APPENDIX A. RESEARCH METHODOLOGY VOLUME I: FIELD ACQUISITION AND DATA COLLECTION PROCEDURES

1.1 SCOPE

This document contains detailed, specific, standard operating procedures and business rules for systematic data acquisition, storage, processing, and analysis to support the model development. Volume I (this appendix) covers the survey work to be completed as well as data gathering activities. Volume II (Appendix B) is specific to protocols for the instrumentation installed on site. The methods used for the analysis and modelling are described in the main body of the report.

1.2 HARDWARE AND SOFTWARE

Table 1 provides a list of hardware and software utilized in this study to complete the necessary survey work. Detailed specifications for each instrument are provided in the digital appendices along with user manuals for further information.

Table A-1: Hardware and software utilized for the field data collection.

Field Acquisition	
Hardware	**Purpose**
Riegl VZ400 Laser Scanner	Collects high-resolution 3D point cloud data for generating models of the bluffs.
Nikon D700 Digital Camera	Collects imagery used to color data from the VZ400 scanner
GoalZero Yeti 150 and 400 Portable Power Stations	Provides power to the VZ400 scanner and other survey devices
Leica P40 Laser Scanner	Collects high-resolution 3D data and associated digital images
Leica GS14 GNSS	Collects high-accuracy global positioning data
Trimble R8 GNSS	Collects high-accuracy global positioning data. Backup if the Leica GS14 is not available.
Kestrel 4500 Pocket Weather Tracker	Provides environmental conditions (temperature, pressure, relative humidity) for calibration of scanners and total station
Garmin eTrex 30x	Allows quick navigation for relocation to locations of past scans
Laptop	Provides temporary backup for data and allows for data quality assessment in the field.
Processing Software	
Software	**Purpose**
Riegl RiSCAN Pro	Visualizes and processes data from VZ400 scanner
Leica Cyclone	Visualizes and processes data from P50, BLK360 and RTC360 laser scanner
Maptek I-Site Studio	Utilized for analysis of point cloud data, change detection, etc.
HingeTri x64\Rambo	Develops surface models, computes surface morphology parameters, rockfall clustering analysis, volumetric analysis to derive magnitude frequency relationships.

Point Reg V3.1	Geo-referencing software for point cloud data developed by Olsen. Also contains several executables for extracting and converting data as well.
3DD to PTX	Converts 3DD files from Riscan into PTX files that can be imported into Cyclone while preserving grid structure. *Ideally, this should be updated to support E57 in the future to speed file transfer*.
Cloud Compare	Change detection and analysis, scripting for file format conversions

1.3 TRAINING REQUIREMENTS

The Project PIs Michael Olsen and Ben Leschinsky provided oversight and guidance of the research team throughout the project to verify that the procedures were satisfactorily followed the deliverables are being produced in a timely fashion and reported to ODOT. Party chiefs were designated and were responsible for planning field work activities as well as coordinating the data acquisition and processing to ensure the requirements are met during the acquisition. Matt O'Banion and Michael Bunn served in this capacity at the start of the project. In Fall 2017, Michael Bunn and Andrew Segnoles became the designated Party Chiefs and leads on the data processing activities. When Michael Bunn graduated in 2019, Andrew Senogles continued the role. In 2022, Bryce Berrett was designated to assist Andrew Senogles as Party Chief until the last survey in Spring 2023. Additional graduate students assisted with field work regularly. Some were also asked to help with processing to avoid data backlogs, as needed.

Successful field acquisition and data collection for SPR 807 requires detailed planning. Numerous pieces of highly specialized equipment, interactions with several land management agencies, and multiple day field efforts mean that those involved with the planning process must have a comfortable understanding of project goals and any previous activities performed toward achieving those goals. Additionally, the planners must be aware of any specific requirements that may prevent the execution of field acquisition and data collection.

In order to understand the goals of SPR 807, Party Chiefs must consult the project workplan (included in the digital appendices). Important details include the timing of field work and project deadlines, as well as the project scope. The planners must also actively attend the regular team meetings, ODOT TAC meetings, and meetings with the research coordinator/project champion so that they are aware of any changes or additions to the workplan.

Due to the duration of the project, numerous individuals will participate in field work for SPR 807. Many of these individuals may not know their predecessors, and verbal communication is not a guaranteed method for project planners to learn of previous activities. An important aspect of this methodology is that it details a consistent, systematic framework for documenting work as it is performed. Planners should be well aware of all documentation so that they can incorporate past knowledge into future surveys.

Finally, there are specific requirements that someone should fulfil before they are able to act as Party Chiefs (Table 2). Ideally all members of the field crew would meet these requirements; however, some are mandatory for the Party Chiefs.

Table 2: Requirements to serve as a Party Chief for the SPR 807 field data acquisition.

Requirement	Minimum Action
Oregon State University Driver Authorization (Party Chiefs)	Submit driver authorization form to the Oregon State University Motor Pool
Survey Training (Party Chief) (Experience with Laser Scanning, GNSS, and Total Station).	Pass CE361 Surveying Theory and CE 566 Laser Scanning and Imaging course at Oregon State University or equivalent experience
Safety Training (All)	Attended the annual geomatics graduate student safety training. Review safety materials prior to starting work. Attend daily safety briefings on-site prior to starting work.

1.4 PLANNING

Field surveys and equipment maintenance for SPR 807 involve the use of a large collection of equipment and are subject to the extreme weather of the Oregon Coast. For these reasons, detailed planning is fundamental to achieving the best outcomes. This section will present recommendations on when field work should be performed along with the details involved in planning a field work trip.

The target time frames to complete regular surveys are:

- **Fall Survey**: September or early October
- **Spring Survey**: May or early June

The Oregon Coast experiences heavy winter rainfall, dry summers, and relatively mild temperatures year-round (Figure 1). Field work may be hindered, or altogether prevented, by heavy rainfall and/or strong winds, and field work should be planned around these constraints during winter months. To satisfy the biannual frequency of field surveys stated in the work plan, it is recommended that work be performed in the spring and fall of each year. While the weather is not as consistently good as during the summer months, the expectation is that both the spring and fall trips will have opportunities to be scheduled during windows of sufficiently good weather. Furthermore, this recommended timing of field trips allows for data acquisition to better constrain the effect of winter months, when coastal erosion is assumed to be most active.

Occasionally an additional set of surveys is warranted (e.g., before/after major storm, major landslide movement, or we want to monitor a site closer). The same policies and procedures should be followed in providing appropriate notification in these surveys as well.

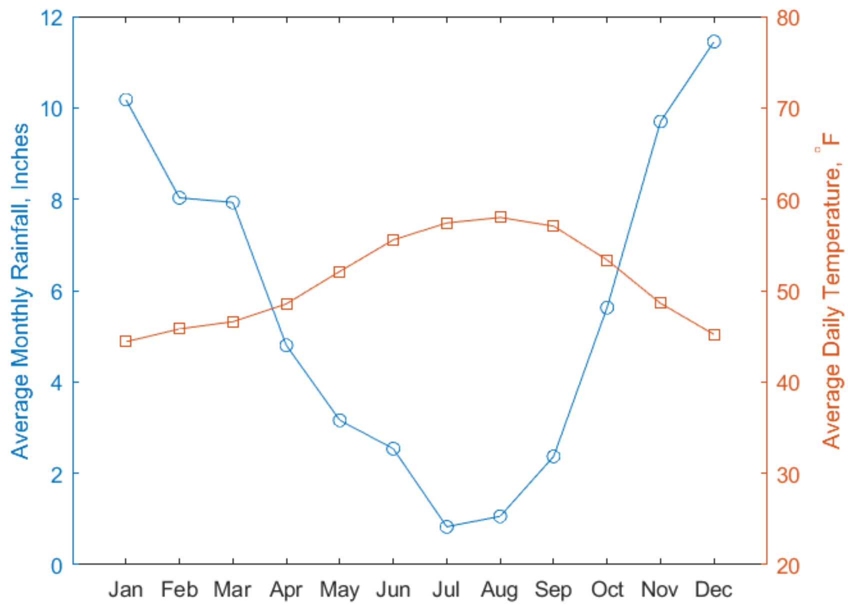

Figure 1. Monthly average rainfall and daily temperature for Newport, Oregon (Western Regional Climate Center).

The planning process for field work should begin approximately one month prior to the desired work time. Preferably, spring field work should occur in April and May, and fall field work should occur in September and October. The purpose of early planning is to ensure that enough personnel are available, that equipment does not require major repair, and that the ODOT right-of-way and State Parks research permits are up to date. A checklist of specific objectives for the one-month planning process may be found in Appendix A, and the expected overview of each field trip may be found in Table 3.

Table 3. Minimum time necessary and survey type for each SPR 807 field trip.

Field trip	Sites visited	Travel time to sites from OSU	Calendar time (includes travel)	Type of survey
North Coast	Silver Point, Arch Cape	2.5 hours	3 Days	TS, TLS
Beverly Beach	Spencer Creek	1 hour	1 – 2 Days	TLS
South Coast	Arizona Inn, Hooskanaden	4 hours	5 Days	TS, TLS, UAV

Note: TS = Total Station, TLS = Terrestrial Laser Scanner, UAV = Unmanned Aircraft Vehicle

In times of questionable weather, it is recommended to build in potential rainy weather days into the schedule. It is also recommended to have alternate dates scheduled in case something unexpected occurs.

A minimum of two people are needed to complete the survey work. However, sometimes it is advantageous to have a second pair come out to perform the total station and GNSS work to reduce the number of days required for the survey.

The site survey plans developed on the onset of the project contain the details on where the scanner, total station and GNSS should be set up. As a rule of thumb, Priority 1 locations should be done at each survey. Priority 2 locations should be completed annually. Priority 3 sites should be done every two years. The completion of each of these should be tracked in a spreadsheet. During the planning, the team should determine if any additional scans are needed beyond the survey plan for each site.

Total station surveys should be completed both in the fall and spring. Note that these surveys were not completed in Fall 2016 since the markers had not yet been installed.

Static GNSS (2m fixed height pole) should be acquired on the control points at the site for each survey, with the exception of Beverly Beach where the ORGN is sufficient. At Arch Cape, a static GNSS base is critical for the scans on the upper section of the road.

Detailed planning for each specific field trip begins one week prior to the first scheduled work day. The purpose of one-week planning is to make all necessary reservations for the field trip and to notify the permitting agencies. Reservations should be made for lodging (See Table A__ for recommendations), a motor pool vehicle, and, if applicable, GPS receivers and total stations. One-week planning is also a good opportunity to create a shopping list of items that can be purchased prior to leaving Corvallis.

Rain and wind are still a possibility during the spring and fall, and the National Weather Service (weather.gov) forecast should be consulted to make a final decision of whether or not a trip should be made. Generally, the reservations associated with one-week planning should be made regardless of the conditions predicted by 7-day forecast. A decision to cancel a trip based on weather should be made 3-days prior to the first day of a field trip (e.g. Monday for a Thursday trip), and it should be based on the weather tolerances listed in Table 4.

Table 4. Survey methods and weather tolerances

	Total Station\GNSS	**Terrestrial Laser Scan**	**UAV**
Rain	Forecast < 0.25 inch/day	Forecast < 0.10 inch/day	Forecast < 0.10 inch/day
Wind	Gusts < 25 mph	Gusts < 25 mph	Gusts < 10 mph

Note that special protocols and training are required if performing a UAS Survey. If a UAS Survey is to be performed, a UAS plan needs to be submitted to Joe Thomas, Chief of Surveys, Oregon DOT a few weeks prior to the planned deployment for review.

1. ***Review Oregon DOT's drone usage policy and manual at: http://www.oregon.gov/ODOT/ETA/Documents_Geometronics/UAS-Operations-Manual.pdf***
2. ***See Digital Appendix for example of a UAS plan.***
3. ***In addition, OSU policies need to be followed: http://research.oregonstate.edu/sites/research.oregonstate.edu/files/uas/uas_official_osu_use_policy.pdf***

1.5 PERMITS

In the event that a permit is close to expiring, steps shall be taken to renew the permit well in advance of the field work. If the permit will expire within 30 days after the next planned survey, the renewal process should be completed at the end of the current survey to ensure ample time to obtain the necessary permits before the field work commences.

Have printed copies of the permits and ODOT IGA with the field crews at all times while performing field work.

Information regarding the permits can be found in Table 5. Renewal for the State Parks Research permit can be performed by contacting Sara Griffith (sara.griffith@oregon.gov). Surveying work in the ODOT right-of-way is covered under an Intergovernmental Agreement (IGA) with ODOT. (See Digital Appendix). The IGA with ODOT requires OSU Risk Management to provide an updated certificate of liability insurance each year of the project (renewed each July). If fieldwork at any of the project sites is expected to enter the ODOT right of way for extended period of time, an encroachment and/or traffic control permit must be filed with the appropriate ODOT District. Contact information for ODOT permitting specialists in the relevant ODOT Districts are included in Table 5. For information and questions regarding the IGA, contact Virginia Williams.

Table 3. Permits or notifications necessary to complete work.

Agency	Permit Number	Expiration Date	Contact	Email	Phone	Applicable Sites
State Parks (OPRD)	037-16	7/21/2028	Sara Griffith	Sara.giffith@oregon.gov	503-986-0737	All
ODOT District 1	IGA - 30530	6/30/2025	Virginia Williams	Virginia.L.Williams@odot.state.or.us	503-325-5853	SIP,AC
ODOT District 4	IGA - 30530	6/30/2025	Carla Wahl	Carla.S.WAHL@odot.state.or.us	541-757-4182	BB (SPC)
ODOT District 7	IGA - 30530	6/30/2025	Jeff Waddington	Jeff.S.WADDINGTON@odot.state.or.us	541-396-1151	AZI, HOOSK

1.6 PREPARATION PROTOCOLS

Checklists are provided in the appendices to help with preparation tasks, which should begin at least one month prior to the field work:

- 1 month checklist (Appendix A)
- 1 week checklist (Appendix A)
- Packing checklist (Appendix A).

Print off each and make notes accordingly. This schedule ensures that ample time is available to inspect/prepare the equipment and make alternative plans as necessary. Before packing the GNSS units, ensure that their settings are correct for RTK. Ensure that they have the OCRS Oregon Coast Zone Coordinate System and Geoid 12A loaded.

1.7 SAFETY PROTOCOLS

- Each crew member should complete basic safety training at least 1 week prior to field work. They should participate in regular lab safety briefings in the geomatics graduate seminar.
- When arriving at each site, have a brief safety discussion pointing out potential hazards.
- Ensure that a first aid kit is readily available.
- Setup at the locations identified. These are located far back in the shoulder, preferably behind the guardrail or adjacent to it. Avoid setting up in the middle of parking lots or locations where construction activity is occuring.
- Be observant of traffic at all times. Stay out of the roadway and shoulder for the field work.
- Minimize the number of times necessary to cross the road. Only cross during very quiet periods of traffic.
- Wear rugged boots and appropriate safety attire (reflective safety vest).
- Place the “Survey work ahead signs” and cones when completing scans adjacent to the roadway.
- Consult the ODOT Geometronics Safety Manual for further suggestions.

1.8 DOCUMENTATION REQUIRED FOR EACH SITE

- Bring a binder of folder for each site that contains:
    - ODOT permit and contact information
    - State Parks permit and contact information
    - Copy of the site plan
    - The field notebook for each site. (There is a specific field notebook for each site so you have that information available from previous surveys).

1.9 DATA TO COLLECT AT EACH SITE

Refer to the detailed site plans for specifics regarding the data to be collected at each site, including lidar, GNSS, Total Station, and UAS SfM. Table 6 summarizes the data collection strategy for each site. The instruments should be setup at approximately the same locations each time for consistency to minimize errors for change analysis.

Table 4. Target data collection strategies for each site

Site	GNSS	Total Station	Scans			UAS SfM	Comments
			PL1	PL2	PL3		
Arch Cape	All surveys: scan positions, Static @ GNSS control points	S	F,S	F	N/A	N/A	
Arizona Inn		S	F,S	N/A	N/A	F – (even years)	The bluff face is inaccessible except for by UAS
Hooskenaden		S	F,S	S	F (odd years)	N/A	
Spencer Creek		N/A	F,S	F,S	N/A	N/A	
SilverPoint		S	F,S	N/A	N/A	N/A	

Abbreviations: SP = Scan Position, CP = Control Point, F= Fall, S = Spring Surveys, PL = Priority Level.

1.10 PROJECT NAMING CONVENTION AND STRUCTURING

Consistent naming and file organization is critical for this project given the number of people who will be working on it over time. The following practices should be carefully implemented, including use of only approved abbreviations (Table 7):

- Use a new project name per site per survey. It should be in the format of YYYYMMDD_SITENAME (e.g., 20161019_AZI)

Note that if a survey spans multiple days at a site, still use only one project for that survey since they will be processed together as a single survey!!

- Subsequently name each scan SP01, SP02, etc. Even if the survey spans multiple days, continue numbering from where you left off the previous day. Make notes in the field book of what was completed each day. Follow the site plan for the scan position names. Make notes of any scan positions where problems occurred.

Table 5. Acceptable abbreviations for field sites for file naming.

Site	Abbreviation	Comments
Arch Cape	AC	
Arizona Inn	AZI	
Hooskenaden	HOOS	
Spencer Creek	SC	Sometimes referred to in prior field work as Beverly Beach (BB)
Johnson Creek Landslide	JCL	
SilverPoint	SIP	

1.11 FIELD ACQUISITION

Field acquisition may be easily assumed to be surveying theory and the operation of survey equipment, but there are numerous additional protocols that should be followed to ensure personal safety and security of data. These protocols can be divided into two groups: 1) special considerations at the site and 2) evening wrap-up activities. Each group varies depending on the site visited and the survey performed, as will be detailed in this section.

Special considerations vary significantly depending on the site, and specifically, where work is being performed at that site. Hazards along the highway are generally due to traffic traveling at high speeds, whereas hazards away from the highway may result from poor weather conditions or rugged terrain.

1.11.1 Upon arrival

- Park in a safe location off of the road. Use flashers when exiting highway if possible.
- Conduct safety briefing and look for potential hazards. Ensure all team members are aware of and can mitigate hazards on site.
- Review the survey plan and determine responsibilities of field crew members.
- Look at tide situation and determine if it makes sense to start on the beach or in the upper sections first.
- For any work near the road, setup safety cones and signs on the shoulder, as appropriate. Follow plan in the permit folder.
- Check the status of the instrumentation on site (See Research Methodology Volume II).

1.11.2 Starting Survey Work:

- Setup the GNSS base station.
- Setup the first scan position in an area with a clear view of the sky and close to the vehicle if possible.
- When travelling long distances with the equipment, power down the scanner and pack up the equipment.
- Carefully attach the scanner to the tripod or wagon base plate. ENSURE THAT THE SCANNER HEAD DOES NOT ROTATE when attaching it.
- Attach the Camera (and USB cable) for the Riegl Scanner.
- Mount the GNSS receiver atop of the scanner. For the Riegl, attache the camera first and then mount the receiver with the nominal 5cm black offset pole.
- When walking along rocky areas, use the backpack and poles to transport the scanner. Take your time and be careful!
- Power up the scanner, GNSS receiver, and GNSS controller. Ensure that the GNSS has initialized before recording data for the first scan position. Proceed with the data collection.

- GNSS offsets:
    - Riegl VZ400: 0.29 m (includes 0.05 m for the black extension). Early in the project (prior to August 2018), an incorrect offset height of 0.302 m was used. The georeferenced scans were corrected by the 0.012 m for the analysis of the previous surveys and the corrected height was used for the processing of scans collected after August 2018.
    - Leica P40: 0.1175 m (See Figure 2). An incorrect height of 0.1584 m was originally used due to a misinterpretation of schematics prior to 3/20/2019. Any data collected with the scanner prior to discovery of this error was corrected.

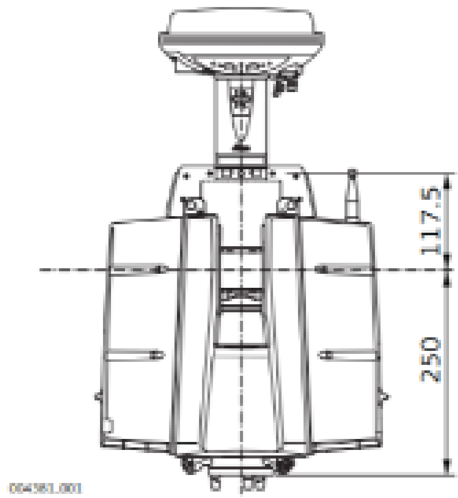

Figure 2. Offsets to the Leica P40\P50 Scanner (image from Leica Geosystems).

- Leica RTC360. A 3D printed prototype version of the mount was used for data collection in May and June 2023. That mount was estimated from basic measurements to have an offset of approximately 0.09 m but was not determined rigorously. The final aluminum mount was fabricated in Summer 2023 which has an offset of 0.1125 m when used in conjunction with the 4 cm quick release.

1.11.3 Scanning operation

***Key point** – Because we are performing a targetless survey for efficiency, we need to obtain a reliable GNSS coordinate for each scan location. Ideally, we have RTK coordinates from the ORGN with static data logged at the rover and a base so that we can compare the two coordinates for each scan location for consistency. This is especially critical for the scans on the road at Arch Cape.*

- Log static data in addition to collecting RTK data from the ORGN.
- Use the m00 format (we can convert to RINEX later if needed). The m00 format stores more information that may be useful in the future for improved processing.
- Start logging data once the scanner is stable and properly positioned.

- Log the GNSS observations for the entire duration of the scan at 1 second increments.
- Be sure to stop logging and store the point before proceeding to the next location.

> ***Key point*** *– For each position, we should log at least 3 minutes of data, but at least 5 minutes is preferable). However, if doing coarse scans for a low priority section, this requirement can be relaxed assuming the RTK GNSS is working well (e.g., Beverly Beach/Spencer Creek).*

- Verify that the scan number and the GNSS point number match. If they are offset, make a note in the field notes and correct at the next position moving forward.
- Make a note in the field notes if you move the scanner/GNSS before finishing logging a data point.
- If a RTK point is not of sufficient accuracy to automatically store then:
  - If GNSS has been working relatively well and it is likely that you can get a point in a few minutes, wait and capture the point before moving to the next position.
  - If GNSS is spotty, try reinitializing and recapturing the point.
  - If GNSS is poor and obtaining a coordinate is unlikely in a reasonable amount of time, store the approximate coordinates, DOCUMENT IN THE FIELD NOTES, and move onto the next position. If this occurs for more than a few scan positions, it may be necessary to repeat that section later.

When complete, use the following process to export the RTK data to a CSV file.

a. Insert a USB drive in the USB port on the bottom side of the Leica CS15 data collector.

b. Several folders will be automatically saved onto the flash drive. These folders are named: Code, Config, Convert, Data, DBX, Download, GNSS, Gsi, and System.

c. Press the escape button on the data collector twice to return to the main menu.

d. Tap “Jobs & Data” then “Export & Copy Data” then “Export ASCII data”

e. Select “Data” for the folder, export to the “USB”, select your job name, and ensure it is configured to export as a comma separated file with the following format “P, E, N, H” which stands for Point ID, Easting, Northing, Elevation

f. Export the file. It will be saved in the “Data” folder on your USB drive.

1.11.4 Field Notes:

A separate field book is provided for each site so that the field crew has the benefit of looking back through previous surveys. Field notes, as a minimum, should contain the following information:

- Location and date of the survey

- Field crew/operators
- Temperature, pressure, relative humidity
- Weather conditions.
- Equipment used
- GNSS offset height used.
- Sketch/map showing locations where the instruments were setup.
- Notes on any problems encountered or when a scan was repeated.
- Scan positions where GNSS positions could not be obtained.
- Capture a photograph of the setup used as well as occasional photos of the field work.
- Any deviations or special situations.

1.12 FINISHING WORK

- Be careful when packing up the equipment and follow the check list to make sure all items are accounted for, and nothing has been lost.
- If the equipment is wet, wipe down the equipment with microfiber clothes as best as possible. Upon returning to the hotel (or lab), remove the instruments from the cases and leave the cases open for a substantial amount of time to dry.
- Do not force equipment in the boxes. Everything should fit snugly in the proper orientation. Do not be afraid to ask for help.
- Make sure that the camera USB cable is placed in the box so that it does not get damaged.
- Secure expensive equipment with padlock in the back of the vehicle.
- Load up the truck and return to the hotel or OSU.

1.13 NIGHTLY CHECKUP

- Put batteries on the chargers. Rotate as necessary through the evening and night.
- Bring in expensive equipment into hotel room (Scanner, total station, GNSS) with you and secure with pad lock.
- **When returning to the hotel, start the data backup process as soon as possible. Data copying and import takes time, so it is good to start right away.**
    - Copy all data from the scanner USB to a backup hard drive.
    - Export an ASCII file from the GNSS controller.
    - Copy the GNSS data (and exported ASCII file) from the microSD cards to the backup hard drive.
    - Copy all data from the total station Compact Flash Card to the backup hard drive.
- When backups are complete, create a new Riscan Project or Cyclone database and begin importing the files (*see Riscan or Cyclone processing sections*).
- Send status update to PIs Olsen and Leshchinsky with work completed as well as any concerns.

- Copy that status update text into a word document in a field notes folder on the backup drive. Add any additional notes relevant to the processing.

DO NOT DELETE DATA FROM THE CURRENT FIELD EFFORT ON THE USB FLASH DRIVES UNTIL RETURNING TO THE OFFICE AND ALL OF THE DATA HAVE BEEN VERIFIED WITH SUCCESSFUL IMPORTED INTO SOFTWARE.

1.14 DATA BACKUP

- Export an ASCII text file with fields of: PointName,X,Y,Z,SigmaX,SigmaY,SigmaZ,TimeStamp

- Copy project files and folder from field to shared drive in the appropriate location.

- Ideally, this backup should be done nightly upon return to the hotel. However, if internet connections are poor, then backup should occur immediately upon returning to the office.

FOLLOW STANDARD PROTOCOLS FOR FILE ORGANIZATION (TABLE 8) AND NAMING IN THE DATA FOLDER!

In addition, there should be a file: YYYMMDD_LocationName_ProcessingNotes.docx where information about the data are logged during processing including any specialized techniques used to process that dataset to overcome issues.

Table 6. Project structure for data organization (L = level)

L0	L1	L2	L3	L4	Description
SiteName	YYYYMMDD_SiteName	0_RawData	0_FieldNotes	-	PDF of all field notes DOC with daily field updates/log Photograph of the field setup.
			1_GPS	-	DBX project files and m00 files, ASCII coordinate export
			2_TotalStation	-	DBX project files
			3_Lidar	-	If Riegl, the .riproject folders If Leica P40 or RTC360, the bin and image files from the project or job.
			4_UAV	-	Folders with photographs.
		1_Processed	0_Lidar	1_CycloneDiagnostics	If Cyclone is used for registration, a txt file of the registration diagnostics as well as tables of target and cloud to cloud errors from the Extract Cyclone Registration Parameters.
				2_GeoreferencingParameters	DAT files with SOPs for Riscan, CSV file of transformation parameters
				3_InclinationData	HK files, csv files with inclination readings for scans
				4_PointReg	PointReg CSV file, RMS evaluation file
				5_PointCloudExports	LAS E57 CLIFF_TXT_ZIP – Zip file of a txt export of the points on the cliff face for subsequent processing.
				6_Potree	Files necessary for potree
				7_SuppProcessingFiles	Project files in CloudCompare, Cyclone, Maptek, or Riscan, as appropriate.
			1_GPS	LGO	LGO Project files
				OPUS	Datasheets of OPUS extended output results. One txt file per session
			2_Adjustment	-	Starnet Project files.
			3_ProcessedCoordinates	-	CSV files with processed total station and GNSS control coordinates.
			4_Models	1_DEM	Includes bil or ESRI grid DEMs, Hillshades, slopes, etc.
				2_OBJ	OBJ model (including mtl and png files) of the cliff face developed for the site (Preferably Zipped together)
				2_OrthoPhotos	GeoTiff orthophotos generated for the site
			5_DataScreenCaptures	-	png files of various screen captures of the data showing overall site, features of interest and any QA/QC evaluations
		2_Site Photos	-	-	Photographs of the site acquired during the survey.

1.15 RETURN FROM FIELD

- Return scanner to the geomatics lab (Covell) storage and place lock securely around the scanners.
- Copy any data off of devices that has not yet been completed.
- Contact Lab Manager to return the GNSS and Total Station equipment to the Owen Survey Lab (Ideally contact them before returning to schedule a time)
- Copy the project template folder structure to the appropriate directory.
- Copy all data to the appropriate places in the raw folder. and sync with the BOX folder. Ideally use the original USB/micro SD devices for the data transfer rather than a copy.
- Begin importing and processing the data in the various processing packages.
- Immediately scan in field notes into a single pdf per site.

Note: The project shared drive is located on disk servers maintained by the college of engineering that provide regular backups and redundancy to ensure the longevity of the data. For further redundancy, we will sync that folder with BOX, where OSU has unlimited storage.

1.16 ADDITIONAL DATA ARCHIVING

In April and October each year, download tidal and meteorological files from NOAA servers.

Be sure to only download data that has been verified not the predicted or preliminary, which usually requires 2 weeks.

1.16.1 Tidal

Tidal data should be downloaded from NOAA https://tidesandcurrents.noaa.gov for the stations listed in Table 9 with the following settings:

- 6 minute increments.
- Units: Meters.
- TimeZone: LST
- Datum: NAVD
- Ensure that it has the measured (verified) fields

Note that data should be downloaded in monthly increments. Download the predicted tide as well so that it can be used as a baseline for comparison to determine storms/abnormal wave activity. It appears that this must be done separately at this time.

Download the meteorological data (from the same site as the tidal data, but follow a different link) with the following settings:

- 6 minute increments.
- Units: Metric.

- TimeZone: LST

It should have fields of Date, Time, Wind Speed, Wind Dir, Wind Gust, Air Temp, Barometric Pressure, and Humidity (*Note that Humidity may not be available for each site*).

Figure 3. NOAA Tidal stations for each site.

Station	Station ID	Weblink to station	Sites
Garibaldi, OR	9437540	https://tidesandcurrents.noaa.gov/ stationhome.html?id=9437540	AC, SIP
South Beach, OR	9435380	https://tidesandcurrents.noaa.gov/ stationhome.html?id=9435380	SC
Port Orford, OR	9431647	https://tidesandcurrents.noaa.gov/ stationhome.html?id=9431647	AZI, HOOSK

1.16.2 Precipitation Data

Download NOAA 15 minute Precipitation Data: https://data.noaa.gov/dataset/u-s-hourly-precipitation-data.

1.16.3 Wave Buoy Data

Download wave buoy information from CDIP (Coastal Data Information Program, http://cdip.ucsd.edu). Unfortunately, only one station is still active in Oregon, CDIP 139 (UMPQUA OFFSHORE,OR). Data that are available include: Date/Time (UTC). Hs (m), Tp (sec), Dp (Deg TN), Ta (s), SST (deg C). Download in monthly increments to be consistent with the tidal data.

Although in analysis we may use aggregated measures such as min,max, average; it is important at this stage to gather the more detailed files to ensure that they are available for the analysis.

1.17 PROCESSING

1.17.1 Initial Project Setup

1. Create a working directory on the shared drive. These instructions will assume that is your R:\
2. Create a working directory on your Solid State Drive (SSD). These instructions will assume that is your E:\. *E:\SPR807_Working\SITE_YYYYMMDD*

1.17.2 GNSS Processing

1.17.2.1 Initial Setup Procedure on your workstation

- Install Geoid 12B. (See ODOT instructions on how to install)
- Create the OCRS Oregon Coastal Zone NAD83(2011) Epoch 2010.00 coordinate system. (download from ODOT OCRS)

- Note that in the future when NGS releases the new datum, we will need to adjust coordinates back to NAD83(2011) Epoch 2010.00. HDTP is currently the principal way to do that, but NGS is creating a new set of tools.

1.17.2.2 Routine Processing

- Wait 14 days for precise ephemeris to be available before starting processing of GNSS data.
- Submit m00 files for base station and static GNSS control points to OPUS.
- **Leica GeoOffice Workflow**
  - Download Precise Ephemeris from IGS [https://igscb.jpl.nasa.gov/components/prods_cb.html]
  - Create new LGO project in the appropriate folder on the project shared drive (If needed, refer to documentation on setting up coordinate systems and geoids in LGO if that has not yet been completed).
  - Import all m00 files
  - (If the Trimble Receiver was used, convert the T02 files to RINEX first before importing to LGO).
  - Import Precise Ephemeris into LGO
  - Identify the Base and the Rover
  - Process
  - Store Baselines
  - Apply Geoid to coordinates
  - Export as ASCII file with uncertainty estimates
  - Export baselines as .asc file
- **Infinity Workflow**
  - Create a new Leica infinity project for the site/epoch with the name "YYYYMMDD_SiteAcronym" Make sure to create a subfolder and save exported data to the project subfolder.
  - Import all raw GNSS data from receiver. Preferably import raw data (*.m00 files) rather than the exported projects from the GNSS controller.
  - Ensure the Geoid (Geoid12B for North America currently) has been loaded and use the OCRS Coastal Zone coordinate system
  - Import the precise ephemeris for the duration of the survey into Leica Infinity. To do this, click the "processing" tab then click the "download" icon (picture of the red tripod). Then right click on one of the NGS stations and click download.
    - Ensure the start and end date cover the length of the survey and the precise ephemeris box is checked and then click "start".

- Assign the base points (points submitted to opus) as "control points" and copy the Cartesian ECEF NAD83 2011 (epoch 2010) coordinates from OPUS into the "Geodetic coordinates" section.
- Ensure "NGS absolute" is selected for antenna calibration.
- Change the ephemeris type to "Precise".
- Identify the control points as base stations and shorter observations as rovers then select the "process" icon.
- Assess the ambiguities and residuals of each position to ensure adequate results.
- Once satisfactory select "store".
- Export the coordinates as a comma delimited ASCII TXT file (.csv) in the form:
  - ID, Easting, Northing, Ortho Height, SD Easting, SD Northing, SD Ortho Height

1.17.3 Star Net Adjustments

- Create new project in the appropriate location on the project shared drive
- Import total station data (LeicaDBX)
- Import GNSS baselines from LGO output (asc)
- Create a CONTROL.dat file in the project directory and add the control point coordinates with the associated uncertainties based on your OPUS and/or LGO solutions
- Ensure the stochastic models are reasonable.
- Perform the adjustment
- QA/QC the results and re-run adjustment as needed.
- Export coordinates and associated uncertainties to a csv file.
- Put this in the appropriate folder on the shared drive.

1.17.4 Scan Registration

The registration process differs depending on which scanner was utilized for the survey, the Riegl VZ-400, Leica P40, or RTC360.

1.17.4.1 Riegl VZ-400 Workflow

1. Transfer raw data (.riproject) to SSD folder (e.g., E:\SPR807_Working\SITE\YYYYMMDD_SITE\YYYYMMDD_SITE.riproject)
2. Create new Riscan project (e.g., E:\SPR807_Working\SITE\YYYMMDD_SITE\YYYYMMDD_SITE.RISCAN) if not already done in the field.

3. RiSCAN Pro (or whatever scanner software you are using)
    a. If needed, Import calibration data (right click on camera under CALIBRATIONS in project manager)
        i. Located in shared drive (equipment – Nikon – the newest .cam file)
        ii. Right Click, Apply to images (camera and mounting)
    b. Import scans (Help->Download and Conversion Wizard->Storage->browse to folder with .rproject)
    c. Right click on the riproject in the browsing tree, select all
    d. (This process can take a while, so it is suggested to time this do occur overnight or during a lunch or class break).
    e. Import exported scan positions
        i. TPL (GLCS) – right click-> Import (select appropriate fields)
    f. Right click each scan, color by images, use all images from the scan position (unless field notes indicate a problem).
    g. Import to each scan
        i. ScanPosXXX – SOP, right click Backsighting Orientation –
        ii. Use GLCS tiepoint, select tiepoint corresponding to scan position, Next
        iii. Alignment – against north, next
        iv. For the alignment angle, use a yaw calculated from the digital compass, if available (Azimuth -90 degrees).
        v. Use inclination sensor – select scan (if there are multiple scans per position, use the scan that is the longest 360 scan unless field notes direct otherwise), Next
        vi. Set SOP, Close (Note that the first scan will ask you to set a POP matrix. Use the values in Table 10 for the POP Matrix – it should default to these values).

Table 7. POP Matrix Values for each site (OCRS Coastal Zone)

Site	**X (m)**	**Y (m)**
SIP	141000	492000
AC	141000	485000
BB	134000	366000
AZI	106000	132000
HOOS	107000	87000

        vii. Repeat for all scans
    h. Coarse Align scans
        i. Open two scans – select a different color for each
        ii. Change view to Global coordinate system
        iii. Click on the Birds eye view box and toggle orthogonal view mode.
        iv. Right click one of the scan positions in the list view, click modify orientation

        1. Action – rotate, Coord system GLCS, click on Z axis and move (be careful not to select any of the other axes)
        2. Find a distant feature and change between both scans to align by rotating. Look at entire scan to verify alignment.
        3. Add in a 3rd scan and repeat process
        4. Continue with all scans. Note that you may want to turn off scans periodically to not bog down the display.
        5. Once happy with course alignment, note the new yaw for each scan position (select the scan position and note yaw from message list box).

4. ALREADY ABOVE (3.F)Create binary files from RXP scans and extract leveling information
    a. Copy example.csv from the PointReg program directory. Rename to "YYYYMMDD_SITE.csv").
    b. Search for all *.rxp files in the current riproject folder.
    c. Copy these to another director (E:\.....\PointReg\)
    d. The scan data files for each scan location need to be named with the following convention: CSVFILENAME_PID_BSID_LID.bov
    e. For example, if the csv file is 20161010_AZI.csv, then the scans would be:
        i. 20161010_AZI_1_1_L.rxp for scan 1
        ii. 20161010_AZI_2_2_L.rxp for scan 2

    and so on.

    f. Drag and Drop the renamed *.rxp files into the bovconverter program (00_BovConverter_V1p4.exe).
    g. Filter by range (typically 15 m to 150 m).
    h. Choose to export both the bov files and hk files.
    i. Drag and drop the resulting *_hk.txt files into the "01_hkreader_V1p4.exe". You can plot the roll and pitch values in excel to verify there isn't unusual scatter or drift.
    j. Drag and drop the resulting *_hk.csv files into the "02_hkInclExtractor_V1p4.exe". This creates the InclinationValues.csv file.
5. Create a PointReg 3.0 CSV file:
    a. Open YYYYMMDD_SITE.csv (copied from example.csv) in excel and copy in the following (steps B-L) in the corresponding premade columns.
    b. XYZ - the XYZ coordinates from the scan, initially entered from the GPS (or other coordinates). Note that these values will be corrected to the scan origin and adjusted in Point Reg after the first run.
    c. Roll,Pitch - obtained from the scan inclination sensors
    d. Yaw - obtained from each scan position in the process above (See step 3. H. iv. 5).

e. GX,GY,GZ - these are the GPS (or other) coordinates for the scanner origin. Note that at first these will be the same as XYZ. However, with multiple runs of the software, XYZ will change (currently only Z). GX GY GZ will remain constant (after the initial correction to account for the unlevel setup).
f. GH = the GPS height. + means that the GPS is above the scanner (most common). A negative height would mean that you set up over a control point.
g. SDGX,SDGY,SDGZ - these are weighting parameters. you can use 1. a standard deviation of multiple RTK GPS points obtained for the scan origin or values provided in OPUS. However, you don't want to mix and match. The idea is to provide higher weight to more consistent, accurate GPS coordinates.
h. GPSCORR:
   0= the coordinates have been corrected for the fact that the GPS was not level.

   1= Point Reg will correct the GPS coordinates. However, first it needs undo the GH offset applied in the scanner controller as a vertically only offset.

   2= Point Reg will correct the GPS coordinates. This assumes no correction was applied in the controller already (e.g. in the controller an antenna height of 0 was entered).

i. ADJUST: Enter 1 in all columns.
j. PID: An ID (number) for the Point
k. BSID: An ID (number) for the backsight point (if not applicable, just enter the same thing as PID.
l. LID: A leveling ID - enter a L for each scan.

6. Create binary files from RiSCAN Scans. (This process takes 1-2 minutes per scan).
   a. Drop *.rxp files in bovconverter
   b. Rename to (csvfilename_pt_bs_level is JCL_1_1_L)
   c. Move all to working folder
   d. The scan data files for each scan location need to be named with the following convention:

      CSVFILENAME_PID_BSID_LID.bov

      For example, if the csv file is example.csv, then the scans would be:

      example_1_1_L.bov for scan 1

      example_2_2_L.bov for scan 2

      and so on.

7. Point Registration (1st Run)

a. Registration Parameters (PointReg *ipcreg.txt* file). Most settings in the file should be adequate and have worked well for processing thousands of scans. The only changes that are recommended are:
    i. Change TRANSX and TRANSY to the POP Matrix values shown in Table 10. (These truncate the digits so you do not get problems in other software that works in floating precision rather than doubles (e.g. in RIscan you have the POP matrix). For example, if you are using coordinates that are 4416351.291, you can use an offset of 4416000 so the coordinates are smaller at 351.291 and do not get truncated in other packages. Note that PointReg does not require this, but is for convenience of other packages.
    ii. Optional – speed up processing by setting ZMIN a value slightly higher than the typical beach elevation and ZMAX to a value slightly higher than the typical cliff top elevation.

b. When settings are completed, run PointReg by dragging and dropping the csv file into *PointReg_v3.exe.*
    i. Select "1 – register point clouds"

c. When PointReg is completed with the first run, inspect the _reg files as well as the AdjustmentReport.csv. There should be consistency in the rotation angles determined for each scan based on its match to other scans. RMS values should ideally be less than 0.05 m. The percent outliers should be consistent with the amount of noise (e.g., vegetation, cars, etc.) present in the scene.

d. If a scan adjusts significantly or appears to not be correct, verify a new rotation angle in Riscan. (you can manually update the angles in riscan by right clicking the SOP and selecting Improve Matrix).

8. If satisfactory, move the Adjustment Report, 20161019_AZI.csv, 20161010_AZI_reg.csv, and 20161019_AZI_updated.csv to a folder "runX" where X corresponds to the run number.
    a. Copy 20161019_AZI_updated.csv back to the main folder and rename to 20161019_AZI.csv
    b. Repeat steps b to f as many times as necessary.
    c. After final PointReg run and results are acceptable
        i. Run point reg in mode 3 to write SOPs
            1. Adjust transx and transy of ipcreg to match POP before running.
        ii. Run point reg in mode 2 to batch evaluate RMS of scans.
        iii. When complete, copy the results from the csv file, the rms.csv file, and dat files to the shared folder so that they are backed up.
9. Update SOPs in RiScan Project
    a. Open RiScan project
        i. Right click SOP for each scan

        ii. Import SOP from pointreg .dat file
        iii. Open 2 scans at a time to make sure they match
            1. Take cross sections
            2. Plane section mode

10. Export scans as E57 and las files from Riscan.
    a. LAS – Right click each scan file and select export, select file type as LAS 1.3
        i. Select Project coordinate system,
        ii. COLOUR: True Colour
        iii. Intensity: Reflectance as intensity
        iv. Click Ok
    b. E57 - Help->Wizard 'Export'->
        i. FORMAT: E57
        ii. Coordinate system: Project coordinate system Range Unit: m
11. Select coloured scans -> OKArchive las & E57 files on project share folder.

1.17.4.2 If Leica P40/P50

If using the Leica P40, the processing strategy will be different.

- Import scans into Leica Cyclone (Import ScanStation Data). Settings: Mixed Pixel filter: moderate. Remove saturated points. You generally do not need the auto registration options or the auto align options.
- Add vertices to each scan position. Use the add registration label to name these targets the same as the name of the scan position in your csv file with the GNSS coordinates.

Be careful to ensure that verticies are placed at 0,0,0. Sometimes the insert vertex tool will use the center of the point cloud instead of the actual origin at 0,0,0.

- Import the GPS coordinates for the scan origin as a text file into a new scan world. Be sure that the ID is brought in as a Target ID.
- Create a new registration in Cyclone Navigator.
- Add in the scan world GPS coordinates. Make sure this scan world is bold as your home scan world.
- Add in two overlapping scans.
- Highlight the two scans and run a visual registration. Move the scans until they match closely (first horizontal translation and rotation, followed by vertical translation). When they are close, run the refine alignment tool.
- Add in additional scans and match them up to their neighbor. Continue progressing until all scans have been matched to at least one neighbor.
- Auto-add constraints. You should see a target id match for each scan position (unless the scan position did not have a GPS coordinate).
- Set the weights on the GPS points to be 0.2. (If the points are of lower accuracy, you can lower the weight further).

- Run the registration. Evaluate the residuals. If things look acceptable (low errors), then auto add additional cloud constraints. If not, select the poor constraint and optimize the alignment a few times. The histogram should get better and better. If it does not, then run the visual registration again and adjust. Disable poor GPS constraints.
- After auto adding cloud constraints, make sure that each scan is matched with other scans that it has sufficient overlap (e.g., left neighbor and right neighbor).
- Once things look good, select all of the cloud to cloud constraints. Optimize the alignment.
- Repeat this several times
- Freeze the registration
- Create and open model space
- Select all scans. Change color to random colors for each scan.
- Look at blending in the dataset.
- View a cross section. Start at one end of the bluffs and take cross sections every 10 m. Make sure the points line up in an adequate profile.
- Be sure to document the processing techniques, deviations, etc. Document any scans with poor GPS.
- You may need to export the data to perform runs in PointReg if the Cyclone solution is inadequate.

1.17.5 Importing data to Cyclone (Riegl scans only)

The following steps are necessary to bring Riegl data into Cyclone after registration:

- Convert to 3dd in Riscan
- Color the 3dd scans
- (Try to export e57 from 3dd)
- Convert 3dd to PTX files. (Suggest creating a new folder PTX and copying all colored 3DD to that folder).
- Import data into Cyclone. Wait a long, long time. (Best done overnight). Uncheck options to extract pipes, targets, etc. but be sure that it is at 100%.

1.18 EDITING

- Cyclone
    - Create layers in Cyclone for beach, noise, cliffs, road, etc.
    - Select points by polygons (add inside fence, remove inside fence)
    - Move them to the appropriate layer.
    - Turn layers off and on to make sure the right data are on the right layers. Adjust accordingly.

- Maptek I-Site can also be used for editing. A polygon can be drawn around the area of interest and the filter by polygon can hide the unwanted points. The attribute tool can be used to label the desired areas.
- Cloud Compare’s cropping tools can also be implemented, but will be less efficient.

1.19 EXPORTING

- After registration, export the full, registered scans to an E57 file. (One file per scan).
- Original Process:
    - Copy the cloud compare “convertE57toLAS.bat” script to the same directory as the E57 file.
    - Run the cloud compare script to generate las files. (If needed, modify the cloud compare executable file path)
    - Delete the bin files
    - Copy the E57 and las files to the appropriate locations.
    - Export the cliff points to a text file in the format X,Y,Z,R,G,B,Intensity.
    - Zip the text file (using maximum zip settings in 7z) and back up the zip file in the appropriate location on the server.

Do not copy the text file itself to the backup server. It is unnecessarily large and should be zipped. This will also save a lot of unnecessary data transfer time.

- Update after 2020: It is preferred to use EZPC’s tools to convert from E57 to laz and to use laz instead of las. Simply drag and drop the files into the EZ_E57_to_LAZ executable. Additionally, the text file is no longer needed and LAZ can be utilized.

For convenience, the CloudCompare script is provided below.

```
for /R %%n in (*.e57) do (
    echo %%n
    C:\LIDAR\CloudCompare_v2.9.0.alpha_bin_x64\cloudcompare.exe -SILENT
    -O -GLOBAL_SHIFT AUTO %%n -SF_OP 0 MULT 65535 -C_EXPORT_FMT LAZ -
    SAVE_CLOUDS
)
```

1.20 MODELING

- Original Process
  - Convert the text file to a bpd file using the converter in HingeTri_X64.
  - Zip the bpd file and back it up in the appropriate location on the server.
  - Run HingeTri_X64.exe. See digital appendix for the preferred settings for the project. Adjust cell size as necessary. (For high res scans should be able to produce a 2 cm model, for ordinary scans, a 5 cm model).
- Update after 2021: The text file is no longer needed. The data are also processed in the Rambo software, which replaces HingeTri_X64.exe.
- Import the resulting obj file into Maptek I-Site and inspect.
- If there is still a lot of noise, you may need to go back and clean the point cloud and regenerate the surface. You can do some simplified model editing in Maptek I-Site Studio but note that Maptek I-Site Studio does not preserve the color information on the model.
- Generate a screenshot of the model, similar to Figure 3 below.

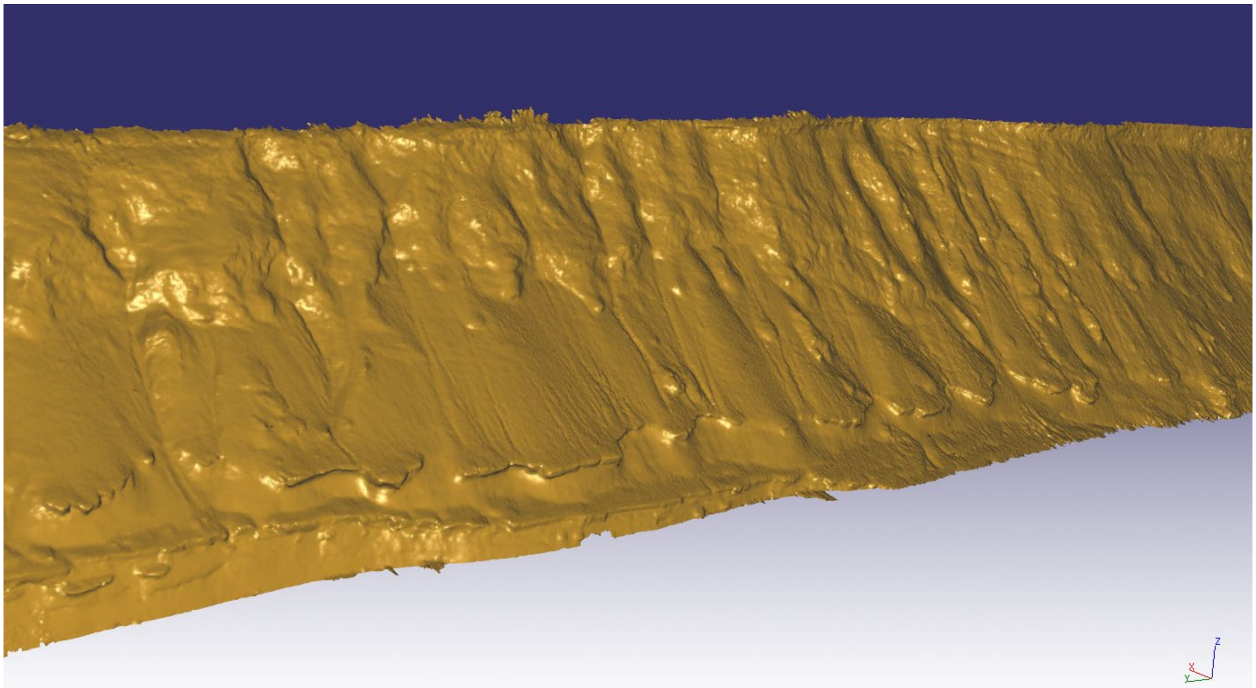

Figure 4. Example surface model with 5 cm resolution of seacliffs at Beverly Beach State Park derived with ground-based lidar.

1.21 BUILDING A POTREE WEBPAGE FOR ONLINE POINT CLOUD VISUALIZATION

For select sites and epochs, clouds were uploaded to a Potree WEbGL interface through the following steps:

Step 1: Go to the PotreeConverter Github repository (https://github.com/potree/PotreeConverter) PotreeConverter_1.4RC2_windows_64bit.zip from the "releases" tab and unzip in a chosen directory
Step2: Open up a Windows command prompt and navigate to the location where you unzipped the PotreeConverter package.
Step 3: Run the following command with your LAS files. For inputting the individual LAS files drag and drop each one individually. If you drag and drop all of them into the command prompt they will be listed with no spaces in-between. Additional options can be included when running the PotreeConverter command, refer to the "Additional Potree Converter Options" reference included below. Be sure to carefully check the parameters since there seem to be a lot of erroneous versions up there. For adding projection information, use the OCRS Coastal Zone NAD83 (m): `("+proj=omerc +lat_0=44.75 +lonc=-124.05 +alpha=5.0 +k=1.0 +x_0=134743.332409 +y_0=369139.027713 +ellps=GRS80 +datum=NAD83 +units=m +no_defs")` and include the output in the PotreeConverter command in accordance with the example below:

```
PotreeConverter.exe G:\potreedir -o G:\potree -p index --projection
"+proj=omerc +lat_0=44.75 +lonc=-124.05 +alpha=5.0 +k=1.0 +x_0=134743.332409
+y_0=369139.027713 +ellps=GRS80 +datum=NAD83 +units=m +no_defs" --overwrite -
-output-format LAS
```

For different coordinate systems (should not be necessary for this project) download the appropriate proj4 file from http://spatialreference.org/.

Step 4: Following preprocessing of the point cloud data and creation of the website files, you should see two new folders in your output (-o) directory titled *libs* and *pointclouds,* a file titled *index.html*, and a file *lasmap_index.html.* Copy all three items and paste into the appropriate webserver subdirectory (e.g., \AC\20170602_ArchCape\) under \\stak\dept_www\research_www\lidar\pointcloud\OregonCoast\.
Step 5: Open a modern web browser with WebGL support and navigate to the index.html file on your webserver (e.g., http://research.engr.oregonstate.edu/lidar/pointcloud/OregonCoast/AC/20170602_ArchCapeTest). You should see something similar to the included image with your point cloud displayed. Description text and logos can be added by modifying the index.html file. Modify this to display ODOT, OSU, and DOGAMI logos. An example of the modified index.html file modified sections (highlighted) is included in Section 1.28.

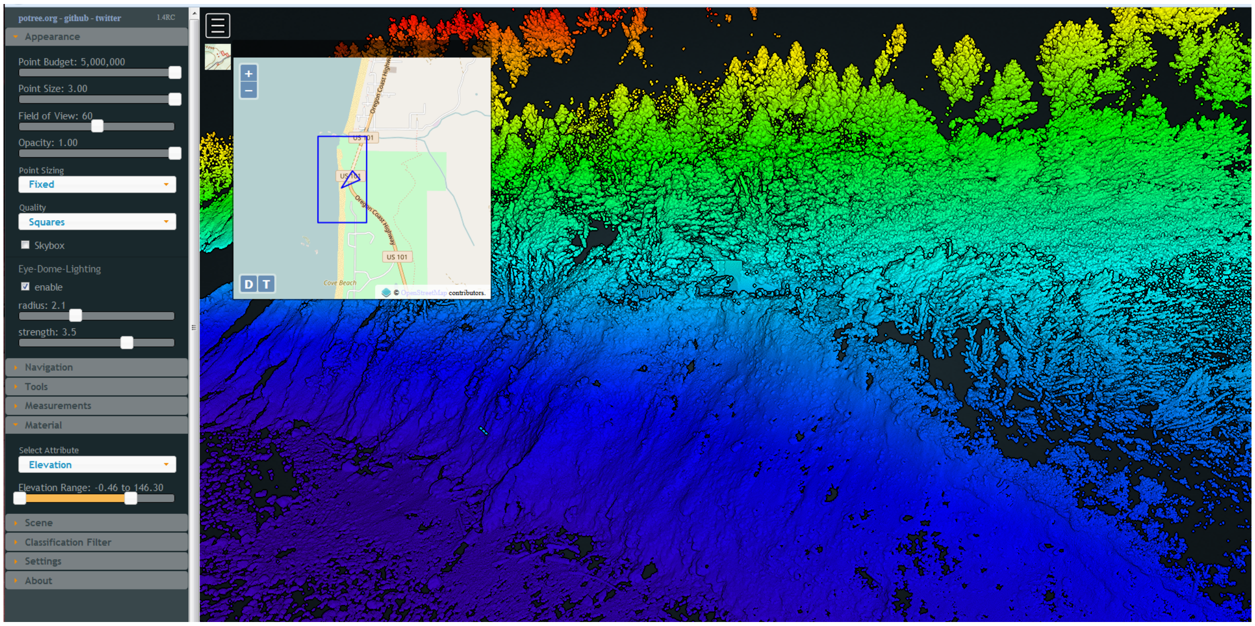

Figure 4. Screenshot of Potree Web-based Point Cloud Viewer for Arch Cape.

Potree Point Cloud Cross-section Tutorial

Potree enables you to extract cross sections of the data. To extract those cross sections, do the following:

- Click on the **menu button** (3 horizontal lines) in the upper left-hand corner of the view window
- Scroll down to the "**Tools**" bar and click
- Select the tool icon that looks like a **multicolored M**.
- When you mouse over the point cloud data, you should now see a red ball attached to your mouse cursor. This allows you to drop nodes and establish the location of your profile
- When you want to finalize your profile **double click** on the last node. Once a profile is finalized, you can still change its location by clicking on the red nodes and dragging them to a different location.
- Now, return to the side menu and click on the "**Measurements**" bar. You should see a Profile item with coordinates listed. Click the "**show 2D profile**" button. This is also where you can delete profiles by clicking the red X.
- A profile of the lidar data should now be visible at the bottom of the screen. The profile will also update in real time if you move the profile throughout the data.
- For best visualization of the profile, I recommend changing the color scheme from RGB to **Elevation**. This can be completed under the "**Material**" bar in the main menu.
- The save button in the upper right corner of the profile window will download a las file containing the points from the profile. This is useful for extracting the data you want to use for further analysis.
- Lastly, if you click on the small map icon found below the main menu button, you can see an Open Street View map of the site and your profile line should be included as a red line.

1.22 PRODUCTS TO BE CREATED

The key data products produced for each survey at each site include:

- Backed up Raw Data from scanner, GNSS, and total station.
- Geo-referenced point cloud
  - For select sites a web interface was created in potree
- 3D surface model of the bluff face(s) (obj) – cleaned of vegetation
- When applicable a DTM model of the site (bil) was created for analysis in ArcGIS (e.g., Arizona Inn and Hooskanaden). The following rasters were also generated (using the mass production code initially but later created by Rambo).
  - Hillshade
  - Slope map

1.23 Documentation Procedures:

- Update processing tracking spreadsheet as major tasks are completed.
- Log field crew members present on each survey.
- Update spreadsheet to include new coordinates of marks and verify stability or movement at those marks.
- Document any deviations, notes, etc. for the processing. (e.g., scans renamed) in the Processing log document. Follow the format listing the names of those involved in the processing.

1.24 SUPPLEMENTAL DIGITAL APPENDICES

The following information are provided in supplemental digital appendices to this document.

- Technical Specifications for Instruments used and User Manuals
  - Riegl VZ-400
  - Leica P40
  - Leica Viva TS15
  - Leica Viva GS14
  - Trimble R8 (when Leica units are not available).
- Custom software settings.
- Permits\agreements (State Parks and ODOT)
- Site Maps (Digital PDFs of the posters showing the site plans)

1.25 PLANNING CHECKLISTS

SPR 807 – One Month Planning

<table>
<tr><td></td><td>Check tide schedule to narrow down potential dates for surveys.</td></tr>
<tr><td></td><td>Contact lab members to determine who would be available. Minimum of 2. Preferably 4 on some dates if doing total station. Identify an alternate.</td></tr>
<tr><td></td><td>Schedule field work days and add to shared calendar

Check to see if any other field work (non-SPR 807) is being planned with any of the survey equipment (TS, Leica GNSS, Riegl Scanner)
Schedule the appropriate number of days for each field trip, plus an equal number of alternative backup days in case of bad weather.

<table>
<tr><th>Field trip</th><th>Sites visited</th><th>Calendar time (includes travel)</th><th>Type of survey</th></tr>
<tr><td>North Coast</td><td>Silver Point, Arch Cape</td><td>3 Days</td><td>TS, TLS</td></tr>
<tr><td>Beverly Beach</td><td>Spencer Creek</td><td>1 – 2 Days</td><td>TLS</td></tr>
<tr><td>South Coast</td><td>Arizona Inn, Hooskanaden</td><td>5 Days</td><td>TS, TLS, UAV</td></tr>
</table>

Include the names of planned personnel for each trip
</td></tr>
<tr><td></td><td>Permits. Verify that permits are up-to-date and physical copy is in good condition.

ODOT Right-of-Way permit, contact Virginia Williams (ODOT)
State Parks Research permit, contact Sara Griffiths (OPRD)
Permit # 037-16, Expires 07/21/2028
If UAS is to be used, notify ODOT UAS contact (and submit request similar to example in the digital appendix) – Also store a copy of the request form in the digital appendix.
</td></tr>
<tr><td></td><td>Inspect equipment:

Is the wagon rolling properly? Tires inflated?
Do the Goal Zero batteries properly hold charge or need to be re-celled?
Test the scanner.
Are the field instrumentation logging data correctly? Do any batteries need to be replaced?
</td></tr>
<tr><td></td><td>Reserve survey equipment

GNSS receivers and total stations may be reserved by sending an email to the geomatics faculty (below) and lab TAs (if known):

Mike Olsen, olsen@oregonstate.edu
Jihye Park, jihye.park@oregonstate.edu
Chris Parrish, christopher.parrish@oregonstate.edu
Bob Schultz, robert.schultz@oregonstate.edu
Chase Simpson (Chase.Simpson@oregonstate.edu)

If using the Leica P40 Scanner, contact the following faculty to ensure it is available:

Yelda Turkan
Mike Olsen, olsen@oregonstate.edu
Ben Leshchinksy
Chris Parrish, christopher.parrish@oregonstate.edu

If performing UAS survey
Contact a certified, trained UAS pilot at OSU to help plan and fly the mission.
</td></tr>
</table>

	○ Prepare ODOT flight request (See example in appendix). ○ Contact Joe Thomas, PLS at Oregon DOT for authorization. ○ Complete appropriate OSU Drone Complier software.
	Reserve lodging • See Table A1: Motel Recommendations • Lodging reservations for specific field trips should be made: ○ North Coast – Seaside ○ Beverly Beach – Newport ○ South Coast – Gold Beach

Table A1. Motel recommendations

Location	Motel Name	Comments	Recommended
Gold Beach	Pacific Reef Resort	• Near restaurants and grocery stores • Very few power outlets • $10 off breakfast at adjacent restaurant	Yes
	Gold Beach Inn	• Used by ODOT staff • Near restaurants and grocery stores	Yes
	Motel 6	• Does not provide shampoo • Far from restaurants and grocery stores • Very few power outlets	No
Newport	La Quinta Inn	• Far from restaurants and grocery stores • Continental breakfast provided	Yes
	Elizabeth Street Inn	• Used by ODOT staff	Yes
Seaside	Best Western: Ocean View Resort	• Near restaurants • Parking space is tight	Yes

SPR 807 – One Week Planning

	Check weather forecast - https://www.nwrfc.noaa.gov/weather/10_day.cgi
	Hold Logistical meeting with all team members • Safety Training • Overview of field work to be completed • Roles and responsibilities • Travel logistics • Ensure cell numbers are available for all members of the field crew (Appendix Z).

	Notify permitting/outside agencies of plans
	• DOGAMI
	  o Jon Allan, jonathan.allan@oregon.gov
	• ODOT Research
	  o Kira Glover-Cutter, Research Coordinator, Kira.M.GLOVER-CUTTER@odot.state.or.us
	  o Curran Mohney, Curran.E.MOHNEY@odot.state.or.us
	• ODOT Right-of-Way Office Contacts:

Site	ODOT District	Contact Name	Contact Email	Phone
SIP,AC	1	Virginia Williams	Virginia.L.Williams@odot.state.or.us	503-325-5853
BB (SPC)	4	Carla Wahl	Carla.S.WAHL@odot.state.or.us	541-757-4182
AZI, HOOSK	7	Jeff Waddington	Jeff.S.WADDINGTON@odot.state.or.us	541-396-1151

• State Parks Research permit, contacts:

Site	State Park Management Unit	Contact Name	Phone Number
Silver Point, Arch Cape	Nehalem Bay	Ben Cox	503-368-5943 x222
Beverly Beach/Spencer Creek	Beverly Beach	Patti Green	541-265-4560
Arizona Inn	Cape Blanco	Casey Nielsen	541-332-6774 x22
Hooskanaden	Harris Beach	Anna Krug	541-469-0224

Permit Expiration Date: _7/1/2028________________________

	Reserve OSU motor pool vehicle: • First priority vehicle is a ¾ -ton pickup truck with 4-wheel drive and a canopy. • Secondary vehicles are a mini-van (North Coast, Beverly Beach) and 12-seat van (South Coast). • The 12-seat van is necessary to hold 2-meter fixed-length tripods for static GPS occupations at Hooskanaden and Arizona Inn, which have poor cell-phone reception. If the 12-seat van must be reserved, ask for the seats to be removed.
	Send reminder email to geomatics faculty about equipment checkout and coordinate with lab manager to arrange a time to check out equipment.
	Start preparing and packing equipment and supplies. • Verify nothing is missing • Verify batteries are charged/start charging batteries • Verify that there is sufficient safety gear for all team members.
	Verify batteries are charged

	Create shopping list and purchase
	• For example, Damprid for each field installation.
	  o Bring 2 extra 10.5 oz. containers
	  o Use 42 oz. bag to refill containers
	  o Replace crystals every field visit (~6 months)

	Make hotel reservations if not already done. (See recommendations in Appendix A)

1.26 EQUIPMENT CHECKLIST

ODOT SPR 807

	Riegl Scanner Case: • Scanner • Power cable (make sure that the two parts of the cable are disconnected) Heavy Duty Tripod (preferably the Leica tripod with the black cap)
	Riegl Camera Case (if using Riegl): • Camera • Camera batteries (Nikon) • Camera-Scanner connection cable (place in a box or padded envelop for protection) • 5 cm tall black 5/8” thread extension • 3 USB Flash Drives • Jump drive (optional) • Camera battery charger
	Leica Scanner Case (if not utilizing the Riegl scanner): • P40 Scanner • Batteries (x 6) • Battery charger (same as for total station and gnss receivers) Heavy duty tripod (preferably the Leica tripod with the black cap)
	2 GNSS Cases: • One preferably being (Leica GNSS #4), which has already been configured for OCRS Oregon Coast Zone • Each with receiver and controller • At least one SIM card • 8 or more Batteries (estimate 4 hours each) • Multi-battery charger 1 (2.0-m) Fixed Height GNSS Pole
	Backpack: • Kestrel environmental meter • Set of hex wrenches • First aid kit • Garbage bags to cover equipment during rainfall • State Parks Permit for SPR 807 • Copies of ODOT IGA Paperwork and Permits (if applicable) • Field Books for each site to be surveyed. • Verizon Ellipsis Jetpack and charger
	SEE OTHER SIDE

	Garden Cart (if using Riegl Scanner):
	• Metal scanner mounting plate
	• 3 Ratcheting tie-down straps
	• Screws for mounting scanner to plate
	  ○ 3 ¼ in. small screws (with allen/hex slot)
	  ○ 1 larger 5/8" bolt screw (with traditional head)

	Miscellaneous: • PK nails • Mallet (Thor) • Flagging tape • Pavement marking chisel • Wooden stakes • Tape measurer • Hand tool kit • Surge protector x2 • Extension cord (optional, but may be useful in hotel with limited power outlets) • Goal zero batteries with chargers (if using Riegl Scanner) • Microfiber clothes to wipe down equipment • Coarse clothes to wipe down cases/tripod legs • Brush to clean tripod legs • Walkie Talkies x4 (and charger).
	Lenovo Laptop Case: • Laptop • Mouse • Charging cable
	Digital Camera • Canon Digital SLR Rebel T5i • Batteries
	Maintenance items for SPR 807 Instruments (See Vol II): • Silicon sealant • Electrical tape • Damprid (or other desiccant) • Wire strippers • Multimeter

1.27 PRIMARY CREW CONTACT INFORMATION

Name	Email	Phone	Cell	Role
OSU				
Michael Olsen	Michael.olsen@oregonstate.edu	(541) 737-9327	(801) 244-4836	Project PI – technical lead for field surveys
Ben Leshchinsky	Ben.Leshchinsky@oregonstate.edu	541-737-8873	(302)547-4146	Co-PI, technical lead for instrumentation
Matt O'Banion	obanionm@oregonstate.edu	-	(530) 601-3477	Party Chief, Field Survey, Processing
Michael Bunn	bunnmi@oregonstate.edu	-	(760) 614-0066	Party Chief, Field Survey
Andrew Senogles	senoglea@oregonstate.edu	-	(541) 224-6757	Field Survey, Processing
Marian Jaimeson	jamiesom@oregonstate.edu	-	-	Field Survey, Processing
Erzhuo Che	chee@oregonstate.edu	-	(541)330-8336	Field Survey, Processing
Bryce Berrett	berretb@oregonstate.edu			
DOGAMI				
Jonathan Allan	Jonathan.Allan@dogami.state.or.us	(541) 574-6658	-	Co-PI, Coastal Geomorphologist
ODOT				
Kira Glover-Cutter	Kira.M.GLOVER-CUTTER@odot.state.or.us	(503) 986-2851	-	ODOT Research Coordinator
Curran Mohney	Curran.E.MOHNEY@odot.state.or.us	(503) 986-3490		ODOT Project Champion, Engineering Geologist
Former Crew Members				
Mahyar Sharifi-Mood	mahyar.sh@gmail.com	-	(917)703-8456	Field Survey

1.28 ADDITIONAL POTREECONVERTER OPTIONS

(Text from PotreeConverter Github):

```
-h [ --help ]                     prints usage
-p [ --generate-page ] arg             Generates a ready to use web page with the given name.
-o [ --outdir ] arg                    output directory
-s [ --spacing ] arg                   Distance between points at root level. Distance halves each level.
-d [ --spacing-by-diagonal-fraction ] arg
                                  Maximum number of points on the diagonal in the first level (sets spacing). spacing = diagonal / value
-l [ --levels ] arg                    Number of levels that will be generated. 0: only root, 1: root and its children, ...
-f [ --input-format ] arg              Input format. xyz: cartesian coordinates as floats, rgb: colors as numbers, i: intensity as number
--color-range arg
--intensity-range arg
--output-format arg                    Output format can be BINARY, LAS or LAZ. Default is BINARY
-a [ --output-attributes ] arg         can be any combination of RGB, INTENSITY, CLASSIFICATION and NORMAL. Default is RGB.
--scale arg                            Scale of the X, Y, Z coordinate in LAS and LAZ files.
--aabb arg                             Bounding cube as "minX minY minZ maxX maxY maxZ". If not provided it is automatically computed
--incremental                          Add new points to existing conversion
--overwrite                            Replace existing conversion at target directory
--source arg                           Source file. Can be LAS, LAZ, PTX or PLY
```

```
# convert data.las and generate web page.
./PotreeConverter.exe C:/data.las -o C:/potree_converted -p pageName

# generate compressed LAZ files instead of the default BIN format.
./PotreeConverter.exe C:/data.las -o C:/potree_converted --output-format LAZ

# convert all files inside the data directory
./PotreeConverter.exe C:/data -o C:/potree_converted

# first, convert with custom bounding box and then append new_data.las afterwards.
# points in new_data MUST fit into bounding box!
./PotreeConverter.exe C:/data -o C:/potree_converted -aabb "-0.748 -2.780 2.547 3.899 1.867 7.195"
./PotreeConverter.exe C:/new_data.las -o C:/potree_converted --incremental

# tell the converter that coordinates are in a UTM zone 10N projection. Also, create output in LAZ format
./PotreeConverter.exe C:/data -o C:/potree_converted -p pageName --projection "+proj=utm +zone=10 +ellps=GRS80 +datum=NAD83
+units=m +no_defs" --overwrite --output-format LAZ

# using a swiss projection. Use http://spatialreference.org/ to find projections in proj4 format
./PotreeConverter.exe C:/data -o C:/potree_converted -p pageName --projection "+proj=somerc +lat_0=46.95240555555556
+lon_0=7.439583333333333 +k_0=1 +x_0=600000 +y_0=200000 +ellps=bessel +towgs84=674.4,15.1,405.3,0,0,0,0 +units=m +no_defs" –
overwrite
```

Modified index.html file (Modifications are highlighted in yellow)

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="utf-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta name="description" content="">
    <meta name="author" content="">
    <title>Potree Viewer</title>

        <link rel="stylesheet" type="text/css" href="libs/potree/potree.css">
        <link rel="stylesheet" type="text/css" href="libs/jquery-ui-1.11.4/jquery-ui.css">
        <link rel="stylesheet" href="libs/openlayers3/ol.css" type="text/css">

        <a style = "float:right; right:10px; top:5px; position:relative; z-index:20;" id="GEERLogo" href="http://www.geerassociation.org/"
target="_blank"> <img src="http://research.engr.oregonstate.edu/lidar/pointcloud/TrainCulvertNZ/geerlogo.png" height="125"
width="125"/></a>
        <a style = "float:right; right:35px; top:5px; position:relative; z-index:20;" id="NSFLogo" href="http://www.nsf.gov" target="_blank">
<img src="http://research.engr.oregonstate.edu/lidar/pointcloud/TrainCulvertNZ/nsf4.gif" height="115" width="115"/></a> //Code for adding
NSF and GEER logos in upper right hand corner

  </head>
```

```
<body>

		<script src="libs/jquery-2.1.4/jquery-2.1.4.min.js"></script>
		<script src="libs/jquery-ui-1.11.4/jquery-ui.min.js"></script>
		<script src="libs/three.js/build/three.js"></script>
		<script src="libs/other/stats.min.js"></script>
		<script src="libs/other/BinaryHeap.js"></script>
		<script src="libs/tween/tween.min.js"></script>
		<script src="libs/d3/d3.js"></script>
		<script src="libs/proj4/proj4.js"></script>
		<script src="libs/openlayers3/ol.js"></script>

		<script src="libs/potree/potree.js"></script>

		<script src="libs/plasio/js/laslaz.js"></script>
		<script src="libs/plasio/vendor/bluebird.js"></script>
		<script src="libs/potree/laslaz.js"></script>

		<script src="libs/plasio/js/laslaz.js"></script>
		<script src="libs/plasio/vendor/blu-ebird.js"></script>
		<script src="libs/potree/laslaz.js"></script>


  <div class="potree_container" style="position: absolute; width: 100%; height: 100%; left: 0px; top: 0px; ">

			<div id="potree_render_area">
				<div id="potree_map" class="mapBox" style="position: absolute; left: 50px; top: 50px; width: 400px; height:
400px; display: none">
					<div id="potree_map_header" style="position: absolute; width: 100%; height: 25px; top: 0px;
background-color: rgba(0,0,0,0.5); z-index: 1000; border-top-left-radius: 3px; border-top-right-radius: 3px;">
					</div>
					<div id="potree_map_content" class="map" style="position: absolute; z-index: 100; top: 25px;
width: 100%; height: calc(100% - 25px); border: 2px solid rgba(0,0,0,0.5); box-sizing: border-box;"></div>
				</div>

				<!-- HEADING -->
				<div id="potree_description" class="potree_info_text"></div>
			</div>

			<div id="potree_sidebar_container"> </div>
  </div>

		<script>

			var onPointCloudLoaded = function(event){
				// do stuff here that should be executed whenever a point cloud has been loaded.
				// event.pointcloud returns the point cloud object
				console.log("a point cloud has been loaded");
			};

			viewer = new Potree.Viewer(document.getElementById("potree_render_area"), {
				"onPointCloudLoaded": onPointCloudLoaded
			});

			viewer.setEDLEnabled(false);
			viewer.setPointSize(3);
			viewer.setMaterial("RGB");
			viewer.setFOV(60);
			viewer.setEDLStrength(2);
			viewer.setPointSizing("Fixed");
			viewer.setQuality("Squares");
			viewer.setPointBudget(7*1000*1000); //Loads more points

			document.title = "PotreeViewer";
			viewer.setEDLEnabled(true); //Loads viewer page with EDL lighting turned on
			viewer.setShowSkybox(false);
			viewer.setMaterialID(Potree.PointColorType.RGB);
```

```
			viewer.setDescription('Terrestrial lidar of the Waima Overbridge (#0838) and culvert located in Kaikoura, New Zealand. Data collection performed by <a href="http://research.engr.oregonstate.edu/geomatics/" target="_blank"> Oregon State University </a> on 12/04/2016 following the M7.8 Kaikoura Earthquake (11/14/2016)'); //Text description of data being visualized

			viewer.loadSettingsFromURL();

			//viewer.setDescription("Potree 1.4RC. Use this for testing purposes only! Check <a href='https://twitter.com/m_schuetz' target='_blank'>here</a> for new updates.<br>"
			//		+ "Report issues on the <a href='https://github.com/potree/potree' target='_blank'>github repository</a> or <a href='mailto:mschuetz@potree.org' target='_blank'>mschuetz@potree.org</a><br>"
			//		+ "Point cloud courtesy of <a href='http://sigeom.ch/' target='_blank'>sigeom sa</a>"
			//
			//);

			viewer.addPointCloud("pointclouds/index/cloud.js");

			viewer.loadGUI();

		</script>
  </body>
</html>
```