CHAPTER 10: PHYSICAL ENVIRONMENT AND NATURAL HAZARDS

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Theme Description:

The natural environment consists of four “spheres”: the biosphere and the physical environment of the atmosphere, hydrosphere, and lithosphere (the earth’s crust). Natural processes result in changes to the environment that occur on temporal scales ranging from hours to millions of years. In this chapter, the lithosphere is divided into the subcategories of **Geology** and **Soils**, the latter reflecting some organic as well as physical properties. Atmospheric conditions fall within the subcategory of **Weather and Climate**, which represents short-term and long-term time scales respectively. The hydrosphere is covered in the Hawai`i I-Plan chapters on Hydrography and Marine Layers.

For each of these physical environment subcategories, long-term conditions are mapped as semi-permanent base layers. Historical, empirical data is also used to map changes in the natural environment. Medium-term changes (e.g. climatic warming, sea level rise or coastal erosion) may be so gradual that they are measured as trends. Continuous observations can be divided temporally into categories based on observed natural breaks (e.g. droughts or the overlapping lava flows that comprise the twenty-year eruption of Kilauea volcano). Shorter-term conditions are often mapped as discrete events. Map layers showing the locations of monitoring stations can be useful when combined with sensor readings.

Some, but not all, changes in the natural environment are treated as hazards, which could potentially result in catastrophic events. Even a gradual change may be considered a natural hazard. Taking the example of coastal erosion, the result can be extensive long-term property loss as well as an increased risk of future catastrophic events (e.g. tsunami runup). Natural hazard mapping can be broken into two categories: delineated areas susceptible to a hazard in the either the likeliest or the worst-case scenario, and detailed maps showing the degree of sensitivity of areas to the hazard.

Risks from natural hazards may be amplified when there is a concurrence of different natural processes (e.g. tsunami coinciding with wind, high tide and rain). So for the subcategory **Natural Hazards**, this chapter does not exclude natural processes in the hydrosphere or the biosphere. For example, wildfire risk is measured by the organic fire fuel levels, drought and wind conditions, and — especially on the Island of Hawai`i — the location of current lava flows. Natural hazards of concern to Hawai`i include: coastal erosion/sea level rise, high waves, tsunami, inland landslide, drought, stream flood, hurricane, windstorm, earthquake, volcanic hazards (emissions, ground deformation and eruptions), and wildfire.

Mapping the risks from natural hazards uses a combination of modeling and empirical, historical data. Whereas an epidemiologist studying a mosquito-born disease might be interested in total quarterly rainfall, a natural hazards planner might want data on the frequency and severity of the largest storms. Unlike other themes covered in the I-Plan, where a single authoritative source is preferred, there are advantages to having multiple analyses of a hazard risk, based on different mixes of historical data and modeling assumptions.

Physical environment and natural hazards as envisioned in the Hawai`i I-Plan is primarily a scientific rather than a policy theme. However, the intended use and even the choice of map name of some of these scientific layers may suggest policy implications (e.g. Flood Insurance Rate Maps and Tsunami Evacuation Zones). The Structures chapter of the Hawai`i I-Plan provides some additional layers of use for natural hazard preparation and mitigation planning. Other planning layers used by Natural Hazard preparedness are not covered in the Hawai`i I-Plan, such as fire response maps showing areas where each agency has primary fire responsibility. A final clarification is to note that this chapter covers natural but not manmade hazards, which are often included among "environmental hazards".

Status:
Status information is summarized in a table at the end of this section.

Geology
Semi-permanent base: The USGS (U.S. Geologic Survey) Hawai`i Volcano Observatory (HVO) has completed an internal GIS version of the Geologic Map of the Island of Hawai`i (http://volcanoes.usgs.gov/About/Highlights/HawaiiMap/HawaiiMap.html), which it has shared with other Federal agencies. As of May 2003, the I-map (USGS Geologic Investigative Series http://pubs.usgs.gov/products/maps/i-maps.html) has been reviewed (including metadata) and is on its way to the publication group in Menlo Park for approval. Recent geologic maps have been created for portions of Haleakala Crater on East Maui, but the paper geologic maps for the remainder of the State are dated, lack spatial accuracy, and have undocumented coordinate systems. These limitations also apply to an unregistered, scanned version of a 1988 USGS statewide geologic map that is freely distributed (http://geology.about.com/library/bl/maps/blhawaiimap.htm).

Historic events: HVO has produced geologic maps of lava flows on the Island of Hawai`i (http://hvo.wr.usgs.gov/kilauea/history/calderageology_map.html, http://hvo.wr.usgs.gov/maunaloa/hazards/historicalflows.html) and Maui (http://hvo.wr.usgs.gov/volcanoes/haleakala/cratermap_large.jpg). HVO regularly updates its map of current lava flows on the east rift zone of Kilauea Volcano (http://hvo.wr.usgs.gov/kilauea/summary/Current_map.html).

The most complete historical, empirical data on locations of earthquake hypocenters (epicenters and depths) with attributes information for date, time and magnitude might be available from the USGS National Earthquake Information Center (NEIC; http://neic.usgs.gov/neis/states/hawaii/hawaii.html) which is collocated with the NOAA/NGDC World Data Center for Seismology in Denver. The Advanced National Seismic System (ANSS) maintains an easily accessible online catalog of earthquake hypocenters going back to 1959 (http://quake.geo.berkeley.edu/cnss/catalog-search.html). Documentation on the historic 1823 to 1959 portion of the earthquake catalog (predating modern instrumentation) is given in Klein and Wright, USGS Professional Paper 1623, available at http://geopubs.wr.usgs.gov/prof-paper/pp1623.

Monitoring locations: On the Island of Hawai`i, HVO has mapped sites island-wide to monitor volcanic deformation using equipment that include: tilt meter, stainmeter, dry-tilt, leveling and GPS stations. For Haleakala on Maui, HVO also has a limited number of seismic and deformation sites. Finally, HVO monitors volcanic emissions from the current Kilauea eruption including sulphur dioxide emissions rates.

Soils

Semi-permanent base: NRCS has SSURGO-certified maps of all Hawaiian Islands based on soil maps published in the 1970s based on research conducted in the 1950s and 1960s. The focus of this existing soil survey mapping was on agricultural land uses and was generalized for other areas. The southern and western portions of the Island of Hawai`i are currently being re-mapped in greater detail. This new mapping effort covers the Hawai`i Volcanoes National Park, and thus reflects a shift in the purpose to include conservation uses. New soil classes have been created in the process. HAVO data may be released as early as 2003 and the Kona area possibly in 2004.

To make soils data more meaningful to end users, the NRCS National Soil Information System (NASIS; http://nasis.nrcs.usda.gov/) provides Hawai`i soil survey data on CDs that contain a polygon boundary file, a soil properties database, and a program called Soil Data Viewer (http://www.itc.nrcs.usda.gov/soildataviewer/about.htm). The program guides the user through the expert interpretation of the data to pull out layers such as crop suitability or highly erodable soils. The decision tree used in the Soil Data Viewer is a national standard that incorporates localized parameters applicable to Hawai`i.

NRCS recommends use of the more detailed (1:24,000) SSURGO soil survey maps for Hawai`i rather than the more generalized (about 1:250,000) STATSGO soil associations map layers. A STATSGO Soils Browser CD (http://www.nrcs.usda.gov/technical/techtools/stat_browser.html) is available for Hawai`i.

Weather and Climate

Semi-permanent base: Many layers exist or will soon be available that characterize of the norm and range of climatic conditions in Hawai`i.

The Office of Planning has digitized estimated daily solar radiation contours from the former Department of Planning and Economic Development, Energy Division 1985 "Sunshine Maps" for the five largest islands (http://www.state.hi.us/dbedt/gis/solrad.htm).

Related to solar radiation, NRCS has digitized adjusted pan-evaporation isolines from a 1985 report by the Department of Land and Natural Resources (DLNR) Division of Water and Land Development (DOWALD) (Report R75, Ekern, P.C. and Chang, J. 1985).

The State Office of Planning digitized the mean annual rainfall isolines (http://www.state.hi.us/dbedt/gis/rainfall.htm) from the mylar maps associated with the DOWALD Rainfall Atlas of Hawaii (Report R76, Giambelluca, T. W. et al 1986)). NRCS digitized the mean monthly rainfall isolines from the printed version of this atlas. These maps cover the six largest islands at differing scales.

The PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Mapping Project based at Oregon State University has modeled layers using 1961-90 data for Hawai`i Average Monthly or Annual Precipitation. The NRCS National Water and Climate Center (NWCC), releases these PRISM layers as a grid with a 30 second (about 1 kilometer) cell size (http://www.wcc.nrcs.usda.gov/climate/prism.html). Due to a shortage of funding, Hawai`i is the only state where the PRISM 30" precipitation data is only available as an ASCII grid. NRCS hosts data for all other states in E00 format as well.

PRISM precipitation data as well as Hawai`i Average Monthly or Annual / Minimum, Maximum or Mean Temperature is distributed at higher resolution (15" cell size) under a licensing fee agreement from Climate Source (http://www.climatesource.com/products.html). Climate Source will soon be releasing monthly and annual Hawai`i PRISM layers for: extreme precipitation, extreme temperature, humidity, hot days (i.e. maximum temperature >= 90F), and degree days. An example of the last is: Heating Degree Day units are computed as the difference between the base temperature and the daily average temperature (calculated by Base Temp. - Daily Ave. Temp.).

Historic data and monitoring locations: Historical meteorological measurements taken at monitoring stations along with the locations of the stations are available from archives located at the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC; http://www.ncdc.noaa.gov/oa/ncdc.html).

The NCDC station locator website has a complete listing of all weather stations in Hawai`i (http://www.ncdc.noaa.gov/oa/climate/stationlocator.html), but only provides generalized coordinates (degrees and minutes). The State Office of Planning digitized a

1997 DLNR layer of the locations of rain gauges, which is likely to have more accurate locations but is possibly dated (http://www.state.hi.us/dbedt/gis/raingauge.htm).

Monthly summaries from a large subset of these weather stations are posted at (http://www.wrcc.dri.edu/summary/climsmhi.html). Honolulu has a NOAA National Weather Service (NWS) Forecast Office in Honolulu which also posts daily as well as recent data for a single weather station on each island (http://www.prh.noaa.gov/hnl/pages/hiclimate.html).

Current Weather and Weather Forecasts: The Honolulu NOAA NWS Forecast Office is one of the 122 national weather forecast offices (http://www.prh.noaa.gov/pr/hnl/). The NOAA National Weather Service has traditionally made weather satellite imagery and weather forecasts available as graphic products stripped of their geo-referencing information. Scientists at the NWS Pacific Regions Headquarters, which is also located in Honolulu, are taking a leading role in building Internet capabilities for viewing current weather forecasts, data and imagery (such as Doppler radar captured at four stations in H Hawai`i) available real-time in georeferenced spatial format (http://www.prh.noaa.gov/hq/wx_rug.ppt).

Miscellaneous

Semi-permanent base: NRCS has created a layer called Major Land Resource Areas (MLRA) for Hawai`i that is useful for smaller scale maps (http://www.nrcs.usda.gov/technical/land/mlra/mlrahi.html with legend at http://www.nrcs.usda.gov/technical/land/mlra/mlralegend.html). The MLRA is defined as a combined mapping unit that incorporates: Physiography (i.e. landforms), Geology, Climate, Weather, Soils, Biological Resources and Human Activities (Agriculture and Urban Development). The spatial revision of MLRA for Hawai`i was completed in 2001, but the definitions of the mapping units are still being fine-tuned.

Natural Hazards

Under sponsorship of the State Civil Defense (SCD; http://www.scd.state.hi.us), the Hawai`i Statewide Hazard Mitigation Forum (http://www.mothernature-hawaii.com/aboutus.html) was established in 1998 to raise public awareness on reducing losses due to natural hazards. Within the Forum, the Multihazard Science Advisory Committee (MSAC) brings together physical science and engineering expertise. This technical group is intended to represent access to an evolving comprehensive base of knowledge on natural hazard phenomena. Within its members, existing GIS spatial hazard layers have been inventoried and new layers created. Other entities within the Forum include: the State of Hawai`i Earthquake Board, Tsunami Board, and Hurricane Board, which allow members to discuss data issues, numerical models, and layers.

This state initiative ties in with the Federal Emergency Management Agency (FEMA) MultiHazard Mapping Initiative (MMI). Together FEMA and NOAA have just launched a national web site for hazards (http://www.hazardmaps.gov/atlas.php).

Although not a source of digital, spatial data, a general reference is the Atlas of Natural Hazards in the Hawaiian Coastal Zone which was produced for USGS (http://geopubs.wr.usgs.gov/i-map/i2761/). Details on the many subcategories of the natural hazard layers are provided below.

Coastal erosion/Sea Level Rise
Detailed maps of long-term historic beach erosion have been created for portions of western and central Maui by the UH SOEST Coastal Geology Group (http://www.soest.hawaii.edu/coasts/cgg_main.html).

Headland landslides/rockslides involve some different modeling considerations.

The mapping of coastal erosion presumes the accurate location of the current coastline, which is a high priority project covered in the marine layers chapter. To avoid double counting, costs for continued mapping of coastal erosion are listed there.

Tsunami
A point layer of recorded tsunami wave heights from five tsunami events has been created by State Office of Planning (http://www.state.hi.us/dbedt/gis/tsunhts.htm) based on Loomis H.G. (1976).

The State Civil Defense (SCD) sponsored Tsunami Technical Review Committee (TTRC) meets twice a year to review tsunami hazard mapping, warning, preparedness, response and recovery issues. SCD participates in the NOAA National Tsunami Hazard Mitigation Program (NTHMP) which has a national strategy to reduce tsunami risks to coastal residents. NTHMP is composed of 5 western coastal states (Alaska, California, Hawai`i, Oregon, Washington) and 3 federal agencies (NOAA, USGS, FEMA). NTHMP in turn has a Tsunami Inundation Mapping Effort (TIME; http://www.pmel.noaa.gov/tsunami/time) housed at the NOAA Pacific Marine Environmental Laboratory (PMEL; http://www.pmel.noaa.gov/tsunami).

NTHMP began funding tsunami inundation mapping in Hawai`i in 1999, and the recent status is shown at http://www.pmel.noaa.gov/tsunami/time/hi/population/index.shtml. The mapping status is summarized into three initiatives: pre-NTHMP, NTHMP and DOD/NASA (collaborative mapping by the Department of Defense and the National Aeronautics and Space Administration).

The pre-NTHMP mapping presumably refers to the tsunami evacuation zone maps that are available from the State Office of Planning (http://www.state.hi.us/dbedt/gis/tsunevac.htm) that were produced by the Pacific Disaster Center (PDC; http://www.pdc.org/iweb/) in 1998 based on earlier maps created by the UH Joint Institute for Marine and Atmospheric Research (JIMAR; http://ilikai.soest.hawaii.edu/JIMAR/).

The NTHMP maps are created from worst-case modeling that looks at seismic events, which can occur inside or outside of the Hawaiian archipelago, bathymetry, and storm wind and rain conditions. One set of numerical models developed by PMEL and UH (http://www.pmel.noaa.gov/tsunami/research.html) are considered to be best suited for external seismic events, whereas other models developed by the UH and Ocean Engineering (http://www.soest.hawaii.edu/tsunami) may be more useful for localized earthquakes. As better bathymetric data becomes available, PDC will be able to refine existing tsunami inundation maps using these models.

Tied into the PMEL hazards assessment is a warning system of which the NOAA Pacific Tsunami Warning Center (http://www.prh.noaa.gov/pr/ptwc) is the local node.

Inland Erosion/Landslide/Rockslide

While many of the data components are available for estimating which areas have highest risk for inland erosion, no known models have been created. NRCS expert interpretation of soils properties (programmed into the SSURGO Soil Data Viewer discussed earlier) for highly erodable soils can be used as a first cut at landslides. For rockslides, the geologic properties together with slope might be important parameters to model. Slides can be triggered by heavy rain, flooding or seismic events. Slides can be triggered by heavy rain, flooding or seismic events. Hawai`i State DOT has released a rockfall study of Oahu highways. The USGS Water Resources Group has issued reports with mapping of historic debris flows and hazard areas, but not comprehensively.

Wildfire/Drought

Historic wildfire boundary layers have been produced by several agencies including the National Park Service (NPS) and the U.S. Fish and Wildlife Service (FWS).

In Hawai`i, wildfire risk modeling can follow three approaches: 1) climatic conditions which can be measured by the Standardized Precipitation Index; 2) vegetation mapping as a source of fire fuel; and 3) monitoring where new lava flows might reach the edge of vegetation (rather than staying within areas previously covered by earlier flows).

Hurricane/Windstorm/Storm Surge

The overwash resulting from storm surge during Iniki, the last hurricane to hit Hawai`i, was digitized by UH SOEST Coastal Geology Group from aerial photography (http://www.state.hi.us/dbedt/gis/iniki_ovrwsh.htm).

PDC has used a proprietary TAOS (The Arbiter of Storms) Model to simulate the storm surge created by hurricanes similar to historical events using low resolution bathymetry and coastal elevation utilizing historical hurricane data (http://www.pdc.org/iweb/capabilities/tropicalcyclone.html). The model needs to be ported to a supercomputer before it can be run using available high-resolution the bathymetry and elevation data and validated for Hawai`i.

In Hawai`i wave set-up is the principal cause of coastal flooding, rather than surge alone. A new model for Storm-Induced Coastal Flooding including both surge and wave set-up has been developed by Kwok Fai Cheung of the University of Hawai`i, Department of Ocean & Resources Engineering. This model has been validated using the Hurricane

Iniki data. It outputs surge, waves, and run-up as a function of time, and it could be used to develop additional overwash zones on other islands based on specified storm scenarios.

Jon Peterka of (Cermak Peterka Petersen, Inc.) and Gary Chock of (Martin & Chock, Inc.), with funding from NASA Office of Earth Science, have created models of hurricane wind speeds and topographic effects (http://www.martinchock.com/Orographicshort1.htm). Peterka's hurricane and typhoon model incorporated an analysis of tropical cyclone track statistics in portions of the Central and Western Pacific basins, to determine the regional average recurrence intervals and frequency of occurrence for mapping hurricane and typhoon wind speeds for Hawai`i and Guam. After testing physical models of island terrain in wind tunnels, Chock constructed a Wind Speed-up Phenomenological Model for predicting mean and peak gust wind "speed-up" based on numerical and landform analysis of a 30M DEM representation of topography. The model has been extended to map wind speedup for all areas of Oahu, Kauai, and to Lanai and Molokai. However, refinements are planned for these islands and further scientific work is needed for Maui and Hawai`i, due to the large land masses on those two islands that are anticipated to create significant mesoscale effects.

Tracking hurricanes and tropical storms is a specialized function within weather forecasting. PDC has a real-time Internet GIS application (http://atlas.pdc.org/) that shows the previous, current and forecast storm positions. This site also has historical storm tracks.

Flood

The Federal Emergency Management Agency (FEMA) produces Digital Flood Insurance Rate Maps (DFIRMs; http://www.msc.fema.gov/dfirm.shtml) at a scale of 1:24,000 for all islands except Niihau. The focus in Hawai`i has been for 100-year flood maps rather than 500-year maps. The resolution of the existing DFIRMs is not very useful for Hawai`i; the City and County of Honolulu regularly cleans the Oahu maps to conform to the scale of their parcel fabric. The State Office of Planning is one source for DFIRM data (http://www.state.hi.us/dbedt/gis/dfirm.htm)

FEMA has initiated a flood map modernization effort, which calls for acquiring LIDAR imagery as described in the elevation and bathymetry chapter. Once the imagery is collected and elevations derived, FEMA will derive new flood map products using historical/empirical information combined with modeling.

Earthquake

USGS has produced six probabilistic Seismic-Hazard Maps for Hawai`i (http://pubs.usgs.gov/imap/2000/i-2724). Of these maps, the "Peak Horizontal Ground Acceleration with 10% Probability of Exceedance in 50 years" sheet has been identified as the preferred source for earthquake hazard definition.

State Civil Defense and the Hawai`i Earthquake Advisory Committee will be developing project priorities and seeking funding on both mapping the seismic qualities of soils and the risks of liquefaction, which is of greatest concern to coastal alluvial areas.

Volcanic eruption/lava flow/emissions
In addition to the historic lava flow mapping discussed within the geology subcategory, a 1:250,000 scale map has been created for Lava Flow Hazard Zones on the Island of Hawai`i (http://www.state.hi.us/dbedt/gis/vhzones.htm).

HVO has created lavashed (sic) maps to model the advance rates of lava flows and thereby determine the amount of warning time that would be expected for evacuation of selected existing and proposed facilities, in particular Kulani Prison (http://hvo.wr.usgs.gov/products/OF98794/OF98794_2.html - prob).

Finally a 2003 publication titled Map Showing Lava Inundation Zones for Mauna Loa, Hawai`i estimates the areas threatened by lava flows from the next eruption of Mauna Loa (http://geopubs.wr.usgs.gov/map-mf/mf2401/).

Layer	Source	Scale, Standards, etc.	Status
Geology			
Geologic Maps of Hawaiian Islands	USGS HVO (Hawai`i Volcano Observatory) trusdell@usgs.gov	Island of Hawai`i (1:100,000) reviewed for quality standards and metadata created.	Island of Hawai`i soon to be released; East Maui partial
Lava flow boundaries (with dates of flows)	USGS HVO (Hawai`i Volcano Observatory) trusdell@usgs.gov	Coverages of volcanoes on the Island of Hawai`i and Haleakala on East Maui. Historical data can show where earlier flows are covered by newer flows (not on Geologic map).	GIS version for internal use; Scans released; Continuous update for Kilauea
Earthquake hypocenters (epicenters and depths) with date, time and magnitude	Advanced National Seismic System (ANSS) http://quake.geo.berkeley.edu/cnss/catalog-search.html	Accuracy has improved over time. Point locations in degrees with four decimal places.	Complete; Continuous update
Volcanic monitoring locations and measurements (seismicity, deformation and emissions)	USGS HVO (Hawai`i Volcano Observatory)	Measurements are as accurate as technology permits	Internal Use; Continuous Update
Soils			
Hawai`i Soil Series	USDA Natural Resources Conservation Service (NRCS) pat.shade@hi.usda.gov	1:24,000 scale. SSURGO certified.	Complete; On CD; Updating portions of Island of Hawai`i
Hawai`i Soil	USDA NRCS	Estimated scale is 1:250,000.	Same as

Associations	pat.shade@hi.usda.gov	STATSGO certified.	Soil Series
Weather and Climate			
Solar radiation ("sunshine maps")	Office of Planning http://www.state.hi.us/dbedt/gis/solrad.htm	Isolines at varying scales. Modeled information so accuracy less of an issue.	Complete
Pan-evaporation	USDA Natural Resources Conservation Service (NRCS) pat.shade@hi.usda.gov	Isolines at varying scales. Modeled information so accuracy less of an issue.	Complete
Rainfall (Median Annual) from Rainfall Atlas of Hawaii	Office of Planning http://www.state.hi.us/dbedt/gis/rainfall.htm	Isolines at varying scales. Modeled information so accuracy less of an issue.	Complete
Rainfall (Mean Monthly) from Rainfall Atlas of Hawaii	USDA NRCS pat.shade@hi.usda.gov	Isolines at varying scales. Modeled information so accuracy less of an issue.	Complete
Rainfall (Average Annual and Monthly) from PRISM & NRCS	USDA NRCS http://www.ftw.nrcs.usda.gov/prism/prismdata_state.html	Grids with 30" cell size. PRISM methods well established.	ASCII Grid complete; EOO not funded
Rainfall (Average Annual and Monthly) from PRISM & Climate Source	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Complete; License Fee
Temperature (Average, Maximum and Minimum, Annual and Monthly)	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Complete; License Fee
Extreme Precipitation	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Under production; License Fee
Extreme Temperature	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Under production; License Fee
Humidity	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Under production; License Fee
Hot Days (i.e. maximum temperature >= 90F)	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Complete; License Fee
Degree Days (i.e. difference between base and daily average)	Climate Source http://www.climatesource.com/products.html	Grids with 15" cell size. PRISM methods well established.	Complete; License Fee
Weather Station Locations	USDA NRCS National Climatic Data Center (NCDC) http://www.ncdc.noaa.gov/oa/climate/stationlocator.html	Most complete list of stations. Rounded to nearest degree.	Complete; Continuous Update
Rain Gauge Locations	Office of Planning http://www.state.hi.us/dbedt/gis/raingauge.htm	Stations as of 1997. Accurate to nearest second. Includes 1997 measurements.	Complete; Not up-to-date
Weather Station Measurements (Monthly Summaries)	Desert Research Institute (DRI) http://www.wrcc.dri.edu/summary/climsmhi.html and	Most recent month only.	Large subset of weather stations

Weather Station Measurements (Daily and 30-day)	NOAA National Weather Service (NWS) Honolulu Forecast Office http://www.prh.noaa.gov/hnl/pages/hiclimate.html	Most recent 30-day only.	Only four weather stations
Miscellaneous			
Major Land Resource Areas (includes physical, biological and human-altered environment)	USDA Natural Resources Conservation Service (NRCS) pat.shade@hi.usda.gov	Estimated scale 1:1,000,000	Complete; Map unit definitions under review
Natural Hazards			
Beach Erosion	UH School of Ocean and Earth Sciences and Technology (SOEST) Coastal Geology Group http://www.soest.hawaii.edu/coasts/cgg_main.html	High precision needed to calculate rates of erosion. Process involves creating new coastal orthoimagery.	Major beaches on Maui completed
Tsunami Wave Heights (historical)	Office of Planning http://www.state.hi.us/dbedt/gis/tsunhts.htm	Accuracy unknown	Complete
Tsunami Evacuation Zones (before 1999)	Office of Planning http://www.state.hi.us/dbedt/gis/tsunevac.htm	Accuracy varies	Partial coverage of at-risk population
Tsunami Inundation Maps (since 1999)	Tsunami Inundation Mapping Effort (TIME) Status: http://www.pmel.noaa.gov/tsunami/time/hi/population/index.shtml UH SOEST and Ocean Engineeing (locally-generated tsunami) http://www.soest.hawaii.edu/tsunami	Improved modeling	Partially Complete; To be revised with better bathymetry
Historic Wildfire Burn Areas	Various: National Park Service (NPS) Sandy_Margriter@nps.gov U.S. Fish & Wildlife Service (FWS) ron_salz@fws.gov	Digitized from annotation of 1:24,000 quads	Island of Hawai`i incomplete; 0% other islands; Update needed
Hurricane Iniki overwash	Office of Planning http://www.state.hi.us/dbedt/gis/iniki_ovrwsh.htm	Source: aerial photography	Complete
Storm Surge using the Arbiter of Storms (TAOS) model	Pacific Disaster Center (PDC) http://www.pdc.org/iweb/capabilities/tropicalcyclone.html	Validation will be needed after running using high quality data, in particular bathymetry.	Model developed; Not yet run with detailed HI data
Storm-Induced Coastal Flooding	UH Department of Ocean and Resources Engineering cheung@oe.eng.hawaii.edu	Validated using Iniki data	Available for testing storm

			scenarios
Hurricane wind speeds and topographic effects ("Wind Speed-up" using Peak/Mean Envelope Methodology)	Martin & Chock Inc. and Cermak Peterka Petersen (CPP), Inc. http://www.martinchock.com/Orographicshort1.htm	Hurricane/typhoon wind speeds modeled for Hawai`i and Guam, but topographic effects portion only calibrated for Hawaiian conditions of smaller, lower islands (not yet Islands of Maui or Hawai`i)	Initial for Oahu, Kauai, Lanai & Molokai; Oahu refinement funded
Storm tracks (for real-time storms the previous, current and forecast positions; and historical storm paths)	PDC http://atlas.pdc.org/	A single point is used to locate the eye of a storm which is a relatively large feature.	Complete Historical; Continuous update in real-time
Digital Flood Insurance Rate Maps	Federal Emergency Management Agency (FEMA) via Office of Planning http://www.state.hi.us/dbedt/gis/dfirm.htm	Current DFIRMs use 1:24,000 contour lines; Future will use LIDAR for elevation and/or orthoimagery for horizontal base	Complete; Revision in progress
Seismic Hazards	U.S. Geological Survey http://pubs.usgs.gov/imap/2000/i-2724	Accuracy does not apply to this predictive model	Complete
Lava Flow Hazard Zones (generalized)	Office of Planning http://www.state.hi.us/dbedt/gis/vhzones.htm described in http://pubs.usgs.gov/gip/hazards/maps.html	Scale 1:250,00	Complete
Lava Inundation Zones for Mauna Loa, Hawai`i (estimates of threatened areas)	USGS HVO (Hawai`i Volcano Observatory) trusdell@usgs.gov http://geopubs.wr.usgs.gov/map-mf/mf2401/	Accuracy does not apply to this predictive model	Complete; Scans released

<u>Data Sources:</u>
Some contacts for sources listed below can be found in the Status section.

Geology:
The sources available from the U.S. Geological Survey's Hawaiian Volcanoes Observatory are well documented in this chapter, but additional sources for future geological data are the numerous departments and programs within UH SOEST including its Hawai`i Institute for Geophysics and Planetology (http://www.higp.hawaii.edu/).

Soils:
NRCS is the source for soils mapping for agricultural and now for conservation purposes. Hawai`i Civil Defense (http://www.scd.state.hi.us) is seeking funding for research into soils mapping for seismic analysis.

Weather and Climate:

Climatic data for Hawai`i is being collected and modeled by the UH Water Resources Research Center WRRC (http://www.wrrc.hawaii.edu/), the UH Joint Institute for Marine and Atmospheric Research (JIMAR; http://ilikai.soest.hawaii.edu/JIMAR/), the UH Hilo Department of Geography and Environmental Studies (http://www.uhh.hawaii.edu/~geograph)as well as by the NRCS National Water and Climate Center (NWDC) and the NOAA National Climatic Data Center (NCDC).

Historic monitoring station location coordinates and archived measurements data should be mined from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC; http://www.ncdc.noaa.gov/oa/ncdc.html).

Natural Hazards:
Natural hazards data sources are likely to come mostly from the member organizations of the State Hazard Forum's Multi-Hazard Scientific Advisory Committee: Martin & Chock, Inc. (engineering firm), PDC, NOAA NWS, NOAA Information Center (ITIC; http://www.prh.noaa.gov/itic), UH SOEST Ocean & Resources Engineering, UH JIMAR, UH SOEST Coastal Erosion Group, USGS HVO, UH Civil Engineering, DLNR Flood Control and Dam Safety Section, and the State Office of Planning.

Standards:

Geology
In 2000, a Digital Cartographic Standard for Geologic Map Symbolization was publicly reviewed (http://ncgmp.usgs.gov/fgdc_gds/mapsymb/mapsymbpdfs.html). The proposal is expected to be revised and submitted to the FGDC in 2002-03.

A North American Digital Geologic Map Data Model is under development through an agreement between the Digital Geologic Mapping Committee of the Association of American State Geologists (AASG) and the USGS National Geologic Map Database project (http://geology.usgs.gov/dm).

Soils
The SSURGO version 2 database structure of the NRCS Hawai`i soil survey data together with the Hawai`i metadata meets the FGDC Soil Geographic Data Standard. This standard is for detailed soil series data at a 1:24,000 scale. (http://www.fgdc.gov/standards/documents/standards/soils). STATSGO, which is not referenced in the standard, is an aggregation of the data contained in SSURGO.

Weather and Climate
An FGDC Spatial Climate Subcommittee was formed in 1999 (http://www.wcc.nrcs.usda.gov/fgdc/subcommittee). The subcommittee has not released any proposed standards, but has endorsed the PRISM program.

Weather data is currently stored in various formats (GRIB, netCDF, GINI, Archive II, BUFR, McIDAS, Gempak, METAR as well as text), none of which is GIS friendly.

Natural Hazards
FEMA has started discussing standards with the FGDC (http://www.fgdc.gov/fgdc/coorwg/2002/cwgjan02.html and http://www.fgdc.gov/02nsdi/agency/fema.pdf). It should be noted that FEMA intends to use I-Teams to help coordinate hazards data collection.

FEMA has specific standards for its Digital Flood Insurance Rate Maps (DFIRMs) listed at http://www.fema.gov/fhm/frm_bsmp.shtm.

Priority:

The building and infrastructure planning and design community utilizes geology, soils and natural hazards data (e.g. earthquake potential, and wind speed-up). Similarly transportation agencies are concerned with natural hazards; several recent landslides in the past couple of years have partially or completely closed highways on Oahu resulting in high repair costs and economic repercussions to local communities.

Soils data is traditionally used for agriculture, which has historically been the third largest sector of Hawai`i's economy. The National Park Service's funding of soils mapping within the Park shows the importance of soil information for non-agricultural applications like conservation. Soils are an important component of water resource management as well.

Weather data is probably the most frequently requested of any type of spatial data, but it is mostly delivered as a final product stripped on the necessary spatial referencing. Geo-referenced, historic weather data for user-defined time periods would be useful to the scientific community in particular. Climate data has wide applicability. Both, precipitation and evapotranspiration (the combined loss of water to the atmosphere via the processes of evaporation and plant transpiration) are important for hydrologic models such as aquifer recharge.

Weather/climate, soils and geology are all base layers for natural hazards analysis.

Natural hazards mapping for the purposes of mitigation and disaster planning have high priority given Hawai`i's setting. Analysis of annualized losses indicates that the highest threats in Hawai`i are: 1) hurricane, 2) seismic, and 3) volcanic hazards. The economic fallout from hurricane Iniki on the island of Kauai lasted for a decade. Kilauea is the most active volcano in the world, and Mauna Loa is showing signs of possible renewed activity.

The priority is high enough that funding for natural hazards mapping has benefited core FGDC themes in the I-Plan, namely Digital OrthoImagery where NRCS is funding the bulk of acquiring the Emerge statewide color infrared DOQQs, and Bathymetry and Elevation where FEMA and local partners are funding the acquisition of LIDAR.

Estimated total investment in this theme:

Investment in mapping the physical environment and natural hazards is not easily broken out from other activities performed by organizations. A narrow view would include the labor and equipment of dedicated mapping professionals. A broad view would include:

- the cost of imagery purchased from soil survey or natural hazards budgets,
- the cost of purchasing, manning and maintaining monitoring equipment, and
- the cost of developing models and potentially run-time on super-computers.

Estimates of annual investment are shown below as a range to indicate both views. However, imagery costs incorporated in earlier chapters are not included in this section to avoid double counting.

Geology: Hawai`i Volcanoes Observatory has been constantly monitoring Kilauea and Mauna Loa volcanoes for over 90 years, with mapping as one of the products of its work. By the narrowest definition, the costs in Hawai`i of mapping volcanism would include 1.5 permanent employees and their equipment taking NPS staff support into account. Additional costs were incurred for Hawai`i data at USGS in Menlo Park. Monitoring instrumentation costs and seismological data archiving need to be considered. (Annual investment: $120,000 - $1,000,000 annually)

Soils: NRCS employs six staff for soil survey mapping in Hawai`i. Additional costs are incurred for Hawai`i data at NRCS in Fort Worth. In support of these activities, USDA has paid the lion's share of the cost of acquiring color-infrared DOQQs (Digital Ortho Quarter Quads) from the Emerge system from 1999 to the present. (Annual investment: $300,000 - $400,000 annually, DOQQs not included)

Weather and Climate: Much of the climatic mapping effort in Hawai`i dates from the mid-1980s. The recent costs for PRISM by Oregon State University, NRCS and Climate Source were not determined. Map-like graphics are the primary product of almost all investment in meteorological monitoring equipment, personnel, weather imagery, forecast modeling and data archiving. (Annual investment: Unknown amount for PRISM - $2,000,000 annually)

Natural Hazards: Natural hazards mapping is usually budgeted in combination with disaster preparation mapping including evacuation routes and structures. Many of the data layers are ad hoc projects (unlike the FEMA flood insurance maps). In addition to government agencies, PDC, which is a non-profit organization, has a large investment in natural hazards data and models. (Estimated total investment: $1,000,000 - $2,500,000)

Estimated current state and local contributions:

The state and counties have contributed towards individual physical environment and natural hazard projects on an ad hoc basis. Over the last decade, the State Office of Planning has often created digital versions of layers mapped by other organizations. Maui County funded its coastal erosion maps. There continues to be county participation in hurricane wind speed-up mapping. For flood mapping, FEMA has been partnering with the state and counties to fund LIDAR acquisition.

What is needed:

Geology: National efforts on producing a geologic map data model standard need to be evaluated for Hawai`i. Mapping lava flows will continue as the current Kilauea eruption progresses into its third decade. Pending final approval of the Geologic Map of the island of Hawai`i in the I-map digital data series, planning now needs to be initiated to create geology maps for the other main Hawaiian Islands. This would probably require a new, multi-year funding initiative within USGS Geologic Division. (Needed: Continued funding at present levels, plus new initiative: estimate $100,000 / year for five years.)

Soils: While NRCS and NPS have covered the current update of soils series data collection and the conversion of the older soil maps, they foresee a need for further documentation on the Hawai`i decision tree for expert interpretation of soil properties. (Needed: Estimate $20,000)

When the Island of Hawai`i is complete, NRCS foresees a need to update the other Hawaiian Islands to include greater detail in the conservation lands and to adjust for changes in agricultural land use over the past forty years. (Needed: Continued funding at present levels)

Weather and Climate: Precise locations of meteorological monitoring stations need to be collected and linked to historic as well as current measurement data. In addition to actual readings, data quality needs to be captured (e.g. notations when rain gauges are filled to capacity). Because Hawai`i has great climatic variability over short distances, the dataset might be expanded to include some privately owned and operated meteorological stations. The database needs to be warehoused in a format that allows free-form temporal queries rather than predetermined time increments. This cleaned data should be the source for PRISM and other potential climatic modeling efforts such as by UH researchers or the State Climatologist. (Needed: Estimate $100,000)

One climatic measure that needs to be modeled and mapped is evapotranspiration. The solar radiation and pan-evaporation map layers are indicative of the maximum potential evaporation, but land cover needs to be added to the model. (Needed: Estimate: $250,000)

The National Weather Service is proceeding with its plans to provide real-time weather information in a spatially geo-referenced format through the Internet. Pilot projects combining this data with traditional geographic data layers should be encouraged. (Needed: Continued funding at current levels plus new funding initiative to turn pilot Internet project into production system.)

Natural Hazards: At present, some of the immediate needs for natural hazards mapping — in addition to acquisition of imagery, bathymetry and LIDAR for elevation — include:

1) completion of the High Wind modeling for Maui and Hawai`i and refinement of the model for Kauai, using the Chock Speed-up Methodology (Needed: $450,000),
2) porting the Storm-Induced Coastal Flooding model to be available to be run for hypothetical storm scenarios as well as in real-time for actual storms on the supercomputer at the Maui High Performance Computer Center (MHPCC; http://www.mhpcc.edu) (Needed: To be determined),
3) continued funding of tsunami inundation mapping (Needed: To be determined), and
4) funding of engineering assessments of the seismic qualities of soils and the risks of liquefaction, which is of greatest concern to areas built on coastal alluvial areas, due to local ground motion amplification. (Needed: To be determined)

What is the likely source:

Geology: USGS
Soils: NRCS
Weather and Climate: NOAA, USGS and NRCS
Natural Hazards: FEMA, USGS (earthquake and volcanic hazards), NOAA (hurricane and tsunami) and DOD

Estimated current allocation of funding:

See investment in theme for geology, soils, and weather and climate. For natural hazards, estimated current allocation of funding is $400,000 mostly in ad hoc projects.

Estimated budget shortfall:

Geology: A new initiative to produce digital geologic maps for seven Hawaiian Islands is being considered by USGS Geologic Division and is not considered to be a shortfall in the I-Plan.

Soils: $20,000 needed for soil interpretation.

Weather and Climate: The most immediate budget shortfall is the NRCS budget for funding PRISM data for Hawai`i at the same level as other states. Although the total shortfall is probably greater, OSU has estimated that the amount needed to created EOO and polygon versions of precipitation layers is $500.

Neither the layer of precise locations of weather stations nor the evapotranspiration climate layer have been budgeted by any agency (Combined estimate is $350,000).

Natural Hazards: Completion of the High Wind speed-up mapping is an identified shortfalls (Estimated costs $450,000). Funding for the SOEST locally-generated tsunami inundation hazards map is on hold. PMEL does not show any progress on externally-generated tsunami inundation maps as of May 2001 (http://www.pmel.noaa.gov/tsunami/time/hi/index.shtml). Coastal erosion mapping is covered in the marine layers chapter.

Possible ways to overcome this gap:

The first places to look are USGS for geology, NRCS for soils, NOAA and NRCS for weather and climate, and FEMA and USGS for natural hazards.

FEMA been transferred to the newly created Department of Homeland Security(DHS), which will alter its mission and possibly lead to new avenues of funding. Also, within DHS, a new agency called the National Cyber Security Division (NCSD) has been set up under the Department's Information Analysis and Infrastructure Protection Directorate.

A separate source of funding is NASA, which funded the development of the Peterka/Chock hurricane winds models.

Most appropriate data steward:

Geology: HVO and/or UH SOEST

Soils: NRCS

Weather and Climate: Probably UH JIMAR, NOAA NWS, or NRCS

Natural Hazards: The likeliest candidates for now are USGS-HVO, PDC, UH SOEST and NOAA International Tsunami Information Center. Possibly State Civil Defense at a later date when they come up to speed on GIS.

Maintenance Process:

Geology: Data maintenance has long been recognized as a necessity for volcanic activity on the Island of Hawai`i and seismic monitoring statewide.

Soils: Currently, the NRCS for soils maps is primarily data maintenance. In updating the soils maps to include conservation purposes, NRCS is also revisiting agricultural areas where land use has changed.

Weather and Climate: Today, climate maps are generally built from thirty years accumulated data, so maintenance will not be an important issue for a long while. In the future, there may be a call for mapping climate change such as global warming. The focus on weather has always been on mapping from new data. The layer with precise locations of weather stations and their dates of operation would need to be maintained.

Natural Hazards: Updating data for natural hazards is likely to be required as new natural hazard models are developed, improved instrumentation or scientific advances lead to better data, or a major natural disaster occurs (such as large magnitude earthquake, resumption of volcanic eruption at Mauna Loa, tsunami, or hurricane).

Estimated Maintenance cost:

Maintenance of weather station locations layer might cost $5,000 annually, if GPS field work were needed. Mostly where data maintenance is needed, it is already included in the budgets, with the exceptions of natural hazards mentioned above. The annual costs of maintaining natural hazards data is likely to vary greatly from one year to the next.