KAI E‘E – MOUNTING SEAS

Grade 9 - Tsunami Unit

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While tsunamis are few and far between in our lives, and especially for our youth, they are still a major danger to our communities. Through the lessons in this unit, students will explore the serious nature of a tsunami as a natural disaster, its causes, possible effects, and the laws of physics that govern this natural phenomenon.

This unit is sequential and prepares students to not only answer objective questions about the science behind tsunamis, but also to solve problems, think critically, and write effectively. Each lesson builds on the previous one and documents from each of the first four lessons lay the foundation for the final assessment in lesson five. The essential question for the unit is: *How do we use the tools of science to help us predict the potential impact of a tsunami on our community?*

Assessment

The Unit Map that follows in this Introduction lays out the Hawaiʻi DOE standards, the Common Core standards, and the Nā Honua Mauli Ola (Hawaiian Guidelines) on which the lessons are designed.

A Unit Pre/Post-assessment is provided on pages 3 - 4. This assessment consists of eight constructed response items aligned to standard benchmarks and key concepts from the lessons. The assessment is designed to administer at the beginning and at the end of the unit. The standard benchmarks and corresponding lessons for each item on the assessment are indicated on the answer sheet provided on pages 5 - 7.

In addition, the Next Generation Science Standards (NGSS) that correlate with the Hawaiʻi Content and Performance Standards have been added to the Unit Map, lessons, and rubrics to assist teachers and students in making the transition to these new standards.

The unit summative assessment includes an individual and a group project, which are described in the Journal (Unit Assessment Overview) and in Lesson 5, the culminating activity. The rubrics provided with the unit are designed to assess students' culminating projects.

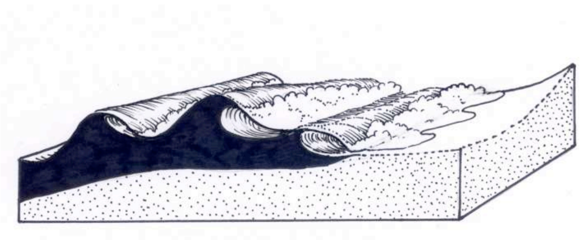
The first four lessons in the unit provide sequential steps to enable the students to successfully complete the culminating projects. The journal, quiz, and map pages provided with each lesson serve as formative assessments. They are designed to lay the foundation for the culminating assessment as well as chronicle the students' learning as they progress through the unit.

The wave graphic that appears on each page is at the top of teacher pages, and at the bottom of student pages so that these pages may be easily identified.

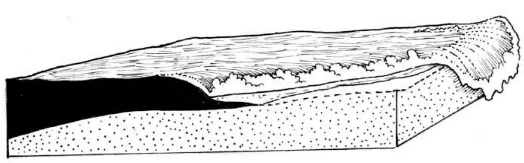
Unit Overview

In **Lesson 1, Tsunamis in Our Community**, students are asked to imagine how a tsunami could affect them. By reading a survivor's account and then reflecting on it in their journals, students imagine the impact of a tsunami on their community. Students examine historical evidence of world-wide and local tsunami frequency and impact on communities, looking for patterns.

In **Lesson 2, Tsunami Surfing**, students learn to calculate the velocity of a tsunami wave using algebraic equations. They also learn why you can surf a wind-generated wave, but not a tsunami. Students then take a closer look at wave height and wavelength.



Wind-generated Wave



Tsunami

Students explore the laws of physics and their relation to waves in **Lesson 3, Kai E'e**. Using physical and digital models, students explore and explain reflection, refraction, diffraction, and seiche.

In **Lesson 4, Tsunami Causes**, students conduct research to investigate causes of tsunamis. They brainstorm and plan their own demonstrations to show how tsunamis are formed, and then share their demonstrations with others. Students also explore the conservation and transfer of energy in relation to tsunamis.

In **Lesson 5, The Decision**, students use two formats to answer the unit essential question. Individually in writing, and then collaboratively. Individually, students analyze documents in an authentic real-life performance task and determine which of two sites is safer to build a new school in a tsunami inundation zone. As a class, students engage in a mock board meeting to come to consensus on their varying opinions developed in the individual written response. Students share their own findings by presenting their information to a large group and draw conclusions about their own school's risk.

Appendix

The Appendix includes tsunami survivor stories from each island. These compelling stories convey a sense of urgency for sharing information about tsunami safety with others in our communities. Topographic maps for inundation zones of schools participating in this project are also included in the Appendix. As a follow-up to the culminating activity in this unit, students are encouraged to evaluate how vulnerable their school site is to tsunamis and to learn about their school's evacuation plan.

KAI E‘E GR. 9 UNIT PRE /POST-ASSESSMENT

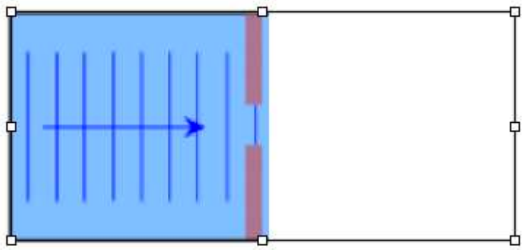
NAME______________________________ **DATE**________________

SCHOOL______________________________

1. Ocean waves bend and change shape as they hit landforms. When a wave moves in a new direction due to a change in the depth of the ocean floor, the process is called: (Circle one.)

Seiche	Wave Interference
Diffraction	Reflection
Refraction	None of the above

2. What would happen to this wave as it passed through a hole in a sea wall like the one shown below? Draw what the wave might do and identify the process.



3. Scientists are always looking for ways to predict natural disasters in order to better protect people. When scientists calculate the speed of a tsunami they use the formula below. Explain what the formula means.

$$\text{speed} = \sqrt{g \times d}$$

4. Explain why tsunami waves move so much faster than wind-generated waves.

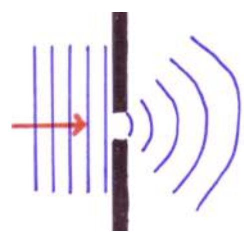
5. Surfers surf wind-generated waves in Hawai‘i and around the world. These waves are created from wind blowing over the surface of the ocean. Tsunamis are created in a different way so the waves are different. What makes a tsunami impossible to surf?

6. Tsunamis will always be a threat to the Hawaiian Islands. Some tsunamis are generated locally and others from far away. What is the most common cause of tsunamis in the Pacific Ocean?

7. Explain how this cause of tsunamis is related to plate tectonics.

8. Energy is never created or destroyed, it only changes form. Where does the energy a tsunami contains come from?

Gr. 9 Unit Pre /Post-Assessment Answer Sheet

Question	Standard / Lesson	Answers	Total Possible Points
1. Ocean waves bend and change shape as they hit landforms. When a wave moves in a new direction due to a change in the depth of the ocean floor, the process is called: (Circle one.) • Seich • Wave Interference • Diffraction • Reflection • Refraction • None of the above	**SC.PH.6.1** Analyze transverse and longitudinal waves in mechanical (e.g., springs, wave tanks) and non-mechanical media (e.g., seismic waves, sound waves) Lesson 3	• Refraction *(1 point)*	1 point
2. What would happen to this wave as it passed through a hole in a sea wall like the one shown below? Draw what the wave might do and identify the process.	**SC.PH.6.1** Analyze transverse and longitudinal waves in mechanical (e.g., springs, wave tanks) and non-mechanical media (e.g., seismic waves, sound waves) Lesson 3	 *(1 point)* Diffraction (the bending of a wave as it travels around or goes through an opening in a barrier) *(1 point)*	2 points

3. Scientists are always looking for ways to predict natural disasters in order to better protect people. When scientists calculate the speed of a tsunami they use the following formula: $$\text{speed} = \sqrt{g \times d}$$ Explain what the formula means. 4. Explain why tsunami waves move so much faster than wind-generated waves.	**PS.6.5** Compare transverse and longitudinal waves and their properties. **PS.7.1** Apply the laws of motion to determine the effects of forces on the linear motion of objects. Lesson 2	• Speed (measured in meters/ second) = square root of g (acceleration due to gravity, which is a constant at 9.81 meters/second^2) x d (water depth in meters, the average depth of the water in which a tsunami travels). $$\text{speed} = \sqrt{g \times d}$$ • Tsunamis have much longer wavelengths than wind-generated waves. (*1 point)* Because of their long wavelength, they lose very little energy as they travel. *(1 point)* A wave loses energy at a rate that is inversely proportional to its wavelength. So a wave with a large wavelength loses energy slower than a wave with a short wavelength. *(2 points)*	3 points 4 points
5. Surfers surf wind-generated waves in Hawaiʻi and around the world. These waves are created from wind blowing over the surface of the ocean. Tsunamis are created in a different way so the waves are different. What makes a tsunami impossible to surf?	**PS.6.2** Explain how the law of conservation of energy is applied to various systems. Lesson 2	• Wavelength is much longer than a wind-generated wave • Wave speed is much faster than a wind-generated wave • Tsunamis often take with them debris that is being propelled by the water with great force. • A tsunami can come ashore as a wall of water like a broken wave, or as a fast-moving surge with no face at all, but never as a surf-able breaking wave. *1 point for each correct response up to 3 points*	Maximum of 3 points

6. Tsunamis will always be a threat the Hawaiian Islands. Some tsunamis are generated locally and others from far away. What is the most common cause of tsunamis in the Pacific Ocean? 7. Explain how this cause of tsunamis is related to plate tectonics.	**ES.8.5** Explain the effects of movements of crustal plates. Lesson 4	• Earthquake or seismic activity *(1 point)* • Seismic activity occurs frequently at the boundaries of Earth's plates. Large earthquakes are generated in subduction zones where one plate slides beneath another. The sudden rising or sinking of the ocean floor then displaces a large amount of water and releases the energy that generates the tsunami. *(3 points)*	1 point 3 points
8. Energy is never created or destroyed, it only changes form. Where does the energy a tsunami contains come from?	**PS.6.2** Explain how the law of conservation of energy is applied to various systems. Lesson 4	• Energy comes from whatever the cause of the tsunami was. It comes from the energy released due to an earthquake, landslide, volcanic eruption, or asteroid impact. *(2 points)*	2 points
		Total possible points:	20

Grade 9 Unit Map

Tsunami

Essential Question: How do we use the tools of science to help us predict the potential impact of a tsunami on our community?

Enduring Understandings:

- Tsunami waves are different than wind and tidal waves because of how they are created and how they move.
- Energy is conserved as tsunamis move through the water and interact with landforms (focus, refraction, reflection, diffraction, seiche)
- Science and math can help us to prepare better for tsunamis, which are a natural phenomenon that regularly impacts Hawai‘i.

Nā Honua Mauli Ola (NHMO) Cultural Pathways:

‘Ike Ho‘okō - Applied Achievement: Demonstrate the use of acquired knowledge through application.

‘Ike Honua - Sense of Place: Be keen observers of their natural environment.

‘Ike Piko‘u -Personal Connection: Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.

Values: kuleana (responsibility) and lōkahi (unity)

Unit Pre/Post-Assessment:

Students complete an assessment with eight constructed response items aligned to standard benchmarks and key concepts addressed in the unit. (Assessment provided in the Unit Introduction)

Culminating Project:

Students use two formats to answer the unit essential question - individually in writing, and then collaboratively.

Individually, students:

- Analyze documents in an authentic real-life performance task and determine which of two sites is safer to build a new school.

As a class, students:

- Engage in a mock board meeting to come to consensus on their varying opinions developed in the individual written response.
- Share their findings by presenting their information to a large group and draw conclusions about their own school's risk from tsunamis.

Total 50-Minute Class Periods for Unit: 9 - 13

Core Content Areas: Science, Language Arts, and Math

Notes on Next Generation Science Standards (NGSS)

This unit map includes Next Generation Science Standards that correlate with the Hawai‘i Content and Performance Standards (HCPS) in Science. To increase the rigor of the unit and begin making the transition to NGSS, consider adjusting the assessments as suggested on the unit map for each lesson.

Suggestions for adapting the assessments to meet NGSS are also included in the margins next to the Teaching Suggestions within the lessons.

Rubrics for the culminating project have been designed for both HCPS and NGSS benchmarks to assist teachers and students in making the transition to NGSS.

1: Tsunamis in Our Community?

How could a tsunami affect me?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Language Arts: Reading Informational Text - Range of Reading and Text Complexity; Integration of Knowledge and Ideas (RI) **Math: Number and Quantity** - Quantity (N-Q) **‘Ike Honua - Sense of Place Pathway**	**RI.9-10.10** By the end of grade 10, read and comprehend history/social studies texts in the grades 9–10 text complexity band independently and proficiently. **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text. **N-Q.HS.3**. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	No science standards addressed in this lesson	• Frequency and effects of tsunamis on communities in Hawai‘i and around the world • Devastating impact of tsunamis on property and lives • Community kuleana (responsibility) for saving lives and property when tsunami warnings are issued

Assessment	Assessment Adjustments for NGSS	Class Periods: 2 - 3
Students: • Write a journal response demonstrating historical empathy, writing effectiveness, writing mechanics, and comprehension of a reading. • Create a table and /or chart based on their research and organization of data. • Write about patterns they see in the data tables and/or charts that they create, demonstrating their ability to interpret data correctly.	Not applicable	Student Pages • Unit Pre-assessment • Student Reading 1 • Journals 1 and 2 • Data Sheet 1 • Maps 1 and 2
Notes		

2: Tsunami Surfing?

Can you surf a tsunami?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 6: Nature of Matter and Energy - Waves **Science 7: Force and Motion** - Laws of Motion **Language Arts: Reading Informational Text** - Integration of Knowledge and Ideas (RI) **ʻIke Hoʻokō - Applied Achievement Pathway**	**PS.6.5** Compare transverse and longitudinal waves and their properties. **PS.7.1** Apply the laws of motion to determine the effects of forces on the linear motion of objects. **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text. **NHMO.7.2** Demonstrate the use of acquired knowledge through application.	**Waves and Electromagnetic Radiation** **HS-PS4-1**. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	• How to calculate the velocity of a wave • Velocity as a bigger factor in determining the energy of destruction than mass • Transverse vs longitudinal wave characteristics • Surface wave versus tsunami wave characteristics • Use of appropriate scales to compare data

Assessment	Assessment Adjustments for NGSS	Class Periods: **1 - 2**
Students: • Compute answers, showing their work, for the equations provided on Student Journal 3. • Analyze information from several sources and accurately explain, in writing, the difference between a wind-generated wave and a tsunami. Notes	Students: • Are presented the problem in Student Journal 3 in reverse. • Using a completed formula with Hawaiʻi as the potential impact zone, they determine the location of the tsunami trigger.	Student Pages • Reading 1 • Journals 3 and 4

3: Kai E‘e

How would our local landforms affect the potential impact of tsunami in our community?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 6: Nature of Matter and Energy - Waves **Science 7: Force and Motion** - Laws of Motion **‘Ike Ho‘okō - Applied Achievement Pathway**	**PS.6.5** Compare transverse and longitudinal waves and their properties. **PS.7.1** Apply the laws of motion to determine the effects of forces on the linear motion of objects. **NHMO.7.2** Demonstrate the use of acquired knowledge through application.	**Waves and Electromagnetic Radiation** **HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. **History of the Earth** **HS-ESS2-1** Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	• How tsunamis move through the water and interact with landforms (defocus, refraction, reflection, diffraction, interference) • Seiche and how standing wave responds to various ocean depths and geography

Assessment	Assessment Adjustments for NGSS	Class Periods: 2 - 3
Students: • Complete a prediction sheet demonstrating their ability to collaboratively predict based on transfer of prior knowledge. • Complete a quiz demonstrating their understanding of reflection, refraction, and diffraction. • Create a map of their shoreline based on using digital media and observing and recording their surroundings.	Students: • Apply the knowledge they have gained from the digital and hands-on model to design or redesign a harbor, showing ocean floor and shoreline features that would reduce potential tsunami damage (include seiche).	Student Pages • Quiz 1 • Journals 5 and 6
Notes		

4: Tsunami Causes

How does nature move ocean water?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 6: Nature of Matter and Energy - Energy and its Transformation **Science 8: Earth and Space Science** - Forces that Shape the Earth **ʻIke Hoʻokō - Applied Achievement Pathway**	**PS.6.2** Explain how the law of conservation of energy is applied to various systems. **ES.8.5** Explain the effects of movements of crustal plates. **NHMO.7.2** Demonstrate the use of acquired knowledge through application.	**History of the Earth** **HS-ESS2-1** Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	• Causes of tsunami waves - earthquakes, landslides, volcanic activity, asteroid impact • Energy transfer and conservation • Methodological factors in research study design that must be taken into account

Assessments	Assessment Adjustments for NGSS	Class Periods: 2 - 3
Students: • Demonstrate and explain the effects of movements of crustal plates and other tsunami causes. • Explain how the law of conservation of energy applies to the release and transfer of energy from a tsunami trigger to the tsunami waves. • Research and explain conclusions about the most common cause of tsunamis.	Students: • Develop a model (diagram) to illustrate how Earth's internal surface processes form a continental or ocean-floor feature, such as a volcano or submarine trench. • Explain how this feature is related to tsunami triggers. • Show spatial and temporal scales for their selected feature.	**Student Pages** • Journals 7 and 8
Notes		

5: The Decision

How do we use the tools of science to help us predict the potential impact of a tsunami on our community?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Investigation **Language Arts: Reading Informational Text** - Integration of Knowledge and Ideas (RI) **Language Arts: Speaking and Listening** - Presentation of Knowledge and Ideas (SL) **‘Ike Piko‘u - Personal Connection Pathway** **‘Ike Ho‘okō - Applied Achievement Pathway**	**PS.1.3** Defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data. **PS.1.6** Engage in and explain the importance of peer review in science. **PS.1.7** Revise, as needed, conclusions and explanations based on new evidence. **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text. **SL.9-10.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation. **NHMO 5.2** Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future. **NHMO.7.2** Demonstrate the use of acquired knowledge through application.	**Engineering Design** **HS-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	• Determine that it is not appropriate to generalize from one anecdotal case • Use appropriate scales to compare data • Recognize methodological factors in research study design that must be taken into account • Recognize possible sources of bias

Assessment	Assessment Adjustments for NGSS	Class Periods: 3
Students: • Use two formats to answer the unit essential question - individually in writing, and then collaboratively. (See page 1 of Unit Map for details.)	Students: • Evaluate their school site's vulnerability to tsunamis and propose actions to reduce vulnerability. • Prioritize criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**Student Pages** • Culminating Project Documents (The Scenario and Community Map) • Rubrics • Unit Post-assessment
Notes		

NAME______________________________ DATE__________ POINTS_____

The Decision: Individual Writing Rubric

Standard Benchmarks / Criteria	Below Points_____	Approaching Points_____	Meets Points_____	Exceeds Points_____
Analytical Reasoning and Evaluation **Physical Science - PS.6.5** **'Ike Ho'okō - Applied Achievement Pathway NHMO.7.2**	• Does not identify facts or ideas that support or refute the argument • Disregards or severely misinterprets important information • Does not make claims about the quality of information and/or uses unreliable information • Does not integrate quantitative or technical analysis with qualitative analysis	• Identifies a few facts or ideas that support or refute the arguments • Disregards important information or makes minor misinterpretations of information • Rarely makes claims about the quality of information and may present some unreliable information as credible • Integrates some quantitative or technical analysis with qualitative analysis	• Identifies several facts or ideas that support or refute the arguments • Demonstrates accurate understanding of the scenario and evidence to support or refute it • Makes a few accurate claims about the quality of information • Integrates quantitative or technical analysis with qualitative analysis	• Identifies several facts or ideas that support or refute the arguments • Demonstrates accurate understanding of the scenario and evidence to support or refute it • Makes several accurate claims about the quality of information • Effectively integrates quantitative or technical analysis with qualitative analysis
Problem Solving **Physical Science - PS.1.3, PS.1.7, PS.6.5** **'Ike Ho'okō - Applied Achievement Pathway NHMO.7.2**	• Provides no clear decision or no valid rationale for the decision • Does not defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data	• Provides or implies a decision and some reason to favor it, but the rationale may be contradicted by unaccounted for evidence • Attempts to defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data	• Provides a decision and a solid rationale based mostly on credible evidence from multiple sources and discounts alternatives • Defends and supports conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data	• Provides a decision and a solid rationale based on credible evidence from a variety sources; Weighs and discusses other options, but comes to a single conclusion based on the evidence provided • Accurately defends and supports conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data

Writing Mechanics and Effectiveness **Language Arts - RI.9-10.7 SL.9-10.4**	• Does not develop convincing arguments • Writing is disorganized and confusing • Does not elaborate on facts and/or ideas • Many errors and limited use of grammatical convention • The response is hard to understand or judge because of writing • Writes sentences that are repetitive or incomplete • Uses simple vocabulary or uses vocabulary incorrectly	• Provides limited or unclear arguments • Provides relevant information but does not weave it into the argument • Source of information unclear • Provides elaboration on facts or ideas a few times • Demonstrates a fair control of grammatical convention with possibly frequent, but minor errors • Sentences read naturally but with simple structure and similar length. • Uses vocabulary communicates ideas, but lacks variety	• Organizes response in a logical way that makes it easy to follow • Source of information 'cited' in the writing (even if not in a formal citation style) • Provides valid elaboration on facts or ideas • Demonstrates a good control of grammatical convention • Consistently writes well-constructed sentences with varied structure and length • Uses varied and sometimes advanced vocabulary to effectively communicate ideas	• Organizes response in a logical and cohesive way that makes it easy to follow • Source of information 'cited' in the writing (even if not in a formal citation style) • Provides valid and comprehensive elaboration on facts or ideas for each point of argument • Demonstrates an outstanding control of grammatical convention • Consistently writes very well-constructed sentences with complex and varied structure and length • Displays an adept use of vocabulary that is precise, advanced, and varied
Extended Activity NGSS - Engineering Design **ETS1-3**	• Did not evaluate our school site's vulnerability to tsunamis and/or propose an action to reduce vulnerability • Prioritization of some criteria and trade-offs did not exhibit thoughtful or meaningful analysis	• Evaluated our school site's vulnerability to tsunamis and proposed an action to reduce vulnerability • Prioritized some criteria and trade-offs that account for a few constraints	• Evaluated our school site's vulnerability to tsunamis and proposed actions to reduce vulnerability • Prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	• Evaluated our school site's vulnerability to tsunamis and proposed meaningful actions to reduce vulnerability • Prioritized criteria and trade-offs with a detailed and thoughtful analysis that accounted for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts

Adapted from: *CLA in the Classroom,* 2010. New York: CLA in the Classroom.

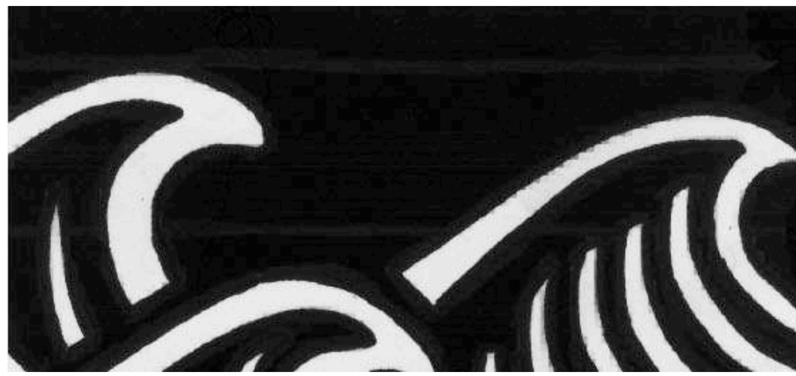
NAMES________________________________ **DATE**__________ **POINTS**_____

The Decision: Board Meeting Rubric
To be filled out by both teacher and student

	Below **Points**_____	**Approaching** **Points**_____	**Meets** **Points**_____	**Exceeds** **Points**_____
Understanding Understanding of the question is demonstrated by the use of cited evidence to prove the position.	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:
Participation Participation takes the form of: listening, speaking, questioning, and probing for specificity.	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:	Teacher Comments: Student Comments:

JOURNAL

KAI E‘E – MOUNTING SEAS
TSUNAMI UNIT



NAME: ______________________________

SCHOOL: ______________________________

DATE STARTED: ______________________________

DATE COMPLETED: ______________________________

Unit Assessment Overview

Unit Essential Question: *How do we use the tools of science to help us predict the possible destructive power of a tsunami on our community?*

Nā Honua Mauli Ola (NHMO) - Hawaiian Cultural Pathways

ʻIke Pikoʻu - Personal Connection Pathway

- Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.

ʻIke Hoʻokō - Applied Achievement Pathway

- Demonstrate the use of acquired knowledge through application.

ʻIke Honua - Sense of Place Pathway

- Be keen observers of their natural environment.
- **Values:** kuleana (responsibility) and lōkahi (unity)

Lessons, Standards, and Student Sheets	Completed ✓
1. **Tsunamis in Our Community** - Math - Number and Quantity 3; Language Arts - Reading Informational Text 7, 10 Student Reading 1, Student Journals 1 and 2, Student Maps 1 and 2, Student Data Sheet 1	
2. **Tsunami Surfing?** - Science 6 and 7; Language Arts - Reading Informational Text 7 Student Reading 2, Student Journals 3 and 4	
3. **Kai Eʻe** - Science 6 and 7 Student Journals 5 and 6, Student Quiz 1	
4. **Tsunami Causes** - Science 6 and 8 Student Journals 7 and 8	
5. **The Decision** - Science 1; Language Arts - Reading Informational Text 7; Language Arts - Speaking and Listening 4 Student Unit Culminating Documents	

INDIVIDUAL PROJECT DUE DATE:________________________

By the end of this unit, you will have the tools necessary to serve as a "school board member" participating in a mock board meeting. To prepare for the board meeting use the unit journals, data sheets, maps, and readings about tsunamis as evidence to individually analyze information and make a determination on which of two sites is safer to build a new school. The scenario for this, including a map of the sites, will be provided. Write a paper to prove your conclusion using evidence from the documents in the unit.

- You will have 30 minutes to individually address the scenario in writing.
- Follow the instructions provided in the scenario.
- Use all documents, not just the document you become an expert on, to make and support a decision about the scenario.
- Nothing else should be on your desk besides the listed documents, the scenario handout, and paper you write on to address the scenario.
- At the end of the allotted time, turn in your written assignment to your teacher.
- A graded copy or a photocopy of your writing will be returned to you so you can use it to prepare for the mock board meeting.
- Be sure to use your 30 minutes well; make sure your writing has an introduction, proves your point using evidence, and has a conclusion.

GROUP PROJECT DUE DATE:________________________

You will engage in a mock board meeting to come to consensus on varying opinions developed in the individual written response. You will share your own findings by presenting your information to a large group and draw conclusions about your own school's risk.

- Hold a mock board meeting addressing the scenario.
- Convene the meeting with desks in a circle and the teacher, as the board chairperson.
- One student will begin by volunteering his/her position on which option to support and why.
- All students will take turns volunteering to support or refute the argument.
- Respond to each other, not just the board chairperson.
- Vote on the results.
- Be prepared to go over the evidence that supports your choice and discuss how you analyzed the evidence.

    What were the key pieces of evidence that led to the selection of the correct site?
    Why is it not appropriate to generalize from an anecdotal case?
    Was there evidence of bias in any of the documents? Explain.
    Do results from all studies apply to all settings? Why or why not?

Tsunamis in Our Community

How could a tsunami affect me?

Activity at a Glance

Students read an account of a tsunami survivor and write a Journal response reflecting on how a tsunami's impact would be different or similar today. Students conduct research and use resources provided to map historic tsunami frequency and impact on communities around the world, looking for patterns.

Key Concepts

- Tsunamis regularly effect communities in Hawai'i and around the world.
- Tsunamis can have a devastating impact on property and lives.
- Community kuleana (responsibility) is important to saving lives and property when tsunami warnings are issued.

Skills

Collecting data through research; organizing data into tables, charts, and/or maps; interpreting data for patterns; historical empathy

Assessment

Students:
- Write a journal response demonstrating historical empathy, writing effectiveness, writing mechanics, and comprehension of a reading.
- Create a table and/or chart based on their research and organization of data.
- Write about patterns they see in the data tables and/or charts that they create, demonstrating their ability to interpret data correctly.

Suggested Timeframe

Two to three 50-minute class periods

Day 1: Introducing the unit; part 1- survivor story
Day 2: Tsunami patterns; mapping

Common Core Standards

Language Arts: Reading for Informational Text (RI) - Literacy in History/Social Studies: Grades 9-10 Range of Reading and Level of Text Complexity

- **RI.9-10.10** By the end of grade 10, read and comprehend history/social studies texts in the grades 9–10 text complexity band independently and proficiently.

Language Arts: Reading - Integration of Knowledge and Ideas

- **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

Math - HS .Number and Quantity: Quantity

- **N-Q.HS.3**. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Nā Honua Mauli Ola

'Ike Honua - Sense of Place Pathway
- **NHMO.8.1** Be keen observers of their natural environment

Materials

Provided
- Unit Pre-assessment (provided in Unit Introduction)
- The Herbert Nishimoto Story (provided in Appendix to be labeled Student Reading 1)
- Student Maps 1 and 2 (enlarge maps for most effectiveness)
- Student Journal 1
- Student Data Sheet 1 - Tsunami Patterns
- Student Journal 2 - Tsunami Patterns
- Tsunami survivor stories (provided in Appendix and on DVD)

For You to Provide
- Access to online research (or print appropriate information from websites provided for extended research)

Getting Ready

✓ Review the Student Assessment Overview and Unit Pre/Post-assessment provided in the Unit Introduction. Copy these documents for each student.

✓ Browse this Teacher's Guide for an overview of content and delivery.

✓ Decide which parts of this guide are most useful for your purposes, and use the Unit Map provided to individualize your delivery. (Note, however, that the culminating activity for the unit uses materials from each lesson, including: Student Readings 1 and 2, Student Data Sheet 1, and Student Journals 4, 5 and 8.)

✓ Make copies of the student pages from this lesson and the Journal pages provided in the Unit Introduction to distribute to each student.

✓ Copy the Historic Timeline of Kai E'e (tsunamis) in Hawai'i from the Appendix and provide a copy for students to place in their Journals.

✓ Copy the Herbert Nishimoto story from the Hawai'i island Appendix for each student. Have students label this story **Student Reading 1**.

Vocabulary

Kai e'e: mounting or rising sea

Tsunami: a series of waves created by a sudden displacement of water

Teacher Background Information

Tsunamis are a real and present threat for all living in Hawai'i, especially those who live in, work in, go to school in, or frequent tsunami evacuation zones. For those, an intimate knowledge of the power of tsunamis, as well as a presence of mind to react appropriately in the face of an emergency can make a huge difference in preventing injuries and saving lives.

Tsunamis have had an impact on the Hawaiian Islands. Being islands in the middle of the Pacific, we are surrounded by tectonic activity, volcanic activity, and areas susceptible to landslides. This means we have every reason to prepare our communities for the inevitable occurrence of a tsunami.

By exploring historical accounts of people who survived tsunamis in Hawai'i, we can gain a clearer understanding of the possible impacts. The story of Herbert Nishimoto takes students back to 1946 to the island of Hawai'i, to Laupāhoehoe and to Hilo. Students read about a tsunami's impact from the point of view of a high school student. Employing historical empathy, students are asked to imagine what Mr. Nishimoto's story would be like today, for them, in their community.

Historic information about tsunamis that have caused 2,000+ deaths is provided with this lesson. Students are asked to graphically organize this information on a map and then to look for patterns. The information and its source are provided in Student Data Sheet 1. More information can be accessed at: http://www.ngdc.noaa.gov/hazard/tsupub.shtml (click on *United States Tsunamis 1690-1988* for U.S. specific information including Hawai'i). The source is detailed and should be previewed by the teacher. Other sources can be substituted for this source, if necessary.

Both the evidence from Mr. Nishimoto's story and the charts and maps will be used in the culminating activity for this unit.

Teaching Suggestions

Introducing the Unit

1. **UNIT PRE-ASSESSMENT: Post the essential question for the unit.**

   Essential Question: *How do we use the tools of science to help us predict the potential impact of a tsunami on our community?*

   - Distribute the **Unit Pre-assessment** and ask students to write their names, the name of the school and the date at the top of the page.
   - Explain that tsunamis are a natural event that have effected Hawai'i since the islands were born. Explain that during the course of the unit, students will be piecing together clues to understand how tsunamis are created, how they impact Hawai'i and how science can help us predict the impact of a tsunami and protect us from them. To get started, ask them to answer the questions on the **Pre-assessment** to the best of their ability. Explain that they will not be graded on the assessment, but it will help to show what they may already know about tsunamis.
   - Collect student responses and save them for comparison with post-assessment at the end of the unit.

2. **Conduct a discussion about tsunamis to identify what students know and wonder about them.**
   - Assign a recorder to record the main points of the discussion on the board.
   - Create two columns on the board: "I know" and "I wonder."

- Ask students to take turns adding to each of the columns until everyone has added at least one item.
- Debrief with the students:
    - Are there any items in the "I know" column that may need more clarification?
    - Are there any " I wonder" items that have been answered in the course of adding to the list?

3. **Hand out the Journal cover and Unit Assessment Overview pages from the Unit Introduction.**
    - Review the documents.
    - Explain that students will be creating a Journal with pages from different lessons as they progress through the unit and work toward answering the unit essential question.

Part 1: A Survivor Story

4. **Hand out Student Reading 1 - The Story of Herbert Nishimoto.**
    - Hand out **Student Journal 1** and go over the questions that are to be answered from the Reading.
    - Ask the class to take 20 minutes (time may be adjusted) to *actively read* the story and discuss what this entails. Note that *Active reading* involves reading with a pen or pencil and:
        - Circling words that need defining
        - Underlining ideas that are worth remembering
        - Writing notes in the margin when part of the Reading answers one of the questions in Journal 1.

5. **Conduct a timed Think-Pair-Share.**
    - Display the two journal questions on the board:
        - How would the experience of Herbert Nishimoto have been similar or different if it took place today?
        - How would it have looked if it was your school and your friends and your community affected?
    - Ask students to stand up, raise their hands, and find a partner.
    - Once they find a partner, ask students to put their hands down (hands up indicates those who do not yet have a partner).
    - Assign one partner to go first (by a random indicator, such as the tallest, or the one whose birthday is closest to January 1, for example).
    - Explain that student 1 has 30 timed seconds to answer one of the questions on the board.
    - Signal the end of 30 seconds and ask student 2 to answer the same question in 30 seconds.

- Signal the end of 30 seconds and ask students to thank their partners.
- Repeat with at least 2 more partners.

6. **Show survivor stories.**
   - Select some of the survivor stories on the DVD provided with this unit.
   - Alternatively, go to: http://www.discovertsunamis.org
     - Click on *Survivor Stories* under *More Resources*.
     - Click on "Bernard and Richard Waltjen."
     - Watch the video.
   - Discuss the survivor stories as a class in relation to Herbert Nishimoto's Story.

7. **Complete Student Journal 1.**
   - Have students use their notes from their *active reading* as well as ideas they gained from the timed think-pair-share to individually complete Student Journal 1.

Part 2: Tsunami Patterns

8. **Hand out Student Data Sheet 1 and Student Maps 1 and 2.**
   - Give a brief overview of the directions and the data on the handouts.
   - Have students work individually to complete the assignment.
   - Enlarge maps for most effective use of scaled-dots and key.
   - Hand out the Historic Timeline of Kai E‘e (tsunamis) in Hawai‘i (from the Appendix) for students to review and add to their Journals.
   - **Option:** Reproduce the maps on larger paper, or modify the activity to be collaborative where students work on a map projected on a white board.

9. **Hand out Student Journal 2.**
   - Ask students to complete Student Journal 2 individually in class or for homework.

10. **Conduct a class discussion.**
    - Discuss the ideas generated in Student Journal 1 and 2 as well as the data organized on Student Map 1.
    - Were any of the questions raised in the first discussion answered?
    - Were any of the "knowns" from the first discussion confirmed or challenged?
    - What other questions have come up from the work done so far?

Extending the Learning

- Have students read and respond to additional tsunami survivor stories for your island. Discuss the history of tsunamis on your island and where they occur. Encourage students to ask elders in the community about their recollection of more recent tsunamis and share information in class. See the stories provided in the Appendix.

Reference

International Tsunami Information Centre, "IOC Tsunami Glossary." Last modified August 08 2008. Accessed September 2, 2011. http://ioc3.unesco.org/itic/contents.php?id=19

Student Journal 1: Herbert Nishimoto Story

Name: ________________________________ **Date:** ________________

Herbert Nishimoto was a high school student at on Hawaiʻi island when a tsunami struck his community.

▶ How would the experience of Herbert Nishimoto have been similar or different if it took place today? How would it have looked if it was your school and your friends and your community affected?

▶ Answer in a full page journal.

Student Data Sheet 1: Tsunami Patterns

Regional and Local Tsunamis Causing 2,000 or More Deaths

Tsunamis have had an impact on the world since before recorded history. This table shows tsunamis that have been observed and recorded **and** have caused 2,000+ deaths.

The U.S. has not been hit by a tsunami that has caused over 2,000 casualties (in recorded history). However, there have been several tsunamis that have hit the U.S. and caused a loss of life.

The largest earthquake ever recorded in the northern hemisphere, the great Prince William Sound earthquake of 1964, struck Alaska at 5:36 p.m. on March 27, Good Friday. It lasted for nearly four minutes and registered a colossal 9.2 magnitude, making it not only the largest earthquake ever recorded in North America, but also the second largest ever measured on Earth, exceeded only by the great Chilean quake of 1960 (9.5 magnitude).

In many steep-sided fjords and bays in Alaska the violent shaking from the earthquake set off slides of rock and debris that roared down slopes into the sea. These slides, along with submarine landslides, displaced huge amounts of water that generated as many as 20 different local tsunamis, which arrived on shores nearby within minutes of the earthquake.

The crustal movement that occurred during the earthquake also uplifted a large area of sea floor. This vertical displacement in turn caused the main "tectonic" tsunami that traveled across

Date	Source / Location	Estimated Dead or Missing
365	Crete, Greece	5,700
887	Niigata Japan	2,000
1341	Aomori, Japan	2,600
1498	Enshunada Sea, Japan	31,000
1570	Central Chile	2,000
1586	Ise Bay, Japan	8,000
1605	Nankaido, Japan	5,000
1611	Sanriku, Japan	5,000
1674	Banda Sea, Indonesia	2,243
1687	Southern Peru	5,000*
1692	Port Royal, Jamaica	2,000
1703	Boso Peninsula, Japan	5,233*
1707	Enshunada Sea, Japan	2,000
1707	Nankaido, Japan	30,000
1746	Central Peru	4,800
1751	NW Honshu, Japan	2,100
1755	Lisbon, Portugal	60,000*
1771	Ryukyu Islands, Japan	13,486
1783	Strait of Messina, Italy	30,000*
1792	Kyushu Island, Japan**	4,300
1854	Nankaido, Japan	3,000*
1883	Krakatau, Indonesia**	36,000

*May include earthquake casualties
**Tsunami generated by volcanic eruptions
(Table continued on following page)

the entire Pacific Ocean, reaching heights of 15 ft (4.5 m) in Washington State, 11 ft (3.4 m) in Oregon, 14 ft (4.3 m) in California, and 12.5 ft (4 m) in Hawai‘i.

A total of 138 people lost their lives; 15 directly due to the earthquake and 123 as a result of the tsunami waves. Of the tsunami deaths, 82 were victims of local landslide-generated tsunamis in Alaska. The remainder were killed by the main tectonically generated tsunami, mainly around Kodiak Island, but there were tsunami deaths outside Alaska. Though there were no deaths in Washington or Hawai‘i, four children were tragically killed by the tsunami near Newport, Oregon, and 13 people died along the coast of northern California.

Other tsunamis have affected Hawai‘i as well, including the tsunami in Mr. Nishimoto’s account.

Use the table provided and plot (using dots of various sizes or other method of creating a key) each location of a tsunami causing 2,000+ casualties on the maps provided. Create a key to indicate the number of casualties by the size of the dot. Record your key on the maps.

●...●

2,000 - 3,000 200,000+

Use the Historic Timeline of Kai E‘e (tsunamis) in Hawai‘i and the map of the Hawaiian Islands to plot tsunamis that have affected our islands. For additional information see: http://www.ngdc.noaa.gov/hazard/tsupub.shtml and click on: *United States Tsunamis 1690-1988*.

1896	Sanriku, Japan	27,122*
1899	Banda Sea, Indonesia	2,460*
1923	Sagami Bay, Japan	2,144
1933	Sanriku, Japan	27,122*
1941	Andaman Sea, India	5,000
1960	Valdiva, Chile	2,200+*
1976	Moro Gulf, Philippines	3,744
1992	Flores Sea, Indonesia	2,500*
1998	Papua New Guinea	2,183
2004	Banda Sea, Indonesia	227,898*
2011	Tohoku, Japan	15,867

*May include earthquake casualties

Source: Adapted from: The International Tsunami Information Centre: http://ioc3.unesco.org/itic/

Student Journal 2: Tsunami Patterns

Name: ____**Date:** ____________

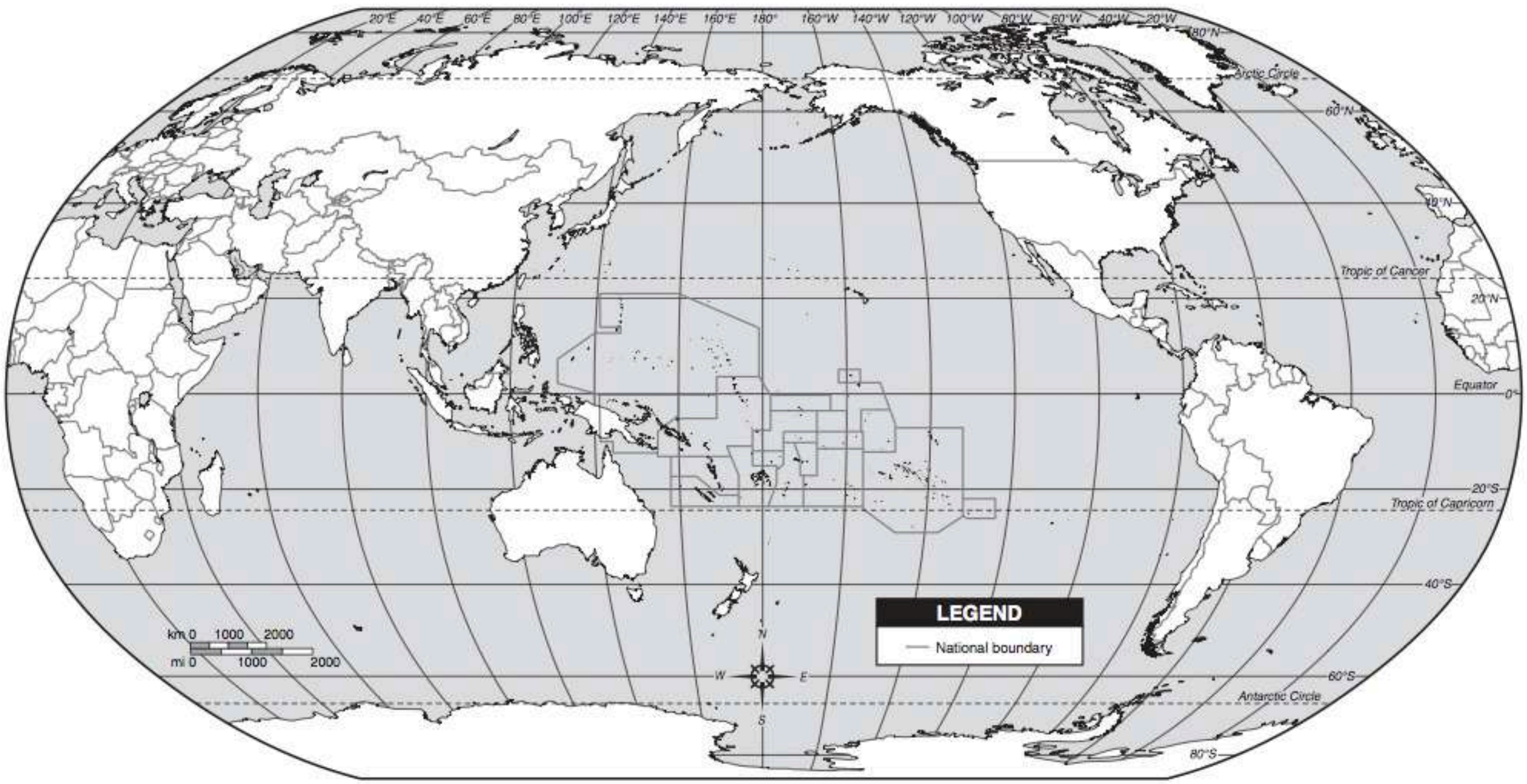
▶ Refer to both the Hawaiʻi and world maps you created. What patterns do you see? Are there any areas that have been hit by more tsunamis than others? Have certain areas had more devastating tsunamis than others?

▶ Write a journal with your observations:

Student Map 1: World

Name: ______________________________________

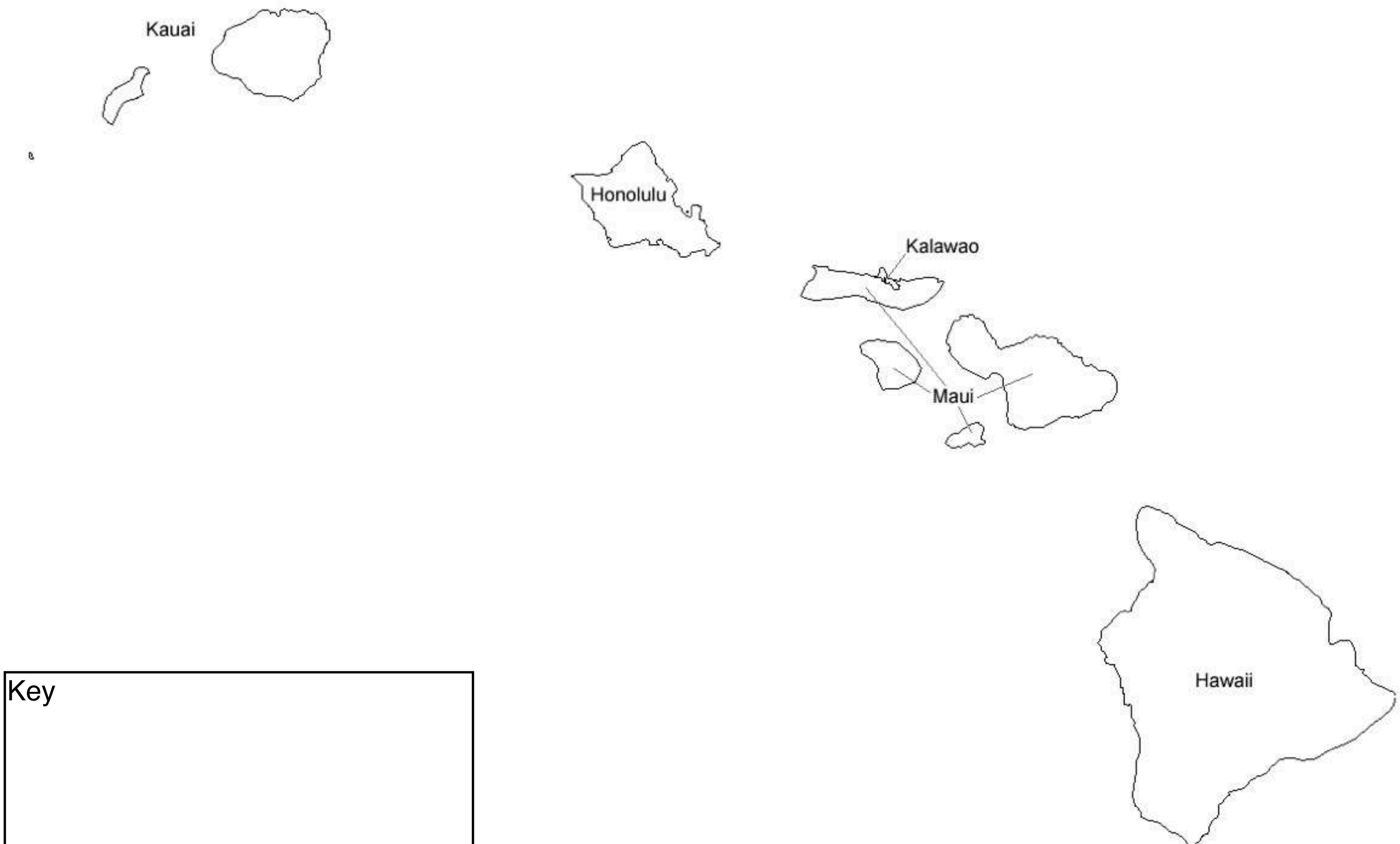
Date: ___________________



Key

Student Map 2: Hawaiian Islands

Name: ____ **Date:** ______________________



Key

Tsunami Surfing?

Can you surf a tsunami?

Activity at a Glance

Students synthesize information to answer questions on Student Journal 3 about tsunamis. They complete a drawing of a tsunami approaching a shoreline (Student Journal 4), and write an explanation of why they can't surf a tsunami.

Key Concepts

- The speed of a tsunami can be calculated with a simple formula.
- Tsunamis have different characteristics than wind-generated waves do.
- It is important to use appropriate scales to compare data.

Skills

Applying information from one scenario to another; using and converting units

Assessment

Students:

- Compute answers, showing their work, for the equations provided on Student Journal 3.
- Analyze information from several sources and accurately explain, in writing, the difference between a wind-generated wave and a tsunami.

Suggested Timeframe

One - two 50-minute class periods, plus homework

Day 1: Physics of tsunami waves
Day 2: Assessing for understanding

Hawai‘i State Standard Benchmarks

Science 6: Physical, Earth and Space Science - Nature of Matter and Energy

- **PS.6.5** Compare transverse and longitudinal waves and their properties.

Science 7: Physical, Earth and Space Science - Forces and Motion

- **PS.7.1** Apply the laws of motion to determine the effects of forces on the linear motion of objects.

Common Core Standards

Language Arts: Reading Informational Text - Literacy in History/Social Studies: Integration of Knowledge and Ideas Grades 9-10

- **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

Next Generation Science Standards

- **HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Nā Honua Mauli Ola

‘Ike Ho‘okō - Applied Achievement Path

- **NHMO.7.2** Demonstrate the use of acquired knowledge through application.

Materials

Provided

- Student Reading 2: Why Can't We Surf a Tsunami?
- Student Journal 3: Tsunami Speed
- Student Journal 4: Height Isn't Everything

For You to Provide

- Slinky toy

Getting Ready

✓ Duplicate all student pages to distribute to each student.

✓ Prepare the introduction to this lesson.

✓ Preview the animation from the Geophysics Institute, University of Alaska Fairbanks: Alaska Tsunami Education Program website: http://www.aktsunami.com/

- Click on *Multimedia*
- Click on *Tsunami Propagation*
- Click on *Wave Particles*

Vocabulary

Longitudinal waves: waves that transfer energy in the same direction as the disturbance

Transverse waves: waves that transfer energy in a direction perpendicular to the direction of the disturbance

Wave period: the number of crests (or troughs) that pass through in a set amount of time

Wavelength: the distance between wave crests or troughs or any two points with the same phase

Wave height: the distance from the top of the crest to the bottom of the trough

Teacher Background Information

Tsunami waves have wavelengths up to 120 mi (~200 km). Tsunami wave velocity depends on the depth of the water, but can average nearly 500 mph (805 km/hr) in the deep Pacific Ocean. With wave height on the open ocean averaging just 3.3 ft (1 m), it may take 30 minutes to an hour for a tsunami to pass under a boat at sea, barely detectable, if at all. These long wavelengths are one significant feature of a tsunami. Since waves only touch the bottom of the ocean in water less than half their wavelength, tsunamis always touch the bottom. A wave with a 33 ft (10 m) wavelength would only feel the effects of the bottom of the ocean in approximately 16.5 ft (5 m) of water.

As soon as a tsunami moves into shallower water its energy begins to drag more and more on the bottom of the ocean, and the front of the wave begins to slow down, allowing the back of the wave to catch up. Once this begins, the wave starts to stack up and gain in height. As the deepest parts of the wave slow down the most, the crest begins to rush ahead (Hyndman et. al. 2006).

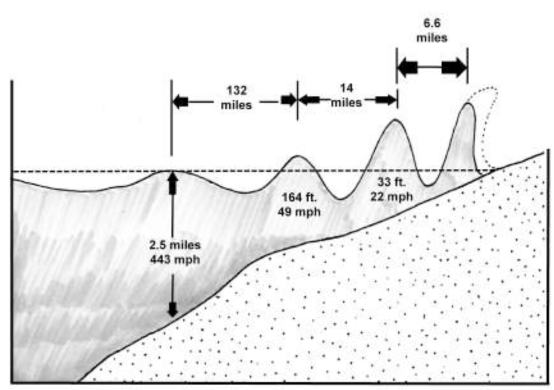


Diagram not to scale

The initial wave height of a tsunami on the open ocean is also important when looking at its effect. A tsunami approximately 3 ft (1 m) in height on the open ocean can drastically shorten its wavelength when entering shallow water. A three-foot (~1 m) wave on the open ocean can become 13 - 16 ft (4 - 5 m) in shallow water. As seen in the 2011 tsunami that hit Japan, run-up heights can be even greater than wave heights, causing great damage.

A tsunami with a wavelength of approximately 93 mi (150 km) traveling 311 mi/hr (500 km/hr) at a depth of 6,562 ft (2,000 m), would have a wavelength pass a given point about every 18 minutes. Since a tsunami is not one wave, but a series of waves, many people are injured when they go down to the shoreline, or return to an inundation zone after the first wave has subsided. It is also a misconception that a trough always reaches land first. Depending upon how the tsunami was caused, either the trough or crest may reach land first. A sudden falling of large chunk of rock in a submarine landslide, for example, might cause a trough to be formed in front. However a sudden explosion of a submarine volcano may cause a crest to be formed at the front.

Which ever way a tsunami is formed, being able to calculate its speed is essential to researchers who use the information to save lives. Models of arrival times have been generated so that an arrival time (give or take a few minutes) can be projected for any location on the planet (once the origin of the tsunami is known). This ability to predict arrival time has saved innumerable lives.

Tsunami speed is calculated using the formula:

$$\text{speed} = \sqrt{g \times d}$$

Speed (measured in meters/second) = square root of g (acceleration due to gravity, which is a constant at 9.81 meters/second^2) x d (water depth in meters; for this lesson, the average depth of the water in which a tsunami travels).

Teaching Suggestions

Part 1: Physics of Tsunami Waves

1. **Present the focus question of the lesson and discuss it.**

   Focus Question: *Can you surf a tsunami?*

   - Discuss students' responses and suggest they learn more about the physics of waves to answer this question.

2. **Give an overview of the physics of tsunami waves.**
   - Define the vocabulary, specifically *wave height, wave period,* and *wavelength*.

- Explain how ocean wave movement is both transverse and longitudinal. You may want to use the animation on the site: Alaska Tsunami Education Program http://www.aktsunami.com/
    - Click on *Multimedia*
    - Click on *Tsunami Propagation*
    - Click on *Wave Particles*
- Give examples of other transverse waves and other longitudinal waves. This can be done with a slinky illustrating the compression of a longitudinal wave and the back-and-forth movement of a transverse wave.
- Explain how to calculate tsunami wave speed.
- Have students try it with a partner and check their answers.
- More multimedia examples are available at: http://discovertsunamis.org/resources.html

NGSS:
Present the problem in Student Journal 3 in reverse.

Using a completed formula with Hawai'i as the potential impact zone, have students determine the location of the tsunami trigger.

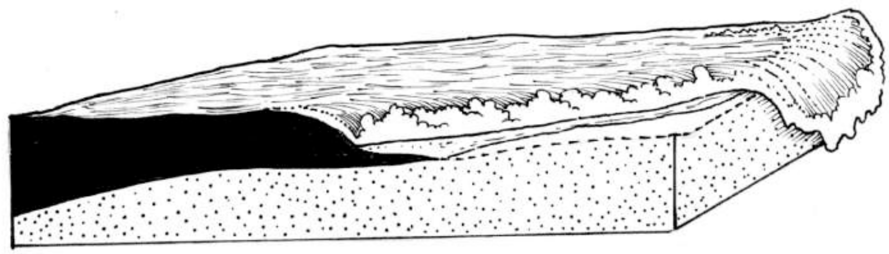
3. **Hand out Student Reading 2 and Student Journal 3.**
    - Go over the instructions as a class.
    - Pair up students and instruct them to use information from the Reading to answer Student Journal 3.
    - If more practice is necessary, see online resources listed in the Extending the Learning section below.

Part 2: Assessing Understanding

4. **Assess students' understanding of tsunamis.**
    - Go to the Alaska Tsunami Education Program www.aktsunami.com/
        - Click on *Multimedia*
        - Click on *Tsunami Generation*
        - Click on *How a Tsunami Forms* (5th option)
    - View the multimedia demonstration and initiate a discussion.
        - Based on what we have learned so far, what you have answered in **Student Journal 3**, and this multimedia demonstration, what do you *know* about tsunamis?
        - What do you *wonder* or want to know about tsunamis?
    - Assign a recorder to record the main points of the discussion on the board.
    - Create two columns on the board: "I know" and "I wonder".
    - Ask students to take turns adding to each of the columns until everyone has added at least one item.
    - Debrief with the students:
    - Are there any items in the "I know" column that may need more clarification?
    - Are there any " I wonder" items that have been answered in the course of adding to the list.

- More multimedia examples are available at: http://discovertsunamis.org/resources.html

5. **Hand out Student Journal 4.**
   - Ask students to complete it individually.
   - Collect and assess for understanding. An illustration of what a tsunami wave might look like when it reaches the shore is provided below.



Extending the Learning

- For more digital modeling and further online resources check out: http://www.whoi.edu/home/interactive/tsunami/indexEnglish.html
- For more information and practice calculating tsunami speed check out: http://cioss.coas.oregonstate.edu/CIOSS/Documents/Outreach/Feb08/5Faster_than_Speeding_Tsunami.pdf

References

Hyndman, Donald, and David Hyndman. *Natural Hazards and Disasters*. Belmont, CA: Thomson Brooks Cole. 2006.

Seismic Safety Commission, "The Tsunami Wave." Last modified 2007. Accessed September 12, 2011. http://www.seismic.ca.gov/tsunami.html.

Uy, Anthony. The University of British Columbia, "The Physics of Tsunamis: The Harbour Wave." Accessed October 1, 2011. http://outreach.phas.ubc.ca/phys420/p420_05/anthony/ThePhysics of Tsunamis.htm.

Student Reading 1: Why Can't We Surf a Tsunami?

Wave period: the number of crests (or troughs) that pass through in a set amount of time
Wavelength: the distance between wave crests or troughs or any two points with the same phase
Wave height: the distance from crest to trough

Tsunami is a Japanese word that literally means *harbor wave*. People have misnamed them tidal waves for years. They are not caused by the gravity of the sun nor moon, which causes the tides. They are also very different from wind-generated waves; the kind the we surf.

Wind-generated Waves

- Wind-generated waves are created when wind blows over the surface of the water, causing energy to transfer from air to water. As energy gathers, these waves gain strength and speed.
- Their speed in deep water is determined by *wavelength* - the distance between two crests. The average wind-generated wave on the open ocean is traveling 25 - 56 mph (40 - 90 km/hr); about as fast as a moped drives.
- They slow down as they enter shallow water as their energy begins to drag against the bottom of the ocean floor. The back of the wave begins to catch up with the front and it piles up getting higher and eventually breaking in shallow water.
- Wind-Generated waves have a *period* of 5 - 20 seconds, on average. That means that there is usually 5 - 20 seconds between wind-generated waves passing under you.
- The average wavelength of a wind-generated wave is 328 - 656 ft (100 - 200 m).

Tsunami

- A tsunami is a series of waves that is created by a sudden displacement of water (maybe by a landslide dumping a huge amount of rock into the ocean all at once, or an earthquake moving a huge volume of rock up or down or sideways).
- Tsunamis move much faster than wind-generated waves (you'll get to calculate how fast in a just a bit).
- Because of their long wavelength, they lose very little energy as they travel. A wave loses energy at a rate that is inversely proportional to its wavelength. So a wave with a large wavelength loses energy slower than a wave with a short wavelength.
- Tsunami waves have wavelengths up to 120 mi (~200 km). Therefore, a powerful tsunami loses energy at a very low rate. They are efficient waves. There is a very simple way to figure out how fast a tsunami is traveling:

Speed (measured in meters/second) = square root of g (acceleration due to gravity, which is a constant at 9.81 meters/second^2) x d (water depth in meters, the average depth of the water in which a tsunami travels).

$$\text{speed} = \sqrt{g \times d}$$

Student Journal 3: Tsunami Speed

Name: ______________________________ **Date:** ____________

Use the information provided in Student Reading 2 to answer the following questions:
Work with a partner to answer questions 1-3.

1. An earthquake off of Alaska could produce a tsunami headed for Hawaiʻi. The average depth of the ocean between Alaska and Hawaiʻi is 5,420 m (17,782 ft). What would the average speed of the tsunami be in meters per second? (Show your work.)

2. Convert your answer from meters per second to kilometers per hour. (Show your work.)

3. The distance between Alaska and Hawaiʻi is approximately 7,725 km (4,800 mi). How long will the tsunami take to reach Hawaiʻi? (Show your work.)

Work individually to answer questions 4-7.

4. An earthquake off of Chile could produce a tsunami headed for Hawaiʻi. The average depth of the ocean between Chile and Hawaiʻi is 4,000 m (13,123 ft). What would the average speed of the tsunami be in meters per second? (Show your work.)

5. Convert your answer from meters per second to kilometers per hour. (Show your work.)

6. The distance between Chile and Hawaiʻi is approximately 10,842 km (6,737 mi). How long will the tsunami take to reach Hawaiʻi? (Show your work.)

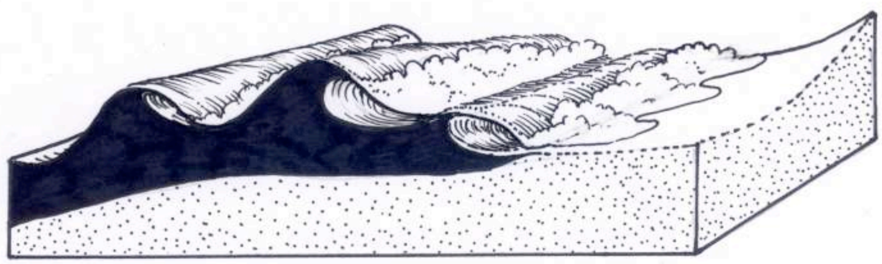
7. Why is it useful to be able to calculate the speed of a tsunami?

Student Journal 4: Height Isn't Everything...

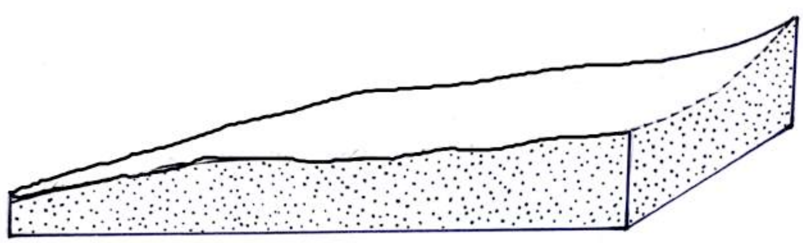
Name: ______________________________ **Date:** ____________

Directions:

Provided is an illustration of a wind-generated wave reaching shore. Notice wave height and wavelength.



1. Describe in either words or as an illustration, using the graphic below, what a tsunami wave might look like as it reaches shore. Address both wave height and wavelength in the illustration.



2. Taking into consideration speed, wave height, and wavelength, why can't you surf a tsunami?

Kai E‘e

How would local landforms affect the potential impact of a tsunami in our community?

Activity at a Glance
Students use physical and digital models to explore reflection, refraction, diffraction, and seiche. Students begin by collaborating to predict how waves will interact with barriers and culminate the lesson with a quiz and a mapping experience.

Key Concepts
- Tsunami waves moving from deep to shallow water will change direction or bend as the part of the wave front that first encounters shallow water slows down and the parts of the wave front still in deeper water continue to move faster (refraction).

- Tsunami waves encountering an obstacle can bend around it or spread out after moving through an opening (diffraction).

- A standing wave in an enclosed or partially enclosed body of water (seiche), and other interactions with barriers and the ocean bottom can dramatically alter a tsunami's impact on land.

Skills
Accessing prior knowledge, drawing diagrams, observing nature, researching digital media

Assessment
Students:
- Complete a prediction sheet demonstrating their ability to collaboratively predict based on transfer of prior knowledge.

- Complete a quiz demonstrating their understanding of reflection, refraction, and diffraction.

- Create a map of their shoreline based on using digital media and observing and recording their surroundings.

Hawai‘i State Standard Benchmarks

Science 6: Physical, Earth and Space Science - Nature of Matter and Energy

- **PS.6.5** Compare transverse and longitudinal waves and their properties.

Science 7: Physical, Earth and Space Science - Forces and Motion

- **PS.7.1** Apply the laws of motion to determine the effects of forces on the linear motion of objects.

Next Generation Science Standards

- **HS-ETS1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

- **HS-ETS1-4** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Nā Honua Mauli Ola

‘Ike Ho‘okō - Applied Achievement Path

- **NHMO.7.2** Demonstrate the use of acquired knowledge through application.

Suggested Timeframe

Two - three 50-minute class periods

Day 1: Tsunami waves and landforms
Day 2: Mapping and predicting

Materials

Provided

- Student Journal 5 - Predicting Wave Behavior
- Student Quiz 1 - Wave Behavior
- Student Journal 6 - Mapping Our Coast
- Reflection, Refraction, diffraction demonstration kit
- Maps (provided in Appendix)

For You to Provide

- Overhead projector or ELMO
- Food Coloring
- Pencils

Getting Ready

✓ Make copies of the student pages to distribute.
✓ Prepare the wave reflection, refraction, and diffraction demonstration.
✓ Review the local coastline maps provided in the Appendix and make a few copies to distribute or display in class.
✓ Preview the Geophysics Institute University of Alaska Fairbanks Alaska Tsunami Education Program website: http://www.aktsunami.com/
- Click on *Multimedia*.
- Click on *Tsunami Propagation*.
- Click on *Wave Interference, Diffraction, Kuril Islands*.

✓ Double check online media listed in Journal 6 for accessibility.

Vocabulary

Diffraction: the process of a wave encountering an obstacle and bending around it or spreading out after going through an opening

Reflection: the change in direction of a wave due to an interface between two different media

Refraction: the change in direction of a wave due to its change in speed

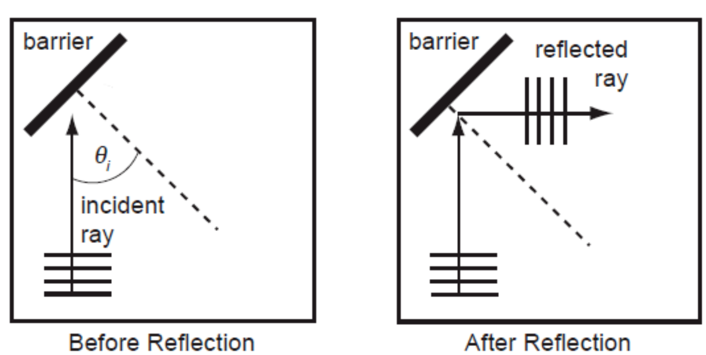
Seiche: a standing wave in an enclosed or partially enclosed body of water, such as a bay

Wave Interference: the phenomenom in which two waves superimpose to form a resultant wave of greater or lower amplitude

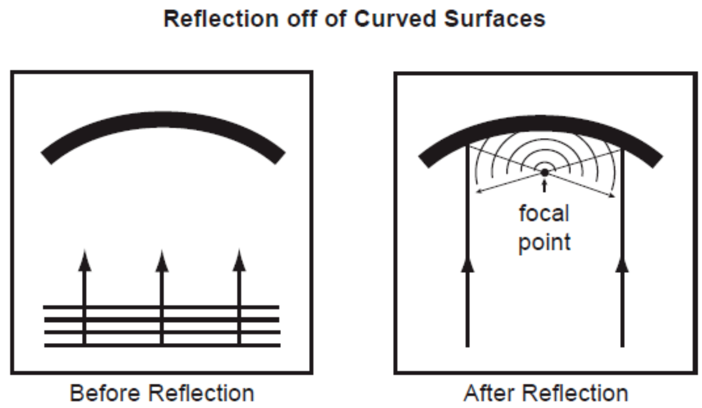
Teacher Background Information

There are many misconceptions about how a tsunami may or may not interact with landforms. On first take, one may believe a bay to be a safer shelter than an exposed coastline when a tsunami hits. However this is not true. A standing wave in an enclosed or partially enclosed body of water (seiche), and other interactions with barriers and the ocean bottom

The Law of Reflection

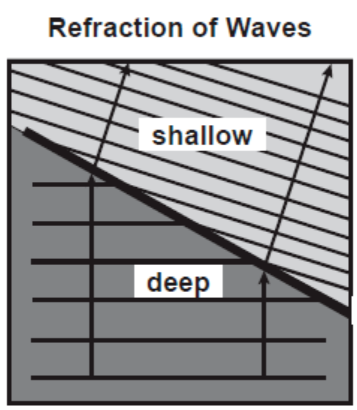


can dramatically alter a tsunami's impact on land.

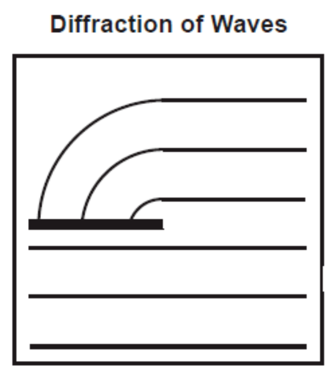


Reflection
Reflection can completely alter a wave's path. When a wave encounters a straight barrier, it bounces off and heads in a different direction. The law of reflection says that the angle of incidence equals the angle of reflection. It is easy to predict where a wave will head once reflected off of a barrier (ATEP 2008).

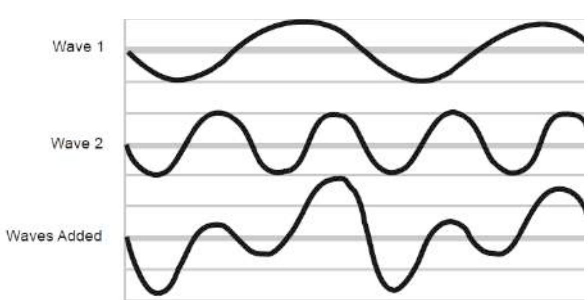
Reflection off Curved Surface
If the barrier is a parabola, then the waves will reflect and focus on a single point called a focal point. Waves entering a bay often times reflect as if they would in the parabola model. Waves hitting a coastline often behave like waves that are reflecting off of a straight barrier (ATEP 2008).



Refraction
Refraction occurs when a wave moves from one media to another. Tsunamis often refract when hitting the continental shelf, or any time they move from deep to shallow water. Not only does speed of the wave change, but the wave direction is impacted as the side that first encounters the shallower water slows down first (ATEP 2008).



Diffraction
Diffraction is the bending of a wave as it travels around or goes through an opening in a barrier. This is the most obvious when a wavelength is greater than the width of the obstacle. As wavelength increases, the degree of diffraction increases (ATEP 2008).



Wave Interference / Seiche
Wave interference occurs when two waves interact. This is often seen in seiche as waves bounce back and forth off of the sides of a bay or other enclosed or semi-enclosed body of water. When two waves interact, a new waveform with different properties is created.

Teaching Suggestions

Part 1: Tsunami Waves and Landforms

1. **Introduce the focus question for the lesson:**
   Focus Question: *How would local landforms affect the potential impact of a tsunami in our community?*

   - Discuss students' initial responses to the question.

2. **Hand out and review Student Journal 5.**
   - Have students form pairs.
   - Ask each pair to take 10 minutes to predict, as best they can, how a wave will act when presented with each new situation presented in the Journal.
   - Suggest that they use pencils on the Journal and reinforce that this is just a prediction where they won't be graded on their guesses.

3. **Conduct a Wave Demonstration.**
   - Use a wave demonstration kit and an overhead projector or an ELMO to show reflection. (Add food coloring to water to make waves appear more clearly).
   - Ask students to predict how the demonstration will turn out and why.
   - Have student groups use the demonstration kit to demonstrate refraction and diffraction and predict how the waves will respond.
   - As students conduct each demonstration, ask them to reflect on how it was different or similar to their predictions. Have students take notes of their observations.
   - Have students diagram the correct wave interactions in their notes and correct their Student Journal 5 as needed.
   - Introduce the concept of a seiche.
   - To replace or supplement the wave demonstration kit, use digital wave models from Alaska Tsunami Education Program: http://www.aktsunami.com/
     - Click *Multimedia*
     - Click *Tsunami Propagation*
     - Click *Wave Interference, Diffraction, Kuril Islands*

   Or go to: http://www.discovertsunamis.org and click on multimedia.

4. **Administer Student Quiz 1.**
   - Review students' responses.

NGSS:

Challenge students to apply the knowledge they have gained from the digital and hands-on model to design or redesign a harbor, showing ocean floor and shoreline features that would reduce potential tsunami damage (include seiche).

Part 2: Mapping and Predicting

5. **Hand out Student Journal 6: Mapping Our Coast.**
   - Introduce students to Google Earth or Google Maps and the National Geophysical Data Center (NGDC) website: http://www.ngdc.noaa.gov/hazard/tsu.shtml
   - Review instructions on Journal 6.
   - Have students use Google Earth or Google Maps and the NGDC website to begin their mapping.
   - Ask students to observe the coastline and other natural features to finish their mapping.
   - Refer to maps provided in the Appendix and hand them out as needed.

6. **Have students work on making wave predictions.**
   - Choose a location for a mock earthquake that could create a tsunami heading for your shoreline.
   - Ask students, in pairs, to predict (using the concepts of reflection, refraction, diffraction, and seiche) what a wave from that location might do as it approached and then hit the shoreline.
   - Remind students that these are just predictions.
   - Discuss predictions with the class as a whole.

Extending the Learning

Have students play the game *Stop Disasters!* Available at: http://www.stopdisastersgame.org/en/home.html

- Have student choose *Tsunami* and then for the first round *Easy*.
- Give students 20 minutes to see how successful they are at saving lives and reducing damage using knowledge they have gained in this lesson.

Reference

Alaska Tsunami Education Program (ATEP). “Lesson 5 – Tsunami Propagation, Wave Behavior (Visual Aid: Wave Behavior, Multimedia Files: Diffraction, Wave Interference, 1964 Seward Model, Kuril Islands)”, Geophysical Institute, University of Alaska Fairbanks. Accessed September 3, 2011. http://aktsunami.org/lessons/912/unit5.html

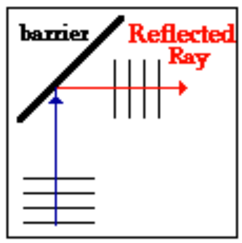
Student Journal 5: Predicting Wave Behavior

Name: ________________________________ **Date:** ______________

Use what you have learned so far and your own observations of nature to predict how a wave will interact with these natural barriers. The first example is done for you. These are just predictions. Use pencil to draw and give it your best shot!

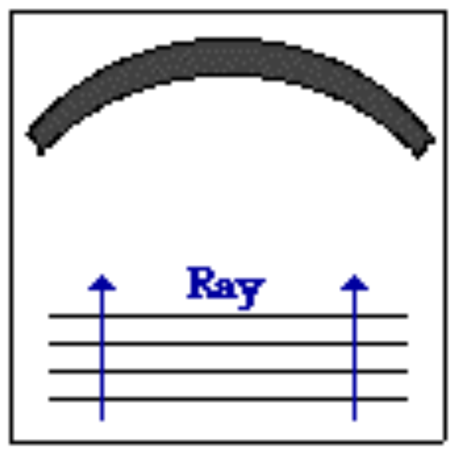
Example: Reflection

Before Reflection

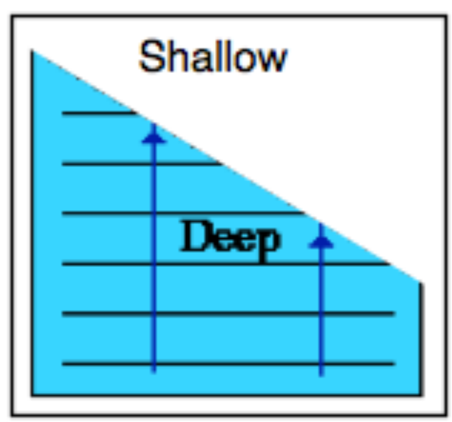


After Reflection

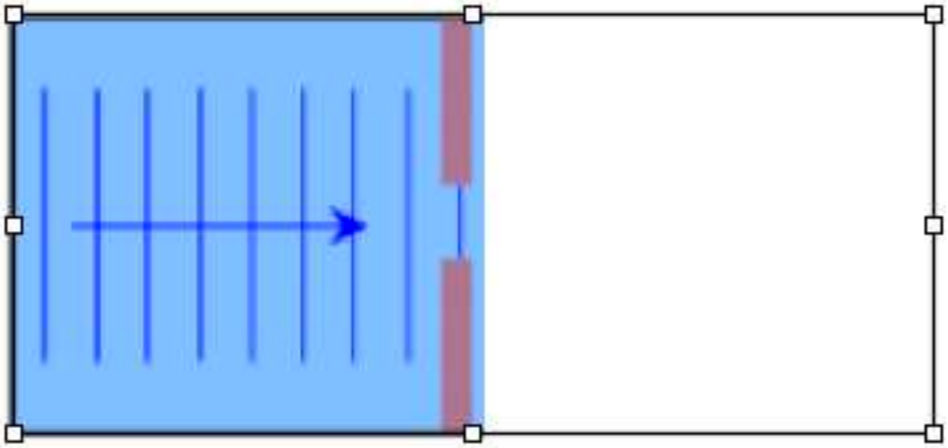
1. Reflection on a Curved Surface: Draw what you think the wave will do once it hits the curved surface and reflects. Use lines to indicate the wave and arrows to indicate direction(s) of the wave (as in the example).



2. Refraction: A wave moving from deep water into shallow water. Use lines to indicate the wave and arrows to indicate direction(s) of the wave as it moves into shallow water (as in the example).



3. Diffraction through a barrier: Draw what you think the wave will do once it hits the barrier in the illustration. Use lines to indicate the wave and arrows to indicate direction(s) of the wave (as in the example).



4. What natural or human-made landforms cause reflection, refraction, and diffraction?

	Definition	Natural Landform	Human-made Landform
Reflection			
Refraction			
Diffraction			
Seiche			

Student Quiz 1: Wave Behavior

Name: ______________________________________ **Date:** ____________

1. Draw an example of **reflection**:

2. Draw an example of **refraction**:

3. Draw an example of **diffraction**:

4. Explain **seiche**:

Student Journal 6: Mapping Our Coast

Name: ______________________________________ **Date:** _________________

Draw a detailed map of ocean barriers and landforms in your community. Use the following resources to create as accurate a map as possible on this page:

1. Google Earth or Google Maps (landforms)
2. National Geophysical Data Center (NGDC): http://www.ngdc.noaa.gov/mgg/coastal/grddas10/grddas10.htm (ocean topography)
3. Observation: with your class, observe the ocean and landforms near your school.

Make sure you include your school, coastline, ocean barriers (such as reefs, large rocks, etc.), ocean depth (from the NGDC website), and any other important information. Label your map.

Draw:

Tsunami Causes

How does nature move ocean water?

Activity at a Glance

Students conduct research to explore causes of tsunamis. They brainstorm and plan their own demonstrations to show how tsunamis are formed, and then share their demonstrations with others.

Key Concepts

- Earthquakes, landslides, volcanic activity, and asteroid impact are all causes of tsunamis.
- Energy driving tsunami waves comes from the potential energy of the tsunami trigger that is transferred into the kinetic energy of the moving waves.

Skills

Researching and building statistical data, explaining complex ideas through modeling

Assessment

Students:

- Demonstrate and explain the effects of movements of crustal plates and other tsunami causes.
- Explain how the law of conservation of energy applies to the release and transfer of energy from a tsunami trigger to the tsunami waves.
- Research and explain conclusions about the most common cause of tsunamis.

Hawaiʻi State Standard Benchmarks

Science 8: Earth and Space Science - Forces that Shape the Earth

- **ES.8.5** Explain the effects of movements of crustal plates.

Science 6: Nature of Matter and Energy - Energy and its Transformation

- **PS.6.2** Explain how the law of conservation of energy is applied to various systems.

Next Generation Science Standards

- **HS-ESS2-1** Develop a model to illustrate how Earth's internal surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Nā Honua Mauli Ola

ʻIke Hoʻokō - Applied Achievement Pathway

- **NHMO.7.2** Demonstrate the use of acquired knowledge through application.

Suggested Timeframe

Two - three 50-minute class periods

Day 1: Brainstorm causes of tsunamis; relationship of plate tectonics to tsunamis.
Day 2: Demonstrations of tsunami triggers
Day 3: Law of conservation of energy and student research into tsunami triggers

Materials

Provided
- Student Journal 7: Creating a Demonstration
- Student Journal 8: Common Causes

For You to Provide
- Supplies to create the demonstration

Getting Ready

✓ Make copies of the the student pages to distribute.
✓ Gather and prepare materials for *Tsunami Causes Demonstration for Options A and B*. (See Teaching Suggestion 4 and Student Journal 7.)
✓ Preview the project website: http://www.discovertsunamis.org
  - Click on *Multimedia*.
  - Scroll down to *Tsunami Generation*.
  - Click on different options to preview.
✓ Double check online media listed in Student Journal 8 for accessibility.

Vocabulary

Convergent boundary: the area where two tectonic plates move towards each other
Divergent plates: two tectonic plates that move away from each other
Kinetic energy: the energy possessed by an object or system due to its motion
Plate tectonics: a geological theory describing how plates in the Earth's lithosphere float and travel on the mantle
Potential energy: stored energy; the energy or ability of an object or system to do work based on its position or internal structure
Strike-slip earthquake: an earthquake created by two tectonic plates slipping past each other in a lateral direction
Subduction: the process by which plates at convergent boundaries push one plate under another
Submarine landslide: a landslide that occurs under water

Teacher Background Information

Tsunamis can be caused by several triggers: earthquakes, landslides, volcanic activity, or asteroid impact. Of these triggers, earthquakes are the most prevalent cause.

Most tsunamis are generated by underwater earthquakes that cause the ocean floor to either suddenly rise or sink. This movement of a large volume of rock displaces a large amount of water, which can cause the long wavelength of a tsunami. Strike-slip earthquakes generally do not produce tsunamis as they do not displace as large a volume of water. Subduction zone earthquakes most often cause tsunamis. Large earthquakes in subduction zones, such as those off of Japan, Kamchatka, Alaska, Mexico and South America, are the most common cases of tsunamis (note: all in the Pacific basin). These subduction zones push one plate under another and store immense amounts of potential energy, like a bow drawn tight. When one plate slips, the potential energy is released resulting in sudden, rapid ground motion. When this occurs under the sea, some of the kinetic energy of the seafloor motion is transferred into the water as kinetic energy in the form of tsunami waves (Hyndman et. al. 2006).

Tsunamis can also be caused by volcanic activity. Underwater volcanic explosions that push rock, gas or ash out in great volume and rapid speed can displace large amounts of ocean water. Similarly, the collapse of the walls of a volcano's caldera into the ocean can push down enough of a volume of water to create a tsunami. Landslides from a volcano flank collapse have created some of the largest tsunamis in the Earth's history. Volcano flank collapses in Hawai‘i have been some of the largest that scientists have found. The windward side of O‘ahu, as well as several parts of the island of Hawai‘i have seen volcanic flank collapses that have created tsunamis of epic proportions. The island of Lāna‘i has evidence of a tsunami carrying blocks of coral as high as 1,070 ft (326 m) above sea level (Hyndman et. al. 2006).

Volcano flank collapses occur in Hawai‘i during the time when the volcano is "settling in" and gradually subsiding on the flexible ocean crust, which makes the volcano unstable and prone to landslides. Much of the caldera, and indeed the northeastern side of the Ko‘olau shield, slid into the ocean in, what must have been, a catastrophic landslide. The Nu‘uanu Slide, as scientists have dubbed it, covers an area of almost 9,000 sq mi (23,310 sq km) on the sea floor (Sinton 1999). Individual blocks of lava as long as 35 mi (56.3 km) were found in the landslide debris. By studying sonar and other remote sensing images of the oceans around our island chain, geologists have identified 17 massive landslides that probably occurred late in the shield-building stage of most Hawaiian volcanoes (Walker 1990).

Similar to flank collapse and volcano-produced landslides, other types of landslides, such as in glacial fjords have caused tsunamis. A large volume of rock quickly moving into the ocean displaces immense amounts of ocean water. While it may seem like the volume of rock plays the biggest part in determining a tsunami's power, the height of the fall is a more important parameter. The Lituya Bay tsunami in Alaska (1958) is a prime example of this (Hyndman et. al. 2006).

Teaching Suggestions

Part 1: Tsunami Causes - Brainstorming

1. **Introduce the focus question for the lesson.**

   Focus Question: *How does nature move ocean water?*
   - Discuss students' responses and list any additional questions that arise.

2. **Conduct a tsunami brainstorm session.**
   - Option A - Students have Internet access individually or in pairs. Students:
     - Go to the website: http://www.aktsunami.com/

- Click on the tab: *Multimedia*.
- Click on the *Tsunami Generation* tab.
- Use the multimedia videos and demonstrations to create a list of all causes of tsunamis they can find in the demonstrations. (earthquake, volcano, landslide, submarine landslide, asteroid impact [not included in multimedia feature])
- Write one to three full sentences to explain how each cause can create a tsunami.
- Share their findings with the full class.

- Option B - Internet access is not available for individual students or pairs of students.
  - Ask a recorder to take notes on the board.
  - Ask students to brainstorm all the possible causes of a tsunami they can think of.
  - Project the website: http://www.aktsunami.com
  - Click on the tab: *Multimedia*. Click on the *Tsunami Generation* tab.
  - Show all applicable demonstrations and discuss how each event can cause a tsunami.
  - Have students write one to three full sentences to explain how each event can create a tsunami.
  - More multimedia examples are available on the project website at: http://discovertsunamis.org/resources.html

NGSS:

Challenge students to develop a model (diagram) to illustrate how Earth's internal surface processes form a continental or ocean-floor feature, such as a volcano or submarine trench, and explain how this feature is related to tsunami triggers. Ask students to show spatial and temporal scales for their selected feature.

3. Discuss the relationship of plate tectonics to tsunamis.

- Explain plate tectonics. Your textbook or http://geology.com/articles/tsunami-geology.shtml can be used as a resource.
- Discuss: *What do plate tectonics have to do with tsunamis?*
- Show an online demonstration of plate tectonics in action at: http://www.aktsunami.com/multimedia.html

Part 2: Demonstrations

4. Have students conduct demonstrations of tsunami triggers.

- Divide the class into five groups.
- Assign each group one tsunami trigger: earthquake, volcano, landslide, submarine landslide, asteroid impact.
- Have groups design a demonstration that would explain how their trigger may generate a tsunami.
- Ask groups to complete **Student Journal 7**.
- Journal 7 asks students to design a demonstration and think of materials to use to create that demonstration. To facilitate the realistic implementation of the demonstrations, you may want to give students a list of available materials prior to groups designing demonstrations.

- Option A:
  - Students create the demonstrations and run them for the class.
- Option B:
  - Students create the demonstrations and run them for a different class (increasing authenticity of activity - real audience).

Part 3: Energy and Tsunami Triggers

5. Conduct a Think-Pair-Share about the law of conservation of energy.
- Introduce or review the law of conservation of energy: *Energy may neither be created or destroyed*.
- Have students form pairs and give them two minutes to answer the following questions: Where does the energy a tsunami contains come from? How does the law of conservation of energy apply to generation of tsunamis?
- Call on pairs to respond to the questions and discuss students' answers.
- Clarify that the energy driving the tsunami waves comes from the potential energy that is released during the tsunami trigger that is then transferred into the kinetic energy of the moving waves.

6. Initiate student research into tsunami triggers.
- Post the research questions on the board: What is the most common cause of large destructive tsunamis? Which tsunami triggers should we be most concerned about?
- Hand out **Student Journal 8**. Assign partners and review the directions:
  - Partners go to the National Geophysical Data Center website: http://www.ngdc.noaa.gov/hazard/tsupub.shtml
  - Students click on: Two Decades of Global Tsunamis 1982-2002.
  - If Internet connection is not available for each pair of students, the resource can be printed ahead of time.
  - Students tabulate 40 events chosen at random. (Define random selection for statistical validity.)
- Challenge students to use the resources to answer **Student Journal 8**.

References

Hyndman, Donald, and David Hyndman. *Natural Hazards and Disasters*. Belmont, CA: Thomson Brooks Cole, 2006.

Sinton, John. May 5, 1999. *Nuuanu Landslide Tore Oahu Apart*. starbulletin.com. Accessed October 11, 2011 http://starbulletin.com/ 1999/05/05/millennium/storya2.html

Walker, George P. L. 1990. *Geology and Volcanology of the Hawaiian Islands*. Pacific Science, Vol. 44, No. 4:315-347. Honolulu: University of Hawaii Press.

Student Journal 7: Creating a Demonstration

Name: ______________________________ **Date:** ______________

Assigned Tsunami Cause: ____________________________________

Directions: Come up with a good way to demonstrate your tsunami cause using materials available to you. Make sure your demonstration is accurate (models correctly what happens in nature).

1. Brainstorm: Take 1 minute individually (without discussion) and brainstorm ideas for how you could create a demonstration.

Brainstorm:

2. Collaborate: Starting with the person who lives closest to school and go one-by-one to the right and share the ideas you brainstormed in step #1 to your group.

3. Vote on which idea to use.

4. Plan your demonstration as a group:

Materials Needed:

Steps to create your demonstration:

Explain in writing how your tsunami-cause generates a tsunami. Include how the law of conservation of energy applies to generation of tsunamis:

Student Journal 8: Common Causes

Name: ______________________________________**Date:** _________________

Your Partner's Name:____

Directions: With your partner, use the National Geophysical Data Center website: http://www.ngdc.noaa.gov/hazard/tsupub.shtml to research the most common cause of large destructive tsunamis. Scroll down to use the resource: Two Decades of Global Tsunamis 1982-2002). Tabulate 40 events chosen **randomly**.

Cause	Number of Occurrences
Earthquake (no indication of landslide)	
Earthquake with reported landslide	
Landslide (no earthquake or volcanic activity reported)	
Volcanic Eruption	
Asteroid Impact	
Other	

As a pair, complete the table above. Review all events in the document and quickly tally them.

Which is the most common cause of large destructive tsunami?

Which causes have something to do with plate tectonics? Explain your answer.

The Decision

How do we use the tools of science to help us predict the potential impact of a tsunami on our community?

Activity at a Glance

Students use two formats to answer the unit essential question - individually in writing, and then collaboratively.

Individually: Students analyze documents in an authentic real-life performance task and determine which of two sites is safer to build a new school.

As a class: Students engage in a mock board meeting to come to consensus on their varying opinions developed in the individual written response. Students share their own findings by presenting their information to a large group and draw conclusions about their own school's risk.

Key Concepts

- It is not appropriate to generalize from one anecdotal case.
- It is important to use appropriate scales to compare data.
- Results from one study might not apply to a different setting.
- Methodological factors in research study design must be taken into account.
- It is important to recognize possible sources of bias when analyzing information and data.

Skills

Critical thinking, analytical reasoning, writing effectiveness, writing mechanics, and effective communication skills

Assessment

Students:

- Complete a writing assignment employing critical thinking, analytical reasoning, writing effectiveness and correct writing mechanics to address the unit essential question.

- Collaborate in teams to analyze documents and present their perspectives in a group mock board meeting.

Hawai‘i State Standard Benchmarks

Science 1: Scientific Investigation

- **PS.1.3** Defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data.
- **PS.1.6** Engage in and explain the importance of peer review in science.
- **PS.1.7** Revise, as needed, conclusions and explanations based on new evidence.

Common Core Standards

Reading for Literacy in History/Social Studies: Grades 9-10 Integration of Knowledge and Ideas

- **RI.9-10.7** Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

Speaking and Listening: Grades 9-10 Presentation of Knowledge and Ideas

- **SL.9-10.4**: Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

Nā Honua Mauli Ola

‘Ike Piko‘u -Personal Connection Pathway

- **NHMO.5.2** Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.

‘Ike Ho‘okō - Applied Achievement Pathway

- **NHMO.7.2** Demonstrate the use of acquired knowledge through application.

Suggested Timeframe

Three 50-minute class periods

Day 1: Introduce the scenario
Day 2: Students work on forming opinions
Day 3: Conduct the Mock Board Meeting

Materials

Provided

- Student Culminating Packet (The Scenario and Community Map documents)
- Documents from prior lessons Student Readings 1 and 2, Student Data Sheet 1, and Student Journals 4, 5, and 8
- Culminating Project Rubrics (provided in Unit Introduction)
- Journal - Unit Assessment Overview and Unit Pre/Post-assessment (provided in Unit Introduction)
- Teacher Answer Key

Getting Ready

✓ Review the Culminating Documents and Teacher Answer Key.
✓ Make copies of the documents in the Student Culminating Packet to distribute to each student.
✓ Ask students to bring their Journals with pages from prior lessons to class.
✓ Make copies of the Culminating Project Rubrics for each student.
✓ Make a copy of the Unit Pre/Post-assessment for each student.

Teacher Background Information

This culminating activity follows the pedagogy of national and international assessments designed to measure not only content, but also higher order skills including critical thinking, analytical reasoning, and the ability to communicate effectively, both orally and in writing. The activity assesses students individually through writing, but also encourages creativity and collaboration in the hōʻike (exhibition) component. If this form of assessment is new to the class, take the time to explain the process and answer questions.

In this activity, students will use documents they have worked on during the unit, as well as materials from the Culminating Packet, to answer a scenario about the safe placement of a new school for a community in an inundation zone vulnerable to tsunamis. Some documents have distractor information or information that may seem to support one answer, but upon further analysis does not. Students form their support of one argument proposed in the scenario in a written statement. Students then engage in a mock board meeting where they are asked to defend their points of view and convince others.

In the second half of the mock board meeting, students are asked to apply knowledge and ideas they have discovered in the unit to their own school's situation, asking how much at risk is their school to damage from tsunamis and how do we know?

Teaching Suggestions

Part 1: Setting Up the Scenario

1. **Introduce the scenario.**
   - Distribute the Culminating Packet to each student.
   - Go over the scenario with the class.
   - Inform students that the culminating activity will be in the form of an individual writing assessment and a mock board meeting presentation. Both will be assessed equally.
   - Review the Culminating Projects description in the Unit Assessment Overview and the rubrics provided in the Unit Introduction for writing and presentations.

2. **Set up the class to begin working on the scenario.**
   - Organize students into groups of four.
   - Explain to students that the groups will help us to form complex ideas through collaboration on higher order thinking.
   - Ask students to go over the scenario and talk about their initial thoughts.
   - Ask each student to have his/her own copy of the following documents: Student Readings 1 and 2, Student Data Sheet 1, and Student Journals 4, 5 and 8.
   - Assign each group member a number: 1 - 4
   - Inform students that each member will become an expert on one or two documents, then bring their expertise back to their group to collaboratively address the scenario.
     - Group Member 1: Student Reading 1
     - Group Member 2: Student Reading 2 and Student Journal 4
     - Group Member 3: Student Journal 5
     - Group Member 4: Student Data Sheet 1 and Student Journal 8

Form groups to maximize various talents of students, including researching, speaking, and critical thinking ability. Also Combine students who are struggling with students who have caught on quickly, and those in between.

3. **Explain the process.**
   - Explain that each group member is to use the document(s) assigned to him/her to become a document expert.
   - Ask all the 1's to take their document(s) and join together in one large group to help each other understand how this document may or may not help to understand the scenario.
   - Repeat these instructions with all of the 2's, 3's, and 4's.
   - Give these four large groups 10-15 minutes to come up with as many ways as they can to determine how the document supports or refutes both options in the scenario.

- Ask the group members to return to their original groups of four as document experts.

Part 2: Forming an Opinion

4. Ask groups to form an opinion.
- Give the groups 20 minutes to form their opinions.
- Ask each group member to report back about how each document supports or refutes both options proposed in the scenario.
- Ask the group to choose an option to support, and to list all evidence that supports that option and all the evidence that refutes the other option.
- Ask each group member to take his/her own notes, which may be used on the individual writing assessment.

5. Allow time for individual writing about the scenario.
- Provide each group member 30 minutes to individually address the scenario in writing.
- Ask students to follow the instructions provided in the scenario.
- Explain that students should use all documents, not just the document they became an expert on, to answer the scenario in their writing process.
- Nothing else should be on the student desks besides the listed documents, the scenario handout, and paper on which to answer the scenario.
- At the end of the allotted time, ask students to turn in their written assignment.

Part 3: Conducting the Mock Board Meeting

6. Prepare for the mock board meeting.
- Return a graded copy or a photocopy of each student's writing for use in preparing for the mock board meeting.
- Apprise students of the procedures of the mock board meeting (outlined below).
- Allow students time to organize and prepare.

7. Conduct the mock board meeting.
- Hold a mock board meeting addressing the scenario.
- Convene the meeting with desks in a circle and you, the teacher, as the board chairperson.

- Ask one student to volunteer his/her position on which option to support and why.
- Ask all students to volunteer to support or refute the argument.
- Encourage discussion that involves all students responding to each other and not just the board chairperson.
- Ask students to vote on the results.

8. Debrief on the culminating project.

- Share with students that the correct choice was to build the school in site A, the original site on the coast.
- Go over the evidence that supports that choice and discuss how students analyzed the evidence.
  - What were the key pieces of evidence that led to the selection of the correct site?
  - Why is it not appropriate to generalize from an anecdotal case?
  - Was there evidence of bias in any of the documents? Explain.
  - Do results from all studies apply to all settings? Why or why not?

9. Administer the Unit Post-assessment.

- Compare student scores with the Pre-assessment. Note any benchmarks that need further work for students or key concepts that may need clarification.
- Congratulate students on their work to complete the unit.

Extending the Learning

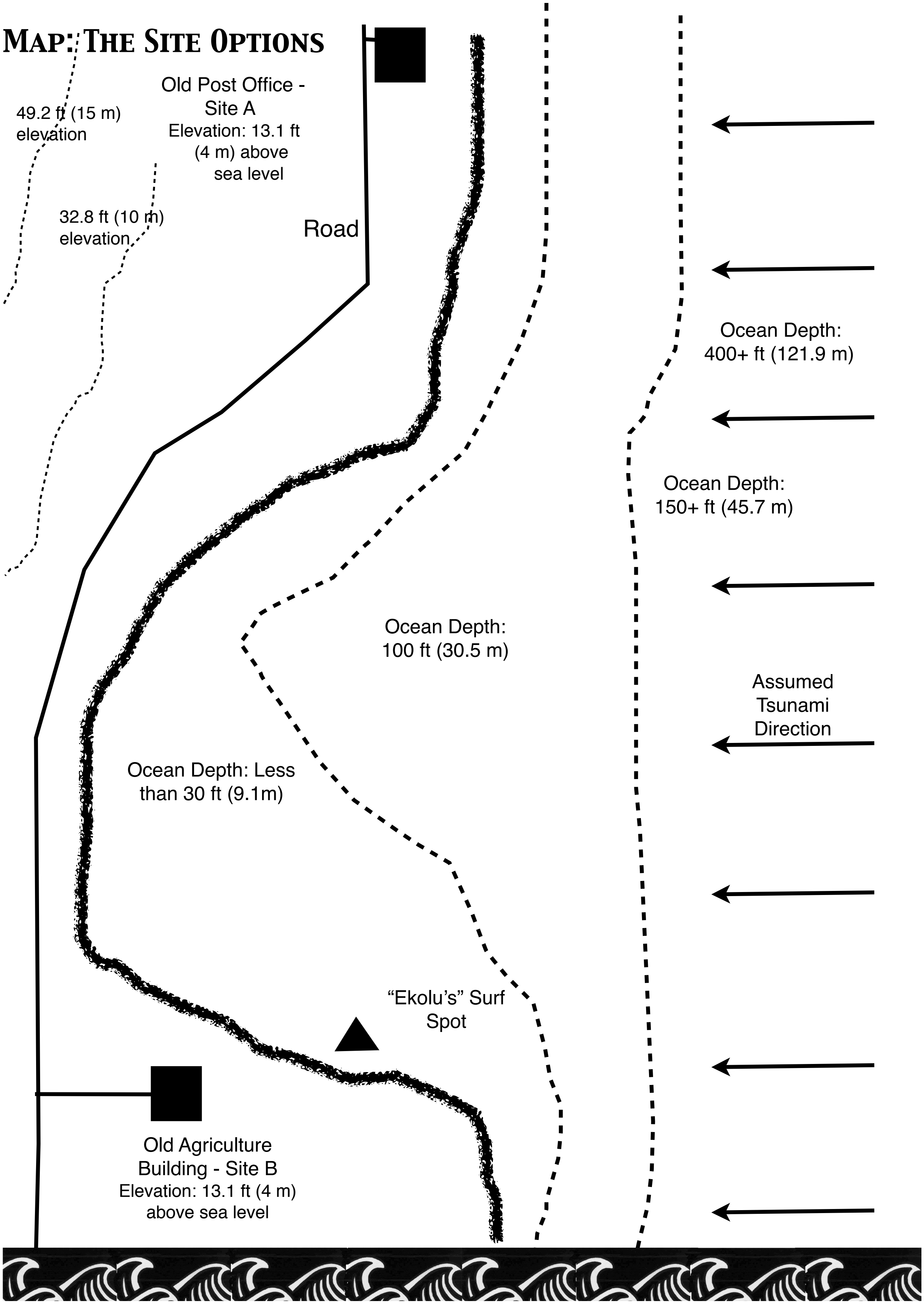
- Have students conduct research to answer the question: With the new knowledge from this unit, how would you evaluate our school site's vulnerability to tsunamis? Refer students to the map of your school's area (provided in the Appendix) and the maps they created in this unit. Have them gather evidence to back up their claims and share their responses with the class.

- Show students the school's tsunami evacuation plan and ask them to evaluate its effectiveness for moving large number of students to higher ground quickly in the event of a tsunami warning.

NGSS:

Challenge students to evaluate their school site's vulnerability to tsunamis and propose actions to reduce vulnerability. Have them prioritize criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Map: The Site Options



Culminating Project Packet: The Scenario

School Board: a committee having supervisory powers and in charge of local public schools
Board Chair: The person in charge of the school board
You are a member of the school board. Your community is planning on opening a new elementary school; the old one is too crowded so a second will be built. Last year, the government offered your community the old Post Office site to build the school and enough funding to begin construction this year. However a member of the *school board*, Pat Tsukazaki, has proposed an alternate site. Here is a letter from the *board chair* sent yesterday:

Dear Members of the School Board,
At our last meeting we approved a plan to build a new elementary school on the old Post Office site (marked site A on the attached map). Recently board-member Tsukazaki has offered a second site option: the old Agriculture Building (site B) that has been recently vacated. Tsukazaki writes:

"The old Post Office site is too vulnerable to tsunamis. In light of recent tsunami scares from Japan and other areas across the Pacific, it is essential to choose a spot for our school that is as protected as possible from tsunamis. No site in our community is 100% safe, but the old Agriculture Building site offers more peace of mind for these reasons:

1. The old Agriculture Building is located less than 20 yards inland from the famous surf site "Ekolu's." That spot regularly gets 20-foot waves during high-surf advisories. We know it can handle big waves. The old Post Office site is next to a calm beach. Certainly if a tsunami came through, the waves would be too much for the beach to handle.
2. Several major tsunamis in Hawai'i's history have been caused by a volcano flank collapse here in the state. If that happened here, we would not have enough time to sound a warning. A tsunami would be on our shores in minutes, not hours. Both sites are located 20 yards away from the ocean. However from the old Agriculture Building site it is possible to see the shore and reef line more clearly. As my friend Herbert Nishimoto said in his account, tsunamis suck out before the wave comes in, so it will give us more chance to see a possible tsunami and we can evacuate the students. The old Post Office site's view is blocked by several small buildings and trees.
3. Certainly the site in the bay will be safer for the school. The old Post Office site is exposed on the coast line."

In one day, the school board will meet to vote on the site. The choice of sites is very important. The safety of the keiki in the community, especially your family's children, is at stake. I am not convinced that the new site is the best choice. According to the NGDC site, tsunamis that hit Hawai'i aren't very powerful and don't kill as many people as tsunamis that hit other areas of the world. Come prepared to the board meeting with your recommendation in written form, ready to discuss and then vote on the best site to build the new school.

Please review the documents and base your decisions on the evidence in them.
Sincerely,
Your Board Chair

Student Writing: The Individual Assessment

Use the documents and write a memo to the chairperson of the school board. Address the following questions on a clean sheet of paper:

1. Board member Pat Tsukazaki makes three main claims about the old Agriculture Building site being a better choice for the new school. How does the evidence in the documents you have at your disposal support or refute board member Tsukazaki's claims?

2. The board chairperson supports the old Post Office site as the site for the new school. How does the evidence in the documents you have at your disposal support or refute the board chairperson's claims?

3. What site do you recommend as the safest site to build the new school. How does the evidence in the documents you have at your disposal support your claim?

Memo

To:

From:

Date:

Subject:

Continue on another sheet.

Teacher Answer Key: The Individual Assessment

Assessment Overview:

The written answer to the question involves critical thinking, analytical reasoning, writing effectiveness, and writing mechanics. The scenario is purposefully set with distractors and irrelevant statements. While this is not meant to be a "trick question" it is meant to replicate a real-life situation where not all data is useful and not all statements are true. As you set up the scenario, let students know that they will not use all the information, that some statements may seem to point to one answer, but actually be irrelevant. The job of the student is to employ critical thinking and analytical reasoning to determine which site seems the most safe. The task requires and allows students to practice skills that are transferable and relevant for the future.

Assessing:

There is a correct answer. As you preview the rubric you will see that the answer is assessed: 1/4 on writing mechanics (the ability to use the English language in a correct way), 1/4 on writing effectiveness (the ability to use the English language to get your point across in a clear and convincing way, 1/4 on analytical reasoning (how well students used the data to support their answer), and 1/4 on critical thinking (the ability to think about the data in complex ways and determine what is appropriate or inappropriate, biased or accurate). While getting the correct answer is important (especially to the latter two assessed categories) it is not the only thing being assessed.

Use of the concepts taught in this lesson, specifically those pertinent to the science of tsunamis, should be encouraged as students prepare to write and should be considered as the writing is assessed. As this is not meant to be transparent and clear to the students, go over the principles of the assessment with the class before the assessment is administered.

The Answer:

1. Board member Pat Tsukazaki makes three main claims about the old Agriculture Building site being a better choice for the new school. How does the evidence in the documents you have at your disposal support or refute board member Tsukazaki's claims?

Board member Tsukazaki's claims are not supported by the documents. He claims:

> "The old Agriculture Building is located less than 20 yards inland from the famous surf site "Ekolu's." That spot regularly gets 20-foot waves during high-surf advisories. We know it can handle big waves. The old Post Office site is next to a calm beach. Certainly if a tsunami came through, the waves would be too much for the beach to handle."

Evidence: Students should use **Student Reading 2** to show that tsunami waves are not like wind-generated waves. A surf spot being able to handle a large wind-generated wave is not an indication that it would be able to handle a tsunami. Students should use wavelength of tsunami vs wind-generated waves to support their answers.

> "Several major tsunamis in Hawai'i's history have been caused by a volcano flank collapse here in the state. If that happened here, we would not have enough time to sound a warning. A tsunami would be on our shores in minutes, not hours. Both sites are located 20 yards away from the ocean. However from the old Agriculture Building site it is possible to see the shore and reef line more clearly. As my friend Herbert Nishimoto said in his account, tsunamis suck out before the wave comes in, so it will give us more chance to see a

> possible tsunami and we can evacuate the students. The old Post Office site's view is blocked by several small buildings and trees."

Evidence: Students should show that this is a false statement. As learned in the unit, a trough or a crest can come ashore first. Students should not generalize from one eyewitness account provided in **Student Reading 1**, nor should they take one incident as general fact for all tsunamis. While the tsunami that Mr. Nishimoto survived (Student Reading 1) did indeed begin with water receding and a trough arriving first, we know that this is not the case for all tsunamis. If people in the school were able to see water receding at a rapid rate, it would be prudent to evacuate. However the school site should not be chosen on the eventuality that a trough will come ashore first. Other factors negate this small advantage.

> "Certainly the site in the bay will be safer for the school. The old Post Office site is exposed on the coast line."

Evidence: Students should use **Student Journal 5** to show that refraction from an abrupt change in ocean depth may in fact turn the tsunami towards the old Agriculture Building site. They should also refer to the idea of seiche and/or the definition of tsunami (harbor wave) to show that a bay is in no way safer than a coast line.

2. The board chairperson supports the old Post Office site as the site for the new school. How does the evidence in the documents you have at your disposal support or refute the board chairperson's claims?

While the board chairman is correct in the site that should be chosen, his reasons why are unfounded and not supported by the evidence.

> "I am not convinced that the new site is the best choice. According to the NGDC site, tsunamis that hit Hawai'i aren't very powerful and don't kill as many people as tsunamis that hit other areas of the world."

Evidence: Students should use **Student Data Sheet 1** and **Student Journal 8** to show that while on the surface this statement seems true, we know that it is not the case. Students learned in Lesson 4 that flank collapse can cause massive tsunamis, some recorded in pre-history to have carried debris over 326 meters up the slopes of Lāna'i. Students should refer to Student Data Sheet 1 and understand that while there have not been tsunamis that have caused over 2,000 deaths in recorded history in Hawai'i, this does not mean there may not be. They should use Student Journal 8 to show that tectonic activity is the most common cause of tsunamis and should refer to the fact that most of that activity is centered in the Pacific, making Hawai'i even more vulnerable.

3. What site do you recommend as the safest site to build the new school. How does the evidence in the documents you have at your disposal support your claim?

Students should support the old Post Office site. While we do not know that it is safer, we do know that there has been no solid case made for the old Agriculture Building site. Furthermore, the old Agriculture Building site sits on the bay, more vulnerable to damage due to seiche and possibly a direct impact due to refraction caused by ocean depth changes. Students may use **Student Reading 2** to talk about speed and warning time if a tsunami was generated from afar. Students may also refer to points made earlier as they refute board member Tsukazaki's claims.