Bethel Cemetery Project:

Procedures and protocols for structure from motion photogrammetry on historic burials

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1 Introduction

This manual explains the procedures and protocols of photo capture for of historic burials. Developed specifically for the Bethel cemetery project, the procedures outlined in this manual are tailored to the project's particular needs for documentation.

In an ideal situation there will be at least one or two teams of two people who are designated for photocapture. At least one person in each team should have some experience taking photos for photogrammetry. Each person involved should read through this manual before getting started.

This manual covers the following topics:

- Equipment
- Paperwork and documentation
- Preparation, photocapture, and georeferencing burials
- In-field photo-alignment check, file label and data redundancy protocols, and documentation crosscheck

2 Objectives

The general goal of the excavation at Bethel cemetery is to excavate and document over 300 (possibly 400) burials at Bethel cemetery previously detected during geophysical survey of the site. For this project, structure from motion (SfM) photogrammetry will be used in lieu of excavation drawings traditionally used for documentation. The **objective** is to produce scale 3D photorealistic models of each burial that also contain geospatial data. These models are intended to have the equal of better precision than a traditional field drawing or hand drawn map on graph paper. They will be digitally measurable and analyzable after excavation has ended.

3 Equipment

This section includes a description of the equipment provided for the SfM photogrammetry component of the Bethel cemetery project. Two photogrammetry kits are provided so that two photogrammetry teams can be working simultaneously.

3.1 Camera

For this project, personnel are provided with a Nikon D5600 DSLR camera with an 18 – 55 mm lens. In addition, the following accessories are provided:

- A tripod / monopod (with carrying case)
- SD cards
- Camera bag
- A set of various camera lenses (UV, Circular polarizing, etc.)

3.2 Scales and color checker

Scale bars purchased through Cultural Heritage Imaging (CHI) are provided with each photogrammetry kit. There should be ten scale bars included in a set. Two of each of the following lengths are provided: 1 meter, ½ meter, ¼ meter, 18 cm, 5 cm (Image 1). These scales are hand calibrated and the coded targets facilitate georeferencing and scaling of the resultant 3D models. Additionally, a color checker should be included in the kit.

Image 1. Scale bars from Cultural Heritage Imaging (CHI). Image above is from their website.

3.3 Photo board

Mini-white boards and dry-erase markers are provided with each kit. This will be used to record context information upon photocapture.

3.4 Total station (TS)

A total station will be on site for general mapping purposes. For the photogrammetry, it will be used to record the coordinates of each burial within the broader spatial context of the site.

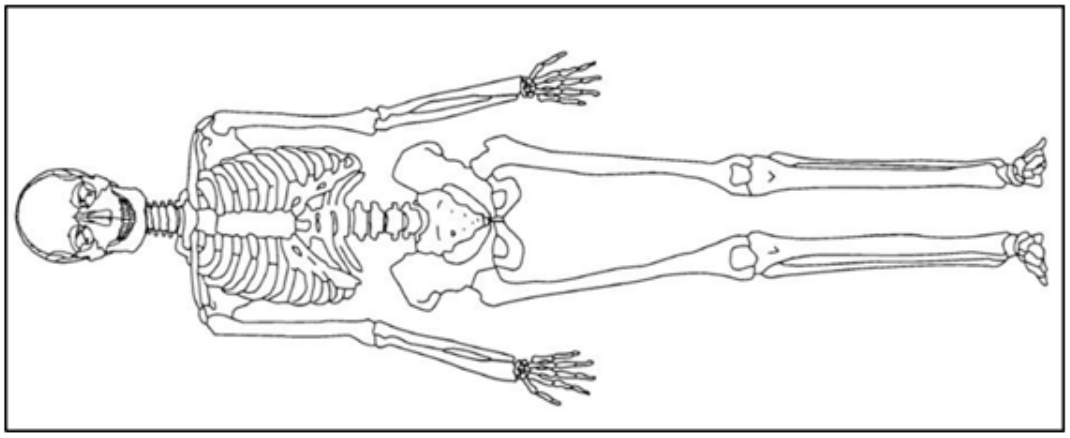
4 Orientation to the paper work

Burial forms will be filled out for each excavation. The final page of the form will be strictly for photogrammetry documentation (Image 2 below).

Photogrammetry

Sketch the approximate location of each photogrammetry scale and control point with a circle around each (e.g., C.P. #1, C.P. #2, etc.). Indicate grid north and record the northings, eastings, and elevations for each control point in the table below.

Control Point	Northing	Easting	Elevation



Photogrammetry Comments: _____

_____

_____

_____

In-field Alignment Check (circle one): Yes No

Camera No.: _____ **S.D. Card No.:** _____ **Photoset/Frames:** _____

Lighting (circle one): Direct Indirect Artificial

Photographer: _____ **Date:** _____

Cardno Burial No.: _____ Excavators: _____ 5

Image 2. Photogrammetry section of burial form.

5 Preparing the burial for photocapture/documentation

Once the excavators have finished preparing the burial for documentation, two important things must be done. (1) The placement of scale bars, and (2) recording the context using a photo board.

Exterior scales should be placed on the ground surface next to the excavation excavation. Two meter long scales will be positioned on the long sides of the excavation, and two ½ meter scales on the shorter sides (Image 3).

Image 3. Photo showing placement of CHI scale bars.

Interior scales should be placed in consultation with the bioarchaeologist in charge of the excavation. They can be placed anywhere in the interior floor of the excavation.

Once the scales are in place the relative locations of the scale bars should be recorded on the burial form by drawing in the scale bars on the diagram provided. Once shooting begins, special care must be taken that the scales do not move until the photocapture is finished.

The photo board should obtain the following information before the photocapture begins: burial number, block number, date, excavator initials, photographer's initials (Figure 1). As described in the next section, the burial with the photo board will be the first photo taken of the photoset.

Place the **color checker** on the exterior ground surface of the excavation. It will be the focus of the second photo taken in the photoset.

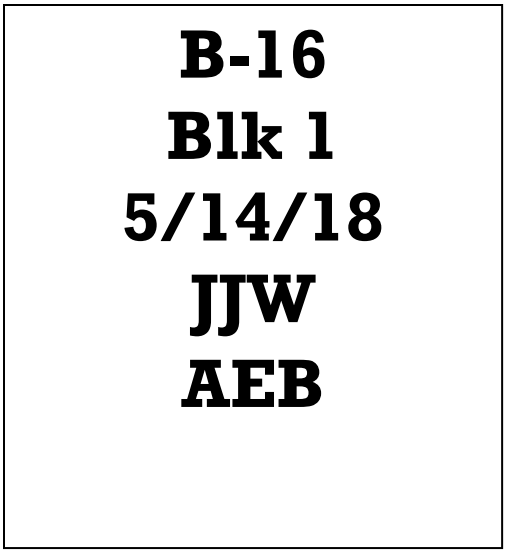


Figure 1. Example of photo board with informational text.

Important: Any complications, challenges, or deviations from the norm (that do not require a complete recapture) should be recorded in the comments section on the burial form. Clear the vicinity before shooting. A wide birth should be given while photocapture is taking place. People moving around that are captured in the photos may affect the photo alignment (this includes legs). Not all of the photos will be taken at a visual extent that will capture the broader area, but to avoid this, clear the vicinity before capturing the burial.

6 Taking the photos

Two methods of taking photos will be discussed in the following section, (1) handheld and (2) tripod/monopod. In either case, the camera should be set to **Aperture mode** with the depth of field set to f-11. Depth of field can be slightly decreased/increased as needed, but f-11 is a safe bet for this kind of shooting. The other numbers should be checked as well. The shutter speed should be relatively fast (1/30 – 1/60 or faster) and the ISO should be within the range of 100 - 600. Ensure that a new memory card is inserted. Set the camera to record in RAW and JPEG. Shooting will be done without changing the zoom on the lens. Keep it set to 18mm.

Important: Before taking any photos that would be considered part of the photoset for alignment, be sure to take a broad context photo of the burial with the photo board in the frame. The photo board must be legible. After taking a photo of the entire burial with the photo board, take a photo of the color checker allowing it to fill the center of the frame.

6.1 Handheld method

It is important to note that this method requires good lighting and a steady hand. The burials will be lit by indirect sunlight and it is likely that this will be the only lighting configuration for most burials. This should provide enough lighting that the use of a tripod will not be required. However, depending on the intensity of the some or other factors such as depth of the burial, the handheld method may not be the best choice.

It is important to check your photos during and after photocapture to ensure good photo quality of the photos in the photoset. This includes checking for sharp and crisp lines and features throughout the entire photo. Additionally, this also includes checking for graininess and noise.

First, take broad contexts shots of the burial (at least 4-6) (Image 4). This will help the overall alignment and ensure that you are capturing enough of the surrounding ground surface to georeference the burial via the exterior scales. Keep in mind that the exterior scales are also part of the object of capture.

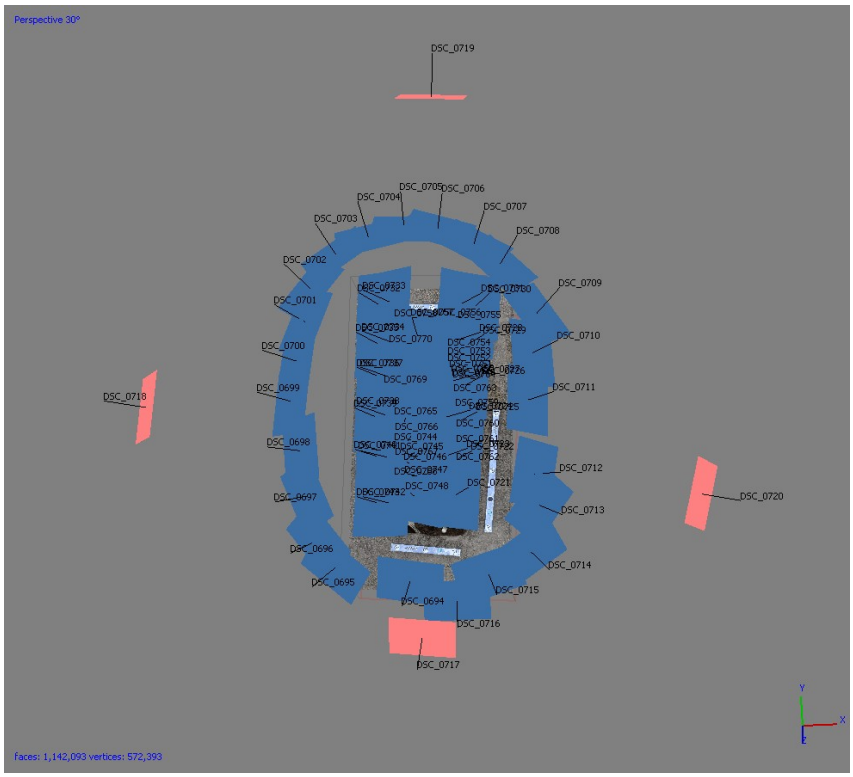


Image 4. Example of contexts shots described in the text.

Second, take a full set of shots at a standing elevation moving around the entire burial at a 45-65 degree angle (Image 5). Make the opposite crease where the wall of the burial meets the interior surface your objective of coverage. Then, take photos moving the camera position along the edge of the trench. Make the opposite crease again the objective as well as the floor of the burial (with individual). It may require two shots per position to cover the burial. Take a steady stance as to reduce the amount of shakiness.

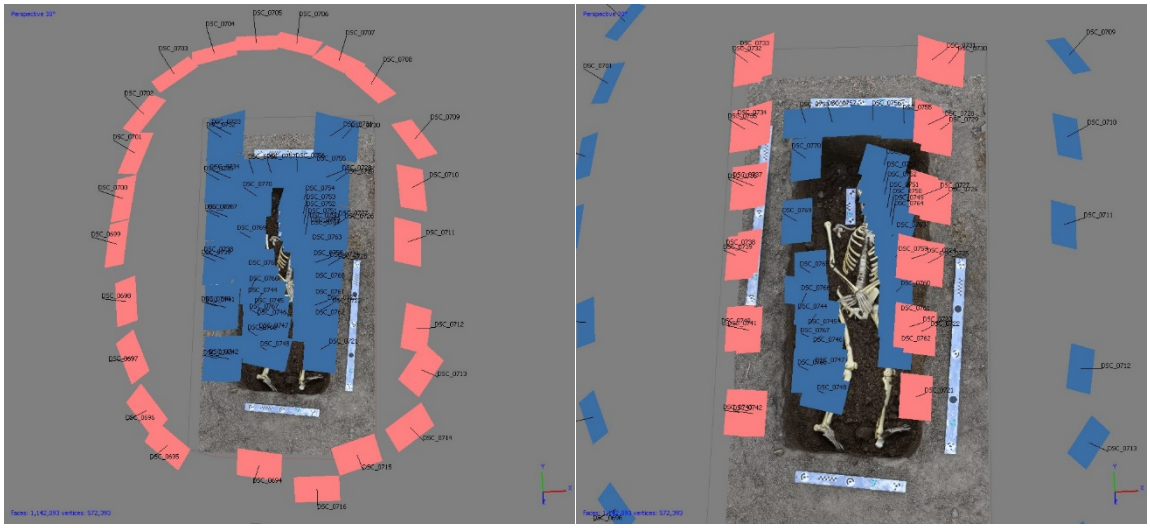


Image 5. Example of standing shots described in the text. Note: (right) two different angled shots photos at each location when shooting positions that follow the edge of the trench.

Third, take kneeling shots of the interior of the grave focusing on capturing the specimen. Take photos in positions along the trench and along the ends (Image 6). Take special care to cover features indicated by bioarchaeologists at the excavation. Be sure to brace your arms against your thighs for support to reduce shakiness (Image 7). If there is a feature that is too deep for kneeling photos, use the monopod (*see* 6.2 for details).

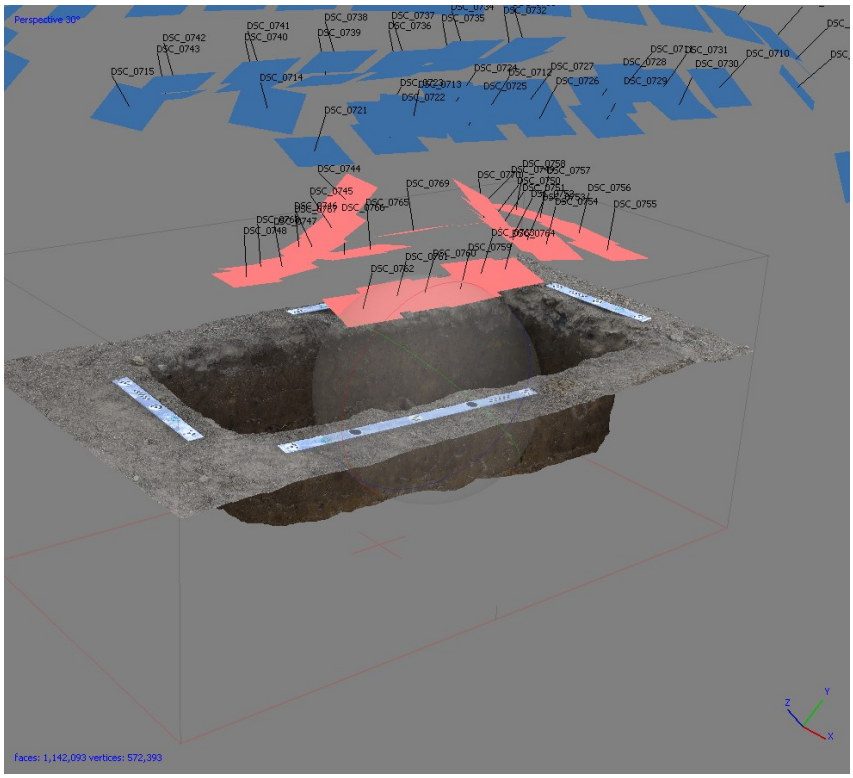


Image 6. Example of kneeling shots described in the text. Take special care to cover features indicated by bioarchaeologists at the excavation.

Image 7. Example of bracing positions at kneeling height. Use legs to brace arms.

Important: After photocapture, check over the photoset to ensure that the photos are of good quality. The photos should show crisp and clear definition over the whole photo. If there is blurriness over the whole photo, it is likely that the photo was taken while

shaking. If there is blurriness on only a portion of the photo, depth of field should be increased a bit to accommodate and the photo(s) should be retaken. If the photos are grainy or noisy, direct or artificial lighting sources should be explored. If shakiness is an issue it may be best to take the photos using the tripod method.

6.2 Tripod/monopod method

The method of shooting with a **tripod** is the same as the handheld method except with the addition of using a tripod for all standing shots and kneeling shots. By placing the tripod in the locations where you wish to take photos and adjusting the height of the tripod, one can accomplish the same task. The only drawback is that it may take longer to capture the photos.

One addition to the process, is the use of Nikon's Snapbridge app or a remote shutter release device. The app can be downloaded to either an Android or iOS system. The reason to use the app/remote release is to cut down on the shake that is introduced by physically pressing the release.

If closer photos of the burial are needed than the tripod method can provide, handheld photos or monopod photos can supplement. **Monopod** photos are best accomplished with a team of at least two people. One to hold the camera and monopod, and one to hold the device with Snapbridge for the photographer who will also press the remote release button. The monopod can be used as an extension to get deeper into the burial. Special care must be used as to not disturb the burial itself. Additionally, the monopod must be well braced to get a steady shot. As the photographer gets into place the assistant should have the device nearby so that the photographer can adjust the camera to get the best shot. Once in position, the assistant will hit the release.

Important: After photocapture, check over the photoset to ensure that the photos are of good quality. The photos should show crisp and clear definition over the whole photo.

6.3 Adapting photocapture

It is possible that photocapture will not be as simple as described in the steps above. The procedure may need to be adapted for a situation that is not ideal. If this is the case, it is not a problem to improvise a bit. Just be sure to get full coverage of overlapping photos (60 – 80%) of the burial including the scales. As described in the procedures above, be sure to cover all angles and that no part of the burial is obscured. It helps to take photos systematically as to not guess whether or not coverage was achieved over certain areas. Context shots are important when improvising. They act as a safety net, ensuring reconstruction.

7 Shooting Control Points (CPs)

After photocapture, control points, or CPs, must be taken. At least six to eight points should be taken per burial. Using the exterior scale bars, choose well-spaced 12-bit targets to shoot in as CPs using the total station. The 12-bit targets are the markers that will auto-register in Agisoft Photoscan software (Image 8). The small prism should be used to shoot in the targets chosen. When shooting the targets use the numbers printed on the scale bars themselves as their numerical designation in the total station and on the burial forms.

Image 8. Burial showing targets (markers) as they are auto-registered in Agisoft Photoscan software.

Important: Be sure to hold the scale in place with one hand while holding the prism with the other. This will ensure that the scale bar does not move while taking CPs (Image 9). Additionally, after shooting in CPs, record the relative locations of the targets recorded on the burial form. Also, complete any other instructions the burial form may indicate.

Image 9. Holding the prism while securing the scale bar.

8 Final steps

8.1 File labeling protocols

A computer loaded with Agisoft Photoscan software will be available for on-site use. The photoset from the burial should be copied to an external hard drive and the designated shared folder.

On the **external hard drive**, a project folder should be established called 'Bethel Cemetery Photogrammetry Data.' A new folder within this folder should be created using the burial number as the file name. Within the burial number folder, a new folder called 'photos' should be created. This is where the photos should be copied.

Files should be copied into a **cloud folder** called 'Bethel Cemetery Data.' A new folder within this folder should be created using the burial number as the file name. Within the burial number folder, a new folder called 'photos' should be created. This is where the photos should be copied (identical to the file structure above).

Example: *Bethel Cemetery Data-->B-X-->photos-->[all photos copied here]*

The shared folder is used to pass photosets between field personnel and lab personnel. Copying the photoset into the shared folder in addition to copying the photos to an external hard drive will ensure data redundancy and enable the photoset to be accessible for postprocessing. On site wifi can be used to sync the shared folder so that the files are indeed accessible from a remote location.

SD cards should not be reused. File SD cards away accordingly and reload the camera with a new SD card. Small 1 x 1 inch, 2 mil, plastic artifact bags work well to store individual SD cards to protect from dust in the field.

Important: Do not delete any photos from the SD card

8.2 In-field alignment

Once the photoset has been copied into the shared folder an alignment should be performed in Agisoft Photoscan. The alignment should be run on **high** with the key point and tie point limits set to **40,000 and 10,000** respectively. If the alignment is not successful, photocapture must be redone. Note that an image quality estimation can be performed by right clicking one of the photos in the image pane and selecting 'estimate image quality' if there is significant trouble aligning photos. This will help determine the problematic shots.

8.3 Paperwork and crosscheck

After photocapture and recording CPs, take a moment to check that all paperwork is complete. Have one other team member crosscheck your work. After crosscheck, notify the bioarchaeologist that they may move forward with excavation. Your job is done! …until the next burial is ready.