

**Using Geographic Information Systems (GIS) to Enhance
Campus Safety, Planning and Building Management**

*A Practicum Submitted in Partial Fulfillment of the Requirements for
the Degree of Master of Science in
Applied Geospatial Sciences*

**Matthew Natividad Tafoya
Department of Geography, Planning and Recreation
Northern Arizona University
June 2016**

**Using Geographic Information Systems (GIS) to Enhance
Campus Planning, Building Management & Safety Assessment**

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

Matthew Natividad Tafoya
Department of Geography, Planning and Recreation
Northern Arizona University

June 2016

Committee Members:

Rebecca Dawn Hawley, Ph.D., Chair

Alan Lew, Ph.D.

Dennis McCarthy, P.E.,

NAU Engineering & Inspection Director, Retired

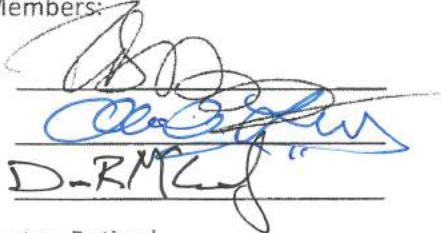


TABLE OF CONTENTS

Table of Contents	2
List of Figures	4
List of Tables	6
Acknowledgments	6
Abstract	7
Letter of Significant Contribution	8
 Chapter 1: BACKGROUND & OBJECTIVES	
1.1 Campus Data Management Technology	9
1.2 Problem Statement	10
1.3 Research Objectives	12
1.4 Research Scope	13
 Chapter 2: LITERATURE REVIEW	
2.1 Historical Summary	19
2.2 Geographic Information Systems	24
2.3 GIS Link to CAD Computer Aided Design	26
2.4 GIS Link to BIM Building Information Modeling	28
2.5 Interoperability	32
 Chapter 3: METHODOLOGY	
3.1 Research Methodology	35

Using GIS to Enhance
Campus Safety, Planning and Building Management

Chapter 4: PROJECT IMPLEMENTATION

4.1 GIS to Enhance Planning	43
4.2 GIS to Enhance Building Management	58
4.3 GIS to Enhance Safety Assessment	87

Chapter 5: RESEARCH SUMMARY

5.1 Research Conclusion	100
5.2 Future Campus GIS	106

References Cited	115
-------------------------	------------

Appendices:

Appendix A: Defined Terms	118
Appendix B: GIS Database Resources	119
Appendix C: Facility Services Department Summary	124
Appendix D: Project Data Tables	126
Appendix E: Work Log Summary	133

Lists of Figures:

Figure 1.4: Facility Services Departments	16
Figure 4.1: Undeveloped land area data project	46
Figure 4.2: Site planning with aerial imagery overlaid with GIS data layers aerial 2D	47
Figure 4.3: Arc Toolbox: Interpolation Toolset	48
Figure 4.4: Auger Drill System Diagram	49
Figure 4.5a: Geotechnical report page: Borehole points	52
Figure 4.5b: Geotechnical report page: Borehole test results	52
Figure 4.6: Site Location IDW Borehole Map	53
Figure 4.7a: Borehole locations mapped based on geotechnical reports	54
Figure 4.7b: Borehole Interpolated Auger Refusal Campus Map	54
Figure 4.8: 3D Borehole Sample	55
Figure 4.9a Site planning: Site location with Borehole Data	56
Figure 4.9b: Site planning: Project Layout with Utility Data Overlay	56
Figure 4.10a: Typical 2D CAD Floor Plan	60
Figure 4.10b Converted 3D Interactive Floor Plan	61
Figure 4.11: HEGIS code sample table	61
Figure 4.12: CAD in ArcGIS: Drawing Layers	65
Figure 4.13: CAD to GIS Line Types	66
Figure 4.14: CAD Default Layer and Properties	68
Figure 4.15: Geodatabase Schema for 3D Model	69
Figure 4.16: CAD layer query to separate layers	70
Figure 4.17a: Georeferenced CAD and Paper Utility Map	71
Figure 4.17b: Digitized Utility to GIS Feature Classes	71
Figure 4.18: 3D Feature Subtypes in Structured Geodatabase	72
Figure 4.19: 2D to 3D add fields step	73
Figure 4.20: 2D to 3D layer conversion step	73

Using GIS to Enhance
Campus Safety, Planning and Building Management

Figure 4.21: Arc Scene: 3D Base Height Step	74
Figure 4.22: Arc Scene 3D Layer Elevation Perspective	75
Figure 4.23: Arc Scene Line Extrusion Perspective	76
Figure 4.24: BIM Model and Asset Attribute Field Window	77
Figure 4.25a & b: BIM Model HVAC layer perspectives	78
Figure 4.25c: Arc Scene BIM Utility Schematic Perspectives	78
Figure 4.26: Floor plan use color code figure	80
Figure 4.27: BIM model in Google Earth figure	80
Figure 4.28: Master Utility CAD file to be reconciled	82
Figure 4.29: Georeferenced Data Windows	84
Figure 4.30: Utility network	86
Figure 4.31: Observation Point Blue Lights	90
Figure 4.32: Visibility Toolbox ArcGIS 10	90
Figure 4.33: Sight Lines Targets Options	91
Figure 4.34: 300ft Light Buffer Polygon	92
Figure 4.35: 300ft Euclidean Distance Raster with 10 equal intervals	92
Figure 4.36: Arc Toolbox Layer to 3D and Add Z information tabs	93
Figure 4.37: Sight line production map figure	95
Figure 4.38: Line of Sight Visibility Code Values	97
Figure 4.39: Visibility Analysis South Campus	98
Figure 4.40: Visibility Analysis Garage Light Restriction	98
Figure 4.41: Full Campus Emergency Blue Light Visibility Analysis Production Map	99
Figure 5.1: Plans Room, Plan Sets for Review	101
Figure 5.2: Plans Room, Flat Plans Storage	102
Figure 5.3: Plans Room, Rolled Plans Storage	102
Figure 5.4: Plans Room, Hanging Plans Storage	103
Figure 5.5: GIS Mobile Interface	107
Figure 5.6: GIS Space Planning Classroom Locator Application	108
Figure 5.7: GIS Parking Services Production Map	110

Using GIS to Enhance
Campus Safety, Planning and Building Management

Figure 5.8: GIS Special Events Parking Application	111
Figure 5.9: GIS Centralization	112
Figure 5.10a: GIS Exterior Augmented Planning	113
Figure 5.10b: GIS Interior Augmented Management	113

List of Tables:

Tables 2.4: CAD Tables Formats	31
--------------------------------	----

Acknowledgements:

My deepest gratitude is to my advisor, Dr. Rebecca Dawn Hawley. I appreciate that my advisor gave me the freedom to explore my ideas and the time to process them and the patience to complete this practicum. Dr. Hawley showed me how to question my thoughts and express clear ideas. I also appreciate the time and support of my other committee members through this extended process.

Most importantly, none of this would have been possible without the love and patience of my wife, Laura Tafoya. It is to her this practicum is dedicated. She has been a constant source of love, concern, motivation, and strength through this process. I would like to express my heart-felt gratitude to my entire family that have aided and encouraged me throughout this endeavor.

Using GIS to Enhance Campus Safety, Planning and Building Management

Abstract:

Campus management, using the latest technology to collect and analyze campus assets, needs to continuously look for efficient and effective management tools. One of the most modern and relevant technological tools that should be used for campus management is the Geographic Information System (GIS). Given the vast amounts of spatial data that exist from various specialty fields, a smart technology based campus management framework should be a more commonly used tool for the life cycle of campus assets. The success of these tools is governed by many factors. The reliability and accurateness of the data is crucial for the success of a GIS framework. The ability for a specialty field or department to update, share and utilize the data input as often as possible is critical for keeping the GIS framework relevant and therefore valuable. One of the major benefits of a GIS system is that many of the necessary analytical tools are already integrated into the system and are available to the end user if applied properly and provides the required database backbone of what is needed to effectively and efficiently manage a campus environment. Given that GIS is a table based visual data application, it is becoming a reliable data management application that is needed in the university environment. GIS is quickly becoming a decision making tool and a smart way of gathering and sharing data. GIS is not a tech support feature but rather the central data decision making repository that can be utilized by administrators, building managers, faculty, and students.

This practicum demonstrates the multiple uses of GIS in diverse projects that campus management supervises.

Using GIS to Enhance
Campus Safety, Planning and Building Management

Letter of Significant Contribution:

June 14, 2016

Dennis McCarthy

Director of Engineering & Inspection, Retired

School of Social & Behavioral Sciences

Department of Geography, Planning & Recreation

Practicum Committee for Matthew Tafoya

Regarding: Letter of Significant Contribution

Dear Committee,

The projects that Matthew has listed in his practicum have made a significant contribution to the mission of Facility Services. The practical application of this effort has enabled the leadership of the department to realize the importance of the endeavor and will continue to devote resources to it.

The site analysis and soil characteristics project has enabled the Planning Design and Construction group to evaluate projects for location and help to develop concept budgets.

The organization and management of building space and building data has assisted the Space Management group in tracking and allocating space for colleges and departments.

The utility reconciliation project is a high priority of the leadership of Facility Services because of the need to know locations of all underground utilities. This is a huge task and the groundwork for the effort has been established.

The evaluation of the location of the blue lights will make the campus a safer place for students and staff.

All of the projects listed in Matthew's practicum have made a significant contribution to Facility Services and have made the work efforts of other groups much more efficient.

Sincerely,

Dennis McCarthy

Chapter 1. Background and Objectives

1.1 Campus Data

Attended by more than 20,000 students each year, the mountain campus at Northern Arizona University consists of approximately 6.6 million gross square feet of building space with an infrastructure system that includes 1.2 million s.f. of roads, 1.7 million s.f. of paved walkways, 62 acres of surface parking lots plus four parking structures, within a 770 acre land property boundary. This infrastructure and building space is managed by one major group, the Facility Services Department. Traditionally this department relies on outside design professionals to design and build the new projects for the campus, but it is this department's responsibility to maintain the project for the duration of the life cycle post construction.

To manage the man-made built environment, it is imperative for this department and the university to identify a diverse set of applications that allows for system integration. The applications that best integrate data from various resources, is the most sustainable in terms of adaptability, scalability and usability. The networking of physical assets with electronic spatial data allows for enhanced data management capabilities. Trends that are identified in 'Digital Technology' state that "The Internet of Things" are impacting the integration of building systems (Hughes 2015). GIS software improves data system organization, storage and accessibility through various sever/cloud networks. GIS also enhances data understanding and interpretation through data analytics. "Enabling the Internet of Things are mesh networks where every device

serves as a node in the network to relay data from point to point. This distributed approach of connectivity can improve reliability and reduce redundancy (Hughes 2015).”

The current status of data system management at Northern Arizona University is not connected to a spatial resource software. This disconnected status does not allow for location (spatial) or relationship based analysis. This is a key factor in managing campus systems (utility, walkways, roadways, building, etc.) and helping serve the users of those systems (students, staff, visitors)

1.2 Problem Statement

The campus environment encompasses a large area of land that comprises a diverse environment with variety of facilities that serve as classrooms, offices, recreational space, dining and resident halls. Plus, there is the support infrastructure system that exists above and below the ground surface that provides the communication, transportation, electric power, water and plumbing services to the university community. These systems are becoming more difficult to manage due to continued campus growth in new construction, building renovation and infrastructure improvements.

Northern Arizona University does not currently utilize a central asset data repository that can track and integrate all the various asset systems and their real world relationships in order to manage and evaluate the conditions and locations on campus. The current asset management system relies on institutional knowledge that is shared with specialized trades groups. Asset data

Using GIS to Enhance
Campus Safety, Planning and Building Management

is currently accessed through disconnected plan sets which represent small windows of information that are not updated to reflect current asset design and condition.

This is major issue for a campus that maintains facility assets with a replacement value of \$1.787 billion and a building and infrastructure capital expenditure of:

- Building renewal¹ projects \$5.456 million
- Infrastructure renewal² \$1.580 million
- Major Maintenance³/System Replacement \$2.676 million

(NAU 2017-2019)

See Appendices: Defined Terms^{1, 2, 3}

In today's economic environment every agency is striving to remain competitive and profitable. Public and private companies are looking for systems that will help manage individual tasks and the entire management process more efficiently. According to a recent ESRI article, the average organization spends a third of its operational resources on these three information segments; design, data management and analysis. A company where GIS technology is used as a tool could increase the organization's revenue by 50 percent, without adding any new customers, by simply expanding its products and services to support customers' activities related to data (Miller 2012). This is mainly due to efficiency, as time is a major cost concern when it comes to designing, managing data and conducting analysis.

Using GIS to Enhance Campus Safety, Planning and Building Management

Just as technology has advanced at a record pace, so to have our building systems and utility networks. The intricate collections of building materials, land infrastructure, component machinery and growing population require an effective system sophisticated enough to capture, organize, manage, process, analyze and report on the countless spatial relationships and dependencies of environmental and man-made eco systems. These elements require progressively more sophisticated tools to help us design and manage them more effectively and efficiently in order to produce sustainable results (ESRI Insider 2011).

Ultimately, GIS integration can serve as this design, management and analytical tool to meet and exceed the university sustainability goals. This is accomplished by determining the environmental impact of each building system and every utility network. A GIS asset based system is a precise framework that can be utilized for asset cycle decision making policies as it relates to an emergent smart building adapted facility management system. Geographic Information Systems (GIS) is considered a smart technology which through property implementation can manage data more effectively, providing significantly more automation during updates, enabling more interaction between data providers and data users. These are the major conditions of smart technology (Esri White Paper 2009). GIS is the critical link for a connected campus where smart data awareness and implementation is achievable for planning, operations and assessment.

1.3 Research Objectives

This practicum seeks to describe, through applicable campus-wide Geographic Information System (GIS) practicum projects, how a GIS system can be used to organize vast

Using GIS to Enhance
Campus Safety, Planning and Building Management

amounts of infrastructure and building data and can be used as a tool for campus construction planning, building management and safety analysis tool through the establishment of a GIS environment where many stakeholders can readily share, update and maintain information about facilities and infrastructure to enhance economy construction, enhanced maintenance and campus safety. Currently there is no comprehensive centralized data repository of building and infrastructure data at Northern Arizona University. There is no common platform whereby various campus stakeholders can rely on as an accurate representation of campus asset data including its physical attributes and their relationship to other assets on campus. There is no comprehensive and reliable database upon which informed decisions can be made by cross referencing related current and archived data. This practicum will focus on the using GIS platform based on ESRI software suite of ArcMap 10 and ArcCatalog 10 & ArcScene 10 in order to provide a unified and complete asset data repository for use by all campus stakeholders.

The research objectives are:

1. Demonstrate how a GIS can be utilized as a planning tool for campus planning, development and construction (PDC);
2. Demonstrate how a GIS can be improve the organization and management of asset data for building and infrastructure;
3. Demonstrate how a GIS can serve as an analytical tool for campus safety analysis;
4. Demonstrate how the unification of data through a systematic GIS monitoring system is a benefit to the University.

1.4 Research Scope

This practicum scope is based on Facility Services Department project requests for GIS data and analysis. Although several projects exist for each department, it is the scope of this practicum to focus on how GIS can be utilized for campus planning, building management and safety analysis. Each application is not necessarily a duplication of the other. The application process is a result of the distinct department request for data services.

For this research distinct data services is defined as those services related to the collection, organization, reconciliation, consolidation, population and/or analysis of a campus systems or facility. It is relevant to note that the data collected, organized and analyzed was derived from record data that is for the following: campus building space consisting of 6.6 million gross square feet and the infrastructure systems that include 1.2 million SF of roads, 1.7 million SF of paved walkways, 62 acres of surface parking lots, four parking structures on a 770-acre land area and a utility database that contains 15 reorganized datasets with numerous customized feature classes and domains.

The ability to obtain sustainability metrics is a major benefit to the integration of GIS based data management into the existing University operations and maintenance systems. Proper sustainability implementation can result in campus economic vitality, healthy student residential living and proper use of environmental resources. There are several metric applications that are used within Facility Services but the highest efficiency is not obtainable if the disparate systems are not integrated in one way or another. Although most applications run

Using GIS to Enhance
Campus Safety, Planning and Building Management

efficiently on their own, it is the disconnected nature between these applications that is a limitation factor to achieve universal management potential. Independent data intensive applications need to be integrated into a centralized data management and visual communication system so that consistently updated and accurate information can be shared and used by various stakeholders to make informed decisions.

The practicum focus on a selection of projects and the various stages of a project's life cycle that Facility Services manages.

A project's life cycle includes:

- The Design & Build Stage:
 - Project Planning
 - Project Site Selection
 - Project Design
 - Project Construction
- The Operations & Maintenance Stage
 - Land Management
 - Building Management
 - Infrastructure & Asset Management
- Sustainability & Replacement Assessment Stage
 - Environmental Assessment
 - Emergency Preparedness & Response Assessment
 - Security Assessment

Using GIS to Enhance Campus Safety, Planning and Building Management

○ Energy Assessment

The project types that are included as part of this practicum include new and redesigned improvements of all asset classification related to: buildings, office space, utilities, walkways, roadways and land.

FACILITY SERVICES DEPARTMENT

Every asset classification under university ownership is managed by six main departments within the Facility Services umbrella. As a member of one of these departments, this study will make specific contributions to the existing management structure.



Figure 1.4: Facility Services Departments

Using GIS to Enhance Campus Safety, Planning and Building Management

The Facility Services Department is tasked with the responsibility of managing new, renovated and improvement projects. The responsibility of Facility Services Department is summarized in the Appendix C. Currently this department does not mandate the use of a central database repository to manage the maintenance and conditions of all campus assets. Currently data for the same asset is maintained by separate specialty sub-departments (trades group). For example, data for a single building asset is maintained by segmented groups. The building's space data is tracked by Space Management, the building's space material is tracked by Hazard Materials and Carpentry, and building's utility systems are track by different specialty trades groups. This would be a good structure of data management if the underlining data was accurate and equally shared between all groups. The issue is that the above groups are not all using the same building data. Some depend on independent surveys of the building, some depend on supervisors' knowledge, some depend on independent database resources and others depend on construction plans that are on file most of which are not current reproduction of the components that exist in a building due to on-going project upgrades.

The current project system that is used by Facility Services (FS) is a software application called TMA Maintenance Management System. This system is mainly used as a project assignment application to track open and closed projects. It is also used to track service calls, estimates, and inspections. It is not used as a management tool to track the attribute conditions of an asset nor does it provide data analysis. The attribute data for assets exists separate from the project renewal and maintenance projects. The attribute data is provided through printed

Using GIS to Enhance
Campus Safety, Planning and Building Management

descriptions on original plan sets and through text formatted O&M manuals (operations and maintenance) and project shop drawings. This segmented distribution of data is a very inefficient way of maintaining asset data for the purpose of maintenance, management and analysis.

GIS is still not widely used as an asset management tool, to which this practicum provides the process in which GIS was utilized for Campus Assessment (Design & Build), Building Management (Operations & Maintenance), and Asset Analysis (Assessment). Given that the Facility Services Department is tasked with building, infrastructure renewal as well as other major maintenance responsibilities it is the emphasis of this practicum to recommend that Facility Services Department integrate a GIS system into every department as a tool to assess asset attributes conditions and relationships.

Chapter 2. Literature Review

This literature review provides the context for the proposed research by linking research of previous case studies of various GIS projects to a systematic GIS framework tailored to campus management systems.

The literature review is organized starting with how technology evolved from early obstacles to more recent specialized integrations. Starting first with the historical inception of other design related software to the latest specialized but varied software programs that include building information modeling software also known as BIM. The practicum project in which a detailed accounting workflow is described in the Chapter 4: Implementation, there is very little published in how GIS was used for my specific planning, building and asset applications, more specifically applying GIS to Borehole interpolation, applying GIS to building information modeling (without using alternative applications) and applying GIS to line of sight analysis of safety blue lights.

2.1 Historical Summary

Automated mapping/facilities management (AM/FM) systems and geographic information systems (GIS) witnessed the growth in popularity in the 1990s that computer-aided drafting and design (CADD) systems did in the 1980s. In the past, most businesses operated as hierarchically structured organizations where individual tasks were accomplished by dividing

Using GIS to Enhance Campus Safety, Planning and Building Management

them among specialized labor pools. The result in many cases are islands of automation, duplication of information from one system to the next, difficulty in sharing data among systems, and problems in training users to operate the multiple systems needed to automate different functions (J. Astroth 1995).

According to the facilities management group at ESRI, the biggest cost to an organization, second to human resources, is asset management (ESRI/ Facilities Management 2010). They state that if assets and facilities can be managed well, an organization can reduce its overall management costs through more efficient maintenance and effective space management as well as improving the ability locate and utilize resources most proficiently. The National Institute of Building Science estimates that facilities consume forty percent of the world's energy (Paradis 2012). Carnegie Mellon University research has indicated that improving productivity in building functions by 3.8 percent would pay for building's design, construction, operations and sustainment. The implementation of a GIS system brings this type of efficiency to facility and campus management.

Adoption Issues

Early adoption obstacles to successful implementation included the need for quantitative definition of financial payback for implementation and integration of a GIS system at the beginning of the project. There was no vision or plan for GIS and a general perspective of treating GIS solely as a technology issue rather than a people issue. There were and continue to be internal organizational barriers whereby retraining is needed and finding and retaining the right

Using GIS to Enhance
Campus Safety, Planning and Building Management

personnel and knowing when to outsource a project due to expertise and budgeting concerns is handled on a case by case basis given that some GIS projects are short projects and others involve long period of collecting, updating reconciliation before any analysis can be done. And finally treatment of GIS as a capital expenditure and not an operating expense remains an accounting issue (Przybyla 2002).

There have been specific challenges in addressing the storage of data for an entire campus including proper data collection from indoor and outdoor asset components as well as specific under and above ground utilities (Lynch 2011). The challenges exist due to the specialized knowledge needed to understand each and every system. The terminology used in each field and the system connection components need custom designed database schemas, so the best scenario is if the GIS database designer also has specialized training in a specific field and GIS in order to be able to build a proper system that is both effective and efficient. This scenario would require dual specialized training which is both cost and time prohibitive.

In order for large organizations to adopt and then implement new management application software they must make sure the program can:

1. Be built upon existing data infrastructure
2. Maintain modularity (compartmentalize)
3. Maintain scalability (one size does not fit all)
4. Support multiple levels expertise and allow for advancement

Using GIS to Enhance Campus Safety, Planning and Building Management

5. Empower Users
6. Simplify Current Processes
7. Protect data Accuracy
8. Leverage big data
9. Provide value
10. Universally accessible

Implementation Benefits

There's a general consensus in the building industry that GIS implementation can lead to better coordination among disciplines and help build quality by eliminating many conflicts associated with traditional 2D approached including Request for Information (RFI) delays (Dehaven 2009).

There is also an effort to transform the building industry in a holistic approach where we design and build in a revolving and updating automated exchange of information method as items are installed or changed. This allows for a constant feedback and ability to adjust or improve construction before completion. This is intelligent design/build but how is that different that automated building? "What is the difference between an intelligent building and normal building automation?" This is a good question! It may be valuable to start with a high level definition of an intelligent building. The one we like is: "Use of technology and process to create a sustainable building that is safer and more productive for its occupants and more operationally efficient for its owners" (Ehrlich 2008). A building's intelligence level can be considered as a point

along a spectrum. At one end are those highly intelligent buildings in which most systems are automated and integrated. In the middle are moderately intelligent buildings in which a few systems share information, and at the far end of the spectrum are buildings in which each system operates independently (Kroll 2007)).

Implementation Issues

A continued effort exists to push for integration of building systems and diverse technologies to develop a network of physical items with software to allow for enhanced management capabilities and data analysis (Hughes 2015). The ability to integrate systems improves data reliability and reduces research time to find and connect the data from various drawing resources. But just as technology has advanced at a record pace so have the design of recent projects. The intricate collections materials, infrastructure machinery and people, with countless spatial relationships and dependencies, require progressively more sophisticated tools to help us design and manage them better (ESRI Insider 2011). Today's asset management system must be ever more complex and sophisticated.

Technology is used heavily for the design and construction of a campus development project. Through the use of computer aided design (CAD) and building information modeling (BIM), new construction projects benefit from technological software. The issue is that these design applications are less functional as asset assessment applications which are needed to manage the built environment. The operations and maintenance life cycle phase of a build environment will consume 64% of the overall cost of a project (Wallis 2012). This life cycle phase

Using GIS to Enhance
Campus Safety, Planning and Building Management

consists of the maintenance, operations and replacement assessment phase of the life cycle of a building. There is virtually no smart technology being used for the maintenance, asset assessment, operations, analysis, and energy sustainability for most of the Northern Arizona University (NAU) built environment. Education based GIS and CAD projects have analyzed various components of the built environment but that data is not utilized by the Facility Services department. GIS by its native design is a spatial data analytical tool that magnifies efficiency and understanding. Researchers benefit from the use of GIS ability to evaluate data from various resources and create data models. Administrators benefit from the use of GIS enhances project communication through applying GIS data as visualization tool. Building Managers also benefit in the use of GIS data to monitor asset maintenance and assess sustainability. Given that GIS is a table based visual data application, it can become a reliable data management application that can be utilized by the university at large. GIS is the state-of-the-art decision making tool that is a smart way of gathering and sharing data. GIS is not a technical support feature but rather a central database repository that provides holistic data perspective that can inform campus administration.

2.2 Geographic Information Systems

At its most basic level, Geographic Information Systems is a marriage of geography and space through database datasets. This framework formation allows us to see our data centric world as a series of patterns, trends and relationships. Roger Tomlinson is credited with designing the first functional Geographic Information System in 1962. His goal was to get as much information into on little map which he called a “Multitudinous Map”. The information he wanted to consolidate on a map was not limited to the traditional map data of contours which describe

the peaks and valleys and every point in between. Topographical maps that described natural occurrences, environmental conditions and landscape vegetation were considered one dimensional given each map concentrated mainly on one of the aforementioned categories.

Tomlinson wanted a map that would combine the environment of the land, air and vegetation in one map. A map that would take into consideration the latitude and longitude, weather, temperature, wind direction and proximity to water features like ocean, river and lakes. Tomlinson – who died in February of 2014 at the age of 80 – is now widely credited with conceiving the first functional Geographic Information System, the computer program responsible for the staggering shift in the way we conceptualize spatial information. Decades after Tomlinson's breakthrough, GIS is everywhere (Aguirre 2014).

Through Tomlinson's efforts we now see the use of GIS for almost every industry, from science to business, from educational research and government surveillance GIS is being used to gather categorize and analyze data. GIS software magnifies data interpretation and understanding through correlation and pattern analysis. Today scientists use GIS tools in their research projects to gather and analyze data. Researchers use GIS to evaluate data from various sources to create data modeling to interpret and possible develop new theories. Administrators use GIS to enhance project communication through infographic presentations and other visualization tools. Building Managers use GIS to monitor building systems and asset sustainability and GIS is quickly becoming a "Go-To" decision making tool. Due to the fact that

Using GIS to Enhance Campus Safety, Planning and Building Management

GIS is a table based data mapping application it is increasingly becoming more commonplace within the university environment.

A GIS system combines location data with both quantitative and qualitative information about spatially referenced features. A GIS allows the user to visualize, analyze and represent this information through infographics such as thematic maps and graphic charts (ESRI/ Facilities Management 2010). A GIS is often first identified with a system to analyze and manage the natural environment and only recently has started to be applied to building and asset management given it resides in the space within the environment. By incorporating the man-made environment with the natural environment users can adopt a critical stance to spatial thinking—they can evaluate the quality of spatial data based on its location and its likely accuracy and reliability; they can use spatial data to construct, articulate, and defend a line of reasoning or point of view in solving problems and answering questions; They can evaluate the validity of arguments based on spatial information (National Research Council 2006).

2.3 GIS Link to CAD Computer Aided Design

There are various resource data contributions that a GIS system is based upon and various links that are established to in order to build a comprehensive database. GIS can incorporate data from scanned TIFF documents, Excel based data tables, Photoshop or Illustrator artwork and shapefiles. A shapefile format is a geospatial vector data format for geographic information system (GIS) software. It is developed and regulated by ESRI as a (mostly) open specification for data interoperability among GIS software products (The Shapefile Interface in GrADS n.d.). The

Using GIS to Enhance
Campus Safety, Planning and Building Management

key point here is that the GIS framework is not limited to single source data but is built on the concept of interoperability. GIS can be a standalone application but the true power is when it is integrated into different applications and also incorporates design elements from different design formats, each of which provide various benefits as well as have limits to the GIS management model.

Computer-aided design (CAD) is the general term that applies to the use of computers in the design of houses, office buildings, interiors and anything else that previously required hands-on drafting. Drafting represents the second “d” in the CADD acronym (National Institute of Building Sciences SMART Alliance 2011). AutoCAD is a specific piece of software used by many architects and designers for commercial design purposes. AutoCAD is a registered trademark of Autodesk. Because different fields use AutoCAD in specific ways, there are several versions of the AutoCAD application for a variety of work types, such as architecture, mapping and piping design.

For the management of the built environment GIS incorporates the majority of its design information from either electronic CAD drawings or hand drawn drafted drawings that need to be scanned to a digital format (TIFF for example) then manually digitized to create matching GIS layers. CAD specializes as a design tool for drafting architectural plans and very detailed and scaled engineering mechanical drawings, whereas GIS specializes in the data organization, relationship and analysis of the same drawn elements. Both GIS and CAD suites have recently started to incorporate 3D modeling aspects. Within the ESRI suite there is an application called ArcGIS Pro whereby 3D modeling is automatically built at the same time as the 2D planar layers.

The Autodesk 3D modeler is separate from its main CAD design application. Once the data is merged or converted the real power that GIS provides is a vast variety of analytical tools that CAD does not. In general the GIS and CAD systems were developed to meet the objectives of different and specialized group even though the underlying data is based on these "separate, but equal" objectives. The result in many cases is islands of digital duplication of information from one system to the other where sharing is sometime difficult among the two systems. There are also learning curve cost matters to resolve in training users to operate the multiple systems and the compatibility concerns between different functions.

GIS development as it relates to Facility Services within a university environment relies heavily on a digital design format called Computer Aided Design and Drafting also referred to as CADD or simply CAD. Although this may seem like generic term for all computer related computer design work like digital art work for advertising or even GIS which is computer based design, CADD is more specifically used to design the built environment from structures and all its elements to the surrounding infrastructure and landscaping. Another type of computer generated design for structures, which is a relatively new, is called Building Information Models or BIM, which uses several different applications to model the construction design of a building.

2.4 GIS Link to BIM Building Information Modeling

A Building Information Model (Model) is a digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward.

Using GIS to Enhance Campus Safety, Planning and Building Management

A basic premise of Building Information Modeling is collaboration by different design specialists adding changes at different phases of the facility design to update or modify asset information in the model providing support and feedback to property managers and stakeholders during design or operation. The model is a shared digital representation founded on open standards for interoperability. When a BIM is implemented, nearly every piece of building information an owner needs to know about the facility throughout its life cycle is made available digitally (Beesley 2013). This is more time consuming after a project is complete given all the data that needs to be replicated for the model. For new projects this process proceeds as the project is designed and then updated as it is built. As the project progresses the model scales and the electronic information in the BIM can be shared, viewed and edited by an assigned core team of designers and project stakeholders including contractors. Even non-technical administrative stakeholders can participate in the discussion given the highly detailed visuals, animations and presentations. Another benefit of the BIM is the ability to share quantities of materials and query work can be isolated and defined. System relationships can be shown in relative scale along with the entire group of facility systems. BIM also can help to prevent errors in clash detection by visually highlighting where elements of a building may come into conflict.

Some have only identified BIM as dealing with 3D modeling and visualization. While important and true, this description is limiting. A more useful concept is that a model should access all pertinent graphic and non-graphic information about a facility as an integrated resource. A primary goal is to eliminate re-gathering or reformatting of facility information, which is wasteful (E. Smith 2008).

BIM is currently being used mainly as a design and construction tool but not as an operations and maintenance management tool as the idea to use a BIM comes from the architectural team. To communicate form and function to the various design teams as well as with the stakeholders. Through the incorporation of 3D aspects, BIM offers increased understanding of project changes. This visualization aspect is the primary driver of the design process toward BIM and away from traditional 2D designs for larger complex projects (Hughes 2015).

GIS incorporates the portions of the model that relate to the operations and maintenance of the project. The facility management team benefits from the “information” the model provides. The attribute data specific to the building systems provide a wealth of data for GIS database population as well as building networking schema. The same update concerns exist for BIM as they do for CAD, as information needs to be updated regularly to stay relevant. The larger issue is the ability for building managers, trades personnel and owners to understand how to manipulate the information given that BIM is not a single format type. There’s a seemingly endless supply of file formats out there and the following represent the top five formats most commonly used that need to be understood by the end users in order to edit and update. A central updating database needs to be established so that one system can access all of these formats.

Using GIS to Enhance Campus Safety, Planning and Building Management

Table 2.4: CAD Table Formats

DWG	<i>This format is almost universally accepted by most model viewing/authoring programs. Also commonly referred to as CAD files, this might be the most ubiquitous digital file format in the AEC industry (and beyond). A common misconception with DWG files is that they only contain 2D information. Although that is typically true, DWG files can absolutely contain 3D objects as either basic planes or full components (known as “blocks”).</i>
DXF	<i>A very close cousin to the DWG, DXFs can be a little larger in file size but are also layer-based and a very commonly accepted format in most platforms.</i>
IFC	<i>These are arguably the most information-rich BIM files out there and can be opened by a number of programs. These are similar to PDFs in that they are not meant to be edited and are a read-only format.</i>
RVT	<i>This is Autodesk’s proprietary format for Revit files. These can vary significantly in size depending on the level of development. They can only be opened in Revit.</i>
NWD	<i>This is Autodesk’s proprietary format for Navisworks files. NWD files are also read-only, although you may be able to save them under a new name and edit from there if the file was saved with that option enabled. These can only be open in Navisworks Freedom or Navisworks Manage.</i>
COBie	<i>Which stands for “Construction Operations Building information exchange” (I am not sure why information exchange is lower case) and is intended for the complete lifecycle of a project. Simply put, COBie is an Excel spreadsheet of all the project data.</i>
I.DGN or I-model	<i>Is a recent offering from Bentley, designed as a compact, read-only method of exchanging models and metadata between their own authoring tools and review software. I.DGN is totally self-contained, offering dgn-based geometry that can be ported out to mobile devices as well as referenced or imported (as cells) into a wide range of products.</i>

2.5 Interoperability

The ability to use different types of information formats and software applications to communicate, exchange data, and use the information that has been exchanged is Interoperability. This is a key component to the projects described in this practicum. It is vital for a GIS user to understand the importance and contents of each resources. Most building and civil design work is rooted in CAD drawings. So for this built environment, much of the data that a GIS will be built from will be CAD data. There are three technologies used to integrate CAD and GIS software systems--file translation, direct read, and shared access to a database (Maguire 2003). Today there are a few hundred thousand GIS users who integrate CAD data into their GIS work flows using standard out-of-the-box solutions that implement the three approaches.

File translation involves conversion of data from one file format to another (e.g., DXF to SHP or SHP to DGN). Because of the differences in CAD and GIS data models and file formats, users need to specify the syntactic and semantic mapping. An example of file translation is the DWG-DXF-Coverage translator in ArcInfo Workstation.

Direct read is conceptually similar to file translation except that data is read and converted on the fly into memory. There is no intermediate format, just an in-memory representation in the GIS. For example, ArcView can read Micro Station DGN files directly so the CAD data can be visualized, queried, and printed in the same map as other GIS data. An alternative to data conversion is shared access to a database. Technically, one system embeds an

application programming interface (API) that allows access to data on the fly. ESRI's CAD Client extension to ArcSDE allows Micro Station or AutoCAD users to store and retrieve CAD elements and GIS features in a DBMS. The ArcSDE access API is embedded inside the CAD system. The API shows up as tools in the CAD user interface (Maguire 2003).

CAD and GIS software systems have evolved largely independently but in parallel over the past 30 years. CAD systems have focused on automating the drafting process with electronic drawings. These systems place high emphasis on 2D graphics, sketching, and coordinate geometry tools. The graphic is the database, and a drawing file is the persistence container, i.e., where the graphics are stored. Typical applications include project engineering and site design, facilities management, and construction drafting.

In contrast, GIS software systems have more formal data models with rule-based editing and topology as well as an emphasis on spatial analysis and high-end cartography. GIS data is stored and managed in databases. Typical GIS applications include mapping, site suitability analysis, and network analysis. The key points here are that at their core CAD and GIS are different and complementary; both are valuable technologies. It is best to describe CAD as a design tool that is best utilized at the beginning of a project for design very accurate angles and lengths but not so much area. In a CAD environment the layer properties are pre-formatted and have very little customization options as far as field assignment, data types, and domain associations. CAD can create very details structure elements and connections conditions. It is best to describe GIS as an assessment tool that is best utilized during the use of a project (in the

Using GIS to Enhance Campus Safety, Planning and Building Management

case of the built environment). The GIS layer properties allow for customized attribute tables that allow for different data types and domain associations. GIS can create element relationship and provides for a variety of assessment tools.

Any attempt to build a single integrated CAD-GIS system is fraught with pitfalls. CAD systems pretending to be GIS suffer from poor handling of object attributes, limited and slow database links, and rudimentary spatial analysis and cartography capabilities. They offer limited capabilities for data integration and sharing. GIS trying to be CAD systems are often accused of being overly complex, being too slow at screen refresh, and having limited sketching and drafting capabilities.

Chapter 3: Methodology

3.1 Research Methodology

The process by which each project was completed is described within each stage of the project's design and analysis steps. The process description follows the project design steps listed in project design summary below. Careful consideration has been given to not include projects within each stage whereby the process is duplicated or very similar. It is the intention of this practicum to describe how the creation and utilization of a GIS can be used in different phases of the life cycle of a man-made built environment.

The data source for each project was developed simultaneously as required by the projects if those datasets did not exist in the Facility Services GIS database system. All existing database resources were developed by the GIS office prior to commencing these projects, all of which were updated prior to the commencement of this practicum. The list of database features and datasets are listed in the Appendix B: GIS Database Resources.

The project design steps that are detailed for each practicum project were organized using the following steps:

1. Establish GIS system architecture hardware and software environment.
2. Hire or train campus personnel and students to conduct various GIS tasks.
3. Develop a GIS design implementation strategic plan.
4. Develop standards and procedures for data preparation, collection and database design.
5. Develop a workflow outline plan.
6. Collect, create and catalog all relevant spatial data.

Using GIS to Enhance
Campus Safety, Planning and Building Management

7. Develop or integrate a base map.
8. Conduct a template project.
9. Priority Application Development/Integration.
10. Deploy GIS application for user functional and analytical sustainability.

Data Research, Collection and Creation

The steps established to develop a GIS for Northern Arizona University Facility Services were based on an initial assessment of the data available to Facility Services. Most of the data were either physically stored in the document storage office or the data was maintained in digital storage files within CAD, GIS and scanned files. There was also the data that was available through the knowledge of resident employees and service professionals who had working knowledge with NAU. This information transfer from employees, also known as Institutional Knowledge, was the hardest to obtain and required a process of building trust with personnel. There is a belief that information is power and that the sharing of specialized information might lead to a loss of power and therefore a loss of value for individuals. There was also the thought that GIS was going to replace personnel given that I was asking many questions and gathering so much information. Thus the slow process of accumulating information started in 2013 when I became a full time employee with NAU (as a student I did not get as much feedback). I started to build trust and understand the process of how data was transferred and stored within the Facility Services Department. From project work order assignment to project planning and project closeout. I started to inventory existing data and catalogue all the data into consolidated files and storage locations for well-organized and non-duplicated referencing. Significant time was rendered to reconcile all map information, verify accuracy of existing databases, collect and consolidate all

Using GIS to Enhance
Campus Safety, Planning and Building Management

field collected data from both internal and external sources as well as systematically catalogue existing record data.

I set up meetings with department personnel to learn their business process and what data was used by each and where the data is stored and/or obtained. I met with project managers to understand how data was provided to Facility Services managers from design professionals and why some information was not included or missing. I met with Facility Services directors to understand the goals of each department and the directive of the Facility Services Associate Vice President and Administration in general.

These initial steps are the basis for this practicum research. My practicum encompasses GIS project objectives, assignment of responsibility, workflow process and analysis goals. By listening to the goals of the department managers, clear project objectives were determined and database organization was established to accomplish them. But in order to accomplish the goals, the projects would have to be broken into manageable pieces given the variety and complexity of some of the projects. All of the data used was based on record information that was stored in the document storage office in either CD or paper documents.

I started the process of cataloguing all the available data that existed in all formats that included scanned electronic PDF, TIFF and electronic CD, CAD and GIS. I was able to locate and catalogue approximately 75% of the total projects that were in Facility Services work assignment record. The data in its various formats was disorganized and was missing portions of record

Using GIS to Enhance Campus Safety, Planning and Building Management

documents some of which were out of date. The data had to be re-organized, catalogued, updated, digitized and then converted to a GIS compatible geodatabase format. It was discovered that some of the electronic information was duplicate information that was saved in different file locations. Most of the record information was out of date and needed to be verified. Approximately 80% of the building CAD floor plan information needed to be updated. Approximately 60% of the CAD utility location data needed to be updated.

In regard to the GIS data, it was not organized properly. All of the GIS data layers for the entire campus existed within one database. This made locating information from a very long list of data very time consuming and also made domain assignment to feature classes very confusing. Also there was no metadata to show when the information was updated to show relevancy and accuracy. In order to correct these issues, 100% of the GIS data was reorganized into a well-established Federal Geographic Data Committee (FGDC) approved system which is designed to “facilitate production and use of geographic data, to reduce costs and improve service and decision making” (Federal Geographic Data Committee n.d.). Through the effective implementation of a GIS, a phased implementation approach to a well-planned GIS brought quick retrieval of accurate data. Through the use of consolidated GIS database system, there was a significant reduction on data retrieval time.

GIS/CAD application Environment

Software products by ESRI (Environmental Systems Research Institute) were used to build the GIS. The majority of the digital formatted data existed in AutoCAD design software by

Using GIS to Enhance
Campus Safety, Planning and Building Management

Autodesk. None of the Facility Services personnel were proficient in GIS and approximately 5% were proficient with CAD. It was determined that the GIS systems had to match the CAD design drawings in order to increase accuracy and reduce duplication for future updating as we plan to continue updates to GIS formatted data for building and infrastructure system management. Other formats that were used as a resource for the GIS database include GPS field survey data, excel spreadsheets, Adobe Illustrator, photo shopped designs, scanned tiff plans, and pdf schematics drawings. All had to be indexed, reformatted and stored into the database system as geo-referenced geodatabase or shapefiles. There were also cropped DEM and orthorectified imagery raster files that were incorporated into the system.

Project Design Workflow Detail

Once a decision to implement a GIS for campus asset management was made then the following action steps were made prior to GIS creation and deployment. Below is a detail of the action steps.

1. Establish GIS system architecture hardware and software environment.
2. The foundation of an enterprise GIS is its architecture design, hardware environment and suite of software. The system architecture should reflect the needs and requirements defined in the strategic plan. Appropriate GIS software system must be purchased or downloaded. There are several companies that offer GIS software applications. For example, the most popular and widely known GIS software developer is ESRI. ESRI provides several product levels most of which require a purchase of some type. There are also GIS applications that are available for free such as GISQ.
3. Hire or train campus personnel and students to conduct various GIS tasks.

Using GIS to Enhance
Campus Safety, Planning and Building Management

4. In regard to training, the university needs to develop a training plan so that the knowledge base within the departments is transferred at various established levels and users receive the appropriate amount of training relative to the level of interaction they have with the system. Proper training for the type and level of GIS work that will be required for the specific department. Not all customer/users will require the same GIS technical skills, so depending on a department's project criteria an appropriately matched GIS professional needs to be assigned.
5. Develop a GIS design implementation strategic plan.
6. It is imperative to understand the objective of a project in order to develop and Implement a GIS strategic plan. A strategic plan is the guiding framework document for establishing the initial vision, goals, objectives, requirements, and other parameters associated with implementing the GIS system.
7. Best practice is to conduct interviews and a SWOT (strength, weakness, opportunities, threats) assessment. SWOT analysis should be developed to figure out what GIS programs would benefit the maintenance and management division of the university. This assessment was made with the input of department heads and trades supervisors on what they want out of GIS system and how it can benefit them.
8. Develop standards and procedures for data preparation, collection and database design.
9. A GIS is more than hardware, software, and data. It must also include standards and procedures that enable the data and technology components of the system to work consistently and efficiently. In a campus environment with different departments and varying GIS requirements, standards and procedures are critical in ensuring the system works correctly. Making sure to update metadata as data created or updated is changed is critical.
10. Develop a workflow outline plan.

Using GIS to Enhance
Campus Safety, Planning and Building Management

11. This plan will be developed to coordinate with the standards and procedures. This outlines how the GIS data is collected, developed, organized, and stored.
12. Collect, create and catalog all relevant spatial data.
13. GIS staff needs to be assigned specific portions of spatial data to research, collect and then centralize. In the case of facility GIS staff, existing spatial data includes: As-built construction drawings, engineering CAD files, legal descriptions, ownership maps, other design submittal documents, paper maps, and digital reports. This data needs to be consolidated, reconciled, updated and then converted to GIS readable data. Most digital data can be converted given a few computer-generated application tools. Older data, however, may need to be digitalized manually.
14. Develop or integrate a base map.
15. The foundation of the enterprise database is a base map and associated data schemas. Developing a base map can be the most time-consuming and expensive part of an enterprise project if one does not already exist. Development of a base map requires careful data matching coordination, layer needs assessment, and data accuracy verification.
16. Conduct a template project.
17. Given the magnitude of investment for an enterprise GIS and the timeline associated with deployment, a template project is an excellent opportunity to merge the planning stages with the implementation stages of project development to early on provide a tangible product that will serve as a way to educate stakeholders and build support for projects.
18. Priority Application Development/Integration
19. The GIS System needs to have the appropriate environment to allow the system to be enhanced over time as systems are replaced or upgraded. This environment should be flexible and low-cost to allow ease of integration. Application development and integration capability need to be

Using GIS to Enhance
Campus Safety, Planning and Building Management

designed into the system early on during the design phase. Initial application development and integration efforts should focus on priority applications.

20. Deploy GIS application for user functional and analytical sustainability.

21. Provide a production version of the GIS application to the end user. Allow time to use and update requirement based in departmental usability. Provide training if necessary or provide staff that will maintain the application.

The following practicum projects incorporated all or some of these steps in order to demonstrate the added value of using GIS for Facility Services projects in demonstrating showing how the creation and utilization of GIS data platform can be seen as a tool for campus asset assessment and analysis by establishing a GIS platform where all participants can readily and transparently share, update and maintain information about facilities and infrastructure to enhance design, construction, operation and maintenance. The objective of the following GIS applied projects is to demonstrate how a GIS is utilized as a land planning tool for campus development planning and how a GIS is used to improve building management through asset data modeling and also how GIS can improve campus safety through the use of GIS analytical tools.

Chapter 4: Implementation Practicum Projects

Given that there is no central repository for campus asset data to organize vast amounts of infrastructure and building data, it is the intent of these practicum project to show how using a GIS can be used as a tool for campus construction planning, building management and safety analysis. The projects show how through the establishment of a GIS environment that many stakeholders can readily share, update and maintain information about facilities and infrastructure data to the benefit of all campus stakeholders that rely on and would benefit from improved campus data accuracy. As there is no comprehensive centralized data repository of building and infrastructure data, there is no common platform whereby various campus stakeholders can rely on as an accurate representation of campus asset data including its physical attributes and their relationship to other assets on campus. There is no comprehensive and reliable database upon which informed decisions can be made by cross referencing related current and archived data.

4.1 GIS to Enhance Planning

Phase 1: Development Assessment

Campus environments encompass large areas of developed and undeveloped areas. There are multiple building types to consider and a diverse set of land environments that need to be engineered. And there are the existing infrastructure systems that need to be located, identified and connected to the appropriate source if it is determined that capacity and expansion opportunities exist. Campus development due to new construction, project improvements and interior renovations all require planning. The initial stage of planning is the

Using GIS to Enhance
Campus Safety, Planning and Building Management

“discovery” period whereby all the above items are researched. This stage of planning requires time and information from the survey, civil and locating professionals.

The current Facility Services process is to obtain ‘As-built’ plans for the area of construction. Due to the fact that several ‘As-built’ documents can exist for any given area it is imperative to retrieve the most recent ‘As-built’. It is also necessary to retrieve all ‘As-builts’ that match the area of construction. It is common practice that each As-built drawing is limited to a designated area of construction. The goal is to find all the match line ‘As-builts’ drawings that cover the area(s) being affected by the new construction project.

Another issue to consider is that depending on the scope of each prior project, not all data is transferred forward in the same manner and accuracy. Tracking and correlating data is a major time consuming effort. Through the implementation of a GIS system, this step of the planning stage, the data retrieval efficiency greatly increased. The GIS framework is an accumulation of data that retains the previous update and allows for continuous updates to keep the information current. Through the efforts to keep all data current, numerous layers can be research at the same time producing a holistic research approach for the entire campus area which includes the new construction zone. Having an updated data source reduces overall research time/costs through the use an efficient GIS system for data locating (ESRI n.d.).

The Facility Services GIS routinely provided planning analysis for perspective projects. This steps and resulting maps for this request are as follows:

Using GIS to Enhance
Campus Safety, Planning and Building Management

1. Obtain proposed project location and extent of construction zone
2. Collect all relevant data that is within and surrounding affected area
3. Combine data into map to show existing infrastructure, utility, buildings and land environment
4. Provide impact assessment (land affected, utility network overlay, pedestrian connectivity, vehicle circulation and emergency access)
5. Provide alternative perspectives if possible
6. Provide metrics on development opportunity
7. Show land excavation area and potential building space with setbacks

Planning new projects starts with assessing existing data. The FS GIS allows for efficient retrieval and holistic assessment of relevant information. This GIS data provides the Planning, Development and Construction (PDC) Department asset and land assessment analysis for campus development opportunities. Figure 4.1 provides assessment of the undeveloped land under campus ownership that adjacent to the I-40 freeway. Northern Arizona University owns significant land assets along that I-40 corridor. Through the collection, organization and mapping efforts of the GIS office, the PDC group is able to determine how much land was available for future development. This project provides land configuration limitations due to utility easement restrictions described in the title report for each parcel. The easement outline boundary is mapped based on the legal description detailed in the title report. The red lines in Figure 4.1 show the restricted develop areas. This project map also shows the areas available for development with parcel data and contour topography.

Using GIS to Enhance Campus Safety, Planning and Building Management

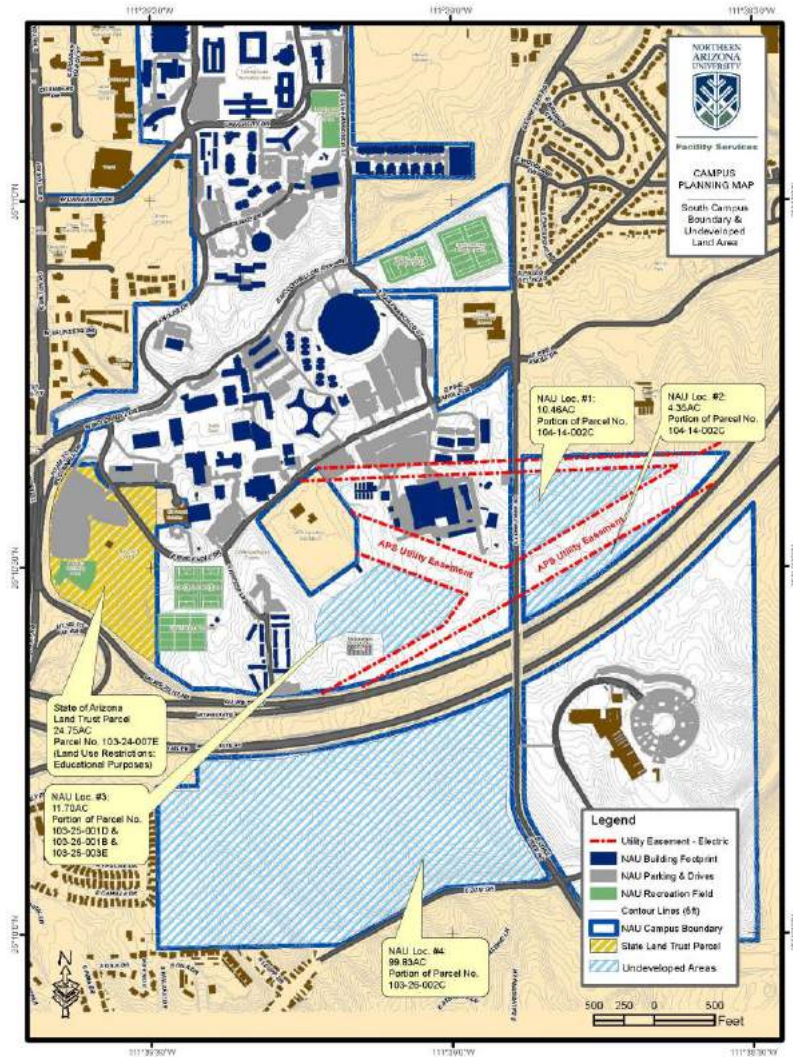


Figure 4.1: Undeveloped land area data project

Phase 2: Site Analysis

A site analysis project was completed for the Planning, Development and Construction Department having the GIS office to provide area data and building concept configuration to determine the feasibility of placing a 20,000 square foot addition to the School of Engineering. The GIS site selection map shows land engineering concerns, required utility line encroachment, affected pedestrian circulation and emergency vehicle access metrics. Figure 4.2 provides data assessment for a specific building size requirement. This is an example of combining GIS data with

Using GIS to Enhance
Campus Safety, Planning and Building Management

CAD building outline overlaid on aerial images to show real world scaled placement. The use of GIS brought immediate clarity.



Figure 4.2: Site planning with aerial imagery overlaid with GIS data layers aerial 2D (top) Building outline over 3D imagery to show area of required excavation (bottom).

The goal was to determine soil characteristics of the underground land area from geotechnical reports in order to determine soil excavation and construction conditions of potential development site location. To determine a holistic campus soils condition I collected and reconciled all fifty-six geotechnical reports that have been completed for the NAU PDC department over the years. The various reports were combined into one consolidated database of boring-hole data. A boring hole is the collection and compilation of structural geologic information from underground field soil collection of the rock mass as seen from a geologic

structure perspective (Teasdale 1989). The boring-hole (drill point) locations were digitized by placing GIS location points on aerial map that correlated with the locations described in the geo technical reports. Although this process would be more exact with digital data, all the data that is available at Facility Services is in the form of PDF formatted reports and paper copies. The reports contained maps with drill point notations with no GPS reference. The values obtained for auger refusal depth holes that were conducted for various construction projects. The auger depth data is what I used for the IDW (Inverse Distance Weighted) geostatistical tool located in the ArcMap toolset (Figure 4.2).



Figure 4.3: Arc Toolbox: Interpolation Toolset

The resulting map shows interpolated auger refusal depths for campus. The tool's geographic extent is limited to the extent of the input data, in this case, all the boreholes on campus that experienced auger refusal. This is a sample of various boring-hole locations that were digitally transferred into GIS based on non-surveyed diagrams for each test location. Feature class point layers were created to input the table attribute information described in each report and is based on auger refusal depths and borehole max depth for the initial assessment.

Using GIS to Enhance
Campus Safety, Planning and Building Management

Other items that were added after the auger refusal map was sediment layer depth. The process was the same for manual entering of depth data into the fields are each test pit location. Although there is some exact placement error when processing scanned maps into the GIS, it is understood that the borehole sample is representative of the soil conditions with that immediate drill area. The typical soil sample auger drills diameter ranges from 18 inches to 36 inches wide. Thus an exact digital point placement in the GIS can have a tolerance of up to three feet (Figure 4.4).

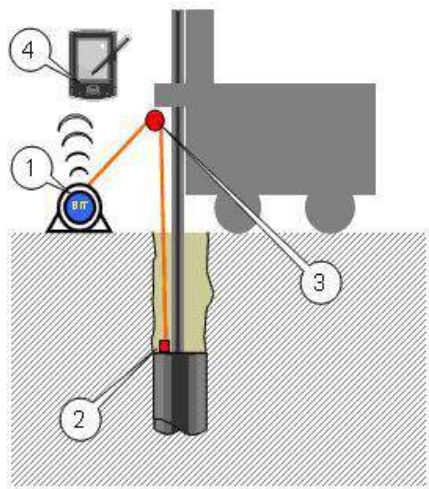


Figure 4.4: Auger Drill System Diagram

This project goal was to provide the Planning Development and Construction department a holistic view of the tabular data collected from all geotechnical reports provided to NAU by environmental engineers. A GIS table of attribute information was created using the borehole cross-sections as was described in the individual reports (Figure 4.5a, 4.5b). The GIS analysis provides an interpolation of probable auger refusal depths of the land areas between the borehole locations.

Using GIS to Enhance Campus Safety, Planning and Building Management

The interpolation GIS function allows for a predicted value in areas where we have no measurable values. There are different methods of interpolation classification. For this project I used the inverse distance weighted (IDW) method which explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. So, IDW assumes that each measured point has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away, thus the name inverse distance weighted (Sheehan 2003).

The following figures are sample data for the subject area. Only hard copies were provided to NAU thus scanning Figure 4.5a was necessary to provide as true replication of report data into the GIS. This process included georeferencing of the scanned documents into the established campus GIS database. The digital data points were created based on these digitized georeferenced reports. The attribute data for these digitized GIS points was based on the data provided in Test Pit Table as described in Figure 4.5b. The key data that was used for this initial assessment is the backhoe (auger) refusal depth metric. This the point at which the sediment impedes and/or stops the auger from digging any further. This is a critical underground level upon which influences building structural design and project development costs.

Using GIS to Enhance
Campus Safety, Planning and Building Management

The importance of this depth condition is determined by the definition of boring depth and boring refusal as it pertains to the construction and geotechnical industry.

Boring Depth:

Usually the boring logs are advanced well below the planned excavation depth to insure that accurate formational trends can be plotted and no weak layers are present near the foundation grade. When the borings are terminated above or just at the planned excavation depth, you must be very wary. This means you cannot be sure of what may be encountered at the bottom of the excavation. Is there going to be rock or water that must be handled? Did an obstruction halt the drilling effort?

Boring Refusal:

This is usually indicated at the bottom to the boring log, if it occurs. If all refusals are well below the planned excavation depth, it will not be a major concern. If a small percentage of the borings have met refusal in the excavation limits it usually means that there are isolated obstructions. It is not possible to determine what the obstruction is unless the soils report or site history reveals the object. A small isolated boulder can stop an auger drill and be of little concern. On the other hand, it could be a ridge of solid rock that will be expensive to remove (pdhonline course n.d.).

Using GIS to Enhance Campus Safety, Planning and Building Management

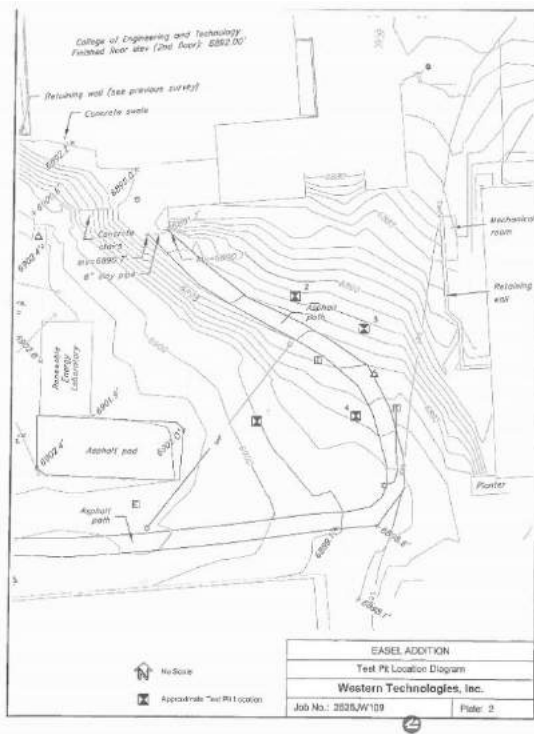


Figure 4.5a: Geotechnical borehole map

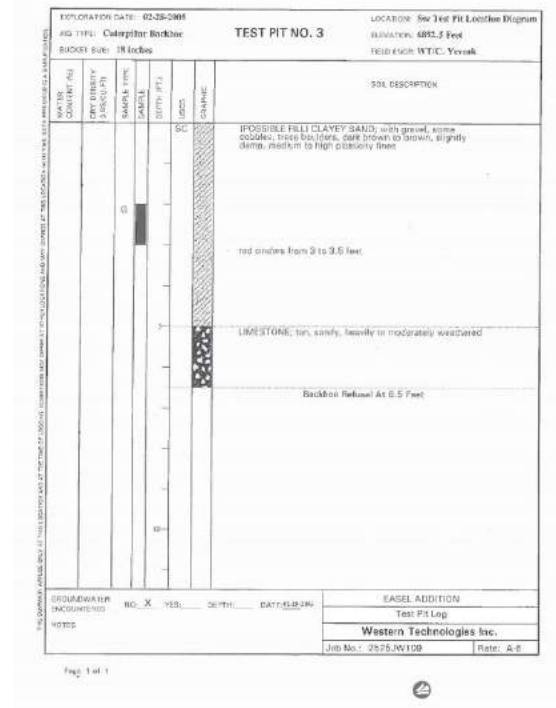


Figure 4.5b: Geotechnical report result

After compiling all the borehole data for the campus it was determined that five borehole samples were completed very close to subject site. The auger refusal map showed that the probability of auger refusal in the area of construction would be within the shallowest range of approximately 1 to 8 feet from the surface. This is consistent with the bore hole samples that showed a very hard subsurface which would require a hard dig almost immediately if this location was to be developed. (Figure 4.6)

Using GIS to Enhance Campus Safety, Planning and Building Management

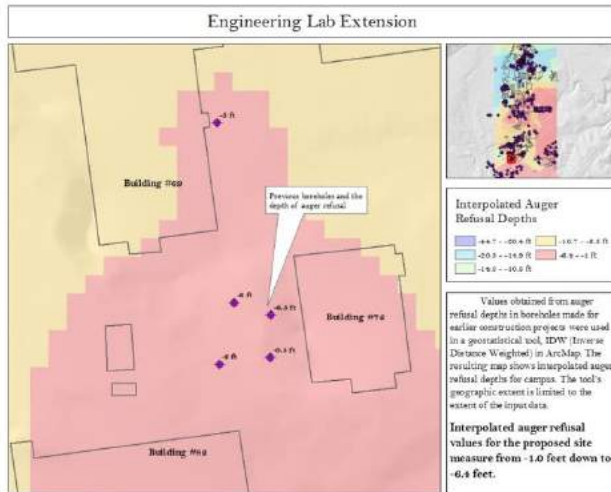


Figure 4.6: Site Location IDW Borehole Map

The IDW tool was used to provide a complete auger refusal value map of the immediate area as well as for the entire campus. The IDW algorithm was processed under the following conditions:

- Limited by the extent of the samples
- Limited by high/low of the samples
- Uses no knowledge of geology – only closeness/proximity
- Uses distance to interpolate – things which are closer to each other are more likely to be similar
- Density of points effect results – more dense, better interpolation
- Interpolated values must fall between the sampled low and sampled high

This Interpolated campus map produced a predicative auger refusal relief map which is based on the depth of where auger refusal is likely to be encountered. Figure 4.7a shows a comprehensive

Using GIS to Enhance
Campus Safety, Planning and Building Management

map of all borehole points taken from all the geotechnical reports that are available in document storage office at facility services. Figure 4.7b is the corresponding interpolated auger refusal map.

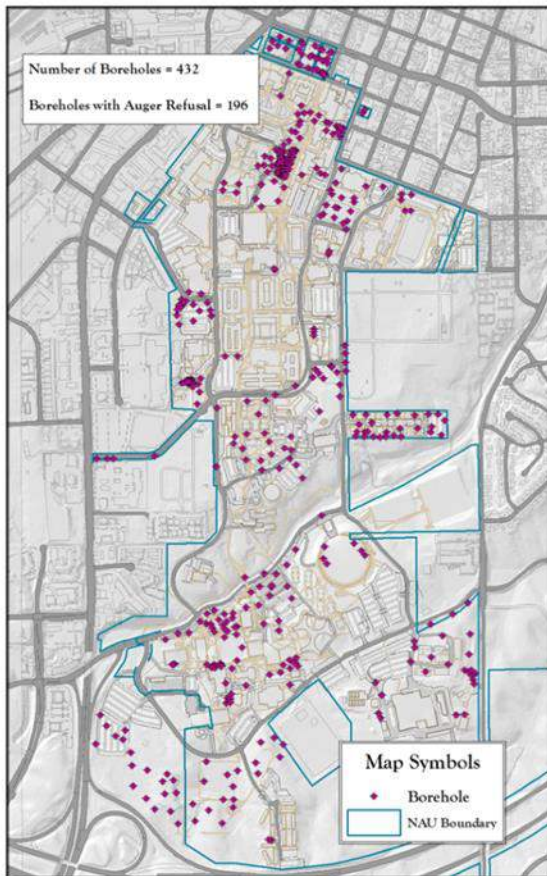


Figure 4.7a: Mapped Borehole Locations

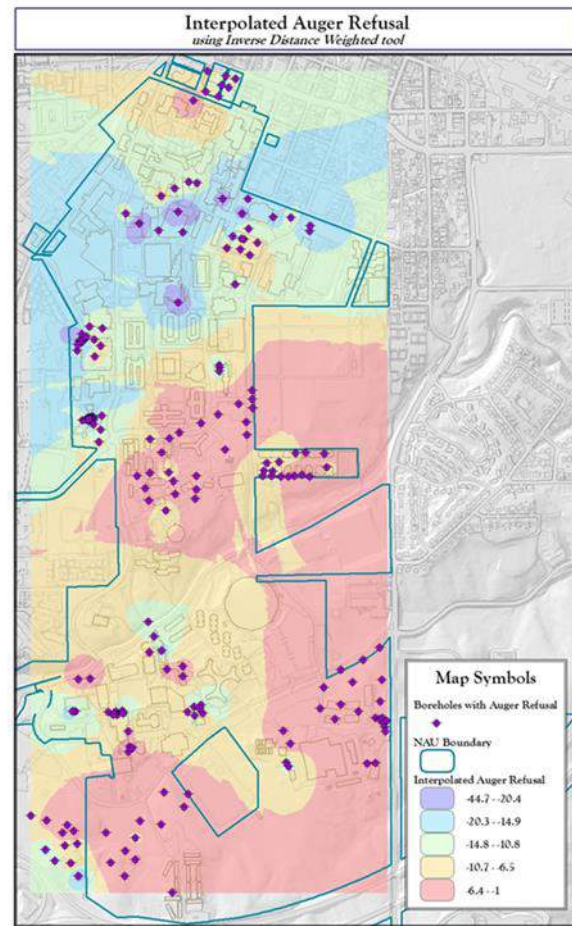


Figure 4.7b: Borehole Interpolated Map

Although this project did not focus on the 3D perspective of the soil layer data, it is interesting to see how the soil layer depths can be represented using the same borehole data. Figure 4.8 is sample diagram of the next step for this project which shows a 3D perspective of borehole locations and a digital elevation model (DEM). The DEM layer can be viewed from

Using GIS to Enhance
Campus Safety, Planning and Building Management

surface elevation as well as different sub terrain levels. The 3D perspective is important because it communicates a holistic view of the predicted underground soil conditions throughout an area thus saving the planning construction and development department time and money when assess a site for future development. Although the 3D perspective is based on the same data as the planar version, the 3D version communicates clearly how the campus sediment layers are connected throughout campus.

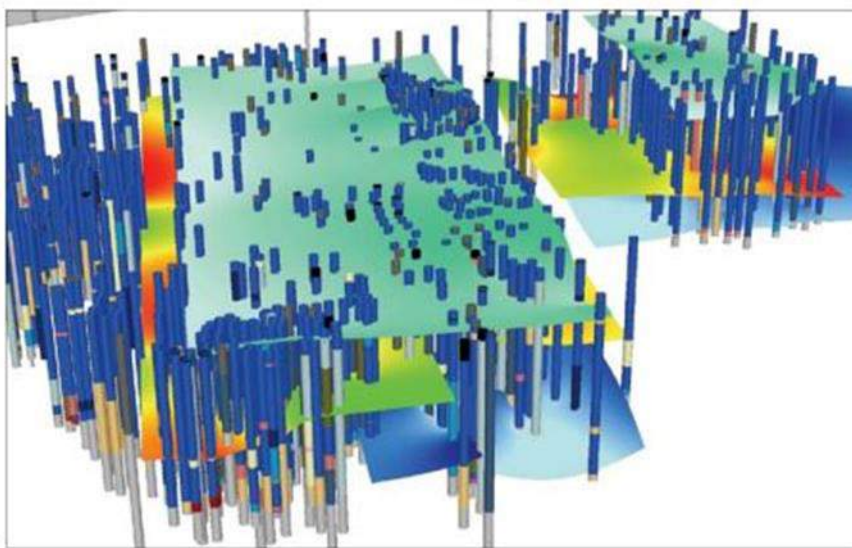


Figure 4.8: 3D Borehole Sample

This type of land assessment provided by the university staff saves the university time and money in having to hire 3rd party engineers to assess each and every possible site development option. Typically there is more than one site that is under consideration for a large development project. This internal GIS assess allows PDC to make informed decisions of which locations are more feasible than others based on known development costs. This allows the selection

Using GIS to Enhance
Campus Safety, Planning and Building Management

committee to narrow down the possible locations before paying the costs of hiring a professional engineer.

An initial site analysis was also completed for a planned project close the NAU Dome. At this site there had already been CAD design plans provided for the subject site. The GIS office was tasks with combining the CAD, GIS, geotechnical and utility to a more comprehensive site analysis. Figure 4.9a shows the incorporations of the geotechnical soil bore holes and Figure 4.9b show the site overlaid with the utility layers to show conflicts and relocation issues.

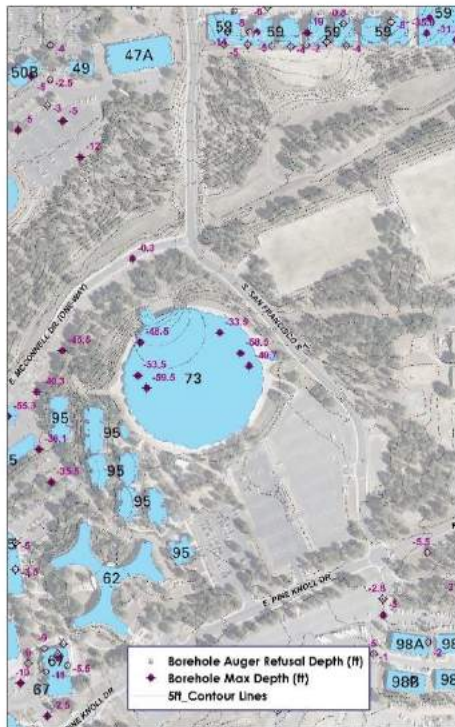


Figure 4.9a Site location with Borehole Data

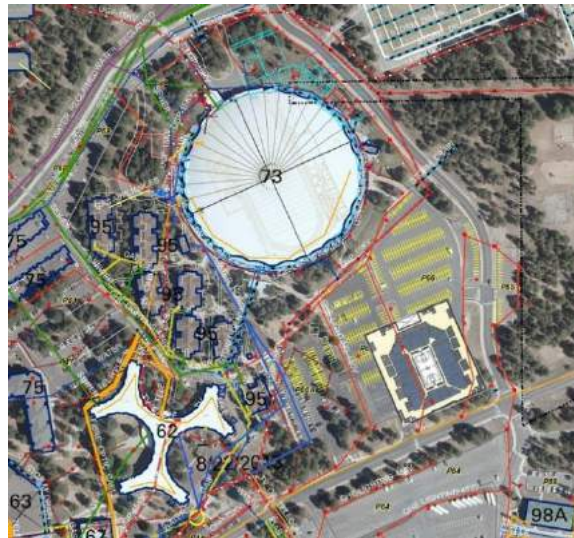


Figure 4.9b: Project Layout with Utility Data Overlay

Using GIS to Enhance Campus Safety, Planning and Building Management

Without the use of a GIS system, Facility Services does not have the ability to systematically analyze or view completely the borehole data that is currently stored on paper binders, some of which exists as pdf copies. GIS can integrate all the various reports into comprehensive map to see the patterns of data and the interpolated real world relationships in order to know soil conditions for future construction projects. A complete campus data map is a tool that helps determine the potential land construction cost for future developments. This determination can be made through the use of a GIS system at various locations throughout campus given the comprehensive collection and digitalization of borehole data all without incurring the cost of another borehole sample. It is good practice that once the potential development sites have been narrowed down that a site civil assessment be conducted by a licensed engineer.

4.2 GIS to Enhance Building Management

Building Management:

There was a request by the Space and Building Management Departments to provide a building management information database that could be used collect, organize and manage building space and building asset data. This was supported by various building management groups to help them track and analyze building conditions, material data and asset maintenance history.

This request provided a perfect opportunity to design a GIS platform that can be used as a unique building information model given that most universities would require the purchase of additional software when providing building information. The GIS is typically used to capture the exterior environment so by utilizing same program for capture interior data would be a significant cost saving to the University. The key element that is typically missing in a GIS when moving to a man-made structure is the 3D perspective and relationship of data as represented in multiple level within a room and between building floors. Building specific application software has been developed to provide for the complex man-made environment that includes building structure, utility, access, space and fire life safety systems.

The process to providing a building information model using GIS software provides a software tool for building and space managers to be able to capture and analyze interior asset data. This project provides a means whereby all interior building information would be captured and referenced to help manage and assess a building's spatial and asset data. This process is not

Using GIS to Enhance Campus Safety, Planning and Building Management

normally done using the ArcGIS suite. There are newer more expensive software programs that can handle 2D and 3D data integration simulations. There are also software applications designed specifically with asset database libraries that build exact replicates of feature classes (this process and application are better utilized during the initial design phase of a project). This project highlights the process of designing a BIM model of an existing facility utilizing a standard ArcGIS Suite and having to convert 2D to 3D using Arc Map 10 and Arc Scene 10. This project incorporates data formats available from the document storage office which is a part of the close out information for existing structures. This includes data from both digital and paper plan sets. Most digital plans sets consisted of either CAD or PDF plans.

Building Design: BIM

Building Information Modeling (BIM) is the most recent application of design drawing for new and remodeled projects. This modeling system can be a beneficial tool that is used throughout the lifecycle of a building and infrastructure project. BIM is not a specific product or technology but rather a collection of applications that together to allow design coordination and project management. More specifically, BIM is the process of using virtual design products to build a model before the actual project is built. This design concept facilitates new way of working on a project by creating a smart object that adjust attribute information as parameters are changed by various design teams. This interactive process allows for changes to be seen in the virtual model and the effects of the changes for the whole project are immediately known to the various teams that are collaborating together based on their specialty.

Using GIS to Enhance Campus Safety, Planning and Building Management

To truly realize the full benefits of a Building Information Model, nearly every building element needs to be either initially designed in an electronic BIM framework that can be transferred as part of a complete model to the stakeholder or if the project is already built then all the same building elements must be created in GIS to duplicate the built environment. It is most efficient to design a BIM from the onset of a project than to duplicate. The information known from the designers is not always known to the BIM designers after a project is complete, and this information becomes less accurate as time passes and a project undergoes renovations, upgrades or other maintenance changes.

Most existing projects are designed in a 2D environment such as a typical CAD floor plan (Figureure 4.10). The 2D design plans must be converted to 3D models to achieve true BIM design. The 3D visualization aspect is a key component to the multidimensional model which is a virtual space that users can relate to real world environments. See comparison of 2D CAD floor plan and converted 3D floor plan in Figure 4.10a and Figure 4.10b.

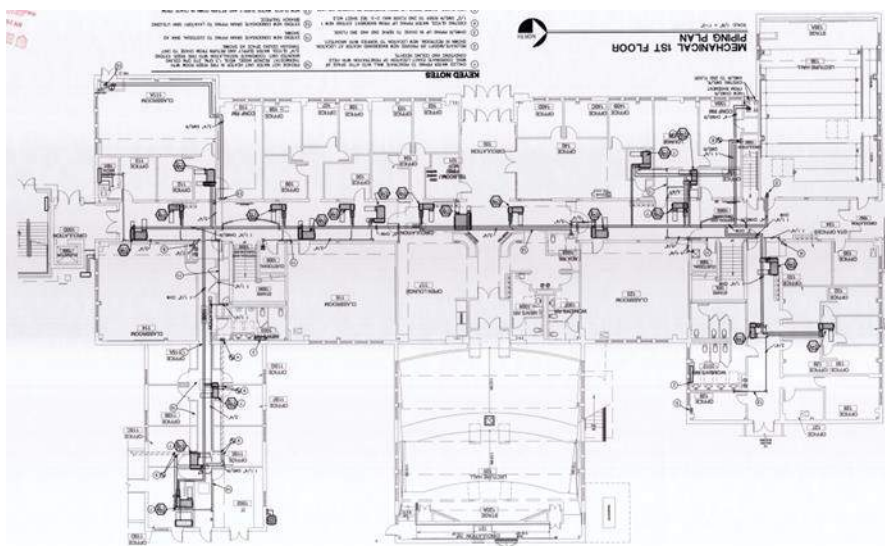


Figure 4.10a: Typical 2D CAD Floor Plan

Using GIS to Enhance Campus Safety, Planning and Building Management

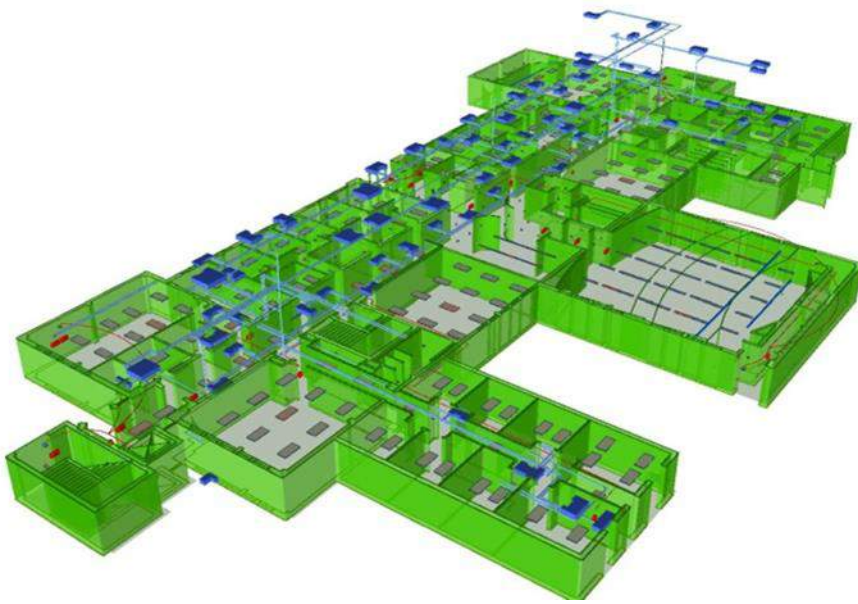


Figure 4.10b Converted 3D Interactive Floor Plan

Space Management

The Space Management Department is charged with maintaining records for a building's interior space. They identify and calculate the use of space and assign classification codes based on Higher Education General Information Survey (HEGIS) codes. This is a standardized code upon which most universities organize their departments and school majors. A sample is shown in Figure 4.11.

HEGIS Codes	
Hegle Code	Description
10	CLASSROOMS
20	DRY LABORATORIES
25	WET LABORATORIES
30	OFFICE FACILITIES
40	STUDY FACILITIES
50	SPECIAL-USE FACILITIES
60	GENERAL-USE FACILITIES
70	SUPPORTING FACILITIES
80	HEALTH CARE FACILITIES
90	RESIDENTIAL FACILITIES

Figure 4.11: HEGIS Code Sample Table

Using GIS to Enhance Campus Safety, Planning and Building Management

In order to build a GIS for this department I needed to design a framework that would incorporate these codes as well as capture data that would help identify space by main department, sub-department and office user, be it an individual or group. Users would also be able to forecast future space requirement based on department growth pattern. Historic data is extremely hard to capture in spreadsheets so a spatial management model with GIS helps analyze your actual space usage, compare it with the planned space usage and improve the ability to make informed decisions. This GIS model would allow for quick space metric and user analysis through the use of visual color coding of information. The goal is to increase space data analysis through visualization efficiency to achieve university growth and departmental utilization goals.

Building Information Modeling development workflow.

In order to develop a building information model using a GIS framework it is necessary to understand the workflow of converting all existing CAD data to GIS layers. CAD design is the most widely used form of building plans. The good news is that CAD is organized into layers similar to GIS feature class types which include: point, line, polyline and annotations, the majority of design work in CAD is created using the line type. Lines are used for rooms and building perimeter and other space related elements. As such, space areas cannot be measured or designated due to the fact that a room in CAD is a combination of four connected lines. The space in between the lines is what is needed to be measured and given attribute information. In CAD the four lines that are drawn to show a room are actually four separate line elements are drawn together to form a square which represents a room on a floor plan. A polyline on the other hand is an enclosed polygon that is used to also show space. Given that most CAD drawings do not utilize the polyline layer type, polygons must be draw to be utilized properly from within GIS.

Using GIS to Enhance Campus Safety, Planning and Building Management

When a CAD drawing is exported to a GIS shapefile, the CAD drawing's layers become a field in the GIS shapefile's attribute table. New point, line, and polygon shapefiles can then be extracted based on each layer (exterior wall, dimensions, utility lines, etc.). Since there is no accepted naming convention for CAD layers and restrictions on the length of layer names, it is often difficult for a new user to decode a CAD layer name. For example, the layer name LA-TR-DE could mean a deciduous tree under the category "landscape". Another difficulty is many CAD drawings contain layers that are not sufficiently "clean", meaning stray pieces of lines or points that belong to one layer could appear on a completely unrelated other layer, or remnants of lines or points used in the development of the drawing but not representative of actual features could remain (trim lines, transit points, etc.). These inconsistencies are not of major concern in the CAD realm, but in GIS it introduces inaccuracies and can corrupt the database.

Depending on project needs, it may or may not be desirable to transfer the entire CAD drawing to GIS. If there is interest only in a few layers of CAD data (trees, roads, buildings, for example), and the remaining CAD data does not need to convert to GIS, you can select only the layers you wish to transfer to GIS, and copy them into a new CAD drawing to be taken into GIS. By selecting only the elements on these layers and copying them to a new drawing, all unnecessary drawing elements will be left behind.

There are several processes used to develop the building information model given that some source data was not available through CAD. The majority of the existing CAD data available in the document storage office was for the interior and perimeter walls only (no utility or other asset layers). The available wall layers are referred to as the building lift data. Most other building asset information like utility systems are only available through scanning paper drawings. These

Using GIS to Enhance
Campus Safety, Planning and Building Management

sources reference the line dimensions and have annotations pointing to room (space) areas but I needed to create the space element to capture area. This was a perfect opportunity to merge these two data sources together to create an all-inclusive building information model.

Procedure for working with CAD to GIS Data:

To obtain a successful CAD to GIS conversion it is important to understand what the desired end product is, looking at what layers will remain together or separate when converting to GIS layers. Within CAD in GIS layer properties, all the layers are shown. This tab allows for specific CAD layers to be turn on or off for viewing within ArcMap. Then layers can be exported to GIS feature classes (Figure 4.12). There are two main methods to consider before converting CAD to GIS using the CAD to feature class tool within the conversion_tools\to_geodatabase toolset.

The actual conversion of the 2D CAD to 2D GIS layers is a relatively simple process. The Arc Toolbox provides a function that will process the conversion rather quickly.

Using GIS to Enhance Campus Safety, Planning and Building Management

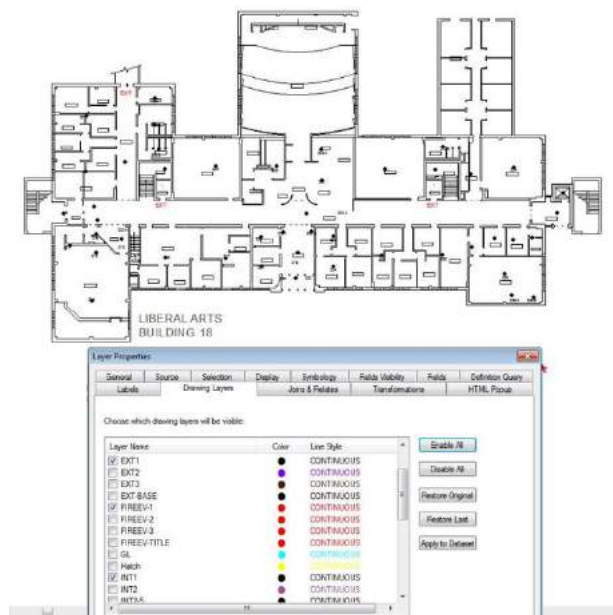


Figure 4.12: CAD in ArcGIS: Drawing Layers

Option 1: Choose to convert all the CAD layers to a feature class dataset. This is done by selecting either the CAD to Geodatabase within the conversion toolbox or selecting the export option with the shortcut window by right-clicking on the layer to be exported.

Option 2: Use the selection tool from the main ArcMap menu and choose select by attribute and choose the layer to be exported. Then choose export data using the same shortcut window as above then choose export selection to a feature class or shapefile. This is a preferred method when the BIM schema is already established and all the related layers can be exported to the respective datasets.

These conversion functions allow the existing layer in CAD to be converted to a geodatabase feature class as either an annotation, point, polyline or closed polyline (Figure 4.13). The main concern for a BIM model is which layers will exist within each feature class. CAD exports

Using GIS to Enhance Campus Safety, Planning and Building Management

all layers together that exist within DWG or DWF files if a selection is not made. This is true even if some layers are turned off in the CAD layers properties. Also the CAD layers must be cleaned up in the CAD environment by deleting unwanted layers and saving new CAD files for each set of desired layers or the entire CAD can be converted to GIS as a dataset and the parsing and updating performed within the GIS environment. I chose the latter given that the purpose of this process was to produce a BIM model using GIS framework. It is also imperative to make sure the CAD and GIS are compatible in terms of 3D properties. If the CAD is designed using polyline Z values and the GIS is not Z enabled, then the CAD layers will have to be saved as regular polyline file.

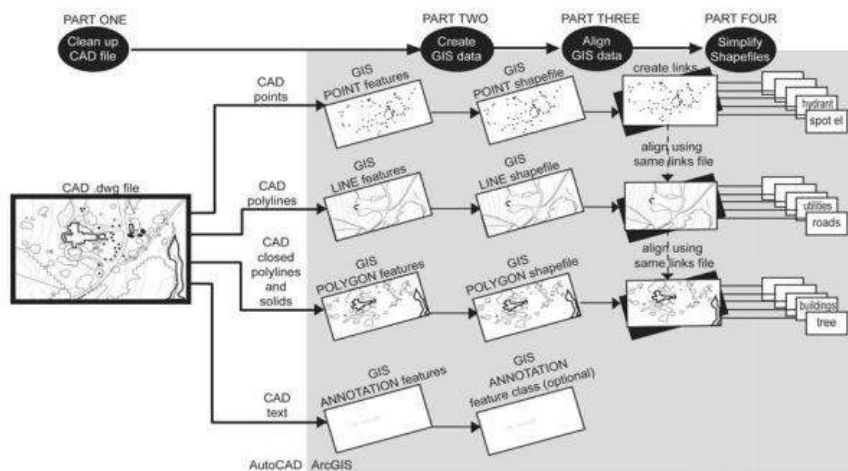


Figure 4.13: CAD to GIS Line Types

The process to revise the CAD files include removing the Z-enabled type when converting to GIS from within the environment tab of the conversion window.

Option 1: To remove Z values change the Z and/or M output value to disabled. This will convert a Z enabled polyline to a regular polyline file.

Using GIS to Enhance
Campus Safety, Planning and Building Management

Option 2: To add a Z value to a file, select the 3D Analyst Tools\3D features then select Feature to 3D by attribute to create a Z enabled file.

Once all the cleanup is made to the CAD files then selection and conversion steps can be completed. I chose to parse the CAD data from within the GIS environment it must be noted that the only update that was done in the CAD environment prior to the conversion to GIS, was the interior wall verification update. This update is vital to keeping both the CAD and GIS systems up to date. Only after room measurement verification was complete for every room in every building on campus was CAD to GIS conversion was initialized. The completion of the CAD updates was vital to the accuracy of the GIS layers given that CAD design is very accurate in term of straight line dimensions and precise angles. CAD designer use line length commands create a wall line to a specific length as well as allows the user to create line angles to specific degrees. These lines can also be drawn by hand but the accuracy of achieving 90, 45, 30 angles is particularly difficult in GIS. This function is built into the line cursor within CAD where a tool function must be used to draw a specific angle in GIS. This is why CAD is the preferred design format. Thus the CAD floor plans (building lift) are first updated in the CAD environment so that the GIS layers are as accurate as possible in dimensions. It must be noted that CAD does not have the capacity to store customizable attribute data for layers. There is a set properties list that exists for every CAD layer as shown in Figure 4.14 below. Additional description information is added in the form of line text and annotations which exist separate from the line layers. They are only associated via text description; no table relationship exists. Even if the line element is deleted the corresponding text description would remain.

Using GIS to Enhance Campus Safety, Planning and Building Management

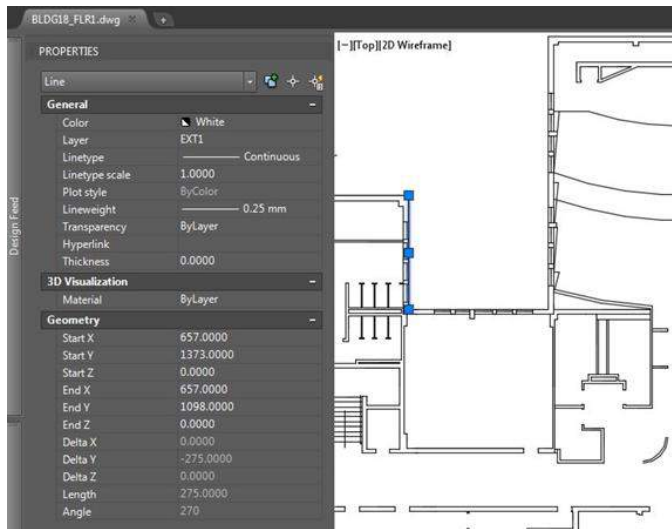


Figure 4.14: CAD Default Layer and Properties

Also prior to converting the CAD data to GIS it is important to georeference the batch DWG data. The process to georeference all layers to the appropriate location on the campus map is important in building a real world model. As placement in the real world helps to show the relationships between buildings for distance routing and provides the basis for a full campus model with related basemap layers of roadways, walkways and parking lots. This step is completed by adding GPS points as a graphic in the map document and using the Go to XY tool on the Tools menu. Select the coordinate system units and enter the XY coordinates. To insert the XY coordinate as a graphic to your ArcMap document, select Add Point. Each building model is placed into the campus map using GPS coordinates for exact accuracy. Only two GPS points per building were used in an effort to reduce warping and preserve the scale of the building perimeter. In my experience the use of more than two points has caused warping of the line data

which is most noticeable at the corners of building which are supposed to maintain 90 degree angles. After the placement of building space all the subsequent layers were either converted into or digitally added within this perimeter space.

The process for cleaning the CAD layers in the GIS environment included identifying all the related layers within the CAD drawing then isolating these layers through selecting by attribute the desired layer that provides the basis of the new feature class. This project requires further parsing of building lift data per floor plan. I initially created a dataset for each floor and a database for each building (Figure 4.15). Which allowed for all assets and systems to be placed within a specific floor dataset and each campus building was designated a separate database. This process allowed for easier sharing and management by building managers.

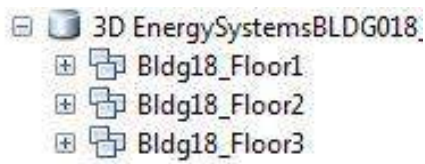


Figure 4.15: Geodatabase Schema for 3D Model

The selection query tool 'Select by Attribute' allows the user to select the appropriate layer(s) that are then highlighted for verification of the correct outline of the CAD layer desired. Then within the drop down menu of the highlighted feature I created a layer from the selected layers and named it floorplan1.

Using GIS to Enhance Campus Safety, Planning and Building Management

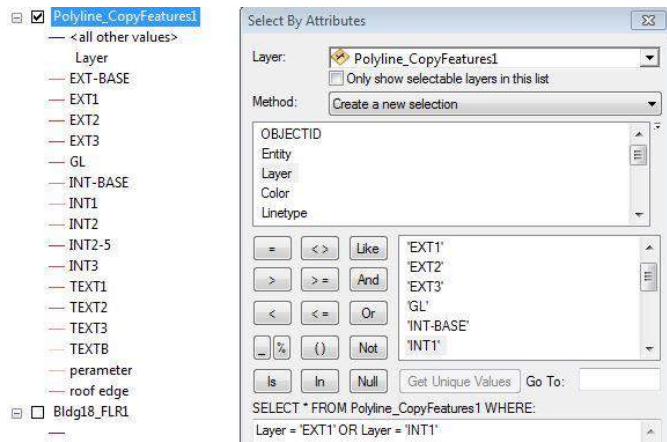


Figure 4.16: CAD layer query to separate layers

If a feature class already exists for CAD layers and there are additional elements that need to be added then the process will include Appending the file. This was used to add additional CAD layers to existing feature classes. I used the Data Management Tool\General to locate the Append tool within the Arc Toolbox. If different CAD datasets are used to update an existing feature class then the Schema Type must be NO_TEST so the input dataset schema do not have to match the target dataset. This will allow for field transfer to be defined field options window within the same append tool.

Procedure for Paper Data:

The interior utility network was added next. These layers only existed in paper hard copies in the document storage office, so the required paper plans had to be scanned to a digital picture format such as PDF, TIFF or JPEG. I used the TIFF format because that scanned best and was a compatible format that could be used to georeference in ArcMap. I georeferenced the interior utility plans to the already georeferenced CAD plans processed in the initial step. It is important to match the perimeter and interior walls as closely as possible (Figure 4.17a). This is a crucial

Using GIS to Enhance
Campus Safety, Planning and Building Management

given all interior digitizing will be referenced from the walls. As I don't have access to electronic drawings of the interior space data, the digitizing method of redrawing the layers that I needed to convert to GIS opening a previously created feature class and editing was worked. I then proceeded to redraw the linear and point data for the HVAC and Electric lighting systems for each floor (Figure 4.17b). The feature class was saved into the corresponding building floor dataset.



Figure 4.17a: Georeferenced Paper Utility Map



Figure 4.17b: Digitized Utility to GIS

The process of digitizing was completed when the GIS layers matched all the plan set layers for the required building systems. The GIS layers were created using a fully developed federally compliant database that included detailed domain and field attribute schemas, so as each feature class and subtype was created the corresponding attributes were updated if the values were known (Figure 4.18). Most of the required feature class attributes are printed on the drawing as an annotation or referred to in a line item schedule on a separate page.

Using GIS to Enhance Campus Safety, Planning and Building Management

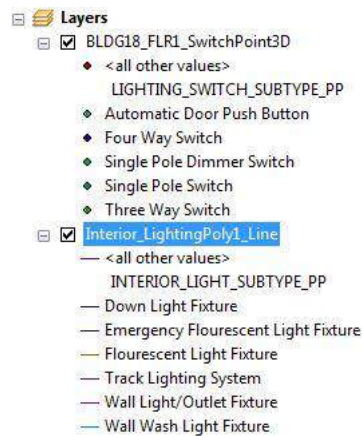


Figure 4.18: 3D Feature Subtypes in Structured Geodatabase

Next was the converting all the above data to 3D to realize the final benefit of BIM which is 3D perspective. This helps the audience/customer relate to the asset/data because it's transformed the information from the traditional flat paper format into a realistic real world model that can be viewed in the computer from various perspectives.

The key attribute in the conversion from 2D data to 3D data is the elevation or Z value. During the creation of new feature class it is imperative that the layer geometry be Z enabled before Z data can be added. The Z enabled option is selected when setting up the geometry properties in the new feature class window. NOTE: Good practice would be to include the Measure value (M) as well in order to use for future routing projects. When the M value is enabled in a linear reference, a measure value that is added to a line feature. M-values are used to measure the distance along a line feature from a vertex to an event such as route stops. The Z enabled feature class allows for addition of Z value information that allows for ArcScene to project the layer to the correct elevation (Figure 4.19). The user must choose both the Z_MAX

Using GIS to Enhance
Campus Safety, Planning and Building Management

and Z_MIN output which will be added as fields. In the case of a roof which has slope, the M_SLOPE and MAX_SLOPE output must also be checked.

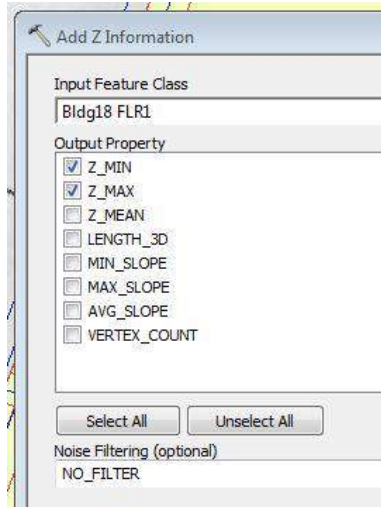


Figure 4.19: 2D to 3D add fields step

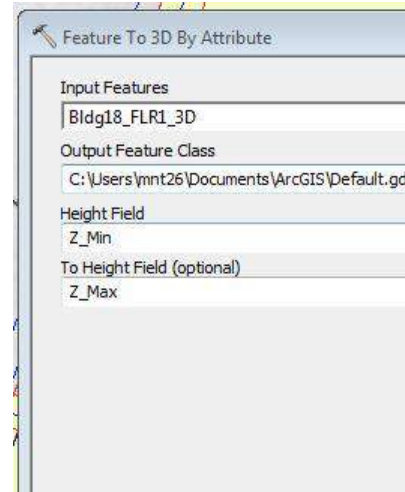


Figure 4.20: 2D to 3D layer conversion step

Next, I opened Arc Scene to build the 3D environment. Using the same feature toolset located in the Arc Toolbox\3D Analyst Tools\3D features\ there is a function called Feature to 3D by attribute (Figure 4.20). This function was used to process all the Z enabled 2D feature class layers to 3D layers by their height attribute. This process allows for the layer to be represented using the designated height value for that layer. If a feature layer is 12 feet above ground level, that is the value to which that layer is shown as compared to layers with no height projection when converted using the feature to 3D attribute. I decided to use two layers per floor so that a top plate and a floor plate is viewable in the 3D model after the extrusion step.

Using GIS to Enhance Campus Safety, Planning and Building Management

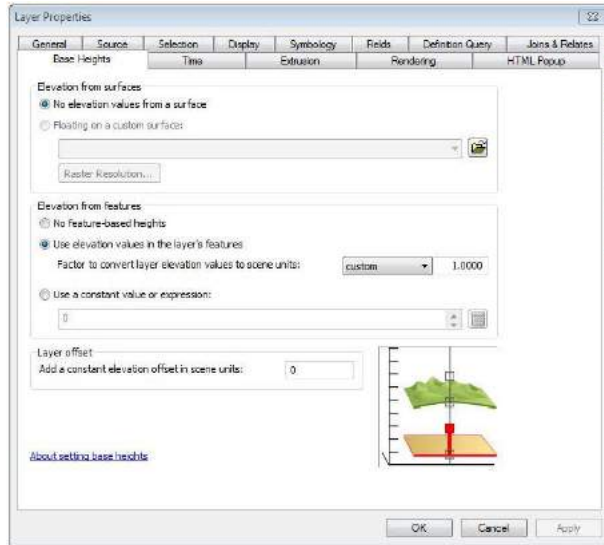


Figure 4.21: Arc Scene: 3D Base Height Step

To be able to see the different layers at their designated height the Layer Properties must be selected to be represented with the height attribute for each layer (Figure 4.21). This option is found in the base heights tab of the layer properties. There are three choices from which to build the height or elevation model (feature based heights, elevation values from layer property and use constant value). I chose “use elevation values in layer properties” to represent the 3D building layers (Figure 4.22). For each layer the elevation from layer height (Z value) was used to build the model independent of an elevation raster such as a DEM. In the BIM the elevation is the height Z value from the ground floor which is represented as height zero in all construction section plan drawings. After establishing the BIM layer heights for all building layers, all layers can be placed into a surface layer or digital elevation model (DEM) at the georeferenced location. This option is also listed in the same layer property window in Arc Scene (Figure 4.21).

Using GIS to Enhance Campus Safety, Planning and Building Management

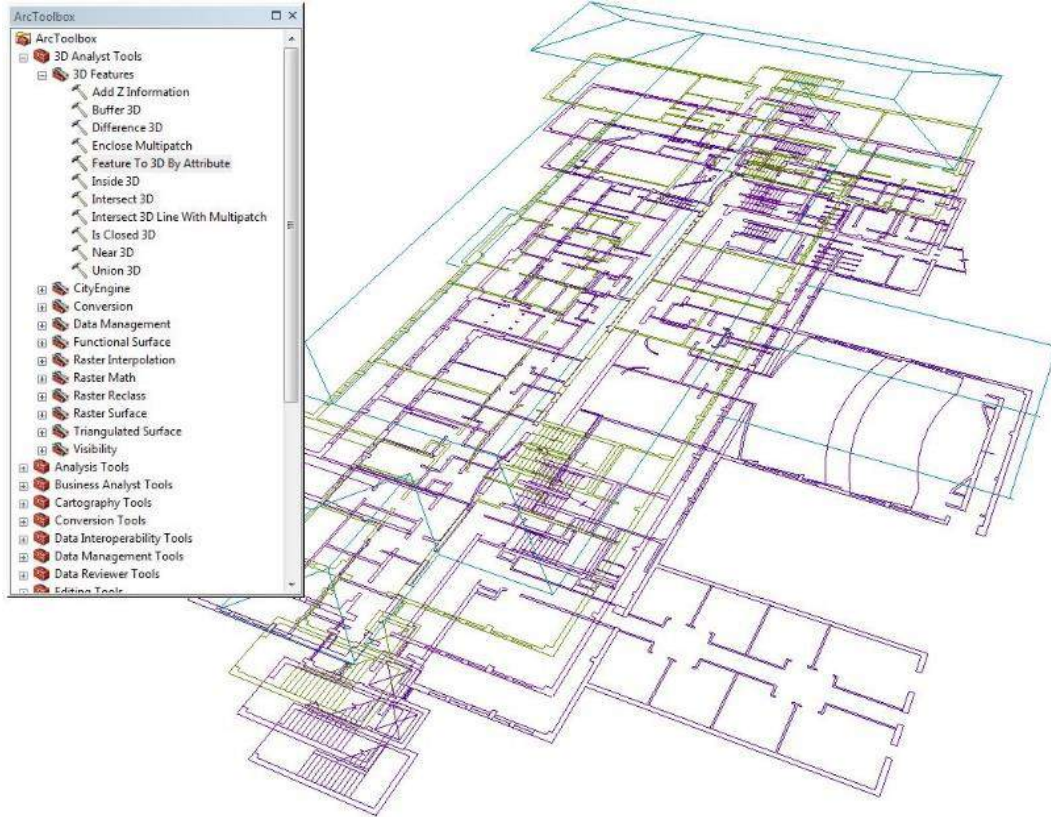


Figure 4.22: Arc Scene 3D Layer Elevation Perspective

Given that most of the data to this point has been 3D representation of CAD to GIS lines, I needed to convert the flat line features to a vertical representation using the extrusion tool. This option is also located in the layer properties tab named extrusion. This tab is only available in ArcScene. The extrusion can be an expression based on elevation plus feet calculation to simple value of height for a given feature class. This feature is used for representation of wall surface is taking elevated floor plan lines and creating a wall space with the same line data (Figure 4.23). Which contains the same attribute data for the entire extrusion of the line. There is no separate

Using GIS to Enhance
Campus Safety, Planning and Building Management

'wall' feature classes created, so if there is a different element that exist within the extrusion area that feature is not represented using this process like a window feature.

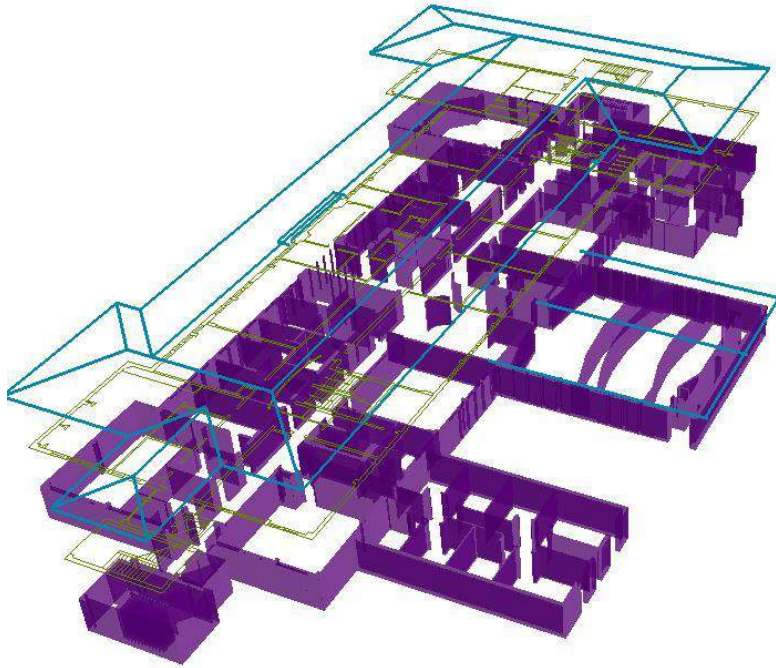


Figure 4.23: Arc Scene Line Extrusion Perspective

When the extruded and elevated layers are loaded together, a 3D building model of the structure is built. All of the attributes that were created using the 2D feature classes are maintained in the 3D environment. Clicking to identify a feature or selecting to update a features attribute, the attribute fields are available to the user to update or assess information. This creates a BIM (Figure 4.24).

Using GIS to Enhance Campus Safety, Planning and Building Management

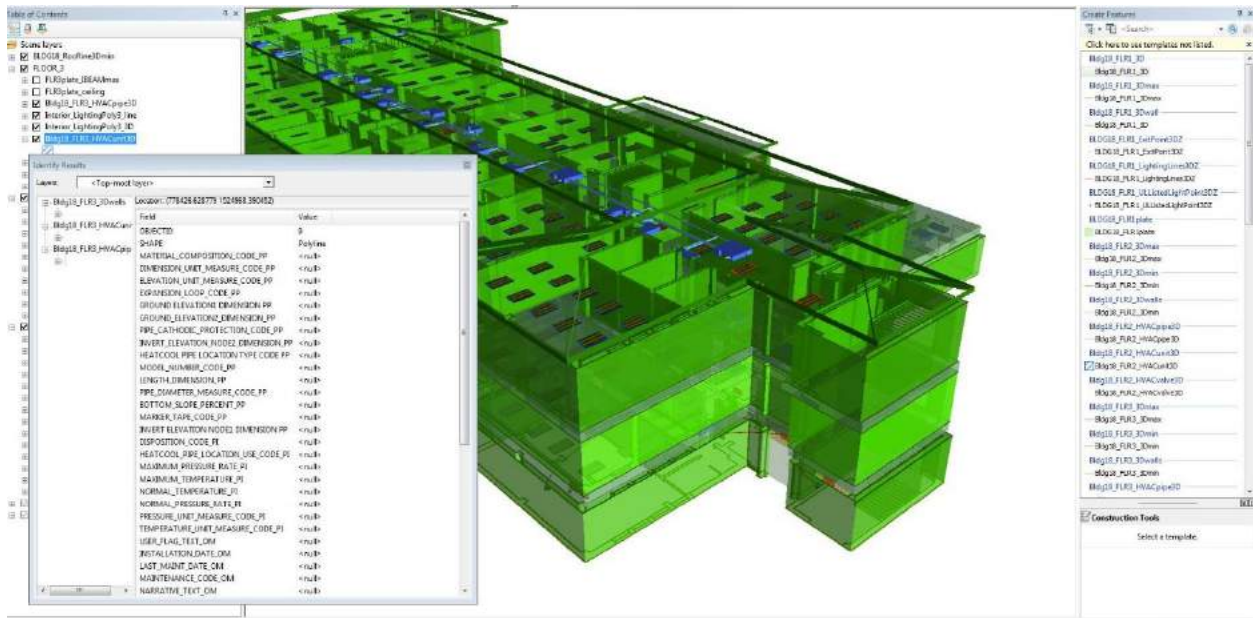


Figure 4.24: BIM Model and Asset Attribute Field Window

The same workflow was completed for all of the digitized linear and point interior asset data. For this project I digitized the HVAC and electric systems so that building managers could see the spatial relationship and placement of these two building environment control systems (Figures 4.25a & b). Each layer can also be isolated within the model to show design schematic, connection points and access (Figure 4.25c). The perspective of the model is controlled by the user allowing for interactive control of the schematic model. Each element in the model is interactive. The user can click on any asset in the model and it will return data information about the asset condition, model, inspection and installation date, etc. The user can update and add additional attribute fields to the asset to customize for specific departments. The asset can also be edited and or deleted just as with 2D layers.

Using GIS to Enhance
Campus Safety, Planning and Building Management

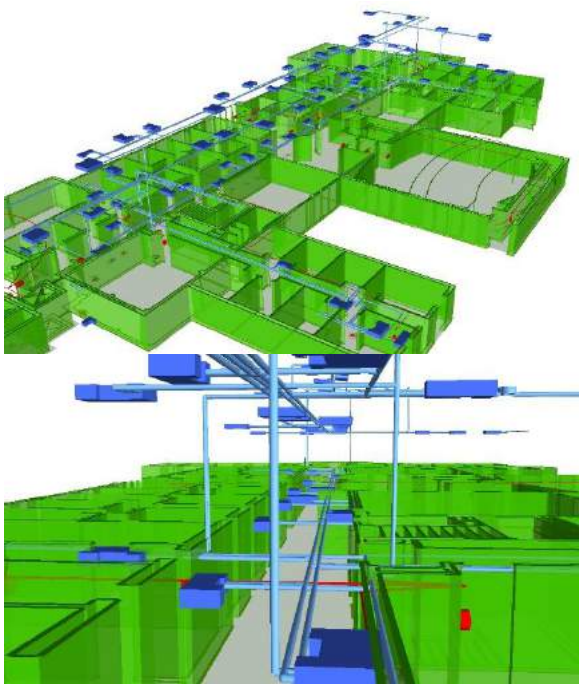


Figure 4.25a & b: BIM Model HVAC layer perspectives

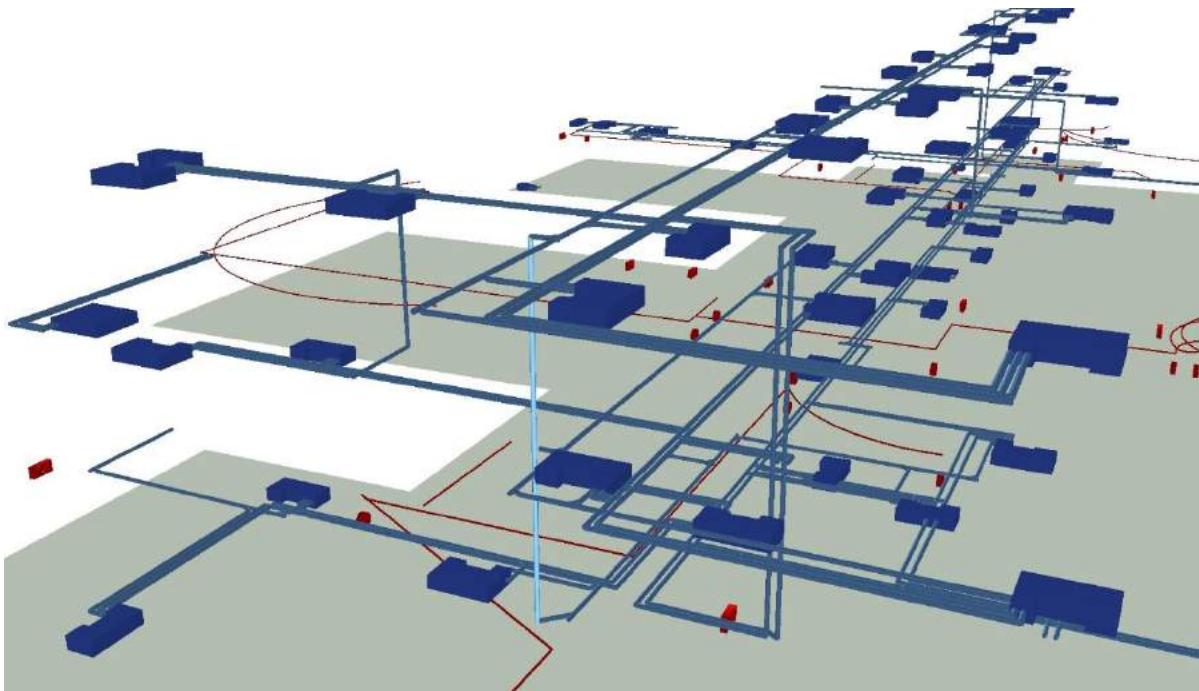


Figure 4.25c: Arc Scene BIM Utility Schematic Perspectives

Using GIS to Enhance Campus Safety, Planning and Building Management

The next step in developing the BIM is to create the space within the line structure. The space between the walls is what will maintain the information needed for the Space Management Department. The CAD to Geodatabase conversion for the floor plans involved line to line data types. The line feature class does not have the ability to maintain area like a polygon does. So although these initial steps are useable by building managers for assessment linear data such as a utility system, lines do not provide calculation of area that is required to be captured and managed by the Space Management Department. The additional step of creating polygons is the beginning of the process to create a building model. It must be noted again, that almost all CAD layers are created using a polyline data type. In order for a space to be created, the room lines must attach together through an AutoCAD block function. CAD normally uses an open door line symbol for the entrances to buildings and rooms creating an opening to all rooms. So to create a space those door opening must be closed. This can be done manually in CAD, but attaching line and closing doors to create space is more time consuming than adding simply adding a new layer. In the CAD format I added a new layer called SPACE and the data type was a closed polyline, also known as a polygon. When a closed polyline is converted to GIS it is seen as a polygon feature which then automatically calculates area metrics instead of just line length. In addition to area, a table field list can be developed to capture room attribute data like room use codes, department user codes, building occupancy data, building materials information and even furniture, fixtures and equipment information (FF&E).

I produced a simple color-coded building use floorplan map to show space planning (Figure 4.26). This is a template of what is possible to assist space management in their assessment and planning of campus space inventory.

Using GIS to Enhance Campus Safety, Planning and Building Management



Figure 4.26: Floor plan use color code figure

Once a BIM is built for every campus facility, I will be able to load all of them into a 3D virtual map space to show real world relationships between structures, parking lots and connecting networks (Figure 4.27).

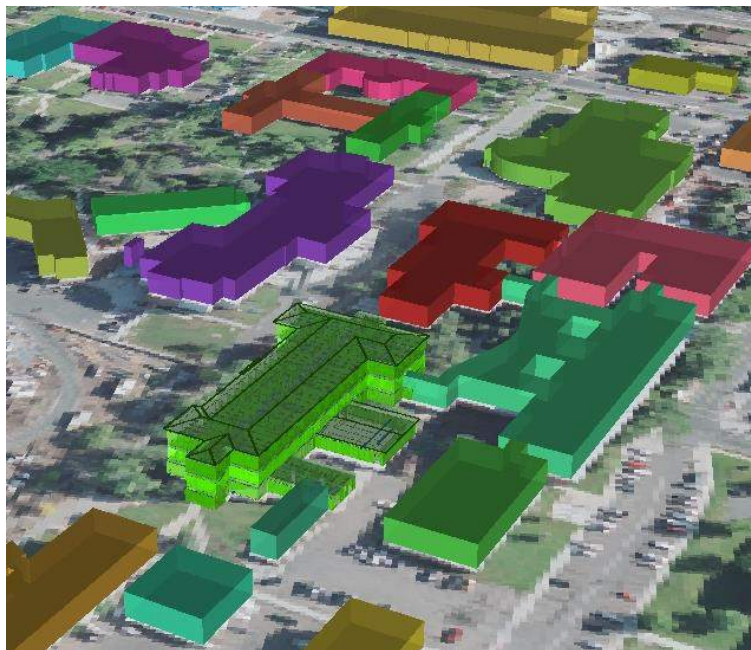


Figure 4.27: BIM model in Google Earth Image

Using GIS to Enhance
Campus Safety, Planning and Building Management

The Space Management Department plans to leverage the GIS database to track and allocate space for colleges and departments. Space information can be easily assessed and changed to different uses and square feet can be immediately calculated for approval and/or consideration by Deans and Administrators. Three D building information models (BIM), once fully developed, will provide a visual tool to communicate current and projected space allocation as well as connectivity between departments, residence halls and parking designations.

Infrastructure & Asset Management: Utility Reconciliation Project

Continuing the effort to provide the campus with a single reliable resource for asset data, I assembled, reconciled, field verified and updated all the site and civil plans for utility data and then created archived and current datasets into a GIS system that is now used to organize vast amounts of infrastructure data that provides utility asset location, attribute and relationships of various utility layers. The goal of this project was to establish a GIS environment for the utility networks that numerous stakeholders can readily share, update and maintain information about the existing underground utility infrastructure.

Asset location updates and utility verification mapping is a major service that the Facility Services Department maintains and provides to internal NAU departments as well as third party vendors that provide design services to NAU.

The archived source of data was maintained in CAD but the utilities department needed an updated mapping system that could maintain attribute data and be used as a resource for

Using GIS to Enhance
Campus Safety, Planning and Building Management

infrastructure updates and network connectivity. GIS is best suited for both of those activities. Before processing a CAD to GDB conversion using ArcGIS I had to verify the validity of the information being transferred. The CAD master utility file did not mention how the data was collected or which resource file was used to create the data. This was a concern moving forward because I did not want to move inaccurate CAD data into a GIS database and still have accurate data. Through a comparison of GPS and As-built engineered data, it was determined that the CAD utility archive was not accurate in many regards. It was lacking in representing all existing data that was built and it did not accurately denote the location information of what was shown to be built (Figure 4.28).

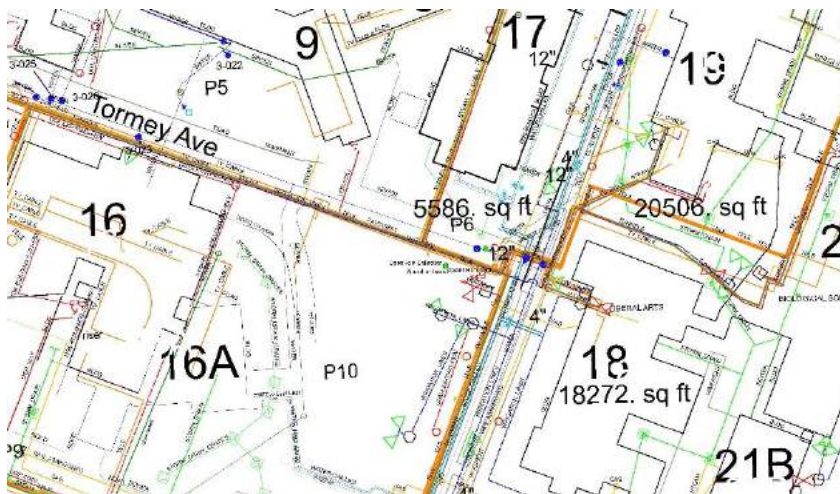


Figure 4.28: Master Utility CAD file to be reconciled

The Utility Reconciliation Project started with a plan to verify all layers of data prior to moving to the GIS format. The resources used for this reconciliation project included As-built infrastructure hard copies. This process involves using georeferenced CAD or scanned documents

Using GIS to Enhance
Campus Safety, Planning and Building Management

into ArcMap for either layer conversion to GIS or manual digitalization of layers to GIS. This method when followed schematically across campus ensures all draw data is transferred to the GIS reconciliation map. There are some issues with some data. As-builts are supposed to follow a procedure of updating by the contractor and design professional. This sometimes does not happen. Another drawing set that is sometimes not provided to NAU is referred to as the architect's record set. This is the design professional's certification of the contractor's 'As-built' set. The As-built drawings are prepared by the contractor. They show in red ink for on-site changes that are certain to occur in the field that differ from the original approved construction documents. Whereas record drawings are prepared by the architect and reflect on-site changes, the contractor notes in the As-built drawings. They are often compiled as a set of on-site changes made for the owner per the owner architect contract (AIA Knowledge Resource Team 1975).

Through discussion with NAU directors and field personnel it is to be determined on a case by case basis as to whether the As-built set is a true and accurate reflection of what was built. The better question is whether the As-built is a true reflection of how things are built. I have identified that the best source of information is field verified global positioning systems (GPS) data. There are two types of field verified information that can be used effectively to update the infrastructure map. The best is the open pit where visual verification of the asset is determined and collected using a highly accurate survey quality GPS device. I used GPS field verification of above ground asset data to ensure As-built data was lining up correctly with asset location. There was opportunity to GPS underground data when pot holes were opened briefly during construction projects. These open pit situations are mainly centered on new projects

Using GIS to Enhance Campus Safety, Planning and Building Management

where new infrastructure was being installed and old assets were being removed. Waiting for an As-built of the completed project was better than trying to follow the construction timeline and having to be onsite almost daily. For smaller projects, collecting open pit information is relevant to updating the network information. This produces small windows of information that update the master maps very slowly.



Figure 4.29: Georeferenced Data Windows

Another good source of information is field collection using global positioning system (GPS) of for asset locations. This is of particular important for assets that will be covered after installation like utilities. There is also GPS collection of blue staked markers that indicate a buried line that is detected through use of ground penetrating sound and sonar equipment. This is not as good as open pit verification but due to the fact that blue stake does not require pot holing or open pit trenching, there is much more information that can be obtained through collecting GPS

Using GIS to Enhance
Campus Safety, Planning and Building Management

data of blue staked surface markers. Of course the data is only as good as the blue stake locating equipment and trained locator but in previous experience with the probing equipment have proven to be very proficient in locating underground line data. A map of blue stake GPS data would significantly help validate the existence and location of utility data where archived CAD and project As-built data needs to be reconciled.

The collection of all above ground infrastructure asset locations using GPS has proven to be very useful in helping to line up underground linear data that does connect to those GPS asset points. The map below highlight areas of underground linear data that need to be updated due to a recent collection of above ground GPS point data. Updating the linear data can be done through the process of finding the As-built plans for this area or in the case of disconnected project data, a simple blue stake line location verification markers to help determine where lines are in the field. The issue with collecting and mapping linear data for campus networks is that the data exist in separate project files from different timelines that do not necessarily fit together nicely like a puzzle. There is some redundancy and gaps in information that needs reconciliation. The purpose of reconciling a combination of geo-referenced As-built data, archived and new CAD data, blue stake location data and various levels of GPS data is to be able to build a geometric network in the future (Figure 4.30).

Using GIS to Enhance
Campus Safety, Planning and Building Management

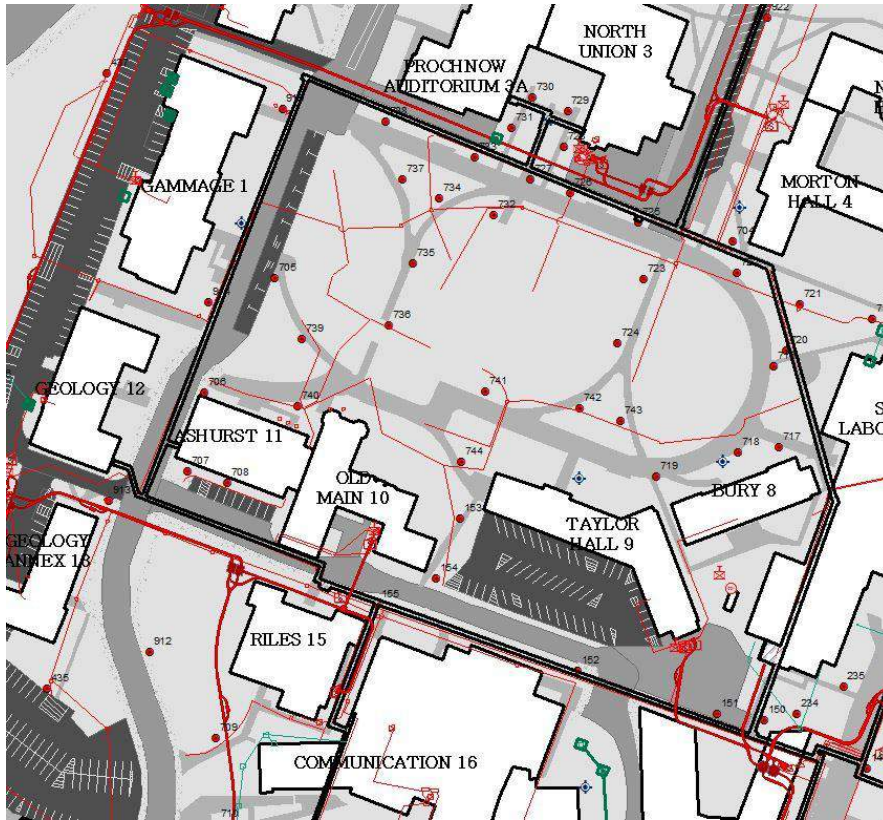


Figure 4.30: Utility network based on GPS points, CAD utility lines both converted to GIS

4.3 GIS to Enhance Campus Safety Assessment:

Blue Light Safety Assessment Project:

Once all data is collected and verified then a GIS environment can be used as a tool to enhance campus safety. Prior to the implementation of a GIS system there was no comprehensive relational data repository that could provide safety analysis to improve on campus security.

Another GIS assisted planning project that was completed as part of this practicum was the decision of where and how many additional blue light stations are needed (if any) around campus. This GIS analysis helped campus administration make an informed decision of whether additional safety lights are needed and if so where would be best locations. Given a limited budget, the GIS office was asked to provide a map that shows areas around campus that warrant additional safety coverage based on visibility and distance from other established locations.

The official request came from the Emergency Management Department which requested a safety analysis map that showed areas on campus where additional safety blue light would help with student safety. I decided to produce a campus map that shows locations of all blue lights as well as the visibility and distance to/from each light location using a 300-foot limit. This distance was the radius that police determined to be a good separation between existing

Using GIS to Enhance
Campus Safety, Planning and Building Management

lights and represents a reasonable distance for a person needing assistance to be able to maintain clear light sight and travel distance to get to in case of emergency.

The safety light devices are equipped with a blue lights that light up with a rotating blue strobe light to attract attention and alert bystanders of a potential situation. These light devices are also hard wired to be linked to the campus police dispatch who are alerted when the light is activated. Some of these light poles also have audible speaker feedback from emergency personnel that could be activated with the light siren.

Safety blue light visibility and distance analysis workflow

As a result, two safety maps were created for the Emergency Management Department. One map was created to show location and simple distance to and from each device location. The second map was a combination of distance and line of sight visibility to or from each light location. The desired distance parameter to be used in both maps was 300 feet.

There are four main feature class layers that must be created to complete a visibility analysis either to or from a blue light location. The analysis requires a two-step process. The first of which is the 'Sight Lines' process, second step is the 'Line of Sight' process. Prior to processing the above major steps I created the features classes that are to be used in the analysis including: observation points, target line, TIN surface condition and 3D multi-patch building layers.

Using GIS to Enhance Campus Safety, Planning and Building Management

First, I created the point features. This is the observation point to or from which is used to determine visibility, also known as line of sight. I collected 116 blue light locations using a Trimble GeoXH survey grade GPS collector device. Thirty of the sites contained 2-way talk capability with NAU dispatch, ten of which were located with parking structure. A sample selection of blue light locations on a dark campus was created to show how the light affected the dark areas of campus (Figure 4.31). For visibility purposes the lights within the garages are the most restricted in regard to visibility given the perimeter walls of the garages are an immediate impact on line of sight analysis. The visibility toolbox is located within the 3D Analyst Arc Toolbox of ArcMap 10 (Figure 4.32). The tools that were used include observation points, construct sight lines and line of sight. The visibility and line of sight tools are very similar functions expect that line of sight allows for the 3D multipatch dataset to be used as an obstruction whereas the visibility tool does not.

Using GIS to Enhance Campus Safety, Planning and Building Management

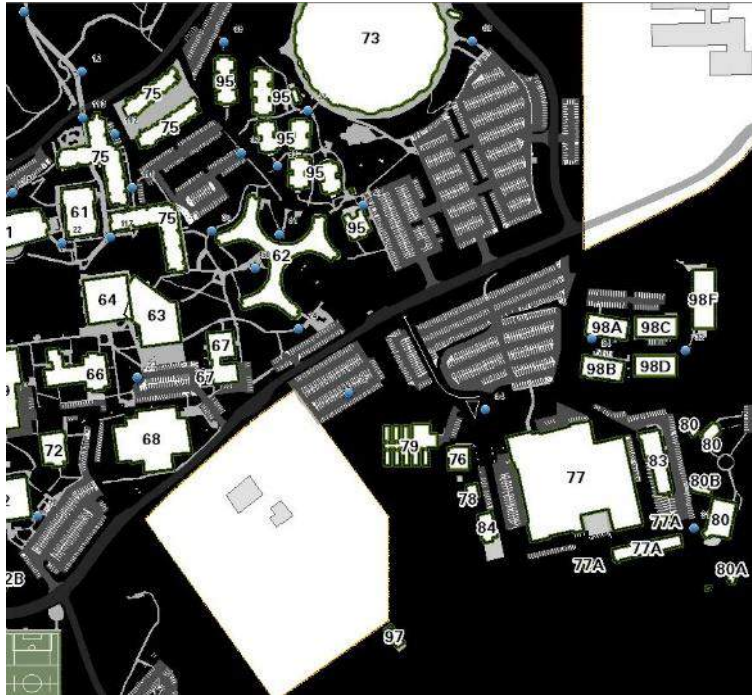


Figure 4.31: Observation Point Blue Lights

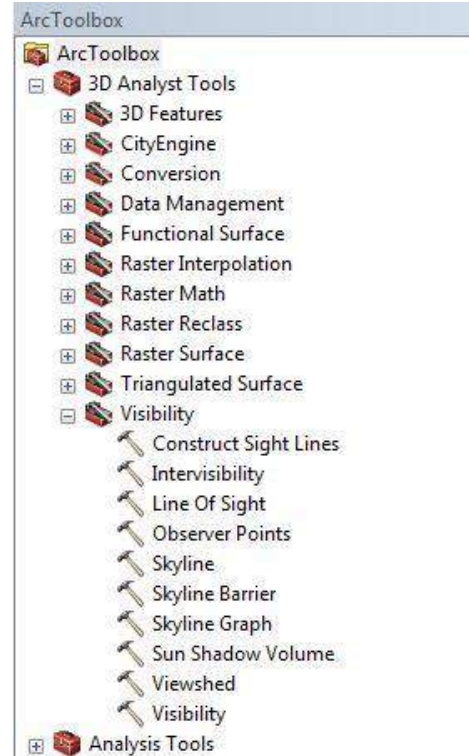


Figure 4.32: Visibility Toolbox ArcGIS

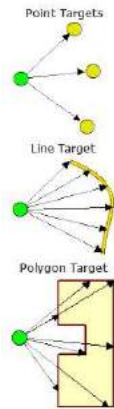
The second feature class used to determine line of sight is the creation of a target feature. The options for a target element includes: point, line, or polygon (Figure 4.33). For this project I created a polygon feature class to represent the visible target from each observation point.

Using GIS to Enhance Campus Safety, Planning and Building Management

The target feature class is the extent to which line of sight is to be established. In the case

Construct Sight Lines

Creates line features that represent sight lines from one or more observer points to features in a target feature class.



of these emergency signals light, I relied on advice from the Emergency Management Department staff. They stated that in cases of emergency that did not want to exceed 300 feet for light visibility and physical running distance. I used the Arc toolbox buffer tool to create 300 foot buffers from each light point. The buffer tool creates a polygon feature class to the distance given for the buffer. This polygon is produced as the target feature class layer using the buffer function (Figure 4.34).

Figure 4.33: Sight Lines Targets Options

Given that I also wanted to show distance away from each light at a maximum of 300 feet, I used the Euclidean Distance tool to highlight how light would visually dissipate in increments of 30 feet as distance increases. I choose 30 feet because it is divisible evenly into 300 by 10 thereby separating the buffered zoned equally (Figure 4.35) and I produced a visually dissipating raster by changing the classification symbology in the properties to show 10 equal interval distance ranges of 30 feet each in a red color ramp. This representation allows for understanding of increasing distance and the possible need to close the gap between current light locations to a color coded distance less than 300 feet.

Using GIS to Enhance
Campus Safety, Planning and Building Management

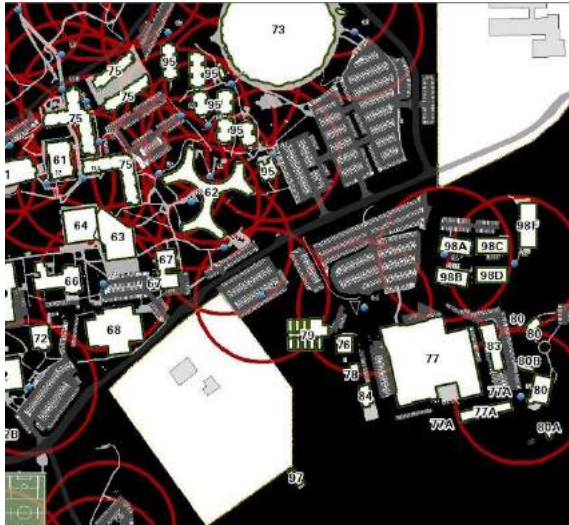


Figure 4.34: 300ft Light Buffer Polygon

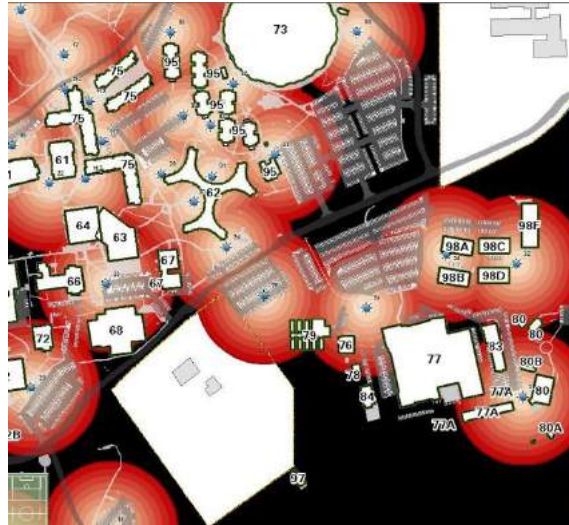


Figure 4.35: 300ft Euclidean Distance Raster with 10 equal intervals

The next feature class created was considered an optional layer because it may or may not exist, depending on the environment being assessed. This class is a multi-patch feature class that is to be used as an obstruction feature in the visibility analysis. A multi-patch feature class is a three-dimensional (3D) version of a 2D polygon feature class. In this case I used the building polygon layer as a real world obstruction to the line of sight. For the line of sight analysis, I used the buildings as a definite obstruction to line of sight visibility, so I created a multi-patch feature class from a recently updated campus building master layout polygon class.

The Arc Map 10 toolbox has a function that converts a polygon feature class to multi-patch feature class. The process included opening the Arc toolbox \ 3D Analyst \ conversion \ feature to 3D by attribute. The original polygon feature class must have been created with a Z field option added at the time of creation. If the feature class is not a polygon with Z value

Using GIS to Enhance Campus Safety, Planning and Building Management

optioned, then a Z field must be added to the polygon class before converting to multi-patch (Figure 4.36).

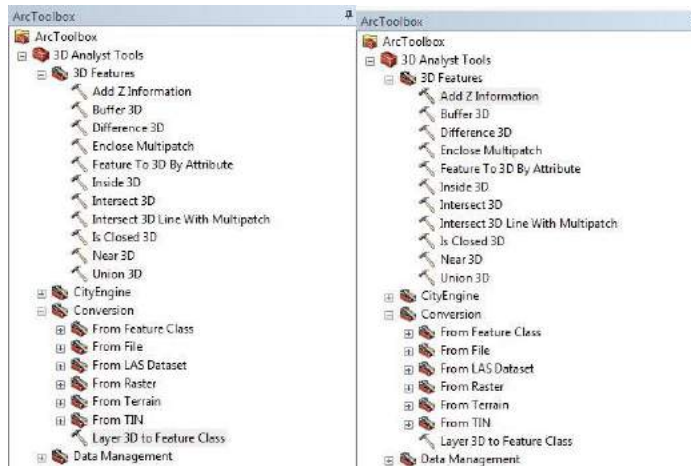


Figure 4.36: Arc Toolbox Layer to 3D and Add Z information tabs

The next feature class layer that is required to perform this analysis is a TIN layer. This layer is only used in the second step of the process. A TIN vector layer was created from a DEM that was obtained from the City of Flagstaff. Arc toolbox conversion tool was used to convert Raster to TIN. This process created the last required layer needed to proceed with the line of sight analysis.

After creating the required layers of a point observation points, target distance lines, multi-patch obstruction features and TIN surface elevation layers I was ready to process the sight lines function. The sight line procedure produces all possible lines from the observation point to all vertices along the target line. In my case the sight lines process produced a radius of lines for the entire 360 degrees of the target's circular line barrier, which is 300 feet from each light point (Figure 4.37). Sight line geometry type is polyline Z (3D lines, which have Z values) so that

Using GIS to Enhance
Campus Safety, Planning and Building Management

meaningful analysis can take place. The input obstructions may be any combination of surfaces and/or features. Surfaces must be either raster or TIN. Each obstruction feature layer geometry type must be multi-patch, line, or polygon. Each line or polygon feature layer must have base height and extrusion information, or its contents will be ignored. Each input sight line may consist of more than two vertices, but only the first and last vertex is used. Each sight line will therefore always be a straight line. The Z values of the first and last vertex of each sight line are the only sources of Z values that are used. The analysis result is saved in the input sight line's feature attribute table in an integer field. By default the name of this field is `VISIBLE`, but the name can be changed with the `visible field name` parameter. The result can be a value of either 1 or 0, where a value of 1 indicates that the sight line is not obstructed by any of the potential obstructions specified in the `Obstructions` parameter, meaning that its starting point and end point are visible to each other. A value of 0 indicates that the sight line is obstructed by at least one surface or feature. NOTE: no barrier information was used in the initial sight lines step.

The sight lines and line of sight functions had to be processed individually (for each observation point and target polygon) given that each point must be limited to its own 300-foot target line for visibility and access. I attempted to process all light locations against all target line barriers in a batch process in an effort to perform the analysis quickly. The batch process does not produce an accurate depiction of the areas that have blue light coverage and the areas outside the 300-foot target limit because when a batch process is performed for all points, all targets are active reference options. This allows for the lines of sight to consider any target limit

Using GIS to Enhance
Campus Safety, Planning and Building Management

as an optional target location. This relationship breaks the project parameter rules that limits visibility and access to 300 feet from each light location.



Figure 4.37: Sight line production map figure

It is important to note that all observation points must also be given a height value that is above the surface value (ground level). For this project I measured the average light height to be 7 feet. This was used in the height (z point) field. This is the value used to convert the 2D feature to 3D for the line of sight analysis to elevate the point off the ground. This is critical given that both the 3D buildings layer and the TIN elevation layer can obstruct the line of sight. If the lighting points are not elevated to the correct Z value at light height then it is possible that the TIN surface model could obstructs the line of sight in some directions. For example, if an observation point and target line are on opposite side of a hill then the surface would become a

barrier to the line of sight if both points are not given real world elevation heights. So when the observation or target point is elevated to a height of seven feet and the TIN contour is not higher than seven feet then the TIN would not be an obstruction to the line of sight. This example would be in addition to the obstruction of a multipatch (3D) building layer.

The second and final step of the analysis is the line of sight function which determines the path of visibility from an observation point to a target taking into account a TIN surface and 3D buildings as potential obstruction to visibility. This process requires the following layers: observation points, sight lines, TIN surface and 3D building (multi-patch). The TIN surface and 3D building layers both are used as possible barriers to the line of sight.

ArcScene 10 was used to process the line of sight analysis. This tool determines visibility of the sight lines over obstructions of a surface and a multi-patch dataset like buildings. The line of sight tool calculates visibility between the observation point and the vertex of each target line feature. In this project the target was a buffer circle at 300 feet from the observation point. The first vertex defines the observation point, whereas the last is the observation target. Visibility is determined along the sight line between these points, and any intermediary vertices in lines with more than two vertices are ignored.

The height of the observation and target points for 2D lines are interpolated from the surface with a default offset of 1 applied to the observer location so that it is above the surface. For 3D line features, the observer and target elevation is solely obtained from the feature's

Using GIS to Enhance
Campus Safety, Planning and Building Management

geometry. If no multi-patch feature is provided, the output line is draped onto the surface. If a multi-patch feature is provided, its features will be factored into the visibility analysis along with the surface, and the resulting lines will extend directly from the observer to the target location.

The output 3D lines store one feature for each sight line that is either entirely visible or not visible, and two features for each sight line that is partially visible. The *Source_OID* field indicates the input feature used to define the sight line, and the values in the *Vis_Code* field indicate the visibility of the sight line, where 1 means visible and 2 means invisible (Figure 4.38). The *Tar_Is_Vis* field describes whether the target point is visible from the observer by using a value of 1 to denote visibility and 0 for non-visibility. A field named *OBSTR_MPID* is also added to identify the multi-patch obstructing the sight line. If the target is obstructed by the surface, this field's value will be -1. If the target is visible, it will be -9999.

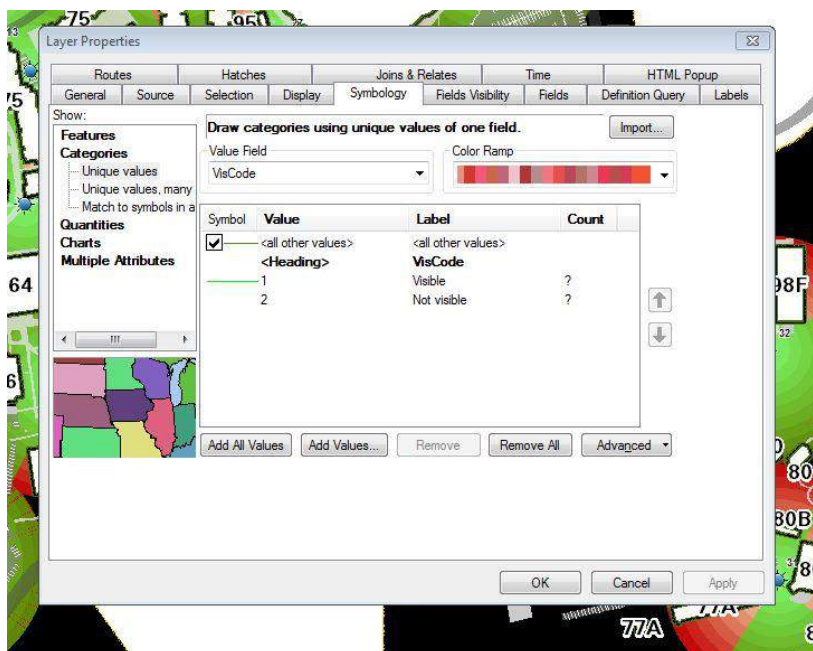


Figure 4.38: Line of Sight Visibility Code Values

Using GIS to Enhance Campus Safety, Planning and Building Management

This process was carried out for each safety light point individually to accurately reflect the visibility overlaps in coverage as well as the areas of blocked coverage. This Blue Light Visibility Analysis map also highlights the areas of non-coverage on campus. These were areas within the campus that were outside the 300-foot access and visibility distance. I highlighted two areas of concern in red for areas of blocked coverage and left the black to represent areas of no coverage. The attached production maps show the different areas on campus (Figure 4.39). The blocked areas around the garage-located light was of particular interest. Without a 3D line of sight analysis a regular map would show light within garage spaces as lighting a 300 feet perimeter around them therefore may consider that area as covered by the safety lights. But as a result of the visibility analysis, the Blue Light Safety Map clearly identifies that the light points that are located within the parking structure are not visible or immediately accessible from the immediate 300 foot area (Figure 4.40).



Figure 4.39: Visibility Analysis South Campus

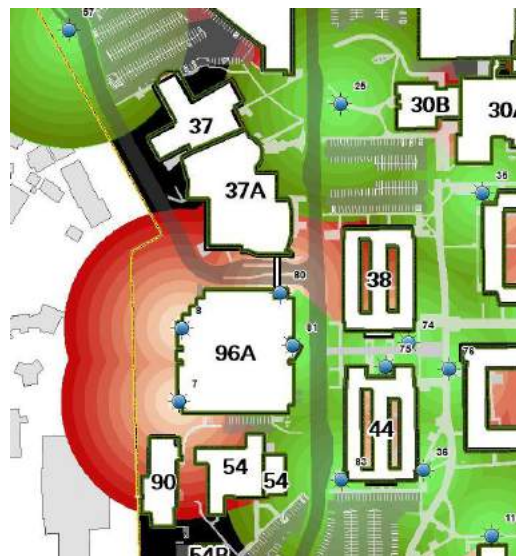


Figure 4.40: Visibility Analysis Light Restriction

Using GIS to Enhance Campus Safety, Planning and Building Management

This was enlightening to the Emergency Management Department who used this safety assessment map to gain budget approval from campus administration to install additional blue safety lights (Figure 4.41).



Figure 4.41: Full Campus Emergency Blue Light Visibility Analysis Production Map

Chapter 5: Research Summary

5.1 Research Conclusion

Department Project Goal Fulfillment

The projects described in this practicum are part of a campus wide endeavor to provide department leaders real world examples of the benefits of using a spatially related organizational database that could provide the basis for a larger campus wide asset management information system. Through working closely with individuals within each department I directly learned their systems and their required assessment criteria in order to develop a GIS system that is now a critical resource of asset data information.

There is a learning curve to go from a paper dependent mentality to a digital reference. This process is not totally accepted by some stakeholders who may have technical difficulties using computer based data. Once the data user learns to reference data through digital medium they slowly become acclimated to search for data digitally and start to realize the search and retrieval efficiency that digital formats can provide.

Facility Services is very satisfied with progress and repurposed use of the archived paper data that is currently being transferred into digital format for GIS representation. Prior to the implementation of a GIS for data organization, storage and analysis, all stakeholders related on the paper copies to locate data and their relationships (Figure 5.1). The process of just locating

Using GIS to Enhance Campus Safety, Planning and Building Management

data was arduous given the stacks of paper plans and even with scanned documents it is very time consuming to locate data given the different years of projects and different project area start and stop points (extents). So connecting the literal lines and points from project frame to project frame was like trying to find the missing puzzles pieces to complete a whole picture for each and every connected layer or network. The following images show the starting point of where stakeholder would look for data prior to the GIS framework. This the plans room at Facility Services (Figures 5.2, 5.3, 5.4).

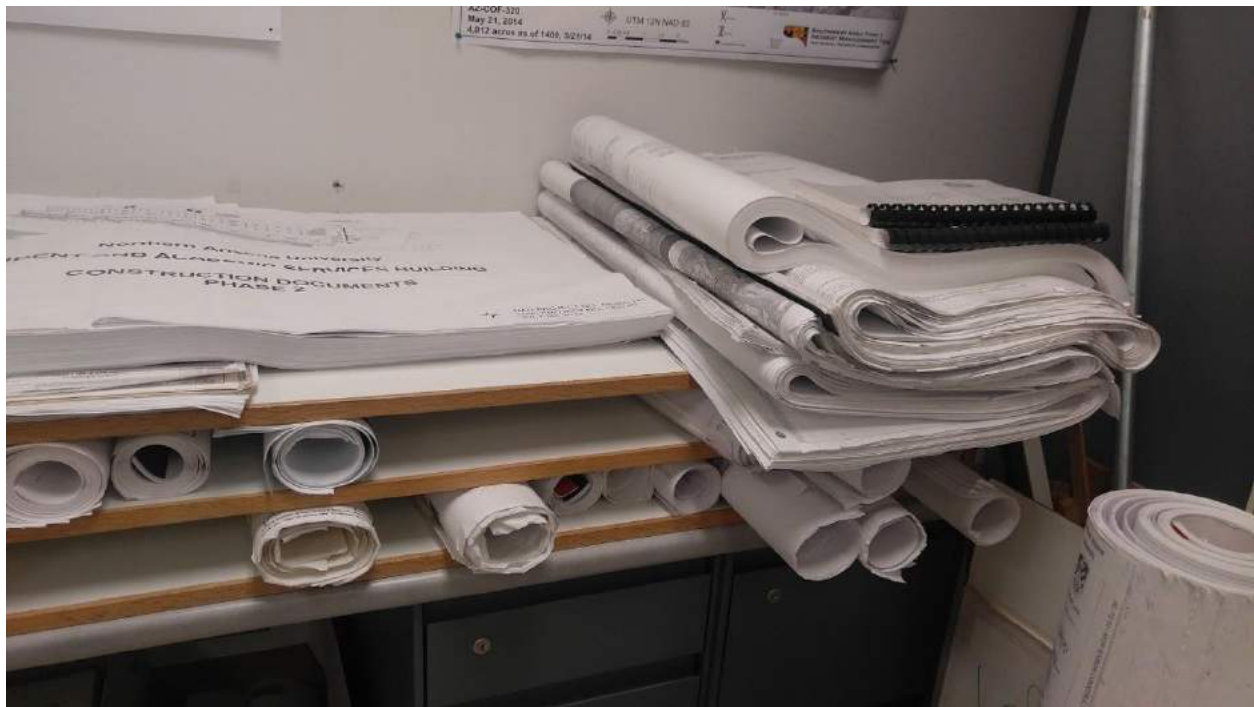


Figure 5.1: Plans Room, Plan Sets for Review

Using GIS to Enhance
Campus Safety, Planning and Building Management



Figure 5.2: Plans Room, Flat Plans Storage



Figure 5.3: Plans Room, Rolled Plans Storage

Using GIS to Enhance Campus Safety, Planning and Building Management



Figure 5.4: Plans Room, Hanging Plans Storage

The process to transfer data to a GIS database has not only allowed for increased perspective and analysis but now allows for quicker data retrieval and data reconciliation updates. The pre planning GIS implemented perspectives have improved development option reviews without having to hire outside consultants. The building management groups now appreciate the GIS based building information modeling given the automatic updating of space data and the location and relationship of interior asset data. And the campus safety GIS analysis has been used by the Emergency Management team to gain approval for additional safety lighting in areas determined to be a safety concern by the GIS visibility assessment map. This safety map has also been used in pre-planning project assessments to determine where additional conduit lines should be added to insure future blue light locations.

Using GIS to Enhance
Campus Safety, Planning and Building Management

Individual learning curve

These practicum projects have enhanced my job experience while serving as the Spatial Data Manager for Northern Arizona University. My job assumed the responsible for the development, reconciliation and maintenance of the University's Geographic Information Systems (GIS) and Computer Aided Design (CAD) systems. The campus GIS/CAD is part of a larger, growing Facilities Information System (FIS), which combines mapping, building floor plans, space use, operations data, capital project information, and other spatial data. I am also responsible for coordinating with department staff, including campus planners, operations and capital project management staff, as well as working to organize and maintain the Document Storage Office (DSO) which is responsible for the Facility Services project document close-out archival for both digital and paper documents. The role includes day-to-day project execution and data deliverables. Projects and tasks may include but are not limited to data collection and integration, map production, advanced spatial analysis, database manipulation and drawing updating and document archiving.

In this practicum I applied professional spatial data engineering and facilities data administration concepts to manage and perform complex tasks that included:

- Providing analysis for complex information requests and document them using formal data definition techniques and naming standards
- Using GIS software to maintain campus planimetric map of campus building, infrastructure, landscape, and land projects.

Using GIS to Enhance
Campus Safety, Planning and Building Management

- Developed 2D architectural drawings of campus buildings from construction “As-built” drawings. Scanned hardcopy drawings and digitize to a GIS format. Field verification and field measurements using GPS survey equipment. Converted CAD building data to GIS by filtering layers to include basic architectural elements.
- Developed campus building 3D models using Building Information Management (BIM) practices. Models were created through a combination of scanned drawings, existing CAD data, GPS field verification, professional field surveys.
- Worked with multiple campus department to develop GIS schema including Utility Department, Planning Development and Construction, Parking Services, Emergency Management, Campus Fire Marshal, Space Management and Facility Services trades groups.
- Converted all utility data to GIS based master control layers. Maintained campus infrastructure maps and information. Infrastructure systems include campus water, sewer, storm, gas, high and low voltage electrical, steam, and telecomm network and fire alarm systems. Information was gathered from existing construction project information, field verification with campus staff, and field surveys. Prepared update reports and map verification for campus staff.
- Organized and maintained campus project’s record document library. Maintained hardcopy documents as well as organized scanned documents to the department’s online documents library. Provided maps and records for department staff.
- Managed the collection and updating of various engineering and environmental information to support campus operations and new development. Collected and

Using GIS to Enhance
Campus Safety, Planning and Building Management

analyzed infrastructure information to support development of campus soil and utility analytical models.

- Managed all campus Geographic Information System (GIS) layers. Performed complex data management and resource research and metadata acquisition for data sets including revision all NAU GIS layers to be compliant with local survey projection system based on a Low Distortion Projection that has increased measurement accuracy given the mountain campus elevation.
- Managed to establish the basis of a central asset data repository that can collect, track, and integrate all the various asset systems and their real world relationships that helps to manage and evaluate the conditions and relationships of all campus assets.

5.2 Future Campus GIS

Utilizing a GIS as the campus asset data repository has many more opportunities that can be leveraged for the benefit of the campus environment. The proceeding a small sample other projects I have initiated using the GIS platform.

GIS for Equal Access and ADA Compliance

GIS offers campus routing services for various users including those with disabilities. Campus routing is about modeling pedestrian pathways, performing routing-style analyses based on ADA code accessibility, and sharing the optional functions as services that can be accessed by various department and/or clients via mobile phones and tablets.

Using GIS to Enhance Campus Safety, Planning and Building Management

Pedestrian pathway data modeling is three dimensional. It models pathways across rolling sidewalks, curbs, crosswalks and parking lots as well as through different floors of buildings, and between floors using elevators, stairs, and so on. GIS web interface portals allow for routing services based on ADA surface conditions to be shared with users for accessibility and campus managers for improvement priority planning. The GIS web portal templates allow for limited but relevant retrieval of campus construction data, ADA accessible parking space data, ADA preferred pathways and other general safety features that may affect planned campus visitations (Figure 5.5). A GIS assistive technology Portal Link method can be designed to represent specific data at specific scale and/scope thus removing the “noise” normally associated with a large amount of website or application information.

Portal Explorer Sample

This sample shows how to use `AppPortal` and related classes to connect to and access content from portals such as ArcGIS Online. You can modify the sample to connect to on premise portals or specific organization subscriptions on ArcGIS Online. You can either log in to the portal as a registered user or access the portal anonymously as a guest user (if the portal permits).



Figure 5.5: GIS Mobile Interface

Using GIS to Enhance Campus Safety, Planning and Building Management

GIS for Enrollment and Destination Services

Another future utilization of the space management GIS database is to use classroom data in LOUIE to help students select classes based on spatial proximity to reduce time and traffic on campus. This is crowd control application of the space management data. This application can be developed to allow students to enter their ID numbers and generate maps that show their classroom locations, as well as the proximity to the next class, based on a specific time and day. This will help students familiarize themselves with the campus and select a schedule that offers reasonable travel times or be able to accurately estimate the amount of time between classes, which also enhances the student campus experience (Figure 5.6).

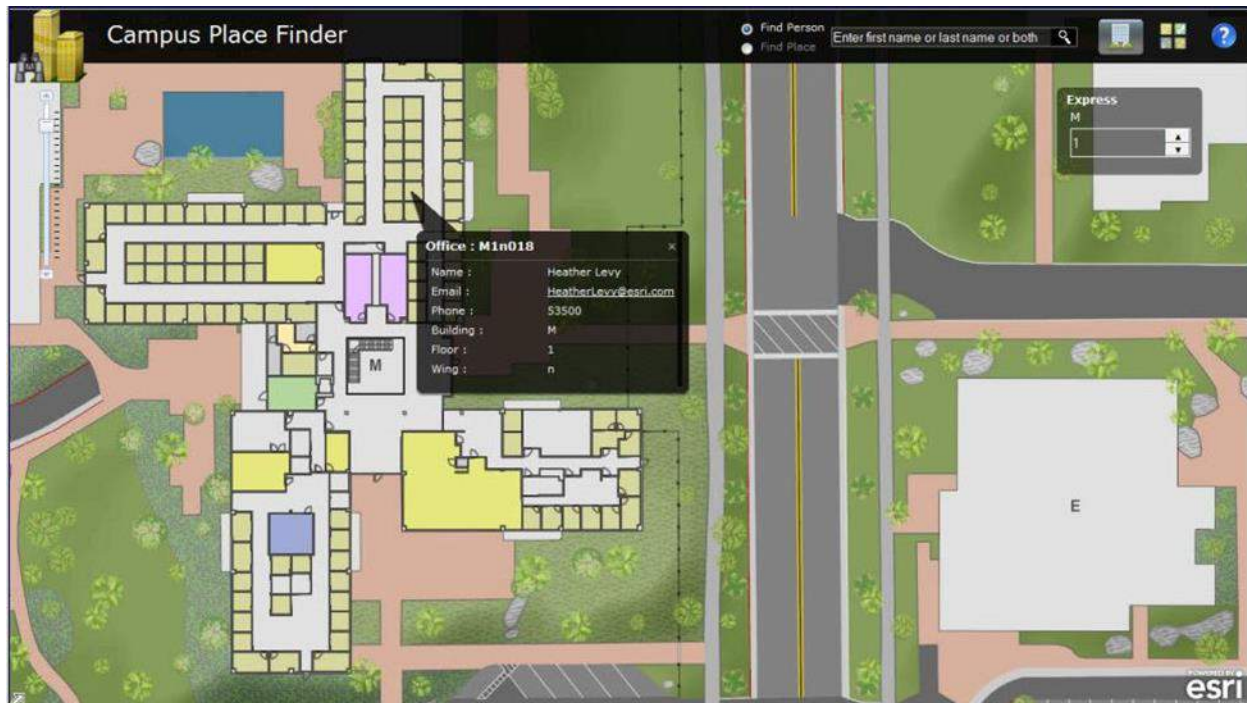


Figure 5.6: GIS Space Planning Classroom Locator Application

Using GIS to Enhance Campus Safety, Planning and Building Management

Using department enrollment data per class subject and classroom space allocation, decision makers can make informed assessments of projected growth and spatial assignment needs. The university can develop an interactive room-finder application using institutional data. Users can input the building name and room number they wish to find and the application will generate a general circulation map showing the a limited layer floor plan with the desired room highlighted.

GIS for Parking Services

Parking Services is a prime example of a recent expansion of the GIS platform to assist in organizing their parking lot fee structure as well as the parking lot use designation. In addition to the data organization and online mapping features, the GIS application would allow for 'smart' assignment of parking passes based on a student's class schedule. This GIS analysis could encourage the use of mass transit and therefore reduce vehicle traffic on campus. GIS can help students and visitors easily find their way around campus and visitors can even look up their destination using the online tool and determine the nearest parking area before arriving on campus. This enhances visitors' experience and helps reduce campus traffic congestion.

The GIS platform was used to establish a customized geodatabase of all parking lots and parking structure. Field data was collected to show parking handicapped parking stall. Field attributes were built to assist in organizing their parking lot fee structure as well as the parking lot use designation. In addition to the data organization the newly implement GIS grid is being used as basis for possible renaming of parking lots based on spatial reference to grid location and proximity to buildings. This project has provided parking services the ability to assess the number

Using GIS to Enhance Campus Safety, Planning and Building Management

of parking spaces that assigned to specific fee structure as well as the number of van, bus, employee and handicapped spaces per lot and the serviceable area for those parking designations (Figure 5.7).

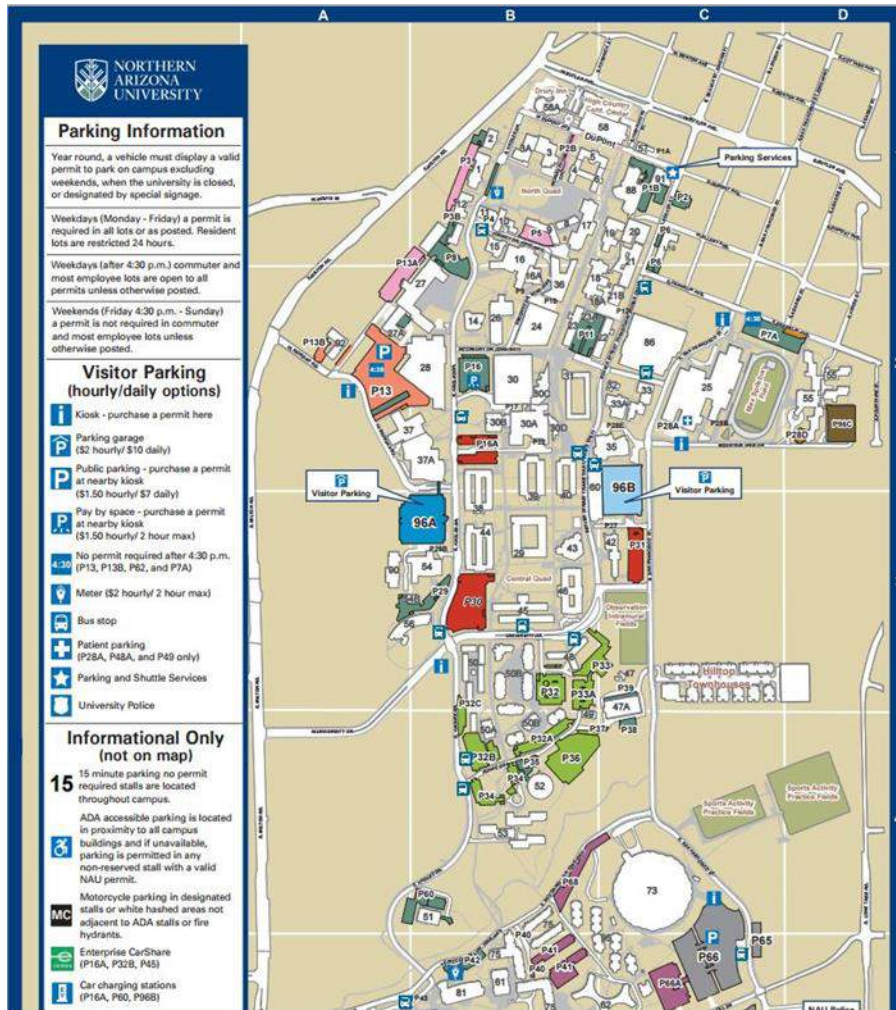


Figure 5.7: GIS based Campus Parking Map

GIS for Special Event Planning

The Special Event Planning GIS map could help public safety, emergency management, public works, or PDC departments to collect and maintain special event plans and publish special event maps. Special events are large events that occur on campus property. Typically, these events are celebrations, athletic or recreational activities that are open to the public. The

Using GIS to Enhance Campus Safety, Planning and Building Management

information used to generate special event maps is primarily obtained from details described in event planning meetings with Athletics and NAU PD or as described in a special event permit application (Figure 5.8).

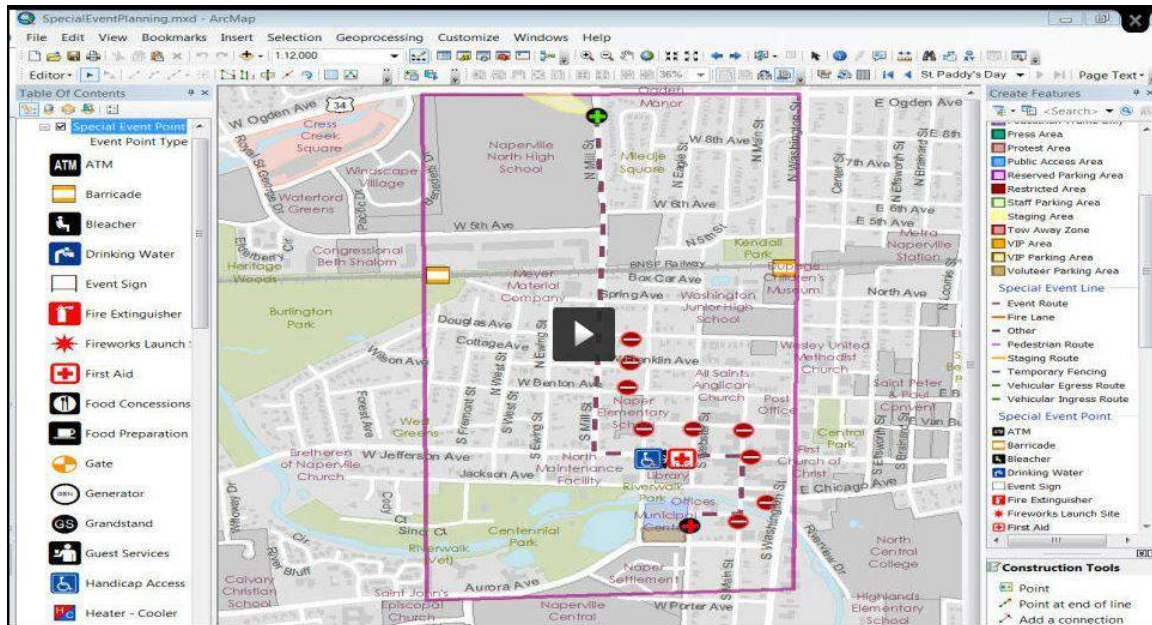


Figure 5.8: GIS Special Events Parking Application

Using GIS to Enhance Campus Safety, Planning and Building Management

GIS Centralization

Once the GIS office is officially designed as the spatial data repository for all campus land, building and infrastructure data then the realization of how asset data can be used by all departments to assess and plan for future growth. GIS has the ability to capture and analyze data from a variety of campus disciplines to be used for the purpose of various department goals (Figure 5.9).



Figure 5.9: GIS Centralization

Using GIS to Enhance Campus Safety, Planning and Building Management

Through the centralization of all asset data management campus administrators will have the ability to view campus with 'x-ray' vision using augmented GIS and mobile devices like phones, tablets and laptops. Through the centralized management of all spatial data, exterior planning (Figure 5.10a) as well as interior space management take on an innovative perspective (Figure 5.10b).



Figure 5.10a: GIS Exterior Augmented Planning



Figure 5.10b: GIS Interior Augmented Management

Conclusion

Through a systematic collection and transfer of all spatial data into a campus GIS enterprise asset repository, exterior and interior asset management will become more efficient and effective. GIS has proven to be the vital link between plan sets to show the complete network of asset layers. GIS has provided a BIM platform that can be used for building model integration. GIS has proven to be useful to gainful insight for campus safety accessibility. The

Using GIS to Enhance
Campus Safety, Planning and Building Management

visibility safety map has proven to be a useful tool for the planning of new and future blue light locations. GIS has proven be a useful planning tool for future development projects and these practicum projects have provided a sample of how asset data integration through GIS can enhanced campus safety, campus asset management, and campus planning.

References Cited:

- Aguirre, Jessica Camille. 2014. *The Unlikely History of Modern Maps*. 06 02. Accessed 09 09, 2015. <http://www.smithsonianmag.com/history/unlikely-history-origins-modern-maps-180951617/?no-ist>.
- AIA Knowledge Resource Team . 1975. "Terminology: As Built Drawings."
- Astroth, Joseph H. 1995. "Combining GIS/CAD/AMFM increases efficeincy, cuts cost." August 1.
- Astroth, Joseph. 1995. "Combining GIS/CADD/AM-FM increases efficiency, cuts cost." *Public Works*, August.
- Beesley, Caron. 2013. *BIM for Govies*. Herndon: DLT Solutions LLC.
- Dehaven, Paul. 2009. *Propose Design Build with BIM*. Stevens & Wilkinson The Beck Group.
- Dobson, Jerry. 2004. "The "G" moves onward (the G in GIS)." *GEO World* , March 1.
- Ehrlich, Paul. 2008. "The intelligence Quotient (Building Automation)." *Engineered Systems*.
- ESRI. n.d. *Facility Management*. Accessed 6 10, 2015. www.esri.com/fm.
- . 2012. *GIS Mapping Software, Solutions, Map Apps and Data*. March 6. esrionline.com.
- ESRI Insider. 2011. "Facilities and GIS ." 11.
- Esri White Paper. 2009. *Enterprise GIS and the Smart Electric Grid*. Esri.
- ESRI/ Facilities Mangement. 2010. *GIS for Asset and Facilites Management* . ESRI .
- Federal Geographic Data Committee. n.d. *National Spatial Data Infrastructure*. Accessed Sept 2014. <https://www.fgdc.gov/framework>.
- Goldschmidt, Paul. 2008. "The intelligence: Quotient: how does intelligent building get so smart, exactly." *Engineered Systems* , September 1.
- Henry, John. 2002. "Engineers finding more uses for GIS." *Arkansas Business* , September 23.
- Hughes, Jensen. 2015. *Trends in Fire Protection and Life Safety*. Jensen Hughes.
- Kroll, Karen. 2007. "A Measure of Building Intelligence ." *Facilitiesnet*.
- Lynch, AnnMarie. 2011. "Building Smart from the Ground Up." *ArcNews*, Fall.
- Maguire, David. 2003. *Improving CAD GIS Interoperability*. ArcNews.
- McElvaney, Shannon. 2012. *Geodesign case study in regonal and urban planning*. Case Study, Redlands: ESRI.

- Miller, William. 2012. *Director of GeoDesign Services*. ESRI, ESRI.
- National Institute of Building Sciences SMART Alliance. 2011. "United States CAD Standard V5." NCS.
- National Research Council. 2006. "Learning to Think Spatially ." (The National Academic Press).
- NAU. 2017-2019. *Capital Improvement Plan*. Annual , Flagstaff: NAU.
- Neutra, Richard Joseph. 1969. *Survival Through Design* . Oxford University Press.
- News Bytes . 2002. "GIS and Small Utility ." *Geospatial Solutions* , October 1.
- Office of Energy Efficiency . 2009. *Energy Smart Hospitals: retrofitting existng facilities* . US Department of Energy , Washington DC: Building Technology Program .
- Paradis, Richard. 2012. *Retrofitting Exsting Buildings to Improve Sustainability and Energy*. Whole Building Design Guide, National Institute of Building Sciences (NIBS).
- pdhonline course. n.d. "Understanding the Geotechnical Report as an Engineering and Construction Reference." *pdhonline.org*. Accessed Dec 12, 2015.
<http://www.pdhonline.org/courses/g106/g106.htm>.
- Prince, Tom. 2010. "Smart decisions: How to future proof your industrial facility." *Sustainable Facility* , September .
- Przybyla, John. 2002. "What stops folks cold from pursuing GIS." *Public Works*, April.
- Sheehan, Micheal. 2003. "Working With Interpolation Tools: IDW, Spline, and Kriging." *mit.edu*. <http://web.mit.edu/course/1/1.966/www/Lab4/>.
- Smith, Edgar. 2008. "Building Information Modeling (BIM)." *Whole Building Design Guide* (National Institute if Building Science) .
- Smith, Gary. 2007. "Building Reality: Integrating 3-D GIS with Community ." *GEO World* , April .
- Spiegel, Shaun Kinikin. 2004 . "Promoting geographic information systems usage across campus." *Computers in Libraries* , May .
- Stalford, Richard Lewis. 1993 . "GIS and Facility Managment ." *Public Works* , April .
- Swaback, Vernon. 2007. "Creating Value: smart development and green design ." *Urban Land Institute* .
- Teasdale, Eugene Shuter and Warren E. 1989. *Application of drilling, coring, and sampling techniques to test holes and wells*. USGS Survey Publicaton .

Using GIS to Enhance
Campus Safety, Planning and Building Management

n.d. *The Shapefile Interface in GrADS*. <http://www.iges.org/grads/gadoc/shapefiles.html>.

Wagner, Mary Jo. 1999. "Pipeline maintenance benefits from GIS development ." *Public Works* ,
January .

Wallis, Patrick. 2012. "The Role of GIS Technology in Sustaining the Built Environment." *The
Role of GIS Technology*. ESRI. Accessed October 2015.

<https://www.esri.com/library/ebooks/sustaining-the-built-environment.pdf>.

Wayne, Chris. 2003. "Profiling cartographic education in GIS ." *Cartography and GIS Science* ,
April .

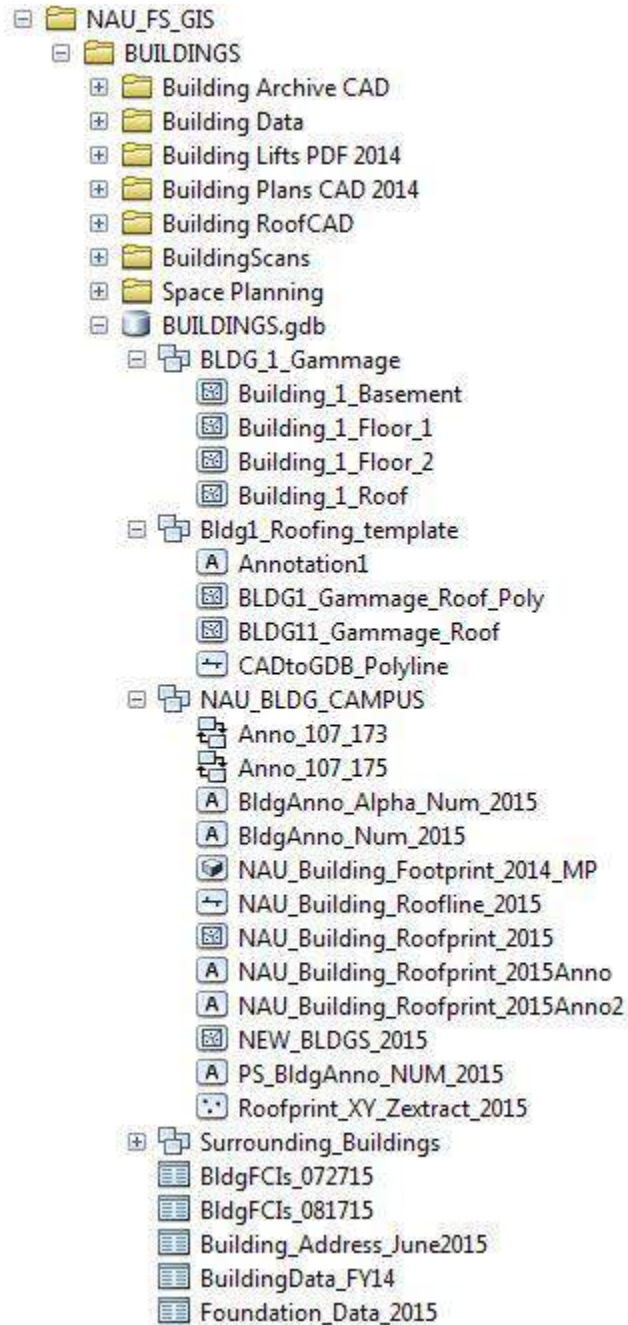
Appendices:

Appendix A: Defined Terms

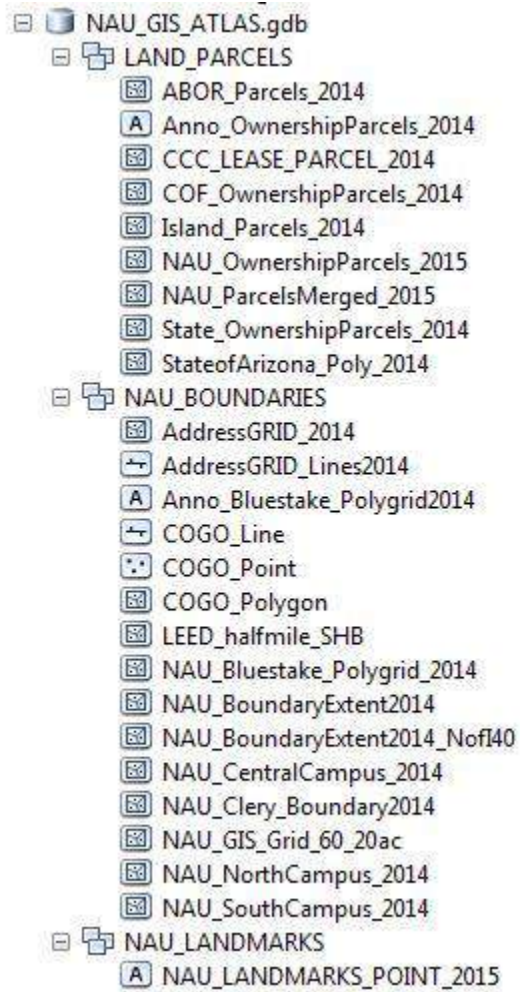
1. Capital Renewal: The reconfiguration of existing space including alterations or upgrading of major systems, components, and fixed equipment which extends the useful life of the building or portion of the building necessitated by facility obsolescence (for both
2. Infrastructure: Renewal or replacement of existing basic support systems and components that deliver to building such common utility services as heating/cooling, water and sewer, electricity, gas, telecommunications, etc. Also includes support systems and components such as roadways, sidewalks, parking lots, external lighting, landscaping and irrigation systems where such systems and components are not part of another new construction projects.
3. Major Maintenance/System Replacement: Renewal and replacement of capitalized building systems and components due to end of useful life, physical plant wear-out, or obsolescence, e.g. renewal of fixed equipment, roof replacements, HVAC, plumbing, electrical, window, flooring, and elevators systems.

Appendix B: GIS Database Resources

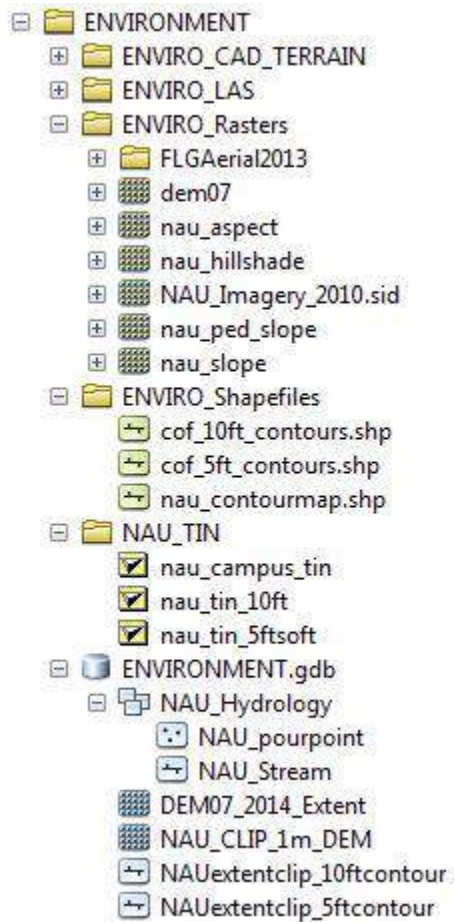
1. NAU Buildings Geodatabase:



2. NAU Atlas Geodatabase:



3. NAU Environment Geodatabase:

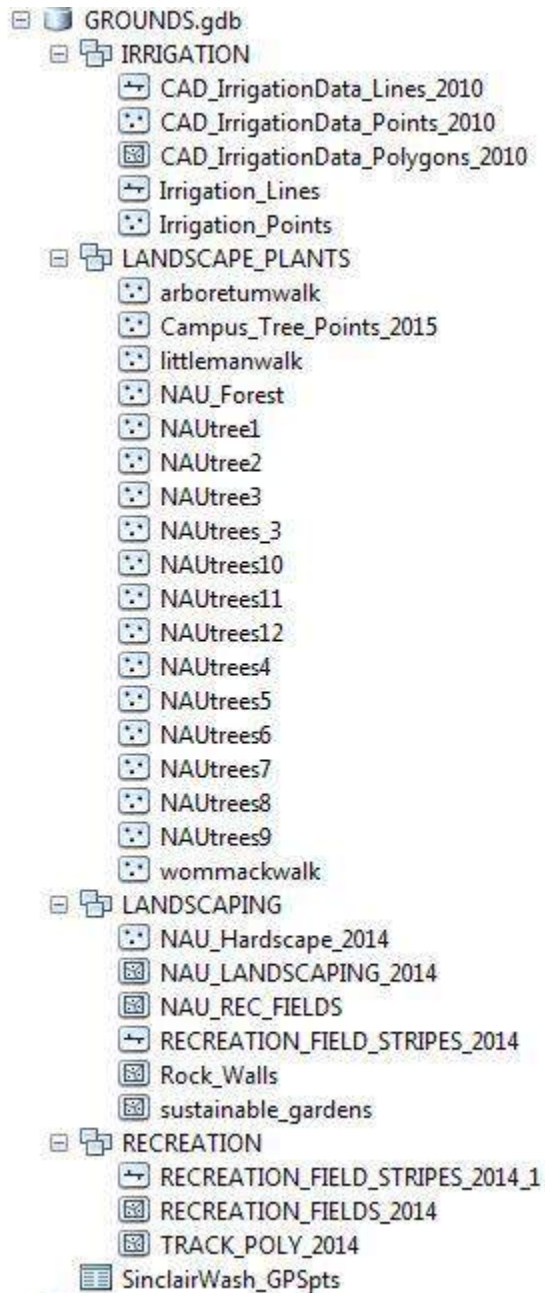


4. NAU Exterior Asset Geodatabase:



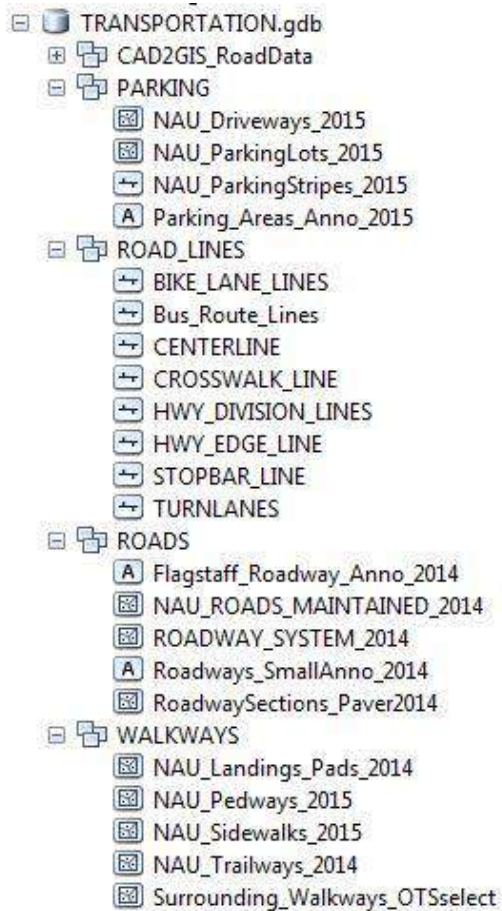
Using GIS to Enhance
Campus Safety, Planning and Building Management

5. NAU Grounds Geodatabase:

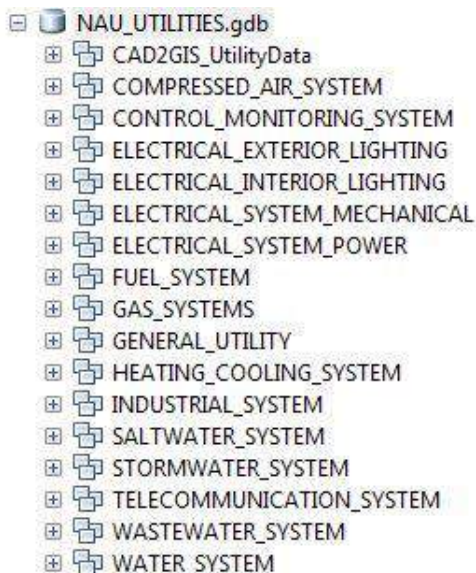


Using GIS to Enhance
Campus Safety, Planning and Building Management

6. NAU Transportation Geodatabase:



7. NAU Utility Geodatabase:



Appendix C: Facility Services Department Summary

1. Administrative Services:

Facility's Administrative Services manages work orders, construction procurement and contracts for NAU projects, coordinates campus requests for maintenance and repairs, provides computer technology support to Facility Services employees and automated building systems across campus, provides historical building data, and is responsible for a variety of capital reporting to the Board of Regents.

2. Fiscal Operations:

The Fiscal Operations group manages reviews and processes all financial activity for the Facility Services department.

3. Planning, Design and Construction

The Planning, Design and Construction (PDC) unit of Facility Services guides the development of large projects on the NAU campus and statewide. From initial decisions regarding which projects should be developed for the year, to bids solicitation preparation, CAD design/renderings and management of construction and facility openings, PDC is responsible. Planning and Development offers complete project management service from architectural design, bid, through construction to warranty acceptance.

4. Engineering:

The Engineering team provides leadership and support to Facility Services and the campus in a number of areas of expertise. The NAU Fire Marshal, through the Fire Prevention Office, is responsible for providing a fire safe campus environment. This includes evaluation of all campus facilities for fire hazards and also fire safety education and training. The NAU Building Official or his duly appointed agent provides code review of construction documents, issues building permits and performs required inspections to ensure compliance with project requirements, NAU Technical Standards and appropriate codes. The GIS/CAD/Document Storage team is responsible for extending the GIS data base of all campus assets, providing CAD drawing support

Using GIS to Enhance
Campus Safety, Planning and Building Management

and managing storage of building drawings and documents. The team also manages the building/infrastructure deferred maintenance program.

5. Maintenance & Operations:

Operations and Maintenance is responsible for the maintenance and continued safe operation of campus facilities, and for prolonging the useful life of facilities. Operations and Maintenance is tasked with operation and maintenance of campus buildings with respect to electrical, custodial, building access, fire life safety, plumbing, general maintenance, carpentry, moving and paint. Operations and Maintenance is also responsible for maintaining the campus grounds and snow removal along with transportation service.

6. Utility Services:

Utilities and Infrastructure provides long-term utilities planning, daily energy management, and upgrade installation management for all utility construction projects, central utility plant operations, budget assessments and locating of all campus infrastructure. Currently the Facility Services Department has approximately 200 feature classes within 35 different datasets within the 3 primary file geodatabases.

Utilities and Sustainability provides long-term utilities planning, ongoing utilities management, and overall management of the campus infrastructure.

Using GIS to Enhance Campus Safety, Planning and Building Management

Appendix D: Project Data Tables

■ Borehole Project:

1. Bore Hole Excel Spreadsheet Notes
2. Bore Hole GIS Table conversion

Borehole Info - Excel																
Matthew Nelvid Tolayo																
Boreholes																
#	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Bldg#	Link to NAU Proj#	Report Name	Report loca By	Closest Bldg Name	# Boreholes	Add'l B	Add'l B	Max c	Test F	Max	Add'l	Notes			
2	56	1 09.560.011	Applied Research and Dev	WT CD	Applied Research & Develo	5	20		39							
3	86	2 09.860.131	Aquatic Tennis Center fine	WT CD	Aquatic Tennis Center	13			51	5	10					
4	70	3 09.700.041	College of Business-Dist	WT CD	College of Business (In S	3			25							
5	38	4 09.580.000	Conference Center	WT CD	Conference Center	26	7		52	7						
6	16A	5 09.160.081	Distance Learning Center	WT CD	Extended Learning	5	3		32							
7	65	6 09.650.031	Engineering and Technolog	WT CD	Engineering & Technology	5			20	3	11					
8	69	7	Engineering and Technolog	WT CD	Engineering & Technology					4						
9	33	8	NAU-HRM Building Additio	WT CD	HRM	3			20							
10	18	9	Liberal Arts BLDG 18 Ext	WT CD	Liberal Arts	1			25							
11	14	10 09.140.001	NAU-NACC Bldg	WT CD	Native American Cultural C	5			45	5						
12	14	11 09.140.091	NAU - NACC	WT CD	Native American Cultural C	4			50							
13	96A	12 09.962.051	New Parking Structure	WT CD	Knolles Drive Parking Stru	18			49							
14	50	13 09.502.031	New Residence Hall	WT CD	Campus Heights Apartmen	11										
15	84	14 09.930.971	New Sculpture Bldg	WT CD	Sculpture Lab					7	3.5					
16	24	15	North Boiler Plant-Bldg 24	WT CD	North Heating & Cooling Pl	6			55							
17	P54	16	Parking Lot #2	WT CD	Parking Area South Apartmen					3						
18	P36	17 08.020.981	Parking Lot #36	WT CD	Parking Area Bilby Resear	4			13							
19	P2, P31A,	18 08.020.991	Parking Lots P-2, P-31A and	WT CD	Various Parking Areas	9			5							
20	P96B	19 08.060.041	Pedestrian Path Retainin	WT CD	Retaining wall	4			4							
21	36	20 11.160.091	Science and Health	WT CD	Science & Health	9	52		65*							
22	42	21 09.420.981	Sechrist Hall Addition	WT CD	Sechrist Hall	3			14.5							
23	67	22	South Chilled Water Plant	WT CD	South Heating & Cooling Pl	5	10		21.5	1						
24	95	23		WT CD	Pine Ridge Village					10						
25	30A	24 09.300.017	Student Union Dry Goods	WT CD	University Union	2			37.5							
26	98	25	Swing Space	WT CD	Swing Space	2			5	9	5.5					
27	56	26	University Drive Reconstru	WT CD	University Dr	4			10							
28	25	27	Womens Soccer Facility	WT CD	Womens Soccer Facility	5			20							
29	17	28	NAU Laboratory Building- /	NAU North CD	Science Lab Facility	15			79							
30	88	29	NAU Catch Basin- Append	NAU North CD	Catch Basin/Pedestrian Wa	3			15							
31	29	30	NAU Residence Hall- Appe	NAU North CD	Aspen Crossing	10										
32	30C	31	NAU Dining Hall Expansion	NAU North CD	University Union	5			35							
33	29	32	Dining Hall Expansion Pre	NAU North CD	Aspen Crossing	2			35							
34	25	33	NAU Wellness Center - Ap	NAU North CD	HLC	11			72							
35	96B	34	NAU Student Housing, Site	NAU North CD	SF Parking Garage	2			68.5							
36	90B	35 09.902.111	NAU SF Garage-Append	NAU North CD	SF Parking Garage	9			83.5							

Bore Hole Excel Spreadsheet Notes

Campus Safety, Planning and Building Management

[illegible]

Bore Hole GIS Table conversion

- Building Information Model Project:

1. BIM Lighting Data Table
2. BIM Emergency Exit Points Table with Z Value

OBJECTID *	SHAPE *	INTERIOR_LIGHTING_TYPECODE_PP	INSTALLATION_DATE_OM	LAST_MAINT_DATE_OM	MAINTENANCE_CODE_OM	Z_COORDIN
1	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
2	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
3	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
4	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
5	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
6	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
7	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
8	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
9	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
10	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
11	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
12	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
13	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
14	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
15	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
16	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
17	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8
18	Point Z	EM-3	4/26/2011	<Null>	routine scheduled	7.8

BIM Emergency Exit Points Table with Z Value

Using GIS to Enhance Campus Safety, Planning and Building Management

Item Description - Interior_LightingPoly1_Line

Description Preview

Preview: Table

OBJECTID *	SHAPE *	FID_Interior_LightingPoly1	INTERIOR_LIGHT_SUBTYPE_PP	Z_Max
1	Polyline Z	379	Emergency Flourescent Light Fixture	10
2	Polyline Z	348	Wall Light/Outlet Fixture	10
3	Polyline Z	380	Emergency Flourescent Light Fixture	10
4	Polyline Z	42	Flourescent Light Fixture	10
5	Polyline Z	38	Flourescent Light Fixture	10
6	Polyline Z	37	Flourescent Light Fixture	10
7	Polyline Z	1	Emergency Flourescent Light Fixture	10
8	Polyline Z	34	Flourescent Light Fixture	10
9	Polyline Z	31	Flourescent Light Fixture	10
10	Polyline Z	53	Emergency Flourescent Light Fixture	10
11	Polyline Z	29	Flourescent Light Fixture	10
12	Polyline Z	28	Flourescent Light Fixture	10
13	Polyline Z	36	Flourescent Light Fixture	10
14	Polyline Z	2	Flourescent Light Fixture	10
15	Polyline Z	347	Wall Light/Outlet Fixture	10
16	Polyline Z	27	Flourescent Light Fixture	10
17	Polyline Z	44	Flourescent Light Fixture	10
18	Polyline Z	33	Flourescent Light Fixture	10
19	Polyline Z	30	Flourescent Light Fixture	10
20	Polyline Z	32	Flourescent Light Fixture	10
21	Polyline Z	41	Flourescent Light Fixture	10
22	Polyline Z	52	Emergency Flourescent Light Fixture	10
23	Polyline Z	15	Emergency Flourescent Light Fixture	10
24	Polyline Z	43	Flourescent Light Fixture	10
25	Polyline Z	331	Down Light Fixture	10
26	Polyline Z	24	Flourescent Light Fixture	10
27	Polyline Z	40	Flourescent Light Fixture	10
28	Polyline Z	22	Flourescent Light Fixture	10
29	Polyline Z	322	Down Light Fixture	10
30	Polyline Z	35	Flourescent Light Fixture	10
31	Polyline Z	39	Flourescent Light Fixture	10
32	Polyline Z	49	Flourescent Light Fixture	10
33	Polyline Z	51	Emergency Flourescent Light Fixture	10
34	Polyline Z	26	Flourescent Light Fixture	10
35	Polyline Z	8	Flourescent Light Fixture	10
36	Polyline Z	11	Flourescent Light Fixture	10
37	Polyline Z	50	Flourescent Light Fixture	10
38	Polyline Z	387	Down Light Fixture	10
39	Polyline Z	25	Flourescent Light Fixture	10
40	Polyline Z	7	Flourescent Light Fixture	10
41	Polyline Z	14	Flourescent Light Fixture	10

(of 546)

BIM Lighting Data Table

Using GIS to Enhance Campus Safety, Planning and Building Management

■ Blue Light Project:

1. Emergency Blue light Building Multipatch (3D) Obstruction Table
2. Emergency Blue Light Observation Point Table
3. Emergency Blue light 300 Buffer Target Table
4. Emergency Blue light Line of Sight Visibility Code Table

Item Description - NAU_Bldg_3D

Description Preview

Preview: Table

FID	Shape	BLDG_ID	BLDG_NUM	PRIM_USE_T	BASE_ELEV	Z_Max
0	MultiPatch M	2	077A	MAINTENANCE SUPPORT	6928.586426	40
1	MultiPatch M	3	077A	MAINTENANCE SUPPORT	6926.258789	40
2	MultiPatch M	4	076	RESEARCH AND LABORATORY	6921.614746	40
3	MultiPatch M	5	077A	MAINTENANCE SUPPORT	6918.030762	40
4	MultiPatch M	6	083	OTHER	6923.689453	40
5	MultiPatch M	7	080	STUDIO LABORATORY	6913.14209	40
6	MultiPatch M	8	080	STUDIO LABORATORY	6914.194336	40
7	MultiPatch M	9	080	STUDIO LABORATORY	6918.837402	40
8	MultiPatch M	10	049	RESEARCH AND LABORATORY	6900.15918	40
9	MultiPatch M	11	047	RESEARCH AND LABORATORY	6900.973145	40
13	MultiPatch M	22	043	STUDENT SUPPORT SERVICES	6897.29248	40
14	MultiPatch M	23	032	RESEARCH AND LABORATORY	6891.276855	40
17	MultiPatch M	29	023A	ACADEMIC	6893.396484	40
20	MultiPatch M	33	021B	ACADEMIC	6891.603516	40
21	MultiPatch M	34	021A	RECREATIONAL	6887.901367	40
22	MultiPatch M	35	023	ACADEMIC	6894.500977	40
24	MultiPatch M	39	021	ACADEMIC	6892.881348	40
25	MultiPatch M	40	018	ACADEMIC	6894.121094	40
28	MultiPatch M	46	020	ACADEMIC	6895.456543	40
30	MultiPatch M	50	091	ADMINISTRATIVE	6891.69873	40
31	MultiPatch M	52	024	CONSTRUCTION AND MAINTENANCE SUPPORT	6896.057617	40
33	MultiPatch M	54	013	ACADEMIC	6903.542969	40
35	MultiPatch M	56	017	RESEARCH AND LABORATORY	6899.936523	40
36	MultiPatch M	57	016	ACADEMIC	6899.734863	40
37	MultiPatch M	58	096A	PARKING GARAGE	6901.783691	40
40	MultiPatch M	65	028	LIBRARY	6899.169922	40
41	MultiPatch M	66	037A	THEATER AND AUDITORIUM	6901.296387	40
45	MultiPatch M	70	052	RESEARCH AND LABORATORY	6897.20459	40
47	MultiPatch M	83	054B	STUDENT SUPPORT SERVICES	6900.081543	40
48	MultiPatch M	84	054A	STUDENT SUPPORT SERVICES	6900.599609	40
51	MultiPatch M	109	098B	STUDENT SUPPORT SERVICES	6917.513672	40
52	MultiPatch M	110	098A	OTHER	6912.337891	40
53	MultiPatch M	111	098C	OTHER	6908.421387	40
54	MultiPatch M	112	098D	STUDENT SUPPORT SERVICES	6912.348633	40
55	MultiPatch M	113	098F	STUDENT SUPPORT SERVICES	6901.405762	40
57	MultiPatch M	118	067	CONSTRUCTION AND MAINTENANCE SUPPORT	6880.485352	40
59	MultiPatch M	122	058A	OTHER	6897.760742	40
61	MultiPatch M	127	068	ATHLETICS	6878.772949	40
62	MultiPatch M	128	096	OTHER	6882.619629	40
65	MultiPatch M	131	067	MAINTENANCE SUPPORT	6878.550781	40
67	MultiPatch M	133	066	ACADEMIC	6880.223633	40

(of 172)

Emergency Blue light Building Multipatch (3D) Obstruction Table

Using GIS to Enhance
Campus Safety, Planning and Building Management

Table						
Emergency Blue Light 3D (Free Standing 8ft Height)						
OBJECTID *	info	LOCATIO	INFO	BLUELIGHT_NUM	Z	SHAPE *
5	0	<Null>	yes	1	8	Point ZM
8	0	<Null>	yes	2	8	Point ZM
6	0	<Null>	<Null>	3	8	Point ZM
33	0	<Null>	yes	4	8	Point ZM
97	0	<Null>	<Null>	6	8	Point ZM
96	0	<Null>		7	8	Point ZM
40	0	<Null>		8	8	Point ZM
47	0	<Null>	yes	9	8	Point ZM
45	0	<Null>	<Null>	10	8	Point ZM
46	0	<Null>		11	8	Point ZM
84	0	<Null>	<Null>	12	8	Point ZM
55	0	<Null>	yes	13	8	Point ZM
72	0	<Null>	yes	14	8	Point ZM
73	0	<Null>	yes	15	8	Point ZM
90	0	<Null>	<Null>	16	8	Point ZM
80	0	<Null>	<Null>	17	8	Point ZM
79	0	<Null>	<Null>	18	8	Point ZM
81	0	<Null>	<Null>	19	8	Point ZM
75	0	<Null>	yes	20	8	Point ZM
74	0	<Null>	<Null>	21	8	Point ZM
68	0	<Null>	<Null>	22	8	Point ZM
67	0	<Null>	yes	23	8	Point ZM
60	0	<Null>	yes	24	8	Point ZM
32	0	<Null>	<Null>	25	8	Point ZM
91	0	<Null>		26	8	Point ZM
70	0	<Null>	yes	27	8	Point ZM
65	0	<Null>	<Null>	28	8	Point ZM
56	0	<Null>	yes	29	8	Point ZM
93	0	<Null>		30	8	Point ZM
78	0	<Null>	yes	31	8	Point ZM
77	0	<Null>	yes	32	8	Point ZM
51	0	<Null>	yes	33	8	Point ZM
95	0	<Null>	<Null>	34	8	Point ZM
24	0	<Null>	yes	35	8	Point ZM
42	0	<Null>	<Null>	36	8	Point ZM
25	0	<Null>	yes	37	8	Point ZM
88	0	<Null>	yes	38	8	Point ZM
85	0	<Null>	<Null>	39	8	Point ZM
86	0	<Null>	<Null>	40	8	Point ZM
14	0	<Null>	<Null>	41	8	Point ZM
31	0	<Null>	yes	42	8	Point ZM
49	0	<Null>		43	8	Point ZM
43	0	<Null>	yes	44	8	Point ZM
92	0	<Null>		45	8	Point ZM
82	0	<Null>	<Null>	46	8	Point ZM

0 (0 out of 116 Selected)

Emergency Blue Light 3D (Free Standing 8ft Height)

Using GIS to Enhance Campus Safety, Planning and Building Management

Emergency Blue Light Observation Point Table

Item Description - BlueLtl_300ft_buffer								
Description	Preview							
Preview:	Table							
FID	Shape *	BLUELIGHT_	ID	LOCAT	INFO	Z	BUFF_DIST	
4	Polygon	1	0		yes	6865	300	
7	Polygon	2	0		yes	6865	300	
5	Polygon	3	0			6865	300	
32	Polygon	4	0		yes	6865	300	
96	Polygon	6	0			6865	300	
95	Polygon	7	0			6865	300	
39	Polygon	8	0			6865	300	
46	Polygon	9	0		yes	6865	300	
44	Polygon	10	0			6865	300	
45	Polygon	11	0			6865	300	
83	Polygon	12	0			6865	300	
54	Polygon	13	0		yes	6865	300	
71	Polygon	14	0		yes	6865	300	
72	Polygon	15	0		yes	6865	300	
89	Polygon	16	0			6865	300	
79	Polygon	17	0			6865	300	
78	Polygon	18	0			6865	300	
80	Polygon	19	0			6865	300	
74	Polygon	20	0		yes	6865	300	
73	Polygon	21	0			6865	300	
67	Polygon	22	0			6865	300	
66	Polygon	23	0		yes	6865	300	
59	Polygon	24	0		yes	6865	300	
31	Polygon	25	0			6865	300	
90	Polygon	26	0			6865	300	
69	Polygon	27	0		yes	6865	300	
64	Polygon	28	0			6865	300	
55	Polygon	29	0		yes	6865	300	
92	Polygon	30	0			6865	300	
77	Polygon	31	0		yes	6865	300	
76	Polygon	32	0		yes	6865	300	
50	Polygon	33	0		yes	6865	300	
94	Polygon	34	0			6865	300	
23	Polygon	35	0		yes	6865	300	
41	Polygon	36	0			6865	300	
24	Polygon	37	0		yes	6865	300	
87	Polygon	38	0		yes	6865	300	
84	Polygon	39	0			6865	300	
85	Polygon	40	0			6865	300	
13	Polygon	41	0			6865	300	
30	Polygon	42	0		yes	6865	300	
48	Polvaon	43	0			6865	300	

Emergency Blue light 300 Buffer Target Table

Using GIS to Enhance
Campus Safety, Planning and Building Management

Table						
Line of Sight from Blue Light (300 feet)						
FID	Shape *	SourceOID	VisCode	TarIsVis	OBSTR_MPID	
35	Polyline ZM	35	1	0	-1	
36	Polyline ZM	35	2	0	-1	
37	Polyline ZM	36	1	0	-1	
38	Polyline ZM	36	2	0	-1	
39	Polyline ZM	37	1	0	-1	
40	Polyline ZM	37	2	0	-1	
41	Polyline ZM	38	1	0	-1	
42	Polyline ZM	38	2	0	-1	
43	Polyline ZM	39	1	0	-1	
44	Polyline ZM	39	2	0	-1	
45	Polyline ZM	40	1	0	-1	
46	Polyline ZM	40	2	0	-1	
47	Polyline ZM	41	1	0	-1	
48	Polyline ZM	41	2	0	-1	
49	Polyline ZM	42	1	0	-1	
50	Polyline ZM	42	2	0	-1	
51	Polyline ZM	43	1	0	-1	
52	Polyline ZM	43	2	0	-1	
53	Polyline ZM	44	1	0	-1	
54	Polyline ZM	44	2	0	-1	
55	Polyline ZM	45	1	0	-1	
56	Polyline ZM	45	2	0	-1	
57	Polyline ZM	46	1	0	-1	
58	Polyline ZM	46	2	0	-1	
59	Polyline ZM	47	1	0	-1	
60	Polyline ZM	47	2	0	-1	
61	Polyline ZM	48	1	0	-1	
62	Polyline ZM	48	2	0	-1	
63	Polyline ZM	49	1	0	-1	
64	Polyline ZM	49	2	0	-1	
65	Polyline ZM	50	1	0	-1	
66	Polyline ZM	50	2	0	-1	
67	Polyline ZM	51	1	0	-1	
68	Polyline ZM	51	2	0	-1	
69	Polyline ZM	52	1	0	-1	
70	Polyline ZM	52	2	0	-1	
71	Polyline ZM	53	1	0	-1	
72	Polyline ZM	53	2	0	-1	
73	Polyline ZM	54	1	0	-1	
74	Polyline ZM	54	2	0	-1	
75	Polyline ZM	55	1	0	-1	
76	Polyline ZM	55	2	0	-1	
77	Polyline ZM	56	1	0	-1	
78	Polyline ZM	56	2	0	-1	
79	Polyline ZM	57	1	0	-1	

0 (0 out of 12541 Selected)

Line of Sight from Blue Light (300 feet)

Emergency Blue light Line of Sight Visibility Code Table

Using GIS to Enhance
Campus Safety, Planning and Building Management

Appendix E: Practicum work log summary (during full time work schedule at Facility Services)

June 2013	Researched GIS for university environments
October 2013	Initiated document and data organization
December 2013	Collected and formatted data for practicum projects
January 2014	Completed GIS building information model project
June 2014	Completed GIS safety assessment project
February 2015	Completed GIS planning project
June 2015	Completed workflow collation process for paper review
Dec 2015	Completed research summary and updated methodology
March 2016	Submitted initial practicum draft for review