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Caltrans/UCSC Coastal Landslides Pilot Study
of the
Historical Assessment of Landslide Volume Contribution to the MBNMS Along the Big Sur Coast, CA

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Introduction

An effort is currently underway to determine the historic volume of material that enters the littoral system from coastal landslides along the Big Sur corridor of Highway 1. This stretch of coastline extends for approximately 200 km from the Carmel River in the north to San Carporforo Creek in the south. The primary tools for this study are two dates of aerial photography, 1942 and 1994. The technique for deriving volumes involves the use of digital photogrammetry to process the photography and to build TIN (Triangulated Irregular Network) models from the corrected and georeferenced stereo imagery. This is a relatively new technique, especially as applied to modeling landscape dynamics in a high relief coastal environment. In order to refine the techniques required for data processing and analysis, two sections of coast were chosen as part of a pilot study.

Data Processing and Methods

Two pilot areas were chosen in collaboration with Caltrans, the MBNMS, the CCC and the USGS, and include both an area with (Pilot Area #2) and without (Pilot Area #1) Highway 1 cut into the coastal slope. Figure 1 shows the locations of the pilot areas relative to the Big Sur coastline within Monterey County. For each area and date of photography, three photographs (2 stereo models) were processed using ground control points from USGS DOQs (Digital Orthoquadrangles) and gps data collected by Caltrans along the centerline of Highway 1.

Two orthophotomosaics for each date were produced for both pilot areas (Figures 2-5). On each of the orthophotomosaics (Figures 2-5), the area within which the volume change was calculated is outlined in green. This boundary is based on landscape morphology (e.g. crests or divides), natural boundaries (e.g. ocean), or the furthest upslope extent in which there is evidence of historic or recent ground movement. This bounded area represents, the extent of the land from which the littoral system could receive input from coastal landslides within each pilot area.

Pilot Area #1 covers an area of 1.3 km^2, and extends along approximately 2.5 km of coastline just south of Pfeiffer Point in the Wreck Beach area. Pilot Area #2 covers a 2.2 km^2 area and extends westward from Lopez Point along an approximately 5.2 km stretch of coastline.

In order to calculate the volume changes within each area, TIN models are extracted from the stereo imagery. Subsequent interactive editing of the models includes removing data points on trees, houses, and in the water, as well as adding breaklines to help constrain the topography. Once the TIN models have been edited for each date of photography, the terrain data is transferred from the photogrammetry software (PCI Apex) to ArcView 3.2a, where volumes are calculated (Table 1) and slope information (Figure 6) can be derived using both 3D Analyst and Spatial Analyst extensions. Figures 7 and 8 show perspective views of the TIN models for both pilot areas. In each figure, the top image is a regional TIN, whereas the lower image shows the portion of the TIN under which the volume change was calculated. In all cases, the volume is calculated above a datum of 1.5 m. This elevation represents the lowest elevation that photogrammetric stereo models can confidently derive elevation without significant visual interference from the movement of waves on the water or in the swash zone on the beach (Hapke and Richmond, 2000).

Results

The rate of volume change (net loss in both cases) is calculated over a time period of 52 years. Since the pilot areas differ in size, the results are presented as m^3 normalized to the km^2 of each area (Table 1). As shown in Table 1, the volumetric loss rate in these 2 areas differs by more than an order of magnitude. While existing geologic maps show that both areas lie within the Franciscan Fm (Hall, 1991), the northern pilot area (#1) is dominated by sandstones and graywackes while the southern pilot area (#2) is located in weaker materials, including ancient landslide deposits and sheared metavolcanic rocks. The existence of a significant embayment of the coast beginning at Lopez Point (Figure

1) is further evidence that the material along this portion of the coastline is less resistant and erodes at a greater rate than pilot area #1 to the north. The error analysis is in progress; to date, there are not reliable error estimates for the volumetric calculations.

Table 1: Pilot Area Data

	Area (km^2)	Linear extent along coast (km)	Volumetric Loss Rate ($m^3/km^3/yr$)
Pilot Area #1	1.3	2.5	2,835 $\pm$?
Pilot Area #2	2.2	5.2	77,094 $\pm$?

Other products that can be derived from the data produced in this study are perspective views of orthophotographs draped over the TIN models (Figure 9). Besides providing interesting graphics, the draped orthophotographs can provide visual information on recent development (roads, houses, etc.) and changes in vegetation (loss or growth) relative to areas of chronic slope failures.

References

Hall, C.A., Jr., 1991, Geology of the Point Sur-Lopez Point region, Coast Ranges, California: A part of the Southern California Allochthon: GSA Special Paper 266, 40 pp.

Hapke, Cheryl and Bruce Richmond, 2000, Monitoring beach morphology changes using small-format aerial photography and digital softcopy photogrammetry: Environmental Geosciences, v.7, no.1, p. 32-37.

Figure Captions

Figure 1: Location Map of the Big Sur Coastline in Monterey County. The red boxes and numbers show the locations of pilot study areas 1 and 2.

Figure 2: 1994 orthophotomosaic of Pilot Study Area #1, just south of Pfeiffer Point. Highway 1 is shown in red; the area outlined in green is the area within which the volumetric change was calculated.

Figure 3: 1942 orthophotomosaic of Pilot Study Area #1, just south of Pfeiffer Point. Highway 1 is shown in red; the area outlined in green is the area within which the volumetric change was calculated.

Figure 4: 1994 orthophotomosaic of Pilot Study Area #2, extending east from Lopez Point. Highway 1 is shown in red; the area outlined in green is the area within which the volumetric change was calculated.

Figure 5: 1942 orthophotomosaic of Pilot Study Area #2, extending east from Lopez Point. Highway 1 is shown in red; the area outlined in green is the area within which the volumetric change was calculated.

Figure 6: Histograms of slopes for pilot areas #1 (top) and #2 (lower) derived from the 1994 TINs of each area. In order to produce a slope map, the TIN is converted to a 2m grid and the slope is determined based on the change of slope from one cell to its neighboring cells.

Figure 7: TIN surface models derived from 1994 photography for Pilot Area #1. The top graphic shows the full TIN model; the lower graphic is the clipped area within which the volume differencing is performed. This area specifically is the aerial extent of each region from which landslide material could enter the littoral system.

Figure 8: TIN surface models derived from 1994 photography for Pilot Area #2. The top graphic shows the full TIN model; the lower graphic is the clipped area within which the volume differencing is performed. This area specifically is the aerial extent of each region from which landslide material could enter the littoral system.

Figure 9: Orthophotomosaics draped over TIN models for pilot area #2, for both 1942 (top) and 1994 (bottom). Note the significant changes in vegetation and the emplacement of a switchback road on the east side of the pilot area from 1942 to 1994.

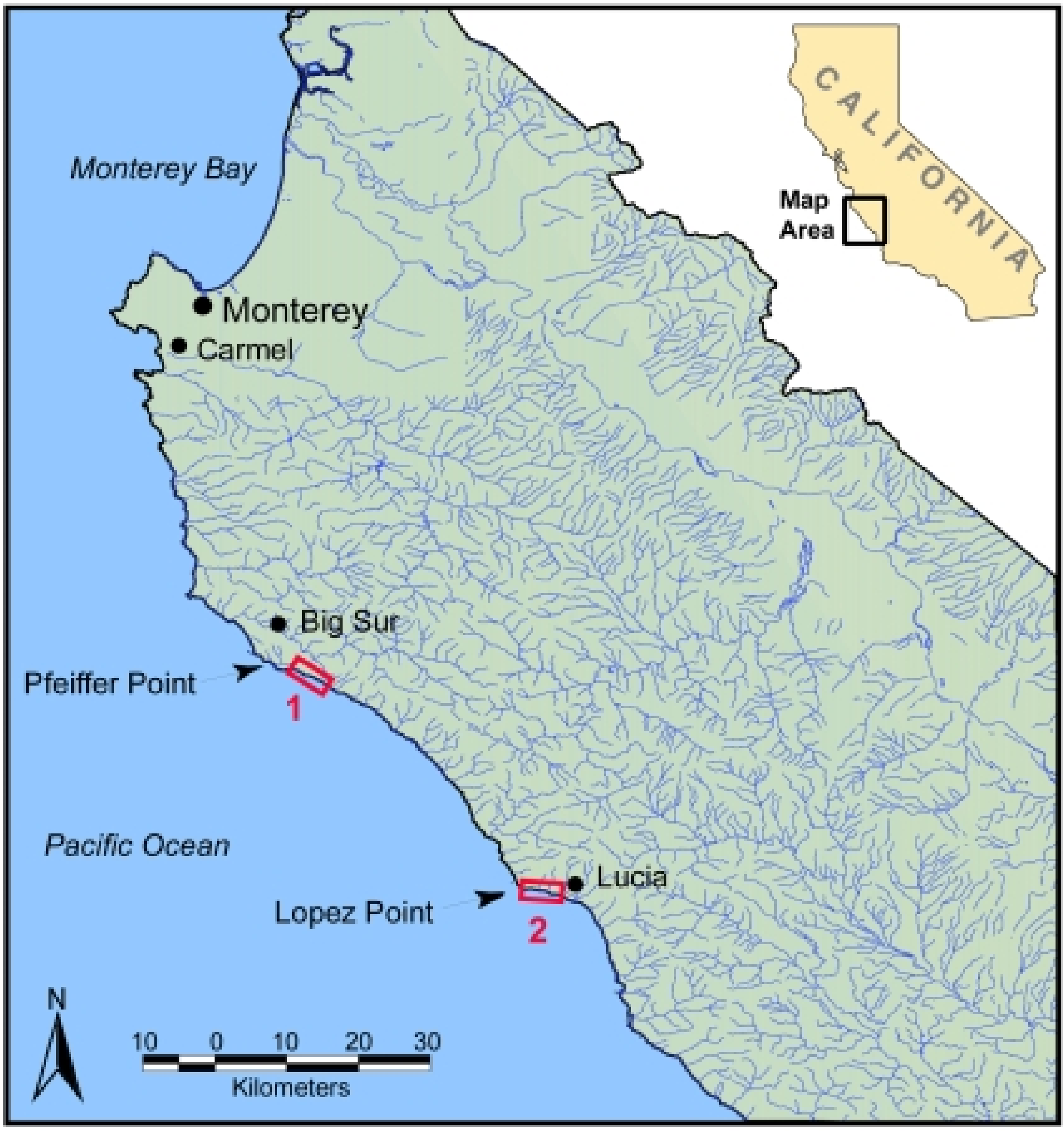
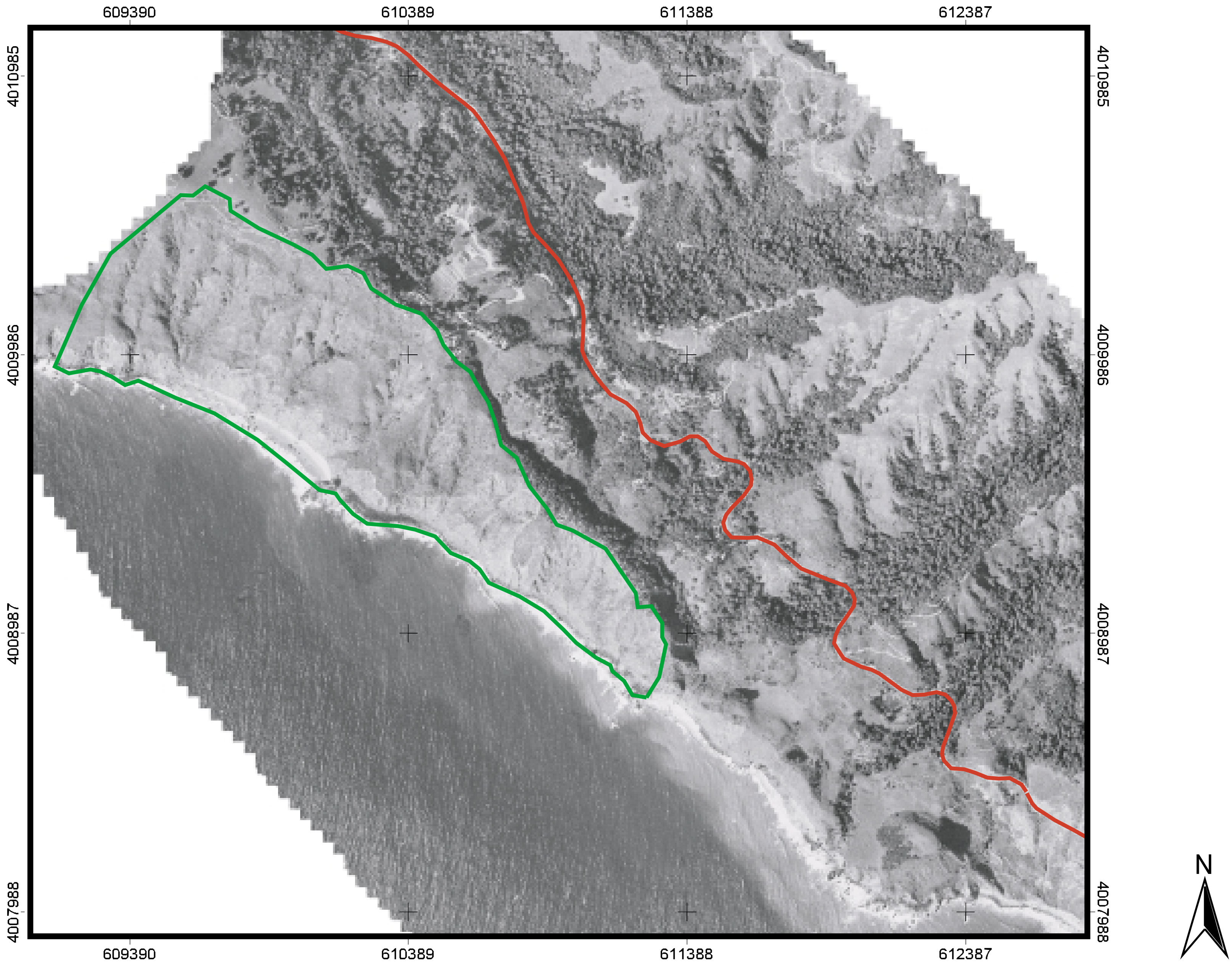

CALIFORNIA
Map Area
Monterey Bay
Monterey
Carmel
Big Sur
Pfeiffer Point
1
Pacific Ocean
Lucia
Lopez Point
2
N
10 0 10 20 30
Kilometers

Figure 1

1994 Orthophotomosaic of Pilot Study Locale 1, Wreck Beach Area, Big Sur Coast, CA



Area of volume calculation

Highway 1

USGS

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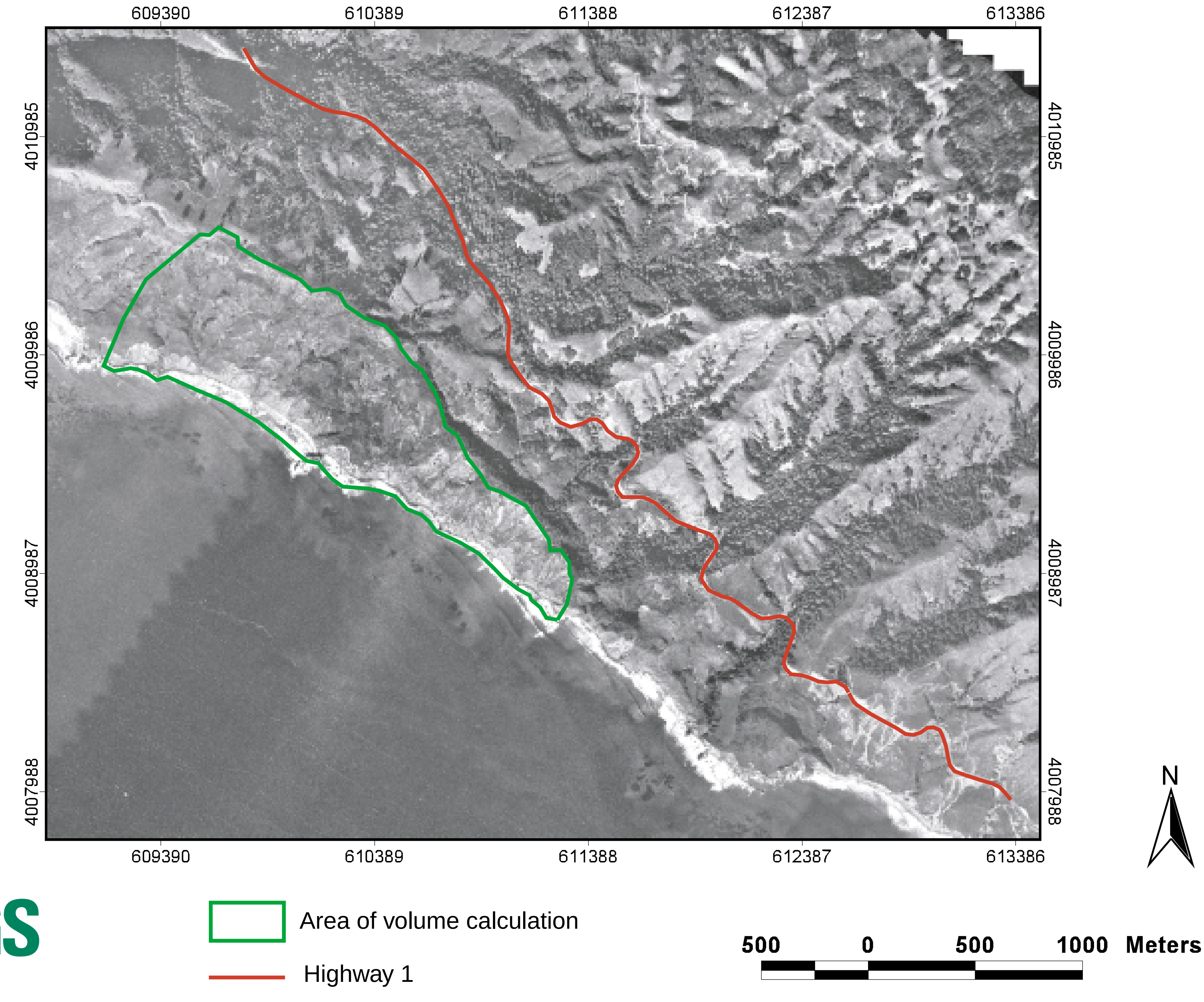
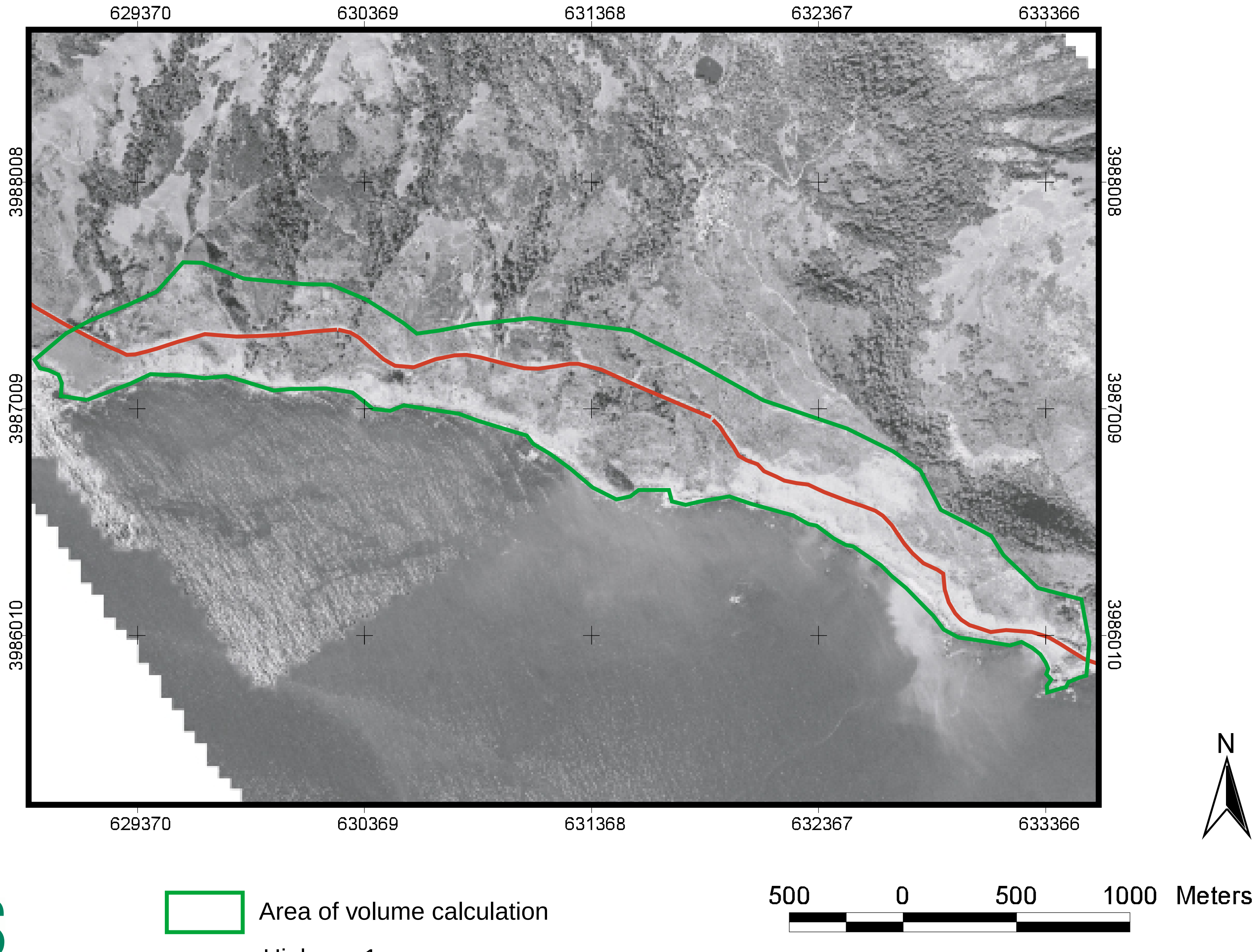
1942 Orthophotomosaic of Pilot Study Locale 1, Wreck Beach Area, Big Sur Coast, CA



USGS

by Cheryl Hapke

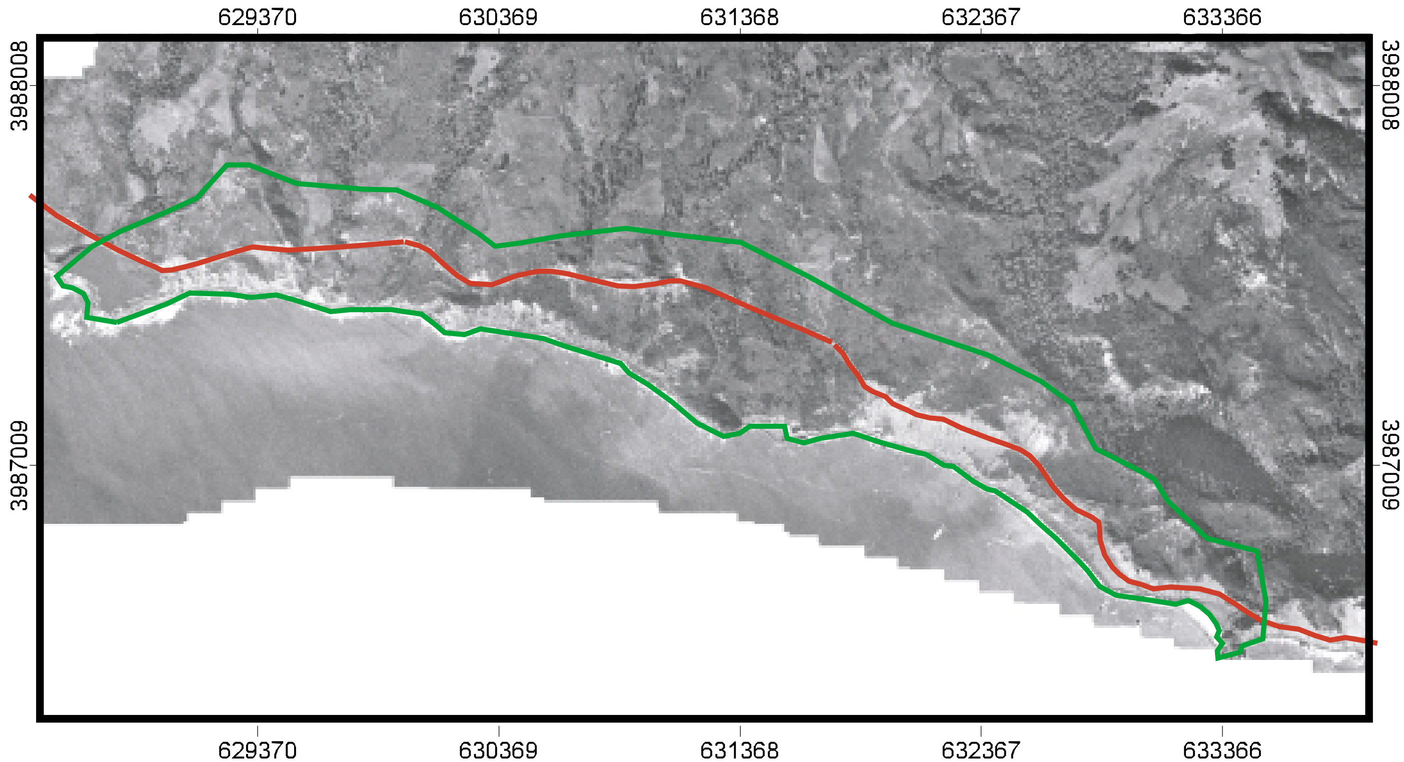
1994 Orthophotomosaic of Pilot Study Locale 2, Lopez Point Area, Big Sur Coast, CA



USGS

by Cheryl Hapke

1942 Orthophotomosaic of Pilot Study Locale 2, Lopez Point Area, Big Sur Coast, CA



Area of volume calculation

Highway 1

500 0 500 1000 Meters

N

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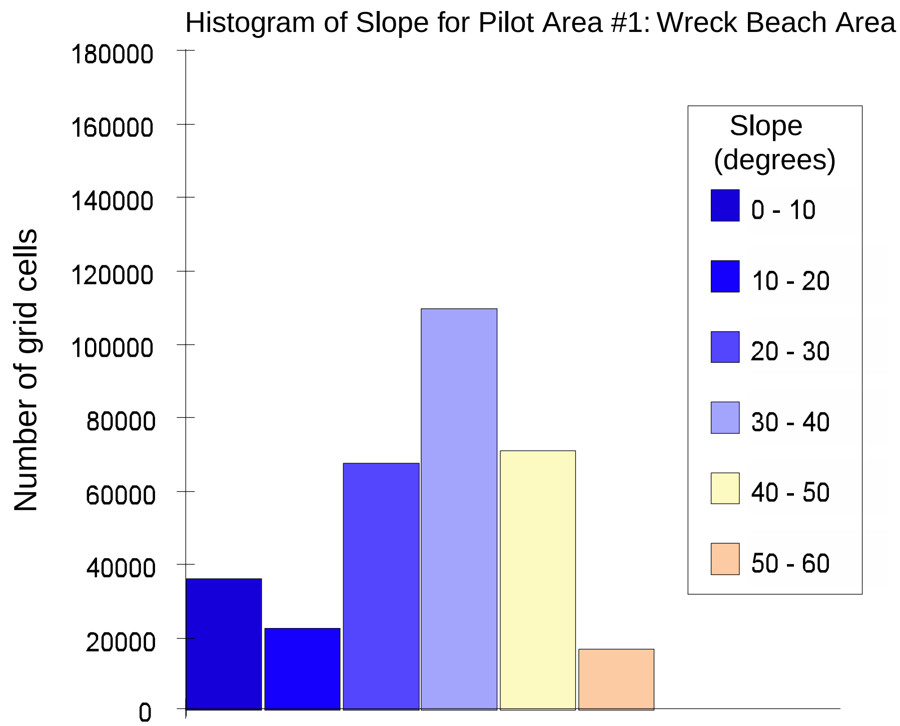
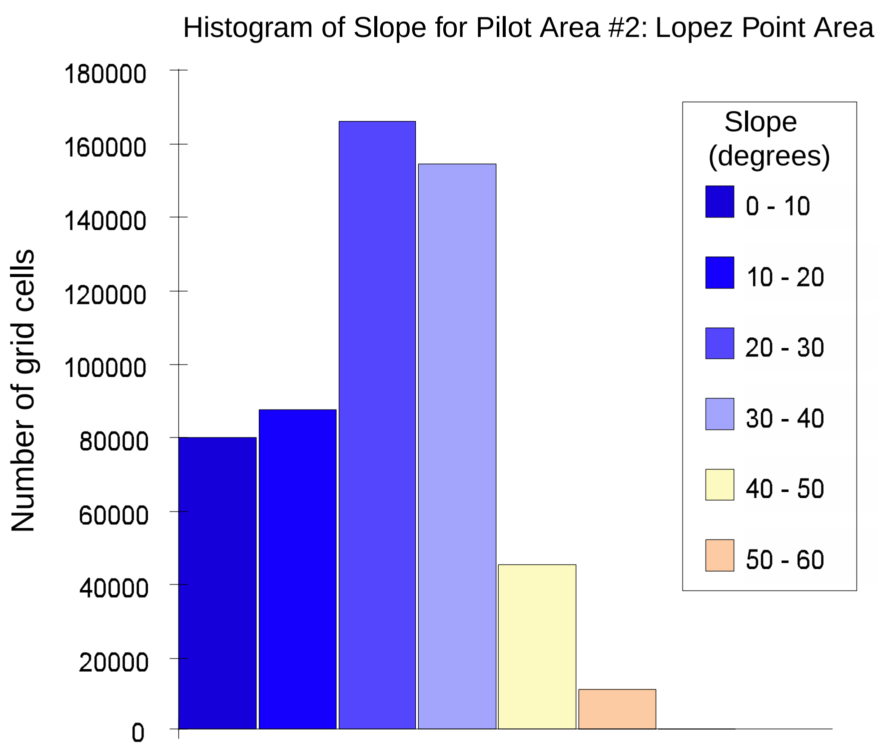

Histogram of Slope for Pilot Area #1: Wreck Beach Area
Number of grid cells
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Slope (degrees)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60


Histogram of Slope for Pilot Area #2: Lopez Point Area
Number of grid cells
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Slope (degrees)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60

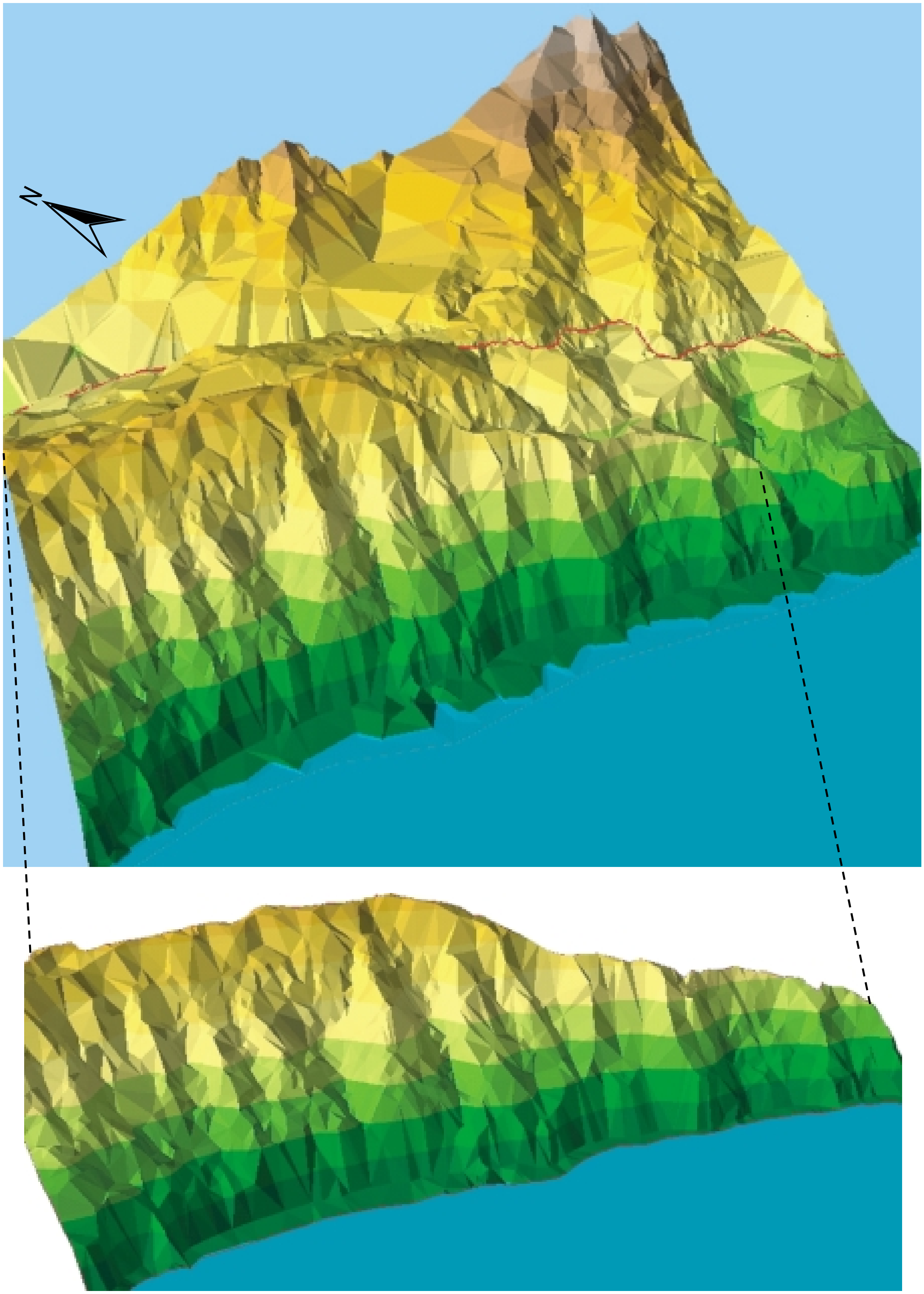


Figure 7

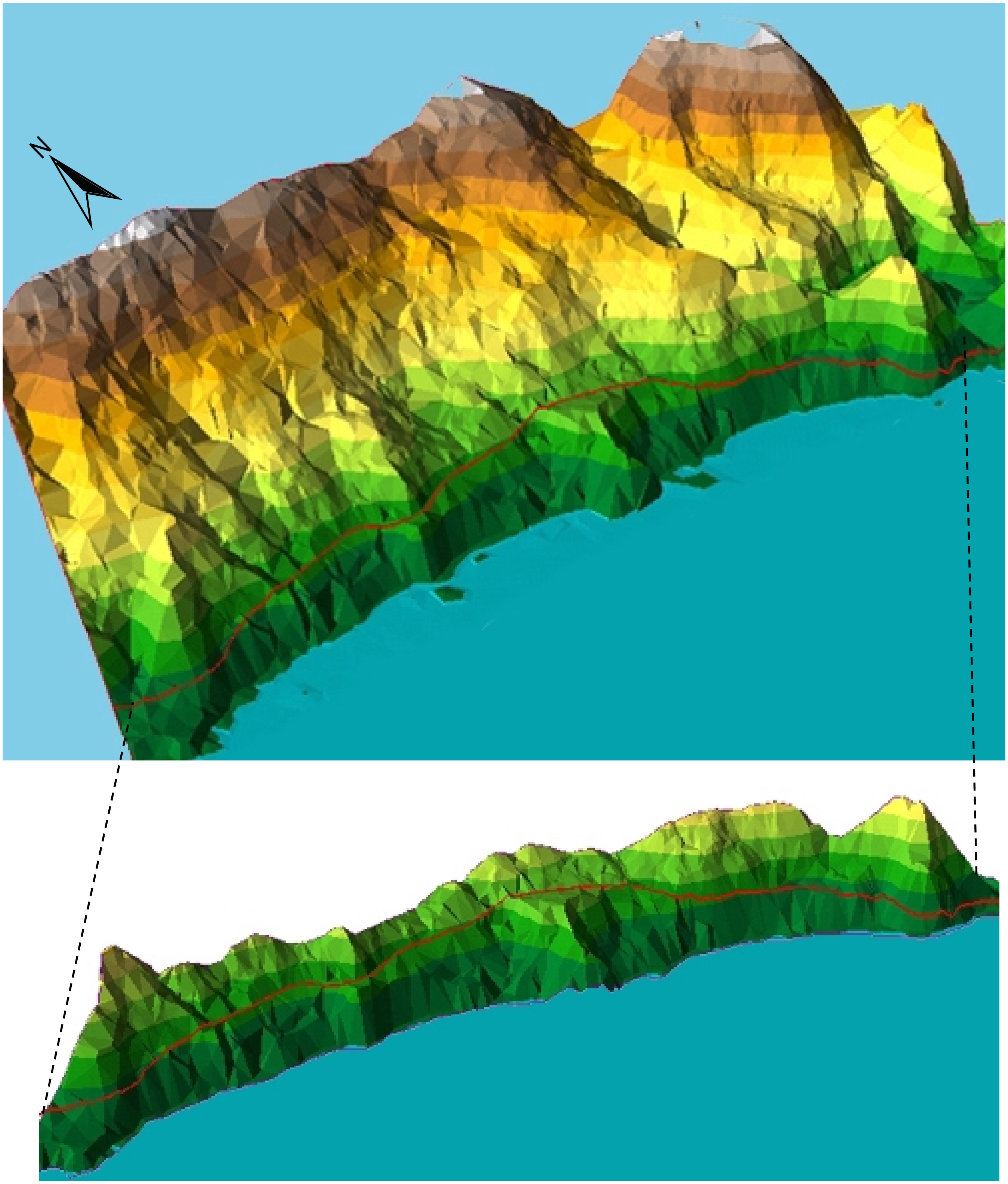


Figure 8

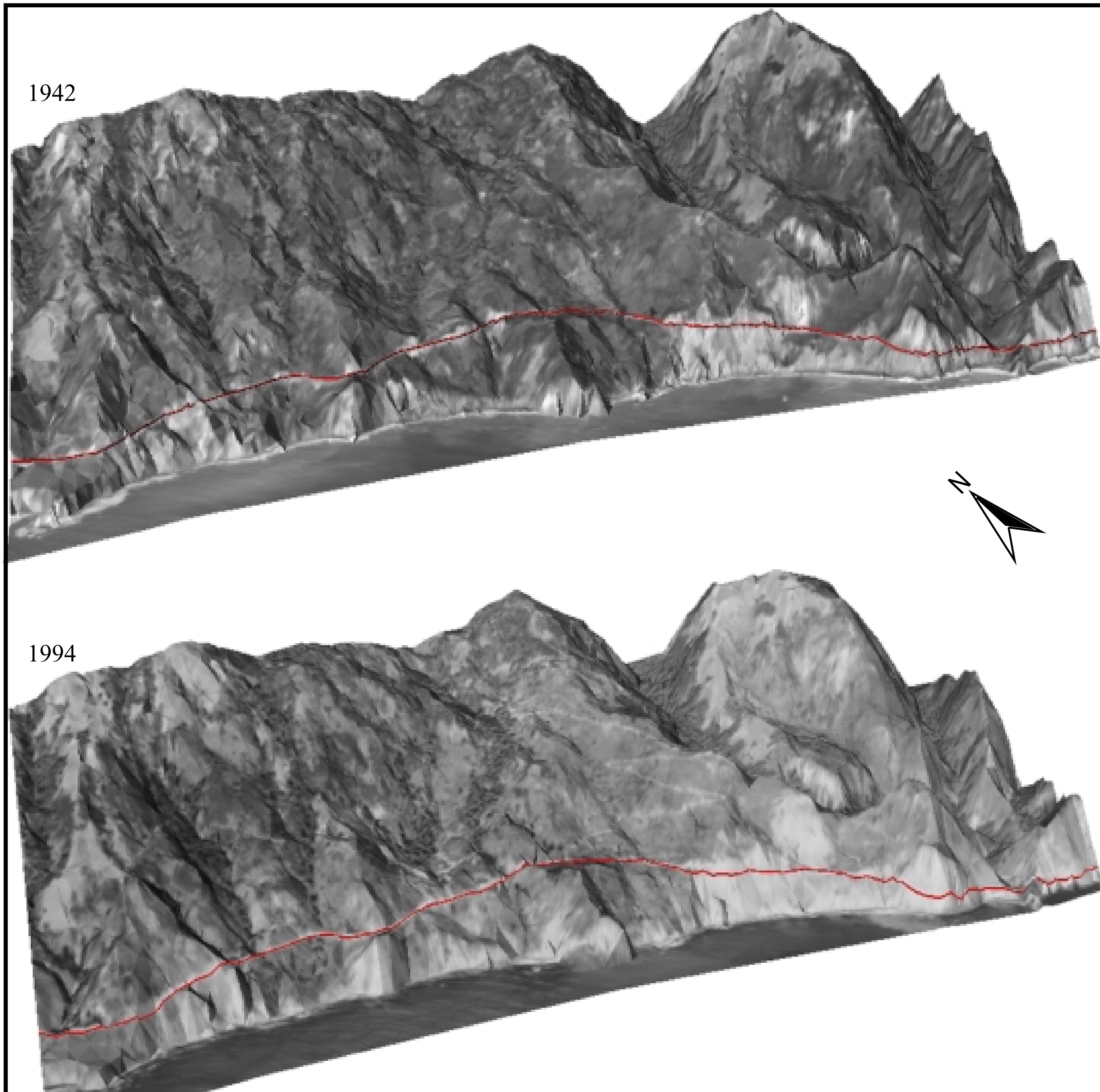


Figure 9