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Northwestern Hawaiian Islands Exploration

Mapping Deep-Sea Habitats

Focus
Bathymetric mapping of deep-sea habitats

Grade Level
5-6, 7-8 (Earth Science)

Focus Question
How can deep-sea areas of the Northwest Hawaiian Islands be mapped to facilitate their exploration with a manned submersible?

Learning Objectives
Students will be able to create a two-dimensional topographic map given bathymetric survey data.

Students will be able to create a three-dimensional model of landforms from a two-dimensional topographic map.

Students will be able to interpret two- and three-dimensional topographic data.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the vocabulary list.

Atoll
Nautical
SCUBA
Exploration
Constraint
Nautical chart
Multibeam swath bathymetry
Topography
Transducer
Backscatter
GPS
Topographic

The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. Also give the list as a handout to the students to refer to after the lesson.

If these topics have not already been covered in your class you will need to add an additional class period to cover all the material. This activity is a bit involved and may require an additional period as well. List all the steps required for the activity on the board so that students can follow step-by-step and you can easily refer to the steps to be sure activity is on track.

Materials
- ❒ Copies of "Loihi Submarine Volcano Bathymetric Data;" one for each student group
- ❒ Copies of "Bathymetric Data Reduction Sheet;" one for each student group
- ❒ (Optional) Copies of "Appendix A Supplemental Data Sets;" one for each student group
- ❒ Tracing paper
- ❒ Pieces of foamcore display board, seven for each student group; 8-1/2" x 11" x 5/32" thick or 11" x 17" x 1/4" thick if students'

maps are enlarged 200% (see Learning Procedure, Step #2; these thicknesses will approximate the correct vertical scale)

- ❒ Glue, preferably spray type used for mounting photographs
- ❒ Sharp scissors or X-Acto knives for cutting cardboard

Audio/Visual Materials

None

Teaching Time

Two 45-minute class periods

Seating Arrangement

Groups of four students

Maximum Number of Students

32

Key Words

Seamount
Bathymetry
Transducer
Backscatter
Topographic contour

Background Information

Nearly 70% of all coral reefs in U.S. waters are found around the Northwestern Hawaiian Islands, a chain of small islands and atolls that stretches for more than 1,000 nautical miles (nm) northwest of the main Hawaiian Islands. While scientists have studied shallow portions of the area for many years, almost nothing is known about deeper ocean habitats below the range of SCUBA divers. Only a few explorations have been made with deep-diving submersibles and remotely-operated vehicles (ROVs), and these explorations have yielded discoveries of new species and species previously unreported in Hawaiian waters. Northwestern Hawaiian Islands are regularly visited by Hawaiian monk seals, one of only two species of monk seals remaining in the world (the Caribbean monk seal was declared extinct in 1994). Waters around the North-western Islands may be an important feeding area for the seals, which appear to feed on fishes that find shelter among colonies of deep-water corals. These corals are also of interest, because they include several species that are commercially valuable for jewelry. The possibility of discovering new species also has commercial importance as well as scientific interest, since some of these species may produce materials of importance to medicine or industry.

A major constraint to exploration of deep-water regions around the Northwestern Hawaiian Islands is the absence of accurate maps of the area. In fact, recent expeditions have found that some islands are not where they are supposed to be according to official nautical charts. Since underwater exploration time in submersibles is severely limited, every dive must be carefully planned to ensure that the submersible can go directly to places that are most likely to provide the information the scientists need. For this reason, underwater mapping is a top priority for the Ocean Exploration 2002 Northwestern Hawaiian Islands Expedition.

Scientists aboard the University of Hawaii's research vessel Kilo Moana will use multibeam swath bathymetry to create detailed pictures of the underwater topography around the Northwestern Hawaiian Islands. Multibeam swath bathymetry (also called "high-resolution multibeam mapping") uses a transducer (a sort of combination microphone/loudspeaker) mounted on the ship's hull to send out pulses of sound in a fan-shaped pattern below the ship, and then records sound reflected from the seafloor through a set of narrow receivers aimed at different angles on either side of the ship. This system collects high resolution water-depth data that can distinguish differences of less than a meter. The system also measures the amount of sound energy returned from the seafloor (called "backscatter"), which can help identify different materials (such as rock, sand, or mud) on the seafloor. The multibeam system is coupled to a global positioning system (GPS) that can pinpoint sea-floor locations within one meter. All data are collected in digital form, which allows them to be processed by computer to produce maps, three dimensional models, or even "fly-by" videos that simulate a trip across the area being mapped in a high-speed submersible! Topographic maps are one of the most common outputs from these systems. On these maps, areas with the same depth are connected by lines, so that mountains (or valleys) are shown as a series of concentric, irregular closed curves. Curves that are close together indicate steep topography, while curves that are farther apart show more gentle slopes.

This activity focuses on how topographic maps are created from multibeam bathymetric data. Students will construct a three-dimensional model of the Loihi submarine volcano from their topographic maps to help visualize the actual form of the seamount.

Learning Procedure

1. Introduce the location of the Northwestern Hawaiian Islands, and point out some of the features that make this area important (discussed above). Discuss the need for accurate maps in planning diving expeditions to deep-sea regions, and explain the general concept of multibeam swath bathymetry. You may need to review the basic idea of topographic maps if students are unfamiliar with these.

2. Distribute copies of "Loihi Volcano Bathymetric Data" and "Bathymetric Data Reduction Sheet" to each student group. Tell the students that the bathymetric data are part of a data set that was produced by a research vessel using multibeam bathymetry. Be sure students understand that each data point represents the depth of water below the research vessel when the vessel was at the location described by the grid coordinates. If you want to relate the grid to an actual map location, the lower left corner of grid cell 1,1 corresponds to latitude 18°-45'N, longitude 155°-20'W. Each grid cell interval corresponds to one minute of latitude or longitude. Note that for the purposes of this exercise, we are not dealing with all of the side-scan data, which would include more than a hundred additional depth readings in each grid cell, and would be much more difficult to process without computer analysis.

   Have each group enter the depth readings from the bathymetric data sheet into the corresponding grid cells on the "Bathymetric Data Reduction Sheet." Next, have the students draw contour lines on the Data Reduction Sheet for depths of 1,000 m, 2,000 m, 3,000 m, and 4,000 m. Tell the students to assume that the depth reading was taken at the center of each grid cell (indicated on the Data Reduction Sheet by the light crossed diagonal lines). In most cases, students will have to interpolate the position of the contour lines; for example, if one grid cell has a depth reading of 2,800 m and an adjacent cell has a depth reading of 3,200 m, students should assume that the 3,000 m contour line passes halfway between the center points of the two cells. Once these three contour lines are drawn, have students draw intermediate contour lines at 500 m intervals (i.e., 1,500 m, 2,500 m, and 3,500 m). When students have completed their contour maps, have them make a master tracing, and seven photocopies. If you want them to make larger models, they can enlarge their master tracing on the photocopier.

3. Have the students mount each copy of their contour map onto a piece of cardboard. Be sure to use enough glue to cover the entire surface of the cardboard. Next, students should prepare the seven layers of their

three dimensional model by cutting along the 4,000 m contour line on one mounted map, then cutting along the 3,500 m contour on the next mounted map, and so on until three layers have been cut out corresponding to each of the seven contour lines constructed on the Data Reduction Sheet. If students are using X-Acto knives, be sure to have a suitable backing (heavy cardboard, cutting board, etc.) to protect work surfaces.

4. Starting with the 4,000 m contour, carefully glue successive contours together to build the three-dimensional model of the volcano.

5. Using the models the students have produced, discuss the advantages of various locations on the volcano for diving missions. Flat regions are more likely to have accumulations of sediment, and will provide different habitats than very steep areas. On the other hand, steep areas obviously have a greater range of depths within a short distance, so these are better sites to study how depth influences the distribution of various species. Identify areas that are likely to offer a variety of habitat types within a short distance. These offer some of the best opportunities to get the most out of limited diving time.

Have the students compare their models with the bathymetric image of the Loihi volcano at http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html. This image provides much more detail than the students' topographic maps because it includes thousands more data points. This sort of detailed mapping is only possible when computer analysis is available.

The BRIDGE Connection

www.vims.edu/bridge/pacific.html

The "Me" Connection

Have students write a first-hand account of an exploratory mission to the Loihi volcano, referring to topographic features revealed by their model.

Connections to Other Subjects

English/Language Arts, Mathematics

Evaluation

Have students write a description of the Loihi volcano based on their model. Have them include geographic location (north-south-east-west directions and/or latitude and longitude), topography (steepness), and depth. Ask them to discuss the advantages and disadvantages of two-dimensional and three-dimensional topographic maps.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/02hawaii/welcome.html to follow the progress of deep-sea mapping in the vicinity of the Northwestern Hawaiian Islands. Additional data sets for topographic map construction may be posted here as the Expedition proceeds.

Resources

http://oceanexplorer.noaa.gov/explorations/02hawaii/welcome.html – Follow the Northwestern Hawaiian Islands Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html – Short article on the Loihi volcano

http://www.soest.hawaii.edu/GG/HCV/loihi.html – More extensive website with information on Loihi and other volcanoes in Hawaii

http://www.sciencegems.com/earth2.html – Science education resources

http://www.martindalecenter.com/ – References on just about everything

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard D: Earth and Space Science

- Structure of the Earth system

For More Information

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Student Handout

Loihi Submarine Volcano Bathymetric Data

Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)
1,1	no data	3,10	2400	6,4	4000	8,13	3200
1,2	no data	3,11	2000	6,5	3400	8,14	3200
1,3	no data	3,12	1900	6,6	2700	8,15	2800
1,4	4600	3,13	2000	6,7	2000	9,1	4400
1,5	4400	3,14	21	6,8	1800	9,2	4000
1,6	4400	3,15	2200	6,9	1600	9,3	3600
1,7	4000	4,1	no data	6,10	1300	9,4	3400
1,8	3800	4,2	no data	6,11	1200	9,5	3900
1,9	3600	4,3	4400	6,12	1700	9,6	4000
1,10	3300	4,4	3800	6,13	2000	9,7	3800
1,11	2700	4,5	3500	6,14	2200	9,8	3700
1,12	2400	4,6	3200	6,15	2000	9,9	3600
1,13	2500	4,7	2800	7,1	4500	9,10	3800
1,14	2600	4,8	2800	7,2	4400	9,11	3600
1,15	2800	4,9	2300	7,3	4000	9,12	3500
2,1	no data	4,10	1800	7,4	3800	9,13	3400
2,2	no data	4,11	1400	7,5	3000	9,14	3300
2,3	no data	4,12	1500	7,6	2400	9,15	3200
2,4	4200	4,13	1600	7,7	2400	10,1	4500
2,5	4100	4,14	1800	7,8	2300	10,2	4200
2,6	4100	4,15	1900	7,9	2300	10,3	4200
2,7	3900	5,1	no data	7,10	2500	10,4	4700
2,8	3400	5,2	no data	7,11	2500	10,5 - 10,15	no data
2,9	3200	5,3	4600	7,12	2700	11,1	4700
2,10	2800	5,4	4000	7,13	2900	11,2	4500
2,11	2400	5,5	3400	7,14	3000	11,3	4700
2,12	2200	5,6	2900	7,15	2500	11,4 - 11,15	no data
2,13	2300	5,7	2300	8,1	4500		
2,14	2300	5,8	1800	8,2	4000		
2,15	2400	5,9	1600	8,3	3600		
3, 1	no data	5,10	1000	8,4	3100		
3,2	no data	5,11	1100	8,5	3000		
3,3	no data	5,12	1200	8,6	3200		
3,4	4000	5,13	1400	8,7	3200		
3,5	3800	5,14	1600	8,8	3100		
3,6	3800	5,15	1800	8,9	3000		
3,7	3700	6,1	no data	8,10	3100		
3,8	3300	6,2	no data	8,11	3100		
3,9	2800	6,3	4500	8,12	3200		

Student Handout
Bathymetric Data Reduction Sheet

16											
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	1	2	3	4	5	6	7	8	9	10	11

Appendix A
Supplemental Data Sets

Two data sets are provided to give students additional opportunities to create two-dimensional topographic maps and three-dimensional models of seafloor features from bathymetric survey data. These data sets include bathymetry for the Blake Ridge (a ridge/bank feature), and Hudson Canyon (a submarine canyon). Bathymetric data for these locations were obtained from NOAA's National Geophysical Data Center using the GEODAS (GEOphysical DAta System) Design-a-Grid tool (*http://www.ngdc.noaa.gov/mgg/gdas/gd_designagrid.html*).

These data sets may be used with the original Mapping Deep-Sea Habitats lesson created for the 2002 Northwestern Hawaiian Islands Expedition (*http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf*), as well as with the Mapping Deep-Sea Features lesson included in the "Learning Ocean Science Through Ocean Exploration" curriculum (*http://www.oceanexplorer.noaa.gov/edu/curriculum/*). Because the latter lesson involves coloring grid cells according to depth, recommended color keys are included with the supplemental data.

The basic procedure for creating three-dimensional models from these data is described in Learning Procedure Steps 2 through 4 of the Mapping Deep-Sea Habitats lesson. Separate Data Reduction Sheets are provided for each data set. Bathymetric data for Data Reduction Sheet grid cells are given in columns beginning with the lower left grid cell. Because these supplemental data cover much larger areas than the Loihi volcano which was the subject of the original lesson, please note the following:

Blake Ridge (Bank)
There are 300 cells in the Data Reduction Sheet grid, each cell representing 4 minutes of latitude and longitude. The entire grid represents an area of 80 nautical miles x 60 nautical miles; about 145 km x 109 km. So the approximate scale of the grid is 1 inch = 19.3 km.

Have students construct contour lines in 200 meter intervals, from 2,000 meters to 4,000 meters. This will result in a model with eleven layers. If the layers are cut from foamcore 0.25 in thick, each layer will represent a vertical dimension of 200 meters and the vertical scale will be 1 inch = 800 m. Be sure students realize that the vertical scale of their model is exaggerated by a factor of about 24 compared to the horizontal scale. There is nothing wrong with this; such exaggeration is often used when constructing models of large features where variations in vertical distance (such as height or depth) are much smaller than variations in horizontal distance.

For bathymetric maps and images of the Blake Ridge (Bank), see
http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep23/media/bathy.html;
http://oceanexplorer.noaa.gov/explorations/03windows/logs/jul24/media/d1fig1.html;
http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep25/media/area_a.html; and
http://oceanexplorer.noaa.gov/explorations/03windows/logs/jul26/media/bdiapir.html.

Hudson Canyon

There are 240 cells in the Data Reduction Sheet grid, each cell representing 2 minutes of latitude and longitude. The entire grid represents an area of 32 nautical miles x 30 nautical miles; about 59 km x 56 km. So the approximate scale of the grid is 1 inch = 9.9 km.

Because the canyon is very steep, the procedure for constructing contour lines needs to be a little different. Have students construct contour lines at 50 meter intervals from depths of 50 meters to 200 meters, then at 200 meter intervals from depths of 201 meters to 1,143 meters. This will result in a model with seven layers. To maintain a uniform vertical scale, contours for depths below 200 meters should be cut from four thicknesses of foamcore (since the interval for these depths is four times greater than the interval for shallower depths).

If the layers are cut from foamcore 0.25 in thick, the vertical scale will be 1 inch = 200 m. This will cause the vertical scale to be exaggerated by a factor of about 48 compared to the horizontal scale, as discussed above.

For bathymetric maps and images of Hudson Canyon, see
http://oceanexplorer.noaa.gov/explorations/02hudson/background/plan/media/hudson_poster.html;
http://oceanexplorer.noaa.gov/explorations/02hudson/background/mapping/mapping.html;
http://oceanexplorer.noaa.gov/explorations/02hudson/logs/sep08/media/3dview.html; and
http://oceanexplorer.noaa.gov/explorations/02hudson/logs/sep12/sep12.html.

Table 1
Blake Ridge (Bank) Bathymetric Data

Lat	Lon	Depth (m)
31° 36′	76° 16′	2725
31° 40′	76° 16′	2722
31° 44′	76° 16′	2697
31° 48′	76° 16′	2672
31° 52′	76° 16′	2641
31° 56′	76° 16′	2612
32° 0′	76° 16′	2530
32° 4′	76° 16′	2511
32° 8′	76° 16′	2462
32° 12′	76° 16′	2435
32° 16′	76° 16′	2363
32° 20′	76° 16′	2312
32° 24′	76° 16′	2262
32° 28′	76° 16′	2201
32° 32′	76° 16′	2149
31° 36′	76° 12′	2716
31° 40′	76° 12′	2715
31° 44′	76° 12′	2711
31° 48′	76° 12′	2670
31° 52′	76° 12′	2657
31° 56′	76° 12′	2609
32° 0′	76° 12′	2524
32° 4′	76° 12′	2517
32° 8′	76° 12′	2472
32° 12′	76° 12′	2452
32° 16′	76° 12′	2392
32° 20′	76° 12′	2330
32° 24′	76° 12′	2269
32° 28′	76° 12′	2209
32° 32′	76° 12′	2151
31° 36′	76° 8′	2728
31° 40′	76° 8′	2726
31° 44′	76° 8′	2700
31° 48′	76° 8′	2697
31° 52′	76° 8′	2668
31° 56′	76° 8′	2622
32° 0′	76° 8′	2579
32° 4′	76° 8′	2552
32° 8′	76° 8′	2486
32° 12′	76° 8′	2459
32° 16′	76° 8′	2405
32° 20′	76° 8′	2330
32° 24′	76° 8′	2250
32° 28′	76° 8′	2230
32° 32′	76° 8′	2207
31° 36′	76° 4′	2753
31° 40′	76° 4′	2719
31° 44′	76° 4′	2713
31° 48′	76° 4′	2690
31° 52′	76° 4′	2672
31° 56′	76° 4′	2654
32° 0′	76° 4′	2622
32° 4′	76° 4′	2572
32° 8′	76° 4′	2523
32° 12′	76° 4′	2470
32° 16′	76° 4′	2417
32° 20′	76° 4′	2318
32° 24′	76° 4′	2311
32° 28′	76° 4′	2316
32° 32′	76° 4′	2266
31° 36′	76° 0′	2819
31° 40′	76° 0′	2710
31° 44′	76° 0′	2709
31° 48′	76° 0′	2695
31° 52′	76° 0′	2670
31° 56′	76° 0′	2656
32° 0′	76° 0′	2624
32° 4′	76° 0′	2587
32° 8′	76° 0′	2529
32° 12′	76° 0′	2469
32° 16′	76° 0′	2414
32° 20′	76° 0′	2387
32° 24′	76° 0′	2395
32° 28′	76° 0′	2427
32° 32′	76° 0′	2358
31° 36′	75° 56′	2900
31° 40′	75° 56′	2734
31° 44′	75° 56′	2688
31° 48′	75° 56′	2685
31° 52′	75° 56′	2681
31° 56′	75° 56′	2670
32° 0′	75° 56′	2640
32° 4′	75° 56′	2576
32° 8′	75° 56′	2517
32° 12′	75° 56′	2467
32° 16′	75° 56′	2480
32° 20′	75° 56′	2468
32° 24′	75° 56′	2527
32° 28′	75° 56′	2549
32° 32′	75° 56′	2575
31° 36′	75° 52′	2931
31° 40′	75° 52′	2813
31° 44′	75° 52′	2719
31° 48′	75° 52′	2665
31° 52′	75° 52′	2667
31° 56′	75° 52′	2660
32° 0′	75° 52′	2637
32° 4′	75° 52′	2558
32° 8′	75° 52′	2498
32° 12′	75° 52′	2520
32° 16′	75° 52′	2564
32° 20′	75° 52′	2638
32° 24′	75° 52′	2666
32° 28′	75° 52′	2737
32° 32′	75° 52′	2820
31° 36′	75° 48′	2989
31° 40′	75° 48′	2866
31° 44′	75° 48′	2746
31° 48′	75° 48′	2658
31° 52′	75° 48′	2631
31° 56′	75° 48′	2655
32° 0′	75° 48′	2666
32° 4′	75° 48′	2583
32° 8′	75° 48′	2544
32° 12′	75° 48′	2597
32° 16′	75° 48′	2701
32° 20′	75° 48′	2762
32° 24′	75° 48′	2812
32° 28′	75° 48′	2862
32° 32′	75° 48′	2937
31° 36	75° 12′	3011
31° 40′	75° 12′	2979
31° 44′	75° 12′	3049
31° 48′	75° 12′	3056
31° 52′	75° 12′	3156
31° 56′	75° 12′	3350

Table 1(continued)
Blake Ridge (Bank) Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
32° 0′	75° 12′	3369	32° 16′	75° 8′	3962	32° 32′	75° 4′	4084
32° 4′	75° 12′	3464	32° 20′	75° 8′	4008	31° 36′	75° 0′	3227
32° 8′	75° 12′	3781	32° 24′	75° 8′	3995	31° 40′	75° 0′	3312
32° 12′	75° 12′	3833	32° 28′	75° 8′	3998	31° 44′	75° 0′	3451
32° 16′	75° 12′	3848	32° 32′	75° 8′	4018	31° 48′	75° 0′	3578
32° 20′	75° 12′	3880	31° 36′	75° 4′	3089	31° 52′	75° 0′	3694
32° 24′	75° 12′	3918	31° 40′	75° 4′	3123	31° 56′	75° 0′	3802
32° 28′	75° 12′	3934	31° 44′	75° 4′	3253	32° 0′	75° 0′	3874
32° 32′	75° 12′	3915	31° 48′	75° 4′	3401	32° 4′	75° 0′	3951
31° 36′	75° 8′	3009	31° 52′	75° 4′	3515	32° 8′	75° 0′	4058
31° 40′	75° 8′	2999	31° 56′	75° 4′	3656	32° 12′	75° 0′	4098
31° 44′	75° 8′	3113	32° 0′	75° 4′	3777	32° 16′	75° 0′	4231
31° 48′	75° 8′	3206	32° 4′	75° 4′	3867	32° 20′	75° 0′	4242
31° 52′	75° 8′	3346	32° 8′	75° 4′	3952	32° 24′	75° 0′	4230
31° 56′	75° 8′	3502	32° 12′	75° 4′	4032	32° 28′	75° 0′	4286
32° 0′	75° 8′	3565	32° 16′	75° 4′	4070	32° 32′	75° 0′	4144
32° 4′	75° 8′	3660	32° 20′	75° 4′	4106			
32° 8′	75° 8′	3831	32° 24′	75° 4′	4107			
32° 12′	75° 8′	3920	32° 28′	75° 4′	4093			

Use Colored Pencils, Markers, or Crayons for Data Ranges:

2,000-2,200 m - red
2,201-2,400 m - red orange
2,401-2,600 m - orange
2,601-2,800 m - yellow orange
2,801-3,000 m - yellow
3,001-3,200 m - yellow green
3,201-3,400 m - green
3,401-3,600 m - blue green
3,601-3,800 m - blue
3,801-4,000 m - blue violet
4,001-4,200 m - purple
4,201-4,400 m - black

Blake Ridge (Bank) Bathymetric Data Reduction Sheet

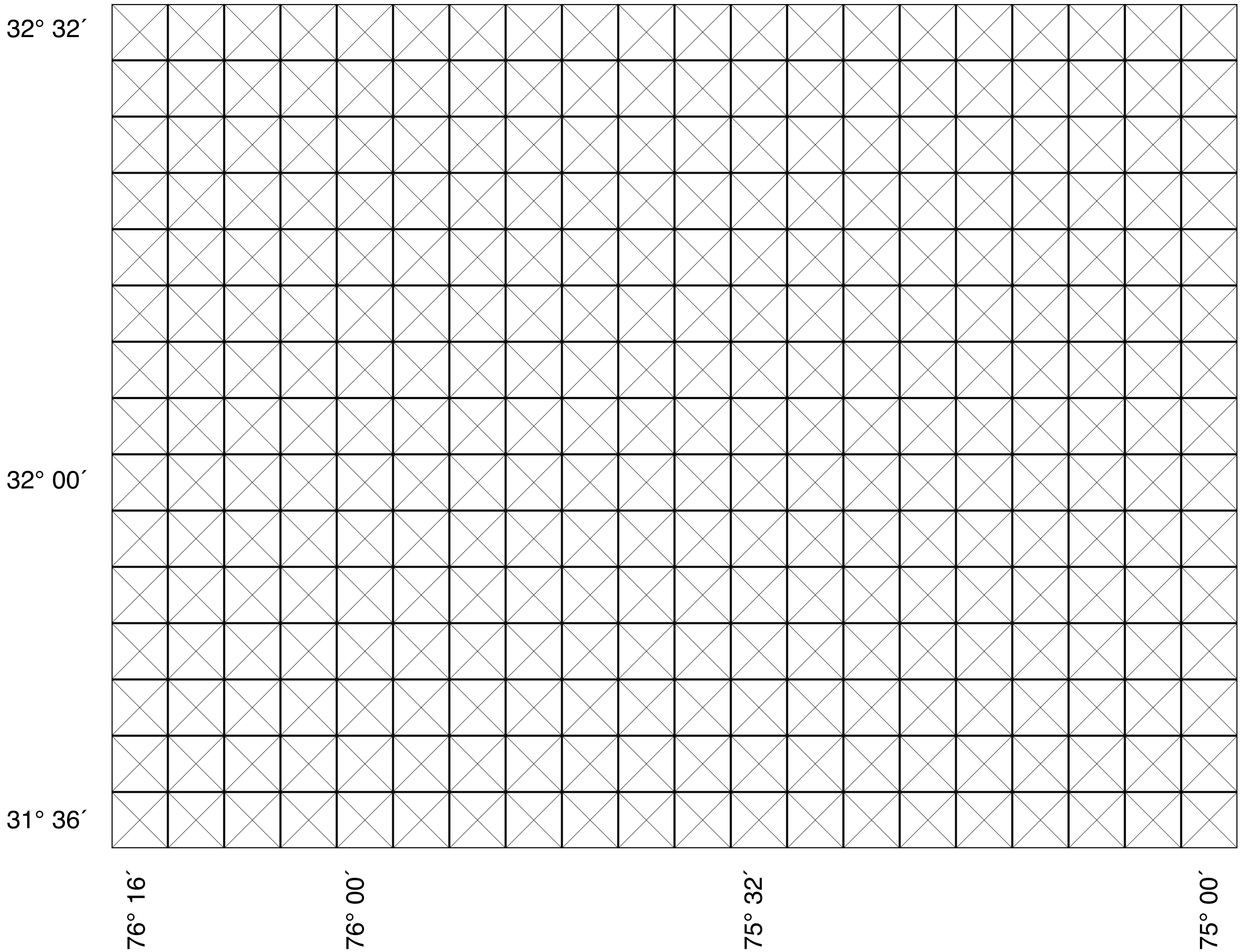

Table 2
Hudson Canyon Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
39° 14′	72° 36′	134	39° 38′	72° 32′	81	39° 32′	72° 26′	116
39° 16′	72° 36′	129	39° 40′	72° 32′	80	39° 34′	72° 26′	110
39° 18′	72° 36′	126	39° 42′	72° 32′	78	39° 36′	72° 26′	99
39° 20′	72° 36′	120	39° 14′	72° 30′	177	39° 38′	72° 26′	204
39° 22′	72° 36′	117	39° 16′	72° 30′	139	39° 40′	72° 26′	149
39° 24′	72° 36′	108	39° 18′	72° 30′	139	39° 42′	72° 26′	92
39° 26′	72° 36′	102	39° 20′	72° 30′	134	39° 14′	72° 24′	316
39° 28′	72° 36′	93	39° 22′	72° 30′	131	39° 16′	72° 24′	197
39° 30′	72° 36′	87	39° 24′	72° 30′	127	39° 18′	72° 24′	164
39° 32′	72° 36′	79	39° 26′	72° 30′	121	39° 20′	72° 24′	143
39° 34′	72° 36′	81	39° 28′	72° 30′	114	39° 22′	72° 24′	138
39° 36′	72° 36′	78	39° 30′	72° 30′	105	39° 24′	72° 24′	133
39° 38′	72° 36′	74	39° 32′	72° 30′	92	39° 26′	72° 24′	130
39° 40′	72° 36′	77	39° 34′	72° 30′	90	39° 28′	72° 24′	125
39° 42′	72° 36′	76	39° 36′	72° 30′	89	39° 30′	72° 24′	121
39° 14′	72° 34′	140	39° 38′	72° 30′	86	39° 32′	72° 24′	219
39° 16′	72° 34′	134	39° 40′	72° 30′	88	39° 34′	72° 24′	262
39° 18′	72° 34′	132	39° 42′	72° 30′	81	39° 36′	72° 24′	143
39° 20′	72° 34′	126	39° 14′	72° 28′	219	39° 38′	72° 24′	296
39° 22′	72° 34′	123	39° 16′	72° 28′	144	39° 40′	72° 24′	165
39° 24′	72° 34′	119	39° 18′	72° 28′	142	39° 42′	72° 24′	93
39° 26′	72° 34′	109	39° 20′	72° 28′	139	39° 14′	72° 22′	346
39° 28′	72° 34′	99	39° 22′	72° 28′	134	39° 16′	72° 22′	228
39° 30′	72° 34′	91	39° 24′	72° 28′	130	39° 18′	72° 22′	188
39° 32′	72° 34′	87	39° 26′	72° 28′	126	39° 20′	72° 22′	157
39° 34′	72° 34′	83	39° 28′	72° 28′	120	39° 22′	72° 22′	144
39° 36′	72° 34′	78	39° 30′	72° 28′	110	39° 24′	72° 22′	139
39° 38′	72° 34′	79	39° 32′	72° 28′	99	39° 26′	72° 22′	130
39° 40′	72° 34′	78	39° 34′	72° 28′	94	39° 28′	72° 22′	127
39° 42′	72° 34′	76	39° 36′	72° 28′	94	39° 30′	72° 22′	150
39° 14′	72° 32′	151	39° 38′	72° 28′	93	39° 32′	72° 22′	394
39° 16′	72° 32′	138	39° 40′	72° 28′	107	39° 34′	72° 22′	289
39° 18′	72° 32′	137	39° 42′	72° 28′	91	39° 36′	72° 22′	147
39° 20′	72° 32′	129	39° 14′	72° 26′	268	39° 38′	72° 22′	190
39° 22′	72° 32′	127	39° 16′	72° 26′	170	39° 40′	72° 22′	141
39° 24′	72° 32′	124	39° 18′	72° 26′	145	39° 42′	72° 22′	103
39° 26′	72° 32′	115	39° 20′	72° 26′	139	39° 14′	72° 20′	391
39° 28′	72° 32′	106	39° 22′	72° 26′	136	39° 16′	72° 20′	278
39° 30′	72° 32′	102	39° 24′	72° 26′	131	39° 18′	72° 20′	218
39° 32′	72° 32′	92	39° 26′	72° 26′	129	39° 20′	72° 20′	176
39° 34′	72° 32′	84	39° 28′	72° 26′	122	39° 22′	72° 20′	154
39° 36′	72° 32′	82	39° 30′	72° 26′	117	39° 24′	72° 20′	146

Table 2
Hudson Canyon Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
39° 26′	72° 20′	137	39° 20′	72° 14′	303	39° 14′	72° 8′	914
39° 28′	72° 20′	129	39° 22′	72° 14′	232	39° 16′	72° 8′	762
39° 30′	72° 20′	239	39° 24′	72° 14′	218	39° 18′	72° 8′	661
39° 32′	72° 20′	475	39° 26′	72° 14′	260	39° 20′	72° 8′	598
39° 34′	72° 20′	186	39° 28′	72° 14′	451	39° 22′	72° 8′	748
39° 36′	72° 20′	107	39° 30′	72° 14′	657	39° 24′	72° 8′	954
39° 38′	72° 20′	103	39° 32′	72° 14′	330	39° 26′	72° 8′	1006
39° 40′	72° 20′	119	39° 34′	72° 14′	128	39° 28′	72° 8′	662
39° 42′	72° 20′	105	39° 36′	72° 14′	125	39° 30′	72° 8′	484
39° 14′	72° 18′	497	39° 38′	72° 14′	121	39° 32′	72° 8′	315
39° 16′	72° 18′	353	39° 40′	72° 14′	121	39° 34′	72° 8′	150
39° 18′	72° 18′	258	39° 42′	72° 14′	121	39° 36′	72° 8′	142
39° 20′	72° 18′	204	39° 14′	72° 12′	821	39° 38′	72° 8′	130
39° 22′	72° 18′	174	39° 16′	72° 12′	606	39° 40′	72° 8′	125
39° 24′	72° 18′	155	39° 18′	72° 12′	433	39° 42′	72° 8′	126
39° 26′	72° 18′	149	39° 20′	72° 12′	362	39° 14′	72° 6′	988
39° 28′	72° 18′	143	39° 22′	72° 12′	307	39° 16′	72° 6′	908
39° 30′	72° 18′	394	39° 24′	72° 12′	310	39° 18′	72° 6′	786
39° 32′	72° 18′	430	39° 26′	72° 12′	444	39° 20′	72° 6′	794
39° 34′	72° 18′	160	39° 28′	72° 12′	675	39° 22′	72° 6′	1143
39° 36′	72° 18′	109	39° 30′	72° 12′	548	39° 24′	72° 6′	639
39° 38′	72° 18′	111	39° 32′	72° 12′	195	39° 26′	72° 6′	730
39° 40′	72° 18′	111	39° 34′	72° 12′	136	39° 28′	72° 6′	549
39° 42′	72° 18′	110	39° 36′	72° 12′	132	39° 30′	72° 6′	398
39° 14′	72° 16′	606	39° 38′	72° 12′	123	39° 32′	72° 6′	360
39° 16′	72° 16′	451	39° 40′	72° 12′	125	39° 34′	72° 6′	180
39° 18′	72° 16′	317	39° 42′	72° 12′	123	39° 36′	72° 6′	150
39° 20′	72° 16′	252	39° 14′	72° 10′	876	39° 38′	72° 6′	138
39° 22′	72° 16′	197	39° 16′	72° 10′	660	39° 40′	72° 6′	135
39° 24′	72° 16′	174	39° 18′	72° 10′	523	39° 42′	72° 6′	129
39° 26′	72° 16′	162	39° 20′	72° 10′	434			
39° 28′	72° 16′	241	39° 22′	72° 10′	422			
39° 30′	72° 16′	583	39° 24′	72° 10′	584			
39° 32′	72° 16′	403	39° 26′	72° 10′	709			
39° 34′	72° 16′	127	39° 28′	72° 10′	756			
39° 36′	72° 16′	119	39° 30′	72° 10′	498			
39° 38′	72° 16′	119	39° 32′	72° 10′	223			
39° 40′	72° 16′	116	39° 34′	72° 10′	147			
39° 42′	72° 16′	118	39° 36′	72° 10′	138			
39° 14′	72° 14′	721	39° 38′	72° 10′	129			
39° 16′	72° 14′	542	39° 40′	72° 10′	124			
39° 18′	72° 14′	383	39° 42′	72° 10′	124			

Use Colored Pencils, Markers, or Crayons for Data Ranges:

50-100 m – red
101-150 m – orange
151-200 m – yellow
201-400 m – green
401-600 m – blue
601-800 m – blue violet
801-1,143 m – purple

Hudson Canyon Bathymetric Data Reduction Sheet