18. *Bosque Chaos*

Description: By the roll of dice, students use the "Changing River" model to see how chance influences natural and human-caused changes in the bosque.

Objective: Students learn to recognize the natural processes for change and change due to human activities.

Materials:

- "Changing River" model, first set up as Rio Bravo
- Dice
- Bosque Chaos component cards for Rio Bravo, Rio Manso and Rio Nuevo

Phenomenon: The physical features of the bosque change over time. Water might cover the bike route, the location of the river sandbar changes from season to season, large trees are uprooted and fall over.

Lesson Questions:

- *Why do things change in the bosque?*
- *What causes the changes?*

18. Bosque Chaos

Grades: 5–12
Time: one hour
Subject: science
Terms: *channel, erosion, meander, nutrients, overbank flooding, oxbow, perennial, sandbar, saplings, sediment, seedlings, watershed*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs

3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
3.ESS3.B Natural Hazards
4.LS1.A Structure & Function
4.ESS2.A Earth Materials & Systems
4.ESS3.B Natural Hazards
5.ESS3.C Human Impacts on Earth Systems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.ESS2.C The Roles of Water in Earth's Surface Processes

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Scale, Proportion & Quantity; Systems & System Models; Energy & Matter: Flows, Cycles & Conservation; Structure & Function; Stability & Change

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information*

(* indicates extension activity)

Background: The Rio Grande drains from a large area, called its **watershed**. Snow throughout the winter builds up in the mountains of southern Colorado and New Mexico and drains into the river in the spring. Before major human alterations, the river rose each spring when the snows melted, carrying a huge amount of water to the Gulf of Mexico. Some years there would be tremendous flooding, in other years, mild overbank high-water levels, or perhaps simply a rise in groundwater levels. In a large flood, the river often changed its course, moving its channel to another location in the floodplain. In the summer, the water level dropped until the summer storms brought more rain to the area. With this cycling of high water to low water, some plants survived and some did not. Features along the river also changed. During a flood, sandbars could be washed away or deposited. The river channel could change course leaving oxbow lakes or dry channels. A variety of factors influence what might happen at a given location at any time. In this activity we use dice to represent these chance aspects of flood dynamics.

Human alterations have decreased flooding and encouraged a long, narrow forest without a diversity of age groups. Fewer young cottonwoods survive each year and wetlands have become rare. Now managers are working to improve the health of the ecosystem to maintain or reinstate as many aspects of Rio Bravo as possible. Complex environmental conditions beyond the control of humans, however, still play an important role in what happens to a particular element of the bosque.

Procedure:

- Have students add to KWL charts—*What do they **Know**? What do they **Want** to know?* And then, *What have they **Learned**?* at the end of the activity. These questions will help drive the learning as they work through the lesson on the question:

  How does a river flood? What effect does spring flooding have on the bosque ecosystem?
  (Asking Questions & Defining Problems)

- As with the "Changing River" activity, you can use the lens of Systems to learn about the role of chance in the bosque ecosystem (see Appendix K). This activity builds on the Changing River activity to model the floodplain ecosystem over a large spatial scale. **(Systems & System Models; Developing & Using Models)**

Section A: Rio Bravo

- Set up the river model as Rio Bravo (see "Changing River" in this chapter).
- The annual flood pulse, created by high spring runoff, brings energy into the river system. With the energy from the increased flow, changes can occur. *What kinds of changes can the energy of the flooding river bring to the bosque ecosystem and to the river channel?* Brainstorm the types of changes that might be expected. **(MS.ESS2.C; Energy & Matter)**
- Pass out dice to students—one per student or, if there are not enough dice, give one to each group of students or designate one dice-roller for each round of the game.
- Pass out the Bosque Chaos component cards for Rio Bravo and have students find an area on the model that fits the description on their cards. Features described on change cards are: Mature Cottonwood Tree, Cottonwood Sapling, Seedlings on a Sandbar, Cattails (Marsh), Native Riparian Shrub, Grassy Meadow, Bare Sandbar, Riverbank, Active River Channel. Students may need to alter the model to fit their cards. Depending on the size of the model, you may want to have the students take turns.
- Ask students to think for a minute, *What types of changes might happen to your model element if there were a large flood?* Have the students read the cards. Explain that it is easier to predict these changes on a larger scale, such as "if there is a flood, some sandbars will be washed away," but much harder to say, "if there is a flood, this sandbar will be washed away."
- Tell the students it is late spring in the river valley. There was heavy snowfall this past winter, and now the melted runoff is coming down from the mountains. The students will roll the dice to determine how their specific feature is changed by the flood. They should now manipulate the model to reflect the change indicated on the card for the number they rolled.

Note: Students will have to work cooperatively to change other components on the river to accommodate each change.

- Have students explain how the river is different from before the flood. *How is it the same?* Have students exchange component cards, select a new feature on the model, and repeat another year's flood. Repeat this exercise as time and interest allow. *What patterns can the students see? Does that feature exist somewhere else on the model after the flood?* **(Patterns)**

Rio Bravo Discussion Questions

Along Rio Bravo, in what ways does water change habitats in the floodplain?
(4.ESS2.A; MS.ESS2.A; MS.ESS2.C)

What types of changes are naturally part of the floodplain ecosystems?

In what ways are bosque plants adapted to these changing conditions? What physical characteristics help these plants to survive and grow under variable natural conditions?
(3.LS2.C; 3.LS4.C; 4.LS1.A; MS.LS2.C; Structure & Function)

What patterns can you see for Rio Bravo over time (what natural cycles were present temporally?)

How did flooding create random changes in spatial patterns observed along the river?
(Patterns)

What type of natural hazard occurred along the river before humans made changes?
(3.ESS3.B; 4.ESS3.B)

How is snowfall in the mountains related to flooding in the bosque?

How does the amount of mountain snow affect plants and animals living in the floodplain?
(Cause & Effect: Mechanism & Explanation)

Consider the natural annual cycle of the river.

How did habitats along the floodplain change naturally in Rio Bravo?

How did the floodplain change over time?

How did the floodplain change spatially?

What caused these changes?

How was stability present over time and space?
(4.ESS2.A; MS.ESS2.A; MS.ESS2.C; Stability & Change; Scale, Proportion & Quantity)

Section B: Rio Manso

- With the river set up as Rio Manso (which may be on a different day), repeat this activity using the Rio Manso component cards. Explain that runoff from the Rio Grande watershed is now held by dams in lakes. Therefore, many of today's changes along the bosque are due to the absence of annual flooding. Ask students to explain some of the kinds of changes that are different and changes that are similar between Rio Bravo and Rio Manso.

Rio Manso Discussion Questions

How have humans altered this system? **(5.ESS3.C)**

What new changes are faced by these organisms, and how do they adjust? **(3.LS2.C; MS.LS2.C)**
Organisms may adapt to changes that occur over long time periods, but often are unable to make adjustments to relatively recent changes. In geologic time, the human-caused changes to the river and floodplain are very new.

What new conditions have been created by human-caused changes?

Are these organisms able to adapt to these human-caused changes along the river? How are they affected? **(3.LS4.D)**

In what ways did humans reduce the impact of flooding on human settlements?
(3.ESS3.B; 4.ESS3.B)
The floodplain naturally changed over time and space with Rio Bravo. Adding dams and channelizing the river affected the Rio Grande's flow and changed the distribution of energy in the system.

How were the natural dynamic spatial and temporal patterns changed by humans?

How did those changes affect the bosque?

How did the distribution of energy change?
(Scale, Proportion & Quantity; Energy & Matter: Flows, Cycles & Conservation)

Explain how random chance can influence the distribution of floodplain habitats.

Explain how human changes have affected the natural patterns of flooding and how this affects floodplain habitats. **(Constructing Explanations & Designing Solutions)**

Young male Summer Tanager
Photograph by Laurel Ladwig

Section C: Rio Nuevo

- Now repeat using the Rio Nuevo component cards. In this version land managers are working to improve the health of the bosque ecosystem. Ask students to explain some of the changes that are different and other changes that are similar to the Rio Bravo and Rio Manso changes.

Rio Nuevo Discussion Questions

What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?

How did those human alterations affect the bosque, and how could they be modified to allow a more natural, dynamic system?

(5.ESS3.C; Constructing Explanations & Designing Solutions)

Assessments:

- The river model is used to show how the role of chance has changed among the three different river systems. Students can create their own models of the bosque under the three different river conditions make posters, 3-D model, video, photos, etc.) and show how the role of chance has changed across these systems. **(Developing & Using Models)**
- Write a Claim, Evidence, Reasoning statement that:
    - Explains the role that random chance played in determining the distribution of floodplain habitats along Rio Bravo.
    - Explains the effect that human alterations have had on the natural patterns of flooding and how this affects the distribution of floodplain habitats along Rio Manso.
    - Explains the role that land managers can play in restoring the health of floodplain ecosystems along Rio Nuevo, and reintroducing aspects of the natural patterns that occured along Rio Bravo. **(Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**

Extensions:

- Combine this activity with "Who Lives Where?" in this chapter. Locate the animals on the model. After each round, explain how each animal fared through the flood or other change.
  Which animals had to move, or could not survive?
  Which animals were able to find new habitat?
  How do improvements from land managers benefit native animals in Rio Nuevo?
  (3.LS4.C; 4.LS1.A; Structure & Function, Engaging in Argument from Evidence)
- Students can investigate how changes to the natural river system, such as the installation of dams and levees and the lowering of the water table, affect the distribution of habitats across the floodplain. Evaluate the importance of flooding in maintaining the diversity of habitats and the impact of human changes on the system. Share these ideas orally, or by writing letters, flyers, posters or books **(Obtaining, Evaluating & Communicating Information; ELA/ Common Core Standards).**
- Propose engineering solutions to help reintroduce chance into Rio Nuevo.

NGSS Connections to Bosque Chaos - Disciplinary Core Ideas

3.LS2.C Ecosystem Dynamics, Functioning and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Change is inherently part of floodplain ecosystems. This dynamic nature means that the exact conditions at a given location are often determined by chance. Organisms may adapt to changes that occur over long time periods, but often are unable to make adjustments to relatively recent changes. In geologic time, the human-caused changes to the river and floodplain are very new. Students learn how these changes affect bosque organisms and habitats, and how rapid human changes have further affected the system.
What types of changes are naturally part of floodplain ecosystems?
How do local plants deal with these changes?
How have humans altered this system?
What new changes are faced by these organisms in Rio Manso, and how do they adjust?

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

Bosque plants have evolved to handle variable conditions found along the natural river course. They have characteristics that help them survive in this environment.
In what ways are bosque plants adapted to the changing conditions experienced along the old river, Rio Bravo?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Although floodplain ecosystems are very dynamic, with frequent changes to habitats occurring at a local scale, native organisms are less able to deal with the types of sudden changes caused by humans.
What new conditions have been created by human-caused changes?
Are native organisms able to adapt to these human-caused changes along the river? How are they affected?

4.LS1.A Structure and Function *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.*

Bosque plants have evolved to handle variable conditions found along the natural river course. They have characteristics that help them survive in this environment.
In what ways are bosque plants adapted to the changing conditions experienced along the old river, Rio Bravo?
What characteristics help these species survive and grow under natural conditions?

4.ESS2.A Earth Materials and Systems *Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.*

Water plays an important role in creating floodplain ecosystems. Under natural conditions, the floodplain is constantly changing from the forces of river water. For example, the active channel moves, sandbars are created or washed away, and sediment is deposited in the forest. These changes affect the organisms living there.
Along Rio Bravo, in what ways does water change habitats in the floodplain?
How do floodplain ecosystems change as a result of floods along the river?

3.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Eliminating flooding has allowed humans to settle in the floodplain.
What type of natural hazard occurred along the river before humans made changes?
In what ways did humans reduce the impact of flooding on human settlements?

4.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Eliminating flooding has allowed humans to settle in the floodplain.
What type of natural hazard occurred along the river before humans made changes?
In what ways did humans reduce the impact of flooding on human settlements?

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Human alterations have changed the dynamic nature of the Rio Grande floodplain and altered many aspects of natural habitats (changing from Rio Bravo to Rio Manso). In Rio Nuevo, students learn how humans are able to make new changes that help restore some of the structure and function of natural floodplain ecosystems.
What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?
How did those human alterations affect the river and bosque? How could they be modified to allow a more natural, dynamic system?

MS.LS2.C Ecosystem Dynamics, Functioning & Resilience

--Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

--Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

Change is inherently part of floodplain ecosystems. This dynamic nature means that the exact conditions at a given location are often determined by chance. Students learn how these changes affect bosque organisms and habitats, and how human changes have further affected the system.

What types of changes are naturally part of the floodplain ecosystems?

How do local, native plants deal with these changes?

How have humans altered this system?

What new changes are faced by these organisms, and how do they adjust?

MS.ESS2.C The Roles of Water in Earth's Surface Processes

Water continually cycles among land, ocean, and atmosphere via transpiration, condensation, and crystallization, and precipitation, as well as downhill flows on land.

-Global movements of water and its changes in form are propelled by sunlight and gravity.

-Water's movement on land cause weathering and erosion, which change the land's surface features.

The annual flood pulse, created by high spring runoff, brings energy into the river system. With the energy from the increased flow, changes can occur. *What kinds of changes can the energy of the flooding river bring to the bosque ecosystem, and to the river channel?* Brainstorm the types of changes that might be expected.

Along Rio Bravo, in what ways does water change habitats in the floodplain?

How do floodplain ecosystems change as a result of floods along the river?

Consider the natural annual cycle of the river.

How did habitats along the floodplain change naturally in Rio Bravo?

What caused these changes?

Ash-throated Flycatcher
Photograph by Laurel Ladwig

Mature Cottonwood Tree

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.
2. No flooding near the tree. Nutrients are trapped in the forest floor litter. The tree grows slowly.
3. The river rises but does not overflow its banks. The water table rises. The tree is healthy and grows.
4. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.
5. Severe flooding erodes the bank and knocks the tree over. The tree dies.
6. The river flows over its banks and floods the area around the tree. Nutrients are increased. The tree is healthy and grows.

Rio Bravo

Cottonwood Sapling

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The main river channel moves away and the sapling continues growing.
2. Beaver cut down the cottonwood sapling.
3. The sapling is bent over by floodwater but survives.
4. It is a dry year, the sapling dies in the summer heat.
5. The main river channel moves away and the sapling continues growing.
6. Beaver cut down the cottonwood sapling.

Rio Bravo

Seedlings on a Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The sandbar is washed away, along with the seedlings.
2. The seedlings remain and the sandbar grows because of sediment being trapped by the plants.
3. The seedlings are buried by sediment and die, resulting in bare sandbar.
4. It is a dry year so seedlings die as the water table quickly drops.
5. The sandbar is washed away, along with the seedlings.
6. The seedlings grow quickly as the high river level drops slowly.

Rio Bravo

Grassy Meadow

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The grassy meadow is higher than floodwater and there is no change.
2. The river channel shifts and flows through this area, which now becomes a river channel.
3. A braid or small channel from the river feeds into the meadow, and the meadow changes to a marsh.
4. The grassy meadow is higher than floodwater and there is no change.
5. Over time, large amounts of sediment are deposited in the meadow and cottonwood seedlings germinate and start growing.
6. The river rises but doesn't flow over its banks. Groundwater levels rise. The grassy meadow grows.

Rio Bravo

Native Riparian Shrub

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The shrub is flooded but enjoys more nutrients and puts on new growth.
2. The flood does not impact the area and the shrub stays the same.
3. The shrub is knocked down by a flood and removed from the area.
4. The flood does not impact the area and the shrub stays the same.
5. The shrub is flooded but enjoys more nutrients and puts on new growth.
6. The shrub is flooded but enjoys more nutrients and puts on new growth.

Rio Bravo

Cattails (Marsh)

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The river rises somewhat in the spring and lowers in the heat of the summer. The marsh area remains healthy.
2. The river rises and changes its channel through the marsh in the spring. There is no longer a marsh at this spot. It is replaced by a river channel.
3. It is a dry year. The marsh dries out and most of the plants die.
4. The river rises somewhat in the spring and lowers in the heat of summer. The marsh area remains healthy.
5. The river rises and changes its channel away from the marsh. A stand of willows (or other riparian shrubs) replaces the marsh.
6. The river rises somewhat in the spring and lowers in the heat of summer. The marsh area remains healthy.

Rio Bravo

Bare Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Cottonwood seedlings start growing on sandbar.
2. Native riparian shrubs (willows) start growing on sandbar.
3. The river rises and the sandbar is washed away.
4. Cottonwood seedlings start growing on sandbar.
5. Native riparian shrubs (willows) start growing on sandbar.
6. The river rises and the sandbar is washed away.

Rio Bravo

Riverbank

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Beavers and muskrats build homes in the bank of the river.
2. Fast spring currents undercut the bank. Bank slips into river and sediment is washed downstream. Move riverbank farther back from original channel.
3. Willow thicket becomes established, providing stability to the riverbank.
4. River changes course and channel is abandoned. Cottonwood saplings grow on old bank.
5. Fast spring currents undercut the bank. Bank slips into river and sediment is washed downstream. Move riverbank farther back from original channel.
6. Sediments from upstream are deposited next to riverbank. Bank expands to flat sandy beach.

Rio Bravo

Active River Channel

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The river changes course, leaving the old channel empty.
2. The flood does not affect the channel in this spot.
3. Sediment is deposited as the flood waters drop and a new sandbar forms.
4. The river cuts across an old meander to create an oxbow.
5. The channel grows wider as banks erode.
6. Sediment is deposited as the flood waters drop and a new sandbar forms.

Rio Bravo

Seedlings on a Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Seedlings are swept away by high water, but sandbar remains.
2. It is a drought year. Surface and groundwater levels drop quickly. The seedlings die.
3. Seedlings are repeatedly grazed by cattle and die.
4. Sandbar is covered in saltcedar so no cottonwood seedlings germinate.
5. It is a drought year. The river dries up and groundwater levels drop quickly. The seedlings die.
6. Sediments are trapped by plants so the sandbar grows and the seedling survives.

Rio Manso

Cottonwood Sapling

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Cattle eat the cottonwood sapling.
2. The river rises, but does not overflow its banks. The groundwater level rises. The sapling has enough water, so continues growing.
3. The cottonwood sapling is killed by a wildfire.
4. Beaver cut down the cottonwood sapling.
5. There is a drought. The water table drops quickly and the sapling dies.
6. Beaver cut down the cottonwood sapling.

Rio Manso

Mature Cottonwood Tree

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The river level rises but does not overflow its banks. The water table rises. The tree benefits from increased water and grows.
2. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
3. No flooding in vicinity of tree. Area becomes dry. Fire burns through area and kills mature tree.
4. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
5. No flooding in vicinity of tree. Area becomes dry. Fire burns through area and kills mature tree.
6. No flooding in the vicinity of tree. Tree becomes weak and dies from insect and disease attacks.

Rio Manso

Cattails (Marsh)

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
2. Marsh area is filled in to allow new home construction.
3. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
4. Marsh is located in an old oxbow of the river. Groundwater along the channel remains high, so marsh remains healthy.
5. Riverside drains were installed to lower the groundwater and allow agriculture. The marsh dries up.
6. Marsh area is filled in to allow the construction of a shopping mall.

Rio Manso

Native Riparian Shrub

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. There is a drought. The water table drops and the native riparian shrub dies. An upland shrub takes its place.
2. The shrub is killed in a wildfire but soon begins to sprout from its roots.
3. The shrub is knocked down by bulldozers constructing a road.
4. There is a drought. The water table drops and the native shrub dies. Non-native shrubs that tolerate drier conditions increase.
5. The river rises but does not flow over its banks. Ground water levels rise and the native shrub grows well with extra water.
6. The shrub is killed in a hot wildfire that is made worse by dead and downed wood in the forest.

Rio Manso

Grassy Meadow

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Grassy meadow is higher than floodwater and there is no change.
2. A very hot fire burns across greasy meadow. Weedy plants such as cockleburs, kochia (KO-sha) and introduced annual grasses replace native perennial grasses which did not survive the fire.
3. River rises and groundwater increases. Grasses receive more water and grow.
4. Grassy meadow is cleared for agricultural field.
5. Cattle overgraze meadow; upland shrubs invade.
6. Grassy meadow is too high for flood water. Grasses die and are replaced by upland shrubs.

Rio Manso

Active River Channel

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The river has been stabilized with jetty jacks so the channel is unaffected by higher water.
2. Clear water is released from up-river dam. Water takes on more sediments and cuts the river bed deeper.
3. Saltcedar and Russian olive have grown along riverbank, further stabilizing the channel.
4. The river has been stabilized with jetty jacks so the channel is unaffected by higher water.
5. Clear water is released from up-river dam. Water takes on more sediments and cuts the river bed deeper.
6. There is an extended drought. There is little runoff and the active river channel dries up in the summer heat.

Rio Manso

Riverbank

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The riverbank is unaffected by the river this year. Bank stays the same.
2. Sediments from upland erosion are deposited next to the riverbank, leaving a broad, sandy beach.
3. Cattle and people walk on the riverbank, causing bank to slide into the river.
4. Beavers and muskrats build homes in the bank of the river.
5. Russian olive trees become established, providing stability to the riverbank.
6. Clear water is released from up-river dam. Water takes on more sediments and cuts river bed deeper. Riverbank becomes higher.

Rio Manso

Bare Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Exotic riparian trees (saltcedar) and cockleburs start growing on sandbar.
2. Cottonwood seedlings start growing on sandbar.
3. Exotic riparian trees (saltcedar) start growing on sandbar.
4. Exotic riparian trees (Russian olive and saltcedar) start growing on sandbar.
5. The river rises and the sandbar is washed away.
6. A dam is built upstream. The clear outflow water picks up sediment and carries the sandbar away.

Rio Manso

Mature Cottonwood Tree

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. There is a drought so no flooding. Nutrients are trapped in the forest floor litter, so tree grows slowly.
2. Managers apply an artificial flood to the forest. Nutrients are increased and the tree grows well.
3. Managers cut down a bank to allow natural flooding in the forest, so the tree grows well.
4. No flooding near the tree. Nutrients are trapped in the forest floor litter, so the tree grows slowly.
5. No flooding in area of tree so area becomes dry. Very hot fire burns through and kills mature tree.
6. Managers remove excess wood from forest, so wildfires burn out and don't kill trees. Tree keeps growing.

Rio Nuevo

Cottonwood Sapling

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The water table remains high so cottonwood sapling continues to grow.
2. Cattle are kept from river by a fence so sapling continues to grow.
3. Beaver cut down the cottonwood sapling.
4. Students help plant cottonwood poles in a restoration project. The sapling survives.
5. There is a drought. The water table drops quickly and the sapling dies.
6. Cottonwood leaf beetle larvae kill the cottonwood sapling.

Rio Nuevo

Seedlings on a Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Seedlings are swept away by high water, but sandbar remains.
2. Sediments are trapped by plants so the sandbar grows and the seedling survives.
3. It is a dry year so seedlings die as the water table quickly drops.
4. Beavers eat some seedlings, but some remain
5. There is a drought. Seedlings die because the sandbar dries out.
6. Managers create artificial flood and water level drops slowly. Seedlings grow quickly.

Rio Nuevo

Grassy Meadow

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Grassy meadow is higher than floodwater and there is no change.
2. Recent fuels management in adjacent forest keeps wildfire moderate, so native grasses recover after fire.
3. Managers apply artificial flood to the area. Grasses receive more nutrients in floodwater and grow well.
4. Grassy meadow is cleared for an agricultural field.
5. Cattle overgraze meadow and upland shrubs invade.
6. There is an extended drought so the grassy meadow dries up. Upland shrubs invade.

Rio Nuevo

Native Riparian Shrub

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The native riparian shrub benefits from artificial flooding and grows well.
2. The shrub is killed in a hot wildfire that is made worse by dead and downed wood in the forest.
3. The shrub is cut to build a new bridge.
4. School children help plant new native riparian shrubs.
5. The native riparian shrub benefits from artificial flooding and grows well.
6. Managers remove some excess wood from forest so next wildfire is not severe and the shrub recovers quickly.

Rio Nuevo

Cattails (Marsh)

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Volunteers help build new wetland, so excellent habitat is provided for wildlife.
2. No funding is available for wetland project and area is converted to a parking lot.
3. It is a drought year, so wetland project is canceled by short-sighted officials.
4. Volunteers help build new wetland, so excellent habitat is provided for wildlife.
5. Constructed wetland is created to treat wastewater from housing development and to create habitat.
6. Potential wetland area is converted to houses.

Rio Nuevo

Bare Sandbar

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. Exotic riparian trees (saltcedar) and cockleburs start growing on sandbar.
2. Cottonwood seedlings start growing on sandbar.
3. Exotic riparian trees (Russian olive and saltcedar) start growing on sandbar.
4. The river rises and the sandbar is washed away.
5. The river rises and the sandbar is redistributed downstream.
6. Native riparian shrubs (willows) start growing on sandbar.

Rio Nuevo

Riverbank

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

1. The riverbank is unaffected by the river this year. Bank stays high.
2. Managers use bulldozers to lower the bank to allow overbank flooding into the forest.
3. Beavers and muskrats build homes in the riverbank.
4. The riverbank is unaffected by the river this year. Bank stays high.
5. Managers use bulldozers to lower the bank to allow overbank flooding into the forest.
6. People and their dogs walk along the riverbank, causing bank to slide into the river and sediment to move downstream.

Rio Nuevo

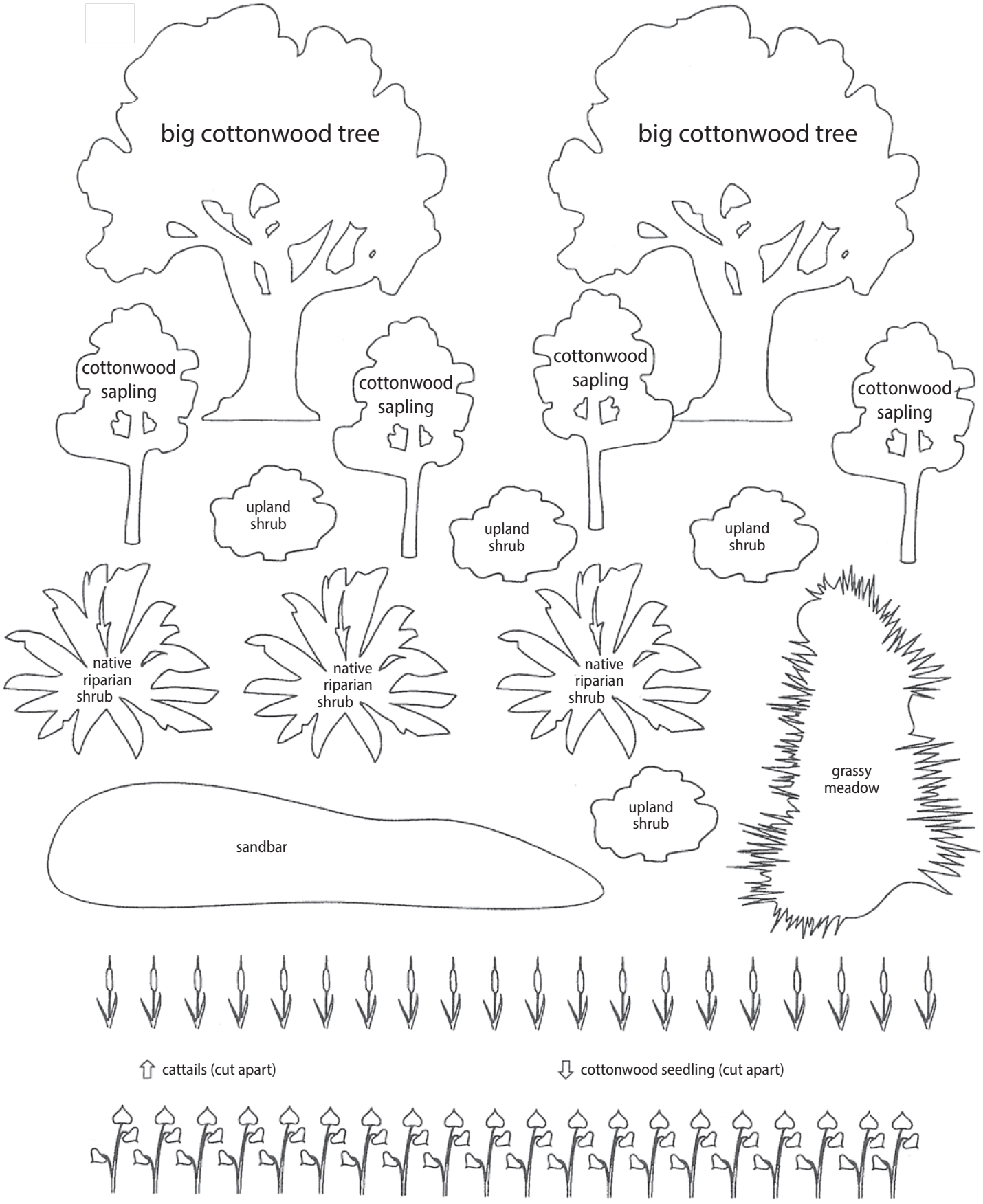
Active River Channel

Roll the dice. Follow the directions for the number it lands on. Example: If you roll the number 2, then follow the directions for item 2 in the list below. There is a greater chance for some things to happen, so some options are listed more than once.

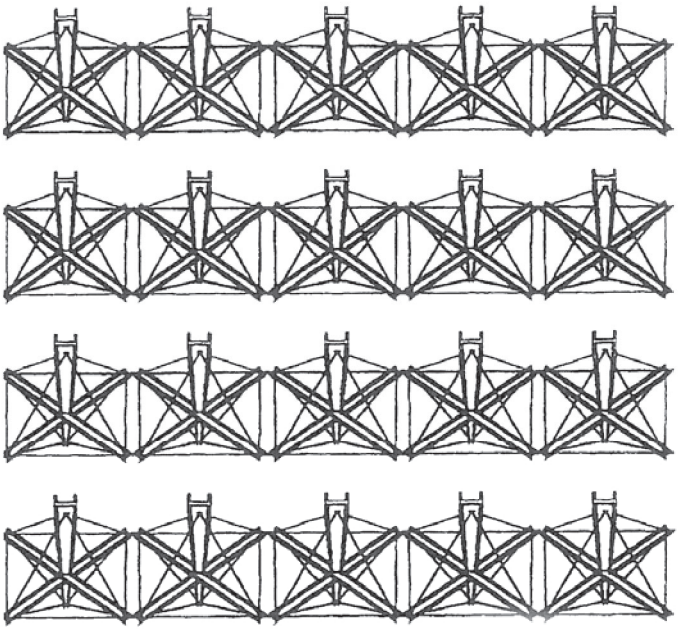
1. Managers lower the bank to allow flooding into the forest. This moves sediment into the channel and a new sandbar forms downstream.
2. This section of the river has been stabilized with jetty jacks so the channel is unaffected by higher water.
3. Jetty jacks have been removed so the channel moves slightly with higher floodwater.
4. Saltcedar and Russian olive have grown along riverbank, further stabilizing the channel.
5. Managers lower the bank to allow flooding into the forest. This moves sediment into the channel and a new sandbar forms downstream.
6. This section of the river has been stabilized with jetty jacks so the channel is unaffected by higher water.

Rio Nuevo

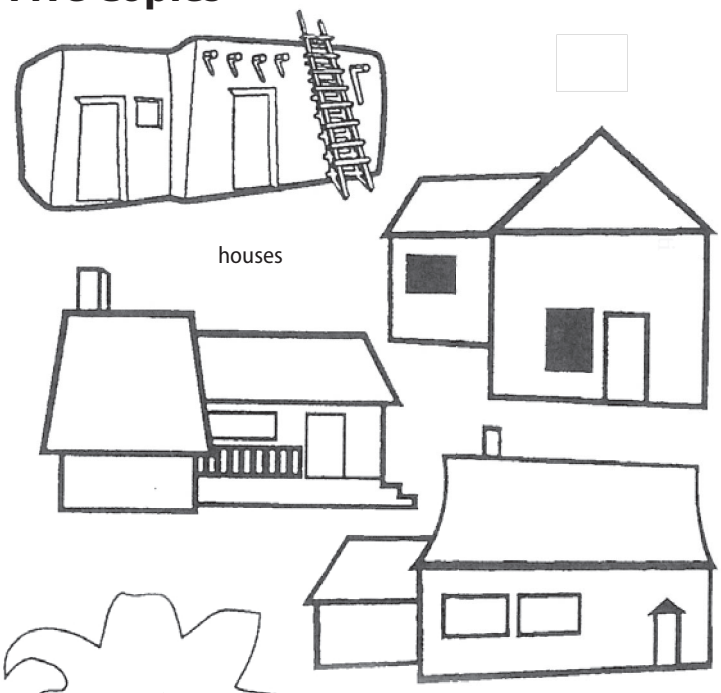
Rio Bravo Model Pieces: Make Five Copies



Rio Manso Model Pieces: Make Five Copies



jetty jacks



houses