ENGINEERING INGENUITY

How did Hawaiians engineer shoreline fishponds to grow fish, while maintaining water quality and preventing siltation?

HAWAIʻI DOE STANDARD BENCHMARKS

Social Studies 7: Geography: WORLD IN SPATIAL TERMS

- **SS.4.7.2** Collect, organize, and analyze data to interpret and construct geographic representations.
- **SS.4.7.3** Analyze the consequences of human modification of the physical environment in Hawaiʻi using geographic representations (including *loʻi kalo* and *loko iʻa*).

Science 1: The Scientific Process: SCIENTIFIC INVESTIGATION

- **SC.4.1.2** Differentiate between an observation and an inference.

Language Arts 4: Writing: CONVENTIONS AND SKILLS

- **LA.4.4.1** Write in a variety of grade-appropriate formats for a variety of purposes and audiences.

KEY CONCEPTS

- Hawaiians constructed *ʻauwai kai* (channels) in the walls of shoreline fishponds to create currents that circulated water and attracted fish with each tidal change. They placed *mākāhā* (sluice grates) in the *ʻauwai kai* to trap fish.
- The circulation of water in the pond aerates the pond with oxygen and flushes out excess sediments and nutrients that can accumulate to unhealthy levels.

ACTIVITY AT A GLANCE

Students build model fishponds in shallow pans and experiment with changing water levels outside the pond wall to simulate what happens with the rising and falling tides.

TIME

1 - 2 class periods

SKILLS

modeling, reasoning, interpreting

ASSESSMENT

Students:

- Sketch a *loko kuapā*, and diagram how the flow of water through the *mākāhā* at both rising and falling tides affects water quality and pond life.
- Describe their observations after working with a fishpond model and the inferences that they make from those observations.
- Write a one-paragraph display label with a clear topic sentence describing the technology of Hawaiian fishponds.

MATERIALS

Provided:

- ✓ *Kāhea Loko* video
- ✓ Learning Log 5
- ✓ student reading

Needed (per group of students):

ʻauwai o ka mākāhā

- ✓ shallow plastic dishpan
- ✓ 1 block modeling clay
- ✓ toothpicks or popsicle sticks
- ✓ cordage from Lesson 2 (or use raffia or florist wire that can be cut with scissors)
- ✓ 2 cups clear water
- ✓ 2 cups water, colored blue
- ✓ empty 2-liter soda bottle or other container for water
- ✓ 2 to 3 feet of flexible tubing or meat baster
- ✓ yellow food coloring
- ✓ 15 small leaves (to represent large fish)
- ✓ oregano or other spice (to represent small fish)

VOCABULARY

ʻauwai kai – ditch connecting the fishpond to the sea (Kikuchi, 1973)

ʻauwai o ka mākaha – the ditch of the sluice grate (Kikuchi, 1973)

circulation – the moving or flowing of something from place to place or in a circle

inference – the act of drawing a conclusion based on observations or evidence

ingenuity – cleverness or skillfulness of conception or design

kahuna – priest or expert

lama – all endemic kinds of hardwood ebony trees (*Diospyros)*

loko kuapā – shoreline fishpond with an outer seawall of rock and coral built on reef flat; a fishpond whose main characteristic is an outer rock seawall with a rock-lined *ʻauwai o ka mākāhā* and *a wooden mākāhā*

loko puʻuone – fishpond with a natural sand bank separating the pond from the sea

mākāhā – sluice grate

nutrient – matter that sustains a living organism and promotes growth

nutrient flushing – the washing away of nutrients

ʻōhiʻa ʻai – mountain apple tree

siltation – to become filled or choked with silt

sluice – an artificial channel for conducting water, often fitted with a grate for regulating the flow of water and removing solid matter

stagnation – to become stale or foul from standing, as a pool of water

ADVANCE PREPARATION

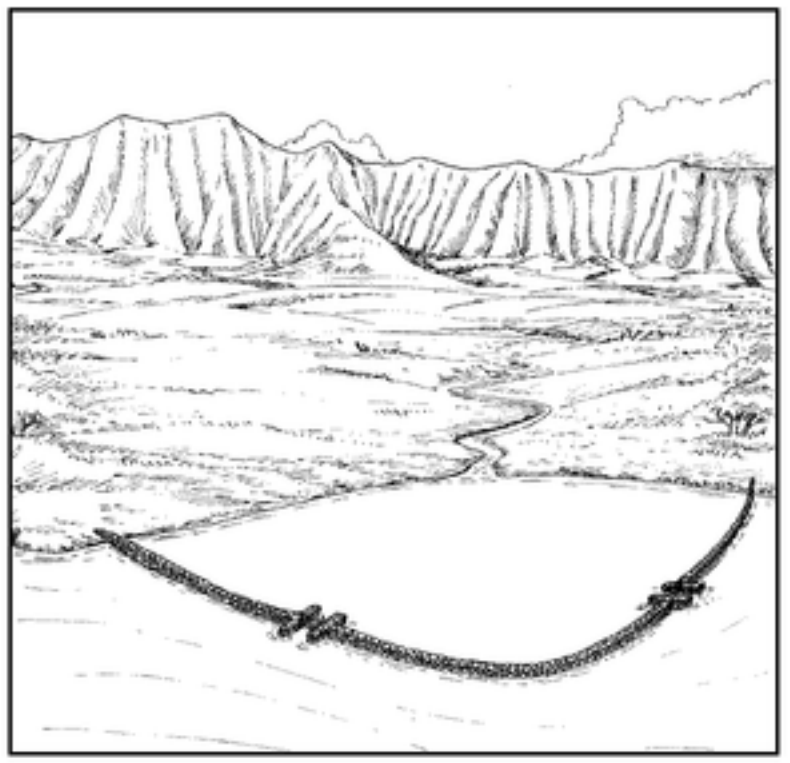
☐ Make a copy of the Learning Log and student reading for each student.

☐ Gather the materials for student groups to create models.

TEACHER BACKGROUND INFORMATION

The Hawaiian fishpond of the *loko kuapā* style is unique to Hawaiʻi because of two features, the *ʻauwai o ka mākāhā* (Kikuchi, 1973) or the *ʻauwai kai* and the *mākāhā*. Hawaiians created these innovative structures by building massive stone walls that extended on to the reef flat. In these walls, they built *ʻauwai kai* (channels) that allowed the exchange of water with each changing of the tide. The tidal changes that occur each day are controlled by the gravitational pull of the sun and the moon on the oceans. Our knowledge has evolved to the point where we can now predict when and even how high or low the tide will be for any given day of the year, and we can access that information by simply looking at a tide calendar. During ancient times, the exact mechanism of tidal fluxes may not have been fully understood. However, ancient Hawaiians knew that the ebb and flow of the seas were correlated with the phases of the moon around which they planned much of their daily activities related to planting crops and fishing.

Hawaiians knew that most fishes are attracted to currents to maximize their food intake, so the *ʻauwai o ka mākāhā* (ditches, or channels) were constructed in the walls of the ponds to create currents with each tidal change. In this manner, fish could be harvested from either within the pond or from the ocean depending on which direction the current flowed as the tide changed. The fishpond *mākāhā* (sluice grate) and pond walls were designed to allow water circulation from the tides. They functioned like a "filter" to help control



loko kuapā

water circulation and prevent stagnation and the build-up of sediments, which is critical to maintaining a healthy, balanced fishpond ecosystem. The *mākāhā* was constructed of a wooden grate with pieces of wood spaced a half inch apart to prevent larger fish in the pond from escaping and small fish to enter (George Uyemura, 2007).

The shallow depth of Hawaiian fishponds provided the optimal light conditions for plankton and *limu* growth. *Limu* and microscopic plankton provide food for the herbivorous fish grown in the pond—the *ʻamaʻama* (mullet) and *awa* (milkfish). The *kiaʻi loko* (fishpond keeper) cared for the pond, just as a farmer tends his pastures for cattle. The *kiaʻi* kept the pond walls intact and checked for excessive *limu* growth and build-up of pond sediments. If the mats of *limu* in the pond grew too thick, the *limu* was thinned by hand. This helped to prevent the depletion of dissolved oxygen in the pond which occurs when large amounts of *limu* decays. And if the bottom sediments of soil and decayed organic matter got too thick, commoners were called upon to help clear this layer of sediment. This is when they would have access to the fish and *limu*, otherwise reserved only for the

aliʻi. The sediments were stirred up and the pond was flushed as the incoming tide circulated in the pond through the *mākāhā*, and the outgoing tide washed some of the sediment out to sea.

The ancient *ʻauwai o ka mākāhā* made from *lama* or *ʻōhiʻa ʻai* wood in the days of early Hawaiʻi (Kikuchi, 1973) did not have the movable water gates that appeared at the turn of the twentieth century. So the location of the different *mākāhā* in the early ponds was critical to water circulation. Later, during the late 1800s, the Chinese and Japanese introduced separate water gates made from wooden planks of different sizes on the ocean side of the *ʻauwai o ka mākāhā* that allowed them to cut down the rate of water exchange and manipulate the plankton density. As with an aquarium of guppies that lacks filtration, fishpond water with no circulation will start to turn green in a few days. Excessive phytoplankton will grow due to the nutrients (excrement/fertilizer) that build up and deplete the oxygen in the water.

TEACHING SUGGESTIONS

1. **Introduce students to the essential question and the standards they will be working on. Introduce fishponds using the student reading and the video provided.**
   - If students have not seen the *Kāhea Loko* (Pacific American Foundation, 2003) introductory video, have them view it before conducting this activity.
   - Have students read the student reading and discuss how the pond functions.
     <u>Discussion Questions</u>
     - What is the purpose of the *ʻauwai kai* (sluice or channel in the wall) and the *mākāhā* (sluice grate)?
       (*The ʻauwai kai provides a current that attracts fish and during the incoming tide, it allows water to flow into the pond and circulate. During the outgoing tide, the sediments and excessive nutrients can be flushed out of the pond. The mākāhā, placed between the walls of the ʻauwai kai traps the fish in the pond.)*

     - How was it easier to catch fish from a pond than in the open ocean?
       (*Fish can be caught easily from a fishpond because the fish are concentrated into a confined area, unlike in the open ocean where the fish are widely dispersed. The fish tend to gather by the ʻauwai kai to swim toward the current that is created by the tides flowing through the channel to get nutrients. The fish can be scooped with nets at this location.*)

2. **Set up the fishpond model-building activity.**
   - Divide the class into groups of "agricultural engineers."
   - Explain to students that a prospective client, Kupuna Kole, is searching for an engineering firm to rebuild her fishpond. The fishpond has not been in use since her father passed away. It is 10 acres large and the pond is filling in with silt that washes down from the stream that feeds into the pond. She has also been told that the water is becoming stagnant because nutrients are building up and depleting the oxygen in the water. The walls and the *mākāhā* have fallen apart and she needs to have the pond rebuilt. Kupuna Kole is requesting that each engineering firm present its model and show how the pond will work to circulate water once again and allow the young fish to enter, but the bigger fish to be trapped.

3. **Distribute model-building materials and challenge groups to design their models.**
   - Challenge each group of engineers to design and build a *kuapā* with an *ʻauwai kai* and a *mākāhā*.
   - Give each group a pan to build the pond and have students select materials from those provided or acquire additional materials to fit their designs.
   - Challenge them to use the cordage (in place of wood) made in the previous lesson to make the *mākāhā*.

4. **Test students' models.**
   - Once students' ponds are built, give each group two cups of water to add to the pan as low tide.
   - After the water has equalized on both sides of the *mākāhā*, ask each group to add a few drops of yellow food coloring to the pond side of the model to represent the stagnant water in Kupuna Kole's pond.
   - Give each group a container with two cups of blue-colored water and a meat baster. Ask students to raise and lower the "tide" on the ocean side of their models and report what happens to the stagnant water in their ponds.
   - Provide some small leaves or other lightweight objects to represent large fish and some oregano to represent small fish. Have students add these "fish" to their ponds and create a current to move the fish toward the *ʻauwai o ka mākāhā*.

5. **Help students to differentiate between what they observe in their models when they raise and lower the tide, and what inferences they can make based on those observations.**
   - Ask students to make observations of what happens to the "fish" in their models and what happens to the color of the water when they raise and lower the tide. Do they observe that the large leaves (fish) don't move past their *mākāhā*? What inference do they make about the function of the *mākāhā* based on this observation?

(The *mākāhā* prevent large fish from escaping from the pond but allow small fish to enter.)

- Explain that the adult fish in the pond are drawn to the *ʻauwai kai* on the incoming tide and will actually swim against the current. This is so they can catch the most amount of food.
- Do they observe changes in the color of the water in the pond when they raise the "tide"? What inference do they make about the function of the *ʻauwai kai* in preventing stagnation and siltation from this observation?

6. **Ask groups to present their models for Kupuna Kole.**
   - Have each group describe how their models will work to: a) circulate the water and prevent stagnation, and b) allow small fish to enter and big fish to be retained.
7. **Ask students to complete Learning Log sheet 5.**
   - Have students work individually to create diagrams showing how the circulating water with the changing tide affects water quality and pond life.
   - Collect the students' written labels for their models, review them and have the students make any necessary corrections, before placing the labels next to their models.

     <u>Discussion Questions</u>

     - Why are tidal fluctuations important to a fishpond?
       (They circulate the water between the ocean and the pond, aerating the pond and flushing silt and distribute nutrients.)
     - How would cementing the rocks of the fishpond wall in place affect the pond?
       (It would keep water from seeping through the walls of the pond, so the only place where the water could circulate and flush silt and nutrients would be through the ʻauwai kai. *This could negatively affect water quality in the pond.)*
     - How are your models different from a real situation?
       (As always, models are simplified representations of reality. With a real fishpond, you would have the effects of wind and waves on the water and human activities upstream as well as the changing tides.)
     - How are observations different from inferences?
       (*Observation is an act of watching attentively; inference is the act of concluding based on the evidence from observation.*)

Adaptations / Extensions

Follow this activity with a field trip to a fishpond (see Lesson 5), and have the students observe the flow of water through the *ʻauwai kai*. Using small floating objects and a stopwatch, have students calculate the flow rate of the water into or out of the pond.

To help your students learn more about Hawaiian fishponds, conduct some of the lessons from *Kāhea Loko: The Call of the Pond* (Pacific American Foundation, 2003) teacher's guide

developed by the Pacific American Foundation (PAF). The units are available online from the PAF Web site at www.thepaf.org. The lessons from Unit 2, "Life in the Pond", are designed to help students reach the Hawaiʻi DOE Science 3 Standard.

REFERENCES

Fullard-Leo, Betty. *Big Fish in Little Ponds*. Copyright © 2006. LBD Coffee LLC dba Coffee Times. Retrieved November 11, 2006, from www.coffeetimes.com/ponds.htm

Kamakau, Samuel Manaiakalani. 1869. *Moʻolelo Hawaiʻi (Hawaiian Traditions), Ke Au Okoa* (newspaper). Honolulu, 1869-71. Translation in manuscript. Bishop Museum Collection. Honolulu, HI. Retrieved November 11, 2006, from www.sacred-texts.com/pac/ku/ku33.htm

Kikuchi, William K. 1973. *Hawaiian Aquacultural System*. The University of Arizona, Ph.D. Dissertation, Anthropology. UMI Dissertation Services. Ann Arbor, MI.

Pacific American Foundation. 2003. *"Kāhea Loko: The Call of the Pond." A Teacher's Guide to Hawaiian Fishponds Grades 4 – 12*. Pacific American Foundation. Honolulu, HI.

Pacific American Foundation. 2003. *"Kāhea Loko: The Call of the Pond."* Video.

Uyemura, George. 2007. Personal Communication.