UT10517

3D Data Gathering for AutoCAD Utility Design Using ReCap and InfraWorks-Seeing Underground

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Learning Objectives

- Discover the different capture methods for 3D data gathering
- Overview using electromagnetic locating and GPR, differences, pros and cons
- Overview using LiDAR and Photogrammetry, differences, pros and cons
- Discover the deliverables-how can it help you?

Description

This class will cover data-gathering methods related to utility design. Typical data gathering may include topographic survey, photos, and site visits. Using all the available methods to gather previously unreachable data and importing it into design is the "Future of Making Things." This is done using current methods, i.e., traditional survey, incorporating 3D models from photogrammetry, LiDAR (light detection and ranging), GPR (ground penetrating radar), and electromagnetic locating. By using some or all of these technologies and harnessing them through Autodesk, Inc., software, we can present a view both above and below the ground, enabling users to see things in a whole new way. This class will introduce basic capture concepts for LiDAR, GPR, photogrammetry, and electromagnetic locating to create a 3D model using Autodesk™ software. We can import these models into InfraWorks software to be incorporated into design. We will briefly go over using Autodesk 360 cloud-computing platform and Memento software as well.

Your AU Experts

Forrest Roy has worked in the underground utility industry for over 15 years. His main area of focus has been on damage prevention and underground utility locating. Since taking over the locate department at Anchorage Municipal Light and Power, he has been focused on using technology to enable crews to envision underground assets before excavation occurs. In 2014 Anchorage Municipal Light and Power won the Small Project Division in the Autodesk Excellence in Infrastructure competition for work on 3D modeling of underground vaults.

Aaron Mason has been using AutoCAD 20 years and worked in engineering support for over 10 years. As the Lead Drafter for Anchorage Municipal Light and Power for the past 4 years he has been responsible for defining and maintaining AutoCAD standards updating the GIS system, producing engineering drawings, researching and implementing new strategies for design software and coordinating field data gathering to incorporate into engineering designs. He is currently responsible for incorporating data gathered through reality capture into design software to augment the engineering design process.

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Introduction

About Anchorage Municipal Light and Power

AML&P provides safe, reliable and affordable electric utility service to over 30,000 residential and commercial customers in its roughly 20-quare-mile service territory. AML&Pserves commercial, university and medical customers in the Downtown and Midtown business districts, as well as industrial loads in Ship Creek and Anchorage Port areas and residents in some of Anchorage's oldest neighborhoods. In addition, AML&P provides bulk power to Joint Base Elmendorf-Richardson and sells electricity to other Alaska Railbelt utilities. AML&P is owned by the Municipality of Anchorage, which purchased the distribution system from the privately owned Anchorage Power & Light Co. in 1932. AML&P is subject to the Regulatory Commission of Alaska.

Since 1932, AML&P has grown to include generation and transmission, as well as upgraded and expanded distribution. The utility has a one-third working interest in the Beluga River gas field, making it one of the only vertically integrated natural-gas-fired utilities on the West Coast. The gas field provides AML&P with a secure and reliable source of fuel for most of its needs through 2018. About 15 percent of AML&P's generation is from renewable hydroelectric resources and the utility has been investing millions in upgrading its aging facility to include clean and efficient natural-gas-fired generation. AML&P is building a 120-megawatt thermal generation plant in east Anchorage which will be one of the most energy efficient thermal-generation plants in the world upon completion in 2016.

How we got here

During the Autodesk University 2013 presentation for Denver International Airport, their use of 3D modeling to express their assets underground captured our attention. That same year we saw the advances that had been made in reality capture and photogrammetry. We were impressed by the results. Based on these early experiments we identified underground vaults as the best starting point to capitalize on these new processes.

In 2014, we were awarded the Infrastructure in Excellence Award (Small Projects Division) for our work using reality capture to model underground vaults. From that as our starting point, we expanded our use of photogrammetry to include exterior, topographic, and trench models. Additionally we now use handheld 3D scanners inside our vaults, terrestrial laser scanners in our substations, and have incorporated our survey and underground utility locates into 3D design.

It is an exciting time for 3D reality capture. Industries are being shaped by the power of this new technology. At the utility level, there is a shift in how information is captured, communicated, and applied in the field and office. Traditional approaches to data gathering are limited, inconsistent, difficult to efficiently incorporate into design, and are prone to errors and ambiguity. Improved methods allow faster comprehension of higher quality data.

We will be focusing on utility engineering design and the as-built process. While there may be some similarities to structural, architectural, mechanical, or artistic methods, these will not be our primary focus. We will cover the use of survey, LIDAR, photogrammetry, ground penetrating radar and electromagnetic locating from a 3D perspective.

Survey

The foundation of traditional design is the site survey. Land surveyors establish horizontal and vertical survey control, assign coordinate systems, survey property boundaries and topography.

These surveys map out the terrain including vegetation, landmarks, streets, sidewalks, buildings, utilities, fences etc. Design locates are requested and participating utilities will mark out their underground facilities. Surveyors include these marks in their drawings.

Each feature is recorded as a single point in three dimensions (x,y,z coordinates). They are assigned survey codes corresponding to their attribute. Survey software and Civil3D are used to connect automatically generate linework for AutoCAD drawings.

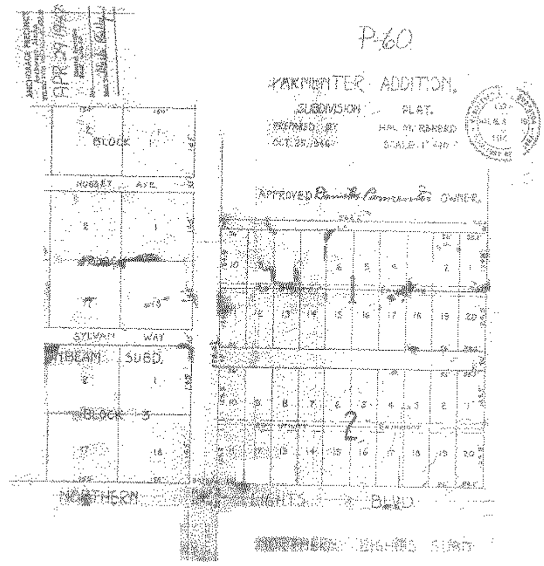


FIGURE 1 SURVEY PLAT

The civil/utility world is much like an iceberg, what you see on the surface is often just a hint of a much larger and more complex infrastructure beneath your feet. For underground utilites this may mean electromagnetic locates, pot holing or ground penetrating radar (or a combination of the three). The only other source of information is as-built record data or unreliable nature of institutional knowledge.

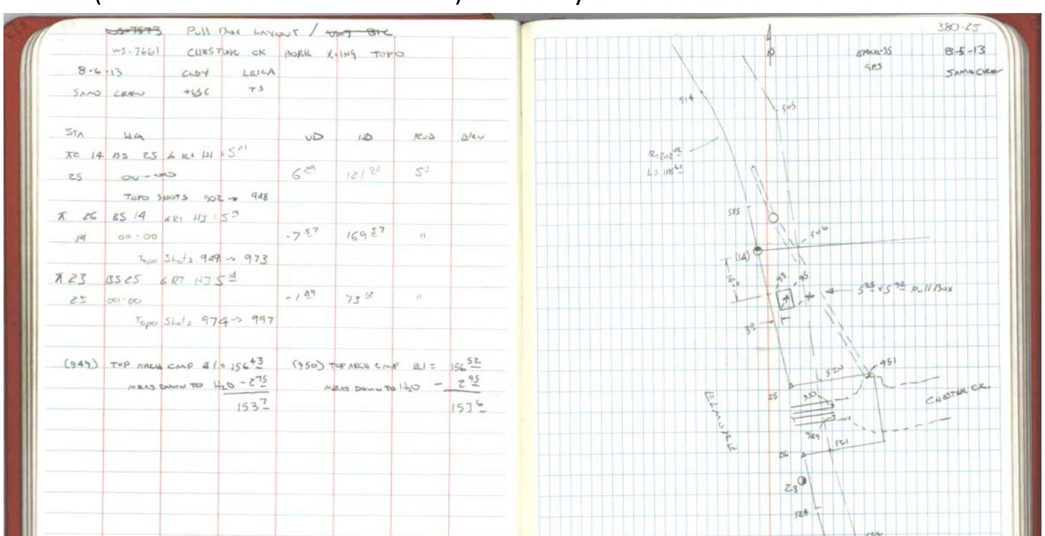


FIGURE 2 SURVEY RECORD FROM FIELDBOOK

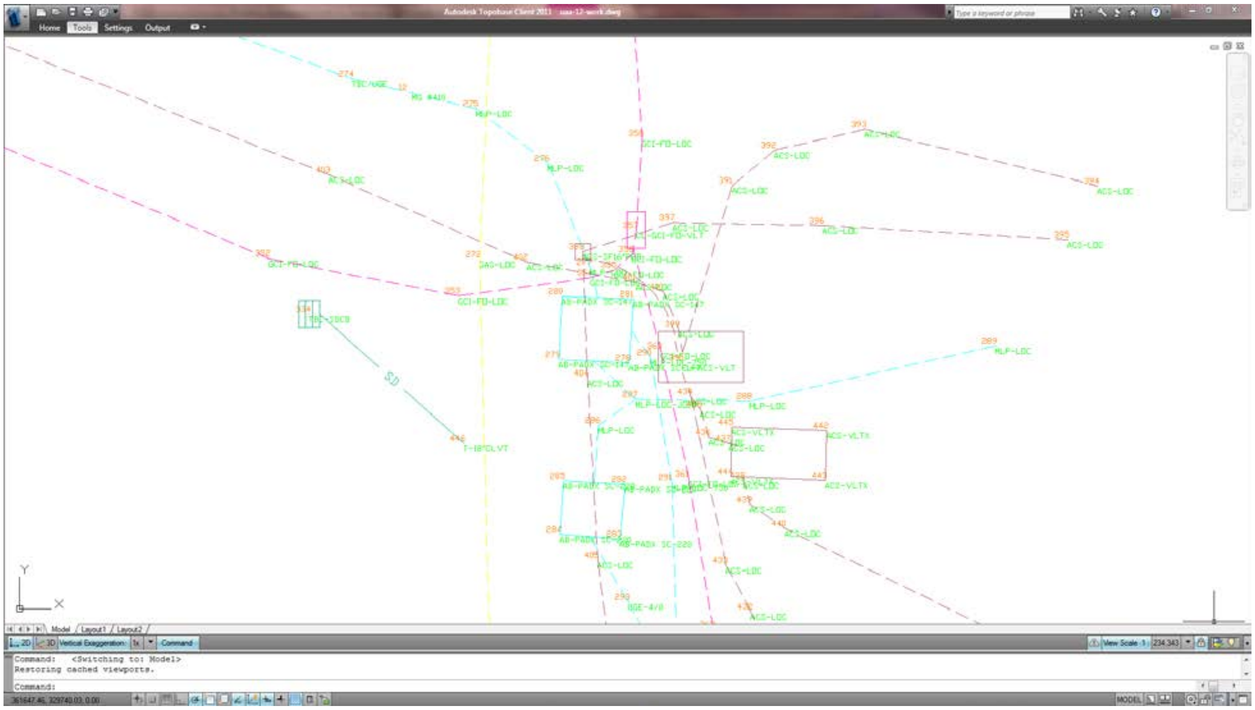


FIGURE 3 SURVEY LINE WORK IN AUTOCAD

Electromagnetic Locating

Laws in the United States and Canada require excavators (of any type) to request underground utility markings from their local utilities. This is usually done through a state or province wide one call center. Some utilities perform these locates themselves and some contract this work out. Utilities are marked according to the American Public Works Association (APWA) uniform color code (or the Canadian Public Works Association-CPWA-in Canada).

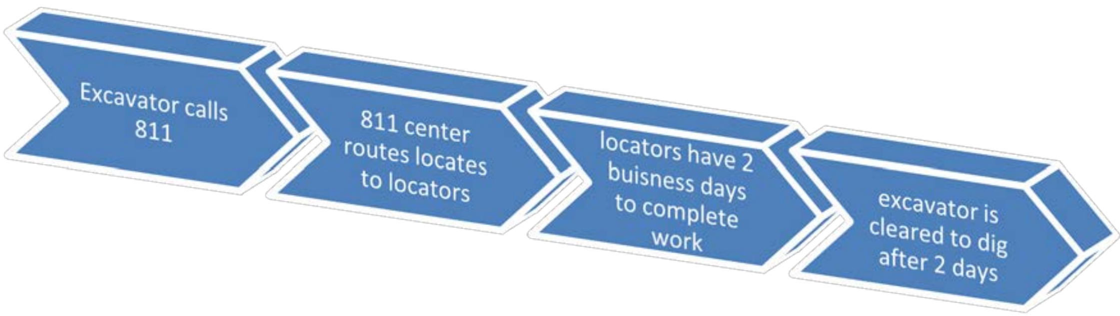


FIGURE 4 UNDERGROUND LOCATE PROCESS

	White - Proposed Excavation
	Pink - Temporary Survey Markings
	Red - Electric Power Lines, Cable Conduit and Lighting Cables
	Yellow - Gas,Oil,Petroleum and Gaseous Materials
	Orange - Telephone, Cable TV, Communication, Alarm and Signal Line
	Blue - Potable Water
	Green - Sanitary Sewers, Storm Sewers and Drain Lines
	Purple - Reclaimed Water, Irrigation And Slurry Lines

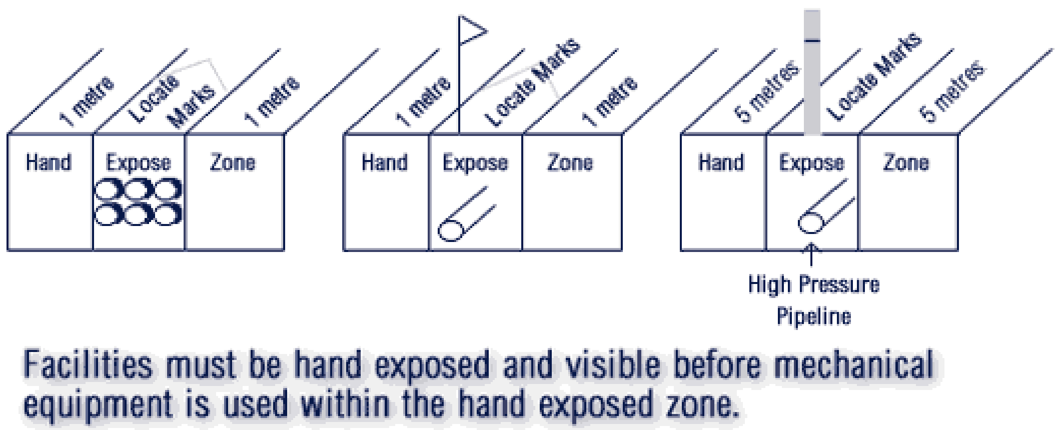


FIGURE 5 APWA COLOR CODE AND TOLERANCE ZONES

Once utilities are located, excavators must use non-mechanical methods (hand digging or vactor excavation etc.) to dig within the tolerance zone of the marks. This varies based on local code but is typically 24 horizontal inches from the edge of the marks.

There are two standard methods of utility locating; passive and active. In the traditional method, a transmitter is connected to the desired conductor (or inducted indirectly as is the case with electrical cables) and the readings are then read by a receiver. The best case scenario, is that the locator has knowledge of which way the conductor is travelling and there are few other utilities in the area. If an area is congested, the magnetic field being generated by the transmitter is interfered with, making it difficult for the technician to accurately identify the target line. Soil conditions and quality of the conductors can also impact the results. Weather can also be a significant factor. Many times rain, snow or traffic can disrupt marks before the surveyor can record them.

FIGURE 6. SIMULATED MAGNETIC FIELD

The quality of the data derived from locates can be suspect at times. Many times, locators cannot or will not have access to the entire data set for which their locating. For example, a locator may be locating a duct structure and not know its contents. Or they may mark a single conductor when in fact a spare pipe is laid with that conductor. They may not call out abandoned cables if their records do not show them.

Depth measurements are not typically given by locators to outside companies. We use our internal survey and locating departments to coordinate data, facilitate research, and work directly with other utilities to gather this information.

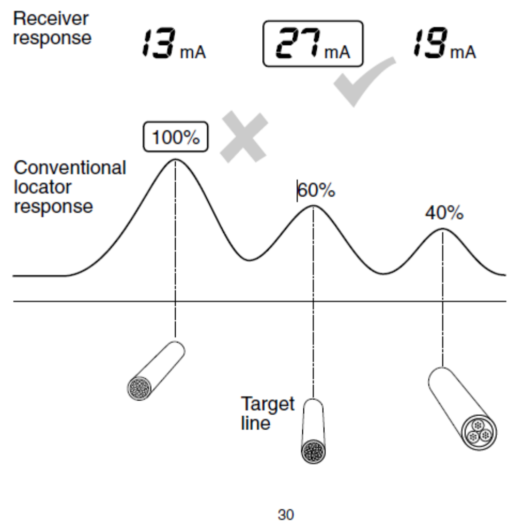


FIGURE 8 SIMPLIFIED VIEW OF DIFFICULTY DETERMINING TARGET CONDUCTOR

FIGURE 7 IT IS DIFFICULT TO ACCURATELY PORTRAY DATA WITH LOCATES

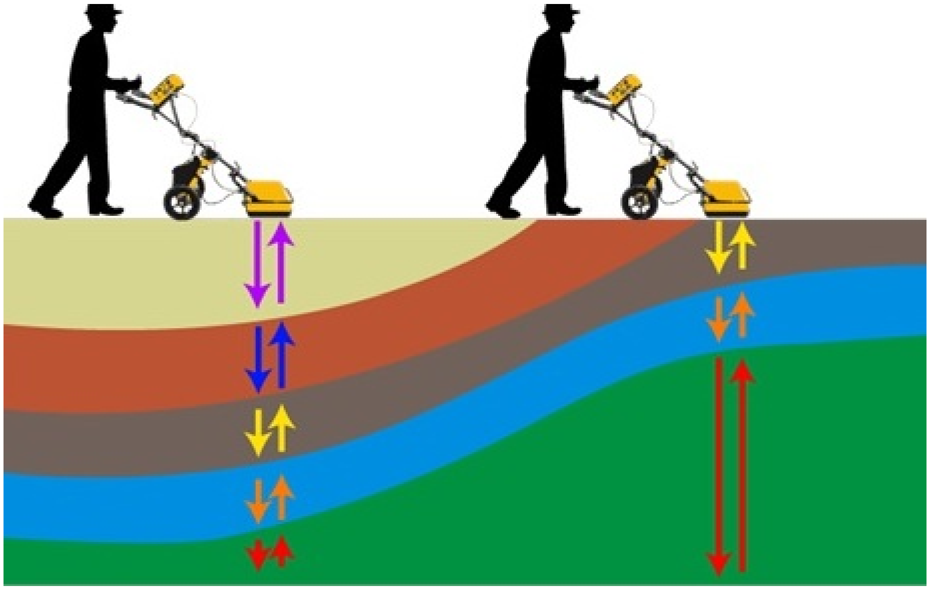
Ground Penetrating Radar

Ground Penetrating Radar is a non-destructive method that uses radar pulses to image the subsurface and is often used for applications such as archeology or utility locating. This method is frequently used in tandem with electromagnetic locating and both have similar interpretation methodologies.

Figure 9 SURVEY GRID FOR GPR SCAN

Additional uses include rebar analysis, road and bridge inspection, geology, environmental assessment, ice and snow analysis, agricultural and forestry uses, mining, railway evaluation, forensics,military and security applications.

As with electromagnetic locating, soil conditions impact the quality of the signals. Typically, wet dense clays are the hardest for the signal to penetrate whereas clean dry sand is optimal. The lower the radar frequency the greater depth of penetration, however, resolution decreases as frequency decreases.



The GPR system consists of an electromagnetic transmitter that emits energy into the ground. As the energy encounters a buried object (or lack of object as in a void) these signals are reflected towards the surface. A receiving antenna records the variations in the return signal. While similar to electromagnetic locating, there is one difference to note: GPR can pick up signals from both metallic and non-metallic sources, an ability that electromagnetic locating cannot. These readings are sent to an onboard computer which processes the signals. Once these readings are aggregated they can be interpreted.

Technique

GPR readings are reflections perpendicular to the user and run in a straight line called a profile line. An anomaly running parallel to this depth slice will not be imaged. In utility locating, most of the anomalies are linear features such as pipes and cables and it is vital to image these correctly. For facilities that are not cables, pipes or rebar, such as underground tanks or for archaeological entities, it may be adequate to image the object without being perpendicular(such as a void), however, a horizontal and vertical grid will be the most efficient way to image an unknown area. To accurately locate cables and pipes, the GPR scanner must be run at perpendicular to the target lines. This can be difficult to do if the operator does not have knowledge of the site.

The traditional workflow involves GPR technicians laying out a grid over the proposed site. Site control is very important, traffic and persons transiting the site can slow down scanning. While the scanning itself is done at a walking pace, the actual layout of the grid is perhaps the most time consuming. The grid spacing is dependant on the subject matter (i.e. how small the objects in question are thought to be). Because the depth slices are razor thin, it is entirely possible to miss a one foot object if the grid spacing is two feet. If the object is known, for example a large tank, then the grid spacing may be larger, but typical spacing for utility work is one foot. This decreases the chance of missing something. Grids can be smaller, however grid spacing should be kept in mind when looking at the size and scope of the proposed job as it adds man hours to the project.

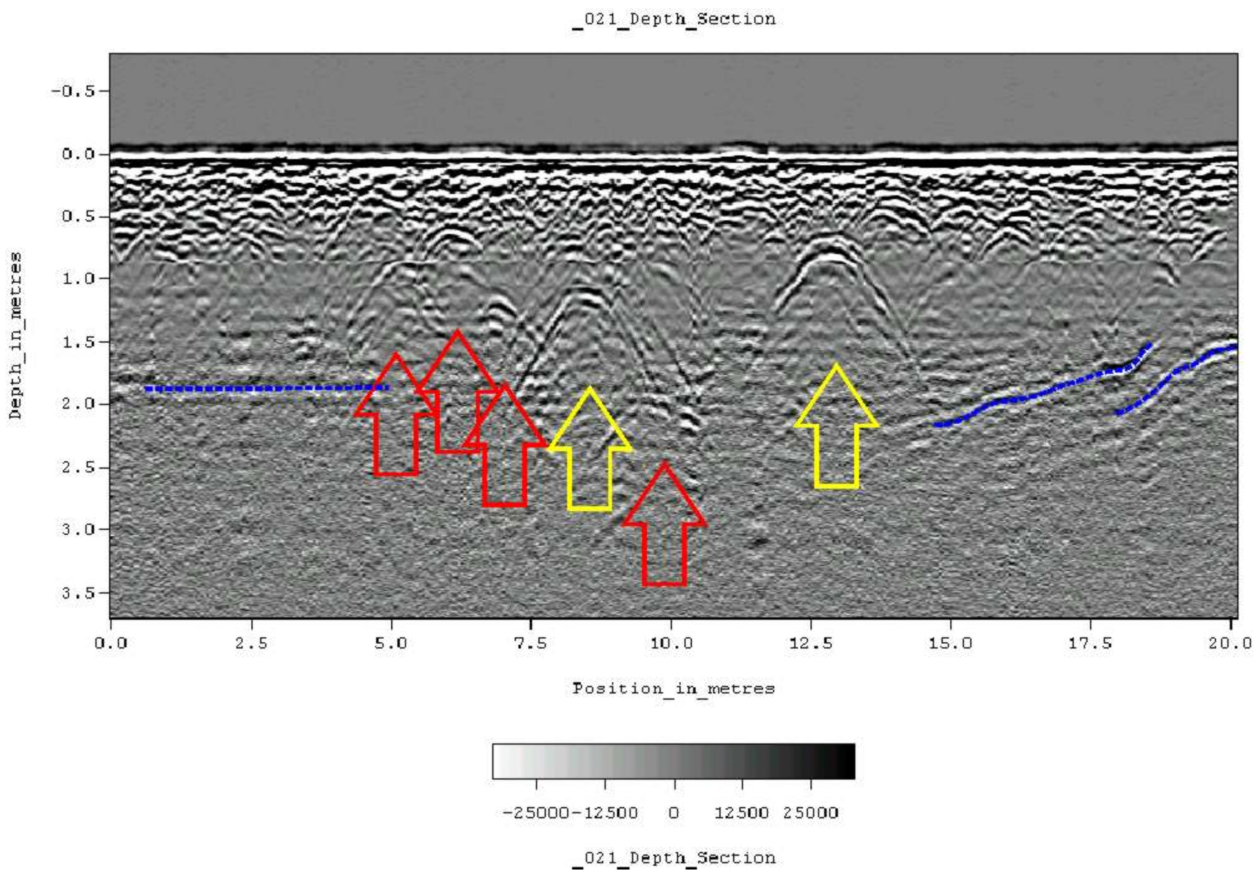


FIGURE 10. "LINE21" BY TAPATIO AT ENGLISH WIKIPEDIA - TRANSFERRED FROM EN.WIKIPEDIA TO COMMONS.. LICENSED UNDER PUBLIC DOMAIN VIA COMMONS - https://commons.wikimedia.org/wiki/File:LINE21.jpg#/media/File:LINE21.jpg

EXAMPLE OF HYPERBOLIC REFLECTIONS

Another factor is the anticipated depth of the target object. The scope of work will dictate which frequencies will be used. For example, rebar may be relatively shallow but water lines may be deeper. The higher the frequency, the greater the resolution will be. At shallow depths a higher frequency will be used but its range and resolution will be limited at greater depths and so a lower frequency will be used. The tradeoff is that the resolution degrades at lower frequencies . There is some overlap between the different frequencies being used but the end result is that the deeper you go, the lower the frequency, and the lower the frequency the lower the resolution. Each frequency change requires the use of another antenna and another full scan of the grid, so keep this in mind when budgeting time for GPR scans.

The profile slices are aggregated into a depth slice of a certain elevation (a few inches). It can be difficult to draw a conclusion from just one piece of profile line or depth slice because on their own they are ambiguous.

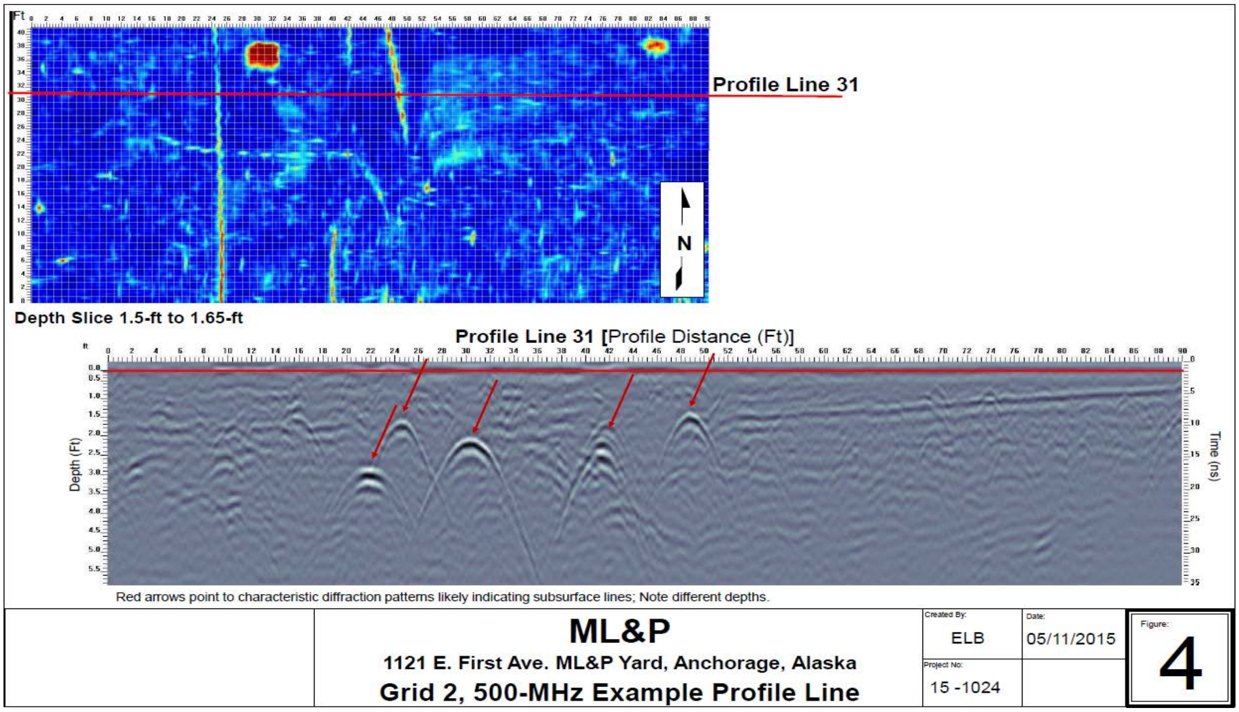


FIGURE 11 PROFILE LINE @500 MHZ

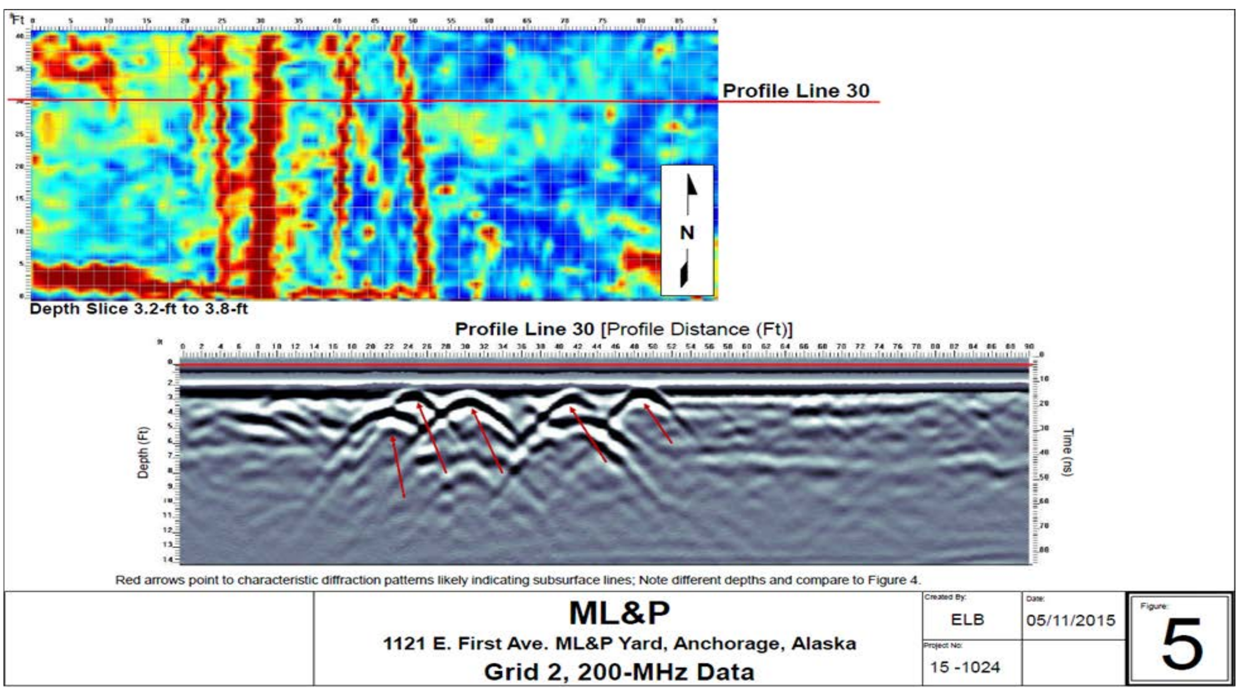


FIGURE 12 PROFILE LINE @ 200 MHZ

In these two examples of the same area above, you can see the difference between the two antenna configurations and how they only show a certain portion of the underground.

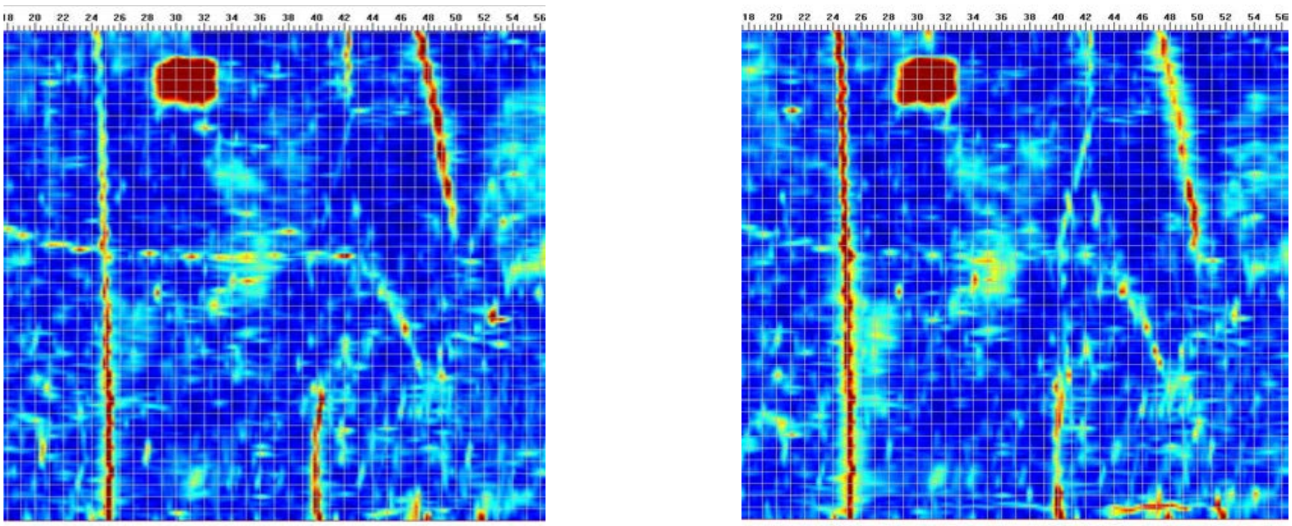


FIGURE 13. 500 MHZ AT 1.250-1.350 FT (LEFT) 500 MHZ AT 1.350 – 1.500 FT (RIGHT)

Figures 13 and 14 demonstrate the depth slices in four consecutive layers. Notice the development of the anomolies as the depth changes.

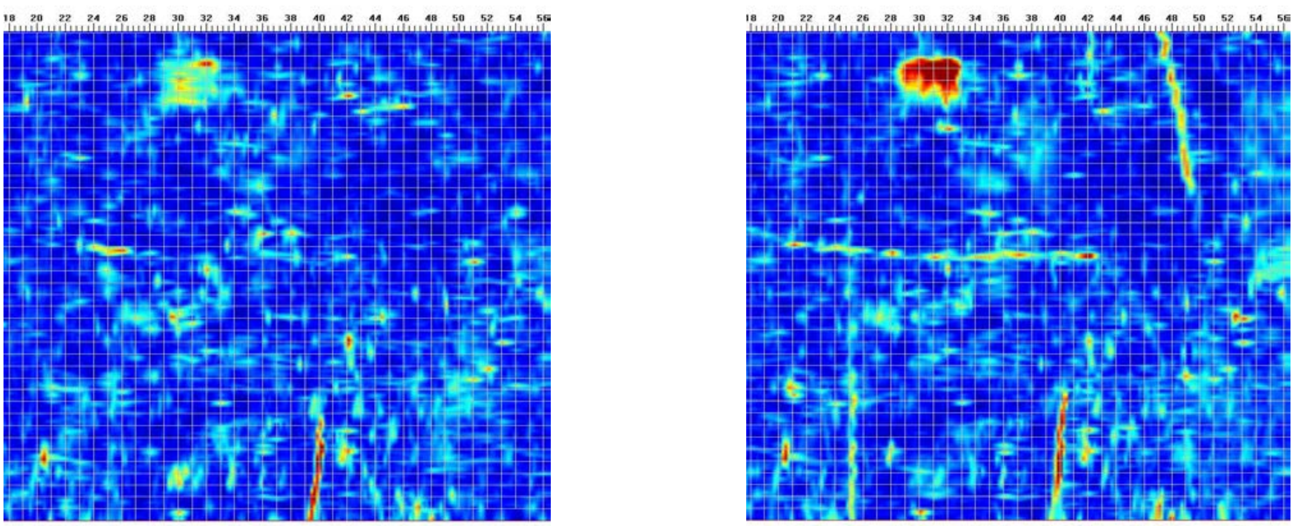


FIGURE 14 500 MHZ AT 1.500-1.650 (LEFT) 500 MHZ 1.650-1.800 (RIGHT)

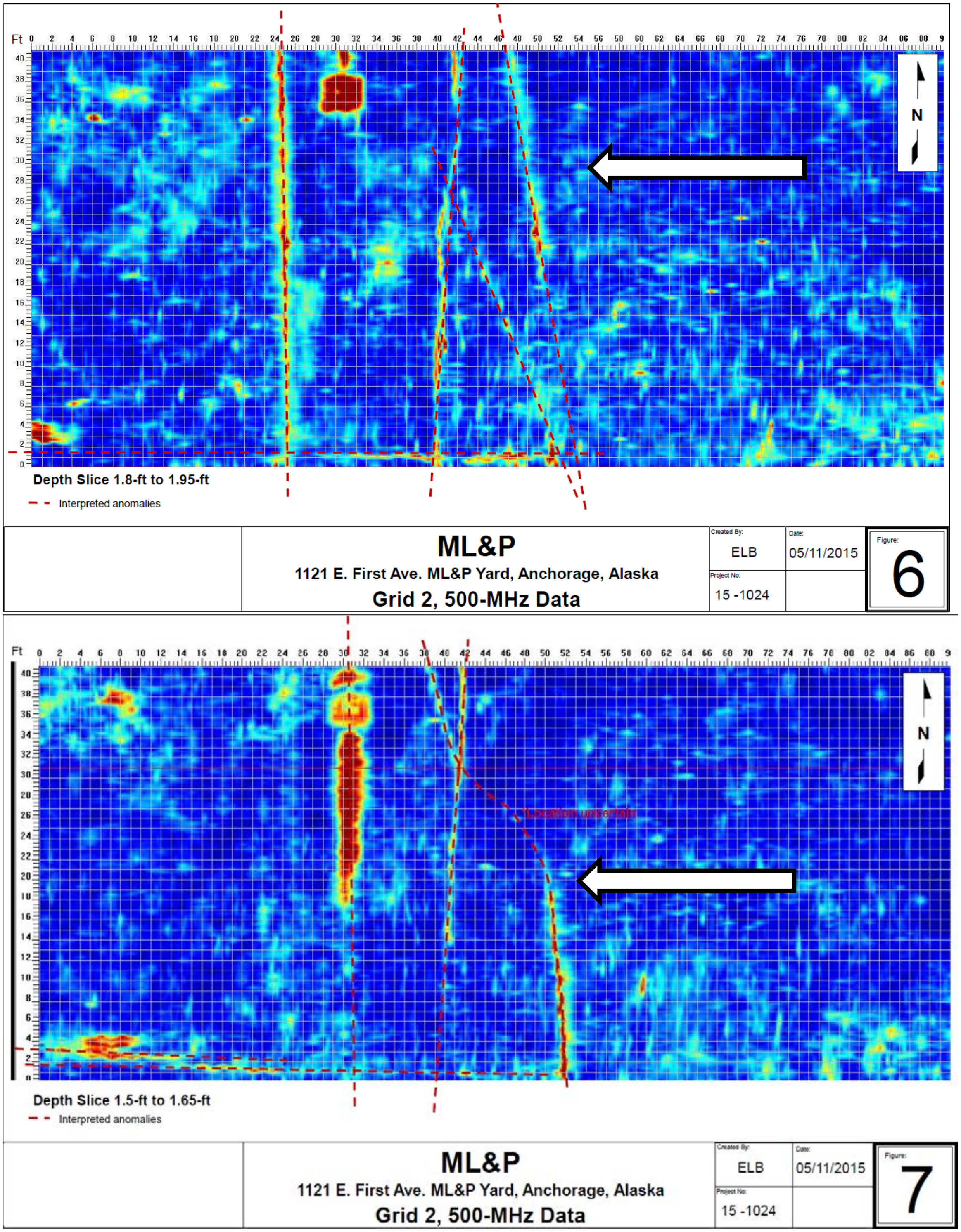


FIGURE 15 INTERPRETED DATA SET

In figure 15 above (see white arrow), the GPR technician mistakenly interpreted the red line as veering west. Upon re-examination, you can see the anomoly in slide 7 is the same as in slide 6 but is diving deeper. Misinterpreations like these can be can be avoided by exporting GPR data into a format that can be viewed as three dimensional data. However, in many instances this data is transferred back to the client by painting lines on the ground. (In figure 16 the mistaken line in pink [white arrow] and the actual line in yellow).

FIGURE 16. SOURCE AAML&P. GPR MARKS PAINTED ON A JOBSITE (PINK DENOTES UNKNOWN ANOMALY).

3D Scanning (LiDar)

Laser scanning is a group of technologies that measure light refractions along a surface.

LIDAR is an old technology from the early 1960s. (LIDAR is often thought of as an acronym of Light Detection and Ranging, but in my research I found it was actually a portmanteau of 'light' and 'radar'. However I found that LIDAR was more commonly treated as an acronym than not. it is also referred to as Laser Imaging, Detection and Ranging.) It is used in a wide range of applications including: agriculture, archaeology, architecture, forestry, geology, meteorology, law enforcement, military, mining, physics, robotics, space flight, surveying and transport among others. For the purposes of this paper, we will concentrate on its use in utility work and emphasize its use in reality capture.

Terrestrial Scanning

Tripod laser scanners are an efficient, non-invasive way to create massive point clouds. These point clouds can be easily imported into AutoCAD software. They are also a great way to visualize projects in ways that were previously not accessible.

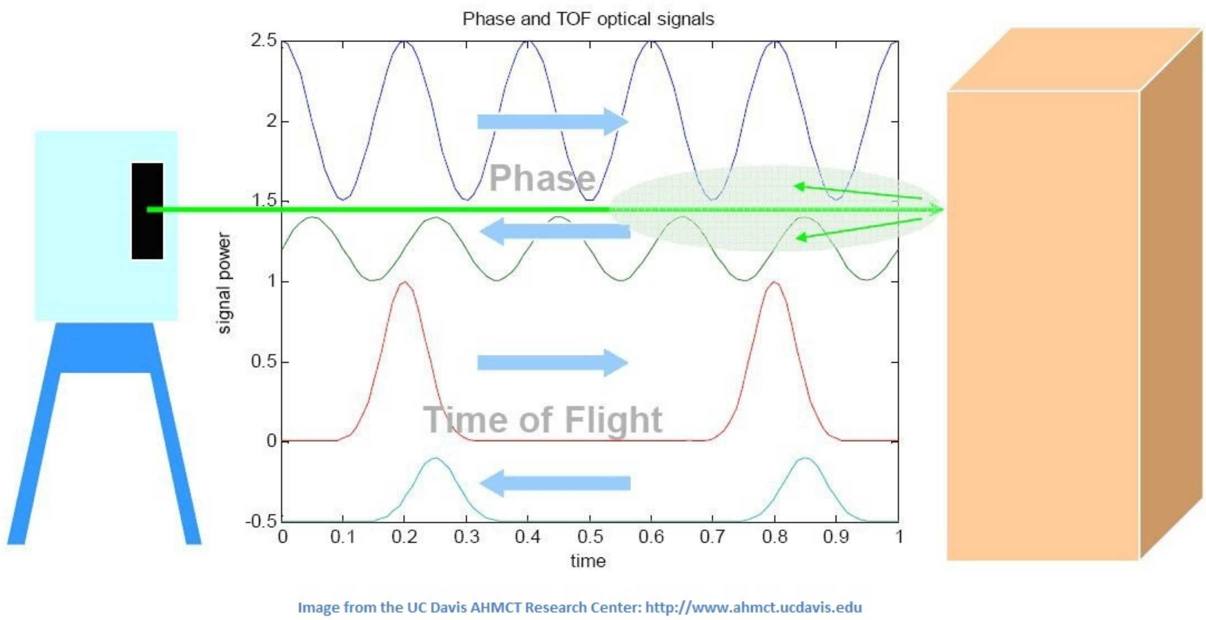


FIGURE 17 TIME OF FLIGHT VS PHASE BASED

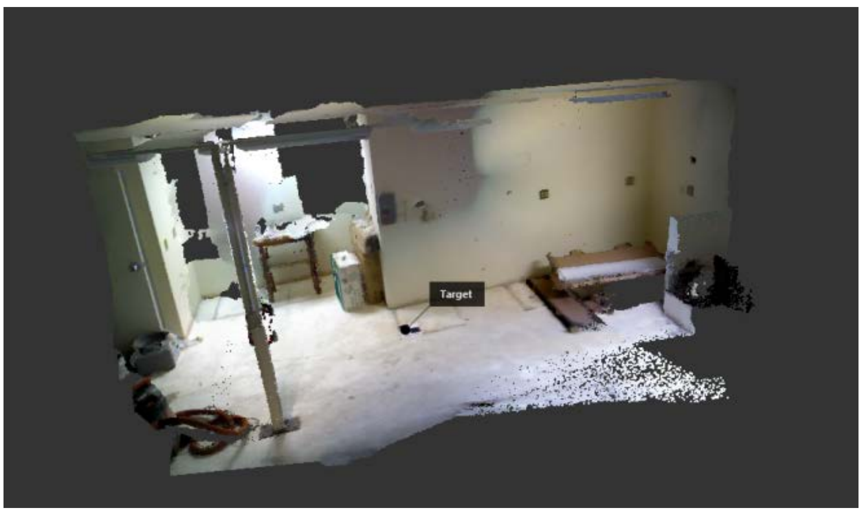
Types of scanners

Time of flight scanners use a laser to measure the time it takes a round trip pulse of light from each point. It is done in a grid pattern going horizontal and vertical. This takes considerably longer than phased based scanners. A benefit to this method is the increased range that the device can measure. Time of flight scanners can capture approximately 50,000 points per second.

Phase based scanners send out a continuous beam of light and measure the phase shifting of the return light. While the range is lower than time of flight scanners the speed is much faster with phase based scanners able to pick up almost a million points per second.

Each point is measured by the laser scanner into an x,y,z coordinate system. The software aggregates these into a point cloud. Large objects such as buildings may require more than one scan. These scans are tied to the position of the scanner itself. By default, these scans have no relation to each other. They must be merged together with congruent points in a method called registration. There are two methods to doing this, target registration and target-less registration or cloud to cloud registration. ReCap simplifies cloud to cloud registration .

Figure 18 three DotProduct-DPI 7 scans



Structured light technology is used by companies like Microsoft for their Kinect technology. When paired with the proper software, this can create a point cloud much faster, and with much lower cost than traditional laser scanning. Thisis one of the primary methods for handheld 3D scanners like the DotPRoduct™.

Registration

In figure 18, each of these scans is a different piece of the same room. In each one the same target is visible. The software is able to merge these point clouds together by using common points tied to the target.

Targets can include paper ‘checkerboard’ targets, or reflective reference spheres. Once the point clouds have been registered the completed model is ready to view.(see figure 19)

Figure 20 is an example of target placement inside a substation. The red circles are sphere targets and the circles with black dots are scanner placements. Each scanner location must be able to see a minimum of three points. It’s important to have scan overlap but time will dictate how much you can devote to placement (each scan can take between 7-12 minutes). In the above figure you can see that the northern, eastern and western portions of the buildings are a little darker. This is due to the scanner only being able to get partial points of those areas.

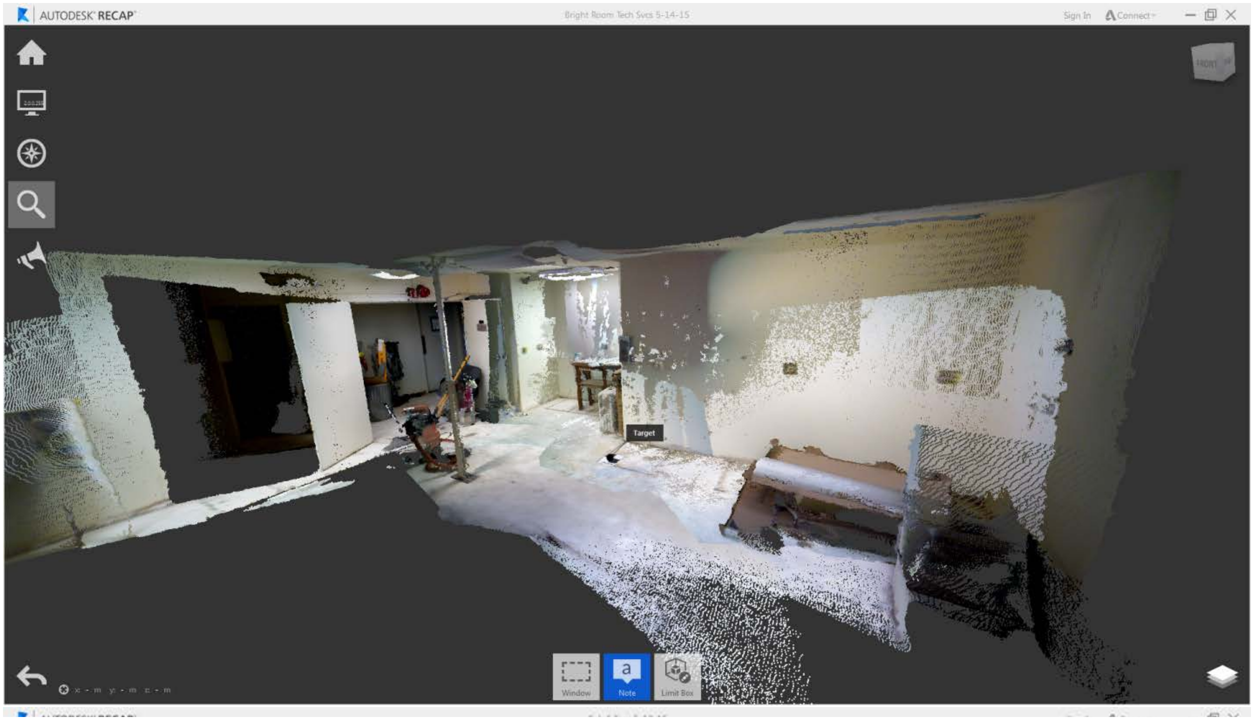


FIGURE 19 SCANS COMBINED

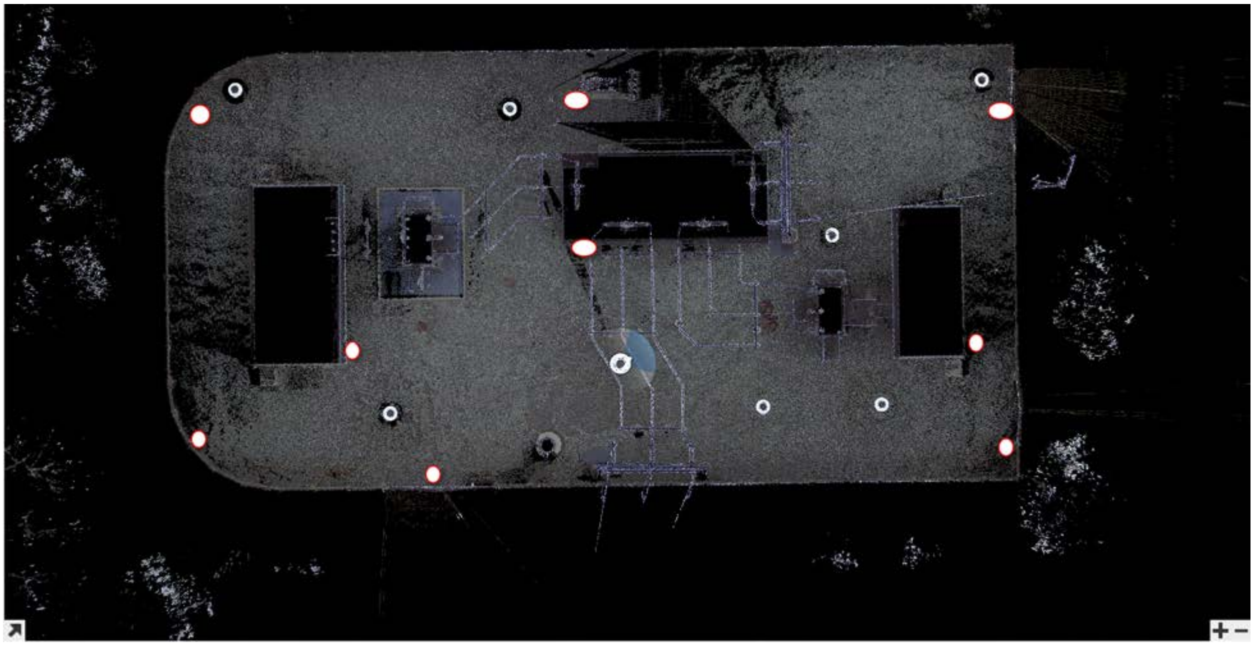


FIGURE 20 FARO LASER SCAN POSITIONS INSIDE SUBSTATION. WHITE DOTS ARE SCANNER LOCATIONS AND RED DOTS ARE TARGET LOCATIONS.

Photogrammetry

Perhaps one of the most innovative uses of an old technology, photogrammetry is the science of taking measurements from photographs. When we speak about it in this context we are referring to a reality capture technique using photographs that produces 3D meshes which can be converted to point clouds. AAML&P has successfully used photogrammetry to model the inside of our vaults and our job sites.

Photogrammetry is used in mapping, architecture, engineering, archaeology, and a variety of applications.

Cameras have ncreased in quality and decreased in cost. Point and shoot cameras, smart phones and high end DSLR cameras can all be used to create 3D models. Higher quality photos prodce higher quality models. Cameras with higher pixel density and larger sensors produce better photos. A fixed focal length lens and good lighting are important to the quality of the model. Autodesk Recap is specifically made to work with the GoPro camera and is calibrated for that lens. The benefit of using a GoPro is the wide angle of the camera makes it *much easier* to overlap photos over each other. Fisheye lenses have been known to distort certain processes and a correction may need to be applied before some photogrammetry software can create an accurate model.

Using a tripod and remote is helpful to stabilize the camera. Any shakiness in the camera can contribute to a slight blurriness in the photo which translates into a poor quality model. This is especially true of the GoPro since it uses a rolling shutter. For our purposes, modeling underground electrical vaults, lighting has been a huge challenge. Many times there isn't enough room to set up a tripod or lights. We have created a dual handed platform that stabilizes the camera and houses bright LEDs to give continuous light in the direction of the camera.

Overlap is crucial for the software to successfully stich photos together to create a successful model. A good rule of thumb is 60% overlap. This allows three pictures to contain a minimum number of duplicate points of at least a 10% margin. The more overlap the better. Some of our most successful models have contained photo sets with 97% overlap. This may be overkill but often times in construction we only have one chance to gather the data.

In order for the photo mesh to be scaled into real world coordinates, there must be known points (ie surveyed points) in the model.

> ***Photogrammetry is more accurate in the x and y direction while range data are generally more accurate in the z direction. This range data can be supplied by techniques like LiDAR, laser scanners (using time of flight, triangulation or interferometry), white-light digitizers and any other technique that scans an area and returns x, y, z coordinates for multiple discrete points (commonly called "point clouds"). Photos can clearly define the edges of buildings when the point cloud footprint can not. It is beneficial to incorporate the advantages of both systems and integrate them to create a better product.***
>
> ***A 3-D visualization can be created by georeferencing the aerial photos and LiDAR data in the same reference frame, orthorectifying the aerial photos, and then draping the orthorectified images on top of the LiDAR grid. It is also possible to***

> ***create digital terrain models and thus 3-D visualisations using pairs (or multiples) of aerial photographs or satellite (e.g. SPOT satellite imagery). Techniques such as adaptive least squares stereo matching are then used to produce a dense array of correspondences which are transformed through a camera model to produce a dense array of x, y, z data which can be used to produce digital terrain model and orthoimage products. Systems which use these techniques, e.g. the ITG system, were developed in the 1980s and 1990s but have since been supplanted by LiDAR and radar-based approaches, although these techniques may still be useful in deriving elevation models from old aerial photographs or satellite images.[1]***

There is a wealth of knowledge on the Autodesk website.[2],[3]

UAVs

It is projected that 700,000 UAVs will be sold in 2015 Q4. Everyday more and more UAVs take to the skies. New uses for drones are being developed all of the time. This new technology has such a far ranging impact on so many industries it has taken regulators by surprise.

UAVs are an excellent tool for photogrammetry, LIDAR and survey. UAVs can cover swaths of area much faster than human crews. This allows for new types of data to be collected, for example daily volumetric measurements, that before were costly or even impossible. A survey that used to take a week can now be completed in half of day. These systems can be automated thereby increasing efficiency.

Using UAVs to capture data for modeling is cheaper and faster than manned aircraft systems since it can be launched and recovered almost anywhere. UAVs can access areas inaccessible to both man and full size aircraft, such as dams, bridges, and power plants.

As UAVs become more sophisticated they can carry heavier, more complex equipmentand fly further and longer. FAA regulations are in flux and changing rapidly but this field will radically change many of our industries. [4]

Incorporating Reality Capture into Design

Design process

Capturing data for design is about fitting a theoretical design into the real world. The designer needs the best possible picture of the real world. Traditional methods incorporate survey, photos and site visits to find this information. With reality capture techniques we can expound upon this to provide a realistic model with which to work. We can also use this technology to access places that were previously unreachable to the designer or would be cost prohibitive to access.

The utility design is about clearance and avoidance, seeing how the proposed assets will work in the real world alongside existing facilities. A single line on a survey may not convey a conduit, duct bank or a culvert the way a model can. Knowing and seeing conflicts in the model can save time and money in the construction process further down the line.

As-built process

Using 3D models in the review process can be valuable. Many times, field reports or photographs may contain missing or conflicting data. Wwe havereceived field reports indicating that 4" pipes were installed but in the design they were planned for 6" pipes. This deiscrepency would normally require an expensive field visit to resolve. Using a model, we can virtually visitthe job site and resolve these issues in the office. Equipment configurations are much clearer and leave little room for ambiguity.

Perhaps one of the most valuable attributes of reality capture in the infrastructure lifecycle is to re-access these areas once they're covered back up. Utility infrastructure lifecycles run inot decades and finding reliable data about what's underground will be critical for future utility needs. We rely on the old work drawings of the past; in the future our 3D models will be used for the same purpose.

Survey Data

Survey data is imported from data collectors and converted into AutoCAD drawings by our survey crew. There are several methods and software packages available to do this, mostly dependent on what brand of Survey hardware you are using in the field. All major brands offer methods to add survey data into AutoCAD drawings. We have traditionally used a program called SurveyLink and currently have Topcon's Magnet software. Our crews generate an AutoCAD drawing that we reference into our design drawings as an external file.

Photogrammetry

Photos are uploaded into Recap 360 or Memento to be stiched in the cloud. Once these models have been made they are exported into a RCM format (mesh). These RCM files can be exported from Memento or Recap 360 into an RCP file(Reality Capture Project file). For the files to be referenced into real world coordinates, the model must be assigned those coordinates at the creation stage.

Point Clouds

The point clouds generated from our photogrammetry in a RCP file format allow for automated import into the current (2016) versions of most Autodesk software. This includes the ability to generate surfaces in Civil3D directly from the ReCap point clouds or to reference the point cloud into the AutoCAD drawing as an external file that allows 3D snapping functionality. Point clouds from other sources, such as a Dotproduct DPI 7, or LIDAR are handled the same way. (There is a free plug in for .dp files for the Recap software).

To reference a point cloud as an external file open the XREF manager dialog, click the drop-down in the top left and select "Attach Point Cloud" (Figure 21). Typically after the file is referenced you will need to align the point cloud to your survey data. This can be done using the "Align" command and two common, easily identifiable points that are common to both the point cloud and the survey file. In order to snap to the points in the referenced point cloud you have to enable your 3D Object Snaps (Figure 22).

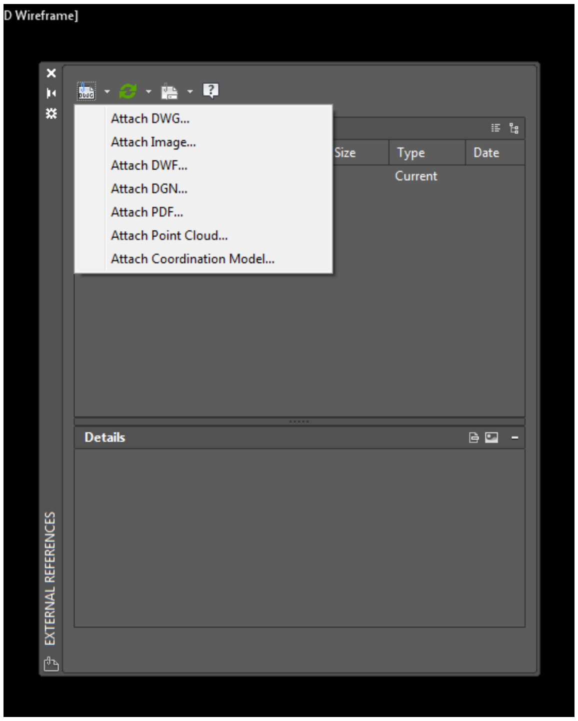


FIGURE 21 XREF DIALOG BOX FOR POINT CLOUD REFERENCE

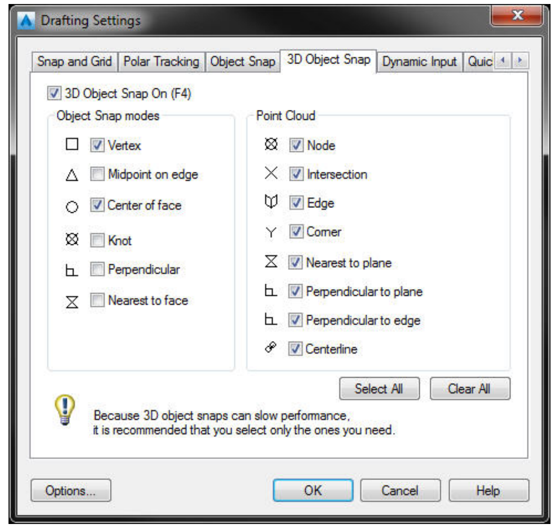


FIGURE 22 3D OBJECT SNAP SETTINGS

To generate a 3D surface from a point cloud in Civil3D you first have to reference the point cloud into Civil3D, this is done by navigating to the "Insert" tab on the ribbon panel and selecting "Attach" from the Point Cloud sub-panel (Figure 22). After you have attached the point cloud there is a direct import function to generate a surface. Starting at the "Home" tab go to the "Create Ground Data" sub-panel select the "Surfaces" drop down and select "Create surface from point cloud (Figure 23).

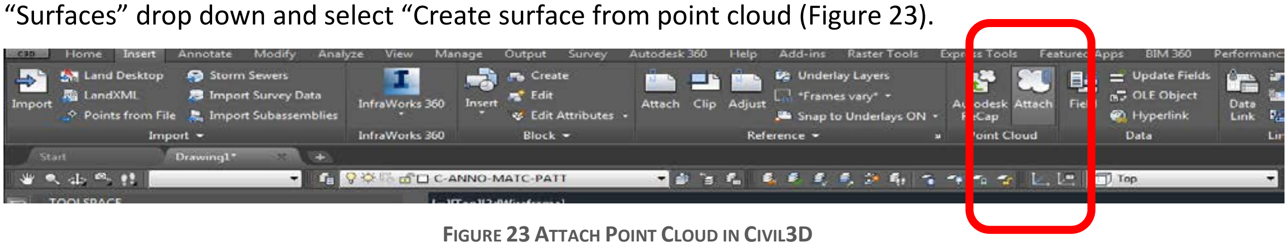


FIGURE 23 ATTACH POINT CLOUD IN CIVIL3D

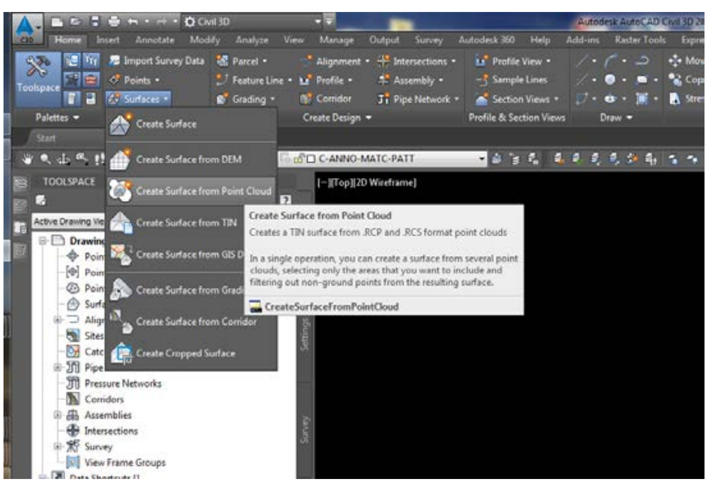


FIGURE 24 IMPORT RECAP POINT CLOUD AS A SURFACE

It is important to note that the point density needs to be reduced when creating a surface from a ReCap model, some typical point densities are just a few mm apart. Points at that density that are used to create a surface can burden your system resources to the point of being unusable. There are a few places where you can manage the point density. The first is when you generate the surface you can specify distance between points in the surface creation dialog box (Figure 24). Another option is editing the surface after it is created. There are several edit options that are available through the Prospector. If you navigate to the surface you have created, expand the submenus and right-click the edits option, it will give you several different options to modify an existing surface (Figure 25).

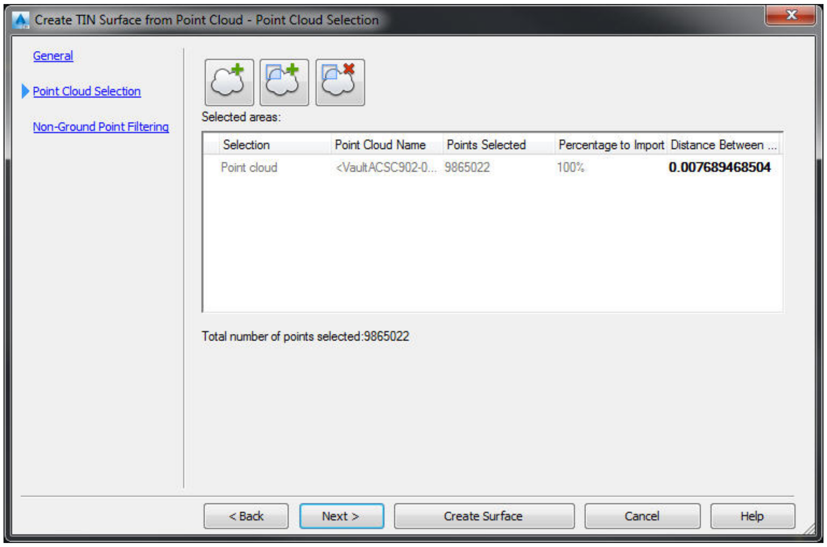


FIGURE 25 MODIFY POINT DENSITY WHEN CREATING A SURFACE

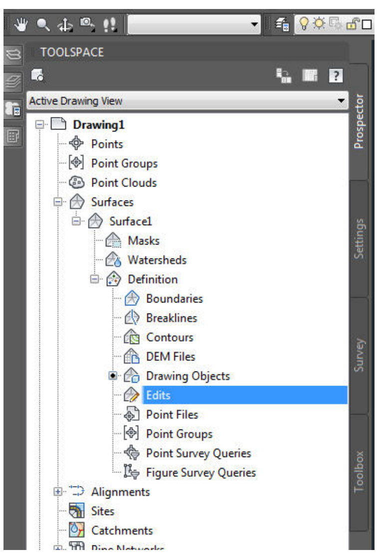


FIGURE 26 EDIT POINT DENSITIES AFTER SURFACE IS CREATED

Once the surface is created you can manipulate it the same as you would any other Civil3D surface (i.e. modify boundary, add/remove points, add breaklines, etc.).

Ground Penetrating Radar

The greatest challenge with incorporating GPR data into an engineering drawing is getting the data in a 3D file format that can be used to generate a point cloud in ReCap. After several attempts we were eventually able to convince our contractor to export the GPR data they provided in an .iv format. Once we had this file format I found an online converter (http://www.3Dtransform.com) that we used to create a .stl file which we then imported into ReCap to generate an .rcp file that we could import directly into our AutoCAD software. Once it was imported into AutoCAD we used the same method used to align the surface point cloud to the survey data outlined earlier in this document.

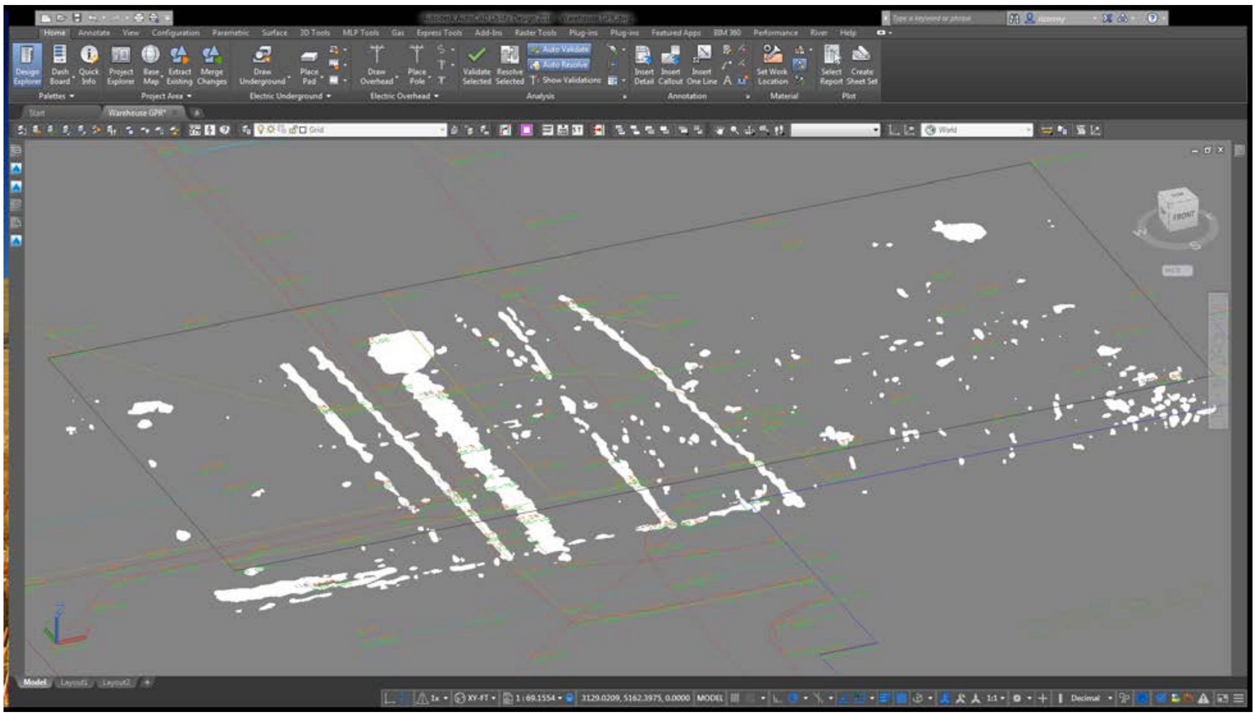


FIGURE 27 GPR DATA ALIGN TO SURVEY BASE DRAWING

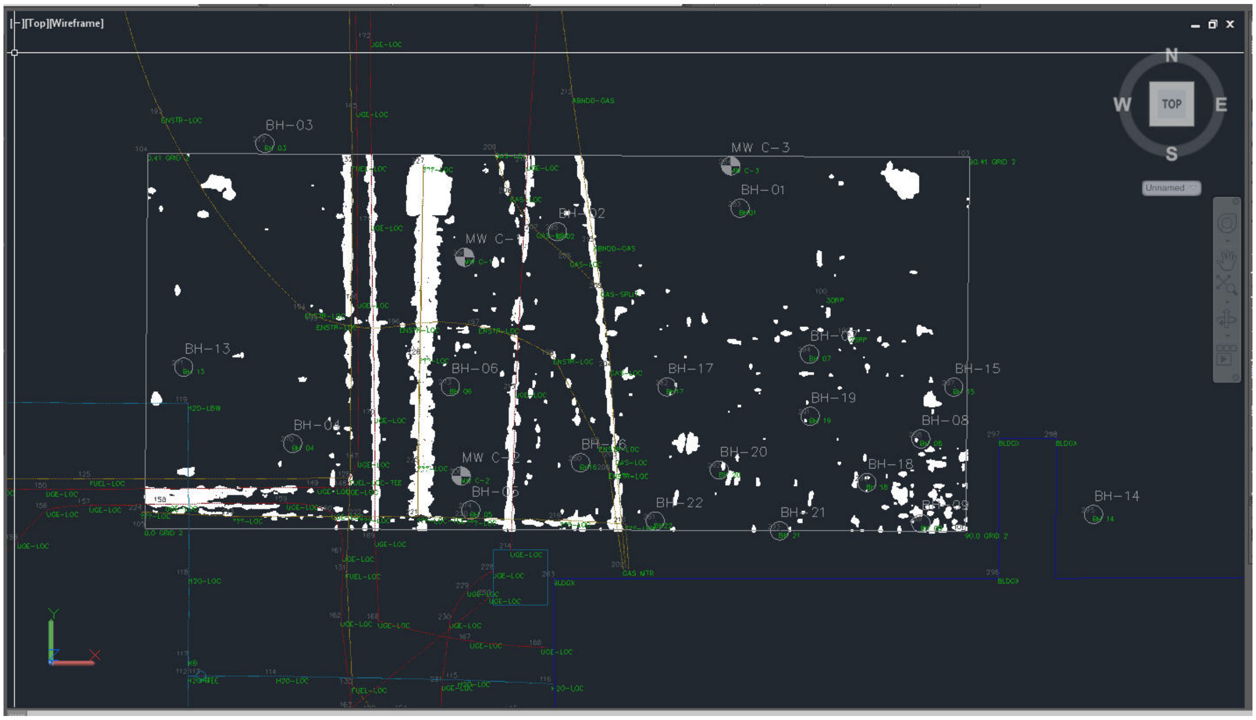


FIGURE 28 GPR GRID LAYOUT

3D Locates

There is a process to pair the underground locate equipment with GPS data collectors. This allows you to assign the actual cable depth to the survey pints which provides you an accurate 3D underground route of your cable locates. The ability to pair these two devices is dependant on the manufacturers of the different pieces of equipment and compatability between the two.

Currently we use a manual process to facilitate this by taking depth readings with the locate equipment at predetermined surveyed locations. We then assign these elevation values to 3D elements in AutoCAD. There are several methods to do this which include but are not limited to drawing 3D polylines, assigning data to points in Civil3D in order to create alignments, and in Autodesk Utility Design 2016 you can modify the Z value for 3D vertices of underground conduit routes using the "AUDTRANSITIONPOINT" command (Figure 29).

TRANSITION POINTS

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ID	Elevation (ft)	Angle (°)	Radius (ft)	Terrain Offset (ft)	Elevation Change (ft)	Projection Length 3D (ft)	Projection Lengt
0	-4.8904	0	0	-4.8904	0	0	0
1	-4.8904	0	0	-4.8904	0	6.5114	6.5114
2	-4.8904	1.5118	0	-4.8904	0	15.2754	15.2754
3	-4.8904	0	0	-4.8904	0	21.0532	21.0532
4	-4.8904	0	0	-4.8904	0	27.7539	27.7539
5	-4.8904	0	0	-4.8904	0	34.4066	34.4066
6	-4.8904	0.7658	0	-4.8904	0	40.2324	40.2324
7	-4.8904	0	0	-4.8904	0	48.93	48.93
8	-4.8904	0	0	-4.8904	0	55.1345	55.1345
9	-4.8904	0	0	-4.8904	0	70.0365	70.0365

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Figure 29 AUDTRANSITIONPOINT Dialog Box

For us the preferred method will be to import our existing data from our GIS into AUD and then re-align that to our surveyed data including assigning elevations of vertices with data gathered from our locate equipment.

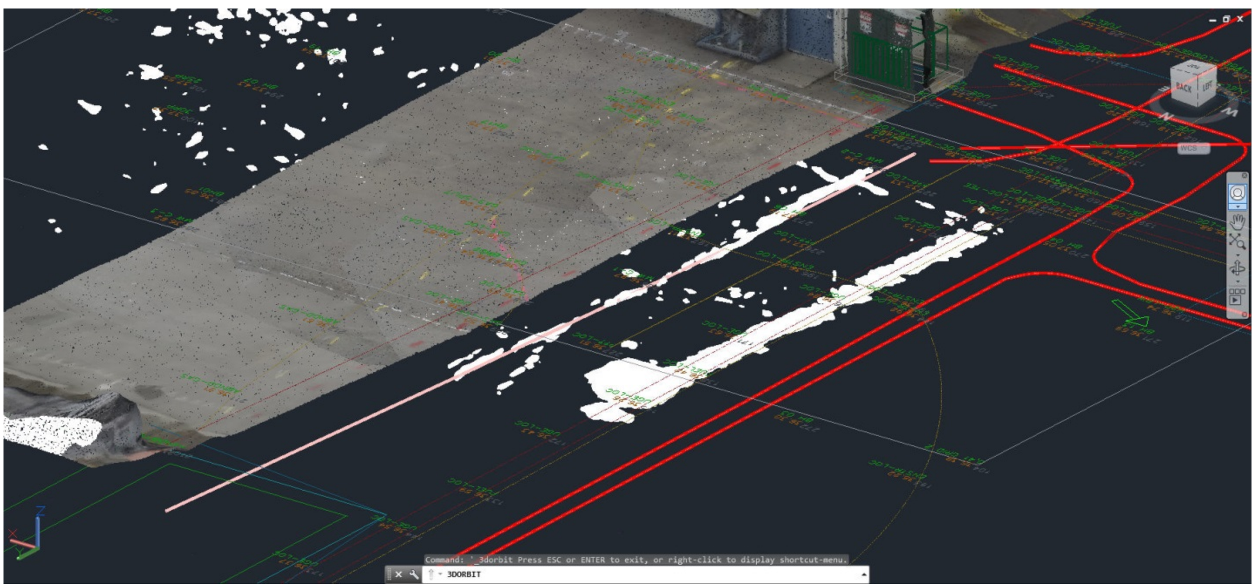

Figure 30: 3D Locates referenced to GPR

Infraworks

Infraworks is a great tool to aggregate 3D information. We currently have our GIS, several terrain and substation models referenced into Infraworks. At the time of this writing we have not finalized a workflow to add complete engineering designs from AUD into infraworks.

[1] https://en.wikipedia.org/wiki/Photogrammetry
[2] https://memento.autodesk.com/resources
[3] http://www.geodetic.com/v-stars/what-is-photogrammetry.aspx
[4] http://www.dronezon.com/learn-about-drones-quadcopters/introduction-to-uav-photogrammetry-and-lidar-mapping-basics/