



## SATELLITE STUDIES WITH MINING GEOIMAGES

### Overview

In this two-part activity, students will learn about the process of open pit mining using Google Earth and a 360 virtual mine tour. They will work in student groups to identify and mark the footprints and boundaries of a mine using satellite imagery and learn how satellites give us valuable information about mines and the areas that surround them. Students will also learn how the practice of mining includes mitigation and reclamation plans. Student groups will research a large mining operation in the United States and create their own mitigation and reclamation plans for their mine.

**Grade Band:** 9-12

**Topic:** Satellite technology and ecological mitigation/restoration in the mining industry

### Real world science topics

- Geology
- Engineering
- Environmental Science and Restoration
- Technology and Science

### Objective

- Students will identify and mark the various facility footprints and boundaries of an open pit mining area using satellite images from Google Earth.
- Students will discover how satellite imagery assists in identifying, preparing, and verifying reclamation and closure goals.
- Students will evaluate the size of a mining area to gain a better understanding of the scale of mining as compared to other industrial and municipal footprints and the usefulness of remote sensing.



## Next Generation Science Standards (NGSS)

### [HS-ESS2-2 Earth's Systems](#)

Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

### [HS-ESS3-2 Earth and Human Activity](#)

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.\*

### [HS-ESS3-4 Earth and Human Activity](#)

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.\*

### [HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics](#)

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.\*

### [HS-ETS1-2 Engineering Design](#)

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-PS4-2 Waves and their Applications in Technologies for Information Transfer](#)

Evaluate questions about the advantages of using digital transmission and storage of information.



**Time Needed:** 1-2 hours

## Background Information

How can satellite imagery be used to aid in the planning and implementation of land reclamation and mine closure goals?

Did you know that before an open-pit mine ever breaks ground and the mining begins, plans are already in place for its end? Throughout the life of a mine, scientists, engineers and geologists are constantly collecting and analyzing data to determine the effect of the mine on the surrounding environment and how they can best minimize its impact. Satellite technology can give us important information about mining, from the growth and impact of a mine over time, to where valuable minerals are located. It can even reveal secrets about vegetation growth, where wildlife are, and how best to restore the land when the mine eventually closes.

## Key Vocabulary

**Open-pit mining** - a mining technique that removes minerals or rock from the earth from a surface excavation

**Environmental mitigation** - programs or projects used to offset known environmental impacts to an ecosystem due to human development or industry

**Mine reclamation** - the process of restoring land that has been mined or creating an alternative land use that is of value

**Remote sensing** - the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.

## Materials

- Student device (laptop or iPad) capable of running Google Earth
- Student Resource Sheet 1
- Student Resource Sheet 2
- Colored pencils or markers
- Satellite Images of Mines (1 per group)
- Mitigation and Reclamation Cards (1 set per group of 4)



## Procedure

### DAY 1:

#### 1. Warm-up Activity (Whole Group)

Project the image (Image 1) of the Cerro Verde Mine on the overhead screen for students. Ask students if they know what human-made structure they are looking at. Explain to students that this is an open-pit mine that is located in Peru that is used to mine copper and molybdenum.

\*If students have devices (laptop, iPad) teacher could have students go to Google Earth ([www.google.com/earth](http://www.google.com/earth)) and type in "Cerro Verde Mine" to be able to look at the mine at various distances and angles.

Now ask students to get with a partner sitting next to them and discuss or informally write down their answers the following questions:

- How did we get this image of Cerro Verde Mine?
- What can we learn about the mine from this image?
- What features do you recognize in the image?
- What do you already know about the process of open-pit mining?

After students have discussed/written down their answers, ask students to share their thoughts and ideas. Tell students that today they will be learning about how technology can help us in all aspects of mining from start to finish - from locating minerals and ore, to restoring the environment when the mine closes.

Record some of the students' ideas and answers on the front board or overhead projector.

### Partner Activity

1. Ask students to go to the following website on their device: <http://www.kennecott.com/virtual-tour>.

*\*If students do not have a device, the teacher may walk them through the virtual tour on a digital board or projector.*



2. Ask students to get into pairs or small groups and explore the virtual tour of the Bingham Canyon Copper Mine. As they click through the stops on the tour, they should look for and discuss the answers to the questions on the **Student Resource Sheet 1: Virtual Mine Tour**.

3. Give students 15 minutes to click through the tour and complete the Student Resource Sheet 1: Virtual Mine Tour with their partner. (Although they are working with a partner, each student should complete the Student Sheet 1.)

4. As a whole group, ask student pairs to share and compare their answers from Student Sheet 1 with the class.

### Small Group Activity

1. Ask students to get into groups of 3-4 (depending on your class size and group preference). Assign each student group an open pit mine that they will focus on for the next part of the lesson. Give each group a copy of the **Student Resource Sheet 2: Mine Profile** for the mine that they were assigned.

Open Pit Mines that student groups will be assigned include:

- Chino (Santa Rita) Mine
- Mahoning Mine
- Morenci Mine
- Red Dog Mine
- Fort Knox Mine
- Thompson Creek Mine

Teacher note: It is critical for students to understand the climatic setting of the example mines. The reclamation possibilities will vary significantly between Red Dog and Fort Knox in the Alaskan tundra versus SW US mining areas versus northern Minnesota and Idaho. Students should be encouraged to reflect the limitations or opportunities from the different settings in their analysis. For example, post mine land use of solar energy development may make a lot of sense in the SW US but would not be the best choice to propose for a mine located near the arctic circle (Red Dog and Fort Knox).



2. Students should go to [www.google.com/earth](http://www.google.com/earth) and search for their mine. Once they have found it, they should explore the area around and in their mine to complete Student Sheet 2: Mine Profile.

Students should use colored pencils to mark footprints they can identify in and around their mine using Google Earth and make a key on their mine profile sheet. They should use the links provided and the internet to answer questions in Part I about their mine.

## DAY 2:

### 1. Warm-up Activity (Whole Group)

Open by projecting Image 1: Cerro Verde Mine on the overhead screen or front board.

Remind students that this is the satellite image of the Cerro Verde Mine that they looked at the beginning of the lesson yesterday. Ask students to share how they think satellite imagery can be valuable in understanding mining.

2. Show students the following clip on various types of satellite imaging on the overhead screen:

<https://www.youtube.com/watch?v=ASuvtr7NgJk>

3. Ask students to think about the answers to the following questions:

- **How might the Cerro Verde Mine have changed the natural landscape?**
- **What do you think should happen when this mine closes? How might satellite imagery be helpful in creating mine closure plans?**
- **How do you think that mining operations take the surrounding community and the environment into account?**

Ask students to share their answers with the class. Write some ideas on the front board.

4. Show students the following video clip on the overhead screen:

<https://www.youtube.com/watch?v=RRjZlYh0qM0>



5. Share the key terms and definitions below with students.

### **KEY TERMS**

**Environmental mitigation** - programs or projects used to offset known environmental impacts to an ecosystem due to human development or industry

**Mine reclamation** - the process of restoring mined lands to a designated post mine land use (natural, residential, commercial, industrial, etc.)

6. Explain to students that before mines even begin mining, they already have plans in place to restore the land when they close and mitigate their environmental impacts throughout the mining process. As a part of Cerro Verde Mine’s environmental plan, they created and maintain a protection plan for a threatened species of bat in Peru, the Long-Snouted Bat.

7. Go to the following link: <https://www.fcx.com/about/multimedia-library#videobatsSA> and play the “Cerro Verde’s Bat Conservation Program” video for students. When the video is finished, ask students if they think this program would be considered mitigation or reclamation? (Students should recognize that it is mitigation.)

8. Ask students to go back to the Virtual Mine Tour from yesterday on their devices.

(<http://www.kennecott.com/virtual-tour>) They should view the last two stops on the tour, the “Inland Sea Shorebird Reserve (ISSR) Overview” and “Daybreak” to see two more unique examples of mitigation and reclamation.

\*Teacher can also show these two segments on the overhead screen if students do not have devices.

### **Small Group Activity**

1. Students should get into their Mine groups from the previous day and go to Part II of their “Mine Profile Sheet.” and get a set of MITIGATION and RECLAMATION CARDS for their group.

2. Student groups should use the internet and provided links to help them brainstorm and create novel mitigation and reclamation programs for their mine. They should use the satellite images and information about the area and communities surrounding their mine to create appropriate programs that could be implemented now or on the land as their mine prepares to close in the future.



3. Groups should work to come up with one novel program for each of the cards. (Remind students that they should not simply copy something that their mine is already doing or has in place.)

They should write a detailed outline of their program on each card that explains why it is appropriate for the area or community that their mine is located in.

#### **Suggestions to guide student research:**

- *How big are the communities surrounding the mine?*
- *What already exists in the area? What could be an added value to the area?*
- *What kinds of recreation are unique to or popular in that area? Is there a need for better facilities for these recreational activities?*
- *When the mine closes, what could the post mining land use be? Back to its natural state? Could it be changed into something else that would benefit the local/regional community and/or wildlife?*
- *What is the climatic setting of the mine?*

4. Have student groups present their mitigation and reclamation plans informally to the class. They can introduce their mine, and some of the information from Part I of their Mine Profile Sheet, and then have one person from the group present each of the cards - the facets of their mitigation and reclamation plans.

#### **Extension**

Student groups could take the mitigation and reclamation programs that they created on their cards and create a formal digital presentation (video, slideshow, etc.) that could be added to their mine's website as a way to inform the public about the how their mine is working to help the community and the surrounding environment.



## Additional Resources/Links

- <http://www.miningfacts.org/environment/what-happens-to-mine-sites-after-a-mine-is-closed/>
- <https://earthshots.usgs.gov/earthshots/node/58#ad-image-0>
- <https://academo.org/demos/open-pit-mines/>
- <https://www.youtube.com/watch?v=ASuvtr7NgJk>
- <https://www.youtube.com/watch?v=xIsUP1Ds5Pg&t=189s>
- <https://www.youtube.com/watch?v=RRjZlYh0qM0>
- [https://www.fcx.com/sites/fcx/files/documents/fast\\_facts/Mining\\_Recl\\_NA\\_2014.pdf](https://www.fcx.com/sites/fcx/files/documents/fast_facts/Mining_Recl_NA_2014.pdf)
- <https://www.fcx.com/operations/north-america>
- <http://www.tcreek.com/nature>
- <https://oceanservice.noaa.gov/facts/remotesensing.html>

## Student capture sheets and Teacher resources

IMAGE 1: Cerro Verde Mine, Peru



Freeport-McMoRan



### Student Resource Sheet 1: Virtual Mine Tour

1. Can you define the boundaries of the mine in the General Overview? How are the boundaries defined?
2. Where does the mining actually take place?
3. What are some examples of specialized technology that is used in the mine?
4. What types of transportation modes are used in the process of mining?
5. What are tailings?
6. What did you learn about open-pit mining that you did not know before

### Student Resource Sheet 2: Mine Profile

**Group Members:**

**Name of our Open Pit Mine:**

**Location of our mine:**

Go to [www.google.com/earth](http://www.google.com/earth) and search for your assigned mine.

In this activity, your group will be looking for certain features of your mine that you learned about in the opening activity. You should use Google Earth on your device to zoom in and out of your mine to allow you to see features of your mine up close.



## PART I - What Can Satellite Imagery Tell Us About Mining?

1. Get a copy of the satellite image sheet of your assigned mine from the teacher.
  
2. Using Google Earth, locate following features on the paper satellite image of your mine by zooming in and out from the image of your mine on your screen. Once you have located the features, you should use colored pencils or markers to circle, color, or identify the features listed below. Finally, you should make a key on the sheet based on the features you can identify in your mine.
  - a. Use GREEN to outline the boundaries of the mine
  - b. Mark a RED "X" anywhere that you think that actual mining is taking place
  - c. Color any tailings you see BLUE
  - d. Circle any buildings in the mine in ORANGE
  - e. Color all mine stockpiles PURPLE.
  - f. Use any other colors you choose to mark other things that you can identify on your satellite image such as mining vehicles, pipelines, or anything else you find. Be sure to add these to your key.
  
3. With your group, do some research to answer the following questions about your mine.
  - a. How big is the open pit at your mine? How deep is it?
  
  - b. What materials are being mined there?
  
  - c. Describe the landscape surrounding your mine. Is it an urban or rural area? Is the terrain flat or mountainous? What type of ecosystem would it be - desert? forests? arctic tundra?



4. Go to the following link and view the images of the Escondida Mine in Chile from the 1970's to the present day.

<https://earthshots.usgs.gov/earthshots/node/58#ad-image-0>

- a. In what ways do you think satellite images are helpful in viewing and understanding mines?
- b. Why do you think it would be valuable to have satellite images of mines from their beginning to the time when they are ready to close?

## **PART II - Mitigation and Reclamation - How Mines Help Communities and the Environment**

1. Obtain a set of MITIGATION and RECLAMATION CARDS for your group.

Your goal for Part II of this activity is to design and present new and unique mitigation and reclamation program for your mine that could be implemented now or on the land as the mine prepares to close in the future.

2. Use satellite images (Google Earth) and information you discover about your mine to create appropriate programs based on the needs of the surrounding communities and ecosystems.
3. Groups should work to come up with **one program** for each of the four cards - Residential/Community, Recreation, Wildlife Preservation, commercial, industrial, and Parks/Natural Areas. (You should not simply copy something that the mine is already doing or has in place.)
4. Your group should write a detailed outline of their program on each card that explains what the program entails and why it is appropriate for the area or community that their mine is located in. You may add sketches of what the park or feature might look like to the back of the card or as an attachment.



### Suggestions to guide your research:

- *How big are the communities surrounding the mine?*
- *What already exists in the area? What could be an added value to the area?*
- *What kinds of recreation are unique to or popular in that area? Is there a need for better facilities for these recreational activities?*
- *When the mine closes, what could the post mining land use be ? Back to its natural state? Could it be changed into something else that would benefit the local/regional community and/or wildlife?*
- *What is the climatic setting of the mine?*

### Helpful links for student groups about their mines:

- Chino (Santa Rita) Mine - [https://geoinfo.nmt.edu/tour/landmarks/chino\\_mine/home.html](https://geoinfo.nmt.edu/tour/landmarks/chino_mine/home.html)
- Mahoning Mine - <http://www.mining.com/hull-rust-mahoning-mine/>
- Morenci Mine - <http://www.mining-technology.com/projects/morenci/>
- Red Dog Mine - <https://www.teck.com/operations/united-states/operations/red-dog/>
- Fort Knox Mine - <http://fb.kinross.com/operations/operation-fort-knox-alaska-usa.aspx>
- Thompson Creek Mine - <http://www.tcreek.com/operations>

5. When you have finished completing your cards, each group will give an informal presentation with general information about their mines (see answers to Part I of this activity) and the mitigation and reclamation programs they have developed. Assign one person from each group one of the cards that they can present.



**SATELLITE IMAGES OF MINES** (Can be copied/enlarged onto individual student sheets)

**CHINO/SANTA RITA MINE**



Map data: Google, DigitalGlobe



**MAHONING MINE**



Map data: Google, DigitalGlobe



**MORENCI MINE**



Map data: Google, DigitalGlobe



**RED DOG MINE**



Map data: Google, DigitalGlobe



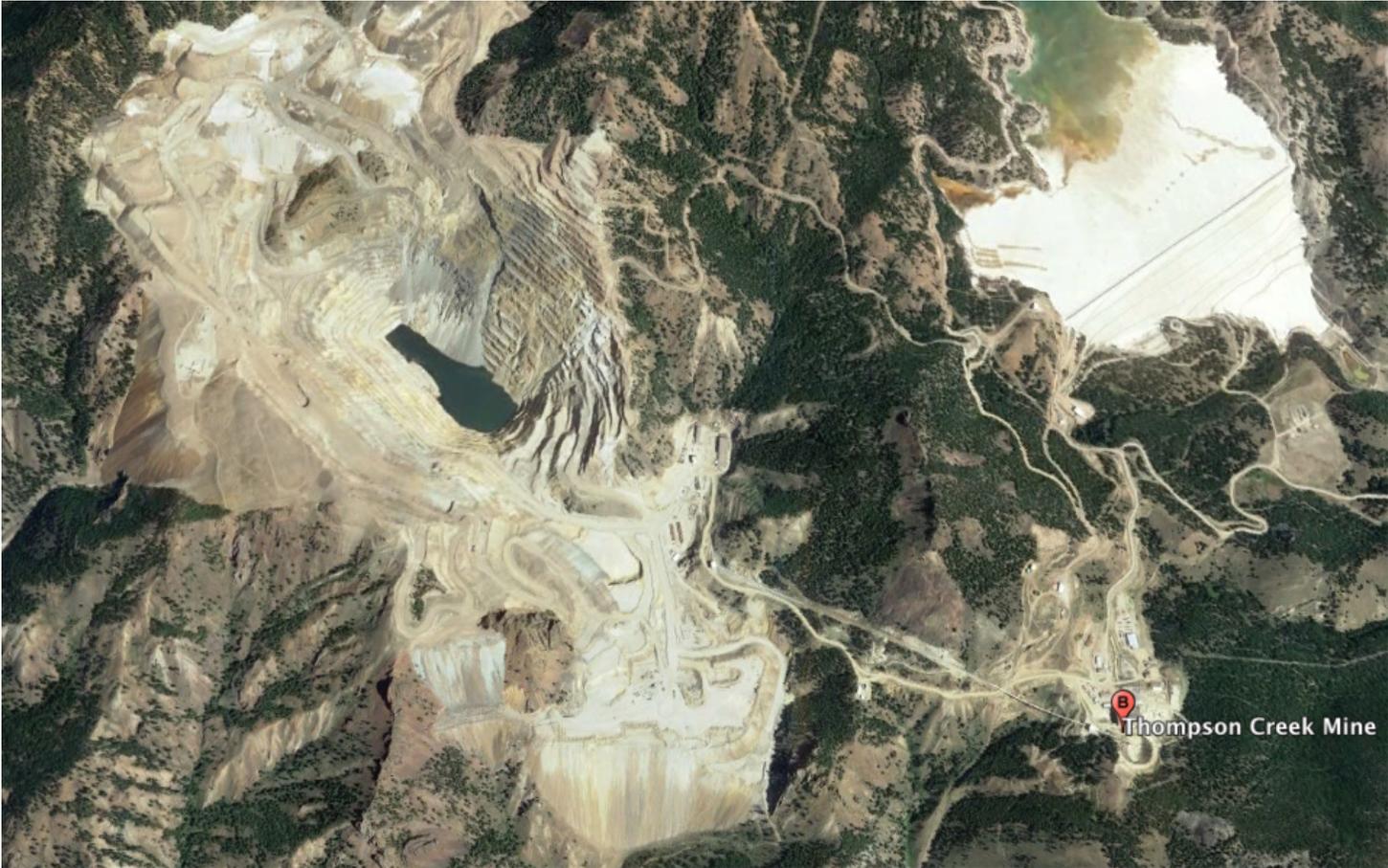
FORT KNOX MINE



Map data: Google, DigitalGlobe



**THOMPSON CREEK MINE**



Map data: Google, DigitalGlobe



MITIGATION AND RECLAMATION CARDS (Teachers can cut these into 4 separate cards or can be larger on separate sheets)

<p><b>RESIDENTIAL and COMMUNITY</b>          (Eco-friendly housing developments, Museums, Educational centers)</p>	<p><b>RECREATION</b>          (Golf courses, sporting facilities, bike paths, diving facilities)</p>
<p><b>WILDLIFE PRESERVATION</b>          (Protection programs for threatened or endangered species, education programs, land that has been set aside for wildlife)</p>	<p><b>PARKS and NATURAL AREAS</b>          (Public parks and gardens, Wetlands, Hiking trails, Nature centers)</p>