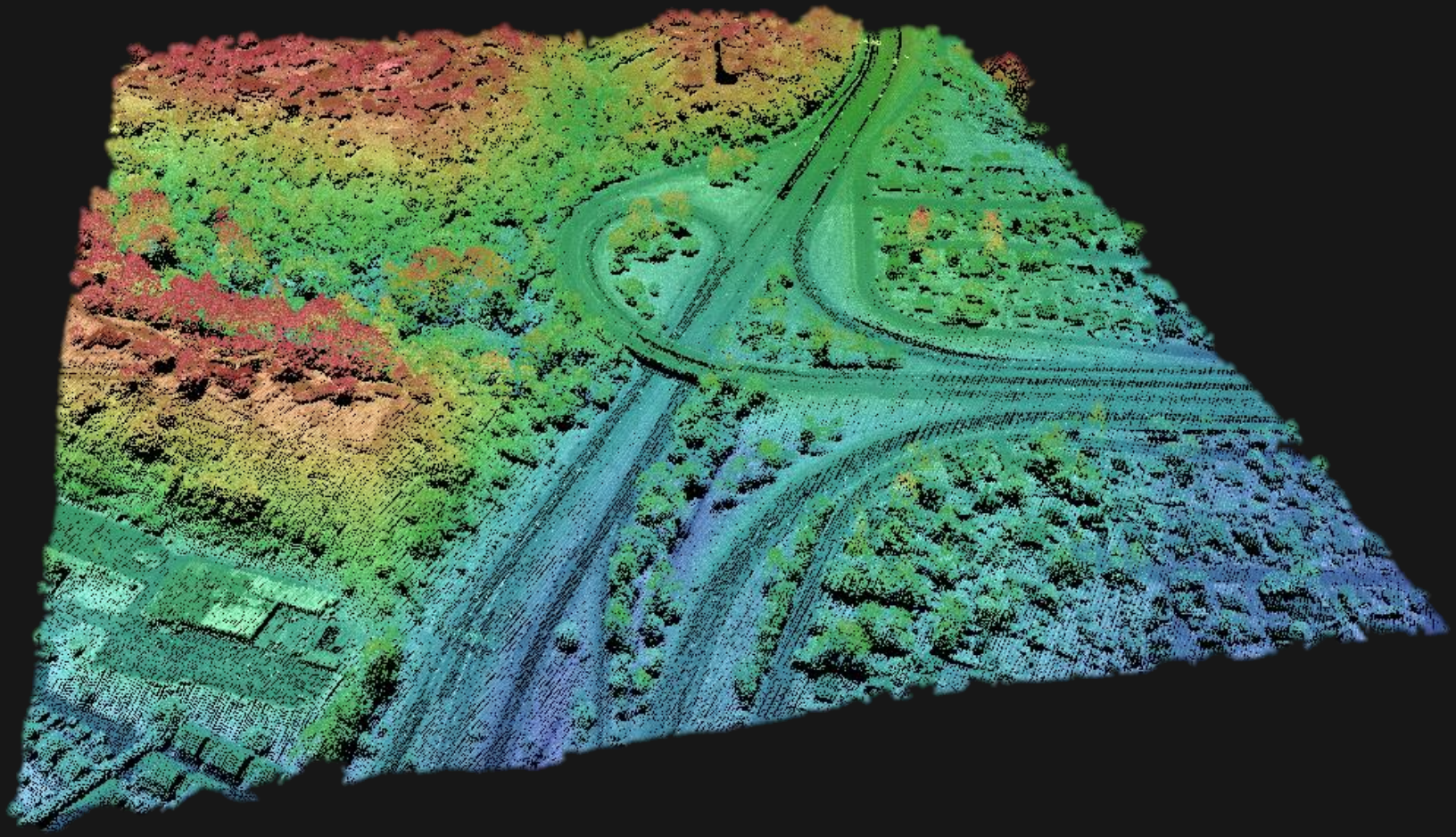
LiDAR and GIS for Trail Design

CA Trails and Greenways– May 2013

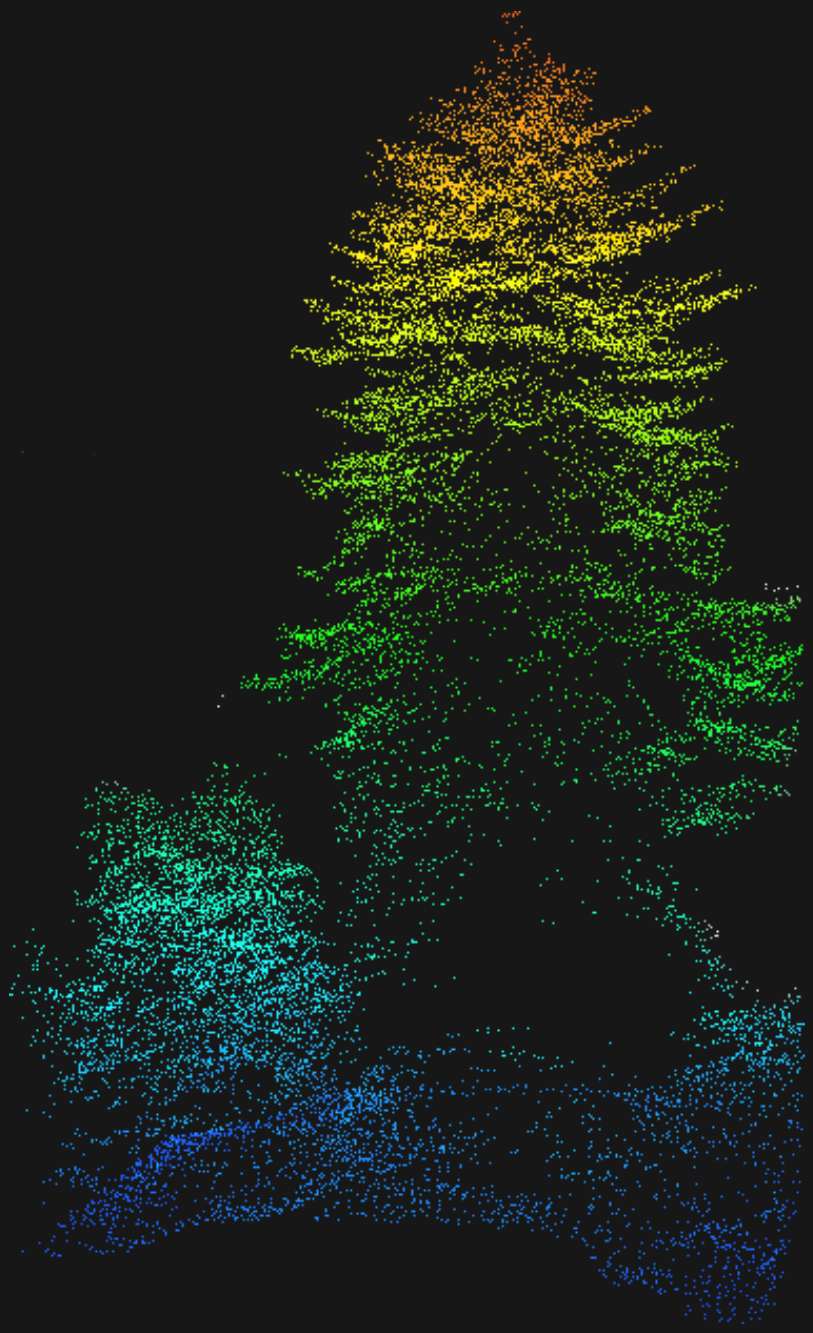


Drew Perkins
Russ White

Contact Info:
trails@mbosc.org
rwhite@calpoly.edu

Overview

- GIS Software and Datasets
- Getting Started with LiDAR
- Using GIS and LiDAR for trail design in the office and field
- Questions?



Free GIS Software Tools

Map Viewers

Google Earth

ArcGIS Explorer

View Imagery, USGS Topos, GPS points and other shapefiles.

Digitize new features, measure distances, and areas. Print, or share maps on-line.

Desktop GIS

Quantum GIS

Working with your data
More advanced editing
Terrain Analysis: Hillshade, Slope, Contours, stream lines…
Print Maps

GPS Utility

DNR GPS

Download tracks and waypoints from GPS to Desktop or vice versa.
(Formerly DNR Garmin)

Google Earth

Google Earth

What is it good for:

- Fast Hi-res Imagery
- Load KML, GPS points
- web and photo links

- Easy sharing online

Limitations:

- symbology
- labeling
- analysis

- no map layout
- low-res print maps

ArcGIS Explorer Online

- ESRI's Free GIS data viewer
  - ArcGIS Explorer Online

Easy access to Imagery, Topo and other Basemaps

Upload GPS points, shapefiles

Add notes and annotations

Save and share maps

ArcGIS Explorer

What is it good for:

- Imagery
- USGS Topo
- GPS/Shapefile viewer

Limitations:

- labeling
- export layers?
- analysis

Simple Information and queries

no map layout tools

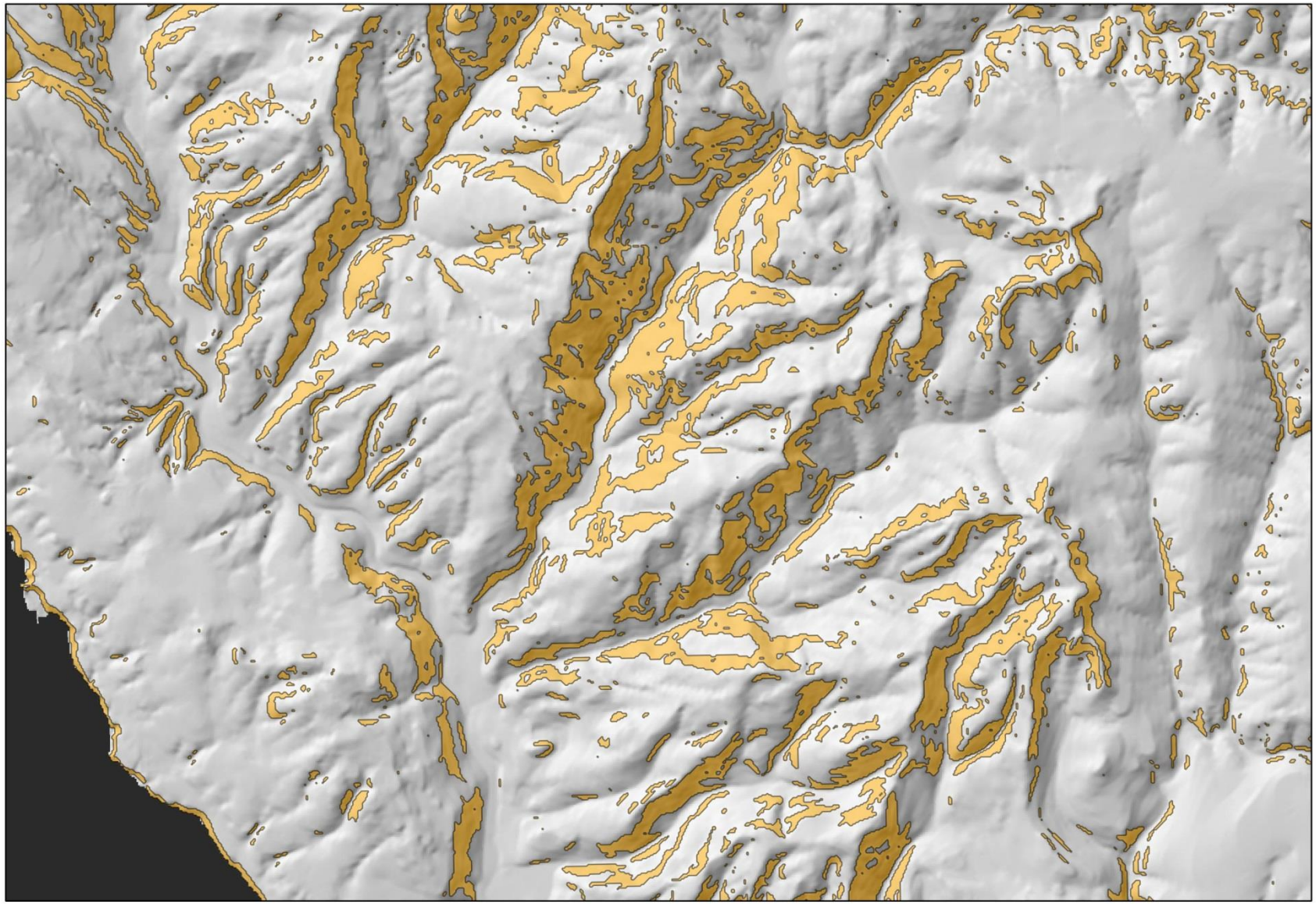
poor printed maps

Quantum GIS + GRASS

- For PC or Mac, QGIS offers a full-featured desktop GIS application

- Open Source: developed, updated and supported by the GIS community
  - (Universities, Federal Agencies, ACOE, users)

Spatial Analysis with Free Quantum GIS Software



Slope > 60%

0 1000 2000 ft.

Little Creek Watershed near Davenport, CA

Slopes Exceeding 60%

USGS 10m DEM

R. White
3/7/2010

Quantum GIS + GRASS

What is it good for:

- Multi-purpose
- diverse file types
- Basic and Advanced Spatial Analysis

It can get the job done

Limitations:

- learning curve
- some tools will fail
- some gaps in functionality

but you've got to put some time in…

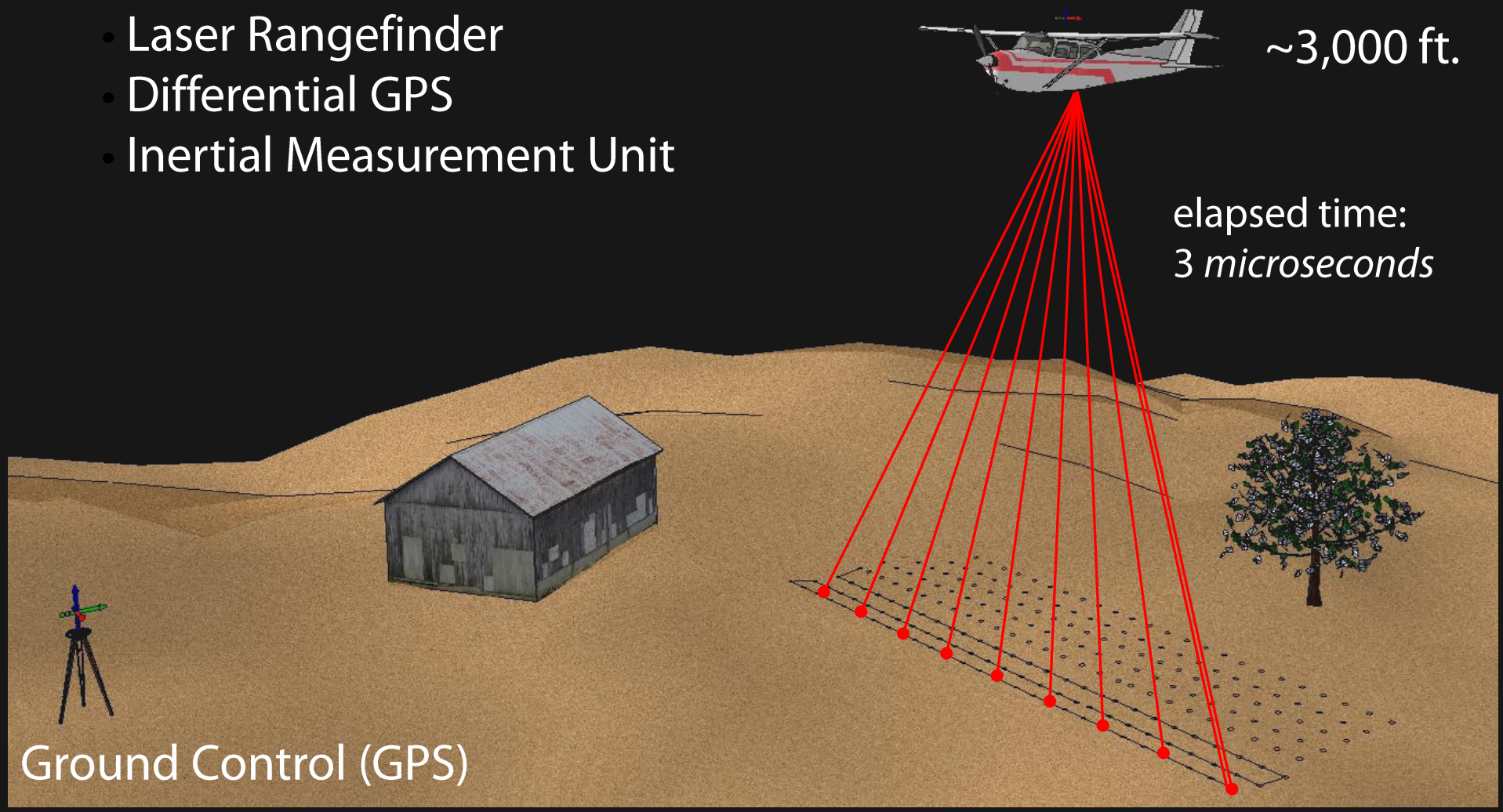
Why GIS?

- Planning and Design process is often collaborative and iterative, and yes, spatial
- Create, share, use, edit, update…
- GIS is an organizational tool
- Access to high quality data, take advantage

Light Detection and Ranging

Survey Aircraft

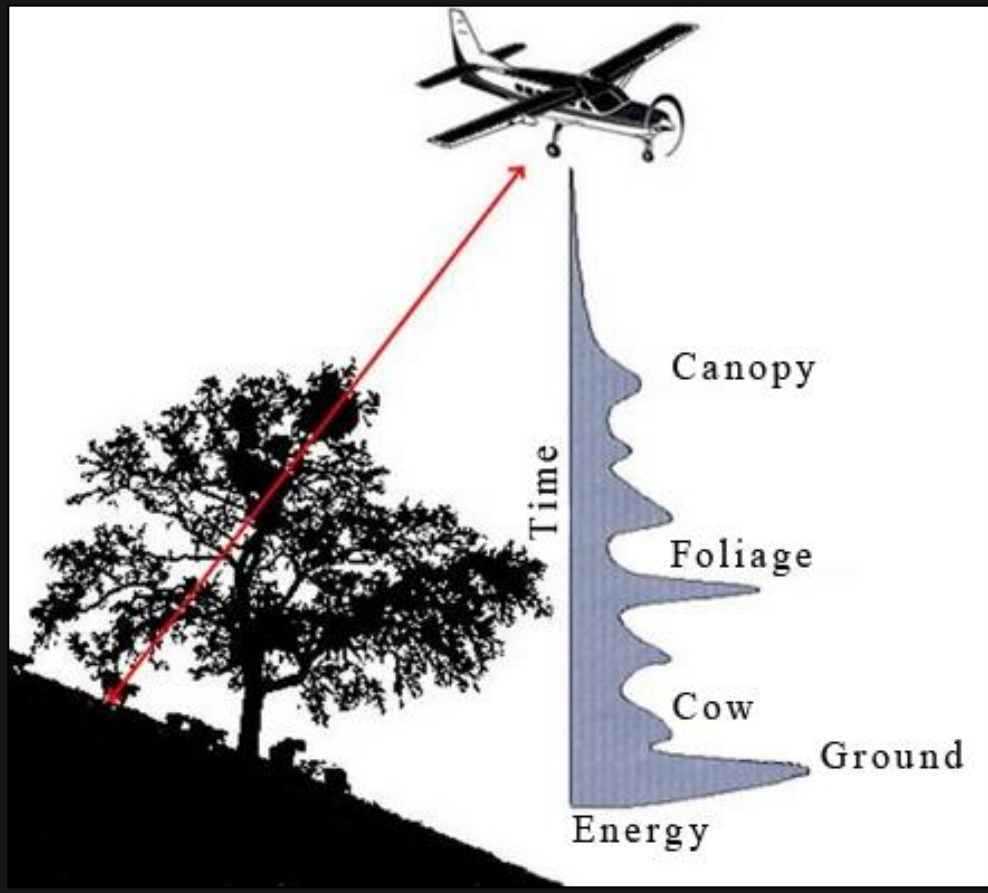
- Laser Rangefinder
- Differential GPS
- Inertial Measurement Unit



Multiple Returns

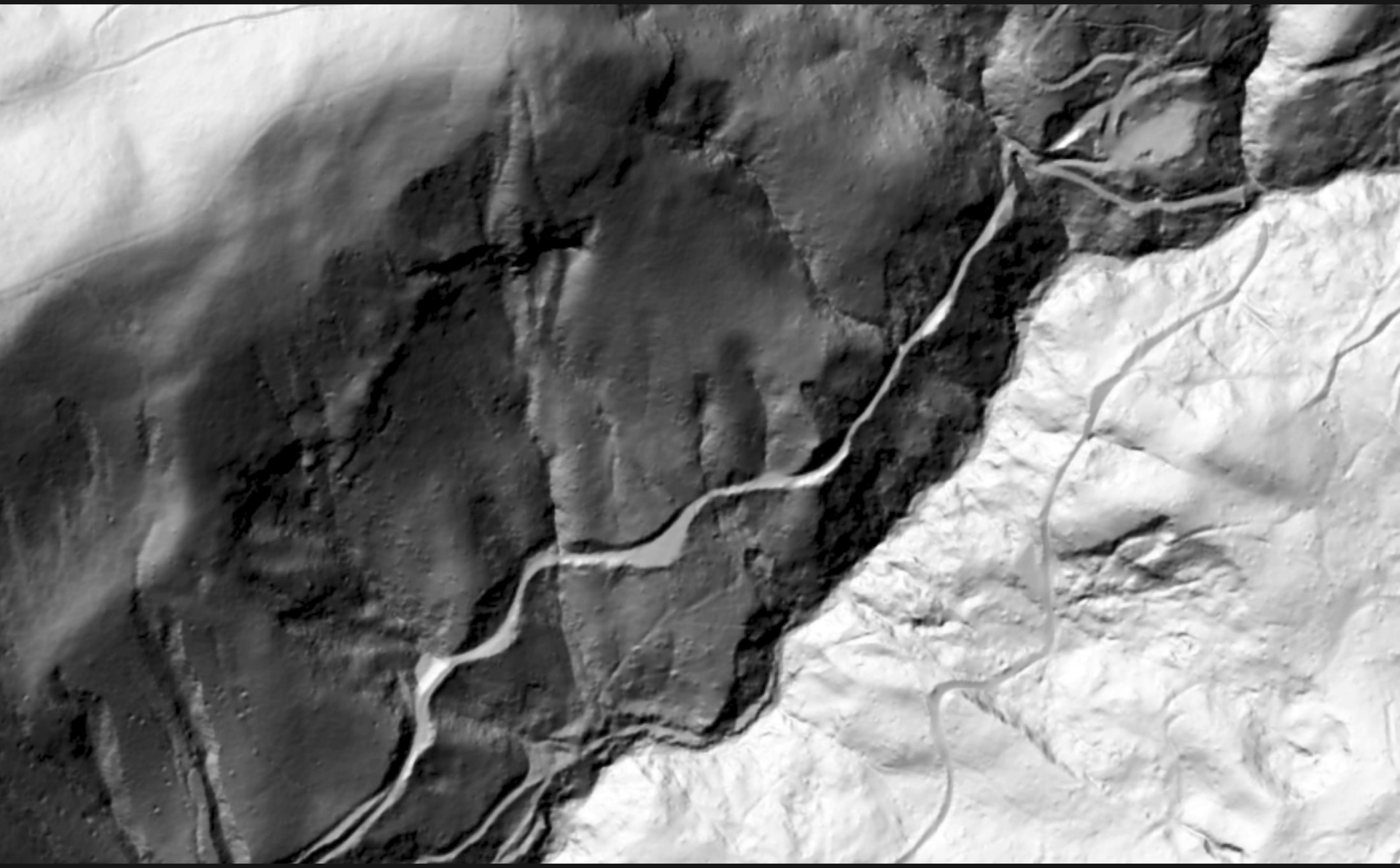
One pulse, many returns

- Typically 1-4 returns per pulse
- Provides vertical profile
- Last returns used to determine the ground surface



http://www.ensisjv.com/Portals/0/lidarimage002.jpg

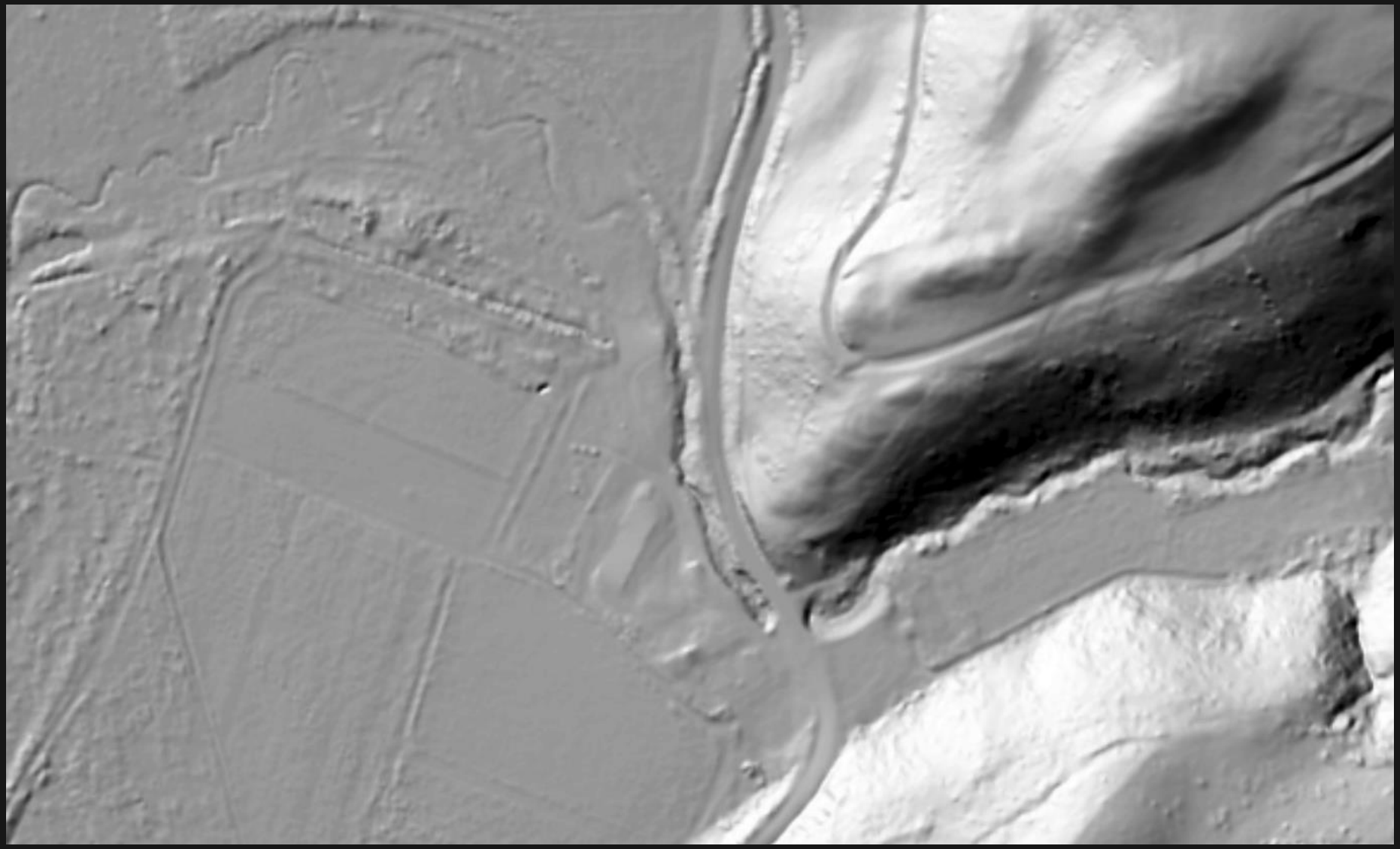
Point Cloud: Profile View



2003 10 DEM

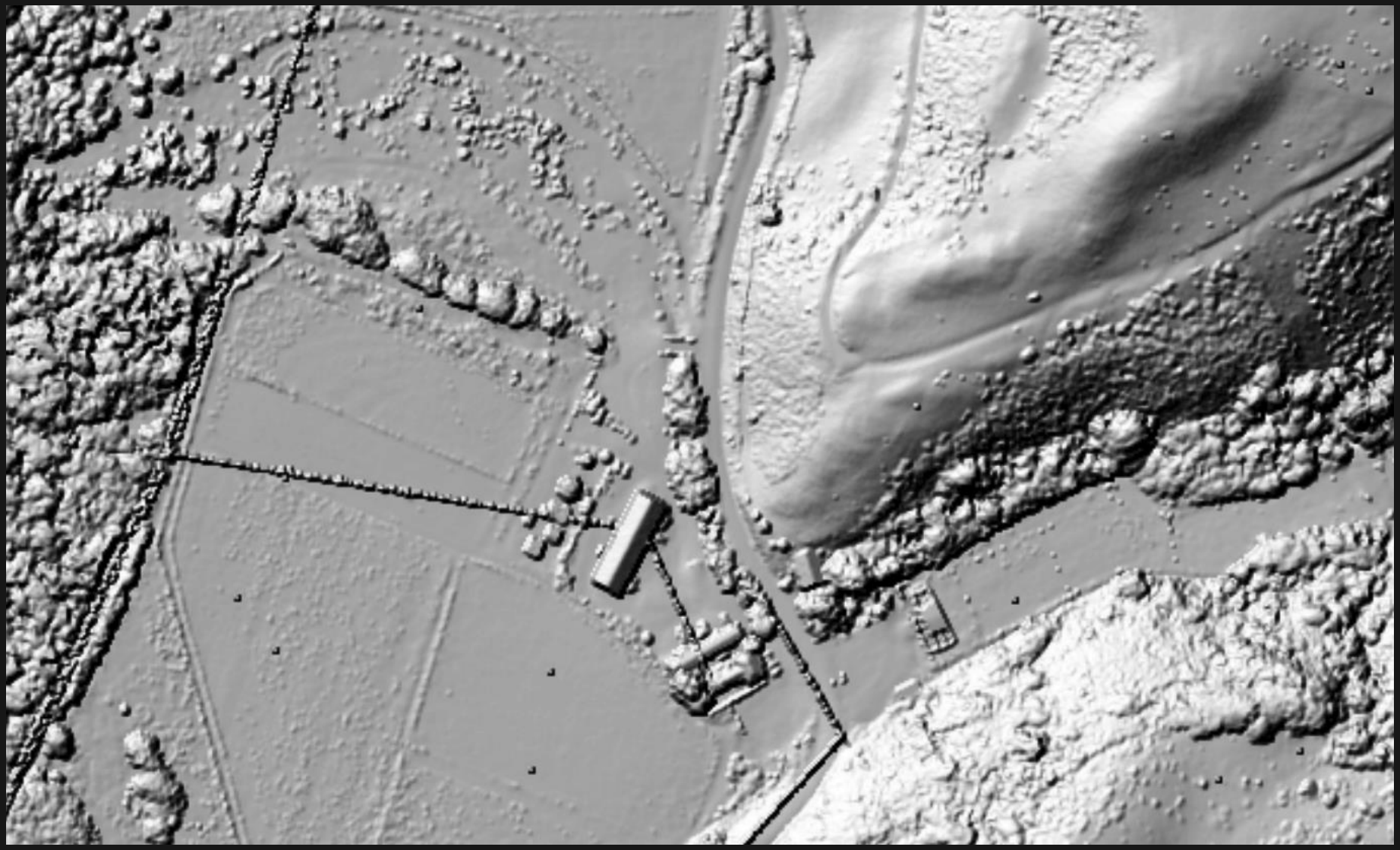
Bare Earth DEM

data must already be filtered



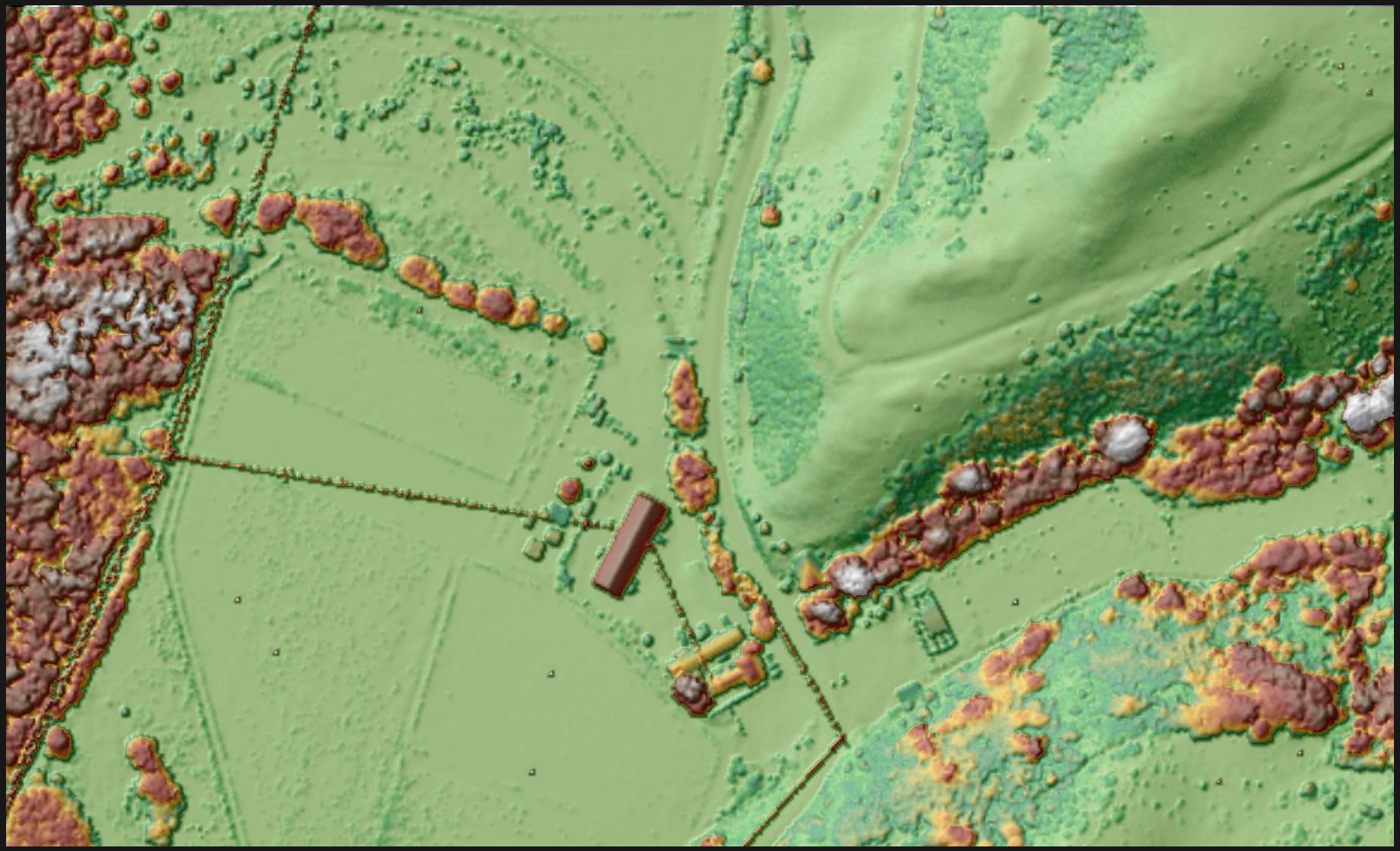
Digital Surface Model (DSM)

Highest elevations



nDigital Surface Model (nDSM)

DSM – DEM = height above ground



Intensity Image

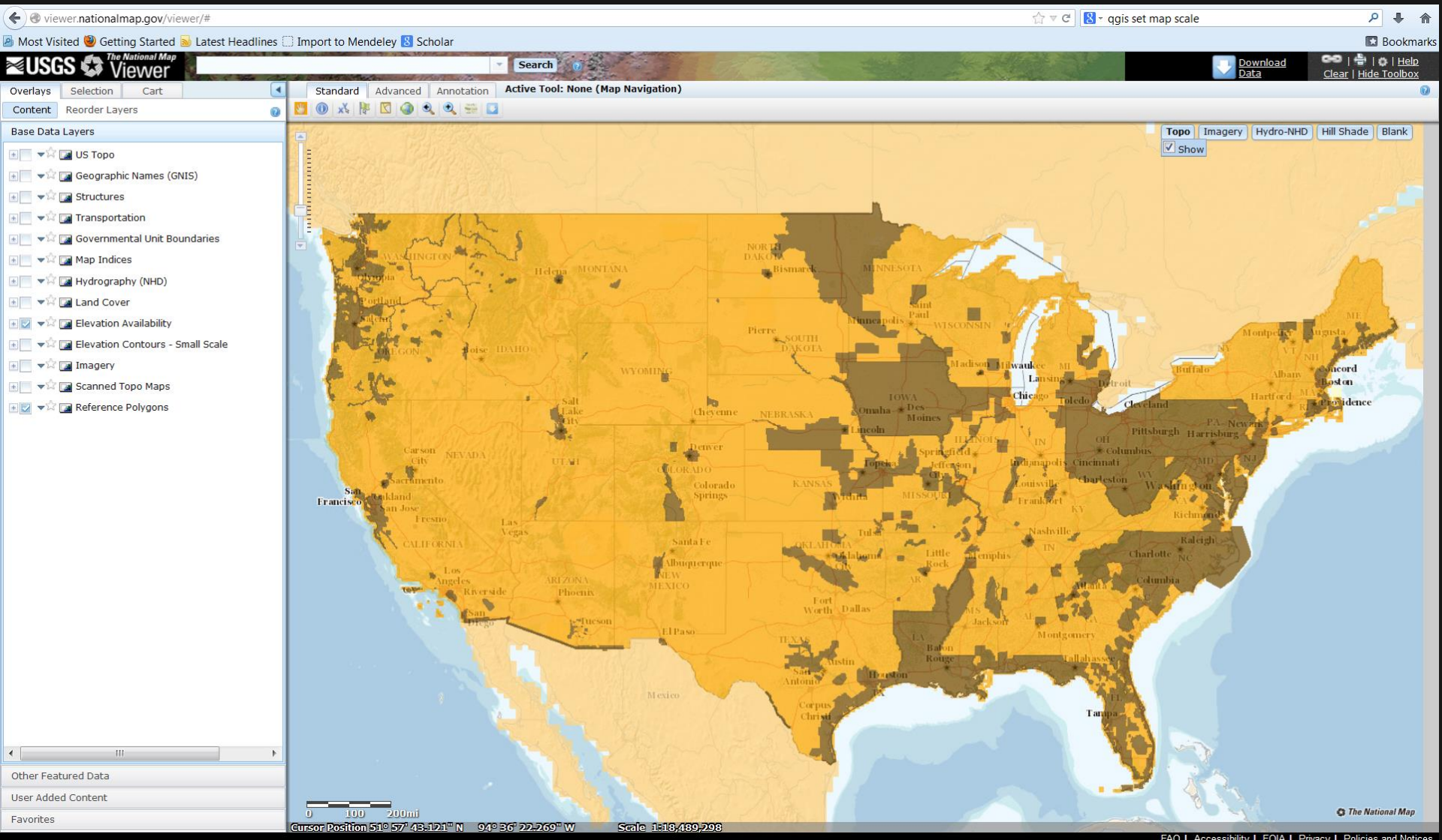
LiDAR reflectance

Hillshade and Imagery

Vegetation Height Layer

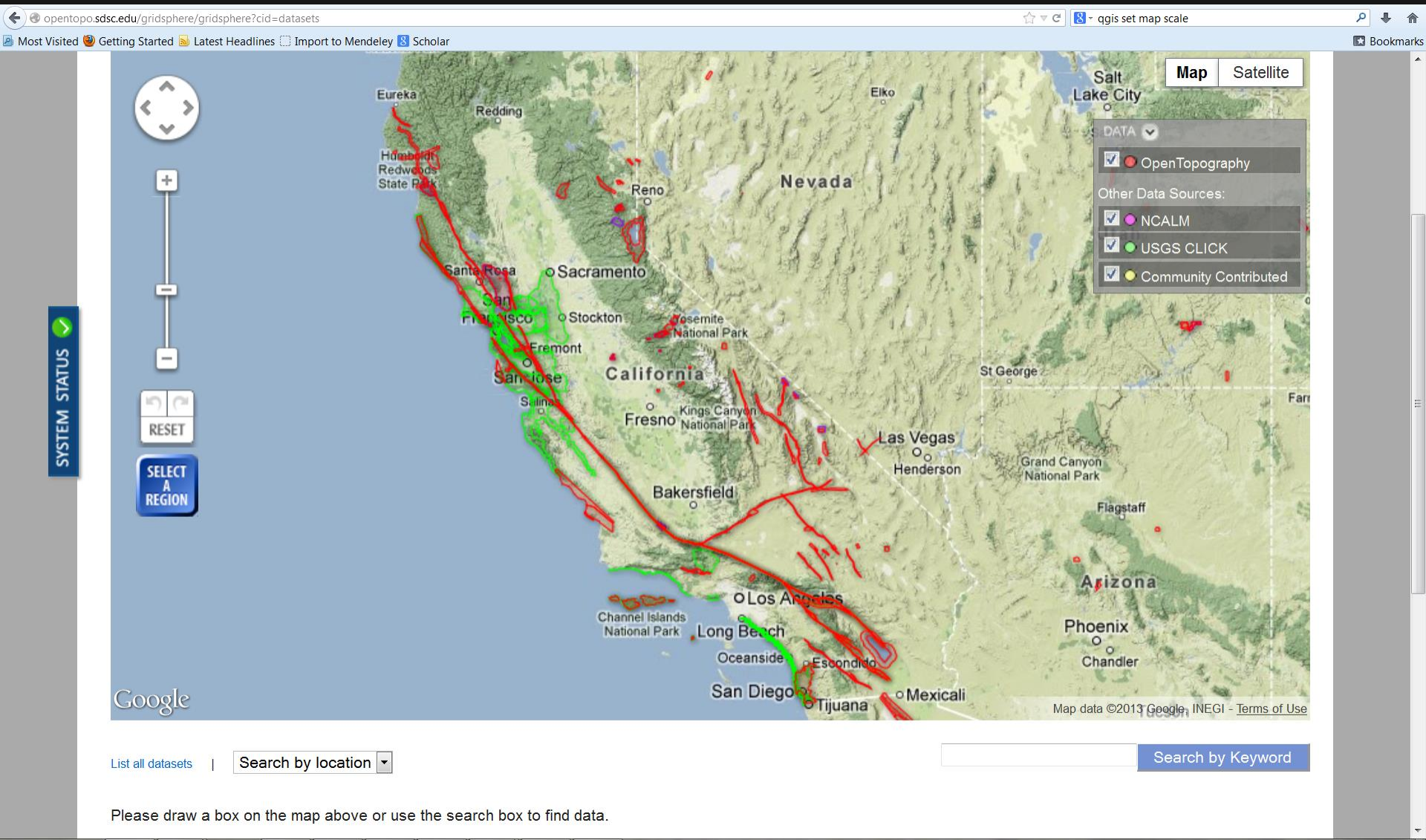
Where is LiDAR Available?

USGS the National Map



Where is LiDAR Available?

NSF Opentopography.org



Where is LiDAR Available?

NOAA Data Access Viewer

www.csc.noaa.gov/dataviewer/index.html?action=advsearch&qType=in&qFld=id&datareg=1&qVal=59#

qgis set map scale

Most Visited | Getting Started | Latest Headlines | Import to Mendeley | Scholar | Bookmarks

DIGITAL COAST
NOAA COASTAL SERVICES CENTER

Data Access Viewer

Enter Location

California, state, United States | Go | or | Draw Area

Selecting a subset of this data set's coverage area will return additional results for the area of interest. Close

25 mile buffer

Refine Search

Data Type | Licensed Data | Data Provider

Results (97) | Data Detail | Cart (0)

Zoom | Share | Clear | Sort by | Data Type (A-Z)

2009 Humboldt Bay CA Habitat
NOAA
Benthic | Download ZIP

2009-2011 CA Coastal Conservancy Coastal Lidar Project: Digital Elevation Model
CA Coastal Conservancy
DEM 4,201,839 MB | Add to Cart

2004 CA IfSAR Digital Terrain Model
NOAA
DEM 69,689 MB | Licensed Data

2004 CA IfSAR Digital Surface Model
NOAA
DEM 69,689 MB | Licensed Data

2002-03 CA IfSAR Digital Elevation Model
NOAA
DEM 79,082 MB | Add to Cart

2012 Stockton, CA IOCM Natural Color Imagery
NOAA
Imagery 13,766 MB | Add to Cart

2012 Redwood City, CA IOCM Natural Color Imagery

Latitude: 40.7603 Longitude: -125.7304 Scale: 1:4622324

Base Maps: Imagery | Streets

Redding, Chico, Reno, Carson City, NEVADA, UTAH, Provo, Sacramento, Vacaville, Fairfield, Antioch, Stockton, Livermore, Fremont, Modesto, San Jose, Salinas, Fresno, Visalia, CALIFORNIA, Bakersfield, Santa Maria, Lompoc, Santa Barbara, Oxnard, Lancaster, Palmdale, Victorville, Santa Clarita, Riverside, Anaheim, Cathedral City, Palm Desert, Indio, Santa Ana, Murrieta, Oceanside, Long Beach, San Diego, Tijuana, Mexicali, Yuma, Las Vegas, Henderson, Saint George, Lake Havasu City, Flagstaff, Prescott, ARIZONA, Phoenix, Mesa

300 km
200 mi

United States Department of Commerce | National Oceanic and Atmospheric Administration

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Accessing High Resolution Topography Data

Select Area of Interest

Horizontal Coordinates: UTM Zone 10 N NAD83 Meters [EPSG: 26910] - **Vertical Coordinates**: NAVD88 [EPSG: 5703]

Data Selection Coordinates: ☐ Manually enter selection coordinates (in the horizontal coordinate system listed above)

X_{min} = 741806.621 Y_{min} = 4335052.97 X_{max} = 747547.89 Y_{max} = 4339170.466

The selection area contains 35,294,346 points.

1b. Choose Return Classification: ◉ Ground ○ Unclassified ○ Water ○ All

2. Point Cloud Data Download:

☐ Point cloud data in LAS format ☐ Point cloud data in LAZ format ☐ Point cloud data in ASCII format

3a. DEM Generation (Local Gridding):

Gridding Method
- ☐ Calculate Zmin grid
- ☐ Calculate Zmax grid
- ☐ Calculate Zmean grid
- ☐ Calculate Zidw grid
- ☐ Calculate point count grid

Gridding Parameters
- Grid Resolution (Default = 1 meter): 1
- Radius value (Default = 1 meter): 1

Grid Format Arc ASCII Grid

Null Filling None

3b. DEM Generation (TIN):

Gridding Method
- ☑ Calculate TIN

Gridding Parameters
- Grid Resolution (Default = 1 meter): 1
- Max. triangle size (Default 50 units): 50

Grid Format GeoTiff

4. Derivative Products:

☑ Generate hillshade and slope grids in grid format: GeoTiff

5. Visualization:

☑ Generate hillshade images and Google Earth files from DEMs

Altitude of the light, (in degrees): 45
Azimuth of the light, (in degrees): 315

☑ Generate additional color-relief and colored hillshades

…minutes later, delivered to email

Job Id	Dataset	Title	Submission	Completion	Duration	Num points	Status
13677930513982002562215	TAHOE	Granlibakken Conference Center	2013-05-05 15:30:51	2013-05-05 15:37:26	395 secs	35,294,346	Done

Download Job Metadata:

metadata-13677930513982002562215.txt

DEM Results:

Download compressed DEM results: dems.tar.gz (TIN)

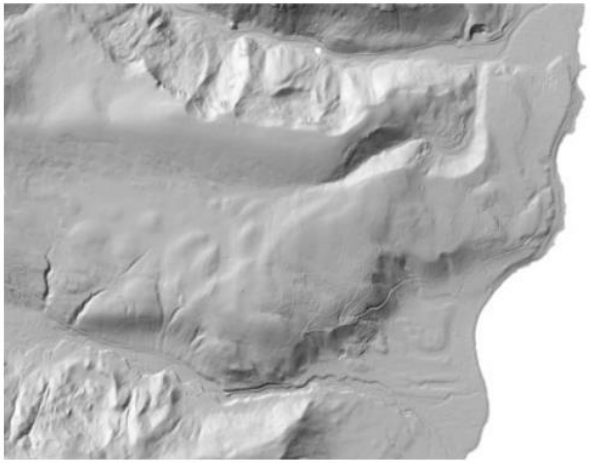
Derivative Product Results:

Download compressed Hillshade & Slope Products: viz.tar.gz (TIN)

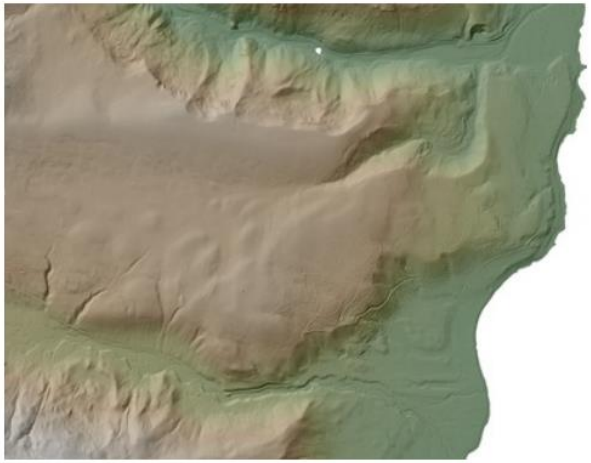
Visualization Products:

Ztin DEM:

Download KMZ file: viz.tin.hs.kmz
View with Google Earth browser plug-in



Download KMZ file: viz.tin.crhs.kmz
View with Google Earth browser plug-in



Open Source Mapping Software

OSGeo4W Your Open Source Compass

OSGeo4W
Your Open Source Compass for Windows

Search

Login | Help/Guide | About Trac | Preferences

Wiki | Timeline | Roadmap | Browse Source | View Tickets | Search

Start Page | Index | History | Last Change

OSGeo4W

Japanese French Polish Deutsch

This is the web site, wiki and issue tracking database for the **OSGeo4W project**. OSGeo4W is a binary distribution of a broad set of open source geospatial software for Win32 environments (Windows XP, Vista, etc). OSGeo4W includes GDAL/OGR, GRASS, MapServer, OpenEV, uDig, QGIS as well as many other packages (over 150).

This project is under the umbrella of the **Open Source Geospatial Foundation**, http://www.osgeo.org/.

Only authenticated (logged in) users can submit and edit tickets, and modify the wiki. Use your OSGeo userid/password to login.

About licenses

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Quick Start for OSGeo4W Users
OSGeo4W User Information
OSGeo4W Packager (Developer) Information
Communication / Coordination

Quick Start for OSGeo4W Users

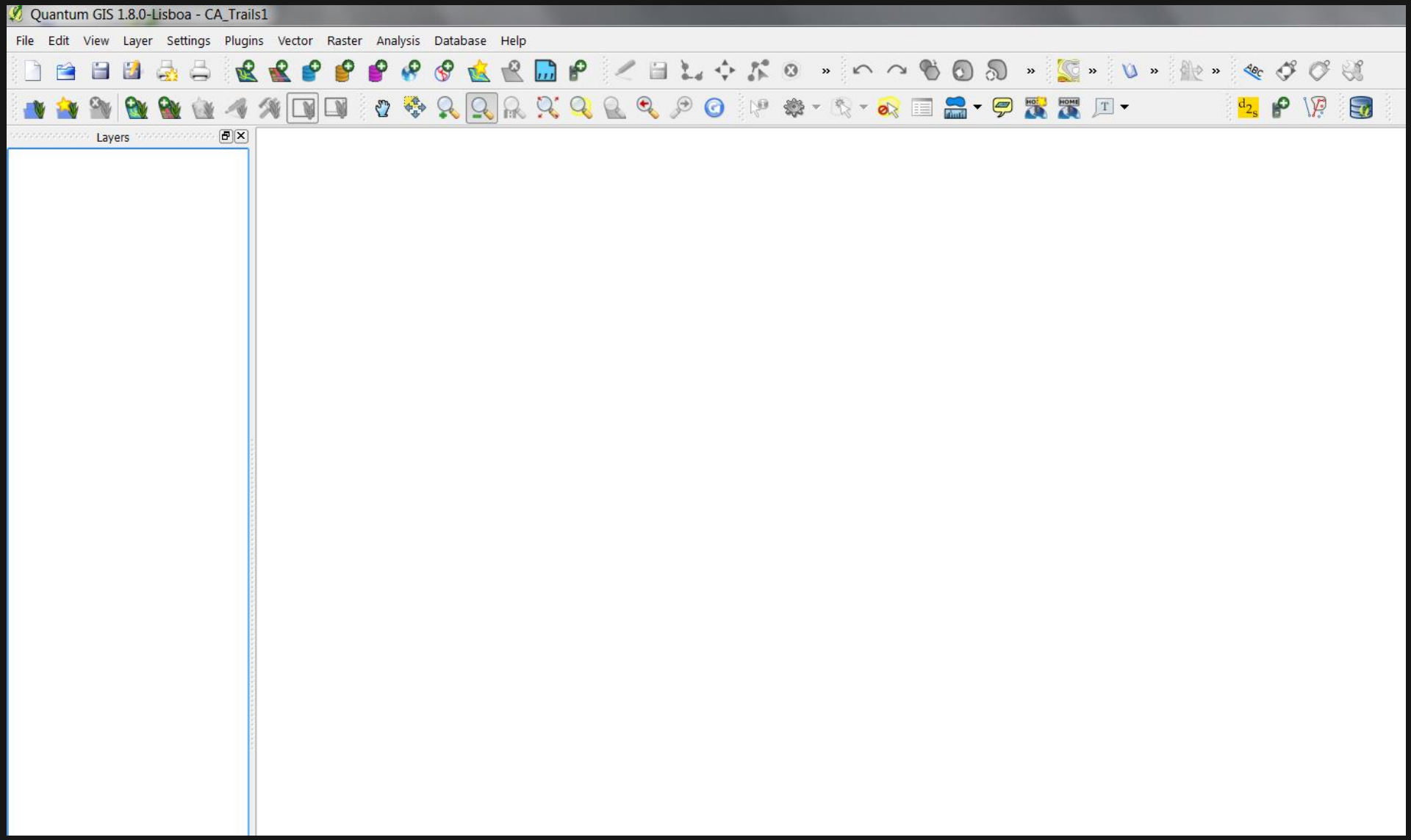
Note: Step 2 must be run on a computer with internet access as the installer downloads individual packages as needed. You may also need to enable your software firewall to allow the installer to have outbound access.

1. Download the OSGeo4W Installer (for users that currently can't access download.osgeo.org for unknown reasons beyond our control, there is an OSGeo4W Installer that references the mirror download2.osgeo.org)
2. Run the installer.
3. Select *Express Install*, and *Next*.
4. Pick one or more packages to install, and *Next*.
5. The selected packages and their required subpackages will be downloaded and installed automatically.

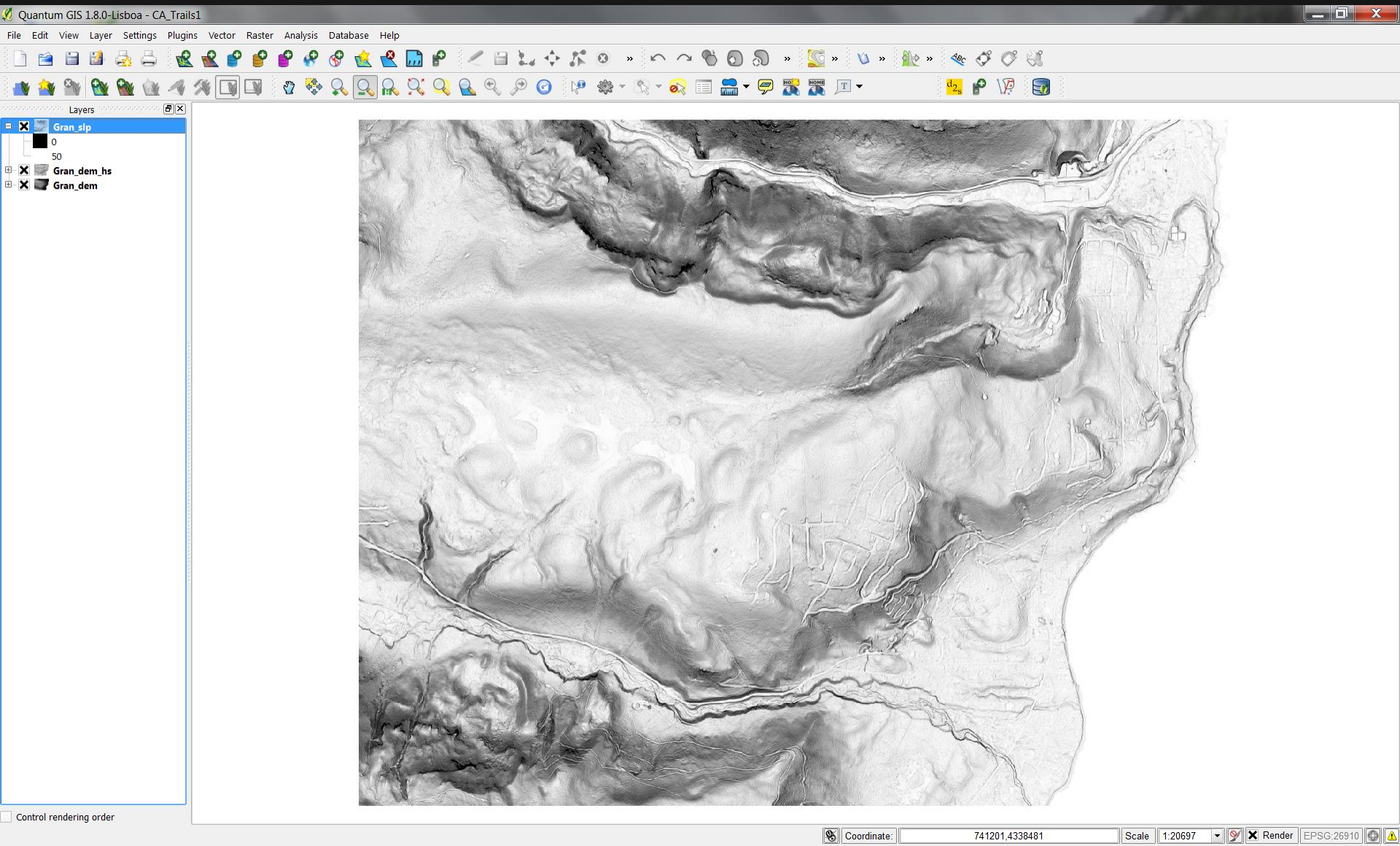
After installation:

- Desktop applications will be found in *Start -> All Programs -> OSGeo4W*
- Commandline applications will be available in the *OSGeo4W Shell* command window.
- Web applications will be available at http://localhost/

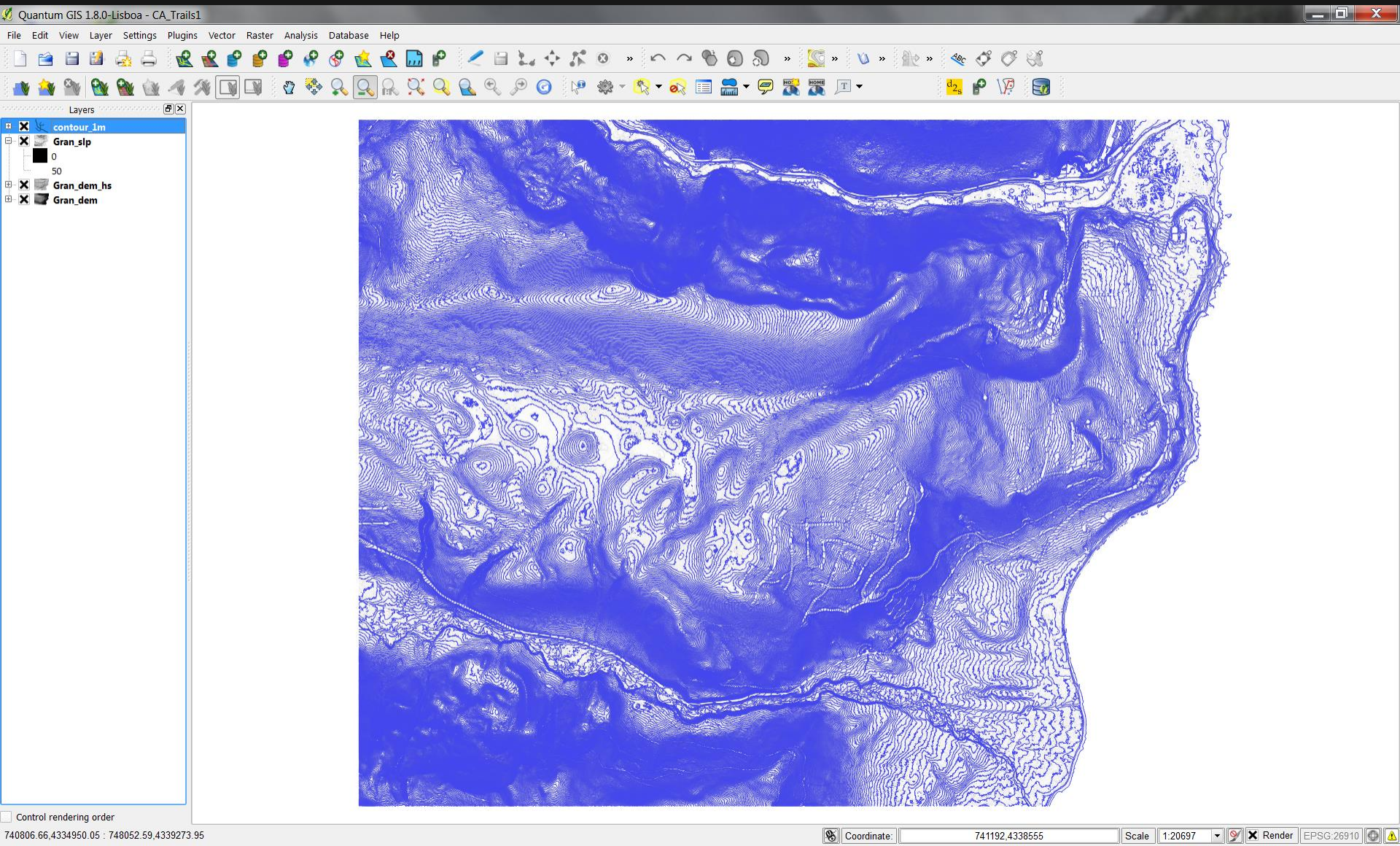
Quantum GIS


Quantum GIS 1.8.0-Lisboa - CA_Trails1
File
Edit
View
Layer
Settings
Plugins
Vector
Raster
Analysis
Database
Help
Layers

DEM, Hillshade and Slope



1m Contours


Quantum GIS 1.8.0-Lisboa - CA_Trails1
File Edit View Layer Settings Plugins Vector Raster Analysis Database Help
Layers
contour_1m
Gran_slp
0
50
Gran_dem_hs
Gran_dem
Control rendering order
740806.66,4334950.05 : 748052.59,4339273.95
Coordinate:
741192,4338555
Scale
1:20697
Render
EPSG:26910

Quantum GIS 1.8.0-Lisboa - CA_Trails1

File Edit View Layer Settings Plugins Vector Raster Analysis Database Help

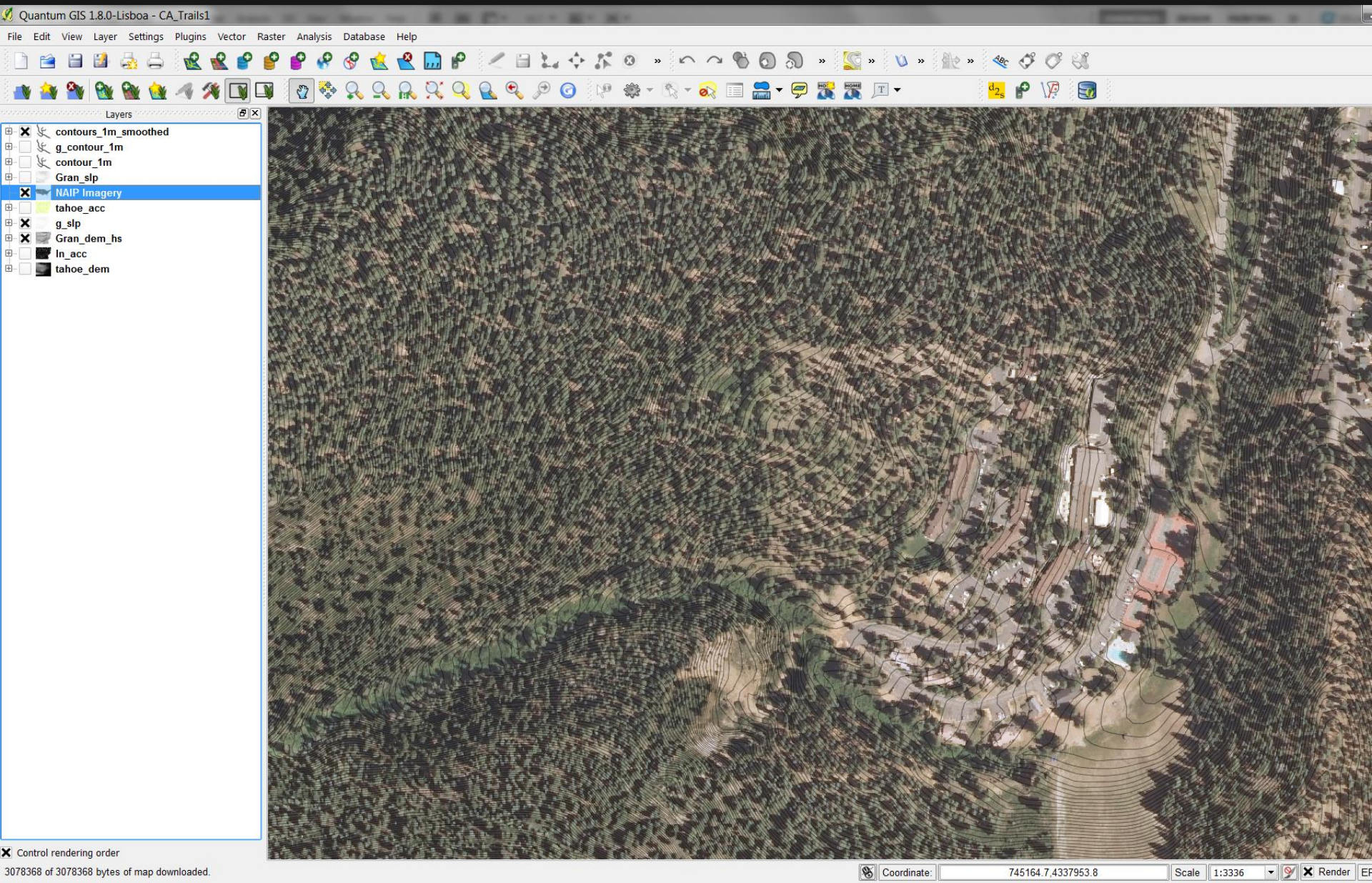
Layers

- contours_1m_smoothed
- g_contour_1m
- contour_1m
- Gran_slp
  - 0
  - 50
- Gran_dem_hs
- Gran_dem

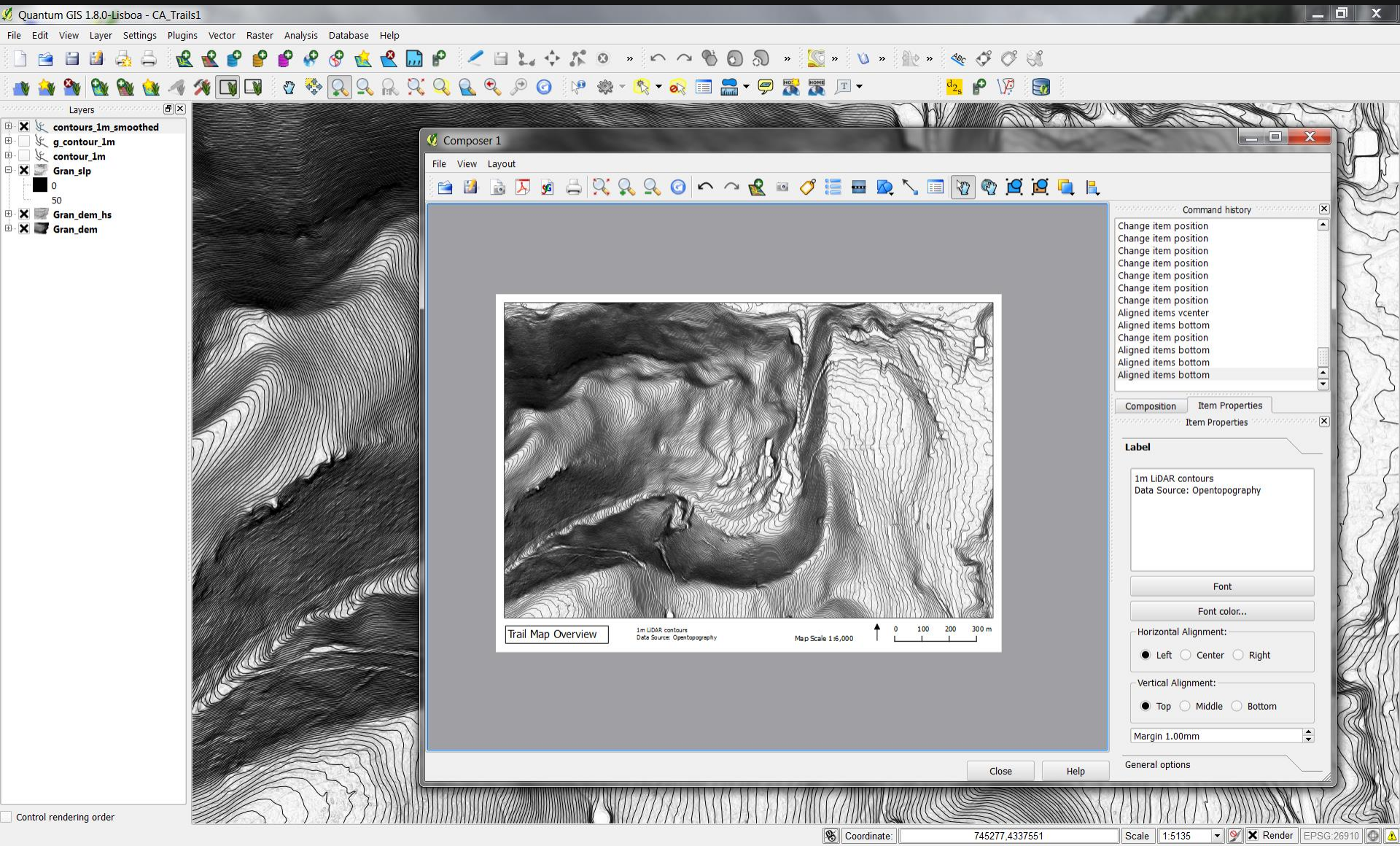
Control rendering order

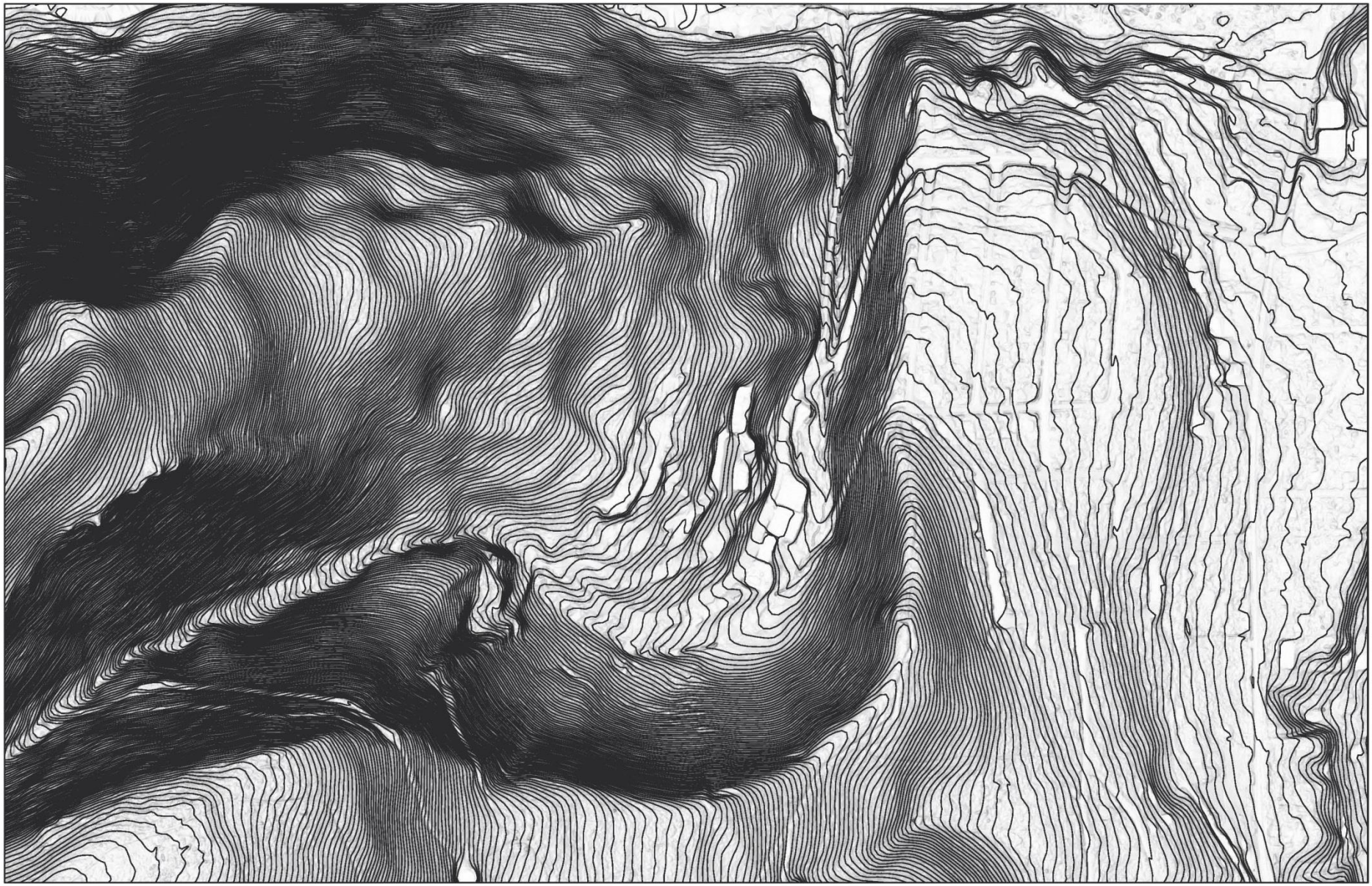
Coordinate: 745736,4337523

Hydrology… Imagery…



Map Composer





Trail Map Overview

1m LiDAR contours
Data Source: Opentopography

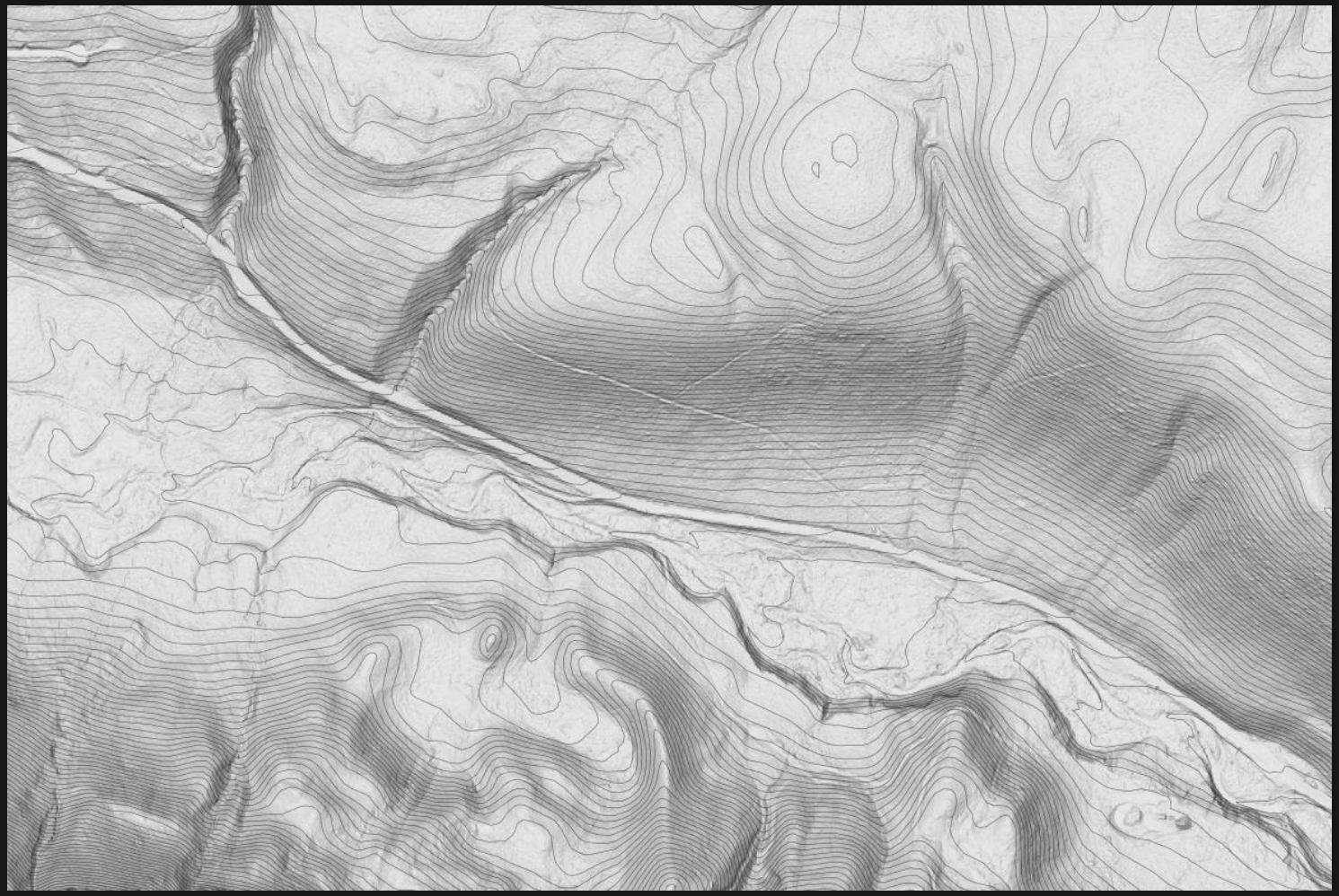
Map Scale 1:6,000

0 100 200 300 m

Why GIS?

- Powerful software (and not always expensive)
- An aid to organization
- Access to high quality data, take advantage

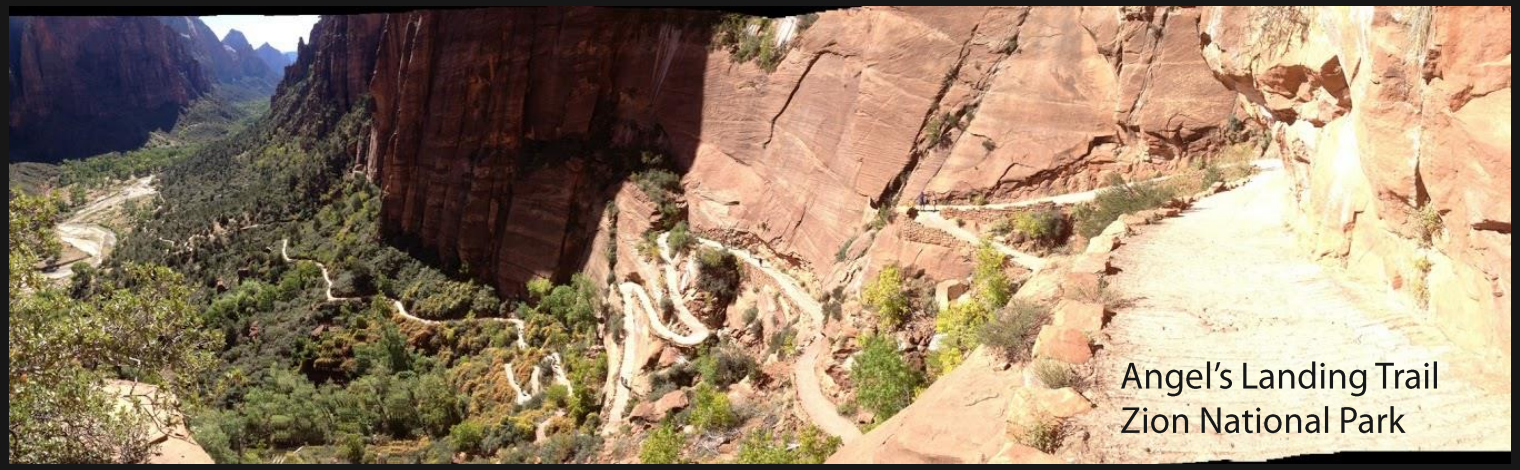
Using LiDAR data for trail layout



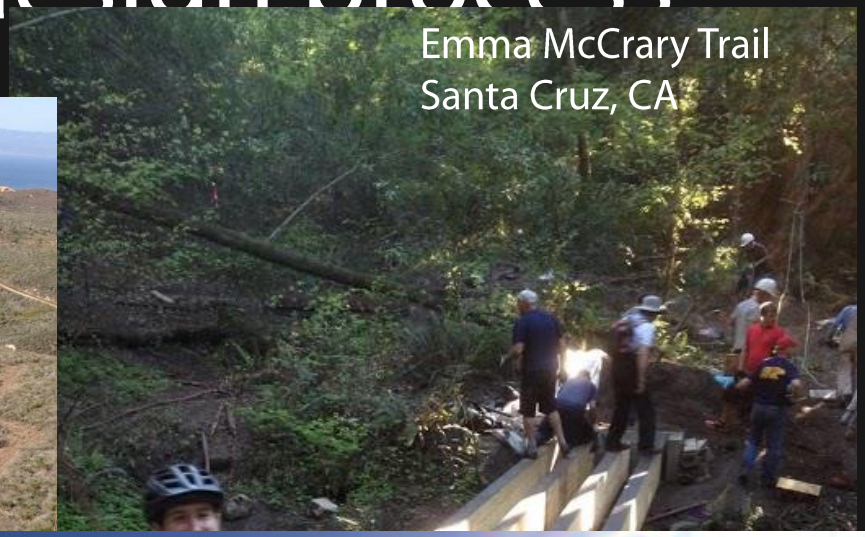
General trail design process

Determine trail purpose and develop specifications.

- Trail type, user types, start point, destination
- Traffic level and season of use
- Soil characteristics
- Grade, width, trail character (primitive, manicured)
- maintenance requirements and resources
- construction method (hand built vs machine built), paid labor or volunteer labor
- **budget**.



General trail design process



biologically sensitive a

General trail design process

Develop and refine potential trail corridors, trying to connect positive control points

and avoid negative control points...

while meeting grade requirements and staying within the construction budget.

General trail design process

There is no perfect alignment and there are almost an infinite number of ways to connect two points with a trail. Good trail design is mastering the art of compromise. Primarily balancing ease and cost of construction, user enjoyment and experience, and future maintenance requirements.

How can LiDAR be used as a **tool**?

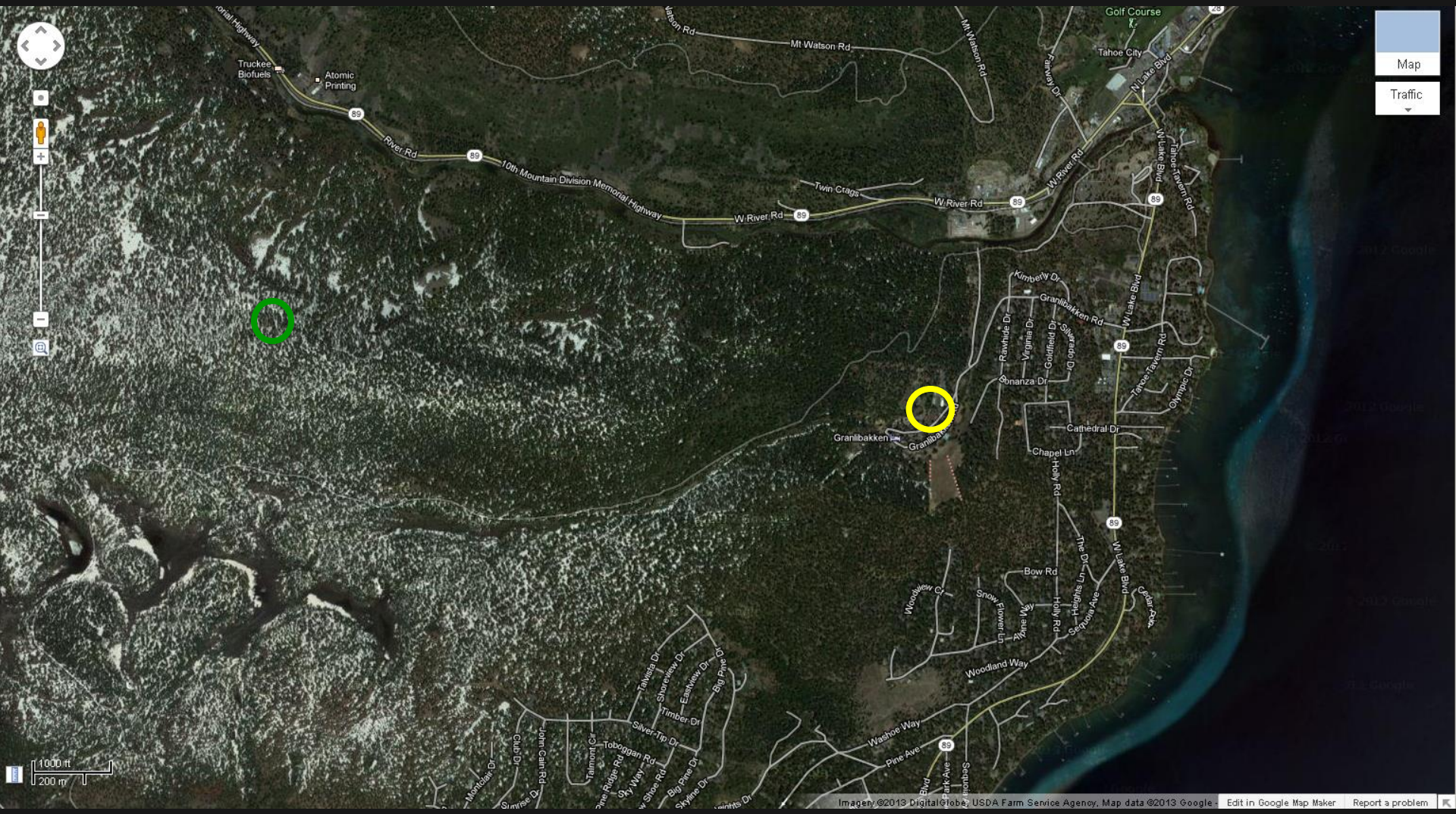
We will design an imaginary trail to demonstrate how LiDAR data can be used in this process

Specs:

- Multi-use, two way
- Maximum corridor grade 6%
- Obey “half rule” (trail grade never steeper than half sideslope)

We will design an imaginary trail to demonstrate how LiDAR can be used in this process

The trail will start right here at Granlibakken


Map
Traffic
Golf Course
Tahoe City
Truckee Biofuels
Atomic Printing
Mt Watson Rd
River Rd
10th Mountain Division Memorial Highway
W River Rd
Twin Crags
N Lake Blvd
W Lake Blvd
Tahoe Tavern Rd
Kimberly Dr
Granlibakken Rd
Rawhide Dr
Virginia Dr
Goldfield Dr
Sonanza Dr
Olympic Dr
Cathedral Dr
Chapel Ln
Holly Rd
Bow Rd
Woodland Way
Washoe Way
Pine Ave
Talweta Dr
Shoreview Dr
Eastview Dr
Big Pine Dr
Timber Dr
Silver Tip Dr
Toboggan Rd
Sky Way
Big Pine Dr
Skyline Dr
John Cain Rd
Club Dr
Sunrise Dr
Montclair Dr
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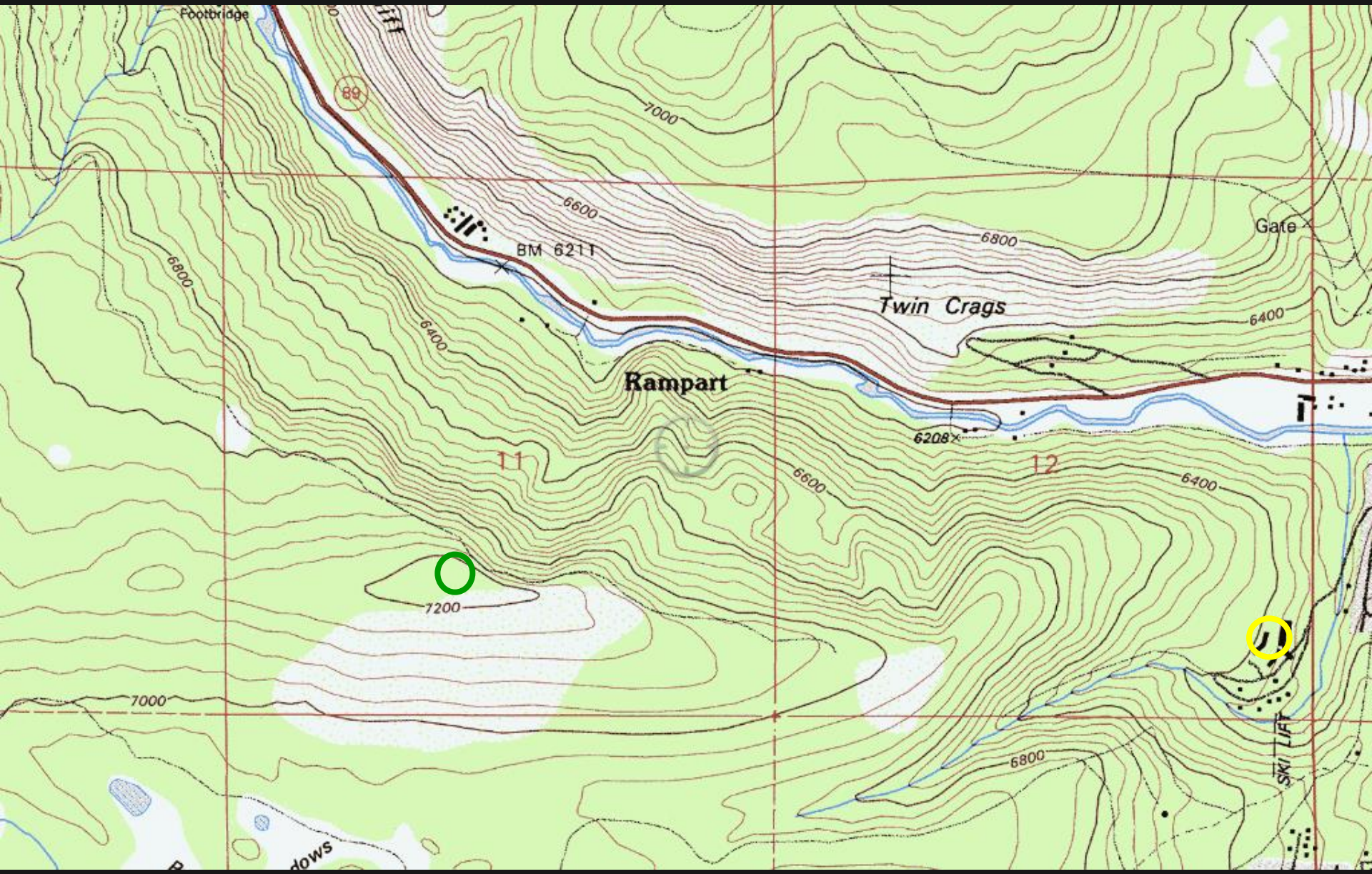
Imagery ©2013 DigitalGlobe, USDA Farm Service Agency, Map data ©2013 Google
Edit in Google Map Maker
Report a problem


Footbridge
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Gate
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Rampart
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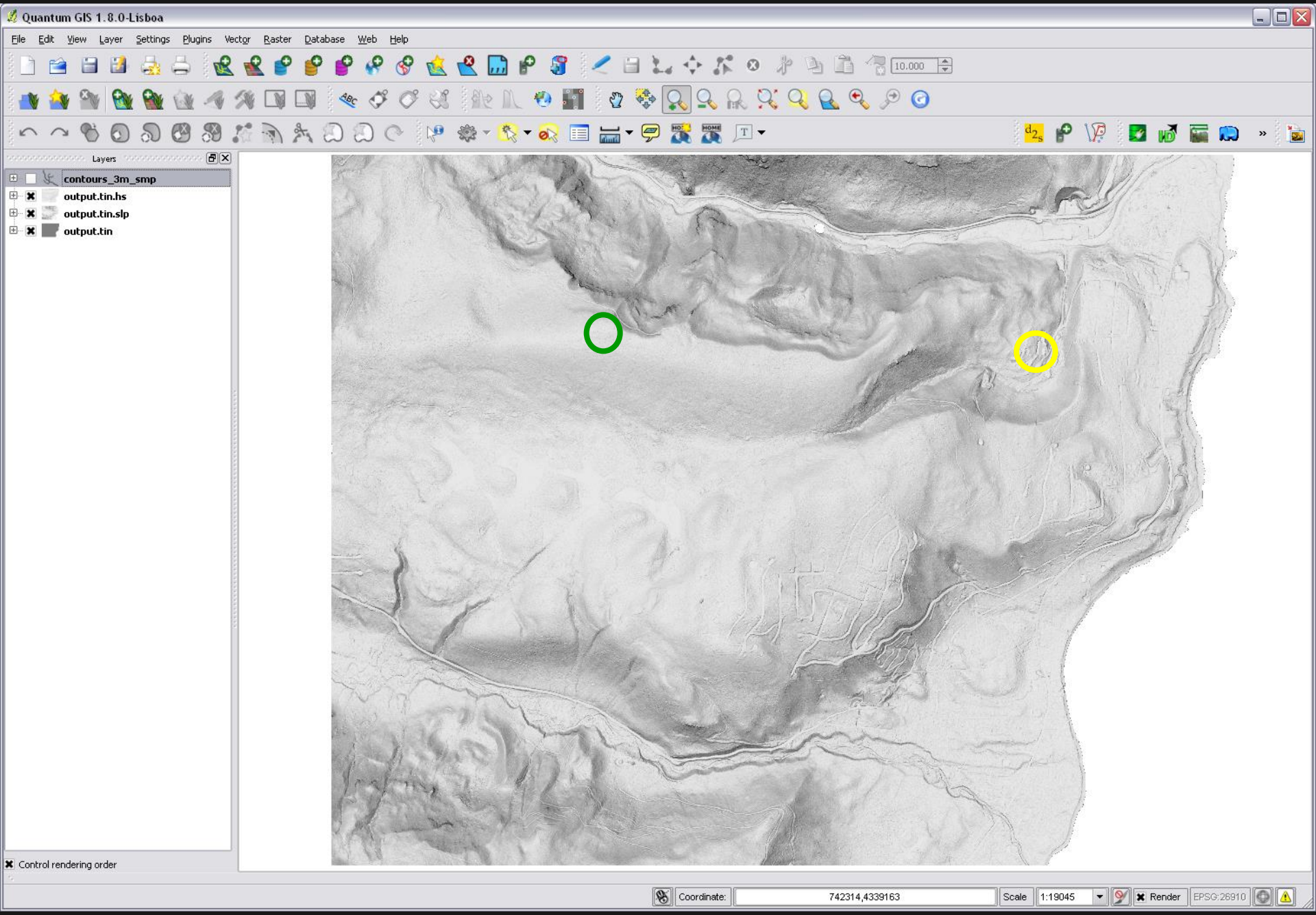
Quantum GIS 1.8.0-Lisboa
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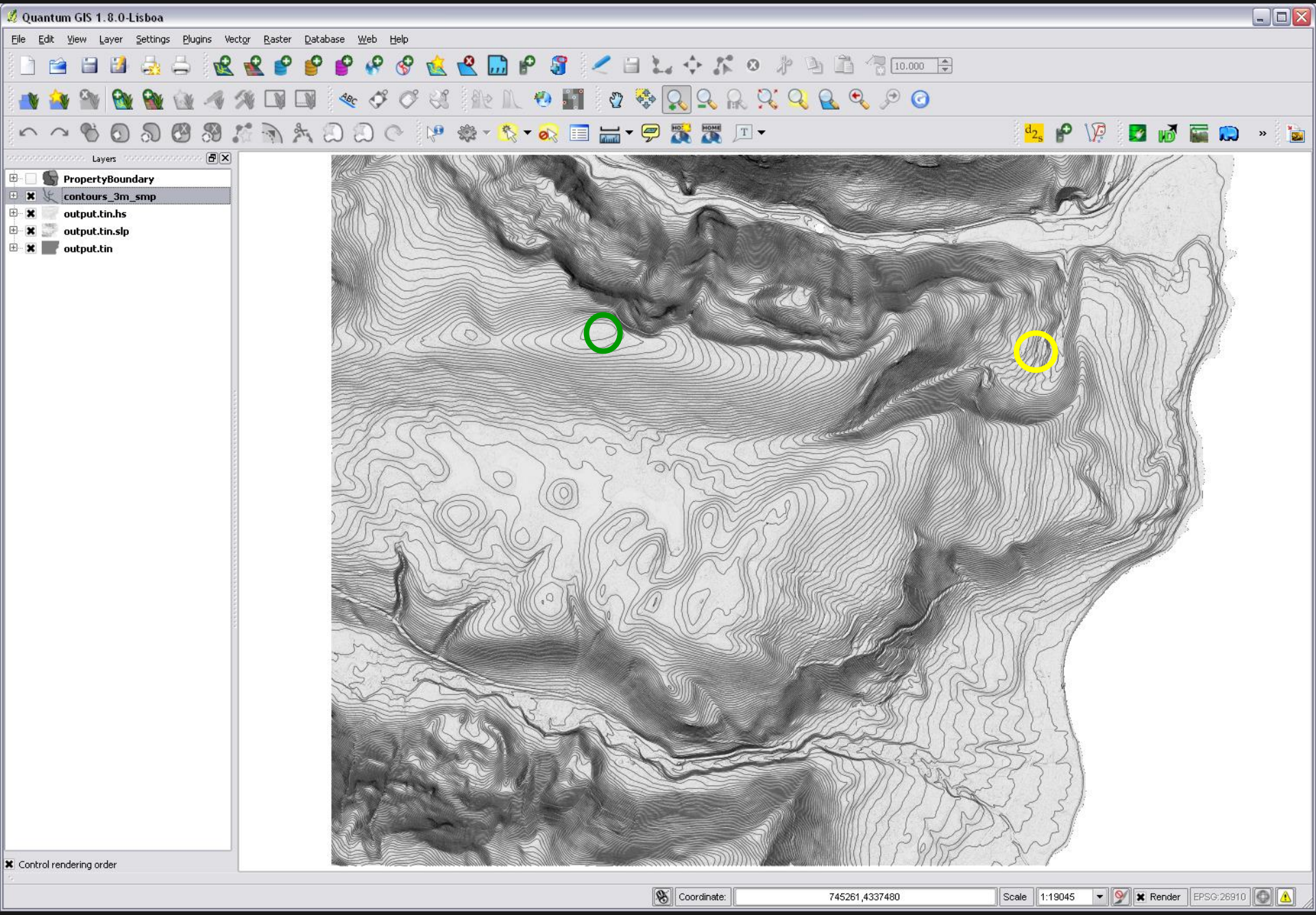
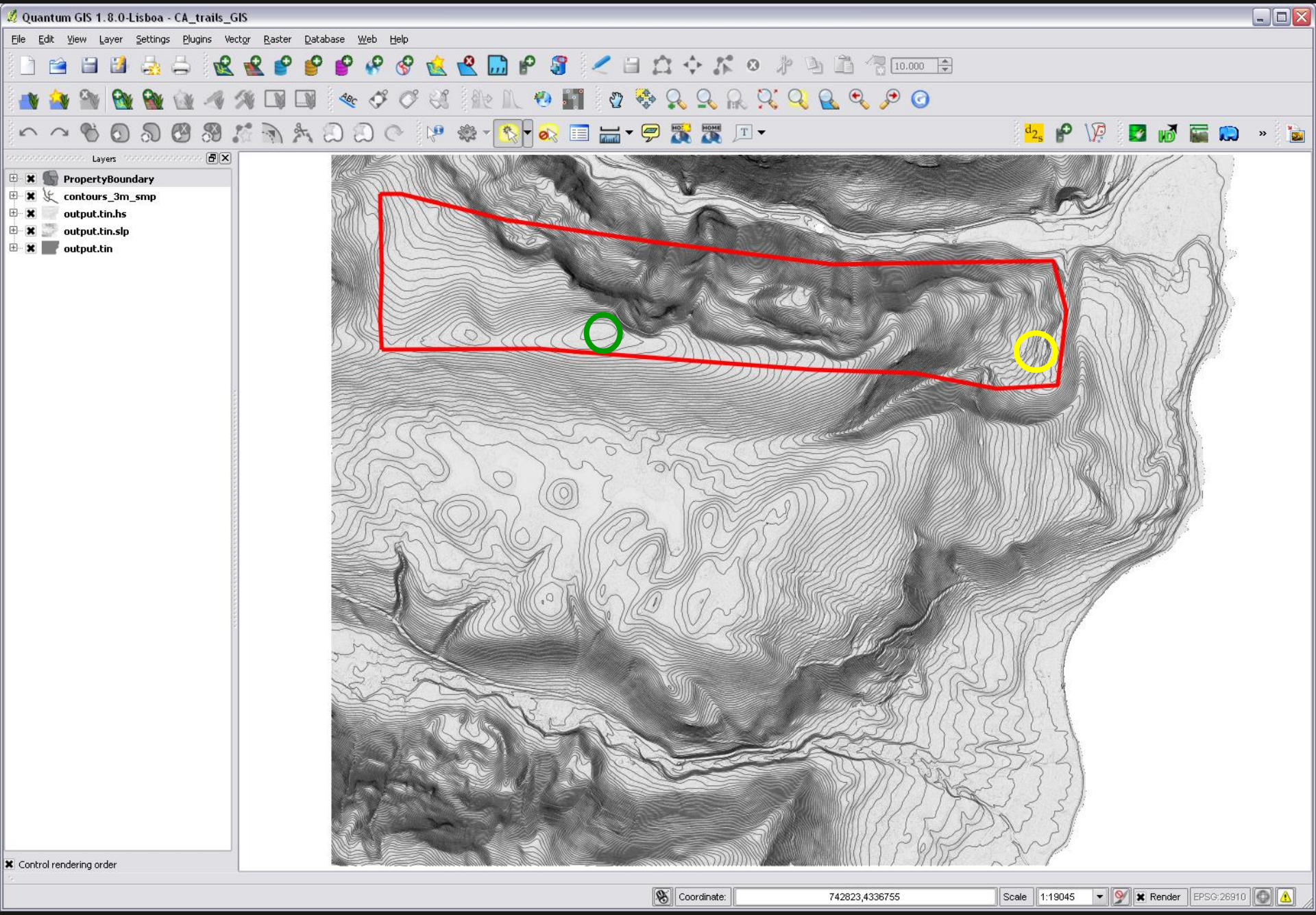


Contour Interval 3m



Contour Interval 3m

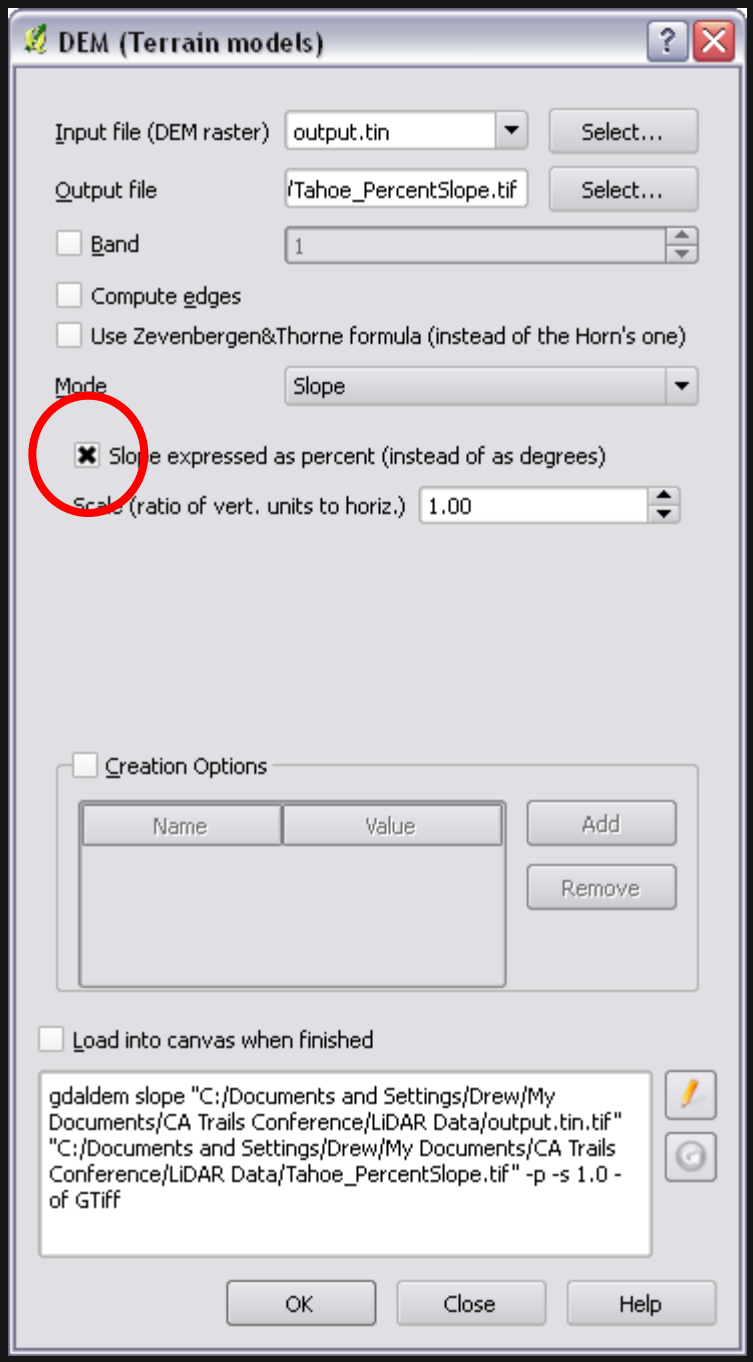
Step 1: Scouting
Main tasks: Learn the terrain and identify control points

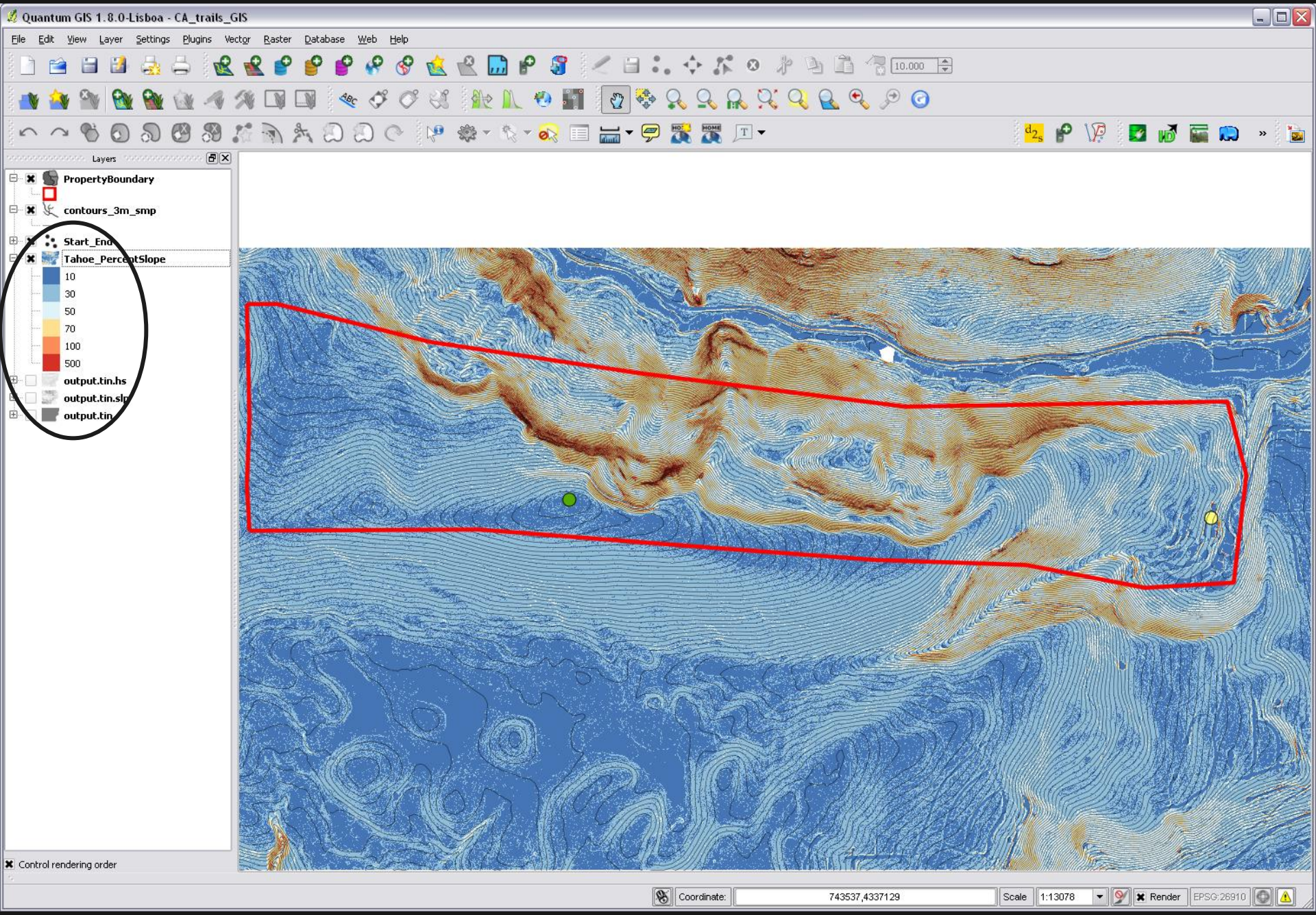
Cliffs, view spots, rock out crops, wet areas, switchback locations.

Still need to hike around to field verify and learn the terrain, but LiDAR can make our field work more efficient.

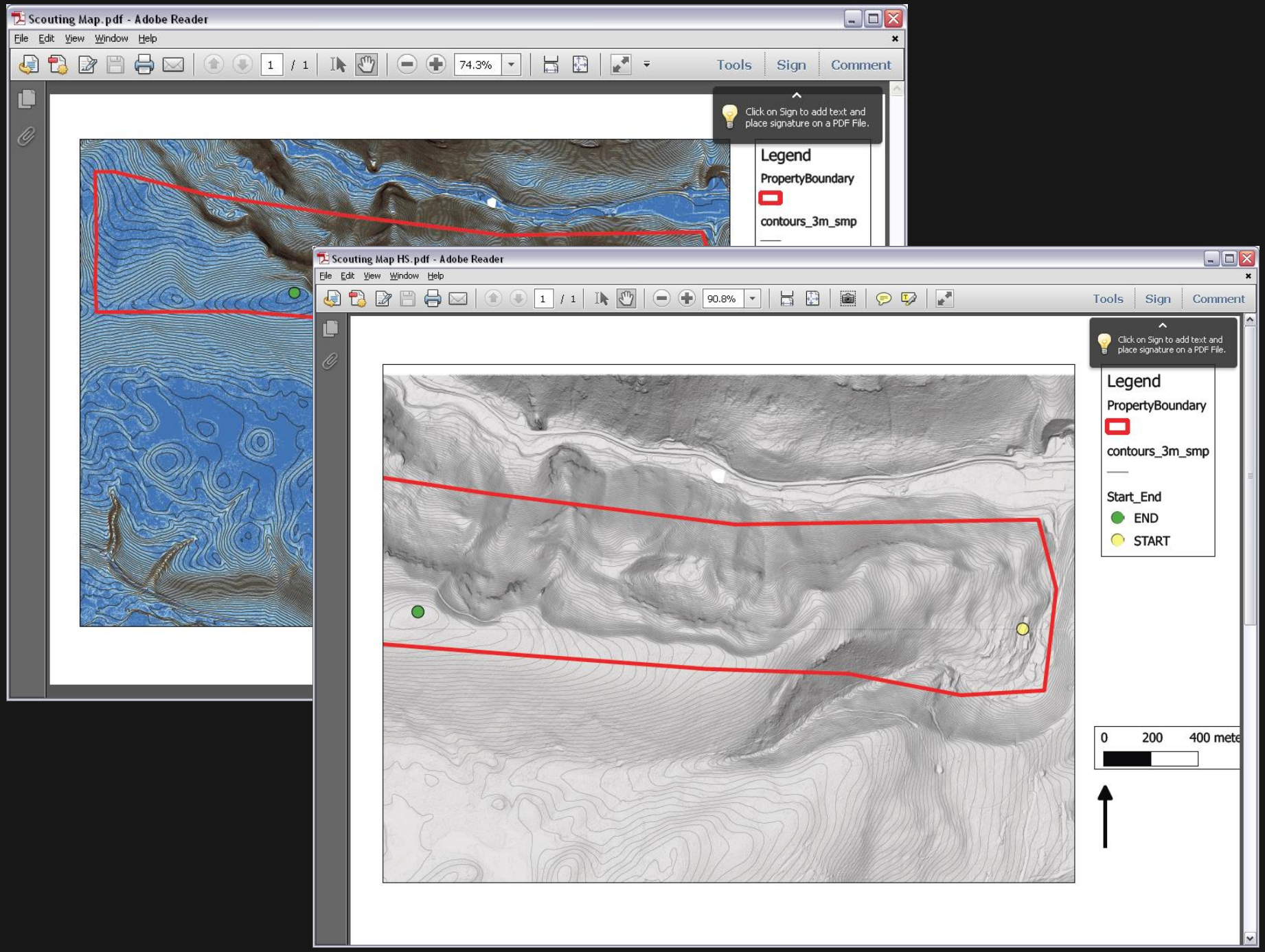
Make slope map

QGIS>Raster>Analysis>
DEM (Terrain Models)





Contour Interval 3m


Scouting Map.pdf - Adobe Reader
File Edit View Window Help
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74.3%
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Comment
Click on Sign to add text and place signature on a PDF File.
Legend
PropertyBoundary
contours_3m_smp
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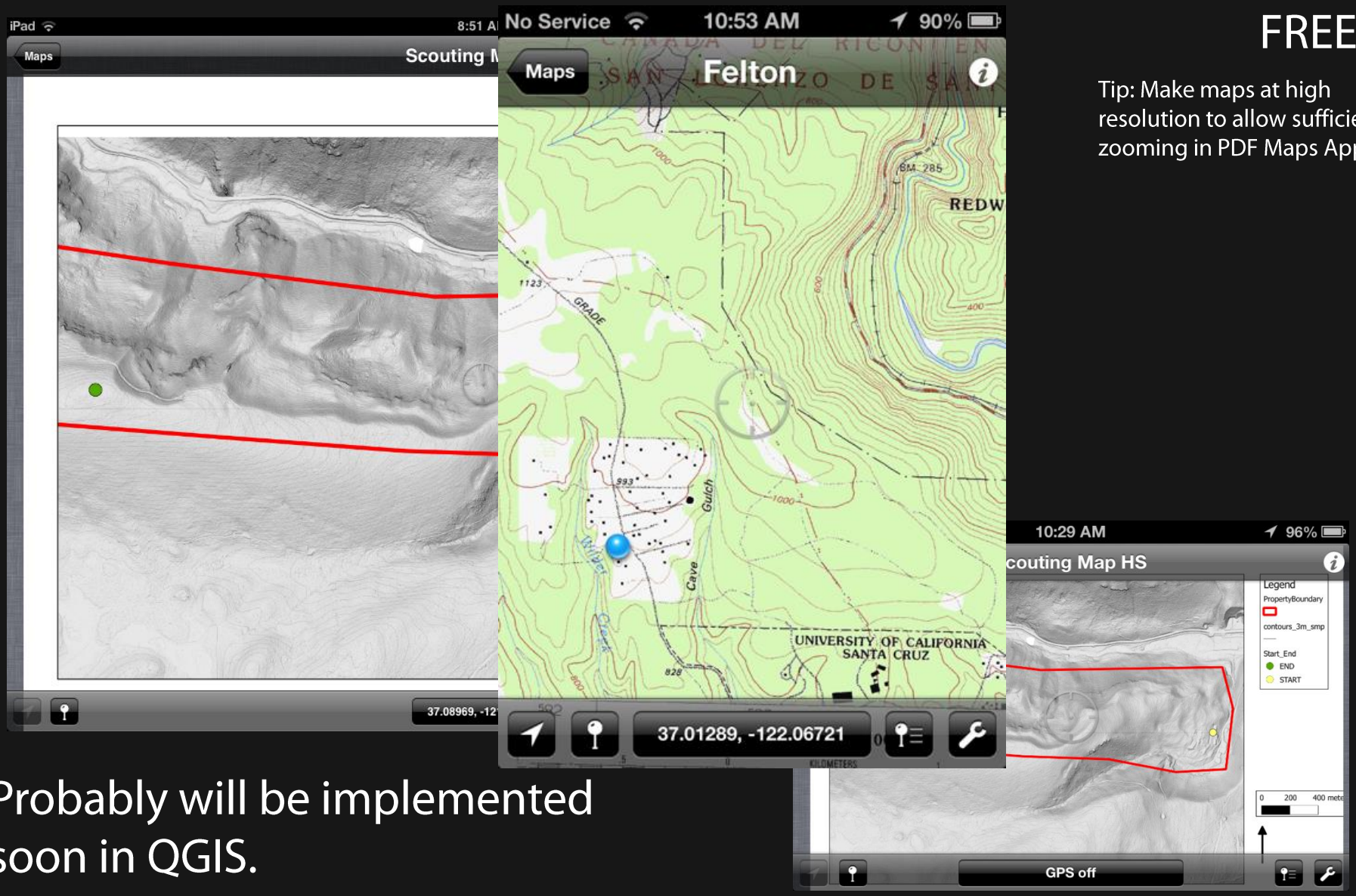
Comment
Click on Sign to add text and place signature on a PDF File.
Legend
PropertyBoundary
contours_3m_smp
Start_End
END
START
0
200
400 mete

Currently cannot create geospatial PDF in QGIS. Can with ArcGIS.

Avenza PDF Maps
Get the app, get the map. ™

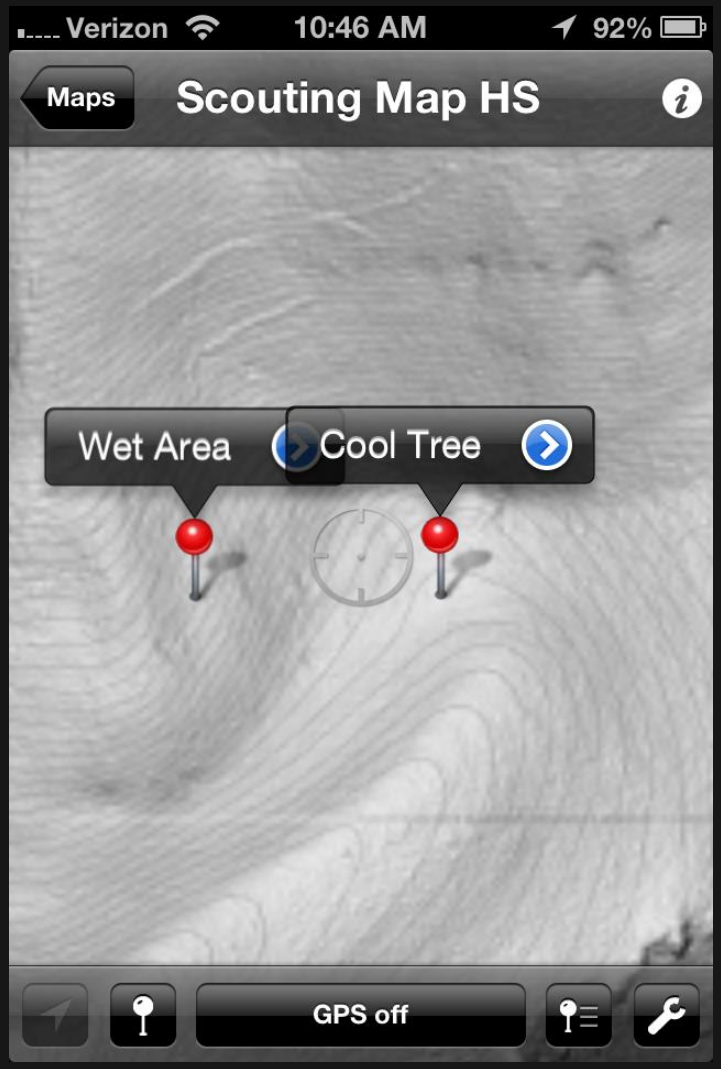
FREE

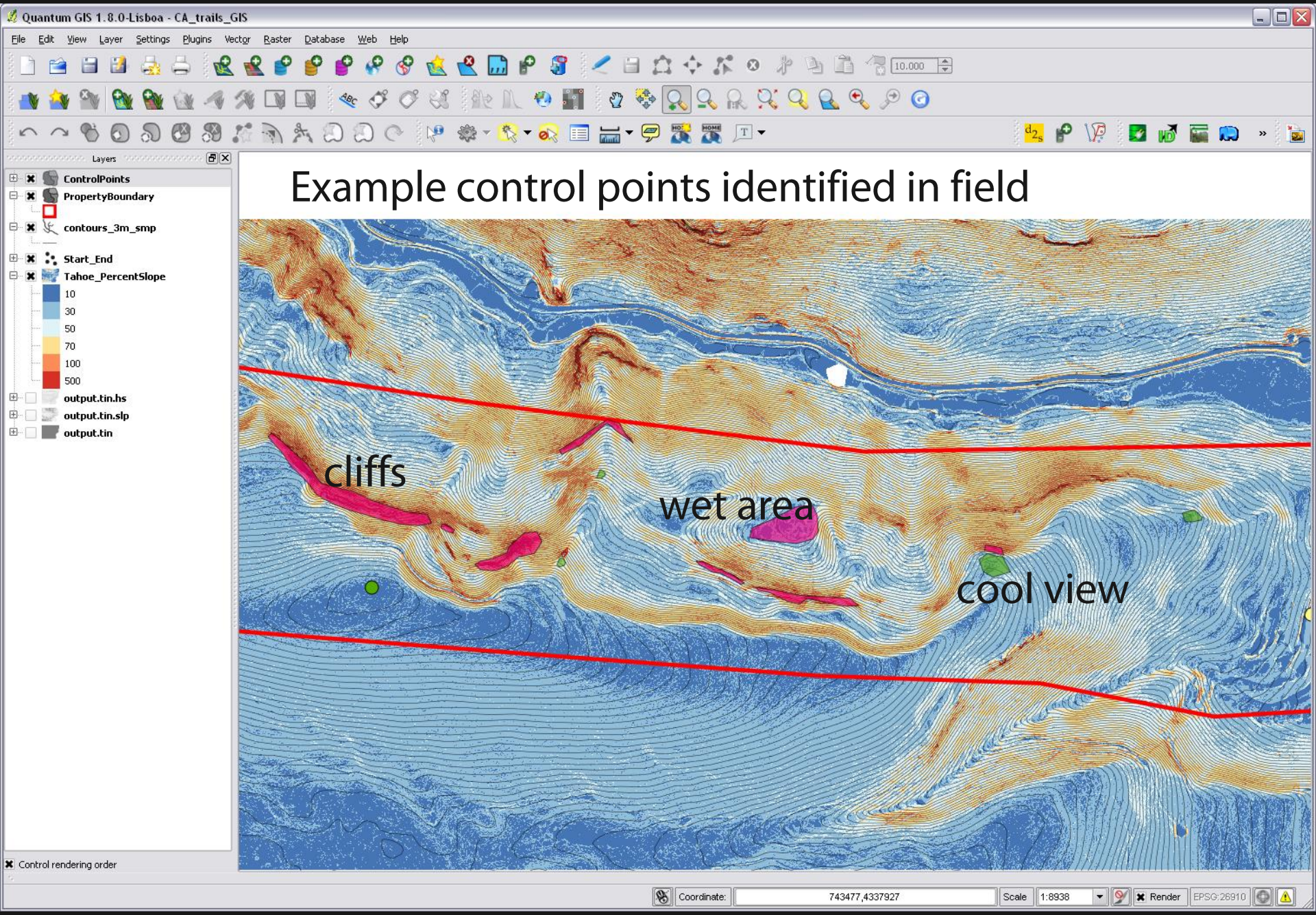
Tip: Make maps at high resolution to allow sufficient zooming in PDF Maps App.



Probably will be implemented soon in QGIS.

Searching...
10:46 AM
92%
Map
Placemark
Placemark 2
Change
Description
Not Set
Photos
Not Set
Location
Not Available
Attributes
What is this?
ON
User Placemarks
Parent Folder
Description
Cool tree
Type
Positive control point
Configure 'User Placemarks'


Verizon
10:46 AM
92%
Maps
Scouting Map HS
Wet Area
Cool Tree
GPS off

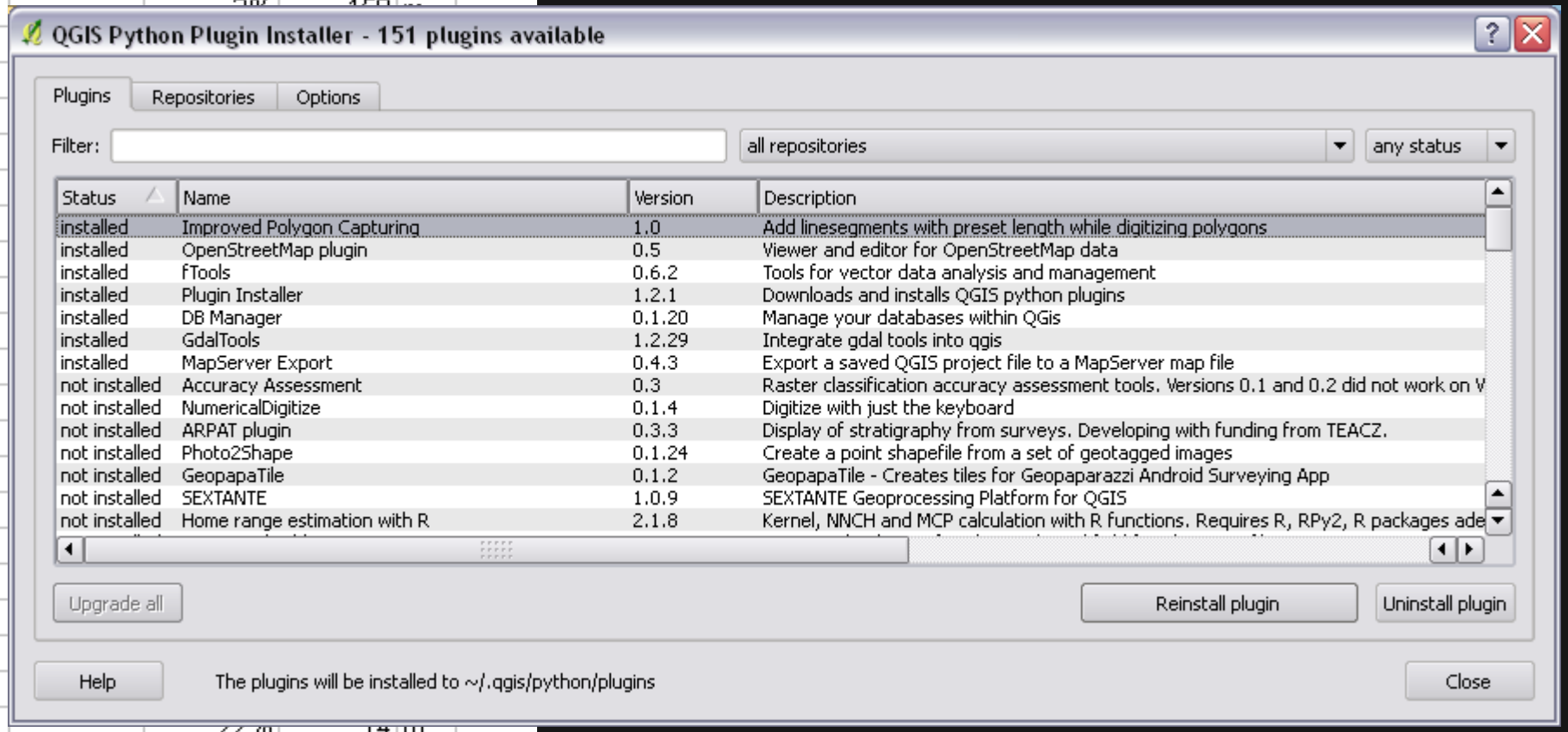


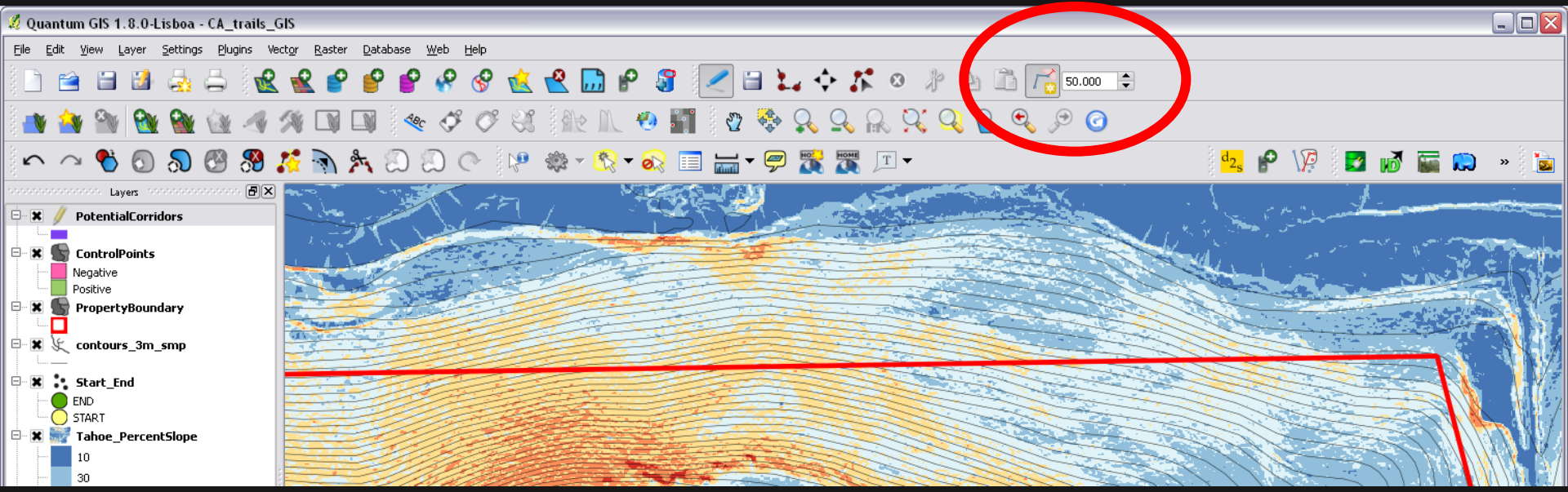
Contour Interval 3m

Step 2: Identify potential corridors (30m wide)

Target maximum average grade = 6%

Contour interval =	3	m
1%	300	m
23%	13	m
24%	13	m
25%	12	m




Quantum GIS 1.8.0-Lisboa - CA_trails_GIS
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View
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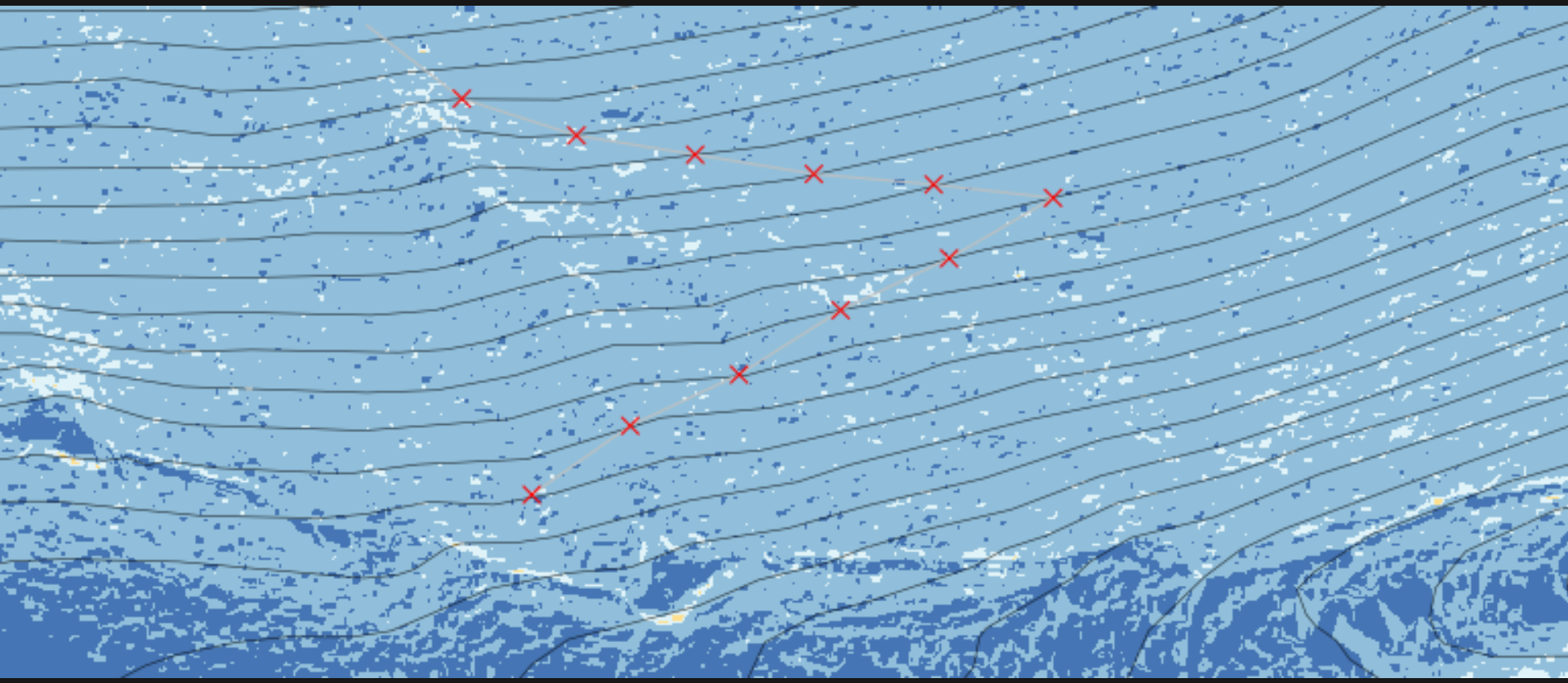
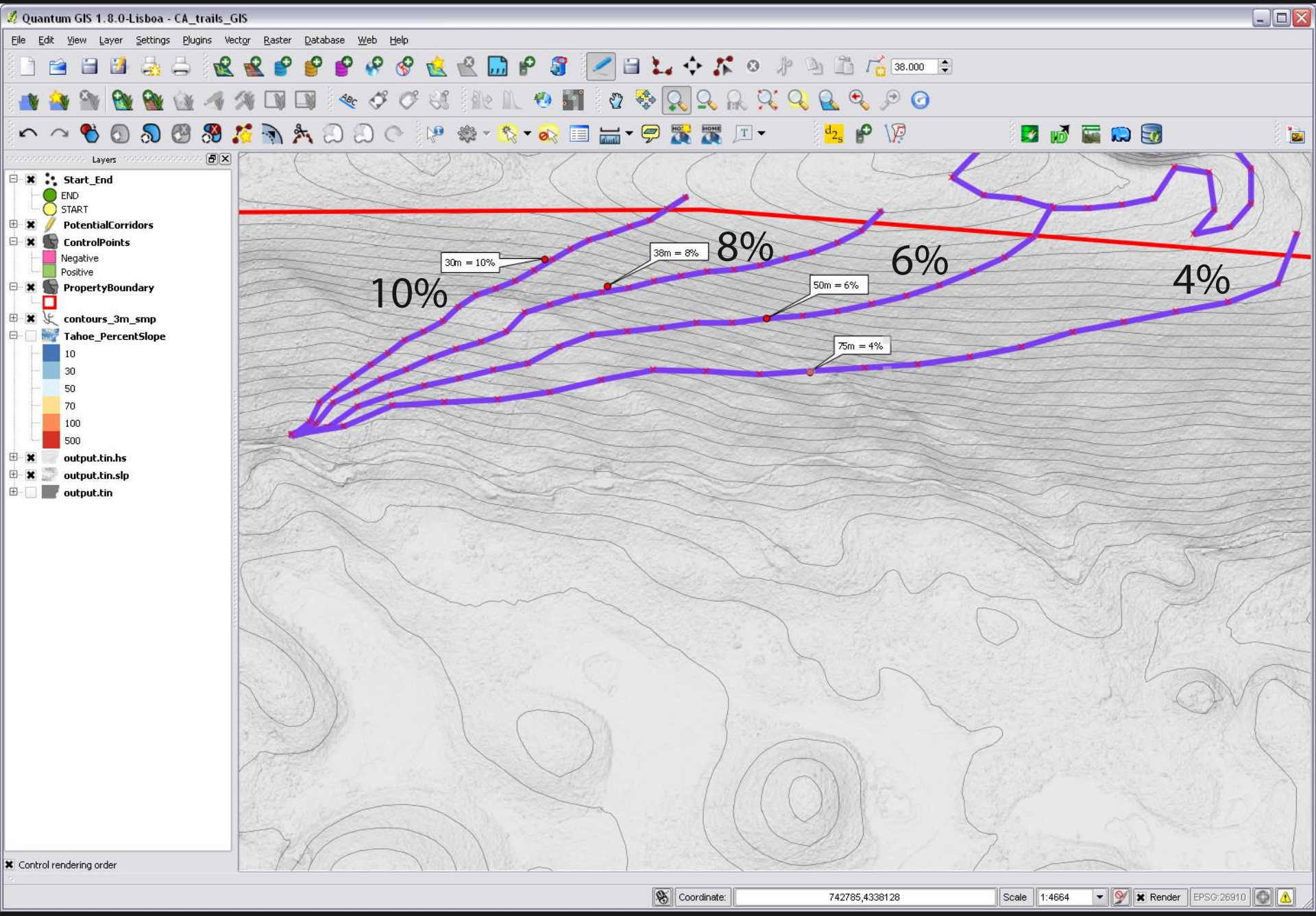
Settings
Plugins
Vector
Raster
Database
Web
Help
50.000
Layers
PotentialCorridors
ControlPoints
Negative
Positive
PropertyBoundary
contours_3m_smp
Start_End
END
START
Tahoe_PercentSlope
10
30




Quantum GIS 1.8.0-Lisboa - CA_trails_GIS
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ControlPoints
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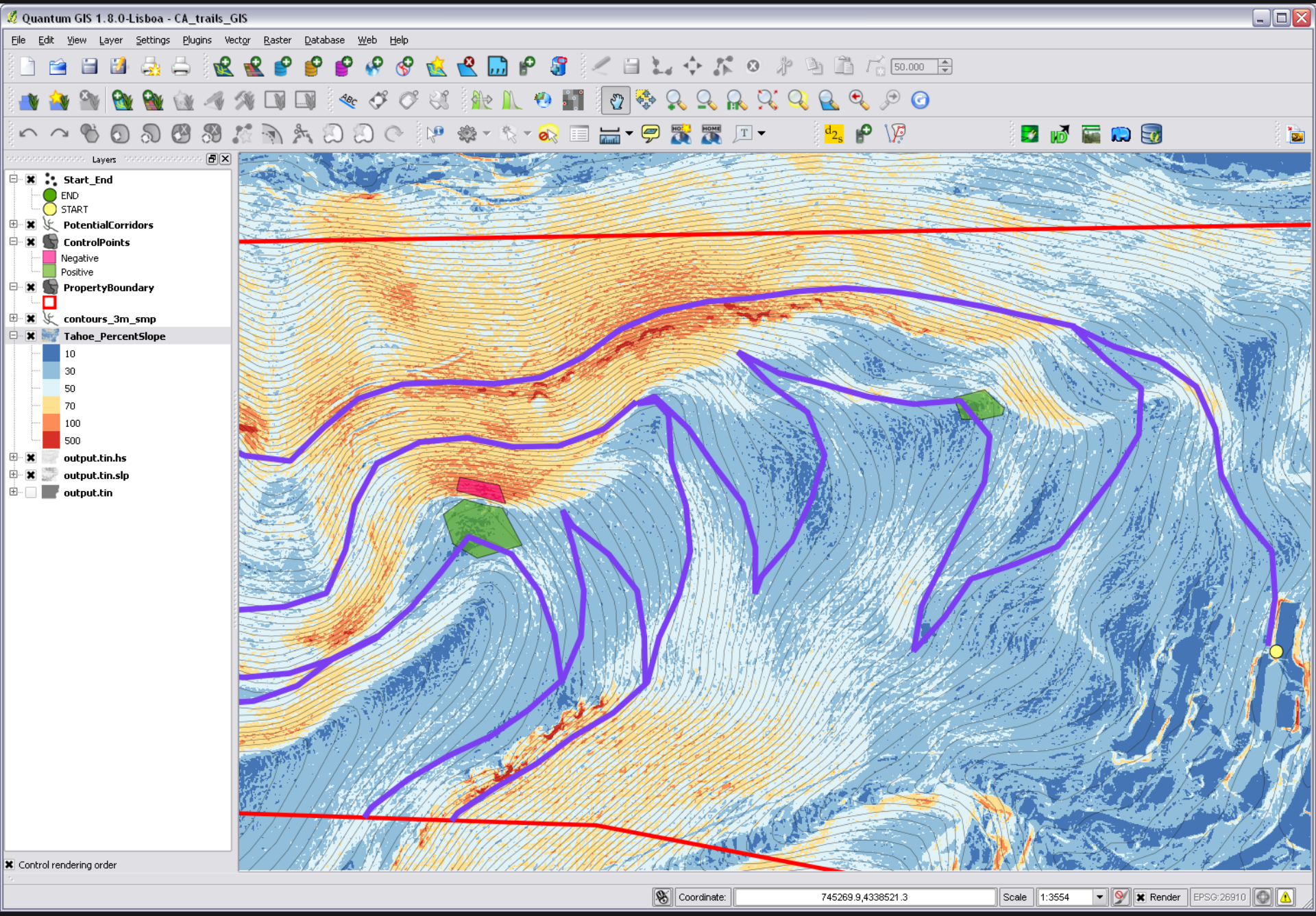
Positive
PropertyBoundary
contours_3m_smp
Tahoe_PercentSlope
10
30
50
70
100
500
output.tin.hs
output.tin.slp
output.tin
Control rendering order
30m = 10%
38m = 8%
50m = 6%
75m = 4%
10%
8%
6%
4%
Coordinate:
742785,4338128
Scale
1:4664
Render
EPSG:26910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ControlPoints
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contours_3m_smp
Tahoe_PercentSlope
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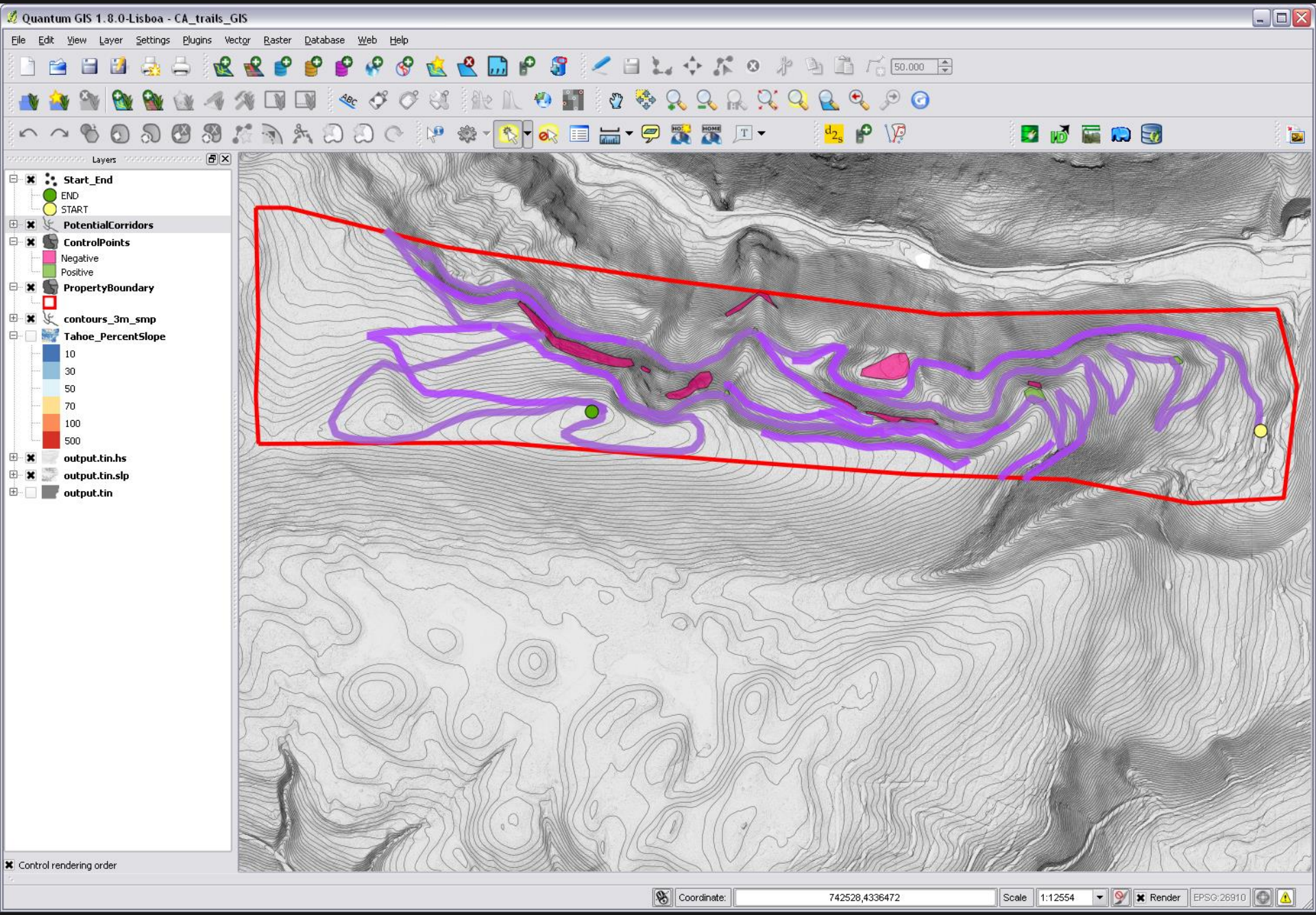
50
70
100
500
output.tin.hs
output.tin.slp
output.tin
Control rendering order
Coordinate:
745269.9,4338521.3
Scale
1:3554
Render
EPSG:26910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output.tin.hs
output.tin.slp
output.tin
Control rendering order
Coordinate:
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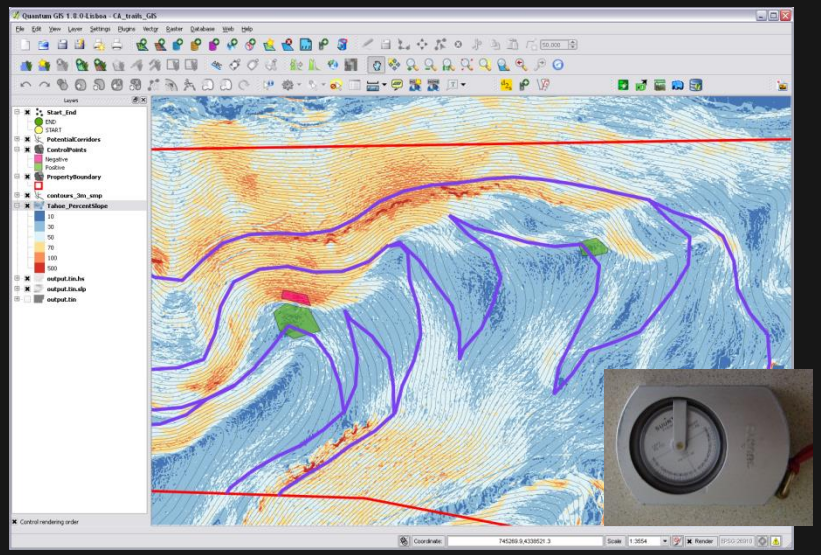
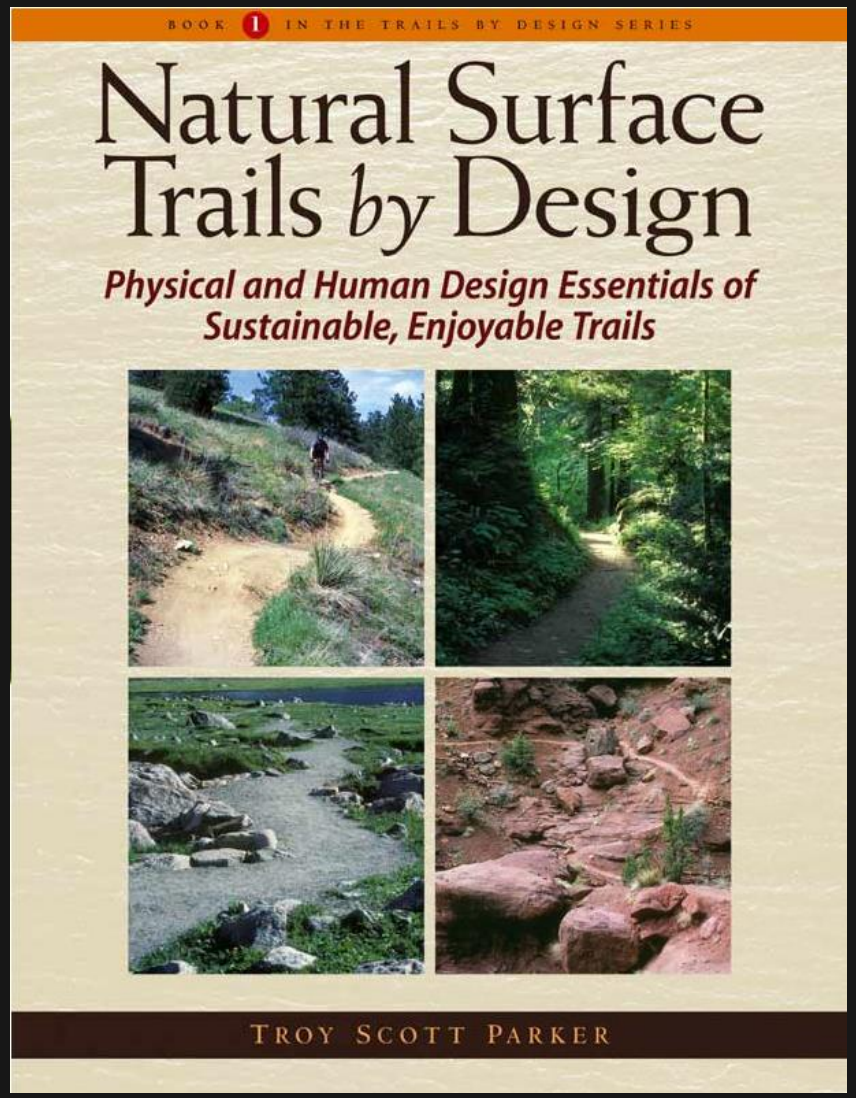
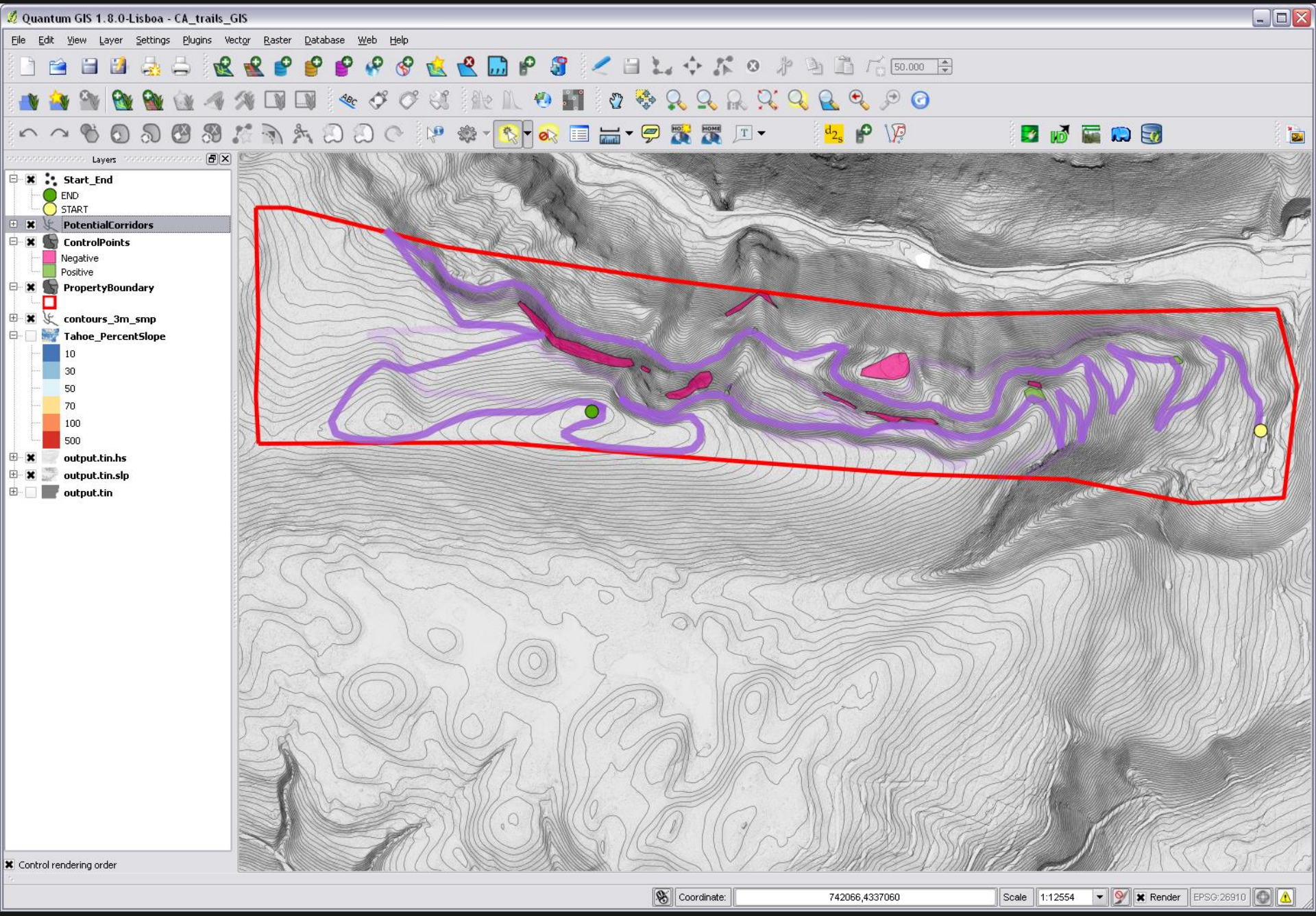
Scale
1:12554
Render
EPSG:26910

Next steps...




BOOK 1 IN THE TRAILS BY DESIGN SERIES
Natural Surface Trails by Design
Physical and Human Design Essentials of Sustainable, Enjoyable Trails
TROY SCOTT PARKER


Quantum GIS 1.8.0-Lisboa - CA_trails_GIS
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ControlPoints
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contours_3m_smp
Tahoe_PercentSlope
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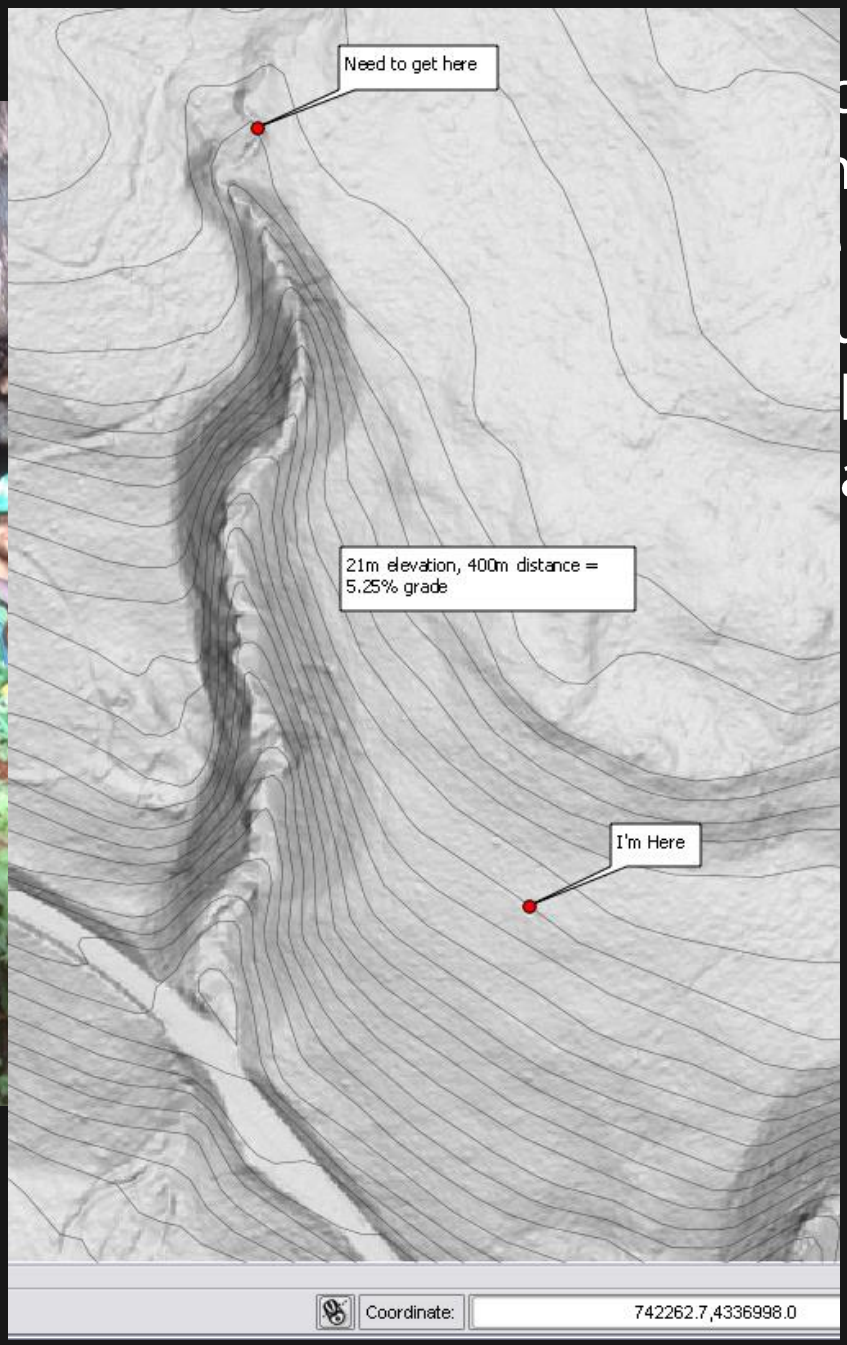
output.tin.hs
output.tin.slp
output.tin
Control rendering order
Coordinate:
742066,4337060
Scale
1:12554
Render
EPSG:26910

Step 3: Corridor flagging
Main task: Identify review corridor

Once you have identified the ideal corridor, now it is time to get out your flagging.

Now working towards corridor 10m wide

(My favorite is Texas Brand GloPink)



ck, steep, forested
nost of Santa Cruz).
your clinometer,
u are not using high
like an iPhone) or
a isn't super

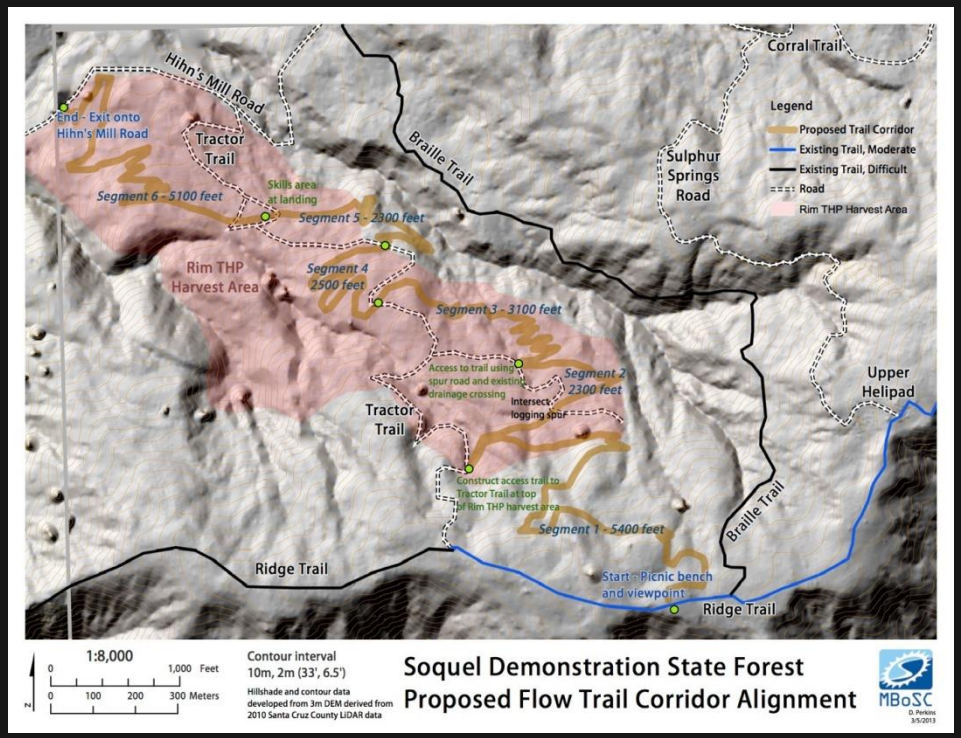
Flagging in heavy brush

Leave the clinometer
at home if..

Montaña de Oro State Park, San Luis Obispo County

Step 4: Reviews and approvals

A good map and terrain data usually can help this process as well!



Step 5: Fine flagging (1m wide)

Conclusion

Very useful LiDAR data and analysis tools are available for free in many locations in the state, and coverage is expanding quickly.

LiDAR data provides a rich topographic dataset that allows a trail designer to work more efficiently and make better decisions.

Greg and I wishing we had LiDAR data at Montaña de Oro State Park
(which actually became available to the public last month)