GEODESY LESSON PLAN

Meet Geodesy

Focus
Introduction to geodesy

Grade Level
9-12

Focus Question
What is geodesy, and why is it important?

Learning Objectives
- Students will be able to define geodesy.
- Students will be able to explain three ways in which geodesy is of practical importance.
- Students will be able to explain how a datum of reference points may be used to describe the location within the area covered by the datum.

Materials
- Masking tape
- Measuring tapes (at least 15 ft long), one for each student group
- Rulers, one for each student group
- Copies of either Geodesy Review (fill-in-the-blank version, with or without word bank) or Geodesy Review Crossword Puzzle, one copy for each student or student group

Audio/Visual Materials
None

Teaching Time
One 45-minute class period.

Seating Arrangement
Groups of 3 - 4 students.

Maximum Number of Students

30

Key Words

Geodesy
Datum
Geoid
Ellipsoid
GPS
CORS

Background

On December 23, 2003 at 11:15 AM, a magnitude 6.5 earthquake shook the town of Paso Robles, California. Two people were killed, and many historic building were severely damaged. Three days later, the city of Bam in southeastern Iran was shaken by a magnitude 6.6 earthquake, which killed more than 30,000 people and damaged more than 85% of the city's buildings. In the days following these disasters, many news reports shared a common theme. One of the scariest things about earthquakes is that they strike without warning. Some reports also commented that the loss of life due to hurricanes has been greatly reduced because we are able to predict when and where these storms are likely to strike. But earthquakes are much less predictable.

Most middle school and high school students know that earthquakes are caused by movements of the Earth's crust. Some students may also know that these movements can be caused by volcanic activity or when blocks that make up the Earth's crust move along fractures (called faults) between the blocks. Are strong earthquakes preceded by smaller movements of the Earth's surface that might give some warning of larger movements? Is there any way to systematically monitor movements of the Earth's surface?

The science known as geodesy involves measuring changes in the location of points on the Earth's surface, as well as the Earth's size and shape. More than 2,000 years ago, scientists and philosophers speculated on the fundamental questions of geodesy. But only recently have scientists been able to precisely measure the Earth's surface using space-based technology.

In addition to helping us improve our ability to predict earthquakes, geodesy is used in the process of building roads and bridges, making maps, landing aircraft, and navigating ships.

The basic approach of geodesy is to repeatedly measure the location of certain fixed reference points on the Earth's surface. Fixed points used by geodesists are marked on the Earth's surface by metal disks set into concrete casings (called benchmarks) or very stable structures called monuments. Many such points that cover a large area are called a datum. For each fixed point in a datum, the distance and direction of adjacent fixed points is measured. So the fixed reference points in a datum can be used to determine the location of any other point in the same area covered by the datum. Traditionally, geodesists used triangulation and trigonometry to determine the location of reference points within a datum. Today, satellites in the Global Positioning System (GPS) are used to determine these locations.

Because the surface of the Earth can move up, down and sideways, the location of a geodesic reference point includes a vertical position as well as a horizontal position. The horizontal position of a reference point is described by its latitude (north-south position) and longitude (east-west position). The vertical position of a reference point is described by its height above or below mean sea level.

The fundamental reference point for latitude measurements is the equator. The latitude of a point on Earth is its angular distance north or south from the equator expressed in degrees and fractions of degrees (minutes, which equal 1/60th of a degree, and seconds which equal 1/3600th of a degree). The North and South Poles have latitudes of 90° N and 90° S respectively.

The fundamental reference point for longitude measurements is the Royal Observatory at Greenwich, England. The longitude of a point on Earth is its angular distance east or west from an imaginary line passing from the North Pole, through the Royal Observatory, to the South Pole. Like latitude, longitude is expressed in degrees and fractions of degrees.

Like horizontal datums, a vertical datum consists of a series of positions marked by benchmarks whose elevation relative to one another is known. The fundamental reference for vertical positions is mean sea level.

Over a relatively small area (the size of an average city, for example), positions within a datum can be accurately calculated as though the Earth were a flat surface. Over longer distances, though, the shape of the Earth becomes increasingly important. While we are accustomed to thinking of the Earth as spherical, it is actually slightly “flattened” at the poles. So, an ellipse is a closer approximation of its true shape. If we draw an outline of the Earth’s elliptical shape on a piece of paper, cut out the shape, and glue a wooden skewer onto a line passing between the North and South Poles, we can spin the skewer rapidly to visualize a three-dimensional shape. This shape is called an ellipsoid and is sometimes used by geodesists to more accurately calculate the relative location of points on the Earth’s surface.

The concept of global mean sea level is complicated by the fact that the Earth’s mass is not uniformly distributed within an elliptical shell. Areas with greater mass have a stronger gravitational attraction than areas with less mass, and these differences cause the actual mean sea level to be different at different locations on the Earth’s surface. To account for these differences, geodesists imagine a three-dimensional surface configured so that the Earth’s gravitational attraction is the same at every point on the surface. This surface is called the geoid, and is a closer approximation to global mean sea level than the ellipsoid.

It is difficult to precisely locate the fundamental reference points for latitude, longitude, and elevation, or to measure the distance from these reference points to any other point on Earth. In comparison, the distance between a group of fixed reference points covering a limited area of the Earth can be measured much more accurately. This is why geodesists use datums of reference points to precisely locate other points on Earth. Throughout the United States, the National Geodetic Survey (NGS) has installed a network of hundreds of continuously tracking GPS stations known as the Continuously Operating Reference Station (CORS) Network. Nearly all of the data produced by the CORS Network are available through the World Wide Web. The lessons "All Shook Up" and "It's Not Your Fault" give hands-on examples of how to use the CORS to study movements of the Earth's crust.

This lesson is intended to introduce students to the basic concepts and importance of geodesy.

Learning Procedure

1.

Tell students to imagine that they are communicating with a foreign astronaut aboard the International Space Station. The astronaut says, "We are testing a new, extremely high resolution telescope today. Let's find out if it's good enough to see you. Tell me where you are, and I'll try to point the telescope to that location. So where are you?"

Ask students how they would answer the question. If they use the name of their school, city, etc., tell them that the astronaut isn't familiar with place names. Eventually (perhaps with your help) students should state that they need to use latitude and longitude to describe their location, or specific distances to reference points known to the astronaut that could be used to establish their location by triangulation. Tell students that accurately describing the location of places on the Earth's surface and monitoring changes in the location of these places is the subject of the science known as geodesy.

Ask students to infer why geodesy might be useful or important. Tabulate their answers on an overhead transparency or marker board. After they have exhausted their ideas (or if they have trouble with the question), show the bridge construction image from: *http://oceanservice.noaa.gov/news/features/supp_sep03.html*. Students should realize that road and bridge construction, map making, and navigating aircraft and ships are among the ways that geodesy is both useful and important. If earthquakes have not been mentioned, show the headline from *http://www.cbsnews.com/stories/2003/12/23/national/main589918.shtml*, or use headline from Appendix A. Ask whether geodesy might be relevant to earthquakes. Students should understand that earthquakes are the result of movements by the Earth's crust, and that geodesists have the tools to record these movements. If smaller movements commonly precede the crustal movements that cause earthquakes, then these smaller movements may provide more warning of earthquake events than is presently known.

2.

Introduce the idea of how a datum of fixed reference points can be used to describe the location of other points.

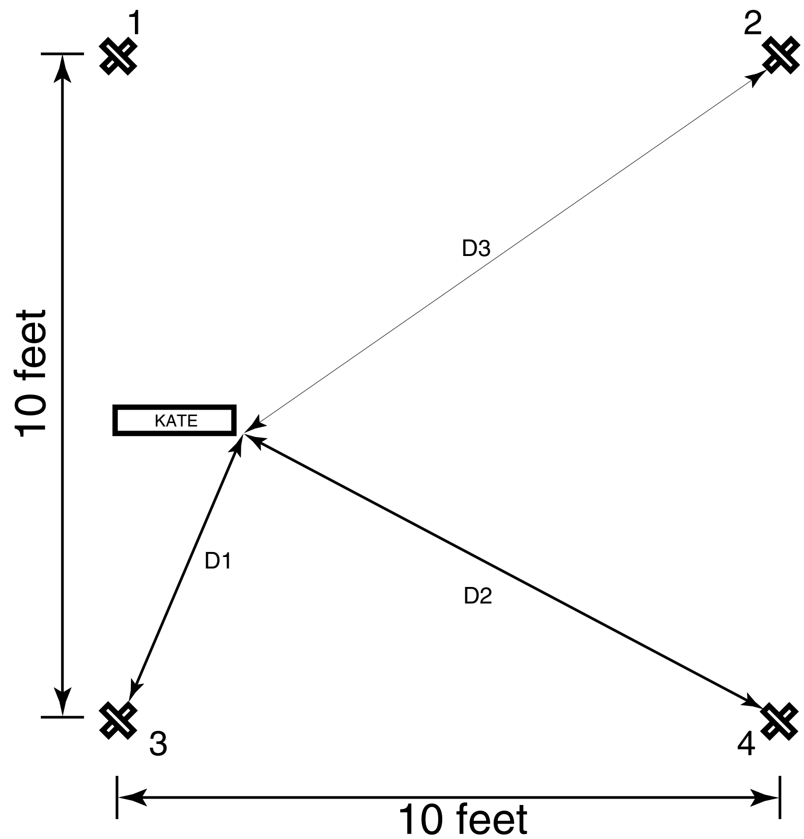
a. Have five students stand in different locations within a cleared 10 ft x 10 ft area marked on the floor with small x's of masking tape at each corner. Write the name of each of the five students on small pieces of masking tape, and use these to mark the location of each student. Ask students to explain how they could describe the location of each student using one or more corners of the square as reference points. Students should realize that each student location can be described by the distance from two of the corners. Be sure students understand that a single measurement is not sufficient to describe a location, and that a third measurement would provide an even more accurate position than two (Figure 1).

Students may suggest that locations could also be described by the angles formed between a line from a given location to a corner and one of the boundary lines extending from that corner to an adjacent corner (see Figure 2). Tell students that this is also a valid way to describe location, and that both techniques are used by geodesists. Say that for this demonstration, we will use the distance method because we can measure distance more easily and accurately than angles.

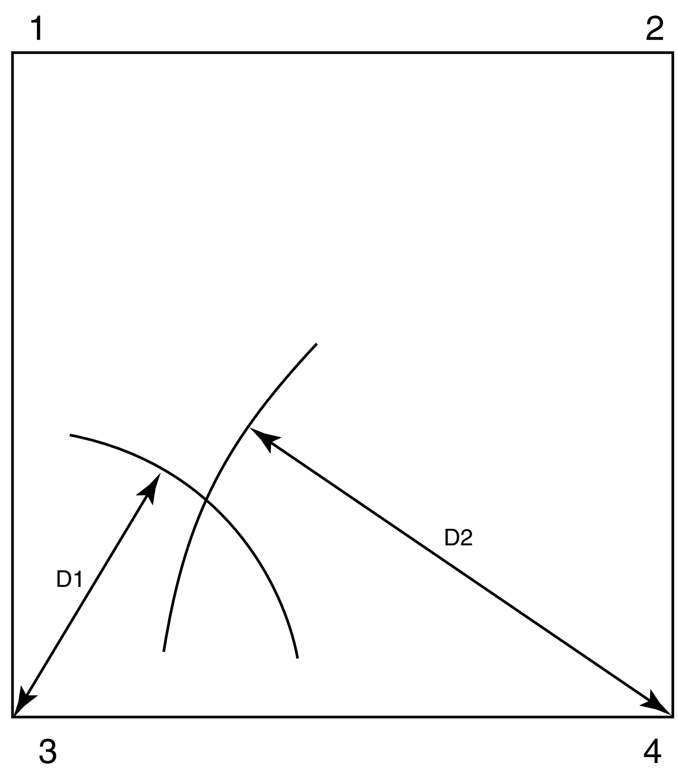
b. Have each student group make the measurements needed to describe the location of each student within the 10 ft x 10 ft area, and use these measurements to diagram the locations, using an appropriate scale so the entire 10 ft x 10 ft area can be diagrammed on a single page (if an 8.5 in x 11 in page is used, a scale of 0.5 in = 1 ft will work). Students should use drafting compasses to translate their measurements to their diagram.

c. Tell students that the diagrams they have constructed represent a datum—a group of fixed reference points covering a specified

Figure 1

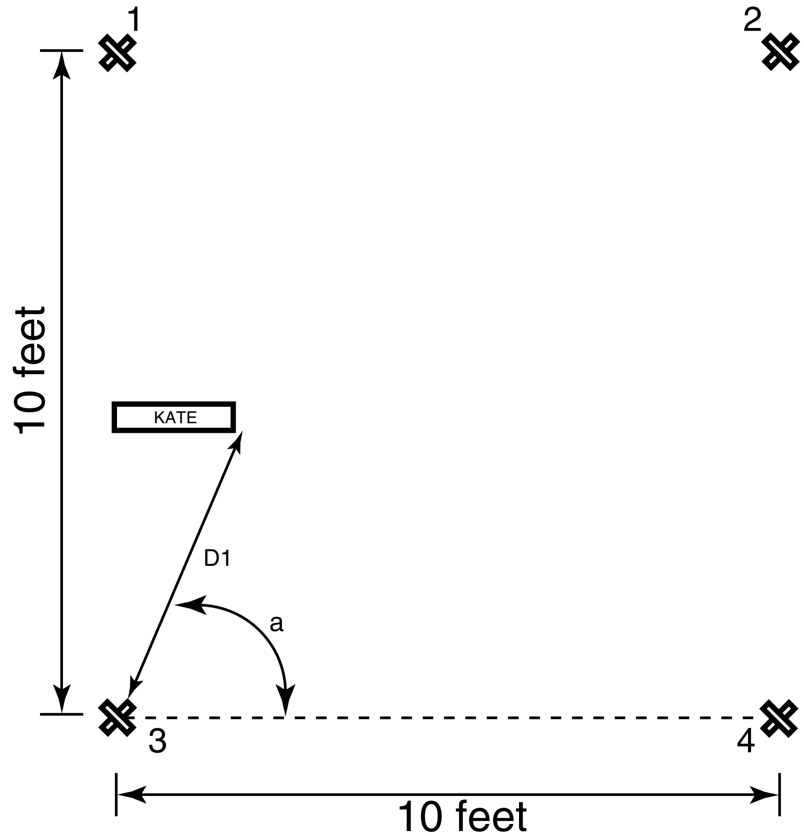


Kate is distance D1 from corner 3, D2 from corner 4, and D3 from corner 2.

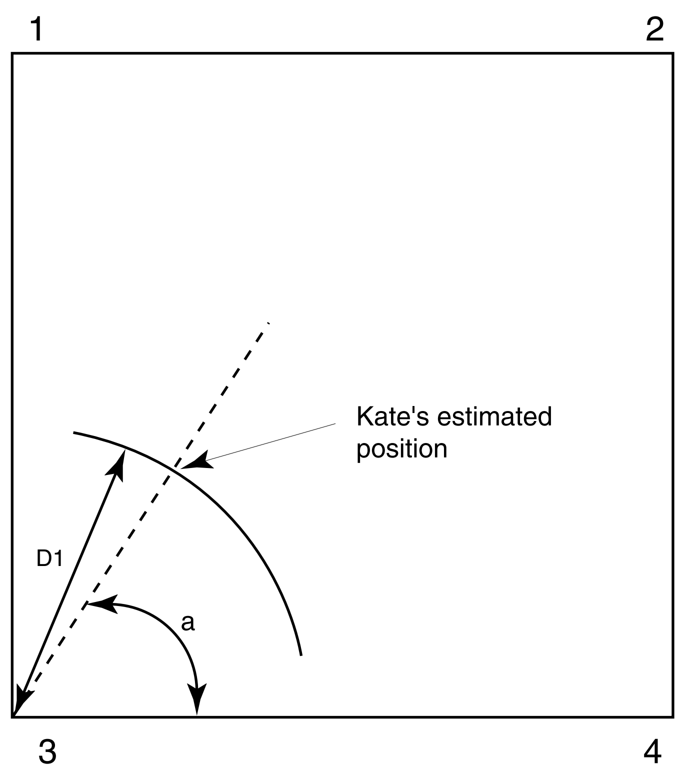


If we draw a reference square using a scale in which one side is equal to 10 feet, then we can use the same scale to draw an arc from corner 3 so that the radius of the arc is equal to D1. Then draw another arc from corner 4 whose radius is equal to D2. The intersection of the two arcs is Kate's estimated position inside the reference square. If we draw a third arc from corner 2 whose radius is equal to D3, the estimated position is more accurate.

Figure 2



Kate is distance D1 from corner 3. "a" is the angle between a line from Kate's position to corner 3, and a line between corners 3 and 4.



We can use the same reference square described in Figure 1. First, draw a line at angle "a" to side 3–4 of the square. Then draw an arc from corner 3 using the same scale so that the radius of the arc is equal to D1. The intersection of the line and the arc is Kate's estimated position inside the reference square.

area. Ask one student to move to a position somewhere inside the 10 ft x 10 ft area, and mark her or her position with a piece of masking tape. Ask students whether they could describe the location of this new position without using the corners of the 10 ft x 10 ft area. Students should realize that they can use two or more points in their datum to describe this location. Have each group make measurements needed to describe the location of this point, and plot this location on their diagram. Tell students that this new point could be added to their datum to provide another reference point, and that when geodesists add new reference points to a datum they say the new points have been "tied in" to the datum.

d. Ask students what data they would have collected to describe the height of the five students used to construct their datum. Students should realize that, again, they could use distance or angular measure from fixed reference points to describe height. The simplest approach would be to measure distance from a fixed reference plane (the floor) to describe the "maximum vertical location" (height) of each student.

e. Tell students that geodesy is based on fixed reference points on the Earth's surface. These points are marked by metal disks that are set into concrete casings (called benchmarks), or very stable structures called monuments. Students should recognize that a large number of these points over a specific area form a datum, and that the known location of these points can be used to determine the location of any other point in the area covered by the datum. Tell students that although satellites in the Global Positioning System are now used to accurately determine the location of reference points within a datum, the methods are still based on the principles of triangulation and trigonometry that geodesists have used for centuries.

3.

Direct students to the geodesy tutorials at *http://oceanservice.noaa.gov/education/welcome.html*. Have each student or student group complete one version of the Geodesy Review, and lead a discussion to review the answers. Be sure that students understand that the location of each reference point in a geodetic datum is described in two ways. The first way is by its latitude and longitude (horizontal position), and height above or below mean sea level (vertical position). The second way is by the distance of the reference point from other reference points. Students should realize that the distance between reference points can be measured much more accurately than the distance of a point from the equator, or from the Royal Observatory at Greenwich, or from mean sea level. This greater accuracy is why the reference points are used to describe the location of other points in the area covered by a datum. Students should also understand that the points used to determine vertical position are not necessarily the same points used to determine horizontal position, so the vertical datum is different from the horizontal datum.

The Bridge Connection

www.vims.edu/bridge/ - Click on "Search" in the box on the upper right corner of the page and enter : "earthquake."

The "Me" Connection

Have students write a short essay on three ways in which geodesy has (or might have) affected their own lives during the past year.

Extensions

1. Have students visit *http://geodesy.noaa.gov/INFO/NGShistory.html* and prepare a brief report highlighting advances in geodesy since its initial establishment as the Survey of the Coast by Thomas Jefferson in 1807.

2. Visit *http://www.exploratorium.edu/faultline/activities/index.html* to learn more about earthquakes.

Resources

http://www.ngs.noaa.gov/CORS/ – Web site for the National Geodetic Survey's network of continuously operating reference stations (CORS) that provide Global Positioning System (GPS) measurements to support accurate determination of locations and elevations throughout the United States and its territories.

http://geodesy.noaa.gov/PUBS_LIB/thePossibilities/Imagine.html – A brochure (in pdf format) explaining the role of geodesy in contemporary America.

http://www.ngs.noaa.gov/OPUS – Web site for the National Geodetic Survey's On-line Positioning User Service (OPUS). This service allows users to submit GPS data files to NGS, where the data are processed to determine a position using NGS computers and software. Calculated positions are reported back via email.

http://oceanservice.noaa.gov/news/features/supp_sep03.html – National Ocean Service Web site story that describes the National Spatial Reference System, Global Positioning System, and why geodesy is important.

http://geodesy.noaa.gov/GEOID/ – National Geodetic Survey Web site with definitions, descriptions, and links to research and information about the geoid, including a slide show on geoid modeling at NOAA. (*http://www.ngs.noaa.gov/GEOID/PRESENTATIONS/2000_11_ScottGudes_SilverSpring_Geoid_at_NGS/2000_11_ScottGudes_SilverSpring_Geoid_at_NGS.ppt*)

http://geodesy.noaa.gov/GRD/ – Web site of the Geosciences Research Division of the National Geodetic Survey, with current projects, data, software and archives

http://geodesy.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003A.HTM – A "classic" report that presents the basic principles of geodesy in an elementary form.

http://einstein.gge.unb.ca/tutorial/tutorial.htm – An introduction to geodesy by the Geodesy Group at the University of New Brunswick.

http://geodesy.noaa.gov/faq.shtml – Frequently Asked Questions about geodesy and the National Geodetic Survey.

http://geodesy.noaa.gov/INFO/NGShistory.html – History of the National Geodetic Survey, which was the first civilian scientific agency in the United States, established by President Thomas Jefferson in 1807

http://geodesy.noaa.gov/geodetic_links.shtml – Links to other organizations, information, and resources about geodesy.

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural and human-induced hazards

GEODESY LESSON PLAN

Appendix A

Deadly Quake Jolts California

PASO ROBLES, Calif, Dec. 22, 2003

An earthquake rocked California's central coast Monday and shook the state from Los Angeles to San Francisco, collapsing old downtown buildings in this small town and killing at least three people.

GEODESY LESSON PLAN

Geodesy Subject Review

1. The science of measuring and monitoring the size and shape of the Earth is ___________________.

2. By looking at the height, angles and distances between numerous locations on the Earth's surface, geodesists create a ___________________.

3. The Earth's surface rises and falls about 30 _____________ ______. everyday under the gravitational influences of the moon and the sun.

4. The Earth's outermost layer is called the _________________.

5. The plates that make up the Earth's outer layer ride atop a sea of molten rock called ___________________.

6. Plate ___________________. is the scientific discipline that looks at how the Earth's plates shift and interact, especially in relation to earthquakes and volcanoes.

WORD BANK

Aristotle
Geographic Information System
benchmarks
Global Positioning System
San Andreas Fault
datums
National Spatial Reference System
longitude
triangulation
time
magma
tectonics
masses
gravity
higher
gravimeters
Thomas Jefferson
geoid
unevenly
latitude
billionths
Continuously Operating Reference Stations
oblate
ellipsoid
geodesy
centimeters
horizontal
crust
vertical
differential
subsidence
refusal

7. The Greek philosopher ____________________ is credited as the first person to try and calculate the size of the Earth by determining its circumference.

8. A method of determining the position of a fixed point from the angles to it from two fixed points a known distance apart. ______________________

9. The Earth is flattened into the shape of an _________________ sphere.

10. To measure the Earth, and avoid the problems that places like the Grand Canyon present, geodesists use a theoretical, mathematical surface called the ____________________ that is created by rotating an ellipse around its shorter axis.

11. To account for the reality of the Earth's surface, geodesists use a shape called the ____________________ that refers to mean sea level.

12. The earth's mass is ____________________ distributed, meaning that certain areas of the planet experience more gravitational "pull" than others.

13. ____________________ are sets of data that are the basis for all geodetic survey work. In the United States, horizontal and vertical datums make up a system called the _________ __________.

14. The ____________________ datum is a collection of specific points on the Earth that have been identified according to their precise northerly or southerly location and easterly or westerly location.

15. The northerly or southerly location of a point on the Earth's surface is known as the point's ___________________.

16. The easterly or westerly location of a point on the Earth's surface is known as the point's ____________________.

17. Surveyors markpositions with brass discs or monuments called ____________________.

18. Surveyors now rely almost exclusively on the ___________ to identify locations on the Earth.

19. The __________________ is where two plates of the Earth's crust meet, and is responsible for many earthquakes in California.

20. The __________________ datum is a collection of positions whose heights above or below mean sea level is known.

21. The traditional method for setting vertical benchmarks is called __________________ leveling subsidence land sinking

22. Gravitational attraction between two bodies is stronger when the __________________ of the objects are greater and closer together.

23. Because the Earth's mass and density vary at different locations on the planet, __________________ also varies.

24. In areas where the Earth's gravitational forces are weaker, mean sea level will __________________.

25. __________________ measure the gravitational pull on a suspended mass.

26. __________________ established the Survey of the Coast, which later evolved into the National Geodetic Survey.

27. The National Geodetic Survey uses markers made from long steel rods driven to __________________ (pushed into the ground until they won't go any farther).

28. GPS receivers calculate the distance to GPS satellites by measuring __________________.

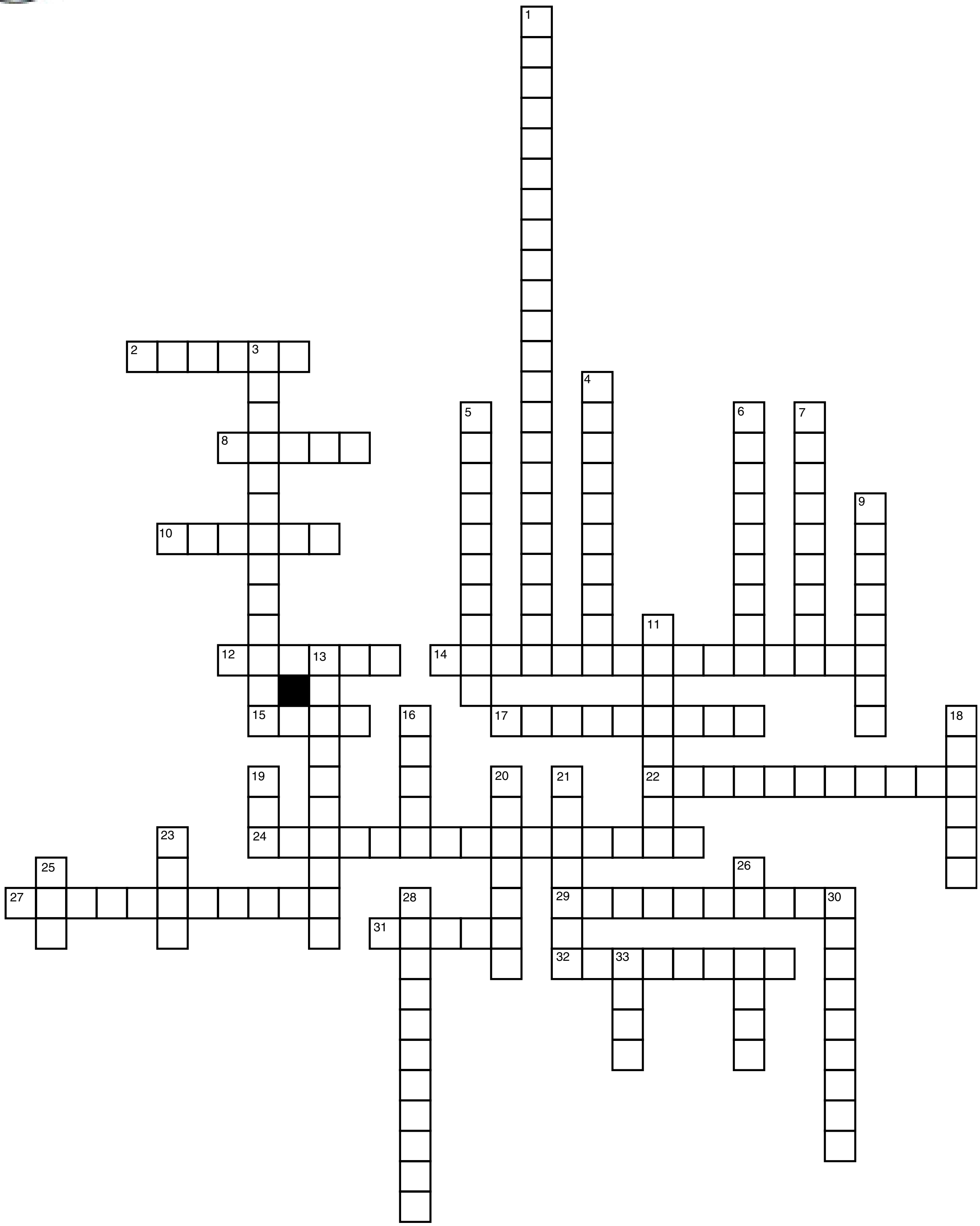
29. GPS satellites have very precise clocks that tell time within three nanoseconds or three __________________. (0.000000003) of a second.

30. ____________________ is a network of hundreds of stationary permanently operating GPS receivers throughout the United States that can be used to accurately determine position.

31. In a ____________________, specific information about a place—such as the locations of utility lines, roads, streams, buildings, and even trees and animal populations—is layered over a set of geodetic data.

GEODESY LESSON PLAN

Geodesy Subject Review: Crossword Puzzle



Across

2. The Earth is flattened into the shape of an _____ sphere.
8. The plates that make up the Earth's outer layer ride atop a sea of molten rock called _____
10. _____ are sets of data that are the basis for all geodetic survey work.
12. In areas where the Earth's gravitational forces are weaker, mean sea level will _____
14. Established the Survey of the Coast, which later evolved into the National Geodetic Survey. [2 words]
15. In the United States, horizontal and vertical datums make up a system called the _____. [abbrev]
17. The easterly or westerly location of a point on the Earth's surface is known as the point's _____.
22. The Earth's surface rises and falls about 30 _____ everyday under the gravitational influences of the moon and the sun.
24. The _____ is where two plates of the Earth's crust meet, and is responsible for many earthquakes in California. [3 words]
27. The traditional method for setting vertical benchmarks is called _____ leveling.
29. land sinking
31. The Earth's outermost layer is called the _____.
32. The northerly or southerly location of a point on the Earth's surface is known as the point's _____.

Down

1. By looking at the height, angles and distances between numerous locations on the Earth's surface, geodesists create a _____. [3 words]
3. A method of determining the position of a fixed point from the angles to it from two fixed points a known distance apart.
4. Surveyors markpositions with brass discs or monuments called _____.
5. GPS satellites have very precise clocks that tell time within three nanoseconds or three _____ (0.000000003) of a second.
6. The Greek philosopher _____ is credited as the first person to try and calculate the size of the Earth by determining its circumference.
7. Plate _____ is the scientific discipline that looks at how the

Earth's plates shift and interact, especially in relation to earthquakes and volcanoes.

9. The Earth's mass is _____ distributed, meaning that certain areas of the planet experience more gravitational "pull" than others.
11. The _____ datum is a collection of positions whose heights above or below mean sea level is known.
13. The _____ datum is a collection of specific points on the Earth that have been identified according to their precise northerly or southerly location and easterly or westerly location.
16. To account for the reality of the Earth's surface, geodesists use a shape called the _____ that refers to mean sea level.
18. Gravitational attraction between two bodies is stronger when the _____ of the objects are greater and closer together.
19. Surveyors now rely almost exclusively on the _____ to identify locations on the Earth. [abbrev]
20. Because the Earth's mass and density vary at different locations on the planet, _____ also varies.
21. The National Geodetic Survey uses markers made from long steel rods driven to _____ (pushed into the ground until they won't go any farther).
23. _____ is a network of hundreds of stationary permanently operating GPS receivers throughout the United States that can be used to accurately determine position. [abbrev]
25. In a _____, specific information about a place—such as the locations of utility lines, roads, streams, buildings, and even trees and animal populations—is layered over a set of geodetic data. [abbrev]
26. The science of measuring and monitoring the size and shape of the Earth
28. _____ measure the gravitational pull on a suspended mass.
30. To measure the Earth, and avoid the problems that places like the Grand Canyon present, geodesists use a theoretical, mathematical surface called the _____ that is created by rotating an ellipse around its shorter axis.
33. GPS receivers calculate the distance to GPS satellites by measuring _____.