

# **The Three Point Survey Reporting Tool for Pioneer Natural Resources**

By Monica Christine Steele

A Practicum Submitted in Partial Fulfillment  
Of the Requirements for the Degree of  
Master of Science  
In Applied Geospatial Science

*Department of Geography, Planning and Recreation  
Northern Arizona University  
May 2019*

Approved:  
Mark Manone, M.A., Committee Chair  
Erik Schiefer, Ph.D.  
Ruihong Huang, Ph.D.

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## **Acknowledgments**

There are many people I am thankful for providing me with help and support while I pursued this academic journey. Always first, I am eternally grateful for my mother, Donna Steele, and my father George Hoffman. Without their encouragement, patience, love and care I would not be where I am today. Additionally, I would like to thank my partner, Solan Watts, who has been a great source of strength for me while I pursued this degree.

My time at Pioneer Natural Resources was a pivotal point in my life. I was challenged to learn about the industry, to develop my GIS skillset, and to overcome daunting hurdles. The chance to work in this professional environment taught me valuable skills as a worker, and helped me understand the value of my own work. Thank you to Les Jagielko and Andrew Gillette for interviewing me and bringing me into the internship program. To my mentors, Tim Tipton and Phillip Accetturo, thank you for your guidance in this project and reassurance along the way. To Karroll Vaughn and the rest of the Well Planning team, thank you for creating an awesome work environment and making me feel welcomed there. Pioneer is a community that I am grateful to have been a part of and I look forward to beginning my career with all of you.

Northern Arizona University has been great to me these past two years. Thank you to Dr. Amanda Stan for having me as your teaching assistant and giving me the opportunity to work while I pursued this degree. To Mark Manone for his role as my advisor, and to my committee members Dr. Erik Schiefer and Dr. Ruihong Huang. I am grateful for my time here in Flagstaff and the chance to continue honing my skillset while helping me along in my professional journey.

## **Abstract**

Pioneer Natural Resources is an Oil and Gas company operating in the West Texas Permian Basin and is headquartered in Dallas, Texas. There are many steps involved in planning out the path of a well before drilling can begin. The Well Planning team consists of professionals from many backgrounds who work to understand the proposed location of the well, interpreting the geology, navigating the legal framework, and creating the plans necessary to move forward towards completion. Part of this planning stage is creating the Three Point Survey, which is a two dimensional map representation of a three dimensional horizontal well. Previously the Coordinators in the Well Planning team were tasked with creating the survey in a program called Petra. However due to limitations with the program there was a need to switch to other software solutions, ideally one that was compatible with ESRI software.

This practicum was centered on developing a new in house solution and workflow that would increase user access while decreasing both run time and human error in the creation of a Three Point Survey. The new Three Point Survey Reporting tool was created using ESRI ArcGIS software, specifically Modelbuilder as the primary tool for development. This process combined two models, one that is used for the generation of the points and coordinate data, and a second which constructs the survey line based off of the points of interest. At the time of its completion, the tool served to be a partial solution to the initial challenge. Those at Pioneer deemed that the workflow was beneficial to the Company's productivity and set forward on improving the tools and then to implementing it into the Well Planning group. This paper serves to outline the chronology of the project, challenges that were encountered during development, and solutions that were reached to create the tool itself.

## **Introduction**

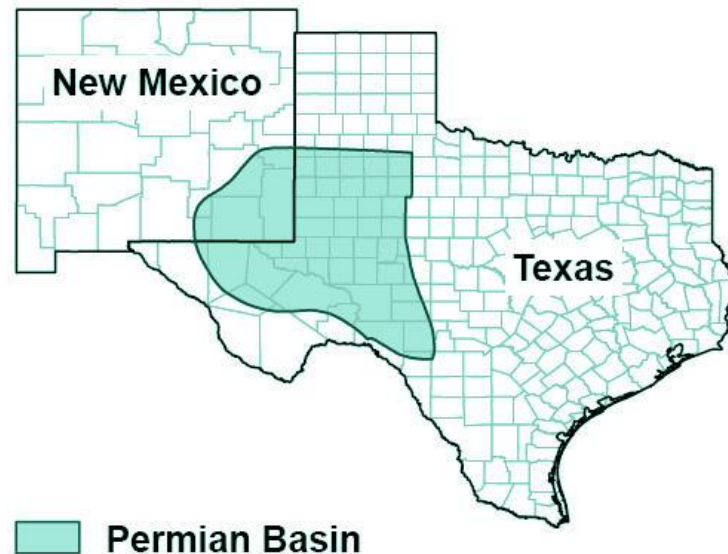
### **Background**

Many oil fields around the world today are focused on hydrocarbon resources such as shales (Letchner 2014). Shales are a class of fine-grained sedimentary rocks originating primarily as plant detritus that accumulated along with sediment. The organic material and typically clay sediments were buried and tightly compacted by overlying strata's weight which facilitated the sedimentation and lithification process. The "shale revolution" in the United States began to blossom between 2005 and 2010, taking advantage of high oil prices, favorable lease availability, and new improvements to technology (Soeder 2018). These new methods may be referred to as unconventional resources, where wells are drilled vertically then horizontally using directional drilling (Letcher 2013). Horizontal drilling allows the operators to target singular shale formations which serve as both the source rock as well as reservoir rock, which are then stimulated by hydraulic fracturing (Soeder 2018).

Hydraulic fracturing utilizes unconventional procedures to stimulate formations to increase the rates of oil and gas that a well can produce. The methods involve increasing the pressure via fluid injection within a reservoir until the rock begins to crack, which increases permeability through new channels (Letcher 2014). The first case of hydraulic fracturing was performed in 1947, and in the decades following the methods have been refined to be safer and more effective (Letcher 2014). As time progresses and additional research is performed on these methods, researchers have been gradually reducing the amount of uncertainty with respect to environmental risks and implications around hydraulic fracturing (Soeder 2018).

Pioneer Natural Resources is a company in the petroleum industry that was formed in 1997 upon the merger that took place between Parker & Parsley Petroleum Company and MESA

Inc. (Pioneering Independent 2018). Pioneer has operated in several locations around the world, including the Alaskan North Slope, but in recent years has sold off these assets. The focus of the company now is directed to the Permian Basin in West Texas (Pioneering Independent 2018).



**Figure 1:** Map of the Permian Basin located in western Texas and southeast New Mexico  
(Smith 2018)

The Permian Basin, as seen in Figure 1, underlies an area of 300 miles long and 250 miles wide throughout West Texas and parts of Southeast New Mexico (Vertrees 2010). The first commercial oil well drilled into the Permian Basin was completed in 1921 on the east side of the basin in Mitchell County, and reached depths of 2,498 feet (Vertrees 2010). When the Permian experienced its first oil boom, Midland, Texas became a hub for the industry as the demand for oil and petroleum products began to increase (Leffler 2010). Development of Midland and surrounding areas was slow initially, as the industry was restricted by limited pipeline availability to transport crude oil to the Gulf Coast refineries. As management practices were improved along with extraction methods, the expansion of the petrochemical industry, and new

discoveries of natural gas, these areas in West Texas have continued to experience development as a result (Olien 2010).

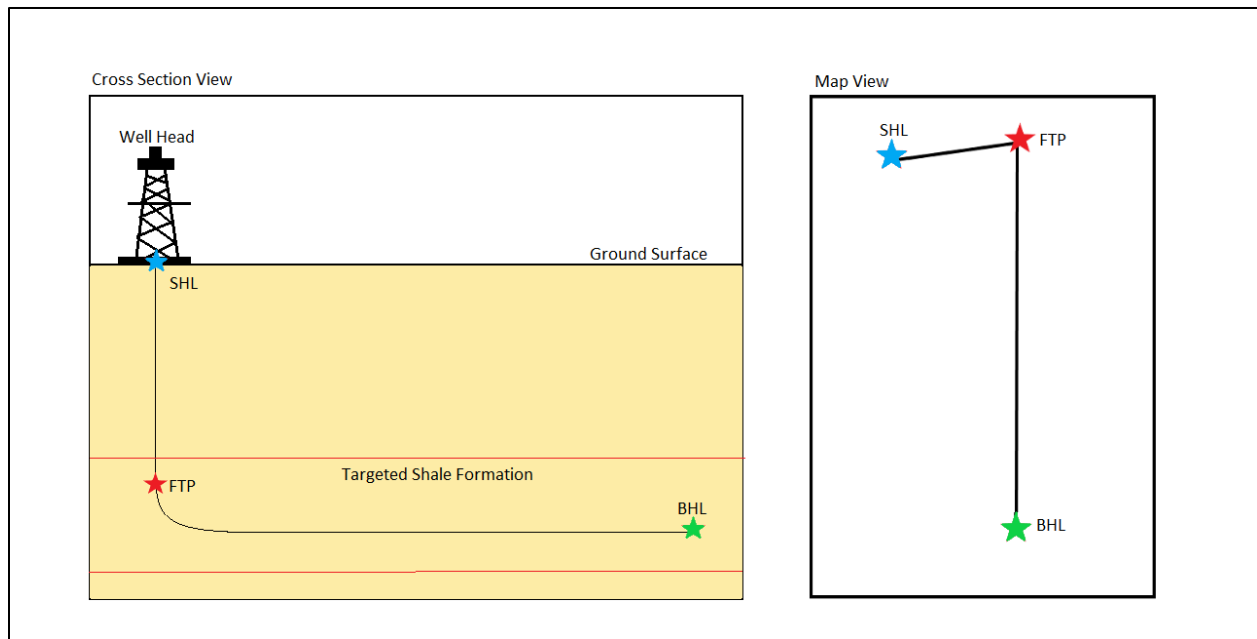
The Texas Railroad Commission is a regulatory body comprised of four divisions: Oil and Gas, Transportation-Gas Utilities, Surface Mining and Reclamation, and Liquefied Petroleum Gas (Prindle 2010). The Railroad Commission not only has strong influence over the industry in Texas, but throughout history it has been a powerful organization as it regulated the primary supply and prices of oil and natural gas produced in the United States (Prindle 2010). The Commission is one of the regulatory bodies dealing with land practices in the Permian Basin. Ownership and boundaries throughout Texas are complicated, as the area in the past being under Spanish and Mexican rule resulted in unique survey methods (Olien 2010). As this area has been occupied for centuries, the surveys that were done by multiple different companies often do not mesh with each other, creating acreages that are irregular in shapes, sizes, and sometimes have gaps of ownerless land.

### *The Three Point Survey*

Planning the construction of modern day horizontal wells is an intricate process. It involves navigating the political channels of land rights, understanding the geology of the particular area, planning how resources will operate in that area, and much more. The planning stage of the well is a thorough and lengthy process with many people contributing to various aspects that need to be considered. One of these components that is created during the planning stages of a well is the Three Point Survey.



The term Three Point Survey is used within Pioneer Natural Resources and will serve as the main focus for this practicum. During the planning stages of a well, the Three Point Survey is created. This survey line serves as the preliminary drawing of where the well is planned to be drilled, although it is subject to change still at this stage. The survey is a two dimensional map representation of what will eventually be a three dimensional horizontal well in reality. Figure 2 depicts what the well may look like as a cross section and how it could be represented in map form. The Three Point Survey aptly consists of three points. There is the surface hole location (SHL), which represents where the beginning of the well will be drilled on the ground level, this is represented by the blue star in Figure 2. Next is the first take point (FTP), which indicates where the drilling would begin to switch from vertical to horizontal motion, as indicated by a red star in Figure 2. Finally, the bottom hole location (BHL), represents the end of the well on its horizontal path, and is denoted by the green star in Figure 2. The bore hole between the SHL and the FTP are not truly vertical lines, rather they are angled to some degree. This is not only makes it easier to drill the borehole but it also allows for multiple wells to originate from the same well pad location. A well pad is the site where construction of the well takes place, and it is common to have three wells being drilled adjacent to each other, however some well pads are being planned to contain up to twelve individual wells.



**Figure 2.** Left: Horizontal well consisting of the surface hole location (SHL) represented by a blue star, the first take point (FTP) represented by a red star, and bottom hole location (BHL) represented by a green star. Right: two dimensional representation of the horizontal well as it would appear as an ArcGIS Polyline. Star location colors correlate to their counterparts on the left hand image.

The creation of the Three Point Survey is a task for the Coordinators who are a part of the Well Planning Team at Pioneer. Construction of the survey has been previously done utilizing a software called Petra. The software itself is very technical and the process to create the Three Point Survey was one that was time intensive and could be subject to human error. Due to developmental limitations, Pioneer has sought to move away from their agreements to use Petra and have sought to find new solutions for the tasks that it has previously been used for, including the creation of the Three Point Survey.

### Practicum Purpose

The purpose of this practicum was to develop a new methodology and tool to capture the Three Point Survey outside of the previously used Petra for the Well Planning Coordinators of Pioneer Natural Resources. The ideal scenario was to create this new tool utilizing ESRI ArcGIS software. Pioneer already has an enterprise GIS system which is widely used throughout all departments of the company. Developing a tool compatible with this software would increase user access through ease of use as well as reduce run time and reduce limitations posed by licensing specific programs.

### Objectives

The following objectives were identified for this internship and practicum:

1. Learn about the Three Point Survey, its applications, and the methods used to capture it utilizing the Petra software.
2. Understand the needs of the Coordinators within the Well Planning team and integrate their input into the creation of a new methodology and tool.
3. Develop a means to quickly capture the Three Point Survey points, and construct the survey polyline utilizing ESRI ArcGIS software.
4. Create a user friendly interface that would be easy for users to learn and implement into their own workflows.
5. Export the tools to the WebMap and test the accuracy in that space.
6. Prepare the team for implementation of the tools.

### Justification

This practicum provides an in depth review of GIS applications that were utilized in order to develop these tools. Through the development of new solutions for spatial problems within ESRI software, there is an increase in user access as an enterprise GIS license is already in use by Pioneer Natural Resources. Additionally, users are typically familiar with ESRI's WebMap and learning how to implement these new tools would not be a difficult endeavor. The implementation of these tools will reduce runtime for the generation of the survey points and the survey line, thus freeing up Coordinators to focus on more pressing assignments. Additionally, a new means of data entry for the creation of the Three Point Survey would help in reducing human error that could potentially arise.

### **Project Timeline**

This project began officially on May 21<sup>st</sup>, 2018, consisting of forty hour work weeks for ten weeks. Time was primarily dedicated to working on the project, with several informative lectures every week regarding the industry and different technologies. The first week of the project began with orientation into Pioneer Natural Resources, getting established in the office, and obtaining access to necessary software and datasets that would be required for the project. The project began with a rough start, as the initial understanding of the Coordinator's needs were not accurate, by week three this was rectified and the project was put on the correct course.

The fourth week of the project consisted of a visit to Midland, Texas to learn about field operations, drilling and completions practices, water management, and to gain the overall understanding of the lifecycle of a well development from start to finish.

Week five and onward were focused on the development of the tools. The process began with developing the proof of concept in ArcMap and manually producing the desired results. Once it was determined that the method was sound, the project shifted to creating the tool utilizing ModelBuilder in ArcMap. By week nine a great focus was put on migrating the solutions from ArcGIS into the WebMap space and testing out the functionality in that space. Week ten marked the conclusion of the project consisting of a presentation of the results to management.

### **Literature Review**

Searching for literature to use as a reference for this project was a challenge. Given the nature of the oil and gas industry, many practices are under the company's proprietary digression. Employees can be reprimanded if certain information is made public. Additionally, given the fact that the scope of this internship was to address a very specific issue within the company, it was difficult to find research that was relevant and valuable to the project. The solution needed to be able to address the specific needs of the Well Planning Coordinators of Pioneer Natural Resources, thus this project relied heavily on creativity and personal ingenuity. Much of the background information and learning required from this project was internal, through one on one discussions with employee to learn about the software they utilize, and their current methodologies. Off of these discussions the plans for how the models would function were created and the research that ensued was on how to best utilize the preexisting geoprocessing tools to accomplish these goals. Furthermore it was vital to understand the context that these models were constructed under, which meant gathering a baseline knowledge of the industry itself.

The article *The Successful Development of Gas and Oil Resources from Shales in North America* by Daniel J. Soeder in 2018 proved to be an informative resource for understanding the industry. Soeder details the science behind hydrocarbon resources such as shale gases and oils from a geologic perspective. He then dives into conventional versus unconventional practices and how the methods from drilling and extraction has developed over the year and by location. Additionally Soeder provides valuable history of the industry in North America and how it has grown in response to new technologies, management practices, and improved research science and exploration. Finally Soeder discusses the implications of hydraulic fracturing in terms of environmental concerns, the research that is being done to evaluate impacts, and how many people's perspectives on the issues have been shifting with new and more thorough information being made available. Understanding how much the industry has changed over the past two decades highlights the need for new and innovative tools to improve workflows and create better extraction strategies.

Another valuable resource that was used to understand the more technical aspects of hydrocarbons and unconventional oil extraction was the book *Future Energy: Improved Sustainable and Clean Options for Our Planet* by Trevor M. Letcher in 2014. In his book Letcher discussed a series of energy sources that have been used throughout human history with a very objective perspective. He goes into geologic and chemical detail of hydrocarbons and how humans are able to develop them for their energy needs. Letcher also details the processes of conventional versus unconventional oil from a geophysics and engineering perspective as well, highlighting how intricate the process is to get correct. This proved to be valuable as the Three Point Survey revolves around the planning of unconventional wells.

One aspect of this project that was a major challenge was the land itself in West Texas. The lease acreages where Pioneer Natural Resources operates are often irregular in shape and size, with many discrepancies and gaps in ownership. This proved to be a major hurdle in the development of the Three Point Survey models. The Texas State Historical Association proved to be very valuable in understanding the nature of the data from a historical perspective. This digital encyclopedia provided information in regards to how land practices in Texas is very complex due to be subjected to Spanish and Mexican rule. The surveys used methods and measurements that were unique to the area, and having several surveys by different companies in the area has led to the irregular grid that exists today.

The focus of this project was to build a tool that had the ultimate goal of visualizing the Three Point Survey. The importance of having these visualizations is that the basic paradigm of understanding shows that “seeing” is a good way to understand something, as discussed by Hardy Pundt in his article *Visualization of Spatial Data for Field Based GIS* (2000). While Pundt was focusing on the importance of visualizations for field users, it rings true to anyone that may utilize spatial data. He discusses that visualization comes naturally to the users, and helps to aid the understanding of real world conditions. Additionally Pundt discusses how success in mapping has its foundation in concrete workflows. All of these points highlight the importance of developing easy to use tools and workflows in software that is either familiar or easy to learn.

Ismail Wadembere also discusses similar ideas to Pundt’s in his 2014 article *Validations of GIS Vector Data during Geo-Spatial Alignment*. GIS allows users to model, analyze, and visualize data in a spatial format, which makes it an appropriate system for constructing the Three Point Survey. He details how GIS is an excellent medium to exchange information between individuals or amongst organizations, and its ease of use and transparency of data has

made it one of the major foundations to spatial decisions in a variety of fields including natural resource extraction and management. This ties into the benefit of having an ESRI Webmap system that can be accessed company wide, allowing all users to gain access to that data with ease. Wadembere also discusses the importance of proper management of spatial data, as datasets can be complex in their structure. This idea was taken to heart in the development of the Three Point Survey models, as one of the goals was to create outputs that were organized and contained only relevant attribute data.

Before an effective model can be built the geoprocessing tools which will be used need to be properly understood. ESRI's online resources provides detailed information regarding all of the tools that a user may encounter while working in ArcGIS. The nature of this project was trial and error, and the information on ESRI's tool references webpage provided the greatest source of information to find new solutions. Ensuring that each tool was properly understood in regards to its functionality, the required inputs, and the type of outputs, helped in the decision process of what was most suitable for the models. In the early stages of this project before it was certain that it would be completed using ModelBuilder, the ESRI toolbox information also served as the primary source of how these tools would need to be coded in Python. Through exploring the toolbox itself and reading the description of tools, the methodology was fleshed out.

Overall this practicum was difficult to research methods that could be adapted to address the project objectives. Its highly specific nature show no set precedents and so it lent itself to creative solutions that were developed primarily through trial and error. However the background research is valuable as it helps to paint the picture of the issues that are being addressed.



## Methodology

Due to proprietary restrictions, data used for this project cannot be published here. Rather, a descriptions of the data will be explained, and all well names and identification numbers have been opted out.

### The Data

The bulk of this project is focused on data from the Well Planning team. During the planning process, a proposal document called a “Pulse Document” is created to outline the particular geology for an area, highlighting target zones, and the footage call information identifying where in the lease the proposed locations would be for the surface hole location, the first take point, and the bottom hole location. Once this information has gone through the necessary channels for approval, the footage call information is sent to a contracted surveyor, who collects GPS points on the land after following the footage call information. The survey company sends back the platted survey to Pioneer, which the coordinators then use to create the Three Point Survey.



X: 1491654.12	Latitude: 31.85700142°
Y: 800366.93	Longitude: -101.97057269°
1480' FEL & 615' FNL - Section 11	

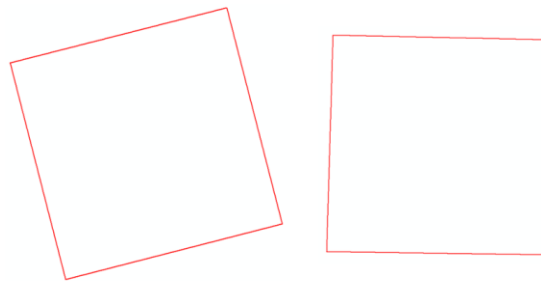
**Figure 3:** An example of survey plat information with footage calls and direction information.

XY coordinates in NAD 1927 and Lat/Long coordinates in WGS 1984 for a single survey point

which were created following the footage call directions.

Figure 3 is an example of the information that would be sent back in the survey plat. It indicates that the directions were for section 11 in the lease holdings, and it gives directions to one survey point. “1480’ FEL & 615’ FNL” translates to the point being located at 1480 feet from the East line of the lease and 615 feet from the North line of the lease. The surveyor followed these directions to find the location of the coordinates seen in Figure 3. This type of information would be used heavily in the creation and testing of the Three Point Survey tool.

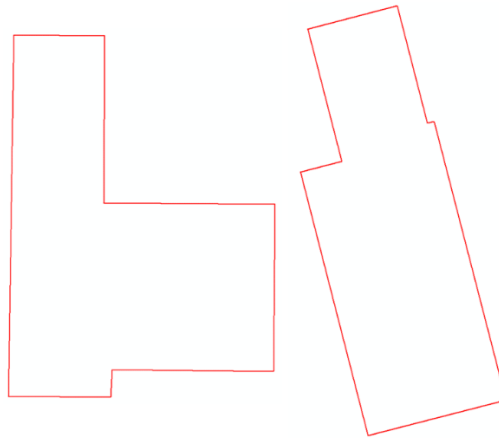
The primary spatial data that was used for this project was a shapefile depicting the lease holdings that Pioneer owns. These are legal boundaries that define where the company may operate within. This shapefile consists of several polygons each depicting a different lease holding.



***Figure 4: Polylines of the typical shapes and orientations of leases within the Permian Basin***

Figure 4 is an example of two leases which have been converted from polygons to polylines. These two squares represent the majority of lease shapes and orientations of those found within the Permian Basin. If a user could imagine that they were standing within the middle of each square, it is fairly easy to understand what cardinal direction a person would assign to each line. The top line would be north, and going clock wise the following lines would be east, south, and

west. While Figure 4 shows the average shape and orientation of lease boundaries, leases are found in many different irregular shapes. Figure 5 shows some of the irregular shapes that appear in Pioneer's acreage.

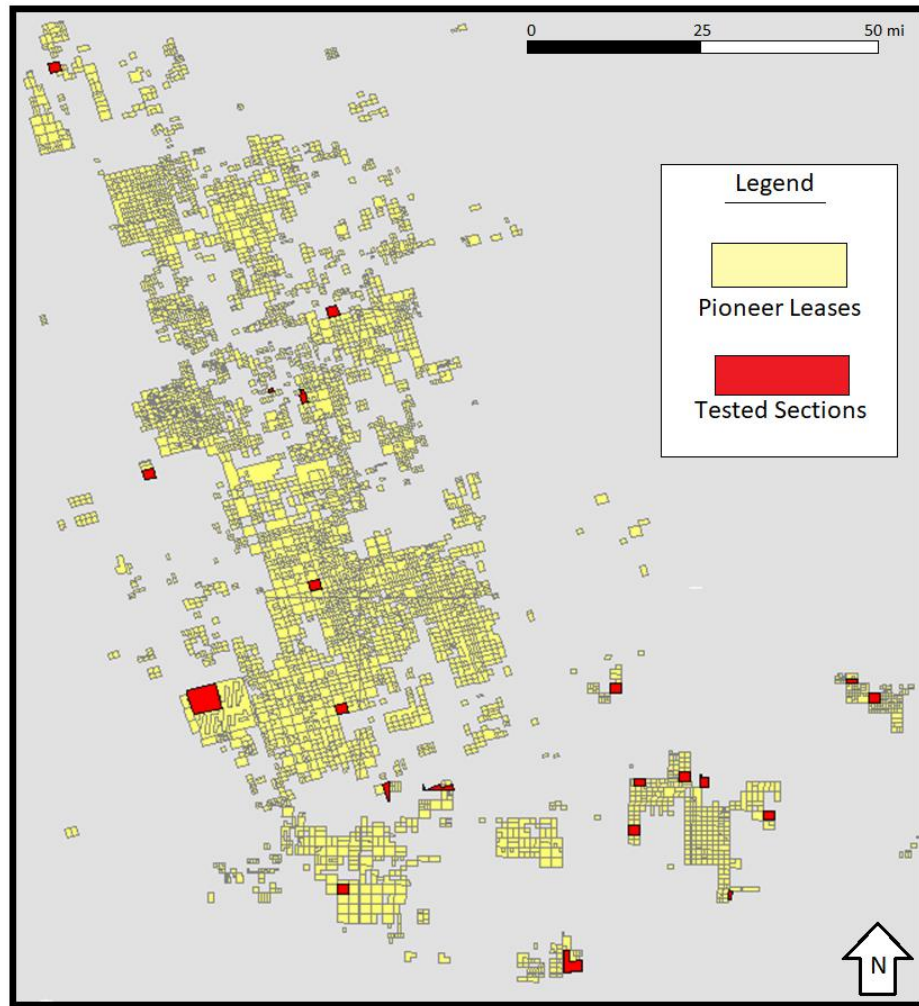


***Figure 5: Polygons of irregular shapes of leases within the Permian Basin***

#### Determining Direction

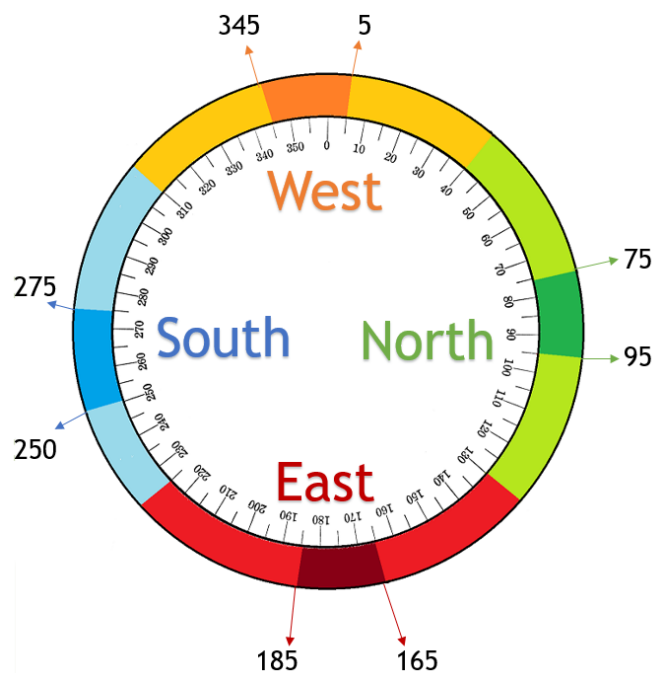
Creating a way for the tool to automatically assign the correct direction was one of the biggest challenges of this project due to the fact that the leases are not uniform in shape, size, and orientation. To overcome this, the tool would use the geometric attributes of the line. Each line in ArcGIS is a vector with direction, and the line bearing indicates the start-to-end bearing of the line ranging from 0 to 360 (ESRI). The 'Add Geometry Attributes' geoprocessing tool automatically calculates the bearing of a selected line and creates a field in the data table with the directional information. In the traditional compass sense, a line bearing of 0 would indicate north, 90 would be east, 180 for south, and 270 for west (ESRI). However, this would not apply to the lease polygons, as the typical north boundary in reality would have its bearing pointing towards the east.

The next step involved determining which line bearing values would correlate to each of the four cardinal directions of the lease boundaries. To do this, 20 lease sections were selected throughout Pioneer's acreage to be test. These selections, as seen in Figure 6, were chosen due to their variety in shape, size, and location throughout the basin.



*Figure 6: Map of leases selected for testing (in red) to determine the range of line bearings would correlate to each of the four cardinal directions*

The twenty lease polygons that were selected were converted into polylines and then split at the vertices so that each segment were individual objects. Once they were split, the line bearing was calculated for all the lines. These were recorded and use to create the range of values that would indicate each cardinal direction. Well Planning Coordinators indicated what they would call the north, south, east, and west line for each lease polygon in order to ensure the tool would properly fulfill their needs.



**Figure 7:** A compass showing the line bearings as they correspond to each of the cardinal directions. Darker portions of each color represent the observed range of line bearings while the lighter portion represents the extra “cushion” range to catch any outliers

Figure 7 shows the line bearing ranges that were calculated and which direction they correspond to. For the north direction, line bearings were between 75 and 95 degrees, and this range was extended to be between 40 and 130 degrees. For the east, the observed range was between 165

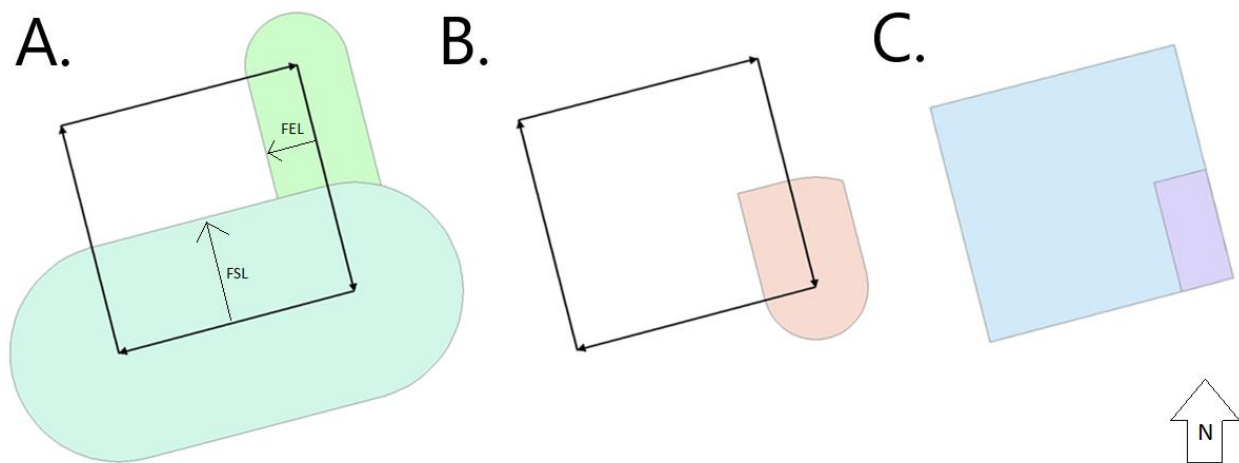
and 185 degrees, which was then extended to 130 and 220 degrees. Next, for the south the observed ranges were between 250 and 275 degrees, and this range was extended to 220 and 310 degrees. Finally, for the west the observed ranges were between 345 and 5 degrees, and this was extended to 310 to 40 degrees. The compass itself is not centered are the “true” compass directions of 0, 90, 180, and 170 degrees as it is a reflection of the lease geometry, which is typically skewed rather than an upright orientation. These classifications were deemed to be consistent with the directions as assigned by the coordinators.

### *Generating Survey Points*

With the procedure established to assign directions to line segments, the methodology development turned to actually generating survey points. For this task, human error was taken into heavy consideration. The coordinator’s technique for creating a Three Point Survey in the Petra software involved inputting the XY coordinates from the platted survey. Typically the XY coordinates are a series of numbers consisting of up to 9 digits to ensure that the point is being drawn in the correct location. With ease of use in mind, other means for creating the survey points were explored. The contracted survey workers generate the XY coordinates utilizing the footage call information, and this information is typically far easier to read and to key in. Figure 3 was an example of footage call information, where numbers are whole integers. Numbers like “1480” and “615” are far less likely to yield a human error during data entry as opposed to “1491654.12” or “800366.93”. Additionally, by creating a tool which utilized these easier numbers to read and key in, it would also decrease how much time coordinators need to spend looking over the numbers to ensure the correct information was utilized. With all of this taken

into consideration, it was decided that the tool would utilize footage call information as opposed to the XY coordinates.

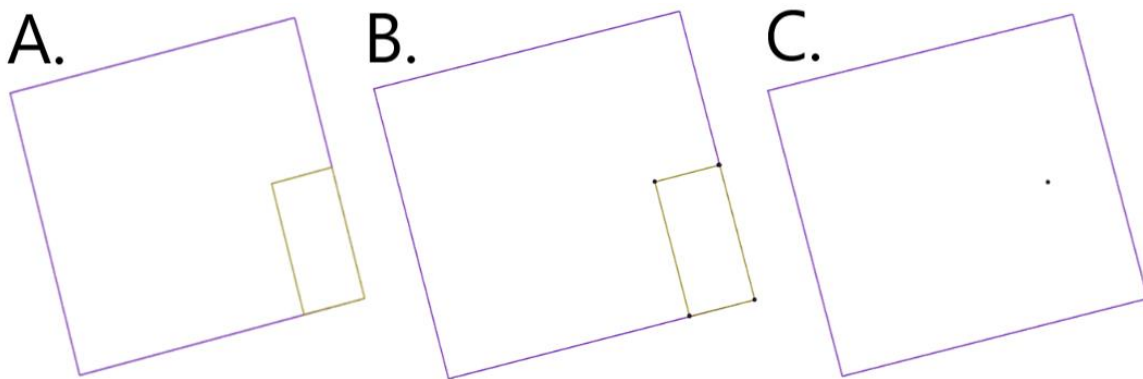
The next step was to create the means to follow the footage call directions and generate the survey points. To do this the idea of buffers were explored. The buffer geoprocessing tool creates a polygon around an inputted shape according to specific distances indicated by the user. Using buffers would serve as a means to follow the footage call information from the directional line of choice. Figures 8 and 9 illustrate how this method would work.



**Figure 8:** The first half of the buffer methodology. A. Two buffers are created parallel to the lease boundary lines as opposed to cardinal directions B. The buffers are intersected together C. The intersection is clipped down with the original polygon

In Figure 8 the first half of this methodology are outline. Based on the directions and footage call information, two buffers are created. This in a sense simulates the surveyors walking those distances from the lease's boundary lines. Once the two buffers have been drawn up, they are intersected together, as where they meet will indicate where the survey point is located. The

intersection is then clipped down with the original polygon. This ensures that the space is limited to within the lease's boundaries, and fewer vertices will in turn be generated. In Figure 9 the second half of the methodology is displayed. In this stage the intersection polygon is converted into a polyline, and from the lines vertices points are created. For typical four sided lease polygons four points would be generated. If the lease's geometry had a slight bend to it, this could lead to additional points being created but it is not problematic. A selection is then performed to highlight the points which fall on the lease's border and these are then deleted. The remaining point represents the survey point of concern. Upon the creation of the desired point, XY coordinated and Latitude and Longitude coordinates were then generated and used to populate the correct data columns within the attribute table. This process is repeated until all three survey points are generated according to the information from the Pulse Document. After The SHL, FTP, and BHL have been created all three points are then connected together to create a polyline in that respective order via the geoprocessing tool "Points to Line".



**Figure 9:** the second half of the methodology. A. The intersection polygon is converted into a polyline B. From the polyline's vertices, points are generated C. Excess points are selected and deleted. The remaining point is the survey point of concern.

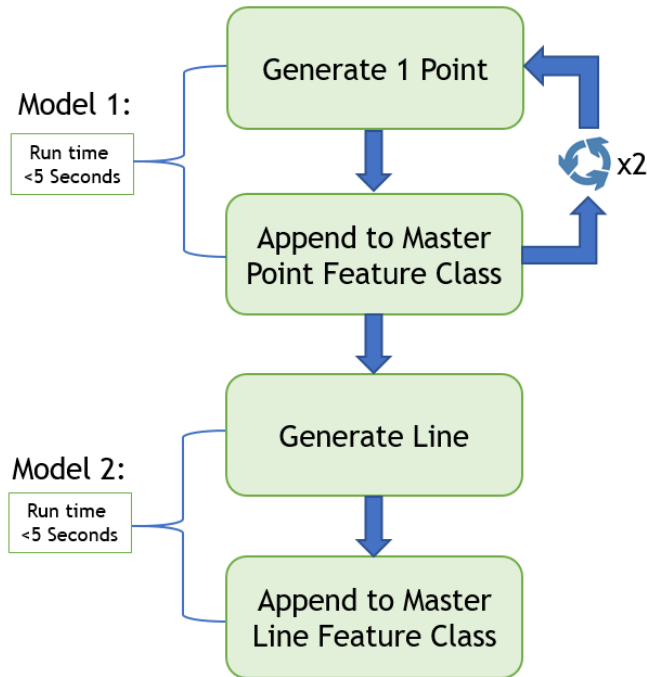


This methodology was tested manually in ArcGIS Desktop using several platted surveys. For the tests the same footage call and directional information as appeared on the plats were used to create three point surveys. Some coordinates that the methodology developed were exact to those created by the contracted surveyors. Others presented slight variations, however the difference was deemed small enough that it could be ignored. These differences will be discussed in more detail within the Results section of this paper.

### *Creating the Tool*

The methodology and results were deemed to be sufficiently accurate and able to meet the needs of the coordinators, and the next step was to create a tool to automatically perform these steps. To do this, it was determined that the tool would be constructed using ModelBuilder. ModelBuilder is an application allowing users to create and edit their own tools through strings of geoprocessing tools and commands. Essentially it is an input/output machine which can be used to automate a workflow. Using ModelBuilder was determined to be the more effective avenue to create the Three Point Survey tool within the allotted amount of time, as opposed to the original plan to construct the tool via Python.

Creating a singular model to automatically generate the three survey points and connect them together into the survey line proved to be a challenge outside of the scope of this project. Rather than developing one model that would complete the entire process on its own, the projected manifested two models. The first model would be dedicated to creating the survey points based on user inputs. This would be iterated three times to create all three survey points in their appropriate locations. The second model would then be used to connect the three survey points into the Three Point Survey line. Figure 10 is a flowchart depicting the process of working through the two models to create the final output.



**Figure 10:** Flowchart depicting the workflow for creating the Three Point Survey. Model 1 is run a total of three times to create all the necessary survey points. Model 2 searches for the three points of concern and connects them together to create the survey line.

One aspect of this project that was explored and implemented was the idea of “master feature classes” During the creation of this tool, all functions were performed locally. As the project began to near its maturation, it was determined that additional steps would need to be considered to reckon with where this data would be located. This idea is also illustrated within the Figure 10 flowchart. For this project, two master feature classes were created to serve as the home for this data. A feature class that would house all generated points, regardless of which type, and a second that would house all generated survey lines. These master feature classes were create with the intention of ensuring that all the data would be in two central locations, helping

preventing gaps in data or potential loss. Additionally, automatically creating a location to send the data to go to is one less step for the user to consider and another avenue to avoid human error.

The selected methods were done so with the idea of reducing the amount of time needed to create a Three Point Survey, while simultaneously reducing human error and increasing user access. These methods and the workflow that it established was determined to be an effective means to achieve these goals, and upon approval the projected moved forward and the two models were created.

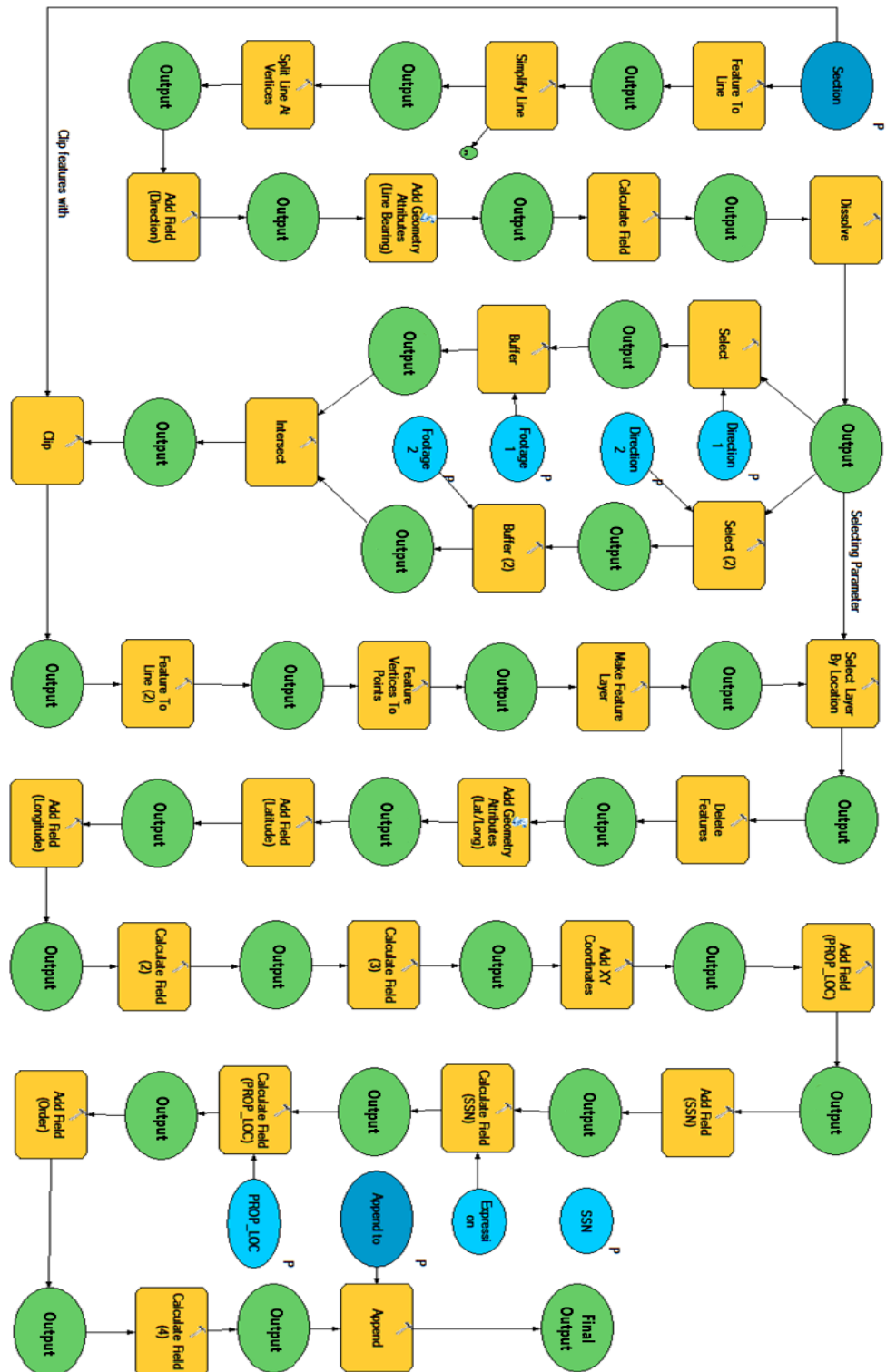
### **The Three Point Survey Tool**

The Three Point Survey Tool is comprised of two models for users to use. The first model (Figure 11) is used to generate the survey points and append them to a “master point feature class”. This process is iterated three times to create all of the required survey points, each one with the appropriate SSN, the unique well identification number, written to its data table. The second model (Figure 14) searches for the three correct points based on SSN to be connected into a polyline and then appended to a “master line feature class”. This section will be a review of each step in the two models.

#### **Model 1: Generating Survey Points**

The first model is used to create the survey points that will be used to construct the Three Point Survey polyline. The data input to create the survey points consist of the polygon representing the lease or section where the well point will be located, the SSN for the well for identification purposes, and the footage call information from the survey plat. Once this data is

collected it can be inputted into the first model. Figure 12 shows what the user would be prompted with to input this information.



**Figure 11:** The Point Generation Model. Yellow rectangles represent geoprocessing functions, green circles represent generated outputs. The "P" symbols denote required parameters which are inputted by the user.

TPS\_POINTS

SSN

Section

PROP\_LOC  
'SHL'

Direction 1  
Direction = 'South'

Footage 1  
☒ Linear unit  
340 Feet

Direction 2  
Direction = 'West'

Footage 2  
☒ Linear unit  
1453 Feet

SSN

The SSN is a unique well identifier that is obtained from the Pulse document. User should input the leading letters "ID" in front of the desired number.

OK Cancel Environments... << Hide Help Tool Help

**Figure 12:** *The user input prompt for point generation as seen in ArcGIS*

The model generates one point at a time, so the user is required to indicate the “PROP\_LOC” or proposed location. The user does this by using the drop down menu to select the desired location, whether it is the SHL, the FTP, or the BHL. This will be important for ensuring that the polyline is drawn in the correct order when the second model is utilized. The Direction selections are also drop down menus for the user to select from, and they can then manually input the desired footage distance as indicated by the plat. Typically this metric is always measured in feet unless otherwise noted on the survey plat. When all the necessary data has been inputted, the user will select “OK” to run the model. Overall the actual processing time to generate the point takes about 5 seconds or less to complete, this was measured both locally and over the company’s network.

The model begins with the inputted lease polygon that the point is being drawn in. For this version of the tool this was primarily done with isolated polygons; however, in the WebMap version of the tool the user would simply perform a selection of the polygon to use as the input. The polygon is then converted into a polyline which is then simplified in order to remove any excess vertices which may result from lines that may have slight inflections. This simplification utilized Point Remove with a tolerance of 100 feet. Once simplified, the lines are then split at its vertices, creating a unique ObjectID for each facet of the shape. The field 'Direction', is added to each section line.

To populate the 'Direction' field, the geoprocessing tool 'Add Geometry Attributes' is utilized to generate the Line Bearing. Once the bearing of the line is calculated, the model performs a calculation to assign it one of the four cardinal directions via Calculate field. The code block to do this is as follows:

*Expression: RCLS(!BEARING!)*

*Expression Type: Python\_9.3*

```
Def RCLS (BEARING):  
    if (BEARING > 0) and (BEARING <40):  
        return "West"  
    elif (BEARING > 40) and (BEARING <130):  
        return "North"  
    elif (BEARING >130) and (BEARING <220):  
        return "East"  
    elif (BEARING >220) and (BEARING <310):  
        return "South"  
    elif (BEARING >310) and (BEARING <360):  
        return "West"  
    else:  
        return Null
```

Once the 'Direction' field has been properly populated, a Dissolve is performed to condense this field down. This is done for the scenario that a polygon's edge may have yielded

excess vertices which were not caught by the Simplify Line step. Thus, if there are multiple “North” lines they would be condensed into one.

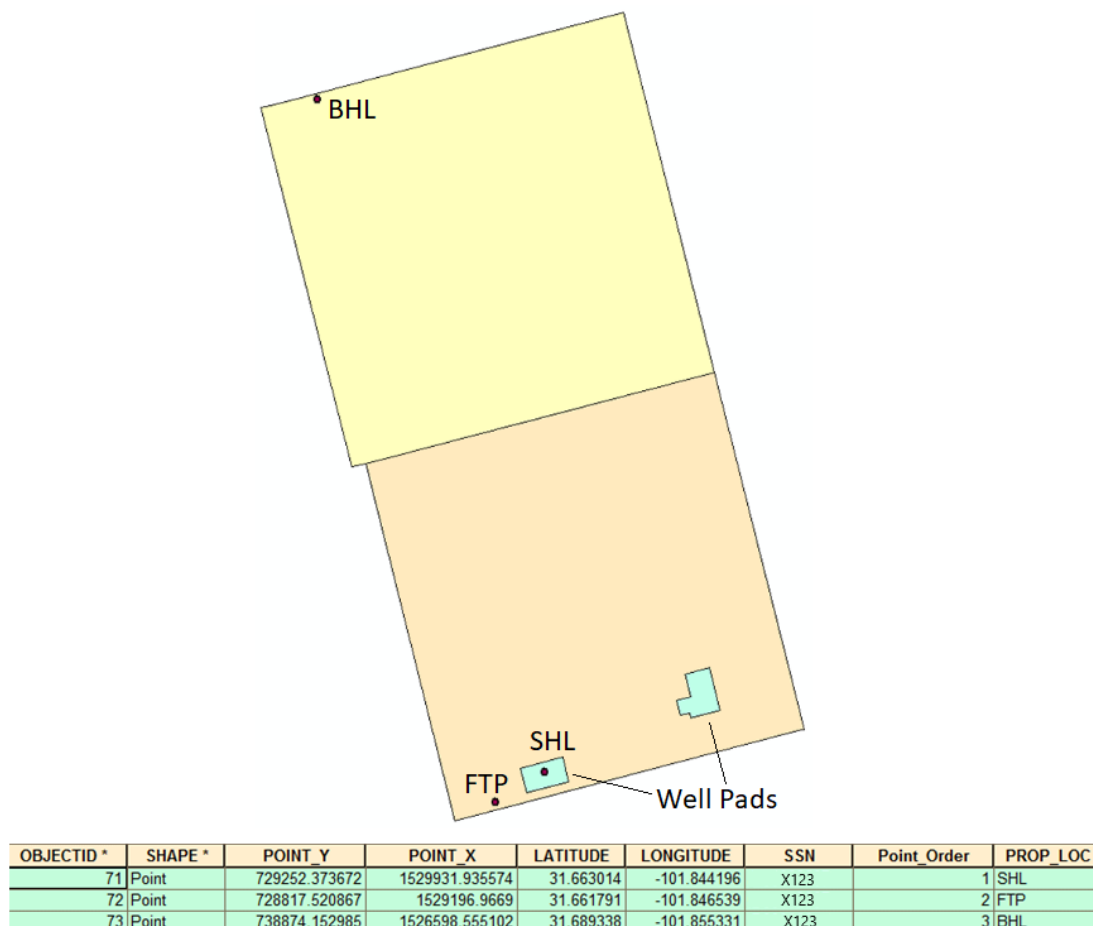
With all of the lines being assigned a cardinal direction, the model then moves on to using the footage call information to construct the survey point. At this stage, the model will perform two selections based off of the directions that the user inputted. The model will select the line that correlates with that direction and generate a buffer using the two inputted footage information. Once the two buffers are created, they are intersected together, and that intersection is then clipped down with the original polygon selection in order to remove excess vertices.

The clipped down intersection is then converted from a polygon to a line. The model then uses the Features Vertices to Points geoprocessing tool to generate a series of points, one which will be the survey point of concern. Extra points are selected by using the original lease lines as a selecting parameter. The points which intersect the lease boundary lines are highlighted to be deleted, and the remaining point which exists is the survey point of concern.

Once the survey point is the only one to remain, the model will begin to write necessary information to it. Add Geometry Attributes is used to generate the Latitude and Longitude coordinates which are then added to their respective fields within the data table. Additionally the XY coordinates are also calculated and added to the field. The results in the data table provide coordinate information in both North American Datum 1927 (NAD 27) and World Geodetic System 1984 (WGS 84), as desired by the Coordinators.

Next the model adds two fields, ‘SSN’ and ‘PROP\_LOC’. These two fields are populated using the information that the user inputted into the prompt prior to running the model. Once this is done, the model adds another field ‘Point\_Order’. The ‘Point\_Order’ field is used to ensure

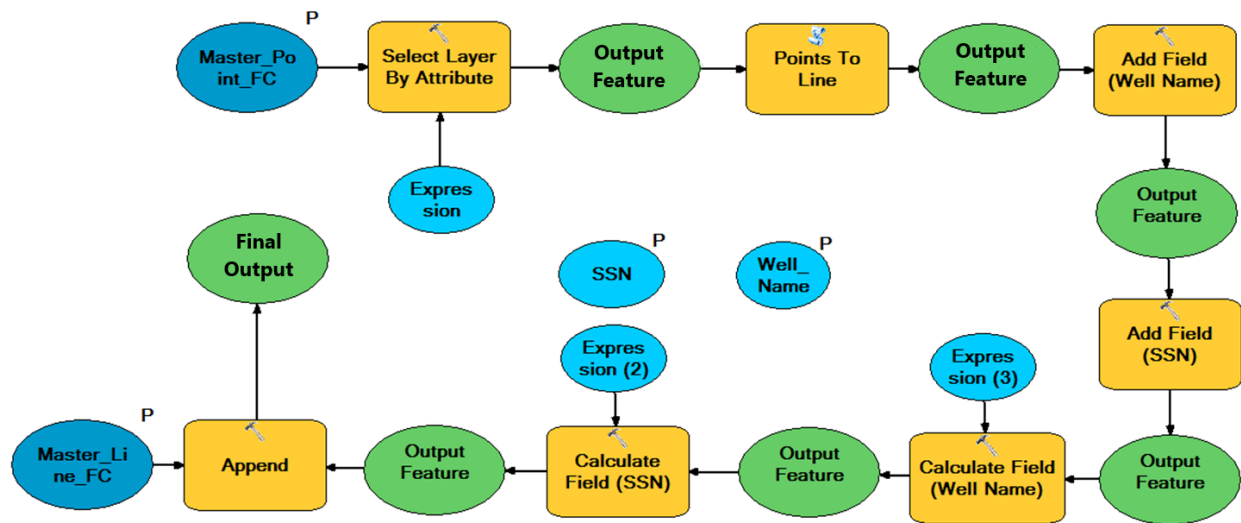
that when the second model is being run, the polyline is drawn in the correct order, which would start with the SHL to the FTP and finishing at the BHL. SHL are assigned a value of “1”, FTP have a value of “2”, and BHL have a value of “3”. The final step takes the final output point and appends it to the “Master Point Feature Class”. Figure 13 is an example of what the output may look like once the first model is run three times, as well as the data table associated with it. It is very common to have the SHL and FTP occupying the same lease polygon, and to have the BHL located in an adjacent lease. In some cases wells can span across three different leases.



**Figure 13:** Final output for model 1, yellow and beige polygons are 2 different lease sections the well would cross, points represent three survey points and blue polygons represent well-pads.



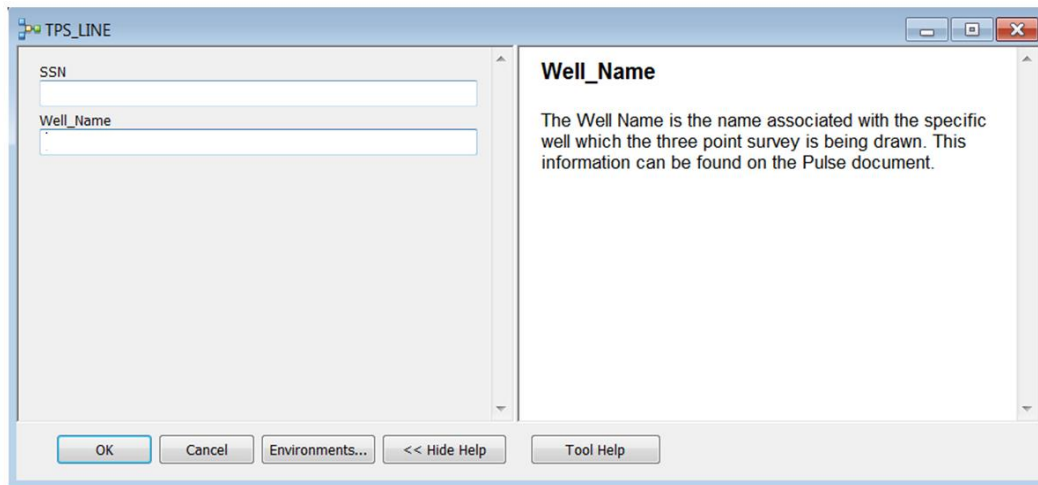
*The SHL point is always located within a well pad polygon. Data table associated with it contains XY coordinates, Lat/Long, SSN, Point Order, and Prop\_Loc.*



**Figure 14: The Line Generation Model**

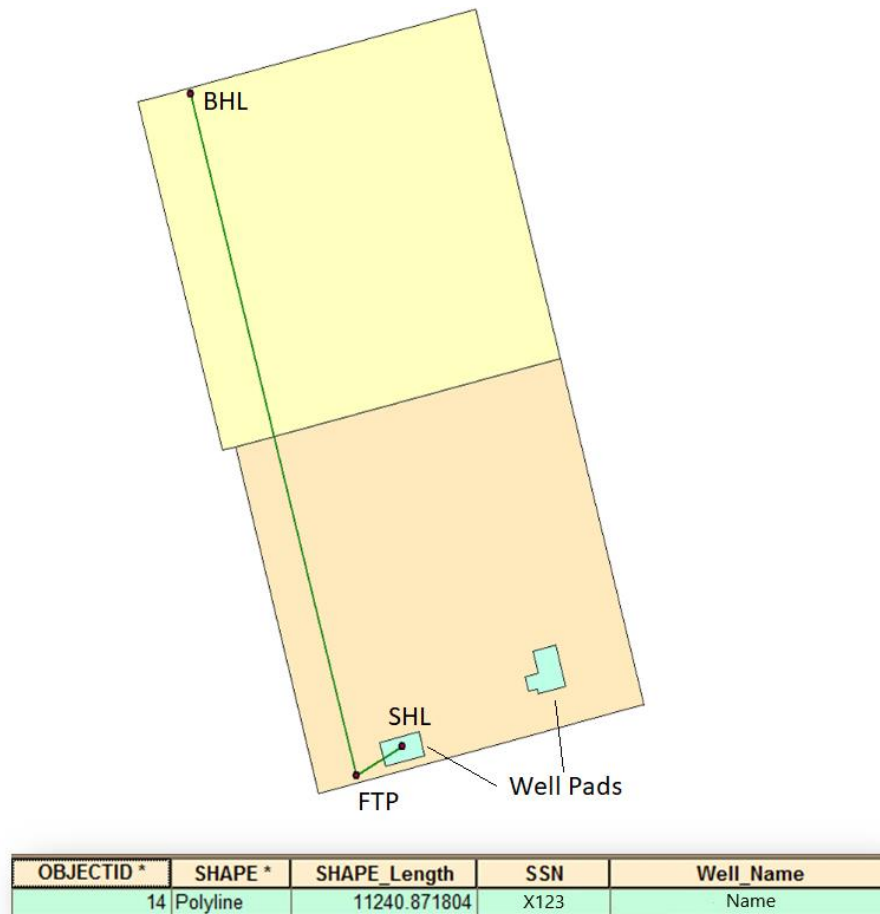
### Model 2: The Line Generation Model

The second model, Figure 14, is used to take the survey points generated by the first model and connect them together into the Three Point Survey polyline. Figure 15 shows what the user interface appears as in ArcGIS Desktop. In this version of the tool, there are only two fields for the user to input, the SSN and the Well Name. The Well Name is an unnecessary parameter for the final version of this tool, but it was used in the development stages to help keep track of data being generated with ease. The SSN that the user inputs again is taken from the survey plat, this number is the same one that was used in the generation of the survey points.



**Figure 15:** User input prompt for Line generation as seen in ArcGIS

The second model begins by searching through the “Master Point Feature Class” to select points which match the inputted SSN. The geoprocessing tool Points to Line is used, and the parameter Sort\_Field is utilized in reference to the ‘Point\_Order’ field. This ensures that the line is drawn in the correct order, starting with SHL, then FTP, and finally BHL. Two fields are then added, ‘Well\_Name’ and ‘SSN’, which are then populated with the information as inputted by the user. In this version of the tool the information written to the line itself is kept simple. Once the tool was functioning in the WebMap space with the other spatial information that already exists, it could be determined which information was relevant to copy to the Three Point Survey Line. Similar to the first model, the final output is appended to a “Master Line Feature Class”. Figure 16 is an example of the final output would look like upon connecting the three survey points together, as well as the data table associated with it.



**Figure 16:** Final output for model 2, connecting together the data points as seen in Figure 13 to create the final Three Point Survey Line. In this version of the tool the data table associated with it contains the SSN and Well name.

## Results

The creation of this tool and its functionality was very successful in achieving almost all of the goals outlined at the beginning of this project. Those goals being to create a tool which can generate the Three Point Survey using ESRI ArcGIS based solutions, reduce the runtime needed to perform these tasks, reduce chances for human error, and increase user access. While the tool

in this form is not the perfect solution, it accomplishes the majority of tasks needed to be performed by the Well Planning Coordinators. Tool limitations will be discussed in the following section, and recommendations were made on how to continue to improve upon this methodology and tool.

In terms of the accuracy of the coordinates that were generated by the tool, they were deemed to be acceptable. The methods was tested on twenty different areas, and the results of the surveyor's coordinates were compared to those generated by the Three Point Survey tool. Some of the generated coordinates that were tested matched those created by the surveyors exactly, while others deviated slightly. During the timeframe of the internship, a conclusion on why this occurred was unable to be reached. However, when consulting the Well Planning team and the VP of Asset team, these differences were seen as negligible, and would not negatively affect functionality.

Due to the nature of this project, the data that was utilized and created are proprietary and cannot be display within this practicum. However, Table 1 is an example of coordinates that were generated by the tool compared to those that were captured by on the ground surveyors. Identification information and other details have been omitted to adhere to company policy.

**Table 1:** Top- XY and Latitude/Longitude coordinates as produced by contracted surveyors.

Bottom- XY and Latitude/Longitude coordinates as produced by the Three Point Survey Tool.

Surveyor Coordinates:

X Coordinate	Y Coordinate	Latitude	Longitude	Point
1594630.05	773269.66	31.7826134	-101.63792699	SHL
1595312.01	773303.93	31.7867752	-101.63573374	FTP
1592638.53	783390.12	31.81401609	-101.64471959	BHL

Three Point Survey Tool Coordinates:

X Coordinate	Y Coordinate	Latitude	Longitude	Point
1594630.111624	773269.360113	31.78626	-101.637927	SHL
1595312.006586	773303.933862	31.786377	-101.635734	FTP
1592638.53129	783390.119727	31.814016	-101.64472	BHL

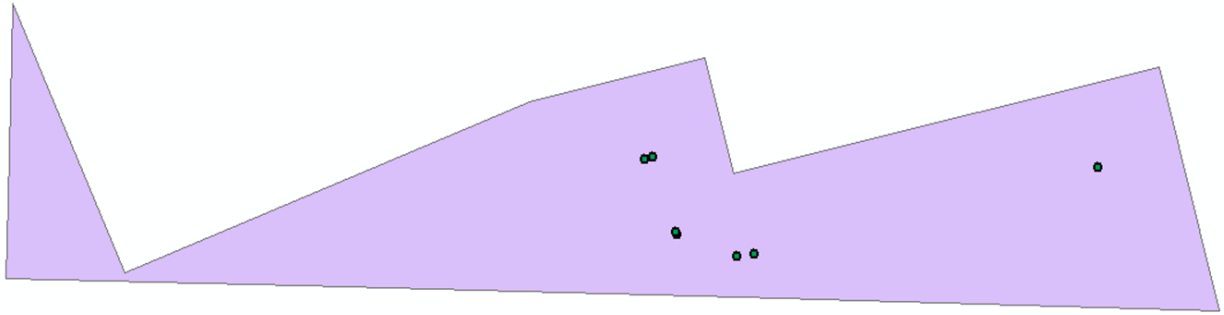
Table 1 compares the surveyor coordinates to the Three Point Survey Tool's generated coordinates. The Tool followed the same footage call and directional information to locate the three survey points and generate the coordinate information. While the coordinates are not exactly the same, the degree in which they differ results in a very minimal difference in real life. For example, comparing the XY coordinates for First Take Point, the distanced measured on the map between the drawn up coordinates are 0.00511 feet apart or 0.06132 inches. While they do not line up exactly, the team was unable to determine why this discrepancy occurs, but the difference was determined to be negligible.

In terms of run time the tool is also considered a success. The Well Planning Coordinator's method to create a Three Point Survey in Petra is an involved process that requires carefully following particular steps. On average it would take around 15 minutes to complete a

Three Point Survey using the Petra methodology. With the Three Point Survey Tool, while it is comprised of the first model which is run three separate times and the second model which is run once, it was a drastic improvement on time management. The first model takes on average less than five seconds to run over the company's network, and the second model also takes less than five seconds. If these times are called five seconds flat the total run time is twenty seconds to generate the survey points and connect them together. The total time from start to finish is dependent on the Coordinator's data entry speed. As the new methodology focuses on utilizing footage calls and directions over inputting XY coordinates, the process was done rather quickly and with ease when applied.

### **Limitations and Recommendations for Future Work**

While the Three Point Survey tool was deemed to be a success, it was not a perfect solution for creating survey lines along all of Pioneer's acreages. The tool is completely effective when dealing with four sided polygons, whether they are square, rectangular, or some other irregular shape. But as discussed earlier, not all of the leases are four sided polygons, as seen in Figure 5. These types of shapes are a minority of Pioneer's acreage, at about 20% or less, but they proved to be troublesome when used as input for the tool. If there are multiple lines which would be classified as the same direction, the tool will select and construct a buffer around each segment which meets its criteria. Through these excess buffers, additional points will be generated, as seen in Figure 17.



**Figure 17:** *An irregular polygon in Pioneer's acreage. Points generated came from one input footage call on North and East directions*

Figure 17 shows an example of the limitations that were observed based on irregular shapes. The points were generated all based off the same North and East footage call information. Instead of yielding one point the tool created seven, which is problematic. The Well Planning team is able to discern where the well placement should be by sectioning off the larger polygon into smaller and simpler polygon. This issue was discussed thoroughly with the Well Planning Coordinators. When dealing with these irregular polygons, they would manually section off the areas of concern within the Petra Software. This proved to be a challenge in how to incorporate this into the automated process, especially in the limited amount of time that was dedicated to this project.

To fix the issue of irregular polygons, it was determined that it was a matter of how the input of the lease polygon was entered. For this project, testing the functionality of the tool was made on either isolated polygons in their own individual layers, or being able to select the polygon of choice from the acreage grid. A new type of input would need to be utilized to resolve this issue. It was determined once the tool was exported into the WebMap space, the user would be able to use an interactive selection. This would mean that the user could draw out the

area that they desired to generate the survey point within. Through this method the irregular polygon is no longer problematic, as long as the user is creating a four sided polygon as their means of selection. This methodology is also similar to that which was utilized in the Petra Software, so the concept is not a foreign one that would require extensive training on.

An unfortunate limitation for this project was an internal server issue. At the time of this project, Pioneer's server was experiencing issues that created several roadblocks for exporting and publishing the tool into the WebMap space. Extensive troubleshooting was performed to address this issues, but the problem was one that had to be addressed on a greater scale. This led to a lack of testing the tool in its final desired form. Upon delivering the Three Point Survey product to the team that would continue on with implementation, this issue was discussed and plans were made to publish and test the tool properly once the server was fully functional.

Another limitation to the tool is the ability to create surveys for wells with an inflection. An inflection in this sense is a well that has an additional point signifying a turn, which may occur depending on the geometry of the lease. These types of wells are uncommon and are more likely to occur in the minority of Pioneer's acreage where lease shapes are atypical from the more standard squares. This issue was not considered amongst the initial scope of the project, however it could be quickly resolved with accounting for an additional point type amongst the Surface Hole Location, First Take Point, and Bottom Hole Location. These inflections will occur on the horizontal portion of the well, so the point order code could simply be adjusted. An Inflection Point could be made an option for the user to select, and it could be coded to have the point order designation of three, while the Bottom Hole Location could shift back to be coded as four. By doing this, the draw order will be the same whether or not there is an inflection present



in the survey being constructed. This is a recommendation that has been made to those assuming responsibility over this project.

When this project was started, the envisioned product was a single tool that could simultaneously generate all the survey points and connect them into a survey polyline. As the project progressed, it became apparent that this would be a challenge beyond the project's scope. This was due to the fact that the majority of wells span across two or more leases. The inputs would need to account for the fact that multiple leases would need to be selected, and the tool would need to successfully distinguish which footage call and directional information was associated with each polygon. There were attempts to reconcile this problem, however it would conflict with one of the other project goals: an easy to navigate user interface. By creating too many simultaneous inputs, it would create a new opportunity for human induced data entry errors to occur. It was determined that the tool and user interface should be kept simple, and the iterative process would not be problematic.

One of the main limitations of this project was the use of ModelBuilder. As an application, ModelBuilder is very useful in automating certain tasks within a workflow. However, it is apparent that as a model becomes more complex it becomes more "sensitive". On several occasions, changes were made that would result in the model being unable to complete its function, or generating null values for particular fields. These issues were often resolved with a reboot of the program, or in one instance, completely copying over all the functions into a new model without making any actual changes. The finicky nature of ModelBuilder for complex processes leads to a need to create an additional solution. Upon beginning this project, it was considered to create a solution through a Python code. However, due to limited experience in Python, this was determined to be an ineffective usage of time, even though it would have been a

great way to sharpen those skills. Once this project was passed onto its successors, it was determined that the Models would serve as the outline to create a Python script to perform the same functions. Having the complete Python script will allow technicians to make changes or updates to the tool as needed without experiencing as many issues that may occur while trying to edit a ModelBuilder tool.

## **Conclusions**

The successful creation of the Three Point Survey Reporting tool was made possible by the help and support of the Well Planning team at Pioneer Natural Resources. Being able to understand the functionality of the Three Point Survey as a component of the planning process and considering the needs of the Coordinators who would be utilizing the tool paved the way to create a tool to accomplish the objectives that were originally laid out for this project. The tool was created as an in house solution that would alleviate reliance on specific expensive software, and serve as a means to improve on the workflow. By creating an easy to navigate user interface, the chances of human error are decreased along with the amount of time required to complete these tasks. GIS solutions being utilized to automate workflow will allow team members to focus on greater tasks at hand and use their time more efficiently. At the time of completion, the product was not a 100% solution, but the groundwork has been clearly outlined for ease of implementation by the project's successors.

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