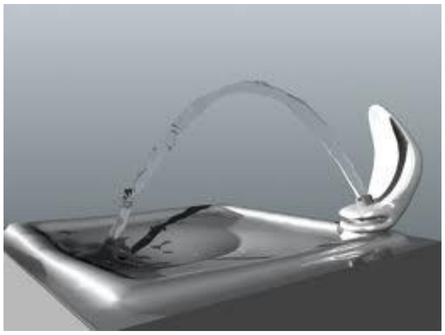
Option B (increase transpiration; decrease evaporation): i think the evaporation will help them get enough water and help them through the problem of the other thing.

Option C (decrease transpiration; increase evaporation): The amount of evaporation and transpiration will both increase due to the additional sprinkler system.

Engineered Systems

The items in this cluster specifically examine how students think about connections between natural and human-engineered systems. Relevant elements of accounts are listed in Table 7.

	Structure & Systems	**Scientific Principles**	**Dependency & Human Agency**
Level 4: Model-based accounts	Describe multiple pathways in detail, including hidden and invisible pathways. Provide details of connections between natural and human-engineered systems.	Explain how/why the water moves by identifying driving forces and constraining factors. Refer to forces such as gravity and pumping.	Identify limitations of human agency or dependence on environmental systems.
Level 3: School Science Stories	Describe one and possibly more pathways, including hidden and invisible pathways. Identify natural-to-human engineered connections.	Do not identify drivers or constraints. Generally do not use force-dynamic language.	Include human systems as part of environmental systems.
Level 2: Force Dynamic Accounts	Describe visible and familiar structures of systems, but do not yet accurately describe or recognize the structure of hidden or invisible components. Vague connections between natural and human-engineered systems.	Use force-dynamics to explain how or why water moves from one location to another.	Portray human systems as operating separately from natural systems; but human systems can be impacted by natural systems.
Level 1: Human-centered Force Dynamic Accounts	Water is represented only in isolated, visible locations. Only visible structures are described. Water is not traced to invisible or hidden locations. Vague or no connections between natural and human-engineered systems	Invoke people or supernatural forces (e.g. God) to move or change water. Otherwise, no mechanisms are provided.	Portray water as serving human needs.



16. Where does the water that is used in your school come from? Please explain how it gets to your school. Trace back as many steps as you can.

Level 4 – Traces water backwards several steps to a natural source. Describes connections between natural and human-engineered systems. Identifies and describes hidden parts of systems. May include specific water treatment methods. Explains driving forces such as gravity or pumps. May include reference to socioeconomic or political systems. May mention factors that constrain or limit water availability.

it comes from underground, goes through a long filtration process wich includes being run through multaple types of filters. Charcoal, sand, etc. then it is transfered to a holding tank. then when i turn on the water at school, gravity forces it through the pipes and to the place i am at.

Level 3 – Traces water back several steps. Puts events in order, but driving forces are not identified. Includes connections between natural and human-engineered systems, although some intermediate steps are not described. May include a generalized description of water treatment.

The water comes from evaporated water from oceans lakes and rivers, which evaporates and forms rain clouds. When it rains, the rainwater is called run off and collects in reservoirs. The water then goes through treatment plants to make it sanitary, and then is run through pipes to our school.

Level 2 – Traces water back at least two steps. Connections between natural and human-engineered systems, if present, are vague. May skip important steps or the order of events may be incorrect. Water treatment is described as purifying or generally cleaning the water. There may be a focus on human-centric needs.

The water from the school comes from a water plant where they purify the water and make sure that it is god enough for kids to drink it. They go from the water plant, and through pipes that go to the water fountains in our school.

Level 1 – Traces water only 1 step back. May invoke supernatural forces to move water (e.g., God). Structures described are visible or familiar structures only. Connections between natural and human-engineered systems are not described.

from the ocean.

The Poudre river,Rain,Lakes,God

17. Where does the waste water from your school go? Please explain how it gets to where it is going. Trace forward as many steps as you can.

Level 4 – Traces water forward several steps back to the natural system. Describes connections between natural and human-engineered systems. Identifies and describes hidden parts of systems. Distinguishes between drinking water treatment and waste-water treatment plants. Explains driving forces such as gravity or pumps. May include reference to socioeconomic or political systems. May mention factors that constrain or limit water treatment.

No examples currently available. A possible answer might look like this:
The water in the drains flows via gravity into the municipal sewer system. The water flows through the pipes in the sewer system to the waste water treatment facility. Pumps are required to move the water through various treatment steps. First filters remove the large materials. Then micro-organisms eat the organic waste. Dead micro-organisms are then filtered from the water. This water is then released into a nearby river where it is diluted by the water flowing in the river.

Level 3 – Traces water forward several steps. Puts events in order, but driving forces are not identified. Includes connections between natural and human-engineered systems, although some intermediate steps are not described.

the waste water from our school goes down a drain which is connected to the school sewage system. the dirty water is emptied into the sewer where it makes its way to the waste management plant. the plant then filters the water as best it can. the filtered water then travles in pipes again to the coast where it is deposited into the ocean.

Level 2 – Traces water forward at least two steps. Does not distinguish between drinking water and wastewater treatment. May include force-dynamic language.

The waste water from our school goes back through the pipes, back to the waste water treatment plant, where it is then treated and pumped back to our school.

it goes to the sewage plants and then to the water plant which purifies it. then it is purified over and over til its drinkable again.

Level 1 – Traces water only 1 step back. May invoke supernatural forces to move water (e.g., God). Structures described are visible or familiar structures only. Connections between natural and human-engineered systems are not described or are vague.

in the sewer

it go to ocean